Hydrologic Forecasting on the American River

Pete Fickenscher, Hydrologist
NOAA, National Weather Service
California-Nevada River Forecast Center
3310 El Camino Avenue, Suite 227
Sacramento, CA 95821-6373

Tel: 916-979-3056 x339
Fax: 916-979-3067
Email: Peter.Fickenscher@noaa.gov
Web: http://www.wrh.noaa.gov/cnrfc

BIOGRAPHICAL SKETCH

Pete Fickenscher developed an interest in water resources growing up in the Central Valley of California. He received his B.S. degree in Civil Engineering and M.S. degree in Water Resources Engineering from Stanford University. For four years Pete taught Fluid Mechanics and Environmental Engineering at Indonesia Christian University in Jakarta, Indonesia. Since 1998, Pete has served as a hydrologist at the California-Nevada River Forecast Center (CNRFC). His focus has been developing and implementing hydrologic models for flood and water supply forecasting.

ABSTRACT

The California-Nevada River Forecast Center (CNRFC), in partnership with the California Department of Water Resources (DWR), operates a continuous hydrologic model of the American River watershed. The primary purpose of the model is to provide real-time forecasts of inflow to Folsom Reservoir, in terms of both the actual inflow and the full natural flow (FNF). The hydrologic model is capable of making both short range (flooding) and long range (water supply) forecasts.

Previously the American River watershed was modeled as four sub-basins, and the model only calculated full natural flow into Folsom reservoir. During the most recent recalibration, the watershed was divided into nine sub-basins in order to include simulations of inflow into the four largest reservoirs (French Meadows, Hell Hole, Loon Lake, and Union Valley). By simulating the upstream reservoirs, the new model is better able to forecast actual inflows into Folsom reservoir.

Calibration of the new American River watershed model was performed for the period of record of October, 1989, through September, 1999. Full natural flow computations were designed so that they would reflect the operational FNF calculations performed by DWR. Statistical analysis on the model's simulated FNF showed an overall improvement in performance, both for water supply forecasting and flood forecasting.

This presentation will focus primarily on model performance during the most recent high flow event (January 1-3, 1997). Simulations of both full natural flow and actual inflow to Folsom Reservoir will be examined, and areas for future improvement in the modeling system will be proposed. Finally, an explanation of operational forecast products will be presented.

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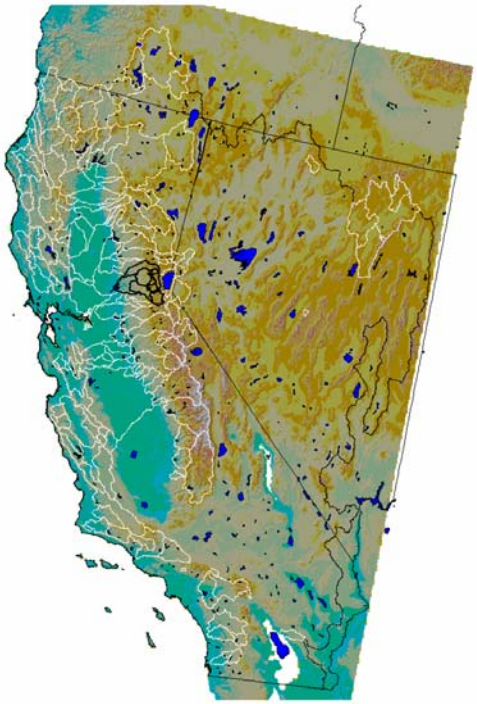
CNRFC Forecast Area

- 196 Basins modeled
- 81 Flood Forecast Points
  - Season: Oct. 15 – Apr. 15
- 47 Reservoir Inflow Points
  - Season: year-round
- 50 Water Supply Points
  - Season: Jan.1 – Jul. 1

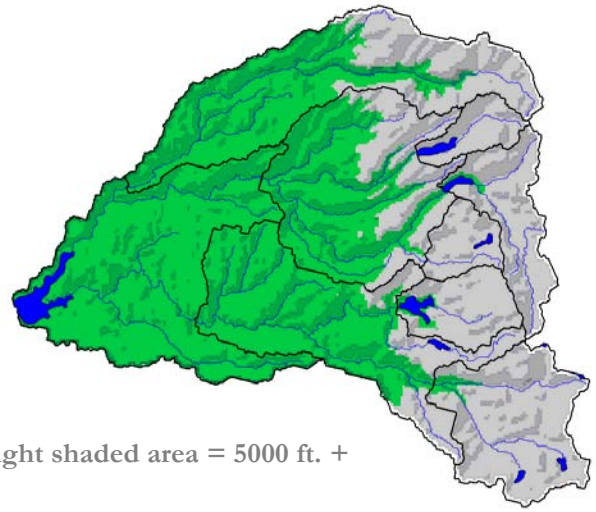


The California-Nevada River Forecast Center (CNRFC), together with the California Department of Water Resources (DWR), operates a continuous hydrologic model of the American River watershed. Each day the model is given real-time precipitation, temperature and flow data. The American River's nine sub-basins comprise only a small portion of the CNRFC's overall responsibility.

NWSRFS Model Components

- RSNWELEV
- SNOW-17
- SAC-SMA
- Reservoirs

  French Meadows
  Hell Hole
  Union Valley
  Folsom



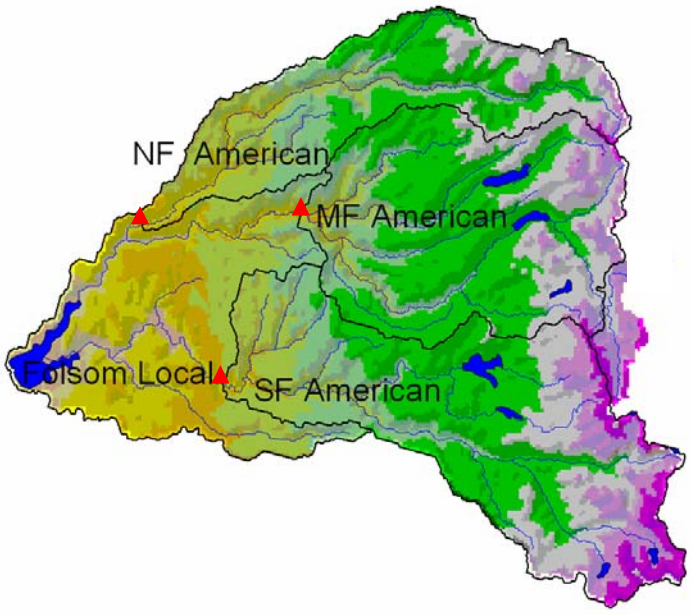
Light shaded area = 5000 ft. +

NWSRFS Documentation:

See http://www.nws.noaa.gov/ohd/hrl/nwsrfs/users_manual/htm/xrfsdocpdf.php

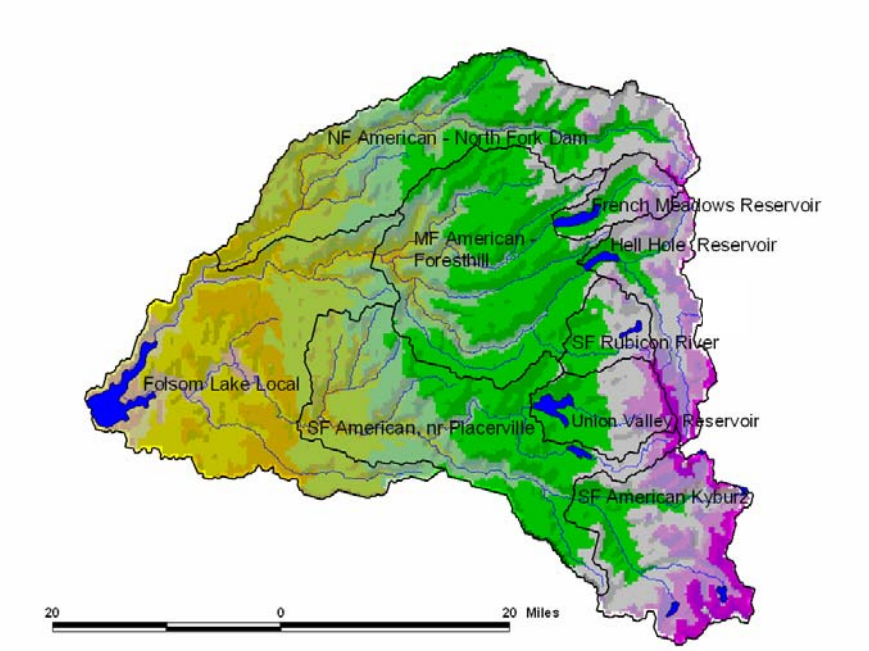
Each basin in the watershed model uses the same core hydrologic model components within the National Weather Service's River Forecast System (NWSRFS).

Previous American Watershed Model



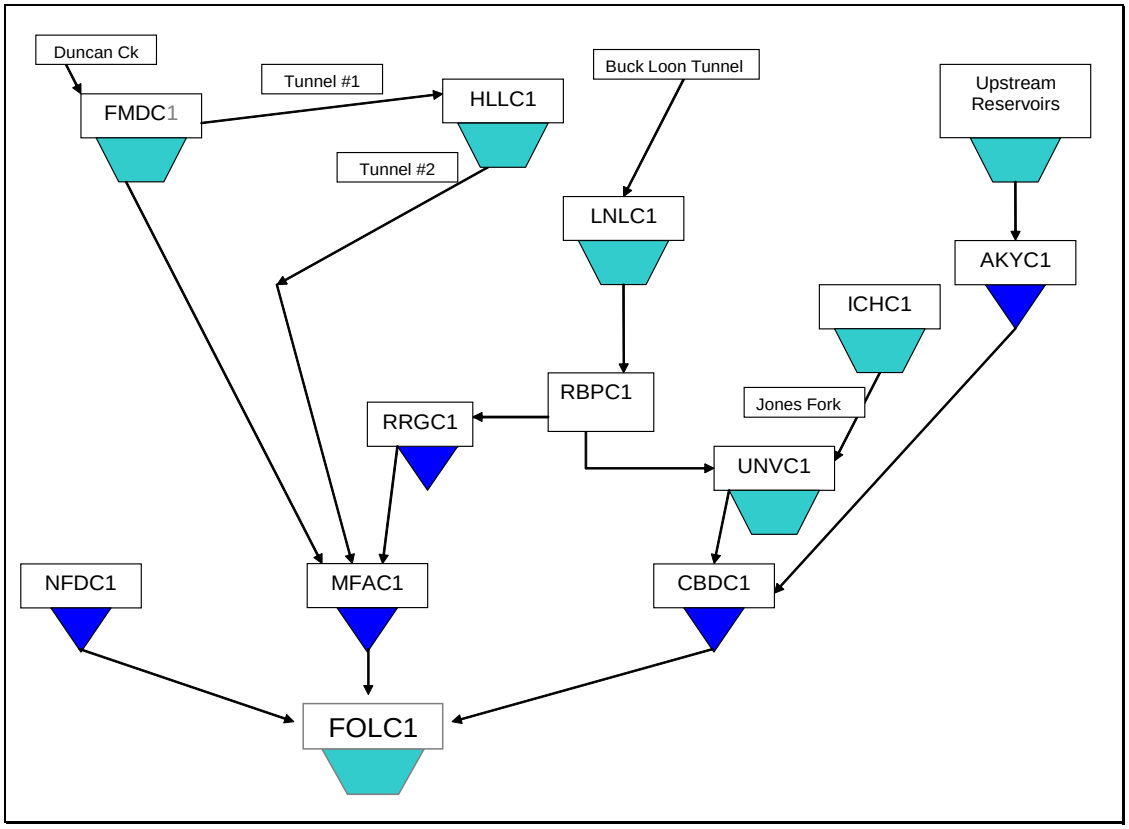
Previously, the operational American River model did not directly model the effect of the upstream reservoirs. Only full natural flow (FNF) was modeled. Therefore, during high flow events, the forecasted inflows tended to be much larger than actual inflows into Folsom reservoir.

New American Watershed Model



The new watershed model incorporates about 75% of the upstream storage in order to better forecast actual inflows into Folsom reservoir. Also inter-basin transfers within the Middle Fork and from the Middle Fork to the South Fork are accounted for and modeled in real-time.

Schematic of "Simplified" Watershed Model

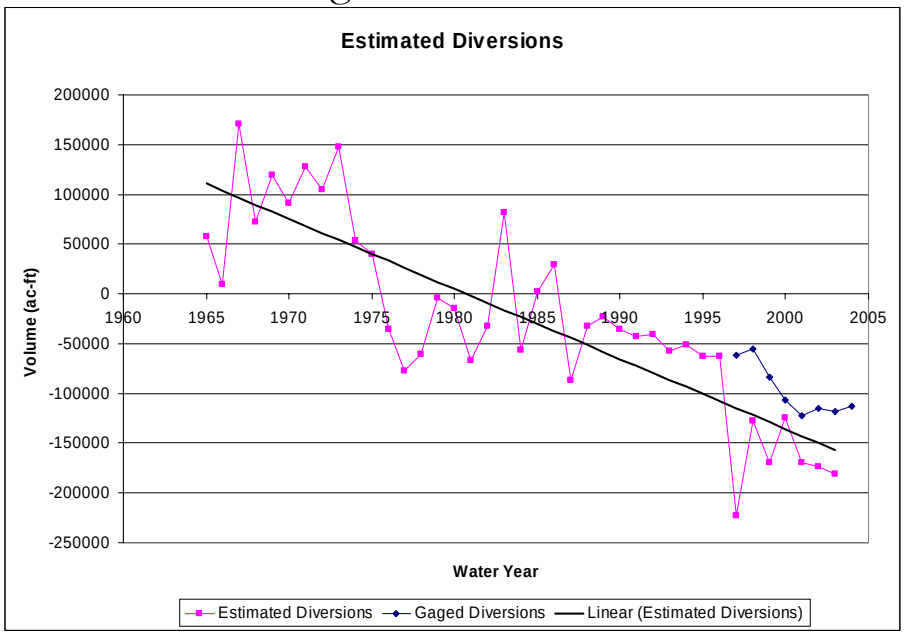


Calibration Goals

- Provide both FNF and Actual Inflow Forecasts
- Flood Forecasting
  - Reduce high flow bias
  - Improve timing of the inflow
- Water Supply Forecasting
  - Reduce April – July Volume bias
- FNF accounting of diversions
  - Simulate DWR daily FNF inflow calculation (16 gages)

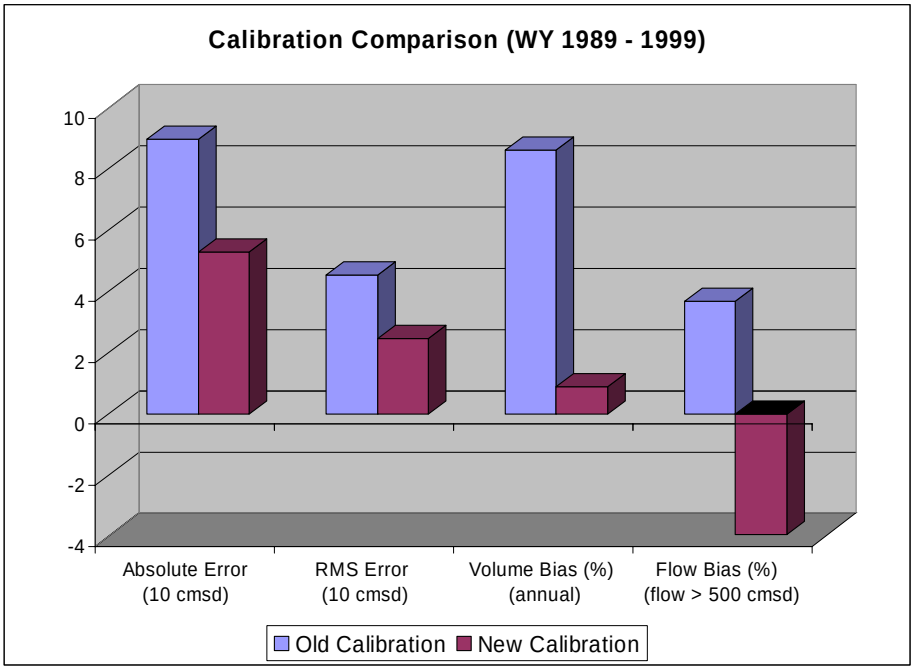
Calibration Goals

Unregulated Diversions

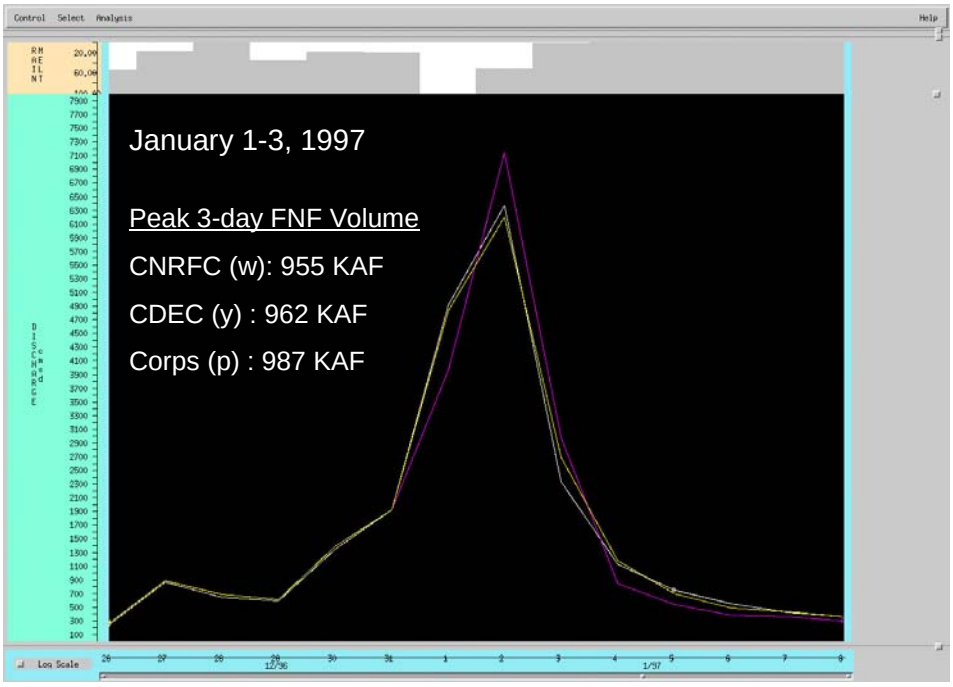


Calculation of ungaged diversions both into and out of the American River watershed has changed tremendously over the years as population in the area has increased. By subtracting out the gaged inflow from the three forks and the simulated inflow into the Folsom local, an estimation of the historical levels of diversions was made. A correct estimation of diversions enhances the accuracy of our long-term water supply forecasts, particularly during the summer months.

Calibration Results

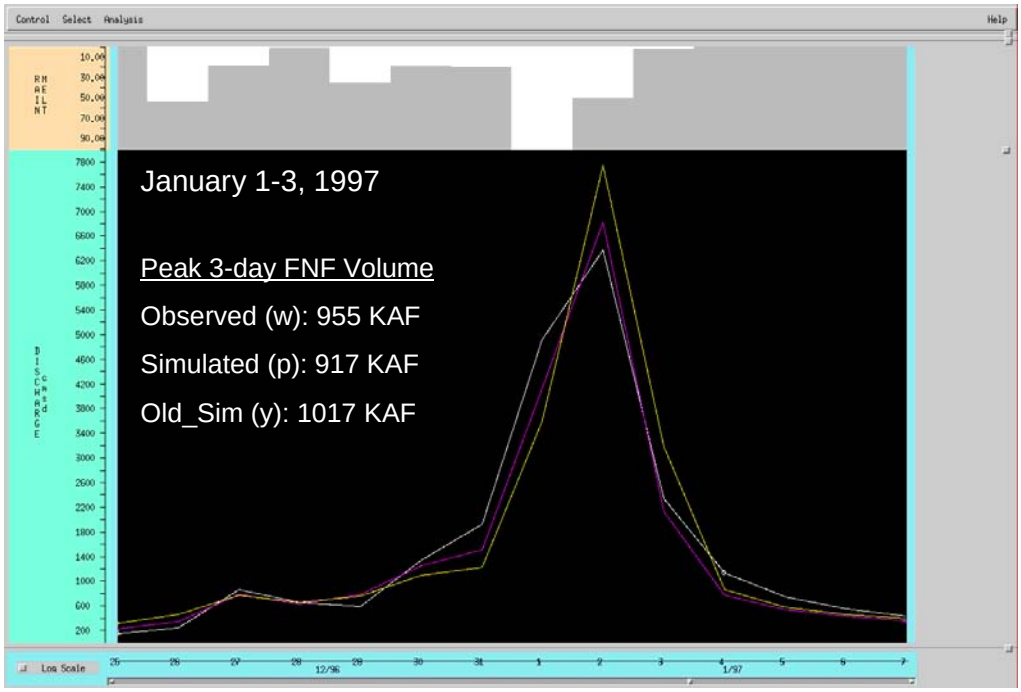


Full Natural Flow Comparison



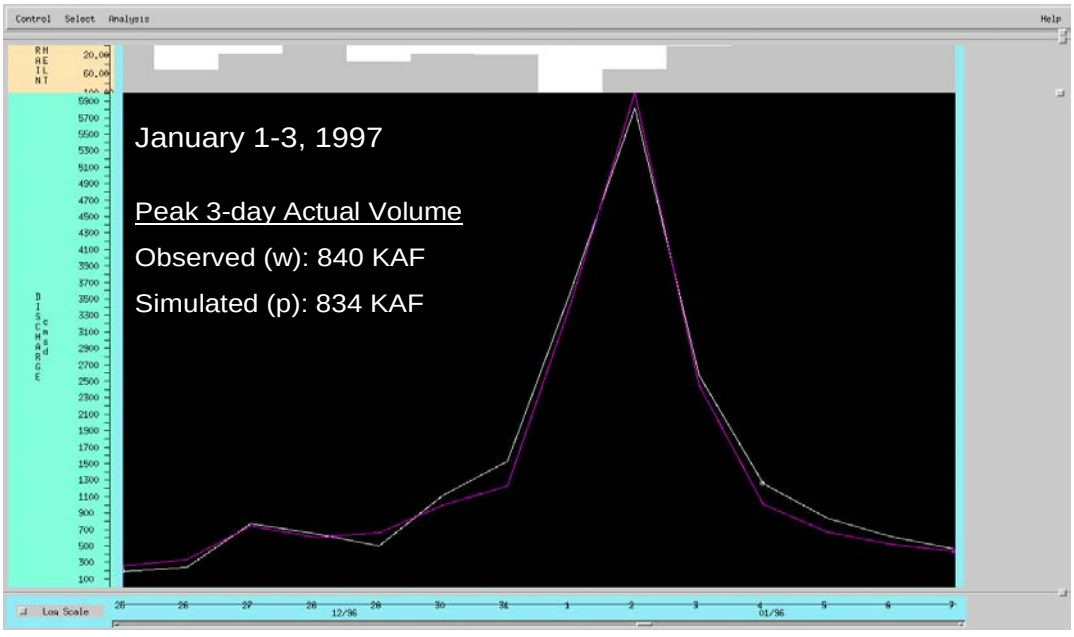
When calibrating the American watershed model, the goal was to simulate the full natural flow into Folsom as calculated by the DWR's California Data Exchange Center (CDEC). DWR's method of calculating the FNF is based on operational constraints, such that inflow into the upstream reservoirs is not routed down to Folsom. FNF calculations mirrored the daily calculations of the DWR. Differences in methodology can be seen in events where the inflows into upstream reservoirs are high.

Calibration Results



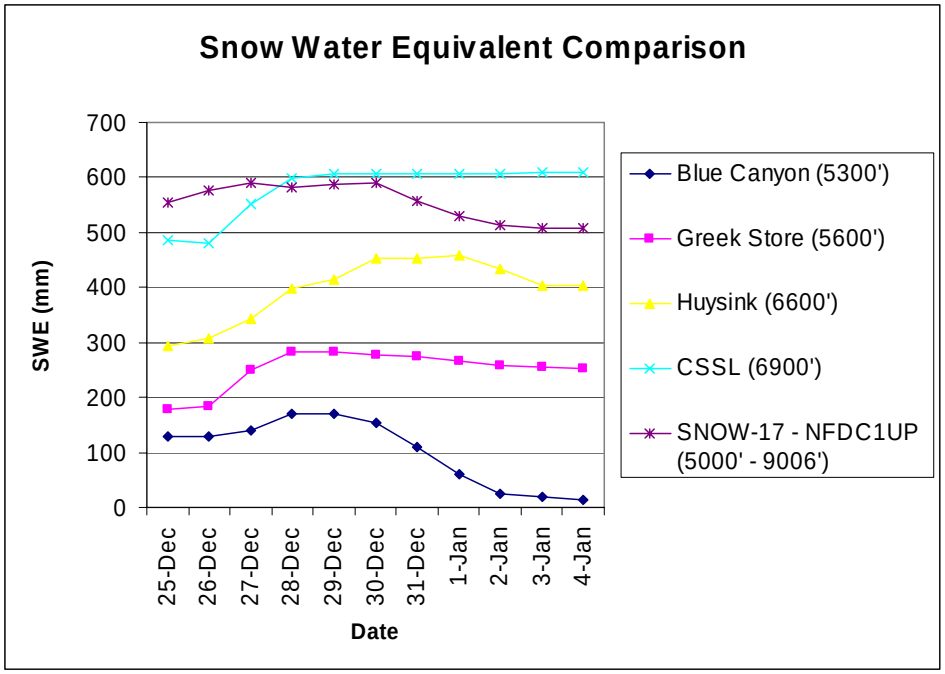
When looking at the peak 3-day FNF into Folsom during the 1997 event, the new simulation predicted 917 KAF, which was more accurate than the previous simulation of 1017 KAF.

Calibration Results



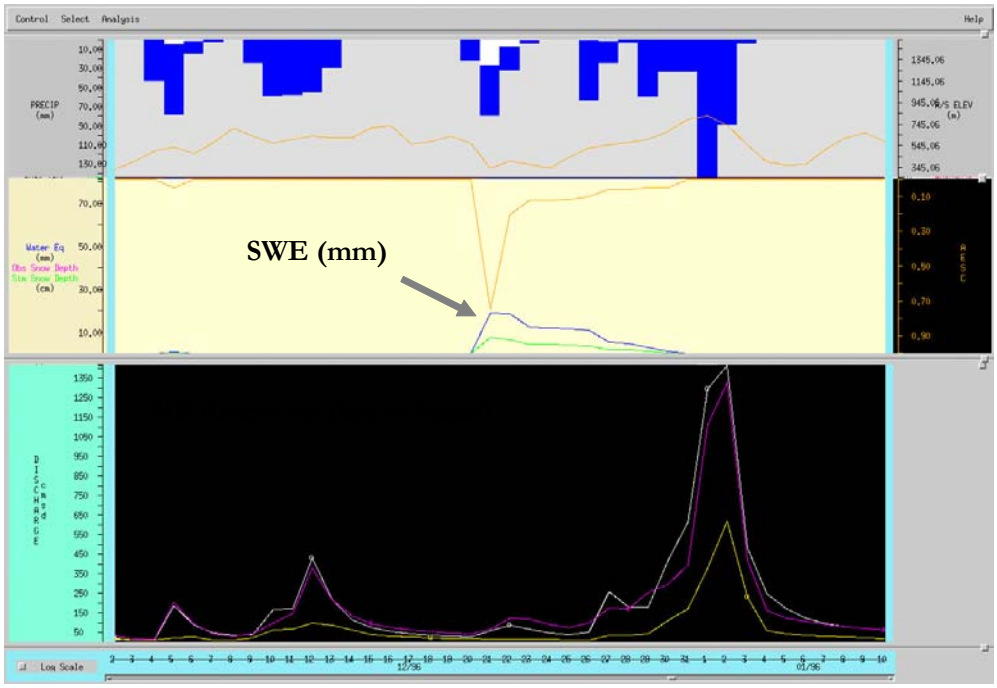
The peak 3-day actual inflow to Folsom was much more accurate. However, this was due to compensating errors. Simulated flow from the SF American was overestimated and simulated flows from the NF American and MF American were underestimated. This simulation also assumed gaged outflow from upstream reservoirs.

Calibration Results



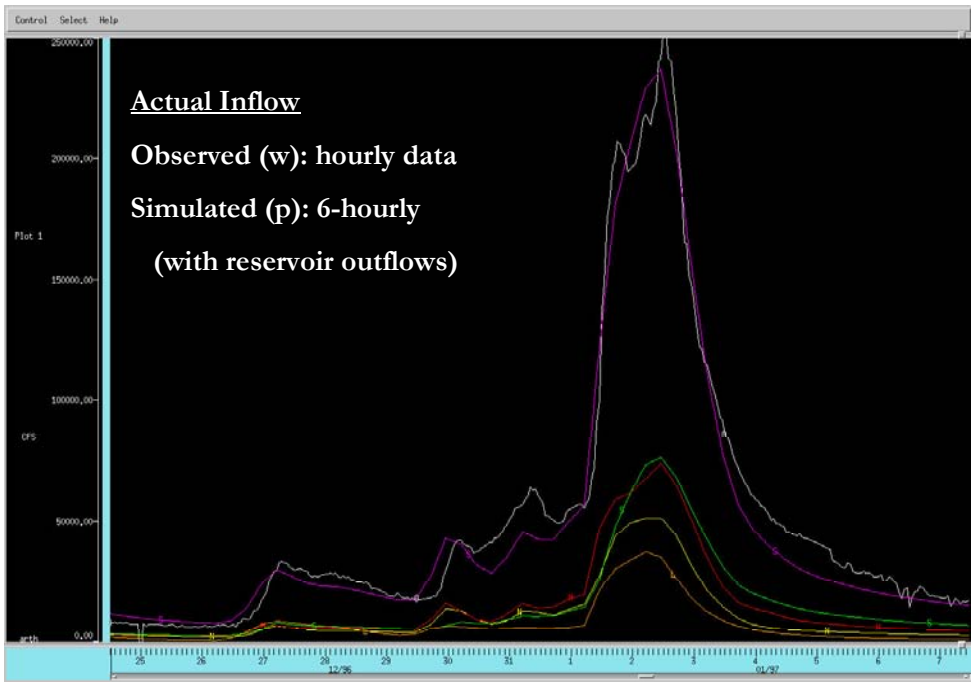
SNOW-17's simulation of the upper zone snowpack and melt during the 1997 event showed a fairly representative response of the high elevation stations to the rain-on-snow event.

Calibration of SNOW-17



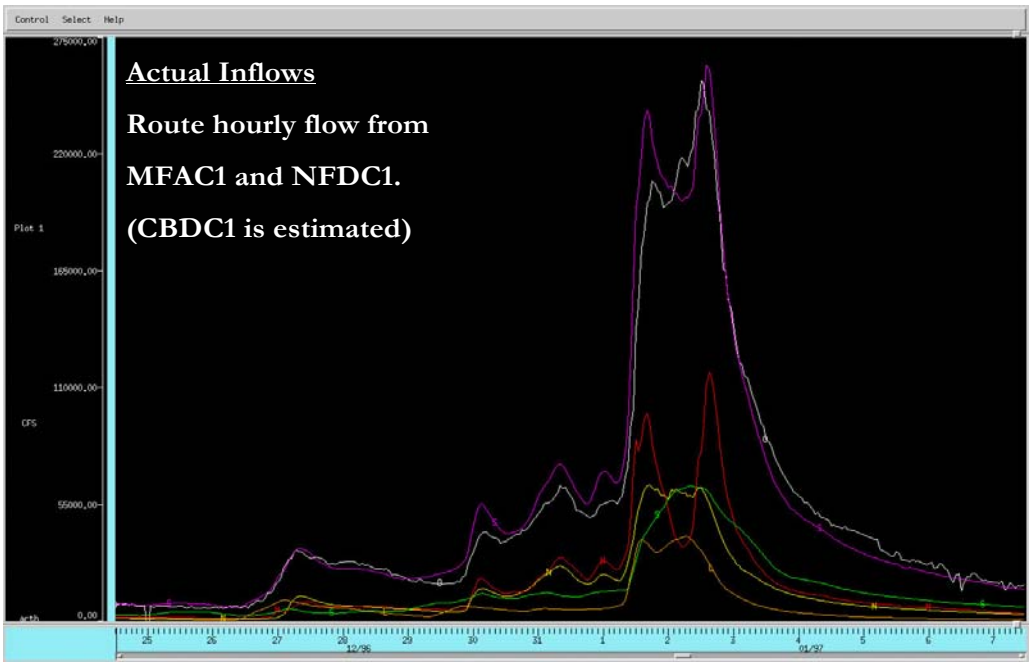
One distinct error was in the NF American's lower zone simulated snowpack prior to the 1997 event. The snow water equivalent (SWE) measured only 19 mm (.75 in.) on Dec. 21, 1996. By the time the heavy rains of Jan. 1-2 arrived, the lower zone snowpack had disappeared.

Calibration Results - Hourly



Hourly inflows to Folsom (in white) show three peaks. Assuming real-time knowledge of reservoir outflows, but no real-time gage data at NFDC1, MFAC1, and CBDC1, the simulated inflow remains close to the observed inflow both in volume and timing.

Calibration Results - Hourly



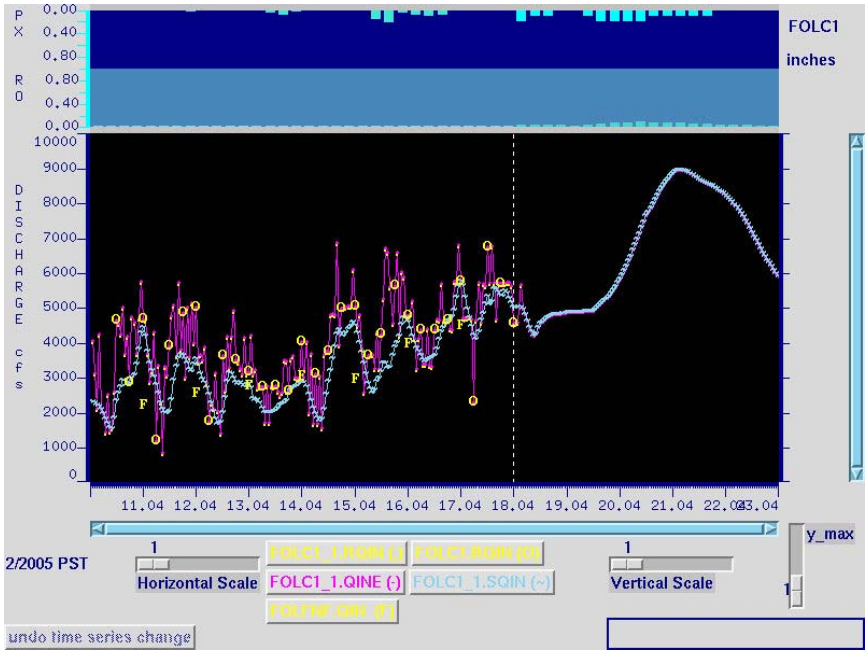
When real-time river gages are added to the model, more definition is added. Note: the gage at CBDC1 was washed out during the 1997 event. The flows used were based on estimations of daily flow at CBDC1.

Calibration Results

- Possible Causes of Undersimulation in Jan. 1997
  - Undercatch of precipitation
  - Non-climatological rainfall event
  - Undersimulation of lower zone snow pack
  - Inadequate MAT calculation

Forecast Products

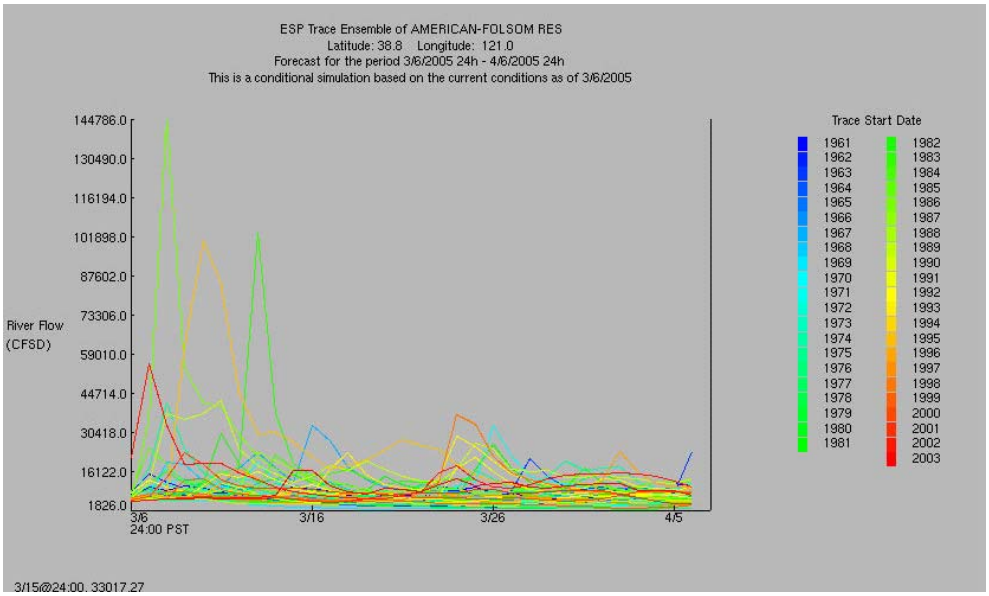
Deterministic Inflow Forecast



Each day CNRFC and DWR forecasters provide the Bureau of Reclamation with a 5-day forecast of both FNF and actual inflows to Folsom reservoir (6-hour time step). At low flow levels, reservoir releases produce a fluctuating inflow. Since we currently do not receive scheduled reservoir releases for the forecast period, the forecast hydrograph is based on the most recent reservoir release levels.

Forecast Products

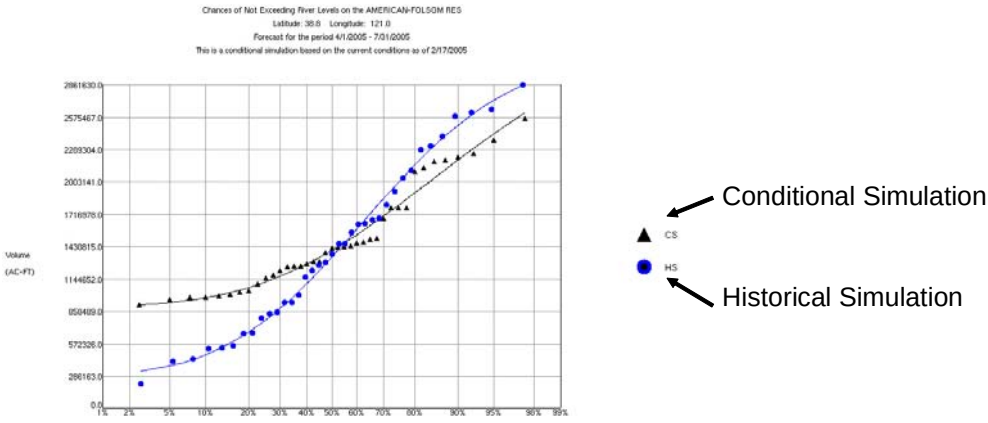
Ensemble Streamflow Prediction (ESP)



Ensemble products are also produced twice a week for reservoir operators. The "spaghetti plot" above presents the *conditional simulations* – simulations produced from historical precipitation and temperature record combined with the current soil and snow conditions.

Forecast Products

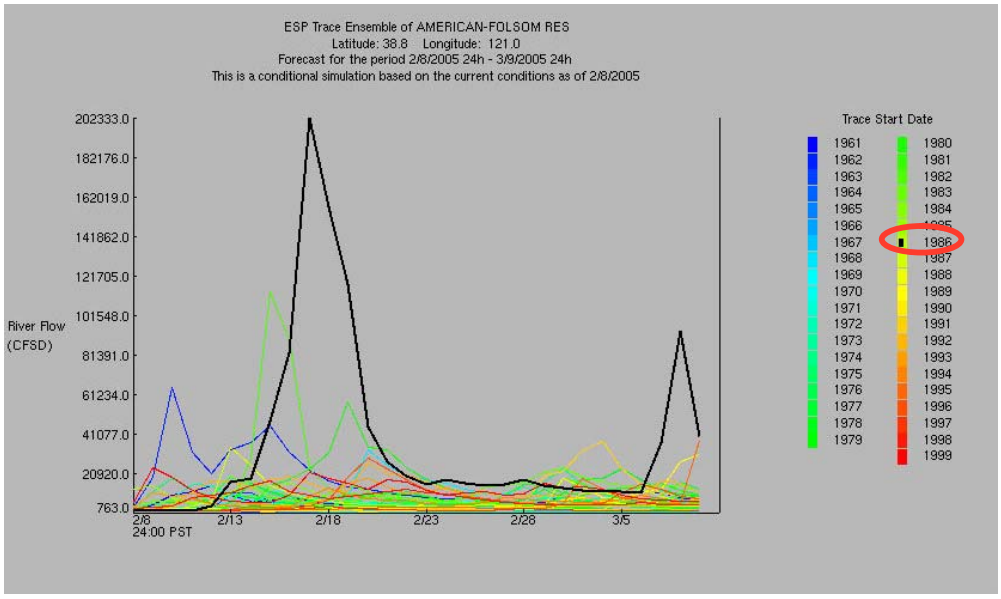
Ensemble Streamflow Prediction (ESP)



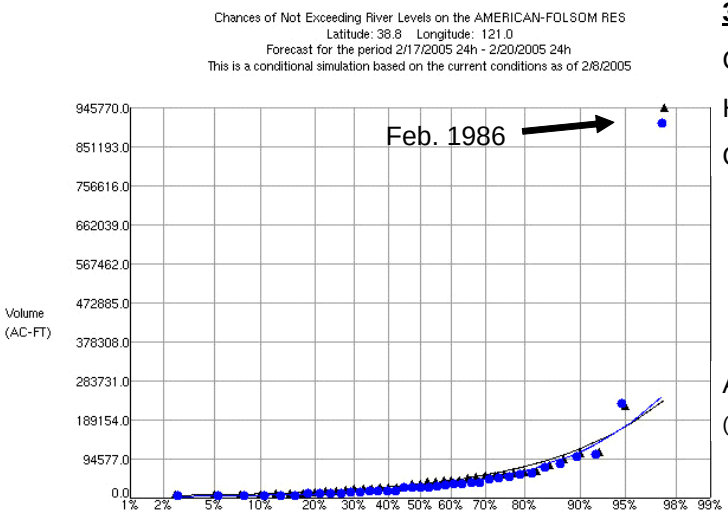
ESP products are valuable for long term forecasts, and they also provide a picture of the relative "wetness" of the basin in comparison to previous years. When the conditional simulation is above the historical simulation, the current soil/snow states are "wetter" in comparison to the past simulation (HS).

Ensemble Products

February 1986 event



Ensemble Products



3-day Peak FNF Volume

Conditional Sim: 946 KAF

Historical Sim: 908 KAF

Observed: 1020 KAF

CS

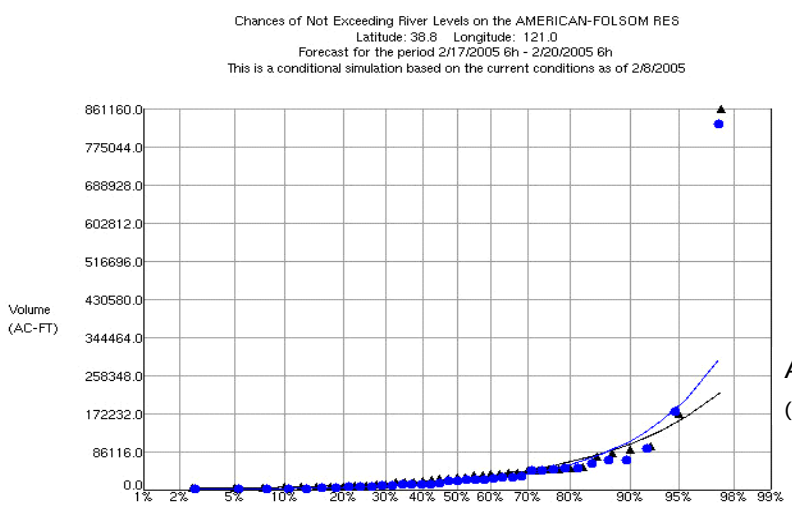
HS

Absolute Error = 11%

(Observed – Historical)

When looking at an exceedance probability plot of the conditional simulation for February 17-19, 2005, the historical event from 1986 is clearly evident. The fact that the conditional simulation is above the historical simulation for 1986, indicates that an even larger inflow would have been expected if the 1986 event had occurred on the snow/soil conditions existing in February of this year.

Ensemble Products



3-day Peak Actual Inflow

Conditional Sim: 861 KAF

Historical Sim: 827 KAF

Observed: 871 KAF

CS

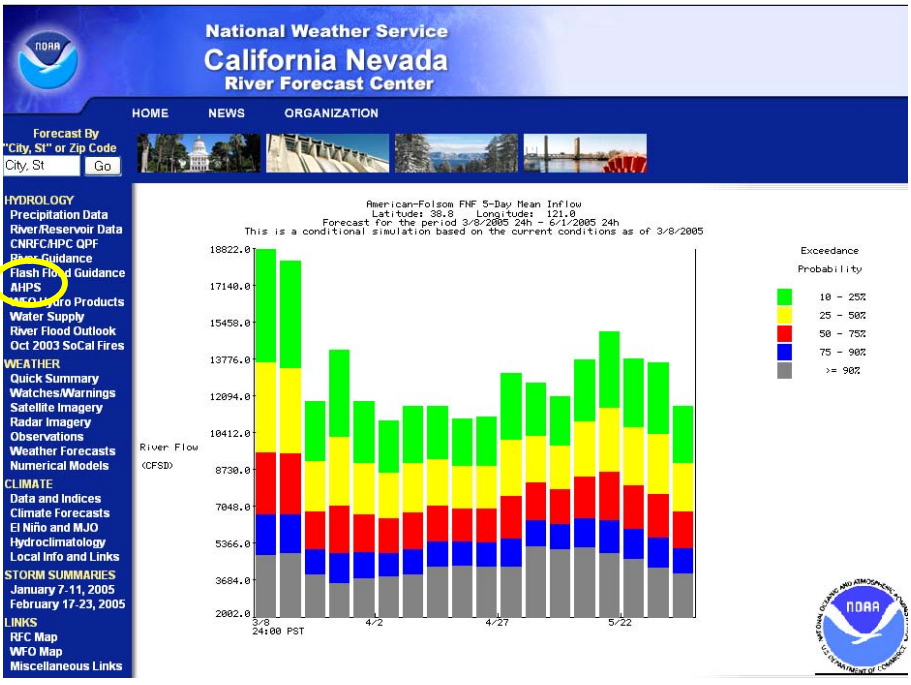
HS

Absolute Error = 5%

(Observed – Historical)

As seen in the simulations of the 1997 event, the actual inflows simulated by the watershed model are closer to the observed actual inflows than the simulated FNF's were to the observed FNF's.

Ensemble Products



Twice each week, a 90-day volume and flow forecasts for the FNF into Folsom are produced, dividing the timeline into 5-day intervals. These products are visible on our website http://www.wrh.noaa.gov/cnrfc under our AHPS (Advanced Hydrologic Prediction Service) link.

Real-time Precipitation Gages