Northwest Power and Conservation Council

June 9, 2009

MEMORANDUM

TO: Fish and Wildlife Committee Members

FROM: John Fazio, Senior System Analyst
Jim Ruff, Manager, Mainstem Passage and River Operations

SUBJECT: Appendix M: Integrating Fish & Wildlife and Power Planning

By statute, mainstem hydroelectric operations specified in the Council's fish and wildlife program automatically become a part of the power plan. The plan is to be designed so that fish and wildlife operations are implemented in an adequate and reliable way. Two attachments (the Hydroelectric Generation section from Chapter 6 and Appendix M) describe how the plan accommodates changes in hydroelectric generation and cost related to fish and wildlife program actions.

Although actions specified in the program have a sizeable impact on hydroelectric generation, current analysis indicates that the power system can reliably provide program actions (and absorb their cost) while maintaining an adequate, efficient, economic and reliable energy supply. On average, hydroelectric generation is reduced by about 1,170 average megawatts, which represents about 10 percent of its firm generating capability. This loss translates into an average regional cost of $434 million per year. Adding related fish capital expenses and other program costs yields a total regional annual cost of $720 million, which amounts to about 20 percent of Bonneville's annual net revenue requirement.

Looking toward the future, there remain a number of uncertainties that could significantly affect both fish and power operations. Generation may be further reduced by actions to increase bypass spill, flow augmentation volumes, or by physically removing dams. On the other hand, spillway weirs offer the potential to increase generation by reducing bypass spill. Climate change models indicate that snow pack and river flows are likely to change, which would affect both power production and fish survival. Finally, agreements among hydroelectric project owners, such as the Canadian Treaty and the Coordination Agreement could change, leading to alternative river operations. The resource strategy developed for the power plan must be sufficiently dynamic and robust to accommodate these potential changes. The plan's action items address this need by proposing the creation of a public forum, which would bring together power planners and fish and wildlife managers to explore ways to address these uncertainties.

Attachments

851 S.W. Sixth Avenue, Suite 1100
Portland, Oregon 97204-1348
www.nwcouncil.org

Steve Crow
Executive Director

503-222-5161
800-452-5161
Fax: 503-820-2370

Chapter 6: Generating Resources (draft 5/24/09)

HYDROELECTRIC GENERATION

The numerous mountain ranges in the Pacific Northwest and British Columbia along with high levels of precipitation, much of which falls as snow, produce large volumes of annual runoff that create the great hydroelectric power resource for this region. The theoretical potential has been estimated to be about 68,000 megawatts of capacity and 40,000 average megawatts of energy. Nearly 33,000 megawatts of this potential capacity has been developed at about 360 projects. Though the remaining theoretical hydroelectric power potential is large, most economically and environmentally feasible sites have already been developed. The remaining opportunities are, for the most part, small-scale and relatively expensive. Among these are addition of generating equipment to irrigation, flood control and other non-power water projects, incremental additions of generation to existing hydropower power projects with surplus streamflow, and a few projects at undeveloped sites. No new projects are expected to be constructed because of the high cost of development and the complex and lengthy licensing process.

Hydroelectric power is by far the most important generating resource in the Pacific Northwest, providing about two-thirds of the generating capacity and about three quarters of electric energy on average. The annual average runoff volume, as measured at The Dalles Dam, is 134 million acre feet but it can range from a low of 78 million acre-feet to a high of 193 million acre-feet. This data is based on an historical water record dating back to 1929. Unfortunately, the combined useable storage in U.S. and Canadian reservoirs is only 42 million acre-feet. This means that the system has limited capability to reshape river flows (meaning power) to better match the monthly shape of electricity demand. The Pacific Northwest is a winter peaking region yet river flows are highest in spring (during the snow melt) when electricity demand is generally the lowest. Because of this, the region has historically planned its resource acquisitions based on critical hydro conditions, that is, the year with the lowest runoff volume over the winter peak demand period. Under those conditions, the hydroelectric system produces about 11,800 average megawatts of energy. On average, it produces nearly 16,000 average megawatts of energy and in the wettest years, it can produce over 19,000 average megawatts. For perspective, the annual average regional demand is about 22,000 average megawatts. In order to reflect the important variability of hydroelectric production as water conditions change, the Council's analysis uses a 70-year water record in its analysis.

Integrating Fish & Wildlife and Power Planning

The Power Act requires that the Council's power plan and Bonneville's resource acquisition program assure that the region has sufficient generating resources on hand to serve energy demand and to accommodate system operations to benefit fish and wildlife.[1] The Act requires the Council to update its fish and wildlife program before revising the power plan, and the

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[1] For more information please see Appendix M: Fish and Wildlife Interactions.

amended fish and wildlife program is to become part of the power plan. The plan is then to set forth "a general scheme for implementing conservation measures and developing resources" with "due consideration" for, among other things, "protection, mitigation, and enhancement of fish and wildlife and related spawning grounds and habitat, including sufficient quantities and qualities of flows for successful migration, survival and propagation of anadromous fish."[2]

On average, fish and wildlife operations reduce hydroelectric generation by about 1,170 average megawatts (relative to an operation without any constraints for fish and wildlife).[3] For perspective, this energy loss represents about 10 percent of the hydroelectric system's firm generating capability[4]. This loss of generating capability translates into an average regional cost of $434 million per year. In addition, fish and wildlife related capital expenses and other program costs are expected to average $287 million[5] per year, bringing the total regional annual cost to $720 million over the next five years. That amount represents about 20 percent of Bonneville's annual net revenue requirement.[6]

These impacts would definitely affect the adequacy, efficiency, economy and reliability of the power system, if they had been implemented over a short term. However, this has not been the case. Since 1980, the region has periodically amended fish and wildlife related hydroelectric system operations and, in each case, the power system has had time to adapt to these incremental changes. The Council's current assessment[7] indicates that the regional power supply can reliably provide actions specified to benefit fish and wildlife (and absorb the cost of those actions) while maintaining an adequate, efficient, economic and reliable energy supply. This is so even though the hydroelectric operations specified for fish and wildlife have a sizeable impact on power generation and cost. The power system has addressed this impact by acquiring conservation and generating resources, by developing resource adequacy standards, and by implementing strategies to minimize power system emergencies and events that might compromise fish operations.

The Council recognizes the need to better identify and analyze long-term uncertainties that affect all elements of fish and power operations. In its action items, the Council addresses this need by proposing the creation of a public forum, which would bring together power planners and fish and wildlife managers to explore ways to address these uncertainties. Long-term planning issues include climate change, alternative fish and wildlife operations, modifications to treaties affecting the hydroelectric system and the integration of variable resources, in particular how they affect system flexibility and capacity. The forum would provide an opportunity to identify synergies that may exist between power and fish operations and to explore ways of taking advantage of those situations.

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[2] Northwest Power Act, Sections 4(e)(2), (3)(F), 4(h)(2)

[3] The comparison study, which includes no actions for fish and wildlife, is represented by hydroelectric operations prior to 1980.

[4] Firm hydroelectric generating capability is about 11,900 average megawatts (2007 Bonneville White Book) and is based on the critical hydro year, which is currently defined to be the 1937 historical water year.

[5] [update?]Taken from Bonneville's 2008 Integrated Program Review, the capital budget estimate for the next five years represents the maximum cost; actual expenditures may be less.

[6] Bonneville's annual net revenue requirement is on the order of $3.5 billion (Bonneville's 2007 Annual Report).

[7] See http://www.nwcouncil.org/energy/resource/Adequacy%20Assessment%20Final.doc.

Hydroelectric Assumptions for the Sixth Plan

Existing System

The current hydroelectric system has a capacity of about 33,000 megawatts but operates to about a 50 percent annual capacity factor because of water supply and limited storage (Northwest dams only store about 30 percent of the annual average river flow volume). For hourly needs, the Northwest's power supply must be sufficient to accommodate increased demands during a sustained cold snap, heat wave or the temporary loss of a generating resource. The hydroelectric system provides up to 24,000 megawatts of sustainable peaking capacity, which is designed to provide for the six highest load hours of a day over a three consecutive day period.

These assumptions for the annual and hourly capability of the hydroelectric system, however, are sensitive to fish and wildlife operations, which have changed in the past and could change in the future. There remain a number of uncertainties surrounding these operations, which could have both positive and negative effects. For example, spillway weirs offer the potential to reduce bypass spill while providing the same or better passage survival. On the other hand, current bypass spill levels are under litigation and are likely to be increased. Climate change has the potential to alter river flows, which affect both power production and fish survival. The potential of dam removal or of operating reservoirs at lower elevations would further reduce power production.

For the Sixth Power Plan, hydroelectric system capability over the study horizon is based on fish and wildlife operations specified in the 2008 biological opinion. The possible impacts to the resource strategy in the power plan due to changes in hydroelectric generation will be examined via scenario analysis. However, it should be noted that the range of potential changes to hydroelectric generation is relatively small compared to the range of other uncertainties in the Portfolio Model.

New hydropower

Though the remaining theoretical hydropower potential of the Northwest is large, most economically and environmentally feasible sites have been developed. The remaining opportunities are for the most part small-scale and relatively expensive. Among these are additions of generating equipment to irrigation, flood control, and other non-power water projects, incremental additions of generation to existing hydropower power projects with surplus streamflow, and a few projects at undeveloped sites. In its Fourth Plan, the Council estimated that about 480 megawatts of additional hydropower capacity is available for development at costs of 9.0 cents per kilowatt-hour, or less. This capacity could produce about 200 megawatts of energy on average (This estimate will be updated). Though the cost of new hydropower remains high compared to other resource alternatives, and the licensing process is complex and lengthy compared to other resources, increasing demand for low carbon resources and resources qualifying for state renewable portfolio standards, has increased interest in new hydropower projects

Hydropower upgrades

More promising are renovations to restore the original capacity and energy production of existing hydropower projects, and upgrades to yield additional capacity and energy. Many existing projects date from a time when the value of electricity was lower and equipment efficiency less than now and it is often feasible to undertake upgrades such as advanced hydro turbines, generator rewinds, and spillway gate calibration and seal improvement. Even a slight improvement in equipment efficiency at a large project can yield significant energy. Though numerous renovations and upgrades have been completed in recent years, improved technology and higher electricity values are likely to have extended the undeveloped potential. Because it has been decades since the last comprehensive assessment of regional hydropower upgrade potential, the regional potential is poorly understood. Informal surveys concluding that hundreds of megawatts of energy, or more are potentially available from upgrades are likely to have comingled the potential results of renovation and upgrades. This Plan calls on Bonneville and other hydro project owners to undertake comprehensive surveys of hydropower renovation and upgrade potential.

Appendix M: Integrating Fish & Wildlife and Power Planning (5/07/09)

SUMMARY

The Columbia River Basin hydroelectric system is a limited resource that is unable to completely satisfy the demands of all users under all circumstances.[1] Conflicts often arise that require policy makers to decide how to equitably allocate this resource. The Council's *Columbia River Basin Fish and Wildlife Program* and *Electric Power and Conservation Plan* must provide measures to "protect, mitigate, and enhance fish and wildlife affected by the development, operation, and management of [hydropower] facilities while assuring the Pacific Northwest an adequate, efficient, economical, and reliable power supply."

By statute, hydroelectric operations to improve fish survival that are specified in the fish and wildlife program become a part of the power plan. The power plan must be designed to provide both an adequate and reliable power supply and an adequate and reliable implementation of fish operations. And, guided by the Council's power plan, Bonneville is to acquire resources to assist in meeting the requirements of the fish and wildlife program.[2] In other words, the mutual impacts of fish and power measures are intended to be examined together. While existing committees are in place to solve in-season problems, no currently active process exists to address long-term planning issues related to both power planning and fish and wildlife operations. The Council would support the creation of an open forum where fish and wildlife managers and power planners could jointly explore strategies to improve both fish and wildlife benefits and hydroelectric power operations. In such a forum, synergistic effects between fish and wildlife operations and power planning could be examined.

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[1] Some of the many uses of the Columbia River hydroelectric system include flood control, power generation, irrigation, recreation, navigation and protection for fish and wildlife.
[2] Northwest Power Act, Sections 4(e)(3)(F), 4(h)(5), 6(a)(2)(B), 16 U.S.C. § 839b.

The Council's current assessment[3] indicates that the regional power supply can reliably provide actions specified to benefit fish and wildlife (and absorb the cost of those actions) while maintaining an adequate, efficient, economic and reliable energy supply. This is so even though the hydroelectric operations specified for fish and wildlife have a sizeable impact on power generation and cost. The power system has addressed this impact by acquiring conservation and generating resources, by developing resource adequacy standards, and by implementing strategies to minimize power system emergencies and events that might compromise fish operations.

On average, hydroelectric generation is reduced by about 1,170 average megawatts, relative to an operation without any constraints for fish and wildlife.[4] For perspective, this energy loss represents about 10 percent of the hydroelectric system's firm generating capability[5]. This loss of generating capability translates into an average regional cost of $434 million per year. In addition, fish and wildlife related capital expenses and other program costs are expected to average $287 million[6] per year, bringing the total regional annual cost to $720 million over the next five years. That amount represents about 20 percent of Bonneville's annual net revenue requirement.[7] These impacts would definitely affect the adequacy, efficiency, economy and reliability of the power system, if they had been implemented over a short term. However, this has not been the case. Since 1980, the region has periodically amended fish and wildlife related hydroelectric system operations and, in each case, the power system has had time to adapt to these incremental changes.

Looking toward the future, there remain a number of uncertainties surrounding the operation of the hydroelectric system, which must be addressed in the development of the power plan. These uncertainties can have both positive and negative effects. For example, spillway weirs offer the potential to reduce bypass spill while providing the same or better passage survival. On the other hand, current bypass spill levels are under litigation and are likely to be increased. Climate change has the potential to alter river flows, which affect both power production and fish survival. The potential of dam removal or of operating reservoirs at lower elevations would further reduce power production. The Council recommends that the region continue to monitor fish and wildlife activities and to continue to develop better analytical methods to assess both power and biological impacts.

BACKGROUND

The many storage and hydroelectric facilities built in the Columbia River Basin provide a number of benefits to the citizens of the Pacific Northwest and Canada. On average, the US

[3] See http://www.nwcouncil.org/energy/resource/Adequacy%20Assessment%20Final.doc.
[4] The comparison study, which includes no actions for fish and wildlife, is represented by hydroelectric operations prior to 1980.
[5] Firm hydroelectric generating capability is about 11,900 average megawatts (2007 Bonneville White Book) and is based on the critical hydro year, which is currently defined to be the 1937 historical water year.
[6] [update?]Taken from Bonneville's 2008 Integrated Program Review, the capital budget estimate for the next five years represents the maximum cost; actual expenditures may be less.
[7] Bonneville's annual net revenue requirement is on the order of $3.5 billion (Bonneville's 2007 Annual Report).

portion of the hydroelectric system provides nearly 75 percent of the electricity needs for the northwest.[8] Operation of the hydroelectric system also influences (in no order of priority):

- Protection from flooding
- Opportunities for recreation
- Water for irrigation
- Water for municipal and industrial uses
- Routes for navigation
- Protection for Native American cultural resources
- Passage for anadromous fish
- Protection for resident fish
- Habitat for wildlife
- Control of water quality and temperature

Operating the system to provide these multiple benefits requires cooperation among federal and non-federal agencies and the Canadian government. Unfortunately, not all desired operations can be provided at all times because of conflicts that arise. For example, water releases in the spring and summer for fish migration would be more valuable to the power system during winter, and water withdrawals identified for irrigation by state and federal law reduce the opportunity for downstream power generation.

The purpose of the power plan is to help the region retain an adequate, efficient, economical and reliable power plan over time. The purpose of the fish and wildlife program is to protect, mitigate and enhance fish and wildlife. The program includes flow and passage measures for salmon that alter hydroelectric system operations and reduce power production. The power plan must take program measures into account in its development of a resource strategy to provide the region an adequate, efficient, economical and reliable power supply while also delivering the operations specified for fish and wildlife – in essence, helping to assure that operations for fish and wildlife are similarly reliable.

Although looked at in a preliminary way during the development of the program, the adequacy, reliability, efficiency and economy of the region’s power supply can only be fully evaluated in the context of a full revision of the Council's power plan. Congress appears to have had this in mind when it anticipated that the Council would develop its fish and wildlife program immediately after passage of the Act.[9] In contrast, the Council was given up to two years to develop the power plan, subsequent to the adoption of a new program.

The costs of using the hydroelectric system to provide suitable conditions for fish and wildlife are largely assigned to the power system and its ability to generate revenue. Part of the purpose of the power plan then is to accommodate these costs and the loss of generating capability that fish and wildlife measures may induce. This means acquiring additional resources, whenever needed, to maintain an acceptable level of adequacy, efficiency, economy and reliability.

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[8] Hydroelectric generation in the Pacific Northwest averages about 16,000 average megawatts and annual demand is about 21,000 average megawatts.
[9] Remarks of Rep. Dingell, Cong. Rec. p. H10683, November 17, 1980.

The interpretation of the Council's mandate to mitigate for the adverse effects on fish and wildlife resulting from the construction of the Columbia River Basin hydropower system while maintaining an adequate and reliable power supply has led to great debate within the region. Some argue that fish and wildlife mitigation requirements must be balanced or integrated with power planning activities. This implies that some sort of cost-effectiveness analysis be done, examining the tradeoff between biological benefits and power system costs, although it continues to be challenging to assess the effectiveness of biological measures. Others argue that fish and wildlife operations should be viewed as firm environmental constraints similar to air and water quality standards. This implies that the power system would build adequate supplies to ensure that fish operations would never be compromised, regardless of cost. These two positions bracket the range of opinions regarding these often conflicting operations.

For the power plan, the Council has chosen to assume that fish and wildlife measures as outlined in its program will be fully implemented to the extent possible. However, it also recommends that regional entities continue to focus on improving the process for project management and accountability of results. Power system planners can provide valuable information (such as projected flows, elevations and costs) to fish and wildlife managers to aid in their development or refinement of measures to improve fish survival. Fish managers should give highest priority to measures that provide desired biological results at a lower power system cost. Similarly, power planners should consider potential effects of new resources on fish and wildlife operations as they develop their resource acquisition strategies.

CURRENT SITUATION

Fish and wildlife actions identified in the 2008 NOAA Fisheries Biological Opinion were incorporated into the Council's 2009 Fish and Wildlife Program. These provisions have substantive effect with regard to the operation of the mainstem hydropower system in the Columbia and Snake rivers. The authors of the biological opinion attempted to use best available science to pick a least-harm hydroelectric power operations plan by assessing the magnitude of potential adverse effects on fish resulting from a wide range of hydroelectric power operation scenarios. The biological effects of the operational scenarios were estimated using the NOAA fisheries COMPASS (Comprehensive Passage and Survival) model, designed specifically for the reaches of the Columbia and Snake rivers extending from Lower Granite Dam to Bonneville Dam.

System Operations for Fish and Wildlife

The mainstem portion of the fish and wildlife program consists of two major types of actions to promote anadromous fish survival that will also affect the power supply; 1) flow augmentation and 2) bypass spill for fish passage. Other portions of the program that increase Bonneville's costs include capital costs for fish passage and the direct cost of other fish and wildlife program actions.[10] These elements of the program are described in more detail below:

- **Flow Augmentation:** Monthly flow objectives are provided for both the Snake and Columbia rivers during the migration season (April through August). The operation calls for certain reservoirs to store water over the winter and spring months for later release

[10] See the Council's 2009 Fish and Wildlife program and NOAA Fisheries' 2008 Biological Opinion.

during the migration season. This effectively reduces the generating capability of the hydroelectric system over the winter but increases generation when runoff is passed through in the spring and when it is released from storage in the summer. However, there is not a one-to-one shift in energy production because of bypass spill requirements.

- **Bypass Spill:** Bypass spill is the re-routing of river flows away from turbine intakes and into fish passage and spillway systems. The survival of migrating juveniles diverted into fish passage systems and over spillways is considerably higher than fish survival rates through the turbines. The program and NOAA Fisheries Biological Opinion calls for the eight federal dams on the lower Snake and Columbia rivers to divert part of their flows through fish bypass systems during spring and summer. Because of these diversions, additional generation obtained from flow augmentation is reduced. Whenever hydroelectric generation is reduced, regional carbon dioxide emissions generally increase because dispatch of fossil-fuel burning resources goes up. Spill also reduces reactive support for the transmission system, which leads to reduced transmission capability and could potentially reduce system reliability.[11]

- **Capital Costs:** These costs include the projected amortization, depreciation and interest payments for fish and wildlife-related capital investments by the Corps of Engineers and Bureau of Reclamation for which BPA is obligated to repay the power share to the US Treasury. This includes construction and installation of fish bypass systems, turbine intake deflector screens, spillway weirs, fish collection systems and land acquisition for habitat purposes.

- **Reimbursable/Direct Costs**: These costs include the hydroelectric system's share of operations and maintenance costs and other non-capital expenditures for fish and wildlife activities by the Corps of Engineers, Bureau of Reclamation and U.S. Fish & Wildlife Service.

- **Direct Program Costs**: These costs include expenditures for non-capital fish and wildlife activities consistent with the Council's fish and wildlife program and NOAA Fisheries' biological opinions. This includes funding for predation control, habitat improvement, monitoring and research, and coordination projects.

Implementing Fish and Wildlife Operations

By statute, hydroelectric operations to improve fish survival that are specified in the Council's fish and wildlife program become a part of the power plan. The power plan must be designed to provide both an adequate and reliable power supply and an adequate and reliable implementation of fish operations. The impacts of those operations are substantial and would definitely affect the adequacy and reliability of the power system, if implemented over a short period of time. However, this has not been the case. Since 1980, the region has periodically amended fish and wildlife-related hydroelectric operations and in each case, the power system has had time to adapt to these incremental changes and has maintained, to the extent possible, an adequate and reliable power supply.

[11] See the February 24, 1998 memorandum from John Fazio to the Council members regarding the transmission impacts of drawing down John Day Dam (Council document 98-3).

A preliminary assessment of the impacts of fish operations on the adequacy, efficiency, economy and reliability of the power supply was made in the fish and wildlife program[12] and a more detailed assessment is provided in this power plan. That assessment (Chapter 13) indicates that the regional power supply can reliably provide the actions specified to benefit fish and wildlife (and absorb their cost) while maintaining an adequate, efficient, economic and reliable energy supply. Moving forward, the Council's resource adequacy standard provides a minimum threshold for resource development that minimizes the likelihood of curtailments to both power and fish operations.

In addition to the adequacy standard, power planners have become more cognizant of non-emergency situations, such as isolated low flow events, night-time over generation conditions and rapid load changes that have compromised fish operations in the past. Planners are actively developing operational protocols to address these situations and to alleviate the pressure to curtail fish operations. In particular, the U.S. Army Corps of Engineers (Corps) describes how it intends to deal with these situations in its planned operations for fish passage for 2009 (Corps document number 1693-2, "2009 Spring Fish Operations Plan").

Emergency Provisions

In spite of best laid plans, emergencies sometimes occur but all utilities have contingency actions in place to offset potential curtailments. For example, during periods of rapid load changes or the loss of a major resource or transmission line, reservoirs can sometimes be drafted below their normal operating elevations to sustain electricity service. This use of additional hydroelectric generation is often referred to as "hydro flexibility." Hydro flexibility is generally used during cold snaps or heat waves when no other resources are available, including imports from out of region. The additional water drafted to produce extra energy is replaced as soon as possible, even if energy must be imported. Most often reservoirs can recover and get back to required refill elevations. However, in the event that hydro flexibility can not be replaced by early spring, less water would be available for flow augmentation. The power plan and in-season planning strategies should be designed to minimize situations when hydro flexibility cannot be replaced prior to the migration season.

Both bypass spill requirements and reduced mainstem reservoir operating limits imposed by the program limit the flexibility of the hydroelectric system. This is important because less flexibility means a reduced ability to meet peaking requirements, provide ancillary services, and integrate wind and other variable resources. Once system flexibility is used up, additional resources may need to be added along with wind generators to provide a reliable supply. This will clearly increase the cost of meeting renewable portfolio standards and will also likely increase carbon emissions.

The biological opinion allows for curtailment of fish and wildlife operations during power system emergencies, as happened in the very low water year of 2001, but it does not specify an upper bound for such actions. It also includes language that allows deviations from normal power system operations during rare occasions when emergency fish passage conditions occur.

Whenever the region's generating capability lags behind demand growth (as happened in the late 1990s), the risk of having to curtail fish and wildlife operations will increase. Using curtailment

[12] Also see the AEERPS appendix in the 2009 fish and wildlife program.

of fish and wildlife operations as a last-resort alternative during rare emergencies is allowed under the biological opinion language[13]. The key word in the previous sentence is "rare." Analysis showing a high frequency of curtailment to fish and wildlife operations would indicate that the power supply is not adequate. Curtailment of fish and wildlife operations cannot be used in lieu of acquiring resources to maintain an adequate regional power supply. In the same way, power system operations should not be jeopardized an inordinate amount to deal with fish emergencies.[14]

Physical and economic analysis of specific fish and wildlife measures can aid in the development of a fish and wildlife curtailment policy, in the event of a power emergency. It would be in the region's interest to have these policies in place prior to an emergency, in order to minimize the risk to fish.

Impacts and Costs

Methodology

The analysis of power system impacts is performed with the GENESYS model.[15] The model simulates the operation of regional resources including hydroelectric facilities over many different future conditions. For the hydroelectric system, key outputs include regulated outflows, reservoir elevations, generation and cost. GENESYS simulates both a monthly and hourly dispatch of available resources to meet regional load. In the monthly mode, it simulates the operation of individual hydroelectric facilities. In the hourly mode, however, the hydroelectric system is operated in aggregate and the peaking capability of that system is approximated using linear programming techniques. This model is designed to address both energy (monthly and annual) needs and capacity (hourly) needs. The analysis described below is based on the operations outlined in the Council's fish and wildlife program, which are consistent with those in NOAA Fisheries' 2008 biological opinion.

It should be noted that prescribed mainstem operations for fish and wildlife remain fluid, in the sense that some of those operations are currently under litigation. The Council's assessment that the current system can accommodate fish operations while maintaining an adequate supply is based on current fish operations. Some of the operations that could change in the near-term include:

- Increased spring and summer bypass spill;
- Removal of the Hungry Horse and Libby late summer/fall operation for bull trout;
- Potential changes to the Non-power Uses Agreement that stores an additional 1 maf for release to support needs of fish;
- Annual changes to supplemental agreements for certain non-power considerations; and
- Reduced bypass spill requirements resulting from installation and effective operation of spillway weirs.

Whenever non-power operations are modified, a new adequacy assessment should be made. However, while the above mentioned actions will all affect power generation to some degree,

[13] Reference the NOAA BiOp RPA number 8 here.
[14] Reference the NOAA BiOp RPA number 9 here.
[15] See http://www.nwcouncil.org/genesys.

none of them would jeopardize the power supply's near-term adequacy. Longer-term changes, which might affect power supply adequacy, are discussed in the section entitled "Dealing with an Uncertain Future" and include issues such as climate change, the expiration of the Canadian Treaty and dam removal.

River Flows and Reservoir Elevations

Mainstem hydroelectric operations to aid fish survival have been incorporated into the power plan and are assumed to be implemented in the base case. In general, these operations are intended to make the river environment more beneficial to both anadromous and resident fish. For migrating fish, river flows in both the Snake and Columbia rivers have been increased during the spring and summer to better match the natural flows that these fish evolved in. Figures M1 and M2 illustrate the average flows at The Dalles and Lower Granite dams for the current operation (labeled BiOp) and for a no-fish-constraint operation (labeled Pre-1980). It is clear in both charts that flows have increased during the spring and summer fish migration periods and that water used for that flow augmentation is replaced during the winter months (thus reducing flows and hydroelectric generation during that time).

Figure M1: Average Outflow at the Dalles Dam

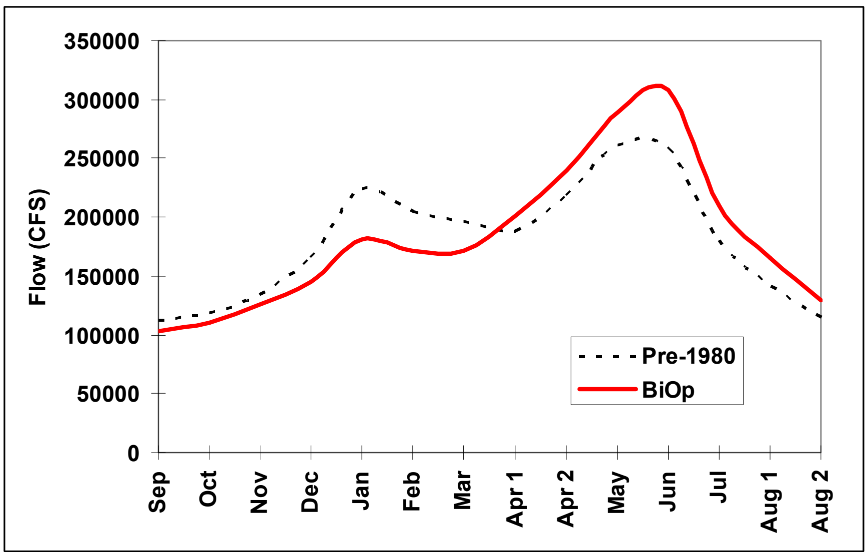
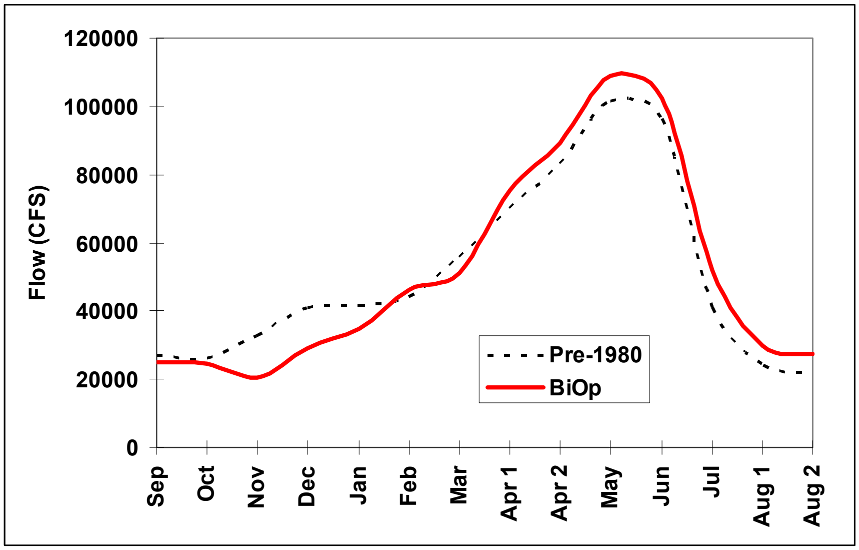


Figure M2: Average Outflow at Lower Granite Dam



In order to reshape river flows, water in reservoirs that would have been used for power production during winter months is kept in storage for later release during spring and summer. The following four charts (Figures M3 to M6) show the average reservoir content for Libby, Hungry Horse, Grand Coulee and Dworshak dams. The pattern of keeping more water in these reservoirs during winter months is clearly apparent in these charts. Additional water is also released at these projects over the summer months, which leaves these reservoirs at lower elevations by the end of August or September. On average, Dworshak reservoir is 80 feet below full, Libby and Hungry Horse are 10 to 20 feet lower and Grand Coulee is between 10 and 12 feet lower by summer's end.

Figure M3: Average Reservoir Content at Libby Dam

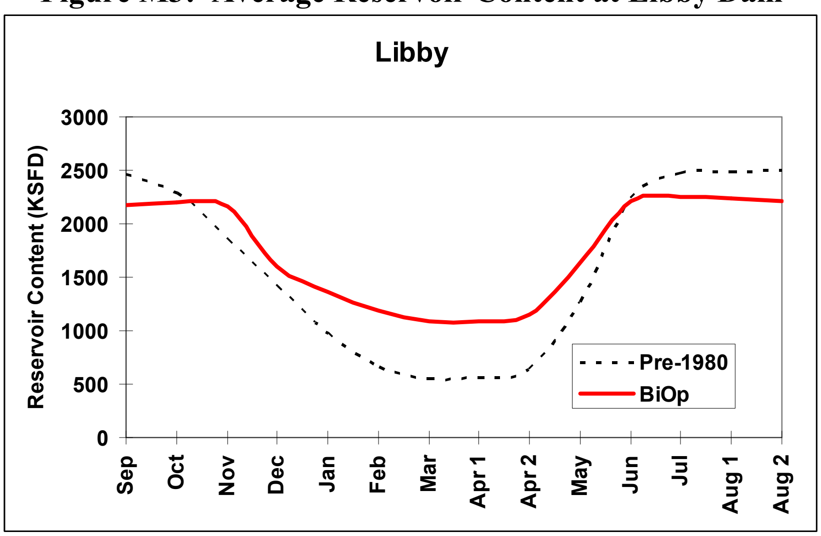


Figure M4: Average Reservoir Content at Hungry Horse Dam

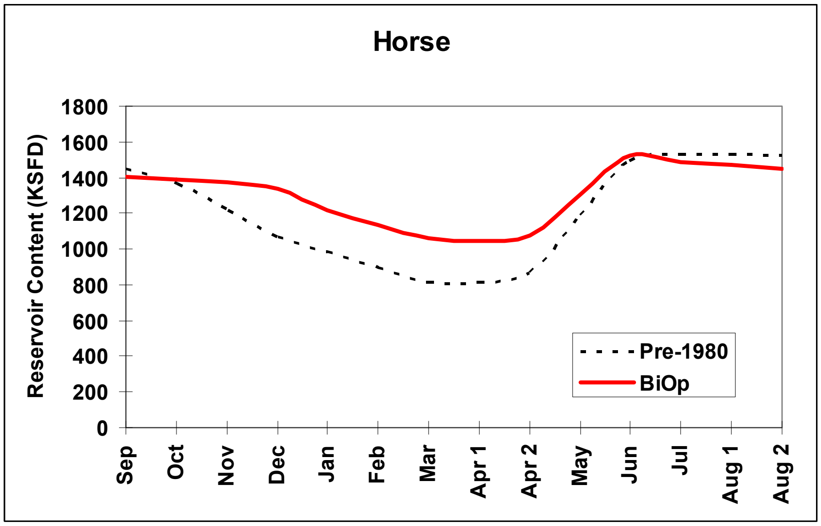


Figure M5: Average Reservoir Content at Grand Coulee Dam

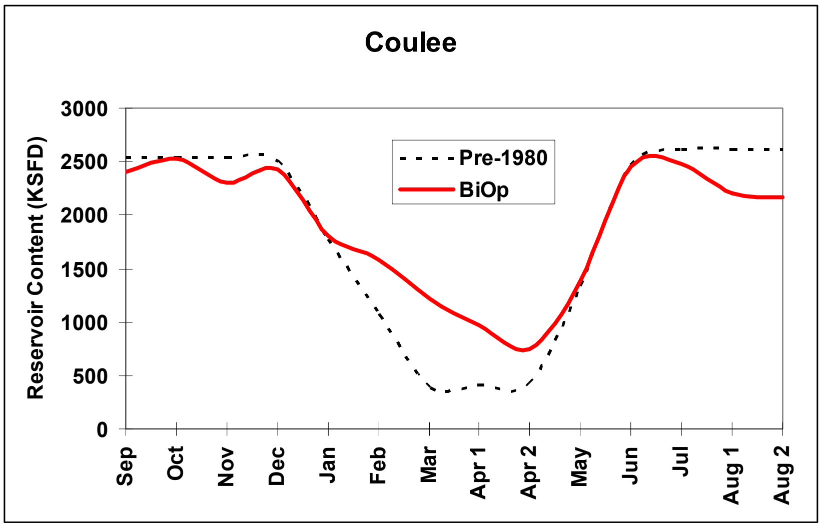
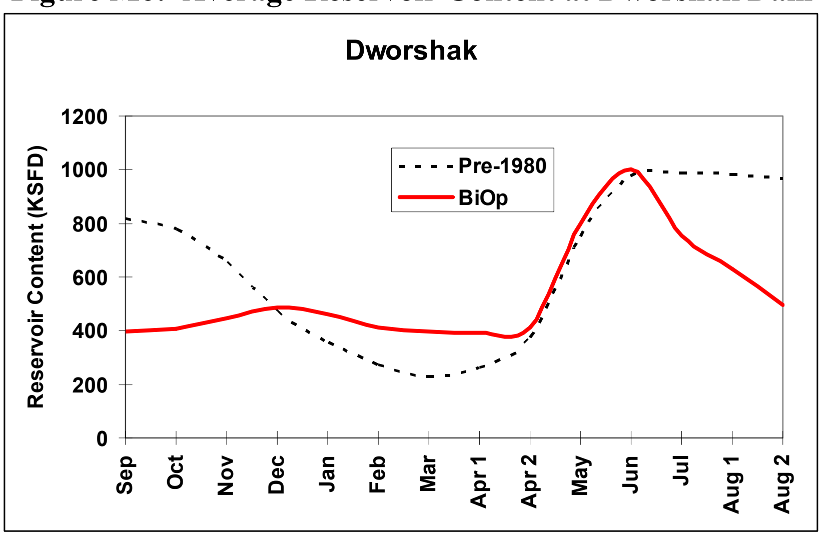


Figure M6: Average Reservoir Content at Dworshak Dam



Hydroelectric Generation and Power System Costs

Council analysis indicates that, on average, implementation of the program will reduce hydroelectric generation by about 1,170 average megawatts, relative to an operation without any constraints for fish and wildlife.[16] For perspective, this energy loss represents about 10 percent of the hydroelectric system's firm generating capability.[17] Figure M7 below shows the monthly average change in hydroelectric generation between current operations and a pre-1980 operation, which includes no fish and wildlife constraints.

Figure M7: Change in Monthly Average Hydroelectric Generation since 1980

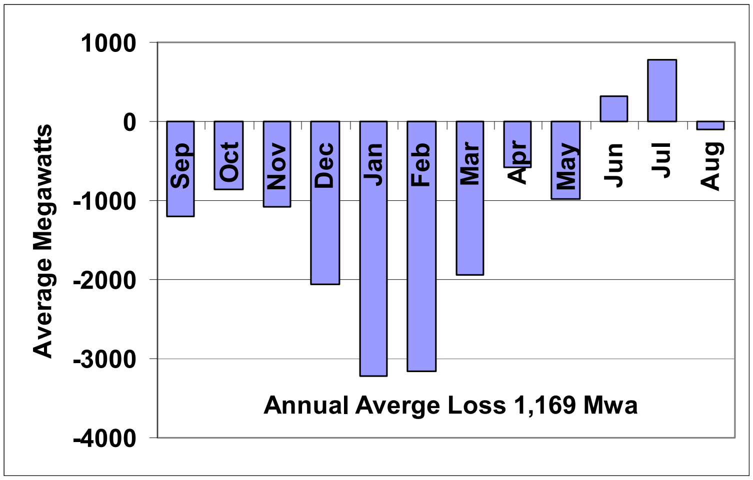
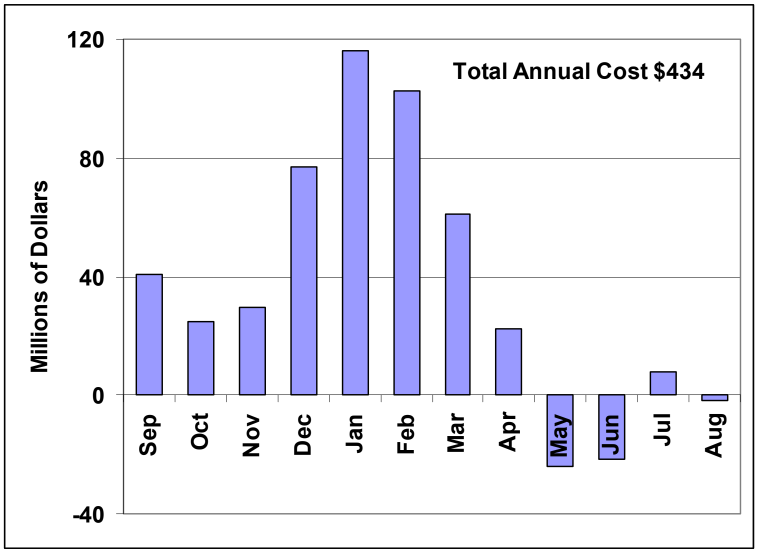


Figure M8 summarizes the average monthly cost of the fish and wildlife program relative to a pre-1980 operation. Positive values in Figure M8 reflect regional costs and negative values represent benefits. Generally, the cost of a particular change in hydroelectric system operation is inversely proportional to the change in generation, so the pattern in Figure M8 is similar but reversed from that in Figure M7. In other words, an operation that causes a decrease in generation usually represents a cost to the system. However, this pattern is not exactly inversely proportional because cost depends on electricity prices and they depend on available generation. For example, May shows a decrease in average generation in Figure M7 but in Figure M8 it shows a net revenue increase. This is because a reduction in the available generation during that month causes electricity market prices to increase. Thus, even though less energy is available for sale, it is being sold at a higher price and produces higher revenues. A more detailed description of how cost is assessed is provided below.

[16] The comparison study, which includes no actions for fish and wildlife, is represented by hydroelectric operations prior to 1980.
[17] Firm hydroelectric generating capability is about 11,900 average megawatts (2007 Bonneville White Book) and is based on the critical hydro year, which is currently defined to be the 1937 historical water year.

Figure M8: Average Monthly Power System Cost



Cost is determined by first assessing the expected monthly secondary (or surplus) sales or market purchases for both current and pre-1980 operations over the entire range of potential water conditions. The secondary energy sales or purchases are converted to dollars by multiplying the associated energy by the expected monthly electricity price. The expected monthly electricity price will vary by water condition and by hydroelectric system generation. The monthly price is further adjusted to take into account peak and off-peak effects. Thus, a pattern of monthly electricity prices is created for each of the 70 water conditions analyzed. This matrix of electricity prices is multiplied by the matrix of energy sales or purchases for each case. The monthly cost or benefit is averaged across all water conditions and is then summed over all months to yield a total, which for this case is $434 million. On average, the power system cost is almost evenly divided between flow augmentation (average cost of $220 million/year) and bypass spill (average cost of $214 million/year).

But that is not the total cost of fish and wildlife operations. Additional costs stem from fish and wildlife related capital expenses over the next five years, which are expected to average $56 million[18]. Moreover, additional expenditures amounting to $231[19] million per year are needed to implement other program measures, including the actions in the 2008 NOAA Fisheries BiOp and 2008 Columbia Basin Fish Accords. The total regional cost of the program is expected to average about $720 million per year over the next five years, which represents about 20 percent of Bonneville's annual net revenue requirement.[20] In rough terms, this translates into $5.00 per month for a typical public utility residential customer's electric bill.

The current power system has absorbed these costs and remains economical, although there are alternative ways of thinking about the economical criterion. One is whether the per-kilowatt-hour costs of the system have increased significantly in comparison to other regions. On this basis, the power system is clearly less economical than it was. However, in terms of absolute

[18] Taken from Bonneville's 2008 Integrated Program Review, the capital budget estimate for the next five years represents the maximum cost; actual expenditures may be less.
[19] The direct Program, 2008 BiOp and Fish Accord budget estimates for the next five years represent budget ceilings; actual expenditures may be less.
[20] Bonneville's annual net revenue requirement is on the order of $3.5 billion (Bonneville's 2007 Annual Report).

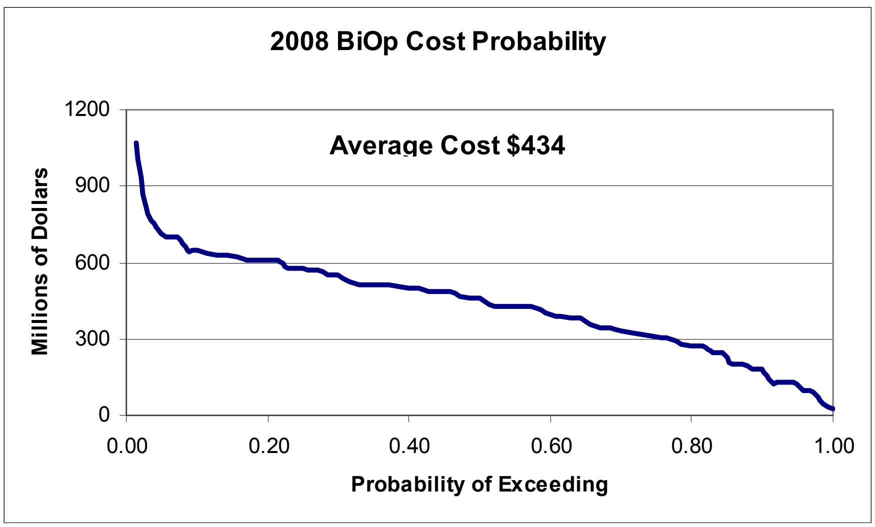
electricity cost, the Northwest still ranks as one of the lowest cost regions in the nation. Unfortunately, this aggregate assessment does not capture potential impacts on specific sectors of the economy. In particular, electricity-intensive industries, such as aluminum smelting, are proportionately harder hit by increases in electricity costs. In fact, most aluminum plants in the region have ceased operation due to high operating costs. Fish recovery costs have contributed to this, although in the current context, they are not the major contributor.

In aggregate, the region's power system has been assessed to be adequate both in terms of energy and capacity needs for at least the next five years.[21] That assessment shows that the balance between resources and loads is above the minimum thresholds defined in the Council's resource adequacy standard.[22] Those minimum thresholds, however, should not be mistaken as a resource planning targets. The types and amounts of resources the Northwest should acquire over and above the minimum thresholds must be assessed in an integrated resource planning process, so that other factors, such as economic risk, can be taken into account.

Cost Uncertainty

Although the average power system cost of the fish and wildlife program is $434 million, it can range from a high of about one billion dollars to a low of just several million dollars, as shown in Figure M9. The likelihood of the region experiencing a cost greater than $600 million in any given year, however, is only about 20 percent. Similarly, the likelihood of a cost less than $300 million is also about 20 percent.

Figure M9: Range of Annual Cost for Fish and Wildlife Operations (2010 operating year, 2008 dollars)



It is beneficial for planners to understand how these costs vary with water conditions. Figure M10 plots the power system cost of the fish and wildlife program as a function of the annual runoff volume. Initially, one might think that costs would be greater in dry years since water is scarcer. However, the pattern of costs shown in Figure M10 does not reflect that relationship. In that figure, costs are low in the dry years as well as the wet years and are highest for more average runoff conditions. In order to explain this apparently non-intuitive phenomenon we

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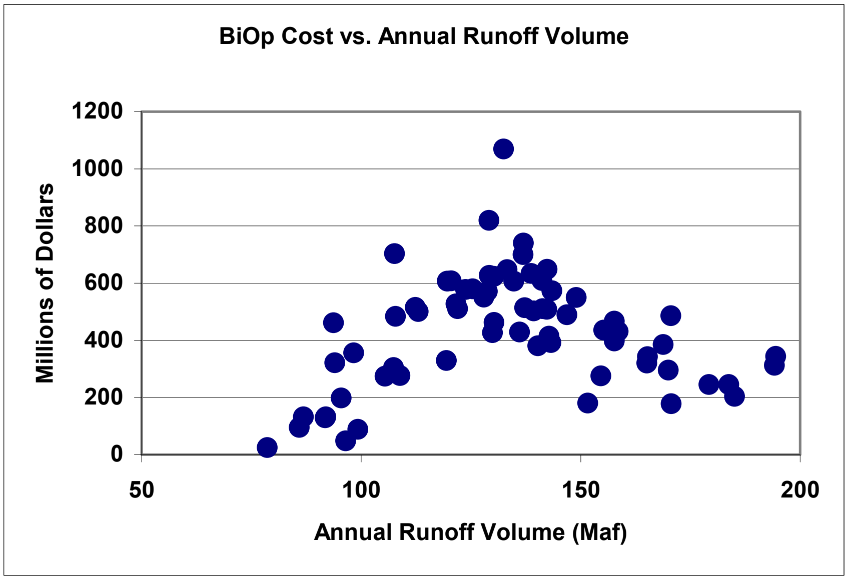
[21] See http://www.nwcouncil.org/energy/resource/Adequacy%20Assessment%20Final.doc.
[22] See http://www.nwcouncil.org/library/2008/2008-07.pdf.

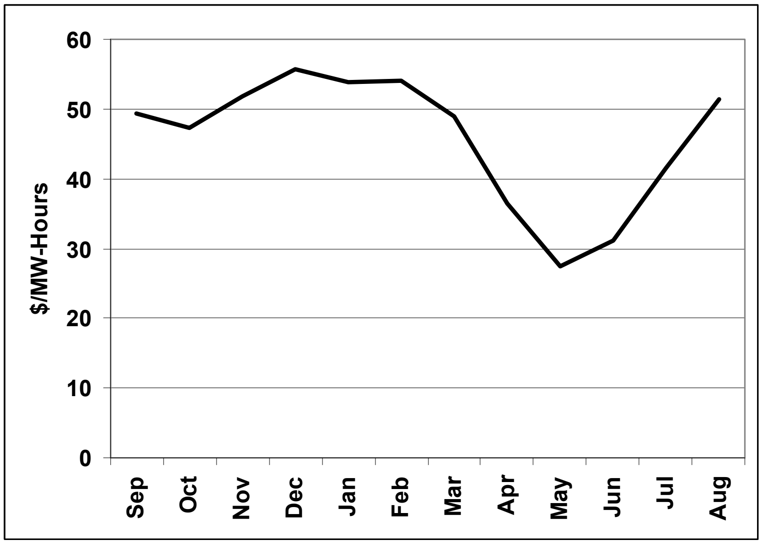
must describe in more detail the two major components of fish and wildlife operations, that is, flow augmentation and bypass spill.

Figure M10: Cost as a function of Runoff Volume



Flow augmentation or holding water back during winter months for release in spring and summer, effectively moves hydroelectric generation from months with high electricity prices into months with lower prices (see Figure M11). The amount of water that is shifted depends on the forecasted runoff volume. Generally more water is held in reservoirs for flow augmentation during dry years. In wet years, water must be evacuated by early spring for flood protection thus leaving less water in reservoirs for augmentation. Given this general observation, one would assume that fish and wildlife costs would be highest in the dry years and lowest in the wet years. However, electricity prices are affected by the availability of hydroelectric generation and in general are higher in years with low runoff volume. So, in some dry years, shifting water from winter months into summer months may actually cost less than in year with average runoff conditions. But that is not the whole story. We must also remember that the costs in Figure M10 also include the effects of bypass spill.

Figure M11: Forecast Bulk Electricity Prices (Mid-Columbia, 2010 operating year, 2008 dollars)



Bypass spill is water that is routed around turbines to enhance survival of migrating smolts. It always represents a loss of generation and revenue. The cost of spill varies with water conditions and electricity prices. Generally, as the runoff volume increases, so does bypass spill because for some projects bypass spill is specified as a percentage of outflow. However, as runoff volumes begin to approach average conditions, spill is often limited by gas super saturation limits imposed by the EPA. That is, once the absolute volume of spill causes gas levels to reach the EPA limit, no more volume is spilled. At this point, bypass spill costs level off.

As runoff volumes continue to increase, however, bypass spill costs actually begin to decrease (illustrated in Figure M12). That is because of a condition referred to as forced spill. When the hydraulic capacity at dams is exceeded, water in excess of that capacity must be spilled. This forced spill volume counts toward the required bypass spill and because forced spill would have occurred anyway, some of the bypass spill requirement is provided at no cost. For very wet years forced spill can equal or sometimes even exceed the required bypass spill volume. The actual relationship between bypass spill cost and runoff volume is shown in Figure M13 and its effect on the overall pattern of fish and wildlife costs (Figure M10) is evident.

Figure M12: Illustration of Bypass Spill Flow as a function of Outflow

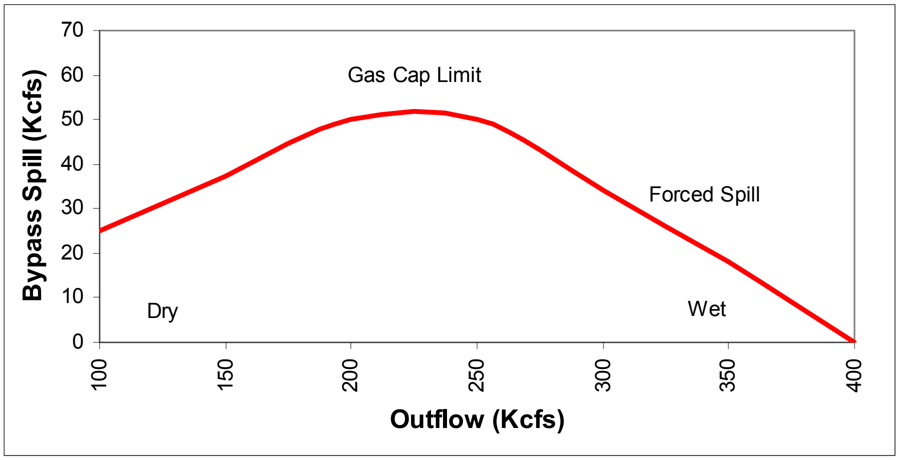
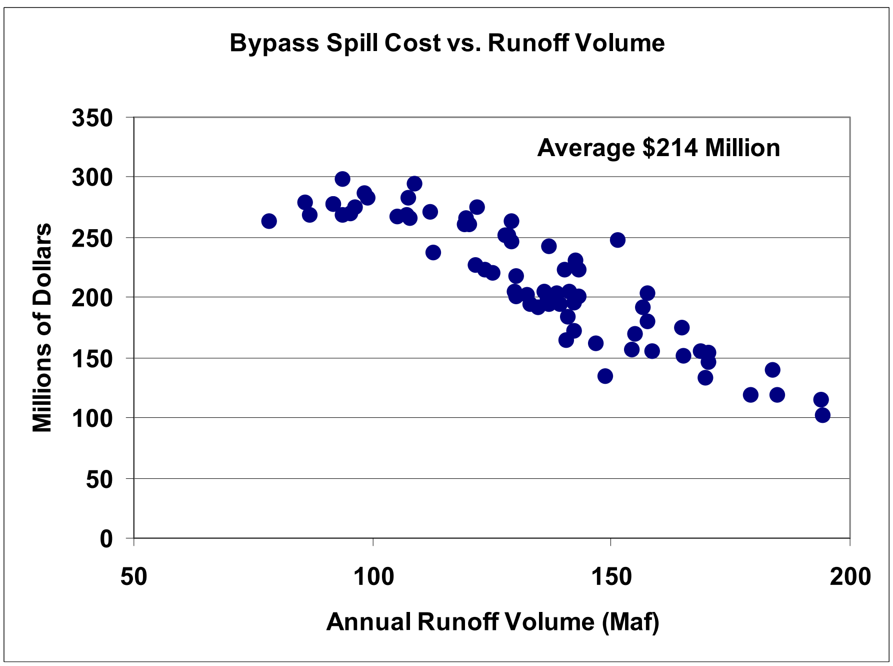


Figure M13: Bypass Spill Cost as a function of Runoff Volume (2010 operating year, 2008 dollars)



Effects on Carbon Emissions

Due to the large share of hydroelectric generation in the Pacific Northwest, electricity-sector CO_2 production here is less (per unit of capacity) than in other regions of the United States. The Northwest's CO_2 production averages about 0.6 pounds per kilowatt compared to about 1.3 pounds per kilowatt for the nation as a whole. Annual CO_2 production varies greatly depending on river flow volumes and corresponding hydroelectric generation, which can range from providing half to nearly all of the region's electricity needs.[23]

Actions that decrease hydroelectric generation will likely increase CO_2 production, depending on what replacement resources are assumed. Three possible approaches to replacing reduced hydroelectric output have previously been considered in more detail[24] by the Council; 1) market purchases, 2) natural gas resources, and 3) conservation and renewable resources. The Council chose to use natural gas replacement resources for its assessment of the region's sensitivity to carbon production because that was the next available cost-effective resource in the Sixth Power Plan. Results discussed below reflect that assumption.

Mainstem operations in the Council's fish and wildlife program reduce hydroelectric generation by about 1,170 average megawatts. The Council has not estimated CO_2 production under a no-fish-constraint scenario; however, it did assess carbon effects of removing the four lower Snake River dams, which can be used as a very rough estimate for the former case. However, under the dam-removal scenario, the hydroelectric system <u>loses</u> about 1,020 average megawatts of annual energy, whereas under the no-fish-constraint operation generation <u>increases</u> by a little more than that amount.

Results for the dam-removal scenario indicate that by 2024 regional CO_2 production will be about 70 million tons per year or 3.6 million tons <u>greater</u> than the base case. Using this case as a guide, the net effect of a no-fish-constraint scenario (which increases hydroelectric generation by 1,170 average megawatts) should <u>decrease</u> CO_2 production by about 3 to 4 million tons by 2024. Unfortunately, the monthly pattern of generation increases for the no-fish-constraint scenario will not be the same as the pattern of monthly generation losses for the dam-removal scenario. Thus, this estimate can only be characterized as an educated guess.

Perhaps a more important discussion is the effect of bypass spill on CO_2 production. Spill operations at the lower Snake and lower Columbia River hydroelectric projects are intended to facilitate the downstream migration of anadromous fish. Changing those operations will affect hydroelectric generation and consequently CO_2 production. Two different spill regimens were assessed; 1) a no-summer-spill case (which increases generation) and 2) a court-ordered-spill case (which increases spill and decreases generation).

The no-summer-spill scenario is based on the energy shape and output of the hydropower system without summer spill at the lower Snake and Columbia River projects. In all other respects, the scenario is identical to the base case. About 550 average megawatts of hydropower energy would be gained under this operation compared to the base case. In this scenario, additional hydroelectric energy would displace about 190 average megawatts of coal generation and about 330 average megawatts of natural gas generation. This reduces average annual CO_2 production in 2024 by 1.1 million tons out of a base case estimate of 67 million tons.

The court-ordered-spill scenario is based on the energy shape and output of the hydropower system under 2006 court-ordered spill operation. In all other respects, the scenario is identical to

[23] Hydroelectric generation ranges from about 11,800 to 19,000 average megawatts while Northwest annual demand is about 22,000 average megawatts.

[24] Council document 2007-15, "Carbon Dioxide Footprint of the Northwest Power System," November, 2007

the base case. About 360 average megawatts of hydropower energy are lost under this operation compared to the base case. In this scenario, about 20 additional average megawatts of coal generation and 360 average megawatts of gas-fired generation are needed to compensate for lost hydroelectric generation. This increases average annual CO_2 production in 2024 by 0.5 million tons.

DEALING WITH AN UNCERTAIN FUTURE

The power plan has a 20-year planning horizon, which requires that potential future changes in the hydroelectric system or fish and wildlife needs over that time period must be assessed. The resource strategy developed in this power plan must be sufficiently robust to accommodate these potential changes in order to continue to provide desired fish conditions and an adequate and reliable power supply. The challenge is to identify the uncertain but possible areas of change, assess the possible range of effects and develop a set of actions to accommodate these changes. This implies that the power plan must be flexible and dynamic so that it can deal with uncertainties if and when they occur.

Likely categories for significant change include additional operations for fish, reduction in hydroelectric system flexibility due to increasing amounts of variable resources (such as wind), possible changes in the Columbia River Treaty, climate change and potential bypass spill reductions associated with spillway weirs.

The Council along with other regional entities, including the Independent Economic Advisory Board[25] recently examined the interactions between fish and power operations and identified several important factors to be considered in the development of this plan:

- In the long term, hydroelectric generation could increase due to installation of spillway weirs at federal dams. Spillway weirs are designed to increase juvenile migrant passage survival while reducing the volume of bypass spill. Unfortunately, evaluation of the effectiveness of these weirs has been mixed and projections of future energy savings cannot be assumed at this time. The Council assumed no long-term increase in hydroelectric generation due to spillway weirs.

- There remains a great deal of uncertainty regarding the amount of future bypass spill, which is still being litigated. It is possible that long-term hydroelectric generation will decrease[26] due to increased spill requirements, similar to the increased spill that a federal judge has required for 2010. However, quantifying this potential loss is difficult because of the possibility of future legal actions. The Council's set of current operations used to develop its resource strategy do not include additional bypass spill.

- Mainstem operations for fish and wildlife tend to reduce the hydroelectric system's flexibility and increase the cost of integrating wind resources. Flexibility of electricity supplies is vital to ensuring a reliable power system. Efforts are underway to quantify this loss of flexibility. Some, but not all, of the effects of this loss of flexibility were

[25] Reference IEAB report here.

[26] Bypass spill is required during the migration season, which runs from April through August. Therefore, potential future reductions in hydroelectric generation would occur for these months.

captured in the Council's analysis for the plan. However, the Council recommends continued regional participation in discussions and analysis of this issue.

- New water management strategies or development of new storage facilities would clearly affect hydroelectric generation in the long term. However, given the current political environment, it is not likely to happen in the short term, if at all. The Council assumes that no new water management strategies or storage facilities will be implemented for the power plan analysis.

- Terrestrial and wetland habitat protection and restoration funded by the fish and wildlife program may create opportunities to develop carbon credits. Discussions of potential benefits to the power system are just barely underway. No assumptions regarding potential future carbon credits were included in the plan.

Other potential long-term changes may include additional or different operations for fish such as:

- Lower operating elevations during the migration season (e.g., John Day Dam at minimum operating pool elevation instead of minimum irrigation pool elevation);
- Additional volumes of water for flow augmentation (i.e., allowing reservoirs to be drafted deeper by summer's end);
- Different pattern of water releases during the migration season;
- Removal of one or more dams;
- Revised Columbia River Treaty operations;
- Revised use of non-treaty storage; and
- Changes to flood control operations

The potential effects of climate change show impacts to both power and fish. Current analysis indicates that the Northwest is likely to see higher winter river flows and lower summer flows. At the same time, winter demand for electricity should decrease and summer demand would increase with rising temperatures. This effect should ease the pressure on the hydroelectric system in winter but make it more difficult over summer months, especially with the addition of more and more variable resources. Also, current renewable portfolio standards have already affected resource acquisition strategies and will likely continue to do so if they are modified or replaced by federal legislation. Potential carbon tax or cap-and-trade mechanisms will also alter future resource plans.

Ongoing changes in power markets and westwide power integration may also bring changes to the way we use and value the power system (e.g. generation in summer may become more and more profitable). These kinds of changes present challenges for fish and wildlife operations, but may also present positive opportunities. For example, releasing more stored water during summer months not only increases revenues but also provides higher river flows for migrating smolts.

For this plan, long-term uncertainties already include load, fuel and electricity prices, runoff conditions and carbon penalties. Uncertainties not explicitly incorporated into resource plan development include the effects of climate change, modifications to fish operations or changes in the Columbia River Treaty. Because of difficulties in quantifying the range and magnitude of these latter uncertainties, it is best to assess these by means of sensitivity analysis. Studies can be performed to determine the potential effects of these changes, either independently or in combination. However, the magnitude of potential impacts must be considered in conjunction with the likelihood of occurrence, that is, a potential uncertainty may have a large impact but might be extremely unlikely. The region should continue to explore and analyze such scenarios to be better prepared should these unlikely events occur.

REGIONAL COOPERATION

Federal agencies have formed several committees to deal with in-season operational issues affecting fish and power. The Technical Management Team (TMT) consists of technical staff from federal, state and tribal agencies that usually meet on a weekly basis during the fish migration seasons to assess the operation of the hydroelectric system. Requests for variations to those operations can be made and discussed at TMT meetings. Conflicts that cannot be resolved at the technical meetings are passed on to the Regional Implementation Oversight Group (RIOG), which consists of higher policy-level staff. This new process of resolving conflicts in proposed hydroelectric operations is untested.

While the existing committee structure is intended to solve in-season problems, no currently active process exists to address long-term planning issues related to both power planning and fish and wildlife operations. The Council encourages the creation of an open forum where fish and wildlife managers and power planners could jointly explore strategies to improve both fish and wildlife benefits and hydroelectric power operations. In such a forum, synergistic effects between fish and wildlife operations and power planning could be examined. For example, conservation savings in irrigation should also provide savings in water quantity, which could benefit fish. Also, the State of Washington is currently exploring options for new storage sites, which would benefit fish, power and irrigation. And finally, potential carbon emission mitigation benefits of actions to acquire or improve fish and wildlife habitat should be assessed.

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Integrating Fish & Wildlife and Power Planning

NORTHWEST 6th POWER PLAN

Council Meeting
Whitefish, MT
June 9-11, 2009

Northwest Power and Conservation Council

Appendix M Outline

I. **Background**: Northwest Power Act Requirements

II. **Current Situation**
- Mainstem Measures
- Effects on the Hydroelectric System
- Cost Estimate
- Impacts to Carbon Emissions

III. **Dealing with an Uncertain Future**

IV. **Regional Cooperation:** Action Items

Background

Northwest Power Act Requirements

- F&W program is part of the power plan
- Plan must provide an adequate, efficient, economical and reliable power supply
- It must also provide adequate and reliable implementation of F&W measures

Current Situation

- Flow augmentation and bypass spill
- Effects on reservoir elevation, refill, flow, and generation
- Cost of mainstem operations
- Cost of F&W program implementation
- Effect on the region's carbon footprint

AEERPS

- Hydro generation loss about 10%
- Cost is significant (about 20% of BPA's NRR)
- Mainstem measures have been implemented over a 30 year period
- Power system has had time to adapt
- Current assessment – power supply is adequate, efficient, economical and reliable

Dealing with an Uncertain Future

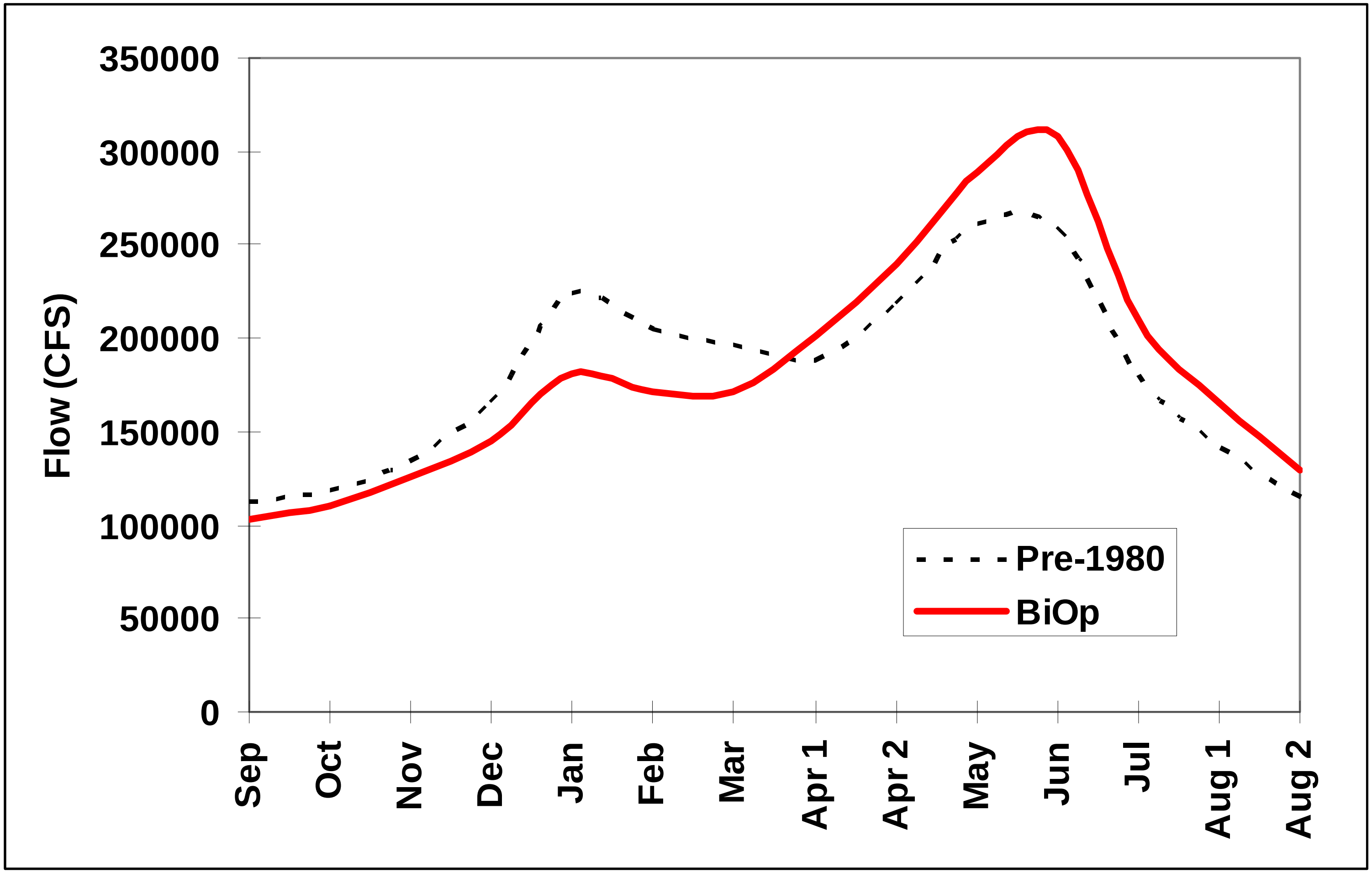
- Climate change and carbon policies
- Alternative F&W operations
  - ✓ Increased bypass spill
  - ✓ Dam breaching
  - ✓ Improved methods for passage
- Loss of hydro flexibility (wind integration)
- Changes to river operation treaties

Regional Cooperation
Proposed Action Items

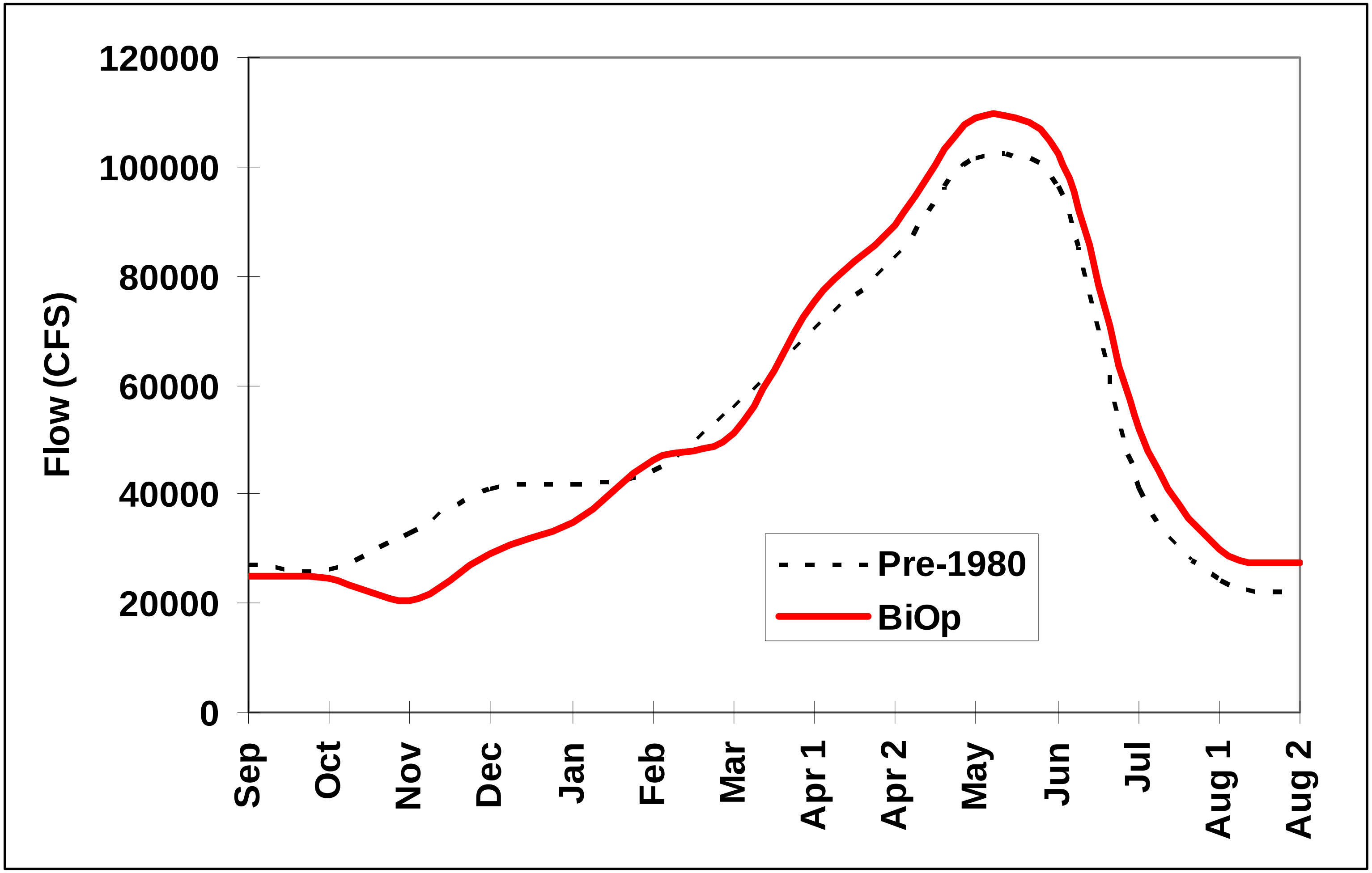
- Create a Long-term Planning Forum
- Design Contingency Plans
- Enhance Analytical Capability
- Monitor Columbia River Treaty Discussions
- Examine Effects of Climate Change

Additional Slides

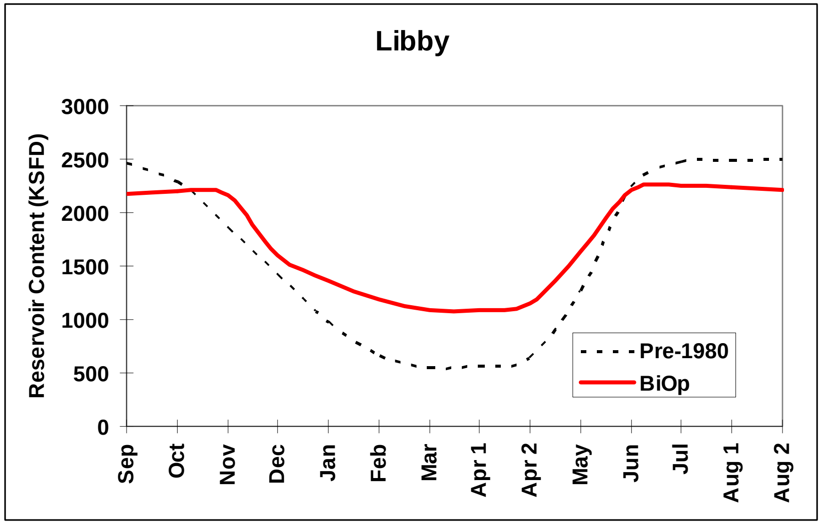
Average Flow at The Dalles

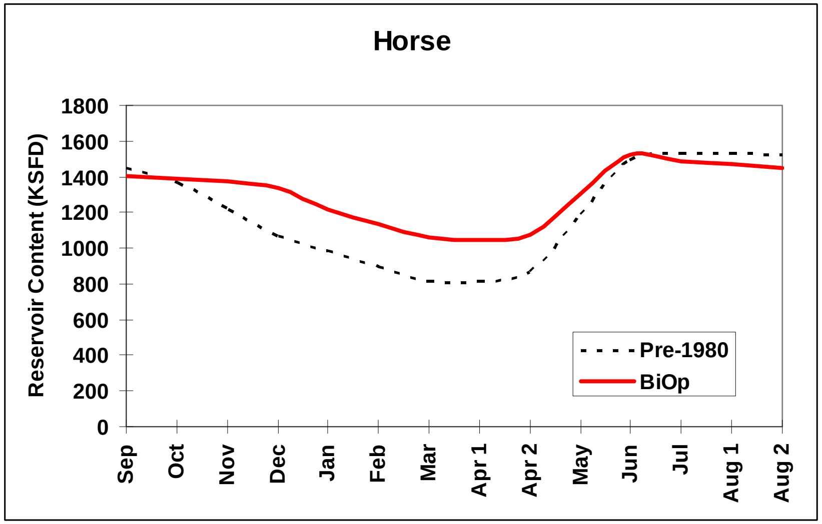


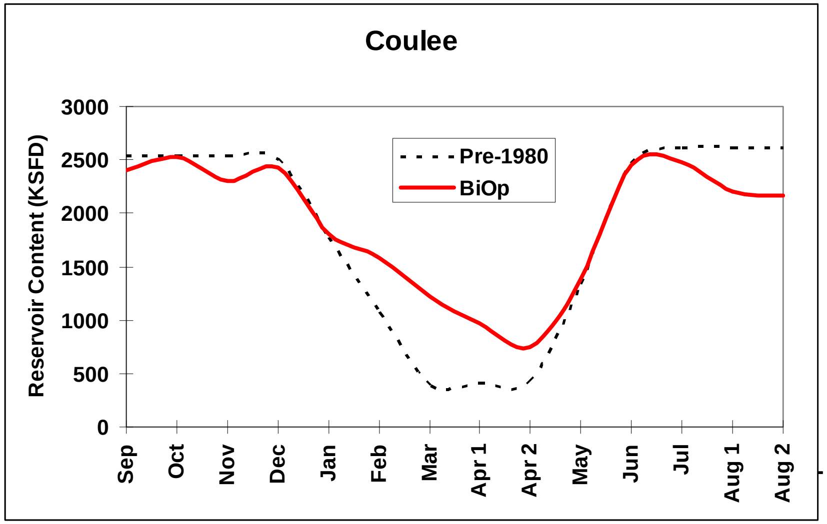
Average Flow at Lower Granite

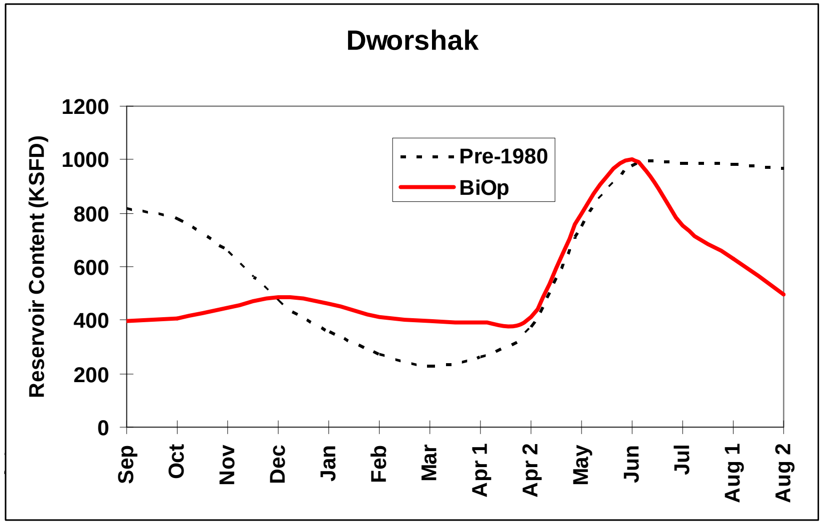


Average Reservoir Contents

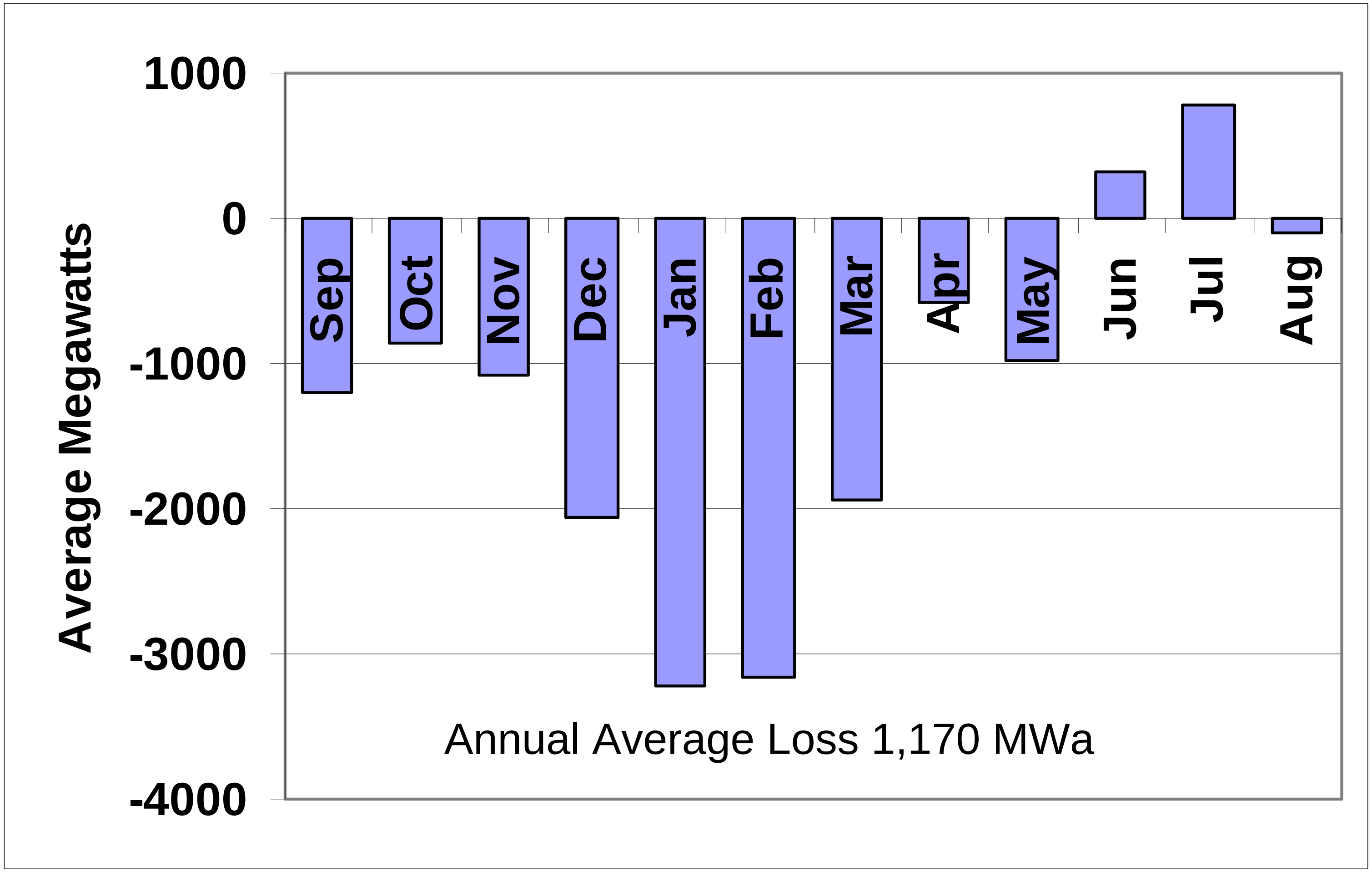




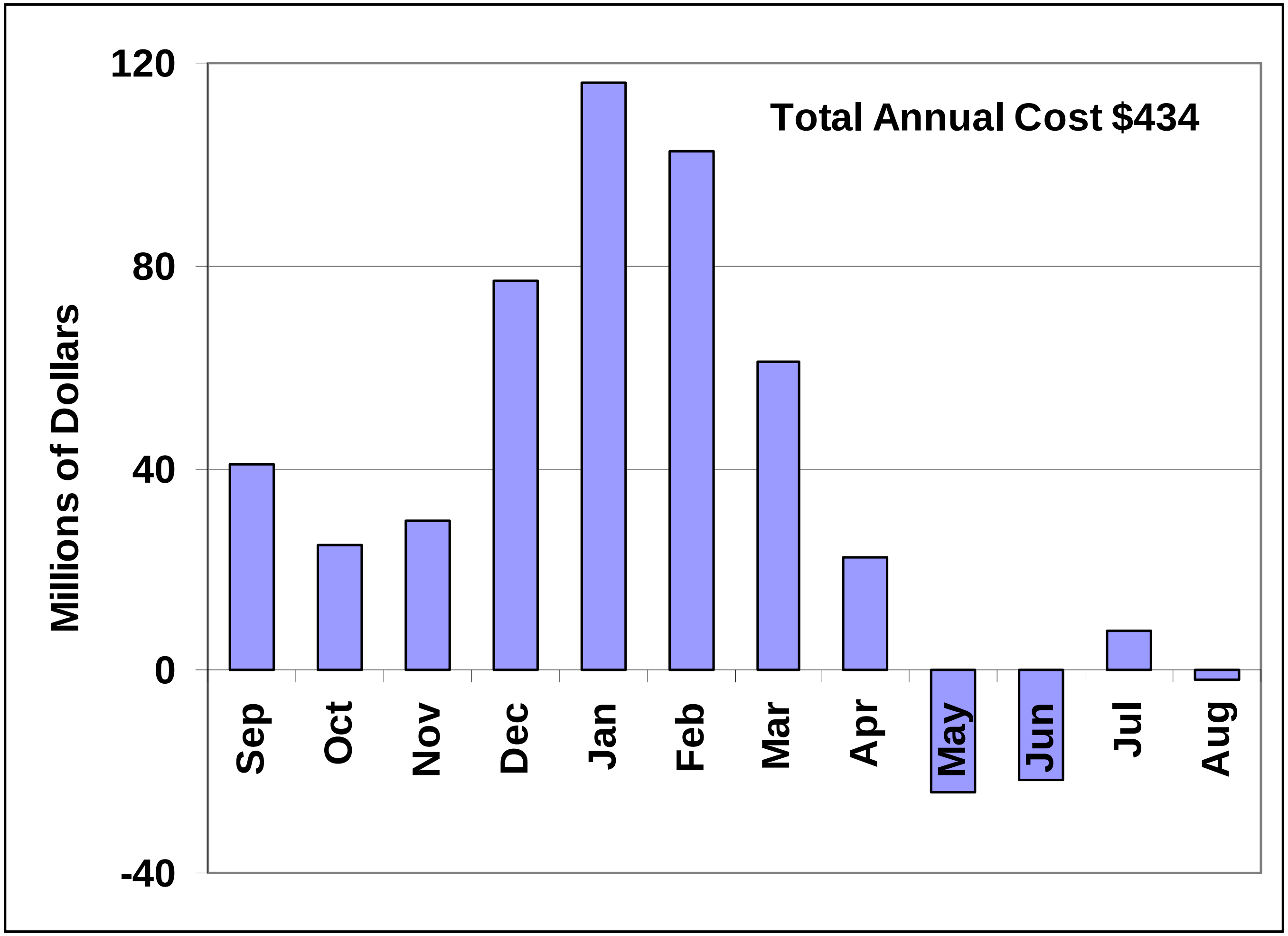




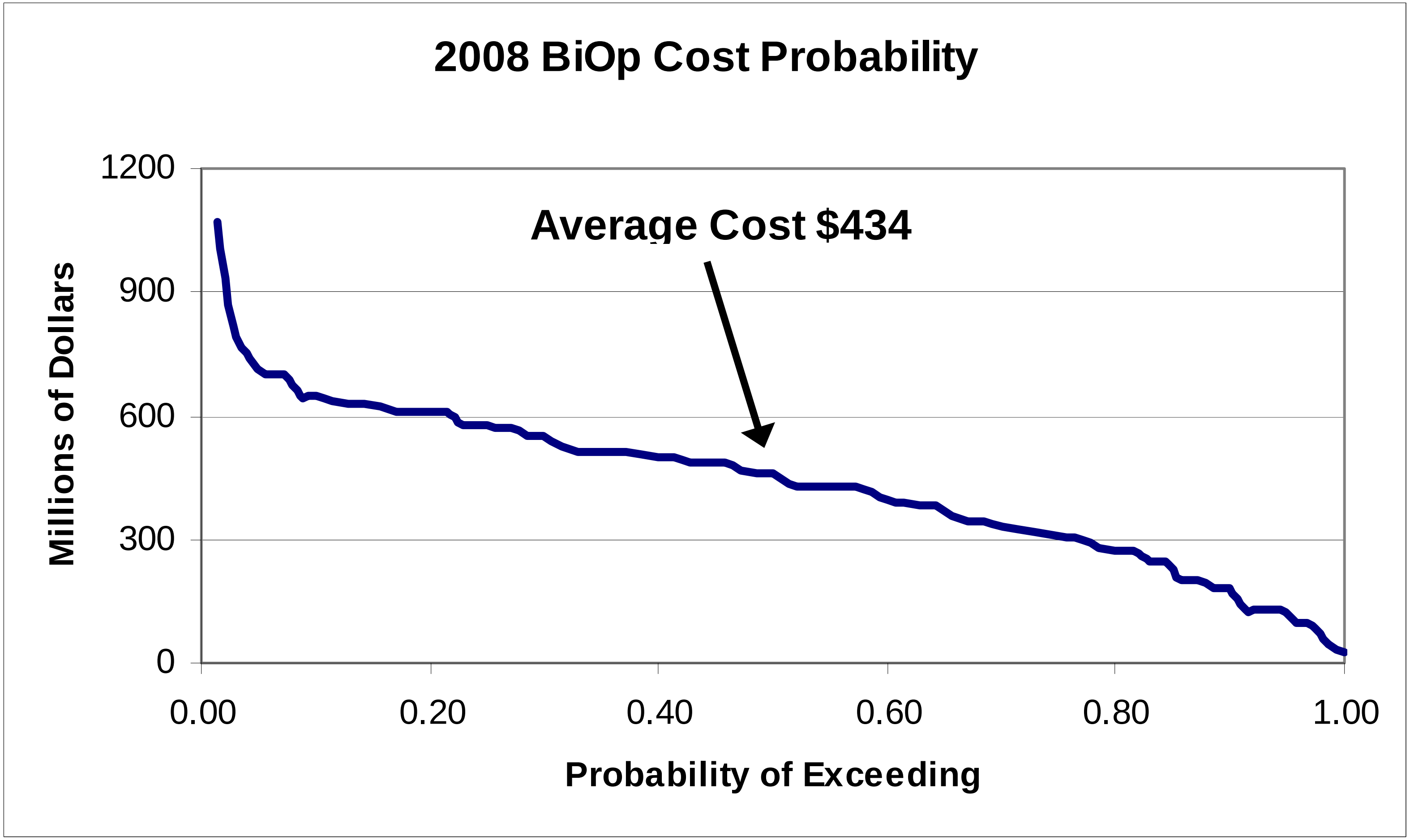
Average Change in Generation



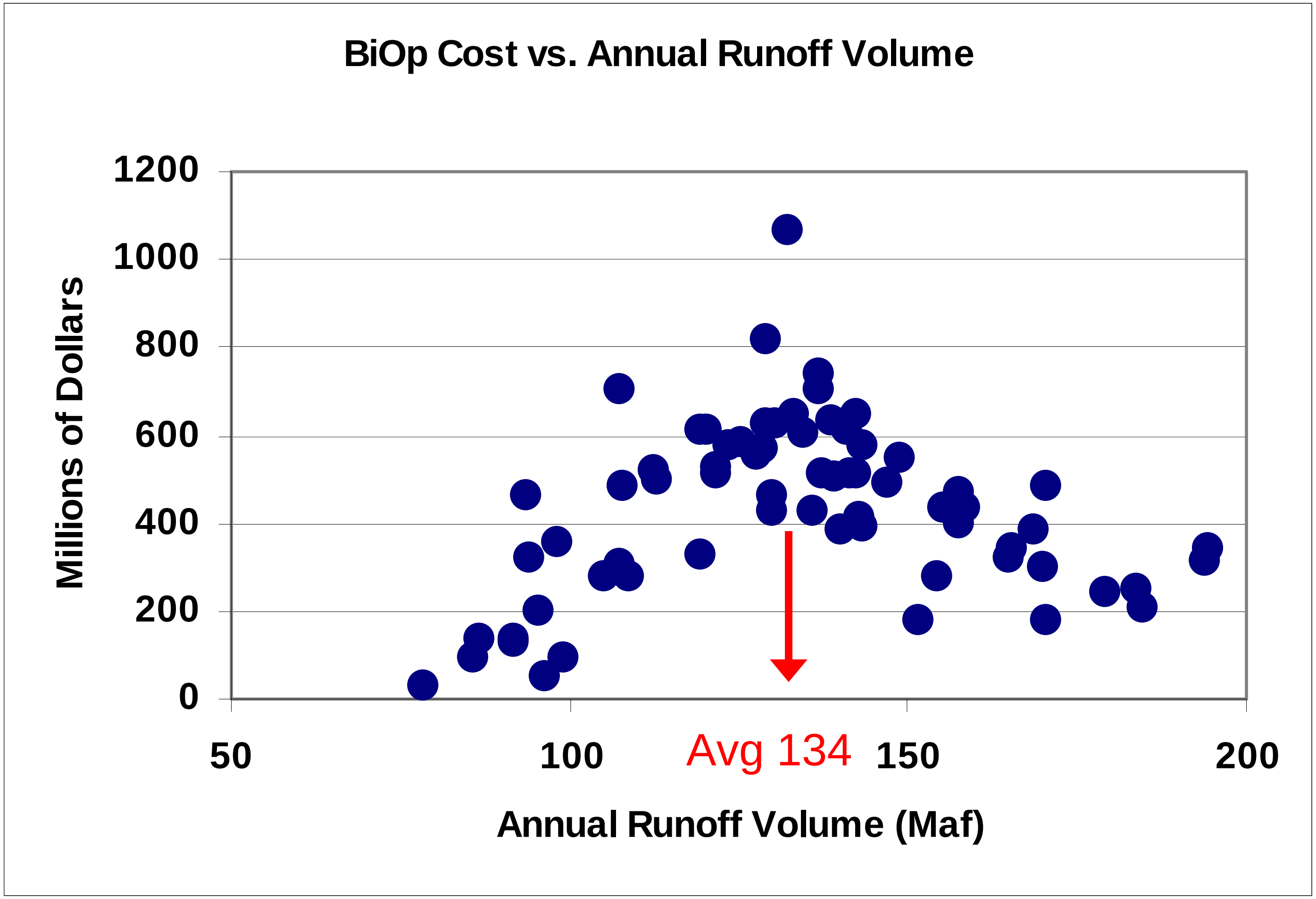
Average Power System Cost



Range of Cost



Total Power System Cost vs. Runoff Volume



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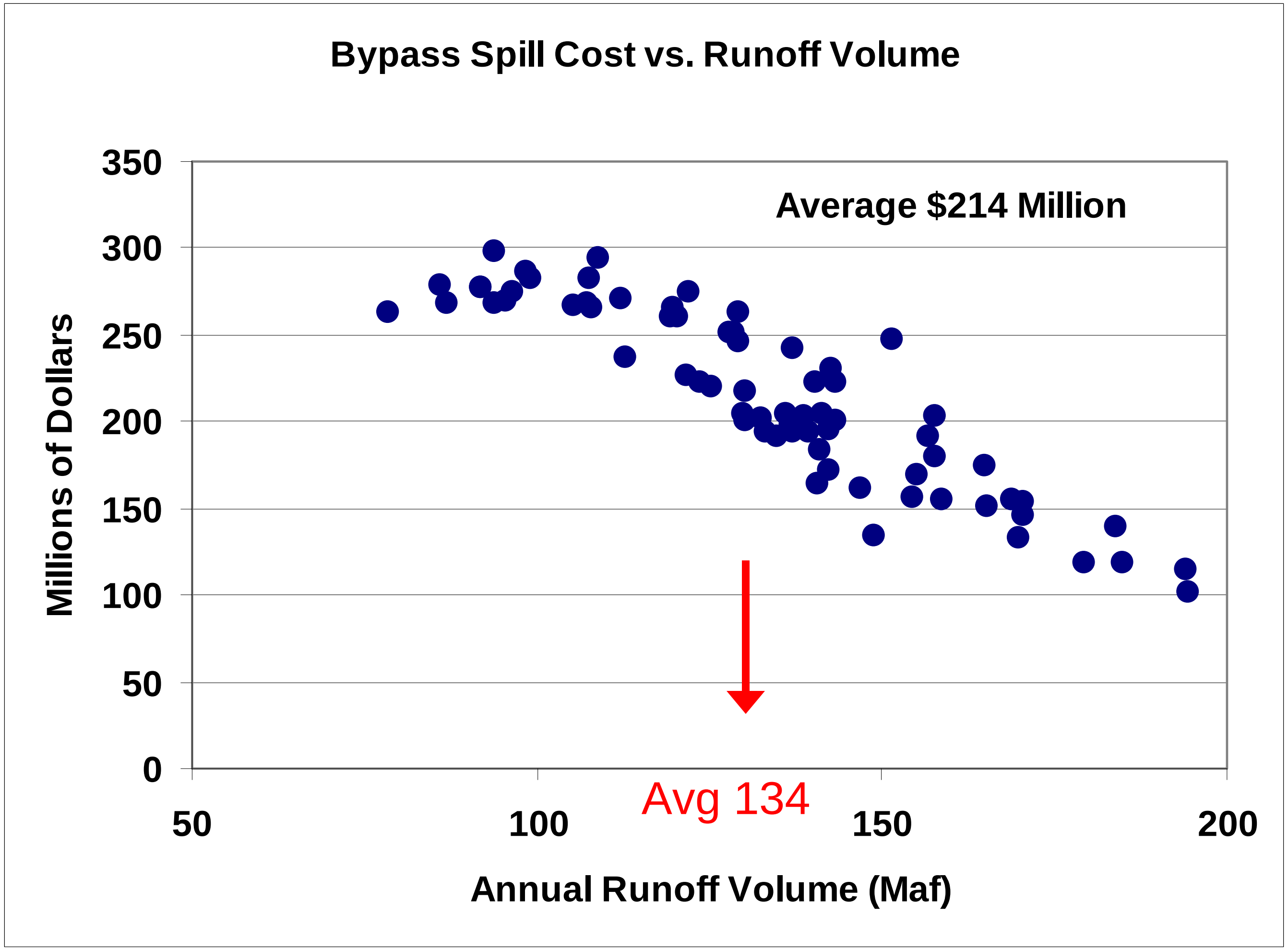
Bypass Spill Cost vs. Runoff Volume



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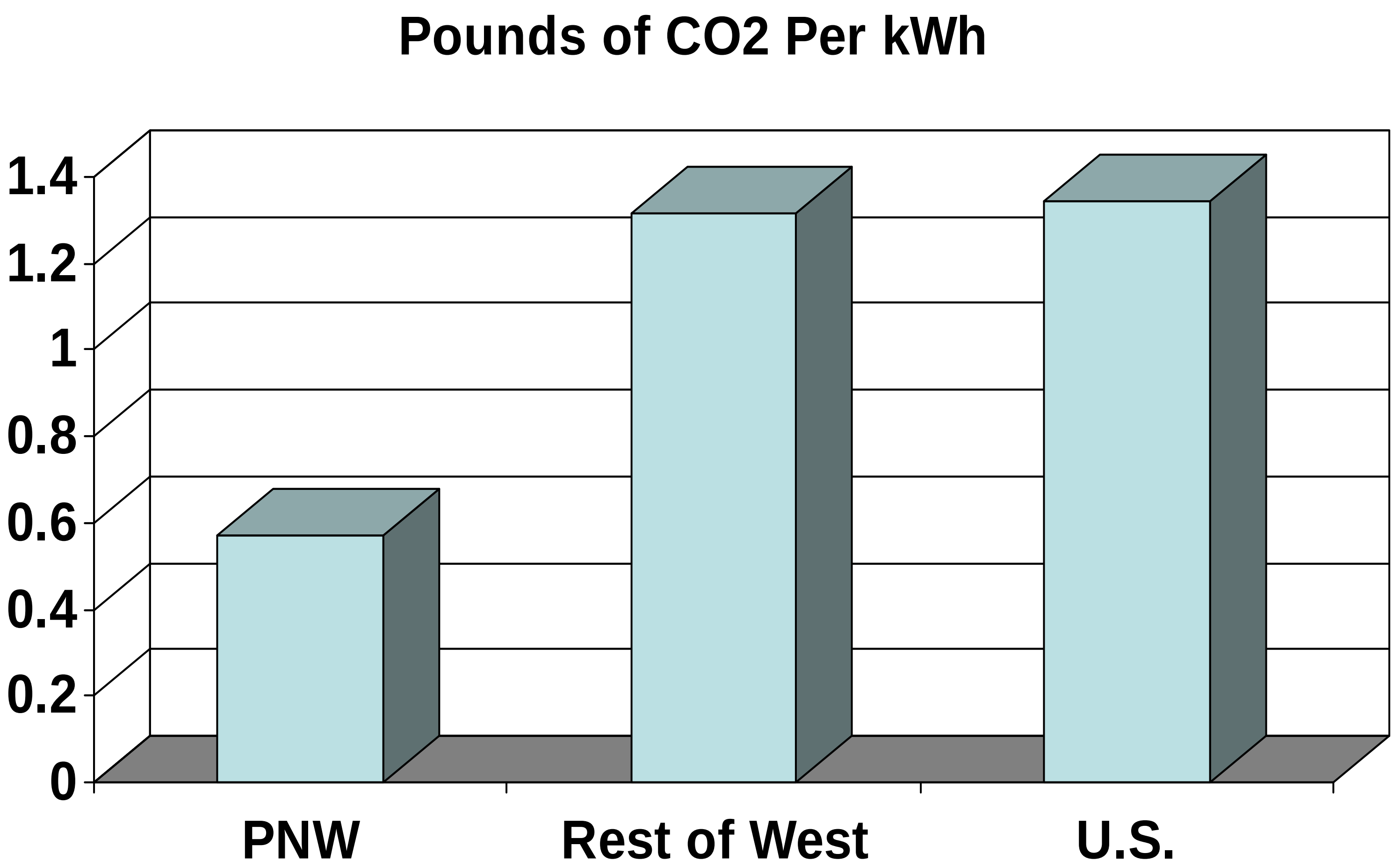
Total Est’d Cost of F&W Program

- $ 434 Million – Mainstem
- $ 56 Million – F&W capital expenses
- $ 231 Million – Non-mainstem program measures

- $ 721 Million – Total cost
- 18 to 24 % – of BPA’s annual net revenue requirement (ranges from $3 to $4 billion)

Carbon Footprint for the Northwest



Emission Impacts of Various Actions