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PORTLAND WATER BUREAU
FROM FOREST TO FAUCET

Hydrodynamic and Temperature Modeling to Support Reservoir Operations

Jacob Krall, Ph.D., P.E.

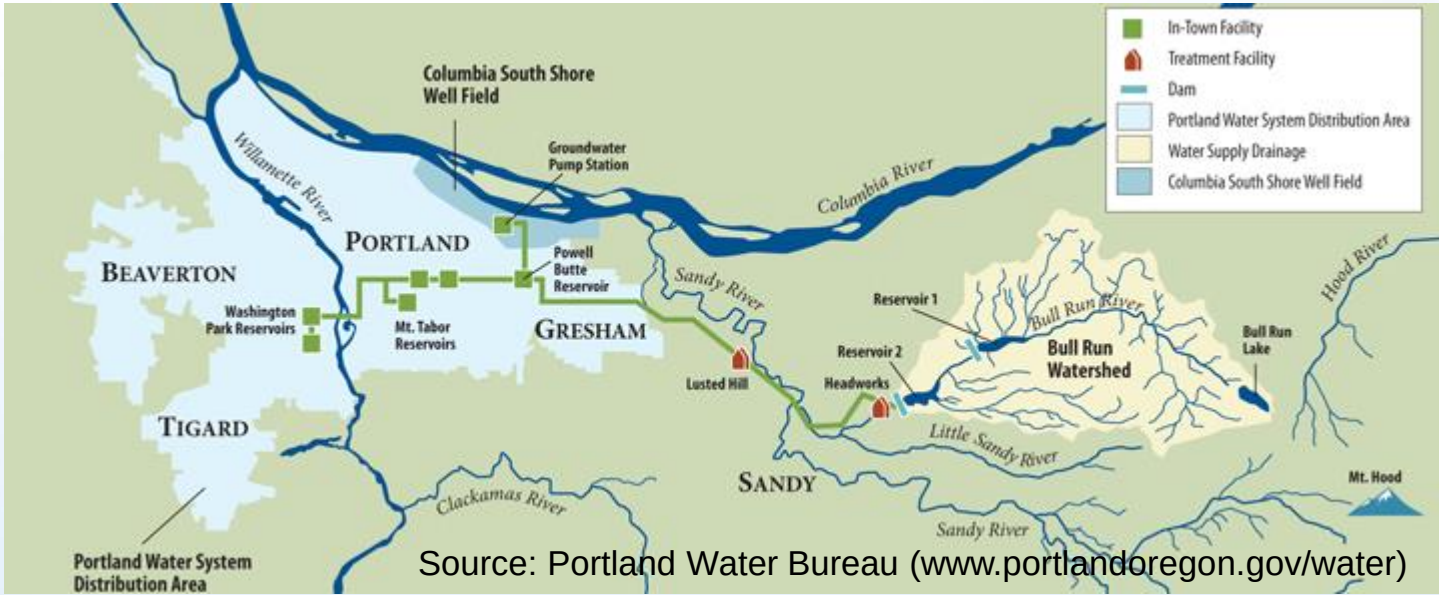
Rob Annear, Ph.D., P.E., Kristin Anderson, and Kavita Heyn

Outline

- Bull Run Reservoir System Overview
- CE-QUAL-W2 Bull Run Model Overview and History
- Modeling to Support Operations of New Multi-Level Intake Structure
- Summary
- Q/A

Bull Run Reservoir System Overview

- Primary drinking water source for Portland
- Located 26 miles East of Downtown Portland
- 102 Square Mile Watershed
- Two Reservoirs, total capacity of ~17 Billion Gallons



Source: Portland Water Bureau (www.portlandoregon.gov/water)

CE-QUAL-W2 Model

- A 2-D (vertical-longitudinal), unsteady finite difference model for hydrodynamics and water quality of rivers, reservoirs, lakes, and estuaries

- Portland State University has been the prime developer of CE-QUAL-W2 for the U.S. Army Corps of Engineers Waterways Experiments Station for the last 20+ years

- Active model development continues in many areas:
  - Numerical schemes
  - Dynamic shading
  - Macrophytes and zooplankton
  - Clear-sky solar formulations
  - Turbulence modeling
  - Turbidity modeling
  - GUI preprocessor

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W2 Capabilities

Hydrodynamics

Water surface elevations
Horizontal/vertical velocities
Temperature/density routines
Flow/head boundaries

Hydraulic Structures

Multiple withdrawal structures
Water level control
Pipes
Distributed tributaries
Tributaries
Multiple withdrawals
Weirs/spillways/gates
Internal weirs

Additional Features

Precipitation
Ice cover
Wind sheltering
Evaporation formulations
Reaeration formulations
Oxygen entrainment at dams

CE-QUAL-W2 Bull Run Model Overview and History

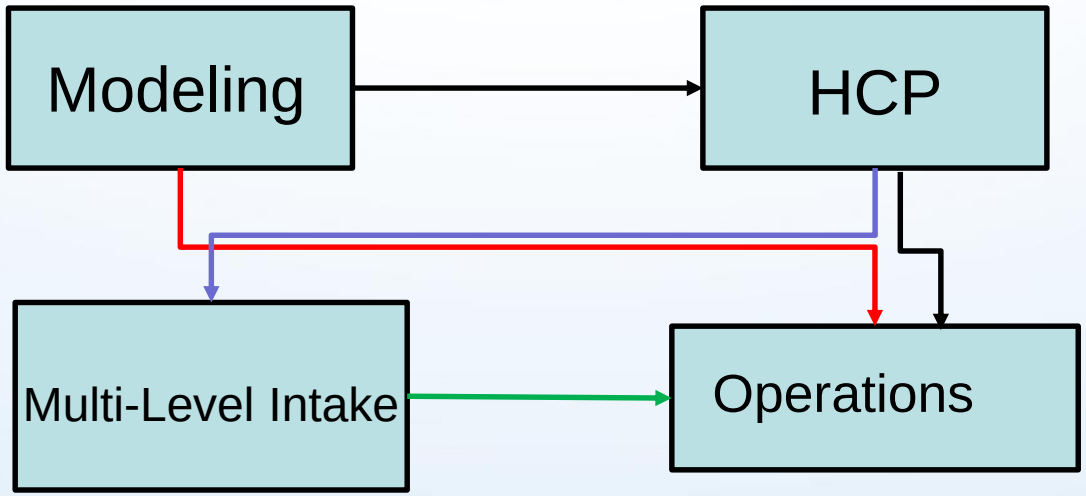
- CE-QUAL-W2 (W2) is a two-dimensional, laterally averaged hydrodynamic and water quality model widely used for river, lake, reservoir and estuary applications

- The W2 model of the Bull Run system was developed by Rob Annear while at Portland State University beginning in 1998.

- Collaboration between PWB and Geosyntec for continued use and development of the model since 2013

Modeling to Support Operations of New Multi-Level Intake Structure

- Previous modeling work informed decision to construct a new multi-level intake structure on the North Tower at Dam 2 as part of The Bull Run water Supply Habitat Conservation Plan (HCP)
- Continued modeling informs operations of the new structure



Modeling to Support Operations of New Multi-Level Intake Tower

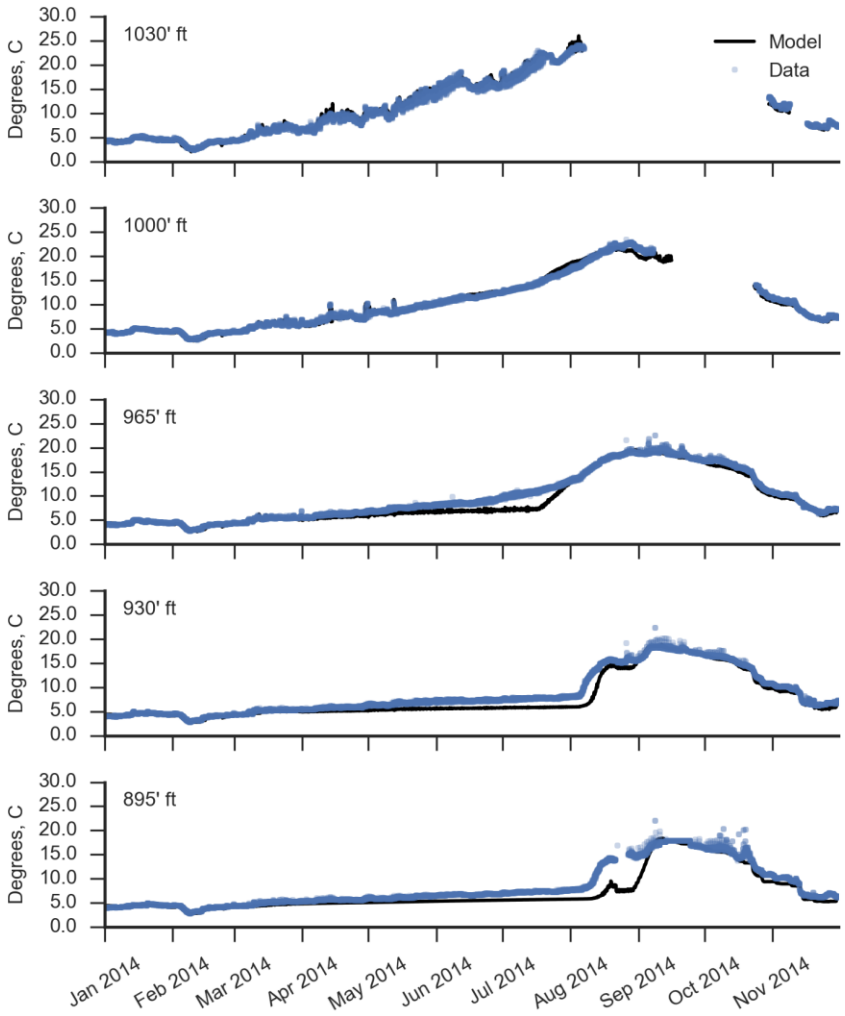
- Bull Run Dam 2 Tower Improvements Project allows the city to draw water from four elevations in Reservoir 2
  - Three gate elevations from the newly constructed North Tower
  - One from the South Tower, at an elevation near the bottom of the Reservoir
- The new infrastructure allows the PWB to better manage water temperatures in Reservoir 2, downstream in the Bull Run River and for in-town demand

Modeling to Support Operations of New Multi-Level Intake Tower

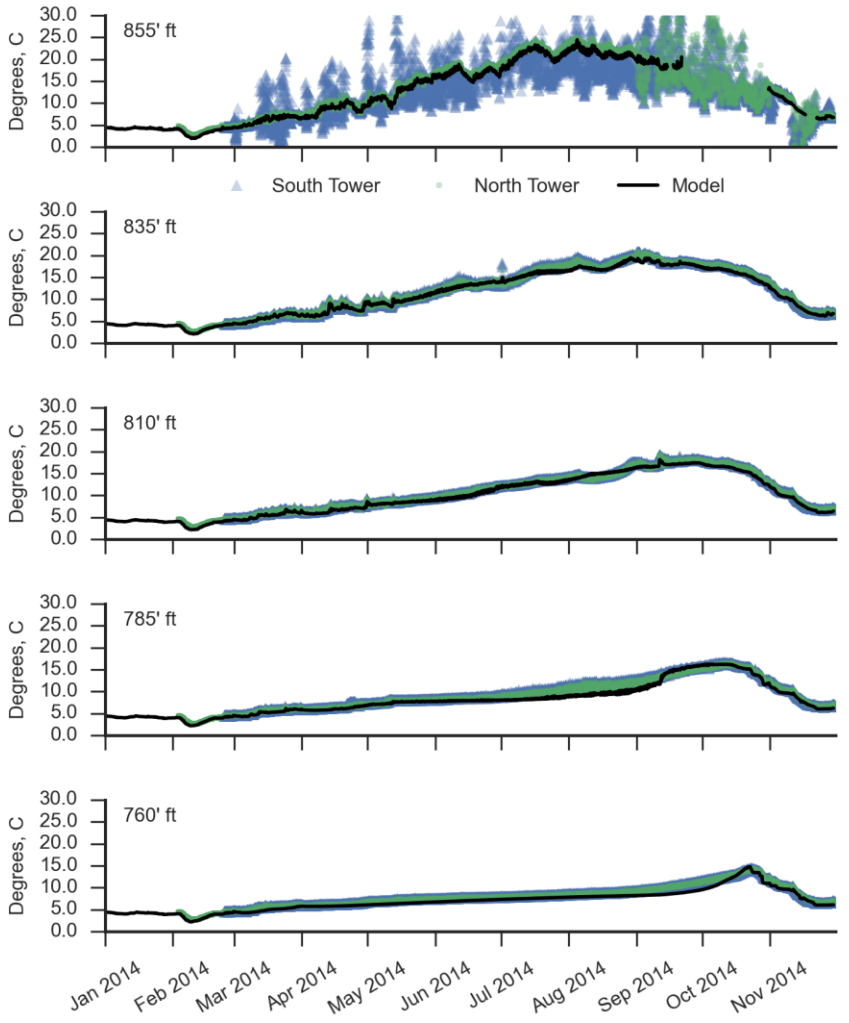
- Modeling work since 2013:
  - Updated Year-2001 and Year-2005 models to the latest version of the W2 code, which added functionality
  - Developed Year-2011, Year-2014 and Year-2015 (in progress) models. Adds more year types for testing management scenarios
  - Calibrated Year-2014 and Year-2015 (in progress) models to reproduce observed reservoir temperatures
  - Developed and analyzed model scenarios, including various North Tower bottom gate closure dates

Sample Model Calibration Plots, 2014

Reservoir 1

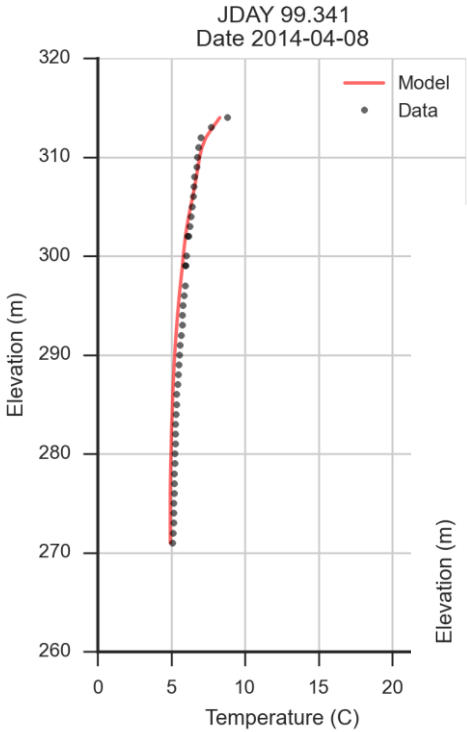


Reservoir 2

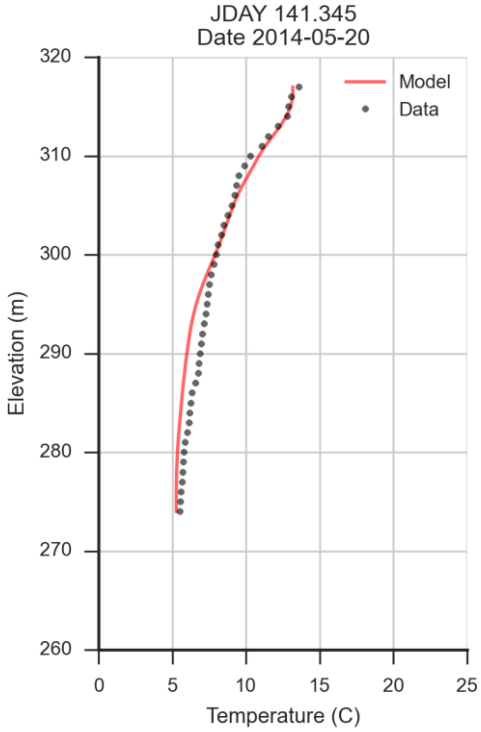


Sample Model Calibration Plots, 2014

Reservoir 1

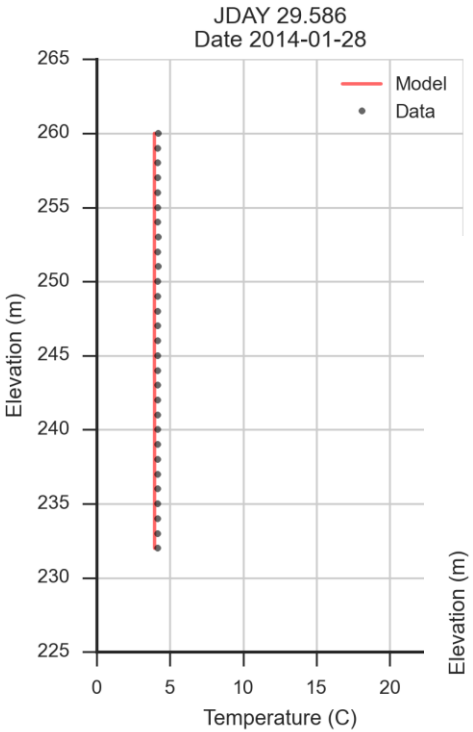


mean squared error: 0.07
ABS mean error: 0.25
root mean squared error: 0.27
mean error: -0.2

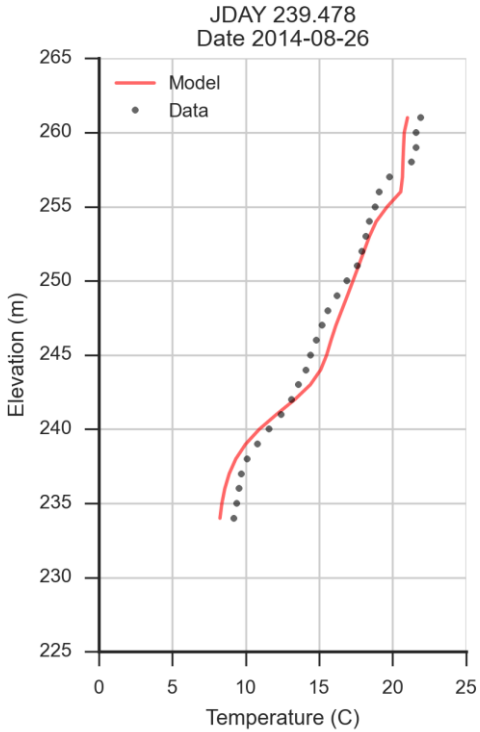


mean squared error: 0.28
ABS mean error: 0.45
root mean squared error: 0.53
mean error: -0.29

Reservoir 2



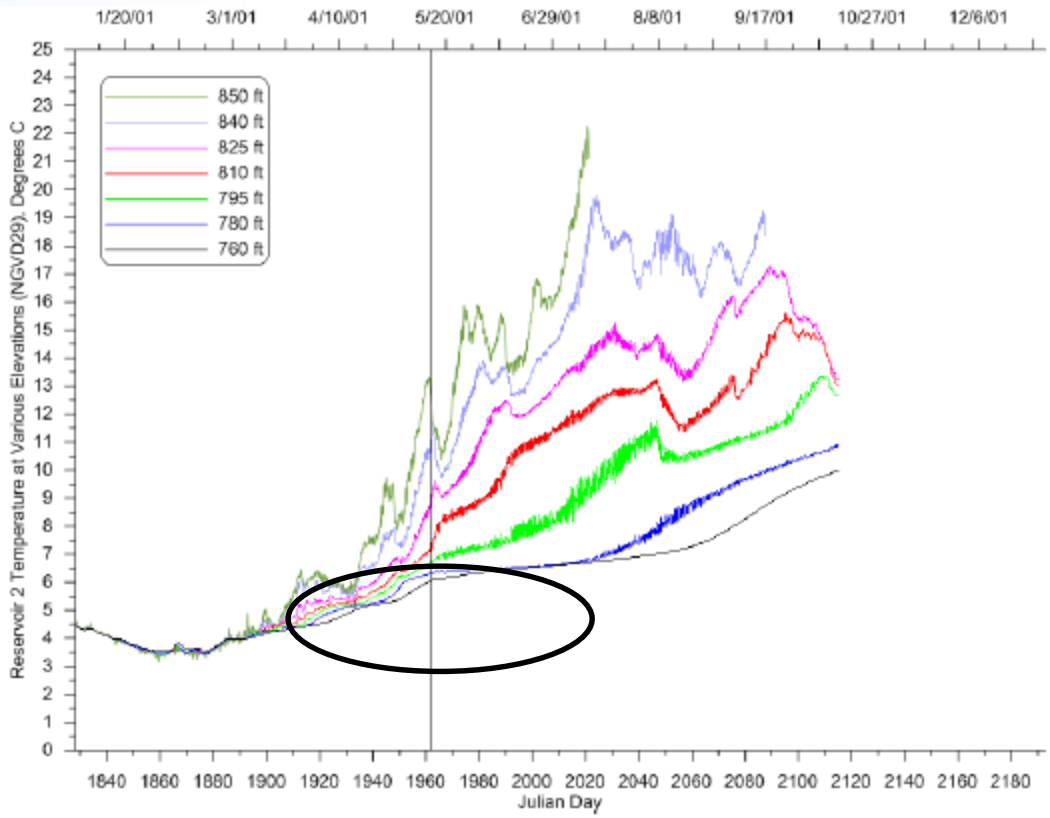
mean squared error: 0.05
ABS mean error: 0.23
root mean squared error: 0.23
mean error: -0.23

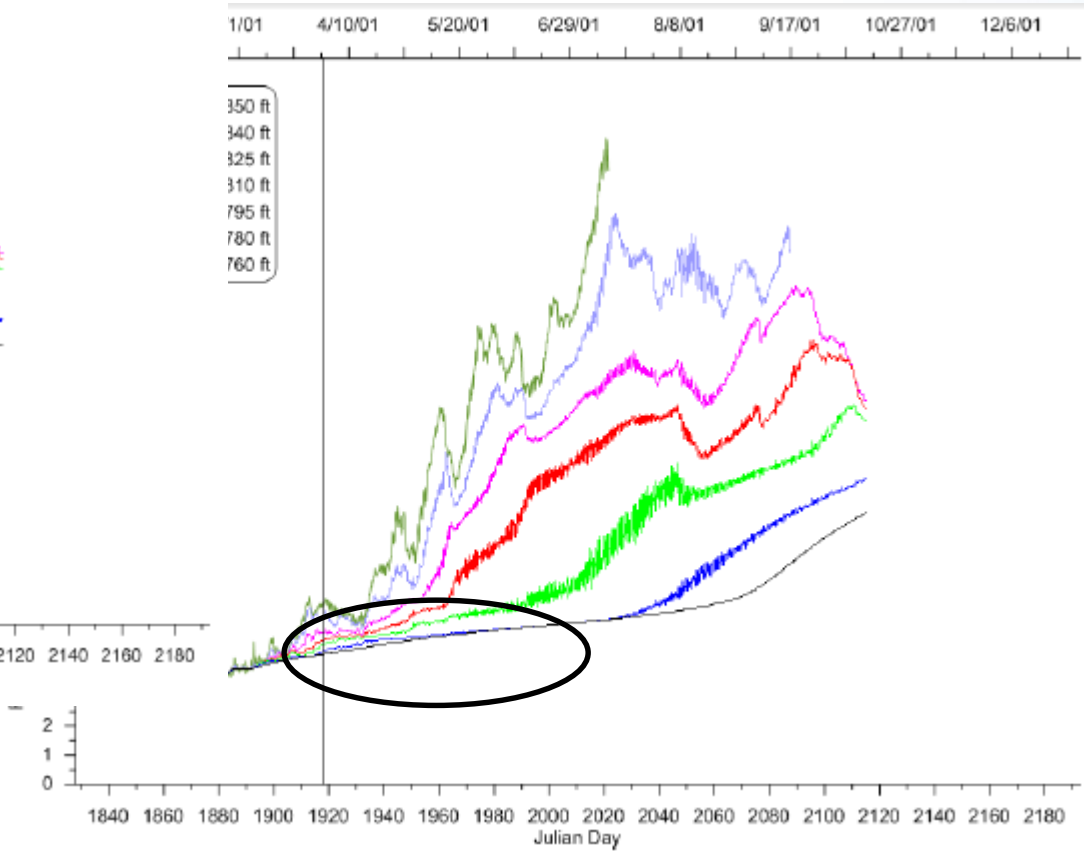


mean squared error: 0.65
ABS mean error: 0.74
root mean squared error: 0.81
mean error: 0.06

Sample Model Results

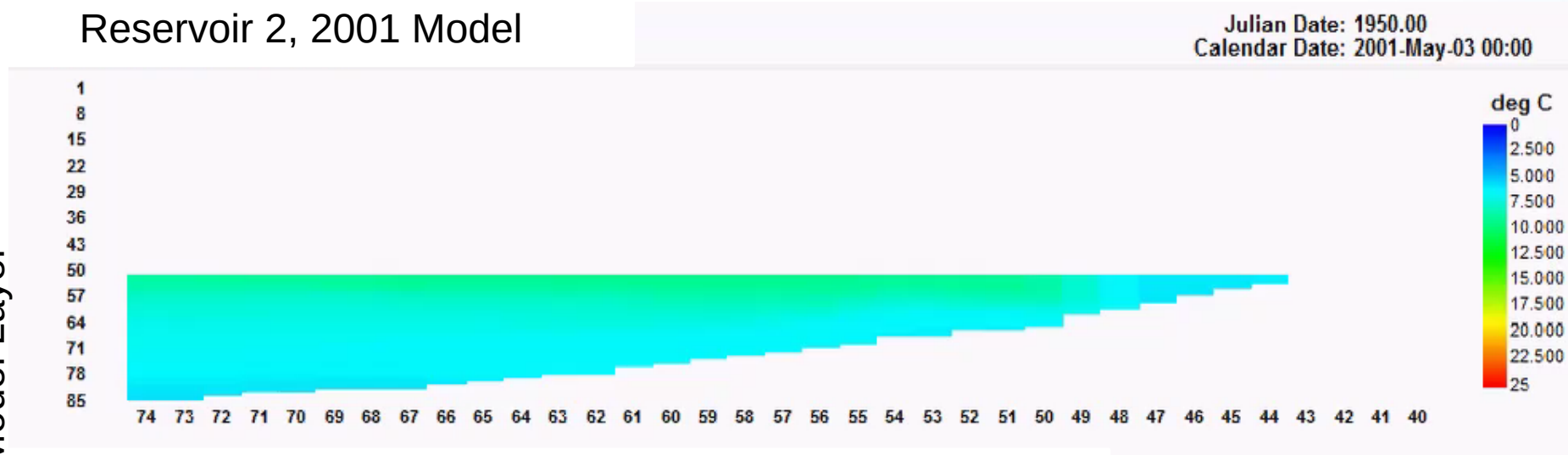
- Earlier gate closure leads to cold water maintained at depth longer.



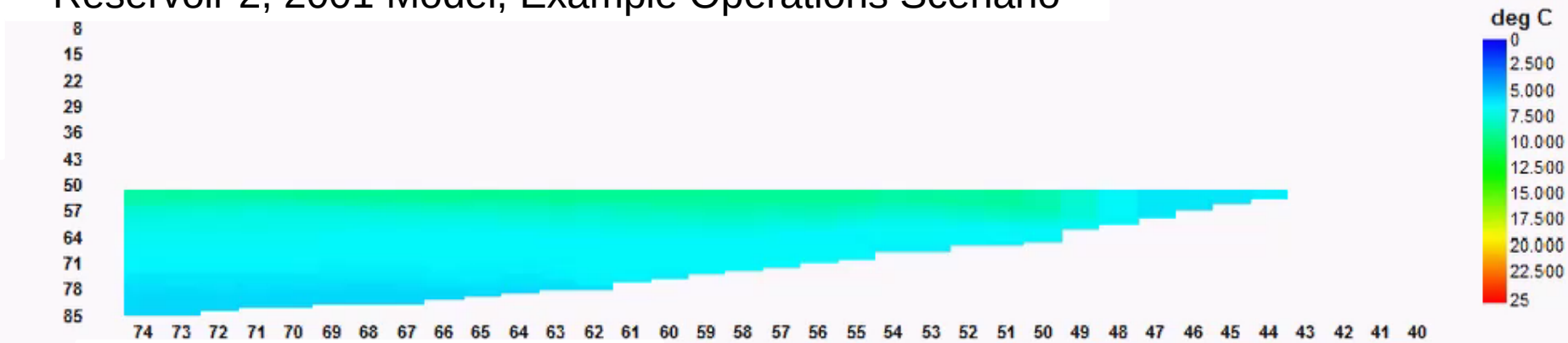


Sample Model Results

Reservoir 2, 2001 Model

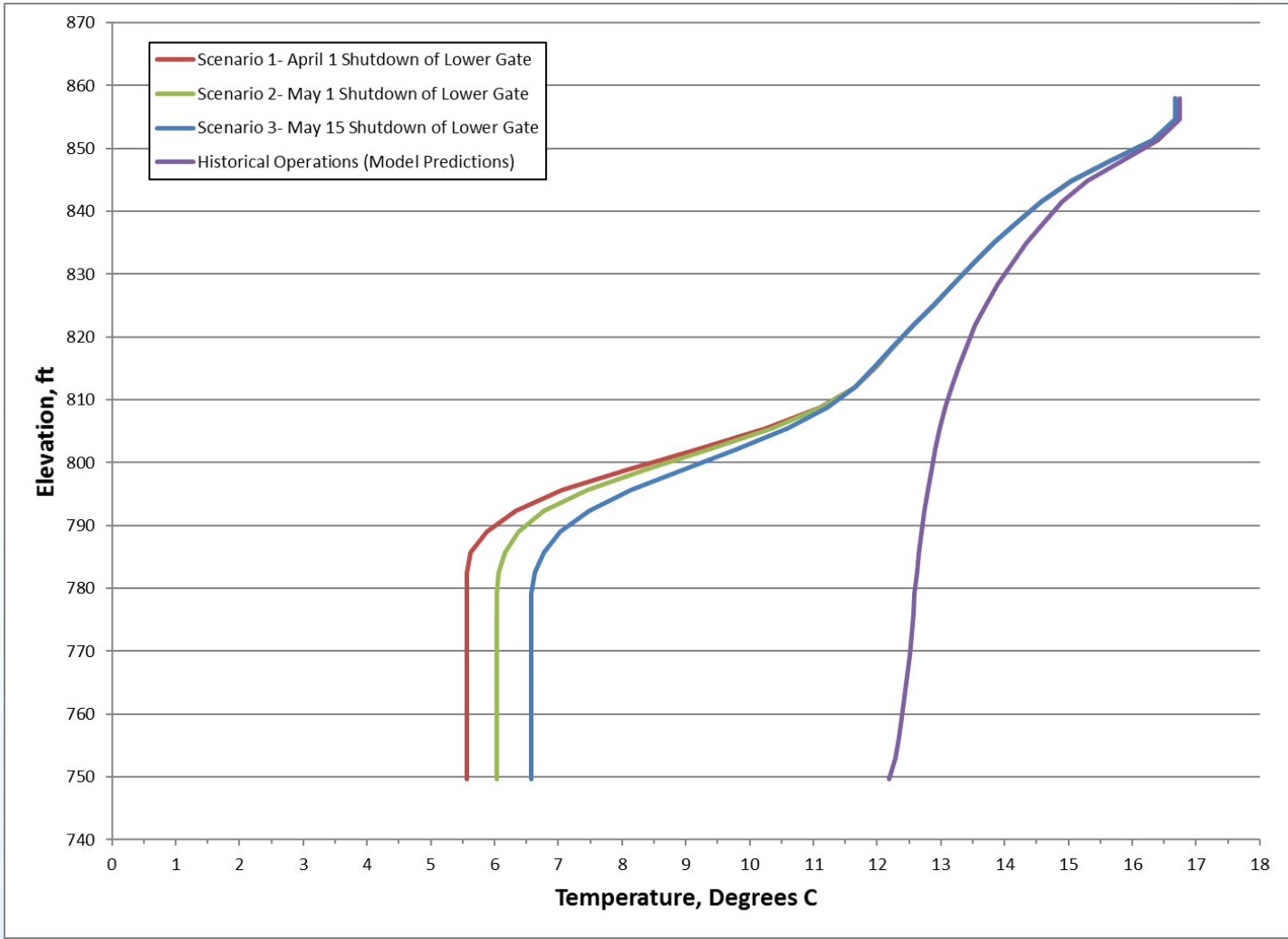


Reservoir 2, 2001 Model, Example Operations Scenario



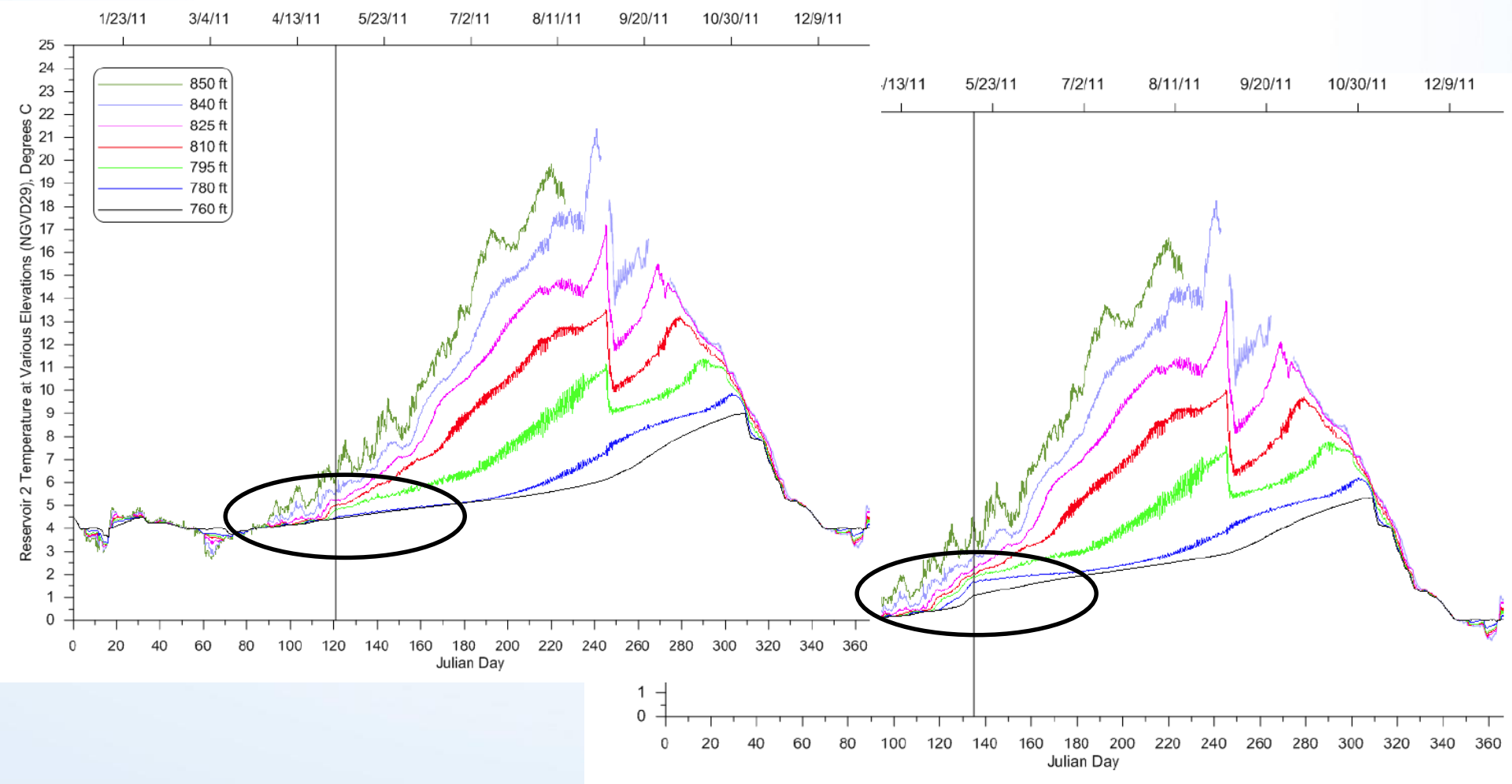
Sample Model Results

- Operating decisions can strongly impact “bank” of cold water in the summer.



Sample Model Results

- Multi-level intake can strongly impact cold-water “bank” even in a high flow year like 2011.



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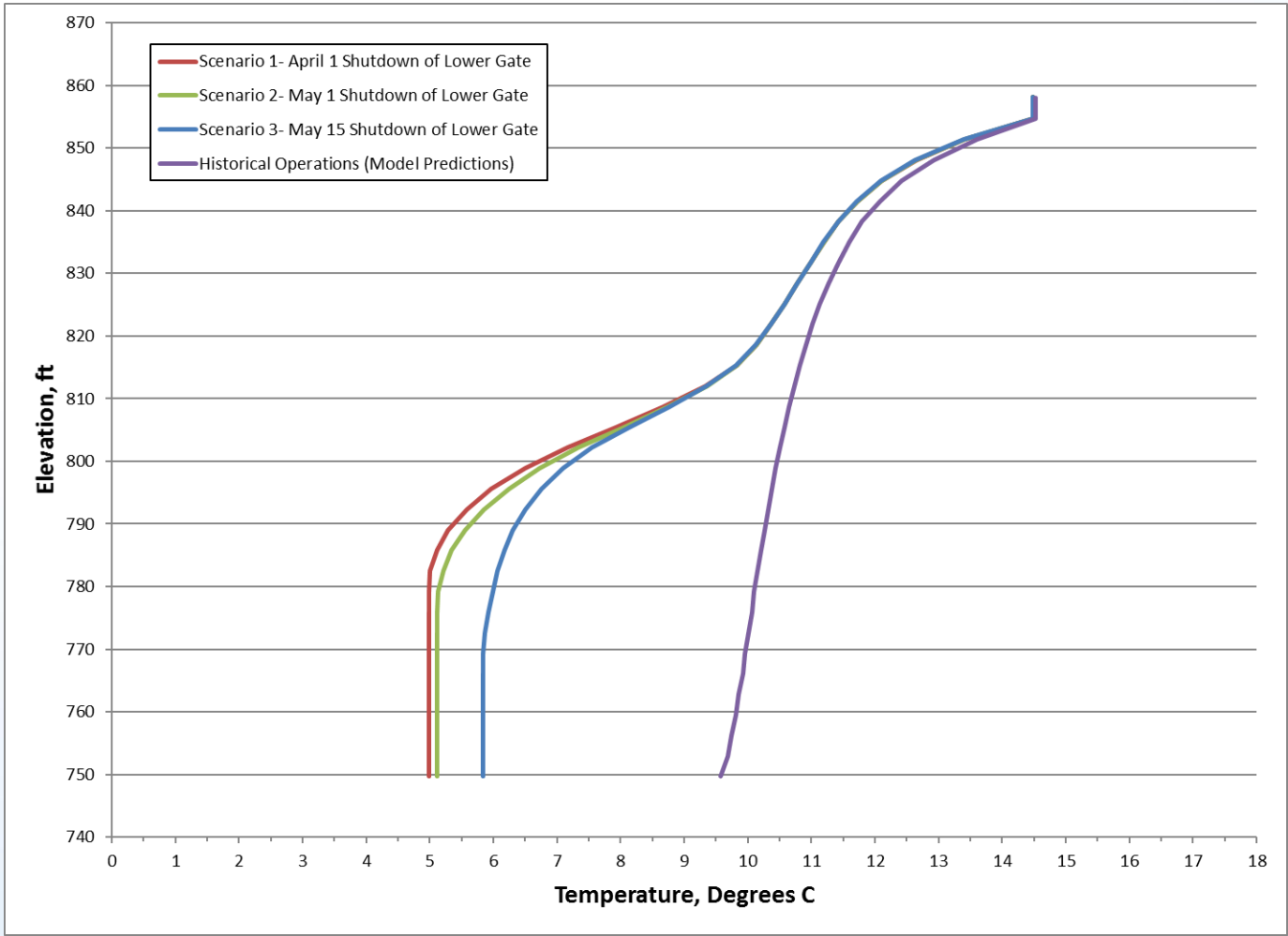

Lessons from Model Results

- New multi-level intake allows for significantly improved operations flexibility.
- Strategic shutoff of lowest elevation on North Tower can maintain cold water “bank” at lower levels of Reservoir 2
  - Remains true for a wide range of flow conditions
- New intake allows for more optimal balancing of multiple important criteria (reservoir temperatures, downstream temperatures, hydropower production, etc.)

Summary and Future Use of the Model

- Hydrodynamic and temperature modeling can be used to inform and support management decisions as well as analyze potential future conditions
  - Test potential reservoir operations
    - E.g. How would 2014 operations have worked in a year hydrologically similar to 2001?
- Analyze potential effects of climate change
    - What might outflow temperatures look like for a median year in the late 2100s under various GCM projections?
    - Work in progress!

- Many other interesting questions could be informed by the model!

Thank you!

Questions?