Improving Hydroelectric System Forecasting and Management in a Changing Climate

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About the project

Climate change forecasts for the Sierra Nevada show the potential for significant reductions in snowpack, as well as altered precipitation and runoff patterns. These impacts will affect hydroelectric power generation, an important part of California's low-carbon energy mix. PG&E's hydroelectric system has a total generating capacity of nearly 4,000 MW and relies on nearly 100 reservoirs and seasonal snowpack storage.

As part of PG&E's climate resilience initiative, the company is working with the University of California and the California Department of Water Resources on a multi-year research project to help PG&E better understand how to continue to optimize hydroelectric generation as precipitation patterns are altered by climate change.

Using California Energy Commission funds, the research team is installing a next-generation hydrologic observatory near PG&E's North Fork Feather River facilities that integrates satellite remote sensing data with a ground-based measurement network. The research will capture data on the variability of snowpack, climate, soil moisture and other factors, which will improve PG&E's monitoring and predictive tools, reduce uncertainty in runoff forecasts and increase resilience to climate change. The project will also assess the costs and benefits of using the intelligent water information system with physically based forecasting, as compared to current empirically derived forecast models.

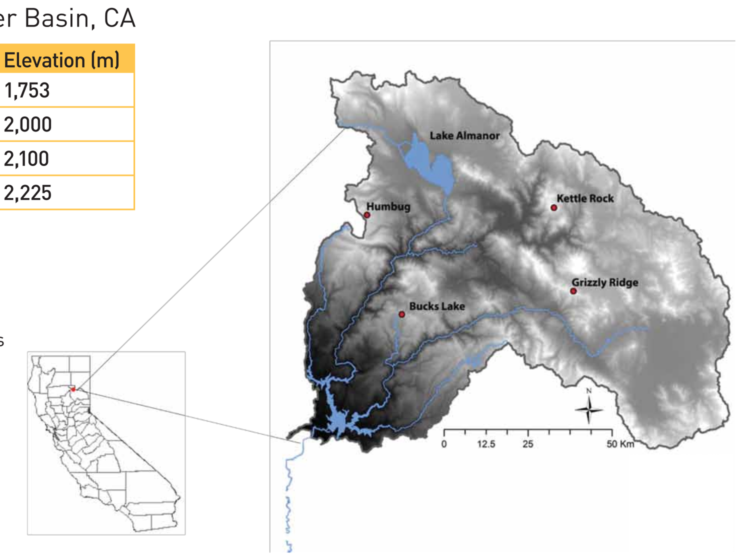
Enhanced planning and operation of PG&E's hydroelectric system is increasingly important as the company expands supplies of variable renewable energy sources, such as wind and solar. Hydroelectric power is a flexible resource that can help integrate these variable renewable energy sources into the system. Doing so will require a better understanding of hydrologic conditions for more precise control of available water supplies for hydroelectric generation.

PROJECT SITE

Feather River Basin, CA

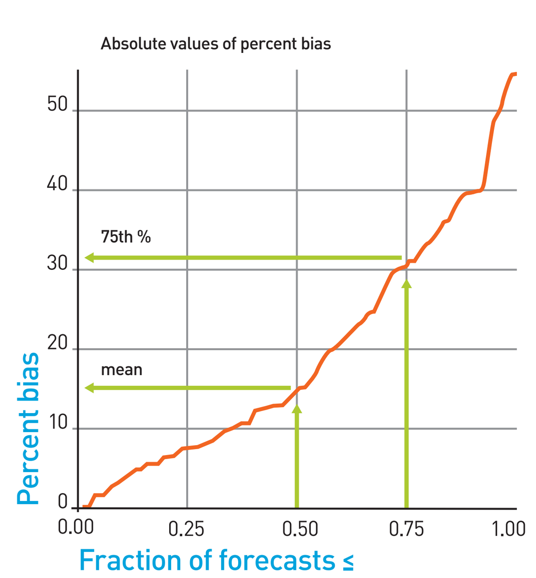
Name	Elevation (m)
Bucks Lake	1,753
Humbug	2,000
Grizzly Ridge	2,100
Kettle Rock	2,225

Elevation, m
High: 2811
Low: 35
Snow pillows



Project drivers

Climate change has the potential to increase bias in empirically derived forecast models.



$$\text{BIAS} = \left|\frac{\text{FORECAST}}{\text{OBSERVED}}\right|$$

Estimates made with simple regression models

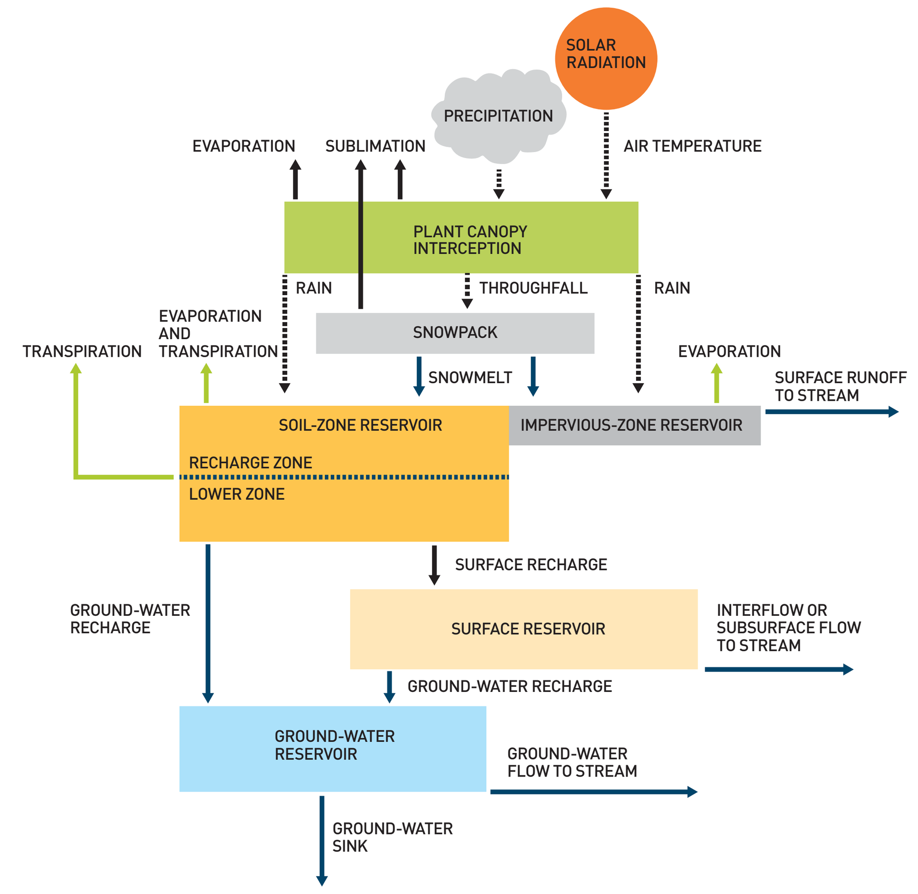
Wet years tend to be under-forecast, dry years over-forecast

Weekly to daily forecasts based on historical data are more biased

Using a physically based model for mountain hydrology

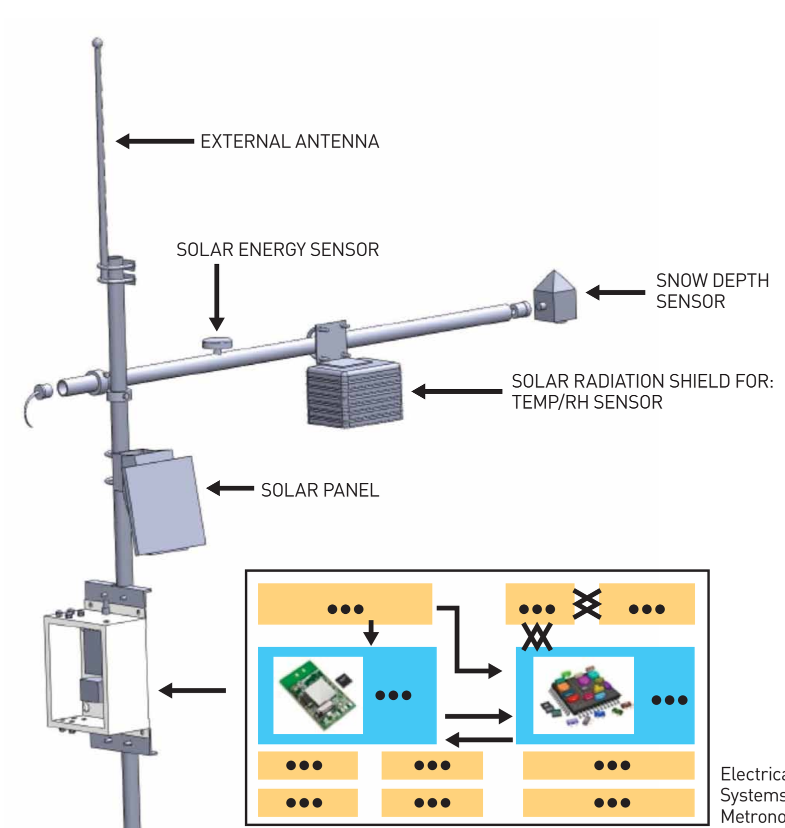
Developed by the U.S. Geological Survey, the Precipitation-Runoff Modeling System (PRMS) is a distributed-parameter, physical process-based modeling system designed to evaluate the response of various combinations of climate and land use on streamflow and general watershed hydrology.

The California Department of Water Resources Snow Surveys section and PG&E Water Management are using the Feather River Basin PRMS to complement empirically derived methods for seasonal runoff forecasting and daily storm hydrograph forecasting.

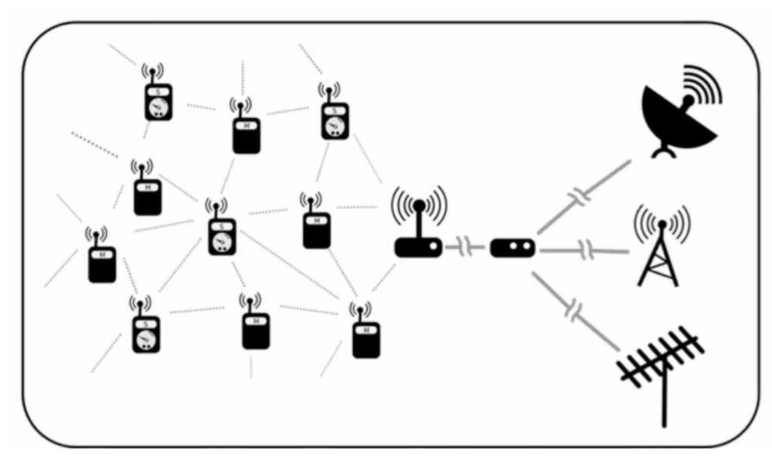


Sensor design and layout

The project team is deploying groups of sensors at each site (a sensor node) to form a network to capture variability of landscape features.



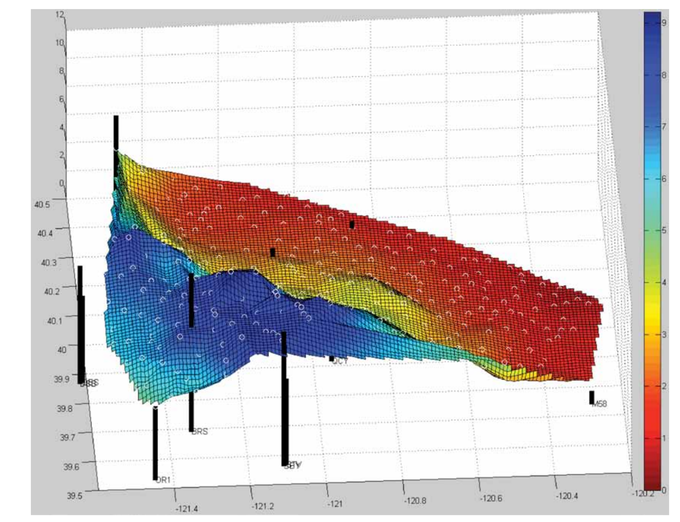
(Buried below-ground are soil moisture, temperature, and matric potential sensors.)



The wireless data logger housing is built with robust industrial materials to withstand the harsh winters of the Sierra Nevada.

Visualizing the data

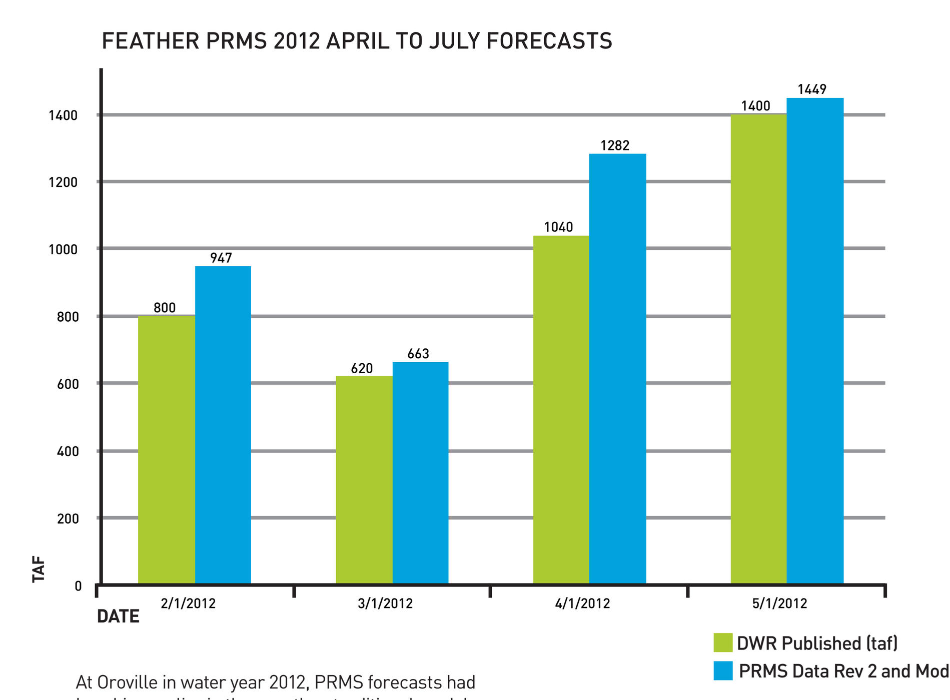
The Feather River Basin PRMS employs a distributed input scheme for areal extrapolation of point observations (shown as black columns) across mountainous terrain—accounting for rain shadows, orographic enhancement, and other important features influencing the hydrologic cycle.



Research staff installing a sensor node at Bucks Lake

Physical vs. empirical forecasts

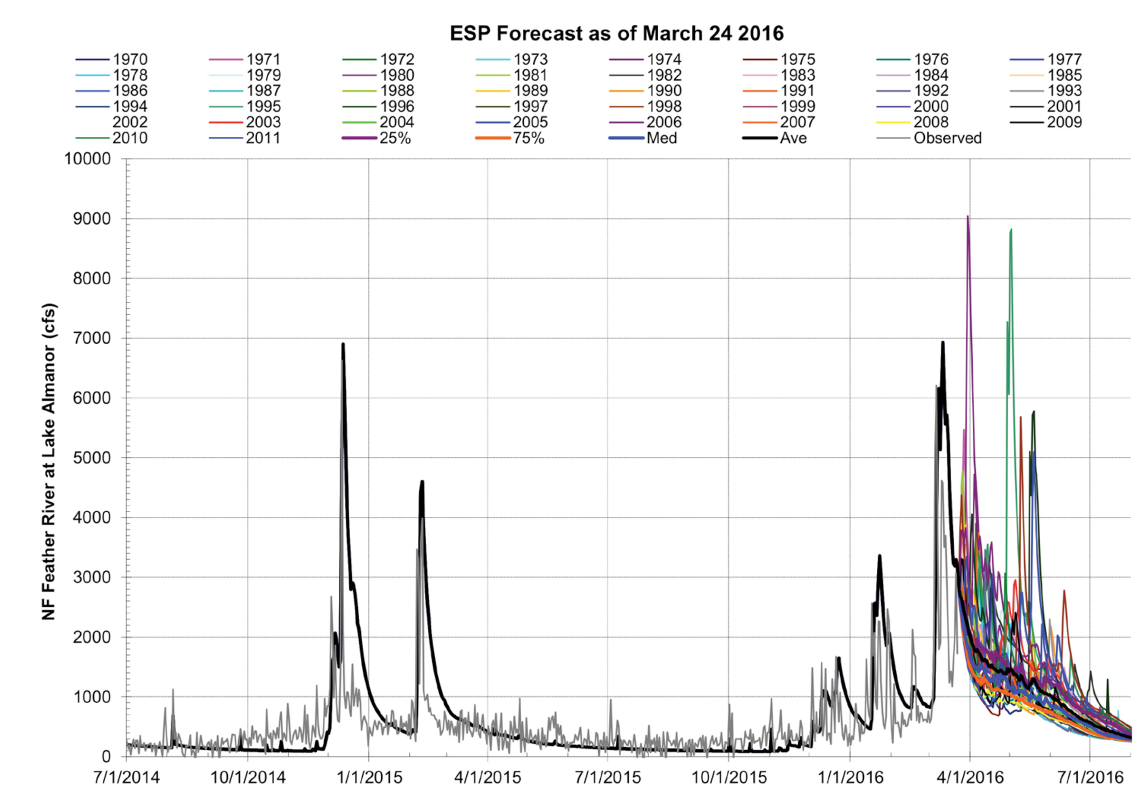
Physically based models, such as PRMS, offer much promise for capturing additional intensity, variability and hydrologic processes that determine runoff outcome, compared to empirically derived methods which currently are more widely used for water allocation and other hydroelectric power operational decisions.



At Oroville in water year 2012, PRMS forecasts had less bias earlier in the year than traditional models.

PRMS performance

Compared to empirically derived methods, the PRMS model captures more data inputs and generates more accurate and earlier determinations of water runoff.



Forecasts from PRMS showed the potential to capture antecedent conditions and runoff recovery for better operational performance.

Discussion

The new sensor installations are designed to augment how data on snow and weather are currently collected. Existing snow and weather station sites are not spatially representative, and tend to be located in flat clearings as opposed to forested and sloped areas, which are important to measure. Much of the North Fork Feather River basin is forested, and the new sensor networks will sample across aspect, slope and vegetation, as well as elevation differences.

The existing measurement network also lacks data on soil moisture, and has very limited measurement of solar radiation and relative humidity. As new monitoring network data become available, the team will be able to measure snowpack storage, snowmelt, soil-water storage, evapotranspiration, and solar radiation—all of which may be used in PRMS calculations—to better understand results, and improve inputs to the model.

Forecasts will be improved by the availability of accurate, spatially dense data on the multiple fluxes and states of the hydrologic cycle. While hydrologic models can estimate these quantities, only with accurate, spatial data can one improve, evaluate and verify forecasting.

PG&E Hydro Operations staff deliver sensors to remote field locations.

Future directions

An important component of the project is quantifying the economic benefits of the new approach. This will include a comparison between the costs and benefits of current empirically derived forecasts with using the new intelligent water information system with physically based forecast models.

Improved predictive planning and scheduling tools to manage hydroelectric water resources are needed to adapt to increasing vulnerabilities and uncertainties of changing climatic water inputs, while meeting today's evolving resource flexibility needs. In addition to the primary benefits of more efficient and effective hydropower operations, secondary benefits from this application may involve better definition or quantification of safety and environmental issues arising from climate change.

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