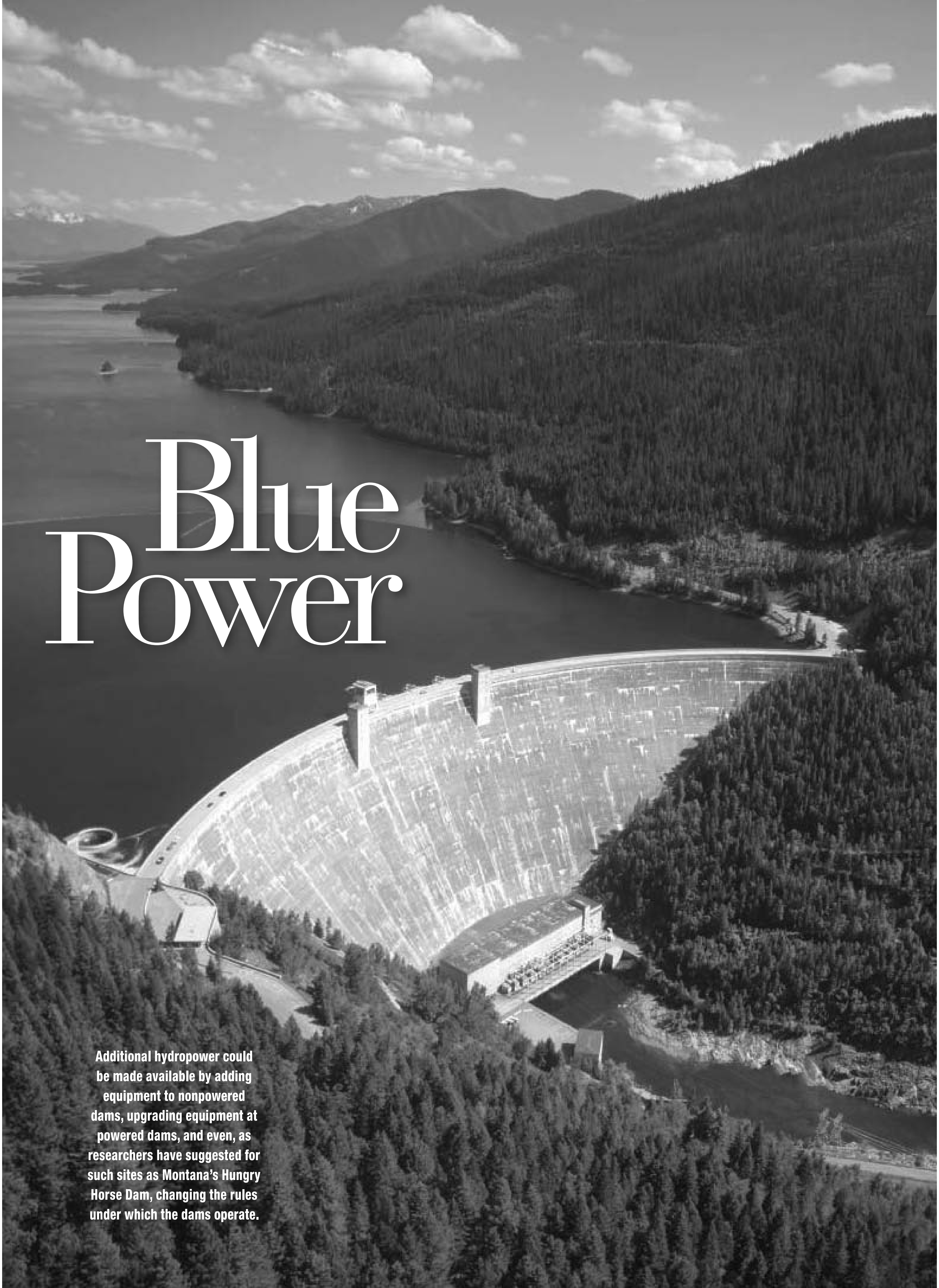
Blue Power



Additional hydropower could be made available by adding equipment to nonpowered dams, upgrading equipment at powered dams, and even, as researchers have suggested for such sites as Montana's Hungry Horse Dam, changing the rules under which the dams operate.

Only about 3 percent of the nation's 80,000 dams are currently equipped to generate electricity. And although not all of the nonpowered dams are suitable for energy production, the best and easiest way to promote "green" energy could be to go "blue"—to add hydropower to as many of the existing dams as possible, along with canals and other overlooked water infrastructure. The existing powered dams could also be upgraded to generate even more hydroelectric energy. ••••• **By Robert L. Reid**

"STOP WASTING America's Hydropower Potential." That was the headline of an op-ed in the January 14, 2016, issue of the *New York Times* cowritten by Senator Lisa Murkowski (R-Alaska) and stating quite bluntly what various technical reports and assessments over the past several years have similarly concluded.

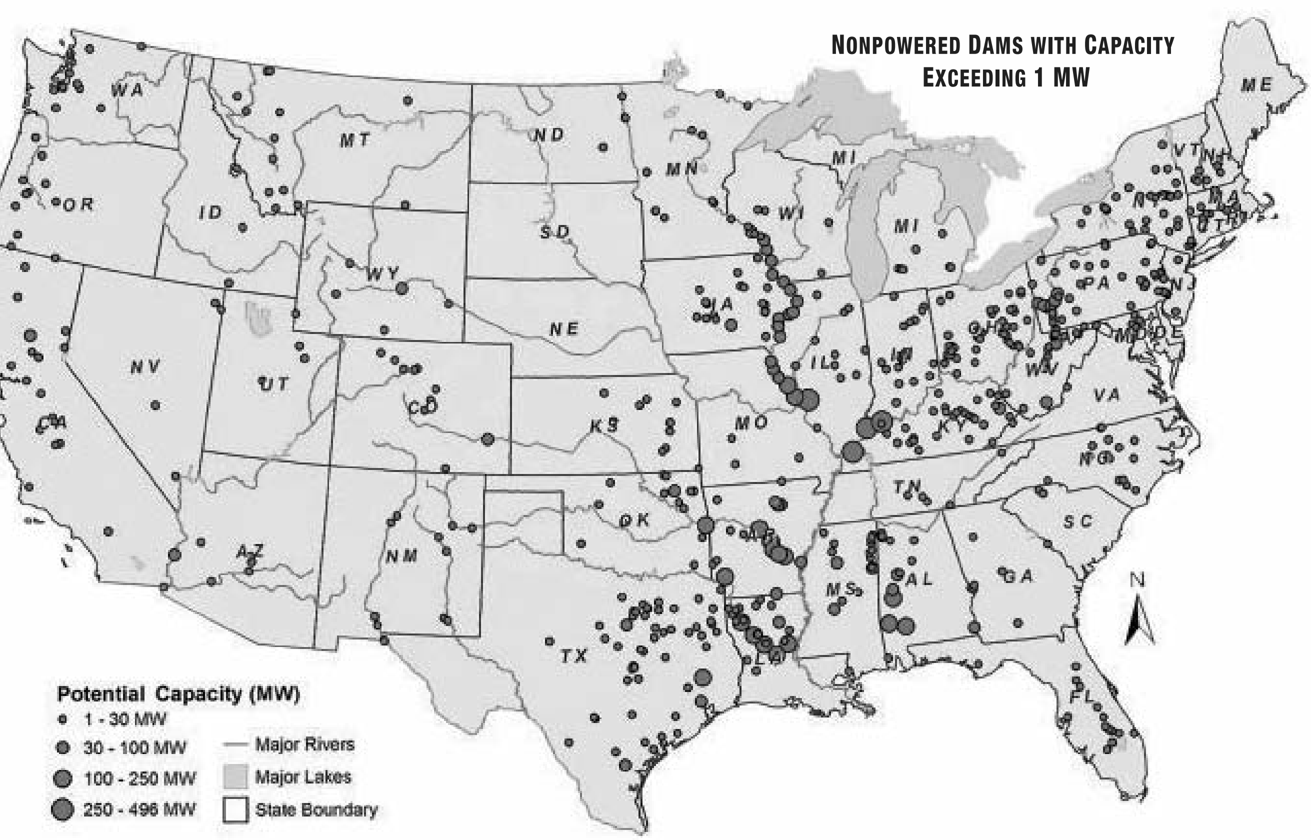
Noting that only 3 percent, or roughly 2,200, of the nation's 80,000 dams currently produce electricity, the op-ed explained that those powered dams account for approximately 6 percent of America's electrical production, or "nearly half of [the nation's] renewable energy, more than wind and solar combined," wrote Murkowski and her coauthor, Jay Faison, the chief executive of the ClearPath Foundation, of Washington, D.C., and Charlotte, North Carolina, which, according to its website, promotes a "conservative clean energy agenda for the 21st century."

Other estimates, including those from the National Hydropower Association (NHA), of Washington, D.C., place the estimate at 7 percent and argue that the large number of currently nonpowered dams means that the figure could go even higher. Murkowski and Faison agree, stating that the United States "could be doing much more to harness the huge potential of hydropower, even without building new dams."

The last part of that statement is perhaps the most critical, as the era of constructing large dams in the United States is largely seen as having ended decades ago. Faisal Hossain, Ph.D., P.H., M.ASCE, an associate professor in the University of Washington's civil and environmental engineering department, stresses that "in the United States, dam building is a thing of the past. We're not going to have any major new dams, especially large ones, being built in this country." In part, that is because "most places where you needed dams for hydropower, flood control, or water supply, they're already there actually—so we've kind of plateaued in some sense," adds Hossain.

But there is still considerable opportunity for increas sing hydropower by adding generating systems at existing nonpowered dams, as well as by upgrading the aging hydropower systems at powered dams, some of which are about

Nonpowered Dams with Capacity Exceeding 1 MW



DAVE WALSH, BUREAU OF RECLAMATION, *OPPOSITE*; U.S. DEPARTMENT OF ENERGY AND OAK RIDGE NATIONAL LABORATORY, *RIGHT*

The addition of generating equipment at the 100 nonpowered dams having the greatest potential would produce enough energy for nearly three million more homes and create thousands of jobs.

100 years old and many have turbines and generators that are about 50 years old and thus are past or nearing the end of their useful life, explains Don Erpenbeck, P.E., the global business line director for MWH Global, a leading hydropower engineering firm based in Broomfield, Colorado. There is also a considerable network of canals and conduits and other overlooked water infrastructure in the United States that could be adapted for producing renewable energy.

As Murkowski and Faison noted, the addition of generating equipment at the 100 nonpowered dams having the greatest potential would produce enough energy "for nearly three million more homes and create thousands of jobs. And upgrading and modernizing the turbines at existing hydropower dams could yield a similar amount of additional electricity-generating capacity."

In this vein, an April 2012 report prepared for the U.S. Department of Energy's Wind Program and Water Power Program determined that the installation of generating equipment at America's nonpowered dams could add as much as 12 GW of renewable energy capacity to the nation's electricity supply. Such an undertaking would be equivalent to increasing the size of the existing conventional hydropower fleet by 15 percent, according to the report, *An Assessment of Energy Potential at Non-Powered Dams in the United States*, which was prepared by Oak Ridge National Laboratory, in Oak Ridge, Tennessee, with input from Idaho National Laboratory, in Idaho Falls, Idaho.

Designed primarily to raise awareness of the potential for additional hydropower, the report analyzed more than 54,000 nonpowered dams using data from the U.S. Geological Survey's river flow gauge stations, as well as waterhead and quality control information on the leading 600 sites, explains Boualem Hadjerioua, Ph.D., M.ASCE, the deputy water power program manager and senior research engineer in Oak Ridge's environmental science division and the principal investigator for the April 2012 report. After rejecting sites for which there were "erroneous geographic information, or erroneous flow or drainage area attributes," or other details that could not be resolved, the Oak Ridge report concluded that "most of the energy potential is found in a relatively small subset of dams." Indeed, out of that initial 54,000 possible dam sites, just 597 nonpowered dams, each offering a potential capacity exceeding 1 MW, would contribute nearly 90 percent of the estimated additional capacity. Moreover, a majority of the potential new capacity "is concentrated in just 100 [nonpowered dams], which could contribute approximately 8 GW of clean, reliable hydropower," while "the top 10 facilities alone could add up to 3 GW of new hydropower," the Oak Ridge report explained.

Of the top 100 nonpowered dams, 81

A 105 MW facility under construction at the Captain Anthony Meldahl Locks and Dam is one of four projects on the Ohio River at which generating equipment is being added to previously nonpowered dams.

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involve facilities owned by the U.S. Army Corps of Engineers, especially facilities that serve as navigation locks on the Ohio River, the Mississippi River, the Alabama River, and the Arkansas River, along with major tributaries of those rivers, the Oak Ridge report stated. Moreover, an additional 260 MW of new capacity could be generated from dams owned by the U.S. Department of the Interior's Bureau of Reclamation, the report concluded. There are also numerous local utility districts that own dams at which power could be added.

Two large-scale models were constructed of the Ohio River upstream and downstream of the Cannelton Locks and Dam to help design the 88 MW plant for that site.

Another report, this one released in July 2013 by the Corps of Engineers' Hydropower Analysis Center, produced a similar, if somewhat reduced, projection of the potential for increasing hydropower. *Hydropower Resource Assessment at Non-Powered USACE Sites* started with the same sites analyzed by the Oak Ridge report but then reduced the number of possible locations to a total of 223 nonpowered dam sites owned by the Corps by applying certain criteria, including what the Corps considered to be "obvious hindrances in developing hydropower." Examining the daily hydraulic head and flow values for all of those 223 sites, the Corps report concluded that there was approximately 6.2 GW of potential energy from those projects but that only about 2.8 GW would be economically feasible.

The Corps is the largest owner and operator of hydropower plants in the United States. Its 75 facilities represent an installed capacity of 21 GW, or roughly 24 percent of the nation's total hydroelectric capacity, explained the Corps report.

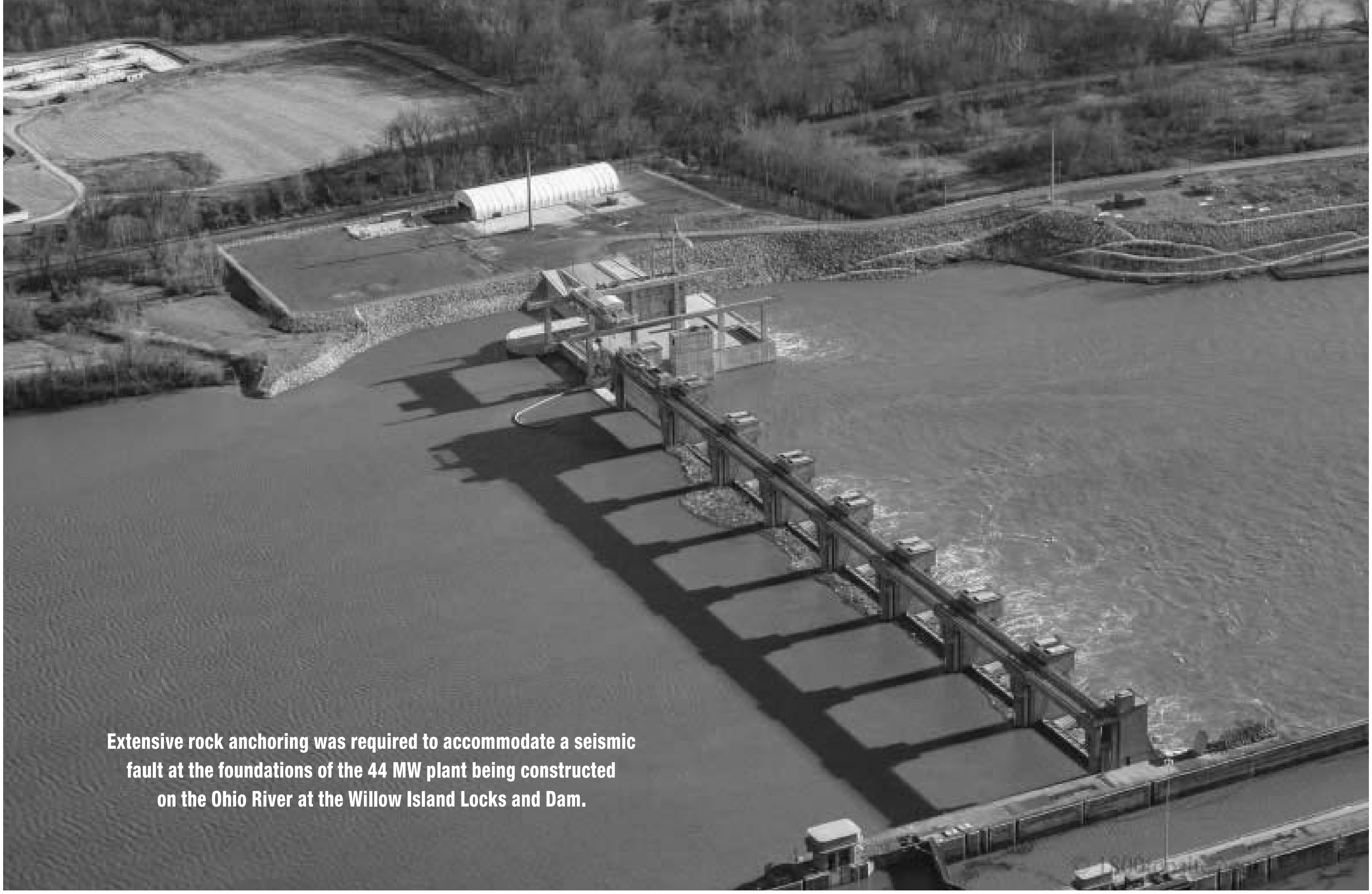
Regardless of whose numbers you use, though, the fact remains that the United States has considerable potential for generating additional hydropower at existing infrastructure. But none of this will be easy. Even with the dams and other facilities in place, formidable engineering challenges and other technical obstacles must be overcome to design and construct the new hydropower facilities. And a number of environmental and bureaucratic obstacles to new hydropower can delay projects for years or kill new hydropower developments outright.

For example, hydropower is the only form of renewable energy in the United States that is frequently licensed at the federal level, through the Federal Energy Regulatory Commission, and the process is a complicated one that takes at least five years to complete and sometimes extends for more than a decade, notes David Zayas, the NHA's senior manager of regulatory affairs and technical services. By comparison, the regulatory authorization of a natural gas combined cycle plant—a nonrenewable energy producer—often takes as little as 18 to 24 months.

When Corps facilities are involved, the regulatory process also entails such requirements as a permit under section 404 of the Clean Water Act and what is called a section 408 permit under the Rivers and Harbors Appropriations Act of 1899, Zayas explains. (The permit's name comes from the fact that the applicable section of the 1899 act is contained in title 33, chapter 9, subchapter I, section 408 of the *United States Code.*) In addition to a host of other federal environmental requirements, developers must seek a water quality certification under section 401 of the Clean Water Act, which enables the state in which the project is based to participate in the approval process, Zayas adds. In particular, the Federal Energy Regulatory Commission will not issue a license until the 401 certification has been completed.

Even the relicensing of existing hydropower dams can take 10 years or more and become a costly experience, noted Murkowski and Faison in their op-ed. In California, they wrote, relicensing costs can "run as high as $50 million a dam—all for the privilege of continuing to operate an existing renewable energy project." One-third of the nation's existing hydropower facilities will have to go through such license renewals by 2030, they added.

There are even efforts under way to dismantle dams that currently generate hydropower, as evidenced by the recently announced plans by state and federal officials to try to remove four hydroelectric dams on the Klamath River in Oregon and California that have been blamed for killing fish



Extensive rock anchoring was required to accommodate a seismic fault at the foundations of the 44 MW plant being constructed on the Ohio River at the Willow Island Locks and Dam.

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and blocking fish migration (see "Klamath River Dams to Undergo Decommissioning, Removal by End of 2020," this issue, page 27).

The hydropower industry also faces a seemingly contradictory obstacle in that this renewable energy source is not always considered as renewable as, say, wind or solar power. For example, hydropower projects are eligible for only half of the federal production tax credit that wind and solar projects receive, and other federal procurement requirements pertaining to renewable energy also treat hydropower differently or exclude it altogether, notes Zayas. What is more, the requirements and credits in state-based renewable energy portfolios differ from state to state and often limit or exclude hydropower projects from renewable energy portfolio incentives, says Raymond J. Wahl, P.E., the director of power supply and operations at Missouri River Energy Services, a hydropower developer and wholesale energy supplier based in Sioux Falls, South Dakota.

Michael Pulskamp, the renewable energy program manager in the Bureau of Reclamation's power resource office in Denver, agrees that "there is definitely some inconsistency in terms of hydropower and how it's treated." He points out that although hydropower is usually included to some extent in renewable portfolios, "typically they either limit it by size or they limit it by when the project was put into service."

Kamau Sadiki, the national hydropower business line manager in the Corps's Washington, D.C., headquarters, speculates that hydropower is treated differently in part because there were so many hydropower facilities already in operation when the renewable energy incentives were being adopted. Thus, lawmakers at the federal and state levels probably worried that hydropower would dominate the incentives market if all of the existing sites were fully included, although Sadiki doesn't think that this approach "makes a lot of sense" in terms of promoting renewable energy.

A key concern in the efforts to add hydropower to nonpowered dams at Corps sites is that these dams were originally authorized by Congress for particular purposes, usually flood mitigation and navigation. And it is those original purposes, not hydropower generation, that take precedence, explains Sadiki, who stresses that any changes to the facilities must not "in any way impact" the original intent for which the dams were constructed.

The section 408 permit expressly addresses that point and was a key issue for the Corps on a series of plants currently under construction at four dam and lock sites along the Ohio River. Designed and constructed for American Municipal Power, Inc., of Columbus, Ohio, the four sites involve an 88 MW plant under construction at the Cannelton Locks and Dam, 3 mi upstream of Cannelton, Indiana; a 105 MW facility under construction at the Captain Anthony Meldahl Locks and Dam, near Neville, Ohio; a 76 MW plant under construction at the Smithland Locks and Dam, near Brookport, Illinois; and a 44 MW plant under construction at the Willow Island Locks and Dam, in Pleasant County, West Virginia. (See "Ohio River Project Adds Hydropower to Army Corps Dam," *Civil Engineering,* January 2016, pages 31–33).

The process for the section 408 permit was utilized to "make sure that we were not impacting the primary purpose

The hydropower industry also faces a seemingly contradictory obstacle in that this renewable energy source is not always considered as renewable as, say, wind or solar power.

of the facility," explains Paul Blaszczyk, P.E., S.E., M.ASCE, a vice president of MWH Global, which is responsible for the engineering of the four American Municipal Power projects on the Ohio River. The Corps was especially concerned with "how we tied into the dam [at each site] and where we physically made connections or butted up against it," Blaszczyk says. "They wanted to make sure that our structures would not adversely impact their structures long term, but also to make sure the impact to existing operations during construction is minimized and acceptable."

At two of the Ohio River sites the engineering work was especially challenging because of the presence of karst near the Smithland power plant foundations and of a seismic fault at the Willow Island foundations, the latter requiring the use of extensive rock anchoring. The Smithland project also demonstrated the lengths to which hydropower developers must sometimes go to accommodate the Corps's concerns over the existing dam and lock structures.

In April 2011 severe flooding in the Ohio River valley made the river's water levels rise dramatically near the Smithland site. They exceeded the 100-year levels and threatened to cause an uncontrolled failure of the cofferdam that had been installed for the construction phase of the new powerhouse. The cofferdam represented a temporary barrier that was maintaining the dewatered excavation at the site, explains Blaszczyk. If the cofferdam were to fail suddenly, the Corps would lose the head pond upstream of the dam, which in turn would have a major effect on navigation. For that reason, as well as to avoid an uncontrolled overtopping of the cofferdam, the Corps requested that the cofferdam be deliberately breached in a controlled manner, says Pete Crusse, American Municipal Power's vice president of hydroelectric construction. Although this controlled breach set back the construction schedule of the Smithland project, it was something that MWH Global was prepared for, says Erpenbeck.

The Smithland experience also highlights a design challenge for hydropower engineering firms, Erpenbeck adds, in that it is unclear which standards apply to the temporary structures used only during the construction phase of these projects. There's no question about the design standards for the permanent works, which must accommodate the probable maximum flood, he adds. But the process of constructing that permanent facility will involve three to five years of temporary structures before the project is completed. And so, Erpenbeck says, the question becomes, "What flood do I build the temporary works for? A 30-year flood? A 100-year flood? For the probable maximum flood? The temporary works are where you have to make some pretty tough decisions."

To help ensure that the addition of powerhouses at Corps dams and locks does not cause any problems, developers, engineers, and Corps personnel will work with hydraulic laboratories to carefully study the site. Use is made here of both computer models and large-scale physical models to better understand how the new powerhouse and related facilities will affect the hydraulic conditions on the river. For example, to evaluate the Cannelton hydropower project, MWH Global worked with Northwest Hydraulic Consultants, of Edmonton, Alberta, to construct a 1:120 scale navigation model nearly 140 ft long that represented an area of the Ohio River nearly 4,000 ft upstream of the dam and roughly 12,000 ft downstream in order to "evaluate and minimize navigational and backwater impacts of the proposed hydroelectric project," explains Blaszczyk. A 1:40 scale sectional model roughly 80 ft long also was created to reproduce a 3,100 ft reach upstream of the dam. It featured 8 of the 12 existing spillway bays, the overflow weir structure, and the proposed powerhouse, including the approach channel, Blaszczyk says.

Such models can incorporate a remotely controlled model of a tug and barge assembly that is used to "simulate the approach to the lock chambers via these models," Blaszczyk explains, "and we put dye in the water to see the flows and take time-lapse photography to make sure that the approach and exit conditions are not adversely affected."

Another project, a 36.4 MW plant under construction at the Corps's Red Rock Dam, 3.8 mi southwest of Pella, Iowa, on the Des Moines River, exemplifies the challenges of the regulatory and permitting process. All told, the project, which is both expected to begin operation by April 2018 and required to meet that deadline according to the time limits attached to its permits, will have taken 13 years to complete, explains an NHA case study. During that process, the project involved nearly 40 plans, permits, and licenses, nearly all of which had to be acquired one at a time and even sequentially. At various points Missouri River Energy Services, the developer, was forced to sign agreements with the equipment supplier and solicit bids to select the general contractor before receiving vital permits and approvals, the NHA study explains.

The section 408 process alone took roughly two and a half years to complete, in part because the Corps was concerned about a potential change in the seepage path around the concrete spillway in the center of the roughly 6,200 ft long earthen structure, says Wahl. The interplay of the requirements for the section 401, 404, and 408 permits, which in this case enabled Iowa officials to examine water quality issues at least twice during the process, also posed complications, although in the end the issues were all resolved satisfactorily, Wahl notes.

It is, however, all part of what Murkowski and Faison called "a broken federal permitting process that has created an unnavigable gantlet for hydropower projects." But efforts are under way in Congress to "get hydropower development back on track," they noted.

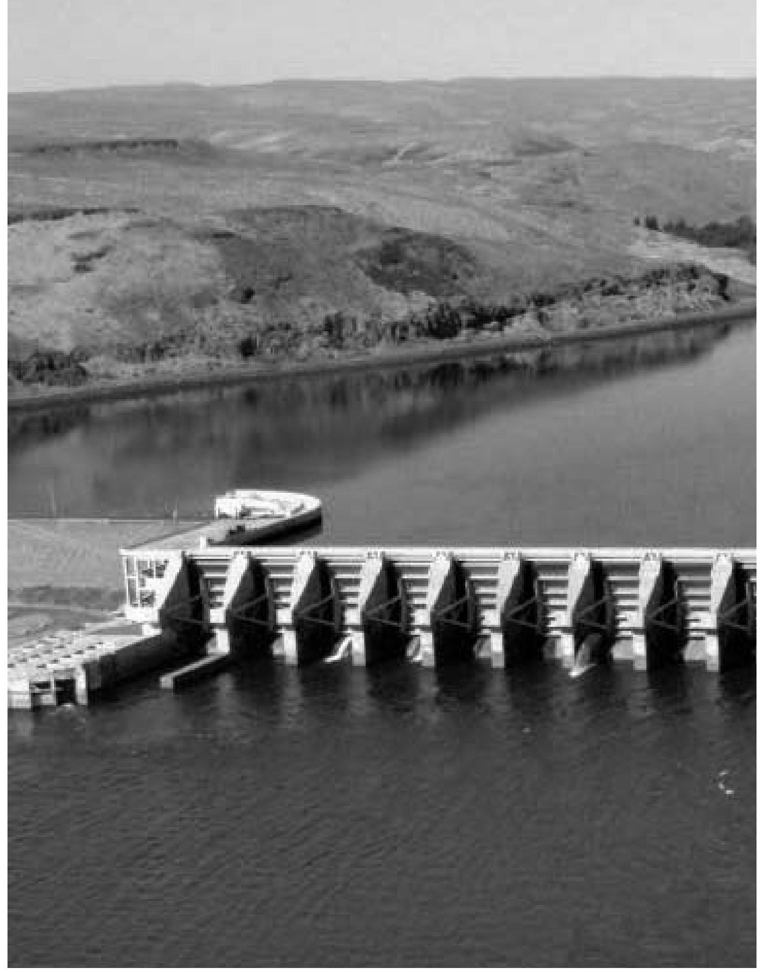
In December, for instance, the House of Representatives passed the North American Energy Security and Infrastructure Act of 2015 (H.R. 8), which is designed to make the hydropower licensing process "more timely, coherent, and collaborative by promoting predictability and requiring timely decisions by regulators," explained an NHA description of the measure. In the Senate, the Energy Policy Modernization Act of 2015 (S. 2012), among other reforms, "would direct agencies to expedite the permitting of new projects and the relicensing of existing ones, and would advance the use of hydropower nationwide," Murkowski and Faison noted. This bill was approved with bipartisan support in July by the Senate Committee on Energy and Natural Resources, which is chaired by Murkowski, and is awaiting a vote by the full Senate.

Whether these measures will ultimately be enacted remains in doubt, however, because President Obama has threatened to veto the House bill "claiming it would undermine environmental safeguards," Murkowski and Faison noted. "The hydropower measures do not have the unintended effect of rolling back environmental protections," says LeRoy Coleman, the NHA's senior manager of strategic communications. "They simply allow for an organized schedule and ensure that state and federal regulators collaborate in the process."

Another measure being considered by Congress is the Fixing Operations of Reservoirs to Encompass Climatic and Atmospheric Science Trends Act, or FORECAST Act (H.R. 813), which was introduced in February 2015 by Representative Jared Huffman (D-California). Huffman has argued that the Corps operates many of its reservoirs "on outdated and obsolete water control manuals, some of which are as much as 60 years old." Thus, the FORECAST Act would require the Corps to update its manuals on the basis of "the latest atmospheric science and weather forecasting," a press release from Huffman's office explained.

Both the FORECAST Act and a related Senate measure, the Water in the 21st Century Act (S. 176), introduced in January 2015 by Senator Barbara Boxer (D-California), are still in their respective House and Senate committees.

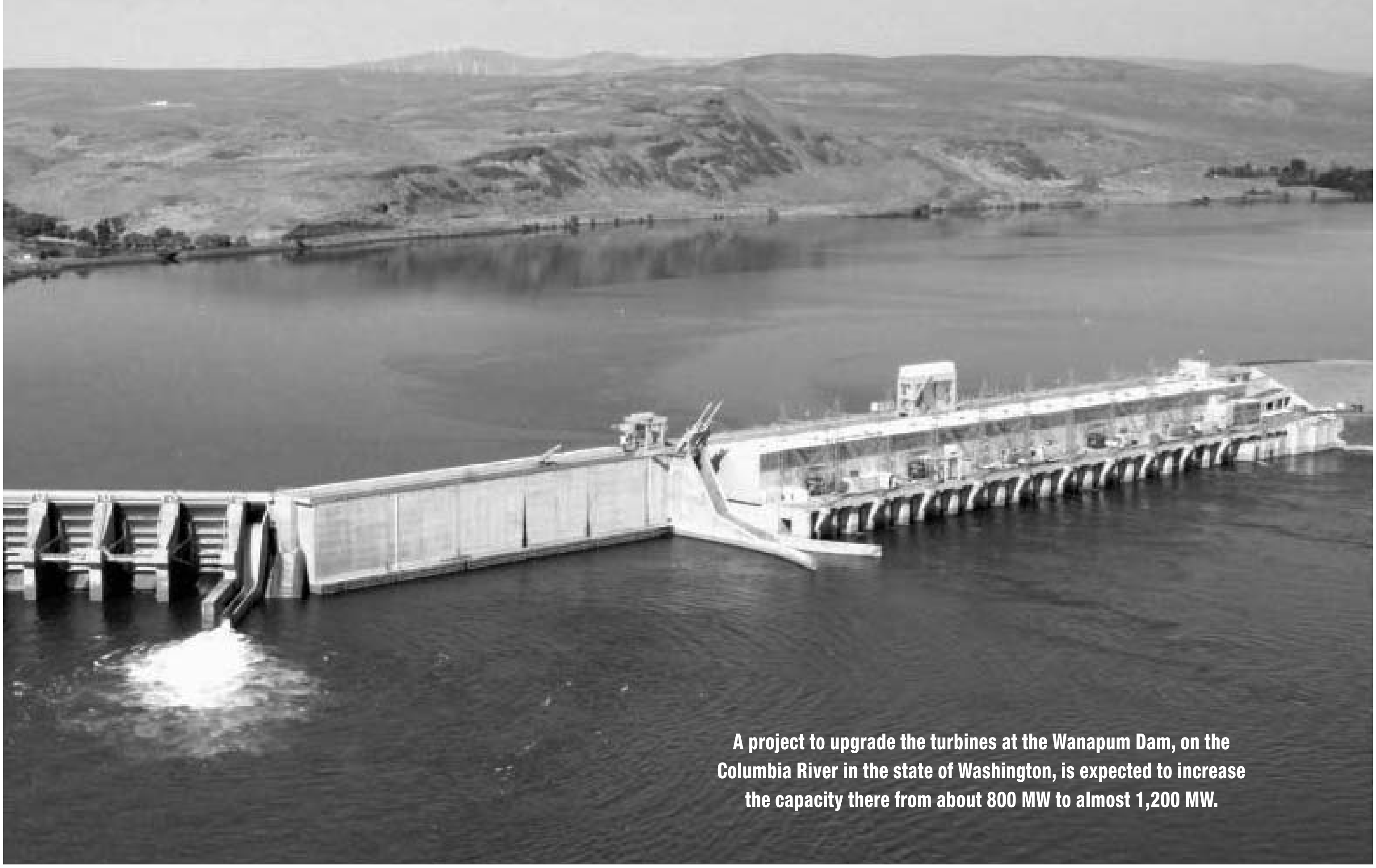
The significance of these two proposals for hydropower lies in the so-called rule curves that the Corps and the Bureau of Reclamation use in determining how much water to retain or release at the reservoirs they operate. Basically, the rule curves currently function to keep the impounded water levels at reservoirs below a certain maximum specified level during flood seasons so that the influx of floodwater can be stored. But "these very rigid rule curves," often established in the 1950s or 1960s, can result in the release of water at hydropower facilities in anticipation of a need for greater flood storage, explains the University of Washington's Hossain, even if it might have been better to retain that water "to keep the water level as high as possible so the turbines are running at full capacity."



Hossain calls this the "missed hydropower potential" and explains that it may not be necessary to release water for additional flood storage space if the forecast weather conditions at monthly to seasonal timescales during a particular period do not match the conditions established in the rule curve on the basis of 60-year-old climatology. Today, Hossain explains, the monthly to seasonal forecasts of weather conditions—including temperature, pressure, and snow cover—are made using state-of-the-art methods widely used by the atmospheric science community, and they feature extensive use of observations and high-resolution numerical models.

"To compromise between flood control and hydropower generation, the traditional and static rule curve sacrifices water generation potential at the expense of a false sense of flood security during periods that are anomalously dry or free of extreme events," wrote Hossain in an essay entitled "Maximizing Hydropower Generation with Observations and Numerical Modeling of the Atmosphere," which he coauthored with Yabin Miao and Xiaodong Chen, both graduate students in the University of Washington's civil and environmental engineering department. The article has been accepted for publication in ASCE's *Journal of Hydraulic Engineering*.

Greater flexibility regarding rule curves could also enable hydropower projects to provide what the hydropower industry calls ancillary services, including grid stabilization, reserve generation, time shift energy storage and delivery, and the integration of variable renewable energy sources on



A project to upgrade the turbines at the Wanapum Dam, on the Columbia River in the state of Washington, is expected to increase the capacity there from about 800 MW to almost 1,200 MW.

the grid. By varying the flow output of a project rather than following a strict rule curve, "you can provide these ancillary services to the grid," says Wahl. "And that could be more valuable than just the energy you're getting out of the project," he explains, because it allows other renewable energy sources to become involved in the marketplace.

What Hossain would like to see is the use of modern weather forecasting capabilities, especially those that use observations and numerical modeling, to provide detailed information "to tweak the decision of how much water to release, how much water to hold, without sacrificing safety against flooding." In their *Journal of Hydraulic Engineering* article, Hossain and his coauthors gave particular attention to Hungry Horse Dam, which is 9 mi southeast of Columbia Falls, Montana, and is operated by the Bureau of Reclamation. Instead of the current rule curves used to operate the dam, the article states, "a more dynamic rule curve," one determined by combining forecasts of the atmosphere based on numerical models with observations of the snowpack and upstream surface water, "has the capability of providing more hydropower potential" without creating any greater flood risk. This more dynamic approach could result in almost 14 additional days of hydropower generation at times of greatest potential during low-flood periods, which could then produce a theoretical increase in hydropower of about 3.7 percent during the flood season, the article explains.

At the Corps, Sadiki disputes the idea that increasing the water levels maintained at reservoirs with hydropower facilities will not also increase the risk of flooding. He especially notes that a changing climate, which "we haven't fully integrated into our analysis," could alter historical rain patterns and hydrology, making it even more difficult to accurately forecast upcoming conditions. Moreover, while the Corps has not altered the rule curves at any dams specifically to increase hydropower generation, there are examples of times during flood seasons when "we kept the water behind a [dam] a bit too long above those rule curves, and another significant event came and we didn't have the storage capacity," Sadiki says. As a result, the water had to be released downstream at a time when it caused damage. "So we don't want to get caught in that situation" because of changes to the rule curves, he states.

For the Corps, the Bureau of Reclamation, and other groups, upgrading, refurbishing, or otherwise modernizing the equipment is a key approach to increasing hydropower generation. "Our biggest challenge now is aging infrastructure," explains Sadiki, who notes that the Corps has estimated it will need roughly $3.4 billion over the next 20 years "to make necessary improvements and also take advantage of upgrade opportunities." Roughly 40 percent of the Corps's hydropower fleet is 49 years old or older, and the rate of forced outages, which are often caused by the shortcomings of aging equipment, is currently well above 5 percent, in contrast to the target range of roughly 2 percent, "simply because we can't resource the needs fast enough to address that issue," Sadiki says.

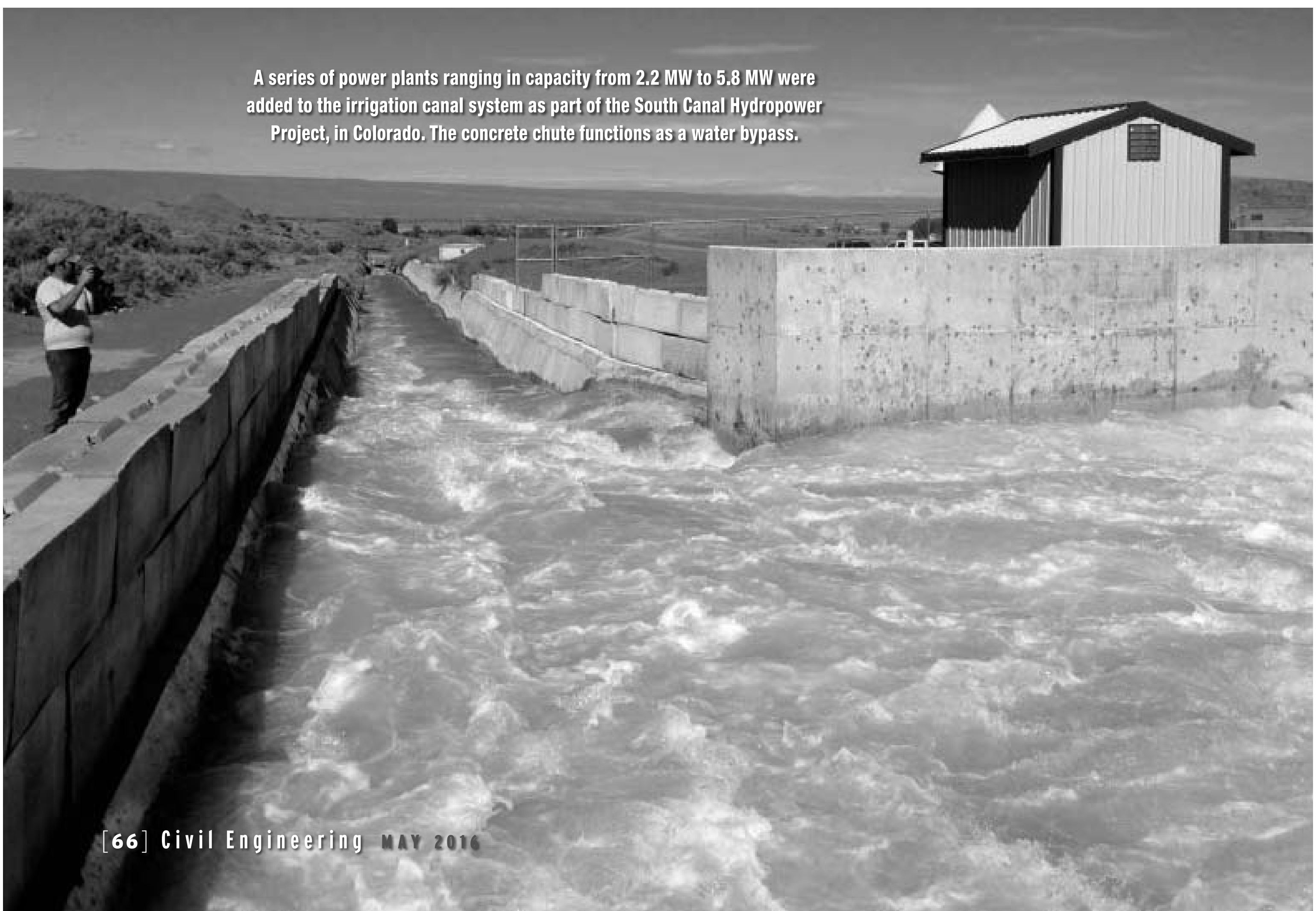
Improvements can range from rewinding generators, which involves essentially rebuilding the existing equipment to increase the efficiency and therefore the energy generation of the units, to, Sadiki says, outright replacement with newer, more advanced technology. In many cases, these improvements bring power generation improvements of 5 to 8 percent, notes Oak Ridge National Laboratory's Hadjerioua. However, improvements even more dramatic are possible.

For example, at the Wanapum Dam, which is on the Columbia River 6 mi downstream of Vantage, Washington, and is owned by the Grant Public Utility District, a project to upgrade the existing 10 turbines with newer, more efficient equipment is expected to increase the generating capacity by roughly 50 percent, from about 800 MW to almost 1,200 MW, says MWH Global's Erpenbeck. Likewise, the construction of a new, 120 MW powerhouse at the Holtwood Dam, which is on the lower Susquehanna River in Holtwood, Pennsylvania, south of Lancaster, and is owned by Talen Energy, of Allentown, Pennsylvania, roughly doubled the capacity there by supplementing the 108 MW powerhouse, which dates to 1910, according to information on the website of the project's engineering firm, Kleinschmidt, which has corporate offices in Pittsfield, Maine.

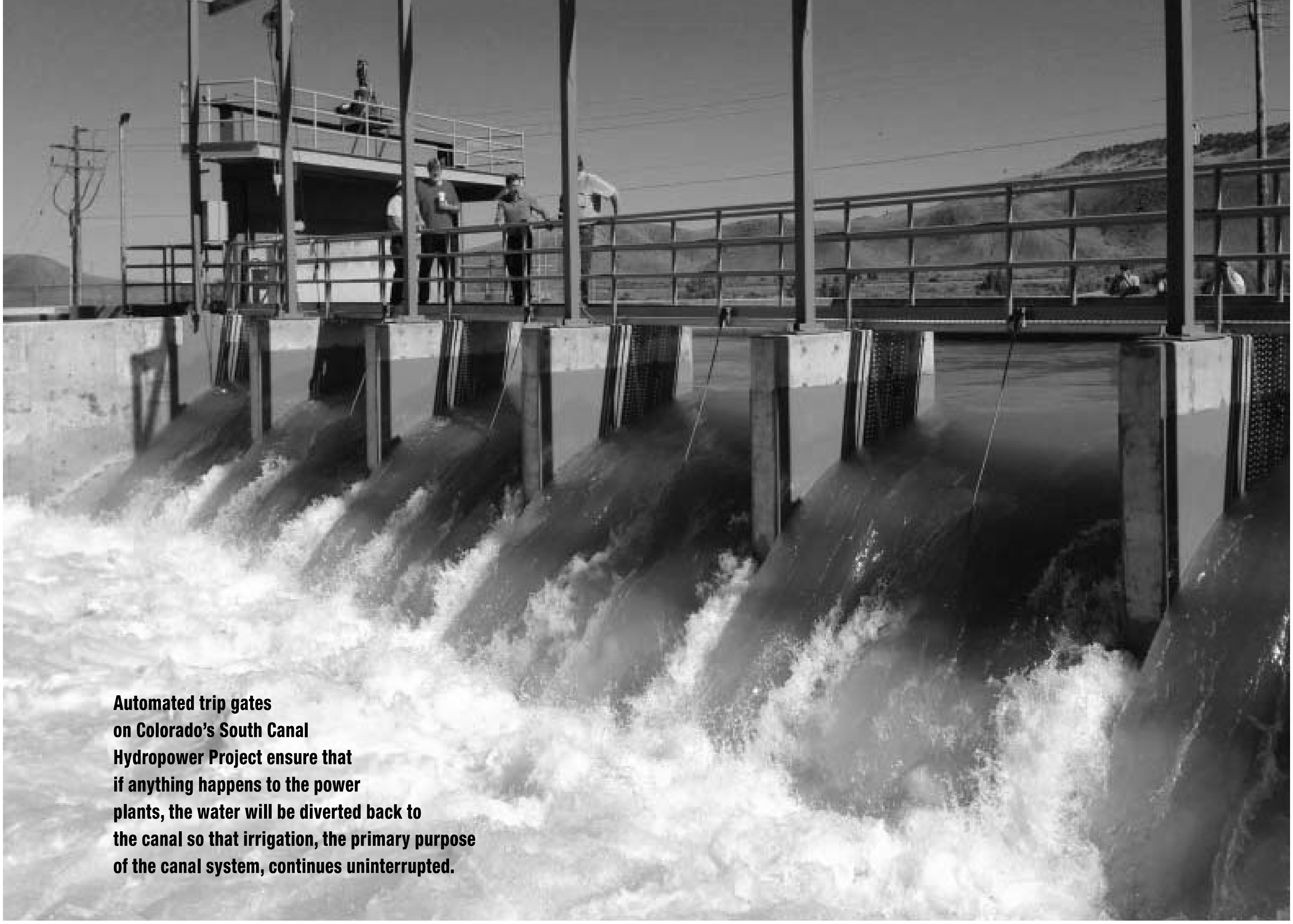
The Holtwood project also added a new fish passage to the site, which is another engineering effort that can be used to increase hydropower generation. For example, a new fish passage system designed by the engineering firm HDR, Inc., of Omaha, Nebraska, at the York Haven Dam, on the lower Susquehanna just below Harrisburg, Pennsylvania, "will also allow us to operate at different flow conditions than what we operate under now, so we'll be able to operate more days of the year and more hours," explains Eli Hopson, J.D., the senior counsel for Cube Hydro Partners LLC, of Bethesda, Maryland, which operates the power plant there. The engineering of the passage involved modeling the river flows to determine the best location for the placement of rocks "to create a flow pattern to mimic the natural flow of the river," adds Hopson.

As noted earlier, dams are not the only nonpowered sites to which hydroelectric systems could be added. In a March 2011 report, *Hydropower Resource Assessment at Existing Reclamation Facilities*, Bureau of Reclamation researchers analyzed 530 sites, including dams and "canals, tunnels, dikes, and siphons," and determined that 191 of them "have some level of hydropower potential," possibly as much as 268 MW.

Pulskamp, who helped prepare the 2011 report, clarifies that many of the bureau's canals are operated for only a portion of the year, say, the seven-month irrigation season. Thus, he explains, of the original 530 sites studied, only about 70 might actually be economically viable. At the same time, technological advances in turbines and generators are making it possible to generate power at lower cost even at smallest sites. For that reason and the fact that there is wide variability in site conditions, Pulskamp says that when the bureau followed up the 2011 report with a supplemental study in March 2012, *Site Inventory and Hydropower Energy Assessment of Reclamation Owned Conduits,* the latter listed 373 canals that had not been considered large enough to be included in the earlier study, but it did not "label those sites as economically viable or not." It simply noted that these sites represented nearly 104,000 kW of additional potential power.



A series of power plants ranging in capacity from 2.2 MW to 5.8 MW were added to the irrigation canal system as part of the South Canal Hydropower Project, in Colorado. The concrete chute functions as a water bypass.



Automated trip gates on Colorado's South Canal Hydropower Project ensure that if anything happens to the power plants, the water will be diverted back to the canal so that irrigation, the primary purpose of the canal system, continues uninterrupted.

SORENSON ENGINEERING, INC., *BOTH*

For a good example of how canals can be adapted to generate hydropower, Pulskamp points to the South Canal Hydropower Project, which is being carried out in western Colorado by the Uncompahgre Valley Water Users Association, headquartered in Montrose, Colorado. Over the past several years, four hydroelectric systems ranging in capacity from 2.2 MW to 5.8 MW have been installed along the 11.4 mi South Canal. A fifth powerhouse is expected to come onstream in June, and additional sites might be added later, explains Steve Anderson, a former licensed civil engineer who is now the manager of the Uncompahgre Valley Water Users Association. Working with Sorenson Engineering, Inc., based in Idaho Falls, Idaho, the Uncompahgre association had stilling basins, penstocks, and the power plants themselves installed along the canal route. And just as hydropower systems added to dams must not interfere with a dam's original purpose, the same is true here. So-called trip gates have been installed at each hydropower system so that, if anything happens to the power plant, the water will be diverted back to the canal to ensure that irrigation will continue uninterrupted, says Anderson.

Despite many obstacles, the future of efforts to increase hydropower production at dams and other water-related sites does indeed look bright. Sadiki points to a program that encourages investment by municipalities, electricity cooperatives, or other customers that buy power from Corps facilities. The program has been in place since around 2000 and so far has raised more than \$800 million. "Without the customers, it would have been extremely difficult for us to be where we are now" in terms of upgrades, refurbishments, and other needed improvements, Sadiki says.

Moreover, since the publication in 2012 of *An Assessment of Energy Potential at Non-Powered Dams in the United States,* "state officials have been calling us to see if dams in their states could be powered," notes Hadjerioua. He explains that since the Oak Ridge report was a national assessment, government officials or potential developers will have to carry out their own feasibility studies to determine the viability of particular dams. Nevertheless, he points with pride to the following statistics: Approximately 160 nonpowered dam projects received a preliminary Federal Energy Regulatory Commission permit, the first step in the regulatory process to add hydropower, between 2012 to 2014, representing 1.35 GW of potential new hydropower. And since those numbers do not include the permits issued by the commission in 2015 or 2016, Hadjerioua says, an even bigger wave of new hydropower could be on its way. **CE**

Reid

Robert L. Reid is the senior editor of Civil Engineering.

Water for Utah's

The Central Utah Water Conservancy District has completed much of the Utah Lake System, an ambitious effort to convey water from eastern Utah to the major population centers in the state's northern and central regions. Successful completion of these projects has entailed overcoming design and construction challenges pertaining to seismic risks, landslides, cavitation control at high-head turnouts, flow and pressure control between the upper and lower delivery systems, and the need to remove accumulated material from within the pipelines to maintain system capacities.

By Mark Breitenbach, P.E., M.ASCE, Nathaniel Jones, P.E., M.ASCE, and Adam Murdock, P.E., M.ASCE

OVER THE LAST DECADE, the Central Utah Water Conservancy District, in Orem, has designed and constructed 13 projects to complete 32 mi of large-diameter pipeline and flow control structures for the Utah Lake Drainage Basin Water Delivery System. Commonly referred to as the Utah Lake System (ULS), this series of pipelines and flow control structures involves more than $300 million of constructed facilities to deliver water to municipal areas and supplement streamflows to protect fish and wildlife in certain local waterways. The project includes six significant flow control structures (120 cfs or more), facilities for launching and receiving "pigs" through 96 in. and 60 in. diameter pipelines, a 6.7 million gal rectangular

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