Ecosystem-Based Function Integration Into the Columbia River Treaty

Columbia Basin Tribes′ Concept

Upper Arrow Lake. *Photo wallpaperup.com*

The Columbia River Treaty (Treaty) was established for flood risk management and hydropower production. The river's ecosystem functions and values were not considered in shaping and implementing the Treaty. This lack of consideration caused serious degradation of the ecosystem and undermined historical tribal economic and social resources that depend on it.

This paper provides a detailed description for potential Columbia Basin structural improvements and system operations that improve and restore ecosystem-based functions that are consistent with the "U.S. Entity Regional Recommendation for the Future of the Columbia River Treaty after 2024," the tribes' definition of ecosystem-based function *(see back page)*, and adaptation for climate change. For a discussion of fish passage and reintroduction—a major component of ecosystem-based function—see the Columbia Basin tribes' and First Nations' joint fish passage paper *(bit.ly/fish-passage)*. The following describes specific scenarios and options for modernizing the Treaty, restructuring its governance, developing a coordinated water management framework, and upgrading structures to integrate ecosystem-based function into a modernized Treaty. Ecosystem-based function must be integrated into Treaty planning and operations on an aggressive schedule.

The Columbia Basin tribes are comprised of fifteen sovereign tribes whose traditional homelands and nations stretch across the Columbia Basin and who have federally-recognized trust and treaty-reserved rights and interests. These rights and interests are substantially affected by the current Treaty operation and management of the Columbia Basin for the narrow purposes of hydropower generation and flood control. The negotiation and implementation of the Treaty substantially affected and continues to substantially affect the rights, interests, and cultural and natural resources of the Columbia Basin tribes. Negotiations to modernize the Treaty must integrate ecosystem-based functions to fully address these federally guaranteed trust and treaty rights.

About this Paper

The Columbia Basin tribes prepared this paper after cessation of the Columbia River Treaty Review Sovereign Participation Process and the U.S. Entity's submission of the Regional Recommendation to the Department of State in December 2013. The contents of this paper are consistent with the consensus regional recommendation. In addition to governance and infrastructure aspects, it addresses operations that might be implemented under the Treaty to integrate three primary purposes (ecosystem-based function, flood risk management and hydropower production). This paper does not represent a position on specific Treaty operations, but rather the intent is to provide a range of scenarios for further analysis and consideration in a collaborative forum used to determine future Treaty operations. And while fish passage and reintroduction are an integral aspect of ecosystem-based function, a substantive discussion of that issue is provided in a separate paper. This paper was approved for distribution by tribal leaders on October 1, 2014 and may be amended following additional analysis and review.

Headwaters of the Columbia River.

Successfully integrating ecosystem-based function into Treaty operations requires achieving several objectives. These include:

- A partially restored spring and early summer peaking hydrograph to improve resident and anadromous fish survival and wildlife habitat and help restore tribal First Foods, with a special focus on ensuring flows in low runoff years allow for hydrologic conditions that promote ecosystem function;
- Increased late summer and early fall flows to improve migration, habitat, and water quality for resident and anadromous fish;
- Stable reservoir elevations to improve resident fish production and better protect tribal cultural resources;
- Increased spring and early summer spill to increase anadromous fish survival;
- Reestablish floodplain habitat to allow for groundwater recharge and restoration of important habitat for riparian dependent wildlife species; and,
- Structural modifications to restore fish passage and improve water management now and handle anticipated climate change impacts now and in the future.

This paper describes a range of Columbia River system operations that improve and partially restore ecosystem function. These are represented by two modeled examples, denoted as 3Ea and 3Eb in the following figures and tables. These examples are compared to current river operations modeled example ("RCC current condition") as defined in the 2014-2024 Columbia River Treaty Review Sovereign Participation Process. The result would be Treaty operations that address three primary purposes: ecosystem-based function, hydropower production, and flood risk management.

The range of actions and river and reservoir operations described in this paper would contribute to a healthier Columbia River ecosystem in the U.S. and Canada while preserving much of the currently altered Columbia River flow regime for hydropower and power system reliability with complementary benefits to recreation, navigation, and water supply. The range of actions and river operations described in this paper would also address the Corps of Engineers' flood risk management objectives, particularly in higher water years (see figures on pages 5-6). These operations also consider adaptations for present and future climate change impacts. The Treaty must be modernized in a manner that promotes and achieves, at a minimum, the range of river operations represented by 3Ea and 3Eb examples. Implementation of the Treaty must allow

First Foods

The First Foods are water, salmon, deer, cous (or roots) and huckleberry. Each First Food consists of ecologically related foods. The salmon grouping includes the various salmon species, including steelhead, and also lamprey, freshwater mussels, trout and other fishes. The deer grouping includes mule deer, white-tailed deer and elk, among other four-legged, hoofed animals. The roots are cous, celery, camas and bitterroot. The berries are huckleberry and chokecherry. All First Foods, all life, depends on water and is always served first in our longhouse ceremonies. Our relationship to salmon and the First Foods is a reciprocal one. The First Foods nourish the native people, while the native people must protect them and the habitats that support them.

for changes based upon accumulation of greater knowledge and experience. For example, both the U.S. and Canada recognize that a modernized Treaty needs to be adaptable to climate change and the corresponding changes in basin meteorology and hydrology. The tribes believe a comprehensive study should be undertaken pursuant to a modernized Treaty to investigate water management options and structural changes at dams that could mitigate the anticipated changes in hydrology and water quality that are already problematic with the current system of dams.

One proven approach for integrating ecosystem-based function into river and reservoir operations is to use a reservoir management strategy called variable discharge or VARQ. VARQ has been successfully implemented at Libby and Hungry Horse dams in the upper Columbia Basin. It addresses ecosystem-based function, flood risk management and hydropower production at these projects in a coordinated manner that takes into consideration the needs for each in low, average and high water years. Significantly, it provides for more stable reservoirs, better assurance of reservoir refill, and seasonal river flows that are more ecologically appropriate. Implementing VARQ operations at all Columbia Basin projects in the United States and Canada would facilitate operations to integrate equally the three primary purposes of ecosystem-based function, flood risk management and hydropower production agreed to in the "U.S. Entity Regional Recommendation for the Future of the Columbia River Treaty after 2024." Importantly, the VARQ approach can incorporate improvements in operations over time as information is collected through implementation and as social needs and climate change occur. VARQ operations at Libby and Hungry Horse Dams are discussed in more detail later in this report.

Hungry Horse Dam

This 564-foot arch dam on Montana's South Fork Flathead River was the third largest dam in the world at the time of its completion in 1953.

Photo courtesy US Bureau of Reclamation.

Treaty Governance

A key aspect of effectively addressing ecosystem-based function in a modernized Treaty is an implementation framework that includes expert technical and policy knowledge and representation for ecosystem function both in the U.S. and Canada. This updated implementation framework is critical to balancing power, flood risk, and ecosystem operations and must be comprised of appropriate experts to ensure a modernized Treaty achieves the maximum optimized benefits for both countries, now and with advancing climate change.

It is essential that representatives from the sovereign tribal governments be designated as the ecosystem representatives within a future governance structure for Treaty development and implementation. Tribal representation is needed to give voice to the ecosystem and add their unique perspective and ecological knowledge to the governance of the Treaty. Tribal representation would also fulfill certain legal rights and obligations the tribes have in managing the ecosystem resources of the Columbia Basin. The tribes are the only parties that truly understand and can adequately represent these values and rights. Tribal representatives need to participate as members of bilateral technical and policy committees within an expanded Treaty governance framework. The tribes are currently analyzing governance models and intend to have more information on this topic later this year.

Structural Modifications

Beaver dam at Grand Teton National Park.
Photo: National Park Service.

Structural modifications at dams are just one aspect of improving ecosystem function throughout the entire Basin. By adding habitat restoration and conservation actions to our efforts, an even greater improvement to water temperatures and ecosystem health can be achieved. Part of integrating ecosystem-based function operations under the Treaty will be to investigate and implement all options for improving water quality and temperatures, including such actions as encouraging beaver dams in the headwaters of watersheds to store and deliver cooler water throughout the year.

Integrating ecosystem-based function into Treaty management requires project structural modifications in addition to balancing water management objectives. These include:

Modification of the spill gates at Grand Coulee Dam

The current maintenance schedule for these gates requires drafting Lake Roosevelt about once every three years to elevation 1255′ (35′ below full pool). This operation causes losses to U.S. and Canadian salmon resources and U.S. resident fish populations, particularly if the maintenance must be performed in a low water year. Drafting the reservoir to elevation 1255′ creates about 2.5 Maf of reservoir space that must then be refilled during the spring, which reduces the freshet for fish migrations and increases entrainment of resident fish. This is a significant amount of water and loss of management flexibility, particularly in drier water years. A more permanent solution to this maintenance practice is required to ensure operations of Grand Coulee that are consistent with ecosystem function, particularly with respect to U.S. and Canadian fishery resources. One solution may be to install stainless steel gates to minimize maintenance. Resolution of this maintenance problem could also contribute to any potential water supply opportunity by ensuring more storage in lower water years when it is most needed. Other modifications to retain colder water in the river and control the generation to "Total Dissolved Gas" at the hydro-facility are being investigated and need to be implemented so long they don't adversely affect reservoir temperatures.

Fish passage facilities

The Columbia Basin tribes and First Nations have described a pragmatic, incremental approach to testing the feasibility of restoring salmon to the upper Columbia River (see Fish Passage and Reintroduction into the U.S. & Canadian Upper Columbia River, An Interim Joint Paper of the U.S. Columbia Basin Tribes and Canadian First Nations, February, 2014 *bit.ly/fish-passage*). A thorough and objective investigation with a commitment to implementation, if warranted, is of paramount importance to the tribes and First Nations for any future Treaty addressing the Columbia River. Restoration of salmon and other migrating fish into historical habitats with their delivery of marine nutrients to inland ecosystems is an important aspect of ecosystem-based function.

High head fish passage at the 312-foot Upper Baker Dam is accomplished by a surface fish collector.
Photo courtesy Puget Sound Energy.

Flood Risk Management

Related to structural changes that should be included in a modernized Treaty, the Columbia Basin tribes envision the need for new flood risk infrastructure in the U.S. to minimize the consequences of high flows. A domestic regional flood risk management review for the Columbia Basin was recommended in the U.S. Entity Regional Recommendation on the Future of the Columbia River Treaty after 2024. A regional flood risk study is needed to determine what levee system upgrades, lower value floodplain reconnections, and floodplain management changes are needed to minimize the risk of damaging floods while providing greater flexibility in operations of U.S. and Canadian reservoirs to integrate ecosystem-based function into Columbia River flow regimes.

Grand Coulee spill.
Photo courtesy Washington State Department of Ecology.

Climate Change Adaptation

Both the U.S. and Canada recognize that a modernized Treaty must be adaptable to changes in basin meteorology and hydrology due to climate change. The current system of dams already negatively affects the Columbia River basin's hydrology and water quality. The tribes believe a comprehensive study should be undertaken pursuant to a modernized Treaty to investigate water management options and structural changes at dams that could not only improve current conditions, but also provide adaptation for anticipated climate change impacts.

Among other things, climate change adaptation measures should include the following:

- Improve runoff volume forecasting and modifying reservoir rule curves;

Half-filled reservoir behind Brownlee Dam.
Photo courtesy Oak Ridge National Laboratory.

- Restore fish access to upper basin habitat that will remain snow dominated and serve as refuges for these species;
- Reduce temperatures at dam fish ladders;
- Increase flows and spill to speed juvenile anadromous fish to estuary and ocean;
- Reestablish floodplain habitat to allow for groundwater recharge, temperature improvements and increase suitability of fish and riparian dependent wildlife habitat;
- Investigate additional temperature control facilities and operations at high head dams to manage downstream river temperatures and implement if warranted so long as this action will not increase reservoir water temperatures; and,
- Improve adult fish ladders to reduce fallback issues.

Unless measures are promptly investigated and pursued, the projected synergistic effects of climate change on water quality and habitat combined with extant impacts caused by the Columbia Basin dams is likely to further degrade ecosystem function to a degree that many of the tribes' and First Nations' trust resources would be irreparably harmed.

Ecosystem-based Function Operations

This section addresses the integration of ecosystem-based function, hydropower production, and flood risk management through modeled operations of the Columbia River Basin. Figures 1-3 demonstrate how the integration of ecosystem operations can partially restore the natural hydrograph for resident and anadromous fish while largely preserving flood risk management and power generation benefits. In these figures, the historical or unregulated peak hydrograph is included for comparison to the other three scenarios Additional ecosystem function and habitat restoration actions in tributaries that aid in temperature

Ecosystem-based function reservoir and river operations scenarios

The two river operations scenarios described in this paper are the continuation of years of modeling work initiated in the Sovereign Participation Process (SPP). They are labeled 3Ea and 3Eb. The 3 denotes it is the third iteration of this modeling, the E denotes it is an ecosystem-focused model, and the 'a' and 'b' denote two scenarios within the range of possible operations. Scenario 3Eb was developed after the cessation of the SPP.

3Ea retains more winter and early spring storage at upstream reservoirs, releasing extra water in the spring and early summer to recreate a partial peaking hydrograph in dry and average runoff years with a sustained declining limb and implements higher fish spill levels.

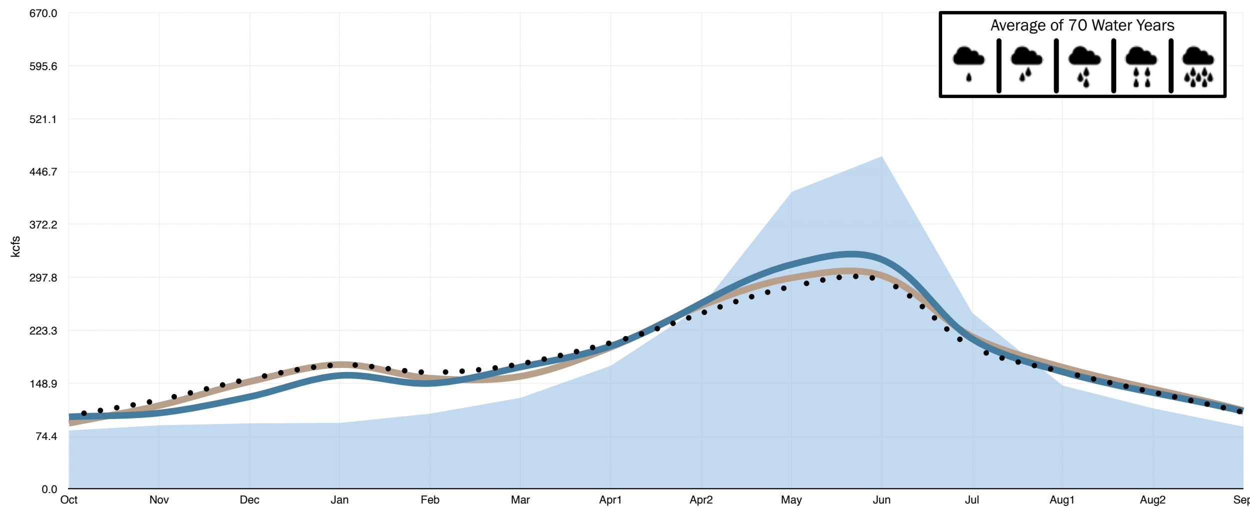
3Eb retains less winter and early spring storage than 3Ea in dry and average runoff years but more than the current condition. This storage is also released in the spring and early summer to create a partial peaking hydrograph with a sustaining limb. Fish spill levels are the same as for 3Ea.

modifications and improvements that provide desired habitat conditions.

In modeling these operations, the historical water year information is separated into quintiles ranging from the wettest to driest water years. Integrating ecosystem operations least affects

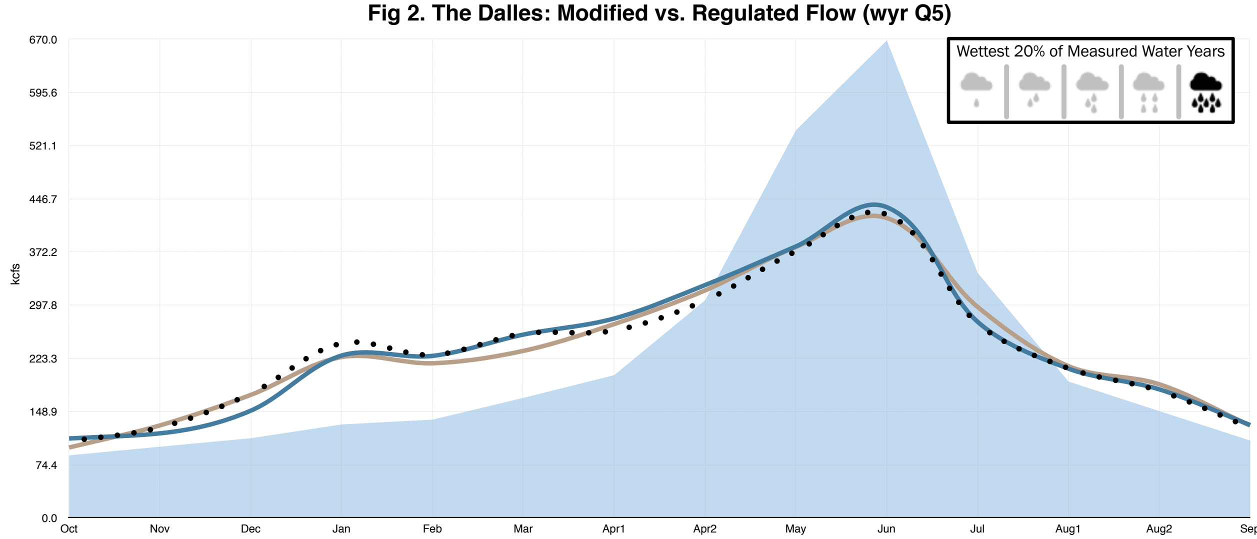
Natural, Unregulated Hydrograph
Current Condition
Ecosystem Scenario 3Ea
Ecosystem Scenario 3Eb

Fig 1. The Dalles: Modified vs. Regulated Flow (wyr ALL)



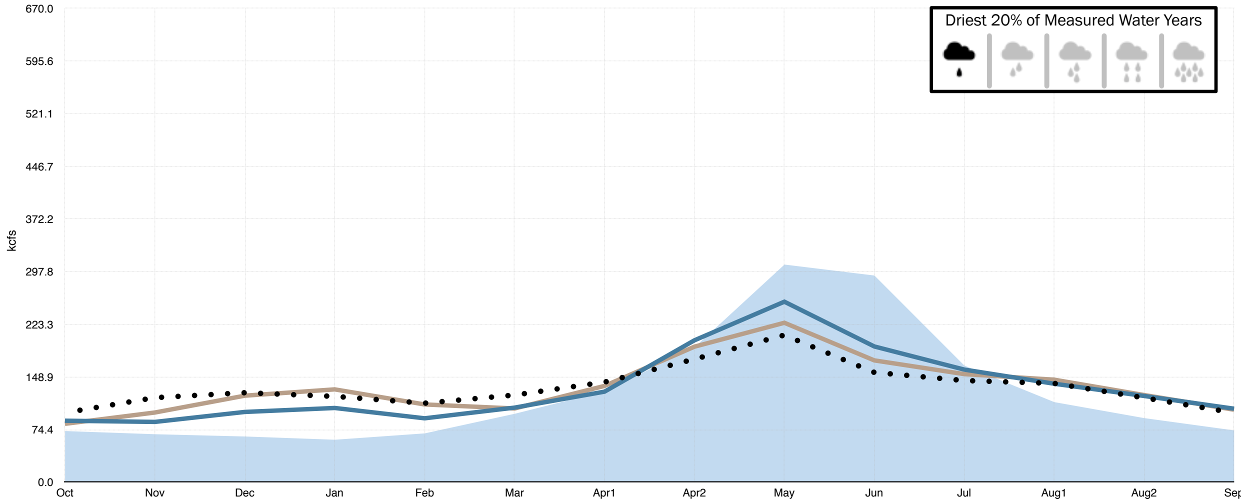
Scenario	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	Jun	Jul	Aug1	Aug2	Sep
Current ·······	103.1	125.3	154.9	174.7	164.2	176.1	205.8	241.8	284.9	293.6	200.1	165.2	138.0	107.9
3Ea	101.6	107.0	129.8	159.7	148.6	171.7	201.3	257.7	315.9	322.9	211.3	164.9	139.3	109.4
3Eb	92.6	117.5	151.1	175.1	155.9	158.6	199.5	258.0	297.1	300.4	214.5	171.4	144.4	110.5
Natural River	82.4	89.7	92.4	93.1	106.1	128.4	173.7	256.8	418.1	468.3	247.7	145.6	113.5	87.7

Fig 2. The Dalles: Modified vs. Regulated Flow (wyr Q5)



Scenario	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	Jun	Jul	Aug1	Aug2	Sep
Current ·······	107.1	126.5	173.8	244.3	228.0	257.9	262.2	304.3	373.0	424.6	272.2	209.3	177.9	126.1
3Ea	111.1	118.3	150.0	227.2	226.7	256.5	279.0	325.8	379.9	434.9	274.5	208.9	179.9	130.0
3Eb	98.5	129.4	172.1	225.1	216.4	233.7	271.2	318.3	379.2	419.7	295.3	212.4	187.0	129.2
Natural River	87.5	99.6	111.5	130.8	137.5	168.0	199.8	304.6	542.7	668.3	342.8	190.8	149.4	108.2

Fig 3. The Dalles: Modified vs. Regulated Flow (wyr Q1)



Scenario	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	Jun	Jul	Aug1	Aug2	Sep
Current ·······	98.2	119.5	126.5	121.3	111.7	123.2	141.5	174.0	208.0	155.2	143.7	139.7	119.3	98.1
3Ea	86.9	85.2	99.3	104.9	90.3	105.4	128.0	200.6	255.2	191.9	159.2	139.2	121.9	103.9
3Eb	82.5	98.5	122.3	131.2	109.9	104.2	136.1	191.6	225.4	172.2	152.8	144.9	123.2	102.5
Natural River	72.3	67.8	64.6	60.0	69.0	96.7	128.6	190.7	307.7	292.2	164.9	113.2	90.6	73.2

Natural, Unregulated Hydrograph
··· Current Condition
Ecosystem Scenario 3Ea
Ecosystem Scenario 3Eb

flow management in the highest water years (Quintile 5. Figure 2) preserving in those years the status quo system flood risk management. For a representative very high flow year in the 70-year record (1974), the peak monthly flow under 3E scenarios are lower than under the current condition (Figure 28, page 28).

The most significant operational changes to effectively integrate ecosystem function in a modernized Treaty are needed in the driest water years (Figure 3) when it is critical that Treaty operational planning provides the capacity to restore spring and early summer freshet flows and preserve additional storage for ecosystem-based function. This operational change will become more important in the future as the Basin is affected by climate change.

In each of this paper's figures, the dotted line represents the effects of current water management actions. For ecosystem considerations, these operations under the current FCRPS Biological Opinion include 1 million acre-feet (Maf) of stored water released from Canada pursuant to an annual agreement. This is the full extent of coordinated operations for ecosystem consideration that is achievable under the current Treaty construct.

The following sections address integration of ecosystem-based function into Treaty operations consistent with the Regional Recommendation and 3Ea and 3Eb. The sections describe each Treaty dam's reservoir operations, spill operations, and impact on flows in the mainstem of the Columbia River below Chief Joseph Dam.

Reservoir Operations

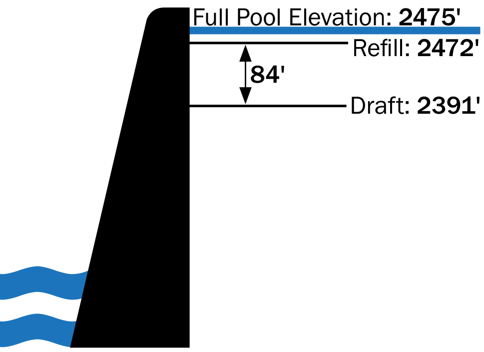
Key changes are required at some Treaty-coordinated U.S. and Canadian dams that significantly affect ecosystem function, resident and anadromous fish, and cultural resources, all of which are tribal trust and treaty resources the U.S. government is obligated to protect. These projects are Mica, Hugh Keenleyside (Arrow), and Grand Coulee dams. Other dams in the Columbia Basin will be managed similar to current operations under this initial integration of ecosystem-based function into Treaty operations as a third primary purpose. The range of operational changes described below (and reflected by scenarios like 3Ea and 3Eb) is likely to require adjustments and improved coordination in the U.S. and Canadian power systems to meet essential load and resource balance metrics and for the U.S. to study and adapt flood risk management. The outcome of these operations may also offer opportunities for water supply, pursuant to the allocation discussion noted as a domestic matter in the Regional Recommendation.

Lake Koocanusa

Created by Libby Dam in Montana, the 90-mile long Lake Koocanusa reaches 48 miles (77 km) to the Canadian border and 42 miles (68 km) further into British Columbia. The lake holds 13% of the water in the Columbia River system. *Photo courtesy US Forest Service.*

The section first describes the range of operations possible under examples 3Ea and 3Eb at Mica and Hugh Keenleyside (Arrow) dams in Canada. It then addresses the same range of operations on Grand Coulee Dam, the largest storage reservoir on the U.S. portion of the Columbia mainstem. Finally, it addresses other projects in the basin. Note that the Y-axis of each reservoir graph is the elevation range (measured in feet above sea level) for that reservoir.

Mica Dam



Mica Dam creates Kinbasket Reservoir, the largest reservoir in the Columbia River Basin. Currently, Kinbasket reservoir is drafted about 84′ from September through February, then begins to refill towards full pool starting about May 1 (Figure 4). However, in the low water years, the reservoir is drafted 10′ deeper to about elevation 2381′ (Figure 6). Refill of about 7.6 million acre-feet (Maf) in Kinbasket Reservoir in May through July reduces the spring freshet flows that U.S. and Canadian salmon stocks require for their migration to the ocean and that other species, such as sturgeon, need to complete their life cycle. This reduction in the freshet is most pronounced and most damaging in the lower runoff years. This standard Mica operation is counter to other basin reservoirs that are normally drafted less in the lower water years. Many ESA-listed populations of salmon, bull trout, and sturgeon that are essential to tribal cultures are adversely affected by this coordinated flood risk and power operation at Mica. The effects of turbine additions at Mica on future project operations are not known.

Ecosystem-based function integration reduces the fall drafting of Kinbasket Reservoir and requires that the full draft be delayed until after the January 1 volume runoff forecast. This and subsequent monthly runoff forecasts could then guide the remaining draft of the reservoir as is done at other system reservoirs. The objective is to draft Kinbasket Reservoir about 10′ to 20′ less in the lower water years, but still allow full draft in the higher water years (Figure 5).

This operation would reduce fall and early winter power production in Canada and the U.S. but allow increased generation of peak power from increased head. As reservoir elevations in April would only be affected in the lower water years, flood risk management should be minimally impacted. By reducing reservoir drafts in lower water years, the potential for more water storage would be increased when it is most needed. By increasing storage, this operation would also provide greater flexibility to respond to climate change.

Mica Dam

This 787-foot dam is the farthest dam up the Columbia River. It is one of the largest earthfill dams in the world.

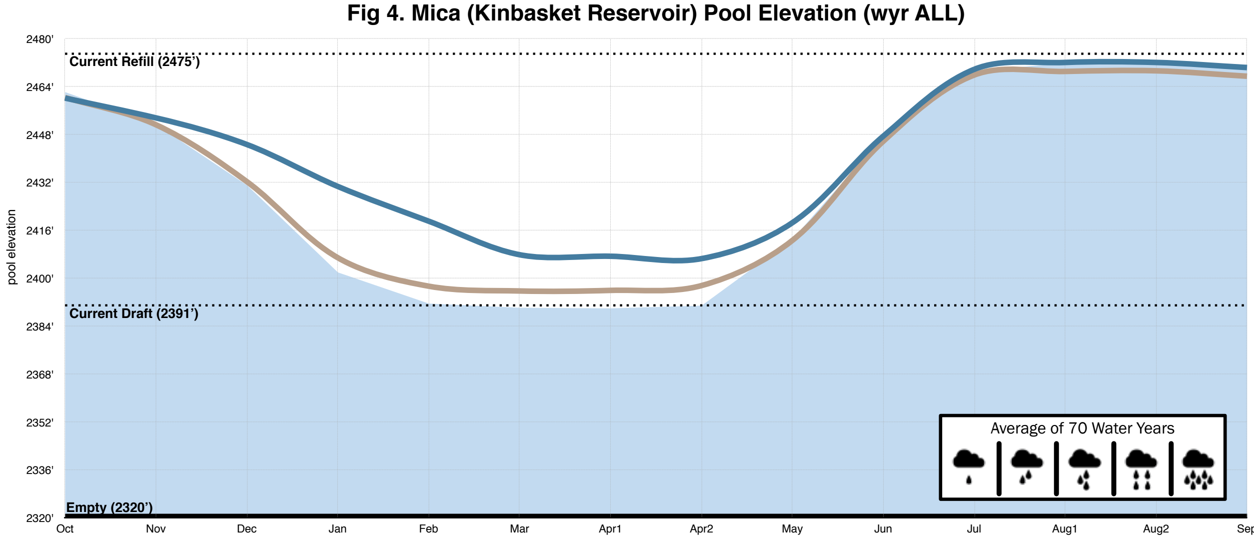
Photo: Wikipedia.

From September through December, Kinbasket Reservoir drafting could follow current operations, drafting to about elevation 2430′. After January 1, further reservoir draft would be guided by monthly basin volume runoff forecasts (at Border and The Dalles Dam). Full draft, to about elevation 2390′ would occur in the higher water years. In the lowest 20% of water years, draft would be limited to about elevation 2400′ (about 20′ higher than current operations). In the lower 20% to 40% water years, reservoir draft would similarly be limited to elevation 2400′, about 10′ higher than current operations.

Figures 4-6 illustrate a range of ecosystem integration represented by examples 3Ea and 3Eb that mitigate for impacts of Mica operations on the natural hydrograph, salmon survival, and sturgeon production downriver in the U.S. This range of operations should also improve resident fish habitat, help protect cultural resources, and reduce dust storms in Kinbasket Reservoir. Reducing reservoir drafting is particularly important in the less than average flow years. In the higher flow years, operations would remain similar to the current condition. Stabilizing Kinbasket Reservoir pool elevations would likely also mitigate effects to the local ecosystem and improve downstream habitat conditions for reintroduction of salmon into Canadian waters.

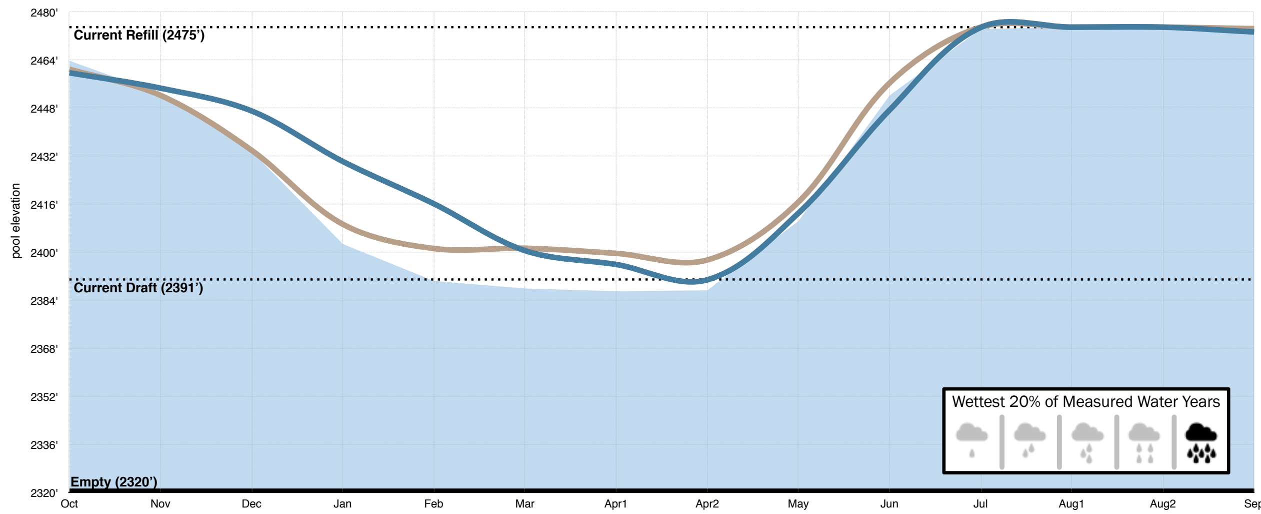
Current Condition
Ecosystem Scenario 3Ea
Ecosystem Scenario 3Eb

Fig 4. Mica (Kinbasket Reservoir) Pool Elevation (wyr ALL)



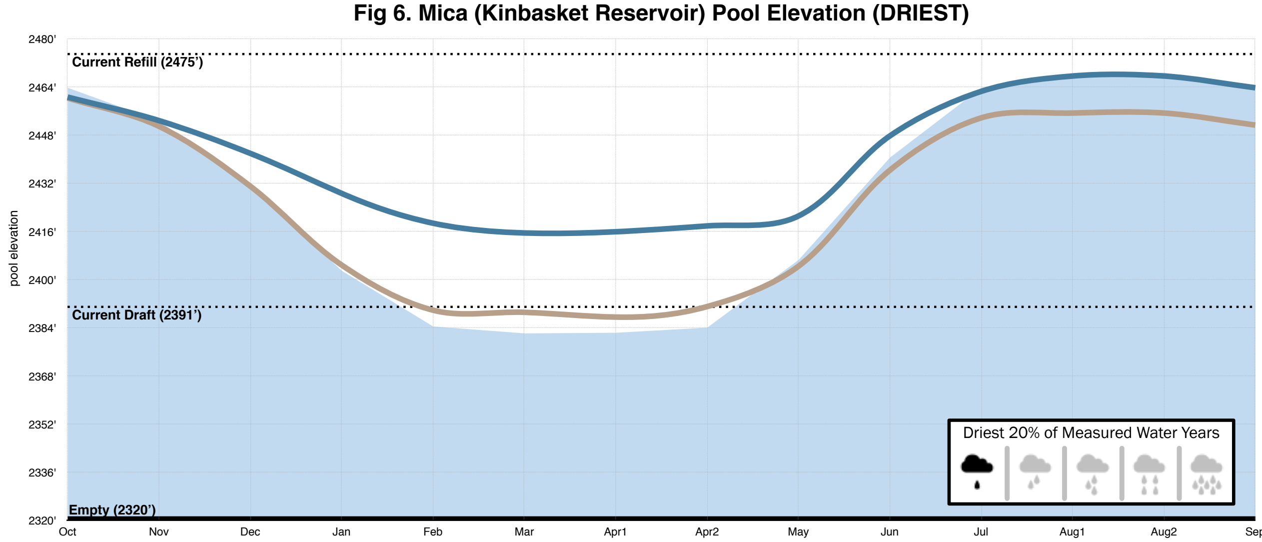
Scenario	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	Jun	Jul	Aug1	Aug2	Sep
Curr. Cond.	2462.2	2451.4	2431.1	2402.0	2391.6	2390.2	2390.0	2390.9	2413.1	2447.6	2469.2	2471.9	2472.8	2471.3
3Ea	2460.2	2453.6	2444.7	2430.7	2419.1	2407.9	2407.4	2406.6	2418.6	2447.5	2469.8	2472.1	2472.1	2470.4
3Eb	2460.4	2451.3	2432.3	2406.9	2397.4	2395.8	2396.0	2397.6	2412.7	2445.8	2467.9	2469.1	2469.3	2467.5

Fig 5. Mica (Kinbasket Reservoir) Pool Elevation (WETTEST)



Scenario	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	Jun	Jul	Aug1	Aug2	Sep
Curr. Cond.	2463.8	2452.9	2433.6	2402.8	2390.5	2388.0	2387.1	2387.4	2410.5	2452.3	2474.4	2475.0	2475.0	2475.0
3Ea	2459.8	2454.7	2447.1	2430.3	2416.2	2400.6	2396.0	2390.9	2413.1	2447.4	2474.9	2475.0	2475.0	2473.4
3Eb	2461.0	2452.3	2434.0	2409.4	2401.3	2401.4	2399.7	2397.5	2416.8	2456.4	2475.0	2475.0	2475.0	2474.5

Fig 6. Mica (Kinbasket Reservoir) Pool Elevation (DRIEST)

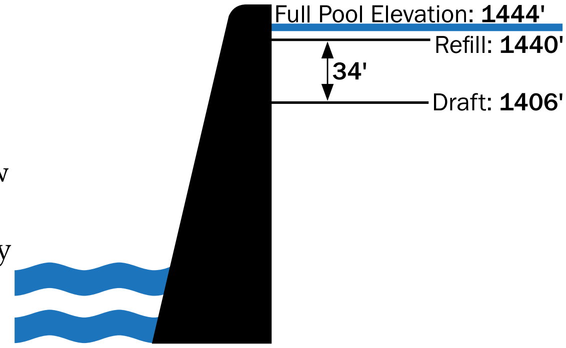


Scenario	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	Jun	Jul	Aug1	Aug2	Sep
Curr. Cond.	2463.8	2452.8	2431.1	2403.0	2384.5	2382.2	2382.4	2384.1	2406.6	2440.6	2463.8	2467.9	2468.8	2464.2
3Ea	2460.7	2452.9	2442.0	2428.7	2418.8	2415.6	2416.8	2417.9	2421.2	2447.8	2462.6	2467.7	2467.7	2463.8
3Eb	2460.4	2451.0	2431.1	2404.9	2389.9	2389.2	2387.6	2391.1	2404.5	2436.4	2453.8	2455.4	2455.4	2451.4

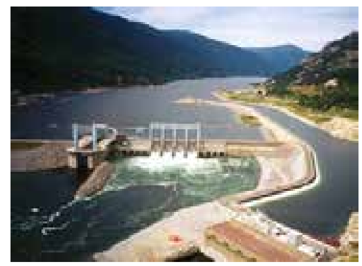
Current Condition
Ecosystem Scenario 3Ea
Ecosystem Scenario 3Eb

Hugh Keenleyside (Arrow) Dam

Arrow Lake was a series of natural lakes whose storage capacity was enhanced by the construction of Hugh Keenleyside Dam. Currently, Arrow Lake is drafted about 34′ from August through March, then begins to refill towards full pool starting about May 1 (Figure 7). However, in the low water years, Arrow is drafted about 5′ less to about elevation 1411′ (Figure 9). Refill of about 3.9 Maf at Arrow Lake in May through July, as with operations at Mica Dam, also reduces spring freshet flows thereby adversely affecting salmon and sturgeon viability.



Ecosystem integration has the August through December drafting of Arrow Lake continue as in current operations, but the full draft should be delayed until after the January 1 volume runoff forecast. This and subsequent monthly runoff forecasts could then guide the remaining draft of the reservoir (Figure 7). The objective is to draft Arrow Lake about 10′ less in the late winter during lower water years, but still allow full draft in the higher water years. This operation would increase lower river flows in mid to late April to restore some of the early spring salmon migration flows. Arrow Lake would still have a similar elevation on May 1 for flood risk management (Figure 8).



Hugh Keenleyside (Arrow) Dam

Keenleyside Dam creates the 144-mile-long Arrow Lakes reservoir. It was originally built to control the flow of water in the Columbia for downstream dams.

Photo: Wikipedia.

This operation would reduce late winter power production in Canada and the U.S., but provide for increased peak energy capacity with higher reservoir head. As Arrow Lake elevations would be similar to the current operations on May 1, flood risk management should be little affected. By reducing Arrow Lake winter drafts in lower water years, the potential for more basin water supply storage could also be increased when it is most needed. By increasing storage, this operation would also provide greater flexibility to respond to climate change.

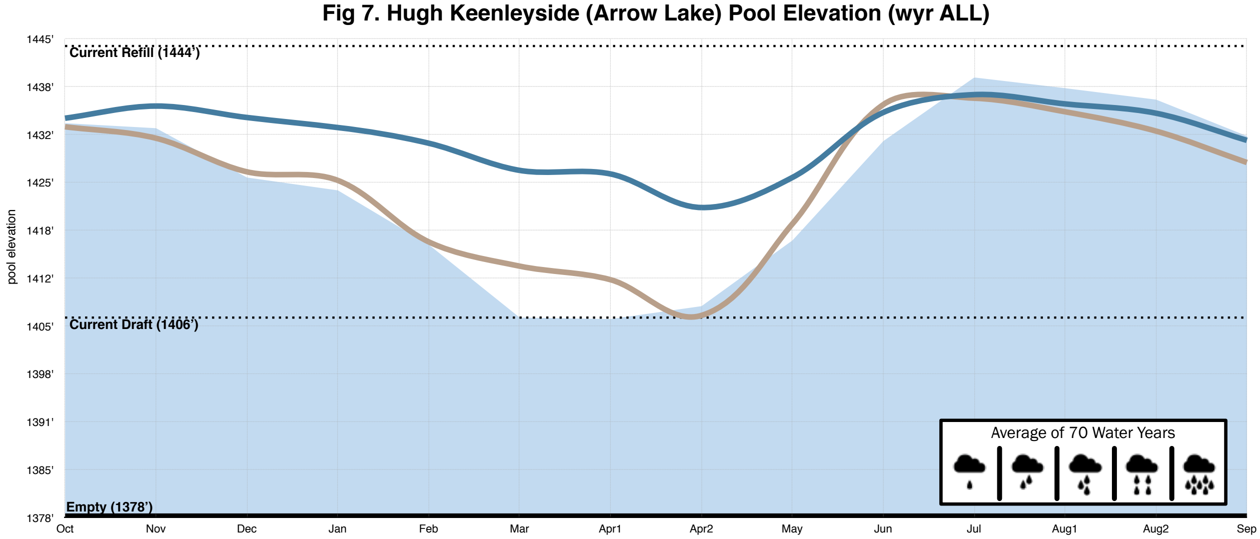
From August through December, Arrow Lake draft would be similar to current conditions. After January 1, further drafting of Arrow Lake would be guided by monthly basin forecasts (at Border and The Dalles Dam). Full drafting of Arrow Lake, to between 1395′ and 1410′ would still occur in the highest 60% of water years as in current operations. In the lowest 40% of water years, draft would be limited to about elevation 1420′ (10′ less) through April 1.

Upper Arrow Lake.
Photo: wallpaperup.com

Figures 7, 8 and 9 demonstrate a range of ecosystem integration represented by scenarios 3Ea and 3Eb that would mitigate for effects of Arrow Lake operations on the natural hydrograph, and salmon and sturgeon survival downriver in the U.S. This range of operations should also improve resident fish habitat in Arrow Lakes. Reducing Arrow Lake draft is particularly important in the less than average flow years. In the higher flow years, operations would remain similar to the current condition. Stabilizing Arrow Lake elevations would likely also mitigate effects to the local ecosystem and improve habitat conditions for reintroduction of salmon back into Canadian waters.

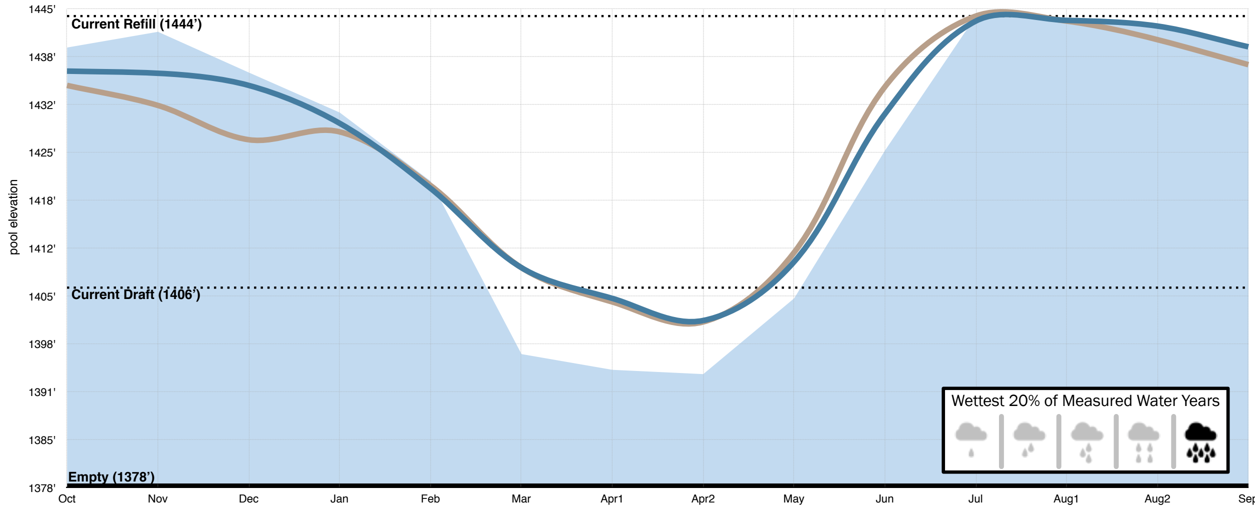
Current Condition
Ecosystem Scenario 3Ea
Ecosystem Scenario 3Eb

Fig 7. Hugh Keenleyside (Arrow Lake) Pool Elevation (wyr ALL)



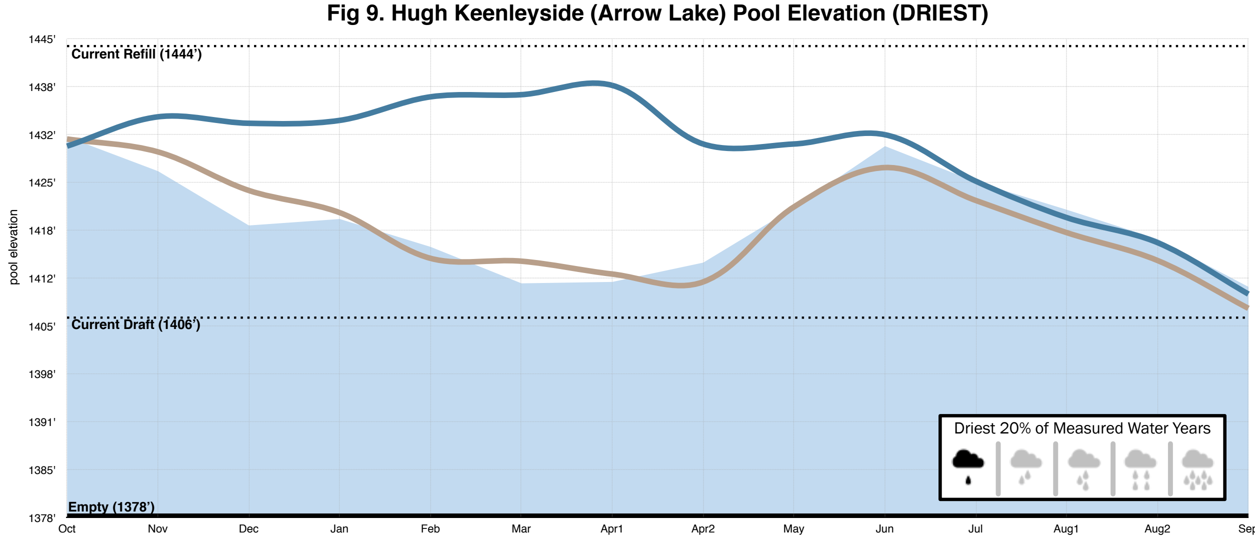
Scenario	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	Jun	Jul	Aug1	Aug2	Sep
Curr. Cond.	1433.2	1432.5	1425.6	1423.8	1416.2	1406.0	1405.8	1407.6	1416.8	1430.7	1439.6	1438.1	1436.5	1431.4
3Ea	1433.9	1435.6	1434.0	1432.6	1430.4	1426.6	1426.1	1421.4	1425.6	1434.7	1437.2	1435.9	1434.6	1430.8
3Eb	1432.7	1431.1	1426.4	1425.2	1416.6	1413.2	1411.3	1406.3	1419.1	1435.8	1436.7	1434.8	1432.1	1427.7

Fig 8. Hugh Keenleyside (Arrow Lake) Pool Elevation (WETTEST)



Scenario	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	Jun	Jul	Aug1	Aug2	Sep
Curr. Cond.	1439.6	1441.8	1436.1	1430.5	1420.9	1396.7	1394.5	1393.9	1404.5	1425.2	1444.0	1443.5	1443.0	1439.4
3Ea	1436.3	1436.0	1434.3	1429.0	1419.9	1408.8	1404.5	1401.4	1409.6	1430.3	1443.3	1443.4	1442.6	1439.7
3Eb	1434.3	1431.5	1426.7	1427.8	1420.3	1408.8	1404.0	1401.2	1410.9	1434.1	1444.0	1443.3	1440.7	1437.2

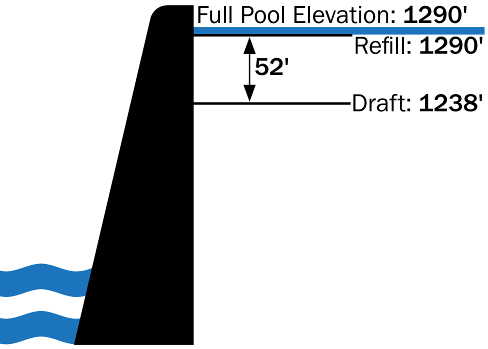
Fig 9. Hugh Keenleyside (Arrow Lake) Pool Elevation (DRIEST)



Scenario	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	Jun	Jul	Aug1	Aug2	Sep
Curr. Cond.	1431.3	1426.5	1418.9	1419.8	1415.9	1410.8	1411.0	1413.7	1421.4	1430.0	1425.0	1421.1	1417.0	1410.3
3Ea	1430.0	1434.1	1433.2	1433.6	1436.9	1437.2	1438.5	1430.3	1430.3	1431.6	1425.1	1420.0	1416.5	1409.3
3Eb	1431.0	1429.2	1423.8	1420.7	1414.3	1413.9	1412.1	1411.0	1421.5	1427.0	1422.4	1417.9	1414.0	1407.3

- Current Condition
- Ecosystem Scenario 3Ea
- Ecosystem Scenario 3Eb

Grand Coulee Dam



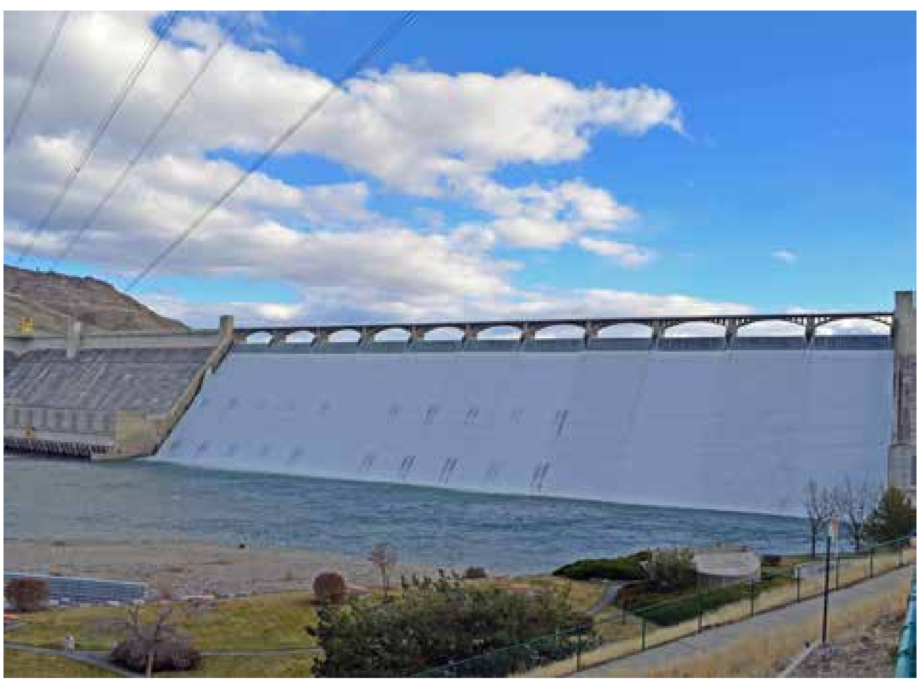
Currently, Lake Roosevelt is drafted about 52′ on average from October through April, then refills to full pool in May through June (Figure 10). The project is then drafted 10′ to 12′ from full pool through the summer. On September 1, a second refill operation begins. Drafting of Lake Roosevelt is based on volume runoff forecasts. In the lowest 20% of water years, the reservoir is drafted about 14′ less than average, to elevation 1252′ (Figure 12); while in the highest 20% of water years, the reservoir is drafted about 18′ more, to elevation 1220′ (Figure 11). Drafting to 1208′ is undertaken when threats of flooding are greatest. Average refill of about 3.5 Maf of Lake Roosevelt in May through July, as at the Canadian projects, also contributes to the cumulative reduction in the spring freshet flows.

Ecosystem integration results in the October through February drafting of Lake Roosevelt in a manner similar to current operations. However, the March and April drafting of the reservoir should be reduced in the lower water years (when the threats of flooding are very low) to improve ecosystem function, including reduction in adverse impacts to tribal cultural resources (Figure 12). In the lowest 20% of water years, the reservoir would be kept about 5′ higher than current operations (elevation 1258′). In the 20% to 40% lower water years, the reservoir draft would be about 25′ less than current operations. However, in the highest 20% water years, the deep draft for flood control would be similar to current operations, to about elevation 1220′ (Figure 11). The objective is to draft Lake Roosevelt less in the early spring of the lower and average water years, but continue full draft in the higher water years. This operation would increase lower river flows in late April through June to restore some of the spring/summer salmon migration flows. This operation would also improve survival and productivity of resident fish populations and reduce their loss through entrainment.

Grand Coulee Dam

Completed in 1942, Grand Coulee Dam is the largest electric-power producing facility in the United States. It is nearly a mile wide, 550 feet tall, and has no fish passage.

Photo: Columbia River Inter-Tribal Fish Commission.

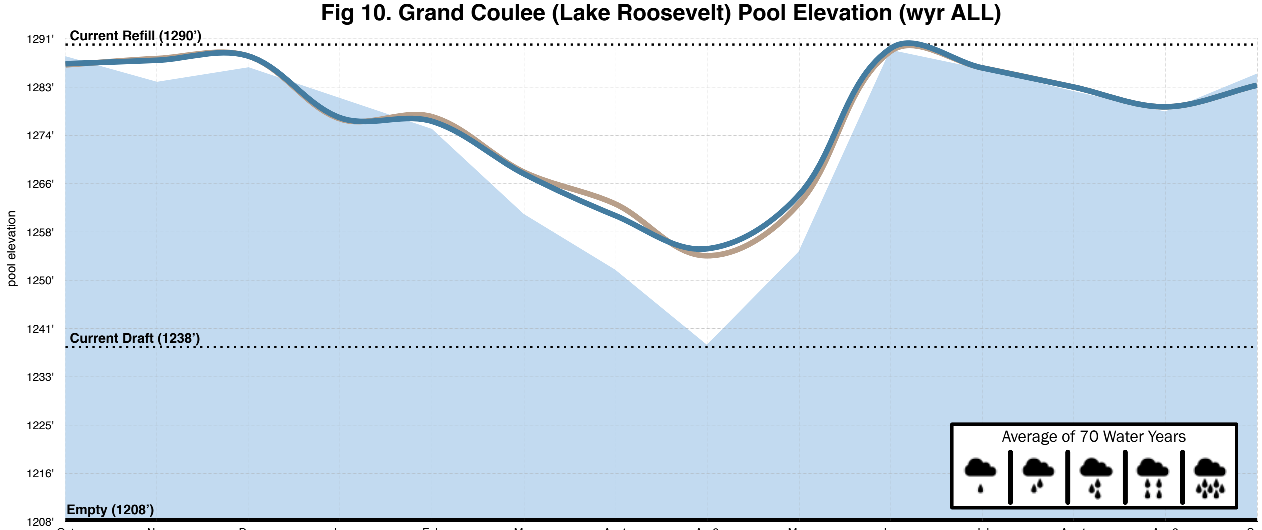


This range of operations reflected by scenarios 3Ea and 3Eb could reduce U.S. power production mostly in the early spring months when loads are lower, electricity prices are lower, and generation alternatives (i.e. wind) are more readily available. Peak power capacity would, however, be increased. By reducing Lake Roosevelt drafts in lower water years, the potential for more basin storage for water supply when it is most needed could also be increased. By increasing storage, this operation would also provide greater flexibility to respond to the impacts of climate change. Other modifications to retain colder water in the river and control the generation to "Total Dissolved Gas" at the hydro-facility also need to be investigated and implemented.

Figures 10, 11 and 12 demonstrate a range of ecosystem integration represented by 3Ea and 3Eb scenarios that would mitigate effects of Grand Coulee Dam operations on the natural hydrograph and salmon survival downriver in the U.S. These operations would also enhance resident fish populations in Lake Roosevelt and better protect tribal cultural resources. Reducing the draft of Lake Roosevelt is particularly important in the less than average flow years. In the higher flow years, operations would remain similar to the current condition.

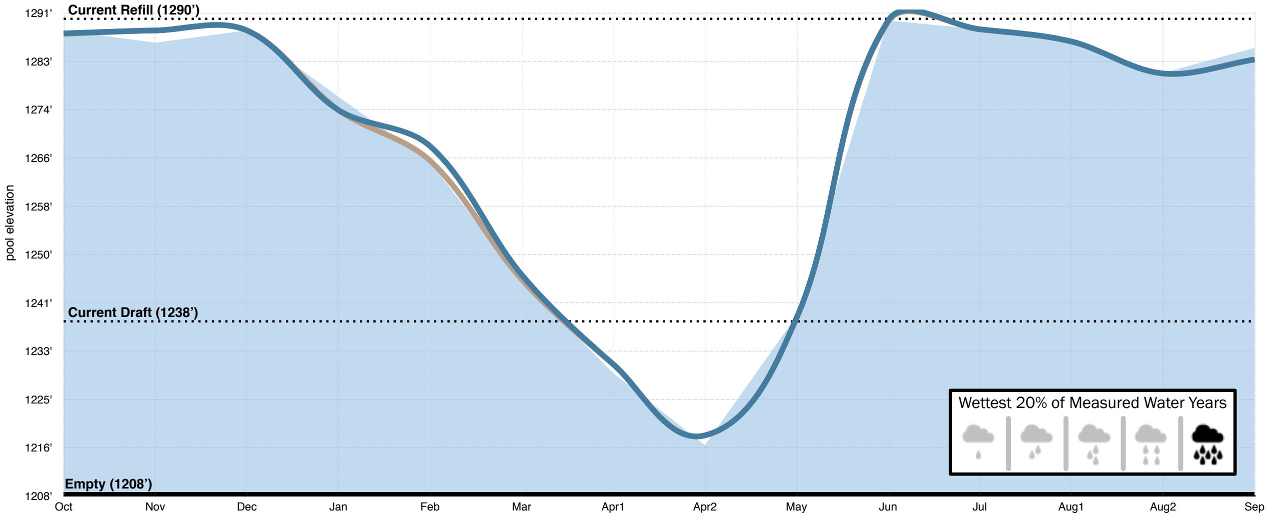
Current Condition
Ecosystem Scenario 3Ea
Ecosystem Scenario 3Eb

Fig 10. Grand Coulee (Lake Roosevelt) Pool Elevation (wyr ALL)



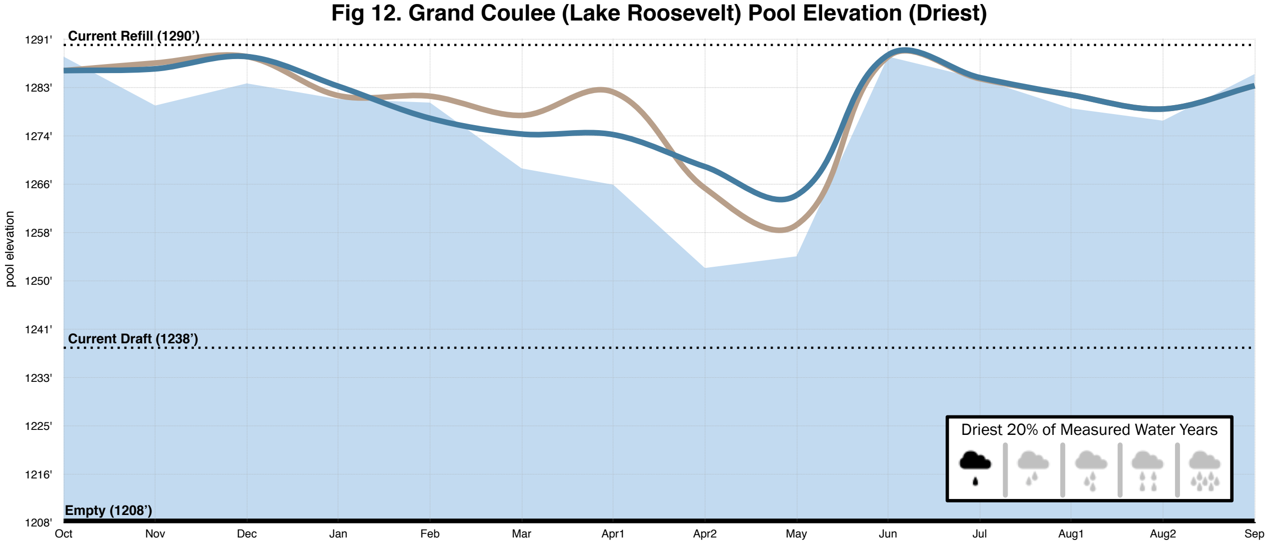
Scenario	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	Jun	Jul	Aug1	Aug2	Sep
Curr. Cond.	1288.0	1283.6	1286.1	1280.8	1275.5	1260.9	1251.3	1238.4	1254.4	1289.1	1285.8	1282.0	1278.5	1285.0
3Ea	1286.7	1287.3	1288.0	1277.4	1276.8	1267.8	1260.6	1254.9	1264.1	1289.3	1286.0	1282.7	1279.3	1283.0
3Eb	1286.5	1287.6	1288.0	1277.2	1277.6	1268.1	1262.6	1253.7	1262.6	1288.8	1286.0	1282.7	1279.3	1283.0

Fig 11. Grand Coulee (Lake Roosevelt) Pool Elevation (Wettest)



Scenario	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	Jun	Jul	Aug1	Aug2	Sep
Curr. Cond.	1288.0	1285.9	1288.0	1276.6	1265.4	1244.9	1229.1	1216.7	1238.9	1289.7	1288.2	1285.9	1280.7	1285.0
3Ea	1287.5	1288.0	1288.0	1274.3	1268.1	1246.0	1230.6	1218.4	1238.6	1289.7	1288.2	1286.1	1280.6	1283.0
3Eb	1287.4	1288.0	1288.0	1274.3	1265.6	1245.2	1230.6	1218.4	1238.6	1289.5	1288.2	1286.1	1280.6	1283.0

Fig 12. Grand Coulee (Lake Roosevelt) Pool Elevation (Driest)



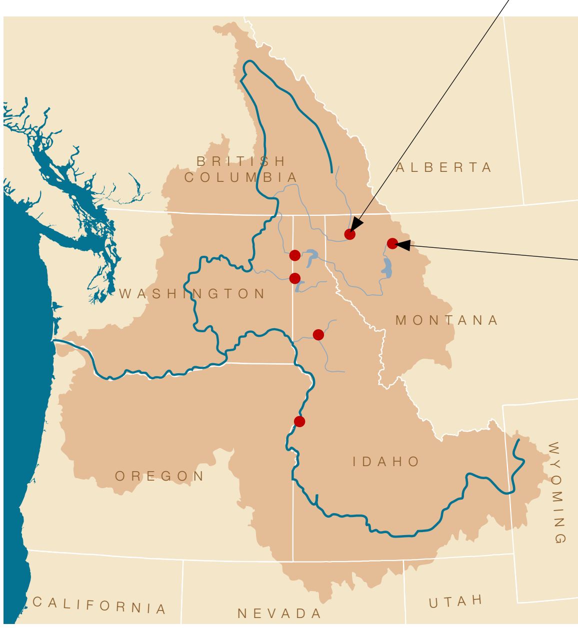
Scenario	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	Jun	Jul	Aug1	Aug2	Sep
Curr. Cond.	1288.0	1279.6	1283.4	1280.7	1280.1	1268.8	1266.0	1251.7	1253.7	1288.0	1284.2	1279.1	1277.0	1285.0
3Ea	1285.6	1285.9	1288.0	1282.9	1277.4	1274.7	1274.6	1269.1	1264.2	1288.3	1284.4	1281.4	1279.0	1283.0
3Eb	1285.6	1286.9	1288.0	1281.3	1281.2	1277.9	1281.9	1265.4	1259.1	1288.0	1284.2	1281.4	1279.0	1283.0

Current Condition
Ecosystem Scenario 3Ea
Ecosystem Scenario 3Eb

Other Projects

While dams and associated reservoirs other than Mica, Arrow, and Grand Coulee should be affected less due to modernizing the Treaty to provide operations in the 3Ea to 3Eb range, some changes are necessary to improve local ecosystem conditions and contribute to restoration of the natural hydrograph for downriver fish production and migration. It is essential that these modifications at the other projects occur to support all the changes called for in the Regional Recommendation proposal to integrate ecosystem-based function, power production, and flood risk management. The tribes expect, over time and with implementation of an adaptive management approach to Treaty operations, that improvements can and will be found that benefit all three purposes of the Treaty.

Libby and **Hungry Horse** dams in Montana are key components of Treaty and system operations. Initiating ecosystem-based function at these projects in recent years was accomplished by using a variable flow flood control strategy called variable discharge or VARQ. VARQ at these projects provides an example for reservoir and dam operation that integrates ecosystem-based function into operations while not compromising local flood control needs at Bonners Ferry on the Kootenai River (Libby Dam) and Columbia Falls on the Flathead River (Hungry Horse Dam). In addition, VARQ operations do not significantly affect system flood control needs or hydropower production.



Current Condition
Ecosystem Scenario 3Ea & 3Eb

Fig 13. Libby (Lake Koocanusa) Pool Elevation (wyr ALL)

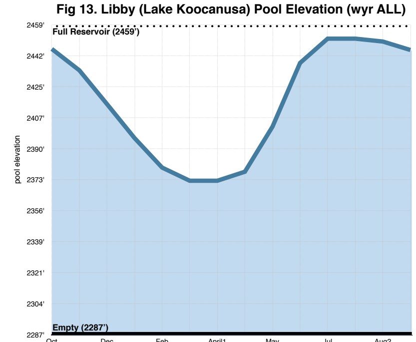


Fig 14. Libby (Lake Koocanusa) Pool Elevation (wyr Driest)

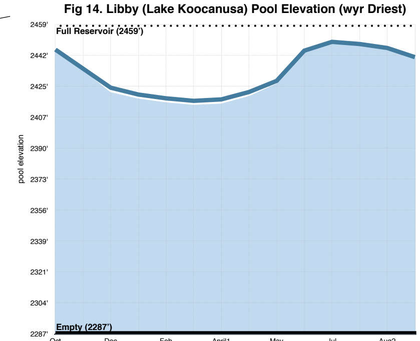
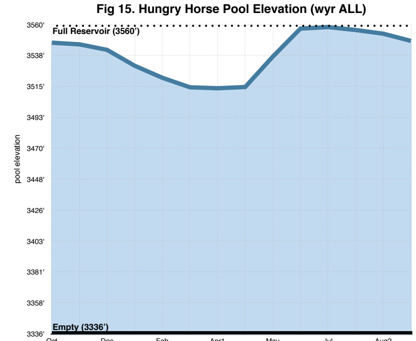


Fig 15. Hungry Horse Pool Elevation (wyr ALL)



Implementation of VARQ at Libby and Hungry Horse dams also provides more reliable spring and summer flows for upriver and downriver fish consistent with ecosystem-based function. Flows released from Libby Dam achieve specific habitat attributes that benefit Kootenai River white sturgeon and bull trout, listed respectively as endangered and threatened under the Endangered Species Act (ESA). Likewise, flows released from Hungry Horse Dam benefit bull trout. Releases from these dams also provide flow augmentation for threatened and endangered salmon and steelhead in the Columbia River. These flows also address provisions that require avoiding adverse modification of critical habitat for all of these ESA-listed species. In addition, VARQ operations provide higher reservoir elevations in the summer and fall, increased probability of reservoir refill, and contribute to a more natural hydrograph.

Implementing VARQ operations at these projects has partially integrated ecosystem-based function into Treaty operations and demonstrates that VARQ operations are a proven tool that can help accomplish this goal. Under the range identified by 3Ea and 3Eb, Libby and Hungry Horse dams operations would largely continue to follow VARQ. In both instances this includes continuing to address important local flood control needs (Figures 13 and 15). However, in the driest water years, Libby would draft up to 4′ less than current operations to improve habitat for resident fish in and below the reservoir, and to increase the spring freshet for resident and anadromous fish survival (Figure 14). It must be noted that other potential operational and structural actions at these two projects will continue to be investigated over time to improve the integration of ecosystem-based function, flood risk management, and hydropower production.

Lake Coeur d’Alene, regulated by **Post Falls Dam**, would not be affected by ecosystem-based function integration and would continue to operate in a manner similar to current conditions (Figure 17).

With ecosystem-based function integration in the near-term, **Albeni Falls Dam** in Idaho would operate similar to the current condition, except in the driest water years when it would draft about 1′ deeper in August and September to increase low flows in the Pend Oreille River (Figure 16). This operation would be evaluated to assess potential benefits to resident fish habitat.

Current Condition
Ecosystem Scenario 3Ea & 3Eb

Fig 17. Post Falls (Lake Coeur d’Alene) Pool Elevation (wyr ALL)

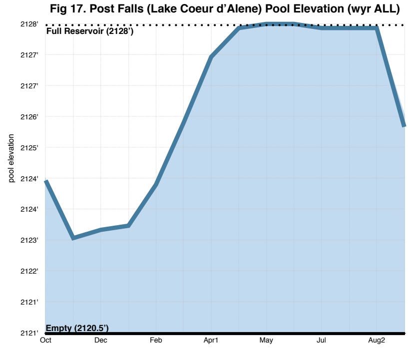
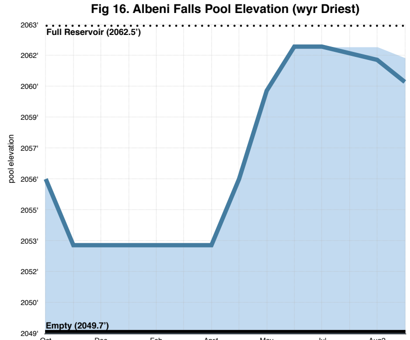


Fig 16. Albeni Falls Pool Elevation (wyr Driest)



For systematic ecosystem integration, **Dworshak Dam** on the Clearwater River in Idaho would be drafted about 6′ less (Figure 19). This ecosystem-based function operation would improve resident fish habitat in the reservoir and improve spring freshet flows for fish survival in the Snake River in all but the highest water years, when current flood risk management protocols are left in place.

Fig 19. Dworshak Pool Elevation (wyr ALL)

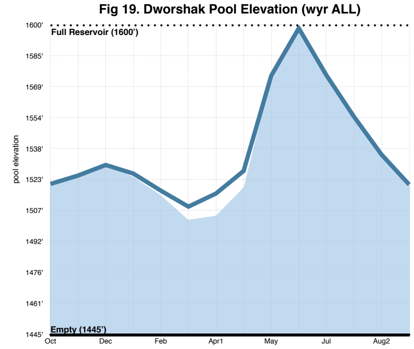
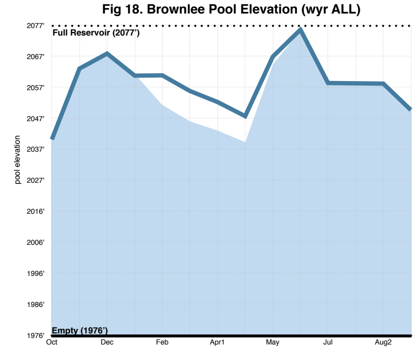


Fig 18. Brownlee Pool Elevation (wyr ALL)



For systematic ecosystem integration, **Brownlee Dam** on the Snake River in Idaho would be drafted about 10′ less (Figure 18). This ecosystem-based function operation would improve resident fish habitat in the reservoir and improve spring freshet flows for fish survival in the Snake River in all but the highest water years.

Brownlee Dam.
Photo courtesy US Army Corps of Engineers.

Spill

Spill at John Day Dam.
Photo courtesy Wikipedia.

Spill through dam spill gates or sluiceways may occur any time of the year from overgeneration, forced spill due to lack of power markets or turbine outages or evacuation of reservoirs for flood risk management. Fish passage spill is an important dam operation for enhancing salmon passage survival over dams and to decrease salmon migration times to saltwater. Dam spill can cause elevated levels of total dissolved gas that can put migrating juvenile and adult salmon at risk of suffering gas bubble trauma. The total dissolved gas (TDG) level maximum for Washington, Oregon, and tribes is 110%, but during fish passage periods, this level is increased to 115 % in Washington and 120% in Oregon. These limits, however, have and can be exceeded for hydropower or flood risk management system operations for significant periods of the year. The 3Ea and 3Eb ecosystem-based function examples assume that the dam spill for fish passage would not exceed the current Oregon standard of 120% TDG. In summer months, July through August, 3Ea and 3Eb examples assume spill levels remain as described in the current FCRPS Salmon Biological Opinion. Increased spill levels are illustrated for the four lower Columbia River dams (Fig. 20) and at four of the mid-Columbia dams (Fig. 21).

For ecosystem integration, fish spills at run-of-river dams with fish passage in the U.S. could be increased, but should not exceed 125% TDG at dams below Chief Joseph Dam from April through June to increase juvenile salmon survival. While current TDG standards limit gas levels to 115-120%, increased spills within TDG biological limits have been shown to increase project-specific and cumulative survival of juvenile salmon and likely lamprey. For this reason, there may be merit in managing for increased spill levels at dams below Chief Joseph Dam provided TDG does not exceed 125%.

Fig 20. Spill levels at the four lower Columbia River Dams

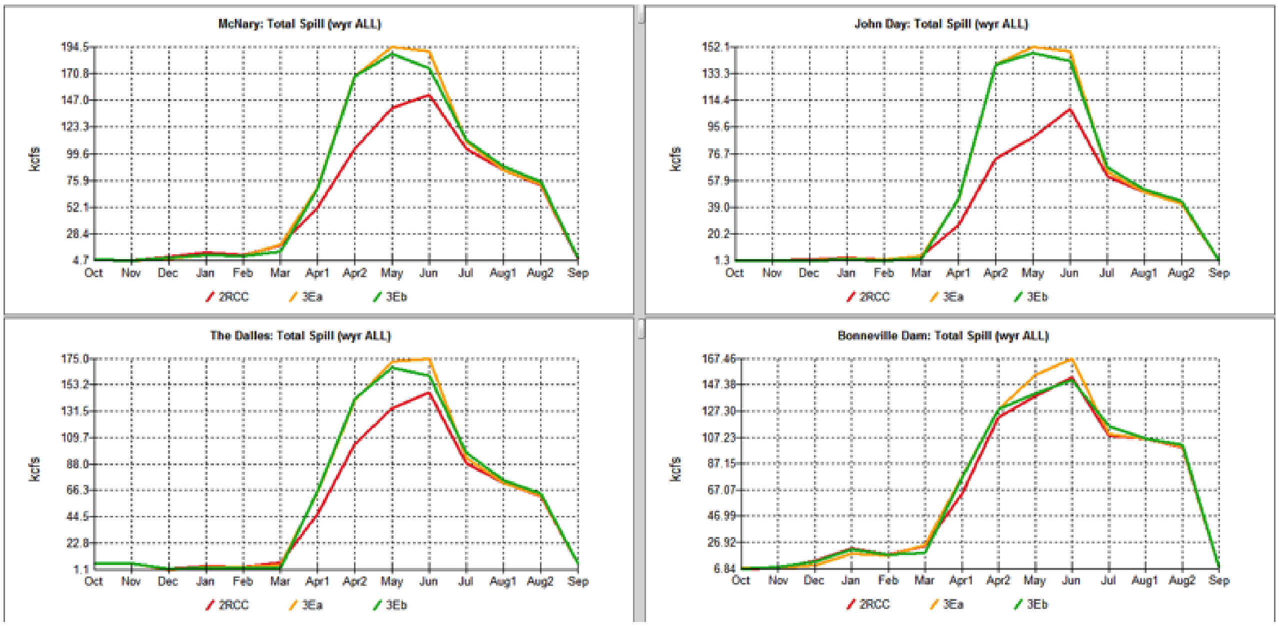
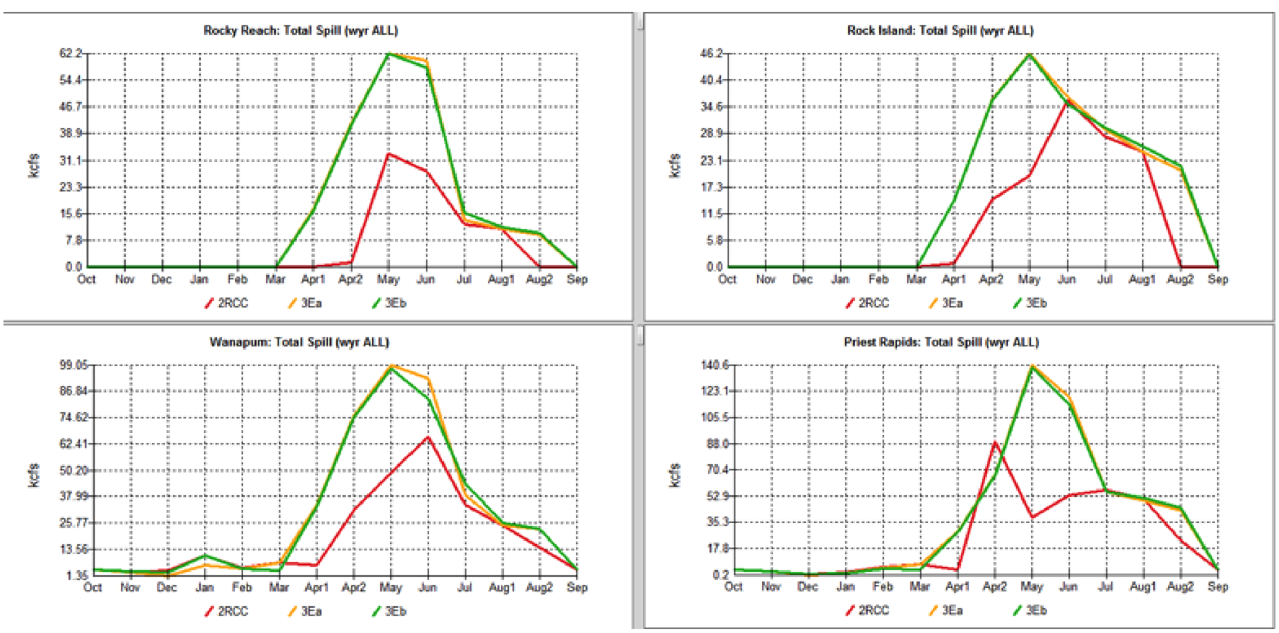


Fig 21. Spill levels at four mid- Columbia River Dams



Columbia River Flows

Grand Coulee Dam.
Photo courtesy US Dept of Transportation.

The range of cumulative operations of U.S. and Canadian dams outlined herein would reduce current Columbia River flows in October and November to more closely resemble the unregulated hydrograph. The outflows from Grand Coulee Dam and therefore flows through the mid-Columbia River would be affected by the integration of operations for ecosystem-based function (Figures 22-24). Changes in water storage and release at Mica and Arrow dams in Canada and at Grand Coulee Dam itself would result in increased spring and summer flows in the moderate to drier runoff years (Figure 24). These flow changes are sought to increase survival of juvenile salmon as they migrate to the ocean and to improve estuarine and ocean entry (plume) habitats. Adult salmon, sturgeon, and lamprey could also benefit from increased spring and summer flows that promote improved water quality and mainstem and estuarine habitat. Water flow is also shaped into the summer months to aid migration and potentially address water quality concerns for aquatic resources. At this time, the tribes are seeking ecosystem integration in a manner that does not increase high peak flows above 600 kcfs at The Dalles Dam in the highest water years (Figure 23) to avoid increases to flood risk under the current reservoir and levee system. Compared to scenario 3Ea, scenario 3Eb largely maintains flows and reservoir operations in the November through February period to limit impacts to base power generation.

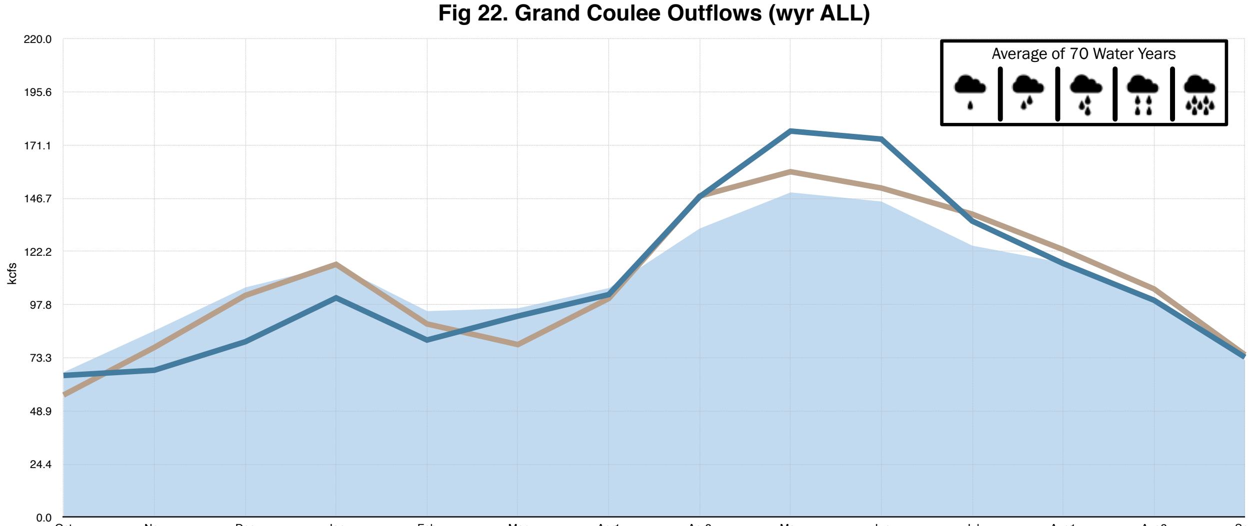
Hanford Reach fall chinook salmon population—a major remaining wild Pacific Northwest salmon population that is essential to many Columbia River tribes and important economically throughout the Pacific Northwest, British Columbia, and Southeast Alaska—is highly dependent on river flows affected by operations pursuant to the Columbia River Treaty. The flows through the Hanford Reach, the last free flowing stretch of the Columbia River in the U.S., are currently regulated under the Vernita Bar Agreement. Under the Agreement, Grant County PUD, in coordination with two other PUDs, the Corps of Engineers, and the Bureau of Reclamation, provides minimum flows of up to 70,000 cfs from Priest Rapids Dam during October-November to improve Hanford fall chinook salmon spawning, but daily river hydro-generation ramping rates to achieve this operation can be detrimental to spawning as redds (spawning nests) may be abandoned or compromised when flows recede.

Scenarios E3a and E3b reduce current monthly Hanford Reach spawning and incubation through cumulative operations of U.S. and Canadian storage projects during October and November. These scenarios generate flows that more closely resemble the historical Hanford Reach fall hydrograph. To mitigate for this flow reduction, continuous hourly flow stabilization within a very narrow range would be required during the October-November critical spawning period. These operations would eliminate salmon production losses due to spawning at elevations that cannot be maintained and redd dewatering that currently occurs under the Vernita Bar Agreement.

So long as daily river ramping rates across the Hanford Reach are maintained within an acceptable stable operation, this type of operation could be an improvement upon the current operations under the Vernita Bar Agreement. Equally important, by reducing winter and early spring mainstem flows and peaking operations during the fall chinook spawning period, the 3Ea and 3Eb operations allow storing of several million acre-feet of water in upriver reservoirs during the late fall, winter and early spring. This storage would be available to augment spring flows to enhance and restore the historical ecosystem, particularly in low flow years.

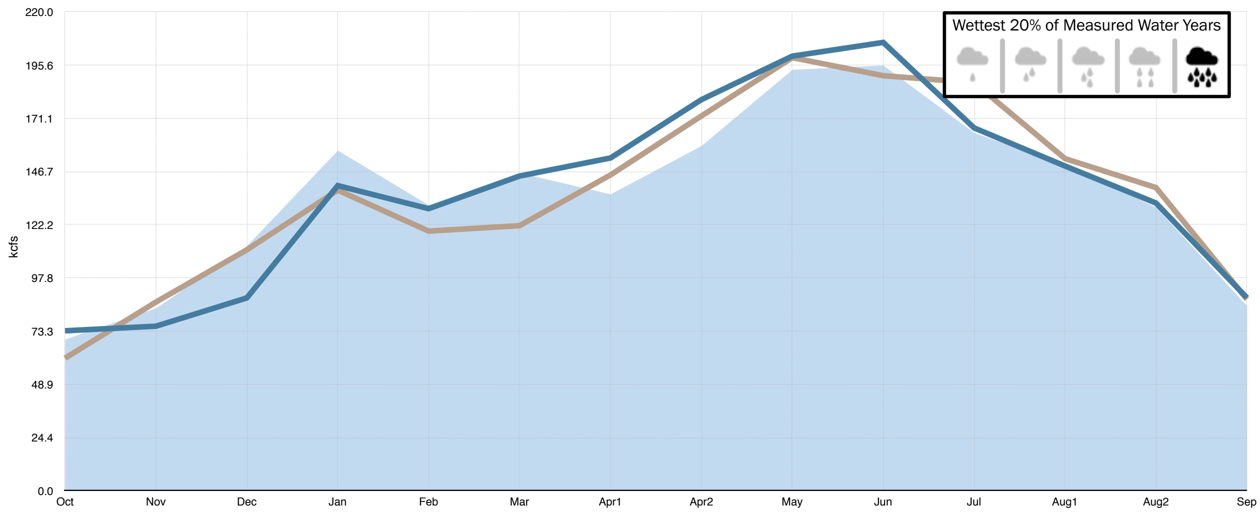
Current Condition
Ecosystem Scenario 3Ea
Ecosystem Scenario 3Eb

Fig 22. Grand Coulee Outflows (wyr ALL)



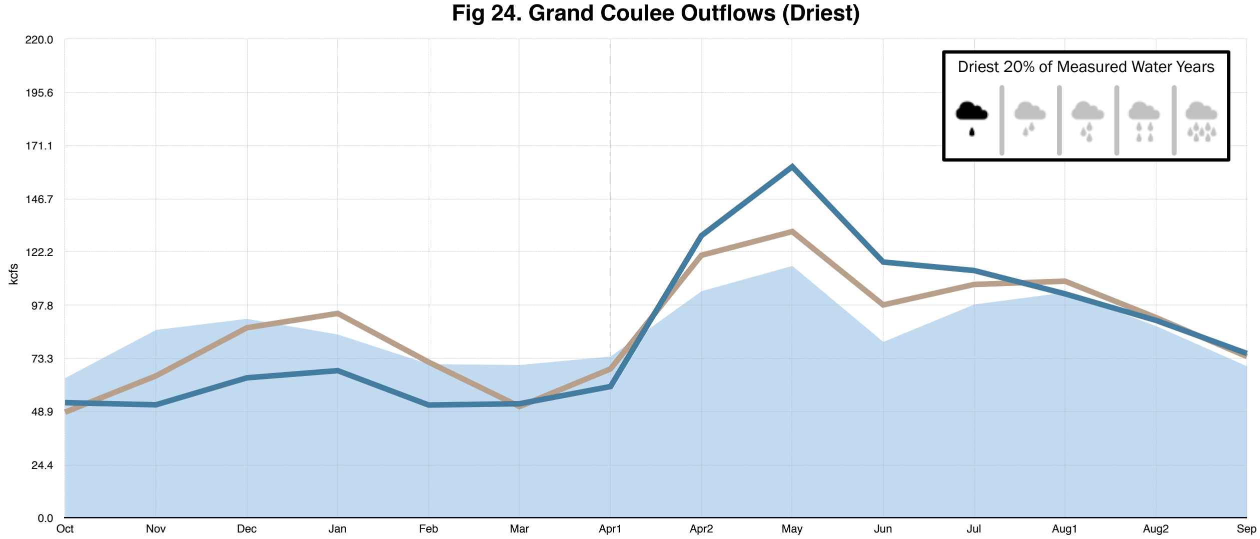
Scenario	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	Jun	Jul	Aug1	Aug2	Sep
Curr. Cond.	66.7	85.8	105.7	115.9	94.8	96.1	105.4	132.8	149.4	145.2	124.9	117.0	98.6	72.1
3Ea	65.2	67.6	80.7	100.9	81.5	92.5	102.4	147.4	177.6	173.9	136.2	116.7	99.8	73.6
3Eb	56.2	78.1	102.0	116.3	88.9	79.4	100.6	147.7	158.9	151.4	139.4	123.1	105.0	74.7

Fig 23. Grand Coulee Outflows (Wettest)



Scenario	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	Jun	Jul	Aug1	Aug2	Sep
Curr. Cond.	69.5	83.8	112.4	156.3	131.2	146.0	136.2	158.4	193.4	195.4	164.4	149.6	130.2	84.9
3Ea	73.5	75.6	88.6	140.2	129.6	144.6	152.9	179.7	199.7	206.0	166.7	149.2	132.2	88.7
3Eb	60.9	86.7	110.7	138.1	119.3	121.8	145.1	172.2	199.0	190.7	187.5	152.6	139.3	88.0

Fig 24. Grand Coulee Outflows (Driest)



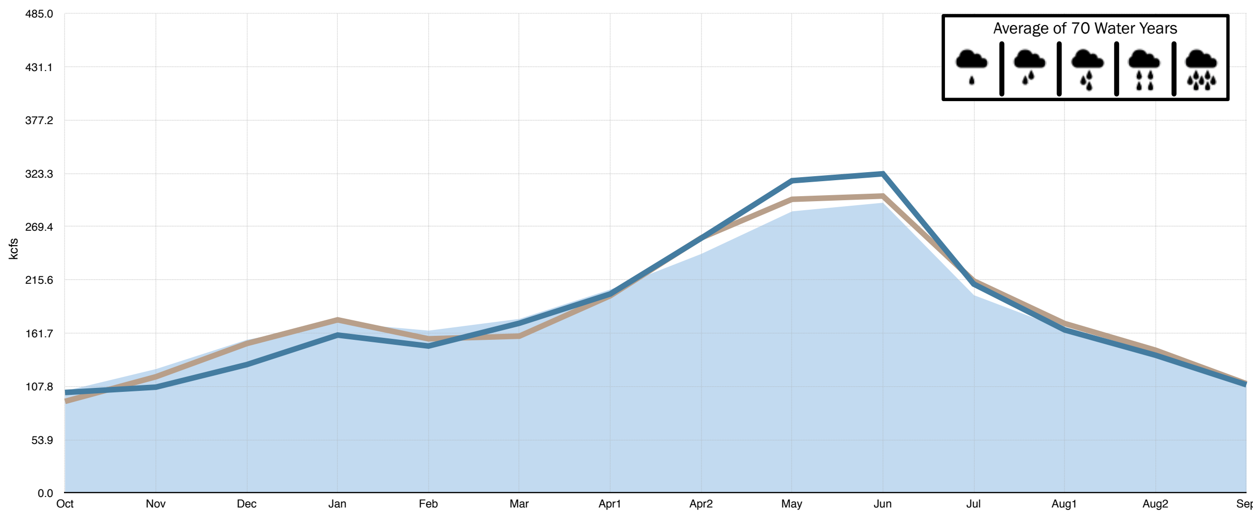
Scenario	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	Jun	Jul	Aug1	Aug2	Sep
Curr. Cond.	64.3	86.4	91.5	84.3	70.7	70.3	74.2	104.2	115.8	80.9	98.1	103.6	88.2	69.7
3Ea	53.0	52.0	64.4	67.7	51.9	52.5	60.4	129.7	161.4	117.6	113.7	103.0	90.8	75.6
3Eb	48.6	65.3	87.4	94.0	71.6	51.2	68.5	120.7	131.6	97.9	107.3	108.8	92.1	74.2

- Current Condition
- Ecosystem Scenario 3Ea
- Ecosystem Scenario 3Eb

Further downriver at The Dalles Dam, ecosystem-based function integration would partially restore natural flows, mostly in the drier water years (Figures 25-27) achieving the benefits noted above. Figures 25-27 show a modest recovery of the spring/summer freshet flows in the lower Columbia River under the range of ecosystem scenarios presented here. The main improvement occurs in the drier water years (Figure 27), while in the wettest years, freshet flows are restrained to maintain current levels of flood risk management. As Figures 1-3 demonstrate, ecosystem operations under these examples would largely preserve the current shaping of river flows for power generation and flood risk management.

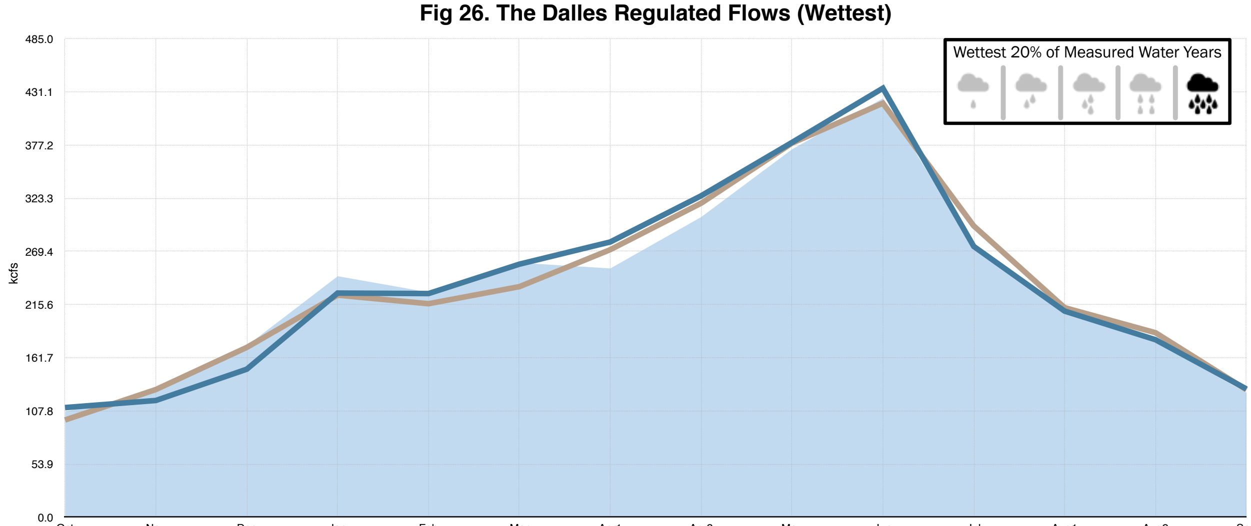
Current Condition
Ecosystem Scenario 3Ea
Ecosystem Scenario 3Eb

Fig 25. The Dalles Regulated Flows (wyr ALL)



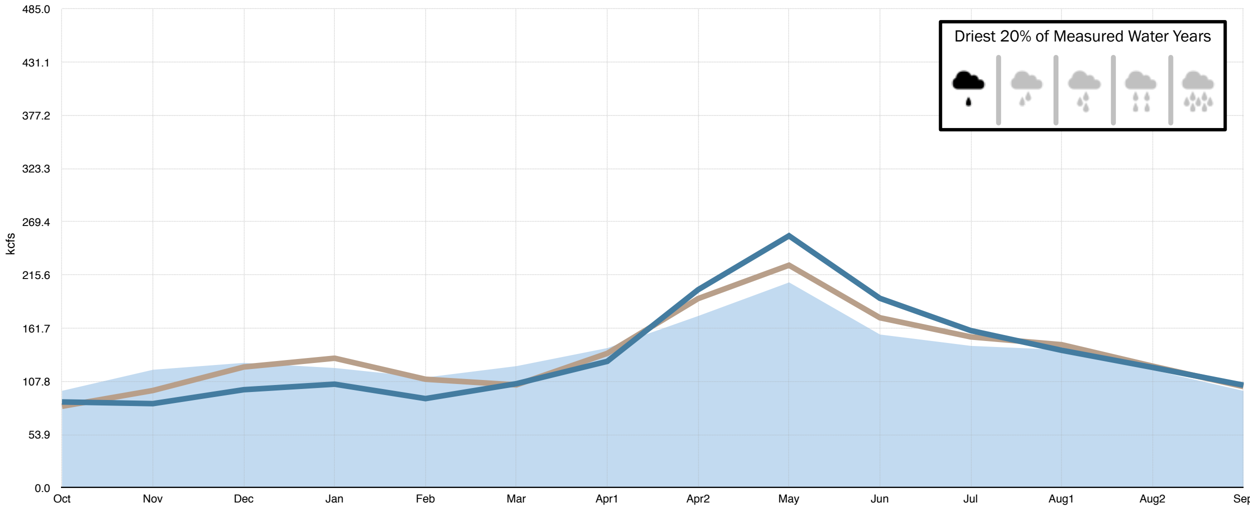
Scenario	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	Jun	Jul	Aug1	Aug2	Sep
Curr. Cond.	103.1	125.3	154.9	172.4	164.2	176.1	205.8	241.8	284.9	293.6	200.1	165.2	138.0	107.9
3Ea	101.6	107.0	129.8	159.7	148.6	171.7	201.3	257.7	315.9	322.9	211.3	164.9	139.3	109.4
3Eb	92.6	117.5	151.1	175.1	155.9	158.6	199.5	258.0	297.1	300.4	214.5	171.4	144.4	110.5

Fig 26. The Dalles Regulated Flows (Wettest)



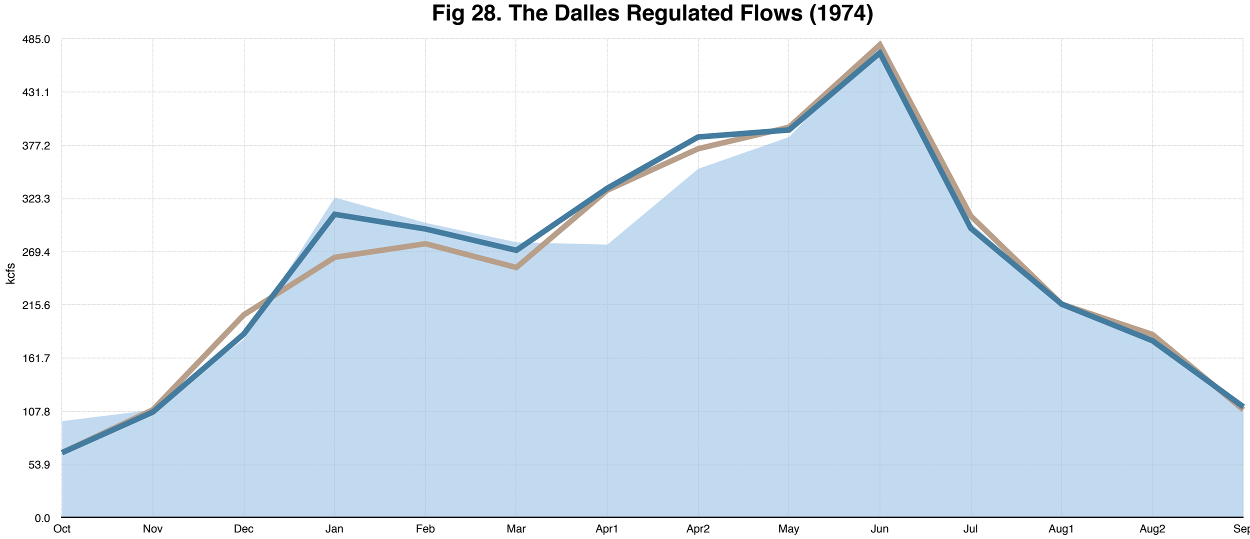
Scenario	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	Jun	Jul	Aug1	Aug2	Sep
Curr. Cond.	107.1	126.5	173.8	244.3	228.0	257.9	252.2	304.3	373.0	424.6	272.2	209.3	177.9	126.1
3Ea	111.1	118.3	150.0	227.2	226.7	256.5	279.0	325.8	379.9	434.9	274.5	208.9	179.9	130.0
3Eb	98.5	129.4	172.1	225.1	216.4	233.7	271.2	318.3	379.2	419.7	295.3	212.4	187.0	129.2

Fig 27. The Dalles Regulated Flows (Driest)



Scenario	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	Jun	Jul	Aug1	Aug2	Sep
Curr. Cond.	98.2	119.5	126.5	121.3	111.7	123.2	141.5	174.0	208.0	155.2	143.7	139.7	119.3	98.1
3Ea	86.9	85.2	99.3	104.9	90.3	105.4	128.0	200.6	255.2	191.9	159.2	139.2	121.9	103.9
3Eb	82.5	98.5	122.3	131.2	109.9	104.2	136.1	191.6	225.4	172.2	152.8	144.9	123.2	102.5

Fig 28. The Dalles Regulated Flows (1974)



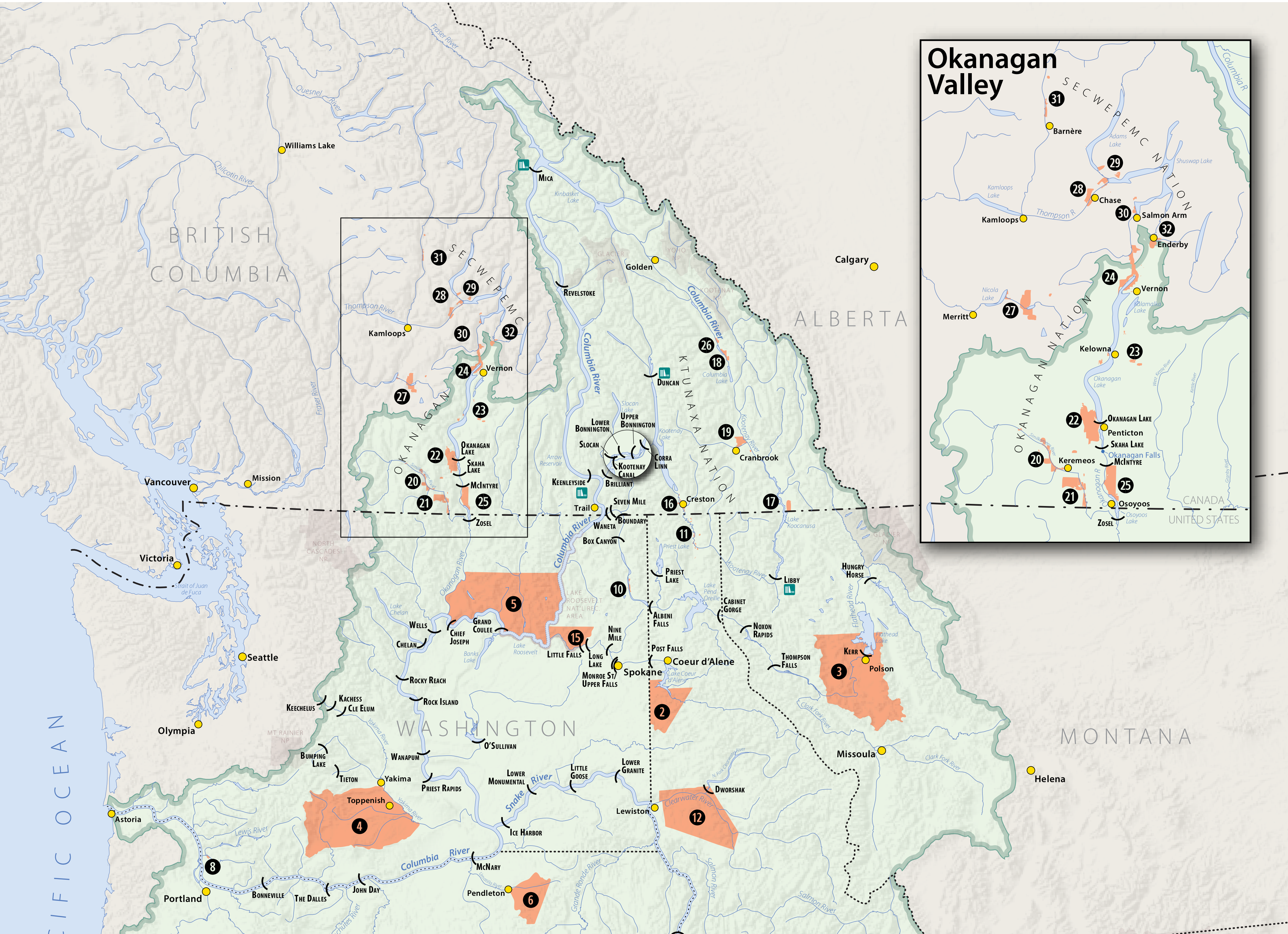
Scenario	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr2	May	Jun	Jul	Aug1	Aug2	Sep
Curr. Cond.	97.8	109.2	180.8	324.3	298.6	279.0	276.6	353.4	385.6	483.2	298.4	217.2	176.3	108.2
3Ea	65.8	107.0	186.0	307.3	292.4	270.8	333.7	385.6	392.7	470.8	293.2	216.3	179.2	112.2
3Eb	65.8	109.3	205.4	263.7	277.5	253.4	331.7	373.7	395.5	479.0	305.6	216.3	185.5	109.3

- Current Condition
- Ecosystem Scenario 3Ea
- Ecosystem Scenario 3Eb

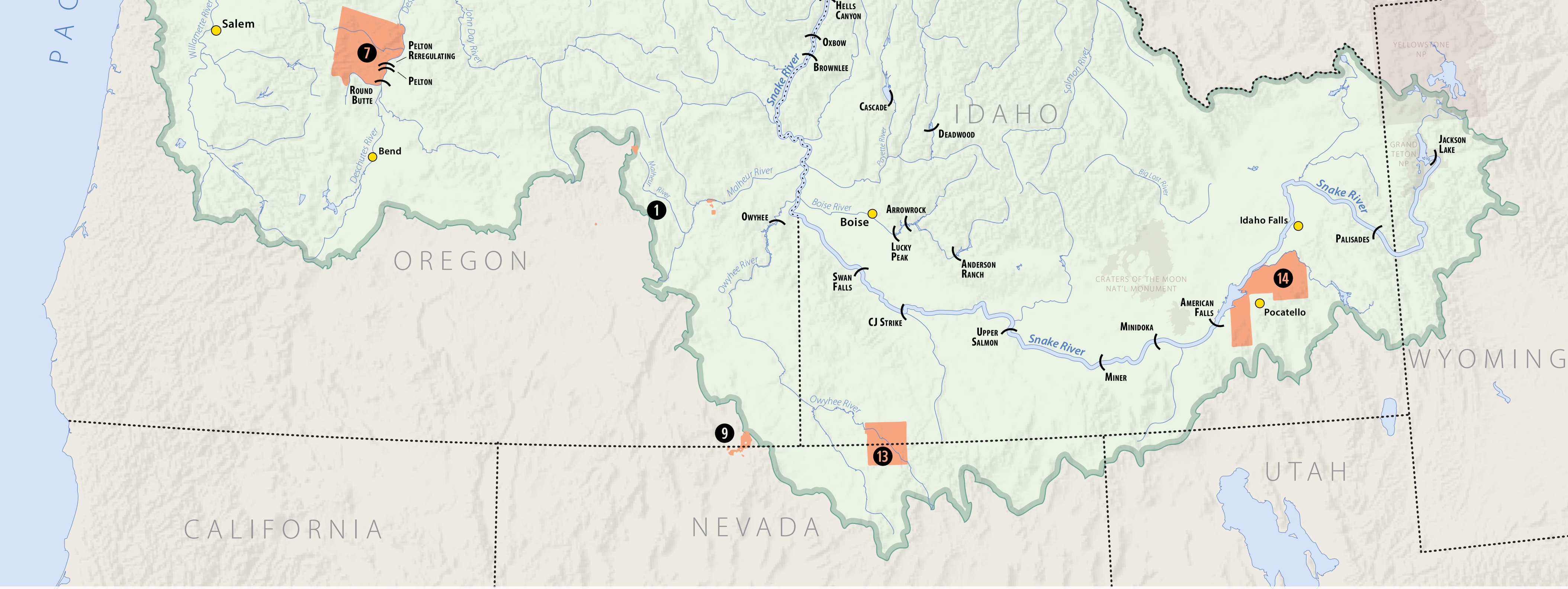
Summary

Under a modernized Treaty called for by the Regional Recommendation, ecosystem integration provides adaptation to current flood risk management under projected climate change conditions such that key reservoirs could remain fuller and promote partial restoration of the spring freshet while still providing adequate flood risk protection. Similarly, under ecosystem integration, future reshaping of regional power operations for peak power generation and less to support base energy needs could also contribute to fuller, more stable reservoir habitats and greater restoration of freshet flows. Increasing the system capacity to store more water in the winter and early spring promotes adaptation to climate change where water demands in the late spring and summer for ecosystem function, hydropower, agriculture, and municipal use are projected to increase as the Columbia Basin likely becomes warmer and drier.

Crown Point overlooking the Columbia River Gorge.



Okanagan Valley
SECWEPEMC NATION
OKANAGAN NATION
KTUNAXA NATION
BRITISH COLUMBIA
ALBERTA
WASHINGTON
MONTANA
PACIFIC OCEAN
CANADA
UNITED STATES
Williams Lake
Kamloops
Vernon
Salmon Arm
Enderby
Chase
Barnère
Merritt
Kelowna
Penticton
Keremeos
Osoyoos
Okanagan Falls
Vancouver
Mission
Victoria
Seattle
Olympia
Calgary
Golden
Cranbrook
Creston
Trail
Spokane
Coeur d'Alene
Polson
Missoula
Helena
Lewiston
Yakima
Toppenish
Pendleton
Astoria
Portland
Mica
Revelstoke
Duncan
Upper Bonnington
Lower Bonnington
Slocan
Corra Linn
Kootenay Canal
Brilliant
Keenleyside
Seven Mile
Waneta
Boundary
Box Canyon
Priest Lake
Albeni Falls
Libby
Hungry Horse
Kerr
Cabinet Gorge
Noxon Rapids
Thompson Falls
Post Falls
Nine Mile
Long Lake
Monroe St/ Upper Falls
Little Falls
Grand Coulee
Chief Joseph
Wells
Chelan
Rocky Reach
Rock Island
Wanapum
Priest Rapids
Keechelus
Kachess
Cle Elum
Bumping Lake
Tieton
O'Sullivan
Lower Monumental
Little Goose
Lower Granite
Ice Harbor
McNary
John Day
The Dalles
Bonneville
Dworshak
Okanagan Lake
Skaha Lake
McIntyre
Zosel
Columbia River
Snake River
Kootenay River
Fraser River
Thompson River
Okanogan River
Clearwater River
Salmon River
Flathead River
Clark Fork River
Yakima River
Lewis River
Grande Ronde River
Chilcotin River
Quesnel River
Strait of Juan de Fuca
Kinbasket Lake
Arrow Reservoir
Slocan Lake
Kootenay Lake
Columbia Lake
Lake Koocanusa
Priest Lake
Lake Pend Oreille
Lake Coeur d'Alene
Flathead Lake
Lake Chelan
Banks Lake
Lake Roosevelt
Lake Roosevelt Nat'l Rec. Area
Adams Lake
Shuswap Lake
Kamloops Lake
Nicola Lake
Kalamalka Lake
Osoyoos Lake
Glacier NP
Yoho NP
Kootenay NP
North Cascades NP
Mt Rainier NP
2 3 4 5 6 8 10 11 12 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32



This map was produced by the Columbia River Inter-Tribal Fish Commission. It is meant for informational and display purposes only and was created with the best data available at the time of production. It does not represent any legal boundaries or information.
Map date: March 2013

North

0 25 50 100 200 Kilometers
0 25 50 100 200 Miles

Columbia Basin Boundary
Reservation or Reserve
Dam authorized by Columbia River Treaty

Tribal Nations in the United States*

1. Burns Paiute Tribe
2. Coeur d'Alene Tribe
3. Conf. Salish and Kootenai Tribes of the Flathead Nation
4. Conf. Tribes and Bands of the Yakama Nation
5. Conf. Tribes of the Colville Reservation
6. Conf. Tribes of the Umatilla Indian Res.
7. Conf. Tribes of the Warm Springs Res. of Oregon
8. Cowlitz Indian Tribe
9. Ft. McDermitt Paiute Shoshone Tribes
10. Kalispel Tribe of Indians
11. Kootenai Tribe of Idaho
12. Nez Perce Tribe
13. Shoshone Paiute Tribe of the Duck Valley Indian Res.
14. Shoshone-Bannock Tribes of the Ft. Hall Res.
15. Spokane Tribe of Indians

** management authorities and responsibilities affected by the Columbia River treaty; does not include all tribes in the Columbia Basin*

First Nations in Canada

Inside the Columbia Basin

KTUNAXA NATION

16 Yaqan nuʔkiy *(Lower Kootenay Indian Band)*
17 ʔakinḱumɫasnuqɫiʔit *(Tobacco Plains Indian Band)*
18 ʔakisq̓nuk *(Columbia Lake Indian Band)*
19 ʔaq̓am *(St. Mary's Indian Band)*

OKANAGAN NATION

20 c'əc'əwixaʔ *(Upper Similkameen Indian Band)*
21 kɬk'ər'míws *(Lower Similkameen Indian Band)*
22 snpíntktn *(Penticton Indian Band)*
23 stqaʔtkʷəɬwt *(Westbank First Nation)*
24 suknaqínx *(Okanagan Indian Band)*
25 swíws *(Osoyoos Indian Band)*

SECWEPEMC NATION

26 Kenpésq̓t *(Shuswap Indian Band)*

Outside the Columbia Basin with Asserted Interests

OKANAGAN NATION

27 spaxomən *(Upper Nicola Band)*

SECWEPEMC NATION

29 Qwʔewt *(Little Shuswap Indian Band)*
28 Sexqeltqín *(Adams Lake Indian Band)*
31 Simpcw *(Simpcw First Nation)*
30 Sḱemtsin *(Neskonlith Indian Band)*
32 Splatsín *(Splatsín First Nation)*

Columbia River Treaty

Definition of Ecosystem-based Function

Adopted by the Coalition of Columbia Basin Tribes, June 2013

Since time immemorial, the rivers of the Columbia Basin have been, and continue to be, the lifeblood of the Columbia Basin tribes. Columbia Basin tribes view ecosystem-based function of the Columbia Basin watershed as its ability to provide, protect and nurture cultural resources, traditions, values and landscapes throughout its length and breadth. Clean and abundant water that is sufficient to sustain healthy populations of fish, wildlife, and plants is vital to holistic ecosystem-based function and life itself. A restored, resilient and healthy watershed will include ecosystem-based function such as:

- Increased spring and summer flows resulting in a more natural hydrograph;
- Higher and more stable headwater reservoir levels;
- Restoring and maintaining fish passage to historical habitats;
- Higher river flows during dry years;
- Lower late summer water temperature;
- Reconnected floodplains throughout the river including a reconnected lower river estuary ecosystem as well as reduced salt water intrusion during summer and fall;
- Columbia River plume and near shore ocean enhanced through higher spring and summer flows and lessened duration of hypoxia; and,
- An adaptive and flexible suite of river operations responsive to a great variety of changing environmental conditions, such as climate change.

Improved ecosystem-based function in the Columbia Basin Watershed is expected to result in at least:

- Increased recognition, protection and preservation of tribal first foods and cultural/sacred sites and activities, First foods include water, salmon, other fish, wildlife, berries, roots, and other native medicinal plants;
- An estuary with an enhanced food web and increased juvenile fish survival;
- Increases in juvenile and adult salmon survival;
- Decreased mainstem travel time for migrating juvenile salmon;
- Increased resident fish productivity that provides stable, resilient populations;
- Increased wildlife productivity that provides stable, resilient populations; and,
- Salmon and other juvenile and adult fish passage to historical habitats in the Upper Columbia and Snake River basins, and into other currently blocked parts of the Columbia River Basin.