September 2010

Columbia River high-water operations

[June 1–14, 2010]

The Federal Columbia River Power System is operated for multiple public purposes, including flood control, irrigation, power production, navigation, recreation and municipal water supply. The system is also operated to protect the river's fish, including salmon, steelhead, sturgeon and bull trout listed as threatened or endangered under the Endangered Species Act. The U.S. Army Corps of Engineers and Bureau of Reclamation, which own the federal dams, operate them within constraints established to assure the requirements of all the multiple purposes are met.

The Bonneville Power Administration markets power from the federal dams within the constraints and requirements for other river purposes. Flood control, protection of fish listed under the Endangered Species Act, compliance with the Clean Water Act and other requirements take precedence over power production.

As part of its mission to market federal hydropower, BPA is the primary high-voltage transmission provider in the Columbia River Basin. Consistent with Federal Energy Regulatory Commission policies for open-access, non-discriminatory high-voltage transmission, BPA integrates new power sources into its transmission grid that request such service.[1] In the past few years, there has been remarkable growth in wind power projects interconnecting to BPA's transmission grid, driven by renewable portfolio standards in Washington and Oregon and increasingly by California's 33 percent renewable portfolio standard.[2] As a result, generating capacity is being developed in the Northwest far in advance of regional power demand.

Due to the wide seasonal and annual variations in Columbia River streamflows and the high variability of wind power output, BPA has been aware for some time that a combination of high streamflows and high wind could pose new challenges for Columbia River system operations. This expectation was fulfilled when high streamflows emerged for a short period this June in an otherwise low-water year. The June high-water event was likely a preview of situations BPA and the region will face again and for longer periods, particularly during years of heavy snowpack.

This paper describes how system operators managed through this first coincidence of high wind and high streamflows. In addition to actions within the hydro system itself, these steps included reducing nuclear plant output, storing water in Canadian reservoirs, providing power at little or no cost to utilities to displace operation of their thermal power plants, and temporarily reducing amounts of balancing reserves provided to wind power projects.

Many parties are involved in some aspect of these operations, but few see the actions of all. This overview is intended to provide a common context for regional conversations on additional approaches BPA and others might take to respond to future high-water events as the multiple demands on the river evolve and the region's wind generating capacity grows.

The Endangered Species Act, Clean Water Act and Biological Opinion on FCRPS operations are binding constraints on federal power production. With the growing imbalance in Northwest power supply and demand, new protocols, policies and tools may be needed to assure reliable and equitable power operation within the physical limits of this highly interdependent system.

1 For details, see *www.bpa.gov/corporate/pubs/fact_sheets/09fs/factsheet_-_Investing_in_the_NW_transmission_system.pdf.*

2 For details, go to *www.bpa.gov/go/wind.*

BACKGROUND

Responding to the unexpected

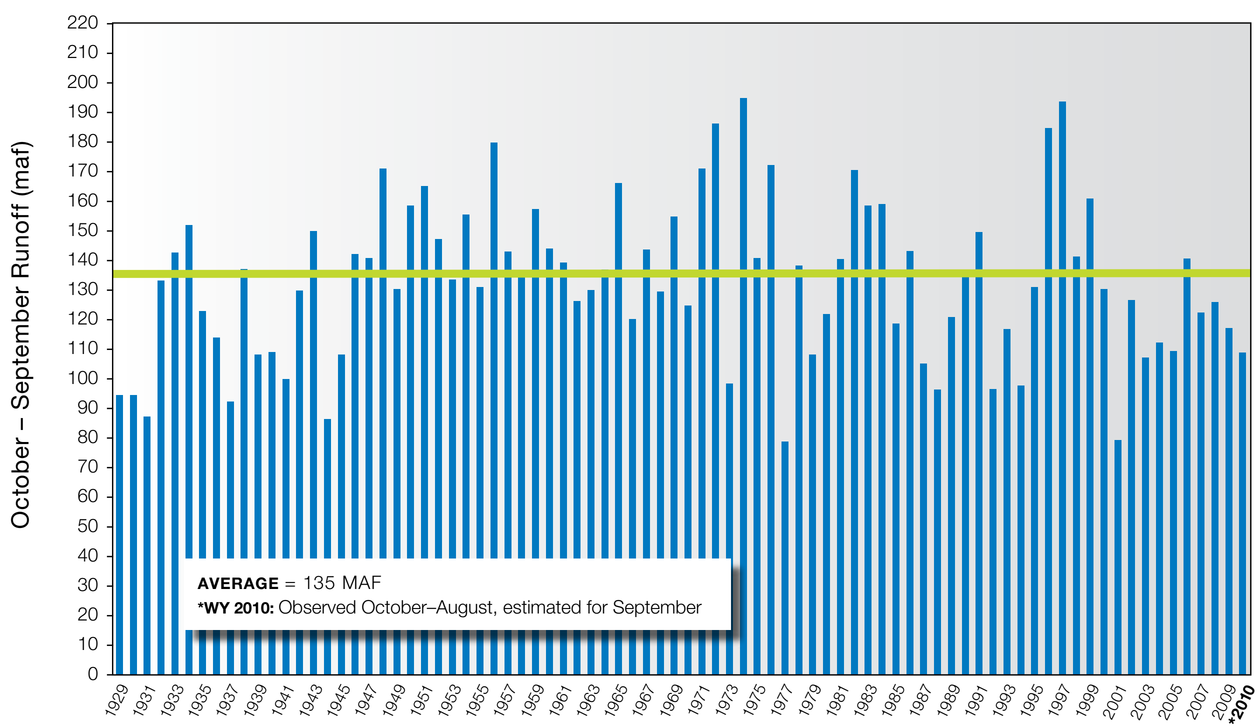
The Columbia River system typically sees periods of high flows in spring as the weather warms and snowpack melts. After a dry winter, spring 2010 river flows were expected to stay fairly low. Throughout April and May, FCRPS operation focused on providing enough river flow and spill to meet objectives designed to protect endangered juvenile salmon migrating to the Pacific and on refilling reservoirs in Idaho, Montana and Washington by July.

In early June, however, a strong Pacific jet stream brought storm systems with heavy precipitation and flooding in some areas. This was the first significant high-water event in several years. Snake River flows nearly tripled from 80,000 cubic feet per second (80 kcfs) to 210 kcfs in five days. Inflows into Lake Roosevelt behind Grand Coulee Dam rose 70 percent. The January through July water supply forecast for the Columbia River Basin increased nearly 10 million acre-feet as measured at The Dalles, Ore. — from about two-thirds to about three-fourths of average — between mid-May (71.2 maf) and mid-June (80.9 maf).

These flows were more than adequate to meet flow and spill objectives for fish passage. Operators' focus shifted to developing strategies and modifying operations to reduce excess spill and keep total dissolved gas (nitrogen saturation) at levels safe for fish. Meeting this objective involved numerous actions quickly taken by many parties, including BPA, the Corps, Reclamation, Energy Northwest, and utilities and independent power producers in the Northwest, British Columbia and California.

Columbia River water year runoff at The Dalles, Ore.

[1929–2010]



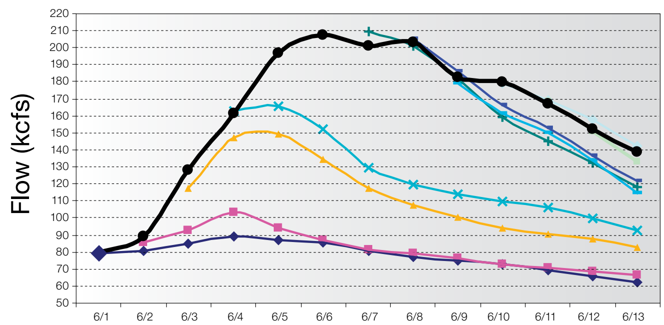
Overall, the 2009–2010 water year was another low-water year in a low-water decade.

Day-average inflows

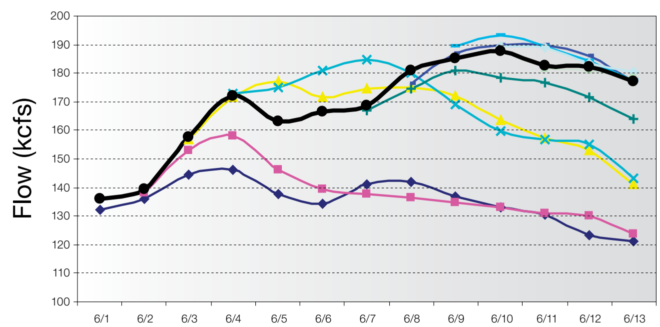
[modeled and actual June 1–13]

These graphs show how fast, hard and unexpectedly high water hit the Columbia River system. They measure successive streamflow forecasts and actual streamflows at Lower Granite Dam on the lower Snake River, Grand Coulee Dam on the mainstem Columbia, and at McNary dam, which lies below the confluence of the Snake and Columbia rivers. The dark blue and magenta lines depict what forecasters expected to see as of June 1 and 2. The heavy black lines are what actually happened. Other lines correspond to updated flow forecasts.

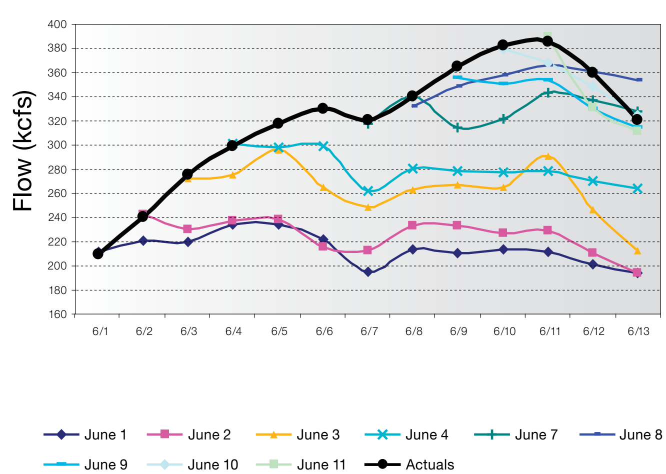
LOWER GRANITE DAM



GRAND COULEE DAM



MCNARY DAM



HIGH FLOWS AND THE COLUMBIA RIVER SYSTEM

High flows in the Columbia River system are not rare; there is a one-in-three chance of flows at least as high as those of early June 2010 occurring in any year and lasting for one month or more.

The Columbia River system has an exceptionally wide range of high and low flows, with a historic minimum to maximum flow ratio of 1 to 35 (compared to 1 to 5 for the Mississippi). Flood control is a significant purpose of many of the Northwest's federal dams. The Vanport Flood of 1948 spurred reservoir development in the upper Columbia and was a major impetus for the Columbia River Treaty with Canada in 1964, which doubled Columbia reservoir storage. Even with the Treaty reservoirs, the federal system can store less than 40 percent of an average year's 134 million acre-feet of runoff.[3]

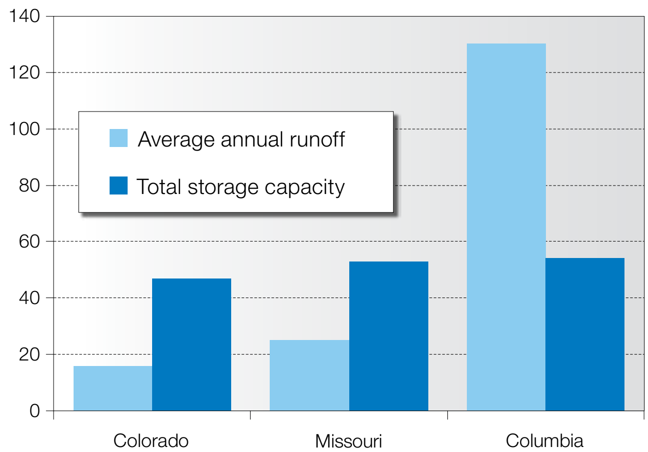
All dams in the Columbia River system are highly interdependent — water released from a headwaters dam can affect flows at up to 19 dams downstream. Northwest utilities coordinate power plant operations to make the best use of this interdependent hydropower under the Pacific Northwest Coordination Agreement[4] established in 1964. Transmission is also an important aspect of this interdependent system. Power generation opportunities can be constrained by transmission availability, and BPA Transmission Services relies heavily on federal hydropower to provide reserves that keep the electrical system in balance and operating reliably.

Water that cannot be stored necessarily flows downstream. Since the 1970s, BPA and other Northwest hydro producers have routinely sold surplus power produced during times of high streamflows at very low rates to utilities in the Northwest and California to encourage operators

3 As traditionally measured at The Dalles, Ore.

4 For details, see, *Columbia River System: The Inside Story*.

Columbia River runoff and storage compared to the Colorado and Missouri rivers



The Columbia River system has limited reservoir storage.

of coal, oil, natural gas and other power plants to reduce output of their plants and replace it with surplus hydropower when available.

In recent years, three new factors have been added to this equation.

1) The wholesale power market was deregulated in the 1990s, and power generation functionally separated from wholesale transmission. This has added numerous market participants such as independent power producers as well as complexities in the relationships among the players. In some circumstances, power generators may not want their generation displaced, because they may have economic incentives or reliability requirements that cause them to continue to generate, even if BPA offers hydro power at $0 per megawatt-hour.

2) Flow augmentation requirements for Columbia and Snake River salmon and steelhead listed under the Endangered Species Act have dramatically changed the way the reservoirs are managed, generally reducing storage space in reservoirs. Operators seek to refill system reservoirs by late June. If the runoff pattern is "flashy" with large surges of runoff, a higher proportion of the runoff may be forced through the system quickly due to lack of available reservoir storage.

3) About 3,000 megawatts of wind power generators have connected to BPA's transmission grid in the Columbia River Basin, adding highly variable renewable generation to the hydro base of the Columbia River system. This growth has been driven by Renewable Portfolio Standard requirements in Oregon, Washington and California, where an executive order would increase the state's current 20 percent RPS to 33 percent by 2020. One of the key variables is the quantity of renewable energy California utilities can provide from out of state resources. The ultimate decision on this issue could have a significant impact on the Northwest and other regions with large renewable resource endowments.

4) The rapid increase in wind power in the Northwest has increased the Northwest power system's maximum generation output significantly, but also requires providing balancing reserves to the wind generators, which now consumes a significant portion of the operating flexibility of the FCRPS. Wind generating capacity connected to BPA's transmission grid is expected to double by 2013. Regionally, including areas outside BPA's balancing authority, more than 5,000 MW of wind generation are currently installed. This also is expected to increase significantly by 2013.

FISH PROTECTION REQUIREMENTS AND SPILL

Juvenile fish migrating downstream in the Columbia and Snake rivers pass through up to eight federal dams.

Under the 2008 Federal Columbia River Power System Biological Opinion for protection of salmon and steelhead listed under the Endangered Species Act, certain amounts of water are required to be spilled at the eight mainstem projects rather than passed through their turbines for fish passage each spring and summer.

However, excessive spill can result in high levels of total dissolved gas in the water, which can cause gas bubble trauma in fish — similar to the bends in divers. To protect fish from gas bubble trauma, state water quality standards under the Clean Water Act limit allowable levels of total dissolved gas to 110 percent saturation at any point of collection on the river.

In some cases, the amount of voluntary spill required for ESA-listed fish under the 2008 BiOp exceeds the limit allowed by the state water quality standards. The states of Washington and Oregon have authorized exceptions to these standards for the purpose of providing improved fish passage. The Corps submits a Gas Abatement Plan to the Department of Ecology of the state of Washington to request an adjustment to the state water quality standards that would allow total dissolved gas levels up to 120 percent of normal gas saturation levels in the tailraces of the eight mainstem dams and 115 percent saturation in their forebays. Additionally, a waiver is requested from the state of Oregon's Department of Environmental Quality to allow total dissolved gas levels up to 120 percent saturation in the tailraces of the eight mainstem dams.

In addition to voluntary spill for fish passage, involuntary spill can occur during high streamflows when all turbines at a dam are running at capacity or when insufficient market for power reduces use of some turbines and there is inadequate reservoir storage available. When this occurs, spill is added incrementally across all federally owned projects to prevent excessively high total dissolved gas levels. While not part of the criteria adjustment requested for the eight mainstem fish passage projects, the Gas Abatement Plan includes spill at Grand Coulee and Chief Joseph dams as operational measures to manage total dissolved gas levels in the Columbia River that result from involuntary spill.

The amount of total spill that can pass the eight mainstem dams without causing dangerous levels of total dissolved gas today is higher than in past decades, because flow deflectors or "flip lips" have been installed on all lower Snake and Columbia federal dams plus Chief Joseph Dam. Flow deflectors allow the energy in the spill to be dissipated closer to the water surface, allowing more of the gas in the spill to dissipate rather than dissolve in the water. Flow deflectors at Chief Joseph Dam, for example, increased allowable spill from 20 kcfs to 100 kcfs.

When flow goes above about 150 kcfs in the Snake River, total dissolved gas levels can no longer be managed to meet the 120 percent limit, where applicable, even with all turbines running at full output. Snake River flows peaked on June 6 at 207 kcfs and remained above 200 kcfs through June 9. At this point, half of the river was flowing through the powerhouse and the other half through the spillway. Because flows were above the project's powerhouse capacity, total dissolved gas levels in the water below Lower Granite Dam reached 130 percent saturation.

The lower Columbia River can sustain much higher flows before reaching total dissolved gas levels above 120 percent. Peak flows during the period were near 400 kcfs in the lower river, but the lower Columbia River dams experienced lower total dissolved gas levels, with elevated levels only at McNary and Bonneville dams. Total dissolved gas levels[5] just below McNary Dam peaked near 122 percent on June 10–11. Total dissolved gas levels peaked at 116 percent June 6, at 117 percent June 12 and 13 and at 118 percent June 23 in the forebay of Bonneville Dam.

Juvenile fish monitored, tested

The Pacific States Marine Commission regularly monitors the condition of migrating salmon smolts. During the first two weeks of June 2010, tests occurred at Lower Granite, Little Goose, Lower Monumental, McNary and Bonneville dams. Of 2,238 fish tested between June 1 and June 22, only 31 fish showed any symptoms of gas bubble trauma. Of these, 23 were

5 Total dissolved gas levels by dam, by hour, are posted at: *www.nwd-wc.usace.army.mil/tmt/wcd/tdg/months.html#L*.

ranked at the mildest level. Only one showed severe symptoms of gas bubble trauma. At these levels of detection, the effects of gas bubble trauma on smolts throughout the first three weeks of June appear to have been minimal.

FEDERAL ACTIONS TAKEN

Generation: less thermal, more hydro

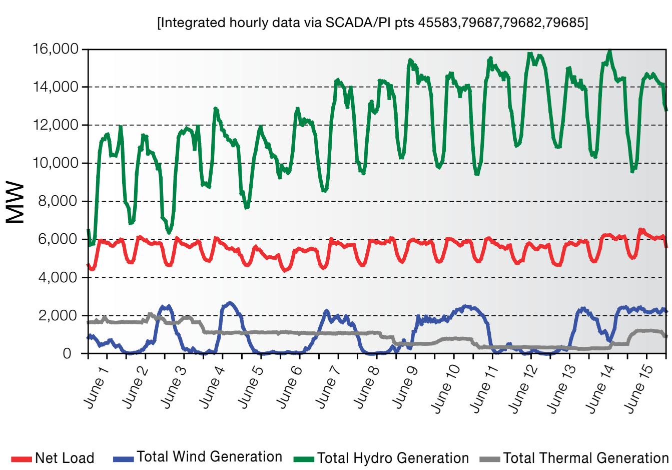
To minimize excess spill, federal hydro generators produced at times more than twice as much power as needed to meet BPA loads. Since generation must equal load, BPA provided power to other utilities to keep as many of the available hydro generators on line as possible. BPA used as much of its Northwest transmission network and interregional intertie transmission as possible to provide surplus hydro power to displace others' generation. BPA sold this power at prices down to $0/MWh to reduce excess spill and manage total dissolved gas levels. Hydropower output reflected the maximum possible production, limited by transmission availability and the market for power at zero cost.

During the event, regional thermal generation significantly declined as utilities consumed very low or no cost BPA hydropower instead. Loads remained fairly flat and low due to cool weather. Wind power fluctuated between zero and almost full output as storms blew through the region.

This graph at left shows the load (red line) and power generation within BPA's balancing authority in the high-flow period, regardless of ownership. The hydro (green line) is primarily federal hydropower; thermal generation (grey line) includes the Columbia Generating Station nuclear plant and resources operated by independent power producers; wind generation (blue line) comes from wind projects with a combined generating capacity of 2,830 MW, primarily east of the Columbia River Gorge, also owned by independent power producers.

BPA balancing authority load, total wind, hydro and thermal generation

[June 1–15, 2010]



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Other steps to reduce excess spill

Maximizing hydropower generation was not enough to manage the high flows and prevent reservoirs from overfilling. Additional water was spilled at several hydro projects to keep reservoirs from getting too full. This additional spill is called lack-of-market spill, since it would not have been necessary had there been additional market for power.

During this period, BPA, the Corps and Reclamation took the following actions to minimize dissolved gas levels while providing other system services, including wind balancing reserves:

- Canceled or delayed all non-essential generating unit outages on the Snake and Columbia dams until flows subsided.
- Moved spill to Grand Coulee, Chief Joseph, Dworshak and Willamette River dams and moved generation to the fish-passage projects.

- Reduced flows at Albeni Falls Dam as much as possible.
- Arranged with the Corps to use 2 feet of flood control space in John Day reservoir to reduce spill and prevent flooding in the lower Columbia (i.e., additional water could be stored behind the dam).
- Shaped as much Hungry Horse Dam and Dworshak Dam generation as possible into hours of heavy electricity use.

Seeking further ways to minimize dissolved gas levels by working with other regional partners, BPA also:

- Asked Energy Northwest to limit the output of the Columbia Generating Station nuclear plant to the lowest possible level that would not risk its ability to return to full power.
- Asked B.C. Hydro to reduce flows at Arrow Dam from 25 kcfs on June 9 to 20 kcfs on June 11 and through the rest of the high-flow period.
- Reduced wind balancing reserves for a few days in an attempt to minimize spill caused by unscheduled energy produced by wind generators.
- Suspended transmission control system maintenance to keep all possible transmission lines in service through the high-flow period.
- Worked with neighboring utilities to defer their non-emergency transmission maintenance, including intertie maintenance, throughout the high-flow period.
- Moved generation around the system to minimize capacity reductions on intertie lines to California while maintaining transmission reliability.

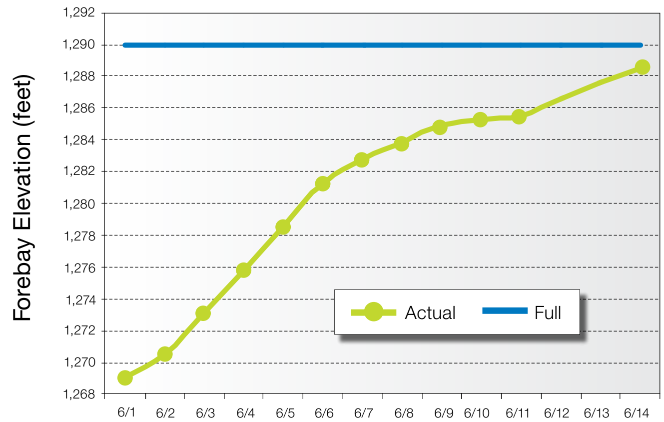
The following sections describe some of these efforts in more detail.

Reservoirs filled quickly

During the event, three of the five large federal Columbia River system reservoirs filled quickly,

Grand Coulee Dam refill

[June 1–14]



Grand Coulee Dam filled quickly to reduce streamflows downstream.

and a fourth was already close to full. The three Columbia River Treaty dams in Canada owned by B.C. Hydro — Mica, Duncan and Arrow — were all full by June 15.

Grand Coulee Dam's Lake Roosevelt filled as much as 2 feet a day in the first half of June and reached full in the third week of June. Grand Coulee Dam in Washington and Dworshak Dam in Idaho each filled about 19 feet during the period. Hungry Horse Dam in Montana filled 11.5 feet. All were near full by the end of the period.[6] Dworshak Dam, which had not been expected to refill this year, filled 2 feet a day and was approaching full by June 8, requiring higher outflows than planned at that reservoir. Albeni Falls was close to full on June 1 and remained so.

The exception was Libby Dam in Montana. Libby was operating to provide flows and spill for endangered Kootenai River white sturgeon and was not available to refill at that time to reduce streamflows downstream.

6 Coulee was 96.1, Horse 94.3 and Dworshak 99.1 percent full by the end of June 13.

Nuclear plant output reduced

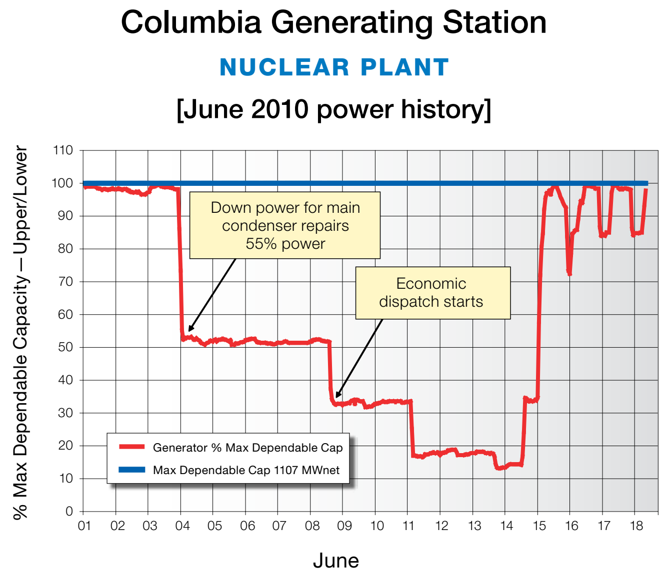
The Columbia Generating Station nuclear plant is owned by Energy Northwest, a consortium of Washington state utilities, and its output is marketed by BPA. It was scheduled to reduce its output on June 4 to repair a condenser leak, which it did. The plant had been scheduled to return to full output on June 7. Instead, at BPA's request, Energy Northwest reduced generation, first to 30 percent on June 8 and then, from June 11 until flows subsided, to less than 20 percent of full output, the lowest level possible without taking the plant to cold restart (a lengthy and risky process). As high flows continued after the peak period passed, Columbia Generating Station continued to cycle from 100 percent output during the day to 85 percent output at night, when loads drop significantly, through June and into July.

Note that "cycling a nuclear plant"— reducing its generation for economic or environmental dispatch — is not normal utility practice and not something BPA takes lightly or recommends as regular utility practice. Nuclear plants are most efficient at steady full output. Because Columbia Generating Station is the sole thermal project in BPA's resource base, BPA has worked with Energy Northwest to develop dispatch protocols to reduce nuclear output during high water when necessary.

Other thermal generation unknown

The thermal generation within BPA's balancing authority area was at very low levels during this period, as shown in the grey line in the graph on page 6.

This graph shows only load and generation in BPA's balancing authority area. BPA's knowledge of specific generation operating outside its balancing authority is limited and in large part anecdotal or inferred from transmission scheduled on BPA lines. Only the Western Electricity Coordinating Council System Coordinator has complete information on which specific resources outside the BPA balancing authority area are running in real time.



Nuclear output was reduced.

Balancing reserves to wind generators reduced

Most of the wind generation located in BPA's transmission grid is owned or under contract to non-federal utilities throughout the Northwest and California. Only about 20 percent is consumed by utilities in BPA's balancing authority. The remaining 80 percent uses BPA transmission capacity to move wind energy to purchasing utilities elsewhere. A key BPA role is to provide transmission services and balancing reserves to the wind generators in BPA's area, regardless of where the wind power is used. Balancing reserves correct for deviations between scheduled and actual wind output within each hour.

Columbia River Gorge wind patterns are extremely variable. Storms passing through the gorge cause very large up and down ramps that are hard to predict with precision. To provide balancing reserves for the roughly 3,000 MW of wind power currently interconnected to the federal system, BPA now sets aside about 850 average megawatts of hydro capability to provide incremental reserves and about 1,050 aMW to provide decremental reserves.[7] That is, BPA runs hydro generation 1,050 MW higher

7 For details, see *www.bpa.gov/corporate/pubs/fact_sheets/10fs/BPA_Wind_Power_Efforts_March_2010.pdf.*

than minimum generation at all times so as to stand ready to reduce hydro generation (dec) if the wind picks up and wind power suddenly increases above its schedule. BPA also runs hydro generation roughly 850 MW below maximum generation at all times to stand ready to increase hydro output (inc) instantly if the wind dies off and wind generation falls below its schedule within an hour.[8] These same inc and dec reserves are also used to account for variations of load in the BPA balancing authority. Gaps between scheduled and actual output are called station control error.

The red lines in the graphs at right show the station control error and how much federal balancing reserve the wind fleet was consuming at any given time, up (inc) or down (dec), on June 1–14. In setting rates for 2010–2011, BPA established amounts of reserves BPA would provide in this rate period. The green and blue lines show the reserve levels.

If wind generation deviation from schedule goes beyond these levels in either direction, BPA dispatchers instruct the wind generators to reduce their output (feather their blades) or BPA curtails their transmission to limit the amount of additional hydro generation provided. These operating directives are administered under BPA's Dispatcher's Standing Order 216 (DSO 216).[9]

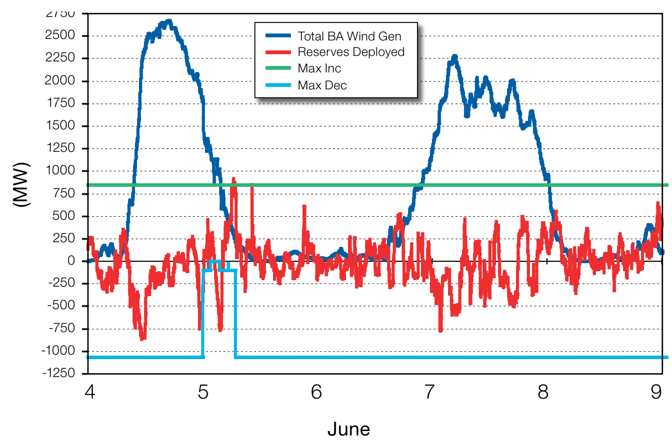
In establishing DSO 216 and rates for 2010–2011, BPA informed wind project owners that there might be times when BPA would have to reduce its balancing reserves temporarily, in case of power system, transmission system or hydro operation requirements such as fish protection. Such reductions, predominantly in dec reserve levels, occurred on June 5 and June 9–13 and can be seen in the changes to the green and light blue lines in the graphs. DSO 216 triggered 24 times in this period, which can be seen on the graphs wherever the red line exceeds either the green or light blue

8 BPA's Wind Integration Team initiatives are designed to reduce these reserve requirements on the federal system and help reduce the operating requirements and impacts of forecast errors. See *www.bpa.gov/corporate/WindPower/wit.cfm.*

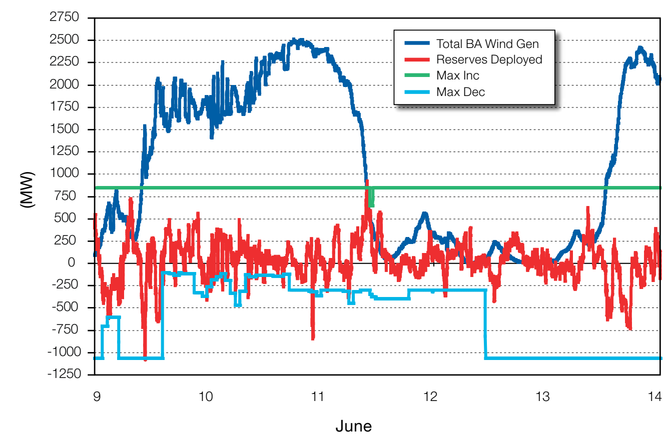
9 For details, see *www.transmission.bpa.gov/wind/op_controls/default.cfm.*

BPA balancing authority wind data

[June 4–8, 2010]



[June 9–13, 2010]



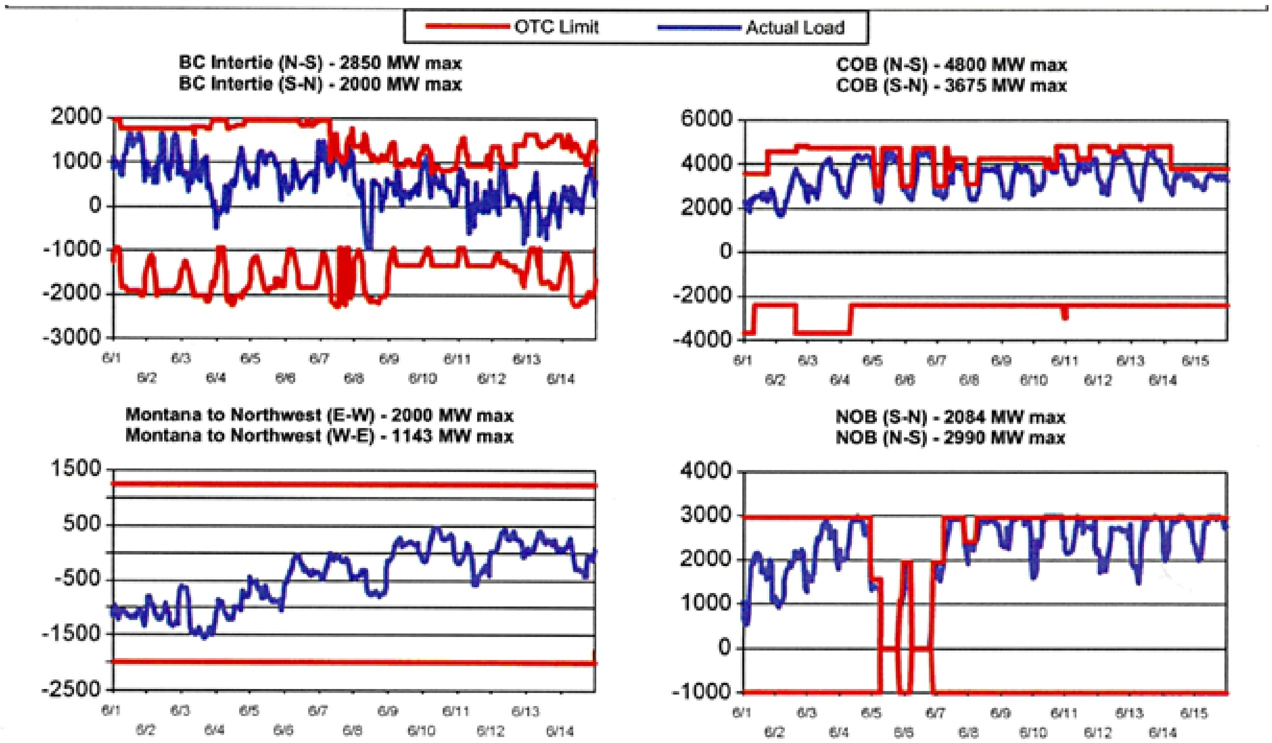
To help meet fish protection requirements at the height of the high water event, BPA reduced balancing reserves that serve wind power projects (light blue and green lines). Only reserves were reduced. All wind power that was scheduled and generated was delivered (dark blue line). The red line shows BPA reserves actually deployed.

line. A lower dec reserve level meant there was less chance that significant changes in the generation level of the wind fleet would cause reductions in hydro generation that would result in additional spill.

In short, to help meet fish protection requirements at the height of the high water event, BPA reduced balancing reserves that serve wind power projects (light blue and green lines).

Transmission flowgate use and availability

[June 1–15]



Transmission availability limited federal hydropower generation.

Importantly, during this period of reduced reserves, all wind generation that was scheduled and produced was delivered. Reducing balancing reserves affected only wind generation in excess of that scheduled and wind generation scheduled but not produced. Overall wind production in June was high, operating above a 33 percent capacity factor.

Transmission operations

Because federal hydropower was generating so far in excess of BPA loads, and wind power and other resources also required transmission, the high water also stressed the transmission grid. Conversely, transmission availability significantly limited opportunities for increasing hydropower generation to diminish dissolved gas levels in the river.

BPA owns and operates three-fourths of the high-voltage transmission in the Pacific Northwest, but is just one of 19 balancing authorities in the greater Northwest Power Pool region. As transmission availability permits, BPA and other Northwest utilities transmit surplus power between regions over intertie transmission lines to northern and southern California, British Columbia, and eastward to Montana and through Idaho to the inland Southwest.

During the high-water period, both the 4,800 MW capacity alternating current intertie to Northern California and the 3,100 MW direct current intertie to Los Angeles experienced intermittent outages and reduced capacity. The DC intertie was restored to full capacity June 8 and the AC on June 10. The somewhat smaller northern intertie to British Columbia saw intermittent 25 percent deratings due to British Columbia Transmission Corporation and

Puget Sound Energy maintenance outages through June 13. Theses reductions in transmission availability limited federal hydropower generation and contributed to the need to spill.

Transmission stresses within the Northwest also affected generation options. Diminished thermal generation shifted the patterns of where generation was occurring, which changed the loading on specific transmission paths.

The complex interdependencies of the Columbia River power and transmission system produced some unexpected outcomes that required adjustments as they became clear. For example, the high flows in the Snake River necessitated backing off Grand Coulee and Chief Joseph flows as much as possible to avoid too much water arriving at one time at McNary Dam at the confluence of the Snake and Columbia. When this occurred at night — when little electricity is used — it meant reducing generation at Grand Coulee and Chief Joseph dams. That, in turn, meant those two dams were no longer providing 600 MW of generation that could be dropped instantly if a transmission line fault occurred, which was required to maintain the carrying capacity of the intertie lines to California. Absent the generation at Grand Coulee and Chief Joseph, the intertie capacity had to be reduced by 600 MW, which reduced the amount of generation BPA could export and thereby increased spill. Once alerted to the problem, BPA transmission and power staff reprioritized where hydro generation would occur to restore the intertie capacity.

On June 11, BPA declared a “no touch” condition for the control center automation used by power system dispatchers, which means no computer system updates or testing took place to ensure no interruption to the computer systems used by dispatchers to monitor, operate and control the power system. The no touch rule ended June 14.

Wholesale power market conditions

Throughout June, BPA conducted forced marketing — sales of surplus power specifically to meet fish protection requirements. The solid black line on the graph below delineates BPA’s success in increasing hydro generation as much as possible during the high-flow period. The light-shaded area shows lack-of-market spill, water spilled rather than directed through hydro turbines for lack of power market and/or transmission to reach potential markets.

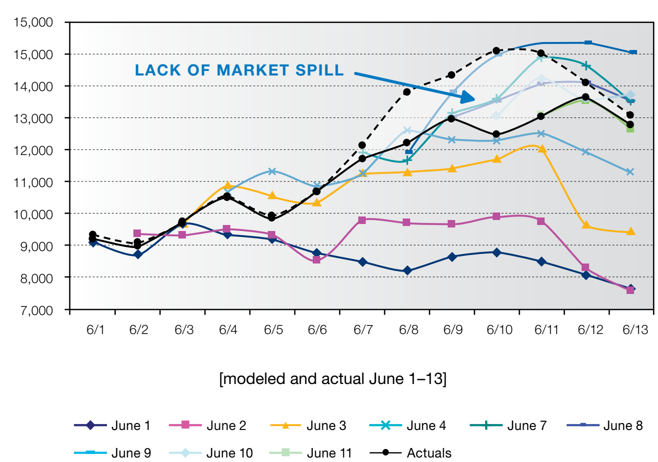
Power markets were saturated across the West Coast. Clearing Up, an industry newsletter, reported that on June 7, power traded below $0/MWh for the first time since June 26, 2008, at the Mid-Columbia wholesale power trading hub. It said negative prices at that hub reached -$5.50/MWh on June 11.[10] The California Independent System Operator reported negative prices during the period exceeding -$20/ MWh.

BPA did not pay purchasers to take power, but gave power away even during heavy load hours. During the two-week period, BPA disposed of more than 50,000 megawatt-hours of electricity for free or for less than the cost of associated transmission.

10 “Spot Prices Below Water For a Spell.” Clearing Up, June 28, 2010. Pg. 6.

Lack of market spill

FCRPS HYDRO GENERATION



The shaded light area shows lack-of-market spill — water that could have been used to generate power and reduce excess spill had a market for power and/or transmission to reach market been available.

Clearing Up concluded, "The irony of free hydropower in a statistically low water-supply year speaks volumes to the limitations of cumulative statistics and the challenges of managing the Columbia system."[11]

By June 12, while lack of market spill declined, BPA was still trying to find markets at $0/MWh. BPA continued to experience lack-of-market spill and sales below variable transmission costs through the rest of June. Total lack of market spill during the event was about 223,000 MWh. For the month, lack-of-market spill was about 745,000 MWh, or about 1,000 aMW.

CONCLUSIONS AND SUMMARY

Through a combination of regional cooperation and extensive urgent efforts, federal operators took action to protect threatened and endangered species in the Columbia River system this June. The Northwest federal hydropower system succeeded in managing through two weeks of high water to minimize effects from gas bubble trauma for endangered and threatened fish in the Columbia River system.

The Corps, Reclamation, BPA and many others participated in this effort. All parties "pulled out all the stops" — used every tool available in existing protocols and arrangements — to manage through the month.

There has been only one above average water year in the Columbia River system in the last decade. The last water year that was significantly above average was 1999, when very little commercial wind generation was on line in the Northwest. This year, the existing tools for addressing high water were stretched to manage successfully through a relatively short high-water period in an otherwise dry year.

Before a prolonged high-water event occurs, it would be well to consider what additional tools, policies and protocols might be developed to assure reliable and equitable power production in the interdependent Columbia River system within the constraints for other river uses.

11 Ibid.