# Generating More Hydropower Using Weather Forecasts

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**THE OPERATION FOR** almost all hydropower dams in the United States is guided by water control manuals that were developed when the dams were constructed many decades ago. Reservoir control manuals are often defined in terms of '*Rule Curves*' that specify the storage targets the reservoir needs to meet at specific time intervals of the year. The dam operator releases water as necessary and as close to the recommended levels in the manual to achieve the respective targets for each stakeholder need [*Loucks et al.,* 2005]. Actual releases vary depending on the storage and dynamic inflows that actually occur.

However, these rule curves do not account for the change in inflow patterns that have resulted due to changes in climate and land cover conditions. Furthermore, releases in the rule curves are specified independently of the future inflow forecasts. In fact, release guidelines are typically based only on existing storage volumes and within-year periods using a climatology of historical flow observations. Now that weather forecasts are widely available in real-time, such archaic use of rule curves misses the opportunity to operate hydropower dams more dynamically at a higher level of efficiency.

For instance, in a weaker-than-average flood-prone month during the flood season, lowering the pool to rule-curve recommended level will result in significant loss in hydropower generation through non-powered release through spillways. This otherwise could have been avoided if inflow forecasts were made ahead of time to maximize the flow through the powerhouse [*Miao et al.,* 2016]. This is just one of the many scenarios where the static and traditional rule curves could be made more adaptive for real-time operations to harvest more hydropower.

Current numerical weather forecasting models can provide reasonable accuracy over short-term period of 5-10 days, which may be sufficient in many cases to forecast, for instance, a peak flood event and adjust the dam operations accordingly. Not only can the weather forecasts provide an emergency flood warning, but incorporating that forecast information to adjust reservoir operations can often result in two-fold benefit of maximizing hydropower production without sacrificing downstream flood safety. A term we introduce here is called "flood-safe hydropower," which we believe can be maximized by making little tweaks to reservoir operations using widely available weather forecasts.

## Flood-safe hydropower benefits: A proof of concept for a U.S. dam

We considered two competing benefits of hydropower and flood control for a dam in the United States (Pensacola dam in Oklahoma) to demonstrate the concept of how weather forecasts can be leveraged to generate more 'flood-safe' hydropower. We used NOAA's Global Forecast system (GFS) of weather forecasts up to 15 days lead time. These forecasts were applied to a hydrologic model to forecast inflow into the Pensacola dam that receives unregulated flow. Finally, we applied a sequential optimization routine with all known constraints defined by hydrologic/hydraulic limits of spillway, turbines and downstream flood safety, environmental flows. The downstream flood safety defined the upper bound of total flow that can be released from the dam via turbines and spillways. We also sought input from the dam operating agency, U.S. Army Corps of Engineers (USACE), and existing public records to make sure the optimization problem was set up as realistically as possible using real-world data.

For a flood event that occurred during March 2012, the flood-safe hydropower optimization strategy revealed a *net benefit* of 13,048 MWh, in addition to what operations without optimization would have yielded. With an average retail price of 7.90 cents/kWh, this benefit amounts to $1,030,792. For the competing objective of

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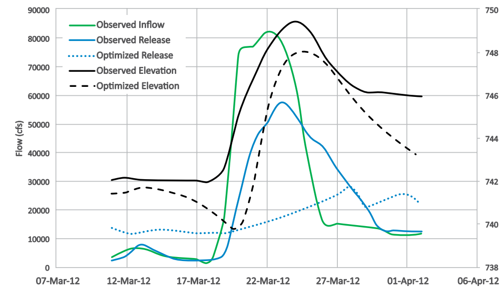
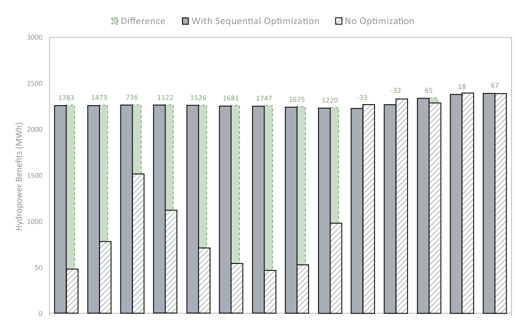



**Figure 1.** (a) Optimized releases and elevations for Pensacola dam along with the respective observed values using real-time sequential run, updating forecasts every alternate day from 11 March to 17 March (b) Daily comparison of hydropower benefits (MWh) obtained using observed operations (without optimization) and from sequential optimization (Ahmad, 2017).



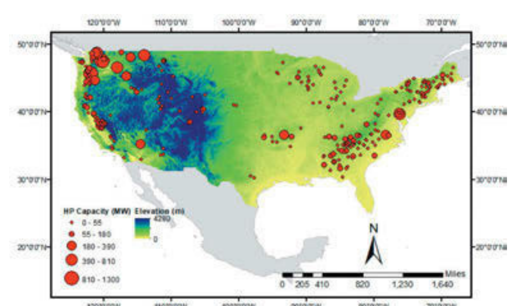




**Figure 2.** Distribution of small to medium hydropower dams in the US that receive unregulated inflow at upper catchments of river basins. The circle size represents turbine capacity.