Thayer Lake Hydropower Development

Kootznoowoo Inc.
ORENCO Hydropower

DOE Grant DE-EE0002504

Final Report

6/30/2017

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I. **Executive Summary**

The Thayer Lake Hydropower Development (THLD) has been under study since the late 1970's as Angoon explored opportunities to provide lower cost renewable power to the Community and avoid the high cost of diesel generation. Kootznoowoo Inc. (Kootznoowoo), the tribal corporation for Angoon's current and past residents, was provided the rights by Congress to develop a hydropower project within the Admiralty Island National Monument. This grant (DE-EE0002504) by the Department of Energy's (DOE's) Office of Indian Energy and a matching grant from the Alaska Energy Authority (AEA) were provided to Kootznoowoo to enable the design, engineering and permitting of this hydropower project on Thayer Creek.

Prior to the grant, the USFS had performed a final environmental impact statement (FEIS) and issued a Record of Decision (ROD) in 2009 for a 1.2 MW hydropower project on Thayer Creek that would Angoon's needs with substantial excess capacity for growth. Kootznoowoo hired Alaska Power & Telephone (AP&T) in 2013 to manage this project and oversee its development. AP&T and its subcontractors under Kootznoowoo's guidance performed several activities, aligned with the task plan defined in the grant. The major activities included:

- Comparison and selection of the preferred project design amongst several alternatives
- Environmental analysis of the project and its impacts on the local environment, especially on the fish habitat in Thayer Creek
- Stream gaging to augment the two years of past data by HDR
- Geotechnical review, including literature review, seismic analysis, geophysical analysis, and subsurface drilling
- Lidar survey of the area, and topographical survey of selected project elements
- Limited engineering of a few project elements.

Based on this work, AP&T initially selected a ~1.2 MW project similar to what had been reviewed and approved in the ROD. The cost estimate for that design was about $34-36 million. A number of factors led to a major change in design. This high cost (which would have resulted in levelized energy prices of over $0.90/kWh if selling to Angoon alone -- compared to the local utilities avoided energy costs at the time of $0.26/kWh) indicated the need to expand sales. In addition, the perceived need to drill the 4300 ft. penstock due to very steep slopes along the penstock route (at a minimum bore diameter of 9 ft.) led to a revised design of 6.3MW and costing an estimated $99 million. This project was envisioned to sell power not only power to Angoon, but to Green's Creek mine and potentially beyond via the Juneau intertie. But the much higher project cost, the inability to provide energy from this project at competitive prices to Green's Creek Mine or Juneau and the need for a much longer transmission line through parts of the National Monument that had not been set aside for project development by Congress, led Kootznoowoo to explore other project options. The two options that AP&T had developed would almost never be economically viable or result in lower energy prices in Angoon. This work had absorbed nearly $2 million of the $2.2 million grant from DOE and AEA.

Kootznoowoo hired ORENCO Hydropower in 2015 to see if an economically viable project could be developed. The initial feasibility analysis work by ORENCO indicated that a much simpler and lower cost project could be developed at the Barrier Falls. This analysis also included value engineering that demonstrated that the cost of several major project elements could be substantially reduced, including the dam, powerhouse, transmission line, access roads and penstock.

In order to verify these findings, Kootznoowoo and ORENCO brought together a team of hydro engineering, permitting and construction experts. Based on this work, it was determined that a 0.85 MW project entirely located in a small footprint north of Thayer Creek could be constructed for about $16 million. During the last ~ 18 months, the project team accomplished the following tasks:

- Surveyed the entire project footprint
- Developed the 30%-60% engineering for each of the major project elements, including the marine facility, access roads, dam, powerhouse, turbine/generator/controls, submarine cable, interconnection with the local utility
- Filed the necessary studies, permits, leases, easements and resource plans with the several federal agencies (USFS, USACE, USFWS) and state agencies (ADF&G, AKDNR land, water and dam safety), with only the AKDEC permit remaining since it is filed shortly before construction
- Received the approved Change Analysis for the new project design from the USFS, the draft permit from the USACE, and the draft lease and easement from the AKDNR
- Worked with the local utility to design the means for the project to provide voltage and frequency control to the electrical system in Angoon.

The other key work was to develop the means to maximize the value of the hydropower project in a community where nearly 30% of gross income is spent on heating and electricity – about 10x the national average. Since the project's capacity of 0.85MW is much more than Angoon's peak demand of 0.36MW, there is as opportunity to use this additional capacity to meet Angoon's energy needs. From this, the integrated hydropower and heat pump and school heating program was developed. The $16 million integrated hydropower project now includes the investments needed for providing heat to the three schools in Angoon (via the electric boilers/heat pumps that will also provide voltage and frequency control) and the heating systems for the 100 residential houses that currently use diesel boilers. The combined benefits of this program create an estimated savings of $750,000 per year, with combined heating and electric savings per household in Angoon of $2000-4000/year, as well as substantially reducing the needed subsidies that the State pays to Angoon through its Price Cost Equalization (PCE) subsidies. As a result, the estimated NPV of benefits from the combined program is over $27 million for a NPV of costs of $14 million, at a benefit to cost ratio of 1.85.

This work was completed at a cost that was about 25% of the expenditures by AP&T.

Kootznoowoo and ORENCO would like to express our appreciation to DOE's Office of Indian Energy for its financial and organization support for the project.

II. **Project Overview**

At the time of the DOE grant, Thayer Lake Hydropower Development (TLHD) was planned as a 1 megawatt (MW) + run of the river hydropower project located in the Tongass National Forest in the Admiralty Island National Monument. The goal of the project has always been to provide energy to the City of Angoon and Angoon Community Association (traditional tribe as recognized by Indian Reorganization Act). At the time of the grant, it was estimated that the project would provide $1.5 million dollars in collective energy savings in displacing another 500,000 gallons of diesel per year. Kootznoowoo Inc. (Kootznoowoo) through TLHD had the goal to completely displace the use of fossil fuel use in Angoon with a goal of 100% renewable energy driven Native community as a hallmark of the only community in the Admiralty Island National Monument Park. The peak demand in Angoon, is currently about 360kW, so the current design project can support substantial growth in electric demand. TLHD will allow Angoon to become energy self-sufficient in energy generation for current and future load growth.

Several important changes have occurred during the grant period. Initially Kootznoowoo was working with AP&T to design the project. During the course of the grant, the project design evolved to a 1.2MW project that was reviewed in the USFS 2009 Record of Decision, then to a 6 MW project, and once ORENCO Hydropower replaced AP&T, to a 0.85 MW project. The current design was recently approved by the USFS in the 2017 Change Analysis.

Given the substantial drop in the cost of diesel fuel over the last several years, the estimated fuel savings declined as well. In order to enable the project to provide substantial savings with the lower diesel costs, the project now includes programs that will also provide electric heating to the three schools in Angoon as well as replace the high cost diesel boilers in about 100 homes with high-efficiency air source heat pumps. The savings from the combined program is now estimated at $750,000 per year.

In November 2015, the Board of Directors of Kootznoowoo Inc. selected a location as the anadromous barrier falls near the mouth of Thayer Creek for the Project (Figure 1). The Project will utilize the existing natural elevation drop (head) of Thayer Creek and operate run-of-river. The proposed Project has a much smaller footprint and fewer Project effects on natural resources than the selected option by the U.S. Department of Agriculture, Forest Service (Forest Service) in the 2009 Angoon Hydroelectric Project, Record of Decision (ROD).

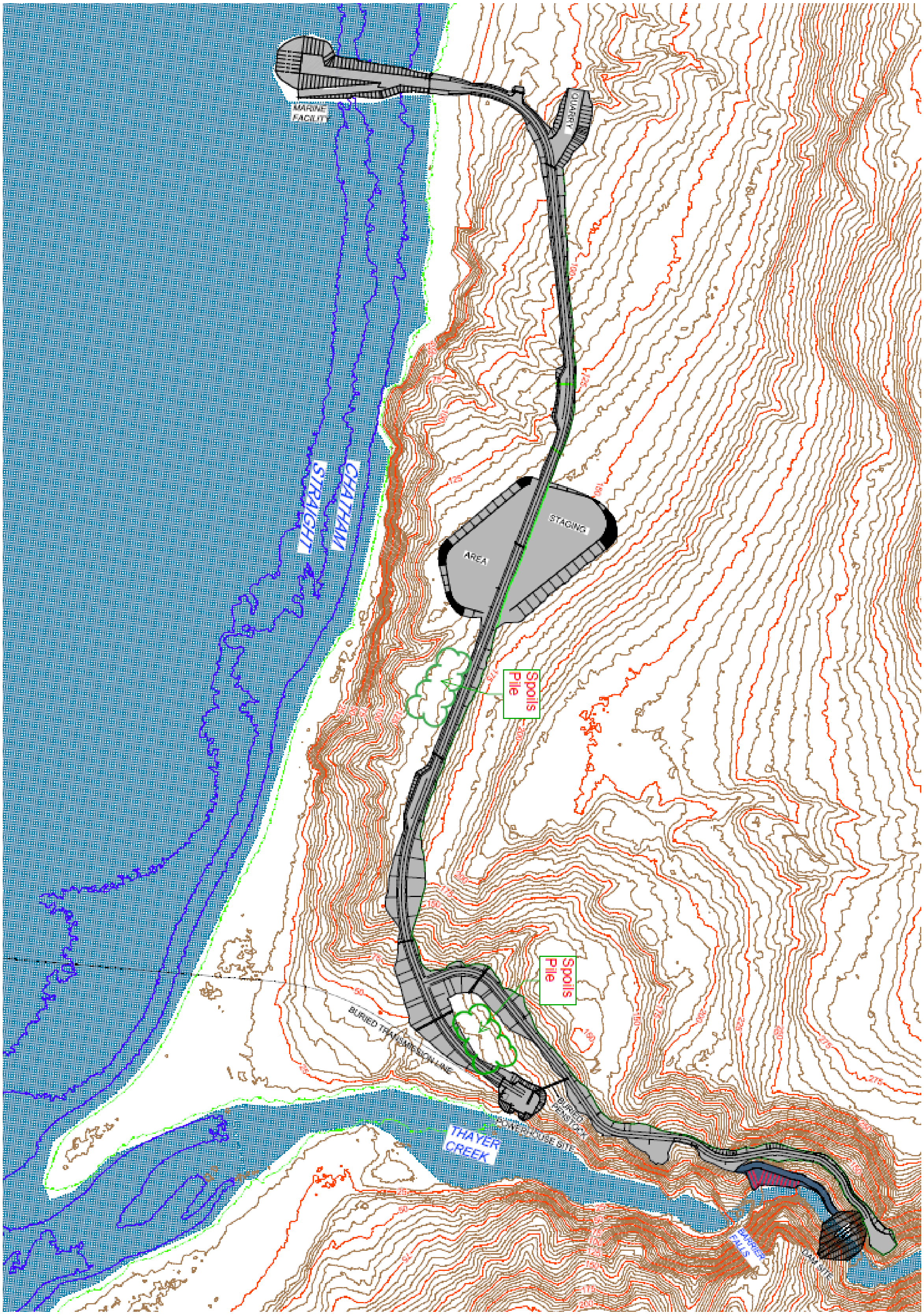


Figure 1: Project location and layout.

The current hydropower Project design includes:

- A marine facility north of Thayer Creek to provide sheltered barge and boat access for construction and operations;
- A temporary staging area about 2 acres in size on the access road about 700 feet south of the marine facility;
- A temporary quarry just inland from the marine facility that will provide rock and gravel needed for the access road and staging area bedding;
- Two spoils areas, each approximately 1 acre in size, that will provide sites for depositing organic spoils from the Project construction;
- 0.85 miles of access road from the marine facility to the dam and powerhouse;
- A 55-foot tall diversion dam located above the barrier falls and about 1500 feet from the Chatham Strait;
- A 60" 1000 ft. long penstock from the dam to the powerhouse;
- A 42" 300 ft. long water conveyance pipeline from the powerhouse to the base of the barrier falls;
- A powerhouse with a 0.85 MW turbine, generator, switchgear and controls;
- An 800 ft. buried 12.5kV transmission line from the powerhouse to the submarine cable in Chatham Straight
- A 6.5 mile 12.5 kV submarine cable going from Thayer Creek to Angoon via Chatham Straight
- An overhead 12.5kV transmission line in Angoon connecting the submarine cable to IPEC's substation.

Based on the work of several engineering and construction firms experienced in hydro development, the preliminary cost estimate for completing development and Project construction is approximately $16 million, down from the $34 million estimated by AP&T for its substantially more complex 1.2 MW design that was similar to the design reviewed in the 2009 USFS ROD.

Table 1 compares the project design approved in the 2009 ROD and the design approved in the 2017 Change Analysis, illustrating the much simpler design, smaller footprint and reduced impact of the current design.

Table 1
Comparison of Project Design in 2009 and Current Design Approved in 2017

Activity	ROD Selected Alternative	Final Design
Special Use Authorization	Yes	Yes

Above Ground Transmission Line	Minimized	0 miles
Buried Transmission Line	6.2 miles as feasible	0.13 miles (700 feet)
Submerged Transmission Line	0.5 miles	6.5 miles
Access Road Marine Facility to Powerhouse	2.2 miles	0.7 miles
Access Road Powerhouse to Dam	2.1 miles	0.25 miles
Access Road Marine Facility to Kootznahoo Inlet	4.0 miles	0 miles
Temporary Access Road Surge Tank	0	0
Road/Transmission Line Clearing Width	46-70 ft. (50 ft. average)	46-70 ft. (50 ft. average)
Diversion Dam Access Road Location	Avoids steep slopes in Thayer Creek Canyon	Follows contour ~0.2 miles on steep slopes in Thayer Creek Canyon.
Pipeline Location	Follows contour in Thayer Creek Canyon	None
Penstock Location	510 ft. of 36 inch penstock from downstream end of pipeline to the powerhouse	1000 ft. of 60 inch penstock from the dam to the powerhouse
Marine Facility	1.8 miles south of Thayer Creek	0.4 miles north of Thayer Creek
Switchyards	3	1
Tailrace Discharge Location	Above or immediately below the lowest anadromous fish barrier	At the bottom of the anadromous fish barrier and at the powerhouse.

Project Development Rights:

The development rights for the Project were granted to Kootznoowoo Inc. in 1982 by federal statute. Kootznoowoo, Inc., the Angoon village corporation, was created in 1971 when the Alaska Native Claims Settlement Act (ANCSA) was signed into law by President Richard M. Nixon. The law was passed to extinguish all aboriginal land claims in Alaska. As a result, there were 12 regional corporations and over 200 village corporations that were expected to bring sustainable economic benefits to Alaska Natives through a combination of land and cash distributions from Congress. Kootznoowoo, Inc. opted to postpone receiving ANCSA entitlements and rights until 1982 when the Alaska National Interest Lands Conservation Act (ANILCA) was signed by President Jimmy Carter. ANILCA, Section 506, defined Kootznoowoo's ANCSA lands entitlement and rights. One of the ANCSA entitlements was the exclusive right to develop hydroelectric resources just north of Angoon to meet the needs of the village since it was surrounded by federal Monument and Wilderness lands.

Project Status:

The conceptual design for the Project has been completed and the detailed engineering is now underway. The Project is also well along in the permitting process. In 2009, the USFS selected a larger more complex design in the Angoon Hydroelectric Project, Record of Decision (ROD). Using value-engineering techniques, a smaller, lower cost design has been selected that will reduce Project effects on natural resources than the alternatives evaluated in the Final Environmental Impact Statement (FEIS) and ROD. Therefore, the USFS had requested a change analysis to the ROD. The draft change analysis was provided to the USFS for review on March 6, 2016. The Project will also require permits from Alaska Department of Natural Resources, Alaska Department of Fish and Game, US Fish and Wildlife Services, the Alaska Department of Dam Safety and the U.S. Army Corp of Engineers. Outreach meetings with all of these agencies are underway.

Project engineering and permitting are well underway. Project construction will be competed in two phases. Phase 1 includes site access and initial site preparation for the marine facility, staging area and quarry, access roads and preliminary site clearing at the powerhouse and dam. Phase 2 includes construction of the powerhouse, dam, penstock and transmission line.

The engineering of the project has advanced substantially with almost all project elements at or beyond 30% engineering. The project team working on the project engineering, permitting and related studies is show in Table 2.

Table 2

Engineering Elements and Responsible Parties:

- **Project Management:** Kootznoowoo Inc., ORENCO Hydropower
- **Marine Facility** – All Points North Surveying and Engineering
- **Access Roads** – All Points North Surveying and Engineering
- **Dam** – ASI Constructors
- **Penstock** – Provost & Pritchard
- **Powerhouse** – Provost & Pritchard, ORENCO Hydropower
- **Hydrology Assessment –** Provost & Pritchard, ORENCO Hydropower
- **Turbine/Generator System** – ORENCO Hydropower
- **Turbine/Generator Switchgear and Controls** –ORENCO Hydropower (and tbd)
- **Transmission Line** – Evergreen Energy, ORENCO Hydropower, Tetratech, RT Casey
- **Electrical Interconnection with IPEC** – Evergreen Energy, ORENCO Hydropower
- **Voltage and Frequency Control in Angoon** – Evergreen Energy, ORENCO Hydropower, IPEC
- **Essential Fish Habitat** – Shipley Group, Delta Environmental Science
- **Wildlife and Plant Habitat** – Bosworth Consulting
- **Flood Plain Modeling –** Provost & Pritchard
- **Geologic Assessment** – ASI Constructors, GeoEngineers

The engineering designs are descried in Section IV – Task Summary.

The permitting of the project has also advanced substantially with all key permits, leases and easements filed (except the DEC construction permit, which will be filed shortly before construction). Table 3 illustrates the permits, leases and easements required.

Table 3

Thayer Creek Hydro Project Permits, Leases and Easements Required:

- **USFS Change Analysis and Biological Assessment/Evaluation** – *filed and approved*
- **USFS Special Use Authorization (and associated 19 resource plans) –** *draft of resource plans filed*

- **US ACE Permits –** *filed and draft permit issued for comments*
- **AK DNR Land Lease -** *filed and draft lease issued for comments*
- **AK DNR Water Rights Permit -** *filed*
- **AK DNR Transmission Line Easement -** *filed and draft easement issued for comments*
- **AK DNR Dam Safety Permit –** *filed and underway*
- **AK D&FG Permit –** *underway (draft permit in place)*
- **AK DEC Construction Permit** – *to be filed near the start of construction*

III. **OBJECTIVES**

Kootznoowoo is the traditional Native Corporation representing community and tribal members of Angoon and their descendants. Kootznoowoo has over 1,000 shareholders and has an elected board of professional directors and hires a professional management. Kootznoowoo has extensive experience in property and land management. In 2004, Kootznoowoo Incorporated submitted an application to the US Forest Service (USFS) requesting authorization for this development. Five years later (and now 9 years after our TLHD feasibility evaluation report) after Angoon has lost 1/3 of its resident population due to high energy and limited economic opportunities, has experienced one of the lowest per capita incomes in the State of Alaska, and has unemployment reaching 87%, the US Forest Service has issued a Final Environmental Impact Statement (FEIS). The Forest Service issued a Record of Decision (ROD) upon which AP&T had planned to use as the basis for the project design.

As stated in the DOE Grant – Statement of Project Objectives:

> *"The primary goal is to completely reduce our Native community from the high cost of diesel and to reduce our electrical cost. The development has the potential of eliminating, entirely the need for diesel and fossil fuels for home heating and electrical needs. Further, Angoon is a stranded community with limited roads and no access to the community unless by vessel or aircraft. The technological expansion of electric and electric- hybrid vehicles offers our community the further ability to reduce the use of fossil fuels in the near future. Secondary and supportive goals and objectives are to rebuild our local economy by bringing back commercial fishing operations, restaurants, and other small businesses that went out of business directly attributed to the high cost of energy; and to improve the quality of life by enhancing our social and cultural costs that have been negatively impacted by the high cost of electricity and diesel.*
>
> *Kootznoowoo has been discussing with potential preconstruction activity contractors that are uniquely qualified to deliver environmentally sound developments that have designed and developed hydropower developments that are Low Impact Hydropower Institute (LIHI) certified. Kootznoowoo is also cognizant in ensuring that all phases of development, construction and operation are completed at the highest cost efficiency with the goal of producing energy at the lowest cost for Tribal*

members and residents. An additional goal of Kootznoowoo is to design the construction of the development to maximize local tribal benefits through local employment and use of shareholder and tribal member resources to help alleviate and provide additional income benefits to the community."

The objectives were enhanced by Kootznoowoo during the last two years, and are now:

1. Focus on developing a hydro that will provide lower cost and renewable electricity to Angoon

2. Focus on a project that is sized to meet local demand and that will support some level of local demand growth – up to ~600-900kW total demand (Current average demand is under 250kW, and peak demand is about 350kW)

3. Consider the ability of project options to be expanded at a future date at a reasonable cost

4. Explore opportunities to reduce total energy costs (electricity, space heating and water heating) in Angoon by using electricity from the hydro project

As illustrated in Figure 2, electric demand in Angoon has remained fairly stable over the last few years, with monthly demand being highest in the winter, and lowest in the summer.

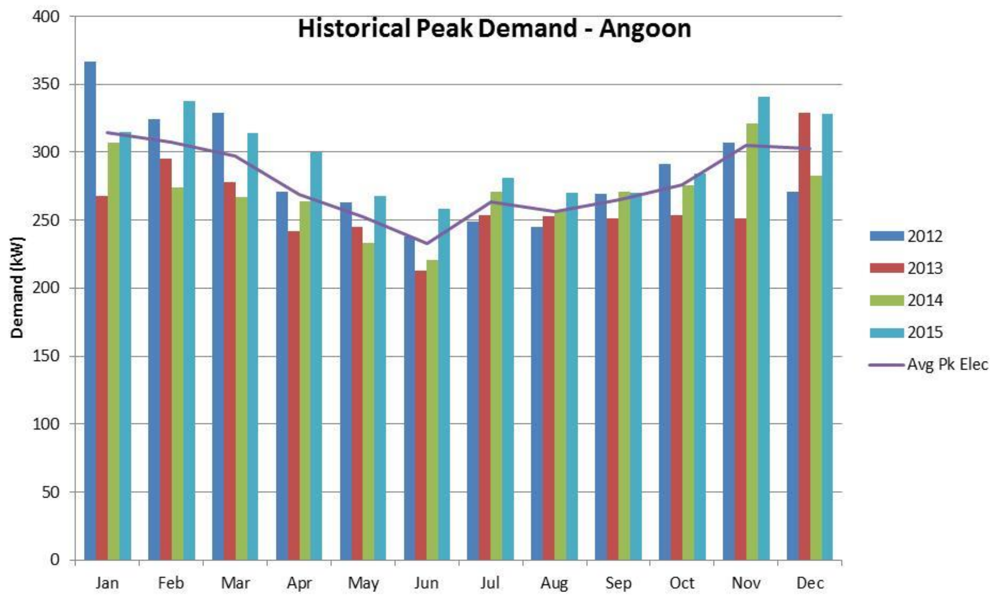


Figure 2:
Angoon's Monthly Electric Demand

Kootznoowoo has a completed Final Environmental Impact Statement (FEIS) for the project. The FEIS and Record of Decision (ROD) address all the necessary licensing articles (conditions) and needed permits, requirements and approvals necessary to construct our proposed project. Due to a decision by Federal Energy Regulatory Commission (FERC), the U.S. Department of Agriculture (USDA) is the licensing department for the Thayer Lake Hydroelectric Development (TLHD). Kootznoowoo's Selected Project Arrangement, the basis for the action alternatives presented in the FEIS, included a diversion dam, intake structure, marine facility, three access roads, two staging areas, transmission lines, a power plant, a surge tank, 6,100 feet of 42-inch diameter pipeline, and 510 feet of 36-inch diameter pipe. The hydroelectric plant would be a run-of-river facility using only the water available in the natural flow of the river. Under normal conditions, run-of-river facilities involve minimal water storage, and power generation fluctuates with the stream flow. The proposed facility would create a 10-20 acre pond behind a small dam. The Forest Service issued a Record of Decision in May 2009 which is the basis of the final design and preconstruction activities. The Angoon Hydroelectric Project ROD describes the selection of Alternative 3 for implementation in the Angoon Hydroelectric Project area. Kootznoowoo asked the Forest Service to do the NEPA process necessary to develop a hydroelectric project to lower the cost of power generation and electric bills in Angoon. Alternative 3, the Selected Alternative, was developed as a means of reducing the amount of vegetative clearing required along the transmission line corridor, reducing potential effects on fish habitat in Thayer Creek, and reducing potential effects of road and pipeline/penstock construction on karst terrain and on steep slopes along Thayer Creek. The Selected Alternative requires buried power line, roads located in uplands, instream flow of at least 40 cfs in Thayer Creek, and other terms and conditions to provide protection to resources in the project area based upon the FEIS. For the preconstruction phase of the Thayer Lake Hydropower Development, Kootznoowoo Incorporated will hire, work closely with and oversee the management of the project with an energy development company that has built hydropower plants in Southeast Alaska and constructed transmission lines in rugged Southeast Alaska. Kootznoowoo is also cognizant in ensuring that all phases of development, construction and operation are completed at the highest cost efficiency with the goal of producing energy at the lowest cost for our tribal members and residents. An additional goal of Kootznoowoo is to design the construction of the development to maximize local tribal benefits through local employment and use of shareholder and tribal member resources to help alleviate and provide additional income benefits to the Tribal community. The 1MW+ hydropower development will replace diesel generation and serve our stranded Native community. Based on Kootznoowoo's specific provision under the Alaska National Interest Lands Conservation Act (ANILCA), Angoon can receive this hydropower benefit indefinitely without the need for relicensing. TLHD will stabilize and provide sustainable low cost energy for Angoon for the foreseeable future. This project in the preconstruction phase will allow us to design the project to plan for additional power generation if local load increases or export opportunities develop in the future. TLHD will be self-sustaining after construction. The 2000 feasibility evaluation report suggests an operating cost of $85,000 per year. Even with inflation and additional personnel that must be trained to respond to emergency outages, Kootznoowoo is ensured that its revenues will exceed costs for the development and provide a sufficient return to the Tribal members.

IV. **Description of Activities Performed**

The grant Statement of Project Objectives, described 18 tasks to be completed. This section describes the progress in each of these tasks. The 18 tasks were:

Task 1 - Administration and management
Task 2 - Review and revise conceptual design
Task 3 - Interconnection studies
Task 4 - Preliminary financial feasibility
Task 5 - Business plan
Task 6 - Power sales agreement

Task 7 - Permits and environmental plans
Task 8 - USFS supplemental EIS
Task 9 - Topographic mapping
Task 10 - Surveying
Task 11 - Geotechnical investigations
Task 12 - Fish studies of bypassed reach
Task 13 - Stream gaging
Task 14 - Contract 1 design (marine facilities, camp and staging areas, access roads)
Task 15 - Contract 2 design (Generating equipment)
Task 16 - Contract 3 design (Diversion structure, penstock, powerhouse, tailrace, substation)
Task 17 - Contract 4 design (Transmission line)
Task 18 - Update of cost estimates and financial feasibility

Task 1: Administration and management

Kootznoowoo originally hired AP&T as the project manager. AP&T had examined several options but focused its engineering work on two primary project designs, neither of which ultimately appeared to be economically viable. Those primary options were:

- 1.2 MW design on Upper Thayer Creek (evaluated and approved in USFS EIS/ROD) and estimated at $34 million construction cost
- 6.3 MW design on Upper Thayer Creek requiring a new transmission line to reach Greens Creek mine or the Juneau grid; estimated at $99 million construction cost.

Kootznoowoo hired ORENCO Hydropower in 2015 to replace AP&T as the project manager. ORENCO recommended that costs would need to be substantially reduced to make the project economically viable. Kootznoowoo also saw no options to sell power outside of Angoon for the next 20 years (when a regional intertie might be built), so the project should be focused on Angoon's needs alone. In addition, AEA also made it clear they would not continue grant funding for the larger 6.3MW project focused primarily on sales to Greens Creek Mine

ORENCO therefore focused on a designing and developing the lowest cost project that is sized to meet local demand and that will support some level of local demand growth – up to ~600-900kW total demand, since current average demand is under 250kW, and peak demand is about 350kW. Kootznoowoo requested project options that could be to be expanded at a future date at a reasonable cost to support load growth, and wanted to explore opportunities to reduce total energy costs (electricity, space heating and water heating) in Angoon.

This report focuses on the work that was done by AP&T that was relevant to the current design, and the subsequent work by ORENCO and its subcontractors on the current design.

Task 2: Review and revise conceptual design

In a September 2013 report, labeled AP&T Alternatives Report, AP&T summarized their comparison of four options. Those four design options are described in the Table 4 below.

Table 4
AP&T Summary of Alternatives

	Alternative 1A (Upper, 1.2 MW)	Alternative 1B (Upper, 6.2 MW)	Alternative 2 (Middle, 1.2 MW)	Alternative 3 (Lower, 1.2 MW)
Summary of Project Arrangement	40' high RCC diversion dam at RM 1.7 4,330 foot-long tunnel Powerhouse 350 feet downstream of anadromous barrier Single unit powerhouse, 80 cfs hydraulic capacity, 250 feet head 1.8 mile long diversion access road 6.4 mile long road and transmission line to Turn Point 1400 feet long HDD cable to Angoon	40' high RCC diversion dam at RM 1.7 4,330 foot-long tunnel Powerhouse 350 feet downstream of anadromous barrier Three unit powerhouse, 400 cfs hydraulic capacity, 250 feet head 1.8 mile long diversion access road 6.4 mile long road and transmission line to Turn Point 1400 feet long HDD cable to Angoon 46 mile long road and transmission line to Greens Creek	25' high concrete diversion dam at RM 1.1 2,780 foot-long tunnel Powerhouse 350 feet downstream of anadromous barrier Single unit powerhouse, 160 cfs hydraulic capacity, 120 feet head 1.0 mile long diversion access road 6.4 mile long road and transmission line to Turn Point 1400 feet long HDD cable to Angoon	80' high RCC dam at RM 0.2 100 foot-long steel penstocks Powerhouse at anadromous barrier Two unit powerhouse, 270 cfs hydraulic capacity, 75 feet head 0.2 mile long diversion access road 6.4 mile long road and transmission line to Turn Point 1400 feet long HDD cable to Angoon
Potential generation	10.7 GWh	35.3 GWh	9.3 GWh	9.2 GWh
Construction cost	$35,855,000	$99,475,000	$29,192,000	$28,656,000
Cost of power	$181/MWh (1) $966/MWh (2)	$173/MWh (1)	$161/MWh (1) $749/MWh (2)	$159/MWh (1) $732/MWh (2)

They chose to focus on the two alternatives (labeled 1A and 1B in their table and described above. The primary alternative was the 1.2 MW design that AP&T estimated would cost $36 million to construct, and had a cost of power to Angoon of $0.966/kWh (assuming that no power could be sold elsewhere (e.g., Greens Creek Mine)). This was quite similar to the project that had been reviewed in the 2009 USFS FEIS and Record of Decision. Alternative 1B had a similar layout but was a larger scale project of 6.2MW and costing an estimated $99 million to construct. This larger project was focused on sales to both Greens Creek mine and to Angoon. These two related projects were the focus of their subsequent engineering work, described in the engineering tasks. At the time, IPEC's avoided energy cost in Angoon was about $0.25/MWh – about 25% of the energy cost of Alternative 1A.

When ORENCO Hydropower was brought in, the initial task was to review and revise the project design in order to create a project that would create economic value and sell power at or below IPEC's avoided energy cost. The screening approach used to compare and select the preferred option is summarized in Figure 3.

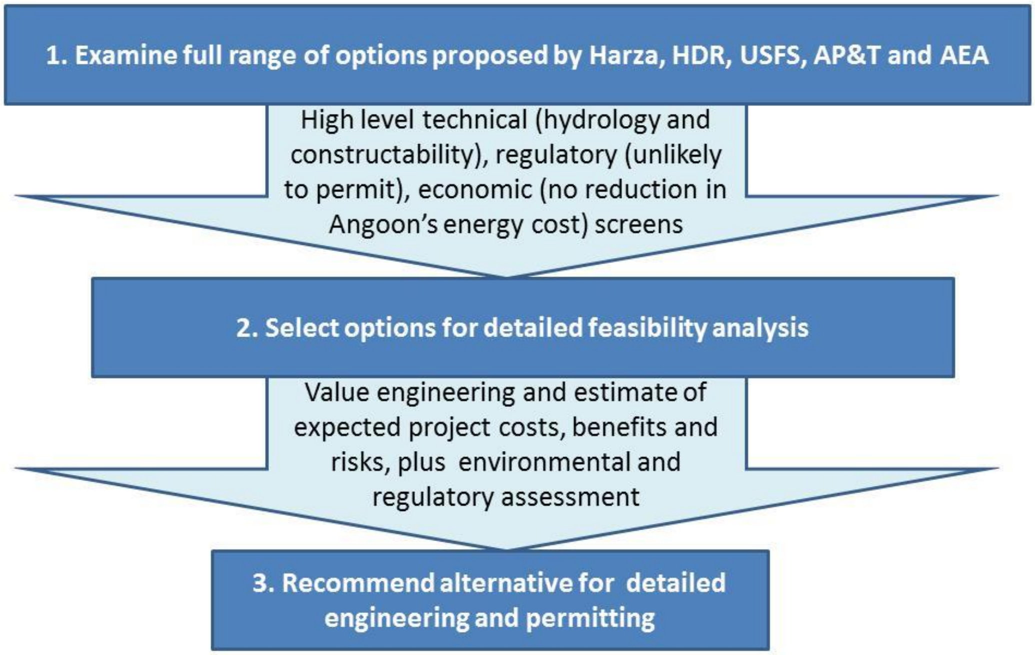


Figure 3
Project Design Screening Approach

There were six alternative designs that ORENCO reviewed that had been proposed over the nearly 40 years that the project has been under study. Those six options are shown in Figure 4, with options 1-4 screened out for economic or technical reasons. Option 1 (1.2 MW design on Upper Thayer Creek selected in the ROD) was found to be economically infeasible. At AP&T's estimated cost of $34 million, they forecasted the project's energy cost would need to be $0.97/kWh at current demand – 6 times IPEC's avoided energy cost. In addition, based on discussions with AP&T, it appeared that AP&T's later cost estimates would add about $10 million in penstock boring costs to the $34 million estimate. Option 2 (6.3 MW design on Upper Thayer Creek), was estimated by AP&T to cost $99 million to construct. The project would have required a long transmission line to Greens Creek Mine, which appears to be very unlikely over the next 20 years. Greens Creek Mine also buys power from Juneau, at substantially lower costs than would be enabled by this project. Option 3, a small project using the water in Notch Creek, was screened out due to preliminary hydrology analysis which indicated that Notch Creek's is frequently dry and could only occasionally support power generation for Angoon. Option 4 (1.2MW project at the Barrier Falls) was screened out in comparison to Option 5, which was better sized to meet Angoon's current and future needs.

The two options that passed the screening analysis were Option 5 -- a smaller project (0.6-0.9MW) located at the Barrier Falls and Option 6 -- a similar sized project design proposed by AEA's project manager that had a small diversion dam on Upper Thayer Creek and a powerhouse located either above or below the Barrier Falls.

PROJECT OPTIONS EVALUATED

1. **1.2 MW design on Upper Thayer Creek (evaluated and approved in EIS/ROD)**
   - $34MM project proposed by HDR and evaluated by AP&T
2. **6.3 MW design on Upper Thayer Creek**
   - $99MM project proposed and evaluated by AP&T
3. **0.4 MW design on Notch Creek**
   - Proposed by AP&T and evaluated by ORENCO and ASI
4. **1.2 MW design at Barrier Falls**
   - Proposed and evaluated by AP&T

Eliminated from detailed evaluation for technical or economic reasons

5. **0.6-0.9 MW design at Barrier Falls**
   - Proposed by Harza in '79 and AP&T and evaluated by ORENCO and ASI
6. **0.6-0.9 MW design on Upper Thayer Creek**
   - Proposed by AEA and evaluated by ORENCO and ASI

Evaluated in detail

Figure 4
Results of Screening Analysis of Alternative Project Designs

The conceptual design for Options 5 and 6 (as they envisioned at the time) is described in Table 5 and illustrated in Figure 5.

Table 5
Description of Project Design Options 5 and 6

	#5 - Barrier Falls Option	#6 - Pipeline Option
Capacity	~600-900kW	~600-900kW (or up to 2MW)
Location	Dam and Powerhouse at Thayer Creek's Barrier Falls, connected by a 550' 60" pipe	Powerhouse 2000' upstream of barrier falls, and Dam a mile upstream, connected by a 4000' ~42" pipe
Dam	45' high and 120' wide (avg.)	20' high and 160' wide (avg.)
Access	By marine facility N of Thayer Creek, with 0.8 mile access road	By marine facility N of Thayer Creek, with 2.5 mile access road
Pipeline (Dam to PH)	550'	4000'
Elect. Transmission	1400' buried cable and 6.5 mile submarine cable	5400' above ground line and 6.5 mile submarine cable

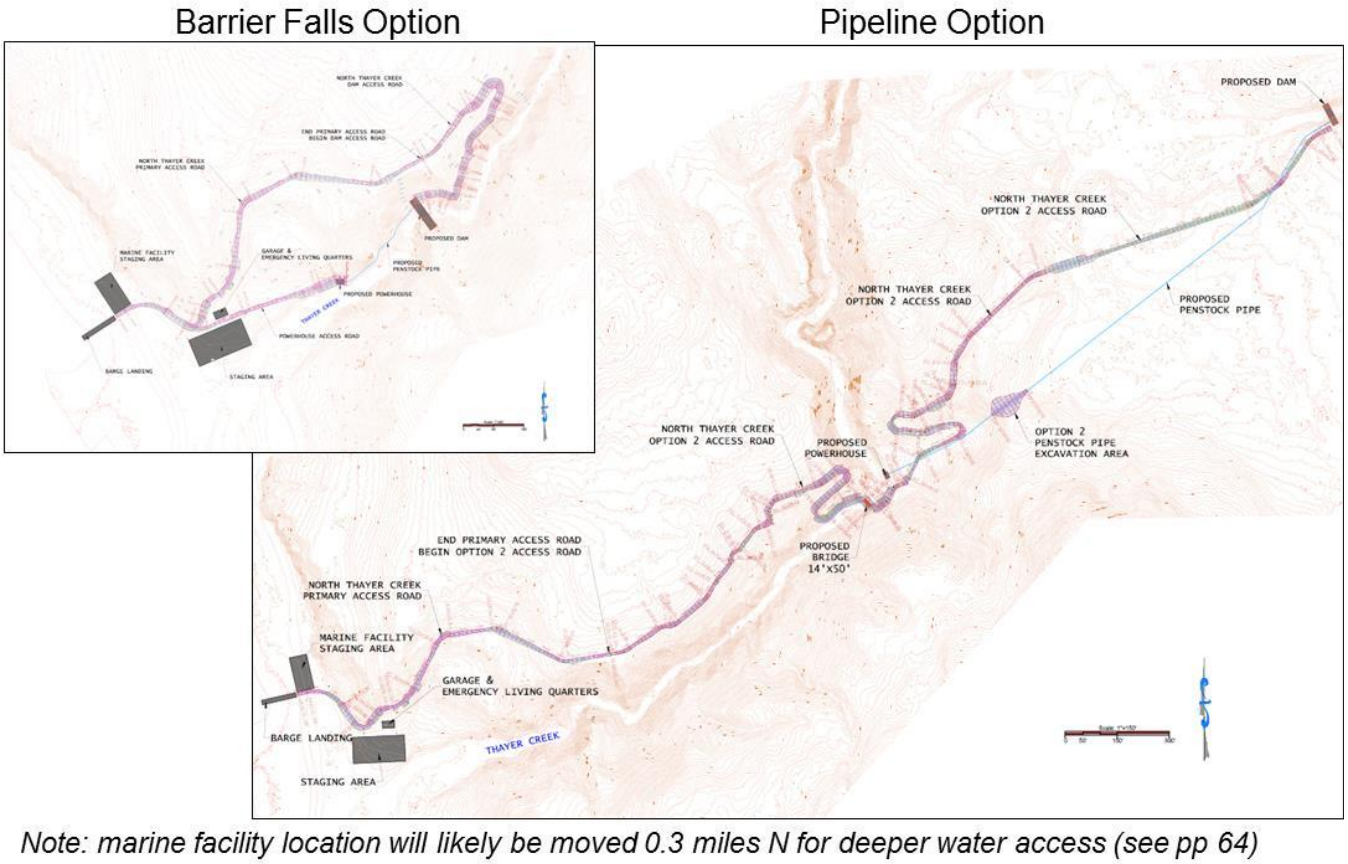


Figure 5
Illustration of Project Design Options 5 and 6

Task 4: Preliminary financial feasibility
(Note: moved ahead of task 3 since this work was performed before the interconnection studies)

The feasibility analysis conducted by the ORENCO and team of hydro project development experts shown in Table 2, compared Options 5 and 6 to AP&T's primary option (Option 1).

In order to design a project that would be economically feasible, the design team used the following objectives to guide its value engineering:

- **Proper Project Sizing:** Reducing the project size to meet the peak energy demand (350kW) in Angoon with room to grow – therefore target project size was 600-900kW (below the 1.2MW planned by AP&T)
- **Reducing Costs:** Reviewing each major cost element and overall contracting approach and develop alternatives to reduce these costs
- **Increasing Economic Benefits:** Exploring ways to increase the projects' economic benefits, especially since the hydropower development costs are all fixed costs with variable costs are near zero. IPEC's distribution costs are also almost entirely fixed costs.As a result, increasing electricity demand in Angoon (e.g., use of heat pumps) drastically reduces the average delivered price of electricity.
- **Reducing Environmental Impacts:** Exploring ways to reduce the environmental impacts of the project (e.g., emissions, acres impacted, etc.)

- **<u>Reducing Development Costs:</u>** Exploring ways to reduce the project development costs – especially simplifying and expediting the permitting process.

The team was able to identify several ways to substantially reduce the cost of the project. As a result of this work, the design team was able to reduce the estimated project cost for Option 5 (Barrier Falls Option) to about $15 million, and Option 6 (Pipeline Option) to about $20 million, well below the $34-36 million cost estimated for AP&T's design. The cost components for these projects costs are shown in Figure 6.

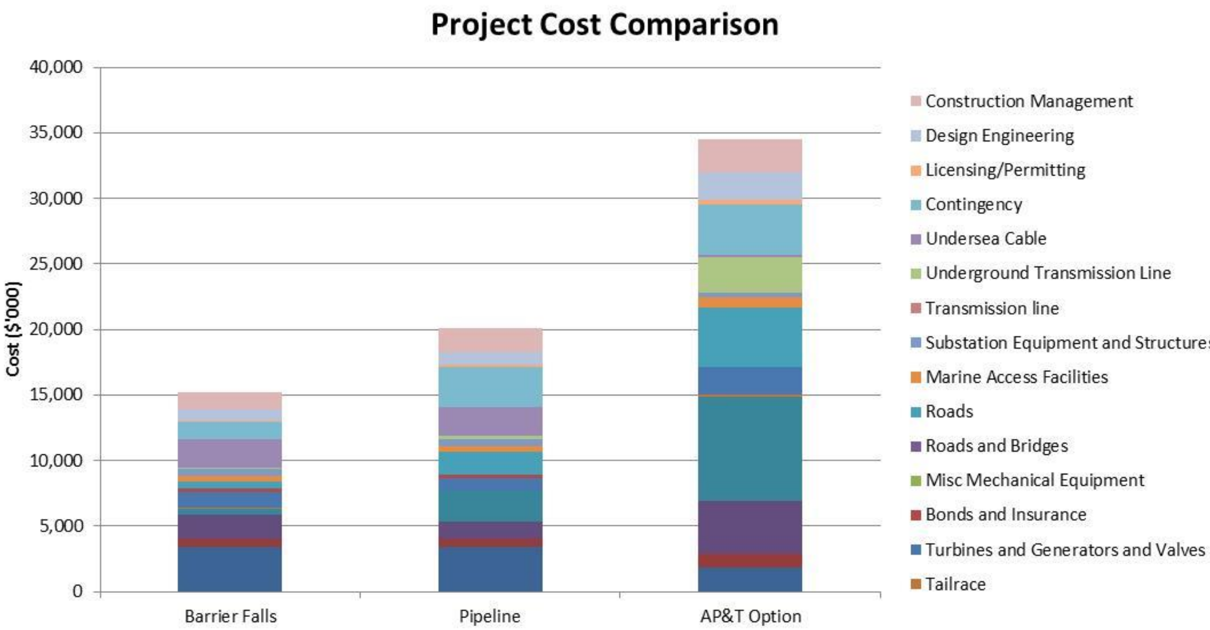


Figure 6
Cost Comparison of Project Design Options 5 and 6 to Option 1

The other key focus of the feasibility analysis was to develop the means to leverage the additional capacity of the hydro in ways that would create value in Angoon.

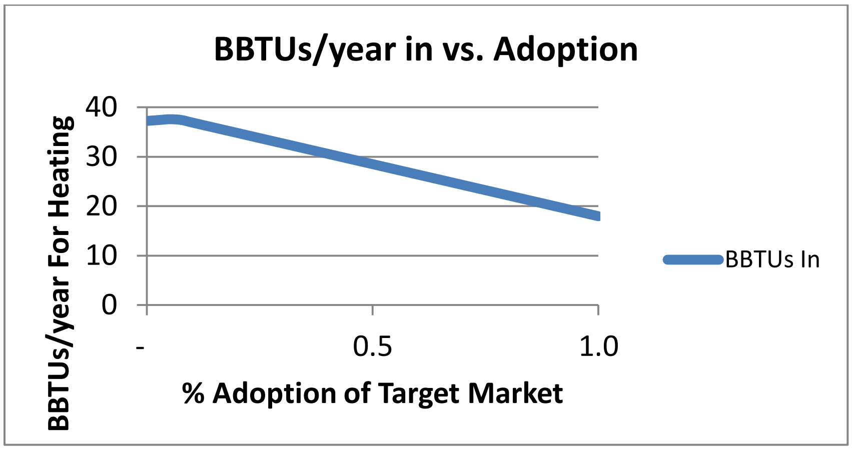
To address the very high electricity and heating costs, Kootznoowoo Inc. and ORENCO Hydropower have developed the integrated hydropower and the high efficiency heat pump program. This integrated system for electricity and heating combines the Thayer Creek hydropower with deployment of heat pumps for about 100 of the 167 homes and businesses in Angoon and for providing heating for the three schools.

Most of the homes (73%) in Angoon use fuel oil/diesel for heating. Wood heating is the second most common heating source. Electric base-board heating is rare given the recent $0.68/kWh price of electricity. The combined equipment and installation cost to renovate a home with a high efficiency heat pump appears to be less than $2,500-3,500 per home for an installation program that includes multiple heads. New high-efficiency ductless heat pumps have proven to be exceedingly effective in climates like Southeast Alaska and are providing substantial savings over fuel-oil furnaces. Ductless units (called minisplits) which, for the smaller houses that are common in Angoon, include an external 30,000-40,000

Btu unit combined with small wall mounted internal units in 1-4 selected rooms and have four important advantages: 1) the retrofit costs tend to be substantially lower since only small pipes are needed to connect the internal and external units, 2) the internal units produce heat at about 110 degrees compared to much cooler temperatures from ducted units increasing the comfort issues of older units, 3) overall efficiency is much higher than ducted units, and 4) it is very easy to only turn on heat in rooms where heat is needed, reducing wasted heat. In looking at the electricity use of ductless heat pump owners in Juneau, it appears that winter usage for heating is about 700/kWh/month, and summer usage is estimated at 300/kWh/month.

Based on an analysis by Stanford University School of Engineering, the planned heat pump program will reduce the Btu's used for space heating in Angoon by 50%, as shown in Figure 7.

Figure 7
Btu's Used in Angoon for Space Heating (function of heat pump penetration in oil heated houses)



Kootznoowoo is planning on acquiring and installing the heat pumps, providing them at a nominal cost under a long-term lease to residents and small commercial buildings with diesel heating in 2018 and 2019. We have estimated that out of the 167 homes in Angoon, over 100 have old diesel boilers or furnaces. We estimate that about 100 homeowners and the few businesses in Angoon would convert to heat pumps under a program such as this. Therefore, our current cost estimates for the space heating replacement ranges from under $2,500 to over $4,000 per home, including: upfront design and installer training costs, equipment costs, shipping costs, heat-pump installation costs and additional electrical interconnection costs. At an average cost of $3,500 per home for 100 homes, total replacement cost would be about $350,000. Of these 100 homes, about half are estimated to have diesel boilers that provide water heating. For these 50 homes, high efficiency heat pump hot water heaters would be provided at an installed cost of $1000 per home, or a total cost of $50,000.

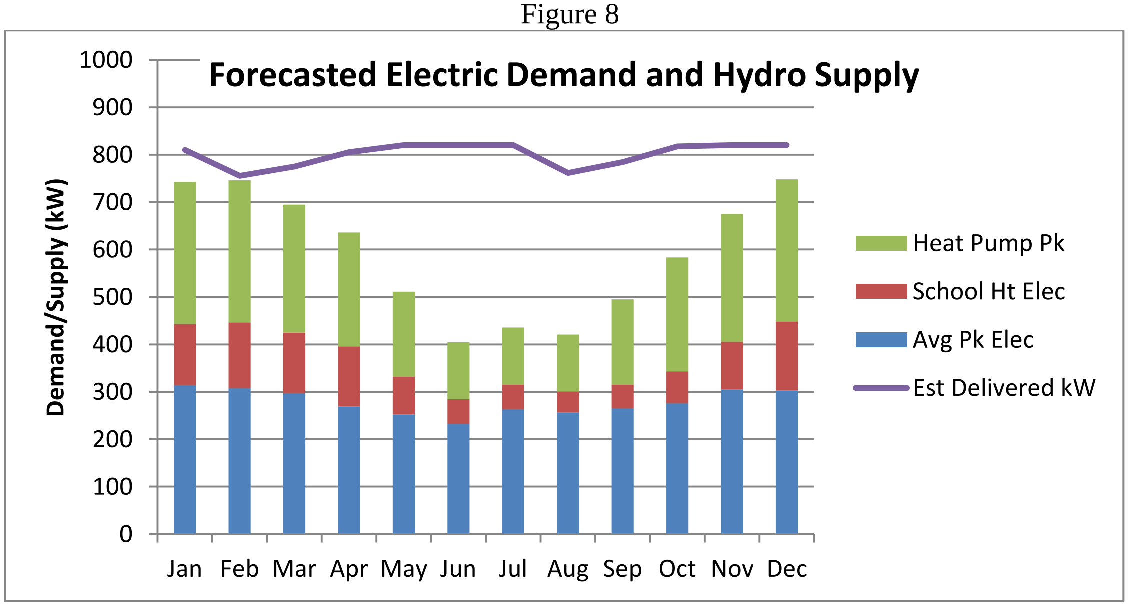
In addition, the three schools in Angoon are currently heated by waste heat from the diesel generators that is piped to the schools. Once the hydro unit is operating, the diesel generators will only run when the hydro is not operating, so the current plan is to install in 2018 an electric boiler (or an electric boiler and commercial heat pump) that would provide the hot water needed for heating the school. This would be combined with a small 30kW load bank to be used by the local utility to provide voltage and frequency control. The cost of this unit and necessary retrofits is estimated at $50,000-$75,000. Therefore, the combined cost of the high efficiency heating program is $450,000-$475,000. Kootznoowoo is requesting a grant from DOE Office of Indian Energy of $225,000, and Kootznoowoo will fund the remainder of the cost through matching funds from debt and equity investment.

There are several reasons why the integrated hydropower and heat pump program is so attractive. These reasons are:

1. The marginal cost of sizing the hydropower project above current demand is a small percentage of the overall project cost (less than 10%) since much of the cost is creating the access to the site and installing the buried/submarine transmission cable to bring power to Angoon. Therefore, the project has been sized at about three times current average demand (820kW vs. 250kW).
2. The variable cost of energy from this hydroelectric project is very low, since there is no fuel cost and only a small variable operations and maintenance cost.
3. The cost structure of the local utility (IPEC) distribution system is also almost entirely fixed cost, with almost no variable cost and a distribution system that appears to be already able to handle the increased load from the heat pumps. This provides the mean to substantially reduce the $0.42 energy delivery charge paid by all of IPEC's customers.
4. The combined effect of reasons 1-3 is that doubling the usage of electricity roughly halves the cost of electricity to consumers in Angoon, and a tripling of usage cuts electricity costs by well over half. (Note: this requires a non-"postage stamp rate" from IPEC).
5. Use of heat pumps for space heating would utilize much of the excess capacity of the hydropower project during the winter, since a single home's heating lead with heat pumps is about 700 kWh per month compared to the current annual monthly electricity peak usage of about 350 kWh. It would also leverage the existing distribution capacity of IPEC's grid. The combined effect of these factors would be that combined pre-subsidy electricity and fuel oil costs would drop from around $750/mo. in the winter to only about $200/mo. Similar but smaller reductions would be seen in the summer months.
6. The integrated program would have substantial excess capacity in the summer months to support economic growth during the seasons when it is most needed.

As shown in Figure 8, the combined electricity usage of current electricity demand, plus the heat pump load, plus the impact of the electric school heating program proposed by IPEC can be met by the available generating capacity of the hydro project and the existing distribution system. It is also important to note that there is substantial excess generating capacity during the spring, summer and fall months -- exactly the times when future economic development for tourism, fisheries, etc. would have the greatest need. This creates the opportunity to supply energy for future growth at very attractive prices.

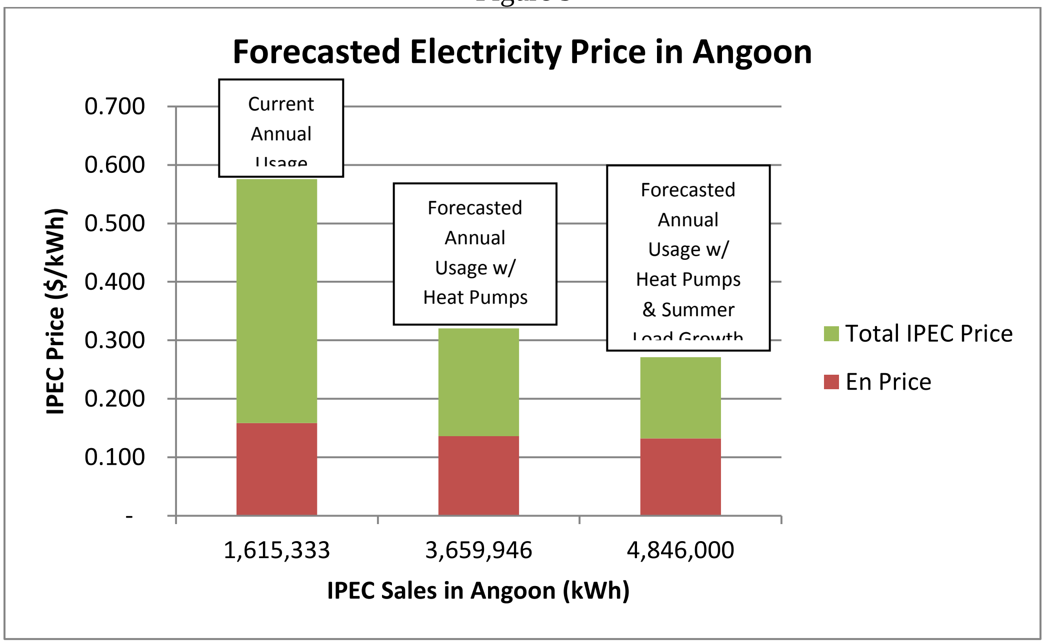
Figure 8



For some time, there has been a reluctance to use electricity beyond the 500 kWh ceiling since the PCE subsidy ceiling has conditioned everyone in Angoon to conserve. The fear of going from a subsidized rate of $0.22/kWh to an unsubsidized rate of $0.58 has resulted in the very low average monthly usage of only 350kWh. But this is reflective of austerity, and not efficiency or comfort. The simplest way to present the idea is, there are no incremental fuel costs with hydropower and little or no incremental costs for IPEC to deliver that additional power, beyond the upgrade of a few distribution line transformers.

This displacement of diesel-fired heating will increase total electricity usage and substantially reduce the average price in electricity as shown in Figure 9.

Figure 9



Our preliminary economic modeling predicts the average household will see a net reduction of $3,200 and $3,900 for the heavy user (electricity and diesel costs). That is very significant in a community where the median income is $28,806. The net effect to the average consumer in Angoon is 11 – 14% of gross income is no longer dedicated to energy and can be put back into the local economy. Of course, we must qualify these forecasts with the statement that actual consumer behavior may differ.

The effect of the high efficiency heat pump on Angoon's collective energy profile is intuitively obvious. In the summer months, there is a reduced need for space heating. In the fall and winter months, the energy demand begins to peak the colder it gets. With each house having a heat pump, our modeling predicts that energy demand in the winter months will optimize our Project design by approaching the 800 kW delivered capacity from the hydro project.

As a result, this Integrated Program would enable:

- Nearly 100% of the energy (space heating, cooling, lighting, etc.) in Angoon to be from renewable sources,
- A substantial reduction in the cost of energy for residential, commercial and industrial customers in Angoon,
- A substantial reduction in the PCE energy subsidy provided by the State of Alaska to small residential customers
- A substantial incentive for economic development.

Task 3: Interconnection studies

Evergreen Energy and ORENCO Hydropower had several meetings with IPEC to clarify the key requirements for interconnecting the project with Inland Passage Electric Cooperative (IPEC - the local utility in Angoon). From those discussions, several key requirements or preferences were established. These included:

- IPEC would need to have a means for voltage and frequency control in Angoon. That control is currently provided by IPEC's diesel generators and associated switchgear, but that will not be available when the hydro project is source of all energy on most days. A natural solution beneficial to all parties grew out of those discussions. An electric boiler (or boiler and commercial heat pump) located at IPEC's power plant would be used to provide that control. Since the three schools and teacher housing in Angoon are heated by waste heat from the diesel generators, the electric boiler would replace that heat and use the existing district heating system. The boiler would also increase electric demand by about 100kW, reducing IPEC's fixed cost delivery charge substantially.
- IPEC wanted to be the operator for the hydro plant and the transmission line to the hydro plant to ensure their reliable operations and maintenance.
- IPEC needed to have remote control and communication capabilities incorporate in the transmission line through inclusion of a fiber optic cable from the hydro plant to IPEC's plant in Angoon.
- IPEC needed the capability to isolate and protect their system from the hydro plant through an isolation switch at the hydro plant.

All of these requirements and preferences have been incorporated in the current project design.

Task 5: Business plan

The key aspects of business plan that have been developed are the plan for financing the project, the power sales agreement (PSA) planning (discussed in more detail in Task 6), the likely approach for risk management and allocation amongst Kootznoowoo and its contractors, and the approach for construction management and future plant operations and maintenance.

In discussions with AEA, it was agreed that the project would be developed as a design-build project. This entails having the project managers, engineers and constructors working side by side from the beginning of the project engineering. This enables a shared view of the constructability of the design, and an aligned view on continually reducing the project cost. It also means that construction can begin at 30-50% engineering, with detailed design decisions being refined as actual site conditions become clear. Design-build projects have consistently proven to be a more cost effective approach than 100% engineering, leading to competitive bidding, and the frequent finger pointing between engineers and constructors as unforeseen circumstances arise during construction.

The estimated cost of the project is an estimated $15.8 million. The plan for financing the project is illustrated in Table 6. AEA had allocated $7 million grant for project construction several years ago. They also committed a $290k grant to complete project engineering and permitting. Kootznoowoo and ORENCO have been actively developing a $3.5 million tax credit under the IRS New Market Tax Credit program for economic development in low-income communities and Native communities. The integrated project can also easily cover $4 million in debt (based on an estimated project debt coverage ratio of about 2.4). Kootznoowoo has been in discussion with both AEA and RUS as sources of project debt. This leaves a $1.1 million shortfall in overall project financing that will likely need to be filled through grants or cost sharing.

Table 6
Project Cost and Financing

Project Cost			**Project Financing**	
Permitting/Engineering	$ 700,000		New AEA Develop Grant	$ 290,000
Construction	$ 14,650,000		AEA Construction Grant	$ 7,000,000
Heat Pumps	$ 450,000		New Market Tax Credit	$ 3,500,000
Total	**$ 15,800,000**		Debt	$ 4,000,000
			Additional Funding Needed*	$ 1,010,000
			Total	**$15,800,000**

The requirements for bonding of the project during construction will be provided by the general contractor on the project.

Although Kootznoowoo and ORENCO have been working closely with the three construction companies for the project, (Channel Construction – marine facility and roads, ASI Constructors – Dam, powerhouse, and RT Casey – submarine cable), the details of the project risk sharing and contract terms are still under discussion.

Task 6: Power sales agreement (PSA)

Kootznoowoo and IPEC signed a Memorandum of Understanding for negotiating a PSA a few years ago. Those discussions are continuing with an updated MOU. IPEC has expressed a strong desire that the PSA price not exceed their avoided energy cost, which is currently about $0.15/kWh, down from an average of about $0.26/kWh over the last several years. In addition, since Kootznoowoo is developing and constructing what will become the source of about 95% of IPEC's energy sales in Angoon, a capacity price paid to Kootznoowoo is also being discussed. In combination, this could allow the energy price to not exceed the IPEC's avoided energy costs.

Kootznoowoo and IPEC have agreed that the operations and maintenance of the hydro project and submarine cable would be handled by IPEC. Since IPEC will be able to substantially reduce its cost of operating its three existing diesel generators in Angoon, these cost savings should be roughly equivalent to the O&M cost of the hydro plant.

Other partnerships arrangements between Kootznoowoo and IPEC are being explored as a means to enable the project developed expeditiously.

Task 7: Permits and environmental plans

Prior to the DOE and AEA grants, the USFS had performed a number of environmental analyses and leveraged prior contractor analyses as part of its FEIS process its ROD. Because the project rights had been allocated to Kootznoowoo Inc. under federal statute related to the creation of the Admiralty Island National Monument, the USDA/USFS was the lead agency for project permitting, and the FERC was not involved.

As listed in Table 3, there are a number of state and federal permits, easements and leases that are required prior to construct any hydro project on Thayer Creek.

AP&T hired Paul Rusanowski of the Shipley Group to perform a detailed environmental analysis related to several aspects of the project – focused primarily on fish habitat, stream flows and the potential project impacts on that habitat. That work is described under Task 12: Fish Studies of Bypassed Reach, and Task 13: Stream Gaging, below.

Besides the Shipley study, there was no other environmental analysis reports submitted by AP&T, and no draft permits, lease requests or easement requests were prepared or submitted to the several agencies.

During 2016 and 2017, Kootznoowoo Inc., ORENCO Hydropower and several subcontractors developed the environmental plans and filed for all of the permits, leases and easements need for the project, except the DEC construction permit which is filed shortly before construction.

The primary effort was obtaining the Supplemental EIS from the USFS for the revised project design, as described below in Task 8: USFS Supplemental EIS.

The permit from the US ACE and the USFS required that a wetlands delineation be performed. Bosworth Botanical Consulting performed that analysis and submitted its report in 2016. The study was titled: *Wetland Delineation Report and Mapping for the Proposed Thayer Creek Hydro Project – Access Road, Penstock and Transmission Line, Dam and Facilities, June 2016.* Table 7 provides is table of contents.

The analysis focused on both identifying wetlands across the footprint of the alternative project designs and proved very helpful in rerouting the access road, construction staging area, transmission line and penstock to virtually almost all wetlands in the Barrier Falls design as illustrated in figures 10 and 11.

Table 7:
Table of Contents
Bosworth Botanical Wetlands Delineation Study, June 2016

Table of Contents

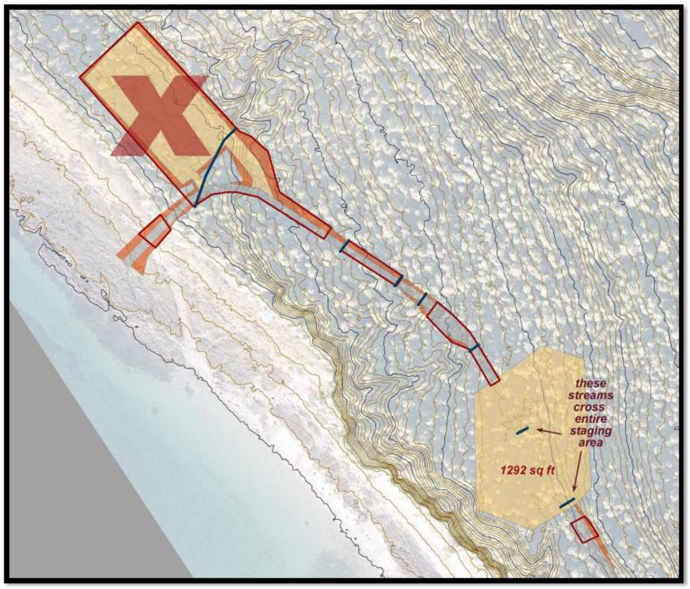


Figure 10
Wetland Delineation #1

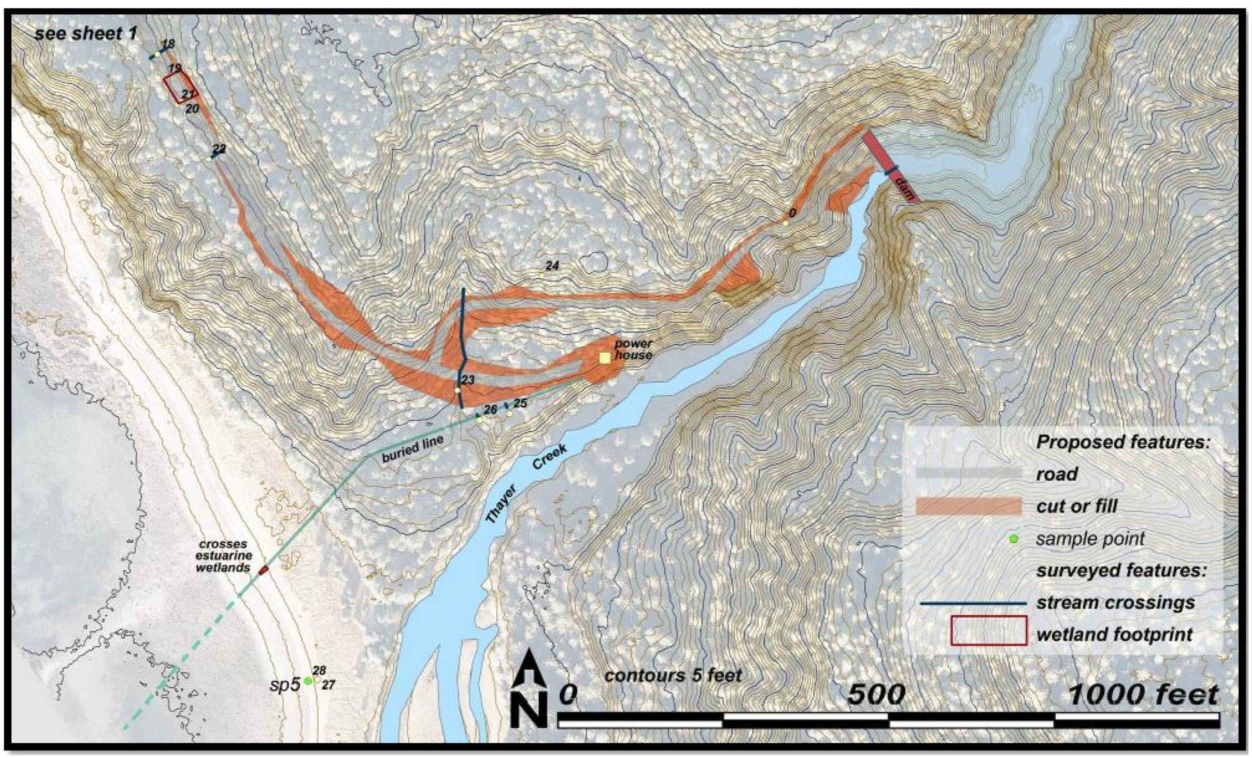


Figure 11
Wetland Delineation #2

Bosworth Biological Consulting also provided an assessment to identify any threatened or endangered plant and animal species. The results of that analysis were provided as part of the USFS Biological Assessment and Evaluation.

Task 8: USFS supplemental EIS

In 2009, the Tongass National Forest prepared and issued a Final Environmental Impact Statement (FEIS) and Record of Decision (ROD) including required terms and conditions to be included in the Special Use Authorization. The Purpose and Need of the project as described in the FEIS states an expectation that the project would "reduce the cost of power generation in Angoon and result in lower electric rates for Angoon residents." The need for change is to address the purpose and need of delivering power to Angoon at a lower rate. The cost of constructing the hydroelectric facility has a direct correlation to how much the utility will have to charge its users. The design approved in the ROD proved difficult to meet the purpose and need due to the expense of the facility.

Since 2009 Kootznoowoo Inc. has performed further studies that have resulted in a revised design. The revised design seeks to minimize the scope of the construction while still meeting Angoon's current and future power needs. It seeks to make the project more economically feasible, better meeting the purpose and need. Further rationale for design changes of components is included later in the analysis.

In general the scope and foot print of the project have been reduced. The dam, impoundment, and powerhouse have been relocated eliminating the need for a pipeline connecting the diversion dam to the penstock; the marine access facility has been moved to a location just north of the mouth of Thayer Creek; the access road has been relocated and shortened; the transmission line connecting the powerhouse to the submarine cable has been shortened; and the overland portion of the transmission line has been replaced with a submarine cable. Figure 12 shows a map of the design features of the project evaluated in the 2009 FEIS and ROD. This can be compared to Figure 1 above that shows the much smaller footprint of the current final design. Table 8 summarizes and compares the original project with the final design.

Table 8
Comparison of ROD Selected Alternative and Final Design.

Activity	ROD Selected Alternative	Final Design
Special Use Authorization	Yes	Yes
Above Ground Transmission Line	Minimized	0 miles
Buried Transmission Line	6.2 miles as feasible	0.13 miles (700 feet)
Submerged Transmission Line	0.5 miles	6.5 miles
Access Road Marine Facility to Powerhouse	2.2 miles	0.7 miles
Access Road Powerhouse to Dam	2.1 miles	0.25 miles
Access Road Marine Facility to Kootznahoo Inlet	4.0 miles	0 miles

Temporary Access Road Surge Tank	0	0
Road/Transmission Line Clearing Width	46-70 ft. (50 ft. average)	46-70 ft. (50 ft. average)
Diversion Dam Access Road Location	Avoids steep slopes in Thayer Creek Canyon	Follows contour ~0.2 miles on steep slopes in Thayer Creek Canyon.
Pipeline Location	Follows contour in Thayer Creek Canyon	None
Penstock Location	510 ft. of 36 inch penstock from downstream end of pipeline to the powerhouse	1000 ft. of 60 inch penstock from the dam to the powerhouse
Marine Facility	1.8 miles south of Thayer Creek	0.4 miles north of Thayer Creek
Switchyards	3	1
Tailrace Discharge Location	Above or immediately below the lowest anadromous fish barrier	At the bottom of the anadromous fish barrier and at the powerhouse.
	FROM 2009 Angoon Hydroelectric ROD Selected Alternative (pgs 12-15)	
Diversion Dam release control structure	A water release control structure at the diversion dam to maintain a minimum instream flow of 40 cfs (cubic feet of water per second)at all times below the diversion dam.	Water release control structures at the powerhouse and dam that in combination maintain a minimum instream flow in the anadromous reach upstream of the powerhouse (i.e., the lower bypass reach) of 40 cfs (cubic feet of water per second).
Bypass reach below diversion dam and barrier falls	• A minimum instream flow of 40 cfs be maintained at all times in the Thayer Creek bypass reach to minimize freezing temperatures and loss of Stream continuity in the bypass reach. • All water not needed for power generation be returned to Thayer Creek at the diversion dam and sent	A minimum instream flow of 40 cfs be maintained at all times in the anadromous reach of Thayer Creek upstream of the powerhouse to minimize freezing temperatures and loss of Stream continuity. • All water not needed for power generation be returned to Thayer Creek at the diversion dam and sent through the bypass

	through the bypass reach.	
Dam Low Gate Feature	• The dam include a low gate feature to pass bedload during specified windows of high flows in May-June and September-October to minimize effects on channel stability and fisheries downstream of the dam. • Floating wood accumulating behind the dam be disposed of into the bypass reach during high flows in May-June and September-October to minimize effects on channel stability and fisheries downstream of the dam.	• The dam include a low gate feature to pass bedload during specified windows of high flows in May-June and September-October to minimize effects on channel stability and fisheries downstream of the dam. • The dam will be designed to enable most of the woody debris to pass over the spillway during high flow periods.
Road from Marine Facility to Powerhouse	• The road from the marine facilities to the powerhouse be routed to minimize effects to areas identified as high vulnerability karst as well as the streams that flow to the karst features and that the diversion dam access road be routed away from steep slopes along Thayer Creek (see Road Cards in Appendix B for road locations).	• The road from the marine facility is routed to avoid areas identified as high vulnerability karst as well as the streams that flow to the karst features.
Diversion Dam/Intake structure and tail race structure	• The intake structure at the diversion dam must be properly installed and screened to protect resident fish. Refer to NMFS reference on intake screen criteria (NMFS 1996). • Design of the diversion	• The dam is located at the bottom of the gorge and above the barrier falls where there are no resident fish. • Design of the tailrace discharge structure must include outfall protection, such as a concrete pad or placed riprap, to decrease or eliminate scouring

	dam must safely pass fish downstream subject to approval by ADFG. • Design of the tailrace discharge structure must include outfall protection, such asa concrete pad or placed riprap, to decrease or eliminate scouring and sedimentation. Must also be designed so as to not be an attractant flow to escaping fish or allow access to the tailrace.	and sedimentation. Must also be designed so as to not be an attractant flow to escaping fish or allow access to the tailrace.
Road-stream crossings	• Road-stream crossings of Class I and II streams (designated in road cards) will be designed to accommodate fish passage (BMPs 14.17, 12.5)	• The access road has been moved to avoid crossing Class I and Class II streams.
Vegetation	**Vegetation** • Avoid disturbance of grassy areas on the west side of the small island near the marine facilities to reduce chance of spread of non-native species present. • Prior to construction, the Forest Service district botanist will mark, on the ground or on aerial photos, the boundaries of the known rare plant populations in or near the proposed project footprint. • To avoid rare plants, spoils will not be deposited in the large tall sedge fen, meadow between the power house and dam.	**Vegetation** • The marine facility has been relocated to avoid the small islands that had sensitive vegetation. • The dam has been relocated so that there will be no impact on the large tall sedge fen meadow.

Rock Pit/Staging Area	• Rock pits and staging areas shall not be located on wetlands.	• The staging areas have been located to avoid wetlands. The lower edge of the 0.5 acre quarry near the marine facility is located on wetlands, but will enable avoiding a large number of barge shipments to bring in road bed material.
Wetland/vegetation removal	• Minimize the loss of tall sedge fen wetlands, which are scarce wetland types on the Tongass National Forest and provide valuable habitat to several terrestrial animals.	• Road access and penstock locations avoid tall sedge fen wetlands.

Figure R-2 Selected Alternative, Buried Transmission Lines

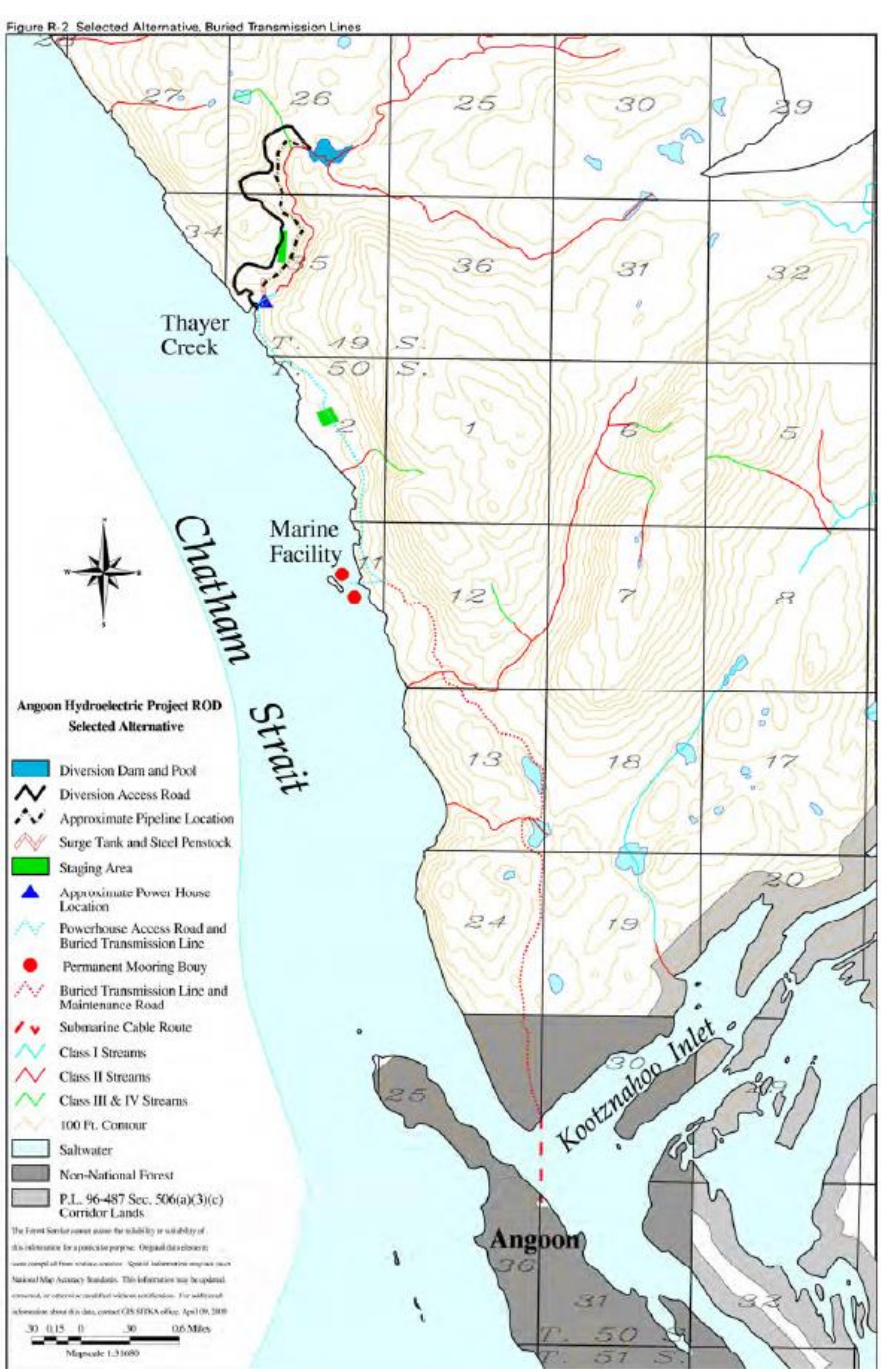


Figure 12: ROD Selected Alternative

Figure 13 provides a detailed view of the dam, the upper bypass reach (which is between the barrier falls and the dam), the lower bypass reach (which is between the powerhouse and the barrier falls, and the powerhouse. The upper bypass reach as discussed below is non-essential fish habitat as discussed below.

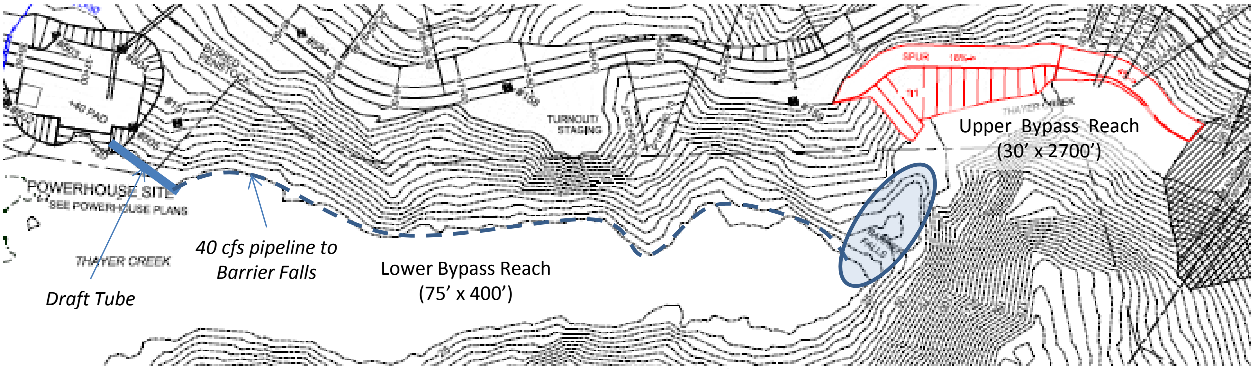


Figure 13: Map of Bypass Reach Downstream of Dam

The Change Analysis developed with the USFS was submitted in August 2016. In addition to the Change Analysis, the USFS requested an updated Biological Assessment and Evaluation, with a final version developed jointly by ORENCO Hydropower, Delta Environmental Sciences and the USFS in 2017.

Kootznoowoo, the USFS and AKDF&G agreed that an opportunity for enhancing the spawning habitat in Thayer Creek should be pursued. This entailed excavating a dry stream bed just downstream of the powerhouse. This area would be protected from the main stream channel by rip rap obtained during construction, with large root wads anchored in this spawning area. This plan is illustrated in figure 14.

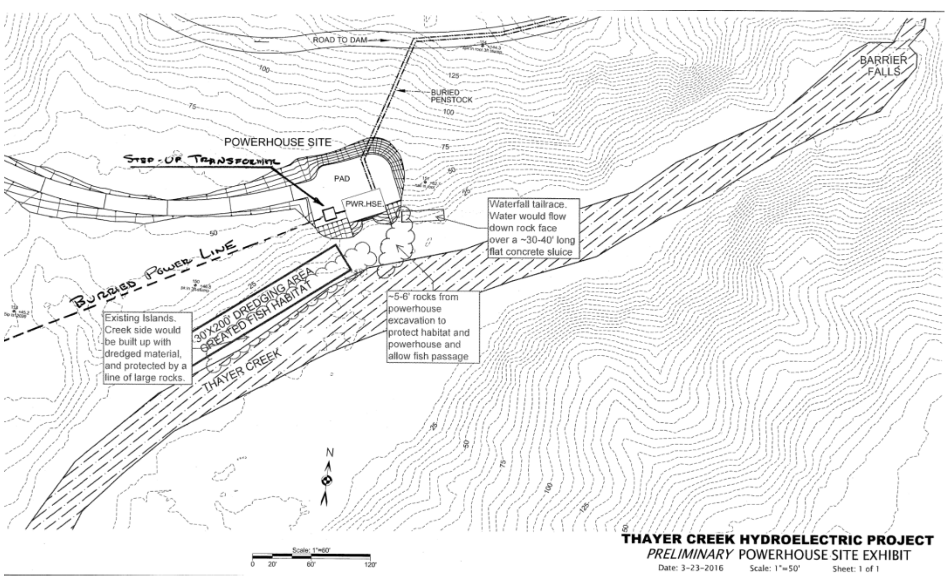


Figure 14: Spawning Habitat Enhancement

Task 9: Topographic mapping

AP&T had subcontracted with Aerometrics to perform topographic mapping by lidar of the Thayer Creek basin. That work proved very valuable in examining alternative project designs; especially for road access design, staging area location, powerhouse location, penstock routes, preliminary wetland delineation assessment, etc. These results were used in all topographic mapping for the project. These results have also been shared any state and federal agencies requesting this data.

Task 10: Surveying

Land Surveys: All Points North Surveying and Engineering was hired by AP&T and later by ORENCO Hydropower to perform the more detailed surveys needed for detailed road, powerhouse, penstock and dam design, building on the lidar data described above. There surveys results are included in the engineering designs provided in the engineering Tasks 15-17.

Submarine Surveys: All Points North Surveying and Engineering also provided single beam submarine surveys as input to the design for the marine facility location and the submarine cable crossings. They also integrated this data with the NOAA survey data for the portion of Chatham Straight between Thayer Creek and Angoon, as input to the preferred submarine cable route. This work is currently being extended by Tetratech and RT Casey as the route for the submarine cable is being finalized.

Task 11: Geotechnical investigations

AP&T hired GeoEngineers to perform a detailed geotechnical analysis for the area. That work focused on integrating past geological analysis in the area and performing geophysical analysis of the subsurface geology near the powerhouse, penstock route and dam location. In addition, subsurface drilling was done near the powerhouse, penstock route and dam location as well. The findings of this analysis are summarized in their 196 pp. report titled *Engineering Geology and Geotechnical Data Report, Angoon Hydropower Project, Admiralty Island, Alaska, July 7, 2015.* The Table of Contents for that report is provided in table 9 and the report attachments are shown in table 10.

Table 9
Table of Contents -- GeoEngineers' Geotechnical Analysis

Table of Contents

Table 10

Table of Contents (Attachments) - GeoEngineers' Geotechnical Analysis

Table of Contents (Continued)

LIST OF TABLES

LIST OF FIGURES

APPENDICES

Since the current design has the dam and penstock located in a different location than AP&T's plan, only part of this work proved useful. The useful work included:

- regional geologic analysis
- regional seismic analysis and
- geophysical analysis and drill site near the powerhouse.

As a result of their analysis and mapping of potential slide areas, the location of the powerhouse and switchyard was moved upstream as far as possible to minimize potential risk from a slide, as shown by the red arrow in figure 15.

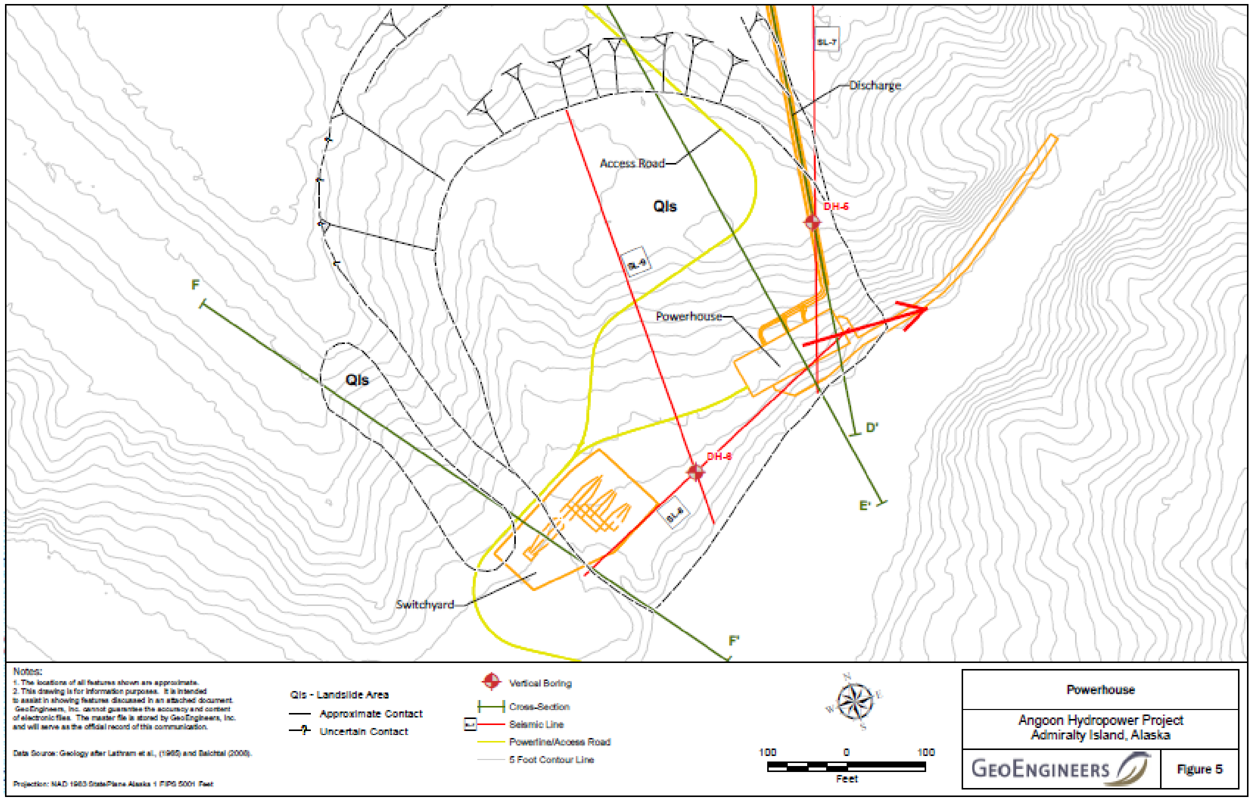


Figure 15
Revised Powerhouse Location due to Geotechnical Review

AP&T's analysis of the geology along the penstock route indicated that the steep slopes along Thayer would make it infeasible to run the proposed 4300 ft. penstock above ground. As a result, AP&T hired Lachel and Associates to evaluate drilling a 4300 ft. tunnel for the penstock. That study is titled: *GEOLOGIC FIELD RECONNAISSANCE AND FEASIBILITY LEVEL DESIGN REVIEW, Thayer Creek Hydroelectric Project, October 14, 2014.* Table 11 provides the table of contents of that report.

Table 11
GEOLOGIC FIELD RECONNAISSANCE AND FEASIBILITY LEVEL DESIGN REVIEW, THAYER CREEK HYDROELECTRIC PROJECT
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That work, duplicated a portion of GeoEngineers work. The analysis indicated that a tunnel was technically feasible, but the minimum diameter for the tunnel was 9 ft., much larger than the planned 42" penstock. Based on conversations with AP&T, it appeared that the cost of the drilled tunnel would add about $10 million to the $36 million project cost. The much larger tunnel would enable the conveyance of much more water from the dam to the powerhouse, and was part of the motivation for the development of the $99 million 6.3 MW project design.

After ORENCO's feasibility analysis recommended pursuit of the Barrier Falls location, ASI Constructors (experts in RCC dam engineering and construction) performed a site visit to the Barrier Falls dam location, and found the geology and location to be highly suitable for an RCC dam of the size planned for the project. Much of the creekbed at the proposed location of the dam is scoured and exposed marble and/or phyllite bedrock that are substantially stronger than the concrete used to construct the dam. ASI Constructors and Applied Geologic subsequently performed an additional site visit to perform a geological reconnaissance and select the preferred location and orientation for the dam. That work resulted in the recommendation to move the dam slightly upstream to location 2B shown in figure 16.

Geotechnical Based Facility Siting

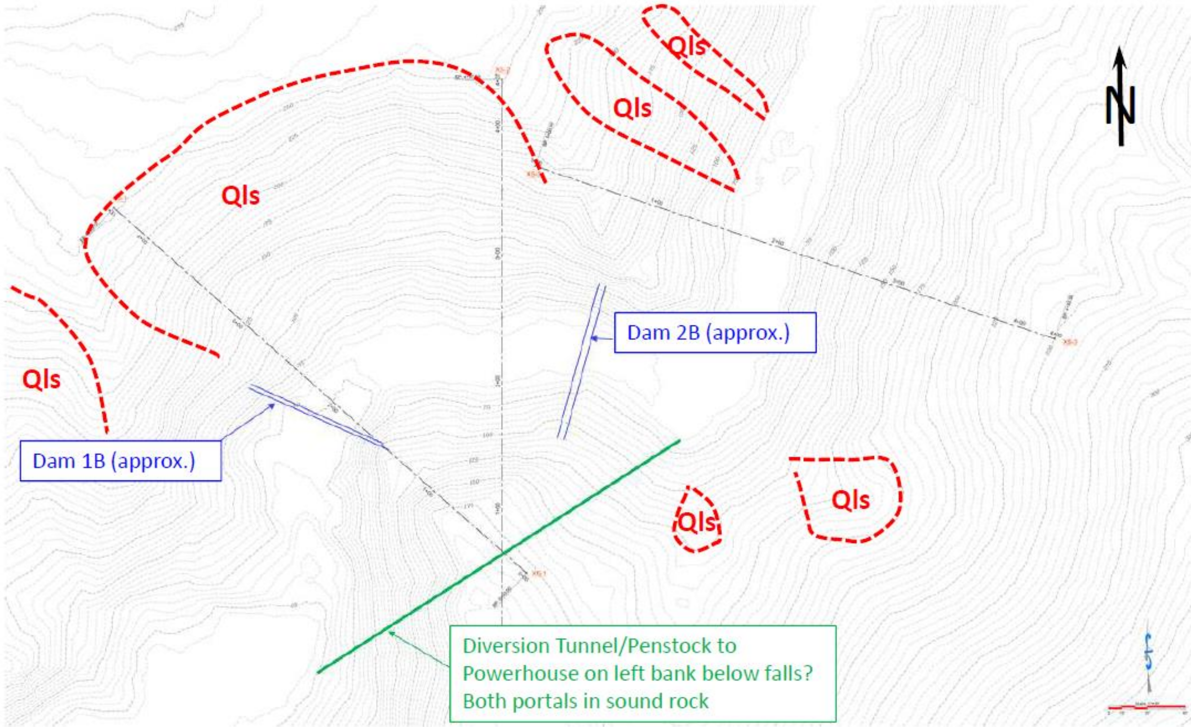

Figure 16
Geological Reconnaissance for Preferred Dam Location

All of this work is input to ASI Constructors dam design that is currently under review by AK DNR's department of dam safety. Based on the remote site location and the minimal impact on property or essential fish habitat, AK DNR classified the dam as a Class III low hazard dam.

Task 12: Fish studies of bypassed reach
AP&T hired Paul Rusanowski of the Shipley Group to perform an environmental analysis of the project and its potential impacts. The study titled *Angoon Hydroelectric Project, Thayer Creek Alaska, 2013/2015,* was submitted in July 2015. The table of Contents for that report is shown below in Table 12.

Table 12

Table of Contents: Shipley Group Environmental Analysis, 2015

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There were also several extensive appendices to the report, as shown in Table 13.

Table 13
Appendices: Shipley Group Environmental Analysis, 2015

Appendix I-1	**Thayer Creek stream profile video records (on DVD disk)**
Appendix I-2	**Thayer Creek anadromous reach substrate ¼ m^2 quadrat video records (on DVD disk)**
Appendix II-1	**Solinst datalogger temperature and water depth records above the gorge on Thayer Creek 4-20-2013 through 4-9-2014 (on DVD disk)**
Appendix II-2	**Solinst datalogger temperature and Water depth records above the gorge on Thayer Creek 4-10-14 through 4-8-15 (on DVD disk)**
Appendix II-3	**Calibration curve and depth/cfs conversion table for Thayer Creek above the gorge**
Appendix III-1	**Summary of fisheries catch data for 2013 Permit SF 2013-037**
Appendix III-2	**Alaska Department of Fish and Game Thayer Creek trip report, August 5-6, 2014**
Appendix III-3	**Summary of fisheries catch data for2014 Permit SF 2014-234**
Appendix III-4	**Summary of fisheries catch data for 2015 Permit SF 2015-072**

Fortunately, Shipley Group surveyed almost all of Thayer Creek including the last 1500 ft. of the Creek that forms the anadromous reach of the Creek. This proved very helpful since the current design only impacts flows in that portion, avoiding the upper portion of Thayer Creek completely. Paul Rusanowski, the lead investigator for Shipley Group, is now with Delta Environmental Science, and he was a key contributor to the Essential Fish Habitat section of the Biological Assessment and Evaluation provided in January 2017.

Task 13: Stream gaging

There were several parties involved in the stream gaging and related analysis. HDR did the original stream gaging work in the late 1990s. AP&T's primary stream gaging subcontractor, Environ, provided no useful information from its analysis that cost over $100,000 due to gage failures and data results that appear implausible. This record was extended by Shipley Group/Delta Environmental Science's gaging in from 2012 to 2016 (with gages still in place). ORENCO Hydropower and Provost and Pritchard integrated this work into a hydrological analysis for the Barrier Falls option. In addition, Provost and Pritchard performed a flood plain analysis to forecast the 100 and 500 year flood levels.

Figure 17 summarizes the daily data across the years when the gages were in place. Thayer Creek

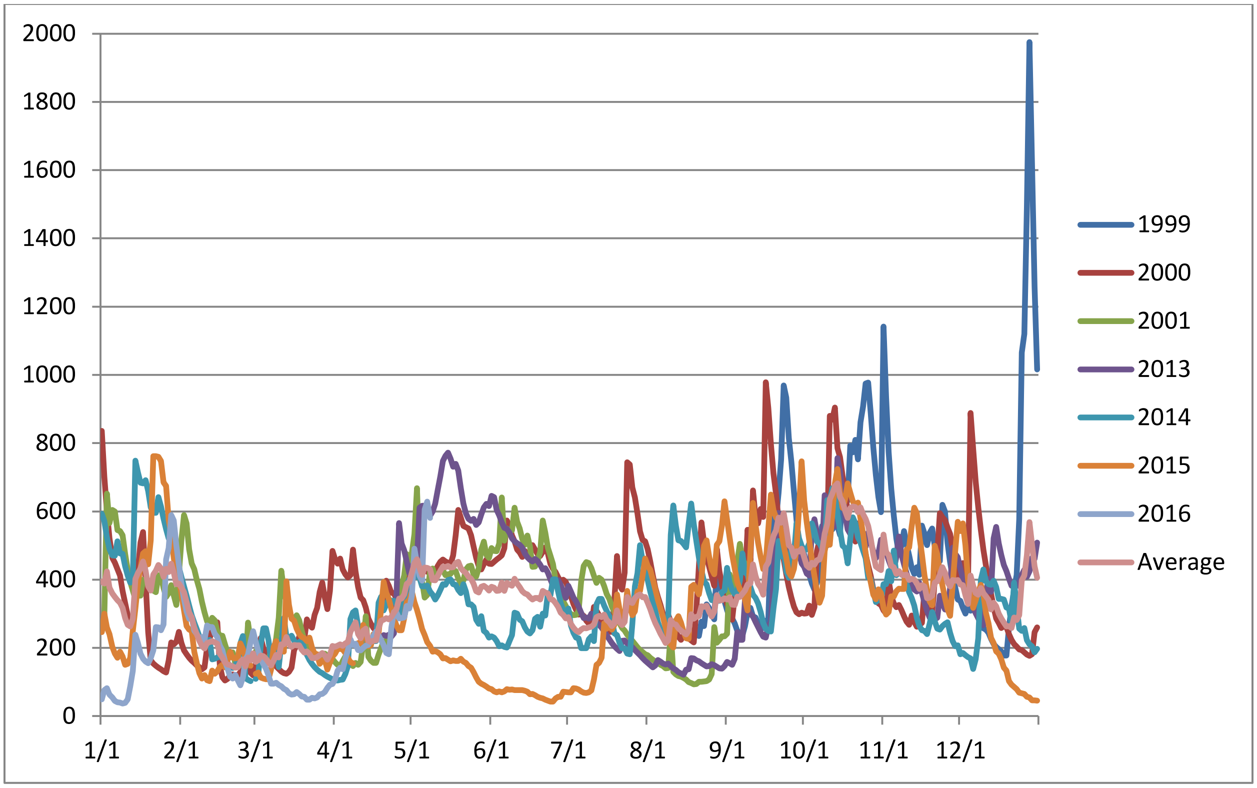

Figure 17
Thayer Creek Flow Data

The ~1800 days of recorded flow data result in the flow duration curve shown in figure 18. The maximum flow recorded was about 2000cfs, and the minimum flow recorded was 37 cfs. Based on this data, hydro unit sized at the planned maximum 170 cfs flow rate would be able to operate at full power 83% of the time, and depending upon the minimum flow requirements of the turbine, would be able to operate from about 95% to 98% of the time. When the hydro unit is shut down, power would be provided to Angoon by one of IPEC's existing diesel generators.

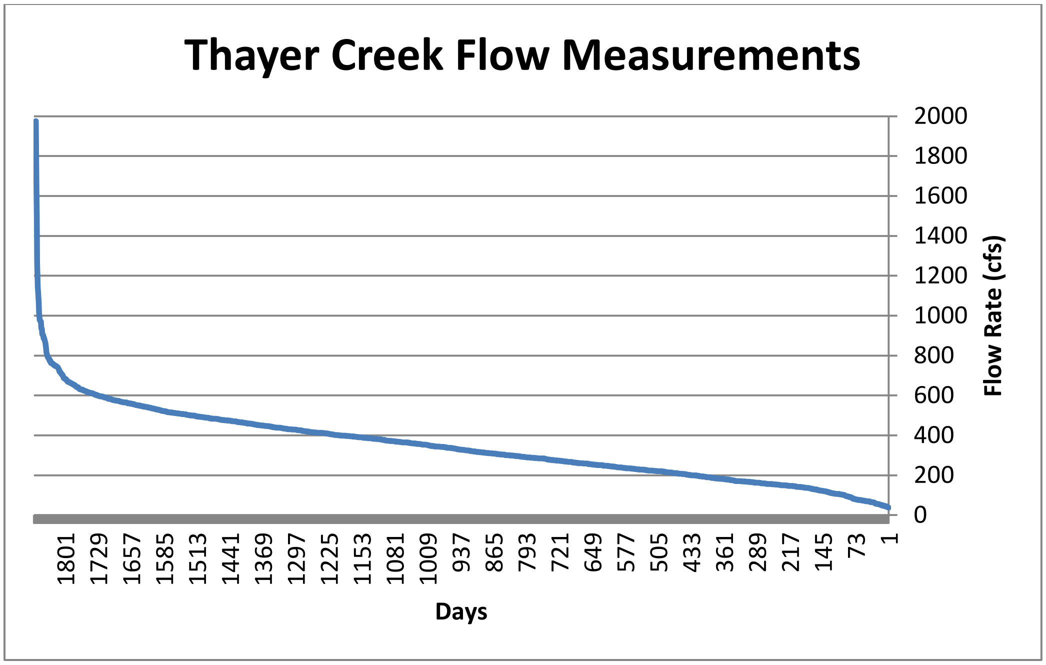

Figure 18
Thayer Creek Flow Duration Curve

While only 5.5 years of stream flow data is available for Thayer Creek, 17 years of data is available on Hasselborg Creek in the Hasselborg Lake watershed, also located on Admiralty Island. The data was collected continuously from July 1951 to September 1968 by the USGS (Station No. 15102000). This provides a longer period of record and likely utilized more consistent data collection methods. The two watersheds are located adjacent to each other. Provost and Pritchard integrated and compared the flow data for both Creeks.

The gauging station for Hasselborg Creek was situated near the outlet of Hasselborg Lake, so streamflow is controlled exclusively by lake levels. Thayer Creek flows are also controlled by lake level in the similarly sized Thayer Lake, but will also be influenced by inputs to Thayer Creek from within the 5.5-river-mile component of the watershed that lays downstream of Thayer Lake. The two watersheds share several similar characteristics, as shown in Table 14 below.

Table 14 – Comparison of Thayer Creek and Hasselborg Lake Watersheds

Description	Watershed	
	Thayer Creek	Hasselborg Lake
Drainage Basin Area (mi^2)	64.9	56.2
Area covered by lakes/ponds	7%	12%
Mean Annual Precipitation (in)[1]	79.3	97.7
Average Elevation (ft)	1,239	1,119
Vegetation	84% Forest 9% Other Vegetation	71% Forest 17% Other Vegetation

1 - Based on 1998 Precipitation Map for Alaska

These similar characteristics make the Hasselborg Creek flow data very reasonable for comparison to Thayer Creek. The USDA Forest Service also believed that Hasselborg Creek data was acceptable for comparison to Thayer Creek flows. In the project's Environmental Impact Statement (USDA, 2009), USDA states:

> "*The basins are very similar, providing a reasonable basis for estimating Thayer Creek streamflow from the Hasselborg Creek streamflow record. Based on the ratio of respective drainage areas, Thayer Creek streamflows at the diversion site have been estimated as 114% of the Hasselborg Creek streamflows at the USGS gage site*." (pg 3-11)

The USDA prepared the graph shown in Figure 19 of predicted Thayer Creek streamflow, based solely on the Hasselborg Creek streamflow record.

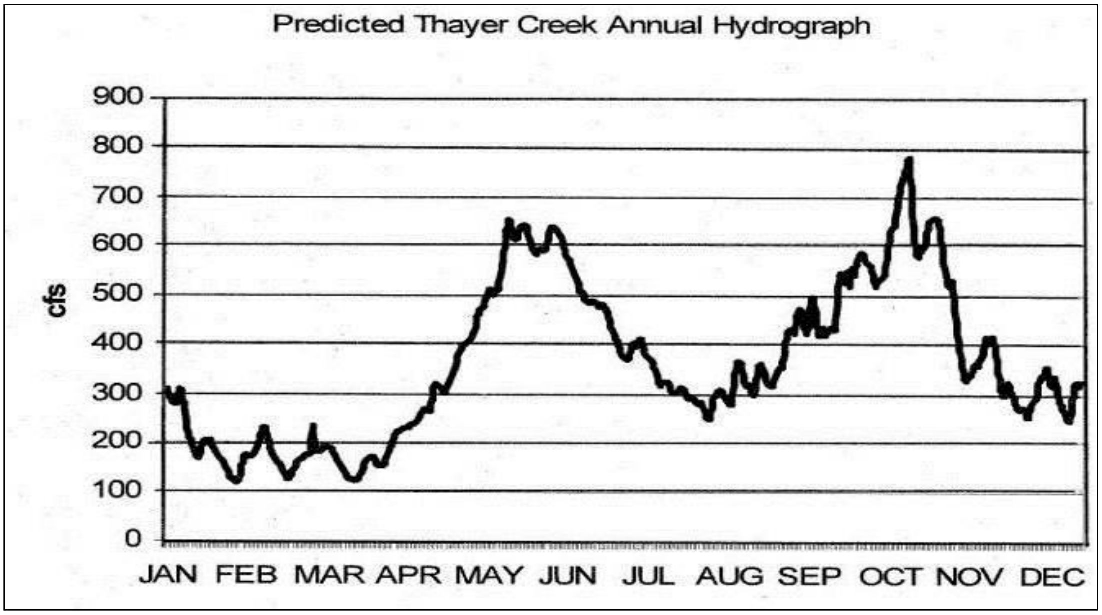

Figure 19 - Mean Daily Streamflow, Thayer Creek, based on Hasselborg Creek streamflow record (source: USDA, 2009)

Furthermore, in 2016, the Alaska Energy Authority provided the following statement in a Project Status and Analysis Memo:

> "*After review of the available data sets AEA concludes that the USGS Hasselborg Creek data scaled to the project basin is likely the most representative hydrology data available with a long enough record to model annual variability*." (pg 11)

Consequently, due to the similar watershed characteristics, and statements by the USDA and Alaska Energy Authority, Hasselborg Creek flows are considered adequate for validating estimated Thayer Creek Flows

In USGS (2003), peak flows were estimated for Hasselborg Lake watershed using actual streamflow data and the log-Pearson Type III Frequency Distribution. The data was reviewed for quality and outliers, and was adjusted when deemed appropriate. These results are useful for comparison to estimated Thayer Creek peak flows, since the two watersheds are similar.

Figure 20 below is a comparison of: 1) Thayer Creek flows based on Regression Equations; 2) Hasselborg Creek flows based on Regression Equations; 3) Hasselborg Creek Flows calculated by the USGS using stream gage data; and 4) Thayer Creek flows based on 114% of Hasselborg stream gage data (as suggested by USDA, 2009).

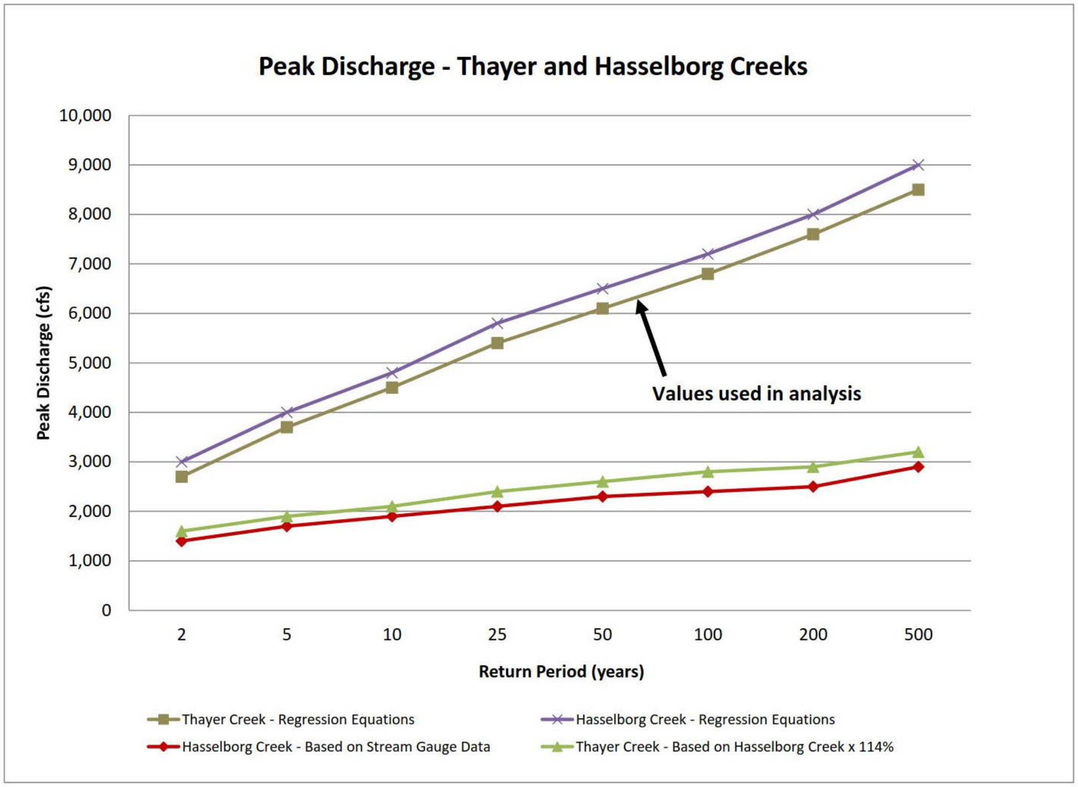

Figure 20
Peak Discharge – Thayer and Hasselborg Creeks

The Thayer Creek flows based on Regression Equations were used to design the dam spillway (as labeled on Figure 2). These values are significantly higher than peak flows for the similar Hasselborg Creek, as well as estimated Thayer Creek flows based on a ratio of drainage basin areas. In addition, the Hasselborg Creek flows using the Regression Equations are significantly larger than Hasselborg Creek flows estimated with stream gage data.

In the two lower lines in Figure 2, the estimated Thayer Creek flows are higher than Hasselborg Creek flows (by 114%), since Thayer Creek has a larger drainage basin. In the two upper lines, the Hasselborg Creek flows are higher, because although Hasselborg Creek has a slightly smaller watershed, it also has higher average annual rainfall, resulting in larger peak flows using the Regression Equations.

It was not possible to validate the Regression Equation results with Hasselborg Creek data, since the values vary significantly. However, the Regression Equations give flows that are 200% to 300% of the estimated peak flows for Hasselborg Creek, and therefore appear to provide very conservative estimates of the IDF.

HEC-HMS Hydrologic Model

HEC-HMS is a standard and widely accepted model for performing hydrologic analyses of watersheds. The model is an accepted method for estimated IDFs in Alaska (Alaska DNR, 2016). The main advantage of HEC-HMS is that it models specific watershed conditions by inputting data on land use, runoff coefficients, soil type, etc. Hence, HEC-HMS is typically more accurate than regression equations. Disadvantages can include difficulty finding all of the necessary data, and questionable results if there is no data to calibrate the model.

The model could be used to estimate peak flows for Thayer Creek. Several challenges would be encountered in using HEC-HMS however, including the following:

1. Peak flows in the watershed may be the result of snowmelt, or rain on snow conditions. Snowmelt can now be modeled in newer versions of HEC-HMS, however, data on snow is limited, and numerous assumptions would need to be made.
2. Detailed soils data are not available from the NRCS Web-based Soils Survey, although some data may be available from other sources. Soils data are important for estimating accurate runoff coefficients. The soil types would need to be assumed based on general data on the region's soils.

In summary, general methods are available for estimating an IDF: 1) Local stream gage data; 2) Regression Equations; and 3) HEC-HMS model. Only 5.5 years of stream gage data is available for Thayer Creek, which is insufficient for meaningful analysis. However, 17 years of data is available for the neighboring Hasselborg Lake watershed, which is very similar to Thayer Creek watershed. The US Forest Service and Alaska Energy Authority both documented that the two creeks were similar and comparisons were valid. Peak flows estimated from Regression Equations are proposed for the IDF. These peak flows exceed estimates for Hasselborg Creek based on stream gage data by 200% to 300%. This indicates that the Regression Equation flows are very conservative and overestimate the IDF. A HEC-HMS model would be difficult and costly to prepare due to lack of all the sufficient data. Furthermore, a HEC-HMS model is not considered necessary for validating the results of the Regression Equations, since they have already been found to be very conservative relative to a similar adjacent watershed.

Based on this analysis, Figure 21 shows the forecasted peak flows for Thayer Creek, with 100 year flood flows estimated at 6800 cfs, and 500 year flood flows as 8200 cfs. This compares to the highest flows recorded over the period of record at 2000 cfs.

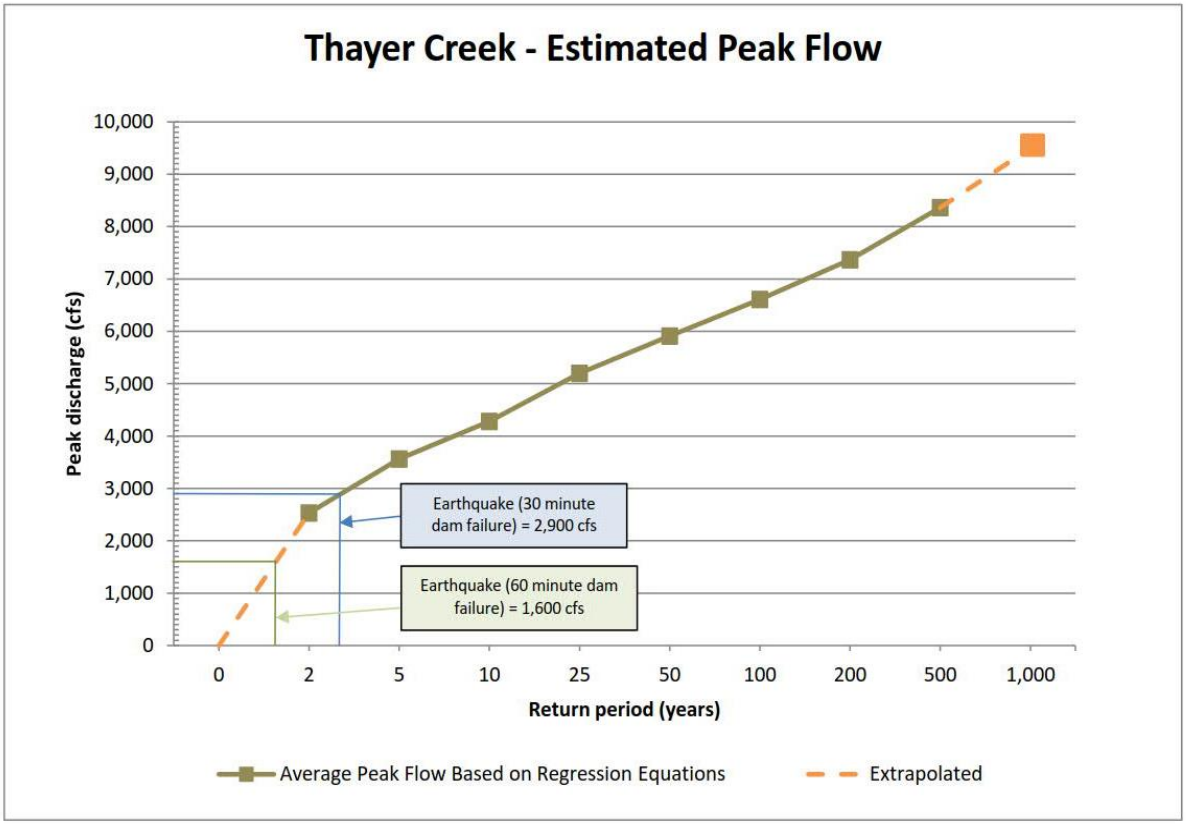

Figure 21
Thayer Creek Estimated Peak Flow

Based on this information, the project design was review to assess possible damage to the project elements from a 100 year or 500 year flood. Figure 22 shows the inundation map during the 500 year flood, indicating that almost all project elements would be able to survive flood conditions. As discussed, later the dam design is based on being able to sustain these flood conditions with little damage.

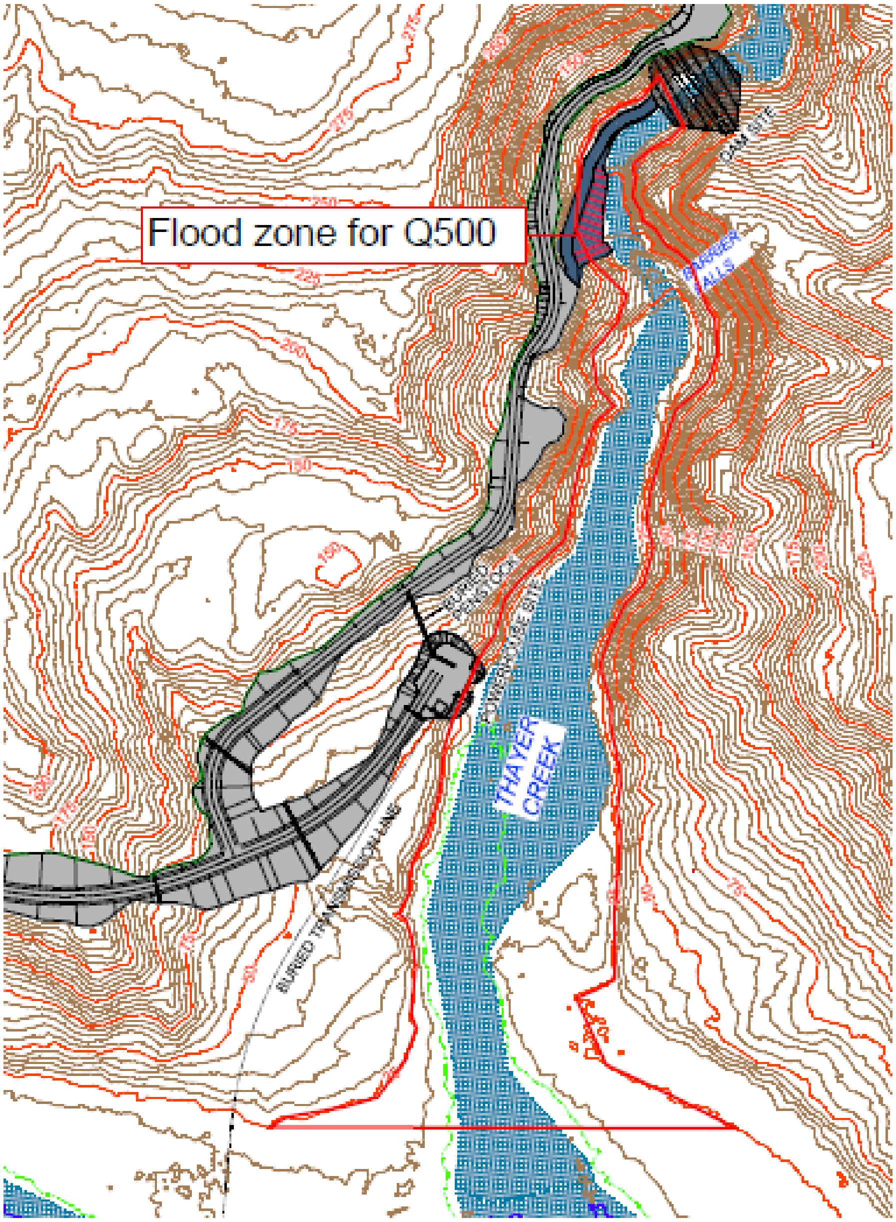

Figure 22
500-year Floodplain of Thayer Creek

Task 14: Contract 1 design (marine facilities, camp and staging areas, access roads)

Preliminary Design by AP&T:
AP&T had performed some initial design work for the marine facility that would provide access to the Thayer Creek site. They had proposed a marine facility for boat access and at Three Crosses, about 2 miles south of Thayer Creek. The about 10 miles of access roads to the bridge across Thayer Creek, powerhouse, dam, penstock and along the transmission line would begin at this point. The marine facility would allow boat and barge access for the construction and operations of the project.

From the marine facility, there was a ~2 mile access road and bridge across Thayer Creek to the powerhouse, an additional ~2 mile access road from the powerhouse to the dam, and a ~4 mile access road for the transmission line to the waters edge north of Angoon.

During the planning of the larger 6.3MW design option, AP&T proposed that the marine facility be located at Stillwater Anchorage with a 6.4 mile access road to the powerhouse and dam.

AP&T initially planned to have a "man-camp" located between 3 Crosses and Thayer Creek to house all non-local construction workers. With the revised marine facility at Stillwater Anchorage, the plan for a man-camp was abandoned and it was assumed that workers would be lodged in Angoon.

Revised Design by ORENCO:
The final design by ORENCO and its subcontractors moved the marine facility about 0.4 miles north of Thayer Creek. This provided several advantages, including: deeper water access than 3 Crosses to simplify barge landings, a significantly shorter access road to the powerhouse and dam (just under 1 mile) compared to 6-8 miles for the prior designs, a nearby staging area and quarry to simplify construction, avoided several eagles nests and wetland areas south of Thayer Creek, avoided any Class I or Class II streams and negated the need for a bridge across the Creek.

The marine facility, designed by All Points North Surveying and Engineering, incorporates a barge landing and a boat ramp for access during construction and operations, as shown in figure 23. Mooring buoys are not included in the final design. The barge landing will be approximately 150 feet long and less than or equal to 30 feet wide on the top. As defined in the US ACE permit, the materials entailed for construction of the facility include: *Discharge 15,000 cubic yards of clean rock fill material into 0.82 acres below the high tide line (approximate elevation +18.6 feet below the 0.0 foot contour) (HTL) and the mean high water mark (approximate elevation +13 feet below the 0.0 foot contour) (MHW) to construct a marine facility consisting of a barge landing and small boat ramp.*

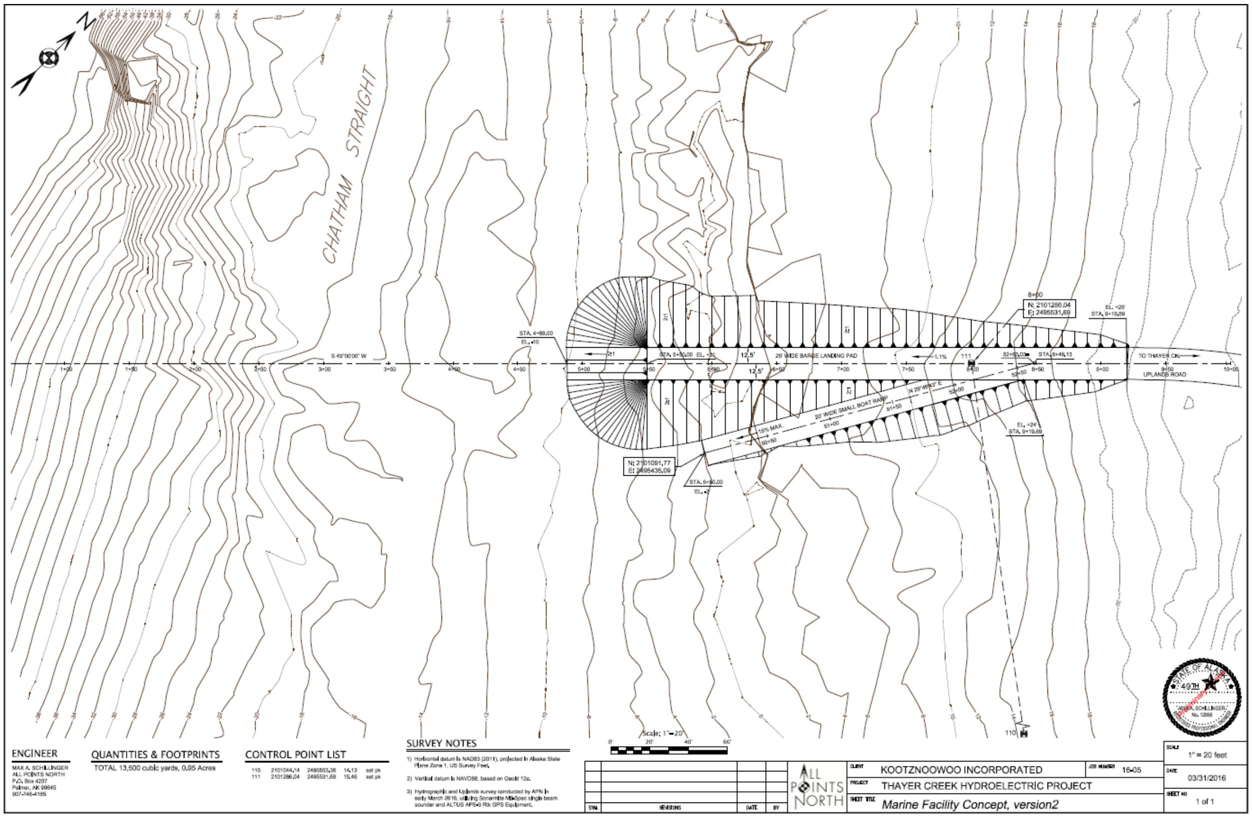

Figure 23
Marine Facility Design

The 0.7 mile access road from the marine facility to the powerhouse is shown in figures 24 and 25. The access roads were designed by All Points North Engineering and Surveying, with substantial input from ASI Construction and Channel Construction. Near the beginning of the road, a small temporary quarry is located to provide bedding material for the access road. The access road is a single lane gravel road with turnouts approximately every 500 ft. About 700 ft. south of the marine facility a staging area is located for storing materials needed during construction and stockpiling materials for future road maintenance. A 20’x 30’ garage will be located at the quarry or the staging area, to house a pick-up truck for access to the dam and powerhouse and a front loader or backhoe for road maintenance.

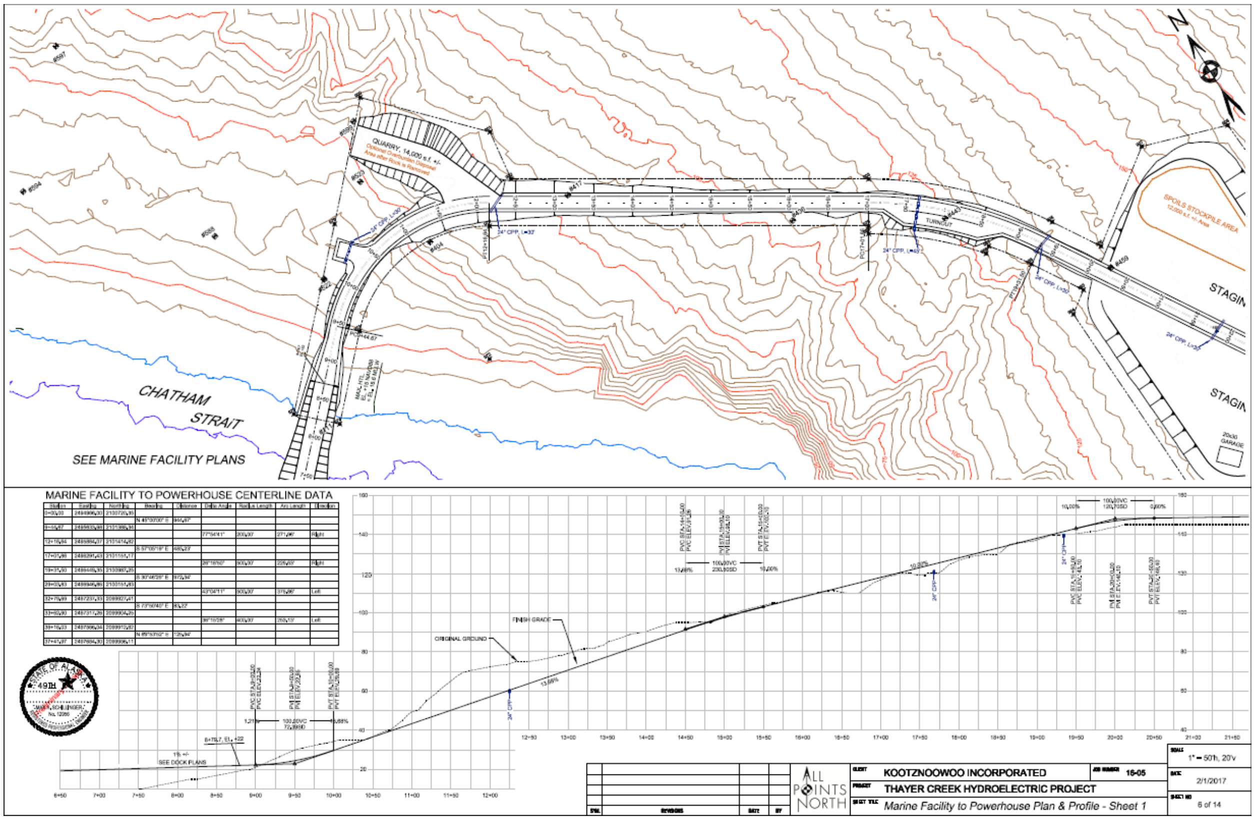

Figure 24
Northern Half of Access Road to Powerhouse

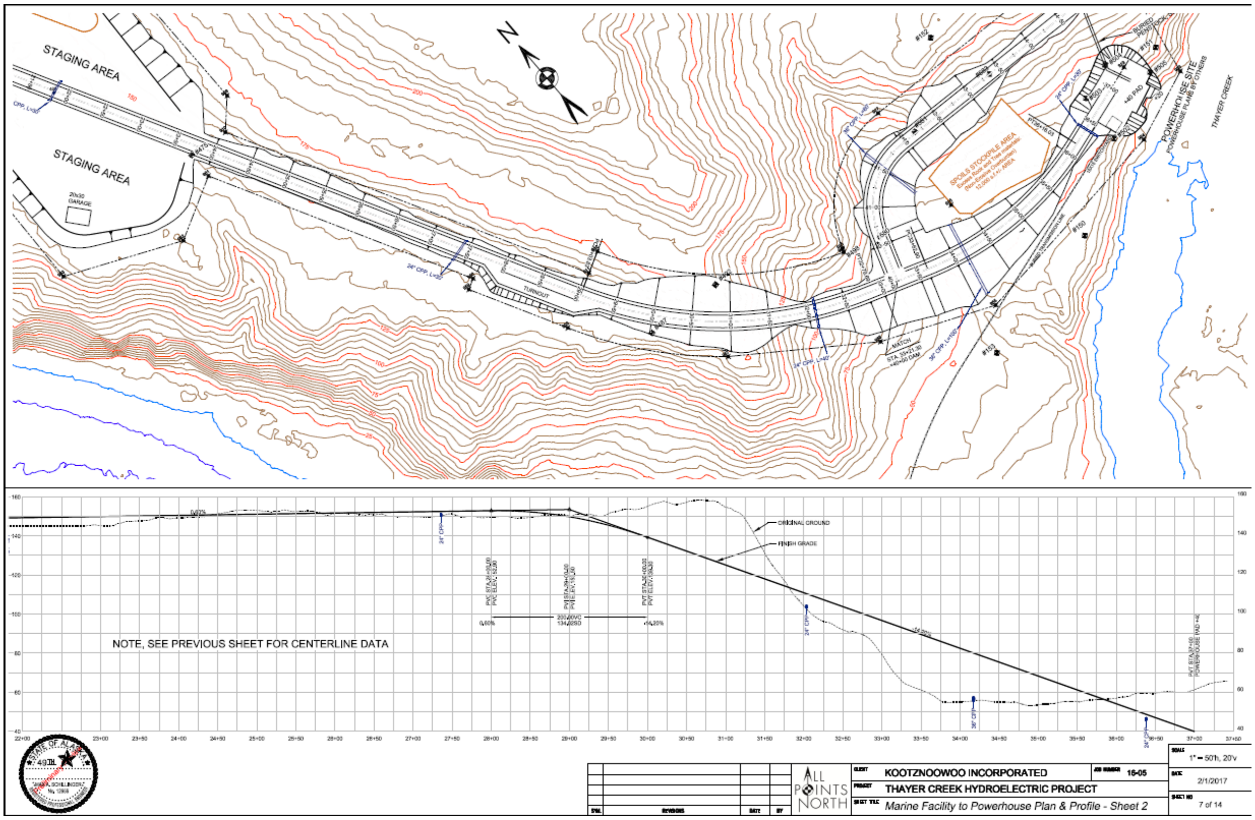

Figure 25
Southern Half of Access Road to Powerhouse

The access road to the dam intersects the powerhouse access road near the powerhouse and is shown in Figure 26.

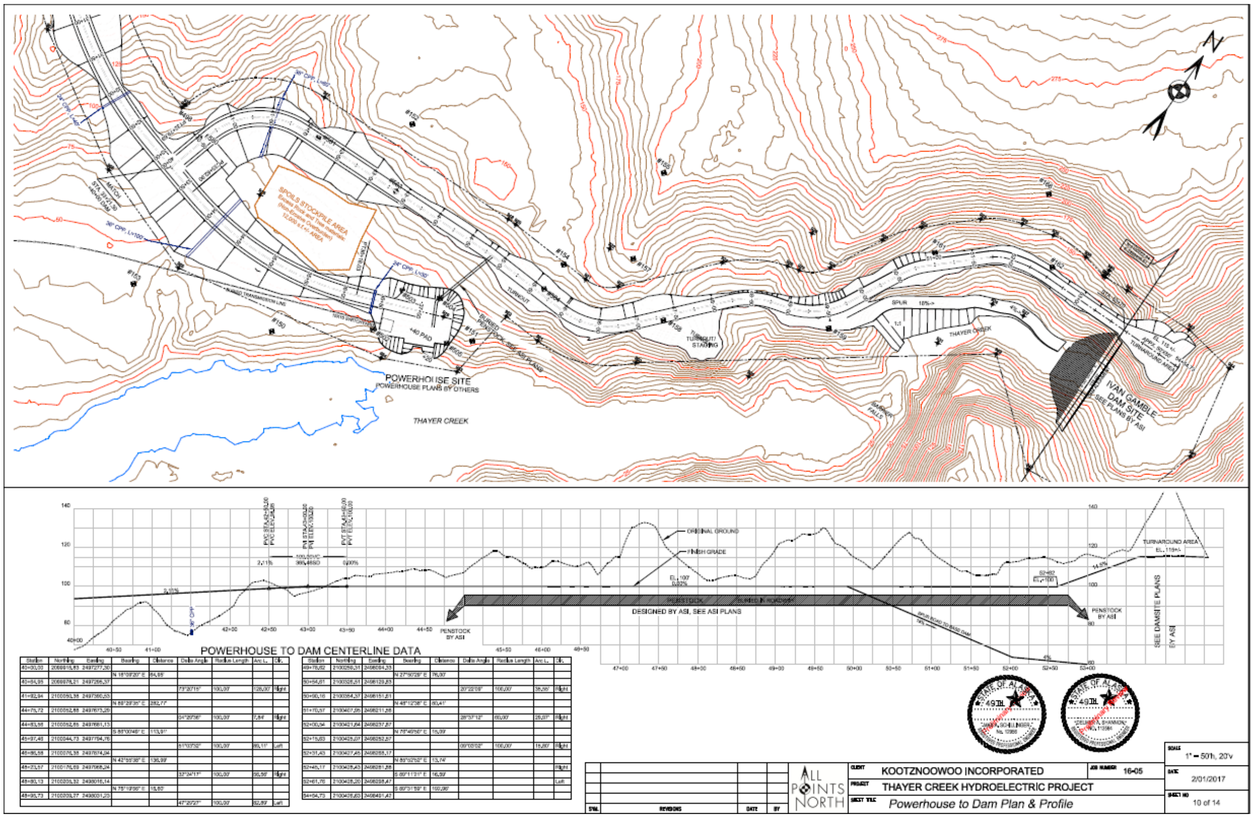

Figure 26
Dam Access Road

The “man-camp” for housing workers during construction has been eliminated, and all workers will be lodged in Angoon and transported to the marine facility each day. A portion of the funds that would have been spent to construct and remove the temporary camp can be allocated to permanently upgrade the several lodges in Angoon, and will create increased revenue for businesses in Angoon, providing additional economic development.

Task 15: Contract 2 design (Generating equipment)

The output of a hydro turbine and generator is a function of the flow rate and the net head (i.e., gross head minus intake and penstock losses and the generator and turbine efficiency. The standard formula for calculating generator output is:

> Generator output (kW) = flow rate (cfs) *(gross head – head loss) (ft) * generator efficiency * turbine efficiency / 11.81

Based on the hydrology discussed above, the planned flow rate is 170 cfs. The proposed dam height is 55 feet. The resulting calculations are shown in Table x, and result in a theoretical maximum output from the generator of 988kW.

Table 15
Estimated Output of Generator

- Gross Head: 83.2’
- Pipeline length: 960’
- Head Loss: 8.3%
- Net Head: 76.3’
- Design flow: 170 cfs
- Turbine Efficiency: 90%
- Generator Efficiency: 93%
- Theoretical Generator Output (kW) = Head (feet) * Flow (cfs) * System Efficiency (%) / 11.81 = 919 kW
- Transmission line efficiency: 91%
- Theoretical Delivered Capacity to Angoon (kW) = 837 kW

Several alternative turbine options have been priced and compared. These include a horizontal Francis unit (priced from Canyon Hydro, HEEW and CWTW), a crossflow unit (priced from Canyon Hydro) or a linear Pelton (priced from Natel Energy). The lowest cost option per kW is a horizontal Francis unit from HEEW or CWTW. The baseline plan is to use a horizontal Francis unit, as shown in the powerhouse design, but the selection of the actual supplier and turbine type is a future decision based on detailed cost and performance comparison. The expected monthly capacity in kW that would be delivered to Angoon is illustrated in figure 27.

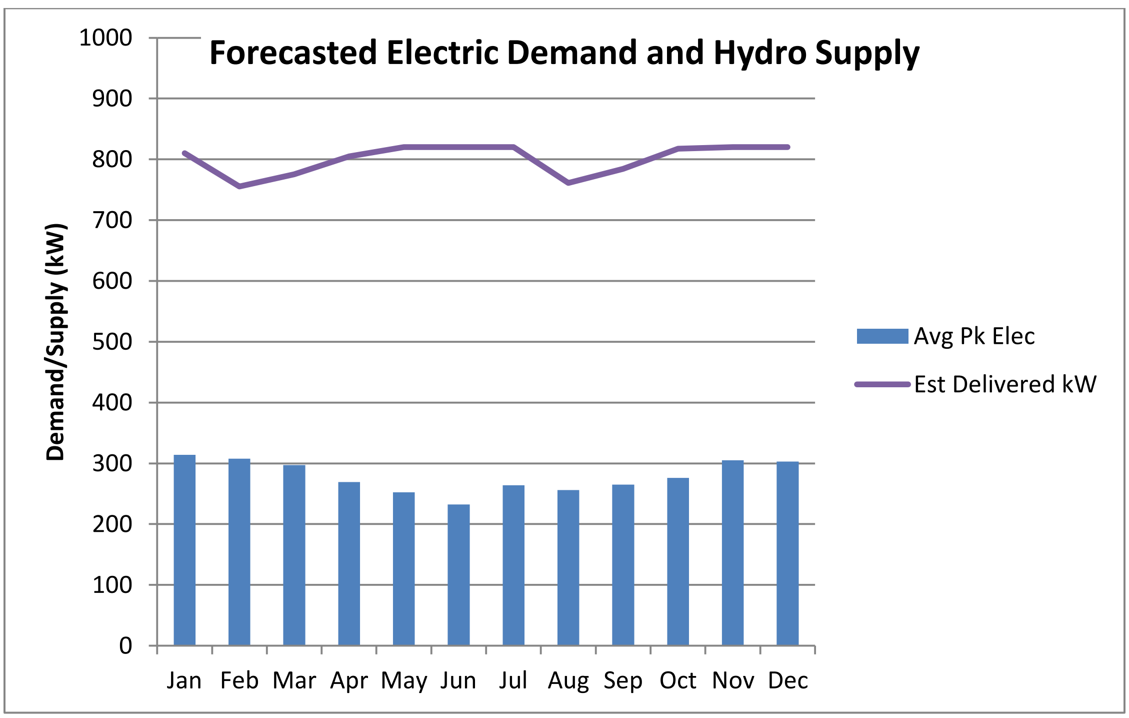

Figure 27
Forecasted Electric Demand and Hydro Supply

Hydro System Control:
The control system for the turbine is likely to be quite simple and reliable. The project operates as a run of river since the dam is not built for storage of water but for increasing the head and output of power from the project. Therefore, a simple float valve can serve to turn off the project on the few days where water flows fall below minimum flow requirement of the turbine. The wicket gates on the turbine will be remotely controlled from Angoon to increase or decrease plant output to meet demand in Angoon.
Voltage and Frequency Control of IPEC's electrical system in Angoon:
Once the hydro unit is operating, IPEC's diesel generators will only run when the hydro is not operating or when the hydro output cannot meet local demand, so the current plan is to install in 2018 an electric boiler (or an electric boiler and a commercial heat pump) that would provide the hot water needed for heating the school. This would be combined with a small 30kW load bank to be used by the local utility to also provide voltage and frequency control for IPEC's electrical system anytime when the diesel units are not operating.

Task 16: Contract 3 design (Diversion structure, penstock, powerhouse, tailrace, substation)

The diversion dam is located about 250 ft upstream of the lower Barrier Falls shown in figure 28.

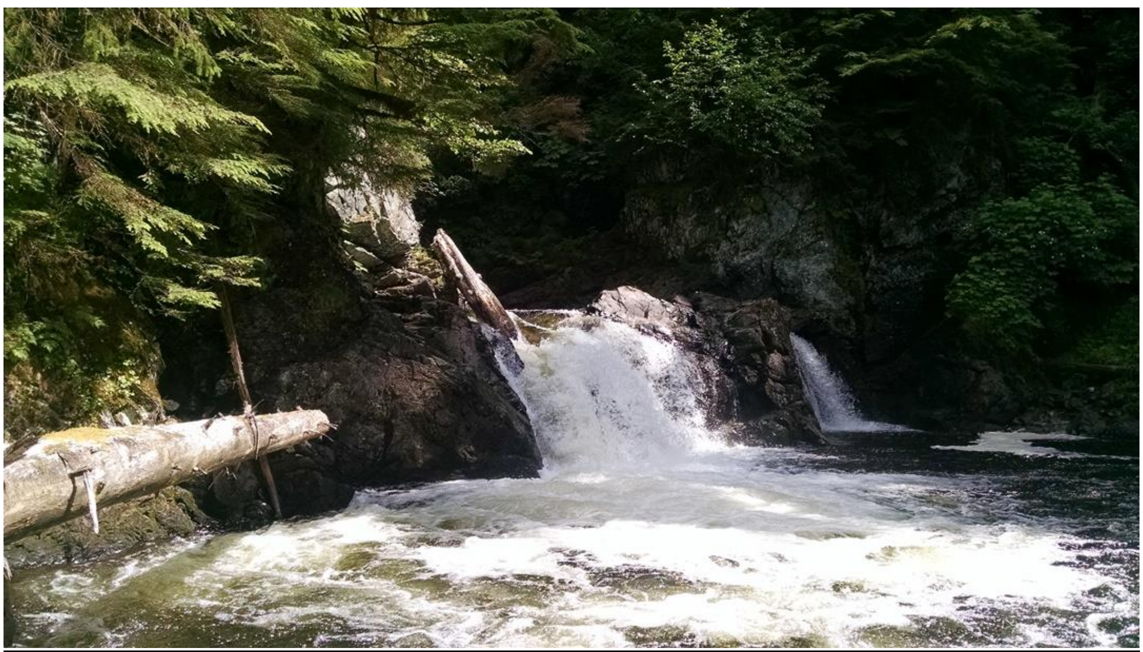

Figure 28
Lower Barrier Falls
(dam is located about 250' upstream of falls)

The dam is located just upstream of the upper barrier falls and will be near the photographers location in figure 29.

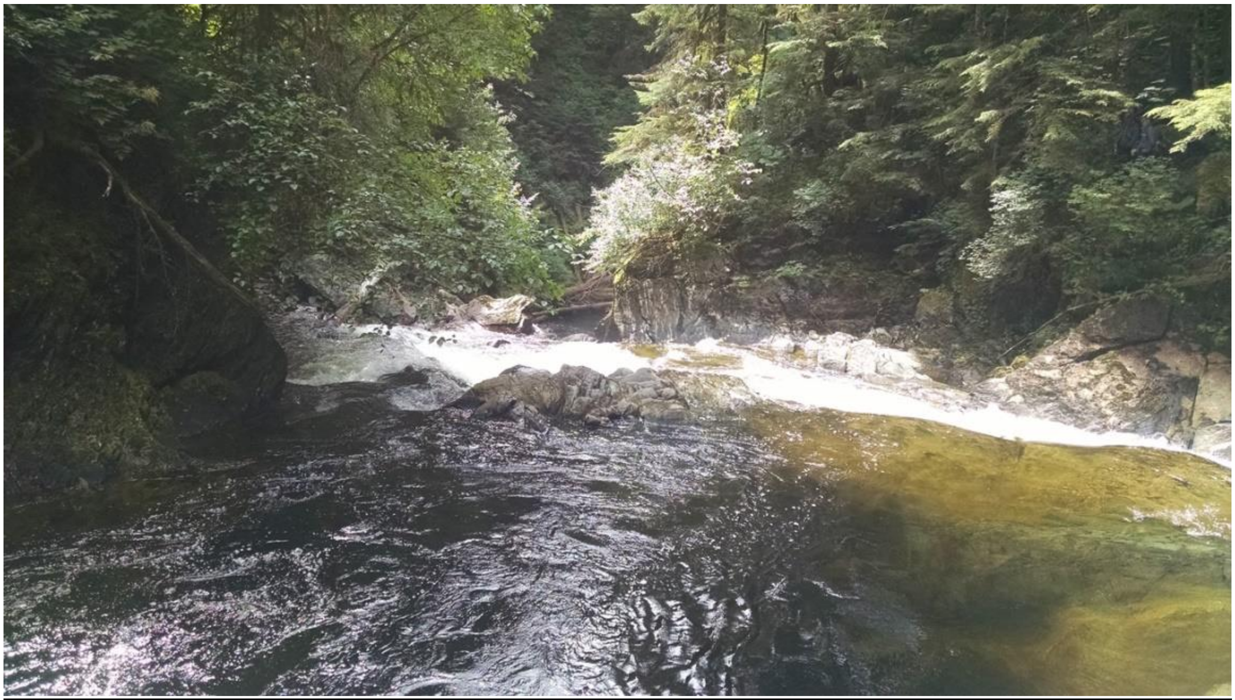

Figure 29
Dam Location above Upper Barrier Falls

The dam, designed by ASI Construction, will be a 60’ high 135’ wide roller compacted concrete (RCC) dam. The top of the dam will serve as a spillway to be able to handle the 500 year flood conditions on the Creek. This design will also allow woody debris to pass over the dam as requested by the USFS and AK DF&G. Figures 30 and 31 show the plan and profile of the dam. An RCC dam was proposed for several reasons, including:

- The RCC dam allows a steep face that reduces materials required
- RCC dams can be built quickly once the concrete facilities are in place (1-2 months)
- RCC dams can also tolerate water inundation during construction, reducing costs and risks.

As a result, ASI’s cost estimates for the dam are about $2.5 million less than the smaller diversion dam that was planned by AP&T.

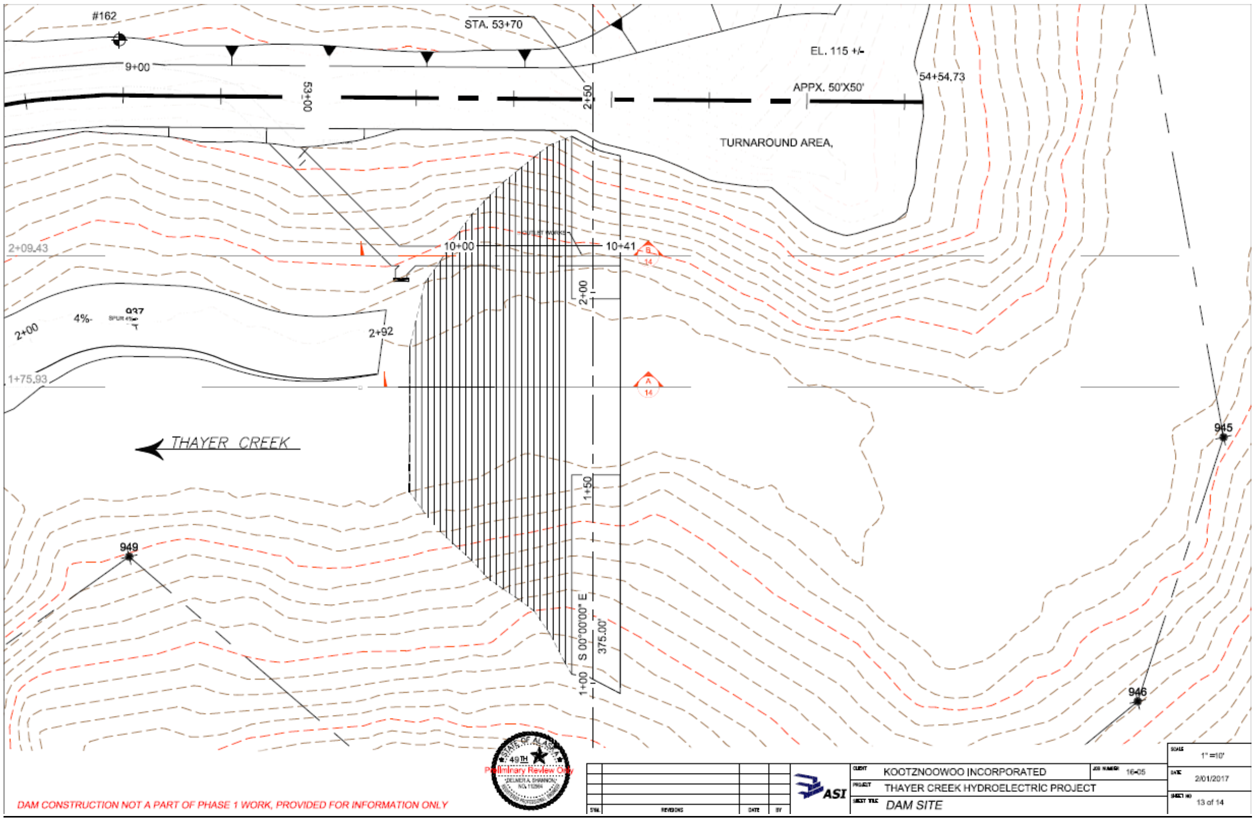

Figure 30
Dam Plan

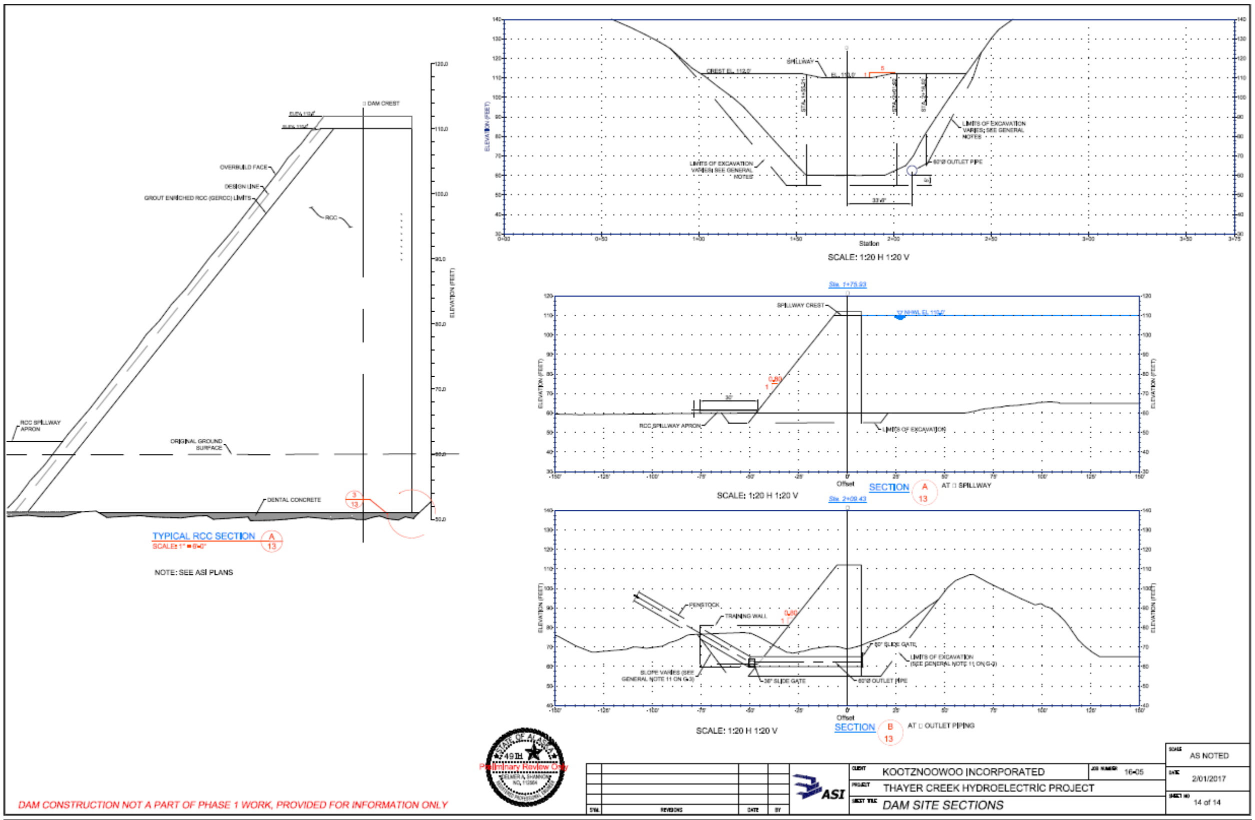

Figure 31
Dam Profile

The penstock from the dam, designed by Provost and Pritchard, is composed of a 60" pipe approximately 1000 ft. in length. As shown in figure 32, most of the penstock will be buried in the dam access road until it is directly above the powerhouse. A separate weir will enable the intake, slide gate and trashrack to be out of the flow of the river and more easily cleaned and protected.

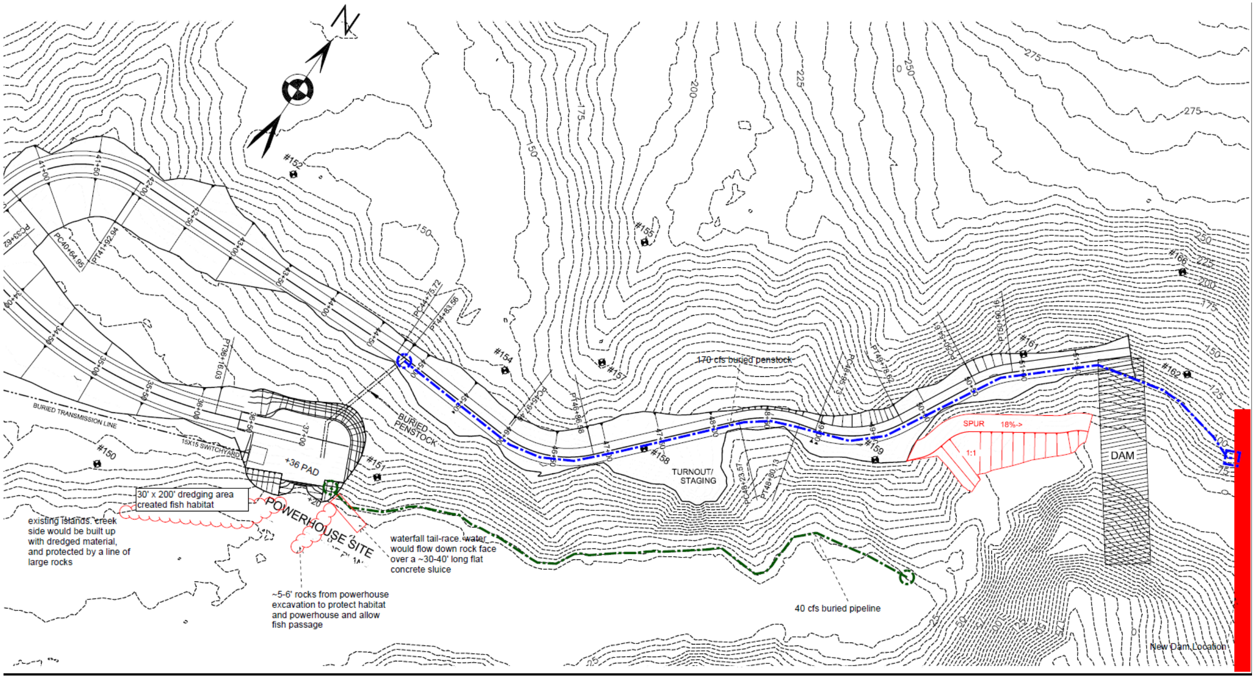

Figure 32
Penstock Design

A separate pipe (to be sized between 36-60”) will pass through the dam and when opened about once per year will allow gravel transport through the dam to enhance the essential fish habitat below the Barrier Falls.

A 42” pipe running from the powerhouse to the barrier falls will convey 40 cfs of water to the upper reach of the essential fish habitat whenever the turbine is in operation. That pipe will be located in the northern most portion of the Creek bed and will be protected by large rip-rap and buried in gravel.

The powerhouse is a 40’x60’x20’ building built to house a single turbine-generator and the associated switchgear and controls. The powerhouse is planned as a prefabricated metal building. The plan and profile of the powerhouse and the hydro equipment (i.e., turbine shut-off valve, turbine, generator and switchgear, are shown in figures 33 and 34. A bridge crane will likely be built into the building to support installation and operations.

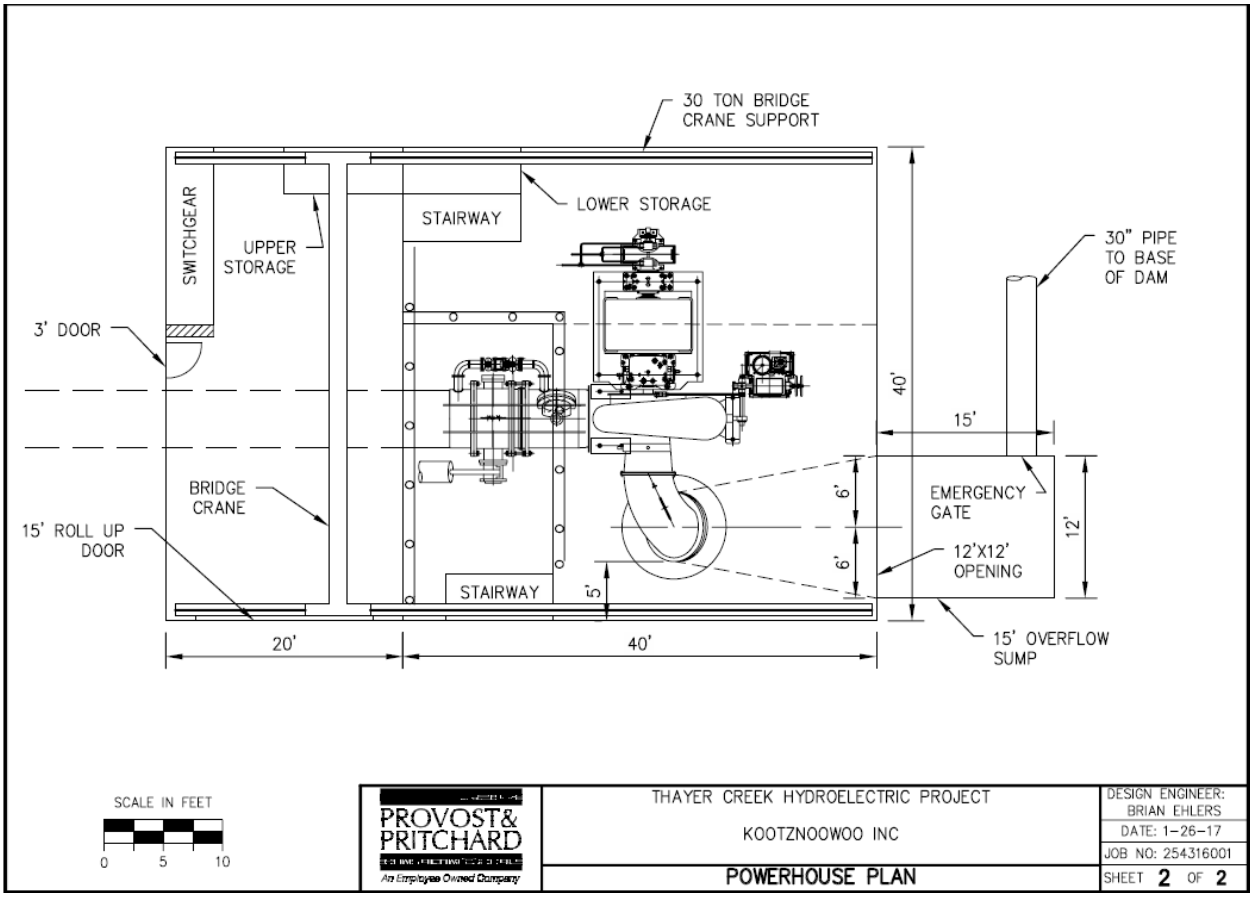

Figure 33
Powerhouse Plan

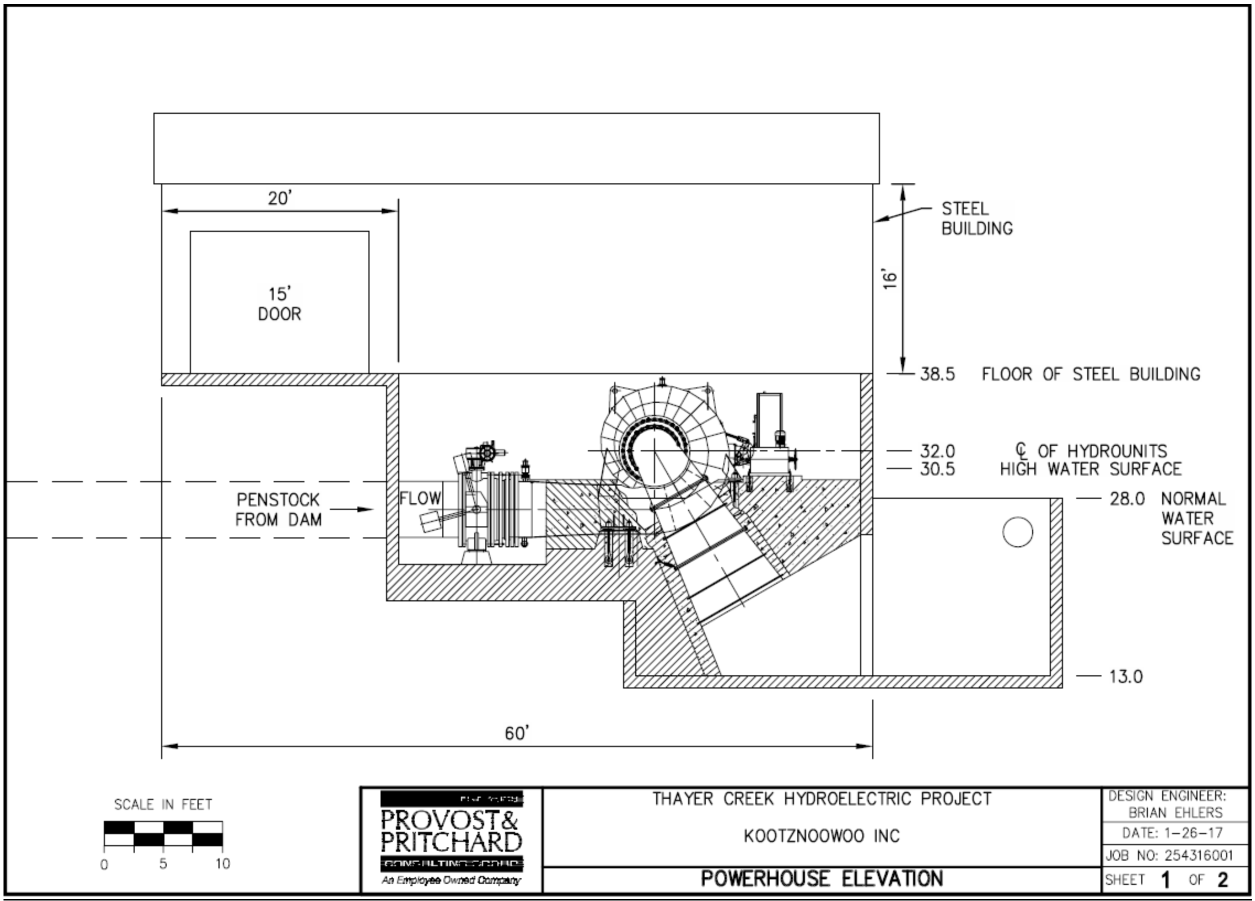

Figure 34
Powerhouse Profile

Task 17: Contract 4 design (Transmission line)

The transmission line from the switchyard located adjacent to the powerhouse to IPEC's substation in Angoon is planned as a 12kV line, matching the voltage if IPEC's distribution system. The 2009 Record of Decision required that the transmission line from the powerhouse to Angoon would be a buried cable, with possible exceptions. AP&T had proposed an overhead line that would follow the 2-mile access road from the powerhouse to 3 Crosses and then the access road to a marine facility at Stillwater Cove. Given the very high current in that area, AP&T had planned to drill the transmission line under the straight from Stillwater cover to Angoon, terminating at a new switchyard in Angoon.

AP&T estimated the cost of the line would be $1.3MM plus about $2.5MM in road access cost to install the line south to the marine facility. In addition, the cost to lay the 0.5 mile cable across Stillwater Cove was substantial due to difficulty of laying and protecting a cable in a high-traffic straight with high velocity tides. AP&T forecasted that the high flows might mandate directional drilling below the sea floor (costing an estimated additional $1-4MM). The alternative of 0.5 mile submarine cable would add a similar amount. As a result, their estimated cost for the transmission line was $4.8-7.8 million. The USFS Record of Decision requirement that the transmission line be buried, would have likely increased this cost estimate substantially

As part of the value engineering work, ORENCO and Evergreen Energy examined four alternatives:

1. Above ground transmission line as planned to Stillwater Cove, 0.5 mile submarine cable

2. Buried transmission line as planned to Stillwater Cove, 0.5 mile submarine cable
3. Tree-mounted ground transmission line with ATV access road, 0.5 mile submarine cable
4. Buried transmission line to mouth of Thayer Creek and 6.5 mile submarine cable to Angoon.

Somewhat surprisingly, the 6.5 mile submarine cable was the lowest cost option, costing about $2.6-4.5 million, compared to about $4.8-$7.8 million for overhead option, and about $5.8-8.8 million for the buried line option. Option 3 would likely be less costly but would likely no longer be allowed under current regulations.

Based on these results, the engineering and permitting focused on the submarine cable option.

Figure 35 shows the route of the submarine cable from Thayer Creek to Angoon.

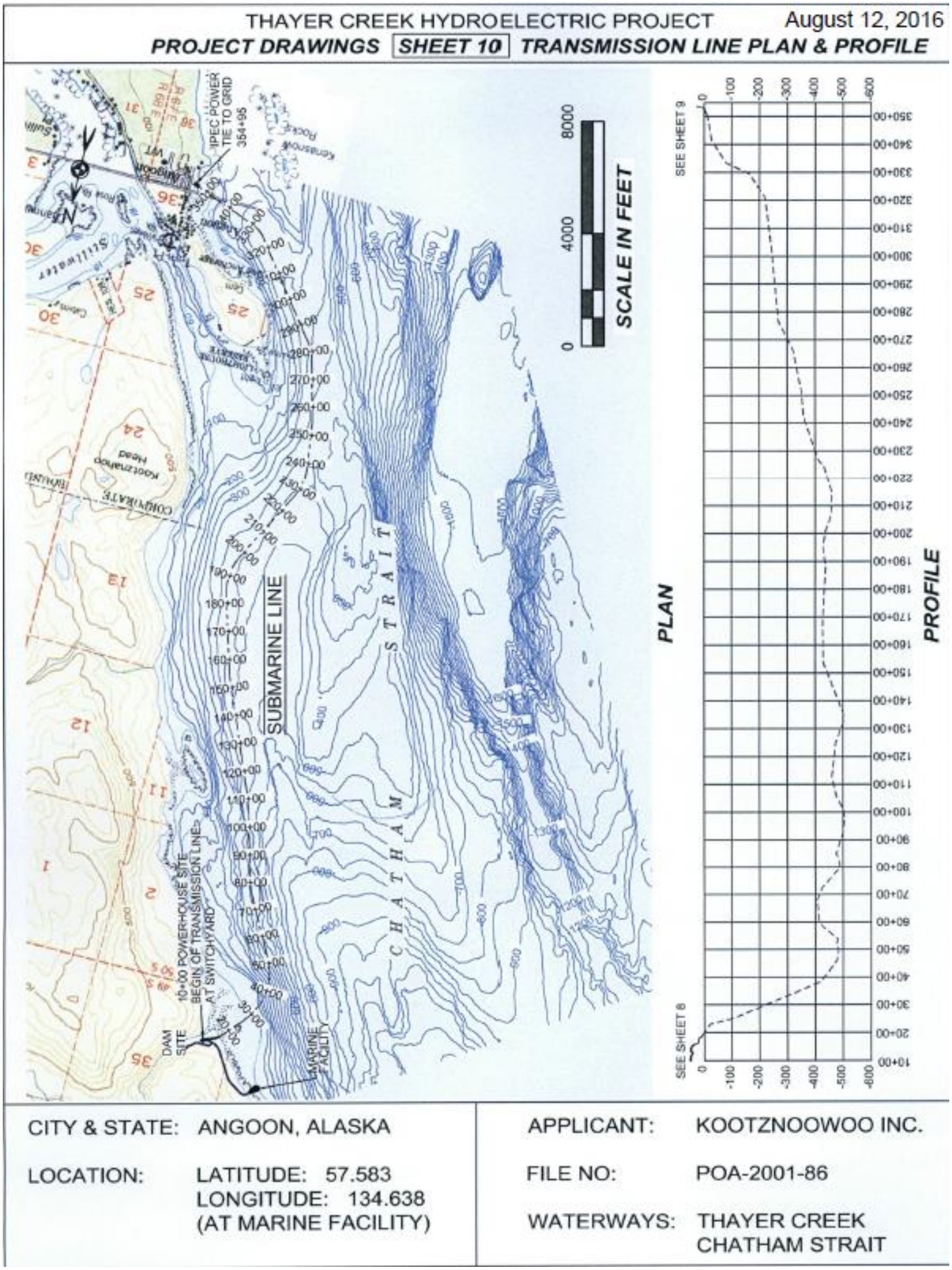

Figure 35
Submarine Cable Route

The 750' potion of the transmission line from the powerhouse to Chatham Straight will be buried, and will terminate at a cable vault. The portion of the submarine cable that connects to the buried cable at the cable vault will be buried or protected as shown in figure x to a depth of about 20-30 ft below low tide, and will be surface laid thereafter. The submarine cable will be marked at the tidal crossing to notify boaters and fishermen, and it will be an armored cable able to withstand being struck by boat anchors or large fishing lines that are used in this region.

The submarine cable will cross the tidal area just below IPEC's powerhouse on Chatham Strait, and about 150ft. south of the outfall from Angoon's wastewater treatment plant, as shown on figure x. The cable must also cross the two GCI cables about 300 ft. north of the outfall from Angoon's wastewater treatment plant per ICPC guidelines for cable crossings. The cables will cross at a water depth of about 50ft. which eases possible future maintenance. The cable will enter a cable vault and then extend underground or overhead to IPEC's substation adjacent to their powerhouse, terminating at a pole-mounted isolation switch,

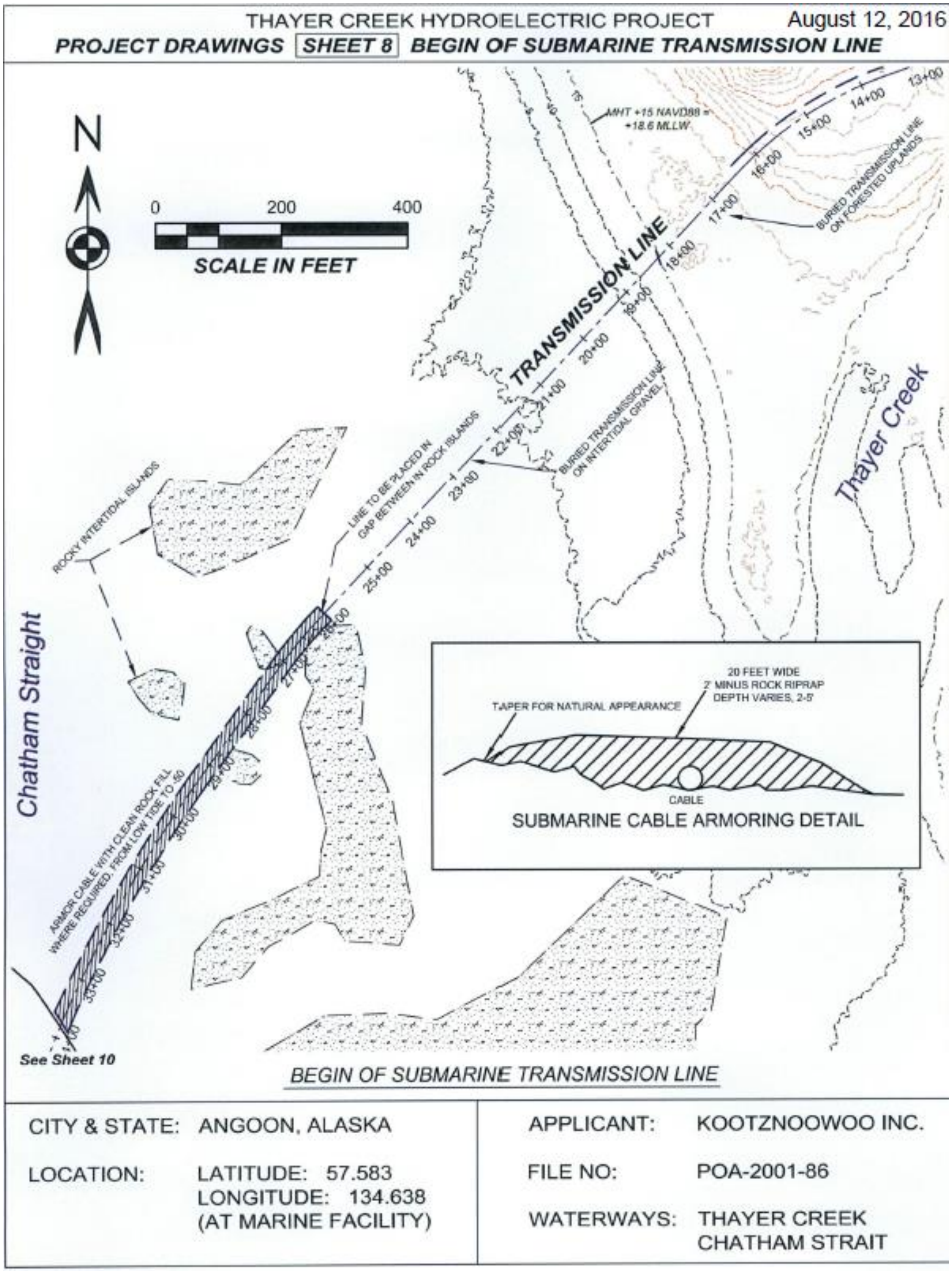

Figure 36
Tideland Cable Crossing by Thayer Creek

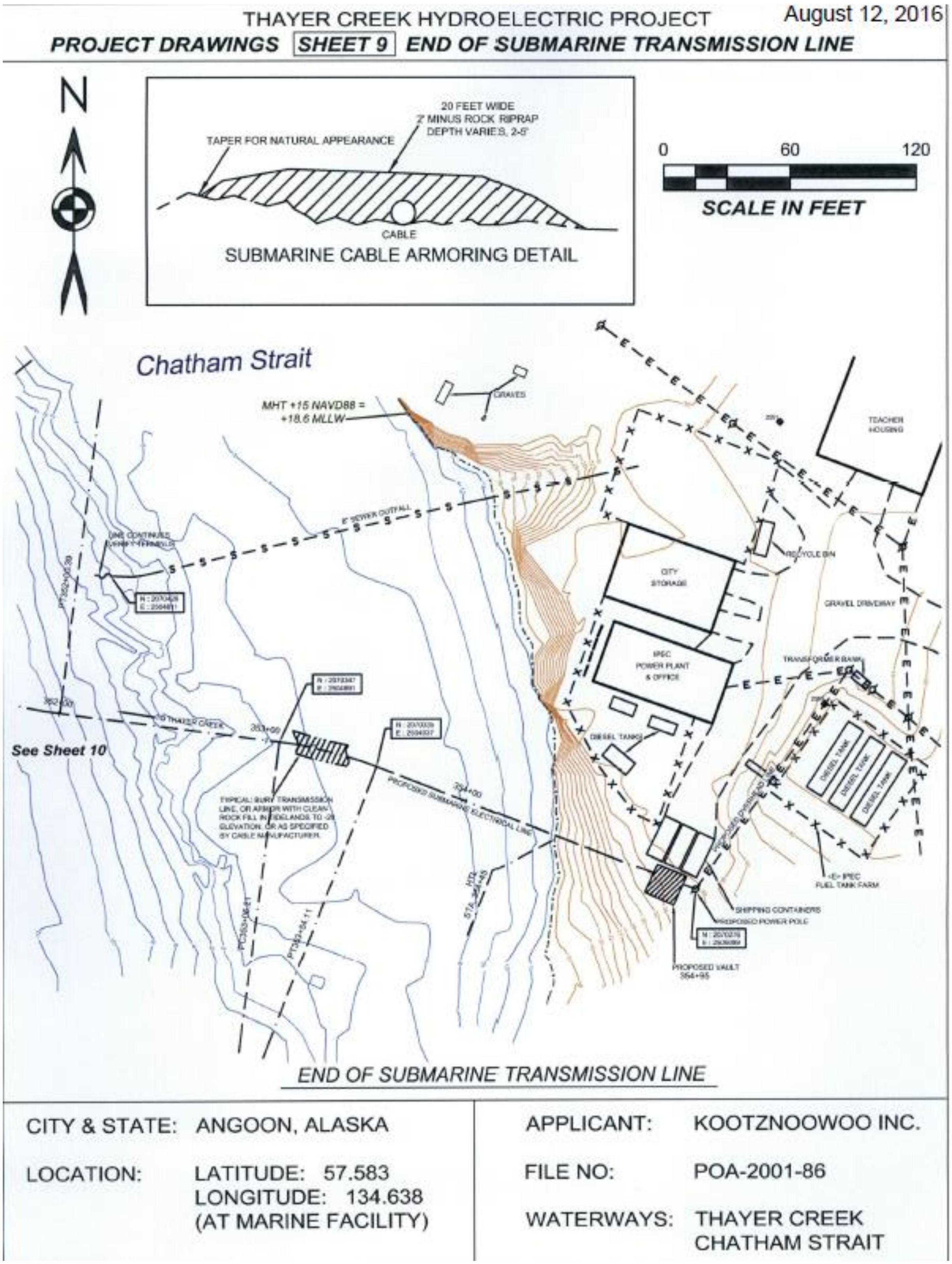

Figure 37
Tideland Cable Crossing by Angoon

Task 18: Update of cost estimates and financial feasibility

The value engineering that reduced the project cost to about $16 million was critical to enabling the project to be economically feasible. The other key change was to integrate the hydro system with enhancements to school and residential heating in Angoon that will utilize much of the spare capacity of the hydro project.

ORENCO worked with AEA to use their model for evaluating the economic benefits of energy projects in SE Alaska. Based on assumptions developed jointly with AEA's project manager for Thayer Creek and their director of finance, the project's net economic benefit was estimated at about $750,000 per year. The NPV of benefits was over $27 million, NPV of benefits of over $12 million, with a resulting 1.85 benefit to cost ratio for the $16 million investment. The assumptions and results of this analysis are shown in Table 16.

Table 16
Economic Benefits of the Project

Results	
NPV Benefits	$27,492,914.83
NPV Capital Costs	$14,838,304
B/C Ratio	1.85
NPV Net Benefit	$12,654,611

Performance	Unit	Value
Displaced Electricity	kWh per year	1,615,333
Displaced Electricity	total lifetime kWh	80,766,650
Displaced Petroleum Fuel	gallons per year	243,227
Displaced Petroleum Fuel	total lifetime gallons	12,161,332
Displaced Natural Gas	mmBtu per year	-
Displaced Natural Gas	total lifetime mmBtu	-
Avoided CO2	tonnes per year	2,469
Avoided CO2	total lifetime tonnes	123,438

Proposed System	Unit	Value

Capital Costs	$	$ 16,075,760
Project Start	year	2018
Project Life	years	50
Displaced Electric	kWh per year	1,615,333
Displaced Heat	gallons displaced per year	114,000
Renewable Generation O&M	$ per year	60,000
Electric Capacity	kW	800
Electric Capacity Factor	%	53%
Heating Capacity	Btu/hr	
Heating Capacity Factor	%	
Total Public Benefit	2015$ (Total over the life of the project)	

V. **Conclusions and Recommendations**

The Thayer Creek hydro project has progressed substantially due to the funding provided by DOE and AEA under this grant. The revised design that has located the project at the Barrier Falls has enabled the project cost to be reduced from $36 million to $16 million, while only reducing the generating capacity from 1.2 MW 0.85 MW – more than is needed to meet Angoon's current electric demand plus providing heating for the schools and displacing oil heating in about 100 homes. The project has now reached the stage of 30-70% engineering on all project elements, and the permits, easements, leases and resource plans are nearing completion.

Based on the current design, the hydro project alone is economically roughly break even, enabling renewable energy to displace nearly all diesel-fired electricity in Angoon. But as an integrated hydro and heating program that includes electric heating for the school and high-efficiency heat pumps for the ~100 homes using oil heating, the combined project creates over $27 million in NPV of benefits, with a benefit to cost ratio of 1.85 based on the AEA model developed for analyzing energy projects in SE Alaska.

The two major next steps are to finalize a power sales agreement between Kootznoowoo and IPEC and to finalize the financing needed to begin construction. Construction has been planned to occur in two phases, with the marine facility and the access roads to be completed in the first season and the dam, powerhouse, penstock and transmission line to be completed in the second season. As a design-build project, the final engineering is performed jointly by the engineers and constructors during construction.

VI. **Lessons Learned**

There were a number of lessons learned from this project. These include:

- There were many opportunities where work initially performed under this grant could have been performed at lower cost. This includes substantial work that was performed that is not even required for a low hazard dam (e.g., the ~$750,000 in geotechnical drilling). DOE or AEA guidance to a grantee could be helpful in identifying unnecessary work or costs that appear excessive.
- The value of hydro projects in rural Alaska can be substantially increased by leveraging the renewable energy output displace other high cost energy uses. A key opportunity lies in drastically reducing the electrical distribution costs for small communities like Angoon that pay $0.42/kWh for distribution and related costs. In this location, increasing electric demand from 1.6 million kWh/year to 3.6 million kWh/year through electric heating, results in every customer in Angoon seeing $0.18/kWh (although part of this savings is shared by the State in the form of reduced PCE payments). This assumes IPEC's "postage stamp" rate is not used. But in total, combined annual heating and electrical costs savings are estimated at over $2000-4000/home. This is an enormous economic impact for households where the 30% of the annual gross income of $28,000 is spent on the heating and electricity.
- Bringing together an experienced team of hydro developers, engineers and constructors enables substantial cost savings to be identified during the project design.
- Ongoing communication is important in retaining support and understanding from the key stakeholders including the residents, the tribe, the city council, the USFS and the tribal corporation.