Optimization of Bradley Lake Hydroelectric Project:

Focus on stream and estuary health

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ABSTRACT: The Beauty Bay estuary is located at the head of Kachemak Bay on the Kenai Peninsula in Alaska. Water to the estuary is supplied by the Bradley River, which in turn is controlled by the Bradley Lake hydroelectric dam. Management of the estuary’s health is of key importance in any management plan. The main factor that is under human control is the incoming water flow. Our management plan seeks to optimize the electric output of the Bradley Lake Hydroelectric Facility while still protecting the health of the estuary and river. The estuary management plan was compared to the Klamath River estuary to learn from its management.
**Historical Background**

Traditional hydropower projects encompass lake-taps, run-of-river projects, or less commonly, dammed rivers. In Alaska, hydroelectric power is currently produced to offset peaks in demand and provide baseline power, such as in the winter and spring months. Bradley Lake Hydroelectric, using dammed rivers, is owned and constructed by Alaska Energy Authority, operated to maximum extent by Railbelt Utilities. Exploration into the Bradley Lake power generation potential first began when the U.S Army Corps of Engineers presented a report dated March 1955 (Johnson, 1961). The project was authorized by Congress in 1962, and despite feasibility, remained stagnant due to lack of federal funds for construction.

In 1982, the Alaska Energy Authority (AEA) assumed responsibility for the project. In April 1984, AEA submitted an application for a construction license to the Federal Energy Regulatory Commission (FERC), and the license was subsequently approved and issued on December 31, 1985 (National Parks Service, 1986). Although the hydroelectric power plant is in a critical habitat area, the positive economic benefits were compared to the impact on land in an environmental impact statement report, and the study concluded all federal requirements were met and the dam project was approved (Alaska Power Authority, 1986). In December 1987, AEA and the Railbelt Utilities entered into a Power Sales Agreement to delineate responsibilities. Under the Power Sales Agreement, 100% of the projects capacity has been sold to the power purchasers: Chugach Electric Association Inc. (CEA, 30.4%); Municipality of Anchorage (25.9%); Alaska Electric Generation & Transmission Cooperative, Inc. (25.8%) acting on behalf of Homer Electric Association, Inc. (HEA, 12.0%) and Matanuska Electric Association, Inc. (MEA, 13.8%); Golden Valley Electric Association, Inc. (GVEA, 16.9%);
and City of Seward (1.0%) (AEA, 2011). The general cost per year is 300 million dollars split between state and utilities (CEA, ML&P, GVEA, MEA, HEA, and City of Seward).

Located near Homer, Alaska, Bradley Lake is in the northeast end of Kachemak Bay on the Kenai Peninsula. Construction began in 1986 on the Bradley Lake Hydroelectric Facility and the project became energized in September 1991 (Parvin, 2011). The dam is a rock-filled concrete faced dam, built 125 feet high and 610 feet long. The penstock is concrete-lined 13-foot diameter tunnel through rock, with a length of 18,610 feet. Intake for the penstock is at 1,080 feet elevation and the powerhouse at sea level. The powerhouse is equipped with two 45-megawatt generators. Average annual production is 380 million kilowatt hours at a production cost of four cents per kilowatt (Parvin, 2011). Bradley Lake Hydro Power project provides 10% of the annual Railbelt electric power needs at the lowest generation cost. Bradley Lake is important to the Railbelt electric system during the cold winter months, when demand for both electric power and gas for heat are at their highest. The utilities, if limited during months of low gas pressure periods (winter) are able to use Bradley Lake power to meet the high electric demand of the Kenai Peninsula, and Anchorage Area.

Bradley Lake Hydro Power is separated into three small diversion dams located on Battle Creek, Middle Fork Bradley River, and Upper Nuka River that feed water into the lake. All three diversion dams have various gauges monitored yearly by United States Geological Survey (USGS). The dam is equipped with a bypass valve that releases water into the Bradley River to maintain a FERC-required minimum flow regime to sustain fish habitat. The three streams diverted into the lake are all gauged and record every 15-minutes, stream height, air temperature, and precipitation. Middle Fork Bradley River and Upper Nuka River are equipped with
polyethylene glycol precipitation gauges that measures total liquid precipitation (Parvin, 2011).
The largest stream that flows into the lake is Kachemak Creek, originating from Kachemak Glacier. Kachemak Creek is ungauged, as are many of the small streams that flow into the lake. Homer Electric Association (HEA) operates and maintains the dam, keeps daily records of lake elevation, power generation, and turbine flow for each of the two generators. Bradley Lake is operated onsite by HEA and remotely by Chugach Power.

**Comparison: Klamath River**

The Beauty Bay estuary is at the head of Kachemak Bay on the Kenai Peninsula in Alaska. The estuary supports a variety of life, including salmon, waterfowl, and mammals. Incoming rivers and streams are glacier fed, from several different glaciers. Coho, chum, and pink salmon are common in the estuary, as are sockeye and chinook in fewer numbers. The river is dammed upstream by the Bradley Lake Dam. Needless to say, management of the estuary depends directly on the hydroelectric dam and management of it. Proposed changes to the area include diverting more water to Bradley Lake and through the dam, which would impact the estuary. The electricity of the dam is a valuable resource and power generation must be managed to preserve the affected estuary. River dams affect flooding, saltwater intrusion, and water temperature (Weitkamp, 1994).

A comparable river system and estuary in southwestern Oregon and northern California is the Klamath River. The Klamath River flows for 240 miles before emptying into the Pacific Ocean. It is dammed eight times along its length, for both hydroelectric and irrigation purposes. The seven hydroelectric dams generate a total of 169 megawatts of electricity. Environmentalists, natives, commercial fishermen, and farmers have all appealed to authorities
to remove dams to improve habitat and water availability. Currently there is a plan in place to dismantle four dams, taking effect after 2020. The dams scheduled for removal account for 163 of the 169 megawatts produced by the river system. Removal of these dams brings up concerns about sediment. Concerns about the health of the wetlands in the Klamath River Estuary (KRE) has been a large factor in the proposed dam removals. Wetlands serve as vital habitat to an array of migrating and resident waterfowl.

“Klamath and Siskiyou mountains make coastal wetlands an integral part of the pacific flyway. Wetland habitats located in or near the KRE are considered regionally important. The endangered Willow Flycatcher is one of many bird species that inhabit the KRE wetlands. Wetlands located near the KRE are the only documented breeding sites for wood ducks within Redwood National and State Parks (RNSP 2004). The Great Blue Heron bones and Mallard feathers are traditionally used in Yurok ceremony, and these species are regarded with high cultural significance. Waterfowl have forever been a supplemental food source for the Yurok People. Waterfowl also provide the public recreational values such as hunting and bird watching. In addition, the health of the Klamath River fishery is vital to the survival of the Yurok People and their way of life. Since time immemorial, the Yurok People have subsisted on the resources readily available in the Klamath River Basin. The primary protein source for Yurok people is fish, which formerly filled the river during regular seasonal runs. Anthropogenic activities over the past century have resulted in substantial declines to Klamath River fish runs and drastically altered or degraded associated habitats. Man-made dams and water diversions in the upper basin and diversions in several major tributaries have significantly reduced Klamath River flows and drastically altered its natural hydrograph. The combination of altered flows, increased sediment delivery rates, and a reduction in quantity and quality of tributary, off-estuary wetlands, and
slough habitats, has greatly impacted the productivity of the KRE.” (Patterson, 2009)

In contrast, the Bradley Lake area has never had a native population or cultural significance. Both estuaries have salmonid populations that are of key concern in management plans. The Beauty Bay estuary salmon populations are not specifically targeted by any commercial fishing activities, whereas the Klamath River Estuary salmon populations are the target of a large commercial fishing operation. The only factor impacting the flow to the estuary is the Bradley Lake Dam and its regulation in relation to power use. The Klamath River also supplies irrigation water to farms along its length, and significant water is lost to irrigation. The Klamath River and estuary are a large tourist attraction, with 20 recreation sites managed by the Bureau of Land Management (BLM) along its length. The Beauty Bay estuary and Bradley River have no recreational or tourist attractions.

Management Plan

Bradley Lake dam performs as a source of supplementary energy for the Railbelt, providing about 5-10% of the annual energy needs. Bradley Lake Dam power is most important to the Railbelt during winter, when there is a high need for electricity and gas for heating (AEA, 2011). Our planned management is to increase the efficiency of energy production in a way that takes into consideration environmental factors and the health of the estuary. Our goals are to establish a strategy for the dam to perform at optimal efficiency, increase monitoring, and initiate water quality observations. Further encouraging cooperation between private industry, academia, and governmental agencies could leverage resources.

**Goal : Optimization**
Currently Bradley Lake provides energy on an as-needed basis to supplement other power sources on the Railbelt. Most of this energy is needed in the winter, when inflow to Bradley Lake is at its lowest point. This method is inefficient as it does not allow for the lake to reach a high elevation. The average maximum elevation of Bradley Lake from 1991-2010 was 1,138-1,181 feet while the average minimum was 1,087-1,128 feet. The variability of the elevation suggests the lack of a water management system (Parvin, 2011). Parvin suggests using a rule-curve to maintain optimal pool elevations. A rule-curve is an established guide to regulate and manage optimum pool elevations (U.S. Army Corps of Engineers, n.d.). Using a rule-curve sacrifices the production of energy for a period of time to increase the elevation (head) of the reservoir. The amount of energy produced from a head of 1,180 feet is 7.3% higher than the amount produced from 1,100 feet. This creates a problem as the most power needed is drawn from the dam during the winter when the water flow is the lowest. The solution is to suspend energy production for periods of time during the spring, summer and fall, helping to produce maximum power efficiently. The break-up of spring, melting of glaciers in summer, and rains of fall can all contribute to fill the reservoir. To maximize energy production for the winter months will require water levels to be drawn from their highest to lowest points and with full reservoirs from the previous months this can be achieved. Suspending energy production is not entirely suspending flow as the FERC requires a minimum flow of 40 ft^3/s in winter and 100 ft^3/s in summer of Bradley River to sustain fish habitat.

**Goal: Increased Monitoring**

To maintain the required minimum flow along with monitor stream health multiple agencies have place gauges in the Bradley Lake Basin. The United States Department
of Agriculture (USDA) maintains three snow telemetry gauges in the basin, measuring snow depth, precipitation, and air temperature. USGS has gauges on the three diverted streams along with one on Bradley River above tidewater (figure X). These gauges record height values, air temperature, and precipitation every 15 minutes. HEA keeps daily records of lake elevation, power generation, and turbine flow.

![Figure X. Location of current stream monitoring gauges. (Rickman, 1996).](image)

For the possibility of optimization through suspension of flow to be effective and beneficial to the streams and the estuary, more gauges should be placed in strategic locations and the data collected from these gauges to be used to create a model of the seasonal changes of flow to and from Bradley Lake and into the estuary. Some possible locations for gauges are at the head of Kachemak Creek, along North Fork Bradley River, and the entrance of Kachemak Creek.
into Bradley Lake. Using these gauges along with ones previously in place, a computerized predictive model could be developed. The importance of seasonal flow is that over the year different forces are put on the river, increasing and decreasing flow.

**Goal: Initiate water quality testing**

Are the current FERC requirements all fishes need for habitat? Flow is not the only factor in a healthy habitat. Salmon along with other fish species, need certain water qualities to successfully thrive and spawn. Suspending flow (even if still complying to FERC standards) will likely lead to changes in the estuarine environment downstream. The water qualities needed by fish include dissolved oxygen, pH, turbidity, and water temperature. Without these, problems can arise with egg fertility and larval survival. Turbidity, the amount of suspended sediments, when high can lead to the smothering of eggs and cause suffocation of juvenile fish. Dissolved oxygen (DO) and water temperature are directly linked. The colder the water the more oxygen it will hold. An environment low in dissolved oxygen is unhealthy for any fish, especially juveniles plus if water is too warm eggs will die, too cold and the water may freeze solid. As previously mentioned there are seasonal forces put upon the river. Not converting these forces through the release of water affects water quality, leading to, if not monitored, an unhealthy estuary and stream. The private industry, AEA in this case, is in control of this flow, the release of water. In order to maintain the health of the streams and their estuary the private industry must work along with scientists, using research and studies to guide the release of water. The private industry working towards optimization and the scientists studying and communicating the effects doing so could have on the streams and estuary.
Past/current Research

Many studies were done before Bradley Lake Dam was installed. This started with the Army Corps studies of the possibility of a dam on Bradley Lake. Many environmental impact studies were also conducted. Feasibility studies were supervised by Stone & Webster Engineering Co., including descriptions of the locale report on water use and quality, reports on aquatic botanical and wildlife resources, geological and soil resources, recreational and aesthetic resources, and land use. Before the project could be approved the impact on the land compared to the economic benefits had to be calculated; this came out in Bradley Lake Hydroelectric Project economic impact statement.

The area surrounding the Bradley Lake hydroelectric dam is to be managed primarily as a power site consistent with FERC license requirements. The management intent here is also to accommodate recreation (particularly at the designated campsites) and public access where the security of the power project, public safety, and liability are not significantly at risk. The area around the dam will also be managed for wildlife habitat and harvest.

In 1986, the Alaska Power Authority and the Federal Regulatory Commission accepted a 168 page paper submitted by Stone and Webster Engineering Corporation for a Middle Fork diversion overland access assessment Bradley Lake Hydroelectric Project. This paper included baseline research on water use and quality, botanical resources, wildlife resources, historic and archaeological resources and visual resources each with baseline descriptions, project impacts and mitigation measures. Erosion and sediment control were a few of the other data included in this assessment paper.

The soil in the area is wet and drains poorly. Baseline description says there are clear water streams fed by surface runoff and groundwater that enter Bradley Lake on the North
Eastern Shoreline and no ice rich permafrost is been identified in the area. Streams are generally inconspicuous, glacier fed and meandering as they cross outwash plains. Suspended solids from glacial action impart a milky cast to streams and lake waters (AEA, 1986).

Baseline research shows major mammals species including moose, mountain goats, black and brown bear in areas surrounding Bradley Lake. Population of 5 to 15 moose to the West End of Bradley Lake, population of 65 mountain goats in the project area, goats disperse summer and concentrate during winter. Goats have been historical harvested for sport in the area. (AEA, 1986)

Starting research on terrain to list all common vegetation in the area including Sitka Alder *Alnus sinuate*, salmonberry (*Rubus spectabilis*) mountain ash (*Sorbus sitchenensis*) as well as bluejoint grass, horsetail, ferns, fireweed, false hellebore and layers of dead herbaceous material. Historic and archaeological resources stated there were no cultural resources at or around Bradley Lake. Apart from one USGS structure at the head of Bradley Lake there were no visually evident features which had been introduced by man into the Bradley Lake basin prior to the Project. Based upon rating standards scenic qualities the Bradley Lake basin is judged to be a class B area. (AEA, 1986)

The assessment paper stated that impacts will be minimized by limiting the disturbance of vegetation by erosion with the use of erosion control blankets and cross stitching before construction and remain in place following construction. Mixtures of native plants were broadcast according to research to reduce disturbances in the ecosystem due to erosion. National Marine Fisheries Service (NMFS) Habitat Conservation division Hydropower programs review states research has been done on hydro dams to ensure compliance with the Federal Energy
Regulatory Commission. NMFS is the agency throughout the licensing process providing terms and conditions to protect mitigate damage to, enhance fish and wildlife habitat affected by hydropower construction and operation before the dam was created. Federal Power Act provides the authority to NMFS protect the ecosystems by recommending license terms; this agency also has responsibilities to the Clean Water Act, the endangered Species Act, the Marine Mammal Protection Act and the Magnuson –Stevens Fishery Conservation and Management Act. (NMFS, 2012)

Before Bradley Lake Hydroelectric facility can be expanded there should be research carried out on the effects of water diversion on upstream animals, plants and terrain. As well as the effects on downstream ecosystem and altered water flow rates on habitat. Computer models of the effects are encouraged to reduce negative impacts and prevent unknown consequences. All expansions or future projects relating to hydropower in the vicinity of Bradley Lake need to be in compliance with all federal, state and local regulations. Bradley Lake water enters the critical habitat of Kachemak Bay necessitating research on contaminants and impacts of altered water temperatures through the process of creating energy.

Future Research

The available reservoir for Bradley Lake power generation is dependent upon seasonal precipitation of rainfall and snowmelt. Additionally two glaciers, Nuka and Kachemak, feed the system. Long term awareness of how climate change affects these sources is instrumental to the ongoing success of utilizing this resource.

Climate change theory suggests that glacier are receding and eventually disappear. However on the ground research (Fleming and Weber, 2012) suggests long-term reservoir inflow
changes expected on physical grounds or suggested by modeling studies do not materialize or are weak— for example, there is little evidence for springtime freshet inflow decreases at south coastal hybrid-regime hydroelectric projects, and only a weak pattern of late-summer flow decreases in glacial rivers. It may actually be the case that warming trends create heavier and more extended periods of fall rains and additional glacial melt in the summer result in available water resources that more closely fit the demand and need for this system. Even so research specifically investigating Bradley Lake Hydroelectric is necessary because if one needs to know how inflow to a given hydroelectric reservoir has been responding to historical climatic shifts, ideally one should specifically study that system.

**Conclusion**

The Bradley Lake Hydroelectric Project puts in place high standards for other dams around Alaska. The dam has been successful in creating supplementary energy for the Railbelt that is cheap and clean. Bradley Lake’s remote location means that there are few complications with agriculture or other human activities. As opposed to the Klamath River in Oregon which not only provides energy but is also diverted to provide water for irrigation. Problems have arisen on the Klamath because these uses have led to salmon die offs, sparking discussion of removing dams for the salmons sake. The only current use of Bradley Lake Hydroelectric is for clean energy.

The power created by Bradley Lake Dam is distributed through the Railbelt, carrying energy from Homer to the Matanuska Valley. Bradley Lake Dam runs on an as-needed basis currently, mostly providing energy during the winter when more energy is needed. This method, as needed, is inefficient however. When a reservoir is drawn from its highest to its lowest point it
creates the most energy, and therefore very efficient. Because Bradley Lake is drawn upon whenever its needed it is never drawn from its highest point. Bradley Lake is for the most part drawn upon in winter, when flow into Bradley Lake is at its lowest point. To optimize energy production energy production should be suspended during the summer, spring, and fall to allow the reservoir to fill up.

There are possible repercussions of suspending flow however and further research is needed. Suspending energy production during the spring for example, during break up. This is the time the reservoir would fill up the most however suspending flow would limit the nutrients and sediments flowing downstream past the dam. The current FERC requirements may not be enough either, flow isn’t the only thing estuarine environments need. Nutrients are washed downstream during the summer, water may warm over the summer in the reservoir, warming the estuary. Both of these having effects on fish habitat. There needs to be cooperation between the scientists and the dam operators. Gauges have been placed on many streams flowing in and out of Bradley Lake, some ran by HEA others by USGS. The flow may change in the coming years do climate change and with these changes so will changes need to arise in the dam operation.

The only way these changes can be effective is if the scientists and the dam operators are communicating. For optimization to be both effective and have little effect on the estuary the scientists and dam operators need to work together. Maintaining the health of the Beauty Bay estuary and the streams feeding hinges on the cooperation of the AEA and the scientific entities conducting research on Bradley Lake, USGS, National Parks Service, and NMFS among others. The goal to optimize Bradley Lake Hydropower needs to look beyond purely economic motivation and focus on the best practices, fully informed by research in keeping the health of the estuary and its streams.
Works Cited:


PacifiCorp, 2011. Klamath River hydroelectric project.

Parvin, E. 2011. Optimization of Bradley Lake hydropower using lake elevation rule curve modeling. (Master’s Thesis)


Weitkamp, L. A review of the effects of dams on the Columbia River estuarine environment, with special reference to salmonoids.