Laurance Lake Temperature Model

by

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Table of Contents

List of Figures

List of Tables

Acknowledgements

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Introduction

Laurance Lake is a reservoir located in Hood River County, Oregon (Figure 1). It is located at the base on Mt. Hood in Oregon (see Figure 2 and Figure 3), discharges into the Middle Fork of the Hood River. The reservoir was constructed in 1968 for irrigation storage and has a capacity 3564 acre-feet at full pool. Since the river violates temperature standards, this study has been designed to construct a hydrodynamic and temperature model of Laurance reservoir in order to assess strategies for improving temperatures in the Middle Fork River.

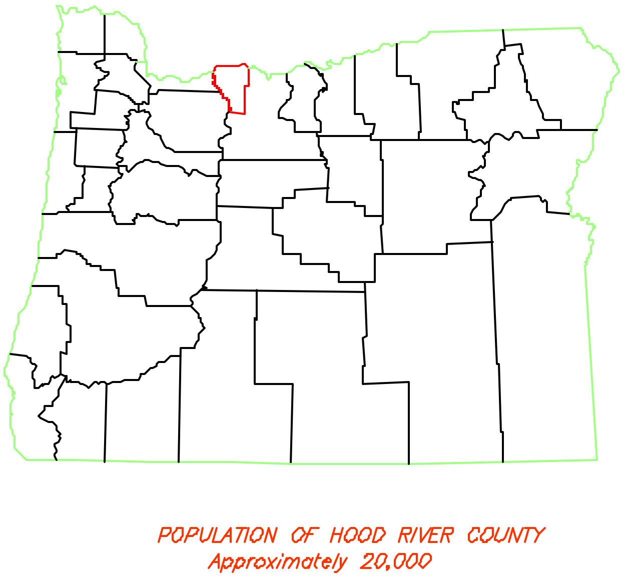


Figure 1. Hood River County, Oregon.

The objectives of the study are then to

- Develop a hydrodynamic and temperature model of Laurance Lake
- Calibrate the model to field data collected from November 2002 through Spring 2004
- Use the model to evaluate strategies for temperature improvement through operational or structural changes to Lake Laurance

The model chosen for development was CE-QUAL-W2 Version 3.2 (Cole and Wells, 2004). This is a two-dimensional unsteady hydrodynamic, temperature and water quality model that includes typical eutrophication parameters (algae, nutrients, temperature, organic matter, dissolved oxygen, pH). PSU, under the support of the Corps of Engineers Waterways Experiment Station, is a center for development of this modeling tool.

In order to model the system, the following data were required:

- Laurance Lake outflow, water level and temperature data at the upstream system boundary (Clear Creek)

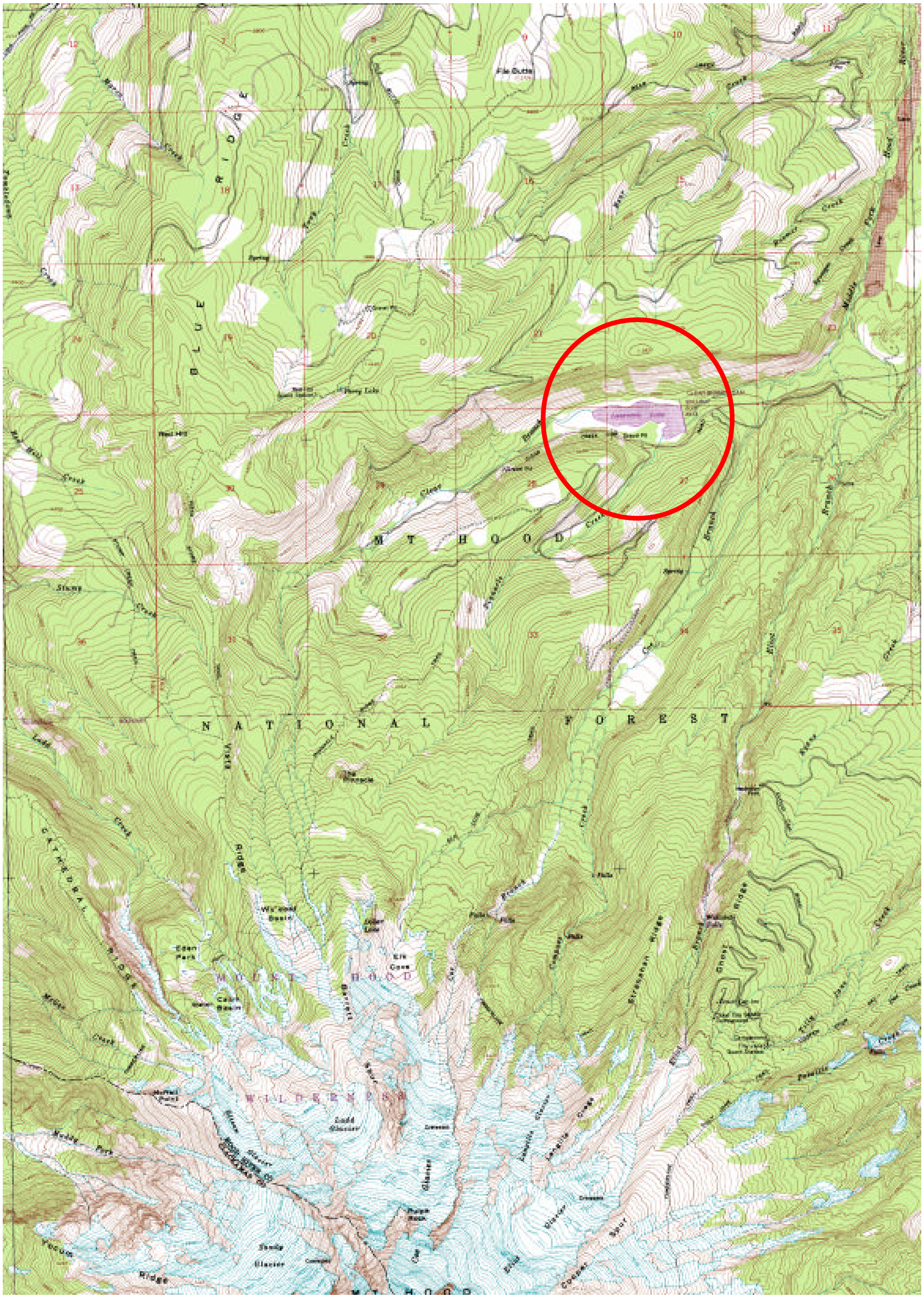


Figure 2. Lake Laurance, Oregon.

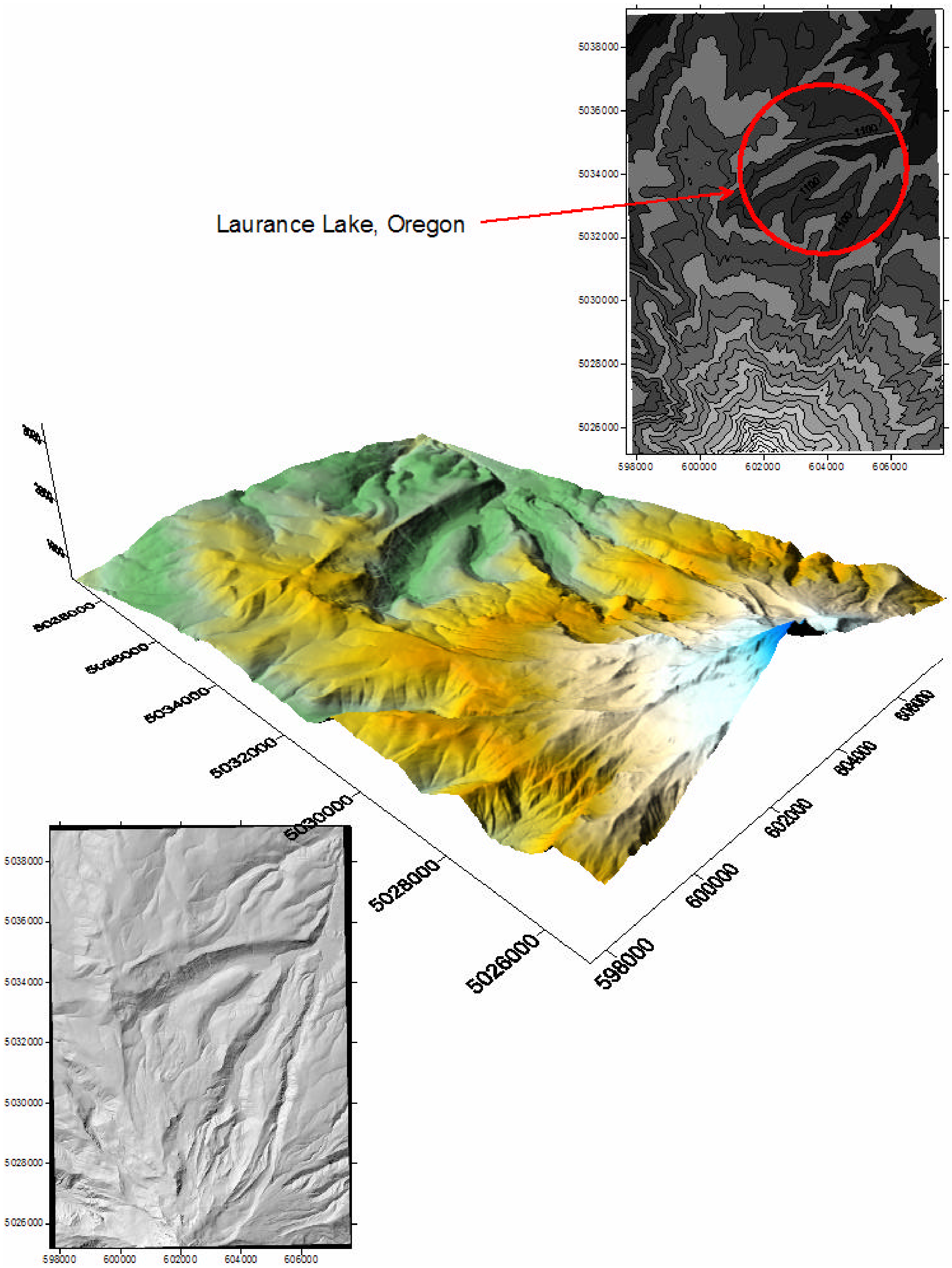


Figure 3. Topography around Laurance Lake.

- Tributary inflows and temperatures
- Meteorological conditions
- Bathymetry of Laurance Lake

Data have been primarily collected from 2002 to 2004. This report summarizes model development. Information provided in this report was organized in the following sections:

- Model Selection
- Model Forcing Data
- Hydrodynamic Calibration
- Temperature Calibration
- Management Scenarios
- Summary and Conclusions

Also discussed are issues relative to the calibration effort. Calibration focused on model predictions of hydrodynamics (flow and water level) and temperature. The model calibration period was from May 1, 2003 to April 30, 2004.

Background Information

The following information from Oregon DEQ and Middle Fork Irrigation District documents temperature issues in the Laurance Lake system (ODEQ and MFID, 2002):

> "The waters in Clear Branch and the Middle Fork Hood River below Clear Branch Dam have been identified as water quality limited for temperature and placed on the 303(d) list as required by the Federal Clean Water Act. Clear Branch and the Middle Fork Hood River are included on the 303 (d) list for exceeding the State of Oregon's Bull trout (*Salvelinus confluentus*) criterion of 10° C. Bull trout inhabit Clear Branch and the Middle Fork Hood River and were listed as a threatened species under the Endangered Species Act in 1998. Clear Branch Dam was constructed under P.L. 566 with the help of the NRCS and is operated and maintained by Middle Fork Irrigation District (MFID). Clear Branch and Coe Branch join together about 0.5 miles below the Clear Branch Dam to form the Middle Fork Hood River."
>
> "The Western Hood Subbasin Total Maximum Daily Load (TMDL) was approved by EPA in January 2002 and lists the "critical period" for Clear Branch below Laurance Lake as year round. Suggested solutions to this temperature problem have included diverting colder Pinnacle Creek water to the base of the dam or a selective withdrawal system in the Lake. MFID is required to develop and implement a "Surface Water Temperature Management Plan" for the operation of the Clear Branch Dam by Oregon Department of Environmental Quality (DEQ). Temperature data has been collected above and below Laurance Lake since 1997. That data is not complete. Flow data for Pinnacle and Clear Branch Creeks feeding Laurance Lake is not available. Anecdotal evidence indicates there is a groundwater influence in Laurance Lake. There are springs at the base of the dam, one has been monitored for temperature and frequently exceeds the 10° C standard. Before a "Surface Water Temperature Management Plan" can be created and a computer model run to examine temperature and flow dynamics, cooling/warming effects of Pinnacle and Clear Branch creeks and ground water influence, more data must be acquired."

Model Selection

Selection of the appropriate water quality model is a function of properly identifying the water quality problem ("conceptualization") and selecting a model which appropriately describes the water quality changes in the water body, is theoretically valid, and can be easily adapted to site-specific physical characteristics of the water body.

The performance of a mathematical model in predicting the existing and future water quality dynamics of a system is dependent on the following steps:

(i) identification of the problem
(ii) selection of model type and relationship of model to the problem
(iii) computational representation
(iv) model response studies or model sensitivity analyses
(v) model calibration
(vi) application of model to evaluate management strategies

Because there are many water quality models available, a choice of the appropriate model would be made after considering the following questions: What physical processes are represented in the model and which are ignored? How are physical processes included in the model? What processes are represented by model coefficients? For example in defining the problem, the following questions could be asked:

(i) What are the dominant physical processes at work and can the chosen model represent those processes? (such as, how does the water move? Is there stratification, wind-driven currents, and/or selective withdrawal?)
(ii) What are the spatial and temporal scales of these processes and can the model represent them? (such as, is steady-state representation adequate, is 1-D, 2-D, or 3-D spatial discretization necessary?)

The choice of the proper model is also based on answering
(1) site specific questions (physical characteristics of the each system component - river or reservoir reach, water quality cycles, algal types),
(2) management objectives (required accuracy, use for future studies),
(3) project resources (data availability, staff constraints, time limitations).

The model chosen for Laurance Lake was the Corps of Engineers model CE-QUAL-W2 Version 3.2. CE-QUAL-W2 Version 3.2 is a dynamic 2-d (x-z) model developed for stratified water-bodies (Cole and Wells, 2004). This is a Corps of Engineers modification of the Laterally Averaged Reservoir Model (Edinger and Buchak 1978). CE-QUAL-W2, whose grid is shown in Figure 4, consists of directly coupled hydrodynamic and water quality transport models. Hydrodynamic computations are influenced by variable water density caused by temperature, salinity, and dissolved and suspended solids. Developed for reservoirs and narrow, stratified estuaries, CE-QUAL-W2 can handle a branched and/or looped system with flow and/or head boundary conditions. With two dimensions depicted, point and non-point loading can be spatially distributed. Relative to other 2-D models, CE-QUAL-W2 is efficient and cost effective to use. This model allows the user to use the ultimate quickest Numerical Scheme for improved numerical accuracy.

In addition to temperature, CE-QUAL-W2 Version 3.2 can simulate many water quality variables. Primary physical processes included are surface heat transfer, short-wave and long-wave radiation and penetration, convective mixing, wind and flow induced mixing, entrainment of ambient water by pumped-storage inflows, inflow density stratification as impacted by temperature and dissolved and suspended solids. Major chemical and biological processes in CE-QUAL-W2 include: the effects of DO of atmospheric exchange, photosynthesis, respiration, organic matter decomposition, nitrification, and chemical oxidation of reduced substances; uptake, excretion, and regeneration of phosphorus and nitrogen and nitrification-denitrification under aerobic and anaerobic conditions; carbon cycling and alkalinity-pH-CO2 interactions; trophic relationships for total phytoplankton; accumulation and decomposition of detritus and organic sediment; and coliform bacteria mortality.

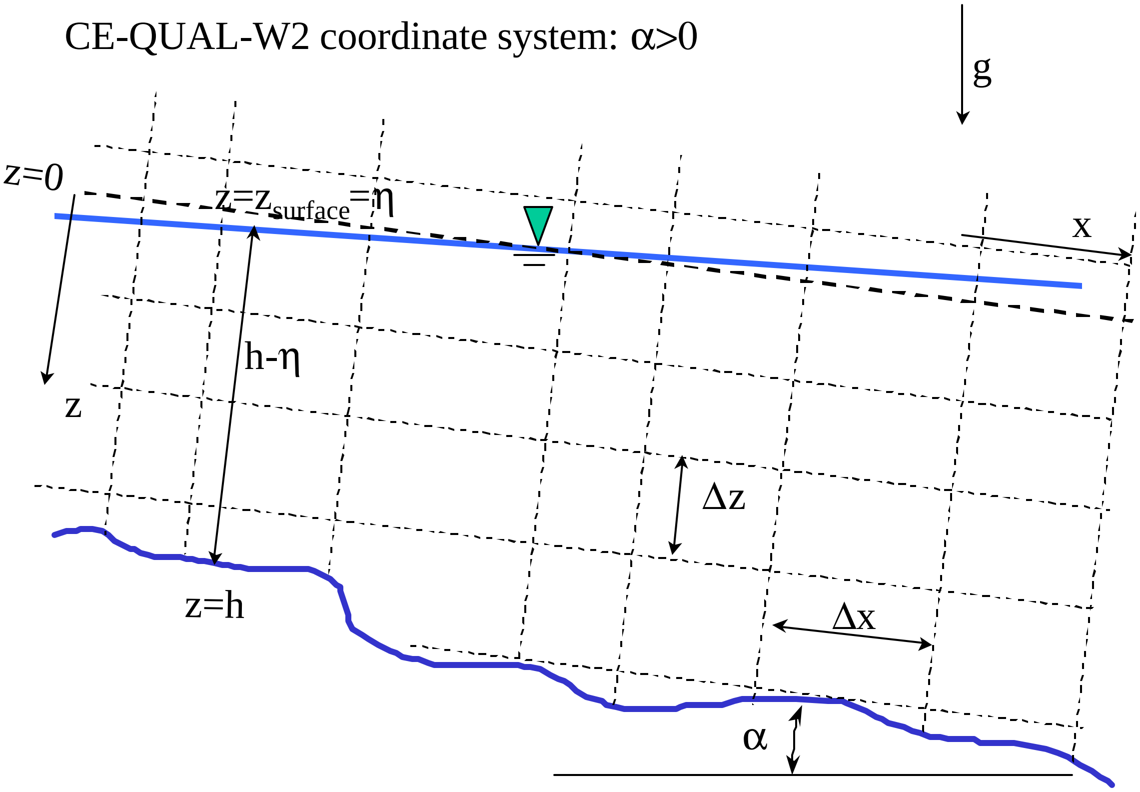


Figure 4. Coordinate system for CE-QUAL-W2 Version 3.2.

Models, such as WQRSS (Smith 1978), HEC-5Q (Corps of Engineers 1986), and HSPF (Donigian, et al. 1984), have been developed for river basin modeling but have serious limitations. One issue is that the HEC-5Q (similar to WQRSS) and HSPF models incorporate a one-dimensional, longitudinal river model with a one-dimensional, vertical reservoir model (one-dimensional for temperature and water quality and zero dimensional for hydrodynamics). The modeler must choose the location of the transition from 1-D longitudinal to 1-D vertical. Besides the limitation of not solving for the velocity field in the stratified, reservoir system, any point source inputs to the reservoir section are spread over the entire longitudinal distribution of the reservoir layer.

Also, other one-dimensional reservoir models, such as the HEC WQRRS (Water Quality River-Reservoir Simulation) model and the Corps's CE-QUAL-R1, are also not adequate to compute 2-D circulation within pool areas. These models conceptualize a pool as well mixed in each horizontal slab, i.e., over the length and the width of the system. By making this assumption, the vertical and longitudinal circulation patterns within a pool cannot be resolved.

Based on the depth Laurance Lake, a one-dimensional reservoir model of the river system would not be adequate because of possible longitudinal and vertical gradients in water quality.

For this project, the CE-QUAL-W2 River Basin Model Version 3.2 (as schematized in Figure 5) was the most appropriate for modeling Laurance Lake since it contains the following elements:

- Two-dimensional, dynamic hydrodynamics and water quality capable of replicating any density stratified environment.
- The hydraulic elements at the dam (outlet pipe and spillway) can be accurately represented
- The model is a state-of-the-art tool with features not found in other models

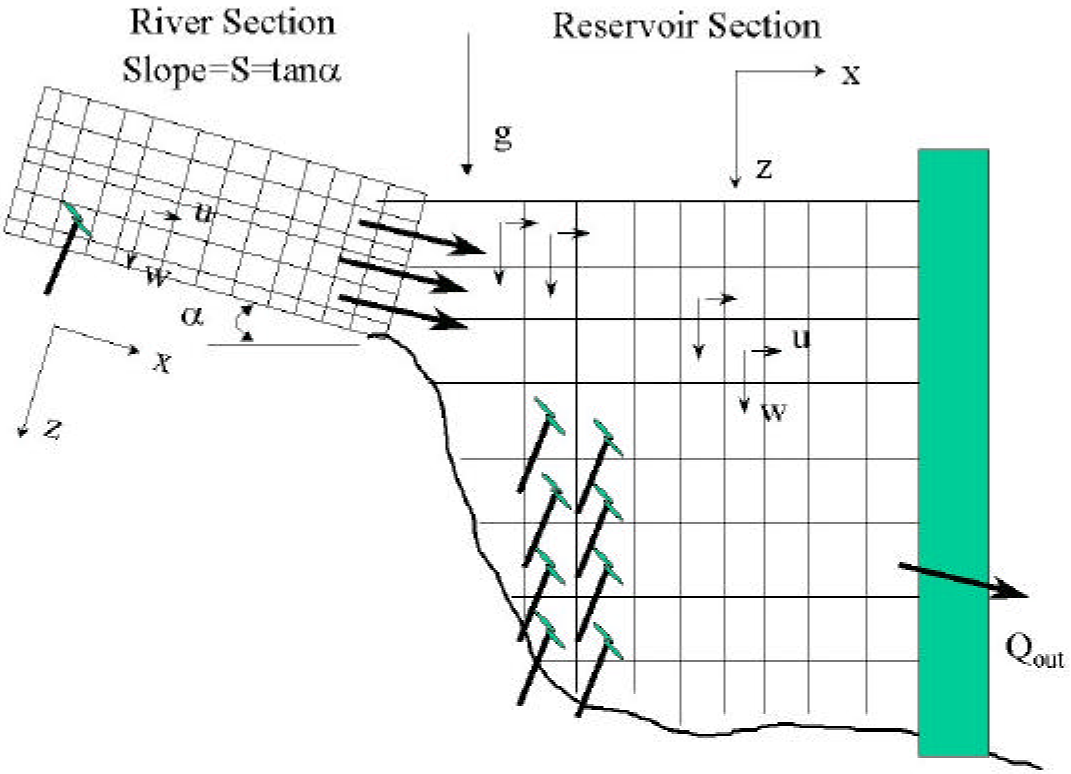


Figure 5. Conceptual schematic of river-reservoir connection in CE-QUAL-W2 Version 3.

This model has been under development for many years and is a public-domain code maintained by the Corps of Engineers, Waterways Experiments Station (WES), located in Vicksburg, Mississippi. Version 3.2 has and is undergoing rigorous testing and has been successfully applied to many river basin systems. Further information about CE-QUAL-W2 Version 3 is shown at http://www.ce.pdx.edu/w2.

Model Forcing Data

The model forcing data consists of the system bathymetry developed into the model grid; the boundary condition flow and temperature; the tributary and flow and temperature; and the system meteorology.

Water quality monitoring sites from which data were used for model development were identified in Figure 6 and were described in Table 1.

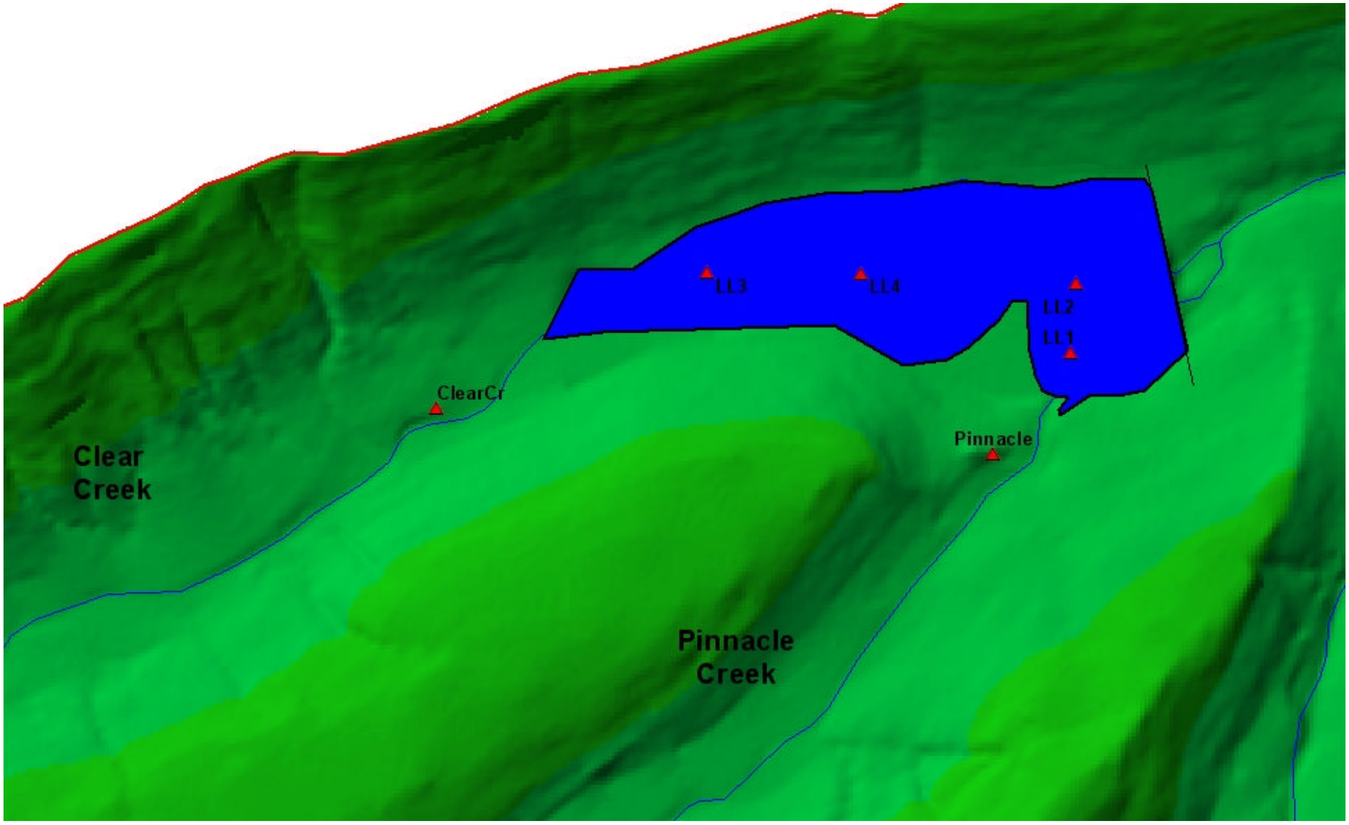


Figure 6. Monitoring sites at Laurance Lake

Table 1. Monitoring sites

Site ID	Description
CC	Clear Creek above Reservoir
PC	Pinnacle Creek above Reservoir
LL1	Laurance Lake at Pinnacle Creek Branch
LL2	Laurance Lake near dam
LL3	Laurance Lake, middle
LL4	Laurance Lake near upstream end

Model Geometry

Laurance Lake Bathymetry

The Long Lake bathymetry was developed using depth soundings, a USGS digital elevation map (DEM), and a bathymetric contour map provided by Middle Fork Irrigation district. The data points used to develop the bathymetry were shown in Figure 7. Model bathymetry was created up to an elevation of 925 meters, 17 meters above the current full pool elevation, to allow the simulation of management scenarios that included raising the dam. In general, data from depth soundings were used to describe bathymetry below current full pool elevations, the bathymetric contour map was used for areas near the bank, and the USGS DEM data were used for elevations well above the full pool elevation.

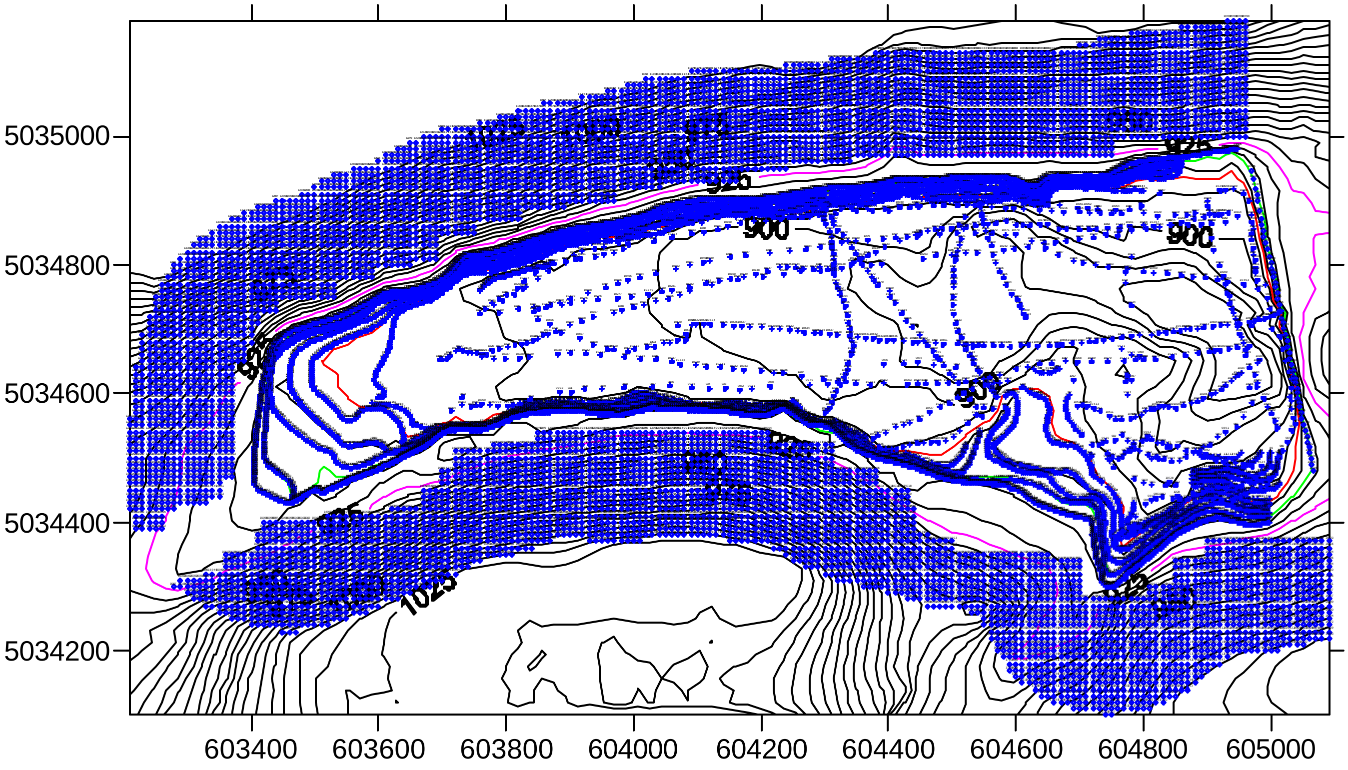


Figure 7. Location of data points used to develop bathymetry

Grid Layout

Figure 8 shows the plan view of the grid layout for the Laurance Lake.

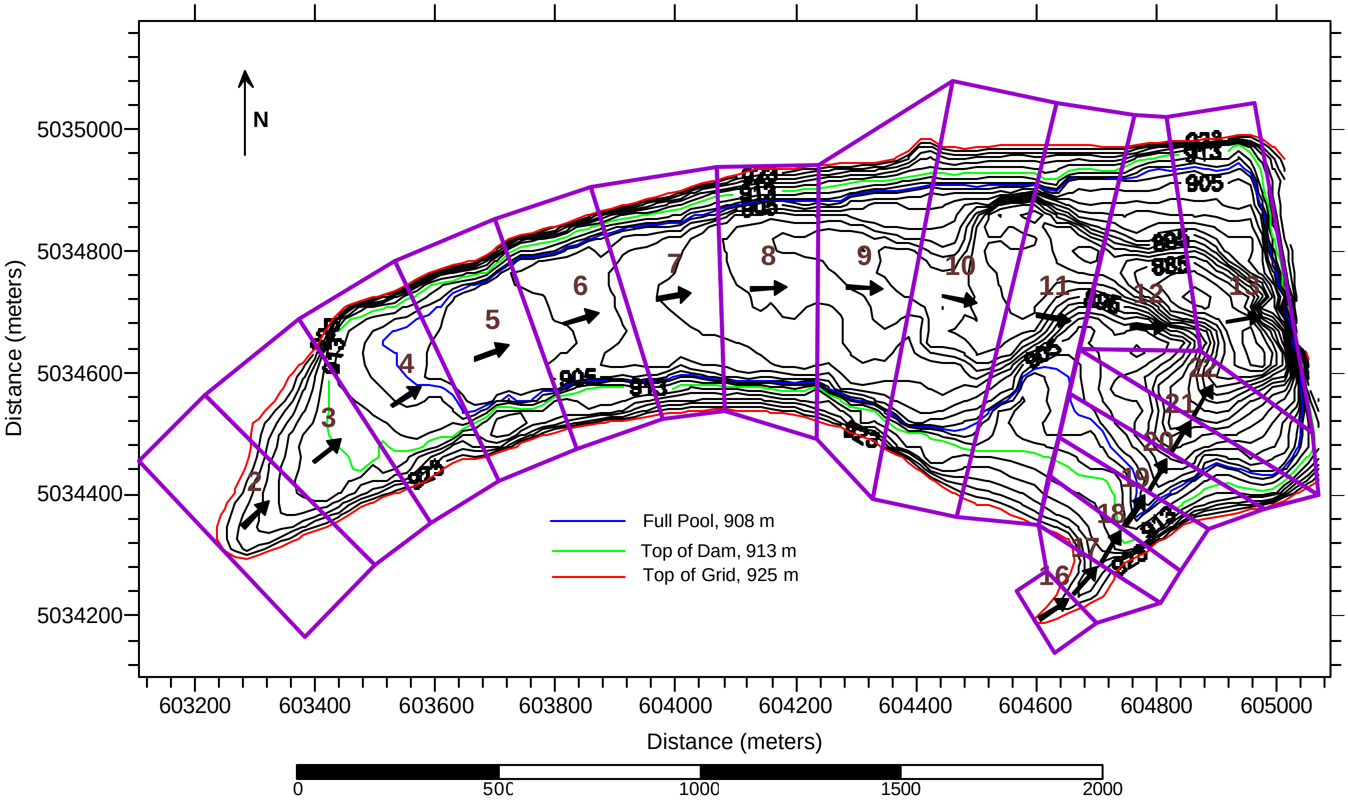


Figure 8. Plan view of the Laurance Lake grid. The arrows show the segment orientation.

The model was divided into two branches, the first representing Clear Creek and the second Pinnacle Creek. Branch 1 had 12 active segments and branch 2 contained 7 active segments. The model segments in branch 1 had a length of 159.6 meters whereas those in branch 2 were 71.3 meters long. There were a total of 90 active model layers each having a thickness of 0.5 meters. Model layers for branch 1 were shown in Figure 9.

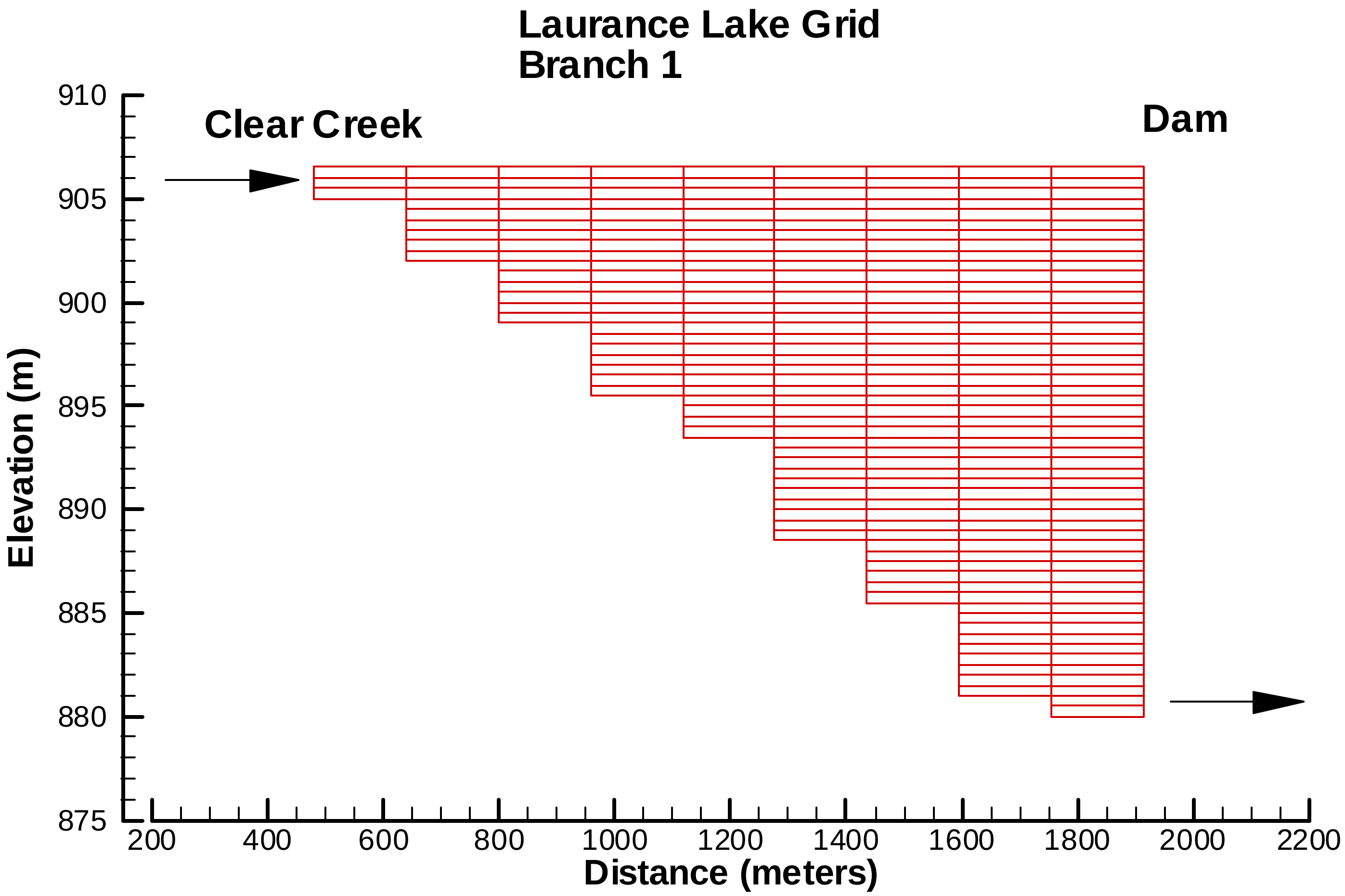


Figure 9. Layer elevations of branch 1. Only layers below the full pool elevation were shown.

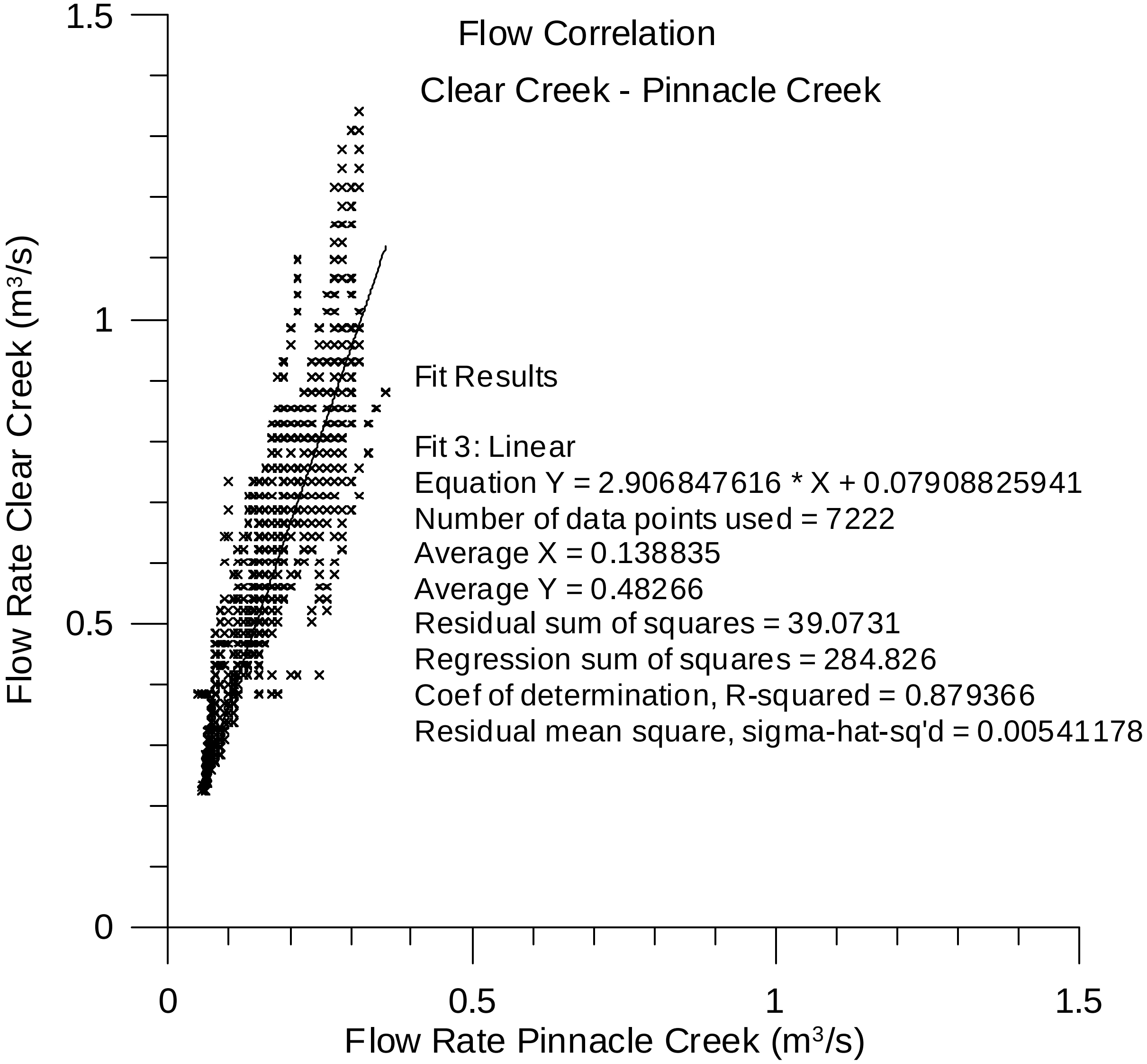
In the CE-QUAL-W2 model, the model user must specify the characteristics and connectivity of the model grid. The following parameters were used in the Laurance Lake model (see Cole and Wells, 2004, for detailed explanation of model grid characteristics):

IMP (# of segments): 23
KMP (# of vertical layers): 92
NWB (# of water-bodies): 1
NBR (# of branches): 2

The branch layout was specified by these parameters for each branch (as specified in the w2_con.npt control file – see Cole and Wells, 2004).

Boundary Conditions

The upstream boundary condition for the Laurance Lake model was Clear Creek. Clear Creek inflows were based on gaging station data and a regression equation developed from a correlation between Clear Creek and Pinnacle Creek flow rates (Figure 10). The regression equation was only used when Clear Creek gaging data were not available. Figure 11 shows the flow rates used for Clear Creek.



Fit Results

Fit 3: Linear
Equation Y = 2.906847616 * X + 0.07908825941
Number of data points used = 7222
Average X = 0.138835
Average Y = 0.48266
Residual sum of squares = 39.0731
Regression sum of squares = 284.826
Coef of determination, R-squared = 0.879366
Residual mean square, sigma-hat-sq'd = 0.00541178

Figure 10. Correlation between Clear Creek and Pinnacle Creek.

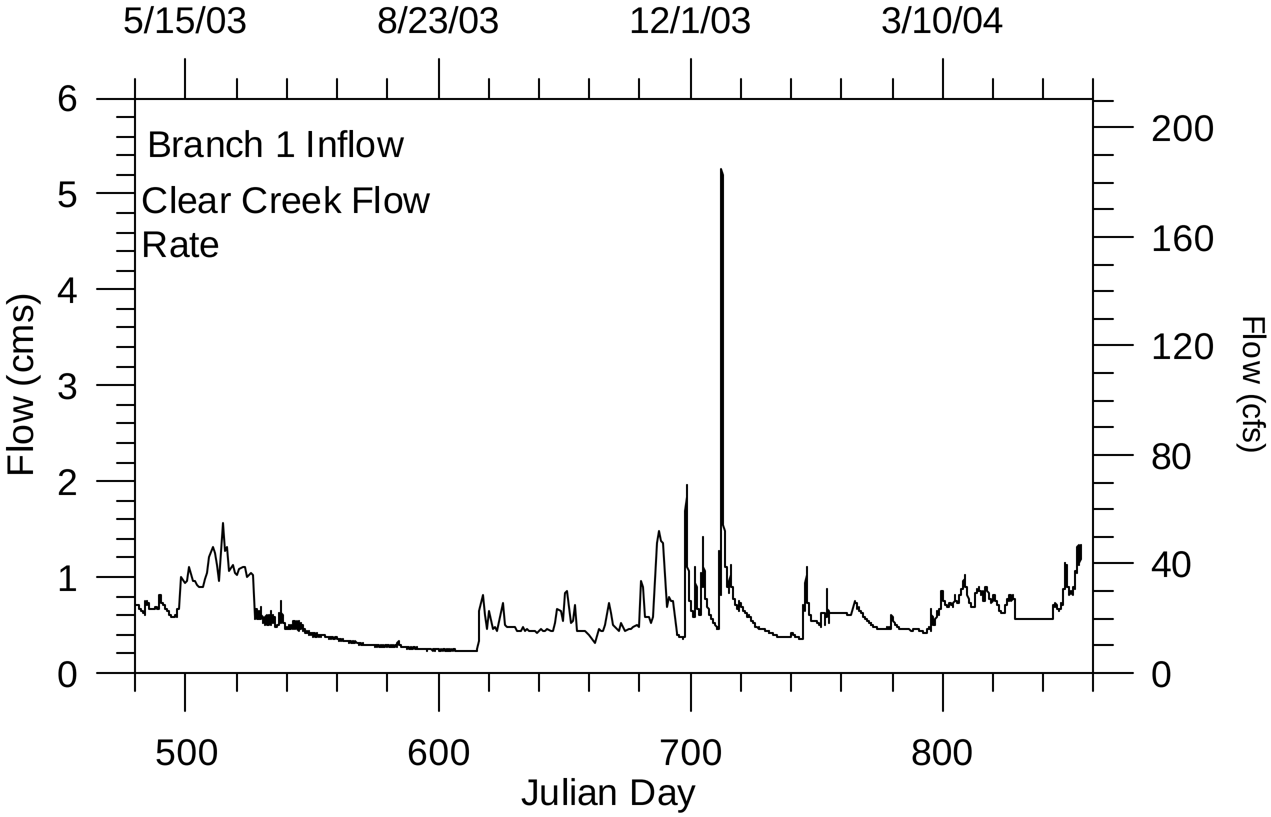


Figure 11. Clear Creek flow rates.

Clear Creek inflow temperatures were based on measured data obtained from a sampling site near the reservoir. Figure 12 shows a plot of inflow temperatures versus time.

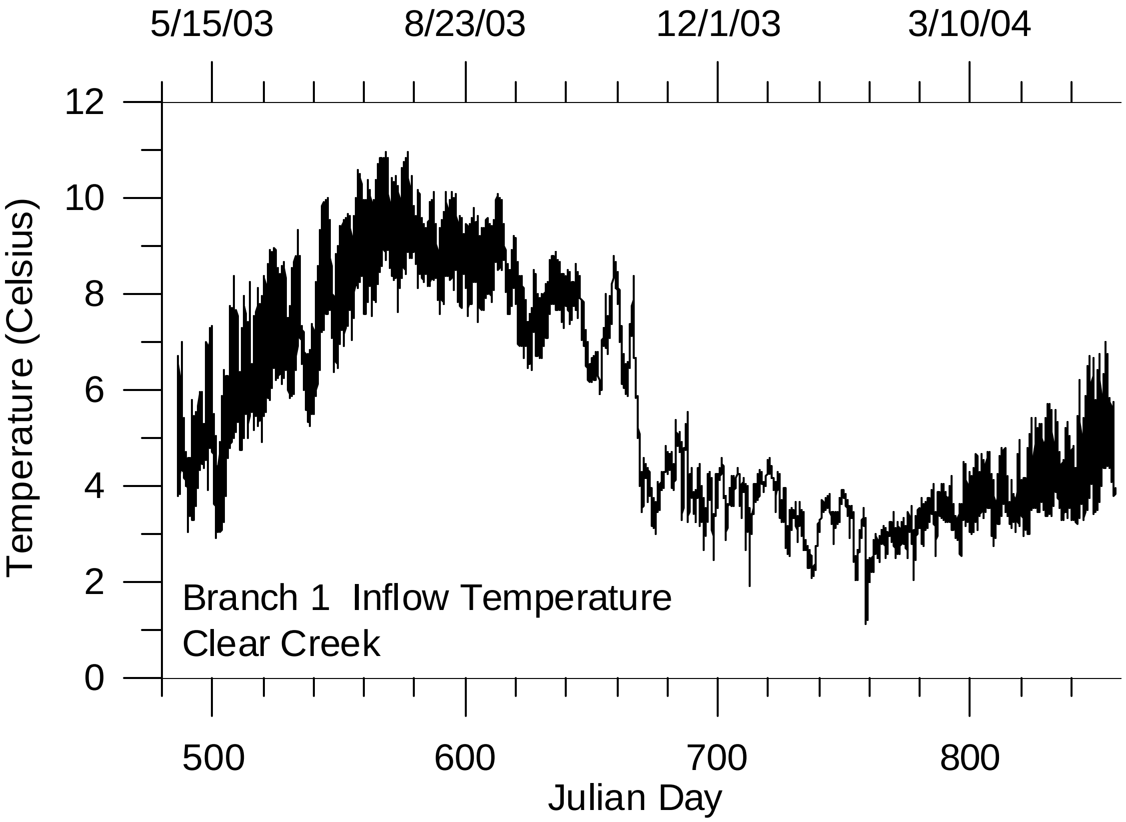


Figure 12. Clear Creek inflow temperatures.

Laurance Lake outflow

The downstream boundary condition was the outflow from Laurance Lake. An outflow record was developed for the model as shown in Figure 13. The outflow file was developed from data provided by Middle Fork Irrigation District (MFID). The outlet pipe is at the bottom of the reservoir adjacent to the dam and was modeled as a point sink.

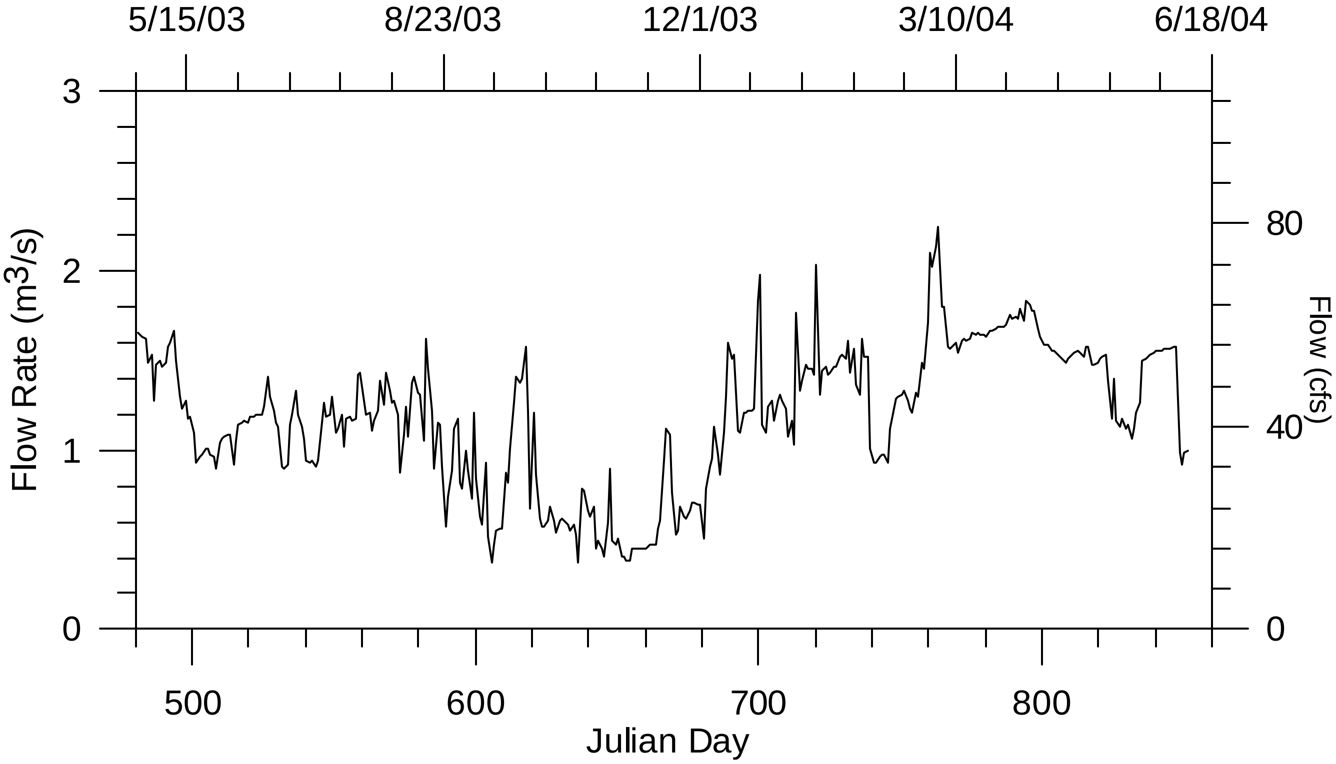


Figure 13. Laurance Lake Outflow

Tributaries

Pinnacle Creek

Pinnacle Creek inflows were shown in Figure 14. Flow rates were developed from gaging station data and a regression equation for time periods when gaging station data did not exist. A regression between Pinnacle Creek and Clear Creek was used during these periods. The correlation between Pinnacle Creek and Clear Creek was shown in Figure 15. Water temperatures used to represent Pinnacle Creek were measured data and were plotted in Figure 16.

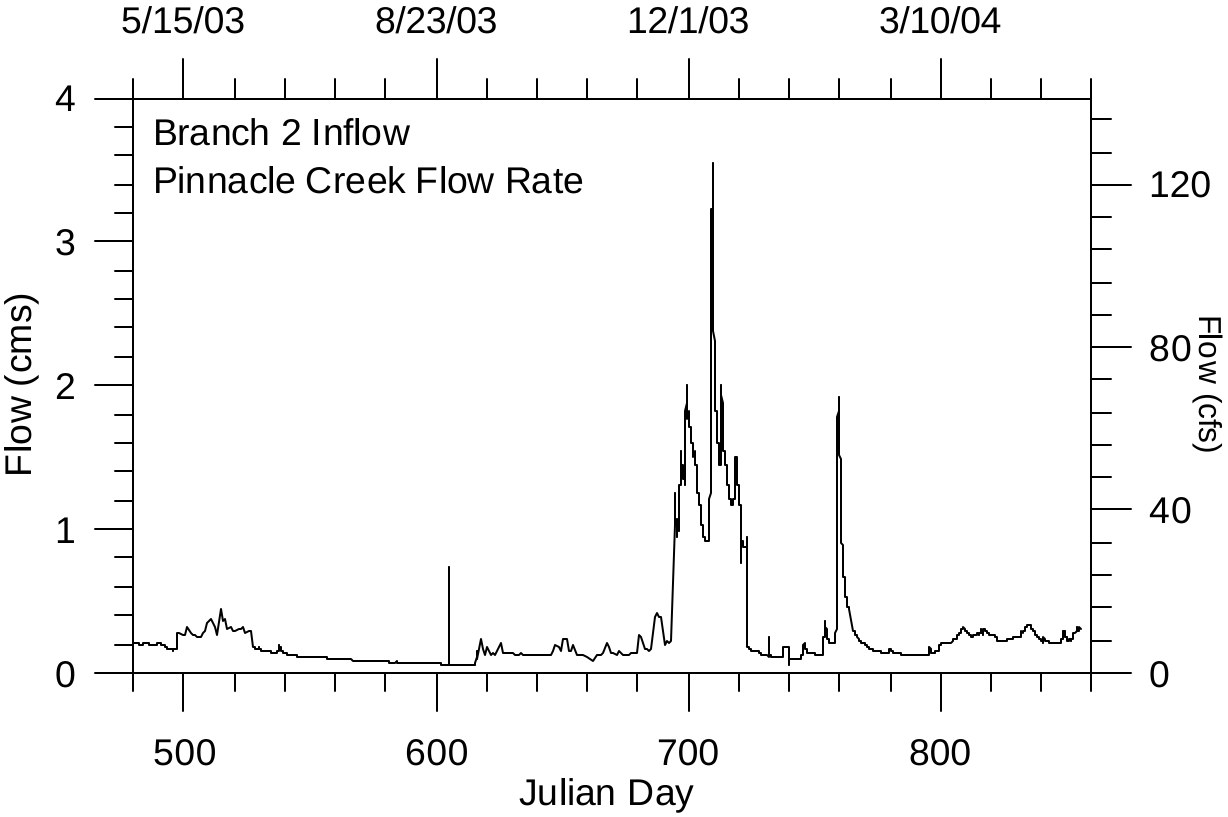


Figure 14. Pinnacle Creek Flow

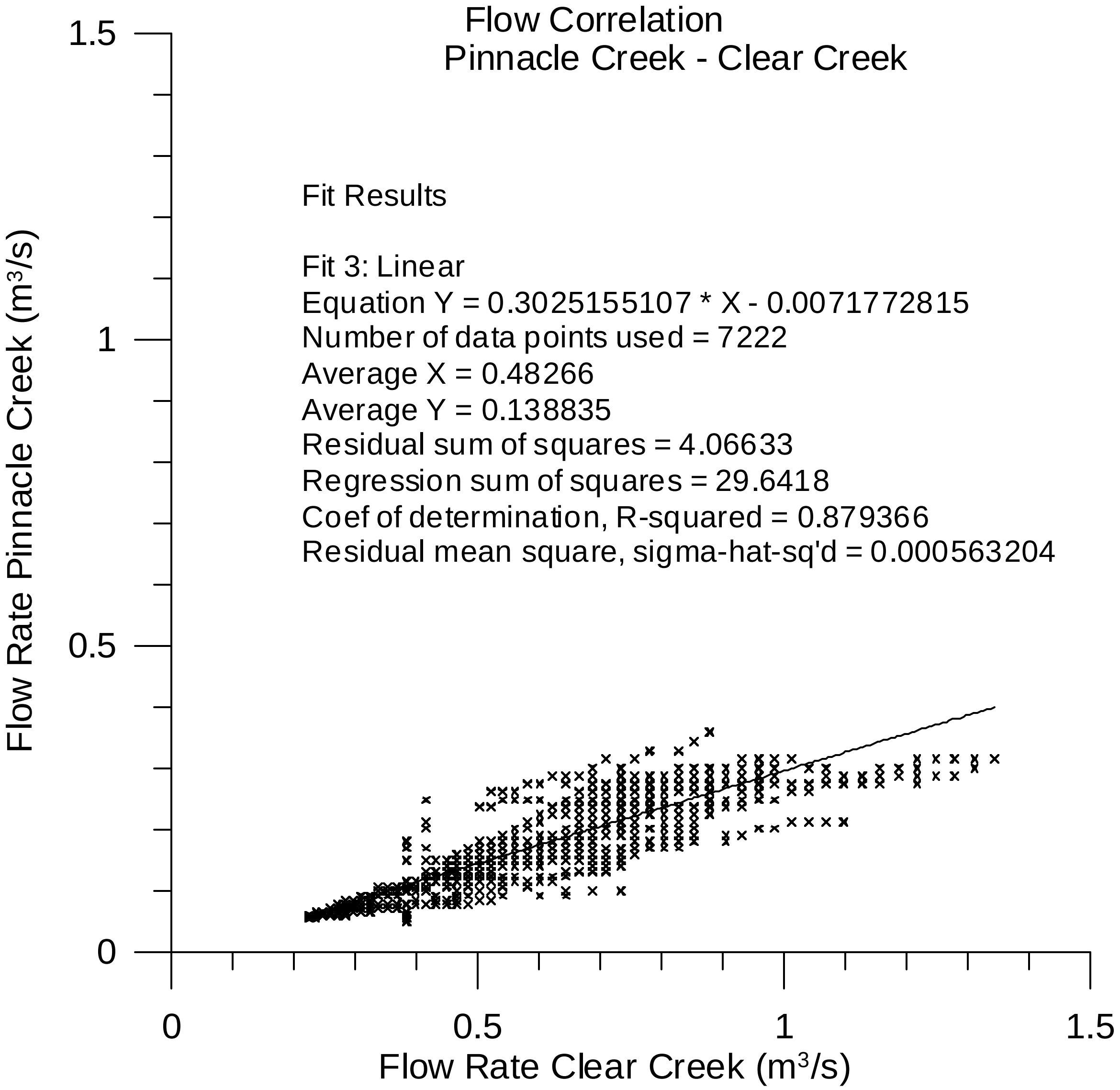


Figure 15. Correlation between Pinnacle Creek and Clear Creek.

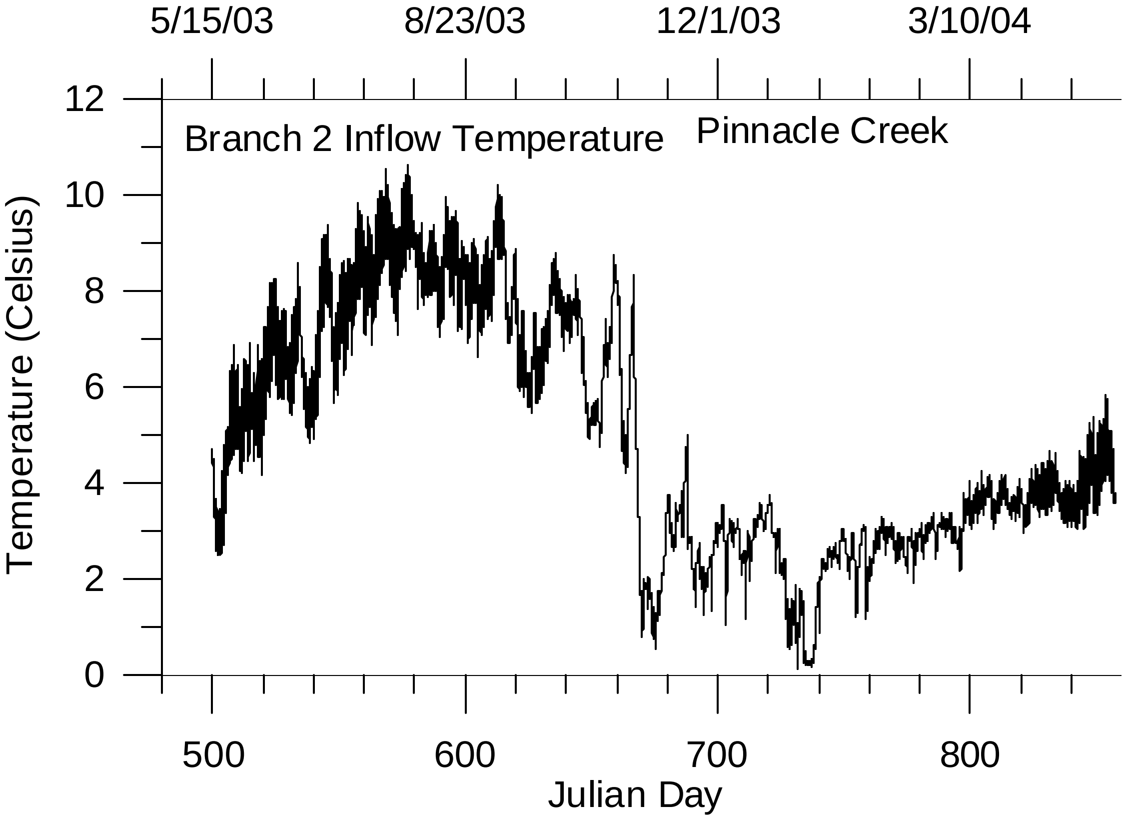


Figure 16. Pinnacle Creek water temperatures

Meteorological Data

Meteorological data for the CE-QUAL-W2 model were measured at the dam and at an agrimet station located at Parkdale. The model utilizes air and dew point temperature, wind speed and direction, and cloud cover or solar radiation. Wind data measured at the dam were accurate only until 8/3/03 (Julian Day 583). Afterwards Parkdale wind speed data were used and wind direction was set to an angle parallel to the axis of the reservoir. Parkdale wind direction data were not used because a comparison between Laurance Lake and Parkdale wind direction showed significant differences. A rose diagram of Parkdale wind direction frequency was shown in Figure 17 and a diagram of Laurance Lake wind direction was shown in Figure 18. Wind at the dam was directed primarily along the axis of the reservoir (see Figure 19 showing the wind rose at the dam superimposed on the lake) whereas the predominant wind directions at Parkdale were from the south and the southwest. Since wind direction data measured at Parkdale were not applicable to Laurance Lake, wind directions for the period when data at the dam did not exist were set to a value of 4.55 radians, which was parallel to the axis of the reservoir. The meteorological station at the dam failed completely on 9/9/03, and afterwards only air temperature, dew point temperature, cloud cover, and short wave radiation data from Parkdale were used. After 11/6/03 (Julian Day 675) air and dew point temperatures regression equations correlating data measured at Laurance Lake and Parkdale were applied. Figure 20 shows the scatter plot and regression equation for air temperature. Figure 21 shows the plot for dew point temperature. The regression equation was not applied before 11/6/03 because using unadjusted Parkdale air and dew point temperature improved model calibration. The regressions were based on data measured over the entire year may not capture the effect of the seasonal trend in air temperature differences during late summer and early fall.

Air and dew point temperatures were shown in Figure 22 and Figure 23, respectively. Figure 24 shows wind speed and Figure 25 shows wind direction relative to time. Cloud cover was plotted in Figure 26.

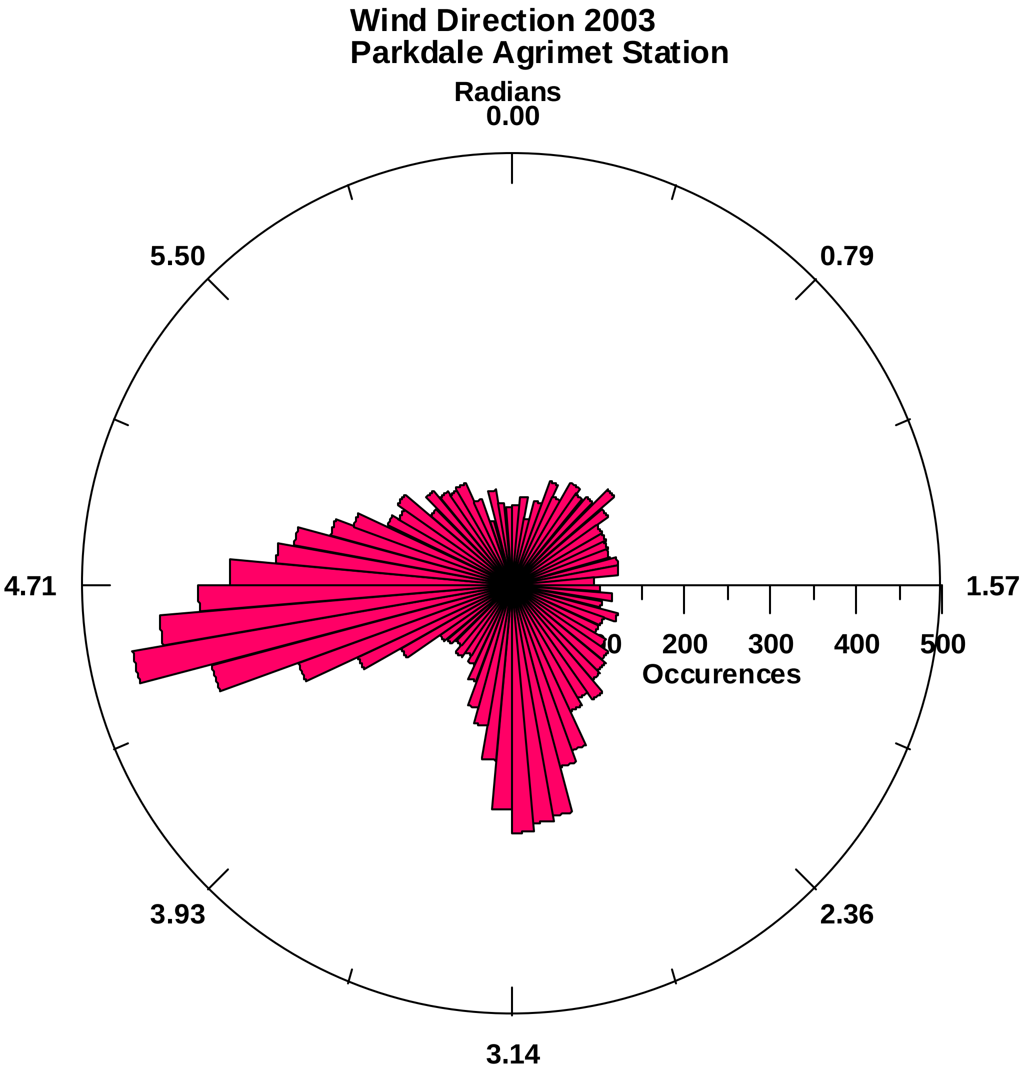


Figure 17. Parkdale wind direction

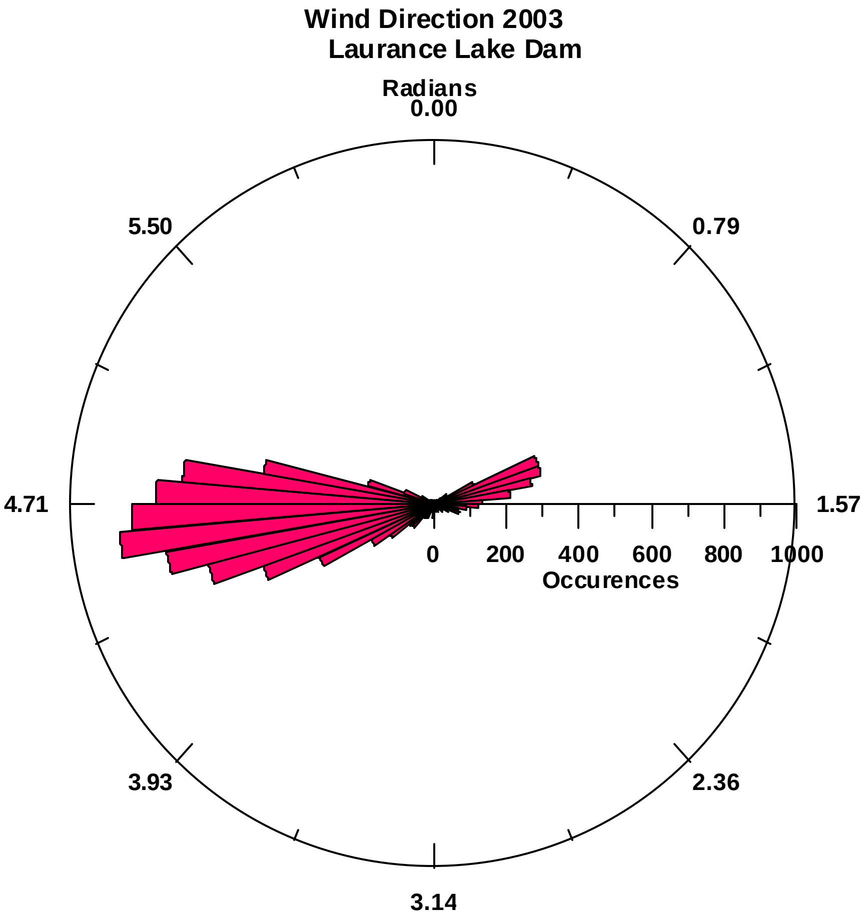


Figure 18. Laurance Lake wind direction

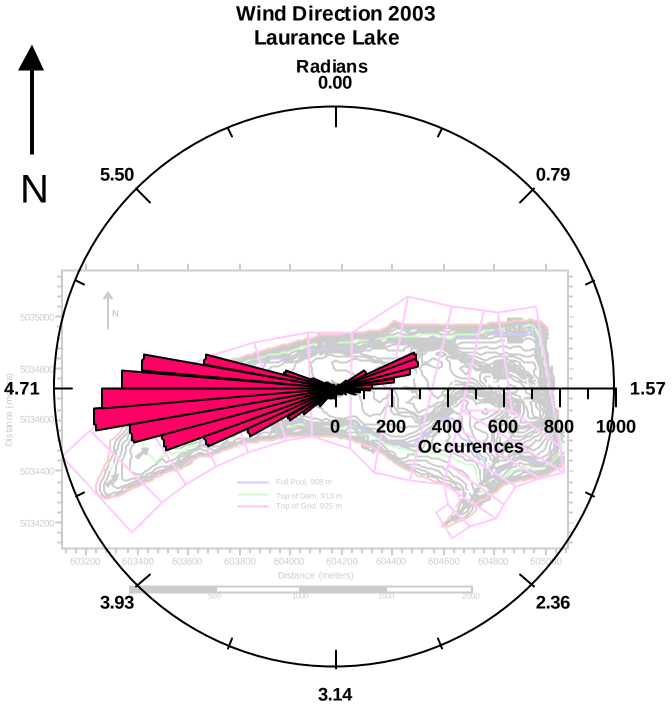
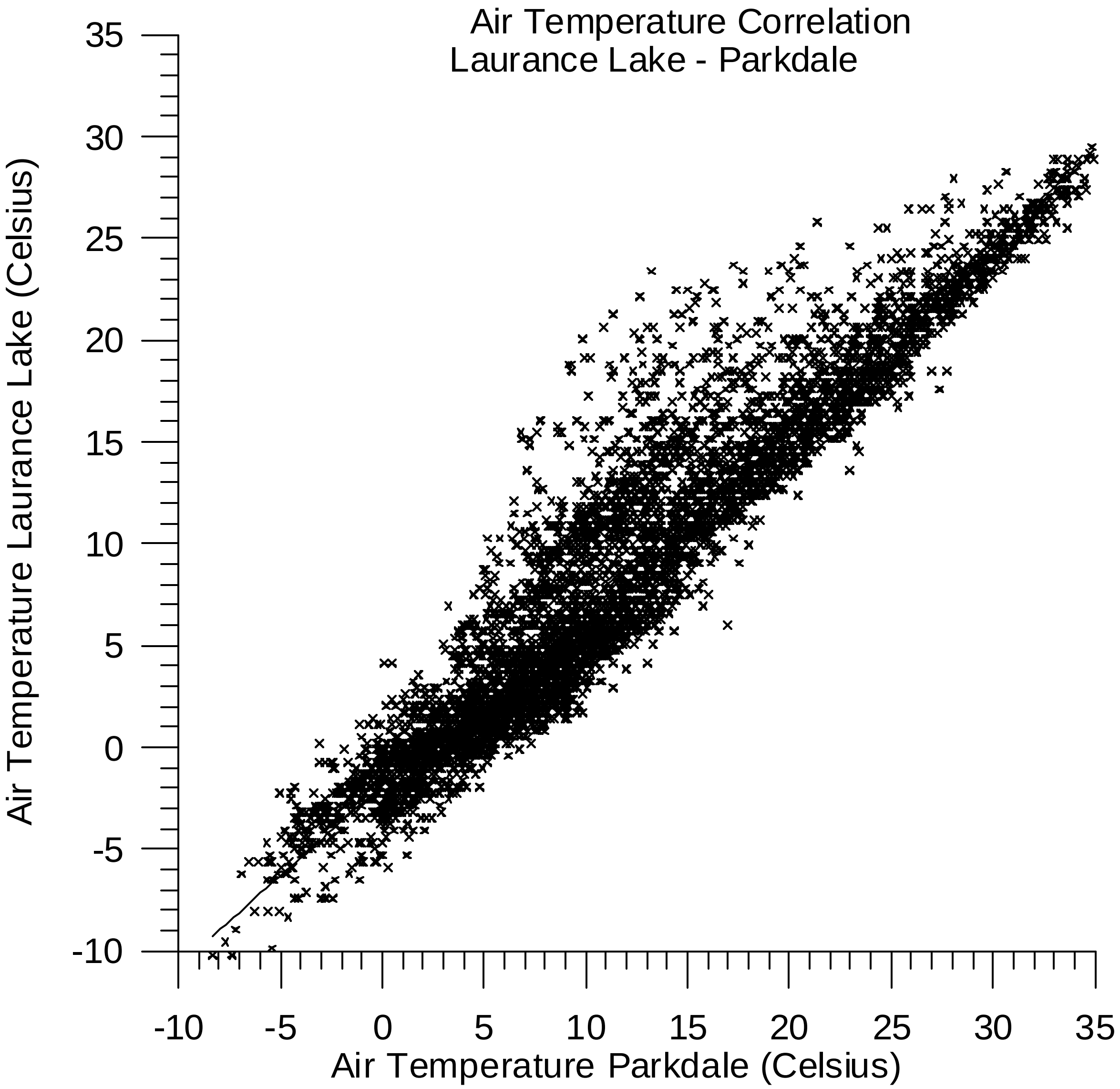


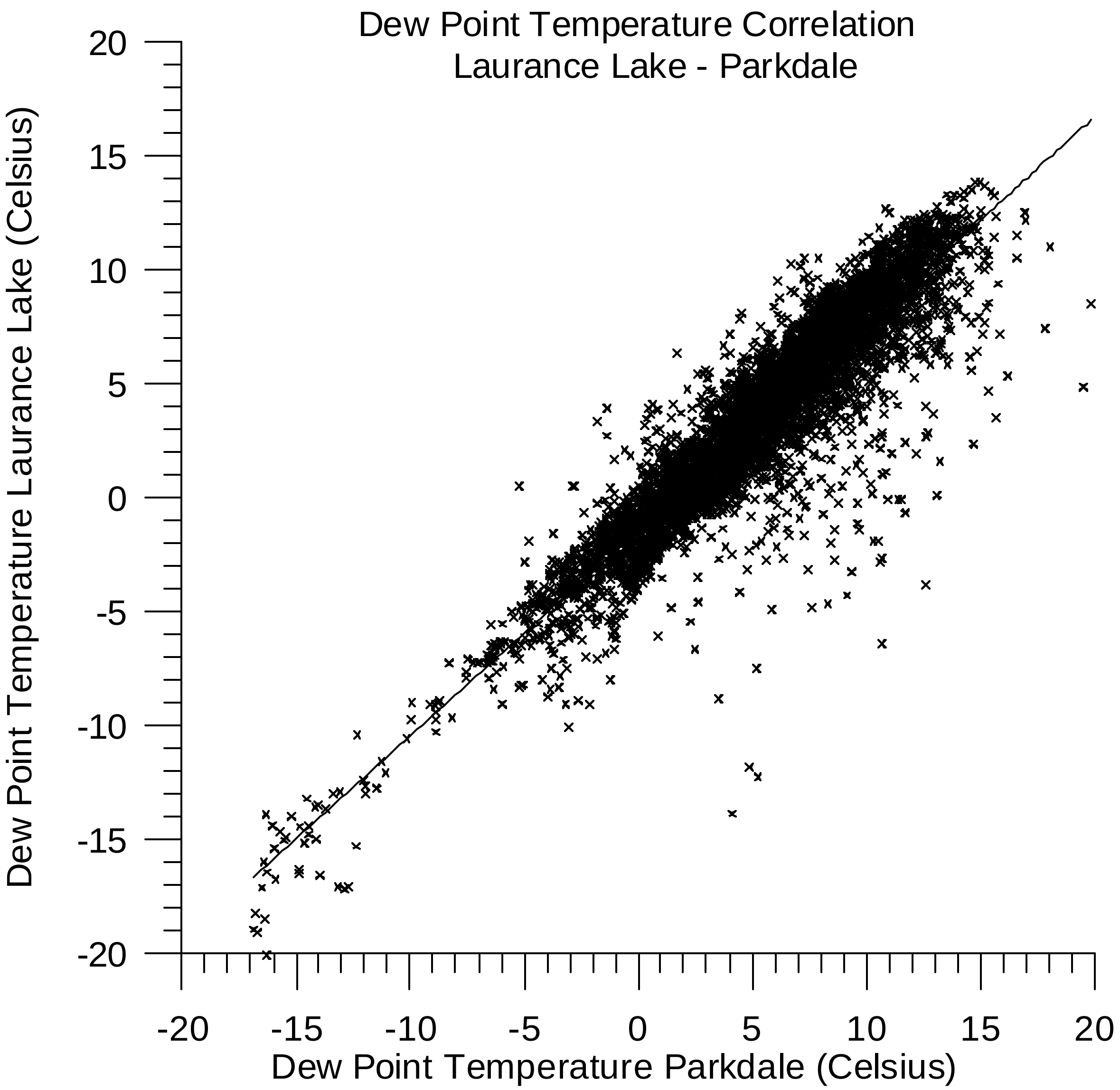
Figure 19. Laurance Lake wind direction at the dam superimposed over the lake axis.



Fit Results

Fit 3: Linear
Equation Y = 0.888659462 * X - 1.86132248
Number of data points used = 5682
Average X = 11.6047
Average Y = 8.45128
Residual sum of squares = 36308.4
Regression sum of squares = 332031
Coef of determination, R-squared = 0.901427
Residual mean square, sigma-hat-sq'd = 6.39232

Figure 20. Scatter plot of Laurance Lake and Parkdale air temperatures.



Fit Results

Fit 3: Linear
Equation Y = 0.905115315 * X - 1.396176783
Number of data points used = 5697
Average X = 5.18157
Average Y = 3.29374
Residual sum of squares = 18243.1
Regression sum of squares = 107586
Coef of determination, R-squared = 0.855017
Residual mean square, sigma-hat-sq'd = 3.20336

Figure 21. Scatter plot of Laurance Lake and Parkdale dew point temperatures.

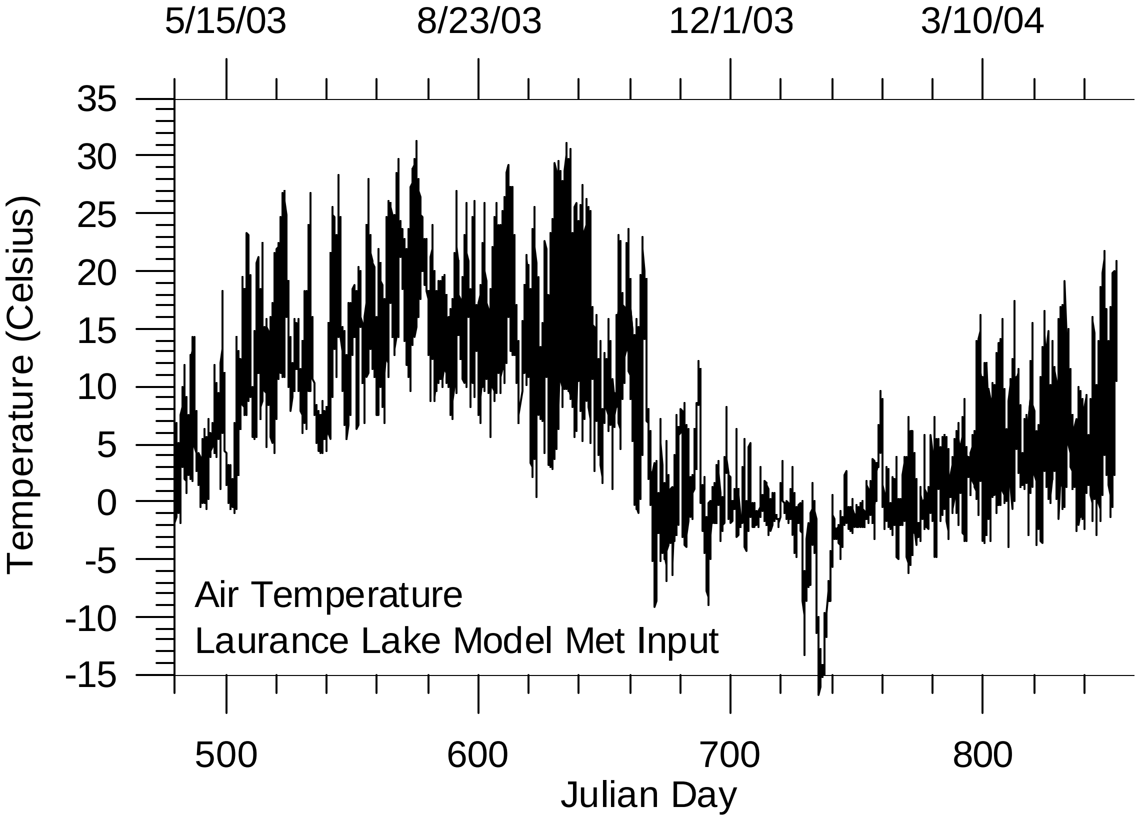


Figure 22. Air temperature, °C

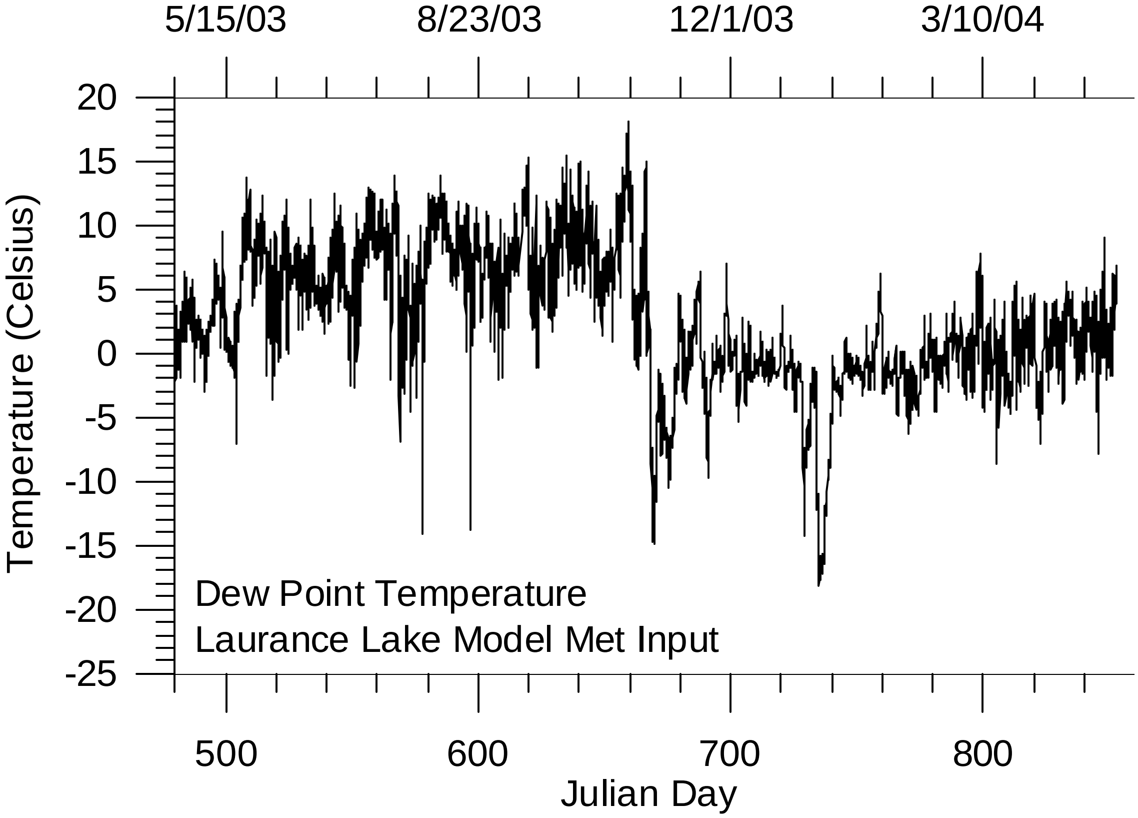


Figure 23. Dew point temperature, °C

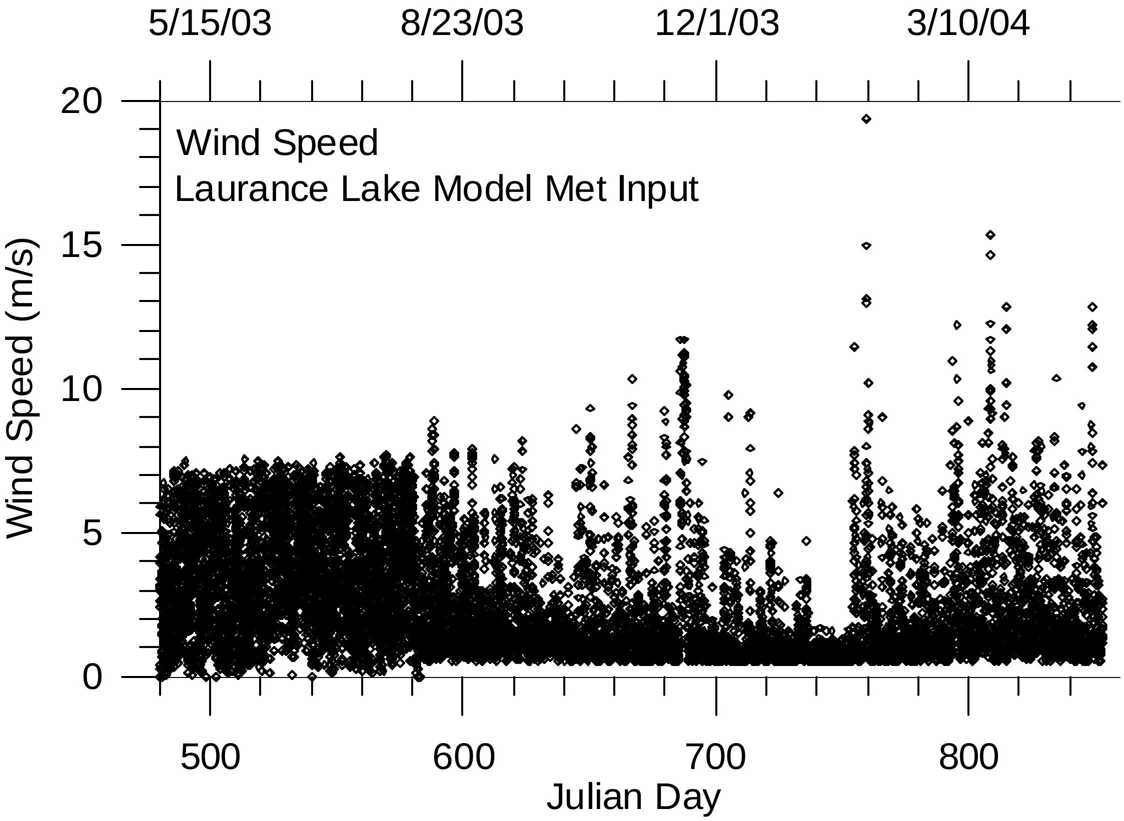


Figure 24. Wind Speed, m/s

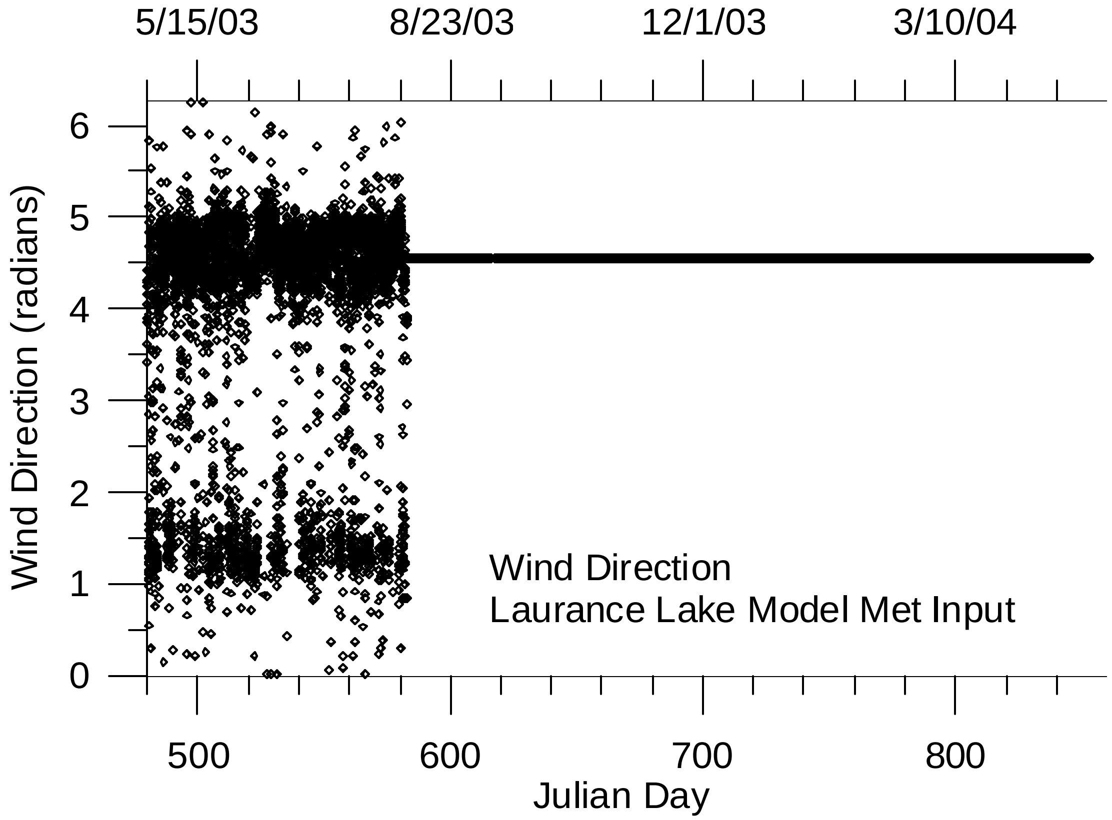


Figure 25. Wind direction used for model input. After Julian Day 583 (8/6/03) wind data measured at the dam did not exist and was set to a value of 4.55 radians, roughly parallel to the axis of the reservoir.

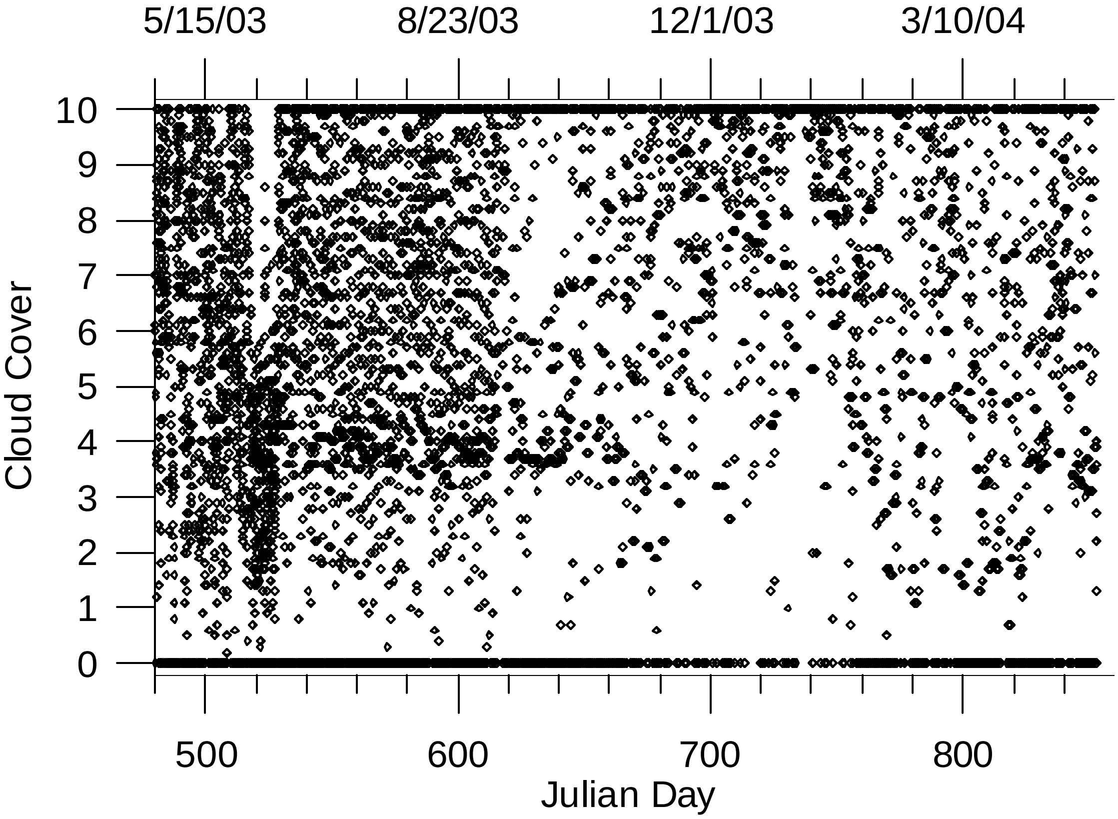


Figure 26. Cloud Cover

Water Year

The calibration period of May 2003 and April 2004 was analyzed in order to determine if it was an average or below average water year. Flow rates measured at the United States Geological Survey gauging station for the Hood River at Tucker Bridge (USGS 14120000) were used. There were 49 years of data available, and it was that assumed that the wetness or dryness of a year on Clear Creek above the dam could be determined by evaluating flows at this site.

A frequency plot showing the number of years that were wetter and dryer than the calibration period was shown in Figure 27. For the period of May through April, 18% of the years were dryer and 82% of the years were wetter.

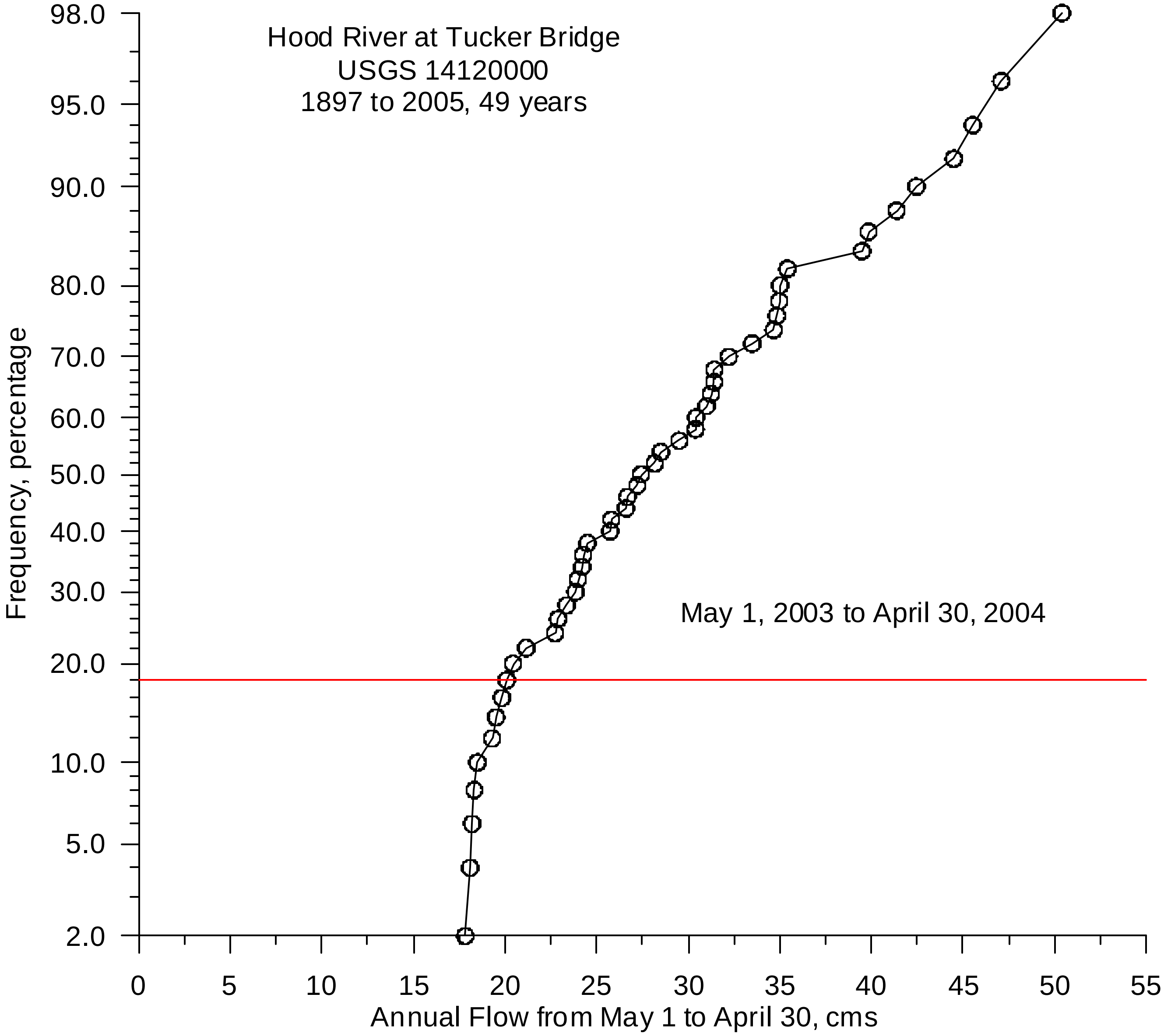


Figure 27. Frequency plot showing the occurrence of years wetter or dryerthan the calibration period. 18% of the years were dryer, 82% were wetter.

Detention Time

Figure 28 shows the detention time plotted versus flow rate for different water levels. At a full pool water surface elevation with combined inflows of 20 cfs, the detention time would be approximately 80 days.

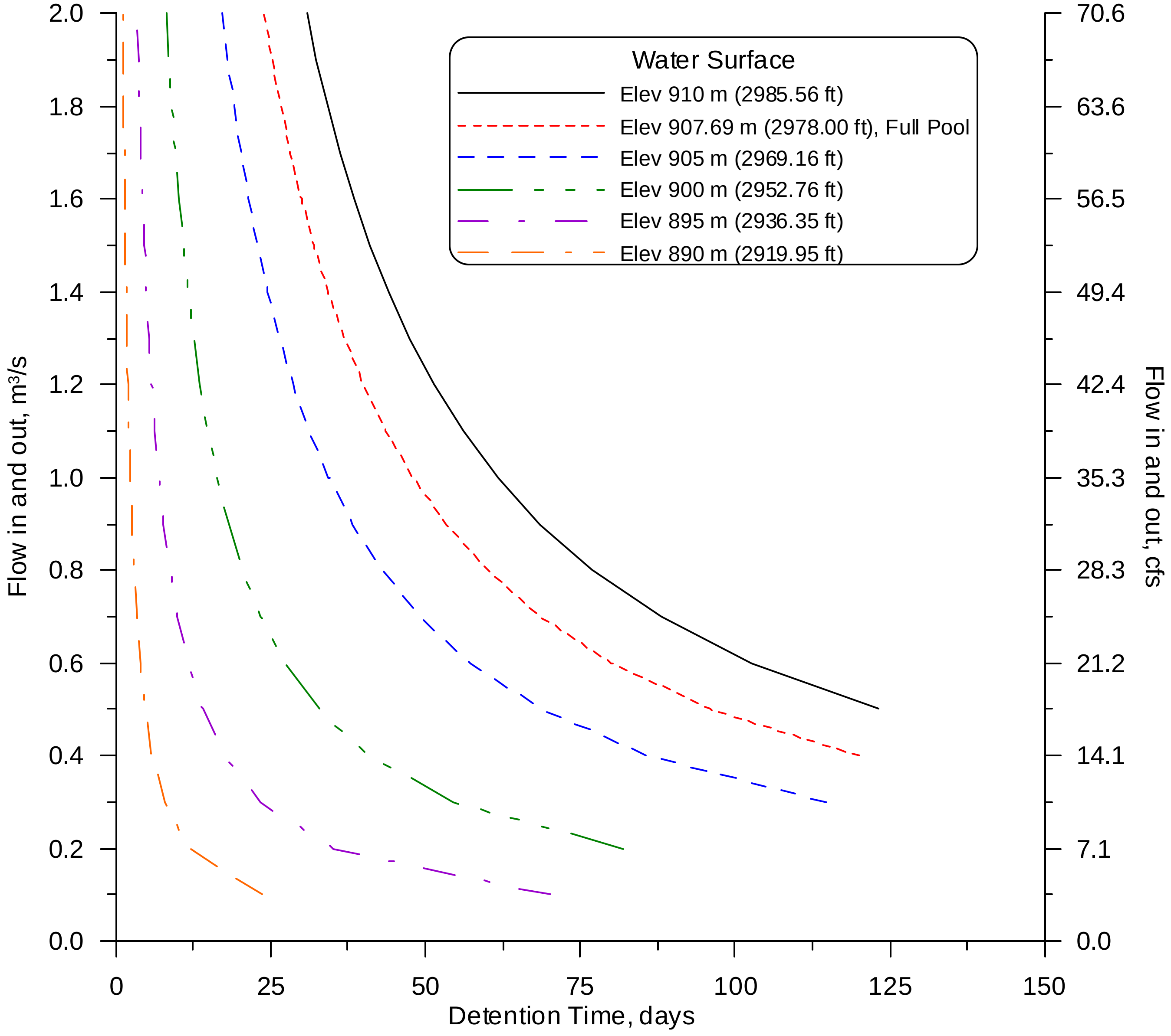


Figure 28. Plot of flow versus detention time for different water level elevations.

Hydrodynamic Calibration

Water level data were compared with model results were shown in Figure 29. Table 2 shows water level statistics. Water levels were calibrated by adding a distributed flow file to compensate for the error in inflow/outflow measurements and to also account for inflows and/or losses directly into the reservoir.

Table 2. Water level error statistics.

n, # of data comparisons	Mean Error M	Absolute Mean Error m	Root Mean Square Error m
365	0.009	0.036	0.078

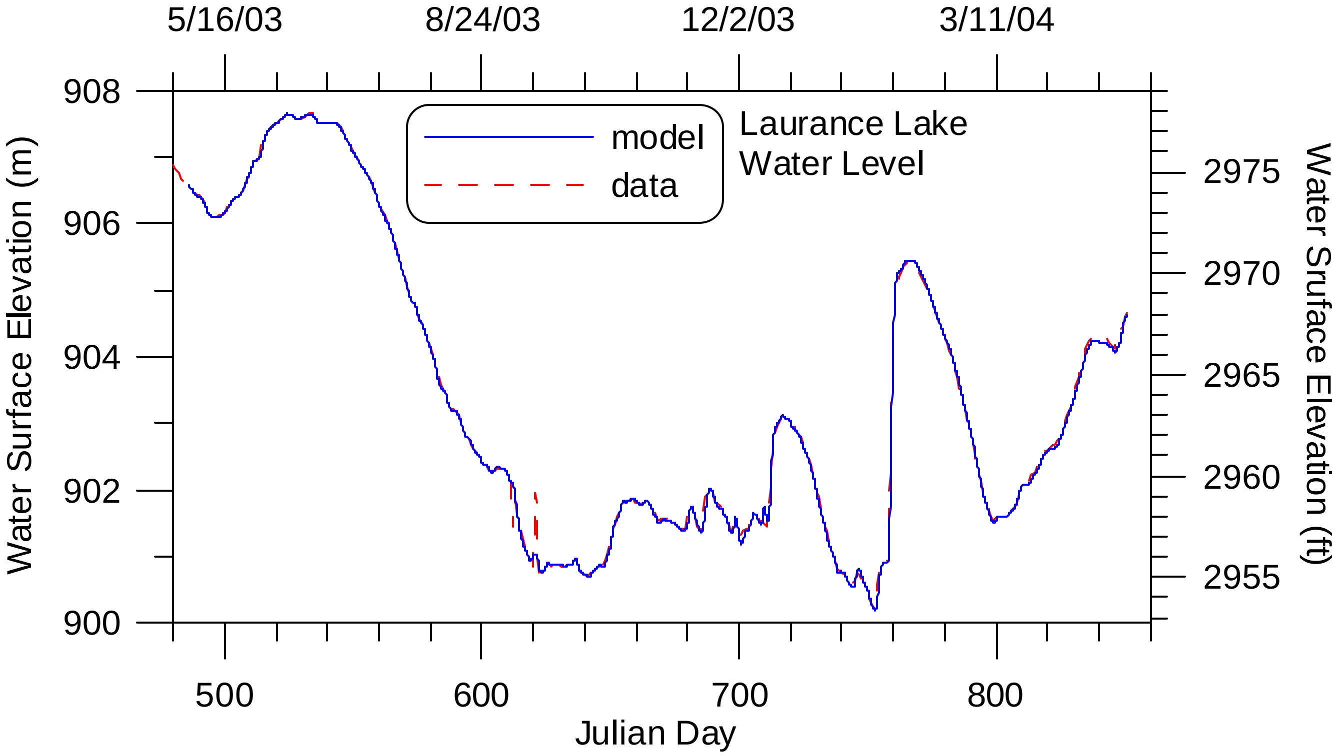


Figure 29. Water level prediction compared with data for Laurance Lake.

Temperature Calibration

Model parameters affecting temperature calibration included wind sheltering coefficients, groundwater inflow temperature, and the accurate representation of reservoir outflows. Temperature predictions in Laurance Lake were particularly sensitive to the wind-sheltering coefficient. When wind data collected at the dam were available, a wind sheltering coefficient of 0.75 was used near the dam and values of 0.60 were used in segments upstream. A time varying light extinction coefficient was used for the entire simulation period. The light extinction coefficient values were based on Secchi disk data, and values ranged from 0.27 to 0.96.

Vertical Profiles

Temperature probes located along the dam were measured continuously over the simulation period. Figure 30 through Figure 33 show the comparison between model predictions and temperatures measured at the dam at 10 day intervals. Table 3 list error statistics between model predictions and data for all the sampling locations in the reservoir.

Table 3. Temperature profile error statistics. 'RMS' represents root mean square error and 'AME' is absolute mean error.

Site	N, # of data profile comparisons	Temperature model –data error statistics	
		AME, ^oC	RMS error, ^oC
Dam	365	0.53	0.59
L1		0.55	0.61
L2		0.58	0.66
L3		0.76	0.84
L4		0.56	0.60

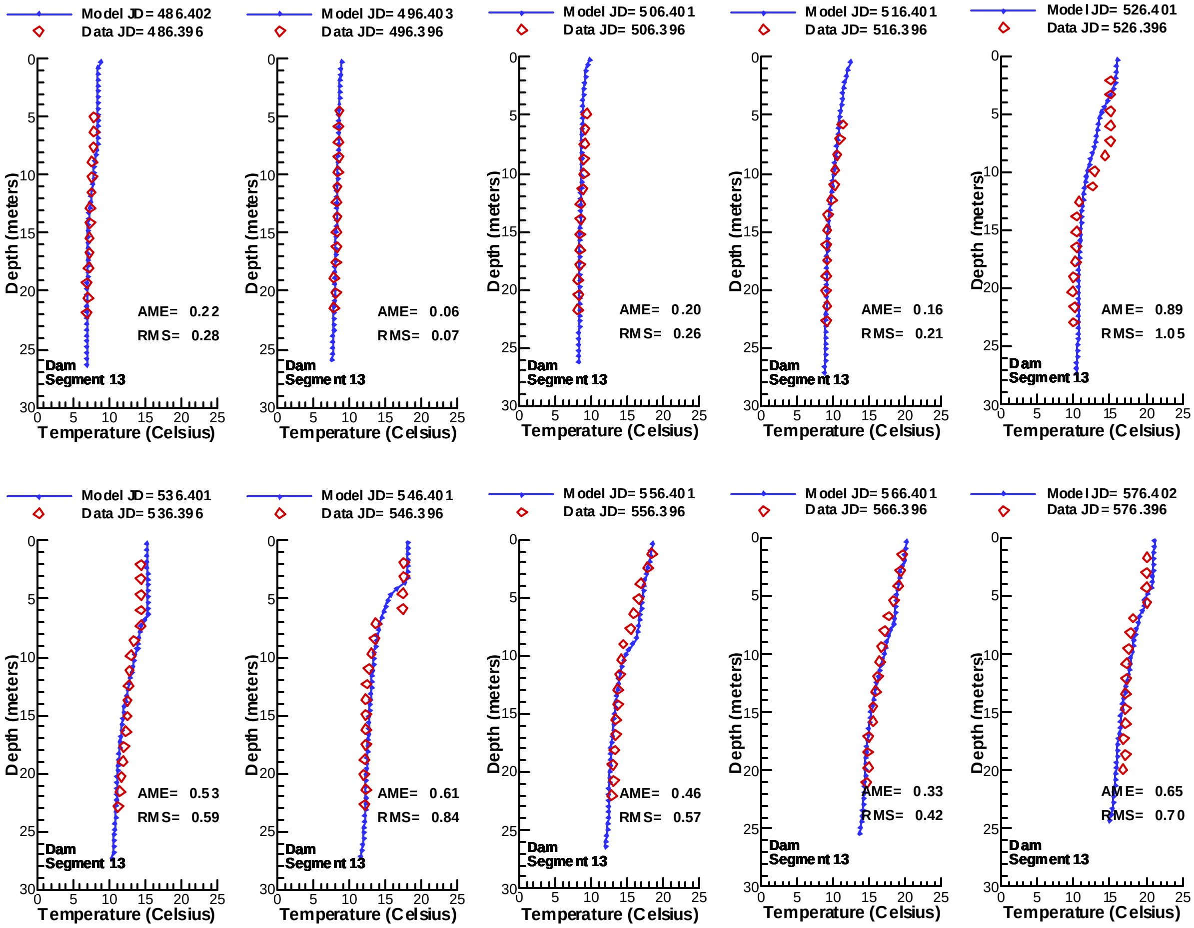


Figure 30. Comparison of model predicted vertical temperature profiles and data collected at dam (Julian Day 486 to Julian Day 586). 'AME' is absolute mean error and 'RMS' is root mean square error.

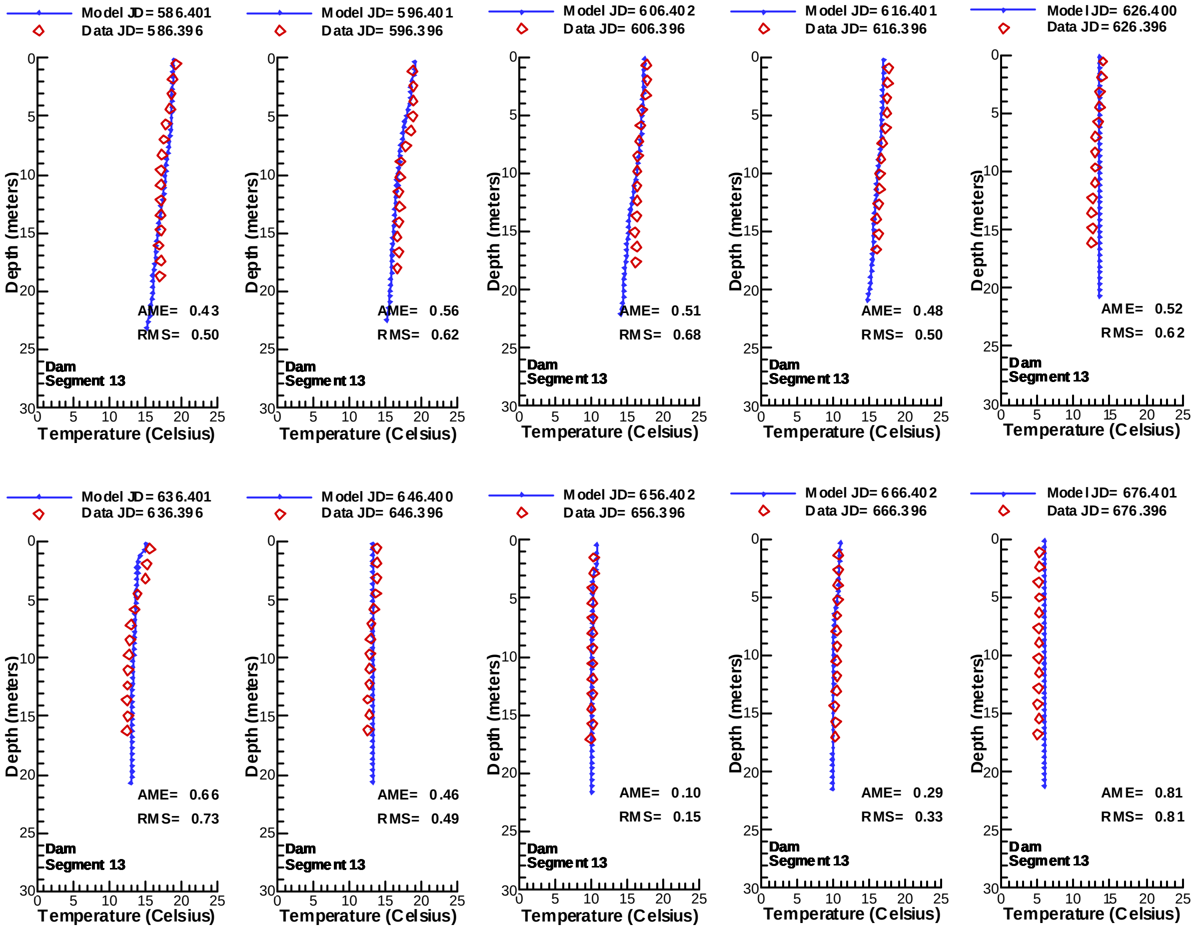


Figure 31 Comparison of model predicted vertical temperature profiles and data collected at dam (Julian Day 586 to Julian Day 676). 'AME' is absolute mean error and 'RMS' is root mean square error.

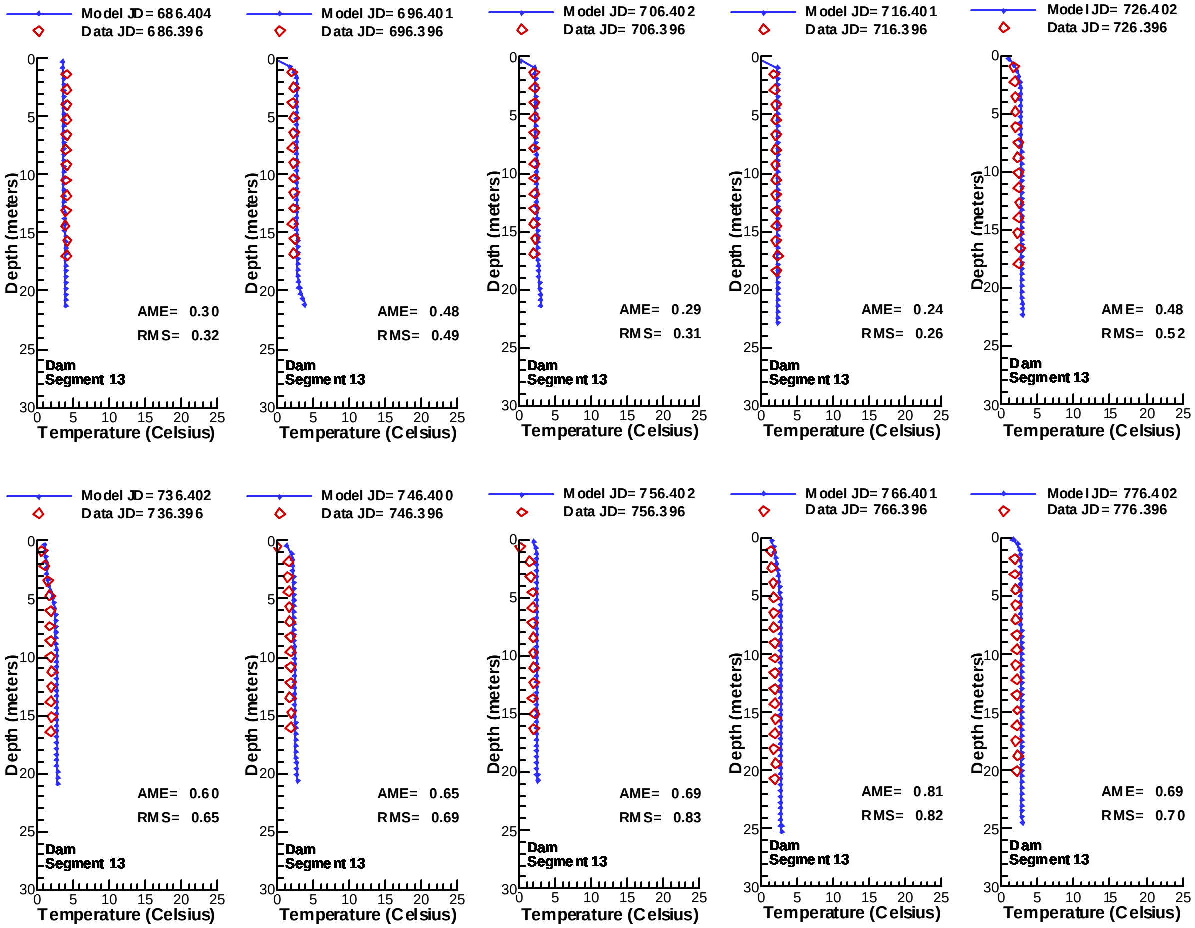


Figure 32 Comparison of model predicted vertical temperature profiles and data collected at dam (Julian Day 686 to Julian Day 776). 'AME' is absolute mean error and 'RMS' is root mean square error.

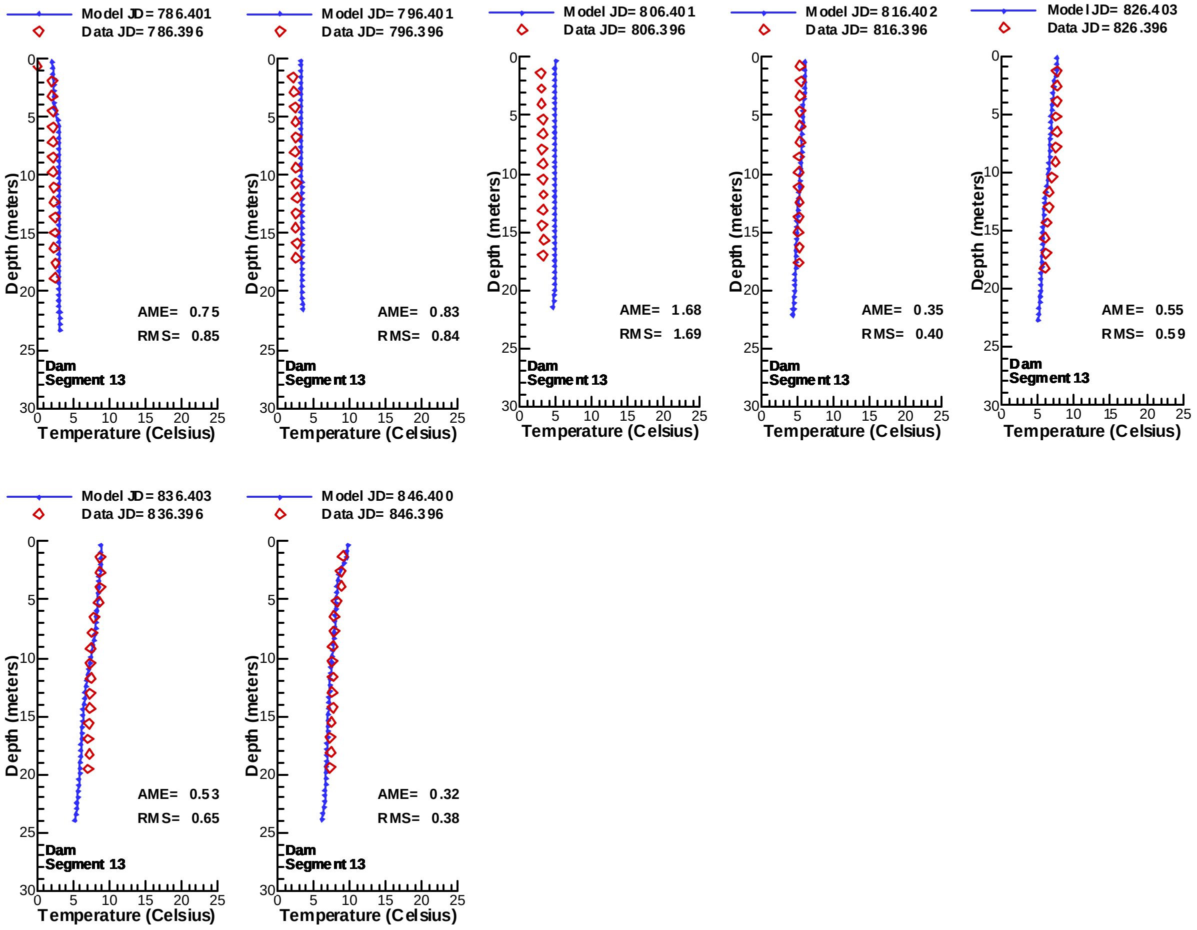


Figure 33. Comparison of model predicted vertical temperature profiles and data collected at dam (Julian Day 786 to Julian Day 846). 'AME' is absolute mean error and 'RMS' is root mean square error.

Management Scenarios – Part 1

The management scenarios were simulated in two parts: (1) an initial 10 scenarios; (2) and an additional 36 scenarios using varied fish flows, water levels and outlet hardware. This section discusses the initial 10 management scenarios which were described in Table 4. Scenario 1 was the base case and was simply the calibrated model without any changes except that the simulation period is May 1, 2003 through October 31, 2003. The scenarios are all identical to the calibrated model except for characteristics listed below in Table 4.

Table 4. Laurance Lake scenario descriptions.

Scenario #	Name	Description
1	Base Case	Calibrated model, Time period May 1 through October 31, 2003
2	Outlet near water surface	Dam outlet is kept at water surface
3	Outlet near bottom or near water surface, Threshold is water temperature of 15 degrees Celsius	Outlet near water surface if outlet temperature below 15 degrees Celsius. Otherwise outlet moved to bottom
4	Dam raised 12 meters	Water surface raised 12 meters above calibrated simulation
5	Dam raised 2 meters	Water surface raised approximately 2 meters above calibrated simulation
6	Pinnacle Creek Diversion	½ of flow from Pinnacle Creek diverted to Clear Creek below dam
7	Outlet at bottom and surface – option 1	Pass all irrigation and powerhouse flows from the surface outlet, pass 3 cfs to Clear Creek below dam until 9/15, then increase to 15 cfs. On 10/1 increase flow to 30 cfs.
8	Outlet at bottom and surface – option 2	Pass all irrigation and powerhouse flows and fish flows to Clear Creek from the surface outlet, once surface outlet becomes > 10^{o}C, pass Clear Creek flows from lake bottom: 3 cfs to Clear Creek below dam until 9/15, then increase to 15 cfs. On 10/1 increase flow to 30 cfs.
9	Outlet at Surface and outlet at bottom	50% of outflows withdrawn near water surface, 50% withdrawn near bottom
10	Dam raised 12 meters, with outlet near surface	Dam outlet is kept near water surface and water surface raised 12 meters above calibrated simulation

Scenario results were summarized by calculating average outflow temperature, plotting outflow temperature versus time, and plotting temperature the difference (? T) between outflow temperature and Clear Creek inflow temperature.

Table 5 lists the average outflow temperature and the average temperature difference between the outflow temperature and Clear Creek inflow temperature for all the scenarios.

Table 5. Laurance Lake scenarios average outflow temperatures and average temperature difference between outflow and Clear Creek inflows. The outflow temperature is the water temperature which would be discharged to Clear Creek below the dam.

Scenario #	# days avg. 7-day max exceed 12 degrees Celsius	Avg. Outflow Temp. (C)	Avg. July – August Outflow Temp. (C)	Avg. Aug. 15 – Oct. 15 Outflow Temp. (C)	Avg. Temp. Difference btw. Outflow and Clear Cr. Inflow (C)	Avg. July-August Temp. Difference btw. Outflow and Clear Cr. Inflow (C)	Avg. Aug. 15-Oct. 15 Temp. Difference btw. Outflow and Clear Cr. Inflow (C)
1	103	12.06	14.32	13.99	4.67	5.69	5.98
2	139	14.43	17.34	14.62	6.52	8.39	6.19
3	112	12.23	14.10	13.96	4.85	5.52	5.97
4	38	10.22	9.52	11.84	2.46	0.78	3.64
5	91	11.93	13.58	14.55	4.54	4.99	6.66
6*	97	11.73	14.03	13.56	4.25	5.38	5.50
7	0	8.32	8.53	9.41	0.86	-0.23	1.34
8	1	8.63	8.53	9.44	1.29	-0.23	1.48
9	36	10.22	10.77	12.08	2.82	2.03	4.15
10	156	15.70	18.41	16.48	7.76	9.52	8.22

*Outflow temperature if diverted Pinnacle Creek Flow is included

The model predicted outflow temperatures of scenarios 1 through 5 were plotted in Figure 34. Model predicted outflow temperatures for scenarios 1, and 6 through 10 were shown in Figure 35. Figure 36 and Figure 37 show the 7-day average of the maximum daily temperature for scenarios 1-5 and scenarios 6-10, respectively. As might be expected, the single outlet near the surface (scenarios #2 and #10) predicted the highest outflow temperatures. Diurnal temperature variations near the water surface were apparent in the predicted fluctuations of outflow temperatures for scenario #2 and #10. These scenarios show how warm the outflow can be if water is withdrawn only at surface. Scenario #3 (outlet at the surface until outflow temperatures reached 15 ^{o}C, then outlet moved to bottom) had warmer outlet temperatures than the base case scenario when the withdrawal was near the surface, but cooler temperatures for a period of time after the outlet was shifted to the bottom. After the outlet was moved to the bottom for scenario #3, the outflow temperatures remained cooler than the existing condition for approximately 35 days (until early July), after which outflow temperatures were equivalent to scenario #1. Raising the dam 12 meters scenario (#4) produced cooler temperatures than all the other scenarios until mid-September, after which the outflow temperatures were greater. The increased reservoir volume of the raised dam scenario resulted in the greater storage of heat gained during the summer, and the reservoir cooled slower relative to the other scenarios during the fall. Scenario #5, which raised the dam 2 meters, resulted in outflow temperatures cooler than the base case by 1-3 degrees Celsius until early August, after which outflow temperatures were a few degrees warmer than the base case. The average outflow temperature for scenario #5 was only 0.1 degrees Celsius cooler than the base case. Diverting half the flow from Pinnacle Creek to below the dam (Scenario #6), bypassing the reservoir, reduced the average outflow temperature by 0.3 degrees Celsius over the base case when the diverted Pinnacle Creek flow is included in the outflow temperature calculation.

There was little difference in the outflow predictions between Scenarios #7 and #8. When considering the water that would be discharged directly to Clear Creek below the dam, these scenarios had considerably cooler outflows that any of the other scenarios. For the July-August time periods outflow temperatures on average were cooler than the Clear Creek inflows. Outflow temperatures finally began increasing during mid-September when the reservoir was significantly drawn down. At no time did the 7 day average of the maximum daily temperature exceed 15 degrees Celsius.

With outflow evenly divided between surface and bottom outlets (Scenario #9), the 7 day average of the maximum daily temperature of outflows to Clear Creek also did not exceed 15 degrees Celsius. Outflow temperatures were within several degrees Celsius of the inflow temperature until early September when cool water at the bottom of the reservoir had been depleted.

The temperature differences between dam outflows and Clear Creek inflows for the scenarios were plotted in Figure 38 and Figure 39. Scenario #1, the base case, showed a maximum temperature difference of 9°C around the beginning of August. The dam raising scenario (#4) predicted the least temperature difference until mid-September, after which the other scenarios predicted smaller temperature differences due to the reservoir cooling more rapidly. Temperature differences predicted by scenario #4 were actually negative for periods in the summer, indicating the water temperatures at the bottom of the reservoir were less than Clear Creek inflows. Scenario #5, raising the dam 2 meters, and scenario #6, the Pinnacle Creek diversion scenario, predicted the next smallest average differences between Clear Creek inflows and dam outflows. The near surface withdrawal scenarios #2 and #10 showed the greatest temperature difference of all the scenarios. Scenarios #7 and #8 which withdrew water from the bottom for Clear Creek fish flows had outflow temperatures close to inflow temperatures up until mid-September.

The model predicted vertical temperature profiles of the scenarios for August 15, 2003 were plotted in Figure 40 and Figure 41. The profiles correspond to the model segment adjacent to the dam. Scenarios with an outlet near the surface that withdrew a large fraction of outflows near the surface (scenarios #2, #7, #8, and #10) predicted the greatest temperature stratification. The 12 meter dam raising scenario (#4) also predicted a large temperature difference between the surface and the bottom despite having only a bottom outlet. The increased depth of this scenario facilitated temperature stratification.

A summary of the scenario results was provided in Table 6.

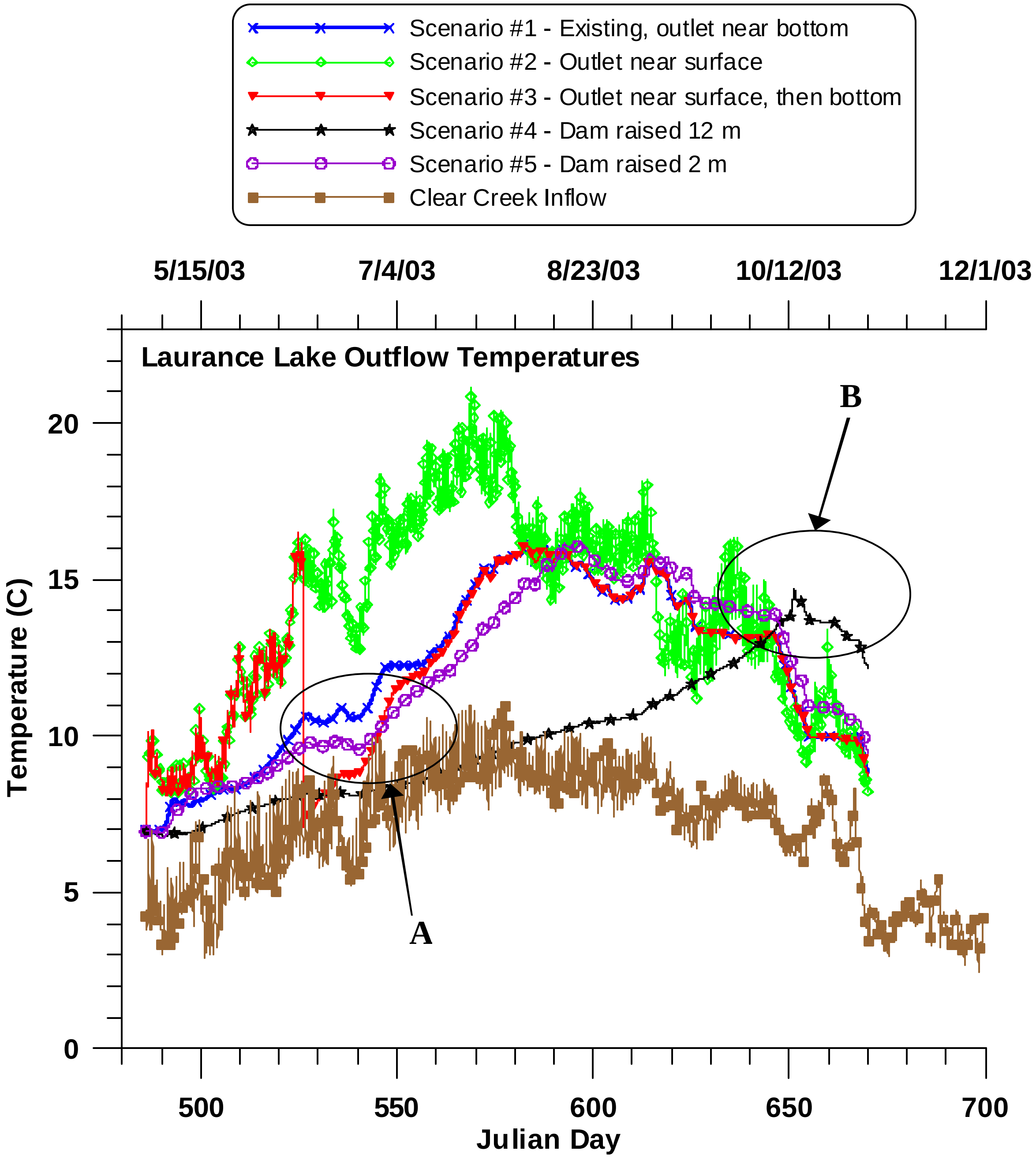


Figure 34 **Model predicted outflow temperatures of scenarios 1-5. Item A points out the cool temperature benefit of scenario #3 which lasts for approximately 2 weeks in late June – early July. Item B shows how the raised dam scenario (#4) will predict warmer outflow temperatures beginning in September, even though earlier in the summer the outflow temperatures were cooler than the base case.**

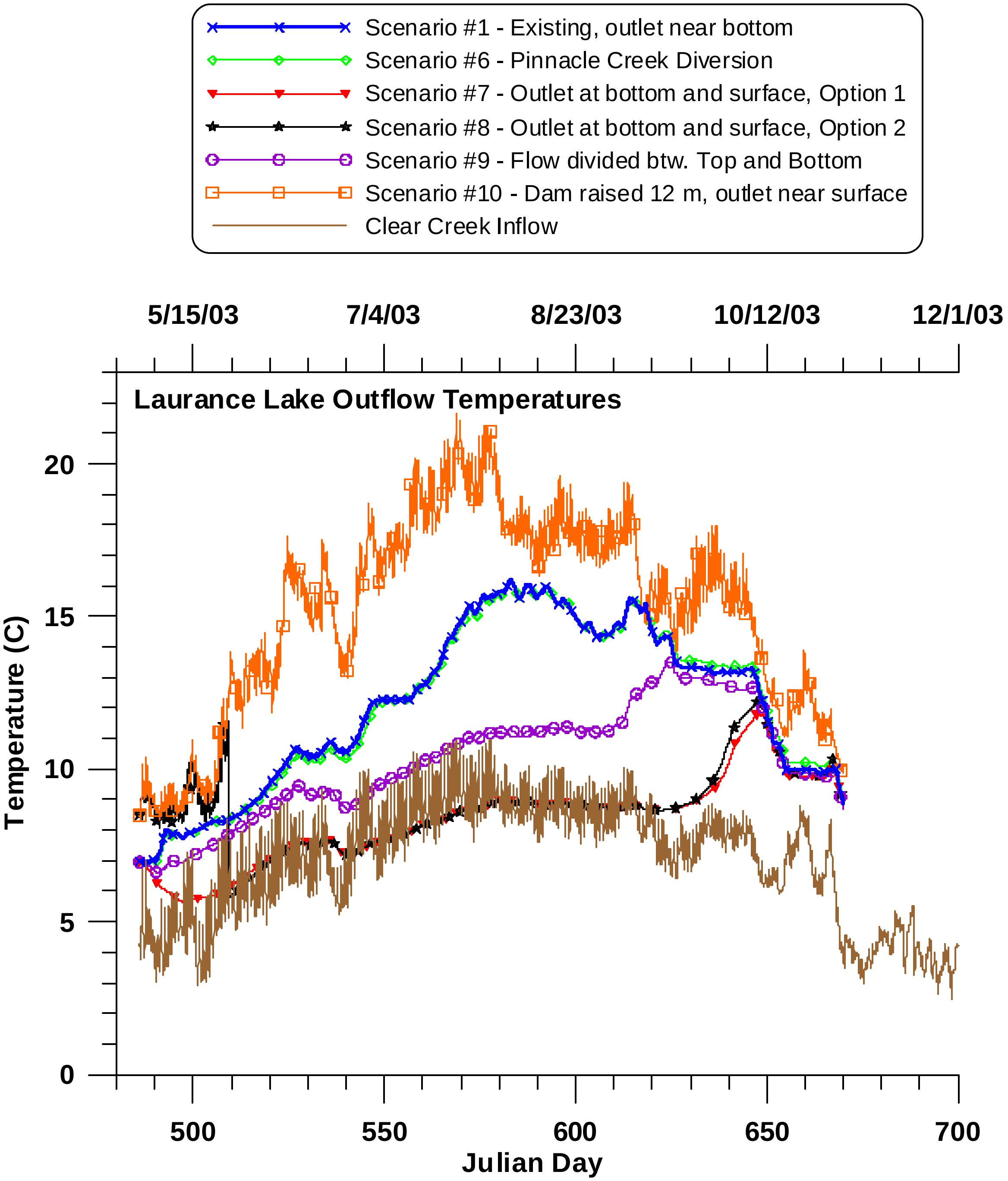


Figure 35 Model predicted outflow temperatures of scenarios 1, 6-10. The outlet temperatures for Scenarios #7, #8 and #9 correspond to the temperatures withdrawn from the bottom outlet only.

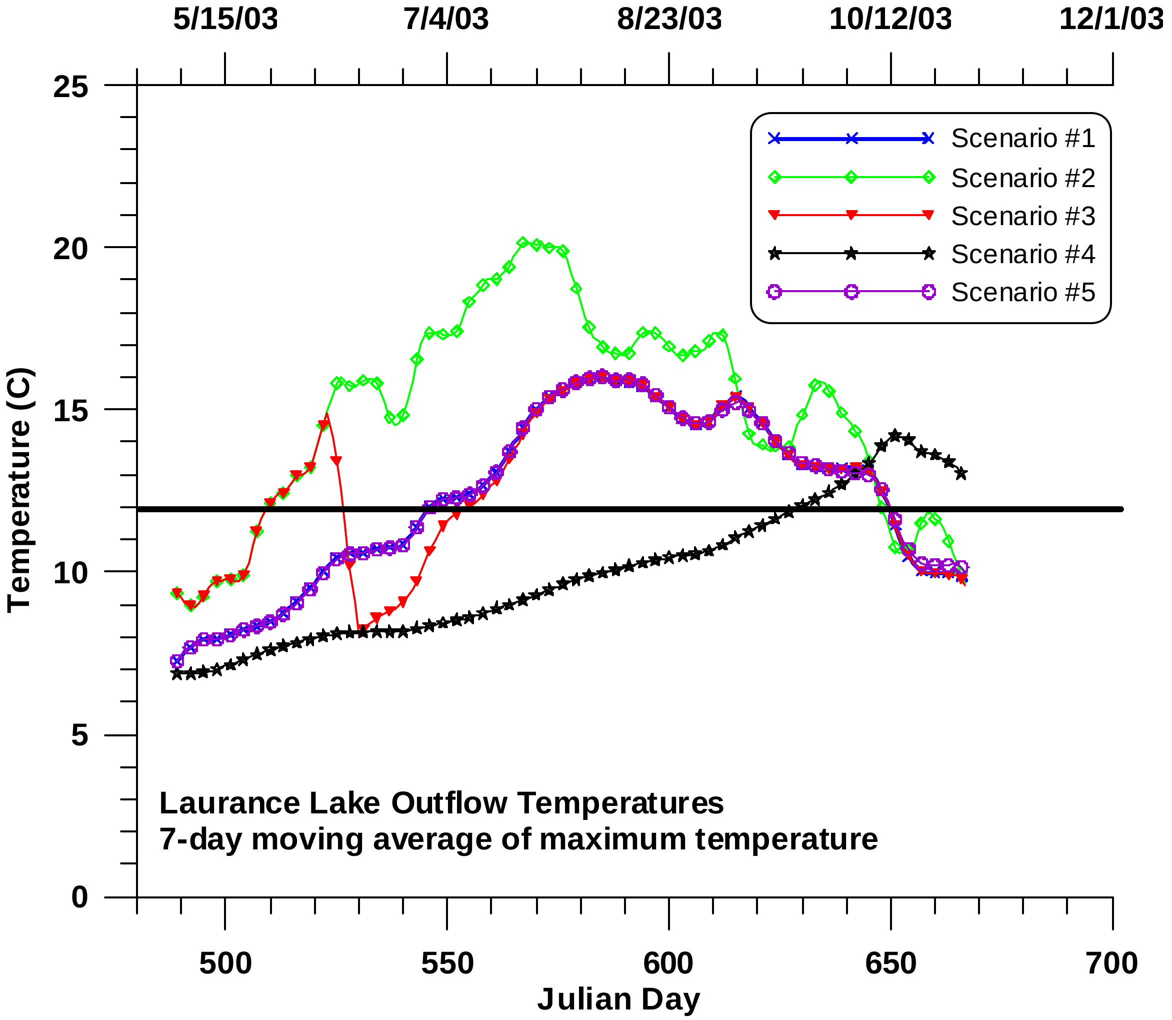


Figure 36. Comparison of 7-day moving average of the daily maximum temperature for scenarios 1-5.

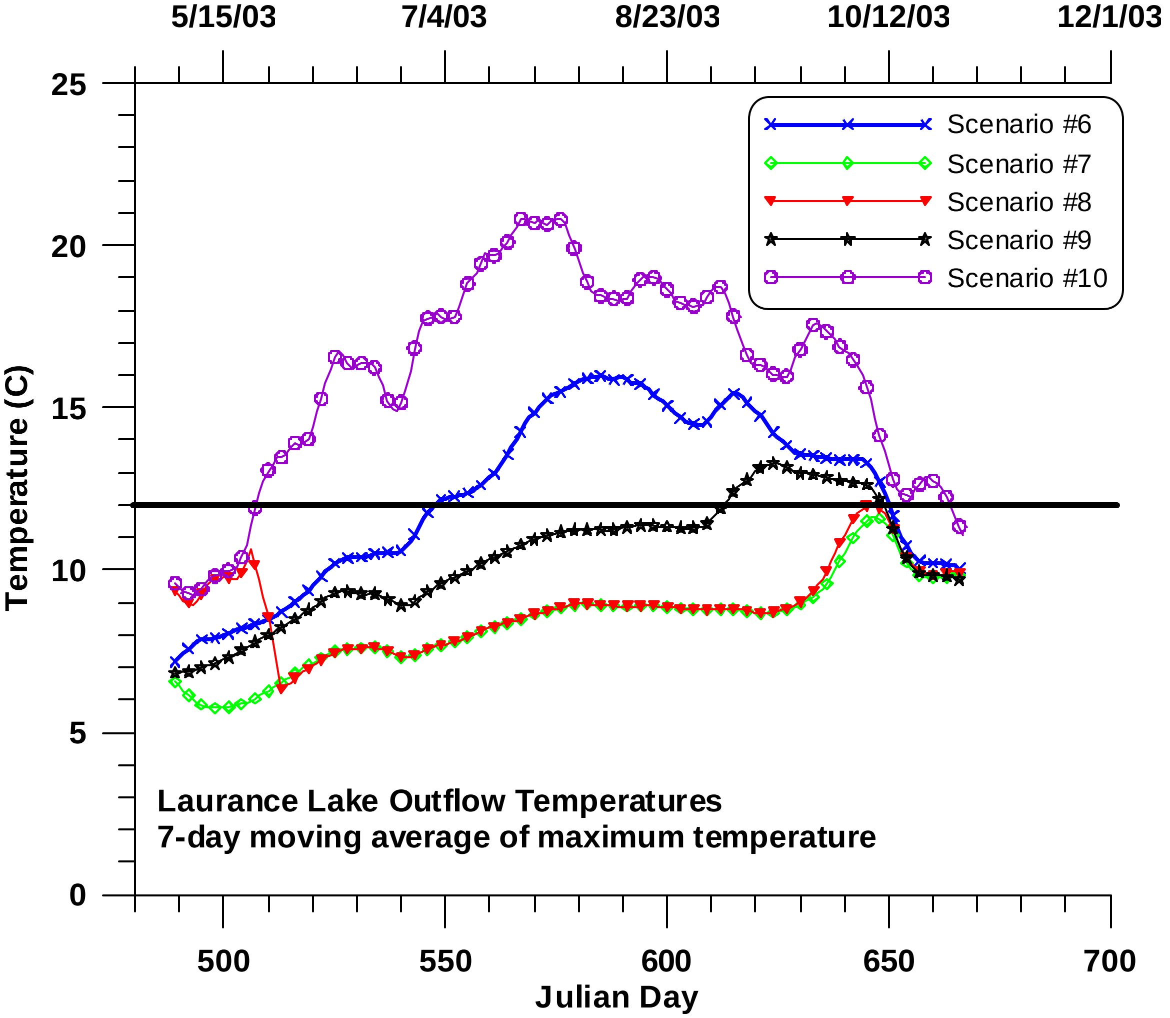


Figure 37. Comparison of 7-day moving average of the daily maximum temperature for scenarios 6-10.

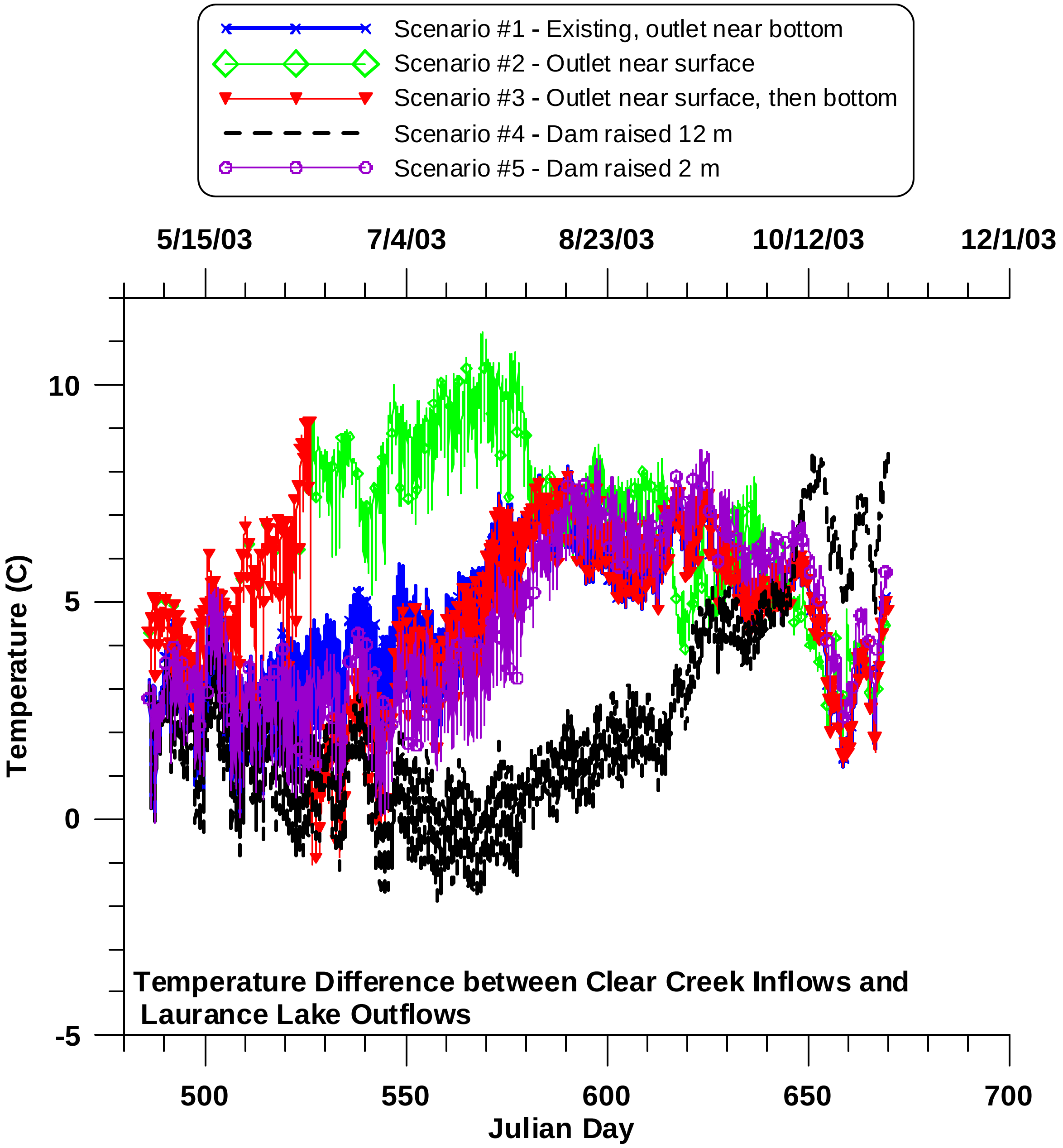


Figure 38 Predicted temperature difference between Clear Creek inflows and dam outflows for scenarios 1-5.

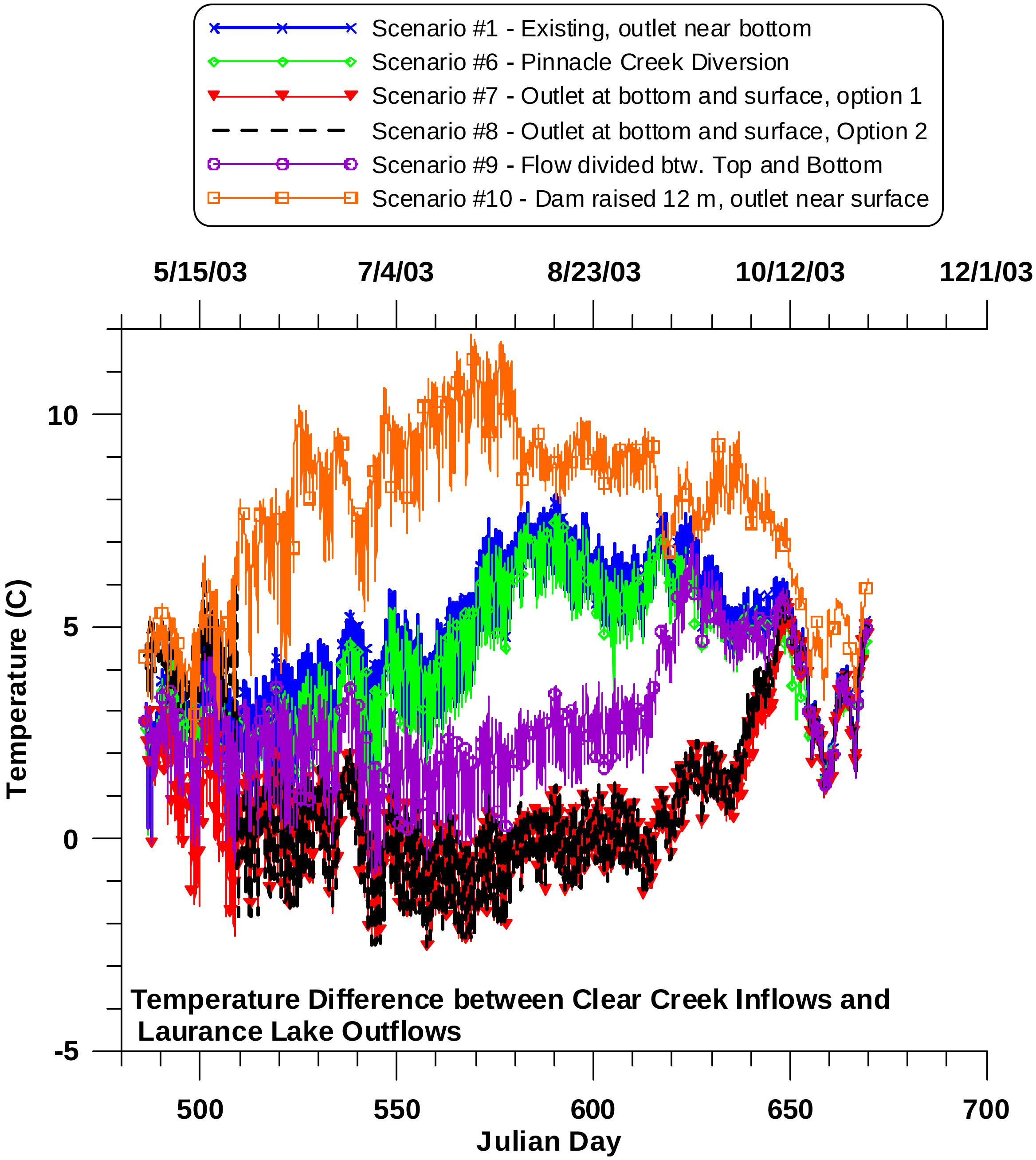


Figure 39 Predicted temperature difference between Clear Creek inflows and dam outflows for scenarios 1, 6-10.

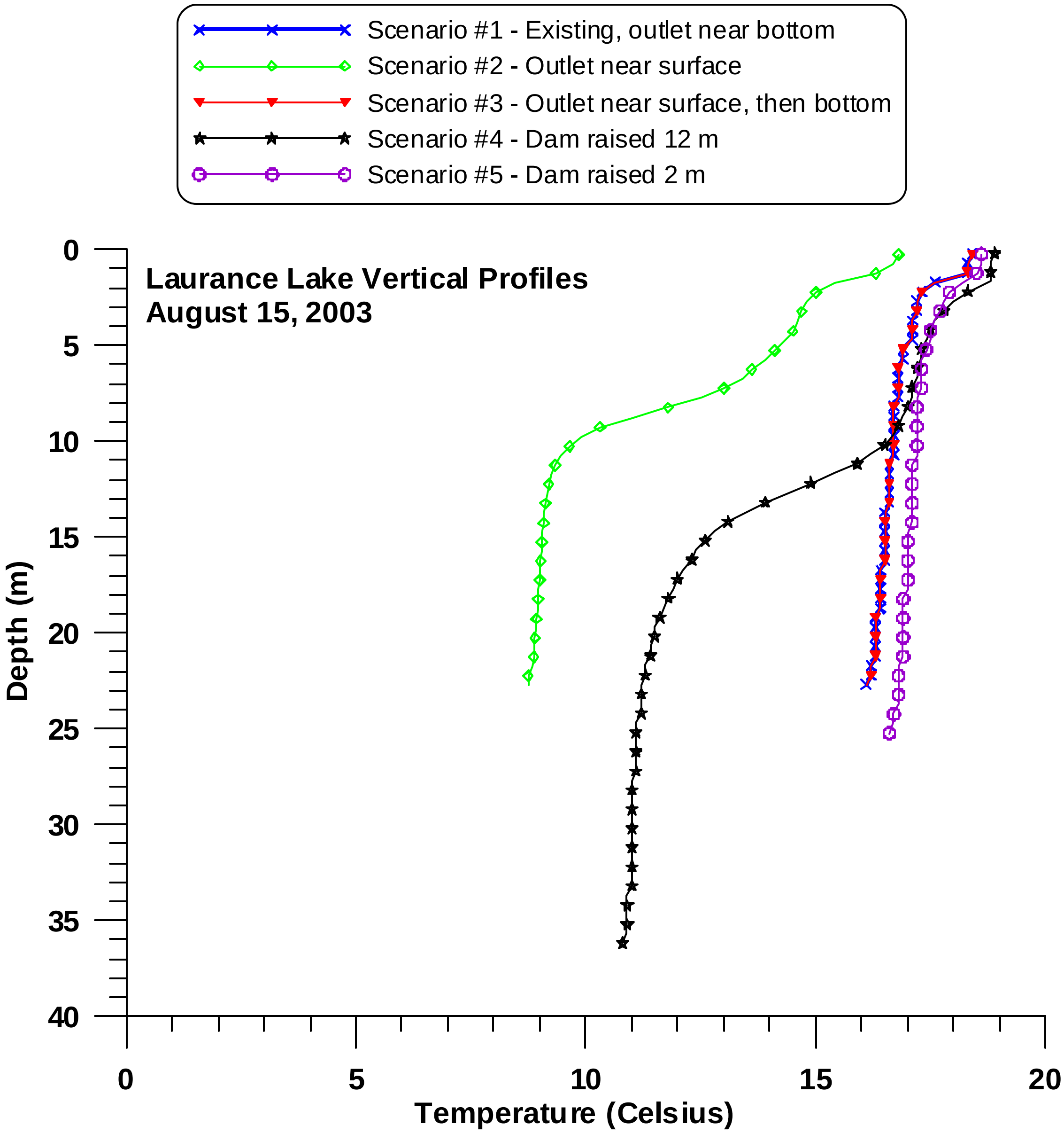


Figure 40 Predicted temperature profile for August 15, 2003 for scenarios 1-5

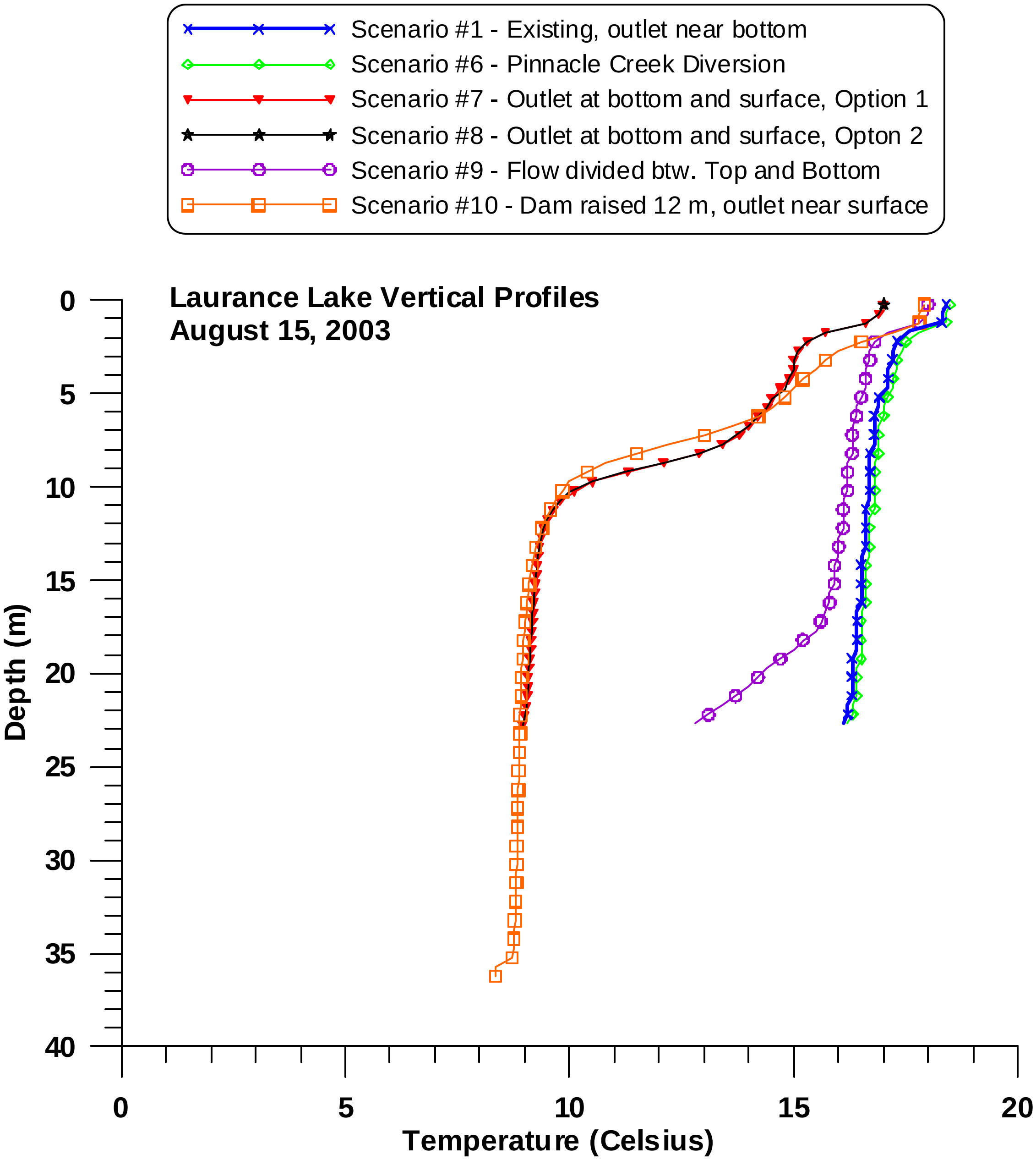


Figure 41 Predicted temperature profile for August 15, 2003 for scenarios 1, 6-10.

Table 6. Summary of scenario results.

Scenario #	Name	Result Summary
1	Base Case	Calibrated model, Time period May 1 through October 31, 2003
2	Outlet near water surface	Warm outflow temperatures
3	Outlet near bottom or near water surface, Threshold is water temperature of 15 degrees Celsius	Improvement for only 2 weeks in late June (see Item A on Figure 34) – early July, but better than base case.
4	Dam raised 12 meters	Cooler for most of the summer, warmer in September-October (see item B in Figure 34)
5	Dam raised 2 meters	Slightly cooler until early August, afterwards slightly warmer
6	Pinnacle Creek Diversion	Slightly improved outflow temperature predictions over entire simulation period
7	Outlet at bottom and surface – option 1	Temperatures for bottom outlet as cool as Clear Creek inflows for most of summer, then warmer starting in September
8	Outlet at bottom and surface – option 2	Very similar results to Scenario 7. Temperatures for bottom outlet as cool as Clear Creek inflows for most of summer, then warmer starting in September
9	Outlet at Surface and outlet at bottom	Generally warmer than base case, but cooler in early August. Maximum outflow temperature couple degrees cooler than base case.
10	Dam raised 12 meters, with outlet near surface	Very warm outflow temperatures

Management Scenarios – Part 2

Scenario Descriptions

The second phase of the management scenarios involved operational changes including altering outflows from the lake for both power/irrigation and fish flows. For example, the minimum flow including seepage from the dam for fish below the dam is approximately 5 cfs. Currently, the flow is increased to 15 cfs on 9/1 and 30 cfs on 9/15 each year. The model was used to explore changing these values as shown in

Table 7.

The modeling was performed to optimize cool temperatures between mid-August and mid-October during the modeling period, the goal being to manage to a 15^{o}C 7-day daily maximum temperature.

Table 7. Current required fish flows below Laurance reservoir and scenario flow range.

Flow period	Existing required flows (including seepage from the dam)	Modeling scenario range
All times	5 cfs	5-10 cfs
After 9/1	15 cfs	5-15 cfs
After 9/15	30 cfs	10-30 cfs

The scenarios listed in Table 8 incorporate differing combinations of fish flows before September 1, from September 1 to September 15, and after September 15. Before 9/1, flow rates of 5, 7.5 and 10 cfs were simulated. From 9/1 to 9/15, flow rates of 5, 10 and 15 cfs were used. After September 15, fish flow rates of 10, 20 and 30 cfs were simulated. For scenarios 11 to 37 water levels in the reservoir were allowed to rise and fall depending on outflows.

Table 8. Flow rates used for fish flows to Clear Creek below dam for Scenarios 11 to 37. Water levels in Laurance Lake were allowed to rise and fall according to outflows.

Scenario #	Fish Flows		
	before 9/1 (cfs)	After 9/1 (cfs)	After 9/15 (cfs)
11	5	5	10
12	5	5	20
13	5	5	30
14	5	10	10
15	5	10	20
16	5	10	30
17	5	15	10
18	5	15	20
19	5	15	30
20	7.5	5	10
21	7.5	5	20
22	7.5	5	30
23	7.5	10	10
24	7.5	10	20
25	7.5	10	30
26	7.5	15	10
27	7.5	15	20
28	7.5	15	30
29	10	5	10
30	10	5	20

Scenario #	Fish Flows		
	before 9/1 (cfs)	After 9/1 (cfs)	After 9/15 (cfs)
31	10	5	30
32	10	10	10
33	10	10	20
34	10	10	30
35	10	15	10
36	10	15	20
37	10	15	30

Additional scenarios with varied fish flows were simulated while keeping the reservoir at full pool. These scenarios were listed in Table 9.

Table 9. Flow rates used for fish flows to Clear Creek below dam for Scenarios 38 to 43. Water level was kept near maximum pool for these scenarios.

Scenario #	Fish Flows		
	before 9/1 (cfs)	After 9/1 (cfs)	After 9/15 (cfs)
38	5	5	10
39	5	10	30
40	5	15	30
41	7.5	15	20
42	10	10	10
43	10	15	30

The final scenarios were described in Table 10. Scenario #44 was identical to scenario 8 but water levels were kept near maximum pool. For this run, fish flows were withdrawn near the surface until outflow temperatures reach 10 degrees Celsius. At that point, fish flows were withdrawn from the bottom of the reservoir while irrigation and powerhouse flows continued to be withdrawn near the surface.

Scenario #45 was identical to scenario #8 except that fish flows were kept a the minimal flow rates of 5 cfs before 9/1, 5 cfs after 9/1 and 10 cfs after 9/15. The goal of this simulation was to preserve cold water at the bottom of the reservoir as far into Septmeber-October as possible.

The last scenario, #46, simulated the effect of ramping fish flow increases that begin in September. Rather than increasing fish flow abruptly, from say, 5 cfs to 15 cfs, the flows were increased to the next level incrementally over a 10 day span. The flow rates used for scenario #46 were 5 cfs until 9/15, then an incremental increase to 15 cfs after 9/15, and then an incremental increase to 30 cfs after 10/1.

Table 10. Description of Scenarios #44, #45 and #46.

Scenario #	Name	Description

Scenario #	Name	Description
44	Outlet at bottom and surface, with water levels near maximum pool	Pass all irrigation and powerhouse flows and fish flows to Clear Creek from the surface outlet, once surface outlet becomes > 10^oC, pass Clear Creek flows from lake bottom: 3 cfs to Clear Creek below dam until 9/15, then increase to 15 cfs. On 10/1 increase flow to 30 cfs.
45	Outlet at bottom and surface; minimal fish flows	Pass all irrigation and powerhouse flows and fish flows to Clear Creek from the surface outlet, once surface outlet becomes > 10^oC, pass Clear Creek flows from lake bottom: 5 cfs to Clear Creek below dam until 9/15, then increase to 10 cfs
46	Existing hardware (outlet at bottom), ramped flow increases	Existing hardware (Outlet at bottom), fish flow increases are "ramped". Flow rates used for fish flows: 5 cfs to Clear Creek below dam until 9/15, then increase to 15 cfs (over 10 days). On 10/1 increase flow to 30 cfs (over 10 days)

Results

The statistics of outflow temperatures for second phase scenarios were listed in Table 11. The 7-day moving average of the daily maximum temperatures of scenarios 11 to 43 were plotted in Figure 42 to Figure 48. Scenario 44 and scenario 45 were plotted in Figure 49 along with scenarios 1, 8, 32 and 38. Figure 50 shows scenario the 7 day average of the maximum temperature of scenarios 1 and 46.

Existing hardware at the dam was used for scenarios 11 through 43. Outflows passed through the existing bottom outlet. Of the scenarios where water levels in the reservoir were allowed to rise and fall according to demand (scenarios 11 through 37), scenario 32 predicted the coolest outflow temperatures for the August 15 to October 15 period. Outflow temperatures during this period averaged almost 2 degrees cooler than the existing condition. However the July-August outflow temperatures were 0.3 degrees Celsius warmer than the existing condition. Scenario 32 used fish flows of 10 cfs before 9/1, 10 cfs after 9/1 and 10 cfs after 9/15. Temperatures were optimized for August through October because the 10 cfs fish flows before 9/1 allowed more warm water to be released during the summer, and the reduced 10 cfs fish flows after 9/1 kept water levels high enough so that water passing through the bottom outlet was cooler.

Scenarios 38 to 43 simulated varied fish flows while keeping water levels near full pool. The impact of keeping water levels near full pool was cooler outflow temperatures in the summer and warmer outflow temperatures in the fall. Outflow temperatures were approximately 0.2 degrees Celsius warmer than the existing condition for these scenarios during the August 15 to October 15 time period.

Scenario #44 kept water levels near maximum pool with a top and bottom outlet. This simulation was nearly identical to scenario 8 except that the reservoir was kept full. All irrigation, powerhouse flows and fish flows to Clear Creek were passed from the surface outlet until the outflow temperatures exceeded 10^oC, afterwards fish flows were passed from the lake bottom at a rate of 3 cfs until 9/15, then an increase to 15 cfs, and finally an increase on 10/1 to 30 cfs. Outflow temperature were similar to those predicted by scenario 8, except that the cooler outflow temperatures lasted later into the fall, followed by a final warm up which occurred when the cool water at the bottom was finally depleted. Figure 49 compares the 7-day average of the maximum daily temperatures of scenario 44 with scenario 8 and some of the other scenarios.

The scenario predicting the coolest outflow temperatures was scenario #45. The use of minimal fish flows from a bottom outlet and drawing irrigation and powerhouse flows from a surface outlet produced cooler temperatures than any of the other scenarios (Figure 49). This scenario did better than scenario #8 because the reduced fish flows allowed cooler water at the bottom of the reservoir to last longer.

Scenario #46 did slightly better than the existing condition simulation (scenario #1). Ramping the fish flow releases reduced the volume of cool water used for fish flows, allowing this cool water to last longer. The average outflow temperature during the August 15 to October 15 period was decreased by approximately of 0.2 degrees Celsius relative to the existing condition.

Table 11. Scenarios 11 through 46 average outflow temperatures and average temperature difference between outflow and Clear Creek inflows. The outflow temperature is the water temperature which would be discharged to Clear Creek below the dam.

Scenario #	# days avg. 7-day max exceed 12 degrees Celsius	Avg. Outflow Temp. (C)	Avg. July – August Outflow Temp. (C)	Avg. Aug. 15 – Oct. 15 Outflow Temp. (C)	Avg. Temp. Difference btw. Outflow and Clear Cr. Inflow (C)	Avg. July-August Temp. Difference btw. Outflow and Clear Cr. Inflow (C)	Avg. Aug. 15-Oct. 15 Temp. Difference btw. Outflow and Clear Cr. Inflow (C)
11	106	12.10	14.34	14.01	4.77	5.71	6.07
12	103	12.04	14.34	13.88	4.67	5.71	5.92
13	103	12.01	14.34	13.89	4.66	5.71	6.01
14	105	12.07	14.34	13.92	4.74	5.71	5.99
15	103	12.03	14.34	13.95	4.68	5.71	5.97
16	103	11.98	14.34	13.85	4.61	5.71	5.94
17	104	12.08	14.34	13.97	4.72	5.71	5.98
18	103	12.06	14.34	14.03	4.68	5.71	6.01
19	103	12.06	14.34	14.01	4.67	5.71	6.00
20	105	12.02	14.54	13.59	4.67	5.94	5.64
21	101	11.95	14.54	13.33	4.58	5.94	5.47
22	102	11.91	14.54	13.30	4.50	5.94	5.52
23	94	11.99	14.54	13.33	4.60	5.94	5.44
24	103	11.91	14.54	13.32	4.55	5.94	5.47
25	89	11.87	14.54	13.08	4.40	5.94	5.29
26	83	11.85	14.54	12.81	4.44	5.94	5.03
27	84	11.64	14.54	12.39	4.27	5.94	4.84
28	95	11.85	14.54	13.09	4.34	5.94	5.22
29	82	11.65	14.63	12.21	4.29	6.02	4.46

Scenario #	# days avg. 7-day max exceed 12 degrees Celsius	Avg. Outflow Temp. (C)	Avg. July – August Outflow Temp. (C)	Avg. Aug. 15 – Oct. 15 Outflow Temp. (C)	Avg. Temp. Difference btw. Outflow and Clear Cr. Inflow (C)	Avg. July-August Temp. Difference btw. Outflow and Clear Cr. Inflow (C)	Avg. Aug. 15-Oct. 15 Temp. Difference btw. Outflow and Clear Cr. Inflow (C)
30	82	11.64	14.63	12.43	4.29	6.02	4.67
31	92	11.73	14.63	12.73	4.22	6.02	4.81
32	81	11.59	14.63	12.03	4.21	6.02	4.37
33	81	11.63	14.63	12.45	4.24	6.02	4.64
34	83	11.78	14.63	12.60	4.21	6.02	4.49
35	80	11.59	14.63	12.11	4.23	6.02	4.47
36	80	11.63	14.63	12.60	4.27	6.02	4.71
37	80	11.77	14.63	12.48	4.19	6.02	4.22
38	99	12.24	12.16	14.20	4.40	3.38	6.09
39	95	12.17	12.16	14.20	4.38	3.38	6.12
40	95	12.19	12.16	14.20	4.39	3.38	6.13
41	99	12.27	12.18	14.24	4.42	3.41	6.13
42	99	12.27	12.20	14.23	4.42	3.43	6.12
43	95	12.21	12.20	14.22	4.40	3.43	6.15
44	5	8.98	8.57	9.23	1.33	-0.20	1.04
45	0	8.59	8.63	9.17	1.21	-0.13	1.13
46	102	11.96	14.34	13.76	4.59	5.71	5.92

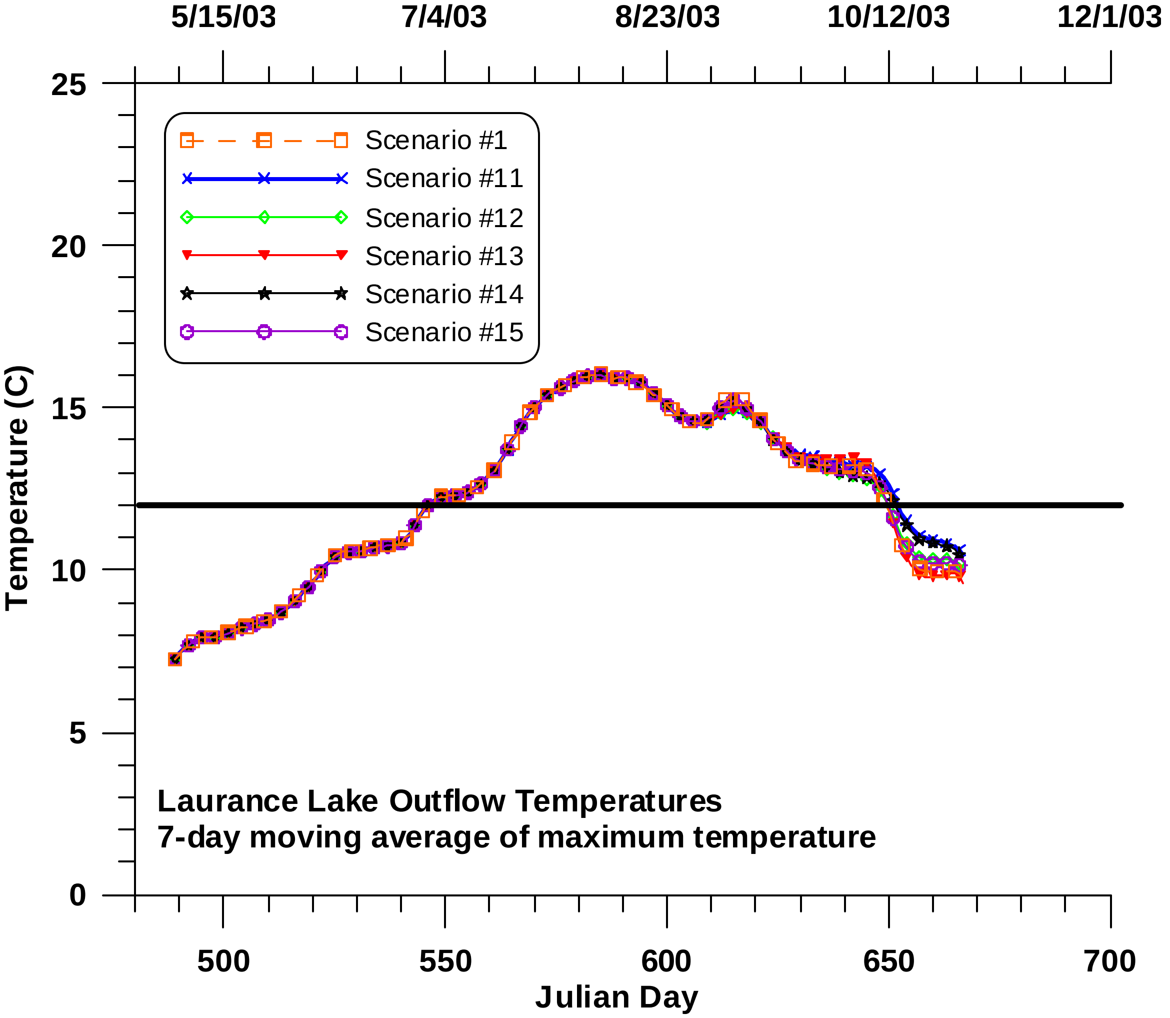


Figure 42. Comparison of 7-day moving average of the daily maximum temperature for scenarios 11-15.

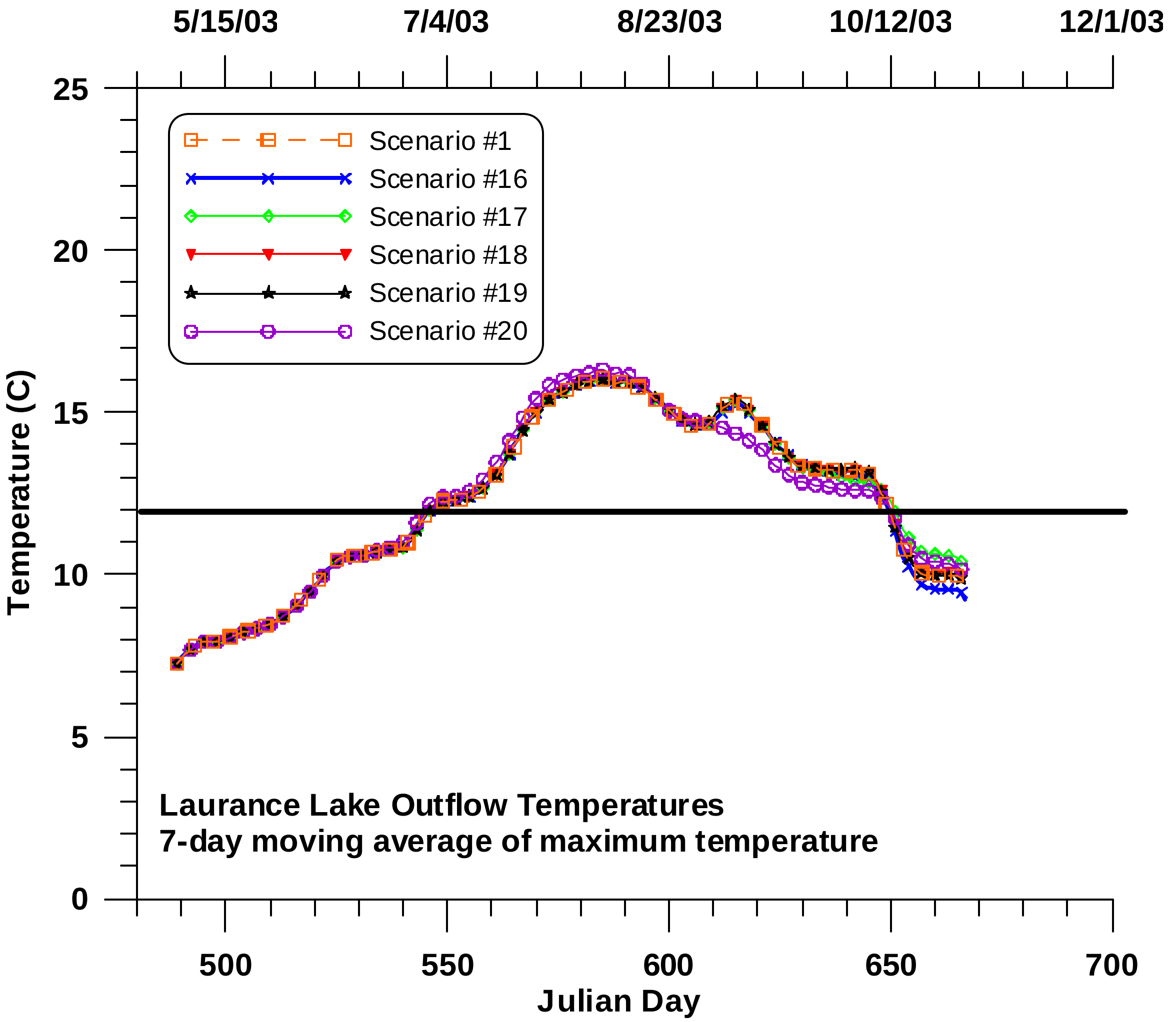


Figure 43. Comparison of 7-day moving average of the daily maximum temperature for scenarios 16-20.

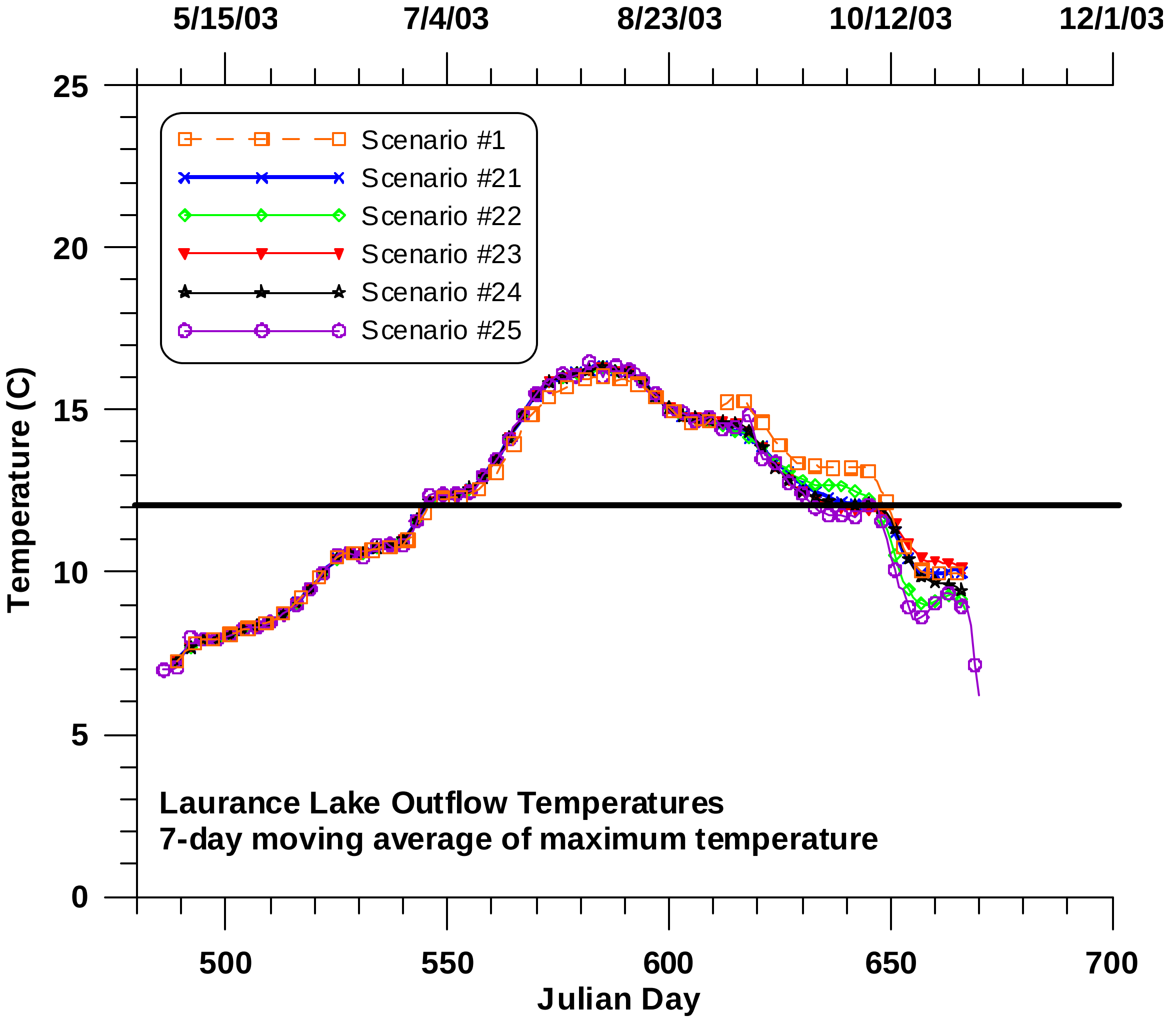


Figure 44. Comparison of 7-day moving average of the daily maximum temperature for scenarios 21-25.

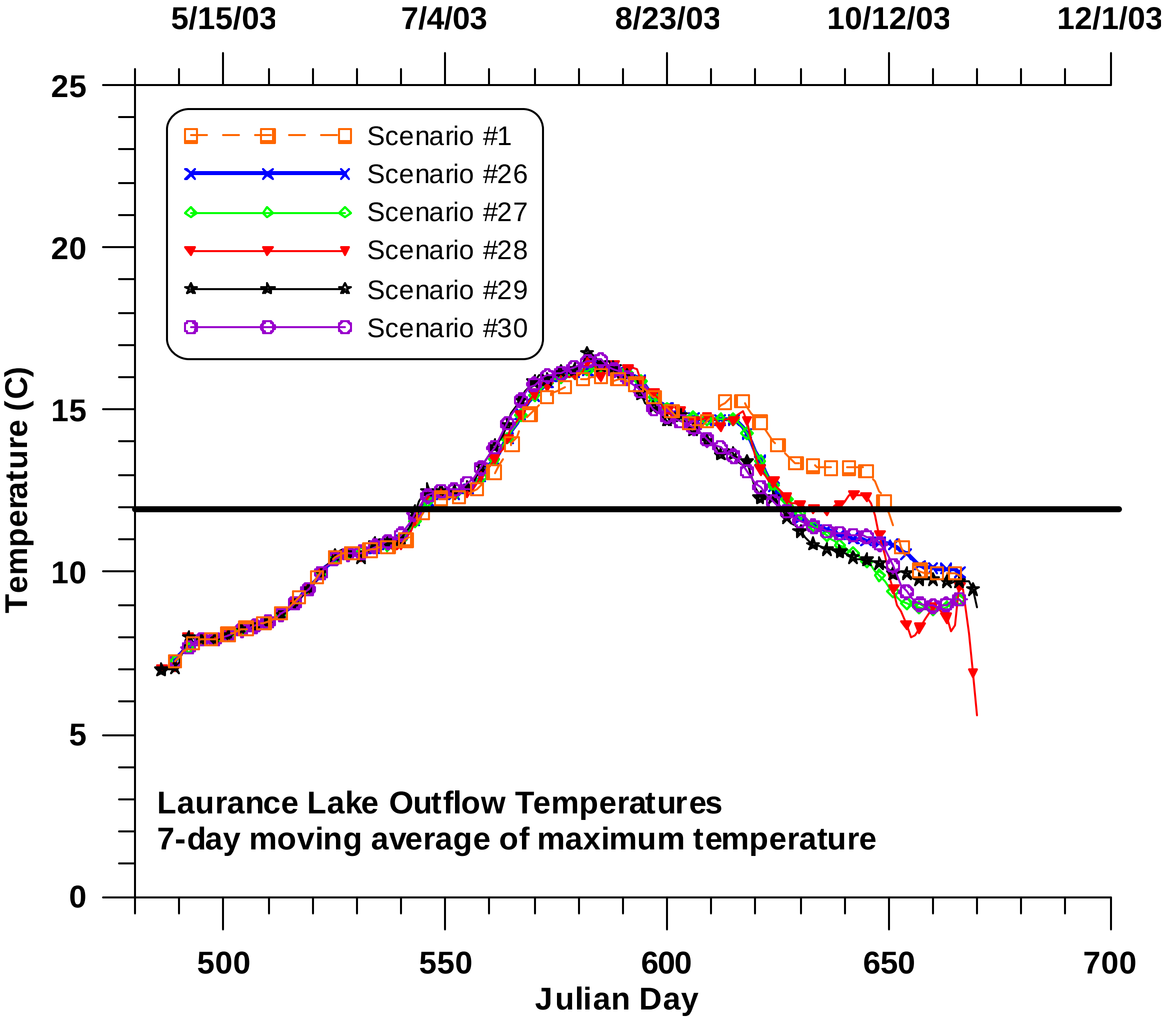


Figure 45. Comparison of 7-day moving average of the daily maximum temperature for scenarios 26-30.

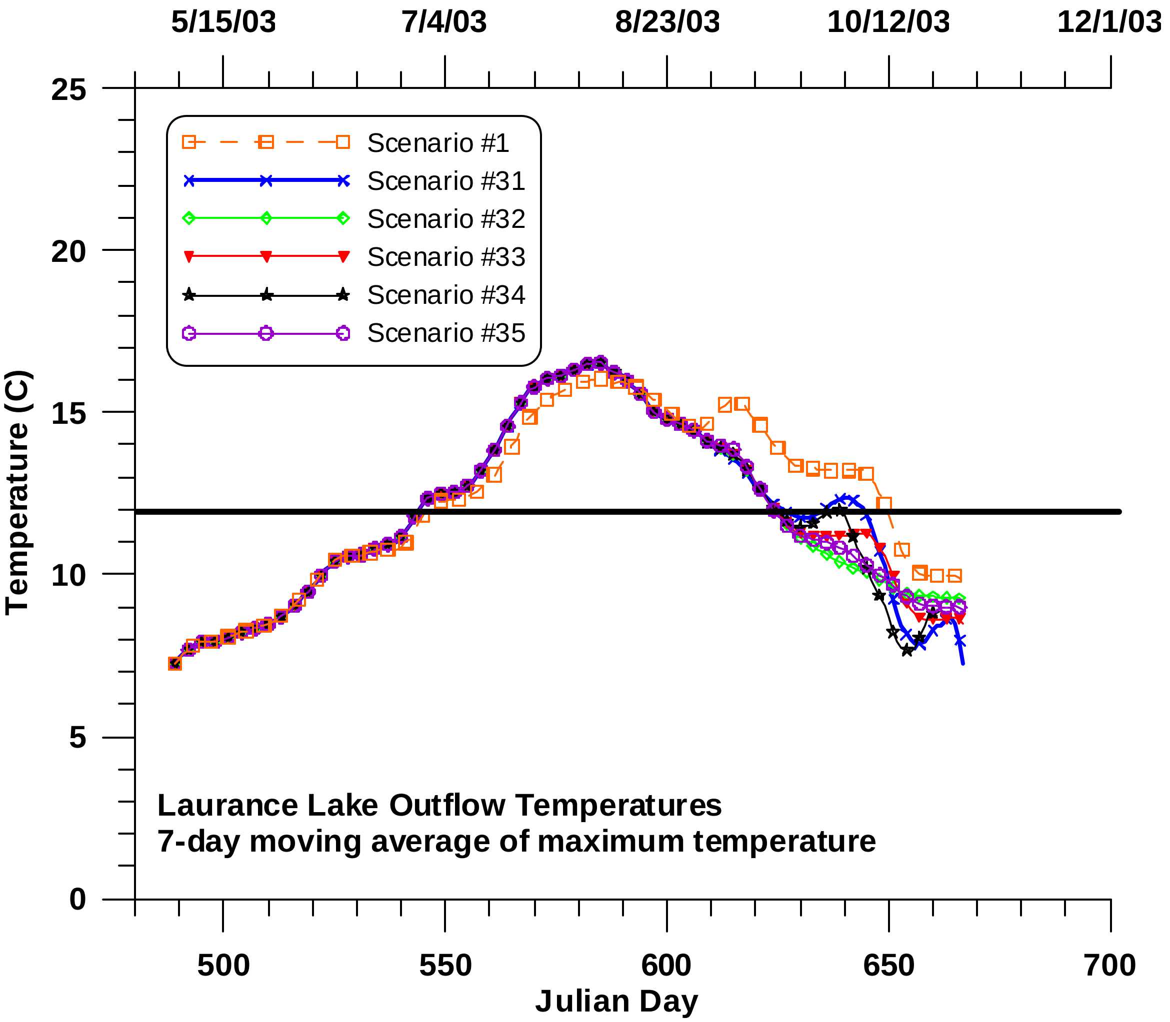


Figure 46. Comparison of 7-day moving average of the daily maximum temperature for scenarios 31-35.

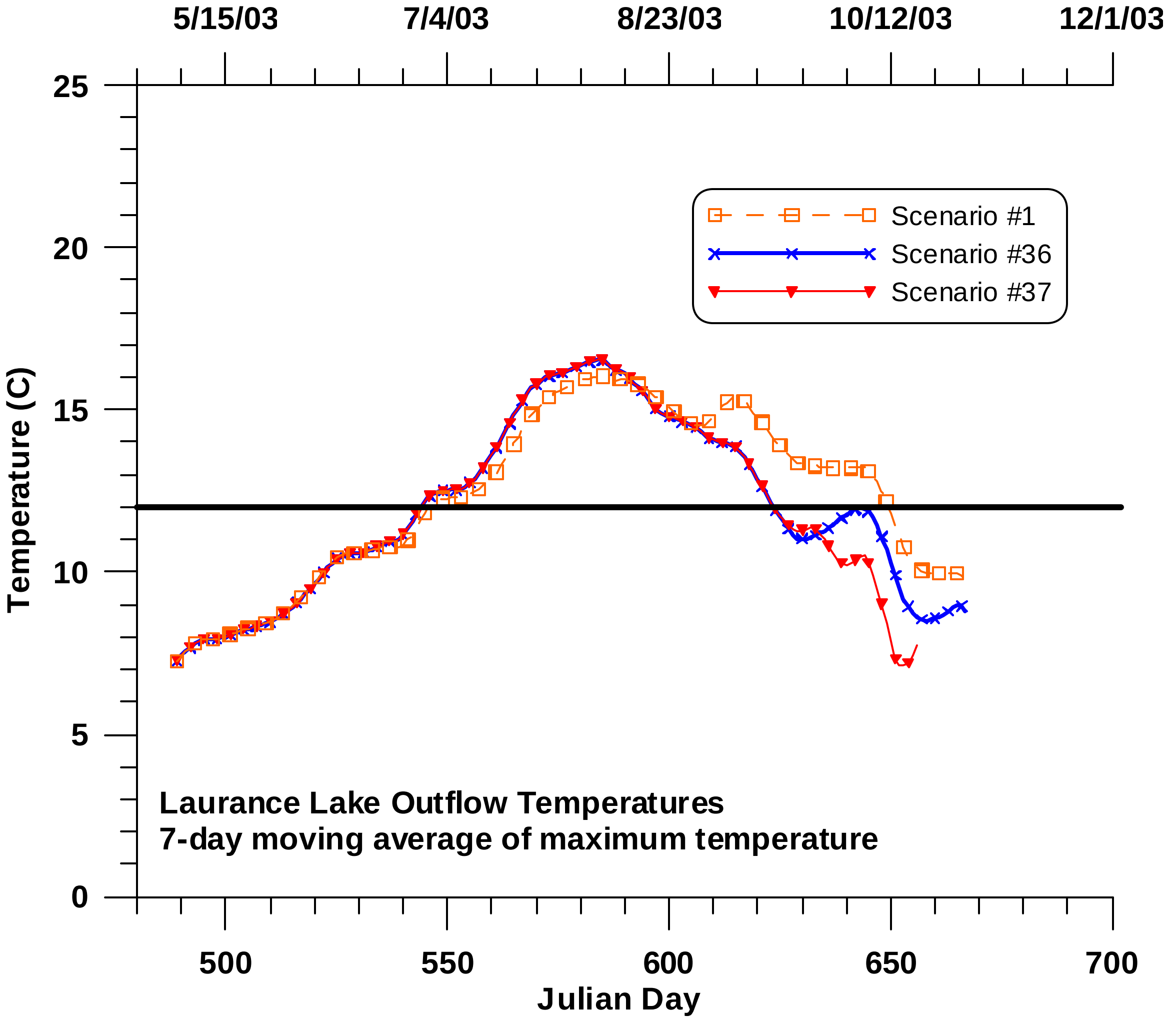


Figure 47. Comparison of 7-day moving average of the daily maximum temperature for scenarios 36-37.

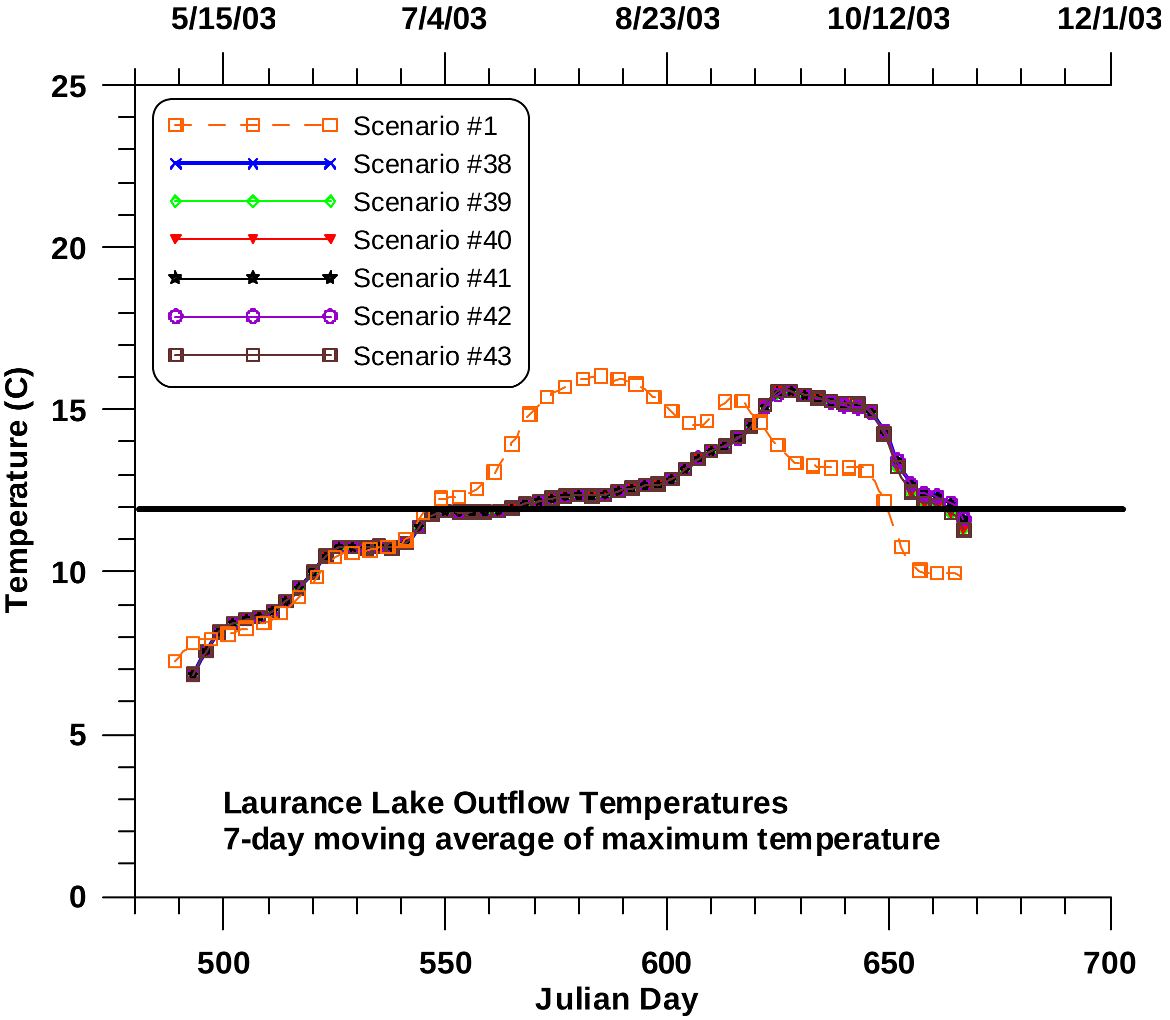


Figure 48. Comparison of 7-day moving average of the daily maximum temperature for scenarios 38-43.

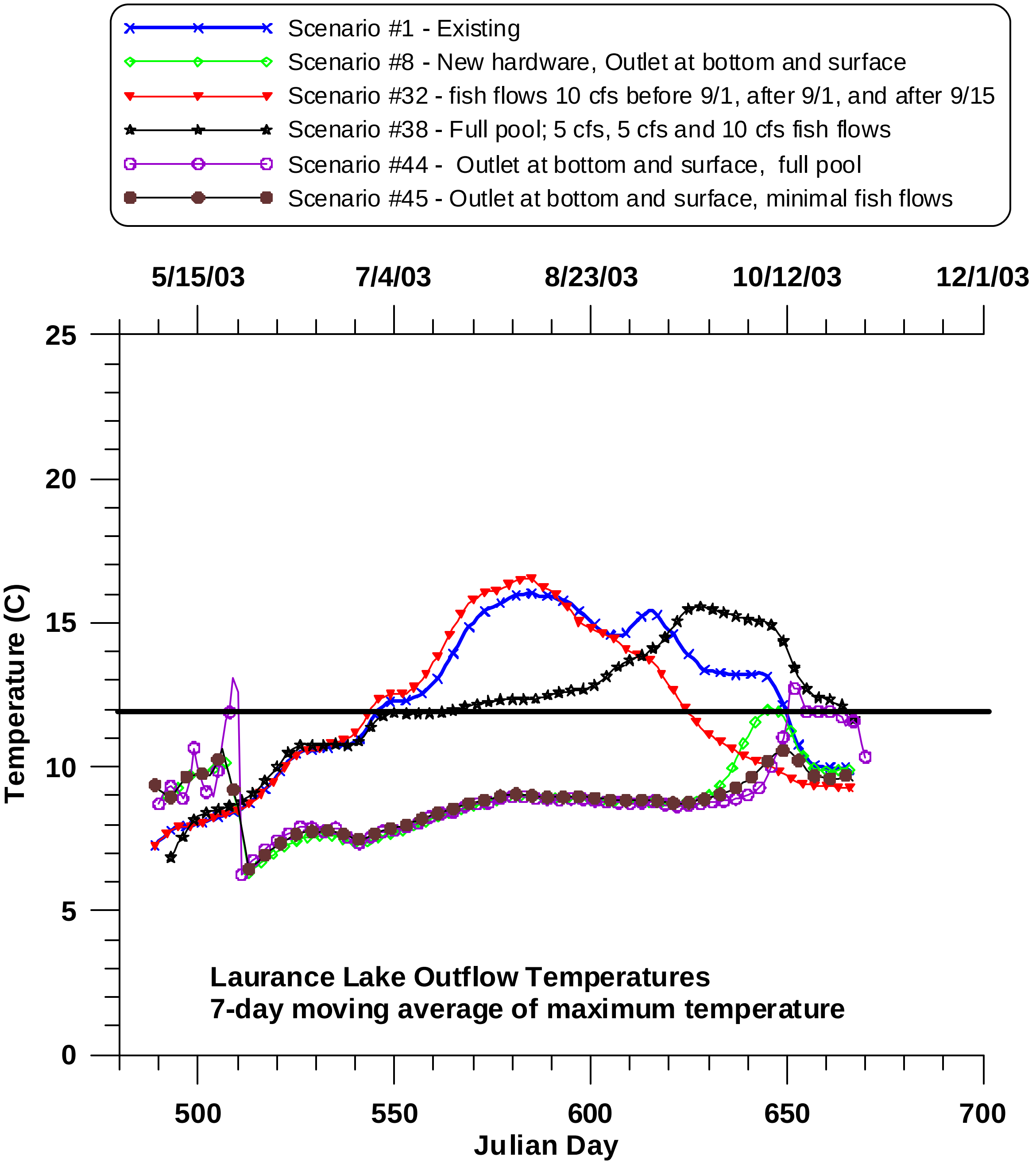


Figure 49. Comparison of 7-day moving average of the daily maximum temperature for scenario #1, #8, #32, #38, #44 and #45.

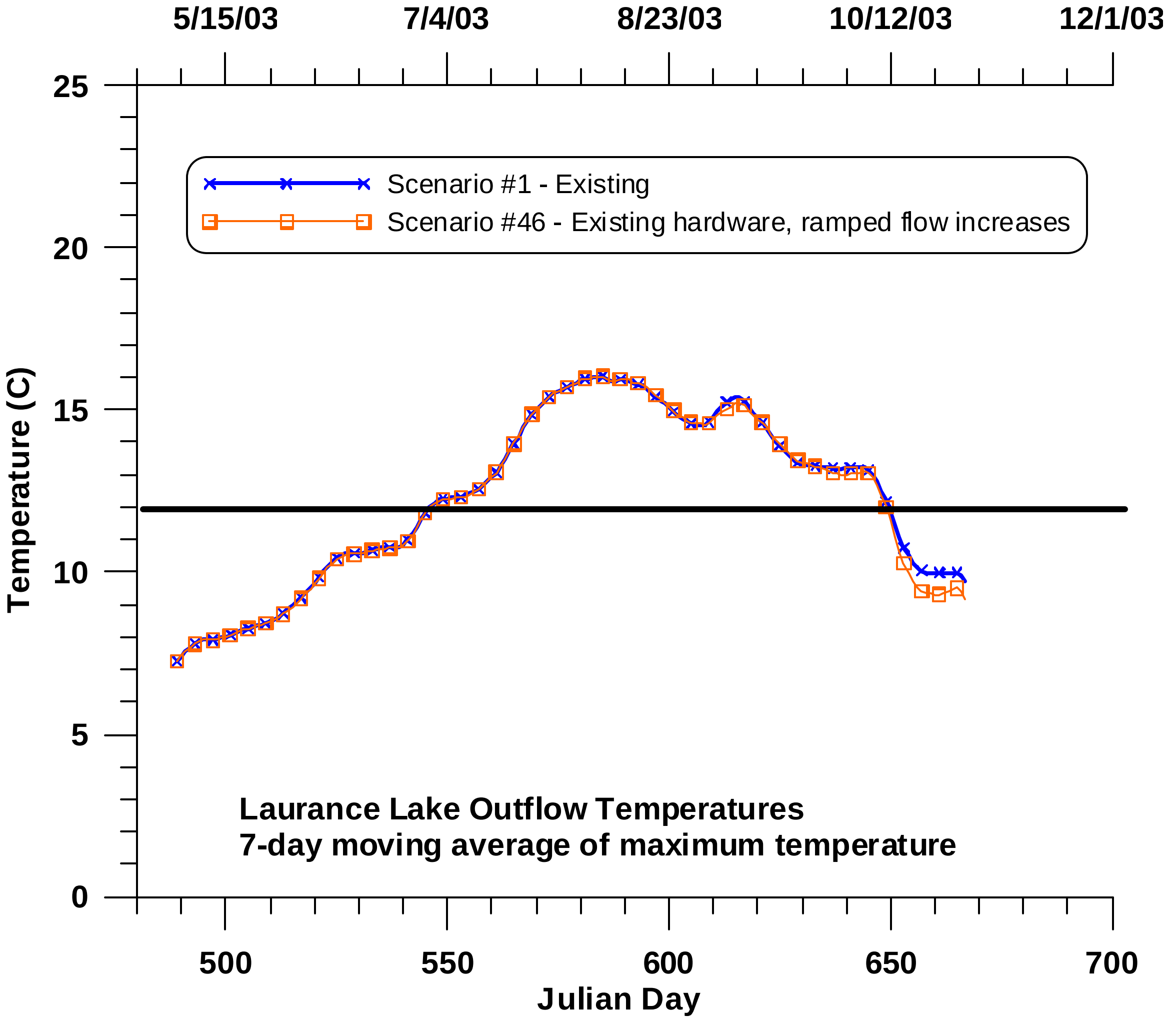


Figure 50. Comparison of 7-day moving average of the daily maximum temperature for scenario 1 and scenario 46.

Table 12. Statistics of selected scenarios 1, 8, 32, 38 and 44.

Scenario #	# days avg. 7-day max exceed 12 degrees Celsius	Avg. Outflow Temp. (C)	Avg. July – August Outflow Temp. (C)	Avg. Aug. 15 – Oct. 15 Outflow Temp. (C)	Avg. Temp. Difference btw. Outflow and Clear Cr. Inflow (C)	Avg. July-August Temp. Difference btw. Outflow and Clear Cr. Inflow (C)	Avg. Aug. 15-Oct. 15 Temp. Difference btw. Outflow and Clear Cr. Inflow (C)
1	103	12.06	14.32	13.99	4.67	5.69	5.98
8	1	8.63	8.53	9.44	1.29	-0.23	1.48
32	81	11.59	14.63	12.03	4.21	6.02	4.37
38	99	12.24	12.16	14.20	4.40	3.38	6.09
44	5	8.98	8.57	9.23	1.33	-0.20	1.04
45	0	8.59	8.63	9.17	1.21	-0.13	1.13
46	102	11.96	14.34	13.76	4.59	5.71	5.92

Summary

A water quality and hydrodynamic model, CE-QUAL-W2 Version 3.2 (Cole and Wells, 2001; http://www.cee.pdx.edu/w2), was applied to Laurance Lake, Oregon. This report summarizes model development and calibration for the CE-QUAL-W2 Version 3.2 model of Laurance Lake.

The system model required that boundary conditions and the topography be determined. Data in support of this modeling effort were shown in this report. This includes data such as:

- Dynamic inflow/discharge rates
- Dynamic inflow/discharge temperatures
- Dynamic inflow/discharge water quality constituents
- Dynamic meteorological data (air temperature, dew point temperature, wind speed, wind direction and cloud cover or short wave solar radiation)
- Model bathymetry

In general, the model reproduces the reservoir responses to the known boundary conditions.

Model scenarios were performed in order to understand the outlet temperature response of the reservoir system. There were 46 scenarios simulated including the following:

- Outlet near water surface (Dam outlet is kept at water surface)
- Outlet near bottom or near water surface, threshold is water temperature of 15^{o}C, Outlet near water surface if outlet temperature below 15^{o}C, otherwise outlet moved to bottom
- Dam raised 12 meters (deep outlet)
- Dam raised 2 meters (deep outlet)
- Pinnacle Creek Diversion where half of the flow from Pinnacle Creek is diverted to Clear Creek below dam
- Outlet at bottom and surface – option 1: Pass all irrigation and powerhouse flows from the surface outlet, pass 3 cfs to Clear Creek below dam until 9/15, then increase to 15 cfs. On 10/1 increase flow to 30 cfs.
- Outlet at bottom and surface – option 2: Pass all irrigation and powerhouse flows and fish flows to Clear Creek from the surface outlet, once surface outlet becomes > 10^{o}C, pass Clear Creek flows from lake bottom: 3 cfs to Clear Creek below dam until 9/15, then increase to 15 cfs. On 10/1 increase flow to 30 cfs.
- Outlet at bottom and surface – option 3: 50% of outflows withdrawn near water surface, 50% withdrawn near bottom
- Dam raised 12 meters, with outlet near surface: Dam outlet is kept near water surface and water surface raised 12 meters above calibrated simulation
- Varying fish flows to Clear Creek
- Varying fish flows to Clear Creek while keeping water levels near full pool
- Outlet at bottom and surface while keeping water levels near full pool: Pass all irrigation and powerhouse flows and fish flows to Clear Creek from the surface outlet, once surface outlet becomes > 10^{o}C, pass Clear Creek flows from lake bottom: 3 cfs to Clear Creek below dam until 9/15, then increase to 15 cfs. On 10/1 increase flow to 30 cfs.

- Outlets at bottom and surface; fish flows from bottom outlet, irrigation and powerhouse flows from surface outlet; fish flows kept at minimal flow rate to allow cool water at bottom of reservoir to last longer
- Ramping the September fish flow increases

Withdrawing water from the surface, then drawing water from the bottom, did lower outlet temperatures over the existing or base case simulation (a lower level outlet). The largest benefit for meeting downstream temperatures during the hot summer months was to withdraw irrigation and powerhouse flows from the surface and withdraw the fish flows for discharge to Clear Creek from the bottom (Scenarios 7, 8, 44 and 45). Keeping water levels near full pool resulted in cooler outflow temperatures in the summer but warmer outflow temperatures in the fall. Reducing fish flows in the fall allowed the volume of cool water at the bottom of the reservoir to last longer into the fall. Scenario #45, which used minimal fish flows along with surface and bottom outlets, predicted the coolest outflows temperatures of any of the scenarios. Figure 49 plots the 7-day moving average of the maximum daily temperature for the some of the more successful scenarios. Figure 51 shows the model predicted temperature difference between Clear Creek inflows and dam outflows for scenarios 1, 8, and 45.

If scenarios such as a lower level outlet are pursued, there should be exploration of the dissolved oxygen impact of these releases.

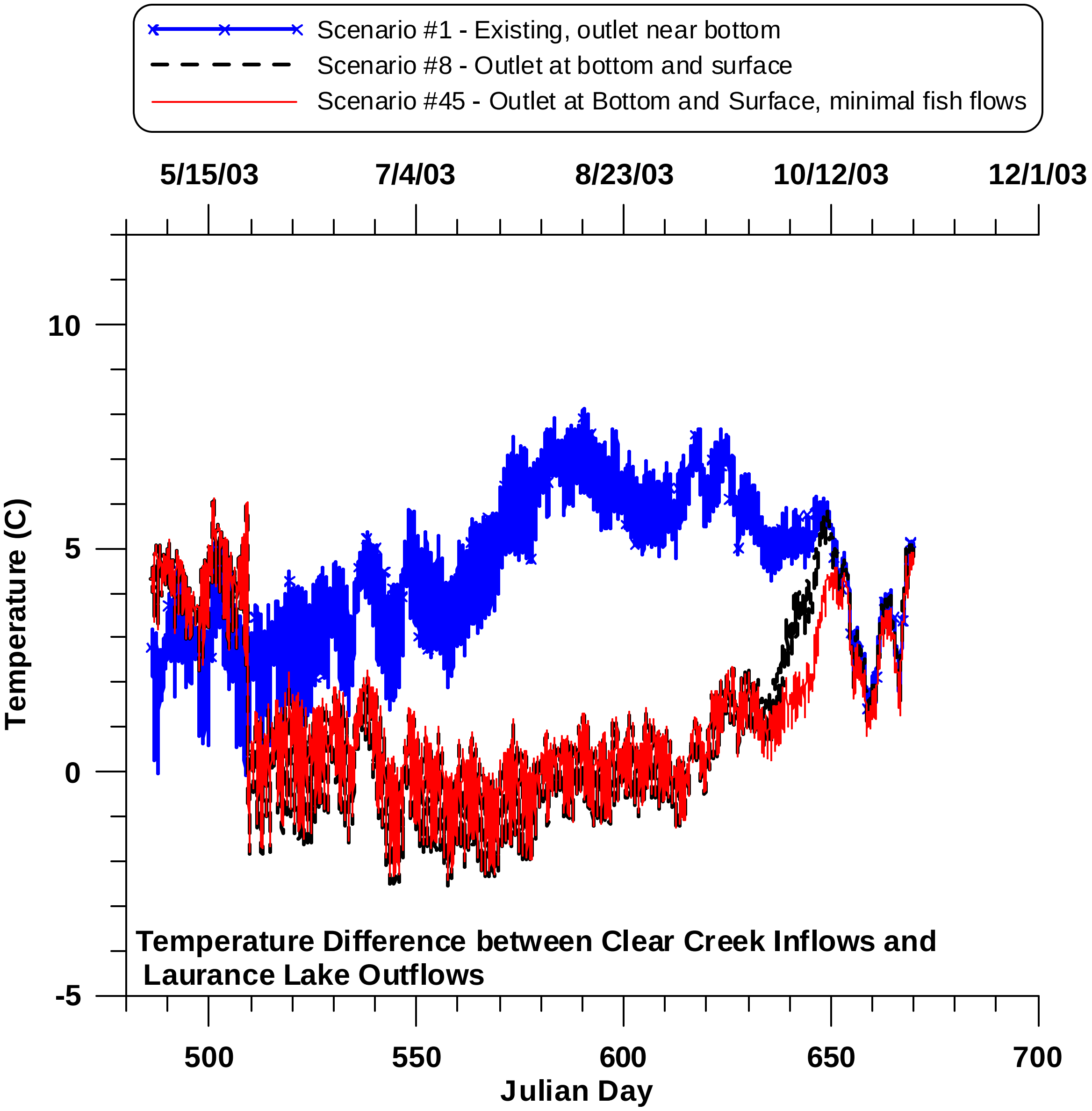


Figure 51. Predicted temperature difference between Clear Creek inflows and dam outflows to Clear Creek for scenarios 1, 8, and 45.

References

Cole, T.M., and S.A. Wells (2004) "CE-QUAL-W2: A two-dimensional, laterally averaged, Hydrodynamic and Water Quality Model, Version 3.2," Instruction Report EL-2004-, US Army Engineering and Research Development Center, Vicksburg, MS.

Edinger, J. E. and Buchak, E. M. (1978). “Numerical hydrodynamics of estuaries.” *Estuarine and Wetland Processes with Special Emphasis on Modeling*, edited by P. Hamilton and K. B. MacDonald, Plenum Press, NY, 115-146

Wells, S. A. (1997) "Theoretical Basis for the CE-QUAL-W2 River Basin Model," Dept. of Civil Engr., Tech. Rpt. EWR-6-97, Portland St. Univ., Portland, OR, 1997.

Appendix A: Model Control File

```
  W2 Model Version 3.2

TITLE C ...............................TITLE....................................
        Laurance Lake Model  Version 3.2
        Portland State University


        Temperature simulation

        Jday 1 = 1/1/2002




GRID         NWB     NBR     IMX     KMX
               1       2      23      92

IN/OUTFL     NTR     NST     NIW     NWD     NGT     NSP     NPI     NPU
               1       1       0       0       0       0       0       0

CONSTITU     NGC     NSS     NAL     NEP    NBOD
               3       1       1       1       0

MISCELL     NDAY
             100

TIME CON  TMSTRT   TMEND730 YEAR
         486.000 851.000    2002

DLT CON      NDT  DLTMIN
               1 1.00000

DLT DATE    DLTD    DLTD    DLTD    DLTD    DLTD    DLTD    DLTD    DLTD    DLTD
         63.5000

DLT MAX   DLTMAX  DLTMAX  DLTMAX  DLTMAX  DLTMAX  DLTMAX  DLTMAX  DLTMAX  DLTMAX
         3600.00

DLT FRN     DLTF    DLTF    DLTF    DLTF    DLTF    DLTF    DLTF    DLTF    DLTF
         0.90000

DLT LIMI    VISC    CELC
WB 1          ON      ON

BRANCH G      US      DS     UHS     DHS     UQB     DQB   NLMIN   SLOPE
BR1            2      13       0       0       0       0       1 0.00000
BR2           16      22       0      13       0       0       1 0.00000

LOCATION     LAT    LONG    EBOT      BS      BE    JBDN
WB 1     45.5000 122.000 880.000       1       2       1

INIT CND     T2I    ICEI  WTYPEC
WB 1    -1.00000 0.00000   FRESH

CALCULAT     VBC     EBC     MBC     PQC     EVC     PRC
WB 1          ON      ON      ON      ON      ON     OFF

DEAD SEA   WINDC    QINC   QOUTC   HEATC
WB 1          ON      ON      ON      ON

INTERPOL   QINIC   DTRIC    HDIC
BR1           ON      ON     OFF
BR2           ON      ON     OFF

HEAT EXCH  SLHTC    SROC  RHEVAP   METIC  FETCHC     AFW     BFW     CFW   WINDH
WB 1        TERM      ON     OFF      ON     OFF 9.20000 0.46000 2.00000  5.0000

ICE COVE    ICEC  SLICEC  ALBEDO   HWICE    BICE    GICE  ICEMIN   ICET2
WB 1          ON  DETAIL 0.25000 10.0000 0.60000 0.07000 0.05000 3.00000
```

```
TRANSPOR   SLTRC   THETA
WB 1    ULTIMATE 0.55000

HYD COEF      AX      DX    CBHE    TSED      FI   TSEDF   FRICC
WB 1     1.00000 1.00000     0.3   8.000 0.00000 1.00000    MANN

EDDY VISC    AZC   AZSLC   AZMAX  PHISET
WB 1          W2     IMP 0.00100     0.0

N STRUC     NSTR
BR1            1
BR2            0

STR INT    STRIC   STRIC   STRIC   STRIC   STRIC   STRIC   STRIC   STRIC   STRIC
BR 1          ON
BR 2

STR TOP    KTSTR   KTSTR   KTSTR   KTSTR   KTSTR   KTSTR   KTSTR   KTSTR   KTSTR
BR1            2
BR2

STR BOT    KBSTR   KBSTR   KBSTR   KBSTR   KBSTR   KBSTR   KBSTR   KBSTR   KBSTR
BR1           91
BR2

STR SINK   SINKC   SINKC   SINKC   SINKC   SINKC   SINKC   SINKC   SINKC   SINKC
BR1        POINT
BR2

STR ELEV    ESTR    ESTR    ESTR    ESTR    ESTR    ESTR    ESTR    ESTR    ESTR
BR1      880.000
BR2

STR WIDT    WSTR    WSTR    WSTR    WSTR    WSTR    WSTR    WSTR    WSTR    WSTR
BR1      0.00000
BR2

PIPES       IUPI    IDPI    EUPI    EDPI     WPI   DLXPI     FPI  FMINPI   WTHLC


PIPE UP    PUPIC   ETUPI   EBUPI   KTUPI   KBUPI


PIPE DOWN  PDPIC   ETDPI   EBDPI   KTDPI   KBDPI


SPILLWAY    IUSP    IDSP     ESP    A1SP    B1SP    A2SP    B2SP   WTHLC


SPILL UP   PUSPC   ETUSP   EBUSP   KTUSP   KBUSP


SPILL DOWN PDSPC   ETUSP   EBUSP   KTDSP   KBDSP


SPILL GAS GASSPC    EQSP  AGASSP  BGASSP  CGASSP


GATES       IUGT    IDGT     EGT    A1GT    B1GT    G1GT    A2GT    B2GT    G2GT   WTHLC


GATE WEIR   GTA1    GTB1    GTA2    GTB2  DYNVAR


GATE UP    PUGTC   ETUGT   EBUGT   KTUGT   KBUGT


GATE DOWN  PDGTC   ETDGT   EBDGT   KTDGT   KBDGT


GATE GAS  GASGTC    EQGT  AGASGT  BGASGT  CGASGT


PUMPS 1     IUPU    IDPU     EPU  STRTPU   ENDPU   EONPU  EOFFPU     QPU   WTHLC
```

```
PUMPS 2     PPUC    ETPU    EBPU    KTPU    KBPU


WEIR SEG     IWR     IWR     IWR     IWR     IWR     IWR     IWR     IWR     IWR


WEIR TOP    KTWR    KTWR    KTWR    KTWR    KTWR    KTWR    KTWR    KTWR    KTWR


WEIR BOT    KBWR    KBWR    KBWR    KBWR    KBWR    KBWR    KBWR    KBWR    KBWR


WD INT      WDIC    WDIC    WDIC    WDIC    WDIC    WDIC    WDIC    WDIC    WDIC


WD SEG       IWD     IWD     IWD     IWD     IWD     IWD     IWD     IWD     IWD


WD ELEV      EWD     EWD     EWD     EWD     EWD     EWD     EWD     EWD     EWD


WD TOP      KTWD    KTWD    KTWD    KTWD    KTWD    KTWD    KTWD    KTWD    KTWD


WD BOT      KBWD    KBWD    KBWD    KBWD    KBWD    KBWD    KBWD    KBWD    KBWD


TRIB PLA    PTRC    PTRC    PTRC    PTRC    PTRC    PTRC    PTRC    PTRC    PTRC
         SPECIFY

TRIB INT    TRIC    TRIC    TRIC    TRIC    TRIC    TRIC    TRIC    TRIC    TRIC
              ON

TRIB SEG     ITR     ITR     ITR     ITR     ITR     ITR     ITR     ITR     ITR
              13

TRIB TOP   ELTRT   ELTRT   ELTRT   ELTRT   ELTRT   ELTRT   ELTRT   ELTRT   ELTRT
           898.0

TRIB BOT   ELTRB   ELTRB   ELTRB   ELTRB   ELTRB   ELTRB   ELTRB   ELTRB   ELTRB
           880.1

DST TRIB    DTRC    DTRC    DTRC    DTRC    DTRC    DTRC    DTRC    DTRC    DTRC
BR 1         OFF
BR 2         OFF

PUMPBACK     JBG     KTG     KBG     JBP     KTP     KBP
               0       0       0       0       0       0

PRINTER      LJC
              IV

HYD PRIN  HPRWBC  HPRWBC  HPRWBC  HPRWBC  HPRWBC  HPRWBC  HPRWBC  HPRWBC  HPRWBC
NVIOL         ON
U             ON
W             ON
T             ON
RHO          OFF
AZ           OFF
SHEAR        OFF
ST           OFF
SB           OFF
ADMX         OFF
DM           OFF
HDG          OFF
ADMZ         OFF
HPG          OFF
GRAV         OFF

SNP PRINT   SNPC    NSNP   NISNP
WB 1          ON       1      19
```

```
SNP DATE    SNPD    SNPD    SNPD    SNPD    SNPD    SNPD    SNPD    SNPD    SNPD
WB 1     63.5000

SNP FREQ    SNPF    SNPF    SNPF    SNPF    SNPF    SNPF    SNPF    SNPF    SNPF
WB 1     1.00000

SNP SEG     ISNP    ISNP    ISNP    ISNP    ISNP    ISNP    ISNP    ISNP    ISNP
WB 1           2       3       4       5       6       7       8       9      10
              11      12      13      16      17      18      19      20      21
              22

SCR PRINT   SCRC    NSCR
WB 1          ON       1

SCR DATE    SCRD    SCRD    SCRD    SCRD    SCRD    SCRD    SCRD    SCRD    SCRD
WB 1     63.5000

SCR FREQ    SCRF    SCRF    SCRF    SCRF    SCRF    SCRF    SCRF    SCRF    SCRF
WB 1     0.50000

PRF PLOT    PRFC    NPRF   NIPRF
WB 1         OFF       1       3

PRF DATE    PRFD    PRFD    PRFD    PRFD    PRFD    PRFD    PRFD    PRFD    PRFD
WB 1     77.7000

PRF FREQ    PRFF    PRFF    PRFF    PRFF    PRFF    PRFF    PRFF    PRFF    PRFF
WB 1     1.00000

PRF SEG     IPRF    IPRF    IPRF    IPRF    IPRF    IPRF    IPRF    IPRF    IPRF
WB 1          10      18      26

SPR PLOT    SPRC    NSPR   NISPR
WB 1         OFF       0       0

SPR DATE    SPRD    SPRD    SPRD    SPRD    SPRD    SPRD    SPRD    SPRD    SPRD
WB 1

SPR FREQ    SPRF    SPRF    SPRF    SPRF    SPRF    SPRF    SPRF    SPRF    SPRF
WB 1

SPR SEG     ISPR    ISPR    ISPR    ISPR    ISPR    ISPR    ISPR    ISPR    ISPR
WB 1

VPL PLOT    VPLC    NVPL
WB 1         OFF       1

VPL DATE    VPLD    VPLD    VPLD    VPLD    VPLD    VPLD    VPLD    VPLD    VPLD
WB 1     63.5000

VPL FREQ    VPLF    VPLF    VPLF    VPLF    VPLF    VPLF    VPLF    VPLF    VPLF
WB 1     1.00000

CPL PLOT    CPLC    NCPL
WB 1          ON       1

CPL DATE    CPLD    CPLD    CPLD    CPLD    CPLD    CPLD    CPLD    CPLD    CPLD
WB 1     486.400

CPL FREQ    CPLF    CPLF    CPLF    CPLF    CPLF    CPLF    CPLF    CPLF    CPLF
WB 1         1.0

FLUXES      FLXC    NFLX
WB 1         OFF       0

FLX DATE    FLXD    FLXD    FLXD    FLXD    FLXD    FLXD    FLXD    FLXD    FLXD
WB 1

FLX FREQ    FLXF    FLXF    FLXF    FLXF    FLXF    FLXF    FLXF    FLXF    FLXF
WB 1

TSR PLOT    TSRC    NTSR   NITSR
              ON       1       1
```

```
TSR DATE    TSRD    TSRD    TSRD    TSRD    TSRD    TSRD    TSRD    TSRD    TSRD
         63.5000

TSR FREQ    TSRF    TSRF    TSRF    TSRF    TSRF    TSRF    TSRF    TSRF    TSRF
         0.10000

TSR SEG     ITSR    ITSR    ITSR    ITSR    ITSR    ITSR    ITSR    ITSR    ITSR
              13

TSR LAYE    ETSR    ETSR    ETSR    ETSR    ETSR    ETSR    ETSR    ETSR    ETSR
         0.00000

WITH OUT    WDOC    NWDO   NIWDO
              ON       1       1

WITH DAT    WDOD    WDOD    WDOD    WDOD    WDOD    WDOD    WDOD    WDOD    WDOD
         1.00000

WITH FRE    WDOF    WDOF    WDOF    WDOF    WDOF    WDOF    WDOF    WDOF    WDOF
         0.00100

WITH SEG    IWDO    IWDO    IWDO    IWDO    IWDO    IWDO    IWDO    IWDO    IWDO
              13

RESTART     RSOC    NRSO    RSIC
             OFF       0     OFF

RSO DATE    RSOD    RSOD    RSOD    RSOD    RSOD    RSOD    RSOD    RSOD    RSOD


RSO FREQ    RSOF    RSOF    RSOF    RSOF    RSOF    RSOF    RSOF    RSOF    RSOF


CST COMP     CCC    LIMC     CUF
             OFF     OFF       1

CST ACTIVE   CAC
TDS           ON
Gen1          ON
Gen2          ON
Gen3          ON
ISS1          ON
PO4           ON
NH4           ON
NO3           ON
DSI          OFF
PSI          OFF
FE            ON
LDOM          ON
RDOM          ON
LPOM          ON
RPOM         OFF
ALG1          ON
DO            ON
TIC           ON
ALK           ON

CST DERI   CDWBC   CDWBC   CDWBC   CDWBC   CDWBC   CDWBC   CDWBC   CDWBC   CDWBC
DOC          OFF
POC          OFF
TOC          OFF
DON          OFF
PON          OFF
TON          OFF
TKN          OFF
TN           OFF
DOP          OFF
POP          OFF
TOP          OFF
TP           OFF
APR          OFF
CHLA         OFF
ATOT         OFF
%DO          OFF
```

```
TSS          OFF
TISS         OFF
CBOD         OFF
pH           OFF
CO2          OFF
HCO3         OFF
CO3          OFF

CST FLUX   CFWBC   CFWBC   CFWBC   CFWBC   CFWBC   CFWBC   CFWBC   CFWBC   CFWBC
TISSIN       OFF
TISSOUT      OFF
PO4AR        OFF
PO4AG        OFF
PO4AP        OFF
PO4ER        OFF
PO4EG        OFF
PO4EP        OFF
PO4POM       OFF
PO4DOM       OFF
PO4OM        OFF
PO4SED       OFF
PO4SOD       OFF
PO4SET       OFF
NH4NITR      OFF
NH4AR        OFF
NH4AG        OFF
NH4AP        OFF
NH4ER        OFF
NH4EG        OFF
NH4EP        OFF
NH4POM       OFF
NH4DOM       OFF
NH4OM        OFF
NH4SED       OFF
NH4SOD       OFF
NO3DEN       OFF
NO3AG        OFF
NO3EG        OFF
NO3SED       OFF
DSIAG        OFF
DSIEG        OFF
DSIPIS       OFF
DSISED       OFF
DSISOD       OFF
DSISET       OFF
PSIAM        OFF
PSINET       OFF
PSIDK        OFF
FESET        OFF
FESED        OFF
LDOMDK       OFF
LRDOM        OFF
RDOMDK       OFF
LDOMAP       OFF
LDOMEP       OFF
LPOMDK       OFF
LRPOM        OFF
RPOMDK       OFF
LPOMAP       OFF
LPOMEP       OFF
LPOMSET      OFF
RPOMSET      OFF
CBODDK       OFF
DOAP         OFF
DOAR         OFF
DOEP         OFF
DOER         OFF
DOPOM        OFF
DODOM        OFF
DOOM         OFF
DONITR       OFF
DOCBOD       OFF
DOREAR       OFF
DOSED        OFF
```

```
DOSOD        OFF
TICAG        OFF
TICEG        OFF
SEDDK        OFF
SEDAS        OFF
SEDLPOM      OFF
SEDSET       OFF
SODDK        OFF

CST ICON   C2IWB   C2IWB   C2IWB   C2IWB   C2IWB   C2IWB   C2IWB   C2IWB   C2IWB
TDS      51.0000
Gen1     100.000
Gen2     0.00000
Gen3     10.0000
ISS1     2.00000
PO4      0.00000
NH4      0.00000
NO3      0.14000
DSI      0.00000
PSI      0.00000
FE       0.10000
LDOM     0.70000
RDOM     2.02000
LPOM     0.10000
RPOM     0.00000
ALG1     1.00000
DO       1.00000
TIC      11.9100
ALK      31.0000

CST PRIN  CPRWBC  CPRWBC  CPRWBC  CPRWBC  CPRWBC  CPRWBC  CPRWBC  CPRWBC  CPRWBC
TDS           ON
Gen1          ON
Gen2         OFF
Gen3         OFF
ISS1          ON
PO4           ON
NH4           ON
NO3           ON
DSI          OFF
PSI          OFF
FE            ON
LDOM          ON
RDOM          ON
LPOM          ON
RPOM         OFF
ALG1          ON
DO            ON
TIC          OFF
ALK          OFF

CIN CON   CINBRC  CINBRC  CINBRC  CINBRC  CINBRC  CINBRC  CINBRC  CINBRC  CINBRC
TDS           ON      ON
Gen1          ON      ON
Gen2         OFF     OFF
Gen3          ON      ON
ISS1          ON      ON
PO4           ON      ON
NH4           ON      ON
NO3           ON      ON
DSI          OFF     OFF
PSI          OFF     OFF
FE            ON      ON
LDOM          ON      ON
RDOM          ON      ON
LPOM          ON      ON
RPOM         OFF     OFF
ALG1          ON      ON
DO            ON      ON
TIC           ON      ON
ALK           ON      ON

CTR CON   CTRTRC  CTRTRC  CTRTRC  CTRTRC  CTRTRC  CTRTRC  CTRTRC  CTRTRC  CTRTRC
TDS          OFF
```

```
Gen1         OFF
Gen2         OFF
Gen3         OFF
ISS1         OFF
PO4          OFF
NH4          OFF
NO3          OFF
DSI          OFF
PSI          OFF
FE           OFF
LDOM         OFF
RDOM         OFF
LPOM         OFF
RPOM         OFF
ALG1         OFF
DO           OFF
TIC          OFF
ALK          OFF

CDT CON   CDTBRC  CDTBRC  CDTBRC  CDTBRC  CDTBRC  CDTBRC  CDTBRC  CDTBRC  CDTBRC
TDS          OFF     OFF
Gen1         OFF     OFF
Gen2         OFF     OFF
Gen3         OFF     OFF
ISS1         OFF     OFF
PO4          OFF     OFF
NH4          OFF     OFF
NO3          OFF     OFF
DSI          OFF     OFF
PSI          OFF     OFF
FE           OFF     OFF
LDOM         OFF     OFF
RDOM         OFF     OFF
LPOM         OFF     OFF
RPOM         OFF     OFF
ALG1         OFF     OFF
DO           OFF     OFF
TIC          OFF     OFF
ALK          OFF     OFF

CPR CON   CPRBRC  CPRBRC  CPRBRC  CPRBRC  CPRBRC  CPRBRC  CPRBRC  CPRBRC  CPRBRC
TDS          OFF     OFF
Gen1         OFF     OFF
Gen2         OFF     OFF
Gen3         OFF     OFF
ISS1         OFF     OFF
PO4          OFF     OFF
NH4          OFF     OFF
NO3          OFF     OFF
DSI          OFF     OFF
PSI          OFF     OFF
FE           OFF     OFF
LDOM         OFF     OFF
RDOM         OFF     OFF
LPOM         OFF     OFF
RPOM         OFF     OFF
ALG1         OFF     OFF
DO           OFF     OFF
TIC          OFF     OFF
ALK          OFF     OFF

EX COEF    EXH2O    EXSS    EXOM    BETA     EXC    EXIC
WB 1     0.55000 0.01000 0.20000 0.45000      ON      ON

ALG EX       EXA     EXA     EXA     EXA     EXA     EXA
         0.20000

GENERIC    CGQ10   CG0DK   CG1DK     CGS
CG 1     0.00000 0.00000 0.00000 0.00000
CG 2     0.00000 -1.0000 0.00000 0.00000
CG 3     1.04000 0.00000 1.40000 0.00000

S SOLIDS     SSS   SEDRC   TAUCR
SS# 1    1.00000     OFF .15E-04
```

```
ALGAL RATE    AG      AR      AE      AM      AS    AHSP    AHSN   AHSSI    ASAT
ALG1     2.00000 0.04000 0.04000 0.10000 0.10000 0.00300 0.01400 0.00000 100.000

ALGAL TEMP   AT1     AT2     AT3     AT4     AK1     AK2     AK3     AK4
ALG1     5.00000 30.0000 35.0000 40.0000 0.10000 0.99000 0.99000 0.10000

ALG STOI    ALGP    ALGN    ALGC   ALGSI   ACHLA   ALPOM   ANEQN    ANPR
ALG1     0.00500 0.08000 0.45000 0.00000 65.0000 0.80000       1 0.00000

EPIPHYTE    EPIC    EPIC    EPIC    EPIC    EPIC    EPIC    EPIC    EPIC    EPIC
EPI1         OFF

EPI PRIN    EPRC    EPRC    EPRC    EPRC    EPRC    EPRC    EPRC    EPRC    EPRC
EPI1         OFF

EPI INIT   EPICI   EPICI   EPICI   EPICI   EPICI   EPICI   EPICI   EPICI   EPICI
EPI1     0.00000

EPI RATE      EG      ER      EE      EM      EB    EHSP    EHSN   EHSSI
EPI1     2.00000 0.04000 0.04000 0.10000 0.00100 0.00300 0.01400 0.00000

EPI HALF    ESAT     EHS   ENEQN    ENPR
EPI1     125.000 1.00000       1 0.00000

EPI TEMP     ET1     ET2     ET3     ET4     EK1     EK2     EK3     EK4
EPI1     5.00000 25.0000 35.0000 40.0000 0.10000 0.99000 0.99000 0.10000

EPI STOI      EP      EN      EC     ESI   ECHLA    EPOM
EPI1     0.00500 0.08000 0.45000 0.00000 65.0000 0.80000

DOM       LDOMDK  RDOMDK   LRDDK
WB 1     0.30000 0.00100 0.01000

POM       LPOMDK  RPOMDK   LRPDK    POMS
WB 1     0.08000 0.01000 0.00100 0.50000

OM STOIC    ORGP    ORGN    ORGC   ORGSI
WB 1     0.00500 0.08000 0.45000 0.18000

OM RATE     OMT1    OMT2    OMK1    OMK2
WB 1     4.00000 30.0000 0.10000 0.99000

CBOD        KBOD    TBOD    RBOD
BOD 1    0.25000 1.01500 1.85000

CBOD STOIC  BODP    BODN    BODC
BOD 1    0.00500 0.08000 0.45000

PHOSPHOR    PO4R   PARTP
WB 1     0.01500 1.20000

AMMONIUM    NH4R   NH4DK
WB 1     0.15000 0.05000

NH4 RATE   NH4T1   NH4T2   NH4K1   NH4K2
WB 1     5.00000 25.0000 0.10000 0.99000

NITRATE    NO3DK    NO3S
WB 1     0.05000 0.00000

NO3 RATE   NO3T1   NO3T2   NO3K1   NO3K2
WB 1     5.00000 25.0000 0.10000 0.99000

SILICA      DSIR    PSIS   PSIDK  PARTSI
WB 1     0.10000 0.10000 0.30000 0.20000

IRON         FER     FES
WB 1     0.50000 2.00000

SED CO2     CO2R
WB 1     0.10000

STOICH 1   O2NH4    O2OM
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WB 1     4.57000 1.40000

STOICH 2    O2AR    O2AG
ALG1     1.10000 1.40000

STOICH 3    O2ER    O2EG
EPI1     1.10000 1.40000

O2 LIMIT   O2LIM
         0.10000

SEDIMENT    SEDC  SEDPRC   SEDCI    SEDK    FSOD    FSED
WB 1          ON      ON 1.00000 0.08000 1.00000 1.00000

SOD RATE   SODT1   SODT2   SODK1   SODK2
WB 1     4.00000 30.0000 0.10000 0.99000

S DEMAND     SOD     SOD     SOD     SOD     SOD     SOD     SOD     SOD     SOD
         0.30000 0.30000 0.30000 0.30000 0.30000 0.40000 0.50000 0.50000 0.50000
         0.70000 0.90000 1.10000 1.30000 1.50000 1.70000 1.90000 1.90000 1.90000
         1.70000 1.50000 1.40000 1.30000 0.00000

REAERATION  TYPE    EQN#   COEF1   COEF2   COEF3   COEF4
WB 1        LAKE       2 0.00000 0.00000 0.00000 0.00000

RSI FILE..................................RSIFN.................................
        rsi.npt

QWD FILE..................................QWDFN.................................
        qwd.npt

QGT FILE..................................QGTFN.................................
        qgt.npt

WSC FILE..................................WSCFN.................................
        wsc.npt

SHD FILE..................................SHDFN.................................
        shd.npt

BTH FILE..................................BTHFN.................................
WB 1    bth.npt

MET FILE..................................METFN.................................
WB 1    met.npt

EXT FILE..................................EXTFN.................................
WB 1    ext.npt

VPR FILE..................................VPRFN.................................
WB 1    vpr.npt

LPR FILE..................................LPRFN.................................
WB 1    lpr.npt - not used

QIN FILE..................................QINFN.................................
BR1     qin_br1.npt
BR2     qin_br2.npt

TIN FILE..................................TINFN.................................
BR1     tin_br1.npt
BR2     tin_br2.npt

CIN FILE..................................CINFN.................................
BR1     cin_br1.npt
BR2     cin_br2.npt

QOT FILE..................................QOTFN.................................
BR1     qout.npt
BR2     qot_br2.npt

QTR FILE..................................QTRFN.................................
TR1     qwb.npt
```

```
TTR FILE..................................TTRFN.................................
TR1     tdt_br1.npt

CTR FILE..................................CTRFN.................................
TR1     ctr_tr1.npt - not used

QDT FILE..................................QDTFN.................................
BR1     qwb.npt
BR2     qdt_br2.npt - not used

TDT FILE..................................TDTFN.................................
BR1     tdt_br1.npt
BR2     tdt_br2.npt - not used

CDT FILE..................................CDTFN.................................
BR1     cdt_br1.npt - not used
BR2     cdt_br2.npt - not used

PRE FILE..................................PREFN.................................
BR1     pre_br1.npt - not used
BR2     pre_br2.npt

TPR FILE..................................TPRFN.................................
BR1     tpr_br1.npt - not used
BR2     tpr_br2.npt

CPR FILE..................................CPRFN.................................
BR1     cpr_br1.npt - not used
BR2     cpr_br2.npt

EUH FILE..................................EUHFN.................................
BR1     euh_br1.npt - not used
BR2     euh_br2.npt

TUH FILE..................................TUHFN.................................
BR1     tuh_br1.npt - not used
BR2     tuh_br2.npt

CUH FILE..................................CUHFN.................................
BR1     cuh_br1.npt - not used
BR2     cuh_br2.npt

EDH FILE..................................EDHFN.................................
BR1     edh_br1.npt - not used
BR2     edh_br2.npt

TDH FILE..................................TDHFN.................................
BR1     tdh_br1.npt - not used
BR2     tdh_br2.npt

CDH FILE..................................CDHFN.................................
BR1     cdh_br1.npt - not used
BR2     cdh_br2.npt

SNP FILE..................................SNPFN.................................
WB 1    snp_wb1.opt

PRF FILE..................................PRFFN.................................
WB 1    prf_wb1.opt - not used

VPL FILE..................................VPLFN.................................
WB 1    vpl_wb1.opt - not used

CPL FILE..................................CPLFN.................................
WB 1    cpl_wb1.opt

SPR FILE..................................SPRFN.................................
WB 1    spr_wb1.opt - not used

FLX FILE..................................FLXFN.................................
WB 1    flx_wb1.opt - not used

TSR FILE..................................TSRFN.................................
        tsr_wb1.opt
```

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WDO FILE..................................WDOFN.................................
        wdo_wb1.opt
```