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

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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].

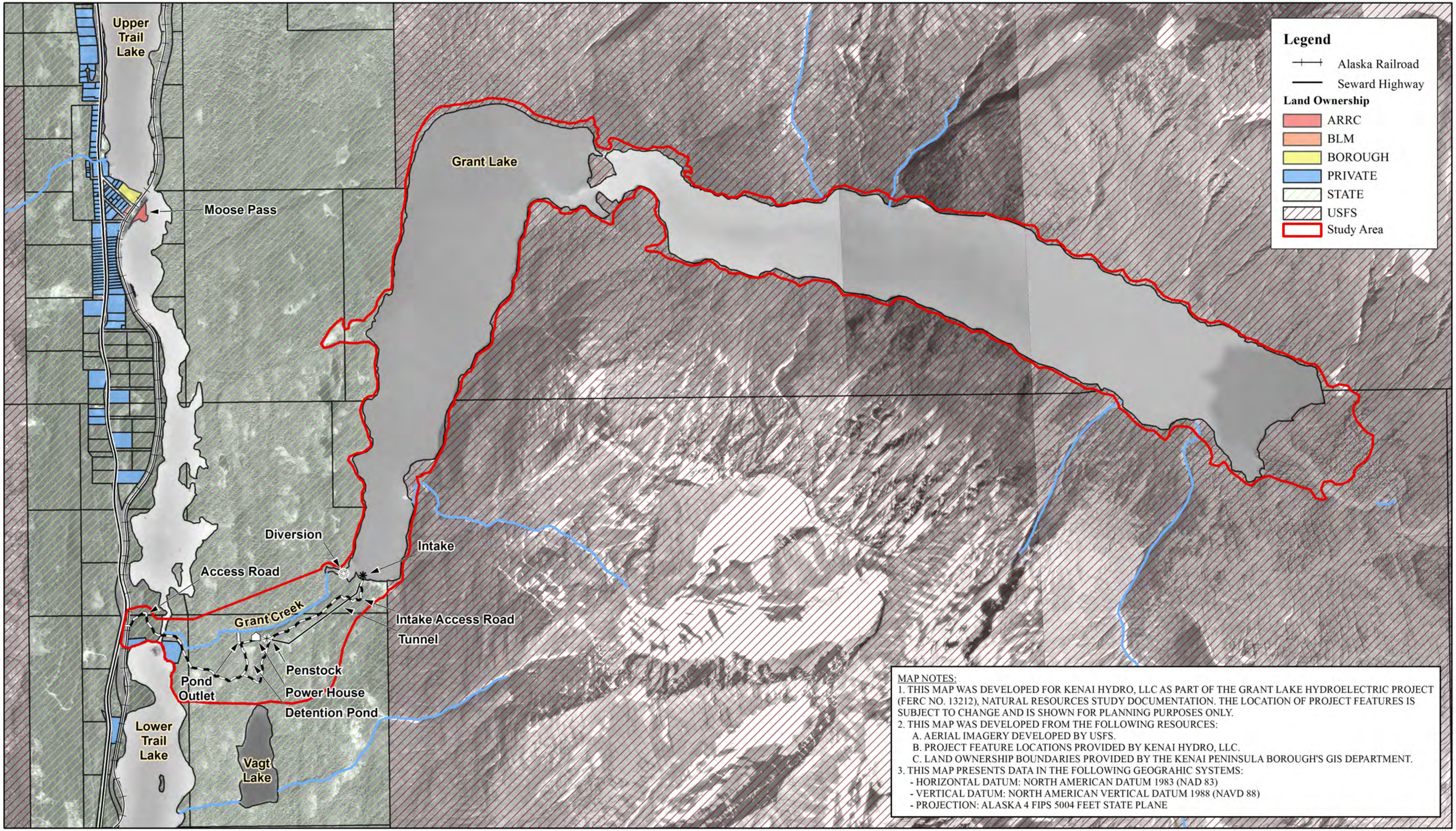
An intake structure would be constructed approximately 500 feet east of the natural outlet of Grant Lake. An approximate 3,200-foot-long, 10-foot diameter horseshoe tunnel would convey water from the intake to directly above the powerhouse at about elevation 628 feet NAVD 88. At the outlet to the tunnel 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.

[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.



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. LAND OWNERSHIP BOUNDARIES PROVIDED BY THE KENAI PENINSULA BOROUGH'S GIS DEPARTMENT.
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

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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
DRAWING
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

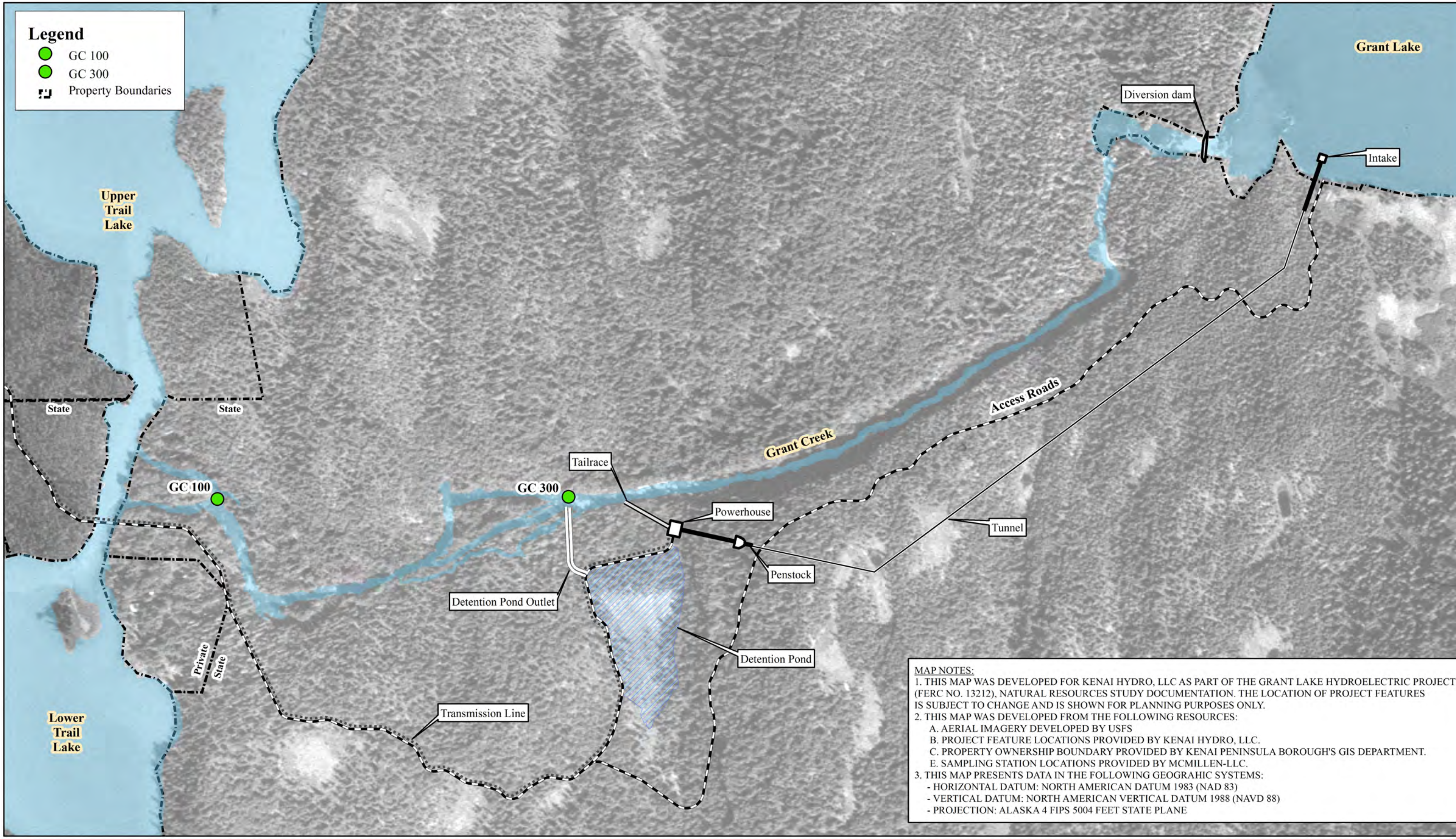
- Provide a reliable measure of baseline stream productivity that can be compared from year to year and with other stream systems.
- Provide some indication of the relative "health" of the Grant Creek ecosystem by employing standard measures that are readily comparable to other Alaska stream systems.

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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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 CONCLUS IONS

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.

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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.

Site ID	Sample Date	Surber No.	Number Identified/ Site	Number Taxa/Site	Ephemeroptera							
					Amelitidae	**Baetidae**	**Baetidae**	**Baetidae**	**Ephemerellidae**	**Ephemerellidae**	**Heptageniidae**	**Heptageniidae**
					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.

Site ID	Sample Date	Surber No.	Number Identified/ Site	Number Taxa/Site	Other MiscellaneousTaxa							
					Oligochaeta	Gastropoda	Gastropoda	Gastropoda	Bivalvia	Bivalvia	Arachnoidea	Ostracoda
					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.

Site ID	Sample Date	Surber No.	Number Identified/ Site	Number Taxa/Site	Other MiscellaneousTaxa		
					Nematoda	Platyhelminthes	
					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 caudidate 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). (Copied from Barbour et al. 1999)

Table A.3-2 Definitions of additional benthic metrics and predicted direction of metric response to increasing perturbation. (Copied from Barbour et al. 1999)

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 Tanytarisinid 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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