

**Summary of
Sacramento River Temperature Model and Forecasting Process Workshop Sessions
January - February 2016**

Background

Pursuant to the 2014 Revised TMP, the US Bureau of Reclamation (USBR) and NOAA National Marine Fisheries Service (NMFS) convened a multi-agency group of technical experts on Sacramento River temperature issues to identify shortcomings with the existing temperature model and make recommendations for model updates or model replacement. This effort is a first step toward improving the Sacramento River water temperature model and related decision-making processes.

Methodology and Objectives

USBR and NMFS convened two facilitated workshops on January 26 and February 5, 2016. The first workshop focused on two primary topics: 1) the model and 2) the forecasting process. Within these main topics the group explored four sub-topics: (1) technical issues with the temperature model, (2) issues with model inputs and forecasting, (3) issues with the overall forecasting process, and (4) issues linked to specific legal or policy constraints. There were 15 participants from the California State Water Resource Control Board (SWRCB), California Department of Fish and Wildlife (CDFW), NMFS, and USBR.

The second workshop focused on presenting the inputs and assumptions used in the HEC5Q Model (the Model), describing 2015 improvements to the Model, and sharing with the group full copies of the Model tool and documentation to enable the agencies to review and run the Model independently and contact USBR with specific follow up questions or topics for discussion. There were 16 participants from SWRCB, CDFW, NMFS, and USBR; most had also participated in the initial workshop.

Outcomes

These workshops increased understanding of technical aspects of the Model among participants. The discussions also highlighted the broad and complex array of considerations that shape USBR's forecasting process (for example, data inputs in the very early part of the season and lake stratification prior to May is not reliable and Model projections before this time are approximations. The workshops also offered an opportunity for the agencies to share specific management concerns and challenges, for the purpose of improving communication and transparency.

By sharing the model tool and documentation, USBR created the opportunity for participants to run various scenarios on their own and provide USBR with feedback on perceived technical shortcomings and data inputs. USBR offered to convene a follow-up session to review questions and concerns. No comments were received following the second workshop and no one requested a second workshop.

Overall understanding of the model by CDFW, SWRCB, and NMFS has improved. There remain some differences of opinion about which scenarios should be run, or about variations in the specific scenarios individual agencies may want run. That said, there appears to be agreement based on the workshops that the Model is being applied appropriately and that outstanding concerns are not a result of issues with the Model itself. USBR's mandate is to balance the entire system and the other agencies now have a clearer understanding of the numerous considerations that go into fulfilling this charge. Additionally, there is now a restructured SRTTG meeting and discussion process in place as we move into the 2016 temperature management season.

Please see the workshop summaries provided in the appendix for additional details and information.

Appendix

- Appendix A: January 26, 2016 Sacramento River Temperature Model and Forecasting Process Workshop
- Appendix B: February 5, 2016 HEC5Q Model Review Session

Appendix A
Sacramento River Temperature Model and Forecasting Process Workshop
801 I Street, 4th floor conference room, Sacramento, CA
Tuesday, January 26th, 9am-3pm

WORKSHOP SUMMARY

Participants:

- Craig Anderson (FWS)
- Eric Danner (NMFS)
- Chad Dibble (CDFW)
- Ken Emanuel (SWRCB)
- Donna Garcia (USBR)
- Robert Hughes (CDFW)
- Josh Israel (USBR)
- Ken Kundargi (CDFW)
- Liz Kiteck (USBR)
- Ron Milligan (USBR)
- Jason Roberts (CDFW)
- Brycen Swart (NMFS)
- Thuy Washburn (USBR)
- Kristin White (USBR)
- Garwin Yip (NMFS)
- Mike Harty, Kearns & West
(Facilitator)

Note-taking:

- Gia Brazil, Kearns & West

Meeting Purpose: bring together a multi-agency group of technical experts on Sacramento River temperature issues to identify potential areas of improvement for better seasonal planning of temperature operations. The workshop is intended to be a first step toward improving the Sacramento River water temperature model and decision making process.

Workshop Overview and Objectives

Brycen Swart (NMFS) presented an overview of the regulatory background (SWRCB Water Rights Orders 90-5 & 91-1; additional requirements in NMFS' 2009 biological opinion). Brycen also reviewed the workshop background and purpose – to improve the accuracy of the model and forecasting process, and identify issues with: 1) the temperature model, 2) model inputs and forecasting, 3) the overall forecasting process, and 4) specific legal or policy constraints.

Reclamation added that there is an array of tools upon which to draw and the goal is to determine how to continuously improve management of cold-water pool resources within existing constraints.

Opening Remarks

Maria Rea (NMFS) and Ron Milligan (Reclamation) offered opening remarks, stating that workshop participants bring a welcomed variety of perspectives. The goal is to work together to develop the best tool(s) and to ensure there are not competing models. Additionally, models need to be nimble and it is important to identify and gather key information gaps, so that they may be addressed. Maria also acknowledged how difficult the task has been in recent years during the drought and expressed appreciation for staff efforts.

The agencies need to work within upcoming deadlines, but take the time to make long-term plans rather than only addressing urgent needs. The purpose of this group is not to engage in the upcoming forecasting and temperature model run effort, but rather, to focus on longer-term planning and use of the temperature model. NMFS acknowledged the challenges with making forecasts in March due to lack of information and stressed the importance of increasing confidence in forecasting, since February is when initial planning decisions are made.

Presentation and Discussion on HEC5Q Model Process

Several participants requested a basic review of the HEC5Q model (“the model”) to assist them in formulating useful and specific technical feedback on ways to improve. Reclamation presented an overview of the inputs, outputs, linked model(s) and the overall process (e.g., DWR unregulated stream data, flow rates and salinity in the Delta). Reclamation also described the timing of various monthly inputs (e.g., DWR’s Bulletin 120 is informed by the monthly snow surveys) to help participants understand why a model run takes approximately three weeks to complete. Participants agreed this helped highlight and clarify the numerous considerations that are taken into account to generate forecasts.

Reclamation noted that part of its obligation is to meet multiple legal and other requirements across a complex system. Salinity management is key and especially critical in drier years. Other priorities include meeting D1641 requirements and minimum flows, protection of listed species, and water supply deliveries to Settlement Contractors. Additionally, Reclamation stated that agency directors are engaged to review critical choices and impacts.

Model improvements have been made over time using lessons learned from previous years. For example, due to the higher ambient temperature in the past few years, Reclamation began using forecasts from several meteorological sources (L3MTO) to produce the temperature profile rather than continuing to use average temperature. Additionally, in 2014 the upper five to six miles of the Sacramento River read 0.6°F warmer than the model, so in 2015 Reclamation adjusted the model for better accuracy. Reclamation works to be adaptive and is looking for ways to continue to improve the model in 2016.

Reclamation emphasized that the model is used to set a temperature target, but actual operational targets are set on a daily basis. The model does not determine operations; it helps to inform Reclamation's seasonal decision-making.

Problem identification and Discussion

The group identified issues falling into two main topics, the model and the forecasting process. Within these main topics, four proposed sub-topics/categories were discussed: (1) technical issues with the temperature model, (2) issues with model inputs and forecasting, (3) issues with the overall forecasting process, and (4) issues linked to specific legal or policy constraints. Overall, participants agreed these were appropriate sub-topics. Participants also agreed that sub-topic (4) issues likely are outside of the scope for this effort.

Reclamation suggested that the discussion not be limited to the HEC5Q model. While challenges and issues with this model should be addressed specifically, the discussion could also include other tools that Reclamation uses for decision-making.

1. Technical Issues with the HEC5Q Temperature Model (and other temperature tools, such as ATC 5, RAP Model, weather forecasts, reconnaissance & planning)

- During the drought there has been an expectation for the model to be increasingly predictive and noted that it was not designed for this purpose. With the limited water, Reclamation has made due with the tools it has, however this makes it more difficult to clearly demonstrate to others how results are being generated.
- The model is not calibrated for low reservoir levels (particularly at the side gates) increasing the uncertainty of results when water is below ~1.6 million acre-feet.

Participants agreed that it is important not to have competing models, but to agree on the tool(s) being used and focus on how to improve them.

2. Issues with Model Inputs and Forecasting

- Transparency and education are key. In order to provide specific and useful feedback, there is a need and desire by other agencies to better understand technical aspects and implications of the model as well as the steps taken when running the model. Ron Milligan indicated these interests are understandable and Reclamation would be willing to share this information under certain conditions that address Reclamation's interests. One interest is in having a shared commitment about generation of model runs: problems are likely to result from unlimited generation of runs to achieve narrow results. The model is not designed to guide operations day-to-day, and it would be problematic if that were not fully appreciated. Adjusting parameters for a specific outcome without a more holistic consideration of the entire system is not how the model is intended to be used.
- There should be a clearer mechanism to share technical and process information on the model. The work being done in the Upper Sacramento River is one piece of the whole system being managed, so helping other agencies to understand the bigger picture is important.
- The RPA called for use of conservative hydrology assumptions. However, conservative assumptions for one part of the system are not necessarily conservative in other parts of the system (e.g., air temperature, stratification), and these could be important drivers.

Participants discussed uncertainty in the model and the need for buffers to help address unavoidable uncertainty. Reclamation noted that part of this margin of safety is the 90% forecast and that the buffers were easier to manage in the first and second years of drought than in the third and fourth years. There are already many places where the buffer was down to zero in 2015. Ultimately, the basic choice is about prioritizing various potential buffers and this should be evaluated annually by senior management.

3. Issues With Overall Forecasting Process

Participants did not discuss any items related to this sub-topic.

4. Issues Linked to Specific Legal or Policy Constraints

Participants discussed the February timing of forecasts. From a technical and operational standpoint, there are numerous pieces of information still missing that are needed to produce more accurate forecasts. These modeling challenges are different than forecasting for decision-making about water releases later in the year (i.e., May). During the drought, forecasts have needed to be increasingly predictive and the model was not designed to serve this purpose.

One perspective is that the model should be able to help identify the full suite of management options to protect listed species and the best-case scenario to save fish. Then, results could be brought to leadership to guide policy choices. Another perspective is that the model *could* be

used this way, but it raises the question of how to balance the rest of the system to ensure other requirements are met. Additionally, there is agreement that it would be more effective if the directors of the management agencies were in agreement about the highest priorities/risks rather than different agencies bringing different potential scenarios to decision makers.

One possibility is that performing a limited number of different model runs (rather than just one) to see a broader array of potential outcomes could be helpful in guiding consensus-based recommendations from the management agencies to the policy-makers.

Agreements and Next Steps

Overall, participants agreed that working collaboratively is valuable and important. Better synergy between agencies will result in better solutions being presented to decision-makers. As one step, Reclamation will give a “tutorial” on running the model and share inputs and assumptions for the purposes of working together to improve the model from a technical standpoint. At the same time, Reclamation (Ron Milligan) will contact other agency decision makers about possible conditions for future shared use of the model.

Participants also agreed it will be important for the directors to support this collaborative tone and to help layout a plan for best next steps.

Next Steps

- Reclamation will host a review and discussion of the HEC5Q model at its Central Valley Operations Office the first week of February.
- Reclamation will email the model documentation report.
- Reclamation will follow up with other agency decision makers about potential conditions for joint use of the model.

Appendix B
HEC5Q Model Review Session
Reclamation's Central Valley Operations Office
3310 El Camino Avenue, Sacramento, CA, Room 302
Friday, February 5th, 9am-12pm

WORKSHOP SUMMARY

Participants

- Chad Dibble, CDFW
- Ken Emanuel, SWRCB
- Donna Garcia, USBR
- Robert Hughes, CDFW
- Josh Israel, USBR
- Sara John, NMFS
- Liz Kiteck, USBR
- Ken Kundargi, CDFW
- Beth Lawson, CDFW
- Ron Milligan, USBR
- Andrew Pike, NMFS
- Diane Riddle, SWRCB
- Brycen Swart, NMFS
- Thuy Washburn, USBR
- Kristin White, USBR
- Garwin Yip, NMFS
- Mike Harty, Kearns & West
(Facilitator)

Note-taking:

- Gia Brazil, Kearns & West

Bulletin 120 and the Assumptions Used in its Development

Dave Rizzardo provided an overview of Bulletin 120 and the process used to produce inputs for the HEC5Q model (“the model”). He explained his group produces monthly results from February 1 through May 1, with weekly updates in between. During December and January they use the water supply index for Sacramento Valley and San Joaquin Valley watersheds. April through July they use snow, precipitation, and full natural flow (this data retrieved from partners) for each watershed.

For the monthly results, there is a 10-day window allowed for collection of snow course data (seven days prior to end of previous month to the third of the existing month). Adjustments are made to account for any snowfall (or lack thereof) in the remaining days in the month, if the snow course data is measured before the end of the month. For precipitation, primarily monthly totals are used, with some measurements aggregated daily. This entire process takes time and is the reason why the forecast is not issued until the sixth day of each month.

Once all the necessary information is gathered it is put into regression equations. For any watershed there are two to three equations used, each with different characteristics/weighting. This allows the engineers to see how weighting variations emphasize different aspects of the forecast and which is the most appropriate to rely on for a given year. Three to four engineers review this data independently. The same is done for snow data; each watershed is indexed and reviewed by two engineers. Outlier data is considered and accounted for and then four to five engineers meet to discuss their independent results and determine a number together. The April and May forecasts then take historical data for a 10%, 50%, and 90% exceedance. Once that is completed, it is locked into the model so the 25%, 75%, and 99% exceedance can be analyzed. At this point, results become more visual outputs to ensure that the pattern makes sense. Once the water year volumes are set they are input into the Sacramento Valley or San Joaquin Valley index.

Overall, the process is very data focused and intensive. This regression type analysis might begin to fail in the future, since historical records may not be effective for informing future climate trends. Therefore, Dave’s agency is currently looking at a more advanced model that uses more real-time inputs.

2015 Improvements to the Model

(forecast meteorological data, adjustment of 0.6°F to better match actual temperatures, curtains to help side gates functionality)

Reclamation walked the group through modifications made going into the 2015 management season. Reclamation made tweaks to the model during the summer to try to adjust to reality. The management point was more in 90-5 realm due to very low cold-water storage and water volumes. The adjustments were done to create better correlation with the Keswick release point.

With forecasting meteorological data, Reclamation tried to incorporate real-time data rather than average data to be more inline with the warmer ambient conditions (i.e., Redding Reach was 0.6°F degrees cooler in model than in reality; Keswick to the CCR gauge was warmer than the model was showing). The last couple of years, Reclamation has been managing much farther upstream, so it seemed appropriate to make some changes upstream. The approach this year will probably be to decide whether to manage numbers at Balls Ferry or higher up the river, then decide whether to modify the model a little bit. This modification is intended to be temporary, not left in as part of the model forever.

Reclamation also added curtains to help with temperature control at the side gates. In 2014, Reclamation tried to avoid full side gate operations until very late in the season and while there were still challenges, operations were much more successful than in 2013. There is no way to test the deployment of the curtains, but Reclamation was able to push out side gate operation in 2014 for an additional 7-11 days than in 2013, so observations suggest the curtain helped prevent the warm water from seeping into the TCD. The curtains are being rolled up today (February 5) for reuse and may be redeployed in mid-April.

Reclamation noted that during the first two months of the year an average dataset is used. Then when the station creates the forecast, Reclamation uses a 50% average. Reclamation also ran a 10% in 2015 (so both 50% and 10%). The average dataset consists of precipitation and temperature in six-hour increments.

In the past, Reclamation would gather the three-month climate predictions from NOAA, then use this information to identify library years in the catalogue most closely aligned as the input into the model. In 2016, Reclamation might use a 2014 or 2015 dataset (warmer average temperatures) for planning to see if forecast accuracy can be improved.

The model uses air temperature and other parameters to come up with equilibrium temperature value that is used in the model's heat exchange equations. Equilibrium temperature is defined as the hypothetical temperature when net heat exchange is zero. The main factors in the model are temperatures and particularly summer temperatures; this drives the L3MTO number. Reclamation offered to set up a call with Levi if participants wanted to do a deep dive into this aspect of the model.

Specific Model Inputs and Assumptions

Reclamation walked the group through the temperature input files and documents that will be provided to participants and reviewed the process for running the model. Reclamation noted that getting the data into and running the model is not time intensive, however changing the G2 records to get a desired outcome without running out of cold water takes quite a bit of time and iteration.

Reclamation noted that in previous years when averages were used in the model the results looked much smoother. Using real-time data provides more accuracy, but the datasets have a

lot of variation, so it requires more adjustments to smooth the model. It also makes it more difficult avoid exceedances.

SWRCB is hiring the consultant RMA to train SWRCB staff in using and running the model and understanding how to interpret results and implications. SWRCB will open this training to anyone on the SRTTG.

As initial questions arise (over ~next month), the group agrees to funnel them through this group. After this transitional period, questions may be directed to RMA (process still to be determined).

Action: Kearns & West will work with Reclamation to organize another meeting in early March to answer questions and discuss next steps for the group.

Tool and Documentation Handoff

Reclamation provided to participants CDs containing documentation the full HEC5Q model. It should be everything participants need to run model. There are two CALFED presentations and an Upper Sacramento calibration report that Reclamation recommends participants review before running the model.

Agency Risk Tolerance/Sideboards for Single-purpose Scenarios; Identify High Priority vs. Low Priority Elements from a Technical Team Point of View

The group agreed that it needs to identify specific questions that will help frame a Directors' level discussion on options for decision-making. The group also noted that some of the risk tolerance and priority elements may need to be more top down. Reclamation will discuss with NMFS leadership the shorter-term (2016) needs and longer-term process. It may also be appropriate for the agency decision-makers to be a part of this discussion.

Participants agree to communicate with Reclamation and this group prior to taking any results from their independent running of the model to their upper management.

Action: Kearns & West will assist Reclamation (Ron Milligan) and NMFS (Garwin Yip) to convene a meeting with management to update them on this group's progress and clarify trade-offs and how to best manage these trade-offs to help ensure a manageable and productive process for this group.

Agreements and Next Steps

- As initial questions (over ~next month), the group agrees to funnel questions through this group. After this transitional period, questions may be directed to RMA (process still to be determined).
- Participants agree to communicate with Reclamation and this group prior to taking any results from their independent running of the model to their upper management.

Next Steps

- If needed, Reclamation will set up a call with Levi if participants have questions about the model after they have had time to review and run on their own.
- Kearns & West will work with Reclamation to organize another meeting in early March to answer questions and discuss next steps for the group.
- Kearns & West will assist Reclamation (Ron Milligan) and NMFS (Garwin Yip) to convene a meeting with management to update them on this group's progress and clarify trade-offs and how to best manage these trade-offs to help ensure a manageable and productive process for this group.