Temperature Modeling of the Chelan River

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Outline

- Background
- Model Selection
- Temperature Model Development and Calibration
- Preliminary Alternatives Analysis
- Next Steps

Background

- Ecology water quality certification requires:
  - Conduct an additional study of water temperature at the dam face to determine how best to design the new outlet structure to maximize the potential for cold water withdrawal at the base of the dam
  - Develop a Quality Assurance Project Plan for water quality monitoring and temperature modeling
  - Conduct a study to determine the geomorphic influences on water temperatures in the Chelan River in order to address temperature, velocity, depth, and substrate to determine the best methods to achieve the biological objectives for cutthroat trout
  - Conduct a riparian feasibility study to better characterize the opportunities for the establishment of riparian vegetation on the banks of the Chelan River
  - Collect data on temperatures in the Chelan River and, if appropriate, evaluate its ability to comply with the temperature standards

Background (cont)

- A discussion with Ecology:

"…concluded that a temperature study of the Chelan River should focus on developing a Use Attainability Analysis (UAA), as defined in WAC 173-201A-510(5), rather than analyzing temperatures changes caused by the Project"

Project Status

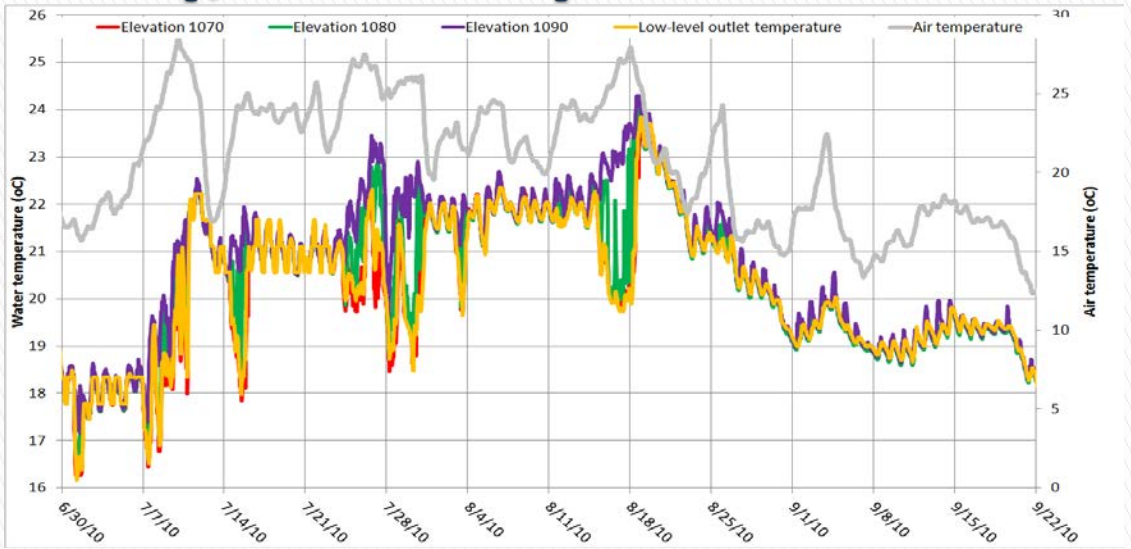
- Model Selection Report (March 12, 2014)
- QAPP (April 2014, revised June 23, 2015)
- Temperature Model Calibration Presentation (June 25, 2015)
- Preliminary Calibration Report (July 16, 2015)
- Analysis of Alternatives (December 2015)

Model Selection

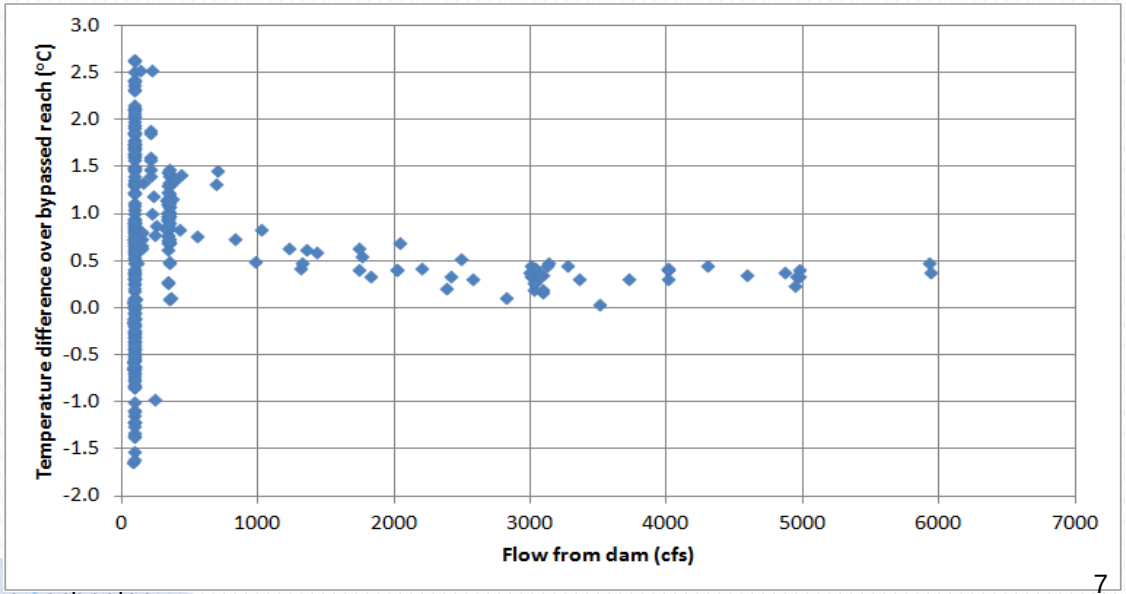
- Evaluation of processes
- Model selection

Model Selection (processes)

- Time series of water temperatures in Lake Chelan forebay during summer of 2010



- Comparison of flow and temperature change in bypassed reach (1-3) during 2011



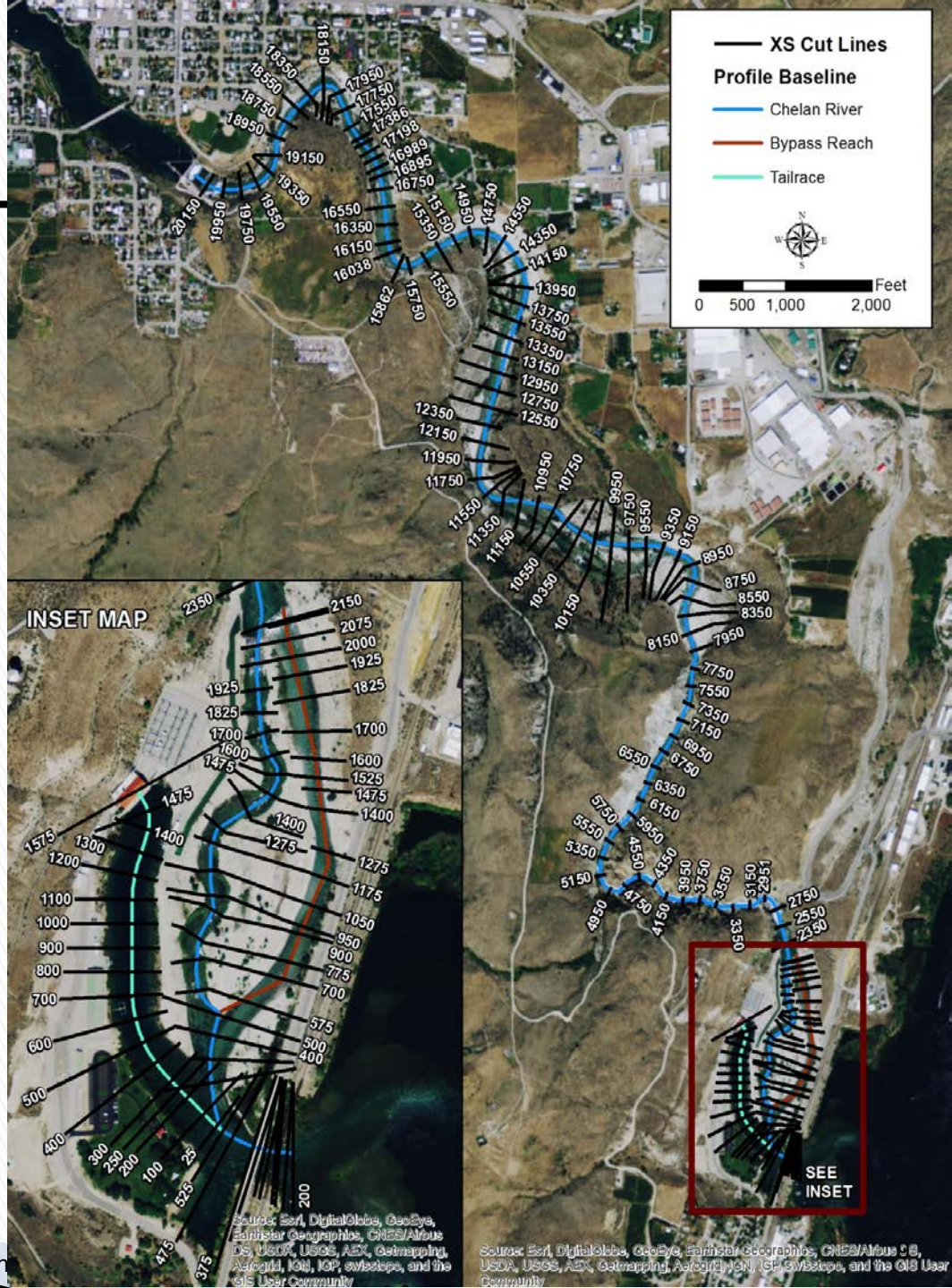
Model Selection (selection)

- QUAL2Kw
  - Has all important processes
  - Continued development and support from Ecology

- HEC-RAS
  - HEC-RAS used to define QUAL2Kw hydrodynamics

Model Development (geometry)

- LiDAR (2009)
- HEC-RAS hydraulic model of Reach 4
  - Modified with new Ecology sections in Habitat Reach
- HEC-RAS model developed with nominal resolution of 200 feet
- Used to develop power functions for QUAL2Kw

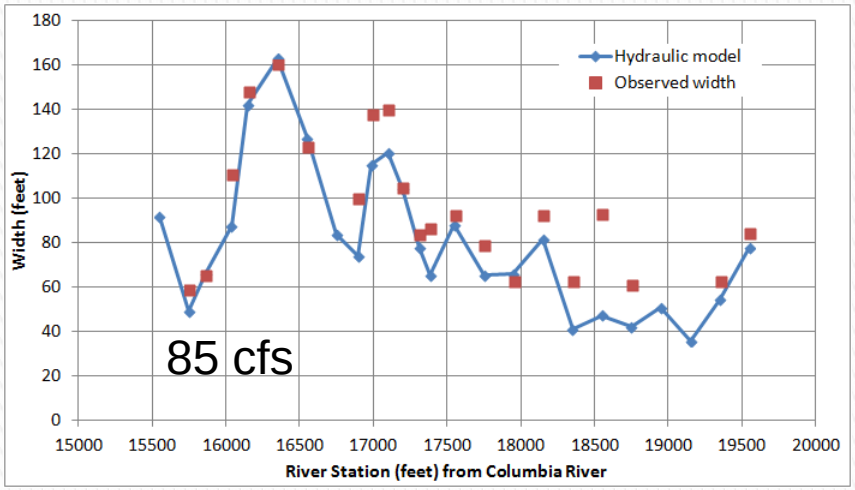


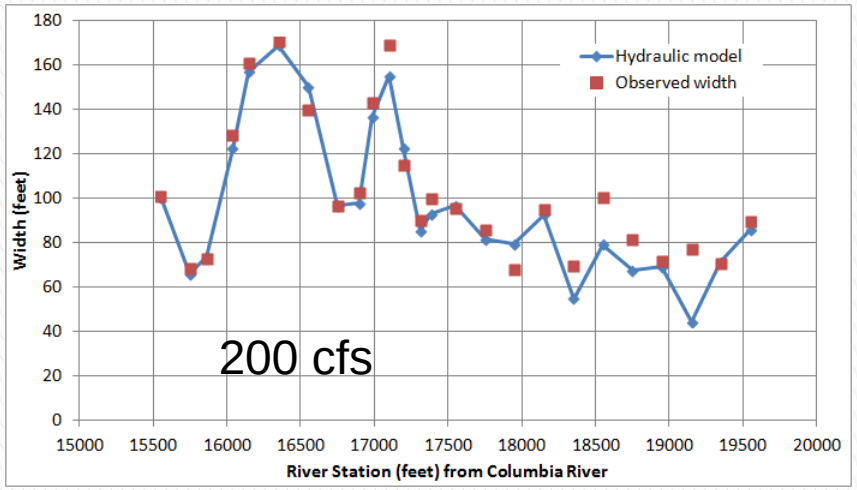
Model Development (hydraulic calibration)

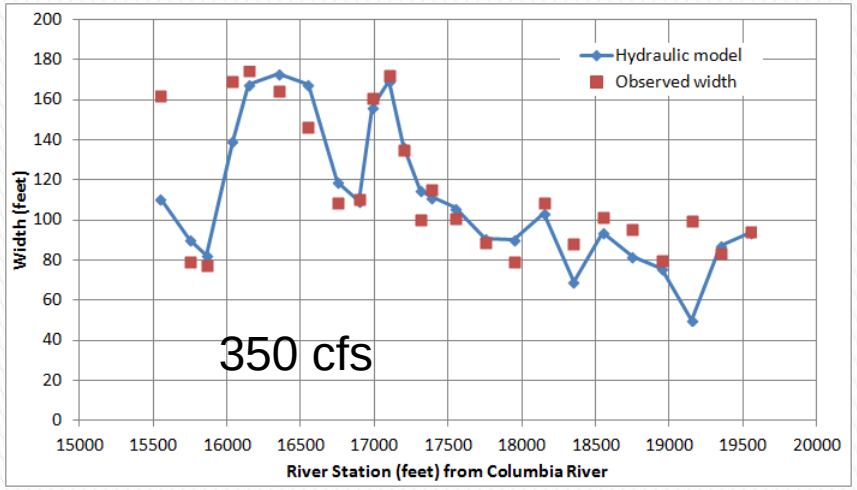
- Values estimated from aerial photographs and existing hydraulic model

River Reach	Channel values	Overbank values
Reach 1	0.07-0.12	0.12
Reach 2	0.07-0.12	0.12
Reach 3 ("The Falls")	0.15	0.15
Habitat Channel	0.05	0.06
Bypass Reach	0.05	0.07
Tailrace	0.05	0.05
Confluence Reach	0.03	0.06

Model Development (hydraulic calibration)

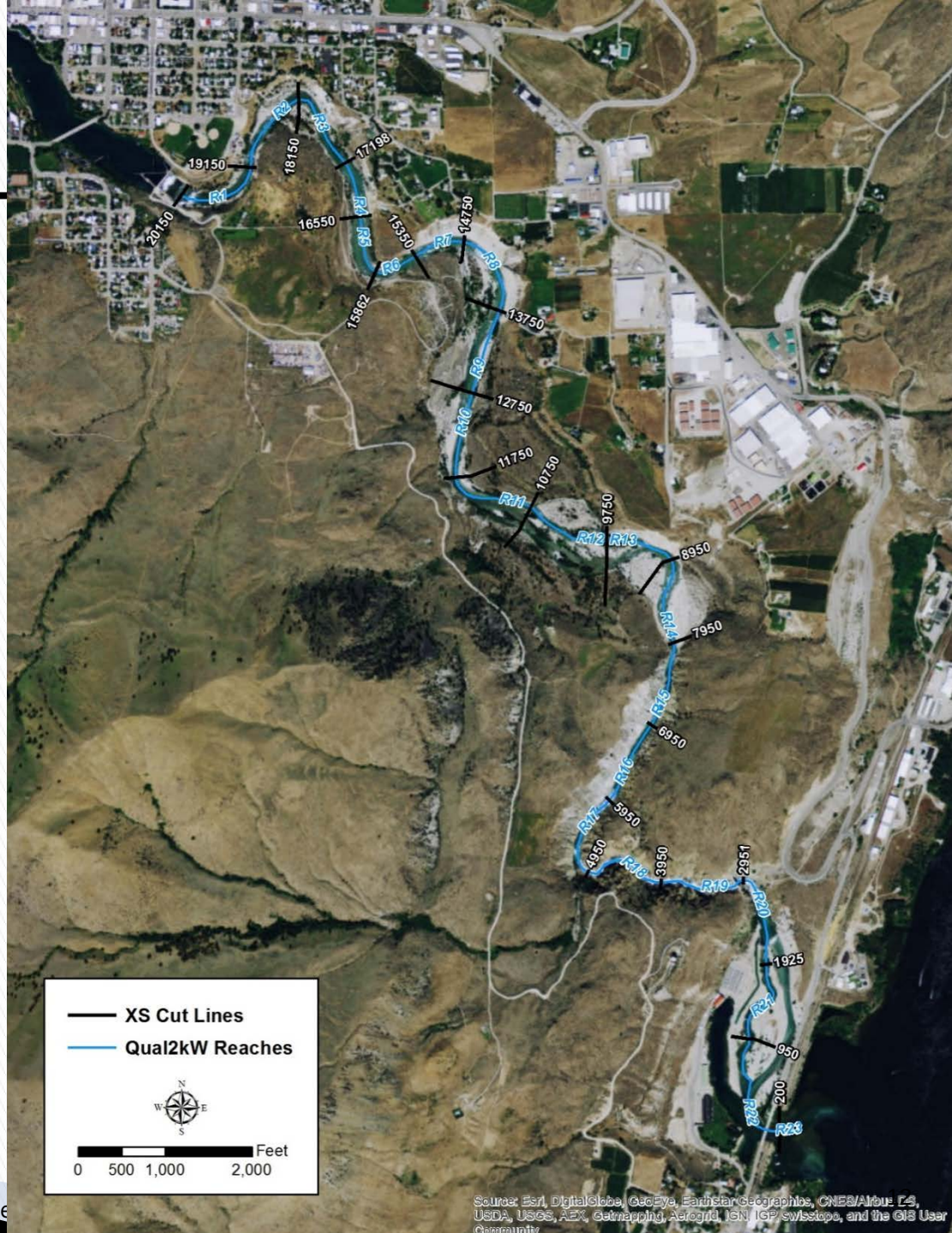






Temperature Model (reaches)

- 23 reaches of approximately 1000 feet, between HEC-RAS cross sections
- Hydraulic power functions developed at boundary HEC-RAS sections from hydraulic model results
  - $U = aQ^b$ $H = \alpha Q^\beta$

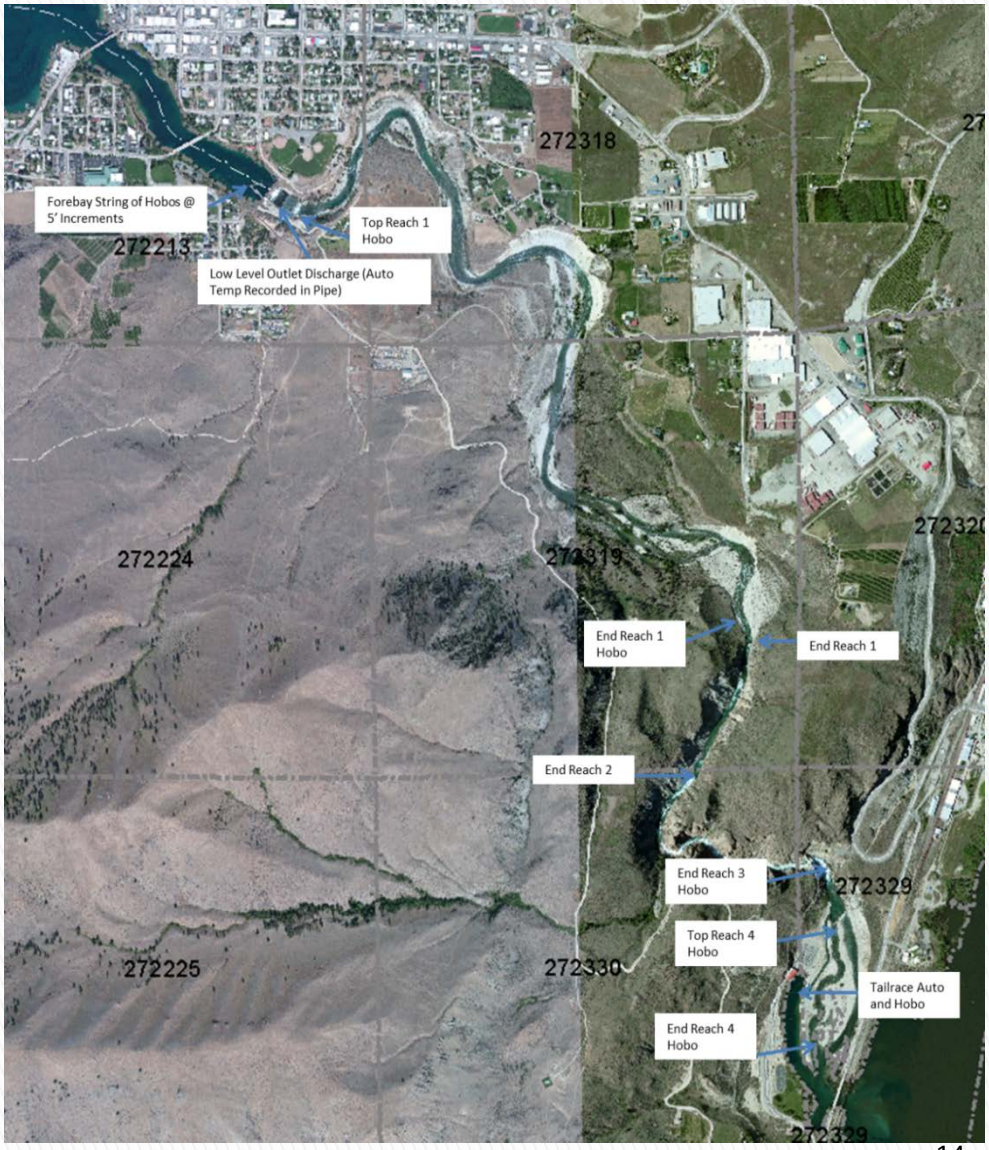


Temperature Model (calibration and validation periods)

Simulation Time Period	Simulation Type	Avg. Low Level Outlet Temperature (°C)	Avg. Air Temperature (°C)	Avg. Low Level Outlet Flow (cfs)
April 7-12: 2010	Validation	8.6	6.6	92
May 1-7: 2013	Validation and Sensitivity	13.6	17	126
September 1-7: 2013	Calibration	21.6	21.5	86
July 27 – August 3: 2014	Validation	21.7	27.7	85
March 23-30: 2015	Validation	9.6	11.2	84

Temperature Model (flow and temperature data)

- Flows through low-level outlet
- Temperatures in low level outlet
- Temperatures measured at ends of Reaches 1, 3, and 4

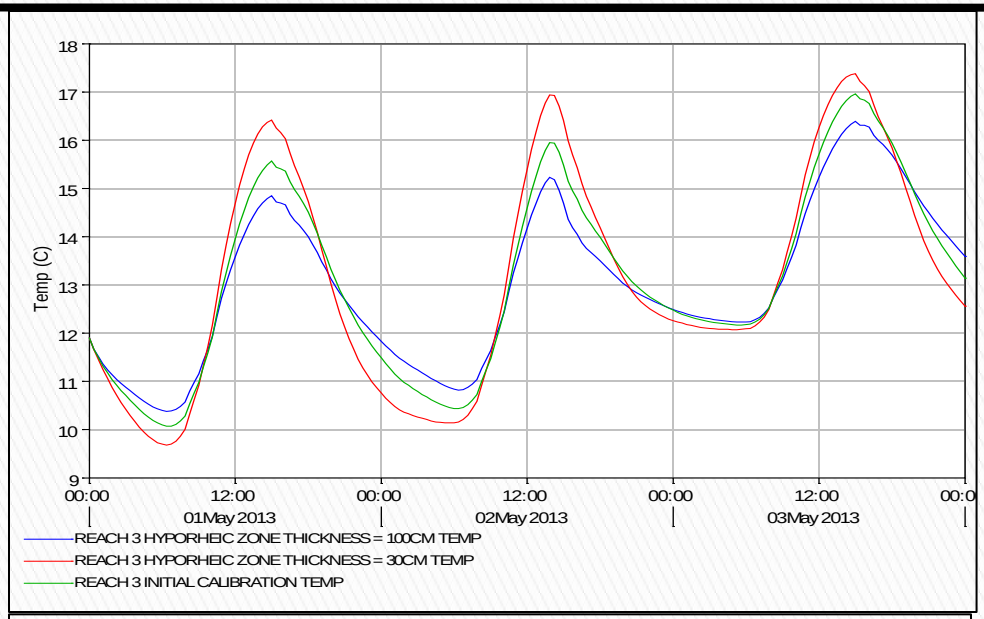


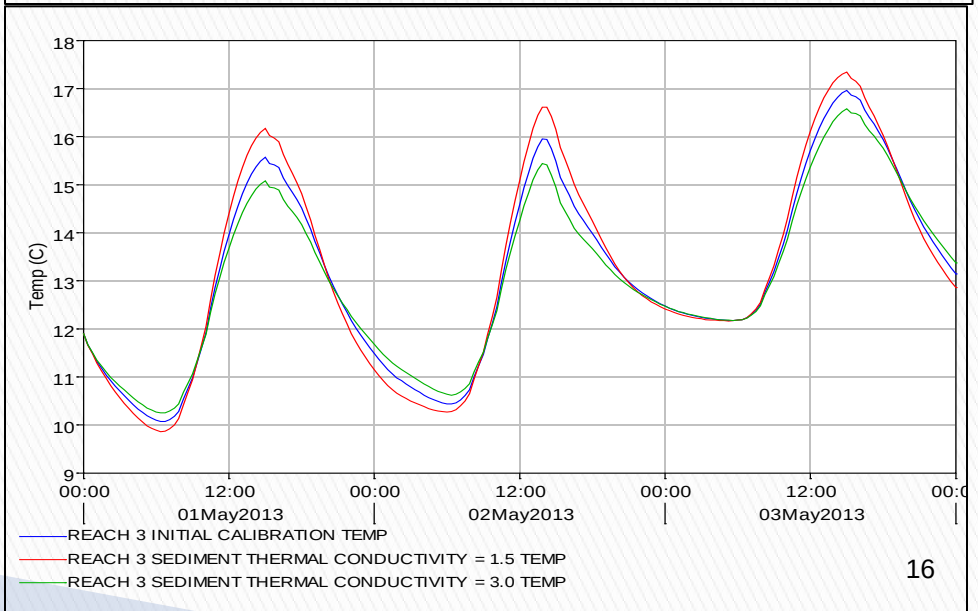
Temperature Model (meteorology)

- AgWeatherNet station at Chelan South
  - Air temperature
  - Dew point temperature/relative humidity
  - Wind speed and direction
  - Solar radiation
- Pangborn Wenatchee Airport
  - Cloud cover
- Shade
  - Used Ecology program Shade.xls with 30 m USGS DEM
  - Existing vegetation shading from Herrera study (2015)

Temperature Model Sensitivity

- Very sensitive to hyporheic flow
  - Zone thickness
  - sediment thermal conductivity
  - sediment thermal diffusivity
- Moderately sensitive to:
  - hyporheic flow fraction
  - deep sediment temperature

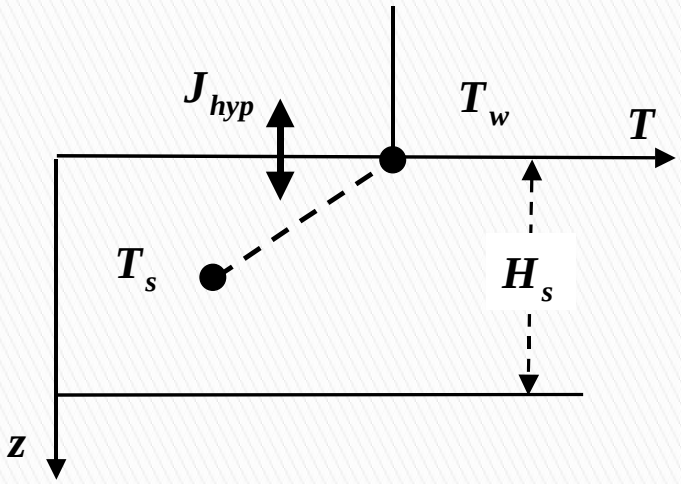




What is Hyporheic Zone

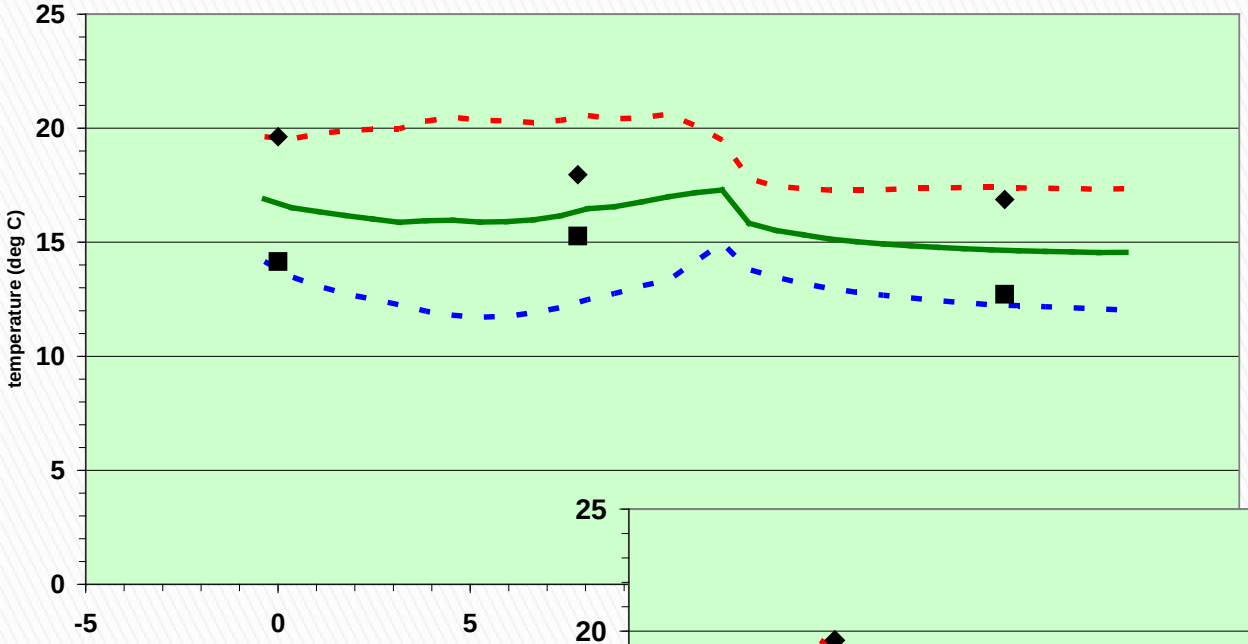
"The **hyporheic zone** is a region beneath and alongside a streambed, where there is mixing of shallow groundwater and surface water. The flow dynamics and behavior in this zone (termed **hyporheic flow** or **underflow**) is recognized to be important for surface water/groundwater interactions" (Wikipedia)

Simple model for heat flux from hyporheic flow exchange



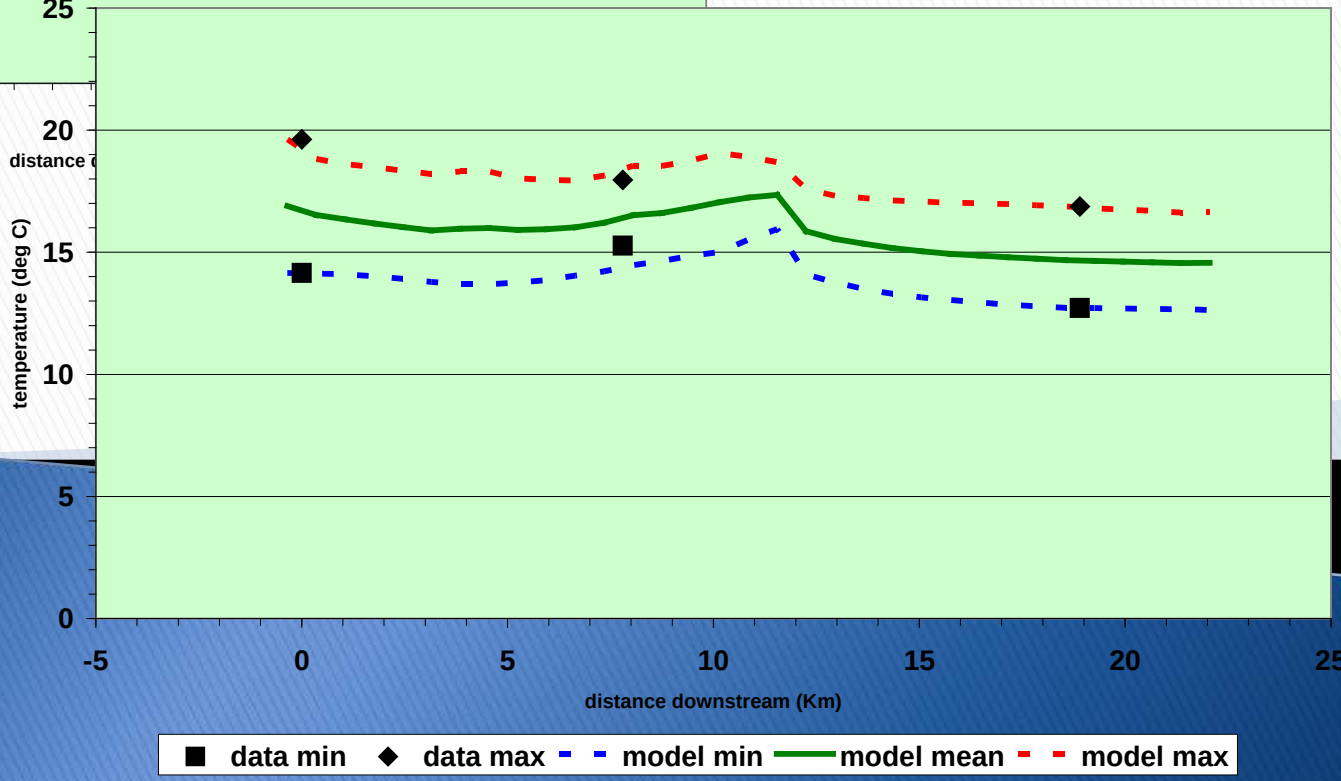
Jhyp = (Ehyp/Asf) * (Ts – Tw) * rhow * Cpw
(e.g. units of cal/cm^2/s)
Ehyp = bulk diffusive flow exchange
between water and hyporheic sediment (cm^3/s)
Asf = surface area of sediment (cm^2)
Ts = hyporheic sediment temperature (deg C)
Tw = surface water temperature (deg C)
rhow = density of water (1 g/cm^3)
Cpw = heat capacity of water (1 cal/g/deg C)

NF Stillaguamish R (8/12/2001)

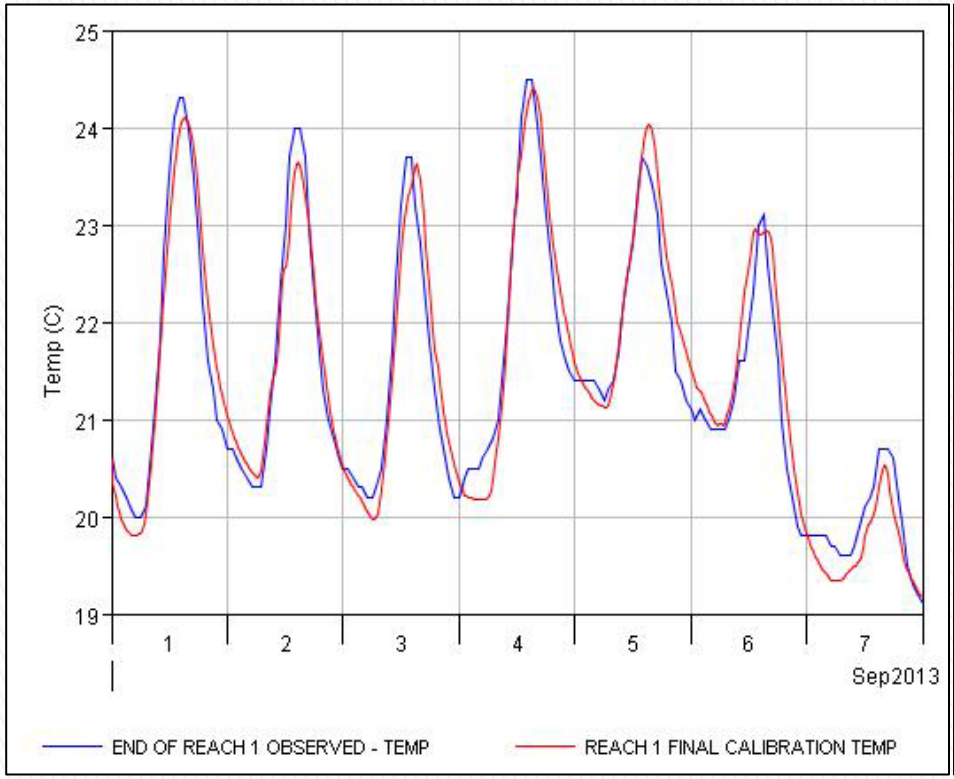


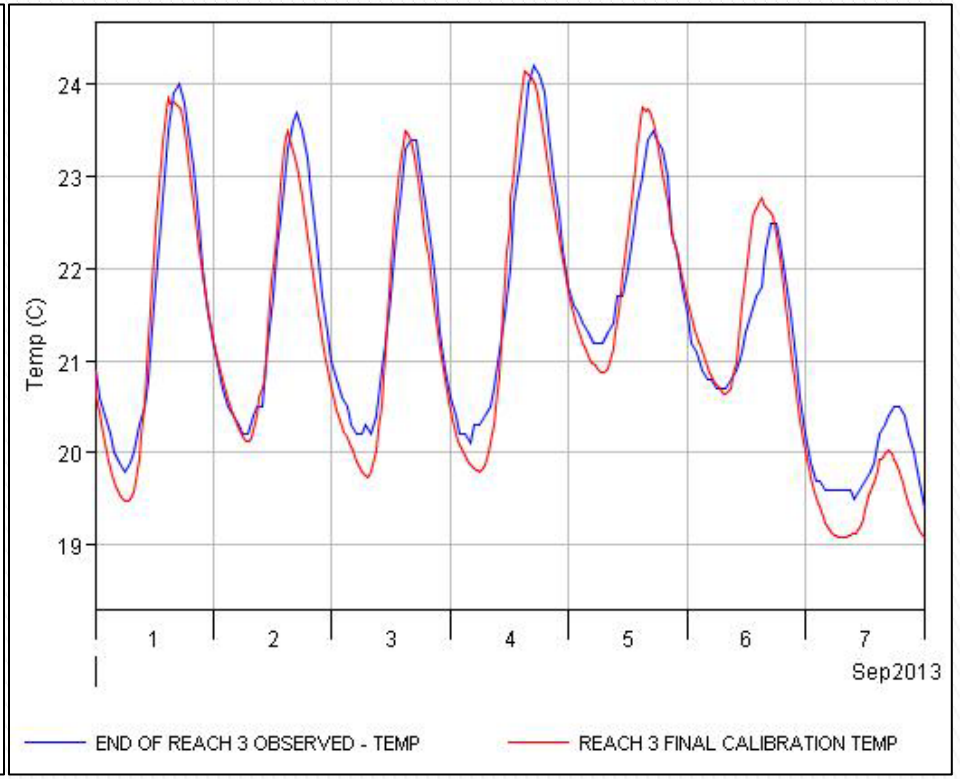
Without hyporheic flow

With hyporheic flow

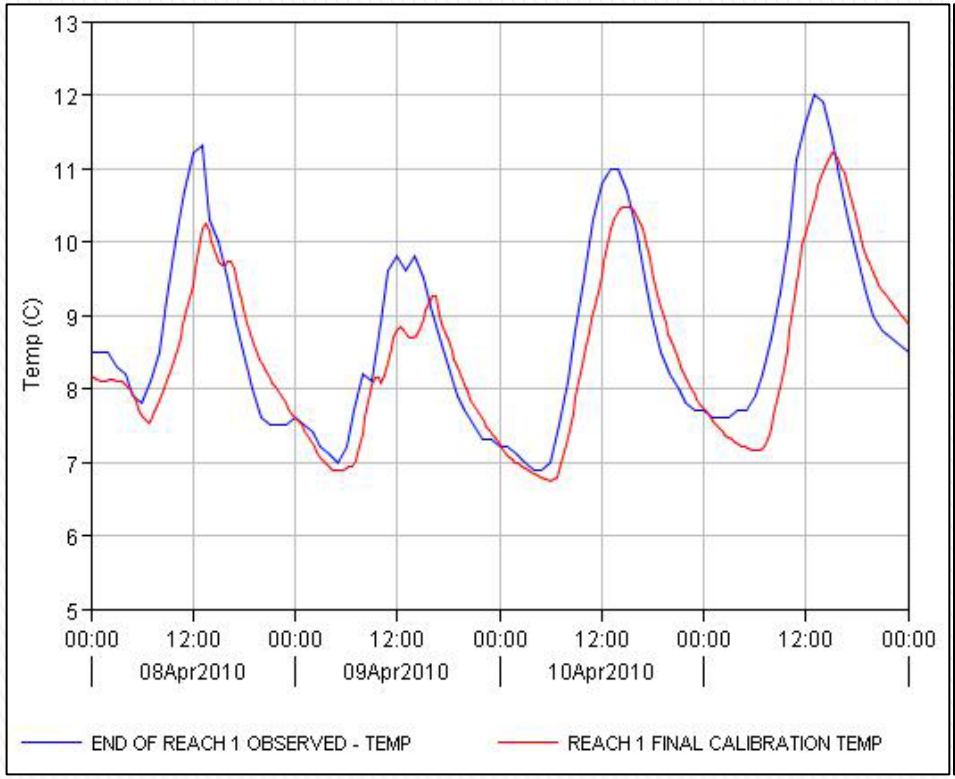


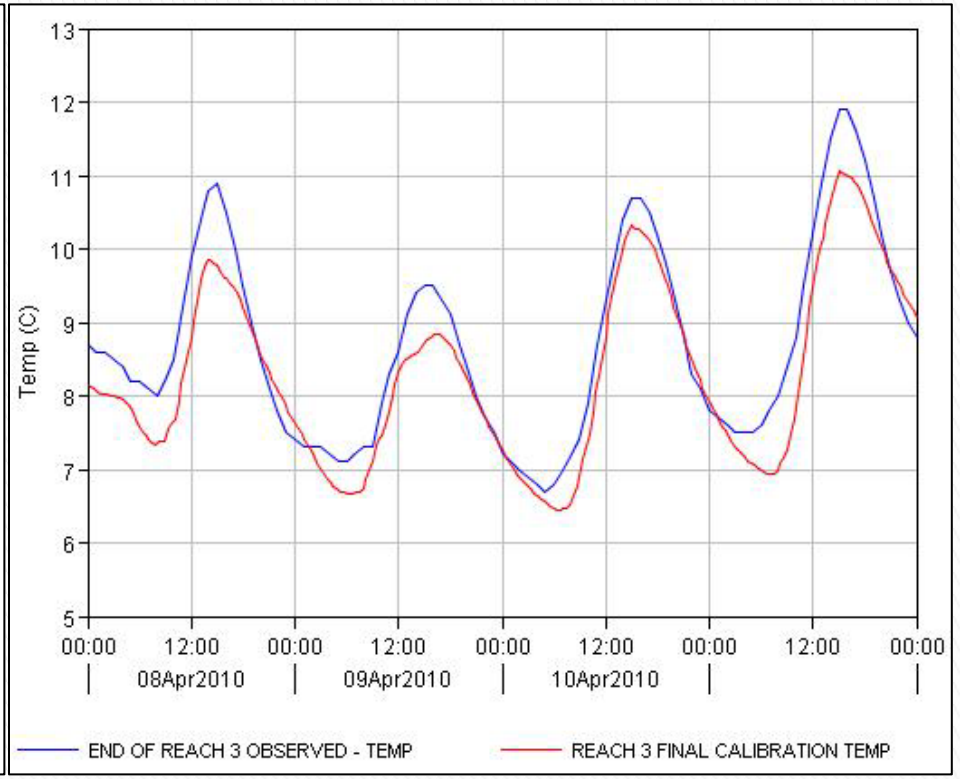
Temperature Model Calibration (Sept 2013)



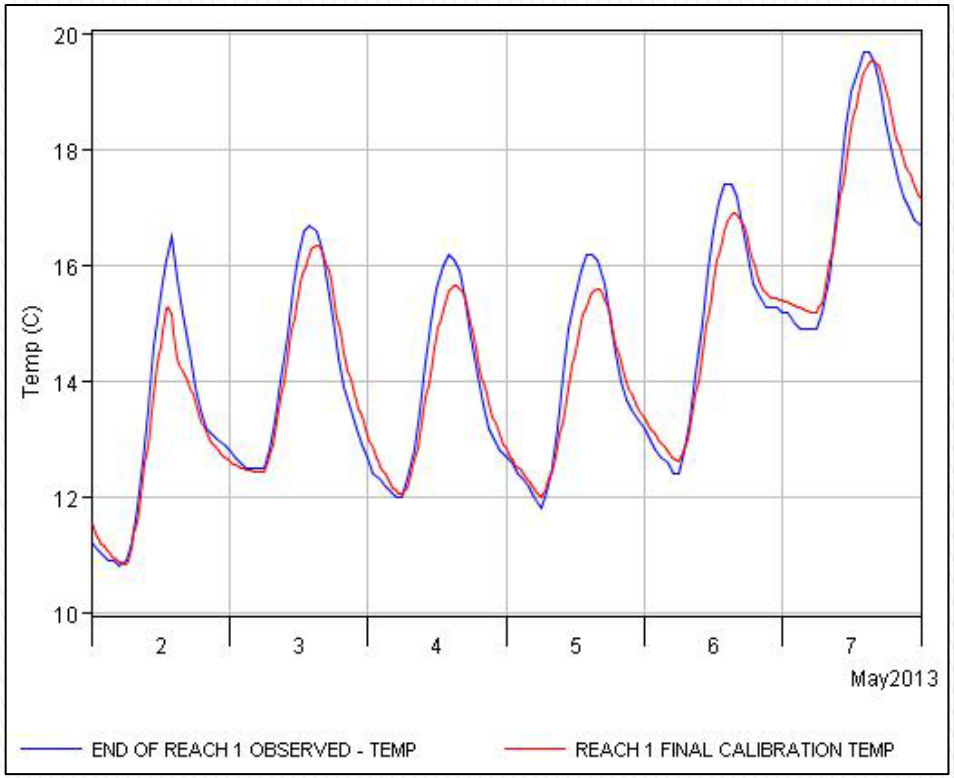


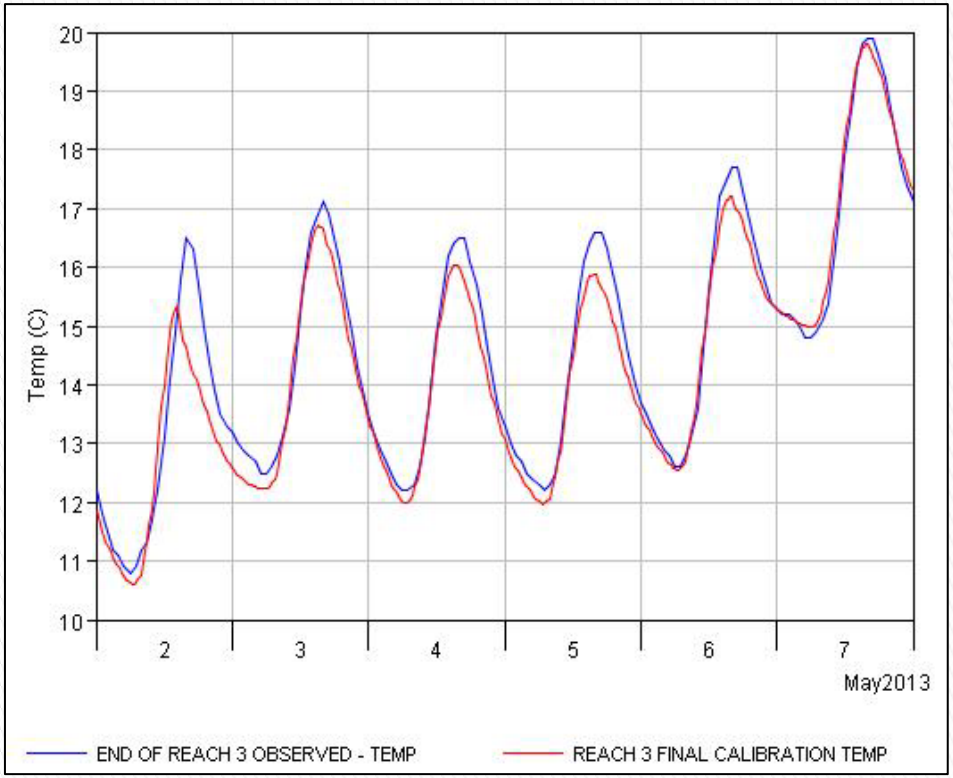
Temperature Model Validation(April 2010)



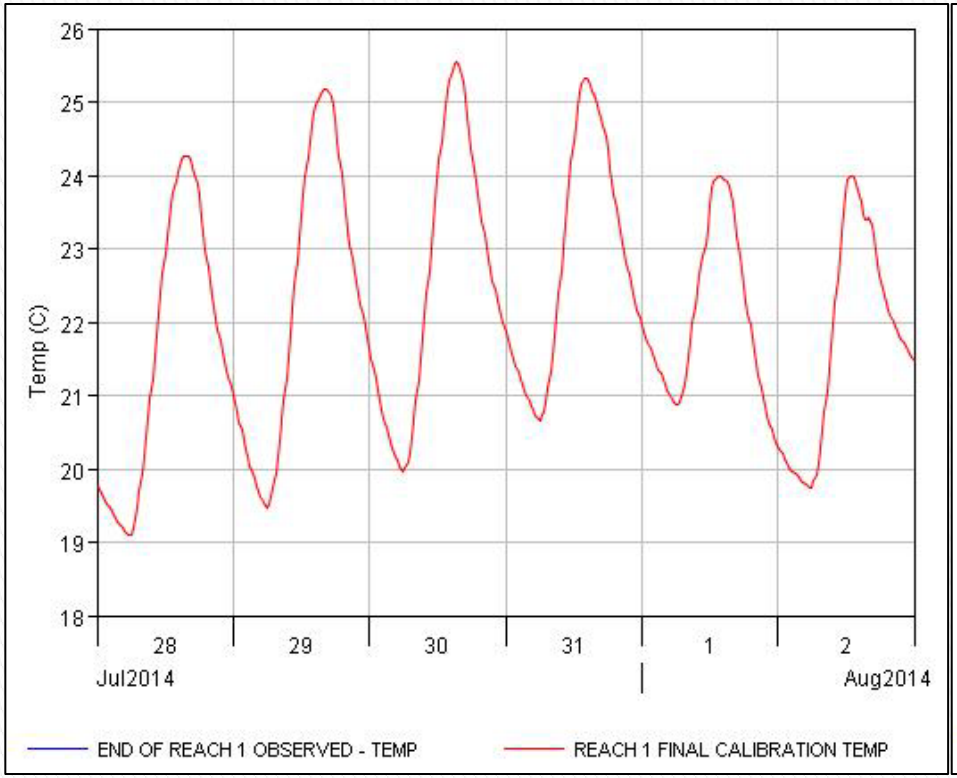


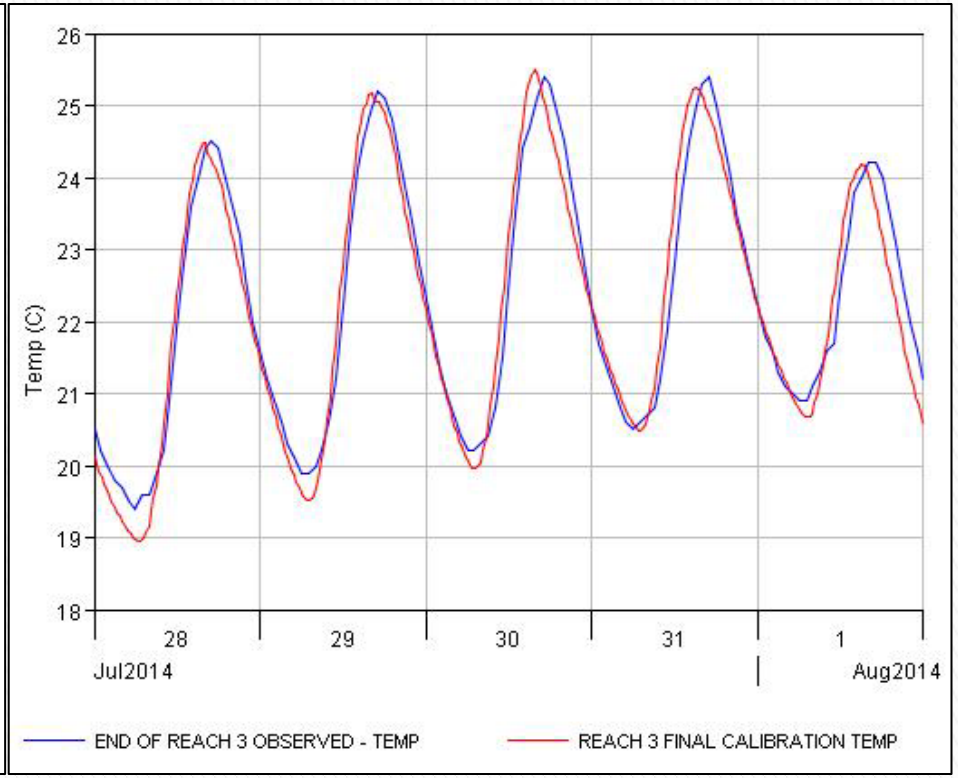
Temperature Model Validation(May 2013)





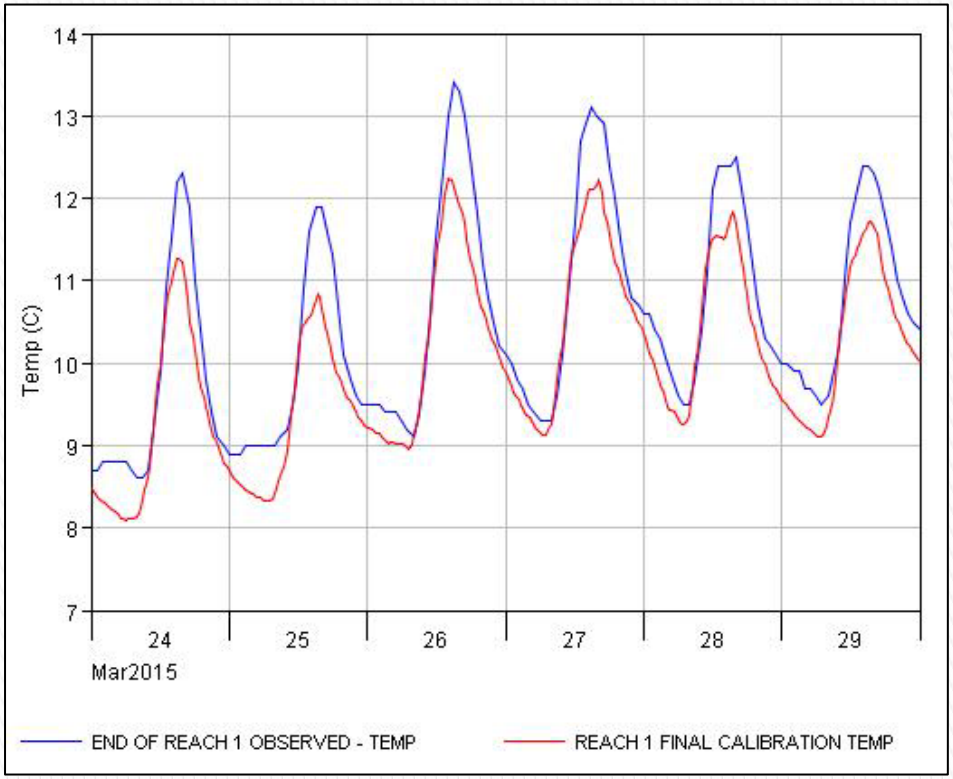
Temperature Model Validation(July 2014)

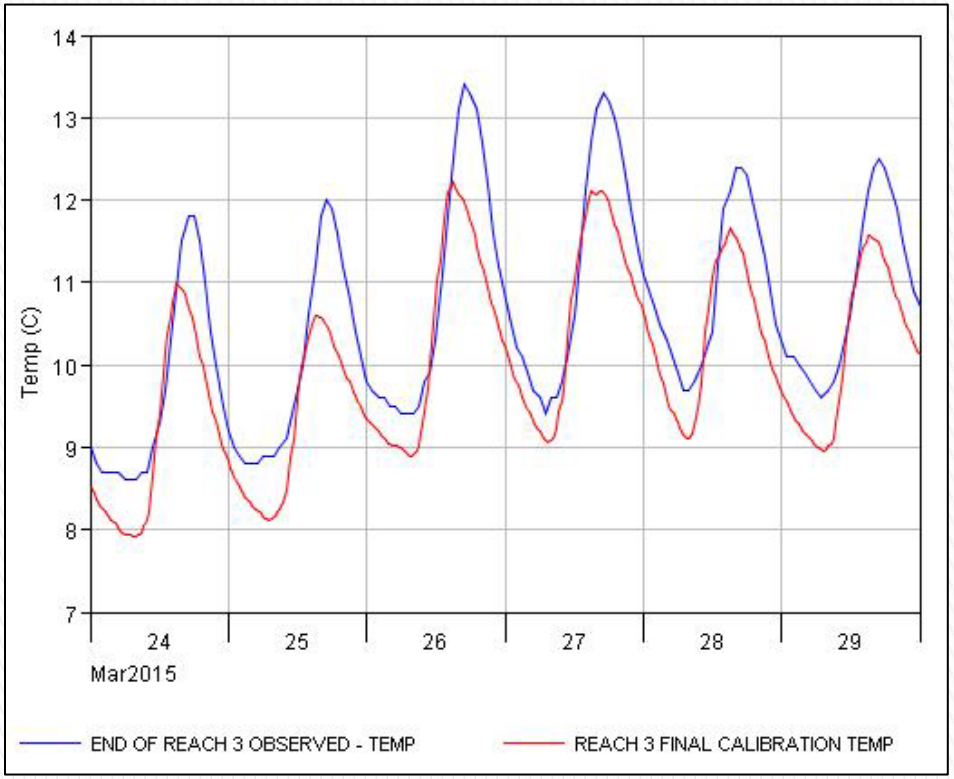




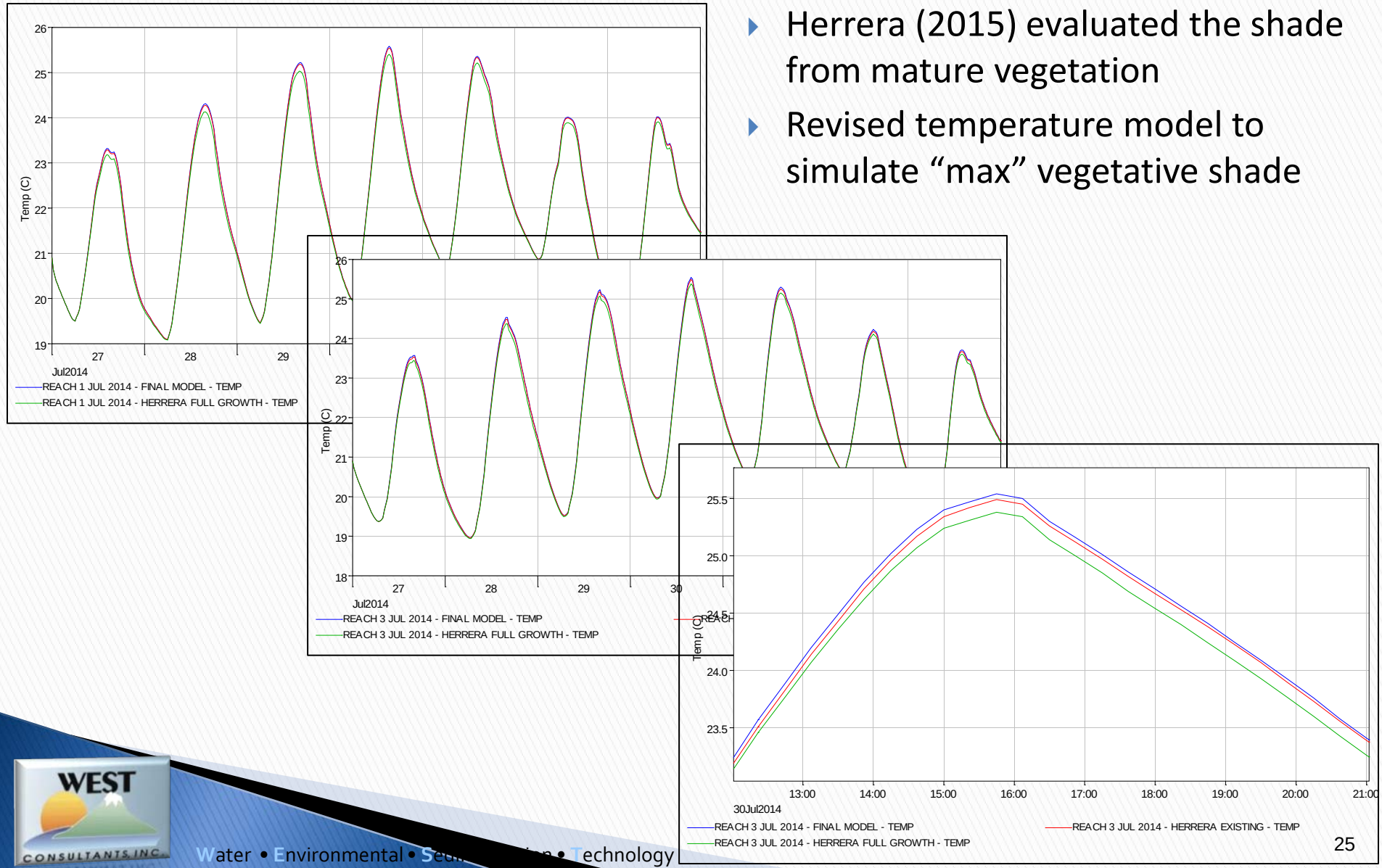
(No observed data available on R1 for Jul 2014 event)

Temperature Model Validation(March 2015)



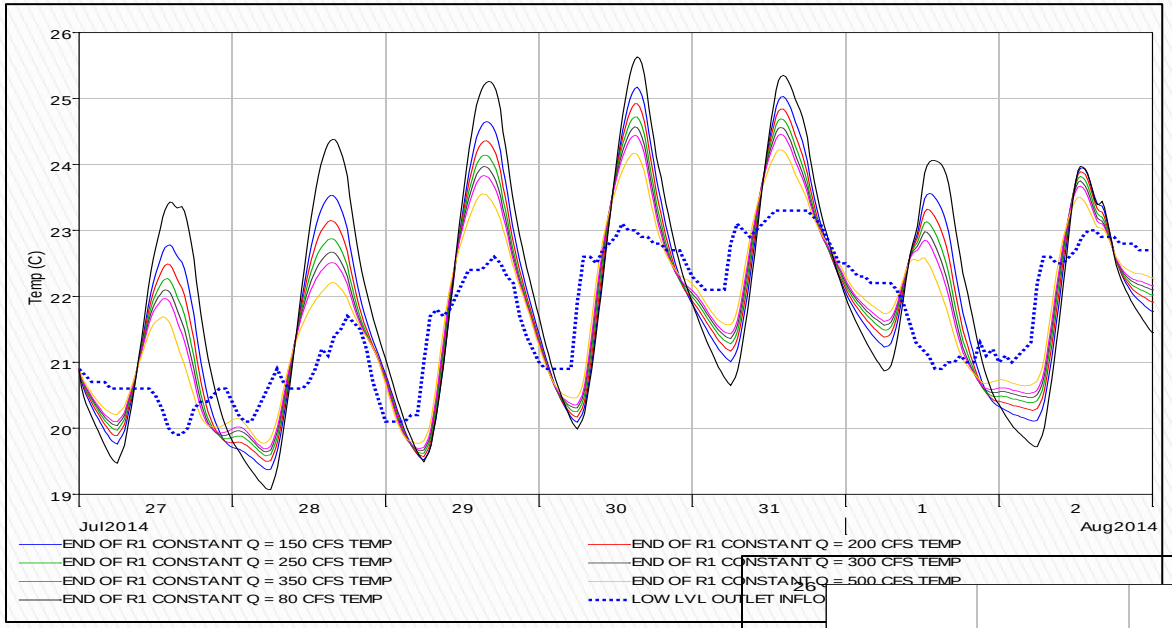


Mature vegetation

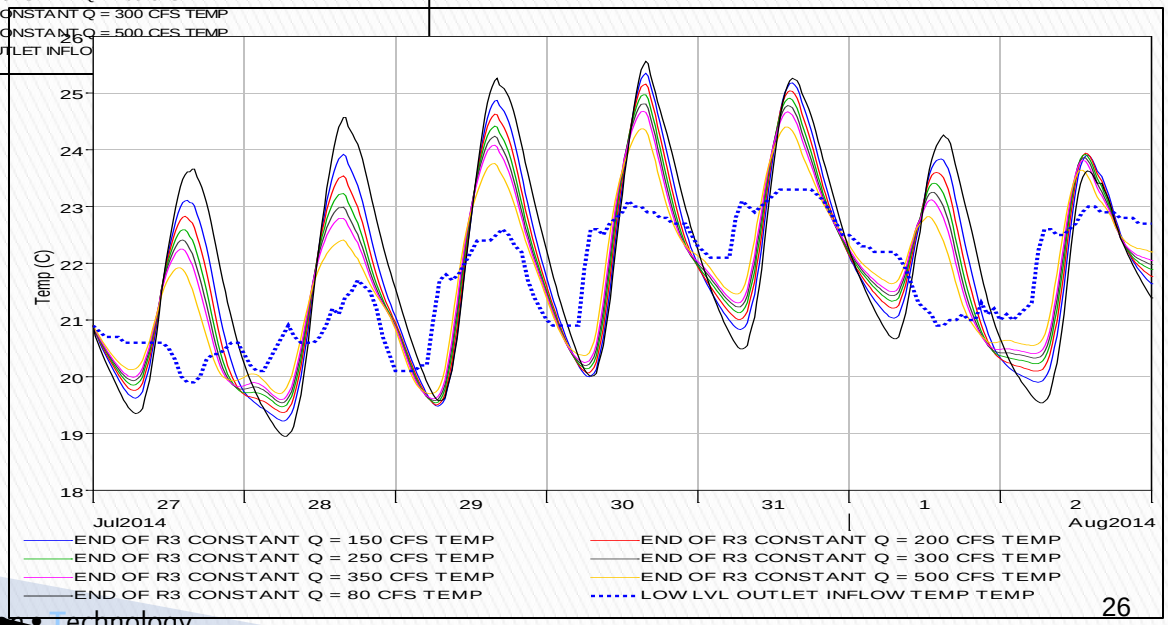


- Herrera (2015) evaluated the shade from mature vegetation
- Revised temperature model to simulate “max” vegetative shade

Effect of Lake Releases



- Simulated Lake releases 150-500 cfs



Discussion

- Temperature model needs hyporheic zone
- Month-to-month results may have groundwater temperature influence
- Calibration/validation graphs and statistics support accurate model
- Mature vegetation may lower maximum temperatures by only 0.25^{o}C
- Data show that larger flows decrease water temperature changes
- If low-flow channel is proposed, need to consider impact on hyporheic zone (excavation)

Next Steps

- Finalize model calibration report
- Define additional UAA alternatives
- Simulate additional UAA alternatives
- Investigate hyporheic zone temperatures
- Recommendations, Report, Meetings

QUESTIONS?