BUREAU OF RECLAMATION

CVP Water Temperature Modeling Platform

Modeling Technical Committee (MTC) Meeting #8

April 6, 2023; 1:00 p.m. – 4:00 p.m.

Welcome!!

- We are looking forward to a productive meeting.
- Virtual meetings can be challenging and frustrating, especially with a large groups - please be patient and flexible. If you are having technical difficulties, please chat with Sarah Hamilton, or Sarah.Hamilton@stantec.com
- Chat Panel will be used for participants to provide comments and queue up questions. Use Raise Hand functions in Q&A session.
- Feedbacks on meeting logistic and suggestions: Yung-Hsin Sun, PhD, PE; sun.yunghsin@sunziconsulting.com

MTC #8: Objectives

- Provide updates on WTMP development, activities and schedule
- Establish common understanding on the results of the last watershed model preparation – Stanislaus River system and opportunities for input
- Provide updates on the approach and progress on characterizing model uncertainty
- Provide common understanding on the planned standardized outputs and visualization options

MTC #8: Agenda

1:00 p.m.	Meeting Logistics, Welcome Remark, and Announcements
1:10 p.m.	Project Status Update
1:30 p.m.	Stanislaus River Water Temperature Model Development – Calibration/Validation
2:20 p.m.	Break (10 min; the only break)
2:30 p.m.	Highlights of Model Development TM (Sac/Trinity and American systems only)
2:45 p.m.	Model Uncertainty: Approach to Identification and Characterization, Initial Findings, and Anticipated Outcome
3:30 p.m.	WTMP Output and Visualization
3:50 p.m.	Next Steps
4:00 p.m.	Adjourn

Note that the Agenda contains the links to register future MTC meetings for your early registration convenience.

Agenda Topics for the 2022 MTC Meetings (Done and Info Posted on Website)

Topic	7/1/2021	10/7/2021	1/6/2022	4/7/2022	7/7/2022	10/6/2022
MTC Orientation	1/2/3	-	-	-	-	-
Project Purposes, Goals, Anticipated Outcomes	1/2/3	3	-	-	-	-
Modeling Framework Selection	1	2	3	-	-	-
Water Temperature Model Selection	1	2	3	-	-	-
Consistency between System Model and Detailed Models	-	1	2	3	-	-
Common Model Preparation and Considerations	-	1	2/3	-	-	-
Sacramento/Trinity River Water Temperature Model	-	-	1	2	2/3	3
American River Water Temperature Model	-	-	-	1	2	2/3
Stanislaus River Water Temperature Model	-	-	-	-	1	1/2
Modeling Framework Implementation	1	-	2	-	-	-
Mid-term Peer Review Outcomes	-	-	-	-	-	1/2/3
Phase II Activities (Introduction only)	-	-	-	-	1/2/3	-

Key: 1 – Introductory Presentation; 2 – Comments and Discussion; 3 – Closure Discussion

Agenda Topics for the 2023 MTC Meetings (Mostly Done; Subject to Change)

Topic	7/7/2022	10/6/2022	1/5/2023	4/6/2023	7/6/2023	10/5/2023
Sacramento/Trinity River Water Temperature Model	2/3	3	-	-	-	-
American River Water Temperature Model	2	2/3	-	-	-	-
Stanislaus River Water Temperature Model	1	1/2	2/3	3	-	-
Modeling Framework Implementation	-	-	2/3	-	3	-
Mid-term Peer Review Outcomes	-	1/2/3	-	-	-	-
Phase II Activities (introduction only)	1/2/3	-	-	-	-	-
Follow-up Model Discussions (as needed)	-	-	-	1/2	2/3	-
Characterization of Model Uncertainty	-	-	1	2	3	-
Communication of Model Uncertainty	-	-	1	1/2	2/3	3
Output and Visualization	-	-	-	1	2	3
Final Peer Review Outcomes	-	-	-	-	-	1/2/3
Celebration	-	-	-	-	-	1/2/3

Key: 1 – Introductory Presentation; 2 – Comments and Discussion; 3 – Closure Discussion

Communication Channels

- Project website with continued updates: https://www.usbr.gov/mp/bdo/cvp-wtmp.html
  - Meeting information/Fact sheets/Deliverables
- Project contact: mppublicaffairs@usbr.gov
- Interim deliverable comments and suggestions: RField@usbr.gov
- MTC: sun.yunghsin@sunziconsulting.com

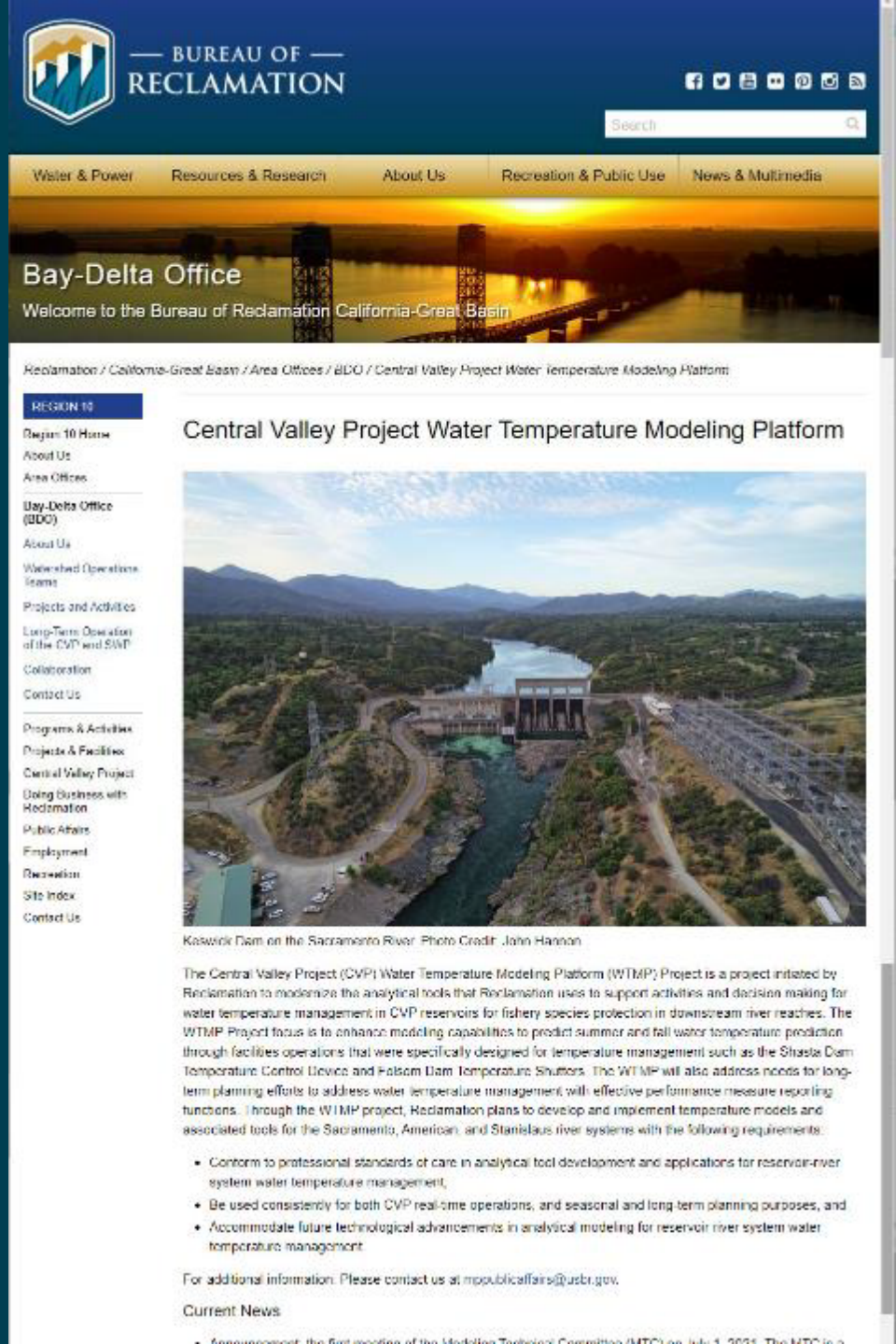


Photo credit: John Hannon, Reclamation

Project Status Update

Randi Field, Hydrologic Engineer, CVO
US Department of the Interior, Bureau of Reclamation

Vision for the WTMP Project (part 1)

- Goal: Deliver quality products to support Reclamation's mission – predict water temperature to support CVP operations
  - Modernize systemwide water temperature modeling and analytics
  - Develop to professional standards and foster transparency
  - Consistent use: real-time, seasonal, and long-term planning
  - Address modeling uncertainty
  - Design for flexibility to accommodate technical advancement
  - Build expertise in Reclamation

Vision for the WTMP Project (part 2)

- Tool: The WTMP project is the technical tool development effort to build the model and supporting mechanisms for water temperature management analysis
- Use: The long-term operation (LTO) teams establish how to apply tools and analysis for water temperature management

Vision for the WTMP Project (part 3)

- Outcome: A living modeling platform to support long-term CVP operations by addressing water temperature modeling needs and challenges.
- Major products:
  - Complete model and platform documentation based on the current installation
  - Water Temperature Modeling Platform
    - Implemented models/model framework with built-in functions to support modeling needs
    - Data Management System and associated data (raw and processed)
  - Outcomes from independent scientific peer review (mid-term and final)
  - Outcomes from the MTC collaboration (communications and participations in product review)

Final Independent Scientific Peer Review

- Host: Delta Stewardship Council
- Scheduled on 9/12/23 – 9/14/23
- Anticipated final report in early November 2023

Active and Upcoming Review Requests

- TM: Model Development (Sac/Trinity and American) (active)
  - Scheduled distribution: 4/4/23; MTC feedback by 5/2/23
- TM: Model Development (revised Sac/Trinity and American, and Stanislaus)
  - Scheduled distribution: 5/23; MTC feedback by 6/23
- TM: Model Uncertainty: Sources
  - Scheduled distribution: 5/23; MTC feedback by 6/23
- TM: Model Uncertainty: Protocols for Estimation
  - Scheduled distribution: 6/23; MTC feedback by 7/23

MTC Meetings

- MTC 08: April 6, 2023 (today)
- MTC WTMP Output Subgroup (TBD; further discussion later)
- MTC 09: July 6, 2023
- MTC 10: October 5, 2023

Remaining Project Milestones

- WTMP implementation
  - 5/23 - Tool development testing version [project team only]
  - 6/23 - Data management system testing deployment [project team only]
  - 8/23 - Information distribution for the final scientific peer review
  - 9/23 - Final scientific peer review
  - 9/23 - Platform implementation completion for acceptance review [project team only]
  - 10/23 - Platform showcase in MTC 10 on 10/5
  - 11/23 - Final scientific peer review report
  - 12/23 - Reclamation's response to final scientific peer review comments and suggestions
  - 3/24 - Final platform documentation completion
- WTMP roll-out Spring 2024

Remaining Project Milestones (Cont.)

- Perspectives after the WTMP's first deployment and rollout:
  - The products from the current implementation will continue to evolve with additional development/refinements on individual models and overall platform.
  - Continued supporting activities include:
    - Continued/improved data collection for improving quality of model analytics
    - Model refinement as facilities are upgraded/modified and new facilities are constructed, if applicable
    - Re-assessment of modeling needs, associated model development and refinements, and model evaluation and calibration/re-calibration
    - Response to advancement in technology
    - A potential user group evolved from the current MTC structure (to be discussed further in future MTC meetings)

Questions on Project Status Updates

Photo credit: John Hannon, Reclamation

Stanislaus River Water Temperature Models – Calibration/Validation

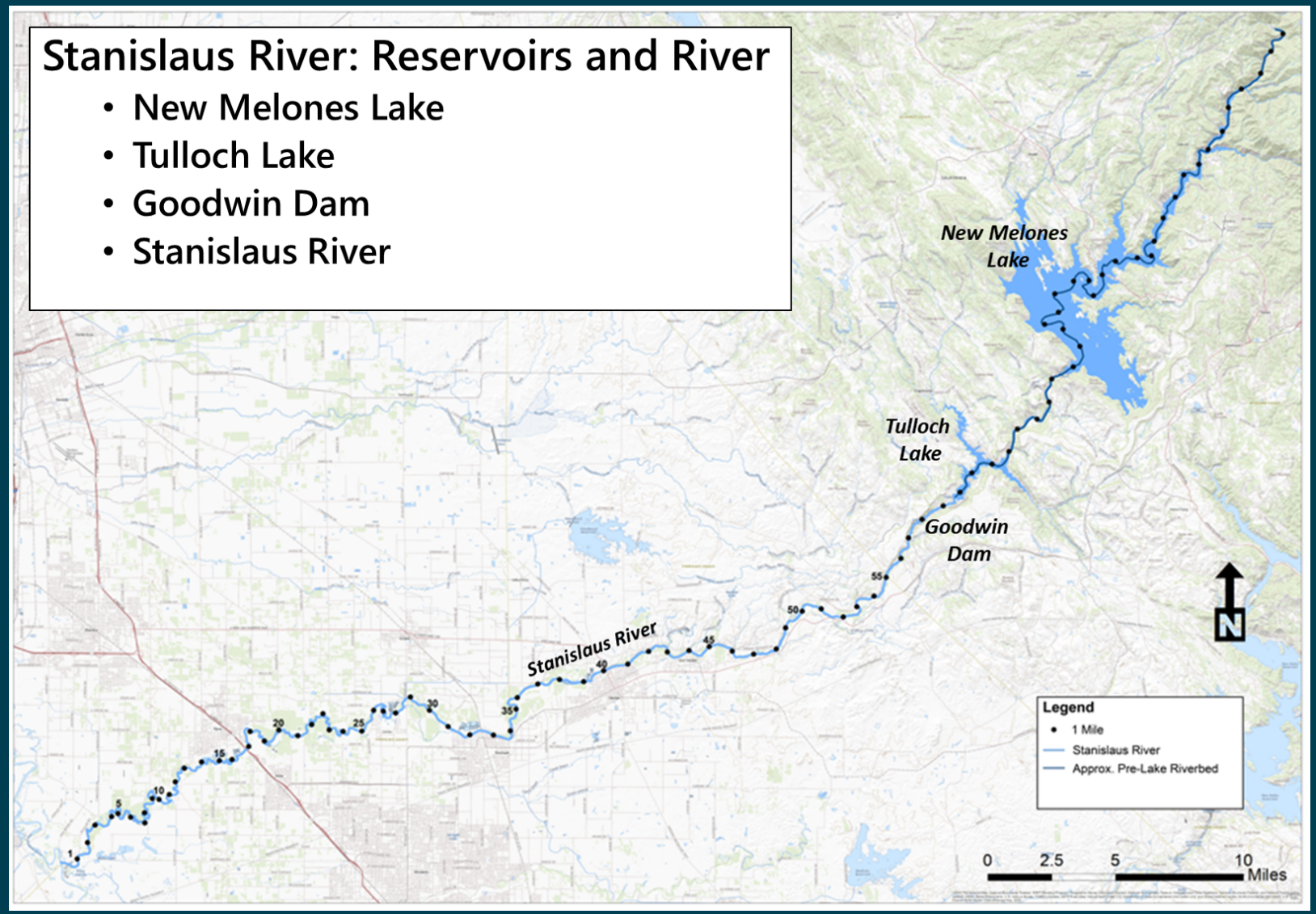
Mike Deas, PhD, PE, Watercourse Engineering, Inc.

John DeGeorge, PhD, PE, RMA

Stanislaus River: Reservoirs and River

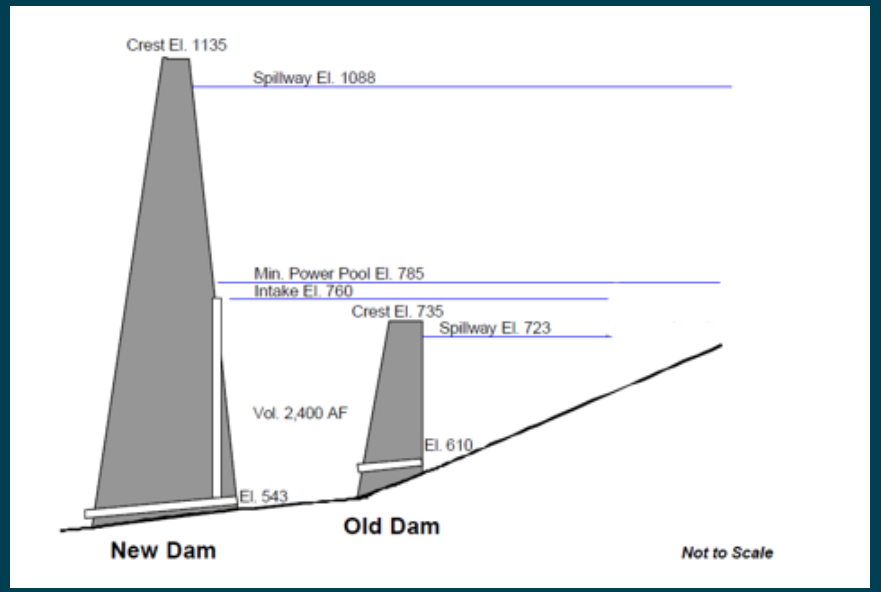
- Stanislaus River Applications
- Recap
- CE-QUAL-W2 and ResSim calibration
- Summary discussion
- Questions

Stanislaus River: Reservoirs and River Schematic



Recap the Discussion in 1/23 MTC Meeting

- Key Features
  - New Melones – old dam
    - CE-QUAL-W2: internal weir
    - ResSim: withdrawal zone constraint
- Data
  - Boundary conditions
    - Hydrology
    - Water temperature
    - Meteorology (Green Springs)
  - Calibration data
    - Water temperature
  - Data limitations (including data needed for calibration)



Available Data

- New Melones Lake

Location (Hourly Tw)	Type	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Tw at confluence of NF&MF	BC	10	7	4	10	11	9	9	6	8	7	5	8	4	1	6	X	X	X	X	X	X	X
Tw at Collierville PH	BC	X	7	3	12	12	12	122	7	5	5	5	12	X	X	X	X	X	X	X	X	X	X
Tw at Stanislaus PH	BC	12	7	4	3	5	5	4	6	9	6	7	11	11	5	6	X	X	X	X	X	X	X
Vertical Profiles	Cal	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	8	X	X	X	X	X	X
New Melones Powerhouse Tailrace	Cal	8	6	5	7	12	12	12	12	12	12	12	12	12	12	12	12	2	X	X	X	X	X

- Tulloch Lake

Location (Hourly Tw)	Type	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
New Melones Powerhouse Tailrace	BC	8	6	5	7	12	12	12	12	12	12	12	12	12	12	12	12	2	X	X	X	X	X
Tulloch Powerhouse Tailrace	Cal	12	12	12	12	9	7	6	12	12	12	12	12	12	12	1	2	2	X	X	X	X	X
Profile at Tulloch Dam	Cal	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	5	X	X	X	X	X
Profile at O'Byrnes Ferry Bridge	Cal	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	7	X	X	X	X	X

Available Data for Stanislaus River

- Stanislaus River

Location (Hourly Tw)	Type	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Goodwin Dam Log Boom (Top)	BC	8	12	12	12	12	12	8	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
DS of Goodwin Reservoir	Cal	2	5	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Ab McHenry Spill	Cal	X	X	X	X	X	6	12	7	12	12	9	4	12	12	12	7	X	X	X	X	X	X
Ab Mid Spill in Ripon	Cal	X	X	X	X	X	5	12	12	12	6	12	12	10	12	12	12	12	1	X	X	X	X
Caswell State Park	Cal	X	X	X	X	X	X	X	X	X	X	11	12	12	12	12	12	12	1	X	4	10	X
Knights Ferry	Cal	10	12	12	12	12	12	12	12	4	8	5	12	12	12	12	12	12	12	12	12	8	X
Ds of Oakdale Rec Area	Cal	12	10	4	12	12	12	12	10	11	8	12	12	12	12	12	7	X	X	X	X	X	X
Oakdale Recreation Area	Cal	12	12	12	12	12	12	12	11	2	8	9	7	9	12	5	X	X	X	X	11	10	X
¼ Mile DS of Orange Blossom Br	Cal	12	12	12	7	12	12	12	8	6	8	12	12	12	12	12	12	12	12	12	12	10	X
¼ Mile US of Jacob ME12ER Park	Cal	10	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
River Bank (DS end Jaboc Meyer Park)	Cal	3	12	12	7	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
River Bank (ACOE Prop Stanislaus Weir)	Cal	X	X	X	X	9	12	5	6	3	11	12	12	12	12	12	12	1	11	12	9	X	X

Available Data for Stanislaus River(continued)

- Stanislaus River

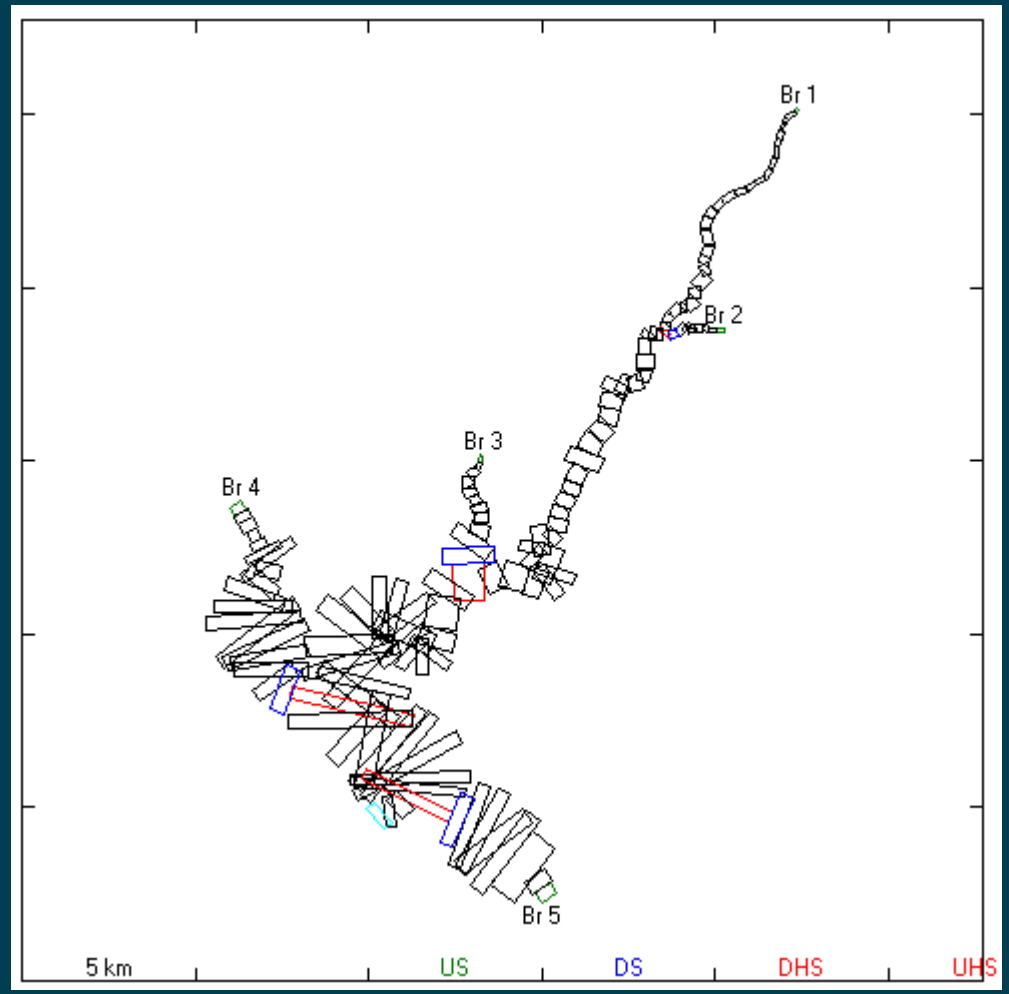
Location (Hourly Tw)	Type	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Inflow SEWD Canal at Goodwin Res	Cal	3	4	3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Spr Ck Cc in Ripon Bel Mid Spill	Cal	X	X	X	X	X	2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Inflow to SSJID Canal at Goodwin Res	Cal	3	3	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Stanislaus River at Hwy 99	Cal	X	X	X	X	X	X	10	6	6	12	12	12	12	12	6	X	X	X	X	X	X	X
Stouffer Park in Ripon	Cal	X	X	X	X	X	2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Approx. ¼ Mile US Confluence w/ SJ R	Cal	9	12	12	12	2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Approx. 100 M AB Confluence w/SJ R	Cal	X	4	12	12	12	11	7	10	7	12	12	12	12	12	12	1	X	X	X	X	X	X
Approx. 200 M AB Confluence w/SJ R	Cal	X	X	X	X	X	6	12	4	2	10	12	12	9	12	12	1	X	X	X	X	X	X

Stanislaus River – Models

- CE-QUAL-W2
  - New Melones Lake
  - Tulloch Lake
- ResSim
  - New Melones Lake
  - Tulloch Lake
  - Goodwin Dam
  - Stanislaus River below New Melones Dam

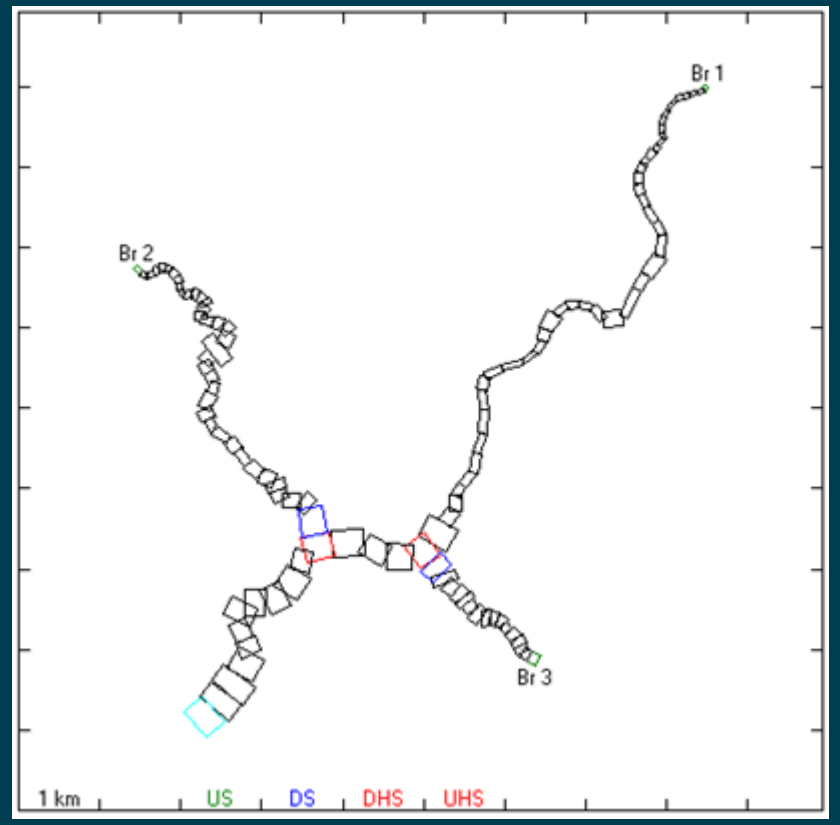
CE-QUAL-W2 Model Development and Calibration – New Melones Lake

- New Melones Lake
  - Inflows
    - Stanislaus River
    - Collierville PH
    - Stanislaus PH
  - New Melones Dam
    - Power Outlet
    - Low Level Outlet
    - Spillway (uncontrolled)
  - Calibration
    - Lake stage (water balance)
    - Vertical temperature profiles
    - Outflow temperature



CE-QUAL-W2 Model Development and Calibration – Tulloch Lake

- Tulloch Lake
  - Inflows
    - New Melones Dam releases
    - Side flow (A/D)
  - Tulloch Dam
    - Power Outlet
    - Low Level Outlet
    - Gated Spillway
  - Calibration
    - Lake stage (water balance)
    - Vertical temperature profiles
    - Outflow temperature

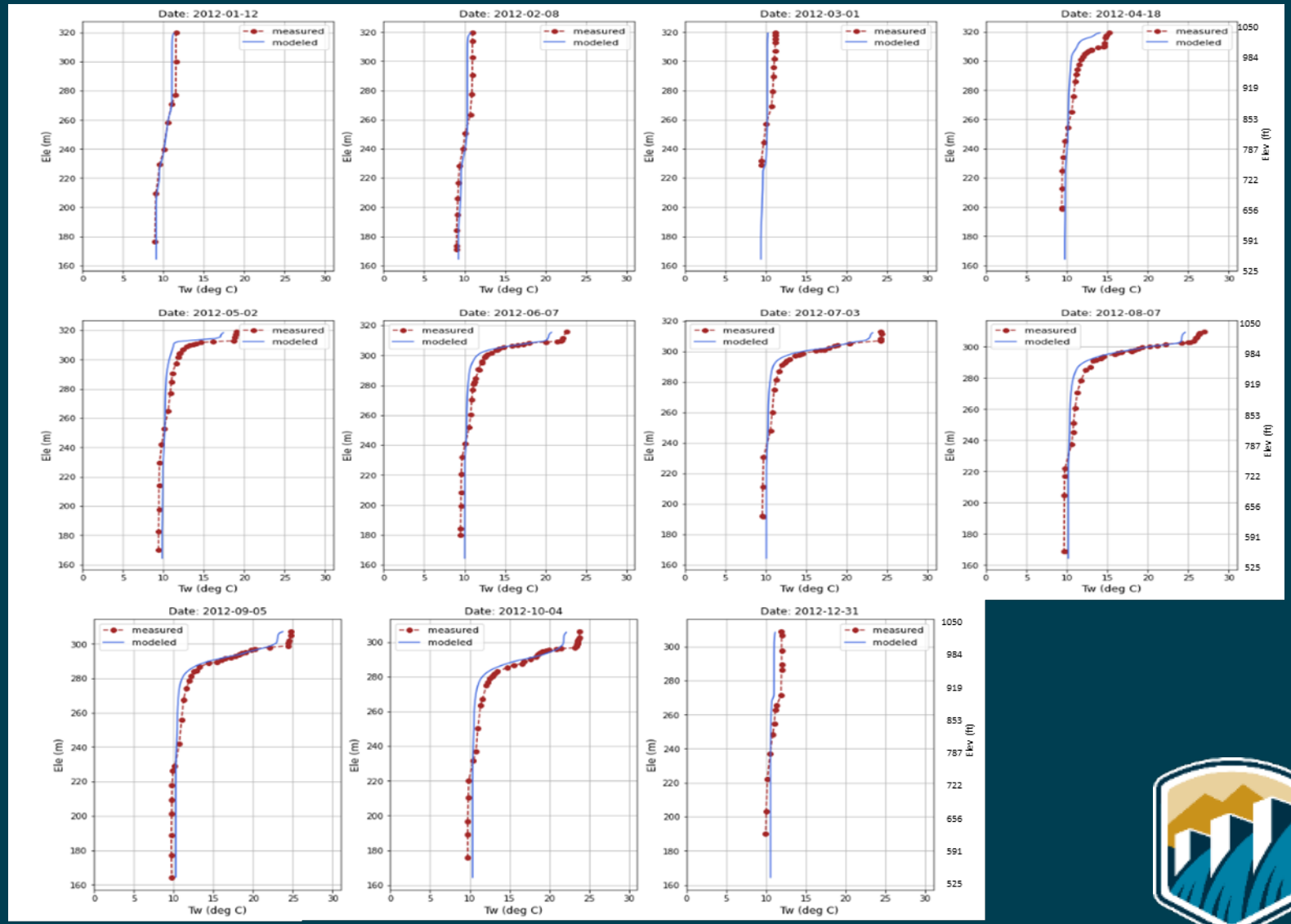


Calibration Parameters

- New Melones and Tulloch Lake (coefficients considered)
  - AFW, BFW, CFW: evaporation coefficients (only slightly modified during calibration)
  - CBHE and TSED: coefficient of bottom heat exchange and sediment temperature
  - BETA: Fraction of incident solar radiation absorbed at the water surface (minimal adjustment)
  - Wind sheltering
  - AZMAX: maximum value for vertical eddy viscosity
  - AX, DX: longitudinal eddy viscosity and longitudinal eddy diffusivity

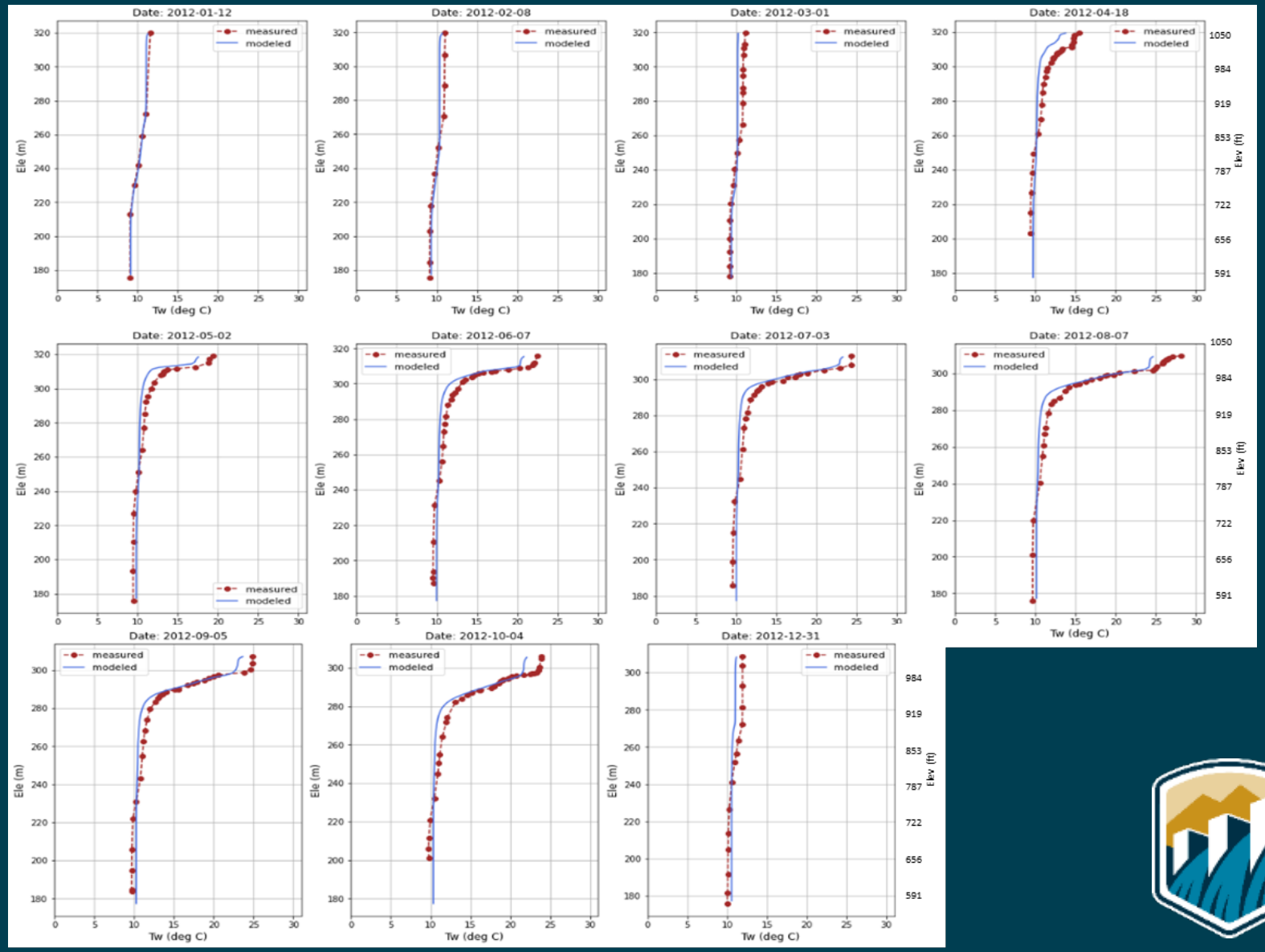
New Melones Profile near Dam (2012)

- Seasonal stratification
- “Thin” epilimnion
- Subtle stratification in hypolimnion
- Depth is greater than 500 feet, which is full pool



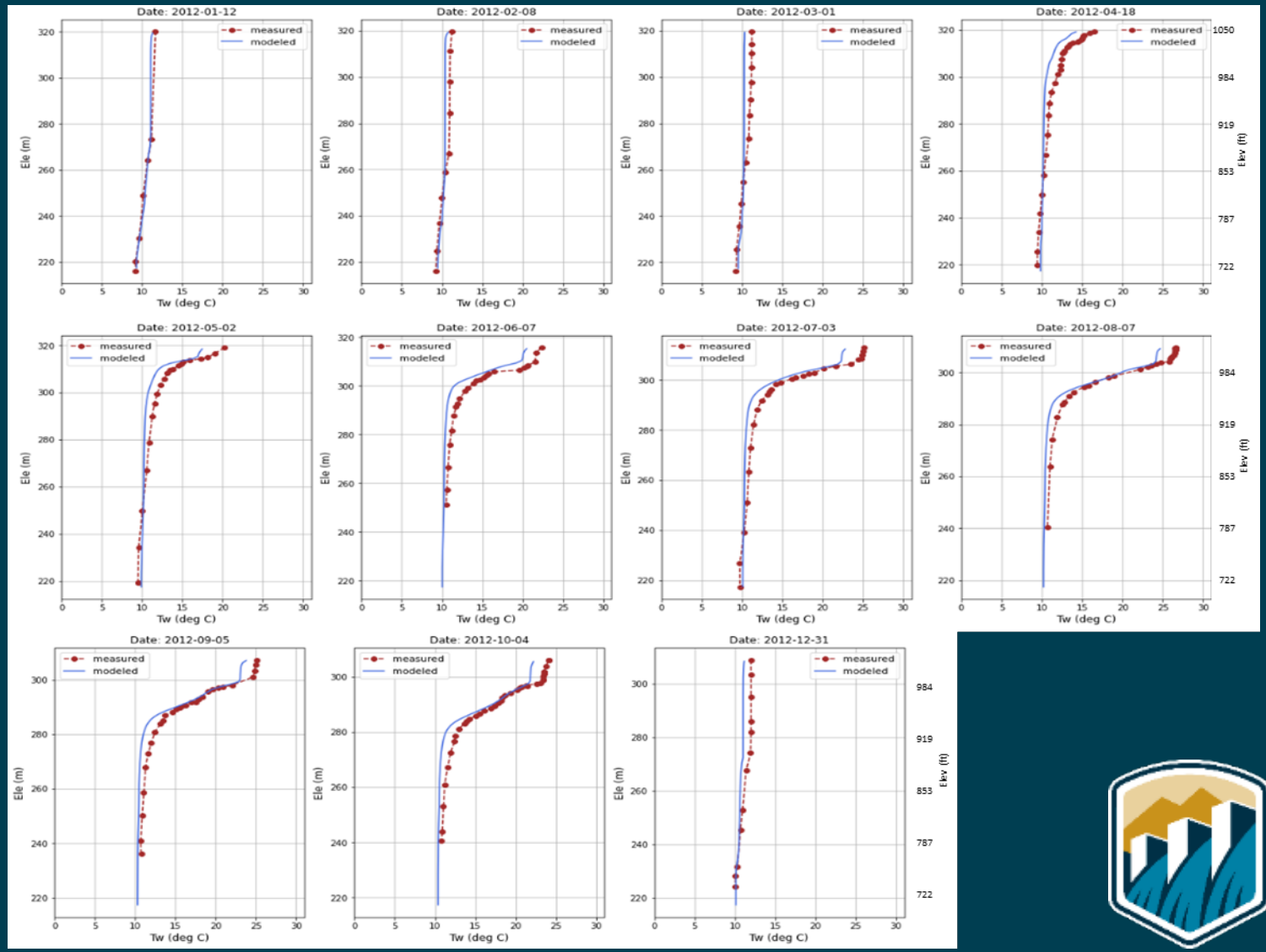
New Melones Profile near Old Dam (2012)

- Similar to those near the new dam
- Depth greater than 450 feet, which is full pool



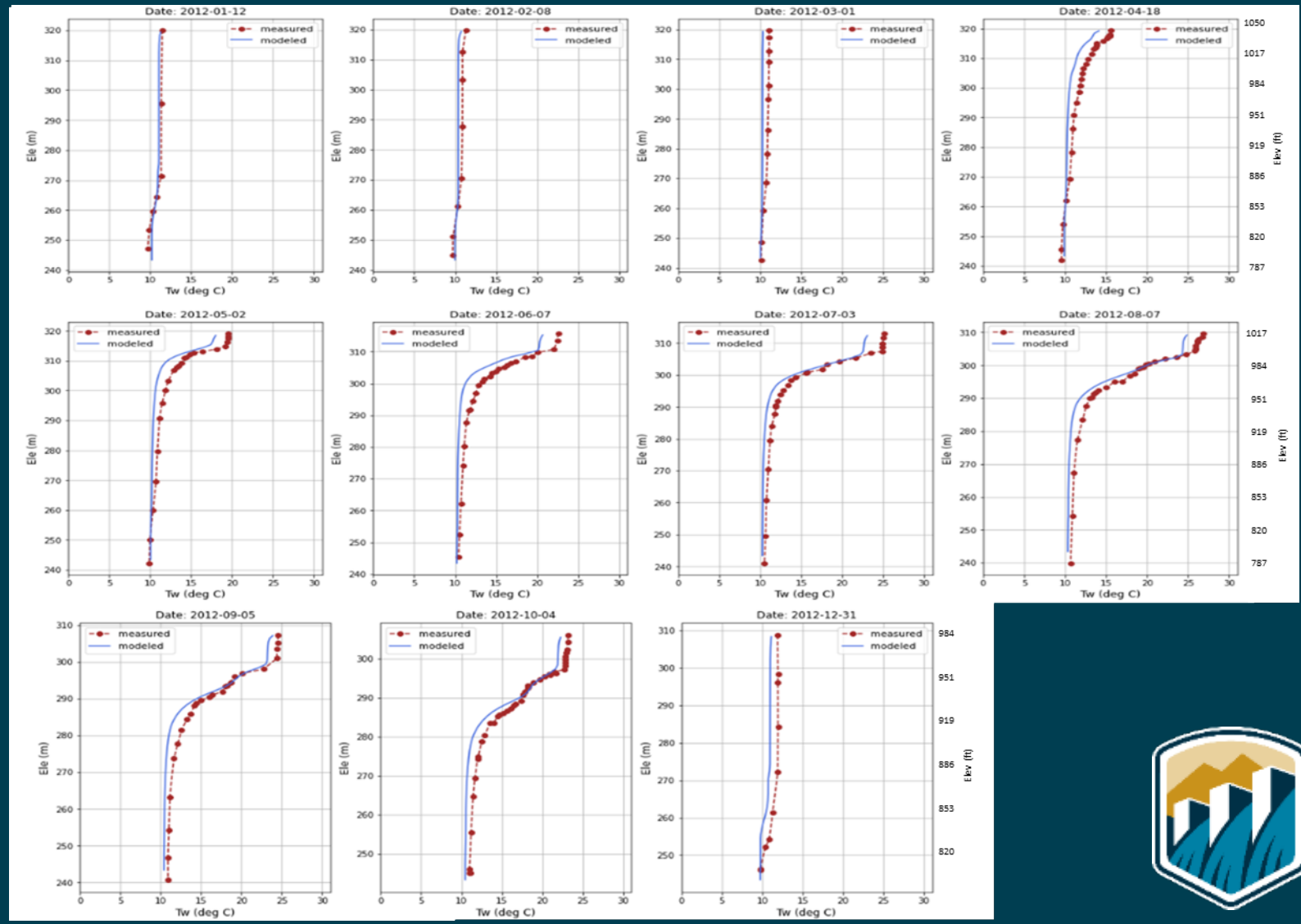
New Melones Profile near Hwy 49 Bridge (2012)

- Depth greater than 300 feet, which is full pool



New Melones Profile near Parrot's Ferry Bridge (2012)

- Depth greater than 250 feet, which is full pool
- More prominent influence of upstream boundary conditions



New Melones Profile near Dam Year 2012

- Calibration: tabular monthly results
- near Dam

Metric	01/12/12	02/08/12	03/01/12	04/18/12	05/02/12	06/07/12	07/03/12	08/07/12	09/05/12	10/04/12	12/31/12
Mean Bias (deg C)	-0.1	-0.04	-0.48	-1.12*	-1.27*	-0.7	-0.82*	0.71	-0.44	0.94*	-0.41
MAE (deg C)	0.19	0.36	0.7	1.29*	1.47*	0.87	0.97	0.92	0.75	1.29	0.63
RMSE (deg C)	0.25	0.39	0.74	1.6*	1.98*	1.05	1.1	1.08	0.87	1.57	0.69
NSE	0.94	0.78	<0*	0.31*	0.6*	0.93	0.95	0.97	0.97	0.85	0.16*

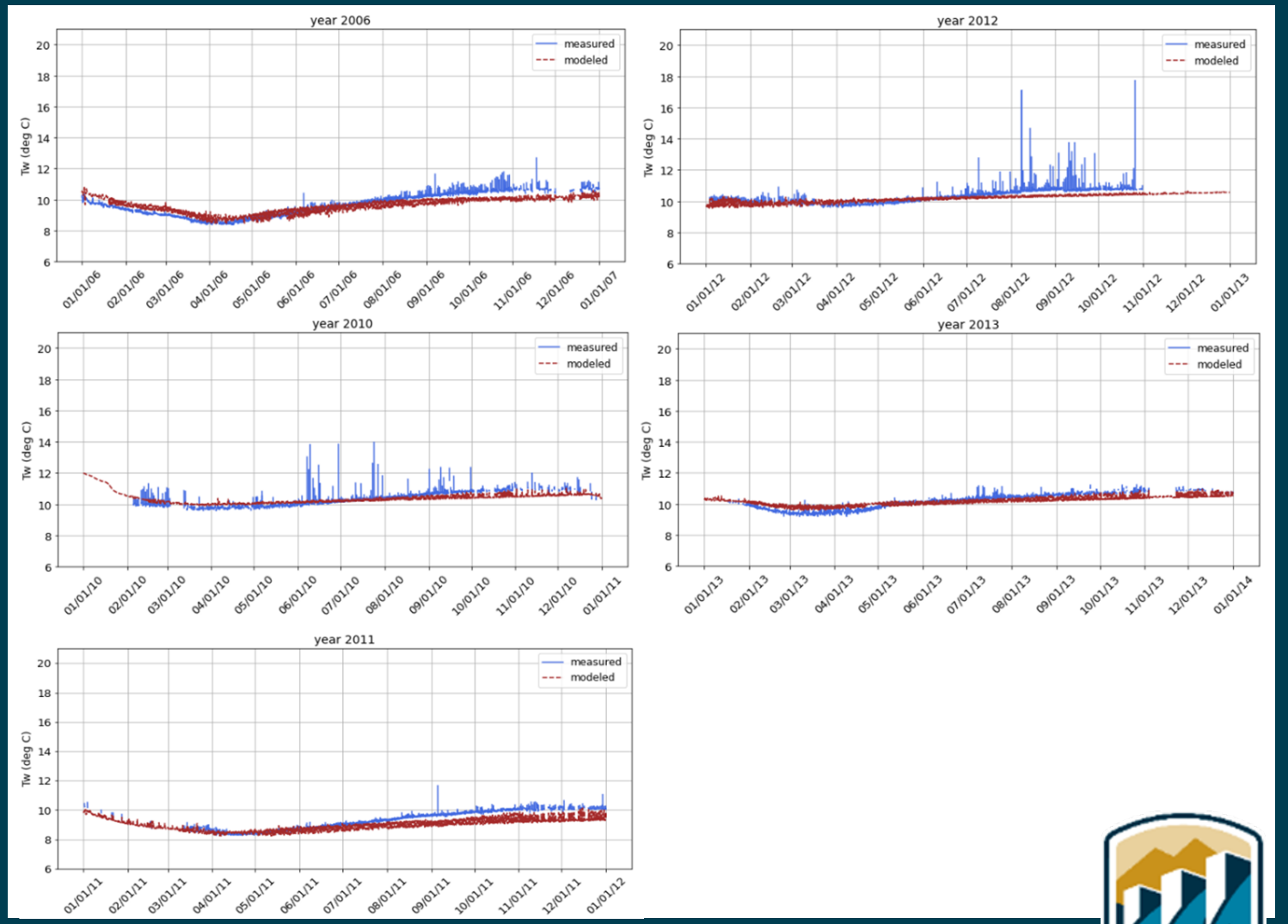
- near Old Dam

Metric	01/12/12	02/08/12	03/01/12	04/18/12	05/02/12	06/07/12	07/03/12	08/07/12	09/05/12	10/04/12	12/31/12
Mean Bias (deg C)	-0.02	-0.13	-0.27	-1.11	-1.08*	-0.88*	-0.79*	1.13*	-0.38	-0.54	-0.29
MAE (deg C)	0.1	0.35	0.46	1.24	1.22*	1.01*	0.92	1.23*	0.74	0.89	0.58
RMSE (deg C)	0.14	0.39	0.53	1.46	1.48	1.14	1.04	1.44	0.87	1.02	0.64
NSE	0.98	0.79	0.51*	0.36*	0.78	0.93	0.95	0.95	0.97	0.96	0.38*

Calibration: Outflow Water Temperature

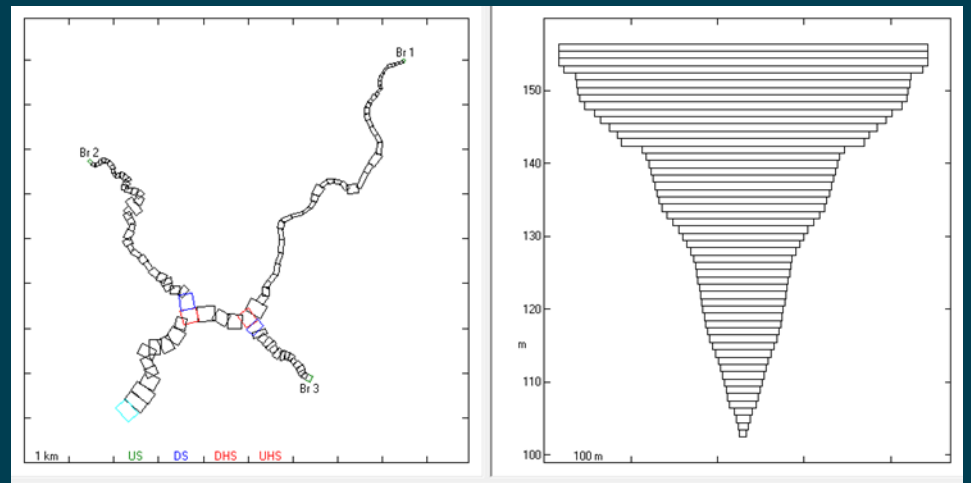
- 2006
- 2010 - 2013

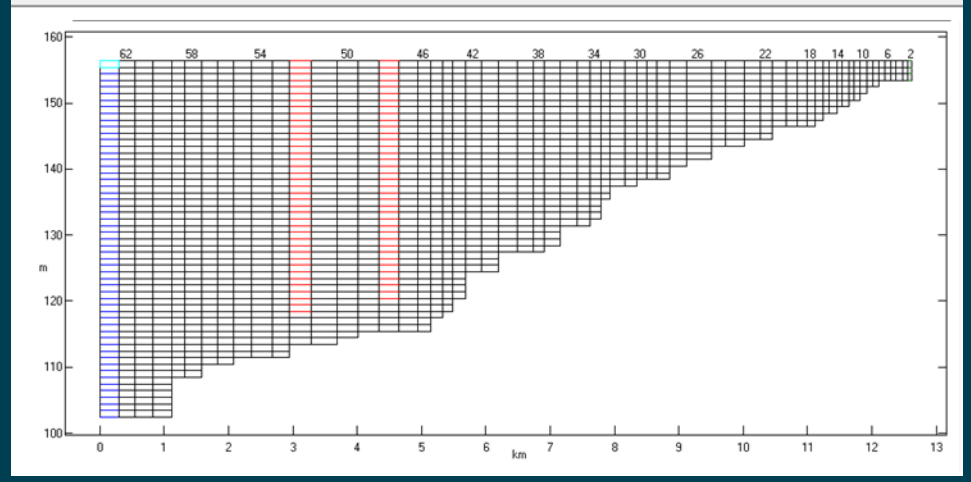
Metric	2006	2010	2011	2012	2013
Mean Bias (deg C)	0.08	0.02	-0.16	-0.06	0.08
MAE (deg C)	0.32	0.2	0.23	0.23	0.23
RMSE (deg C)	0.37	0.31	0.29	0.37	0.28
NSE	0.72	0.55*	0.77	0.39*	0.64*
Count	5,250	2,784	4,036	3,008	3,526

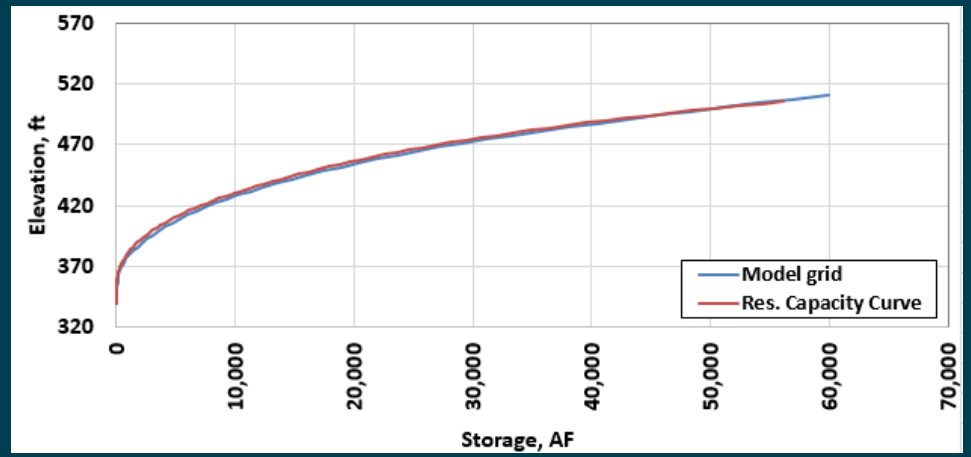


Tulloch Lake

- Final CE-QUAL-W2 grid
- Three branches
- Stage-volume representation

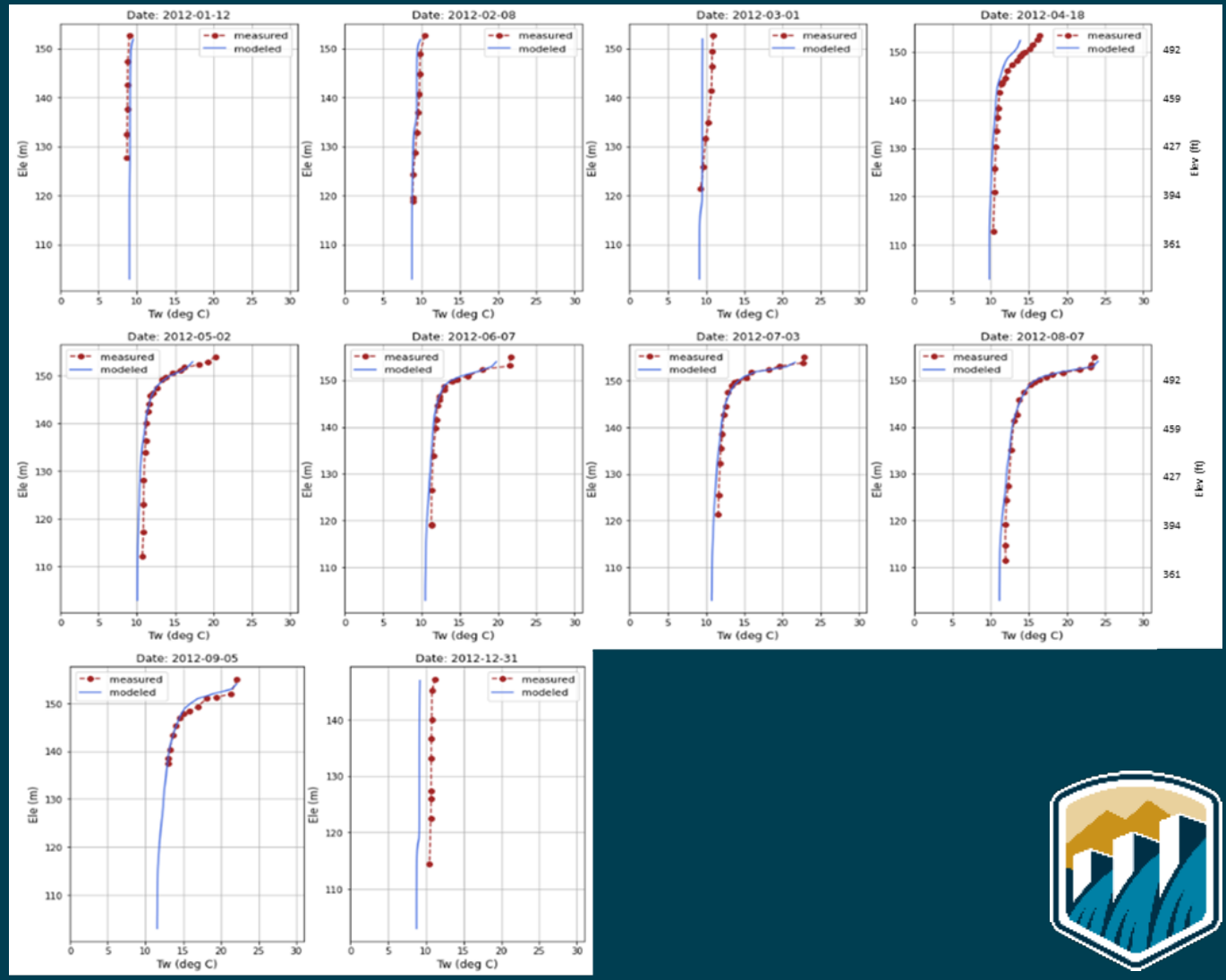






Tulloch Lake Profile near Dam (2012)

- Seasonal stratification (isothermal to isothermal)
- “Thin” epilimnion
- Epilimnion temperatures are a lower priority
- NSE values – winter (December)



Tulloch Lake Profile near Dam Year 2012

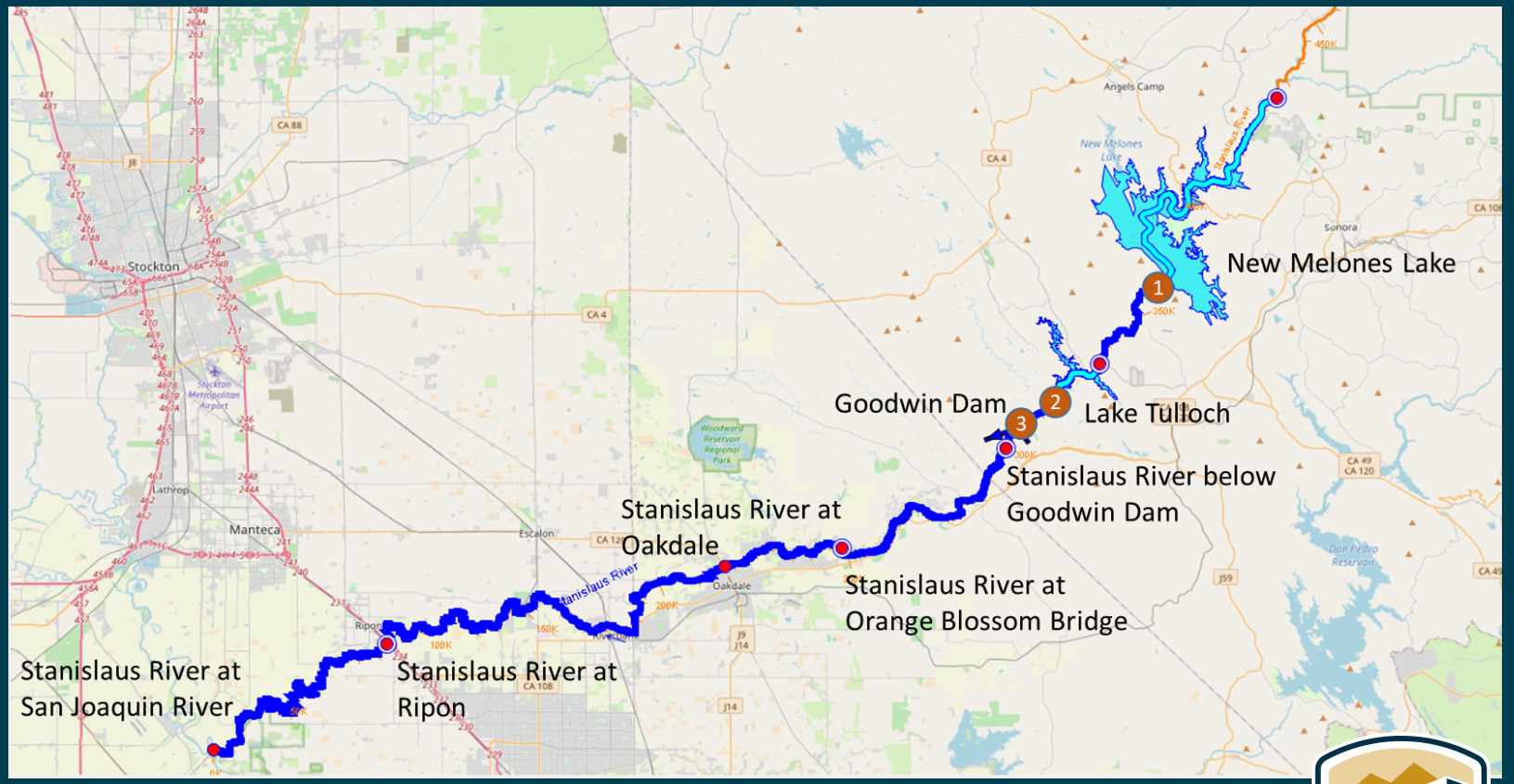
- Calibration: Tabular monthly results
  - Near Dam

Metric	01/12/12	02/08/12	03/01/12	04/18/12	05/02/12	06/07/12	07/03/12	08/07/12	09/05/12	10/04/12	12/31/12
Mean Bias (deg C)	0.4	-0.27	-0.8*	-0.94*	-0.37	-0.52	-0.17	-0.28	-0.44	0.4	-1.66*
MAE (deg C)	0.4	0.27	0.84	0.94	0.57	0.56	0.47	0.42	0.46	0.4	1.66*
RMSE (deg C)	0.4	0.31	0.97	1.15	0.91	0.8	0.63	0.49	0.67	0.4	1.66*
NSE	<0.0*	0.58*	<0.0*	0.64*	0.91	0.94	0.97	0.98	0.95	<0.0*	<0.0*

Stanislaus ResSim Model Schematic

- Calibration Simulation Period: December 4, 2004, through May 8, 2014

1. New Melones Dam
   - Power Outlet
   - Low Level Outlet
   - Spillway (uncontrolled)
2. Tulloch Dam
   - Power Outlet
   - Low Level Outlet
   - Gated Spillway
3. Goodwin Dam
   - Oakdale Diversion
   - South San Joaquin Diversion

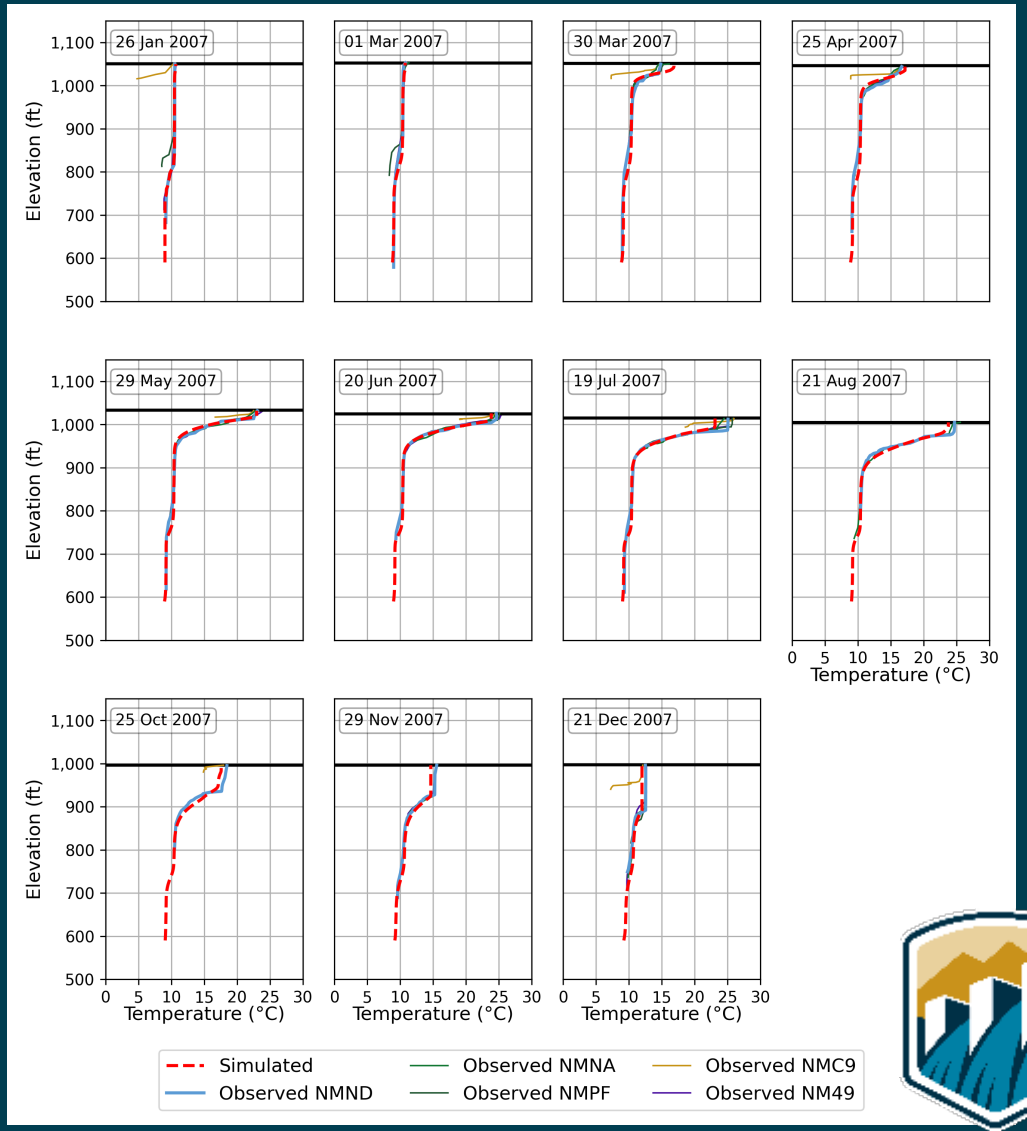


New Melones Lake Calibration Results for 2007

- Water Temperature Profiles near Dam
- 2007

Statistics	1/26/07	3/1/07	3/30/07	4/25/07	5/29/07	6/20/07
Mean Bias (deg C)	-0.03	0.05	0.16	0.06	-0.02	0.02
MAE (deg C)	0.06	0.10	0.31	0.31	0.19	0.23
RMSE (deg C)	0.08	0.16	0.52	0.49	0.31	0.34
NSE	0.98	0.94	0.87	0.94	0.99	0.99

Statistics	7/19/07	8/21/07	10/25/07	11/29/07	12/21/07
Mean Bias (deg C)	-0.19	-0.04	-0.01	0.03	-0.08
MAE (deg C)	0.34	0.43	0.54	0.35	0.42
RMSE (deg C)	0.74	0.65	0.65	0.40	0.45
NSE	0.97	0.98	0.96	0.96	0.81

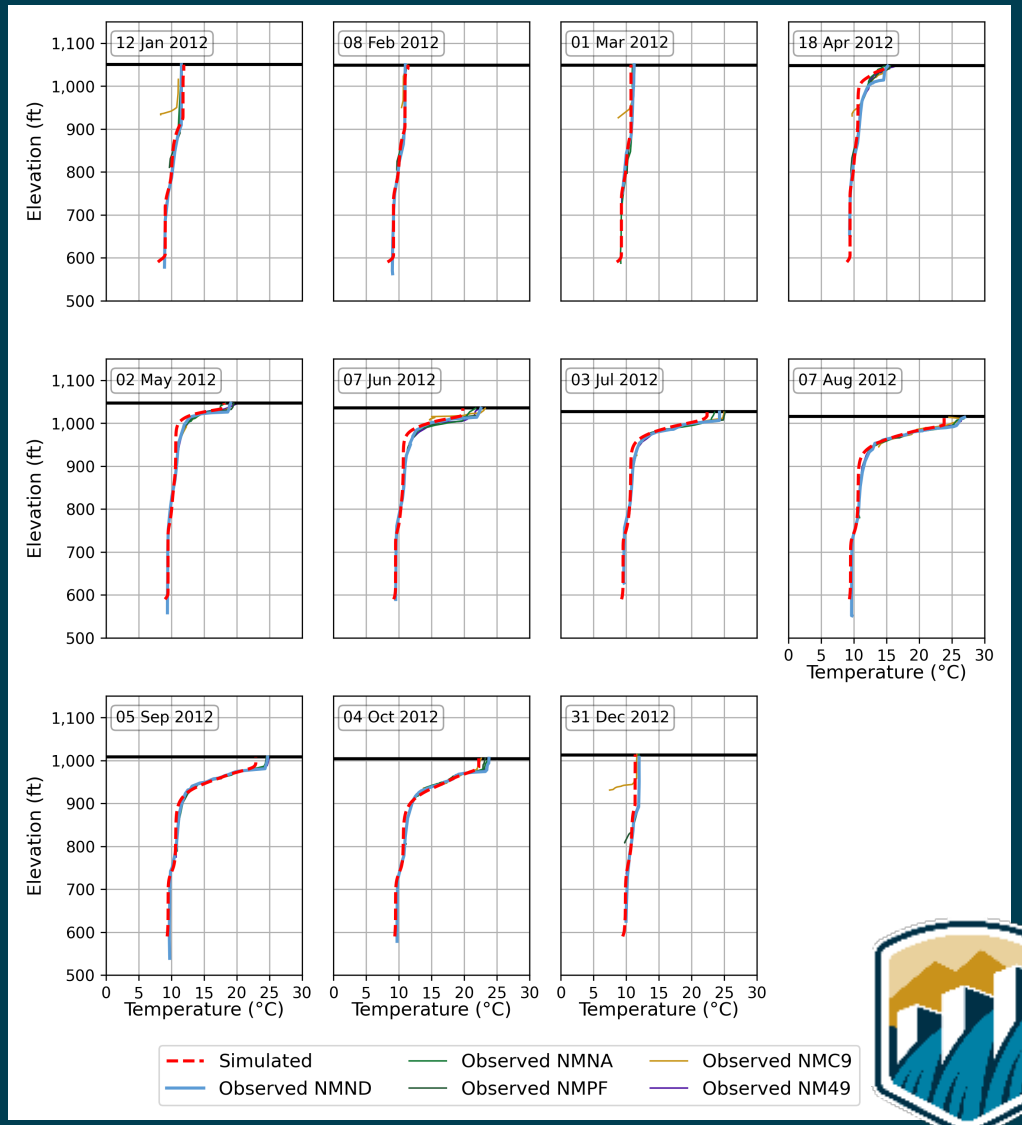


New Melones Lake Calibration Results for 2012

- Water Temperature Profiles near Dam
- 2012

Statistics	1/12/12	2/8/12	3/1/12	4/18/12	5/2/12	6/7/12
Mean Bias (deg C)	-0.02	-0.01	-0.14	-0.35	-0.21	-0.37
MAE (deg C)	0.20	0.09	0.21	0.40	0.29	0.42
RMSE (deg C)	0.23	0.13	0.25	0.73	0.49	0.76
NSE	0.95	0.97	0.82	0.79	0.95	0.94

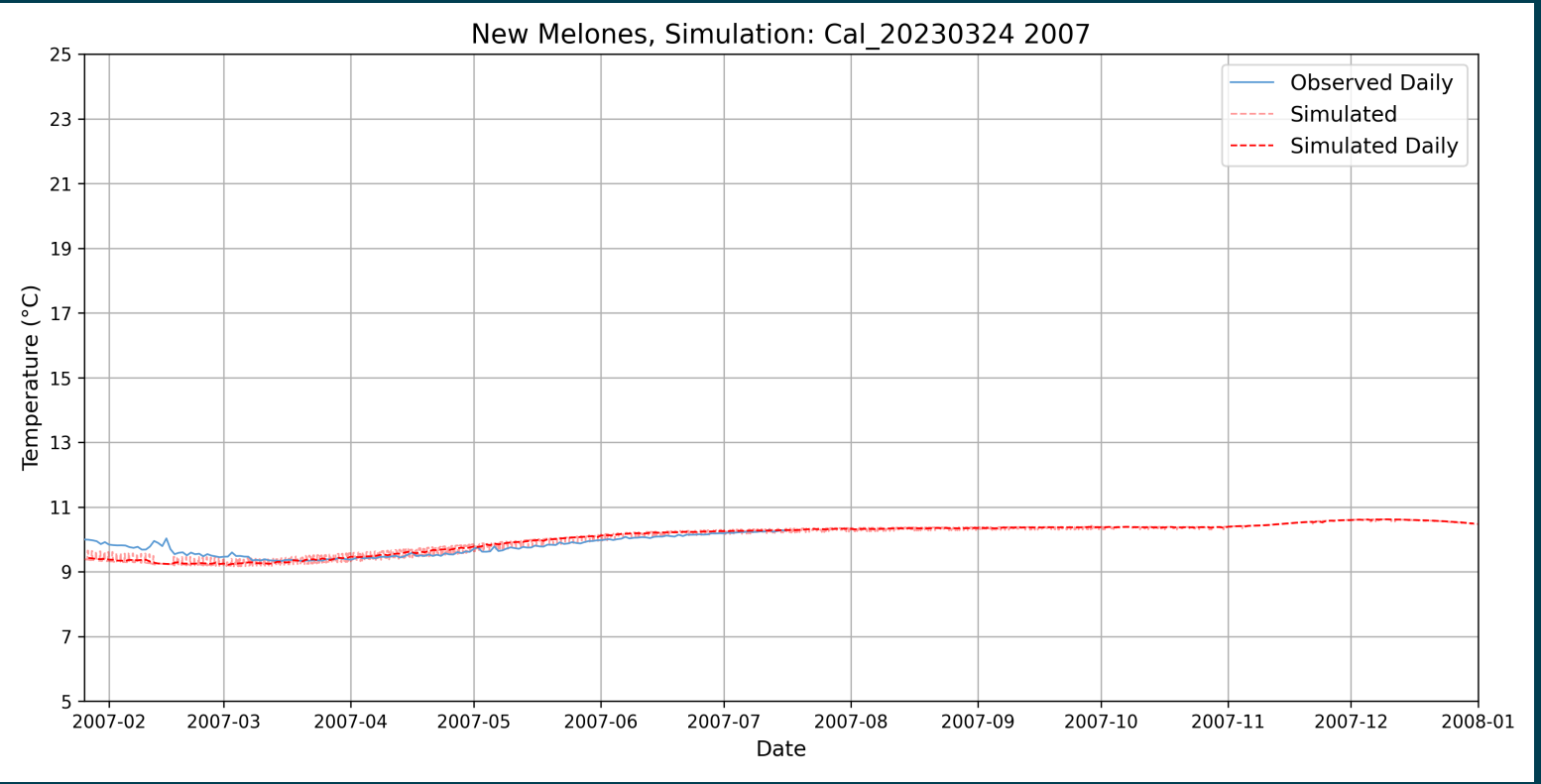
Statistics	7/3/12	8/7/12	9/5/12	10/4/12	12/31/12
Mean Bias (deg C)	-0.36	-0.44	-0.24	-0.26	-0.30
MAE (deg C)	0.43	0.44	0.39	0.38	0.31
RMSE (deg C)	0.70	0.76	0.60	0.54	0.38
NSE	0.97	0.97	0.98	0.98	0.77



New Melones Lake Calibration Results

- Outflow Temperature
- 2007 (2012 not in output report yet)

Statistics	2007
Mean Bias (deg C)	-0.02
MAE (deg C)	0.17
RMSE (deg C)	0.22
NSE	0.43

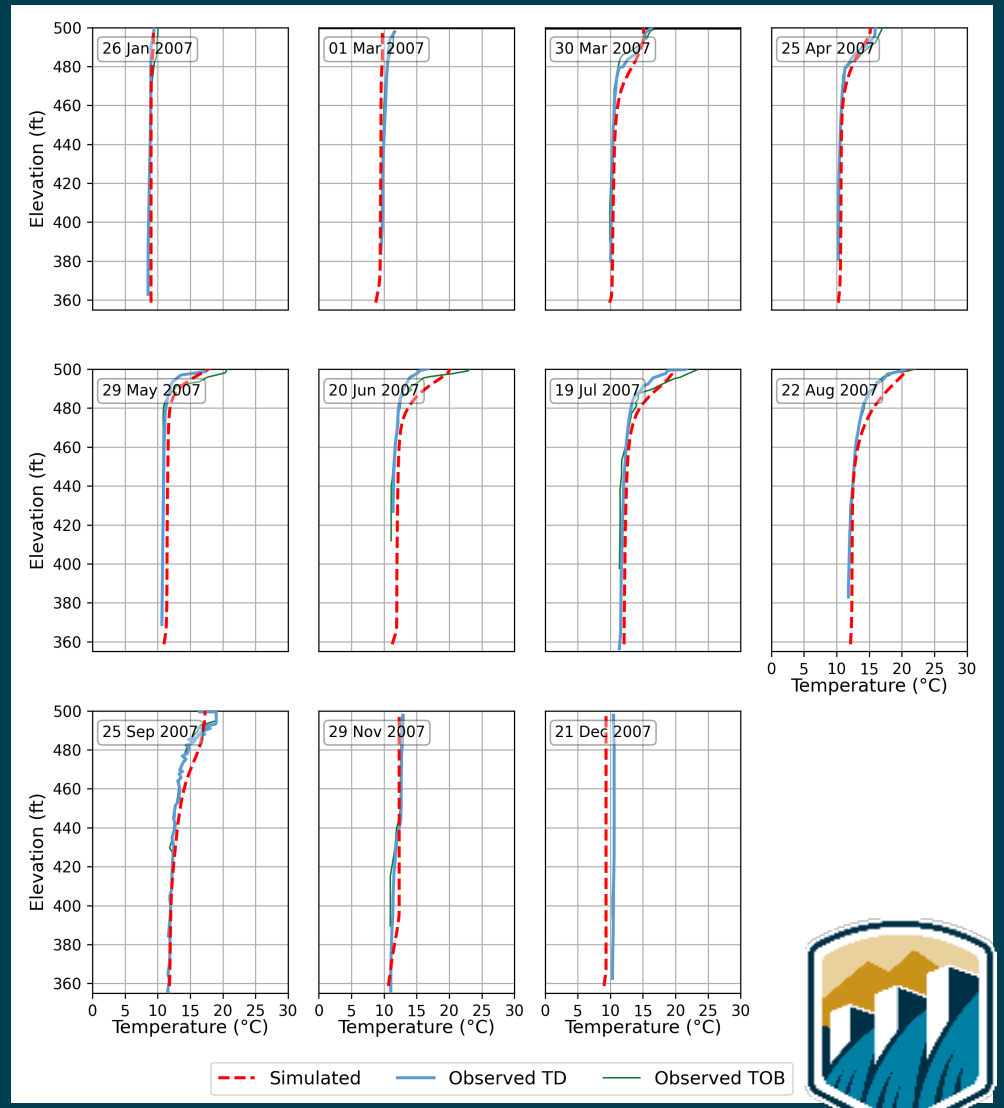


Tulloch Lake Calibration Result for 2007

- Temperature Profiles near Dam
- 2007
  - Nash-Sutcliff metric is not useful with reservoir is isothermal

Statistics	1/26/07	3/1/07	3/30/07	4/25/07	5/29/07	6/20/07
Mean Bias (deg C)	0.24	-0.55	0.39	0.19	0.68	1.2
MAE (deg C)	0.24	0.55	0.48	0.41	0.74	1.5
RMSE (deg C)	0.28	0.65	0.64	0.49	0.83	2.0
NSE	Less than 0	Less than 0	0.85	0.92	0.83	0.60

Statistics	7/19/07	8/22/07	9/25/07	11/29/07	12/21/07
Mean Bias (deg C)	0.36	0.52	0.31	0.17	-1.2
MAE (deg C)	0.97	0.77	0.60	0.47	1.2
RMSE (deg C)	1.5	1.1	0.86	0.54	1.2
NSE	0.80	0.88	0.84	0.32	Less than 0

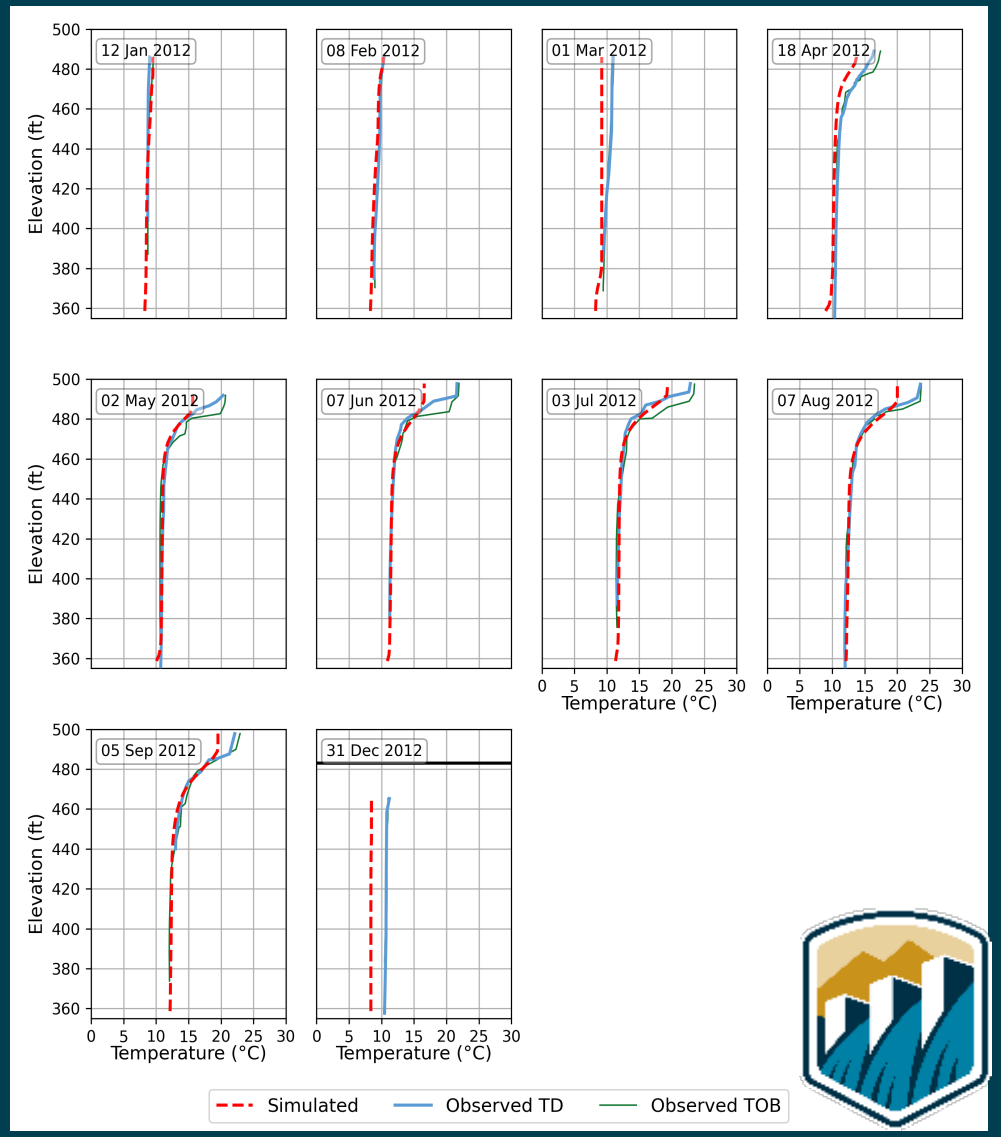


Tulloch Lake Calibration Result for 2012

- Temperature Profiles near Dam
- 2012
  - Nash-Sutcliff metric is not useful when reservoir is isothermal

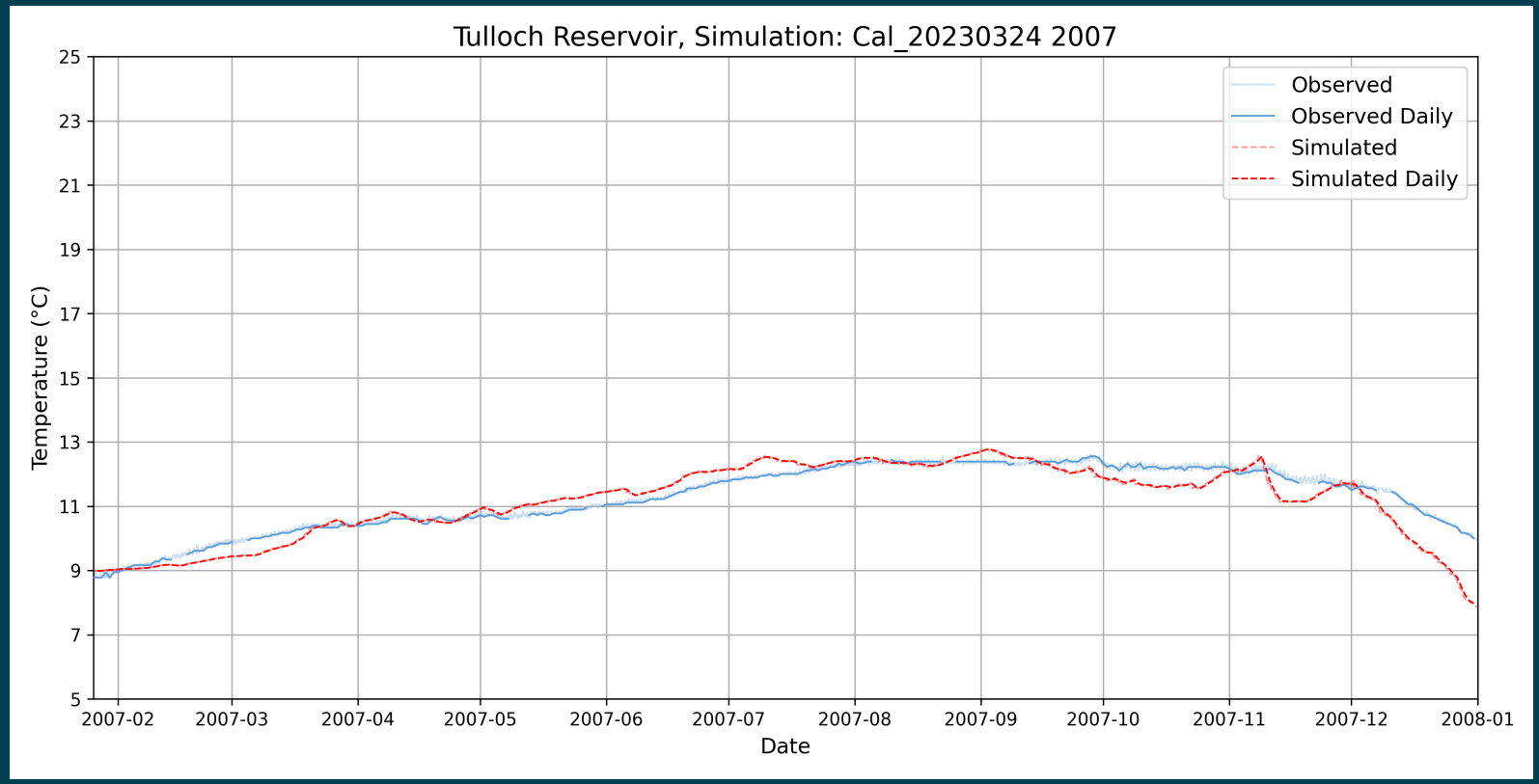
Statistics	1/12/12	2/8/12	3/1/12	4/18/12	5/2/12	6/7/12
Mean Bias (deg C)	0.19	-0.32	-1.1	-0.86	-0.33	-0.32
MAE (deg C)	0.26	0.32	1.1	0.86	0.34	0.57
RMSE (deg C)	0.33	0.34	1.2	1.1	0.91	1.4
NSE	Less than 0	0.32	Less than 0	0.57	0.82	0.76

Statistics	7/3/12	8/7/12	9/5/12	12/31/12
Mean Bias (deg C)	-0.10	-0.14	-0.62	-2.3
MAE (deg C)	0.43	0.50	0.70	2.3
RMSE (deg C)	0.88	0.94	1.1	2.3
NSE	0.90	0.91	0.89	Less than 0



Tulloch Lake Calibration Result

- Outflow Temperature
- 2007
  - Issue with inconsistent Cloudiness values in Met Data potentially causing water temperature to be too cool in winter and spring

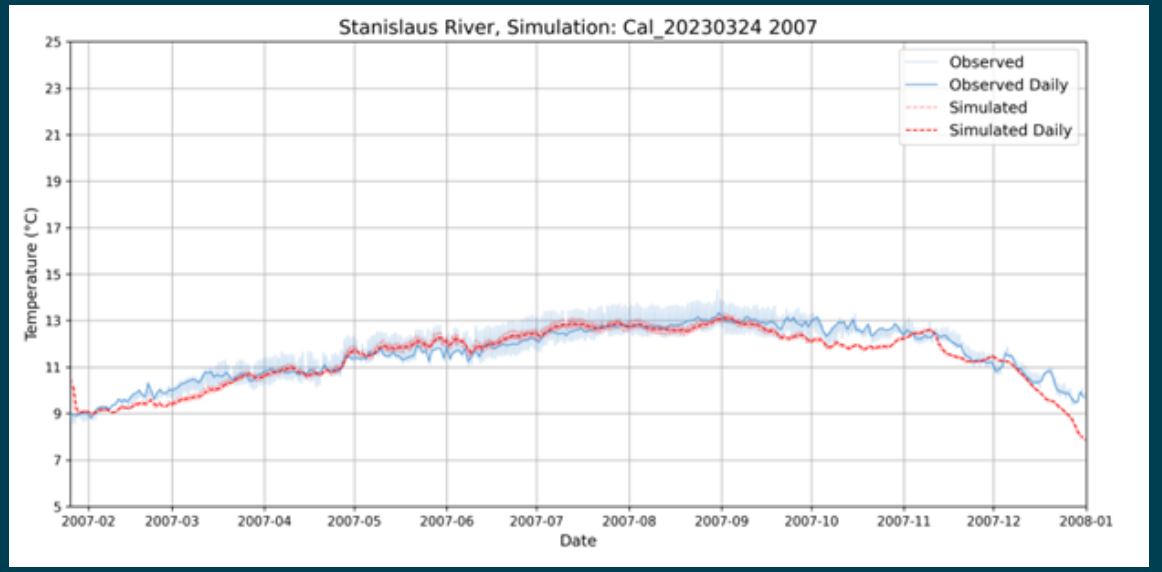


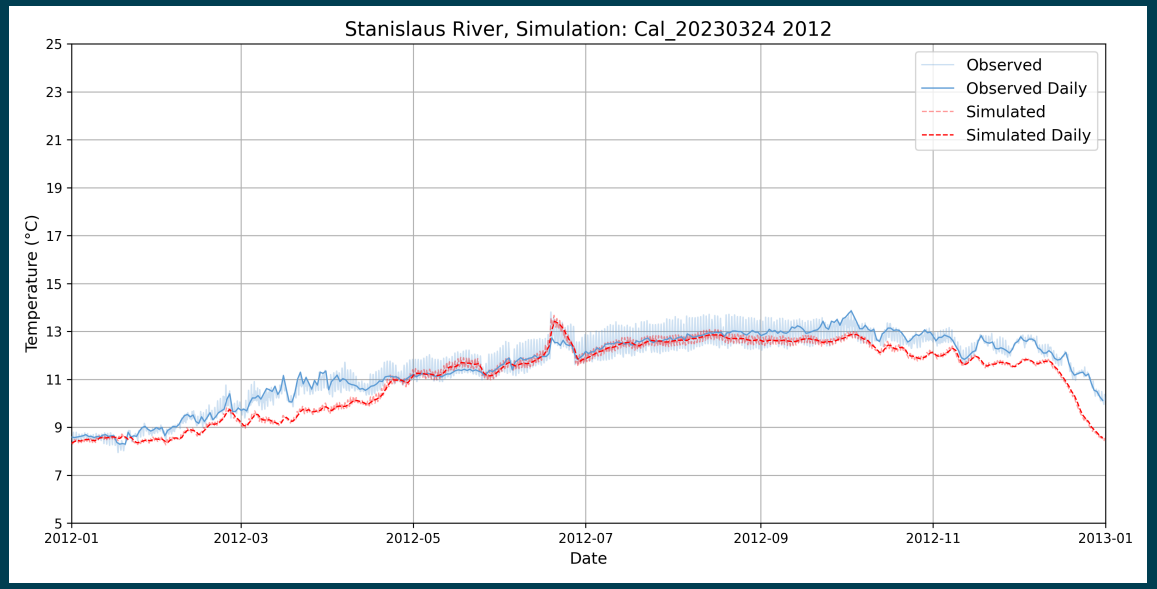
Statistics	2007
Mean Bias (deg C)	-0.12
MAE (deg C)	0.36
RMSE (deg C)	0.49
NSE	0.75

Goodwin Dam Calibration Result

- Outflow Temperature
- 2007 and 2012

Statistics	2007	2012
Mean Bias (deg C)	-0.23	-0.44
MAE (deg C)	0.38	0.50
RMSE (deg C)	0.48	0.64
NSE	0.84	0.80

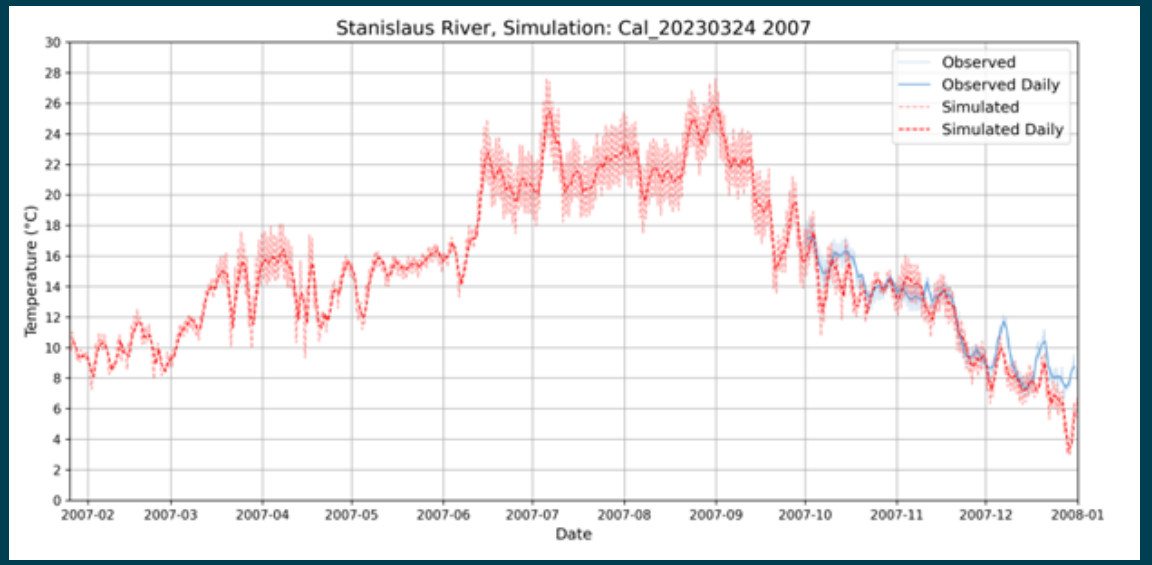


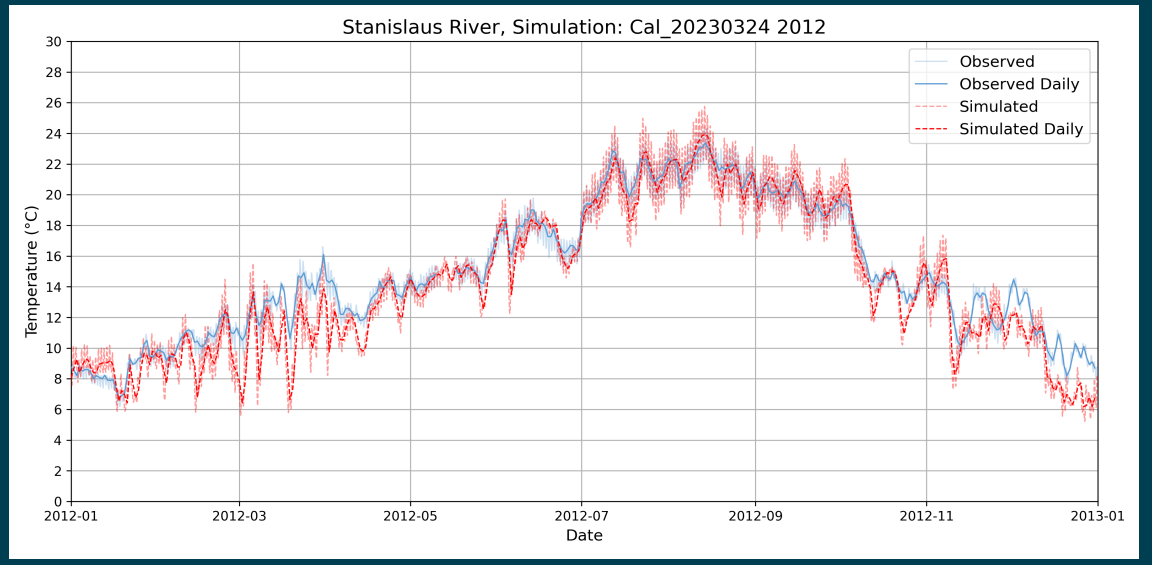


Stanislaus River Calibration Result

- River Temperature at Ripon
- 2007 and 2012

Statistics	2007	2012
Mean Bias (deg C)	-0.62	-0.67
MAE (deg C)	1.1	1.2
RMSE (deg C)	1.4	1.5
NSE	0.77	0.88





Summary of Stanislaus Model Calibration

- CE-QUAL-W2 and HEC ResSim models were developed for the Stanislaus River system
- Represented the inundated old dam in both models
- Models were calibrated using available data with significant limitations
- Overall model performance good considering data challenges
- Existing CE-QUAL-W2 and ResSim Models are available for water temperature planning studies. However, for more detailed studies, additional information is required.

Summary of Stanislaus Model Calibration – Data Limitations

- Upstream boundary conditions for New Melones create notable challenges for model calibration.
- Specifically, Lack of consistent, long-term, comprehensive monitoring at the following locations has a direct impact on model performance
  - Boundary conditions (year-round)
    - Stanislaus River
    - South Fork Stanislaus River
    - Collierville PH
    - Stanislaus PH
  - Calibration data (year-round)
    - New Melones and Tulloch Lake profiles are absent since 2016
    - New Melones release temperatures
    - Stanislaus River at appropriate locations for model testing.

Summary of Stanislaus Model Calibration - Recommendations

- Develop a comprehensive and robust monitoring program
  - Focus on addressing the spatial and temporal data needs of flow and sub-daily temperature modeling
  - Spatial extent: Stanislaus River system from the headwaters of New Melones Lake to the confluence of the San Joaquin River
  - A coordinated multi-agency collaboration for data collection and monitoring can be most efficient
- The continued implementation of WTMP will include additional model development, if warranted, and calibration/re-calibration based on additional available data.

Questions on Stanislaus River Water Temperature Models?

Break (10 min)

Photo credit: John Hannon, Reclamation

Highlights of Model Development TM (Sac/Trinity and American only)

Mike Deas, PhD, PE, Watercourse Engineering, Inc.

Model Development TM for MTC Review

- Distributed on 4/4; Comments by 5/2.
- Covering the Sac/Trinity and American River Systems
- Revised version expected in late May 2023 for MTC review, including:
  - Revised sections for the Sac/Trinity and American River systems with MTC comments incorporated.
  - New section for the Stanislaus River System for MTC review
- Model development efforts expected to complete May 2023 after incorporating MTC comments
- This highlight section is to aid MTC members in reviewing this TM with substantial information.

TM Organization

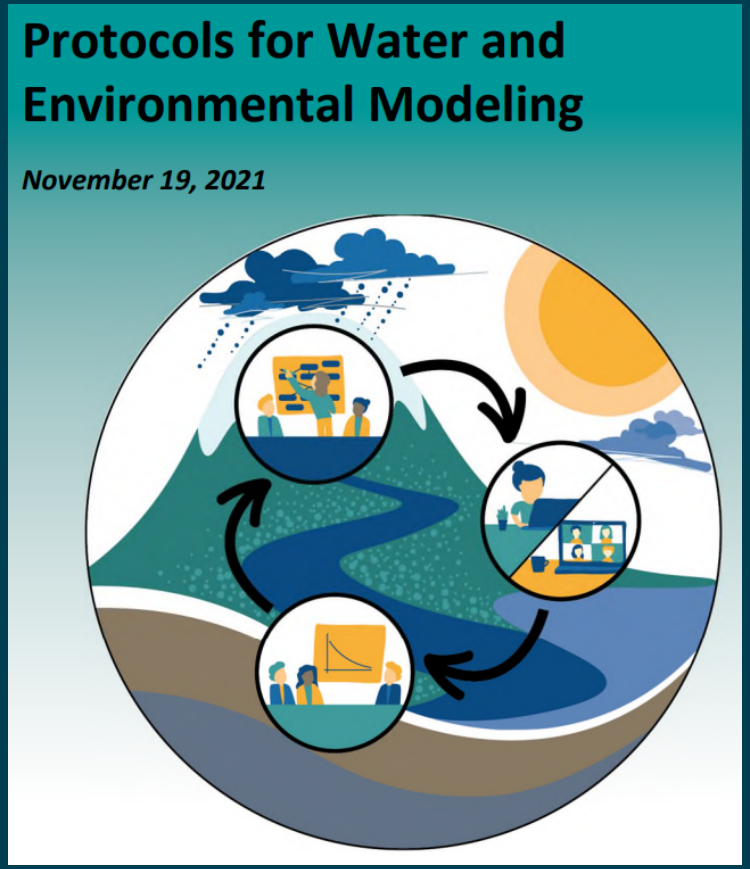
- Chapter 1. Introduction
- Chapter 2. Background
  - Systems and unique attributes
- Chapter 3. Model Development
  - Sacramento/Trinity
    - CE-QUAL-W2 – control parameters, geometry
    - ResSim – control parameters, geometry
    - Boundary conditions, Initial conditions
- Chapter 4. Calibration, Validation Sensitivity
  - Introduction
  - CE-QUAL-W2
  - ResSim

TM Organization (cont'd)

- Chapter 5. Model Development
  - American
    - CE-QUAL-W2 – control parameters, geometry
    - ResSim – control parameters, geometry
    - Boundary conditions, Initial conditions
- Chapter 6. Calibration, Validation Sensitivity
  - Introduction
  - CE-QUAL-W2
  - ResSim
- Chapter 7. Concluding Comment
- Chapter 8. References

TM Highlights

- Employment of CWEMF protocols (as applicable)
  - "good" modeling practices
  - https://cwemf.org/wp/resources-3/modeling-protocols-report/
- Multiple models and multiple systems with extended calibration periods
- Automated reporting and extensive model performance information
- Detailed background
  - Systems/Basins
  - Unique attributes
  - Task 7 Data Development TM nexus/support



TM Highlights (cont'd)

- Calibration approach
  - Pre-defined performance metrics (Objective driven)
  - Target reservoir and river performance descriptions to guide calibration
  - Unique role of validation (calibration and metric comparisons)
- Sensitivity analysis
  - Defined sensitivity levels for calibration
  - Employ model performance metrics
  - Phase II activities (forecasting)
- Outcome: performance measures suggest that the calibrated models are adequate for their intended applications

TM Review Guidance

- All comments welcome
- Priorities?
  - Calibration and sensitivity approaches
  - Your river basin of interest
- Minor known issues to be addressed in the revised version
  - Some formatting and style inconsistency
  - Peer review comments provided for context only (no actions from the MTC members are required)
  - Forecast sensitivity analysis is to be discussed together with model uncertainty (in a later TM)
  - Appendices will be available in the next few days
- Thank you (in advance)!

Questions on Model Development TM?

- Check your email for TM review request and instructions for downloading the TM (a very large file; 72MB) and uploading your comments. Comments by 5/2/2023.
- No email? Contact Yung-Hsin Sun @ sun.yunghsin@sunziconsulting.com

Photo credit: John Hannon, Reclamation

Model Uncertainty

Mike Deas, PhD, PE, Watercourse Engineering, Inc.
Yung-Hsin Sun, PhD, PE, Sunzi Consulting LLC

Outline

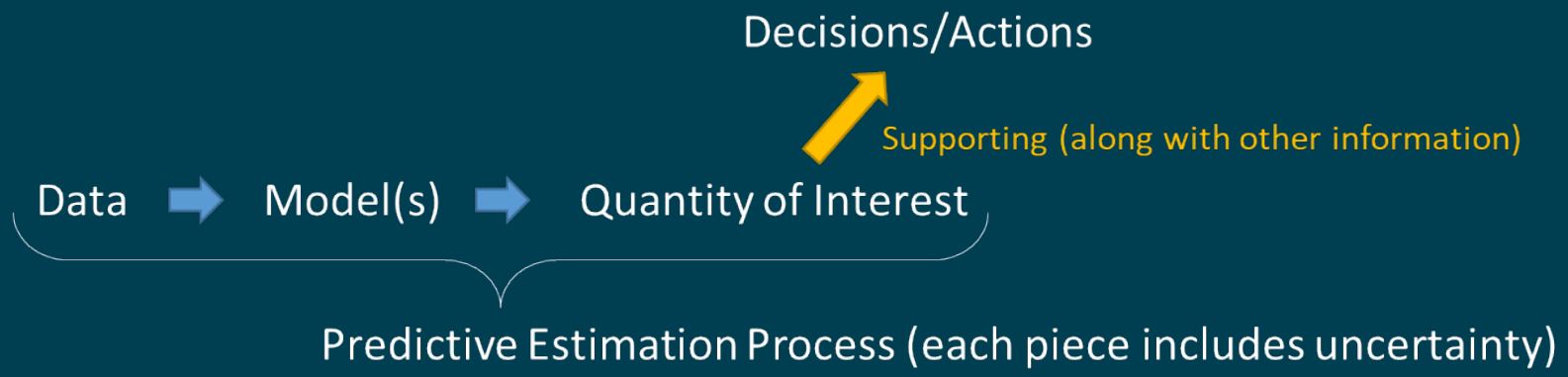
- Approach to identification and characterization, interim findings and anticipated outcome
- Recap – sources of uncertainty
- Additional identified uncertainty sources

Uncertainty as the Last Major Element for WTMP Development and Implementation

- Recap of last MTC discussion
  - Identified sources of uncertainty and proposed treatments
  - Introductory discussion on data needs for
    - Forecasting water temperature at a downstream location
    - To assist the assessment of regulatory compliance
- Today – Drilling down into the uncertainty discussion
  - Aim to better characterize sources of uncertainty and treatments in WTMP implementation (model and forecasting)
  - Explore communicating uncertainty

Why We Care about Uncertainty?

- Properly informed decisions/actions require understanding of uncertainty associated with the predicted quantity of interest.



Recap

- Identified four general areas of uncertainty and treatment in WTMP modeling
  - Facility installation (not under investigation)
  - Observed data (area of interest)
  - Forecast data (area of interest)
  - System representation
    - Modeled physical system (not under investigation)
    - Operational (area of interest)
    - Unique attributes (area of interest)

Additional Identified Areas of Uncertainty

- Parameter estimation (calibration)
- Second generation data
  - Model output used as model input
    - Internal to WTMP (area of interest)
    - External to WTMP (not under investigation)
- Different models
  - HEC ResSim and CE-QUAL-W2 (area of interest)

Sources of Uncertainty

Source	Where to Find it	Potential Implication
Input uncertainties - calibration	Initial conditions and boundary conditions	Initial conditions and boundary conditions provided using measured data would be subject to measurement errors and uncertainties. This includes limited accuracy of the sensors, and in some cases, the time and location of measurements.
Input uncertainties - forecast	Initial conditions and boundary conditions	Initial conditions and boundary conditions provided using forecast data would be subject to the prediction/forecast errors and uncertainty from the corresponding predictive estimation process. Forecast operations are included herein.
System error or discrepancies	Results from using a mathematical representation describing a phenomenon in the model	For the WTMP this is focuses on geometric representation, parameterization or representation of unique attributes (e.g., TCD, submerged dam), and multiple models.
Parameter uncertainty	Designated parameters for the model representation	Parameter uncertainty is usually quantified through calibration using known values (or measured data) and are thus, subject to uncertainty.
Model propagation uncertainties	Inherited from upstream models, passed to downstream models	Accumulation and/or cancelation of error/uncertainty.

Uncertainty Protocols - Activities

- Develop estimates/estimation procedures for uncertainty in datasets and models identified as potential sources of uncertainty, including forecasts
  - Phase I activity and to be documented in an upcoming Uncertainty Sources TM
- Develop estimates/estimation procedures for translating uncertainty through the modeling system to model results
- Apply models to a range of simulations and develop potential approaches to communicate uncertainty in model results (e.g., forecasts, hindcasts)

Uncertainty in Datasets and Models

- Calibration
  - Quantification of uncertainty associated with the data and parameter estimation was included in calibration (e.g., calibration parameters)
  - Resulting predictive errors were assessed using model performance metrics to determine its fitness and acceptability
- Forecasting
  - After calibration, the model is used for the predictive/forecasting estimation process
  - Model uncertainty assessed in calibration will not be explicitly used for quantifying the uncertainty of the predictive/forecasting estimation process

Approach to Explore Forecast Uncertainties in WTMP Implementation

- Uncertainty associated with models (calibration) resides in the predictive/forecasting estimation process
- Next phase is to focus is on input forecast uncertainty, including
  - Initial conditions
    - Storage/stage
    - Temperature
  - Boundary conditions
    - Meteorological
    - Hydrological conditions
    - Water temperature

Forecasting: Approach to Explore Uncertainties in WTMP Implementation

- A range of approaches
- Others
  - Position analysis
  - Monte Carlo analysis
  - Others

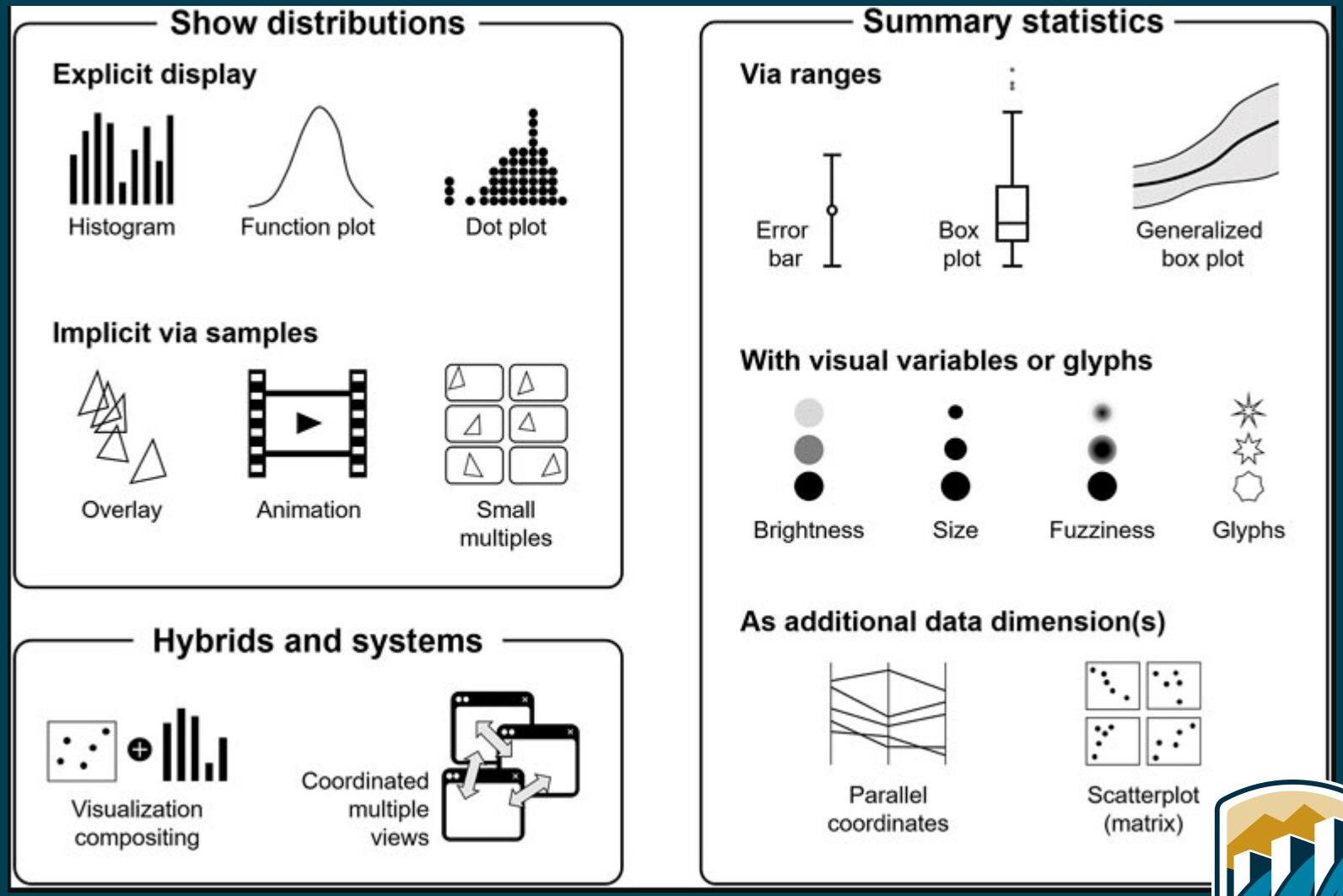
Single Scenario Forecast	Selective Scenario Forecasts	Ensemble Forecasts	Multi-Model Ensemble Forecasts
One representative realization of the future scenario (representative…hopefully)	Currently used multiple but selective exceedance points (e.g., 50%, 75%, 90%, 95%, 99%) for hydrologic and meteorological conditions, with paired water temperature boundary conditions. Scenarios are not considered equally possible.	A large number of scenarios with a representative range and probability of hydrologic and meteorological conditions. All scenarios are considered equally possible.	Using different models in the predictive estimation process for ensemble forecast.
Not used as it provides insufficient information for modern decision making, but implementable in the WTMP	To be implemented in WTMP. Results can be used to bracket possible outcomes with risk consideration, but no formal risk assessment can be done. Not probabilistic.	Could be implemented in WTMP in the future [the platform can accommodate it].	Same as ensemble forecasts. Potential for future inclusion in WTMP driven by the needs and benefits of using different models.

Translating Uncertainty Through Models

- Propagation of uncertainty in
  - Initial conditions
  - Forecast boundary conditions
- Accumulation, cancellation, correction
  - Implications (system response)
    - Large reservoirs
    - Small reservoirs
    - River reaches

Communicating Uncertainty

- Wide range of options
  - Tabular
  - Graphical
  - Other
- Reporting



Source: https://www.frontiersin.org/articles/10.3389/fbinf.2022.793819/full

Uncertainty: Discussion

- Data and modeling uncertainty
  - Have we characterized sources appropriately?
  - Does calibration and sensitivity testing provide useful information?
  - Are potential forecasting approaches reasonable?
- Translating uncertainty through models
  - What questions are important to decision-makers regarding model error propagation?
- Communicating Uncertainty
  - What information is useful?
  - What methods are most typically used, are they effective?

Uncertainty in the WTMP: Reminder

- Considerations when characterizing uncertainty in the WTMP framework
  - WTMP is a tool, not a decision-making body
  - WTMP models represent an approximation of a combination of complex natural processes and built river-reservoir systems
  - Pragmatic for implementation and ability to assess resulting benefits
- Next Steps on Model Uncertainty
  - Model application
  - Documentation

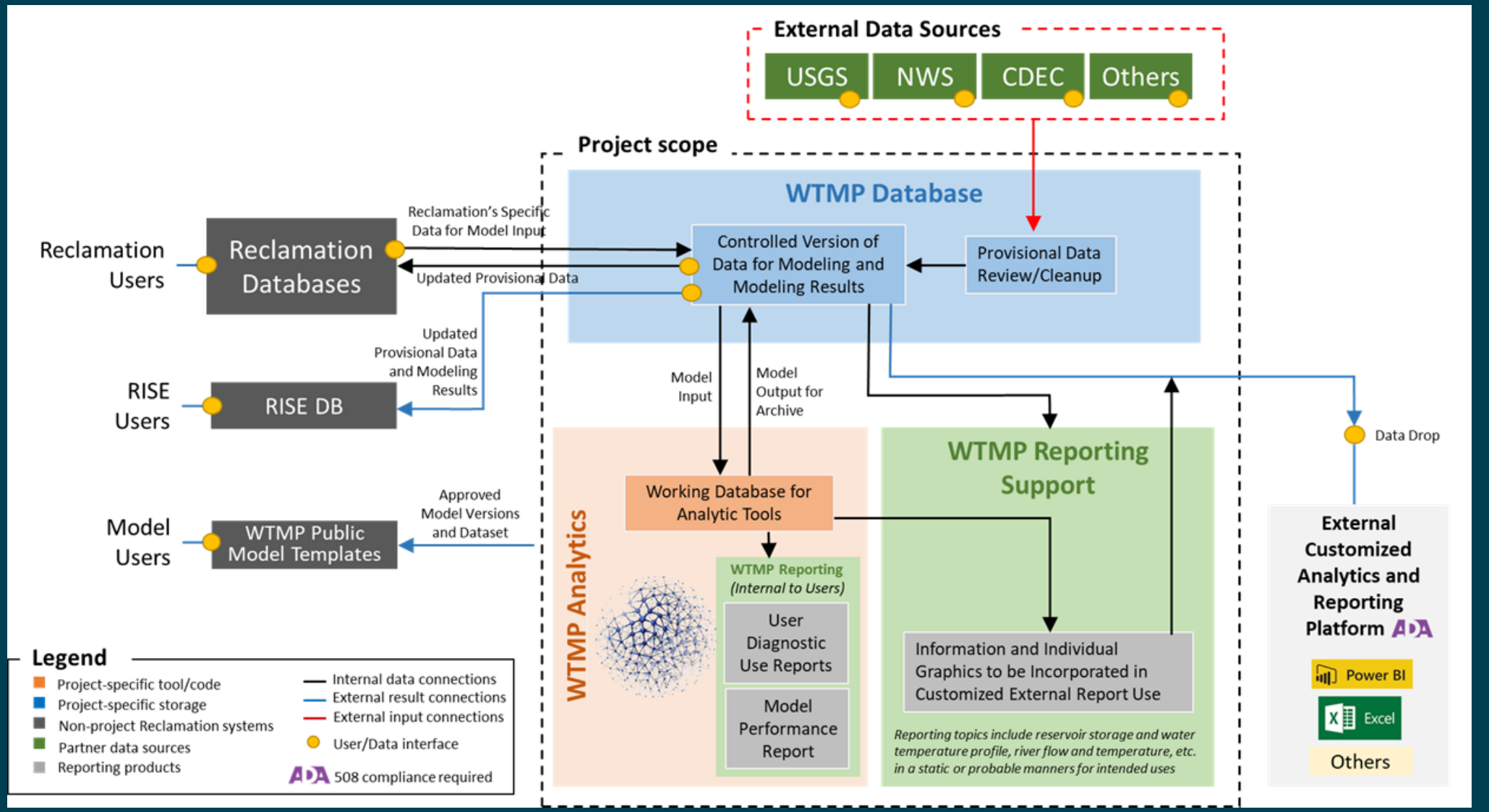
Questions on Model Uncertainty?

Photo credit: John Hannon, Reclamation

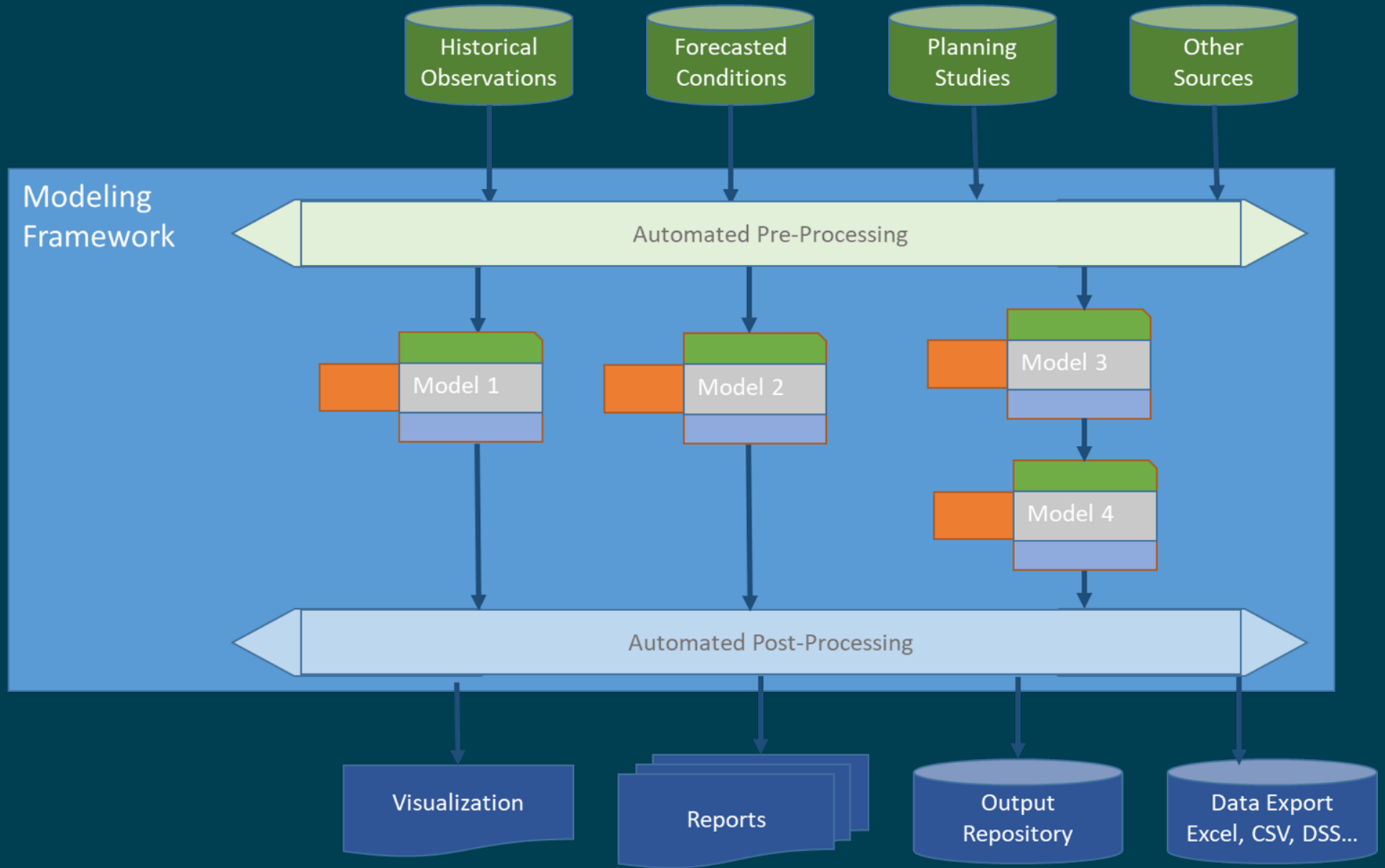
WTMP Output and Visualization

John DeGeorge, PE, RMA

Water Temperature Modeling Platform (WTMP)



WTMP Analytics Framework

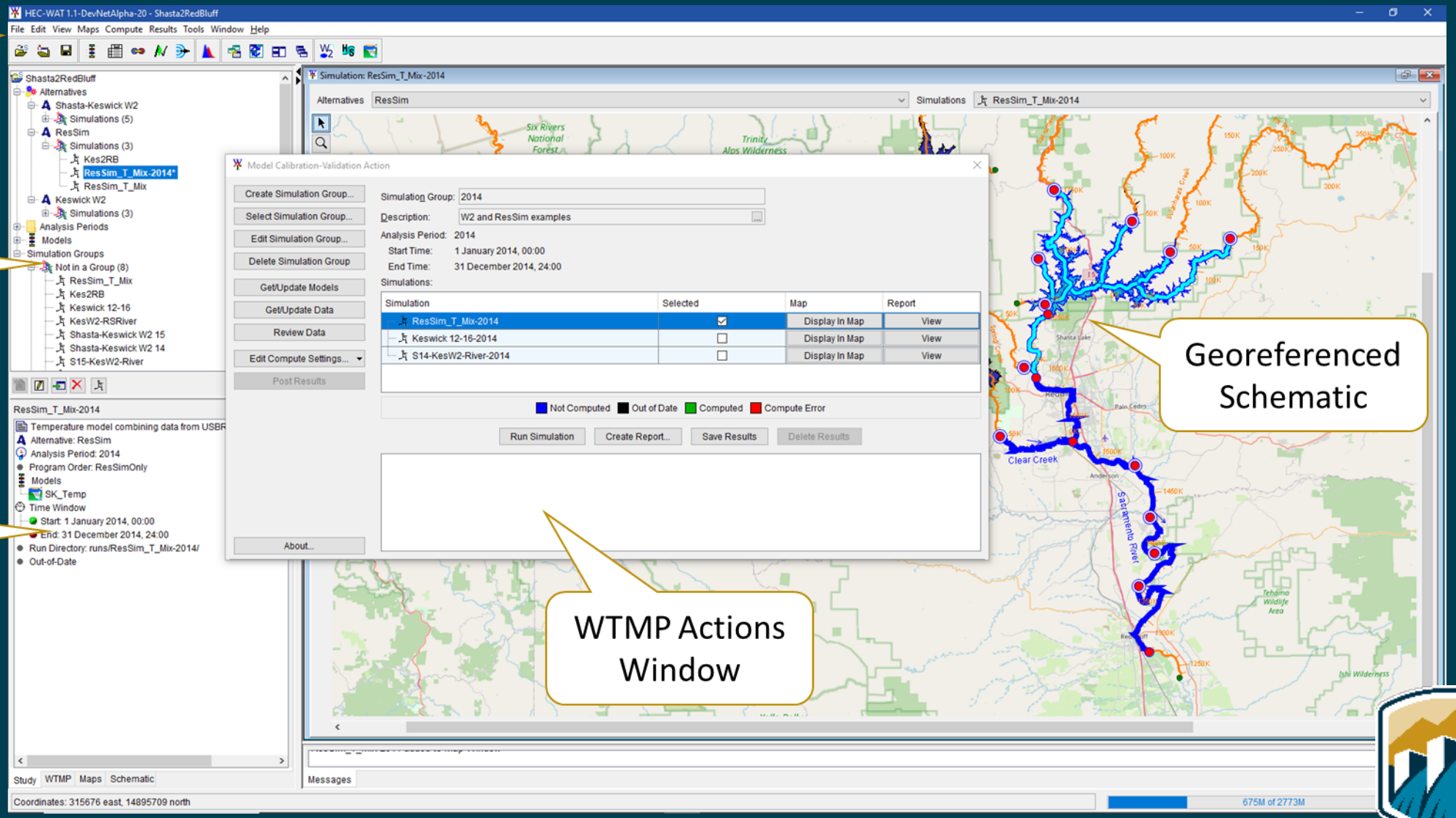


WTMP Modeling Framework User Interface

Menus and Toolbar Buttons

Study Tree

Study Element Details

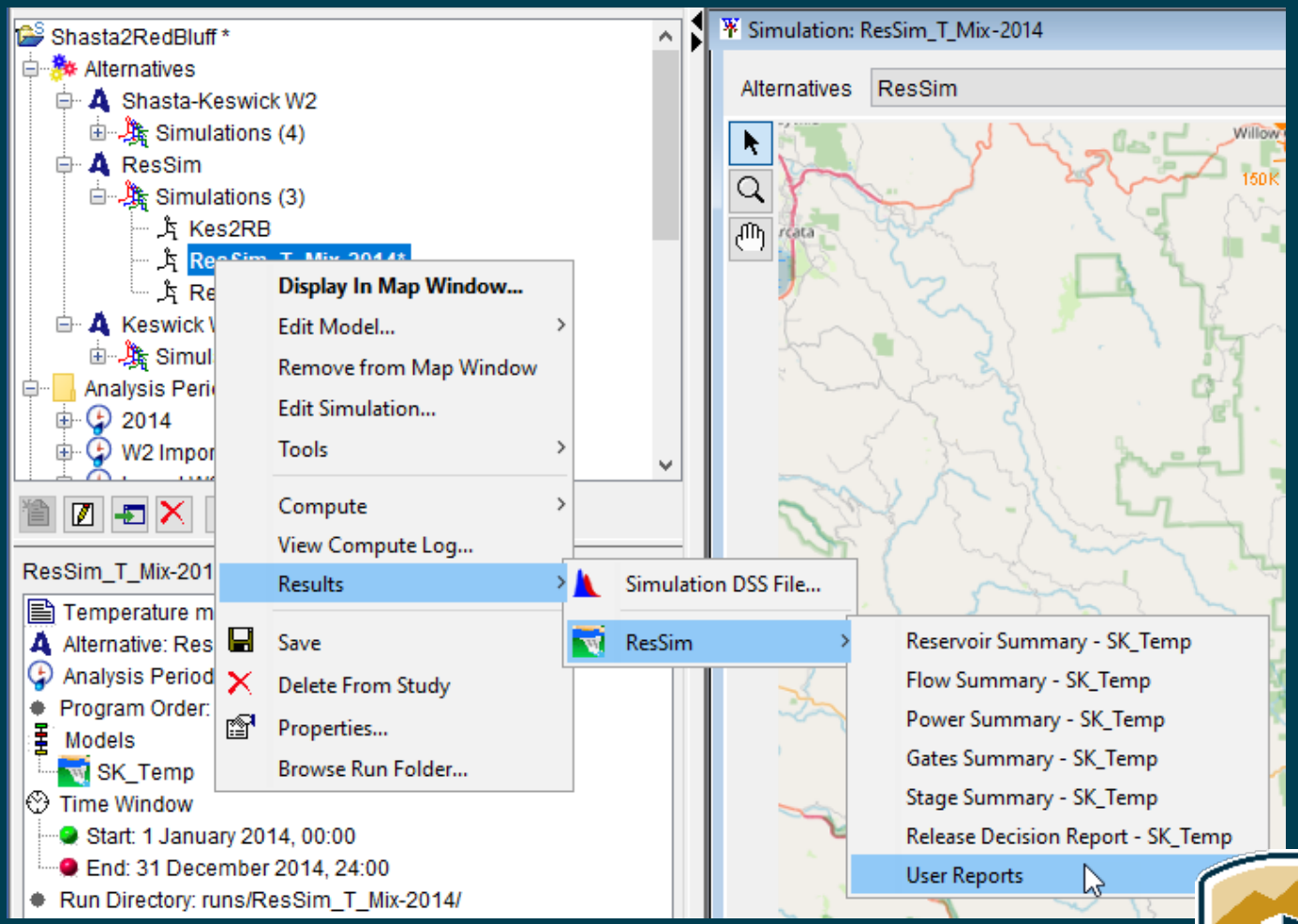


HEC-WAT/WTMP Terminology

Term	Definition
Study	[Text Descriptor] A name or descriptor describing the suite of physical or operational conditions to be assessed. A study is the highest-level grouping within HEC-WAT. A study is composed for Model Alternatives, Analysis Periods, WAT Alternatives and Simulations/Simulation Groups.
Study Folder	Directory structure containing all of the HEC-WAT configuration data (including data extracted from the DMS) and simulation results.
Platform	An overarching software framework composed of Model Program(s) and data sources (e.g., WTMP).
Data Management System	The WTMP specific system to store the data used by HEC-WAT and the Model Alternatives.
Model Program	Numerical modeling software (e.g., CE-QUAL-W2 , ResSim, HEC5Q). Not associated with a specific configuration (not location-, watershed-, or condition-specific, no set Analysis Period).
Model Alternative	A specific configuration (location- or watershed- or condition-specific, but no Analysis Period) of a Model Program (e.g., an existing conditions configuration for Shasta in W2 called “Shasta-Exist-W2”).
Program Order	A template defining the sequence of Model Program computations. This is a sequence of slots that are filled with Model Alternatives and defines the order in which Model Programs are run (e.g., CE-QUAL-W2, CE-QUAL-W2, ResSim would be a program order with three slots and the model programs would be run in the order of CE-QUAL-W2, followed by CE-QUAL-W2, and ending with ResSim).
Alternative	[Text Descriptor] A name or descriptor describing a physical or operational condition to be represented by one or more Simulations. This is the second-highest level grouping within HEC-WAT. An Alternative is composed of Simulations.
Simulation	A computable data set that includes one Model Alternative selected for each “slot” in a Program Order. The Simulation references Model Alternative(s) and an Analysis Period.
Simulation Group	A collection of independent Simulations for the same Analysis Period.
Model Linking	Definition of the linkage that allows substitution of time dependent input data with observed data or output from models computed within a Program Order.
Analysis Period	A time window.

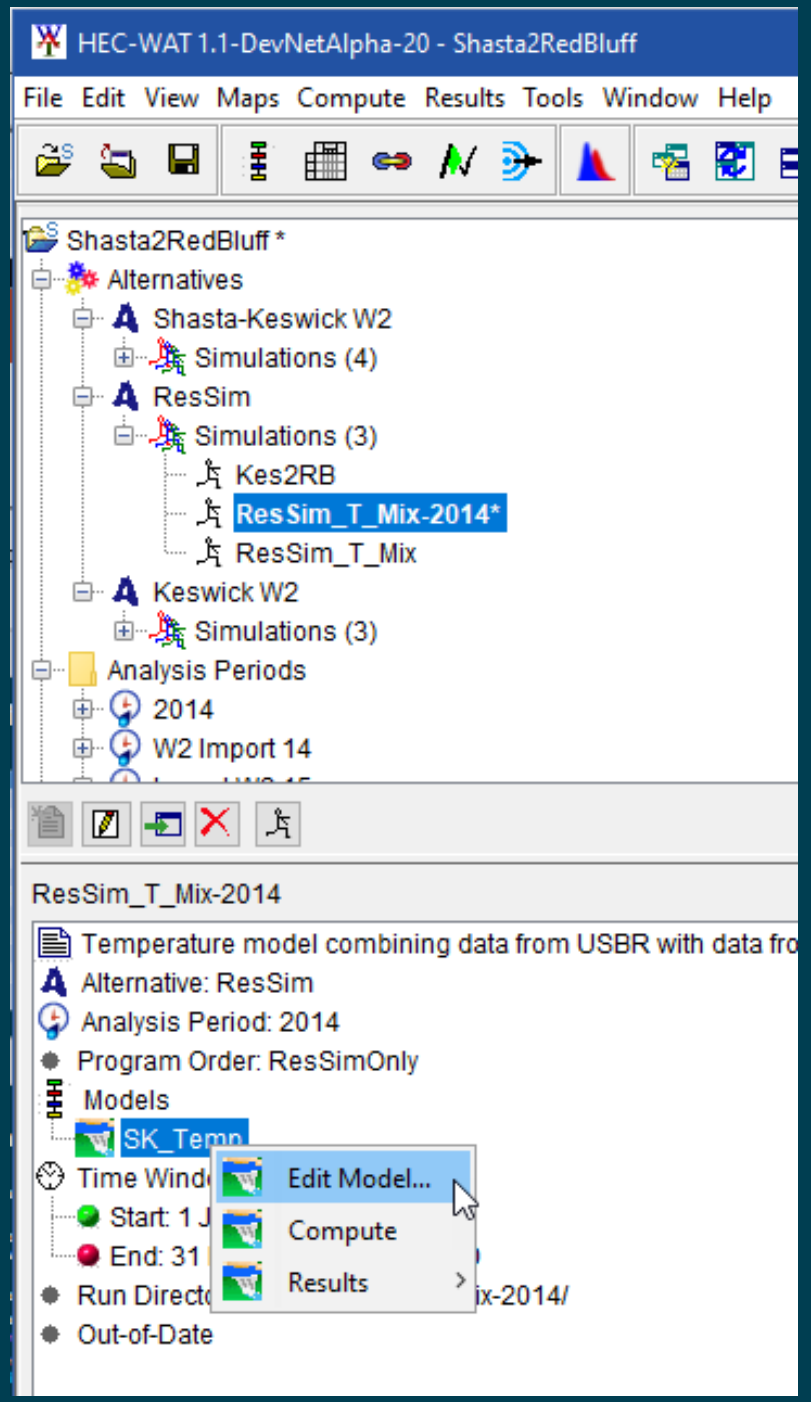
Accessing information from the HEC-WAT Study Tree

- Model Alternative details
- Native Editors (HEC-ResSim only at this time)
- Locating the model directories
- Access to time series data



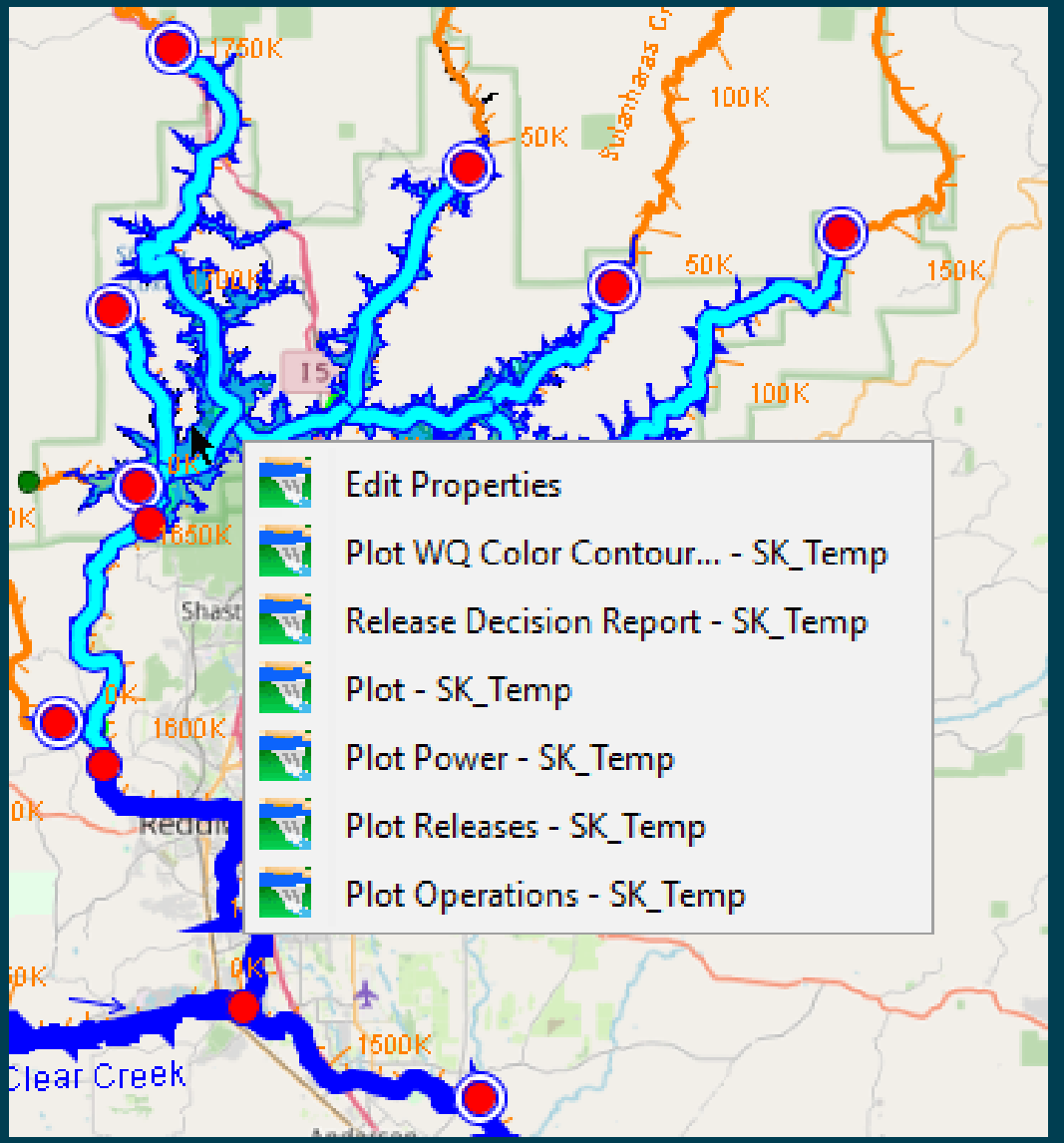
Model editing

- W2 model configuration
  - Most files can be edited in the <study>\cequal-w2 folder
  - Limited editing tools are available through the W2 plug-in
- ResSim model configuration
  - Most native ResSim editors are accessible from HEC-WAT context menus
  - The full ResSim interface can also be opened directly against the ResSim data in the HEC-WAT study



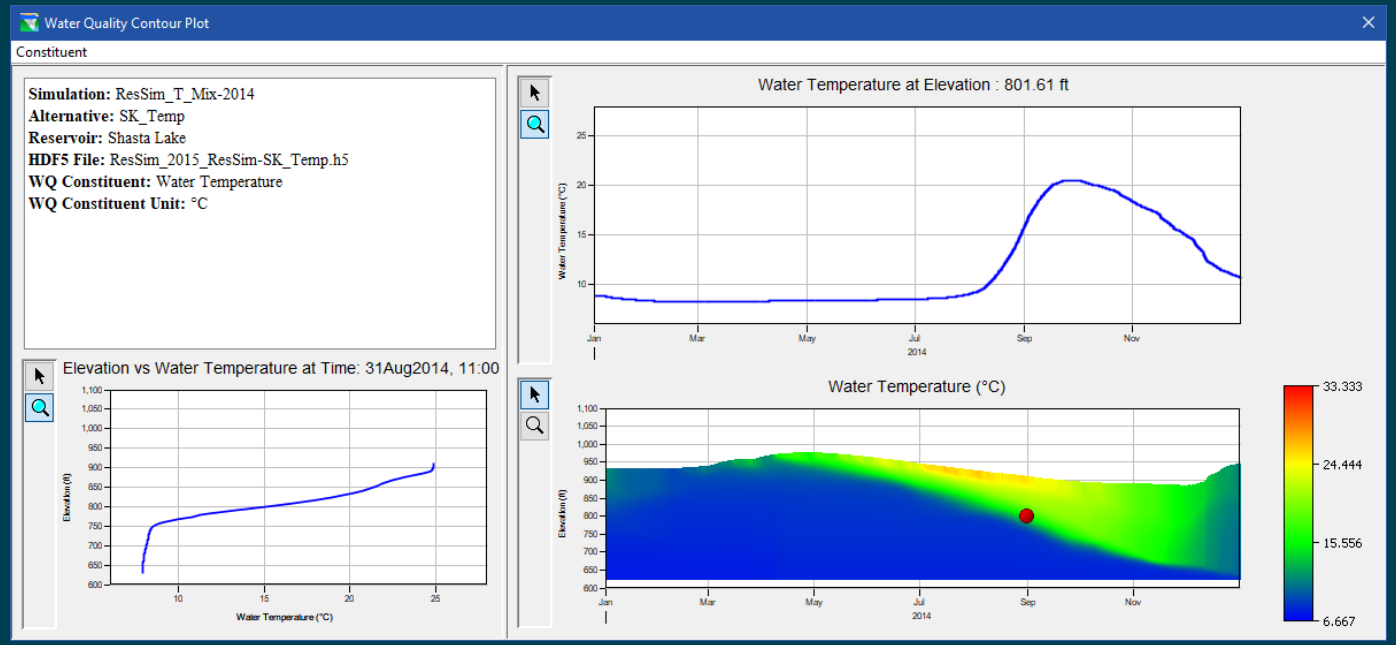
Display editors, plots, and tables from the HEC-WAT Schematic

- Display of Schematic Elements
- Right Click context menus
- Access to Native Editors (HEC-ResSim only at this time)
- Plots
- Tabulations



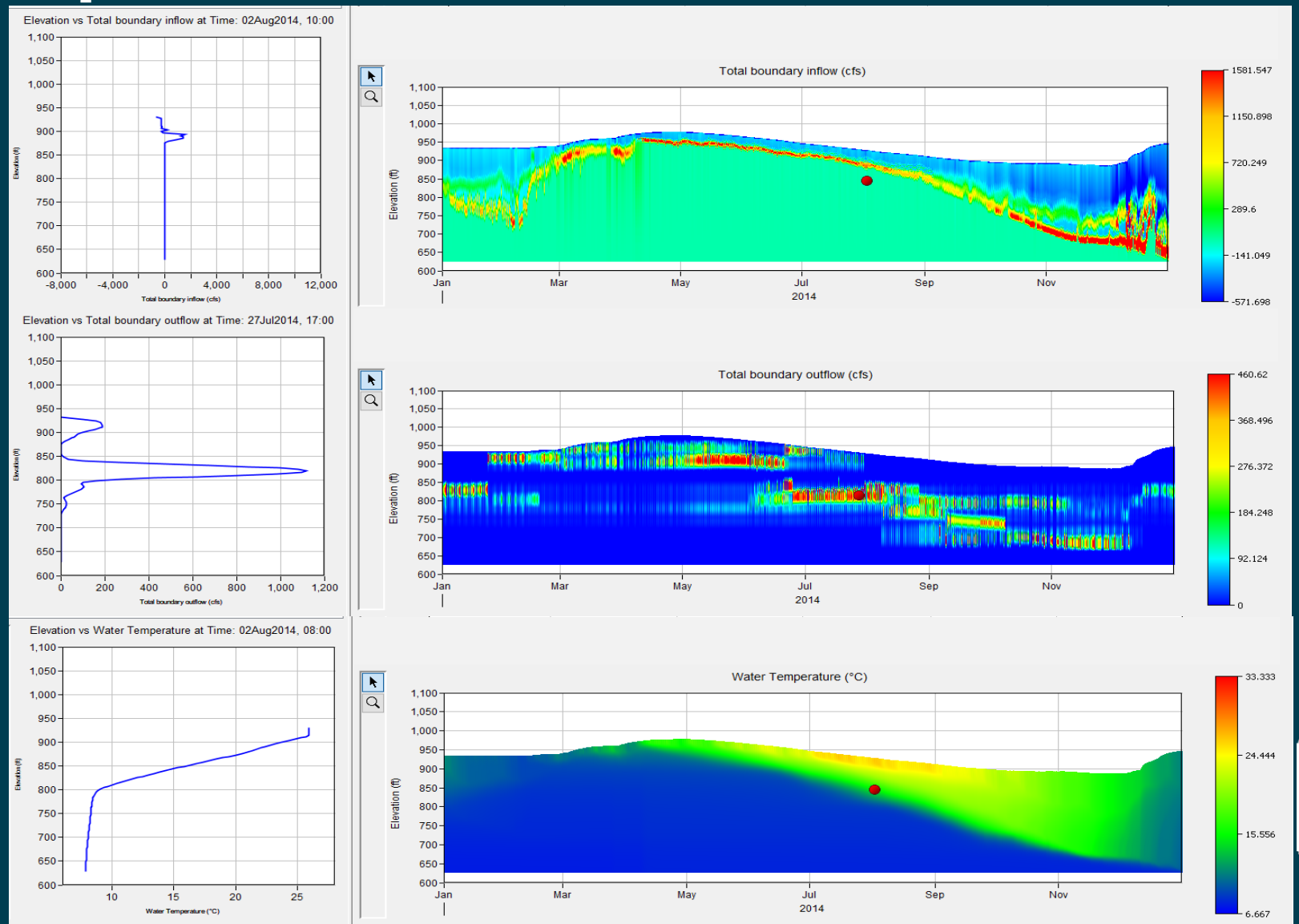
HEC-ResSim Interactive Reservoir Profile Plotting Tool (part 1)

- Open from the schematic
- Components of the Plot
  - Depth vs Time water quality contour plot
  - Profile Plot
  - Water Quality time series at a selected elevation
- Click or drag a marker point on the color contour to select the time and elevation for the profile plots
- Menu controls selection of constituent to display

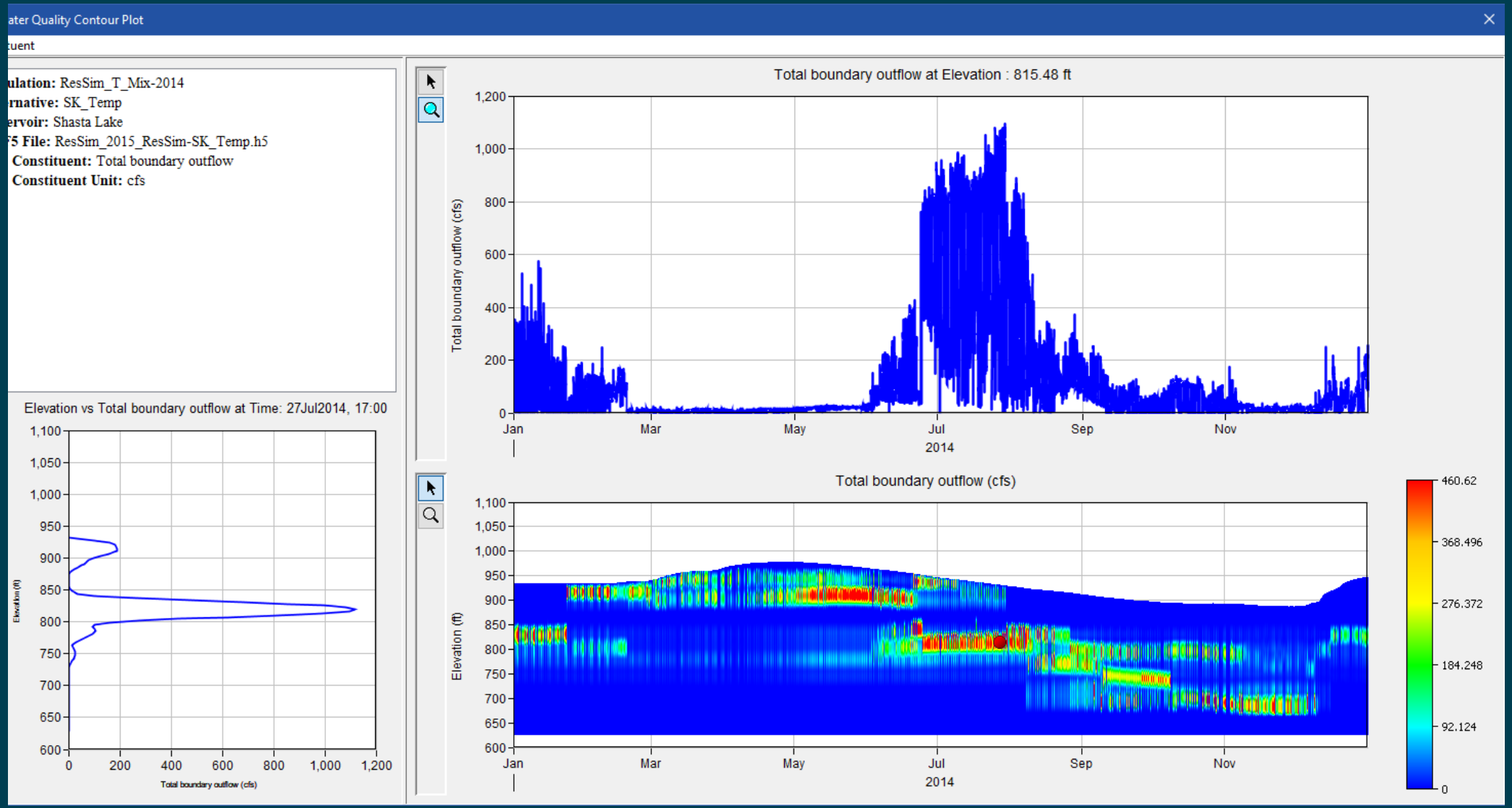


HEC-ResSim Interactive Reservoir Profile Plotting Tool (part 2)

- Example Reservoir Contour Plots
  - Total Boundary Inflow
  - Total Boundary Outflow
  - Water Temperature

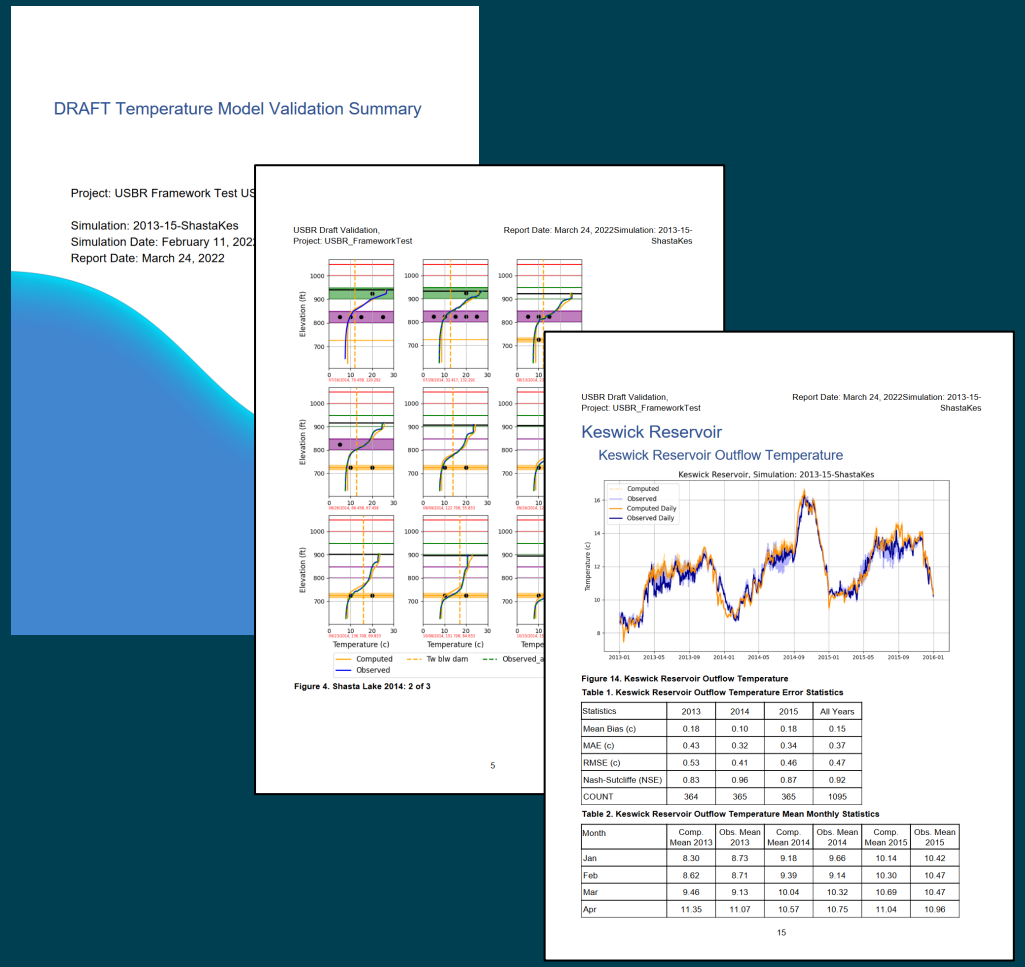


Contour Plot of Reservoir Outflow Distribution



WTMP Automated Reporting

- Overview of design concept
- Configuration of reports
- Plotting options
- Tabulation options
- Graphic options
- Metadata



DRAFT Temperature Model Validation Summary

Project: USBR Framework Test US

Simulation: 2013-15-ShastaKes
Simulation Date: February 11, 202
Report Date: March 24, 2022

USBR Draft Validation,
Project: USBR_FrameworkTest

Report Date: March 24, 2022Simulation: 2013-15-ShastaKes

Figure 4. Shasta Lake 2014: 2 of 3

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USBR Draft Validation,
Project: USBR_FrameworkTest

Report Date: March 24, 2022Simulation: 2013-15-ShastaKes

Keswick Reservoir

Keswick Reservoir Outflow Temperature

Keswick Reservoir, Simulation: 2013-15-ShastaKes

Figure 14. Keswick Reservoir Outflow Temperature

Table 1. Keswick Reservoir Outflow Temperature Error Statistics

Statistics	2013	2014	2015	All Years
Mean Bias (c)	0.18	0.10	0.18	0.15
MAE (c)	0.43	0.32	0.34	0.37
RMSE (c)	0.53	0.41	0.46	0.47
Nash-Sutcliffe (NSE)	0.83	0.96	0.87	0.92
COUNT	364	365	365	1095

Table 2. Keswick Reservoir Outflow Temperature Mean Monthly Statistics

Month	Comp. Mean 2013	Obs. Mean 2013	Comp. Mean 2014	Obs. Mean 2014	Comp. Mean 2015	Obs. Mean 2015
Jan	8.30	8.73	9.18	9.66	10.14	10.42
Feb	8.62	8.71	9.39	9.14	10.30	10.47
Mar	9.46	9.13	10.04	10.32	10.69	10.47
Apr	11.35	11.07	10.57	10.75	11.04	10.96

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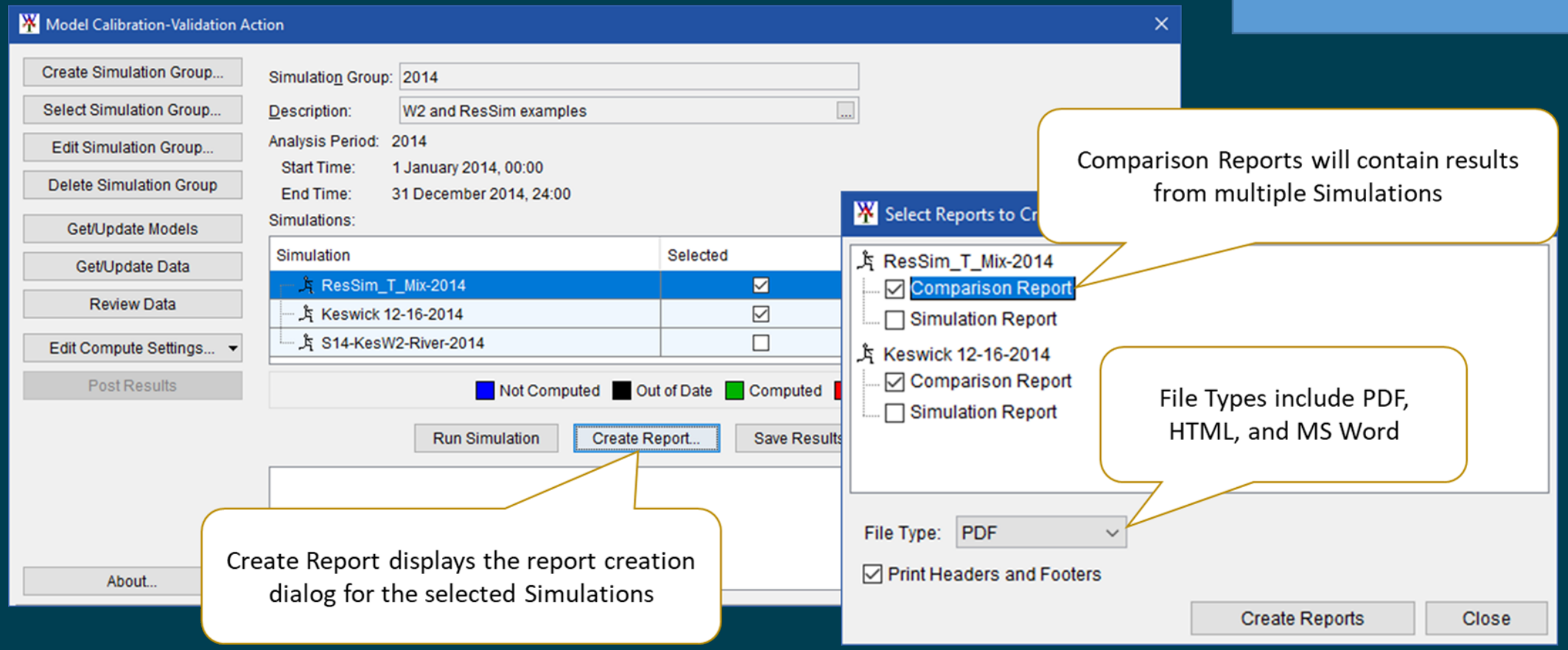
Creating Reports

comparison report (CSV)

Model type, Model Alternative, Chapter Template

```
ResSim, WQ_dsTrib3, Shasta_ResSim.XML
ResSim, WQ_dsTrib3, Keswick_ResSim.XML
ResSim, WQ_dsTrib3, UpperSac_ResSim.XML
```

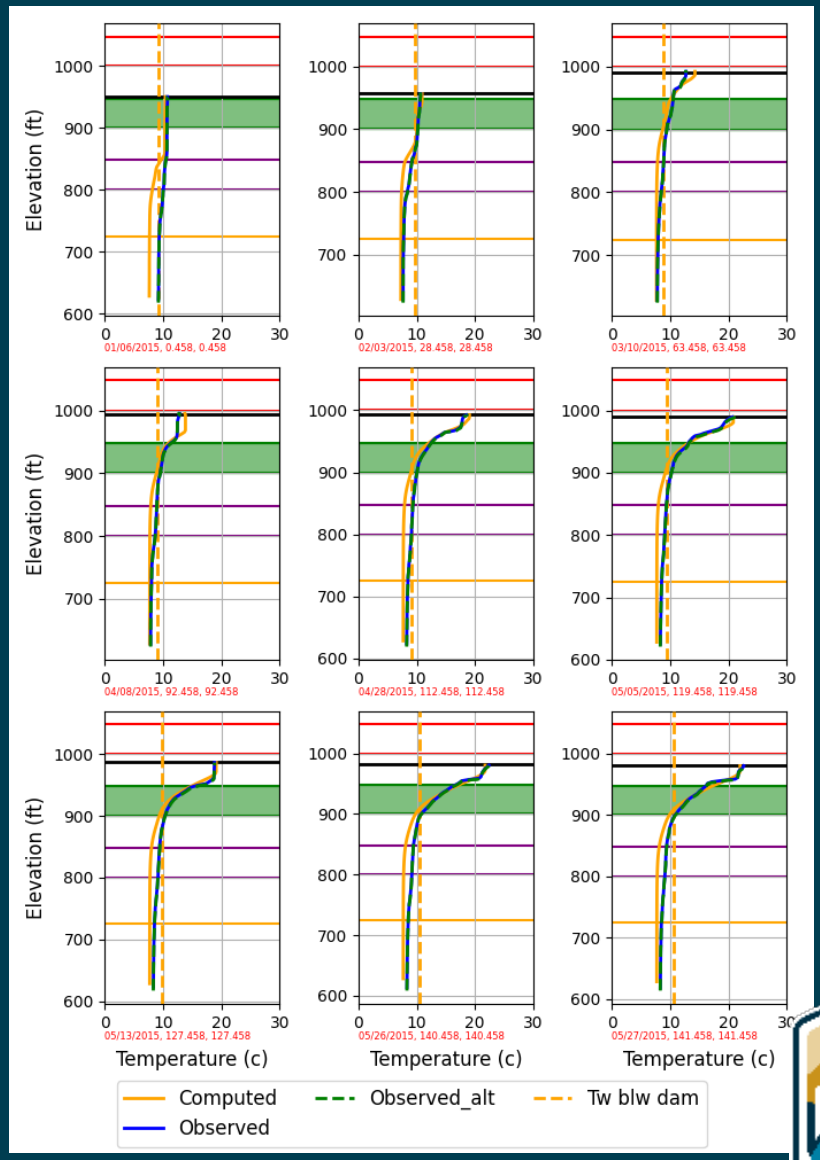


Chapter Configuration Files XML format

- Separated by Sections – report table of contents will show Chapter and Section headings
- Sections contain one or more report Objects
- A set of report Objects have been implemented, this set can be expanded by writing new Python code
- Syntax has been created to reference model and observed data, this may need to be extended to support other sources (new models)
- Current Report Objects
  - Text Blocks with String Substitution
  - Profile Plots
  - Time Series Plots
  - Error Statistics Table
  - Monthly Statistics Table
  - Single Statistics Table
  - Profile Statistics Table
  - Contour Plots
  - Reservoir Contour Plots
  - Operation Plots

Profile Plot Object – subset of documentation

Name	Description	Example
Description	Name of the figure in the Table of Figures and figure name	<Description>Shasta Lake w tribs %%year%%</Description>
Xlabel	Label for X axis of plots at the bottom of a given page of plots	<XLabel>Temperature (C)</XLabel>
Ylabel	Label for Y axis of plots at the left side of a given page of plots	<YLabel>Elevation (ft)</YLabel>
SplitbyYear	Boolean value. If True, separates plots by year. Each year will have its own counter (ex 1 of 3) and be denoted in the table of figures. When a new year starts in the plots, a new plot page will be added, instead of continuing the current plot page in a new panel, even if the max amount of panels per page isn't reached. Default: True	<SplitByYear>False</SplitByYear>
Parameter	Specifies the parameter of data for the plot series. Used to set units flags and grab correct data from model results.	<Parameter>Temperature</Parameter>
ProfilesPerRow	Determines the number of plot panels per row per page Default: 3	<ProfilesPerRow>3</ProfilesPerRow>
RowsPerPage	Determines the number of rows of plots per page Default: 3	<RowsPerPage>3</RowsPerPage>
Gridlines	Boolean to set gridlines on all Profile Plots. Default: True	<Gridlines>True</Gridlines>
UseDepth	Boolean field to determine if profile plots use depths or elevations. Depths start at 0 and increase positively further down the plot. Elevations use the water surface elevation Default: False	<UseDepth>False</UseDepth> <UseDepth>True</UseDepth>
DatesSource	Determines the dates of the Profile Plots. Can either be set to a defined lines <Flag> value (See Line Flags) or a list of calendar dates or Julian dates. If the defined line flag is used, each available date in the dataset (currently only works for Observed data). If a list of dates is to be used, datessource must include a set of subitems of <date>. If left blank, a regular interval of dates is selected using the start and end times of the model run. Default: Observed	<DatesSource>Observed</DatesSource>



Example Time Series Plot Objects

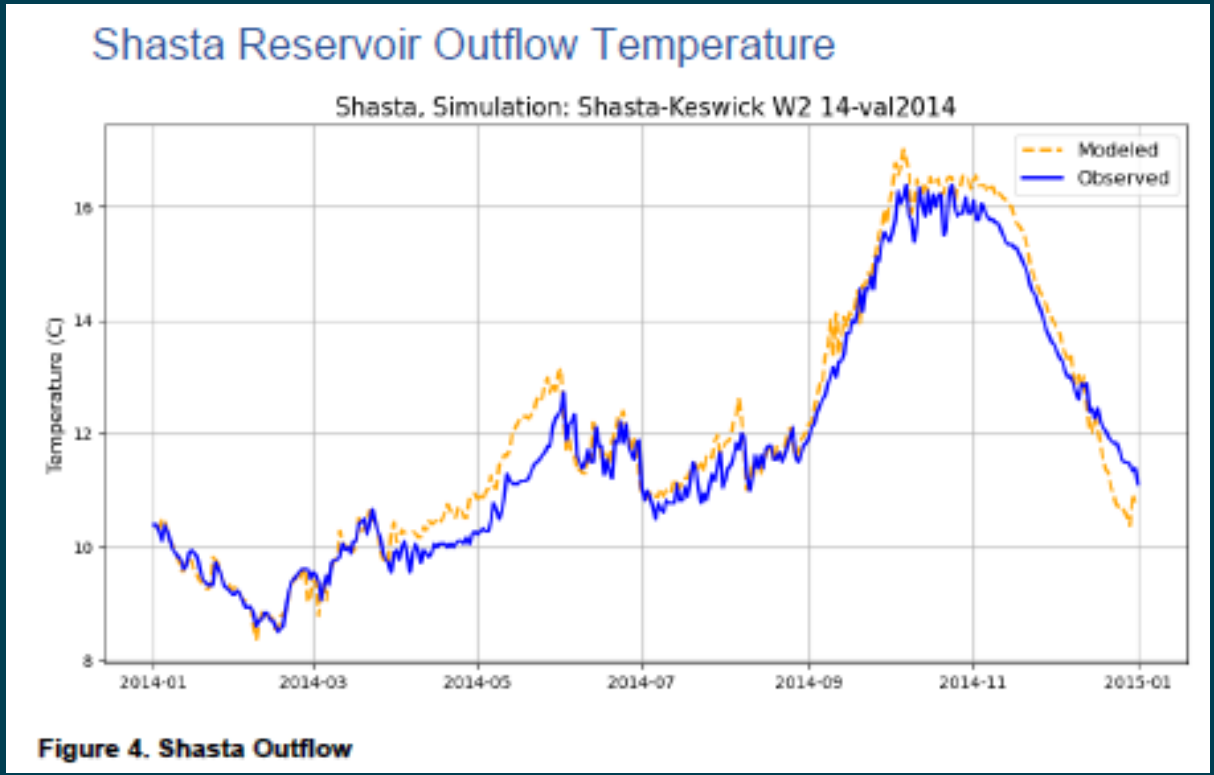
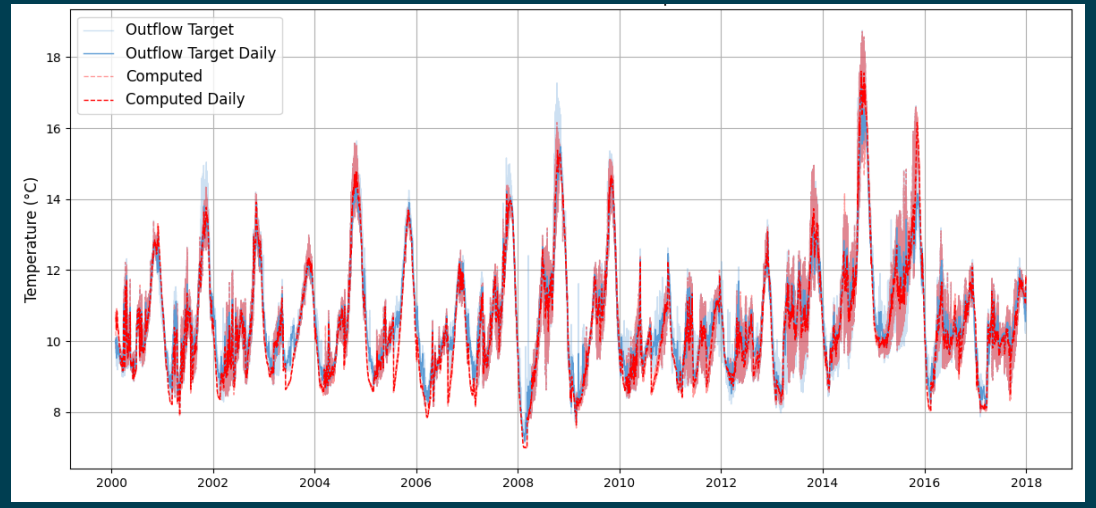
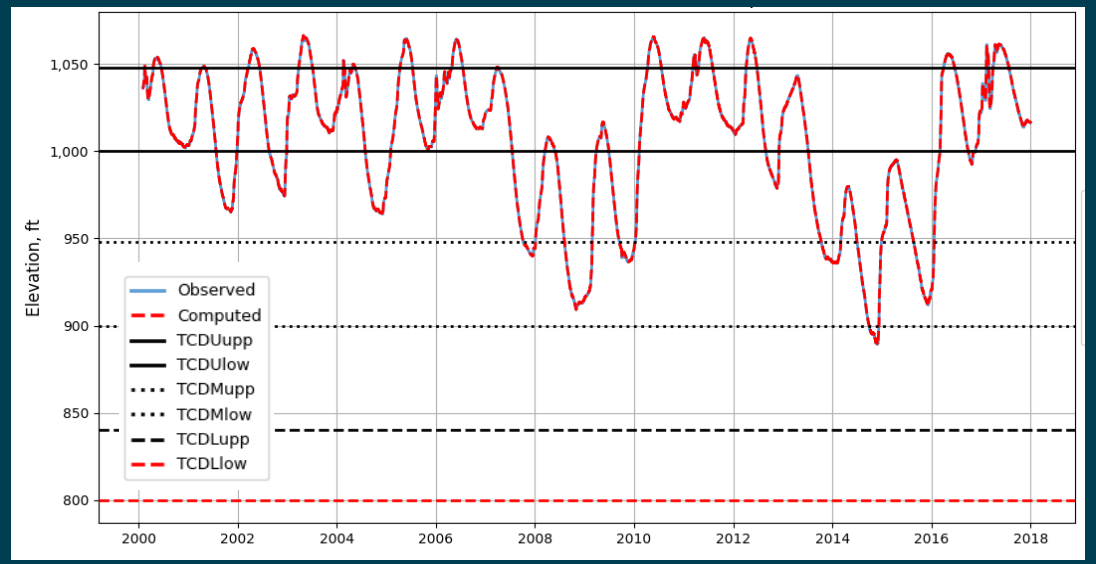


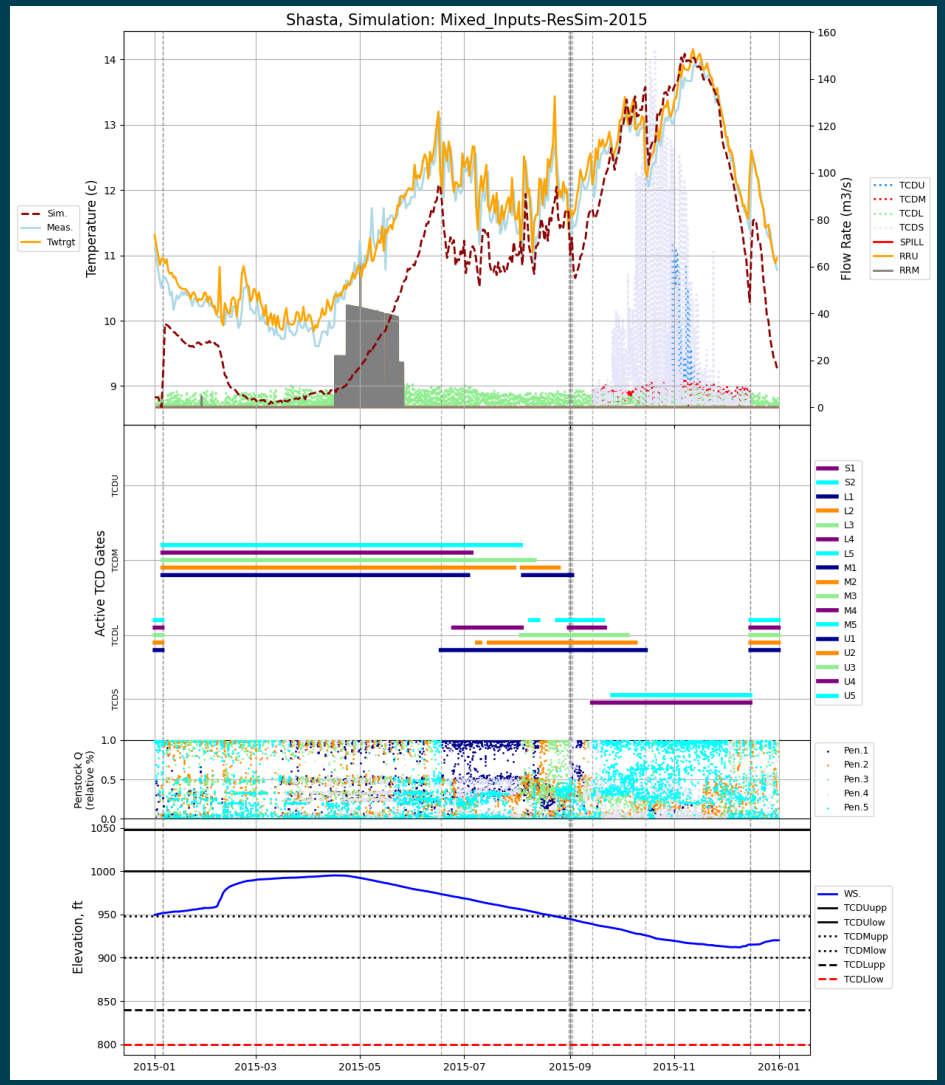
Figure 4. Shasta Outflow

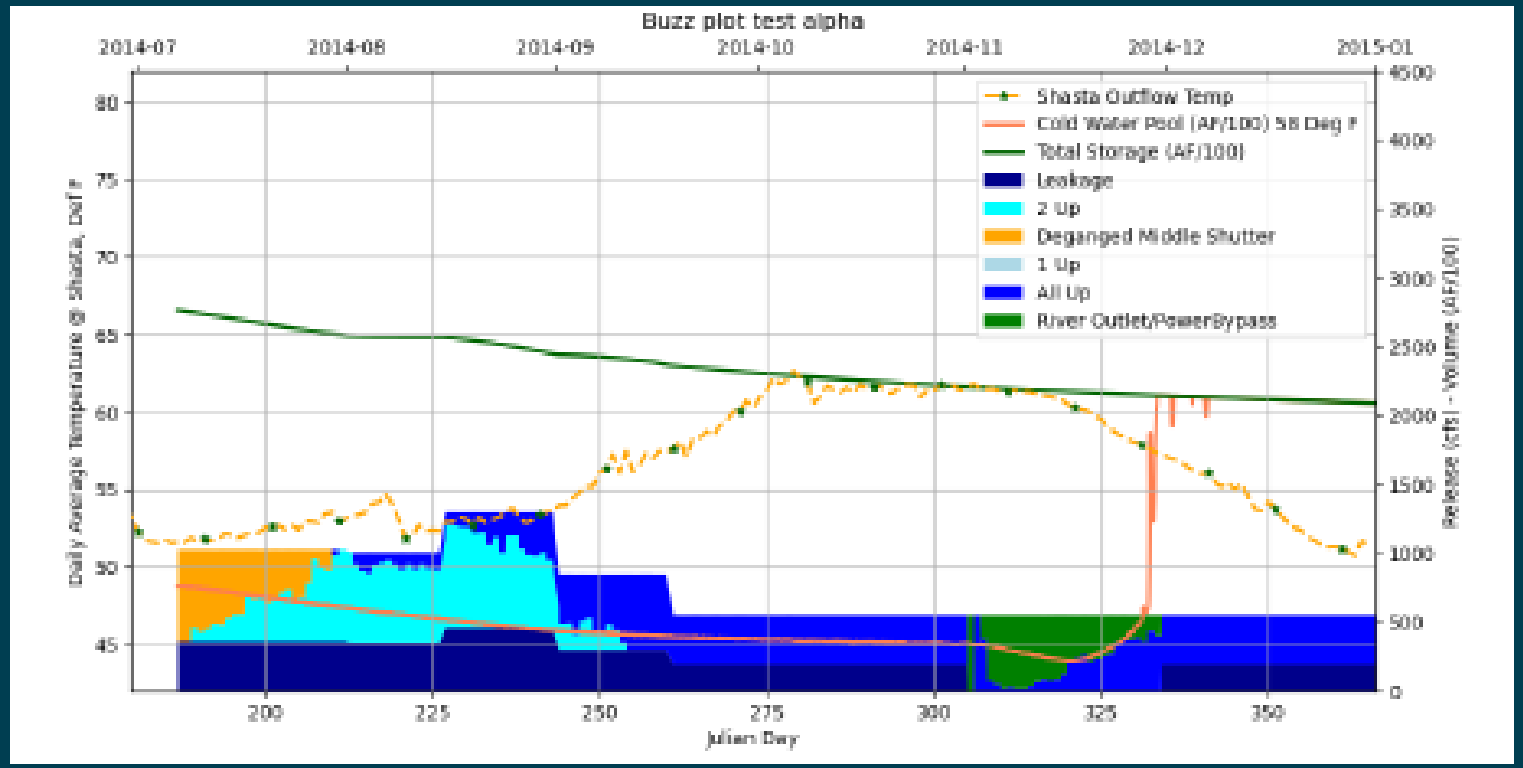




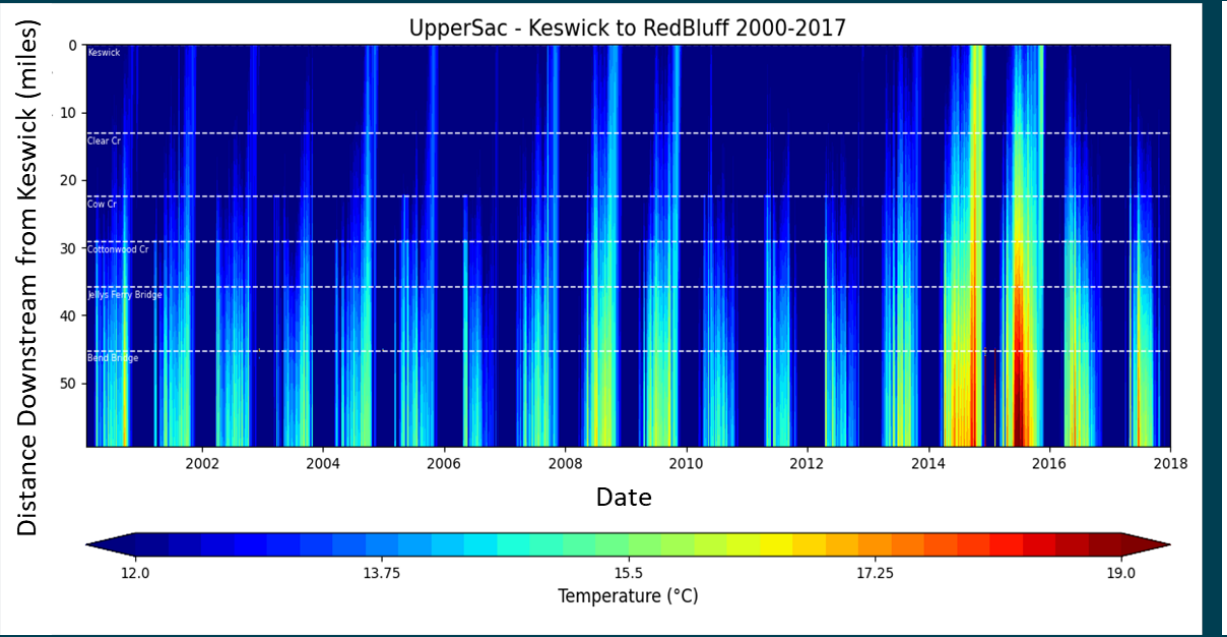
Example Complex Plot Objects

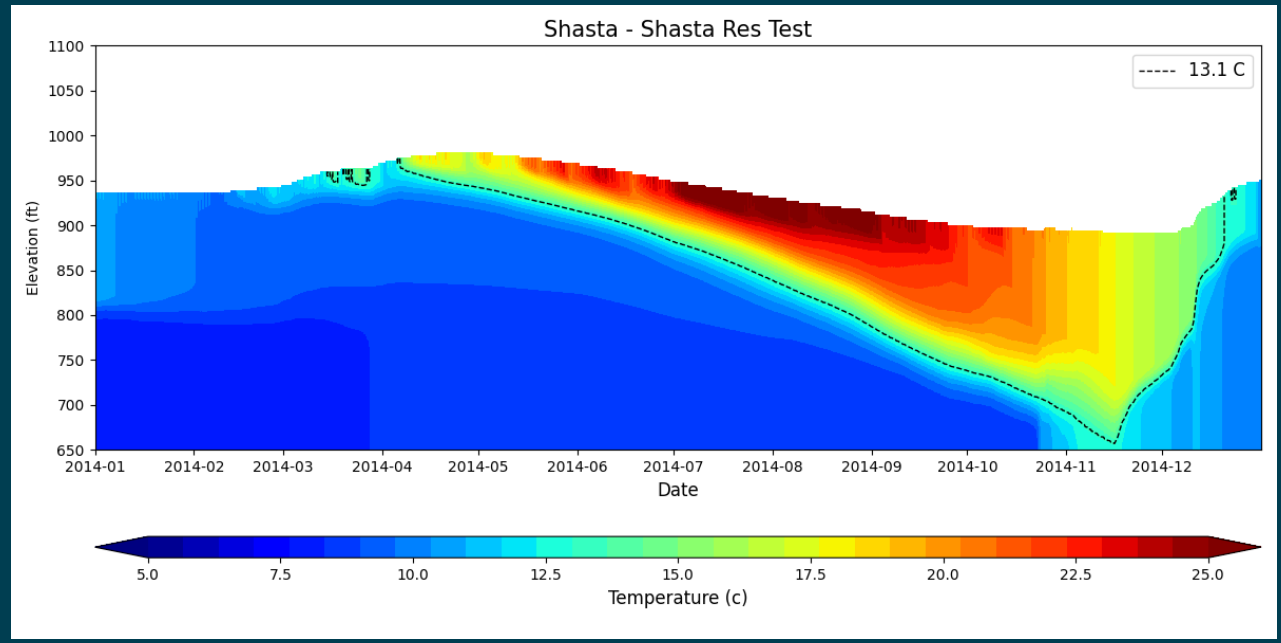
- Shasta Operations Plot





Example Contour Plot Objects





Example Table Objects

- Shasta Outflow Error Statistics Table

Statistics	2014	All Years
Mean Bias (deg C)	0.23	0.23
MEA (deg C)	0.37	0.37
RMSE (deg C)	0.47	0.47
Nash-Sutcliffe (NSE)	0.95	0.95
COUNT	365	365

- Shasta Outflow Temperature NSE, invalid under .65 Statistics Table

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	0.97	0.27	0.13	0.57	0.86	-	-	0.98	0.98	0.97	0.89	0.80
2014	0.92	0.49	0.56	0.72	0.91	0.96	0.98	0.97	0.96	0.92	0.53	0.28
2015	-0.02	-0.30	0.48	0.83	0.95	0.96	0.98	0.97	0.96	0.86	0.33	0.54
All	0.86	0.22	0.50	0.79	0.93	0.96	0.98	0.97	0.97	0.91	0.67	0.66

- Shasta Outflow Mean Monthly Statistics Table

Month	Comp. Mean 2014	Obs. Mean 2014
Jan	9.71	9.77
Feb	9.00	9.03
Mar	9.92	9.91
Apr	10.46	9.99
May	11.98	11.13

- Shasta Lake with Tributaries in 2013 Profile Statistics Table

Statistics	08Jan2013	05Feb2013	12Mar2013	03Apr2013	08May2013	20May2013
Mean Bias (deg C)	0.56	0.59	0.76	0.80	0.89	0.82
MEA (deg C)	0.76	1.08	0.97	0.87	1.01	0.94
RMSE (deg C)	0.92	1.21	1.10	1.04	1.16	1.14
Nash-Sutcliffe (NSE)	0.22	-0.26	0.29	0.67	0.85	0.92

Other Needs?

- WTMP platform can accommodate additional needs after the initial deployment.
  - Output and visualization, when the purpose and format are defined
  - Communication with other channels, when security and communication protocols are established
- We propose an WTMP Output Subgroup in May 2023 for additional discussion.

Questions for WTMP Output and Visualization

- Thoughts about concepts and options presented today?
- Thoughts and suggestions for the WTMP output subgroup in May 2023?

Photo credit: John Hannon, Reclamation

Wrap Up and Next Steps

Randi Field, CVO

Yung-Hsin Sun, PhD, PE, Sunzi Consulting LLC

WTMP Next Steps

- Major tasks:
  - Distribute model development TMs for review (all three systems)
  - Continued Stanislaus River model development
  - Continued WTMP implementation and testing
  - Uncertainty characterization and communication
- WTMP output subgroup

WTMP Next Steps (continued)

- Upcoming MTC Meetings and other events:
  - April 17-19, 2023; CWEMF Annual Meeting (WTMP Session on 4/17 at 10:30)
  - July 6, 2023; 1:00 p.m. – 4:00 p.m. MTC 09.
  - September 12-14 - Final scientific peer review hosted by DSC
  - October 5, 2023; 1:00 p.m. – 4:00 p.m. MTC 10.
  - Spring 2024 – WTMP rollout

Upcoming MTC and Topics

- MTC 09 Meeting: July 6, 2023; 1:00 p.m. – 4:00 p.m.
- Upcoming topics:
  - Model uncertainty
  - WTMP output and visualization
  - Other topics, as needed
- You have the registration link already in the Agenda – do it today.

Information Sharing and Contacts

- Key WTMP team members
  - Randi Field, RField@usbr.gov
  - Mike Deas, Mike.Deas@watercourseinc.com
  - John DeGeorge, jfdegeorge@rmanet.com
  - Craig Addley, Craig.Addley@stantec.com
  - Jeff Schuyler, Eyasco, Inc. jeff@eyasco.com
  - Yung-Hsin Sun, sun.yunghsin@sunziconsulting.com
- Project Information:
  - Contract: mppublicaffairs@usbr.gov
  - Website link - https://www.usbr.gov/mp/bdo/cvp-wtmp.html


NEXT MTC MEETING: July 6, 2023;
1:00 p.m. – 4:00 p.m.
BUREAU OF
RECLAMATION