Kenai Hydro, LLC
3977 Lake Street
Homer, AK 99603

August 13, 2014

Secretary Kimberly D. Bose
Federal Energy Regulatory Commission
Attn: DHAC, PJ-12.2
888 First Street, NE
Washington, DC 20426

- FILED ELECTRONICALLY -

Final Grant Lake Natural Resource Study Reports

Dear Secretary Bose:

Kenai Hydro, LLC (KHL) hereby submits its Final 2013 Natural Resource Study Reports (Reports) for the proposed Grant Lake Project. The complete set of reports includes:

- Aquatic Resources Study Report
- Geomorphology Study Report
- Aquatic Habitat Mapping and Instream Flow Study Report
- Macroinvertebrate and Periphyton Study Report
- Water Quality, Temperature and Hydrology Study Report
- Terrestrial Resource Study Report
- Recreation and Visual Resources Study Report

On March 18, 19 and 20, 2014, KHL held a meeting with the Stakeholders (and FERC), to discuss the results from the 2013 study efforts and answer any associated questions. Prior to the meeting, the Reports were distributed to the Stakeholders and although it wasn't required per the TLP, KHL elected to request informal comments to ensure the continuation of a collaborative process that will hopefully lead to a comprehensive Draft License Application (DLA) submittal to the Stakeholders for formal review. Based on those comments, KHL elected to make some modifications to the Reports prior to deeming them "Final" and ready for filing with FERC.

In addition to being the lead consultant for the licensing and natural resource aspects of the Grant Lake Project, McMillen, LLC has been retained by KHL to conduct all of the engineering and operational feasibility work leading up to and including the development of the engineering exhibits associated with the FERC License Application (LA). Significant progress has been made with respect to the engineering and operational feasibility of the Grant Lake Project. As a result of this progress and the associated analysis, an engineering and operational "Workshop" was held with Stakeholders in Anchorage on July 7, 2014. Primary topics of discussion included Project infrastructural refinements, proposed operational scenarios, and a proposed instream flow regime in the bypass section (Reach 5) of Grant Creek.

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Over the course of the past 6 months, significant progress has been made with respect to development of the Project and collaboration with Stakeholders. The amount and tenor of the communication and feedback has been encouraging. We have communicated our intent of distributing a DLA to Stakeholders (and FERC) in early 2015 and worked closely with Stakeholders to address and resolve fundamental issues in advance of the DLA.

KHL is committed to keeping FERC apprised of developments during Draft and Final License Application development and plans to have scheduled progress/advisory calls with our FERC Representative, Ken Hogan during this phase of the process. As always, please don't hesitate to call or email if you have any questions or concerns.

Sincerely,

/s/ Mikel Salzetti

Mikel Salzetti
Project Manager
Kenai Hydro, LLC

Incorporated into this package are the following documents:

- The Study Reports outlined above
- Meeting Minutes of the 3/18, 3/19 and 3/20 meetings held in Anchorage, Alaska along with the associated presentations that were given at the meetings
- An comment matrix based upon the informal comments received
- Meeting Minutes of the 7/7 Engineering and Operational Workshop held in Anchorage Alaska along with the associated presentations given at the meeting.

*Note – Due to the large file size of some of the documents, this "package" will be submitted via multiple filings.

Final Grant Lake Project 2013 Natural Resource Study Reports

Grant Lake Hydroelectric Project (FERC No. 13212)

Aquatic Resources Study – Grant Creek, Alaska
Fisheries Assessment Report

Prepared for
Kenai Hydro, LLC

Prepared by
Mark D. Miller and John R. Stevenson
BioAnalysts, Inc.

June 2014

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Acronyms and Abbreviations

ADF&G	Alaska Department of Fish & Game
AEIDC	Arctic Environmental Information Data Center
AUC	area-under-the-curve
AWC	Anadromous Waters Catalog
cfs	cubic feet per second
CIAA	Cook Inlet Aquaculture Association
CPUE	catch per unit effort
DLA	Draft License Application
FERC	Federal Energy Regulatory Commission
FL	fork length
GPS	Global Positioning System
IFIM	Instream Flow Incremental Methodology
KHI	Kenai Hydro, Inc.
KHL	Kenai Hydro, LLC
LA	License Application
LWD	large woody debris
mm	millimeter
MW	megawatt
NAVD 88	North American Vertical Datum of 1988
NGVD 29	National Geodetic Vertical Datum of 1929
NOI	Notice of Intent
PAD	Pre-Application Document
PM&E	protection, mitigation and enhancement
Project	Grant Lake Hydroelectric Project
TWG	Technical Working Group
USGS	U.S. Department of the Interior, Geological Survey
WUA	weighted usable area

Note: Measurements within this document are given in metric units with the exception of Section 1.1 (the description of the proposed project). Measurements within that section are given in English units in order to be consistent with other Grant Creek resource documents.

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Aquatic Resources Study – Grant Creek, Alaska Fisheries Assessment Report Grant Lake Hydroelectric Project (FERC No. 13212)

1 INTRODUCTION

On August 6, 2009, Kenai Hydro, LLC (KHL) filed a Pre-Application Document (PAD; KHL 2009), along with a Notice of Intent (NOI) to file an application for an original license, for a combined Grant Lake/Falls Creek Project (Federal Energy Regulatory Commission [FERC] No. 13211/13212 ["Project" or "Grant Lake Project"]) under Part I of the Federal Power Act (FPA). On September 15, 2009, FERC approved the use of the Traditional Licensing Process (TLP) for development of the License Application (LA) and supporting materials. As described in more detail below, the proposed Project has been modified to eliminate the diversion of water from Falls Creek to Grant Lake. The Project will be located near the community of Moose Pass, Alaska in the Kenai Peninsula Borough, approximately 25 miles north of Seward, Alaska and just east of the Seward Highway (State Route 9).

The fish assessment portion of the Aquatic Resources Study Plan (KHL 2013) was designed to address information needs identified in the PAD, during the TLP public comment process, and through early scoping conducted by FERC. This study report presents existing information relative to the scope and context of potential effects of the Project. This information will be used to analyze Project impacts and propose protection, mitigation, and enhancement (PM&E) measures in the draft and final LAs for the Project.

1.1 Proposed Project Description

The Project is located near the community of Moose Pass in the Kenai Peninsula Borough, approximately 25 miles north of Seward and just east of the Seward Highway. It lies within Section 13 of Township 4 North, Range 1 West; Sections 1, 2, 5, 6, 7, and 18 of Township 4 North, Range 1 East; and Sections 27, 28, 29, 31, 32, 33, 34, 35, and 36 of Township 5 North, Range 1 East, Seward Meridian (U.S. Geological Survey [USGS] Seward B-6 and B-7 Quadrangles).

The proposed Project would be composed of an intake structure at the outlet to Grant Lake, a tunnel, a surge tank, a penstock, and a powerhouse. It would also include a tailrace detention pond, a switchyard with disconnect switch and step-up transformer, and an overhead or underground transmission line. The preferred alternative would use approximately 15,900 acre-feet of water storage during operations between pool elevations of approximately 692 and up to 703 feet North American Vertical Datum of 1988 (NAVD 88)[1].

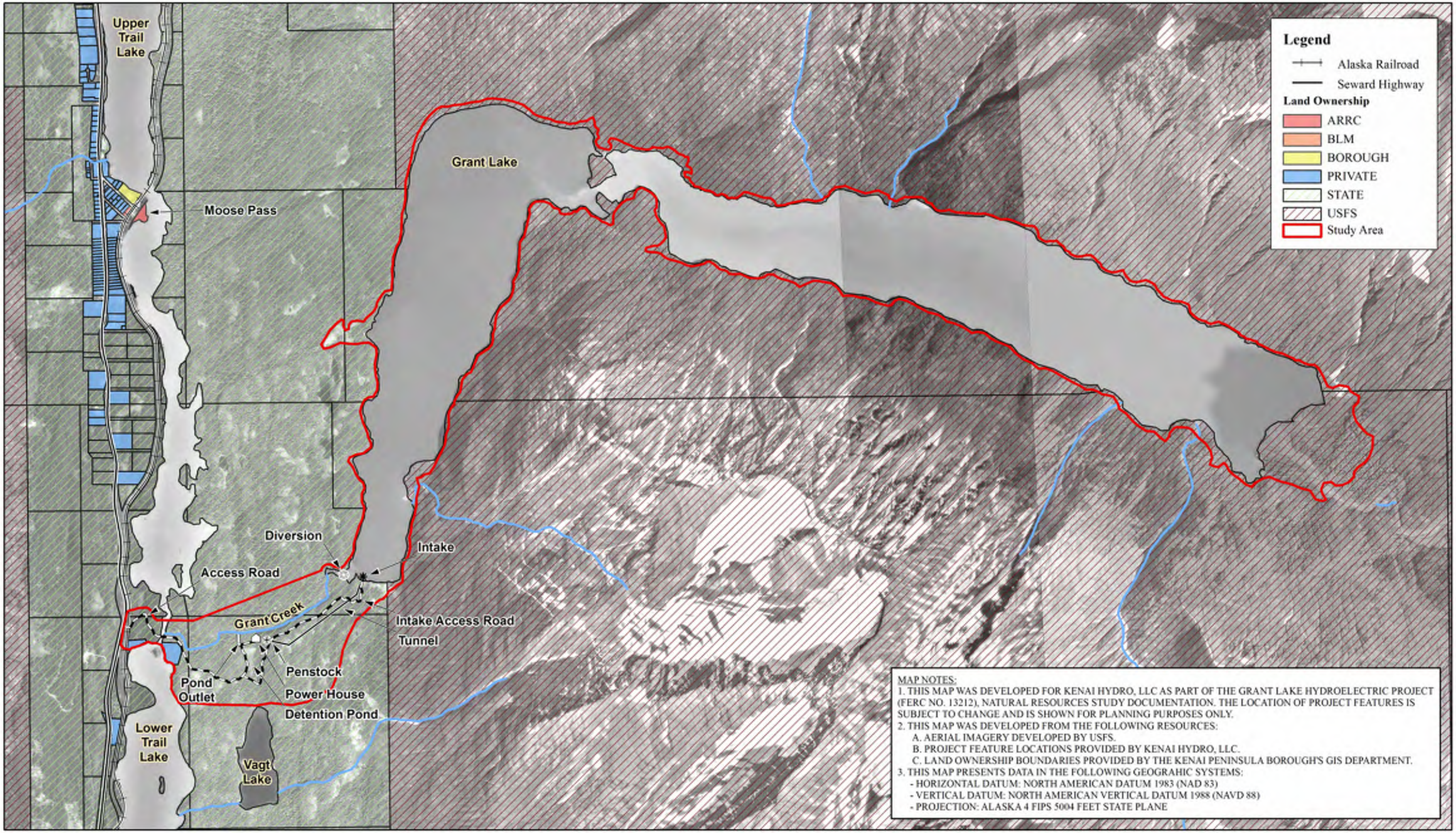
[1] The elevations provided in previous licensing and source documents are referenced to feet mean sea level in NGVD 29 [National Geodetic Vertical Datum of 1929] datum, a historical survey datum. The elevations presented in the Grant Lake natural resources study reports are referenced to feet NAVD 88 datum, which results in an approximate +5-foot conversion to the NGVD 29 elevation values.

An intake structure would be constructed approximately 500 feet east of the natural outlet of Grant Lake. An approximate 3,200-foot-long, 10-foot diameter horseshoe tunnel would convey water from the intake to directly above the powerhouse at about elevation 628 feet NAVD 88. At the outlet to the tunnel a 360-foot-long section of penstock will convey water to the powerhouse located at about elevation 531 feet NAVD 88. An off-stream detention pond will be created to provide a storage reservoir for flows generated during the rare instance when the units being used for emergency spinning reserve are needed to provide full load at maximum ramping rates. The tailrace would be located in order to minimize impacts to fish habitat by returning flows to Grant Creek upstream of the most productive fish habitat.

Two concepts are currently being evaluated for water control at the outlet of Grant Lake. The first option would consist of a natural lake outlet that would provide control of flows out of Grant Lake. A new low level outlet would be constructed on the south side of the natural outlet to release any required environmental flows when the lake is drawdown below the natural outlet level. The outlet works would consist of a 48-inch diameter pipe extending back into Grant Lake, a gate house, regulating gate, controls and associated monitoring equipment. The outlet would discharge into Grant Creek immediately below the natural lake outlet.

In the second option, a concrete gravity diversion structure would be constructed near the outlet of Grant Lake. The gravity diversion structure would raise the pool level by a maximum height of approximately 2 feet (from 703 to 705 feet NAVD 88), and the structure would have an overall width of approximately 120 feet. The center 60 feet of the structure would have an uncontrolled spillway section with a crest elevation at approximately 705 feet NAVD 88. Similar to the first option, a low level outlet would be constructed on the south side of the natural outlet to release any required environmental flows when the lake is drawn down below the natural outlet level. The outlet works would consist of a 48-inch diameter pipe extending back into Grant Lake, a gate house a regulating gate, controls, and associated monitoring equipment. The outlet would discharge into Grant Creek immediately below the diversion structure.

Figure 1.1-1 displays the global natural resources study area for the efforts undertaken in 2013 and 2014 along with the likely location of Project infrastructure and detail related to land ownership in and near the Project area. Further discussions related to specifics of the aforementioned Project infrastructure along with the need and/or feasibility of the diversion dam will take place with stakeholders in 2014 concurrent with the engineering feasibility work for the Project. Refined Project design information will be detailed in both the Draft License Application (DLA) and any other ancillary engineering documents related to Project development. The current design includes two Francis turbine generators with a combined rated capacity of approximately 5.0 megawatts (MW) with a total design flow of 385 cubic feet per second (cfs). Additional information about the Project can be found on the Project website: http://www.kenaihydro.com/index.php.



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Drawing Scale: 0 0.25 0.5 1 Miles

McMILLEN, LLC

Developed For: Homer Electric Association, Inc. A Touchstone Energy Cooperative

GRANT LAKE HYDROELECTRIC PROJECT - FERC PROJECT #P-13212

GRANT LAKE NATURAL RESOURCES STUDY

Figure 1.1-1
Natural Resources Study Area

REV | DATE | BY | DESCRIPTION

DESIGNED: Jake Woodbury
DRAWN: Jake Woodbury
CHECKED: C. Warnock
ISSUED DATE: 1/9/2014
SCALE: 1:27,000
DRAWING

1.2 Overall Goals Identified During Project Scoping

The goals of the study efforts described in this report were to provide baseline information; those data, in conjunction with existing information will be used to develop potential alternative flow regimes, which in turn will be assessed to determine potential Project impacts on aquatic resources. These impact assessments will identify potential protection, mitigation, and enhancement measures to be presented in the draft and final LAs.

The goals of this suite of studies were to provide supporting information on the potential resource impacts of the proposed Project that were identified during development of the PAD, public comment, and FERC scoping for the LA, as follows:

- Impact of Project operation on sediment transport (relative to the availability of spawning gravels) due to changes in flow in Grant Creek.
- Impact of Project operation (fluctuating lake levels in Grant Lake, changes in seasonal flow in Grant Creek, reduced flows between the dam and powerhouse on Grant Creek) on fish abundance and distribution.
- Impact of Project construction and operation on biological productivity and abundance of fish food organisms in Grant Creek and Grant Lake.
- Impact of Project intake structure operation on fish populations.
- Impact of Project construction on fish habitat in Grant Creek.
- Impact of Project facilities (increased access) on fish populations due to potential increased recreational fishing.
- Impact of Project construction and operation on commercial, sport, and subsistence fisheries supported by the Kenai River watershed.

Specific objectives and quantitative objectives are presented below for each individual study component.

1.3 Existing Information

Information relating to aquatic resources has been collected during previous investigations into the potential development of hydroelectric generation at Grant Creek as well as during pre-licensing studies conducted by KHL in 2009 and early 2010. In the following sub-sections, Sections 1.3.1 and 1.3.2, we describe the findings from these studies.

1.3.1 Pre-2009 Studies

Previous FERC licensing efforts in the 1960s and 1980s for a proposed hydroelectric project at Grant Lake included studies of fish resources in Grant Lake and Grant Creek. Arctic Environmental Information and Data Center (AEIDC 1983) conducted fish sampling from 1981 to 1982 as part of a comprehensive environmental baseline study effort and the USFWS (1961) conducted limited sampling from 1959 to 1960. An instream flow study was completed in 1987 as part of a preliminary FERC LA prepared by Kenai Hydro, Inc. (not related to the current Kenai Hydro, LLC; Envirosphere 1987, KHI 1987a, and KHI 1987b).

1.3.1.1 Grant Creek Fish Resources

Both anadromous and resident fish are present in Grant Creek, including salmon, trout, and other species. Spawning Chinook (Oncorhynchus tshawytscha), sockeye (Oncorhynchus nerka), and coho (Oncorhynchus kisutch) salmon, as well as rainbow trout (Oncorhynchus mykiss) and Dolly Varden (Salvelinus malma) are found in the lower reaches of Grant Creek (Ebasco 1984; Johnson and Klein 2009). Rearing Chinook, coho and rainbow trout are also present (Ebasco 1984, Johnson and Klein 2009). Round whitefish (Prosopium cylindraceum) and arctic grayling (Thymallus arcticus) were caught during angling surveys but are not assumed to spawn in Grant Creek (Ebasco 1984).

Upper Grant Creek is impassable to salmon one mile upstream of the mouth (Johnson and Klein 2009), with most fish habitat concentrated within the lower portion of stream. Habitat for juvenile fish exists mainly in stream margins, eddies, deep pools, and side channels offering reduced velocities (Ebasco 1984). Substrate material is coarse throughout the entire length of the creek due to high water velocity that tends to wash away smaller gravels (Ebasco 1984). Isolated areas of suitable spawning gravels occur in the lower half of the stream (Ebasco 1984).

Periodic minnow trapping on Grant Creek from July 1959 through January 1961 captured juvenile Chinook salmon, coho salmon, Dolly Varden char, and sculpin (extent of sampling area unknown; USFWS 1961). Minnow trapping and electrofishing in the lower reaches of Grant Creek for week-long periods in October 1981 and March, May, June, and August 1982 yielded higher catches of trout, salmon, and Dolly Varden in the fall and summer than in winter and spring (AEIDC 1983). Catches of Dolly Varden were generally most abundant in the minnow traps, followed by juvenile Chinook, juvenile rainbow trout, and juvenile coho. Juvenile Chinook were the most commonly caught fish during electrofishing surveys (Ebasco 1984).

Ebasco (1984) estimated that Grant Creek supported 250 Chinook spawners and 1,650 sockeye spawners. The stream was also estimated to support 209 8-inch "trout" (including Dolly Varden and rainbow trout) (Ebasco 1984). Spawning coho were not observed (Ebasco 1984) but have been recorded as being present at unknown levels in the stream by the Anadromous Waters Catalog (AWC) published by the Alaska Department of Fish and Game (Johnson and Klein 2009). Maximum counts from intermittent stream surveys by the Alaska Department of Fish & Game (ADF&G) were 76 Chinook (1963) and 324 (1952) sockeye salmon.

1.3.1.2 Grant Lake Fish Resources

Sampling during 1981-1982 found no fish in any of the tributaries to Grant Lake (AEIDC 1983). Sculpin and three-spine stickleback were the only fish found to inhabit Grant Lake. A series of impassable falls near Grant Lake's outlet prevents colonization of the lake by salmonids via Grant Creek (Ebasco 1984). Density of three-spine stickleback was ten times higher in the lower basin than the upper basin of Grant Lake (AEIDC 1983).

Because of the impassable falls below Grant Lake's outlet, no anadromous fish species occur in Grant Lake and its tributaries (USFWS 1961, AEIDC 1983, Ebasco 1984), and Grant Lake is not included in the AWC (Johnson and Daigneault 2008). Grant Lake appears to support only resident populations of sculpin–including Slimy sculpin (*Cottus cognatus*) and Coast Range sculpin (*Cottus aleuticus*) and three-spine stickleback (*Gasterosteus aculeatus*) (AEIDC 1983, USFWS 1961, Johnson and Klein 2009).

Although Sisson (1984) reported that Dolly Varden and a few rainbow trout occupied Grant Lake, subsequent investigations (USFWS 1961, AEIDC 1983, Marcuson 1989) have documented only sculpin and stickleback. From 1983-1986, coho salmon fry were stocked in Grant Lake by ADF&G, with limited success, though some enhanced returns to Grant Creek were recorded (Marcuson 1989).

1.3.1.3 Instream Flow

Environmental analyses that emphasized the relationship between stream flow and aquatic habitats (instream flow studies) were conducted on Grant Creek in the 1980s by Kenai Hydro, Inc. (KHI; unrelated to Kenai Hydro, LLC). These documents were compiled in support of a LA for hydropower development on Grant Creek. The documents include reports and written communications between KHI and state and federal agencies in 1986 and 1987 relative to a FERC LA for the proposed Grant Lake Hydroelectric Project (FERC No. 7633-002). Included were draft and final reports of a limited but complete Instream Flow Incremental Methodology (IFIM) investigation and negotiated minimum instream flows and ramping rates (Envirosphere 1987, KHI 1987a, and KHI 1987b). A technical memorandum was drafted and shared with the Instream Flow Technical Working Group (TWG) participants in 2009 detailing the results of the previous instream flow study efforts (HDR 2009a).

1.3.2 2009 and 2010 Aquatic Resources Studies

The 2009 aquatic resources study program was implemented to assist with the current FERC licensing effort. After collaboration with stakeholders, emphasis was placed on updating existing information, acquiring more complete data required for specific issue analysis, and providing background information needed to develop more focused studies after initiation of the formal FERC licensing process. The studies were continued in 2010 but the program was discontinued in July, 2010 after further stakeholder collaboration in an effort to revise the study plans and make them more quantitative in nature.

1.3.2.1 Fish Resources

The 2009 fisheries study (HDR 2009b) focused on the following objectives:

- Determine the relative abundance and distribution of juvenile fish in Grant Creek.
- Determine the relative abundance and distribution of resident Dolly Varden and rainbow trout in Grant Creek.
- Estimate abundance and run timing of spawning salmon.
- Estimate abundance and run timing of spawning adult resident fish.
- Determine fish presence and distribution in Grant Lake.

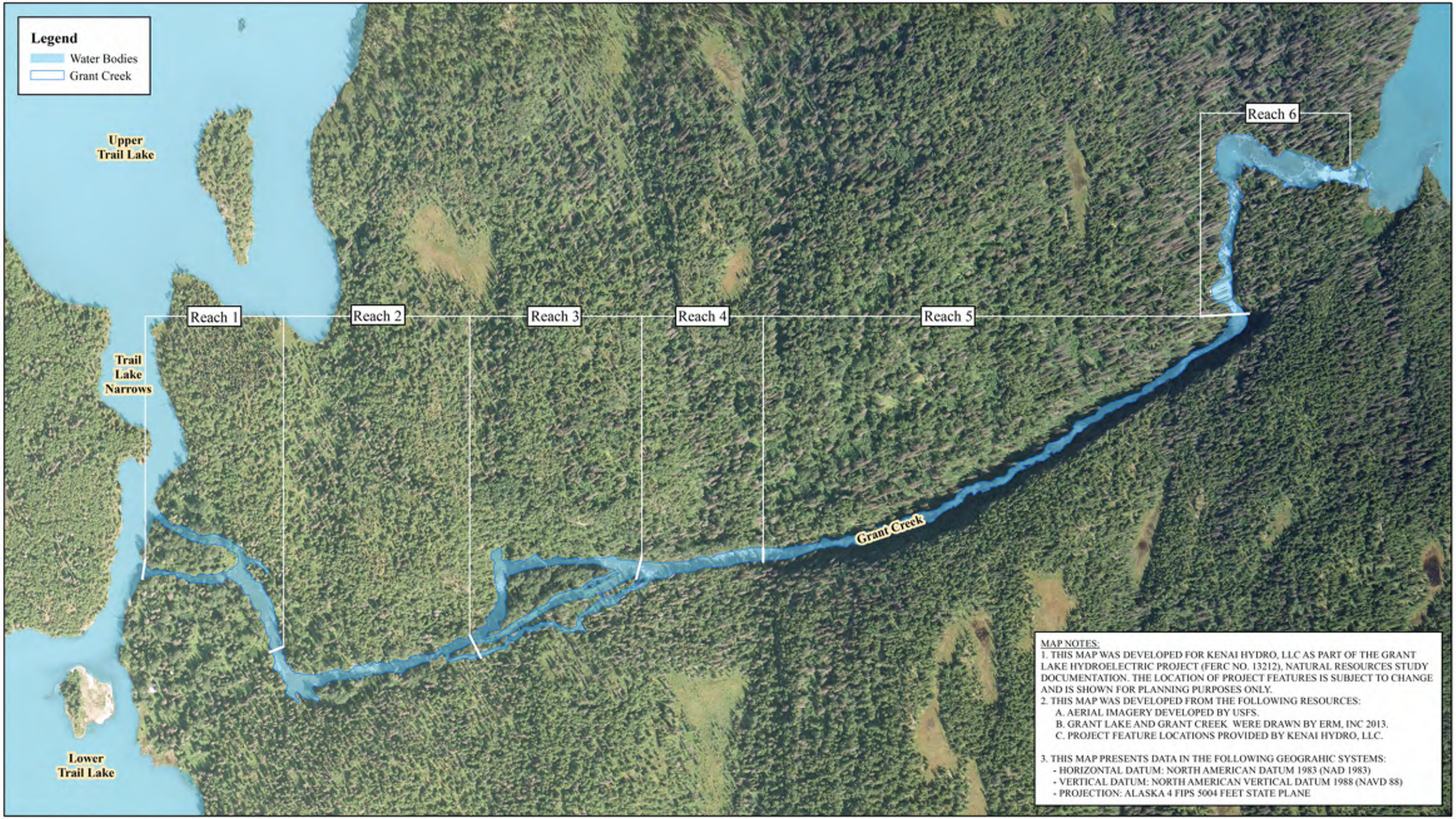
Consistent with studies conducted by AEIDC (1983), Grant Creek was divided into study Reaches 1 through 6 (Figure 1.3-1). Reaches 1 through 4 were roughly equal in length and Reaches 5 and 6 were established based on geomorphologic characteristics (HDR 2009b).

Relative abundance and distribution of juvenile fish were determined by minnow trapping and calculating the catch-per-unit-effort (CPUE) for each reach. Reaches 1 through 4 were sampled relatively evenly, with nine to 13 minnow traps per reach. Terrain was difficult to access in Reaches 5 and 6, so these reaches were sampled less frequently and with only three and five sites, respectively. A total of 50 baited minnow traps were placed throughout the creek in Reaches 1 through 6; mesh size was 0.6 cm. The creek was sampled monthly, with the exception of Reach 6, which was sampled in June and August only. Dolly Varden were found to be the most abundant species in Grant Creek and distributed throughout Grant Creek Reaches 1 through 5, although they had a greater relative abundance in Reaches 4 and 5. Coho salmon was the next most abundant species and individuals were distributed throughout Reaches 1 through 5. However, coho appeared to have the greatest relative abundance in Reach 1. Chinook salmon was the next most abundant species. There was a noticeable decrease in Chinook abundance in upstream reaches, and they were not caught above Reach 4. Other fish present in small numbers were sockeye salmon, rainbow trout, sculpin, and three-spine stickleback. Most salmon captured were young-of-the-year with few larger juveniles present (HDR 2009b).

Relative abundance of larger size resident salmonids (i.e., rainbow trout and Dolly Varden) was determined by calculation of angling CPUE (HDR 2009b). A total of 18 angling sites were established along the creek, and each site was fished for 30 minutes approximately every 10 days, from early June through late September. Rainbow trout (n = 68) were found to be more abundant than Dolly Varden (n = 9) and were caught throughout the creek, although their relative abundance was higher in Reaches 3 through 5 than in Reaches 1 and 2. Dolly Varden were captured in Reaches 1, 2, and 3; their relative abundance was highest in Reach 1.

This study was also aimed at determining the timing of spawning of adult resident fish; however, it appeared that spawning, if present, occurred before or after the 2009 study period, since little evidence of spawning fish was seen (HDR 2009b). Rainbow trout angling studies were continued in the spring and early summer of 2010 to confirm the presence of spawning and determine fish numbers. The progression of reproductive condition and the presence of adult rainbow trout in spawning condition confirmed that spawning did occur in Grant Creek in 2010. Capture success was too low to allow population estimates. Adult rainbow trout were observed in the upper portions of the canyon reach.

Abundance and run timing of spawning anadromous fish was estimated through data collected during foot surveys (HDR 2009b). Foot surveys occurred approximately every 10 days beginning in mid-June and ending in late September. Both sockeye and Chinook salmon were seen in the lower five reaches. Chinook salmon reached Grant Creek first around the beginning of August. Sockeye salmon did not arrive until the end of August. Escapement of Chinook salmon was estimated to be 231 fish, and escapement of sockeye salmon was estimated at 6,293. Fish distribution and presence in Grant Lake and its tributaries were assessed using minnow traps, electrofishing, and gill nets (HDR 2009b). Sampling occurred at nine gill netting sites, 18 electrofishing sites, and 28 minnow trapping sites. Three-spine stickleback was the dominant species in the lake followed by sculpin. No other species of fish was captured (HDR 2009b).



MAP NOTES:
1. THIS MAP WAS DEVELOPED FOR KENAI HYDRO, LLC AS PART OF THE GRANT LAKE HYDROELECTRIC PROJECT (FERC NO. 13212), NATURAL RESOURCES STUDY DOCUMENTATION. THE LOCATION OF PROJECT FEATURES IS SUBJECT TO CHANGE AND IS SHOWN FOR PLANNING PURPOSES ONLY.
2. THIS MAP WAS DEVELOPED FROM THE FOLLOWING RESOURCES:
   A. AERIAL IMAGERY DEVELOPED BY USFS.
   B. GRANT LAKE AND GRANT CREEK WERE DRAWN BY ERM, INC 2013.
   C. PROJECT FEATURE LOCATIONS PROVIDED BY KENAI HYDRO, LLC.

3. THIS MAP PRESENTS DATA IN THE FOLLOWING GEOGRAHIC SYSTEMS:
   - HORIZONTAL DATUM: NORTH AMERICAN DATUM 1983 (NAD 1983)
   - VERTICAL DATUM: NORTH AMERICAN VERTICAL DATUM 1988 (NAVD 88)
   - PROJECTION: ALASKA 4 FIPS 5004 FEET STATE PLANE

REV	DATE	BY	DESCRIPTION

N

Drawing Scale:
0 100 200 400 600 Feet

MCMILLEN, LLC
1401 SHORELINE DRIVE BOISE, ID 83702
OFFICE: 208.342.4214 FAX: 208.342.4216

Developed For:
Homer Electric Association, Inc.
A Touchstone Energy Cooperative

GRANT LAKE HYDROELECTRIC PROJECT - FERC PROJECT NO. 13212

GRANT LAKE NATURAL RESOURCES STUDY

Figure 1.3-1
Grant Creek Reaches

DESIGNED J. Woodbury
DRAWN J. Woodbury
CHECKED C. Warnock
ISSUED DATE 3/4/2014

DRAWING

SCALE: 1:4,000

1.3.2.2 Instream Flow

The collaborative process for a study of "instream flow" effects in Grant Creek was initiated in 2009 (HDR 2009b). The primary goal of the 2009 instream flow study program was to establish a TWG consisting of state and federal resource agency staff, KHL staff, and interested members of the local community. Once established, the TWG met three times during the 2009 study season to review the results of the 2009 aquatic baseline study efforts, discuss and agree upon an acceptable instream flow evaluation method, and request additional information to support the selection of an instream flow method (HDR 2009b).

As part of the instream flow study, and at the request of the TWG, a sampling event was conducted from June 23-25, 2009 on Grant Creek to characterize the types of aquatic habitats used by resident fish and rearing fish (HDR 2009b). Aquatic habitat was described at each sample site by recording macro-, meso-, and micro- habitat characteristics. During the June sampling event, snorkeling was the primary method used to document fish presence. Electrofishing was used primarily to confirm species identification and calibrate fish length estimates (HDR 2009b).

1.3.3 Need for Additional Information

Early study programs and the 2009-2010 baseline study program conducted by KHL have provided a significant amount of background information regarding aquatic resources in the Project area. Following analysis of the 2009 and 2010 study results, information gaps were identified for further study to support the FERC licensing process. The field studies conducted in 2013 were intended to provide information on the following general topics. Specific objectives for study components will be described below for each component.

- Juvenile fish use of winter habitats.
- Better definition of fish use of micro-habitats and overall species composition and relative abundances in Reaches 1 through 4.
- Extent of rainbow trout spawning in Grant Creek.
- Use of Reach 5 by juvenile and adult fish, with additional emphasis on spawning Chinook salmon use of Reach 5.
- Delineation of aquatic habitats available in Grant Creek; identify key habitats for fish and describe and distinguish the factors that may influence fish use of the key habitats over those habitat units not occupied by fish in Grant Creek.
- Estimation of salmon spawning escapement in Grant Creek.
- Examination of how important individual habitat units may be affected by changes in flow due to the operation of the proposed Project using instream flow assessment methods.
- Fish resources and habitat use of the Trail Lake Narrows at the proposed bridge site.

2 STUDY OBJECTIVES

Study objectives were developed for the 2013 research period based on existing data, and data gaps identified through consultation with the Stakeholders. Most objectives were a continuation of the 2009 and 2010 research effort; while other objectives were the result of additional stakeholder consultation. The objectives encompass adult and juvenile anadromous salmonids, as well as adult and juvenile resident species. The following is a brief description of the 2013 study objectives. The methods employed to achieve these objectives are discussed in detail in Section 4.

2.1 Grant Creek Salmon Spawning Distribution and Abundance

The purpose of this study component was to characterize spawning salmon distribution, run timing, and relative abundance in Grant Creek. This study effort consisted of two principal components and several subcomponents:

- Use of a counting weir to obtain a direct count of all salmon entering Grant Creek during the open water season.
  - Weir counts were compared to counts from foot surveys similar to those conducted during 2009 to calibrate earlier surveys and obtain an estimate of observer error when viewing fish from the stream bank.
- A radio telemetry study to assess the spawning distribution of Chinook, sockeye, and coho salmon, with emphasis on Reach 5 (Canyon Reach).

2.1.1 Salmon Escapement to Grant Creek – Relative Species Abundance

- Assessment of numbers and species of salmon in Grant Creek.
- Identify key species and critical time periods for environmental assessment.
- Identify key species and critical time periods as may be applied to design of Project mitigation measures.
- Calibration of escapement estimates from foot surveys conducted in 2009.
- The primary objective is to obtain a nearly complete count of salmon of each species entering Grant Creek.

2.1.2 Distribution of Spawning Salmon in Grant Creek

- Identify critical spawning habitats as required for general assessment of Project impacts.
- Identify habitat areas appropriate for use in instream flow analysis.
- Provide input for project mitigation needs by identifying sensitive stream segments.

2.2 Grant Creek Resident and Rearing Fish Abundance and Distribution

The purpose of this study component was to characterize distribution and abundance of all species of resident and rearing fish and run timing of rainbow trout in Grant Creek. This study effort consisted of the following components:

- Weir inventory and telemetry study to assess run timing, relative abundance, and spawning habitat location for rainbow trout.
- Investigation of juvenile fish presence in Reach 5 of Grant Creek using minnow traps and other sampling techniques.
- Minnow trap and video sampling in late winter/early spring at likely overwintering habitats to determine salmonid overwintering presence in Grant Creek.

- Snorkel sampling to determine fish use of meso-habitats in Grant Creek.

2.2.1 Adult Rainbow Trout Abundance, Distribution, and Spawning in Grant Creek

- Assessment of relative numbers of rainbow trout in Grant Creek.
- Identification of sensitive time periods for environmental assessment.
- Identify important spawning and feeding habitats for general assessment of project impacts.
- Provide input for Project mitigation needs by identifying sensitive stream segments.
- Obtain a count of adult rainbow trout entering Grant Creek during the open water season.
- Determine distribution of trout by tracking radio-tagged fish.

2.2.2 Resident and Rearing Fish Use of Reach 5

- Assessment of rearing fish use of habitats within Reach 5.
- Assessment of the juvenile fish productivity of Reach 5 relative to the remainder of Grant Creek.
- Assessment of the need for mitigation measures within Reach 5.
- Use of an inclined plane trap to monitor outmigrants from Reach 5.

2.2.3 Resident and Rearing Fish Use of Open Water Habitats in Lower Grant Creek

- Assessment of rearing fish use of habitats within lower Grant Creek as required for project impact assessment.
- Assessment of the juvenile fish productivity of Reaches 1-4 relative to the remainder of Grant Creek.
- Assessment of the need for mitigation measures within Lower Grant Creek.
- Selection of high fish use areas for incorporation in the instream flow study.
- Obtain a count of adult rainbow trout, Dolly Varden, and other resident species entering Grant Creek during the open water season.
- Use an inclined plane trap to monitor outmigrants from Reach 5.

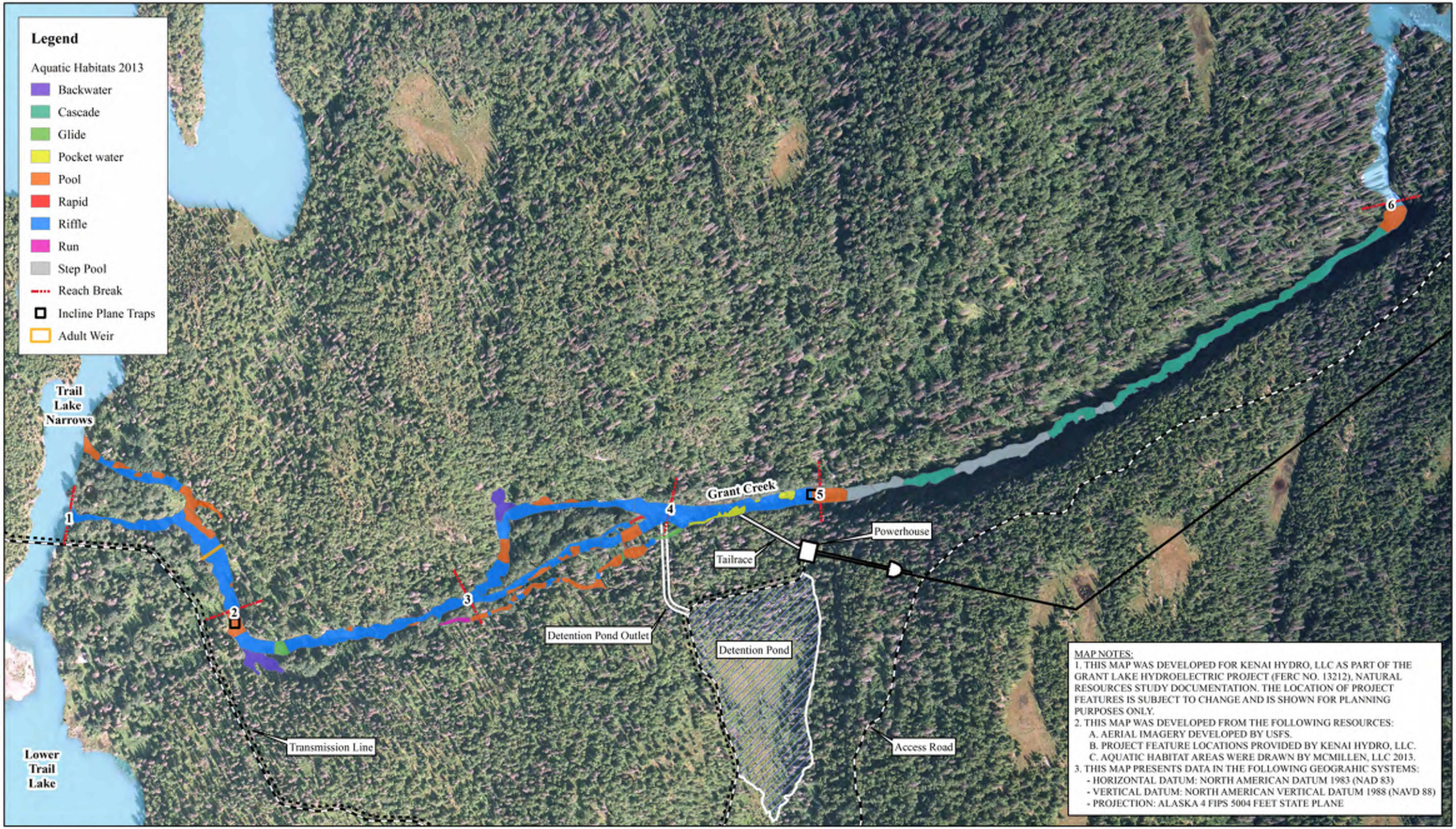
2.3 Trail Lake Narrows Fish and Aquatic Habitats

- Determine fish use in the vicinity of the proposed access road bridge crossing of Trail Lake Narrows in order to minimize impact to aquatic resources potentially resulting from bridge design, construction timing, and construction methodology.
- Determine habitat use to optimize bridge location and design.

3 STUDY AREA

3.1 Grant Creek

Consistent with studies conducted by AEIDC (1983) and KHL (HDR 2009b), Grant Creek was divided into study Reaches 1 through 6. Reaches 1 through 4 were roughly 0.125 mile each in length and Reaches 5 and 6 were established based on geomorphologic characteristics, and were collectively about 0.5 miles in length (HDR 2009b). Aquatic habitats in reaches 1-5 were documented within the efforts of the IFIM team to help quantify and describe the distribution of habitats in Grant Creek, 2013 (McMillen, LLC 2014; Figure 3.1-1). The material is presented here to describe the study area followed by a brief description of reaches 1-5 on Grant Creek.



MAP NOTES:
1. THIS MAP WAS DEVELOPED FOR KENAI HYDRO, LLC AS PART OF THE GRANT LAKE HYDROELECTRIC PROJECT (FERC NO. 13212), NATURAL RESOURCES STUDY DOCUMENTATION. THE LOCATION OF PROJECT FEATURES IS SUBJECT TO CHANGE AND IS SHOWN FOR PLANNING PURPOSES ONLY.
2. THIS MAP WAS DEVELOPED FROM THE FOLLOWING RESOURCES:
   A. AERIAL IMAGERY DEVELOPED BY USFS.
   B. PROJECT FEATURE LOCATIONS PROVIDED BY KENAI HYDRO, LLC.
   C. AQUATIC HABITAT AREAS WERE DRAWN BY MCMILLEN, LLC 2013.
3. THIS MAP PRESENTS DATA IN THE FOLLOWING GEOGRAPHIC SYSTEMS:
   - HORIZONTAL DATUM: NORTH AMERICAN DATUM 1983 (NAD 83)
   - VERTICAL DATUM: NORTH AMERICAN VERTICAL DATUM 1988 (NAVD 88)
   - PROJECTION: ALASKA 4 FIPS 5004 FEET STATE PLANE

REV | DATE | BY | DESCRIPTION

N

Drawing Scale: 0 150 300 600 Feet

MCMILLEN, LLC

Developed For: Homer Electric Association, Inc. A Touchstone Energy Cooperative

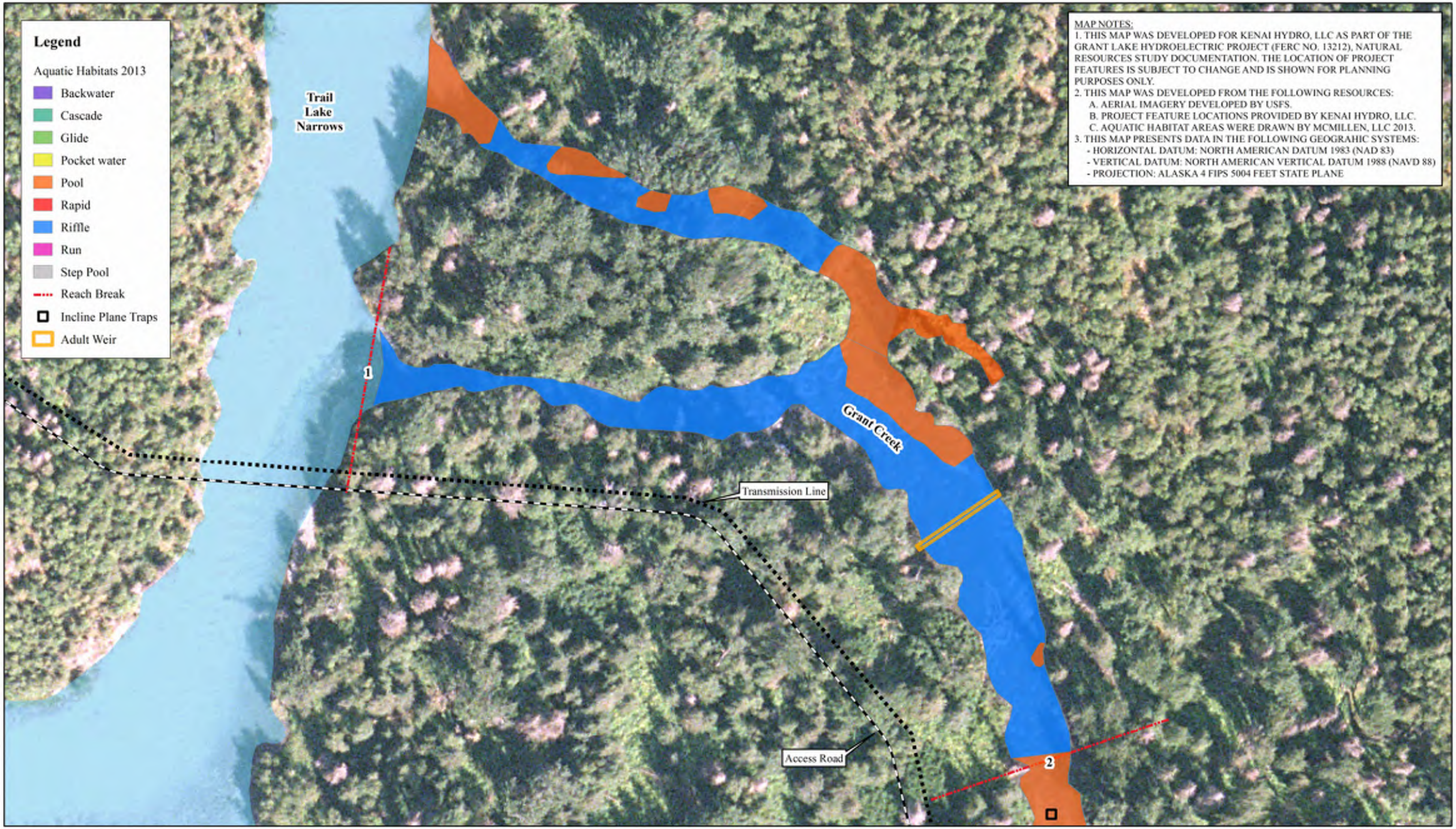
GRANT LAKE HYDROELECTRIC PROJECT - FERC PROJECT NO. 13212

GRANT LAKE NATURAL RESOURCES STUDY

Figure 3.1-1
Grant Creek Aquatic Habitats
Reaches 1 - 5

Designed: J. Woodbury
Drawn: J. Woodbury
Checked: M. Miller
Issued Date: 2/18/2014
Scale: 1:3,300

Drawing: 1 of 6



N

Drawing Scale: 0 25 50 100 Feet

MCMILLEN, LLC

Developed For: Homer Electric Association, Inc. A Touchstone Energy Cooperative

GRANT LAKE HYDROELECTRIC PROJECT - FERC PROJECT NO. 13212

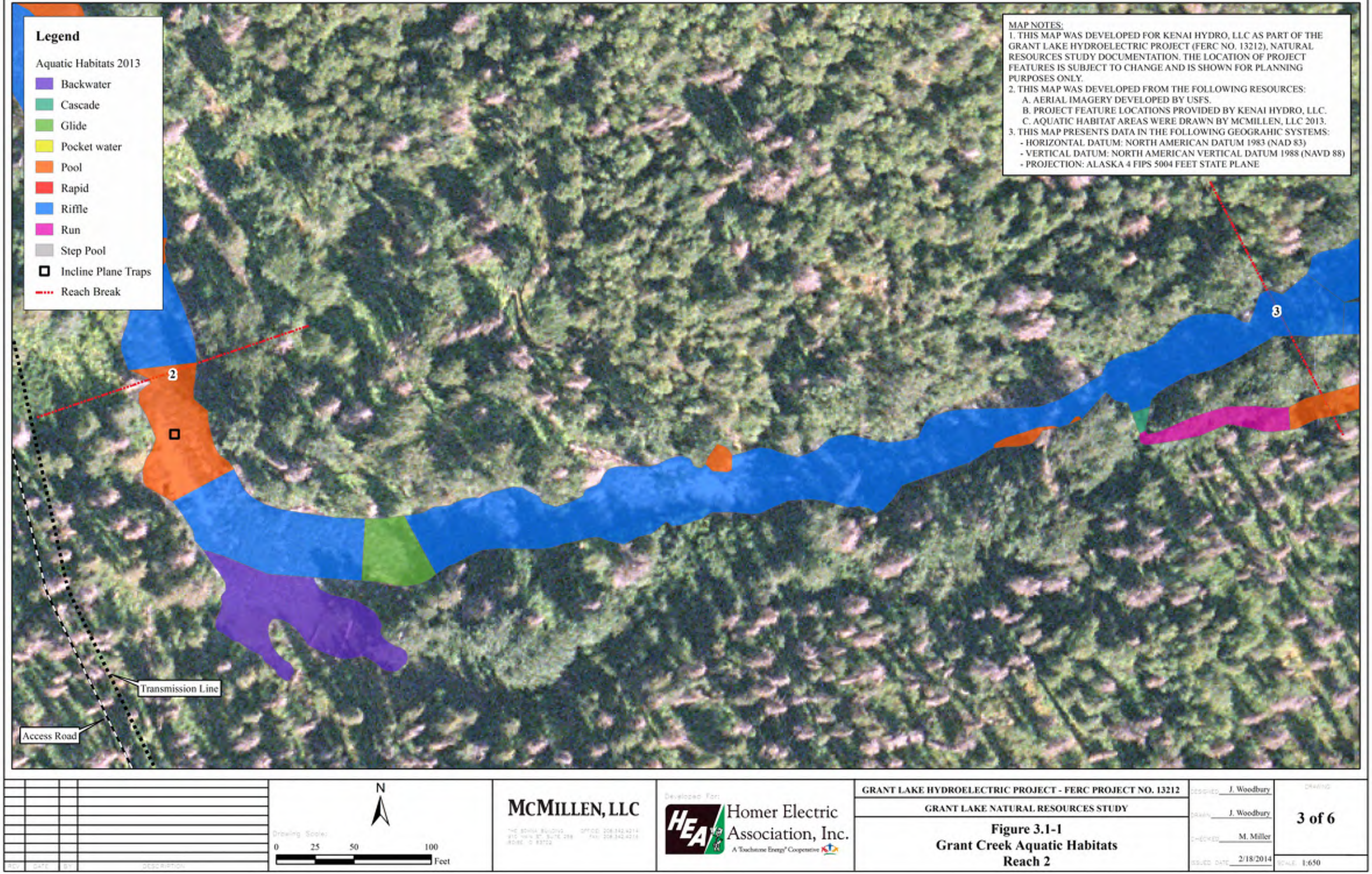
GRANT LAKE NATURAL RESOURCES STUDY

Figure 3.1-1
Grant Creek Aquatic Habitats
Reach 1

DESIGNED	J. Woodbury
DRAWN	J. Woodbury
CHECKED	M. Miller
ISSUED DATE	2/18/2014
SCALE	1:800

DRAWING 2 of 6

REV | DATE | BY | DESCRIPTION



REV DATE BY DESCRIPTION

MCMILLEN, LLC

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A Touchstone Energy Cooperative

GRANT LAKE HYDROELECTRIC PROJECT - FERC PROJECT NO. 13212

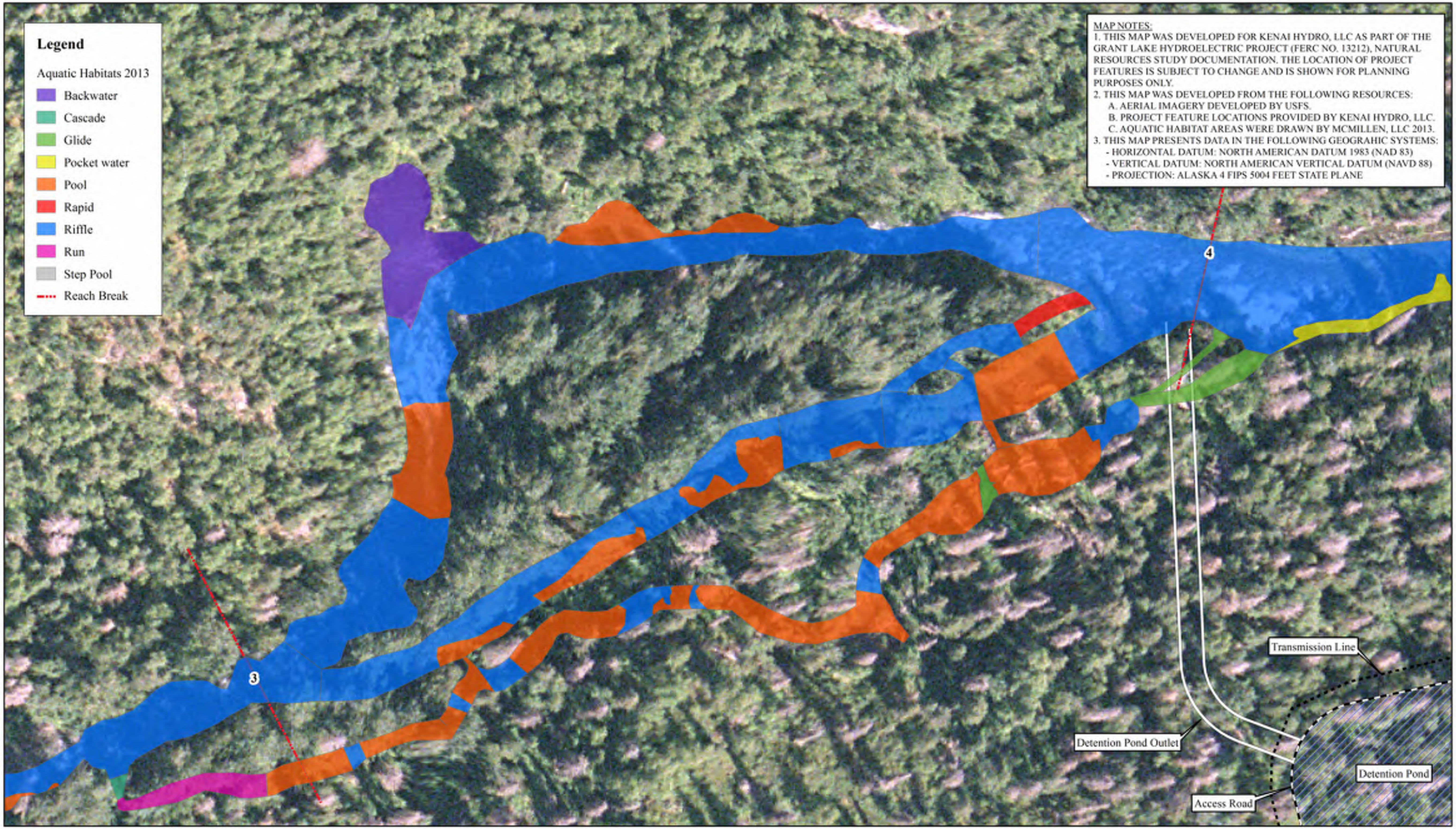
GRANT LAKE NATURAL RESOURCES STUDY

Figure 3.1-1
Grant Creek Aquatic Habitats
Reach 2

DESIGNED: J. Woodbury
DRAWN: J. Woodbury
CHECKED: M. Miller
ISSUED DATE: 2/18/2014

DRAWING
3 of 6

SCALE: 1:650



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GRANT LAKE HYDROELECTRIC PROJECT - FERC PROJECT NO. 13212

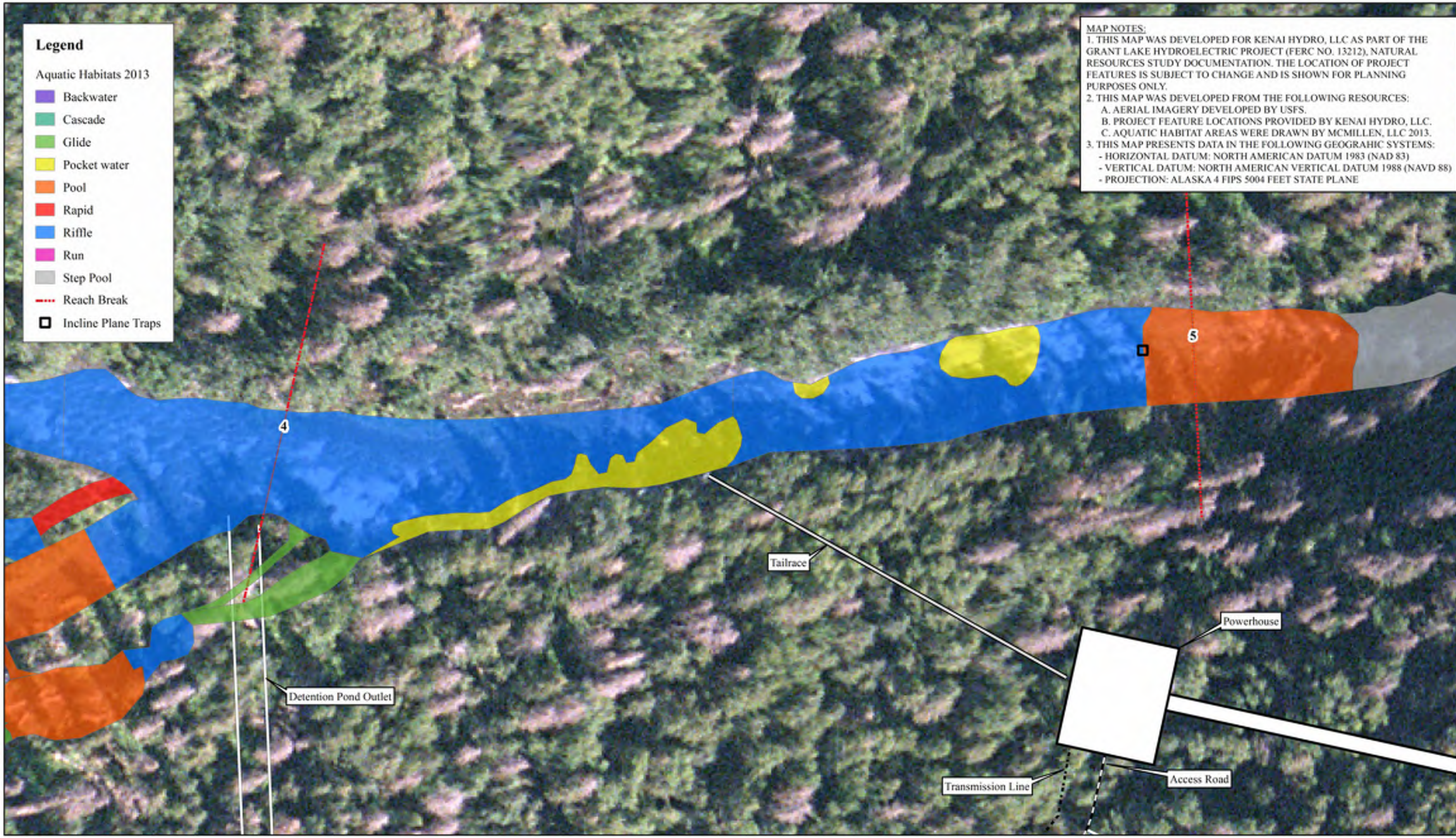
GRANT LAKE NATURAL RESOURCES STUDY

Figure 3.1-1
Grant Creek Aquatic Habitats
Reach 3

DESIGNED: J. Woodbury
DRAWN: J. Woodbury
CHECKED: M. Miller
ISSUED DATE: 2/18/2014

DRAWING: 4 of 6
SCALE: 1:700

REV | DATE | BY | DESCRIPTION



N

Drawing Scale:

0 25 50 100 Feet

MCMILLEN, LLC

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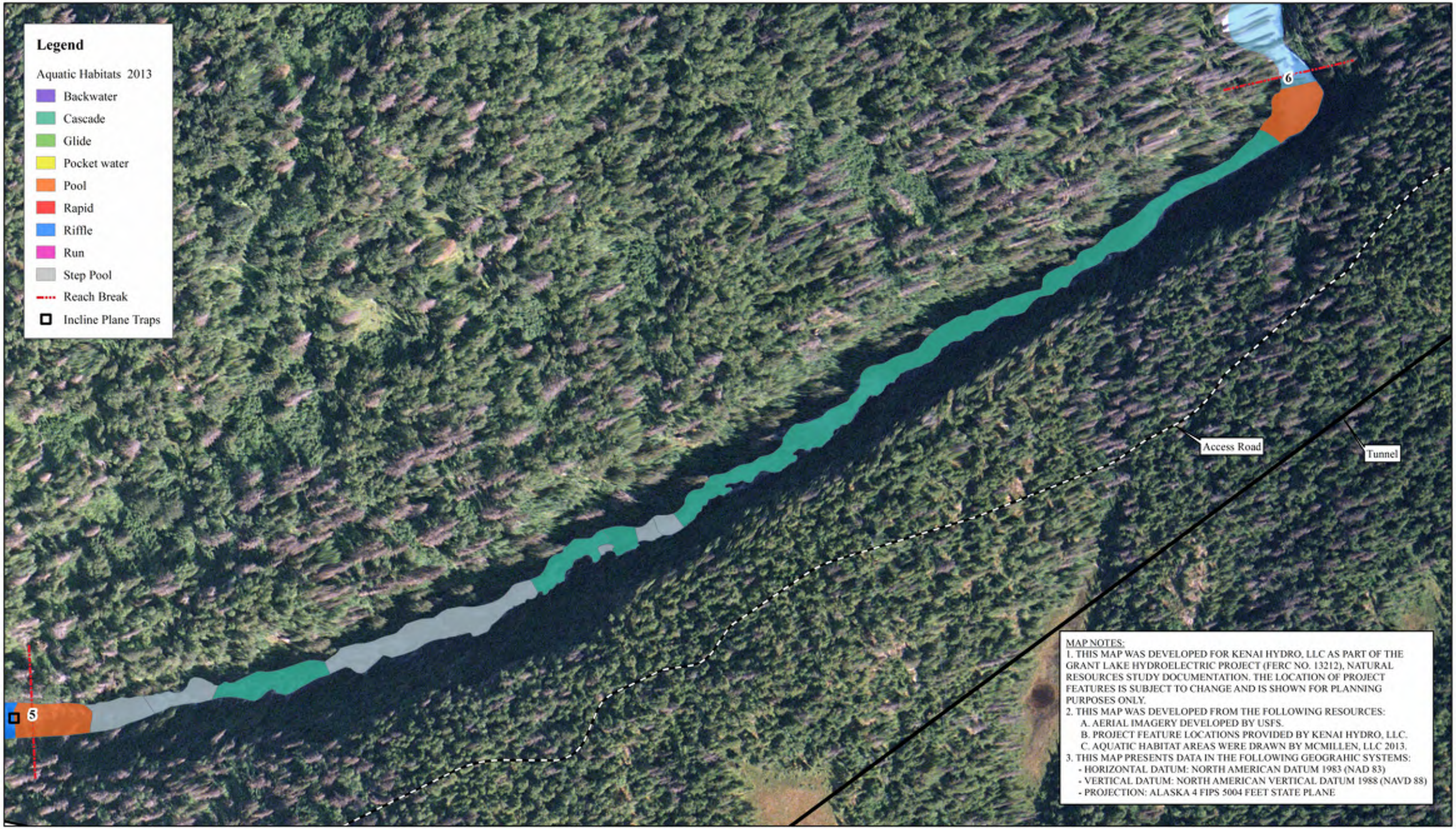
GRANT LAKE HYDROELECTRIC PROJECT - FERC PROJECT NO. 13212

GRANT LAKE NATURAL RESOURCES STUDY

Figure 3.1-1
Grant Creek Aquatic Habitats
Reach 4

DESIGNED	J. Woodbury
DRAWN	J. Woodbury
CHECKED	M. Miller
ISSUED DATE	2/18/2014
DRAWING	5 of 6
SCALE	1:550

REV DATE BY DESCRIPTION



N

Drawing Scale: 0 50 100 200 Feet

MCMILLEN, LLC

Developed For: Homer Electric Association, Inc. A Touchstone Energy Cooperative

GRANT LAKE HYDROELECTRIC PROJECT - FERC PROJECT NO. 13212

GRANT LAKE NATURAL RESOURCES STUDY

Figure 3.1-1
Grant Creek Aquatic Habitats
Reach 5

DESIGNED	J. Woodbury
DRAWN	J. Woodbury
CHECKED	M. Miller
ISSUED DATE	2/18/2014
DRAWING	6 of 6
SCALE	1:1,500

REV DATE BY DESCRIPTION

Reach 1, which extends approximately 0.125 miles upstream of the confluence of Grant Creek, includes a small distributary off the right bank. The distributary becomes watered when Grant Creek flows exceed 190 cfs (Figure 3.1-2). This channel consists of pools and riffles that provided habitat for juvenile salmonids, as well as some small pockets of spawning gravels. The mainstem portion of Reach 1 includes pool and riffle habitat at lower flows, but becomes more turbulent as flows increase. Reach 1 also contains suitable gravels and cobbles for salmonid spawning. Reach 1 contains some pool habitat for adult salmon staging.

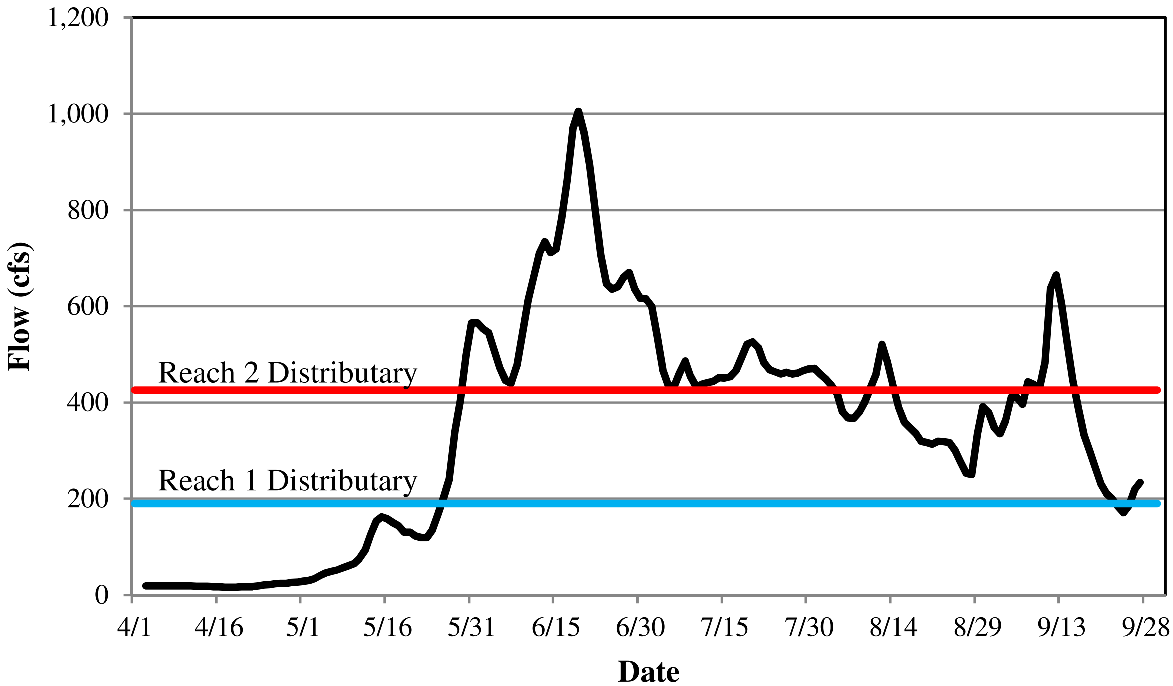


Figure 3.1-2. Grant Creek mean daily flows as measured at the Reach 3 gaging station, 2013. Flows at which the Reach 1 Distributary (190 cfs; blue line) and the Reach 2 Distributary (426 cfs; red line) begin to flow are depicted.

Reach 2 consists primarily of turbulent fast water riffle habitat, but does have some unique features. A small distributary branches from the mainstem just upstream from the Reach 1/2 break on the left bank. This channel flows through a parcel of private property and empties into Lower Trail Lake downstream of the Narrows. During its course, the channel splits into two channels at higher flows, which rejoin downstream. This channel contains a wide variety of habitat, including riffles, pools, glides, etc., and does have some smaller gravel deposits, which would be suitable for resident species spawning (i.e., rainbow trout and Dolly Varden). This channel is only watered when flows within the mainstem of Grant Creek exceed 425 cfs (Figure 3.1-2).

Upstream of this distributary within Reach 2, there are three backwater pools, which vary in size depending on flows. Another pool immediately upstream of the Reach 1/2 break was the location where the downstream incline plane trap was deployed, and contained both juvenile rearing habitat and suitable spawning gravels. These pool habitats were also used for adult salmon resting and staging.

Reach 3 contains the greatest habitat diversity of all reaches within the study area. As with all reaches, the mainstem consists primarily of turbulent fast water riffle habitat at higher flows. In addition to the mainstem, two additional channels exist within Reach 3. Both of these channels branch off the mainstem of Grant Creek on the left bank near the Reach 3/4 break. The larger of the two channels is situated between the mainstem of Grant Creek and the southernmost channel, and is referred to as the "Predominate Side Channel". This side channel consisted primarily of turbulent fast water riffle habitat, but does include a substantial log jam just downstream of its diversion that creates a dammed pool. The second channel consists of a wide variety of habitat, and includes riffles, glides and pools; this channel is referred to as the "Secondary Side Channel". Both channels provide rearing and spawning habitat, and become watered as soon as the snow and ice cover melt. In 2013, flow was observed in both channels when Reach 2 and 4 mainstem flows were measured at 17 cfs.

Within the mainstem of Grant Creek, two backwater pools on the right bank provide spawning habitat, adult staging, as well as juvenile rearing habitat. Downstream of those backwater pools, a large scour pool exists, which provides staging and spawning for adult salmon, as well as rearing for juveniles.

Reach 4 consists primarily of turbulent fast water riffle habitat at most flow levels. At higher flows, a small channel diverges off the right bank of the mainstem, and rejoins the mainstem channel downstream. At the upper portion of Reach 4, near the Reach 4/5 break, there is a scour pool. This pool was the location of the upper incline plan trap. While spawning gravel does exist within Reach 4, it is contained primarily in small pockets mainly downstream of large boulders, and along stream margins.

Reach 5, which is approximately 0.5 miles long, consists primarily of turbulent cascade and step pool habitat. During the majority of the study period, it was not possible to access much of Reach 5, and even at lower flows only the lower section of Reach 5 could be sampled. Likewise, access into the upper portion of Reach 5 was problematic. During the September minnow trap sampling period, the area immediately downstream of the falls was assessed using rappelling techniques. However, it was not possible to extend the sampling further downstream than the access point due to dangerous flow conditions.

3.2 Trail Lake Narrows

The Trail Lake Narrows is located between Upper and Lower Trail Lakes, and is where the Grant Creek confluence is located. The Narrows is also the location where the proposed access road will cross the Trail Lake system. Because of the potential impacts associated with the construction of the bridge and subsequent use of the access road on fish residing downstream of the bridge, this location was surveyed in July 2013. The survey area included the Narrows from the downstream edge of the Grant Creek confluence to the lower reaches of the channels flowing to both the right and left of the island located immediately below the Narrows, as well as the downstream shore of the island. Riffle habitat is dominant in this area from the confluence of

Grant Creek to almost the downstream end of the island. This area contains juvenile rearing habitat, spawning habitat and adult salmon staging habitat.

4 METHODS

During the course of the study, a number of methods were employed to accomplish the objectives outlined in Section 2. Juvenile sampling included the daily operation of two juvenile incline plane traps, monthly minnow trapping, snorkeling and beach seining. Adult sampling included the daily operation of an adult picket style weir, weekly radio telemetry tracking, redd surveys, visual surveys and carcass surveys. The remainder of this section will describe how each survey method was conducted, and how the data were used to address each study objective.

4.1 Grant Creek Salmon Spawning Distribution and Abundance

4.1.1 Salmon Escapement to Grant Creek

A weir was placed about 150 meters upstream of the Grant Creek confluence, and was designed, installed, and operated by Cook Inlet Aquaculture Association (CIAA). The weir was an A-frame picket design, which was situated perpendicular to the flow (Figure 4.1-1). One and a half meter long pickets were secured in place by two cross members (top and bottom) that were attached to the upstream side of each A-frame. The cross members contained holes that allowed pickets to be slid down until they rested on the stream bottom. Each picket could be removed for cleaning or the relocation of the adult trapping facilities, which was necessary as flow levels fluctuated. The gap between each picket was about 2.5 cm. Adult traps were placed on both sides of the weir to allow upstream and downstream movement past the weir. A work station and recovery/holding area were placed on the upstream side of the weir for biological sampling.

Figure 4.1-1. The A-frame weir used on Grant Creek to count adult salmon, rainbow trout and Dolly Varden in 2013.

The weir was checked every day, seven days per week by on-site staff living in a man camp on the shore of Grant Creek. Weir operations began on May 23, and the weir operated continuously except for the period from June 18 to June 22 when high flows (>969 cfs) required the removal of numerous pickets to maintain weir integrity. Installation of 3-meter pickets became necessary during high flows and their installation was complete on July 5 to replace shorter pickets first installed. Prior to the installation of the 3-meter pickets, especially during high flow, water and potentially fish could flow over the top of the weir. The weir was removed on October 24. Hourly counts typically occurred between the hours of 0800 and 2100 each day.

Upstream and downstream passage past the weir was compiled hourly and summed to document daily counts. Salmon escapement to Grant Creek was assessed as the sum of the daily counts for net upstream passage. While the operation of the weir provided a daily count of fish by species migrating upstream of the weir, it did not account for the number of fish that migrated into Grant Creek and resided and/or spawned downstream of the weir. To attain an estimate of total escapement within Grant Creek (both up and downstream of the weir), it was necessary to calculate escapement using the Area-Under-the-Curve methodology (Bue et al. 1998).

4.1.1.1 Escapement Estimate: Area-under the Curve (AUC)

There were three components required to estimate salmon escapement (Ê) to Grant Creek using area-under-the-curve methodology. The first component was to conduct systematic visual counts within the study area while salmon were present. The second component was to provide an estimate of the average time an individual salmon remained alive in the study area. This is commonly called stream or survey life ($\hat{S}$). The last component was an estimate of observer efficiency ($\hat{B}$). A secondary objective of this study component was to apply the estimates of stream life and observer efficiency estimated from Grant Creek in 2013 to visual counts in 2009.

To obtain an estimate of total escapement within Grant Creek (both up and downstream of the weir), it was necessary to calculate escapement using the Area-Under-the-Curve methodology (Bue et al. 1998), which is calculated as:

$$\hat{E} = \frac{\hat{A}}{\hat{S}\,\hat{B}}$$

Where:
$\hat{E}$ = is an estimate of Escapement;
$\hat{A}$ = is an estimate of Area-Under-the-Curve;
$\hat{S}$ = is an estimate of Stream Life; and
$\hat{B}$ = is an estimate of Observer Efficiency.

Area-under-the-curve ($\hat{A}$) was estimated using a trapezoidal approximation procedure similar to that described in English et al (1992),

$$\hat{A} = \sum_{i=2}^{n} \frac{(t_i - t_{i-1})(c_i + c_{i-1})}{2}$$

Where: $t_i =$ was the Julian date of the visual survey and
$c_i =$ was the visual count of salmon for the i^{th} survey.

4.1.1.1.1 Stream Life

Stream life was estimated for each species of interest (i.e., Chinook, sockeye, and coho) using Floy tags, radio tags and pooled data. It should be noted that all fish that were tagged with a radio transmitter were also tagged with a Floy tag. The estimate of stream life in this report is defined as the mean length of time between tagging at the weir and the time tags were recovered. The Floy tags used in this study were a T-bar anchor tags (model FD-94 Anchor Tags) that were individually numbered for all fish and colored for each species (Chinook-white, sockeye-yellow, coho-red). The unique number made it possible to calculate the span of time between tagging and the time of recovery. Floy tags were placed near the dorsal fin on the right side of the fish with a needle inserted into the body to anchor the tag (T-bar) through the dorsal fin ray. There were 33 Chinook, 533 sockeye, and 176 coho Floy tagged at the weir.

The radio tags used in this study were Lotek models MCFT2-3A and MCFT2-3B equipped with mortality switches that allowed researchers to identify dead fish. All anadromous salmonids that were radio-tagged were collected at the weir as they migrated upstream. A total of 14 frequencies in the 148 MHz range were used for the three species of anadromous salmonids and the two species of resident salmonids radio-tagged. To minimize the likelihood of signal collision, transmitters with four different burst rates (4.0, 4.5, 5.0, and 5.5 seconds between transmissions) were deployed. The transmitters emitted a different code sequence once the transmitter became stationary for 12 hours, as compared to the normal code sequence. This signal identified dead fish. All anadromous species were gastrically radio-tagged and resident species were surgically implanted with transmitters. Collectively, a total of 145 fish were radio-tagged; 9 Chinook, 65 sockeye, 50 coho, 20 rainbow trout, and 1 Dolly Varden.

4.1.1.1.2 Observer Efficiency

Observer efficiency was estimated from the relationship of visual survey counts to weir counts on Grant Creek. Observer efficiency was estimated by the slope of the linear fit of survey counts regressed against an adjusted weir count. The adjusted weir count was the cumulative weir counts by species on the days of visual surveys corrected for stream life and fish passage on the day of the visual survey. Like Bue (1998), the assumption was that the relationship between the estimated number of live salmon in a creek (independent variable-weir count) and survey counts (dependent variable) was linear, and observers would not see salmon in a creek when none were present (the fitted line passed through the origin).

4.1.1.1.3 Area-Under-the-Curve (Visual Surveys)

Visual surveys were used to document the number of live salmon in Grant Creek to estimate area-under-the-curve. Visual surveys were conducted on Grant Creek from the confluence of Trail Lake Narrows to about one half the way up the canyon in Reach 5. Visual counts in Grant Creek were segregated as counts above the weir and by counts downstream from the weir. Visual surveys were conducted every week (5-10 days) between the hours of 10:00-14:00 hours.

Attempts were made to keep survey conditions fairly uniform by hour of the day, weather, and stream conditions to make sure observer efficiency was not unduly affected. Visual counts were rescheduled if heavy rain, severe wind or stream conditions (flooding) precluded adequate survey conditions. Visual counts were conducted from the beginning of August until the end of the first week of November.

In August, a crew of two biologist wearing polarized sunglasses walked upstream on each bank of Grant Creek (total of 4 observers). The location of all observed fish was recorded on maps, with species and number counted. Later, when flows decreased (i.e., mid-September), it was possible at times to walk within Grant Creek at some locations during surveys.

4.1.1.1.4 Telemetry and Carcass Surveys

Mobile telemetry surveys and carcass surveys were an integral part of estimating escapement to Grant Creek and for collecting biological information. Telemetry surveys were performed twice per week, typically on Mondays and Thursdays. Fish locations were determined using standard triangulation techniques (Eiler 2012). Fish locations were recorded with Global Positioning System (GPS) waypoints and on maps of Grant Creek. During each survey, two receivers were used and the crews split the number of frequencies monitored. Splitting the number of frequencies monitored during a mobile survey helped to expedite the telemetry surveys.

Carcass surveys were performed each week but survey crews sampled fish opportunistically any time they traveled within the study area. At the time of carcass recovery, date, species, sex, location, and tag information were recorded. For females, eggs retained were noted and for all fish the tail was removed and the carcass returned to Grant Creek.

4.1.2 Life History Characteristics

Salmon were counted and sampled at the weir and carcass surveys were conducted to document the life history characteristics of spawning salmon in Grant Creek, 2013. Biological data needed to document run timing, sex ratios, egg retention, age structure, genetic stock identification and size (length and weight) were either collected at the weir or during carcass surveys. All fish counted at the weir were identified to species and enumerate. A subsample of the fish was sampled for specific data collection needs (biological data and tagging).

Run timing was determined by summing the number of fish passed the weir each week of the year. The start, peak and end of a particular salmon run on Grant Creek was simply the week when the first, greatest number and last fish passed the weir, respectively.

The sex ratio of all salmon except sockeye was determined from inspection of nearly 100 percent of the fish past the weir. For sockeye, the sample rate was lower (70 percent) to accommodate the greater abundance of fish at the weir. For anadromous salmon, gender was determined easily with a quick visual assessment of each fish.

Egg retention information was collected on spawned out female carcasses by inspecting the abdominal cavity and counting the number of eggs retained. Average egg retention was assessed by dividing the total number of eggs retained by the number of females assessed. Prespawn mortalities were noted but were presumed to have died before spawning; therefore, they were not included in the estimate.

Salmon collected at the weir were measured from mid-eye to fork length (mm) and weighed (gm) to describe the size of returning salmon to Grant Creek. Mean and standard deviations were generated for each species and gender.

Scale samples for Chinook and coho salmon were taken at the weir and delivered to the ADF&G for age determination. For sockeye salmon, otoliths were extracted from 100 sockeye salmon carcasses to prevent difficulties of age determination associated with scale reabsorption. Sockeye otoliths were delivered to CIAA for age determination. Two methods were used to describe age. The first method describes the total age of the fish (egg-to-spawning adult, i.e., gravel-to-gravel). The second method is termed the "European Method" and identifies the number of winters the fish spent in freshwater before migrating to the ocean as well as the number of winters the fish spent in the ocean. For example, a fish designated as 1.2 spent one winter in freshwater and two in the ocean. A fish designated as 0.3 migrated to the ocean in its first year and spent three winters in the ocean. Fish designated as 0.3 or 1.2 are considered 4-year-old fish, from the same brood year.

The axillary processes from 100 sockeye, 33 Chinook, and 100 coho salmon were removed and placed into vials for genetic analysis of returning salmon to Grant Creek. The tissue samples were delivered to ADF&G. Analysis of these samples is not contained within this report.

4.1.3 Distribution of Spawning Salmon in Grant Creek

The distribution of spawning salmon in Grant Creek was documented during spawning (redd) surveys and radio telemetry surveys. During redd surveys, the location and number of redds were recorded on maps of Grant Creek. For radio telemetry surveys, the location of tagged fish were also noted on maps of Grant Creek. The combination of both survey techniques is useful in defining spawning habitat especially when turbidity precludes observations of spawning in deeper water. The primary goal of these surveys was to identify sensitive spawning habitats in Grant Creek

Redd surveys were conducted weekly during the spawning period, and were similar to visual surveys in that crews hiked along the banks of Grant Creek, and recorded the locations of any redds observed. Given the high turbidity levels in Grant Creek during these surveys, most redds were located by first observing a fish, or observing digging activity. For all redds, the location and species in attendance were noted. At some locations where a large number of redds were constructed (i.e., spawning aggregates), it was difficult to identify individual redds. In such cases, the number of redds was estimated based upon data from past surveys, and the number of females defending redds.

Radio telemetry surveys were also employed to identify spawning locations. As discussed previously, telemetry surveys were conducted twice per week, and triangulation techniques were employed to identify the location of tagged fish. Since males often spawn with more than one female they could reveal multiple spawning locations within the study area. Females typically build and defend a single redd. The goal was to radio-tag three females for each male tagged.

The location of redds and tagged fish were compiled on maps and by reach and habitat type to describe the spawning distribution of salmon in Grant Creek.

4.2 Grant Creek Resident and Rearing Fish Abundance and Distribution

4.2.1 Adult Rainbow Trout Abundance, Distribution, and Spawning in Grant Creek

As with the anadromous species, the weir was the foundation of rainbow trout research in Grant Creek in 2013. The weir provided the opportunity to enumerate and capture rainbow trout for biological sampling and tagging. Biological sampling included length-weight and scales samples. Radio-tagged fish in turn provided information on spawning distribution and areas of feeding. Weir counts provided information on run timing and abundance. The abundance estimate for rainbow trout was assessed as total count of adult rainbow trout migrating upstream of the weir and run timing was simply the distribution of daily counts of rainbow migrating upstream past the weir.

Adult rainbow captured at the weir were assessed for spawning condition, and if determined to be active spawners and greater than 300 millimeters (mm) in length fork length (FL), they were surgically implanted with a radio-transmitter. Gender and spawning condition for rainbow trout and Dolly Varden was based on professional judgment of morphological characteristics (color, abdomen development, reproductive products, ovipositor extension, kype, etc.). For all fish, scale samples were collected in order to determine age, and each radio-tagged fish was tagged with a uniquely numbered Floy tag. Tagged fish were transported approximately 75 meters upstream, and released into a quiet cove located on the right bank to facilitate recovery. Rainbow trout captured at the weir were supplemented with fish captured through angling. Initially, the intent was to tag a total of 30 rainbow trout and 10 Dolly Varden. However, the weir did not become fully functional until early July when longer pickets were installed to preclude fish passage (both up and downstream) over the weir. Therefore, it was necessary to capture resident fish through angling efforts.

Radio-tagged trout were tracked twice per week for the duration of the study period, and their location at the time of detection was determined using triangulation techniques. Those positions were recorded on maps of the study area.

Redd surveys for rainbow trout were conducted at least once per week following the method described previously for anadromous species. Researchers also checked opportunistically as they were in the study area at least 5 days a week.

4.2.2 Resident and Rearing Fish Use of Reach 5

Due to the nearly vertical walls, steep gradient, and high flows within Reach 5, assessment of resident and rearing fish use of this area was challenging. Sampling techniques that could be conducted throughout the study period included minnow trapping and radio telemetry surveys. Telemetry surveys could be conducted from the top of the canyon wall, which allowed the survey of all of Reach 5. Minnow trapping was limited to the lower and upper portions of Reach

5, with the upper section accessed through rappelling. Snorkeling was conducted early in the study period (April and May), and was limited to the lower third of the canyon. Due to the substrate in Reach 5, which consists primarily of large boulders, beach seining was not conducted within this portion of Grant Creek.

In order to assess the use of Reach 5 by juvenile rearing fish, an incline plane trap was deployed at the Reach 4/5 break to identify and enumerate juvenile salmonids as they migrated downstream and out of Reach 5.

The juvenile incline plane trap was located in a scour pool immediately downstream of the Reach 4/5 break, and was operated seven days per week, 24 hours per day unless either high flows or debris load made operations either ineffective or too dangerous to operate. The trap was cleaned at least twice per day and more frequently when debris became an issue. All fish collected at the trap were removed from the live box using aquarium nets and transferred to a 18.9-liter bucket for transfer to the processing station located on the left bank. Fish were then anesthetized in a mixture of clove oil and water (6 drops of clove oil per 3.8 liters of water), measured (to the nearest millimeter), and weighed (to the nearest tenth of a gram), and then recovered in fresh water. Fish were held until equilibrium was achieved, and were then released into a low flow area within Reach 4 of Grant Creek.

Initially, the study objective was to estimate relative abundance of various salmonid juveniles within Reach 5 using the incline plane trap; that is, if sufficient numbers were captured to conduct efficiency trials of the trap, and in turn use a Petersen equation to estimate overall abundance. However, it was known from previous research (HDR 2009b) that it was unlikely that sufficient numbers of juveniles migrating downstream and out of Reach 5 would be captured to estimate abundance. While marking and release protocols were developed and ready for use, relatively few fish were captured during the study period. Furthermore, due to high flows during the period of May 30 to September 19, trapping operations were terminated due to the risk of the trap breaking free from its moorings, the risk of death and injury to captured fish, poor trapping conditions, and the danger to the field personnel when accessing the trap. As such, the focus of the incline plane trap once it was re-installed was to simply establish presence and enumerate the various species collected in the trap, and to collect weight and length data.

In addition to the incline plane trap, minnow trapping and snorkeling were utilized to determine rearing fish use of Reach 5. Due to the high flows described previously, snorkeling within Reach 5 was only possible in April and in May. Snorkel sites were selected based on likelihood of juvenile rearing. Snorkel sites typically encompassed an entire habitat unit; that is, if the site was within a pool, the entire pool was snorkeled unless the habitat unit exceeded 100 meters in length, in which case a sub-sample of the habitat unit was evaluated. The number of individuals snorkeling a given site was dependent on the size of the snorkel site, but was typically two individuals. All sample sites were measured, which included length and at least one width, and more if the stream width was highly variable. Measurements were used to calculate area to provide a density metric for comparisons between sites and reaches. All fish observed during the snorkel surveys were classified by species and categorized into 20 mm length bins. To ensure accuracy, snorkelers called out data, which was recorded by an individual on shore. Due to the cold water temperatures in April and May (0.5° C in April, and 4.0° C in May), all snorkeling occurred at night since juvenile fish were not active during daylight hours.

Minnow trapping was conducted monthly from April through October. Minnow trap locations throughout the study period were representative of habitats available to rearing salmonids. In some cases, suitable habitat could not be sampled simply due to access (Reach 5). However, during the course of the study, a total of 330 minnow traps were deployed within Grant Creek.

Minnow traps were constructed with 6.4 mm galvanized square wire mesh, and were approximately 40.6 cm long, 22.9 cm wide, with a 2.2 cm entrance at each end of the trap. At the time of deployment, a 16.4 cubic centimeter mass of cured and sterilized salmon eggs was placed in a PVC tube approximately 2.5 cm in diameter and approximately 7.6 cm long, with bait mesh stretched over each end and secured with rubber bands as an attractant. In addition to the bait tube, a river rock was placed into the trap to help weigh it down. The trap was then placed into the desired location parallel to flow, and was secured to shore with a length of parachute cord.

At the time of deployment, characteristics of the site were recorded, which included:

- The minnow trap number (every minnow trap set had a unique and sequential number);
- Habitat type (e.g., turbulent fast water riffle);
- General position within the channel (i.e., right bank, center, or left bank);
- Presence of large or small woody debris, overhead vegetation, or if there was an undercut bank;
- The time the trap was set; and
- The unique GPS waypoint.

Traps typically fished 24 hours before they were processed. At the time of processing, fish were placed into an 18.9-liter bucket for transport from the minnow trap site to the processing station. Fish were placed into a solution of water and clove oil (6 drops per 3.8 liters of water). Once anesthetized, fish were identified to species, and were measured (nearest millimeter) and weighed (to the nearest tenth of a gram). Fish were then placed into a 18.9-liter bucket of fresh water and allowed to recover before being released in the general area of capture.

A fixed-site telemetry station and mobile telemetry surveys were used to assess the use of Reach 5 by adult resident fish. As discussed previously, a total of 20 adult rainbow trout and 1 Dolly Varden were surgically implanted with digitally encoded transmitters. Telemetry surveys occurred twice per week, and were conducted as far upstream into Reach 5 along the left bank as possible. Additional surveys were conducted from the canyon rim from the right bank as necessary. If a tagged fish was detected within Reach 5, it was tracked until its position could be determined using triangulation techniques. In addition to mobile surveys, a fixed-antenna system was installed.

The fixed-antenna system consisted of two underwater antenna arrays, the downstream array at the Reach 4/5 break and the other array approximately 25 meters upstream. Underwater telemetry systems were used in lieu of aerial systems to minimize the likelihood of signal bounce due to the canyon walls, and to reduce the detection range so that fish entry into Reach 5 could be determined. Each array consisted of 4 bared coaxial antennas that were evenly spaced along a steel cable, which was secured to each shoreline and weighted down so that the antennas were on the bottom of Grant Creek. The four antennas were combined with a 4-way combiner, which was then amplified and the signal transmitted via coaxial cable to a Lotek SRX/DSP receiving system. Each antenna array was attenuated so as to balance the system to provide equal signal reception with the transmitter an equidistant from each antenna array (Evans and Stevenson 2012). Each antenna array was monitored independent of the other, so that it was possible to determine when a tagged fish moved upstream into Reach 5, the direction of travel, and when a tagged fish migrated downstream of Reach 5. Each antenna array had a detection range of approximately 15 meters.

4.2.3 Resident and Rearing Fish Use of Open Water Habitats in Lower Grant Creek

Assessment of use by resident and rearing fish in lower Grant Creek was accomplished with the same suite of techniques as in Reach 5. That is, radio telemetry was used to determine movement and feeding habitat of adult rainbow trout; and juvenile use was assessed using an incline plane trap, minnow trapping, and snorkeling. In addition, beach seining was also used to assess juvenile resident and rearing fish use of Reaches 1-4.

To identify potential feeding and spawning habitat of adult rainbow trout, methods were employed as discussed above. That is, mobile surveys were conducted twice per week, and all locations were determined using triangulation techniques, which were recorded on maps.

The incline plane trap was located within a scour pool immediately upstream of the Reach 1/2 break. The purpose of this trap was to intercept juvenile salmonids migrating downstream within Grant Creek. The intent of deploying two traps; one at the bottom of Reach 5, and the other as close as possible to the Grant Creek confluence was to estimate relative abundance within Reach 5, and the Reach 1-4 sections of Grant Creek separately. As discussed, it was not possible to fish the upper trap for the better portion of the study period, so it was not possible to determine juvenile use of Reaches 1-4 exclusively. However, the continuous operation of the lower trap did allow abundance above that trap (including Reach 5) to be estimated. To do so, it was necessary to conduct efficiency trials of the lower trap. To estimate efficiency, captured juveniles were marked using a Bismark Brown dye solution (0.4 gm/18.9 liters of water) for 30 minutes, and then released upstream of the trap. Recapture rates were then calculated for each species of juveniles. Operation of the incline plane trap was conducted 24 hours per day, seven days per week. The exception to this protocol was when either high flows or debris load made operations either ineffective or too dangerous to operate the trap.

To estimate abundance within Reaches 1-5, we used a season-wide estimator that accounts for trap efficiency, data gaps due to trap outages, and provides estimates of standard error. The season-wide estimator of total juvenile abundance $\left(\overset{*}{N}\right)$ is the sum of estimated abundance when the index counts at the incline plane trap are present $(\tilde{N})$ and during periods when such data are missing$\left(\hat{N}_j\right)$, i.e.,

$$\overset{*}{N} = \tilde{N} + \sum_{j=1}^{k} \hat{N}_j$$

Where:

k = number of missing trap index count events during the season.

A detailed description of the calculations used to estimate juvenile abundance is presented in Appendix 1 (Skalski and Townsend 2014).

Scatter plots and line graphs were used to describe the size and time of emigration for juvenile salmonids captured in the lower incline plane trap on Grant Creek. Fork length (mm) and weight (0.2 grams resolution) of nearly all juvenile fish were taken to document the size of downstream migrants. The date of capture documented the time of emigration and helped to identify periods of downstream migration and movement. The size and time of emigration provided some insight into the basic life history of juvenile fish in Grant Creek.

Minnow trapping and snorkeling were conducted as described in Section 4.2.2, and will therefore not be discussed here. Beach seining was also employed within several sites in Reaches 1-4. However, due to the large and irregular substrate, seining was only partially effective and was abandoned as a means to sample juvenile fish in Grant Creek. Numbers of fish captured with beach seining are not reported for Grant Creek because of limited success. Beach seining was successfully used in the Trail Lake Narrows in areas of smaller substrate.

4.3 Trail Lake Narrows Fish and Aquatic Habitats

The Trail Lake Narrows was sampled to determine species diversity and relative abundance. The Narrows was sampled from the downstream margin of the Grant Creek confluence to the downstream margin of the island immediately below the Narrows, and included both channels on each side of the island. Angling was the only means of assessing adult salmonid (rainbow and Dolly Varden) presence, and was conducted during a single day in July. A total of seven angling stations were used and were selected to represent the area of potential impact associated with the installation and use of an access road into the Study Area. On July 17, 2013, two personnel fished each angling station for 30 minutes, and recorded both fish captured, and fish that were hooked but not landed. Captured fish were identified as to species, and length (mm) and weight (grams to the nearest tenth of a gram) were recorded. For fish that were hooked but not landed, species and an estimate of length were noted when possible.

To assess juvenile presence and relative abundance, minnow trapping and beach seining were used in the Trail Lake Narrows area. Snorkeling was not possible because of high turbidity (i.e., poor visibility). Over the course of a week, a total of 52 minnow traps were deployed (13 set locations with a total of 4 traps per set). As with all minnow trapping efforts, traps fished for about 24 hours, and a description of the location was recorded. Beach seining occurred the night of July 23 and a total of three sites were seined. Three seines were composited at each location and typically occurred where fine gravel and sand were present. Beach seining was based on the methodology described in Hahn et al. (2007). A 15.2-m long, 0.6-cm mesh beach seine with a bottom lead line and an upper cork line was used. One crew member would wade into the water at the selected site with the net attached to a 1.5-m pole, all the time keeping the bottom of the net on the stream bottom. The second individual would unspool netting from the stream edge from a second 1.5-m pole in order to keep it somewhat taught as the first individual encompassed the desired area. Once the sample area had been enclosed, both individuals moved towards each other along the bank margin trapping fish within the seine. Fish from minnow traps and beach seines were transferred to an 18.9-L bucket where they were anesthetized in a clove oil solution (6 drops per 3.8 L of water). Fish were enumerated by species, measured (to the nearest millimeter), weighed (to the nearest tenth of a gram) and then allowed to recover in a bucket of fresh water. Once equilibrium was achieved, fish were released back into the general area of capture.

5 RESULTS

In the sections that follow, the results of field collection efforts accomplished on Grant Creek in 2013 are presented.

5.1 Grant Creek Salmon Spawning Distribution and Abundance

To assess the abundance and distribution of spawning salmon, fish were enumerated at the weir to estimate spawning escapement, while redd surveys and radio telemetry surveys documented the distribution of spawning.

5.1.1 Salmon Escapement to Grant Creek – Relative Species Abundance

As discussed in Section 4.1.1, a weir was placed in Reach 1 of Grant Creek to intercept, count and sample adult salmonids migrating upstream. Daily fish counts were used to estimate run timing and provided an overall estimate of escapement to Grant Creek. Some fish intercepted at the weir were sampled to obtain estimates of age structure, length, weight, and to secure genetics samples for the ADF&G. The weir also allowed researchers to Floy tag and radio tag adult salmonids. Genetic samples were delivered to ADF&G but those analyses will not be presented in this report.

5.1.1.1 Weir Count

There were 1,439 salmon that passed upstream of the weir on Grant Creek while 52 of those salmon passed back downstream of the weir for a net passage of 1,387 salmon (Table 5.1-1). Sockeye salmon were the dominant run of salmon entering Grant Creek with 1,117 counted above the weir. There were 10 pink, 23 Chinook and 237 coho salmon counted above the weir. The net passage of salmon across the weir does not include salmon that entered and potentially spawned in Grant Creek downstream from the weir.

In the next section, total spawning escapement was assessed using area-under-the-curve methodology to provide total spawning escapement to Grant Creek in 2013.

Table 5.1-1. Upstream, downstream and net passage of pink, Chinook, sockeye and coho salmon across the weir in Grant Creek, 2013.

Species	Upstream Passage	Downstream Passage	Net Passage
Pink Salmon	12	2	10
Chinook Salmon	35	12	23
Sockeye Salmon	1,153	36	1,117
Coho Salmon	239	2	237
Total	1,439	52	1,387

5.1.1.2 Escapement Estimate: Area under the curve (AUC)

Several different surveys (i.e., visual, telemetry and carcass) were performed on Grant Creek to estimate escapement with the area under the curve methodology (Bue 1998). The information documents estimates for stream life, observer efficiency, and escapement for 2013 and 2009 (recalibrated count).

5.1.1.2.1 Stream Life

Stream life was estimated as the mean of the pooled recovery of Floy tagged and radio tagged salmon in Grant Creek. The pooled information was used because radio tags alone did not adequately cover the entire passage distribution of fish across the weir. Tag schedules for the salmon migration to Grant Creek were based on visual surveys conducted in 2009 for Chinook and sockeye. In 2009, the peak visual counts for Chinook and sockeye occurred the third week of August and second week of September, respectively. Peak counts of Chinook and sockeye occurred 1-2 weeks earlier in 2013. There was little information on the run timing of coho salmon. The pooled data provided a better estimate of stream life particularly for fish earlier in the run for sockeye and later in the run for coho salmon.

Stream life estimates are provided for pooled data, radio tags only and Floy tags only. Mean stream life for the pooled data for Chinook, sockeye and coho salmon was 11 days, 14 days and 16 days, respectively (Table 5.1-2). Stream life was different for the two tags employed, but the mean stream life from radio tags was consistently 4-6 days less than that estimated from Floy tags.

Table 5.1-2. Stream life estimates for the combined recovery of Floy tagged and radio tagged Chinook, sockeye and coho salmon in Grant Creek, 2013.

Species	Tagged	Recovered	Percent Recovered	Stream Life			
				Mean	SD	Min	Max
Combined Recovery							
Chinook	33	14	42	11	6.2	4	22
Sockeye	533	195	37	14	5.9	2	30
Coho	176	77	44	16	5.9	1	37
Radio Tags Only							
Chinook	9	7	78	8	3.9	4	14
Sockeye	65	40	62	9	2.6	2	15
Coho	50	32	64	14	4.6	1	22
Floy Tags Only							
Chinook	33	7	21	13	7.5	4	22
Sockeye	533	155	33	15	5.8	4	30
Coho	176	45	26	18	6.3	8	37

5.1.1.2.2 Observer Efficiency

Observer efficiency was estimated from the relationship of visual survey counts to weir counts on Grant Creek. Because salmon die periodically throughout the spawning season, an adjustment was made to the cumulative weir count to adjust for mortality. The mean stream life estimated from salmon in Grant Creek was applied to the cumulative count to account for mortality. The count was also adjusted to correct for fish passage on the date and time of the visual survey.

By way of example, on August 29 the cumulative weir count for sockeye salmon passed the weir was 720 fish (Table 5.1-3). To adjust the cumulative weir count on that date for stream life, we subtracted the cumulative weir count of sockeye that had passed the weir 14 days prior (August 15). The cumulative count of sockeye 14 days prior was 15 fish. The adjusted count was 705 fish (720-15=705). The weir count was also adjusted by 99 fish on the date of the visual survey because those fish had not passed the weir by the time the visual survey was conducted. The final adjusted weir count equaled 606 sockeye (705-99=606). During the visual survey on August 29, 442 sockeye were observed above the weir on Grant Creek. Therefore, the observer efficiency for the August 29 visual survey for sockeye was 72.9 percent (442/606).

Table 5.1-3. Cumulative weir counts for sockeye adjusted for a stream life of 14 days and for fish passage at the weir on dates of visual surveys.

Date	Cumulative Weir Count	Adjusted for Stream Life (14 days)	Fish passage adjusted for time of day	Adjusted Weir Count	Visual Counts
8/2/2013	0	0	0	0	0
8/9/2013	8	0	0	8	2
8/16/2013	15	5	4	6	3
8/23/2013	169	8	35	126	85
8/29/2013	720	15	99	606	442
9/6/2013	1,021	244	13	764	543
9/16/2013	1,115	933	1	181	211
9/21/2013	1,115	1,061	0	54	52
9/28/2013	1,115	1,111	0	4	2
10/4/2013	1,116	1,115	0	1	0
10/10/2013	1,117	1,115	0	3	1

During visual surveys, observers typically underestimated the number of live salmon in Grant Creek. The plots of visual counts to adjusted weir counts revealed strong linear relationships for salmon in Grant Creek (Figure 5.1-1). Observer efficiency (slope of the line) was 0.60 for Chinook, 0.72 for sockeye, and 0.75 for coho. The trend in observer efficiency for salmon in Grant Creek fit our general expectations. For Chinook, we expected the lowest observer efficiency because they remained in deeper, faster waters during higher flows making them the most difficult to observe. In general, sockeye remained near the stream banks in shallower water making them easier to see than Chinook. For coho salmon, observations during stream surveys were more favorable because of reduced flow and better water clarity.

Stream life and observer efficiency estimates for salmon in Grant Creek were used to estimate total escapement to Grant Creek and as a comparison to the weir count. Stream life and observer efficiency estimates were also applied to calculations of area-under-the-curve estimates for Chinook and sockeye provided in the 2009 escapement (HDR 2009b). In the 2009 escapement estimates, outside literature sources and professional judgment were used to estimate both stream life and observer efficiency. No escapement estimates for coho in Grant Creek were provided in 2009.

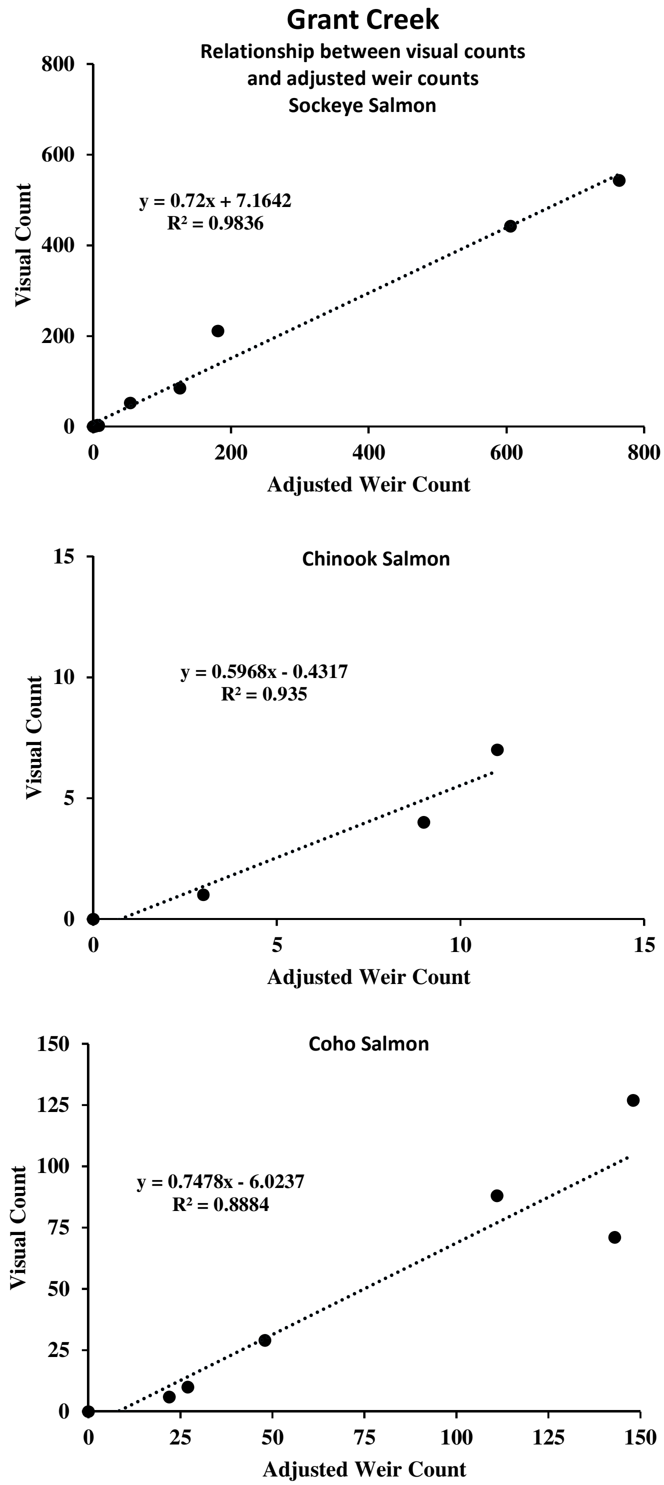


Figure 5.1-1. Observer efficiency relationships for sockeye, Chinook and coho salmon in Grant Creek, 2013.

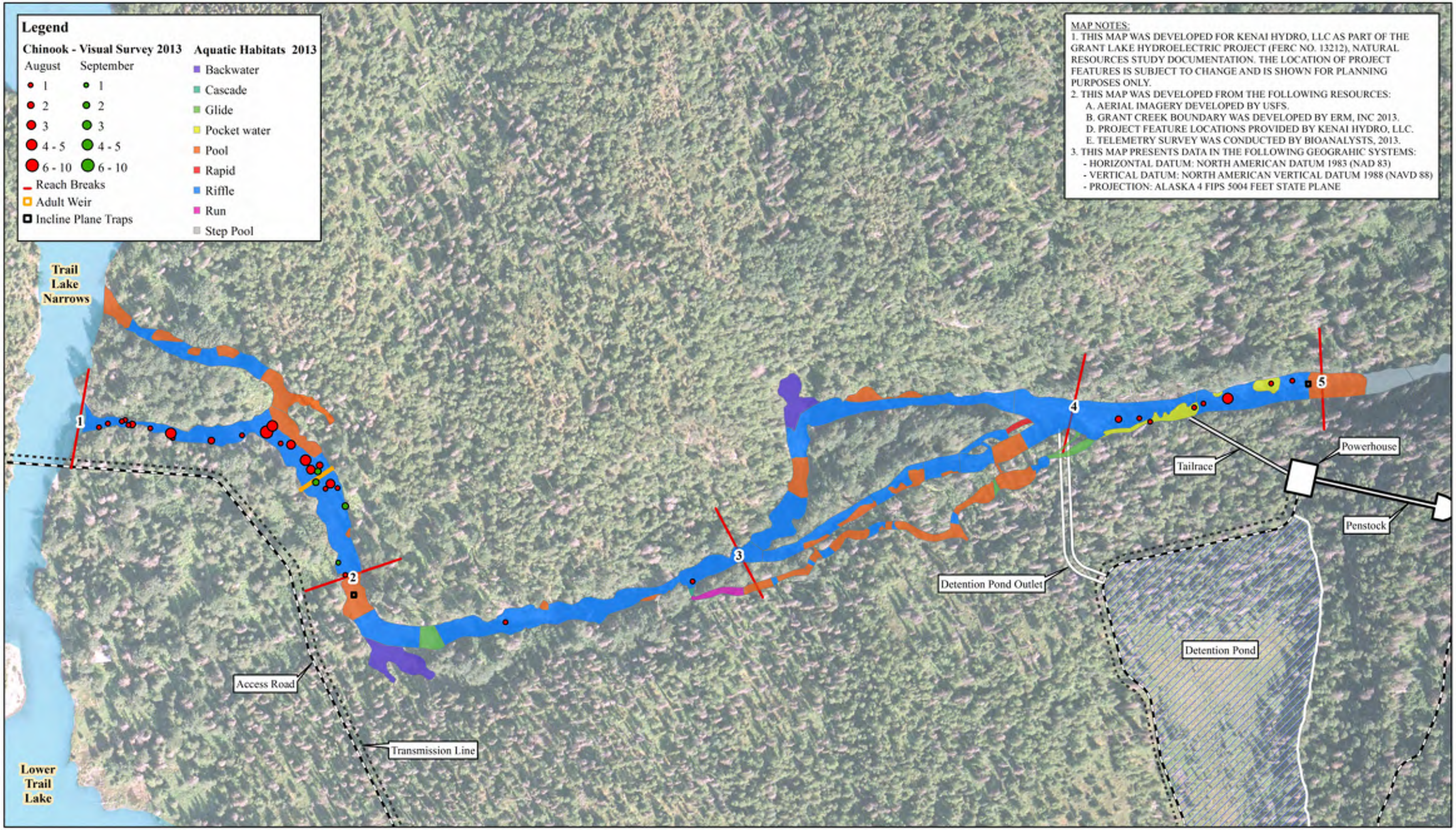
5.1.1.2.3 Estimated Escapement: AUC

In this section, two escapement estimates are provided for Grant Creek based on visual counts. The first estimate is the estimated escapement above the weir and the second estimate is for the entire stream. Visual counts were conducted from the beginning of August until the end of the first week of November (Table 5.1-4; Figures 5.1-2, 5.1-3 and 5.1-4). Visual counts were separated as "below weir" and "above weir" during each survey to make direct comparisons to the total escapement above the weir. Plots of area-under-the-curve estimated for Chinook, sockeye and coho salmon are presented in Figure 5.1-5.

Peak visual counts (above the weir) for Chinook, sockeye and coho salmon occurred on August 28, September 6 and October 10, 2013, respectively. It should also be noted that three coho were observed on the last visual survey on November 7. It was assumed that by the next week no coho would be observed in Grant Creek and if there were any remaining fish it would have a minor effect on AUC estimates.

Table 5.1-4. Visual counts of sockeye, Chinook and coho salmon above and below the weir in Grant Creek, 2013.

Date	Day of Year	Sockeye		Chinook		Coho	
		Below Weir	Above Weir	Below Weir	Above Weir	Below Weir	Above Weir
8/2/2013	214	0	0	0	0	0	0
8/9/2013	221	0	2	0	0	0	0
8/16/2013	228	8	3	14	1	0	0
8/23/2013	235	43	85	22	6	0	0
8/29/2013	241	59	442	19	11	0	0
9/6/2013	249	45	543	2	4	0	0
9/16/2013	259	12	211	0	0	0	6
9/21/2013	264	10	52	0	0	0	10
9/28/2013	271	0	2	0	0	14	29
10/4/2013	277	0	0	0	0	7	71
10/10/2013	283	0	1	0	0	8	127
10/18/2013	291	0	0	0	0	4	88
10/24/2013	297	0	0	0	0	3	63
11/1/2013	305	0	0	0	0	2	12
11/7/2013	311	0	0	0	0	1	2



REV	DATE	BY	DESCRIPTION

N

Drawing Scale:

0 100 200 400 Feet

MCMILLEN, LLC

Developed For:

Homer Electric Association, Inc.

A Touchstone Energy® Cooperative

GRANT LAKE HYDROELECTRIC PROJECT - FERC PROJECT NO. 13212

GRANT LAKE NATURAL RESOURCES STUDY

Figure 5.1-2
Visual Surveys
Chinook Salmon

DESIGNED J. Woodbury

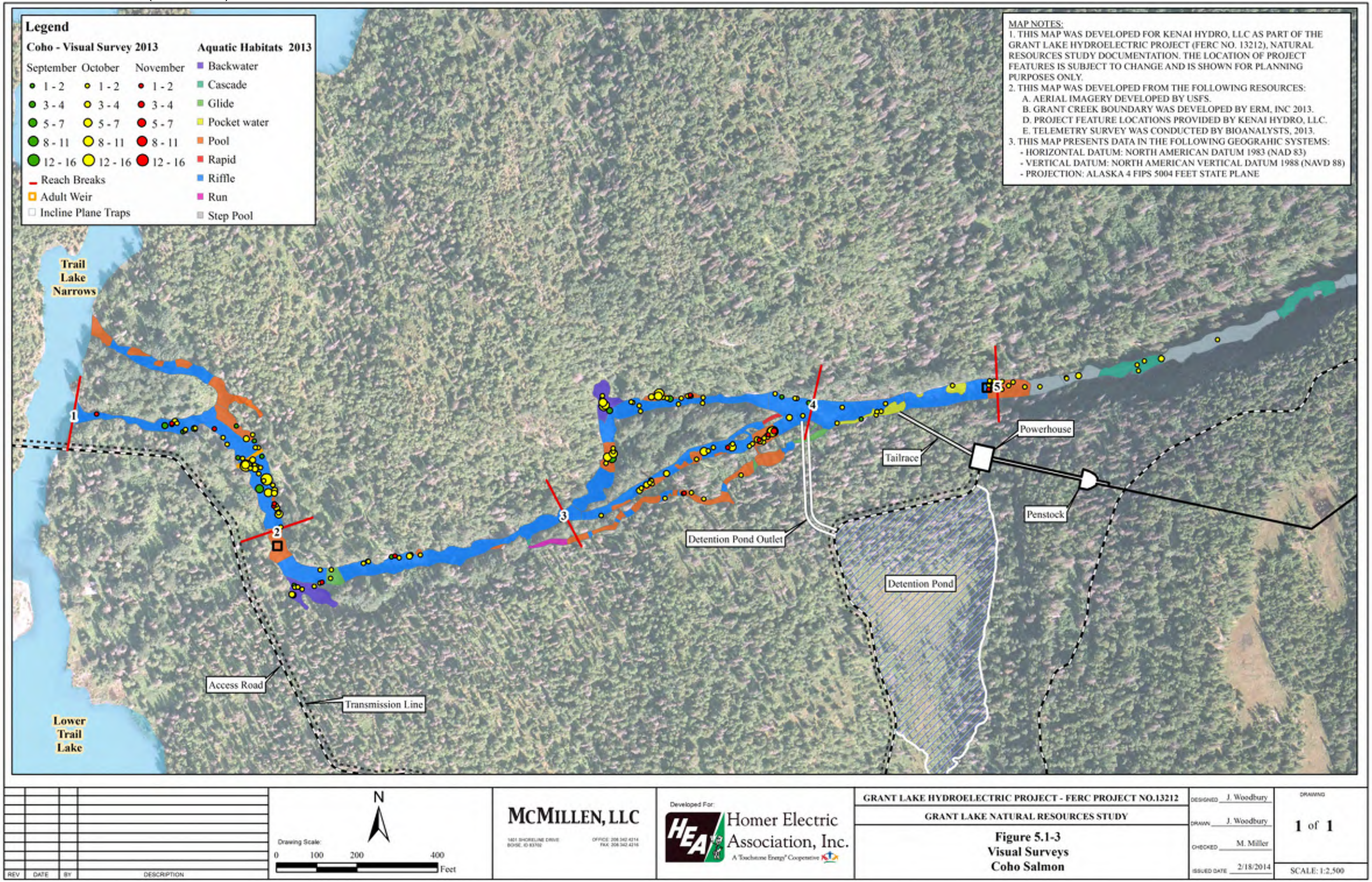
DRAWN J. Woodbury

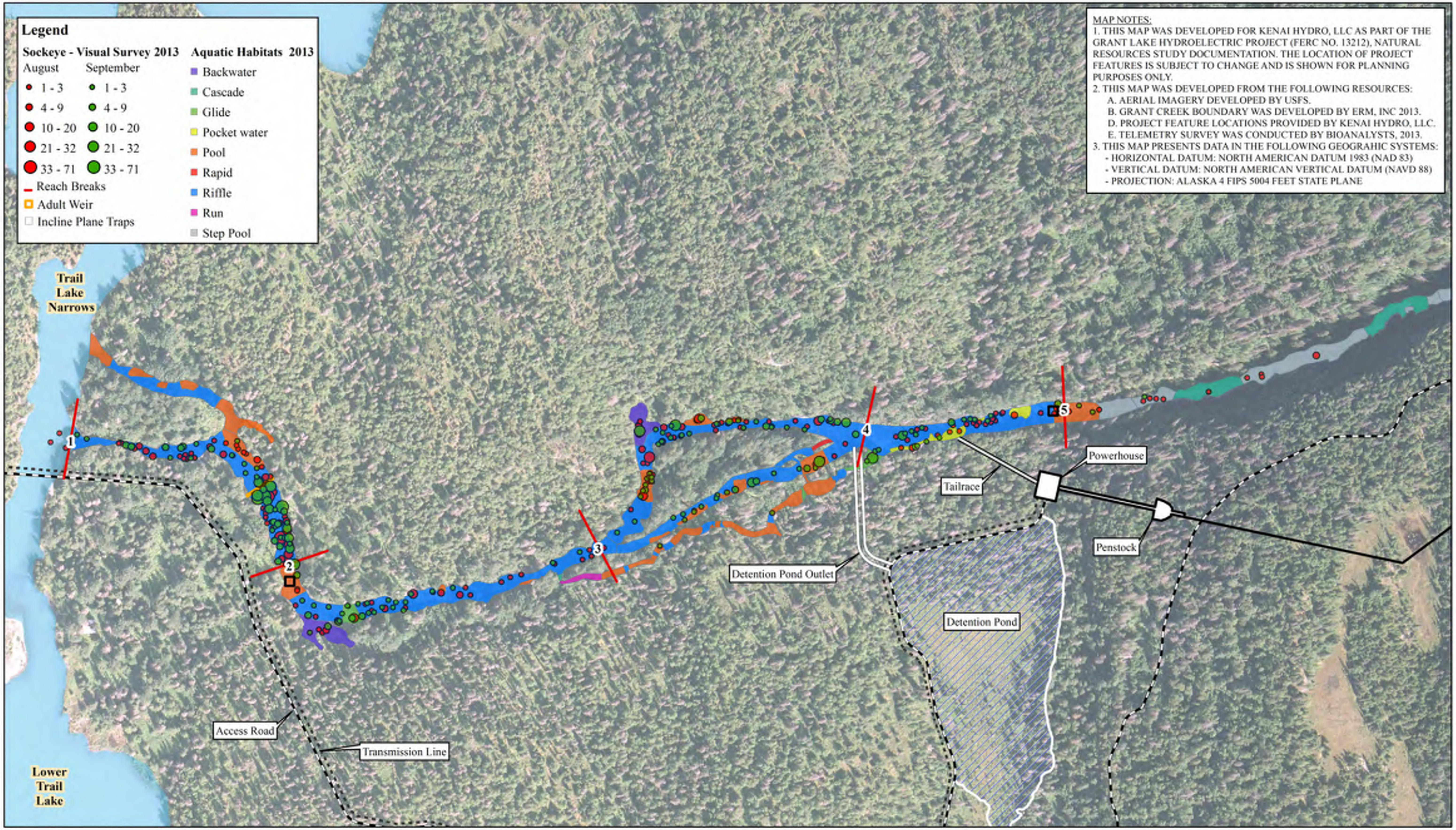
CHECKED M. Miller

ISSUED DATE 2/18/2014

DRAWING 1 of 1

SCALE: 1:2,000


Legend
Coho - Visual Survey 2013
September October November
1 - 2
3 - 4
5 - 7
8 - 11
12 - 16
Reach Breaks
Adult Weir
Incline Plane Traps
Aquatic Habitats 2013
Backwater
Cascade
Glide
Pocket water
Pool
Rapid
Riffle
Run
Step Pool
MAP NOTES:
1. THIS MAP WAS DEVELOPED FOR KENAI HYDRO, LLC AS PART OF THE GRANT LAKE HYDROELECTRIC PROJECT (FERC NO. 13212), NATURAL RESOURCES STUDY DOCUMENTATION. THE LOCATION OF PROJECT FEATURES IS SUBJECT TO CHANGE AND IS SHOWN FOR PLANNING PURPOSES ONLY.
2. THIS MAP WAS DEVELOPED FROM THE FOLLOWING RESOURCES:
A. AERIAL IMAGERY DEVELOPED BY USFS.
B. GRANT CREEK BOUNDARY WAS DEVELOPED BY ERM, INC 2013.
D. PROJECT FEATURE LOCATIONS PROVIDED BY KENAI HYDRO, LLC.
E. TELEMETRY SURVEY WAS CONDUCTED BY BIOANALYSTS, 2013.
3. THIS MAP PRESENTS DATA IN THE FOLLOWING GEOGRAHIC SYSTEMS:
- HORIZONTAL DATUM: NORTH AMERICAN DATUM 1983 (NAD 83)
- VERTICAL DATUM: NORTH AMERICAN VERTICAL DATUM 1988 (NAVD 88)
- PROJECTION: ALASKA 4 FIPS 5004 FEET STATE PLANE
Trail Lake Narrows
Lower Trail Lake
1
2
3
4
5
Powerhouse
Tailrace
Penstock
Detention Pond Outlet
Detention Pond
Access Road
Transmission Line
REV DATE BY DESCRIPTION
N
Drawing Scale:
0 100 200 400 Feet
McMILLEN, LLC
Developed For:
Homer Electric Association, Inc.
A Touchstone Energy Cooperative
GRANT LAKE HYDROELECTRIC PROJECT - FERC PROJECT NO.13212
GRANT LAKE NATURAL RESOURCES STUDY
Figure 5.1-3
Visual Surveys
Coho Salmon
DESIGNED J. Woodbury
DRAWN J. Woodbury
CHECKED M. Miller
ISSUED DATE 2/18/2014
DRAWING
1 of 1
SCALE: 1:2,500



REV	DATE	BY	DESCRIPTION

N

Drawing Scale:
0 100 200 400 Feet

MCMILLEN, LLC

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Homer Electric Association, Inc.
A Touchstone Energy Cooperative

GRANT LAKE HYDROELECTRIC PROJECT - FERC PROJECT NO.13212

GRANT LAKE NATURAL RESOURCES STUDY

Figure 5.1-4
Visual Surveys
Sockeye Salmon

DESIGNED J. Woodbury
DRAWN J. Woodbury
CHECKED M. Miller
ISSUED DATE 2/18/2014

DRAWING
1 of 1

SCALE: 1:2,500

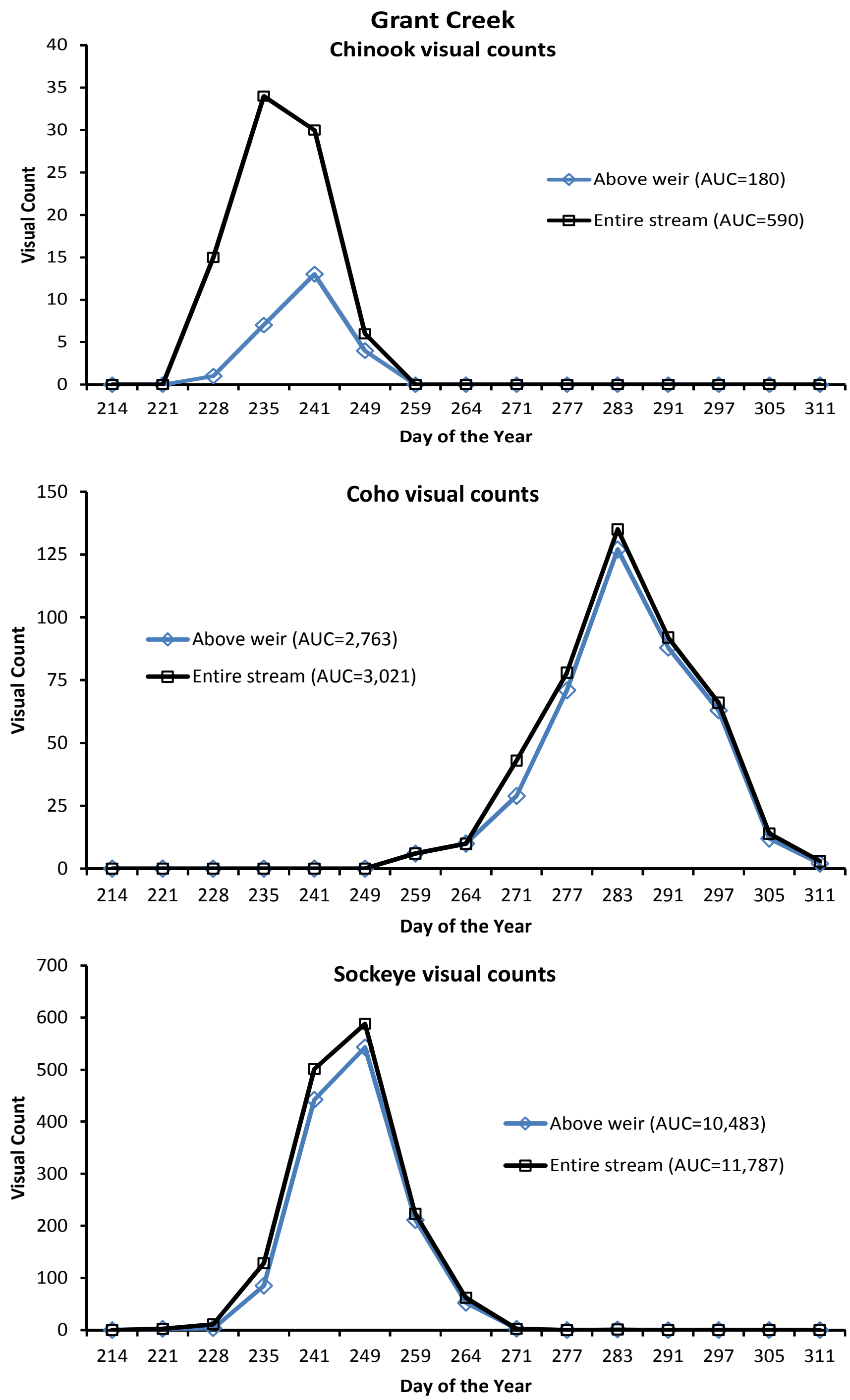

Figure 5.1-5. Plots of visual counts used to estimate area-under-the-curve for Chinook, sockeye and coho salmon in Grant Creek, 2013.

Estimates of escapement above the weir based on visual counts (AUC) were within ±12 percent of the weir counts (Table 5.1-5). Escapement estimates for the entire stream were 90 Chinook, 1,169 sockeye and 252 coho salmon.

Table 5.1-5. Escapement estimates for salmon in Grant Creek at the weir and estimated from area-under-the curve with stream life and observer efficiency

Species	Stream Life (s)	Observer Efficiency (v)	Escapement Estimates 2013			Escapement Estimate 2009	
			Weir Count	Above Weir (AUC)	Entire Stream (AUC)	Estimate	Adjusted
Pink	---	---	10	---	---	---	---
Chinook	11	0.60	23	27 (112%)	90 (391%)	231	148
Sockeye	14	0.72	1,117	1,040 (93%)	1,169 (105%)	6,293	2,705
Coho	16	0.75	237	231 (97%)	252 (106%)	---	---

The area-under-the-curve estimates for sockeye and coho salmon for the entire stream add an additional 52 sockeye and 15 coho salmon to the weir count. These additional fish downstream from the weir fit within our expectation of the number of spawning fish for both sockeye and coho salmon. However, the difference in the Chinook weir count (23 fish) and the estimate for the entire stream (90 fish) implies that 67 additional Chinook spawned downstream of the weir. That estimate appears to be too high because we did not observed that much more additional spawning activity below the weir. Given the level of movement (downstream) for Chinook across the weir, it is likely that the Chinook observed during visual counts downstream of the weir may have spawned in the Trail Lake Narrows or elsewhere. That is, our visual surveys counted fish that moved into lower Grant Creek but did not remain there to spawn, which inflated the number of fish in Grant Creek downstream of the weir. We offer two arguments in support of this conclusion:

1. There were 35 Chinook that crossed upstream of the weir and 12 fish migrated back downstream. That equates to about 34 percent fallback rate. The percent of fallback for sockeye (3 percent) and coho (<1 percent) was much lower.
2. There were three Chinook salmon redds observed downstream of the weir. There were 3 redds counted above the weir with an escapement of 23 fish, which equates to about 7.6 fish per redd above the weir. There were 67 additional fish estimated by AUC downstream of the weir and only three redds.

A more realistic estimate of total escapement to Grant Creek for Chinook salmon is 46 fish (6 redds x 7.6 fish/redd = 46 fish).

In 2009, the estimated escapement using area under the curve methodology was 231 Chinook and 6,293 sockeye salmon (HDR 2009b). Recalibrating those counts by stream life and observer efficiency from 2013 adjusted those counts to 148 Chinook and 2,705 sockeye salmon (Table 5.1-5).

5.1.2 Life History Characteristics

Adult salmon were counted and subsampled at the weir to describe life history characteristic of the spawning population. The information documents the run timing, size and age structure of returning salmon to Grant Creek.

5.1.2.1 Run Timing

Run timing for adult salmon to Grant Creek extended over a 13 week period beginning at the end of July and finishing near the end of October. Chinook and pink salmon both entered Grant Creek over a four week period (Table 5.1-6). Pink salmon passed the weir on Grant Creek from the first week of August to the end of August. Chinook salmon passed the weir from the second week of August through the first week of September. Peak passage for pink and Chinook salmon occurred on week 32 and 33, respectively. The adult migration for sockeye occurred over a ten week period beginning the last week of July with a peak at the end of August and the second week of October. Two individual sockeye extended the run timing an additional three weeks after the majority of the run was complete. Coho salmon began entering Grant Creek the second week of September, peaked the first week of October and ended the last week of October when the weir was removed (October 24).

Table 5.1-6. Run timing by week of the year for pink, Chinook, sockeye and coho salmon assessed at the weir on Grant Creek, 2013.

Week of Year	Dates	Pink	Chinook	Sockeye	Coho
31	Jul 28- Aug 03	0	0	5	0
32	Aug 04 - Aug 10	6	0	3	0
33	Aug 11- Aug 17	2	11	16	0
34	Aug 18 - Aug 24	1	3	220	0
35	Aug 25 - Aug 31	1	7	601	0
36	Sep 01 - Sep 07	0	2	201	0
37	Sep 08 - Sep 14	0	0	65	16
38	Sep 15 - Sep 21	0	0	4	17
39	Sep 22 - Sep 28	0	0	0	40
40	Sep 29 - Oct 05	0	0	1	96
41	Oct 06 - Oct 12	0	0	1	42
42	Oct 13 - Oct 19	0	0	0	21
43	Oct 20 - Oct 26	0	0	0	1
	Total	**10**	**23**	**1,117**	**237**

5.1.2.2 Size (length and weight)

Length and weight measurements were collected at the weir to describe the size of returning salmon to Grant Creek (Table 5.1-7). Female Chinook salmon were larger than males (mean length and weight). Male and female sockeye were similar with males slightly heavier and longer than females. For coho salmon, the size of males and females was similar. On average, male coho salmon tended to be heavier than females but females were on average longer than males. For pink salmon, males tended to be longer and heavier than females.

Table 5.1-7. Mean, maximum, and minimum length and weight of Chinook, sockeye and coho salmon measured at the weir on Grant Creek, 2013.

Species	Sex	Length cm (mid-eye to fork)					Weight (kg)				
		Mean	SD	Max	Min	Number	Mean	SD	Max	Min	Number
Chinook	F	88	5.8	98	81	6	10.4	2.6	14.5	7.6	6
	M	71	13.7	104	38	27	5.9	3.8	16.4	0.6	27
Coho	F	59	4.0	68	45	116	3.3	0.7	5.0	1.4	116
	M	58	4.3	67	45	116	3.5	1.0	6.5	1.5	116
Sockeye	F	54	3.5	60	42	415	2.6	0.5	3.8	1.0	415
	M	55	4.6	77	33	361	3.0	0.7	4.9	0.5	360
Pink	F	42	2.3	46	39	9	1.0	0.2	1.3	0.8	9
	M	45	3.8	51	40	6	1.3	0.4	2.1	0.9	6

Note: Samples size for fish measured may include some fish that past upstream of the weir and subsequently passed back downstream.

5.1.2.3 Age Structure

In this section, information is reported on the length-and-age-at-return and freshwater life history for Chinook, coho and sockeye salmon. For Chinook and coho salmon, scale samples were collected at the weir and for sockeye, otoliths were extracted from carcasses and used for age determination. Length measurements were from mid-eye to fork of the caudal fin.

Chinook salmon returned to Grant Creek at 3 to 6 years of age with most (84 percent) returning as 4 and 5-year old fish (Table 5.1-8). Three year old fish made up about 4 percent and 6-year old fish made up about 3 percent of the fish sampled. The age structure of male and female Chinook salmon differed slightly with one male returning at three years of age. Coho salmon returned at three to five years of age with most (90 percent) returning as 4-year old fish. Three year old fish made up about 4 percent and 5-year old fish made up about 7 percent of the fish sampled. The age structure of male and female coho salmon was similar in age-at-return with slightly more male fish returning at five years of age than females. Sockeye salmon returned at four to six years of age with most (95 percent) returning as 5-year old fish. Female sockeye returned as 4 and 5 year old fish. Males returned as 4, 5 and 6-year old fish.

Table 5.1-8. Age-at-return for coho, Chinook and sockeye salmon sampled in Grant Creek, 2013.

Sex	Total Age								Total
	Age-3		Age-4		Age-5		Age-6		
	No.	Percent	No.	Percent	No.	Percent	No.	Percent	
Chinook Salmon									
Female	0	0.0	0	0.0	4	80.0	1	20.0	5
Male	1	5.0	12	60.0	5	25.0	2	10.0	20
Total	1	4.0	12	48.0	9	36.0	3	12.0	25
Coho Salmon									
Female	3	3.5	78	91.8	4	4.7	0	0.0	85
Male	3	3.6	73	88.0	7	8.4	0	0.0	83
Total	6	3.6	151	89.9	11	6.5	0	0.0	168
Sockeye Salmon									
Female	0	0.0	3	5.9	48	94.1	0	0.0	51
Male	0	0.0	0	0.0	47	95.9	2	4.1	49
Total	0	0.0	3	3.0	95	95.0	2	2.0	100

In general, mean length increased with age for returning salmon to Grant Creek. Mean length increased the most for Chinook between 3 and 4-year old fish (Table 5.1-9). For Chinook salmon, females were larger than males at 5-year old fish but as 6-year old fish. Female coho salmon were slightly larger than males as 4-year old fish, smaller as 3-year old fish and the same as 5-year old fish. Like Chinook, mean length increased the most for coho between 3 and 4-year old fish. For sockeye salmon, males tended to be larger than females and the largest increase in mean size was between 4 and 5-year old fish.

Table 5.1-9. Length-at-age for returning coho salmon sampled at the Grant Creek weir in 2013. Length (cm) was measured from mid-eye to the fork of the caudal fin.

Sex	Age-3		Age-4		Age-5		Age-6	
	No.	Mean Length (cm)	No.	Mean Length (cm)	No.	Mean Length (cm)	No.	Mean Length (cm)
Chinook Salmon								
Female	0	---	0	---	4	86.0	1	97.5
Male	1	37.5	12	65.1	5	77.0	2	100.3
Total	1	37.5	12	65.1	9	81.0	3	99.4
Coho Salmon								
Female	3	52.1	78	59.0	4	60.3	0	---
Male	3	60.6	73	58.4	7	60.3	0	---
Total	6	56.4	151	58.7	11	60.3	0	---
Sockeye Salmon								
Female	0	---	3	48.6	48	56.1	0	---
Male	0	---	0	---	47	57.1	2	58.1
Total	0	---	3	48.6	95	56.6	2	58.1

The European method of age designation documents the general freshwater life history for adult salmon returning to Grant Creek. For Chinook, all fish spent 1 winter (1.x) in freshwater before migrating to the ocean (Table 5.1-10). The amount of time that coho spent in freshwater varied the most of returning salmon. Most (88 percent) coho salmon spent two winters (2.x) in freshwater while about 2 percent migrated to the ocean in their first year of life (0.x). Coho salmon that had spent one winter in freshwater (1.x) made up 4 percent and fish that spent 3 winters (3.x) in freshwater made up about 6 percent. Most (97 percent) adult sockeye returning to Grant Creek spent one year in freshwater (1.x) before migrating to the ocean. A few (3 percent) sockeye remained in freshwater for two years (2.x) before they migrated to the ocean.

Table 5.1-10. General freshwater life history of Chinook, coho and sockeye salmon returning to Grant Creek, 2013.

Species	0.x		1.x		2.x		3.x		Total
	No.	Percent	No.	Percent	No.	Percent	No.	Percent	
Chinook	0	0	25	100	0	0	0	0	25
Coho	3	2	7	4	148	88	10	6	168
Sockeye	0	0	97	97	3	3	0	0	100

Notes:
European Age Designation
0.x = Juvenile fish migrated to the ocean in its first year of life (no freshwater annulus).
1.x = Juvenile fish migrated to the ocean in its second year of life (one winter in freshwater).
2.x = Juvenile fish migrated to the ocean in its third year of life (two winters in freshwater).
3.x = Juvenile fish migrated to the ocean in its fourth year of life (three winters in freshwater).

5.1.2.4 Egg Voidance

Female carcasses were examined to describe spawner success (egg retention). Table 5.1-11 presents the number of carcasses recovered, mean egg retention and the number of females assessed.

Table 5.1-11. Number of Chinook, sockeye, pink, and coho salmon recovered during carcass surveys on Grant Creek, 2013.

Species	Females	Males	Total Recovered	Mean Egg Retention	Number Females Assessed
Chinook	5	10	15	255	5
Coho	28	35	63	289	28
Pink	8	3	11	100	2
Sockeye	266	218	484	81	257

5.1.3 Distribution of Spawning Salmon in Grant Creek

The distribution of spawning salmon in Grant Creek was investigated by conducting redd surveys and mobile telemetry surveys. Redd surveys were conducted at least once a week during the spawning period to document the location, number, and time of redd construction in Grant Creek. Documenting the number of redds in Grant Creek was at times hampered by stream flow, turbidity and mass spawning. Mobile surveys documented the locations of tagged fish during the course of the spawning period, which aided in documenting important spawning locations and resting pools. Both surveys were used together to help identify sensitive time periods and habitats for salmon reproduction.

The following pages document the locations where redds were observed and where radio tagged salmon were documented.

Pink, Chinook, sockeye and coho salmon spawned in Grant Creek during the summer and fall of 2013 (Figures 5.1-6 through 5.1-9). The number of new redds observed during each week of the study period was documented by week of the year (1-52). As expected, the distribution of redds closely follows the distribution of visual detections (Figures 5.1-2 through 5.1-4) and mobile telemetry surveys (Figures 5.1-10 through 5.1-12).

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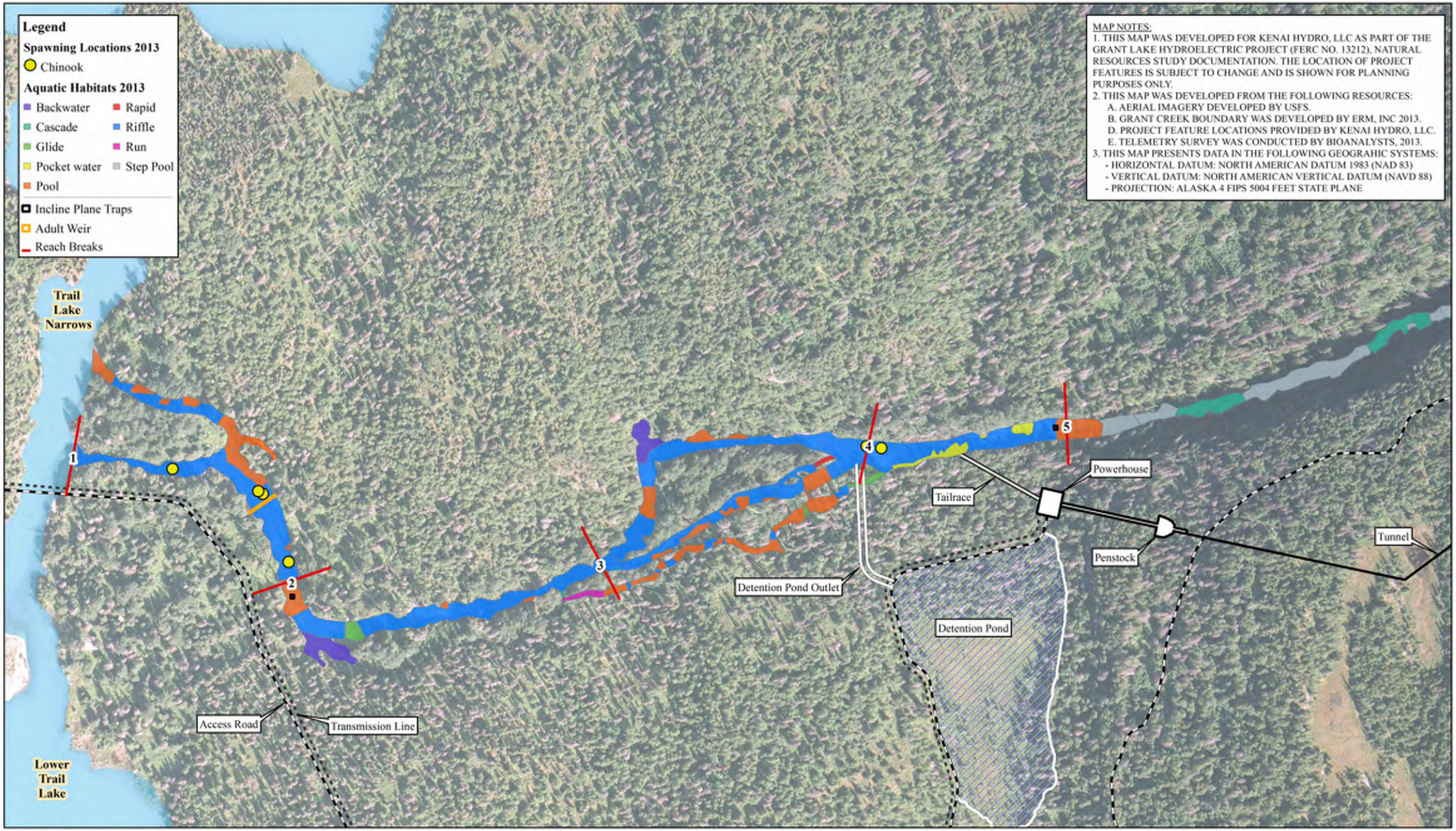

REV | DATE | BY | DESCRIPTION

N

Drawing Scale:
0 100 200 400 Feet

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GRANT LAKE HYDROELECTRIC PROJECT - FERC PROJECT NO.13212

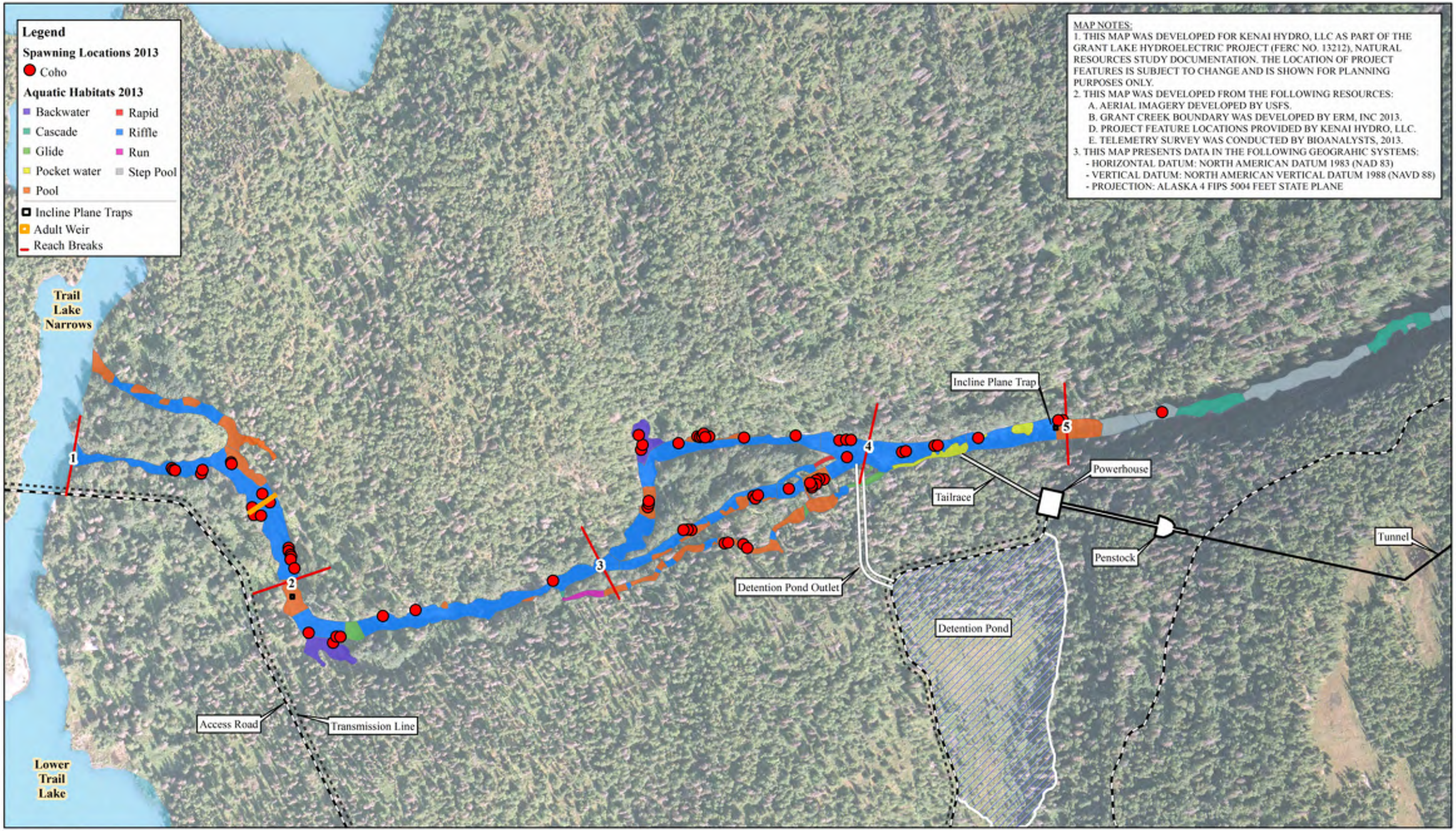
GRANT LAKE NATURAL RESOURCES STUDY

Figure 5.1-6
Spawning Locations
Chinook Salmon

DESIGNED J. Woodbury
DRAWN J. Woodbury
CHECKED M. Miller
ISSUED DATE 2/25/2014

DRAWING
1 of 1

SCALE: 1:2,500



REV	DATE	BY	DESCRIPTION

MCMILLEN, LLC

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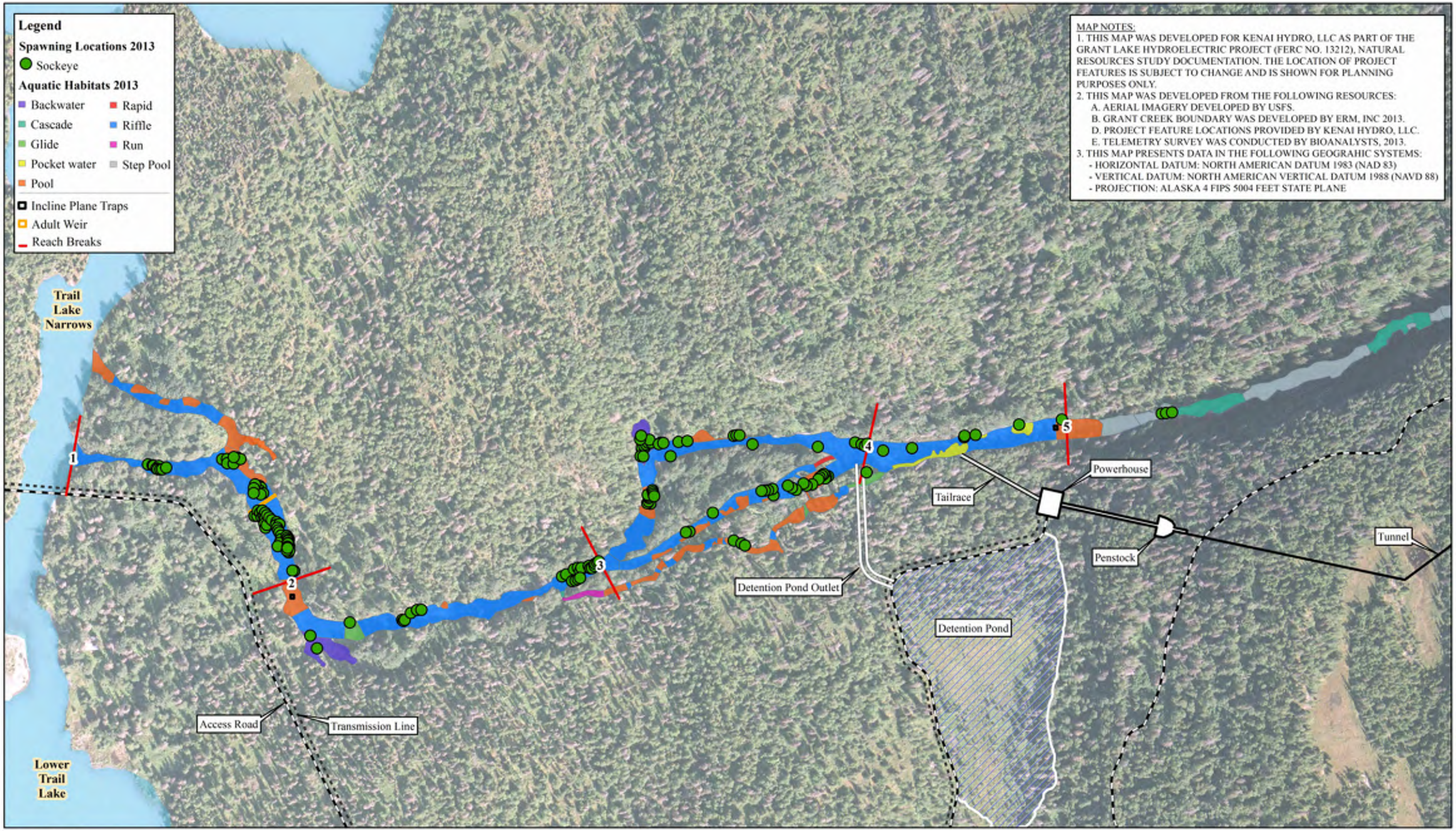
GRANT LAKE NATURAL RESOURCES STUDY

Figure 5.1-7
Spawning Locations
Coho Salmon

DESIGNED J. Woodbury
DRAWN J. Woodbury
CHECKED M. Miller
ISSUED DATE 2/25/2014

DRAWING 1 of 1

SCALE: 1:2,500



REV	DATE	BY	DESCRIPTION

N

Drawing Scale: 0 100 200 400 Feet

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1401 SHORELINE DRIVE BOISE, ID 83702 OFFICE: 208 342 4214 FAX: 208 342 4216

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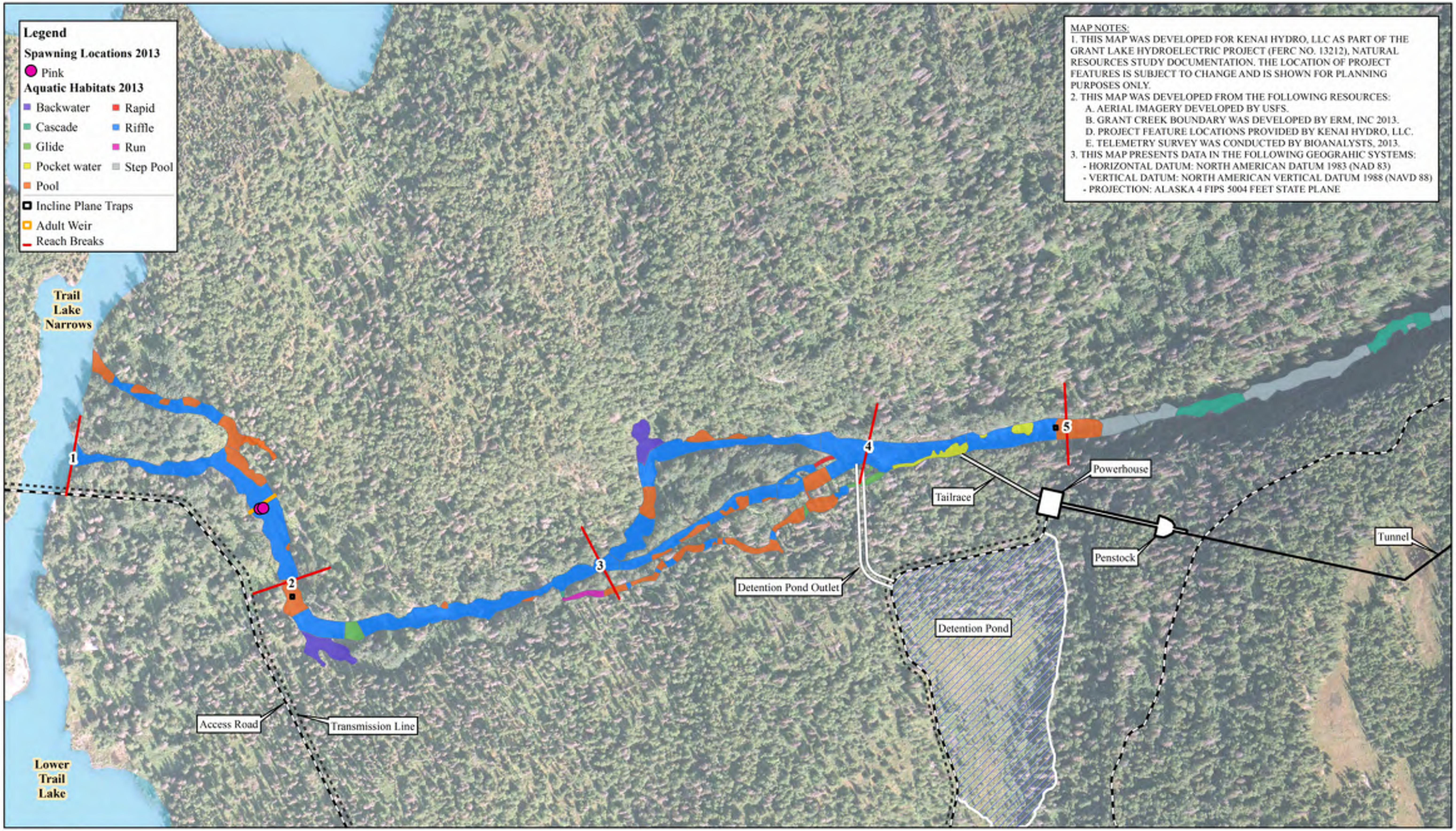
GRANT LAKE NATURAL RESOURCES STUDY

Figure 5.1-8
Spawning Locations
Sockeye Salmon

DESIGNED J. Woodbury
DRAWN J. Woodbury
CHECKED M. Miller
ISSUED DATE 2/25/2014

DRAWING
1 of 1

SCALE: 1:2,500



REV	DATE	BY	DESCRIPTION

N

Drawing Scale: 0 100 200 400 Feet

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GRANT LAKE NATURAL RESOURCES STUDY

Figure 5.1-9
Spawning Locations
Pink Salmon

DESIGNED J. Woodbury
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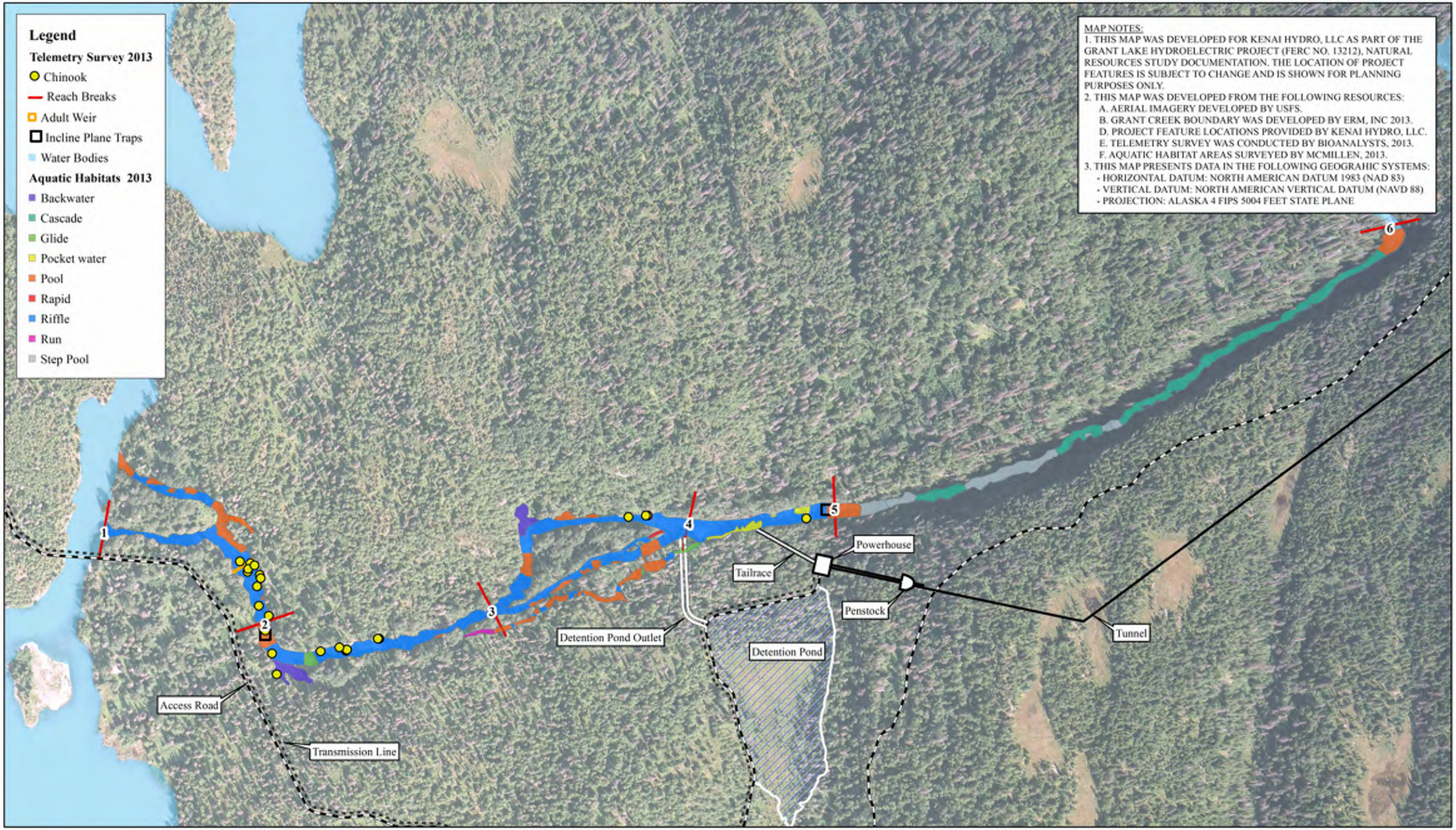
CHECKED M. Miller
ISSUED DATE 2/25/2014

DRAWING 1 of 1

SCALE: 1:2,500



REV	DATE	BY	DESCRIPTION

N

Drawing Scale: 0 150 300 600 Feet

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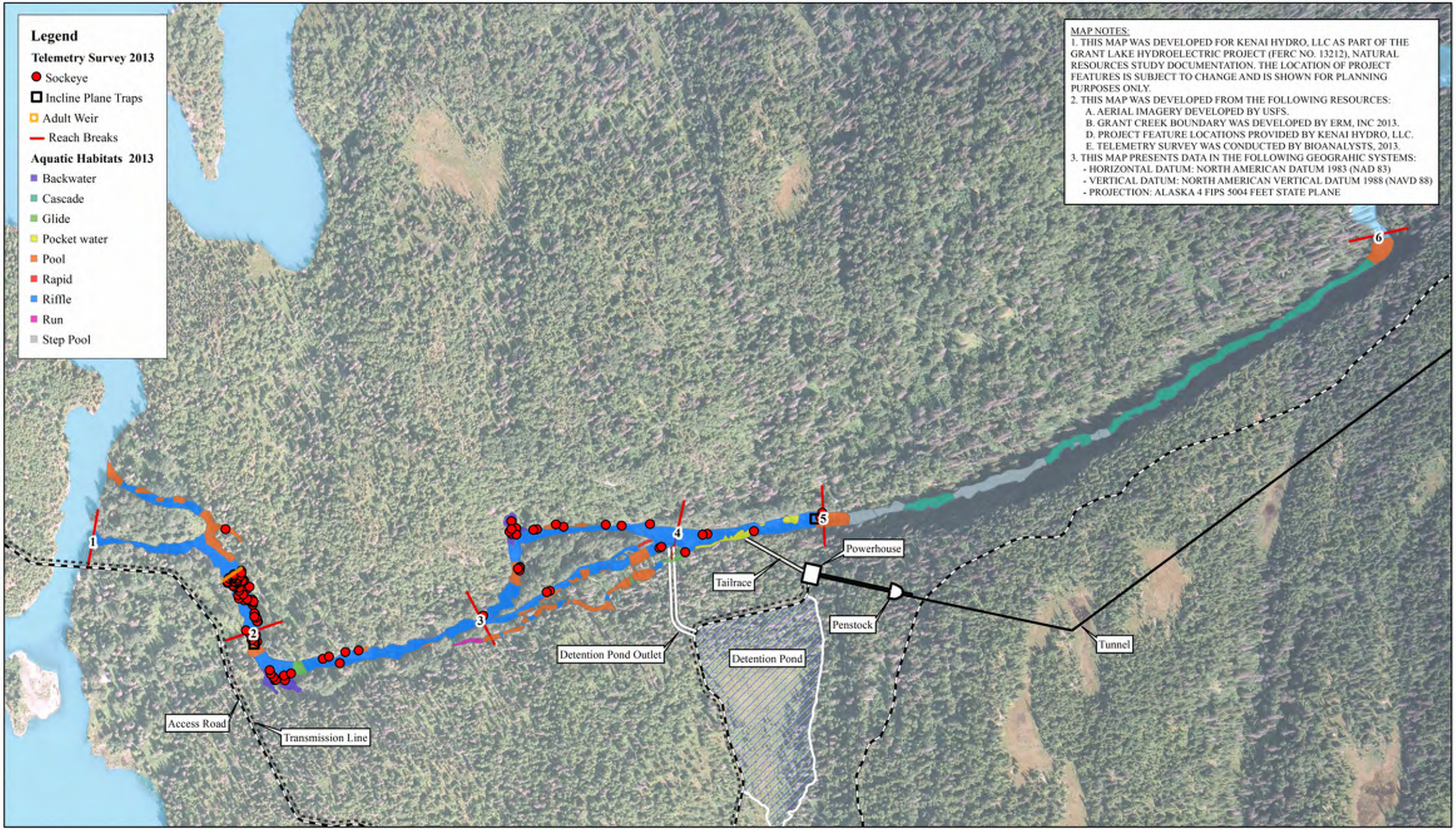
GRANT LAKE NATURAL RESOURCES STUDY

Figures 5.1-10
Telemetry Survey Data
Chinook Salmon

DESIGNED	J. Woodbury
DRAWN	J. Woodbury
CHECKED	J. Stevenson
ISSUED DATE	2/25/2014

DRAWING 1 of 1

SCALE: 1:3,400



REV	DATE	BY	DESCRIPTION

N

Drawing Scale: 0 150 300 600 Feet

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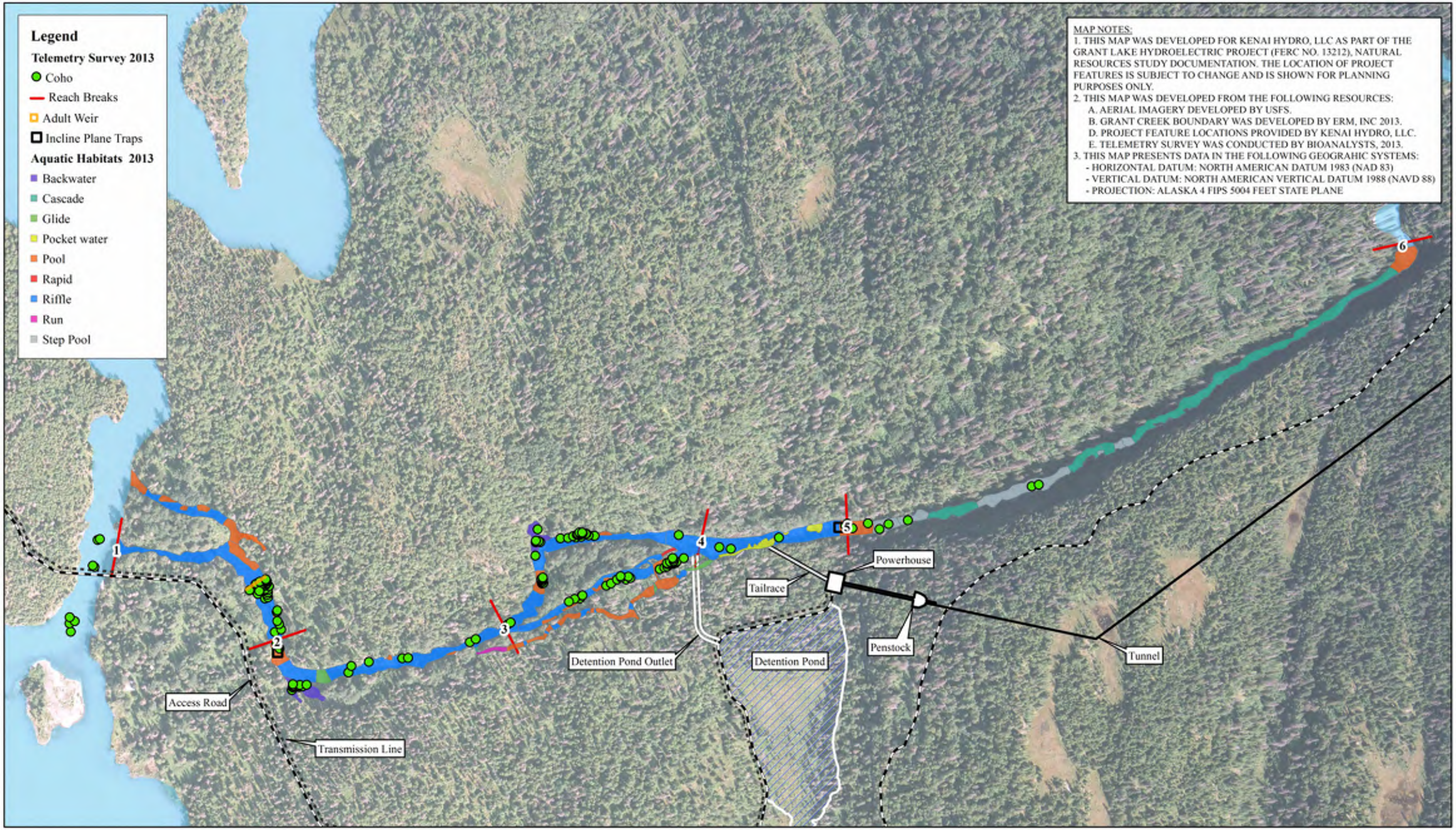
GRANT LAKE NATURAL RESOURCES STUDY

Figure 5.1-11
Telemetry Survey Data
Sockeye Salmon

DESIGNED J. Woodbury
DRAWN J. Woodbury
CHECKED J. Stevenson
ISSUED DATE 2/25/2014

DRAWING 1 of 1

SCALE: 1:3,400



REV	DATE	BY	DESCRIPTION

N

Drawing Scale: 0 150 300 600 Feet

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GRANT LAKE NATURAL RESOURCES STUDY

Figure 5.1-12
Telemetry Survey Data
Coho Salmon

DESIGNED J. Woodbury
DRAWN J. Woodbury
CHECKED J. Stevenson
ISSUED DATE 2/25/2014

DRAWING 1 of 1

SCALE: 1:3,400

5.1.3.1 Time of Spawning

Salmon began building redds the first week of August and ended spawning activity at the end of October (Table 5.1-12). Pink salmon began spawning in early August with only two redds constructed near the weir in Reach 1. Chinook salmon began spawning in mid-August and built six redds in a three week period. Sockeye began spawning at the end of August building 308 redds within the first two weeks. By the third week (week 37) new redds and old redds could not be distinguished in the mass spawning aggregates. Spawning activity (active digging) was observed until the last week of September. Coho began spawning the first week of October and were complete at the end of the month constructing 72 redds in Grant Creek.

Table 5.1-12. Number of new redds constructed in Grant Creek by week of the year for pink, Chinook, sockeye and coho salmon in 2013. A designation of "MS" (Mass Spawning) means that new redds and old redds for could not be distinguished in the mass spawning aggregates.

Week	Dates	Species				Total
		Pink	Chinook	Sockeye	Coho	
31	Jul 28 - Aug 03	0	0	0	0	**0**
32	Aug 04 - Aug 10	2	0	0	0	**2**
33	Aug 11 - Aug 17	0	0	0	0	**0**
34	Aug 18 - Aug 24	0	1	0	0	**1**
35	Aug 25 - Aug 31	0	3	200	0	**203**
36	Sep 01 - Sep 07	0	2	108	0	**110**
37	Sep 08 - Sep 14	0	0	MS	0	**0**
38	Sep 15 - Sep 21	0	0	MS	0	**0**
39	Sep 22 - Sep 28	0	0	MS	0	**0**
40	Sep 29 - Oct 05	0	0	0	5	**5**
41	Oct 06 - Oct 12	0	0	0	47	**47**
42	Oct 13 - Oct 19	0	0	0	13	**13**
43	Oct 20 - Oct 26	0	0	0	6	**6**
44	Oct 27 - Nov 02	0	0	0	1	**1**
45	Nov 03 - Nov 09	0	0	0	0	**0**
	Total	**2**	**6**	**308**	**72**	**388**

5.1.3.2 Spawning Distribution

The distribution of spawning salmon in Grant Creek was document with both redd surveys and mobile telemetry surveys. The distribution of salmon redds was concentrated (95 percent) within Reaches 1-3 of Grant Creek (Table 5.1-13). Sockeye and coho salmon spawned in every reach of Grant Creek while Chinook only spawned in Reach 1, 3 and 4. The spawning locations of sockeye and coho salmon often overlapped in several locations in reaches 1 and 3. Pink salmon only spawned in Reach 1. There was less spawning in Reach 2 (15 percent), Reach 4 (4 percent) and Reach 5 (1 percent). Spawning only occurred in a few locations in Reaches 4 and 5.

Table 5.1-13. Number and proportion of redds counted in each reach of Grant Creek for pink, Chinook, sockeye and coho salmon in 2013.

Reach	Species				Total	Proportion
	Pink	Chinook	Sockeye	Coho		
1	2	4	144	18	**168**	**0.433**
2	0	0	52	7	**59**	**0.152**
3	0	1	102	38	**141**	**0.363**
4	0	1	7	7	**15**	**0.039**
5	0	0	3	2	**5**	**0.013**
Total	**2**	**6**	**308**	**72**	**388**	**1.000**

Radio telemetry tracking occurred throughout the spawning period for Chinook, sockeye and coho salmon. Radio tracking was used to determine the distribution of salmon within Grant Creek (Figures 5.1-10 through 5.1-12). Those distributions likely include migration (wandering), spawning and resting (pools) behaviors within Grant Creek.

Of the nine Chinook that were radio-tagged, seven were detected within Reach 1, three within Reach 2, none in reaches 3 and 4, and five within Reach 5 (Table 5.1-14). While five Chinook were detected within Reach 5, no redds were associated with these detections nor were any Chinook redds observed in Reach 5. In reaches 3 and 4 there were no unique fish detections but at least two redds were observed in those reaches. In Reach 2 there were 3 fish detected but no redds were observed in that reach. In Reach 1 there were 7 fish detected and 4 redds observed.

Table 5.1-14. The number of unique detections of radio-tagged adult salmon by species and reach within Grant Creek.

Reach	Chinook (n = 9)	Sockeye (n = 65)	Coho (n = 50)	Total	Proportion
1	7	48	40	95	**0.41**
2	3	14	12	29	**0.13**
3	0	18	30	48	**0.21**
4	0	3	6	9	**0.04**
5	5	20	26	51	**0.22**
Total	**15**	**103**	**114**	**232**	**1.00**

Unique detections by reach for sockeye more closely resemble observed redds by reach as presented in Table 5.1-13. Of the 65 radio-tagged sockeye, 48 were detected in Reach 1, 14 in Reach 2, 18 in Reach 3, 3 in Reach 4, and 20 in Reach 5 (Table 5.1-14). There were 20 sockeye detected in Reach 5 and at least 3 redds were observed. In reach 3 there were 18 sockeye detected and 102 redds were observed. In Reach 2 there were 14 fish detected and 52 redds observed. Reach 1 had 48 fish detected and there were 144 redds observed in this reach.

Of the 50 coho salmon radio-tagged, 40, 12, 30, 6, and 26 tagged fish were observed in reaches 1-5, respectively (Table 5.1-14). Coho were detected in all reaches of Grant Creek and indeed spawned in all reaches of Grant Creek like sockeye salmon. The majority of coho salmon were detected in Reaches 1 and 3 and these were the areas where most of the spawning occurred.

Clearly, detection of radio tagged fish helped describe the distribution of salmon entering Grant Creek, but it did not always indicate that spawning occurred. However, most fish appeared to be closely associated with either spawning areas or resting pools. The proportion of redds observed in Grant Creek was similar to the proportion of fish detected within each reaches. Reach 5 was the most notable divergence with several fish detected in the lower portion of reach 5 but few redds identified in this reach. The number of radio tagged detections in that reach may indicate exploratory behavior and/or the inability to detect redds in the lower section of reach 5.

5.1.3.3 Spawning Habitat

In Grant Creek, most redds were located in the mainstem areas, but also occurred in side channels and backwater areas (Table 5.1-15). Sockeye and coho both spawned in mainstem, side channel and backwater areas while pink and Chinook only spawned in mainstem areas. In mainstem areas, spawning usually occurred along the stream margins or in areas protected from the main current. Chinook were the exception, building redds mid-channel within the stronger current. In side channels, salmon spawned throughout the width of the channel and in backwater areas, salmon usually selected locations close to the mainstem where suitable stream velocity and substrate were present.

Table 5.1-15. Location of salmon redds within different channel areas of Grant Creek.

Species	Backwater Areas	Mainstem Areas	Side Channel Areas	Total
Chinook	0	6	0	**6**
Coho	4	49	19	**72**
Pink	0	2	0	**2**
Sockeye	27	239	42	**308**
Total	**31**	**296**	**61**	**388**

The majority of redds in Grant Creek were located in riffle (71 percent) and pool (19 percent) habitat (Table 5.1-16). In Reach 1, spawning for pink, sockeye and coho salmon most often occurred in riffle and pool habitat along the stream margins in the mainstem areas away from the thalweg and the highest stream velocities. Chinook spawned only in riffle habitat most often mid-channel where higher velocity and larger spawning substrates occurred. In Reach 2, most spawning occurred in mainstem riffle habitat along the stream margins for sockeye and coho salmon. Irregularities along the stream margin (large woody debris [LWD], bedrock, boulders) of riffle habitat created areas of lower velocity and suitable spawning substrate. Sockeye and coho also spawned in the stream margins of some pool habitat (lateral scour pool) of Reach 2. In Reach 3, most spawning occurred in pool habitat in mainstem (scour pools) and side channel areas (dammed pools). One large backwater area (pool habitat) was also used by sockeye and coho salmon. In Reach 4, spawning occurred in mostly riffle habitat along the stream margins of the right bank. Spawning also occurred along the left bank in pocket water (riffles w/ pockets) formed by velocity breaks such as boulders or tree roots that allowed spawning gravels to accumulate. In Reach 5, spawning occurred in step pool habitat along the stream margins often behind large boulders or bedrock outcroppings (velocity breaks) where gravels and cobbles accumulated.

Table 5.1-16. Location of pink, Chinook, sockeye and coho salmon redds within reaches and aquatic habitats of Grant Creek. A designation of "NA" means that the habitat type was not available in that reach of Grant Creek.

Species	Reach - Area	Riffle	Pool	Back -water	Step Pool	Glide	Pocket Water	Total
Pink	1 - Mainstem	2						2
	2 - Mainstem							
	3 - Mainstem							
	3 - Predominate Side Channel							
	3 - Secondary Side Channel							
	4 - Mainstem							
	5 - Mainstem							
Chinook	1 - Mainstem	4						4
	2 - Mainstem							
	3 - Mainstem	1						1
	3 - Predominate Side Channel							
	3 - Secondary Side Channel							
	4 - Mainstem	1						1
	5 - Mainstem							
Sockeye	1 - Mainstem	129	15					144
	2 - Mainstem	47		4		1		52
	3 - Mainstem	18	19	23				60
	3 - Predominate Side Channel	27	11			1		39
	3 - Secondary Side Channel		3					3
	4 - Mainstem	6	1					7
	5 - Mainstem				3			3
Coho	1 - Mainstem	15	3					18
	2 - Mainstem	6		1				7
	3 - Mainstem	6	10	3				19
	3 - Predominate Side Channel	7	8					15
	3 - Secondary Side Channel	1	3					4
	4 - Mainstem	5	2					7
	5 - Mainstem				2			2
	Total:	**275**	**75**	**31**	**5**	**2**	**0**	**388**
	Proportion:	**0.71**	**0.19**	**0.08**	**0.01**	**0.01**	**0.00**	**1.00**

The majority of radio tagged salmon were detected in riffle (62 percent) and pool (24 percent) habitat (Table 5.1-17). The proportion of detections in aquatic habitats of Grant Creek follows the distribution of redds. The slightly higher detection rate of fish in pools may be a related to staging and resting behavior as well as spawning. Backwater areas along the mainstem also appeared to be important spawning areas. In general, close inspection of maps that depict redd locations and detections of tagged fish show a cluster of activity in mainstem riffle areas near pool habitat.

Table 5.1-17. Number of detections for radio tagged Chinook, sockeye, and coho salmon in aquatic habitats of Grant Creek, 2013.

Species	Reach	Riffle	Pool	Back-water	Step Pool	Glide	Pocket Water	Total
Chinook	1 - Mainstem	10						10
	2 - Mainstem	6	2	2				10
	3 - Mainstem		2	1				3
	3 - Predominate Side Channel							0
	3 - Secondary Side Channel							0
	4 - Mainstem							0
	5 - Mainstem				1			1
Sockeye	1 - Mainstem	49	2					51
	2 - Mainstem	6	4	7				17
	3 - Mainstem	9	7	4				20
	3 - Predominate Side Channel	4						4
	3 - Secondary Side Channel							0
	4 - Mainstem	3						3
	5 - Mainstem							0
Coho	1 - Mainstem	57	1					58
	2 - Mainstem	6	3	10				19
	3 - Mainstem	12	27	7				46
	3 - Predominate Side Channel	6	14					20
	3 - Secondary Side Channel					1		1
	4 - Mainstem	3	3					6
	5 - Mainstem		2		4			6
	Total:	**171**	**67**	**31**	**5**	**1**	**0**	**275**
	Proportion:	**0.62**	**0.24**	**0.11**	**0.02**	**<0.01**	**0.00**	**1.00**

5.2 Grant Creek Resident and Rearing Fish Abundance and Distribution

5.2.1 Adult Rainbow Trout Abundance, Distribution, and Spawning in Grant Creek

A weir was placed in Reach 1 of Grant Creek to intercept, count and sample adult salmonids migrating upstream. Daily fish counts were used to estimate run timing and provided an overall estimate of escapement to Grant Creek. Dolly Varden and rainbow trout were intercepted at the weir to help facilitate radio tagging. Fish captured at the weir that were radio-tagged were also Floy-tagged.

The migration period for rainbow trout lasted 6 weeks from May 24 to June 29 and resulted in the capture of 13 adult rainbow trout (Table 5.2-1). The abundance of adult rainbow trout in Grant Creek based on weir counts may be biased low. This conclusion is based on the observation of two radio tagged rainbow trout, which were released upstream of the weir in June and were subsequently captured downstream from the weir in July while angling. Neither of these fish were captured and released downstream of the weir. Later, both of these fish were detected upstream of the weir; again without being captured at the weir.

Table 5.2-1. Weekly passage of rainbow trout and Dolly Varden across the weir in Grant Creek, 2013.

Week of the Year	Dates	Rainbow Trout	Dolly Varden
21	May 19 - May 25	3	0
22	May 26 - Jun 01	1	0
23	Jun 02 - Jun 08	1	0
24	Jun 09 - Jun 15	1	0
25	Jun 16 - Jun 22	3	0
26	Jun 23 - Jun 29	4	0
27	Jun 30 - Jul 06	0	0
28	Jul 07 - Jul 13	0	0
29	Jul 14 - Jul 20	0	0
30	Jul 21 - Jul 27	0	0
31	Jul 28- Aug 03	0	0
32	Aug 04 - Aug 10	0	0
33	Aug 11- Aug 17	0	0
34	Aug 18 - Aug 24	0	1
35	Aug 25 - Aug 31	0	4
36	Sep 01 - Sep 07	0	6
37	Sep 08 - Sep 14	0	3
38	Sep 15 - Sep 21	0	0
39	Sep 22 - Sep 28	0	0
40	Sep 29 - Oct 05	0	0
41	Oct 06 - Oct 12	0	0
42	Oct 13 - Oct 19	0	0
43	Oct 20 - Oct 26	0	0
	Total	13	14

The relatively low abundance of rainbow trout passing the weir might be attributed to the date the weir was placed into Grant Creek. Some adult rainbow trout may have moved upstream into Grant Creek before the weir was in place. Angling was initiated to help capture fish for radio tagging. Within the first two weeks, 16 adult sized (>300 mm FL) rainbow trout were tagged. Many of these fish were captured upstream of the weir. In July two observers in dry suits and snorkel gear inspected the weir and found no obvious areas of entry from mid-channel to the left bank. The right bank undercut could not be inspected and is suspected to have been large enough to provide some supplementary passage to rainbow trout.

The migration period for Dolly Varden lasted 4 weeks from August 18 to September 14, with the capture of 14 Dolly Varden (Table 5.2-1). Only one Dolly Varden was large enough for tagging, and which appeared to be in spawning condition. Angling efforts in Grant Creek proved unsuccessful to capture adult Dolly Varden for tagging.

5.2.2 Resident and Rearing Fish Use of Reach 5

To monitor fish use of upper Grant Creek, adult rainbow trout were surgically implanted with radio tags to monitor their movements and use of Reach 5. A total of 20 adult rainbow trout were radio-tagged, and included a portion of the fish collected at the weir, and a number of fish captured above the weir using angling techniques. Minnow traps and snorkel surveys were also used to assess the relative abundance of juvenile fish in upper Grant Creek.

Of the 20 adult rainbow trout that were surgically implanted with radio-transmitters, three males and one female were detected within Reach 5 subsequent to their release. All four were detected by the underwater antenna arrays located at the Reach 4/5 break. Because there were two antenna arrays located approximately 30 meters apart, and they were monitored individually, it was possible to determine when the tagged fish approached the Reach 4/5 break, and when they migrated past that point and into Reach 5. Likewise, it was possible to determine the direction of travel, and when a tagged fish migrated downstream and out of Reach 5. Of the four radio-tagged fish that entered Reach 5, two were also detected during mobile surveys of the "Canyon Reach" (Reach 5), providing a more detailed assessment of their positions.

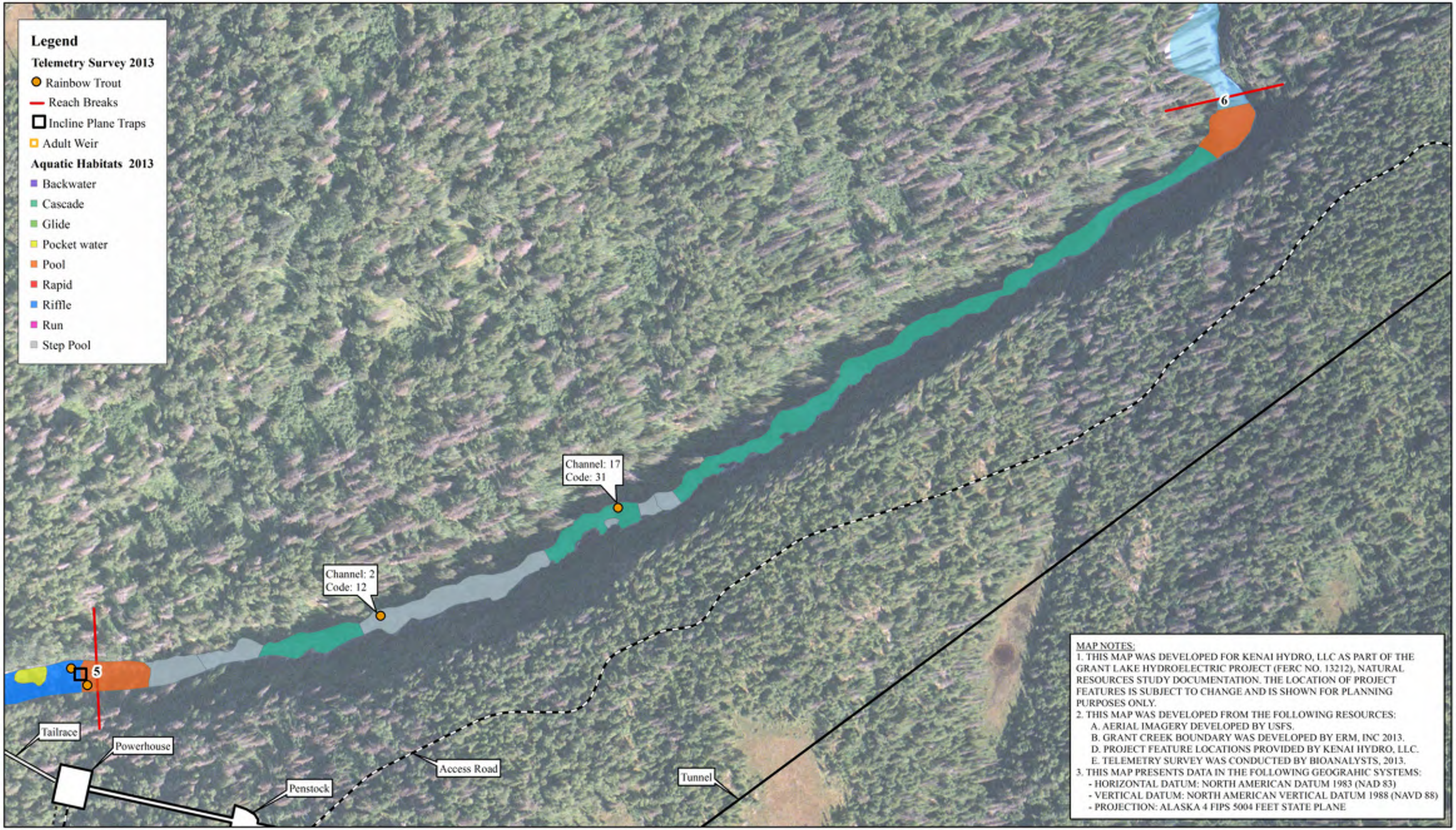
On average, it took 9.9 days after tagging and release for the four fish to migrate upstream through Grant Creek and be detected by the antenna array located at the Reach 4/5 break (median of 6.6 days; range of 2.0 to 24.4 days; Table 5.2-2). Three of the four fish made a single foray into Reach 5, spending on average 0.27 days within Reach 5. The fourth fish, a male, made three different forays into Reach 5; the first lasting 4.35 days, the second 0.72 days, and the last foray lasting 0.75 days, each venture into Reach 5 being separated by about 6 hours.

Table 5.2-2. The travel time and length of residence of radio-tagged rainbow trout detected in Reach 5 of Grant Creek.

Fish I.D. (Channel/Code)	Sex	Travel Time from Release to Reach 4/5 Break (days)	Length of Time within Reach 5 (days)
2/12	Female	6.12	0.80
2/19	Male	24.37	0.01
17/31	Male	2.00	4.35
			0.72
			0.75
17/46	Male	7.05	0.01

The tagged female (Fish I.D. 2/12) spent 0.80 days in Reach 5, and was detected at the time of a mobile telemetry survey. During this survey, this fish migrated upstream to a point approximately 135 meters above the Reach 4/5 break (Figure 5.2-1). The location where this fish was detected was further scrutinized at the time of the telemetry survey, and its position was determined using a bared-coaxial underwater antenna, which allows accuracy on the order of 3 meters or less.

The radio-tagged male (Fish I.D. 17/31), which made multiple forays into Reach 5, spent the most time in Reach 5, and migrated the farthest upstream of the Reach 4/5 break (about 250 meters; Figure 5.2-1). Its location was ascertained during a mobile survey where its position was triangulated from the top of the canyon rim from the right bank. As such it was not possible to collect any information as to the specific location (i.e., habitat type, substrate, etc.).



REV	DATE	BY	DESCRIPTION

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GRANT LAKE NATURAL RESOURCES STUDY

Figure 5.2-1
Telemetry Survey Data
Rainbow Trout - Reach 5

DESIGNED J. Woodbury
DRAWN J. Woodbury
CHECKED J. Stevenson
ISSUED DATE 2/25/2014

DRAWING 1 of 1

SCALE: 1:1,675

Minnow trapping and snorkeling were used in upper Grant Creek (Reach 5 only) from April through October to document species diversity, relative abundance, and distribution. Over the course of the study, there were 57 individual minnow traps (effort=1,318 hours) placed in different locations capturing 205 fish in upper Grant Creek (Table 5.2-3; Figure 5.2-2). Snorkeling was only conducted in April and May when stream flows and water clarity allowed. Three step pools were snorkeled in April and two were snorkeled in May identifying 16 fish in upper Grant Creek.

Table 5.2-3. Number of minnow traps, total effort, and number of fish captured in Reach 5 of Grant Creek from April through October 2013.

Upper Grant Creek Minnow Trapping				
Reach	**Number of Traps**	**Total Effort (days)**	**Total Effort (hrs)**	**Number of Fish**
5	57	54.9	1,318	205

Dolly Varden and rainbow trout were the most numerous fish captured in minnow traps followed by Chinook, sculpins sp. and coho (Table 5.2-4). Juvenile Dolly Varden comprised half of the fish captured in minnow traps.

Table 5.2-4. Number, proportion and CPUE of fish caught in Reach 5 of Grant Creek with minnow traps from April through October 2013.

Upper Grant Creek Minnow Trapping			
Species	**Number**	**Proportion**	**CPUE (fish/hr)**
Chinook	31	0.15	0.024
Coho	5	0.02	0.004
Dolly Varden	102	0.50	0.077
Rainbow Trout	48	0.23	0.036
Sculpin sp.	19	0.09	0.014
Grand Total	**205**	**1.00**	**0.156**

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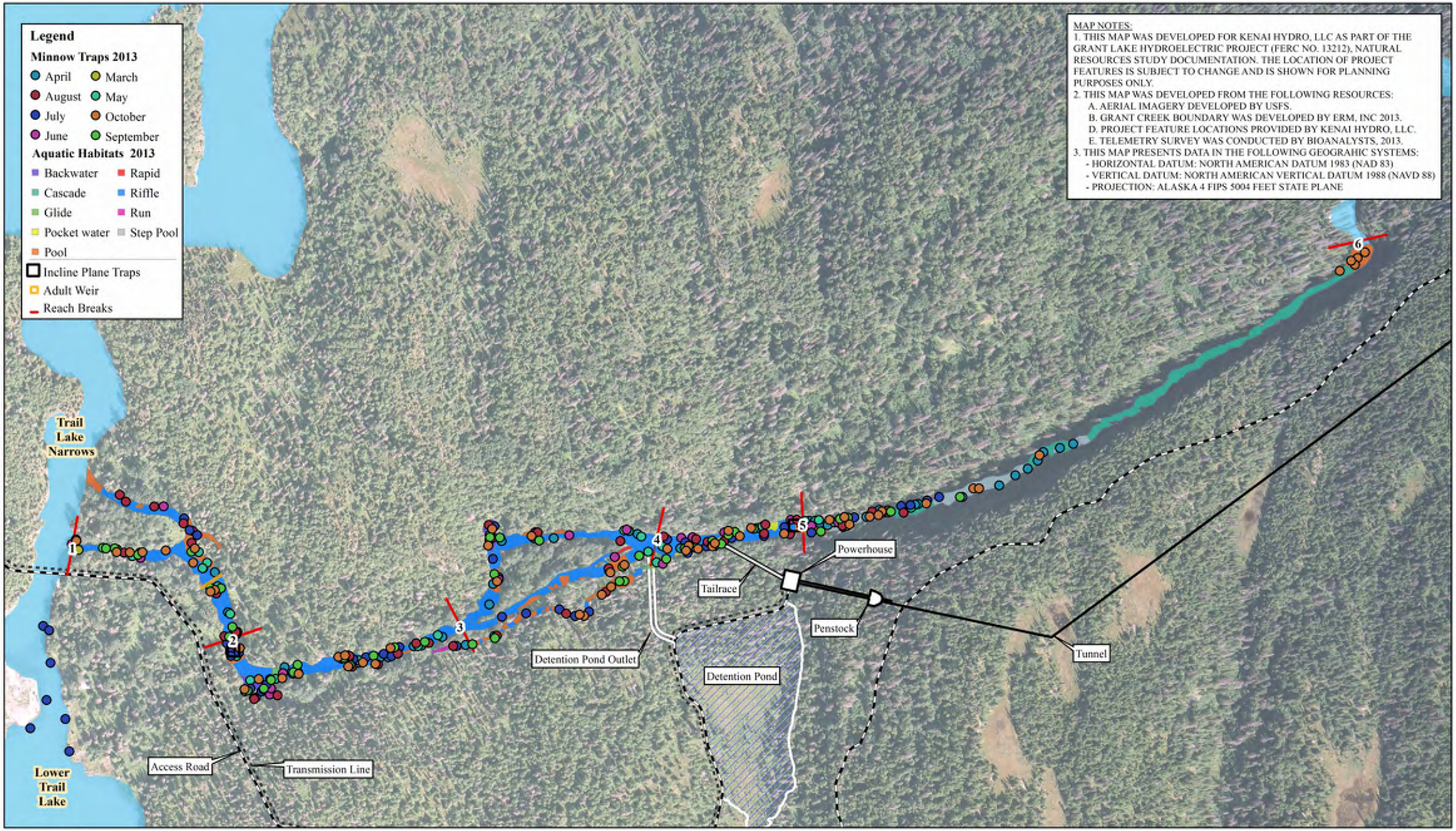

REV	DATE	BY	DESCRIPTION

N

Drawing Scale: 0 150 300 600 Feet

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GRANT LAKE HYDROELECTRIC PROJECT - FERC PROJECT NO.13212

GRANT LAKE NATURAL RESOURCES STUDY

Figure 5.2-2
Minnow Trap Observations
By Month

DESIGNED J. Woodbury
DRAWN J. Woodbury
CHECKED M. Miller
ISSUED DATE 2/18/2014

DRAWING 1 of 1

SCALE: 1:3,400

The relative abundance of fish observed in Reach 5 of Grant Creek varied over time (Table 5.2-5). Repeated minnow trap sampling from April through October in upper Grant Creek showed that relative abundance was lowest in May and increased to September (Figure 5.2-3; Table 5.2-5). In general, peak abundance (catch) occurred from June through October. CPUE for juvenile Chinook increased from April to a peak in September and declined in October (Figure 5.2-3). Juvenile Chinook varied in size from 68-118 mm FL. CPUE for juvenile coho salmon peaked in September and fish ranged in size from 60-95 mm FL. For Dolly Varden, the greatest CPUE occurred in August but was fairly stable during the summer (June-August). The size range of Dolly Varden captured in upper Grant Creek varied from 71-151 mm FL. Catch of juvenile rainbow trout peaked in September and October (Table 5.2-5). Rainbow trout captured in upper Grant Creek varied from 54-143 mm FL. No fish were captured in the plunge pool downstream from the anadromous fish barrier in September when peak catch rates were generally highest for most other species (except Dolly Varden).

Table 5.2-5. Number of fish captured in minnow traps by month for upper Grant Creek from April through October 2013.

Month	Number						
	Chinook	**Coho**	**Dolly Varden**	**Rainbow Trout**	**Sculpin sp.**	**Three-spine Stickleback**	**Total**
APR	2	0	1	5	0	0	8
MAY	1	0	1	4	0	0	6
JUN	0	0	18	1	0	0	19
JUL	1	0	23	3	1	0	28
AUG	1	1	20	4	3	0	29
SEP	18	4	17	16	5	0	60
OCT	8	0	22	15	10	0	55
Total	31	5	102	48	19	0	205

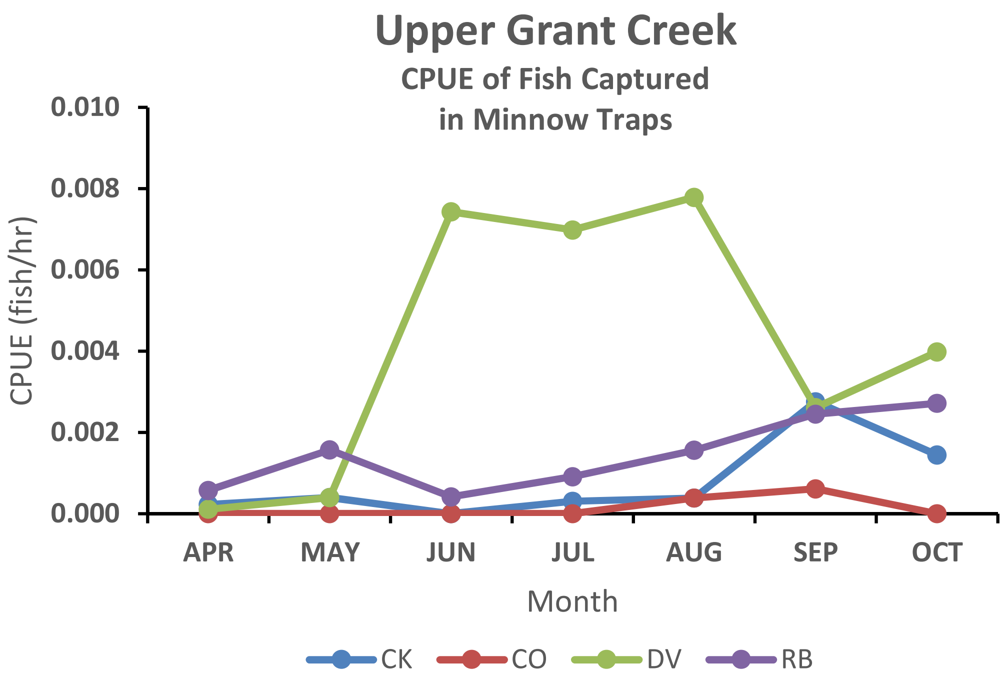

Figure 5.2-3. Catch-per-unit-effort (CPUE) for juvenile Chinook, coho, Dolly Varden and rainbow trout from minnow trapping in upper Grant Creek from April through October, 2013.

Night time snorkel surveys in April and May within Reach 5 of Grant Creek documented 7 rainbow trout in April and 9 rainbow trout in May. These fish were observed in step pool habitat and varied in size from 60-280 mm FL.

The upper incline plane trap was installed within a scour pool, which was located immediately downstream of the Reach 4/5 break. Trap installation was completed on April 28, and the trap was permanently removed on October 16. The trap was operated 24 hours per day, seven days per week with a number of exceptions. Due to few fish being captured, the trap was not operated the first three weekends of the study (May 4 and 5; May 11 and 12; and May 18 and 19). As Grant Creek flows increased, the trap became increasingly problematic to operate. In addition to high debris loads, the water velocity entering the trap was approaching 1 meter per second, with large rolling waves. This caused flow entering the trap to surge, making it difficult to optimize the trap settings. Efforts were made to reposition the trap within the pool; however there was little flexibility in adjustment within the pool due to boulders. Towards the end of May, velocities had reached a point where it was difficult to access the trap, and the level of risk to personnel had become unacceptable. Therefore, on May 30 the trap was taken out of operation, and on June 1 the trap was moved to a position along the left bank and the trap was secured. It wasn’t until September 19 that flow subsided to a point where the trap could be moved into fishing position, and trapping operations re-initiated.

During the juvenile migration, problems associated with the lower incline plane trap located at the Reach 1/2 break became apparent. Juvenile salmonid fry were being observed along flooded areas of Grant Creek, yet none of these fry-sized fish were being observed in the incline plane trap live box. Through ad hoc investigations, it was determined that the mesh size on the live box, as well as the incline plane of the trap was too large, which allowed juvenile fish to escape the trap. Modifications were made to both the incline plane and the live box; since the upper incline plane trap located at the Reach 4/5 break was constructed identically to the lower trap, alterations were made to it as well.

As discussed in the Methods Section, a goal of the study was to estimate abundance of juvenile fish within Grant Creek, and to partition that estimate into two sections; Reach 5, and Reaches 1-4. An estimate of abundance at the lower incline plane trap would represent all of Grant Creek; that is, from the trap upstream to the waterfall at the top of Reach 5. To partition that estimate into the two sections, it is then necessary to get an estimate of abundance for just Reach 5. Given that the upper incline plane trap was inoperable during much of the juvenile migration due to high flows, the collection of adequate numbers of fish to estimate trap efficiency at the upper trap was not possible. As such, results for the upper incline plane trap, which are presented below only include actual counts of fish collected at the trap, and results for the lower incline plane trap presented in Section 5.2.3 include abundance estimates that are for all of Grant Creek.

During the operation of the upper incline plane trap, a total of 172 fish were processed. Of those, there were 8 Chinook, 1 coho, 7 Dolly Varden, 5 rainbow trout, 19 sculpin, and 132 sticklebacks. Due to the low numbers of species of interest, no fish were marked to assess trap efficiency.

5.2.3 Resident and Rearing Fish Use of Open Water Habitats in Lower Grant Creek

To monitor fish use of lower Grant Creek, adult rainbow trout were surgically implanted with radio tags to monitor their movements. Minnow traps and snorkel surveys were also used to assess the relative abundance of juvenile fish in upper Grant Creek.

During the period of May 24 to July 11, a total of 20 adult rainbow trout were surgically implanted with radio-transmitters; one in May, six in June, and 13 in July (Table 5.2-6). Of those 20 fish, 8 were female, 11 were male, and the sex of one other was undetermined. The age of adult rainbow trout (>300 mm) varied from three to seven years old, which is similar to what has been observed in the Upper Kenai River (Hayes and Hasbrouck 1996). The mean weight was 543.5 grams (range of 252.6 to 1,571.2 grams), and the mean length was 358.4 mm, with a range of 300 to 500 mm (Figure 5.2-4).

Table 5.2-6. The date of tagging, transmitter coding, capture method, sex, weight and length of 20 adult rainbow trout tagging in Grant Creek, Alaska 2013.

Date	Channel	Code	Capture Method	Sex	Age	Weight (g)	Length (mm)
24-May-13	2	11	Angling	Unknown	---	462.6	343
6-Jun-13	17	31	Weir	Male	3	1571.2	500
15-Jun-13	2	17	Weir	Male	3	767.4	402
17-Jun-13	17	44	Weir	Female	6	548.2	357
17-Jun-13	2	12	Weir	Female	3	969.4	431
25-Jun-13	17	32	Angling	Female	7	406.2	345
28-Jun-13	2	18	Angling	Female	3	334.0	309
1-Jul-13	2	21	Angling	Female	3	634.0	382
1-Jul-13	17	25	Angling	Male	6	252.6	304
3-Jul-13	2	22	Angling	Male	7	269.2	309
3-Jul-13	17	45	Angling	Male	4	457.8	348
3-Jul-13	17	26	Angling	Male	4	551.6	373
4-Jul-13	2	13	Angling	Female	3	535.4	357
5-Jul-13	17	33	Angling	Female	3	724.8	411
5-Jul-13	2	19	Angling	Male	3	398.2	329
7-Jul-13	17	46	Angling	Male	3	582.6	385
9-Jul-13	17	37	Angling	Female	3	314.4	318
10-Jul-13	17	38	Angling	Male	5	487.2	335
11-Jul-13	2	23	Angling	Male	3	284.2	300
11-Jul-13	17	27	Angling	Male	3	318.0	329
					Mean	**543.5**	**358.4**

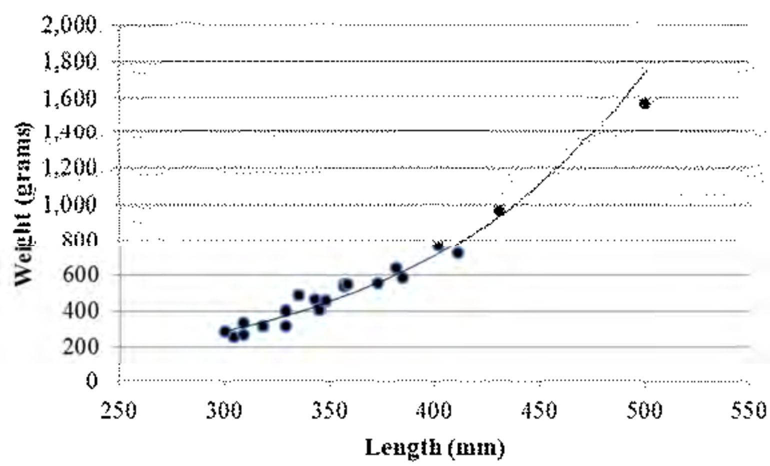

Figure 5.2-4. The length-weight relationship of radio-tagged adult rainbow trout in Grant Creek, 2013.

During the course of the study, all 20 fish were detected at some time by one of the fixed-telemetry stations located at the Reach 4/5 break and near the confluence of Grant Creek, or during one of the mobile telemetry surveys. Of those, four fish were detected within Reach 5 (see Section 5.2.2), while 17 fish were detected at the lower site.

During the course of 37 mobile surveys, a total of 198 contacts were made with radio-tagged adult rainbow trout within Reaches 1-4 of Grant Creek; 124 contacts in Reach 1, 40 in Reach 2, 31 in Reach 3, and 3 in Reach 4 (Figure 5.2-5). Of the 20 radio-tagged fish, 18 were detected during mobile surveys. The other two fish that were not detected during mobile surveys were detected shortly after tagging (three to six hours) by the fixed-telemetry array downstream of the weir as the fish migrated downstream and exited Grant Creek into the Trail Lake Narrows.

Mobile detections of rainbow trout can be assessed by their location within a reach (i.e., mainstem, backwater areas, and side-channels) and habitat type. Of the 124 detections within Reach 1, all were located within the mainstem, with 23 fish locations noted within pools, and 101 fish locations within riffle habitat (Table 5.2-7). A total of 40 detections occurred within the Reach 2 mainstem, with 19 fish locations within pool habitat, 13 in riffle habitat, and 8 within backwater areas. Within the Reach 3 mainstem, 9 detections were observed in pool habitat and 11 in riffle habitat. Within the Reach 3 Predominant Side Channel, three detections were observed in pool habitat and 11 detections within riffle habitat, and three detections were recorded in the Reach 3 Secondary Channel within pool habitat. Finally, a total of three detections were observed in the Reach 4 mainstem; with 1 detection in each of the pool, riffle, and pocket water habitats.

Table 5.2-7. Habitat use by location based on mobile telemetry surveys for radio-tagged rainbow trout in Grant Creek, AK, 2014.

Reach - Area	Riffle	Pool	Back-Water	Step Pool	Glide	Pocket-Water	Total
1 - Mainstem	101	23					**124**
2 - Mainstem	13	19	**8**				**40**
3 – Mainstem	11	9					**20**
3 – Predominant Side Channel	5	3					**8**
3 – Secondary Side Channel		3					**3**
4 - Mainstem	1	1				**1**	**3**
Total	**131**	**58**	**8**	**0**	**0**	**1**	**198**

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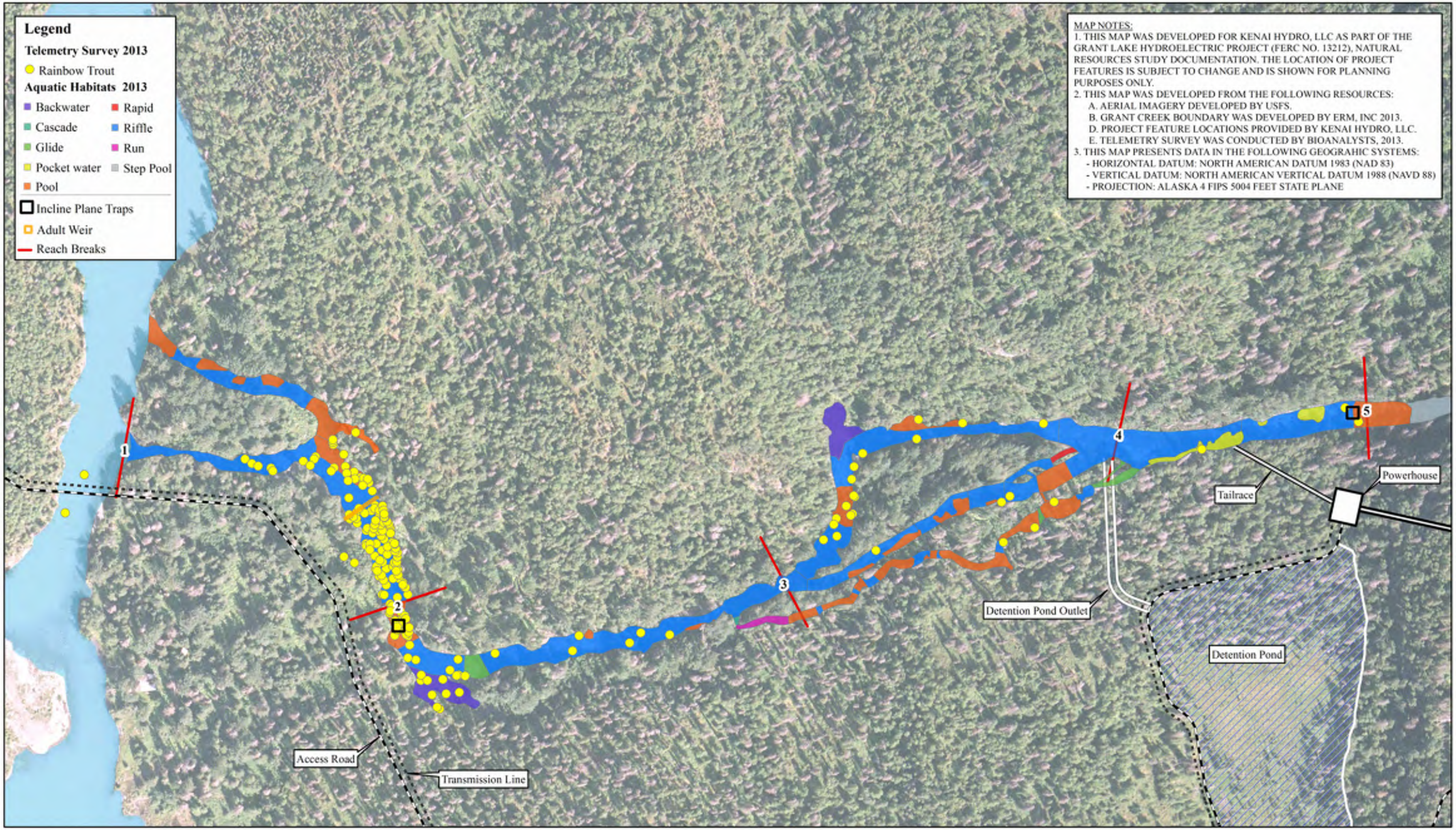

N

Drawing Scale:
0 75 150 300 Feet

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GRANT LAKE NATURAL RESOURCES STUDY

Figure 5.2-5
Telemetry Survey Data
Rainbow Trout Reaches 1 - 4

DESIGNED	J. Woodbury
DRAWN	J. Woodbury
CHECKED	J. Stevenson
ISSUED DATE	2/25/2014

DRAWING
1 of 1

SCALE: 1:2,000

REV	DATE	BY	DESCRIPTION

Furthermore, of the 20 radio-tagged rainbow trout, all 20 were detected at some point within Reach 1 (either by the fixed telemetry station or during mobile surveys). Fourteen of the twenty tagged rainbow were also detected in reaches two and three, three in Reach 4, and as discussed previously, four in Reach 5 (Table 5.2-8). The tagged Dolly Varden was not detected at any time after release.

Table 5.2-8. The number of radio-tagged rainbow trout and Dolly Varden detected by reach within Grant Creek, Alaska 2013.

Reach	Rainbow (n = 20)	Dolly Varden (n = 1)
1	20	0
2	14	0
3	14	0
4	3	0
5	4	0

The detections of fish in Reach 1 and 2 occurred throughout the period radio-tagged rainbow trout were detected within Grant Creek (May 25 through October 17), whereas detections in Reach 3 occurred primarily shortly after tagging (June 20 through August 15); and the single detection in Reach 4 occurred on June 28. As discussed in Section 5.2.2.1, no rainbow trout redds were observed in Grant Creek in 2013. However, due to the poor water clarity and high flows, that was not unexpected. Detections primarily in Reach 3 shortly after tagging, coupled with suitable pockets of gravel at the locations of detection may suggest that rainbow trout spawning possibly occurred in Reach 3; including both the mainstem of Grant Creek and the secondary channel. The location of detections in Reach 3 for rainbow trout correspond with the location of observed redds for both sockeye and coho. And while spawning substrates for the three species varies to some degree, the observations for Chinook, sockeye, and coho indicate that due to the limited amount of spawning gravel in Grant Creek, the fish will spawn in what visually appears to be marginal spawning habitat. However, it should be noted that observations of radio-tagged rainbow in Reach 3 may well have been due to tagged fish taking advantage of feeding opportunities at those locations.

As can be seen in Figure 5.2-5, the majority of rainbow trout detections were in Reach 1 and to a lesser extent, the lower portion of Reach 2. These areas were also where the greatest concentration of sockeye and coho spawned. Detections of rainbow trout in these areas occurred throughout the tracking period and toward the end of the study. Near the end of the study period, these areas were the only locations where tagged rainbow resided. These factors indicate that while it is possible that some rainbow spawned within this area, fish likely resided within this area to take advantage of feeding opportunities.

Review of the last date of detection by either mobile surveys or the fixed-site telemetry system provides an opportunity to determine the date of exodus from Grant Creek. Mobile telemetry surveys continued until tagged fish were no longer detected in Grant Creek, which included tagged Chinook, sockeye, and coho. The last telemetry survey was conducted on October 29; however, the date of last detection for rainbow trout during a mobile survey in Grant Creek was on October 17. Some fish were detected later than October 17 by the fixed-site telemetry system near the confluence; but these detections were likely the result of tagged fish travelling downstream and exiting Grant Creek into the Trail Lake Narrows. For 18 tagged rainbow trout, the mean and median date of last detection in Grant Creek was September 1, with the earliest date of exodus being June 17, and the latest date being October 26 (Table 5.2-9). Two additional fish appear to have expired during the study period. The transmitter of one fish (Fish I.D. 2/17) was tracked to the general area under a bald eagle nest along the left bank (looking downstream) of Reach 1 shortly after being tagged. While the transmitter was never recovered, its position remained constant over the course of several months. The transmitter of a second fish (Fish I.D. 17/31), which had been detected in Reach 5 numerous times, was recovered on shore near a log jam near the top of the secondary channel in Reach 3. The transmitter antenna had a number of kinks that appeared to be due to bite marks.

Table 5.2-9. The date of last detection for 18 radio-tagged adult rainbow trout in Grant Creek, Alaska, 2013.

Channel	Code	Last Date of Detection
2	11	23-Oct-13
2	12	13-Jul-13
2	13	9-Sep-13
2	18	28-Jun-13
2	19	30-Jul-13
2	21	17-Oct-13
2	22	26-Oct-13
2	23	27-Jul-13
17	25	17-Oct-13
17	26	25-Aug-13
17	27	17-Aug-13
17	32	2-Oct-13
17	33	1-Oct-13
17	37	17-Oct-13
17	38	5-Aug-13
17	44	17-Jun-13
17	45	19-Oct-13
17	46	16-Jul-13
	Mean:	1-Sep-13
	Median:	1-Sep-13
	Min:	17-Jun-13
	Max:	26-Oct-13

A single Dolly Varden female was surgically implanted with a transmitter on September 10, and weighed 1,844 grams and was 545 mm FL. This fish was not detected during any mobile surveys, and was never detected by one of the fixed-telemetry sites. Given the extensive telemetry surveying of Grant Creek, it is likely that the transmitter either failed after release, or the fish was captured by a predator that removed the carcass from the study area. Subsequent efforts to trap additional Dolly Varden at the weir and through angling proved unsuccessful.

Minnow trapping was used in lower Grant Creek (Reaches 1-4) from April through October to document species diversity, relative abundance, and distribution. Minnow trapping was also conducted to help establish important or sensitive juvenile rearing habitat. Over the course of the study there were 273 individual minnow traps (effort=6,137 hours) placed in different locations describing fish in distinct reaches, channel locations, and habitat units. Over 3,468 fish were captured, measured and weighed to describe baseline conditions in lower Grant Creek (Table 5.2-10). The following section discusses the results of this effort from a broad scale (reach) to a more focused habitat unit basis. The assumption is that CPUE at the reach, channel and habitat unit scale are a good indicator of relative abundance, distribution and fish-habitat associations.

Table 5.2-10. Number of minnow traps, total effort, and number of fish captured in lower Grant Creek from April through October 2013.

Lower Grant Creek Minnow Trapping				
Reach	**Number of Traps**	**Total Effort (days)**	**Total Effort (hrs)**	**Number of Fish**
1	63	60.6	1,454.4	899
2	77	72.1	1,713.6	819
3	69	63.6	1,567.2	1,187
4	64	59.4	1,404.0	560
Total	**273**	**255.7**	**6,139.2**	**3,465**

In lower Grant Creek, relative abundance of fish caught in minnow traps expressed as both CPUE and proportion of total catch was highest in Reach 3 followed by Reach 1, Reach 2, and then Reach 4 (Table 5.2-11). The CPUE in the lower gradient reaches (1-4) of Grant Creek were more than two times the CPUE observed in the higher gradient section of Reach 5 (Table 5.2-11). This information indicates that juvenile fish were most abundant in lower Grant Creek and in particular, Reach 3.

Table 5.2-11. Number, proportion, and CPUE for fish caught in Lower Grant Creek from April through October of 2013.

Reach	Number of Fish	Proportion	CPUE (fish/hr)
1	899	0.26	0.62
2	819	0.24	0.48
3	1,187	0.34	0.76
4	560	0.16	0.40
Total	**3,465**	**1.00**	**0.56**

Juvenile Chinook and Dolly Varden were the most numerous fish captured in minnow traps on Grant Creek followed by rainbow trout, coho, sculpins sp. and three-spine sticklebacks (Table 5.2-12). Few juvenile sockeye were captured in minnow traps in either Grant Creek (no fish) or Trail Lakes Narrows (1 fish) and is likely related to their early life history and behavior. That is, shortly after emergence sockeye generally tend to migrate into lakes as fry where they feed and grow (Burgner 1991). The size of post-emergent sockeye fry in Grant Creek would likely have been too small (<40 mm FL) to effectively capture in Grant Creek. Also, the period of exposure to minnow trapping would have also been very brief before they emigrated from Grant Creek.

Table 5.2-12. Number, proportion and CPUE of fish caught in lower Grant Creek with minnow traps from April through October, 2013.

Lower Grant Creek Minnow Trapping			
Species	**Number**	**Proportion**	**CPUE (fish/hr)**
Chinook	1,244	0.359	0.20
Dolly Varden	1,142	0.330	0.19
Coho	420	0.121	0.07
Rainbow Trout	397	0.115	0.06
Sculpin sp.	258	0.074	0.04
Three-spine Stickleback	4	0.001	0.00
Grand Total	**3,465**	**1.000**	**0.56**

The relative abundance of fish observed in Grant Creek varied over time. Repeated minnow trap sampling from April through October in lower Grant Creek showed that relative abundance increased from fairly low levels in April and May representing late winter and early spring stream conditions to much higher levels in late spring, summer and fall (June-October) (Figure 5.2-6; Table 5.2-13). In general, peak abundance (catch) occurred during the summer. CPUE for juvenile Chinook increased from April to a peak in September and declined in October (Figure 5.2-6). Recently emerged Chinook fry (<50 mm FL) were first noted in minnow traps in June but fry of this size were also noted in July and August. Juvenile Chinook varied in size from 45-110 mm FL. CPUE for juvenile coho salmon increased steadily from May to a peak in August and declined in September and October (Figure 5.2-6). Recently emerged coho fry (<50 mm FL) were first noted in minnow traps in July but fry of this size were also noted in August, September (1-fish) and October (1-fish). Juvenile coho varied in size from 42-106 mm FL. For Dolly Varden, the greatest CPUE occurred in June and remained fairly stable in summer and fall. No Dolly Varden less than 50 mm FL was captured in minnow traps. Dolly Varden varied in size from 52-165 mm FL. Catch of juvenile rainbow trout decreased from April to June and remained relatively low into July and August. In September and October there was a noticeable increase in juvenile rainbow trout. Small rainbow trout fry (<50 mm FL) were noted in April (1-fish), May (2-fish) and June (1-fish). However, the majority of small rainbow trout fry were observed in September and October. Rainbow trout varied in size from 43-146 mm FL.

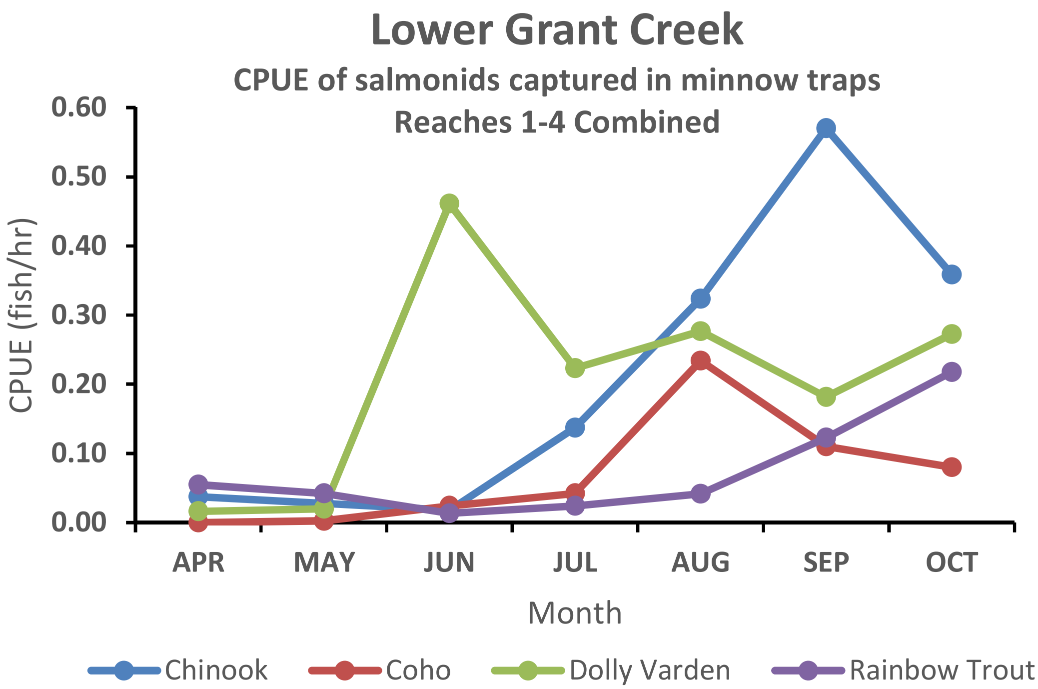

Figure 5.2-6. CPUE for juvenile Chinook, coho, Dolly Varden and rainbow trout from minnow trapping in lower Grant Creek from April through October, 2013.

Table 5.2-13. Numbers of fish collected from minnow trapping in lower Grant Creek from April through October 2013.

Fish Species	Month							
	Apr	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Total**
Chinook	33	24	15	120	280	484	288	1,244
Coho	0	2	20	37	202	93	66	420
Dolly Varden	14	17	371	174	220	143	203	1,142
Rainbow Trout	46	34	10	18	32	92	165	397
Sculpin sp.	19	7	35	40	50	29	78	258
Three-spine Stickleback	0	0	1	1	2	0	0	4
Total	**112**	**84**	**452**	**390**	**786**	**841**	**800**	**3,465**

Most of the patterns of change in fish abundance and CPUE over time is likely the result of new recruits (age-0 fish) that become available for capture (>40 mm FL) in minnow traps post emergence in spring (Chinook and coho) or summer (rainbow trout). What is less apparent is the increase in abundance of Dolly Varden, which is likely explained in part, by new recruits but also habitats that became available (side channels) as flows increased. The low catch of most fish during April and May does not appear to be a bias in sampling method and comports well with snorkel observations at those times.

Most fish that occur in Grant Creek were present in all reaches of lower Grant Creek (Table 5.2-14). No juvenile sockeye or arctic grayling were captured in lower Grant Creek. There were a few three-spine sticklebacks captured in lower Grant Creek (reaches 1 and 3). The number of Chinook and Dolly Varden captured in lower Grant Creek was similar as was the number of coho and rainbow trout.

Table 5.2-14. Number of fish captured in minnow traps in different reaches of lower Grant Creek from April through October 2013.

Fish Species	Lower Grant Creek Reaches (Number)				Total
	1	2	3	4	
Chinook	370	351	390	133	**1,244**
Coho	89	116	176	39	**420**
Dolly Varden	306	150	418	268	**1,142**
Rainbow Trout	75	115	126	81	**397**
Sculpin sp.	57	87	75	39	**258**
Three-spine Stickleback	2	0	2	0	**4**
Total	**899**	**819**	**1,187**	**560**	**3,465**

In lower Grant Creek, CPUE was highest (0.758 fish/hr.) in reach 3 for all fish except sculpins (Table 5.2-15). CPUE for juvenile Chinook was similar in reaches 1 and 2, but for coho the capture rate was nearly twice as high in Reach 3 as other reaches. For rainbow trout, capture rates were fairly uniform in all reaches of lower Grant Creek. Similar to Chinook, Dolly Varden had the highest capture rates in reaches 1 and 3. Unlike Chinook, Dolly Varden had a higher capture rate in Reach 4 than in Reach 2. In lower Grant Creek the capture rates for sculpins was fairly uniform across all reaches. The capture rates presented for lower Grant Creek indicate that there may be some channel or habitat characteristics within different reaches preferred by some fish species.

Table 5.2-15. CPUE for fish captured in minnow traps in different reaches of lower Grant Creek from April through October 2013.

Fish Species	Lower Grant Creek Reaches (CPUE)				Total
	1	2	3	4	
Chinook	0.254	0.203	0.256	0.093	**0.203**
Coho	0.061	0.067	0.115	0.027	**0.068**
Dolly Varden	0.210	0.087	0.274	0.188	**0.186**
Rainbow Trout	0.052	0.066	0.083	0.057	**0.065**
Sculpin sp.	0.039	0.050	0.049	0.027	**0.042**
Three-spine Stickleback	0.001	0.000	0.001	0.000	**0.001**
Total	**0.618**	**0.473**	**0.778**	**0.393**	**0.564**

Capture rates were assessed for juvenile fish in lower Grant Creek by location within the active channel and habitat unit. Channel descriptors were used to describe the location of three broad categories: side channels areas, backwater areas or mainstem areas.

In lower Grant Creek, CPUE was highest in side channel areas followed by backwater areas and then locations within the main stream channel (mainstem) (Figure 5.2-7). Side channels occur mostly in Reaches 1 and 3 and backwater areas occur only in Reaches 2 and 3. Aquatic habitats are discussed in more detail in the Instream Flow Study, Final Report (KHL 2014a).

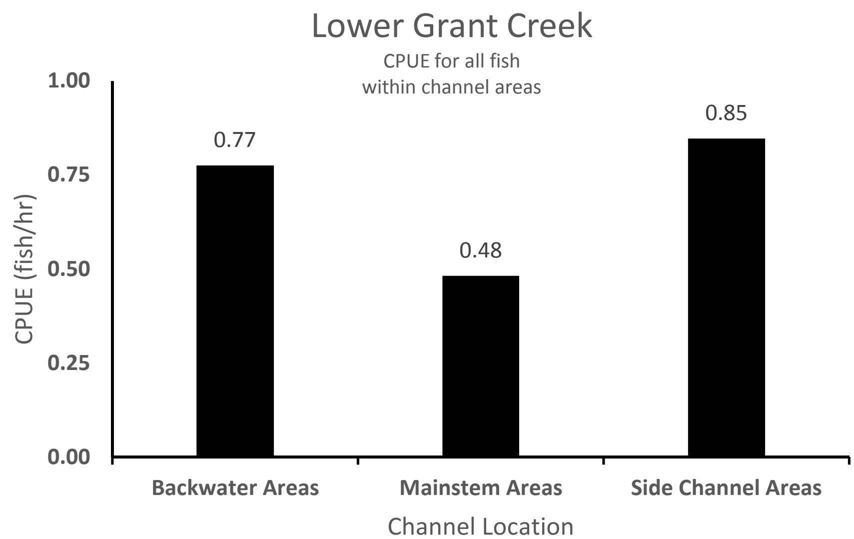

Figure 5.2-7. CPUE for fish captured in minnow traps placed in backwater, side channel and mainstem areas of lower Grant Creek from April through October 2013.

Capture rates for salmonids varied within channel types on lower Grant Creek (Figure 5.2-8). For juvenile Chinook and coho, capture rates were highest in backwater areas while Dolly Varden and rainbow trout CPUE was the highest in side channels. Mainstem areas dominated by riffle habitat had the lowest CPUE for juvenile Chinook and coho. Dolly Varden had the lowest capture rates in backwater areas and rainbow trout capture rates were the same in both mainstem and backwater areas.

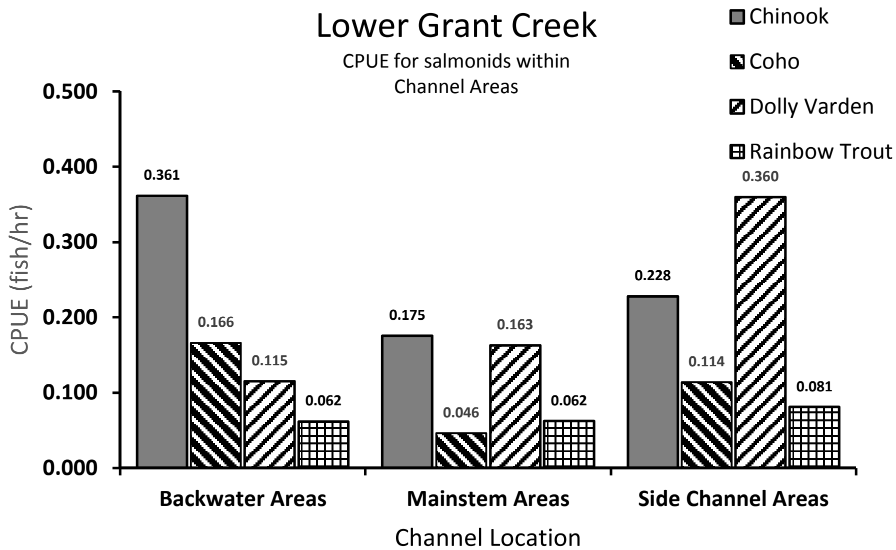

Figure 5.2-8. CPUE for salmonids captured in minnow traps placed in backwater, side channel and mainstem areas of lower Grant Creek from April through October 2013.

In lower Grant Creek, CPUE for salmonids varied by species and habitat unit type (Figure 5.2-9). Catch rates for juvenile Chinook were nearly equal between pools and glides and the least in riffles and pocket water. For coho, the catch rate was highest in pools followed by riffles. No coho were captured in glides. Catch rates for Dolly Varden were highest in glides and runs and lowest in riffle habitat. Juvenile rainbow trout had the highest catch rates in glides and pocket water and was the least in pool habitat. The high catch rates in glide and run habitats are somewhat counterintuitive with basic habitat preferences for most juvenile salmonids. Both of these habitat types were rare in lower Grant Creek.

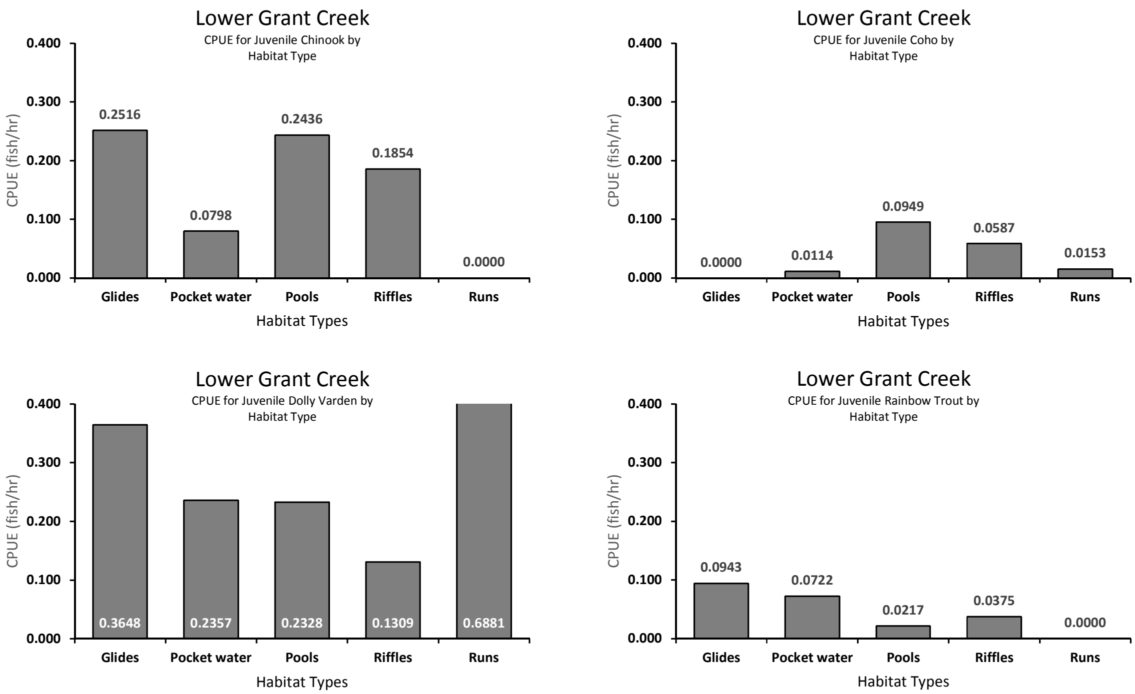

Figure 5.2-9. CPUE for salmonids captured in minnow traps placed in different habitat unit types of lower Grant Creek from April through October, 2013.

Minnow trapping in lower Grant Creek showed that salmonids were present in all reaches of lower Grant Creek with the highest catch rate (0.778 fish/hr) noted in Reach 3. Reach 3 contained all channel types (mainstem, backwater and side channels), which increases both channel and habitat diversity compared to other reaches. The capture rates of salmonids in lower Grant Creek indicate that side channel and backwater areas are important rearing areas (Figure 5.2-7). In particular, catch rates for juvenile Chinook, coho and Dolly Varden were highest in these channel locations likely because large woody debris or greater depth and/or lower velocities provided good juvenile rearing habitat (Figure 5.2-8). Juvenile coho and Chinook tend to prefer large, deep pools with abundant cover (McMahon 1983; Raleigh et al. 1986). Capture rates for rainbow trout were much more even by reach, channel and habitat designation. Rainbow trout, as generalist, appear to have similar requirements for abundant cover but depth (pool habitat) may be less important (Raleigh et al. 1984).

Nighttime snorkeling was used in both April and May to assess species diversity, distribution and relative abundance of fish in lower Grant Creek. From June through October, the water was too turbid to snorkel effectively. In April, low flows (18 cfs) and cold water (0.5-1.5°C) were the prevailing stream conditions. In May, both flow (150 cfs) and water temperature (4.0°C) had increased. These conditions are a good approximation of winter and early spring stream conditions in lower Grant Creek.

In mid-April, most salmonids were observed in pool habitat available in the mainstem and backwater areas of lower Grant Creek (Table 5.2-16). The highest fish density (fish/100 m^2) occurred in backwater areas available in Reach 3. Backwater areas in Reach 2 were frozen over and inaccessible to snorkeling. Riffle habitat had the lowest fish densities in lower Grant Creek. Side channel habitat was covered in snow and ice and was not available for sampling via night time snorkel surveys. Pool habitat (mainstem and backwater) that occurs in lower Grant Creek provides important overwinter habitat.

Table 5.2-16. Number and density of salmonids observed during night time snorkel surveys in lower Grant Creek in April 2013.

Month	Channel	Habitat	Species				Total	Total Area Sampled (m^2)	Fish Density (fish/100 m^2)
			Chinook	Coho	Dolly Varden	Rainbow Trout			
April	Mainstem	Glide	23	0	2	17	**42**	933.2	4.50
		Pool	202	0	15	140	**357**	7,192.6	4.96
		Riffle	5	0	2	32	**39**	8,462.5	0.46
	Backwater	Pool	46	1	1	35	**83**	793.6	10.46
		Total	**276**	**1**	**20**	**224**	**521**	**17,381.9**	**3.00**

Juvenile Chinook were the most abundant fish observed in lower Grant Creek followed by rainbow trout, Dolly Varden, and coho. Almost all juvenile Chinook observed were within the size range of 60-80 mm FL (Table 5.2-17). A few juvenile Chinook (4 fish) were in observed in the 80-100 mm FL size class. All juvenile Chinook observed in April are likely age-1 fish that overwintered in mostly pool habitats of lower Grant Creek. No juvenile Chinook fry (< 40 mm) or age-0 fish were observed in April. Rainbow trout varied in size from about 40-180 mm FL. Most were observed within the size class of 100-120 mm FL. It is reasonable to assume that several age classes overwintered in pool habitat of lower Grant Creek. There were few Dolly Varden and a single coho observed in lower Grant Creek in April. Dolly Varden varied in size from 40-160 mm FL and the single coho that was observed was within the 40-60 mm size class. There were probably several age classes of Dolly Varden overwintering in lower Grant Creek. Night time snorkel observations appear to comport well with minnow trapping that occurred in April. Juvenile Chinook and rainbow trout were the most abundant salmonids observed in April while Dolly Varden and coho were less abundant.

Table 5.2-17. Abundance of salmonids observed in 20-mm increments during night time snorkels surveys in lower Grant Creek in April and May 2013.

Month	Species	Size Classes (20-mm FL increments)									Total
		40 (20-40)	60 (40-60)	80 (60-80)	100 (80-100)	120 (100-120)	140 (120-140)	160 (140-160)	180 (160-180)	>180	
April	Chinook	0	0	272	4	0	0	0	0	0	**276**
	Coho	0	1	0	0	0	0	0	0	0	**1**
	Dolly Varden	0	1	4	11	3	0	1	0	0	**20**
	Rainbow Trout	1	17	31	56	73	32	11	3	0	**224**
	Total	**1**	**19**	**307**	**71**	**76**	**32**	**12**	**3**	**0**	**521**
May	Chinook	0	2	161	42	0	0	0	0	0	**205**
	Coho	0	4	7	1	0	0	0	0	0	**12**
	Dolly Varden	0	0	0	1	2	2	0	0	0	**5**
	Rainbow Trout	0	7	1	9	55	48	20	17	21	**178**
	Total	**0**	**13**	**169**	**53**	**57**	**50**	**20**	**17**	**21**	**400**

In mid-May, as flows and temperature increased most salmonids were still observed in pool habitat available in the mainstem, backwater, and side channel areas of lower Grant Creek (Table 5.2-18). Chinook and rainbow trout were still the most abundant fish observed in lower Grant Creek in May. There were a few Dolly Varden and coho observed. Pools in backwater areas had the highest fish density while riffles in the mainstem areas had the lowest fish density. Interestingly, riffle habitat in side channels had the second highest fish density in May. Glide habitat (non-turbulent fast water) classified in April had become turbulent and less glide-like with increased flows in May.

Table 5.2-18. Number and density of salmonids observed during night time snorkel surveys in lower Grant Creek in May 2013.

Month	Channel	Habitat	Species				Total	Total Area Sampled (m^2)	Fish Density (fish/100 m^2)
			Chinook	Coho	Dolly Varden	Rainbow Trout			
May	Mainstem	Pool	98	1	2	99	**200**	6,138.6	3.26
		Riffle	0	0	0	2	**2**	1,226.3	0.16
	S. Channel	Pool	6	0	1	34	**41**	1,137.1	3.61
		Riffle	7	1	0	22	**30**	676.1	4.44
	Backwater	Pool	94	10	2	21	**127**	1,111.4	11.43
May Total			**205**	**12**	**5**	**178**	**400**	**10,289.5**	**3.89**

Three different size classes of juvenile Chinook were observed in lower Grant Creek (Table 5.2-17). The 40-60 mm FL (2-fish) likely represent recent emerged age-0 fish while Chinook greater than 60 mm FL (203-fish) represent age-1 juvenile Chinook. Chinook emergence had probably started in May. In May, the range in coho size was similar to Chinook but with fewer fish. Coho emergence may have also begun in May. Rainbow trout varied in size from about 40 mm to greater than 180 mm FL. Most (161-fish) were observed within the size classes greater than 100 mm FL. From April to May, there was an increase in the number of larger rainbow trout in lower Grant Creek. Some of the shift in abundance of larger rainbow trout might be explained by growth but it is likely that feeding and spawning opportunities were bringing larger fish into Grant Creek. The number of Dolly Varden observed from April to May decreased and there were fewer small fish observed. The low abundance of Dolly Varden observed by both snorkeling and minnow trapping in winter and early spring might suggest that the higher abundance of Dolly Varden observed later in the year might be the result of both new recruitment and immigration into lower Grant Creek.

The lower incline plane trap was installed on April 30, 2013 and was in operation until October 16, 2013. The trap typically operated 24 hours per day, seven days per week, with few exceptions. The trap was not fished the first two weekends of operation (May 4-5 and May 11-12) since few fish were being captured by the trap. Trapping operations were suspended on three occasions: June 18-23 due to high flows that created safety issues for crews accessing the trap as well as an influx of debris due to bank flooding; September 11-15, also due to high flows and debris; and October 14 due to wind storms that resulted in an excessive amount of leaf litter in the trap. In each of these cases, trap operation was compromised during the period leading up to the time of outage. Throughout the study, the incline plane trap was checked and cleaned at least twice per day, and more frequently when necessary. During the period leading up to the June 18-23 outage, personnel remained on site 24 hours per day, and the trap was checked and cleaned approximately every 3 to 4 hours. During other periods of high debris load, CIAA staff assisted in the maintenance of the trap by checking and cleaning it typically at 2200 hours and 0200 hours.

As the juvenile migration progressed, it became apparent due to the absence of sockeye fry being captured that the incline plane trap was either not capturing fry sized fish, or it was not retaining them in the live box once captured. Salmonid fry were being observed along the margins of Grant Creek where the foot trails had been flooded. However, few fry sized fish were captured in the trap, nor were they being captured in the minnow traps. Both the incline plane trap's live box and the minnow traps were constructed with 0.6 cm square mesh. Through a series of tests, it became apparent that fry sized fish could escape the incline plane and minnow traps once entrained. As such, both incline plane traps were modified by installing 0.3 cm mesh in critical areas, and installing aluminum flashing around the bottom of the live box to create a sanctuary for captured fish. After these modifications, some fry sized fish were captured in the trap; albeit probably after the majority of the sockeye fry migrated into the Trail Lakes system.

In addition to trap outages and the initial poor efficiency in capturing fry sized fish, another complicating factor hindered the trapping of juvenile fish at the incline plane trap as they migrated out of Grant Creek. Upstream of the incline plane trap, located on the left bank is a distributary that at higher flows becomes watered, and which juvenile fish can migrate downstream bypassing the incline plane trap. This channel begins to overflow at approximately 426 cfs, and meanders in a southeasterly direction and eventually dumps directly into Lower Trail Lake without reconnecting to Grant Creek. During periods of flow, this channel was sampled using minnow traps, and contained a relatively high density of juvenile salmonids, suggesting its use as a migratory corridor. Because of this distributary, it was necessary to assess the need to block the juvenile migration into two periods; a period of relatively lower flow (≤ 425 cfs) when the distributary was "dry", and a period of higher flow (≥ 426 cfs), when the distributary was "wet". Furthermore, it was necessary to calculate trap efficiency for each species separately for each flow period in order to estimate juvenile abundance within Grant Creek. Based on the season-wide estimator described in Section 4.2.3, we calculated trap efficiencies for the lower incline plane trap. Estimation of abundance assumes that all fish used to estimate trap efficiency were active migrants; that there was no mortality between the release location and the incline plane trap; and that the marked fish behaved as the natural population would, that is, they distributed naturally within Grant Creek. To meet these requirements, the release location was selected based on guidelines described in Volkhardt, et al. (2007).

As can be seen in Table 5.2-19, ample numbers of Chinook, coho, and Dolly Varden were released to provide a season wide estimate of trap efficiency. However, collectively only 12 sockeye were released, with no recoveries. As such, it is not possible to get an abundance estimate for sockeye in Grant Creek. Likewise, only 13 rainbow trout were marked and released, with a single recovery. For rainbow, it is also not possible to estimate Grant Creek abundance. An additional point of interest is that during periods of higher flow, when migrating juveniles had the opportunity to utilize the upstream distributary, the capture efficiency was actually higher than when the channel was dry. This seems counter intuitive; however, this observation is consistent across all species. While undoubtedly a portion of the outmigrating salmonids were diverted into the distributary, the higher flows may have improved conditions that diverted juvenile fish that did not enter the distributary into the trap, resulting in higher trap efficiencies for all species.

Table 5.2-19. The number of fish released and recovered by species for the two flow blocks and their corresponding trap efficiencies.

	Low Flow Condition		High Flow Condition		Trap Efficiency	
Species	**Release**	**Recapture**	**Release**	**Recapture**	**Low**	**High**
Chinook	380	45	68	10	0.118	0.147
Coho	169	19	110	13	0.112	0.118
Sockeye	3	0	9	0	0.000	0.000
Dolly Varden	248	2	571	41	0.008	0.072
Rainbow Trout	8	0	5	1	0.000	0.200

To determine whether it was necessary to block the data into the high and low flow periods, a test of homogeneity based on a chi-square test of 1 degree freedom using a 2 x 2 contingency table was performed:

	High	**Low**
Caught	r_1	r_2
Not caught	$R_1 - r_1$	$R_2 - r_2$

Where:

R = the total number of fish released during trap efficiency trials; and
r = the number of R recaptured at the trap.

The tests of homogeneity during high and low flow conditions found no difference for Chinook and coho salmon; however, there was a flow effect for Dolly Varden. Therefore, a single estimate of trap efficiency was used to estimate abundance for Chinook and coho (0.123 and 0.115, respectively), whereas two seasonal estimates of trap efficiency were used for Dolly Varden (0.008 during the low flow period, and 0.072 during the high flow period).

Since there were a few data gaps due to the incline plane trap being down during high flow and debris conditions, missing days of data were extrapolated based on the calculations described in Appendix 1. The following table presents estimates of abundance for Chinook, coho, and Dolly Varden in Grant Creek, which represents all of Grant Creek upstream of the lower incline plane trap, including Reach 5 (Table 5.2-20).

Table 5.2-20. The number of juvenile migrants by species captured within the lower incline plane trap, and corresponding abundance estimates and standard errors based on capture efficiencies in Grant Creek.

			Dolly Varden		
Statistic	**Chinook**	**Coho**	**Low Flow**	**High Flow**	**Total**
Observed n	577	360	296	673	
Est. N	4,797.6	3,164.9	36,766.0	9,665.2	46,431.2
S.E. N	603.2	546.2	25,979.5	1,470.9	26,021.1

These values should be considered as estimates for parr sized fish only. That is, until the early part of July the incline plane trap was ineffective at catching fry sized fish (≤ 50 mm). By the time the incline plane trap had been fixed, the majority of fry sized fish (i.e., sockeye fry) had already migrated out of Grant Creek.

While an estimate of abundance for Dolly Varden is included, this species exhibits a different life history compared to Chinook, coho, or sockeye. Chinook and coho typically emigrate as both sub-yearlings and yearlings while sockeye migrate out shortly after emergence as sub-yearlings. Dolly Varden on the other hand may rear in small spawning streams for up to 4 years. As such, for Dolly Varden only a small portion of each year class were likely sampled, excluding of course sub-yearlings, which would not have been captured in the trap until after it had been modified. As a final note, the abundance estimates are for the geographical area from the Grant Creek Falls to the lower incline plane trap; which excludes approximately 210 meters from the trap to the Grant Creek confluence. This latter portion of Grant Creek has the highest density of observed spawning for all species of salmonids in Grant Creek; for which the progeny of these spawners would not be captured by the incline plane trap.

Based on fish size and time of sampling at the lower incline plane trap it is clear that juvenile salmonids of multiple age classes over-wintered in Grant Creek (Figure 5.2-10). For juvenile

Chinook, most fish were in the 80 mm range beginning about May 15. These fish are yearling Chinook that have overwintered in Grant Creek. This observation is supported by snorkel surveys conducted in April and May where juvenile Chinook (age-1) were commonly observed. Later, from June to the beginning of August, there appears to be two predominant size classes of juvenile Chinook captured in the trap. The larger individuals of the migration were in the 100-110 mm size class and represent yearling fish. The smaller individuals were around 50-80 mm, which would be consistent with sub-yearling fish. Later, in mid-August, there is a broad distribution of size for juvenile Chinook, and indicates a dominant subyearling migration with fewer yearling fish migrating out of Grant Creek.

For coho salmon juveniles, very few individuals were captured in the trap until the latter part of July (Figure 5.2-10). The fish that were captured earlier in the migration (end of May) however, were in the 60 mm range, and were likely over-wintering yearling fish. Later (early July through early September), coho juveniles ranged in size of 50-100 mm, and likely represent both sub-yearling and yearling fish. From these data, it appears that there were a few coho that over-wintered in Grant Creek. This observation is supported by few juvenile coho being observed during snorkel surveys in April and May.

For rainbow trout, based on the size distribution it appears that multiple year classes were captured early during the spring migration (i.e., mid-May to early June). As spring spawners, rainbow trout fry emerge in the summer, and due to cold water temperatures they do not grow substantially during the winter months. In Figure 5.2-10, it appears that there are at least two size classes of fish captured at the lower incline plane trap in the spring. There were individuals in the 50 mm size range that had overwintered in Grant Creek emerging the previous summer (brood year 2012). In the spring, there were also individuals in the 80-120 size range that likely emerged two years ago (i.e., brood year 2011). In the fall, rainbow trout had a similar size range indicating age-0 fish had recently emerged in the summer of 2013 and some individuals the previous year (age-1+).

For Dolly Varden, juveniles in the range of 80-110 mm were captured beginning mid-May. This indicates substantial over-wintering for Dolly Varden juveniles, which was substantiated with snorkel surveys in April and May. The abundance of migrating Dolly Varden was greatest in July and likely represents multiple age classes.

Collectively, a total of 3,942 fish were processed at the lower incline plane trap (this total does not include extrapolated numbers to account for trap outages); and includes 577 Chinook, 360 coho, 22 sockeye, 969 Dolly Varden, 36 rainbow trout, 833 sculpin (both slimy and coast range), 1,089 three-spine stickleback, and 56 round whitefish. Figure 5.2-11 shows the emigration period of Chinook, coho, and Dolly Varden, respectively. Sockeye have not been included in this analysis as the majority of sockeye migrating out of Grant Creek were likely not captured at the trap due to deficiencies associated with the trap prior to the early July retrofitting and the small size and likely rapid outmigration of sockeye to the Trail Lake system.

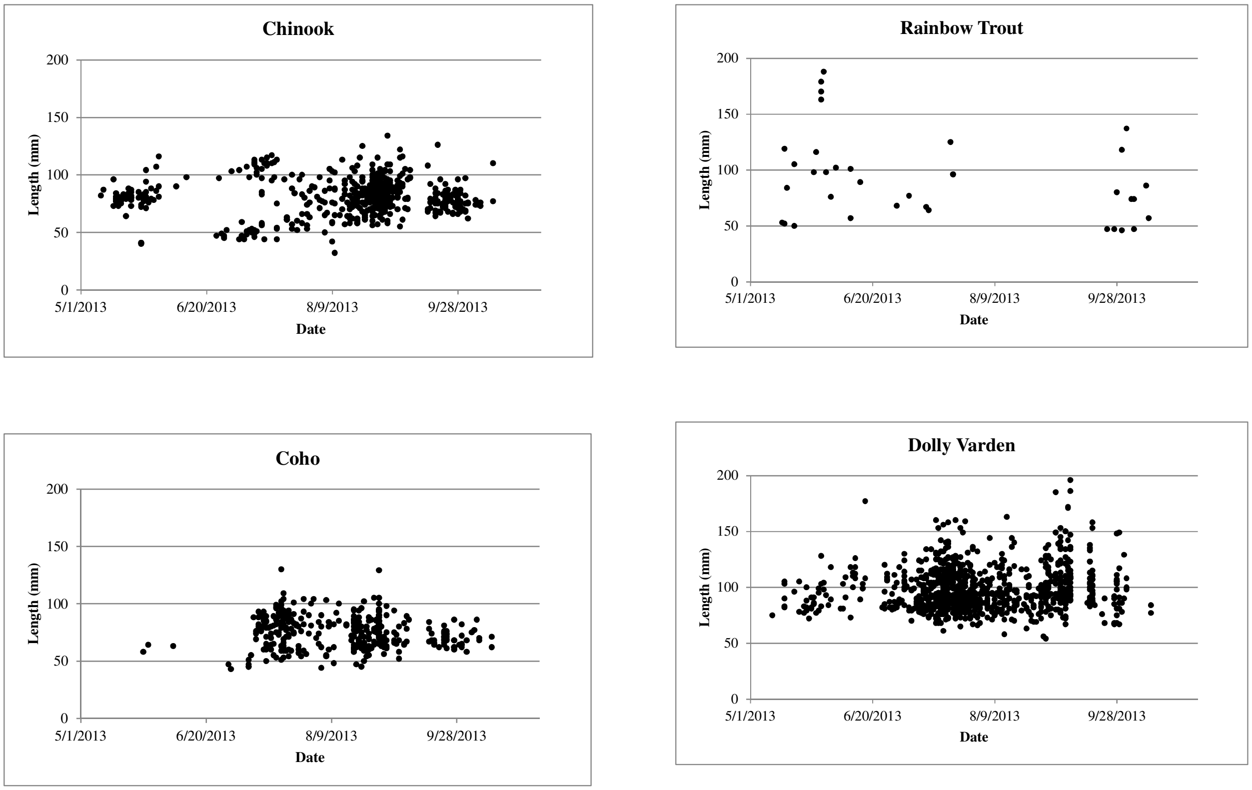

Figure 5.2-10. The distribution of size by date for Chinook, coho, rainbow trout, and Dolly Varden captured in the lower incline plane trap, Grant Creek, Alaska 2013.

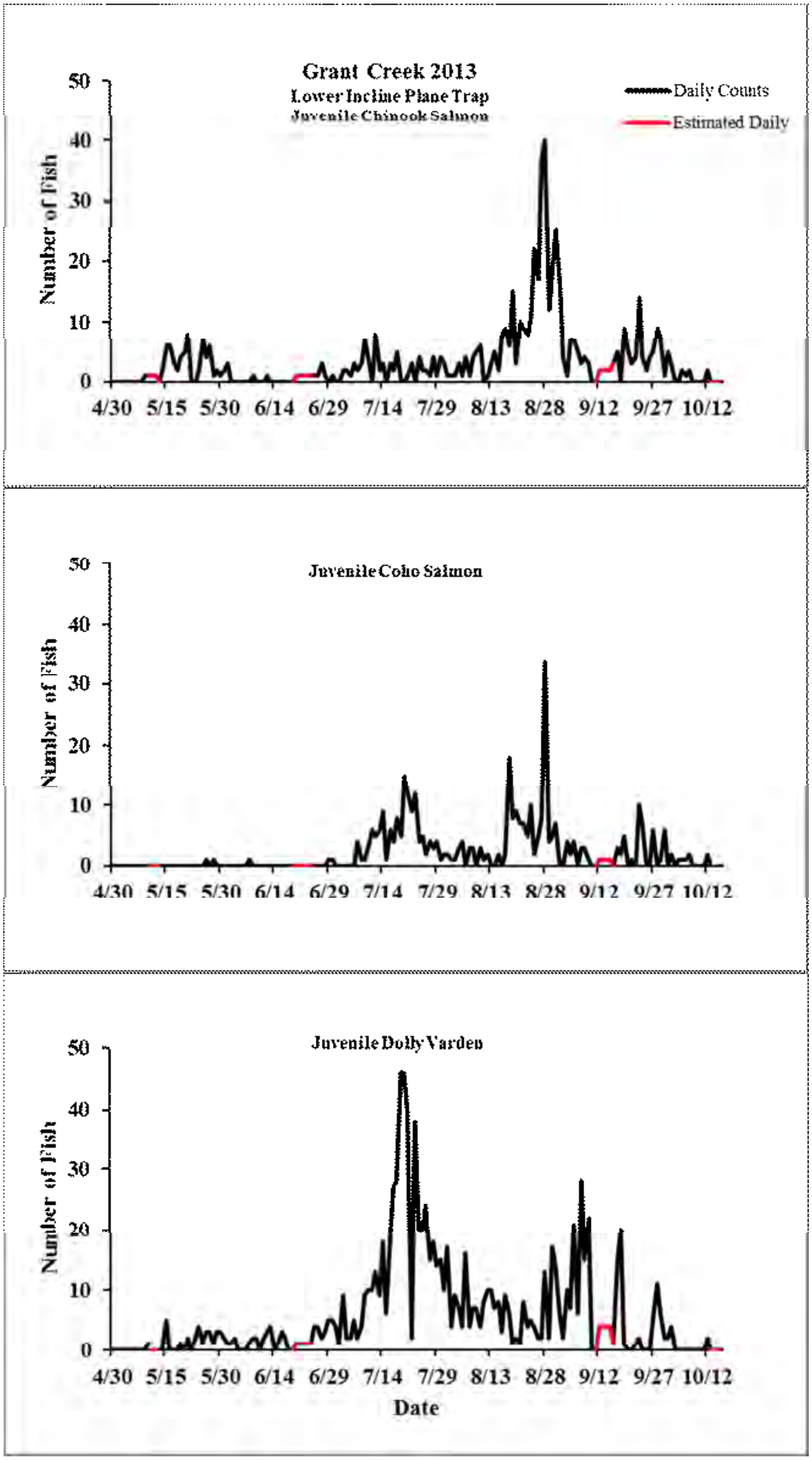

Figure 5.2-11. Emigration timing for Chinook, coho, and Dolly Varden juveniles at the Lower Incline Plane Trap in Grant Creek, Alaska, 2013. Estimated or extrapolated values are highlighted red.

5.3 Trail Lake Narrows Fish and Aquatic Habitats

The Trail Lake Narrows was sampled in July to assess species diversity and relative abundance. Minnow trapping, beach seining and angling were employed to describe baseline conditions in an area of potential impact associated with the installation and use of an access road into the Project Area (Figure 5.3-1). Minnow traps were set in 13 locations with a total fishing effort of 1,133 hours capturing 381 fish (Table 5.3-1).

Table 5.3-1. Number of minnow traps, total effort, number of fish captured and CPUE in the Trail Lake Narrows in July 2013.

Lower Grant Creek Minnow Trapping					
Reach	**Number of Traps**	**Total Effort (days)**	**Total Effort (hrs.)**	**Number of Fish**	**CPUE (fish/hr.)**
Trail Lake Narrow	52	47.2	1,133	381	0.34

Juvenile Chinook and three-spine sticklebacks were the most numerous fish captured in minnow traps followed by coho, Dolly Varden, sculpins sp., rainbow trout and sockeye (Table 5.3-2). CPUE for Chinook and coho was lower in the Trail Lake Narrows than Reaches 1-4 of Grant Creek but greater than Reach 5 of Grant Creek. CPUE for Dolly Varden and rainbow trout in the Trail Lake Narrows was less than all reaches of Grant Creek. Juvenile Chinook captured in minnow traps in July varied in size from 45-121 mm FL indicating that both age-0 and age-1 fish were present. Coho varied in size from 45-97 mm FL. The size range for coho also suggests that age-0 and age-1 fish resided in the Trail Lake Narrows. Rainbow trout varied in size from 63-71 mm FL. Dolly Varden varied in size from 57-184 mm FL, which likely represents several age classes.

Table 5.3-2. Number, proportion and CPUE of fish caught in the Trail Lake Narrows with minnow traps in July 2013.

Lower Grant Creek Minnow Trapping			
Species	**Number**	**Proportion**	**CPUE (fish/hr)**
Chinook	108	0.283	0.095
Dolly Varden	52	0.136	0.046
Coho	62	0.163	0.055
Rainbow Trout	4	0.010	0.004
Sockeye	1	0.003	0.001
Sculpin sp.	38	0.100	0.034
Three-spine Stickleback	116	0.304	0.102
Grand Total	**381**	**1.000**	**0.336**

REV	DATE	BY	DESCRIPTION

N

Drawing Scale: 0 25 50 100 Feet

MCMILLEN, LLC

Developed For: Homer Electric Association, Inc. A Touchstone Energy Cooperative

GRANT LAKE HYDROELECTRIC PROJECT - FERC PROJECT NO.13212

GRANT LAKE NATURAL RESOURCES STUDY

Figure 5.3-1
Minnow Traps &
Angling Locations

DESIGNED J. Woodbury
DRAWN J. Woodbury
CHECKED M. Miller
ISSUED DATE 2/18/2014

DRAWING 1 of 1

SCALE: 1:900

Beach seining was employed at night in three locations where lower velocities and small substrates were conducive to this sampling method. Juvenile Chinook were the most abundant fish captured in beach seines followed by round whitefish and sculpins (Table5.3-3). Other species made up less than five percent of the catch and no coho were captured using beach seining.

Table 5.3-3. Number and proportion of catch for fish seined in beach areas of the Trail Lake Narrows in July 2013.

Species	Abundance	Proportion
Chinook	100	0.58
Dolly Varden	2	0.01
Rainbow Trout	2	0.01
Sculpin sp.	27	0.16
Sockeye	4	0.02
Three-spine Stickleback	5	0.03
Round Whitefish	33	0.19
Total	**173**	**1.00**

Seven angling stations were used to capture fish within the Trail Lake Narrows area (Table 5.3-4). Single, barbless hooks on spinners were used, which allowed the expeditious release of adult salmon (Chinook, sockeye or pink) that were known to be in the area. However, no adult salmon were captured. There was a total of 13 adult trout/char that were hooked, with five of those fish being captured (effort=1 hr./station) for a CPUE of 0.7 fish/hr. Fish that were identified as salmonids were fish that came off the hook close enough to the angler to be identified (4fish). Some fish came off the hook much closer to the angler and species and an estimate of length could be provided (4fish). Five fish were captured and measured for length and weight before release.

Adult salmon, rainbow trout and Dolly Varden occur in the Trail Lakes Narrows area, which is also an upstream migration corridor for fish destined to spawn in Grant Creek and all other tributaries of upper Trail Lake. Likewise, this area is also a downstream migration corridor for salmonid production upstream. Dolly Varden and rainbow trout probably reside in the area taking advantage of juvenile salmon that migrate through or reside in this area. Juvenile Chinook were the most numerous fish captured with minnow traps and beach seines.

Spawning may also occur in this area; depressions (redds) were observed in suitable spawning gravels and sockeye carcasses were recovered in the area that had not been previously sampled. The redds could only be observed after water levels had resided in October.

Table 5.3-4. Angling station and number and size and weight of rainbow trout and Dolly Varden observed in July 2013.

Station	Species	Length (mm FL)	Weight (g)
1	Rainbow Trout	343	424.2
	Rainbow Trout	299	241.8
	Dolly Varden	180	NA
	Dolly Varden	160	NA
	Salmonid	NA	NA
2	Dolly Varden	240	NA
	Rainbow Trout	301	294.0
	Salmonid	NA	NA
3	Salmonid	NA	NA
	Salmonid	NA	NA
4	Dolly Varden	268	191.0
5	No Fish	-	-
6	Rainbow Trout	381	523.8
	Rainbow Trout	220	NA
7	No Fish	-	-

6 CONCLUSIONS

In the section that follows, we summarize the results of fisheries research conducted on Grant Creek in 2013, and describe potential areas of sensitivity that may be affected by hydroelectric development and systems operation.

6.1 Summary of Grant Creek Research

6.1.1 Anadromous Adult Salmonids

Escapement - The key species of adult salmon returning to Grant Creek include pink, Chinook, sockeye and coho salmon. Sockeye salmon were the dominant run entering Grant Creek with 1,117 fish counted above the weir. There were also 10 pink, 23 Chinook and 237 coho salmon counted above the weir. Estimates of salmon escapement based on visual counts (AUC) were within ±12 percent of the weir counts for returning salmon. The estimated escapement based on visual counts for the entire stream were 90 Chinook, 1,169 sockeye and 252 coho salmon.

The estimates for sockeye and coho appeared to be reasonable based on the spawning activity observed below the weir. However, the difference in the Chinook weir count (23 fish) and the estimate for the entire stream (90 fish) implied that 67 additional Chinook spawned downstream of the weir. That estimate appears to be high based on the spawning activity observed below the weir. An estimate of 46 Chinook is a more realistic estimate based on the fish per redd ratio of 7.6 fish/redd that was observed above the weir in 2013.

Run Timing – The period of adult salmon migration into Grant Creek occurs from the end of July and extends over a 13 week period to near the end of October. Pink salmon passed the weir on Grant Creek from the first week of August to the end of August. Chinook salmon passed the weir from the second week of August through the first week of September. Peak passage for pink and Chinook salmon occurred during the weeks of August 4 and August 11, respectively. The adult migration for sockeye occurred over a ten week period from the last week of July to the second week of October. Peak passage for sockeye occurred at the end of August. Coho salmon began entering Grant Creek the second week of September, peaked the first week of October and ended the last week of October. Run timing for Chinook and sockeye in 2013 was at least 1 week earlier than observed in 2009 (HDR 2009b). The sensitive time period based on run timing for adult salmon extends from the last week of July to the last week of October.

Spawning Timing and Distribution – The period of salmon spawning activity in Grant Creek extends over 13 weeks from first week of August to end of October. Pink salmon began spawning in early August with two redds constructed in Reach 1 of Grant Creek. Pink salmon were not observed in Grant Creek during 2009 visual surveys (HDR 2009b). Chinook salmon began spawning in mid-August and built six redds in a three week period. Sockeye began spawning at the end of August building 308 redds within the first two weeks. Sockeye spawning activity was noted until the last week of September. Coho began spawning the first week of October and were complete at the end of the month constructing 72 redds in Grant Creek. The sensitive time period for adult salmon based on spawning was from the first week of August to the end of October.

The majority (95 percent) of critical spawning habitat was concentrated within Reaches 1-3 of Grant Creek. Most (62 percent) documented redds were located in the mainstem areas primarily within riffle (62 percent) and pool (13 percent) habitats. Spawning also occurred in side channels (16 percent) and backwater areas (8 percent). In Reach 1, spawning for pink, sockeye and coho salmon most often occurred in riffle and pool habitat along the stream margins in the mainstem areas away from the thalweg and the highest stream velocities. Chinook spawned only in riffle habitat most often mid-channel where higher velocity and larger spawning substrates occurred. In Reach 2, most spawning occurred in mainstem riffle habitat along the stream margins for sockeye and coho salmon. Irregularities along the stream margin of riffle habitat created areas of lower velocity and suitable spawning substrate. Sockeye and coho also spawned in the stream margins of some pool habitat of Reach 2. In Reach 3, most spawning occurred in pool habitat in mainstem and side channel areas. One large backwater area was also used by sockeye and coho salmon. Spawning activity in Reach 4 was fairly low (4 percent) but did occur in riffle habitat along the stream margins of the right bank. Spawning also occurred along the left bank in pocket water. Spawning in Reach 5 was also low (1 percent) and occurred along the stream margins in step pool habitat in the lower end of the reach.

6.1.2 Resident Adult Salmonids

Run Timing and Abundance – Rainbow trout and Dolly Varden are identified as key species migrating into Grant Creek. The period of migration for rainbow trout lasted 6 weeks from the end of May to the end of June. The weir was not operational at the start of May, which could extend the period of migration by at least three weeks. There were 13 adult rainbow trout that passed the weir on Grant Creek. The abundance estimate is probably low considering the lack of coverage early in the season and based on undocumented passage of previously tagged fish. The migration period for Dolly Varden lasted 4 weeks from mid-August to mid-September. There were 14 Dolly Varden that passed the weir on Grant Creek.

Spawning Distribution - Of the 20 adult rainbow trout that were surgically implanted with radio transmitters, three males and one female were detected within Reach 5 subsequent to their release. Based on radio telemetry mobile surveys and detections by the fixed-site system at the Reach 4/5 break, it does not appear that any of the radio-tagged rainbow trout spawned within Reach 5. However, while no redds or adult rainbow trout were observed during surveys of Reach 5, given the poor water clarity, the probability of spotting live fish or redds was extremely low. Furthermore, no rainbow trout redds were observed anywhere within Grant Creek in 2013. The fact that suitable gravel exists in Reach 5 to support rainbow spawning, and the fact that rainbow trout fry were captured in minnow traps within Reach 5 strongly suggests that spawning does occur within this portion of Grant Creek; to what extent, however, is unknown.

It should be noted that it is possible that many of the tagged rainbow trout were not in spawning condition. The original intent was to have the weir operational on May 1, as rainbow will begin their spawning migration when stream temperatures reach about 4° C. However, due to a variety of factors, including high flows and the undercut bank discussed in Section 4.1.1, the weir was not fully functional until early July. Prior to that time, it is highly likely that a proportion of the rainbow trout that migrated past the weir was not intercepted, and therefore a proportion of the spawning population was missed.

The detections of fish in Reach 1 and 2 occurred throughout the period radio-tagged rainbow trout were detected within Grant Creek (May 25 through October 17), whereas detections in Reach 3 occurred primarily shortly after tagging (June 20 through August 15); and the single detection in Reach 4 occurred on June 28. As discussed in Section 5.2.2.1, no rainbow trout redds were observed in Grant Creek in 2013. However, due to the poor water clarity and high flows, that was not unexpected. Detections primarily in Reach 3 shortly after tagging, coupled with suitable pockets of gravel at the locations of detection suggest that it is possible that rainbow trout spawned in Reach 3; including both the mainstem of Grant Creek and the secondary channel. The location of detections in Reach 3 for rainbow trout correspond with the location of observed redds for both sockeye and coho. And while spawning substrates for the three species varies to some degree, the observations for Chinook, sockeye and coho indicate that due to the limited amount of spawning gravel in Grant Creek, the fish will spawn in what visually appears to be marginal spawning habitat. However, it should be noted that observations of radio-tagged rainbow in Reach 3 may well have been due to tagged fish taking advantage of feeding opportunities at those locations.

Feeding Distribution - Mobile detections of rainbow trout can be further scrutinized as to location by reach (i.e., mainstem, backwater areas and side-channels) and habitat type. Of the 124 detections within Reach 1, all were located within the mainstem, with 23 detections within pools and 101 detections within riffle habitat. A total of 40 detections occurred within the Reach 2 mainstem, with 19 detections within pool habitat, 13 in riffle habitat and 8 detections within backwater areas. Within the Reach 3 mainstem, 9 detections were observed in pool habitat and 11 in riffle habitat. Within the Reach 3 Predominant Side Channel, three detections were observed in pool habitat and 11 detections within riffle habitat, and three detections were recorded in the Reach 3 Secondary Channel within pool habitat. Finally, a total of three detections were observed in the Reach 4 mainstem; with 1 detection in each of pool, riffle and pocket water habitat.

Furthermore, of the 20 radio-tagged rainbow trout, all 20 were detected at some point within Reach 1 (either by the fixed telemetry station or during mobile surveys). Fourteen of the twenty tagged rainbow were also detected in reaches two and three, three in Reach 4, and as discussed previously, four in Reach 5. The tagged Dolly Varden was not detected at any time after release.

The majority of rainbow trout detections were in Reach 1 and to a lesser extent, the lower portion of Reach 2. These areas were also where the greatest concentration of sockeye and coho spawned. Detections of rainbow trout in these areas occurred throughout the tracking period and toward the end of the study. Near the end of the study period, these areas were the only locations where tagged rainbow resided. These factors indicate that while it is possible that some rainbow spawned within this area, fish likely resided within this area to take advantage of feeding opportunities.

6.1.3 Juvenile Salmonids

Grant Creek Juvenile Abundance and Emigration – There was a total of 4,798 Chinook, 3,165 coho and 46,431 Dolly Varden juveniles that were estimated to have migrated out of Grant Creek in 2013. These estimates represent Reaches 1-5 upstream of the lower incline plane trap and only includes parr sized fish. The trap was modified in early July to capture fry-sized fish (<50 mm), but it was likely too late to capture the majority of fry sized fish (i.e., sockeye, Chinook and fry) as they likely already migrated out of Grant Creek. For juvenile Chinook, emigration from Grant Creek peaked in mid-to-late August and again in September. A smaller peak occurred in May as age-1 fish emigrated from Grant Creek. Juvenile emigration for coho also peaked in mid-to-late August and in mid-to-late July. Juvenile emigration for Dolly Varden peaked in July and again in late August-early September.

Use of Reach 5 – Reach 5 of Grant Creek provides some juvenile rearing habitat but it is low in comparison to Reaches 1-4. The predominance of cascade habitat in Reach 5 likely influences the amount of juvenile habitat. Minnow trapping in step pool and pool habitat conducted in Reach 5 of Grant Creek from April through October captured 205 fish. Juvenile rearing habitat in Reach 5 occurs for Chinook, coho, rainbow trout, Dolly Varden and sculpin sp. Dolly Varden were the most numerous fish observed. The CPUE for all fish in Reach 5 was low (0.16 fish/hr) relative to Reaches 1-4 (0.56 fish/hr). Juvenile rearing habitat consisted mostly of step pool habitat and stream margins during most of the year. Snorkeling conducted in April and May documented that a few (16 fish) rainbow trout (60-280 mm fork length) rear in Reach 5 during winter and early spring.

No estimate of abundance in Reach 5 was obtained with the upper incline plane trap. Due to extreme flow conditions, trapping at this location was terminated. Trap operation resumed on September 19. Due to extremely high seasonal flows, it is unlikely that any emigrant trapping method (incline or screw trap) will produce the estimates of interest from Reach 5.

During the operation of the upper incline plane trap, a total of 172 fish were processed. Of those, there were 8 Chinook, 1 coho, 7 Dolly Varden, 5 rainbow trout, 19 sculpin and 132 sticklebacks. Due to the low numbers of species of interest, no fish were marked to assess trap efficiency, and therefore no estimates of abundance are available.

Use of Reaches 1-4 – Reaches 1-4 of Grant Creek provide the majority of juvenile rearing habitat in Grant Creek. Minnow trapping from April through October captured 3,468 fish. Relative abundance of fish caught in minnow traps expressed as both CPUE and proportion of total catch was highest in Reach 3 followed by Reach 1, Reach 2 and then Reach 4. Reach 3 contained the greatest diversity of habitats with pools and riffles represented in many areas (side channels, backwater areas and mainstem).

Snorkel surveys in mid-April demonstrated that Chinook, coho, rainbow trout and Dolly Varden overwinter in Reaches 1-4 on Grant Creek. In winter, most salmonids were observed in pool habitat available in the mainstem and backwater areas of lower Grant Creek (Reaches 1-4). The highest fish density (10.5 fish/100 m^2) occurred in backwater areas available in Reach 3. Riffle habitat had the lowest fish densities (0.5 fish/100 m^2). Side channel habitat was covered in snow and ice and was not available for sampling via night time snorkel surveys. Pool habitat (mainstem and backwater) that occurs in Reaches 1-4 of Grant Creek provides important overwinter habitat.

In Reaches 1-4 of Grant Creek juvenile Chinook and Dolly Varden were the most numerous fish captured followed by rainbow trout, coho, sculpins sp. and three spine sticklebacks. Repeated sampling showed that relative abundance increased from fairly low levels in April and May representing late winter and early spring stream conditions to much higher levels in late spring, summer and fall (June-October).

Recently emerged Chinook fry (<50 mm FL) were first noted in minnow traps in June but fry of this size were also noted in July and August. Juvenile Chinook varied in size from 45-110 mm fork length. Recently emerged coho fry (<50 mm FL) were first noted in minnow traps in July but fry of this size were also noted in August, September (1-fish) and October (1-fish). Juvenile coho varied in size from 42-106 mm FL. For Dolly Varden, the greatest CPUE occurred in June and remained fairly stable in summer and fall. No Dolly Varden less than 50 mm FL were captured in minnow traps. Dolly Varden varied in size from 52-165 mm FL. Catch of juvenile rainbow trout decreased from April to June and remained relatively low into July and August. In September and October there was a noticeable increase in juvenile rainbow trout. Small rainbow trout fry (<50 mm FL) were noted in April (1-fish), May (2-fish) and June (1-fish). However, the majority of small rainbow trout fry were observed in September and October. Rainbow trout varied in size from 43-146 mm FL.

The highest CPUE in Reaches 1-4 of Grant Creek occurred in side channel areas followed by backwater areas and then locations within the main stream channel. Side channels occur mostly in Reaches 1 and 3 and backwater areas occur only in Reaches 2 and 3. For juvenile Chinook and coho, capture rates were highest in backwater areas while Dolly Varden and rainbow trout CPUE was the highest in side channels. Mainstem areas dominated by riffle habitat had the lowest CPUE for juvenile Chinook and coho.

In Reaches 1-4 of Grant Creek, CPUE for salmonids varied by species and habitat unit type. Catch rates for juvenile Chinook were nearly equal between pools and glides and the least in riffles and pocket water. For coho, the catch rate was highest in pools followed by riffles. No coho were captured in glides. Catch rates for Dolly Varden were highest in glides and runs and lowest in riffle habitat. Juvenile rainbow trout had the highest catch rates in glides and pocket water and was the least in pool habitat.

Minnow trapping in lower Grant Creek showed that salmonids were present in all reaches of Grant Creek with the highest catch rate (0.78 fish/hr.) noted in Reach 3. Reach 3 contained all channel types (mainstem, backwater and side channels), which increases both channel and habitat diversity compared to other reaches. The capture rates for salmonids in Reaches 1-4 of lower Grant Creek indicate that side channel and backwater areas are important juvenile rearing areas.

6.1.4 Trail Lake Narrows

Adult salmon, rainbow trout and Dolly Varden occur in the Trail Lakes Narrows area. The Trail Lake Narrows area is an upstream migration corridor for fish destined to spawn in Grant Creek and all other tributaries of upper Trail Lake. Likewise, this area is also a downstream migration corridor for salmonid production upstream. Dolly Varden and rainbow trout probably reside in the area taking advantage of juvenile salmon that migrate through or reside in this area. This area may also provide spawning and resting areas for adult salmon. Redds in suitable spawning gravels and sockeye carcasses were found that had not been sampled. Chinook and coho salmon may spawn in this area as well.

Juvenile Chinook and three-spine sticklebacks were the most numerous fish captured in minnow traps followed by coho, Dolly Varden, sculpins sp., rainbow trout and sockeye. CPUE for Chinook and coho was lower in the Trail Lake Narrows than Reaches 1-4 of Grant Creek but greater than Reach 5. Juvenile Chinook captured in minnow traps in July varied in size from 45-121 mm FL indicating that both age-0 and age-1 fish were present. Coho varied in size from 45-97 mm FL. The size range for coho also suggests that age-0 and age-1+ fish were present in the Trail Lake Narrows. Rainbow trout varied in size from 63-71 mm FL. Dolly Varden varied in size from 57-184 mm FL with several age classes represented.

6.2 Potential Impacts Associated with the Construction and Operation of a Grant Creek Dam

This section summarizes potential impacts associated with the construction of the proposed Project. It should be noted that this summary is not intended to replace a detailed analysis of expected impacts using integrated Physical Habitat Simulation System (PHABSIM) results at a later date. It does, however, address perceived flow modification impacts based on operations as currently proposed for an average water year. Some potential impacts associated with the Project are not addressed in this section but will be more fully addressed in the DLA. Those potential impacts are:

- Gravel Recruitment – see Geomorphology Report (KHL 2014b);

- Temperature Variances – see Water Quality, Temperature and Hydrology Report (KHL 2014c);
- Outfall Design and Location; and
- Established Minimum Flows, Operational Scenarios and Ramping Rates.

The following assumptions were used to assess potential impacts:

- During the months of December through April, the powerhouse would generally be operated at a low level; that is, the smallest unit operating at sub-maximum capacity with a minimum flow condition (unknown level) established in the bypass segment of Reach 5;
- During the month of May, the lake level would be maintained, the minimum flow condition would be maintained through Reach 5, and the remainder of Grant Creek would be primarily operated as run-of-river. Therefore, the amount of flow through the powerhouse would be equal to the balance of run-of-river flow minus the Reach 5 minimum flow barring unforeseen circumstances such as higher or lower than normal run-off during this period;
- During June and July, the powerhouse would be operated at peak capacity with minimum flow conditions through Reach 5; and
- During the period of August through November, the system would be primarily operated in a run-of-river mode (based on current hydrology); that is, there would be a minimum flow condition within Reach 5, and the surplus would be ran through the powerhouse.

It should be noted that some variability still exists and that engineering feasibility work is currently underway to accurately refine the operating regime and fully specify infrastructural and operational parameters. This finalized work, after collaboration with stakeholders, will be fully documented in the Draft and Final LAs.

The operations described above would likely result in lower flows within Reach 5 throughout the year, with the period of December through April least impacted, and with the period of May through November lower relative to historic levels depending on minimum flow constraints. In June and July, once Grant Lake is refilled, flows within Reach 5 will increase but they will again be lower than historic levels.

Within Reaches 1-4 during the period of December through April, flows are expected to exceed historic levels, with the exception of December. For the months of May through November, excluding June and July, flows through Reaches 1-4 will follow run-of-river regimes (historic levels). In June and July, flows within Reaches 1-4 will decrease relative to historic levels until Grant Lake is refilled. Once the lake is refilled, flow levels within Grant Creek will return to run-of-river levels. As an additional note, it is likely that operations, in general, will sustain high flows for longer periods permitting the more consistent connection of side channel habitats.

6.2.1 Reach 5

6.2.1.1 Egg Incubation

A decrease in flows during the incubation period would result in more exposure of the channel bed and bank within Reach 5. The degree to which this will negatively affect salmonid incubation is unknown. However, given the nature of the canyon reach, which consists of nearly vertical walls, channel morphology may limit channel bed and bank exposure. Only 1 percent of the documented spawning that occurred in Grant Creek was in Reach 5.

Project operations are expected to result in decreased sediment transport through Reach 5 due to lower flows. This will decrease gravel recruitment to the stream including Reaches 1-4 (KHL 2014b). These alterations within Reach 5 may have the potential to negatively impact both resident and anadromous salmonid species.

6.2.1.2 Adult Spawning

Project operations may have varied impacts to spawning adult salmon and resident fish. With lower flows, some areas suitable for spawning may no longer be available to spawning salmonids, with a net loss in suitable spawning habitat. Proposed operations of the Project will likely result in more stable flows during spawning for both anadromous and resident species, which will likely have a neutral to slightly positive effect (reduced scour).

6.2.1.3 Juvenile Rearing

Decreased winter flows will likely have no net impact on rearing juveniles within Reach 5. The canyon reach is primarily cascade (57 percent), step pool (29 percent) and pool (14 percent) habitat, which provides ample rearing habitat at current winter flow conditions. However, a decrease in summer flows (and velocities) may increase juvenile habitat during that period of time. Natural flow conditions during high flow periods result in extremely high velocities within the canyon reach, resulting in a loss of suitable habitat (lower velocity areas) for juveniles. A decrease in flows may result in more juvenile habitat relative to current conditions.

6.2.2 Reaches 1-4

Hydrological impacts to Reaches 1 through 4 based on the Project operations described in the previous section are expected to result in an increase in the annual instream baseline flow (i.e., January through April); run-of-river operations in May; decreased flows in June and July until Grant Lake is refilled, at which time flows would revert to run-of-river; run-of-river flows August through November; and a slight decrease in flows in December.

These hydraulic conditions may result in the Reach 3 side channels being open throughout the winter. While current flows within Grant Creek are sufficient to maintain flow within these channels, they become snowed over. Higher flows may be sufficient to keep that from occurring.

The Reach 2 distributary would likely begin to flow later in the summer than it does under current conditions within an average water year, and would become watered once Grant Lake refilled during the June-July period. As flows for the period of August through November will likely be operated in a run-of-river mode, the Reach 2 distributary will dry up as it currently does in an average water year; that is, sometime in August.

Given the lower flows necessary to maintain flow within the Reach 1 distributary (109 cfs), it would remain watered during the period of May through November (based on an average water year).

6.2.2.1 Egg Incubation

The proposed operations would likely have a positive effect on incubating eggs within the mainstem of Grant Creek for anadromous species; particularly in areas that dewater or have minimum sub-surface flows during winter months (e.g., margins where fish have spawned, near the left bank upstream of the weir, etc.). This assumes of course, that baseline flows will be maintained at a high enough level relative to the natural conditions to keep these areas watered. To what extent survival will be increased is unknown at this time.

Likewise, increased late fall, winter and early spring baseline flow will likely benefit incubating eggs within the Reach 3 Predominant and Secondary side channels. Both of these channels begin to flow as soon as the snow and ice melt, but intra-gravel conditions during winter incubation are unknown. However, any increased flows during this period would likely improve incubation survival, assuming that flow is maintained within these channels during the incubation period. Again, to what extent is unknown.

For the Reach 2 distributary, there will likely be no net change in egg incubation. Under both current and potential hydrological conditions, that distributary is not watered continuously during the spawning/incubation period for either resident or anadromous salmonids. As such, there are no eggs incubating within this distributary.

Likewise, it is unlikely that there would be any net change to the Reach 1 distributary regarding egg incubation. No spawning was observed in this distributary despite flows occurring throughout most of the period of spawning observed in Grant Creek. This channel does not have substrate conducive to salmonid spawning, and therefore no change would be expected.

6.2.2.2 Adult Spawning

During the period of anadromous salmonid spawning within the mainstem of Grant Creek (August through October), the proposed operating scenario would result in run-of-river conditions. Therefore, no impact is anticipated. For resident species, which likely spawn in May and the first half of June, flow will likely be the same as natural conditions in May, and somewhat less in early June due to the refilling of Grant Lake. As the flow alterations in early June are relatively minor, no impact would be expected.

During anadromous and resident spawning in the Reach 3 side channels, flows are expected to be run-of-river (as described in the preceding paragraph). As such, no benefit or negative impact would be expected.

During stream surveys in 2013 of the Reach 2 distributary, no spawning of resident or anadromous species was documented. While this channel will likely be dewatered for a greater period of time relative to natural conditions, it does not occur during the anadromous spawning period. And while resident species could spawn within this channel, under natural conditions redds would become dewatered and developing embryos would die. As such, no change impacts or benefits would be expected for resident spawning.

6.2.2.3 Juvenile Rearing

Within the mainstem of Grant Creek, under proposed operations flows would increase during winter months, decrease slightly in June and July and follow run-of-river flows in May and August through November. In winter, modest increases in flow may result in an increase of juvenile over-winter rearing habitat. In general, weighted usable area (WUA) for juveniles increases at the lower end of the flow regime in Grant Creek with increases in flow (KHL 2014a). During June and July when flows are somewhat decreased, it may result in more juvenile habitat being maintained. That is, under high flow conditions, some juvenile habitat becomes more turbulent with greater velocity, which decreases available juvenile habitat. It should be noted however, that when flows increase dramatically, the margins of Grant Creek begin to flood, which provide excellent habitat for juvenile salmonids, especially young of the year. Given these scenarios, it is not possible to determine what impact may be expected without further IFIM analysis. That is, general trends in WUA for fry tend to increase with flow in some areas while for other areas WUA decreases.

As discussed above, it is possible that higher winter flows may result in the Reach 3 side channels being open during winter months. Should this occur, it would make a large amount of over winter habitat available to rearing juveniles. Given the quality of these side channels, this would certainly increase juvenile overwinter habitat. During the spring, summer and fall periods, the available habitat would not likely change much, if at all. Therefore, no impact or benefit would be expected.

For the Reach 2 distributary, the altered flow regimes would likely result in that channel being dewatered for a greater period of time relative to natural conditions, and would likely occur during the June/July period. This alteration would result in the loss of a substantial amount of juvenile rearing habitat that is currently utilized by both anadromous and resident species. To what extent this alteration would have on juvenile fish is unknown.

The Reach 1 distributary should remain watered similarly under the altered conditions relative to natural conditions. As such, no impact or benefit would be anticipated.

6.2.3 Global Issues

The discussion presented in the preceding sections is based on one possible operating scenario. Issues and perceived impacts may change depending on refinements to that scenario. As that scenario is refined, aquatic impacts will be refined accordingly and will be further detailed in the DLA. While only mentioned briefly in the previous section, minimizing impacts associated with ramping rates, temperature variances and gravel recruitment should be considered during the Project design phase and when developing Project operations. Establishment of minimum flow requirements, both in Reach 5 and lower Grant Creek, as well as outfall design should be considered as the Project is more fully developed. Ongoing efforts in the Aquatic Resources Working Group will help refine potential impacts, which will assist in development of PM&E measures and preparation of the DLA.

In this section there is a brief discussion of some aspects of Project operation that may be addressed in the DLA as operational scenarios are fully developed. For example, the rate in which Project flows are ramped up, and especially decreased can result in stranding and mortality of juvenile salmonids. Stranding has the potential to isolate fish in areas of the river channel where predators or increased water temperatures can cause mortality. Typically, smaller juvenile fish are the most vulnerable to potential stranding because of their habitat preference and poor swimming ability. The incidence of stranding for juvenile fish is affected by river channel configuration, time of day, substrate type and water temperature among other factors.

Seasonal temperature variances may occur in winter and early spring as warmer water from Grant Lake is bypassed through the project downstream to Grant Creek (KHL 2014c). Temperature changes as small as 2°C can affect the rate of egg development during the incubation period, thus effecting time of hatching and emergence (Scannell 1992). Accelerated development leading to early emergence can have several disadvantages such as decreased foraging ability or emergence before suitable prey species are available and increased susceptibility to predation (Scannell 1992).

A reduction in gravel recruitment to Grant Creek is likely to diminish the quantity and quality of spawning habitat in Grant Creek (KHL 2014b). As discussed in KHL (201b), these impacts are likely to occur incrementally over time, and are typically measured in years and decades as the result of flow bypassed around the canyon reach. The canyon area of Grant Creek (Reaches 5 and 6) is the primary source of sediment recruitment.

7 VARIANCES FROM FERC-APPROVED STUDY PLAN AND PROPOSED MODIFICATIONS

In this section, variances that occurred from the FERC-approved study plan are discussed.

The upper incline trap had to be taken out of operation because of dangerous working conditions and potential loss/destruction of equipment. Due to extremely high seasonal flows, it is unlikely that any emigrant trapping method (incline or screw trap) will produce the estimates of interest from Reach 5.

For the lower incline plane trap, the size of mesh used on the incline plane and more importantly the live box did not allow for capture and retention of small age-0 fish (<50 mm). No estimate of fry size fish is provided. The estimate provided in this report is largely for parr and smolt sized emigrants from Grant Creek. Modifications to the trap were completed in mid-July to improve trap efficiency but this was probably too late for most of the smaller age-0 emigrants.

The weir was placed in Grant Creek in late May, which may have been too late to assess total abundance and run timing for adult rainbow trout. The location of the weir may have also been an issue. The weir was placed across a stream channel with an undercut bank that likely allowed rainbow trout to move both upstream and downstream of the weir. In July, when the weir was inspected, measures were taken to close the gap with additional pickets. Unfortunately, this was too late for the rainbow trout migration period. As a result, angling was used to secure rainbow trout for tagging. Most of the fish captured and tagged from angling occurred in July, which is likely past the spawning period. As such, it was not possible to identify areas of rainbow trout spawning within Grant Creek. Natural high flows during the upstream migration of adult rainbow trout make accurate data collection related to this component of Grant Creek research an annual issue.

8 REFERENCES

AEIDC (Arctic Environmental Information and Data Center). 1983. Summary of environmental knowledge of the proposed Grant Lake hydroelectric project area. Final Report submitted to Ebasco Services, Inc., Redmond, Washington, University of Alaska, Anchorage, Alaska.

Bue, B.G., S.M. Fried, S. Sharr, D.G. Sharp, J.A. Wilcock, and H.J. Geiger. 1998. Estimating salmon escapement using area-under-the-curve, aerial observer efficiency, and stream-life estimates: the Prince William Sound example. *North Pacific Anadromous Fisheries Commission. Bulletin. No. 1:240-250.*

Burgner, R. L., 1991. Life history of sockeye salmon (Oncorhynchus nerka). Pages 4-117 in *C. Groot, and L. Margolis, editors. Pacific salmon life histories. University of British Columbia Press.* Vancouver, B.C., Canada.

Ebasco (Ebasco Services, Inc.). 1984. Grant Lake Hydroelectric Project Detailed Feasibility Analysis. Volume 2. Environmental Report. Rep. from Ebasco Services Incorporated, Bellevue, Washington.

English, K.K., R.C. Bocking, and J.R. Irvine. 1992. A robust procedure for estimating salmon escapement based on the area-under-the-curve method. *Canadian Journal of Fisheries and Aquatic Sciences 49:1982-1989.*

Envirosphere. 1987. Instream flow and habitat analysis Grant Lake hydroelectric project. Prepared for Kenai Hydro, Inc.

Evans, S. D., and J. R. Stevenson. 2012. Optimization of radio telemetry receiving systems. Pages 139-162 in N. S. Adams, J. W. Beeman, and J. H. Eiler, editors. *Telemetry techniques: a user guide for fisheries research. American Fisheries Society, Bethesda, Maryland.*

Hahn, P. K. J., R. E. Bailey, and A. Ritchie. 2007. Beach seining. Pages 267-324 in D. H. Johnson, B. M. Shrier, J. S. O'Neal, J. A. Knutzen, X. Augerot, T. A. O'Neil, and T. N. Pearsons. *Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, Maryland.*

Hayes, S. R., and J. J. Hasbrouck. 1996. Stock assessment of rainbow trout in the Upper Kenai River, Alaska, in 1995. Anchorage, AK, Alaska Department of Fish and Game, Fishery Data Series No. 96-43.

HDR. 2009a. Technical Memorandum - Review of 1986-1987 Grant Lake FERC application documents for instream flow considerations. Prepared for Grant Lake/Falls Creek Hydroelectric Technical Working Group.

HDR (HDR Alaska Inc.) 2009b. Grant Lake Hydroelectric Project Environmental Baseline Studies Report, 2009 Draft. Prepared for: Kenai Hydro, LLC.

Johnson, J., and M. Daigneault. 2008. Catalogue of waters important for spawning, rearing, or migration of anadromous fishes – Southeastern Region, Effective June 2, 2008. Alaska Department of Fish and Game, Special Publication No. 08-06, Anchorage, AK.

Johnson, J. and K. Klein. 2009. Catalog of waters important for spawning, rearing, or migration of anadromous fishes – Southcentral Region, Effective June 1, 2009. *Alaska Department of Fish and Game, Special Publication No. 09-03, Anchorage, AK.*

Kenai Hydro, Inc. 1987a. Grant Lake hydroelectric project additional information.

Kenai Hydro, Inc. 1987b. Grant Lake hydroelectric project FERC No. 7633-002 additional information final report with agency license terms and conditions for selected alternative I and power contract information.

KHL (Kenai Hydro, LLC). 2009. Pre-Application Document Grant Lake/Grant Creek and Falls Creek Project (FERC No. 13211 and 13212.

KHL. 2013. Grant Lake Project (FERC No 13212), Aquatic Resources Final Study Plan. Prepared by BioAnalysts Inc. for Kenai Hydro, LLC. March 2013.

KHL. 2014a. Grant Lake Hydroelectric Project (FERC No. 13212). Aquatic Resources Study – Grant Creek Aquatic Habitat Mapping and Instream Flow Study, Final Report. Prepared by McMillen LLC for Kenai Hydro, LLC. June 2014.

KHL. 2014b. Grant Lake Hydroelectric Project (FERC No. 13212), Water Resources – Geomorphology, Final Report. Prepared for Kenai Hydro, LLC. Prepared by Element Solutions for Kenai Hydro, LLC. June 2014.

KHL. 2014c. Grant Lake Hydroelectric Project (FERC No. 13212), Water Resources Study – Water Quality, Temperature and Hydrology, Final Report. Prepared by McMillen, LLC for Kenai Hydro, LLC. June 2014.

Marcuson, P. 1989. Coho salmon fry stocking in Grant Lake, Alaska. Prepared for: U.S. Forest Service, Seward Ranger District, Chugach National Forest.

McMahon, T. E. 1983. Habitat suitability index models: coho salmon. U.S. Dept. Int., Fish Wildl. Servo FWS/OBS-82/10.49. 29 pp.

Raleigh, R. F., T. Hickman, R. C. Solomon, and P. C. Nelson. 1984. Habitat suitability information: Rainbow trout. U.S. Fish Wildlife Service. FWS/OBS-82/10.60. 64 pp.

Raleigh, R. F., W. J. Miller, and P. C. Nelson. 1986. Habitat suitability index models and instream flow suitability curves: Chinook salmon. U.S.

Scannell, P. K. W. 1992. Influence of temperature on freshwater fishes: A literature review with emphasis on species in Alaska. Juneau, AK, Alaska Department of Fish and Game. Technical Report no. 91-1.

Sisson, D. 1984. Fishing the Kenai Peninsula. Alaska Fieldbooks Co.

Skalski, J. R., and R. L. Townsend. 2014. Estimating salmonid outmigrant abundance at Grant Creek. Report prepared for BioAnalysts, Inc., Redmond, WA.

USFWS (U.S. Fish and Wildlife Service). 1961. Ptarmigan and Grant Lakes and Falls Creek, Kenai Peninsula, Alaska, progress report on the fish and wildlife resources. Department of the Interior. Juneau, Alaska.

Volkhardt, G. C., S. L. Johnson, B. A. Miller, T. E. Nickelson, and D. E. Seiler. 2007. Rotary screw traps and inclined plane screen traps. Pages 235-266 in D. H. Johnson, B. M. Shrier, J. S. O'Neal, J. A. Knutzen, X. Augerot, T. A. O'Neil, and T. N. Pearsons. *Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, Maryland.*

Appendix 1: Estimating Salmonid Outmigrant Abundance at Grant Creek

Estimating Salmonid Outmigrant Abundance at Grant Creek

To:
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13 February 2014

Introduction

The purpose of this analysis is to estimate the outmigrant abundance of salmonid species at Grant Creek in 2013. An incline plane trap was used to obtain a daily index count, which could then be adjusted for trap collection efficiency. This analysis estimates outmigrant abundance of Chinook salmon, coho salmon, and Dolly Varden over the outmigration season. The estimation process accounts for missing index data and provides standard error calculations. We also report the number of rainbow trout and sockeye captured at the incline plane trap but no estimates of their abundance are provided. Sample sizes were too small for reliable estimates of rainbow trout and sockeye salmon.

Study Design

A single incline plane trap was located downstream from an overflow channel along Grant Creek (Figure 1). That trap provided daily or near daily index counts of captured fish by species. Above the trap and overflow channel, periodic calibration releases were performed (Figure 1) to estimate the trap efficiency of the include lane. The calibration releases actually estimate the joint probability of a fish staying in Grant Creek and being detected (i.e., captured) by the incline plane trap. Similarly, the fish at the trap also represent fish that stayed in Grant Creek and were captured at the trap. Hence, the migrant abundance estimated is the number of juveniles present at the location of the efficiency releases. The overflow channel on Grant Creek became active at a flow ≥426 cfs and potentially directed fish past the incline plane trap during the three periods 30 May-3 August, 10-14 August, and 7-15 September.

Statistical Methods

Season-Wide Estimator

The season-wide estimator of total juvenile abundance $\left(\overset{*}{N}\right)$ is the sum of estimated abundance when the index counts at the incline plane trap are present $(\tilde{N})$ and during periods when such data are missing $\left(\hat{N}_j\right)$, i.e.,

$$\overset{*}{N} = \tilde{N} + \sum_{j=1}^{k} \hat{N}_j$$

where k = number of missing trap index count events during the season.

Specifically, the estimate of total migrant abundance can be written as follows:

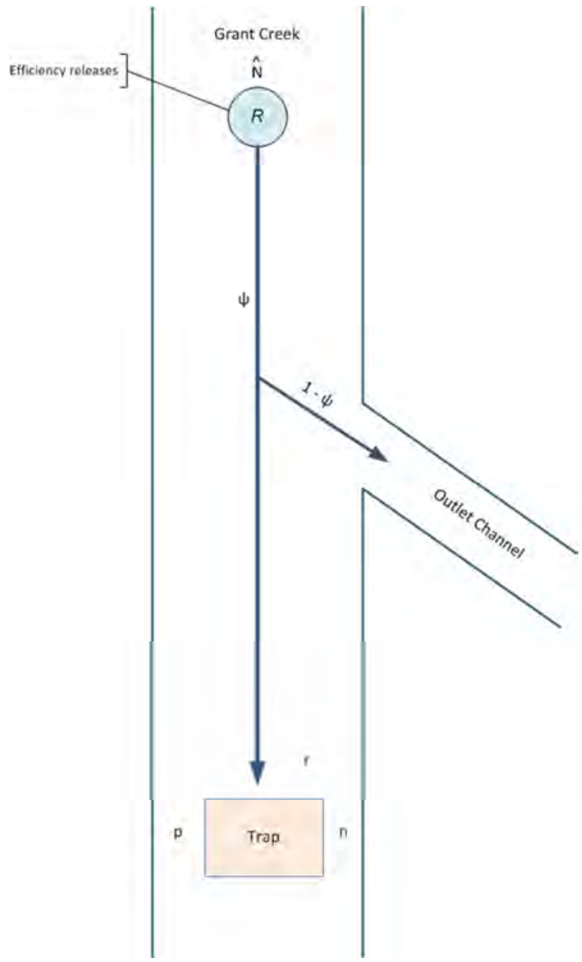

Figure 1. Schematic of migrant abundance $(\hat{N})$ estimation process including trap efficiency releases (*R*), downstream recovery numbers (*r)*, the probability of capture at the trap (*p*), probability a migrant remains in the river (ψ), and the number of fish caught in the trap (*n*). As such, $E(n) = N\psi p$ and $E(r) = R\psi p$, permitting abundance estimation as $\hat{N} = n/(r/R)$.

$$\overset{*}{N} = \frac{n}{\left(\frac{r}{R}\right)} + \sum_{j=1}^{k} \left[\frac{\left[\frac{n_{ji-2} + n_{ji-1} + n_{ji+1} + n_{ji+2}}{4}\right] d_j}{\left(\frac{r}{R}\right)} \right] \quad (0)$$

where

n = total index count at incline plane during periods of operations,

R = total number of fish released during trap efficiency trials,

r = number of *R* recaptured at trap,

n_{ji-1} = number of index fish caught one day prior to the *j*th data gap (*j* = 1, …, *k*),

n_{ji-2} = number of index fish caught two days prior to the *j*th data gap (*j* = 1, …, *k*),

n_{ji+1} = number of index fish caught one day after the *j*th data gap (*j* = 1, …, *k*),

n_{ji+2} = number of index fish caught two days after the *j*th data gap (*j* = 1, …, *k*),

K = number of data gaps in incline plane index counts.

$$\mathrm{Var}\left(\overset{*}{N}\right) = \mathrm{Var}\left(\tilde{N}\right) + \sum_{j=1}^{k} \mathrm{Var}\left(\hat{N}_j\right) \quad (0)$$

Estimator (1) and variance (2) were stratified for high and low flow seasons for two fish stocks where detection efficiencies were significantly different between periods.

In the case where there are missing index counts, the sampling process has three sources of variance as follows:

1. Binomial sampling $n \sim \mathrm{Bin}(N, p)$.
2. Estimator of the missing value by $\hat{n}$.
3. Estimator of the trap efficiency using the efficiency releases.

The overall variance during these missing data events can be calculated in stages as follows:

$$\mathrm{Var}\left(\hat{N}_j\right) = \mathrm{Var}_1\left[E_2\left[E_3\left(\frac{\hat{n}}{\hat{p}}\middle| 1,2\right)\right]\right] + E_1\left[\mathrm{Var}_2\left[E_3\left(\frac{\hat{n}}{\hat{p}}\middle| 1,2\right)\right]\right] + E_1\left[E_2\left[\mathrm{Var}_3\left(\frac{\hat{n}}{\hat{p}}\middle| 1,2\right)\right]\right]$$

where 1, 2, and 3 refer to the sampling stages listed above. Then

$$
\begin{aligned}
\mathrm{Var}\left(\hat{N}_j\right) &\approx \mathrm{Var}_1\left[E_2\left(\frac{\hat{n}}{p}\middle|1\right)\right]+E_1\left[\mathrm{Var}_2\left(\frac{\hat{n}}{p}\middle|1\right)\right]+E_1\left[E_2\left(\frac{\hat{n}^2\mathrm{Var}(\hat{p})}{p^4}\right)\right]\\
&=\mathrm{Var}_1\left[\frac{n}{p}\right]+E_1\left[\frac{1}{p^2}\mathrm{Var}(\hat{n})\right]+E_1\left[\frac{\mathrm{Var}(\hat{p})}{p^4}\left(\mathrm{Var}(\hat{n})+E(\hat{n})^2\right)\right]\\
&=\frac{N_j p(1-p)}{p^2}+\frac{\mathrm{Var}(\hat{n})}{p^2}+\frac{\mathrm{Var}(\hat{p})}{p^4}\left(\mathrm{Var}(\hat{n})+E_1\left(n^2\right)\right)
\end{aligned}
$$

$$
\mathrm{Var}\left(\hat{N}_j\right)=\frac{N_j(1-p)}{p}+\frac{\mathrm{Var}(\hat{n})}{p^2}+\frac{\mathrm{Var}(\hat{p})}{p^4}\left(\mathrm{Var}(\hat{n})+\left(N_j p(1-p)+N_j^2p^2\right)\right) \qquad (0)
$$

where

$\hat{n}_j=\left(\dfrac{n_{ji-2}+n_{ji-1}+n_{ji+1}+n_{ji+2}}{4}\right)d$ = estimate of missing index data,

d = duration of data gap,

$\mathrm{Var}(\hat{n})=\dfrac{s_n^2d^2}{4}$,

$\hat{p}=\dfrac{r}{R}$ = estimate of trap efficiency,

$\mathrm{Var}(\hat{p})=\dfrac{\hat{p}(1-\hat{p})}{R}=\dfrac{\left(\frac{r}{R}\right)\left(1-\frac{r}{R}\right)}{R}$, and

$\hat{N}_j=\dfrac{\hat{n}_j}{\hat{p}}$ = abundance estimate for *j*th period.

In the case where the index count (n) is available, the variance of the estimate of fish abundance $\left(\tilde{N}\right)$ is estimated by

$$\tilde{N}=\frac{n}{\hat{p}}$$

and has two sources of variance:

1. Binomial sampling $n\sim\mathrm{Bin}\left(N_j p\right)$.
2. Estimate of the trap efficiency using the efficiency releases.

The overall variance during these time period can be calculated in stages as follows:

$$
\begin{aligned}
\operatorname{Var}\left(\tilde{N}\right) &= \operatorname{Var}\left(\frac{n}{\hat{p}}\right) \\
&= \operatorname{Var}_n\left[E_p\left(\frac{n}{\hat{p}}\middle| n\right)\right] + E_n\left[\operatorname{Var}_p\left(\frac{n}{\hat{p}}\middle| n\right)\right] \\
&\approx \operatorname{Var}_n\left[\frac{n}{p}\right] + E_n\left[n^2\operatorname{Var}\left(\frac{1}{\hat{p}}\right)\right] \\
&= \operatorname{Var}_n\left[\frac{n}{p}\right] + E_n\left[n^2\frac{\operatorname{Var}(\hat{p})}{p^4}\right] \\
&= \frac{Np(1-p)}{p^2} + \frac{\operatorname{Var}(\hat{p})}{p^4}\left[\operatorname{Var}(n) + E(n)^2\right] \\
&= \frac{N(1-p)}{p} + \frac{\operatorname{Var}(\hat{p})}{p^4}\left[Np(1-p) + N^2p^2\right] \\
&= \frac{N(1-p)}{p} + \frac{p(1-p)}{p^4R}\left[Np(1-p) + N^2p^2\right] \\
\operatorname{Var}\left(\tilde{N}\right) &= \frac{N(1-p)}{p} + \frac{N(1-p)^2}{p^2R} + \frac{N^2(1-p)}{pR}
\end{aligned}
\qquad (4)
$$

where

$$
\hat{p} = \frac{r}{R},
$$

$$
\tilde{N} = \frac{nR}{r}.
$$

Test of Homogeneous Trap Efficiency

A test of homogeneous trap efficiency between high and low flow periods was performed using a 2 × 2 contingency table of the form

	High	Low
Caught	r_1	r_2
Not caught	$R_1 - r_1$	$R_2 - r_2$

A test of homogeneity was based on a chi-square test of 1 degree of freedom.

Results

Raw counts of the total number of individuals captured at the incline trap per species ranged from 36 to 969 (Table 1). Efficiency release sizes were too small to convert counts to absolute abundance for rainbow trout and sockeye salmon. Tests of homogeneous trap efficiency during low and high river flow conditions found no difference for Chinook salmon and coho salmon but a flow effect for Dolly Varden (Table 2). Hence, a single estimate of trap collection efficiency was used in the estimation of outmigration abundance for Chinook salmon and coho salmon, while two seasonal values were used for Dolly Varden (Table 2).

The incline trap study estimated juvenile abundance in Grant Creek at the site of the calibration (i.e., trap efficiency) releases. For Chinook salmon, total outmigration was estimated to be $\hat{N}$ = 4,797.7 (95% confidence interval = (3,615.4–5,980.0)). For coho salmon, total outmigration was estimated to be $\hat{N}$ = 3,164.9 (95% CI = (2,094.3– 4,235.5)). The seasonally stratified estimate of total outmigration abundance for Dolly Varden was estimated to be 46,431.2 (95% CI = (-4,570.2–97,432.6)) (Table 2).

Two factors contributed to high standard errors associated with the total abundance estimates. The first was the highly variable daily count on either side of the three "data gaps" observed during the study. Though only 2- 4 days long (a total of 10 days, approximately 7% of the study), these gaps contributed abundance estimates with large associated variance. The greater issue was the low detection efficiencies, which especially affected the Dolly Varden abundance estimate, as its expansion factor during the low flow period was approximately 12 times that of the other species at the trap.

Table 1. Number of juvenile salmonids caught by species at the incline plane trap during the 2013 outmigration at Grant Creek.

Species	Count (*n*)
Chinook salmon	577
Coho salmon	360
Dolly Varden	969
Rainbow trout	36
Sockeye salmon	22

Table 2. Summary of trap efficiency release numbers (*R)* and number of smolts recaptured (*r)* under high and low flow conditions for three species of salmonids. Chi-square tests of homogeneity (df = 1) were performed comparing low and high flow recovery information.

	Low Flow Condition		High Flow Condition		Trap Efficiency			Test for Trap Efficiency Difference	
Species	Release	Recapture	Release	Recapture	Low	High	Combined	χ^{2*}	p
CK	380	45	68	10	0.118	0.147	0.123	0.2136	0.6440
CO	169	19	110	13	0.112	0.118	0.115	0.0000	1.0000
DV	248	2	571	41	0.008	0.072		12.8685	0.0003

*Estimated with Yates continuity correction

Table 3. Estimates of total outmigrant abundance through Grant Creek. Estimates separated by periods with daily index counts and with gaps in the index count. In the case of Dolly Varden, the estimation was also stratified by low- and high-flow trap efficiency periods.

			Dolly Varden		
	Chinook	Coho	Low Flow	High Flow	Total
Observed n	577	360	296	673	
Est. N	4,699.9	3,138.8	36,704.0	9,372.8	46,076.8
Var N	361,252.8	297,453.8	674,913,300.0	2,112,700.0	677,026,000.0
SE N	601.0	545.4	25,979.1	1,453.5	26,019.7
Gap n	12.0	3.0	0.5	21.0	
Est N	97.7	26.2	62.0	292.5	354.5
Var N	2,538.3	929.5	20,981.3	50,786.1	71,767.4
SE N	50.4	30.5	144.8	225.4	267.9
Total					
Est N	4,797.7	3,164.9	36,766.0	9,665.2	46,431.2
Var N	363,791.1	298,383.3	674,934,281.3	2,163,486.1	677,097,767.4
SE N	603.2	546.2	25,979.5	1,470.9	26,021.1

Grant Lake Hydroelectric Project (FERC No. 13212)

Water Resources – Geomorphology

Final Report

Prepared for
Kenai Hydro, LLC

Prepared by
P. Pittman
Element Solutions

June 2014

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Acronyms and Abbreviations

AEIDC	Arctic Environmental Information Data Center
cfs	cubic feet per second
DLA	Draft License Application
EPA	Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
GIS	Geographic Information System
KHL	Kenai Hydro, LLC
LA	License Application
mm	millimeter
MW	megawatt
NAVD 88	North American Vertical Datum of 1988
NGVD 29	National Geodetic Vertical Datum of 1929
NOI	Notice of Intent
OHWM	ordinary high water mark
PAD	Pre-Application Document
PM&E	protection, mitigation and enhancement
Project	Grant Lake Hydroelectric Project
USFS	U.S. Department of Agriculture, Forest Service
USGS	U.S. Department of the Interior, Geological Survey
WSE	water surface elevation

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Water Resources – Geomorphology
Final Report
Grant Lake Hydroelectric Project (FERC No. 13212)

1 INTRODUCTION

On August 6, 2009, Kenai Hydro, LLC (KHL) filed a Pre-Application Document (PAD; KHL 2009), along with a Notice of Intent (NOI) to file an application for an original license, for a combined Grant Lake/Falls Creek Project (Federal Energy Regulatory Commission [FERC] No. 13211/13212 ["Project" or "Grant Lake Project"]) under Part I of the Federal Power Act (FPA). On September 15, 2009, FERC approved the use of the Traditional Licensing Process (TLP) for development of the License Application (LA) and supporting materials. As described in more detail below, the Project has been modified to eliminate the diversion of water from Falls Creek to Grant Lake. The Project will be located near the community of Moose Pass, Alaska in the Kenai Peninsula Borough, approximately 25 miles north of Seward, Alaska and just east of the Seward Highway (State Route 9).

The Water Resources Study Plan (Plan) was designed to address information needs identified in the PAD, during the TLP public comment process, and through early scoping conducted by FERC. The following study report presents the results of the geomorphological components of the Plan along with previously existing information relative to the scope and context of potential effects of the Project. This information will be used to analyze Project impacts and propose protection, mitigation, and enhancement (PM&E) measures in the draft and final LA's for the Project.

The Project is located near the community of Moose Pass, approximately 25 miles north of Seward and just east of the Seward Highway. It lies within Section 13 of Township 4 North, Range 1 West; Sections 1, 2, 5, 6, 7, and 18 of Township 4 North, Range 1 East; and Sections 27, 28, 29, 31, 32, 33, 34, 35, and 36 of Township 5 North, Range 1 East, Seward Meridian (U.S. Geological Survey [USGS] Seward B-6 and B-7 Quadrangles).

The proposed Project would be composed of an intake structure at the outlet to Grant Lake, a tunnel, a surge tank, a penstock, and a powerhouse. It would also include a tailrace detention pond, a switchyard with disconnect switch and step-up transformer, and an overhead or underground transmission line. The preferred alternative would use approximately 15,900 acre-feet of water storage during operations between pool elevations of approximately 692 and up to 703 feet North American Vertical Datum of 1988 (NAVD 88)[1].

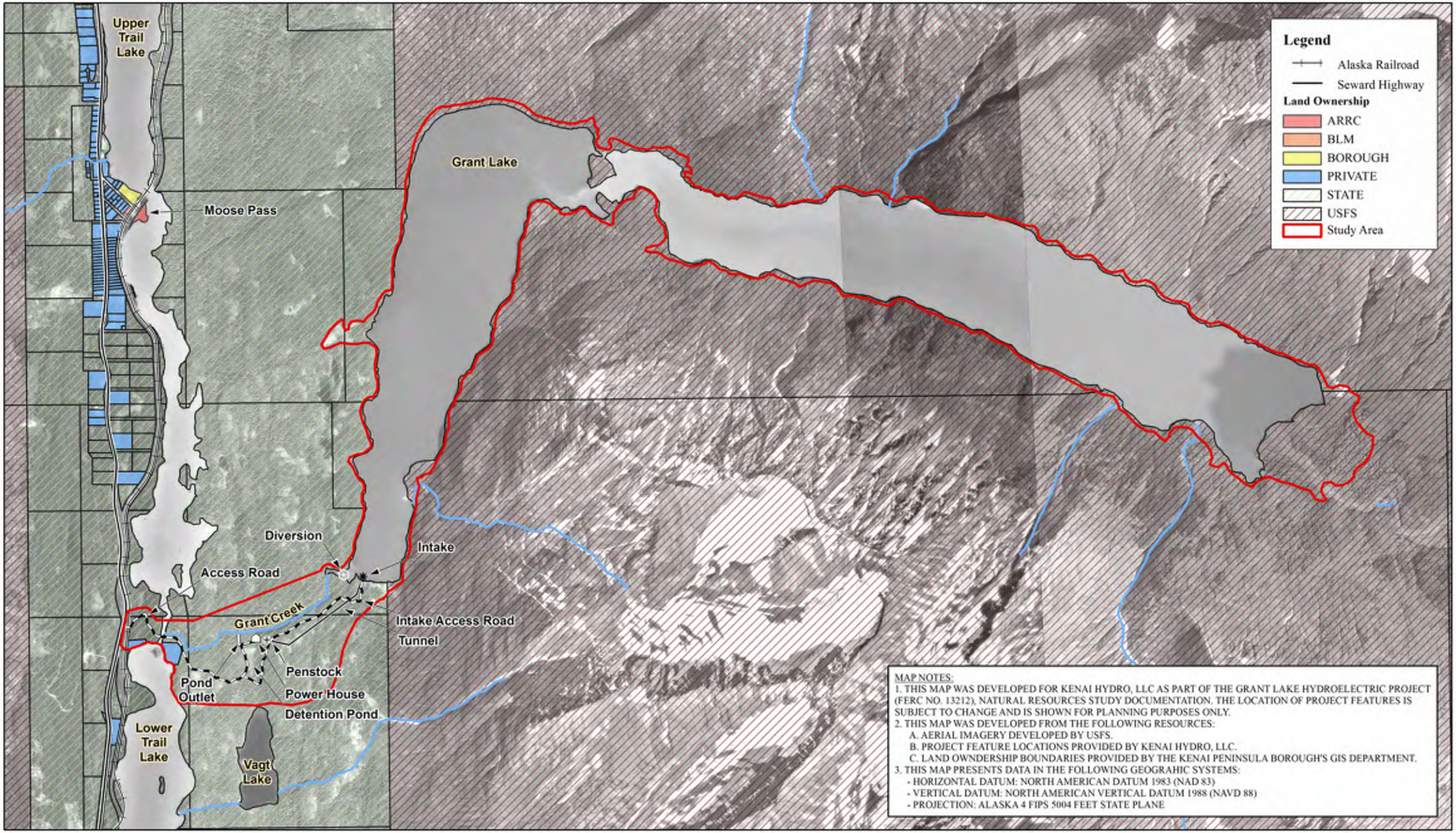
[1] The elevations provided in previous licensing and source documents are referenced to feet mean sea level in NGVD 29 [National Geodetic Vertical Datum of 1929] datum, a historical survey datum. The elevations presented in the Grant Lake natural resources study reports are referenced to feet NAVD 88 datum, which results in an approximate +5-foot conversion to the NGVD 29 elevation values.

An intake structure would be constructed approximately 500 feet east of the natural outlet of Grant Lake. An approximate 3,200-foot-long, 10-foot diameter horseshoe tunnel would convey water from the intake to directly above the powerhouse at about elevation 628 feet NAVD 88. At the outlet to the tunnel a 360-foot-long section of penstock will convey water to the powerhouse located at about elevation 531 feet NAVD 88. An off-stream detention pond will be created to provide a storage reservoir for flows generated during the rare instance when the units being used for emergency spinning reserve are needed to provide full load at maximum ramping rates. The tailrace would be located in order to minimize impacts to fish habitat by returning flows to Grant Creek upstream of the most productive fish habitat.

Two concepts are currently being evaluated for water control at the outlet of Grant Lake. The first option would consist of a natural lake outlet that would provide control of flows out of Grant Lake. A new low level outlet would be constructed on the south side of the natural outlet to release any required environmental flows when the lake is drawdown below the natural outlet level. The outlet works would consist of a 48-inch diameter pipe extending back into Grant Lake, a gate house, regulating gate, controls and associated monitoring equipment. The outlet would discharge into Grant Creek immediately below the natural lake outlet.

In the second option, a concrete gravity diversion structure would be constructed near the outlet of Grant Lake. The gravity diversion structure would raise the pool level by a maximum height of approximately 2 feet (from 703 to 705 feet NAVD 88), and the structure would have an overall width of approximately 120 feet. The center 60 feet of the structure would have an uncontrolled spillway section with a crest elevation at approximately 705 feet NAVD 88. Similar to the first option, a low level outlet would be constructed on the south side of the natural outlet to release any required environmental flows when the lake is drawn down below the natural outlet level. The outlet works would consist of a 48-inch diameter pipe extending back into Grant Lake, a gate house a regulating gate, controls, and associated monitoring equipment. The outlet would discharge into Grant Creek immediately below the diversion structure.

Figure 1.0-1 displays the global natural resources study area for the efforts undertaken in 2013 and 2014 along with the likely location of Project infrastructure and detail related to land ownership in and near the Project area. Further discussions related to specifics of the aforementioned Project infrastructure along with the need and/or feasibility of the diversion dam will take place with stakeholders in 2014 concurrent with the engineering feasibility work for the Project. Refined Project design information will be detailed in both the Draft License Application (DLA) and any other ancillary engineering documents related to Project development. The current design includes two Francis turbine generators with a combined rated capacity of approximately 5.0 megawatts (MW) with a total design flow of 385 cubic feet per second. Additional information about the Project can be found on the Project website: http://www.kenaihydro.com/index.php.



N

Drawing Scale:

0 0.25 0.5 1 Miles

MCMILLEN, LLC

Developed For:

Homer Electric Association, Inc.

A Touchstone Energy Cooperative

GRANT LAKE HYDROELECTRIC PROJECT - FERC PROJECT #P-13212

GRANT LAKE NATURAL RESOURCES STUDY

Figure 1.0-1
Natural Resources Study Area

DESIGNED Jake Woodbury
DRAWN Jake Woodbury
CHECKED C. Warnock
ISSUED DATE 1/9/2014
SCALE 1:27,000

2 STUDY OBJECTIVES

The Grant Lake and Grant Creek Fluvial Geomorphology Study consisted of two independent study components: a Grant Lake shoreline erosion study and a Grant Creek spawning substrate recruitment study. The goals of the studies were to provide supporting information on the potential resource impacts of the Project that were identified during development of the PAD, public comment, and FERC scoping for the LA. The objectives of the studies are described below.

2.1. Grant Lake Shoreline Erosion Study

The primary study objective of the Grant Lake shoreline erosion study was to provide a basis for predicting and assessing potential lake shore erosion in Grant Lake as a result of general reservoir operations. Operations will affect the timing, duration and range of water surface elevations (WSE), and thus change the Grant Lake shoreline geomorphic conditions. The Grant Lake shore geomorphic study was a qualitative inventory of shoreline conditions that affect erosion potential based on professional judgment.

2.2. Grant Creek Spawning Substrate Recruitment Study

The primary objective of the Grant Creek spawning substrate recruitment study was to provide a basis for predicting and assessing potential changes to material movement, sedimentation, and gravel recruitment that may occur in Grant Creek with proposed operational management, especially as related to the long-term maintenance of fish spawning substrate. Operation of the Project would alter the flow regime and create a situation where some amount of flow will bypass the canyon reach. The Grant Creek spawning substrate study combines quantitative and qualitative elements.

3 STUDY AREA

The Project vicinity is near the town of Moose Pass, Alaska, approximately 25 miles north of Seward, just east of the Seward Highway (State Route 9). The specific geomorphology assessment study area includes Grant Lake shoreline and Grant Creek within the lower portion of the Grant Lake watershed.

3.1. Grant Lake Geomorphic Setting

Grant Lake is an approximately 6-mile long, 1,600 acre (2.5 square mile) lake located in a 68,000 acre (44 square mile) watershed within the Chugach Mountains of Kenai Range east of Moose Pass. Inlet Creek is the predominant stream in the upper portion of the watershed and drains melting alpine glaciers and snow from the nearby mountains into Grant Lake at the eastern end of the lake. Grant Lake itself sits in the lower portion of the watershed, capturing over 95 percent of the watershed area.

Grant Lake is located in a deep glacially-carved basin flanked by the high bedrock peaks of Lark and Solars Mountains. Grant Lake encompasses two almost separate bathymetric lake basins that are separated by a shallow submerged ridge at a narrow "neck" that connects the two basins at right angles (EBASCO 1984). The upper basin is oriented primarily east-west, whereas the lower basin is oriented primarily north-south. Much of the overall shoreline littoral zone is steep bedrock. The deepest point within the lower basin is approximately 262 feet deep and the upper basin is 283 feet deep (EBASCO 1984).

3.2. Grant Creek Geomorphic Conditions and Processes

The Grant Creek watershed occupies approximately 44 square miles with a majority of its watershed bound by the steep mountains of the Kenai Range. Grant Creek itself is approximately 5,800 feet long and flows west from the outlet of Grant Lake to the "narrows" between Upper and Lower Trail lakes. Grant Creek has a mean annual flow of 200 cubic feet per second (cfs), with an average gradient of 200 feet per mile. In its upper half, Grant Creek passes through a steep bedrock canyon with three substantial waterfalls. In its lower half, Grant Creek becomes less steep with boulder and cobble dominant alluvial substrate. Grant Creek is a high energy stream with a wide variability in flow regime.

4 METHODS

4.1. Methods to Evaluate Grant Lake Shoreline Erosion

The methods to conduct the shoreline erodibility assessment of Grant Lake consisted of both a desktop analysis using existing information and a field evaluation of conditions observed along the shoreline by boat at a relatively high lake stage (approximately 2 feet of water depth over the outlet to Grant Creek which is estimated to be 703 feet NAVD 88). For the field evaluation, it was assumed that the Project WSE would be approximately 3 to 5 feet higher than at the time of our site visit on August 24, 2013 assuming water depths at the invert would be a maximum of 3 to 5 feet deep. Minimum Project WSE would be 692 feet NAVD 88, or approximately 11 feet lower than at the time of our field visit. The desktop analysis utilized integrating previous studies and information, including bathymetric mapping, LiDAR, digital orthographic photos, and geologic mapping. Spatial information was evaluated and findings were mapped in a Geographic Information System (GIS). The analysis drew upon a number of assumptions as described below.

For conditions and impacts to the littoral zone at elevations that were submerged at the time of the field visit, it was assumed that the geomorphic units identified and mapped at the shoreline near the ordinary high water mark (OHWM) were the same in the submerged areas to at least the depth of the proposed managed WSE. The rationale for this assumption is that most of the steep shoreline was bedrock, or landforms that result from hill-slope process deposition (e.g. alluvial fan), continue downslope. In two instances, the landforms did not fit this model (at both distal ends of the lake), in these instances, the extent of geomorphic unit was inferred based upon the assumption that the unit continued in submerged areas to at least the bathymetric break in slope. In both instances, the bathymetric break in slope occurred below the proposed minimum WSE.

Methods

The erodibility assessment was initiated with a GIS desktop analysis. The analysis included remotely mapping the geomorphic features of the Grant Lake shoreline area. This was accomplished by evaluating a combination of spatial data sets in conjunction with historic studies and information and making an informed geological interpretation. The data sets that were used included:

- 2002 Aerial Photos of Grant Lake: USFS, 1996-2004, 2-5 meter, Black/White, UTM 6 NAD 27
- Google Earth oblique view aerial photos
- 4-foot contours generated from 2002 LiDAR using GIS: Aero-Metric Inc., 2008, 10-foot resolution, format: LiDAR point cloud data 1.1.
- Surface Geology Maps (EBASCO 1984)

The interpretation of landforms involved analysis of slope/relief, shape, contributing upland area, fluvial/non-fluvial influence, vegetation, texture and previous geological assessments. A “Geomorphic Unit” was developed based on geomorphic process for the landforms along the shoreline and each Geomorphic Unit was mapped within 200-foot buffer from the shoreline in GIS. The following Geomorphic Units were established for this analysis:

- Alluvial Deltaic Deposits
- Alluvial Fan Deposits
- Beach/Littoral Deposits
- Colluvial Deposits
- Landslide Deposits
- Bedrock

The depositional units were characterized based on typical sediment size and character of depositional material (layered strata versus massive consolidated strata, sorted versus unsorted sediment) with the rationale that smaller sediment size and layered strata were relatively more susceptible to erosion than larger sediment sizes and massive consolidated deposits. As a result, a relative erodibility of the geomorphic unit was generated such that the aforementioned units are listed from most susceptible to erosion to least susceptible. The geomorphic units in the area buffering the shoreline were field validated. Photographs of “type-sections” of geomorphic units are provided in Appendix 1. Mapping of geomorphic units is shown in Figure 4.1-1.

Wind generated waves are likely the predominant erosional process acting on the Grant Lake shoreline during present conditions. To evaluate the wind-generated wave erosion potential, an overlay of relative fetch potential was applied with the rationale that larger waves had more energy and were more effective at eroding the shoreline area than were smaller waves. Field observations of wave run-up potential were made during the boat-based survey and documented with photographs.

Evaluation

The evaluation was initiated by compiling all existing spatial information into a GIS-based platform. The geomorphic units were integrated with the fetch parameters to determine relative erodibility (Table 4.1-1). The resulting relative erodibility was mapped in GIS.

Table 4.1-1. Relative erodability integrating erosion susceptibility with wave energy potential.

Relative Fetch Distance	Geomorphic Unit					
	Alluvial Deltaic	**Alluvial Fan**	**Beach**	**Colluvium**	**Landslide (bedrock)**	**Bedrock**
Short	Moderate	Moderate	Moderate	Low	Low	Low
Medium	Moderate-High	Moderate-High	Moderate-High	Moderate-Low	Moderate-Low	Low
Long	High	High	High	Moderate	Moderate	Low

The integration of the relative erodibility susceptibility of the Geomorphic Units with the fetch distance to determine relative erodibility along the shoreline relies upon the following assumptions:

1. As the fetch increases the wave size increases, and therefore the wave-generated erosional processes increase with fetch
2. The geomorphology/geology within each mapped unit was assumed to be consistent throughout that individual unit.

In addition to wind-generated wave erosion potential, erosion due to changes in base elevation which could cause stream incision of streams that outlet along the shoreline during lower lake WSE conditions was considered.

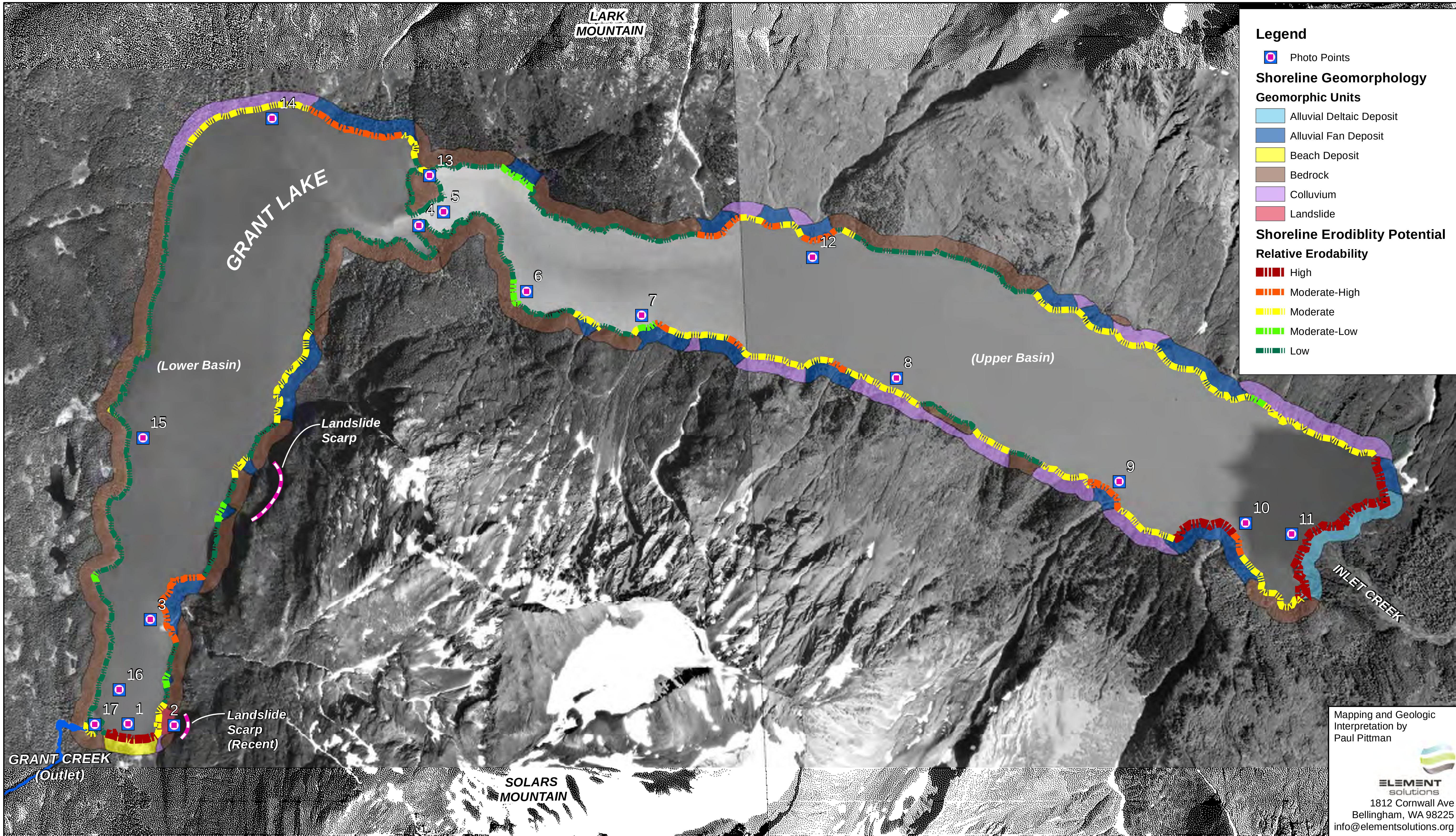
4.2. Methods to Evaluate Grant Creek Geomorphic Response

General Methods

The methods identified in the study plan to evaluate the sediment transport effecting salmon spawning substrate conditions following operational scenarios, included the following tasks:

1. assessment of the substrate at existing spawning areas including aspects of embeddedness and substrate size composition;
2. quantification of material transport conditions under the existing and projected flow regimes; and
3. qualitative geomorphic assessment of existing sediment supply conditions.

Figure 4.2-1 refers to the study area and sampling locations.



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Drawing Scale:

0 310 620 1,240 1,860 2,480 Feet

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A Touchstone Energy Cooperative

GRANT LAKE HYDROELECTRIC PROJECT - FERC PROJECT #P-13212

GRANT LAKE NATURAL RESOURCES STUDY

FIGURE 4.1-1: GRANT LAKE GEOMORPHOLOGY RELATIVE SHORELINE EROSION

DESIGNED
DRAWN
CHECKED
ISSUED DATE

FIGURE 4.1-1

SCALE:

REV | DATE | BY | DESCRIPTION

REV | DATE | BY | DESCRIPTION

N

Drawing Scale:
0 70 140 280 420 560
Feet

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GRANT LAKE HYDROELECTRIC PROJECT - FERC PROJECT #P-13212

GRANT LAKE NATURAL RESOURCES STUDY

FIGURE 4.2-1: GRANT CREEK GEOMORPHOLOGY SAMPLE SITES

DESIGNED
DRAWN
CHECKED
ISSUED DATE

FIGURE 4.2-1

SCALE:

Assumptions

The general operational scenario for the Project would result in bypassing some amount of flow from the canyon reach and the potential for an alteration of the natural flow regime. The specifics of the alteration cannot be detailed yet as ongoing work from an engineering feasibility standpoint and further discussions with stakeholders related to instream flows are needed prior to accurately defining the operational flow regime. What is certain is that the current natural flows would be modified as a result of Project operations and it is likely that peak flows would be decreased as a result of operations. For this assessment, in lieu of specific operational parameters that are yet to be worked out with stakeholders, an assumed operational peak flow of approximately 385 cfs (based upon general design parameters) was used.

The focus of this study was on the potential impacts to the spawning-size range of sediment. The following species of concern are documented to use Grant Creek for spawning: Chinook (*Oncorhynchus tshawytscha*), sockeye (*Oncorhynchus nerka*), coho (*Oncorhynchus kisutch*), rainbow trout (Salmo gairdneri *Oncorhynchus mykiss*) and Dolly Varden (*Salvelinus malma malma*). The range of documented preferred spawning sediment size classes that encompass these species can typically range from 5- 50 cm, with rainbow trout preferring the smaller substrate range and Chinook utilizing the larger substrate range (Russell 1974; Jones 1975; Suchanek et al. 1984; Milhous 1998; Bovee 1982; Swan 1989; Kondolf 1993). While these are the literature referenced “preferred” substrate size ranges, utilization of sediment sizes beyond this range does occur in reality. This is likely the case in Grant Creek, where sediment is typically larger than the stated preferred size classes. Although there is great variability in spawning substrate size preference between individual fish, different species and different river systems, the general size range is limited at the upper end by a substrate size that a particular fish has the physical ability to dislodge and at the lower range by a substrate size that reduces egg survivability during incubation. Substrate size alone is not a useful predictor of spawning potential (Geist and Dauble 1998).

Surface Sampling Methods

Surface sampling, also referred to as Wolman or frequency-by-numbers, was conducted on May 10, 2013 to characterize surface substrate size at various bedforms often utilized for spawning. Subsurface sampling methods utilized a random point sampling method to collect and measure surface sediment B-axis dimensions. Measurements were made using a Wolman template for a 100-stone count in areas of probable spawning. The grid spacing and measurement area was determined by field conditions such that the sample area was isotropic in the horizontal directions.

Subsurface Bulk Sampling Methods

Subsurface bulk sampling, also referred to as frequency-by-weight, was conducted on May 10, 2013 to characterize subsurface substrate size at anticipated spawning areas. Subsurface methods utilized field and laboratory sieving technics at four sampling sites in Reaches 1-4 downstream of the canyon to characterize subsurface conditions. The sampling sites were established at or near locations historic spawning or anticipated spawning at established instream flow monitoring sites in order to integrate the instream flow modeling outputs into the sediment transport equation. Based upon professional judgment, fewer sampling sites were needed due to the homogeneity of the substrate and field conditions. The sampling sites were spatially referenced for future monitoring.

Subsurface bulk samples were collected in areas assumed to have a high probability for salmon spawning based on the surface substrate size conditions and channel bed form (point or lateral bars that were immediately above the wetted channel margin at a flow of approximately 50 cfs). The surface armoring was removed as sample locations to the depth of at least one stone depth of the maximum surface stone diameter. Sieving many subsamples of a large sample volume was used to reduce bias and account for the large grain size observed at Grant Creek (Church et al. 1987). The largest grain size present in the sample is used as a basis for the sample volume following the reasoning that the largest particles will be the fewest in number and, therefore, least well represented. Because of the large grain sizes present at the site, it was infeasible to remove the full sample for laboratory measurement; therefore field sieving methods were used. The subsurface material was field sieved and weighed on site using the 2 percent criterion of Church et al. (1987) as the largest stone exceeded 90 mm which yielded individual sediment sample weights in excess of 450 pounds (200 kilograms). Sediment passing the 45 mm screen was sieved at a lab. A total of 4 bulk sample measurements were conducted in the Project reach.

Embeddedness Measuring Methods

The embeddedness sampling included measurements of approximately 50 stones of surface substrate of a particle size range that falls within the range of spawning substrate sizes for species using Grant Creek. Measurements of particle diameter (Dt) in the vertical direction and depth of embedment (De) were made of stones in the approximately D50 size class to achieve the Embeddedness Ratio. Embeddedness measurements were made at two sample sites in which Wolman counts were conducted.

Surface Marker Observation Methods

Surface marking methods were employed to field evaluate the presence or absence of sediment transport resulting from flows experienced in the 2013 season and to use to test sediment incipient motion calculations. Two areas of in situ surface substrate were marked at Sample Site 1 in which a Wolman Count and Bulk Sampling was performed. Substrate marking was accomplished by painting two one-meter square areas just above the low flow wetted margins adjacent to the Bulk Sample sites in situ conditions. These painted areas were inundated with higher flows (>100 cfs) and reevaluated following three months of high flow conditions to identify if thresholds of bed mobility were reached and compare to the modeling results.

Hydrology, Hydraulics and Incipient Motion Analysis Methods

Sediment transport analysis integrates the proposed maximum operation flows (385 cfs) and 2013 measurements of hydraulic characteristics at select sites utilizing the instream flow modeling outputs. Incipient motion particle size analysis was the method selected to determine the threshold of mobility for particles of various sizes given the proposed hydraulic condition.

Incipient motion particle size analysis was used to estimate the particle size that is anticipated to be transported at proposed operational flow (~350 cfs) and compare it to the spawning substrate size range to determine the impacts to the spawning substrate size range under the operational flow regime. A certain degree of sediment transport is necessary to maintain spawning substrate quality (Kondolf 1993). The incipient motion equation and literature-referenced calibration estimates were used to estimate the incipient motion particle size. The equation is:

$$\tau^* = \frac{\tau_o}{(\gamma_s - \gamma_w)\, D_s}$$

Where:

- τ^* = Dimensionless Shield's parameter
- τ_o = Channel bed shear, pounds per square foot (psf)
- γ_s = Unit weight of sediment, assumed to be 165 pounds per cubic foot (pcf)
- γ_w = Unit weight of water, 62.4 pcf
- D_s = Size of sediment at incipient motion, feet

The values of the dimensionless Shield's parameter depend upon the size and shape of the substrate. A Shield's parameter value of 0.03 was considered for the Grant Creek calculation based on previous work by Inter-Fluve in the Cooper Lake Hydroelectric Project (FERC No. 2170; Inter-Fluve 2004) relicensing analyses, which referenced a study for small platy sediment forms (Mantz 1977). However, a range of different Shield parameter values were considered based upon the heterogeneity of the substrate shape and based on field observations and professional judgment.

Geomorphic Field Assessment

A qualitative geomorphic assessment of the sediment supply for Grant Creek was conducted on August 24, 2013. Analysis was based on observations from the field, understanding of the Grant Lake watershed, known geological conditions, and professional interpretation of observed geomorphic processes.

5 RESULTS

5.1. Grant Lake Shoreline Geomorphic Conditions and Processes Results

The results of the geomorphic shoreline mapping are shown on Figure 4.1-1. The shoreline conditions of Grant Lake are influenced by geologic conditions, geomorphic processes, and climate. Alluvial, colluvial and mass wasting processes, including avalanche, deliver sediment to the shoreline area and deposits of sediment locally bound the shoreline. The upper basin receives the dominant sediment load being transported to the lake via hill-slope and fluvial processes.

While most geologic and geomorphic processes effecting the littoral zone occur at relatively slow rates, evidence of large mass wasting events in Grant Lake were observed, which can create punctuated change along shorelines and stream channels, including rapid change in sediment supply, shoreline boundary changes, and large pressure generated waves, and erosion. It is hypothesized that the alluvial plain morphology of Grant Creek was influenced by a relatively recent landslide generated wave originating from Grant Lake. Large mass wasting events can have dramatic effect on the landscape.

<u>Natural Influences on Grant Lake WSEs and Littoral Conditions</u>

Grant Lake shoreline geomorphology is influenced by climate and seasonal variability. The lake remains ice free for approximately half of the year. During the ice-free period, WSEs fluctuate in response to snow melt, glacial melt, and precipitation. Wind generated wave processes erode, rework, deposit, and transport sediment in the littoral zone during the ice-free periods. The narrow confined valleys flanking the lake control wind direction and intensity. Wind direction from east or west will have the greatest effect on the upper lake basin whereas this wind direction will have little effect on the lower lake basin. Conversely, wind directions from north or south will have the greatest effect on the lower lake basin and only negligible effect on the upper lake basin. Because the lake orientation is divided by a 90 degree “bend” approximately mid-point, the effective maximum fetch is only approximately 3-miles. The largest wind-generated waves will be at the shorelines at the end of the fetch runs. The near shore bathymetric conditions also effect wave height and run up potential.

The highest WSEs typically occur in the summer months when snow melt and precipitation probability are highest or episodically in fall when transient snow and precipitation occur. WSE of Grant Lake is controlled by the Grant Creek outlet elevation (703 feet NAVD 88) and the hydrologic inputs from the watershed. The ordinary high WSE of the lake is at approximately 703 feet NAVD 88 based on previous estimates (EBASCO 1984). The OHWM has apparent elevation increases where wind generated wave run up occurs, including at the outlet at Grant Creek.

Grant Lake WSE is lowest in the winter months when the watershed is frozen, virtually halting hydrologic input. During ice-on conditions, the effect of wind generated waves is likely negligible except during ice break-up conditions. Anecdotal information would suggest that the lake WSE can fluctuate by several feet between high and low water. It is not known if the WSE drops below the elevation of the outlet control. If so, it is possible that some continued outlet of water occurs from the fractured or jointed bedrock present at the outlet. The presence of hydraulic loss at the outlet sill would also explain the fairly steady low flow rates observed in Grant Creek throughout the winter months when hydrologic inputs into Grant Creek are negligible.

<u>Project Operations Influencing Grant Lake WSEs</u>

Two design alternatives that affect the Grant Lake WSEs are being considered; one that allows for approximately 11 feet of WSE fluctuation but maintains the existing outlet elevation, and one that increases the outlet elevation by 2 feet and allows for 13 feet of WSE fluctuation. For this analysis, the more extreme of the two alternatives was considered since it will have the greatest influence on shoreline geomorphology. Table 5.1-1 provides a summary of the proposed operational changes to WSE.

The alternative to raise the natural outlet invert by 2 feet would be accomplished by constructing a concrete gravity diversion structure at the outlet of Grant Lake. The gravity diversion structure would raise the pool level by a maximum height of approximately 2 feet, and the structure would have an overall width of approximately 120 feet. The center 60 feet of the structure would have an uncontrolled spillway section with a crest elevation estimated at approximately 705 feet NAVD 88. A low level outlet would be constructed on the south side of the natural outlet to release any required environmental flows when the lake is drawn down below the natural outlet level. The outlet works would consist of a 48-inch diameter pipe extending back into Grant Lake, a gate house a regulating gate, controls, and associated monitoring equipment. The outlet would discharge into Grant Creek immediately below the diversion structure.

The primary release of water from Grant Lake for hydroelectric generation would be a concrete intake tower structure located approximately 500 feet east of the natural outlet of Grant Lake and adjacent to the shore. The intake would allow for drawdown of Grant Lake to elevation of approximately 692 feet NAVD 88. The intake can be designed to allow the Project to draw water near the surface at various levels of storage, if deemed necessary.

5.2. Grant Creek Geomorphic Conditions and Assessment Results

5.2.1. Grant Creek Geomorphic Setting and Conditions

The Grant Lake watershed is situated on the Kenai Peninsula within the Kenai Mountain Range. Metasedimentary and Metavolcanic rocks from the Valdez Group (Mesozoic Era) dominate the bedrock geology of the Grant Lake watershed and the Project area (Tysdal and Case 1979). The Valdez group within the watershed is composed primarily of greywacke, slate, and sandy slates (EBASCO 1984). The watershed has several faults and fracture zones that cut through it (Hartman and Johnson 1978; EBASCO 1984).

The most recent and prevailing influence on the geomorphology of the Grant Lake Watershed was the Pleistocene glaciations. Major continental glaciers have occupied portions of Kenai Peninsula at least four times over the past 1.6 million, the most recent ending approximately 11,000 years ago. The most recent major glaciation was the Naptwne Glaciation which occurred in the late Pleistocene, ending in the early Holocene (approximately 11,000 years ago) (Wilson et al 2012). The Grant Lake Watershed has been influenced by continental glaciers for much of its glacial history however the most recent glacial stade, the Elemendorf Stade, included mostly advances of Alpine glaciers that were concurrent with the continental glaciers. These glacial stades and interglacial periods have greatly altered the landscape by eroding bedrock, carving out the lake basin, steepening the valley walls, and depositing minor amounts of sediments. Glaciers have, for the most part, retreated to the upper limits of the watershed and only a few small alpine glaciers and snow fields are present today.

Grant Creek drains Grant Lake. It is a steep mountain stream with several falls, a narrow canyon, and a steep alluvial plain (Figures 4.2-1 and 5.2-1). In its upper half, the stream passes through a narrow bedrock canyon with three substantial waterfalls. The lower half of Grant Creek is a broader alluvial plain with a decreased stream gradient. It is likely that a faulting zone has facilitated the development of Grant Creek and the deep canyon that is associated with it. Grant Creek follows the Grant Creek Fault which has likely caused a shearing zone that has weakened the rock in this area and allowed the erosive power of Grant Creek flows to quicken the erosion of the canyon (EBASCO 1984). Additional linear features have also been identified in the watershed and several of these features are located on the ridgeline just west of Grant Lake and are in line with the abandoned relict drainage outlets that were formed when the lake level was higher. Grant Lake is in the process of lowering as it erodes the outlet sill and continues to incise the canyon.

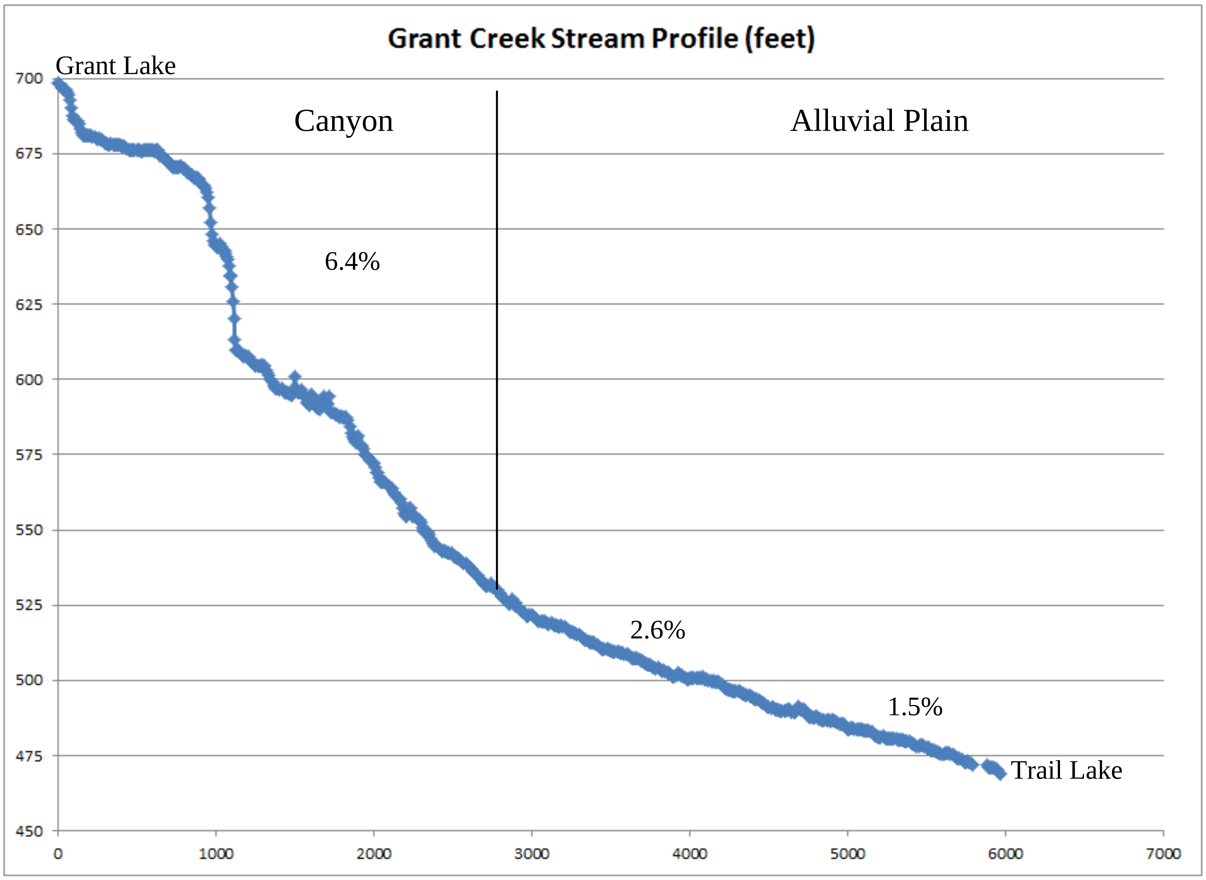


Figure 5.2-1. Grant Creek stream profile generated from LiDAR (2002). Vertical axis is in feet NAVD 88 and horizontal axis is in feet as measured from the outlet at Grant Creek.

Geomorphic interpretation of the alluvial plain landform indicates that relatively large hydrologic event(s) that are much larger than the historically observed hydrology have occurred and formed the broader alluvial plain. Substantial channel "rill" and fan topography near the canyon outlet and large alluvial transported boulders across a broad alluvial fan suggests a massive flow with sediment transport and deposition. The scale of the event(s) that formed the alluvial plain is likely substantially larger than snow-melt/rain flows where the largest recorded flow was 2,140 cfs (EBASCO 1984). It is hypothesized that the "event" was the result of an impact to Grant Lake that sent a surge of water over the Grant Creek outlet at the south end of Grant Lake. The event could have been a landslide or earthquake initiated seiche or an ice-jam dam break flood. The presence of very large sediment particles in the channel and on the alluvial plain that are beyond the transport capacity of the observed stream are relict of this event.

The alluvial plain channel has predominant substrate size that ranges from boulder to cobble and decreases from boulder-dominant substrate into a cobble-dominant substrate in the downstream direction (EBASCO 1984). The Grant Creek alluvial plain is bound by bedrock topography. The alluvial plain stream channel is approximately 25 feet at bankfull width on average, whereas the width of the alluvial plain is substantially larger than the bankfull and active channel which suggests that Grant Creek has historically occupied and eroded the alluvial plain margins.

Three generalized geomorphic channel form reaches currently exist in Grant Creek; the Canyon Reach, the Anastomosing Reach, and the Alluvial Fan Distributary Reach. The Canyon Reach (Reaches 5 and 6) is a confined bedrock channel and the primary source of sediment recruitment for Grant Creek. The channel in this section is steep and bedrock lined with limited sediment storage, both in volume and temporal duration. Most sediment is stored in the Canyon Reach sediment wedges formed behind boulder obstructions. Extremely large flows are capable of mobilizing these wedges and net incision into the bedrock is the trend. A series of headcuts (falls) are migrating up the stream in the direction of Grant Lake. In geologic time, these headcuts will migrate to Grant Lake and the lake water surface will drop to the new control elevation.

The Anastomosing Reach is within the partially confined alluvial plain and is net depositional zone with periods of incision occurring during low sediment input rates. Loss in hydraulic confinement and a change in gradient allow for sediment deposition within this reach when sediment input rates are high and transport capacity is low. It is anticipated that these conditions are episodic and driven by upper watershed conditions (hydrologic or geologic events) coinciding with a large sediment supply stored within the canyon reach. A low flow, primary channel carries the predominant flow and a series of side channel and floodplain channels are wetted at various flow conditions. The anastomosing reach changes relatively rapidly in both horizontal and vertical orientation depending upon the sediment load and is a more dynamic geomorphic reach than the Canyon Reach. Horizontal movements result from either lateral channel erosion or avulsion. It is anticipated the alluvial deposits overlay a bedrock base and that there is a robust hyporheic-ground water interaction, and that there is minimal hydrologic loss in this reach. The Anastomosing Reach channel and bedforms are sensitive to changes in flow regime and sediment load. Loss of side channel connectivity will result in a single thread channel, which decreases hydraulic complexity, concentrates stream power, and often results in increased channel incision.

The Alluvial Fan Distributary Reach is an unconfined, net depositional reach. Distributary channel networks that disperse flow to Lower Trail Lake and the Narrows are accessed at a wide range of flows. The Alluvial Fan Distributary Reach is likely the most dynamic reach in Grant Creek with respect to horizontal and vertical channel movements and avulsions. The reach is very sensitive to disturbances, particularly sediment supply and flow regime changes. Hydraulic complexity in The Alluvial Fan reach is hydraulically less complex than the Anastomosing Reach and it is probable that there is a slight hydrologic loss experienced in this reach.

The Anastomosing Reach of Grant Creek likely provides the greatest overall ecological function and salmonid productivity relative to the other reaches. The rationale for this hypothesis is that the reach has:

- the greatest hydraulic complexity;
- the greatest wetted channel length at moderate flows
- a more balanced wetted perimeter to depth at moderate flows;
- a higher probability of maintaining low and hyporheic connectivity in the winter;
- is more stable than the Alluvial Fan Reach; and
- lower velocity and stream power than the Canyon Reach.

Sediment Supply and Transport Influences on Grant Creek Geomorphology

A small amount of suspend and dissolved sediment load from the upper watershed reaches Grant Creek. However, Grant Lake acts to arrest all bedload sediment transport from the upper watershed area. Therefore, the sediment supply for Grant Creek, excluding the throughput suspended sediment load, is the canyon reach. With the majority of the sediment source for Grant Creek being derived from the canyon walls, the geological formations present along this length of stream channel play a critical role. The primary process for generating new bedload sediment in Grant Creek are the erosional forces that incise the canyon causing wall undermining and mass wasting (rock fall) from the canyon walls and exposing the geology to freeze-thaw and other surface erosion processes.

While Grant Creek within the alluvial plain exhibits net deposition over time, it is under "normal" hydrologic conditions a supply limited stream, meaning that the sediment transport capacity of the stream is greater than the sediment supply to the stream. A supply limited stream tends to migrate less laterally and vertically than a transport limited stream, and channel form is more "stable". Supply limited streams also tend to be armored, incised, and exhibit a straight versus meandering channel form.

Sediment Form Influences on Grant Creek Geomorphology

Of the three geological formations present along the creek channel, the greywacke is the more resistant rock type, whereas the sandy slate and slate are more friable and tend to supply the majority of sediment to the stream bed. The greywacke units control the base elevation in Grant Lake by creating the outlet sills and forming waterfalls. In time, erosion of the greywacke and head-cut retreat of the canyon would lower Grant Lake.

The sediment being recruited to Grant Creek is angular, with the slate having a "platy" particle morphology (A-axis and B-axis are similar, disproportionately small C-axis) and the greywacke having long "blocky or brick-like" particle morphology (large A-axis, similar disproportionately small B and C-axes). The high stream power in the canyon and the relatively short transport distance from the sediment source in the canyon to the depositional areas downstream results in relatively large grain size with high degree of angularity of the particles compared to other streams of similar discharge with a greater spatial extent of bedload sediment inputs. Blocky and platy sediment morphologies with the same B-axes dimensions have different volumes (think of a dinner plate versus a watermelon that both have similar B-axis diameter), and therefore a different surface area to mass, which effects transport characteristics. Angular sediment also transports across the channel bed (rolling and saltating) and entrains differently than does rounded. The particle morphology of Grant Creek likely increases the armoring qualities of the bed and thus adds to the overall stability of the channel form.

Hydrologic Influences on Grant Creek Sediment Transport and Geomorphology

The hydrology of Grant Creek is predominantly driven by the cycle of melting snow and precipitation in the summer and frozen watershed conditions in the winter. Historic hydrologic monitoring was conducted by a U.S. Department of the Interior, Geological Survey (USGS) operated gage between 1947 and 1959 and subsequent modeling indicates that Grant Creek has a mean annual flow of ~198 cfs (AEIDC 1983). Grant Creek was gauged in the spring of 2013 and a flow range of approximately 16 to 1,005 cfs was documented. The months of June through August typically produce the highest mean monthly flows (approximately 450 to 500 cfs) (AEIDC 1983). The highest measured flow was 2,140 cfs (EBASCO 1984). Recurrence intervals have not been calculated for this watershed.

It is the bankfull and peak flows that dominate the fluvial geomorphic processes at Grant Creek. The stream bed is comprised of large sediment particles and the bed is armored, so only the larger flows are able to mobilize the bed armoring, transport sediment en masse, and reorganize bedforms. The sustained flows offered by snow melt conditions allow for a longer duration of time for which to organize the substrate, construct and arrange the geomorphic channel bed structures, and allow channel form development.

A larger, but unmonitored hydrologic event likely occurred on Grant Creek in September 2012 when many other gauged streams in the vicinity of Grant Creek experienced flows of record. Some residual high water marks on Grant Creek were observed which showed that the 2012 event was larger than the highest 2013 flow. Using the existing stage gage and rating curve to estimate the flows, the 2012 flow was likely between approximately 1,500 and 2,000 cfs. The September 2012 flow was short duration and occurred late in the season and winter conditions set in soon after, therefore reducing the amount of time for flows following the event to process the transported sediment and adapt to the modified channel bed forms. As a result, the 2013 higher flow season responded to the disturbances from the 2012 event and there were several channel changes, including recapture of some floodplain channels, an avulsion, and partial abandonment of previously occupied low flow channels. The primary driver for these changes was likely a redistribution of bedload sediment and localized vertical channel bed changes, which affected localized WSEs. The observation shows that the channel form and bed forms and the interaction with the floodplain and floodplain side channels are dynamic, and thus habitat that relies on the availability, extent, and quality of substrate are related to sediment transport processes.

Non-climate driven hydrologic events likely occur within Grant Creek. The Grant Creek watershed is within an active seismic area and a large scale landslide, avalanche or earthquake caused seiche could occur. In the event that a large scale landslide did occur and deliver large volumes of material rapidly into Grant Lake, then large waves or seiches could propagate throughout the lake basin and into Grant Creek. It is probable that the hydrograph from one of these events, although brief in nature, would be substantially greater in magnitude than climate driven hydrographs.

5.2.2. Quantitative Sediment Characterization Summary

The Grant Creek channel bed is vertically stratified with at least two distinct layers; armored or pavement layer, and subsurface (Table 5.2-1). A sub-pavement layer was not distinct. The surface is highly armored which is enhanced by angular particle forms and the surface has low embeddedness and is relatively low in fine grained sediment. The subsurface is well-graded cobble and gravel with sand and nominal fines (less than 1 percent of sediment by volume is 1 mm (medium sand) or smaller). The subsurface material is anticipated to be easily remobilized when the armoring is removed.

Table 5.2-1. Surface (Wolman grid) sampling (frequency-by-numbers) results.

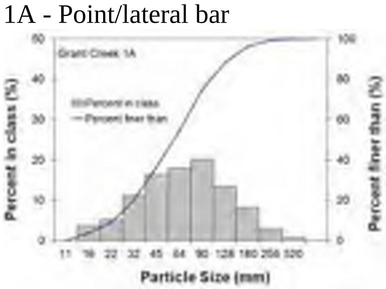
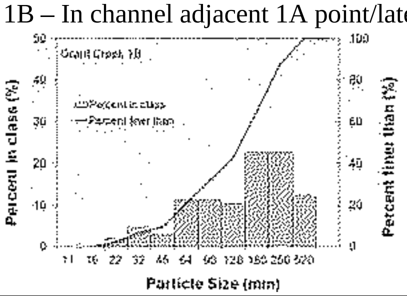
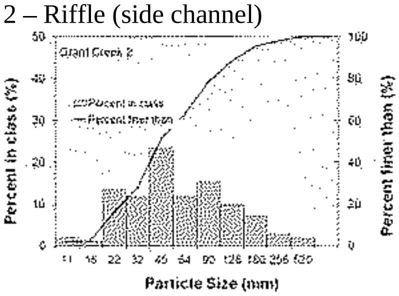
Sample ID - Description	Diameter Statics	Size (mm)
1A - Point/lateral bar	D16	30
	D50	59
	D84	115
	D-Maximum	>520
1B – In channel adjacent 1A point/lateral bar	D16	55
	D50	154
	D84	524
	D-Maximum	>600
2 – Riffle (side channel)	D16	16
	D50	48
	D84	110
	D-Maximum	>520

Table 5.2-1, continued…

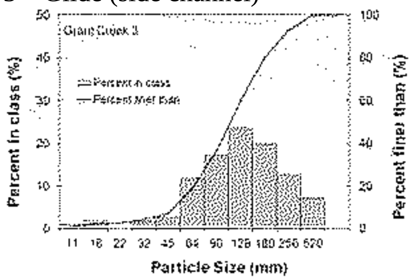
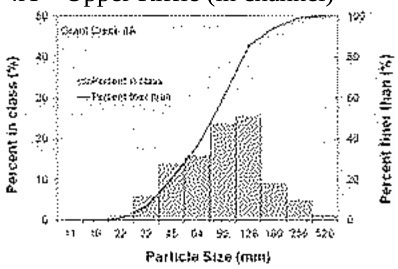
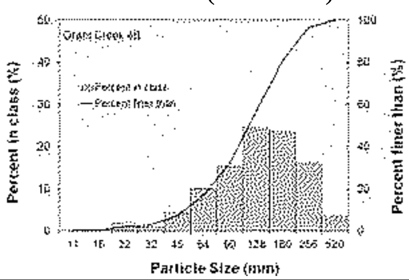
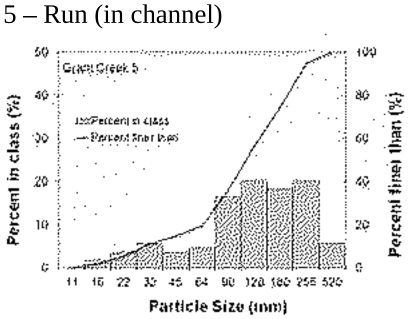
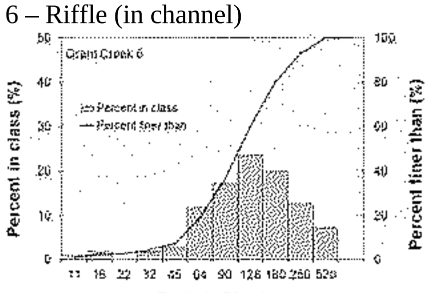
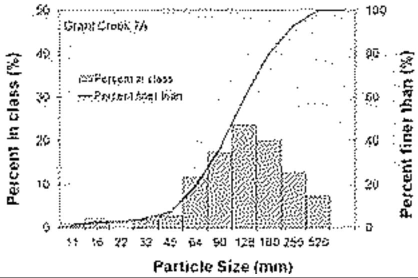
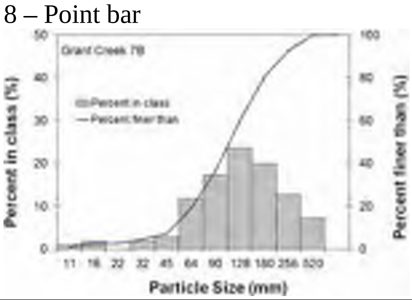
<table>
<tr><td rowspan="4">3 – Glide (side channel)

</td><td>D16</td><td>58</td></tr>
<tr><td>D50</td><td>118</td></tr>
<tr><td>D84</td><td>183</td></tr>
<tr><td>D-Maximum</td><td>>520</td></tr>
<tr><td rowspan="4">4A – Upper Riffle (in channel)

</td><td>D16</td><td>40</td></tr>
<tr><td>D50</td><td>78</td></tr>
<tr><td>D84</td><td>122</td></tr>
<tr><td>D-Maximum</td><td>>520</td></tr>
<tr><td rowspan="4">4B – Lower Riffle (in channel)

</td><td>D16</td><td>62</td></tr>
<tr><td>D50</td><td>133</td></tr>
<tr><td>D84</td><td>190</td></tr>
<tr><td>D-Maximum</td><td>>520</td></tr>
<tr><td rowspan="4">5 – Run (in channel)

</td><td>D16</td><td>51</td></tr>
<tr><td>D50</td><td>121</td></tr>
<tr><td>D84</td><td>209</td></tr>
<tr><td>D-Maximum</td><td>>520</td></tr>
<tr><td rowspan="4">6 – Riffle (in channel)

</td><td>D16</td><td>49</td></tr>
<tr><td>D50</td><td>111</td></tr>
<tr><td>D84</td><td>177</td></tr>
<tr><td>D-Maximum</td><td>>520</td></tr>
</table>

Table 5.2-1, continued…

7 – Point bar 	D16	35
	D50	77
	D84	145
	D-Maximum	>256
8 – Point bar 	D16	51
	D50	83
	D84	151
	D-Maximum	>520

Surface Analysis Results Summary

In summary, the wetted low-flow channel areas are substantially coarser and more armored than are the lateral and point bars (Table 5.2-2). No trend in surface sediment decrease moving in the downstream direction was observed. It is hypothesized that local hydraulics and the two distinct particle forms (platy and blocky) influences particle size to transport relationship and deposition more than channel gradient in this turbulent system. The instream D50 is generally larger than literature referenced “preferred” spawning substrate size; however, in the case of Grant Creek the spawning species are utilizing the areas with large, armored surface substrate.

Table 5.2-2. Subsurface volume (bulk) sampling (frequency-by-weight (volume)) results.

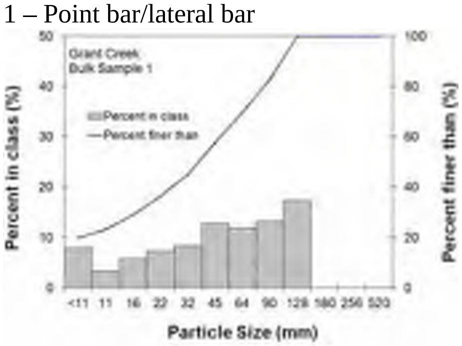
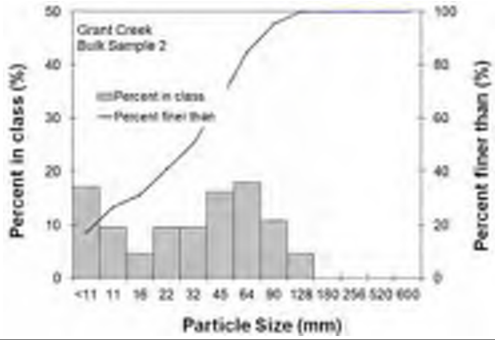
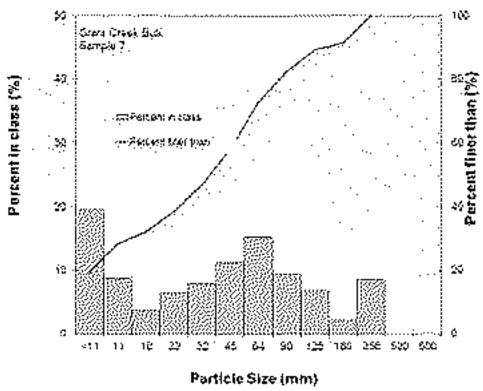
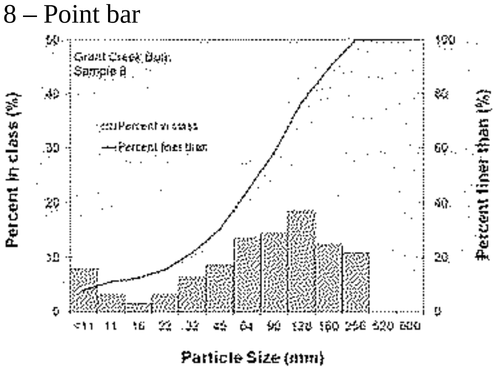
Sample ID - Description	Diameter Statics	Size (mm)
1 – Point bar/lateral bar 	D16	20
	D50	52
	D84	133
	D-Maximum	>128

Table 5.2-2, continued…

2 – Riffle in side channel 	D16	17
	D50	21
	D84	38
	D-Maximum	>128
7 – Point bar 	D16	17
	D50	28
	D84	98
	D-Maximum	>256
8 – Point bar 	D16	31
	D50	74
	D84	147
	D-Maximum	>256

<u>Subsurface Analysis Results Summary</u>

The subsurface is less coarse than the surface, except at Sample Site 1, where the subsurface had a higher percentage by size class of large particles and yet a similar D50 size. It is hypothesized that the subsurface in Sample Site 1 represented a hyperconcentrated flow deposit as it lacked sorting and imbrication structure that was apparent in the other subsurface sample sites. Subsurface sediment was overall well-graded cobble and gravel with sand with minimal fines. Similar to the surface analysis, there was not a general trend in decreasing D50 particle size in the downstream direction because of the influence of localized hydraulics and relict hyperconcentrated lag deposits. It should be noted that inaccuracies in bulk sampling can be pronounced in bimodal distributions containing large clasts and where lag deposits from hyperconcentrated/dam outburst type alluvial deposits are found, as is the interpreted conditions of Grant Creek.

Embedment Results

Field observations of embeddedness resulting from fine-grained sediment deposition in the interstitial spaces of the surface armoring were found to be extremely low. The reasons for this are hypothesized to be that: the Grant Creek system is relatively starved of fine sediment and that the current flow regime transports most fines through the system as throughput, and the low sediment delivery rate and high flows result in armored condition.

General clast-to-clast embedment was difficult to measure because of the particle forms, particularly platy, and the generally well armored conditions. Qualitatively, clast-to-clast embedment appeared relatively high because of armoring. Because of the high percentage of imbricated platy sediment particles, there is low confidence in the values measured, and therefore it is our opinion that quantitative results are not reliable. However, it is not anticipated that the operational scenario will not increase the deposition of fines in the stream, therefore there should not be an increase in fines filling the interstitial spaces of the surface sediment within the spawning reach.

Sediment Incipient Motion Analysis Results

Grant Creek is an example of a complex system for the following reasons:

- Grant Creek is a high gradient, boulder dominated stream with turbulent flow. Bedform and channel bank irregularity, in addition to instream boulder and bedrock structures, create turbulence with secondary flow influences that can be much more influential on sediment transport than in planer bed conditions. Attempts to calculate or measure shear stress values in mountain rivers are complicated by the channel bed roughness and the associated turbulence and velocity fluctuations (Wohl, 2000).
- Sediment particle shapes are unique and vary from referenced calibrated models. The sediment shapes present in the Grant Creek are angular platy particles and angular blocky or “brick” shaped particles. These two shapes will each mobilize and transport differently relative to each other. These two shapes are different from the assumed particle shape used to develop and calibrate models, which are spherical shapes. Spherical particle shapes will have a different transport characteristic than either platy or brick shapes. In addition, each particle form will lay and organize differently on the channel bed and each has a different mass to B-axis ratio; therefore, incipient motion will be different for each particle represented in Grant Creek as well as different than predicted by equations developed using spherical models.
- Sediment transport rates at Grant Creek are very low. There are three phases of sediment transport associated with very low bedload transport rates, also known as marginal transport. Incipient motion and net transport rates in these systems are very sensitive to changing hydraulic conditions and bed material moves only partially; thus entrainment is size-selective (Hassan et al. 2005; Wilcock and McArdell 1993).
- The Grant Creek channel bed is locally armored. Sediment transport characteristics, specifically incipient particle motion, in armored gravel-bed rivers is often controlled by

patches of fine sediment and bedforms (e.g. Garcia et al. 1999). Bedload transport characteristics vary from the initiation of particle movement to the point when the breakup of the armor layer occurs when the channel becomes unstable at the reach scale.

- Inter-particle relationships are not represented in model assumptions, so hiding effect and "patches", which can have significant influence on particle movement are not considered.

A given particle will move only when the shear stress acting on it is greater than the resistance of the particle to movement. The magnitude of shear stress required to move a given particle is known as the critical shear stress. The resistance of the particles to movement, and thus its entrainment, will vary depending on its size, its size relative to surrounding particles, how it is oriented, and the degree to which it is embedded. The size of the particle will influence the weight of the particle. The size of the particles relative to surrounding particles will affect the amount of shear stress the particle is exposed to via the "hiding" factor. Orientation of the particle will affect the force required to roll the particle along the bed. Packing or embeddedness will affect the amount of shear stress that the particle is exposed to.

The substrate particle forms, as previously described, are distinctly different and literature supporting Shield parameter values for both platy and blocky particle forms is extremely limited. It is hypothesized that platy particle forms in a cohesionless, heterogeneous particle shape planer bed will mobilize in lower flows and be more easily entrained than will blocky particle forms of similar B-axis dimensions in the same flow conditions if the platy particles are loose and unorganized. However, if the platy sediment has become highly imbricated in a more homogeneous particle shape grouping, thus increasing particle-to-particle contact forces and decreasing fluid forces acting on a given surface area (skin friction), then the platy particle will require a higher flow to initiate mobilization than the blocky sediment. Based on the lack of strongly imbricated, homogenous surface present at Grant Creek, it is anticipate that the platy particles will be mobilized more easily than the long axis blocky particles. It should also be noted that Grant Creek channel bed is, for the most part, not planer, thus bed shear stress is primarily associated with form drag rather than skin friction on individual particles, which is the force that moves particles.

The incipient motion calculation estimated that the proposed maximum operational flow (385 cfs) will likely initiate mobilization of surface sediment within the preferred spawning substrate range (10 mm – 50 mm). At 385 cfs, it is anticipated that substrate mobility will be partial, limited to only smaller particles and that movement of particles will be intermittent, localized, and primarily from the deeper channel areas or where turbulence is high. Mobilization of particles will also depend upon the degree of armoring, bedform, and particle shape. Table 5.2-3 is a summary of the estimated upper particle size threshold being mobilized at 385 cfs.

Table 5.2-3. Summary of incipient motion calculations at 385 cfs.

Sample Site	τ(blocky)	τ(platy)	τb (pounds/sf)	Ds(blocky) mm	Ds(platy) mm	D50 surface mm	D50 subsurface mm
1	0.06	0.03	1.85	92	183	59	52
2	0.06	0.03	0.79	39	79	48	21
7	0.06	0.03	1.32	65	131	77	28
8	0.06	0.03	1.12	55	111	83	74
			Average	62.8	126	67	44

Field observations, marker analysis, and professional judgment would suggest that the predicted particle sizes are high for the platy particle forms using the Shield's parameter of 0.03. It also is possible that the values obtained for the blocky substrate are too high as well. These outputs predict that there would be substantial bedload movement at a 385 cfs flow. Very little bedload sediment transport appeared to be occurring at flows near the proposed operational flow. Additionally, flows near the proposed operational flow also coincided with spawning activity. The point bar at Sample Site 1 had only experienced minor sediment transport even with the 1000 cfs flows, so it is unlikely that widespread surface sediment breakup occurred at 1000 cfs flows. However, channel bed changes and resulting WSE changes occurred in 2013 occurred following the higher flows; therefore, some degree of local bedload transport does occur with flows between 350 cfs and 1,000 cfs.

Sediment Delivery Potential Results

Sediment delivery and transport in Grant Creek is divided between two transport characteristics; suspended sediment load and bedload sediment. Suspended sediment load passes through Grant Creek with very little deposition in the alluvial reach as a result of the steep stream gradient, turbulence and low sediment load. The primary source of suspended sediment is from the glacial headwaters. Much of the suspended sediment load settles out into Grant Lake. The suspended sediment that passes through Grant Lake is extremely fine and has a very low settling rate, which also decreases the potential for deposition to occur within Grant Creek.

There are four primary sources of bedload sediment in Grant Creek; lakeshore littoral sediment input, canyon reach input, channel bed and channel bank remobilization (bank erosion, incision), and mechanical breakdown of instream sediment during mobilization. Field investigation determined that the bedload sediment supply in Grant Creek is extremely limited and that the canyon is the predominant source of bedload sediment. Bedload sediment delivery arrives episodically, either from a rock fall within the canyon, or a littoral contribution resulting from a large wind storm occurring at high lake WSEs. Remobilization of channel bank and channel bed sediment can provide a sediment input to lower reaches, but does not recharge or replenish the whole stream system. Large hydrologic events are necessary to mobilize and transport sediment from the canyon and deliver the sediment to the lower reaches as well as to mechanically breakdown instream sediment.

6 CONCLUSIONS

6.1. Grant Lake Shoreline Erosion Study Conclusions

The analysis utilized methods prescribed in the Study Plan previously developed by KHL and resource agencies and finalized in March 2013. Since operational WSE changes have not yet been fully defined, the shoreline erosional change was difficult to completely determine. Additionally, because of the presence of snow and ice occurring during low WSE, it was not feasible to conduct a low lake WSE analysis. As a result, the analysis relied upon the previously described conditions and available information. Lastly, the geomorphic analysis does not include a geotechnical evaluation of existing slope stability or changes in slope stability resulting from changes in Grant Lake WSE.

The anticipated impacts to shoreline erosion potential from the proposed operational WSE fluctuation are likely to be relatively minor over the long term for the following reasons:

- Proposed operational conditions only increase the WSE fluctuation range by a maximum of 2 feet above existing natural lake WSE fluctuations
- Most of the change in WSE range is a decreased WSE that occurs in winter during ice-on conditions when wave and stream erosion processes are less active.
- The shoreline littoral area is predominantly bedrock or coarse, angular boulders with a low susceptibility to erosion.
- Influence of wind-generated waves in Grant Lake is not a substantial erosional process because the open fetch was limited to a maximum of approximately 3 miles, and therefore wind wave heights were limited. In the areas where fetch was greatest and bathymetric conditions favored high wave run up, only a slight increase in OHWM elevation demonstrating that maximum wind-wave heights were estimated to be a maximum of approximately 5 feet at Inlet Creek and 3 feet at Grant Creek outlet.
- In the areas where erosion potential was greatest, only minimal erosion; in part because of the depositional nature of the geomorphic units these areas and the apparent high depositional rate. With the exception of the Beach geomorphic unit, all other areas are actively delivering sediment to the shoreline area at rates that are greater than the erosion potential.
- It is anticipated the WSE fluctuations under proposed operational conditions will decrease the duration of time that the WSE holds at any one elevation, especially peak WSE levels, therefore decreasing the frequency of wave events occurring at any one elevation and reducing the effects of wave erosion at any one shoreline elevation.
- Because of the limited extent of littoral transport observed in the field, the effects on the Beach geomorphic unit and other isolated pocket beaches is anticipated to be relatively minor. It should be noted that an interruption of limited littoral-transported sediment supply to Grant Creek will occur following the construction of the gravity diversion structure (if this option is selected), but it is anticipated that the sediment volumes and delivery rates are relatively small and only occur episodically and likely infrequently.
- The impacts of erosion along the shoreline from an elevated lake WSE above the current OHWM will be most dramatic in the first few years as loose and fine grained sediment are "winnowed" from the shoreline deposits by wave action leaving behind an armored shore. In some areas shoreline retreat and temporary vertical bluffs are expected,

particularly in the more erodible alluvial deposits. This impact will be greatest in low-sloping shorelines, fine-grained depositional areas, and areas with greater fetch, Inlet Creek in particular will see the greatest shoreline changes. In addition, the vegetation along the shoreline that is functioning to bind soils and slopes together with root mass will lose this function as the vegetation in the inundated and dies. It is possible that the shoreline will take up to a decade to recover from the initial disturbance created by the increased WSE.

- The areas most susceptible to erosion from stream incision caused by decreases in base elevation are the alluvial deposits (Alluvial Deltaic and Alluvial Fan geomorphic units). The potential effects of channel incision will be the steepening of stream gradient, coarsening of streambed sediments, straightening of stream channels, decreased floodplain connectivity, increased instream flow velocities and depths, and bank steepening and retreat.

The potential for ice jams exists in Grant Lake, particularly at the narrow, shallow sill mid-way down the lake and at Grant Creek outlet. The temporary elevation increase of WSE and resulting shoreline erosion is possible during these potential episodes, as is the potential stream erosion in Grant Creek resulting from an ice jam break. While landslides and ice-jams can be significant geomorphic processes, the recurrence interval and magnitude is unknown, but likely infrequent.

The greatest ongoing potential for geomorphic impact is the potential incision of the inlet streams at the shoreline margin, Inlet Creek at the east end of the lake in particular. The effects of impact is lessened since these streams do not possess populations of any fish species other than the potential for the stickleback and sculpin known to be the only two species that inhabit Grant Lake. The degree of impact will be limited by the timing of high flows in combination with the extent and duration of low lake WSE conditions. As lake WSE increases, the probability and extent of stream incision impacts decreases.

6.2. Grant Creek Spawning Substrate Recruitment Study Conclusions

The analysis utilized methods prescribed in the Study Plan previously developed by KHL and resource agencies and finalized in March 2013. In general, bedload transport is not a simple exercise to measure or predict. There is a high degree of uncertainty and low degree in output confidence in uncalibrated bedload transport modeling. A collaborative approach to addressing these potential issues is recommended.

Grant Creek is a complex, steep stream that demonstrated a wide range of variability both with the substrate and bedform conditions and transport is not adequately captured using referenced Shield's parameter values (Yager 2012). Regardless, the proposed operational conditions have the potential to have a geomorphic response as summarized in Table 6.2-1.

Table 6.2-1. Potential geomorphic responses from Project operational conditions.

Proposed Change	Potential Geomorphic Response
Decreased frequency and magnitude of Grant Creek peak flows	• Reduced shear stress potential resulting in decreased net sediment transport potential • Decreased movement potential for large sediment material • Continued sediment transport of smaller and intermediate sediment sizes from the surface or subsurface following bioturbation (specifically spawning) • Decreased potential for armor remobilization • Increased relative armoring trend over time resulting from smaller particle "winnowing" (migrating in a downstream direction) • Decreased remobilization of sub-surface sediment except in spawning areas • Increased potential for channel stability (decreased lateral migration, net increase for channel incision potential) • Increased potential for development of a single-thread channel • Loss of floodplain connectivity • Decreased potential for scour and organization of depositional channel bed forms • Decreased bedform quantity and associated loss of hydraulic complexity • Decreased sediment supply resulting from lateral migration
Decreased frequency and duration of Grant Creek low flows	• Decreased potential for fine-grained sediment deposition
Flow bypass of the canyon reach	• Reduced sediment supply availability • Decreased ice-jam dam outburst potential • Decreased potential for slope instability in canyon reach • Decreased potential for bedrock outlet control degradation (erosion) and long-term Grant Lake WSE reduction

Of the potential geomorphic responses listed above, the following geomorphic responses are anticipated to have impacts to spawning substrate. Many of the geomorphic response and the resulting impacts to spawning substrate are anticipated to occur incrementally over time measured in years and decades. It is anticipated that there will be high potential for:

- An increased coarsening of surface bedload sediment as the sediment supply decreases from a bypass of the Canyon Reach and smaller surface sediment is transported out of the reach by operational flow. As a result, there is likely to be degradation spawning substrate quantity and quality resulting from this geomorphic response.
- Increased armoring and pavement depth in spawning areas as subsurface fines are mobilized and winnowed out of the system following bioturbation pavement breakup (from spawning). As a result, there is likely to be a degradation of spawning substrate quality resulting from this geomorphic response.
- Decreased geomorphic channel form complexity (loss of side-channel and floodplain connectivity, development of a single-thread channel) resulting from decreased sediment supply will increase primary channel incision and stream velocity. As a result, there will likely be a decrease in spawning substrate quantity resulting from this geomorphic response.
- Decreased quantity of channel bedforms (riffles and bars) resulting from decreased sediment supply and decreased sediment transport with a reduced flow regime. As a

result, there will likely be a decrease in hydraulic complexity that is expected to degrade spawning substrate quality and reduce its availability resulting from this geomorphic response.

It is the conclusion of this analysis that there will be an ecological impact related to the anticipated geomorphic responses resulting from operational conditions. There is a direct relationship between stream flow and sediment transport and aquatic habitat availability and quality (Pitlick and Wilcock 2001). Bedload sediment supply in combination with a variable flow regime creates and modifies channel bedforms, controls sediment transport and storage, affects surface texture through selective transport, influences channel migration, and has a direct influence on aquatic habitat. The flux rate of coarse material combined with high flow magnitude and duration create an important component of sediment mass balance and geomorphic response in a stream and modification of these variables and can have ecological significance both for salmonid spawning, juvenile rearing, and invertebrate production. While a variable flow regime is vital to creating and maintaining spawning substrate, it is possible that some moderation of the Grant Creek flow range under certain management scenarios could provide some positive impacts to redd survival.

Geomorphic bedform features create hydraulic processes that support ecologic function, in particular channel and bedform complexity create hydraulic conditions favorable for spawning and rearing habitat by creating interstitial flow pathways between surface water, hyporheic, and ground water zones (Geist et al. 1998). Geomorphic bedforms are created, organized and destroyed by flow variability, higher flows that mobilize bedforms are particularly important in this process. Salmonid spawning tends to occur at the transitions between pools and riffles associated with lateral bar deposition (Bjornn and Reiser 1991; Church and Jones 1982).

A management scenario that integrates some degree of flow variability to provide flows of sufficient peak and duration to enable spawning substrate mobilization and organization could be utilized to offset some of the impacts to substrate quality. Additionally, a management scenario that allows periodic, sediment flushing flows through the canyon reach could provide for recruitment and transport of the sediment necessary to maintain spawning substrate quantity in the lower reaches. This management scenario would have to be coordinated with reservoir level and habitat utilization period(s). Another alternative could be to develop a sediment nourishment program to replace the lost sediment recruitment opportunity created from the canyon bypass.

7 VARIANCES FROM FERC-APPROVED STUDY PLAN AND PROPOSED MODIFICATIONS

There were three variances from the FERC and agency-approved study plan that occurred in the geomorphology analysis. One is that a dataset for the embeddedness assessment task was not provided. The rationale for action was that unique field conditions made for non-reproducible results with high data uncertainty. The second was that the number of subsurface sampling sites and sample size and sieve methods was modified to fit actual field conditions. The sediment particle size was too great to remove the prescribed sample size and to have it processed by a lab.

The number of sample sites was decreased based on relative homogeneity of conditions observed and an unanticipated low quantity of gravel bars exposed at low flow.

8 REFERENCES

AEIDC (Arctic Environmental Information and Data Center). 1983. *Summary of environmental knowledge of the proposed Grant Lake hydroelectric project area*. Final Report submitted to Ebasco Services, Inc., Redmond, Washington, University of Alaska, Anchorage, Alaska.

Bjorn, T.C., and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. in W.R. Meehan (ed.), Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19, Bethesda, Maryland. Pp 83-138.

Bovee, K.D. 1982. A guide to stream habitat analysis using the instream flow incremental methodology. US Fish and Wildlife Service, Instream Flow Group Information Paper 12, Fort Collings, Colorado.

Church, M., and D. Jones. 1982. Channel bars in gravel-bed rivers. *in* R.D. Hey, J.C. Bathurst, and C.R. Thorne (eds.), Gravel-bed rivers. John Wiley & Sons, New York. pp 291-338

Church, M. A. , D. G. McLean, and J. F. Wolcott. 1987. "River Bed Gravels: Sampling and Analysis." Sediment Transport in Gravel-Bed Rivers. Ed. C. R. Thorne, J. C. Bathurst, and R. D. Hey. John Wiley and Sons, pp. 43-88.

Ebasco. 1984. Grant Lake Hydroelectric Project Detailed Feasibility Analysis. Volume 2. Environmental Report. Rep. from Ebasco Services Incorporated, Bellevue, Washington.

Hassan, M.A., M. Church, T.E. Lisle, F. Brardinoni, L. Benda, and G.E. Grant. 2005. Sediment transport and channel morphology of small, forested streams. J. Amer. Water Resources Assoc.41(4):pp 853-876.

Garcia, C., J. B. Laronne, and M. Sala. 1999. Variable source areas of bedload in a gravel-bed stream, J. Sedimentary Res., 6, pp 27–31.

Geist, D.R., and D.D. Dauble. 1998. Redd Site Selection and Spawning Habitat Use by Fall Chinook Salmon: The Importance of Geomorphic Features in Large Rivers. Environmental Management Vol. 22, No. 5, Springer-Verlag, New York. pp. 655-669.

Hartman, C.W. and P.R. Johnson. 1978. Environmental Atlas of Alaska. University of Alaska, Institute of Water Resources. 95 pp.

Haufler, J.B., C.A. Mehl, and S. Yeats. 2010. Climate change: anticipated effects on ecosystem services and potential actions by the Alaska Region, U.S. Forest Service. Ecosystem Management Research Institute, Seeley Lake, Montana, USA.

Inter-Fluve. 2004. Cooper Creek Sediment and Geomorphology Investigation, Final Report (FERC No. 2170) prepared for HDR Alaska, Inc. Anchorage Alaska.

Jones, D.E. 1975. Steelhead and Sea-run Cutthroat Trout Life History Study in Southeast Alaska. ADF&G, anadromous fish studies. Annual Performance Report. Vol. 17. Study AFS-42-4, 28 p.

KHL (Kenai Hydro, LLC). 2009. Pre-Application Document Grant Lake/Grant Creek and Falls Creek Project (FERC No. 13211 and 13212. August 2009.

Kondolf, G. M., and M. G. Wolman. 1993. The sizes of salmonid spawning gravels. Water Resources Research 29: pp. 2275–2285.

Mantz P A. 1977. Incipient transport of fine grains and flanks by fluids-extended Shields diagram. J. Hydraul. Div., Am. Soc. Civil. Eng. 103: pp. 601–615.

Milhous. R., 1998. Modeling of instream flow needs; the link between sediment and aquatic habitat, *Regulated Rivers*, 14, pp. 79-94.

Pitlick, J. and P. Wilcock. 2001. Geomorphic Processes and Riverine Habitat; Water Science and Application. Vol. 4. Pp 184-198.

Russell, R. 1977. Rainbow trout studies, Lower Talarik Creek-Kvichak. ADF&G, Fed. Aid in Fish Rest. Completion rept. Vol. 18. Proj. F-9-9, Job G-II-E.

Suchanek, P.M., R.L. Sundet, and M.N. Wenger. 1984. Resident fish habitat studies. Part 6 in D.C. Schmidt, S.S. Hale, D.L. Crawford, and P.M. Scchanek, eds. ADF&G, Susitna Hydro Aquatic Studies, Rept. 2: resident and juvenile anadromous fish investigations (May-October 1983).

Swan, G.A. 1989. Chinook salmon spawning surveys in deep waters of a large, regulated river. *Regulated Rivers: Research and Management* 4: pp. 355-370.

Tysdal, R.G. and Case, J.E. 1979. Geologic map of the Seward and Blying Sound quadrangles, Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map 1150, 12 p., 1 sheet, scale 1:250,000.

Wilcock, P.R. and B.W. McArdell. 1993. Surface-based fractional transport rates: Mobilization thresholds and partial transport of a sand-gravel sediment, Water Resour. Res., 29, pp. 1297-1312.

Wilson, F.H., Hults, C.P., Schmoll, H.R., Haeussler, P.J., Schmidt, J.M., Yehle, L.A., and Labay, K.A. 2012. Geologic map of the Cook Inlet region, Alaska, including parts of the Talkeetna, Talkeetna Mountains, Tyonek, Anchorage, Lake Clark, Kenai, Seward, Liamna, Seldovia, Mount Katmai, and Afognak: U.S. Geological Survey Scientific Investigations Map 3153, 76 p., 2 sheets, scale 1:250,000.

Wohl, E. 2000. Mountain Rivers. American Geophysical Union. Washington, D.C.

Yager, E. M., W. E. Dietrich, J. W. Kirchner, and B. W. McArdell. 2012), Prediction of sediment transport in step-pool channels, Water Resour. Res., 48, W01541, doi:10.1029/2011WR010829

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Appendix 1: Grant Lake Shoreline Geomorphology Site Photos

Note: Locations of photos are shown on Figure 4.1-1.

Geomorphic Unit "Type Sections" and Field Notes

Photo 1 (by P.Pittman, 8/24/2013): Grant Lake typical "*Beach Deposit*" Geomorphic Unit.

Field Note - WSE at visit is was approximately 2 feet over the Grant Creek outlet invert.at this location of the lake is approximately 3 -feet higher than the WSE at the time of the field visit and likely represents an apparent OHWM increased because of wave run up. The OHWM in protected areas of the lake was approximately 1 to 2 feet above the WSE at the time of the field visit. An increase in WSE of 2 feet will cause a shoreward retreat of the shoreline and vegetation loss below the OHWM.

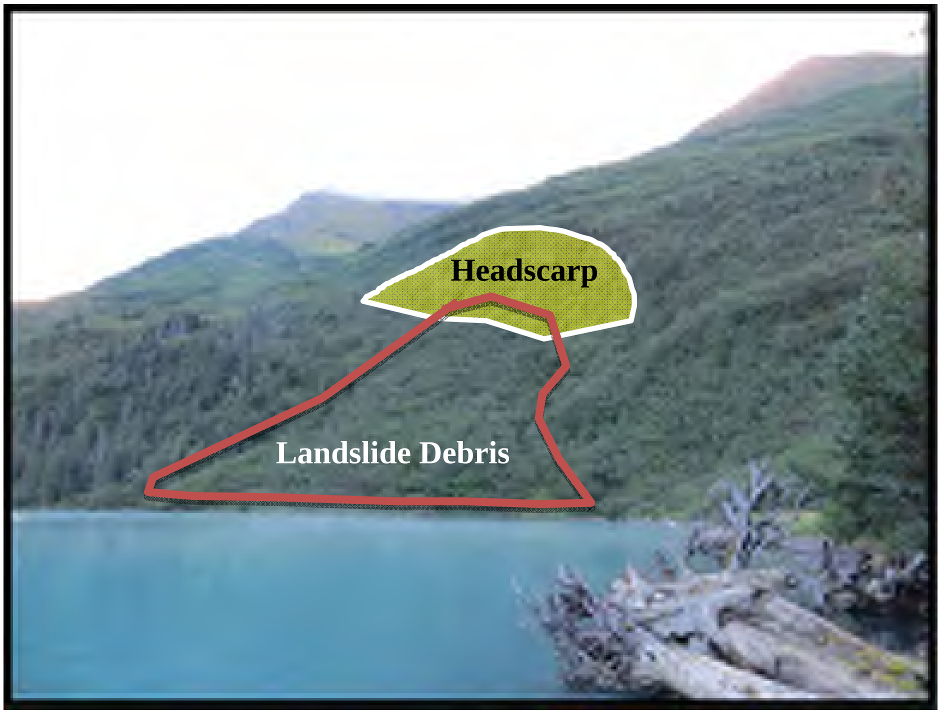

Photo 2 (by P.Pittman, 8/24/2013): Grant Lake typical "*Landslide*" Geomorphic Unit and field interpretation.

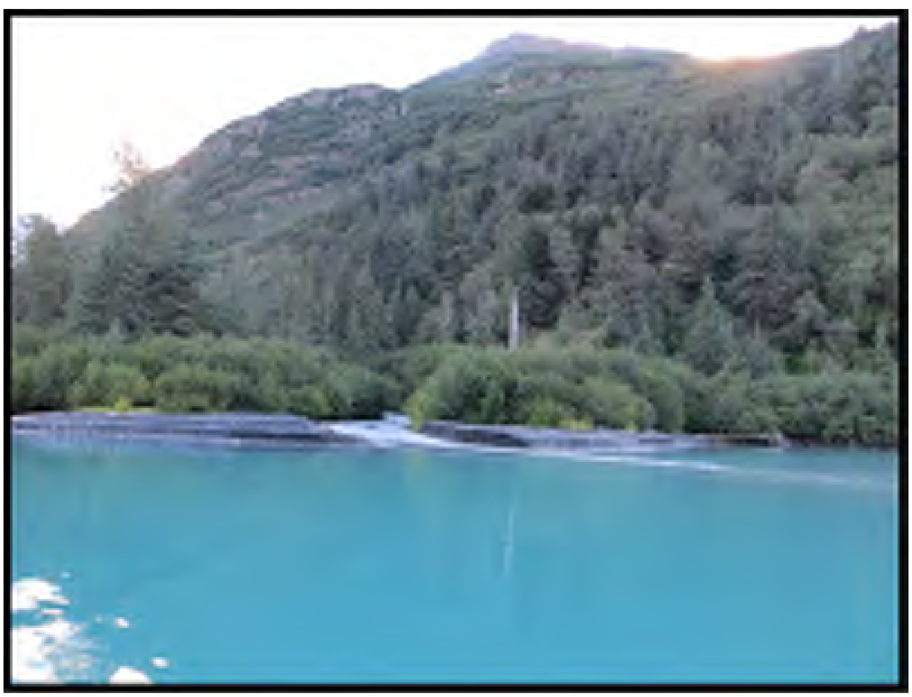

Photo 3 (by P.Pittman, 8/24/2013): Grant Lake typical "*Alluvial Fan Deposit*" Geomorphic Unit.

Photo 4 (by P.Pittman, 8/24/2013): Grant Lake typical "*Bedrock*" Geomorphic Unit.

Photo 5 (by P.Pittman, 8/24/2013): Grant Lake typical "*Bedrock*" Geomorphic Unit at the Grant

Field Note: Lake narrows between the upper basin and lower basin. At low WSE conditions, the gap will narrow and water depths will be 2-feet or less, and it is anticipated that the submerged topographic saddle is bedrock.

Photo 6 (by P.Pittman, 8/24/2013) Field Note: Grant Lake pocket beach along a bedrock shoreline.

Photo 7 (by P.Pittman, 8/24/2013): Grant Lake typical "*Alluvial Fan Deposit*" Geomorphic Unit showing contribution from both alluvial transport and avalanche activity.

Photo 8 (by P.Pittman, 8/24/2013): Grant Lake typical "*Colluvium*" Geomorphic Unit.

Photo 9 (by P.Pittman, 8/24/2013): *Field Note* - Evidence of shoreline erosion occurring on an "*Alluvial Fan Deposit*" Geomorphic Unit.

Photo 10 (by P.Pittman, 8/24/2013): "*Alluvial Fan*" Geomorphic Unit.

Field Note - Streams along the Grant Lake shoreline are susceptible to WSE and incision, armoring, channel straightening, and loss of floodplain connectivity is anticipated with decreases in WSE, particularly if WSE remains low during high flow conditions.

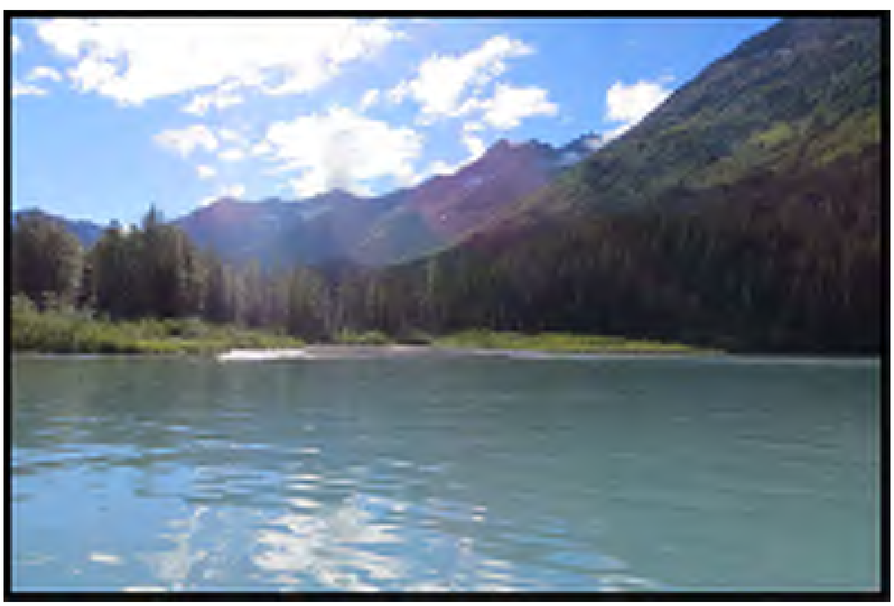

Photo 11 (by P.Pittman, 8/24/2013): Grant Lake typical "*Alluvial Deltaic*" Geomorphic Unit at Inlet Creek.

Photo 12 (by P.Pittman, 8/24/2013): *Field Note* - Interspersed alluvial fan and colluvium deposits dominate the shoreline of the Grant Lake upper basin.

Photo 13 (by P.Pittman, 8/24/2013): *Field Note* - Accumulation of organic debris and forest encroachment at a shallow gap in the Grant Lake narrows between the upper and lower basin. This accumulated debris will likely be inundated and dislodged when the lake WSE is increased. During low WSE conditions, an isthmus will be exposed.

Photo 14 (by P.Pittman, 8/24/2013): *Field Note* - WSE increase cause a retreat of shoreline vegetation and temporary shoreward erosion will occur as a result of the loss of root strength and winnowing of finer sediments and soils. The erosion should self-mitigate once root strength and vegetation can reestablish in the disturbed areas.

Photo 15 (by P.Pittman, 8/24/2013): *Field Note* - Steep bedrock shorelines dominate the shoreline areas of the Grant Lake lower basin.

Photo 16 (by HDR, circa spring 2009): *Field Note* - Low WSE under natural conditions at the "Beach Deposit" Geomorphic Unit.

Photo 17A (by HDR, 6/10/2009)

Photos 17B (by HDR, 6/10/2009)

Photos 17A and 17B: *Field Note* - Grant Lake outlet at Grant Creek. Bedrock sill grade control visible beneath water (approximately 2 feet deep estimated at time of field visit.

Photo 17C (by HDR, circa spring 2009): *Field Note* - Grant Lake outlet at Grant Creek where the proposed gravity diversion structure will be constructed.

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Grant Lake Hydroelectric Project (FERC No. 13212)

Aquatic Resources Study – Baseline Studies of Macroinvertebrates and Periphyton in Grant Creek Final Report

Prepared for
Kenai Hydro, LLC

Prepared by
S. Morsell
Northern Ecological Services

June 2014

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Acronyms and Abbreviations

ANOVA	Analysis of Variance
APA	Alaska Power Authority
ASCI	Alaska Stream Condition Index
CFR	Code of Federal Regulations
DLA	Draft License Application
ENRI	Environment and Natural Resources Institute
EPT	Ephemeroptera/Plecoptera/Trichoptera
FERC	Federal Energy Regulatory Commission
HBI	Hilsenhoff Biotic Index
KHL	Kenai Hydro, LLC
LA	License Application
µm	micrometer
MW	megawatt
NAVD 88	North American Vertical Datum of 1988
NGVD 29	National Geodetic Vertical Datum of 1929
NOI	Notice of Intent
PAD	Pre-Application Document
PM&E	protection, mitigation and enhancement
Project	Grant Lake Hydroelectric Project
USGS	U.S. Department of the Interior, Geological Survey
µS/cm	conductivity
MgCO3	magnesium carbonate
mL	milliliter

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Aquatic Resources Study – Baseline Studies of Macroinvertebrates and Periphyton in Grant Creek Final Report Grant Lake Hydroelectric Project (FERC No. 13212)

1 INTRODUCTION

On August 6, 2009, Kenai Hydro, LLC (KHL) filed a Pre-Application Document (PAD; KHL 2009), along with a Notice of Intent (NOI) to file an application for an original license, for a combined Grant Lake/Falls Creek Project (Federal Energy Regulatory Commission [FERC] No. 13211/13212 [“Project” or “Grant Lake Project”]) under Part I of the Federal Power Act (FPA). On September 15, 2009, FERC approved the use of the Traditional Licensing Process (TLP) for development of the License Application (LA) and supporting materials. As described in more detail below, the proposed Project has been modified to eliminate the diversion of water from Falls Creek to Grant Lake. The Project will be located near the community of Moose Pass, Alaska in the Kenai Peninsula Borough, approximately 25 miles north of Seward, Alaska and just east of the Seward Highway (State Route 9).

Aquatic macroinvertebrates and periphyton are vital elements of the food web that supports area fisheries. They represent the primary levels of productivity in the aquatic ecosystem and can be used as indicators of aquatic habitat condition (Barbour et al. 1999, Merritt and Cummins 1996). Acquiring information on the baseline characteristics of macroinvertebrate and periphyton populations provides tools for tracking aquatic habitat quality.

Macroinvertebrates are non-vertebrate organisms that can be seen without magnification. Most of those encountered are the larval and pupal stages of insects that live closely associated with aquatic habitat substrates. Periphyton are single-celled micro-algae that live attached to the substrate and are primary producers in the aquatic ecosystem.

The Macroinvertebrate and Periphyton baseline studies elements of the Aquatic Resources Study Plan (KHL 2013) was designed to address information needs identified in the PAD, during the TLP public comment process, and through early scoping conducted by FERC. The following study report presents existing information relative to the scope and context of potential effects of the Project. This information will be used to analyze Project impacts and propose protection, mitigation, and enhancement (PM&E) measures in the Draft and Final LAs for the Project.

1.1. Project Description

The Project is located near the community of Moose Pass, approximately 25 miles north of Seward and just east of the Seward Highway. It lies within Section 13 of Township 4 North, Range 1 West; Sections 1, 2, 5, 6, 7, and 18 of Township 4 North, Range 1 East; and Sections 27, 28, 29, 31, 32, 33, 34, 35, and 36 of Township 5 North, Range 1 East, Seward Meridian (U.S. Geological Survey [USGS] Seward B-6 and B-7 Quadrangles).

The proposed Project would be composed of an intake structure at the outlet to Grant Lake, a tunnel, a surge tank, a penstock, and a powerhouse. It would also include a tailrace detention pond, a switchyard with disconnect switch and step-up transformer, and an overhead or underground transmission line. The preferred alternative would use approximately 15,900 acre-feet of water storage during operations between pool elevations of approximately 692 and up to 703 feet North American Vertical Datum of 1988 (NAVD 88)[1].

An intake structure would be constructed approximately 500 feet east of the natural outlet of Grant Lake. An approximate 3,200-foot-long, 10-foot diameter horseshoe tunnel would convey water from the intake to directly above the powerhouse at about elevation 628 feet NAVD 88. At the outlet to the tunnel a 360-foot-long section of penstock will convey water to the powerhouse located at about elevation 531 feet NAVD 88. An off-stream detention pond will be created to provide a storage reservoir for flows generated during the rare instance when the units being used for emergency spinning reserve are needed to provide full load at maximum ramping rates. The tailrace would be located in order to minimize impacts to fish habitat by returning flows to Grant Creek upstream of the most productive fish habitat.

Two concepts are currently being evaluated for water control at the outlet of Grant Lake. The first option would consist of a natural lake outlet that would provide control of flows out of Grant Lake. A new low level outlet would be constructed on the south side of the natural outlet to release any required environmental flows when the lake is drawdown below the natural outlet level. The outlet works would consist of a 48-inch diameter pipe extending back into Grant Lake, a gate house, regulating gate, controls and associated monitoring equipment. The outlet would discharge into Grant Creek immediately below the natural lake outlet.

In the second option, a concrete gravity diversion structure would be constructed near the outlet of Grant Lake. The gravity diversion structure would raise the pool level by a maximum height of approximately 2 feet (from 703 to 705 feet NAVD 88), and the structure would have an overall width of approximately 120 feet. The center 60 feet of the structure would have an uncontrolled spillway section with a crest elevation at approximately 705 feet NAVD 88. Similar to the first option, a low level outlet would be constructed on the south side of the natural outlet to release any required environmental flows when the lake is drawn down below the natural outlet level. The outlet works would consist of a 48-inch diameter pipe extending back into Grant Lake, a gate house a regulating gate, controls, and associated monitoring equipment. The outlet would discharge into Grant Creek immediately below the diversion structure.

Figure 1.1-1 displays the global natural resources study area for the efforts undertaken in 2013 and 2014 along with the likely location of Project infrastructure and detail related to land ownership in and near the Project area.

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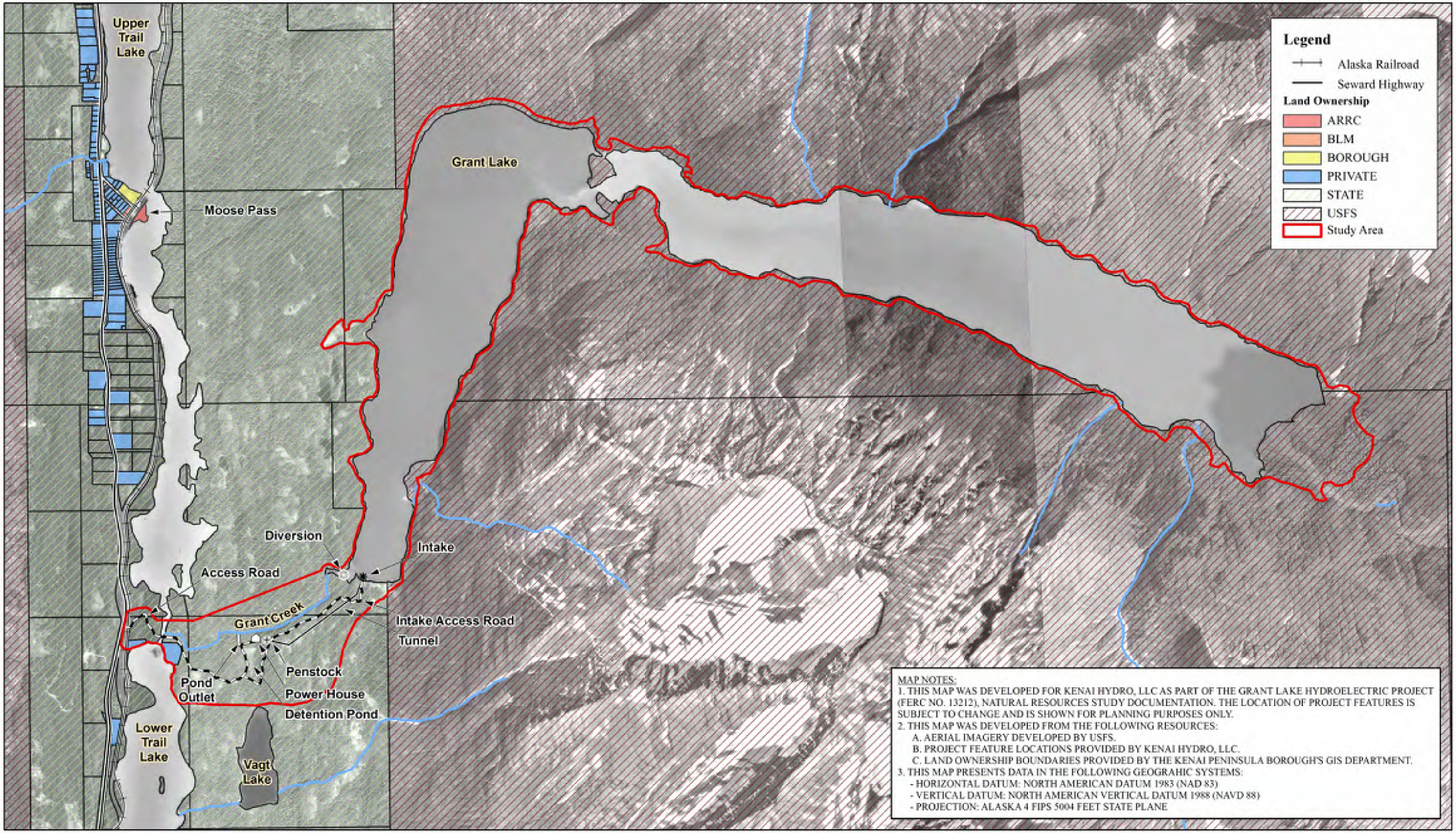
[1] The elevations provided in previous licensing and source documents are referenced to feet mean sea level in NGVD 29 [National Geodetic Vertical Datum of 1929] datum, a historical survey datum. The elevations presented in the Grant Lake natural resources study reports are referenced to feet NAVD 88 datum, which results in an approximate +5-foot conversion to the NGVD 29 elevation values.



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McMILLEN, LLC

Developed For: HEA Homer Electric Association, Inc. A Touchstone Energy Cooperative

GRANT LAKE HYDROELECTRIC PROJECT - FERC PROJECT #P-13212

GRANT LAKE NATURAL RESOURCES STUDY

Figure 1.1-1
Natural Resources Study Area

DESIGNED: Jake Woodbury
DRAWN: Jake Woodbury
CHECKED: C. Warnock
ISSUED DATE: 1/9/2014
SCALE: 1:27,000

Further discussions related to specifics of the aforementioned Project infrastructure along with the need and/or feasibility of the diversion dam will take place with stakeholders in 2014 concurrent with the engineering feasibility work for the Project. Refined Project design information will be detailed in both the Draft License Application (DLA) and any other ancillary engineering documents related to Project development. The current design includes two Francis turbine generators with a combined rated capacity of approximately 5.0 megawatts (MW) with a total design flow of 385 cubic feet per second. Additional information about the Project can be found on the Project website: http://www.kenaihydro.com/index.php.

1.2. Environmental Baseline Studies Background

Previous investigations into the feasibility of hydropower development at Grant Lake have produced valuable information on Project area environmental resources. Early hydrologic and geologic evaluations were conducted in the 1950s (Ebasco 1984). Further environmental resource studies were conducted in the early 1980s; the most extensive of which was performed by Ebasco Services, Inc. for the Alaska Power Authority (APA) (Ebasco 1984). Preliminary environmental baseline studies were initiated by KHL at the start of the licensing process in 2009. Results of those studies were reported in 2010 (HDR 2010).

Initial macroinvertebrate studies in Grant Creek, were conducted in 1981 and 1982 using Surber samplers. These methods were continued, with the addition of samples collected using the Alaska Stream Condition Index (ASCI) protocols, in 2009. After review of the macroinvertebrate study results, investigators decided to eliminate the ASCI methods from the study program. Fewer taxa were collected using the ASCI method compared to the Surber sampler method and the predominant habitat in Grant Creek is riffle run, the habitat targeted by the Surber sampler protocols. Periphyton studies were also performed in 1982 and concentrated on the identification of diatom taxa (Ebasco 1984).

In 2009, periphyton investigations relied on the analysis of concentrations of chlorophyll-a to measure productivity of algal primary producers in the Grant Lake/Grant Creek system. The macroinvertebrate and periphyton studies conducted in 2013 and reported here, followed the same methods as used in 2009 to provide a comparable dataset and the required two annual sampling events.

The objectives of the macroinvertebrate and periphyton studies carried out on Grant Creek included:

Project-Related Objectives

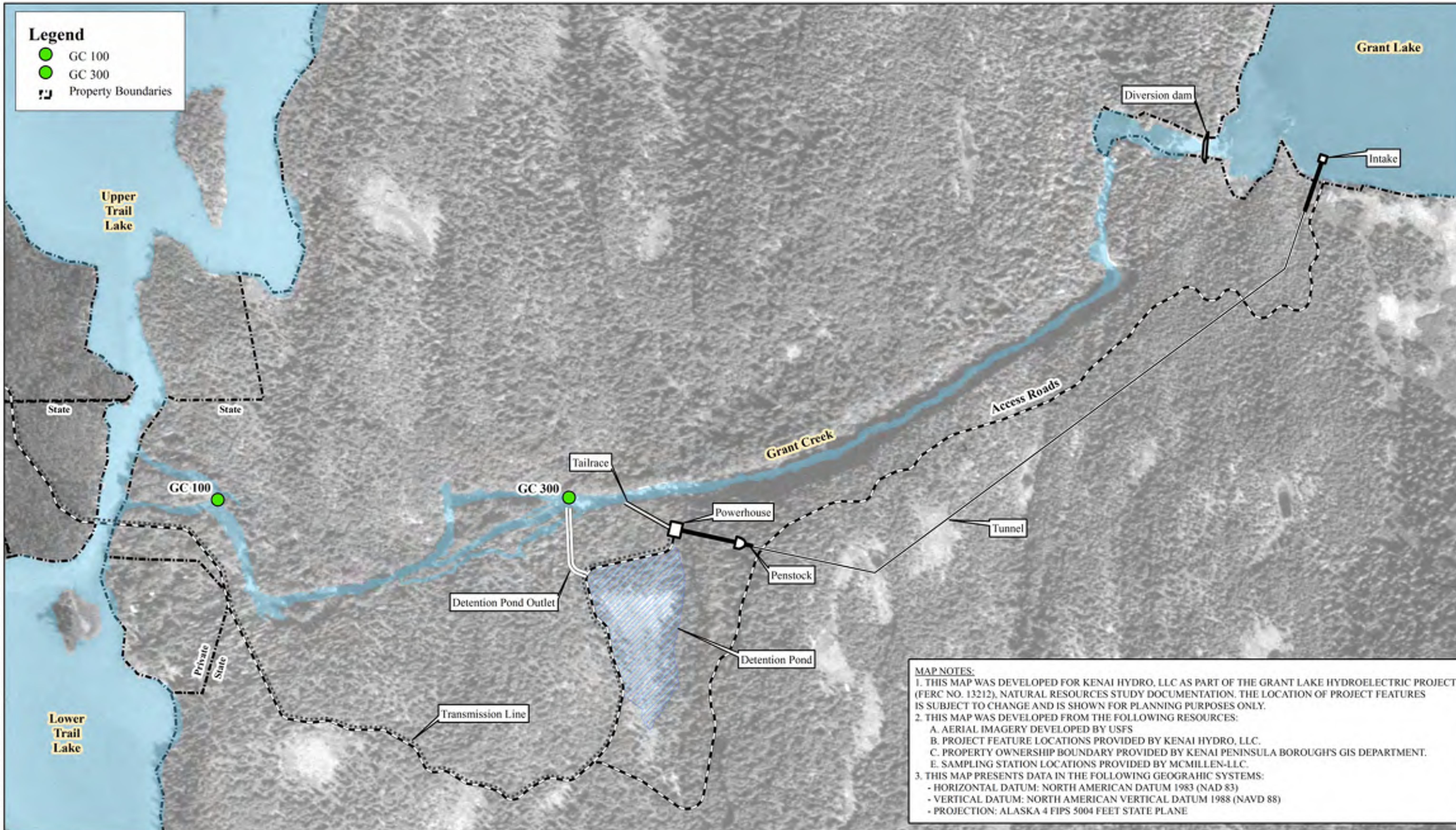
- Provide a reliable measure of baseline stream productivity that can be compared from year to year and with other stream systems.
- Provide some indication of the relative "health" of the Grant Creek ecosystem by employing standard measures that are readily comparable to other Alaska stream systems.

Quantitative Objectives

- Standard methods were used that required replicate samples within uniform riffle habitat areas to minimize the effect of between sample variability. Five replicates are generally recommended for initial sampling. An analysis of variance was employed to determine adequacy for baseline use.

2 STUDY AREA

The study area comprised Grant Creek, which flows for approximately one mile from Grant Lake on the west to Trail Lakes narrows on the east. The mean annual flow is approximately 200 cfs in a channel with an average gradient of 200 feet per mile, according to hydrologic investigations conducted by KHL (KHL 2014). Two sites were sampled, GC100 and GC300 (Figure 2.0-1). These sites were also the locations of concurrently running investigations of water quality, hydrology, geomorphology, and fisheries tasks. The sites were chosen prior to the 2009 studies as representative of channel conditions below the steep bedrock canyon in the upstream half of Grant Creek (HDR 2010). Photos of GC100 and GC300 taken in August 2013 appear in Appendix 1.



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Drawing Scale: 0 100 200 400 600 800 Feet

MCMILLEN, LLC

Developed For: Homer Electric Association, Inc. A Touchstone Energy Cooperative

GRANT LAKE HYDROELECTRIC PROJECT - FERC PROJECT NO. 13212

GRANT LAKE NATURAL RESOURCES STUDY

Figure 2.0-1
Grant Creek Macroinvertebrate & Periphyton Study Sites: GC100 and GC300

DESIGNED: J. Woodbury
DRAWN: J. Woodbury
CHECKED: S. Morsell
ISSUED DATE: 1/31/2014

DRAWING
SCALE: 1:4,500

3 METHODS

Benthic macroinvertebrate and periphyton samples were collected on August 14, 2013 at GC100 and GC300.

3.1. Macroinvertebrates

Samples were collected using a Surber sampler according to methods described in Eaton et al. 1995. The use of a Surber sampler is a semi-quantitative method to determine the density and composition of macroinvertebrate populations on selected stream bottom habitats (riffle/cobble). The sampler includes a 363-micrometer (µm) mesh size net and a metal "substrate" frame (1 ft^2) that delineates the area sampled. The material within the frame is disturbed and the cobbles scrubbed clean of debris and organisms. The debris and organisms flow into the net and are trapped. Five pseudo-replicates were sampled in selected riffle-cobble areas within the stream reaches at GC100 and GC300. Photos of the reaches are included in Appendix 1. Organisms collected were preserved as five separate replicates in 70 percent isopropyl alcohol.

In 2009, the ASCI method (Major and Barbour 2001) was used in conjunction with the Surber sampler to collect macroinvertebrates. The ASCI sampling method was used to begin developing baseline descriptions of macroinvertebrate populations in a range of habitats within the sampling reach. This method uses a D-frame kick net to sample representative habitats in a 100 meter sampling reach. Twenty subsamples are collected proportionately throughout these habitats. All organisms collected by ASCI methods in 2009 were composited into one sample per site and preserved in 70 percent isopropyl alcohol. Habitat information, such as riparian vegetation and stream substrate types, was also collected.

At each site ambient water quality measurements were recorded at the time samples were collected. Parameters measured were temperature (°C), specific conductivity (µS/cm), dissolved oxygen (percent and concentration as mg/L), and pH.

In 2013, macroinvertebrate samples were shipped to Northern Ecological Services for sorting and identification to genus or the lowest practicable taxon. Samples collected by the Surber method were sorted until all organisms were removed from sample debris. Samples collected in 2009 were sorted and identified. In 2009, in addition to the Surber samples there were ASCI samples, which were subsampled until a target of 300 (+/- 10 percent) organisms were counted (Major and Barbour 2001). Macroinvertebrates were identified to genus or the lowest practicable taxon.

3.2. Periph yton

On August 14, 2013 concurrent with macroinvertebrate sampling, periphyton samples were collected at sites GC100 and GC300. Periphyton were sampled by removing material from 10 cobbles selected from a riffle/cobble area that had not been disturbed (ADF&G 1998 and Barbour et al. 1999). Material was scrubbed from a five centimeter square area on each cobble and rinsed onto a 45- µm glass fiber filter attached to a hand vacuum pump. Water was extracted from the sample and 1-milliliter (ml) saturated magnesium carbonate (MgCO3) solution added to the filter as a preservative. The dry filter was wrapped in a larger filter (to absorb any residual water) that was then wrapped in aluminum foil (to prevent exposure to light) and placed in a labeled zipper seal bag with silica gel desiccant. The samples were placed on ice and frozen before transport to the laboratory. Chlorophyll *a* concentrations were analyzed by SGS Laboratory, Anchorage.

3.3. Data Analysis

Organisms from both Surber and ASCI macroinvertebrate samples were identified to genus or the lowest practicable taxon (Merritt et al. 2008; Pennak 1953; Stewart and Stark 2002; Wehr and Sheath 2003; and Wiggins 2009). Taxonomic data was used to calculate several descriptive population metrics:

- Population density as numbers/m^2
- Taxa richness
    - Overall taxa richness
    - Ephemeroptera taxa richness
    - Trichoptera taxa richness
    - Plecoptera taxa richness
- Taxonomic composition as a percent of total number identified in sample
    - Percent Ephemeroptera
    - Percent Trichoptera
    - Percent Plecoptera
    - Percent Ephemeroptera/Plecoptera/Trichoptera (EPT)
    - Percent Chironomidae
    - Percent dominant taxon
- Population trophic characteristics
    - Percent filterers
    - Percent gatherers
    - Percent predators
    - Percent scrapers
    - Percent shredders
    - Filterer richness
    - Gatherer richness
    - Predator richness
    - Scraper richness
    - Shredder richness
- Hilsenhoff Biotic Index (HBI) scores
- ASCI habitat assessment scores

These metrics were calculated for each replicate. Averages and standard deviations were calculated for non-trophic metrics.

Periphyton chlorophyll *a* analysis results were translated to concentration per area (µg/cm^2) reported as averages with standard deviations.

Analysis of variance (ANOVA) was calculated using selected metrics developed from the replicate samples of macroinvertebrates and periphyton to evaluate spatial and temporal variability.

4 RESULTS

The second macroinvertebrate and periphyton sampling event for the Grant Lake Project was completed successfully on August 14, 2013. The results of the previous sampling event, conducted in 2009, were reported in 2010. The data obtained from the 2009 sampling has been combined with that collected in 2013 and appears in the tables of data and analysis results that follow and in Appendix 2.

4.1. Macroinvertebrates

In 2013, macroinvertebrates were collected using only the Surber sampler method. As discussed in the 2010 report, the ASCI sampling protocols were not used after the first sampling event. Greater numbers of organisms and wider ranges of taxa were collected using Surber samplers. In addition, the Surber sampling method produces data with greater quantifiability and the discussion of results focuses on data collected using Surber sampler methods. Nevertheless, the ASCI protocols require sampling the entire range of habitat within the sample reach and those results are included in the tables below where appropriate.

A combined total of 35 macroinvertebrate taxa were identified in samples collected at sites GC100 and GC300 in 2009 and 2013. They are listed in Table 4.1-1.

Table 4.1-1. List of macroinvertebrate taxa collected at Grant Creek sampling sites GC100 and GC300, 2009 and 2013.

Order	Family	Genus
Ephemeroptera	Ameletidae	Ameletus
	Baetidae	Unidentified
		Acentrella
		Baetis
	Ephemerellidae	Drunella
		Ephemerella
	Heptegeniidae	Cinygmula
		Epeorus
Plecoptera		Unidentified
	Chloroperlidae	Unidentified
		Haploperla
		Neaviperla
		Plumiperla
		Suwallia
		Triznaka
	Nemouridae	Zapada
	Perlodidae	Unidentified
		Isoperla
	Taeniopterygidae	Unidentified
Trichoptera	Apataniidae	Moselyana
	Brachycentridae	Brachycentrus
		Micrasema
	Glossosomatidae	Glossosoma
	Hydropsychidae	Arctopsyche
	Limnephilidae	Ecclisomyia
	Rhyacophilidae	Rhyacophila
Diptera		Unidentified
	Chironomidae	Unidentified
	Empididae	Chelifera
		Clinocera
	Simuliidae	Simullium
Bivalvia (Class)	Sphaeriidae	Unidentified
Gastropoda (class)	Gastopoda Unid.	Unidentified
	Lymnaeidae	Lymnaea
	Planorbidae	Unidentified
	Valvatidae	Unidentified
Crustacea (Phylum)	Ostracoda (Class)	Unidentified
Arachnoidea (Class)	Hydracarina (Sub-Order)	Unidentified
Oligochaeta (Class)	Unidentified	Unidentified
Nemotoda (Phylum)	Unidentified	Unidentified
Platyhelminthes (Phylum)	Turbellaria (Class)	Unidentified

The numbers of taxa and of individual organisms within each taxa were used to calculate a series of metrics that describe the macroinvertebrate populations at each site. Table 4.1-2 lists metrics describing the macroinvertebrate populations with regard to the density (number of organisms per square meter) and the variety (richness) of the taxa assemblage.

Table 4.1-2. Grant Creek macroinvertebrate population density and taxa richness metrics, 2009 and 2013. [1,2]

Sample Site	Date	Sample Type	Density (no. / m^2)	Taxa Richness	Ephemeroptera Taxa Richness	Plecoptera Taxa Richness	Trichoptera Taxa Richness	EPT Taxa Richness
GC100	08/06/09	Surber[1]	12034 (4697)	19 (0.8)	6 (0.75)	3 (0.80)	3 (0.40)	12 (0.5)
GC100	08/14/13	Surber	19282 (7877)	20 (1.5)	6 (0.00)	3 (0.49)	2 (1.02)	12 (0.8)
GC300	08/06/09	Surber	2204 (1764)	15 (3.1)	4 (1.36)	3 (1.33)	3 (1.60)	10 (3.4)
GC300	08/14/13	Surber	12835 (3275)	21 (2.3)	6 (0.49)	3 (1.02)	3 (0.89)	12 (1.7)
GC100	08/06/09	ASCI[2]	2740	10	4	2	1	7
GC300	08/06/09	ASCI	530	12	1	2	1	4

Notes:
1. Data reported are averages (followed by + or - standard deviation in parentheses) of five replicate Surber samples.
2. Data reported are totals for composited samples.

Results appear fairly consistent between sites and years, with the exception of samples collected in 2009 at GC300. At GC300 in 2009 density (2,204 organisms/m^2 compared to 19,282-12,034 organisms/m^2), taxa richness (15 taxa compared to 21-19 taxa), Ephemeroptera taxa richness (4 taxa compared to 6 taxa), and EPT taxa richness (10 taxa compared to 12 taxa) were lower than other samples.

Table 4.1-3 lists percent composition metrics. Again results from samples collected at GC300 in 2009 vary noticeably from the other samples. The results reflect the fact that samples collected at GC300 in 2009 contained fewer Chironomidae (41 percent of organisms compared to 83-88 percent of organisms). Therefore, the percent of the macroinvertebrate population represented by EPT taxa was greater at GC300 in 2009 than at GC100 in 2009 or at GC100 and GC300 in 2013.

The data in Table 4.1-4, functional feeding group metrics, also illustrates the overall similarity in the macroinvertebrate populations between sites and years, with the exception of GC300 in 2009. Chironomidae generally fall under the category of "gatherers" and the numbers are lower at GC300 in 2009 than in the other samples (56 percent gatherers compared to 91-88 percent gatherers). Conversely, the number of organisms within functional feeding groups comprised largely of EPT taxa are higher than other samples. For example, predators comprised 8 percent at GC300 in 2009 compared to 4-3 percent in other samples and scrapers comprised 17 percent compared to 3-1 percent.

Table 4.1-3. Grant Creek macroinvertebrate population composition by percent metrics, 2009 and 2013.[1]

Sample Site	Date	Sample Type	% Ephemeroptera	% Plecoptera	% Trichoptera	% EPT	% Chironomidae	% Dominant Taxa
GC100	08/06/09	Surber	3.9 (2.2)	2.6 (2.1)	1.3 (0.7)	7.7 (4.8)	84.7 (7.7)	84.7 (7.7)
GC100	08/14/13	Surber	2.6 (0.9)	1.4 (0.6)	0.4 (0.1)	4.4 (1.4)	88.5 (3.9)	88.5 (3.9)
GC300	08/06/09	Surber	18.0 (4.4)	8.9 (3.3)	4.6 (3.9)	31.5 (5.7)	41.0 (18.6)	48.4 (13.2)
GC300	08/14/13	Surber	6.4 (2.4)	1.8 (0.7)	0.5 (0.2)	8.7 (2.6)	83.3 (4.8)	82.3 (5.5)
GC100	08/06/09	ASCI	1.4	0.5	0.2	2.1	13.1	82.9
GC300	08/06/09	ASCI	1.3	1.6	0.7	3.6	7.5	77.8

Notes:
1. Averages, followed by + or - standard deviation in parentheses, are of five replicate Surber samples.

Table 4.1-4. Grant Creek macroinvertebrate functional feeding group metrics based on entire sample from each site, 2009 and 2013.

Sample Site	Date	Sample Type	% Filterers	% Gatherers	% Predators	% Scrapers	% Shredders	Filterer Richness	Gatherer Richness	Predator Richness	Scraper Richness	Shredder Richness
GC100	08/06/09	Surber	5	89	3	2	2	4	10	7	6	1
GC100	08/14/13	Surber	5	91	3	1	1	3	8	6	5	1
GC300	08/06/09	Surber	15	56	8	17	3	4	7	10	5	2
GC300	08/14/13	Surber	5	88	4	3	1	3	6	5	4	0
GC100	08/06/09	ASCI	83	14	2	1	0	1	3	4	3	1
GC300	08/06/09	ASCI	79	10	8	2	0	3	4	3	1	0

Biotic indices were developed to describe the quality of aquatic habitat based on the tolerance to disturbance of the organisms present. Each taxon is given a tolerance rating between 0 and 10, with 0 being the least tolerant. The HBI scores in Table 4.1-5 continue the pattern of variance between data collected at GC300 in 2009 and the other samples. The HBI value for GC300 in 2009 was 4.71 compared to 5.60-5.81 for the other samples.

Table 4.1-5. Grant Creek macroinvertebrate biotic indices and habitat assessments, 2009 and 2013.

Sample Site	Date	Sample Type	Hilsenhoff Biotic Index[1]	ASCI Habitat Assessment[2]
GC100	08/06/09	Surber	5.76	
GC100	08/14/13	Surber	5.81	
GC300	08/06/09	Surber	4.71	
GC300	08/14/13	Surber	5.60	
GC100	08/06/09	ASCI	7.5	200
GC300	08/06/09	ASCI	7.1	190

Notes:
1. Scale from 0-10, with 10 indicating greatest water body impairment.
2. Scale from 0-200, with 200 indicating most impaired macroinvertebrate habitat.

Measurements of ambient water quality parameters – temperature, specific conductivity, dissolved oxygen, and pH – were collected concurrent with sampling. KHL also measured these parameters at GC100 and GC300 as part of its Water Resources Study – Water Quality, Temperature and Hydrology (KHL 2014). Both sets of measurements are reported in Table 5.1-6, below.

Table 4.1-6. Grant Creek ambient water quality at time of sample collection, 2009 and 2013.

Sample Site	Date	Temperature (°C)	Specific Conductivity (µS/cm)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	pH
GC100	08/06/09	12.32	87	77.5	8.29	7.40
GC100	08/14/13	13.38	72	104.0	10.80	7.14
GC300	08/06/09	11.49	89	61.3	8.22	7.39
GC300	08/14/13	13.31	72	106.0	11.16	7.29
2013 Measurements						
GC100	Aug/13	12.65	60	102.5	10.95	7.18
GC300	Aug/13	12.45	60	102.8	11.02	7.09

Water quality measurements were fairly consistent between years, sites, and investigators, except for dissolved oxygen measurements in 2009. Low dissolved oxygen measurements in 2009 (8.29 mg/L-8.22 mg/L in 2009 compared to 11.16 mg/L-10.80 mg/L in 2013) were attributed to a possibly faulty instrument as discussed in the Grant Lake/Falls Creek Hydroelectric Project Environmental Baseline Studies, 2009 report (HDR 2010). Refer to the Water Resources Study

– Water Quality, Temperature and Hydrology, Final Report, for a discussion regarding dissolved oxygen measurement differences (KHL 2014).

4.2. Periph yton

Periphyton (single celled algae) are primary producers in the foodweb of stream habitats. One way to charcterize the productivity of a stream is to evaluate the population of periphyton by measuring the amount of chlorophyll *a* present in the algal coating scraped from the stream substrate. Average concentrations of chlorophyll *a* in Grant Creek samples from 2009 and 2013 varied between years and sites (Table 4.2-1). Concentrations of chlorophyll *a* were greater at GC100 than GC300, although the spatial variability appeared to be less in 2013 than in 2009 (5.85 and 4.4 µg/cm^2 in 2013 compared to 34.79 and 12.70 µg/cm^2 in 2009). Both magnitude of the concentrations measured in 2009 and their variability were greater than in 2013.

Table 4.2-1. Average[1] concentrations of chlorophyll *a* from periphyton collected in Grant Creek, 2009 and 2013.

Sample Site	Date	Chlorophyll *a* Concentration (µg/cm^2)
GC100	08/06/09	34.79 (23.76)
GC100	08/14/13	5.85 (4.92)
GC300	08/06/09	12.70 (9.94)
GC300	08/14/13	4.4 (2.84)

Notes:

1. Averages, followed by standard deviation in parentheses, are of 10 replicate samples.

4.3. Analysis of Variance (ANOVA)

ANOVA was calculated using several selected metrics to demonstrate whether the macroinvertebrate and periphyton data collected is adequate for describing the baseline condition in Grant Creek. The results are listed in Tables 4.3-1 and 4.3-2, below. P values greater than 0.05 indicate that there was no significant variability between the data sets.

Table 4.3-1. Results of ANOVA (P values) for selected macroinvertebrate metrics.

Metric	Between Years		Between Sites	
	GC100	GC300	2009	2013
Density (no. / m^2)	0.1525	0.0004	0.0044	0.1690
Taxa Richness	0.1894	0.0130	0.0680	0.2792
EPT Taxa Richness	0.2165	0.4211	0.2755	0.8327
% EPT	0.2145	8.42^{-05}	0.0002	0.0198
% Scrapers	0.0468	0.0002	8.65^{-05}	0.2631
% Gatherers	0.3302	0.0026	0.0016	0.4093
% Predators	0.2069	0.0032	0.0049	0.6871

ANOVA of metrics of different years and sites that did not include GC300 2009 (such as taxa richness between GC100 2009 and GC100 2013) did not result in significant variation (P>0.05), demonstrating that the data collected at GC300 in 2009 may represent an outlier.

Table 4.3-2. Results of ANOVA (P values) for periphyton chlorophyll *a* concentrations.

Metric	Between Years		Between Sites	
	GC100	GC300	2009	2013
Chlorophyll *a* (µg/cm^2)	0.0022	0.0269	0.0192	0.4536

5 CONCLUSIONS

Comparison between the population metrics of baseline data and metrics calculated from data collected in the future for monitoring can provide an indication of changes in water quality and aquatic habitat. Table 5.0-1 summarizes the expected responses of macroinvertebrate populations to habitat impairment or perturbation (Barbour et al. 1999). The source tables for this information are included in Appendix 3.

Table 5.0-1. Predicted responses of several metrics to habitat impairment or perturbation (excerpted from Barbour et al. 1999).

Metric	Definition	Predicted Response to Perturbation
Taxa Richness	Measures overall variety of the population	Decrease
EPT Taxa Richness	Number of taxa in the EPT orders	Decrease
% EPT	Percent of population in EPT orders	Decrease
% Scrapers	Percent of population that scrape or graze upon periphyton	Decrease
% Gatherers	Percent of population that “gather”	Variable
% Predators	Percent of population that are predators. Can be made restrictive to exclude omnivores.	Variable
Hilsenhoff Biotic Index	Uses tolerance values to weight abundance in an estimate of overall pollution. Originally designed to evaluate organic pollution	Increase

The ANOVA performed on several metrics developed from data collected in 2009 and 2013 indicates that the baseline information obtained to date would be useful for monitoring change in the water quality and habitat in Grant Creek. Samples collected at GC300 in 2009 do vary significantly from the other samples, however. Significantly lower numbers of Chironomidae in the sample (41 percent of organisms compared to 83-88 percent of organisms in other samples) appear to account for the major differences in the metrics (Table 4.1-3). This situation may not be descriptive of the baseline for a number of reasons: sampler error, sample processing and identification errors, or insufficient data to reduce statistical variability. Studies conducted in the early 1980's found no seasonal variation in macroinvertebrate abundance in Grant Creek (Ebasco 1984).

While the most useful application of the data collected from baseline studies is future monitoring of Project impacts, the metrics developed to describe macroinvertebrate populations in Grant Creek can also be used for comparison with other streams in the region. Direct comparisons may be limited by differences in sampling methods and physical categories assigned to sampling locations selected by researchers. The USGS as part of their National Water-Quality Assessment Program studied characteristics of the Cook Inlet Basin (Brabets et al. 1999) that included using macroinvertebrate data collected with Surber sampler methods. In addition, the Environment and Natural Resources Institute (ENRI) of the University of Alaska, Anchorage, has developed macroinvertebrate reference conditions for the Cook Inlet Basin using their ASCI protocols (Major et al. 2000 and 2001; and Rinella and Bogan 2007).

The USGS 1999 report discusses watershed characteristics generalized for the entire Cook Inlet Basin, whereas the ENRI 2000 and 2001 reports group streams as low gradient fine substrate, low gradient large substrate, and high gradient and the ENRI 2007 report groups streams by disturbance class: reference, Class 1, and Class 2, excluding glacially influenced streams. Regardless, a relative comparison of the information collected from Grant Creek can be made with these evaluations of Cook Inlet watershed streams.

Comparison of Grant Creek macroinvertebrate metrics with the means of Cook Inlet streams reported by the USGS (Brabets et al. 1999), indicates that Grant Creek provides less optimal habitat for macroinvertebrates than other Cook Inlet streams (Table 5.0-2). Grant Creek exhibits lower percent EPT, shredders, scrapers, and predators, and higher percent Diptera/Chironomidae and gatherers than the mean for other Cook Inlet streams.

Table 5.0-2. Mean percent composition of the aquatic insect fauna in streams of the Cook Inlet Basin, Alaska [modified from Oswood and others (1995)] (excerpted from Brabets et al. 1999) and in Grant Creek, 2009 and 2013.

Fauna	Percent Composition Cook Inlet Watershed Streams	Percent Composition Grant Creek, 2009 and 2013 [1]
Taxonomic Structure		
Coleoptera	0.0	NA
Diptera	34.0	74.4 [2]
Ephemeroptera	41.3	7.7
Plecoptera	17.5	3.6
Trichoptera	7.2	1.7
Functional Group		
Shredders	11.6	1.8
Scrapers	11.2	5.8
Collector-filterers	6.6	7.5
Collector-gatherers	60.5	81.0
Predators	10.0	4.5

Notes:
1. Includes GC300 2009 which varies significantly from the other samples.
2. Chironomidae only.

Comparison of Grant Creek metrics with riffle/run, high gradient (> 2 percent) Kenai Peninsula Pacific Coastal Mountain Ecoregion stream metrics reported by ENRI (Major et al. 2000 and 2001), also indicates that Grant Creek habitat is more stressful for macroinvertebrate populations than other streams in the region. The cumulative ASCI scores from 2009 (HDR 2010) calculated using several core metrics fall into the “poor” range: GC100 ASCI 2009 = 18 and GC300 ASCI 2009 = 18 (Tables 5.0-3 and 5.0-4).

Table 5.0-3. Scoring thresholds for core metrics used to calculate ASCI scores (excerpted from Major et al. 2000), and Grant Creek: average of GC100 and GC300, 2009.

Stream Type	Metric	Index Score Metric Value				Grant Creek Values
		6	4	2	0	
RRM and RRH[1]	No. of Taxa	>16	12-16	7-11	<6	11
	No. of Ephemeroptera	>4	3-4	1-2	<1	3
	No. of Plecoptera	>4	3-4	1-2	<1	2
	No. of Trichoptera	>4	3-4	1-2	<1	1
	% EPT	>29	20-28	10-19	<10	1.4
	% Chironomidae	<39	39-59	60-79	>79	10.3
	% Dominant Taxon	<50	49-66	67-83	<83	80.4

Notes:
1. RRM and RRH – riffle run moderate gradient and riffle run high gradient.

Table 5.0-4. ASCI scores based on core metrics (excerpted from Major et al. 2000), and score for Grant Creek: average of GC100 and GC300, 2009.

Ecoregion and Stream Type	Maximum	Score				Grant Creek Score
		Very Good	Good	Poor	Very Poor	
Pacific Coastal Mountains						
All Stream Types	42	>29	20-29	10-19	<10	18

The reports referenced above assign streams to various classes because the metrics respond differently to water quality change depending on the physical characteristics of the stream. Ultimately, describing the baseline condition on Grant Creek for future comparisons is of the most use. Water quality investigations in Grant Creek completed in 2009 and 2010, and expanded on in 2013, showed overall water quality to be high (HDR 2010; KHL 2014). It was concluded that because of the similarity in water quality between Grant Lake and Grant Creek, there would be very little impact on the water chemistry of Grant Creek due to Project operations. Drawing water for Project use from a specified depth in Grant Lake would best duplicate the existing water temperature regime in Grant Creek, preventing change to that habitat parameter.

Grant Creek macroinvertebrate populations reflect both the pristine water quality and challenging habitat conditions present. Previous and current studies indicate that the benthic macroinvertebrate diversity is typical of cold, glacial fed streams (Ebasco 1984). These conditions result in macroinvertebrate populations comprised of taxa that have a low tolerance for water quality impairment but can also thrive where the growing season is short and streamflows variable. Given this and as would be expected, the most abundant taxa in Grant Creek were Chironomidae, followed by Ephemeroptera, Plecoptera, and clams.

Regarding chlorophyll *a* concentrations as a measure of periphyton abundance, the data show considerable variability as shown in Table 4.3-2.

6 VARIANCES FROM FERC-APPROVED STUDY PLAN AND PROPOSED MODIFICATIONS

There were no variations from the FERC-approved study plans for the Aquatic Resources Study, Macroinvertebrates and Periphyton in Grant Creek.

7 REFE RENCES

ADF&G (Alaska Department of Fish & Game). 1998. Methods for Aquatic Life Monitoring to Satisfy Requirements under 1998 NPDES Permit: NPDES AK-003865-2, Red Dog Mine Site. Division of Habitat and Restoration, Fairbanks, Alaska

Brabets, T.P., G.L. Nelson, J.M. Dorava, and A.M. Milner. 1999. Water-Quality Assessment of the Cook Inlet Basin, Alaska – Environmental Setting. Water-Resources Investigations Report 99-4025. National Water-Quality Assessment Program. U.S. Geological Survey. Anchorage, Alaska.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

Ebasco. 1984. Grant Lake Hydroelectric Project Detailed Feasibility Analysis. Volume 2. Environmental Report. Rep. from Ebasco Services Incorporated, Bellevue, Washington.

HDR Alaska, Inc. 2010. Grant Lake/Falls Creek Hydroelectric Project (FERC P-13211/13212) Environmental Baseline Studies, 2009. Prepared for Kenai Hydro, LLC. Anchorage, AK.

KHL (Kenai Hydro, LLC). 2009. Pre-Application Document Grant Lake/Grant Creek and Falls Creek Project (FERC No. 13211 and 13212). August 2009.

KHL. 2013. Grant Lake Hydroelectric Project (FERC No. 13212) Aquatic Resources Final Study Plan. Prepared for Kenai Hydro, LLC. March 2013.

KHL. 2014. Grant Lake Hydroelectric Project (FERC No. 13212) Water Resources Study – Water Quality, Temperature and Hydrology, Final Report. Prepared by McMillen LLC for Kenai Hydro, LLC. June 2014.

Major, E.B., A. Prussian, and D. Rinella. 2000. 1999 Alaska Biological Monitoring and Water Quality Assessment Program Report: Final Report. Environment and Natural Resources Institute. University of Alaska, Anchorage. For: Alaska Department of Environmental Conservation, Division of Air and Water Quality. Anchorage, AK.

Major, E.B., B.K. Jessup, A. Prussian, and D. Rinella. 2001. Alaska Stream Condition Index: Biological Index Development for Cook Inlet 1997-2000: Summary. Environment and Natural Resources Institute. University of Alaska, Anchorage and Tetra Tech, Inc. Owings Mills, MD. For: Alaska Department of Environmental Conservation, Division of Air and Water Quality. Anchorage, AK.

Major, E.B. and M.T. Barbour. 2001. Standard Operating Procedures for the Alaska Stream Condition Index: A Modification of the U.S. EPA Rapid Bioassessment Protocols, Fifth Edition. Alaska Department of Conservation. Anchorage, AK.

Mandaville, S.M. 2002. Benthic macroinvertebrates in freshwaters – taxa tolerance values, metrics, and protocols. (Project H-1). Soil and Water Conservation Society of Metro Halifax. Available online at http://chebucto.ca/Science/SWCS/SWCS.html

Merritt, R.W., K.W. Cummins, and M.B. Berg, Eds. 2008. *An Introduction to the Aquatic Insects of North America, Fourth Edition*. Kendall Hunt Pub. Co. Dubuque, IA.

Pennak, R.W. 1953. *Freshwater Invertebrates of the United States*. The Ronald Press Co. New York, NY.

Rinnella, D.J. and D.L. Bogan. 2007. Development of Macroinvertebrate and Diatom Biological Assessment Indices for Cook Inlet Basin Streams – Final Report. Environment and Natural Resources Institute. University of Alaska, Anchorage. For: Alaska Department of Environmental Conservation, Division of Air and Water Quality. Anchorage, AK.

Stewart, K.W. and B.P. Stark. 2002. *Nymphs of North American Stonefly Genera (Plecoptera), Second Edition.* The Caddis Press. Columbus, OH.

Wehr, J.D. and R.G. Sheath, Eds. 2003. *Freshwater Algae of North America, Ecology and Classification.* Academic Press. San Diego, CA.

Wiggins, G.B. 2009. *Larvae of the North American Caddisfly Genera (Trichoptera), Second Edition.* University of Toronto Press, Inc. Toronto, Canada.

Appendix 1: GC100 and GC300 Site Photos, August 2013

This appendix contains the following figures:

Figure A.1-1. Sampling site GC100 looking across channel to the south, August 14, 2013.

Figure A.1-2. Sampling site GC300 looking across channel to the south, August 14, 2013.

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Appendix 2: Macroinvertebrate and Periphyton Data Tables

Appendix 2a. Macroinvertebrate Data Tables

Appendix 2b. Periphyton Data Tables

Appendix 2a. Macroinvertebrate Data Tables

This appendix contains the following tables:

Table A.2a-1. Grant Creek macroinvertebrate taxonomic data, Ephemeroptera, 2009 and 2013.

					Ephemeroptera							
					Amelitidae	**Baetidae**	**Baetidae**	**Baetidae**	**Ephemerellidae**	**Ephemerellidae**	**Heptageniidae**	**Heptageniidae**
Site ID	**Sample Date**	**Surber No.**	**Number Identified/ Site**	**Number Taxa/Site**	***Ameletus***	***Baetidae unid.***	***Acentrella***	***Baetis***	***Drunella***	***Ephemerella***	***Cinygmula***	***Epeorus***
GC100	08/14/13	1	1207	18			4	8	4	4	3	4
GC100	08/14/13	2	2743	22			5	11	8	16	2	2
GC100	08/14/13	3	1267	18			8	9	6	6	5	6
GC100	08/14/13	4	1114	21			6	12	17	4	3	3
GC100	08/14/13	5	2626	20			7	14	14	11	3	2
GC300	08/14/13	1	880	23			6	12	20	8		1
GC300	08/14/13	2	990	20			7	12	13	3		1
GC300	08/14/13	3	1246	26			8	22	20	9	10	2
GC300	08/14/13	4	1751	21			15	57	86	24	5	1
GC300	08/14/13	5	1095	18			17	21	14	9	7	2
GC100	08/06/09	1	697	18			4	3	1	6		5
GC100	08/06/09	2	1859	19	1		6	5	6	7	4	6
GC100	08/06/09	3	1337	20			11	9	5	11	2	1
GC100	08/06/09	4	976	18			5	5	4	10		12
GC100	08/06/09	5	721	18		1	8		15	8	4	22
GC300	08/06/09	1	203	20			2	2	21	6	10	9
GC300	08/06/09	2	517	17			6	1	58	8	12	10
GC300	08/06/09	3	55	13					2	3	6	
GC300	08/06/09	4	151	15					11	5	6	2
GC300	08/06/09	5	98	11					4	2	5	
GC100	08/06/09	ASCI	421	10		1				1	2	2
GC300	08/06/09	ASCI	306	12						4		

Table A.2a-2. Grant Creek macroinvertebrate taxonomic data, Plecoptera, 2009 and 2013.

					Plecoptera										
						Chloroperlidae						Nemouridae	Perlodidae	Perlodidae	Taeniopterygidae
Site ID	**Sample Date**	**Surber No.**	**Number Identified/ Site**	**Number Taxa/Site**	**Plecoptera unid.**	**Chloroperlidae unid.**	***Suwallia***	***Haploperla***	***Neaviperla***	***Plumiperla***	***Triznaka***	***Zapada***	**Perlodidae unid.**	***Isoperla***	**Taeniopterygidae unid.**
GC100	08/14/13	1	1207	18			2					9	6		
GC100	08/14/13	2	2743	22			5					11	13		
GC100	08/14/13	3	1267	18			1					6		3	1
GC100	08/14/13	4	1114	21			8					15	5		
GC100	08/14/13	5	2626	20			8					12	2	10	
GC300	08/14/13	1	880	23			4					5	8	1	
GC300	08/14/13	2	990	20				1					6	2	
GC300	08/14/13	3	1246	26	2		6					20	6	4	
GC300	08/14/13	4	1751	21			7					13	8		
GC300	08/14/13	5	1095	18			2						15		
GC100	08/06/09	1	697	18		1				2		9		1	
GC100	08/06/09	2	1859	19						3		16			
GC100	08/06/09	3	1337	20		3		1		8		11			
GC100	08/06/09	4	976	18		1				4		10			
GC100	08/06/09	5	721	18					1	8		38		1	
GC300	08/06/09	1	203	20			6	2		3		15		1	
GC300	08/06/09	2	517	17							14	11			
GC300	08/06/09	3	55	13		1				2		1			
GC300	08/06/09	4	151	15					1	6		3			
GC300	08/06/09	5	98	11			12								
GC100	08/06/09	ASCI	421	10								1		1	
GC300	08/06/09	ASCI	306	12						4				1	

Table A.2a-3. Grant Creek macroinvertebrate taxonomic data, Trichoptera, 2009 and 2013.

					Trichoptera						
					Apataniidae	**Brachycentridae**		**Glossomatidae**	**Limnephilidae**	**Rhyacophilidae**	**Hydropshychidae**
Site ID	**Sample Date**	**Surber No.**	**Number Identified/ Site**	**Number Taxa/Site**	***Moselyana***	***Brachycentrus***	***Micrasema***	***Glossasoma***	***Ecclisomyia***	***Rhyacophila***	***Arctopsyche***
GC100	08/14/13	1	1207	18		2		2			
GC100	08/14/13	2	2743	22		2		3		1	1
GC100	08/14/13	3	1267	18		4					
GC100	08/14/13	4	1114	21		4			1		1
GC100	08/14/13	5	2626	20		7		3			
GC300	08/14/13	1	880	23		3		1		1	1
GC300	08/14/13	2	990	20		1			1		
GC300	08/14/13	3	1246	26		4		1			2
GC300	08/14/13	4	1751	21		2		3	4	1	
GC300	08/14/13	5	1095	18		4		2			
GC100	08/06/09	1	697	18	1	6		1			
GC100	08/06/09	2	1859	19		2		3			2
GC100	08/06/09	3	1337	20		4		8			1
GC100	08/06/09	4	976	18	2	4		10			2
GC100	08/06/09	5	721	18		4		11			1
GC300	08/06/09	1	203	20		2		1			1
GC300	08/06/09	2	517	17		1	1	10	1	1	
GC300	08/06/09	3	55	13				1	2		
GC300	08/06/09	4	151	15		2		9	1	2	4
GC300	08/06/09	5	98	11							1
GC100	08/06/09	ASCI	421	10				1			
GC300	08/06/09	ASCI	306	12		2					

Table A.2a-4. Grant Creek macroinvertebrate taxonomic data, Diptera, 2009 and 2013.

					Diptera					
						Chironomidae	Empididae			Simuliidae
Site ID	**Sample Date**	**Surber No.**	**Number Identified/ Site**	**Number Taxa/Site**	**Diptera unid.**	**Chironomidae unid. - total**	**Empididae unid.**	***Chelifera***	***Clinocera***	***Simulium***
GC100	08/14/13	1	1207	18		1109			4	7
GC100	08/14/13	2	2743	22		2423		2	31	12
GC100	08/14/13	3	1267	18		1153			15	28
GC100	08/14/13	4	1114	21		903			6	21
GC100	08/14/13	5	2626	20		2372		2	25	36
GC300	08/14/13	1	880	23	1	715		3	4	2
GC300	08/14/13	2	990	20		908		1	16	4
GC300	08/14/13	3	1246	26		965		1	16	5
GC300	08/14/13	4	1751	21		1425			24	
GC300	08/14/13	5	1095	18		925			14	3
GC100	08/06/09	1	697	18		619	1	1		5
GC100	08/06/09	2	1859	19		1740			3	13
GC100	08/06/09	3	1337	20		1142		3	3	11
GC100	08/06/09	4	976	18		832		2	5	8
GC100	08/06/09	5	721	18		508		1	9	28
GC300	08/06/09	1	203	20		73		1	2	1
GC300	08/06/09	2	517	17		333			1	
GC300	08/06/09	3	55	13		14			1	
GC300	08/06/09	4	151	15		92				1
GC300	08/06/09	5	98	11		18			1	
GC100	08/06/09	ASCI	421	10		55				
GC300	08/06/09	ASCI	306	12		23		2	4	3

Table A.2a-5. Grant Creek macroinvertebrate taxonomic data, other miscellaenous taxa, 2009 and 2013.

					Other MiscellaneousTaxa							
					Oligochaeta	Gastropoda	Gastropoda	Gastropoda	Bivalvia	Bivalvia	Arachnoidea	Ostracoda
Site ID	Sample Date	Surber No.	Number Identified/ Site	Number Taxa/Site	Oligochaeta - unid	Gastropoda- unid	Planorbidae- unid	Valvatidae	Bivalvia unid	Sphaeriidae	Hydracarina - unid	Ostracoda - unid
GC100	08/14/13	1	1207	18	4					9	2	
GC100	08/14/13	2	2743	22	6					155	15	6
GC100	08/14/13	3	1267	18	4					9	1	
GC100	08/14/13	4	1114	21	6					68	5	7
GC100	08/14/13	5	2626	20	7					68	6	7
GC300	08/14/13	1	880	23	12		1			59	4	3
GC300	08/14/13	2	990	20	2		1			7	2	
GC300	08/14/13	3	1246	26	15		3			85	15	4
GC300	08/14/13	4	1751	21	1		6	1		64	3	
GC300	08/14/13	5	1095	18	8					33	7	1
GC100	08/06/09	1	697	18	5					3	22	
GC100	08/06/09	2	1859	19					16		24	1
GC100	08/06/09	3	1337	20		1			81		19	
GC100	08/06/09	4	976	18					44		15	1
GC100	08/06/09	5	721	18					37		16	
GC300	08/06/09	1	203	20					36		9	
GC300	08/06/09	2	517	17					39		10	
GC300	08/06/09	3	55	13	2				17		3	
GC300	08/06/09	4	151	15							6	
GC300	08/06/09	5	98	11	2	1			49		3	
GC100	08/06/09	ASCI	421	10					349		8	
GC300	08/06/09	ASCI	306	12			7		238		17	

Table A.2a-6. Grant Creek macroinvertebrate taxonomic data, other miscellaneous taxa, 2009 and 2013.

					Other MiscellaneousTaxa		
					Nematoda	Platyhelminthes	
Site ID	Sample Date	Surber No.	Number Identified/ Site	Number Taxa/Site	Nematoda	Turbellaria	Lymnea
GC100	08/14/13	1	1207	18		24	
GC100	08/14/13	2	2743	22		13	
GC100	08/14/13	3	1267	18		2	
GC100	08/14/13	4	1114	21		19	
GC100	08/14/13	5	2626	20		10	
GC300	08/14/13	1	880	23		6	
GC300	08/14/13	2	990	20	1	1	
GC300	08/14/13	3	1246	26	1	20	
GC300	08/14/13	4	1751	21		1	
GC300	08/14/13	5	1095	18		11	
GC100	08/06/09	1	697	18	1		
GC100	08/06/09	2	1859	19	1		
GC100	08/06/09	3	1337	20	2		
GC100	08/06/09	4	976	18			
GC100	08/06/09	5	721	18			
GC300	08/06/09	1	203	20			
GC300	08/06/09	2	517	17			
GC300	08/06/09	3	55	13			
GC300	08/06/09	4	151	15			
GC300	08/06/09	5	98	11			
GC100	08/06/09	ASCI	421	10			
GC300	08/06/09	ASCI	306	12			1

Appendix 2b. Periphyton Data Table

This appendix contains the following table:

Table A.2b-1. Grant Creek periphyton chlorophyll *a* concentrations, 2009 and 2013.

Sample Site ID	Date	Replicate	Chlorophyll *a* (µg/cm^2)
GC 100	8/14/2013	1	7.3
GC 100	8/14/2013	2	4
GC 100	8/14/2013	3	4.5
GC 100	8/14/2013	4	3.8
GC 100	8/14/2013	5	4.5
GC 100	8/14/2013	6	5.6
GC 100	8/14/2013	7	3.6
GC 100	8/14/2013	8	20
GC 100	8/14/2013	9	3.6
GC 100	8/14/2013	10	1.6
GC 100	8/6/2009	1	12.5
GC 100	8/6/2009	2	51.5
GC 100	8/6/2009	3	16.8
GC 100	8/6/2009	4	15
GC 100	8/6/2009	5	40.1
GC 100	8/6/2009	6	19.8
GC 100	8/6/2009	7	37.6
GC 100	8/6/2009	8	82
GC 100	8/6/2009	9	7.48
GC 100	8/6/2009	10	65.1
GC 300	8/14/2013	1	2.4
GC 300	8/14/2013	2	1.6
GC 300	8/14/2013	3	1.9
GC 300	8/14/2013	4	5.2
GC 300	8/14/2013	5	5.4
GC 300	8/14/2013	6	2.1
GC 300	8/14/2013	7	9.8
GC 300	8/14/2013	8	9
GC 300	8/14/2013	9	4.5
GC 300	8/14/2013	10	2.1
GC 300	8/6/2009	1	19
GC 300	8/6/2009	2	4.54
GC 300	8/6/2009	3	8.28
GC 300	8/6/2009	4	10.7
GC 300	8/6/2009	5	2.94
GC 300	8/6/2009	6	4.81
GC 300	8/6/2009	7	5.87
GC 300	8/6/2009	8	36
GC 300	8/6/2009	9	23.2
GC 300	8/6/2009	10	11.7

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Appendix 3: Metrics Trends Tables from the EPA RBP (Barbour et al. 1999)

This appendix contains the following tables:

Table A.3-1.

Definitions of best candidate benthic metrics and predicted direction of metric response to increasing perturbation (compiled from DeShon 1995, Barbour et al. 1996b, Fore et al. 1996, Smith and Voshell 1997).

Category	Metric	Definition	Predicted response to increasing perturbation
Richness measures	Total No. taxa	Measures the overall variety of the macroinvertebrate assemblage	Decrease
	No. EPT taxa	Number of taxa in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies)	Decrease
	No. Ephemeroptera Taxa	Number of mayfly taxa (usually genus or species level)	Decrease
	No. Plecoptera Taxa	Number of stonefly taxa (usually genus of species level)	Decrease
	No. Trichoptera Taxa	Number of caddisfly taxa (usually genus or species level)	Decrease
Composition measures	% EPT	Percent of the composite of mayfly, stonefly, and caddisfly larvae	Decrease
	% Ephemeroptera	Percent of mayfly nymphs	Decrease
Tolerance/Intolerance measures	No. of Intolerant Taxa	Taxa richness of those organisms considered to be sensitive to perturbation	Decrease
	% Tolerant Organisms	Percent of macrobenthos considered to be tolerant of various types of perturbation	Increase
	% Dominant Taxon	Measures the dominance of the single most abundant taxon. Can be calculated as dominant 2, 3, 4, or 5 taxa.	Increase
Feeding measures	% Filterers	Percent of the macrobenthos that filter FPOM from either the water column or sediment	Variable
	% Grazers and Scrapers	Percent of the macrobenthos that scrape or graze upon periphyton	Decrease
Habit measures	Number of Clinger Taxa	Number of taxa of insects	Decrease
	% Clingers	Percent of insects having fixed retreats or adaptations for attachment to surfaces in flowing water.	Decrease

Table A.3-2.

Definitions of additional potential benthic metrics and predicted direction of metric response to increasing perturbation.

Category	Metric	Definition	Predicted response to increasing perturbation	References
Richness measures	No. *Pteronarcys* species	The presence or absence of a long-lived stonefly genus (2-3 year life cycle)	Decrease	Fore et al. 1996
	No. Diptera taxa	Number of "true" fly taxa, which includes midges	Decrease	DeShon 1995
	No. Chironomidae taxa	Number of taxa of chironomid (midge) larvae	Decrease	Hayslip 1993, Barbour et al. 1996b
Composition measures	% Plecoptera	Percent of stonefly nymphs	Decrease	Barbour et al. 1994
	% Trichoptera	Percent of caddisfly larvae	Decrease	DeShon 1995
	% Diptera	Percent of all "true" fly larvae	Increase	Barbour et al. 1996b
	% Chironomidae	Percent of midge larvae	Increase	Barbour et al. 1994
	% Tribe Tanytarsini	Percent of Tanytarsinid midges to total fauna	Decrease	DeShon 1995
	% Other Diptera and noninsects	Composite of those organisms generally considered to be tolerant to a wide range of environmental conditions	Increase	DeShon 1995
	% *Corbicula*	Percent of asiatic clam in the benthic assemblage	Increase	Kerans and Karr 1994
	% Oligochaeta	Percent of aquatic worms	Variable	Kerans and Karr 1994
Tolerance/ Intolerance measures	No. Intol. Snail and Mussel species	Number of species of molluscs generally thought to be pollution intolerant	Decrease	Kerans and Karr 1994
	% Sediment Tolerant organisms	Percent of infaunal macrobenthos tolerant of perturbation	Increase	Fore et al. 1996

Table A.3-2. (cont.)

Definitions of additional potential benthic metrics and predicted direction of metric response to increasing perturbation (continued).

Category	Metric	Definition	Predicted response to increasing perturbation	References
	Hilsenhoff Biotic Index	Uses tolerance values to weight abundance in an estimate of overall pollution. Originally designed to evaluate organic pollution	Increase	Barbour et al. 1992, Hayslip 1993, Kerans and Karr 1994
Tolerance/ Intolerance measures (continued)	Florida Index	Weighted sum of intolerant taxa, which are classed as 1 (least tolerant) or 2 (intolerant). Florida Index = 2 X Class 1 taxa + Class 2 taxa	Decrease	Barbour et al. 1996b
	% Hydropsychidae to Trichoptera	Relative abundance of pollution tolerant caddisflies (metric could also be regarded as a composition measure)	Increase	Barbour et al. 1992, Hayslip 1993
Feeding measures	% Omnivores and Scavengers	Percent of generalists in feeding strategies	Increase	Kerans and Karr 1994
	% Ind. Gatherers and Filterers	Percent of collector feeders of CPOM and FPOM	Variable	Kerans and Karr 1994
	% Gatherers	Percent of the macrobenthos that "gather"	Variable	Barbour et al. 1996b
	% Predators	Percent of the predator functional feeding group. Can be made restrictive to exclude omnivores	Variable	Kerans and Karr 1994
	% Shredders	Percent of the macrobenthos that "shreds" leaf litter	Decrease	Barbour et al. 1992, Hayslip 1993
Life cycle measures	% Multivoltine	Percent of organisms having short (several per year) life cycle	Increase	Barbour et al. 1994
	% Univoltine	Percent of organisms relatively long-lived (life cycles of 1 or more years)	Decrease	Barbour et al. 1994

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Recreational and Visual Resources Study

Grant Lake Hydroelectric Project (FERC No. 13212)

Prepared for:
Kenai Hydro, LLC

Prepared by:
D. Adams and K. Graham
USKH Inc.

June 2014

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Acronyms and Abbreviations

ADF&G	Alaska Department of Fish & Game
ADNR	Alaska Department of Natural Resources
ADOT&PF	Alaska Department of Transportation and Public Facilities
ATV	all-terrain vehicle
dB	decibels
DLA	Draft License Application
FERC	Federal Energy Regulatory Commission
FPA	Federal Power Act
GIS	Geographic Information System
GPS	Global Positioning System
INHT	Iditarod National Historic Trail
KHL	Kenai Hydro, LLC
KRSMA	Kenai River Special Management Area
LA	License Application
MP	milepost
MW	megawatt
NAVD 88	North American Vertical Datum of 1988
NGVD 29	National Geodetic Vertical Datum of 1929
NOI	Notice of Intent
PAD	Pre-Application Document
PM&E	protection, mitigation and enhancement
Project	Grant Lake Hydroelectric Project
TLP	Traditional Licensing Process
USFS	U.S. Department of Agriculture, Forest Service

Recreation and Visual Resources Study
Final Report
Grant Lake Hydroelectric Project (FERC No. 13212)

1 INTRODUCTION

On August 6, 2009, Kenai Hydro, LLC (KHL) filed a Pre-Application Document (PAD; KHL 2009), along with a Notice of Intent (NOI) to file an application for an original license, for a combined Grant Lake/Falls Creek Project (Federal Energy Regulatory Commission [FERC] No. 13211/13212 ["Project" or "Grant Lake Project"]) under Part I of the Federal Power Act (FPA). On September 15, 2009, FERC approved the use of the Traditional Licensing Process (TLP) for development of the License Application (LA) and supporting materials. Per the TLP, KHL underwent consultation with the requisite stakeholders in relation to the development of a series of natural resource studies that were completed in 2013. One of these was the Recreation and Visual Resources Study. Recreation and visual resources are important attributes that are highly valued by the public as important considerations for any project. This report seeks to record, analyze, and document current features and the potential effects of the Grant Lake Project on these resources.

The proposed Grant Lake Hydroelectric Project would be located near the community of Moose Pass, Alaska (population 206), approximately 25 miles north of Seward, Alaska (population 3,016), just east of the Seward Highway (State Route 9); this highway connects Anchorage (population 279,671) to Seward. The Alaska Railroad parallels the route of the Seward Highway, and is also adjacent to the Project area. The community of Cooper Landing (population 369) is located 24 miles to the northwest and is accessible via the Sterling Highway (State Route 1) which connects to the Seward Highway approximately 10 miles northwest of Moose Pass. The proposed Project location is in the mountainous terrain of the Kenai Mountain Range.

2 GOALS AND OBJECTIVES

The goal of this study was to identify recreational and visual resources that may be affected by the construction and operation of the proposed Project, identify both positive and negative effects to those resources created by the Project, and to suggest measures that could be implemented to mitigate potential impacts. The specific objectives of the study were to:

- Determine availability of recreation resources and the quality of those resources.
- Determine quality of the scenic environment.
- Evaluate impacts of:
  - Project construction and operation on distribution of local and tourist recreational use, access and recreational experience on Grant Lake, Grant Creek, and Vagt Lake.
  - Project construction and operation on the distribution and abundance of fish and wildlife for anglers and hunters.
  - Project construction and operation (including roads and facilities) on visual quality in the area.

- o Project roads and transmission line corridors (if not buried in road grade) on aesthetic and visual resources (including impacts on Scenic Byway viewpoints and views from existing recreational trails and use areas).
- o Project construction and operation on local and regional recreation resources.
- o Project facilities and operation (including road access, safety, and use) on local residential land use on Grant Creek and along the road corridor.
- o Project construction and operation on quality of life characteristics of the area (i.e., noise, changed access to remote area, light pollution).

3 SCOPE OF WORK

The research and fieldwork associated with the scope of work for this Recreational and Visual Resources Study was conducted in the summer of 2013. The study was conducted according to the approach described in the *Recreational and Visual Resources Study Plan* (KHL 2013). The specific work tasks included;

- Continuation of work that was completed in 2010
- In-office reviews of existing conditions
- (1) Winter site and (1) Summer visits for data collection of existing use and on-site observations
- (1) Sight-seeing flight for recreational and visual impact analysis
- Creation of (4) visual simulations of key observation points showing Project impacts
- Consultation of land management agencies and stakeholders regarding recreation and visual resources
- Evaluation of an alternative route of the Iditarod National Historic Trail (INHT)

4 METHODS

On-foot site visits in conjunction with a small aircraft flight were the primary sources of observations. These were performed in 2013.

An initial winter survey was conducted by Kim Graham on March 3, 2013. This site visit was conducted on snow shoes and with access to Trail Lake narrows provided via the Vagt Lake trail. This winter survey observed winter recreation activities and recorded; any evidence of other trail usage, existing noise levels, and potential winter viewsheds. Waypoints were recorded with a Global Positioning System (GPS) unit, and transferred with notes and decibel readings into a Geographic Information System (GIS) shapefile. On May 31, 2013, Dwayne Adams and Kim Graham, studied the Project site (on foot) and marked an alternative route for the INHT. This re-route was recorded with GPS waypoints, and then transferred to a GIS shapefile with collected notes. A separate summer survey was conducted on July 12, 2013, by Kim Graham, using the same instruments and recording information in a similar fashion. A final aircraft survey was conducted on August 25, 2013, by Kim Graham, recording viewsheds from a typical sight-seeing flight using a digital camera. Table 4.1-1 documents the entirety of the survey schedule.

Table 4.1-1. Survey schedule.

Site Visit Purpose	Date	Instruments	Data Collected	Staff
Winter Survey	March 3, 2013	Camera, GPS unit, Decibel reader	Winter use, winter viewsheds, field observations	Kim Graham
INHT reroute	May 31, 2013	Camera, GPS unit, Decibel reader	Alternative trail reroute, trail viewpoints	Dwayne Adams and Kim Graham
Summer Survey	July 12, 2013	Camera, GPS unit, Decibel reader	Summer use, summer viewsheds, field observations	Kim Graham
Aircraft flight	August 25, 2013	Camera	Sight-seeing route, aerial viewsheds	Kim Graham

Under the guidance of the U.S. Department of Agriculture, Forest Service (USFS) document *Landscape Aesthetics, A handbook for Scenery Management*, viewer groups were identified and were the basis for discussion of potential impacts of the Project (USFS 1995). These viewer groups were then used, in conjunction with the collected information and the outlined scope of work, to identify key observation points from which users would be able to see the Project. These points were developed into full visual simulations through computer programs including Photoshop, Sketchup, and Indesign. Impacts were further discussed and combined with potential mitigation measures.

5 STUDY OVERVIEW

The Project is located near Moose Pass, Alaska, a small community located on the Kenai Peninsula of Alaska. The area is heavily dominated by mountains, low density populations, and diverse ecosystems. The overall landscape character is natural, with diverse topography, large lakes, fast moving rivers, alpine tundra, and taiga forest. It is home to long-standing trail systems to the west and ancient ice-fields to the east. Figure 5.0-1 displays the Project's general geographic location.

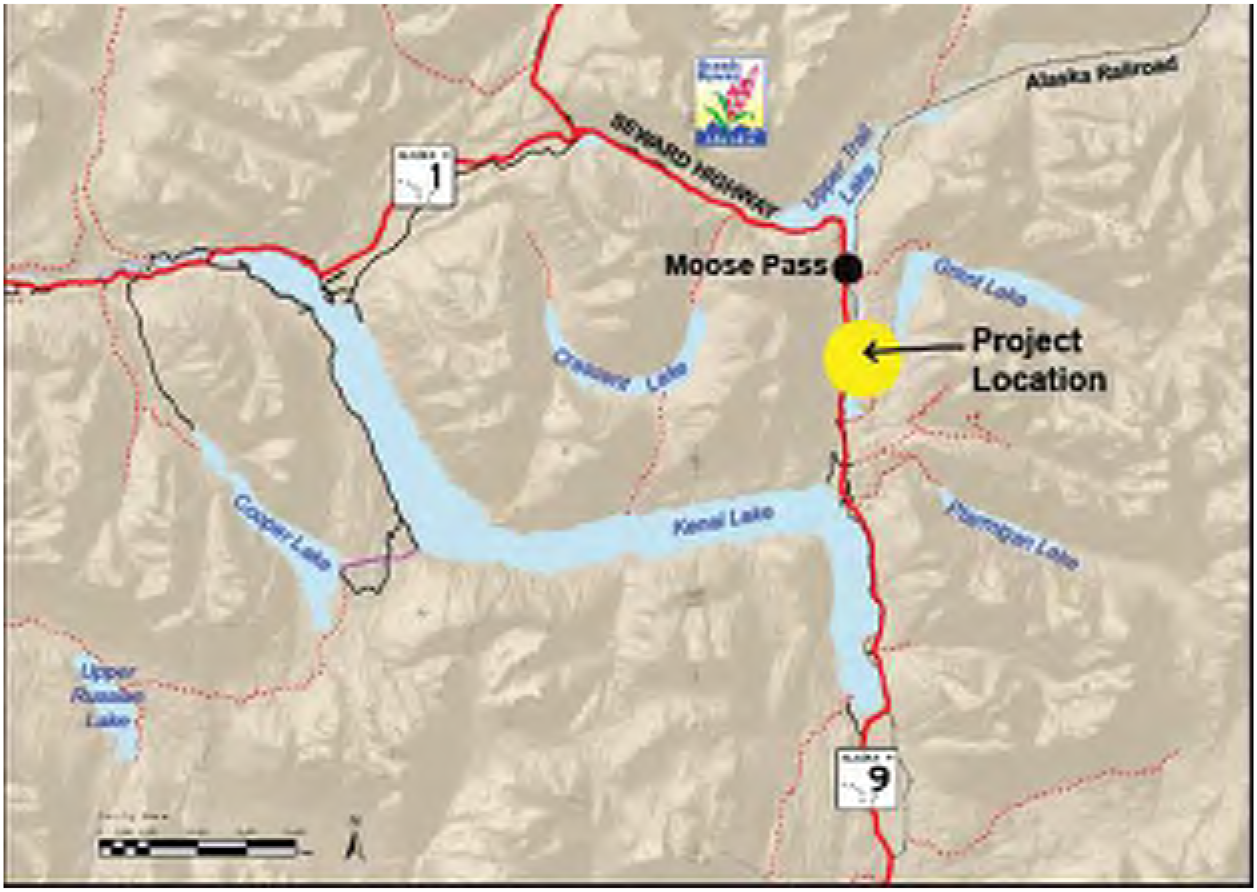


Figure 5.0-1. Project location.

The area has a long standing history of hydroelectric power, dating back to the early 1900s. Other hydroelectric projects in the area include the Cooper Lake Hydroelectric Project, approximately 20 miles away, near the community of Cooper Landing, as well as as Bradley Lake near Homer, Eklutna north of Anchorage, and Marathon Creek in Seward which provided power to Seward General Hospital in the past.

The Project location is also subject to a large volume of people passing through the area, many of whom are tourists and most of whom are traveling for scenic enjoyment. The Seward Highway, connecting Anchorage to Seward, is used by travelers either driving to Anchorage for supplies or to Seward for recreation. This highway is one of the most used highways in the state, and holds the honor of being a Scenic Byway. Its value as being a scenic resource is well established.

5.1 Study Boundaries

General boundaries for the Recreation and Visual Resources Study were approximately five radial miles around the Project area. These boundaries extend from Moose Pass, to the top of the ridgelines around Grant Lake itself, south around Lower Trail Lake, north along the highway corridor, and back to Moose Pass (Figure 5.1-1). The Project area was defined by mountain ridges which provide a distinct separation of the Project area from other adjacent uses.

For the purposes of this report, the recreation resources will be discussed as Component 1, and the visual resources will be Component 2. Each component shares the same study boundaries but is discussed separately.

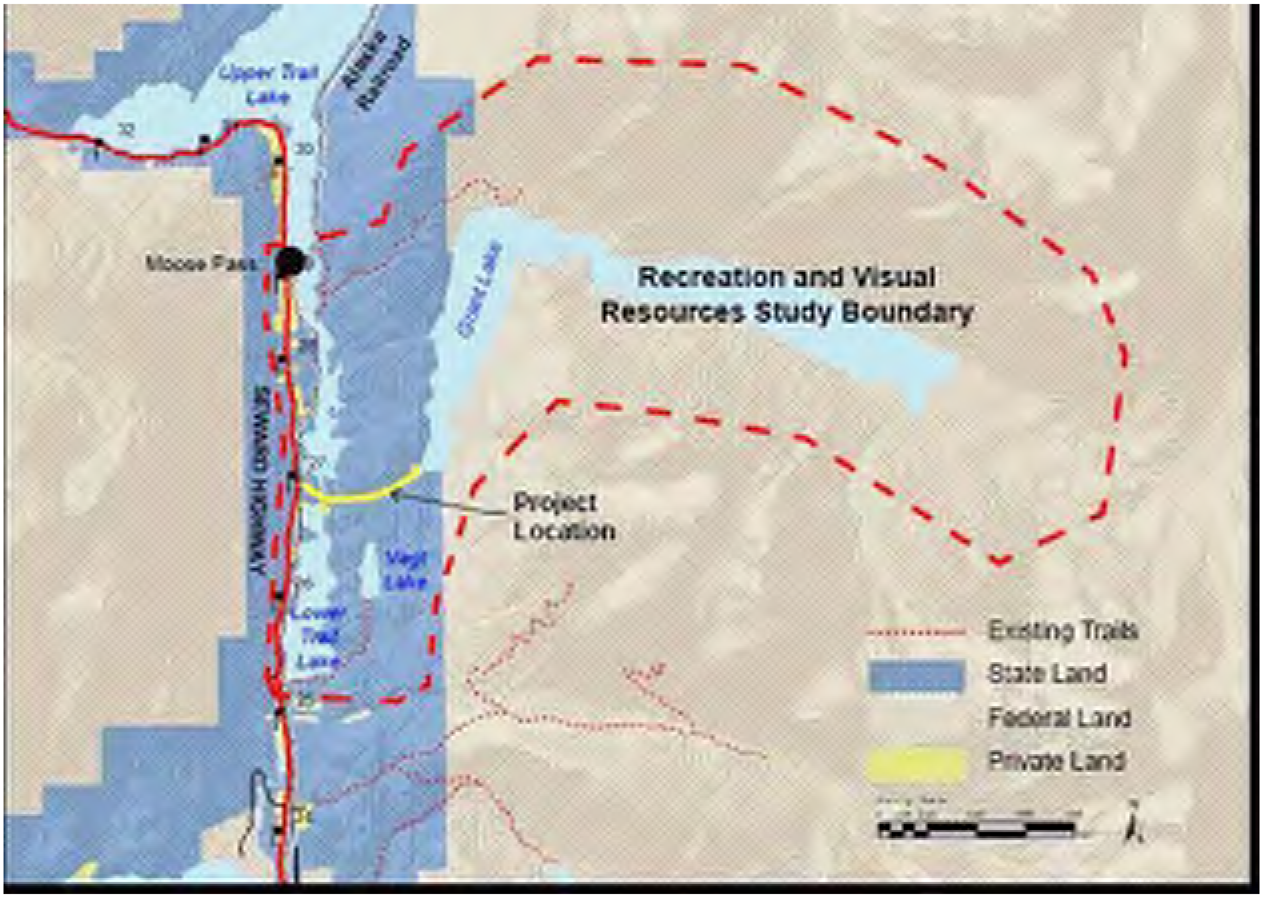


Figure 5.1-1. Study area boundary.

5.2 General Project Components

The Project components are concentrated around the outlet of Grant Lake and the bottom of the canyon reach (Reach 4/5 break) near the mid-point of Grant Creek. Figure 5.2-1 displays the global natural resources study area for the efforts undertaken in 2013 and 2014 along with the likely location of Project infrastructure and detail related to land ownership in and near the Project area.

The proposed Project would be composed of an intake structure at the outlet to Grant Lake, a tunnel, a surge tank, a penstock, and a powerhouse. It would also include a tailrace detention pond, a switchyard with disconnect switch and step-up transformer, and an overhead or underground transmission line. The preferred alternative would use approximately 15,900 acre-feet of water storage during operations between pool elevations of approximately 692 and up to 703 feet North American Vertical Datum of 1988 (NAVD 88)[1].

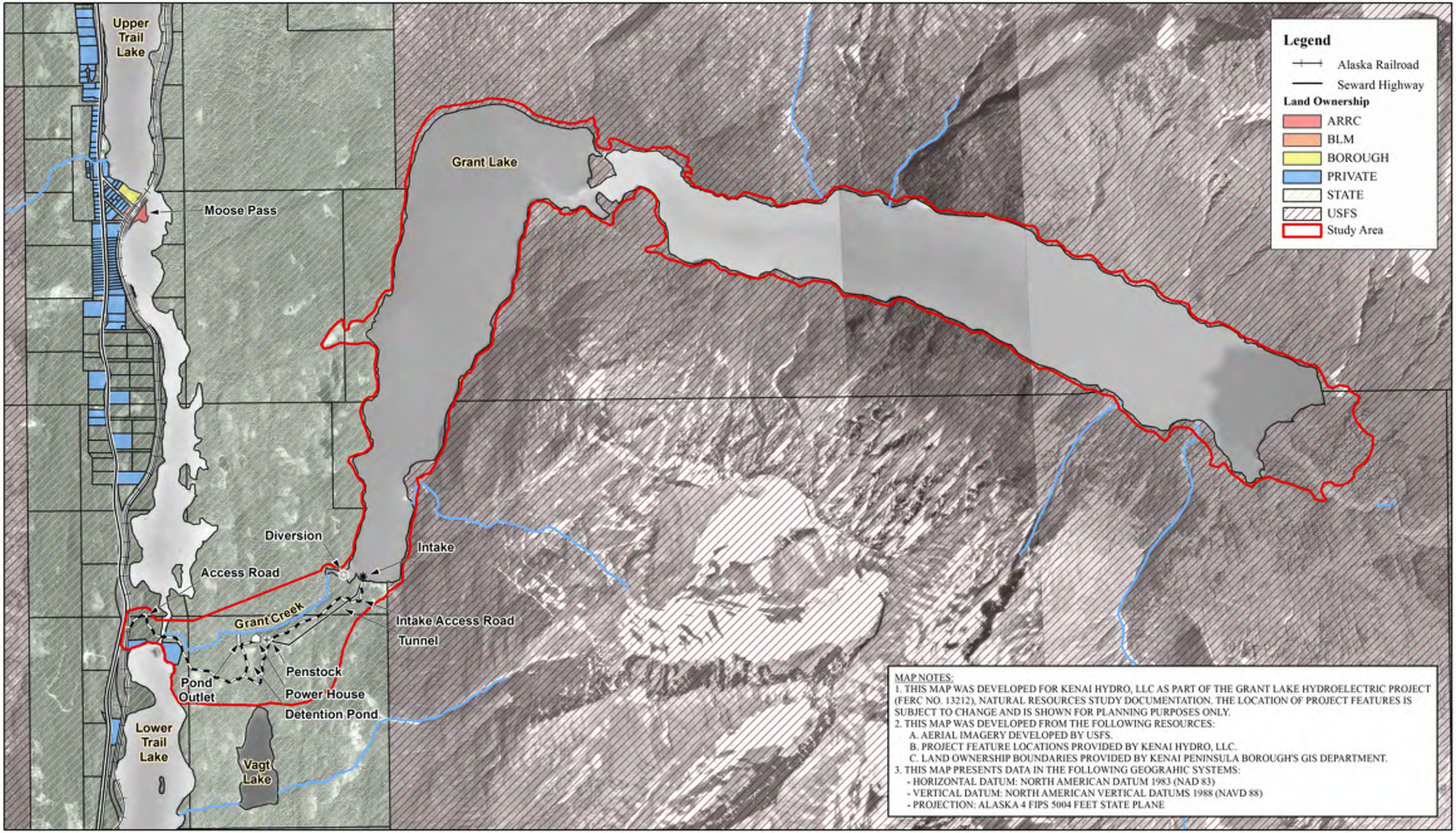
An intake structure would be constructed approximately 500 feet east of the natural outlet of Grant Lake. An approximate 3,200-foot-long, 10-foot diameter horseshoe tunnel would convey water from the intake to directly above the powerhouse at about elevation 628 feet NAVD 88. At the outlet to the tunnel a 360-foot-long section of penstock will convey water to the powerhouse located at about elevation 531 feet NAVD 88. An off-stream detention pond will be created to provide a storage reservoir for flows generated during the rare instance when the units being used for emergency spinning reserve are needed to provide full load at maximum ramping rates. The tailrace would be located in order to minimize impacts to fish habitat by returning flows to Grant Creek upstream of the most productive fish habitat.

Two concepts are currently being evaluated for water control at the outlet of Grant Lake. The first option would consist of a natural lake outlet that would provide control of flows out of Grant Lake. A new low level outlet would be constructed on the south side of the natural outlet to release any required environmental flows when the lake is drawdown below the natural outlet level. The outlet works would consist of a 48-inch diameter pipe extending back into Grant Lake, a gate house, regulating gate, controls and associated monitoring equipment. The outlet would discharge into Grant Creek immediately below the natural lake outlet.

In the second option, a concrete gravity diversion structure would be constructed near the outlet of Grant Lake. The gravity diversion structure would raise the pool level by a maximum height of approximately 2 feet (from 703 to 705 feet NAVD 88), and the structure would have an overall width of approximately 120 feet. The center 60 feet of the structure would have an uncontrolled spillway section with a crest elevation at approximately 705 feet NAVD 88. Similar to the first option, a low level outlet would be constructed on the south side of the natural outlet to release any required environmental flows when the lake is drawn down below the natural outlet level. The outlet works would consist of a 48-inch diameter pipe extending back into Grant Lake, a gate house a regulating gate, controls, and associated monitoring equipment. The outlet would discharge into Grant Creek immediately below the diversion structure.

Further discussions related to specifics of the aforementioned Project infrastructure along with the need and/or feasibility of the diversion dam will take place with stakeholders in 2014 concurrent with the engineering feasibility work for the Project. Refined Project design information will be detailed in both the Draft License Application (DLA) and any other ancillary engineering documents related to Project development. The current design includes two Francis turbine generators with a combined rated capacity of approximately 5.0 megawatts (MW) with a total design flow of 385 cubic feet per second. Additional information about the Project can be found on the Project website: http://www.kenaihydro.com/index.php.

[1] The elevations provided in previous licensing and source documents are referenced to feet mean sea level in NGVD 29 [National Geodetic Vertical Datum of 1929] datum, a historical survey datum. The elevations presented in the Grant Lake natural resources study reports are referenced to feet NAVD 88 datum, which results in an approximate +5-foot conversion to the NGVD 29 elevation values.



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Drawing Scale:
0 0.25 0.5 1 Miles

McMILLEN, LLC

Developed For:
Homer Electric Association, Inc.
A Touchstone Energy Cooperative

GRANT LAKE HYDROELECTRIC PROJECT - FERC PROJECT #P-13212

GRANT LAKE NATURAL RESOURCES STUDY

Figure 5.2-1
Natural Resources Study Area

DESIGNED: Jake Woodbury
DRAWN: Jake Woodbury
CHECKED: C. Warnock
ISSUED DATE: 1/9/2014
SCALE: 1:27,000

Project features as currently envisioned are summarized in Table 5.2-1.

Table 5.2-1. Grant Lake Project features.

Number of Generating Units	2	
Turbine Type	Francis	
Rated Generator Output		
Unit 1	1.0 MW	
Unit 2	4.0 MW	
Maximum Rated Turbine Discharge		
Unit 1	75 cfs	
Unit 2	310 cfs	
Turbine Centerline Elevation	526 ft NAVD 88	
Normal Tailwater Elevation		
Minimum	517 ft NAVD 88	
Maximum	520 ft NAVD 88	
Average Annual Energy	19,700 MWh	
Normal Maximum Reservoir Elevation	703 ft NAVD 88	
Normal Minimum Reservoir Elevation	692 ft NAVD 88	
Gross Head	183 ft	
Net Head at Maximum Rated Discharge	171.6 ft	
Grant Lake		
Drainage Area	44 mi^2	
Surface Area	1,790 ac	
Active Storage Volume	15,900 ac-ft (Elevation 703 to 692 feet NAVD 88)	
Average Annual Natural Outflow	139,650 ac-ft	
Average Annual Natural Outflow	193 cfs	
Grant Creek Diversion		
Type (2 options under consideration)	None (natural lake outlet)	Concrete Gravity Dam
Maximum Height	NA	2 ft
Overall Width	NA	120 ft
Spillway Crest Length	NA	60 ft
Crest Elevation	703 ft NAVD 88	705 ft NAVD 88
Water Conveyance		
Intake	Tower	
Invert Elevation	660 ft NAVD 88	
Lower Pressure Pipeline		
Type	Welded steel	
Length	200 ft	
Diameter	48 in	
Pressure Tunnel		
Type	10-ft horseshoe	
Length	3,200 ft	

Velocity at Maximum Turbine Discharge	3.9 fps
Surge Tank	
Diameter	96 in
Base Elevation (preliminary)	655 ft NAVD 88
Top Elevation (preliminary)	765 ft NAVD 88
Penstock	
Type	Welded steel
Length	360 ft
Diameter	72 in
Powerhouse	
Approximate Dimensions	45 ft x 60 ft x 30 ft high
Finished Floor Elevation	531 ft NAVD 88
Tailrace Detention Pond	
Approximate Acreage	5 ac
Approximate Capacity	15 ac-ft
Outlet Conveyance Length	300 ft
Tailrace	
Type	Open channel
Length	200 ft
Option 1	
Transmission Line	
Type	Overhead or underground
Length	Approximately 3.5 miles
Voltage	24.9 kV
Access Roads	
Type	Single lane gravel surfacing with turnouts
Length	Approximately 4.0 miles; including 3.0 miles to the powerhouse and 1.0 mile to the intake (portions will be new road)
Option 2	
Transmission Line	
Type	Overhead or underground
Length	Approximately 1.0 mile
Voltage	115 kV
Access Roads	
Type	Single lane gravel surfacing with turnouts
Length	Approximately 1.95 miles; including 1.0 mile to the powerhouse and 0.95 mile to the intake (this will be a new road)

The Project access would leave the Seward Highway at approximately milepost (MP) 26.9. This route would travel eastward to cross Trail Lakes at the downstream end of the narrows between Upper and Lower Trail lakes and then continue eastward to the powerhouse. This route would be approximately 1 mile long. It would cross Alaska Railroad tracks near an existing railroad crossing for a private driveway. The road would cross the narrow channel connecting Upper and Lower Trail lakes with an approximately 100-foot-long single lane bridge. This bridge is proposed as a clear span with the west abutment located on bedrock and the east abutment on fill. The proposed route would avoid cuts and travel along the base of some small hills on the south side of Grant Creek to the Powerhouse. This proposed access road would have one 90-degree crossing of the INHT.

The intake access road would be approximately one mile long, beginning at the powerhouse. The road would ascend a 230-foot bluff to get to the top of the southern lip of the Grant Creek canyon. The road would then generally follow the southern edge of the canyon until it descends to Grant Lake.

The entire road complex would be gravel with a 14-foot top width. Maximum grade would be 16 percent. Periodic turnouts would be provided to allow construction traffic to pass. Fifty-foot radius curves would be used to more closely contour around the small steep hills of bedrock to limit the extent of the excavation and the height of the embankments.

The intake would direct water into a tunnel ending with the penstock and powerhouse at the base of the slope. Once the water passes through the powerhouse, it would pass through a control weir and then flow through an open channel approximately 200 feet long. This channel would have an auxiliary detention pond that would provide supplementary water storage for emergency spinning reserve. The rip-rap lined channel would end at the existing creek bed and the water would be returned to Grant Creek.

The powerhouse would be located on the southern side of Grant Creek near the end of the canyon section (Reach 4/5 break). The powerhouse would be approximately 45 feet by 60 feet by 30 feet high and would have a finished floor elevation of 531 feet NAVD 88. The powerhouse would be a pre-engineered metal building on a concrete foundation.

From the powerhouse, a transmission line would link with the existing overhead electrical transmission lines located to the west of the Seward Highway. Both underground and overhead transmission lines to deliver energy from the Project to the grid are being evaluated. In addition to any overhead transmission structures, the facilities would include a switchyard at the powerhouse consisting of a pad-mounted disconnect switch and a pad-mounted step-up transformer. The transmission line would run from the powerhouse parallel to the access road where it would intersect the City of Seward distribution line or Chugach Electric's transmission line depending on current engineering feasibility work and utility interconnect agreements made with these electric utilities. The interconnection would have a pole mounted disconnect switch. If used, the poles would be designed as tangent line structures on about 250-foot centers.

6 COMPONENT 1 – RECREATION RESOURCES

6.1 Management Plans -- Goals and Intents

For the Grant Lake area, there are a number of management plans that propose processes and measures to protect and facilitate habitat, recreation, and visual resources. The following is a list of affected management plans and a summary of relevant content.

6.1.1 Kenai River Comprehensive Management Plan

The Kenai River Comprehensive Management Plan (ADNR 1997) proposes that a number of state parcels adjoining Trail Lakes and Trail River be incorporated into the Kenai River Special Management Area (KRSMA) and proposes that these actions be accommodated within the Kenai Area Plan. It also proposes a 200-foot vegetated buffer be provided along the shore of the lakes and river. These proposals are provided to protect fish populations and resources of the Kenai River.

6.1.2 Kenai Area Plan

From the Kenai Area Plan (ADNR 2001), public recreation and tourism presents goals of keeping public areas open and available for use. This management plan supports recreation and tourism activities such as backcountry skiing, hiking, snowmaching, and sightseeing. Specifically from this plan, the INHT trail and trail corridor is to have a conveyance of a 1,000-foot-wide easement to include a visual and sound buffer between the recreation corridor and adjacent uses. No permanent structures or equipment are to be placed within the trail corridor. In keeping with this management plan, the Project has provided an alternate route for the INHT easement, keeping the 1,000-foot-wide corridor away from any permanent structures and adjacent uses.

The Kenai Area plan has designated Grant Lake within region 2B, with the Grant Lake Project area affected by Units 380G, 380F, and 381. Figure 6.1-1 illustrates where these units are located with respect to Grant Lake. These particular areas have been identified for their Public Recreation and Tourism uses and protection of existing habitat. They are recognized as being strongly oriented toward recreation, particularly with respect to the trails and surrounding lakes.

Figure 6.1-1. Kenai Area Plan map, enlargement of Grant Lake designation..

6.1.3 Revised Land and Resource Management Plan

Most of the Project area is located on Kenai Peninsula Borough, State of Alaska and a minimal amount of private land. Lands east of the western shore of Grant Lake lies within Chugach National Forest. Those lands are managed in accordance with the Revised Land and Resource Management Plan for Chugach National Forest (USFS 2002). The plan is currently being updated. Until revisions are final the 2002 plan remains "current". This management plan provides guidance for all resource management activities on national forest land within the Chugach National Forest.

The area in and around Grant Lake is managed as part of the Kenai Mountains Roadless Area, encompassing 319,600 acres. It is managed to meet goals for improved and developed recreation opportunities while maintaining landscape character and providing for timber management.

Grant Lake is designated within the 2002 Revised Land and Resource Management Plan with a prescription for "Fish, Wildlife, and Recreation Management". Areas north and east of the lake are managed as "Backcountry". "Fish, Wildlife, and Recreation Management" provides a "desired future condition" of "ecological processes, moderately affected by human activity, dominate…Evidence of resource management may be present." "Backcountry" areas present a desired future condition of "ecological processes, largely unaffected by human activity…provide excellent opportunities for solitude, tranquility, isolation, quiet, challenge, and a degree of risk when traveling backcountry" (USFS 2002).

6.2 Recreation Users

The area surrounding Grant Lake provides numerous recreation resources. They vary in access and usability throughout the seasons and by daily weather conditions. Recreational uses also vary between motorized versus non-motorized use. Existing forms of recreation include (Figure 6.2-1):

- Hiking/Walking
- Camping
- Fishing
- Boating
- Hunting
- Snowmachining
- Snowshoeing
- Cross Country Skiing
- Ice fishing
- Aerial Sight-Seeing
- Driving for Pleasure

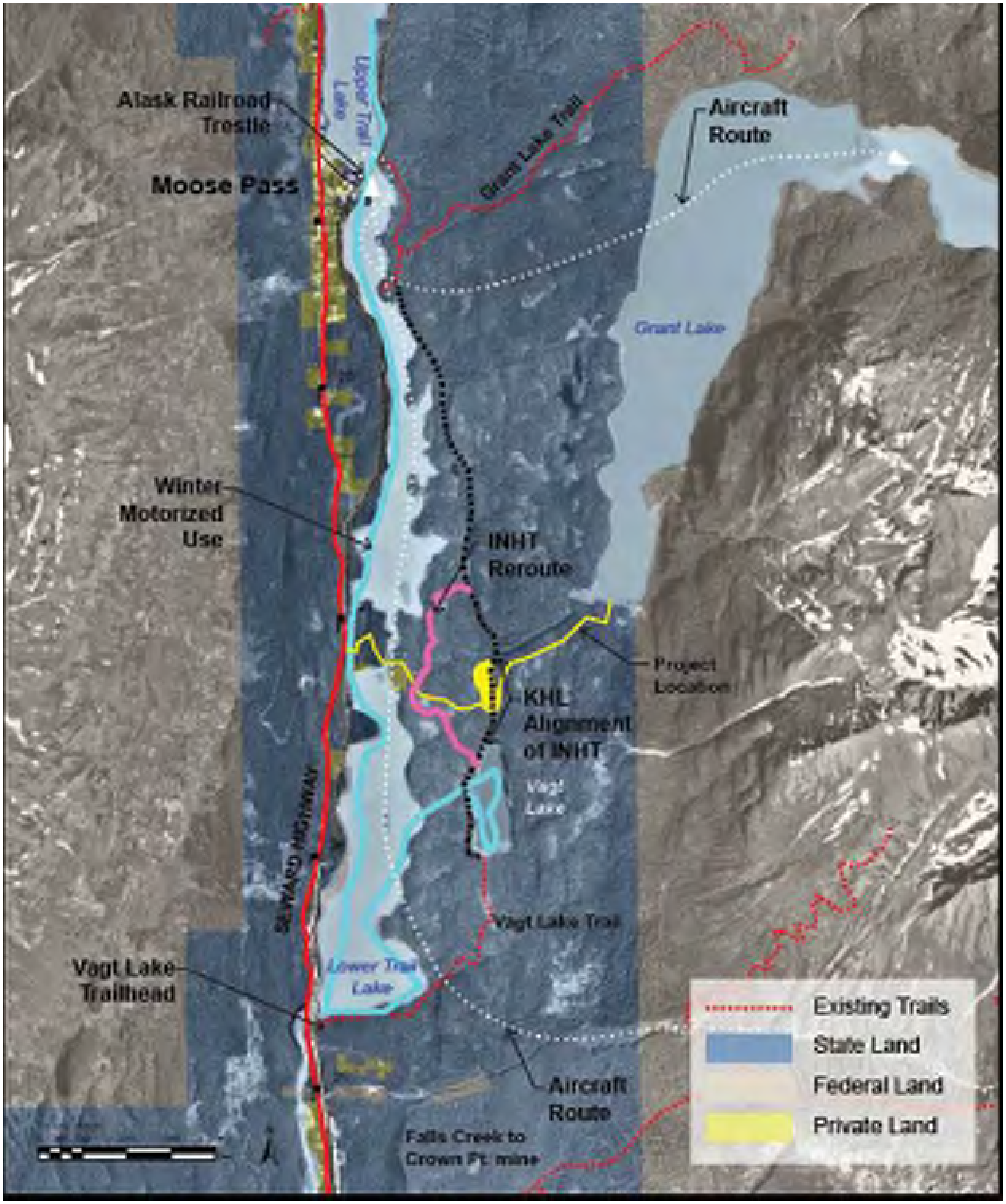

Figure 6.2-1. Recreation resources map.

6.2.1 Existing Observed Winter Use

During the winter survey, snowmachine users were observed unloading and parking at the Vagt Lake Trailhead and traveling northeast across Lower Trail Lake (Figure 6.2-2) to a partially flagged route through the trees up to Vagt Lake. An alternative start point was in Moose Pass, near an existing boat ramp. Other snowmachine users were observed traveling north-south along the western shores of both Trail Lakes and beyond across Upper Trail Lake toward Johnson Pass. Users did not ride through the Narrows as the water was open and flowing quite strongly through the area. This appears to be a normal phenomenon, keeping a portion of Lower Trail Lake open during the winter months. Open water was also observed at the Alaska Railroad trestle, located between Moose Pass and the rail line. Users traveled on the railroad tracks for passage around these open water areas. The Alaska Railroad Corporation signs the tracks and considers this use as trespassing.

Though there may be some use of Grant Lake for snowmachining, there was no evidence of trails leading to Grant Lake from trails along the Trail Lakes shoreline. Terrain challenges and the lack of a well-defined trail may limit the interest in snowmachining at the lake. However, it is expected that the mine access road that is north of Grant Creek may provide access to Grant Lake for snowmachining.

Baseline noise in the area measured consistently at 40 decibels (dB). Conditions during measurement included a gentle wind and background road noise from the highway. At the time snowmachine users passed by along the lake creating decibel readings that spiked to 75-80 dB.

Along the Vagt Lake Trail, local residents were observed hiking and snowshoeing as recreation. Cross country ski tracks were also found leading from the Vagt Lake Trailhead to Vagt Lake (Figures 6.2-3 and 6.2-4). Though it is difficult to identify the number of users, it appeared that snow had fallen within 48 hours and numerous tracks were observed. No further winter use was observed at the time of the survey.

Figure 6.2-2. Trail Lake.

Figure 6.2-3. Vagt Lake trailhead.

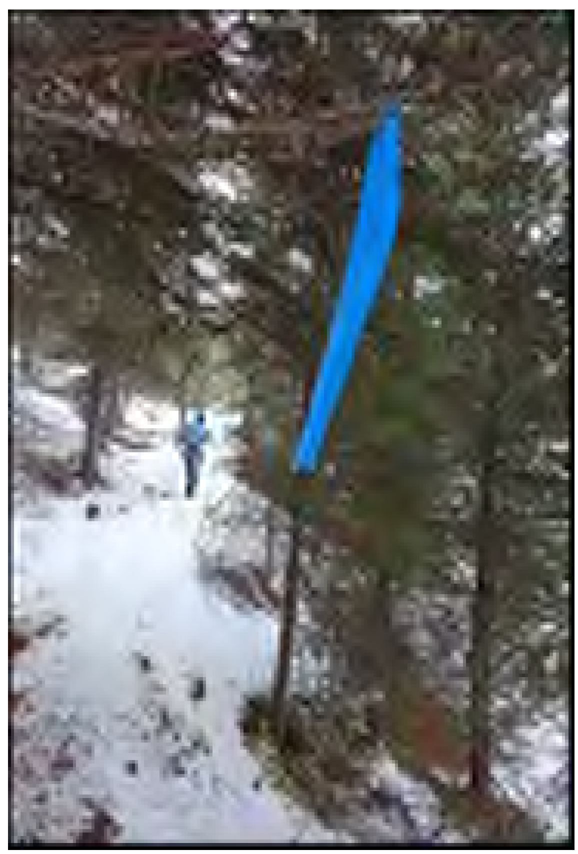

Figure 6.2-4. Trail near north end of Vagt Lake.

6.2.2 Existing Observed Summer Use

Summer uses included hiking on Vagt Lake Trail, camping at Vagt Lake, fishing in Upper Trail Lake, Lower Trail Lake, and Vagt Lake, some motorized all-terrain vehicle (ATV) activity on Grant Lake Trail, and small aircraft takeoffs and landings at Trail Lake. Additionally, the team providing fishery research for the Project noted approximately 12 anglers on Grant Creek, over the entire summer and fall data gathering period.

Boaters from Vagt Lake trailhead were observed floating down Trail River to Kenai Lake as well. Trail River does not provide the river experience nor the length of river to be a viable commercial float experience though some floating of the river does take place as a recreation activity.

Evidence of ATV use from Trail Lake to Grant Lake is shown in Figures 6.2-5 and 6.2-6. This activity is presumed to be in connection with mining activities in the area. Again, it is difficult to quantify the use but it is sufficient to maintain a clear and distinct trail.

Figure 6.2-5. Grant Lake trail.

Figure 6.2-6. Grant Lake Trail through meadow.

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At the time of the survey, noise levels ranged from 40 dB to 50 dB. No nearby motorized use was occurring during the inspection. Noise was generated from highway traffic, and though the Seward Highway had increased usage in comparison to the winter survey, noise levels did not exceed 50 dB.

Driving for pleasure, as with tourism-related bus traffic, is a key recreation activity along the Seward Highway corridor. Alaska Department of Transportation & Public Facilities (ADOT&PF) reports a range of average annualized daily traffic count ranging between 1,568 vehicles per day in 2012 to 1,614 vehicles per day in 2010 (ADOT&PF 2011). In 2012, this traffic had a highest “maximum average daily traffic count” of 3802 vehicles in July and a low maximum average daily traffic count of 611 in January. Most of these drivers and passengers are expected to be traveling partly to enjoy scenery, regardless of the primary reason for the trip.

6.3 INHT

The INHT is proposed within a dedicated easement inside of the Project area. In the effort to reconnect the Seward-Girdwood portion, an easement of 1,000 foot width was issued by the Alaska Department of Natural Resources (ADNR) in August of 2004. This is more specifically described in November of 2004 in the Final Finding and Decision, ADL 228890, Grant of Public Easement, Iditarod National Historic Trail, Seward to Girdwood (ADNR 2004). According to this document, the INHT will connect at MP 25, or the outlet for Lower Trail Lake and this trailhead will be upgraded with a parking lot to hold up to 50 vehicles. The trail continues north using the Vagt Lake Trail to the northeast tip of Upper Trail Lake where the trail crosses back onto federal land. There is some light use of the trail to Vagt Lake and there have been trail improvements from the south, to Vagt Lake, to accommodate this use. However, north of Vagt Lake the trail is merely flagged and use appears to vary from occasional to non-existent.

6.4 Sight-Seeing Flights (Aircraft)

Small aircraft provide sight-seeing flights several times a day in the summer months. The typical routes are from Moose Pass, over Grant Lake to Prince William Sound for viewing of the glaciers and Harding Icefield, then back to Moose Pass by flying over Falls Creek. Aircraft are typically float planes thast leave from Trail Lake (see Figure 6.4-1). These same aircraft are utilized for hunting and fishing purposes in the area. It has been noted that Grant Lake is not used as a fishing destination but is a drop-off location for hunting of mountain goats, caribou, bear, and moose.

Figure 6.4-1. Floatplane tie up, Trail Lake.

6.5 Hunting and Fishing

6.5.1 Hunting

Under the Alaska Department of Fish & Game (ADF&G), Grant Lake is within Game Management Unit 7 (Figure 6.5-1) which covers the eastern portion of the Kenai Peninsula. The area is open for black bear, brown bear, caribou, Dall sheep, moose, mountain goat, wolf, and wolverine. These hunts are permitted through the ADF&G, with regulations pertaining to residents and non-residents alike, and vary according to season.

Figure 6.5-1. Game Management Unit 7 map.

Table 6.5-1 reflects the harvested quantities of the game species as recorded by ADF&G in 2012.

Table 6.5-1. Harvest within Game Management Unit 7 (ADF&G 2013).

Species	Hunt Number	Hunters	Harvest
Black Bear	General Season	6,129	1,469
Brown/Grizzly Bear	RB300	389	25
Caribou	DC001	89	24
Dall Sheep	General Season	2,001	599
Moose	General Season	19,202	3,758
Mountain Goat	DG339	2	0

Although Table 6.5-1 encompasses a broader area than the study area. The amount of backcountry area and the terrain that is represented by the Grant Lake study area relative to full game management unit would suggest that the area is hunted for all or most of the game species indicated.

6.5.2 Fishing

Vagt Lake is an ADF&G stocked lake, making it an enticing destination for recreationists. The lake is a 2 mile walk from the Vagt Lake trailhead, allowing it to be a convenient and enjoyable walk through the woods around Lower Trail Lake. Preliminary discussions have noted that Grant Lake is not actively used for fishing as the only species known and/or documented to be in the lake are sculpin and stickleback. Grant Creek is fished for rainbow trout and Dolly Varden but is closed to the taking of salmon. During the seven month period of fish sampling conducted by fisheries biologists for the Project, approximately 12 fishermen were observed on Grant Creek.

6.6 Recreation Impacts and Potential Mitigation Opportunities

The Project is expected to have specific effects as described below.

6.6.1 Winter Use

With provision of road access to Grant Creek, it is expected that winter use will increase as a result of the safe passage around/over Trail Lakes and the development of a roadway to Grant Lake. Assuming KHL allows public access, it will be much easier for snowmachine users, skiers, and hikers to navigate over or around Upper and Lower Trail Lakes without the risk posed by open water. Dependent upon access provisions that are provided by the Project for public use, including parking, it is possible that Grant Lake would provide snowmobiling and ready access for those wanting to snowmobile on the lake and off into the headlands above the lake. While this presents opportunities for motorized and non-motorized winter recreation, it also expands the presence of humans and compromises the setting for those seeking quiet and solitude.

While recreational opportunities will increase, the provision of access to the public is an issue that will have to be negotiated between KHL and the USFS.

6.6.2 Summer Use

As with winter use, the summer use levels are expected to increase. If the establishment of a fifty car parking lot at the Vagt Lake Trailhead as proposed by the Grant of Public Easement for the INHT does occur, that alone will trigger an expanded use by user groups. Additionally, the bridge across the narrows, if provided, will provide quick and easy access for summer recreation around the Grant Lake area; something that is limited at present. Also, it may assist in lessening trespass that occurs on the Alaska Railroad crossing of Lower Trail Lake. The issue of access is an issue that will require coordination with management agencies as this ability to expand recreation use has the same effect as with winter use; greater recreation opportunity but greater presence of humans in an area that currently receives little use.

6.6.3 INHT

Currently, there is a conflict between the Project and the INHT with the powerhouse and ancillary facilities being located within the easement. While the current access road alignment limits crossings of the trail to one 90-degree crossing, under the current Project proposal, the INHT would essentially run directly through the middle of the powerhouse. For the safety of the public, it is expected that the Project may require security measures to prevent vandalism or damage and the structures and fencing may not be in keeping with the setting appropriate for the INHT.

The Project is in the process of proposing that the INHT be re-routed to the west, but still retain a 500-foot setback from the privately owned parcels located near the Trail Lake shoreline. This re-routed section would provide the desired buffer for the trail while giving users a more enjoyable views of the lakes. It also bypasses some marshy areas and exposes users to more distinctive landforms, water characteristics, and areas of outstanding scenic quality KHL is currently consulting with the requisite stakeholders related to this issue and a series of site visits and meetings will be held during the remainder of 2013 and 2014 to collaboratively reach an agreement on an acceptable re-route of the proposed trail around the single Project feature currently acting as an impediment. All consultation and agreements reached will be comprehensively documented in the FERC LA.

6.6.4 Sight-Seeing Flights (Aircraft)

It is not expected that sight-seeing flights will be affected by the Project. Although there will be temporary construction activity and changes to the landscape as a result of the Project infrastructure, sight-seeing users will still enjoy the lakes, rivers, mountains, and ice-fields that surround Moose Pass.

6.6.5 Hunting and Fishing

Impacts to hunting as a result of the Project include a possible increase in hunting pressure as a result of the proposed access road that would more easily facilitate access to Grant Lake.

Currently, most individuals are expected to gain access to hunted areas via float plane. A roadway that would allow hunters to either unload a boat at Grant Lake, or to easily hike up the road with a pack raft, would greatly increase the numbers of hunters that would hunt around Grant Lake and the surrounding backcountry.

There would also likely be an increase in fishing activity on Grant Creek. Currently, Grant Creek receives limited fishing activity due both to limited access and the lack of an open salmon fishery. The availability of a roadway that facilitates creek access would open the opportunity for trout and dolly varden fishing along the creek. While the fishery is assumed to be limited in the future to non-anadromous species, the availability of a creek on the road system would enable those fishermen who simply fish for the recreational experience and thus fishing pressure on the creek would likely increase.

6.6.6 Noise

Noise sources would include vehicles that are traveling the access roadway to the powerhouse and to the intake structure. However, the facility is proposed to operate remotely with access on a monthly basis during normal operational periods. For those limited visits, sound levels at 50 feet from the source of pickup trucks and automobiles would range in the neighborhood of 70-80dB (Reed 2010). Thus recreation users of the roadway or the INHT would be subjected to short periods of noise above that of the ambient noise of 40dB in the winter and 40-50dB in the summer.

The provision of a roadway may induce snowmachine traffic to the roadway and may also induce an increase in use of Grant Lake and the surrounding areas. Snowmachines generate sound levels as high as 83dBA at 50 feet from the source (Reed 2010) and the sound can be detrimental to the experience of non-motorized users in an area. While this is a moderate to major impact to that use, the use of Grant Lake by non-motorized users tends to be small to absent in the winter in particular, thus the overall impact to existing conditions would be relatively small.

6.6.7 Construction

Construction impacts would be temporary and would affect trail use and fishing along Grant Creek. The presence of construction equipment and construction noise would provide a short-term but major impact to the environment desired by those recreating along the creek. Construction is planned to take place only in the summer months, thus noise and lighting impacts during the winter months, would be limited. Noise impacts would be expected to some degree in the summer though the construction site is generally removed from residences and visitor destinations, depending on the individual part of the infrastructure that is being constructed.

6.6.8 Compliance with Current Management Plans

The proposed facilities will have a relatively minor effect to existing recreation use in the area. Project facilities are located beyond the 200-foot buffer proposed by KRSMA. Because the lands are retained in State ownership for purposes of habitat protection, there is no prescribed 200 foot buffer in the Kenai Area Plan. Still, the roadway and Project facilities would be located on State of Alaska land that is proposed for habitat protection and recreation uses. Proposed facilities could enhance the ability to meet recreation goals with the provision of increased access to trail and backcountry resources, though there would be some limited compromise of habitat protection goals in order to provide for the road and transmission line.

This may not fully meet management intent of Chugach National Forest for lands that are designated and managed as “backcountry”. These areas are available for non-motorized recreation, however the provision of road access to Grant Lake may induce increased use of the backcountry for snowmachining. While the numbers of non-motorized users is small, this may not be in conformance with the management intention of the USFS.

6.6.9 Recreational Opportunities

The proposed Project provides an opportunity for increased recreation access to the area. The access road could provide Grant Lake access that is currently difficult and unavailable to many recreationists. Having the access could increase boating opportunities and access to backcountry that provides spectacular views and wildlife viewing. The Project could also allow increased access to hunters, allowing quicker access to background peak areas. The Project could provide parking to facilitate use of both hiking to Grant Lake on the Project access roadway, and to the INHT.

While the opportunity for increased recreation activity is provided, this has a negative aspect of possibly increasing the evidence of humans within this area of forest and on Grant Lake. Wilderness areas are managed for their pristine conditions and their lack of the evidence of human disturbance. If an increase in recreational opportunities is undesirable, a gate could be installed on the access road at any point to limit access to authorized personnel only. Close coordination with agencies will be needed to determine how access will be managed to meet agency goals.

7 COMPONENT 2 – VISUAL RESOURCES

The USFS document *Landscape Aesthetics, A handbook for Scenery Management* provides an established guide for the analysis of landscapes, and furthermore, provides a useful framework for review of scenic quality (USFS 1995). The process employs steps for the definition of landscape units as “ecological units” and provides guidance for defining “viewer groups”, “landscape character”, “scenic integrity”, and “scenic classes”. From this collected process, the resulting information is used to determine the impacts to visual resources by the proposed Project.

Landscape components are the physical elements that make up the visual environment, including landform, water, vegetation, and man-made development. The general landscape setting of the Project area is characterized by numerous mountains, rivers, lakes, alpine tundra, and taiga forest. The area is strongly characterized as being a classic “U” shaped glacial valley, and the junction of east-west and north-south drainages. The drainage flows north to south from Upper Trail Lake into Kenai Lake and the Grant Lake drainage from its mountainous backdrop, east to west to its connection to Trail Lake. The Project area landscape character ranges from the developed small road community of Moose Pass to primitive backcountry with pristine lakes and serrated alpine peaks.

7.1 Ecological Units

To provide a framework for analyzing the visual environment, three landscape units have been identified based on the interaction of existing land use patterns, topography, and distance from the Project. Each unit is defined with respect to its scenic attractiveness and scenic integrity and identification of these units is an important key to analyzing the visual effects of the Project. The respective units and associated matrix are documented in Figure 7.1-1 and Table 7.1-1, respectively.

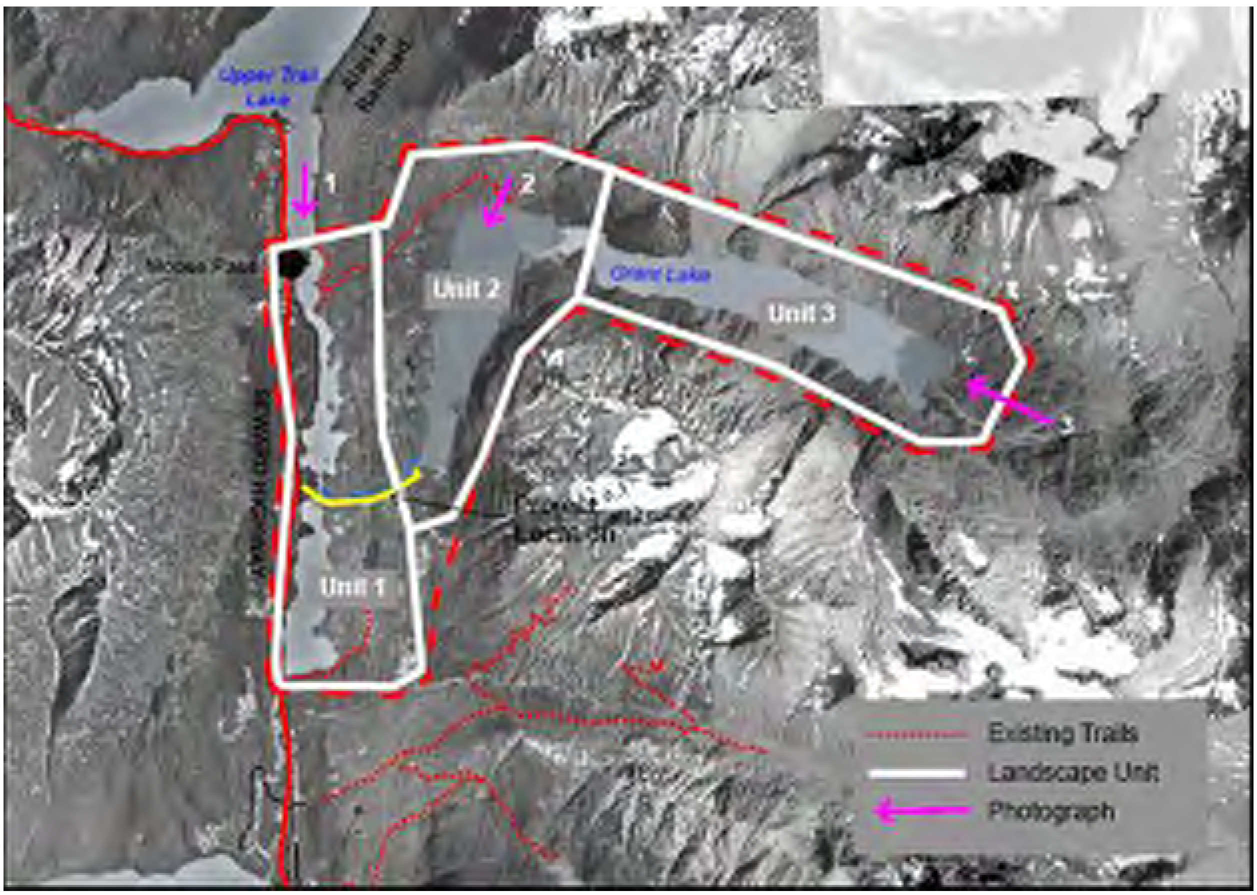

Figure 7.1-1. Unit key map**.**

Table 7.1-1. Unit key matrix.

Unit	Title	Description	Elevation
1	Trail Lakes Valley	Corridor of Trail Lakes valley from Moose Pass to Lower Trail Lake bridge	Lake level to ~300 feet above
2	Grant Lake West	Western half of Grant Lake	Lake level to ~300 feet above
3	Grant Lake East	Eastern half of Grant Lake	Lake level to ~300 feet above

7.2 Viewers

There are three major types of viewer groups or constituents in the Project area. The groups were identified based on the existing land uses and travel routes. Table 7.2-1 identifies the viewer groups and their expectations and values for the viewshed of the Project. These viewers are described in terms of their "concern levels". "Concern levels are a measure of public importance placed on landscapes viewed from travelways and use areas." (USFS 1995) There are three concern levels, with high (1) denoting those viewers who would have high interest in the surrounding landscape.

Table 7.2-1. Viewer group and expected values for the viewshed.

Viewer Group	Expected Values
Residents	Generally have a desire for protection of visual quality, including views from roadways, waterways, and individual residences. Generally cautious concerning changes to visual environment.
Recreationists/ Tourists	Includes both road and rail traffic. Generally have high appreciation for visual quality of an area and desire for undisturbed areas. Also share a desire for views from roadways and waterways.
Aircraft	High variability in visual values and the acceptance of changes to existing visual conditions. Many are sight-seers with high degree of sensitivity to visual quality.

There are variations in the number of residents, recreationists, tourists, and viewers from aircraft throughout the year. Summer months are typically characterized by a significant increase in viewers, particularly as a result of tour travel, as well as fishing and hunting activities. This visitor population drops drastically after these seasons have passed into the winter months. Both numbers of on the ground viewers and the air traveler populations are much lower during winter and early spring. Float planes, which are docked on Upper Trail Lake during the summer months, are removed from the lake in the winter. There is little small aircraft traffic in the winter compared to numbers of float plane takeoffs and landings that occur from May through September. These visitors typically have a high level of appreciation for scenic values and scenic integrity. In fact, it is these values that bring them to visit this area.

The population of Moose Pass is generally stable through the entirety of the year. The State of Alaska Department of Labor and Work Force Development (2013) reports 219 residents in Moose Pass in April of 2010, 240 residents in July of 2011, and 231 in July of 2012. This would seem to indicate relative stability given that April is more indicative of winter conditions than summer conditions in Moose Pass. The residents of Moose Pass can be characterized as treasuring their "small town" culture and the environment in which they are located. They have a high value for the setting in which the town is located and have a high level of value for scenic integrity.

Seward, located approximately 25 miles south of Moose Pass, experienced approximately 355,000 visitors in the Summer of 2011 (McDowell 2011). Virtually all of these visitors pass through Moose Pass by either road or rail. Rail passenger service is only available in the summer. A majority of the road traffic passes through the community in the summer months as well. In 2012, this traffic had a highest "maximum average daily traffic count" of 3802 vehicles in July and a low maximum average daily traffic count of 611 in January (ADOT&PF 2013).

There are a number of recreationists who travel on the eastern side of the valley via trails or on Trail Lakes in the winter. Most trail use is limited in the Vagt Lake area, to the south of the Project components. Winter use within the Project area is generally confined to the Vagt Lake area or is located on the Trail Lake frozen surface and includes snowmachiners, snowshoers and skiers. There are a small number of fishermen who travel along the Grant Creek bank but the number is quite limited as salmon fishing is restricted on the creek. There is evidence that some residents/recreationists hike along Grant Creek though the size of the trails indicate that this use is very limited. These recreationists typically have a high level of appreciation for the conduct of their recreation activities and value the undisturbed setting.

Hikers typically gain access to Grant Lake via the Grant Lake trail which is located north of the Project and provides access to a mine site located at the northern corner of the lake. There are also known to be some recreationists who fly small boats or pack in rafts for traveling along the shoreline of Grant Lake. Some of these include hunters trying to gain access to remote areas to the north and west of Grant Lake. Both hikers and hunters value the setting of their recreation pursuit and prefer an undisturbed landscape.

7.3 Visual Character

7.3.1 Landscape Visibility

Landscape visibility addresses the relative importance and sensitivity of what is seen and perceived in the landscape. It consists of three elements:

- Travel ways and use areas
- Concern levels
- Distance zones

Landscape visibility is also a function of several other considerations, including:

- Context of viewers
- Duration of view
- Degree of discernible detail
- Seasonal variations
- Number of viewers.

The first area of analysis involves determining whether the Project area can be seen from travel ways and use areas. Travel ways represent linear concentrations of public viewing. Use areas are specific locations that receive concentrated public viewing. For this Project, primary travel ways and use areas include the road system running north-south along the western shores of Trail Lakes. Secondary travel ways include the small aircraft sight-seeing routes from Upper Trail Lake west to Prince William Sound and back.

As discussed in Section 7.2, viewer concern for their surroundings is an important part of the analysis of the importance of visual quality impacts. As described, almost all viewers have a high sensitivity to either the presence of undisturbed landscapes, or sensitivity to changes of the landscape as viewed from their homes. Thus the concern level of almost all viewers of the landscape is considered to be high, being a concern level of “1”.

7.3.2 Distance Zones, Viewer Exposure, and Seasonal Variations

Distance zones define the viewing distances of the viewer. The zones are noted as foreground, middleground, and background. The viewing distances are based on the amount of details that the observer can perceive. Distance zones help determine what portions of the landscape are more critical to the visual character and what areas are more sensitive to change. For example, travelers on the highway are more aware of changes to the foreground of the landscape than the background, given the same level of change of the landscape. Table 7.3-1 better defines distance zones.

Table 7.3-1. Distance zones (USFS 1995).

Distance Zones	Distance	Description	Distance Zones	Distance
Foreground (fg)	0 – 0.5 miles	Distinguish vegetative detail and full use of senses	Foreground (fg)	0 – 0.5 miles
Middleground (mg)	0.5 – 4 miles	Distinguish large boulders, small openings in the forest	Middleground (mg)	0.5 – 4 miles
Background (bg)	4 miles to horizon	Distinguish groves of trees, large openings in the forest.	Background (bg)	4 miles to horizon

This Project is dominated by Foreground and Middleground distance zones. Almost all views are from the valley floor and the natural topography obscures views of most background areas east or west of primary view areas. Views are available to background to the north and south, but only to the tops of peaks to the east, east of Grant Lake.

Viewer exposure is a function of the type of view seen; the distance, perspective, and duration of the view. The term exposure may also refer to the number of people exposed to a particular view. It is expressed by the numbers, distance, duration, and speed of view for each of the Viewer Groups. Table 7.3-2 outlines viewer groups and the associated exposure periods based on observations of their use patterns and use periods.

Table 7.3-2. Viewer groups and exposure period.

Viewer Group	Exposure Period
Residents	Continual
Recreationists/ Tourists	Varies-generally minutes, hours for fishermen on Grant Lake and hunters in Grant Lake basin
Aircraft	Varies-generally seconds or minutes

Seasonal variations are characterized by leaf loss within the Project area between summer and winter conditions. Summer foliage tends to obscure views with restriction of views beyond a distance of as much as several hundred feet for undisturbed areas. Also, the presence of foliage tends to provide screening of some views from the Seward Highway across Trail Lake. These views are extended to greater distances, across the lake, during winter months.

Winter months provide greater contrast of manmade disturbances since disturbed lands provide planes or lines that are visible since a lack of vegetation provides a strong contrasting line or plane within the landscape. This depends on whether vegetation between the viewer and disturbance obscures or modifies the view.

7.3.3 Scenic Attractiveness

There are three values used to describe the scenic attractiveness of an area. These classes are developed to determine the relative scenic value of landscapes. They measure the scenic importance of a landscape based on human perceptions of intrinsic beauty of landform, water characteristics, vegetation pattern, and cultural land use. Table 7.3-3 characterizes scenic attractiveness classifications.

Table 7.3-3. Attractiveness classes and description (USFS 1995).

Class	Title	Description
A	Distinctive	Areas where landform, vegetative patterns, water characteristic and cultural features combine to provide unusual, unique, or outstanding scenic quality. These landscapes have strong positive attributes of variety, unity, vividness, mystery, intactness, order, harmony, uniqueness, pattern, and balance.
B	Typical	Areas where landform, vegetative patterns, water characteristics, and cultural features combine to provide ordinary or common scenic quality. These landscapes have generally positive, yet common, attributes of variety, unity, vividness, mystery, intactness, order harmony, uniqueness, pattern, and balance. Normally they would form the basic matrix within the ecological unit.
C	Indistinctive	Areas where landform, vegetative patterns, water characteristics, and cultural land use have low scenic quality. Often water and rockform of any consequence are missing in class C landscapes. These landscapes have weak or missing attributes of variety, unity, vividness, mystery, intactness, order, harmony, uniqueness, pattern, and balance.

7.3.4 Scenic Classes

Scenic classes indicate the relative importance, or value, of discrete landscape areas having similar characteristics of scenic attractiveness and landscape visibility. Scenic classes are determined using the matrix in Table 7.3-4.

Table 7.3-4. Scenic class matrix (USFS 1995).

Scenic Attractiveness	Distance Zone and Concern Levels		
	Fg1	Mg1	Bg1
A	1	1	1
B	1	2	2
C	1	2	3

7.4 Landscape Analysis Discussion

7.4.1 Unit 1: Trail Lakes Valley

The Trail Lakes Unit includes almost all travel ways and viewers, except some of those traveling by aircraft. It also includes recreationists using trails or fishing the shoreline of Grant Creek. Further it would include those traveling on the frozen surface of Trail Lake in the winter. Residents, recreationists, and aircraft have varying degrees of visibility for this unit, as their exposure is fluctuating from a few seconds to continual. Their concern level and exposure periods provide a high level of sensitivity to changes in the viewshed.

The area is characterized in Figure 7.4-1, with a long view to the south down Upper to Lower Trail Lakes, with Kenai Lake far in the background. Travel patterns of viewers are shown in Figure 7.4-2. Viewers are primarily residents of Moose Pass and travelers on the Alaska

Railroad or Seward Highway. Viewers are afforded foreground views, and the area has a highly distinctive scenic attractiveness, or Class A as defined in Table 7.3-3. Most views are foreground due to the enclosed nature of the Trail Lake basin. Background views are occasionally available with breaks in vegetation for those traveling on the Seward Highway or the Alaska Railroad, or living in Moose Pass. Shoreline vegetation tends to be deciduous, mixing with conifers with increasing elevation, turning to a primarily coniferous forest up to the u-shaped valley crest. Views are provided to alpine settings in the background. The landscape is typified by forest, dominant water features of high complexity and high level of order, and low density development in Moose Pass that tends to be of small scale and complementary to the landscape. The landforms, vegetative patterns, and water characteristics are intrinsically unique, with the majority of the existing landscape well preserved.

Figure 7.4-1. Looking south across Trail Lakes toward Kenai Lake.

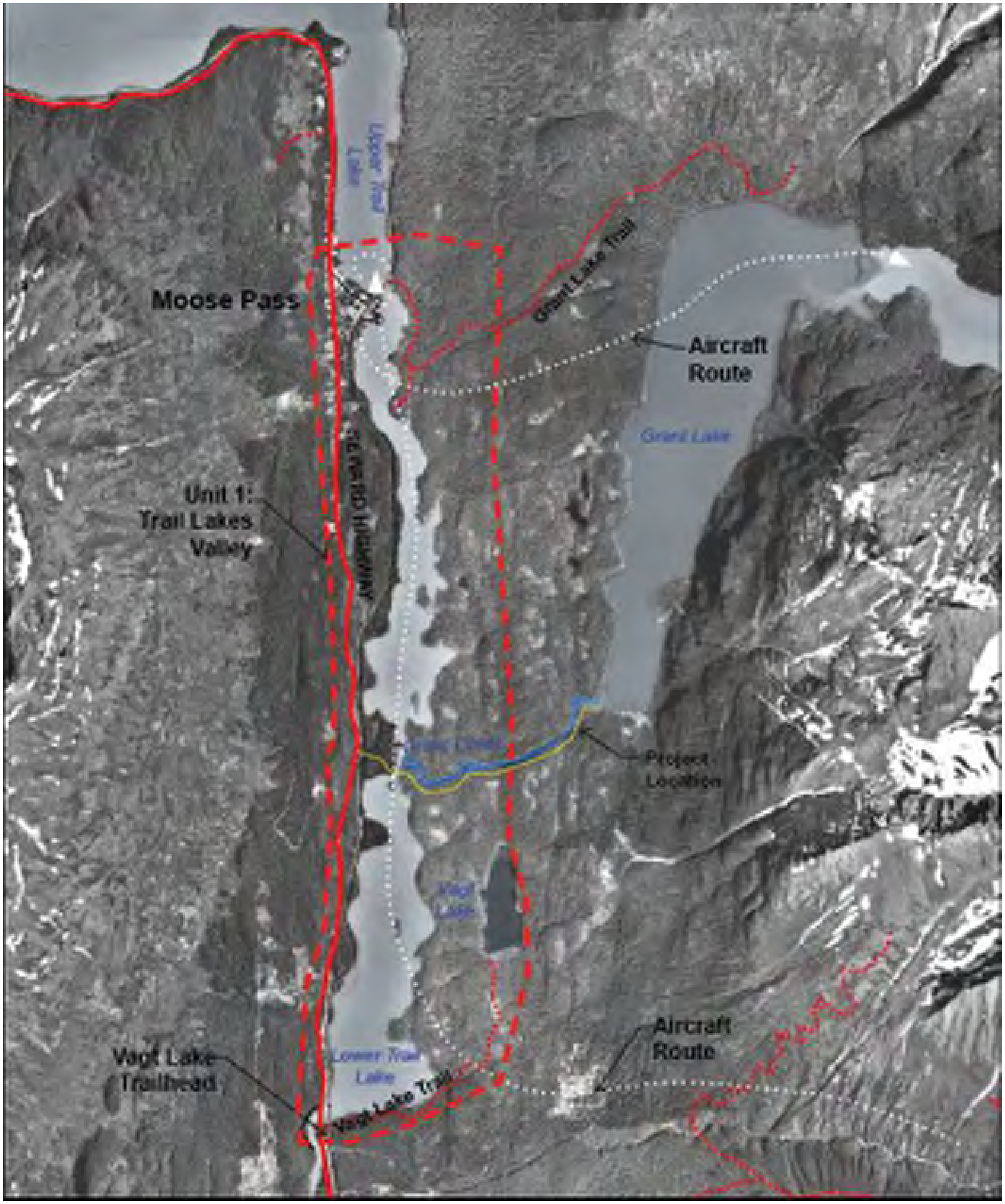

Figure 7.4-2. Unit Map 1: Trail Lakes Valley.

Project components within this area include the access roadway, the powerhouse, possibly transmission lines, ancillary support structures including parking, fencing, rock-lined channel, and the auxiliary detention pond.

The roadway entrance and a short portion of its length would be visible from the Seward Highway and the Alaska Railroad. Other Project components would be visible to those who fish Grant Creek and to the limited number of hikers who may on occasion follow the creek. The natural topography of the unit does offer enough variation to allow some features to blend more, or to be masked by the undulating landforms and density of the vegetation. This provides screening of proposed Project components, which will be seemingly hidden or concealed within the landscape for almost all viewers.

7.4.2 Unit 2: Grant Lake West

The Grant Lake West landscape unit is highly distinctive (Class A as defined in Table 7.3-3), and virtually fully intact with little to no evidence of human presence, as shown in Figure 7.4-3. This view is from the north, looking south towards the project features, specifically the outfall of the lake. Figure 7.4-4 illustrates travel patterns for those who visit this unit. The area has few viewers, no residents within the unit, and recreationists/tourists restricted to either those using the limited amount of trail access or those viewing the area by aircraft. The viewer exposure period ranges from hours for those traveling by trail or seconds/minutes for those traveling by aircraft.

This unit is characterized by Grant Lake and the surrounding mountains. The limited number of viewers located within the area would have foreground views. However, for most viewers, who are located in Moose Pass or on the road/rail corridor, the area is unseen. Vegetation remains an evergreen and deciduous forest around the lake and dissipates into alpine tundra with elevation. Large openings provide a mix of perennial herbaceous plants, with numerous Alaskan wildflowers.

Figure 7.4-3. Looking south across Grant Lake from Grant Creek Trail.

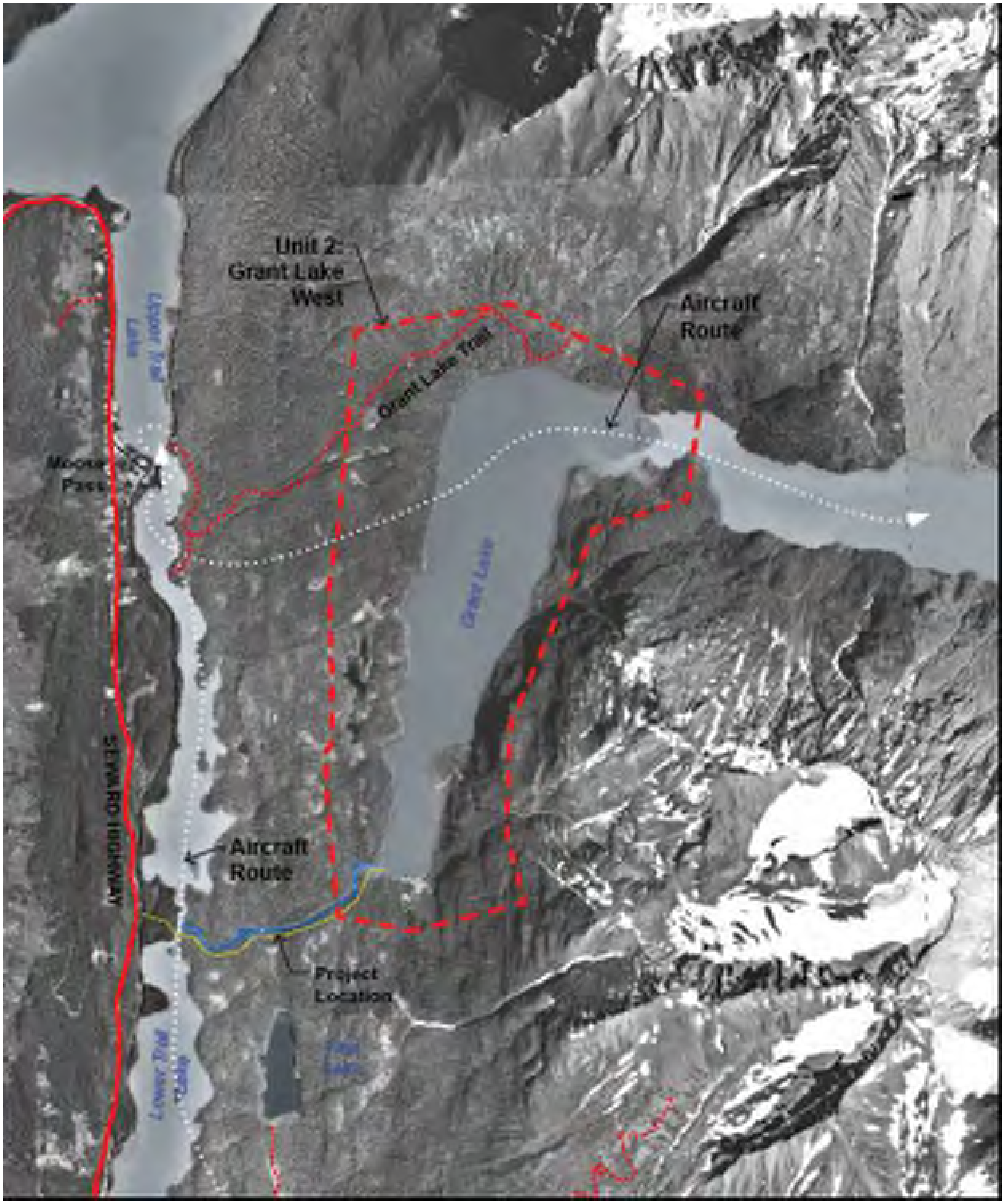

Figure 7.4-4. Unit Map 2: Grant Lake west.

Project components that would be located within the area would include the Project's intake structure and the access roadway, located at the southerly most portion of the lake, near the Grant Lake outfall. These components would generally be unseen by those along the lake shore. The intake structure would be seen by boaters who currently gain access via packraft or plane. It would be seen in the middleground for those who hike around the lake and can view the opening of the lake to Grant Creek. Aircraft would be able to see the structures as well though the exposure time would be limited.

7.4.3 Unit 3: Grant Lake East

Naturally obscured by the sharp easterly turn of Grant Lake, this eastern portion of Grant Lake is a u-shaped valley that feeds to the previously discussed unit, separated by a thin neck of water. The valley is entirely undisturbed as in evidence in Figure 7.4-5. The distance from this unit to the Project is approximately 3-6 miles with no direct line of sight to Project components.

Viewer exposure is restricted to aircraft and the occasional recreationist and/or hunter who may access the area by trail and possibly travel by packraft (Figure 7.4-6). Aircraft views are typically from relatively high elevations and duration of the view changes dramatically dependent upon altitude and weather. These groups may include hunters as well. Though the area does not contain any Project components, proposed lake level changes may create a visual variation that may be noticeable by those gaining access to the area. Seasonal flows currently provide for some variations in lake levels thus an exposed shoreline does occur during the year. The lower level attributed to the KHL would persist for more periods of time though the character would be similar to that of historic patterns, perhaps slightly pronounced.

Figure 7.4-5. Looking west across Grant Lake.

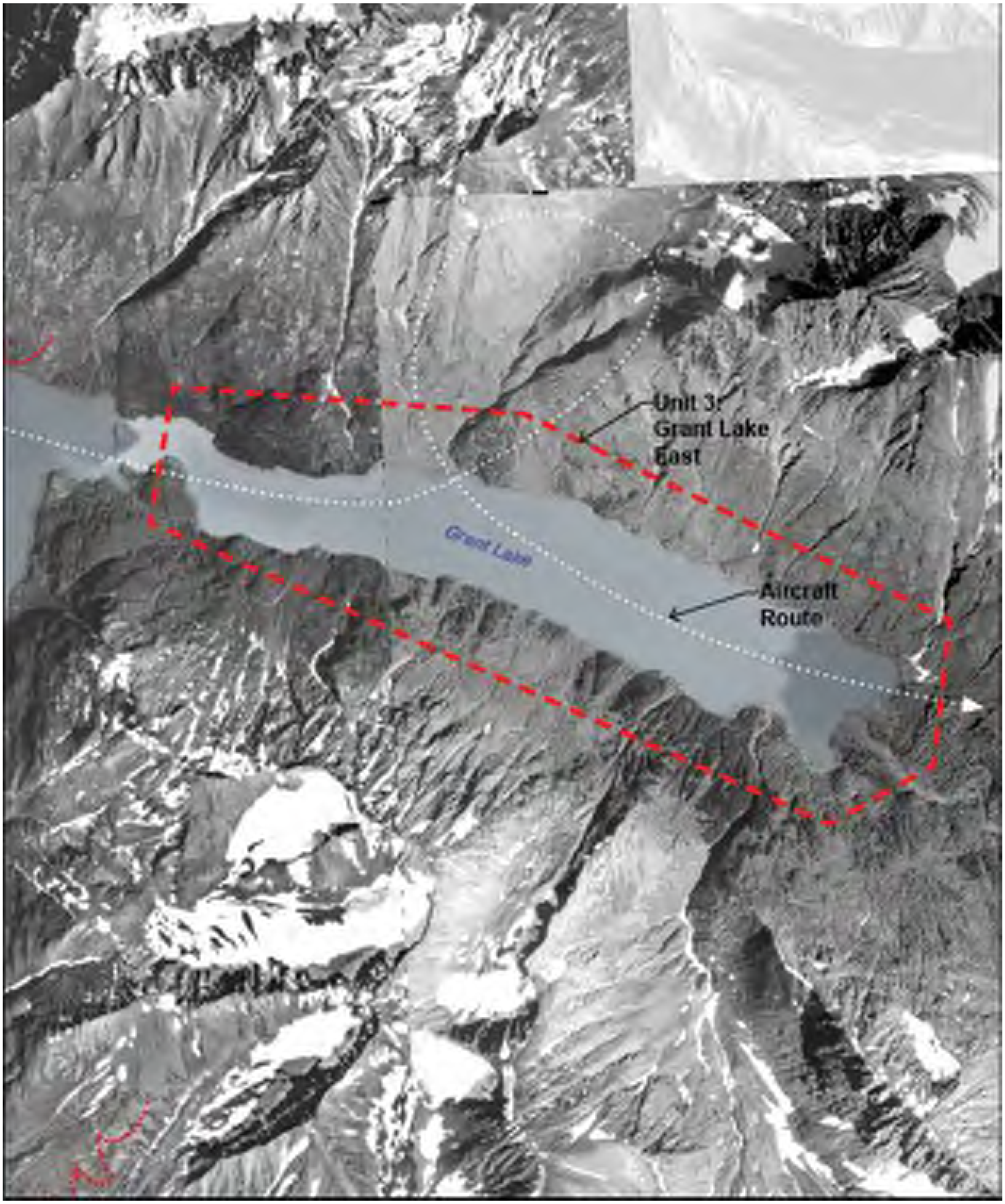

Figure 7.4-6. Unit Map 3: Grant Lake east.

The scenic attractiveness of the viewshed remains distinctive, or Class A per Table 7.3-3. Peaks provide a serrated skyline with a complex mix of snow, valleys, and well-patterned vegetation.

The area is a pristine wilderness with unique landforms and water features. Vegetation is sparse, with forest surrounding the lake and covering the valley floor, with alpine tundra at upper elevations.

7.5 Views

For the purposes of showing potential Project impacts, key views were selected and developed to create visual simulations. The following key views were selected as having the most valuable potential in showing Project components and visual impacts. The location of these key views is indicated in Figure 7.5-1.

- Key View 1: view of the Trail Lakes narrows access road crossing area from the Seward Highway
- Key View 2: view of the intake structure and lake shoreline
- Key View 3: view of proposed facilities from the Seward Highway or Alaska Railroad (winter)
- Key View 4: view of the access road or powerhouse from the right-of-way for the proposed INHT.

Figure 7.5-1. Location of key views.

7.5.1 Key View 1: Access Road from Seward Highway

Key view #1 is the view of the Project access road from the Seward Highway. The new access road leaves the Seward Highway at approximately MP 26.9, crosses the Alaska Railroad tracks, then continues east to the proposed bridge.

The highway corridor between Lower Trail Lake and Upper Trail Lake tends to be viewed as a “closed forest” as the existing vegetation blocks the majority of viewing points along the road. Moreover, the narrowness of the road leads the viewer’s eye forward until the vegetation recedes at both Lower Trail Lake and Moose Pass itself.

This access road may become more visible with the winter months and loss of foliation; however, the scale of the roadway would be similar to that of a driveway which is a common feature along the highway. There is an existing driveway to private land approximately 100 yards south of the proposed new roadway. It is expected the existing roadway would be closed and the old entrance maintained as a turnoff as shown in the before/after visual simulation in Figures 7.5-1 and 7.5-2) One issue that could increase the visual presence of the road would be an agency decision that would open the KHL Project access to wide public use. If public access is desirable by agencies, the roadway could have an increased presence and be marked by road signs and possibly the width of the roadway increased to offer vehicle turn lanes. Figures 7.5-2 and 7.5-3 display the current view and the likely view with the Project component (access road) in place, respectively, with the assumption that the roadway will be non-public.

Figure 7.5-2. Key View 1: before.

Figure 7.5-3. Key View 1: after.

7.5.2 Key View 2: View of Intake Structure and Lake Shoreline

This key view simulation shows the small intake structure located at the southern shores of Grant Lake, the diversion dam to the west, the remaining stream and stream bed once diverted, and the small access road to the intake structure. Also with in this view is the powerhouse itself, the detention pond, and the outlet diversion. Each Project component is linked by a small gravel road, with the upper access road not maintained in the winter. The current Project design has the level of the lake rising up to two feet above natural conditions , but as the edges of the lake are quite steep, the effect will be less noticeable as the change does not widen but simply raises the level of the lake in this area. Over time there may be a recognizable ring of vegetation as flooded vegetation at the shoreline edge dies out and becomes evident. However, there are currently natural seasonal fluctuations of the lake level that provide an exposed shoreline at low water levels thus the new condition will be an small expansion of an existing condition that occurs on the lake. While this will be discernible on the ground and may be noticeable, it will be less so, if evident at all from the air. Figures 7.5-4 and 7.5-5 display the current view and the likely view with the Project components (lake infrastructure) in place, respectively.

Figure 7.5-4. Key View 2: before.

Figure 7.5-5. Key View 2: after.

7.5.3 Key View 3: View of Facilities from Seward Highway

As the highway corridor is quite narrow, and the vegetation impedes most views, the only open areas whereby a viewer from the Seward Highway would have a vantage point of the Project would be near Lower Trail Lake. The bridge crossing, powerhouse, and primary access road will not be visible to most viewers from the Seward Highway. The upper access road connecting the powerhouse to the intake structure may be more visible, as it climbs in elevation, however most vegetation is evergreen thus it is not expected that the roadway will be visible to most Seward Highway viewers in the summer or winter. Figures 7.5-6 and 7.5-7 display the current view and the likely view with the access road being slightly visible climbing the hillside in the right-center of the photo, in the distance. The change would be negligible, particularly considering that viewers at this location are traveling at a speed of approximately 50 miles per hour. Drivers are focused on views down the road while passengers are focused on more visible landscape of the lake and Crown Point Peak, more to the east, 45-90 degrees to the location that the access road would be.

Figure 7.5-6. Key View 3: before.

Figure 7.5-7. Key View 3: after.

7.5.4 Key View 4: Access Road or Powerhouse from the Right-of-Way for the Proposed INHT

The INHT trail will intersect with the powerhouse access road, intersecting south of Grant Creek and east of Lower Trail Lake. This intersection would be a marked intersection that would provide views to an opening in the forest allowing more visibility and exposure to the Project. This intersection could serve as a trailhead in the future dependent on the desire of managing agencies. Figure 7.5-8 displays the current view and the likely view with the Project component (access road) in place respectively. In the simulation, the access road is illustrated at a crossing of the INHT and assumes a gravel surface for both the trail and the road at this crossing location. A sign would provide direction for hikers and other users.

Figure 7.5-8. Key View 4: before and after.

7.6 Visual Impacts and Potential Mitigation Opportunities

The Grant Lake Project area is a highly distinctive, well-seen, and valued area of the Kenai Peninsula. Of particular note is that much of the landscape is undisturbed and much is little used and is unseen by most people. Following is a summary of key observations.

Landscape Character: The landscape of the Project area is characterized by complex mountains with serrated ridgelines and a highly ordered landscape. Water features are striking with turquoise waters and clear streams that provide marked contrast with the colors and patterns of the forest. Vegetation is typical of the area, primarily of a mixed deciduous/coniferous forest that leads to high altitude alpine vegetation that is highly patterned and colorful, contrasting with geological features and scree slopes. The community of Moose Pass is also distinctive, and is small scale, in keeping with the landscape. The area is highly memorable.

Scenic Attractiveness: The landscape remains a Class A, or distinctive landscape (as previously defined in Table 7.3-3) throughout the Project area. The foreground, middleground, and background each are unique and attractive to viewers.

Scenic Integrity: The majority of the Project area is intact and undisturbed, allowing for a high level of scenic integrity. Currently, the only evidence of human presence is associated with the road and rail corridor, including the community of Moose Pass. While these elements provide evidence of human presence, the roadway, the railway, and the community of Moose Pass are within scale and context of the setting.

Viewer Groups: Residents, recreationists/tourists, and aircraft are the primary viewers of the Project area. Most views are constrained to the Seward Highway, the Alaska Railroad, and residents of Moose Pass, and those who travel by snowmachine, skis, snowshoes, or on foot.

Landscape Visibility: The Project area is viewed by the viewer groups from all distance zones; however, the natural topography of the area limits distance zones to the foreground for most viewers.

Concern Levels: Concern levels are high, as the area is used and viewed by a wide range of viewers, all of whom value the area for its high visual quality and intactness.

Scenic Class: The scenic class and the scenic attractiveness of the area remain at the highest level of 1, due to the unique landforms, vegetative patterns, and outstanding topography, and thee concern level of the viewers.

7.7 Project Effects

7.7.1 Project Components

Intake Structure: The intake structure would include a gravity diversion structure and intake tower that would be approximately 15 feet above the lake surface. The structure would be hidden for most viewers excepting the small number of those traveling along the shoreline by boat, or by those traveling above the lake by aircraft. The structures would be minor elements in the landscape. The concrete tower would contrast with the lake surface providing a striking light color against the turquoise waters of the lake. However, the size of the structure relative to the lake, as seen from the air provides a minor change to the landscape.

Shoreline Alteration: The change in lake level could provide evidence of vegetation die back as the vegetation adapts to changing lake levels. This vegetation as it dies, or the remaining shoreline as the lake level changes, would provide an expanded shoreline around the lake. While this could occur, there are currently natural seasonal fluctuations at the shoreline edge and during drought conditions the shoreline currently is visible as an exposed edge, thus the possible shoreline expansion would be an increase to the visibility of the shoreline rock edge, not a new condition. This will be visible to those traveling by foot but less conspicuous to those traveling over the area by plane. This would be a minor change to the shoreline landscape.

Access Roadway: The access roadway would be visible from the Seward Highway, from the Alaska Railroad tracks, and for those traveling by boat, raft, snowmachine, snowshoe, or skis on Trail Lake. It would also be visible from the air. It would generally be unseen by residents of Moose Pass. From the Seward Highway it would read as a side road or driveway intersecting the highway, a common element along the roadway. The road would also be seen by those who would use the INHT at the time that construction takes place. At this point in time, the INHT is a dedicated easement but not constructed. For those affected, the bridge crossing of the Trail Lake narrows would be similar in scale and scope to that of the Alaska Railroad crossing that currently exists. The roadway would continue into the forest and only several hundred feet would be visible for users along Trail Lake. Thus the roadway would be a moderate change to the landscape though generally unseen by most viewers.

Auxiliary Detention Basin: The detention basin would generally be unseen except from the air. It would be seen from the INHT as mapped, though not constructed at this time. The basin would generally be confined within an existing depression in the landscape. Thus, the form of the feature would approximate that of the existing landscape. However, the fluctuating water levels will change the nature of the vegetation as the vegetation adapts to growing conditions. There would also be minor site structures that would be associated with the detention basin, pipes, and infrastructure. These structures and the changes to the landscape would be moderate changes to the landscape but would be largely unseen, depending on whether the INHT easement is relocated or not.

Powerhouse/Ancillary Features: The powerhouse would be a visible, man-made structure in a natural setting as would other components such as parking and associated channels and site structures. They would not replicate the area’s landscape in form though the Project components could be colored or painted to be complementary to the landscape. The components would be unseen by most viewers excepting those hiking, skiing, snowshoeing, or fishing along Grant Creek. It would also be evident to those hiking along the INHT, should it be constructed as currently planned.

Powerlines: The proposed Project has yet to define whether powerlines would be above or below grade. Currently, the only transmission lines within the Project area are those located west of the community of Moose Pass, largely out of view of the casual observer. Underground lines would generally be unseen, excepting where a powerline might tie to the existing powerlines west of the Moose Pass community and the occasional ancillary facilities that are assumed to be minor structures in keeping with the scale of the community. The construction of powerlines above ground could possibly present an impact to visual resources, dependent on their location. While other Project facilities would be screened by existing vegetation or replicate existing visual features in the Project area, the powerlines would contrast with the setting and visual resources.

Construction: Construction activities would have little impact to visual resources excepting during the temporary construction activities associated with the roadway and bridging of Trail Lake. The presence of construction equipment could be a minor to moderate impact to visual resources during the construction period depending on how construction equipment was staged. However, the location of almost all Project components is unseen from key viewpoints and most viewers. The construction would generate noise that would be heard by recreationists as pilings were driven, should pile or sheet driving be required. Further, lights may be needed for construction that would be evident in mornings and evenings during winter construction, should winter construction take place.

Operations and Maintenance: Routine operations and maintenance will typically take place monthly during normal operations. There will be dust generated on the gravel road and noise generated by vehicles traveling on the roadway, but this activity is expected to be limited in period and of little detriment to visual quality. During the winter months there would be lights from the vehicles monthly but again, this would be of little consequence to visual quality. The powerhouse itself would have security lighting that would be on through darkness on winter nights. This lighting is expected to be very localized, only at the powerhouse. The lighting is assumed to have cutoffs to ensure that there is little fugitive light. Given the density of the forest at the powerhouse site, there should be little indication of lighting, if any, that would compromise the dark skies visible from key view points or from any locations near Moose Pass.

7.7.2 Potential Mitigation Opportunities

The primary Project impacts would be localized and unseen by most viewers. For the hikers, skiers, snowshoers, and fishermen who recreate along Grant Creek, or to future users of the INHT (if constructed as planned), the impacts provide moderate though localized visual impacts. Project components could be designed to provide some separation of Project facilities from Grant Creek and could be designed to provide colors and textures that are complementary to the landscape.

Construction could be staged such that equipment was kept on site, outside of views. Also, it could be staged to limit pile or sheetpile driving and hours of construction and lighting limited to prevent intrusion to dark skies and noise interjected to the community.

With respect to the INHT, an alternative route could be provided that would be a net benefit to the trail user experience. The trail is located such that views are limited and the trail provides a generally homogenous vegetation and terrain experience from the northward shore of Vagt Lake. An alternative alignment could reduce the presence of Project components relative to the trail location as planned and could provide enhanced views to Trail Lake and background peaks. KHL is currently consulting with the requisite stakeholders related to this issue and a series of site visits and meetings will be held during 2014 to collaboratively reach an agreement on an acceptable re-route of the proposed trail around the single Project feature currently acting as an impediment. All consultation and agreements reached will be comprehensively documented in the FERC LA.

8 REFERENCES

ADF&G (Alaska Department of Fish and Game). 2013. Alaska Game Species. http://www.adfg.alaska.gov/index.cfm?adfg=hunting.species

ADNR (Alaska Department of Natural Resources). 1997 Kenai River Comprehensive Management Plan.

ADNR. 2001. Kenai Area Plan. .

ADNR. 2004. Final Finding and Decision, ADL 228890, Grant of Public Easement, Iditarod National Historic Trail, Seward to Girdwood.

ADOT&PF (Alaska Department of Transportation & Public Facilities). 2013. "Annual Traffic Volume Report, 2010, 2011, 2012. http://www.dot.state.ak.us/stwdplng/mapping/trafficmaps/trafficdata_reports_cen/2012_ATVR.pdf

Alaska Department of Community and Economic Development. 2011. Alaska Visitor Statistics Program. Prepared by the McDowell Group.

KHL (Kenai Hydro, LLC). 2009. Pre-Application Document Grant Lake/Grant Creek and Falls Creek Project (FERC No. 13211 and 13212). August 2009.

KHL. 2013. Recreational and Visual Resources Study Plan for the Grant Lake Hydroelectric Project, FERC No. 13212. March 2013.

Reed et al. 2010. SPreAD-GIS: an ArcGIS toolbox for modeling the propagation of engine noise in a wildland setting.

State of Alaska, Department of Labor and Workforce Development. 2013. Cities and Census Designated Places, 2010-2012. http://labor.state.ak.us/research/pop/popest.htm

USFS (U.S. Department of Agriculture, Forest Service, Chugach National Forest). 1995. Landscape Aesthetics: A handbook for Scenery Management.

USFS. 2002. Revised Land and Resource Management Plan.

USFS. 2008. Final Finding and Decision, ADL 228890, Grant of Public Easement, Iditarod National Historic Trail, Seward to Girdwood, Trail River Landscape Assessment: Chugach National Forest.

Grant Lake Hydroelectric Project (FERC No. 13212)

Water Resources Study –
Water Quality, Temperature and Hydrology
Final Report

Prepared for
Kenai Hydro, LLC

Prepared by
C. Sauvageau and A. Scott
McMillen, LLC

June 2014

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Appendices

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Acronyms and Abbreviations

ADCP	Acoustic Doppler Current Profiler
ADEC	Alaska Department of Environmental Conservation
AEIDC	Arctic Environmental Information Data Center
CFR	Code of Federal Regulations
DLA	Draft License Application
EPA	Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
KHL	Kenai Hydro, LLC
LA	License Application
MW	megawatt
NAVD 88	North American Vertical Datum of 1988
NGVD 29	National Geodetic Vertical Datum of 1929
NOI	Notice of Intent
NTU	Nephelometric Turbidity Units
ORP	oxygen reduction potential
PAD	Pre-Application Document
PM&E	protection, mitigation and enhancement
Project	Grant Lake Hydroelectric Project
QA	quality assurance
RPD	Relative Percent Difference
TLN	Trail Lake Narrows
TBM	temporary benchmark
USFS	U.S. Department of Agriculture, Forest Service
USGS	U.S. Department of the Interior, Geological Survey

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Water Resources Study –
Water Quality, Temperature, and Hydrology
Final Report
Grant Lake Hydroelectric Project (FERC No. 13212)

1 INTRODUCTION

On August 6, 2009, Kenai Hydro, LLC (KHL) filed a Pre-Application Document (PAD; KHL 2009), along with a Notice of Intent (NOI) to file an application for an original license, for a combined Grant Lake/Falls Creek Project (Federal Energy Regulatory Commission [FERC] No. 13211/13212 ["Project" or "Grant Lake Project"]) under Part I of the Federal Power Act (FPA). On September 15, 2009, FERC approved the use of the Traditional Licensing Process (TLP) for development of the License Application (LA) and supporting materials. As described in more detail below, the proposed Project has been modified to eliminate the diversion of water from Falls Creek to Grant Lake. The Project will be located near the community of Moose Pass, Alaska in the Kenai Peninsula Borough, approximately 25 miles north of Seward, Alaska and just east of the Seward Highway (State Route 9).

The Water Resources Study Plan was designed to address information needs identified in the PAD, during the TLP public comment process, and through early scoping conducted by FERC. The following study report presents existing information relative to the scope and context of potential effects of the Project. This information will be used to analyze Project impacts and propose protection, mitigation, and enhancement measures in the draft and final LA's for the Project.

The Project is located near the community of Moose Pass, approximately 25 miles north of Seward and just east of the Seward Highway. It lies within Section 13 of Township 4 North, Range 1 West; Sections 1, 2, 5, 6, 7, and 18 of Township 4 North, Range 1 East; and Sections 27, 28, 29, 31, 32, 33, 34, 35, and 36 of Township 5 North, Range 1 East, Seward Meridian (U.S. Geological Survey [USGS] Seward B-6 and B-7 Quadrangles).

The proposed Project would be composed of an intake structure at the outlet to Grant Lake, a tunnel, a surge tank, a penstock, and a powerhouse. It would also include a tailrace detention pond, a switchyard with disconnect switch and step-up transformer, and an overhead or underground transmission line. The preferred alternative would use approximately 15,900 acre-feet of water storage during operations between pool elevations of approximately 692 and up to 703 feet North American Vertical Datum of 1988 (NAVD 88)[1].

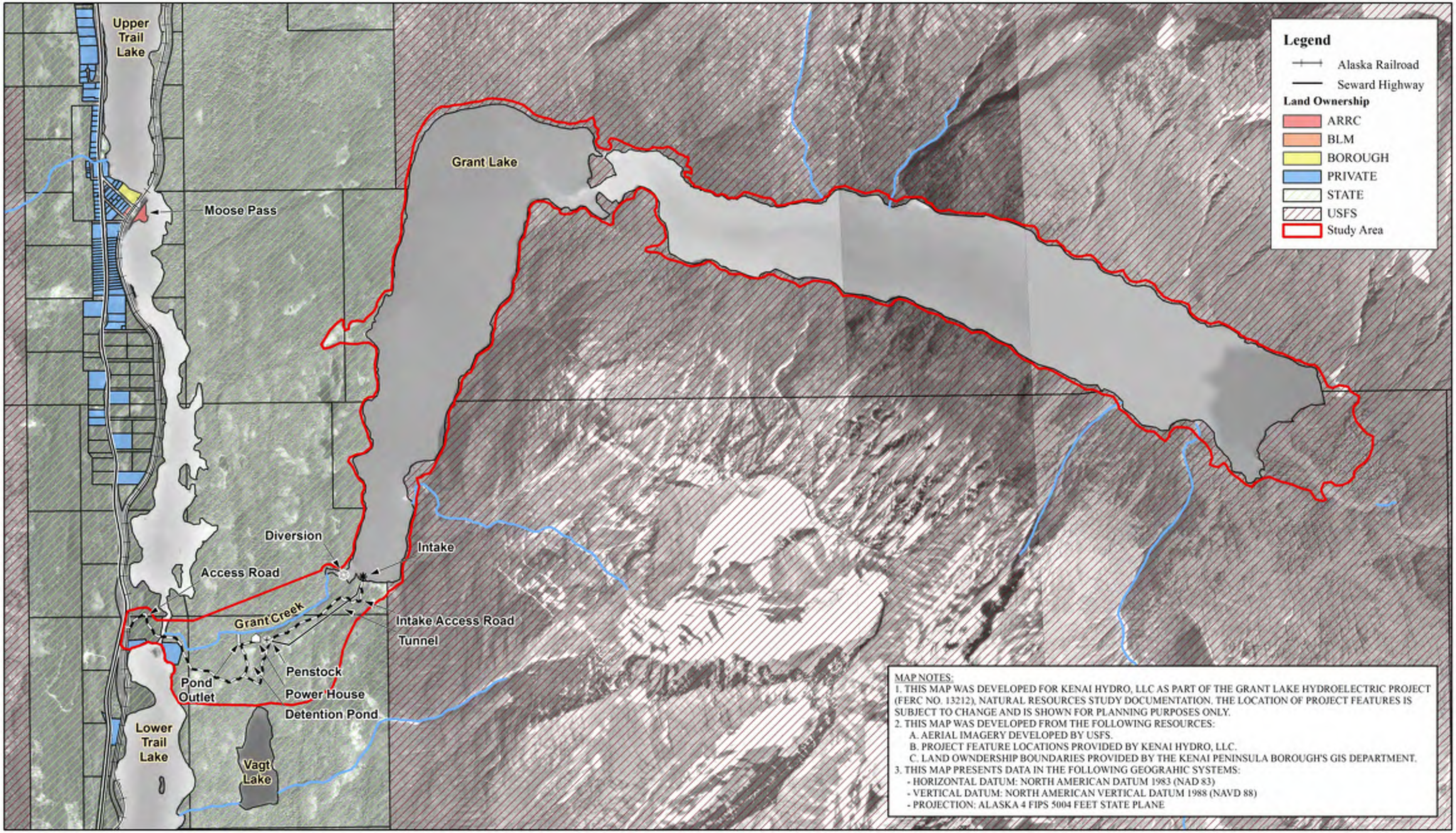
[1] The elevations provided in previous licensing and source documents are referenced to feet mean sea level in NGVD 29 [National Geodetic Vertical Datum of 1929] datum, a historical survey datum. The elevations presented in the Grant Lake natural resources study reports are referenced to feet NAVD 88 datum, which results in an approximate +5-foot conversion to the NGVD 29 elevation values.

An intake structure would be constructed approximately 500 feet east of the natural outlet of Grant Lake. An approximate 3,200-foot-long, 10-foot diameter horseshoe tunnel would convey water from the intake to directly above the powerhouse at about elevation 628 feet NAVD 88. At the outlet to the tunnel a 360-foot-long section of penstock will convey water to the powerhouse located at about elevation 531 feet NAVD 88. An off-stream detention pond will be created to provide a storage reservoir for flows generated during the rare instance when the units being used for emergency spinning reserve are needed to provide full load at maximum ramping rates. The tailrace would be located in order to minimize impacts to fish habitat by returning flows to Grant Creek upstream of the most productive fish habitat.

Two concepts are currently being evaluated for water control at the outlet of Grant Lake. The first option would consist of a natural lake outlet that would provide control of flows out of Grant Lake. A new low level outlet would be constructed on the south side of the natural outlet to release any required environmental flows when the lake is drawdown below the natural outlet level. The outlet works would consist of a 48-inch diameter pipe extending back into Grant Lake, a gate house, regulating gate, controls and associated monitoring equipment. The outlet would discharge into Grant Creek immediately below the natural lake outlet.

In the second option, a concrete gravity diversion structure would be constructed near the outlet of Grant Lake. The gravity diversion structure would raise the pool level by a maximum height of approximately 2 feet (from 703 to 705 feet NAVD 88), and the structure would have an overall width of approximately 120 feet. The center 60 feet of the structure would have an uncontrolled spillway section with a crest elevation at approximately 705 feet NAVD 88. Similar to the first option, a low level outlet would be constructed on the south side of the natural outlet to release any required environmental flows when the lake is drawn down below the natural outlet level. The outlet works would consist of a 48-inch diameter pipe extending back into Grant Lake, a gate house a regulating gate, controls, and associated monitoring equipment. The outlet would discharge into Grant Creek immediately below the diversion structure.

Figure 1.0-1 displays the global natural resources study area for the efforts undertaken in 2013 and 2014 along with the likely location of Project infrastructure and detail related to land ownership in and near the Project area. Further discussions related to specifics of the aforementioned Project infrastructure along with the need and/or feasibility of the diversion dam will take place with stakeholders in 2014 concurrent with the engineering feasibility work for the Project. Refined Project design information will be detailed in both the Draft License Application (DLA) and any other ancillary engineering documents related to Project development. The current design includes two Francis turbine generators with a combined rated capacity of approximately 5.0 megawatts (MW) with a total design flow of 385 cubic feet per second. Additional information about the Project can be found on the Project website: http://www.kenaihydro.com/index.php.



N

Drawing Scale: 0 0.25 0.5 1 Miles

MCMILLEN, LLC

Developed For: Homer Electric Association, Inc. A Touchstone Energy Cooperative

GRANT LAKE HYDROELECTRIC PROJECT - FERC PROJECT #P-13212

GRANT LAKE NATURAL RESOURCES STUDY

Figure 1.0-1
Natural Resources Study Area

DESIGNED: Jake Woodbury
DRAWN: Jake Woodbury
CHECKED: C. Warnock
ISSUED DATE: 1/9/2014
SCALE: 1:27,000

REV | DATE | BY | DESCRIPTION

2 STUDY OBJECTIVES

Together with existing information, the goal of the Water Resources Study effort was to provide baseline information, and where applicable, information on alternative flow regimes, which will inform an assessment of potential Project impacts on water resources. The impact assessments and potential protection, mitigation, and enhancement measures will be presented in the draft and final LAs.

The goals of this suite of studies were to provide supporting information on the potential resource impacts of the proposed Project that were identified during development of the PAD, public comment, and FERC scoping for the LA, as follows:

- Impact of Project construction and operation (lake level fluctuations, changes in flow) on Grant Lake and Grant Creek water quality, hydrology, and water temperature.
- Impact of Project construction and operation on water quality of Lower Trail Lake and Trail Creek.

Specific study objectives and quantitative objectives are presented below for each individual study component.

2.1. Water Quality and Temperature

Water quality studies were conducted to further document baseline conditions in Grant Lake, Grant Creek and Trail Lake Narrows. Describing the baseline conditions in each of these systems is necessary for understanding how Project operations may affect water quality. Water quality parameters were chosen for analysis based on several factors: parameters sampled in previous studies, parameters that may be affected by land use practices in the Project area, and fresh water criteria that have been developed by the Alaska Department of Environmental Conservation (ADEC) for the growth and propagation of fish, shellfish, other aquatic life, and wildlife.

Temperature monitoring was conducted to further document baseline conditions in Grant Lake and Grant Creek prior to any Project activities. Obtaining baseline information on the seasonal temperature regime was necessary to provide data necessary to assess potential Project impacts to stream temperatures under various operational scenarios. These temperature data are also necessary to provide input data required for the planning of mitigation measures.

2.2. Hydrology

Hydrology studies were conducted in order to further document baseline flow conditions in Grant Lake and Grant Creek. Describing the baseline conditions in each of these systems is necessary for understanding how alterations to seasonal flow regimes might affect aquatic resources. Results will be used in conjunction with historical data to support the concurrently conducted instream flow study, the engineering feasibility effort, and other related studies. A major goal for the study was to establish, calibrate, and maintain a rating curve at the historical U.S. Department of the Interior, Geological Survey (USGS) Station currently referred to as

GC200. Another goal was to determine if Grant Creek gains or loses water within the Canyon Reach (Reaches 5 and 6). To meet these goals, the study had two components as follows:

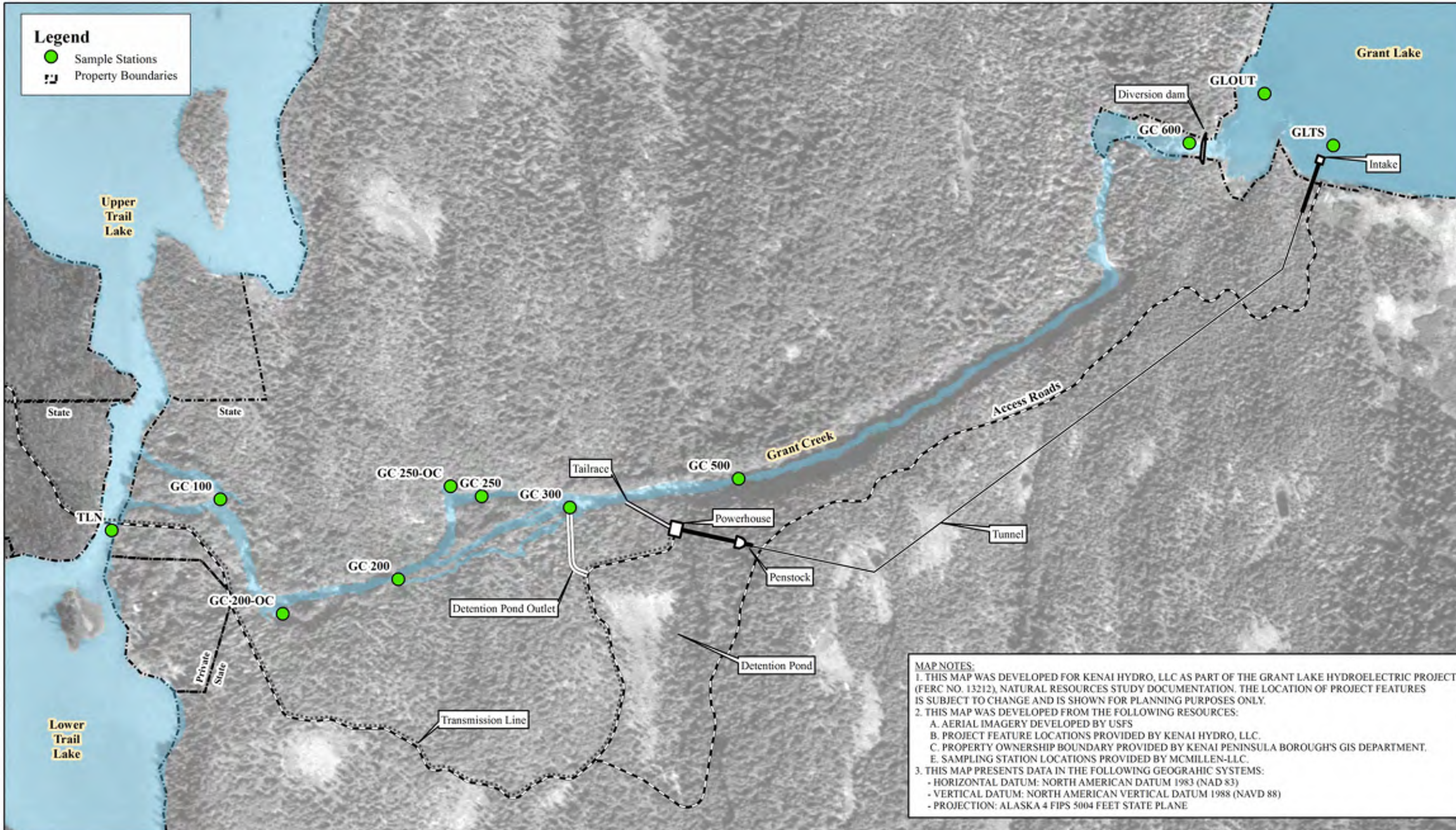
- Installation of staff gage and continuously recording stage recorder at the historical USGS gage station on Grant Creek (GC200). Continue discharge measurements at GC 200 to generate and validate an updated rating curve and extend the stream flow period of record.
- Take discharge measurements at Grant Lake outlet and near the proposed powerhouse location during stable, low-flow conditions to determine if Grant Creek gains or loses water with in the Canyon Reach.
- Provide input data required for the planning of mitigation measures.

3 STUDY AREA

The Project area is located near the town of Moose Pass, Alaska (pop. 206), approximately 25 miles north of Seward, Alaska (pop. 3,016), just east of the Seward Highway (State Route 9); this highway connects Anchorage (pop. 279,671) to Seward. The Alaska Railroad parallels the route of the Seward Highway and is also adjacent to the Project area. The town of Cooper Landing is located 24 miles to the northwest and is accessible via the Sterling Highway (State Route 1), which connects to the Seward Highway approximately 10 miles northwest of Moose Pass.

Grant Creek is approximately 5,180 feet long (approximately one mile) and flows west from the outlet of Grant Lake to the narrows between Upper and Lower Trail lakes (Figure 3.1-1). The Grant Creek watershed is approximately 44 square miles and the watershed contains Grant Lake as well as a portion of the Kenai Mountain Range with glacier capped peaks as high as 5,500 feet. Grant Creek has a mean annual flow of 193 cfs, with an average gradient of 207 feet per mile; its substrate includes cobble and boulder alluvial deposits and gravel shoals (Ebasco 1984). The stream is 25 feet wide, on average. In its upper half, the stream passes through a rocky gorge with three substantial waterfalls; in its lower half, the stream becomes less turbulent as it passes over gravel shoals and diminishing boulder substrate (Ebasco 1984). Grant Creek's mobile substrate is comprised of well packed, unsorted broken angular rock, and there is minimal rounded material. Some fines may be found in small eddies and a few backwaters.

Inlet Creek is the predominant stream in the upper portion of the watershed and drains melting alpine glaciers and snow from the nearby mountains into Grant Lake on the eastern banks. Grant Lake itself sits in the lower portion of the watershed. Grant Lake encompasses two almost separate bathymetric lake basins, which are separated by a shallow submerged ridge at the "narrows" that connects the two basins at right angles (Ebasco 1984). The deepest point within the lower basin is approximately 262 feet deep and the upper basin is 283 feet deep (Ebasco 1984).



N

Drawing Scale:

0 100 200 400 600 800 Feet

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A Touchstone Energy Cooperative

GRANT LAKE HYDROELECTRIC PROJECT - FERC PROJECT NO. 13212

GRANT LAKE NATURAL RESOURCES STUDY

Figure 3.1-1
Water Quality, Temperature, and Hydrology Study Locations - 2013

DESIGNED	J. Woodbury
DRAWN	J. Woodbury
CHECKED	C. Sauvageau
ISSUED DATE	1/9/2014

DRAWING

SCALE: 1:4,522

REV | DATE | BY | DESCRIPTION

4 METHODS

4.1. Water Quality and Temperature

Water Quality

The field methods were designed to document current water quality conditions at selected locations and depths within Grant Lake, Grant Creek and Trail Lake Narrows (Figure 3.1-1). Two sites were sampled in Grant Lake (GLTS and GLOut); three sites in Grant Creek (GC100, GC200, GC300); and one site in Trail Lake Narrows (TLN). Sampling frequencies varied for each site and included sampling one sampling event in August for the Grant Lake and Grant Creek sites and three sampling events (June, August and September) for the Trail Lake Narrows site. Parameters sampled at these study locations as well as ADEC criteria are specified in Table 4.1-1.

Sampling was conducted at a single depth of approximately 1.0 meter at all creek sites and at an approximate depth of 1.8 meters in Trail Lake Narrows. Grab samples were taken for lab analyses with a van dorn style sampler from a well mixed portion of the stream and Narrows sites. The same van dorn style sampler was used at lake sites Samples were collected at the surface (>1 meter) and mid-level depths at the GLOut site and surface, middle and bottom (>1 meter off substrate) depths at the GLTS site. *In situ* sampling was done using a Hydrolab® MiniSonde 5 multi-parameter probe at all sites. *In situ* sampling was done at a depth of approximately 1.5 meters on Grant Creek and at Trail Lake Narrows. The Grant Lake *in situ* sampling was conducted on a vertical transect at one meter increments from the surface to the bottom of the water column.

Table 4.1-1. Water quality parameters sampled in Grant Lake, Grant Creek and Trail Lakes Narrows, CY 2013.

Parameter	Units	ADEC Water Quality Standards*
Alkalinity ($CaCO_3$)	mg/L	no criteria
Total dissolved solids (TDS)	mg/L	≤ 1000 mg/l
Total suspended sediment (TSS)	mg/L	no criteria
Kjeldahl Nitrogen	mg/L	no criteria
Nitrate/Nitrite	mg/L	10 mg/l
Orthophosphate	mg/L	no criteria
Total phosphorous	mg/L	no criteria
Lead	µg/L	16.4 µg/l (acute); 0.64 µg/l (chronic)
Hardness	mg/L	no criteria
Calcium	mg/L	no criteria
Magnesium	mg/L	no criteria
Sodium	mg/L	<2.55 mg/l
Potassium	mg/L	no criteria
Low level mercury	µg/L	1.4 µg/l (acute); 0.77 µg/l (chronic)
Fluoride	mg/L	no criteria
Chloride	mg/L	860 mg/l (acute); 230 mg/l (chronic)
Sulfate	mg/L	no criteria
pH	S.U.	≥6.5 to ≤8.5
Temperature	°C	May not exceed 20°C at any time; maximum temperatures may not exceed, where applicable: migration routes: ≤15°C; spawning areas: ≤13°C; rearing areas: ≤ 15°C; egg/fry incubation: ≤13°C.
Dissolved oxygen (DO)	mg/L	>7mg/l and <17 mg/l in waters used by anadromous fish; >5mg/l and <17 mg/l for waters not used by anadromous fish
Specific Conductivity	mS/cm	no criteria
Oxygen Reduction Potential (ORP)	mV	no criteria
Turbidity	NTU	Not to exceed 25 NTU above natural conditions. For all lake waters, may not exceed 5 NTU above natural conditions.
* Based on the following water use class/subclass: (1) fresh water/(C) growth and propagation of fish, shellfish, other aquatic life, and wildlife		

4.1.1. Sampling Procedure

Every attempt was made to adhere to the following sampling procedures during collection of all samples. These procedures included:

- Calibrate multi-probe per manufacturer's instructions before every field visit.
- Multi-probe data collection was recorded in a hand held data storage device as well as written as field notes from instantaneous readings in the field. To insure the best accuracy of the *in situ* sampling and to alleviate concerns during past sampling efforts, two multi-probe units were deployed at each site and the results were compared and averaged.
- For grab sample water collections, all sample bottles were labeled with the specific parameter, date, and location.
- Samples were collected from the actively flowing channel at stream sites into the van dorn style sampler and then transferred to laboratory-supplied bottles. The sampler was flushed with onsite stream water from each site prior to collection. Field personnel approached the site and remained downstream of the sampling point to avoid disturbing stream sediments.
- Sampling work was done from a boat at both lake sites. Grab sample locations were located and identified with a hand-held GPS.
- Lake grab samples were collected using a van dorn style collector to obtain vertical individual water samples at preselected depths for both sites.
- All samples (stream and lake) were placed on ice as soon as possible after collection and delivered to the laboratory within the approved holding time constraints.

4.1.2. Field Sampling Quality Assurance Procedures

Field sampling quality assurance (QA) ensured that field procedures produced high quality data, with 5 to 10 percent of sampling efforts commonly dedicated to QA. Field duplicates were used. A field duplicate consisted of a second sample collected immediately after the initial sample in the field. The field duplicate assessed variability in lab results that may be attributed to collection and/or lab analytical errors. All samples examined using the QA duplicate assessment method fell within the analytical lab's acceptable Relative Percent Difference (RPD) of +/- 20 percent.

Field duplicates were taken during two of the three field visits for surface water quality grab samples, both time at the Trail Lake Narrows site. Lab analysis was done by SGS North America Inc. (SGS) located in Anchorage, Alaska. SGS provided all sampling bottles with the appropriate preservation techniques (e.g., acid preservation) for individual parameters, specified appropriate quantities of water needed for all of the analyses, and conducted the analyses. Grab sample protocol was utilized for each water quality sampling event. In the field, all water samples were labeled, preserved if necessary, placed on ice and transported to SGS's Anchorage lab. The laboratory analyzed all samples and field duplicates for parameters listed in Table 4.1-1 except for the flowing *in situ* parameters: 1) temperature, 2) dissolved oxygen, 3) specific conductance, and 4) oxygen reduction potential (ORP). Turbidity and pH were measured both in the field and by the lab. Chain-of-custody forms were used during each sampling trip to document all field, delivery, and laboratory personnel handling sample containers. Samples were analyzed within the Environmental Protection Agency (EPA) recommended holding times.

Temperature

Stream temperature data loggers were re-established at four previously monitored sites (GC 100, GC 200, GC 250, and GC 300) on Grant Creek (HDR 2000 and 2010). Two additional temperature data loggers were also established within the upper and lower canyon reach of Grant Creek (GC 500 and GC 600) as well as at two off-channel locations (GC 200-oc and GC 250-oc) where rearing salmonids were observed (Figure 3.1-1). The historical continuous temperature monitoring site in Grant Lake (GLTS) was also re-established. HOBO® Water Temp Pro v2 (ModelU22-001) temperature loggers were installed at all stream and lake locations to continuously monitor temperature in 2013. The HOBO Pro V2 logging thermistor has an operating range of -40 to 50 ºC, and is accurate to 0.2 ºC over 5 0 ºC. At the eight Grant Creek locations, each logger was placed in weighted, protective housings on the bottom of the channel and safeguarded by cables attached to shoreline trees. At the Grant Lake site, a thermistor string was installed in June 2013 along a vertical transect to a depth of 20 meters. HOBO® Pro v2 data loggers were attached to the string at ten distinct sampling depths of 0.2, 0.5, 1.5, 3.0, 6.0, 9.0, 12.0, 15.0, 18.0 and 19.5 meters. All data loggers were set to record temperature at 1-hour intervals.

Water temperatures were monitored from early April through late September 2013. Continuous temperature monitoring at all sites will continue through the 2013-2014 winter. Thermistor downloads will be conducted in the late spring or summer of 2014. This supplemental data documenting the winter period will be distributed to stakeholders and included in the Water Resources portion of Exhibit E in the LA.

4.2. Hydrology

Following guidelines from previously permitted installation activities, a stream gaging station was installed at GC 200 that consisted of a staff gage and a continuous stage data logger. Each stage measurement device was individually anchored to the stream bank and near the shoreline to avoid catching floating debris. The primary data logger used for this study was a USGS-approved bubbler/pressure transducer system manufactured by Design Analysis Associates, Inc. rated to an accuracy of 0.02 percent. Two Onset® U20-001-04 level loggers (accuracy of 0.075 percent) were also installed to serve as a secondary stage recording system. Onset® level loggers are non-vented devices, and therefore must also record barometric pressure to accurately track changes in water levels. Both of these data loggers accurately recorded pressure, which were then related to the water surface elevation of the staff gage. The data loggers were set to record water depth at 15-minute intervals.

The staff gage was mounted vertically in the stream channel to measure water depth for the full range of flow conditions. The Design Analysis data logger was housed in a shoreline enclosure with the bubbler line protected in conduit and 2”galvanized pipe within the wetted channel. The in-channel Onset® level logger was attached to the staff gage and housed in 2” ABS pipe for protection and to attenuate fluctuations in water surface elevations. The Onset® level logger needed for barometric compensations was stored in the USGS gaging house adjacent to the shoreline. Figure 4.1-1 shows multiple views of the gage enclosure, data logger, bubbler line, and staff gage installation.

Figure 4.1-1. GC 200 enclosure, data logger, bubbler line, and staff gage installation.

During field visits, manual readings of the staff gages and the time were recorded. These manual staff gage readings were compared with the stage values provided by the data logger during the same time interval.

A differential survey was performed for each of the data loggers and the staff gage to check on vertical stability during gage operation. A cross sectional survey of the channel at the gage location was also conducted in April 2013. Multiple temporary benchmarks (TBM) were established at the stream gage location to provide differential vertical datum checks for the gage equipment to monitor movement. The Grant Creek stream gage for the 2013 season is tied into an elevation established arbitrary datum based on local TBMs.

Data loggers were operated during ice free months (i.e., April-October). The stream gage was visited every 6-8 weeks through late-September. The field team download data from the data loggers and took a discharge measurement to build and calibrate the rating curve. Additional discharge measurements were taken by the instream flow team when wading conditions were safe. During winter site maintenance station visits, activities will include battery change-outs and staff gage recordings. This supplemental data documenting the winter period will be distributed to stakeholders and included in the Water Resources portion of Exhibit E in the LA.

<u>Instantaneous Discharge Measurements</u>

Collecting instantaneous discharge data from Grant Creek required two methods depending upon flow conditions. It is not possible to wade Grant Creek during flow events above 400 cfs. Potential instantaneous discharge measurement methods included the following:

- Wading method (low to medium-flow events on Grant Creek).
- Acoustic Doppler Current Profiler (ADCP) method (medium to high-flow events on Grant Creek).

All instantaneous discharge measurements yielded comparable results and followed field procedures laid out in Rantz et al (1982). The stream gage site was visited at least monthly, and instantaneous discharge measurements were taken until freeze-up as stream conditions permitted, to establish and calibrate the rating curve.

Wading Method – Instantaneous discharge measurements were taken using a top-setting wading rod with a Swoffer current meter.

Procedures for taking discharge measurements using a current meter in ice-free conditions are outlined below.

1. Visually check wading rod and current meter for damage. Repair damage to equipment and replace batteries as necessary.
2. Calibrate and test the current meter at the start of each field event according to manufacture protocols.
3. Anchor survey measuring tape tautly across the stream perpendicular to the direction of stream flow and attach it on either side of the stream with the low numbers of the tape on the left side of the stream. Calculate the width of the entire stream cross section.
4. Determine the spacing of the vertical partial sections (referred to as "verticals"). This is typically accomplished by splitting the entire stream cross section into approximately 25 to 35 verticals. The number of verticals will be based on an estimated distribution of the discharge across the entire cross section. Space the verticals to meet the USGS objective that no vertical partial section should contain more than 10 percent of the total discharge. The ideal measurement is one in which no partial section contains more than 5 percent of the total discharge. However, the placement of verticals should never be closer than a horizontal distance of 0.20 feet.
5. The person wading in the stream will call out the location of the first vertical with respect to the surveyor's tape to the person on shore who is recording data (data recorder). The station or vertical location is recorded to the nearest 0.1 feet.
6. Using the wading rod, the person wading in the stream will measure water depth at that vertical to the nearest 0.05 foot. The wading person will call out this depth reading to the data recorder and adjust the height of the current meter on the top-set wading rod according to the depth at that vertical. For water columns less than or equal to 2.5 feet deep, a single velocity measurement at 60 percent of the water column height will be collected. If the water is more than 2.5 feet deep, measurements should be made at 20 and 80 percent of the water-column height.
7. The person wading will stand downstream of the survey measuring tape, facing upstream and holding the wading rod vertical in the water with the current meter facing directly into the current. The wading person should stand to the side, rather than directly behind the meter, to avoid influencing velocity readings. Occasionally flow at a vertical may not be perpendicular to the tape due to a rock upstream or other flow restrictions. If the obstruction cannot be cleared and the flow is more than 20 degrees off perpendicular, the person in the stream should orient the meter directly into the flow and call out the angle

of flow with respect to perpendicular. A correction will be applied to the velocity measurement from the vertical when calculating the discharge.

8. The person wading will observe visual output of velocity measurements at each vertical. Velocity measurements averaged over a 40 second period before being recorded. The person recording data will record this and other appropriate information on the field form.
9. Repeat above procedure at each vertical.

ADCP Method - During higher flows when wading was not a safe option due to deep and fast-water conditions, the ADCP method was employed to obtain discharge measurements. An ADCP determines the velocity of water by sending sound pulses into the water column and measuring the change in frequency of the sound pulses. When this change in frequency (i.e. Doppler Shift) is reflected back to the ADCP transducer, it can be translated into water velocity. The ADCP also has an acoustic component within the transducer to measure water depth and horizontal distance. The ADCP sends sound pulses to the bottom of the stream channel and measures the travel time for each sound pulse to return to the ADCP. By mounting the ADCP to a small watercraft, it can be ferried across the channel to measure channel width, depth, and velocity verticals. Once the ADCP has effectively completed these measurements, discharge can be calculated using the conventional velocity-area method.

5 RESULTS

5.1. Water Quality and Temperature

Water Quality

Baseline water quality sampling for this Project was conducted during multiple years. Historical water quality data was collected by various entities and summarized for earlier Project scoping efforts (Ebasco 1984). Limited sampling was conducted in 2009 and 2010 and expanded sampling was conducted in 2013 to supplement and expand the previous sampling efforts. All 2013 sample results were compared to standards presented in the Alaska Department of Environmental Conservation's 18 AAC 70 Water Quality Standards Publication – Amended April 8, 2012 to establish whether standards were being met.

Sampling efforts in 2013 were conducted during three trips including June, August and September. A total of twenty-four parameters were monitored during the sampling period. Ten of the parameters monitored have established water quality standards (see Table 4.1-1).

Trail Lakes Narrows

Three sampling events were conducted at this site (June, August, and September 2013). Table 5.1-1 provides the results of 2013 sampling for this site. No parameter sampled exceeded water quality standards during any sampling event. Specific parameters of aquatic interest (dissolved oxygen, pH and temperature) met standards for all sampling periods. Compared to the Grant Lake and Grant Creek sites, Trail Lakes Narrows routinely had the highest turbidity readings of all sites in 2013. This site was also the only site sampled for diesel and gas components, both of which were below detection levels for all three sample events. Some minor variability was noted between *in situ* and laboratory pH values at the TLN site. This discrepancy is most likely due to the pH field probe accuracy, which tends to be less reliable than lab measurements.

Table 5.1-1. Water quality sampling results for the Trail Lake Narrows (TLN) site – 2013. [1,2]

Hydrolab Readings		Hydrolab #1 June 2013	Hydrolab #2 June 2013	Hydrolab #1 August 2013	Hydrolab #2 August 2013	Hydrolab #1 Sept 2013	Hydrolab #2 Sept 2013
Temp	**°C**	9.05	9.08	11.81	11.94	8.39	8.51
Sp. Cond	**mS/cm**	0.08	0.08	0.07	0.04	0.07	0.07
Dissolved Oxygen	**% Sat**	102.5	102.5	102.9	102.1	87.4**	102.6
Dissolved Oxygen	**mg/l**	11.88	11.85	11.19	11.09	10.8**	11.82
ORP	**mV**	399	385	526	315	387	335
pH	**S.U.**	7.51	7.63	7.63	6.32	7.06	6.60
Turbidity	**NTU**	9.4	*	*	*	9.4	*
Depth	**m**	1.6	1.7	2.0	2.0	1.0	1.0
Analytical Lab Results			DUP				DUP
pH	**S.U.**	7.60	7.60	6.90		7.20	7.10
Turbidity	**NTU**	8.5	8.8	13.0		11.0	11.0
T. Hardness	**mg/l**	38.9	41.2	33.0		36.8	33.8
T. Alkalinty	**mg/l**	25.1	25.5	18.7		22.0	21.8
TDS	**mg/l**	44	49	43		54	50
TSS	**mg/l**	3.1	5.7	11.3		4.1	3.8
T. Nitrate+Nitrite	**mg/l**	0.35	0.39	0.14		0.27	0.25
K. Nitrogen	**mg/l**	ND	ND	ND		ND	ND
T. Phosphorus	**mg/l**	ND	ND	0.03		ND	0.01
Orthophosphate	**mg/l**	ND	ND	0.02		0.02	0.02
Chloride	**mg/l**	0.32	0.32	0.21		0.21	0.21
Fluoride	**mg/l**	ND	ND	ND		ND	ND
Sodium	**mg/l**	1.17	1.15	0.91		0.99	1.05
Calcium	**mg/l**	13.6	14.4	11.3		12.5	11.4
Magnesium	**mg/l**	1.2	1.3	1.2		1.4	1.3
Potassium	**mg/l**	0.53	0.59	ND		0.62	0.56
Sulfate	**mg/l**	16.0	16.0	13.1		15.0	15.0
Lead	**µg/l**	0.2	ND	0.40		0.30	0.23
Low level Mercury	**µg/l**	0.0017	0.0016	0.0036		0.0022	0.0022
Gas Range Organics	**mg/l**	ND	ND	ND		ND	ND
Diesel Range Organics	**mg/l**	ND	ND	ND		ND	ND

Notes
ND: not detected
1. Probe manufacturer confirmed LDO sensor was malfunctioning – Hydrolab #1 values not accurate
2. Faulty turbidity probe

Grant Creek

There were three sampling sites on Grant Creek, all located below the canyon reach. Each site was sampled once in August 2013. The 2013 results indicated all parameter levels were below ADEC standards. Little variability between these creek sites was observed in 2013. Turbidity values ranged from 4.0-4.6 NTUs, dissolved oxygen ranged from 10.95-11.02 mg/l, and pH values from 7.00-7.18 S.U.

Three sites initially established in 2009 were sampled again in 2010 and 2013. Results from the three years of sampling are presented in Tables 5.1-2 through 5.1-4. No parameter sampled exceeded water quality standards during the three sampling events. Grant Creek results showed little variation between years for most parameters. Differences in sampling results for dissolved oxygen between 2009/2010 and 2013 may be a result of equipment calibration or faulty sensor issues with the equipment used in 2009-2010. The 2013 sampling used duplicate multi-probe *in situ* instruments in an attempt to alleviate this problem and insure accurate results.

Table 5.1-2. Water quality sampling results for the Grant Creek GC100 site – 2009, 2010, and 2013. [1,2]

Hydrolab Readings		Jun-09	Aug-09	Jun-10	Aug-13
Temp	°C	9.44	12.32	8.55	12.65
Sp. Cond	mS/cm	0.08	0.09	0.09	0.06
Dissolved Oxygen	% Sat	68.7	77.5	91.9	102.5
Dissolved Oxygen	mg/l	7.85	8.29	10.74	10.95
ORP	mV	na	na	212	422
pH	S.U.	7.39	7.4	7.23	7.18
Turbidity	NTU	0.77	10.10	1.14	4.10
Depth	m	na	na	na	1.9
Lab Analyses					
pH	S.U.	na	na	na	7.00
Turbidity	NTU	na	na	na	4.1
T. Alkalinity	mg/l	24	23	25	20.4
T. Hardness	mg/l	na	na	na	34.2
TDS	mg/l	53.8	62.5	52.0	45.0
TSS	mg/l	0.70	2.49	0.71	1.78
T. Nitrate/Nitrite	mg/l	0.46	0.30	0.27	0.18
K. Nitrogen	mg/l	ND	ND	ND	ND
Orthophosphate	mg/l	ND	ND	ND	ND
T. Phosphorus	mg/l	ND	ND	0.022	ND
Chloride	mg/l	na	na	0.293	0.225
Fluoride	mg/l	na	na	ND	ND
Sodium	mg/l	na	na	1.10	0.98
Calcium	mg/l	na	na	12.6	11.6
Magnesium	mg/l	na	na	1.28	1.24
Potassium	mg/l	na	na	0.52	0.53
Sulfate	mg/l	na	na	18.0	15.5
Lead	µg/l	0.597	ND	0.597	ND
LL Mercury	µg/l	ND	0.0015	ND	0.0015

Notes
1 na: not sampled
2 ND: not detected

Table 5.1-3. Water quality sampling results for the Grant Creek GC200 site – 2009, 2010, and 2013. [1,2]

Hydrolab Readings		Jun-09	Aug-09	Jun-10	Aug-13
Temp	°C	7.4	11.26	8.51	12.46
Sp. Cond	mS/cm	na	0.07	0.09	0.06
Dissolved Oxygen	% Sat	60.9	75.1	92.3	101.5
Dissolved Oxygen	mg/l	7.31	8.22	10.79	10.89
ORP	mV	na	na	216	408
pH	S.U.	7.66	7.39	7.39	7.02
Turbidity	NTU	0.75	11.10	1.17	4.00
Depth	m	na	na	na	1.9
Lab Analyses					
pH	S.U.	na	na	na	7.00
Turbidity	NTU	na	na	na	4.0
T. Alkalinity	mg/l	25.0	23.5	25.5	20.6
T. Hardness	mg/l	na	na	na	34.4
TDS	mg/l	60	44	50	51
TSS	mg/l	0.8	3.4	0.7	2.9
T. Nitrate/Nitrite	mg/l	0.455	0.292	0.269	0.190
K. Nitrogen	mg/l	ND	ND	ND	ND
Orthophosphate	mg/l	ND	ND	ND	ND
T. Phosphorus	mg/l	ND	ND	ND	ND
Chloride	mg/l	na	na	0.284	0.225
Fluoride	mg/l	na	na	ND	ND
Sodium	mg/l	na	na	1.14	1.18
Calcium	mg/l	na	na	13.3	11.7
Magnesium	mg/l	na	na	1.26	1.25
Potassium	mg/l	na	na	0.52	0.54
Sulfate	mg/l	na	na	17.9	15.1
Lead	µg/l	3.09	ND	ND	ND
LL Mercury	µg/l	ND	0.0016	ND	0.0013

Notes
1 na: not sampled
2 ND: not detected

Table 5.1-4. Water quality sampling results for the Grant Creek GC300 site – 2009, 2010, and 2013.

Hydrolab Readings		Jun-09	Aug-09	Jun-10	Aug-13
Temp	°C	7.47	11.49	8.53	12.45
Sp. Cond	mS/cm	0.09	0.09	0.09	0.06
Dissolved Oxygen	% Sat	61.3	77.1	93.7	102.8
Dissolved Oxygen	mg/l	7.34	8.40	10.94	11.02
ORP	mV	na	na	209	421
pH	S.U.	7.30	7.72	7.52	7.09
Turbidity	NTU	0.8	11.9	1.0	4.6
Depth	m	na	na	na	1.8
Lab Analyses					
pH	S.U.	na	na	na	7.00
Turbidity	NTU	na	na	na	4.6
T. Alkalinity	mg/l	25.0	23.0	25.3	20.7
T. Hardness	mg/l	na	na	na	34.9
TDS	mg/l	57.5	60.0	54.0	45.0
TSS	mg/l	0.8	2.9	0.7	3.1
T. Nitrate/Nitrite	mg/l	0.42	0.32	0.36	0.18
K. Nitrogen	mg/l	ND	ND	ND	ND
Orthophosphate	mg/l	na	na	ND	ND
T. Phosphorus	mg/l	0.023	ND	ND	ND
Chloride	mg/l	na	na	0.29	0.22
Fluoride	mg/l	na	na	ND	ND
Sodium	mg/l	na	na	1.1	1.0
Calcium	mg/l	na	na	13.0	11.9
Magnesium	mg/l	na	na	1.3	1.3
Potassium	mg/l	na	na	0.5	0.5
Sulfate	mg/l	na	na	17.9	15.3
Lead	µg/l	0.392	ND	ND	ND
LL Mercury	µg/l	na	0.0020	ND	0.0018

Notes
1 na: not sampled
2 ND: not detected

Grant Lake

The 2013 sampling was repeated at the two original sites (HDR 2009, 2010). Results from the three years of sampling are presented in Tables 5.1-5 and 5.1-6. There were two distinct sampling sites, site GLTS representing typical lake conditions of the lower basin and site GLOut representing outflow conditions into Grant Creek. The GLTS site was located in the immediate vicinity of the proposed intake structure location. Both sites were sampled in August 2013. Each site was sampled vertically at selected depths for grab analyses and at one meter depth intervals for *in situ* parameters. No parameter sampled exceeded water quality standards during the August sampling event.

In situ sampling during 2013 at the GLTS site was done from the surface down to a bottom depth of 17 meters. Dissolved oxygen ranged from 103.6 percent saturation at the surface to 94.5percent saturation at the bottom. A mid-depth (8.0 meters) reading was 100.9 percent saturation. Dissolved oxygen concentrations for these same depths ranged from a surface reading of 11.15 mg/l, increasing to 11.76 mg/l at the bottom. A mid-depth concentration was 11.18 mg/l. The pH levels ranged from 7.26 S.U. at the surface to 7.42 S.U. at the bottom. Instantaneous temperature readings ranged from 12.3 °C at the surface to 6.24 °C at the bottom. A mid-depth temperature was 10.98 °C.

In situ sampling during 2013 at the GLOut site was done from the surface down to a mid-depth of 5 meters. Dissolved oxygen ranged from 103.3 percent saturation at the surface to 98.0 percent saturation at the mid depth. Dissolved oxygen concentrations for these same depths ranged from a surface reading of 11.14 mg/l to 10.69 mg/l at the mid depth. The pH levels ranged from 6.33 S.U. at the surface to 6.79 S.U. at the mid-depth. The instantaneous temperature readings ranged from 12.2 °C at the surface to 11.6 °C at the mid-depth.

Data for the two lakes sites was initially collected in 2009 and repeated in June of 2010. Results appear similar for nearly all parameters where three years of data exists. Differences in sampling results for dissolved oxygen between 2009/2010 and 2013 may be a result of poor equipment calibration or faulty sensor issues with the equipment used in 2009/2010. The 2013 sampling used duplicate multi-probe instruments in an attempt to alleviate this problem and insure accurate results.

Differences at sites GLout and GLTS in dissolved oxygen and pH values were also noted between the 2013 results and the 2009-2010 results. It is unclear whether this is a result of fluctuating annual conditions or faulty sampling equipment as noted earlier. However, Grant Lake water quality data summarized by Ebasco (1984) indicate that the 2013 results are more in line with historical results.

Table 5.1-5. Water quality sampling results for the Grant Lake GLOut site – 2009, 2010, and 2013. [1,2]

Hydrolab Readings		Jun-09	Jun-09	Aug-09	Aug-09	Jun-10	Jun-10	Aug-13	Aug-13
Depth	m	0-Surf	4-Mid	0-Surf	6-Mid	0-Surf	6-Mid	0-Surf	3-Mid
Temp	°C	7.95	7.27	14.87	11.49	9.38	9.30	12.17	11.81
Sp. Cond	mS/cm	na	na	0.09	0.09	0.08	0.08	0.08	0.08
Dissolved Oxygen	% Sat	64.4	63.8	55.2	52.3	75.5	74.0	103.3	101.9
Dissolved Oxygen	mg/l	7.64	7.70	5.57	5.71	8.61	8.50	11.14	11.08
ORP	mV	na	na	na	na	73	29	334	332
pH	S.U.	7.27	7.37	7.24	7.24	6.98	7.06	6.28	6.59
Turbidity	NTU	0.82	na	4.18	na	1.46	1.14	4.50	5.10
Lab Analyses									
pH	S.U.	na	na	na	na	na	na	7.10	7.00
Turbidity	NTU	na	na	na	na	na	na	4.5	5.1
T. Alkalinity	mg/l	23.8	23.2	24.0	24.0	26.0	25.6	20.8	20.9
T. Hardness	mg/l	na	na	na	na	na	na	35.6	36.5
TDS	mg/l	51.3	40.0	32.5	47.5	57.0	64.0	46.0	52.0
TSS	mg/l	0.60	0.50	1.96	2.77	ND	0.75	2.08	2.75
T. Nitrate/Nitrite	mg/l	0.414	0.651	0.268	0.298	0.311	0.344	0.206	0.175
K. Nitrogen	mg/l	ND	ND	ND	ND	ND	ND	ND	ND
Orthophosphate	mg/l	ND	ND	ND	ND	ND	ND	ND	ND
T. Phosphorus	mg/l	ND	ND	ND	ND	ND	ND	ND	ND
Chloride	mg/l	na	na	na	na	0.298	0.291	0.221	0.220
Fluoride	mg/l	na	na	na	na	ND	ND	ND	ND
Sodium	µg/l	na	na	na	na	1.16	1.12	0.95	0.95
Calcium	µg/l	na	na	na	na	13.8	13.4	11.5	11.6
Magnesium	µg/l	na	na	na	na	1.32	1.27	1.18	1.2
Potassium	µg/l	na	na	na	na	0.53	0.53	0.51	0.51
Sulfate	mg/l	na	na	na	na	17.6	17.9	15.3	15.4
Lead	µg/l	ND	ND	ND	ND	ND	ND	0.24	ND
LL Mercury	µg/l	ND	ND	0.0014	0.0021	0.0011	0.0011	0.0011	0.0014

Notes
1 na: not sampled.
2 ND: not detected.

Table 5.1-6. Water quality sampling results for the Grant Lake GLTS site – 2009, 2010, and 2013. [1,2]

Hydrolab Readings		Jun-09	Jun-09	Jun-09	Aug-09	Aug-09	Aug-09	Jun-10	Jun-10	Jun-10	Aug-13	Aug-13	Aug-13
Depth	m	0-Surf	10-Mid	19-Bot	0-Surf	9-Mid	17-Bot	0-Surf	6-Mid	17-Bot	0-Surf	9-Mid	17 - Bot
Temp	°C	8.64	5.41	4.33	14.66	10.37	6.09	9.36	9.25	4.41	12.29	10.98	6.24
Sp. Cond	mS/cm	0.09	0.09	0.09	0.09	0.09	0.1	na	na	na	0.08	0.08	0.09
Dissolved Oxygen	% Sat	68.4	61.3	55.5	56.2	52.1	48.4	76.2	74.1	66.5	103.6	100.9	94.5
Dissolved Oxygen	mg/l	7.96	7.74	7.2	5.63	5.82	5.99	8.73	8.52	8.63	11.15	11.18	11.76
ORP	mV	na	na	na	na	na	na	91	26	65	319	320	327
pH	S.U.	7.43	7.49	7.06	7.56	7.2	7.06	6.68	6.82	6.43	7.26	7.42	7.42
Turbidity	NTU	0.6	na	na	3.87	na	4.8	0.81	1.14	1.17	3.9	7.8	4.8
Lab Analyses													
pH	S.U.	na	na	na	na	na	na	na	na	na	6.80	6.80	6.80
Turbidity	NTU	na	na	na	na	na	na	na	na	na	3.9	7.8	4.8
T. Alkalinity	mg/l	23.5	24.5	24	24.8	24.6	25.4	25.8	25.3	25.8	20.2	20.9	22.6
T. Hardness	mg/l	na	na	na	na	na	na	na	na	na	36.1	36.9	39.7
TDS	mg/l	75.0	68.8	61.3	46.3	48.8	45.0	67.0	64.0	63.0	43.0	45.0	49.0
TSS	mg/l	0.7	1.0	0.8	1.9	2.6	2.8	0.5	ND	0.7	2.7	2.6	4.2
T. Nitrate/Nitrite	mg/l	0.42	0.42	0.41	0.28	0.30	0.32	0.30	0.31	0.30	0.17	0.19	0.31
K. Nitrogen	mg/l	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Orthophosphate	mg/l	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.01	ND
T. Phosphorus	mg/l	ND	0.021	ND	ND	ND	ND	ND	ND	ND	ND	0.02	0.04
Chloride	mg/l	na	na	na	na	na	na	0.30	0.29	0.47	0.22	0.22	0.27
Fluoride	mg/l	na	na	na	na	na	na	ND	ND	ND	ND	ND	ND
Sodium	mg/l	na	na	na	na	na	na	1.16	1.15	1.16	0.95	0.96	1.08
Calcium	mg/l	na	na	na	na	na	na	13.5	13.3	13.4	11.6	11.6	13.0
Magnesium	mg/l	na	na	na	na	na	na	1.3	1.3	1.3	1.2	1.2	1.3
Potassium	mg/l	na	na	na	na	na	na	0.53	0.51	0.52	0.51	0.53	0.52
Sulfate	mg/l	na	na	na	na	na	na	18.0	17.9	17.9	15.1	15.4	16.9
Lead	µg/l	ND	1.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
LL Mercury	µg/l	ND	ND	ND	0.0015	0.0016	0.0017	ND	ND	ND	0.0011	0.0015	0.0015

Notes
1 na: not sampled
2 ND: not detected

<u>Temperature</u>

2013 Results

A total of nine temperature sites were monitored in 2013 including six main channel Grant Creek sites, two off-channel Grant Creek sites and one Grant Lake site. All of these sites provide water temperature data for the 2013 season. Appendices 1a and 1b summarize the 2013 temperature record at all of the sampling locations.

Grant Creek

Six sites were monitored in 2013 on Grant Creek. They included four previously established sites (GC100, GC200. GC250, GC300), two new upstream sites (GC500 and GC600) in the canyon reach and two off channel sites (ISF 230 and ISF 300) selected based on observed fish utilization.

Daily mean temperature hydrographs for the six main channel Grant Creek sites are presented in Figure 5.1-1. Mean daily temperatures at all sites track are very similar to one another with the exception of GC600 in early to mid April. GC600 is located less than 100 feet from the outlet of Grant Lake and may be less affected by changes in air temperature when outlet flows are low and Grant Lake is still under ice cover.

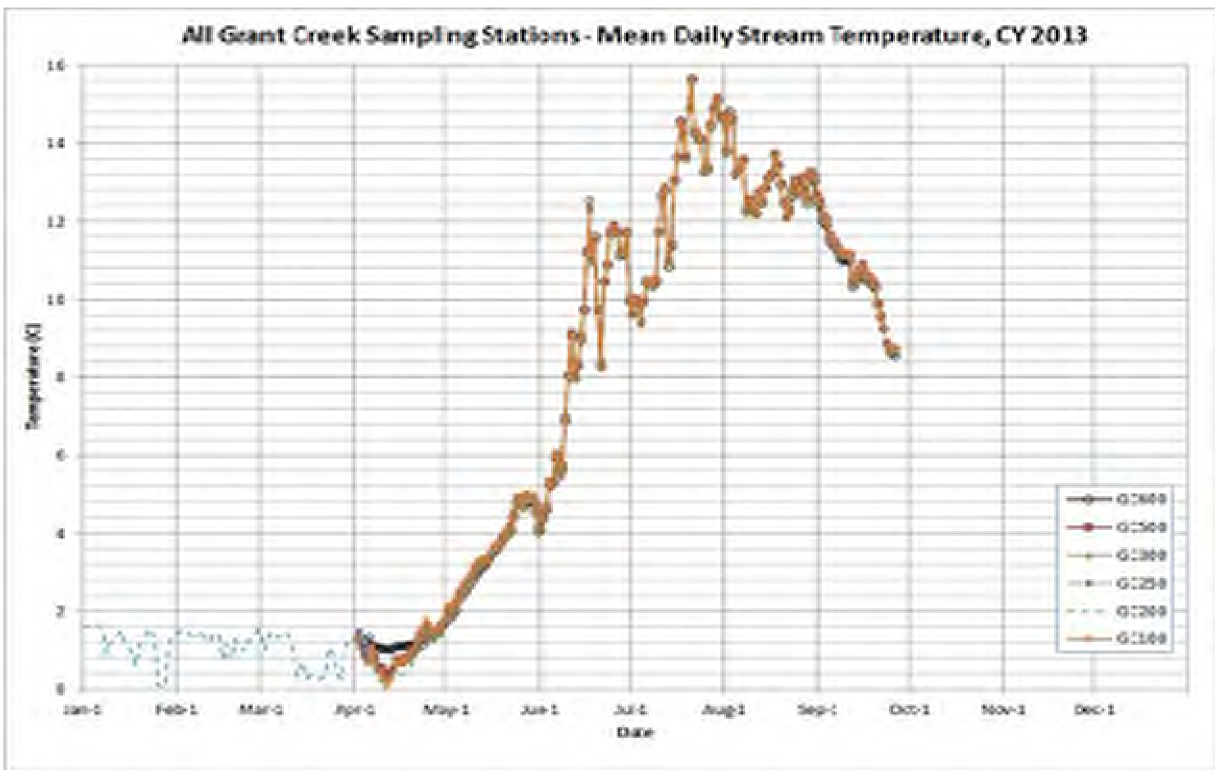


Figure 5.1-1. Daily mean water temperatures all Grant Creek main channel sites – 2013.

Winter temperature data was collected at one site (GC200). The January-April 2013 record indicates that the minimum daily mean water temperature for this period was 0.0 ° C and the maximum daily mean water temperature for this period was 1.8 ° C. The daily mean average temperature for January was 1.2 °C; for February it was 1.3 °C; and for March and April it was 0.9 °C. Following the month of April, mean daily temperature values increase through the month of August (mean monthly average of 12.1 °C), before decreasing once again in September (mean monthly average of 8.6 °C).

Grant Creek water temperatures demonstrate little inter-station variations in 2013 throughout longitudinal profile of Grant Creek. Figure 5.1-2 shows a comparison of daily mean water temperatures between the farthest upstream site (G600) and the farthest downstream site (G100). As stated earlier GC600 temperatures may be buffered from extreme late winter air temperatures due to its proximity of releases from the ice covered lake.

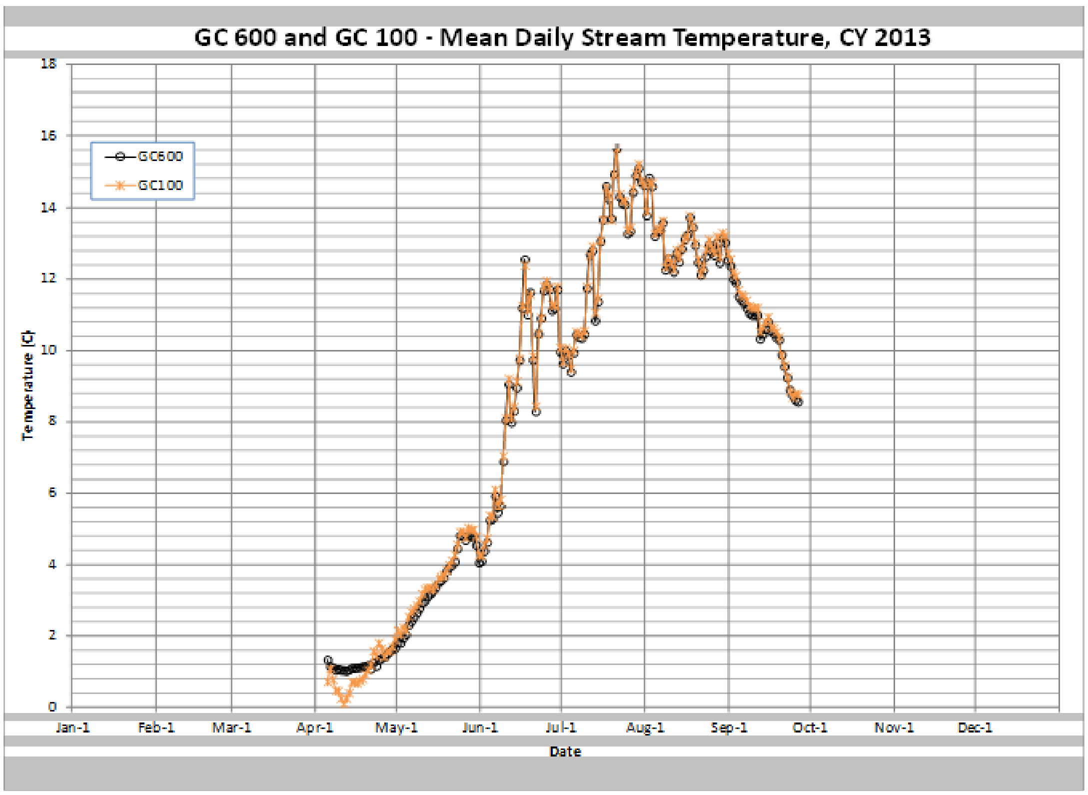


Figure 5.1-2. Comparison of daily mean water temperatures upstream and downstream Grant Creek sample stations – 2013.

Additional stream temperature data was collected at two off site channel locations. These backwater areas were selected in coordination with members of the Aquatic Resources study team that detected juvenile salmonids (resident and anadromous) rearing at these two locations. Figure 5.1-3 shows the results of daily mean temperatures at both off channel sites (GC 200-oc and GC 250-oc) from June through late September 2013 in comparison to main channel temperatures. Site GC 200-oc temperatures remained cooler and more stable when compared to temperatures recorded at GC 250-oc. The cooler temperatures at GC 200-oc are likely due to different physical characteristics of site (greater depth, denser canopy cover, and more isolation from main channel flows) as well as more groundwater influence. In general, both off channel sites were slightly cooler when compared to main channel temperatures. Although GC 250-OC was slightly cooler than main channel temperatures, the inter-daily temperature fluctuations still appeared to follow patterns detected in the main channel. This may be due in part to potential groundwater influences at each site.

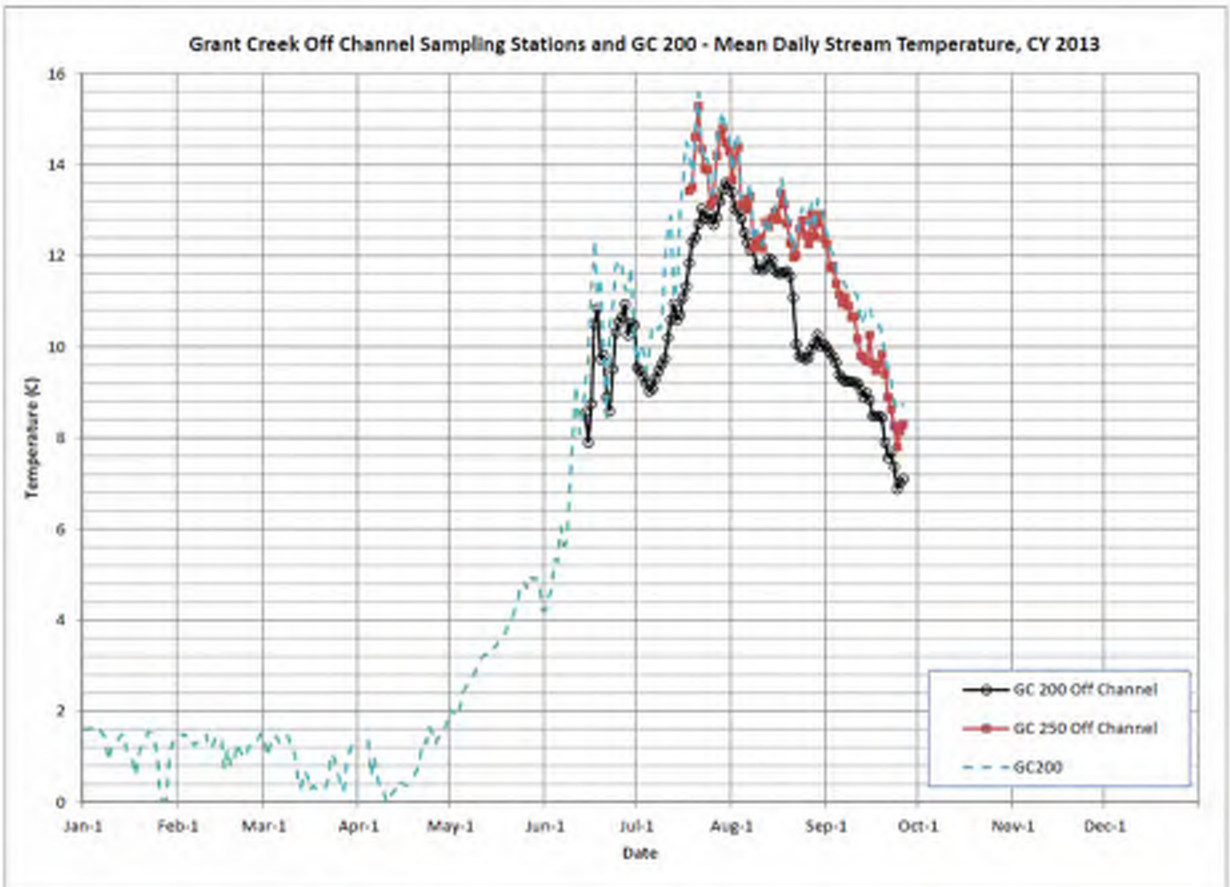


Figure 5.1-3. Comparison of daily mean water temperatures between two off channel rearing locations and the main channel of Grant Creek – 2013.

Grant Lake

The temperature monitoring site in Grant Lake (GLTS) from the 2009/2010 work was re-established in the same approximate location for 2013. This site was monitored using a vertical temperature string which recorded temperatures at ten distinct depth intervals from the surface to a bottom depth of 19.5 meters.

Grant Lake water temperature hydrographs are presented in Figure 5.1-4. The temperature monitoring results show two distinct seasonal characteristics within Grant Lake. The first characteristic is that winter water temperatures increased with depth. This trend was noted from January through mid to late May. The second trend is that summer water temperatures decreased with depth, starting in June and extending through early September. A maximum difference of about 10 °C between the surface (0.2 meter) and the deepest sampling node (19.5 meter) was recorded in late July through early August.

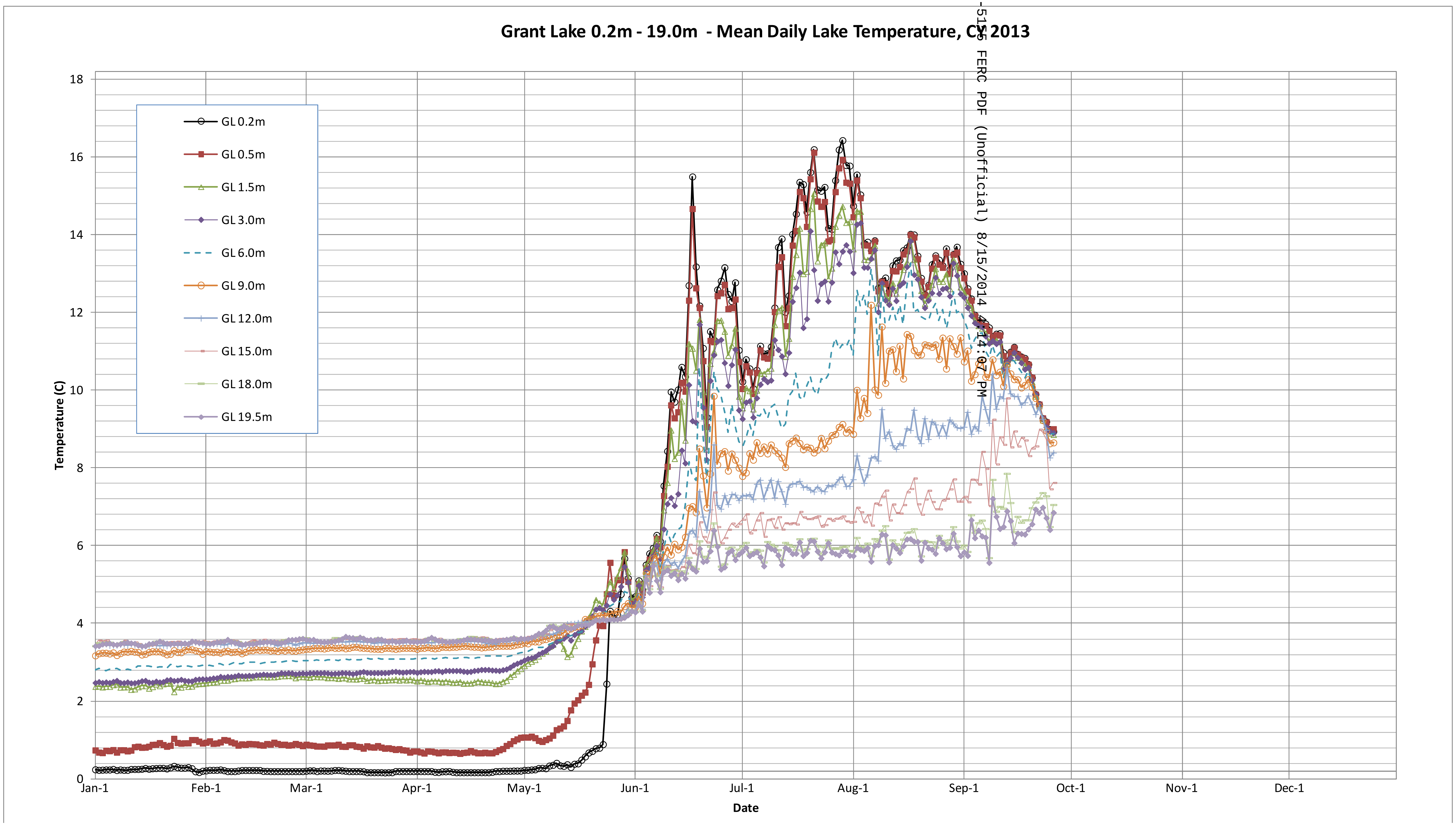


Figure 5.1-4. Comparison of daily mean water temperatures in Grant Lake near the proposed intake structure – 2013.

Figure 5.1-5 displays the seasonal temperature profile of Grant Lake in 2013. A noted temperature difference from top to bottom does exist throughout the year, but changes appear subtly during periods of ice cover and become more pronounced during the ice-free season. As confirmed in Figure 5.1-6, these temperature patterns have been consistent based on historical temperature profile results (AEIDC 1983; HDR 2009)

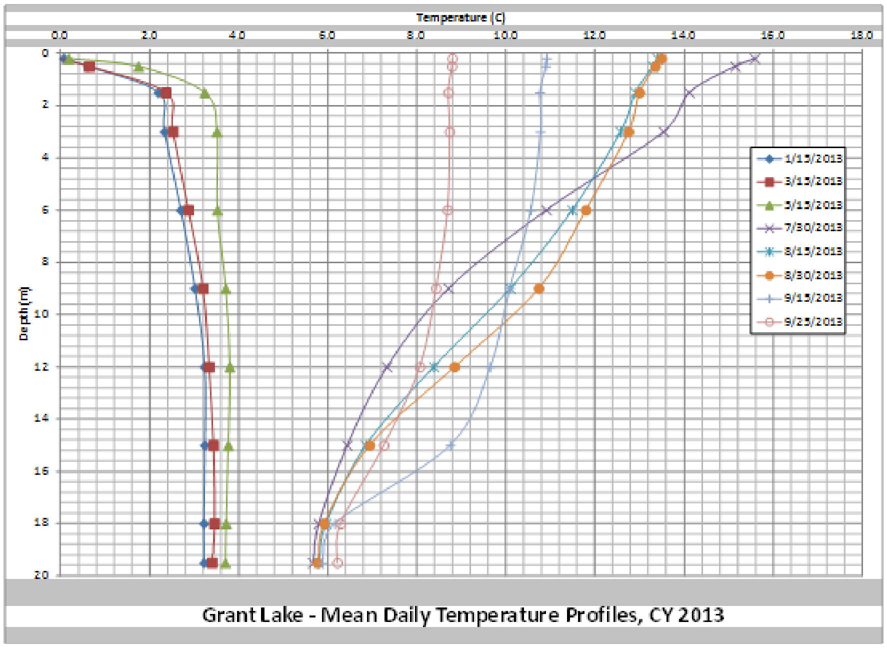
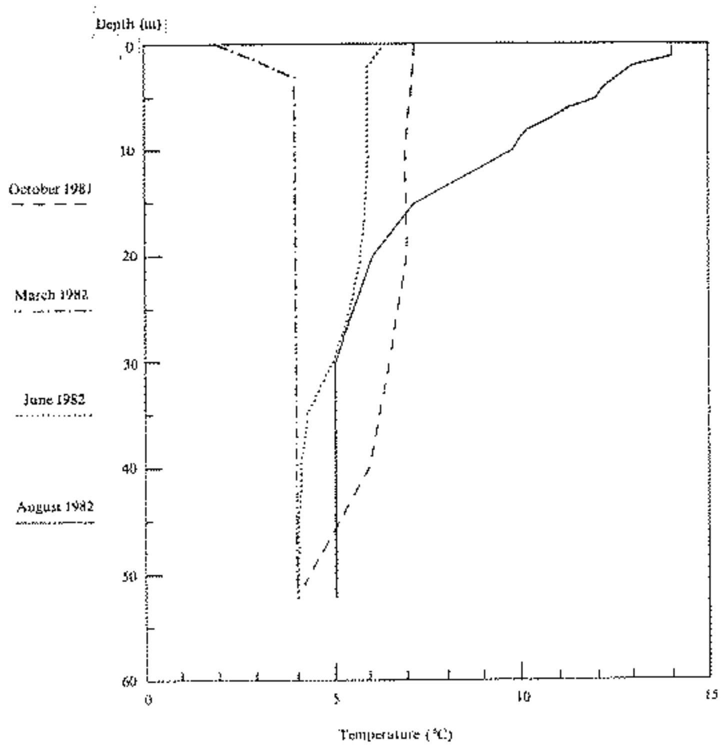
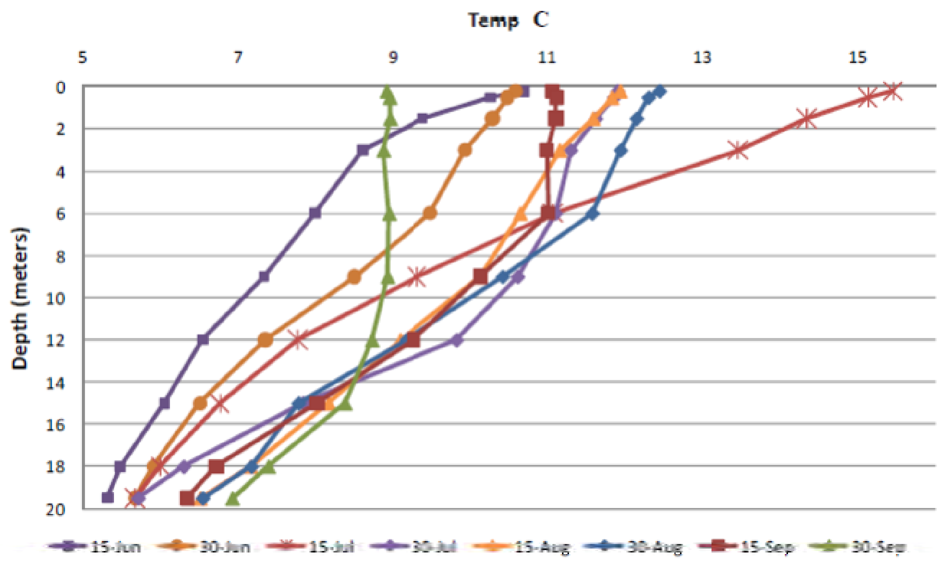


Figure 5.1-5. Daily mean water temperature profiles in Grant Lake near the proposed intake structure



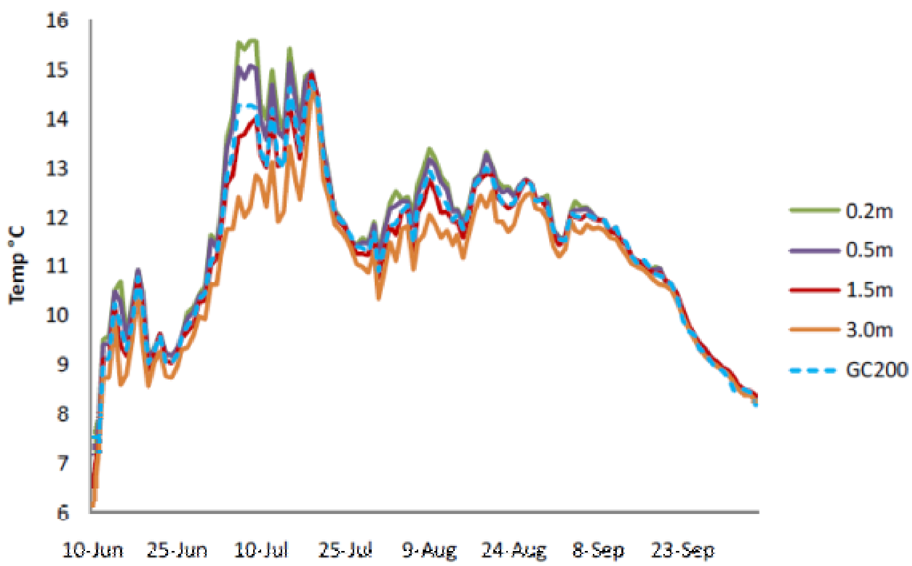
a)



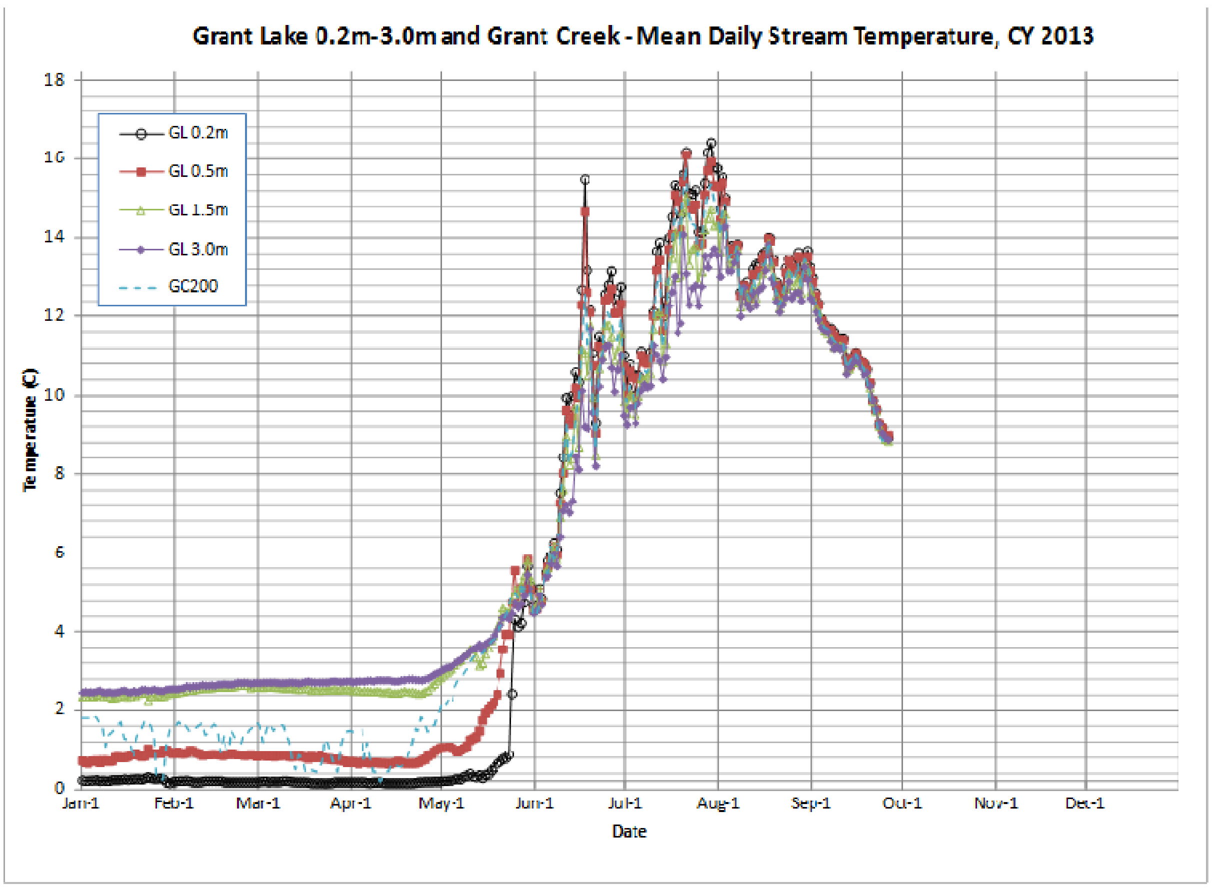
b)

Figure 5.1-6. Historical water temperature profiles in Grant Lake from a) AEIDC and b) HDR.

Temperature results from Grant Lake and Grant Creek indicate lake water temperatures closely mirror and influence creek water temperatures during periods when the lake is ice-free. The strongest correlation appears to be between creek temperatures and the upper surface lake depths (0.2 – 3.0 meters). Figure 5.1-7 shows a comparison of Grant Lake water temperatures from the four shallow sampling depths compared to Grant Creek (GC200) in 2009 and 2013.



a)



b)

Figure 5.1-7. A comparison of daily mean water temperatures for shallow depths (≤ 3m) of Grant Lake and Grant Creek in a) 2009 and b) 2013.

A further review of the data reveals that water temperatures in Grant Lake at a depth of 1.5 meters most closely match Grant Creek water temperatures during ice-free periods (Figure 5.1-8). For the May-September monitoring period, mean monthly temperatures at GLTS-1.5m and GC 200 are within 0.5 °C. In the 2013 winter period (January-April), mean monthly temperatures at GLTS-1.5m are up to 1.5 °C warmer than Grant Creek (GC200) temperatures. The trend of Grant Creek and GLTS-1.5m water temperatures nearly matching during the ice-free season is also confirmed by the 2009 temperature monitoring efforts (HDR 2009) and revealed in Figure 5.1-7.

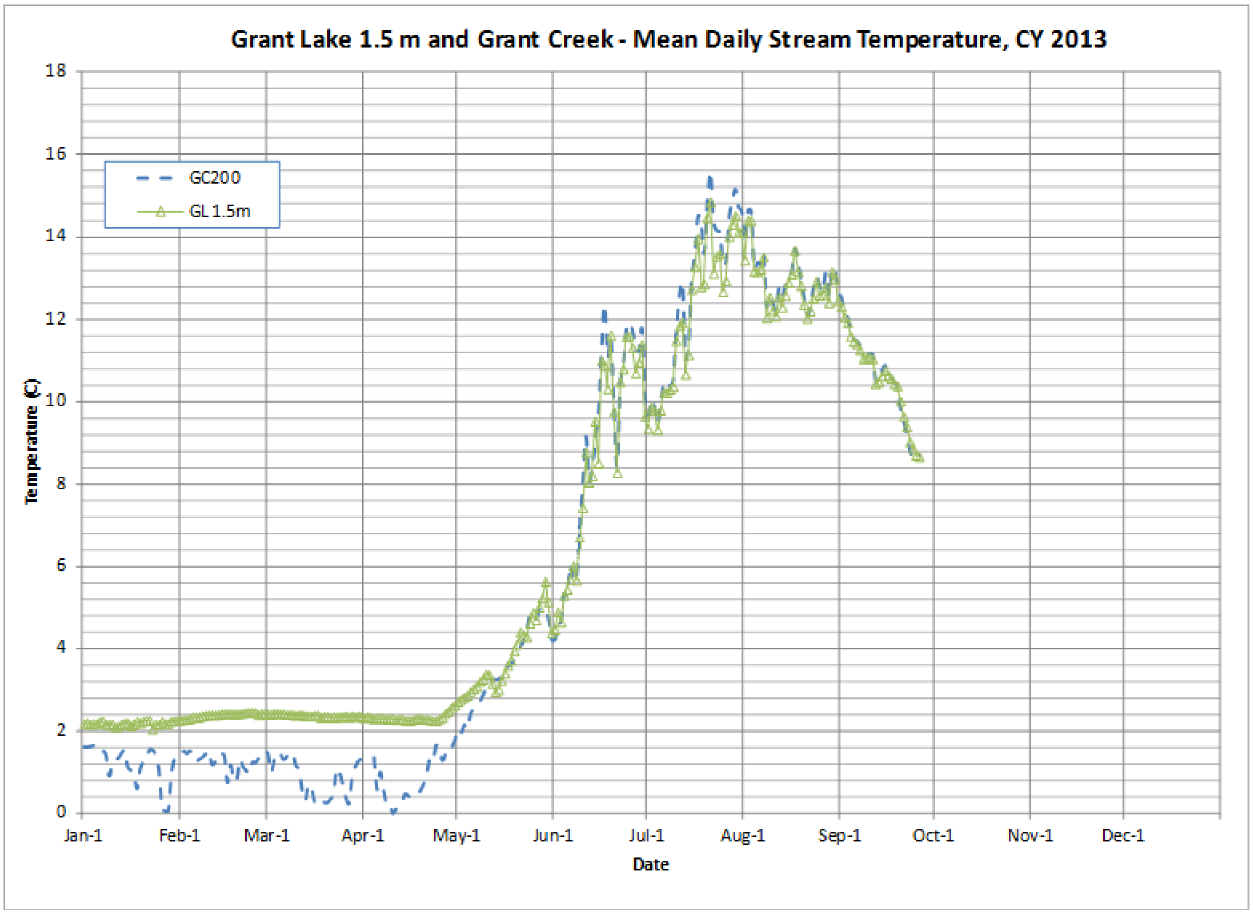


Figure 5.1-8. A comparison of daily mean water temperatures for Grant Lake at a depth of 1.5 meter and Grant Creek – 2013.

Instantaneous temperature profiles and continuous temperature monitoring in 1983 (AEIDC 1983) and 2009 (HDR 2009) have been summarized. Appendices 1c and 1d contain all of the available Grant Creek and Grant Lake temperature data since the 2009 study report was filed.

It should be noted that Grant Lake temperature data presented in this report for the years 2010 through the first half of 2013 were compiled from the thermistor string recovered on June 15, 2013. Although the thermistor string drifted slightly from the GLTS location, these data represent a valid and comparable data set for describing vertical temperature changes in the lower basin of Grant Lake. Also, Grant Lake temperature data is available at all of the sampling depths from 2010-2013, but based on the gradual changes in water temperatures by depth, only surface (1.5 meters), middle (9.0 meters), and near bottom (18.0 meters) temperature records are provided.

There is very little inter-annual variation of temperatures near the surface of Grant Lake. The differences in the spring warming period are most likely linked to ice breakup while peak summer temperatures and declining fall temperatures are responding to ambient air conditions. Inter-annual variations within the mid-column and bottom of Grant Lake are less pronounced than at the surface. Peak temperatures at 9.0 meters were found in early August during the 2011 and 2013 seasons, while the 2012 maximum mean daily temperature occurred in early July. Near the bottom of the Grant Lake monitoring station, daily mean temperatures peak in early to mid September. Over the three year monitoring period, the 1.5 meters, 9.0 meters, and 18.0 meters stations had annual variations in maximum mean daily temperature values of 1.8 °C, 1.7 °C, and 1.3 °C respectively.

Grant Creek

Grant Creek water temperatures were monitored and summarized in 2009 (HDR 2009). A thermologger recovered at station GC250 in April 2013 provides continuous temperature data for the fall of 2009, all of 2010, and for the first days 37 days of 2011. Site GC 200, approximately 450 feet downstream of GC250, has temperature data for last 21 days of December 2012 through late September 2013.

The trend for Grant Creek temperatures, based on the data set, is to be at or below 2 °C during the winter months (December through late April). Water temperatures begin to rise sometime in late April or early May depending upon ice break up in Grant Lake. Water temperatures continue to rise throughout June and July before peaking sometime between mid-July to mid-August. Figure 5.1-9 summarizes all of the recent Grant Creek temperature records.

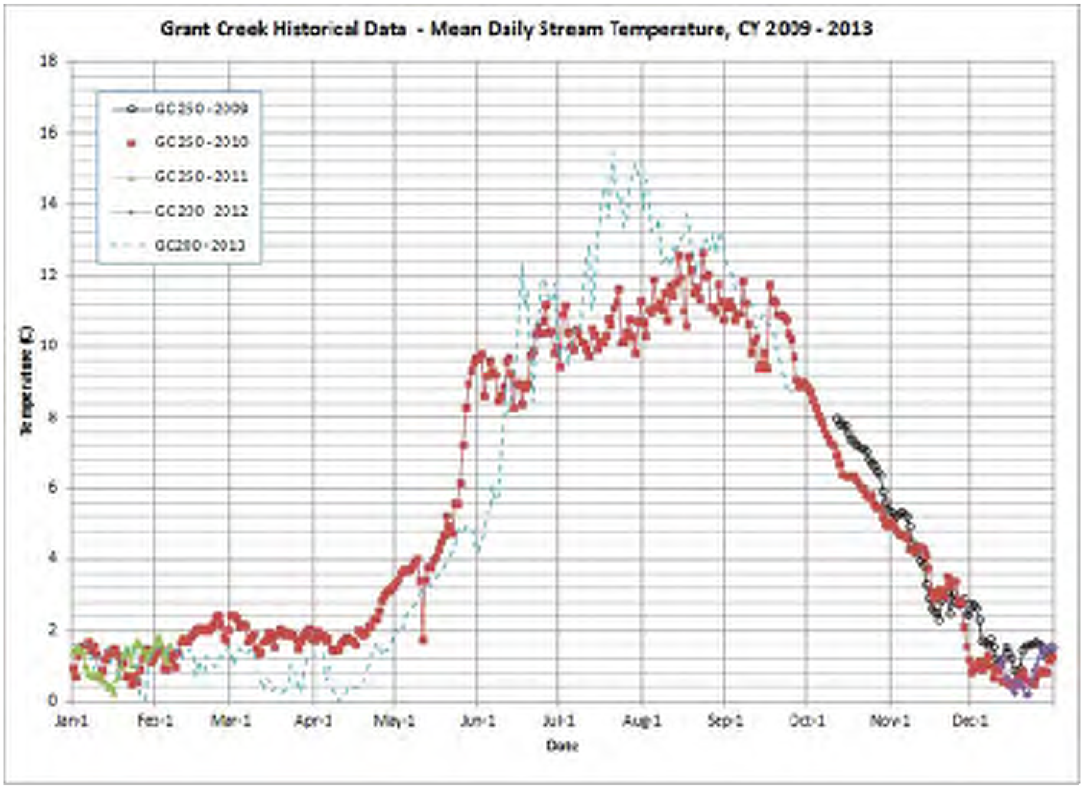


Figure 5.1-9. A comparison of daily mean water temperatures for Grant Creek, CY 2009 – 2013.

Data indicates that Grant Creek water temperatures, on average in 2010, were warmer (+0.5 °C) in the winter months and cooler (-3.5 °C) in the summer months when compared to 2013 results. Grant Creek water temperatures peaked in mid-August 2010 near 13 °C and in late July 2013 near 16 °C. The 2010 and 2013 datasets have limited overlapping data for the fall period. Although limited, the two years do show a similar late summer trends of slowly decreasing mean daily temperatures through mid-September before beginning a steady decline. The limited 2009 fall data also mirrors this same steady temperature decline though late November before freeze-up occurs.

5.2. Hydrology

<u>2013 Stream Gaging</u>

The GC 200 stream gage operated properly during the entirety of the April 2- September 27, 2013 monitoring period. A total of ten discharge measurements were taken to create and validate the stage-discharge relationship at Grant Creek and provide mean daily flow data from April 3 – September 27, 2013. The Grant Creek rating table is defined by two stage discharge equations. As seen in Table 5.2-1, Rating 1LF accurately predicts discharges for gage height values ranging from 0.30-0.99 feet, while Rating 1HF provides discharge values for stages ranging from 1.00-3.59 feet. The flow record for the 2013 season is considered to be of excellent reliability, with 10 discharge measurements validating the rating curve within 9.4 percent (Table 5.2-2). The

USGS criteria for and excellent stream flow record is that 95 percent of the discharge records are accurate within 10 percent. Mean daily flow statistics, discharge, and stage hydrographs are provided in Appendix 2a.

Table 5.2-1. Grant Creek ratings based on 2013 stage-discharge relationship at GC200.

DISCHARGE RATING # 1
GRANT CREEK NEAR MOOSE PASS, ALASKA

GAGE HEIGHT (FEET)	DISCHARGE IN CFS (Expanded precision)									
	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.30	9.49	10.04	10.6	11.2	11.8	12.4	13.0	13.6	14.2	14.9
0.40	15.5	16.2	16.9	17.6	18.3	19.0	19.7	20.5	21.2	22.0
0.50	22.7	23.5	24.3	25.1	25.9	26.8	27.6	28.4	29.3	30.1
0.60	31.0	31.9	32.8	33.7	34.6	35.5	36.4	37.4	38.3	39.3
0.70	40.3	41.2	42.2	43.2	44.2	45.2	46.3	47.3	48.3	49.4
0.80	50.5	51.5	52.6	53.7	54.8	55.9	57.0	58.1	59.3	60.4
0.90	61.5	62.7	63.9	65.0	66.2	67.4	68.6	69.8	71.0	72.3
1.00	74.8	76.4	78.0	79.7	81.3	83.0	84.7	86.4	88.1	89.8
1.10	91.6	93.4	95.1	97.0	98.8	101	102	104	106	108
1.20	110	112	114	116	118	120	122	124	126	128
1.30	130	133	135	137	139	141	144	146	148	150
1.40	153	155	157	160	162	164	167	169	172	174
1.50	177	179	182	184	187	189	192	195	197	200
1.60	203	205	208	211	213	216	219	222	225	227
1.70	230	233	236	239	242	245	248	251	254	257
1.80	260	263	266	269	272	275	278	282	285	288
1.90	291	294	298	301	304	308	311	314	318	321
2.00	325	328	331	335	338	342	345	349	353	356
2.10	360	363	367	371	374	378	382	386	389	393
2.20	397	401	405	408	412	416	420	424	428	432
2.30	436	440	444	448	452	456	460	464	469	473
2.40	477	481	485	490	494	498	502	507	511	515
2.50	520	524	529	533	538	542	547	551	556	560
2.60	565	569	574	579	583	588	593	597	602	607
2.70	612	616	621	626	631	636	641	645	650	655
2.80	660	665	670	675	680	685	691	696	701	706
2.90	711	716	721	727	732	737	742	748	753	758
3.00	764	769	775	780	785	791	796	802	807	813
3.10	818	824	830	835	841	846	852	858	864	869
3.20	875	881	887	892	898	904	910	916	922	928
3.30	934	940	946	952	958	964	970	976	982	988
3.40	994	1001	1007	1013	1019	1025	1032	1038	1044	1051
3.50	1057	1063	1070	1076	1083	1089	1096	1102	1109	1115

Q = 74.74453*(GH-0.01)^1.66750 for outside gage values 0.33 - 0.99
Q = 76.40686*(GH-0.01)^2.10189 for outside gage values 1.00 - 3.59

USE RATING April 4, 2013 to ______

Rating prepared by Charles Sauvageau June 21, 2013

Table 5.2-2. Grant Creek (GC200) discharge measurement summary for the 2013 season.

Q Meas #	Date	Stream Gage Water Level (ft)	Measured Discharge (ft^3/s)	Calculated Discharge (ft^3/s)	Percent Difference (meas/calc)	Comments
				Rating 1 LF		
1	4/4/2013	0.45	18.3	18.9	-3.3%	
2	4/19/2013	0.41	16.6	16.1	2.8%	
3	5/3/2013	0.64	34.3	34.3	0.0%	
4	5/9/2013	0.88	59.6	58.4	2.0%	
5	5/10/2013	0.93	63.1	64.0	-1.5%	
				Rating 1 HF		
6_{HF}	5/14/2013	1.40	145.5	152.7	-4.7%	
7_{HF}	6/12/2013	2.84	694.0	680.4	2.0%	
8_{HF}	8/21/2013	2.00	312.2	324.6	-3.8%	
9_{HF}	9/27/2013	1.78	257.6	253.7	1.5%	
10_{HF}	10/11/2013	1.49	167.4	174.2	-3.9%	

<u>Historical Stream Gaging</u>

A summary of USGS stream gaging records at Grant Creek from 1948-1958 and 1982-1983 are also provided in Appendix 2b. These summarized data include an 11 year average of mean/minimum/maximum daily flow statistics as well as discharge hydrographs. Based on the 2013 data, mean daily discharges follow a similar pattern as the 11 year average (Figure 5.2-1). There are two deviations in the 2013 mean daily flow record when compared to the 11 year record. In late May through the entire month of June, the ascending limb of the hydrograph is steeper and flows are maintained at a detectably higher volume above the USGS average. Secondly, the descending limb of the hydrograph shows a detectable increase in stream flows starting in early September that continues into the middle of the month.

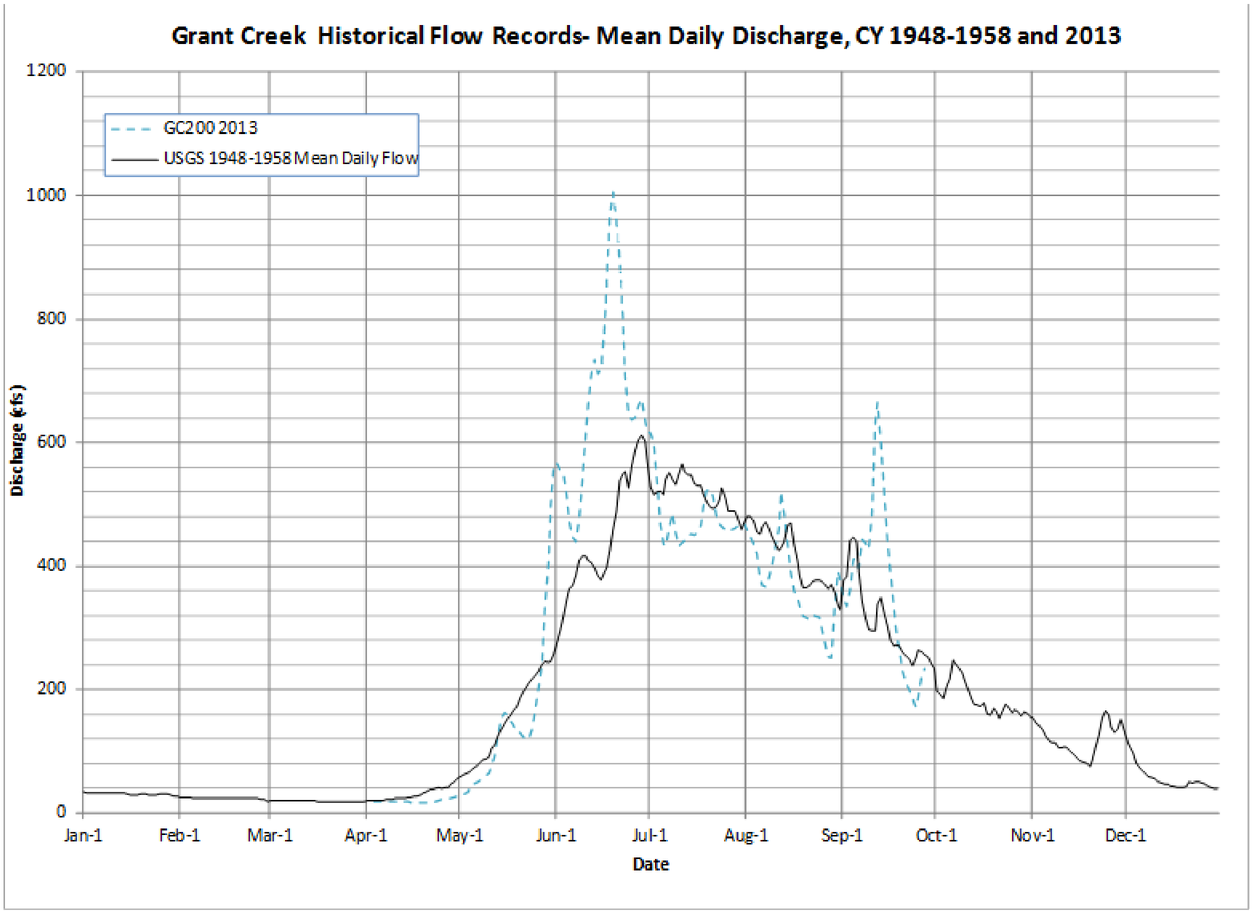


Figure 5.2-1. Comparison of historical and 2013 mean daily flow records

<u>Accretion Study</u>

April 4- 5, 2013, discharge measurements were taken at cross sections at the top and bottom of the Canyon Reach. Due to limited daylight and winter conditions, the upper and lower reaches of the Canyon could not be accessed in a single day. However, as seen in Figure 5.2-2, the hydrograph for April 4th-5th indicate stable flow conditions. The results show that there was 18.1 cfs and 18.3 cfs at the upstream and downstream segments of the Canyon Reach respectively (Tables 5.2-3 and 5.2-4). Results of this effort indicate that no water is lost or gained as it is conveyed down the canyon under low flow conditions. As snowmelt occurs in the spring and flows begin to increase rapidly, there may be some seeps or small runoff channels that enter the Canyon Reach. However, the accretion volumes of these seasonal channels are unlikely to increase flows in the lower section of the Canyon by more than a few cfs.

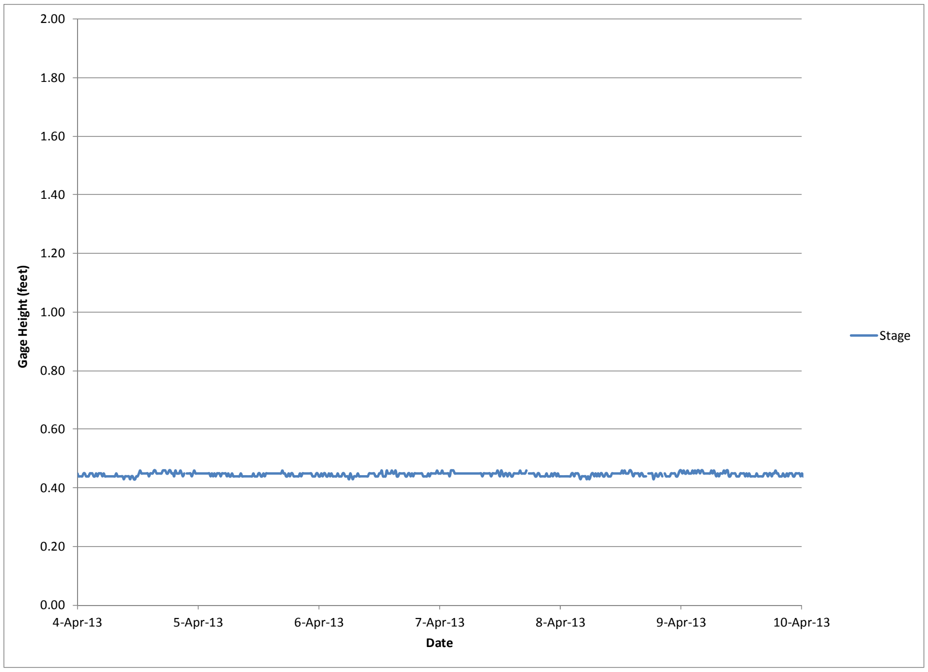


Figure 5.2-2. 15 minute stage hydrograph during accretions studies April 4-5, 2013

Table 5.2-3. Detailed discharge calculation at cross section near upper Grant Creek Canyon Reach.

				Outside Gage	H350 Recorder	HDR Staff on LBA	
Stream Name:	**Grant Creek**						Load N
Location:	**U/S end of Canyon Reach**	**Time Start:**	11:25 AM	0.45	0.45	-0.37	
Q Transect:	500' D/S Grant Lake Outlet	**Time Finish:**	12:01 PM	0.45	0.45	-0.37	
Date:	4/5/2013						
Field Crew:	CS,TR				**Discharge:**	**18.1**	

Station	Depth	Vel 1	Vel 2	Vector	Comment	Vel. Avg.	Width	Area	Corr. Vel.	Cell Q	% of Q
22.6	0.00	0.00			LBWE	0.00	0.40	0.00	0.00	0.00	0.00%
23.4	0.30	0.02				0.02	0.90	0.27	0.02	0.01	0.03%
24.4	0.70	0.14				0.14	0.90	0.63	0.14	0.09	0.49%
25.2	1.10	0.39	0.12			0.26	0.80	0.88	0.26	0.22	1.24%
26.0	1.40	0.67				0.67	0.80	1.12	0.67	0.75	4.14%
26.8	1.70	1.01				1.01	0.80	1.36	1.01	1.37	7.57%
27.6	1.90	0.82				0.82	0.80	1.52	0.82	1.25	6.87%
28.4	1.90	0.25				0.25	0.60	1.14	0.25	0.29	1.57%
28.8	1.70	1.01				1.01	0.40	0.68	1.01	0.69	3.79%
29.2	1.30	1.99				1.99	0.60	0.78	1.99	1.55	8.55%
30.0	1.25	1.41				1.41	0.60	0.75	1.41	1.06	5.83%
30.4	1.30	0.88				0.88	0.40	0.52	0.88	0.46	2.52%
30.8	1.10	0.43				0.43	0.60	0.66	0.43	0.28	1.56%
31.6	1.70	0.51				0.51	0.80	1.36	0.51	0.69	3.82%
32.4	1.30	0.73				0.73	0.80	1.04	0.73	0.76	4.18%
33.2	0.80	0.60				0.60	0.80	0.64	0.60	0.38	2.12%
34.0	0.90	0.72				0.72	0.60	0.54	0.72	0.39	2.14%
34.4	0.70	1.10				1.10	0.40	0.28	1.10	0.31	1.70%
34.8	0.65	1.47				1.47	0.40	0.26	1.47	0.38	2.11%
35.2	0.70	2.02				2.02	0.80	0.56	2.02	1.13	6.23%
36.4	0.70	2.67				2.67	0.80	0.56	2.67	1.50	8.24%
36.8	0.60	2.11				2.11	0.40	0.24	2.11	0.51	2.79%
37.2	0.80	1.57				1.57	0.60	0.48	1.57	0.75	4.15%
38.0	0.95	1.43				1.43	0.80	0.76	1.43	1.09	5.99%
38.8	1.05	0.53				0.53	0.80	0.84	0.53	0.45	2.45%
39.6	0.30	0.75				0.75	0.80	0.24	0.75	0.18	0.99%
40.4	0.20	0.69				0.69	0.80	0.16	0.69	0.11	0.61%
41.2	0.20	0.42				0.42	0.80	0.16	0.42	0.07	0.37%
42.0	0.30	0.67				0.67	0.60	0.18	0.67	0.12	0.66%
42.4	0.00	0.00				0.00	1.30	0.00	0.00	0.00	0.00%
44.6	0.00	0.00				0.00	1.50	0.00	0.00	0.00	0.00%
45.4	0.80	0.07				0.07	0.90	0.72	0.07	0.05	0.28%
46.4	0.90	0.07				0.07	1.00	0.90	0.07	0.06	0.35%
47.4	0.80	0.7				0.70	1.00	0.80	0.70	0.56	3.09%
48.4	0.70	0.38				0.38	1.00	0.70	0.38	0.27	1.47%
49.4	0.30	0.54				0.54	1.00	0.30	0.54	0.16	0.89%
50.4	0.50	0.44				0.44	1.00	0.50	0.44	0.22	1.21%
51.4	0.00	0.00			RBWE	0.00	0.50	0.00	0.00	0.00	0.00%

Table 5.2-4. Detailed discharge calculation at cross section near lower Grant Creek Canyon Reach.

			Outside Gage	H350 Recorder	HDR Staff on LBA	Load M
Stream Name:	**Grant Creek**					
Location:	**D/S end of Canyon Reach**	**Time Start:**	1:38 PM	0.45	0.45	-0.37
Q Transect:	near ISF Transect 430	**Time Finish:**	2:07 PM	0.45	0.45	-0.37
Date:	4/4/2013					
Field Crew:	CS,TR			**Discharge:**	**18.3**	

Station	Depth	Vel 1	Vel 2	Vector	Comment	Vel. Avg.	Width	Area	Corr. Vel.	Cell Q	% of Q
4.9	0.00	0.00			LBWE	0.00	0.55	0.00	0.00	0.00	0.00%
6.0	0.30	0.04				0.04	1.30	0.39	0.04	0.02	0.09%
7.5	0.25	0.02				0.02	1.20	0.30	0.02	0.01	0.03%
8.4	0.00	0.00				0.00	1.00	0.00	0.00	0.00	0.00%
9.5	0.00	0.00				0.00	0.80	0.00	0.00	0.00	0.00%
10.0	0.40	0.21				0.21	0.75	0.30	0.21	0.06	0.34%
11.0	0.70	1.15				1.15	0.85	0.60	1.15	0.68	3.74%
11.7	1.00	1.42				1.42	0.70	0.70	1.42	0.99	5.43%
12.4	1.05	1.28				1.28	0.70	0.74	1.28	0.94	5.14%
13.1	1.10	1.92				1.92	0.70	0.77	1.92	1.48	8.07%
13.8	1.30	1.47				1.47	0.70	0.91	1.47	1.34	7.30%
14.5	0.45	1.90				1.90	0.70	0.32	1.90	0.60	3.27%
15.2	0.80	2.23				2.23	0.70	0.56	2.23	1.25	6.82%
15.9	0.75	1.08				1.08	0.70	0.53	1.08	0.57	3.10%
16.6	1.05	0.61				0.61	0.70	0.74	0.61	0.45	2.45%
17.3	1.05	1.97				1.97	0.70	0.73	1.97	1.45	7.91%
18.0	1.05	1.63				1.63	0.70	0.73	1.63	1.20	6.54%
18.7	0.90	1.67				1.67	0.70	0.63	1.67	1.05	5.74%
19.4	0.90	1.07				1.07	0.70	0.63	1.07	0.67	3.68%
20.1	0.70	1.62				1.62	0.70	0.49	1.62	0.79	4.33%
20.8	0.90	1.20				1.20	0.70	0.63	1.20	0.76	4.13%
21.5	0.80	0.95				0.95	0.70	0.56	0.95	0.53	2.90%
22.2	0.60	1.05				1.05	0.70	0.42	1.05	0.44	2.41%
22.9	0.55	1.18				1.18	0.70	0.39	1.18	0.45	2.48%
23.6	0.60	0.72				0.72	0.70	0.42	0.72	0.30	1.65%
24.3	0.65	1.15				1.15	0.70	0.46	1.15	0.52	2.86%
25.0	0.60	0.61				0.61	0.70	0.42	0.61	0.26	1.40%
25.7	0.40	1.01				1.01	0.70	0.28	1.01	0.28	1.54%
26.4	0.50	1.36				1.36	0.70	0.35	1.36	0.48	2.60%
27.1	0.55	0.95				0.95	0.70	0.39	0.95	0.37	2.00%
27.8	0.50	0.47				0.47	0.70	0.35	0.47	0.16	0.90%
28.5	0.50	0.38				0.38	0.70	0.35	0.38	0.13	0.73%
29.2	0.60	0.02				0.02	0.85	0.51	0.02	0.01	0.06%
30.2	0.40	0.11				0.11	0.55	0.22	0.11	0.02	0.13%
30.3	0.00	0.00				0.00	0.50	0.00	0.00	0.00	0.00%
31.2	0.00	0.00				0.00	0.55	0.00	0.00	0.00	0.00%
31.4	0.40	0.01				0.01	0.40	0.16	0.01	0.00	0.01%
32.0	0.50	0.01				0.01	0.55	0.28	0.01	0.00	0.02%
32.5	0.00	0.00				0.00	0.80	0.00	0.00	0.00	0.00%
33.6	0.00	0.00				0.00	0.60	0.00	0.00	0.00	0.00%
33.7	0.20	0.01				0.01	0.70	0.14	0.01	0.00	0.01%
35.0	0.20	0.13				0.13	1.15	0.23	0.13	0.03	0.16%
36.0	0.20	0.04				0.04	1.30	0.26	0.04	0.01	0.06%
37.6	0.00	0.00			RBWE	0.00	0.80	0.00	0.00	0.00	0.00%

6 CONCLUSIONS

6.1. Water Quality and Temperature

Water Quality

The Grant Lake watershed which includes Grant Creek and Trail Lake Narrows is a high quality watershed based on ADEC water quality criteria. The Trail Lake Narrows flows directly past the mouth of Grant Creek and receives additive flow from it to combine with the majority of its existing water coming from Upper Trail Lake. Baseline water quality sampling results from 2009, 2010 and 2013 indicate this watershed has excellent water quality which is to be expected due to its remote location and pristine condition. Human impacts appear minimal throughout the watershed. Where impacts are occurring, they are primarily associated with the community of Moose Pass and the Trail Lakes themselves. In addition to its current excellent water quality, a comparison of sampling results from the three sampling years for all sites indicates little or no changes in water quality has occurred over the five year period for nearly all parameters. Two notable exceptions were dissolved oxygen and pH.

Dissolved oxygen results (both mg/l and percent saturation values) for 2013 were similar to those collected in 1981 (AEIDC 1983) for Grant Lake but higher in Grant Creek when compared to the 1981 data. The 2013 and 1981 dissolved oxygen levels were substantially different (higher) than those collected in 2009 and 2010. A Grant Lake oxygen profile in June 1981 (AEIDC 1983) found levels ranged from 11.3-12.2 mg/l from the surface to 50 feet deep (Appendix 3). Tables 4-2 through 4-6 provide the 2009 thru 2013 dissolved oxygen results. As stated in the results sections, the lower dissolved oxygen levels measured during 2009-2010 were most likely due to faulty probes or poor calibration procedures. Sampling efforts in 2013 deployed separate multi-probe instruments at each site to achieve more reliable results. Based on the 1981 and 2013 results, dissolved oxygen concentrations are at or near saturation throughout the water column. All other *in situ* parameter sampling results were similar when comparing 1981, 2009/2010 and 2013 data.

In summary and based upon our comprehensive assessment, the water quality parameters in Grant Lake and Grant Creek are very similar and in such low concentrations, that the proposed seasonal changes in Grant Lake outflows as a result of the proposed Project would have very little impact on the water chemistry of Grant Creek.

Temperature

Grant Creek exhibits the typical characteristics of a south central Alaskan, temperate forest stream. Typically, low flows occur in winter (generally November through April) when ice and snow cover keep overland water sources frozen. Ambient air temperatures appear to directly affect stream temperatures throughout the year. However, the extreme upper end of Grant Creek appears to receive some buffering from extreme late winter air temperatures due to its proximity to outflows from an ice covered Grant Lake. During periods of ice cover, the lake temperatures are much more stable compared to Grant Creek temperatures. Once the lake becomes ice free, ambient air temperatures begin to influence daily mean water temperatures in the upper portions of the water column of the lake and this in turn, directly influences creek water temperatures.

Generally in late spring (mid-May), air temperatures warm due to extended periods of daylight and ice begins to break up on Grant Lake. Once breakup occurs, the stream temperatures are closely correlated to lake water temperatures at a depth of 1.5 meters. Temperatures peak in August as runoff flows recede and lake temperatures increase. This also coincides with the majority of anadromous fish returning to the stream to spawn. Stream temperatures steadily descend throughout the fall.

Grant Lake vertical temperature profiles show two distinct characteristics that are typical for lakes that experience long periods of ice cover (Bengtsson 2012). The first characteristic noted is that winter water temperatures increase with depth. This trend was noted from January through mid to late May. Following ice breakup temperatures begin to warm up on the surface and remain cooler at depth. The largest temperature difference between the lake surface and at depth occurs in mid August through mid September. By late September the water column is of Grant Lake is nearly isothermic. The onset and duration of ice cover appears to have a substantial effect on the timing of Grant Lake temperature changes.

Baseline temperature data for both Grant Creek and Grant Lake were collected to assist in development of Project design and potential mitigation measures. Proposed Project designs indicate water withdrawals from Grant Lake would occur near the GLTS site (Figure 3.1-1). A review of 2009 and 2013 water temperature data from Grant Creek and Grant Lake indicates a depth of 1.5 meters below the water surface in Grant Lake most closely mimics water temperatures in Grant Creek (Figures 5.1-7 and 5.1-8).

6.2. Hydrology

The primary study objectives of extending the period of record and assessing accretion flows within the canyon reach of Grant Creek were achieved. Discharge measurements ranging from 17 cfs to 694 cfs were completed and accurately defined the stage-discharge relationship. The 2013 discharge record was similar to the historical USGS record with a few deviations from the general pattern in June and September 2013. The higher flows in June most likely resulted from a sustained heat wave. These warm temperatures resulted in elevated rates of snow and glacial melt which caused higher discharges. In September 2013, a pattern of sustained precipitation is what caused flows to spike above the 11 year average.

A period of stable, low flow conditions in early April allowed for the accurate measurement of discharge at the upstream and downstream sections of the Canyon Reach. The results indicate that all of the water entering the canyon reach is conveyed downstream, with no net losses or gains for the 0.5 mile section of Grant Creek.

7 VARIANCES FROM FERC-APPROVED STUDY PLAN AND PROPOSED MODIFICATIONS

7.1. Water Quality and Temperature

There were no substantial variances from the FERC and agency-approved study plan.

7.2. Hydrology

There were no substantial variances from the FERC and agency-approved study plan.

8 REFERENCES

AEIDC (Arctic Environmental Information Data Center). 1983. *Summary of environmental knowledge of the proposed Grant Lake hydroelectric project area*. Final Report submitted to Ebasco Services, Inc., Redmond, Washington, University of Alaska, Anchorage, Alaska.

Bengtsson, L., R.W. Herschy and R.W Fairbridge. 2012. Encyclopedia of Lakes and Reservoirs. Department of Water Resources Engineering, Lund University, Lund, Sweden. 954 pgs.

Ebasco Services Incorporated. 1984. Grant Lake Hydroelectric Project Detailed Feasibility Analysis. Volume 2. Environmental Report. Rep. prepared for Alaska Power Authority.

HDR. 2009. Grant Creek Proposed Hydroelectric Project Reconnaissance Report, Draft. Prepared For Kenai Hydro, LLC, Homer, Alaska.

HDR. 2010. Grant Lake/Grant Creek And Falls Creek Project - Aquatic Resources Draft Study plan. Prepared For Kenai Hydro, LLC, Homer, Alaska.

KHL (Kenai Hydro, LLC). 2009. Pre-Application Document Grant Lake/Grant Creek and Falls Creek Project (FERC No. 13211 and 13212). August 2009.

Rantz, S.E., and others. 1982. Measurement and Computation of Streamflow, Volume 1: Measurement of Stage and Discharge. U.S. Geological Survey Water Supply Paper 2175.

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Appendix 1: Grant Lake and Grant Creek Temperature Records

Appendix 1a. Grant Creek Temperature Records - 2013

Appendix 1b. Grant Lake Temperature Records – 2013

Appendix 1c. Historical Grant Creek Temperature Records – 1982; 2009-2012

Appendix 1d. Historical Grant Lake Temperature Records – 2010-2012

Appendix 1a. Grant Creek Temperature Records – 2013

This appendix contains the following figures and tables:

Table A.1a-1. Grant Creek – GC 100 daily mean temperature (C), calendar year 2013.

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	m	m	m	m	2.2	4.2	9.7	13.9	12.6	m	m	m
2	m	m	m	1.6	2.0	4.6	10.1	14.7	12.2	m	m	m
3	m	m	m	1.1	2.2	4.7	9.9	14.7	12.1	m	m	m
4	m	m	m	0.9	2.1	5.4	9.5	13.3	11.7	m	m	m
5	m	m	m	0.7	2.5	5.3	10.0	13.4	11.6	m	m	m
6	m	m	m	1.1	2.7	6.1	10.5	13.4	11.5	m	m	m
7	m	m	m	0.8	2.8	5.7	10.5	13.6	11.4	m	m	m
8	m	m	m	0.5	2.9	5.8	10.4	12.3	11.3	m	m	m
9	m	m	m	0.5	3.0	7.0	10.5	12.6	11.2	m	m	m
10	m	m	m	0.2	3.2	8.1	11.8	12.4	11.2	m	m	m
11	m	m	m	0.1	3.3	9.2	12.6	12.3	11.2	m	m	m
12	m	m	m	0.3	3.4	8.1	12.9	12.8	10.5	m	m	m
13	m	m	m	0.4	3.4	8.4	11.1	12.6	10.7	m	m	m
14	m	m	m	0.7	3.3	9.1	11.5	12.9	10.8	m	m	m
15	m	m	m	0.7	3.4	9.8	13.1	13.1	10.9	m	m	m
16	m	m	m	0.7	3.6	11.3	13.7	13.2	10.7	m	m	m
17	m	m	m	0.7	3.7	12.4	14.6	13.8	10.6	m	m	m
18	m	m	m	0.8	3.7	11.1	14.3	13.5	10.5	m	m	m
19	m	m	m	0.9	3.9	11.6	13.7	13.0	10.4	m	m	m
20	m	m	m	1.0	4.0	9.8	14.9	12.6	9.9	m	m	m
21	m	m	m	1.2	4.1	8.4	15.7	12.1	9.6	m	m	m
22	m	m	m	1.6	4.3	10.5	14.4	12.3	9.3	m	m	m
23	m	m	m	1.4	4.6	10.9	14.2	12.8	8.9	m	m	m
24	m	m	m	1.8	4.9	11.8	14.2	13.1	8.7	m	m	m
25	m	m	m	1.6	4.9	11.9	13.4	12.9	8.8	m	m	m
26	m	m	m	1.4	4.8	11.8	13.5	12.7	8.8	m	m	m
27	m	m	m	1.6	5.0	11.3	14.5	13.2	m	m	m	m
28	m	m	m	1.6	5.0	11.3	15.0	12.6	m	m	m	m
29	m	---	m	1.7	5.0	11.8	15.2	13.3	m	m	m	m
30	m	---	m	1.9	4.8	10.1	14.8	13.2	m	m	m	m
31	m	---	m	---	4.3	---	14.7	12.7	---	m	---	m
Mean	m	m	m	1.0	3.6	8.9	12.7	13.1	10.6	m	m	m
Min	m	m	m	0.1	2.0	4.2	9.5	12.1	8.7	m	m	m
Max	m	m	m	1.9	5.0	12.4	15.7	14.7	12.6	m	m	m

Notes: m – missing data

Table A.1a-2. Grant Creek – GC 200 daily mean temperature (C), calendar year 2013.

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	1.6	1.4	1.4	1.3	2.0	4.2	9.7	13.9	12.5	m	m	m
2	1.6	1.5	1.0	0.6	1.9	4.5	10.0	14.7	12.1	m	m	m
3	1.6	1.4	1.3	m	2.1	4.7	9.9	14.6	12.1	m	m	m
4	1.6	1.5	1.5	1.3	2.1	5.3	9.5	13.2	11.7	m	m	m
5	1.7	1.4	1.4	0.6	2.4	5.3	10.0	13.4	11.5	m	m	m
6	1.6	1.3	1.3	1.0	2.5	6.0	10.5	13.3	11.5	m	m	m
7	1.5	1.3	1.4	0.6	2.6	5.6	10.4	13.6	11.4	m	m	m
8	1.4	1.4	1.5	0.2	2.7	5.8	10.4	12.3	11.2	m	m	m
9	0.9	1.4	1.4	0.2	2.9	7.0	10.5	12.6	11.1	m	m	m
10	1.2	1.5	1.1	0.0	3.0	8.0	11.7	12.4	11.2	m	m	m
11	1.3	1.2	1.1	0.1	3.2	9.2	12.6	12.2	11.1	m	m	m
12	1.3	1.2	0.5	0.2	3.2	8.1	12.9	12.8	10.5	m	m	m
13	1.5	1.4	0.3	0.3	3.2	8.4	11.0	12.6	10.6	m	m	m
14	1.5	1.5	0.7	0.5	3.2	9.1	11.4	12.8	10.8	m	m	m
15	1.1	1.4	0.6	0.4	3.4	9.7	13.0	13.1	10.9	m	m	m
16	1.0	0.7	0.3	0.4	3.4	11.2	13.6	13.2	10.6	m	m	m
17	0.9	1.2	0.4	0.4	3.6	12.4	14.5	13.7	10.6	m	m	m
18	0.6	0.8	0.3	0.4	3.6	11.1	14.3	13.4	10.5	m	m	m
19	1.1	0.8	0.3	0.6	3.8	11.5	13.6	13.0	10.3	m	m	m
20	1.2	1.3	0.3	0.7	3.9	9.8	14.9	12.5	9.8	m	m	m
21	1.3	1.1	0.3	1.0	4.0	8.4	15.6	12.1	9.5	m	m	m
22	1.5	1.0	0.5	1.3	4.2	10.4	14.4	12.3	9.2	m	m	m
23	1.5	1.0	1.1	1.3	4.5	10.9	14.2	12.8	8.8	m	m	m
24	1.4	1.2	1.0	1.7	4.8	11.8	14.1	13.0	8.6	m	m	m
25	1.1	1.2	0.7	1.5	4.8	11.9	13.3	12.8	8.7	m	m	m
26	0.1	1.3	0.4	1.3	4.7	11.7	13.4	12.7	8.7	m	m	m
27	0.1	1.4	0.2	1.4	4.9	11.3	14.5	13.1	m	m	m	m
28	0.1	1.5	0.9	1.4	4.9	11.2	14.9	12.6	m	m	m	m
29	0.9	---	1.1	1.6	4.9	11.8	15.2	13.2	m	m	m	m
30	1.3	---	1.3	1.8	4.7	10.1	14.7	13.2	m	m	m	m
31	1.3	---	1.3	---	4.2	---	14.6	12.7	---	m	---	m
Mean	1.2	1.3	0.9	0.9	3.5	8.9	12.7	13.0	10.6	m	m	m
Min	0.1	0.7	0.2	0.0	1.9	4.2	9.5	12.1	8.6	m	m	m
Max	1.7	1.5	1.5	1.8	4.9	12.4	15.6	14.7	12.5	m	m	m

Notes: m – missing data

Table A.1a-3. Grant Creek – GC 250 daily mean temperature (C), calendar year 2013.

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	m	m	m	m	2.1	4.2	9.7	13.9	12.5	m	m	m
2	m	m	m	1.5	2.0	4.5	10.1	14.7	12.2	m	m	m
3	m	m	m	1.1	2.2	4.7	9.9	14.7	12.1	m	m	m
4	m	m	m	0.9	2.1	5.4	9.5	13.3	11.7	m	m	m
5	m	m	m	0.8	2.5	5.3	10.0	13.4	11.6	m	m	m
6	m	m	m	1.1	2.6	6.1	10.5	13.4	11.5	m	m	m
7	m	m	m	0.8	2.7	5.6	10.5	13.6	11.4	m	m	m
8	m	m	m	0.5	2.8	5.8	10.4	12.3	11.2	m	m	m
9	m	m	m	0.5	3.0	7.0	10.5	12.6	11.2	m	m	m
10	m	m	m	0.3	3.2	8.1	11.8	12.4	11.2	m	m	m
11	m	m	m	0.2	3.3	9.2	12.6	12.3	11.2	m	m	m
12	m	m	m	0.3	3.3	8.1	12.9	12.8	10.5	m	m	m
13	m	m	m	0.5	3.4	8.4	11.0	12.6	10.6	m	m	m
14	m	m	m	0.8	3.3	9.1	11.5	12.9	10.8	m	m	m
15	m	m	m	0.7	3.4	9.8	13.1	13.1	10.9	m	m	m
16	m	m	m	0.7	3.6	11.3	13.7	13.2	10.7	m	m	m
17	m	m	m	0.8	3.7	12.4	14.6	13.8	10.6	m	m	m
18	m	m	m	0.8	3.7	11.1	14.3	13.5	10.5	m	m	m
19	m	m	m	0.9	3.9	11.6	13.6	13.0	10.4	m	m	m
20	m	m	m	1.0	4.0	9.8	14.9	12.5	9.9	m	m	m
21	m	m	m	1.1	4.1	8.4	15.7	12.2	9.6	m	m	m
22	m	m	m	1.5	4.3	10.5	14.4	12.3	9.3	m	m	m
23	m	m	m	1.4	4.6	10.9	14.2	12.8	8.9	m	m	m
24	m	m	m	1.7	4.9	11.8	14.2	13.1	8.7	m	m	m
25	m	m	m	1.5	4.9	11.9	13.3	12.9	8.8	m	m	m
26	m	m	m	1.4	4.7	11.8	13.4	12.7	8.8	m	m	m
27	m	m	m	1.5	5.0	11.3	14.5	13.2	m	m	m	m
28	m	m	m	1.5	5.0	11.3	15.0	12.6	m	m	m	m
29	m	---	m	1.7	5.0	11.8	15.2	13.3	m	m	m	m
30	m	---	m	1.8	4.8	10.1	14.8	13.2	m	m	m	m
31	m	---	m	---	4.2	---	14.7	12.7	---	m	---	m
Mean	m	m	m	1.0	3.6	8.9	12.7	13.1	10.6	m	m	m
Min	m	m	m	0.2	2.0	4.2	9.5	12.2	8.7	m	m	m
Max	m	m	m	1.8	5.0	12.4	15.7	14.7	12.5	m	m	m

Notes: m – missing data

Table A.1a-4. Grant Creek – GC 300 daily mean temperature (C), calendar year 2013.

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	m	m	m	m	2.0	4.2	9.6	13.8	12.5	m	m	m
2	m	m	m	1.4	1.9	4.5	10.0	14.7	12.1	m	m	m
3	m	m	m	1.1	2.1	4.7	9.9	14.6	12.1	m	m	m
4	m	m	m	0.9	2.1	5.3	9.4	13.2	11.7	m	m	m
5	m	m	m	0.8	2.4	5.3	10.0	13.4	11.5	m	m	m
6	m	m	m	1.1	2.6	6.0	10.5	13.4	11.5	m	m	m
7	m	m	m	0.8	2.7	5.6	10.4	13.6	11.4	m	m	m
8	m	m	m	0.5	2.7	5.7	10.4	12.3	11.2	m	m	m
9	m	m	m	0.5	2.9	7.0	10.5	12.6	11.2	m	m	m
10	m	m	m	0.4	3.1	8.1	11.7	12.4	11.2	m	m	m
11	m	m	m	0.2	3.2	9.1	12.6	12.2	11.2	m	m	m
12	m	m	m	0.4	3.3	8.1	12.8	12.8	10.5	m	m	m
13	m	m	m	0.5	3.3	8.4	11.0	12.5	10.6	m	m	m
14	m	m	m	0.7	3.3	9.1	11.4	12.8	10.8	m	m	m
15	m	m	m	0.7	3.4	9.8	13.1	13.1	10.9	m	m	m
16	m	m	m	0.7	3.6	11.3	13.6	13.2	10.6	m	m	m
17	m	m	m	0.8	3.6	12.3	14.5	13.7	10.6	m	m	m
18	m	m	m	0.8	3.7	11.0	14.2	13.5	10.5	m	m	m
19	m	m	m	0.9	3.8	11.5	13.6	13.0	10.4	m	m	m
20	m	m	m	1.0	3.9	9.8	14.9	12.5	9.9	m	m	m
21	m	m	m	1.1	4.0	8.4	15.6	12.1	9.6	m	m	m
22	m	m	m	1.4	4.2	10.5	14.3	12.3	9.3	m	m	m
23	m	m	m	1.3	4.5	10.9	14.1	12.8	8.9	m	m	m
24	m	m	m	1.6	4.8	11.8	14.1	13.1	8.7	m	m	m
25	m	m	m	1.5	4.8	11.9	13.3	12.8	8.8	m	m	m
26	m	m	m	1.3	4.7	11.7	13.4	12.7	8.7	m	m	m
27	m	m	m	1.4	4.9	11.2	14.5	13.2	m	m	m	m
28	m	m	m	1.5	4.9	11.2	14.9	12.6	m	m	m	m
29	m	---	m	1.6	4.9	11.7	15.2	13.3	m	m	m	m
30	m	---	m	1.8	4.7	10.0	14.7	13.2	m	m	m	m
31	m	---	m	---	4.2	---	14.6	12.7	---	m	---	m
Mean	m	m	m	1.0	3.6	8.9	12.7	13.0	10.6	m	m	m
Min	m	m	m	0.2	1.9	4.2	9.4	12.1	8.7	m	m	m
Max	m	m	m	1.8	4.9	12.3	15.6	14.7	12.5	m	m	m

Notes: m – missing data

Table A.1a-5. Grant Creek – GC 500 daily mean temperature (C), calendar year 2013.

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	m	m	m	m	2.0	4.2	9.6	13.8	12.5	m	m	m
2	m	m	m	1.3	1.9	4.4	10.0	14.7	12.1	m	m	m
3	m	m	m	1.1	2.1	4.7	9.9	14.6	12.0	m	m	m
4	m	m	m	0.9	2.1	5.3	9.4	13.2	11.7	m	m	m
5	m	m	m	0.8	2.4	5.3	10.0	13.4	11.5	m	m	m
6	m	m	m	1.1	2.5	6.0	10.5	13.3	11.5	m	m	m
7	m	m	m	0.8	2.6	5.5	10.4	13.6	11.3	m	m	m
8	m	m	m	0.6	2.7	5.7	10.4	12.3	11.2	m	m	m
9	m	m	m	0.6	2.9	7.0	10.5	12.6	11.1	m	m	m
10	m	m	m	0.4	3.1	8.1	11.7	12.4	11.2	m	m	m
11	m	m	m	0.3	3.2	9.1	12.6	12.2	11.1	m	m	m
12	m	m	m	0.4	3.2	8.0	12.8	12.8	10.5	m	m	m
13	m	m	m	0.5	3.3	8.3	10.9	12.5	10.6	m	m	m
14	m	m	m	0.8	3.3	9.0	11.4	12.8	10.8	m	m	m
15	m	m	m	0.8	3.4	9.7	13.1	13.1	10.9	m	m	m
16	m	m	m	0.7	3.6	11.2	13.6	13.2	10.6	m	m	m
17	m	m	m	0.8	3.6	12.3	14.5	13.7	10.6	m	m	m
18	m	m	m	0.8	3.6	11.0	14.2	13.4	10.5	m	m	m
19	m	m	m	0.9	3.8	11.5	13.6	13.0	10.4	m	m	m
20	m	m	m	1.0	3.9	9.7	14.9	12.5	9.9	m	m	m
21	m	m	m	1.1	4.0	8.3	15.6	12.1	9.6	m	m	m
22	m	m	m	1.3	4.1	10.4	14.3	12.3	9.3	m	m	m
23	m	m	m	1.3	4.4	10.9	14.1	12.8	8.9	m	m	m
24	m	m	m	1.6	4.8	11.7	14.1	13.1	8.7	m	m	m
25	m	m	m	1.4	4.8	11.9	13.3	12.8	8.8	m	m	m
26	m	m	m	1.3	4.7	11.7	13.4	12.7	8.7	m	m	m
27	m	m	m	1.4	4.9	11.2	14.5	13.1	m	m	m	m
28	m	m	m	1.4	4.8	11.2	14.9	12.6	m	m	m	m
29	m	---	m	1.6	4.9	11.7	15.2	13.3	m	m	m	m
30	m	---	m	1.8	4.7	10.0	14.7	13.2	m	m	m	m
31	m	---	m	---	4.1	---	14.6	12.7	---	m	---	m
Mean	m	m	m	1.0	3.5	8.8	12.7	13.0	10.6	m	m	m
Min	m	m	m	0.3	1.9	4.2	9.4	12.1	8.7	m	m	m
Max	m	m	m	1.8	4.9	12.3	15.6	14.7	12.5	m	m	m

Notes: m – missing data

Table A.1a-6. Grant Creek – GC 600 daily mean temperature (C), calendar year 2013.

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	m	m	m	m	1.8	4.1	9.6	13.8	12.4	m	m	m
2	m	m	m	m	1.8	4.4	10.0	14.8	12.0	m	m	m
3	m	m	m	m	1.9	4.6	9.9	14.6	11.9	m	m	m
4	m	m	m	m	2.0	5.2	9.4	13.2	11.5	m	m	m
5	m	m	m	1.3	2.3	5.3	9.9	13.3	11.4	m	m	m
6	m	m	m	1.1	2.4	5.9	10.4	13.4	11.3	m	m	m
7	m	m	m	1.1	2.5	5.5	10.4	13.6	11.2	m	m	m
8	m	m	m	1.0	2.6	5.6	10.3	12.3	11.0	m	m	m
9	m	m	m	1.1	2.8	6.9	10.5	12.6	11.0	m	m	m
10	m	m	m	1.0	2.9	8.0	11.7	12.3	11.0	m	m	m
11	m	m	m	1.0	3.0	9.1	12.7	12.2	11.0	m	m	m
12	m	m	m	1.0	3.1	8.0	12.8	12.7	10.3	m	m	m
13	m	m	m	1.0	3.2	8.3	10.8	12.5	10.4	m	m	m
14	m	m	m	1.1	3.3	9.0	11.4	12.8	10.6	m	m	m
15	m	m	m	1.1	3.4	9.7	13.1	13.1	10.8	m	m	m
16	m	m	m	1.1	3.5	11.2	13.7	13.2	10.6	m	m	m
17	m	m	m	1.1	3.6	12.5	14.6	13.7	10.5	m	m	m
18	m	m	m	1.1	3.6	11.0	14.2	13.4	10.4	m	m	m
19	m	m	m	1.1	3.8	11.6	13.7	12.9	10.3	m	m	m
20	m	m	m	1.2	3.9	9.7	14.9	12.5	9.9	m	m	m
21	m	m	m	1.1	4.0	8.3	15.7	12.1	9.5	m	m	m
22	m	m	m	1.2	4.1	10.5	14.3	12.2	9.2	m	m	m
23	m	m	m	1.2	4.4	10.9	14.1	12.6	8.9	m	m	m
24	m	m	m	1.3	4.8	11.7	14.1	13.0	8.7	m	m	m
25	m	m	m	1.4	4.8	11.8	13.3	12.7	8.6	m	m	m
26	m	m	m	1.4	4.7	11.7	13.3	12.7	8.6	m	m	m
27	m	m	m	1.5	4.8	11.1	14.4	13.0	m	m	m	m
28	m	m	m	1.6	4.8	11.2	14.9	12.4	m	m	m	m
29	m	---	m	1.6	4.8	11.7	15.1	13.1	m	m	m	m
30	m	---	m	1.7	4.5	10.0	14.7	13.0	m	m	m	m
31	m	---	m	---	4.0	---	14.6	12.5	---	m	---	m
Mean	m	m	m	1.2	3.5	8.8	12.7	13.0	10.5	m	m	m
Min	m	m	m	1.0	1.8	4.1	9.4	12.1	8.6	m	m	m
Max	m	m	m	1.7	4.8	12.5	15.7	14.8	12.4	m	m	m

Notes: m – missing data

Table A.1a-7. Grant Creek off-channel rearing area – GC 200oc daily mean temperature (C), calendar year 2013.

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	m	m	m	m	m	m	9.5	13.4	10.0	m	m	m
2	m	m	m	m	m	m	9.5	13.0	9.9	m	m	m
3	m	m	m	m	m	m	9.3	13.0	9.8	m	m	m
4	m	m	m	m	m	m	9.2	12.8	9.7	m	m	m
5	m	m	m	m	m	m	9.0	12.5	9.4	m	m	m
6	m	m	m	m	m	m	9.1	12.3	9.3	m	m	m
7	m	m	m	m	m	m	9.3	12.1	9.2	m	m	m
8	m	m	m	m	m	m	9.5	12.2	9.2	m	m	m
9	m	m	m	m	m	m	9.6	11.7	9.2	m	m	m
10	m	m	m	m	m	m	9.7	11.8	9.2	m	m	m
11	m	m	m	m	m	m	10.2	11.7	9.2	m	m	m
12	m	m	m	m	m	m	10.6	11.8	9.1	m	m	m
13	m	m	m	m	m	m	10.9	11.9	8.9	m	m	m
14	m	m	m	m	m	8.6	10.6	11.9	9.0	m	m	m
15	m	m	m	m	m	7.9	10.7	11.7	8.8	m	m	m
16	m	m	m	m	m	8.7	11.1	11.6	8.5	m	m	m
17	m	m	m	m	m	10.5	11.3	11.6	8.5	m	m	m
18	m	m	m	m	m	10.8	11.8	11.6	8.5	m	m	m
19	m	m	m	m	m	9.7	12.3	11.7	8.4	m	m	m
20	m	m	m	m	m	9.8	12.4	11.5	7.9	m	m	m
21	m	m	m	m	m	8.9	12.7	11.1	7.6	m	m	m
22	m	m	m	m	m	8.6	13.0	10.1	7.7	m	m	m
23	m	m	m	m	m	9.5	12.8	9.8	7.4	m	m	m
24	m	m	m	m	m	10.3	12.8	9.8	6.9	m	m	m
25	m	m	m	m	m	10.5	12.9	9.7	7.0	m	m	m
26	m	m	m	m	m	10.7	12.7	9.8	7.1	m	m	m
27	m	m	m	m	m	10.9	12.8	9.9	m	m	m	m
28	m	m	m	m	m	10.3	13.2	10.1	m	m	m	m
29	m	---	m	m	m	10.5	13.4	10.3	m	m	m	m
30	m	---	m	m	m	10.5	13.6	10.0	m	m	m	m
31	m	---	m	---	m	---	13.6	10.1	---	m	---	m
Mean	m	m	m	m	m	9.8	11.3	11.4	8.7	m	m	m
Min	m	m	m	m	m	7.9	9.0	9.7	6.9	m	m	m
Max	m	m	m	m	m	10.9	13.6	13.4	10.0	m	m	m

Notes: m – missing data

Table A.1a-8. Grant Creek off channel rearing area – GC250oc daily mean temperature (C), calendar year 2013.

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	m	m	m	m	m	m	m	13.7	12.3	m	m	m
2	m	m	m	m	m	m	m	14.2	11.7	m	m	m
3	m	m	m	m	m	m	m	14.4	11.8	m	m	m
4	m	m	m	m	m	m	m	13.1	11.4	m	m	m
5	m	m	m	m	m	m	m	13.2	11.2	m	m	m
6	m	m	m	m	m	m	m	13.0	11.0	m	m	m
7	m	m	m	m	m	m	m	13.3	11.1	m	m	m
8	m	m	m	m	m	m	m	12.2	10.9	m	m	m
9	m	m	m	m	m	m	m	12.3	10.6	m	m	m
10	m	m	m	m	m	m	m	12.4	10.7	m	m	m
11	m	m	m	m	m	m	m	12.2	10.2	m	m	m
12	m	m	m	m	m	m	m	12.7	9.8	m	m	m
13	m	m	m	m	m	m	m	12.6	9.8	m	m	m
14	m	m	m	m	m	m	m	12.8	9.7	m	m	m
15	m	m	m	m	m	m	m	13.0	10.3	m	m	m
16	m	m	m	m	m	m	m	12.8	9.6	m	m	m
17	m	m	m	m	m	m	m	13.4	9.5	m	m	m
18	m	m	m	m	m	m	13.4	13.1	9.6	m	m	m
19	m	m	m	m	m	m	13.5	12.7	9.8	m	m	m
20	m	m	m	m	m	m	14.6	12.3	9.4	m	m	m
21	m	m	m	m	m	m	15.3	12.0	8.9	m	m	m
22	m	m	m	m	m	m	14.3	12.0	8.6	m	m	m
23	m	m	m	m	m	m	13.9	12.6	8.3	m	m	m
24	m	m	m	m	m	m	13.9	12.8	7.8	m	m	m
25	m	m	m	m	m	m	13.1	12.5	8.2	m	m	m
26	m	m	m	m	m	m	13.3	12.3	8.3	m	m	m
27	m	m	m	m	m	m	14.2	12.9	m	m	m	m
28	m	m	m	m	m	m	14.6	12.4	m	m	m	m
29	m	---	m	m	m	m	14.8	12.7	m	m	m	m
30	m	---	m	m	m	m	14.5	12.9	m	m	m	m
31	m	---	m	---	m	---	14.3	12.4	---	m	---	m
Mean	m	m	m	m	m	m	14.1	12.8	10.0	m	m	m
Min	m	m	m	m	m	m	13.1	12.0	7.8	m	m	m
Max	m	m	m	m	m	m	15.3	14.4	12.3	m	m	m

Notes: m – missing data

Appendix 1b. Grant Lake Temperature Records – 2013

This appendix contains the following figures and tables:

Table A.1b-1. Grant Lake – GL 0.2m daily mean temperature (C), calendar year 2013.

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.0	0.0	0.0	0.0	0.0	4.5	10.0	14.5	12.8	m	m	m
2	0.0	0.0	0.0	0.0	0.0	4.9	10.6	15.3	12.4	m	m	m
3	0.0	0.0	0.0	0.0	0.0	4.7	10.4	14.8	12.2	m	m	m
4	0.0	0.0	0.0	0.0	0.0	5.3	9.8	13.6	11.7	m	m	m
5	0.0	0.0	0.0	0.0	0.1	5.6	10.3	13.6	11.6	m	m	m
6	0.1	0.0	0.0	0.0	0.1	5.7	10.9	13.4	11.5	m	m	m
7	0.0	0.0	0.0	0.0	0.1	6.1	10.7	13.7	11.5	m	m	m
8	0.0	0.0	0.0	0.0	0.1	5.9	10.7	12.4	11.4	m	m	m
9	0.0	0.0	0.0	0.0	0.2	7.3	10.9	12.6	11.2	m	m	m
10	0.0	0.0	0.0	0.0	0.2	8.2	11.9	12.7	11.2	m	m	m
11	0.1	0.0	0.0	0.0	0.1	9.8	13.5	12.4	11.3	m	m	m
12	0.1	0.0	0.0	0.0	0.1	9.5	13.7	13.0	10.8	m	m	m
13	0.1	0.0	0.0	0.0	0.2	9.8	11.8	13.1	10.5	m	m	m
14	0.1	0.0	0.0	0.0	0.1	10.4	12.2	13.2	10.8	m	m	m
15	0.1	0.0	0.0	0.0	0.2	10.2	13.8	13.4	10.9	m	m	m
16	0.1	0.0	0.0	0.0	0.2	12.5	14.3	13.5	10.7	m	m	m
17	0.1	0.0	0.0	0.0	0.3	15.3	15.2	13.8	10.7	m	m	m
18	0.1	0.0	0.0	0.0	0.4	13.0	15.1	13.8	10.6	m	m	m
19	0.1	0.0	0.0	0.0	0.5	12.0	14.4	13.3	10.5	m	m	m
20	0.1	0.0	0.0	0.0	0.5	10.9	15.4	12.7	10.1	m	m	m
21	0.1	0.0	0.0	0.0	0.6	9.1	16.0	12.3	9.7	m	m	m
22	0.1	0.0	0.0	0.0	0.6	11.3	15.0	12.5	9.4	m	m	m
23	0.1	0.0	0.0	0.0	0.7	11.1	14.9	13.0	9.1	m	m	m
24	0.1	0.0	0.0	0.0	2.2	12.4	15.0	13.3	9.0	m	m	m
25	0.1	0.0	0.0	0.0	4.1	12.6	14.0	13.2	8.8	m	m	m
26	0.1	0.0	0.0	0.0	3.9	13.0	13.9	13.0	8.7	m	m	m
27	0.1	0.0	0.0	0.0	4.0	12.3	15.2	13.4	m	m	m	m
28	0.1	0.0	0.0	0.0	4.6	12.1	16.0	12.9	m	m	m	m
29	0.0	0.0	0.0	0.0	5.5	12.6	16.2	13.3	m	m	m	m
30	0.0	0.0	0.0	0.0	5.0	10.8	15.6	13.5	m	m	m	m
31	0.0	0.0	0.0	0.0	4.5	10.0	15.6	13.0	m	m	m	m
Mean	0.1	0.0	0.0	0.0	1.3	9.6	13.3	13.3	10.7	m	m	m
Min	0.0	0.0	0.0	0.0	0.0	4.5	9.8	12.3	8.7	m	m	m
Max	0.1	0.0	0.0	0.0	5.5	15.3	16.2	15.3	12.8	m	m	m

Notes: m – missing data

Table A.1b-2. Grant Lake – GL 0.5m daily mean temperature (C), calendar year 2013.

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.5	0.7	0.7	0.5	0.9	4.4	9.8	14.3	12.7	m	m	m
2	0.5	0.8	0.7	0.5	0.9	4.8	10.4	15.2	12.3	m	m	m
3	0.5	0.7	0.7	0.5	0.9	4.6	10.3	14.7	12.1	m	m	m
4	0.5	0.7	0.6	0.5	0.9	5.2	9.7	13.5	11.7	m	m	m
5	0.5	0.7	0.6	0.5	0.8	5.4	10.3	13.5	11.6	m	m	m
6	0.5	0.8	0.6	0.5	0.8	5.6	10.8	13.4	11.5	m	m	m
7	0.5	0.8	0.7	0.5	0.8	6.0	10.6	13.6	11.5	m	m	m
8	0.5	0.7	0.7	0.5	0.8	5.8	10.6	12.3	11.3	m	m	m
9	0.5	0.7	0.7	0.5	0.9	7.1	10.8	12.6	11.2	m	m	m
10	0.5	0.7	0.7	0.5	1.1	7.8	11.8	12.5	11.2	m	m	m
11	0.5	0.7	0.6	0.5	1.1	9.4	13.0	12.3	11.2	m	m	m
12	0.6	0.7	0.6	0.5	1.2	9.1	13.2	12.9	10.7	m	m	m
13	0.6	0.7	0.7	0.5	1.3	9.2	11.5	12.9	10.5	m	m	m
14	0.6	0.7	0.7	0.5	1.6	10.0	11.9	13.0	10.8	m	m	m
15	0.6	0.7	0.6	0.5	1.7	9.8	13.5	13.3	10.9	m	m	m
16	0.6	0.7	0.6	0.5	1.8	12.1	13.9	13.4	10.7	m	m	m
17	0.7	0.7	0.6	0.5	1.9	14.5	14.9	13.8	10.6	m	m	m
18	0.7	0.7	0.6	0.5	2.0	12.4	14.7	13.7	10.6	m	m	m
19	0.7	0.7	0.6	0.5	2.2	11.9	14.0	13.2	10.5	m	m	m
20	0.7	0.7	0.6	0.5	2.8	10.6	15.2	12.6	10.1	m	m	m
21	0.6	0.7	0.7	0.5	3.4	8.9	15.9	12.2	9.7	m	m	m
22	0.7	0.7	0.6	0.5	3.8	11.1	14.7	12.5	9.4	m	m	m
23	0.8	0.7	0.6	0.5	3.7	11.0	14.5	12.9	9.1	m	m	m
24	0.7	0.7	0.6	0.5	4.6	12.2	14.7	13.2	9.0	m	m	m
25	0.7	0.7	0.6	0.6	5.4	12.3	13.6	13.0	8.8	m	m	m
26	0.7	0.7	0.6	0.7	4.5	12.5	13.7	13.0	8.8	m	m	m
27	0.7	0.7	0.6	0.7	4.9	11.9	14.9	13.3	m	m	m	m
28	0.8	0.7	0.5	0.8	4.9	11.9	15.5	12.8	m	m	m	m
29	0.8	---	0.5	0.8	5.6	12.1	15.7	13.3	m	m	m	m
30	0.8	---	0.5	0.9	4.9	10.5	15.1	13.3	m	m	m	m
31	0.7	---	0.5	---	4.4	---	15.1	12.9	---	m	---	m
Mean	0.6	0.7	0.6	0.5	2.5	9.3	13.1	13.2	10.7	m	m	m
Min	0.5	0.7	0.5	0.5	0.8	4.4	9.7	12.2	8.8	m	m	m
Max	0.8	0.8	0.7	0.9	5.6	14.5	15.9	15.2	12.7	m	m	m

Notes: m – missing data

Table A.1b-3. Grant Lake – GL 1.5m daily mean temperature (C), calendar year 2013.

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	2.2	2.3	2.4	2.3	2.7	4.5	9.3	13.4	12.3	m	m	m
2	2.2	2.3	2.4	2.3	2.8	4.9	9.9	14.4	12.1	m	m	m
3	2.2	2.3	2.4	2.3	2.8	4.7	9.8	14.4	11.9	m	m	m
4	2.2	2.3	2.4	2.3	2.9	5.3	9.3	13.2	11.6	m	m	m
5	2.2	2.3	2.4	2.3	3.0	5.4	9.8	13.2	11.5	m	m	m
6	2.2	2.3	2.4	2.3	3.0	5.7	10.2	13.2	11.4	m	m	m
7	2.2	2.3	2.4	2.3	3.1	6.0	10.2	13.5	11.3	m	m	m
8	2.2	2.4	2.4	2.3	3.2	5.7	10.3	12.0	11.0	m	m	m
9	2.2	2.4	2.4	2.3	3.3	6.7	10.4	12.5	11.1	m	m	m
10	2.2	2.4	2.4	2.3	3.4	7.4	11.5	12.2	11.1	m	m	m
11	2.1	2.4	2.4	2.3	3.4	8.8	11.8	12.1	11.0	m	m	m
12	2.1	2.4	2.4	2.3	3.2	8.0	11.9	12.6	10.4	m	m	m
13	2.2	2.4	2.4	2.3	2.9	8.2	10.7	12.3	10.5	m	m	m
14	2.2	2.4	2.4	2.3	3.0	9.5	11.1	12.6	10.6	m	m	m
15	2.2	2.4	2.4	2.3	3.2	8.5	12.7	12.9	10.8	m	m	m
16	2.1	2.4	2.4	2.3	3.4	11.0	13.3	13.1	10.6	m	m	m
17	2.2	2.4	2.4	2.3	3.6	10.9	14.0	13.7	10.6	m	m	m
18	2.2	2.4	2.3	2.3	3.7	10.3	12.8	13.2	10.4	m	m	m
19	2.2	2.4	2.3	2.3	4.0	11.6	12.9	12.8	10.4	m	m	m
20	2.2	2.4	2.4	2.3	4.1	9.8	14.5	12.4	10.0	m	m	m
21	2.3	2.4	2.3	2.3	4.4	8.3	14.9	12.0	9.6	m	m	m
22	2.3	2.5	2.3	2.3	4.3	10.5	13.1	12.2	9.4	m	m	m
23	2.0	2.5	2.3	2.2	4.3	10.8	13.5	12.5	9.0	m	m	m
24	2.2	2.5	2.3	2.3	4.6	11.6	13.6	12.9	8.9	m	m	m
25	2.2	2.5	2.3	2.3	4.9	11.6	12.7	12.6	8.7	m	m	m
26	2.2	2.4	2.4	2.3	4.7	11.3	12.9	12.6	8.7	m	m	m
27	2.2	2.4	2.3	2.4	5.0	10.7	14.0	12.8	m	m	m	m
28	2.2	2.4	2.4	2.5	5.2	11.0	14.3	12.4	m	m	m	m
29	2.2	---	2.3	2.6	5.6	11.4	14.5	13.2	m	m	m	m
30	2.2	---	2.4	2.6	5.1	9.6	14.1	13.0	m	m	m	m
31	2.3	---	2.3	---	4.4	---	14.1	12.5	---	m	---	m
Mean	2.2	2.4	2.4	2.3	3.8	8.7	12.2	12.8	10.6	m	m	m
Min	2.0	2.3	2.3	2.2	2.7	4.5	9.3	12.0	8.7	m	m	m
Max	2.3	2.5	2.4	2.6	5.6	11.6	14.9	14.4	12.3	m	m	m

Notes: m – missing data

Table A.1b-4. Grant Lake – GL 3.0m daily mean temperature (C), calendar year 2013.

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	2.3	2.4	2.5	2.5	2.9	4.3	9.1	12.8	12.2	m	m	m
2	2.3	2.4	2.5	2.6	2.9	4.8	9.5	14.1	11.9	m	m	m
3	2.3	2.4	2.5	2.6	2.9	4.5	9.5	14.1	11.7	m	m	m
4	2.3	2.4	2.5	2.6	2.9	5.2	9.1	13.0	11.5	m	m	m
5	2.3	2.4	2.5	2.6	3.0	5.2	9.6	13.0	11.5	m	m	m
6	2.3	2.4	2.5	2.6	3.0	5.5	9.9	13.2	11.4	m	m	m
7	2.3	2.4	2.5	2.6	3.1	5.8	10.1	13.4	11.2	m	m	m
8	2.3	2.4	2.5	2.6	3.2	5.5	10.0	11.8	11.0	m	m	m
9	2.3	2.4	2.5	2.6	3.2	6.2	10.1	12.6	11.1	m	m	m
10	2.3	2.5	2.5	2.6	3.3	6.9	11.1	12.1	11.0	m	m	m
11	2.3	2.5	2.5	2.6	3.4	7.0	10.8	12.0	11.0	m	m	m
12	2.3	2.5	2.5	2.6	3.4	6.8	10.7	12.4	10.3	m	m	m
13	2.3	2.5	2.5	2.6	3.5	7.1	10.2	12.1	10.5	m	m	m
14	2.3	2.5	2.5	2.6	3.4	8.3	10.8	12.5	10.6	m	m	m
15	2.3	2.5	2.5	2.6	3.5	7.9	12.1	12.6	10.8	m	m	m
16	2.3	2.5	2.5	2.6	3.6	9.9	12.4	13.0	10.6	m	m	m
17	2.3	2.5	2.6	2.6	3.6	9.0	12.8	13.6	10.5	m	m	m
18	2.3	2.5	2.5	2.6	3.7	9.0	11.4	12.8	10.3	m	m	m
19	2.3	2.5	2.5	2.6	3.9	11.5	11.6	12.7	10.4	m	m	m
20	2.3	2.5	2.5	2.6	4.0	9.4	13.9	12.2	10.1	m	m	m
21	2.3	2.5	2.5	2.6	4.2	8.0	12.9	11.9	9.7	m	m	m
22	2.4	2.5	2.5	2.6	4.2	10.0	12.1	12.1	9.4	m	m	m
23	2.3	2.5	2.5	2.6	4.1	10.7	12.5	12.3	9.1	m	m	m
24	2.3	2.5	2.5	2.6	4.3	11.1	12.6	12.7	8.9	m	m	m
25	2.4	2.5	2.6	2.6	4.6	11.1	12.1	12.3	8.7	m	m	m
26	2.3	2.5	2.6	2.6	4.4	10.5	12.6	12.4	8.7	m	m	m
27	2.3	2.5	2.5	2.7	4.5	9.9	13.4	12.4	m	m	m	m
28	2.3	2.5	2.5	2.7	4.8	10.5	13.0	12.2	m	m	m	m
29	2.4	---	2.5	2.8	5.3	10.8	13.4	13.1	m	m	m	m
30	2.4	---	2.6	2.8	4.9	9.3	13.5	12.8	m	m	m	m
31	2.4	---	2.6	---	4.3	---	13.4	12.3	---	m	---	m
Mean	2.3	2.5	2.5	2.6	3.7	8.1	11.5	12.7	10.5	m	m	m
Min	2.3	2.4	2.5	2.5	2.9	4.3	9.1	11.8	8.7	m	m	m
Max	2.4	2.5	2.6	2.8	5.3	11.5	13.9	14.1	12.2	m	m	m

Notes: m – missing data

Table A.1b-5. Grant Lake – GL 6.0m daily mean temperature (C), calendar year 2013.

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	2.6	2.7	2.9	2.9	3.1	4.3	8.3	10.7	11.6	m	m	m
2	2.6	2.7	2.9	2.9	3.1	4.6	8.6	12.4	11.4	m	m	m
3	2.6	2.7	2.9	2.9	3.1	4.3	8.9	12.0	10.9	m	m	m
4	2.6	2.8	2.9	2.9	3.2	5.1	8.6	12.2	11.1	m	m	m
5	2.6	2.8	2.9	2.9	3.2	5.1	9.2	11.8	11.3	m	m	m
6	2.6	2.7	2.9	2.9	3.2	5.4	9.1	12.9	11.3	m	m	m
7	2.6	2.7	2.9	2.9	3.2	5.7	9.3	12.1	10.8	m	m	m
8	2.6	2.8	2.9	2.9	3.3	5.2	9.1	10.7	10.6	m	m	m
9	2.6	2.8	2.9	2.9	3.3	5.7	9.3	12.5	11.0	m	m	m
10	2.6	2.8	2.9	2.9	3.4	6.2	9.4	11.5	10.7	m	m	m
11	2.6	2.8	2.9	2.9	3.4	5.9	9.2	11.6	10.8	m	m	m
12	2.6	2.8	2.9	2.9	3.4	6.1	8.8	11.9	10.1	m	m	m
13	2.7	2.8	2.9	2.9	3.5	6.2	8.9	11.6	10.5	m	m	m
14	2.7	2.8	2.9	2.9	3.5	6.3	9.6	12.0	10.6	m	m	m
15	2.7	2.8	2.9	2.9	3.5	6.8	9.8	11.5	10.6	m	m	m
16	2.7	2.8	2.9	2.9	3.6	8.0	10.2	12.5	10.4	m	m	m
17	2.7	2.8	2.9	2.9	3.6	7.6	9.6	13.1	10.3	m	m	m
18	2.7	2.8	2.9	2.9	3.7	7.5	9.6	11.8	10.1	m	m	m
19	2.7	2.8	2.9	2.9	3.9	10.4	9.9	11.9	10.3	m	m	m
20	2.7	2.8	2.9	3.0	3.9	8.6	10.1	11.7	10.0	m	m	m
21	2.6	2.8	2.9	3.0	4.0	7.4	9.8	11.6	9.7	m	m	m
22	2.7	2.8	2.9	3.0	4.0	8.8	9.7	11.6	9.4	m	m	m
23	2.7	2.8	2.9	3.0	4.1	10.3	10.1	11.9	9.1	m	m	m
24	2.7	2.8	2.9	3.0	4.1	9.8	10.0	12.0	8.8	m	m	m
25	2.7	2.8	2.9	3.0	4.2	9.7	10.2	11.6	8.7	m	m	m
26	2.7	2.8	2.9	2.9	4.3	9.2	10.8	11.9	8.7	m	m	m
27	2.7	2.8	2.9	3.0	4.4	8.7	11.1	11.4	m	m	m	m
28	2.7	2.9	2.9	3.0	4.4	9.4	10.8	11.8	m	m	m	m
29	2.7	---	2.9	3.0	4.6	8.9	11.0	12.3	m	m	m	m
30	2.7	---	2.9	3.0	4.6	8.5	10.9	11.8	m	m	m	m
31	2.7	---	2.9	---	4.2	---	11.1	11.9	---	m	---	m
Mean	2.7	2.8	2.9	2.9	3.7	7.2	9.7	11.9	10.3	m	m	m
Min	2.6	2.7	2.9	2.9	3.1	4.3	8.3	10.7	8.7	m	m	m
Max	2.7	2.9	2.9	3.0	4.6	10.4	11.1	13.1	11.6	m	m	m

Notes: m – missing data

Table A.1b-6. Grant Lake – GL 9.0m daily mean temperature (C), calendar year 2013.

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3.0	3.1	3.1	3.1	3.3	4.2	7.6	8.7	10.5	m	m	m
2	3.0	3.1	3.1	3.2	3.3	4.5	7.7	9.8	10.8	m	m	m
3	3.0	3.1	3.2	3.2	3.3	4.3	8.2	9.1	10.0	m	m	m
4	3.0	3.1	3.2	3.2	3.3	5.1	8.0	9.6	10.2	m	m	m
5	3.0	3.0	3.2	3.2	3.3	5.0	8.5	9.2	10.5	m	m	m
6	3.0	3.1	3.2	3.2	3.4	5.5	8.2	12.0	10.6	m	m	m
7	3.0	3.1	3.2	3.2	3.4	5.6	8.3	9.8	10.1	m	m	m
8	3.0	3.1	3.2	3.2	3.4	5.1	8.2	9.7	10.1	m	m	m
9	3.1	3.1	3.2	3.2	3.5	5.5	8.4	11.4	10.6	m	m	m
10	3.1	3.1	3.2	3.2	3.5	5.8	8.2	10.0	10.2	m	m	m
11	3.1	3.0	3.2	3.2	3.5	5.6	8.2	10.8	10.3	m	m	m
12	3.1	3.1	3.2	3.2	3.6	5.8	8.1	10.8	9.9	m	m	m
13	3.1	3.1	3.2	3.2	3.6	5.7	7.8	10.3	10.5	m	m	m
14	3.0	3.1	3.2	3.2	3.7	5.8	8.4	10.9	10.2	m	m	m
15	3.0	3.1	3.2	3.2	3.7	6.0	8.5	10.1	10.1	m	m	m
16	3.1	3.1	3.2	3.2	3.7	6.8	8.6	11.2	10.1	m	m	m
17	3.1	3.1	3.2	3.2	3.7	6.8	8.4	11.2	9.9	m	m	m
18	3.1	3.1	3.2	3.2	3.9	6.7	8.3	10.8	9.9	m	m	m
19	3.1	3.1	3.2	3.2	3.9	8.3	8.3	10.7	10.1	m	m	m
20	3.0	3.1	3.1	3.2	3.9	7.6	8.3	10.7	9.9	m	m	m
21	3.0	3.1	3.1	3.2	4.0	6.8	8.2	11.0	9.6	m	m	m
22	3.0	3.1	3.1	3.2	4.0	7.7	8.3	11.0	9.4	m	m	m
23	3.1	3.1	3.2	3.2	4.0	9.7	8.6	10.9	9.0	m	m	m
24	3.1	3.1	3.2	3.2	4.0	7.9	8.3	11.0	8.8	m	m	m
25	3.1	3.1	3.2	3.2	4.0	8.2	8.5	10.6	8.4	m	m	m
26	3.1	3.1	3.1	3.2	4.1	8.2	8.6	11.1	8.5	m	m	m
27	3.1	3.1	3.2	3.2	4.1	7.7	8.7	10.4	m	m	m	m
28	3.1	3.1	3.2	3.2	4.1	8.2	8.9	11.1	m	m	m	m
29	3.1	---	3.2	3.3	4.2	8.0	8.9	10.9	m	m	m	m
30	3.1	---	3.2	3.3	4.3	7.8	8.7	10.7	m	m	m	m
31	3.0	---	3.2	---	4.2	---	8.8	11.2	---	m	---	m
Mean	3.1	3.1	3.2	3.2	3.7	6.5	8.3	10.5	9.9	m	m	m
Min	3.0	3.0	3.1	3.1	3.3	4.2	7.6	8.7	8.4	m	m	m
Max	3.1	3.1	3.2	3.3	4.3	9.7	8.9	12.0	10.8	m	m	m
Notes: m – missing data												

Table A.1b-7. Grant Lake – GL 12.0m daily mean temperature (C), calendar year 2013.

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3.2	3.2	3.3	3.3	3.4	4.1	7.1	7.5	8.9	m	m	m
2	3.2	3.3	3.3	3.3	3.4	4.4	7.1	8.1	9.2	m	m	m
3	3.3	3.3	3.3	3.3	3.4	4.2	7.1	7.8	8.7	m	m	m
4	3.3	3.3	3.3	3.3	3.5	5.0	7.0	7.4	8.9	m	m	m
5	3.2	3.3	3.3	3.3	3.5	4.9	7.4	7.6	8.8	m	m	m
6	3.2	3.2	3.3	3.3	3.5	5.4	7.5	8.1	9.7	m	m	m
7	3.2	3.3	3.3	3.3	3.5	5.3	7.0	8.1	9.3	m	m	m
8	3.3	3.3	3.3	3.3	3.5	4.9	7.3	8.0	9.0	m	m	m
9	3.3	3.3	3.3	3.3	3.5	5.3	7.5	9.3	10.2	m	m	m
10	3.2	3.2	3.3	3.3	3.6	5.5	7.0	8.6	9.3	m	m	m
11	3.3	3.2	3.3	3.3	3.6	5.3	7.5	8.7	9.6	m	m	m
12	3.3	3.3	3.3	3.3	3.7	5.4	7.2	8.4	9.6	m	m	m
13	3.2	3.3	3.3	3.3	3.8	5.2	6.9	8.3	10.4	m	m	m
14	3.2	3.3	3.3	3.3	3.8	5.4	7.3	8.4	9.7	m	m	m
15	3.2	3.3	3.3	3.3	3.8	5.5	7.4	8.4	9.6	m	m	m
16	3.2	3.3	3.3	3.3	3.8	6.1	7.4	8.8	9.6	m	m	m
17	3.3	3.3	3.3	3.3	3.8	6.2	7.5	8.8	9.4	m	m	m
18	3.2	3.3	3.3	3.3	3.8	6.0	7.3	9.3	9.5	m	m	m
19	3.2	3.3	3.3	3.3	3.8	7.2	7.3	8.6	9.7	m	m	m
20	3.2	3.3	3.3	3.3	3.9	6.5	7.2	8.4	9.4	m	m	m
21	3.2	3.2	3.3	3.3	3.9	6.2	7.2	9.1	9.2	m	m	m
22	3.3	3.3	3.3	3.3	3.9	6.7	7.3	8.5	9.4	m	m	m
23	3.3	3.3	3.3	3.3	3.9	8.4	7.2	9.0	9.1	m	m	m
24	3.2	3.3	3.3	3.3	3.9	6.8	7.2	8.9	8.8	m	m	m
25	3.2	3.3	3.3	3.3	3.9	6.7	7.4	8.6	8.1	m	m	m
26	3.2	3.2	3.3	3.3	3.9	7.1	7.3	8.9	8.2	m	m	m
27	3.3	3.3	3.3	3.4	3.9	6.9	7.4	8.6	m	m	m	m
28	3.3	3.3	3.3	3.4	3.9	7.1	7.5	9.0	m	m	m	m
29	3.3	---	3.3	3.4	4.0	7.1	7.6	8.9	m	m	m	m
30	3.3	---	3.3	3.4	4.2	7.0	7.3	8.8	m	m	m	m
31	3.3	---	3.3	---	4.1	---	7.3	8.8	---	m	---	m
Mean	3.3	3.3	3.3	3.3	3.7	5.9	7.3	8.5	9.3	m	m	m
Min	3.2	3.2	3.3	3.3	3.4	4.1	6.9	7.4	8.1	m	m	m
Max	3.3	3.3	3.3	3.4	4.2	8.4	7.6	9.3	10.4	m	m	m
Notes:	**m – missing data**											

Table A.1b-8. Grant Lake – GL 15.0m daily mean temperature (C), calendar year 2013.

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3.2	3.3	3.4	3.4	3.4	4.1	6.5	6.4	7.1	m	m	m
2	3.4	3.3	3.4	3.4	3.5	4.3	6.6	6.8	6.9	m	m	m
3	3.3	3.3	3.3	3.4	3.4	4.1	6.1	6.7	7.5	m	m	m
4	3.4	3.4	3.3	3.4	3.5	5.0	6.2	6.4	7.5	m	m	m
5	3.3	3.3	3.3	3.4	3.4	4.8	6.5	6.6	7.4	m	m	m
6	3.3	3.4	3.3	3.4	3.5	5.3	6.6	6.3	8.2	m	m	m
7	3.3	3.3	3.3	3.4	3.5	5.0	6.0	6.9	7.8	m	m	m
8	3.3	3.4	3.4	3.4	3.6	4.7	6.5	6.9	6.8	m	m	m
9	3.4	3.4	3.4	3.3	3.7	5.2	6.5	7.1	9.0	m	m	m
10	3.3	3.3	3.4	3.4	3.7	5.3	6.3	7.2	7.9	m	m	m
11	3.3	3.3	3.4	3.3	3.7	5.2	6.5	6.5	8.6	m	m	m
12	3.3	3.3	3.4	3.4	3.8	5.2	6.2	6.9	8.4	m	m	m
13	3.3	3.3	3.4	3.4	3.8	5.0	6.4	6.6	9.6	m	m	m
14	3.2	3.4	3.4	3.4	3.8	5.3	6.4	6.6	8.3	m	m	m
15	3.2	3.3	3.4	3.4	3.8	5.2	6.4	6.9	8.7	m	m	m
16	3.2	3.3	3.4	3.4	3.8	5.8	6.4	7.2	8.4	m	m	m
17	3.3	3.4	3.4	3.4	3.8	5.6	6.7	7.3	8.6	m	m	m
18	3.3	3.4	3.4	3.4	3.8	5.6	6.5	7.5	8.5	m	m	m
19	3.4	3.4	3.4	3.5	3.8	6.4	6.5	6.9	8.1	m	m	m
20	3.3	3.4	3.4	3.4	3.8	6.0	6.5	6.6	8.3	m	m	m
21	3.3	3.3	3.4	3.4	3.9	5.9	6.5	7.0	8.4	m	m	m
22	3.3	3.4	3.4	3.4	3.9	6.2	6.6	7.2	8.8	m	m	m
23	3.3	3.4	3.4	3.4	3.9	7.2	6.3	6.9	8.7	m	m	m
24	3.3	3.4	3.4	3.4	3.9	6.3	6.3	6.7	8.5	m	m	m
25	3.3	3.4	3.4	3.4	3.9	5.9	6.5	6.7	7.3	m	m	m
26	3.3	3.3	3.4	3.4	3.9	6.0	6.4	7.0	7.4	m	m	m
27	3.3	3.4	3.4	3.4	3.9	6.2	6.5	7.0	m	m	m	m
28	3.3	3.4	3.4	3.4	3.9	6.4	6.5	7.3	m	m	m	m
29	3.3	---	3.4	3.4	4.0	6.3	6.6	7.5	m	m	m	m
30	3.3	---	3.4	3.4	4.0	6.4	6.4	6.9	m	m	m	m
31	3.4	---	3.4	---	4.1	---	6.4	6.9	---	m	---	m
Mean	3.3	3.3	3.4	3.4	3.8	5.5	6.4	6.9	8.1	m	m	m
Min	3.2	3.3	3.3	3.3	3.4	4.1	6.0	6.3	6.8	m	m	m
Max	3.4	3.4	3.4	3.5	4.1	7.2	6.7	7.5	9.6	m	m	m

Notes: m – missing data

Table A.1b-9. Grant Lake – GL 18.0m daily mean temperature (C), calendar year 2013.

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3.2	3.3	3.4	3.4	3.4	4.1	5.8	5.7	5.8	m	m	m
2	3.3	3.3	3.4	3.4	3.4	4.3	5.9	6.0	5.6	m	m	m
3	3.3	3.3	3.4	3.4	3.4	4.1	5.6	5.8	6.6	m	m	m
4	3.3	3.3	3.4	3.4	3.5	5.0	5.6	5.7	6.1	m	m	m
5	3.3	3.3	3.3	3.4	3.5	4.7	5.7	5.9	6.4	m	m	m
6	3.3	3.4	3.3	3.4	3.5	5.3	5.7	5.5	6.5	m	m	m
7	3.3	3.4	3.3	3.4	3.6	5.0	5.4	6.0	6.2	m	m	m
8	3.3	3.4	3.4	3.4	3.7	4.7	5.9	5.9	5.5	m	m	m
9	3.3	3.3	3.4	3.3	3.8	5.2	5.8	6.2	7.5	m	m	m
10	3.3	3.3	3.4	3.3	3.7	5.3	5.8	6.3	6.7	m	m	m
11	3.3	3.3	3.4	3.3	3.7	5.1	5.7	5.5	6.8	m	m	m
12	3.3	3.3	3.4	3.3	3.8	5.2	5.4	5.9	6.8	m	m	m
13	3.3	3.3	3.4	3.4	3.7	5.0	5.9	5.8	7.7	m	m	m
14	3.2	3.3	3.4	3.4	3.7	5.1	5.8	5.7	6.9	m	m	m
15	3.2	3.3	3.5	3.4	3.7	5.1	5.8	6.0	6.2	m	m	m
16	3.3	3.3	3.5	3.5	3.8	5.5	5.7	6.1	6.6	m	m	m
17	3.3	3.3	3.4	3.5	3.8	5.3	6.0	6.2	6.4	m	m	m
18	3.3	3.3	3.4	3.4	3.8	5.2	5.7	6.2	6.5	m	m	m
19	3.3	3.3	3.4	3.4	3.8	5.9	5.7	5.9	6.5	m	m	m
20	3.3	3.3	3.4	3.4	3.8	5.5	6.0	5.5	6.8	m	m	m
21	3.3	3.3	3.4	3.4	3.9	5.5	6.0	5.9	6.9	m	m	m
22	3.3	3.4	3.4	3.4	3.9	5.8	5.8	5.9	7.0	m	m	m
23	3.3	3.4	3.4	3.4	3.9	6.4	5.6	5.9	7.2	m	m	m
24	3.3	3.4	3.3	3.4	3.9	5.8	5.8	5.8	7.1	m	m	m
25	3.3	3.4	3.4	3.4	3.9	5.3	5.9	6.1	6.3	m	m	m
26	3.3	3.4	3.4	3.4	3.9	5.3	5.7	5.9	6.9	m	m	m
27	3.3	3.4	3.4	3.4	3.9	5.7	5.7	5.9	m	m	m	m
28	3.3	3.4	3.4	3.5	3.9	5.8	5.7	6.0	m	m	m	m
29	3.3	---	3.4	3.4	4.0	5.5	5.8	6.3	m	m	m	m
30	3.3	---	3.4	3.4	4.0	5.7	5.8	5.9	m	m	m	m
31	3.3	---	3.4	---	4.2	---	5.7	5.7	---	m	---	m
Mean	3.3	3.3	3.4	3.4	3.8	5.2	5.8	5.9	6.6	m	m	m
Min	3.2	3.3	3.3	3.3	3.4	4.1	5.4	5.5	5.5	m	m	m
Max	3.3	3.4	3.5	3.5	4.2	6.4	6.0	6.3	7.7	m	m	m

Notes: m – missing data

Table A.1b-10. Grant Lake – GL 19.5m daily mean temperature (C), calendar year 2013.

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3.2	3.3	3.4	3.3	3.4	4.1	5.7	5.5	5.6	m	m	m
2	3.2	3.3	3.4	3.3	3.4	4.3	5.7	5.7	5.5	m	m	m
3	3.3	3.3	3.4	3.3	3.4	4.1	5.5	5.7	6.5	m	m	m
4	3.3	3.3	3.3	3.4	3.5	4.9	5.6	5.7	6.0	m	m	m
5	3.3	3.3	3.3	3.4	3.5	4.6	5.6	5.7	6.2	m	m	m
6	3.3	3.3	3.3	3.4	3.5	5.3	5.5	5.4	6.0	m	m	m
7	3.3	3.4	3.3	3.4	3.6	4.9	5.3	5.8	6.0	m	m	m
8	3.3	3.3	3.3	3.4	3.7	4.6	5.8	5.8	5.4	m	m	m
9	3.3	3.3	3.3	3.3	3.7	5.1	5.7	6.1	7.0	m	m	m
10	3.3	3.3	3.4	3.3	3.7	5.2	5.7	6.1	6.5	m	m	m
11	3.3	3.3	3.4	3.3	3.7	5.0	5.6	5.4	6.2	m	m	m
12	3.3	3.3	3.5	3.3	3.7	5.1	5.3	5.8	6.3	m	m	m
13	3.2	3.3	3.4	3.3	3.7	4.9	5.7	5.7	6.7	m	m	m
14	3.2	3.3	3.4	3.4	3.7	5.1	5.7	5.6	6.4	m	m	m
15	3.2	3.3	3.4	3.4	3.7	5.0	5.6	5.8	5.9	m	m	m
16	3.3	3.3	3.4	3.4	3.8	5.4	5.6	6.0	6.1	m	m	m
17	3.3	3.3	3.4	3.4	3.8	5.2	5.9	6.0	6.1	m	m	m
18	3.3	3.3	3.4	3.4	3.8	5.1	5.5	5.9	6.1	m	m	m
19	3.3	3.3	3.4	3.4	3.8	5.7	5.6	5.9	6.2	m	m	m
20	3.3	3.3	3.4	3.4	3.8	5.4	5.9	5.4	6.4	m	m	m
21	3.3	3.3	3.4	3.4	3.9	5.4	5.9	5.9	6.7	m	m	m
22	3.3	3.3	3.4	3.3	3.9	5.7	5.7	5.7	6.6	m	m	m
23	3.3	3.3	3.4	3.4	3.9	6.2	5.5	5.7	6.8	m	m	m
24	3.3	3.4	3.3	3.4	3.9	5.8	5.6	5.6	6.5	m	m	m
25	3.3	3.4	3.4	3.4	3.9	5.2	5.9	6.0	6.2	m	m	m
26	3.3	3.4	3.3	3.4	3.9	5.2	5.6	5.9	6.7	m	m	m
27	3.3	3.4	3.3	3.4	3.9	5.6	5.6	5.7	m	m	m	m
28	3.3	3.4	3.3	3.4	3.9	5.7	5.6	5.8	m	m	m	m
29	3.3	---	3.4	3.4	4.0	5.4	5.7	6.1	m	m	m	m
30	3.3	---	3.3	3.4	4.0	5.6	5.7	5.8	m	m	m	m
31	3.3	---	3.3	---	4.1	---	5.5	5.5	---	m	---	m
Mean	3.3	3.3	3.4	3.4	3.7	5.2	5.6	5.8	6.3	m	m	m
Min	3.2	3.3	3.3	3.3	3.4	4.1	5.3	5.4	5.4	m	m	m
Max	3.3	3.4	3.5	3.4	4.1	6.2	5.9	6.1	7.0	m	m	m

Notes: m – missing data

Appendix 1c. Historical Grant Creek Temperature Records – 2013

This appendix contains the following figures and tables:

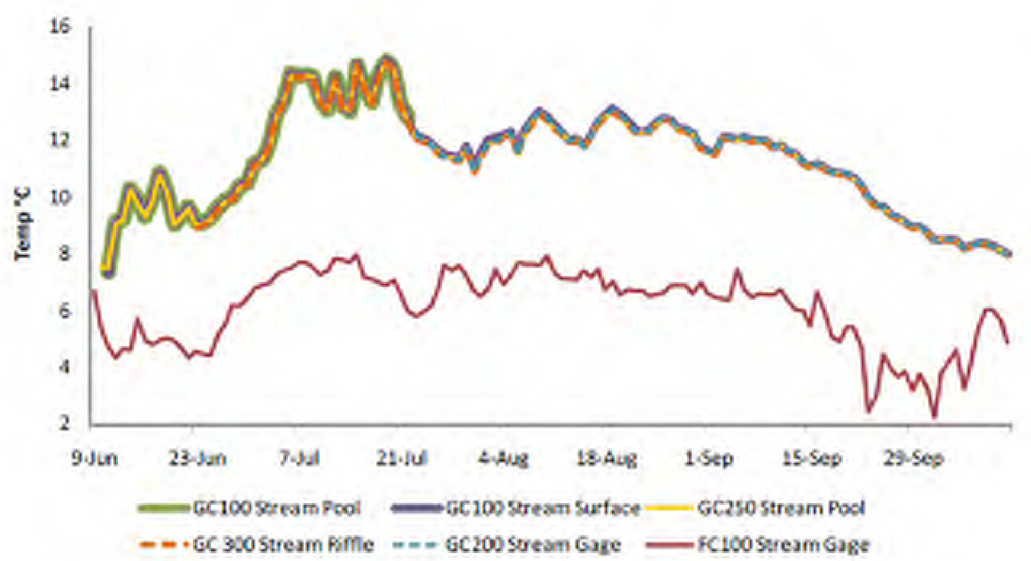

Figure A.1c-1. Grant Creek and Falls Creek – daily mean temperature (C), calendar year 2009. *(Figure reproduced from HDR 2009)*

Table A.1c-1. Grant Creek – near USGS gaging station 15246000 daily mean temperature (C), calendar year 1982. *(Table reproduced from Ebasco 1984)*

TABLE 3.1.4

WATER TEMPERATURE GRANT CREEK NEAR GAGING STATION

MEAN DAILY TEMPERATURE °C

Day	Sept	Oct	Nov
1	11.5	7.8	3.2
2	11.0	7.8	3.5
3	11.0	7.6	3.3
4	11.5	7.5	3.1
5	11.2	7.3	3.2
6	11.0	7.0	3.1
7	10.9	6.8	2.9
8	10.6	6.5	2.8
9	10.3	6.4	3.1
10	10.4	6.5	3.0
11	10.3	6.3	3.0
12	9.8	6.5	3.0
13	9.5	6.3	3.1
14	9.6	6.1	3.3
15	9.1	6.0	3.1
16	9.2	5.9	3.0
17	9.1	5.9	2.4
18	9.0	5.8	1.9
19	9.0	5.6	1.1
20	9.0	5.4	1.1
21	9.0	4.9	1.8
22	9.0	4.7	1.8
23	8.7	4.6	1.8
24	8.6	4.4	1.8
25	8.3	4.2	
26	8.2	3.8	
27	8.2	3.4	
28	8.1	3.1	
29	8.0	3.3	
30	7.9	3.2	
31	-	3.1	

Table A.1c-2. Grant Creek – near USGS gaging station 15246000 instantaneous water temperature (C), 1982-1983. *(Table reproduced from Ebasco 1984)*

TABLE 3.1.2

WATER TEMPERATURES - AT GAGING STATION

GRANT CREEK NEAR MOOSE PASS

Date	Temperature (°C)
11-24-82	1.9
01-21-83	1.8
03-23-83	2.7
05-17-83	5.5
06-16-83	8.7
07-08-83	12.5
08-05-83	13.5
09-01-83	11.5
10-03-83	7.0
11-04-83	4.4
12-07-83	3.0

Table A.1c-3. Grant Creek – GC250 daily mean temperature (C), calendar year 2009.

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	m	m	m	m	m	m	m	m	m	m	5.4	2.7
2	m	m	m	m	m	m	m	m	m	m	5.1	2.7
3	m	m	m	m	m	m	m	m	m	m	5.2	2.6
4	m	m	m	m	m	m	m	m	m	m	5.3	2.3
5	m	m	m	m	m	m	m	m	m	m	5.4	1.7
6	m	m	m	m	m	m	m	m	m	m	5.3	1.7
7	m	m	m	m	m	m	m	m	m	m	5.2	1.6
8	m	m	m	m	m	m	m	m	m	m	4.9	1.8
9	m	m	m	m	m	m	m	m	m	m	4.5	1.5
10	m	m	m	m	m	m	m	m	m	m	4.4	1.2
11	m	m	m	m	m	m	m	m	m	m	4.3	1.1
12	m	m	m	m	m	m	m	m	m	8.0	4.0	1.0
13	m	m	m	m	m	m	m	m	m	7.8	3.9	1.2
14	m	m	m	m	m	m	m	m	m	7.8	3.3	1.5
15	m	m	m	m	m	m	m	m	m	7.8	2.9	1.3
16	m	m	m	m	m	m	m	m	m	7.6	2.6	1.2
17	m	m	m	m	m	m	m	m	m	7.4	2.6	0.9
18	m	m	m	m	m	m	m	m	m	7.4	2.5	0.6
19	m	m	m	m	m	m	m	m	m	7.2	2.3	0.9
20	m	m	m	m	m	m	m	m	m	7.2	2.9	1.4
21	m	m	m	m	m	m	m	m	m	7.1	3.0	1.6
22	m	m	m	m	m	m	m	m	m	7.1	3.1	1.6
23	m	m	m	m	m	m	m	m	m	7.0	2.5	1.6
24	m	m	m	m	m	m	m	m	m	6.8	3.0	1.6
25	m	m	m	m	m	m	m	m	m	6.7	2.8	1.7
26	m	m	m	m	m	m	m	m	m	6.6	2.8	1.6
27	m	m	m	m	m	m	m	m	m	6.5	2.8	1.6
28	m	m	m	m	m	m	m	m	m	6.4	2.9	1.5
29	m	---	m	m	m	m	m	m	m	5.9	2.5	1.3
30	m	---	m	m	m	m	m	m	m	5.6	2.4	1.3
31	m	---	m	---	m	---	m	m	---	5.4	---	1.5
Mean	m	m	m	m	m	m	m	m	m	7.0	3.7	1.6
Min	m	m	m	m	m	m	m	m	m	5.4	2.3	0.6
Max	m	m	m	m	m	m	m	m	m	8.0	5.4	2.7

Notes: m – missing data

Table A.1c-4. Grant Creek – GC250 daily mean temperature (C), calendar year 2010.

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.9	1.4	2.4	1.7	3.4	9.6	9.4	10.7	11.1	8.8	5.1	0.8
2	0.7	1.4	2.4	2.0	3.4	9.8	10.9	10.3	11.3	8.7	5.0	1.0
3	1.3	1.4	2.3	1.8	3.6	8.6	11.2	11.0	11.1	8.5	4.8	1.0
4	1.6	0.9	2.1	1.9	3.7	9.2	10.4	10.9	10.7	8.3	4.7	1.1
5	1.6	0.9	2.2	1.7	3.7	9.6	10.0	11.9	10.9	8.0	4.7	0.9
6	1.6	1.2	2.1	1.8	3.7	9.3	9.9	11.1	10.9	7.9	4.7	1.1
7	1.7	1.3	1.7	1.5	3.8	9.2	10.5	11.2	11.8	7.7	4.6	1.3
8	1.4	1.0	1.8	1.4	3.9	8.5	10.4	11.0	11.2	7.5	4.3	1.0
9	1.6	1.4	1.9	1.4	4.0	8.6	10.1	11.5	10.6	7.4	4.3	0.7
10	1.3	1.7	1.5	1.5	3.4	8.9	10.1	10.7	9.8	7.3	4.2	0.9
11	0.7	1.8	1.3	1.7	1.8	9.6	9.9	11.7	10.1	7.2	4.4	0.9
12	0.9	1.7	1.4	1.8	3.4	9.7	9.7	11.4	10.3	6.9	4.4	0.6
13	1.2	1.7	1.7	1.8	3.8	9.2	10.5	11.8	9.4	6.7	4.3	0.6
14	1.4	1.8	1.7	1.7	3.8	8.3	10.3	12.6	9.5	6.4	4.1	0.7
15	1.3	1.9	2.0	1.7	4.0	9.0	9.9	11.9	9.8	6.4	3.8	0.5
16	1.5	2.0	1.8	1.6	4.1	8.9	10.2	11.0	9.4	6.3	3.1	0.5
17	1.5	2.1	1.5	2.0	4.3	8.4	10.1	10.6	11.7	6.3	2.9	0.4
18	1.3	2.0	1.9	2.0	4.5	8.8	10.3	12.5	11.3	6.4	3.0	0.5
19	1.1	2.1	2.0	1.9	4.7	8.9	10.8	12.2	11.3	6.2	3.1	0.7
20	1.1	2.0	2.0	1.9	5.2	9.7	10.6	11.5	10.9	6.1	3.1	0.9
21	0.7	2.1	1.9	2.1	4.9	9.9	11.1	11.7	10.9	6.0	3.0	0.6
22	0.7	2.2	2.0	2.1	4.7	10.4	11.3	11.3	10.8	6.0	3.5	0.6
23	0.5	2.4	1.9	2.3	5.6	10.6	11.6	12.6	10.7	5.8	3.3	0.5
24	0.7	2.4	1.9	2.3	5.6	10.4	10.1	11.9	10.4	5.8	3.4	0.5
25	0.6	2.2	1.8	2.6	6.1	10.7	10.2	12.0	10.2	5.8	3.4	0.7
26	0.9	1.8	1.5	2.9	7.2	11.2	10.4	11.1	9.7	5.5	2.9	0.8
27	1.2	1.7	1.7	3.0	8.3	10.4	10.8	11.1	9.1	5.4	2.8	0.9
28	1.5	2.0	1.9	3.1	8.9	10.4	10.3	11.0	8.9	5.5	2.1	0.8
29	1.4	---	2.0	3.1	9.3	9.8	9.8	11.7	9.0	5.2	1.6	0.8
30	1.1	---	2.0	3.2	9.5	10.0	10.7	11.3	8.9	5.0	1.2	1.2
31	1.2	---	1.8	---	9.7	---	11.3	10.7	---	4.9	---	1.2
Mean	1.2	1.7	1.9	2.1	5.0	9.5	10.4	11.4	10.4	6.6	3.7	0.8
Min	0.5	0.9	1.3	1.4	1.8	8.3	9.4	10.3	8.9	4.9	1.2	0.4
Max	1.7	2.4	2.4	3.2	9.7	11.2	11.6	12.6	11.8	8.8	5.1	1.3

Table A.1c-5. Grant Creek – GC250 daily mean temperature (C), calendar year 2011.

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	1.4	1.7	m	m	m	m	m	m	m	m	m	m
2	1.5	1.8	m	m	m	m	m	m	m	m	m	m
3	1.6	1.6	m	m	m	m	m	m	m	m	m	m
4	1.4	1.4	m	m	m	m	m	m	m	m	m	m
5	1.4	1.1	m	m	m	m	m	m	m	m	m	m
6	1.0	1.6	m	m	m	m	m	m	m	m	m	m
7	0.8	m	m	m	m	m	m	m	m	m	m	m
8	0.7	m	m	m	m	m	m	m	m	m	m	m
9	0.8	m	m	m	m	m	m	m	m	m	m	m
10	0.8	m	m	m	m	m	m	m	m	m	m	m
11	0.8	m	m	m	m	m	m	m	m	m	m	m
12	0.6	m	m	m	m	m	m	m	m	m	m	m
13	0.5	m	m	m	m	m	m	m	m	m	m	m
14	0.4	m	m	m	m	m	m	m	m	m	m	m
15	0.4	m	m	m	m	m	m	m	m	m	m	m
16	0.3	m	m	m	m	m	m	m	m	m	m	m
17	0.6	m	m	m	m	m	m	m	m	m	m	m
18	0.7	m	m	m	m	m	m	m	m	m	m	m
19	1.0	m	m	m	m	m	m	m	m	m	m	m
20	1.3	m	m	m	m	m	m	m	m	m	m	m
21	1.5	m	m	m	m	m	m	m	m	m	m	m
22	1.4	m	m	m	m	m	m	m	m	m	m	m
23	1.0	m	m	m	m	m	m	m	m	m	m	m
24	1.6	m	m	m	m	m	m	m	m	m	m	m
25	1.7	m	m	m	m	m	m	m	m	m	m	m
26	1.6	m	m	m	m	m	m	m	m	m	m	m
27	1.4	m	m	m	m	m	m	m	m	m	m	m
28	1.2	m	m	m	m	m	m	m	m	m	m	m
29	1.4	---	m	m	m	m	m	m	m	m	m	m
30	1.4	---	m	m	m	m	m	m	m	m	m	m
31	1.5	---	m	---	m	---	m	m	---	m	---	m
Mean	1.1	1.6	m	m	m	m	m	m	m	m	m	m
Min	0.3	1.1	m	m	m	m	m	m	m	m	m	m
Max	1.7	1.8	m	m	m	m	m	m	m	m	m	m
Notes: m – missing data												

Table A.1c-6. Grant Creek – GC200 daily mean temperature (C), calendar year 2012.

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	m	m	m	m	m	m	m	m	m	m	m	m
2	m	m	m	m	m	m	m	m	m	m	m	m
3	m	m	m	m	m	m	m	m	m	m	m	m
4	m	m	m	m	m	m	m	m	m	m	m	m
5	m	m	m	m	m	m	m	m	m	m	m	m
6	m	m	m	m	m	m	m	m	m	m	m	m
7	m	m	m	m	m	m	m	m	m	m	m	m
8	m	m	m	m	m	m	m	m	m	m	m	m
9	m	m	m	m	m	m	m	m	m	m	m	m
10	m	m	m	m	m	m	m	m	m	m	m	m
11	m	m	m	m	m	m	m	m	m	m	m	1.0
12	m	m	m	m	m	m	m	m	m	m	m	1.1
13	m	m	m	m	m	m	m	m	m	m	m	1.3
14	m	m	m	m	m	m	m	m	m	m	m	0.6
15	m	m	m	m	m	m	m	m	m	m	m	0.6
16	m	m	m	m	m	m	m	m	m	m	m	0.4
17	m	m	m	m	m	m	m	m	m	m	m	0.2
18	m	m	m	m	m	m	m	m	m	m	m	0.5
19	m	m	m	m	m	m	m	m	m	m	m	0.6
20	m	m	m	m	m	m	m	m	m	m	m	0.4
21	m	m	m	m	m	m	m	m	m	m	m	0.2
22	m	m	m	m	m	m	m	m	m	m	m	0.2
23	m	m	m	m	m	m	m	m	m	m	m	0.6
24	m	m	m	m	m	m	m	m	m	m	m	0.9
25	m	m	m	m	m	m	m	m	m	m	m	1.1
26	m	m	m	m	m	m	m	m	m	m	m	1.2
27	m	m	m	m	m	m	m	m	m	m	m	1.4
28	m	m	m	m	m	m	m	m	m	m	m	1.5
29	m	m	m	m	m	m	m	m	m	m	m	1.4
30	m	---	m	m	m	m	m	m	m	m	m	1.6
31	m	---	m	---	m	---	m	m	---	m	---	1.6
Mean	m	m	m	m	m	m	m	m	m	m	m	0.9
Min	m	m	m	m	m	m	m	m	m	m	m	0.2
Max	m	m	m	m	m	m	m	m	m	m	m	1.6
Notes: m – missing data												