PRELIMINARY HYDROLOGIC ASSESSMENT OF PUGET COVE PONDS NEAR YAKUTAT ALASKA

PREPARED FOR THE YAKUTAT REGIONAL AQUACULTURE ASSOCIATION BY ALASKA HYDROSCIENCE

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1 INTRODUCTION

On Feb. 15, 2015 I conducted a site visit of ponds just east of Puget Cove near Yakutat. I was accompanied by Nate Endicott of the Yakutat Regional Aquaculture Association. The objective of the site visit was to explore the feasibility of utilizing runoff from the ponds and surrounding area for YRAA hatchery water supply. In addition to visiting the ponds we conducted a brief survey of the shoreline in search of outflow from the ponds. We found one possible outflow source located at Shaw Cove (lat. 59° 34.566' long. -139° 42.421 approximately). The outflow at this stream was approximately 4-6 cubic feet per second suggesting a fairly large drainage area and potential outflow from the ponds of interest. This stream is listed in the ADF&G Anadromous Waters Catalog (AWC-183-10-10500) for the presence of pink and coho salmon.

In order to determine the feasibility of the ponds and surrounding drainage area as a potential water source for a salmon hatchery, I executed calculations of surface and drainage area and theoretical water yield under 200 gal/min and 800 gal/min water extraction scenarios. The measurements and estimates of water yield and a summary of the geologic setting are contained in the following document.

1.1 Setting

The ponds at the study site were formed at the terminus of the Hubbard/Yakutat Bay Glacier as it retreated about 900 year ago (Trabant and others, 2003). They represent two of the larger ponds on the peninsula of land extending north between Puget Cove and Sawmill Cove to the northeast of Yakutat (Figure 1). This type of kame and kettle topography (Bates and Jackson, 1980) is widely distributed in a southwest to northeast direction along the southeast margin of Yakutat Bay. Topographic maps of the area indicate a head differential of about 50 feet from the pond surfaces to sea level.

1.2 Proposed Plan

The proposed plan for the design of facilities utilizing the water from these ponds consists of withdrawing water from the western pond and routing it through hatchery facilities to the east (Figure 2). The water would then discharge into Puget Cove. Currently the ponds do not discharge in this direction and our survey of the shoreline suggests they might discharge to the northeast in Shaw Cove. The water requirements of the hatchery would depend on the number of salmon being incubated. For the purpose of these feasibility estimates I used flow rates of 200 gal/min and 800 gal/min as design flow rates. These flow rates represent water requirements for the incubation of 10 million and 40 million chum salmon eggs, respectively.

2 METHODS

2.1 Estimates and Calculations

In order to determine if the Puget Cove Ponds might be a viable water source for the project I conducted an estimate of the drainage area of the proposed site. In addition to calculations of drainage area I also calculated the surface area of the ponds. The surface area of the ponds was used to generate potential storage volumes of the ponds for a range of hatchery operation scenarios.

The estimated site drainage area was used in combination with streamflow data from Ophir Creek (USGS station no. 15129600), Situk River (USGS station no. 15129500), Old Situk River (USGS station no. 15129510), Lost River and annual values of Yakutat precipitation to determine a range of potential water yields of the site. Annual runoff, daily mean discharges, and streamflow statistics from Ophir Creek, Old Situk River, and Situk River were determined directly from the USGS water data annual summary reports. Mean annual runoff for the lost river was calculated from stream gage data provided by the Alaska Department of Fish and Game. Drainage area for the Lost River gage was calculated from topographic maps using Google Earth Pro combined with topographical data from the University of Alaska's Geographic Information of Alaska website.

Figure 1. Showing the ponds selected for evaluation of potential water yield on the east side of Puget Cove.

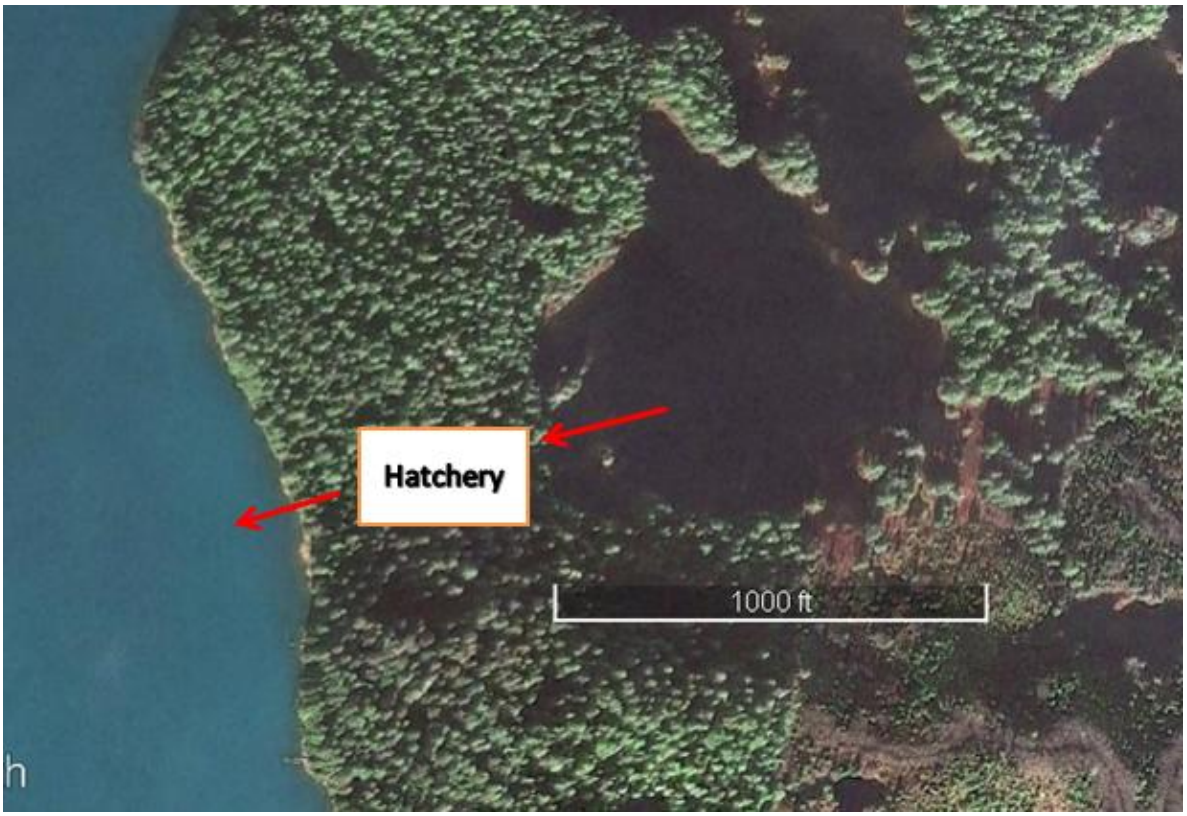

Figure 2. Location of proposed hatchery facilities.

2.1.1 Drainage Area Delineation

The drainage area calculations were conducted using both topographic maps and Google Earth satellite imagery. The drainage area computed for the Puget Cove Ponds is considered an estimate. The coarse scale of the topographic data combined with the low relief kettle and kame topography, makes it difficult to accurately delineate drainage divides. The drainage area estimated for the Puget Cove Ponds (Figure 3) was approximately 0.24 square miles. Given the terrain and topographic data available the drainage area estimate could be in error by perhaps 25-percent.

2.2 Discharge Estimates

2.2.1 Project Design Discharges

For the purpose of these feasibility estimates I used flow rates of 200 gal/min and 800 gal/min as design discharges. The discharge estimates that follow suggest that the successful execution of the project will likely require a water storage component in order to meet water requirements during periods of low precipitation or extended periods of snow/cold weather at even the 200 gal/min design flow. The ponds themselves represent an existing storage component that may be adequate to support smaller design flows. Assuming an effective small scale reservoir can be designed, the design flows may somewhat larger than the lowest expected annual mean discharge due to the fact that operation will only require

flow approximately 7.5 months of the year. As such, during the period when no water is required (perhaps March-June), water input might be accumulated as storage.

2.2.2 Simulations of Annual Mean Discharge

Rather than estimating mean annual runoff using Yakutat mean annual precipitation values (about 144 in/yr), mean annual runoff values from nearby stream gages were used to provide refined estimates of actual water yields that might be expected from the proposed site. Mean annual runoff values will provide a more conservative estimate of water yield as it integrates losses from direct precipitation such as evaporation and transpiration. Mean annual runoff values are generated by dividing the mean annual discharge by drainage area of the gaged basin. The data shown in Table 1 suggests runoff increases to the south and east along the Yakutat Forelands with the greatest runoff values obtained at Situk River and Old Situk River. However, some of these runoff statistics (Lost River: 5 years and Old Situk River: 3 years) were generated with short gage records that might bias the runoff values.

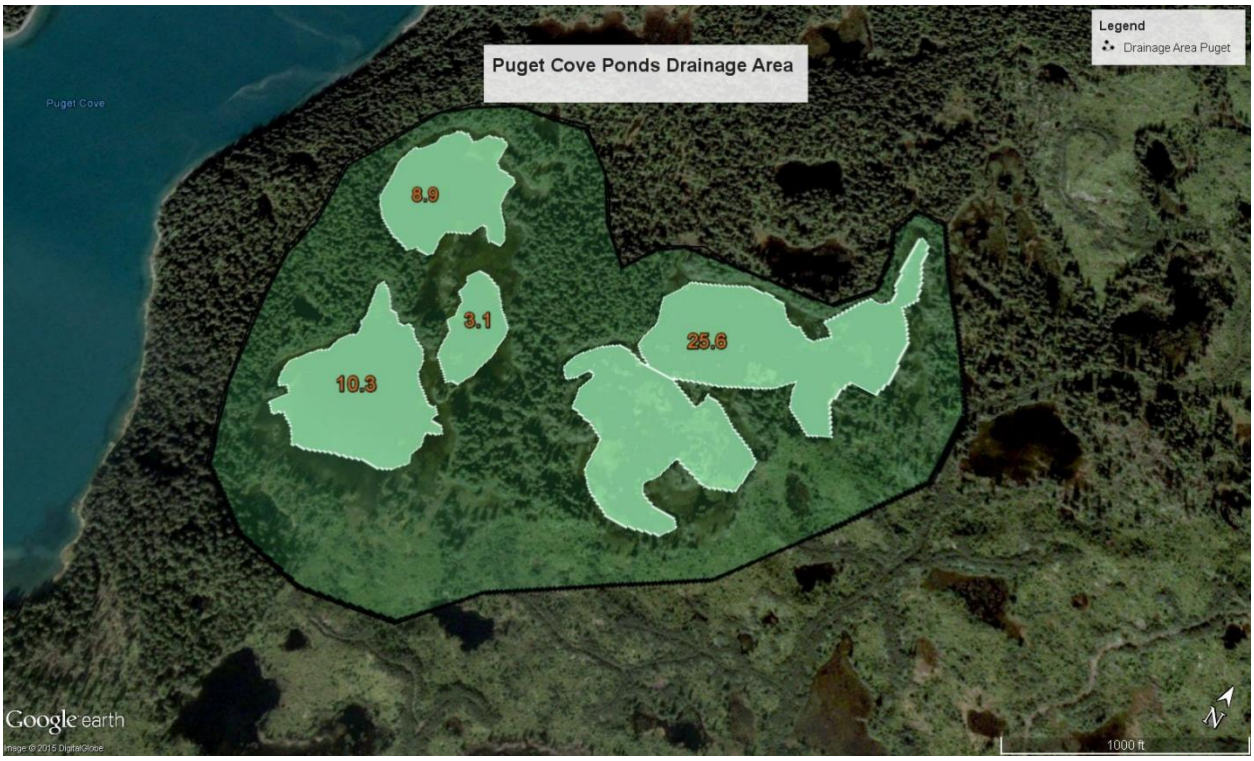

Figure 3. Showing the estimated drainage area for Puget Cover Ponds and surface area of the ponds during low flow conditions.

Table 1. Drainage area, mean annual discharge, and runoff in inches per year for four streams in the Yakutat area.

Site	Drainage Area (mi^2)	Mean Annual Discharge (ft^3/s)	Runoff (inches/yr)
Situk River	36	306	115
Ophir Creek	2.5	16	87
Lost River	10.9	84	105
Old Situk River	4.78	42.5	121

Given the spatial pattern of increasing runoff to the south and east it is likely best to assume the runoff from the Puget Cove Ponds would be more accurately simulated using data from Ophir Creek or the Lost River. Using the values generated from Table 1 the potential expected mean annual discharge of the Puget Cove Ponds can be estimated by scaling discharge to the drainage area. For example, the drainage area of the proposed site (0.24 mi^2) can be divided by the drainage area of Ophir Creek (2.5 mi^2) to obtain a multiplier of 0.096. Multiplying this number by the mean annual discharge of Ophir Creek provides an expected mean discharge of about 1.5 ft^3/s (670 gal/min). Repeating this process using the Lost River runoff data provides and expected mean discharge of 1.85 ft^3/s (830 gal/min). However, these are average values and assume all of the runoff can be utilized for project operations. In Figure 4 I've generated simulated annual mean discharge values using a scaled hydrographic comparison with USGS Ophir Creek data from 1992-2012. The figure also includes simulated annual mean discharges from a scaled hydrographic comparison with ADF&G Lost River data from 2007-2011.

The values for simulated annual mean discharge shown in Figure 4 are estimates assuming similar basin characteristics and precipitation input as Ophir Creek (blue line) and Lost River (red line). I've used both sites to provide a range of expected values. There is the potential that runoff values could be significantly different than those generated in the simulations. The estimates generated using Ophir Creek hydrology data may underestimate the mean annual discharge. Ophir Creek had the least runoff of all the streams examined in the region. However, the long period of record from the Ophir Creek gaging station illustrates the annual variability of runoff. Although the simulated long term average is about 670 gal/min, 9 out of 20 years had annual discharges less than 600 gal/min.

2.2.3 Simulations of Daily Mean Discharge

In order to provide an approximation of daily mean discharges from the Puget Cove Ponds I scaled Lost River and Ophir Creek daily hydrographs using the same methods as those in the annual hydrographs in Figure 4. I used the daily discharge hydrographs from Ophir Creek and the Lost River for the 2007 and 2011 water years (water years are measured from Oct. through Sept. 30). Figure 5 and Figure 6 show daily mean discharge simulations for the Puget Cove Pond site. It is difficult to determine which simulations demonstrate runoff patterns most likely to represent those of the Puget Cove Pond sites. These calculations were included to illustrate the range of daily mean discharges that might be expected

in a year with a cold winter and large snow-pack accumulation (e.g., 2007), and a year with near average annual discharge for Ophir Creek. Design flow lines of 200 and 800 gal/min are included in the figures to demonstrate the periods where discharges would fall below the design flows.

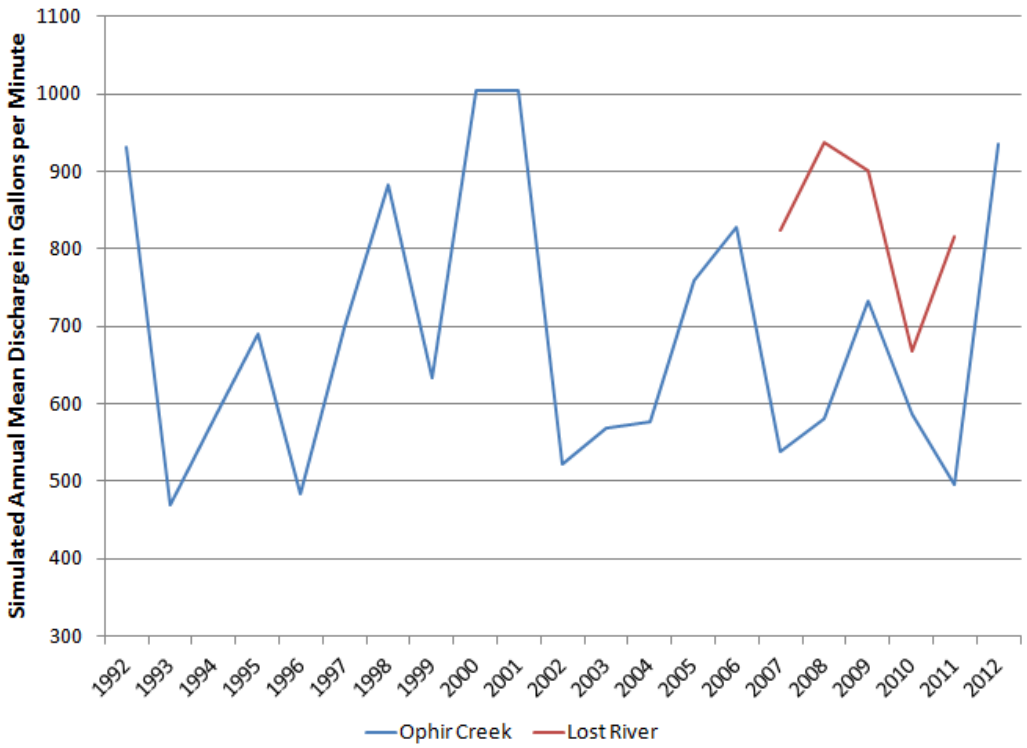

Figure 4. Simulated annual mean discharge of Puget Cove Ponds using streamflow from Ophir Creek (blue) and Lost River (red).

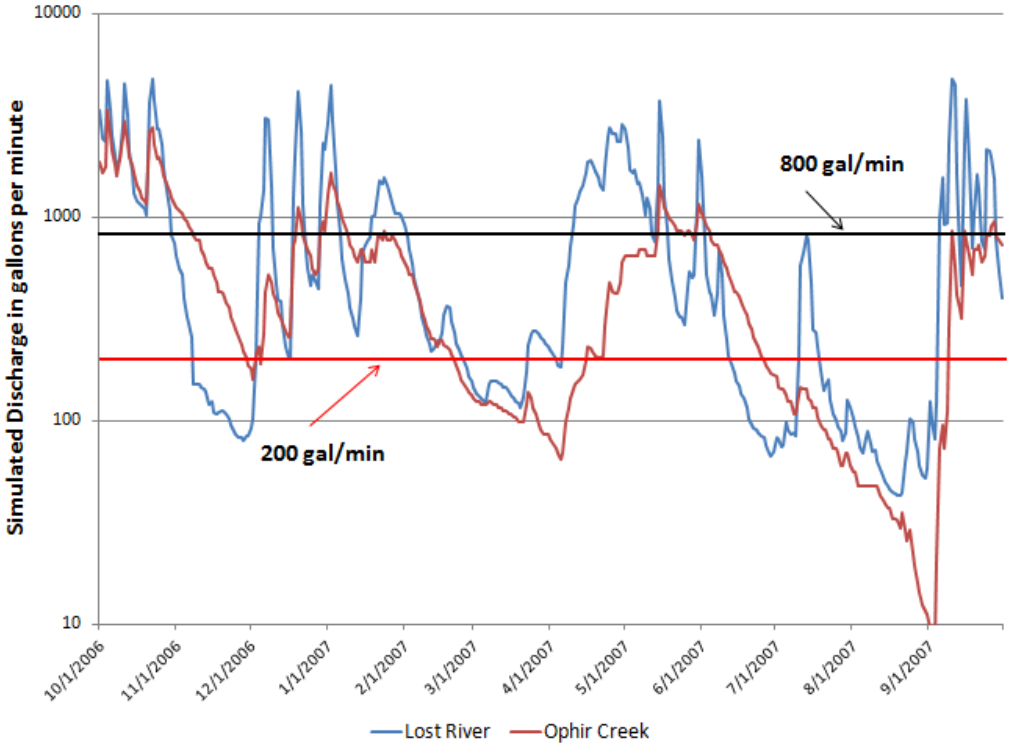

Figure 5. Daily mean discharge simulation of the Puget Cove Pond site using hydrologic data from Ophir Creek (red) and the Lost River (blue) for the 2007 water year.

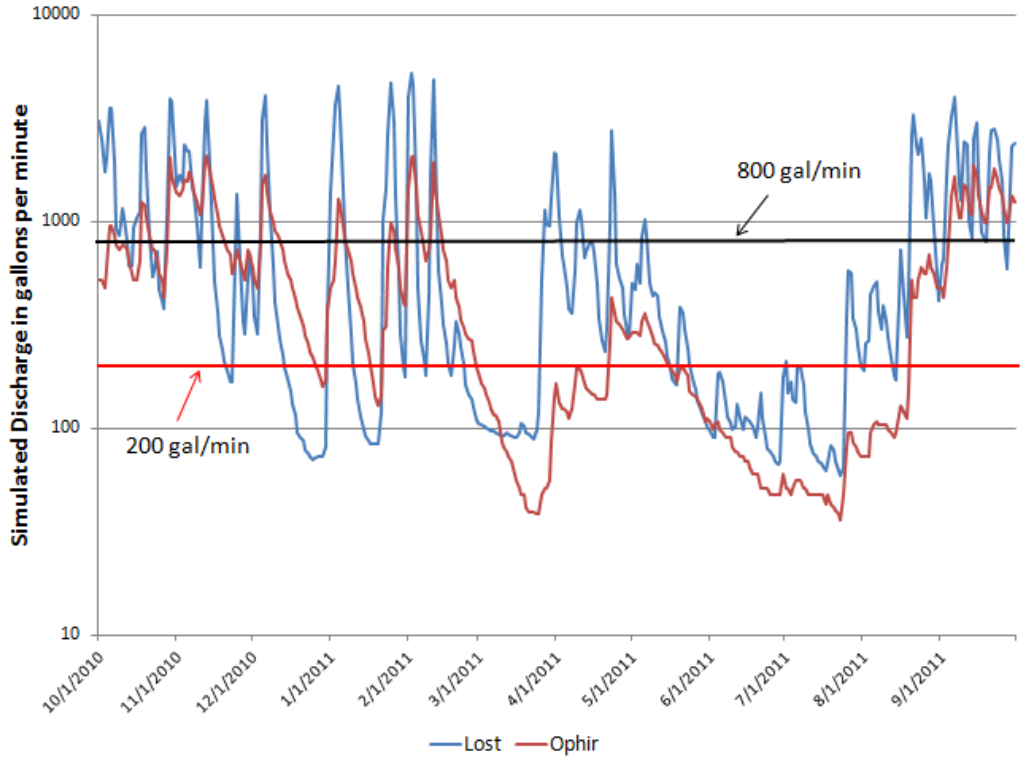

Figure 6. Daily mean discharge simulations for the Puget Cove Pond site using hydrologic data from Ophir Creek (red) and the Lost River (blue) for the 2011 water year.

2.3 Surface Area and Volume Calculations

The daily mean flow simulations suggest the runoff from the Puget Cove Ponds will periodically be insufficient to meet the flow requirements of even the smallest design discharge of 200 gal/min. During these flow deficits, additional flow would depend on water provided from storage. In order to determine storage potential of the ponds I estimated surface area of the two ponds using Google Earth Pro with imagery from Sept. 13, 2004. The 2004 imagery represents a more conservative estimate of surface area relative to newer imagery. The older imagery appears to have been obtained during low-flow conditions. I checked this assumption with stream flow values on Ophir Creek and the Situk River for the same date as the imagery. Ophir Creek was flowing at just 1.3 ft^3/s, flows of this magnitude are exceeded 96.5 % of the time. I did not construct flow exceedence curves for the Situk River but it had a discharge of 159 ft^3/s, which is about 30% of normal for September. The surface area of the ponds is shown in Figure 7 and a range of volume estimates using assumed depths in are presented in Table 2. Surface area and volume calculations would increase slightly if measurements were conducted during high flow periods; however it appears that the western pond will separate into separate basins during low flow complicating the storage function of the ponds. Basin separation of the western pond is shown in Figure 8. Storage values (Table 2) would be reduced by the thickness of the ice during winter periods.

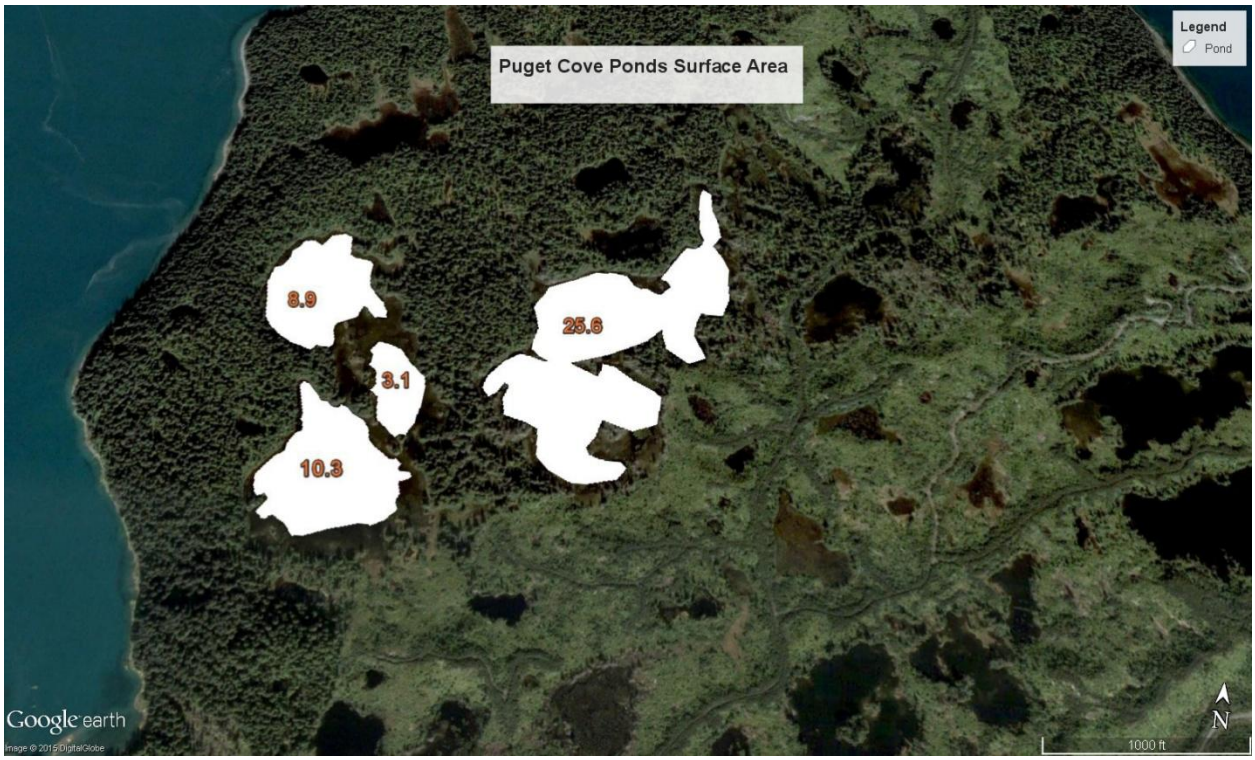

Figure 7. Surface area computations for Puget Cove Ponds.

Table 2. Puget Cove Ponds surface area during low flow conditions.

Area (acres)	Area (sq ft)	Volume (5 ft deep)	Volume (10 ft deep)	Volume (15 ft deep)	Volume (20 ft deep)
50.1	2,182,356.	10,911,780	21,823,560	32,735,340	43,647,120

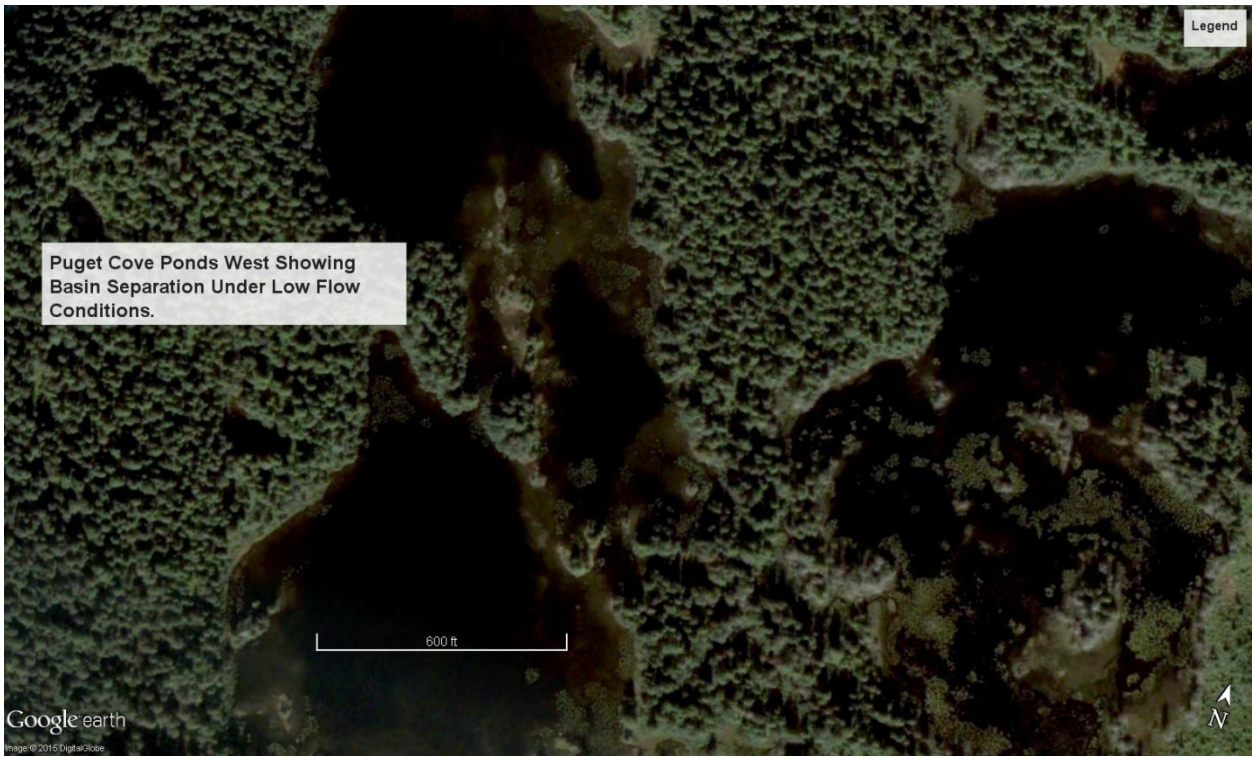

Figure 8. Demonstrating basin separation of western Puget Cove Pond during low flow conditions.

2.4 Storage and Depletion Calculations

I produced a storage depletion table using a range of assumed depths of the ponds in Table 3. Preliminary results from these calculations suggest maintaining adequate flow rates for the full scale project (800 gal/min) may be theoretically possible but will hinge on a number of important assumptions that can't be easily tested.

Table 3**.** Storage depletion times for Puget Cove Ponds using assumed depths of 5-20 feet.

	Pond depth (in feet)			
	5 ft	10ft	15 ft	20 ft
Flow rate	Depletion time (in days)			
800 gallons/min	71	142	213	284
200 gallons/min	283	566	850	1133

3 DISCUSSION

3.1 Water Quantity

The Puget Cove Pond site may accumulate enough water for your project needs. However, capturing the water for project operations would likely be difficult. The simulations and measurements presented suggest there may be enough contributing drainage area to provide a mean annual discharge of 500-800 gal/min during most years. However, simulations of daily mean discharge demonstrate a large range of daily discharges (Figure 5 and Figure 6) with discharges frequently less than 200 gal/min. This dictates that you would frequently be required to draw from storage to meet your water requirements.

3.1.1 Storage Considerations

The ponds have considerable storage capacity; however, our site visit indicates the ponds currently drain away from Puget Cove, likely to the north into Shaw Cove. In order to execute the proposed plan the existing drainage would have to be rerouted to the east into Puget Cove in combination with the construction of a reservoir system capable of storing nearly all of the water that may runoff during periods of high discharge. The ability to develop an effective reservoir system would depend on a number of assumptions that can't be easily tested. In order to develop a full capacity project capable of delivering a continuous discharge near 800 gal/min the following assumptions would have to be met:

- A reservoir system could be engineered such that discharge from the ponds can be fully utilized or nearly fully utilized.
- The actual annual discharge from the ponds would have to be greater than discharges simulated using Ophir Creek discharge data.
- The drainage area used in these calculations would need to be greater than or equal to the estimate provided.
- The ponds would have to be modified to provide connectivity of all basins as the water levels are drawn down during periods of low flow.

If the appropriate storage could be achieved it may be possible to supply continuous discharges somewhat larger than those approximated with the simulations from Ophir Creek. The project will likely require water withdrawal just 7.5-8 months of the year. If runoff during the remainder of the year (March-June) could be stored it would increase the amount of water available for hatchery operations. If actual runoff approximates that of the Lost River rather than Ophir Creek the amount of water available may increase by as much as 20% (Table 1 and Figure 4).

3.1.1.1 Alternative Facility Locations

The proposed plan (Figure 2) could be moved to an alternative location downstream of the ponds. This might allow for the accumulation of additional drainage area and associated runoff. This would not eliminate the need for the reservoir system to provide supplemental water as operations would require frequent access to stored water. The simulations computed for Figure 5 and Figure 6 showed that

discharges less than 800 gal/min for 280 and 257 days of the year, during water years 2011 and 2007, respectively. These same simulations indicated discharges less than 200 gal/min for 157 and 125 days, during water years 2011 and 2007, respectively. These simulations suggest the need for near continuous accessibility to stored water. This is likely the reason numerous hatcheries in southeast Alaska draw their water source from a lake.

3.1.1.2 Permitting

To obtain the storage needed would require reducing or eliminating water from the Puget Cove Ponds. If they are an important sources of water for the stream located at Shaw Cove it would likely result in a large flow reduction. The stream is listed in the Alaska Department of Fish and Game Anadromous Waters Catalog (AWC-183-10-10500) for the presence of pink and coho salmon. Withdrawing stream water from a stream listed in the AWC may result in additional permitting complications. My conversation with Sam Rabung (ADF&G) suggested that permitting might still be possible but each permit (project) would be evaluated on a case by case basis.

3.2 Water Quality

3.2.1 Water Temperature

There are no existing water temperature data for the Puget Cove Ponds. The geographic setting suggests the thermal regime of these ponds could be problematic for fish culture. The tannin coloration and exposure to sunlight suggest the water temperatures may exceed optimum temperatures for salmon propagation. I reviewed USGS water temperature record of the Situk River for several years and found that typically water temperatures are within an acceptable range. During warm dry summers the water temperatures in the Situk River were as high as 19 °C in late July and 17.5 °C in early August (USGS Annual Data Report, 2009). The best available estimates of summer water temperatures come from the USGS Situk River water-temperature records. Situk River flows from the surface of a lake that should have similar thermal conditions to the ponds. Water temperature from the Puget Cove Ponds will likely be in excess of the Situk River during the months of June, July, and August. Elevated water-temperatures in the Puget Cove Ponds could prove to be problematic during the months of July and August during egg take from mature adults. During most winters the ponds will be ice covered with water temperatures near 0 °C.

3.2.2 Dissolved Oxygen

The potential for hypoxia (dissolved oxygen deficiency) exists for some or all of the Puget Cove Ponds. Deficits in dissolved oxygen in shallow lakes and ponds can result from severe light attenuation through snow and ice cover. When this occurs the production of oxygen through photosynthesis is reduced or eliminated although a biological oxygen demand persists in the pond. The existing biological oxygen demand can reduce dissolve oxygen levels to concentrations insufficient to support incubation of salmon eggs or other organisms. This type of winterkill is common in many types of shallow and/or productive

lakes in temperate latitudes (Wetzel, 1983). If the ponds are drawn down during low-flow periods it would likely exacerbate any problems with low levels of dissolved oxygen.

3.2.3 pH

The pH of water is a measure of its hydrogen-ion activity and can range from 0 (acidic) to 14 (alkaline) standard units (Hem, 1985). The tea colored water in many of the ponds, muskegs, and streams in the Yakutat area suggest large concentrations of tannins in the water. High tannin water is often acidic and would need to be evaluated for pH and its affect with aluminum incubators (S. Reifenstuhl, personal communication).

4 SUMMARY

The Puget Cove Pond drainage may accumulate enough water for a 500-800 gal/min project during most years. However, the feasibility assessment presented here suggests that this site remains a marginal to poor option for a water source. Capturing an adequate water supply for 800 gal/min project operations will likely be difficult. While the annual mean discharge simulations and estimates provided suggest there may be enough contributing drainage area to support a hatchery it would likely have to be reduced in scale. The most conservative simulations based on drainage area scaling of Ophir Creek hydrographs suggests you may be able to obtain continuous flow rates of around 500-600 gal/min. Daily mean discharge simulations indicated that a near continuous withdrawal from pond/reservoir storage would be needed to meet your water requirements. In order to meet storage requirements the pond complex (as it exists) would require engineering and modification capable of effectively storing nearly all of the water input for project operations. In order to provide adequate storage it would be necessary to dam the pond outlets in order to increase storage capacity, and connect the ponds such that stored water could be accessed from all 4 basins as the water levels are drawn down.

The potential development of an effective reservoir would hinge on the ability to easily dam the pond outlet/outlets such that the storage increase would meet your continuous flow requirements. This could be determined from a detailed topographic survey of the area. A field visit to the pond outlets would likely inform you as to the plausibility of construction. The ideal situation would be a narrow notch outlet that would allow for an earthen dam that could raise the water surface elevation with a minimum amount of fill. Providing a hydrologic connection between the ponds could be achieved through excavation and appropriate piping. The engineering and construction of the reservoir would represent a considerable amount of work and flow simulations indicate the water source is marginal. However, estimates of runoff availability could be improved with additional discharge measurements or stream gages on the pond outlets.

Should you consider more detailed analyses of the Puget Cove Ponds I would suggest several things that could improve estimates of feasibility. Mapping the drainage of the ponds may allow you to determine if constructing a small reservoir is feasible. If the reservoir scenario appears plausible I would begin collecting discharge data. If the ponds do not have a hydrologic connection I would collect discharge data at both sites. There is a possibility that a large portion of the water in the basin is lost through infiltration into the groundwater. If so, the runoff values estimated by scaling Ophir Creek streamflow

could be greater than actual runoff from the pond. If actual discharges are less than simulated discharges the project might not be cost effective. Measurements of the depths of the ponds should be conducted to determine approximate depths. Collection of water quality samples and field parameters would also be needed to determine the site's potential as a viable water source.

The Puget Cove Pond site appears to be a marginal site for your proposed plan in terms of both water quantity and quality. The ultimate success of your project will be largely determined by your water source. Most of the effective hatcheries I am aware of in southeast Alaska draw from much larger drainage basins with considerable storage in the form of mountain lakes. Salmon hatcheries in southeast Alaska are frequently located in remote locations because hydrologic conditions are favorable. The hatcheries located in Juneau (DIPAC) and near Sitka (Medvejie) both draw water sources from much larger sources than any available in the immediate vicinity of Yakutat.

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