Translating Forecast Uncertainty into Information for Emergency Management under Folsom Reservoir Flood Operations

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BIOGRAPHICAL SKETCH

David is a Professor of Civil and Environmental Engineering and Director of the Institute for Dam Safety Risk Management at Utah State University. He is also a Principal with RAC Engineers & Economists. His professional experience includes Director of the Utah Center for Water Resources Research, Branch Manager of Denver Operations for Law Engineering, and civil construction and design in the U.K.

Since 1997 David has led the Utah State University team that has worked with the U.S. Bureau of Reclamation (USBR), Sacramento Area Flood Control Agency, Sacramento District, U.S. Army Corps of Engineers, and other agencies to develop and implement software for improving operations and emergency management associated with Folsom Reservoir using real time inflow forecasts.

Over the past twenty years, David has pioneered the development and application of risk assessment and risk management to dam safety, with applications to more than 400 dams for the USBR, the U.S. Army Corps of Engineers, Ontario Power Generation, and in Australia and England.

David is active in many professional societies. He is a member of the Board of Directors for the U.S. Society on Dams.

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Abstract

This paper summarizes the capabilities and range of applications for a Decision Support System for real time flood operation and associated planning activities for the Folsom Project in California. Under an off-line Planning Mode, the Reservoir Release Forecast Model (RRFM) is being used to test alternatives operating rules. A real-time Operational Mode of the RRFM is operated by the USBR's Central Valley Operations Office in conjunction with the SS-SAC hydrologic model, which is operated by the NWS California-Nevada River Forecast Center. The RRFM will make possible the risk-based operation of the Folsom Project, as authorized by the Water Resources Development Act of 1999, through consideration of uncertainty in inflow forecasts to increase the level of flood protection provided in Sacramento.

The RRFM has many applications in addition to developing and testing operating rule changes, including possible pre-release strategies, and as a tool for real time flood operation. These include operator training, emergency management table top exercises, and for assisting downstream emergency managers in developing protocols for using RRFM release forecasts to improve emergency planning.

Introduction

Flood operation of reservoirs requires that information be made available in a form that can be readily assimilated by operators. In some cases, large flood releases have the potential to cause significant downstream damage and loss of life. In these cases it is important to effectively communicate information about reservoir operation to those responsible for public safety and emergency response.

In the past, it has been common practice to base reservoir operating rules on current information about reservoir storage without direct use of inflow forecasts. The justification has been that inflow forecasts are uncertain. However, there is a growing interest in taking account of forecast

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information, including forecast uncertainties, to improve levels of flood protection through more effective use of available reservoir capacity.

This paper describes a Decision Support System (DSS) for real time flood operation and associated planning activities for the Folsom Project on the American River above Sacramento, California. The Water Resources Development Act of 1999 (WRDA 1999) specifically required the Secretary of the Army, in cooperation with the Secretary of the Interior, to update the Flood Management Plan for Folsom Dam to reflect the operational capabilities created by a modification to increase outlet capacity and by improved weather forecasts based on the Advanced Hydrologic Prediction System (AHPS) of the National Weather Service (NWS). The overall goal is to obtain as much flood control as can reasonably be achieved with the existing infrastructure.

To realize this goal, a DSS has been developed through the efforts of a multi-agency team. The DSS, the Folsom Reservoir Release Forecast Model (RRFM), has been developed by Utah State University (USU). It provides a means of examining various tradeoffs associated with the timing of reservoir releases as they affect downstream flood control, lead time for evacuation in the event of releases that are expected to exceed levee capacity, and dam safety. Another tradeoff that can be examined is between pre-releases to provide additional flood control space and the potential for loss of stored water for other project purposes such as water supply and hydro power generation if the vacated space is not refilled. These risk-risk tradeoffs can be examined during a flood event using an Operational Mode of the RRFM or off-line using the Planning Mode of the RRFM. The model has many other uses including operator training and emergency management table top exercises.

This paper provides background on Folsom flood operations and an overview of RRFM capabilities. The Deterministic and Uncertainty Options of the Operational (real time) Mode and the Batch and Interactive (pseudo real-time) Options of the Planning (off-line) Mode are described. Existing, planned and potential applications of the RRFM and some planned improvements to the RRFM are summarized. The paper closes with some conclusions on the potential benefits of RRFM for reservoir flood operation.

Background on Folsom Operations

In addition to its hydropower, water supply and recreation purposes, the Folsom project plays an important role in protecting Sacramento from flooding. Combined with a levee system, it is estimated that the project will provide about a 1 in 100 annual exceedance probability (AEP) level of protection after levee strengthening is completed. Increased outlet capacity is being added to the Folsom Dam, thus expanding the potential for forecast-based pre-releases to increase flood control space immediately before floods and to raise the protection level to about 1 in 175 AEP. Operation of the project during the 1986 flood was the subject of a National Research Council report (NRC 1995).

Since 1996, a multi-agency group has worked with the USU team to develop, test and implement the RRFM for real-time operations of the Folsom Project. The working group currently includes the U.S. Bureau of Reclamation (USBR), the U.S. Army Corps of Engineers (Corps), the Sacramento Area Flood Control Agency (SAFCA), the National Weather Service (NWS), the California Division of Water Resources (DWR), MBK Engineers, the American River Flood Control District, the U.S. Fish and Wildlife Service (USFWS), the Hydrologic Research Center (HRC), and the California Extreme Precipitation Project (Cal-EPP).

As part of this multi-agency effort, the NWS California-Nevada River Forecast Center (CNRFC), working with the HRC, implemented the State-Space version of the Sacramento Soil Moisture Accounting Model (SS-SAC) and calibrated three forks of the American River (Carpenter and Georgakakos 2001). Since February 1997, the CNRFC has continuously operated the SS-SAC model as a part of the NWS River Forecasting System (NWSRFS) and delivered inflow forecasts with associated inflow forecast error variance estimates to the USBR's Central Valley Operations Office (CVO) for use in operating Folsom.

Concurrently, the USBR contracted with USU to develop the RRFM to process the inflow forecasts from SS-SAC into probabilistic forecasts of reservoir releases. The Deterministic Operational Mode RRFM is currently operational in the USBR's CVO. The Uncertainty system components for the Operational and off-line Planning Modes of the RRFM are in the model verification stage.

Reservoir Release Model Overview

The RRFM can be used in an Operational (real time or on-line) Mode or a Planning (off-line) Mode, as represented schematically in Figure 1. Under the Deterministic Operational Mode, which is currently in use by the USBR, the model captures various input variables, including inflow forecasts from the NWS CNRFC SS-SAC model. Through application of the flood control and emergency spillway release rules, it provides forecasts of release rates and timing, downstream river stages, and reservoir refill. It can be used during flood operations to run "what if" scenarios to explore alternative operating strategies. Under the Uncertainty Operational Mode, it can also provide probabilistic estimates for these forecast variables based on propagating forecast uncertainties through reservoir operation.

Operational (Real Time) Mode

Deterministic option. The Deterministic Operational Mode of RRFM has the following capabilities for use by Folsom Reservoir operators under the Deterministic Option:

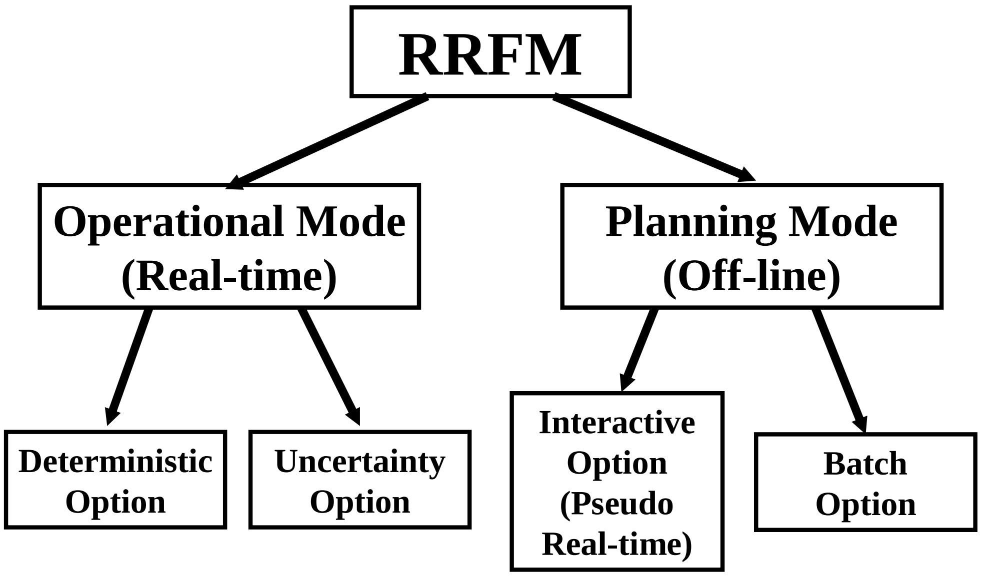

Figure 1. Reservoir release forecast model modes and options.

1) Real-time capture of the NWS CNRFC reservoir inflow forecasts for a five-day forecast period.

2) Real-time capture of other observed and forecast information needed to implement existing operating rules and downstream flow routing, including information on headwaters reservoirs.

3) Perform flood control diagram (FCD) and emergency spillway release diagram (ESRD) rule calculations to obtain rule releases over the forecast period.

4) Perform reservoir routing calculations using "rule releases" over the forecast period, including a check on available release capacity determined by the pool elevation and the availability of individual spillway and outlet works gates.

5) As an operator option, perform parallel reservoir routing calculations over the forecast period using operator-specified releases that differ from rule releases so that these alternative release scenarios can be explored before the selected release is adopted in 6). Options include a maximum surcharge and a maximum release ESRD to explore bounding case scenarios.

6) At the choice of the operator, adopt either the rule or operator-specified releases for actual operation within the flexibility provided under the existing criteria. Corps' approval of any deviations from existing criteria is necessary.

7) Obtain “deterministic estimates” of forecast lead times for exceeding various reservoir release flow rates and river stages at critical downstream locations.

8) Generate a release order for field personnel at the reservoir.

The Operational Mode RRFM was developed with significant input by CVO operators. As such it provides many flexible and practical user friendly features (Chauhan et al 2002) including the following:

a) Graphical-user interface.

b) Display of all reservoir routing calculations in a flexible interactive form with a “spreadsheet-like” appearance.

c) Notification of automatically captured inputs, but their use to update forecasts is under the operator’s control.

d) Visualization of key information with the flexibility for the operator to tailor graphical displays.

e) Archiving of all inputs and calculations in a “database of record” with the capability for including operator’s notes.

Uncertainty option. The Uncertainty Operational Mode RRFM includes the capability to propagate uncertainties in inflow forecasts through reservoir operation and forecasting of downstream river stages. It has the following additional capabilities over the Deterministic Option described above:

1) Real-time capture of forecast estimation error variances for reservoir inflow forecasts from NWS CNRFC for the 5-day forecast.

2) Generation of an ensemble of reservoir inflow forecasts, preserving the correlation statistical structure in the forecast uncertainties using a Monte Carlo approach.

3) Perform FCD and ESRD calculations over the forecast period for each generated forecast in the ensemble to generate an ensemble of rule releases.

4) As an operator option, perform parallel reservoir routing calculations for each generated inflow forecast in the ensemble using operator-specified releases so that alternative release scenarios can be explored before one is adopted in 5).

5) Operator adopts either the rule or operator-specified releases. Corps approval is needed for any deviations from the rules.

6) Obtain probability distributions of forecast lead times for exceeding various reservoir release flow rates and river stages at downstream locations and for reservoir refill levels.

Thus, the Operational Mode RRFM has the capability for estimating and displaying probability distributions representing forecast uncertainties for the following variables:

a) Lead time for exceeding critical reservoir release flow rates.

b) Lead time for exceeding river stages at downstream locations for use by community emergency planners for triggering various stages of evacuation-related activities.

c) Reservoir refill levels for use in a pre-release rule.

Planning (Off-Line) Mode

The Planning Mode RRFM provides an off-line capability to test alternative operating rules, including pre-release rules, and emergency management protocols for using forecast information from RRFM. The Planning Mode RRFM generates ensembles of inflow forecasts at a series of forecast issuance times for any flood event, based on the statistical structure of historic forecast errors. The event could be an historical flood, a design flood, or an event constructed in some other manner. This event is referred to as a “hypothetical” flood event. A range of hypothetical events can be used to thoroughly tests alternative operating rules or emergency management protocols, including making estimates of false alarm and missed alarm rates.

The Planning Mode RRFM can be run under two options:

- **Batch option** – RRFM runs through an entire hypothetical flood event in a single run, generating an ensemble of inflow forecasts for each forecast period (typically for a 5-day forecast period with six-hour spacing between forecasts), but without stopping to allow any user inputs. Under a suboption, a set of historic forecast can be used instead of a hypothetical flood event.

- **Interactive option** – RRFM generates an ensemble of inflow forecasts for the first forecast period and then pauses to allow user inputs to be specified, just as would be the case in real-time operation. At the command of the user, RRFM continues with the next forecast period and then pauses again to allow user inputs. This option is also referred to as a “pseudo real-time” option, because with this option the “spreadsheet” like capability, “what if” scenario simulation, and other features of the Operational (real-time) Mode of RRFM are all available to the user. This option is designed for use in a table top simulation or training exercise for operators or emergency managers. Essentially the only difference between this interactive option of the Planning Mode and the Operational Mode is that instead of capturing forecasts from the NWS CNRFC in real time for an actual event as it unfolds, they are statistically generated by RRFM to represent the inflow forecast uncertainties for the hypothetical flood event as if it were unfolding during the simulation exercise.

In addition to the above, the operating rule and reservoir routing algorithms in RRFM can be run off-line within an Excel spreadsheet. These algorithms were developed in the RRFM software as a software component. The component technology utilized is the Component Object Model (COM) developed by Microsoft for the Windows(tm) family of operating systems. Development of the RRFM software application, utilizing the COM software model enables the underlying code for these algorithms to be accessed within an Excel spreadsheet through a programming interface with Visual Basic for Application (VBA). This allows the user the flexibility of a spreadsheet for pre- and post processing, combined with the power of RRFM to implement rule and other calculations. It has been used extensively by the Corps for testing alternative operating rules and by the USBR for routing extreme floods.

The Planning Mode RRFM has the following capabilities[5]:

1) Input a hypothetical event hydrograph.

2) Generate an ensemble of reservoir inflow forecasts for the first forecast period, preserving the serial correlations in the forecast errors for individual forecasts and cross correlations between successive forecasts using a Monte Carlo approach.

3) Perform FCD and ESRD calculations for all forecasts in the ensemble, using prescribed rules or a trial version of generalized rules defined through setting parameters in a generalized procedure, to obtain "rule releases" over the forecast period.

4) Perform reservoir routing calculations using rule releases over the forecast period for all forecasts in the ensemble to obtain probability distributions of rule releases and reservoir refill levels.

5) *For the Interactive Option only: as an operator option, perform parallel reservoir routing calculations using operator-specified releases for all forecasts in the ensemble, so that these alternative release scenarios can be explored before one is adopted in 7).*

6) Perform flow routing of rule releases *(and operator-specified releases for the Interactive Option only)* through Sacramento over the forecast period for all forecasts in the ensemble to obtain probability distributions of river stages at downstream locations used for triggering emergency management actions.

7) *For the Interactive Option only: operators adopts either the rule or operator-specified releases for simulated actual operations.*

8) Obtain probability distributions of forecast lead times for exceeding various reservoir release flow rates and river stages at downstream control points.

[5] Italics are used to distinguish those capabilities that apply only to the Interactive (pseudo real-time) Option of the Planning Mode RRFM. All other capabilities apply to both the Batch and Interactive Options of the Planning Mode RRFM.

9) Return to 2) and continue with the next forecast period (typically 5-days long with six-hour spacing between forecasts).

10) Create a summary output for the entire hypothetical event including various statistics.

Figure 2 is an example of probabilistic forecast output from RRFM. It shows lead time plotted against forecast issuance time. The 25%, 50% and 75% probabilities that an X cfs release rate will be exceeded by a particular lead time are plotted on vertical lines at each forecast issuance time. Approximately 14 unevenly spaced forecasts are plotted. Longer lead times are associated with higher confidence that this release rate will be exceeded. Fluctuations in the forecast curves are real and come from forecasts made during the 1997 New Year's Flood using estimates of forecast errors made for that event. The figure also illustrates probabilistic emergency warning triggers. These are discussed in the next section under Development of Emergency Management Protocols.

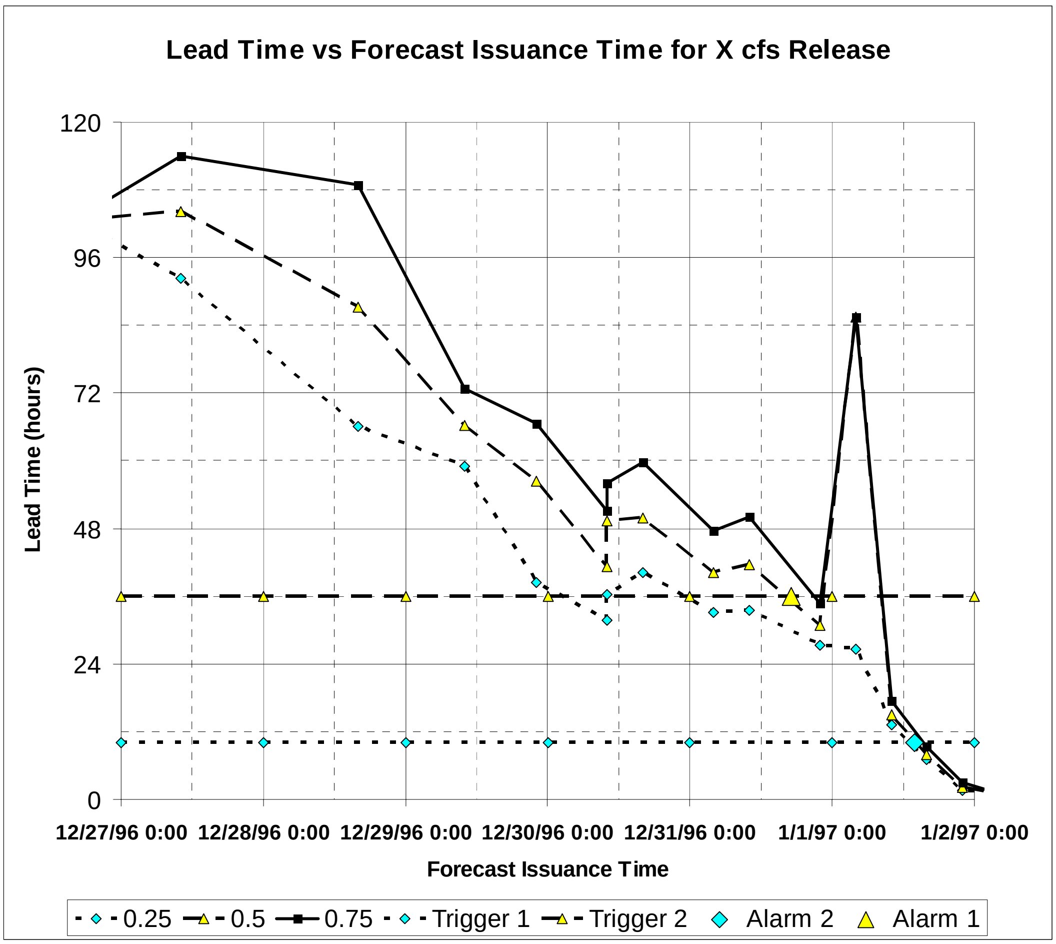

Figure 2. Example of probabilistic triggering of evacuation alarms.

Applications of RRFM

Various existing, planned and potential applications of RRFM are summarized in this section.

Flood operation – Deterministic operational mode. Various versions of the Deterministic Operational Mode RRFM have been installed for use by the USBR Central Valley Project Operations Office (CVO) since December 1998. A beta version of the Uncertainty Option was delivered in December 2002. The USBR has received several training sessions in using the model, which is available for their use in the event of a major flood.

Development of forecast-Based operations – Planning mode via COM. The Planning Mode features of RRFM, through the use of the COM component within an Excel environment, have been used extensively by the Sacramento District of the Corps of Engineers since July 2000 for operational studies of the Folsom Project to explore possible rule changes.

Routing design floods – Planning mode via COM. The Planning Model features of RRFM, through the use of the COM component within an Excel environment, has been used by the USBR in Denver since 2001 for routing of extreme floods through Folsom Reservoir.

Development of forecast-Based operations – Uncertainty planning mode. As a sub-component of the Corps' Folsom Dam Modifications Project, an Advanced Release Rule is being developed to allow operators to make more efficient use of both the additional release capacity and inflow forecasting to provide additional flood protection, as authorized under WRDA 1999.

A set of operational parameters have been formulated to allow the optimization of flood control strategies and other reservoir purposes during the flood season using the Uncertainty Planning Mode RRFM. These parameters would need to be formally agreed by all stakeholders and then would be incorporated into the Operational Mode RRFM for use by the USBR CVO. The Corps of Engineers will continue to monitor flood control releases for compliance with federal regulations. Some preliminary analyses have been conducted using spreadsheets by the HEC (2002).

Reservoir operator training – Interactive planning mode. Training exercises for reservoir operators can be conducted using the Interactive Planning Mode RRFM. As new operators are assigned, this is expected to provide an effective approach to training and the development of experience that might never occur if one waited for actual events to occur. Such training is routine and required for other critical technological systems that have potential impacts similar to that of a major flood control project.

Test-bed for developments in forecast technology – Uncertainty planning mode. RRFM is being considered as an integral component of proposed NOAA test-bed (Ralph 2003) for the American River Basin (ARB). The two-year pilot demonstration field project would focus sophisticated weather observation tools and methods on the ARB with the goal of improving precipitation and runoff forecasts. The Planning Mode RRFM would be used to assess the value added for reservoir flood operation in terms of improvements in the accuracy and reductions in the reservoir inflow forecast uncertainties. The Operational Mode RRFM would then be adapted to incorporate new forecast technologies that are demonstrated to be worth while.

The pilot project proposes to augment present operational monitoring with automated determination of the snow/rain transition altitude using wind profiling radar data and high-resolution mapping of precipitation across the ARB using scanning polarimetric radar. As an option, airborne dropsondes would be used at strategic upstream locations over the Pacific Ocean to provides vertical profiles of atmospheric temperature, humidity, pressure, and wind conditions for input to numerical weather prediction models to enhance longer term (>24 hours) precipitation forecasts.

Development of emergency management protocols – Interactive and batch uncertainty planning mode. It is common for emergency managers to establish emergency response triggers when certain river elevations are reached. RRFM will provide uncertainty estimates in flood forecasts that make possible a new type of trigger in the form of probabilistic forecasts of future river stages instead of depending on observed current river stages. This has the potential for more effective use of lead-time in emergency management.

Figure 2 contains an example of two probabilistic triggers for emergency response. This example is purely hypothetical and should not be interpreted as having any applicability to the situation in Sacramento. The first trigger, represented by the triangular symbol, is associated with a 50% confidence of exceeding a release of X cfs within 36 hours. It might, for example, set an alarm for certain activities needed to prepare for a full scale evacuation. The second trigger, represented by the diamond-shaped symbol, could be for a full scale evacuation. It is associated with a 25% confidence of exceeding X cfs within the next 10 hours. Note that there is a significant difference between the timing of alarms that are triggered (read on the Forecast Issuance Time scale) for a longer lead time (e.g. 36 hours) depending on the confidence level that is selected. As would be expected, these differences diminish as the time of the peak inflow is approached at January 1, 1997 22:00.

It is planned to use the Interactive Planning Mode RRFM in a “table top” simulation setting for emergency mangers to develop and test emergency management protocols using simulated forecasts generated in a sequential manner, one forecast period at a time, just as would occur in a real flood event without the knowledge of future forecasts. In this way, alternative protocols can be developed through trial and error using a range of flooding events with realistic forecast uncertainties. Once a narrower range of protocols has been developed, these will be subject to extensive testing and optimization using the Batch Option of the Planning Mode RRFM. This option will quickly run a wide range of flood events and allow statistical testing of characteristics such as different types and degrees of false alarm rates and missed alarm rates. Once emergency management protocols have been adopted, the probabilistic forecast information, needed to trigger emergency response actions, will be provided to emergency managers from the Operational Mode RRFM.

In other USU work, the effectiveness of evacuation for major floods, including dam break floods, is being represented in a model that is under development for the Corps and various Australian organizations through ANCOLD (Aboelata et al 2003a and 2003b)

Table top exercises for emergency managers – Interactive planning mode. Table top simulation or training exercises for emergency managers can be conducted using the Interactive Planning Mode RRFM for a wide range of floods.

Operation under communications black-out – Operational mode. Typically, staff located at a reservoir is responsible for carrying out orders transmitted to them from reservoir operators remote from the project itself. However, in extreme weather conditions, communications might be lost. In this unlikely situation, the operators at the reservoir would need to make their own decisions on how to operate until communications were restored. Such a situation would make it impossible to coordinate operations with operators at other reservoirs or with emergency mangers.

Operations in a communications blackout would have to be based on only conditions that are observable at the reservoir and other information available to the operators at the reservoir prior to loosing communications. If operations during a black-out are determined by the operators at the reservoir using a predetermined rule this would provide a way to anticipate the actions of operators during a communications blackout. These rules could be coded into a portable computer at the reservoir site. The same rules would be incorporated into the Operational RRFM so that it will automatically predict the actions of the operators in the event of a communications blackout.

Development of guidelines for communications black-out – Planning mode. To develop appropriate guidelines for a communications blackout, a range of scenarios could be considered using the Planning Mode RRFM over a wide range of floods.

Planned Improvements

Operational mode. Consideration is being given to adding day-to-day reservoir operation functions to the Operational Mode RRFM to improve the familiarity of CVO operators with use of the software and to increase their readiness to use it in the event of a major flood.

The CNRFC has developed protocols that its forecasters use to assign uncertainties to hydrometeorologic inputs to ARB rainfall-runoff modeling. Consideration is being given to strengthening the basis for these “degree of belief” input uncertainty estimates. Recent work by the Georgakakos et al (2003) on the evaluation of Quantitative Precipitation Forecast (QPF) models could assist with the development of such protocols. These improvements will have a direct effect on the performance of the Operational Mode RRFM.

Consideration is being given to further improving the estimation of reservoir inflows through replacing the SS-SAC model with an ensemble generation approach to rainfall-runoff modeling. Such an approach would mean that the Operational Mode RRFM would no longer need to generate inflows since inflow forecast would be provided in an ensemble format.

Planning mode. The characterization of forecast errors in the alpha version of the Planning Mode RRFM is based on a single event, the 1997 New Year's flood. It is planned to improve this characterization based on work being conducted by the HRC (Carpenter and Georgakakos 2003). Thirty-five years of data are being reprocessed using current forecast techniques to estimate forecast errors over many events.

Potential pre-release rules are being parameterized to provide a high degree of flexibility in defining on- and off-triggers and level of advance releases. These rules will utilize probability distributions of forecasts of peak inflow rates, inflow volumes, peak release rates, and reservoir refill volumes over the forecast period.

An extension of the parameterized operating rules could be the use of formal optimization techniques for exploring a wide range of alternative rules and flood events.

Multiple reservoir system. Plans have been completed for development, testing and implementation of an RRFM for a two river-two reservoir system with a common control point. The plan calls for a phased implementation to realize the benefits of forecast-coordinated operations using RRFM as rapidly as practicable, while allowing time for a transition from current procedures.

In the first phase of this project, the Deterministic Operational Mode RRFM will be implemented using current operating rules, currently available forecast information, and an improved unsteady flow routing model. In a second phase, improvements will be made to the inflow forecasting system, including adding some new gages. The third phase will involve development of an ensemble generation hydrologic model for inflow forecasting, and the Uncertainty Options for the Operational and Planning Mode RRFM, including Batch and Interactive Planning Mode options. The third phase will include development and testing of revised operating rules to take advantage of the capability provided by RRFM to consider forecast uncertainties for coordinating operation of the two reservoirs and development of emergency management protocols. A final fourth phase will comprise implementation and maintenance of the Uncertainty Operational Mode RRFM with the new operating rules and emergency management protocols. This RRFM is proposed to include selected electronic dissemination of reservoir release and river flood stage forecasts to emergency managers and other approved parties.

It is planned to use this Planning Mode RRFM to evaluate the risks and benefits associated with alternative operating rules considering forecast uncertainties. Examples of factors that are proposed for consideration include the following:

- Probability of exceeding target flow rates at downstream control points.
- Probability of exceeding levee crest elevations.
- Confidence with which floodway capacity can be fully utilized versus the risk of overtopping levees due to forecast inaccuracies.

- Potential for modulating flows at downstream control points using reservoir releases and forecasting of unregulated inflows.

- Potential impacts on water supply through estimates of the reservoir refill probability following pre-releases and any tradeoff between refilling different reservoirs.

- Any tradeoff between reducing downstream water levels by use of pre-releases and refilling probability.

- Effects on forecast lead time and confidence in forecasting lead time needed for emergency management actions.

- Effect on the rates and levels of false and missed alarms for emergency management protocols.

- Net economic benefits using loss estimates.

Conclusions

RRFM has been developed in response to a desire to increase the level of flood control that can be achieved with existing infrastructure through more effective use of forecast information. Initially, this has been approached deterministically, but forecast uncertainties have now been explicitly included in the Operational Mode RRFM.

The Planning Mode RRFM is designed for development of operating rules and emergency management protocols in an uncertain forecast context rather than the unrealistic perfect knowledge assumption that most reservoir simulation models require. RRFM is designed to evaluate the benefits of developments in data gathering, remote sensing and modeling capabilities for flood forecasting and then to assist reservoir operators and emergency managers in realizing the benefits of improvements in the accuracy and confidence associated with reservoir inflow forecasts.

The Interactive Planning Mode RRFM will provide a unique interactive simulation training tool for reservoir operators and a table top simulation tool for emergency planners to gain experience over a wide range of floods.

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Advance Release Working Group for Folsom Dam Modifications to the development of the Folsom RRFM are also recognized.

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