Modified PSH Concept with Wind & Solar at Eklutna Lake with River Restoration and Fish Passage

Municipality of Anchorage

Anchorage Hydropower Utility

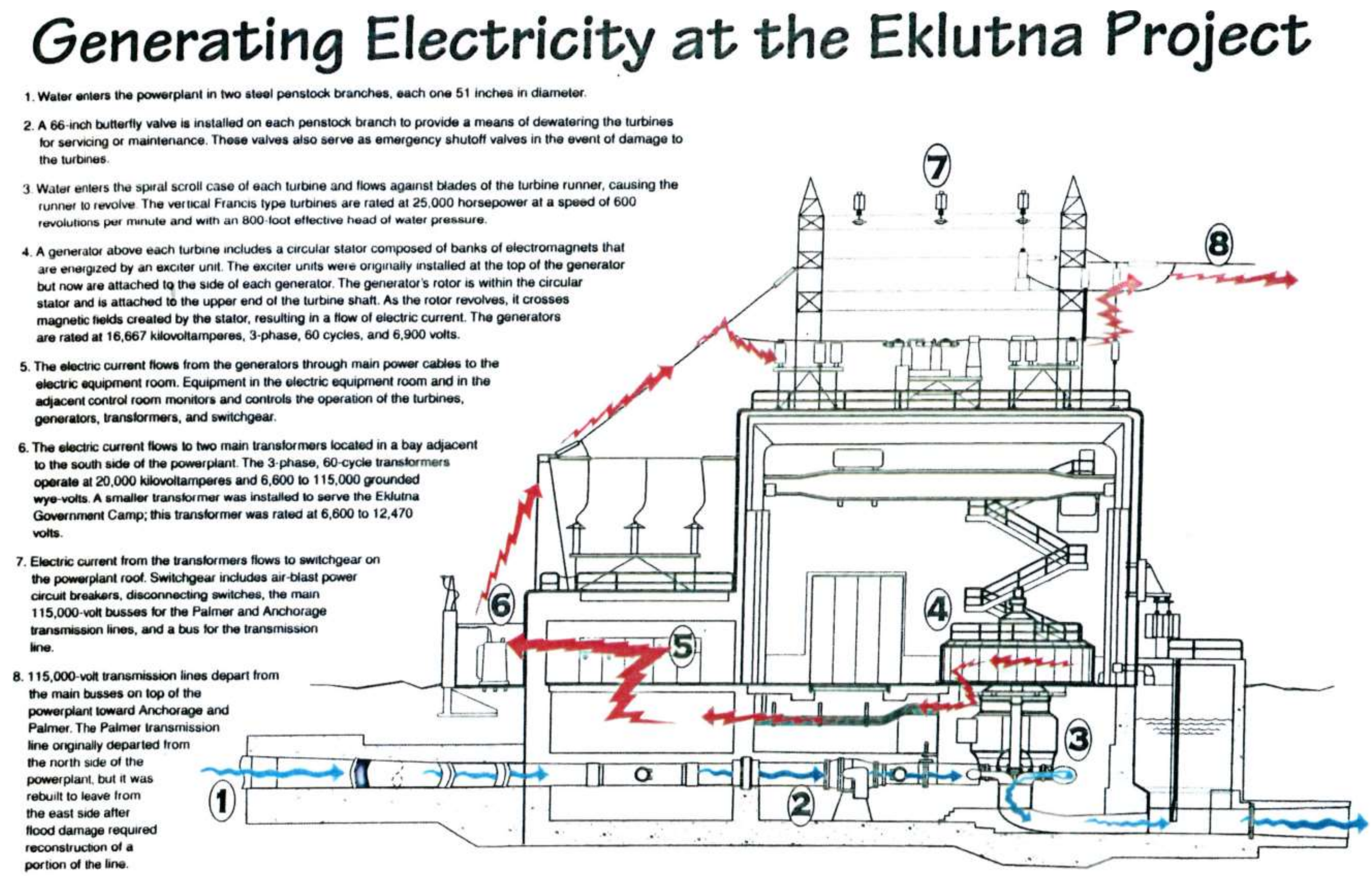
Presentation to the Joint Worksession of the Anchorage Assembly and the Native Village of Eklutna

Friday August 23, 2024

1pm Conf 155 City Hall

Presentation Topics/Goals:

- Eklutna Water Resource Background
- What is PSH?
- Why PSH?
- Preliminary Eklutna Reservoir Baseline Analysis
- Variations (there are numerous variations of PSH at Eklutna that can be considered)
- Disclaimers (many assumptions have taken place and much vetting and analysis is needed)
- We are looking for feedback to determine if this is worth evaluating and pursuing any further as part of proposed 2-year pre-implementation period



Existing/Current Setup:

Eklutna Lake currently feeds hydropower & municipal public water supply, but it is not providing downstream river flows or fish passage

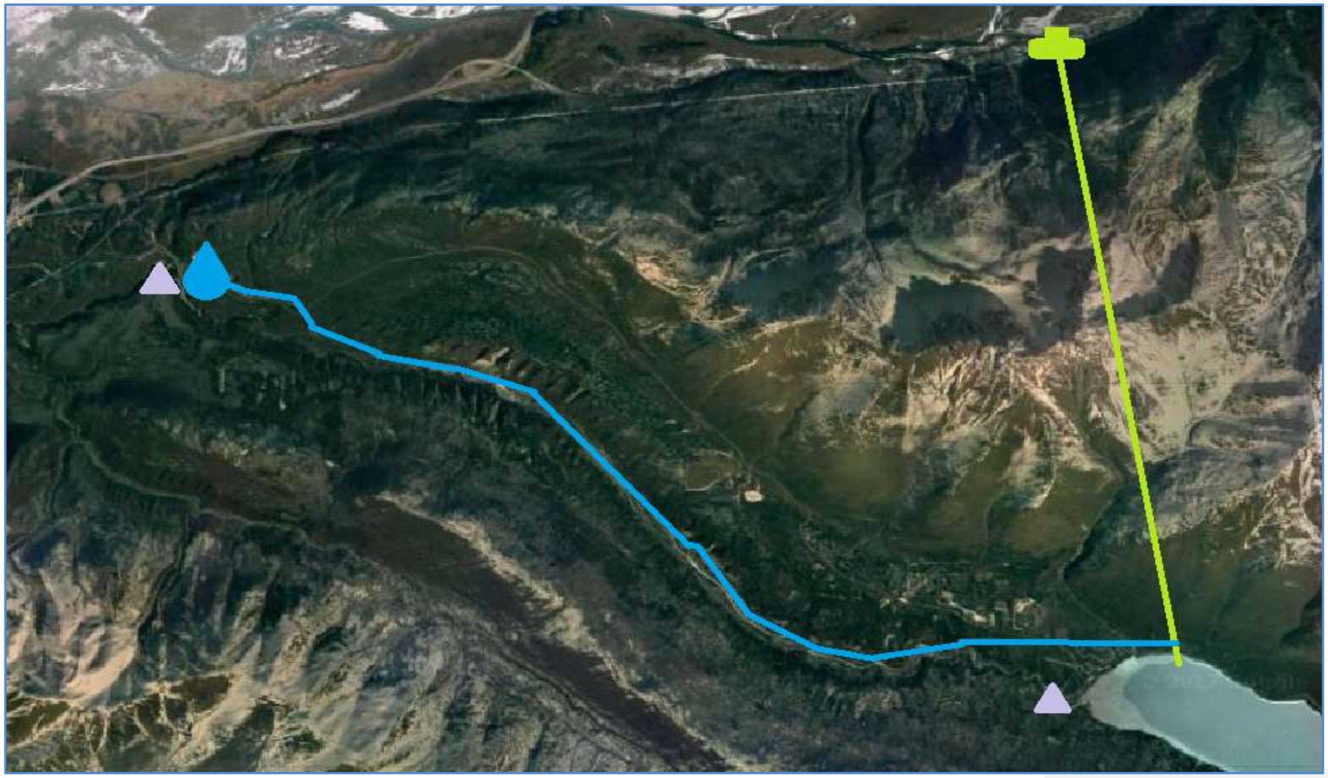


Table 2. 2022 Railbelt Utility Generation Mix[8]

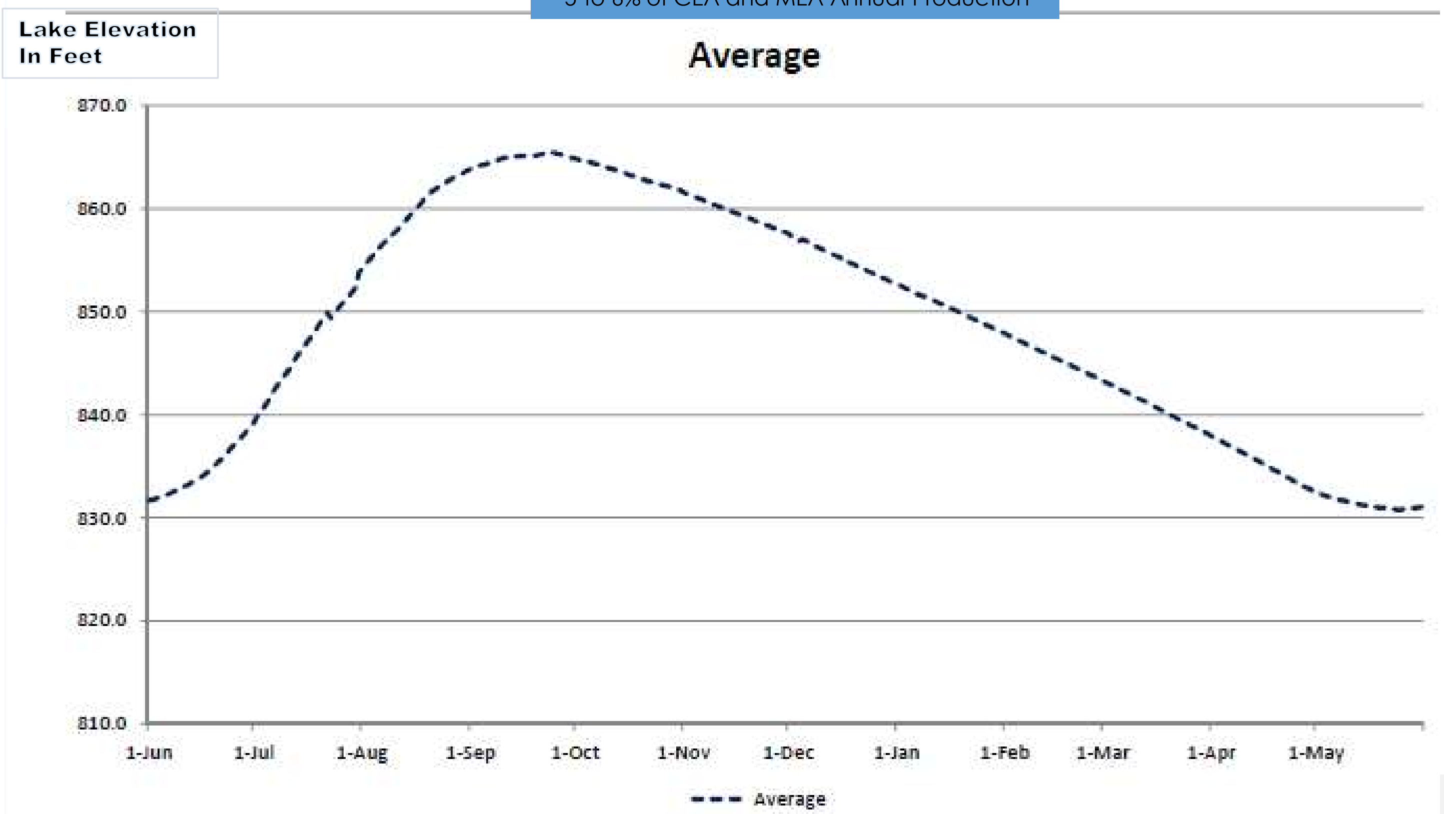
Technology	Capacity (MW)	Energy (GWh)	Generation Fraction
Natural gas	1,332.6	3,052	64%
Coal	117.5	545	11%
Oil	268.9	444	9%
Hydropower	189.8	578	12%
Wind	44.5	107	2%
Landfill gas	11.5	41	1%
Total	**1,965**	**4,766**	**100%**

Utility	Annual Sales (GWh)	Customer Accounts (thousands)	Fraction of Railbelt Annual Demand (%)
Chugach Electric Association	1,903	113	43
Golden Valley Electric Association	1,244	48	28
Matanuska Electric Association	766	69	17
Homer Electric Association	453	33	10
City of Seward Electric Department	53	3	1
Total[b]	**4,404**	**266**	**100**

[a] "Annual Electric Power Industry Report, Form EIA-861 detailed data files." EIA,

Existing/Current Operations:
Eklutna Lake level varies by @ 40 feet seasonally
Approx 250k acre-ft/year water diverted for Power*
Approx 163 GW-hr/year Power Produced**

**5 to 6% of CEA and MEA Annual Production



WY1718	ACRE-FT	CALC MWH
JUN	37,084	24,105
JUL	66,598	43,289
AUG	54,582	35,478
SEP	40,127	26,082
OCT	16,759	10,894
NOV	6,676	4,340
DEC	6,275	4,079
JAN	5,222	3,395
FEB	3,736	2,428
MAR	3,165	2,057
APR	2,704	1,758
MAY	8,639	5,616
TOTALS	251,569	163,520

Table 2-1. Default Year-Round Instream Flow Regime.

Month	Flow (cfs)	Volume (acre-feet)
January	27	1,660
February	27	1,500
March	27	1,660
April	27	1,607
May	34	2,060
June	40	2,380
July	40	2,460
August	40	2,460
September	40	2,380
October	40	2,460
November	34	1,993
December	27	1,660
Total	-	24,280

*Another @25k acre-ft/year diverted for Municipal Water Use

*25k acre-ft/year proposed for year-round instream flows by Hydro Owners Proposed Final F&W Program

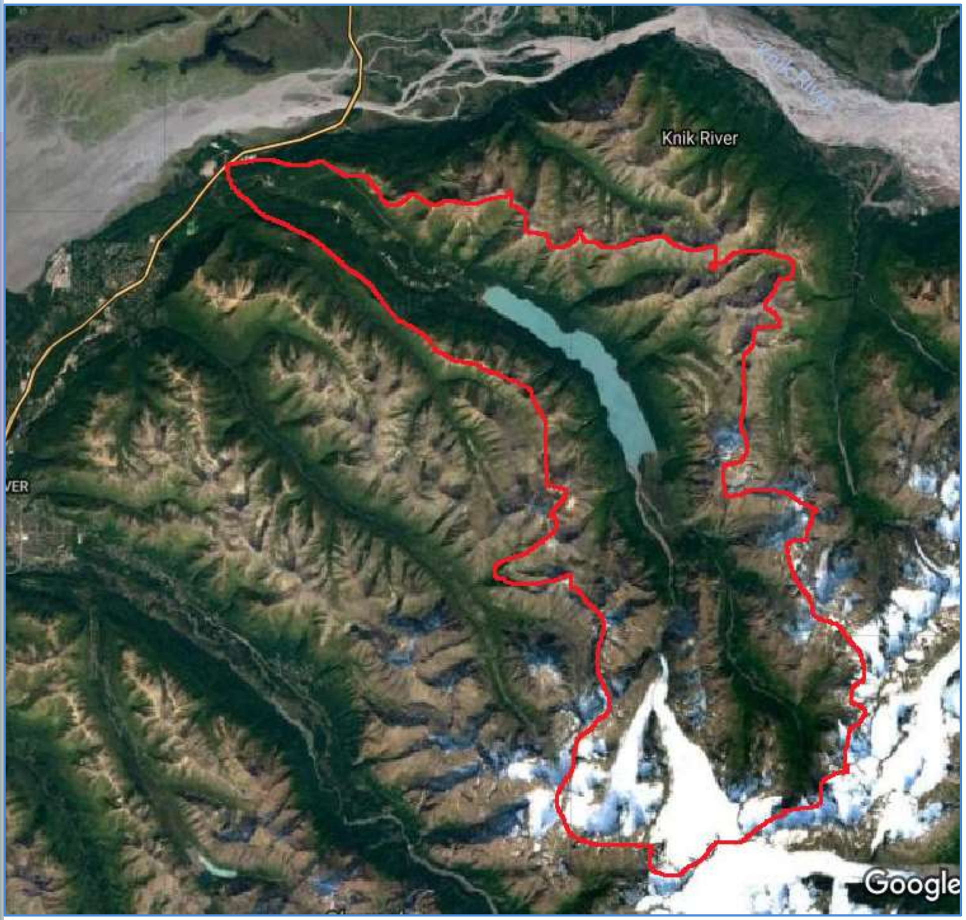
Water is a shared resource and the identified competing interests for the *limited* water at Eklutna Lake are:

- Power Generation
- Municipal Water Supply
- Instream River Flows

Photo 14: General view of the natural bypass channel at

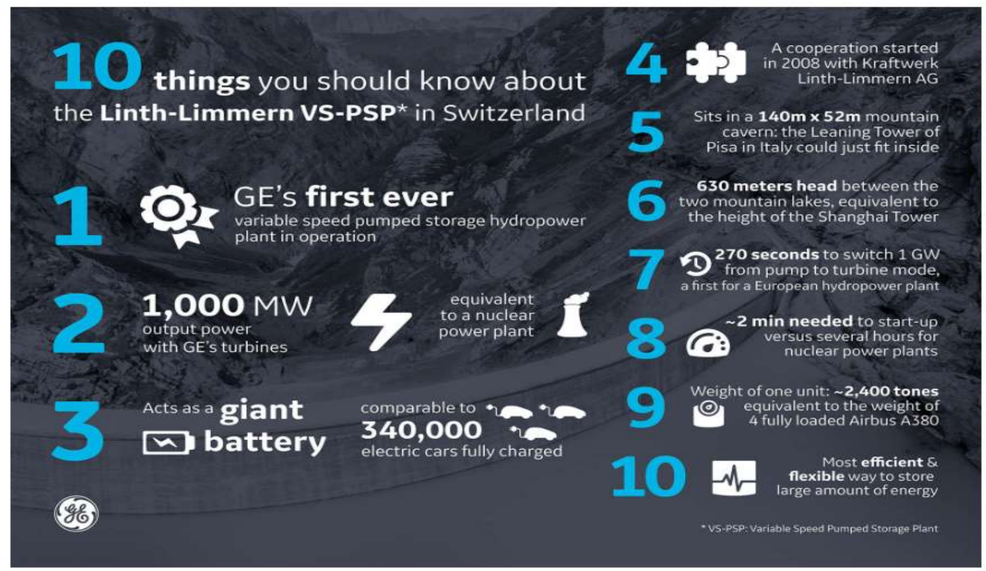
- How do we achieve a fair balance with the limited water that is recharged in Eklutna Lake annually?
- **What if we could add more water to maintain or improve existing power production, meet municipal water supply needs and provide full instream river flows with a river connection to Eklutna Lake for fish passage?**

We recognize that Eklutna watershed goes from glaciers to tidewater; as does the Knik River watershed; watersheds are adjacent to one another, both have large glacial lakes, and water quality is *likely* very similar; this begs the question, can pumped storage hydro (PSH) be analyzed in 'another' way to utilize existing infrastructure and additional supplemental water?



"Unlike batteries, PHS absorbs all that excess energy from renewables, which avoids waste, and then it gives you long-term, reliable and flexible power dispatch," he adds. Engineers at GE Renewable Energy built pumpec storage units for a massive project in Linthal, Switzerland. It is capable of quickly producing or absorbing 1 gigawatt (1,000 MW) of power, while storing up to 34 GWh of energy. "You cannot reasonably do that with traditional battery storage," Alex Schwery, chief consulting engineer at GE Renewable Energy's Hydro Power unit, told GE Reports. "It doesn't work."

Building a battery on top of the Alps is certainly extreme engineering. But there are few other options now. The scale and penetration of renewables on the grid makes smoothing over intermittency a herculean challenge.

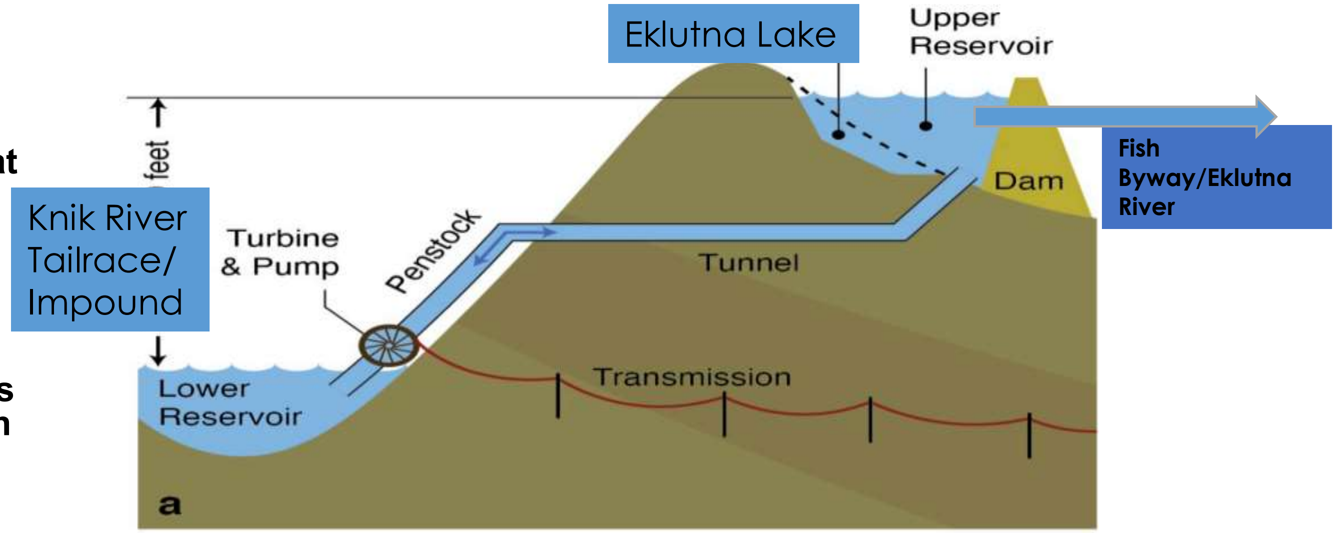


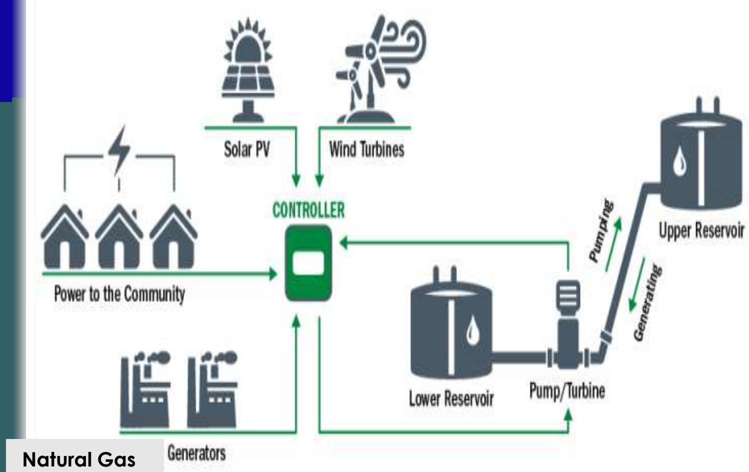
Infographic credit: GE Renewable Energy.

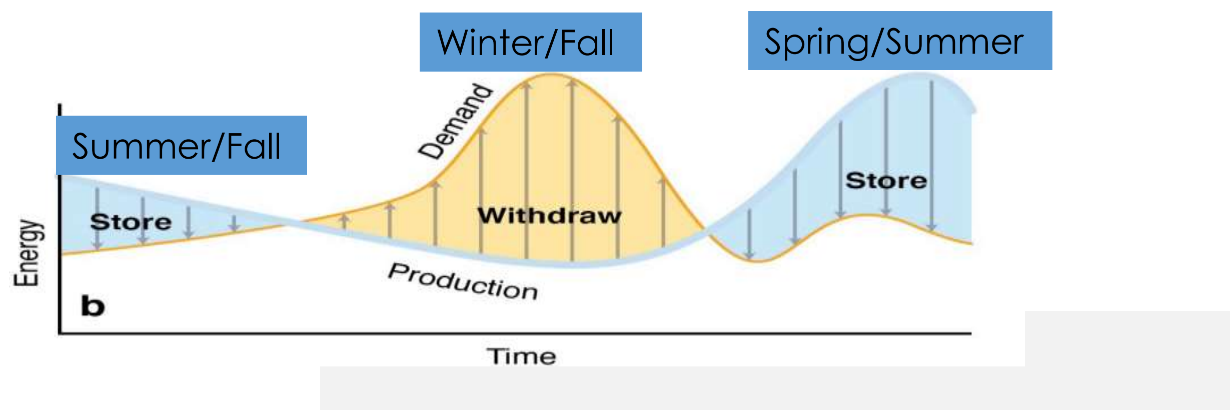
What is Pumped Storage Hydro?

- Pumped Storage Hydro (PSH)
  - **Proven natural large scale energy storage solution* used worldwide that provides carbon free power production, storage and grid stabilization**
  - **aka Pumped Energy Storage (PES) and Pumped Hydro Storage (PHS)**
  - **The Eklutna Concept proposed builds upon and is a variation and extension of a prior proposed PSH idea**

***PSH is the bulk current energy storage capacity in the US (Hydrowires USDOE)**







Why PSH? As we contemplate the fact that Southcentral AK is in a natural gas crisis with expensive imported natural gas for heat and power expected by 2028

- First, we recognize the following:
- Electric rates will increase; estimates range from 10 to 50% (fuel is @25% of CEA and @50% of MEA rates)
- Natural gas/heating rates will increase more than electric rates (fuel is @85% of gas bill)
- @80% of railbelt electricity comes from natural gas turbine generators; very little wind or solar
- Solar & Wind are fuel free and are eligible for ITC and PTC, but are not reliably dispatchable without storage solutions (batteries*, hydro) *batteries only provide short term storage, typically only hours

Alaska regulators back Enstar's plan to build $57 million pipeline to import natural gas

By Alex DeMarban
Updated: 1 day ago
Published: 1 day ago

Hilcorp warns Alaska utilities about uncertain Cook Inlet natural gas supplies

By Alex DeMarban
Updated: May 17, 2022
Published: May 17, 2022

Investment Tax Credit and Production Tax Credit

The Investment Tax Credit (ITC) and Production Tax Credit (PTC) allow taxpayers to deduct a percentage of the cost of renewable energy systems from their federal taxes. These credits are available to taxable businesses entities and certain tax-exempt entities eligible for direct payment of tax credits (see Tax Credit Monetization below).

Certain projects are eligible for either the ITC or PTC, but not both.

Eligible for ITC or PTC	Eligible for ITC	Eligible for PTC
multiple solar and wind technologies, municipal solid waste, geothermal (electric), and tidal	energy storage technologies, microgrid controllers, fuel cells, geothermal (heat pump and direct use), combined heat & power, microturbines, and interconnection costs	biomass, landfill gas, hydroelectric, marine and hydrokinetic

Through at least 2025, the Inflation Reduction Act extends the Investment Tax Credit (ITC) of 30% and Production Tax Credit (PTC) of $0.0275/kWh (2023 value), as long as projects meet prevailing wage & apprenticeship requirements for projects over 1 MW AC.

Why Pumped Storage Hydro?

- Pumped Storage Hydro
  - **Complements fuel free renewable power and can store weeks/months of spring/summer power for peak winter demand when wind/solar unavailable, offsetting natural gas demand**
  - **Balances wind output variability and solar seasonality and maximize their benefit by generating artificial demand, that has a critical and delayed beneficial use**
  - **Can maintain higher lake level for increased hydro efficiency and power production**
  - **AND can provide river/lake connectivity for full fish passage and all 12 miles of river restoration**
  - **Existing infrastructure is in place for initial phase keeping costs low**
  - **Scalable; allows for future build out and benefit if energy conditions change**

Table B-5. Existing Railbelt Renewable Generators

Name	Nameplate Capacity (MW)	Type
Fire Island Wind	18	Wind
Eva Creek Wind	24.6	Wind
Delta Wind Farm	1.9	Wind
JBER	11.5	LFG
Willow Solar	1	Solar
Houston Solar	6 (8.5 DC Rating)	Solar

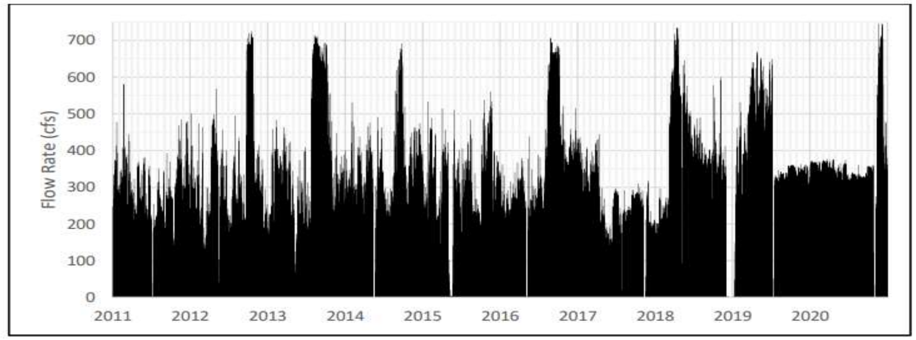


Figure 4.4-1. Daily Flow Rate (Total) to Eklutna Power Plant; 2011-2021.

Table 4.3-2. Eklutna Turbine Hill Curve.

Flow Rate (cfs)	Net Head (ft) 650	668	686	705	723	741	759	777	795	814	832	850
0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
40	35.8%	36.4%	36.7%	37.5%	38.0%	38.3%	38.5%	38.8%	38.8%	39.1%	39.4%	39.9%
80	66.3%	66.5%	66.5%	66.6%	66.6%	66.5%	66.5%	66.4%	66.3%	66.2%	65.9%	65.7%
120	78.5%	78.5%	78.6%	78.5%	78.5%	78.5%	78.3%	78.2%	78.0%	77.8%	77.6%	77.1%
160	85.0%	85.2%	85.2%	85.3%	85.3%	85.2%	85.1%	85.0%	84.9%	84.7%	84.5%	84.0%
200	88.5%	88.7%	88.8%	89.1%	89.1%	89.1%	89.1%	89.1%	89.0%	88.9%	88.7%	88.3%
240	89.7%	90.1%	90.4%	90.9%	91.0%	91.1%	91.1%	91.1%	91.1%	91.0%	91.0%	90.7%
280	89.4%	90.0%	90.5%	91.1%	91.4%	91.5%	91.6%	91.7%	91.8%	91.8%	91.7%	91.6%
320	88.0%	88.4%	88.8%	89.7%	90.0%	90.4%	90.7%	91.0%	91.2%	91.4%	91.5%	91.5%
360	88.0%	88.4%	88.8%	89.3%	89.5%	89.7%	89.9%	90.0%	90.1%	90.1%	90.1%	90.0%
400	88.0%	88.4%	88.8%	89.3%	89.5%	89.7%	89.9%	90.0%	90.1%	90.1%	90.1%	90.0%

The Eklutna Battery

BY CRAIGMEDRED ON MARCH 9, 2018 • (31 COMMENTS)

Graphic courtesy AlaskansKnowClimateChange.com

If Alaska was Switzerland, the natural equivalent of a giant, rechargeable battery able to provide renewable power for the state's largest city forever would likely be up and running in the Chugach Mountains above Eklutna by now.

Switzerland switched on its most powerful "green battery" in the Linthal Valley four years ago. Even before that project was complete, Norway saw the potential to combine wind, solar and hydropower into contained, rechargeable systems and began trying to position itself to become the green battery for all of Europe.

The workings of these systems that have come to be called green-batteries are fundamentally simple: Renewable energy that would otherwise go to waste is used to pump water uphill where it is stored for future use as hydropower.

If wind turbines or solar panels are producing more power than can be used in the moment, the extra energy is shifted to pumps that move water from lower elevation reservoirs to higher elevation reservoirs. If water is spinning through hydro turbines when electric demand is low, as often happens, the excess power is shunted away to pump water back uphill and store it.

PSH is not a new Concept at Eklutna:

Integrating Renewables to the Grid with Closed Loop pumped storage hydro (PSH) has been considered at Eklutna, but it was dismissed because it not well understood as it was perceived to require new and very expensive infrastructure*, and it didn't appear to offer additional water or provide downstream river flows

***in the billions of dollars**

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Pumped Hydro Storage

ENABLING THE ENERGY TRANSITION

Centralized synchronous plants will be less dominant in the future energy mix and with the massive penetration of intermittent renewables such as wind and solar and their impact on the grid reliability is huge. Supply of energy is variable and services to maintain voltage or frequency of the grid cannot be met by inverter-based resources.

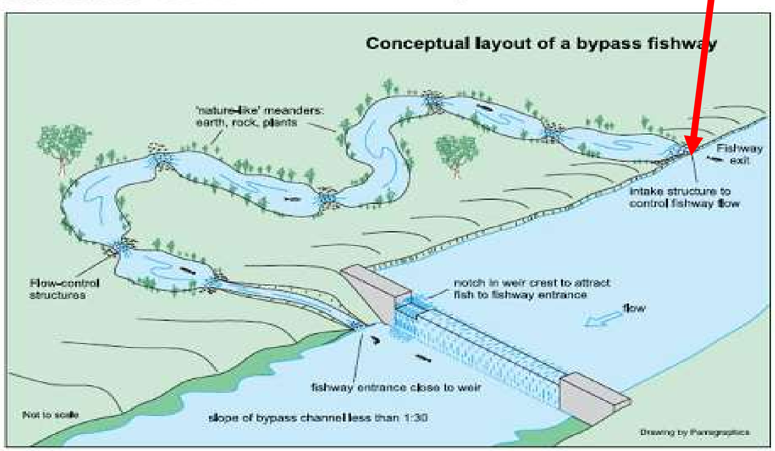
Hydropower can play a defining role in the energy transition thanks to the balancing and system services to the grid that facilitate the integration of variable renewables.

With higher needs for storage and grid support services, Pumped Hydro Storage is the natural large-scale energy storage solution. It provides all services from reactive power support to frequency control, synchronous or virtual inertia and black-start capabilities. It brings support that was previously managed by fossil-fueled power plants but with even more reactivity and in a sustainable manner without CO_2 emissions.

For years, Pumped Hydro Storage has offered a cost-effective way to provide reliable large-scale balancing and grid services. New pumped hydro storage technologies—such as variable speed capability—give plant owners even more flexibility by providing grid

This Proposal Modifies and Scales Back the Original Concept:
Eklutna Lake & Knik River offer an opportunity for an Open Looped PSH System backed by Renewable Wind & Solar with Fish Passage

Photo 15: Natural bypass channel for salmonids on the river Loue (Chatillon sur



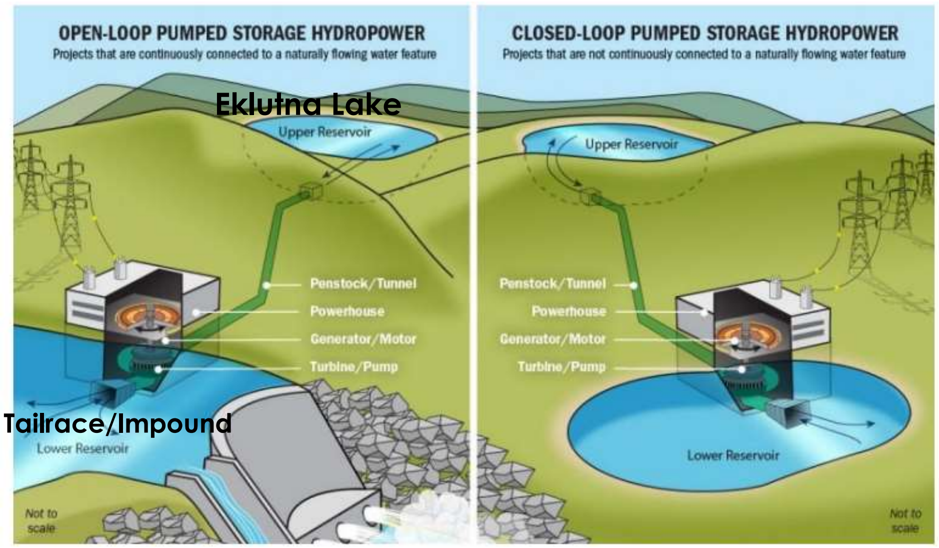


Figure 4-7 Illustration of Open-loop and Closed-loop PSH Systems (Source: DOE, undated)

For a small-scale PSH projects, a common approach is to install independent pump and generato sets, rather than customized, reversible pump-turbines. Such sets allow systems operators to use off-the-shelf components and scale them by increasing or decreasing the number of sets installed to reduce equipment costs. Scaling the size and number of pump and generator sets can also allow for greater control of the rate of pumping into the upper reservoir.

Certain conventional hydroelectric plants can be converted to pumped storage plants, known as pump-back PSH plants. This conversion adds separate pumps or reversible turbines to allow water to be moved from a lower reservoir back to an upper reservoir. Water can be pumped back during periods of low energy demand when excess energy from wind and/or solar generation is available. This approach reduces the need for curtailment of variable wind/solar generation and can conserve water in the upper reservoir, which can be important during dry seasons or periods of high energy demand and when there is not much wind/solar energy available.

Lake Outlet Reference Elevations, Bypass Fishway Concept

Eklutna Pond Gate Operates 860 to 870 when lake connects with pond
Eklutna Lake Gate operates from 850 to 870 but preferred and only route between 850 to 860 when lake is not connected to pond

Eklutna Hydroelectric Project
1991 Fish & Wildlife Agreement Implementation
Draft Study Plans

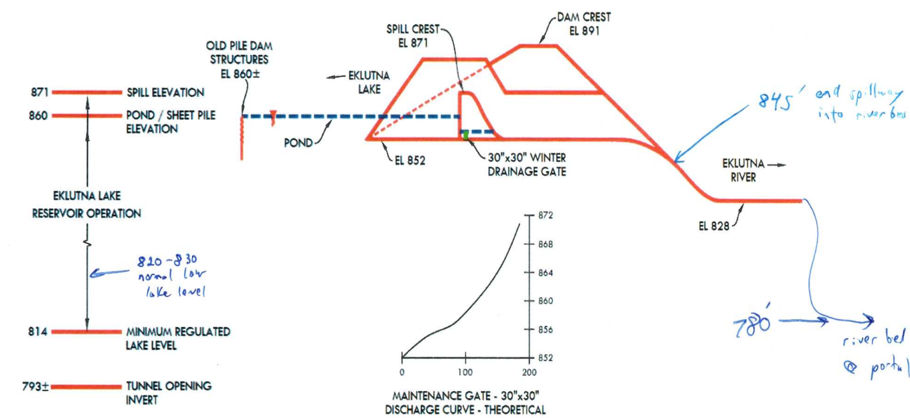


Figure 2-6. Profile of Project Dam and Spillway, Critical Elevations, and Drainage Gate Discharge Curve

In Summary:

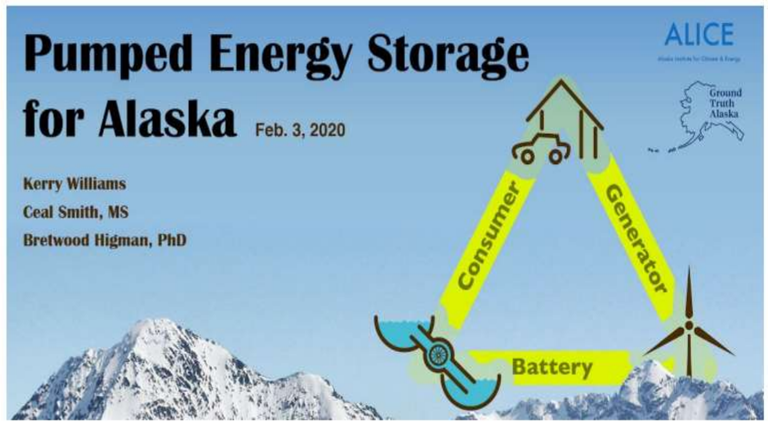
PSH/PES/PHS is a tried, trued, and sustainable energy practice and is backed by a statewide study and by others including historically by the Governor

HydroWIRES
U.S. DEPARTMENT OF ENERGY

The Prospects for Pumped Storage Hydropower in Alaska

July 2023

ANL-23/17



Siting at Eklutna: While PES can potentially work in other locations, the primary focus of this paper is on the Eklutna project, at the request of the governor. Eklutna is located inside Chugach State Park, centrally located near existing high-capacity transmission, the highway, the port of Anchorage, and the majority of the Railbelt energy consumers. As a result, it is likely to provide the greatest energy benefits at the lowest cost.

Additionally, the Eklutna PES project has the potential to help mitigate long-standing water resource conflicts in the Eklutna watershed. By raising the level of Eklutna Lake, increasing downstream flows and improving water management, the Eklutna PES could increase water availability for energy generation, stabilize the water supply for Anchorage and assist salmon restoration efforts currently underway.[10] It would also help Chugach and Matanuska Electric Association fulfill their legal obligations to mitigate fish and wildlife resources affected by the original Eklutna Hydroelectric project.[11] Analysis of these additional potential benefits exceeds the scope of this paper.

Acknowledgements

The authors compiled this report at the request of Governor Dunleavy at no cost to the State of Alaska. Thanks to Kachemak Geospatial, Dr. Anna Liljedahl and Scott Gruhn for their valuable insights and contributions to this report.

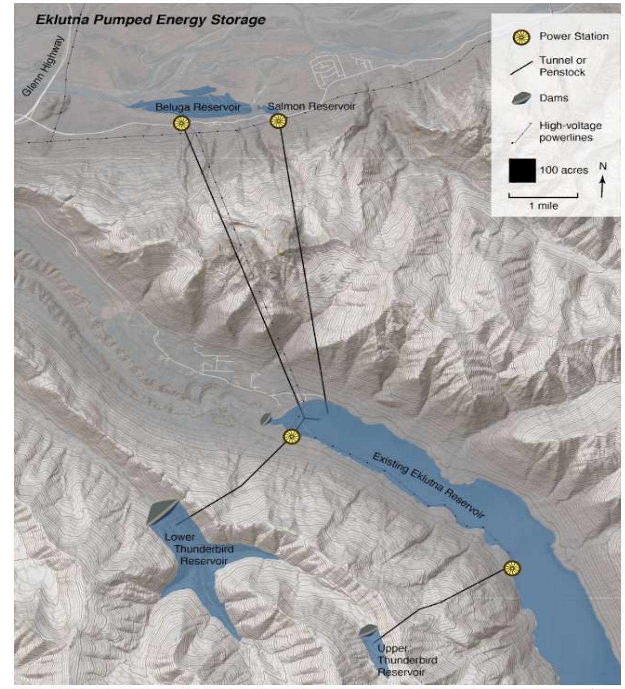


Figure 7. Eklutna Pumped Energy Storage. *This complex consists of five reservoirs, two in the Thunderbird watershed, two in the Knik River floodplain, plus Eklutna Lake.*

Executive Summary

Alaska's Railbelt has expensive electricity, generated from expensive fuel. Most of it comes from a single source -- Cook Inlet Natural Gas -- leaving us vulnerable to swings in price or supply. Prices may increase further, due to taxes and regulations aimed at emissions reductions, or decreases in fossil fuel subsidies. Here we outline a way to meet our power needs more economically and cleanly by combining two proven cost-effective technologies: wind power and pumped energy storage (PES). Wind power is exploding across the lower 48, as technology has improved and costs have dropped. One thing that has stymied power producers from bringing wind into Alaska is the challenge of integrating large amounts of variable power into our small and isolated grid. PES can solve this problem, pumping water uphill when energy is abundant, and running it back down when power is needed. This decades-old technology is long-proven, fish-friendly, and can create the cheapest "batteries" in the world.

Finally: Modified Proposed Eklutna PSH Preliminary Baseline Reservoir Analysis

Modified Eklutna PSH Baseline Reservoir Analysis

175,000 acre-ft between 814 to 871 feet (57 feet) theoretical operational zone

Assume* vertical walls and that is 3,000 acre-ft of water storage per foot of lake elevation

*In reality, with likley bathtub bathymetry, there will be slightly less storage/foot at lower lake levels

Current active operations average range between 830 to 870

For Fish byway operations, lake levels will need to be held between 850 to 870 (dam invert to spillway)

Will lose 20 feet of active operations (btw 830 to 850)

That equates to 60,000 acre-feet of lost potential water, plus 25,000 acre-ft lost to proposed instream flows

Need to make up at least 85,000 acre-ft of water to allow for fish passage and keep gross power production at parody**

****this is an improvement over existing proposed Hydro Owner F&W Plan as they will lose 10% of gross power prodcution**

as noted above, the storage loss will be less b/c of likely bathtub bathymetry

85,000 acre-ft equates to 3,700,000,000 cubic feet

3 months is 7,776,000 seconds

Need 475 cfs of flow pumped into Eklutna Lake for 90 days (3 summer months June, July, August)***

@240 cfs per reversible turbine pump

240 cfs at 900 ft of head (with losses) @90% efficiency is 20MW of power needed per pump

*** If more time is allocated to pumping beyond 90 days, then pumping flows can go decrease for less power demand,

or more water can be pumped into the lake for larger instream flows

*** Selected peak summer months based on much lower power demand and much higher solar/wind power potential

Analysis is not complete: Need to consider the fact that during pumping, no water will be diverted for power, which averages 350 cfs

Therefore, when the diversions take place for power production, diversions will likely need to increase to the 600 to 700 cfs flows

more often to drawn down the lake level and prevent unintended lake spills and power production loss, which ideally could occur during winter peak power demands

Natural peak inflows occur during June, July and August, and lowest lake levels are in May and June, but they will go from lows of 830 to lows of 850

Because of bathtub bathymetry and extra pond storage, there could be up to 100,000 acre-ft storage (850 to 870) to accommodate

850 cfs of natural lake inflows, plus 425 cfs of pumped inflows, minus 40 cfs of instream flows and 30 cfs of water supply diversions

This nets to 1,200 cfs a total lake inflow for June, July, August...or 215,000 acre-ft, meaning the pump schedule will need to be shifted and/or not continuous

to avoid a 115, 000 acre-feet overflow; This should not problematic as the sun and wind are not continuous either.

This is an iterative process with multiple water budgeting variations to evaluate

Table 4.1-1. Eklutna Lake Technical Parameters.

Description	Value
Max Regulated Water Surface Elevation	871.0 ft
Minimum Operating Water Surface Elevation	814.0 ft
Max Water Surface Area	3,500 Acres
Active Storage	174,800 Acre-Ft

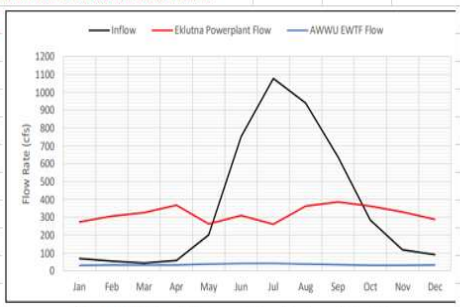


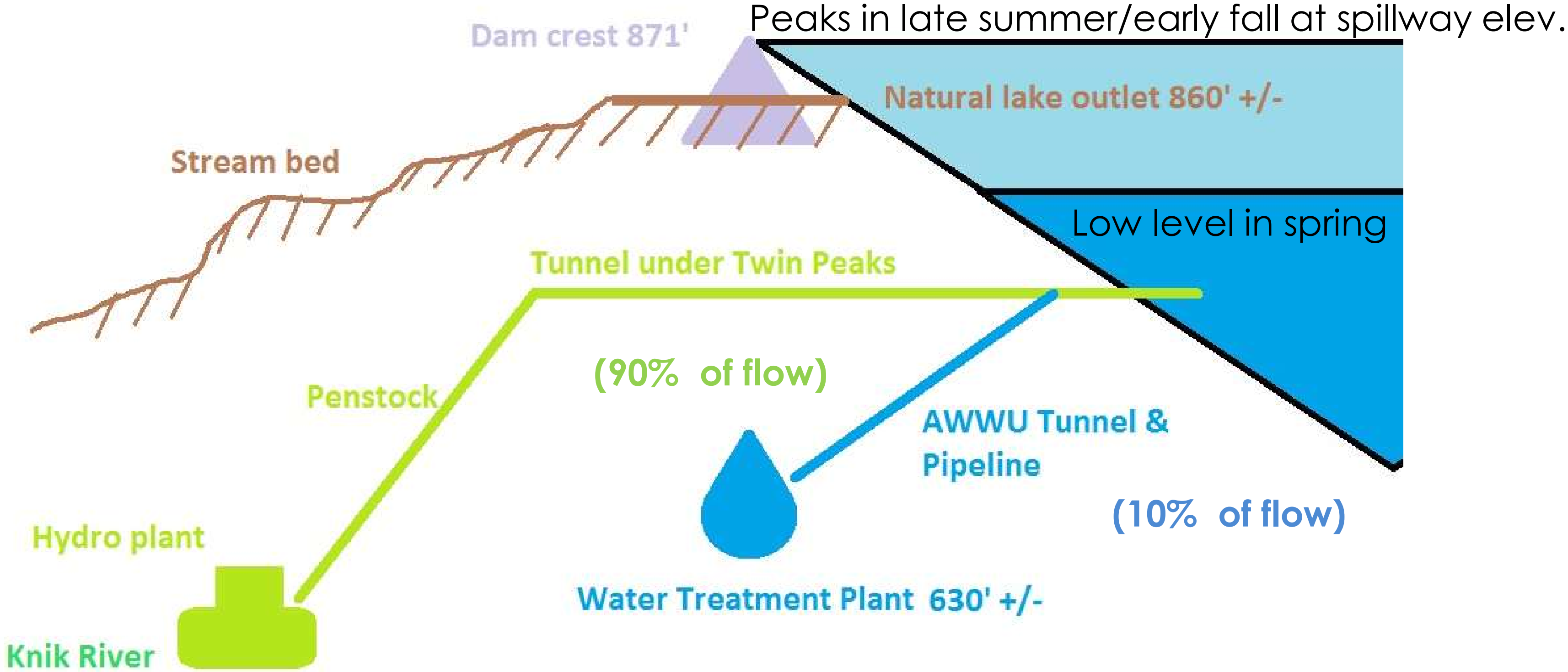
Figure 4.1-4. Eklutna Lake Average Inflows/Outflows; 2011 - 2021.

115k acre-ft overflow would provide increased instream river flows that would

much more closely match the proposed NVE instream river flows over 100 cfs

- **Much Vetting is necessary**, but if done judicially at Eklutna it could offer:
- No loss of power production and potentially more; offsetting natural gas
- Full instream river flows, fish passage and lake connectivity
- Provide for downstream control and protection of municipal water supply infrastructure
- Require minimal infrastructure investment (assuming existing tunnel infrastructure can be reused) other than turbine/pump/control upgrades, bypass fish channel and hydro owners/MOA/IPP would need to build new solar/wind and/or negotiate with existing wind/solar operators to maximize their renewable output, when possible, to fill the lake for @90 days annually

Questions, Gaps, Variations and Discussion?



- Does this meet full restoration objectives of stakeholders?
- Does this meet prudent utility practices?
- Eklutna tailrace fishery impact?
- Is there a tidal impact? Turbidity control measures?
- Will fish return with a blended water (imprint markers)?
- Solar and wind generation siting, funding, existing?
- Reversible Turbine Pump? Separate?
- Turbidity control, Other?

- **<u>Multiple Variations Available (not a fully inclusive list)</u>**
- Open Loop vs. Closed Loop, lower impoundment
- Assortment of flow regime and seasonal variations to model
- Additional/redundant penstocks, additional/redundant pump/turbines, upper impoundments, etc.
- Blending water variations with Knik River
- Lower or higher fish gate elevations