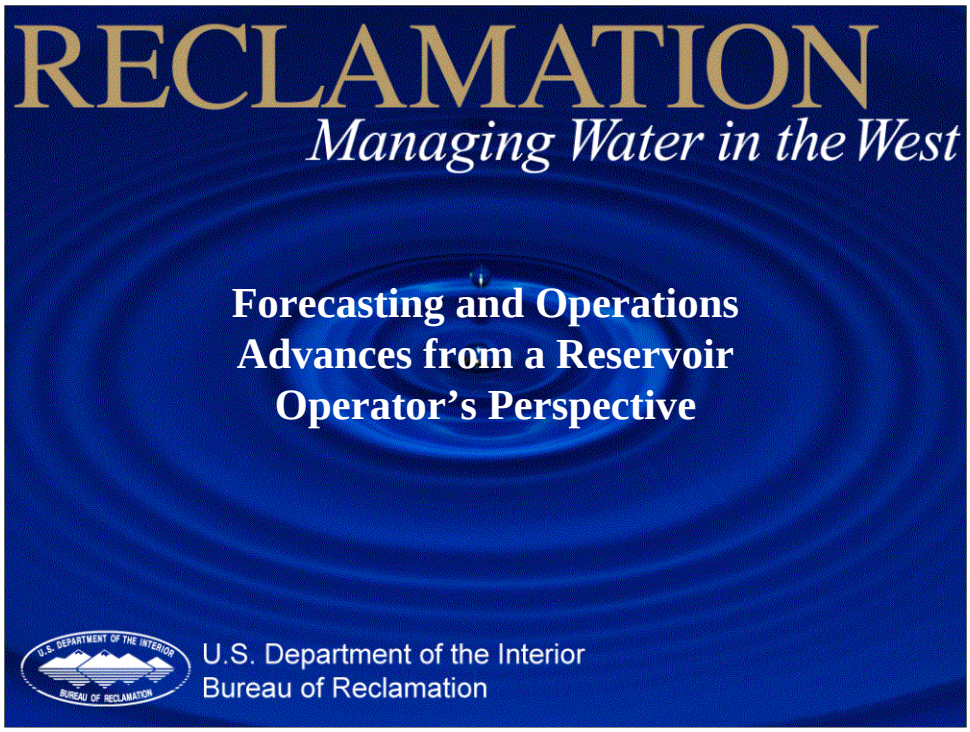
RECLAMATION
Managing Water in the West
Forecasting and Operations Advances from a Reservoir Operator's Perspective
U.S. Department of the Interior
Bureau of Reclamation

Forecasting and Operations Advances from an Operator's Perspective

- Introduction to Central Valley Project Features and Operations
- Co-location of NWS, DWR, and RFC
- Product and Tools
- Impacts to CVP Operations
- Future of Operations forecasts
- Challenges

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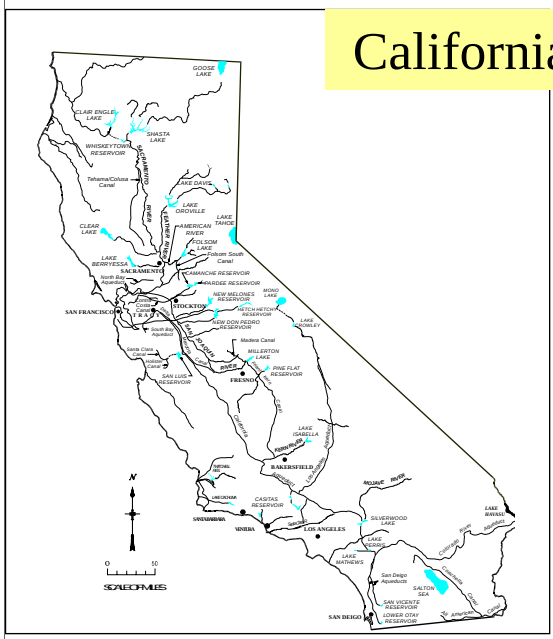

- Three major types of water projects in California
- Federal Central Valley Project (CVP)
- State of California State Water Project
- Numerous local irrigation districts and water districts

CVP Water Summary

- 20 Dams and Reservoirs
- 500 Miles (800 Kilometers) of Canals
- 11 Powerplants
- 10 Pumping Plants
- 20 Percent of State's Developed Water Supply (about 7 million acre-feet, 8.6 billion cu meters)
- 30 Percent of the State's Agricultural Supply (about 3 million acres of farm land, 1.2 mil hectares)
- 13 Percent of State's M&I Supply (about 2 million people served)

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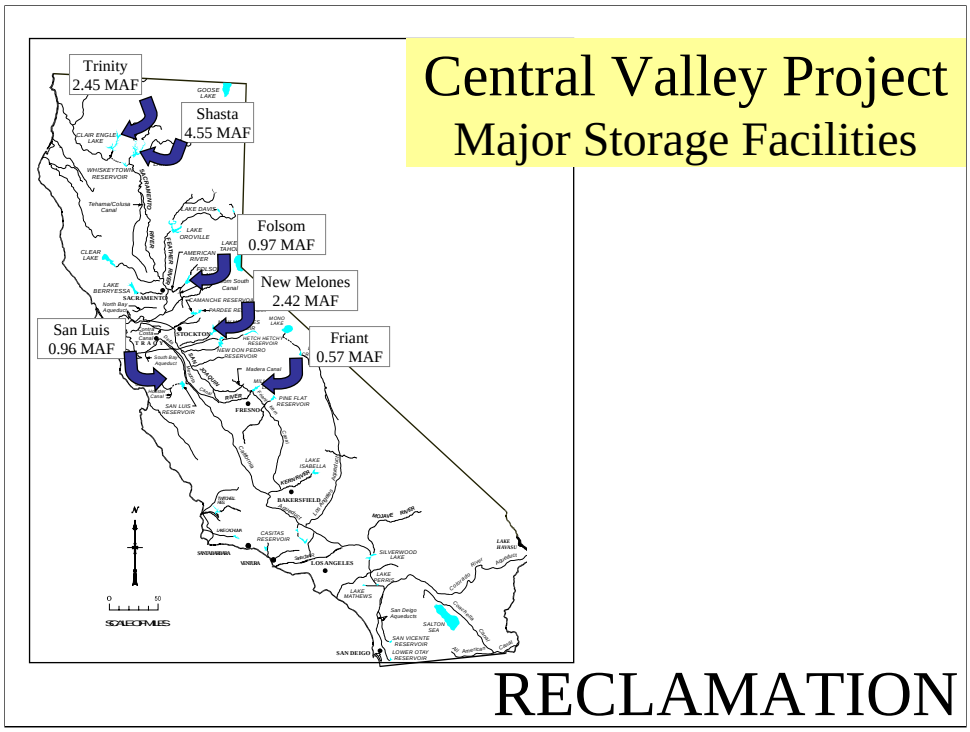
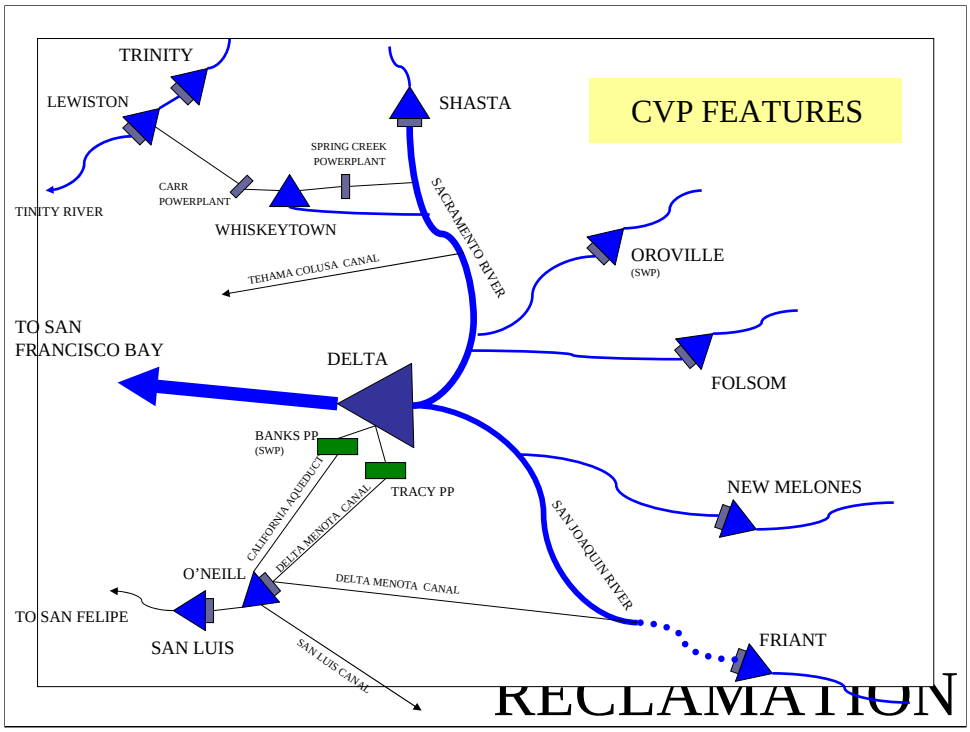
- CVP facts



- The CVP is the nation's largest water development project.
- The CVP stretches from the Cascade Range in Northern California to the southern San Joaquin Valley.
- 6 major storage reservoirs



- Schematic of the CVP
- The CVP consists of major storage facilties, power plants, pumping plants, canals, and distribution systems.
- The project utilizes rivers to convey water to the Delta where project water is pumped into the Delta-Mendota Canal for storage and delivery in the San Joaquin Valley, San Benito County, and Santa Clara County.
- CVP water is also delivered to Contra Costa Water District in the East Bay area
- New Melones Dam and Reservoir and Friant Dam and Millerton Lake are part of the CVP, but are not operationally integrated into the CVP.
- San Luis Reservoir, San Luis Canal, and Dos Amigos Pumping Plant are jointly owned and operated with the State Department of Water Resources.
- The CVP and SWP share the responsibility to meet the in-basin needs of the Sacramento Valley and Sacramento-San Joaquin River. This includes Delta water quality and flow objectives and Sacramento River diversions.

CVP Project Objectives

- Water Supply
- Flood Control
- Environmental Requirements
- Power Generation
- Recreation

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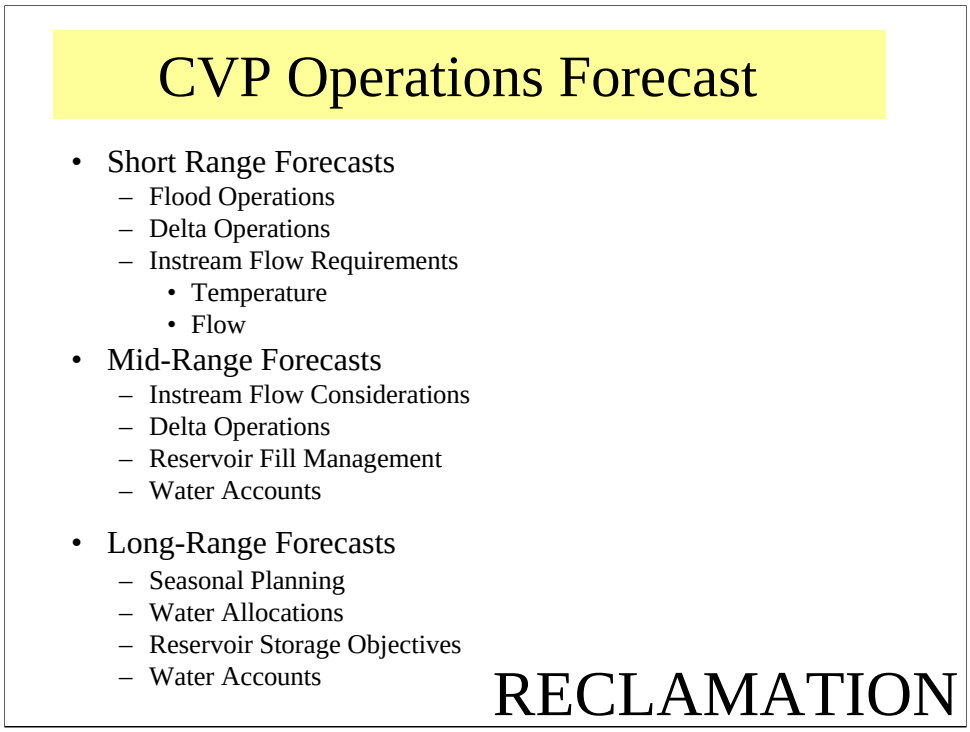
- The CVP is a multipurpose project with often conflicting objectives.
- Maximize storage for irrigation, municipal and industrial, and refuge water supply.
- Vacate reservoir for flood protection.
- Provide adequate instream flow, cool water, minimum flow fluctuations, and attraction and pulse flows for the fishery
- Provide flow to protect Delta environment.
- Generate power to pump project water and for sales to customers
- Provide for reservoir and river recreation



• Reclamation generally uses three types of forecasts to plan and operate the CVP.

• Short range weather, stream flow, and tidal forecasts are used for real time and daily decisions on flood control operations, releases for Delta water quality and export demands, and instream flow needs such as water temperature for fish habitat and minimum fishery flow.

• Medium range (3 to 5 day) forecasts are used to plan Delta needs, flood control operations, reservoir fill management, instream flow needs, power use and generation, and other water accounting.

• Long range forecasts (1 month to 12 months) are used in the seasonal planning of the CVP operations. These are used to determine water allocations to users, plan reservoir operations and carryover targets, plan and coordinate water operations and accounting, and plan power use and generation.

• This discussion will focus primarily on the short to medium range forecasts. A quick inspection of recent seasonal reservoir inflow projections the past five years compared against projections made in the early 1980's did not show any readily apparent improvements. Improvements have surely been made but these are probably hidden due to the limited data set analyzed and the many factors that can influence runoff forecasts from year to year.

Co-Location with DWR, NWS, and RFC

- Joint Operations Center
- Communication internal and external
- Sharing Data
- Staffing and Interagency Cooperation

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- One of the most significant improvement to planning and operations the CVP is the co-location of Central Valley Operations Office (CVO) with the Department of Water Resources, and the National Weather Service.
- Prior to 1995 CVO was located at the Federal building on Cottage Way while DWR and NWS were located in the downtown Sacramento in the Resources Building.
- CVO had one meteorologist as a member of the staff.
    - Served as a liaison between the operations center at the Resources building and CVO
    - Provided weather briefings and inflow forecasts to CVO
    - Provided CVO with his interpretation of upcoming events
- Since co-location with DWR and NWS at the JOC in 1995, we have had coordinated briefings and unlimited access to RFC
    - Personal contact with meteorologists and hydrologists as opposed to reading a bulletin
    - Benefits of interpretations from numerous models
    - Free flow of information to and from the RFC
- Direct line to CDEC system, eliminates delays from heavy internet traffic
- Coordination of reservoir releases and information on release plans
- Basin-wide, we now have ready access to real time information on unusual conditions in the river system via internet and cell phones

Products and Tools

- Similar documents but improved detail and accuracy
  - Forecast of smaller basins
  - Extended days
- Climate data
- Access to numerous forecasts
- Satellite and radar real time
- Hand prepared tables vs spreadsheet and computer use

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- Looking back Sac Bulletin is still a Sac Bulletin, QPF still the same basic QPF, 3 day inflow forecast still 3 day inflow forecast, zonal weather forecast still zonal weather forecast...BUT….
  - Small basins identified and forecasted
  - Have more detailed forecast information, 3 day forecast is now extended to 5 days, 10 day forecast with fair level of confidence
  - More forecasted impaired runoff forecasts
  - Electronic transfer of inflow forecasts
  - Frequent updates on QPF and inflow forecasts during severe weather
- More climate data (long range forecasts) available today with more confidence in ability to predict long range trends. Eg. El Nino conditions
- Daily briefings often present various model output providing a broader perspective of potential events. Numerous models are also available on internet.
- Real time satellite and radar images available for operators adding much more information than past single point or station information. Nothing like seeing a line of orange or red on a radar image working the way toward your reservoir.
- A review of reservoir routings performed in 1986 finds pages of handwritten spreadsheets showing a single scenario. The capabilities that the personal computer have added are huge. Data can be loaded in an instant and dozens of potential scenarios reviewed. Historical storms events can be modeled easily.

Impacts to CVP Operations

- Improved accuracy and detail in planning operations
- Improved water supply
- Improved power generation
- Improved public safety
- Improved scheduling of outages
- Reduced fishery impacts - flow fluctuations, peak flow, larger cold water pool, sustaining instream flows
- Reduced high flow impacts from flood release
- Improved dissemination of information over internet

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• Difficult to discern actual impact to operations, but benefits are there. It is difficult to create a base case with so much influencing the CVP operations and decision making process.

• Generally, improved planning of operations and operation of the facilities.

• Leads to enhanced ability to meet project objectives - water supply, power generation, improved public safety

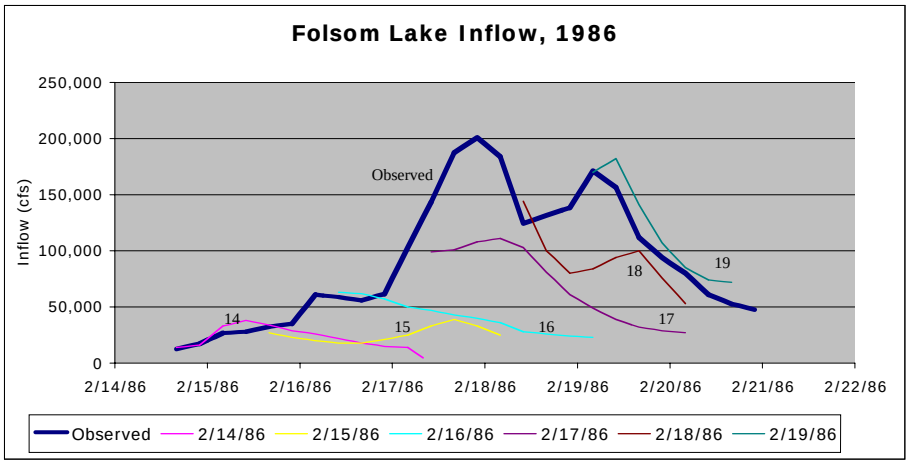
• Improved planning assists in scheduling facility maintenance and system outages

• Improved flood operations assists in minimizing project impacts to the fishery by reducing flow fluctuations, reducing peak flow (debate on high flow benefits for river channel), developing larger water supply and cold water pool, and adding certainty to sustained instream flow

• Flood control diagrams often specify that once a reservoir is encroached, the release should match inflow and be maintained until the reservoir is out of encroachment. Improved forecasting can help us improve on this by allowing the operator minimize the peak release.

• Internet use has created a vast source of information for not only the operator but also for the general public. Now, the public has almost instant access to weather information as well as reservoir operations and streamflow data.

Impacts to CVP Operations



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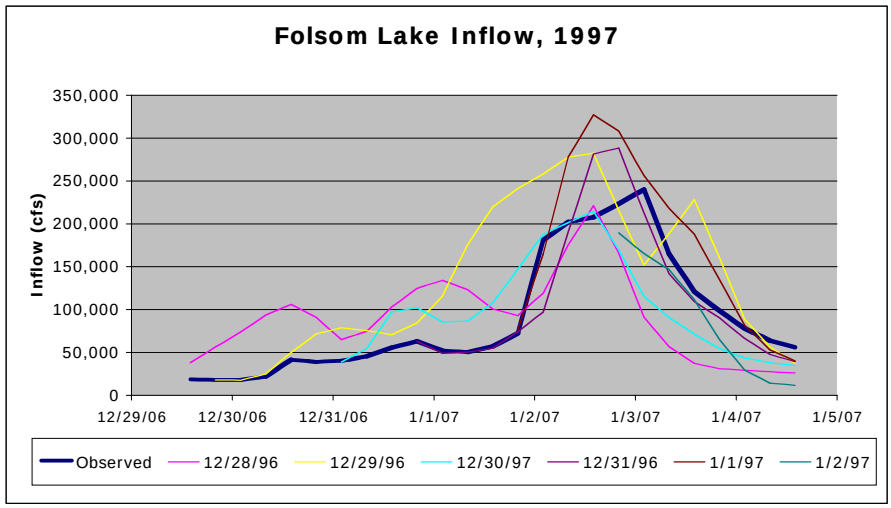
Forecast Data and Other Observations

- Folsom inflow forecast for 1986 flood from CVO files
- Typical 3 day forecast
- Consistently under forecast the peak inflow for this event

Impacts to CVP Operations



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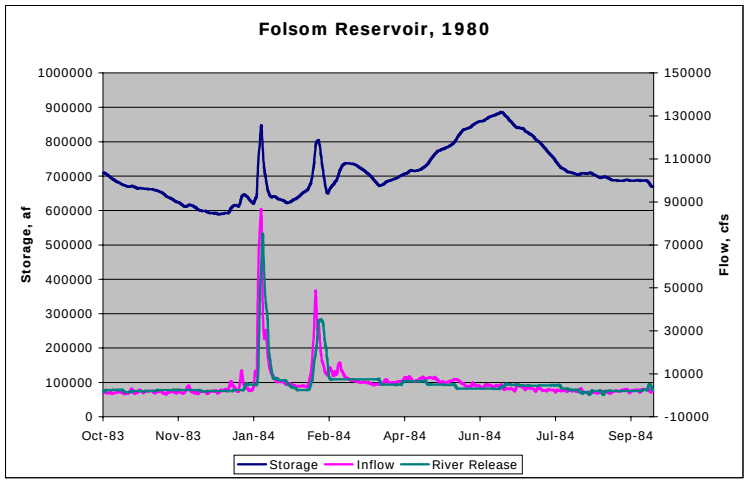
- 1997 New Year Flood event
- Increased number of days forecast with a good level of accuracy, 5 days in advance
- Predicted general shape and magnitude of the storm event a few days in advance. This is important in the amount of time it provides for operators prepare for the upcoming flood operation. Ensure that reservoir storage is at the proper level, check equipment and facility status (gates, generators/turbines, spillways), prepare staffing, coordinate with local agencies

Impacts to CVP Operations



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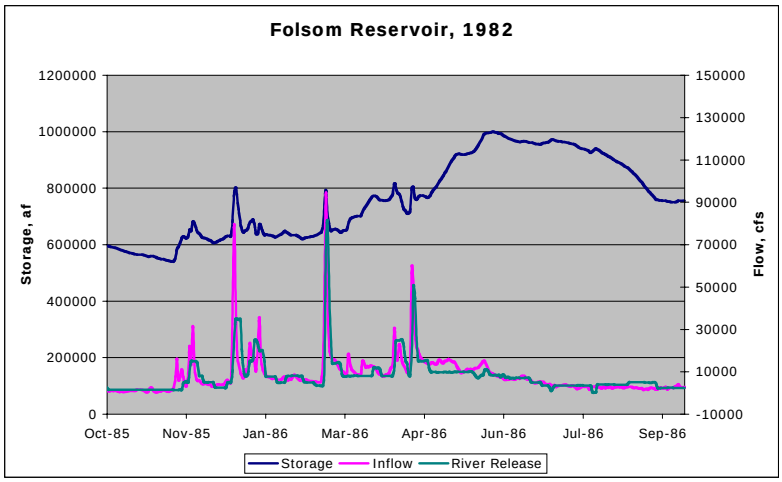
- Typical reservoir operation from 1980
- Difficult to determine exactly the basis the decisions related to the reservoir operations without some serious analysis of historical data. But, note the quick efficient release response to inflow when encroached and the fluctuation of release flow in response to changing inflow. Reservoir release was near peak daily inflow

Impacts to CVP Operations



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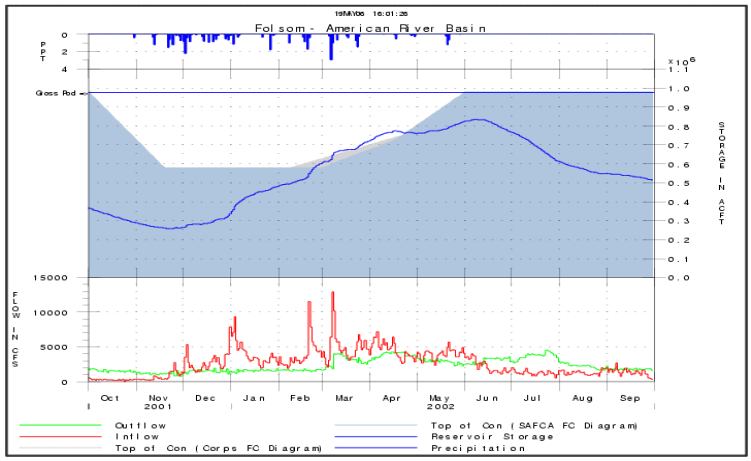
- Reservoir operation in 1982, a wetter year with Folsom filling

Impacts to CVP Operations



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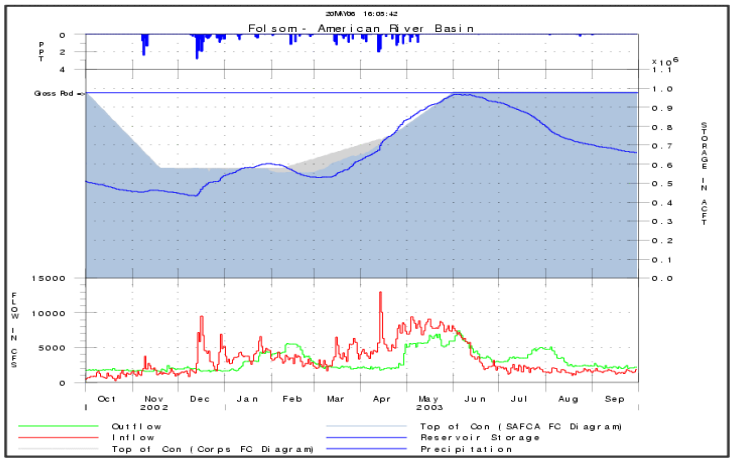
- More recent operation, Folsom Reservoir in 2002, maybe not a fair comparison with lower peak inflow, but useful to illustrate some operational objectives made easier with improved forecasting abilities.
- Note that this is a drier year and CVO might have been a little tighter reservoir release operations.
- When encroached in the flood control diagram on the fill side (spring), the release was typically less than inflow. This operation utilized short range forecasts of reservoir inflow, longer term forecasts of future storms, and snowmelt forecasts.
- Less flow fluctuations result in less stranding and isolation impacts to the fish and more water conservation with a greater cold water pool in the reservoir.
- Potential power generation benefits by staying within powerplant capacity
- Not to say that this may not have been done 20 years ago, but certainly the current technology makes it a lot easier. This is a result of factors such as improved forecasts, additional knowledge of fishery concerns, and improved interagency coordination

Impacts to CVP Operations



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- Folsom Reservoir in 2003, wetter than 2002 and we did fill the reservoir
- Still note the attempt to minimize flow fluctuations through the flood season
- Tested a couple of methods to minimize fishery impacts while encroached in the flood pool. Tried to a shorter higher release to get out of encroachment as soon as possible to minimize the opportunity for steelhead to spawn at a higher flow that we would not be able to sustain through the season, and tried a lower more sustained release to slowly get out of encroachment.

Future of Operations Forecasts

- Use of forecasted inflow
  - Flood forecasting and seasonal
- Ensemble forecasting and probability distribution functions
- More detailed precipitation and runoff estimates in flood operations
- More scenarios to run and more time to anguish over operations

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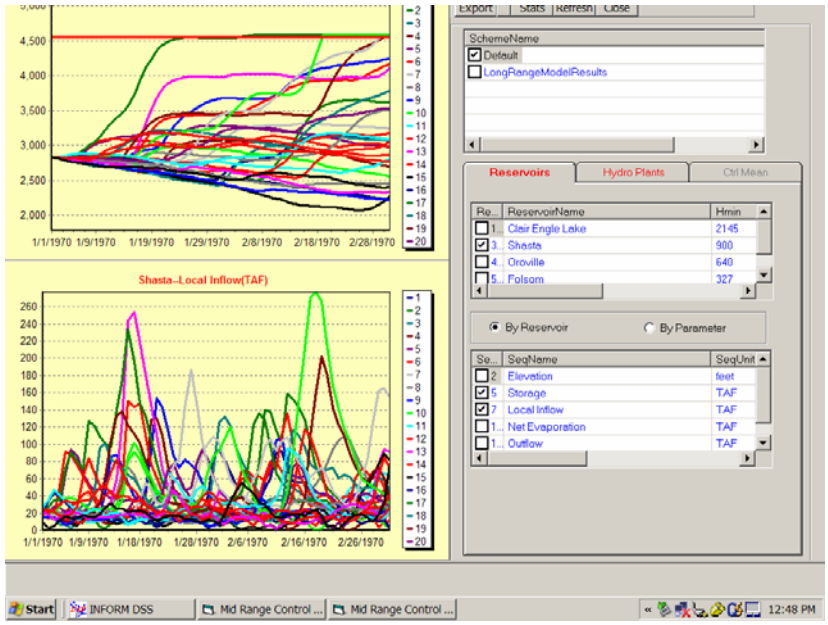
- Probably will see more flood control diagrams and flood operations place a high level of reliance of forecasted inflow. The use of forecasted inflow will grow from just the anticipated inflow over the next few hours to use of forecasts a day or days in advance.
- Ensemble forecasts of streamflow are becoming available. The operators challenge is to adequately incorporate them into reservoir operations. In flood operations we typically analyze only the most probable outcome as well as a one or two extremes. Our seasonal and mid-range operations forecasts usually reflect only the 90% and 50% exceedence forecasts. A forecast of a series of potential flows would present the operators with the difficult task of modeling each potential scenario. As the water project system grows the operational complexity grows, and operating rules and constraints do not necessarily follow a regular pattern. For example, the CVP water supply allocation can actually drop in a wetter year. There are studies under way attempting to evaluate the value of utilizing ensemble forecasts in water project operations
- More detailed precipitation and runoff estimates will improve difficult operations we have in operating for downstream flow requirements during flood events.
- More data means the opportunity to evaluate more scenarios and do more reservoir routings. More advanced knowledge of storms allow us more time to anguish over potential outcomes.



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- Example of an ensemble inflow forecast for Shasta Reservoir with potential reservoir storage outcome for each scenario

Challenges

- Forecasting and planning operations in the land of theory
  - Forecasting
  - Equipment operation
  - System response
- Keep it simple

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- For these extreme events, we are predicting events and operations that we may not have seen in the recent past, or ever experienced. How much confidence do we have that the forecasted events will unfold as predicted.
- Can models accurately reflect these monster storms?
- How will our equipment, valves, gates, and structures able to withstand the forces placed on them? These may be at the design limits of the facilities.
- Will the system respond as expected? The flow may be at levels previously unseen. We will be operating in areas on the design curves that were only experienced on a computer or in equations, eg flow rating tables, or gate release tables.
- In an extreme event our equipment and personnel may be tested to the limits. We may not know how effectively or quickly equipment and personnel can respond to the required actions in advance of these events.
- Exercise caution not to make flood operations overly complex or technical. Something to be said for a simple emergency spill diagram that can be utilized by an individual isolated at a dam operating knowing only the reservoir elevation and calculated storage, inflow, and release.
- Be wary of Murphy's Law and Keep It Simple.