OVG CONSULTING

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Value to The Pacific Northwest Hydrogeneration Dams from Whooshh Technology

PREPARED FOR WHOOSHH INNOVATIONS LLC

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Introduction

This engagement was entered between OVG Consulting Inc. ("Consultant") and Whooshh Innovations LLC ("Whooshh" or "Client"). The Client invented a fish passage system creating an efficient, cost-effective, environmentally sustainable way to move live and harvested fish safely, gently, and hygienically. The system works on the principle of pressure differentials to convey fish through a soft, flexible tube to their destination, supported by custom-designed and turnkey solutions for fish transporting. Some of the industrial applications for the system are seafood processing, hatchery/broodstock operations, as well as aquaculture—land-based and net pen. The technology is well-suited for salmonids and works for a wide variety of other fish species and sizes. Currently, the Client is considering expanding its target market to hydrogeneration dams. It is expected that this particular class of customers will benefit from the improved rate of survival of migratory fish passing through hydrogeneration dams. OVG was retained to prepare this study on the value from the Whooshh technology to this target market. This engagement focuses on calculation of the revenues to power producers lost due to water being diverted for passing the adult fish through the hydrogeneration dams in the Pacific Northwest (Columbia River and Snake River basins).

The main deliverables of the engagement are

1) This report containing the description of assumptions, calculation mechanisms, findings, observations, and references;

2) MS PowerPoint slides presenting the major findings.

Approach and Major Assumptions

The Consultant followed the standard business management study "top-down" approach, which consisted of the following steps:

- Review of the current regulatory and industry environment in relation to the Whooshh technology and its applications.
- Review of the industry challenges and limitations as related to the Client's solution competitive advantage.
- Analysis of the Whooshh technology's value to the regional hydrogeneration dams.
- Calculation of the monetary benefits to the regional hydrogeneration dams from the Client's solution. Calculation of the revenues lost by hydrogeneration dams from diverting waterflows away from their generation turbines to fish ladders.

Assumptions specific to each type of analysis and calculations are presented in the pertinent sections. The Consultant identified the basic assumptions for the whole study, as described below.

1. Whooshh system replaces fish ladders currently installed on the hydrogeneration dams.
2. Whooshh system's capacity is adequate, or can be expanded, to replace the existing fish ladders.
3. Whooshh system is nearly waterless; waterflows, freed from the fish ladders installed on hydrogeneration dams, are added to the hydro volumes available for power generation.
4. Analysis is executed for hydrogeneration facilities equipped with the adult fish migration facilities (fish ladders) located on Columbia or Snake river systems, which can be considered as "proxy" for other regional dams.
5. Analysis includes only those facilities, which report and release data in public domain. The Consultant identified eight dams that meet the above criteria:
    a. Columbia River
        i. Bonneville Dam
        ii. The Dalles Dam
        iii. John Day Dam
        iv. McNary Dam
    b. Snake River
        i. Ice Harbor Dam
        ii. Lower Monumental Dam
        iii. Little Goose Dam
        iv. Lower Granite Dam
6. Fish ladders are assumed to operate at the design capacity; the study excludes any actual operational outputs.

7. Value of waterflows from each fish ladder is equal to the power generated from the same amount of water on each pertinent hydrogeneration dam plus energy for pumps providing the auxiliary water supply.

8. Monetary value of waterflows from each fish ladders is calculated as revenues from selling this power on the nearby wholesale power markets:

   a. Pacific Northwest market (Mid-C trading hub);

   b. California market (SP-15 and NP-15 trading hubs).

9. The study is limited in its scope to only power generation revenues; it excludes any consideration given to the capital, O&M and any other costs associated with the existing fish migration facilities.

Hydrogeneration Potential and Limitations

Federal Vision for the Growth

Hydropower has been the dominating source of electricity in the Pacific Northwest. The likelihood of its retained and even increased prominence is very high. According to the 2017 Long-Term Reliability Assessment[1], hydro generation comprised 24,927 MW or 41.8% of the total generation stack in the Northwest Power Pool-US in summer 2017. With the net internal demand expected to grow by 2.5 GW over the next ten years, it is likely that its large portion will be generated on hydro-powered facilities. Additionally, almost 16% (9.5 GW) of the regional power electricity is still sourced by coal-fueled power plants, which are likely to come under pressure to be replaced with cleaner power generation resources in the near future. Hydro generation represents such a resource. This expectation is supported by the recently increased attention to hydrogeneration on the federal level.

The Hydropower Vision[2] released by the US Department of Energy establishes a long-term roadmap for the future of the United States' hydro sector. It sets goals for the hydropower industry and research community to achieve higher levels of hydropower deployment within a sustainable national energy mix. The report sets the ultimate goal of increasing the domestic capacity from 101 GW to nearly 150 GW of reservoir, run-of-river and pumped-storage hydropower by 2050 with the growth potential attributed to:

- 4.8 GW of new development on non-powered dams;
- 6.3 GW in upgrades on existing hydropower;
- 35.5 GW of new pumped-storage projects; and
- 1.75 GW in new stream-reach developments. 2017 report.

The five action areas that would help achieve the Hydropower Vision include:

1. Technology Advancement: development of innovative technologies will help reduce costs and improve both power production efficiencies and environmental performance.

2. Sustainable Development and Operation: integrated approaches that balance environmental, social and economic factors.

3. Enhanced Revenue and Market Structures.

4. Regulatory Process Optimization.

5. Enhanced Collaboration, Education and Outreach.

The Consultant believes that the Whooshh technology fits into at least the first two areas of the Hydropower Vision by providing environmentally-centered improvements to the hydrogeneration system

[1] NERC 2017 Long-Term Reliability Assessment, <https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_LTRA_12132017_Final.pdf>

[2] Hydropower Vision: A New Chapter for America's 1st Renewable Electricity Source by US Energy Department, July 26, 2016 < https://www.energy.gov/eere/water/articles/hydropower-vision-new-chapter-america-s-1st-renewable-electricity-source>

with the focus on economical benefits. The Client's technology can be viewed as standing squarely at the crossroads of the growing interests in hydrogeneration technologies and that of sustainable, environmentally friendly solutions.

Limitations and Concerns of the Existing Technologies. Advantages of the Whooshh Technology.

While hydropower is touted as a clean and renewable generation resource, it possesses a multitude of characteristics, which result in serious environmental damage to fish migrating seasonally across dams.

The construction and operation of mainstem hydroelectric dams continue to impair adult salmonid and lamprey migration to spawning locations by higher water temperatures unsuitable for salmon; hazardous passage through dams via fish ladders; fallback at fish ladder exits; and increased opportunities for salmon predators[3]. Besides, ongoing inspections, maintenance accompanied by periodic closures of ladders, repairs and upgrades add to the cost and/or create impediments to smooth fish passage.

According to the data reported by the Columbia River Basin Federal Caucus[4], in years 2010-2014, salmonids survival rates varied among different species. While Snake River fall chinook, Upper Columbia spring chinook and Upper Columbia steelhead all surpassed NOAA Fisheries' survival standard, Snake River spring/summer chinook and Snake River steelhead were below the standard, as shown in Figure 1: Adult Salmon Survival Standard Report for 2010-2014.

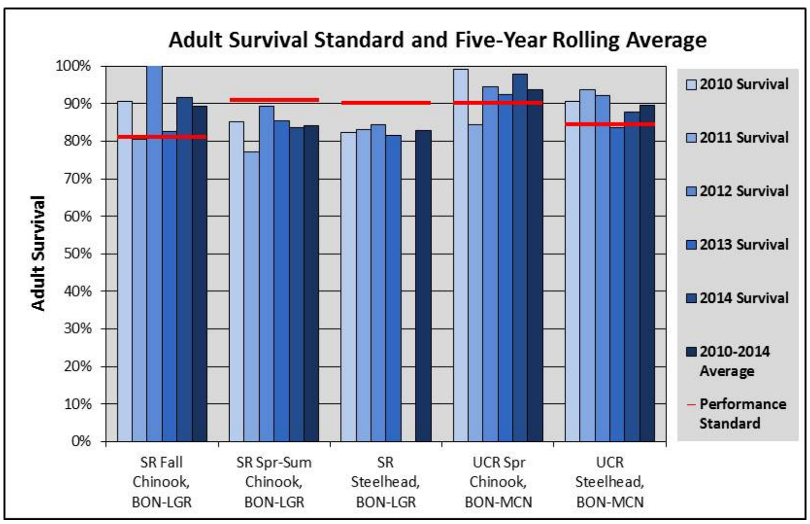

Figure 1: Adult Salmon Survival Standard Report for 2010-2014

All eight hydropower dams selected for this study, have fish ladders integrated into their original designs. Ever since their construction, multiple efforts have been put in place with the objectives to improve the upstream migration habitat for adult salmonids and ensure better monitoring procedures. The majority of

[3] Technical Recommendation 9 (formerly Adult Salmon Passage). Adult Fish Migration <http://plan.critfc.org/2013/spirit-of-the-salmon-plan/technical-recommendations/adult-salmon-passage/>
[4] Adult Survival Standard report by the Columbia River Basin Federal Caucus, <https://www.salmonrecovery.gov/image/default-source/default-album/adultsurvivalstandardgraph-2014apr.jpg?sfvrsn=2>

these concerns and investments made in mitigation efforts[5] [6]could have been prevented or reduced with the installation of Whooshh technology. Below are some examples of these ongoing and seemingly eternal efforts by the state and local authorities to reduce the damage from the dams and fish ladders' faulty designs.

Water temperature: Impoundments on the Columbia and Snake rivers have altered the water temperature conditions. Water temperatures often exceed water quality standards, which often lead to delay in migration and fish mortality. An example of this was summer 2015 when the passage of sockeye on the Snake river fell to very low numbers due to excessive water temperature. Idaho Fish and Game department implemented an emergency trap and haul operation for sockeye in the Snake River in July 2015.

Fish Counts: Until recently, the majority of adult salmon have been counted at dams by real-time human observations - prone to errors and failing to account for stocks such as the listed Snake River sockeye, which often pass in significant numbers at night. Only recently, automated monitoring systems for the adult fish facilities have been put in place.

Lamprey passage: Lamprey populations in the Pacific Northwest have been declining drastically; structural improvements are being installed at many ladders. Ladder improvements to benefit salmon have been co-designed to assist lamprey during their upstream passage as well.

Fishway modifications: There has been a need in fish ladders at some projects and additional attraction water at fishways at all projects. This need is particularly evident during average to high runoff years, when water volumes passed through powerhouses and spillways are many times more than those from ladder and powerhouse entrances. Because fishway attraction flows are insufficient, adults are delayed in collection channels and dam tailraces. Adult salmon often "fall out" from ladder and powerhouse entrances, especially during high flows. Attraction flows, which are generated by electric pumps dependent on turbine power production and conveyance systems, are at risk in the event of system failure. Thus, McNary Dam has been facing ongoing concerns in operations of the both fish pumps. Fish Pump #2 was out of service during the entire 2016 fishway season.

On the Bonneville dam, over the last several years, many staff gauges have been broken or gone missing. These unreadable/broken/missing staff gauges combined with failures of the PLC systems can make it difficult to determine if the project fishways are within criteria.

On Little Goose, Fish Pump #1 was out of service during the entire 2015 season and partly in 2016.

Large amounts of trash also impede salmon passage through adult fishways.

Table 1: Improvements to Adult Passage on Hydropower Dams on Columbia and Snake Rivers since 1995 lists some fishway modifications executed on dams with the objective of improving adult fish passage.[7] [8]

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[5] Adult Fishway Inspections on the Columbia and Snake Rivers, Annual Report 2016 <http://www.fpc.org/documents/fishway_inspection/AdultFishwayInspections2016.pdf>

[6] Technical Recommendation 9 (formerly Adult Salmon Passage). Adult Fish Migration < http://plan.critfc.org/2013/spirit-of-the-salmon-plan/technical-recommendations/adult-salmon-passage/>

[7] FCRPS Biological Assessment. Overhaul of the System <https://www.fws.gov/pacific/fisheries/hatcheryreview/Reports/snakeriver/SR--0082007FCRPSAppendix.pdf>

[8] Adult Fishway Inspections on the Columbia and Snake Rivers, Annual Report 2016 <http://www.fpc.org/documents/fishway_inspection/AdultFishwayInspections2016.pdf>

Dam	Adult Fish Passage Improvement
Bonneville Dam	To enhance collection system effectiveness and reliability of PH 1, gates were taken out of entrances 1, 2, 64, and 65 to provide 8 feet of opening and floating gate/orifice operating system modified with new motors and control system.
	Adult fallback has been reduced by changing project procedures at Bonneville to give priority to operating PH II, which moves downstream generation flow away from adult fish passage exits.
	To provide for monitoring PIT-tags on adults, adult PIT-tag detectors were installed in PH1 and PH 2.
	To reduce marine mammals' presence in the ladders, Sea Lion Exclusion Devices (SLED) were installed in PH1 and PH 1.
	Multiple enhancements to the improved lamprey passage. • In 2002, a lamprey passage system (LPS) was designed and installed in the Bradford Island fishway exit. In 2004, the Bradford Island LPS was extended to the forebay and added PIT-tag readers and resting boxes. • In 2007, a dual ramp LPS was installed in the auxiliary water supply (AWS) channel of the Washington shore fishway. • At the Cascade Island fishway, "keyhole" entrance weirs were installed in 2009 to aid lamprey in entering the ladder. In addition to the modified entrance weir, rock floors, a PIT-tag reader, and a prototype LPS were added to the Cascade Island ladder in 2009. • In 2010/2011, raising the Washington shore picketed leads along with adding a ramp up to the base of the picketed leads to improve the use of the LPS in the AWS channel and to reduce the use of the serpentine section of the Washington shore fishway (a known problem area for lamprey). • The picketed leads at the Washington shore count station were replaced in 2012 with ¾-inch gap pickets. • Over the winter maintenance period of 2012/2013: on Washington Shore entrance Lamprey Flume installed the prototype Lamprey Flume System (LFS) at the north downstream entrance intended to provide a bypass route around the fishway; on Bonneville Cascade Island LPS was converted into a fully volitional passage route with an exit directly into the forebay, adjacent to the Cascades Island fish ladder exit.
The Dalles Dam	Modifications made to allow for adult entrance channel dewatering to improve inspection and maintenance for reliability of adult ladder system.
	The addition of a spill wall and changed spill patterns decreased adult fall back.
	In recent years, improvements have been implemented in fishways intended to aid in the passage of adult Lamprey.
John Day Dam	Rehabilitated auxiliary water pumps provides reliable auxiliary water supply for attraction/passage of fish.
	The exit section of the Oregon fish ladder was modified prior to the 2003 fish passage season. No longer is the section a serpentine-like ladder but is now more similar to The Dalles north shore fish ladder exit. The modification reduced holding of fish in the fish ladders while still providing a good passage route from the overflow weir section to the exit from the fish ladder. New serpentine sections were added in 2004 to reduce adult leaping and injury in the upper sections of the ladder. Over the winter of 2009/2010 the exit section modification occurred on the north shore fish ladder and included lamprey passage improvements.
McNary Dam	Adult PIT-tag detection systems in both fish ladders improves PIT-tags monitoring of adult passage through mainstem dams.

Dam	Adult Fish Passage Improvement
	Replaced powerhouse collection system stop logs with new stop logs increases reliability of adult fish passage system.
	The water supply for the Washington fishway was changed from the pressurized system to a non-pressurized system as Wasco/ Klickitat PUDs installed a small turbine on the water supply from the forebay that produces electricity for the PUD and also supplies flow to meet gate depth and head differential requirements for the two main entrance gates.
	In August 2013, Marine Industrial Construction of Wilsonville, Ore., was awarded a contract to build, deliver and install the lamprey-passage structure installed in the downstream entrance of the Oregon-shore fish ladder when a revised entrance was installed at the south shore fish ladder to improve entry conditions[9]
Ice Harbor Dam	North shore auxiliary water supply system modified, new fish pumps installed to improve effectiveness and reliability of the auxiliary water system
	Adult PIT-tag detection systems improve PIT-tag monitoring.
	Improvements have been installed in fishways to aid in the passage of adult lamprey. Adult lamprey passage improvements were made to upper fish ladder weirs at Ice Harbor Dam during the winter of 2011/2012. These included cutting horizontal slots in weirs at the fishway floor to allow adult lamprey attachment through a level pathway through the weir. Ramps were installed from the fish ladder floor to the bottom of elevated salmon orifices in the upper ladder weirs to assist lamprey moving through these areas. Additionally, plates were installed on diffuser grating adjacent to orifices in the north fish ladder to provide attachment surfaces for lamprey in higher-velocity areas.
Lower Monumental Dam	All three auxiliary water supply pumps rehabilitated to ensure fish ladder auxiliary water system efficacy and reliability.
	Improvements have been installed in Lower Monumental Dam fishways intended to aid in the passage of adult lamprey. Improvements were made to upper fish ladder weirs during the winter of 2011/2012. These included cutting horizontal slots in weirs at the floor to allow adult lamprey attachment through a level pathway through the weir. Additionally, ramps were installed from the fish ladder floor to the bottom of elevated salmon orifices in the upper ladder weirs to assist lamprey in maintaining attachment as they move through these areas.
Little Goose Dam	Installed picketed leads in collection system channel to decrease adult fish falling out of the channel into the tailrace.
	Improved auxiliary water supply.
	Over the last several years, improvements have been installed in fishways intended to aid in the passage of adult lamprey. • In 2011, picketed leads were modified near the floor of the adult fish ladder at the count station to enable adult lamprey passage under the picketed leads, providing a low-velocity passage route for lamprey around the adult fish count slot. • Over the 2012/2013 winter maintenance period, horizontal slots were cut in weirs at the floor to allow adult lamprey attachment through a level pathway through the weir. Additionally, ramps were installed from the fish ladder floor to the bottom of elevated salmon orifices in the upper ladder weirs to assist lamprey in maintaining attachment as they move through these areas.
Lower Granite Dam	PIT-tag detectors added for monitoring of returning adult fish.
	In 2015, the passage of sockeye fell to very low numbers due to excessive water temperature and the formation of an eddy at the southern powerhouse created by the focused spill and

[9] McNary Northshore Fishway Hydro Project<http://www.nww.usace.army.mil/Locations/District-Locks-and-Dams/McNary-Lock-and-Dam/>

Dam	Adult Fish Passage Improvement
	minimal powerhouse flow. After that, the dam was using rental and auxiliary pumps that pull deeper and cooler water from the Lower Granite forebay into the fish ladder. After testing a temporary solution in 2014-2015, the Corps constructed two permanent “intake chimneys” in 2016 to pump water from deep in the reservoir to cool the adult fish ladder, plus the adult fish trap built into the fish ladder[10].
	Fish trap modified and expanded to improve adult fish handling conditions.
	Modified diffuser and transition pools improve adult passage by eliminating fishway fallout.
	Improved auxiliary water supply increases reliability of ladder operation.
	Over the last several years, improvements have been installed in Lower Granite Dam fishways intended to aid in the passage of adult lamprey. • In 2011, picketed leads were raised and secured 1.5″ off of the floor of the adult fish ladder at the count station to enable adult lamprey passage under the picketed leads, providing a low-velocity passage route for lamprey around the adult fish count slot. • Over the 2012/2013 winter maintenance period, horizontal slots were cut in weirs at the floor to allow adult lamprey attachment through a level pathway through the weir. Additionally, ramps were installed from the fish ladder floor to the bottom of elevated salmon orifices in the upper ladder weirs.

Table 1: Improvements to Adult Passages on Hydropower Dams on Columbia and Snake Rivers since 1995

[10] USACE Fact Sheets <http://www.nww.usace.army.mil/Locations/District-Locks-and-Dams/Lower-Granite-Lock-and-Dam/>

Value of Hydrogeneration Waterflows to the Region

The Columbia River and Snake River basins represent a very high value to the Pacific Northwest region on the cultural, industrial, agricultural, environmental, among others, levels. This analysis is focused on environmental (adult fish migration) and economic aspects. To assess the importance of the waterflows used for the hydrogeneration, the Consultant analyzed the relation between the adult fish migration patterns and waterflows used for generating electric power.

Adult fish migration patterns are built on data reported by Columbia Basin Research (University of Washington) data (DART Adult Passage Daily Counts for All Species) on fish counts[11]. The Consultant used counts for Steelhead, Chinook, Sockeye and Coho passing the analyzed projects in the years 2016 and 2017. Adult fish count monitoring dates used for the analysis are provided by Fish Passage Center[12]. Data for waterflows on dams is also reported by Fish Passage Center[13] as Total Water Discharge.

The graphs below show fish counted for individual species and also as a sum of all species. For the analysis completeness, the Consultant reviewed the fish migration patterns on dams versus electricity prices on the major wholesale open power markets. Electricity prices are calculated as weighted average wholesale day-ahead trades reported by ICE and published by EIA[14].

Graphs provide clear evidence that the peak of salmon crossing occurs during the periods of low waterflows (August – October). These are also the times when electricity prices at most trading hubs start rising. This pattern could be better observed in year 2017. Hence, the value of receding waterflows increases especially during the fall salmon runs. This conflict is aggravated by the need in hydrogeneration when markets demonstrate an increasing demand in electricity. Another observation, which can be drawn from the graphs, is a consistently dropping count of salmon as fish pass through dams starting at Columbia Bonneville dam and ending at Lower Granite dam on the Snake river.

It is evident that even an incremental improvement in technology allowing for safer fish passage and increased waterflows will contribute both environmental and economic benefits.

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[11] Columbia Basin Research (University of Washington) data (DART Adult Passage Daily Counts for All Species) <http://www.cbr.washington.edu/dart/query/adult_daily>

[12] Adult Fish Count Dates <http://www.fpc.org/currentdaily/HistFishTwo_7day-ytd_Adults.htm>

[13] Fish Passage Center data <http://www.fpc.org/river/flowspill/FlowSpill.asp>

[14] Daily Electricity Price Indexes, ICE, <https://www.theice.com/index>, EIA wholesale energy markets reports <https://www.eia.gov/electricity/wholesale/>

Columbia River Basin Hydropower Generators

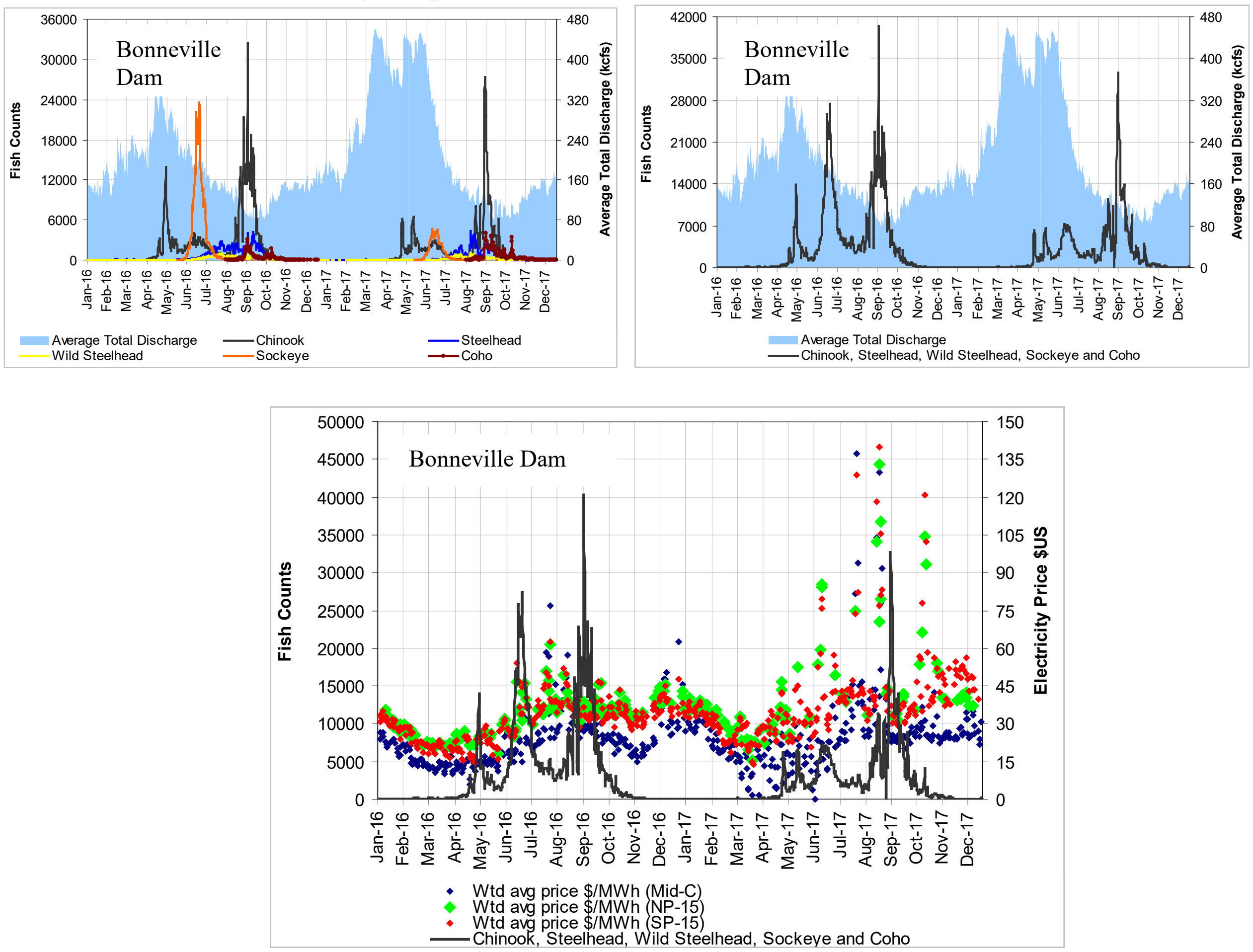
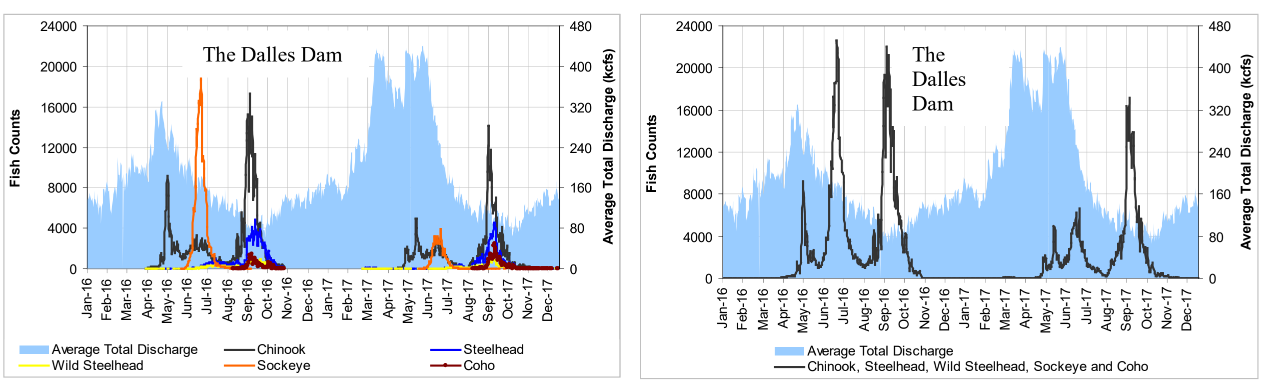


Figure 2: Fish Migration Patterns (by species and cumulative) Versus Power Generation Waterflows and Wholesale Power Markets on Bonneville Dam



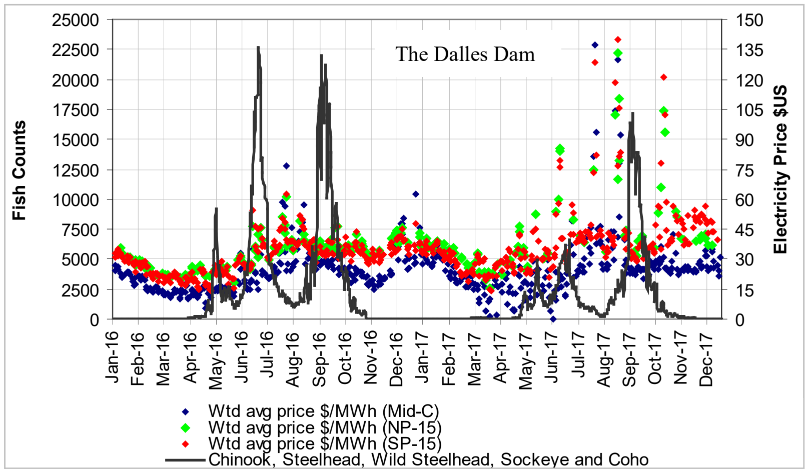


Figure 3: Fish Migration Patterns (by species and cumulative) Versus Power Generation Waterflows and Wholesale Power Markets on The Dalles Dam

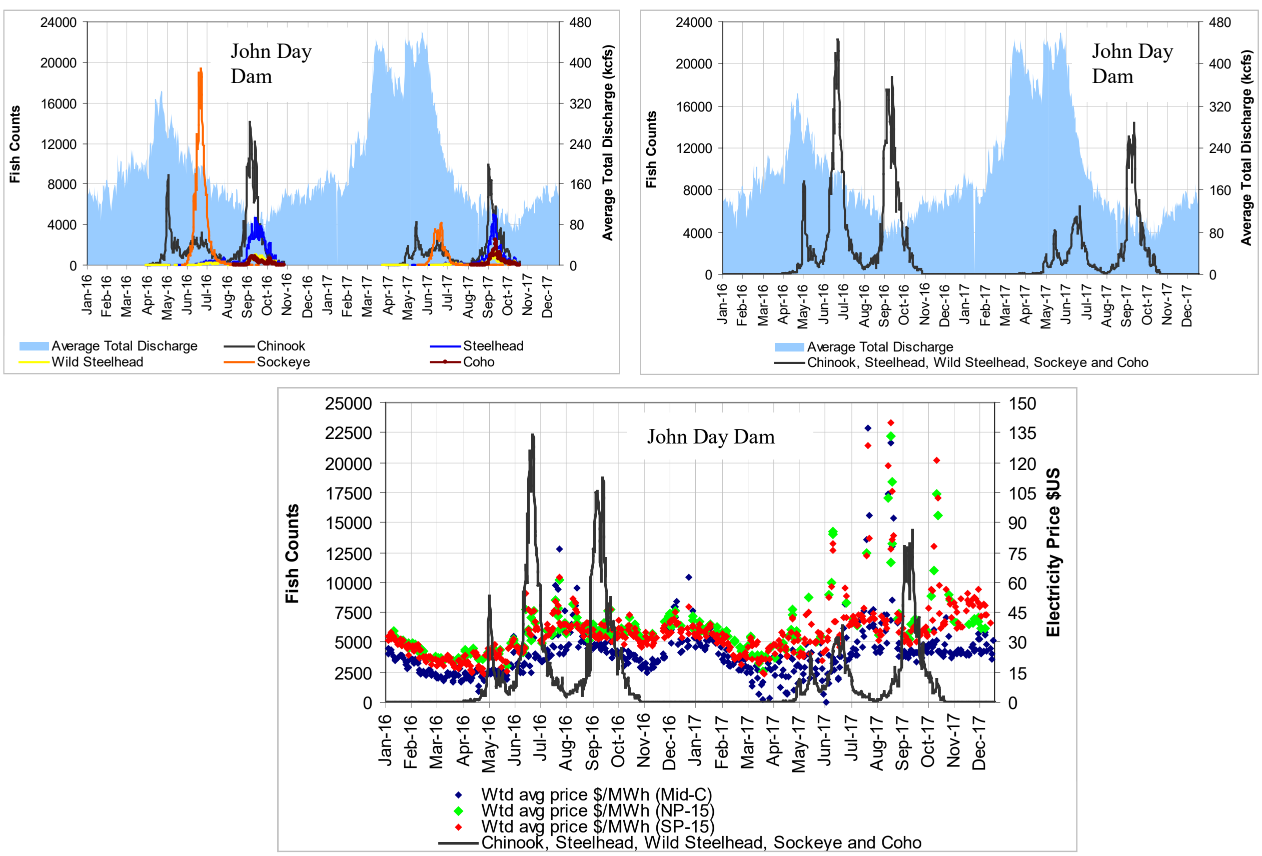


Figure 4: Fish Migration Patterns (by species and cumulative) Versus Power Generation Waterflows and Wholesale Power Markets on John Day Dam

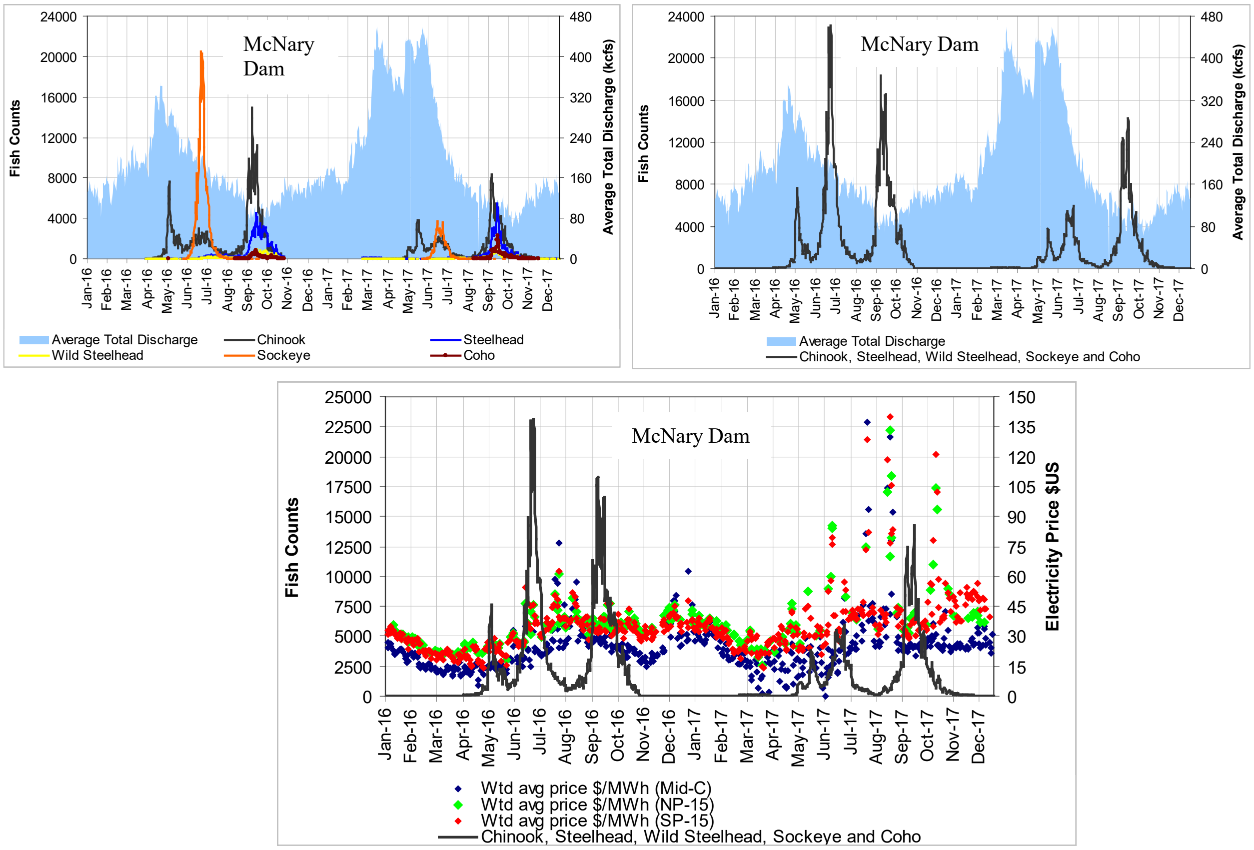
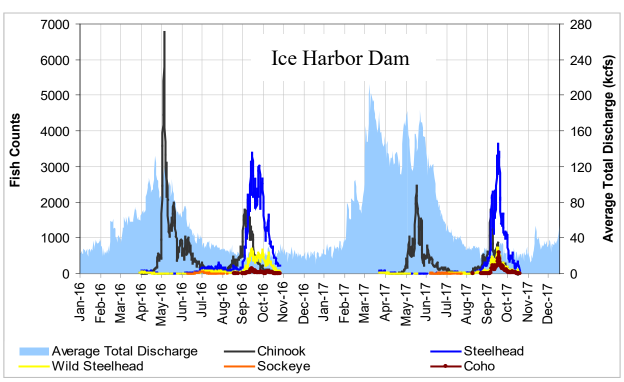
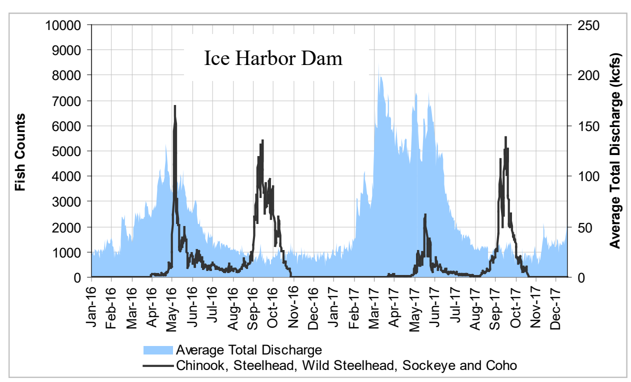


Figure 5: Fish Migration Patterns (by species and cumulative) Versus Power Generation Waterflows and Wholesale Power Markets on McNary Dam

Snake River Basin Hydropower Generators





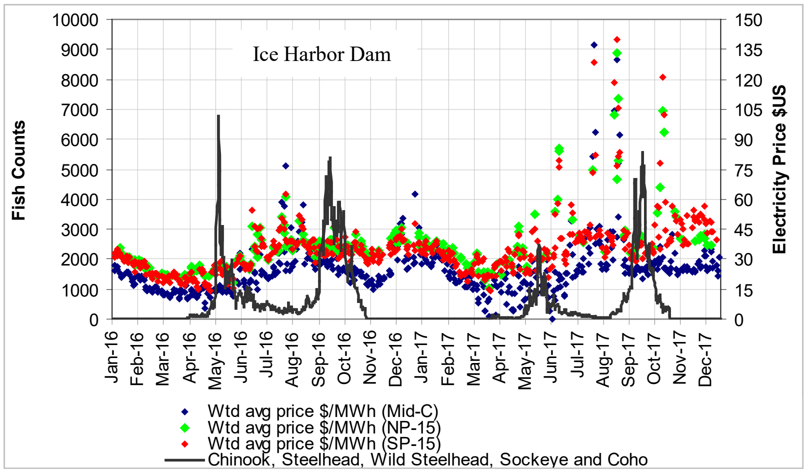


Figure 6: Fish Migration Patterns (by species and cumulative) Versus Power Generation Waterflows and Wholesale Power Markets on Ice Harbor Dam

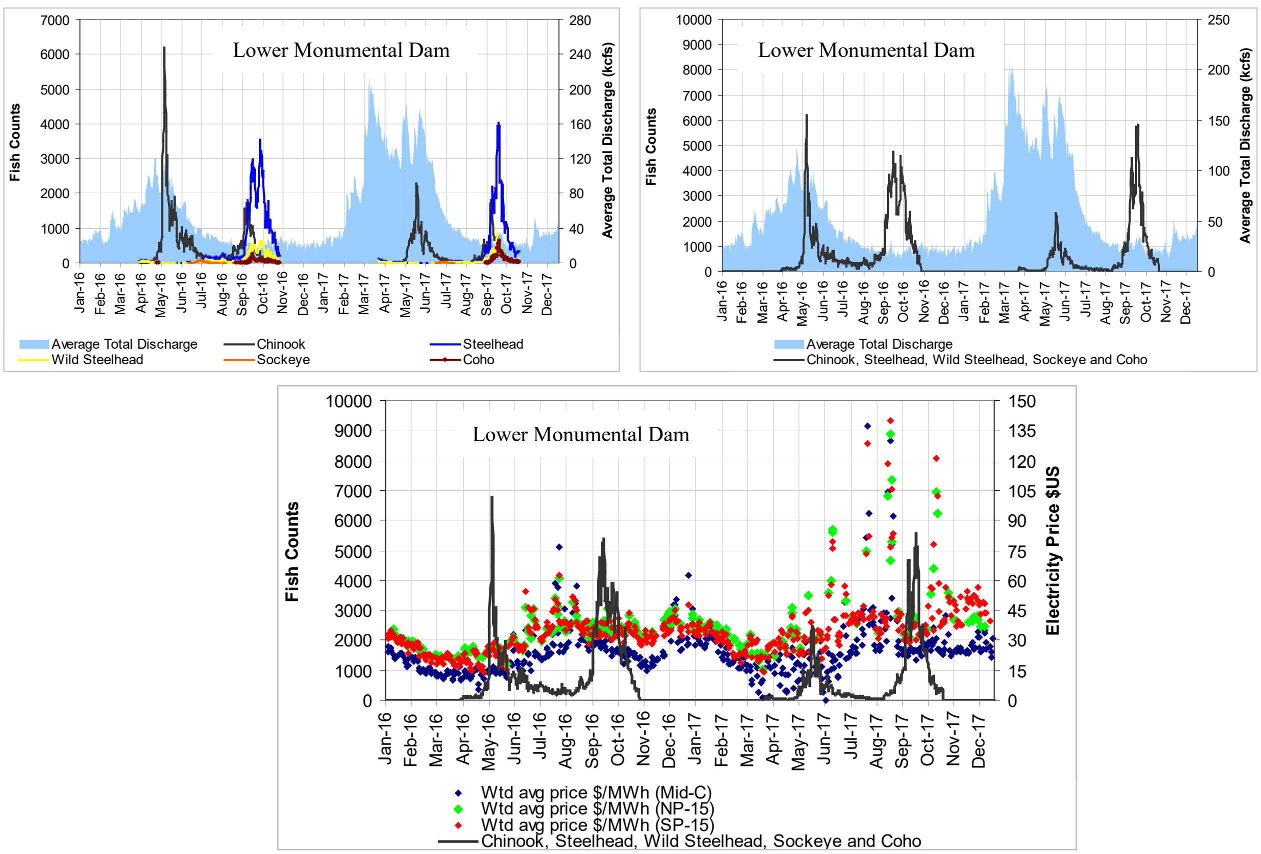


Figure 7: Fish Migration Patterns (by species and cumulative) Versus Power Generation Waterflows and Wholesale Power Markets on Lower Monumental Dam

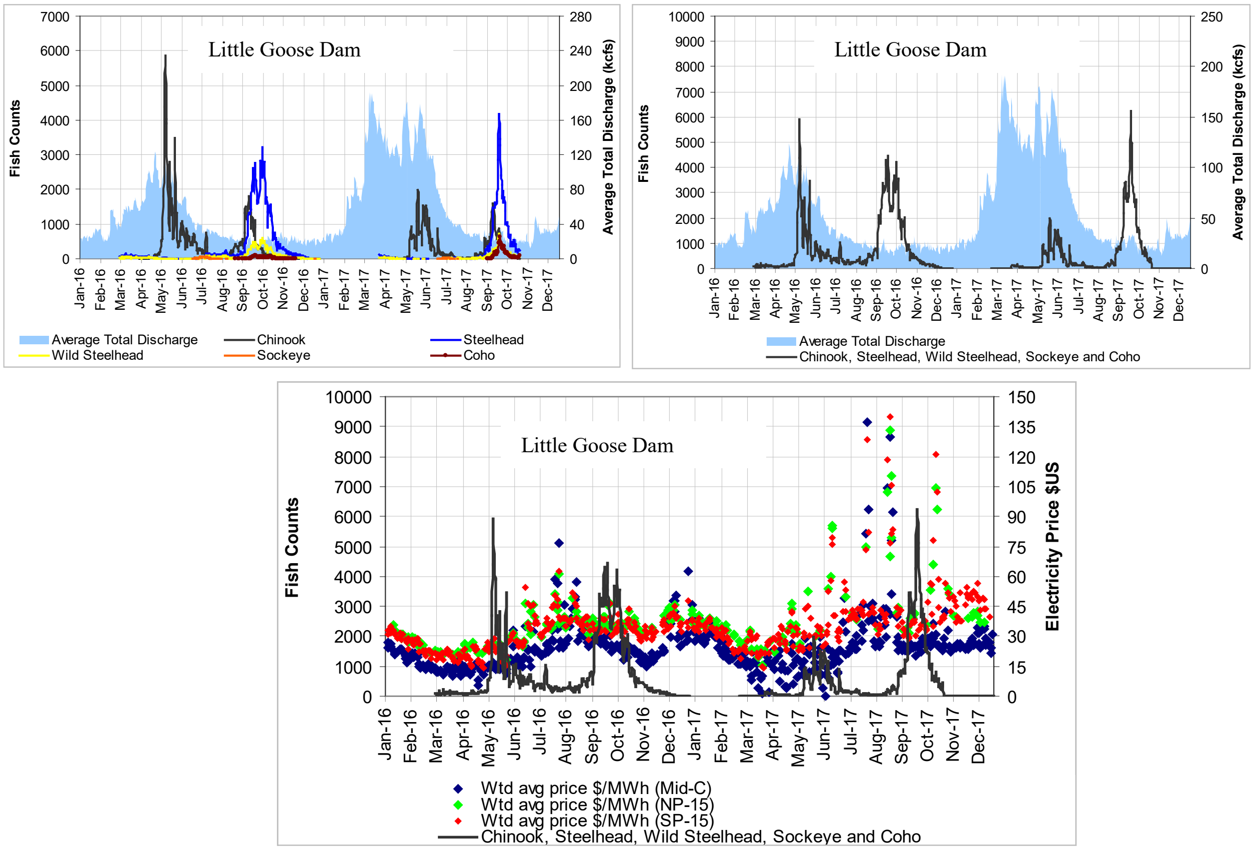
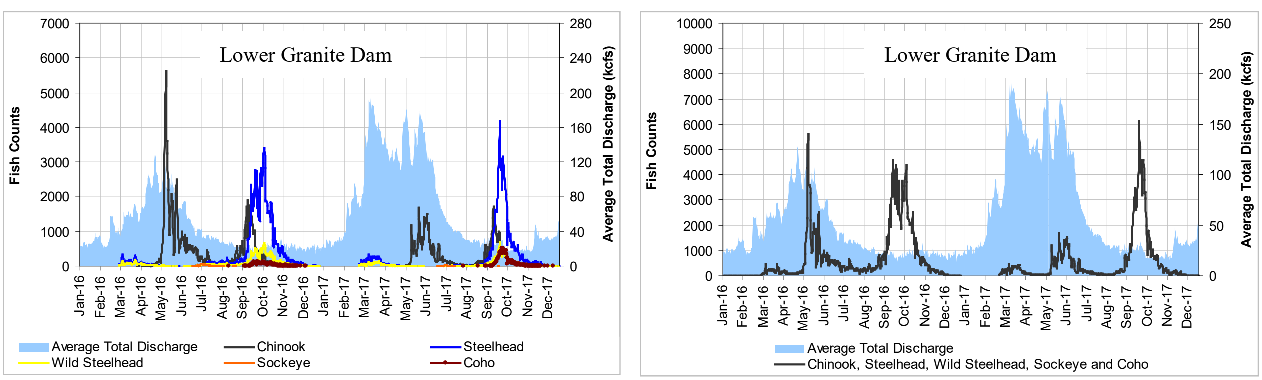


Figure 8: Fish Migration Patterns (by species and cumulative) Versus Power Generation Waterflows and Wholesale Power Markets on Little Goose Dam



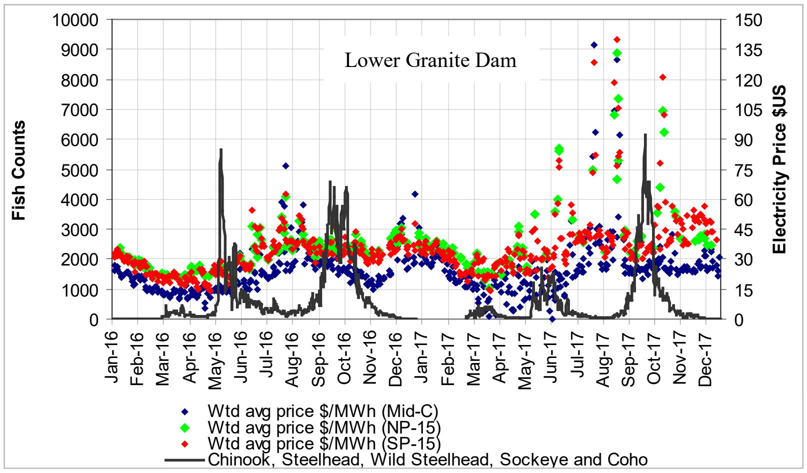


Figure 9: Fish Migration Patterns (by species and cumulative) Versus Power Generation Waterflows and Wholesale Power Markets on Lower Granite Dam

Surplus Power Potentially Generated from Adult Fish Passages' Waterflows

Calculation Mechanism, Data and Assumptions

The Consultant assumes that the value of the Client's technology can be calculated as the power generation surplus from waterflows that originate from the replacement of fish ladders with the Whooshh system, and which is then added back to the hydrogeneration stock. These amounts are calculated for each hydrogeneration project as described below.

1. The surplus water flow rate (volume) is calculated for each project on the basis of information summarized in Table 2: Powerhouse Capacity and Effective Height, Table 3: Description of Adult Fish Passage Facilities, Normal Operation, Pumped Water, Closing Periods and OVG Assumptions Based on Adult Fish Passage Facility Design and Inspections (Columbia River)., Table 4: Description of Adult Fish Passage Normal Operation, Pumped Water, Closing Periods and OVG Assumptions Based on Adult Fish Passage Facility Design and Inspections (Snake River). While each project has fish ladders built during the time of the original construction, they all differ in design and operational mode. They have different numbers of pumps for auxiliary water inflow, arrangements for using the excess water from spill, and each has gone through a series of different modifications and repairs. The summary of all waterflows, either reported directly by the project as the entrance water flow rate, or calculated by the Consultant from water pumped to the fish ladders or spilled from the juvenile fish passage system, is summarized in Table 5: Adult Fish Passage Facilities – Technical Parameters. The results are presented in m3s.

Powerhouse Capacity and Effective Height

River System	Dam	Hydropower Generators	Height
Columbia	Bonneville	First powerhouse has two 43 MW units and eight 54 MW units - 518 MW total powerhouse capacity. Second powerhouse has eight 76.5 MW units - 532 MW total powerhouse capacity[15]	197 feet[16]
	The Dalles	The powerhouse has fourteen 78 MW units and eight 85,975 kW units – 1779.8 MW total powerhouse capacity[17]	200 feet[18]
	John Day	The powerhouse has sixteen 135 MW units – 2160 MW total powerhouse capacity[19]	184 feet[20]

[15] Columbia and Snake Rivers Hydroelectric Project Information <http://www.cbr.washington.edu/hydro>
[16] Dams in Washington <http://nwdams.com/dams-in-washington>
[17] Columbia and Snake Rivers Hydroelectric Project Information <http://www.cbr.washington.edu/hydro>
[18] The Dalles Lock and Dam < http://celilo.lakesonline.com/DamInfo.asp?DamID=ADC19622-ADA8-4338-904A-7A296BFD170A>
[19] Columbia and Snake Rivers Hydroelectric Project Information <http://www.cbr.washington.edu/hydro>
[20] Dams in Washington <http://nwdams.com/dams-in-washington>

River System	Dam	Hydropower Generators	Height
	McNary	The powerhouse has fourteen 70 MW hydroelectric generator units – a 980 MW total powerhouse capacity[21]	183 feet[22]
Snake	Ice Harbor	The powerhouse has three 90 MW units and three 111 MW units – 603 MW total powerhouse capacity[23]	100 feet[24]
	Lower Monumental	The powerhouse has six 135 MW units – 810 MW total powerhouse capacity[25]	100 feet[26]
	Little Goose	The powerhouse has six 135 MW units – 810 MW total powerhouse capacity[27]	100 feet[28]
	Lower Granite	The powerhouse has six 135 MW units - 810 MW total powerhouse capacity[29]	100 feet[30]

*Table 2**: Powerhouse Capacity and Effective Height***

[21] Columbia and Snake Rivers Hydroelectric Project Information <http://www.cbr.washington.edu/hydro>
[22] Dams in Washington <http://nwdams.com/dams-in-washington>
[23] Columbia and Snake Rivers Hydroelectric Project Information <http://www.cbr.washington.edu/hydro>
[24] Washington Dams <http://www.nww.usace.army.mil/Locations/>
[25] Columbia and Snake Rivers Hydroelectric Project Information <http://www.cbr.washington.edu/hydro>
[26] Washington Dams <http://www.nww.usace.army.mil/Locations/>
[27] Columbia and Snake Rivers Hydroelectric Project Information <http://www.cbr.washington.edu/hydro>
[28] Washington Dams <http://www.nww.usace.army.mil/Locations/>
[29] Columbia and Snake Rivers Hydroelectric Project Information <http://www.cbr.washington.edu/hydro>
[30] Washington Dams <http://www.nww.usace.army.mil/Locations/>

Adult Fish Passage Normal Operation, Pumped Water, Closing Periods and Resulting OVG Assumptions (Columbia River)

Dam	Adult Fish Passage Normal Operations	Pumped water	Closing periods for maintenance[31] [32]	OVG water flow rate assumptions	OVG water flow delivery assumptions
Bonneville	The original design of Bonneville Dam included three locations of "fishways", one on each end of the Spillway Dam (in it's day the Spillway Dam was on the north side of the Columbia), and one at the Powerhouse on the Oregon side. Each "fishway" consisted of a collecting system, a fish ladder, and a pair of fish-locks. The fish ladders and fish-locks could be operated simultaneously or separately.[33] Between the two powerhouses is the spillway (part of the original construction) that incorporates 18 spillbays to pass excess or designated flow past the project. Gravity-flow water supplies flow to the main fishway entrances at PH1 and the spillway entrances. At PH2, the two fish turbines each supply a maximum of 5,000 cfs of water to the auxiliary water system that distributes flow to the four main entrances and the orifice gates along the powerhouse collection channel. At PH2, approximately 5,000 cfs of water was originally distributed from these small turbines to the East, West, and South fishway entrances as well as to the orifice gates along the powerhouse collection channel[34]	The two fish turbines each supply a maximum of 5,000 cfs of water to the auxiliary water system that distributes flow to the four main entrances and the orifice gates along the powerhouse collection channel.[35]	2016: Bradford Island Fishway: November 15, 2015 - March 16, 2016 Cascades Island Fishway (no UMT): October 19, 2015 to November 30, 2015 Washington Shore Fishway: No Outage 2018: Bradford Island Fishway: December 1, 2017-February 28, 2018. Cascades Island Fishway: Not Dewatering. Washington Shore Fishway: Not Dewatering.	Reduced by 30% in December, January and February.	As two turbines supply a maximum of 5,000 cfs of water to the auxiliary water system OVG assumes that at least 7% of this capacity is supporting fish ladders.
The Dalles	The Dalles Dam has two fish ladders—one on each shore—to provide a passage route for upstream-migrating fish, including adult salmon and steelhead, lamprey, sturgeon, shad, and others. [36]The Fish Ladders Entrance Water Flow Rate: North Ladder: 1,200 cfs South Ladder: 1,500 cfs. [37]	The Fish Ladders Entrance Water Flow Rate: North Ladder: 1,200 cfs South Ladder: 1,500 cfs [38]	2016: East Fish Fishway: December 1, 2015 - February 28, 2016 North Fish Fishway: November 16, 2015 November 30, 2015 January 8, 2016 - February 28, 2016 2018: East Fish Fishway: December 1, 2017 - February 28, 2018. North Fish Fishway: January 16, 2018 – January 30, 2018.	Reduced by 30% in December, January and February.	Maximum Entrance Water Rate is 2,700 cfs based on the USACE Fact Sheets.

[31] 2016 Annual Report <http://www.fpc.org/documents/annual_FPC_report/2016AnnualReport_Final2.pdf>
[32] 2017-2018 Columbia and Snake River Fishway Outages <http://www.fpc.org/currentdaily/HistFishTwo_7day-ytd_Adults.htm>
[33] Bonneville Dam Fish Ladders <http://columbiariverimages.com/Regions/Places/bonneville_dam_fish_ladders.html>
[34] Bonneville Dam Fish Ladders <http://columbiariverimages.com/Regions/Places/bonneville_dam_fish_ladders.html>
[35] Bonneville Dam Fish Ladders <http://columbiariverimages.com/Regions/Places/bonneville_dam_fish_ladders.html>
[36] The Dalles Dan and Lake Celo <http://www.crso.info/projects/TDD.html>
[37] Fact Sheet <http://www.nwp.usace.army.mil/Portals/24/docs/locations/thedalles/FS_The_Dalles_2013.pdf>
[38] Fact Sheet <http://www.nwp.usace.army.mil/Portals/24/docs/locations/thedalles/FS_The_Dalles_2013.pdf>

Dam	Adult Fish Passage Normal Operations	Pumped water	Closing periods for maintenance[31 32]	OVG water flow rate assumptions	OVG water flow delivery assumptions
John Day	Facilities for passing fish upstream over the Dam include a powerhouse collection system with fishway entrances at each end and along the downstream face of the powerhouse, and a 24-ft-wide fish ladder with 1-on-10 slope on both sides of the river.[39] The Fish Ladders Entrance Water Flow Rate: North Ladder: 1,000 cfs South Ladder: 2,700 cfs[40]	Removal of the existing AWS Pumps, installation of upgraded AWS Pump Systems, installation and fabrication of a new Power Distribution System and incidental related work at the John Day Dam, North Fish Ladder in 2009 -2013.[41]	2016: North Fish Fishway: December 1, 2015 - December 14, 2015 South Fish Fishway: January 8, 2016 - February 28, 2016 2018: North Fish Fishway: December 5, 2017 – December 17, 2017. South Fish Fishway: January 9, 2018 - February 28, 2018.	Reduce by 50% in January, February and first week of December.	Maximum Entrance Water Rate is 3,700 cfs based on the USACE Fact Sheets.
McNary	There are two fish ladders for adult migrating salmon and steelhead to use. The project uses attraction water from the north shore fish ladder on the McNary Dam for power generation. – Attraction water flow is diverted through penstocks, runs through the turbine and is then routed back to the entrance of the fish ladder to attract migrating fish and lamprey. The intake structure at McNary is located at the bottom of the dam and draws water from about 80 ft below the surface of the dam forebay.[42]	10 MW turbine generator located in the fish attraction water system for the McNary Dam North Shore Fishway.[43]	2016: Washington Shore Fishway: January 3, 2016 – January 22, 2016 Oregon Shore Fishway: January 24, 2016 - February 29, 2016 2018: Washington Shore Fishway: January 1, 2018 – January 31, 2018. Oregon Shore Fishway: February 1, 2018 - February 27, 2018.	Reduce by 50% in January and February.	McNary North Shore Fishway Hydro Project generator produces approximately 10 MW of power.[44]

Table 3: Description of Adult Fish Passage Facilities, Normal Operation, Pumped Water, Closing Periods and OVG Assumptions Based on Adult Fish Passage Facility Design and Inspections (Columbia River).

39 .Fish Ladders for John Day Dam, Columbia River, Oregon and Washington; Hydraulic Model Investigations <https://www.researchgate.net/publication/235118608_Fish_Ladders_for_John_Day_Dam_Columbia_River_Oregon_and_Washington_Hydraulic_Model_Investigations>

40 Fact Sheets <http://www.nwp.usace.army.mil/Portals/24/docs/locations/johnday/JohnDay_FS_2013.pdf>

41 THE JOHN DAY NORTH FISH LADDER AWS PUMP REPLACEMENT <https://olssonelec.com/portfolio/the-john-day-north-fish-ladder-aws-pump-replacement/>

42 McNary Northshore Fishway Hydro Project <https://nwhanew.memberclicks.net/assets/5-mcnary%20northshore%20fishway%20hydro%20project.pdf>

43 McNary Northshore Fishway Hydro Project <http://www.klickitatpud.com/yourPUD/projects/mcnary.aspx>

44 McNary Northshore Fishway Hydro Project <https://nwhanew.memberclicks.net/assets/5-mcnary%20northshore%20fishway%20hydro%20project.pdf>

Adult Fish Passage Normal Operation, Pumped Water, Closing Periods and Resulting OVG Assumptions (Snake River)

Dam	Adult Fish Passage [45]	Pumped water[46]	Closing periods for maintenance[47] [48]	OVG water flow rate assumptions	OVG water flow delivery assumptions[49] [50] [51]
Ice Harbor	Two fish ladders provide adult fish upstream passage through Ice Harbor Lock and Dam. The north shore facilities: one downstream entrance is used and the other two entrances are closed in normal operation. The auxiliary water is supplied by two electric pumps with a third pump as a backup. The south shore facilities: from six to eight are normally used to provide the required flows. The excess water from the juvenile fish passage facilities is routed into the fish pump discharge chamber to provide additional attraction flow.	Eight electric pumps providing 8.5 m3/s or 300 cfs each at 1.2 meters. The excess water from the juvenile fish passage facilities approximately 5.7 m3 /s or 200 cfs is routed into the fish pump discharge chamber to provide additional attraction flow.	2016: North Shore Fishway: February 6, 2016 - February 29, 2016 South Shore Fishway: January 1, 2016 - February 5, 2016 2018: North Shore Fishway: February 4, 2018 - February 28, 2018. South Shore Fishway: January 1, 2018 - February 3, 2018	Reduced by 50% in January and February.	Assume that 6 pumps provide 8.5 m3/s water each at 1.2 meters all the time excluding maintenance period as at least 6 electric pumps were operating during most inspections. Plus 5.7 m3/s of water is routed into the fish pump discharge chamber to provide additional attraction flow based on original design.
Lower Monumental	The adult fish handling facilities are comprised of north and south shore fish ladders and collection systems with a common attraction water supply. The north shore fish ladder connects to two north shore entrances and to the powerhouse collection system. The two north shore entrances, two downstream south powerhouse entrances, and four of the floating orifices are used during normal operation. The attraction water supply is provided from one common pumped system. Fish passage, however, is isolated between the north and south ladder systems.	Each turbine-driven pump is capable of producing 23.6 m3/s (835 cfs) at 1.2 meters (4 feet) TDH. Excess water from the juvenile fish bypass system (approximately 5.7 to 6.8 m3/s [200 to 240 cfs]) is added to the auxiliary water supply system for the powerhouse collection system.	2016: North Shore Fishway: January 1, 2016--February 28, 2016 South Shore Fishway: February 18, 2016-February 29, 2016 2018: North Shore Fishway: January 1, 2018–-January 31, 2018. South Shore Fishway: February 1, 2018 - February 28, 2018.	Reduce by 50% in January and February.	Assume that system provides at least min of water 23.6 M3/s all the time excluding maintenance period. Plus 5.7 m3/s of water is routed into the fish pump discharge chamber to provide additional attraction flow based on original design.
Little Goose	One fish ladder on the south shore, two south shore entrances, a powerhouse collection system, north shore entrances with a transportation channel through the spillway to the powerhouse collection system, and attraction water supply system. The powerhouse collection system is comprised of four floating orifices, two downstream entrances, one side entrance from the spillway basin on the north end of the powerhouse, and a common transportation channel that are normally used. The north shore entrances are comprised of two downstream facing entrances and a side entrance from the spillway basin. The two downstream entrances are used normally.	Each attraction water pump provides 24.0 m3 /s or 850 cfs) at 1.2 meters (4 feet) TDH. Additional water (approximately 5.7 m3/sor 200 cfs is supplied to the attraction water supply system from the juvenile fish passage facilities primary dewatering structure.	2016: January 4, 2016 –February 19, 2016 2018: January 2, 2018 - February 28, 2018	Reduce by 100% in January and February.	Assume that 3 pumps provide 24.0 M3/s all the time excluding maintenance period. Plus 5.7 m3/s of water is routed into the fish pump discharge chamber to provide additional attraction flow based on original design.

[45] Temporary Fish Passage Plan <http://www.nww.usace.army.mil/portals/28/docs/environmental/lsrstudy/Appendix_D-AnnexC.pdf>
[46] Temporary Fish Passage Plan <http://www.nww.usace.army.mil/portals/28/docs/environmental/lsrstudy/Appendix_D-AnnexC.pdf>
[47] 2016 Annual Report <http://www.fpc.org/documents/annual_FPC_report/2016AnnualReport_Final2.pdf>
[48] 2017-2018 Columbia and Snake River Fishway Outages <http://www.fpc.org/currentdaily/HistFishTwo_7day-ytd_Adults.htm>
[49] Adult Fishway Inspections <http://www.fpc.org/documents/fishway_inspection/AdultFishwayInspections-2014.pdf>
[50] Adult Fishway Inspections <http://www.fpc.org/documents/fishway_inspection/AdultFishwayInspections2016.pdf>
[51] Fishway Inspections < http://www.fpc.org/documents/fishway_inspection/70-13.pdf>

Dam	Adult Fish Passage [45]	Pumped water[46]	Closing periods for maintenance[47] [48]	OVG water flow rate assumptions	OVG water flow delivery assumptions[49] [50] [51]
Lower Granite	The adult fish passage facilities including one fish ladder on the south shore, two south shore entrances, a powerhouse collection system, north shore entrances with a transportation channel through the spillway to the powerhouse collection system, and an attraction water supply system are usually used for normal operation. The north shore entrances are made up of two downstream entrances and a side entrance from the spillway basin. The two downstream entrances are used normally.	The pumping system provides from 12.7 to 29.7 m3 /s (450 to 1,050 cfs) at 1.2 meters (4 feet) TDH using 350 to 800 hp and two pumps providing 29.7 m3/s (1,050 cfs) at 1.2 meters (4 feet) TDH using 800 hp each.	2016: January 2, 2016 –February 28, 2016 2018: January 1, 2016 –February 28, 2016	Reduce by 100% in January and February.	Assume that 2 pumps provide 29.7 m3/s and one pump provide 12.7 m3/s all the time excluding maintenance period

Table 4: Description of Adult Fish Passage Normal Operation, Pumped Water, Closing Periods and OVG Assumptions Based on Adult Fish Passage Facility Design and Inspections (Snake River)

Adult Fish Passage Facilities – Technical Parameters

River System	Dam	Height H (feet)	Adult Fish Ladder: Entrance Water Flow Rate F (kcfs)	Adult Fish Ladder: Powerhouse System (MW)	Water induced by pumping system: Attraction Water System (Pumped)	Water induced by pumping system: Water Flow Rate F (kcfs)	Water induced by pumping system: Number of Pumps	Water induced by pumping system: Pumping Required Water (m)	Water from Juvenile fish system: The Excess Water from the Juvenile fish passage facilities	Water from Juvenile fish system: Water Flow Rate F (kcfs)	Total water flow rate / volume (kcfs)	Total water flow rate / volume (m3s)
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*4+7x8+11*	
Columbia	Bonneville	197	3500	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3500	99.1
	The Dalles	200	2700	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2700	76.5
	John Day	184	3700	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3700	104.8
	McNary	183	N/A	10	N/A	N/A	N/A	N/A	N/A	N/A	***NOTE 2***	
Snake	Ice Harbor	100	N/A	N/A	Yes	300	6	1.2	Yes	200	2000	56.6
	Lower Monumental	100	N/A	N/A	Yes	835	3	1.2	Yes	200	2705	76.6
	Little Goose	100	N/A	N/A	Yes	850	3	1.2	Yes	200	2750	77.9
	Lower Granite	100	N/A	N/A	Yes	1050	2	1.2	Yes	N/A	2550	29.7
						450	1					12.7

Table 5: Adult Fish Passage Facilities – Technical Parameters

NOTE 1: N/A means that data is not available for calculations
NOTE 2: the amount of surplus generation is calculated for 10 MW

2. To arrive at the waterflow daily patterns, the surplus waterflow rate (volume) is adjusted as per the following assumptions:

a. Adult fish ladders operate constantly over the year. Based on the 10-year average adult fish migration data,[52] fish can pass dam in any season or any day during the year.

b. If there are no reported issues, all pumps are in operational mode supplying the required amount of water. The only exception is Ice Harbor dam where only 6 out of 8 pumps work, according to the multiple inspection reports.

c. Adult fish ladder operations are interrupted during maintenance periods, as described in Table 3: Description of Adult Fish Passage Facilities, Normal Operation, Pumped Water, Closing Periods and OVG Assumptions Based on Adult Fish Passage Facility Design and Inspections (Columbia River)., Table 4: Description of Adult Fish Passage Normal Operation, Pumped Water, Closing Periods and OVG Assumptions Based on Adult Fish Passage Facility Design and Inspections (Snake River).

d. In the spring and summer, spills are triggered by juvenile fish migrating down the river. As the Whooshh system is designed for passage of adult fish, spill levels remain unchanged after implementation of the Whooshh system[53]. Spills and other fishway operations for juvenile fish passage remain unchanged and do not affect adult fish passage.

3. The potential power generation surplus is calculated per Formula 1: Hydropower Available with the outcomes resulting from Step 1 and Step 2. The hydropower available to the dam is equal to

$$P = F*\rho *G * H * Ef$$

where

- F, the volume of water flow through the dam, is measured in m^3/s
- H is measured in meters
- ρ *is* a density of water = 1000 kg/m^3
- G is a gravity = 9.81 m/s^2
- Ef is an Efficiency Factor.

Formula 1: Hydropower Available

Efficiency Factor is calculated based on the hydrogenerator historical data, Average Generation Flow and Average Generation. The Consultant uses USACE historical generation data[54] and calculated averages of years 2016 and 2017.

4. Some dams use the Auxiliary Water Systems for the make-up waterflows pumped to various transition pools in the ladder, such as bifurcation or trifurcation pools, trap pools, exit control

[52] Columbia Basin Research (University of Washington) data (DART Adult Passage Daily Counts for All Species) <http://www.cbr.washington.edu/dart/query/adult_daily>
[53] Salmon Recovery <https://www.salmonrecovery.gov/Newsroom/LinksMapsResources>
[54] USACE Historical Generation Data <http://www.nwd-wc.usace.army.mil/dd/nwdp/project_daily/webexec/rep>

sections, or counting station pools. The energy used to run these pumps is also added to the potential power generation surplus amounts. To deliver make-up flows with the certain water flow rate (F) to the height (H), the pumping system uses the following amount of power:

$$P = F * \rho * G * H \ / Ef$$

where

- F, the volume of water flow through the pump, is measured in m^3/s
- H is measured in meters
- ρ *is* a density = 1000 kg/m^3
- G is a gravity = 9.81 m/s
- Ef is an Efficiency Factor.

Formula 2: Power available from displaced pumps

The potential power generation surplus for each project is calculated on daily basis.

Resulting Potential Power Generation Surplus

The resulting potential hydrogeneration surplus is summarized in Table 6: Summary of Potential Power Generation Surplus. The average surplus hydro flows can contribute to between 1.6% and 10.6% of additional power generation, which accounted to about 127 MW of generation on average in 2016 and 2017.

	Columbia River System				Snake River System				Total
	Bonneville	The Dalles	John Day	McNary	Ice Harbor	Lower Monumental	Little Goose	Lower Granite	
2016 (MW)	14.1	15.3	25.7	9.2	14.1	19.7	9.3	17.4	**124.8**
2017 (MW)	13.1	14.8	25.3	9.2	13.8	19.5	17.5	17.5	**130.7**
Average 2016-2017 (MW)	**13.6**	**15.1**	**25.5**	**9.2**	**13.9**	**19.6**	**13.4**	**17.4**	**127.7**
2016 (%)	2.1%	2.3%	2.7%	1.6%	10.1%	12.4%	5.4%	10.5%	
2017 (%)	1.8%	2.1%	2.5%	1.6%	8.4%	8.8%	7.5%	8.7%	
Average 2016-2017 (%)	**1.9%**	**2.2%**	**2.6%**	**1.6%**	**9.2%**	**10.6%**	**6.4%**	**9.6%**	

Table 6: Summary of Potential Power Generation Surplus

Below are detailed graphs developed on a daily basis for each project on 2016-2017 historical generation data.

Columbia River Basin Hydropower Generators

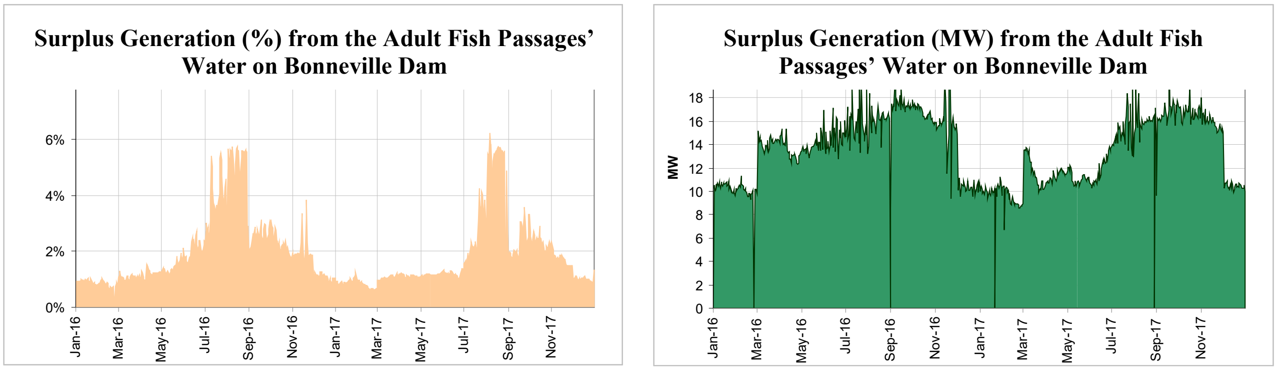


Figure 10: Additional Generation (%, MW) from the Adult Fish Passages' Water on Bonneville Dam

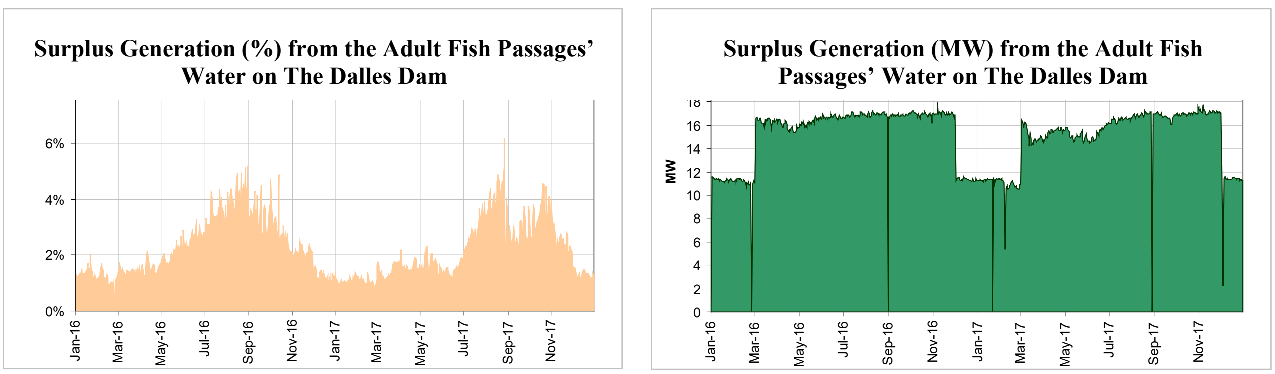


Figure 11: Additional Generation (%, MW) from the Adult Fish Passages' Water on The Dalles Dam

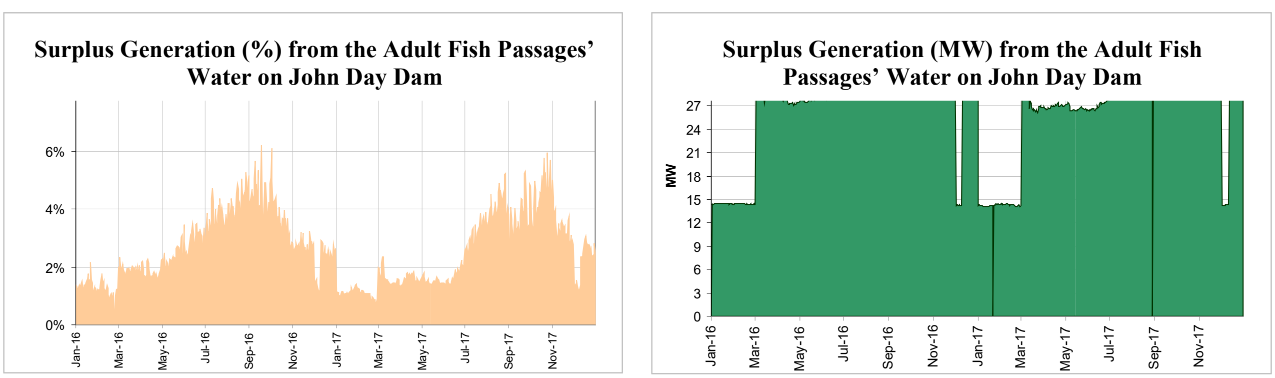


Figure 12: Additional Generation (%, MW) from the Adult Fish Passages' Water on John Day Dam

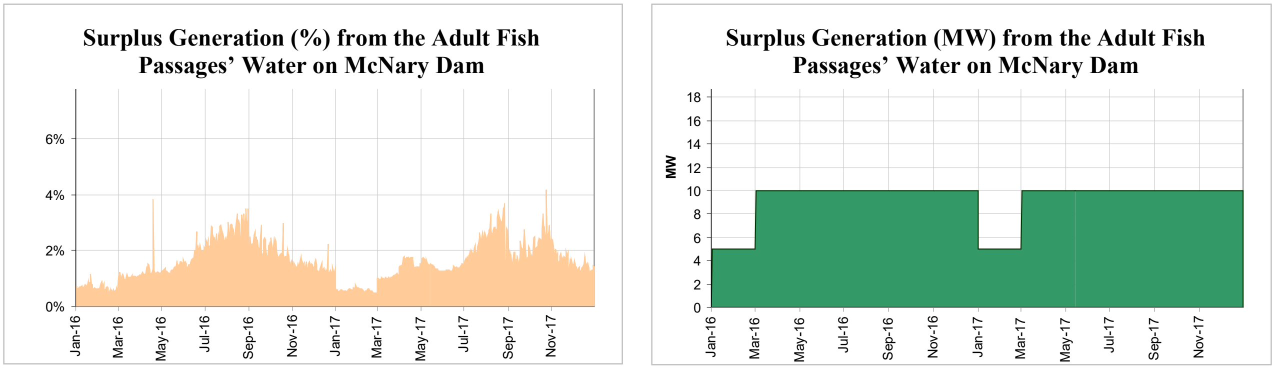


Figure 13: Additional Generation (%, MW) from the Adult Fish Passages' Water on McNary Dam

Snake River Basin Hydropower Generators

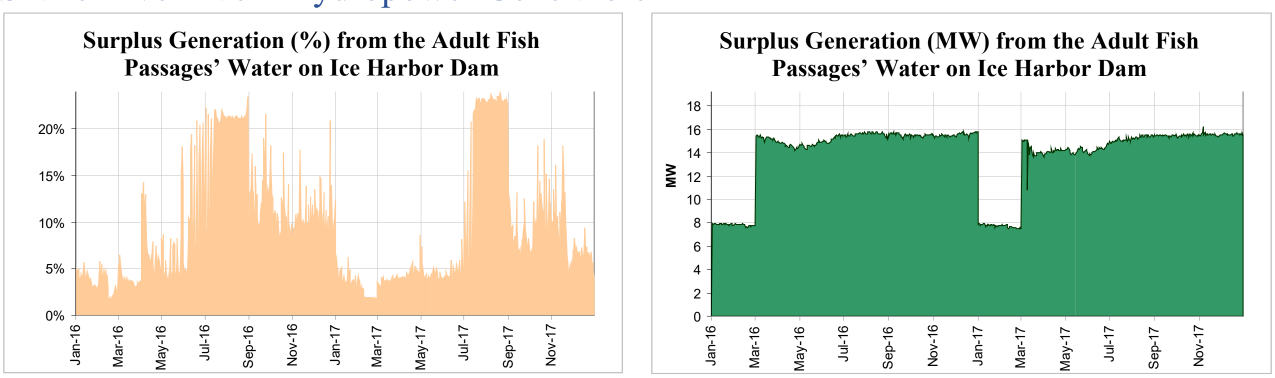


Figure 14: Additional Generation (%, MW) from the Adult Fish Passages' Water on Ice Harbor Dam

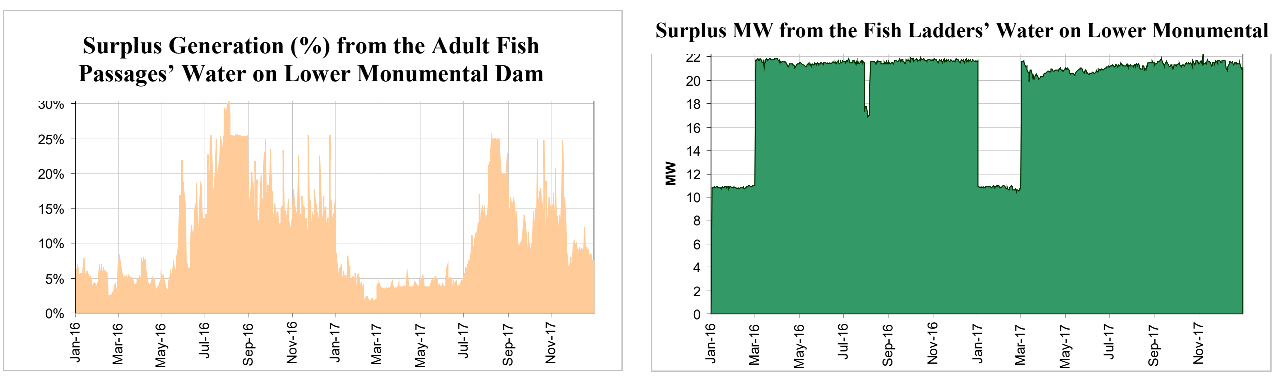


Figure 15: Additional Generation (%, MW) from the Adult Fish Passages' Water on Lower Monumental Dam

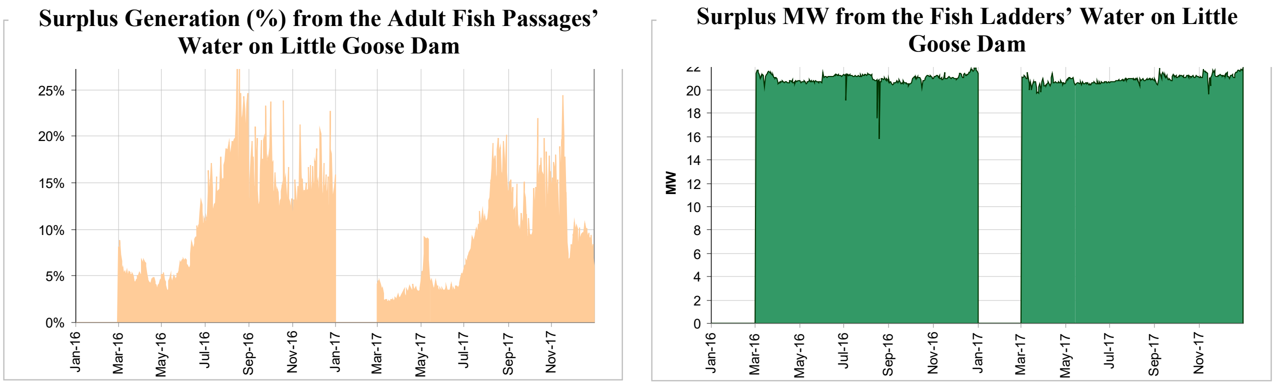


Figure 16: Additional Generation (%, MW) from the Adult Fish Passages' Water on Little Goose Dam

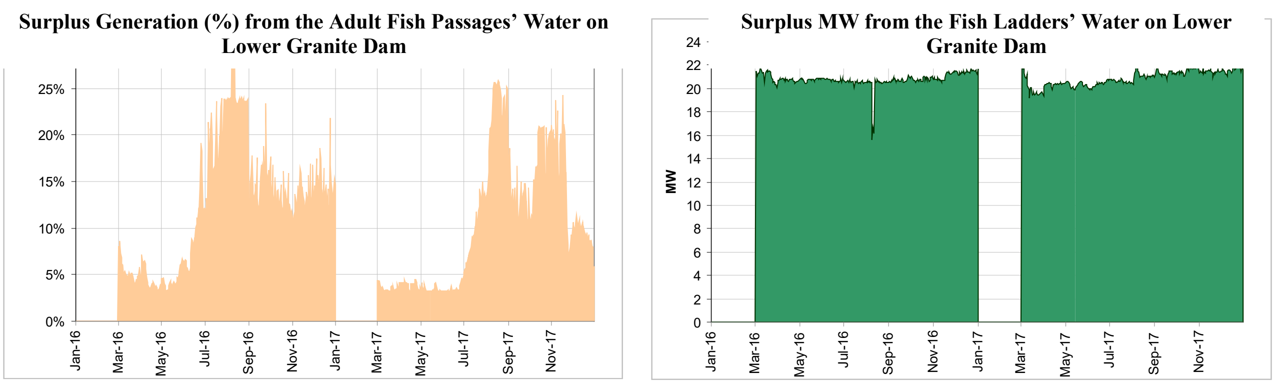


Figure 17: Additional Generation (%, MW) from the Adult Fish Passages' Water on Lower Granite Dam

Monetary Value of the Potential Hydrogeneration Surplus

Calculation Mechanism, Data and Assumptions

The monetary value of the potential power generation resulting from waterflows diverted for fish passage is calculated for each project under study. The potential power generation surplus, calculated as described in the section Surplus Power Potentially Generated from Adult Fish Passages' Waterflows , is multiplied by the spot prices reported for the regional markets. The Consultant prepared calculations for year 2016 and 2017 for the following electricity pricing locations:

- Northwest Mid-C hub;
- California NP-15 hub;
- California SP-15 hub.

Calculations are developed under the following assumptions:

1. Generated power is traded in the spot market.
2. The cost of power delivery (transmission) is not included in calculations; it is assumed there are no transmission constraints.
3. During the snow melting and spilling season (April – June), electricity is most likely generated and traded only during the high load hours (peak), which are 16 hours x 5 days, excluding holidays. Due to a high availability of water and low shoulder season demand, the value of water is relatively low and surplus waterflows are likely to be spilled. Hence, surplus waterflows available during off-peak hours are assumed to be spilled as they cannot be collected for later use. As a result, it is assumed that only generation produced during peak hours is traded on the wholesale markets.
4. During the rest of the year, which is characterized by higher demand (summer and winter), and shortage of supply (low waterflows in fall), the generated electricity is traded during peak hours. Hydropower generators are highly dispatchable because they can store fuel (water) and release it when needed (assuming all reliability and fish migration requirements are taken into consideration). It allows them to trade power during the hours of high electricity demand (and accordingly the highest spot price). Hence, waterflows available in off-peak hours are retained for trading later, during peak hours.
5. Monetary value of the potential hydrogenation surplus is calculated based on peak wholesale day-ahead historical electricity prices collected by ICE[55] and republished by EIA[56] for year 2016

[55] Daily Electricity Price Indexes, ICE, <https://www.theice.com/index>
[56] EIA wholesale energy markets reports <https://www.eia.gov/electricity/wholesale/>

and 2017 and additional generation (MW) from surplus water from adult fish passages plus freed generation from the pump(s) operation.

6. Electricity can be sold to the market only when the market needs the energy. During the days when EIA and ICE do not report prices, the Consultant assumes there is no market demand and excludes these days from calculations

Historical Surplus Revenues (2016-2017)

The Consultant estimated the potential revenues from selling the water surplus to the regional hubs for each project.

The resulting monetized value from the potentially freed hydrogeneration surplus is summarized in Table 7: Unrealized Monetary Value of the Surplus Hydrogeneration. If sold on either of three regional hubs in 2016, the surplus hydro flows could yield between $876k (McNary), if sold on NP-15, and $4.3M (John Day), if sold on SP-15 hub. If sold on either of three regional hubs in 2017, the surplus hydro flows could yield between $736k (McNary), if sold on NP-15, and $5.3M (John Day), if sold on SP-15 hub.

The total 2016-2017 average unrealized revenues for all hydrogeneration projects vary from $11.6M on SP-15 hub to $25M on SP-15 hub.

	Columbia River System				**Snake River System**				**Total ('000 $US)**
	Bonneville, ('000 $US)	**The Dalles, ('000 $US)**	**John Day, ('000 $US)**	**McNary, ('000 $US)**	**Ice Harbor, ('000 $US)**	**Lower Monumental, ('000 $US)**	**Little Goose, ('000 $US)**	**Lower Granite, ('000 $US)**	
Mid-C - 2016	1,789	1,927	3,261	1,185	1,833	2,543	2,306	2,277	**17,121**
Mid-C - 2017	1,958	2,162	3,642	1,310	1,991	2,791	2,477	2,483	**18,814**
Mid-C average 2016-2017	**1,874**	**2,045**	**3,452**	**1,248**	**1,912**	**2,667**	**2,392**	**2,380**	**17,968**
NP-15 - 2016	1,357	1,445	2,398	876	1,354	1,873	1,704	1,690	**12,697**
NP-15 - 2017	1,075	1,232	2,040	736	1,114	1,567	1,325	1,326	**10,415**
NP-15 average 2016-2017	**1,216**	**1,339**	**2,219**	**806**	**1,234**	**1,720**	**1,515**	**1,508**	**11,556**
SP-15 - 2016	2,362	2,546	4,280	1,549	2,390	3,325	3,003	2,967	**22,422**
SP-15 - 2017	2,792	3,118	5,255	1,905	2,883	4,053	3,683	3,691	**27,380**
SP-15 average 2016-2017	**2,577**	**2,832**	**4,768**	**1,727**	**2,637**	**3,689**	**3,343**	**3,329**	**24,901**

Table 7: Unrealized Monetary Value of the Surplus Hydrogeneration (2016-2017)

Below are detailed graphs developed on daily basis for each project on 2016-2017 historical market price data.

Columbia River Basin Hydropower Generators

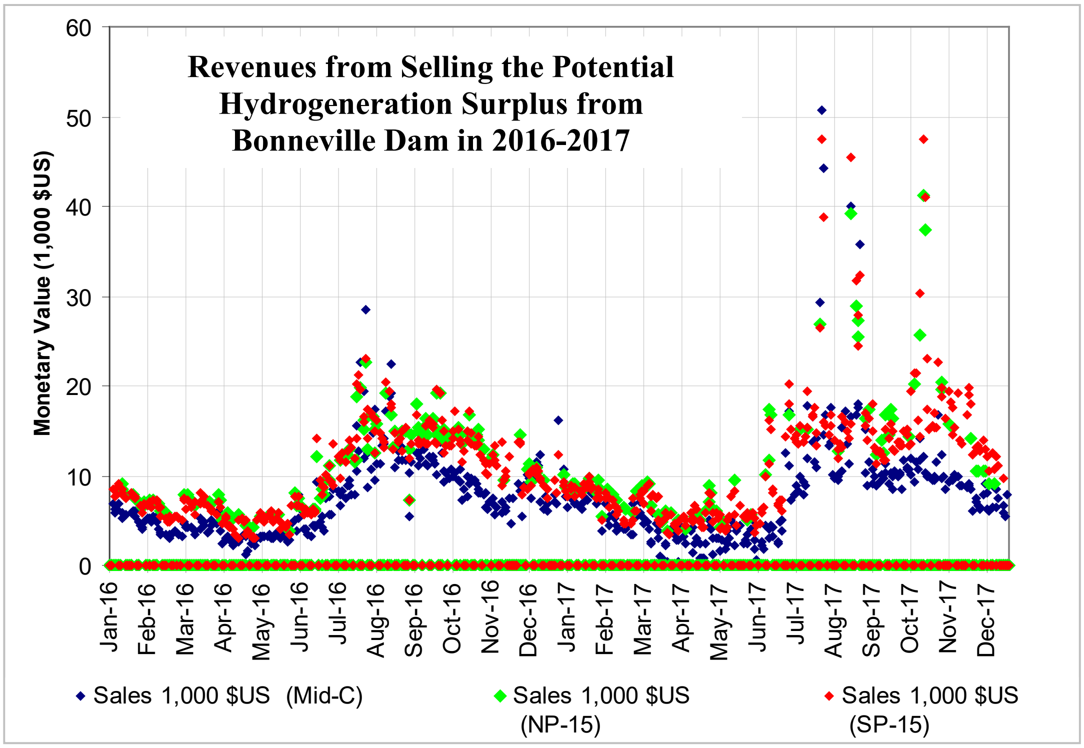


Figure 18: Revenues from Selling the Potential Hydrogeneration Surplus from Bonneville Dam in 2016-2017

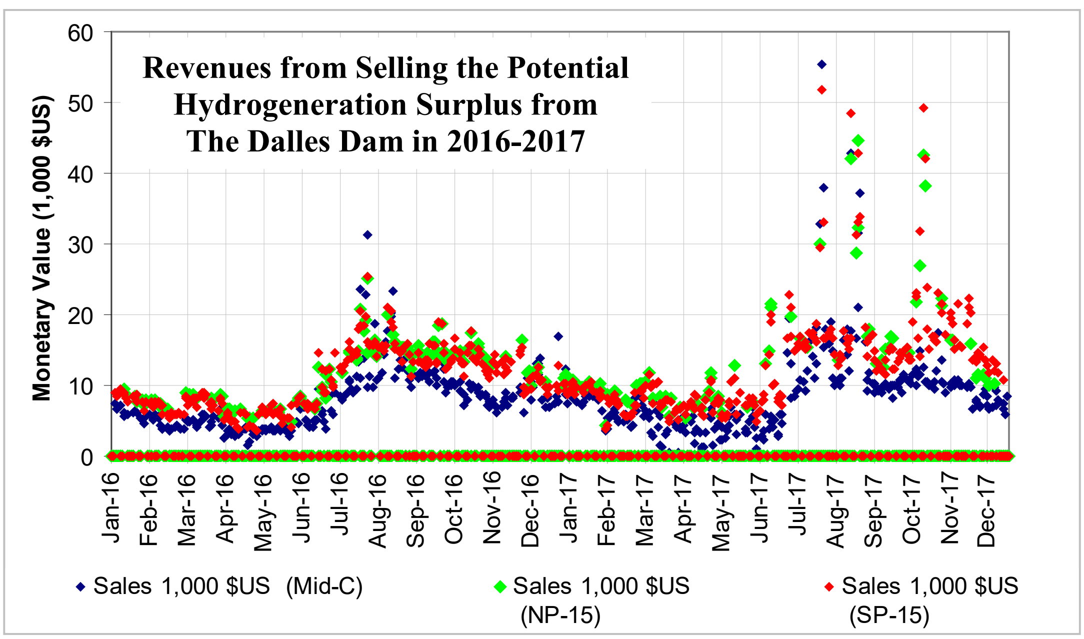


Figure 19: Revenues from Selling the Potential Hydrogeneration Surplus from The Dalles Dam in 2016-2017

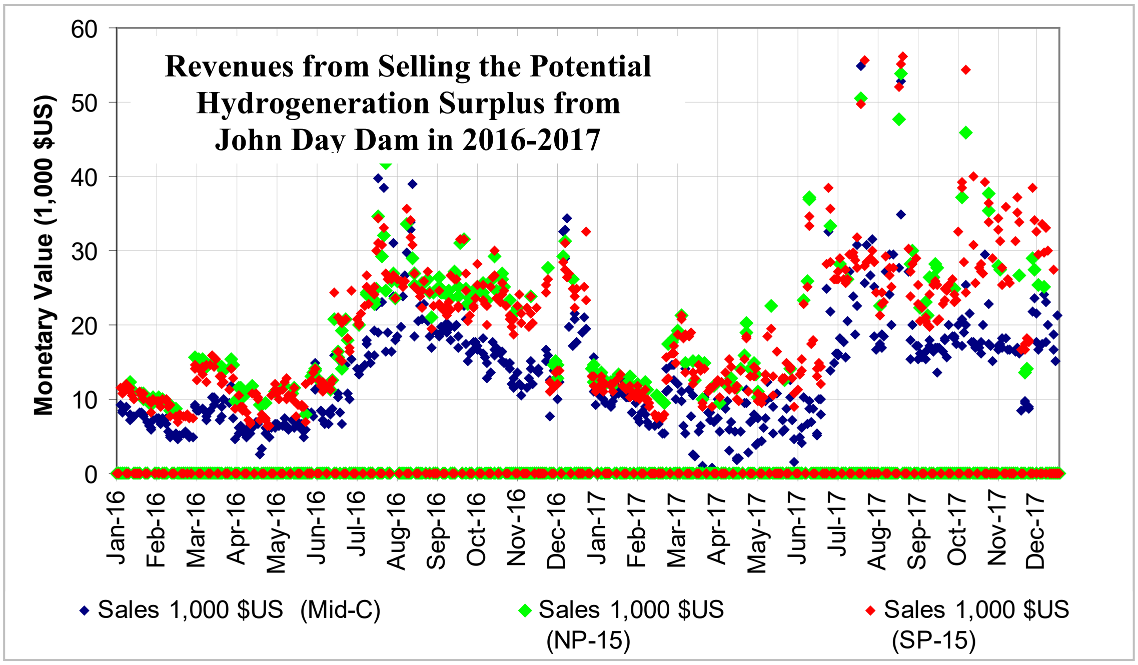


Figure 20: Revenues from Selling the Potential Hydrogeneration Surplus from John Day Dam in 2016-2017

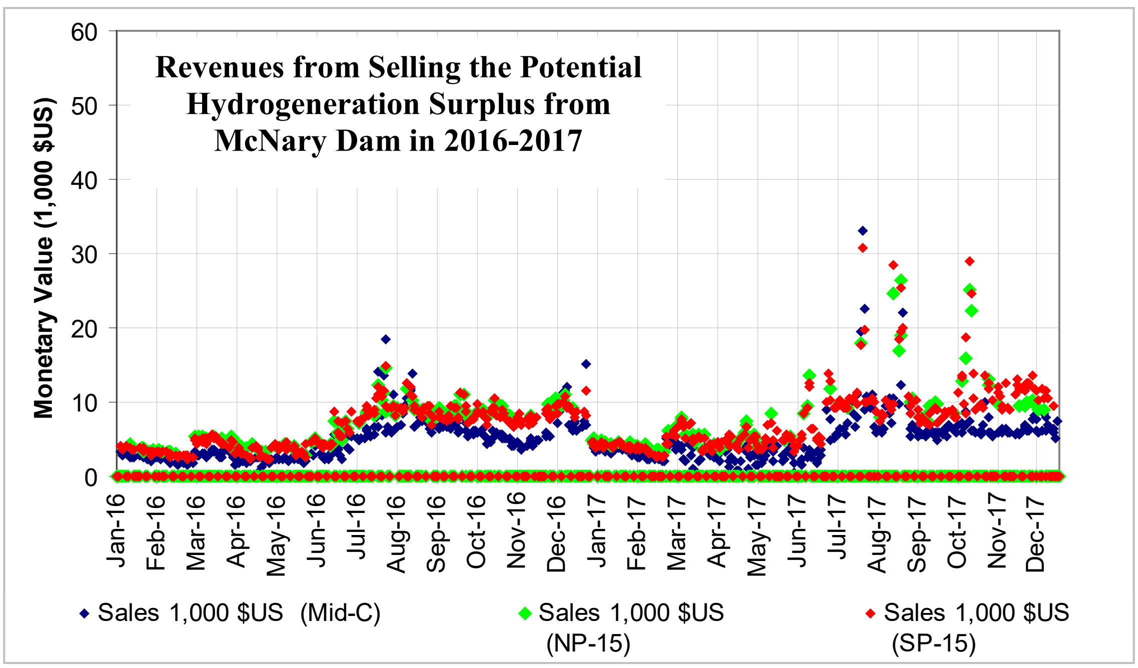


Figure 21: Benefits of Selling the Potential Hydrogeneration Surplus from McNary Dam in 2016-2017

Snake River Basin Hydropower Generators

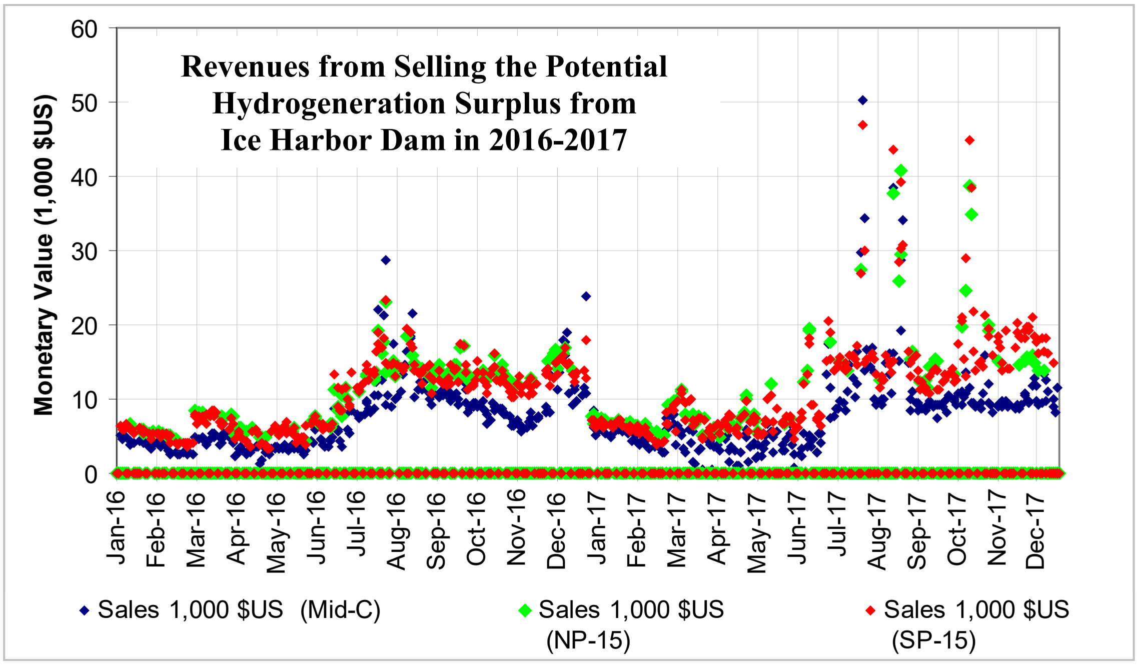


Figure 22: Revenues from Selling the Potential Hydrogeneration Surplus from Ice Harbor Dam in 2016-2017

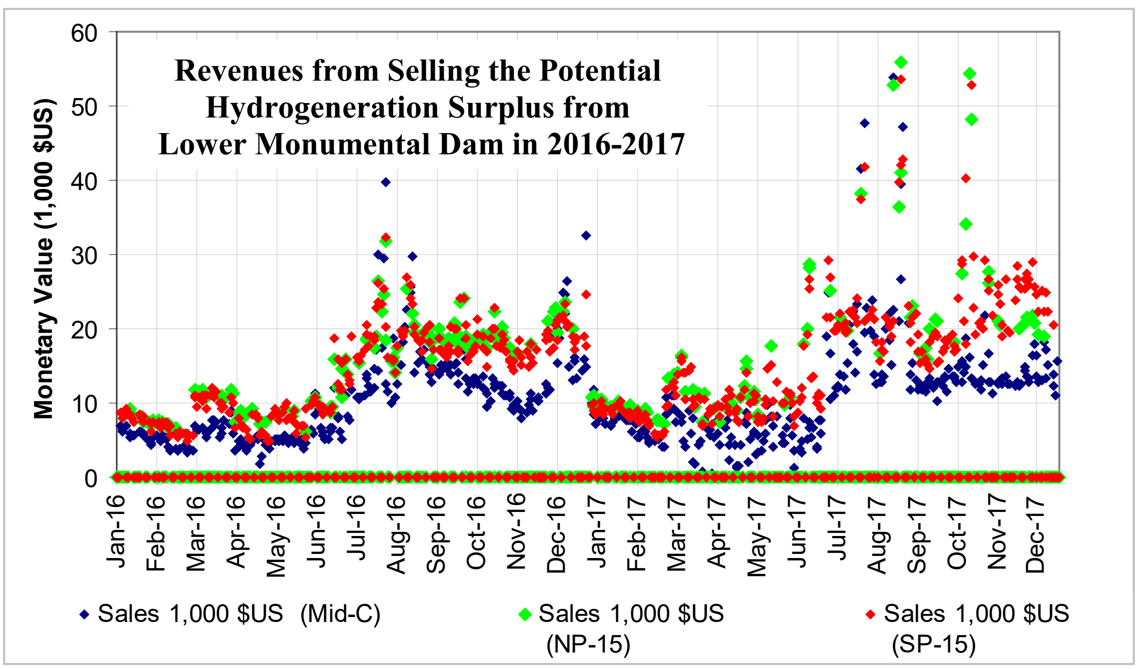


Figure 23: Revenues from Selling the Potential Hydrogeneration Surplus from Lower Monumental Dam in 2016-2017

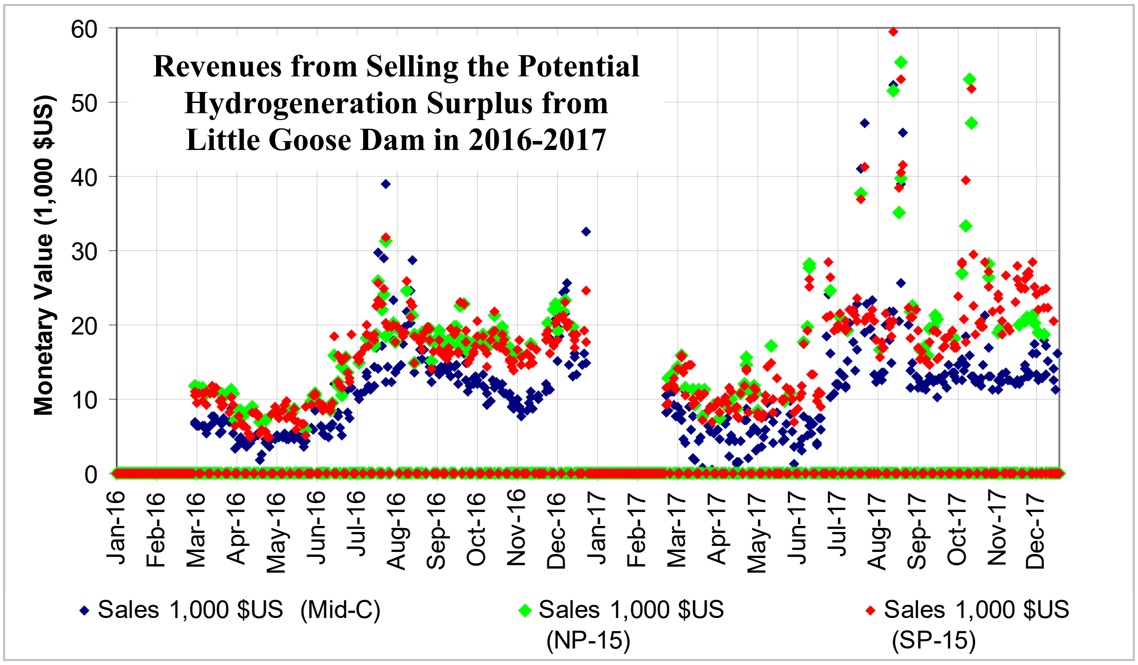


Figure 24: Revenues from Selling the Potential Hydrogeneration Surplus from Little Goose Dam in 2016-2017

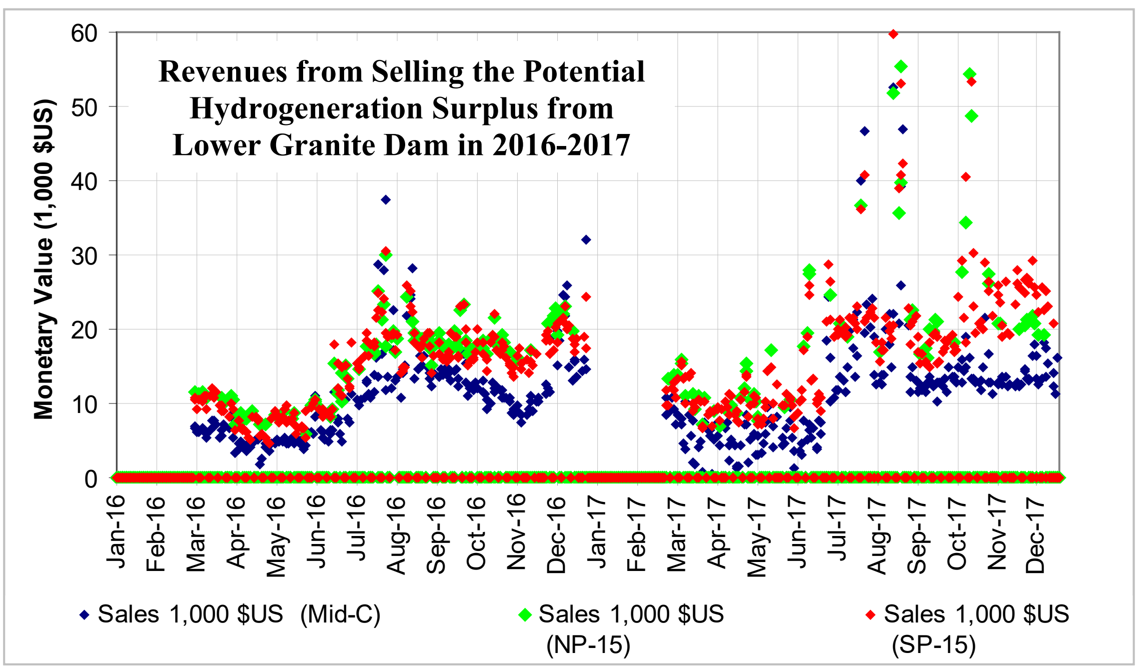


Figure 25: Revenues from Selling the Potential Hydrogeneration Surplus from Lower Granite Dam in 2016-2017

Future (2018) Surplus Revenues

To build future projections for the unrealized surplus revenues, the Consultant applied the historical patterns of electricity trading on each trading hub for 2017 and electricity price forecast reported by the Energy Information Administration (EIA)[57]. This forecast is based on the electricity price increase expected by EIA and the projected annual inflation rate in the United States[58]. EIA projects electricity price increase in 2018 by 0.1%. The Consultant applies the projected US annual inflation rate of 2.38%.

The results are summarized in Table 8: Projected Monetary Value of the Surplus Hydrogeneration (2018). The total potential revenues to all eight projects vary between $10.6M if all electricity is sold in NP-15 and $21.8M if all electricity is traded on SP-15.

	Columbia River System				Snake River System				Total ('000 $US)
	Bonneville, ('000 $US)	The Dalles, ('000 $US)	John Day, ('000 $US)	McNary, ('000 $US)	Ice Harbor, ('000 $US)	Lower Monumental. ('000 $US)	Little Goose, ('000 $US)	Lower Granite, ('000 $US)	
Mid-C	1,909	1,646	3,118	1,083	1,693	2,298	1,569	1,555	**14,872**
NP-15	1,366	1,178	2,231	775	1,212	1,645	1,123	1,113	**10,642**
SP-15	2,793	2,407	4,560	1,583	2,477	3,362	2,295	2,274	**21,751**

Table 8: Projected Monetary Value of the Surplus Hydrogeneration (2018)

[57] Annual Energy Outlook 2018 < https://www.eia.gov/outlooks/aeo/>
[58] Projected annual inflation rate in the United States < https://www.statista.com/statistics/244983/projected-inflation-rate-in-the-united-states/>