BUREAU OF RECLAMATION

CVP Water Temperature Modeling Platform

Modeling Technical Committee Meeting 1

July 1, 2021; 1 – 4 pm

Welcome!!

We are looking forward to a productive meeting, please consider –

- Remote meeting. Remote collaboration meetings can be challenging and frustrating, especially with larger groups – please be patient and flexible. If you are having technical difficulties, please chat with Sarah Hamilton.
- Chat Panel will be used for participants to provide comments and queue up questions. Use Raise Hand functions in Q&A session.
- Agenda includes presentation and Q&A sessions

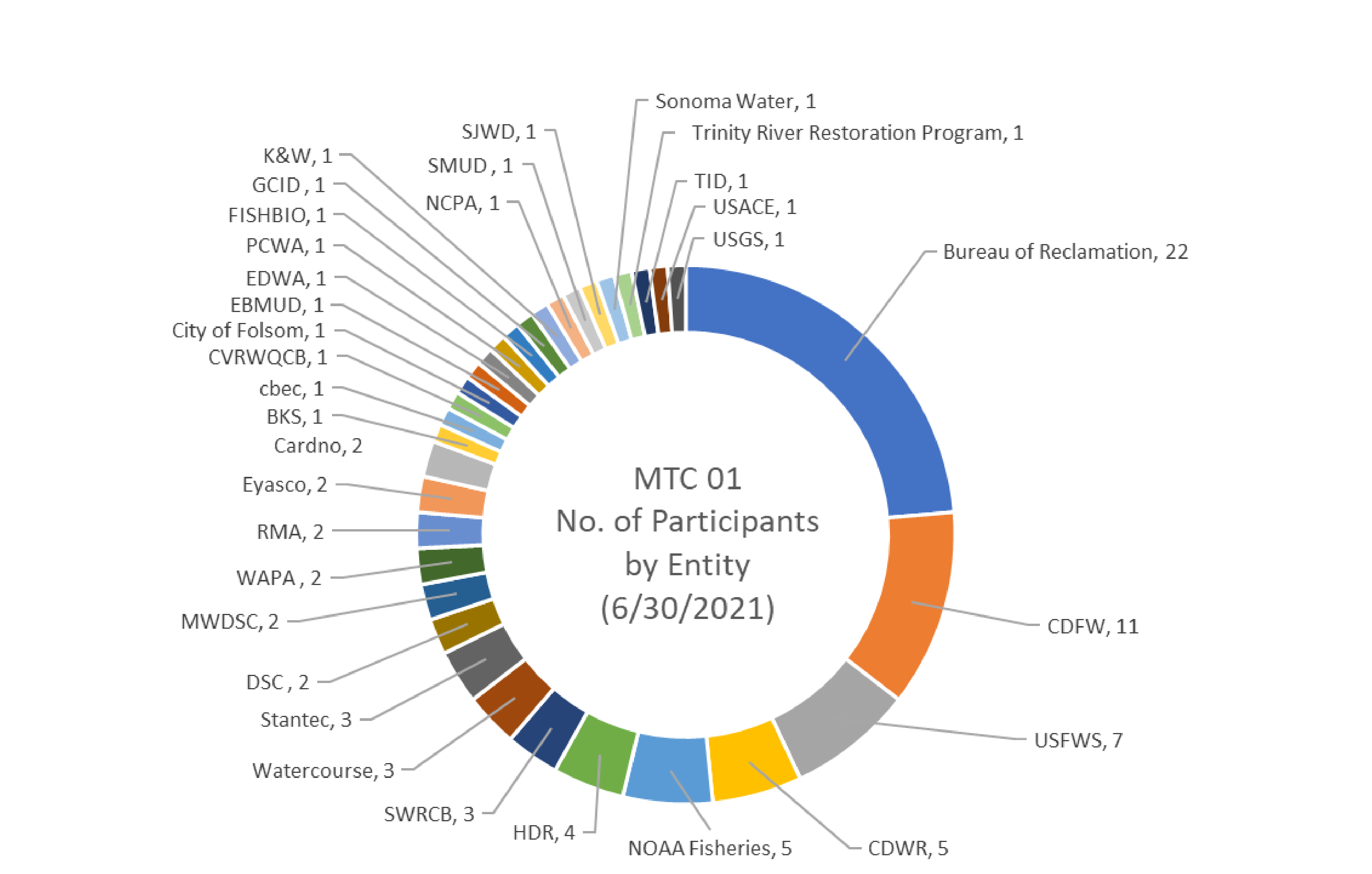
Workshop Agenda

Objective:

Kickoff the MTC process to collaborate the WTMP development, covering the Sacramento, American, and Stanislaus river systems.

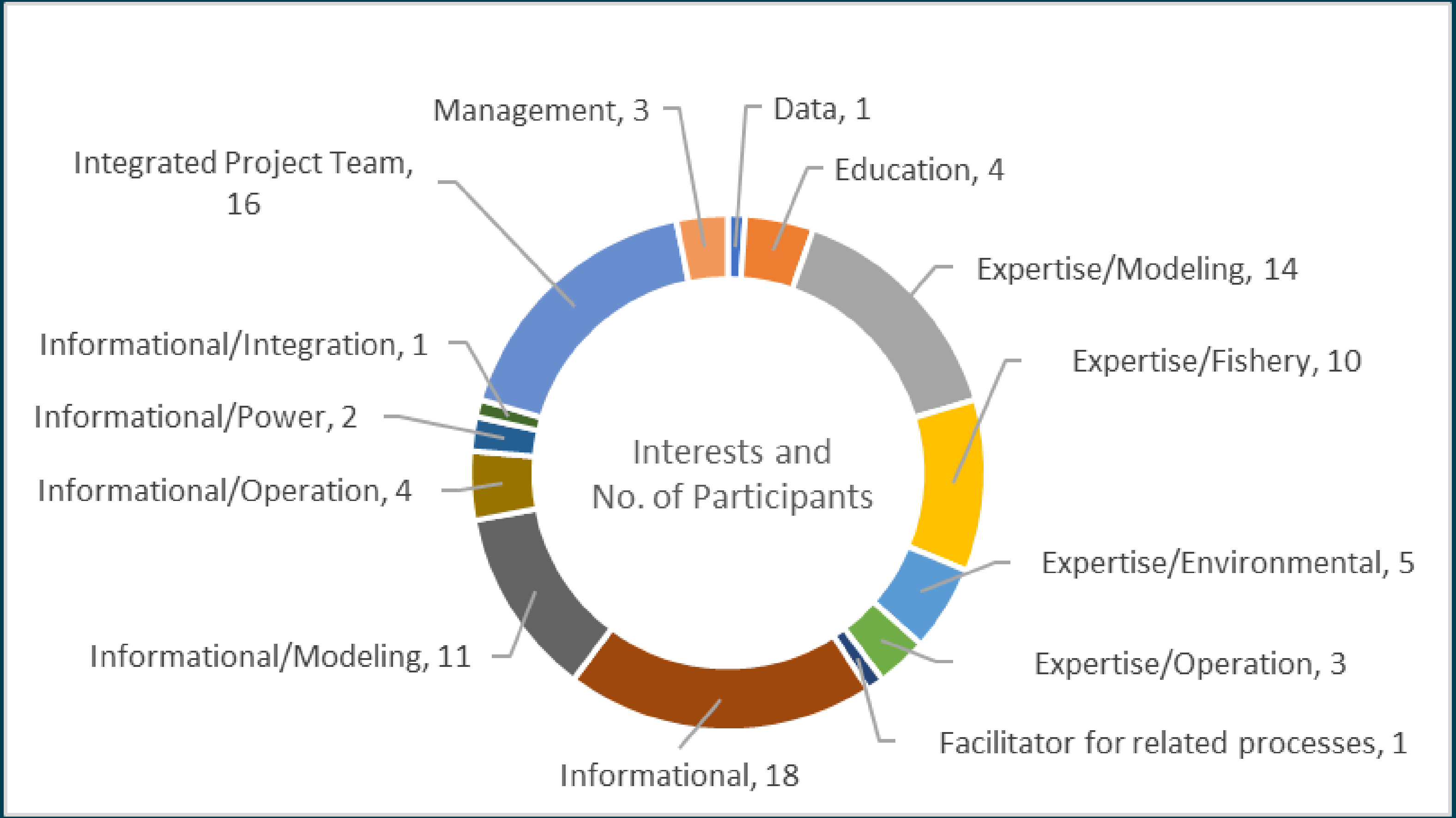
1:00	**Meeting Logistics and Welcoming Remarks** Yung-Hsin Sun, Stantec David Mooney/Kristin White/Derya Sumer, Reclamation
1:15	**WTMP Overview and Orientation for the MTC (including 5 min Q&As)** Randi Field, Reclamation Mike Deas, Watercourse/Yung-Hsin Sun, Stantec
2:00	**Break**
2:05	**Water Temperature Model and Framework Review and Selection, Part 1: Models and Framework** Randi Field/Mike Deas/John DeGeorge
3:10	**Break**
3:15	**Water Temperature Model and Framework Review and Selection, Part 2: Initial Application** Randi Field/Mike Deas/John DeGeorge
3:45	**Wrap Up and Next Steps** Yung-Hsin Sun
4:00	**Adjourn**

Registration



Registration Poll

- What is your primary interest in joining the MTC meetings?



Opening Remarks

David Mooney
Office Manager
Bay Delta Office
Region 10 – California-Great Basin

Executive Sponsor

Kristin White
Operations Manager
Central Valley Operations Office
Region 10 – California-Great Basin

Alternate

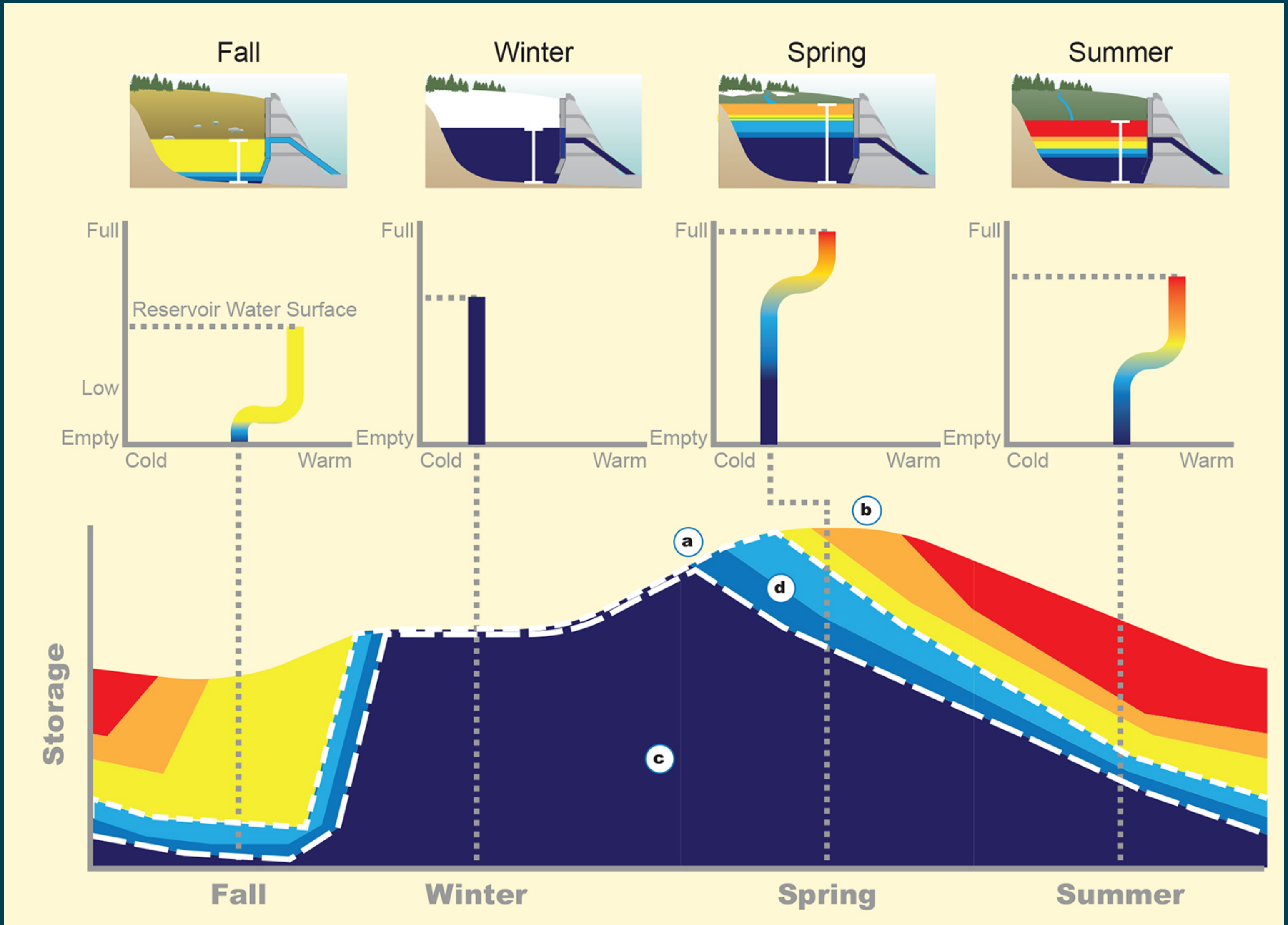
Derya Sumner
Water Supply and Operations
Analysis Branch Chief
Division of Planning
Region 10 – California-Great Basin

WTMP Overview

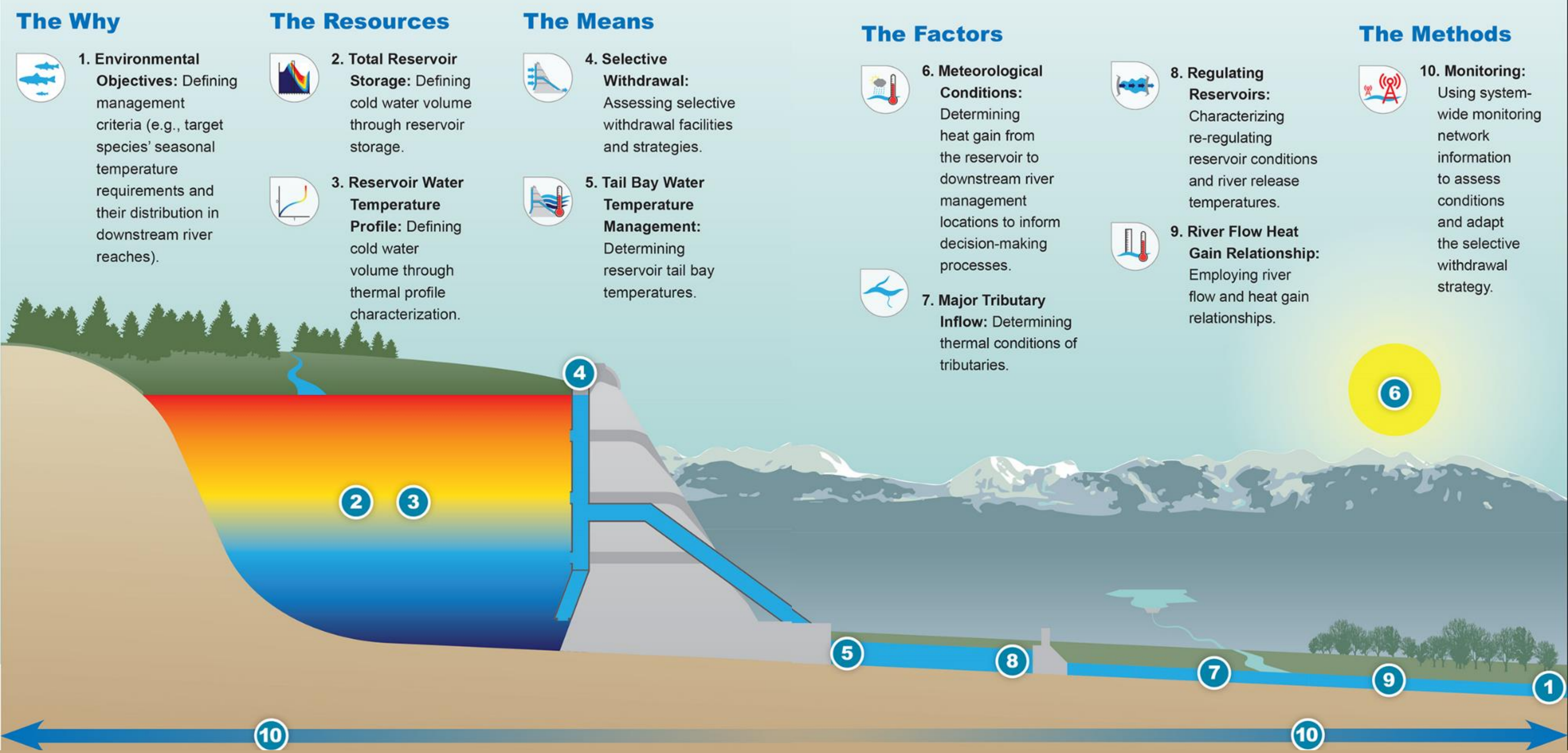
- Project Needs and Anticipated Outcome

Randi Field, Civil (Hydrologic) Engineer, CVO

Water Temperature Management Story



Elements of Temperature Management



Reference: Reclamation, 2017. Water Temperature Management in Reservoir-River Systems through Selective Withdrawal, Reference Technical Memorandum for Central Valley Project Operation, California. September.

Modernize Business Practice to Support the CVP Operations

- Expect high quality
- Build trust and confidence
- Optimize flexibility
- Design for compatibilities/efficiencies
- Plan for long-term horizon
- Enhance within agency expertise

Need High Quality

- Objective: Set High Standards
- Requirements:
  - Documentation: Robust - Transparent
  - Assumptions: Explicit
  - Demonstrate Performance: Continuous Testing – How well does the model perform?

Need Confidence and Trust - Tools add value and are useful

- Objective: Open process
- Requirements:
  - Access: Transparent – Share information
  - Clarify Limitations: Informed consumer/user
  - New Data: Continual Improvements
  - Collaborative Forum: Modeling Technical Committee
  - Demonstrate Performance: Testing
  - Peer Review: Independent evaluation

Need **Flexibility** to respond

- Objective: Design for change
- Requirements:
  - Accessible Model: Modify code and adapt to change
  - Modeling Modes: Address both real-time, seasonal and long-term planning
  - Risk and Uncertainty Assessment: New capabilities

Need Compatibility and Efficiency for practical applications

- Objective: Leverage technology
- Requirements:
  - Framework: Robust structural organization/compatibility
  - Model Setup and Organization: Consistency
  - Data Management: Essential
  - Streamline Procedures: Ease of use and error reduction
  - Apply time saving techniques: Automate tasks when appropriate
  - Modeling Modes: Address both real-time, seasonal and long-term planning

Need to Build Tools for Longer-term Use with Stable Support

- Objective: Adapt to current funding and contracting constraints
- Requirements:
  - Design for Change: Anticipate future needs
  - Build Institutional Knowledge: Empower staff

Need to develop Expertise

- Objective: Broaden knowledge and technical capability
- Requirements:
  - Communication: Share information
  - Investment: Build knowledge base
  - Organization capacity building: Empower staff

Vision for WTMP Project

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 – foster transparency
- Consistency cross uses: Real-Time, Seasonal, and Long-term Planning
- Accommodate technological advancements

Modeling Technical Committee (MTC)

- Positive Experience for Shasta-Keswick W2 model development experience (2016 – 2020)
- Community-based collaborative model development
- Request your support and collaboration, leveraging your technical expertise and passion:
  - Consistent engagement
  - Timely project product review as available
  - Constructive input and comments
  - (if all works well…) Future user group on water temperature modeling

More information later

WTMP Overview
- Workplan and Schedule

Mike Deas, Watercourse Engineering

Presentation Overview

- Project Team
- Technical Charge
- Project Area
- Tasks
  - Phase I
  - Phase II
- Project Schedule
- Current Status and Next Steps

Project Team

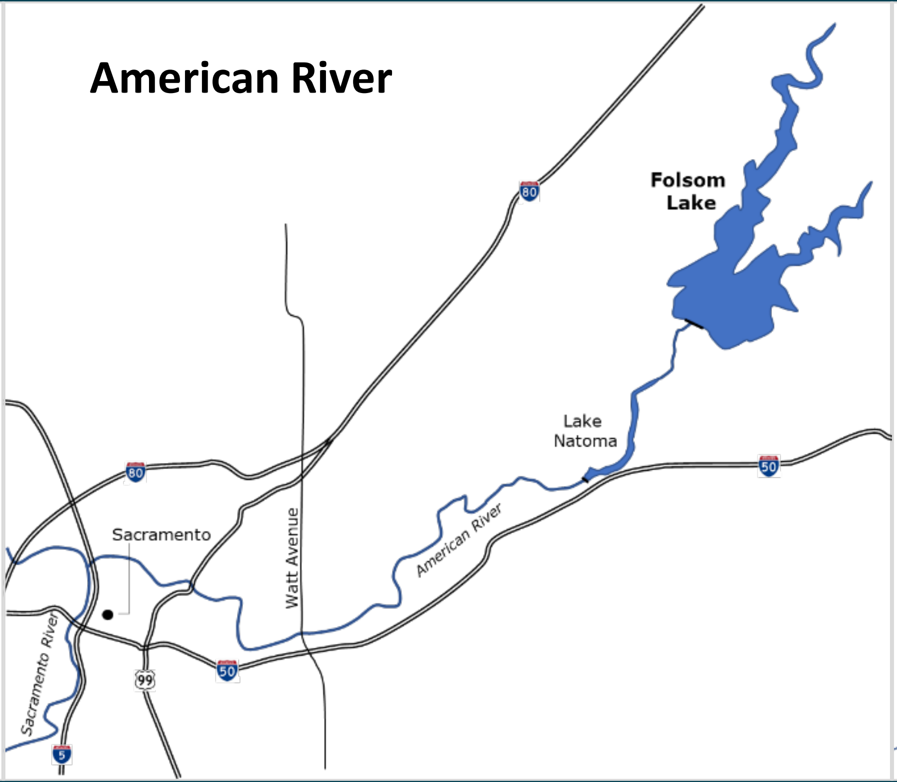
- Watercourse Engineering, Inc.
- Resource Management Associates, Inc (RMA)
- Cardno
- Eyasco, Inc.
- Stantec
- Tom Camara Graphics

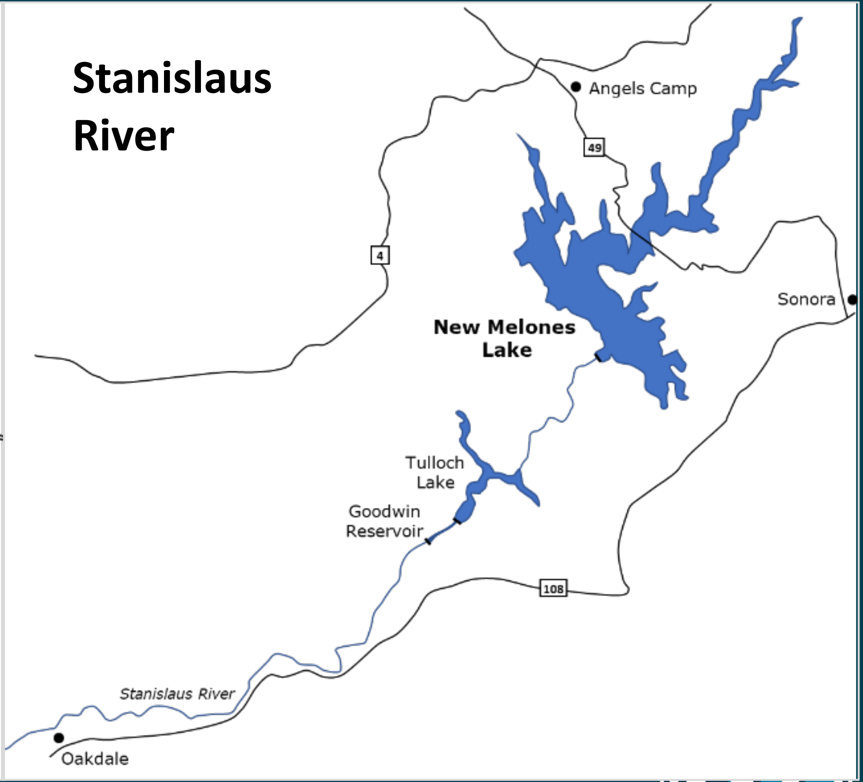
Technical Charge

- Develop tools to support Reclamation's water temperature management activities
  - Data management
  - Model development
  - Model management (framework)
  - Model reporting
  - Documentation
  - Other
- Representative, Useful, Relevant, Longevity

Project Area

- Sacramento/Trinity, American, Stanislaus Rivers





Tasks

- Phase I
  - Project Organization
  - Model Development
- Phase II
  - Model Implementation
  - Peer Review

- Inter-related activities

Project Tasks

Workplan (Phase I)	Stakeholder Outreach	Institutional Knowledge	Data Management
Model Framework	Model Selection	Data Development	Source of Uncertainty
Model Calibration/ Validation	Model Development	Workplan (Phase II)	Model Implementation
Model Documentation (Phase I)	Output Communication	Phase II Documentation	Peer Review Support

Phase I

Phase II

Peer Review

Phase I

Task	Objective
Task 1. Project Workplan	Develop workplan and schedule for the overall modeling project with emphasis on Phase I – Task 1 through Task 10
Task 2. Stakeholder Involvement and Outreach	Outreach activities
Task 3. Develop Reclamation's Institutional Knowledge	Technology transfer
Task 4. Data Management	Develop data management plan for Phases I and II of project
Task 5. Model Framework Design and Refinement.	Develop a system-wide model framework for use throughout project area
Task 6. Model Selection/Design	Select models for each of the elements of the framework
Task 7. Data Development	Identify necessary input data to models and obtain necessary data
Task 8. Model Development	Develop and revised or refined models
Task 9. Calibration, Validation, and Sensitivity	Calibrate and validate models
Task 10. Documentation Phase I	Documentation of Phase I model development

Phase II

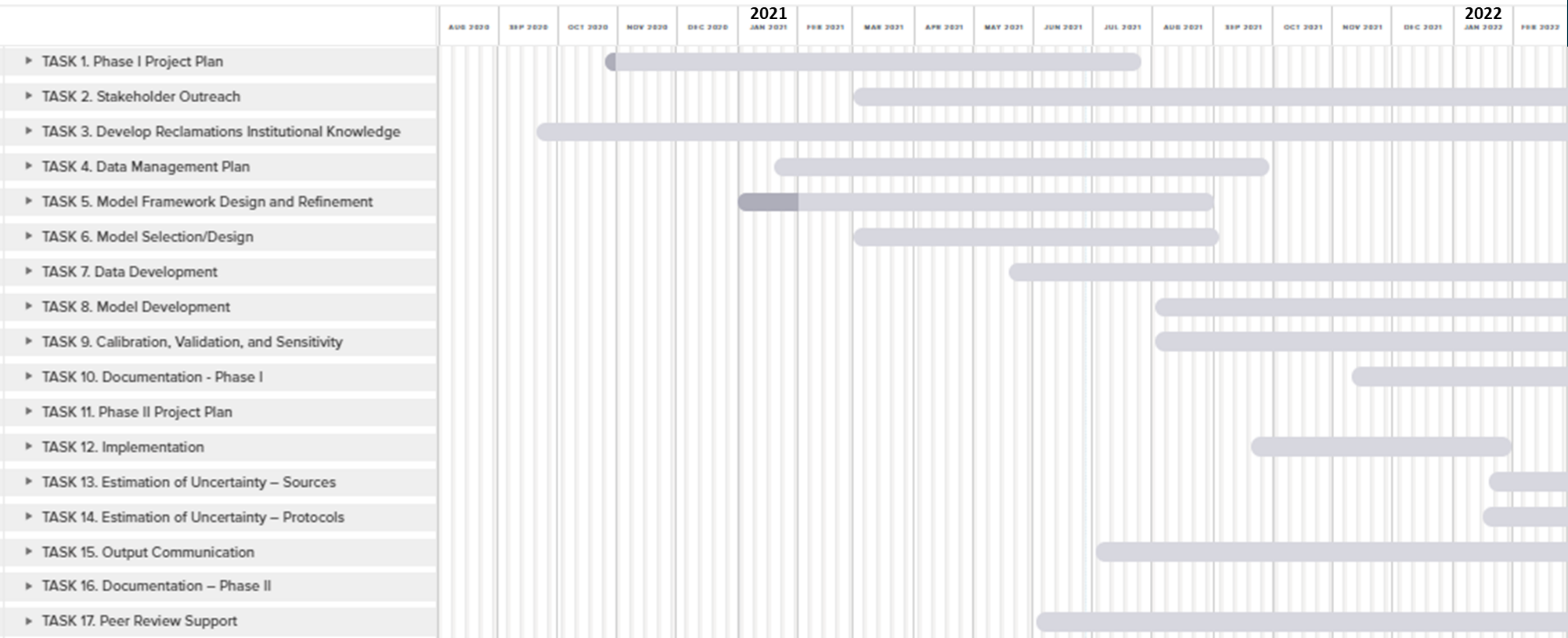
Task	Objective
Task 11: Phase II Workplan	Develop a detailed workplan and schedule for Phase II – Task 11 through Task 17
Task 12: Implementation	Determine schedule for downstream/in-river simulation, real time/seasonal, and planning applications
Task 13: Estimation of Uncertainty – Sources	Develop and communicate <u>sources</u> of uncertainty in estimates of water temperature downstream of regulating reservoirs.
Task 14: Estimation of Uncertainty – Protocols	Develop and communicate <u>protocols</u> for estimating uncertainty bounds in estimates of water temperature downstream of regulating reservoirs. Task 14 will be combined with Task 13
Task 15. Output Communication	Develop output communication/visualization tools and data presentation approaches
Task 16: Documentation – Phase II	Documentation of Phase II activities
Task 17. Peer Review	Provide support for peer review of model components and overall framework.

Project Schedule

• Model and Framework Selection	Summer 2021
• Model Development	
• Sacramento	Spring 2022
• American	Fall 2022
• Stanislaus	Winter 2022/23
• Phase II Tasks (Initial)	
• Workplan	Fall 2021
• Uncertainty sources and protocols	summer 2022 ->
• Output/communications	Fall 2023
• Documentation (task and system specific)	

Project Schedule (Example, Subject to Change)

9/2023



Current Activities

- Task 1: Workplan (Draft)
- Task 2: Community Participation Plan (Draft)
- Task 3: Technology Transfer (ongoing)
- Task 4: Data Management Plan (Draft)
- Task 5: Model Framework (Draft)
- Task 6: Model Selection (Draft)
- Task 17: Peer Review

Next Steps

- Task 7: Data Development
  - All Basins
- Task 8: Model Development
  - Sacramento/Trinity
  - American
  - Stanislaus

- 3-month and 12-month “look ahead”

WTMP Overview
- MTC Orientation and Expectation

Yung-Hsin Sun, PhD, PE, Stantec Consulting Services Inc.

Modeling Technical Committee (MTC)

- Despite of its name, it is more an open forum for collaborative model development.
- Technical focused discussions centering around water temperature modeling tools, data and applications.
- Scheduled quarterly meetings – First Thursday (1 – 4 pm) of the first month of each calendar quarter till the end of 2023
- In-person meetings are possible in the future (TBD); online participation is always provided.

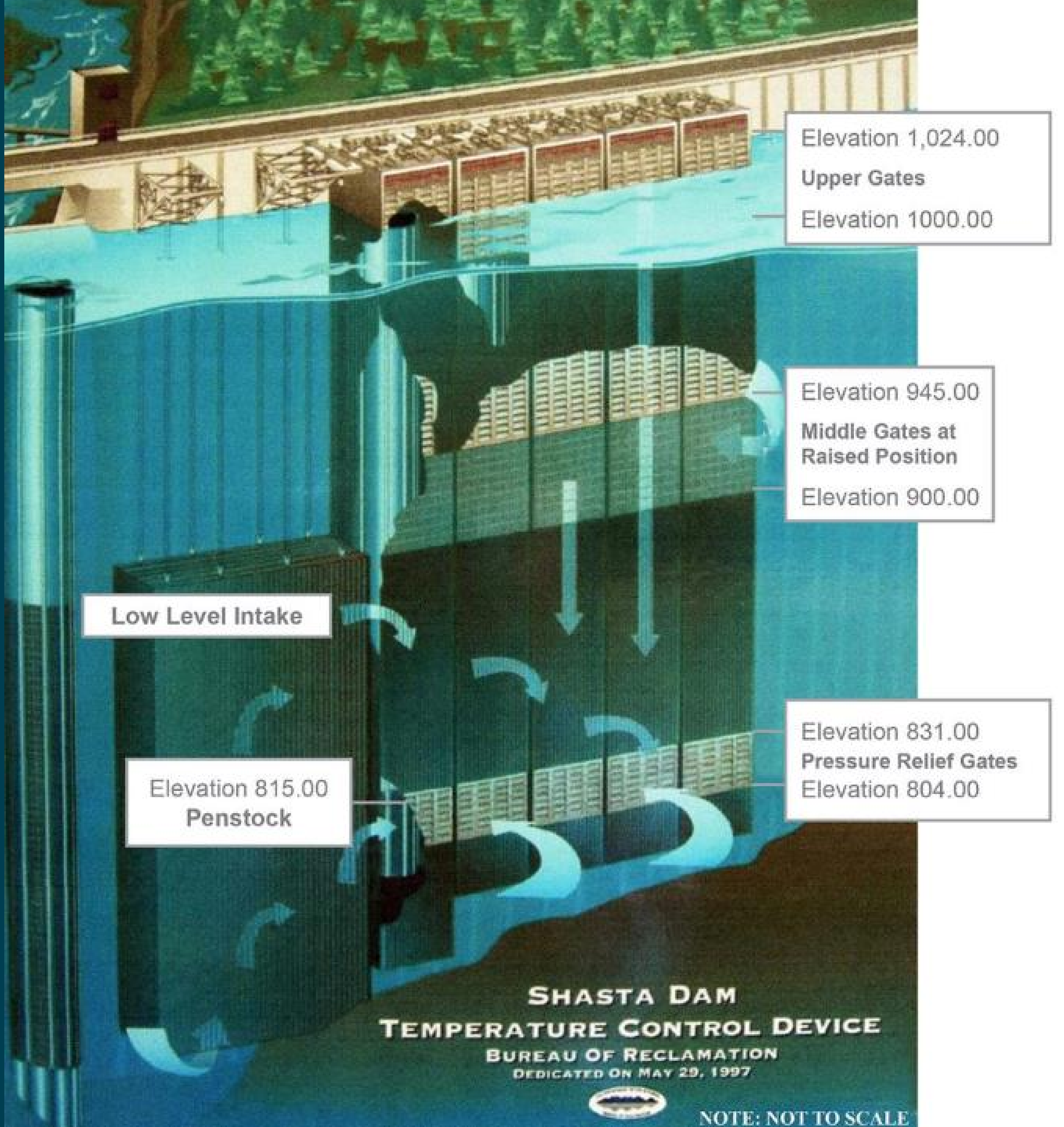
Modeling Technical Committee (MTC; Cont’d)

- Registration for individual meeting is required. The agenda will be distributed ahead with notification.
- Additional email communication for updates, information sharing and product review requests.
  - Product review will be in a draft Technical Memorandum format for better context and convenience.
  - Interim progress and information will be discussed in the MTC meetings.

Overall Project Stakeholder Involvement

- Project contract: mppublicaffairs@usbr.gov
- Project Website: https://www.usbr.gov/mp/bdo/cvp-wtmp.html
- Modeling Technical Committee (MTC) – Quarterly
- Manager Briefings – Annually (TBD)
- Stakeholder SharePoint Site (TBD)
- More information to come

Questions



Elevation 1,024.00
Upper Gates
Elevation 1000.00
Elevation 945.00
Middle Gates at Raised Position
Elevation 900.00
Low Level Intake
Elevation 831.00
Pressure Relief Gates
Elevation 804.00
Elevation 815.00
Penstock
SHASTA DAM
TEMPERATURE CONTROL DEVICE
BUREAU OF RECLAMATION
DEDICATED ON MAY 29, 1997
NOTE: NOT TO SCALE

Short Stretch Break

Water Temperature Model and Framework Review and Selection

- Part I: Models and Framework

Randi Field, Civil (Hydrologic) Engineer, CVO

Photo credit: John Hannon, Reclamation

Water Temperature Model and Framework Review and Selection

- Water Temperature Model Selection

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

Presentation Overview

- Task Description
- Model Selection Criteria
- Models
- Model Selection

Model Selection/Design (Task 6)

Select models for each of the elements of the framework based on objectives and selection criteria. Determine the appropriate spatial and temporal resolution of the selected models, and conduct any additional necessary design specification for the models.

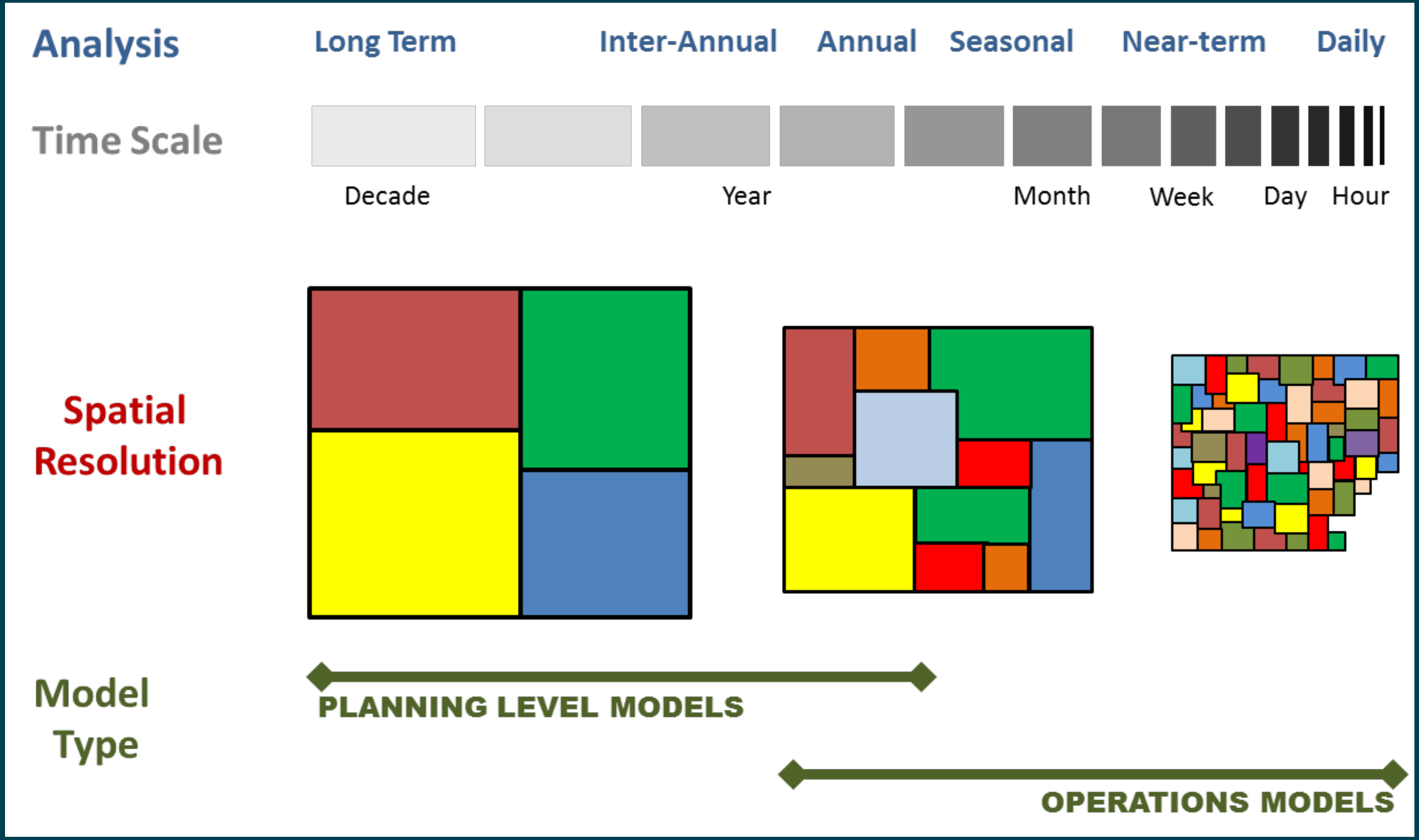
Model Selection Criteria

- Purpose: screen potential models for selection and implementation in the Water Temperature Modeling Platform (WTMP)
  - 28 model criteria developed
  - Grouped into subcategories
  - Each criterion assessed, where feasible, as high, medium, or low priority
  - Criterion identified as “required” and “preferred”
- Selection criteria are important and necessary to ensure models fit project need

Modeling Need(s)

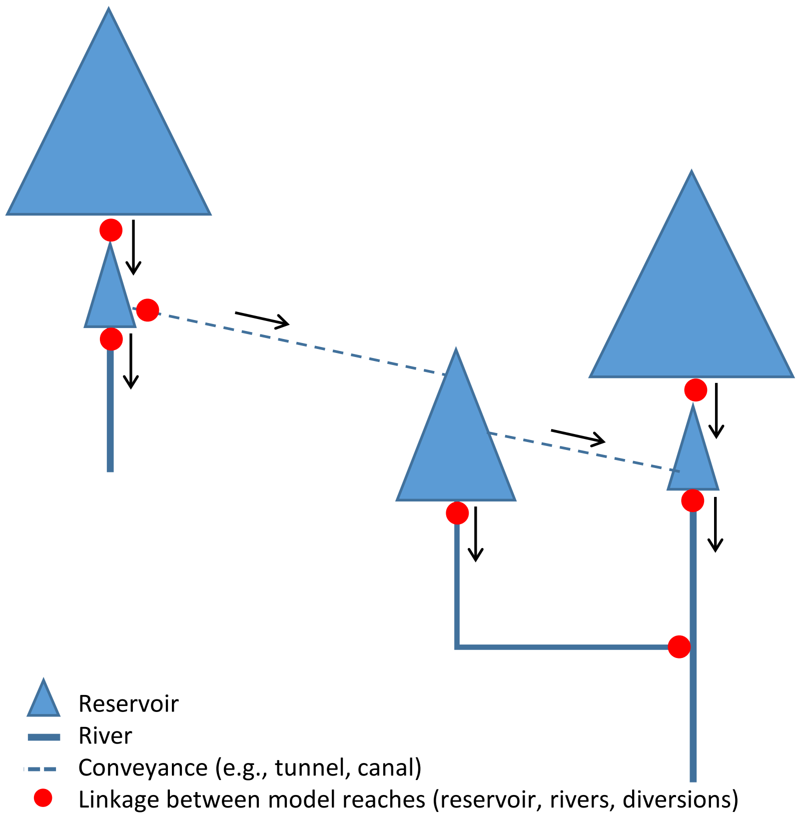
- Relatively computationally efficient, but accurate, reservoir-river model to support
  - Reclamation's annual temperature management planning activities (Sacramento River, American River)
  - Planning level analyses requiring long-term simulations (e.g., CALSIM 80+ year hydrology), ensemble analyses, Monte Carlo analyses, or similar)
- Refined models to capture selected elements with higher resolution to represent key features that may not be completely represented in a simpler model representations.

Model Spatial and Temporal Considerations

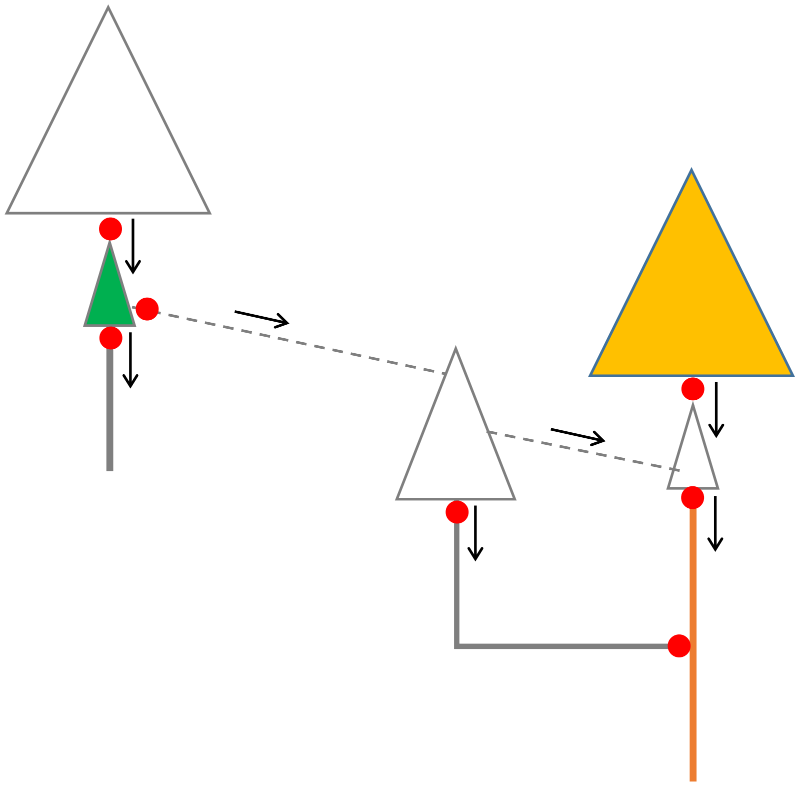


Model Types/Definitions

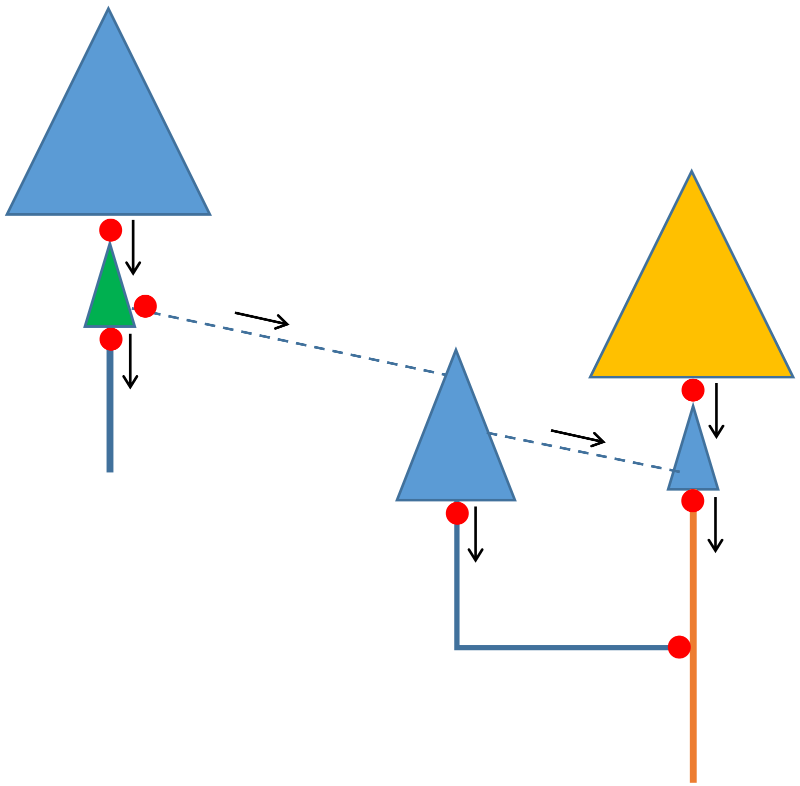
System Model



Element Model



Modeling Framework



Model Selection Criteria: Subcategories

- Numerical Model Criteria – representation of physical system in a model
- Linkage – addresses if models are discrete (reach specific) or system-wide and if framework compatible
- Input/Output (I/O) – model pre- and post-processors and data structures
- Support – user specific information
- CVP Features – ability to represent specific features CVP
- Qualitative – additional qualitative criteria

Numerical Model Criteria

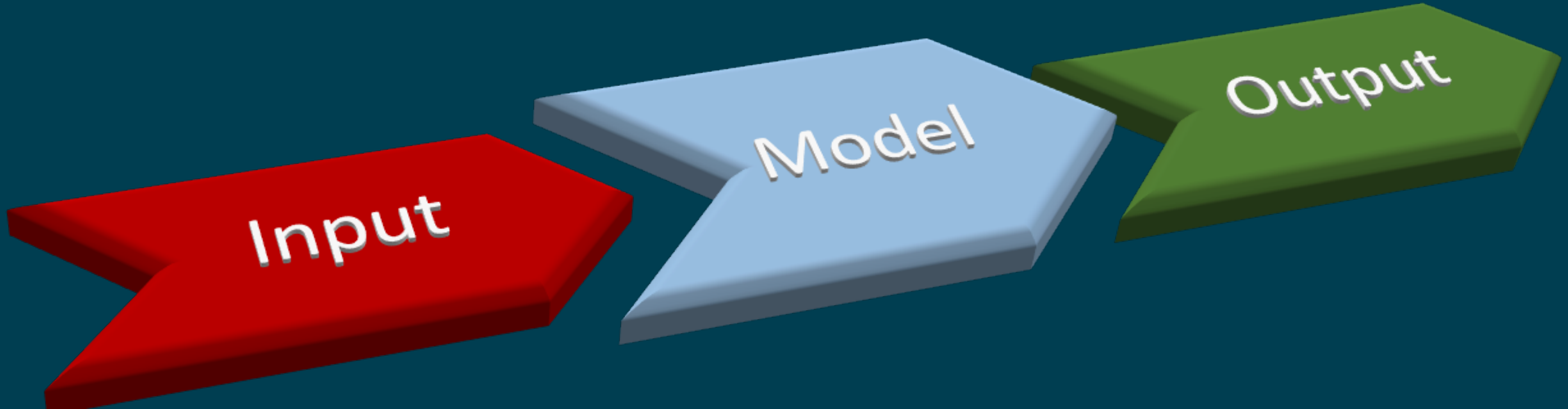
Criteria	Notes/Comments	Priority
1. Model type (River/Reservoir)	Reservoir (vertical profile and outflow temperature), River (longitudinal temperature)	H
2. Number of dimensions (1, 2)	Tradeoffs between lower/higher dimensional representations and computational efficiency	H
3. System geometric representation	Appropriate spatial resolution to represent reservoir/river element	H
4. Dynamic flow model	Ability to capture flow conditions over a range of time scales (hours, days, months)	H
5. Water temperature representation	Comprehensive heat budget formulation	H
6. Time step	Sub-daily required	H
7. Computational performance consideration	Computation time considered for screening analyses as well as planning analyses	H

Linkage Criteria

Criteria	Notes/Comments	Priority
8. System Model or discrete reach	Model can represent entire system (reservoir and river hydrology and water temperature) or a discrete segment/element of system (e.g., reservoir model)	M
9. Modeling framework compatible	Model can share I/O with other models in a framework	H/M

Input/Output (I/O) Criteria

Criteria	Notes/Comments	Priority
10. Pre-processor	Assess and manage inputs	H
11. Post-processor	Assess, visualize, and report output (graphical and tabular)	H
12. Data structure facilitates model calibration/application	To facilitate modeling, calibration, and error detection	L



Support Criteria

Criteria	Notes/Comments	Priority
13. Model applications	Model been used in applications similar to this project.	H
14. Actively supported	Actively supported models	H
15. Public domain, peer reviewed, and accessible model modifications	To assess critical model assumptions, verify model modifications, and provide model transparency	H
16. Fee	Model is free or is there a minimal cost for software	H
17. Documentation	Technical reports on model construction (equations, solution methods, testing) and user manuals	H
18. Training and/or user group	Support ongoing model application	M/L

CVP Features Criteria

Criteria	Notes/Comments	Priority
19. Specific features:	Represent current or planned project facilities	-
A. Temperature control curtains	Lewiston Lake and Whiskeytown Lake	H
B. Submerged weirs/dams	Submerged dam upstream of New Melones Dam	H
C. Selective withdrawal	Shasta Lake and Folsom Lake	H
D. Automated simulations to target tailbay temperature	Model target reservoir release temperatures	H
E. Automated simulations to target river temperature	Model target downstream river temperatures	H
F. Shade	Topographic and/or riparian vegetation shade	M

Qualitative Criteria

Criteria	Notes/Comments	Priority
20. Qualitative	-	-
A. Ease of use	Relatively easily operated (data input, model run, and output accessed)	M
B. Credibility	A history of successful use and previous peer review or institutional review/support	H
C. Easy to incorporate uncertain input parameters	External (preferred) rather than internal	M
D. Collaboration with model developers	Model developers have an interest in collaboration	M

Model Selection

- Modeling Objective(s)
- Model Types
  - System
  - Element
    - Reservoir
    - River
  - Framework approach

Reservoir and System Models

Model	Sponsor	Type
CE-QUAL-W2	PSU, USACOE	Reservoir
DYRESM	CWR-UWA	Reservoir
HEC-5Q	USACOE	System
HEC-ResSim	USACOE	System
Riverware	CADSWES	System

CADWES: Center for Advanced Decision Support for Water and Environmental Systems
CWR-UWA: Center for Water Resources, University of Western Australia
PSU: Portland State University
USACOE: US Army Corps of Engineers

River Models (1/2)

Model	Sponsor	Type
CE-QUAL-RIV1	USACOE	River
EPD-RIV1	GEPD	River
Heat Source	ODEQ	River
HEC-5Q	USACOE	System
HEC-RAS	USACOE	River
HEC-ResSim	USACOE	System
QUAL2K	Tufts Univ., USEPA, WDOE	River

GEPD: Georgia Environmental Protection Division
ODEQ: Oregon Department of Environmental Quality
USACOE: US Army Corps of Engineers
USEPA: US Environmental Protection Agency
WDOE: Washington Department of Ecology

River Models (2/2)

Model	Sponsor	Type
RAFT	NOAA-SFSC	River
RBM10	USEPA	River
River Modeling System(RMS)	Loginetics	River
Riverware	CADSWES	System
RMA2/RMA4	Aqueveo	River

CADWES: Center for Advanced Decision Support for Water and Environmental Systems
NOAA-SFSC: National Oceanic and Atmospheric Administration-Southwest Fisheries Science Center
USACOE: US Army Corps of Engineers
USEPA: US Environmental Protection Agency

Initial Selection

- Assessed each criteria
  - (Y/N, H/M/L)
    - Yes and Yes*
  - Required (R), Preferred (P)
  - Unknown, n/a

- Quantitative and Qualitative

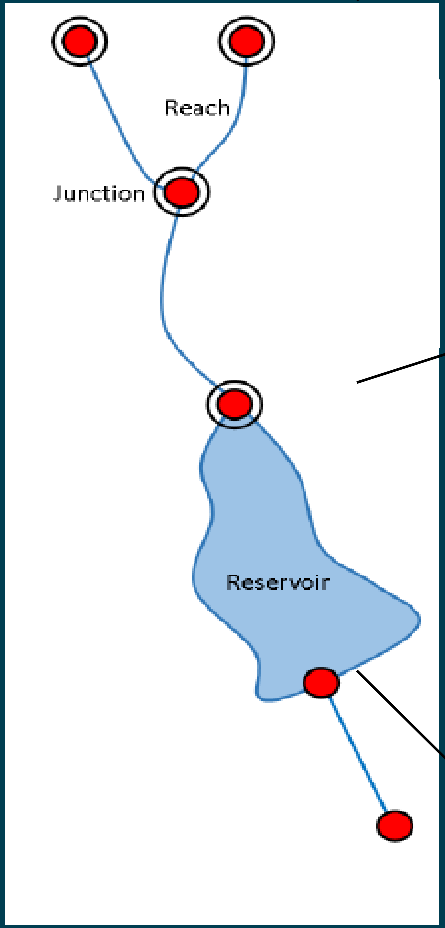
Selection Criteria	Comments	Need	CE-QUAL-W2	DYRESM	HEC-5Q (system)	HEC-ResSim (system)	Riverv (syste
			Discrete	Discrete	System	System	Syst
1. Type (river/reservoir)	Is the model designed for predicting vertical distributions and release water temperatures in a reservoir reach?	R	Yes	Yes	Yes	Yes	Ye
Short-term/forecasting	Within season (days, weeks, months)	R	Yes	Yes	Yes	Yes	Ye
Long-term planning	Extended simulations (years, decades)	R	Yes*	Yes*	Yes	Yes	Ye
2. # of Dimensions (1, 2)			2	1	1	1	1
3. System geometric representation	Principal dimension(s)		Longitude/ Vertical	Vertical	Longitude	Longitude	Verti
	Detailed vertical resolution? Y/N	R	Yes	Yes	Yes	Yes	N
4. Dynamic Flow Model	Y/N	P	Yes	No	No	No	N
5. Water temperature representation	Full Heat Budget: Y/N	R	Yes	Yes	No	Yes	Ye
6. Time Step (sub-daily?)	Y/N	R	Yes	Yes	Yes	Yes	Ye
7. Computational performance consideration	Faster/Slower	-	Slower	Faster	Faster	Faster	
8. System Model or discrete reach		-	Discrete	Discrete	System/ Discrete	System/ Discrete	Syste
9. Modeling framework compatible	Readily incorporated into a framework: Y/N	P	Yes		Yes	Yes	Ye
10. Pre-Processor	Y/N	P	Yes	Yes	No	Yes	
11. Post Processor	Y/N	P	Yes	Yes	Yes	Yes	Ye
12. Data structure facilitates model calibration/application	Y/N	P	Yes		Yes	Yes	Ye
13. Similar Model Applications	High/Medium/Low	P	Medium		Medium	Low	
14. Actively Supported	Y/N	R	Yes	Yes	No	Yes	Ye
15. Public Domain, Peer Reviewed, or Accessible Modifications	PD/PR/AM	R	PD/PR/AM	-/PR/-	PD/-/AM	PD/PR/AM	-/PR
16. Fee	Fee for software and/or support: Y/N	R	No	Yes	No	No	Ye
17. Documentation	Y/N	R	Yes	Yes	Yes	Yes	Ye
18. Training and/or User Group	Y/N	P	Yes	Yes	No	Yes	Ye
19. CVP Specific features							
A. Temperature Control Curtains	Y/N	R	Yes	No	No	No	N
B. Submerged Weirs/Dams	Y/N	R	Yes	No	No	No	N
C. Selective Withdrawal	Y/N	R	Yes	Yes	Yes	Yes	
D. Automated simulations to meet downstream temperature targets: tailbay	Y/N	R	Yes		Yes	Yes	
E. Automated simulations to meet downstream temperature targets: river reach	Y/N	P	n/a	n/a	Yes	Yes	

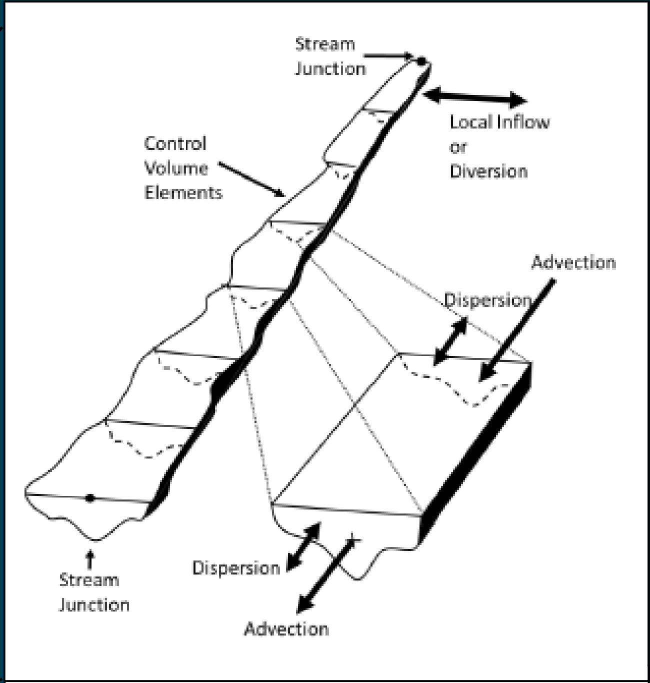
System Model: HEC-ResSim

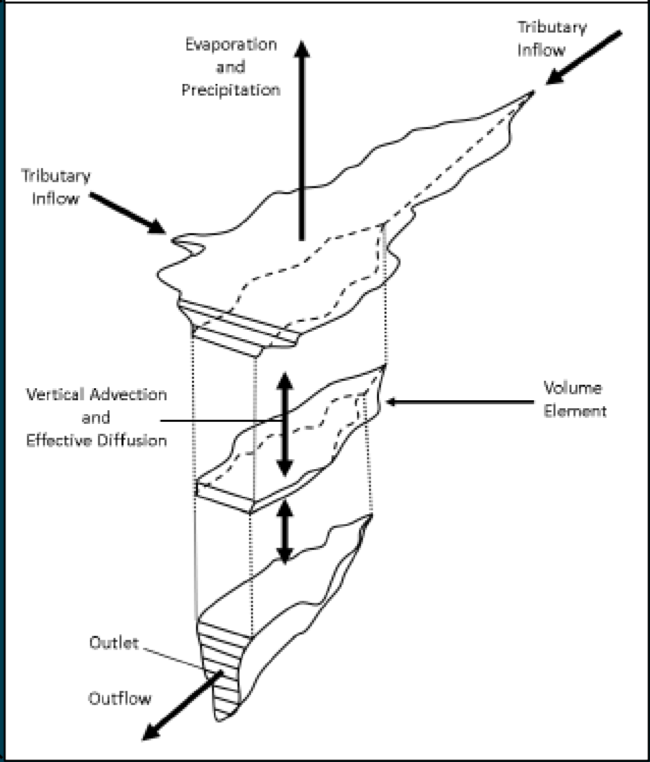
- Non-uniform flow, non-steady state flow
- Full heat budget
- Selective withdrawal (tailbay target)
- Sub-daily time step
- Monte Carlo and Ensemble analyses
- Incorporate new logic via “plug-ins”
- Interface with other models (e.g., CE-QUAL-W2)
- Operate as a stand-alone model or as part of a modeling framework
- Pre- and post-processors
- Comprehensive documentation (model, pre- and post-processors)
- Active support (model, pre- and post-processors)
- Access to the model developers, collaboration
- User groups, training
- Other

System Model: HEC-ResSim

- Reservoirs (1-D)
  - Vertical gradients
  - Laterally and longitudinal averaged
- River (1-D)
  - Longitudinal gradients
  - Laterally and vertically averaged

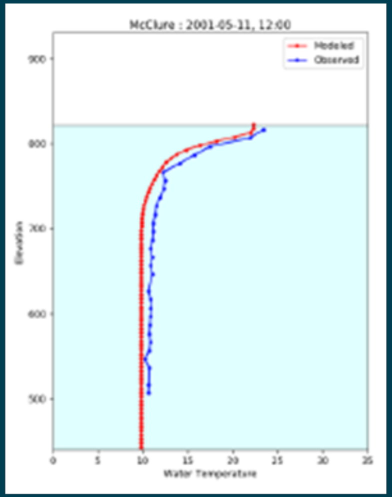


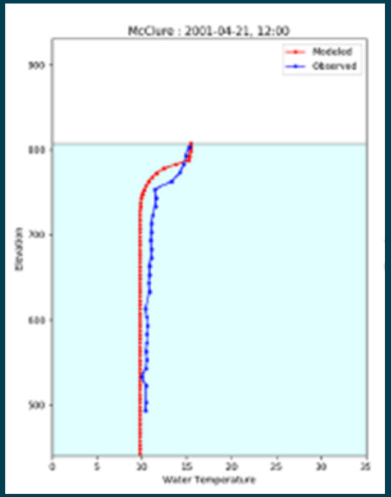


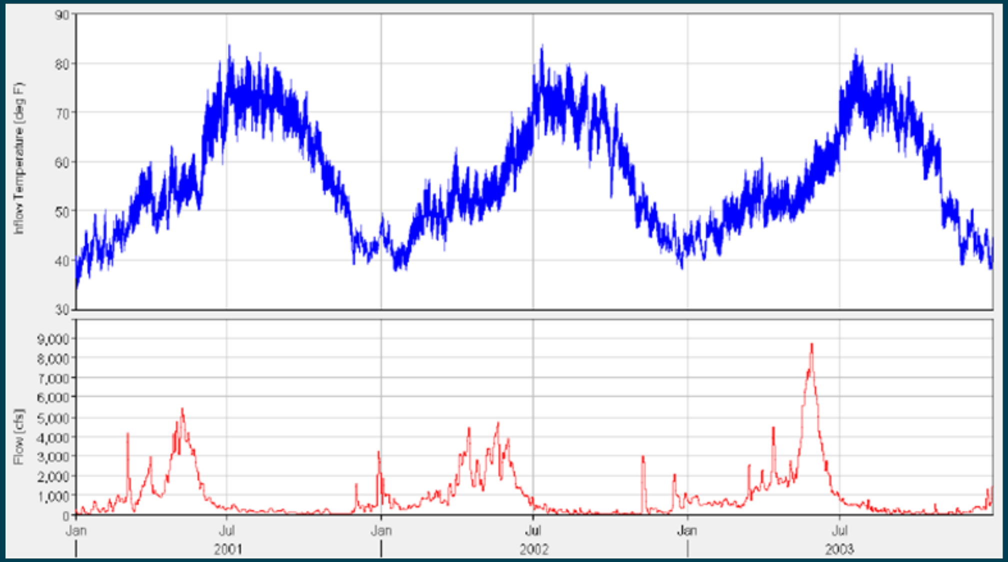


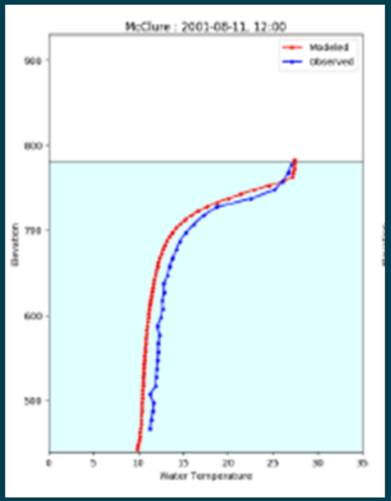
Model Output

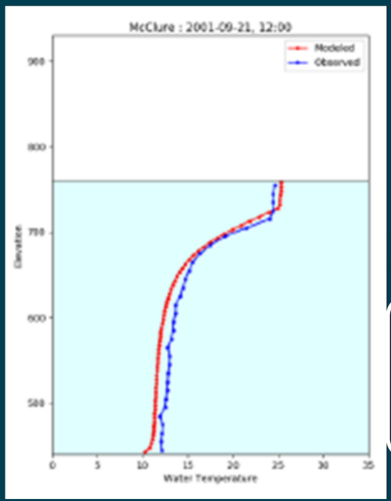
- Reservoir Outflow (time series)
- Reservoir Stage (time series)
- Outflow Water Temperature (time series)
- Vertical Temperature Profiles









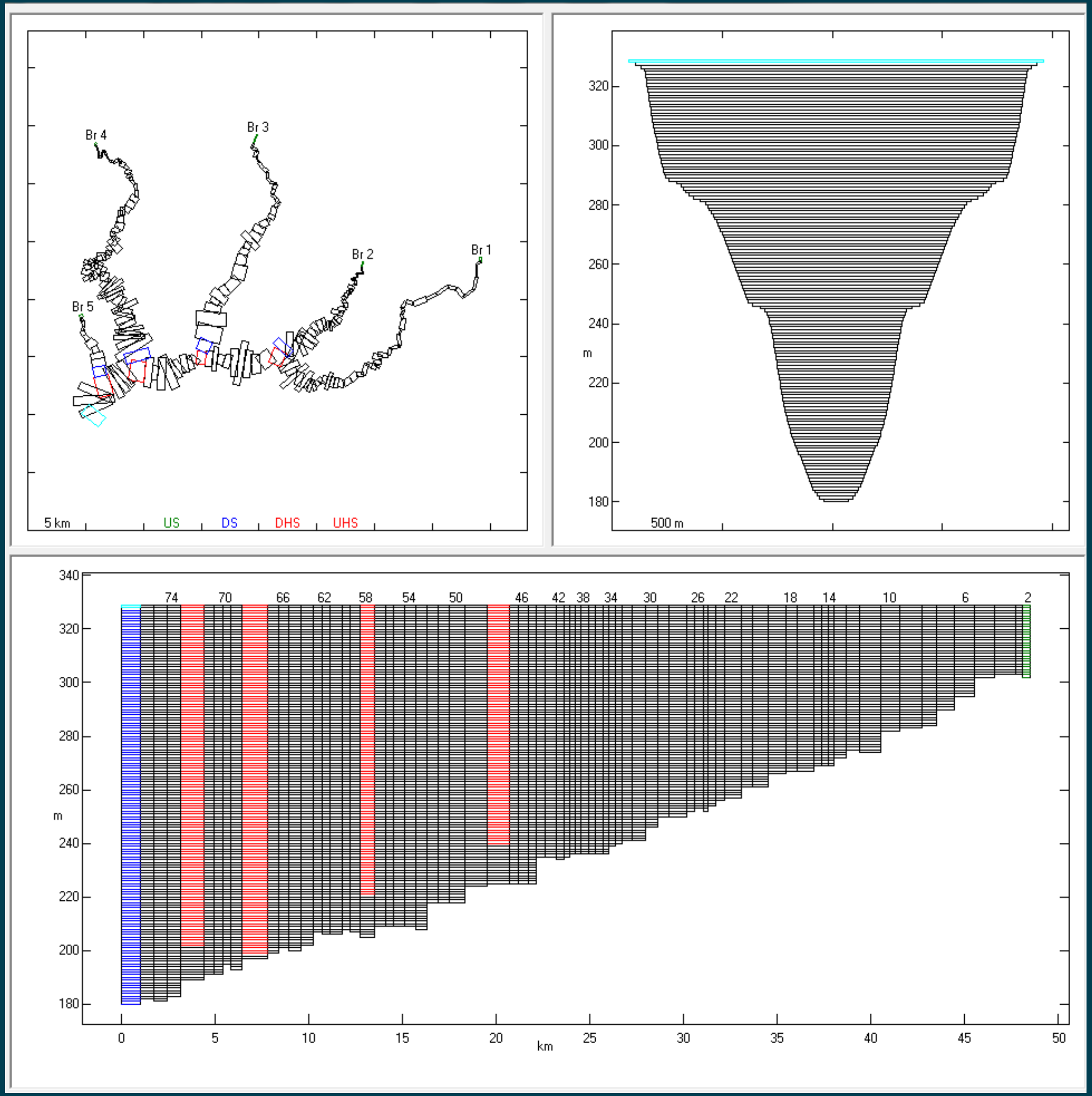


Reservoir Model: CE-QUAL-W2

- Two-dimensional representation
- Non-uniform flow, non-steady state flow
- Full heat budget
- Selective withdrawal (tailbay target)
- Sub-daily time step
- Supports branching networks (e.g., dendritic nature of reservoir)
- Existing applications (Shasta, Keswick, Lewiston, Folsom, Natomas)
- Pre- and post-processors
- Comprehensive documentation (model, pre- and post-processors)
- Active support (model, pre- and post-processors)
- Access to the model developers, collaboration
- User groups, training
- Operate as a stand-alone model or as part of a modeling framework
- Other

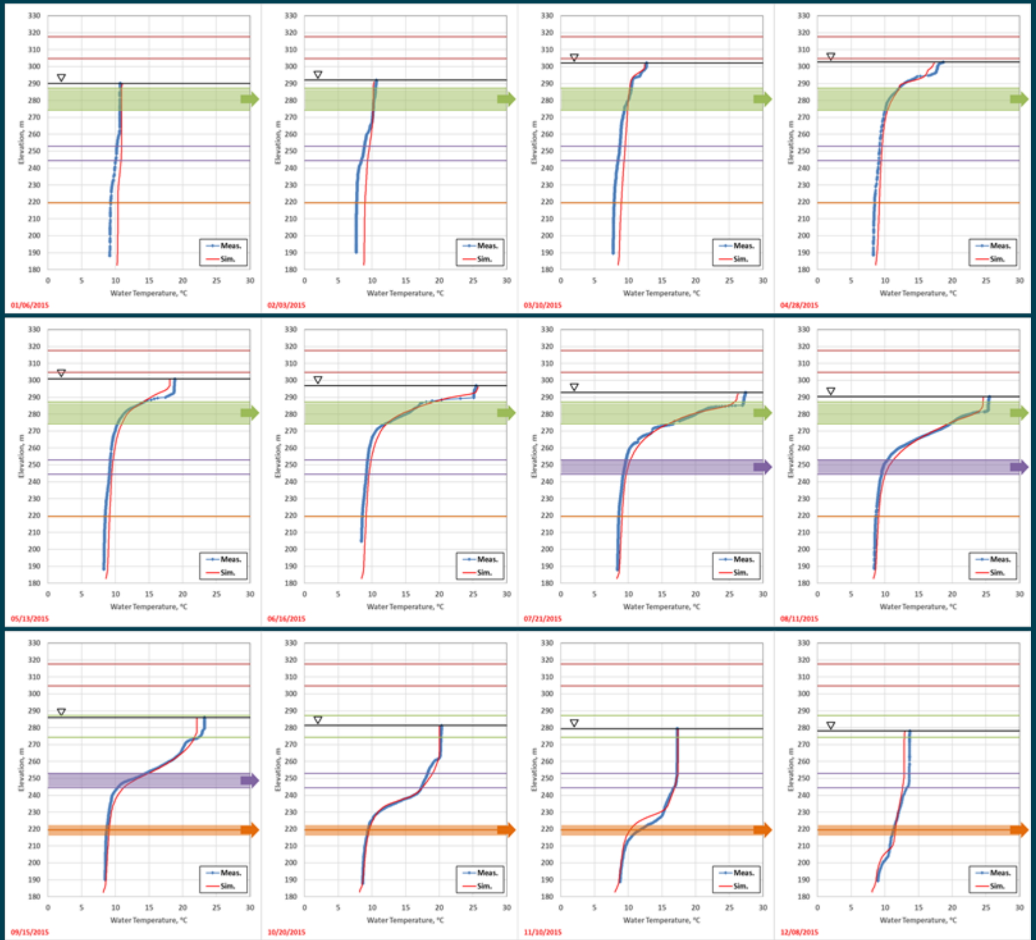
Reservoir Model: CE-QUAL-W2

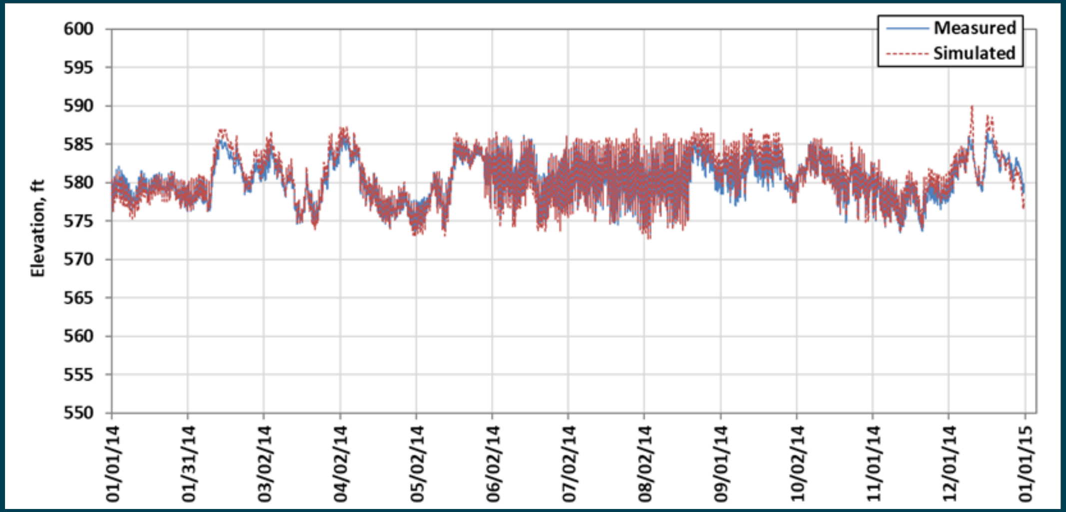
- Reservoirs (2-D)
  - Vertical gradients
  - Longitudinal gradients
  - Laterally averaged



Model Output

- Reservoir Outflow (time series)
- Reservoir Stage (time series)
- Outflow Water Temperature (time series)
- Vertical Temperature Profiles

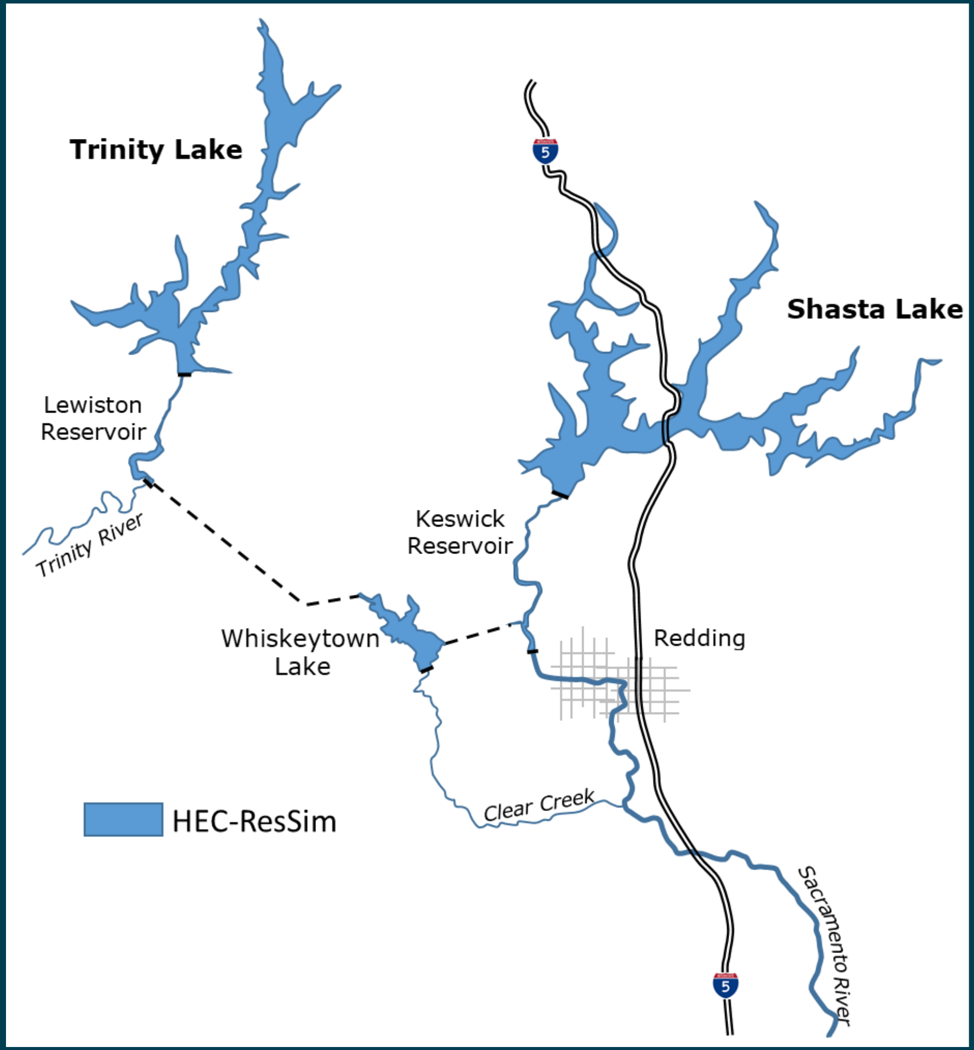




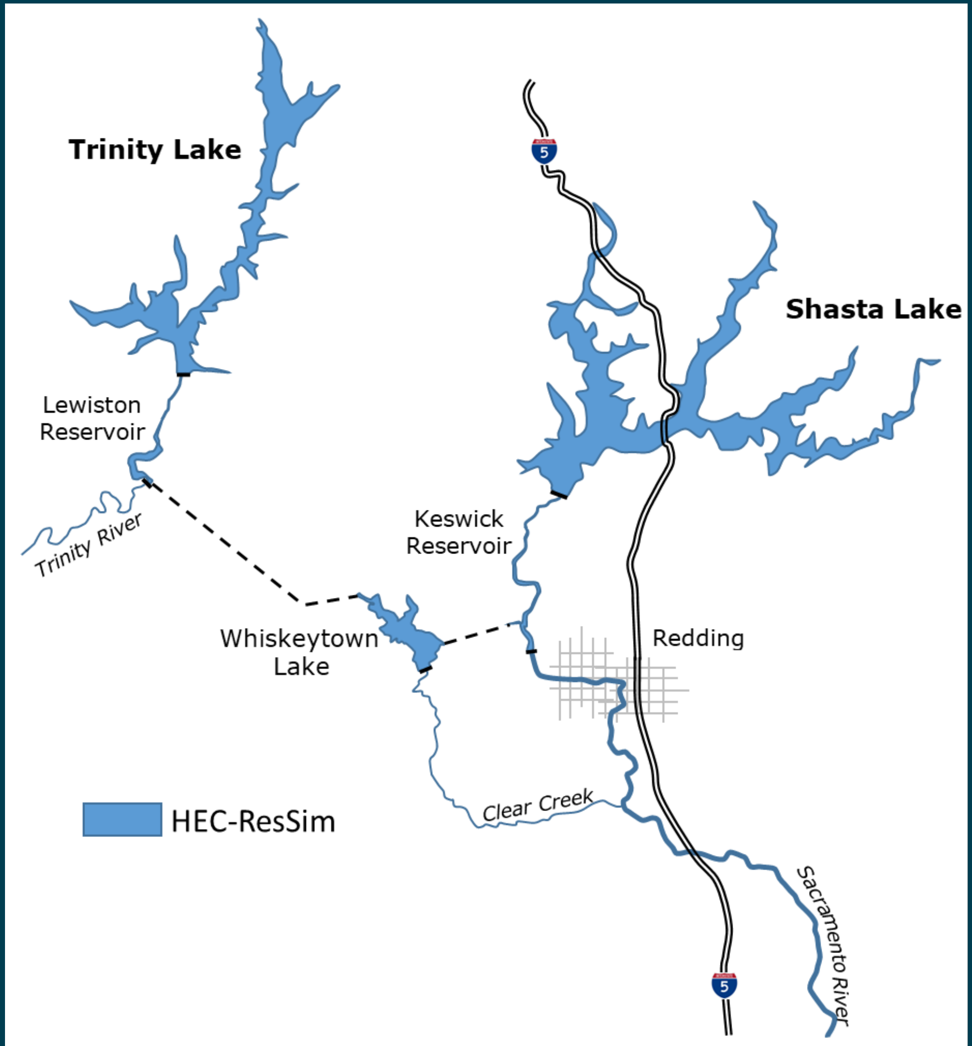
River Model: HEC-ResSim

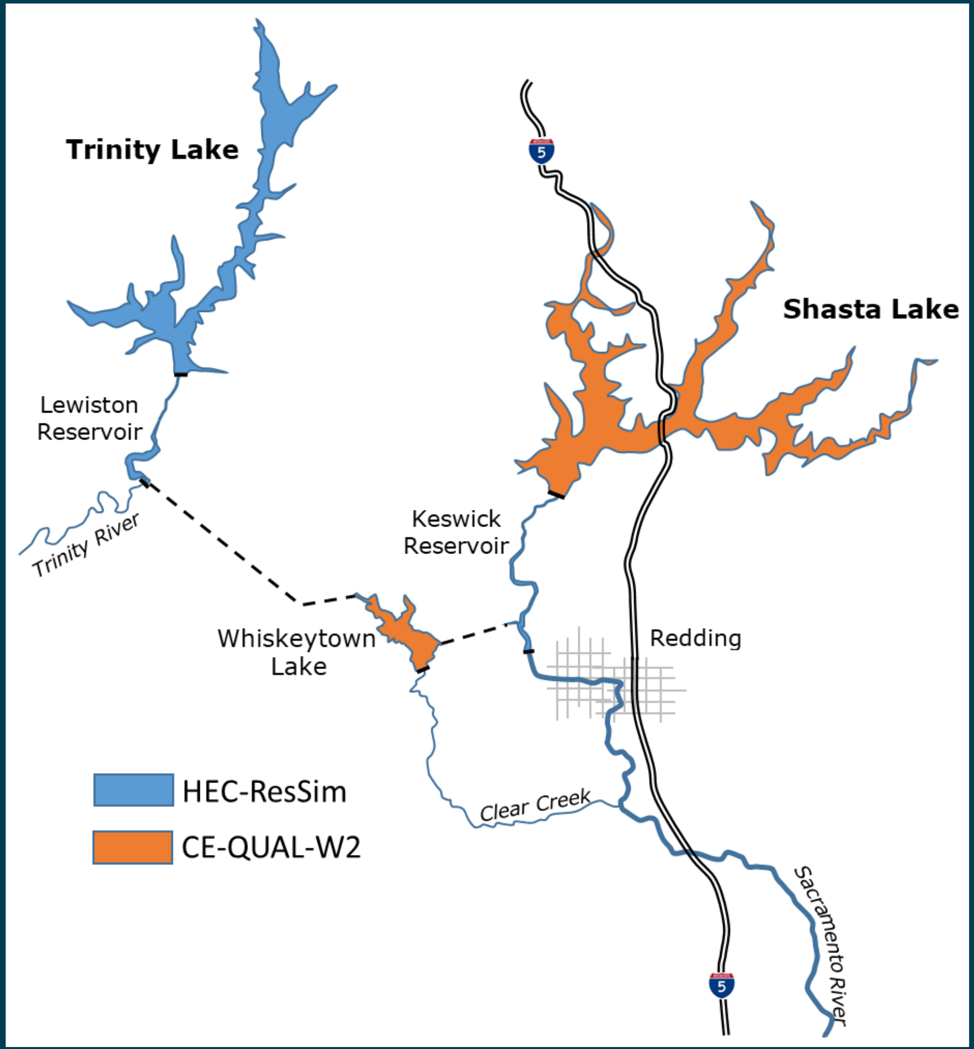
- River representation (1-D)
  - Longitudinal gradients
  - Laterally and vertically averaged
- Consistent with current river temperature modeling approach in all systems
- Attributes previously discussed

Example: Shasta/Trinity



Example: Shasta/Trinity





Summary

- Developed model criteria
- Identified prospective models
- Initial model selection

  - System: HEC-ResSim
    - https://www.hec.usace.army.mil/software/hec-ressim/
  - Reservoir: CE-QUAL-W2
    - http://cee.pdx.edu/w2/
  - River: HEC-ResSim

- Models reside in a framework

Photo credit: John Hannon, Reclamation

Water Temperature Model and Framework Review and Selection

- Modeling Framework Selection

John DeGeorge, Ph.D, P.E., RMA

Modeling Framework Selection - Overview

- Purpose of a Modeling Framework
- Team Roles
- Candidate Frameworks
- Selection Criteria
- Framework Comparison
- Selection

Overview of Framework and Objectives

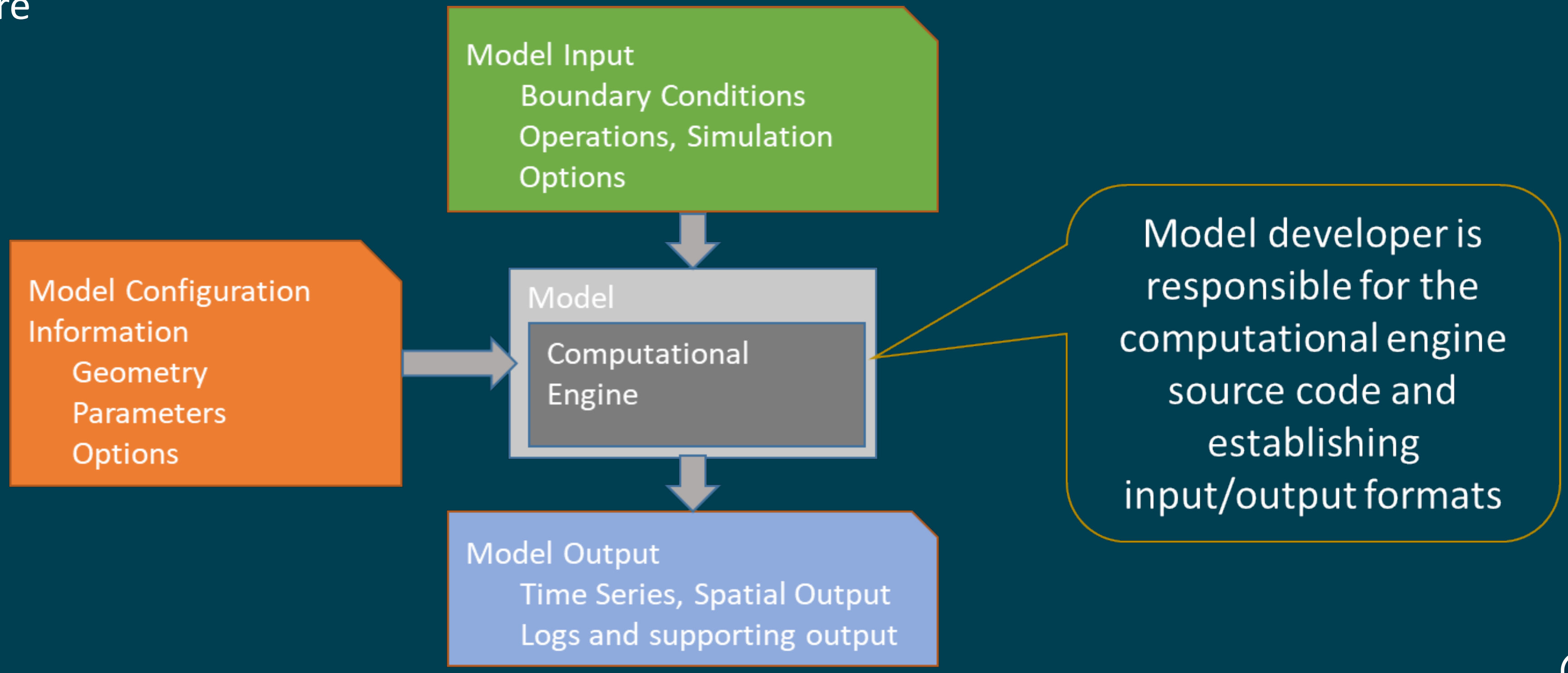
Enhance Efficiency, Consistency, Adaptability and Transparency

- Ease model application and output interpretation
  - Reduce requirement for training on file editing and information flow
  - Reduce the time it takes to carry out modeling activities
  - Facilitate standard approaches for data management and reporting
  - Automate repetitive modeling tasks
- Facilitate the use of multiple models individually or in a sequence
- Managing updates and addition of new features
- Reducing input error and errors in general!

Model, Configuration, Input and Output

"Model" in this context refers to a computational software program, for example:

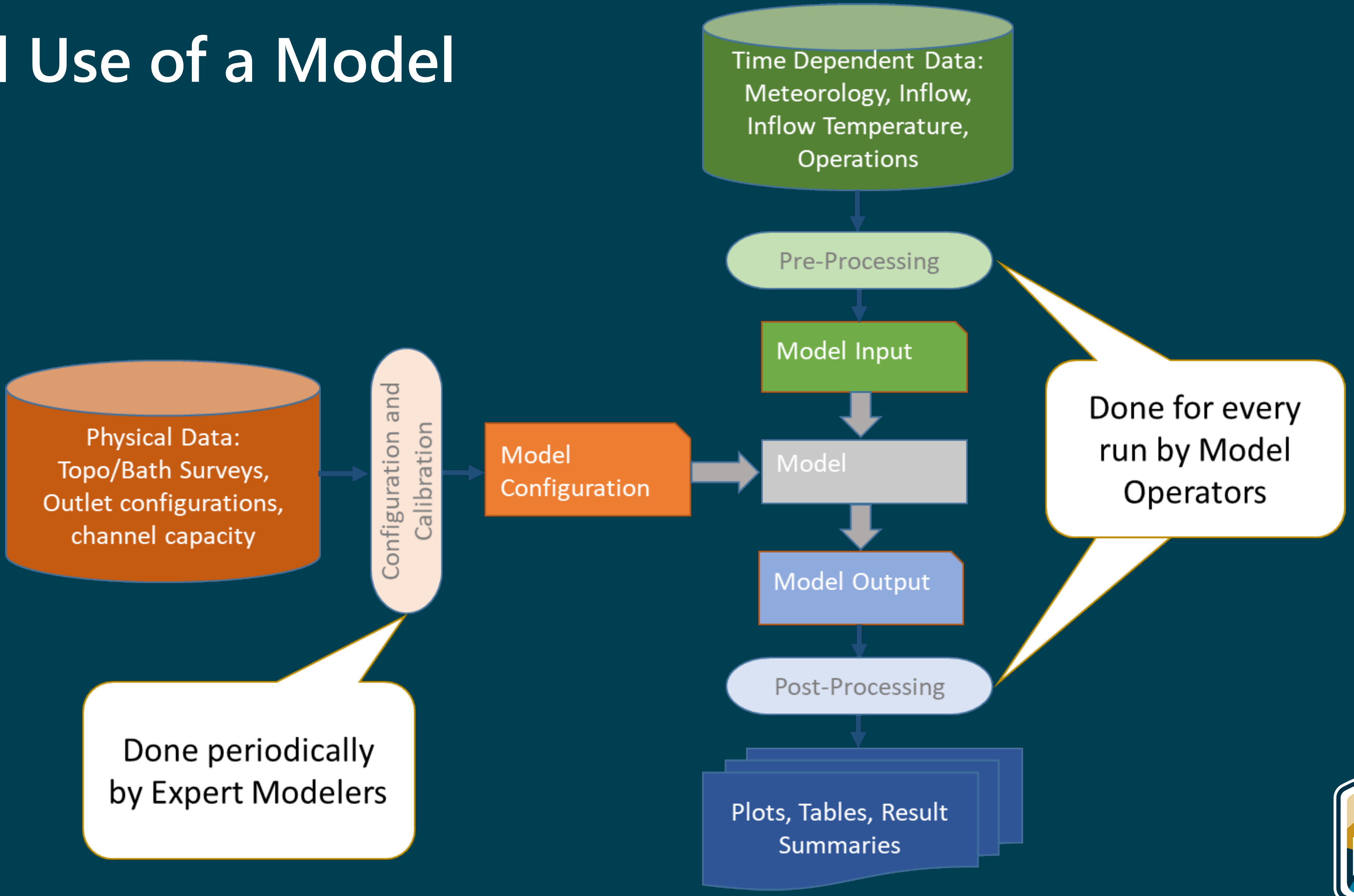
CE-QUAL-W2
HEC-5Q
HEC-ResSim
CALSIM II
DSM2
…



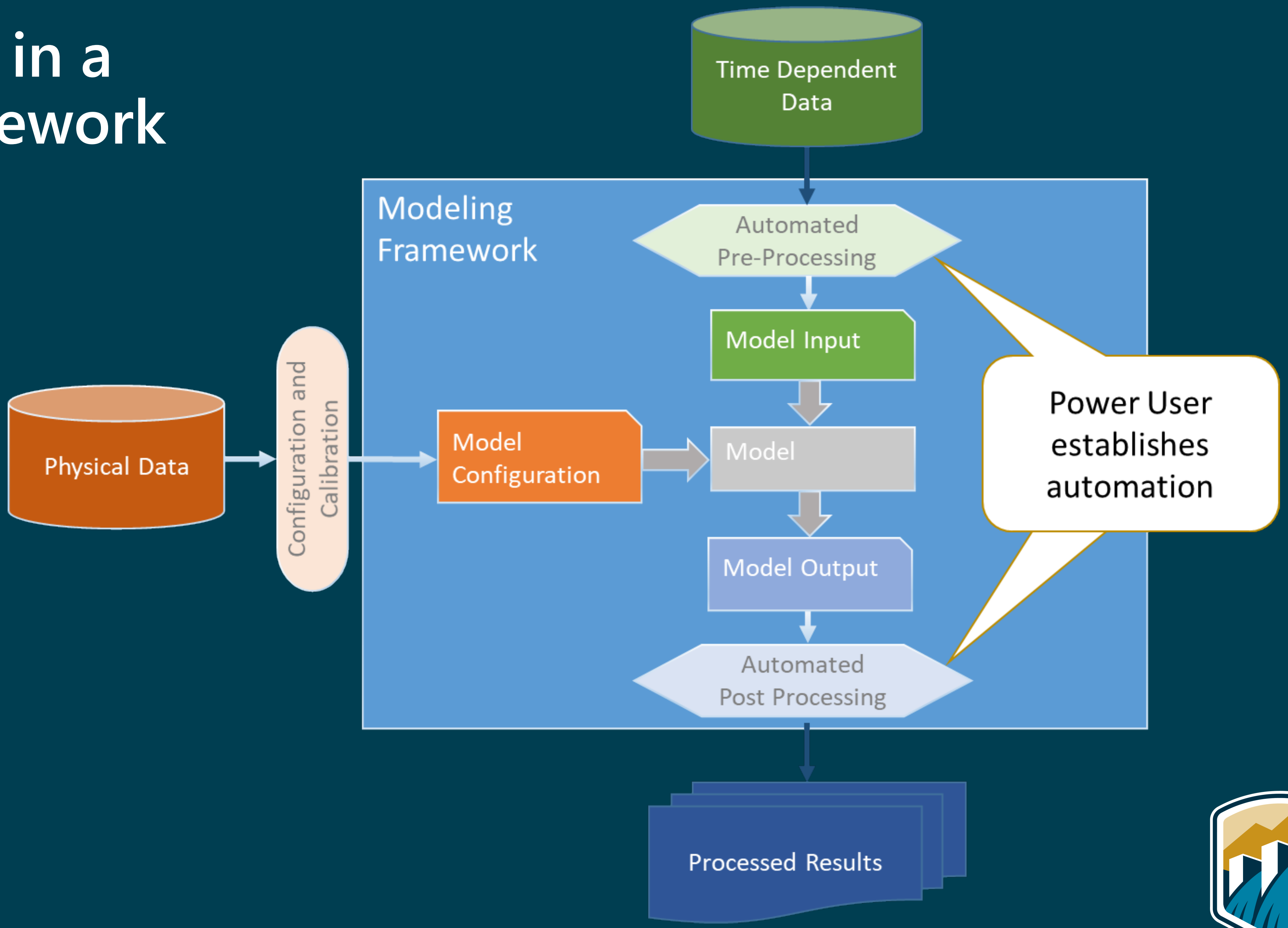
Team Roles

- Model Developer
  - Responsible for the development and maintenance of a model's computational engine
- Expert Modeler
  - Responsible for configuration and calibration of a model for a particular system
- Power User
  - Configures automated processing for pre- and post- processing, designs reports, manages model linkages
- Model Operator
  - Carries out modeling studies
- IT Support
  - Manages the IT infrastructure to facilitate team modeling and provide connectivity to web data sources

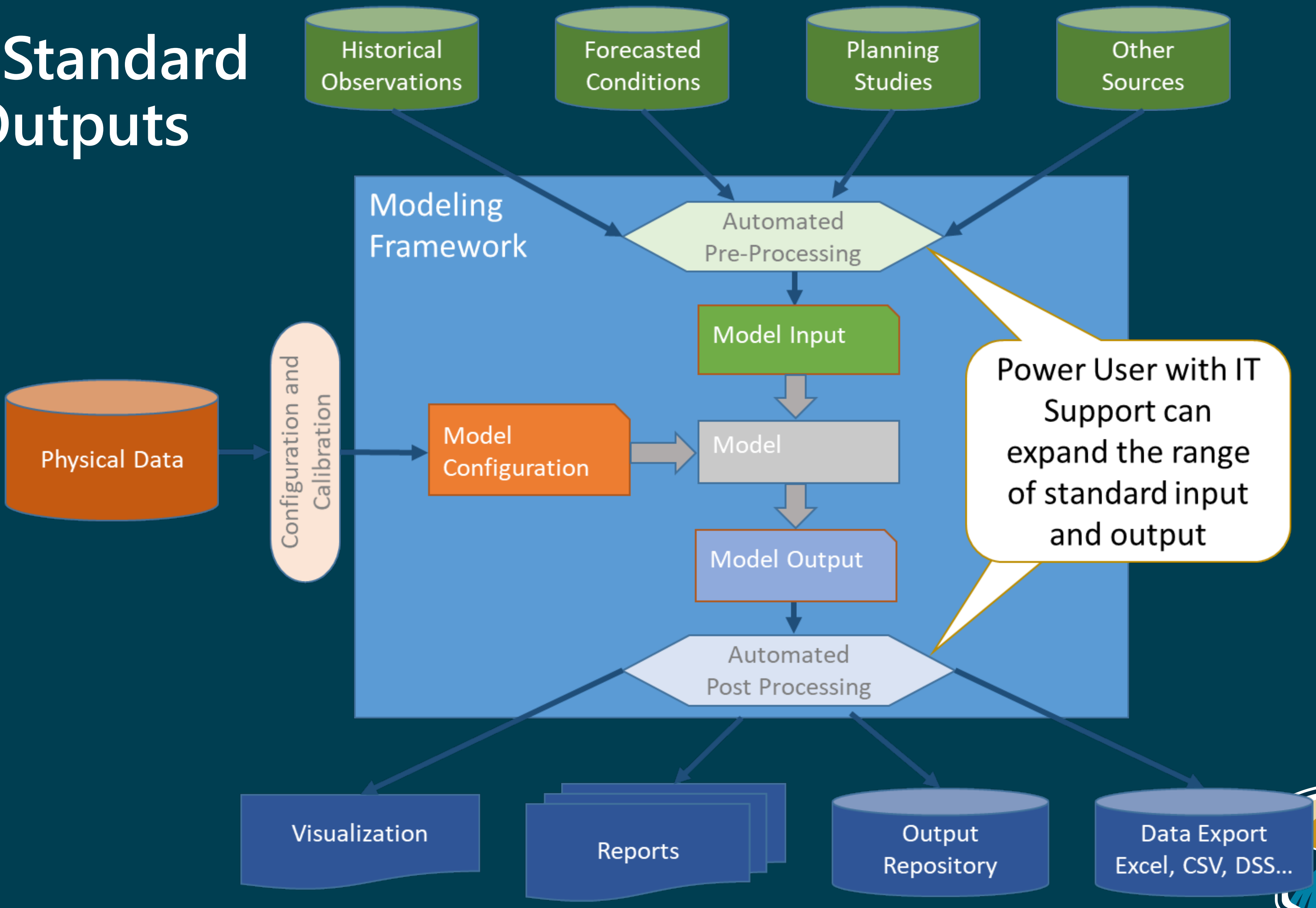
Operational Use of a Model



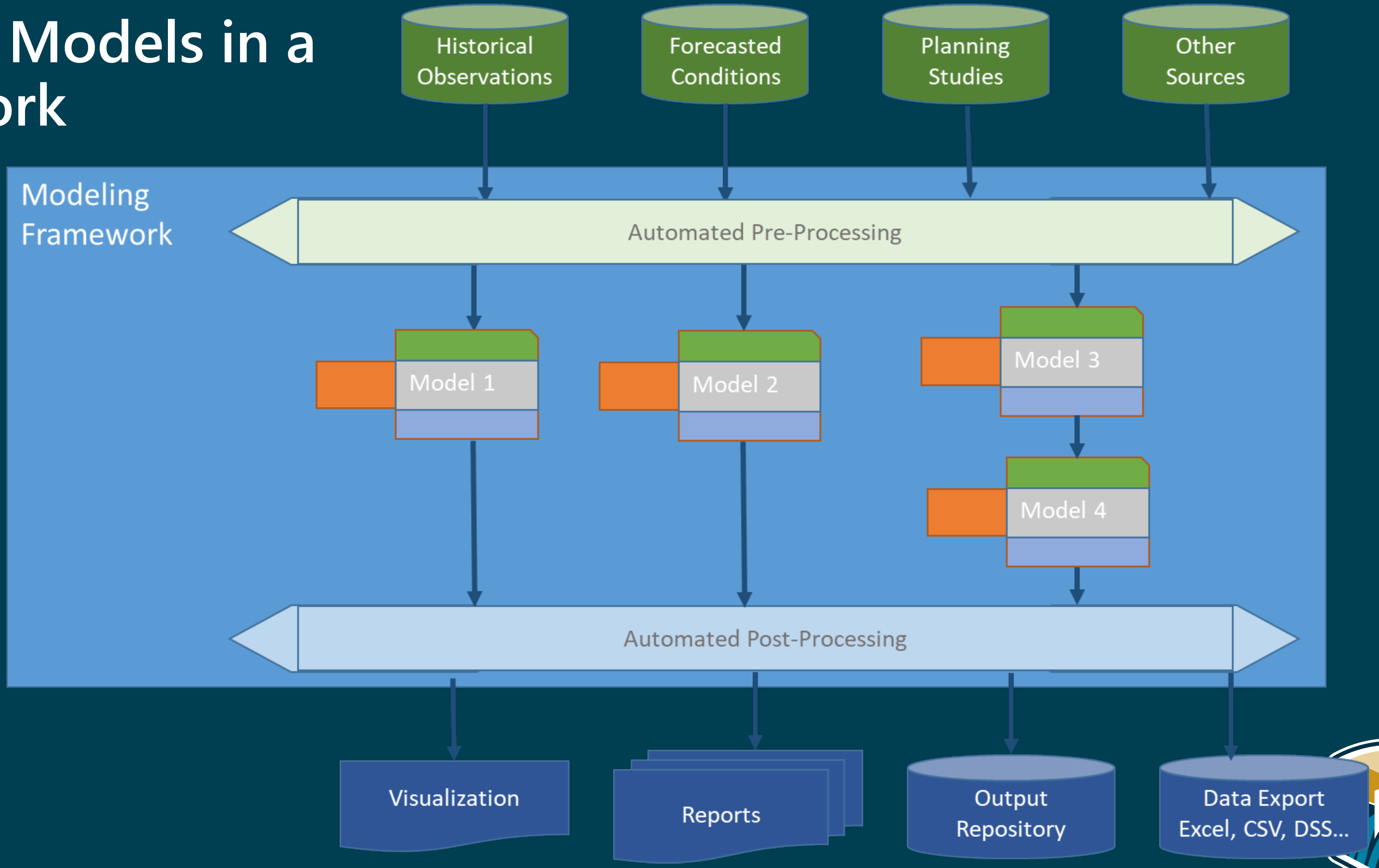
A Single Model in a Modeling Framework



Automating Standard Inputs and Outputs



Multiple Models in a Framework



Candidate Frameworks

Type	Name	Description	Primary Author	Description	Link
Application Programming Interface	OpenMI	Open Modeling Interface	OpenMI Association	defines API to be implmented by a model	https://www.openmi.org/
Application Programming Interface	BMI	Basic Model Interface	University of Colorado	defines API to be implemented by a model "wrapper"	https://csdms.colorado.edu/wiki/BMI
Software Platform	OMS3/CSIP	Object Modeling System	Colorado State University	interoperable and lightweight modeling framework for component-based model and simulation development on multiple platforms	https://alm.engr.colostate.edu/cb/project/oms/
Software Platform	ESMF	Earth System Modeling Framework	NASA, NOAA, NCAR, DoD	high-performance, flexible software infrastructure for building and coupling weather, climate, and related Earth science applications	https://earthsystemmodeling.org/
Software Platform	HydroCouple	-	University of Utah	cross platform component-based modeling framework for integrated modeling for environmental and earth science applications	http://www.hydrocouple.org/
Software Platform	CSDMS	Community Surface Dynamics Modeling System	University of Colorado	cyber-infrastructure to promote the quantitative modeling of earth surface processes	https://csdms.colorado.edu/
Software Platform	Delft-FEWS	Flood Forecasting System	Deltares	Framework for a forecasting system utilizing a variety of models	https://oss.deltares.nl/web/delft-fews/
Framework Software with User Interface	Delta Shell	-	Deltares	integrated modelling environment which provides a platform that can be used to integrate various models, data and tools	https://www.deltares.nl/en/delta-shell-framework/
Framework Software with User Interface	HEC-WAT	Watershed Analysis Tool	USACE Hydrologic Engineering Center	model integration tool that allows multi-disciplinary teams to perform water resources studies and risk analysis	https://www.hec.usace.army.mil/software/hec-wat/
Framework Software with User Interface	HEC-RTS	Real Time Simulation	USACE Hydrologic Engineering Center	comprehensive data acquisition and hydrologic modeling system for short-term decision support of water control operations in real time	https://www.hec.usace.army.mil/software/hec-rts/

General Requirements

- Efficiently use several models, individually or in a sequence
- Support work flows for several typical modeling activities
- Utilize common boundary conditions and operational controls across models
- Create reports using common formats across models
- Manage updates of model executable programs and configuration data sets
- Allow for introduction of new modeling tools over time
- Focus on the efficiency of production modeling activities

Selection Criteria – Model Support

Ability to Satisfy a Criterion: Y-yes out of the box, S-with Scripting, C-with Coding, N-no does not support

Model Support Criterion	Importance	OSM3/CISP	ESMF	HydroCouple	CSDMS	Delft-FEWS	Delta Shell	HEC-WAT	HEC-RTS
What types of models can be utilized in the framework?	-	-	-	-	-	-	-	-	-
CEQUAL-W2	Must	S	S	Y	S	C	C	Y	C
HEC5Q	Preferred	S	S	S	S	C	C	S	S
HEC-ResSim	Preferred	S	S	S	C	Y	C	Y	Y
HEC-RAS	Preferred	S	S	S	C	Y	C	Y	Y
General command line models	Must	S	S	S	S	S	Y	Y	Y
General GUI based models	Desired	C	C	C	C	C	C	C	C
Scripted processes	Must	S	S	S	S	S	S	S	S
Excel worksheets	Preferred	S	S	S	S	C	S	S	S
What form of model coupling is supported?	-	-	-	-	-	-	-	-	-
Loose coupling	Must	Y	Y	Y	Y	Y	Y	Y	Y
Tight coupling	Not Desired	Y	Y	Y	Y	N	Y	N	N
What forms of flow control are available when running a sequence of models?	-	-	-	-	-	-	-	-	-
Linear sequence	Must	Y	Y	Y	Y	Y	Y	Y	Y
IF-THEN-ELSE conditionals	Desired	S	S	Y	S	S	S	C	C
Loops	Preferred	S	S	Y	S	Y	S	C	C
Ensemble Sets	Preferred	S	S	Y	S	Y	S	C	Y
Monte Carlo Iteration	Desired	S	S	S	S	C	S	Y	C
Sensitivity Analysis	Desired	S	S	S	S	C	C	C	C
Uncertainty Analysis	Desired	S	S	S	S	C	C	C	C

Selection Criteria – Data Management

Ability to Satisfy a Criterion: Y-yes out of the box, S-with Scripting, C-with Coding, N-no does not support

Data Management Criterion	Importance	OSM3/CISP	ESMF	HydroCouple	CSDMS	Delft-FEWS	Delta Shell	HEC-WAT	HEC-RTS
Does the framework support/facilitate automated configuration file and time series management?	-	-	-	-	-	-	-	-	-
Data Acquisition	Desired	C	C	C	C	Y	C	C	Y
Boundary Condition Management	Must	C	C	Y	Y	Y	Y	Y	Y
Alternative Configurations	Must	C	C	C	C	C	C	Y	Y
Analysis Period Specifications	Must	C	C	C	C	Y	Y	Y	Y
Simulation (run) Management	Must	C	C	S	Y	Y	Y	Y	Y
Forecasting Support	Desired	C	C	C	C	Y	C	C	Y
Planning Support	Must	C	C	C	C	Y	C	Y	C
Configuration Version Control	Preferred	C	C	C	C	C	C	S	S
Result Posting and Archiving	Preferred	C	C	C	C	C	C	S	Y

Selection Criteria – User Interface

Ability to Satisfy a Criterion: Y-yes out of the box, S-with Scripting, C-with Coding, N-no does not support

User Interface Criterion	Importance	OSM3/CISP	ESMF	HydroCouple	CSDMS	Delft-FEWS	Delta Shell	HEC-WAT	HEC-RTS
What user interface capabilities can the framework provide to improve the useability, efficiency, and transparency of modeling activities?	-	-	-	-	-	-	-	-	-
Configure model linking	Must	Y	Y	Y	Y	Y	Y	Y	Y
Model parameter editing	Desired	Y	C	Y	Y	S	C	Y	Y
Run control	Must	Y	C	C	Y	Y	Y	Y	Y
Alternative Management	Must	C	C	C	C	C	C	Y	Y
Plotting Results	Must	C	C	C	Y	Y	Y	Y	Y
Reporting	Must	C	C	C	C	C	C	C	C
Workflow Guidance	Preferred	C	C	C	C	C	C	C	Y

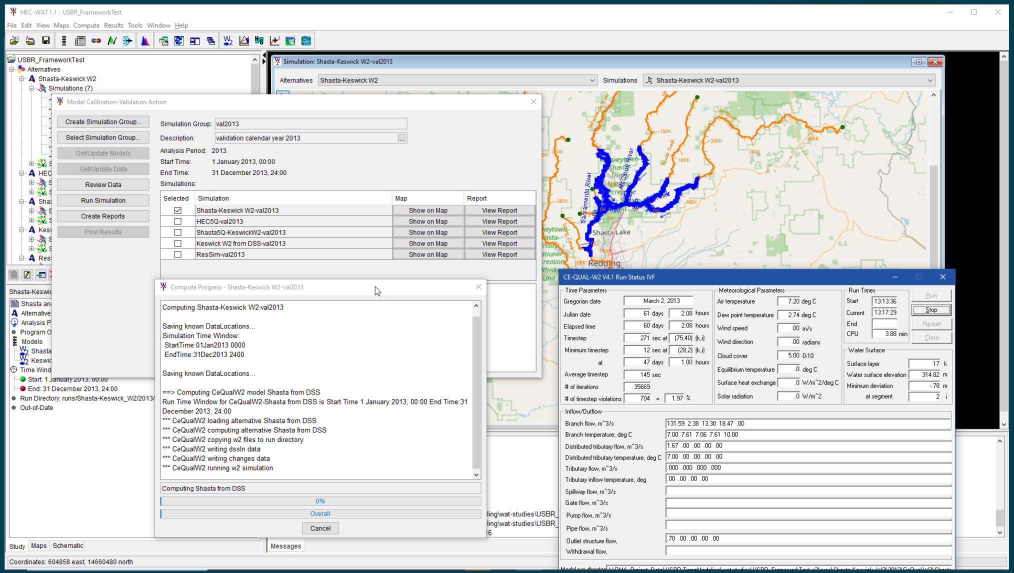
Selection Criteria – Installation and Configuration

Ability to Satisfy a Criterion: Y-yes out of the box, S-with Scripting, C-with Coding, N-no does not support

Installation and Configuration Criterion	Importance	OSM3/CISP	ESMF	HydroCouple	CSDMS	Delft-FEWS	Delta Shell	HEC-WAT	HEC-RTS
Where are model and framework configuration and time series data stored?	-	-	-	-	-	-	-	-	-
Desktop Workstation	Must	Y	Y?	Y	C	Y	Y	Y	Y
Local Server	Preferred	C	C	C	Y	Y	C	Y	Y
Cloud Server	Desired	C	C	C	Y	Y	C	Y	Y
Where are computations performed?	-	-	-	-	-	-	-	-	-
Desktop Workstation	Must	Y	Y?	Y	C	Y	Y	Y	Y
Local Server	Preferred	Y	Y	Y	Y	Y	C	Y	Y
Cloud Server	Desired	Y	Y	Y	Y	Y	C	Y	Y
What kind of software application is the primary user interface that model operators will interact with?	-	-	-	-	-	-	-	-	-
Desktop Application	Must	C	C	Y	C	Y	Y	Y	Y
Web Application	Desired	C	C	C	Y	C	C	C	C
What is the primary development language for the framework?	-	-	-	-	-	-	-	-	-
Java	Preferred	x	–	–	–	x	–	x	x
Python	Preferred	–	–	?	x	–	–	x	x
.NET	Desired	–	–	–	–	–	x	–	–
C/C++/Fortran	Not Desired	–	x	x	–	–	–	–	–

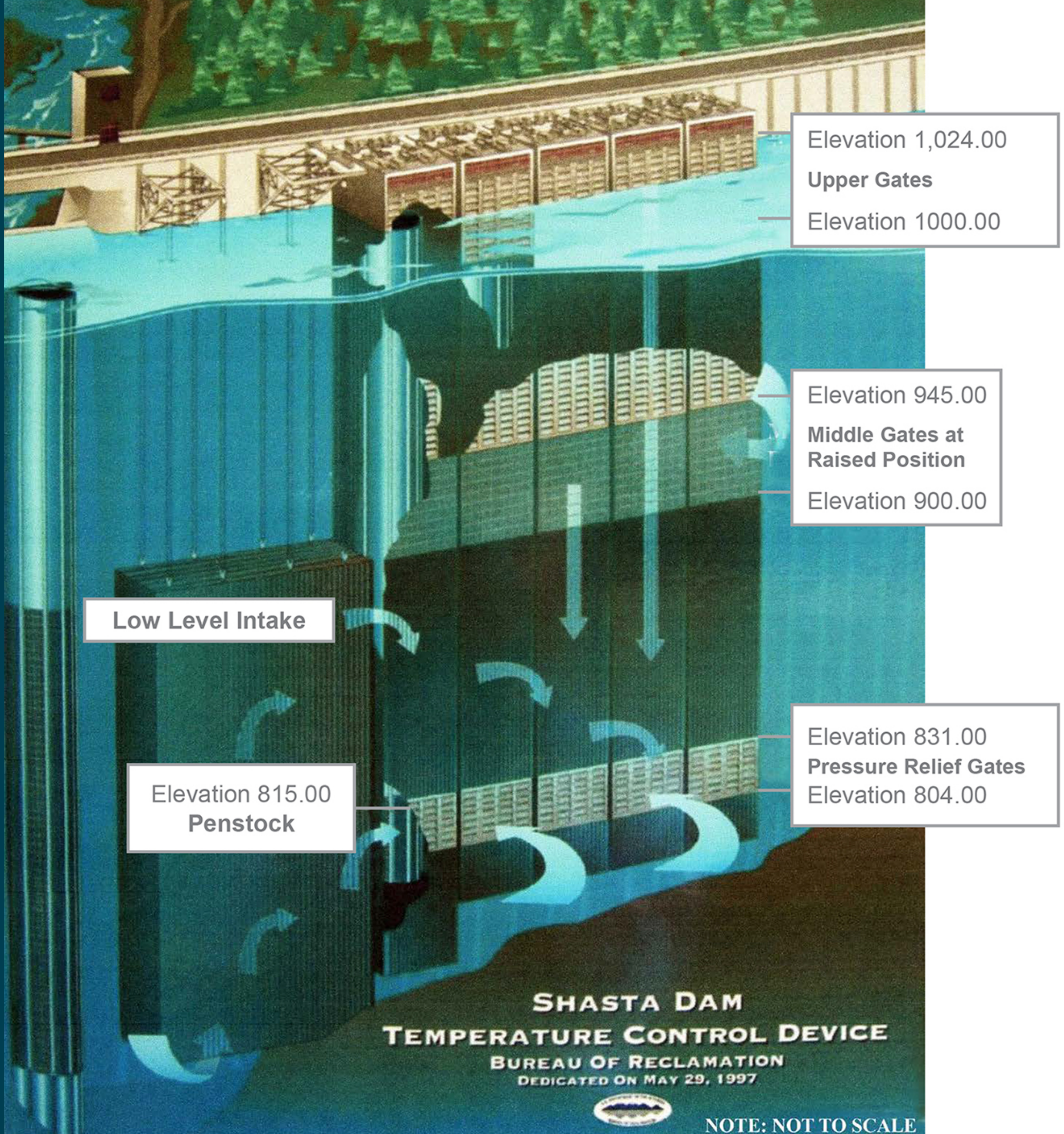
Initial Recommended Framework

- HEC-Watershed Analysis Tool (HEC-WAT)
  - Product of the USACE Hydrologic Engineering Center
  - Freely Distributable
  - Supports local and Cloud based computation
  - Existing support for CE-QUAL-W2, HEC-ResSim, and HEC-RAS
  - Plug-in Application Programming Interface (API) for extension of modeling capabilities
    - Data Management
    - User Interface
    - Computational Model Support
    - Reporting



https://www.hec.usace.army.mil/software/hec-wat/

Questions


Elevation 1,024.00
Upper Gates
Elevation 1000.00
Elevation 945.00
Middle Gates at Raised Position
Elevation 900.00
Low Level Intake
Elevation 831.00
Pressure Relief Gates
Elevation 804.00
Elevation 815.00
Penstock
SHASTA DAM
TEMPERATURE CONTROL DEVICE
BUREAU OF RECLAMATION
DEDICATED ON MAY 29, 1997
NOTE: NOT TO SCALE

Short Stretch Break

Water Temperature Model and Framework Review and Selection

- Part II: Initial Application

Randi Field, Civil (Hydrologic) Engineer, CVO

Photo credit: John Hannon, Reclamation

Water Temperature Model and Framework Review and Selection

- Trial Implementation of the Recommended Modeling Framework

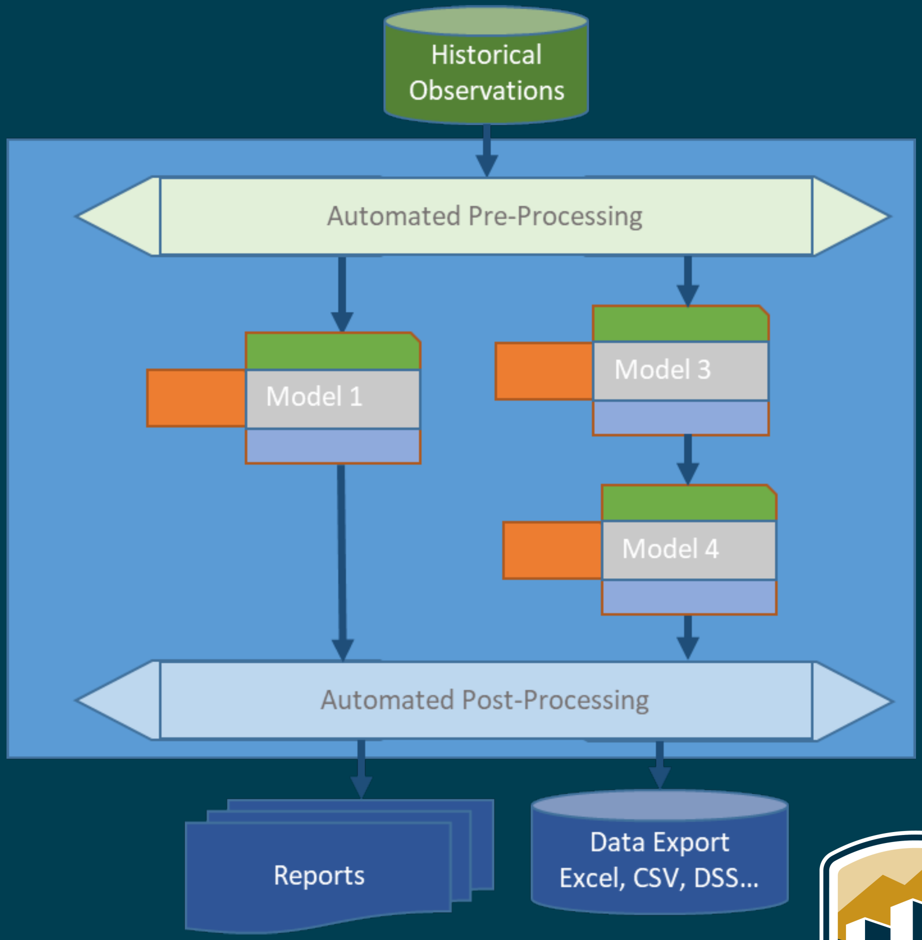
John DeGeorge, Ph.D., P.E., RMA

Modeling Framework Test

- Purpose of the Modeling Framework Test
- Models in the Test
- Use Cases
- HEC-WAT Implementation
  - Workflow Action Plug-in
  - Input Data Review
  - Simulation
  - Automated Reports
- Next Steps

Purpose of the Modeling Framework Test

- Demonstrate
  - Running several models from a common set of input data
  - Using a guided workflow to accomplish a modeling objective (“Use Case”)
    - Validation of a set of models using newly available data as the first example
  - Creating reports from several models using a common report format



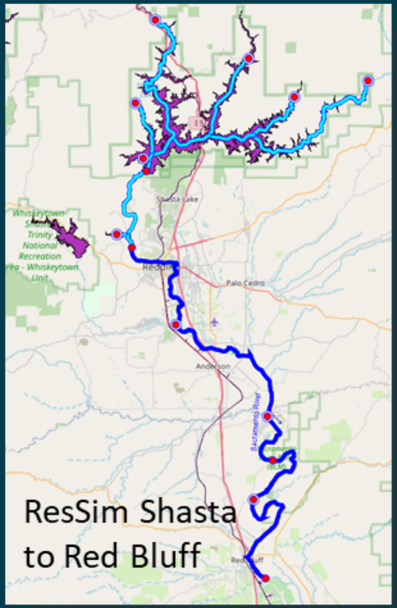
Models in the Test

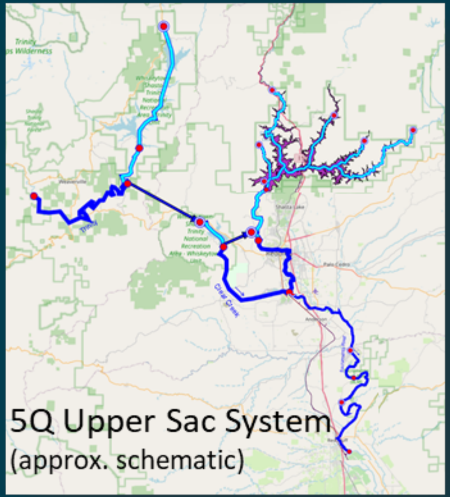
- CE-QUAL-W2, Shasta and Keswick Reservoirs
- HEC-ResSim, Shasta and Keswick* Reservoirs, Sacramento River to Red Bluff
- HEC-RAS**, Sacramento River to Red Bluff
- HEC5Q***, Upper Sacramento System

*HEC-ResSim Keswick representation very simple at this point

**HEC-RAS WQ not yet tested

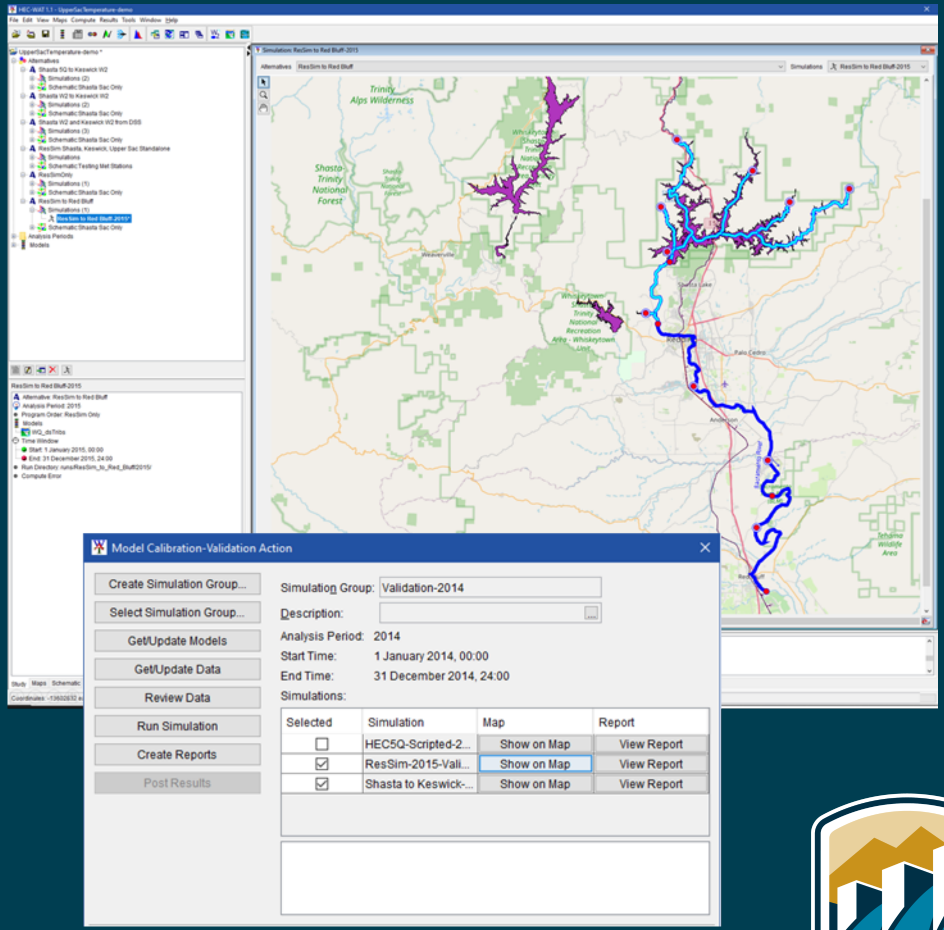
***HEC5Q results are provided for comparison





Activities associated with this Test

- WAT plug-in development to manage validation use case workflow
- Improvement of existing CEQUAL-W2 plug-in for HEC-WAT to support better support linking and reporting
- Basic configuration of HEC-RAS Geometry and Water Quality model below Shasta
- Basic configuration and calibration of HEC-ResSim water quality model for Shasta, Keswick, and upper Sacramento River to Red Bluff
- Implementation of common reporting tool
- Creation of an HEC-WAT study to support model validation simulations 2013-2016



Boundary Conditions

- Meteorologic Data
- Shasta Inflows and Initial Conditions
- Keswick Inflow, Inflow Temperature, and Initial Conditions
- Upper Sacramento Inflow Flow, Inflow Temperature

Time Series Data	W2 Shasta	W2 Keswick	ResSim	RAS	5Q
Air temp	X	X	X	X	-
Dewpoint temp	X	X	X	X	-
Wind Speed	X	X	X	X	X
Wind Direction	X	X	X	X	-
Cloud Coverage	X	X	X	X	-
Shortwave Radiation	X	X	X	X	X
Equilibrium Temperature	-	-	-	-	X
Vertical Profile Initial conditions-Shasta	X	-	X	-	X
Vertical Profile Initial conditions-Keswick	-	X	X	-	X
Pit River Arm inflow time series	X	-	X	-	-
Squaw Creek Arm inflow	X	-	X	-	-
McCloud River Arm inflow	X	-	X	-	-
Sacramento River Arm inflow	X	-	X	-	-
Big Backbone Creek Inlet inflow	X	-	X	-	-
Pit River Arm temp	X	-	X	-	-
Squaw Creek Arm temp	X	-	X	-	-
McCloud River Arm temp	X	-	X	-	-
Sacramento River Arm temp	X	-	X	-	-
Big Backbone Creek Inlet temp	X	-	X	-	-
Combined Shasta Inflow	-	-	-	-	X
Combined Shasta Inflow Temperature	-	-	-	-	X
Shasta local balance flow	X	-	X	-	X
Shasta local balance flow temperature	X	-	X	-	-
Historical Shasta Outlet and TCD Operation**	X	-	X	-	X
Shasta outflow (Keswick Inflow)	-	X	-	-	-
Shasta outflow temperature (Keswick inflow temperature)	-	X	-	-	-
Spring Creek inflow	-	X	X	-	X
Spring Creek temperature	-	X	X	-	X
Keswick local balance flow	-	X	X	-	X
Keswick local balance flow temperature	-	X	X	-	-
Keswick outflow	-	-	-	X	-
Keswick outflow temperature	-	-	X	X	-
Clear Creek inflow	-	-	X	X	X
Clear Creek temperature	-	-	X	X	X
Other tributary inflows (Cottonwood, etc.)	-	-	X	X	X
Other tributary temperature (Cottonwood, etc.)	-	-	X	X	X
ACID diversion	-	-	X	X	X

Use Cases

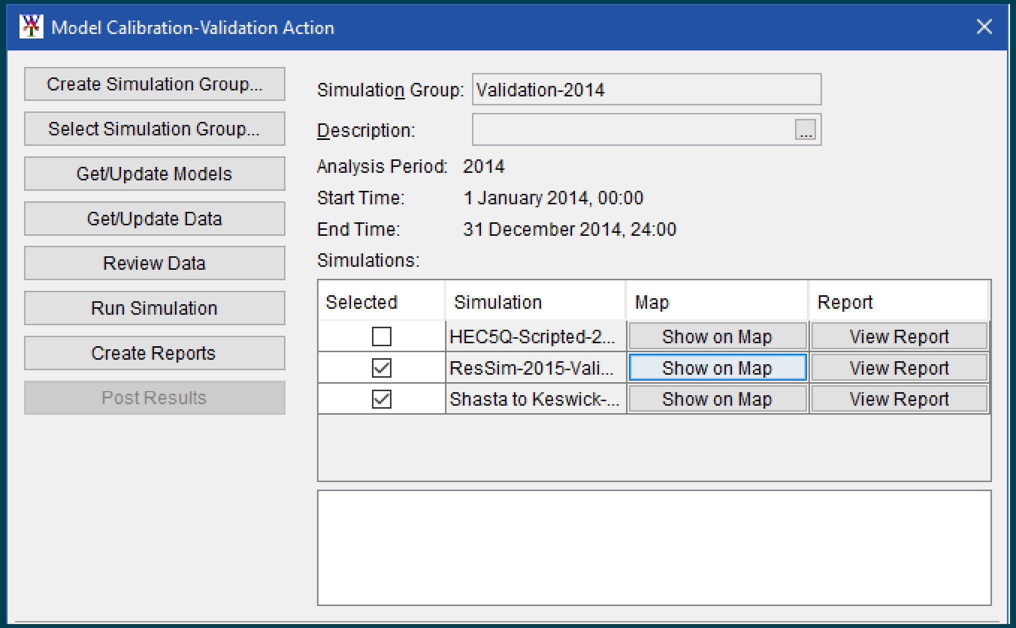
- Calibration
- Validation
- Sensitivity and Uncertainty Analysis
- Temperature Management Plan Development
- Planning Analysis
- Ensemble Simulation

- The example for today’s meeting is model validation

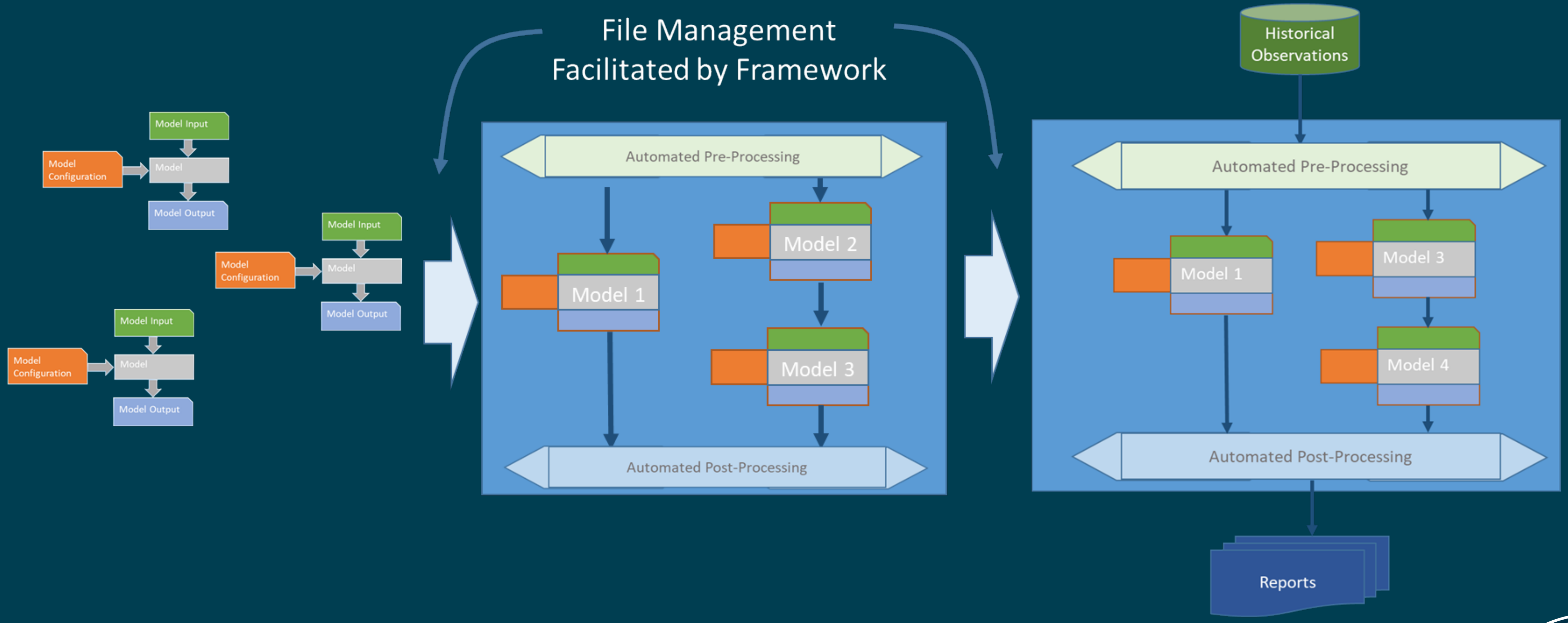
Model Validation Use Case Example

New observed data has become available and the existing model(s) need to be tested with the new data

- Get updated data from the Data Management System (will be demonstrated later after further development)
- Review the new data
- Set up a new set of simulations for the period with new data
- Perform the simulations
- Create reports to document the ability of the existing models to reproduce observations
- Post key results to the Data Management System (will be demonstrated after further development)



Model Data Management

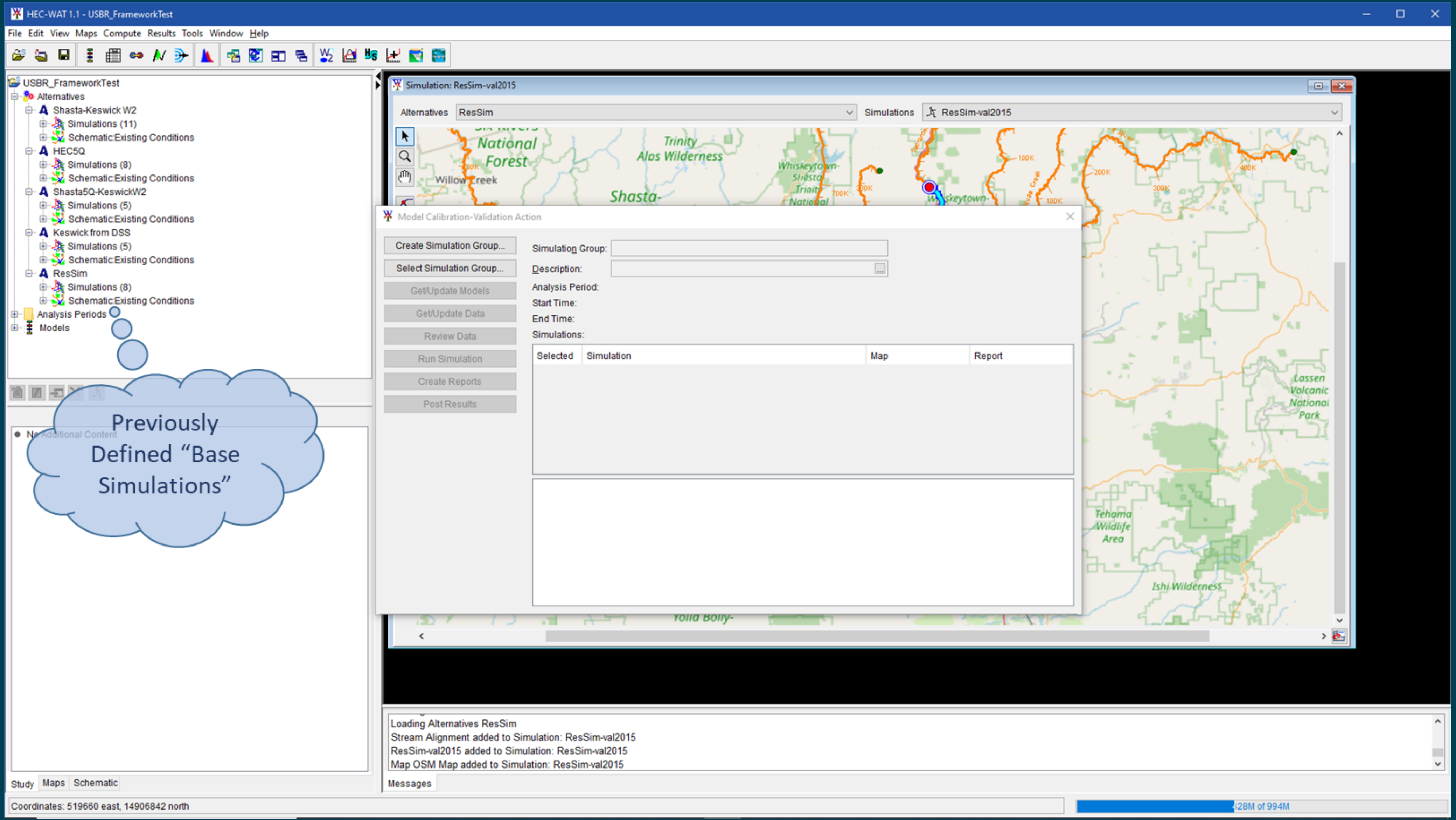


Configuration and Initial Calibration outside of Modeling Framework

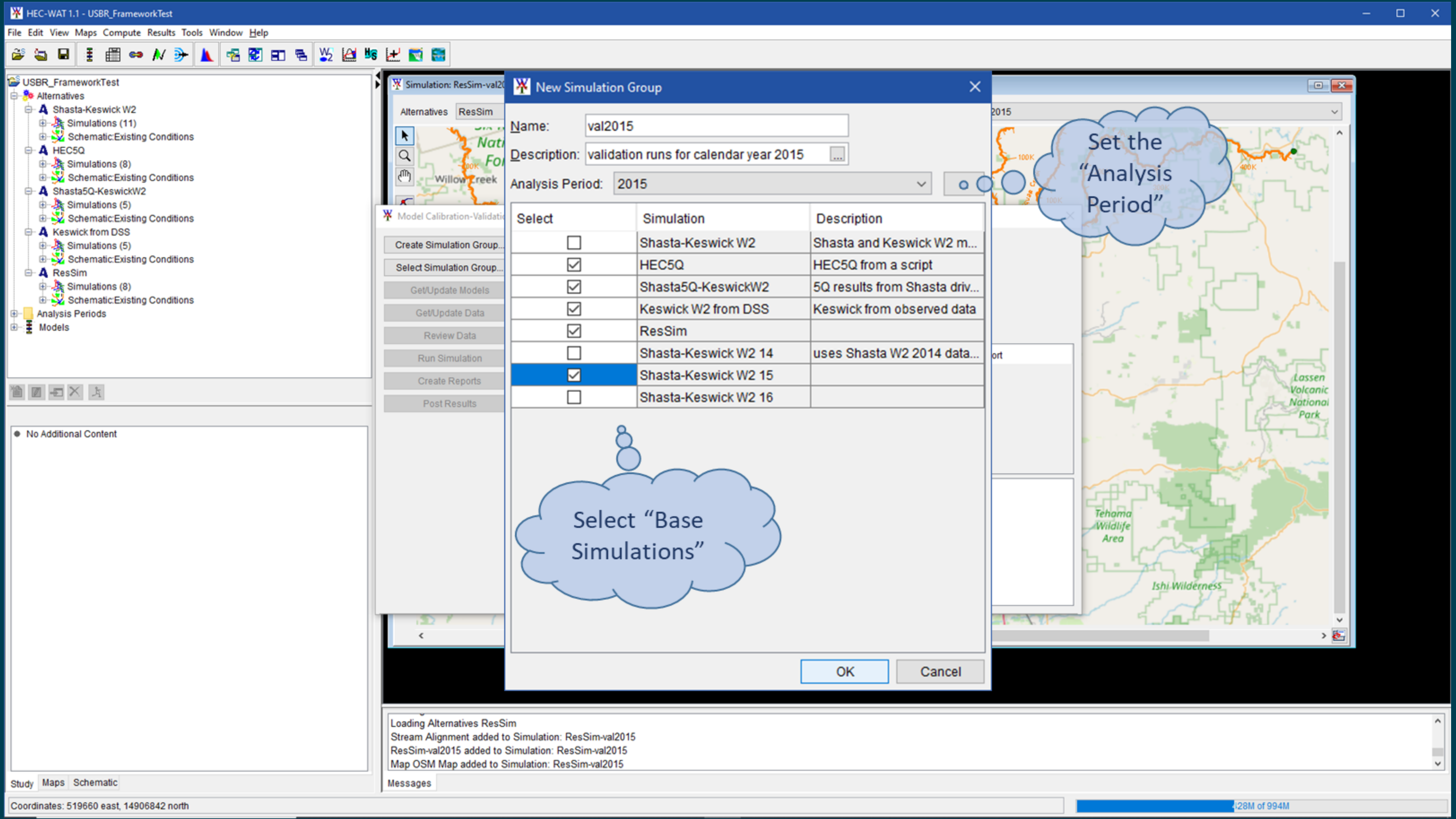
Model Linking within the Framework (“Base Simulations”)

Production runs supporting a Use Case

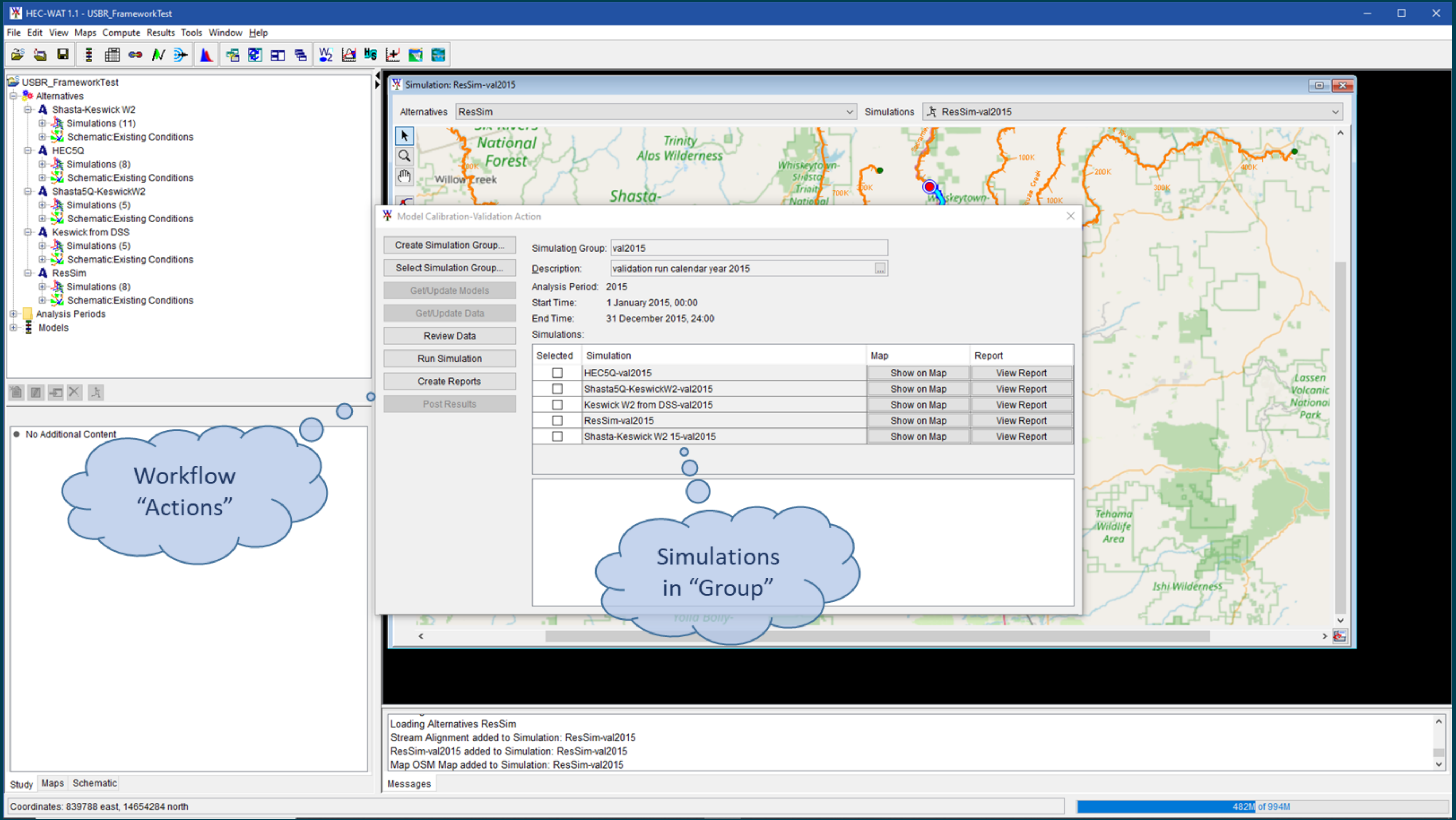
Demonstration Screens - Open the HEC-WAT Study



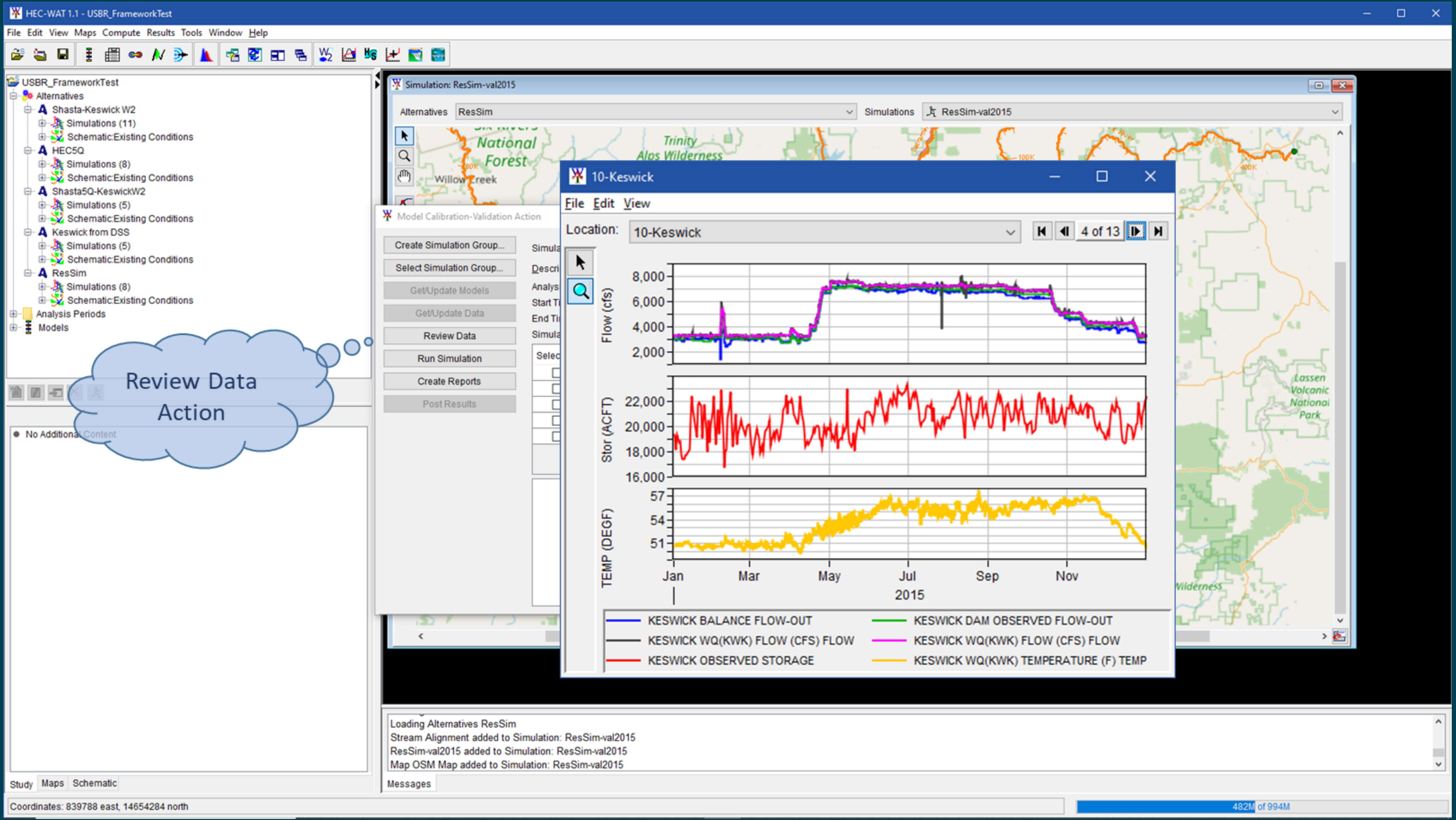
Demonstration Screens – Create a Simulation Group



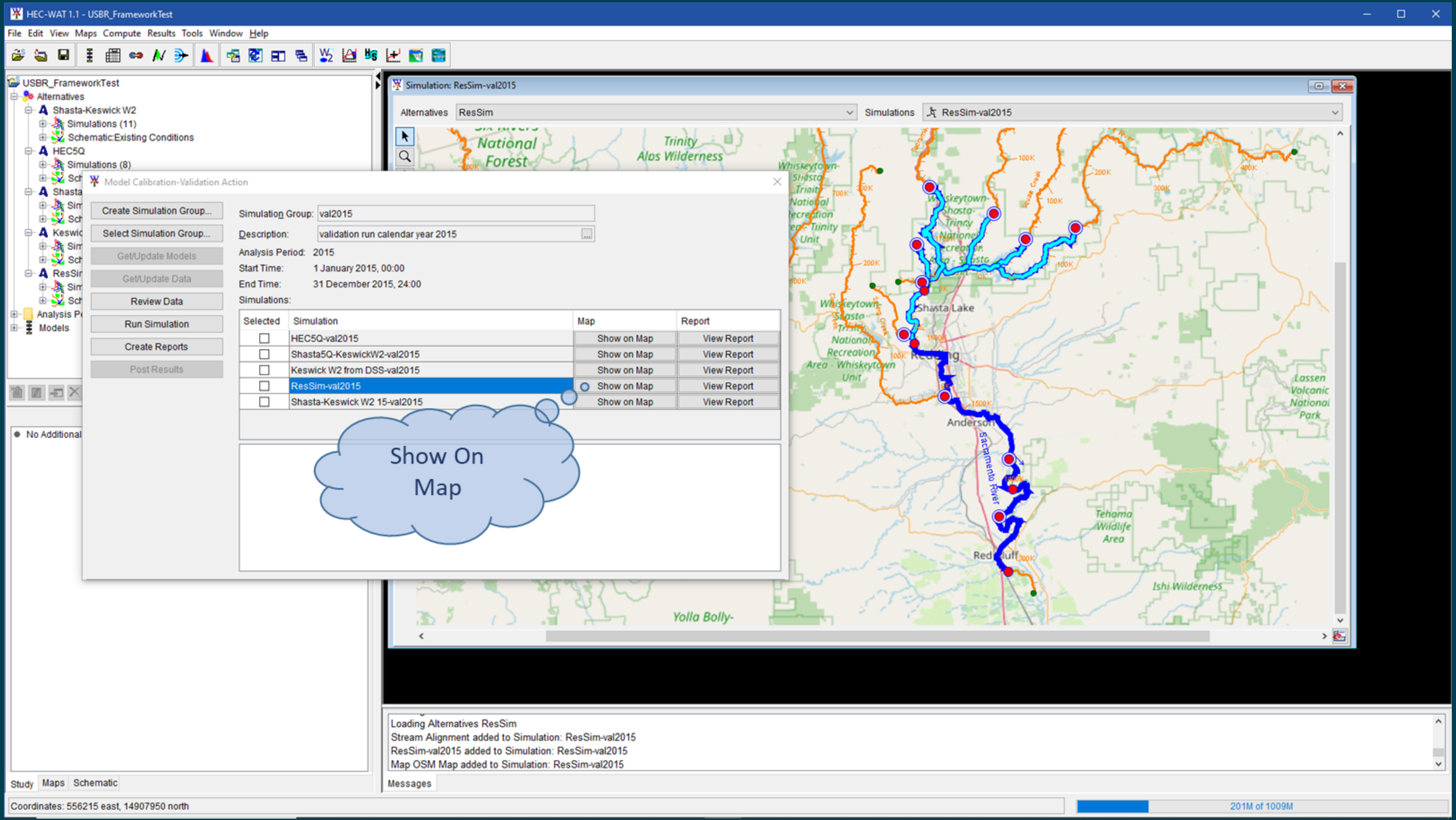
Demonstration Screens – Workflow Action Screen



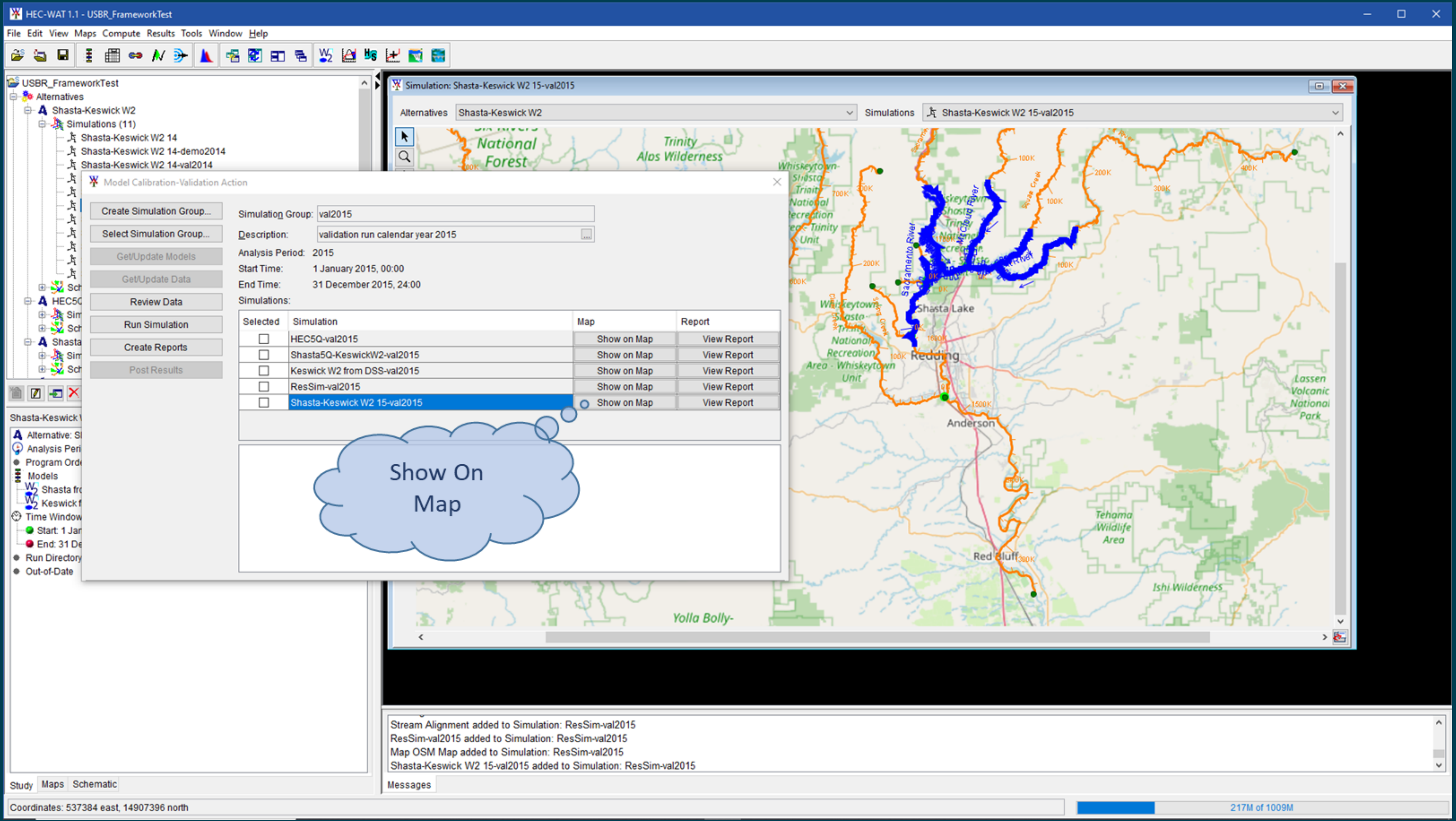
Demonstration Screens – Input Data Review



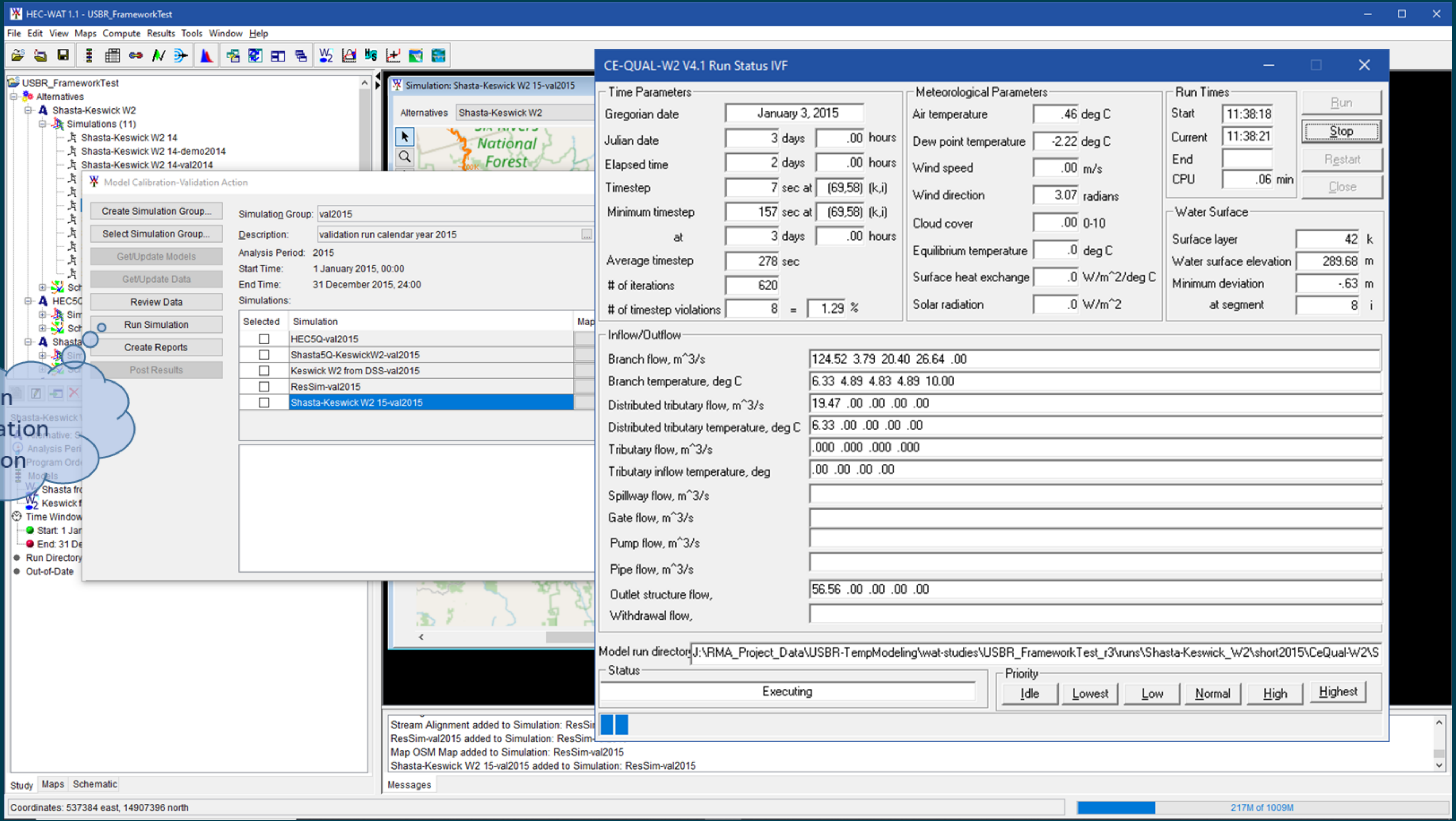
Demonstration Screens – ResSim Model Displayed



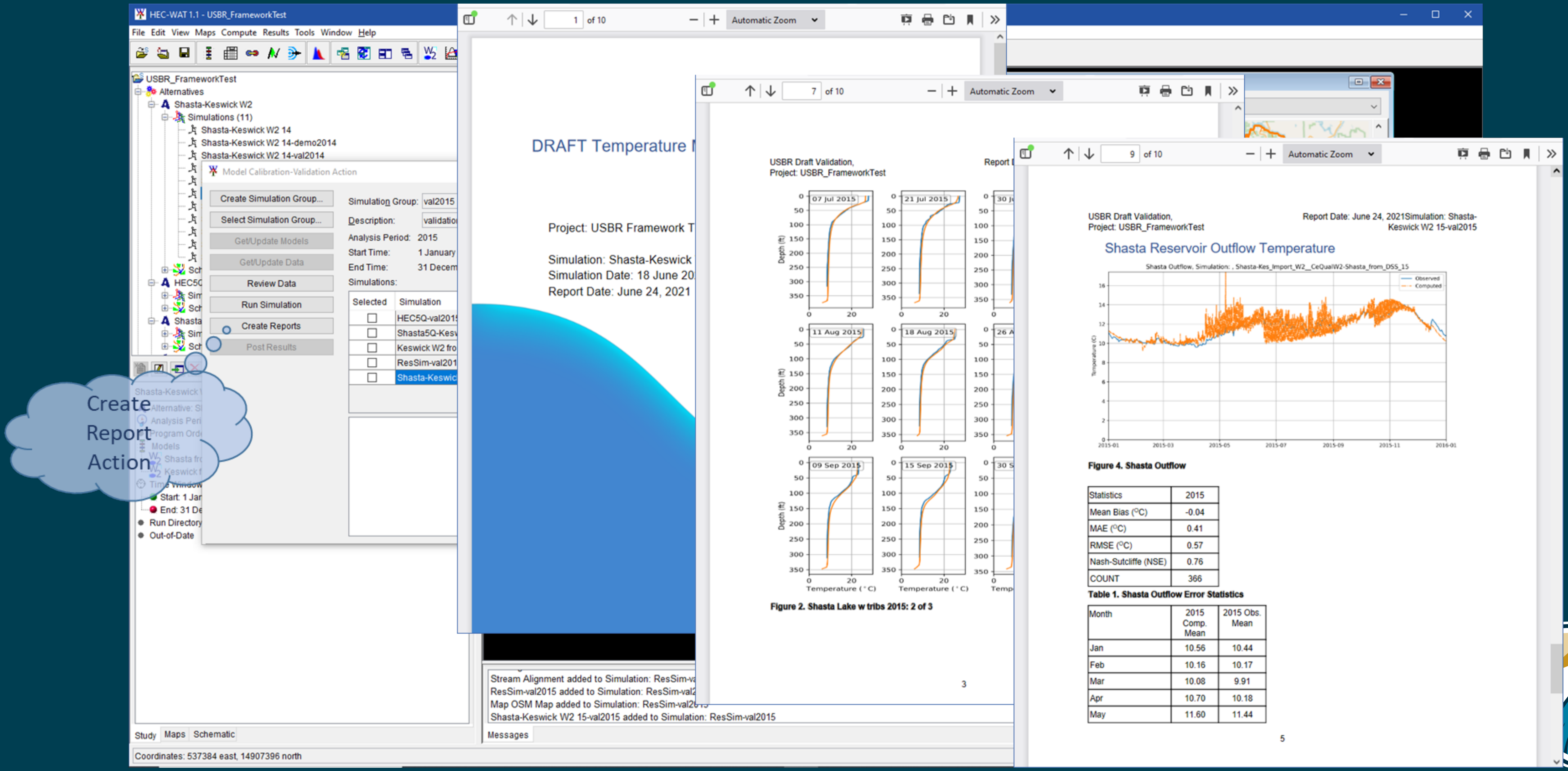
Demonstration Screens – W2 models Displayed



Demonstration Screens – W2 Compute Window



Demonstration Screens – Automated Report



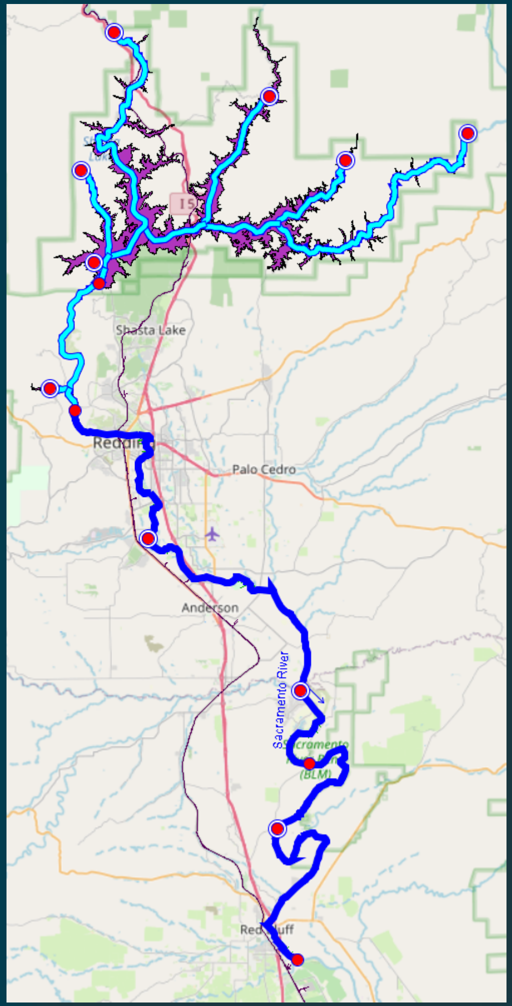
Enhancement to WAT Capabilities
Design Opportunities

Extensions to be implemented using HEC-WAT Plug-in API

- Use of Remote Data Source (extract and post from/to web data service)
- Interface to Facilitate Production Use Cases
- Automated Report Generation
- Version (“Artifact”) Management for model computational code and configuration data sets

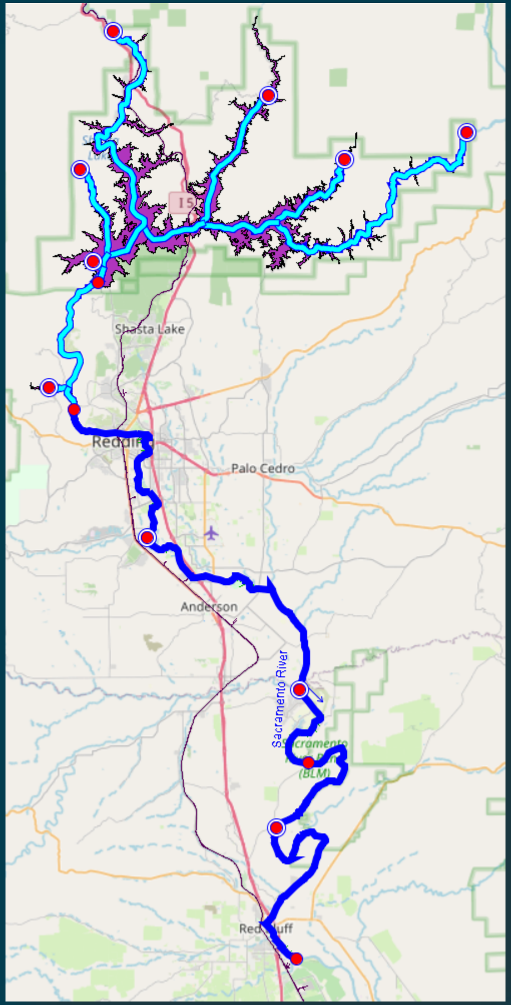
Summary Findings

- HEC-WAT is capable linking and running the selected models in HEC-WAT
- Approximate Computation time for 1 year of simulation
  - HEC5Q - ~10 seconds (6 hour time step)
  - CE-QUAL-W2 Shasta - ~15 min
  - CE-QUAL-W2 Keswick - ~20 min
  - HEC-ResSim - ~45 seconds (1 hour time step)
- Accuracy of the models has not yet been evaluated in detail, further testing in progress
- Initial development of a Use Case Workflow plug-in for HEC-WAT was successful
- Initial implementation of common reporting was challenging, but shows promise

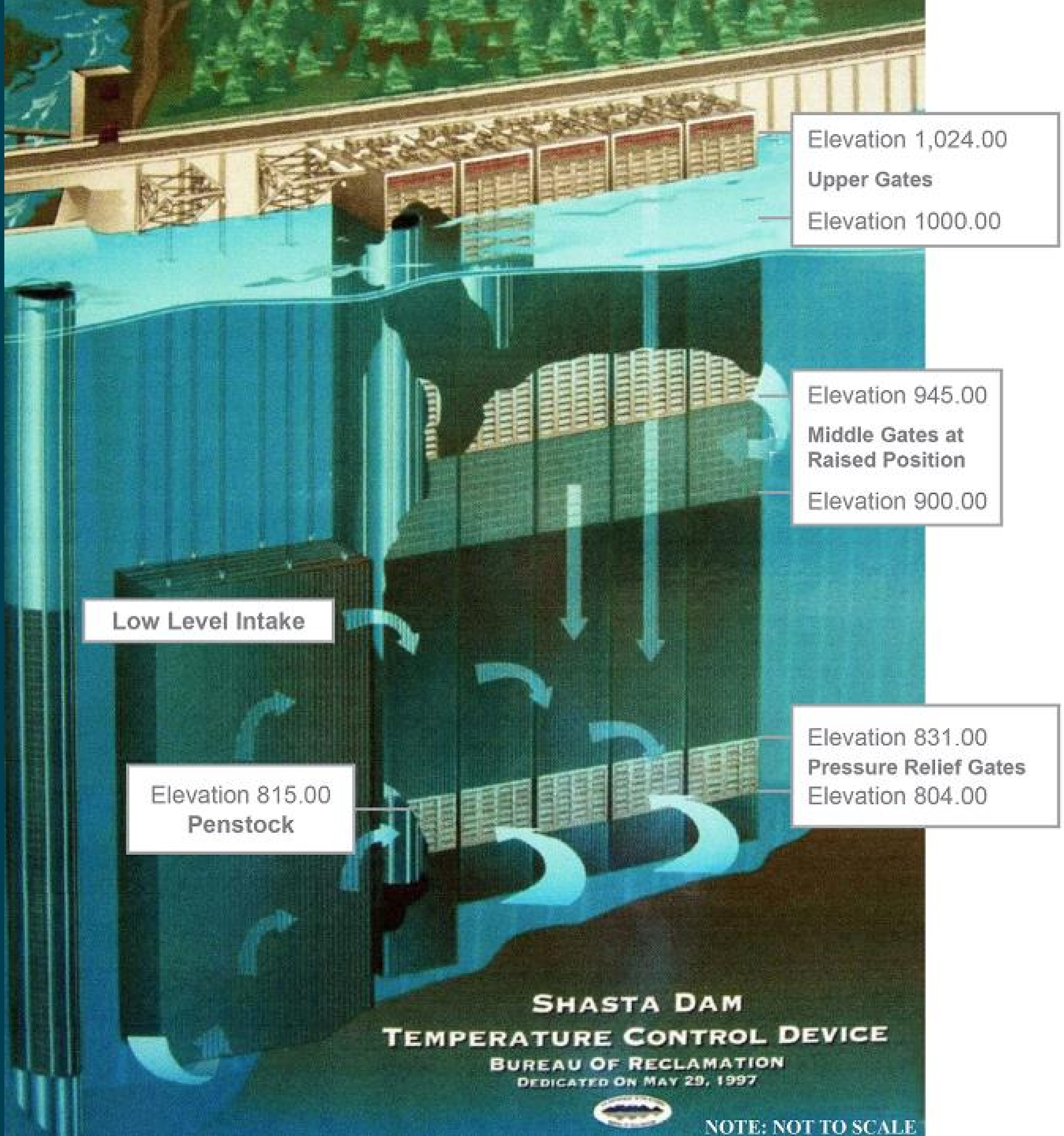


Next Steps

- Refinement of model linking and improvement of model plug-ins to support time dependent operation control
- Common reporting design and model result post-processing to support additional report formats
- Definition and representation of additional use cases
- Further calibration of new models
- Appropriate design to provide correct level of user customization and long-term maintenance
- Toward Deployment
  - Integration with Data Management System
  - Refinement of model/data management concepts to support coordinated team modeling by Reclamation staff and other collaborators
  - Version management for software and model configuration data



Questions



Elevation 1,024.00
Upper Gates
Elevation 1000.00
Elevation 945.00
Middle Gates at Raised Position
Elevation 900.00
Low Level Intake
Elevation 831.00
Pressure Relief Gates
Elevation 804.00
Elevation 815.00
Penstock
SHASTA DAM
TEMPERATURE CONTROL DEVICE
BUREAU OF RECLAMATION
DEDICATED ON MAY 29, 1997
NOTE: NOT TO SCALE

Photo credit: John Hannon, Reclamation

Wrap Up and Next Steps

Randi Field, CVO

Yung-Hsin Sun, Stantec

Upcoming MTC and Topics

- Next MTC Meeting: October 7, 2021; 1 – 4 pm
- Upcoming topics (planned):
  - More about the Framework
  - Model development for Sacramento-Trinity System
- The email for signing up will be out – registration required.

Information Sharing and Contacts

- Project contact: mppublicaffairs@usbr.gov
- Key team members presenting today
  - Randi Field, RField@usbr.gov
  - Mike Deas, Mike.Deas@watercourseinc.com
  - John DeGeorge, jfdegeorge@rmanet.com
  - Yung-Hsin Sun, yung-hsin.sun@stantec.com
- Stakeholder Information SharePoint Site Access:
  - Should be open for business soon.
  - Registered participants will be added for access.
  - Communication: 184031386@stantec.com

Have a Great July 4th.

Be Safe.

NEXT MTC MEETING: October 7, 2021; 1 – 4 pm

BUREAU OF RECLAMATION