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MEMORANDUM

TO: Mr. Orri Vigfusson

FROM: Margaret Filardo, Ph.D.

DATE: November 15, 2013

RE: Review of Further Scientific Information on the Thjorsa River Hydro-development

In response to your request, we have reviewed the document “Evaluation of available research on salmonids in the river Thjorsa in S-Iceland and proposed countermeasures and mitigation efforts in relation to three proposed hydroelectric power plants in the lower part of the river”. Attached are our comments.

An independent evaluation of "Evaluation of available research on salmonids in the river Thjorsa in S-Iceland and proposed countermeasures and mitigation efforts in relation to three proposed hydroelectric power plants in the lower part of the river" was conducted for the Steering Committee of the Icelandic Master Plan for Conservation and Development of Hydro- and Geothermal Energy sites.

- This evaluation in very comprehensive and well done. There are several warnings included in this report that must be given full consideration. Of particular importance is the emphasis that there is considerable data available to suggest that mitigating for the installation of hydroelectric projects is rarely successful in maintaining naturally spawning, self-sustaining populations of salmon.

- In this context it should be recognized that when the Columbia River hydrosystem was developed it was never intended to drive Columbia River salmon to near extinction. Regional intent was to preserve the ecosystem and the Native American, sport, and commercial economies that relied upon the fisheries.

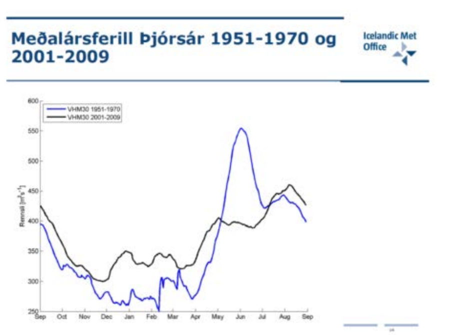
- An estimated 11.9 billion U.S. dollars* were spent between 1979 and 2008 attempting to recover Columbia River salmon stocks (*Northwest Power and Conservation Council, 2010). At present, a minimum of 250 million dollars, derived from power revenues, are spent annually relative to fish and wildlife mitigation. Additional monies are spent relative to operations, maintenance, and development of fish facilities.

- An estimated 10 to 16 million naturally produced salmon returned to the Columbia River annually pre-development, and in spite of over 35 years of implementing, and continuing to modify mitigation efforts, we have failed to recover natural populations that remain as endangered species and are at risk of extinction.

The following information is provided to support, complement, and augment the information provided in the review.

Flow Alteration

- From the graph below it is obvious that the natural flow of the Thjorsa has been significantly altered by the hydro development already in place. Further modification could place undue stress on natural populations of Atlantic salmon, and likely other species, below the present development by further altering the seasonal flow pattern.



- In addition to the seasonal flow alteration that has already taken place due to hydro development, the addition of reservoirs in the lower Thjorsa would have significant impacts on fish survival.

- Based on the experience in the Columbia River in the United States, juvenile fish migration time would increase with the development of reservoirs in the Thjorsa. Increasing the time it takes for juvenile fish to migrate to sea decreases juvenile survival and subsequently, the survival of returning adults. This reduction in survival is due to increased exposure time to predation and increased temperature, and by altering timing of seawater entry.

- To put it into perspective the Columbia River pre-development fish migration time from the Snake River to the present day site of Bonneville Dam (the lowest mainstem dam in the system) was estimated at 2 days whereas post development, the fish migration over the same distance now averages 19 days.

- Water particle transit time is the amount of time it takes for a water particle to travel from across a distance and is a function of volume (WTT = volume/flow). The addition of reservoirs to a free flowing river increases water particle transit time by increasing the cross-sectional area of the river, significantly increasing the volume of water.

- Because of the high correlation observed between WTT and juvenile fish migration speed, water particle transit time in the Columbia River is used as a surrogate for fish migration time.

- Using a series of hydrologic assumptions it was estimated that the free flowing WTT from the point on the Thjorsa that coincides with the proposed upstream end of the reservoir above the proposed Hvammur hydroproject to point downstream of the Urridafoss project would be near 0.14 days under all flow conditions. If development takes place the resulting WTT are estimated in the following table under a range of flow conditions:

Flow **(m^3sec^{-1})**	**WTT** **(days)**
Mean Flow*	1.69
Summer Flow**	8.99
Minimum Flow***	48.21

*Mean Flow (m^3sec^{-1}) Hvammur = 310; Holt = 330; Urridafoss = 370
**Summer Flow (m^3sec^{-1}) Hvammur = 60; Holt = 60; Urridafoss = 60
***Minimum Flow (m^3sec^{-1}) Hvammur = 10; Holt = 15; Urridafoss = 10

- The proposed 1-meter reduction in reservoir volume would have a minimal effect on the WTT and consequently, fish migration time. Consequently, even with this proposal a significant adverse impact on fish migration time would occur.

Flow (m^3sec^{-1})	**WTT** (days)	**WTT** (1M Urridafoss and Holt)
Mean Flow*	1.69	1.61
Summer Flow**	8.99	8.52
Minimum Flow***	48.21	45.72

*Mean Flow (m^3sec^{-1}) Hvammur = 310; Holt = 330; Urridafoss = 370
**Summer Flow (m^3sec^{-1}) Hvammur = 60; Holt = 60; Urridafoss = 60
***Minimum Flow (m^3sec^{-1}) Hvammur = 10; Holt = 15; Urridafoss = 10

- Experience in the Columbia has shown that after a river has been harnessed into a series of reservoirs and impoundments, flow cannot be increased sufficiently to return to pre-development water transit times or fish travel times.

Habitat Alteration

- Changes in habitat availability for spawning and interference with incubation, emergence and early life stages of juveniles have all been observed in the Columbia and are related to daily and seasonal flow fluctuations. These impacts to spawning, incubation, emergence and early life stages of juveniles have contributed to the decline in salmonid survival.

- Operation of projects can cause daily and seasonal flow fluctuations which can affect suitable spawning habitat by limiting by either dewatering these areas or by varying velocities over spawning habitat so that redd construction is discouraged during the nest building period (Hatten et al. 2009). Daily and seasonal flow fluctuations also can decrease connectivity of spawning habitat to foraging nursery areas and may entrap fish in pools that become separated from the main channel or strand fish on the substrate (Anglin et al. 2006).

- In addition to seasonal flow variations, daily flow fluctuations at each of the projects due to daily load following could have serious implications to survival in spawning and rearing areas downstream. In the Columbia River there are two locations where both daily flow and hourly flows are regulated over long periods of time (up to five and six months). Both minimum flow levels that allow for sufficient spawning and hourly flow fluctuations are minimized and evaluated daily by interagency committees during that time period. Flow levels are established following twice weekly spawning ground surveys conducted by foot, by boat or by helicopter.

Juvenile Passage

- The estimates for survival through Kaplan turbines are very optimistic. Performance standard testing of juvenile survival via passage routes conducted at six different Columbia River dams (2009–2012) showed a range of turbine survival estimates between 80% and 97%.

- Performance standard tests have utilized radio and acoustic tags, which do not fully represent the juvenile population. Smolts are rejected from test groups due to size and condition and, therefore, represent survival only of the healthiest smolts in the population. Recorded rejection rates have ranged from 3.2% to 16.4% of the population collected for tagging. Therefore, survival estimates for these fish are considerably higher than the general population that migrates past the Columbia River mainstem dams.

- The test group is further affected because smolts included in the dam-passage treatment group are released at multiple locations upstream, and some pass through several projects before being included in the test group. This process may eliminate from the sample weaker fish more susceptible to mortality due to tag burden; so only tagged fish most likely to survive dam passage are included in the test group. The inclusion of multiple control groups for each performance test raises concerns that dam passage survival estimates may be artificially inflated. This inflation can be caused by random effects or the unequal mortality between groups from factors such as predation in the tailrace.

- Kaplan turbines on the Columbia River operate during the fish migration season within a very narrow efficiency range, which is well below the maximum energy output of each turbine. Operation outside of this range imposes additional mortality on juvenile migrants.

- Furthermore, turbine survival estimates underestimate the impact of dams on fish. At-project estimates do not capture the indirect effects of project passage, primarily delayed or latent mortality associated with bypass system passage. Delayed mortality is the mortality associated with passage through the hydrosystem that is expressed during later life stages in the estuary or ocean (Budy et al. 2002, Schaller & Petrosky 2007, and Schaller et al. in press).

- The location of juvenile bypass exits and the environmental conditions can greatly affect survival below the hydroelectric project. Increased avian and piscivorous predation can contribute to mortality at the juvenile exit location if conditions are not sufficient in terms of flow and hydrology.

- Reservoir mortality in the Columbia River can be significant after fish have experienced multiple bypasses though hydroelectric dams. The cumulative effect of passing through multiple dams and reservoirs can have direct and delayed impacts on salmon survival (Schaller et al. 2007, Tuomikoski et al. 2012, 2013). Again, the delayed mortality from the accumulation of multiple dam and reservoir passages can manifest into poor survival during estuary and marine life stages (Budy et al. 2001, Schaller & Petrosky 2007, and Schaller et al. In Press).

Evaluation of Proposed Development and Fishery Impacts

- In order to evaluate if the Thjorsa River population can be a natural spawning and self-sustaining population, after hydroelectric project development in the lower river, a

Population Viability Analysis must be conducted. The analysis could be conducted using life stage estimates from those available from the Thjorsa and Atlantic Salmon population estimates from other river systems (possibly available for the Alta River in Norway). These type of viability analyses have been conducted for Columbia River salmon (Kareiva et al. 2000, Wilson 2003), and proved useful in evaluating population sustainability and recovery strategies. When conducting these type of population viability assessments a full range of assumptions for life stage survival rates and impacts of project development should be considered, in order to evaluate the efficacy of countermeasures and mitigation.

- Juvenile survival rates should be empirically estimated through mark/recapture techniques for repeated years through those sections of the river that are planned to be developed. Simulation modeling, using a full range of assumptions for juvenile survival impacts from development through the lower river, should be compared to empirical estimates of juvenile survival rates without development. The model predictions must consider cumulative passage impacts from the proposed projects including reservoir passage and delay, and the associated delayed mortality effects from project passage.

- The single most important step is to obtain empirical estimates of smolt-to-adult survival rates for the Thjorsa River population. Given the potential for delayed mortality the ultimate impacts of the proposed hydrosystem development would need to evaluate success in terms of smolt-to-adult survival. The most recent evidence (Schaller et al. 2013 In Press) suggests that a high percentage (76%) of Snake River juvenile salmon that survived the migration through the hydrosystem subsequently died in the marine environment due to their juvenile migration experience. Accurately simulating post development smolt-to-adult survival rates and comparing those to the present estimates is important information to evaluate the efficacy of countermeasures and mitigation.

- Fishery impacts and adult passage are fairly established for anadromous salmon species, but very little information is available for Arctic Char, brown trout or eels. Unlike salmon species that are anadromous, eels are catadromous where the adults migrate downstream to the ocean and juvenile migrate upstream from the ocean. In addition to migrating at different life stages, eels also tend to exhibit demersal behavior, while juvenile salmon are located in the upper parts of the water column. The passage countermeasures applied to the anadromous model of fish mitigation may not be at all applicable to this species.

- Arctic Char populations, similar to Bull Trout in the Columbia River basin, (Anglin et al. 2010; Budy et al. 2004 and 2009) may migrate at multiple ages. Therefore, fish much larger than salmon smolts migrating to sea may be attempting to negotiate downstream passage structures designed for fish of different sizes. In addition, the time period during which juvenile migration takes place is different than observed for salmon smolts.

- The type of juvenile passage facilities located at Lower Granite and Bonneville Dam proposed for implementation at Urridafoss (removable spillway weirs or side channel collectors) are used to augment passage accomplished with other juvenile fish passage facilities at these dams. These are both impoundment type dams and are not similar to the diversion type (penstock) dam proposed at Urridafoss.

- Dye studies conducted on a model of the proposed Urridafoss project suggests that a very high proportion of the colored water can be diverted to the bypass collector. Dye tests (colored water) are indicators of the hydraulic conditions encountered by fish approaching a project, but due to fish avoidance behavior are not used to determine the proportions of fish that pass via a specific route. Consequently, the efficiency estimate of 90–95% for fish passage through the bypass channel is likely overly optimistic.

- The location of juvenile bypass exit and the water velocity at the outfall location are important considerations in determining predation mortality after passing the juvenile facility. Any delay due to eddy formation can increase exposure time to predators and increase mortality.

- Plunging water (over a juvenile bypass as proposed for Urridafoss) can entrain atmospheric gases and increase the saturation of total dissolved gases in the water column. Research from the Columbia conducted since 1995 suggests that there can be a detrimental effect of total dissolved gases if the levels are greater than 135% supersaturation. The effect is lessened in the Columbia due to water depth and consideration of the total dissolved gas levels produced and the depth of the water where juveniles are exposed must be considered in determining overall impacts to survival.

- The assumptions made are that adult passage facilities can be built that will be effective at passing adult migrants around the dam. There is certainly much knowledge and experience associated with adult passage. However, there is no consideration of the fact that when rivers are dammed and flows through a reach are significantly reduced, low flow barriers to the adult salmon migration can be created. There is literature to support the concept that barriers to adult migration are created when the water depth is significantly decreased due to hydro development. (Thompson, 1972; Reiser and Bjorrn, 1979). In many rivers of the Pacific Northwest of the United States, dams and water withdrawals reduce flows to a level where significant numbers of passage barriers are created to adult salmon and bull trout migration (Anglin 2012).

- It would be important to evaluate how many low-flow instream barriers would be created in Thjorsa River by the placement of the three hydro dams. To estimate the potential extent of these barriers a survey to measure the bathymetry of the river between and below the dams should be made. Then a physical model of the river could be built to determine how many and the location of all the low flow barriers to migration that are created. This evaluation would be a critical element in determining the overall impact of the dams to the salmon population productivity.

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