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# MEMO

DATE: September 13, 2004

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COPIES: Matt St. John, North Coast Regional Water Quality Control Board
Mike Johnson, University of California, Davis

FROM: Mike Deas, Watercourse Engineering, Inc.
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RE: Completion of the Shasta River Flow and Temperature Modeling Phase

Please find enclosed the report presenting the Shasta River flow and temperature modeling implementation, testing, and calibration.

# Introduction

This document is a review of the Shasta River modeling project status as of August, 2004. The implementation, calibration, and validation of the model with respect to hydrodynamics and temperature are complete. Three seven day periods were modeled for flow and temperature:

- 7/02/2002 to 7/08/2002
- 8/29/2002 to 9/04/2002
- 9/17/2002 to 9/23/2002

The period from 9/17/2002 to 9/23/2002 was used for calibration of the model, and the other two periods were modeled using the same input parameters, for the purpose of validation. These periods approximately represent early-summer, mid-summer, and late-summer/early-fall conditions in the Shasta River and include a sufficient range of flows and water temperatures to test the model.

# Task 1. Calibration

## *Task 1.1 Available Data Review*

The periods of calibration and validation of the model were chosen based on availability of data. Presented in Table 1 and Table 2 are the available field observations for flow, temperature, and meteorological data.

**Table 1. Available measured flow data for 2002**

| Start Date | Start Time | End Date | End Time | Notes |
|---|---|---|---|---|
| 5/21/02 | 14:00 | 6/03/02 | 16:00 | for all entries, up to 3 hours at a time may be missing from data |
| 6/19/02 | 15:00 | 7/09/02 | 19:00 | |
| 8/21/02 | 16.00 | 8/31/02 | 14:00 | |
| 8/31/02 | 15:00 | 9/06/02 | 12:00 | data gaps in Mouth and A12 |
| 9/16/02 | 15:00 | 10/05/02 | 6:00 | |
| 10/09/02 | 2:00 | 10/15/02 | 10:00 | |

**Table 2. Available measured temperature data at Louie Road from 2002**

| File Name | Start Date | End Date |
|---|---|---|
| 10603 | 5/20/2002 | 6/03/2002 |
| 10614 | 6/04/2002 | 6/14/2002 |
| 10703 | 6/15/2002 | 6/23/2002 |
| 20904 | 8/06/2002 | 9/04/2002 |
| 2002930 | 9/05/2002 | 9/30/2002 |

Available periods of measured temperature data, complete at all sites for 2002, not including Louie Road, are:

- 4/18/2002 to 6/04/2002
- 7/02/2002 to 10/15/2002

Available periods of measured meteorological data for 2002 are:

- 1/01/2002 to 5/14/2002
- 6/04/2002 to 12/31/2002

Thus, the periods of full and complete measured data are:

- 8/21/2002 to 9/04/2002
- 9/16/02 to 9/30/2002
- 10/09/2002 to 10/15/2002.

Louie Road data was a limiting condition in the early-summer, thus temperature for this location was calculated for the summer period, as outlined below.

## *Task 1.2 Temperature at Louie Road*

In order to derive Louie Road water temperature data for the period 6/04/2002 to 10/02/2002, a heat budget model was used to simulate expected water temperatures. This model calculates heat flux, and consequent changes in water temperature, on an hourly basis at the air-water interface of a pond of specified dimensions. The model assumes that the pond is fully mixed in the vertical and horizontal directions. Given a pond size, an initial pond temperature, and hourly meteorological data the model is used to simulate water temperature in changing meteorological conditions.

Water temperatures for June through October 2002 were synthesized using a temperature equilibrium model calibrated to existing data (derived from graphs of Louie Road water temperature from summer 2002). Hourly Louie Road water temperatures were approximated by the temperature of water coming into equilibrium with local atmospheric conditions that change through the day but are assumed constant over discrete one-hour periods.

The temperature model used, Watercourse Equilibrium Temperature Model (Watercourse, 2002), solved equations of heat transfer to estimate total heat energy transmitted from the atmosphere to a body of water, and consequent temperature gain or loss, within a specified time period. The governing equation was a simplification of the advection-diffusion equation found in Equation ( 1 ).

$$\frac{dT_w}{dt} = S = \frac{q_n A}{C_p \rho V} \tag{1}$$

Where:

| | |
|---|---|
| $T_w$= | water temperature (°C) |
| $t$= | time step (in this case, 1 hour = 3600s) |
| $S$= | sources and sinks (°C$s^{-1}$) |
| $q_n$= | net heat flux ($Wm^{-2}$) |
| $A$= | area of pond surface ($m^2$) |
| $C_p$= | specific heat of water at 15°C (4185.5 $Jkg^{-1}$°$C^{-1}$ where a J = 1 W-s) |
| $\rho$= | calculated density of water ($kgm^{-3}$) |
| $V$= | volume of pond ($m^3$) |

The model was calibrated to observed temperatures at Louie Road for May through September 2002. Two parameters, water depth and an evaporation coefficient, were adjusted to allow the model to simulate observed temperatures. Water depth affected the relative diurnal range of water temperatures, altering the extent of daytime heating, nighttime cooling and the heat storage capacity of the simulated water body. The evaporation coefficient was used to adjust the average daily temperature of the water body.

Meteorological conditions were assumed to be the same as conditions observed at Brazie Ranch. In the heat budget calculations, the model used cloud cover, dry bulb temperature, wet bulb temperature, average barometric pressure, wind speed and shortwave solar radiation. Cloud cover, wet bulb temperature, and average barometric pressure were not reported at Brazie Ranch. Values for these parameters were either assumed or calculated from other meteorological data. Cloud cover was assumed to be zero throughout the period of interest. Average barometric pressure was assumed constant and calculated as a function of elevation. Wet bulb temperature was estimated from dry bulb temperature, average barometric pressure, and relative humidity.

## *Task 1.3 Calibrating Coefficients*

During calibration, the input coefficients calibrated were: Manning's roughness coefficient (n), the wind speed evaporative cooling coefficients (here, aa, $m^3$/mb/s and bb, $m^2$/mb for the equation $\psi$ = aa + bb*wind), and the thermal diffusivity of bed material (K, $cm^2$/hr). Sensitivity analysis was performed by assessing the maximum and minimum of the range of default values for the parameters; the model was sensitive to changes in the thermal diffusivity of the bed material and the wind speed evaporative cooling coefficients. The values chosen based on the calibration are presented in Table 3. (Extensive documentation of the calibration phase will be available as an appendix of the final document.)

**Table 3. Best values based on calibration of period 9/17/2002 - 9/23/2002**

| Coefficient | Value |
|---|---|
| aa | 2.5E-9 $m^3$/mb/s |
| bb | 1.0E-9 $m^2$/mb |
| n | 0.05 |
| K | 50.0 $cm^2$/hr |

## *Task 1.4 Extending the Model to Dwinnell Reservoir*

The existing model was extended to Dwinnell Reservoir. It should be noted that the river azimuths were also recalculated for input into the control inputs file (*.ric) file in order to correspond to the instructions in the user's guide. The river azimuths used in all previous simulations, including calibration, were offset by 180 degrees. In all subsequent simulations, re-calibrated river azimuths are used. However, there is a negligible difference in results between simulations run using the old and corrected river azimuths. The shading file (*.ris), provided by Abbott (2002), was extended to Dwinnell Reservoir by estimating the shading input at the previous most upstream previous node (RM 31.83) was the same as the new nodes extending to RM 36.38. (Previously, Abbott's shading file was altered to allow no less than 50% transmittance of solar radiation, by a simple linear mapping. This was justified based on the little actual shade available on the Shasta River.) The estimated boundary condition for flow was set at 5 cfs to provide a continuous wetted channel between the dam and Parks Creek. The water temperature at Dwinnell Dam was set equal to that at Louie Road. Differences between the original and extended models are presented in Table 4 and Table 5. Extending the model to Dwinnell did not significantly affect the results of the simulations.

## Table 4. Notes on differences in hydrodynamics files (*.aii): original and extended models

| Lateral Inflow Number | Lateral Inflow | Location on River | River Mile for Flow Input in *.aii File (Original Version) | River Mile for Flow Input in *.aii File (Extended Version) | Notes | Flow Calculations for Original File | Flow Calculations for Extended File |
|---|---|---|---|---|---|---|---|
| | USBC | 36.38 | --- | --- | --- | 0.6*LOU | 5 cfs |
| 1 | Shasta Above Parks | 31.8 | --- | 31.83-31.70 | point source | --- | 0.6*LOU-5 cfs |
| 2 | PKS | 31.0 | 31.04-30.98 | 31.04-30.98 | point source | 0.4*LOU | 0.4*LOU |
| 3 | BIG SPRINGS | 29.9 | 29.90-29.79 | 29.90-29.79 | point source | GID-LOU+40(GID DIV) | GID-LOU+40(GID DIV) |
| 4 | GID/HUSEMAN DIVERSION | 26.9 | 26.92-26.87 | 26.92-26.87 | point source | -40 | -40 |
| 5 | GID->A12 | 26.9-21.9 | 26.92-21.95 | 26.92-21.95 | distributed | A12-GID | A12-GID |
| 6 | A12->SRF | 21.9-17.9 | 21.89-17.88 | 21.89-17.88 | distributed | SRF-A12 | SRF-A12 |
| 7 | SWUA DIVERSION | 16.8 | 16.81-16.76 | 16.81-16.76 | point source | -42 | -42 |
| 8 | SRF->DWR | 17.9-14.7 | 17.79-14.66 | 17.79-14.66 | distributed | DWR-SRF+42(SWUA DIV) | DWR-SRF+42(SWUA DIV) |
| 9 | DWR->YAR | 14.7-10.3 | 14.57-10.31 | 14.57-10.31 | distributed | YAR-DWR | YAR-DWR |
| 10 | YAR->AND | 10.3-7.9 | 10.23-7.90 | 10.23-7.90 | distributed | AND-YAR | AND-YAR |
| 11 | AND->MOUTH (note: Yreka Creek is at RM 7.6) | 7.9-0.0 | 7.65-7.56 | 7.65-7.56 | point source | MOUTH-AND | MOUTH-AND |

USBC-Upstream Boundary Condition
PKS-Parks Creek (RM 31.0)
GID-Grenada Irrigation District (RM 26.9)
A12-Highway A12 (RM 21.9)
SRF- Shasta River At Freeman Lane (RM 17.9)
SWUA- Shasta Water Users Association (RM 16.8)
DWR- Monteque-Grenada Road (DWR Weir) (RM 14.7)
YAR- Yreka Ager Road (RM 10.3)
AND- Anderson Grade (RM 7.9)

**Table 5. Notes on differences in temperature input (*.rib) between original and extended models. Note, in the new, extended version, the sub-reaches with distributed flow inputs have the temperature input in the center of the sub-reach.**

| Lateral Inflow Number | Location | Notes | Original Input Location | Input Location for Extended File |
|---|---|---|---|---|
| 1 | Shasta Above Parks | point source | | 31.83 |
| 2 | PKS | point source | 31.04 | 31.04 |
| 3 | BIG SPRINGS | point source | 29.90 | 29.90 |
| 4 | GID/HUSEMAN DIVERSION | point source | 26.92 | 26.92 |
| 5 | GID-A12 | distributed | 26.87 | 24.42 |
| 6 | A12-SRF | distributed | 21.82 | 19.89 |
| 7 | SWUA DIVERSION | point source | 17.76 | 16.81 |
| 8 | SRF-DWR | distributed | 16.81 | 16.19 |
| 9 | DWR-YAR | distributed | 14.44 | 12.40 |
| 10 | YAR-AND | distributed | 10.17 | 9.05 |
| 11 | AND-MOUTH (this input is at Yreka Creek) | point source | 7.65 | 7.65 |

## *Task 1.5 Instabilities in Temperature*

In the final stages of calibration and validation, the results of temperature showed instabilities (oscillations), which had been somewhat visible in the results of the calibration period. An example of this instability is shown in Figure 1.

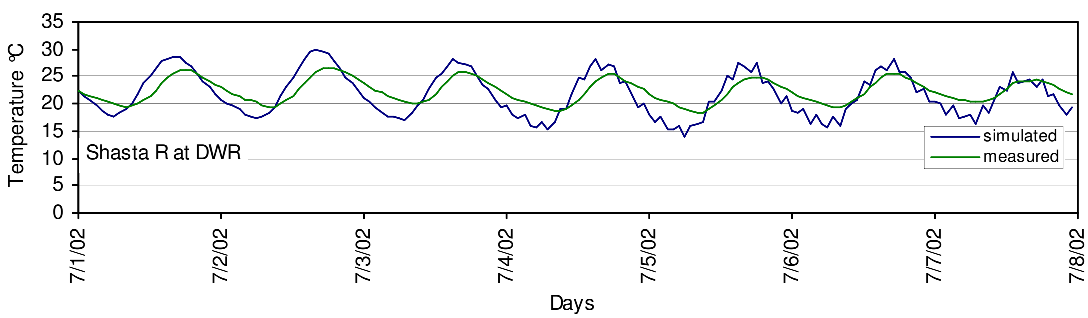


**Figure 1. Temperature at DWR Weir for validation period 7/02/2002 – 7/08/2002 with theta = 0.5**

The RQUAL numerical solution is performed using a 4-point implicit scheme which is subject to these instabilities. Increasing the theta value from 0.50 to 0.55 in the RQUAL file was sufficient to dampen the oscillations in all simulations. The range for theta, as given in the User's Guide p. 114, is 0.5-0.6.

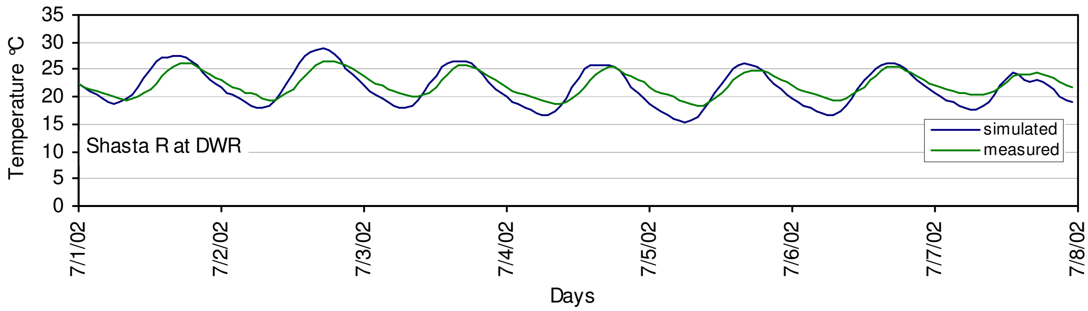


**Figure 2. Temperature at DWR Weir for validation period 7/02/2002 – 7/08/2002 with theta = 0.55**

### *Task 1.6 Geometry at Mouth*

Near the mouth of the Shasta River, the simulated temperatures were at times underestimated and diverged somewhat from field observations,. An attempt was made to assess the sub-reach geometry from RM 7.9 to 0.0 to determine the sensitivity of the model results to river geometry. Narrowing the geometry near the mouth did not change the results of the simulation, i.e., the model was insensitive to river width in this sub-reach. Some possible explanations for the model performance in this reach may include local meteorological conditions in this step, rocky canyon, as well as a more complete assessment of the geometry over the entire reach versus just in the vicinity of the confluence with the Klamath River.

## Task 2. Validation and Final Results

Validation was performed by running two alternate seven-day periods with the same coefficient inputs as the calibrated model. Input flow, temperature and meteorological data measured during the period modeled were used for the simulations. No alterations were made to the model in implementing the simulations for the purpose of validation.

The boundary condition for temperature at Dwinnell Dam and Parks Creek was assumed to equal the temperature at Louie Road. Model boundary conditions for Big Springs was assumed to equal the temperature measured at Highway A12. GID is closer to Big Springs, but the *measured* temperature at GID was consistently out of phase with the *measured* temperatures all the other locations.

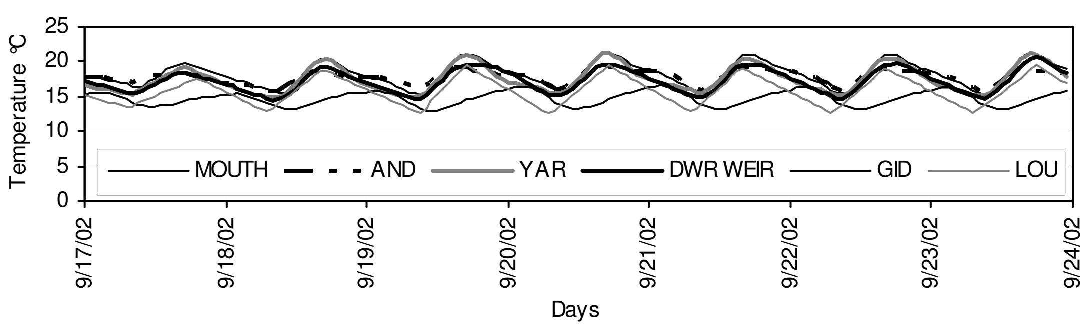


**Figure 3** compares measured data at several Shasta River locations and clearly indicates

that temperatures observed below the GID Dam are out of phase with other observations. This was not an anomalous condition identified only in 2002: it has consistently been identified well back in the 1990's.

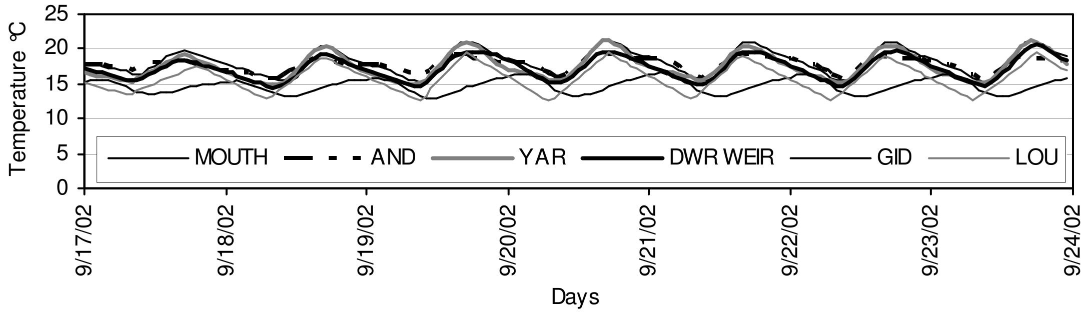


**Figure 3. Measured temperature at five locations for the period 9/17/2002 – 9/24/2002**

It is postulated that the presence of the reservoir behind the GID Dam increases retention time, increases depth, and reduces velocity. These impounded conditions result in a thermal lag when compared to a free-flowing river reach. The phase shift in water temperature below the diversion dam is mostly eliminated by Highway A12 because meteorological conditions quickly restore the thermal signature of the river.

The model simulated temperature at GID does not match the phase of the observed temperatures because the impoundment is not explicitly represented in the model. To test the hypothesis that the impoundment is modifying the local thermal regime, the model was applied to this reach with a fictitiously elevated Manning coefficient within the impounded reach. Setting this bed roughness coefficient to 0.3 (an order of magnitude greater than calibration values), resulted in deeper slower flows. When the model was altered to include a high Manning's coefficient simulated temperature at GID matched field observations in phase (Figure 4). The discrepancy between the two traces is due to using A-12 temperatures as the Big Springs inflow temperature – A-12 is probably warmer than actual Big Springs inflow temperatures due to the heating that occurs between the two locations as water travels downstream. Even with the increased roughness in the GID impoundment reach, the model also simulates the return to meteorologically dominated temperatures measured at A12 (Figure 5).

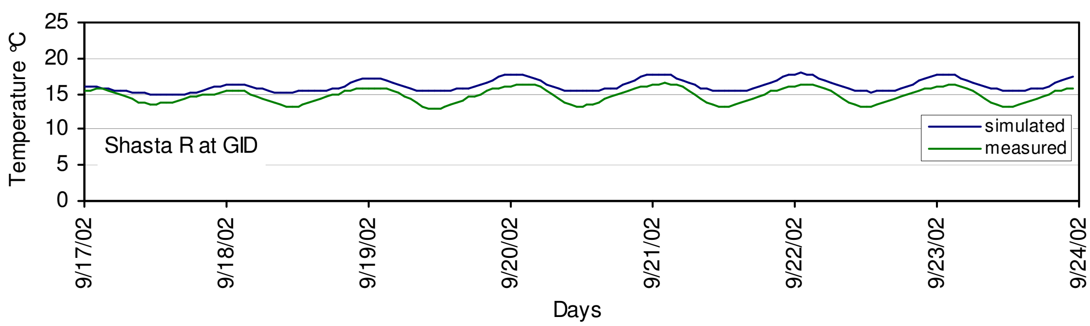


**Figure 4. Temperature at Grenada Irrigation District from 9/17/2002 – 9/23/2002 modeled with Manning's n = 0.3 from RM 22-29 and n = 0.05 at all other locations—all other conditions are identical to the calibrated model for this period, as described in this report**

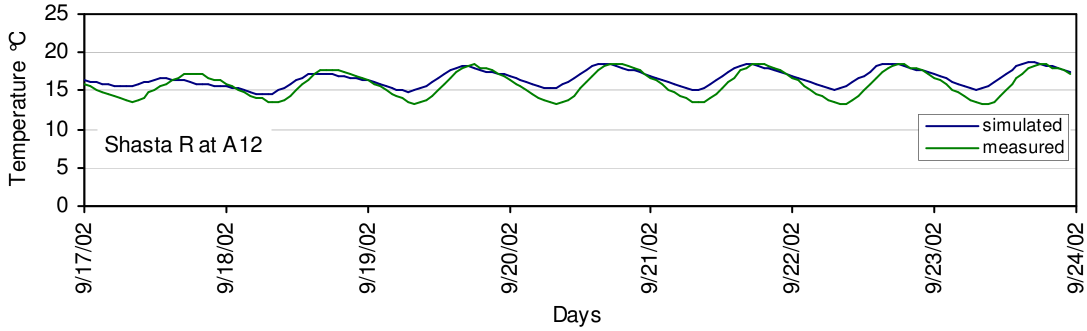


**Figure 5. Temperature at Highway A12 from 9/17/2002 – 9/23/2002 modeled with Manning's n = 0.3 from RM 22-29 and n = 0.05 at all other locations—all other conditions are identical to the calibrated model for this period, as described in this report**

At the Mouth, another lag between measured and modeled temperature appears. This is likely due to meteorological conditions in the canyon near the mouth that differ from the meteorological input used for the model, which is measured at Brazie Ranch. In this sub-reach it is postulated that the rocky canyon walls emit long-wave radiation well into the evening, heating the river later in the day and increasing the lag in temperature.

The results for the calibrated simulation for the period 9/17/2002 - 9/23/2002 and simulations for the validation periods 8/29/2002 – 9/04/2002 and 7/02/2002 – 7/08/2002 are presented in Table 7 through Table 12 and Figure 6 through Figure 35. Note that results in the form of summary statistics and graphs are available at 11 locations for temperature and 8 locations for flow; the locations presented below are representative. The mean absolute error is consistently less than 10 percent of the actual value for flow and temperature; i.e., within 1 to 2 °C and 1 to 3 cfs.

## *Work In Progress*

- **Task 1. Review of available water quality data and identification of additional data needs.** This task has been substantially completed; however, ongoing model testing and assessment of benthic algae and organic sediment distributions are pending results of field studies from the North Coast Regional Water Quality Control Board.
- **Task 2. Implementation and calibration of the water quality portion of the Shasta River model.** Implementation of the water quality portion of RQUAL is complete, i.e, the model is up and running with the desired water quality parameters, but as yet uncalibrated. Comparison of water quality output with limited measured data for 2002 is underway.

# Future Work

- Task 3. Formulation and testing of the algae-nutrient sub-model
- Task 4. Status Meeting (**Completed**)

- Task 5. Formulation of preliminary alternatives (**Scheduled for early October**)
- Task 6. Updating the model based on 2004 field data (**Ongoing**)
- Task 7. Identify and formulate final alternatives for assessment
- Task 8. Assessment of final alternatives
- Task 9. Reporting

A revised timeline is outlined in Table 6.

**Table 6. Revised timeline for the Shasta River Flow and Water Quality Modeling Project**

| Task | Description | Scheduled Completion |
|---|---|---|
| Task 1 | Review of available water quality data and identification of additional data needs. | Mid- to Late-September |
| Task 2 | Implementation of the water quality portion of RQUAL | Mid- to Late-September |
| Task 3 | Formulation and testing of the algae-nutrient sub-model | Mid- to Late-September |
| Task 4 | Status Meeting | Completed |
| Task 5 | Formulation of preliminary alternatives | Late-September to early-October |
| Task 6 | Updating the model based on 2004 field data | September/October |
| Task 7 | Identify and formulate final alternatives for assessment | October |
| Task 8 | Assessment of final alternatives | November-December |
| Task 9 | Reporting | TBD |

**Table 7. Summary hourly flow statistics for best calibration, 9/17/2002 - 9/23/2002**

| | Louie Road | A12 | DWR | Anderson Grade | Mouth |
|---|---|---|---|---|---|
| Mean Bias | 0.05 | -0.20 | -0.13 | -0.26 | -0.21 |
| Mean absolute error (MAE) | 0.48 | 1.21 | 1.99 | 1.56 | 1.64 |
| Root mean squared error (RMSE) | 0.58 | 1.42 | 2.68 | 1.92 | 2.05 |
| N (number of hours) | 168 | 168 | 168 | 168 | 168 |

**Table 8. Summary hourly temperature statistics for best calibration, 9/17/2002 - 9/23/2002**

| | Louie Road | A12 | DWR | Anderson Grade | Mouth |
|---|---|---|---|---|---|
| Mean Bias | 0.13 | 0.70 | 0.03 | -0.30 | -0.55 |
| Mean absolute error (MAE) | 0.44 | 0.92 | 1.04 | 1.04 | 1.50 |
| Root mean squared error (RMSE) | 0.58 | 1.12 | 1.21 | 1.21 | 1.73 |
| N (number of hours) | 168 | 168 | 168 | 168 | 168 |

**Table 9. Summary hourly flow statistics for validation period 8/29/2002 – 9/04/2002**

| | Louie Road | A12 | DWR | Anderson Grade | Mouth |
|---|---|---|---|---|---|
| Mean Bias | -0.25 | -0.62 | 0.57 | 0.77 | 0.65 |
| Mean absolute error (MAE) | 0.67 | 3.34 | 1.47 | 1.19 | 1.83 |
| Root mean squared error (RMSE) | 0.89 | 4.67 | 1.87 | 1.46 | 2.36 |
| N (number of hours) | 168 | 168 | 168 | 168 | 149 |

**Table 10. Summary hourly temperature statistics for validation period 8/29/2002 – 9/04/2002**

| | Louie Road | A12 | DWR | Anderson Grade | Mouth |
|---|---|---|---|---|---|
| Mean Bias | 0.30 | 0.97 | -0.02 | -0.54 | -0.93 |
| Mean absolute error (MAE) | 1.10 | 1.31 | 1.28 | 1.24 | 1.89 |
| Root mean squared error (RMSE) | 1.36 | 1.60 | 1.54 | 1.53 | 2.28 |
| N (number of hours) | 168 | 168 | 168 | 168 | 168 |

**Table 11. Summary hourly flow statistics for validation period 7/02/2002 – 7/08/2002**

| | Louie Road | A12 | DWR | Anderson Grade | Mouth |
|---|---|---|---|---|---|
| Mean Bias | -0.32 | 0.80 | -0.61 | -0.94 | -0.75 |
| Mean absolute error (MAE) | 1.22 | 4.86 | 2.35 | 2.41 | 3.14 |
| Root mean squared error (RMSE) | 1.68 | 6.50 | 2.87 | 3.08 | 4.04 |
| N (number of hours) | 168 | 168 | 168 | 168 | 168 |

**Table 12. Summary hourly temperature statistics for validation period 7/02/2002 – 7/08/2002**

| | Louie Road | A12 | DWR | Anderson Grade | Mouth |
|---|---|---|---|---|---|
| Mean Bias | 0.07 | 0.06 | -1.36 | -1.99 | -2.21 |
| Mean absolute error (MAE) | 0.24 | 1.15 | 2.01 | 2.04 | 2.65 |
| Root mean squared error (RMSE) | 0.32 | 1.35 | 2.36 | 2.47 | 3.13 |
| N (number of hours) | 168 | 152 | 168 | 168 | 168 |

# Graphs of Calibrated Period and Validation Periods

## *Calibration Period (9/17/2002 – 9/23/2002):*

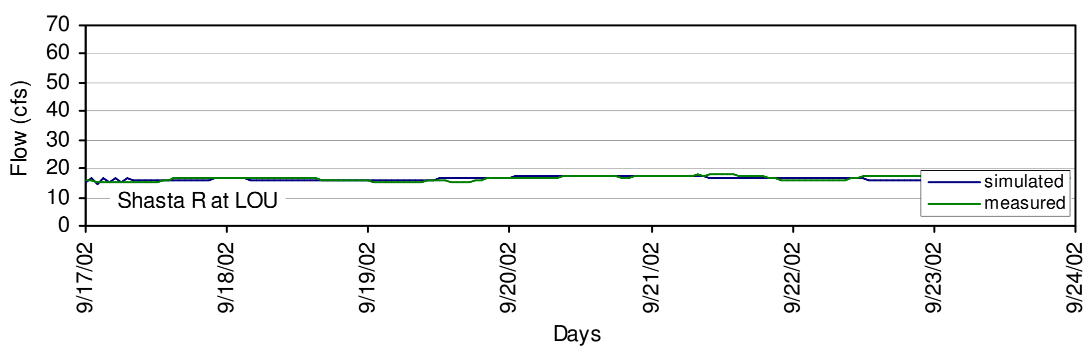


**Figure 6. Flow at Louie Road for 9/17/2002 – 9/23/2002**

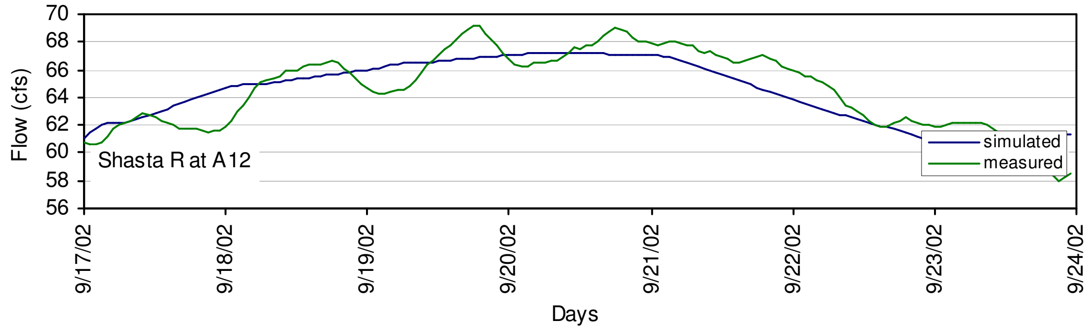


**Figure 7. Flow at Highway A12 for 9/17/2002 – 9/23/2002**

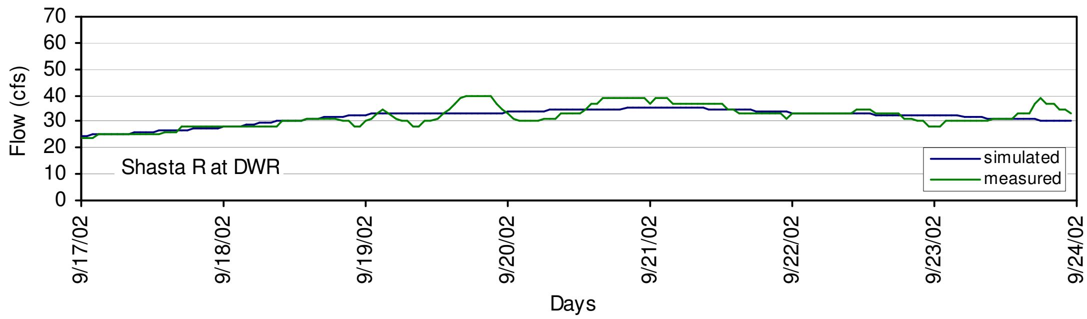


**Figure 8. Flow at DWR Weir for 9/17/2002 – 9/23/2002**

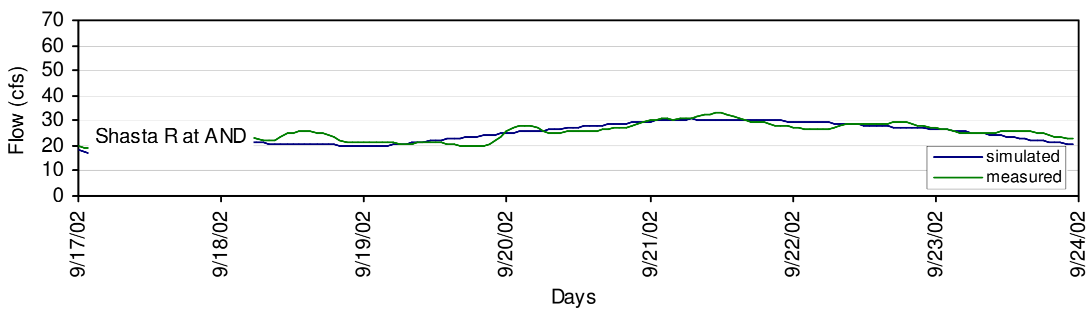


**Figure 9. Flow at Anderson Grade for 9/17/2002 – 9/23/2002**

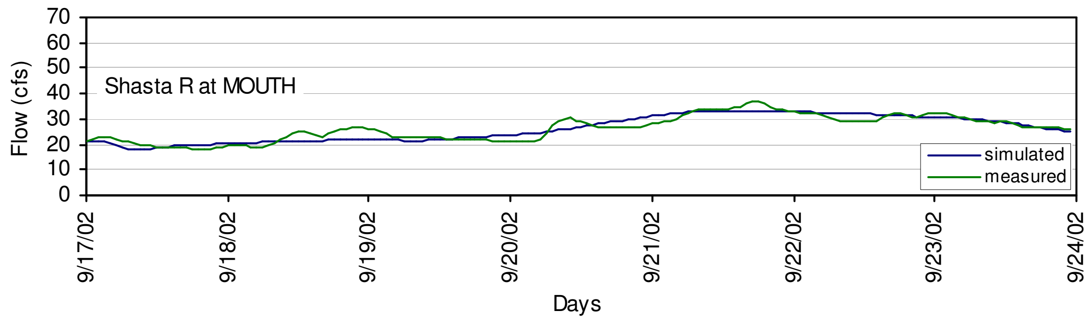


**Figure 10. Flow at the Mouth for 9/17/2002 – 9/23/2002**

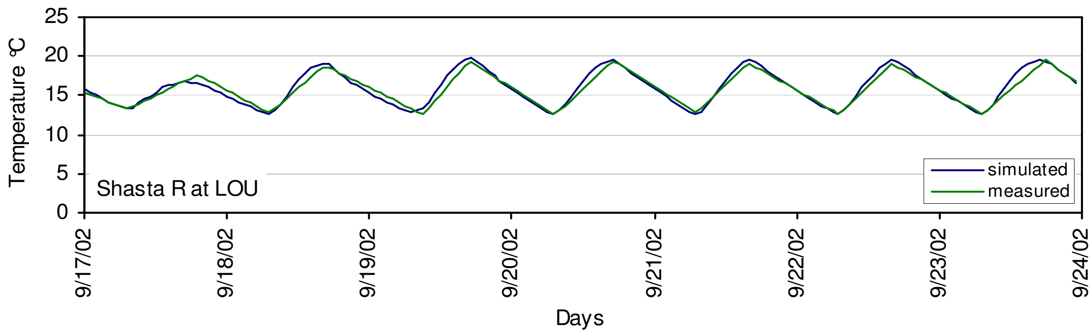


**Figure 11. Temperature at Louie Road for 9/17/2002 – 9/23/2002**

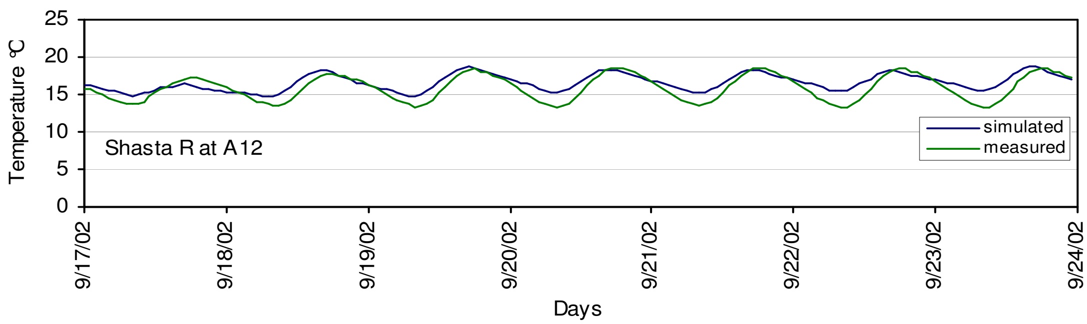


**Figure 12. Temperature at Highway A12 for 9/17/2002 – 9/23/2002**

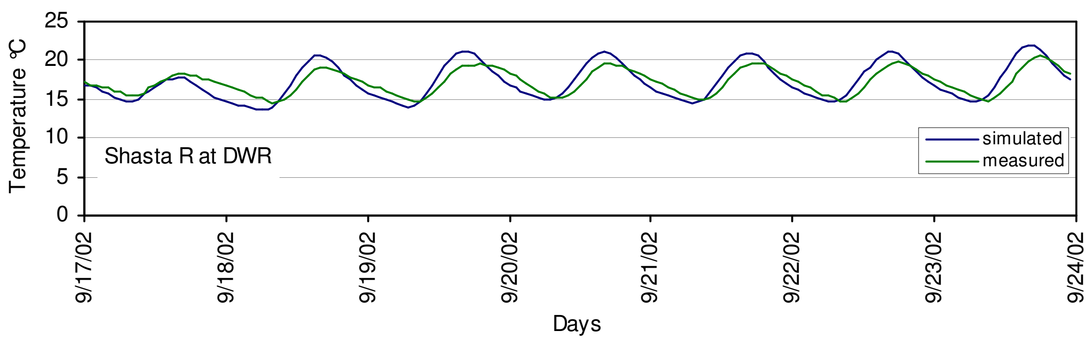


**Figure 13. Temperature at DWR Weir for 9/17/2002 – 9/23/2002**

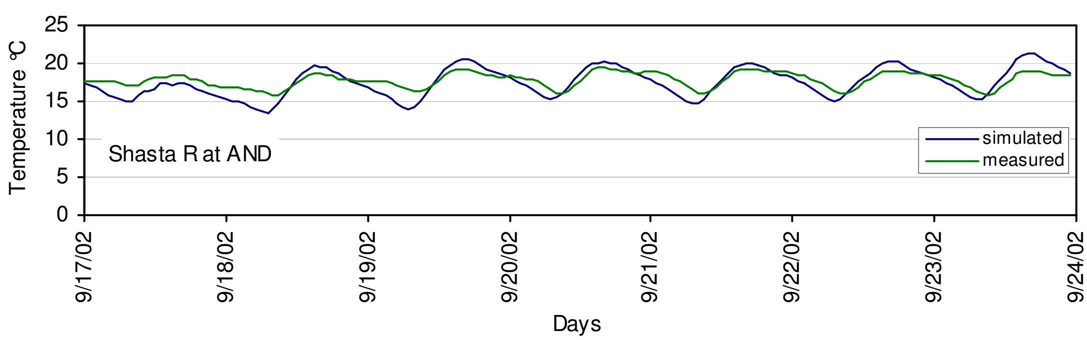


**Figure 14. Temperature at Anderson Grade for 9/17/2002 – 9/23/2002**

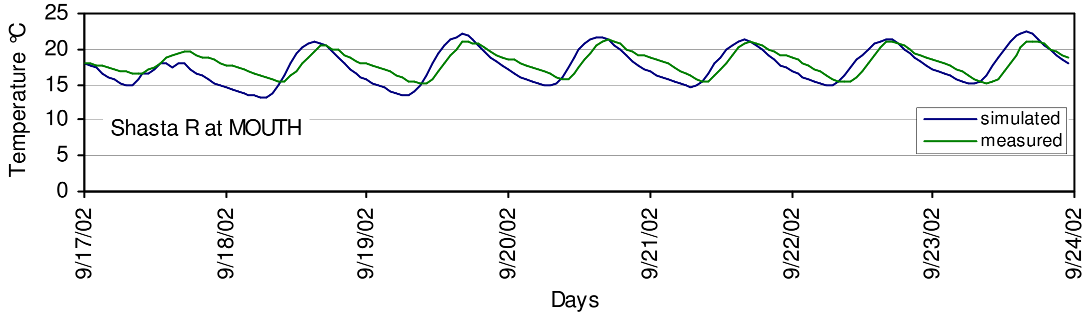


**Figure 15. Temperature at the Mouth for 9/17/2002 – 9/23/2002**

## ***Validation Period (8/29/2002 – 9/04/2002):***

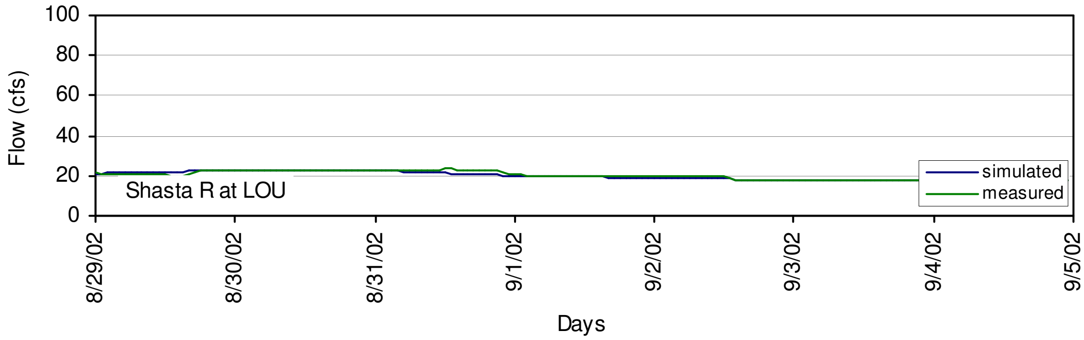


**Figure 16. Flow at Louie Road for 8/29/2002 – 9/04/2002**

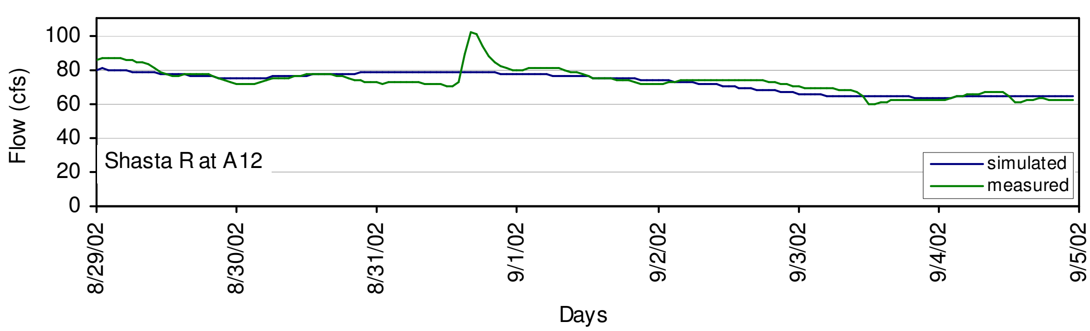


**Figure 17. Flow at Highway A12 for 8/29/2002 – 9/04/2002**

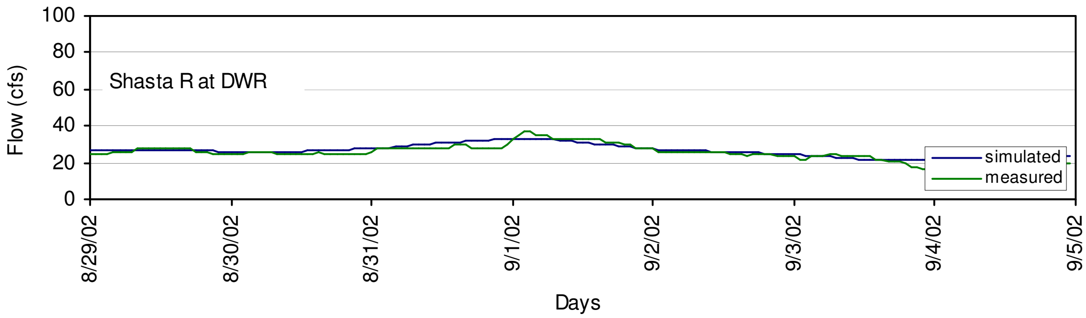


**Figure 18. Flow at DWR Weir for 8/29/2002 – 9/04/2002**

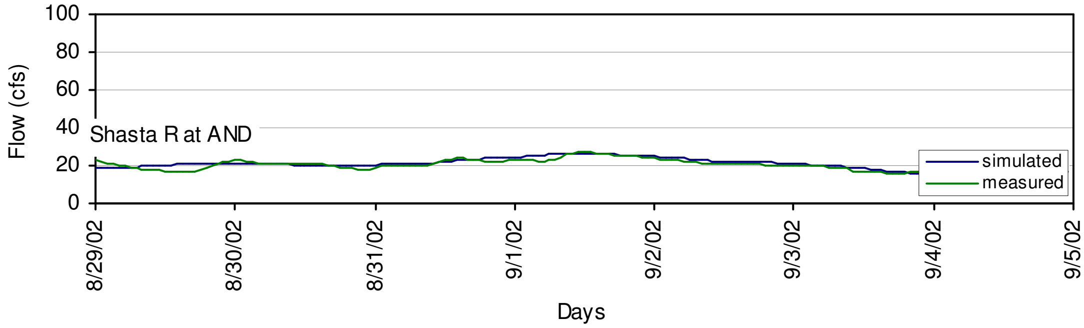


**Figure 19. Flow at Anderson Grade for 8/29/2002 – 9/04/2002**

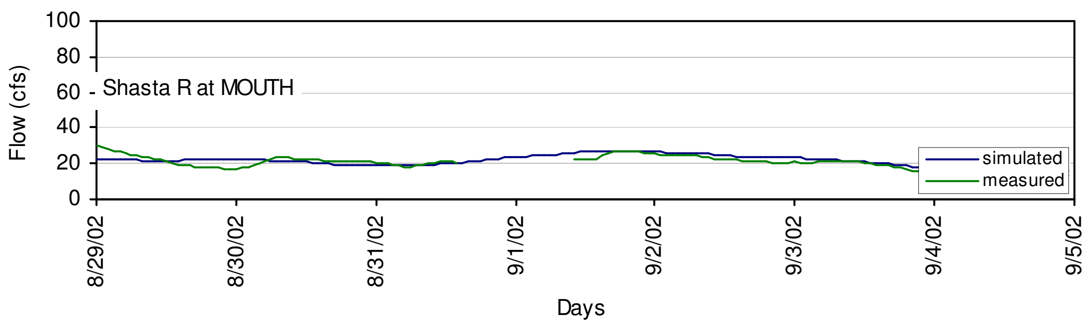


**Figure 20. Flow at the Mouth for 8/29/2002 – 9/04/2002**

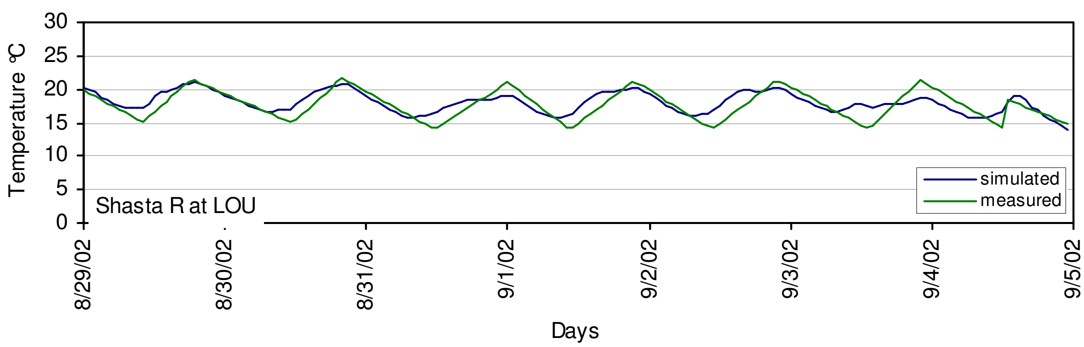


**Figure 21. Temperature at Louie Road for 8/29/2002 – 9/04/2002**

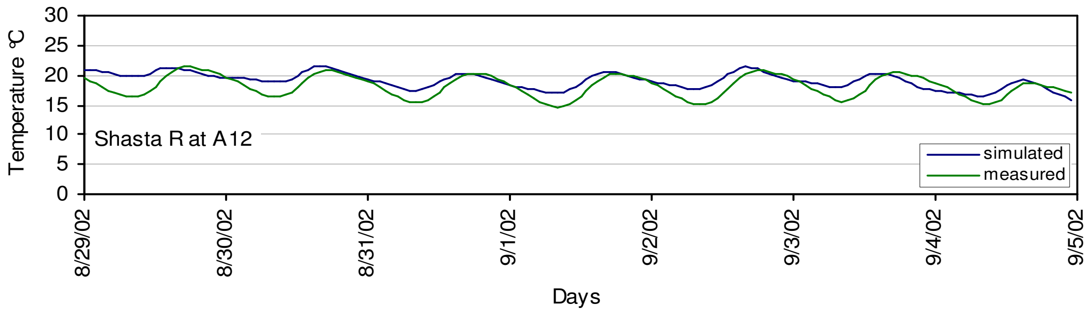


**Figure 22. Temperature at Highway A12 for 8/29/2002 – 9/04/2002**

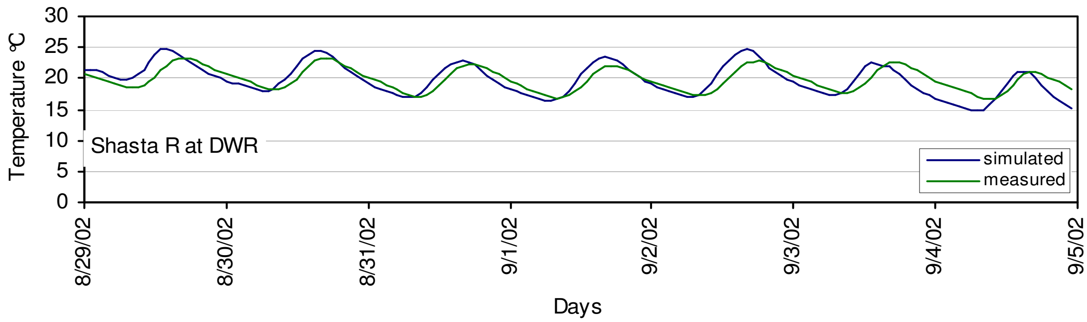


**Figure 23. Temperature at DWR Weir for 8/29/2002 – 9/04/2002**

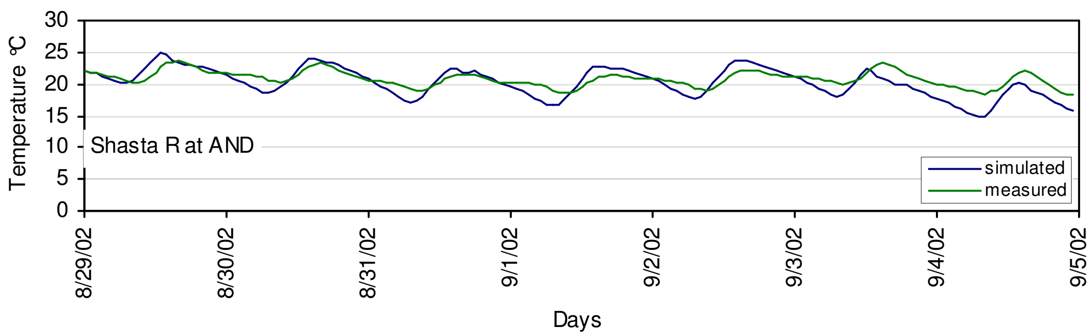


**Figure 24. Temperature at Anderson Grade for 8/29/2002 – 9/04/2002**

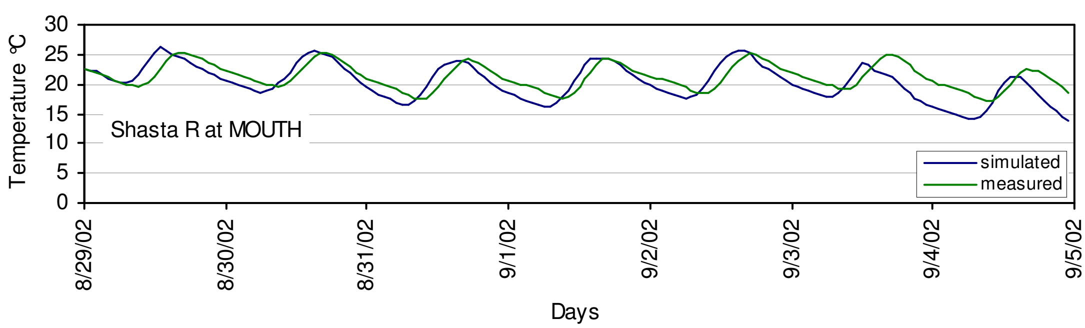


**Figure 25. Temperature at the Mouth for 8/29/2002 – 9/04/2002**

## *Validation Period (7/02/2002 – 7/08/2002):*

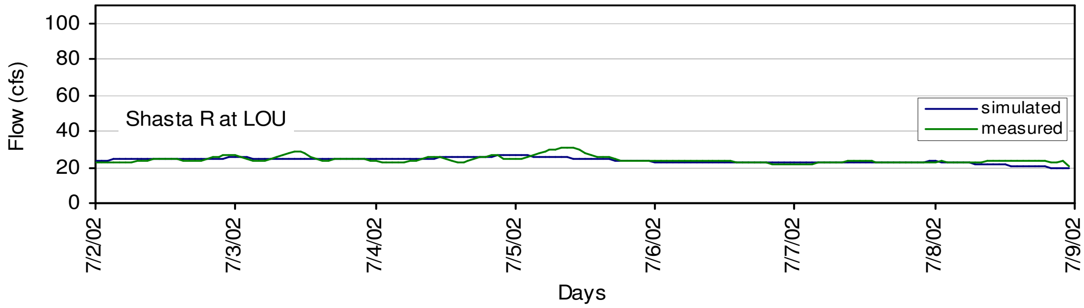


**Figure 26. Flow at Louie Road for 7/02/2002 – 7/08/2002**

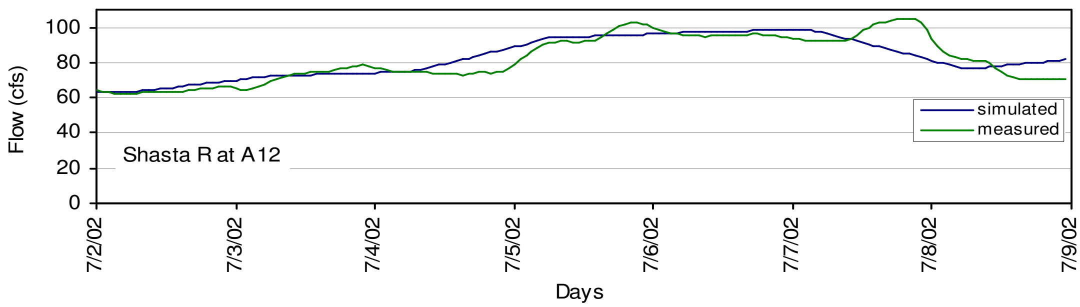


**Figure 27. Flow at Highway A12 for 7/02/2002 – 7/08/2002**

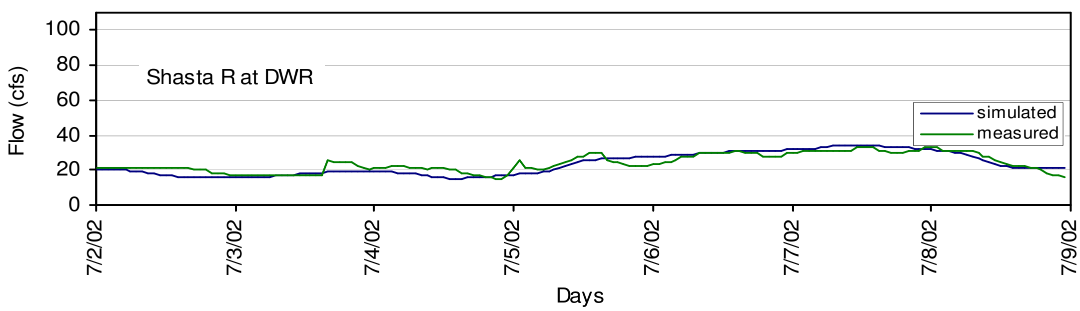


**Figure 28. Flow at DWR Weir for 7/02/2002 – 7/08/2002**

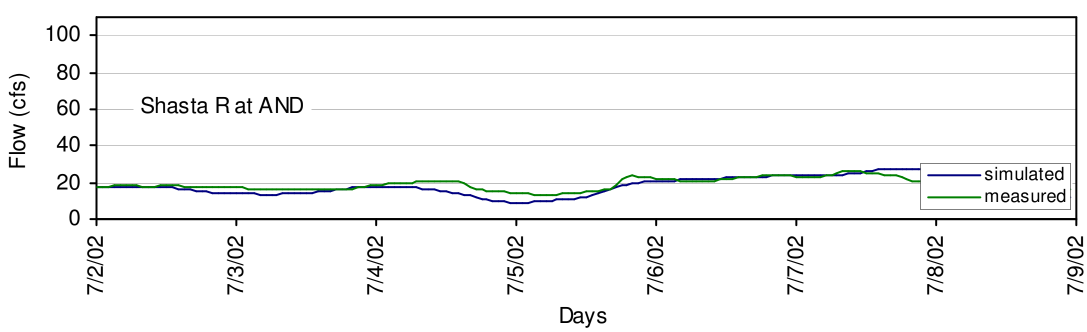


**Figure 29. Flow at Anderson Grade for 7/02/2002 – 7/08/2002**

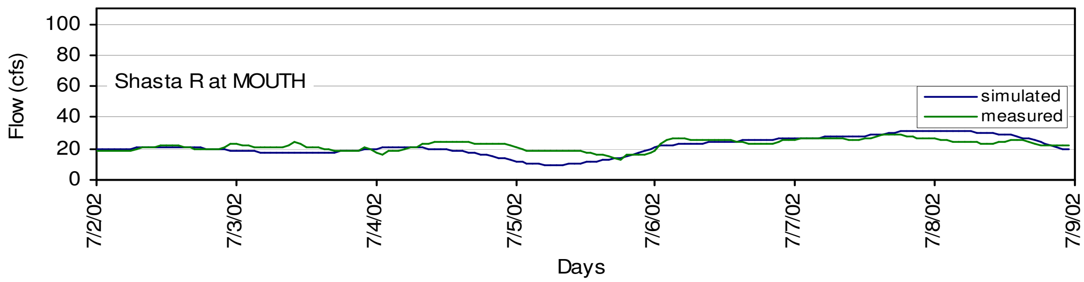


**Figure 30. Flow at the Mouth for 7/02/2002 – 7/08/2002**

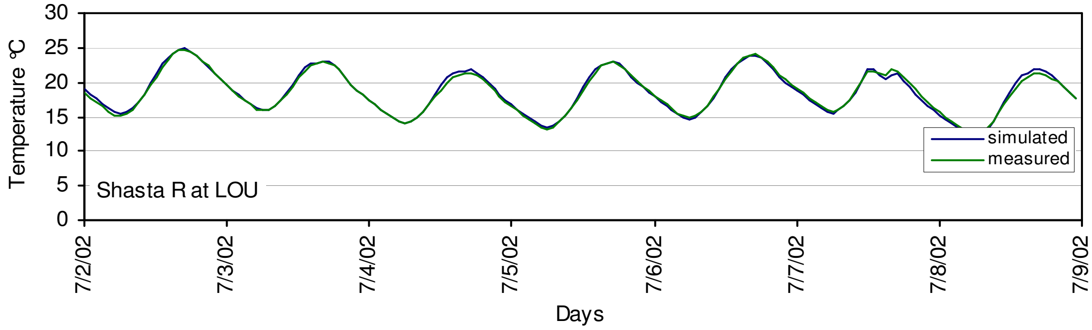


**Figure 31. Temperature at Louie Road for 7/02/2002 – 7/08/2002**

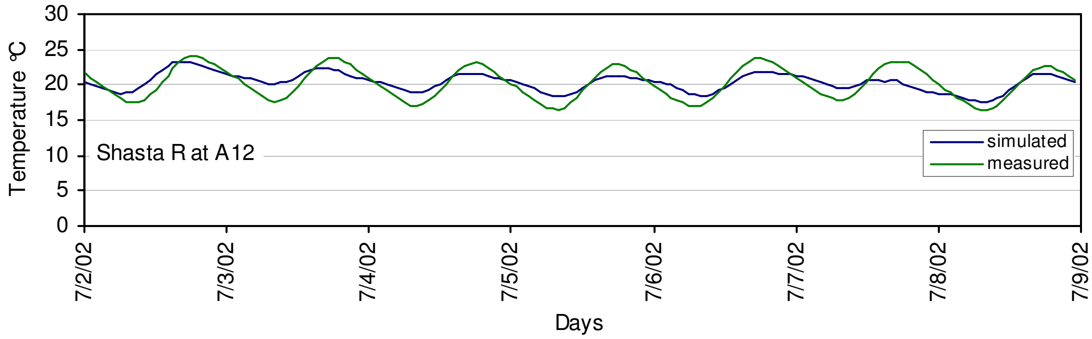


**Figure 32. Temperature Highway A12 for 7/02/2002 – 7/08/2002**

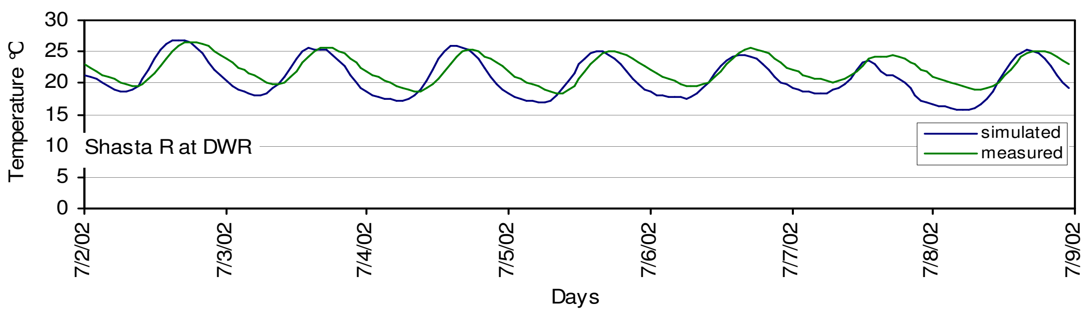


**Figure 33. Temperature DWR Weir for 7/02/2002 – 7/08/2002**

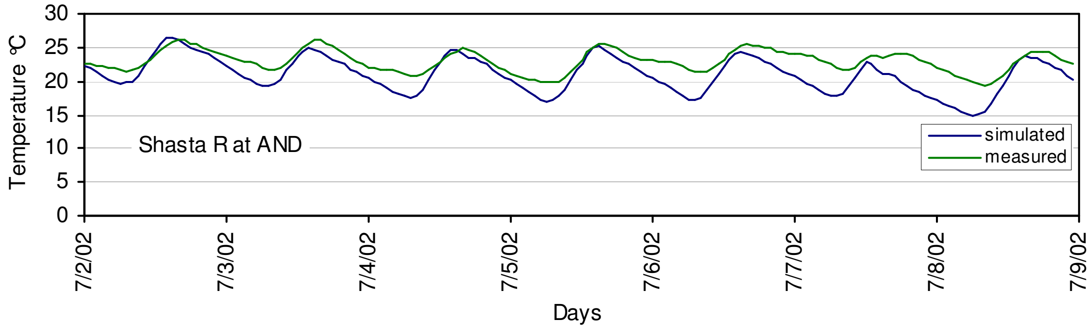


**Figure 34. Temperature Anderson Grade for 7/02/2002 – 7/08/2002**

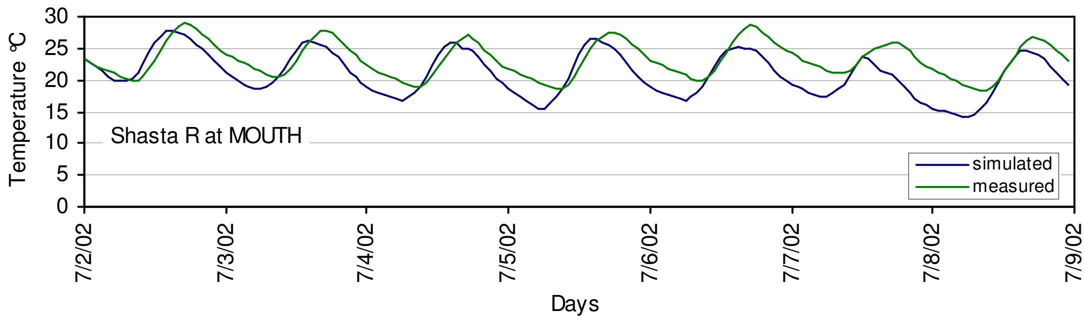


**Figure 35. Temperature the Mouth for 7/02/2002 – 7/08/2002**

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