*Gunnuk Creek*
*Hydroelectric Project*

# Reconnaissance Report

**Prepared for:**

**Inside Passage Electric Cooperative**
**P.O. Box 210149**
**Auke Bay, AK 99821**

**Prepared by:**

**HDR Alaska, Inc.**
**2525 C Street**
**Anchorage, Alaska 99503**

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# Executive Summary

The Inside Passage Electric Cooperative (IPEC) received a State of Alaska Renewable Energy Fund Grant to perform a reconnaissance study of the hydroelectric potential in the Gunnuk Creek drainage basin, near Kake, AK. Currently all of Kake's electrical energy is supplied by diesel generation. A new hydroelectric project on Gunnuk Creek could provide the community with a source of renewable energy.

This study looked at three possible options for developing hydropower. Of these, only one has significant potential. The preferred project would be an expansion and rehabilitation of an existing hydroelectric project (7kW) that makes use of the existing water supply dam and hatchery facilities. Costs and construction risks are minimized because the dam and intake facility have already been constructed, and no new transmission lines or access roads are required.

The new project would have an installed capacity of 500 kW and would produce approximately 1,600 MWh annually, or 55% of Kake's average annual requirements. The project would save an estimated 6.2 million gallons of diesel fuel over its 50 year design life. The estimated development cost is $5.5M and has a corresponding benefit/cost ratio of 3.2. Additional benefits of the project would be increased reliability of the water supply to the hatchery should it re-open and the reduction of 62,400 tons of harmful $CO_2$ emissions over its life.

It is estimated that the project could become fully operational within 18-24 months. The next steps in project development are:

- Initiate discussions with ADF&G regarding requirements for instream flow in the bypass reach.
- Develop joint use agreement with the State of Alaska for the use of the hatchery water supply and powerhouse site. Replacement of the pipeline and stabilization of the route has the added benefit of increasing the reliability of the hatchery water supply.
- Initiate discussions with the Southeast Alaska Land Trust to confirm project is consistent with the conservation easement that is in place.
- Final design of the project to include surveying the plan and profile of the pipeline route, soils exploration along pipeline route and preparation of design plans and specifications.

# 1 Introduction

The Inside Passage Electric Cooperative (IPEC) contracted with HDR Alaska, Inc. to evaluate the potential of developing a hydroelectric project on Gunnuk Creek to service the village of Kake, Alaska. Kake is located on Kupreanof Island approximately 100 air miles southwest of Juneau and 40 miles northwest of Petersburg. It lies at approximately 56° 58' N latitude and 133° 56' W longitude and is nestled in the Tongass National Forest.

The scope of work defined for this project included:

- Data collection and review of previous studies;
- Field reconnaissance;
- Evaluation of hydrology and collection of streamflow data;
- Development of conceptual project layouts;
- Estimation of energy production and project costs;
- Permit and licensing assessment;
- Preparation of this reconnaissance report.

This report should be considered a high-level overview intended to identify projects which demonstrate a basic measure of feasibility and to eliminate projects that have evident fatal flaws from an engineering or environmental perspective; this report also provides information to enable IPEC to determine the economic feasibility of a project and to pursue funding for future phases of the project.

## 1.1 Site Visit

A visual field reconnaissance was conducted on June 25, 2014 by a senior project engineer and a geotechnical engineer. The field reconnaissance consisted of an aerial flight of the Gunnuk Creek drainage via a helicopter chartered from Juneau. The purpose of the reconnaissance was to begin to evaluate the feasibility of constructing a small hydroelectric project to service the community of Kake, and to identify locations of project features. Specific objectives of the aerial reconnaissance were to:

- Identify potential area for diversion/intake construction.
- Assess possible powerhouse locations.
- Assess suitability for buried- or above ground penstock
- Review site access for construction and operations and maintenance.
- Review route for potential transmission line and tie in locations.

The reconnaissance throughout Gunnuk Creek focused on two areas that had been identified as potential project locations: middle Gunnuk Creek for a run-of-river project, and in upper Gunnuk Creek for a dam/storage project. A separate geotechnical report memorandum included in Appendix A describes the field reconnaissance and provides an overview map of the two areas visited.

An additional site visit was made January 13, 2015 to assess the lower portion of Gunnuk Creek and consisted of an inspection of the water supply dam and existing penstock route to the hatchery.

# 2 Background Information

## 2.1 Existing Development

Existing development in the Gunnuk Creek basin is described below.

### *2.1.1 Hatchery*

A fish hatchery is located approximately 2000 ft. upstream of the mouth of Gunnuk Creek on the west bank. The hatchery was constructed in the late 1970's and produced pink, chum and coho salmon until 2013. Water was diverted from the water supply dam (described below) and conveyed to the hatchery through a 2,150-foot-long, 10-in diameter HDPE pipeline. A 7 kW hydroelectric generator is housed in a powerhouse just upstream of the hatchery and acts as a pressure reducing valve.

In 2013 the hatchery operation became insolvent and went into bankruptcy. The facilities are now owned by the State of Alaska and the hatchery is not operational. The Northern Southeast Regional Aquaculture Association (NSRAA) is the most likely candidate to acquire the hatchery and resume operations.

**Figure 1 - Gunnuk Creek Hatchery (NSRAA photo)**

### *2.1.2 Water Supply Dam*

The City of Kake has long taken its water supply from Gunnuk Creek. In July 2000 the City's timber crib water supply dam was breached by a log during a flood. Through a Congressional authorization the U.S. Corps of Engineers was directed to construct a new water supply dam. The dam was also to include provisions for future hydropower expansion. Construction of the new dam was started in 2005 and completed in 2007. The dam is readily accessed from existing roads.

The dam is a concrete gravity structure and forms a 2.1 acre reservoir. The spillway is at elevation 89.0 fmsl and is 42-feet wide. Between the two spillway bays is a low level outlet for flushing sediment deposits during high flows. The intake includes trashracks, fish screens with automatic cleaners and provisions for both water supply and hydroelectric pipeline connections.

**Figure 2 - Existing Dam on Gunnuk Creek**

### *2.1.3 Water Supply Intake*

When the original timber crib water supply dam failed, the City established a temporary water supply intake in Alpine Lake, high within the Gunnuk Creek basin. Upon completion of the new water supply dam, the City used the facilities to pump water uphill to their water storage tank. Excessive pumping costs prompted the City to revert back to the Alpine Lake system which runs by gravity. That system is still in use today.

## 2.2 Previous Studies

The potential for hydroelectric power in Kake, and specifically within Gunnuk Creek, has been the subject of previous assessments, including:

- *Preliminary Appraisal Report, Hydroelectric Potential for Angoon, Craig, Hoonah, Hydaburg, Kake, Kasaan, Klawock, Klukwan, Pelican, and Yakutat;* Prepared by Robert W. Retherford Associates, Anchorage Alaska for the Alaska Power Authority, 1977.
- *Tyee-Kake Intertie Project, Detailed Feasibility Analysis, Final Report Volume I* Prepared by EBASCO Services Incorporated for the Alaska Power Authority, March 1984.
- *Evaluation of the Hydroelectric Potential Near Selected Sealaska Communities;* Prepared by Alaska Power & Telephone, 2005.
- *Gunnuk Hydro Reconnaissance Report 1/15/2014,* Prepared by Christensen et al. 2014.

Retherford's preferred development would utilize two earth filled dams and a 14,500 AF reservoir in the upper basin, a 2800 foot-long penstock and a 1.8 MW powerhouse located near tidewater. In 1979 the Retherford concept was reviewed by Harza Engineering for the Alaska Power Authority and subsequently dropped in favor of the Cathedral Falls project. More recently Gunnuk Creek has been looked at by the Sealaska Corporation and Christensen

Associates. Given the estimated size of the impoundment dams necessary, the 1977 plan has been largely dismissed as uneconomical.

The 1984 EBASCO report discusses the potential for a run of the river project at Gunnuk Creek to meet some of Kake's energy needs. The 1984 arrangement would utilize the original water supply dam and follow the route of the previous wood stave penstock and water line to the fish hatchery.

In 2005, the Sealaska Corporation conducted a feasibility study to determine the potential sustainability of small hydroelectric projects on Southeast Alaska native lands. The report presents potential modifications to previous hydroelectric project layouts for both the Gunnuk Creek and Catherdal Falls drainages. The 2005 report discusses the potential of a powerhouse being sited at the hatchery for maximum generation (~500 kW), as well as a smaller project (25-50 kW) that would be sited in the vicinity of the existing dam. The 2005 report did not evaluate cost but did recommend a detailed feasibility study be conducted.

The most recent reconnaissance-level investigation of the hydropower potential around Kake identifies a two-phased approach for small hydroelectric projects. The reconnaissance report, based on field and desk studies, was initially completed in 2013 and revised in January 2014[1] (Christensen et al. 2014). Phase 1 is described as a run-of-the-river design estimated to meet more than half of Kake's annual electrical load. The study identifies the top of the canyon, located approximately 2.7 miles inland of Kake, as a potentially feasible intake site (elevation 330 feet above mean sea level (MSL). This layout would require, at minimum, a 10-ft high impoundment structure and approximately 2.75 mile penstock. Phase 1 was identified as the most cost-effective approach.

The recent study evaluated an additional project to supplement Phase 1 production during the low flow periods. Phase 2 would create a 141 acre reservoir to cover low flow periods so that the project could meet the remainder of Kake's annual electrical load. Under Phase 2, a 50-ft by 350-ft dam would be required to create the reservoir. Christensen estimated the annual mean flows to the reservoir as 13.5 cfs, and identifies the presence of an out-of-basin stream that could potentially provide an additional 9 cfs to the project. The study recommends that additional stream gaging, land-based surveys for design work and a more detailed cost-benefit analysis be completed for Phase 2.

Complete references can be found on the Alaska Energy Data Inventory website (www.akenergyinventory.org).

### 2.3 Fish Resources

The Alaska Department of Fish and Game (ADF&G) Anadromous Waters Catalog (AWC) identifies Gunnuk Creek (AWC code: 109-42-10040) as providing habitat for pink salmon (*Oncorhynchus gorbuscha),* chum salmon (*O. keta*), coho salmon (*O. kisutch*), and steelhead (*O. mykiss*) from its mouth to a point about one mile upstream from tidal influence, at the base of the Gunnuk Creek dam (ADF&G 2014a). The dam prevents the upstream migration of fish. Neither

[1] The 1/15/2014 study was conducted by staff from the Sustainable Southeast Partnership, the Kake Community Catalyst, and the Southeast Alaska Conservation Council.

the AWC nor the ADF&G Alaska Freshwater Fish Inventory (AFFI) provides fisheries information for Gunnuk Creek or its tributary streams upstream of the dam (ADF&G 2010b). While no fish distribution data were available, the presence of resident forms of Dolly Varden (*Salvelinus malma*) and/or cutthroat trout (*O. clarki*) upstream of the falls is probable.

## 2.4 Water Rights

Water from the Gunnuk Creek drainage is the primary source of drinking water for the residents of Kake. The City of Kake has a certificate of appropriation (ADL 43611) for up to 5 cfs from Gunnuk Creek with the point of diversion at the Gunnuk Creek dam. Current water consumption is estimated at less than 1 cfs (0.65 MGD). The intake is located at Alpine Lake which is high up within the Gunnuk Creek basin.

The City of Kake also has a permitted water right (LAS 11970) for 12 cfs for the purpose of hydroelectric generation. This permit was granted 06/02/1989 and has never been perfected. A stipulation of this permit is that the first 11 cfs of flow must remain in Gunnuk Creek to support downstream habitat.

Additionally, the Kake Nonprofit Fisheries Corporation has two water rights totaling 2.5 cfs (ADL 102406, LAS 118/75) with the point of diversion being the Gunnuk Creek dam. The hatchery also has a seasonal appropriation to withdraw 2.5 cfs at the hatchery but this would not affect any hydroelectric alternative. With the hatchery currently closed, it is unclear how long these water right permits could remain in affect.

## 2.5 Land Ownership

The majority of lands in the Gunnuk Creek watershed are owned by Sealaska Regional Corporation, followed closely by the Kake Tribal Corporation. Other land owners include the state of Alaska, the United States Forest Service (USFS) and the City of Kake as shown in Figure 3.

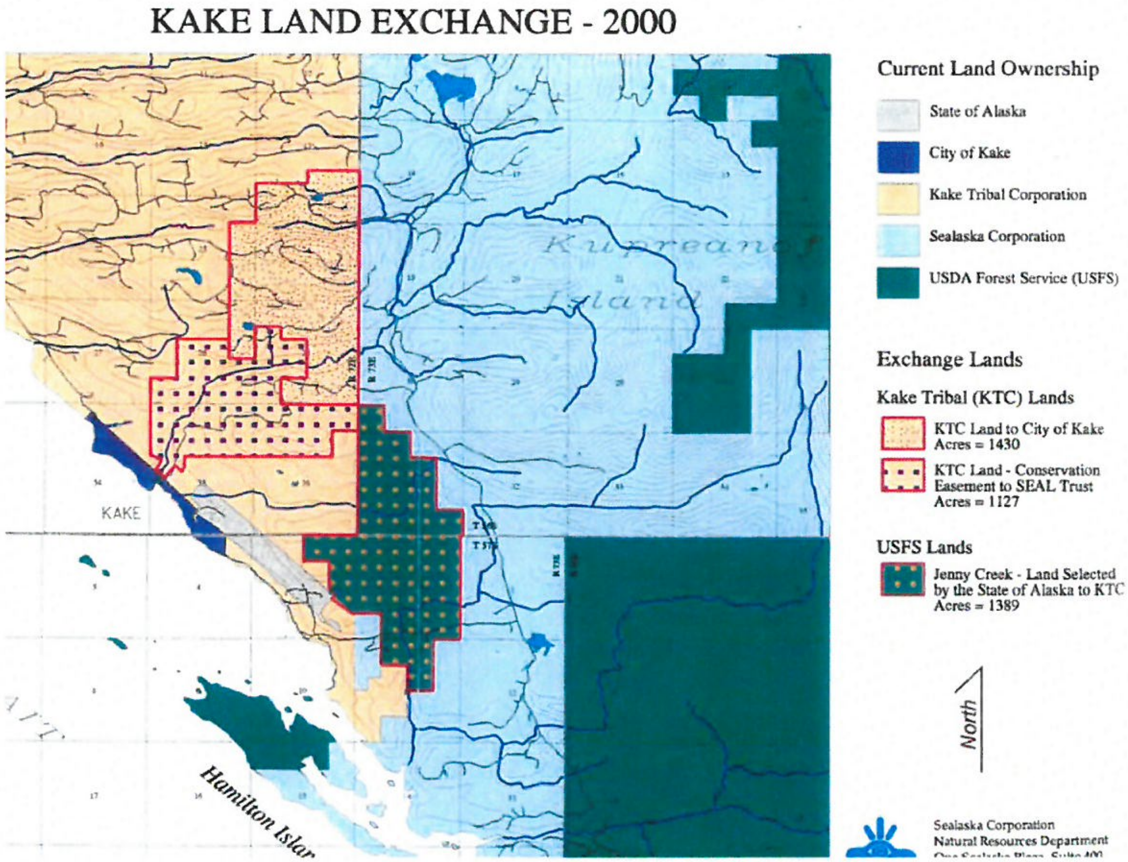


**Figure 3 - Gunnuk Creek Land Ownership**

Conservation easements have been granted to the Southeast Alaska Land Trust for large parcels of land throughout the Gunnuk Creek drainage. The Lower Gunnuk Creek Watershed Protection Project was a result of petitioning in 1995 by the people of Kake to protect the integrity of Gunnuk Creek. Under the agreement and aided by federal legislation, land was conveyed to the City of Kake. Subsequently, conservation easements were attached to those lands and to the remaining Kake Tribal Corporation land within the watershed. Conservation easements include an approximate 1,120-acre parcel in the lower reaches of the Gunnuk Creek drainage, and a 1,430-acre parcel farther upstream. While ownership of the Gunnuk Creek hatchery assets was recently transferred to the state of Alaska, the land is located within the easement boundaries.

Per the terms of the conservation easement,

> *"Maintenance, renovation or replacement of water lines and power lines and electrical utilities on the Property is allowed. The construction and maintenance of dams and power lines and electrical utilities within the watershed is allowed. Any plans for construction, remodeling or reconstruction of waterlines, dams or power lines shall be submitted to SEAL Trust for review and approval to ensure that they are consistent with the Purpose and Conservation Values."*

This provision included in the easement would seem to indicate that new development could be allowed on lands covered by the easement. However, a legal opinion on this matter would be needed. Such an opinion is beyond the scope of this report.

# 3 Hydrology

Gunnuk Creek has a drainage basin of approximately 16 mi$^2$ on Kupreanof Island in Southeast Alaska. Much of the basin is composed of relatively broad valley floors between hills ranging in elevation up to 2,200 ft. The basin includes a small lake, and no glaciers. About 2 mi. above the mouth of the creek, it enters a steep narrow canyon for a mile before emptying onto a fan-like coastal plain where it flows through Kake.

## 3.1 Existing Data

The U.S. Geological Survey (USGS) operated a continuous streamgage (15087565) on Gunnuk Creek from September, 2005 through September, 2008. From September 1, 2005 to September 1, 2007, the gage was located about ¼ mile downstream from a dam on Gunnuk Creek used for public and fish hatchery water supply. The drainage area for this gage is 15.4 mi$^2$. Control for the stage-discharge rating was a natural cobble riffle (USGS Station Analysis, from the files of the Alaska Science Center, Water Year 2007). On September 1, 2007, the streamgage was moved to just upstream of the dam, using the dam spillway as the stage-discharge control (USGS Station Analysis, from the files of the Alaska Science Center, Water Year 2008). The average annual flow during the recording period was 97 cfs. The average monthly flows for this gage are shown in Figure 4.

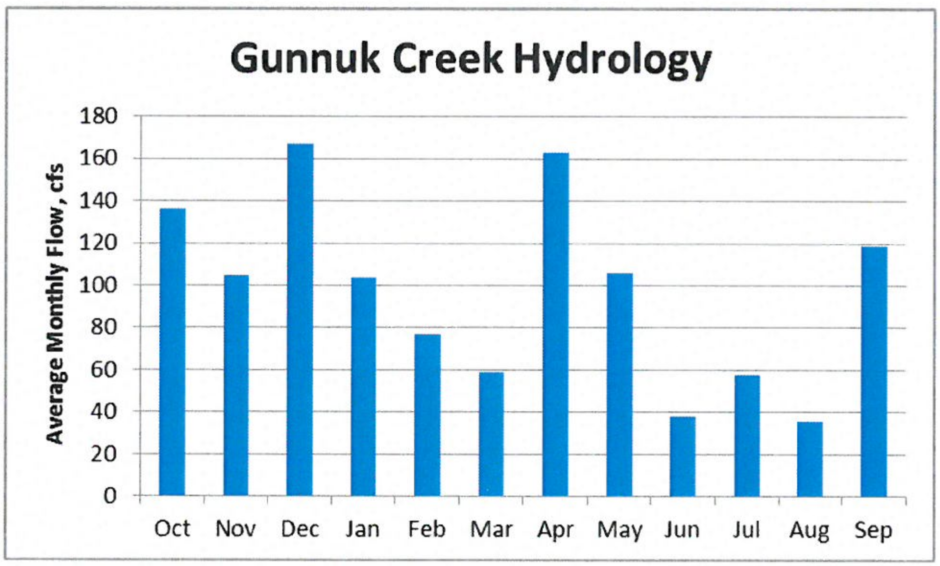


**Figure 4 - Gunnuk Creek Average Monthly Flow, WY 2005-2008**

At both locations, winter temperatures occasionally form ice on the stream, causing backwater that affects the stage-discharge rating. During these periods, mean daily discharge was estimated from nearby streamgages. Freezing temperatures throughout the basin result in extreme low flow at times in the winter. However, low flow periods can occur in any season. Mean daily discharge was less than 10 ft$^3$/sec at least once in every month except September, April, and May. High flows in Southeast Alaska are commonly caused by fall and winter storms. Spring snowmelt can cause periods of higher than average flow in April and May, but that rarely produces high peak flows.

The Environmental Assessment prepared for the replacement of the City's water supply dam references flow data collected from the hatchery during operations and cites an average annual flow of 68.1 cfs. We were unable to obtain this data in order to review what was being measured or how the data was obtained. Therefore, it is not used as part of this report.

### 3.2 Streamflow Extension

Three years of continuous site specific streamflow data is unusually good in remote Alaska, but still might not be adequate to assess the long-term streamflow characteristics. In Alaska, seasonal streamflow trends are affected by the Pacific Decadal Oscillation (PDO) (Mantua and others, 1997; Neal and others, 2002; Hodgkins, 2009). During positive, or warm, phases of the PDO, streamflow tends to be higher in winter-spring and lower in June, and during negative, or cool, phases of the PDO, streamflow tends to be lower in winter-spring and higher in June. Shifts in the PDO occurred in 1925 (negative to positive), 1947 (positive to negative), 1977 (negative to positive), and likely in 2006 or 2007 (positive to negative) (JISAO, 2014). Therefore, the streamflow data collected during 2005-2008, spanning a phase shift of the PDO, may provide a fair estimate of streamflow during longer periods.

Some of the streamgages in Southeast Alaska have longer records and can be used to extend the streamflow records at the Gunnuk Creek by statistical methods. Streamflow analysis techniques are used to extend records from a short-record station by use of regression with stations with longer records when the concurrent records from the stations are well correlated (Curran, 2012).

Records from 14 USGS streamgaging stations with concurrent records with Gunnuk Creek were compared with the streamflow record at Gunnuk Creek. Streamgaging stations with records that were not concurrent with Gunnuk Creek, streams with regulated flow, or streamgages with relatively short records were not considered. Two stations stand out as having better correlations with Gunnuk Creek than the others, Staney Creek and Old Tom Creek. The Staney Creek streamflow record was collected at 2 different sites, 15081500 Staney Creek near Craig (Lat. 55°48'57", Lon. 133°07'58" NAD27, 51.6 $mi^2$) and 15081497 Staney Creek near Klawock (Lat. 55°48'05", Lon. 133°06'31" NAD27, 50.6 $mi^2$), but the records are considered equivalent (USGS, 2014).

Gunnuk Creek daily mean discharge was regressed against Old Tom Creek and Staney Creek (combined) daily mean discharge. Both stations yielded statistically significant regressions (Table 1). Old Tom Creek has one of the longest records of any streamgage in Alaska, which is advantageous for record extension. However, when a regression of Gunnuk Creek on Old Tom Creek was computed and the residuals were examined, residuals from Old Tom Creek showed considerable scatter at lower discharges compared to the residuals from the Staney Creek regression. This indicates that although the overall regression is robust, the regression of Gunnuk Creek against Old Tom Creek likely introduces more error at lower discharges than the regression of Gunnuk Creek against Staney Creek. The regression of Gunnuk Creek against Staney Creek is slightly more significant, and the scatter of residuals is greatest at larger discharge when streamflow is not as critical to determining feasibility of a low-head or run-of-the-river facility. The best-fit equation is:

$$\log(Y) = 0.931*\log(X) - 0.512$$

where Y=Gunnuk Creek estimated daily mean discharge and X=Staney Creek daily mean discharge.

**Table 1 - Gunnuk Creek Gage Correlations**

| Station | USGS Station Name | Location (lat/long NAD27) | Drainage Area ($mi^2$) | Datum of Gage (approximate) (feet) | Period of Record | | Correlation Coefficient ($r^2$) |
|---|---|---|---|---|---|---|---|
| 15081497 | Staney Creek near Klawock | 55°48'05"/ 133°06'31" | 50.6 | 50 | 9/1/1989 | Current (2014) | 0.6396 |
| 15081500 | Staney Creek near Craig | 55°48'57"/ 133°07'58" | 51.6 | 2 | 10/1/1964 | 9/30/1981 | |
| 15085100 | Old Tom Creek near Kasann | 55°23'44"/ 132°24'25" | 5.9 | 10 | 7/1/1949 | Current (2014) | 0.4988 |

Figure 5 shows the comparison of measured discharge with the discharge predicted by the regression of Gunnuk Creek against Staney Creek for the overlapping period of record.

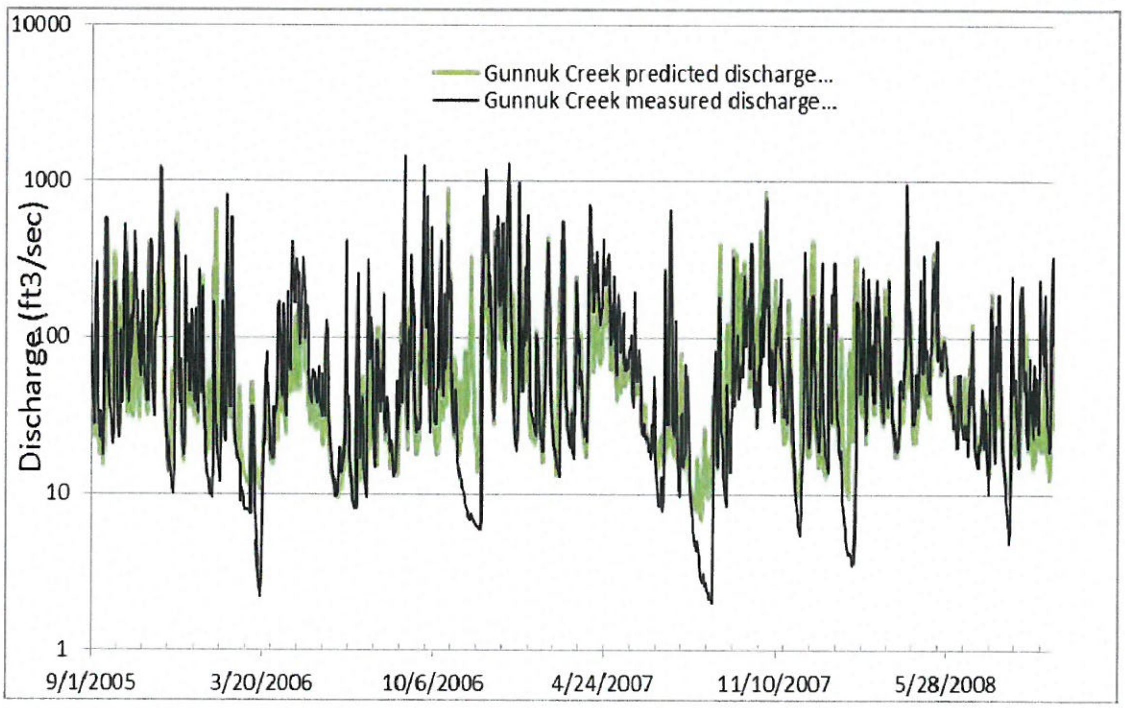


**Figure 5 - Staney Creek Correlation**

## 3.3 Flow Duration

To determine flow duration characteristics from the Gunnuk Creek extended data, mean daily discharge data were sorted, ranked, and the time that a given flow was equaled or exceeded computed by dividing the rank by the total number of observations plus 1, expressed in percent. A flow duration table from the extended record at Gunnuk Creek is presented in Table 2.

**Table 2 - Gunnuk Creek Flow Exceedance Data**

| | Percent Exceedance | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1% | 2% | 5% | 10% | 20% | 30% | 50% | 70% | 80% | 90% | 95% | 98% | 99% |
| October | 808 | 625 | 427 | 296 | 199 | 144 | 81 | 50 | 38 | 25 | 17 | 12 | 9.4 |
| November | 708 | 589 | 376 | 247 | 153 | 107 | 62 | 37 | 28 | 18 | 13 | 9.0 | 7.1 |
| December | 693 | 537 | 372 | 254 | 151 | 98 | 52 | 31 | 22 | 13 | 9.4 | 7.2 | 5.7 |
| January | 683 | 487 | 297 | 197 | 115 | 79 | 41 | 22 | 16 | 9.9 | 6.5 | 3.7 | 3.0 |
| February | 507 | 364 | 239 | 167 | 104 | 69 | 38 | 23 | 17 | 11 | 7.3 | 4.2 | 3.5 |
| March | 365 | 286 | 201 | 136 | 87 | 62 | 37 | 22 | 17 | 11 | 8.7 | 7.1 | 5.5 |
| April | 441 | 330 | 210 | 157 | 92 | 71 | 49 | 35 | 28 | 22 | 19 | 15 | 12 |
| May | 302 | 241 | 168 | 120 | 84 | 65 | 43 | 27 | 21 | 14 | 11 | 7.8 | 6.8 |
| June | 157 | 127 | 82 | 64 | 45 | 35 | 23 | 14 | 11 | 7.8 | 5.2 | 4.1 | 3.8 |
| July | 192 | 139 | 84 | 57 | 33 | 24 | 16 | 10 | 8.4 | 6.7 | 4.9 | 3.8 | 2.8 |
| August | 304 | 220 | 136 | 79 | 49 | 32 | 17 | 10 | 7.9 | 5.2 | 4.0 | 2.9 | 2.4 |
| September | 713 | 532 | 342 | 227 | 127 | 83 | 44 | 24 | 18 | 11 | 7.1 | 3.3 | 2.6 |

# 4 Project Alternatives

## 4.1 Alternative 1 – Expansion/Rehabilitation of Existing Hydroelectric Project

This alternative is an expansion/rehabilitation of the existing hydroelectric facilities on Gunnuk Creek. This alternative would utilize the existing water supply dam and intake works located on Gunnuk Creek. A new 2,100 foot-long 54-inch diameter steel penstock would connect from the existing outlet works in the dam and would replace the existing 10-inch diameter HDPE penstock/hatchery supply pipe.

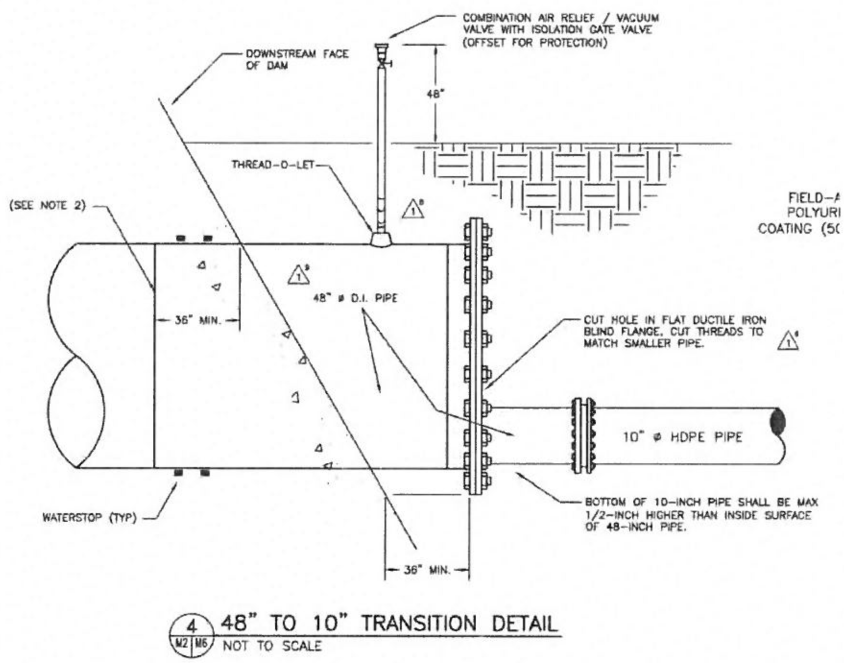


**Figure 6 - Existing outlet works in dam**

The new penstock would follow the same route as the existing penstock. Areas of bank erosion along the existing penstock route would be stabilized.

A new 22' x 36' powerhouse would be constructed adjacent to the existing hatchery building. The powerhouse would use the foundation of the existing Coho building. The functionality of the backup water supply for the hatchery through the foundation would remain in place. The new powerhouse would contain a single crossflow-type hydroelectric turbine with an installed capacity of 500 kW[2].

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[2] IPEC has indicated a target installed capacity of 500 kW.

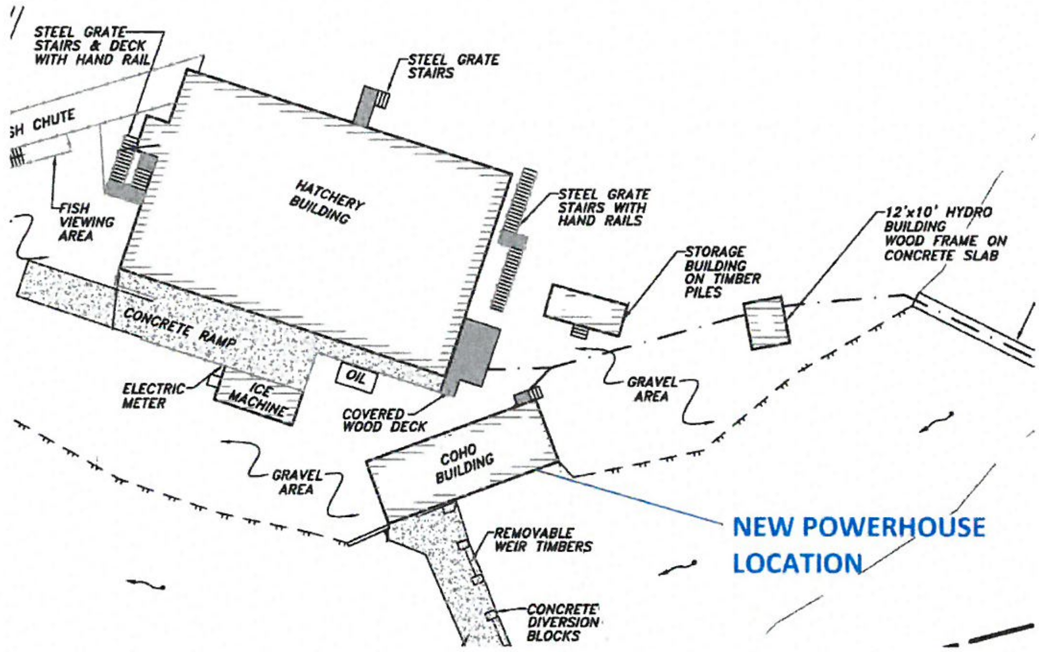


**Figure 7 - New powerhouse location at hatchery**

Access to the intake and powerhouse would be through existing roads and interconnection would be via the existing overhead electrical supply to the hatchery.

There is not a way of creating enough storage to allow for seasonal regulation so the project would operate in a near run-of-the-river mode. Operational flexibility on a daily basis could be enhanced by adding a small amount of working storage behind the dam. This could be accomplished by adding inflatable gates in the spillway bays. The technical considerations of this option would need to be further investigated during final project design.

Key project parameters are presented in Table 3 below.

**Table 3 - Alt. 1 Project Parameters**

| | |
|---|---|
| Headwater, ft | 89 |
| Tailwater, ft | 20 |
| Gross Head, ft | 69 |
| Net Head, ft | 60 |
| Design Flow, cfs | 130 |
| Capacity, kW | 500 |
| Drainage Area, $mi^2$ | 15.4 |
| Avg. Inflow, cfs | 97 |
| Active Storage, AF | 0 |

### 4.2 Alternative 2 – Mid-Basin Run-of-river Project

Alternative 2 is a run-of-river project located approximately in the middle of the Gunnuk Creek drainage basin and is similar in nature to the Phase 1 project identified in the Christensen report.

Diversion of Gunnuk Creek would occur just downstream of the confluence of two forks at about elevation 300, approximately 2.7 miles upstream from tidewater. At the point of diversion, the drainage area is estimated to be 10.6 mi$^2$. The facilities would be comprised of a simple diversion structure, an intake, a sluiceway capable of releasing incremental flows and a spillway. Water would be conveyed to the powerhouse via a 36-inch diameter 10,000-foot-long steel penstock. The powerhouse would be located around elevation 100 and would be a simple concrete reinforced structure that would contain a single Turgo-type turbine, synchronous generator and associated switchgear and controls. The installed capacity would be 500 kW. Access to the powerhouse site would be with a new 0.25 mile road beginning near the existing water tank. Transmission would be via an overhead pole line following the access road. The general location of features is shown in Figure 8.

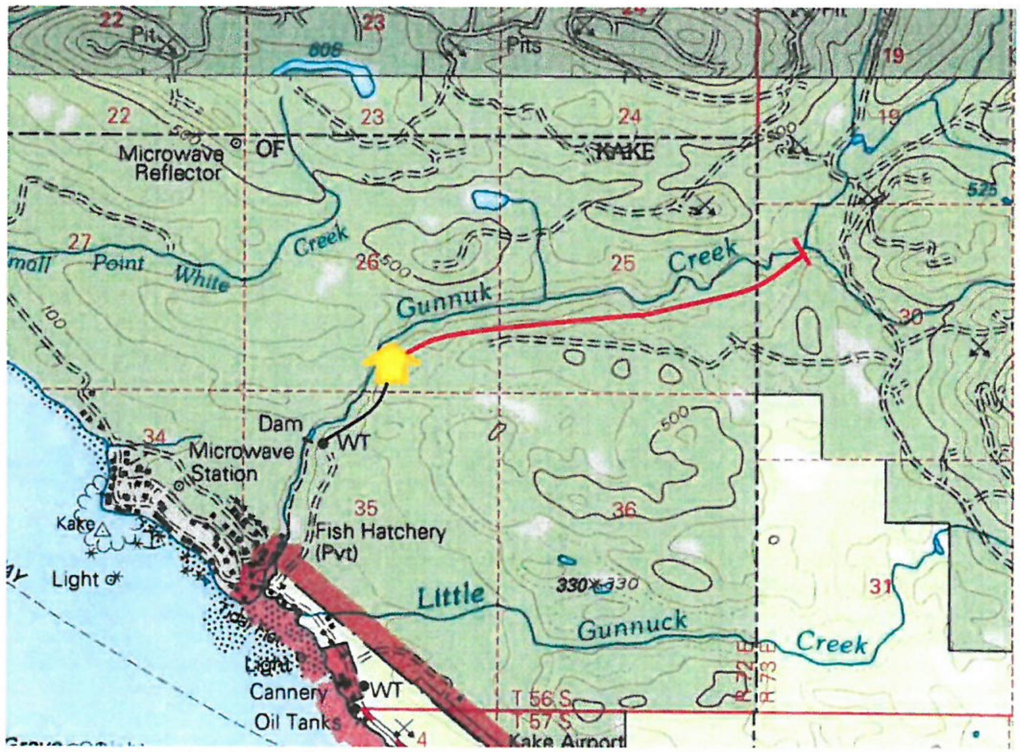


**Figure 8 - Alternative 2 Conceptual Project Layout**

Key project parameters are presented in Table 4.

**Table 4 - Alt. 2 Project Parameters**

| | |
|---|---|
| Headwater, ft | 300 |
| Tailwater, ft | 100 |
| Gross Head, ft | 200 |
| Net Head, ft | 170 |
| Design Flow, cfs | 46 |
| Capacity, kW | 500 |
| Drainage Area, $mi^2$ | 10.6 |
| Avg. Inflow, cfs | 65 |
| Active Storage, AF | 0 |

## 4.3 Alternative 3 –Storage Project

Alternative 3 is a storage project located approximately in the middle of the Gunnuk Creek drainage basin and is similar in nature to the Phase 2 project identified in the Christensen report with the notable difference being that the reservoir would be located on the adjacent sub-basin.

Diversion of Gunnuk Creek would occur at about elevation 450, approximately 3.9 miles from tidewater. At the point of diversion, the drainage area is estimated to be 5.7 $mi^2$. The facilities would be comprised of a 50-foot-high, 900-foot-long concrete faced rock fill dam, an intake, and a spillway. It is assumed that an approximate 10-15-foot-high, 700-foot-long saddle dike would also be required. The reservoir created would have a surface area of approximately 500 acres and a usable storage volume of 7,500 acre-feet.

Water would be conveyed to the powerhouse via a 40-inch diameter 4,000-foot-long steel penstock. The powerhouse would be located around elevation 300 and would be a simple concrete reinforced structure that would contain a single Francis-type turbine, synchronous generator and associated switchgear and controls. Since this is a storage project, the installed capacity has been set at 1,000 kW to accommodate future load growth. Access to the site would be with 1.0 miles of new road extending from the existing road system. Transmission would be via a 3-mile-long overhead pole line following the existing roads in the area. The general location of features is shown in Figure 9.

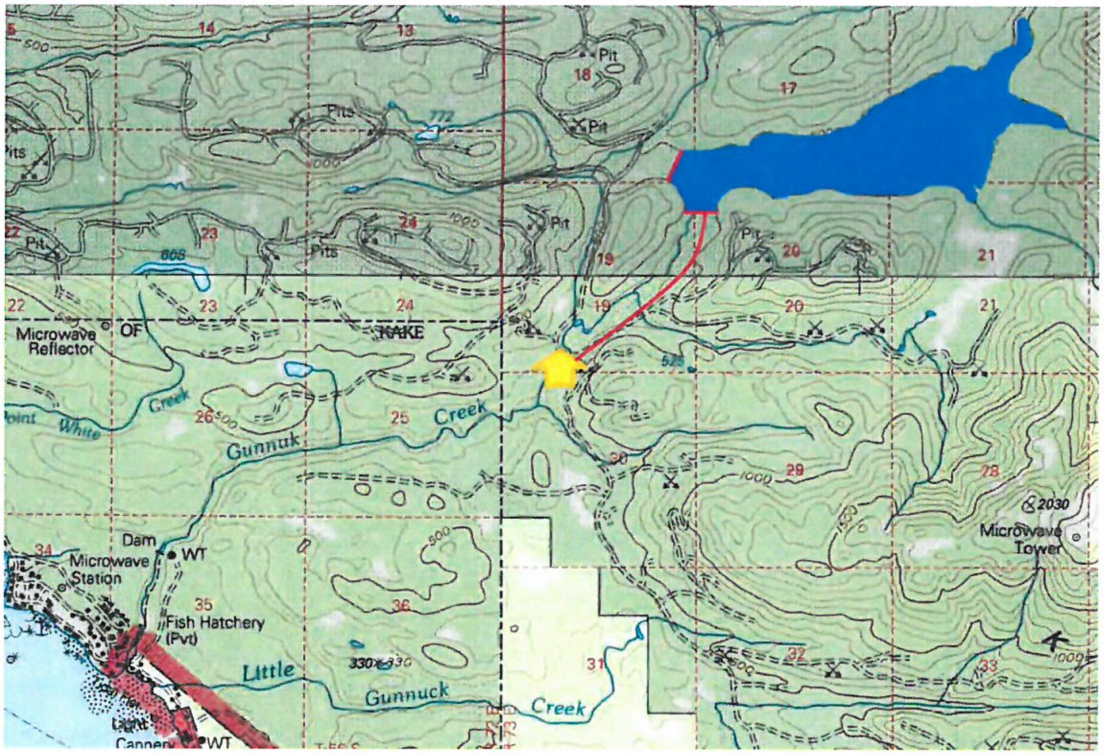


**Figure 9 - Alt. 3 Conceptual Project Layout**

Key project parameters are presented in Table 5.

**Table 5 - Project Parameters**

| | |
|---|---|
| Headwater, max. ft | 500 |
| Headwater, min. ft | 470 |
| Tailwater, ft | 300 |
| Gross Head, ft | 200 |
| Net Head, ft | 174 |
| Design Flow, cfs | 85 |
| Capacity, kW | 1,000 |
| Drainage Area, $mi^2$ | 5.7 |
| Avg. Inflow, cfs | 36 |
| Active Storage, AF | 7,500 |

# 5 Permitting/Licensing

Typically hydroelectric projects are regulated under Federal Energy Regulatory Commission (FERC) guidelines. The jurisdiction granted to FERC to issue licenses and exemptions was established by Section 23(b) of the Federal Power Act of (1976) [3], which:

> *"...requires that waterpower projects be licensed if they are located on navigable waters of the United States, occupy any part of the public lands or reservations of the United States, use surplus water or waterpower from a Federal Government dam, or, if constructed after August 26, 1935 are located on any part of a non-navigable water subject to Congress' Jurisdiction under the Commerce Clause and affect the interests of the interstate or foreign commerce."*

Any proposed Gunnuk Creek hydroelectric project would appear to lack the specific criteria that would necessitate any license or exemption from FERC because the project:

1. does not involve any waterbody having known current or historic navigational uses such as the passage of people or goods, and so is located on non-navigable waters,
2. will not use surplus water or water power from a federal dam,
3. will be located on non-navigable waters and is not subject to the authority of Congress under the Commerce Clause, or
4. will not occupy lands or reservations of the United States.

The opinion that a FERC license would not be required for a Gunnuk Creek hydropower project is based on the lack of FERC jurisdiction and not on an exemption granted by that agency. Consultation with FERC will need to be done to verify and document that this project is not under FERC jurisdiction.

The following permits would likely be required for the proposed project:

- Alaska Department of Fish and Game (ADF&G) Division of Habitat Title 16 Fish Habitat Permit
- US Army Corps of Engineers Section 404 permit
- Alaska Department of Natural Resources (ADNR) Water Rights Permit

[3] Section 23(b), 16 USC subpart 817.

# 6 Energy Generation

Energy generation for Alternatives 1 and 2 was estimated using HDR's proprietary software "Hydroelectric Evaluation Program" (HEP). HEP has been specifically designed to model run-of-river operations. HEP uses tabulated daily flows, turbine and generator efficiencies, friction coefficients and physical parameters to simulate energy production through a period of streamflow record. Turbine and generator efficiencies are determined from tables. Output from HEP consists of effective capacity rating of the unit(s), simulated production in MWh, percent operating time and overall plant factor.

Energy generation for Alternative 3 was estimated using a reservoir simulation model. The model uses average monthly flow data and stage/storage characteristics to optimize dispatch using inflows and storage to maximize energy generation. Outputs from the model include estimated monthly generation and pool elevations.

## 6.1 Assumptions

The following were key assumptions used in modeling energy production:

- USGS gage number 15087565 data was used for the energy analysis. Long term synthesized stream data was used for the sensitivity analysis.
- For the alternatives with storage, a water-to-wire efficiency was assumed at 85%. For the generating equipment likely to be used at this project, turbine efficiencies can vary greatly depending on the flow. However, at this level of study a constant level of efficiency was considered appropriate because the storage would allow for optimized dispatch. The reservoir was assumed to start 75% full on October 1st and was constrained to return to the starting elevation at the end of September to maintain year-to-year continuity. This was determined to be the best operating strategy to maximize the use of fall runoff.
- Tailwater elevation was assumed to remain constant over all flows. In practice, it would likely vary slightly; however, not enough data were available to refine this assumption.
- For daily simulations, head loss was calculated using the daily flow and water conveyance system parameters. For monthly simulations, head loss was assumed to average 7%.
- Losses for station service and transformers were estimated to reduce gross generation by 2%.
- For Alt. 1 it is assumed that minimum instream flows will be as requested by ADF&G in the Environmental Assessment prepared for the construction of the new water supply dam. Alt. 2 and 3 are above the anadromous barrier and have short bypass reaches. As such, a minimum instream flow of 5 cfs has been assumed. Table 6 shows the minimum instream flows used in modeling.

**Table 6 - Minimum Instream Flows**

| | MIF, cfs | |
|---|---|---|
| | **Alt. 1** | **Alts. 2&3** |
| Oct | 20 | 5 |
| Nov | 20 | 5 |
| Dec | 15 | 5 |
| Jan | 15 | 5 |
| Feb | 15 | 5 |
| Mar | 15 | 5 |
| Apr | 20 | 5 |
| May | 20 | 5 |
| Jun | 15 | 5 |
| Jul | 10 | 5 |
| Aug | 10 | 5 |
| Sep | 15 | 5 |

## 6.2 Results

An estimate of the annual average generation potential for each of the alternatives is presented in Table 7 below. The usable energy from a new hydroelectric project is a measure of how well the generation from the project matches up with the load on a seasonal basis. Energy generation in Kake for the period 2000-2014 has averaged 2,860 MWh/year and has varied seasonally as shown in Figure 10. For this analysis, the generation from the various alternatives was compared to the five-year monthly average of system load to estimate usable energy.

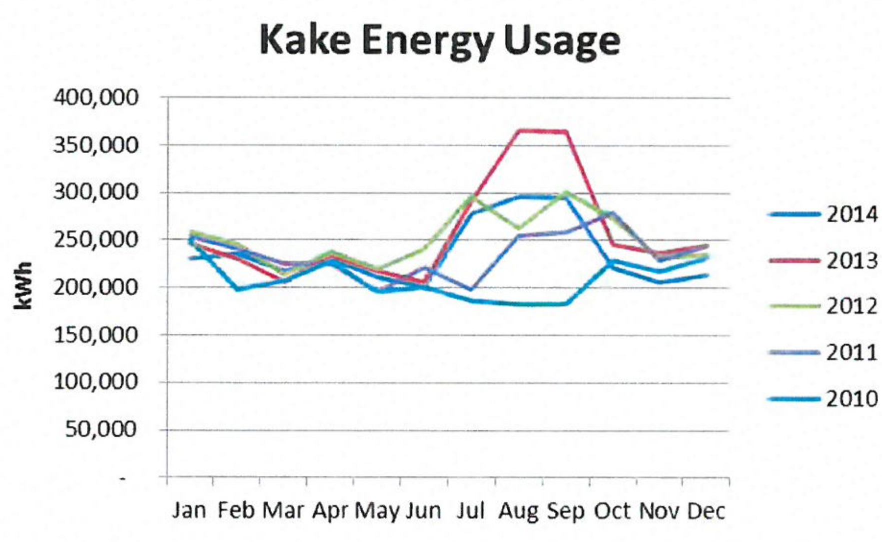


**Figure 10 - Kake Energy Usage**

**Table 7 - Average Annual Generation**

| Alternative | Capacity (kW) | Avg. Annual Energy (MWh) | Usable Annual Energy (MWh) |
|---|---|---|---|
| 1 – Existing Dam | 500 | 1,620 | 1,620 |
| 2 – New R.O.R | 500 | 2,590 | 2,400 |
| 3 – New Storage | 1,000 | 4,150 | 2,860 |

### 6.3 Sensitivity Analysis

To assess the suitability of using the short-term hydrological record from USGS gage number 15087565 for energy modeling, energy generation was also estimated by integrating the flow duration data for the synthesized long-term flow record (Table 2). Using this approach, the synthesized data produced annual energy estimates of 88%, 96% and 84% for Alternatives 1, 2 and 3 respectively. This indicates that the expected long term energy generation from the alternatives could be slightly less than presented in Table 7. However, due to the coarseness of the synthetic flow duration data and the strength of the correlation coefficient, the results are inconclusive.

The minimum instream flow assumption for Alt. 1 was based upon ADF&G comments made during the consultation process for the new dam. However, the City's water right has a minimum instream flow requirement of 11 cfs continually. If this assumption was made, the average annual generation estimate for Alt. 1 would increase by 100,000 kWh/year.

# 7 Cost Estimates

An opinion of probable construction costs was derived for each of the alternatives presented above. The approach used was to develop base work units and unit prices and then apply these units and prices consistently to the various alternatives. Vendor budgetary quotes and recent construction cost information was used to estimate equipment and materials. This approach allowed a common platform from which to establish priority amongst the alternatives, although slight differences do exist. It should also be noted that the project sizes for the various alternatives may not be the true optimum. For example, future refinement may determine that the design flow for the turbine should be slightly greater or smaller than what was assumed. A sensitivity analysis performed as part of the energy generation estimating process indicated assumed values were appropriate.

Although future refinement of the estimated unit costs or generation estimates may affect the final benefit/cost evaluation, it should not affect the ranking of the alternatives amongst themselves.

The following assumptions were used in the cost estimate:

- Indirect construction costs associated with engineering, construction management, licensing, permitting and the owner's internal costs were added to the direct construction cost estimate as percentages.
    - Design engineering was assumed to be 10% of the total direct construction costs.
    - The Owner's General Administration and Overhead of the design and construction was assumed to be 1% of the total direct construction costs.
    - Construction management was assumed to be 10% of the total direct construction costs.
- A contingency of 30% was added to the total of the direct construction costs to reflect uncertainties of layout and design that wouldn't be resolved until later in the development process. For alternative 1 the contingency was reduced to 20% reflective of the existing development and the knowledge of the alternative.

Table 8 presents the results of the reconnaissance level cost estimates for the three alternatives considered.

**Table 8 - Summary of Costs**

| | Alt. 1 | Alt. 2 | Alt. 3 |
|---|---|---|---|
| Total Direct Construction Costs | $3,761,000 | $11,812,000 | $24,507,000 |
| Contingency | $752,000 | $3,544,000 | $7,352,000 |
| Engineering | $376,000 | $1,181,000 | $2,451,000 |
| Licensing & permitting compliance | $38,000 | $118,000 | $245,000 |
| Owner's General Administration & overhead | $38,000 | $118,000 | $245,000 |
| Construction Management | $376,000 | $1,181,000 | $2,451,000 |
| Subtotal | $5,341,000 | $17,955,000 | $37,250,000 |
| Interest During Construction | $124,000 | $887,000 | $1,841,000 |
| Total | $5,465,000 | $18,842,000 | $39,091,000 |

# 8 Economic Evaluation

A detailed economic evaluation was not included in the scope of this work. However, in order to provide a conceptual view of the economics, an evaluation was made using the State of Alaska's Renewable Energy Fund Round 9 evaluation worksheet. The analysis assumed the "diesel off" scenario. The capital cost was assumed to be equally distributed over two years for Alts. 1 & 2 and three years for Alt. 3. Diesel efficiency was assumed to be 13.0 kWh/gallon reflective of the current diesel generation efficiency.

The table below provides the benefit/cost ratio of the alternatives for two energy generation scenarios.

**Table 9 - Benefit/Cost Summary**

| | Alt. 1 | Alt. 2 | Alt. 3 |
|---|---|---|---|
| Max. Energy Generation | 3.13 | 1.34 | .97 |
| Usable Energy Generation | 3.13 | 1.22 | .60 |

# 9 Conclusions and Recommendations

- A small run-of-river hydroelectric project making use of the existing water supply dam (Alt. 1) is the best development option for Gunnuk Creek at this time. Costs are minimized because the dam and intake facility have already been constructed, and no new transmission lines or access roads are required. Re-use of the foundation of the Coho building at the hatchery reduces excavation and in-water work risk. It is the best understood of all the alternatives considered and therefore there is higher confidence in the analysis.

  It is estimated that the project could become fully operational with 18-24 months. The next steps in project development are:

  - Initiate discussions with ADF&G regarding requirements for instream flow in the bypass reach.
  - Develop joint use agreement with the State of Alaska for the use of the hatchery water supply and powerhouse site. Replacement of the pipeline and stabilization of the route has the added benefit of increasing the reliability of the hatchery water supply.
  - Initiate discussions with the Southeast Alaska Land Trust to confirm project is consistent with the conservation easement that is in place.
  - Final design of the project to include surveying the plan and profile of the pipeline route, soils exploration along pipeline route and preparation of design plans and specifications.

- A mid-basin run-of-river project (Alt. 2) appears to have some initial economic merit however there is a lot of uncertainty about its development. The concept presented here should be viewed as "what might a new run-of-river project look like" rather than a strict project definition. Alternative 2 is based upon limited topographic information and site evaluation. The largest uncertainty lays in the definition of the penstock route. It is presumed that there would be great difficulty in getting the penstock out of the incised channel which would allow it to follow an overland route. It may be possible to partly alleviate this problem by moving the intake upstream to a higher elevation but this would come with increased cost and would significantly decrease the drainage area. In order to begin to address these questions, a detailed feasibility study would need to be conducted.

- A new storage project (Alt. 3) could meet all of Kake's needs now and for sometime into the future, but the high cost of developing seasonal storage makes it cost prohibitive. Like Alternative 2, Alternative 3 is based upon limited topographic information and site evaluation. There are many technical issues that would need to be evaluated and overcome before making a determination if the site is even suitable for a dam.

# Appendix A

# Geotechnical Reconnaissance Report

Golder Associates

August 25, 2014 1406769

Paul Berkshire, PE
HDR Alaska, Inc.
2525 C Street, Suite 305
Anchorage, AK 99503-2632

**RE: GEOTECHNICAL RECONNAISSANCE, GUNNUK CREEK HYDROELECTRIC PROJECT**

Dear Paul:

In response to your request, Golder Associates Inc. (Golder) made a preliminary geotechnical reconnaissance of the Gunnuk Creek watershed as part of a potential hydroelectric project near Kake, Alaska. This reconnaissance was made by Bob Dugan of Golder in the company of Paul Berkshire of HDR on June 25, 2014.

The purpose of the reconnaissance was to assess the general geologic conditions and identify potential sites that might be suitable for a hydroelectric dam and related facilities.

## 1.0 METHODOLOGY

### 1.1 Review of Existing Information

The reconnaissance was preceded by the review of existing geologic mapping by the U.S. Geological Survey (Gehrels and Berg, 1992) (Muffler, 1976) and reports provided by HDR that included a Preliminary Appraisal Report for Hydroelectric Potential (Alaska Power Authority,1977) prepared by Robert W. Retherford Associates and a Hydropower Reconnaissance Report (PCE, 2013) by PCE. The PCE report concluded that hydropower options near Kake are limited due to relatively gentle topography and regionally low precipitation. The 1977 report stated that a suitable storage basin existed at approximately stream mile 3.5 of Gunnuk Creek requiring two earth-filled dams on the two forks of the stream.

We also reviewed document by the Alaska State Dam Engineer (Cobb, 2003). This report addresses the failure of the timber dam in 2000 and the concrete dam that was constructed on Gunnuk Creek at the 125 foot elevation. This new dam replaced the failed timber dam at the same location. This report notes that upstream erosion tends to fill the reservoir with sediment and debris, requiring significant maintenance.

### 1.2 Site Reconnaissance

For the reconnaissance in Kake we met with Peter Bibbs of the Inside Passage Electric Cooperative (IPEC), Adam Davis, a Kake resident and Community Catalyst, and Bob Christensen of Sustainable Southeast. It is our understanding that IPEC is in the early stages of identifying a potential new hydroelectric dam site. The reconnaissance included an aerial inspection of Gunnuk Creek watershed, landing and inspection of a local quarry located approximately 3 miles upstream of the outlet, and ground inspection of an area upstream of the quarry where various tributaries converged. The project vicinity and area with various features are shown in Figures 1 and 2.

### 1.3 Image Interpretation

Several types of imagery and remote sensing data were used to gain understanding of the terrain. Imagery types included NASA Landsat satellite imagery dated between 2000-2002, 1m satellite RGB imagery dated June, 2006, from USGS High Resolution State Orthoimagery for the Southeastern



**Golder Associates Inc.**
2121 Abbott Road, Suite 100
Anchorage, AK 99507 USA
Tel: (907) 344-6001 Fax: (907) 344-6011 www.golder.com

Areas, Alaska, published 2011, and color aerial photographs. 30-meter elevation data was also used to create hillshade images, and in 3-D analyses of the site. The elevation data used was acquired by the Shuttle Radar Topography Mission (SRTM) using Interferomic C-band Spaceborne Imaging Radar, dated February 2000, and published and distributed by of NASA, NGA and the USGS. Recent USGS topographic maps, 1:63,360 scale USGS Topographic maps; Petersburg D-6, AK (1995), and Sumdum A-6, AK (1994) were also acquired and used for the analyses.

These datasets were reviewed in both a 2-D and 3-D perspectives using software programs including Globalmapper 15 and QT Modeler.

## 2.0 GENERAL SITE CONDITIONS

The Gunnuk Creek watershed is underlain by the Cannery Formation which is composed of a thick sequence of Permian/Devonian-age sedimentary and volcanic rocks. These units include fine-grained tuffaceous argillite and graywacke plus subordinate chert, limestone, and andesitic volcanic rocks. The Cannery Formation is known to be intensely deformed by both complex folding and faulting and the rocks are typically highly fractured (Muffler, 1967). The rock appears to have undergone low–grade metamorphism. The region was intensely glaciated during the Pleistocene which scoured the bedrock. Glacially-derived unconsolidated materials mantle the bedrock including glacio-marine deposits at lower elevations.

The Gunnuk Creek watershed and adjacent areas are traversed by a series of parallel east-west trending lineaments interpreted to be inactive faults. The spacing of the lineaments typically range from 0.25 to 0.5 miles, as shown in Figure 3. These lineaments have formed small linear depressions which are occupied by tributaries of Gunnuk Creek. Gunnuk Creek both follows and cuts across several of these lineaments at a sub-perpendicular angle between Alpine Lake and the outlet at Kake.

The ground surface is heavily vegetated so exposures of the bedrock and mineral soils are limited. The area has been extensively logged and a logging road provides access to Alpine Lake and other portions of the watershed. Bedrock consisting of a highly fractured argillite with thin quartz veins is exposed in a quarry approximately 3.5 miles inland of the coast near Gunnuk Creek, as shown in Figure 4. It is also exposed under the bridge that spans the creek upstream of the quarry, as shown in Figure 5. The exposures in the quarry and under the bridge both have steeply dipping bedding. Most of the upper reaches of the Gunnuk Creek floodplain appear to be relatively broad and flat with meandering channels suggesting that several feet, or more, of sediments and organic materials overlie the bedrock in the valley bottoms. By contrast, much of the 2.5 miles of the creek closest to the outlet is characterized by more deeply-incised, narrow, and linear channels.

## 3.0 POTENTIAL DAM SITES

Identifying potential sites for a hydroelectric dam on Gunnuk Creek is challenging due the masking of the terrain by heavy vegetation and the lack of high-resolution bare-earth imagery. The best options for further investigation from a geologic standpoint appear to be Sites 1 and 2 identified in Figures 2 and 3. These sites seem to offer the best chance for limiting the length of the dam and encountering shallow bedrock on the channel bottom and valley sidewalls. They also appear to provide for more reservoir area and hydraulic head than other locations. Depending on the height of the dam at Site 1, a second dam may be necessary on an adjacent tributary to the north to contain or expand the reservoir.

A third potential site would be coincident with the bridge immediately upstream of the quarry. Bedrock is visible in the steam under the bridge indicating that shallow bedrock may extend the length of the dam and thus limit the removal of surficial sediments for a dam keyed into bedrock. A potential problem with this site is the length of the dam. Based on SRTM 30m data, a 10 foot high dam would be approximately 400 feet long and a 15 foot high dam would be approximately 550 feet long.

## 4.0 RECOMMENDATIONS

Going forward, we recommend that a detailed LiDAR survey be conducted. The survey area should include the entire watershed, if funding allows, but at a minimum it should include the vicinity of Sites 1 and 2. This would provide the data for bare-earth modeling of the ground surface and detailed contour mapping. Currently, the 100 foot interval contours on the USGS mapping is the best available and it is too vague for siting on the relatively gentle terrain.

If these sites meet the criteria for reservoir size and head then they should be investigated in the field to determine the specific geologic conditions and to optimize the dam location within the vicinity of the identified site. While the geology of the Cannery Formation that underlies the area is complex and contains several different lithologies, there were no obvious fatal flaws observed in the rock that could preclude construction of a dam keyed into bedrock.

We appreciate to opportunity to work with you on this project. Please contact us with any questions.

**GOLDER ASSOCIATES INC.**

Robert G. Dugan, CPG
Principal Engineering Geologist

Mark R. Musial, PE
Principal and Geotechnical Practice/Program Leader

RGD/MRM/mlp

Attachments: References
Figure 1 Vicinity Map
Figure 2 Project Location Map
Figure 3 Hillshade Map
Figures 4 and 5 Bedrock Photographs

# REFERENCES


Cobb, Charles, F. 2003. The Kake Dam Failure: Community and Engineering Response; written by the State Dam Engineer.

Gehrels, G.E. and Berg, H.C. 1992. Geologic Map of Southeast Alaska, Map I-1867, published by U.S. Geological Survey.

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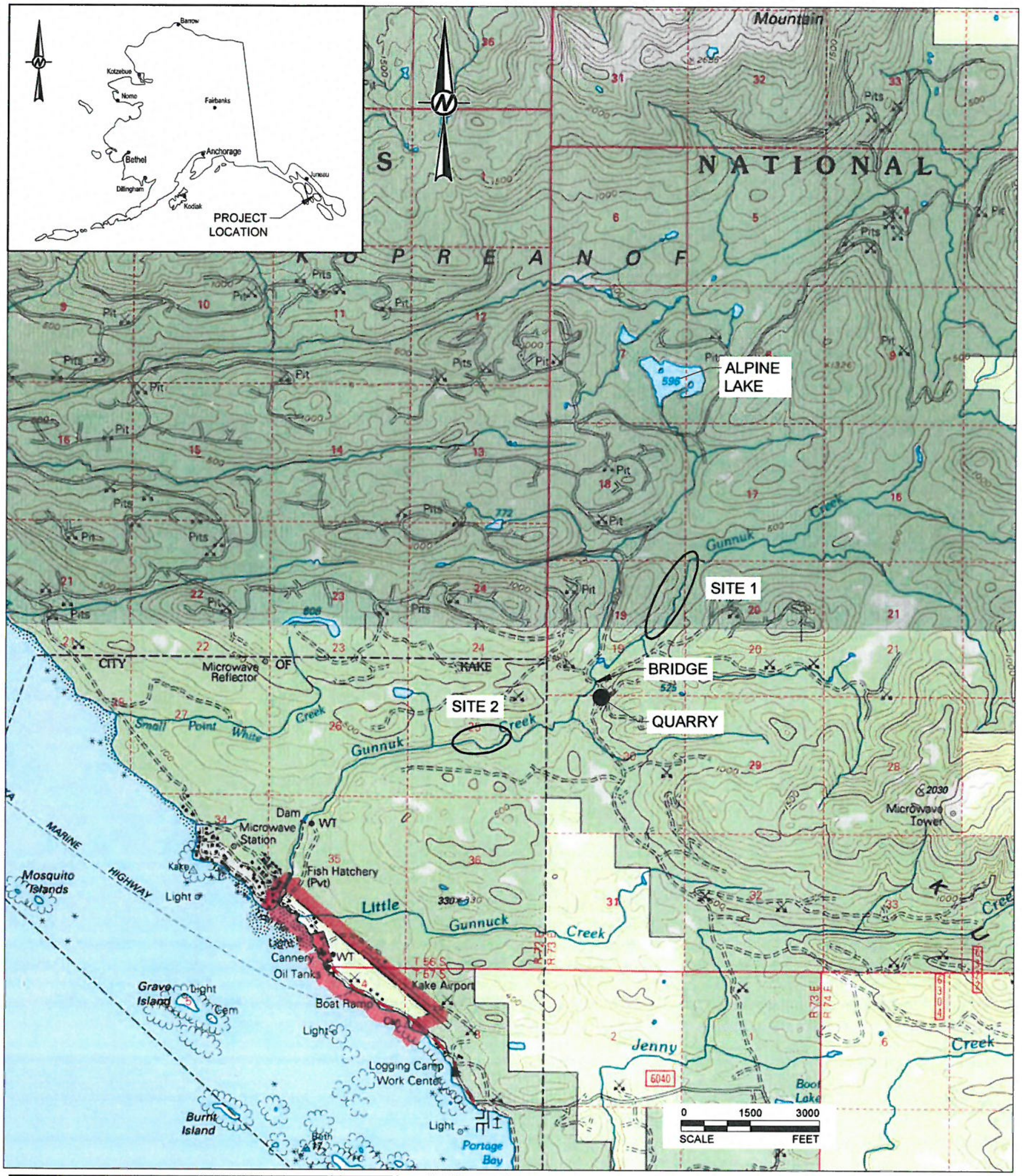


**REFERENCE**

1:63,360 SCALE TOPOGRAPHIC MAPS, PETERSBURG D-6, AK (1995), AND SUMDUM A-6, AK (1994) PRODUCED AND DISTRIBUTED BY USGS.

CLIENT
HDR

PROJECT
GUNNUK CREEK HYDRO

KAKE, ALASKA

CONSULTANT
Golder Associates

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| YYYY-MM-DD | 2014-08-25 |
| PREPARED | APG |
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| REVIEW | RGD |
| APPROVED | MRM |

TITLE
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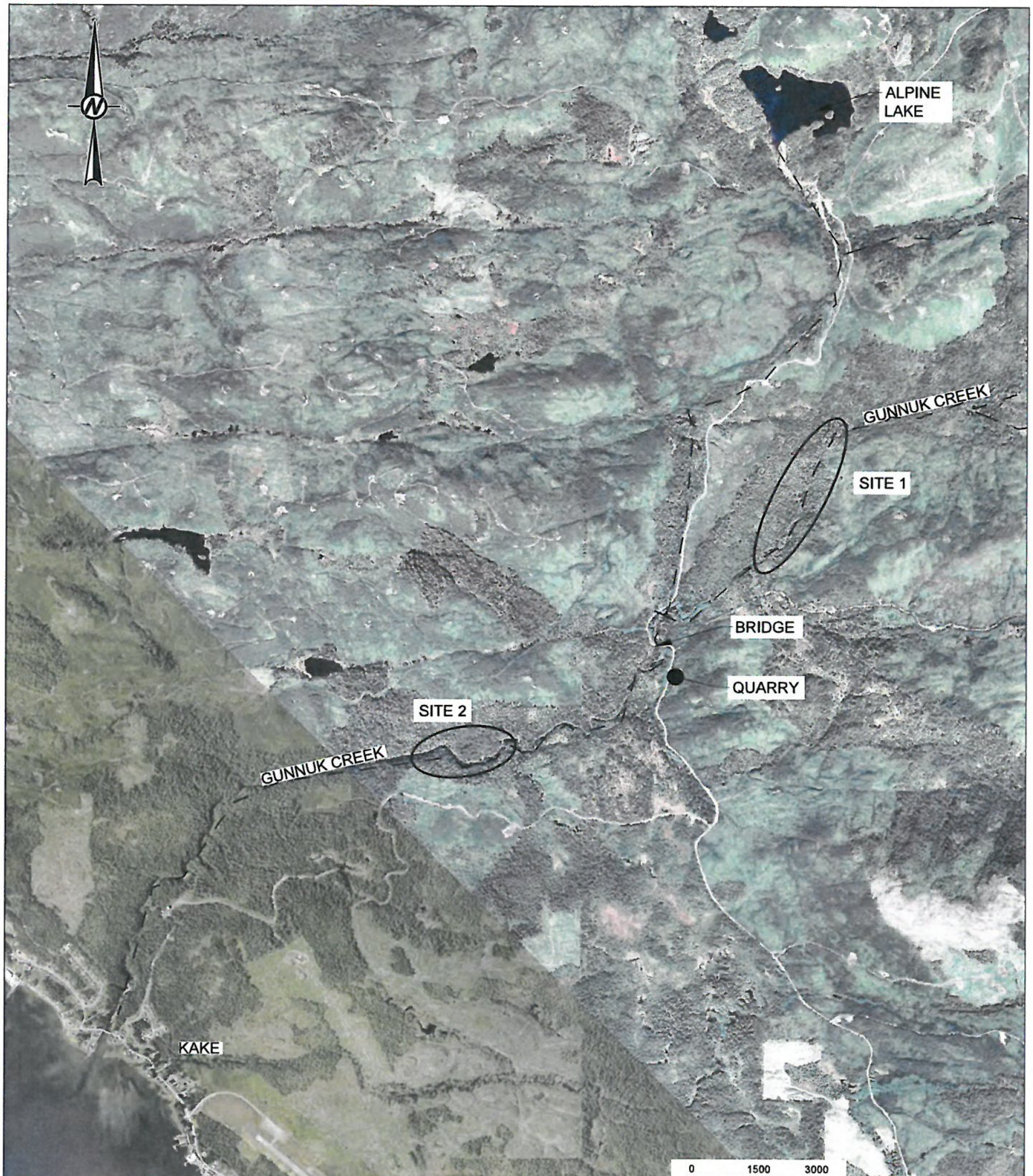


**REFERENCE**

1M SATELLITE IMAGERY DATED JUNE, 2006, FROM USGS PROJECT HIGH RESOLUTION STATE ORTHOIMAGERY FOR THE SOUTHEASTERN AREAS, ALASKA, AND DISTRIBUTED BY SDMI.

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CONSULTANT
Golder Associates

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| REVIEW | RGD |
| APPROVED | MRM |

PROJECT
GUNNUK CREEK HYDRO

KAKE, ALASKA

TITLE
**PROJECT LOCATION MAP**

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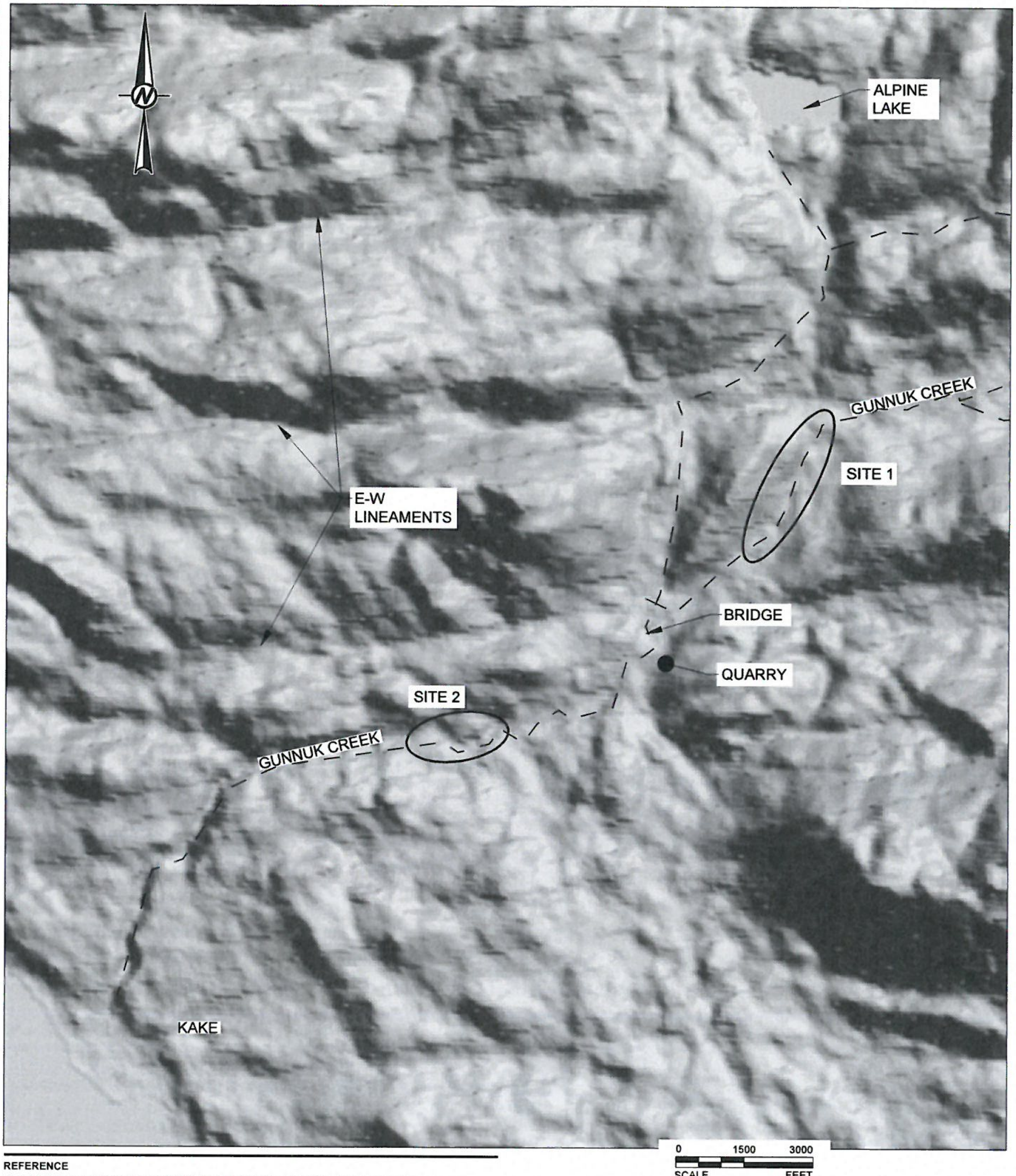


**REFERENCE**

HILLSHADE GENERATED FROM SHUTTLE RADAR TOPOGRAPHY MISSION (SRTM) USING INTERFEROMIC C-BAND SPACEBORNE IMAGING RADAR, DATED FEBRUARY 2000, AND PUBLISHED AND DISTRIBUTED BY OF NASA, NGA AND THE USGS

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| PROJECT | GUNNUK CREEK HYDRO<br>KAKE, ALASKA |
| TITLE | **HILLSHADE MAP** |

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META-SEDIMENTARY BEDROCK EXPOSED IN QUARRY NEAR GUNNUK CREEK APPROXIMATELY 3 MILES UPSTREAM FROM KAKE

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| CLIENT | HDR |
| CONSULTANT | Golder Associates |
| YYYY-MM-DD | 2014-08-25 |
| PREPARED | APG |
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| REVIEW | RGD |
| APPROVED | MRM |
| PROJECT | GUNNUK CREEK HYDRO<br>KAKE, ALASKA |
| TITLE | BEDROCK PHOTOGRAPH |
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BEDROCK EXPOSED IN THE ACTIVE CHANNEL OF GUNNUK CREEK UNDER THE BRIDGE APPROXIMATELY 3+ MILES UPSTREAM FROM KAKE.

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PROJECT
GUNNUK CREEK HYDRO

KAKE, ALASKA

TITLE
**BEDROCK PHOTOGRAPH**

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