Public Comment
Bay Delta Plan Workshop 3
Deadline: 10/26/12 by 12 noon

Technical Staff Comments to the State Water Resources Control Board re: the Comprehensive (Phase 2) Review and Update to the Bay-Delta Plan, Public Workshop 3, Analytical Tools: Using Structured Decision Making (SDM) to manage uncertainty and improve decisions

RECEIVED
10-26-12
SWRCB Clerk

Key Points

- Structured Decision Making (SDM) should be used to develop a decision support model that evaluates trade-offs and consequences among alternative management actions.
- A decision-support model developed through SDM allows for efficient and strategic monitoring by assessing where reducing uncertainty (though monitoring data) could influence management decisions.
- The SDM process provides a framework for explicitly incorporating additional information (e.g., monitoring data) into the decision-making process to effectively achieve adaptive management.
- The resulting decision-support tool should be used to examine consequences of alternative flow management scenarios to determine costs and benefits to trust resources.

What is Structured Decision Making?

Throughout the first two public workshops, many presenters commented on the need for additional science, monitoring, and adaptive management to better inform periodic updates to the Bay-Delta Plan. While we agree that additional science and monitoring are important, we believe that the key to updating the Bay-Delta Plan is to create a sound process for making the best possible decisions using the best currently available science within an adaptive management framework. In many cases, more science may not lead to better environmental management decisions, because decision-makers are asking more from science than it can deliver (Gregory, et al., 2006). Ultimately, science cannot make the decision about water quality objectives; the decision is based on stakeholder values about water management and fishery resources. Science should be used to inform the decision-making process and evaluate the relative ecological risk associated with management alternatives. However, science cannot determine what level of risk is acceptable.

Implementing a sound decision-making process is crucial as a complement to the body of scientific and technical information that informs environmental management (Gregory, et al., 2006).The core steps in a decision-making process include:

- Define the decision context
- Clarify value-based objectives, identifying fundamental (what do we want) from means (how do we get there) objectives
- Identify a range of alternatives for achieving objectives
- Examine consequences of the alternatives, including uncertainties and risk
- Explore trade-offs and make recommendations

Science can help to inform objectives, identify alternatives, quantify uncertainty, examine consequences, and explore trade-offs. However, making good decisions requires a process for integrating facts with stakeholder values. In the case of iterative decisions (such as periodic updates to the Bay-Delta Plan), adaptive management should be explicitly incorporated in the decision-making process to allow for flexibility and learning in the case of additional information.

We recommend that the Board use Structured Decision Making (SDM) as a tool to make good decisions in the context of uncertainty. SDM is an organized approach to assessing problems and identifying and evaluating alternatives in order to reach decisions that are focused clearly on achieving fundamental objectives. SDM is based in decision theory and risk analysis, and can be used to effectively develop a science-based decision making framework that is increasingly being applied to natural resource management questions (Dorazio & Johnson, 2003; U.S. Fish and Wildlife Service, 2008; Clemen, 1996; Conroy, et al., 2008) . The SDM process recognizes that resource management decisions are highly complex; thus, decisions are broken down into elements that help manage this complexity. Key SDM concepts include making decisions based on clearly articulated objectives, dealing explicitly with uncertainty, identifying management action alternatives, exploring consequences of alternative actions and assessing tradeoffs, and ultimately choosing a decision and action plan. Benefits to this approach include decisions that are deliberative, transparent, and defensible, thus are more likely to achieve objectives and be accepted by others. The SDM process would assist the Board in adopting defensible water quality objectives by: (1) clearly stating the beneficial uses that flow criteria are intended to achieve, (2) identifying the set of alternative water quality objectives (management action alternatives) that may achieve the stated beneficial uses, (3) considering mathematical models and other decision-support tools that can help evaluate the consequences of alternative water quality objectives, (4) clearly articulating the trade-offs and uncertainty associated with each set of consequences, and (5) making a decision that optimizes among the set of consequences and trade-offs, and explicitly identifies ways in which adaptive management will inform further evaluation among a set of alternative water quality objectives (Figure 1).

Design monitoring programs to inform decision making

Monitoring should not be conducted for its own sake, but as a means to improve management outcomes. In particular, monitoring should be conducted where there are uncertainties about how the system responds to management and where there is potential for monitoring information to improve future management decisions (Lyons, et al., 2008). Conceptual and/or quantitative models can be developed as part of the SDM process that allow for exploration of where additional monitoring is likely to improve decision-making and where continuous baseline monitoring is needed to identify potential changes in status or trends. Sensitivity analysis of key parameters in a model can illuminate where additional information would most improve outcomes.

Adaptive management is a special case of SDM and is best applied when decisions have some degree of uncertainty, are iterated, and are linked over time (i.e., an action at time t affects another action at time t+1). Management actions are important learning opportunities for iterated decisions (U.S. Fish and Wildlife Service, 2008). However, a decision process and associated monitoring program must be in place that (1) allows for collection and analysis of relevant data, and (2) provides a decision framework that allows application of new data to inform subsequent management decisions. Adaptive management approaches are often recommended in environmental management; however, successful implementation is rare and reflects the tension between short-term preferences of stakeholders for low-cost approaches and medium- and long-term requirements for reducing uncertainty and increasing ecological certainty (Gregory, et al., 2006). To develop a defensible adaptive management alternative, managers should: (1) identify criteria that will be used to compare the results of alternative actions, (2) clearly state competing hypotheses, (3) identify candidate treatments, (4) describe the anticipated change in a management decision, (5) demonstrate that the predictive ability of the experiment is sufficient to allow informed ranking of alternative actions, (6) identify evidence that will be used to draw inferences from the monitoring data, (7) prescribe a protocol for oversight of monitoring programs and interim decisions, and (8) clearly communicate the motivation and reasons for embracing an adaptive management approach.

The importance of an adaptive management approach and supporting monitoring cannot be overstated. Resource management decisions are almost always made with some degree of uncertainty; what makes a decision good is the process by which it was generated (which can be controlled) and the degree to which the decision framework is built to incorporate new information as it is available to reduce uncertainty and improve decision outcomes.

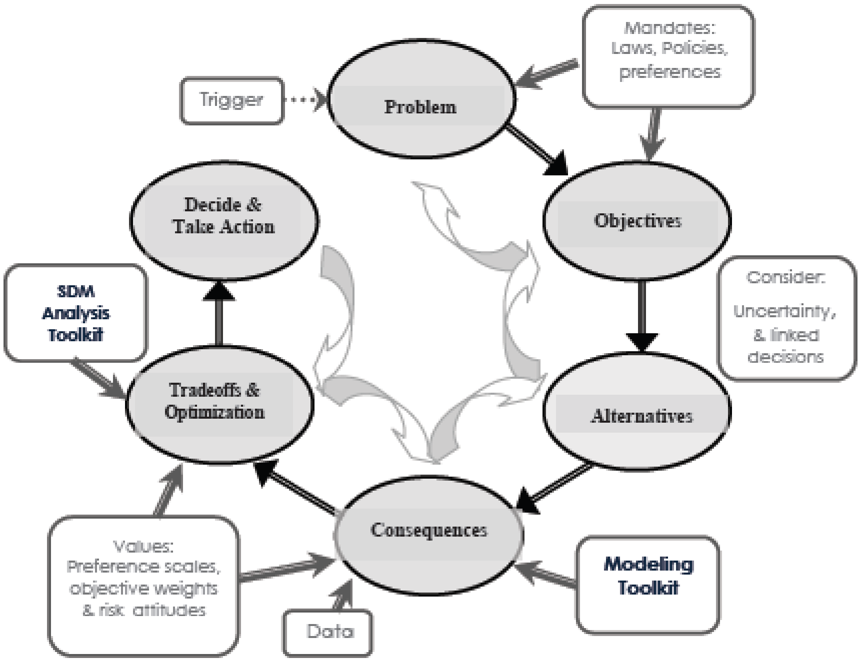


Figure 1. Structured Decision Making steps. From USFWS 2008.

American River Spawning and Rearing Habitat Restoration Program: a case study

We are currently using SDM to improve decision-making and more closely link monitoring and adaptive management within the context of implementing parts of the Central Valley Project Improvement Act (CVPIA). The following case study of how we are using SDM to make better decisions on gravel placement and rearing habitat restoration to improve anadromous fish production and growth in the Lower American River (LAR) can help illustrate the application of an SDM process to adaptive management.

Define decision context -- In response to the steady declines of Central Valley anadromous salmonids, Congress passed CVPIA in 1992. One of the sections of CVPIA, §3406(b)(13) (Channel and Floodplain Restoration Program), mandated the Department of the Interior to "develop and implement a continuing program for the purpose of restoring and replenishing, as needed, spawning gravel lost due to the construction and operation of Central Valley Project dams... and other actions that have reduced the availability of spawning gravel and rearing habitat " including "…the American River downstream from Nimbus Dam…" The program is also mandated to "include preventive measures, such as re-establishment of meander belts and limitations on future bank protection activities, in order to avoid further losses of instream and riparian habitat."

The gravel program is currently creating a planning framework that will assist in management decisions and prioritizing monitoring projects on an annual and long-term basis to measure success and improve restoration activities. As part of this effort, we participated in a Structured Decision Making workshop (Hammon, et al., 1999; Peterson & Evans, 2003; Lyons, et al., 2008) to develop a decision support tool to facilitate implementation of alternative management actions in the Lower American River (LAR). Our goals for this process were to:

(1) Define the fundamental and key means objectives for the gravel program's activities;
(2) Elucidate the key variables and mechanisms that must be understood in order to determine if restoration actions are achieving the fundamental objective;
(3) Develop a rapid prototype model for comparing alternative restoration actions within a model framework that can be further developed with additional data; and
(4) Incorporate the ability to assess the value of information relative to implementing restoration actions as a tool for prioritizing research and monitoring.

Determine fundamental objectives -- Defining clear objectives is arguably the most important step in a decision-making process, although many decision makers often assume that objectives are commonly understood and quickly move on to the steps of information gathering, modeling, and analysis (Gregory, et al., 2006). Our team spent the better part of a day redefining an objective that we initially thought was clear and sufficient (achieve doubling of natural production of anadromous fish populations from 1967-1991 levels). After much discussion about performance measures that directly reflected the management actions available to the Program, we defined the fundamental objective as "determine the most efficient use of management resources to improve the number, size diversity, and condition of fall-run Chinook salmon outmigrants leaving the LAR" (i.e., maximize the number, size diversity, and condition of outmigrants per dollar spent using available resources). To achieve this objective, our key means objectives were to maximize the quality and amount of spawning and rearing habitat for Chinook salmon.

Identify management alternatives -- Alternative habitat restoration actions include: (1) small and (2) large amounts of gravel injection, (3) small and (4) large gravel and structural (e.g., woody material and boulders) placements, and floodplain/side channel enhancement by (5) excavation and (6) channel fill. Management decisions include (1) type of action; (2) location of action and (3) maintenance of previously restored sites. Other potential management actions (e.g., flow, temperature management) are also important, but could not be considered within the context of the Channel and Floodplain Restoration Program.

Examine consequences, tradeoffs, and uncertainty -- We are developing a decision support tool (figure 2) to evaluate the consequences and tradeoffs of implementing alternative management actions. Monitoring data is being used to parameterize this model and sensitivity analyses will be performed to examine the sources and consequences of uncertainty. Results of sensitivity analyses can be used to prioritize monitoring with the highest value for decision making. Our fundamental objective was reflected in our model utility function (the terminal node of our conceptual model, figure 2) which provides a common measurement of the relative costs and benefits of alternative actions and reductions of uncertainty (e.g., investing in monitoring activities). The optimal management decision (which could be a restoration action, research and monitoring, or a combination of the two) is the decision that provides the most desirable ecological outcome relative to its costs, thus considering both ecological response and economic constraints (Stewart-Koster, et al., 2010). Ultimately, the gravel program plans to add a second fundamental objective to also maximize the number, size diversity, and condition of steelhead smolts leaving the American River.

To determine the marginal gain in the number of outmigrating smolts resulting from alternative management actions, we examined the relationships between four model components (figure 2): (1) future habitat availability; (2) fry emergence; (3) potential juveniles; and (4) Chinook outmigrants. The future habitat availability component was defined by relationships between alternative restoration actions, discharge during spawning or rearing, and time since the previous restoration action. Fry emergence was dependent on future spawning habitat, spawning potential, and escapement. Potential juveniles were defined by fry emergence, juvenile habitat zone potential, future in-channel rearing habitat, and future seasonally inundated habitat. Chinook outmigrants were related to potential juveniles and system dynamics, a measure of the uncertainty in whether spawning or rearing habitat was limiting the population from year to year. Ultimately, these biological components and management action components provided an estimate of the number of outmigrants per unit cost in response to each alternative management action on the LAR.

Value of decision structuring -- The decision structuring process is an important step in developing transparent project design, identification of potential near- and long-term benefits, and refining monitoring and research needs. Our recent experience with SDM demonstrates the on-going struggle for fisheries managers to incorporate ecological assumptions and processes, such as the utility of value-marginal gain, into restoration planning. Development of decision support tools and node parameterization highlight the importance of narrowing the number of conceptual processes thought to influence gravel enhancement, while acknowledging that many of the factors driving fry emergence and rearing success are outside the scope of the LAR Gravel and Floodplain Restoration Program.

The introduction of our group to the SDM decision making process allowed us to identify key objectives, a key step in the decision making process, and ultimately, the appropriate restoration actions associated with LAR gravel augmentation program that best achieve those objectives. The development of clear objectives and a restoration evaluation model highlights relevant information needed for measuring the success of the program. A potential dilemma is that the higher priority information needed to better parameterize our model may be costly to obtain (Roni, et al., 2002). The utility value concept will be beneficial to use in prioritizing LAR gravel enhancement management actions, research, and monitoring, as well as other CVPIA restoration actions and agency mission responsibilities.

Application to the Bay-Delta Plan update

There are many available case studies that illustrate the success of SDM in facilitating a collaborative approach to making environmental management decisions. One useful case study is the use of SDM to develop flow recommendations for the Bridge River, a tributary of the Fraser River in British Columbia, and a river with concerns about salmon production, water use, and power generation (Failing, et al., 2012). Fisheries biologists, government regulators, electric utility staff, and aboriginal community representatives participated in a collaborative process that incorporated the best available science into decision-making while addressing uncertainty. One of the key lessons learned from this example is that making broadly supported decisions requires not only sound science but also a value-based dialog about trade-offs across multiple objectives; experimental and monitoring results alone will not produce a decision. In addition, the SDM framework established a clear road map that focused on the decision-making task despite the pressures of difficult value-based conflicts. Some implications for SDM practice outlined in this case study include:

- Treat restoration problems as multi-objective decisions
- Include all relevant objectives, even if they are hard to quantify
- Do not expect experimental results alone to lead to clear restoration choices
- Implement adaptive management within a structured decision-making framework that addresses value judgments and uncertainties
- A deliberative approach to trade-offs within a well-structured decision problem is consistent with the principles of decision analysis
- Recognize that long-term experimental programs need to be responsive to changing information, values, and political realities.

As in the case of the Bridge River and the American River Spawning and Rearing Habitat Restoration Program examples, the first step in developing a SDM approach is to assemble a small working group that includes decision makers, technical experts, and stakeholder representatives. With the assistance of a SDM expert coach, the working group designs the decision-making framework to address the multiple competing objectives of the group members and includes the elements necessary for evaluating a full suite of restoration alternatives, usually in the context of one or more workshops. Use of an expert coach is key to (1) ensure that the right people are included on the initial and any subsequent working groups at the policy and technical levels, (2) lead the working group through the SDM framework, ensuring each step is adequately addressed, and (3) act as an objective voice in the process. We believe the SDM framework is appropriate and useful for making sound decisions in the context of multiple competing objectives, and we encourage the Board to consider using this approach. We can provide more information, additional case studies, and contact information for expert coaches if requested.

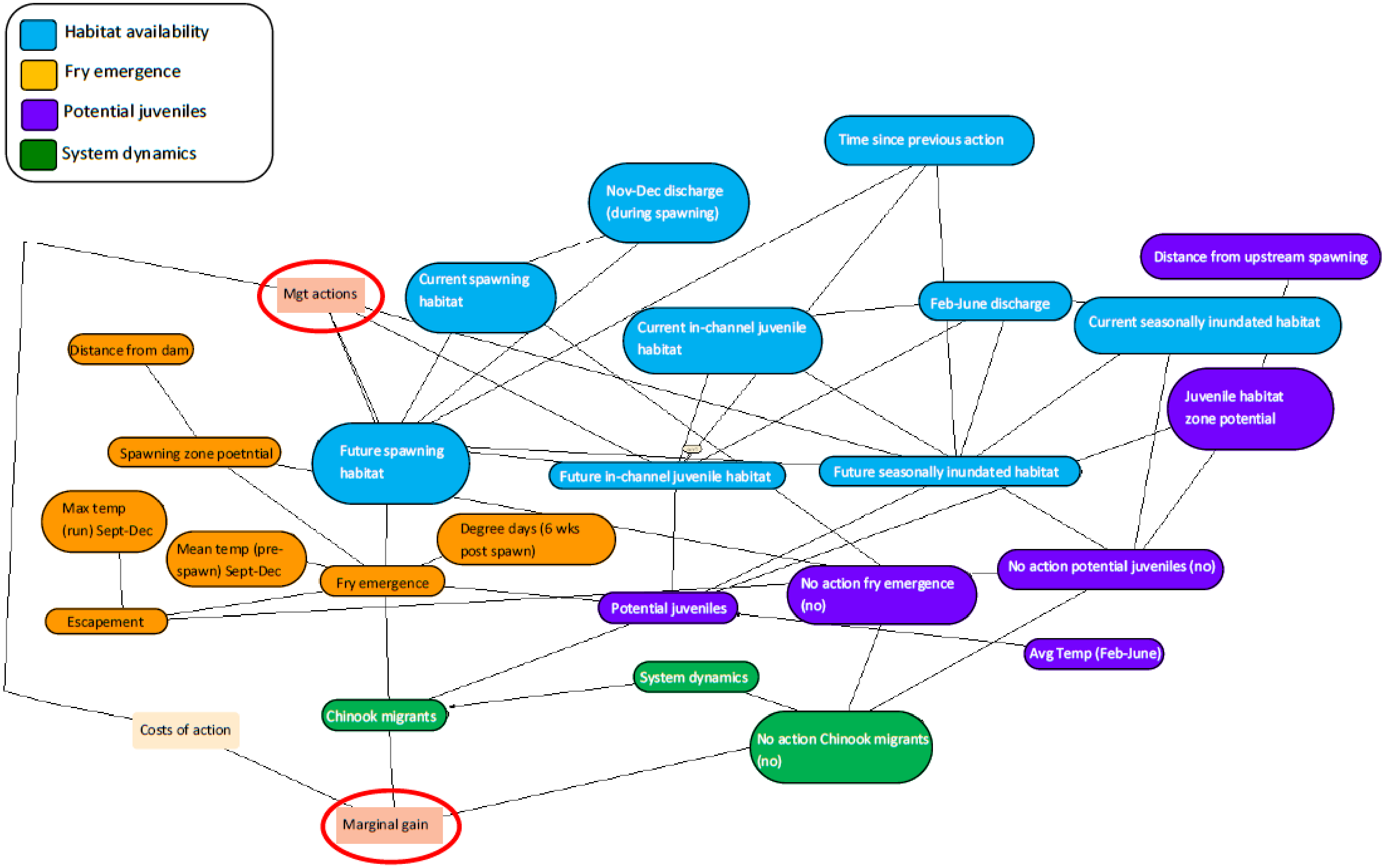


Figure 2. Conceptual model for decision support tool for Chinook salmon spawning and rearing habitat restoration. The purpose of the model is to determine which management action(s) maximize marginal gain (number, size, and condition of Chinook outmigrants per dollar spent).

References

Clemen, R. T., 1996. *Making Hard Decisions.* Belmont, CA: Duxbury.

Conroy, M. J. et al., 2008. Application of decision theory to conservation management: recovery of Hector's dolphin. *Wildlife Research,* Volume 35, pp. 93-102.

Dorazio, R. M. & Johnson, F. A., 2003. Bayesian inference and decision theory-a framework for decision making in natural resource management. *Ecological Applications,* Volume 13, pp. 556-563.

Failing, L., Gregory, R. & Higgins, P., 2012. Science, uncertainty, and values in ecological restoration: a case study in Structured Decision-Making and Adaptive Management. *Restoration Ecology,* Volume Early View, pp. 1-9.

Gregory, R., Failing, L. & Higgins, P., 2006. Adaptive management and environmental decision making: A case study application to water use planning. *Ecological Economics,* Volume 58, pp. 434-447.

Gregory, R. L., Failing, L., Ohlson, D. & McDaniels, T. L., 2006. Some pitfalls of an overemphasis on science in environmental risk management decisions. *Journal of Risk Research,* Volume 9, pp. 717-735.

Hammon, J. S., Keeney, R. L. & Riaffa, H., 1999. *Smart choices: A practical guide to making better life decisions.* New York: Broadway Books.

Lyons, J. E., Runge, M. C., Laskowski, H. P. & Kendall, W. L., 2008. Monitoring in the context of structured decision-making and adaptive management. *Journal of Wildlife Management,* Volume 72, pp. 1683-1692.

Peterson, J. T. & Evans, J. W., 2003. Quantitative decision analysis for sport fisheries. *Fisheries,* 28(1), pp. 10-21.

Roni, P. et al., 2002. A review of stream restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific Northwest watersheds. *North American Journal of Fisheries Management,* Volume 22, pp. 1-20.

Stewart-Koster, B. et al., 2010. The use of Bayesian networks to guide investments in flow and catchment restoration for impaired river ecosystems. *Freshwater Biology,* Volume 55, pp. 243-260.

U.S. Fish and Wildlife Service, 2008. *Structured Decision Making: Fact Sheet*.

RECLAMATION

Managing Water in the West

Suggested Approaches to the Use of Analytical Tools for Evaluating Water Supply, Hydrodynamic & Hydropower Effects—SWRCB Workshop #3

U.S. Department of the Interior
Bureau of Reclamation

November 13 & 14, 2012

Analytical Tools

- **WATER SUPPLY EFFECTS: CalSim II, Calite**
- **HYDRODYNAMIC EFFECTS: DSM2, RMA, Temperature Models**
- **HYDROPOWER EFFECTS: PLEXOS & other Optimal Power Flow (OPF) Production Cost Models**

Temperature Models

- **Development of Central Valley Temperature Models authorized & partially funded: CVPIA, Section 3406(g)(2)**
- **Sacramento, Trinity, Feather, American, Stanislaus and San Joaquin Rivers**
- **OBJECTIVES:**
  - **To improve temperature prediction versus reservoir storage**
  - **To support reservoir operations to restore fisheries in the Central Valley and comply with biological opinion RPAs**
  - **To analyze the effects of operational scenarios on temperature and thereby to maximize beneficial water uses**
- **EFFECTIVE COLLABORATION:**
  - **Resource Agencies: Reclamation, DWR**
  - **Regulatory Agencies: SWRCB, USFWS, NMFS, CDFG**
  - **Local Districts: OID, SSJID, SEWD**

2008 OCAP Graphic of Temperature Models

Figure 9-5 General spatial representation of the temperature model networks.

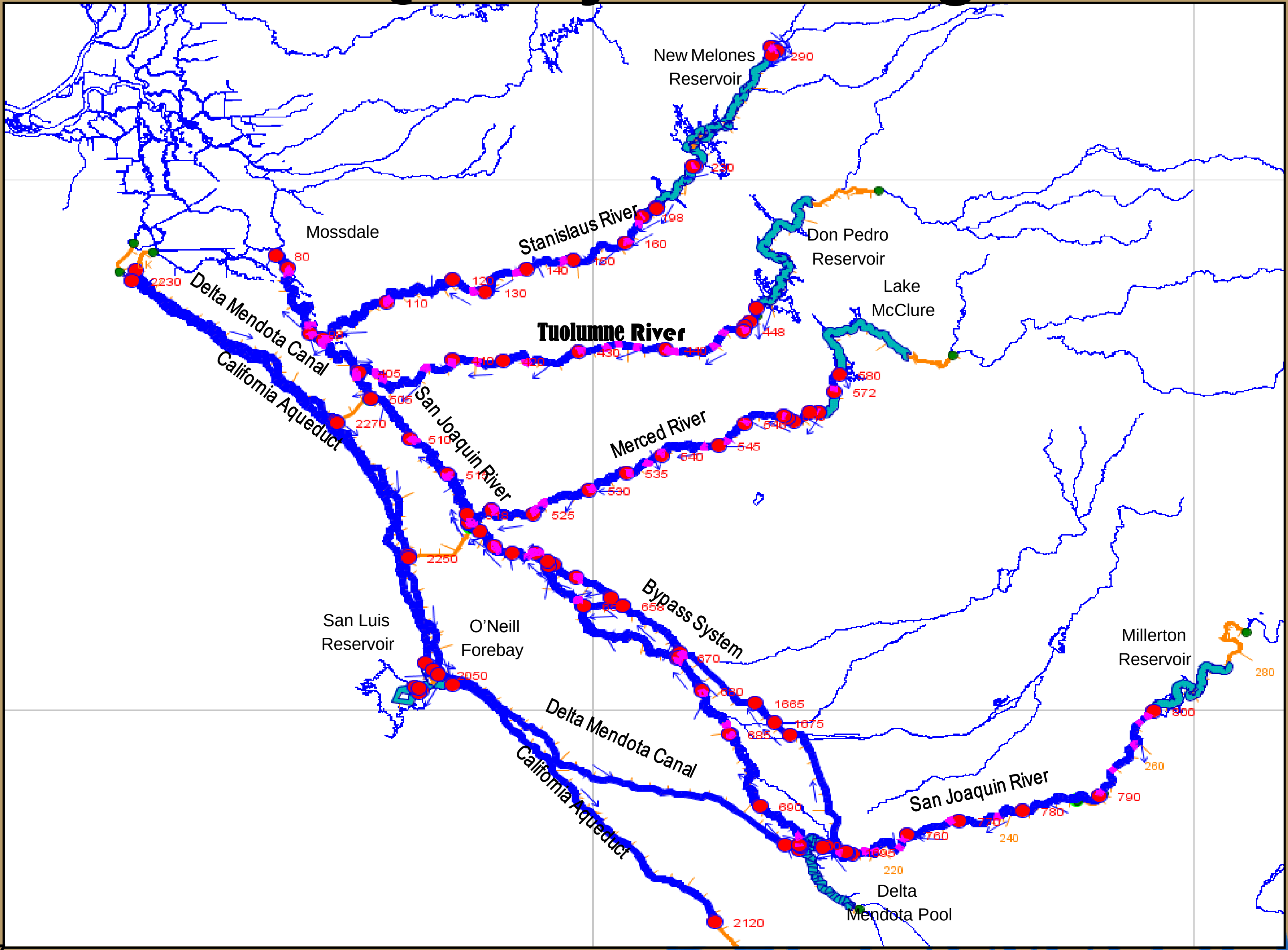
Temperature Models

- **Current Tools:**
  - **Based on HEC-5Q modeling system that use hydrological, meteorological, and operational conditions by using HEC5 and HEC5Q model codes with daily time-steps for flows and 6-hourly time-steps for water temperatures**
  - **CE-QUAL-W2 models**
  - **Monthly outputs from Calsim II are processed to provide daily input data for the temperature models--processors work through Data Storage System (DSS) files;**
- **Future Tools:**
  - **Development of multi-dimensional hydrodynamic model with recent bathymetry-- NMFS, USACE and EPA**
  - **Integrate water temperature simulation algorithm within a water operation model (e.g. CalSim II) and optimize the model with water temperature as the target variable**

SJR: Water Quality Modeling

- **Initiated in 1999 on Stanislaus River to analyze the relationship among the following parameters:**
  - **Reservoir operations**
  - **Water temperature regimes**
  - **Fish survival (Fall-run Chinook Salmon and Steelhead Rainbow Trout)**
- **Extended to Tuolumne and Merced tributaries**
  - **Funded through CALFED Bay-Delta Program**
  - **Extending to SJR Basin below Stevinson**
- **Extended to entire San Joaquin Basin (incl. Bypass)**
  - **To model thermal impacts of SJR restoration alternatives &**
  - **CVP/SWP components (canals and storage facilities between the Delta and Mendota Pool)**
  - **EC modeling also included**

SJR: Water Quality Modeling



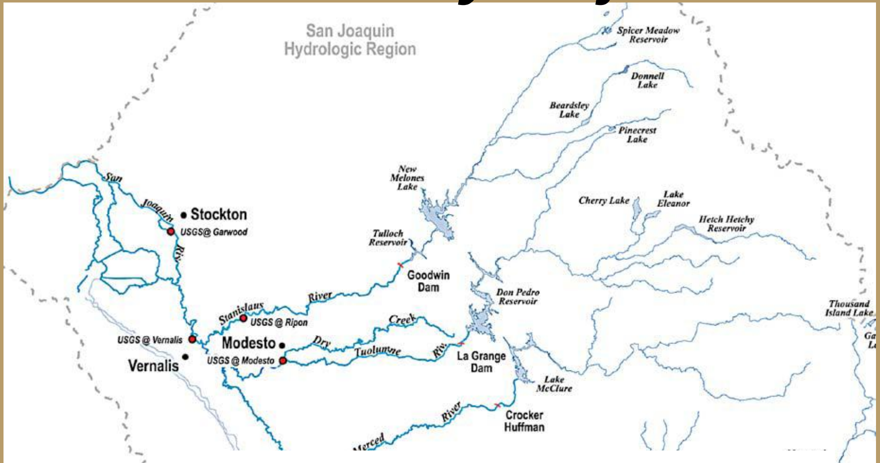
Modeling Effects of SWRCB Alternative Standards

- **CalSim II is powerful Planning Tool, but does not paint complete picture**
  - **Models current operations, water rights, contracts, etc.**
  - **Monthly time step & use of perfect foresight in San Joaquin Basin → issues re: evaluation of operational implementation**
  - **Temperature analysis is currently not integrated**
  - **Hydro generation is estimated through post processing**
- **PLEXOS**
  - **Hourly dispatch of all generation in Western Interconnection respecting transmission constraints; model under contract to Reclamation is focused on CAISO market.**
  - **Used to estimate value of hydro generation**
    - **On-peak, Off-peak generation**
    - **Ancillary Services**
    - **Capacity through post processing**

CASE STUDY: Modeling Alternative SJR Flow Objective

SWRCB's Oct 2011 *Technical Report on Scientific Basis for Alternative SJR Flow & So. Delta Salinity Objectives*

- **Salmon doubling narrative goal (1967-91 population)**
- **Flow augmentation to mimic the shape of the unimpaired hydrograph**
- **Tributary compliance points**
- **Feb-June release X% (e.g. 20-60%) unimpaired inflow**
- **Vernalis base flow proportionately from tributaries**
- **Adaptive Management**



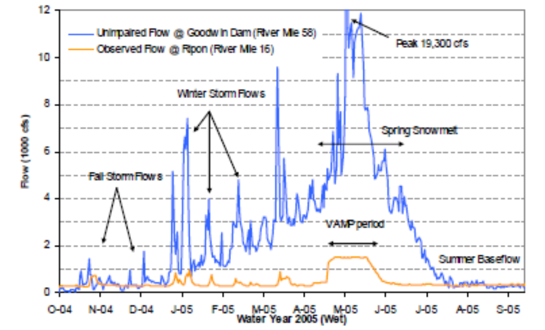


Figure 2.1. Typical Stanislaus River Annual Hydrograph of Daily Average Unimpaired and Observed Flows during a Wet Water Year (2005) Illustrating Important Hydrograph Components

CASE STUDY

- **Comparison of New Melones Operations under D-1641/VAMP, 20%, 40%, 60% bypass of unimpaired inflow standard**
- **CALSIM II D-1641/VAMP ASSUMPTIONS:**
  - **Future Level of Development (2020)**
  - **VAMP releases according to SJR Agreement**
  - **D-1641 base flow (capped in drier years) and Vernalis salinity standards met with releases from New Melones**
  - **OID/SSJID Senior Water Rights modeled per 1988 Stipulation Agreement**
  - **CVP contract = 155 TAF maximum**
  - **DO standards on Stanislaus June-Sept**
  - **RPA releases; no 1500 cfs capacity constraint**
  - **Full San Joaquin River Restoration Program releases**

Modeling Alternative SJR Flow Objective

Modeling Assumptions/Changes from D-1641/VAMP:

Differences from D-1641/VAMP Assumptions

- SWRCB 20%, 40%, and 60% of unimpaired flow standards implemented at mouths of tributaries
- No releases for VAMP or for D-1641 base flows or fall flows

Modeling Changes

- Current Calsim II methodology cannot be used for 40% and 60% bypass standards→ changes to methodology presented in following slides

Modeling Proposed SJR Flow Objective

- Alternate delivery allocation used
  - To enable meeting 40% and 60% standards
  - In March, model computes available water supply based on Mar-Sept inflows (perfect foresight), releases necessary to meet flow standards, and useable storage in New Melones
  - All project obligations impacted at higher standards
  - Minimum New Melones storage was 80 taf in all scenarios, except 60% run, which was 150 taf. This was necessary to maintain release capacity
- All results are preliminary

Modeling Proposed SJR Flow Objective

Useable storage in New Melones:

- Determined by taking the difference between end of Feb storage and an end of Sept storage target. If storage target is higher then Feb storage, then useable storage is 0.
- End of Sept storage target is set by multiplying storage in previous Sept by a proportion which is related to Mar-Sept inflow. So storage is used more aggressively in years with less inflow.

40% run

Mar-Sept inflow (taf)	Proportion
200-700	0.3–1.1
700-1000	1.2-1.4
1000-2000	1.4

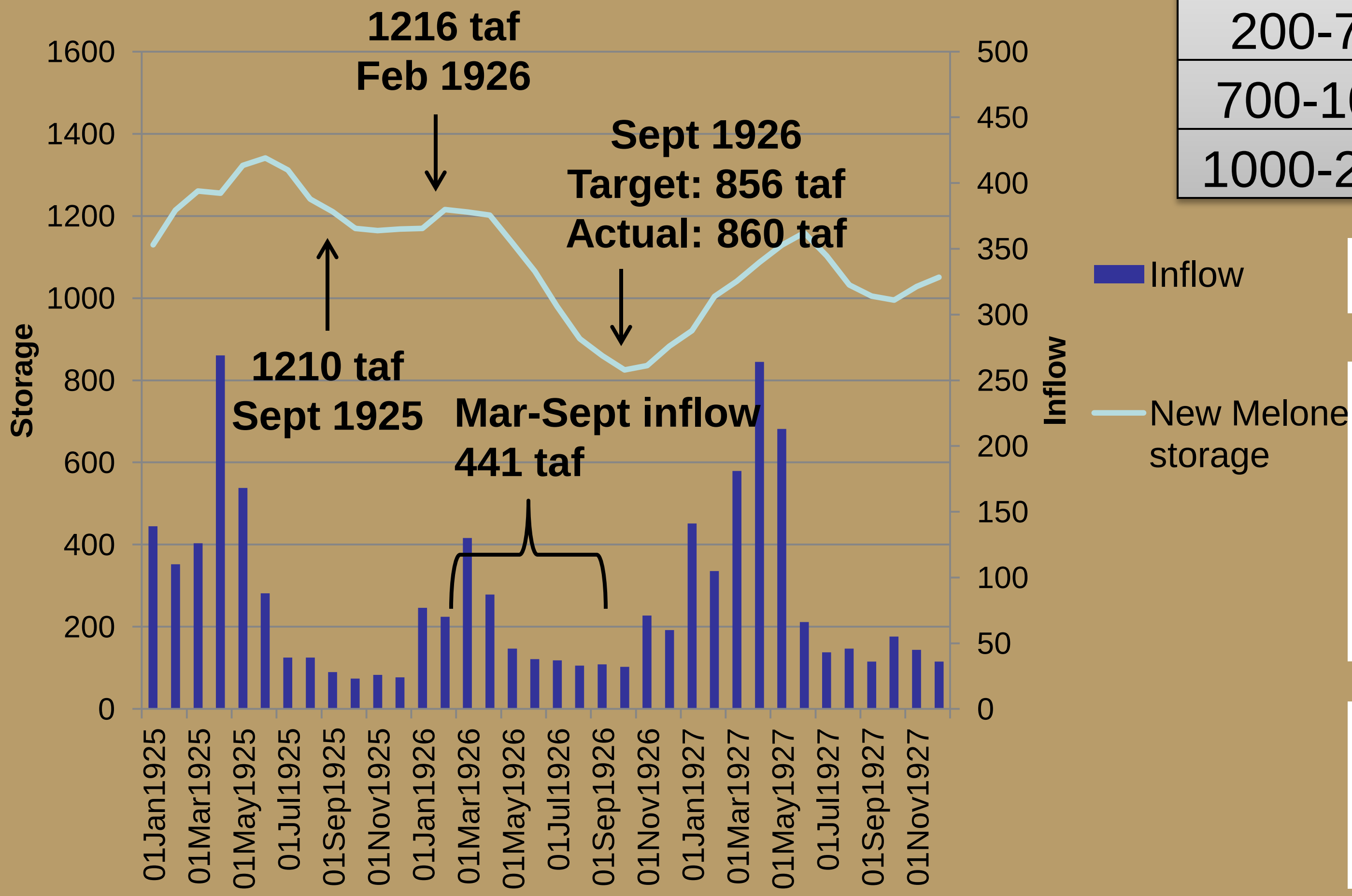
60% run

Mar-Sept inflow (taf)	Proportion
200-700	0.2-0.5
700-1000	0.8-1.4
1000-2000	1.4

Modeling Proposed SJR Flow Objective

Storage Target Example for 1926:

Mar-Sept inflow (taf)	Proportion
200-700	0.3–1.1
700-1000	1.2-1.4
1000-2000	1.4



1216 taf
Feb 1926

Sept 1926
Target: 856 taf
Actual: 860 taf

1210 taf
Sept 1925

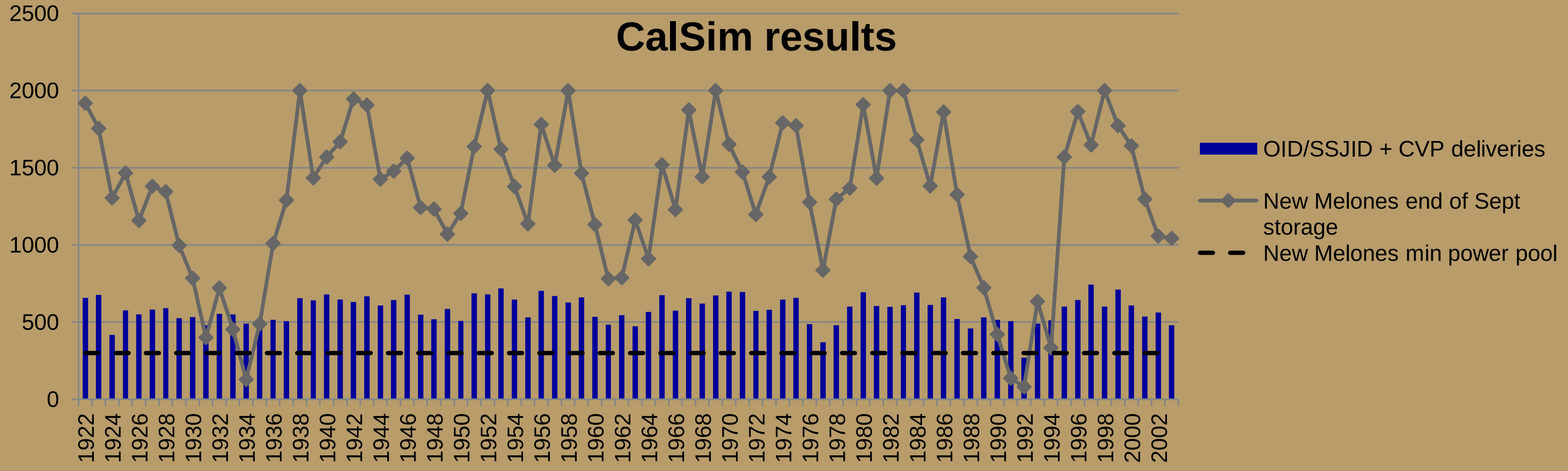
Mar-Sept inflow
441 taf

Proportion 0.69

Storage target calculation
1210 – 80 = 1130
1130*0.69 = 776
776 + 80 = 856 taf

Useable storage
1216 – 856 =
360 taf

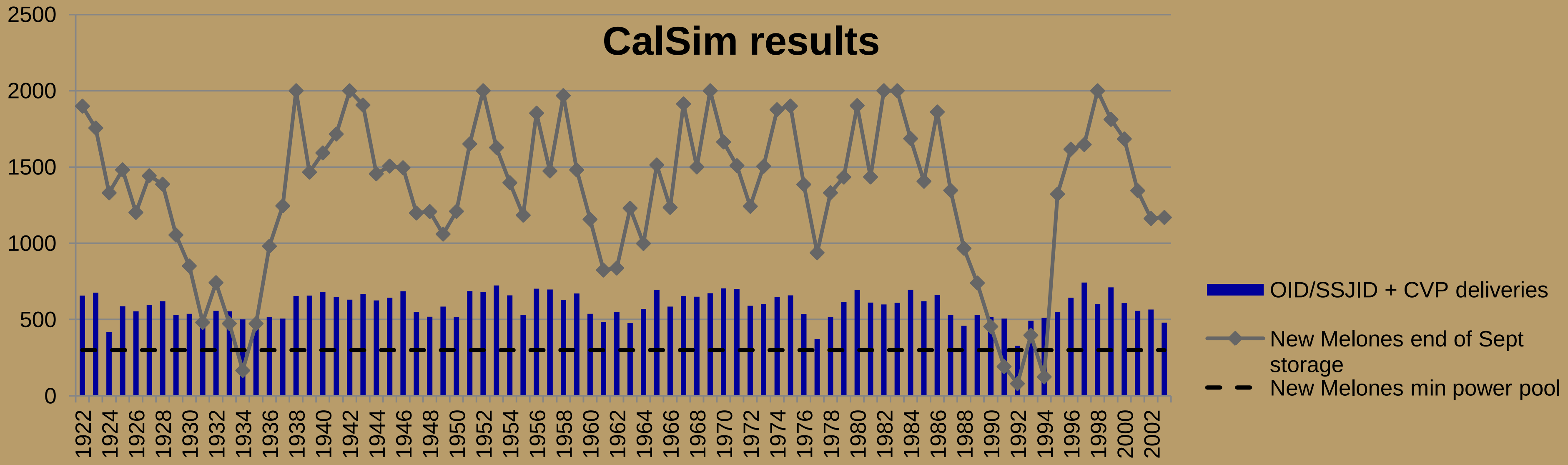
D-1641/VAMP Study



Average of all years Water Deliveries = 585 TAF

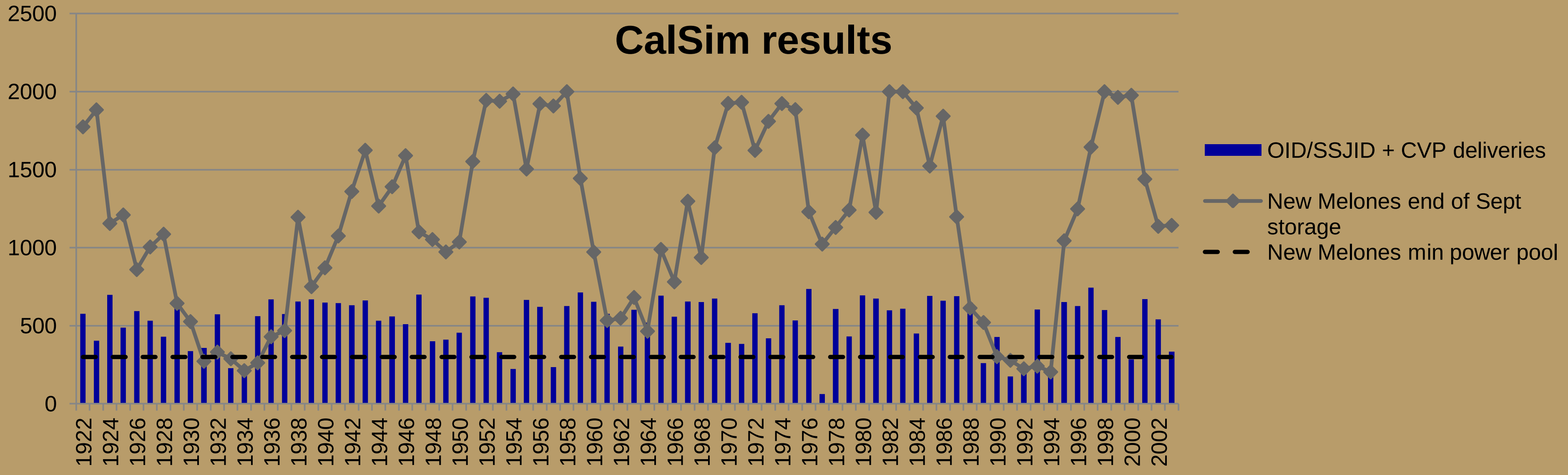
RECLAMATION

Bypass of 20% Unimpaired Inflow



Average of all years Water Deliveries = 591 TAF

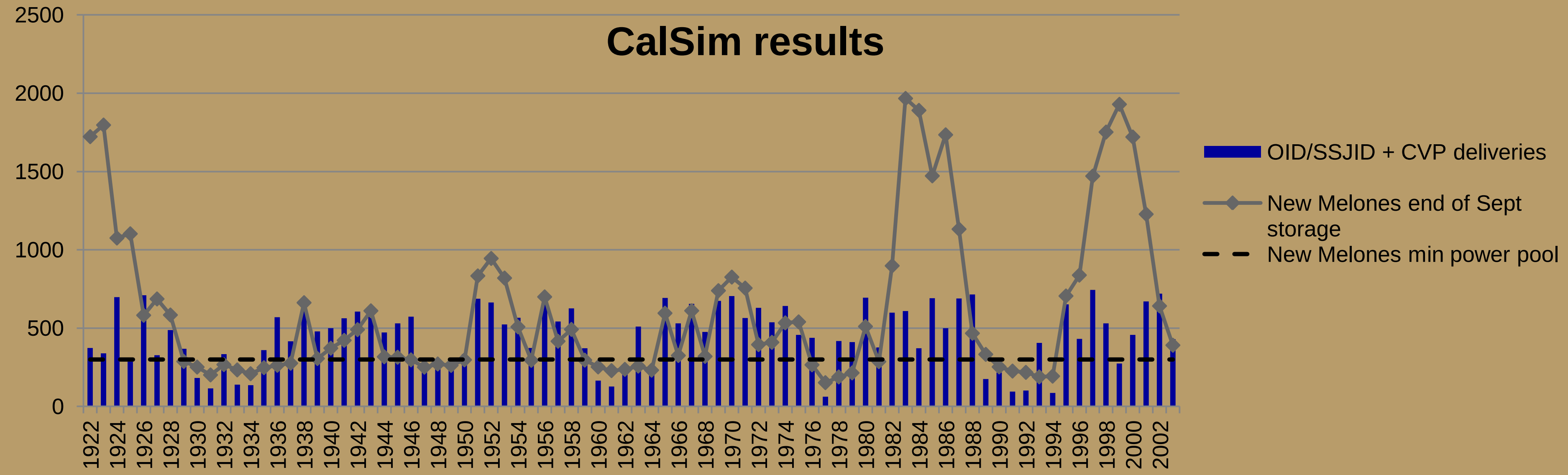
Bypass of 40% Unimpaired Inflow



Average of all years Water Deliveries = 529 TAF

RECLAMATION

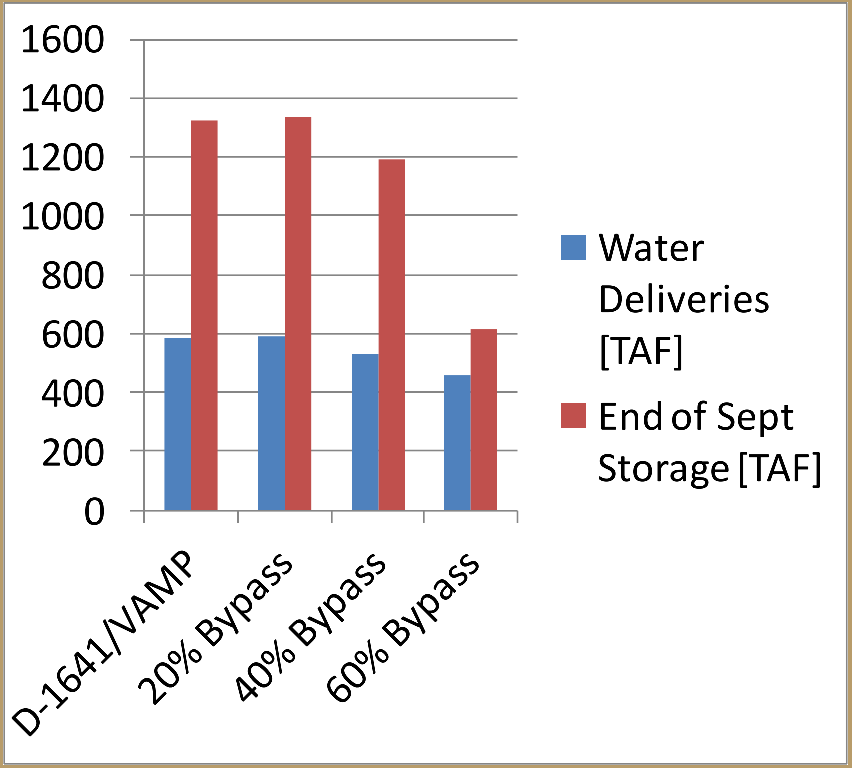
Bypass of 60% Unimpaired Inflow



Average of all years Water Deliveries = 456 TAF

Implications of Modeling Results

Comparison of CALSIM Modeling Results:



Impact of 60% Unimpaired Inflow Standard:

- ~25% reduction in total water deliveries
- >50% reduction in Oct 1 storage likely resulting in significant power, recreation & temperature impacts
- Operational uncertainty
- Modeling to lessen storage impact→ increased water supply impact

RECLAMATION

Encourage SWRCB to use Suite of Tools to set new Standards

- **TOOLS THAT ASSESS ALL EFFECTS WILL HOPEFULLY RESULT IN STANDARDS THAT:**
  - **Allow for sustainable operation of reservoirs like New Melones**
  - **Balance beneficial use of environmental flows with beneficial use of water supply, power, temperature needs for fishery resources, recreation, etc.**
  - **Require flows commensurate with impacts**
- **OPERATIONAL CONSIDERATIONS ARE NECESSARY TO CREATE IMPLEMENTABLE STANDARD**

OPERATIONAL CONSIDERATIONS: CENTRAL VALLEY RESERVOIR MANAGEMENT

Multiple purposes and beneficial uses

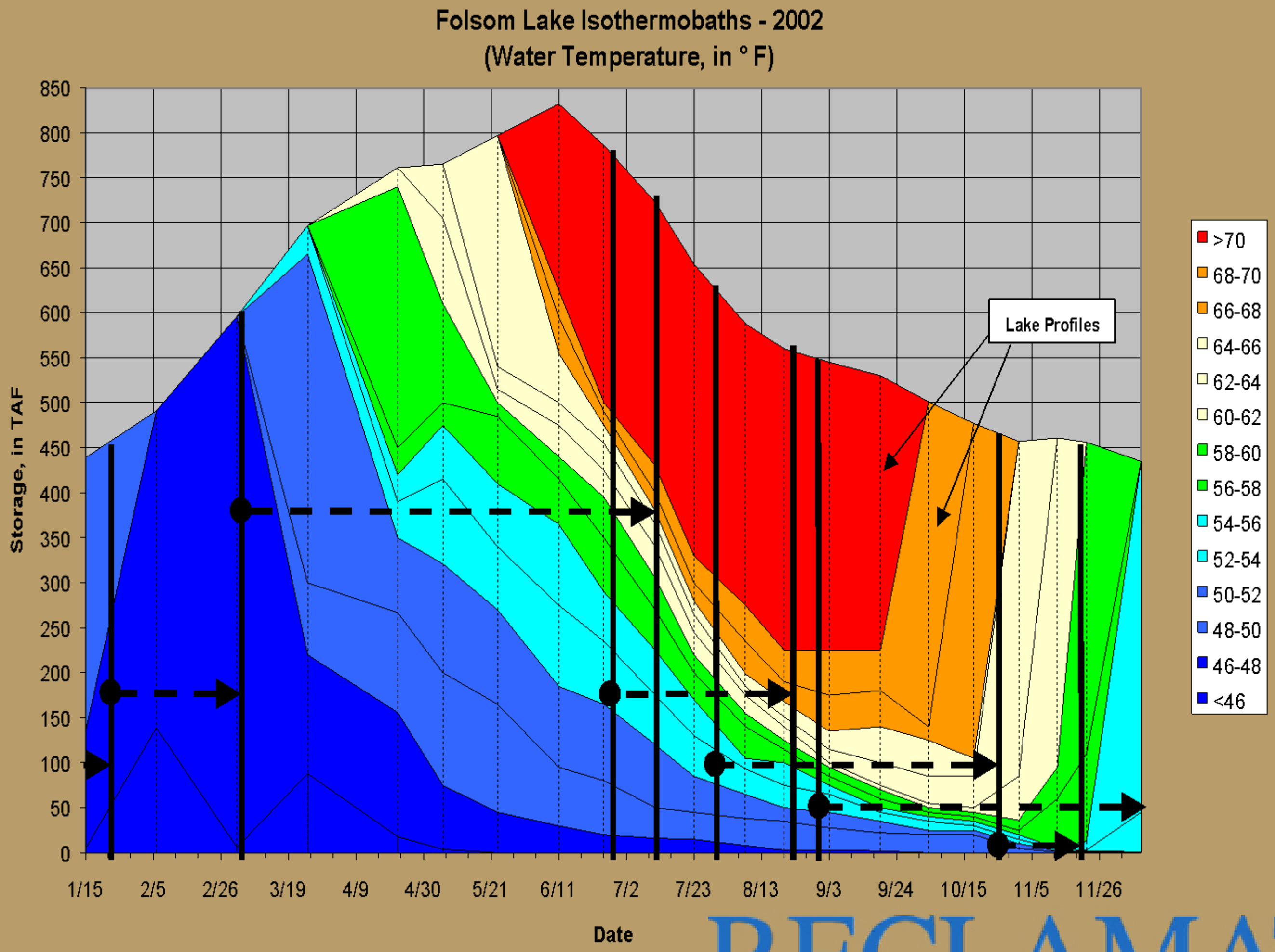
A unit of water serves multiple purposes

There will always be competing goals and objectives

Plan objectives should attempt to create situations where an acre-foot of water can meet as many purposes and goals as possible

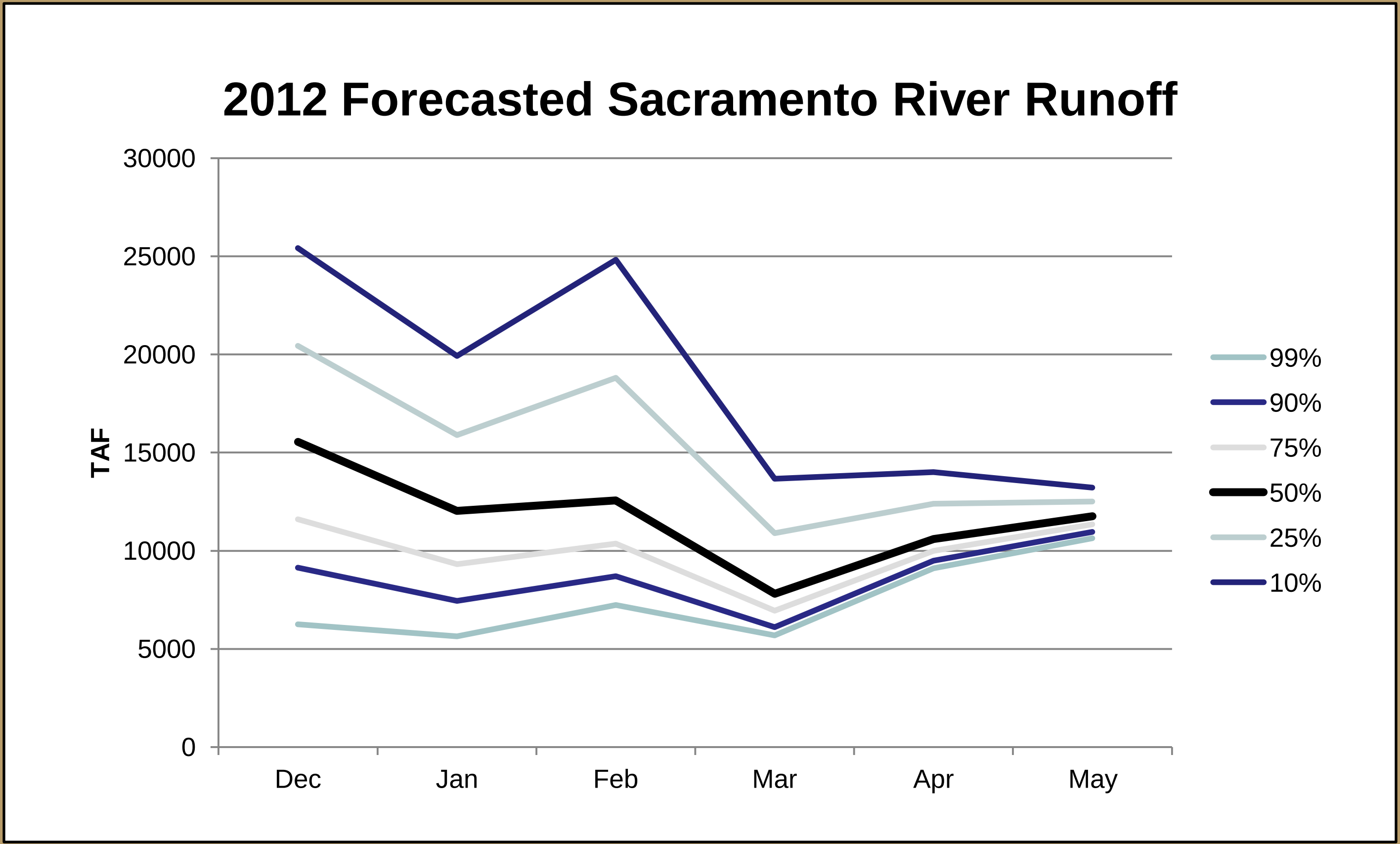
CENTRAL VALLEY RESERVOIR MANAGEMENT

Cold Water Pool Management Example



Folsom Lake Isothermobaths - 2002
(Water Temperature, in ° F)

CENTRAL VALLEY RESERVOIR MANAGEMENT



RECLAMATION

“Real Time” Reservoir Management

Seasonal planning and real time operations

Operation by reacting to current and changing conditions

Use and availability of real time data

Forecasting and use of forecasts

Scheduling considerations/Response time

When operating in a complex, unpredictable natural environment; experience is essential

Model Use in Reservoir Operations

Reservoir system model limitations

- Built in Institutional Constraints
- Forecasting Realities
- Time Step and Scale
- Use of past Hydrologic Data

Valuable to compare scenarios and to evaluate risk, but
Cannot predict outcomes or direct operations