

# INTEGRATED FORECAST AND RESERVOIR MANAGEMENT (INFORM) FOR NORTHERN CALIFORNIA:

## SYSTEM DEVELOPMENT AND INITIAL DEMONSTRATION

*by*

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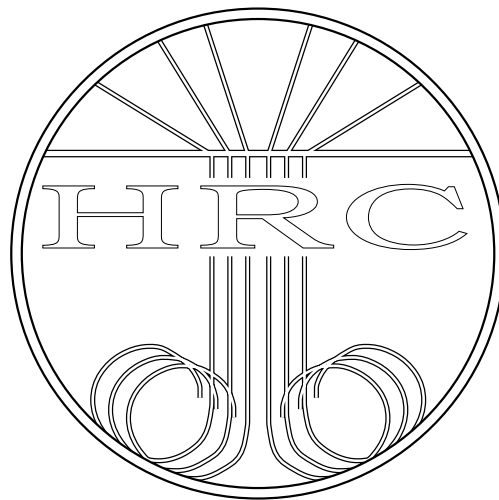
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## **Abstract**

This report describes the first three-year phase of the Integrated Forecast and Reservoir Management (INFORM) project. The primary INFORM objective is to demonstrate the utility of present-day meteorological/climate and hydrologic forecasts for the Northern California river and reservoir system, including all major reservoirs on the Trinity, Sacramento, Feather, American, and San Joaquin rivers, and the Sacramento-San Joaquin Delta. In close collaboration with water forecast and management agencies of the region, a software system was designed and implemented in a distributed manner, with components that ran at various agency and research centers. The system contains real-time short-range forecast components, off-line longer-range forecast components, and off-line decision components that span forecast and decision time scales from hours to seasons. In all cases, forecast uncertainty is explicitly characterized and used for risk-based decision support. Extensive tests with historical data and an initial 5-month period of operational “dry run” testing for the wet season of 2005-2006 showed that system components perform well, and clearly demonstrated the value of the system in advancing the current state of forecast, management and planning operations in the region. The main recommendation is to continue the demonstration of the INFORM system for two to three more years to reliably quantify real-time performance and utility for planning and management, and to explore more fully the various applications to which the system is suited.

## **Key Words**

Ensemble precipitation forecasting; ensemble temperature forecasting; ensemble flow forecasting; risk-based decision support; adaptive reservoir management.



# Executive Summary

## Introduction

Considerable investments have been made toward improving the quality and applicability of climate, synoptic, and hydrologic forecast information, and earlier retrospective studies have demonstrated clearly that the management of water resource systems with large reservoirs can potentially benefit from such information. However, prior to this project no focused program has ever aimed to quantify and demonstrate these benefits in an operational environment. There are three main reasons why this has not been previously accomplished:

- (a) synoptic and climate forecasts include substantial uncertainty, and their effective use in management requires procedures that explicitly account for that uncertainty both in flow forecast and decision models/processes,
- (b) existing reservoir management procedures depend on presently available information and operate under set institutional constraints, so that nontrivial technical and institutional changes are required to use information of a different type (i.e., improved hydrologic, synoptic, or climate timescale forecasts),
- (c) the development and application of such systems requires that the technical teams maintain a close relationship with the operational users, and have a clear understanding of their operational environment.

As a result, up to this point few reservoir managers have been able or willing to dedicate the considerable effort required to utilize new approaches and realize the benefits of improved forecast information.

## Purpose

The purpose of the Integrated Forecast and Reservoir Management (INFORM) Project is to demonstrate increased water-use efficiency in Northern California water resources operations through the innovative application of meteorological/climate, hydrologic and decision science.

## Project Objectives

In accordance with its purpose, the particular objectives of INFORM are to:

- (a) implement a prototype integrated forecast-management system for the primary Northern California reservoirs, both for individual reservoirs as well as system-wide; and
- (b) demonstrate the utility of meteorological/climate and hydrologic forecasts through near-real-time tests of the integrated system with actual data and management input, by comparing its economic and other benefits to those accruing from current management practices for the same hydrologic events.

## **Project Outcomes**

To achieve the general objectives of the INFORM project, the authors performed the following technical tasks:

- (a) Created the Oversight and Implementation Committee for project oversight and assistance with system implementation and tests.
- (b) Developed, implemented and performed validation of climate and weather INFORM components for Northern California with historical data and real-time data.
- (c) Developed, implemented and performed validation of hydrologic INFORM reservoir-inflow forecasts with historical and real-time data for all major reservoirs of Northern California.
- (d) Developed, implemented and performed validation of decision INFORM components with historical and real-time data for the Northern California water resources management system.
- (e) Integrated INFORM system climate, hydrology and decision components and performed initial operational tests producing real-time ensemble forecasts out to lead times of 16 days four times daily for the wet season 2005-2006.
- (f) Performed assessments of the integrated forecast-decision system value via retrospective simulation experiments.
- (g) Held INFORM design, assessment and training meetings with operational forecast and management agency staff.

## **Conclusions**

There are several technical and specific conclusions that have been drawn from the outcomes of the project in the areas of meteorology/climate, hydrology, and decision science. These conclusions are detailed in the report (Chapter 7). The most important conclusion of the report is that, with available real-time availability of forecast information from the National Centers for Environmental Prediction and with real-time observed precipitation and temperature as well as hydrologic model state values from the California Nevada River Forecast Center, integrated forecast-management systems are realizable as effective operational decision support tools for management and planning of California water resources. Such systems assist water managers in translating forecasts and their uncertainty into a range of effective risk-based policies. In addition, these systems can advance current operational practices by (a) incorporating forecast uncertainty in decisions on a range of time scales, and (b) allowing for regional coordination of management decisions.

## **Recommendations**

Perhaps the most important recommendation arising from this work is to continue the INFORM demonstration experiments for two or (more usefully) three additional operational seasons beyond the system “dry run” wet season of 2005-2006 in continued close collaboration with the forecast and management partner agencies in Northern California. These additional operational seasons are necessary for the reliable evaluation of the INFORM system performance and utility in specific situations, for the application of any system corrections and adjustments that appear necessary from system evaluation, for the establishment of a protocol for its operational use by the collaborating agencies; and for exploring alternative applications for the system that have been suggested by sponsor agencies.

A second overarching recommendation pertains to the use of the INFORM system in a stand-alone mode for climate change simulations. The INFORM system closely emulates several of the actual forecast and management procedures used in routine operations in Northern California. As such, it constitutes a realistic simulation system for impact analysis in this region using the output of state-of-the-science global climate models that predict climatic variability and change. Such impacts include potential future climatic influences on precipitation, temperature, and snowmelt and runoff patterns in the Sierra Nevada resolved on the scale of INFORM catchments (from hundreds to thousands of square kilometers), the effects of increased demand scenarios, and the effectiveness of alternative management scenarios for improved water-use efficiency.

## **Benefits to California**

A significant benefit of this first phase of INFORM for Northern California is its contribution toward the integration of operational water supply forecast and management activities by federal and state agencies toward increased water use efficiency. The mutual technology transfer and science cooperation between research centers and operational agencies is another. Lastly, even in its current prototype form, the INFORM system provides a unique resource for operational and management agencies in Northern California. These agencies may benefit by using this system as a tool for evaluating potential decision policies pertaining to the use of Northern California’s water supply during real time operations and for seasonal planning, both for the present and future years.

