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Pend Oreille River, Box Canyon Model: Model Scenario Simulations

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Technical Report EWR-03-07, July 2007

Portland State UNIVERSITY

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Introduction

The Washington Department of Ecology is interested in developing a temperature Total Maximum Daily Load (TMDL) allocation for the Pend Oreille River between the Albeni Falls Dam (U.S. Army Corps of Engineer's reservoir) and Box Canyon Dam as shown in Figure 1. The Pend Oreille drainage basin is shown in Figure 2. An existing model of the Box Canyon reach was updated from CE-QUAL-W2 Version 3.0 to Version 3.5. This current research involves improving the calibration of the original model (1997 and 1998) and expanding the model using 2004 as an additional data set for calibration.

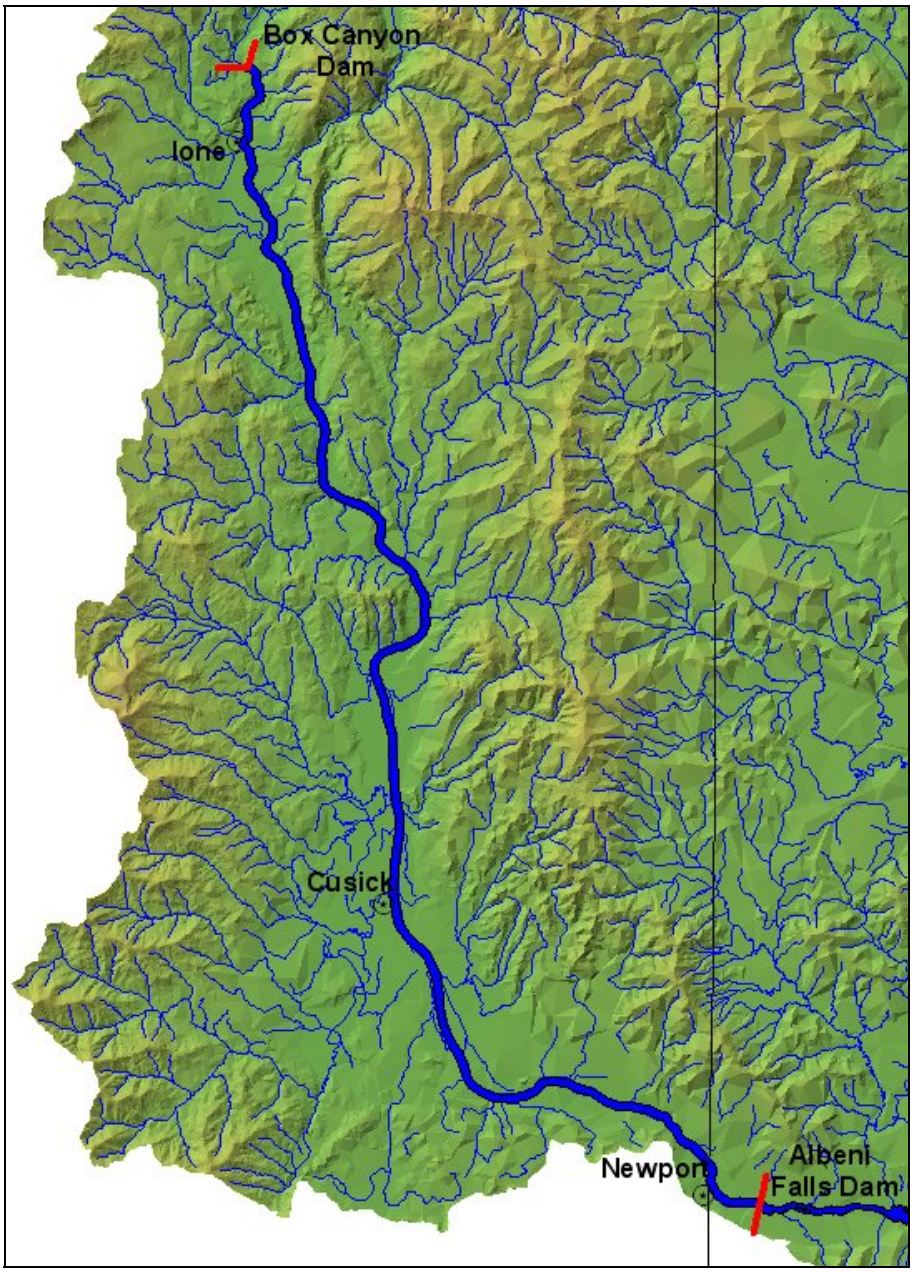

Figure 1: Pend Oreille River downstream of Albeni Falls Dam.

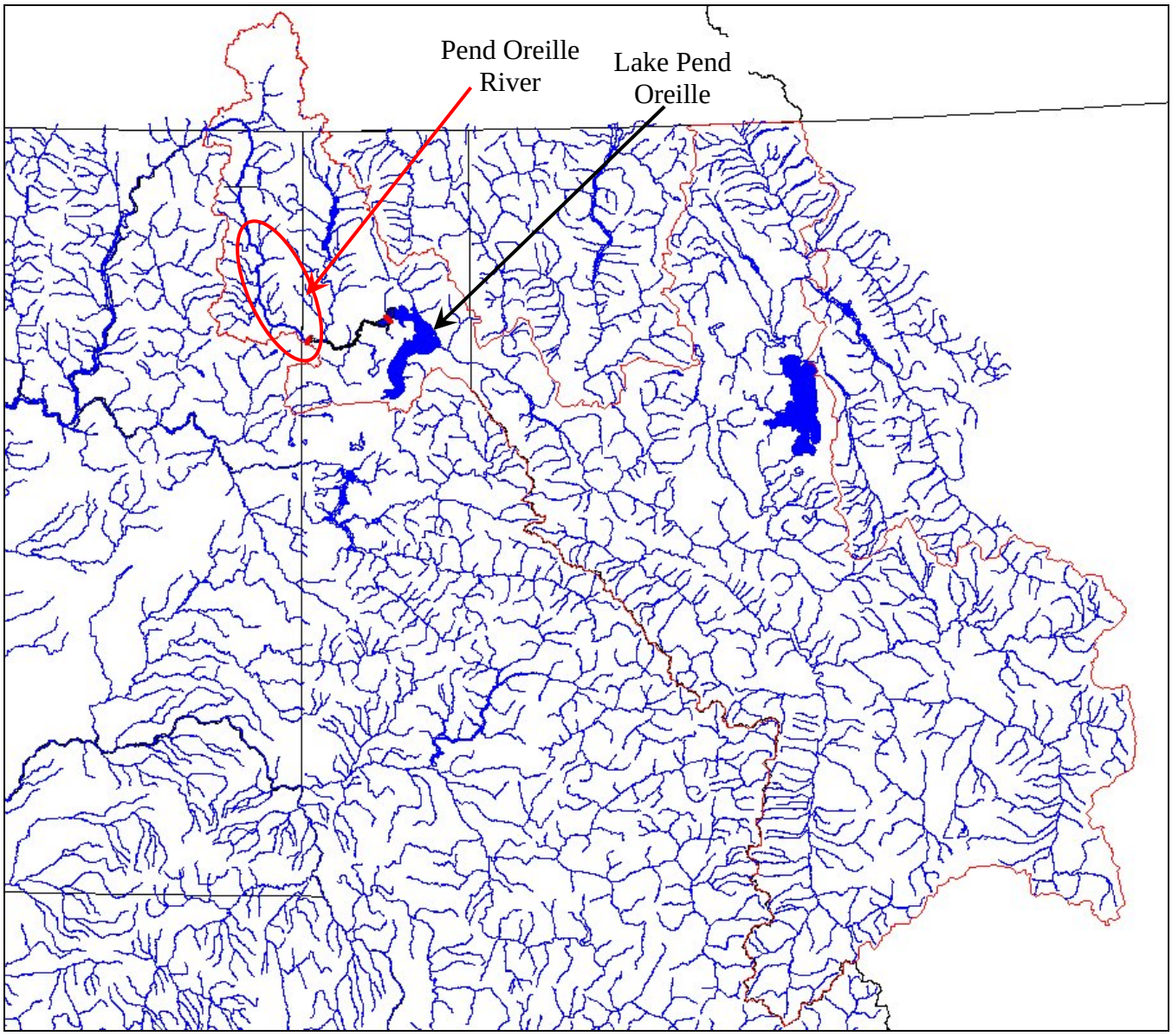

Figure 2: Pend Oreille River Basin.

The use of field data from 2004 as an additional calibration year was chosen to improve the confidence in the model's predictive ability for temperature. Hence, the model simulations were run from January 1st to December 31st in each of the 3 years of model simulation: 1997, 1998 and 2004.

The model chosen for development is CE-QUAL-W2 Version 3.5 (Cole and Wells, 2006). This is a two-dimensional unsteady hydrodynamic and water quality model that includes typical eutrophication parameters (algae, nutrients, temperature, organic matter, dissolved oxygen, pH). The PSU-WQRG (Water Quality Research Group) is a center for development of this modeling tool (see http://www.cee.pdx.edu/w2).

The model simulation for scenarios was run from January 1st, 2004 to September 25th, 2005. The model development and calibration is well documented in the companion report:

Annear, R. L.; Berger, C. J.; and Wells, S. A. (2006) "Pend Oreille River, Box Canyon Model: Model Development and Calibration," Technical Report EWR-04-06, Department of Civil and Environmental Engineering, Portland State University, Portland, OR.

Table 1 lists the model scenarios considered for the Pend Oreille River in Washington.

Table 1: Pend Oreille River, Box Canyon Model Scenarios.

Number	Name	Upstream	Downstream Dam	NPDES	Tributaries	Mainstem shade
1	Existing	Current	Impounded	present	current	Current
2	Existing-NPDES	Current	Impounded	removed	current	Current
2.5	Existing - Tribs PNV	Current	Impounded	present	PNV temps	Current
3	Natural - Impounded	Natural	Impounded	removed	PNV temps	PNV shade
4	Existing - Unimpounded	Current	Unimpounded	present	current	Current
7	Existing - mainstem PNV	Current	Impounded	present	current	PNV shade
7.5	Existing - Upstream Natural	Natural	Impounded	present	current	Current
8	Natural	Natural	Unimpounded	removed	PNV temps	PNV shade

The model scenarios completed from Table 1 resulted in the following model comparisons:

1. Existing Conditions to Natural Conditions (Scenarios 1 and 8)
2. Point Source Contributions (Scenarios 1 and 2)
3. Non-point Source Contributions (Scenarios 1 and 2.5)
4. Box Canyon Dam contribution to Natural Condition (Scenarios 3 and 8)
5. Box Canyon Dam contribution compared to existing Conditions (Scenario 1 and 4)
6. Vegetation Bank Shading Contribution (Scenarios 1 and 7)
7. Albeni Falls Dam contribution (Scenarios 1 and 7.5)

Comparisons were made between model scenarios using the following model outputs:

1. Time Series Comparisons
    a. Locations
        - River Mile 87.7 (Model Segment 17)
        - River Mile 72.4 (Model Segment 115)
        - River Mile 69.8 (Model Segment 132)
        - River Mile 63.7 (Model Segment 171)
        - River Mile 61.2 (Model Segment 187)
        - River Mile 43.7 (Model Segment 300)
        - River Mile 34.6 (Model Segment next to dam)
        - River Mile 34.5 (Box Canyon Dam Outlet)
    b. Statistics
        - Daily average: volume weighted (over the full vertical column)
        - Daily maximum: highest value in water column
2. Longitudinal Profile Comparisons
    a. Dates
        - May 7th, 2004
        - August 24th, 2004
    b. Statistics
        - Daily average: volume weighted

- Daily maximum: highest value in water column

In addition to the time series and longitudinal profile comparisons between model scenarios, statistics were developed to evaluate how statistically significant the similarities between the model scenario outputs were. Table 2 lists the P-value statistics used when comparing the model output between scenarios.

Table 2: P-value statistics used for comparing model results between scenarios.

P-value	Description	Interpretation
$P < 0.1$	statistically significant	Model results between scenarios are the same, i.e. no difference
$0.1 < P < 0.2$	probably statistically significant	Model results between scenarios are similar
$0.2 < P < 0.3$	possibly statistically significant	Model results between scenarios have some similarities
$0.3 < P$	not statistically significant	Model results between scenarios are not the same.

Evaluation of Natural Conditions to Existing Conditions

The cumulative thermal loading contributions to the Pend Oreille River from existing conditions were evaluated by comparing results from model scenario 8 (natural conditions) and scenario 1 (existing conditions). Flow rate and depth for the simulations were compared adjacent to the dam location (RM 34.6) and at RM 63.7. Predicted depths were shown in Figure 3 and Figure 4. The depths of the un-impounded scenario 8 are clearly shallower. Flows were plotted in Figure 5 and Figure 6.

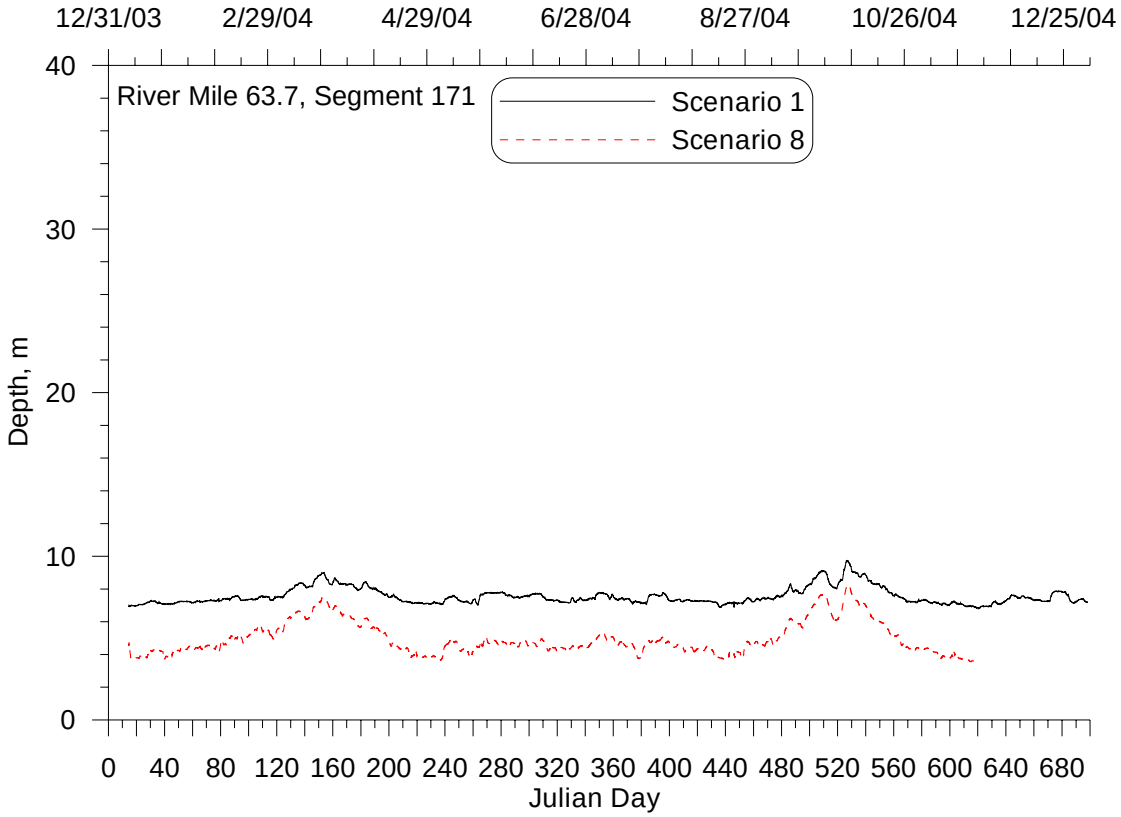

Figure 3. Comparison of model predicted depths for scenario 1 and scenario 8 at RM 63.7.

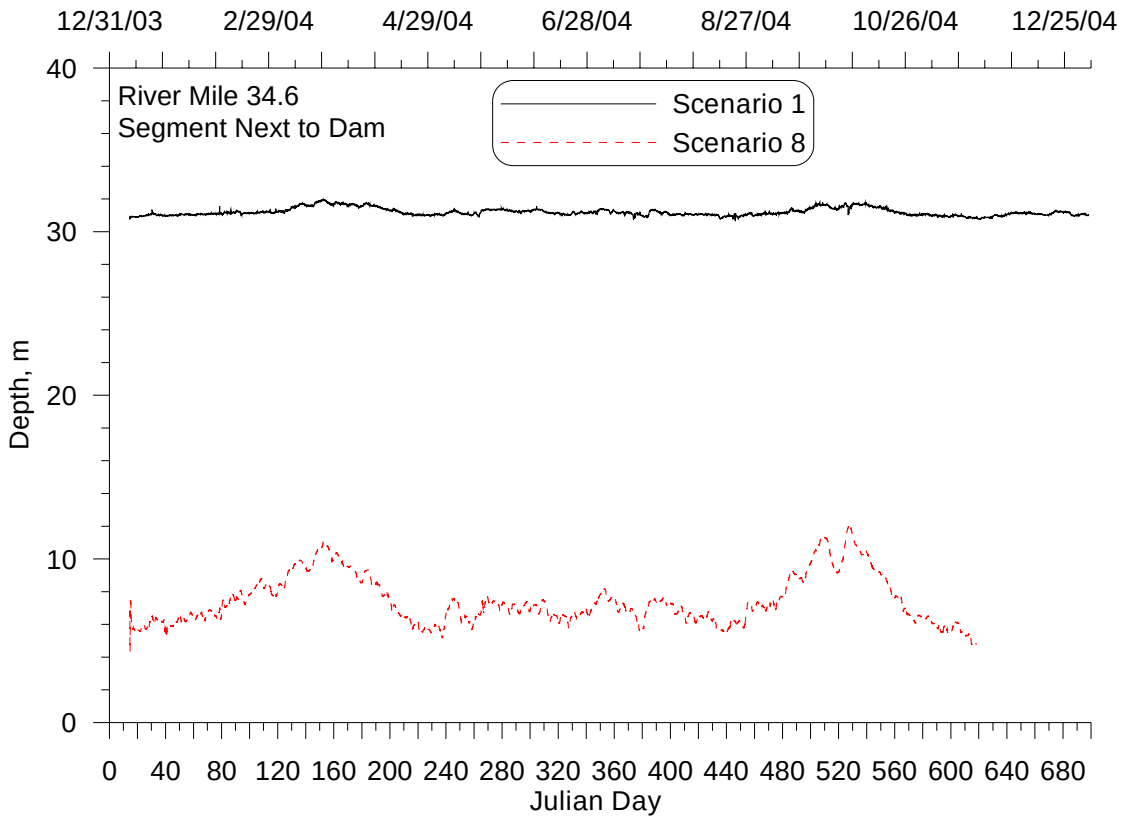

Figure 4. Comparison of model predicted depths for scenario 1 and scenario 8 at RM 34.6.

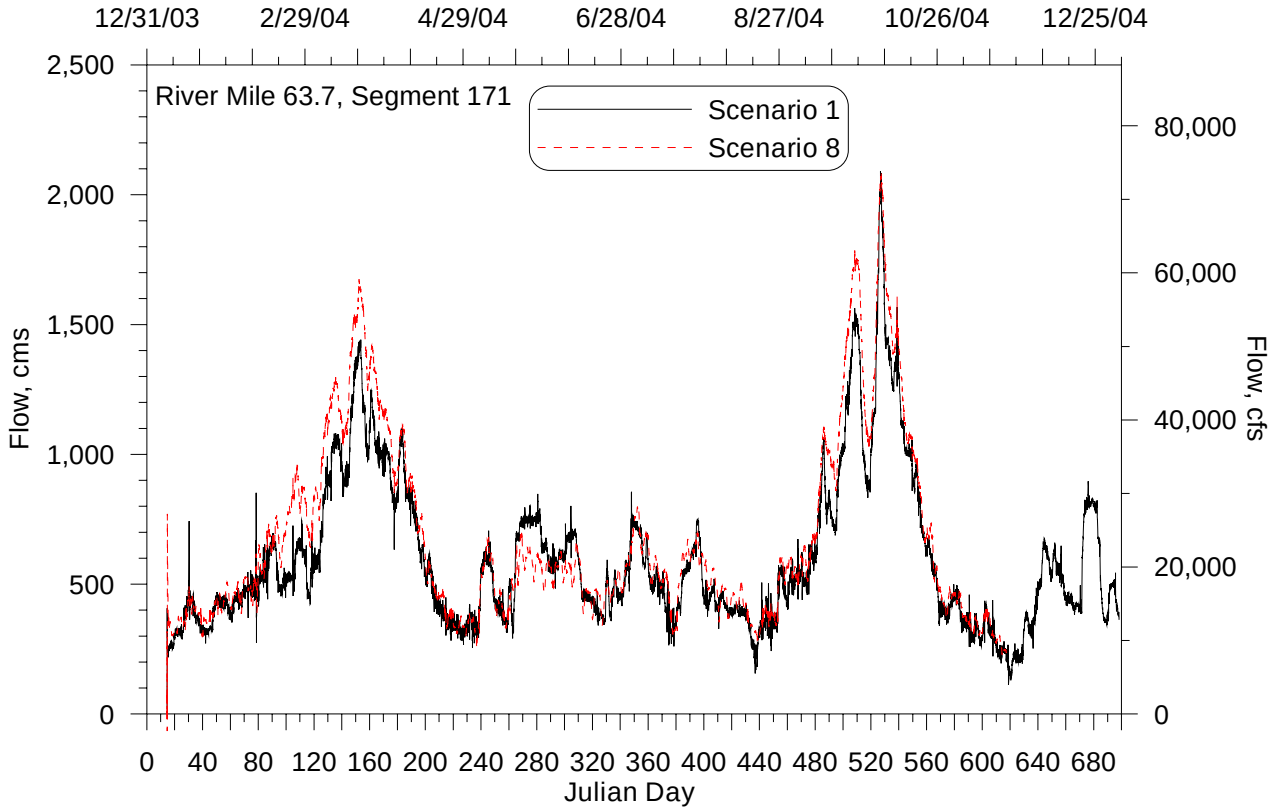

Figure 5. Comparison of model predicted flows for scenario 1 and scenario 8 at RM 63.7.

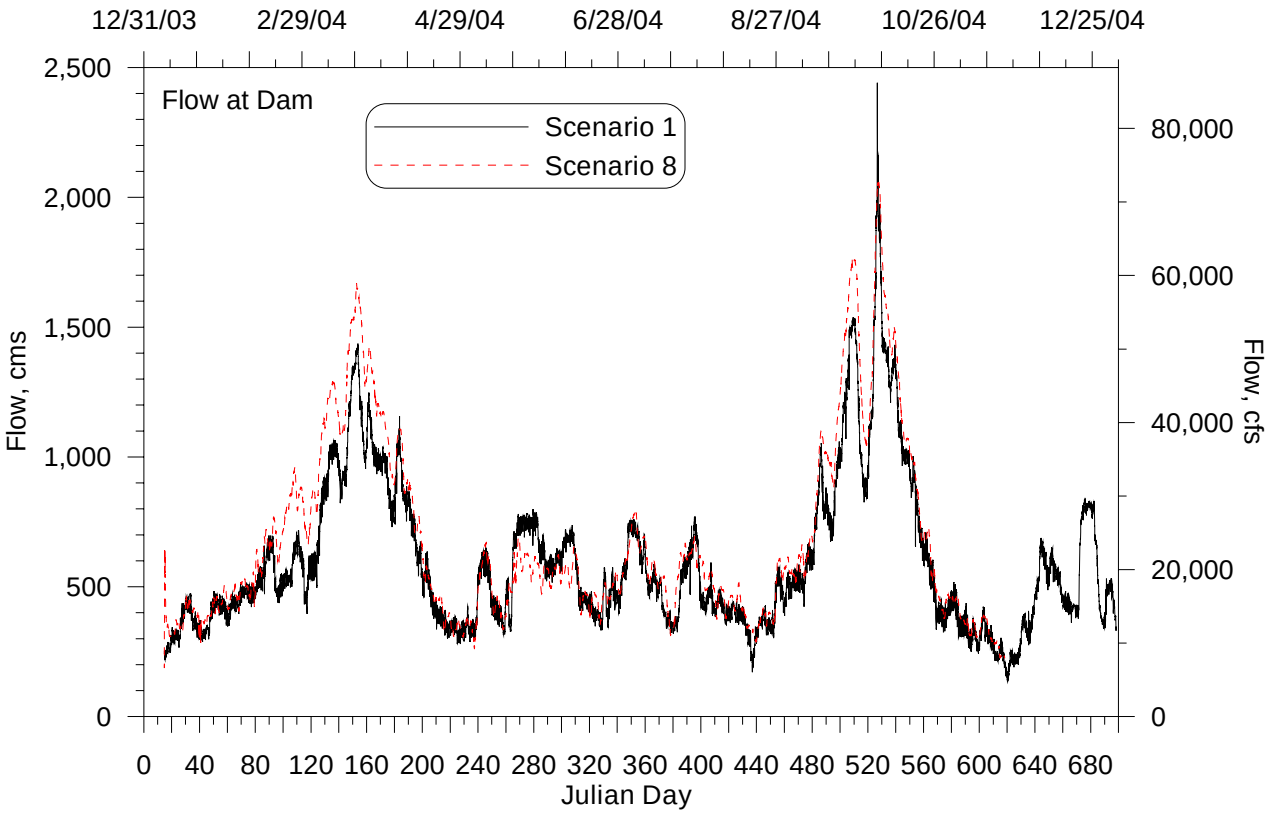

Figure 6. Comparison of model predicted flows for scenario 1 and scenario 8 at RM 34.6.

Time Series Plots

Daily Average Temperatures

The volume weighted daily average temperatures for the natural conditions scenario 8 are compared with the existing conditions scenario 1 in Figure 7 through Figure 14. Daily average temperatures of the natural condition scenario 8 are generally warmer in the summer and cooler in the fall. The P value statistics are shown in Table 3. The P value statistics for the daily average temperature suggest the two scenarios are the same. This shows the limitation of strictly using P values to identify differences between scenarios. The scenarios tested equivalent because the average over the whole simulation of the daily average values of the two scenarios are not that different. Although one scenario may be warmer or cooler during part of the year, the differences over the whole simulation period even out. The P-value statistic can identify an average bias over the whole simulation, but not during specific time periods (or seasons).

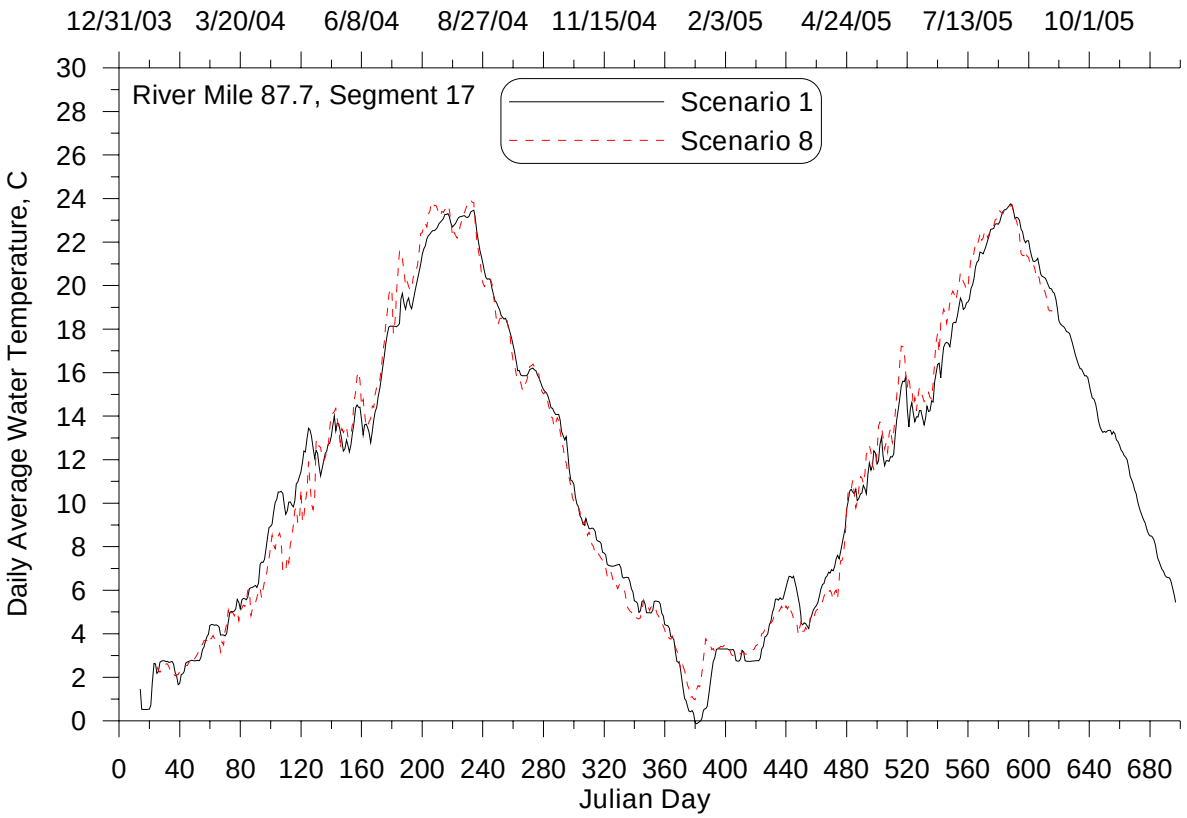

Figure 7. Comparison of segment 17 (RM 87.7) daily average water temperatures of the existing conditions scenario 1 and the natural conditions scenario 8.

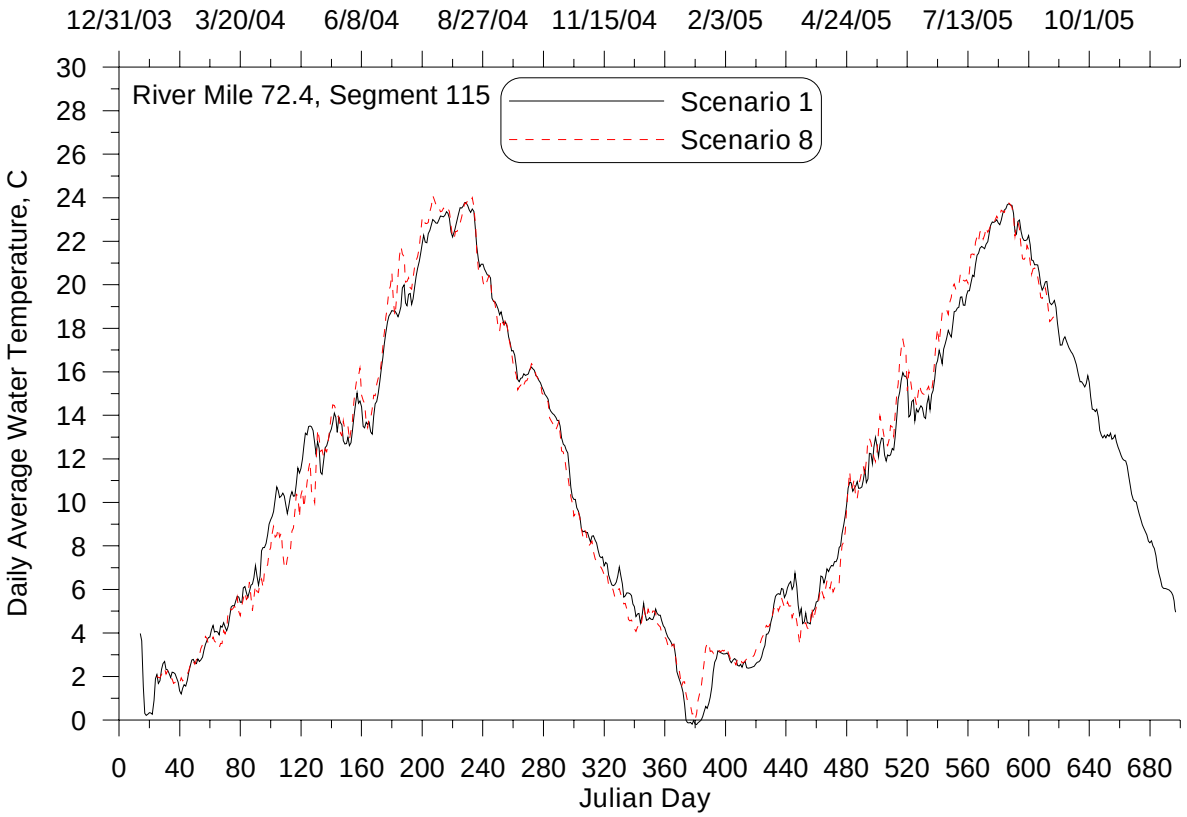

Figure 8. Comparison of segment 115 (RM 72.4) daily average water temperatures of the existing conditions scenario 1 and the natural conditions scenario 8.

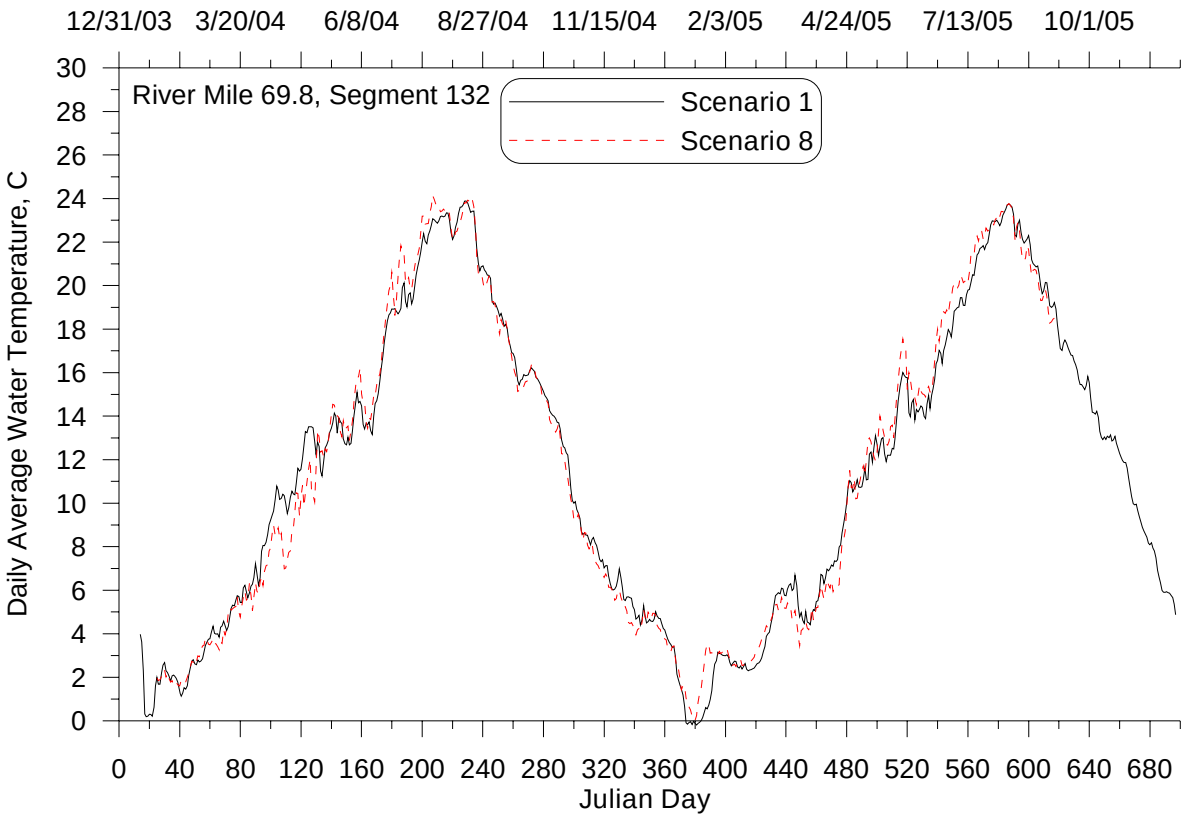

Figure 9. Comparison of segment 132 (RM 69.8) daily average water temperatures of the existing conditions scenario 1 and the natural conditions scenario 8.

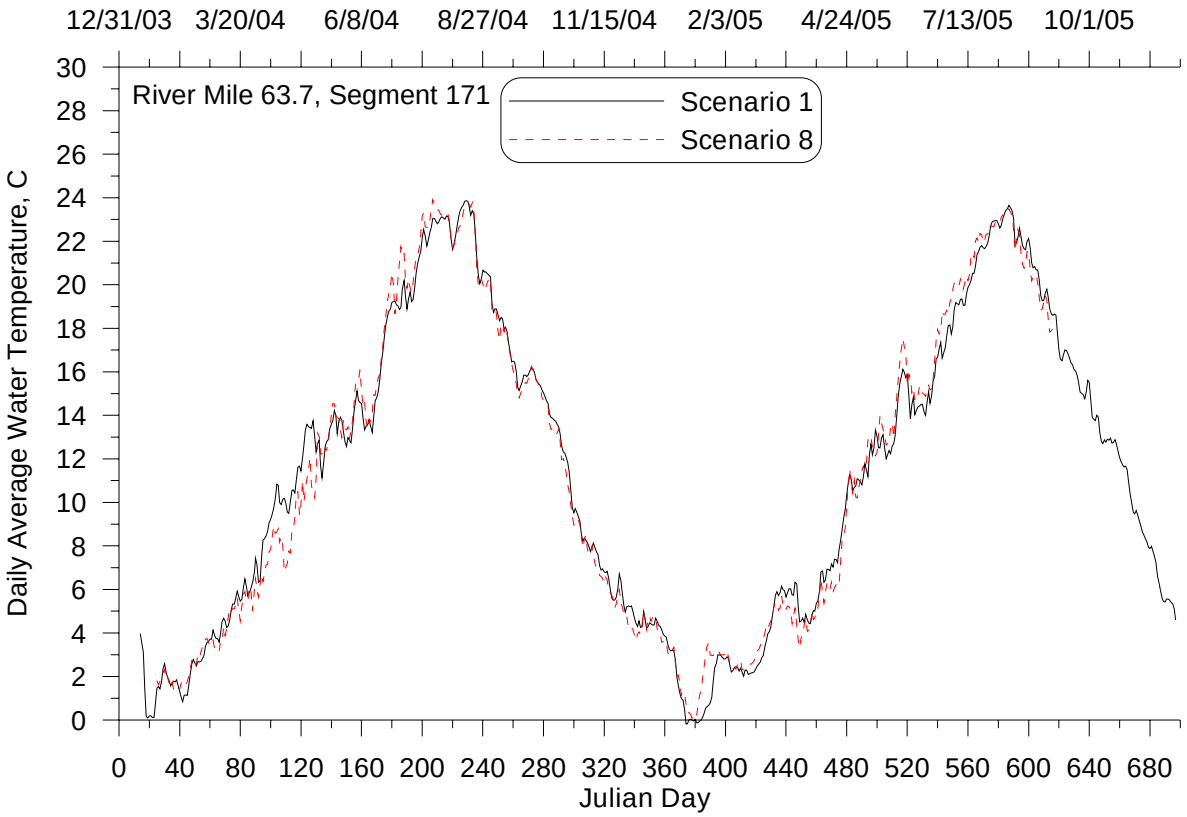

Figure 10. Comparison of segment 171 (RM 63.7) daily average water temperatures of the existing conditions scenario 1 and the natural conditions scenario 8.

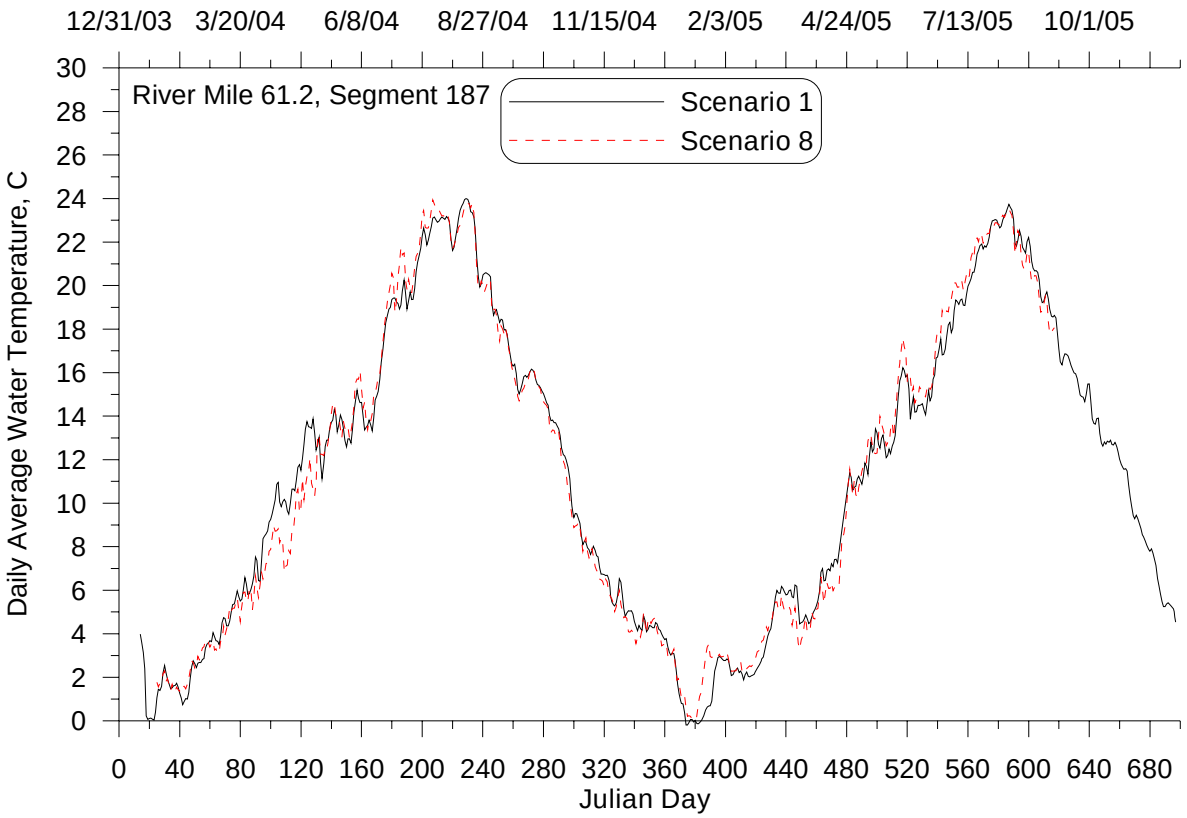

Figure 11. Comparison of segment 187 (RM 61.2) daily average water temperatures of the existing conditions scenario 1 and the natural conditions scenario 8.

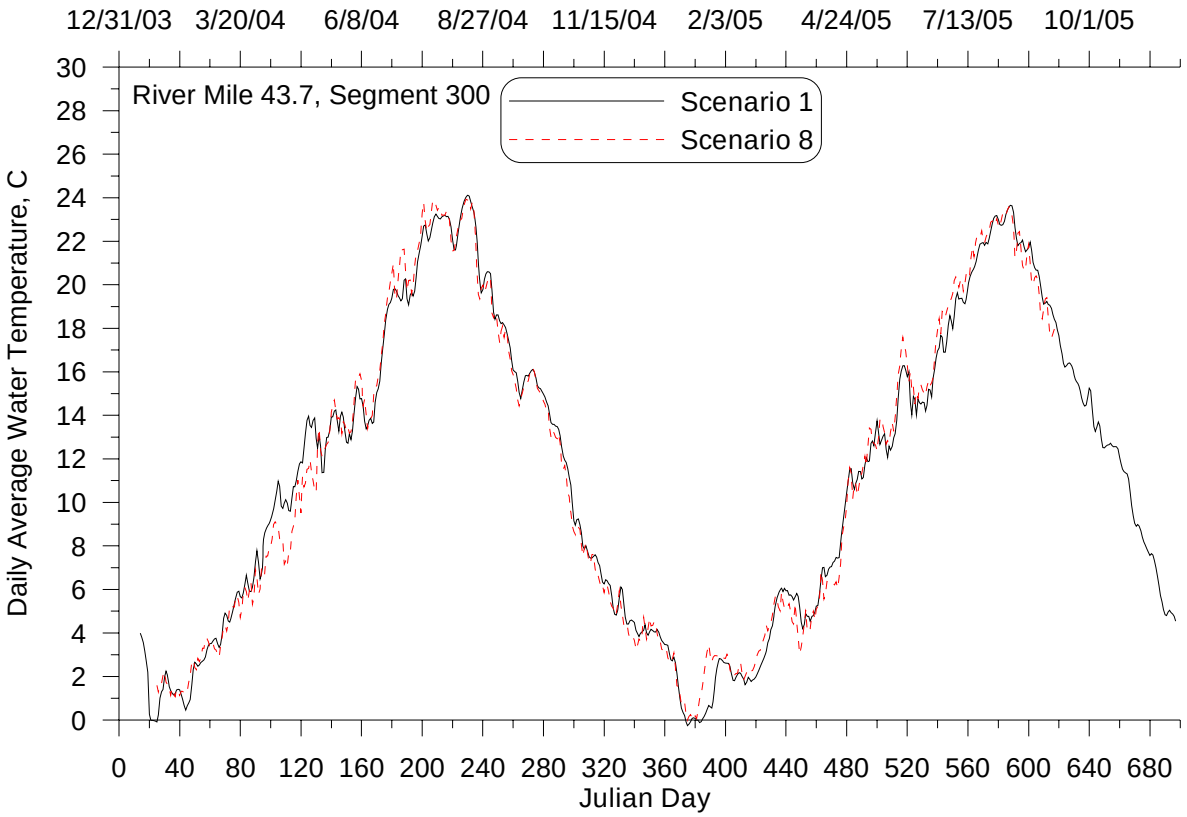

Figure 12. Comparison of segment 300 (RM 43.7) daily average water temperatures of the existing conditions scenario 1 and the natural conditions scenario 8.

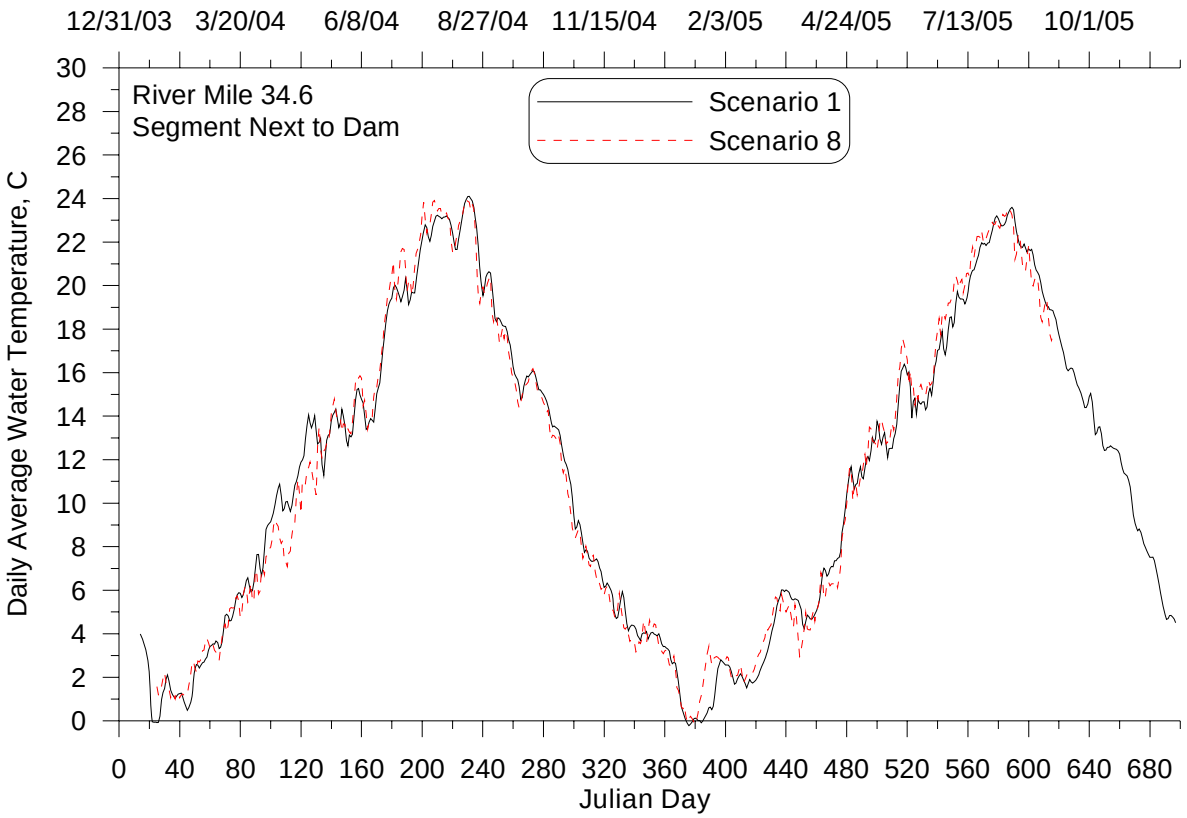

Figure 13. Comparison of model segment adjacent to Box Canyon Dam (segment 358 for impounded, segment 360 for unimpounded) daily average water temperatures of the existing conditions scenario 1 and the natural conditions scenario 8 at RM 34.6.

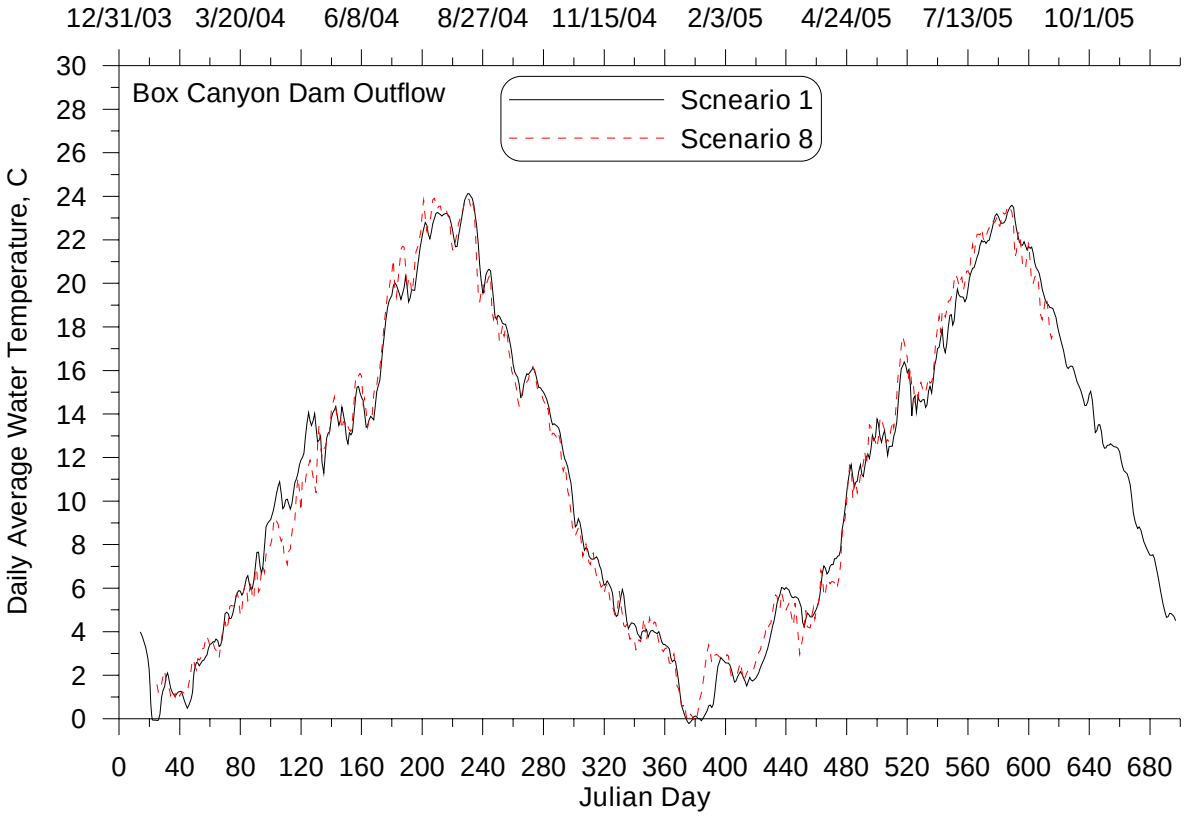

Figure 14. Comparison of Box Canyon Dam daily average outflow temperatures of the existing conditions scenario 1 and the natural conditions scenario 8.

Table 3: Statistical significance in the daily average time series results between the natural (8) and existing condition (1) scenarios.

River Mile, Model Location	P-value	Result
River Mile 87.7 (Model Segment 17)	0.082	Model results between scenarios are the same, i.e. no difference
River Mile 72.4 (Model Segment 115)	0.062	Model results between scenarios are the same, i.e. no difference
River Mile 69.8 (Model Segment 132)	0.047	Model results between scenarios are the same, i.e. no difference
River Mile 63.7 (Model Segment 171)	0.043	Model results between scenarios are the same, i.e. no difference
River Mile 61.2 (Model Segment 187	0.048	Model results between scenarios are the same, i.e. no difference
River Mile 43.7 (Model Segment 300)	0.052	Model results between scenarios are the same, i.e. no difference
River Mile 34.6 (Model Segment next to dam site)	0.059	Model results between scenarios are the same, i.e. no difference
River Mile 34.5 (Box Canyon Dam Outlet)	0.064	Model results between scenarios are the same, i.e. no difference

Daily Maximum Temperatures

Daily maximum temperatures comparing the existing conditions scenario 1 and natural conditions scenario 8 are shown in Figure 15 through Figure 22. The daily maximum temperatures of the natural conditions scenario 8 were generally warmer in the summer, but temperatures cooler than the existing conditions scenario were occasionally predicted in the spring, fall and winter. Scenario 8 is unimpounded and shallower, thus making the river more susceptible to diurnal heating and cooling. P value statistics comparing the daily maximum temperatures of the scenarios are listed in Table 4. The P values suggested definite differences between the scenarios at multiple locations.

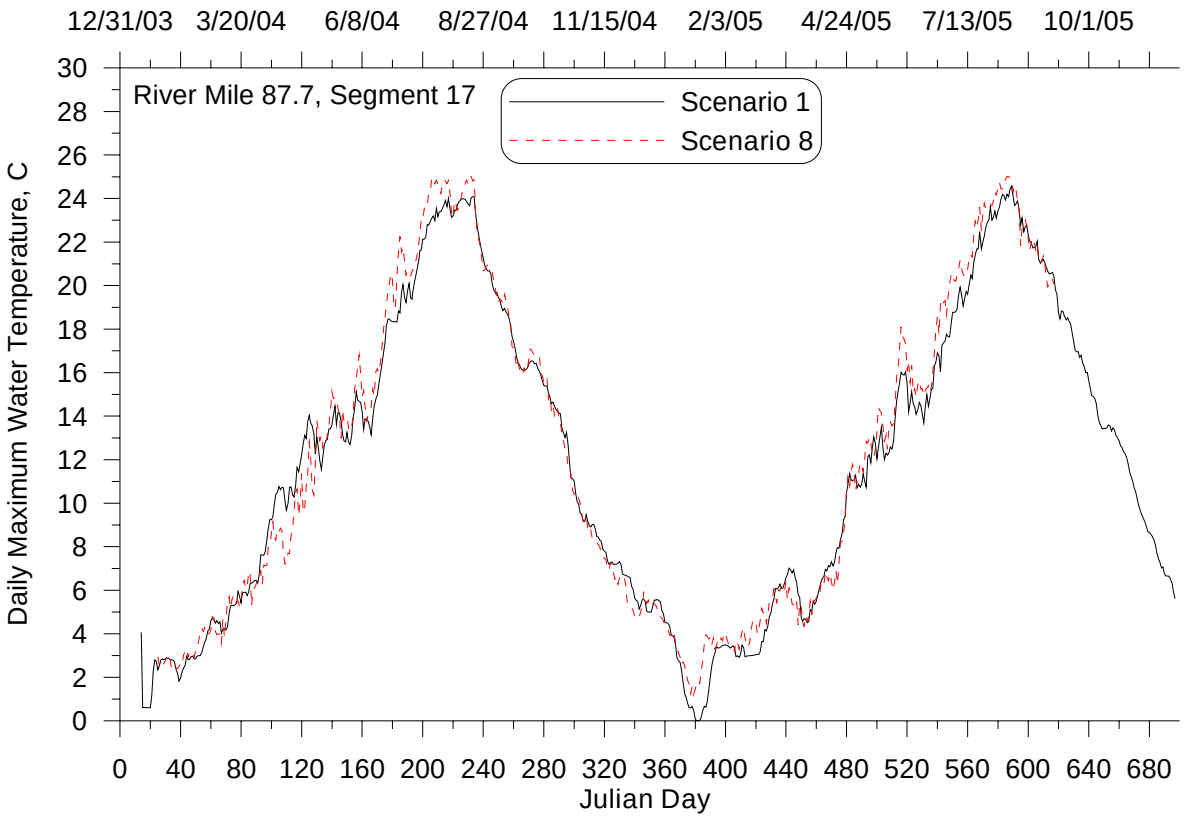

Figure 15. Comparison of segment 17 (RM 87.7) daily maximum water temperatures of the existing conditions scenario 1 and the natural conditions scenario 8.

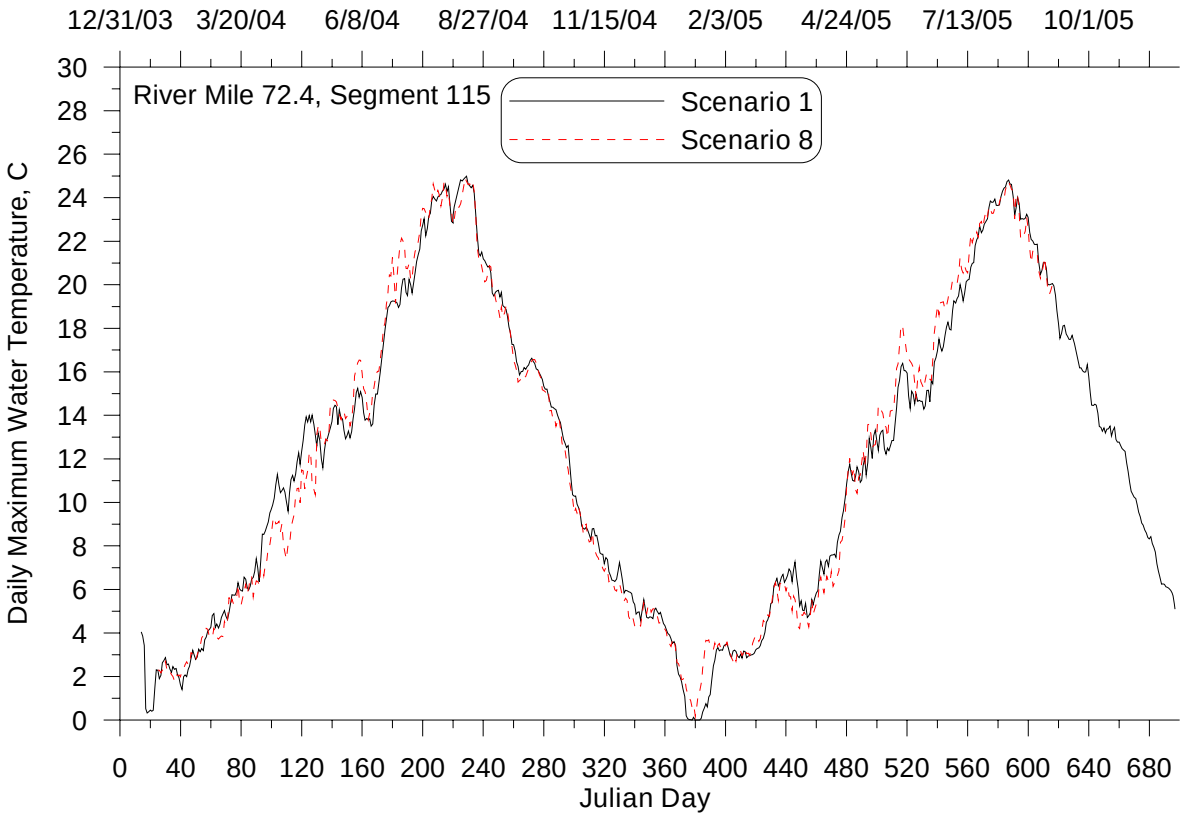

Figure 16. Comparison of segment 115 (RM 72.4) daily maximum water temperatures of the existing conditions scenario 1 and the natural conditions scenario 8.

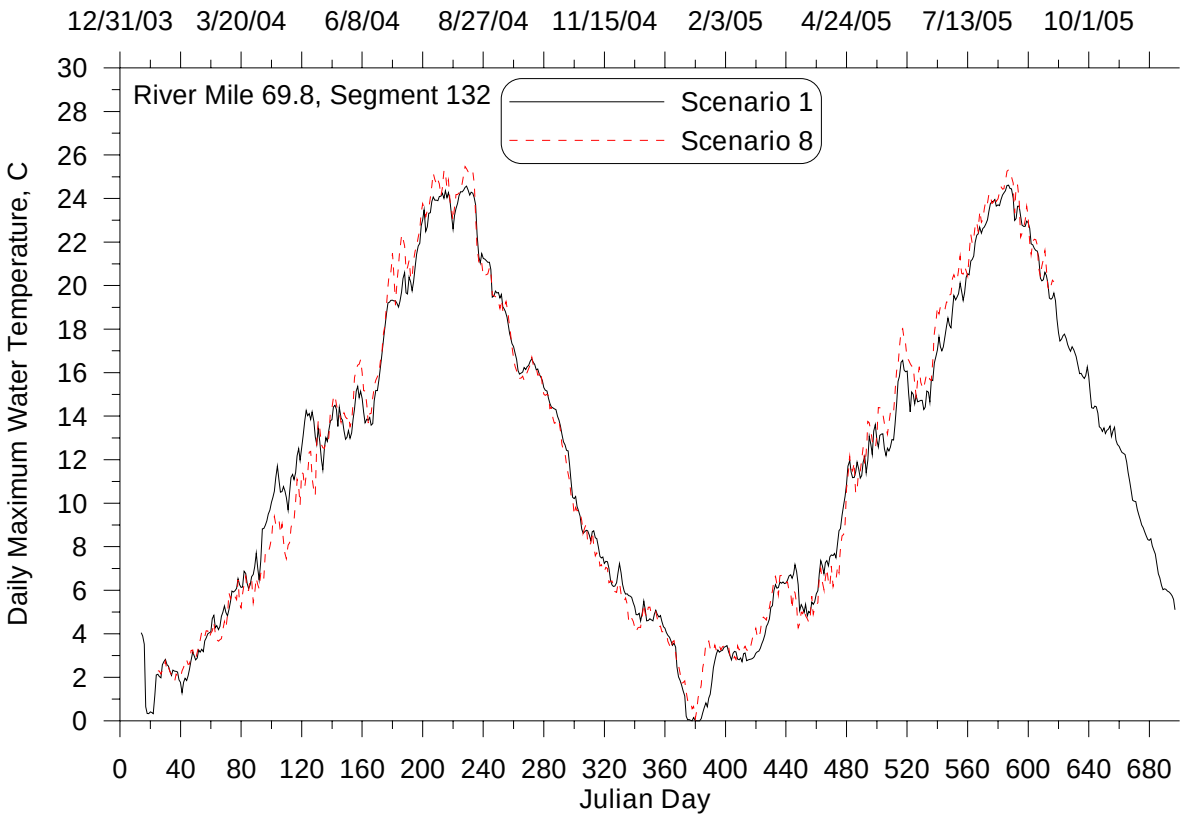

Figure 17. Comparison of segment 132 (RM 69.8) daily maximum water temperatures of the existing conditions scenario 1 and the natural conditions scenario 8.

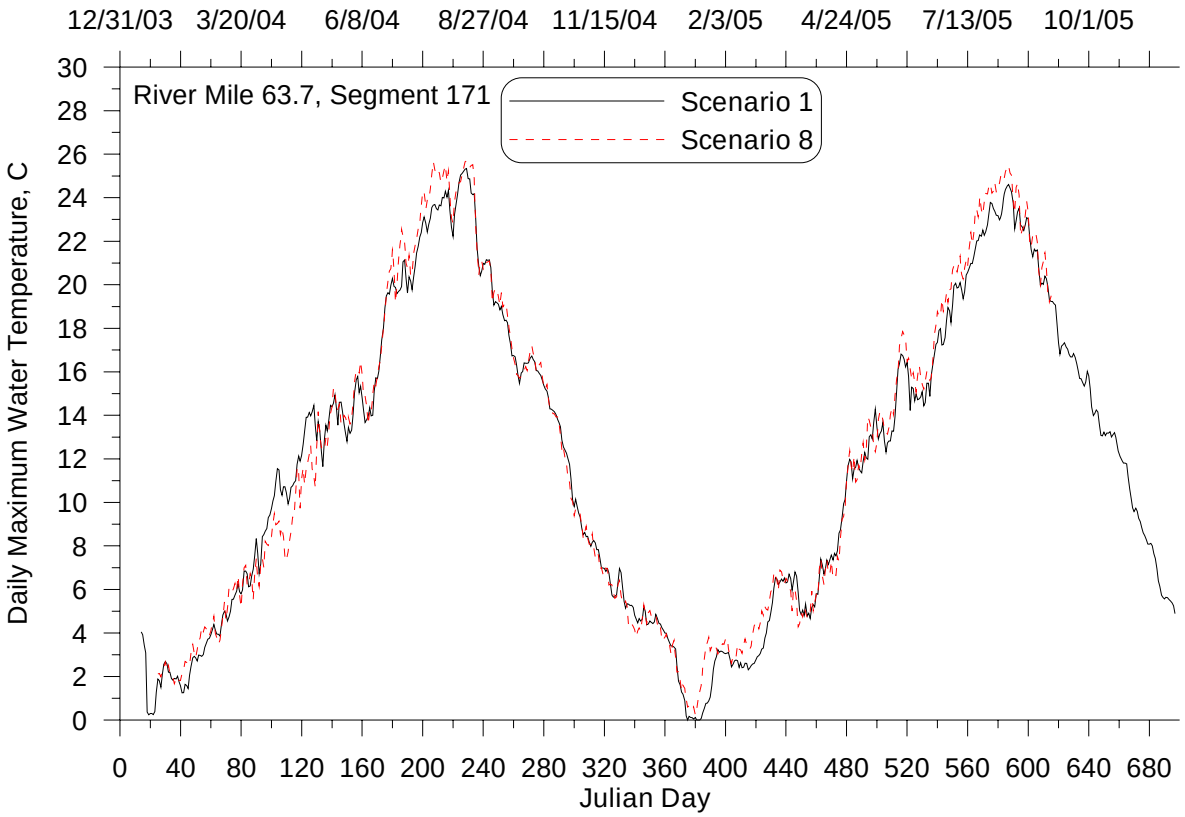

Figure 18. Comparison of segment 171 (RM 63.7) daily maximum water temperatures of the existing conditions scenario 1 and the natural conditions scenario 8.

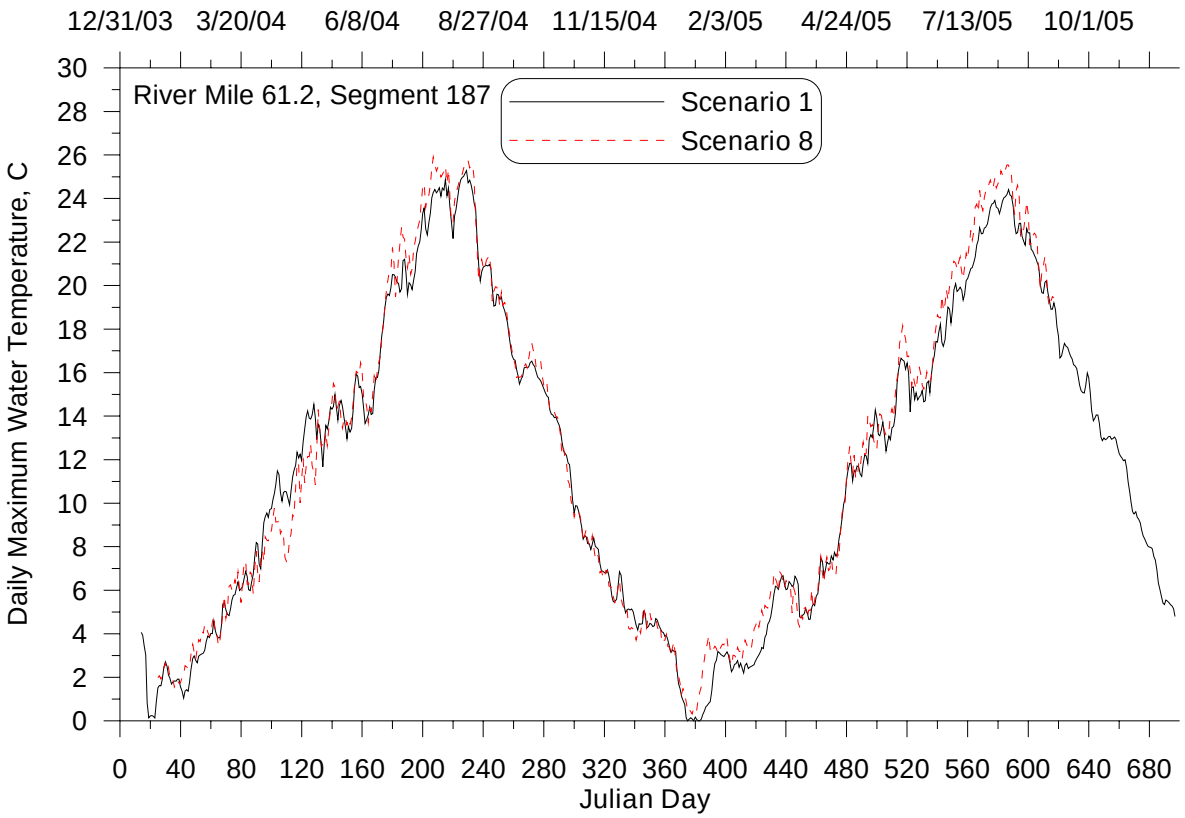

Figure 19. Comparison of segment 187 (RM 61.2) daily maximum water temperatures of the existing conditions scenario 1 and the natural conditions scenario 8.

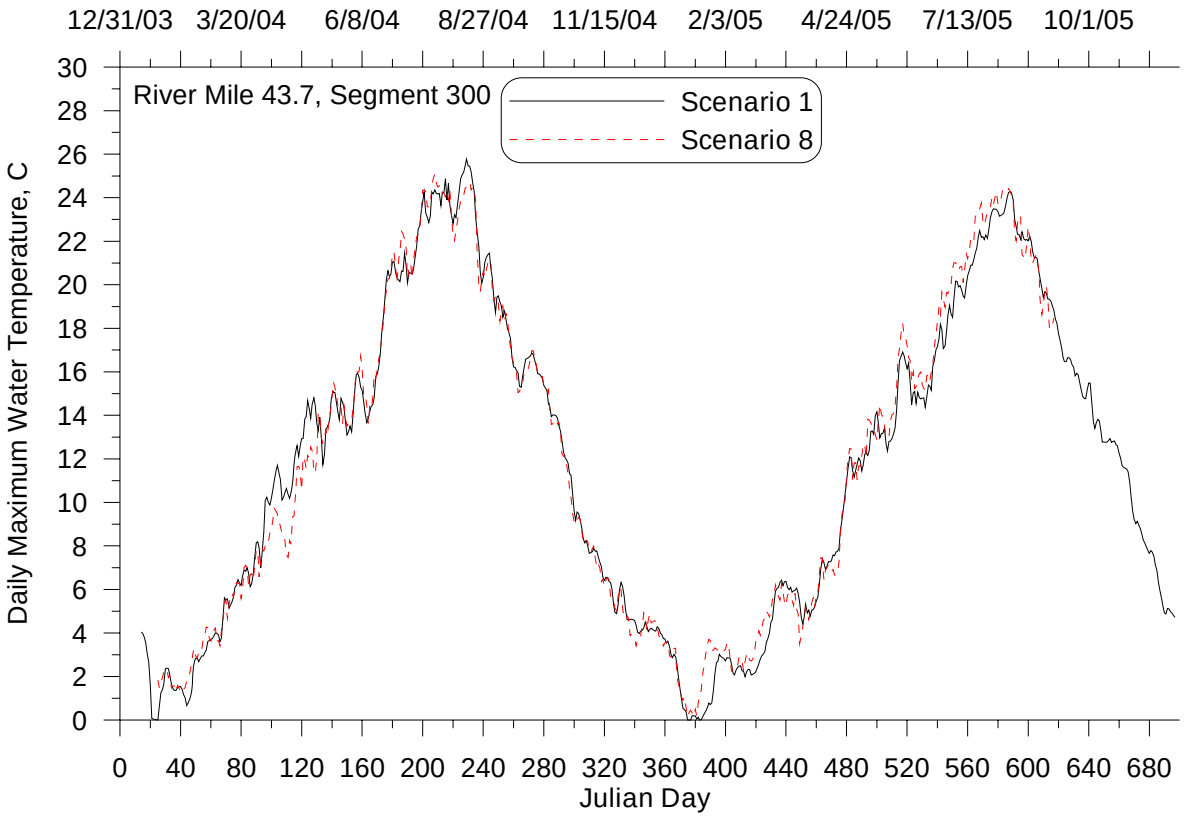

Figure 20. Comparison of segment 300 (RM 43.7) daily maximum water temperatures of the existing conditions scenario 1 and the natural conditions scenario 8.

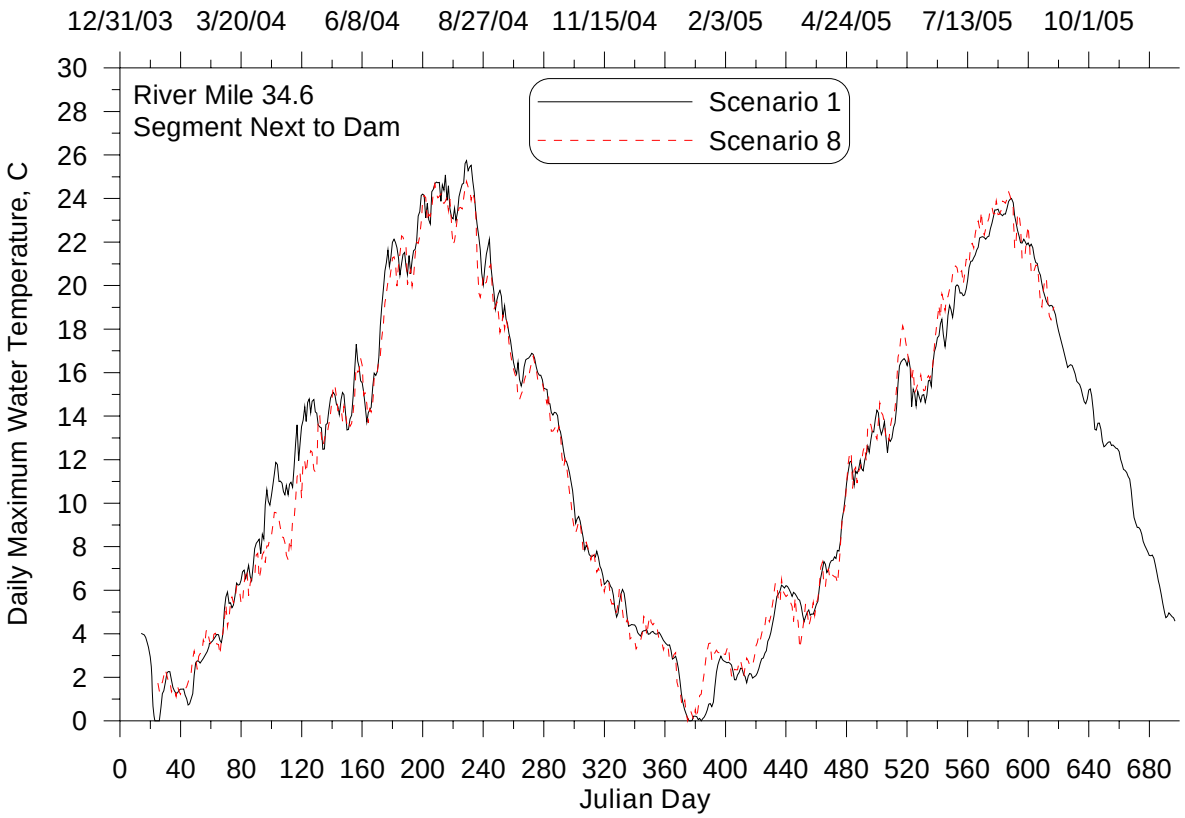

Figure 21. Comparison of model segment adjacent to Box Canyon Dam daily maximum water temperatures for the existing conditions scenario 1 and the natural conditions scenario 8 at RM 34.6.

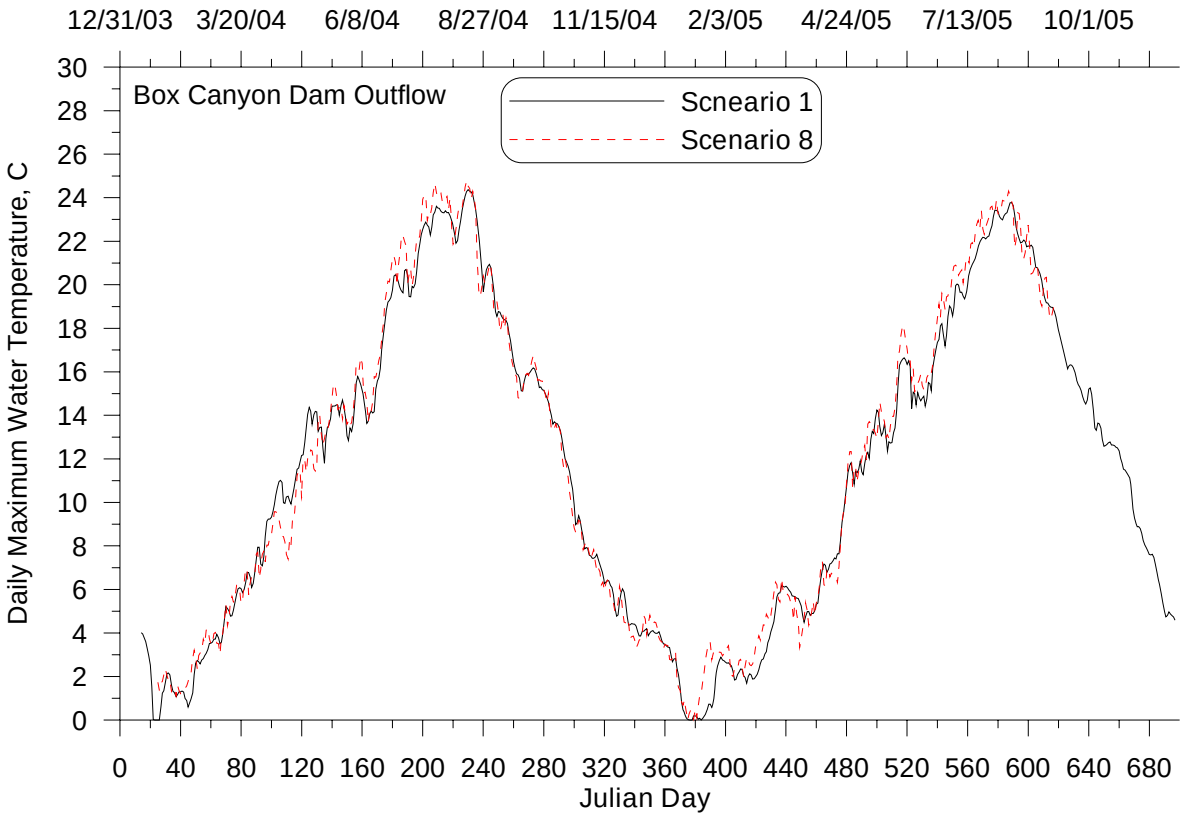

Figure 22. Comparison of Box Canyon Dam daily maximum outflow temperatures of the existing conditions scenario 1 and the natural conditions scenario 8.

Table 4: Statistical significance in daily maximum time series results between the natural (8) and existing (1) scenarios.

River Mile, Model Location	P-value	Result
River Mile 87.7 (Model Segment 17)	0.341	Model results between scenarios are not the same
River Mile 72.4 (Model Segment 115)	0.075	Model results between scenarios are the same, i.e. no difference
River Mile 69.8 (Model Segment 132)	0.245	Model results between scenarios have some similarities
River Mile 63.7 (Model Segment 171)	0.459	Model results between scenarios are not the same
River Mile 61.2 (Model Segment 187	0.542	Model results between scenarios are not the same
River Mile 43.7 (Model Segment 300)	0.162	Model results between scenarios are similar
River Mile 34.6 (Model Segment next to dam)	0.256	Model results between scenarios have some similarities
River Mile 34.5 (Box Canyon Dam Outlet)	0.341	Model results between scenarios are not the same

Longitudinal Profiles

The May 7 and the August 24, 2004 longitudinal profiles of daily average temperature are shown in Figure 23 and Figure 24, respectively. Longitudinal profiles of daily maximum temperature for these dates are plotted in Figure 25 and Figure 26. Table 5 and Table 6 show the P value statistics of the longitudinal profiles. The plots and P values show differences between the scenarios for daily average and daily maximum temperatures.

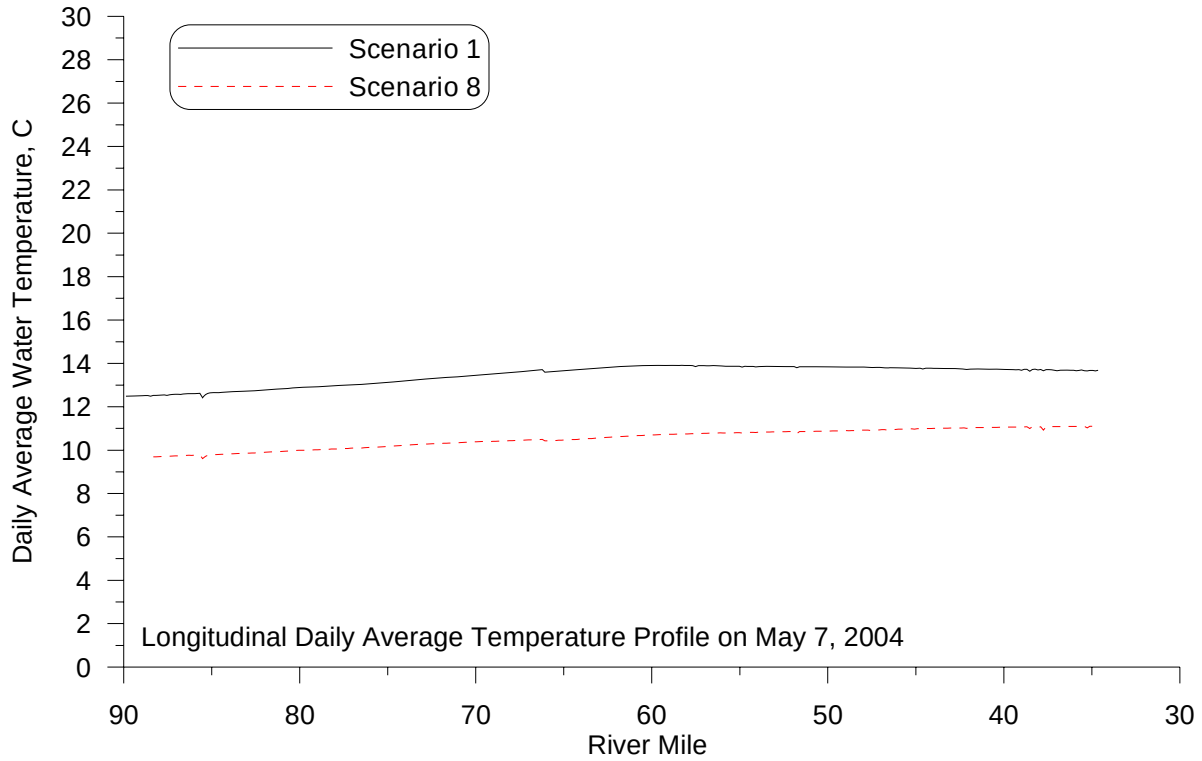

Figure 23. Comparison of longitudinal daily average temperature profile on May 7, 2004 between the natural conditions scenario 8 and the existing conditions scenario 1.

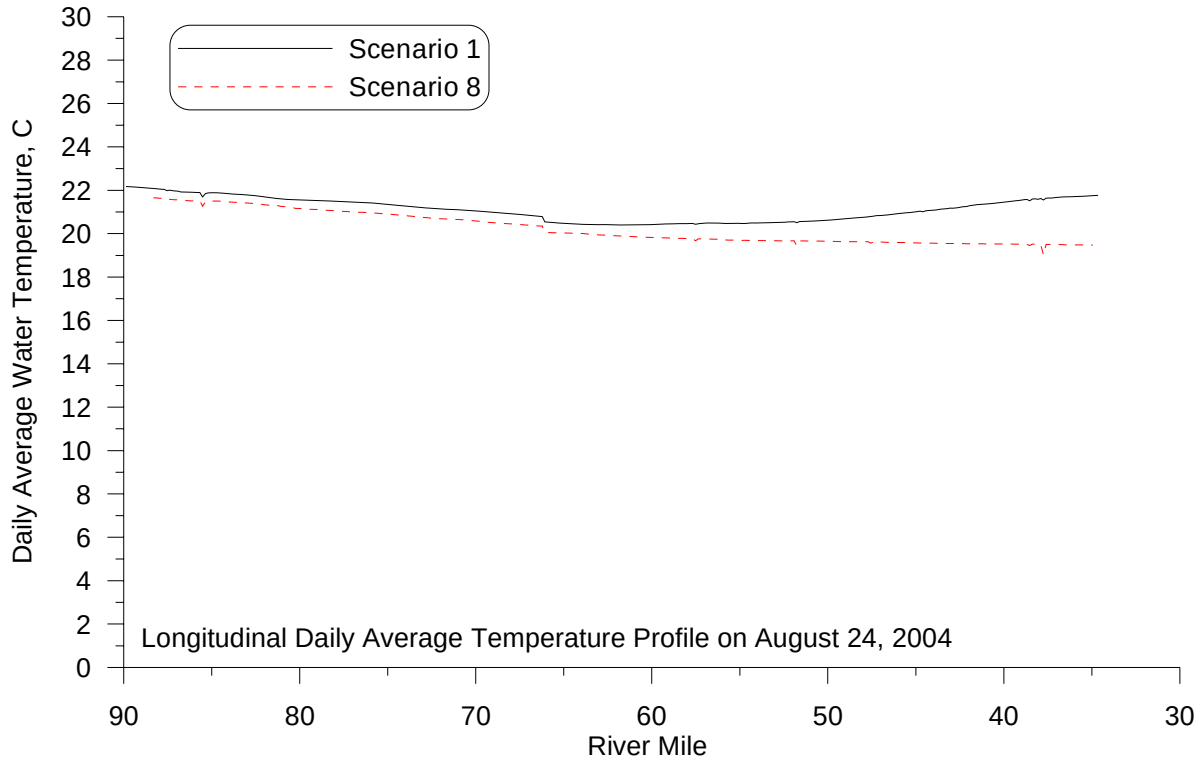

Figure 24. Comparison of longitudinal daily average temperature profile on August 24, 2004 between the natural conditions scenario 8 and the existing conditions scenario 1.

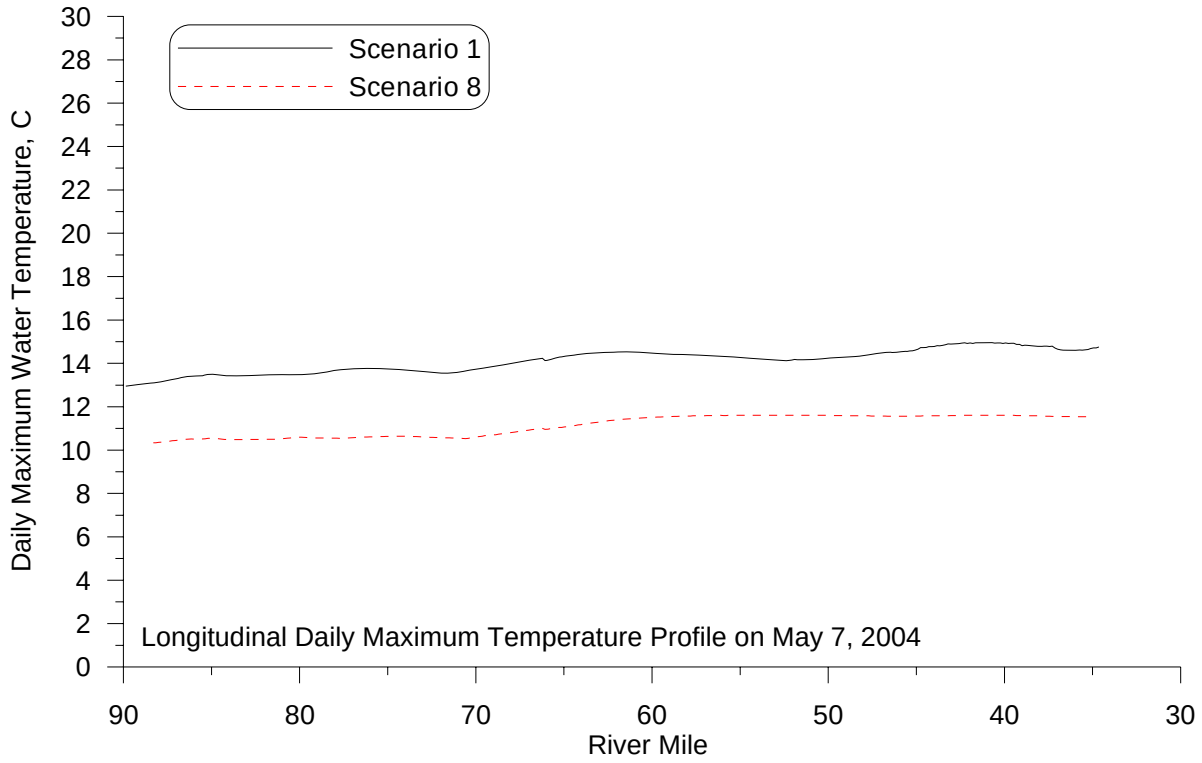

Figure 25. Comparison of longitudinal daily maximum temperature profile on May 7, 2004 between the natural conditions scenario 8 and the existing conditions scenario 1.

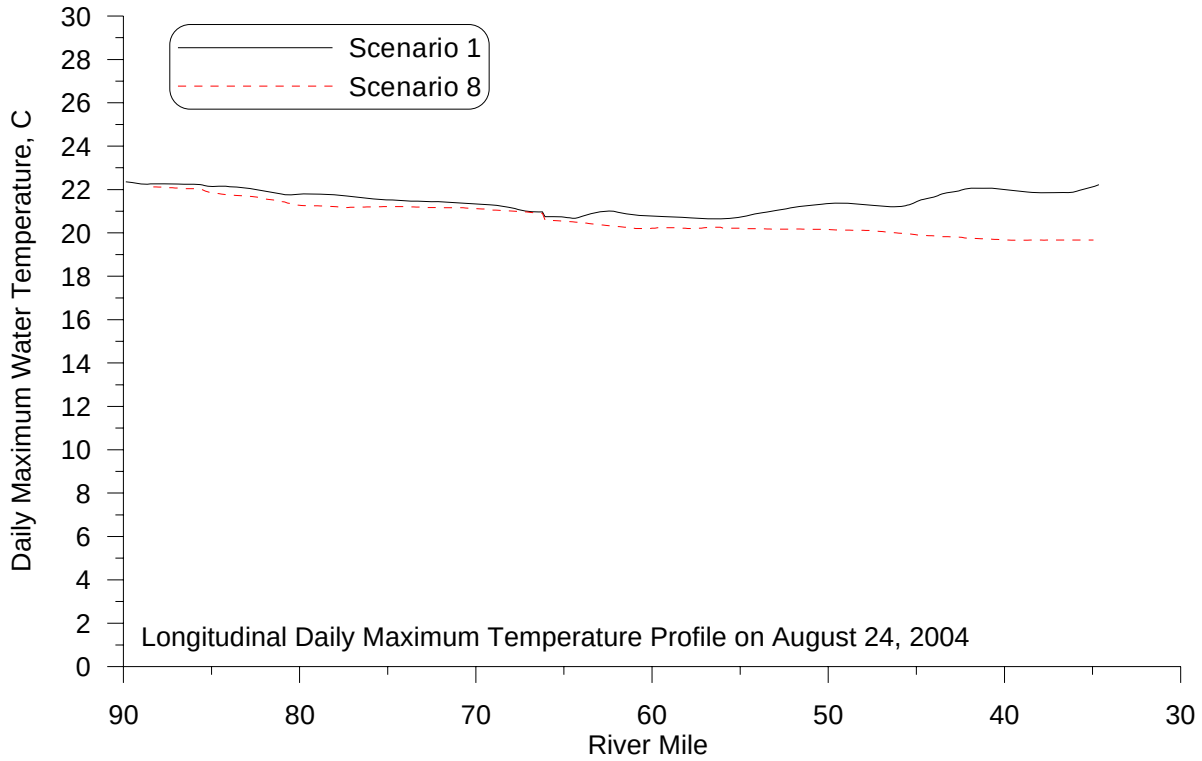

Figure 26. Comparison of longitudinal daily maximum temperature profile on August 24, 2004 between the natural conditions scenario 8 and the existing conditions scenario 1.

Table 5: Statistical significance of daily maximum temperature in the longitudinal profiles on May 7th, 2004 and August 24th, 2004 between the natural (8) and Existing Conditions (1) Scenarios.

Scenario 1 and Scenario 8 Comparison	P-value	Result
May 7th daily maximum temperature	1.000	Model results between scenarios are not the same
August 24th daily maximum temperature	1.000	Model results between scenarios are not the same

Table 6: Statistical significance of daily average temperature in the longitudinal profiles on May 7th, 2004 and August 24th, 2004 between the natural (8) and Existing Conditions (1) Scenarios.

Scenario 1 and Scenario 8 Comparison	P-value	Result
May 7th daily average temperature	1.000	Model results between scenarios are not the same
August 24th daily average temperature	1.000	Model results between scenarios are not the same

Evaluation of WLA/point source contributions

The point source thermal loading contributions to the Pend Oreille River are evaluated by comparing results from Model Scenario l (Existing Conditions) and Scenario 2 (Existing Conditions with no point sources, NPDES).

Time Series Plots

Daily Average Temperatures

The daily average temperatures of the existing conditions scenario 1 and the existing conditions with no point sources scenario 2 are shown in Figure 27 through Figure 34. P values statistics comparing the daily average temperatures are listed in Table 5. There were no differences between the scenarios in model predictions of daily average temperature.

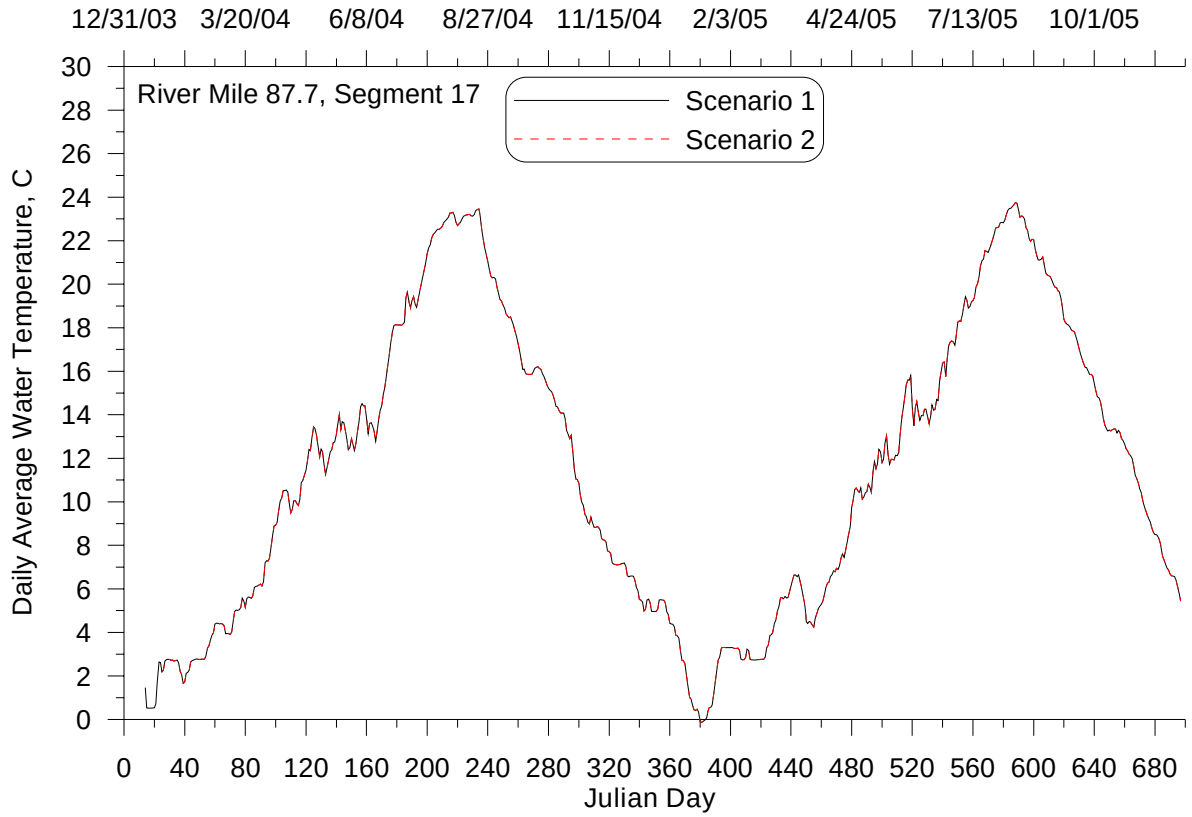

Figure 27. Comparison of segment 17 (RM 87.7) daily average water temperatures of the point sources removed scenario 2 and the existing conditions scenario 1.

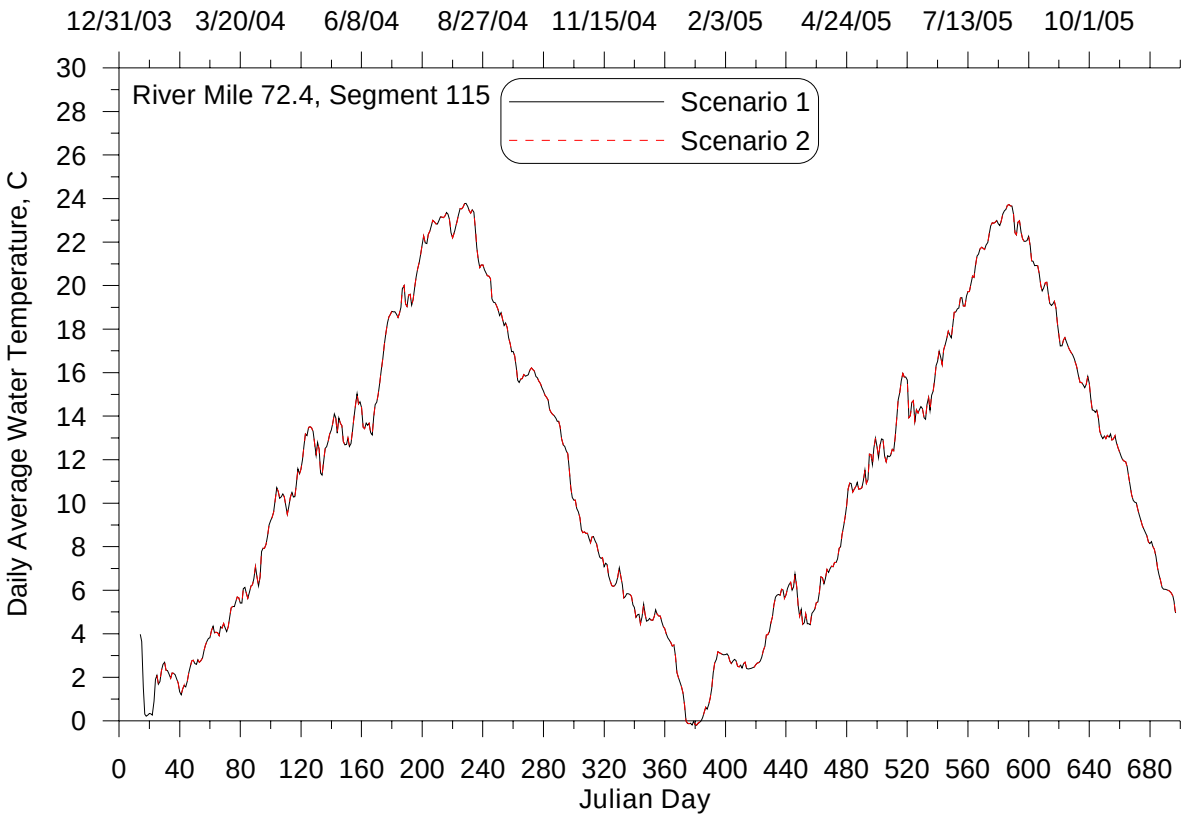

Figure 28. Comparison of segment 115 (RM 72.4) daily average water temperatures of the point sources removed scenario 2 and the existing conditions scenario 1.

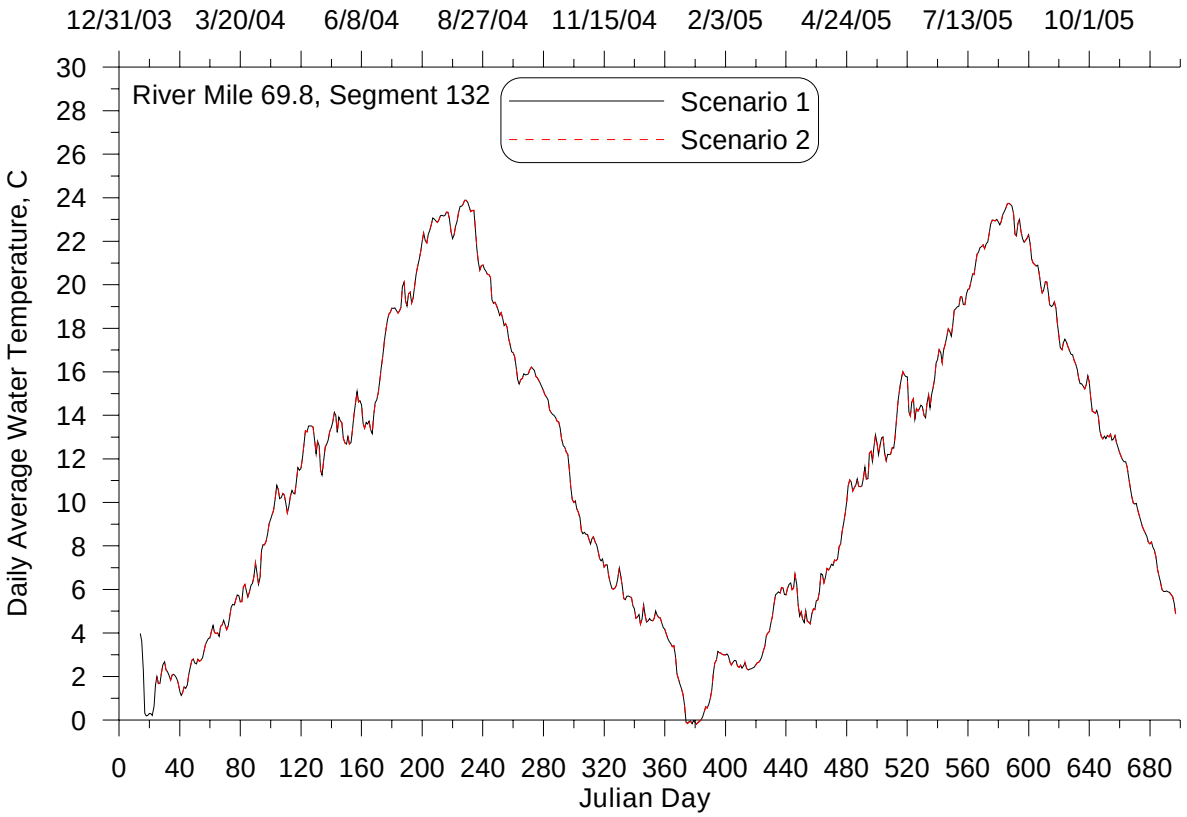

Figure 29. Comparison of segment 132 (RM 69.8) daily average water temperatures of the point sources removed scenario 2 and the existing conditions scenario 1.

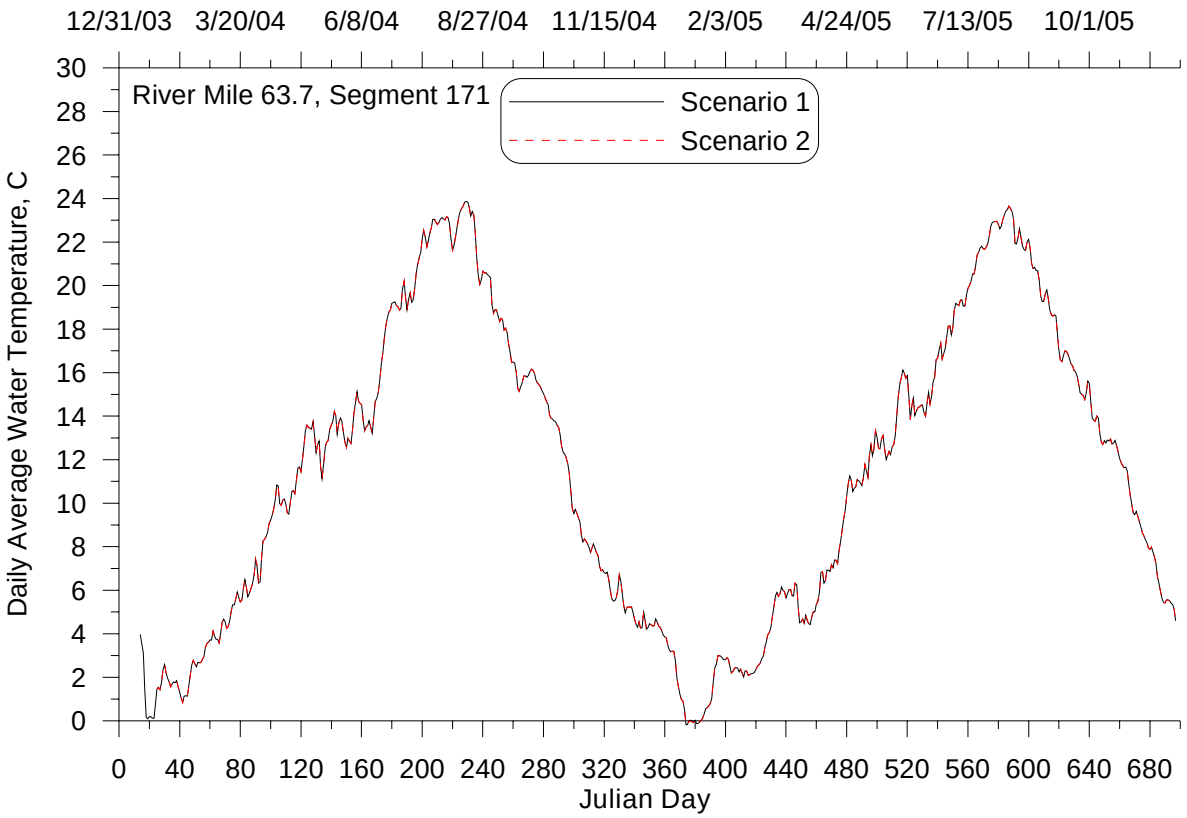

Figure 30. Comparison of segment 171 (RM 63.7) daily average water temperatures of the point sources removed scenario 2 and the existing conditions scenario 1.

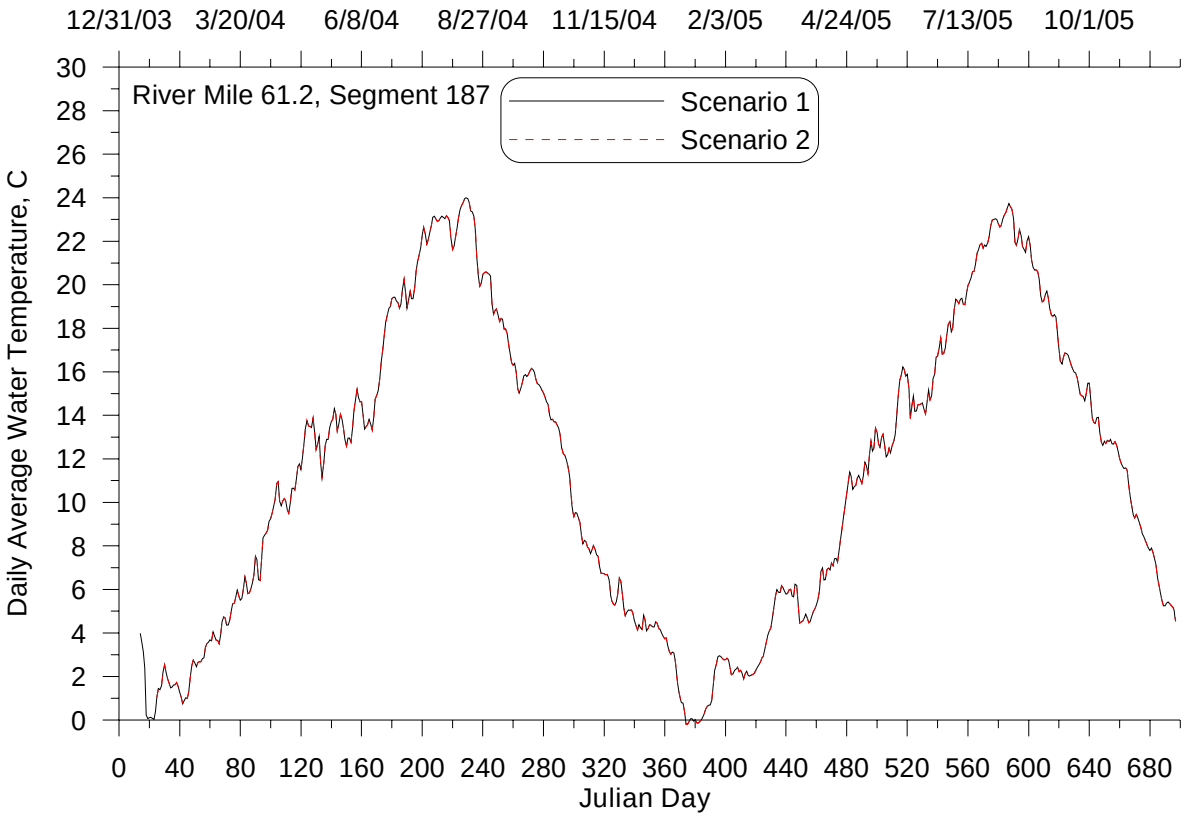

Figure 31. Comparison of segment 187 (RM 61.2) daily average water temperatures of the point sources removed scenario 2 and the existing conditions scenario 1.

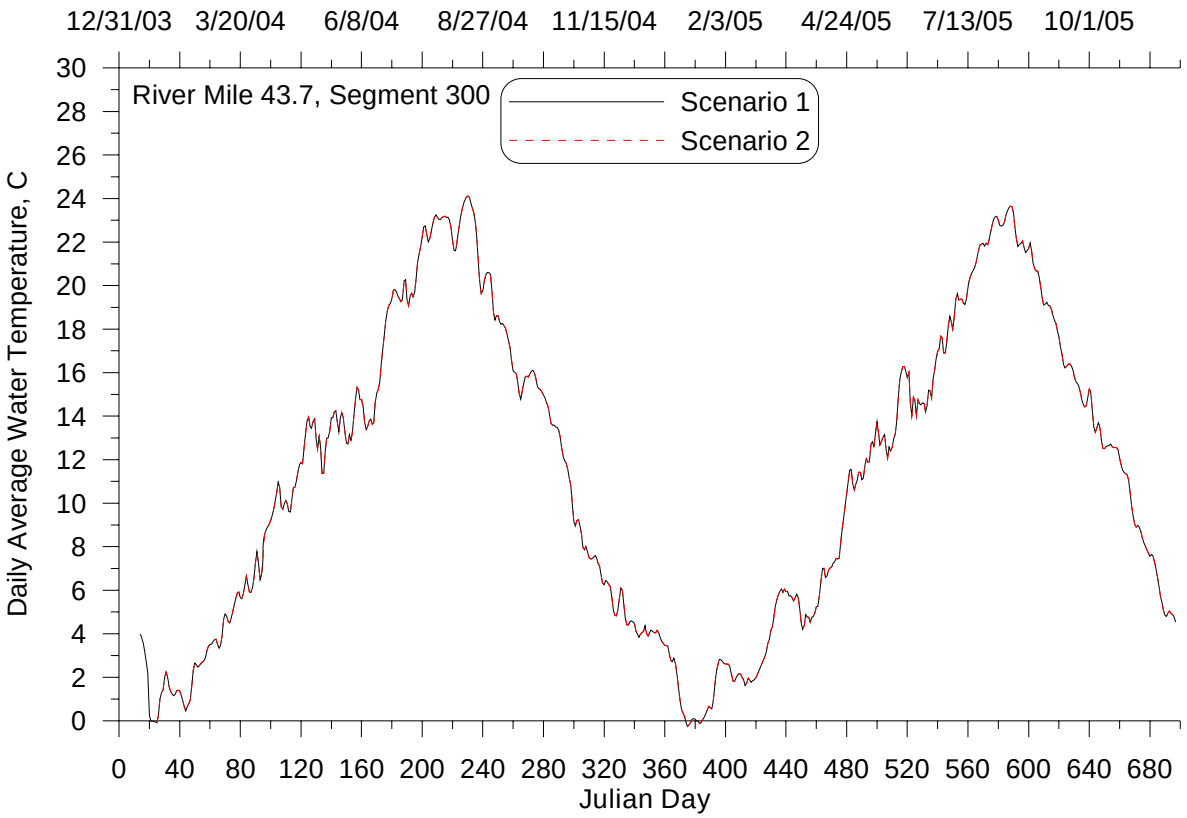

Figure 32. Comparison of segment 300 (RM 43.7) daily average water temperatures of the point sources removed scenario 2 and the existing conditions scenario 1.

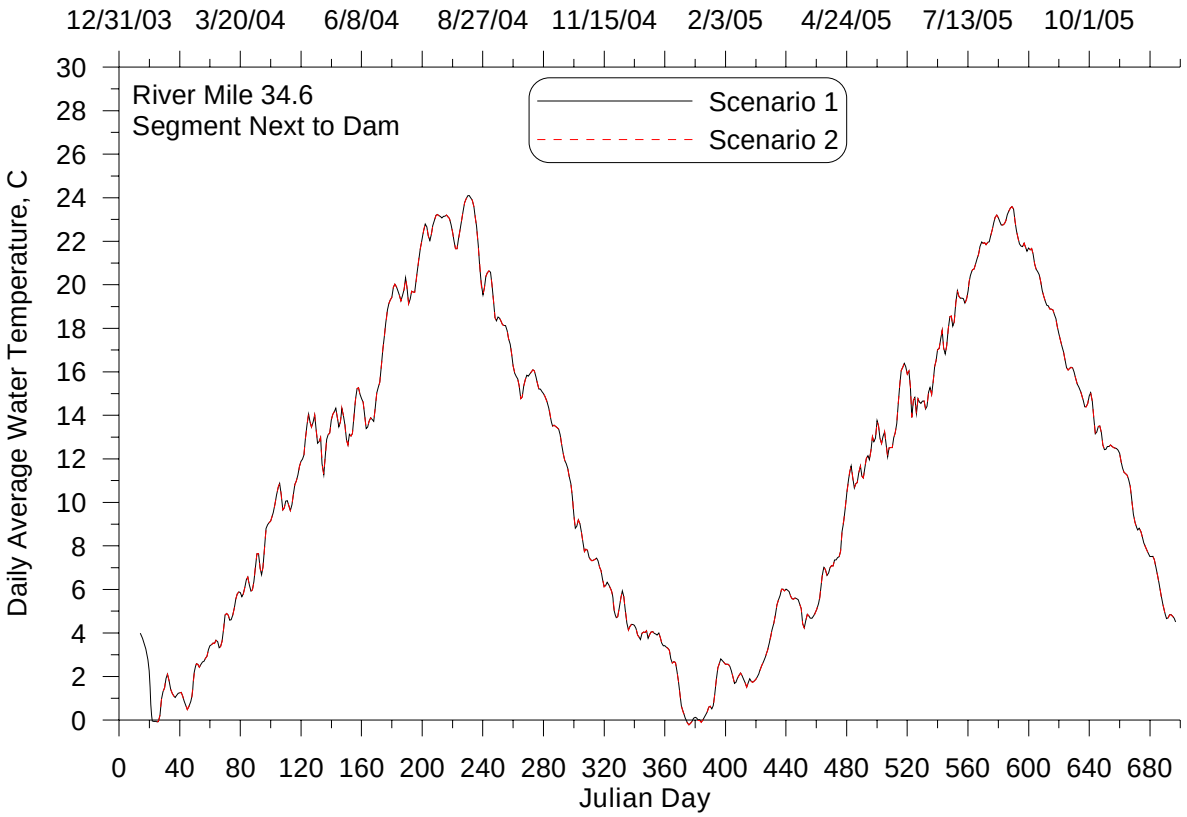

Figure 33. Comparison of model segment adjacent to Box Canyon Dam (segment 358) daily average water temperatures of the point sources removed scenario 2 and the existing conditions scenario 1 at RM 34.6.

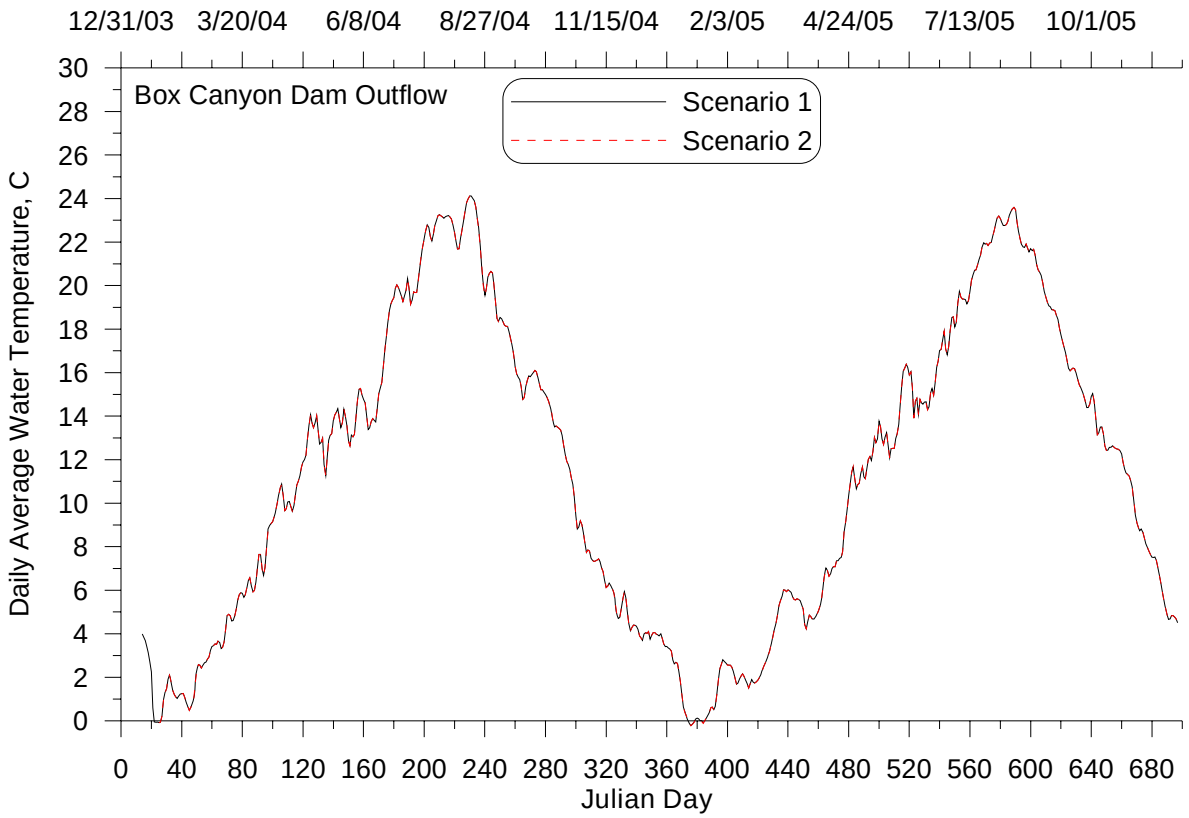

Figure 34. Comparison of Box Canyon Dam daily average outflow temperatures between the point sources removed scenario (2) and existing conditions scenario (1).

Table 7: Statistical significance in daily average temperature time series results between the point source contributions (2) and Existing Conditions (1) Scenarios.

River Mile, Model Location	P-value	Result
River Mile 87.7 (Model Segment 17)	0.005	Model results between scenarios are the same, i.e. no difference
River Mile 72.4 (Model Segment 115)	0.002	Model results between scenarios are the same, i.e. no difference
River Mile 69.8 (Model Segment 132)	0.006	Model results between scenarios are the same, i.e. no difference
River Mile 63.7 (Model Segment 171)	0.006	Model results between scenarios are the same, i.e. no difference
River Mile 61.2 (Model Segment 187	0.006	Model results between scenarios are the same, i.e. no difference
River Mile 43.7 (Model Segment 300)	0.005	Model results between scenarios are the same, i.e. no difference
River Mile 34.6 (Model Segment next to dam)	0.005	Model results between scenarios are the same, i.e. no difference
River Mile 34.5 (Box Canyon Dam Outlet)	0.005	Model results between scenarios are the same, i.e. no difference

Daily Maximum Temperatures

Daily maximum temperatures of scenario 2 (existing conditions) and scenario 1 (point sources removed) are compared in Figure 35 through Figure 42. The P values statistics of these scenarios are listed in Table 8. There were no differences predicted in maximum daily temperature.

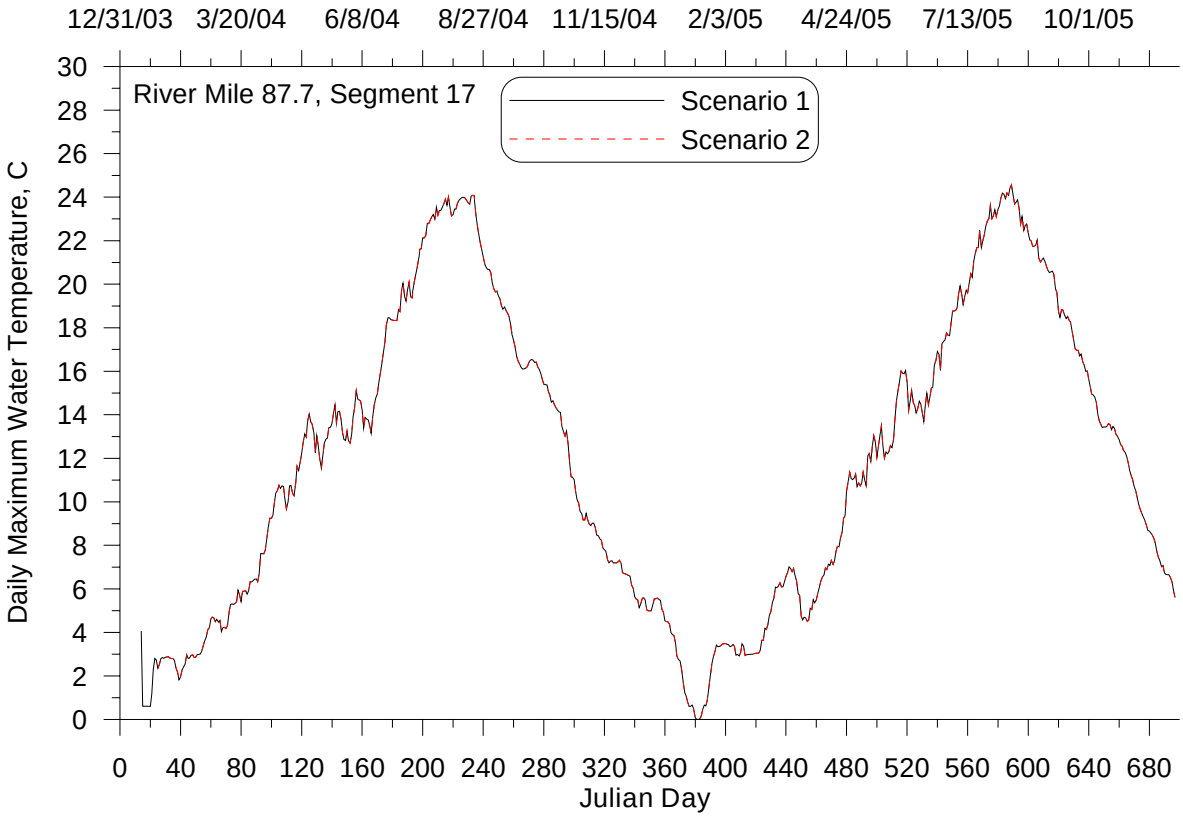

Figure 35. Comparison of segment 17 (RM 87.7) daily maximum water temperatures of the point sources removed scenario 2 and the existing conditions scenario 1.

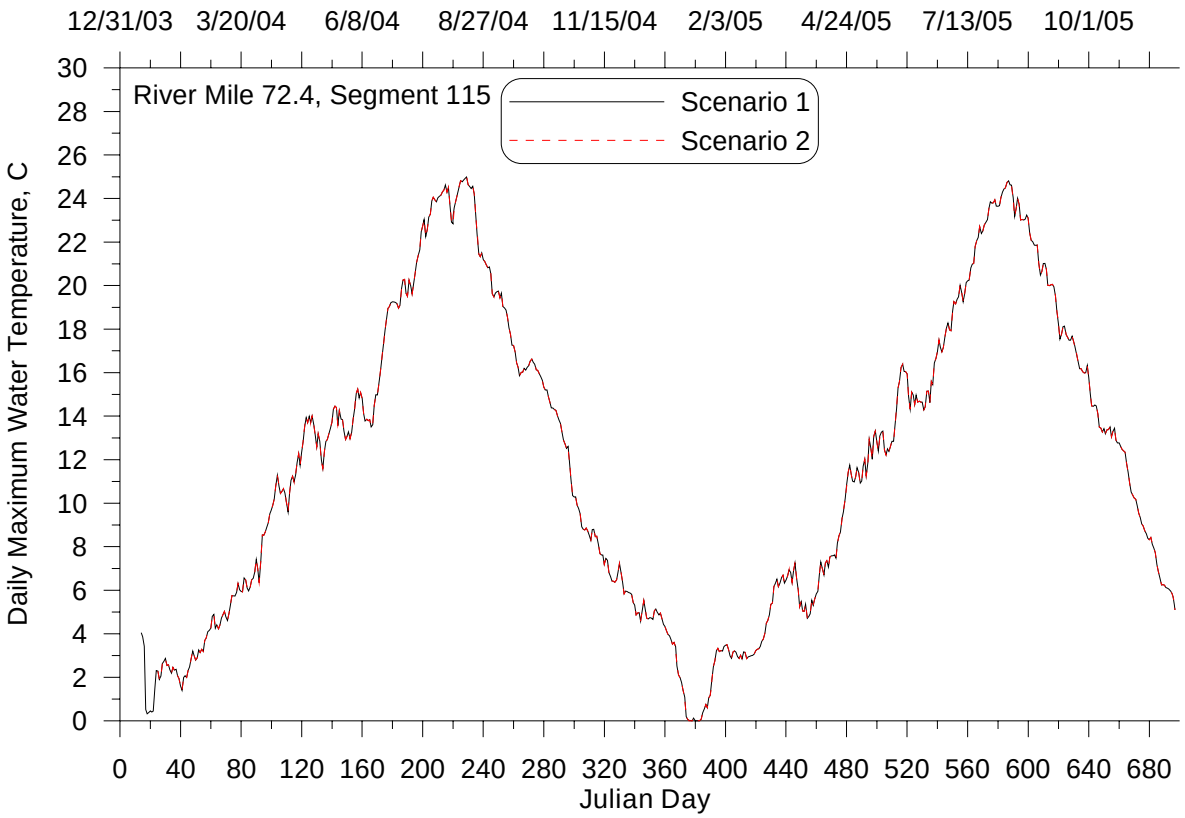

Figure 36. Comparison of segment 115 (RM 72.4) daily maximum water temperatures of the point sources removed scenario 2 and the existing conditions scenario 1.

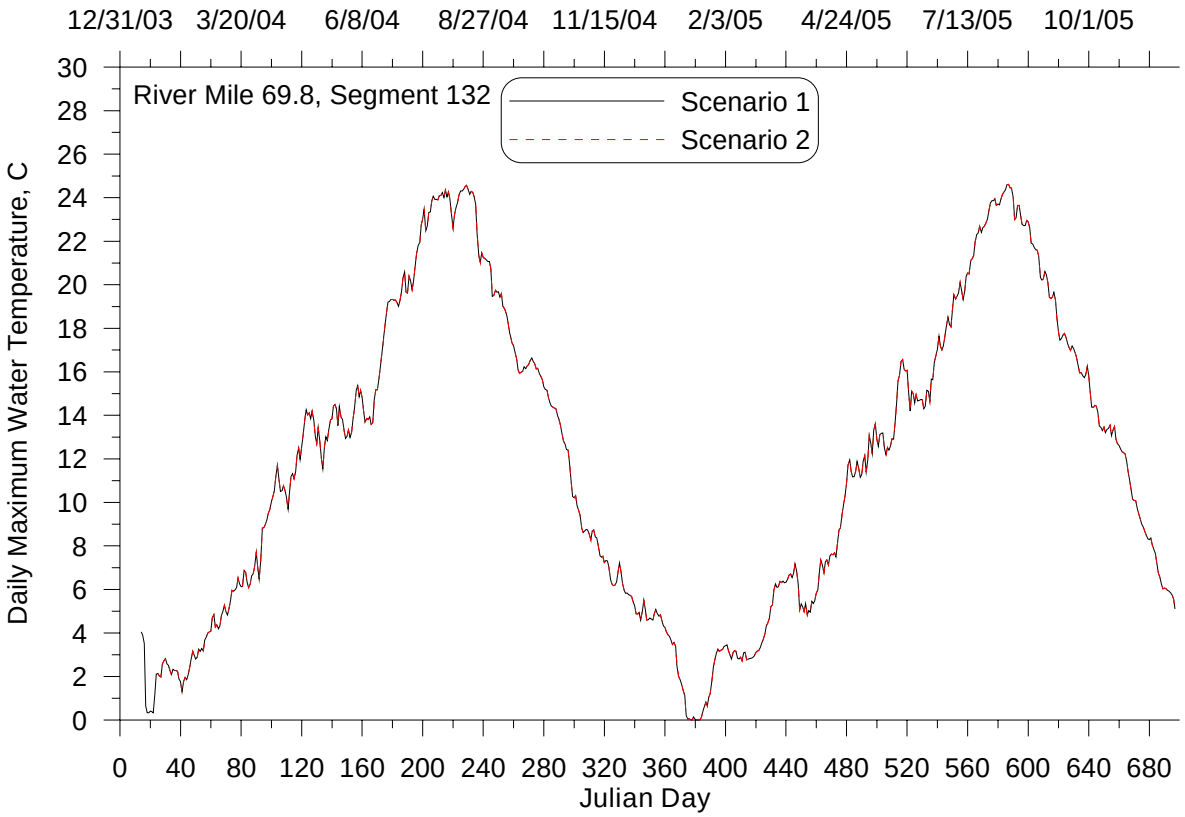

Figure 37. Comparison of segment 132 (RM 69.8) daily maximum water temperatures of the point sources removed scenario 2 and the existing conditions scenario 1.

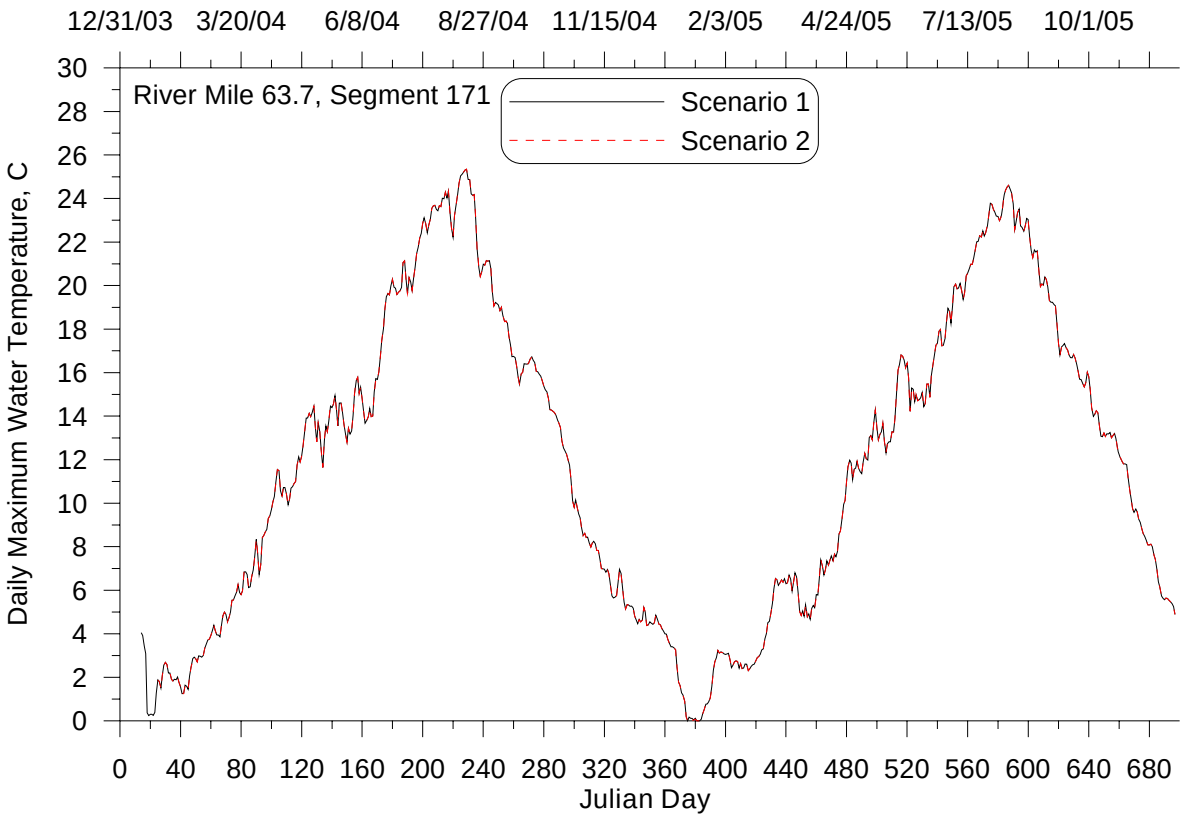

Figure 38. Comparison of segment 171 (RM 63.7) daily maximum water temperatures of the point sources removed scenario 2 and the existing conditions scenario 1.

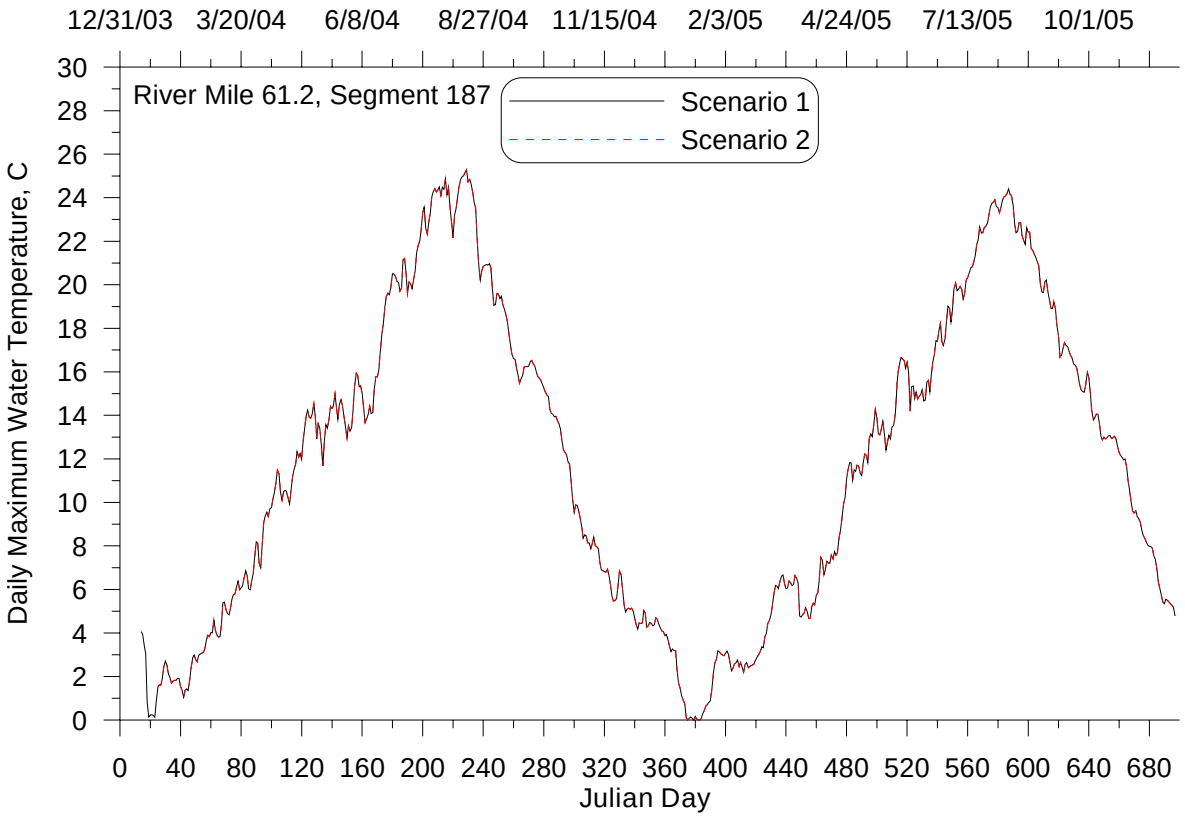

Figure 39. Comparison of segment 187 (RM 61.2) daily maximum water temperatures of the point sources removed scenario 2 and the existing conditions scenario 1.

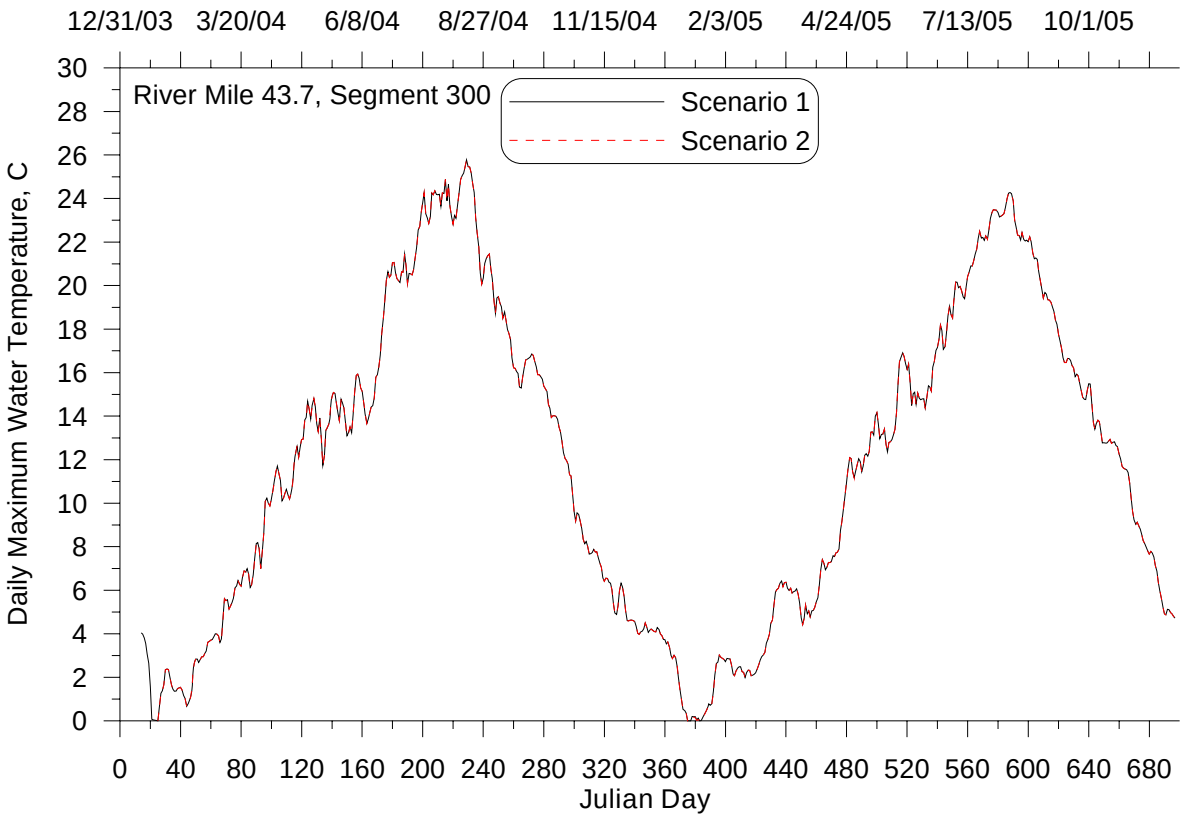

Figure 40. Comparison of segment 300 (RM 43.7) daily maximum water temperatures of the point sources removed scenario 2 and the existing conditions scenario 1.

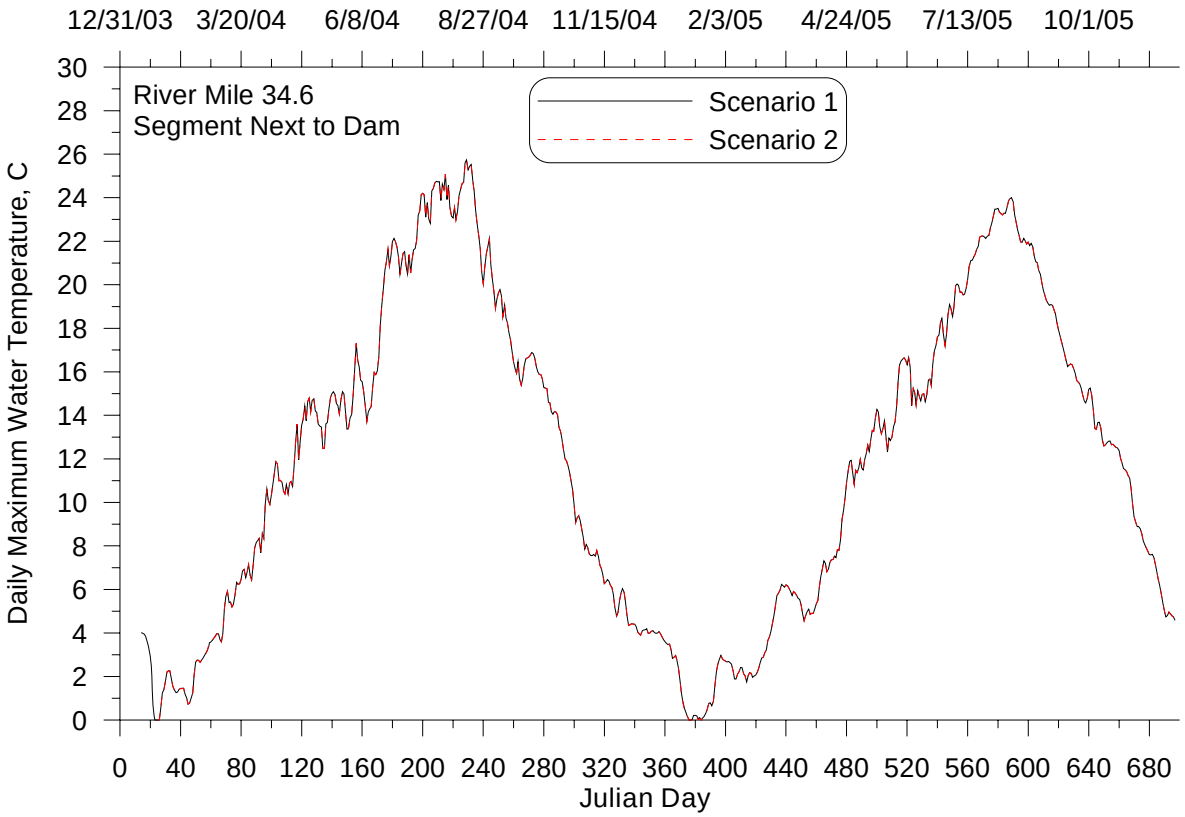

Figure 41. Comparison of model segment adjacent to Box Canyon Dam (segment 358) daily maximum water temperatures of the point sources removed scenario 2 and the existing conditions scenario 1 at RM 34.6.

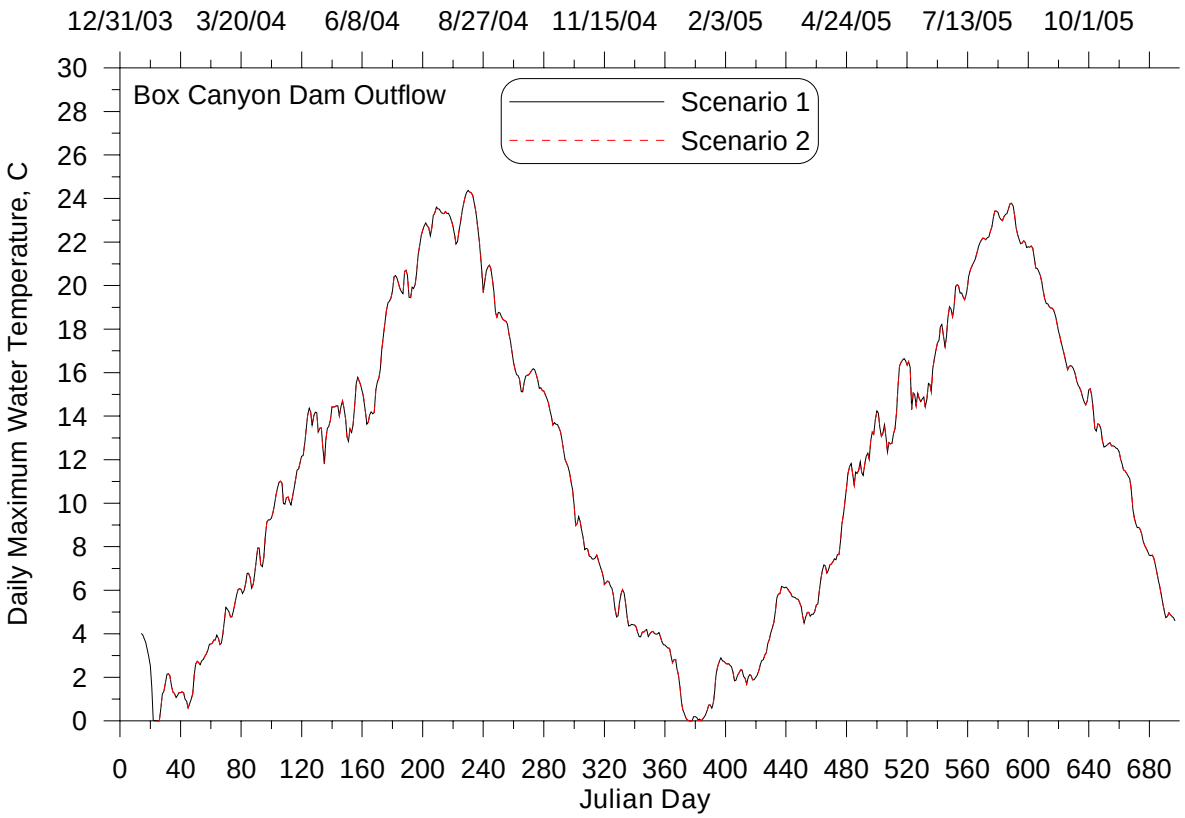

Figure 42. Comparison of Box Canyon Dam daily maximum outflow temperatures between the point sources removed scenario (2) and existing conditions scenario (1).

Table 8: Statistical significance in daily maximum time series results between the point source contributions (2) and Existing Conditions (1) Scenarios.

River Mile, Model Location	P-value	Result
River Mile 87.7 (Model Segment 17)	0.004	Model results between scenarios are the same, i.e. no difference
River Mile 72.4 (Model Segment 115)	0.002	Model results between scenarios are the same, i.e. no difference
River Mile 69.8 (Model Segment 132)	0.006	Model results between scenarios are the same, i.e. no difference
River Mile 63.7 (Model Segment 171)	0.006	Model results between scenarios are the same, i.e. no difference
River Mile 61.2 (Model Segment 187	0.006	Model results between scenarios are the same, i.e. no difference
River Mile 43.7 (Model Segment 300)	0.004	Model results between scenarios are the same, i.e. no difference
River Mile 34.6 (Model Segment next to dam site)	0.004	Model results between scenarios are the same, i.e. no difference
River Mile 34.5 (Box Canyon Dam Outlet)	0.004	Model results between scenarios are the same, i.e. no difference

Longitudinal Profiles

Longitudinal profiles (daily maximum and daily average temperature) are plotted in Figure 43 through Figure 46. The P value statistics comparing these profiles are listed in Table 9 and Table 10. There were no differences between the scenarios for May 7 and August 24, 2004.

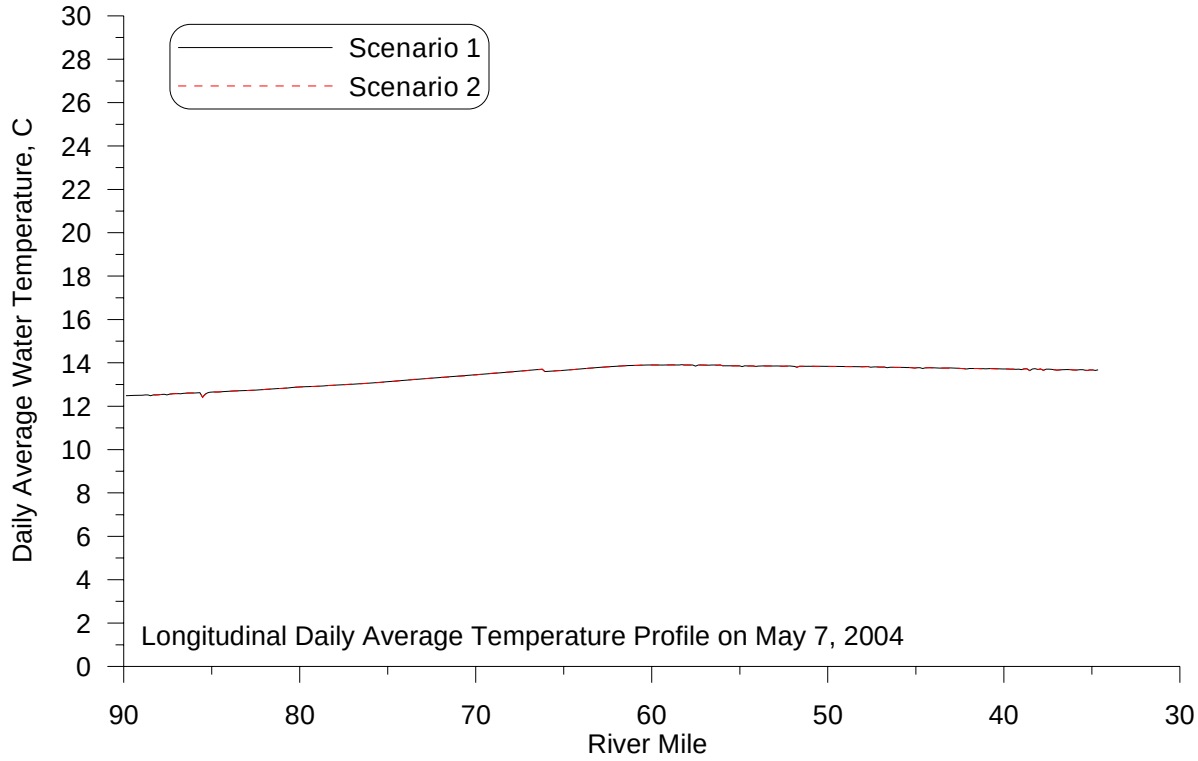

Figure 43. Comparison of longitudinal daily average temperature profile on May 7, 2004 between the no point sources scenario 2 and the existing conditions scenario 1.

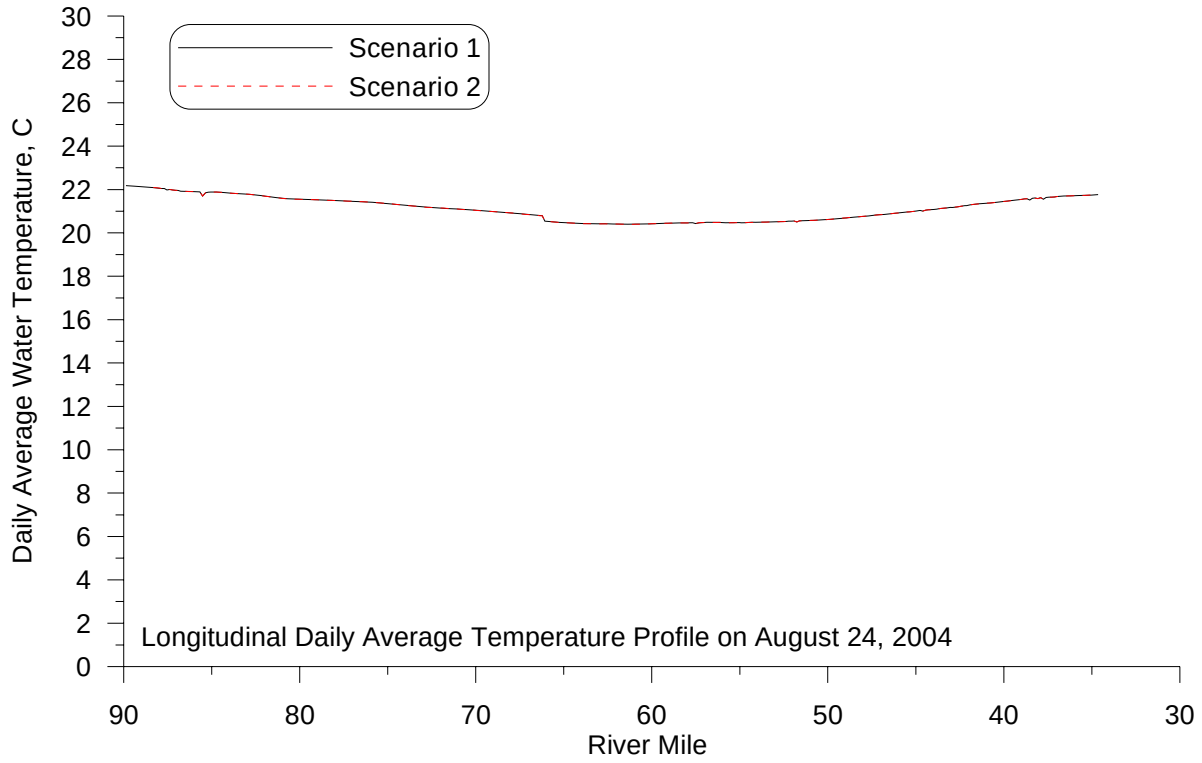

Figure 44. Comparison of longitudinal daily average temperature profile on August 24, 2004 between the no point sources scenario 2 and the existing conditions scenario 1.

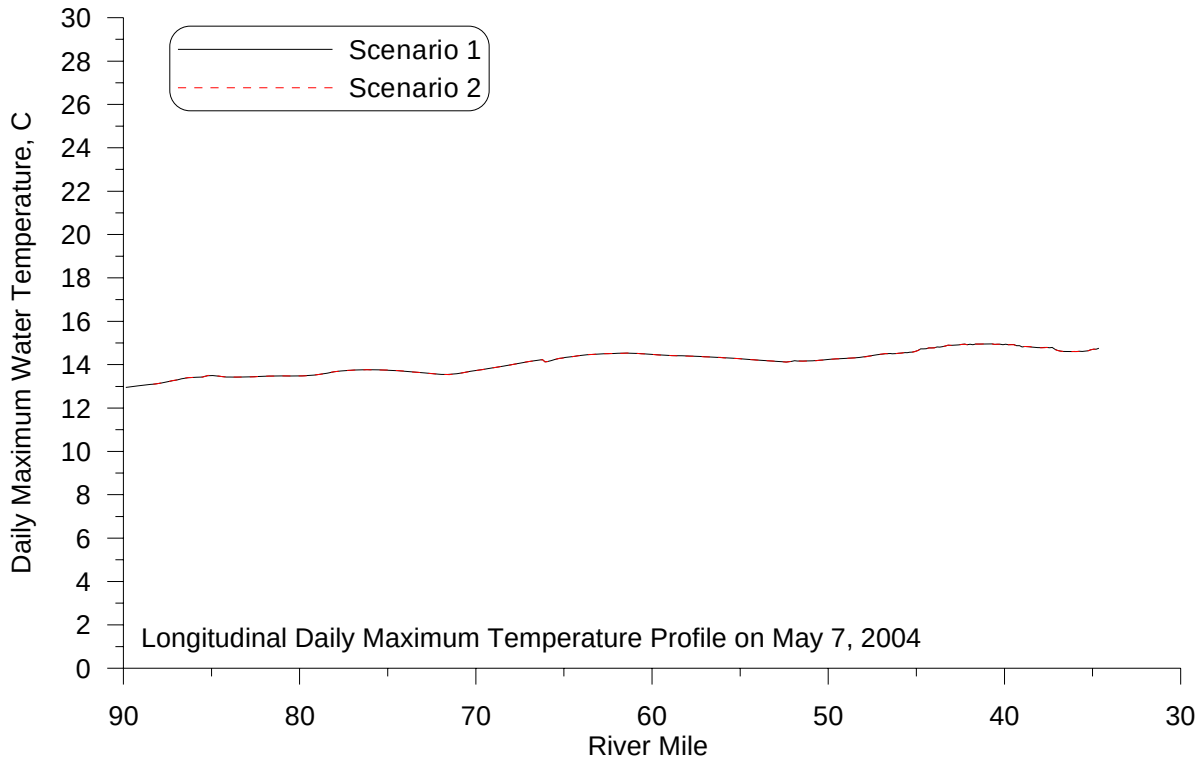

Figure 45. Comparison of longitudinal daily maximum temperature profile on May 7, 2004 between the no point sources scenario 2 and the existing conditions scenario 1.

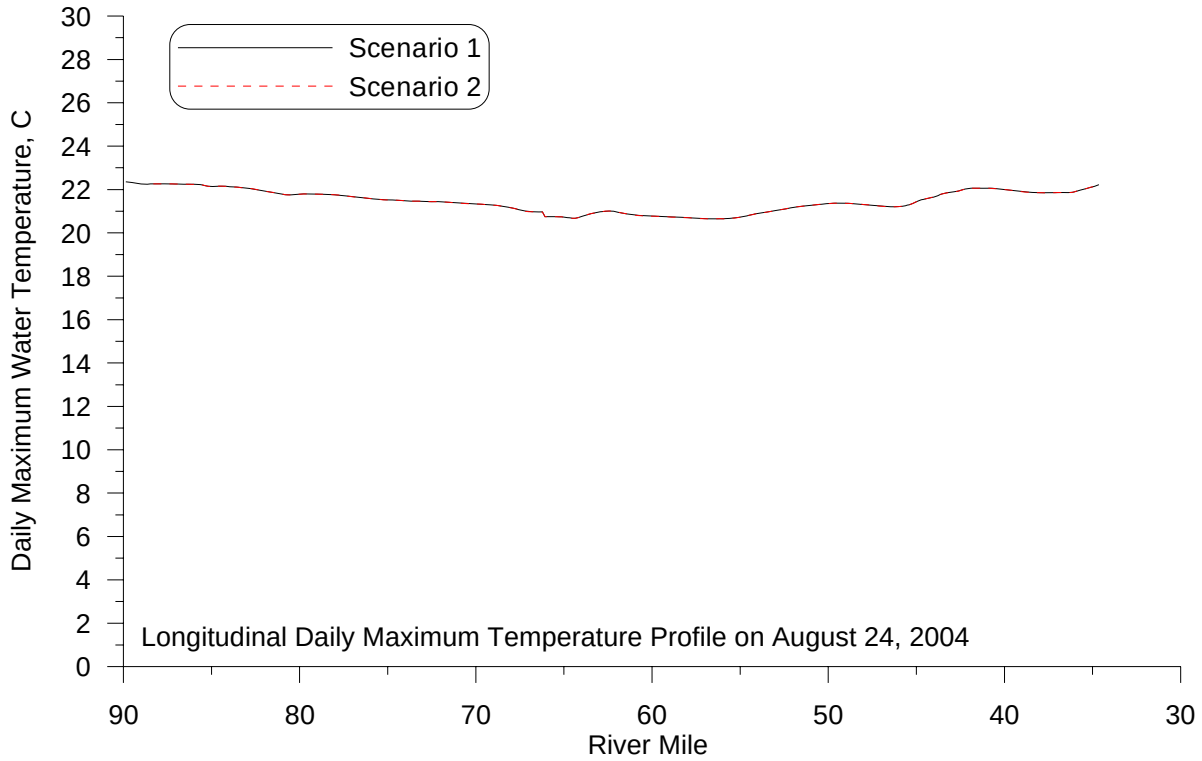

Figure 46. Comparison of longitudinal daily maximum temperature profile on August 24, 2004 between the no point sources scenario 2 and the existing conditions scenario 1.

Table 9: Statistical significance of daily maximum temperature in the longitudinal profiles on May 7th, 2004 and August 24th, 2004 between the no point sources (2) and Existing Conditions (1) Scenarios.

Scenario 1 and Scenario 2 Comparison	P-value	Result
May 7th daily maximum temperature	0.023	Model results between scenarios are the same, i.e. no difference
August 24th daily maximum temperature	0.021	Model results between scenarios are the same, i.e. no difference

Table 10: Statistical significance of daily average temperature in the longitudinal profiles on May 7th, 2004 and August 24th, 2004 between the no point sources (2) and Existing Conditions (1) Scenarios.

Scenario 1 and Scenario 2 Comparison	P-value	Result
May 7th daily average temperature	0.021	Model results between scenarios are the same, i.e. no difference
August 24th daily average temperature	0.019	Model results between scenarios are the same, i.e. no difference

Evaluation of non-point source contributions

The non-point source thermal loading contributions to the Pend Oreille River are evaluated by comparing results from Model Scenario l (Existing Conditions) and Scenario 2.5 (Existing Conditions with PNV temperatures for tributaries).

Time Series Plots

Daily Average Temperatures

The daily average temperature plots of the existing conditions scenario 1 and existing conditions with PNV temperatures for tributaries scenario 2.5 are shown in Figure 47 through Figure 53. The daily average temperature P value statistics for scenario 1 and 2.5 are listed in Table 11. There were slight differences in daily average temperature between the simulations.

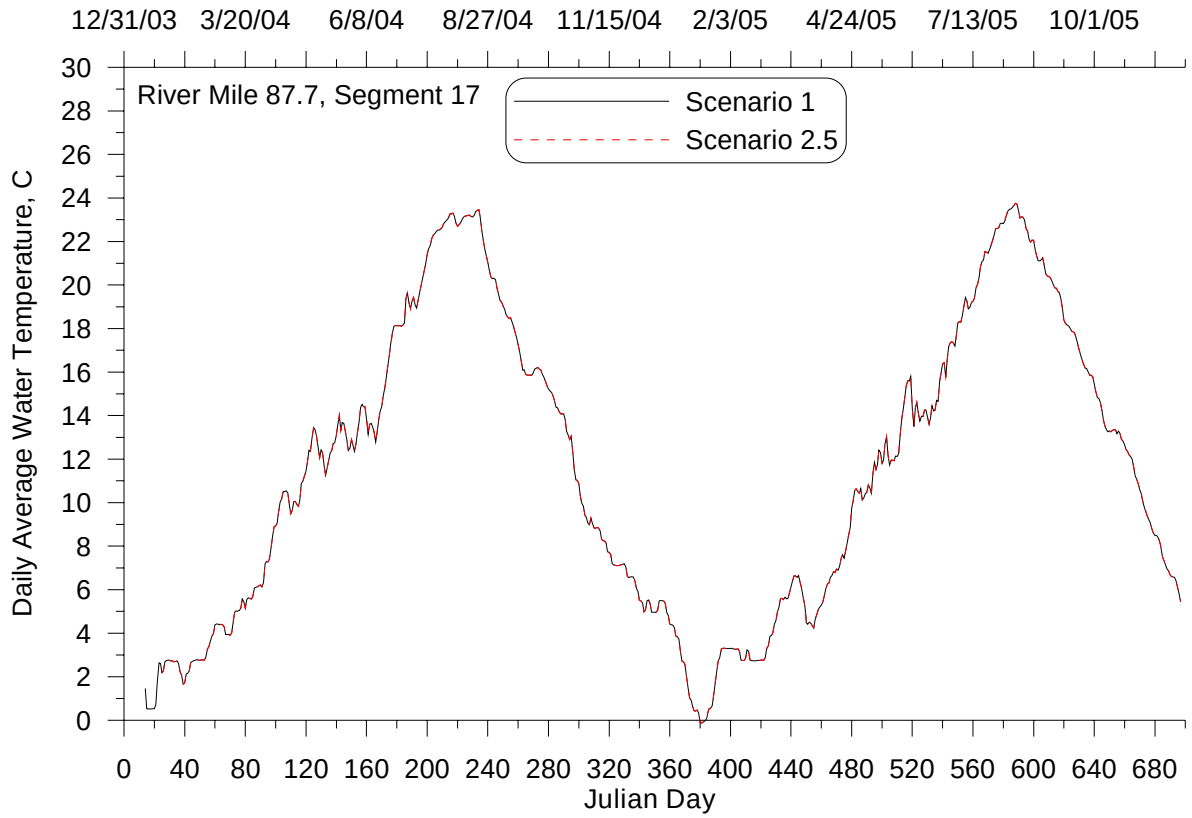

Figure 47. Comparison of segment 17 (RM 87.7) daily average water temperatures of the PNV temperatures for tributaries scenario 2.5 and the existing conditions scenario 1.

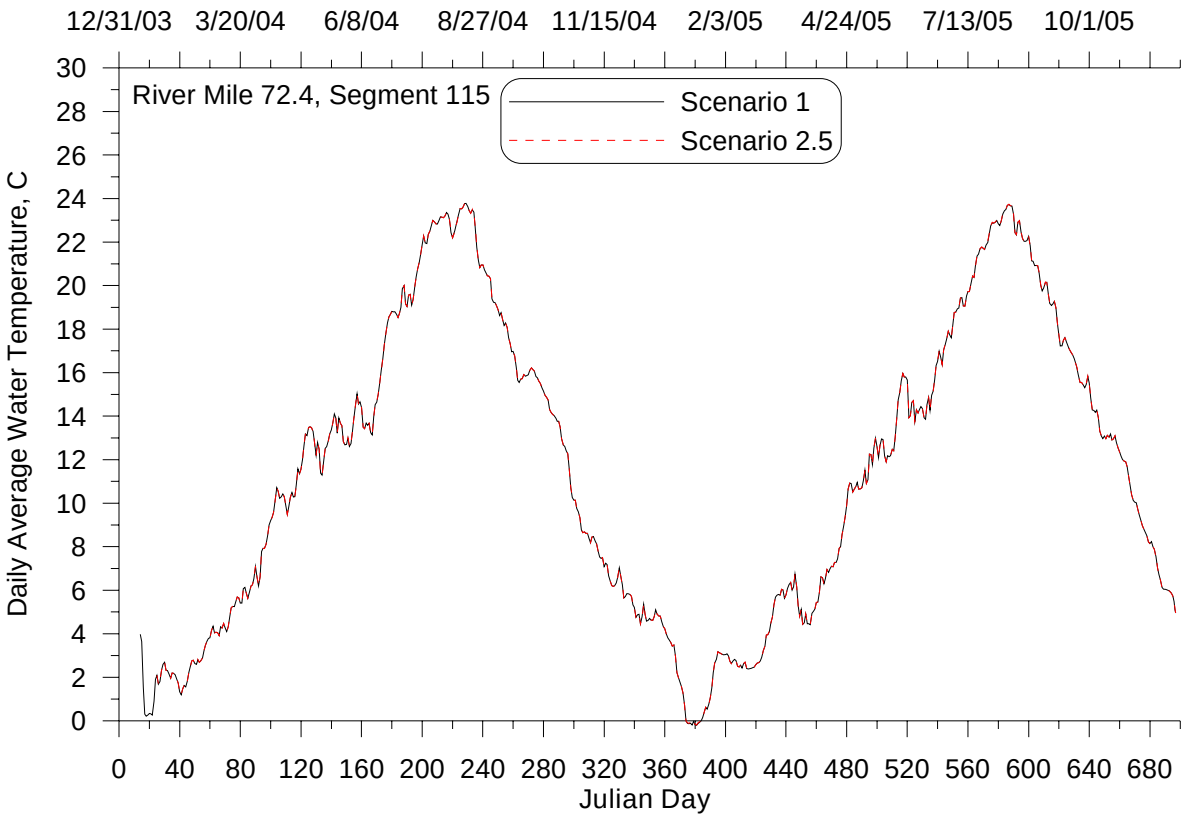

Figure 48. Comparison of segment 115 (RM 72.4) daily average water temperatures of the PNV temperatures for non-point sources scenario 2.5 and the existing conditions scenario 1.

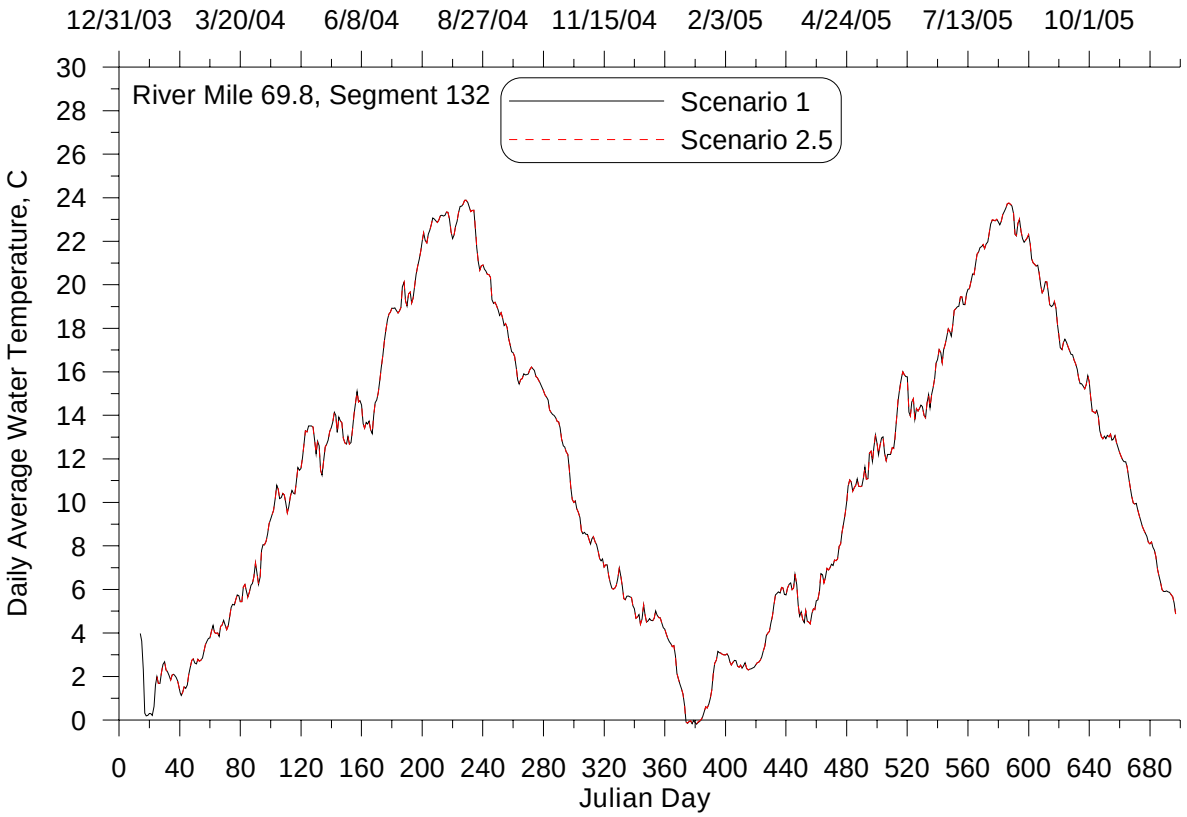

Figure 49. Comparison of segment 132 (RM 69.8) daily average water temperatures of the PNV temperatures for non-point sources scenario 2.5 and the existing conditions scenario 1.

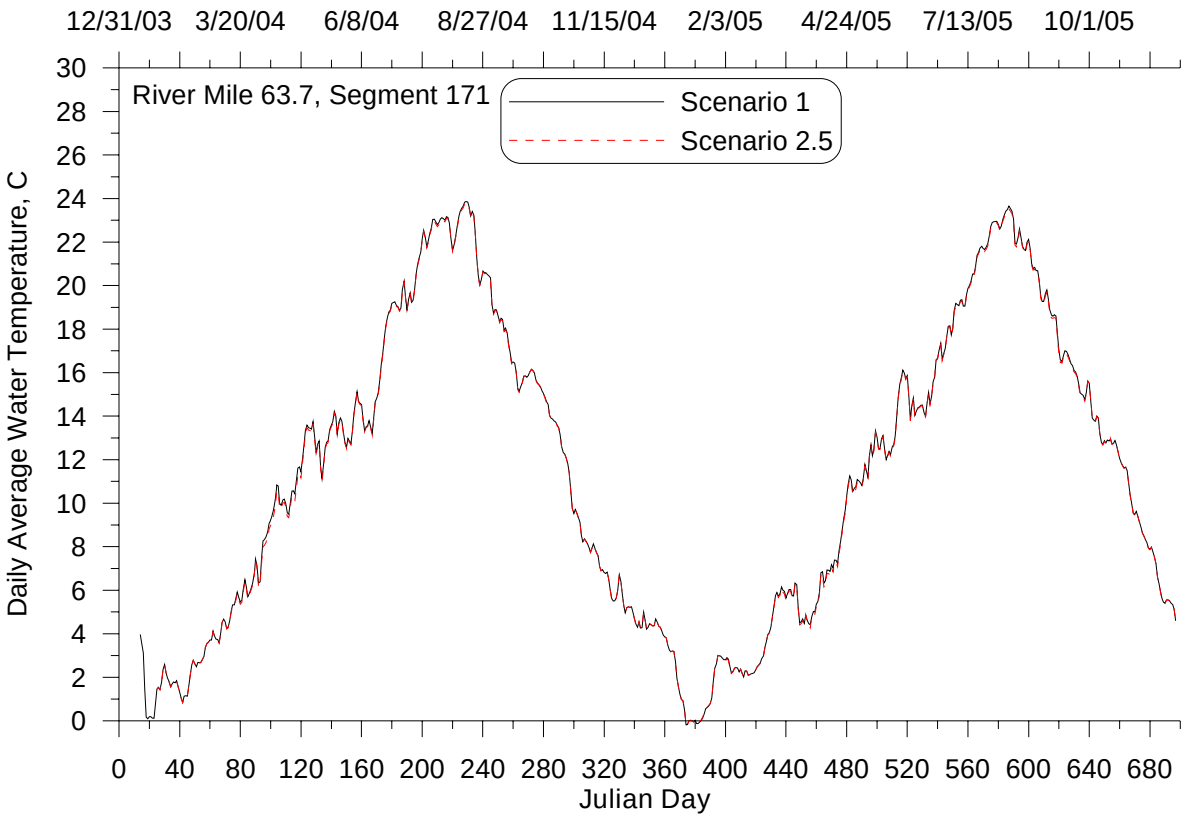

Figure 50. Comparison of segment 171 (RM 63.7) daily average water temperatures of the PNV temperatures for non-point sources scenario 2.5 and the existing conditions scenario 1.

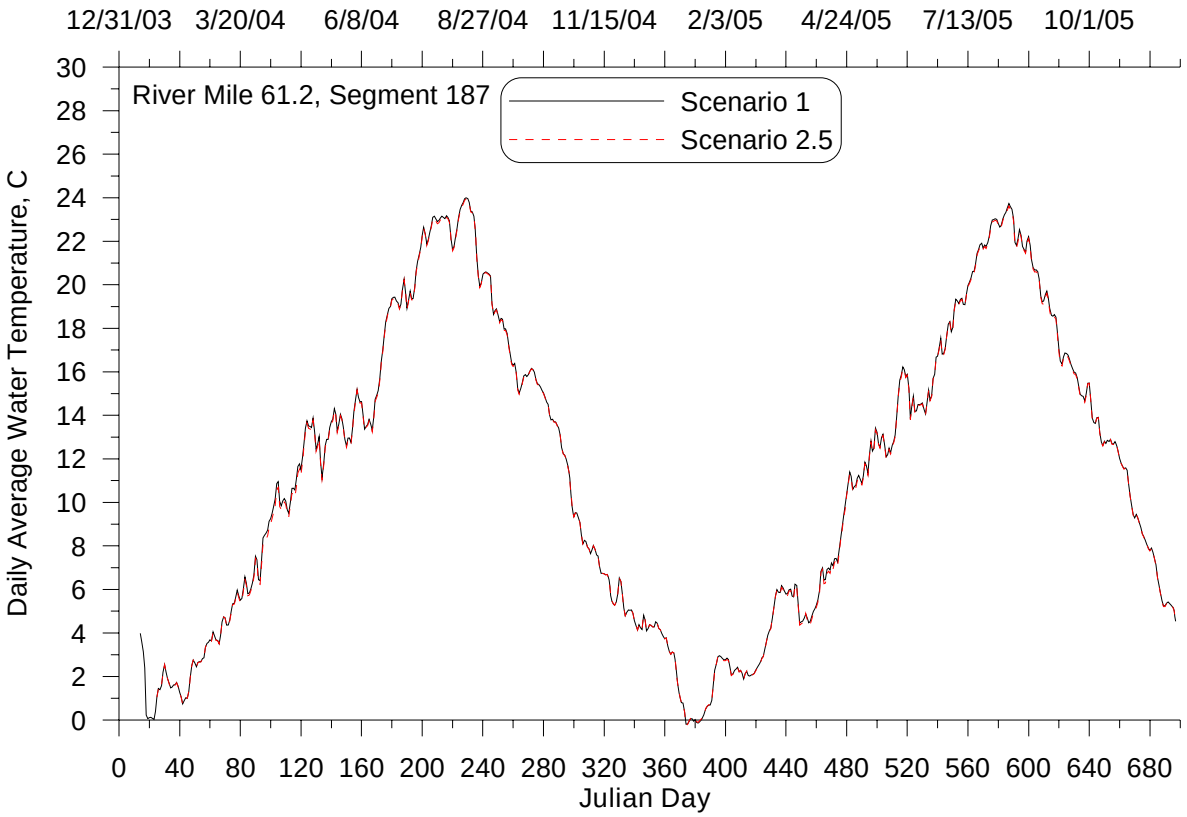

Figure 51. Comparison of segment 187 (RM 61.2) daily average water temperatures of the PNV temperatures for non-point sources scenario 2.5 and the existing conditions scenario 1.

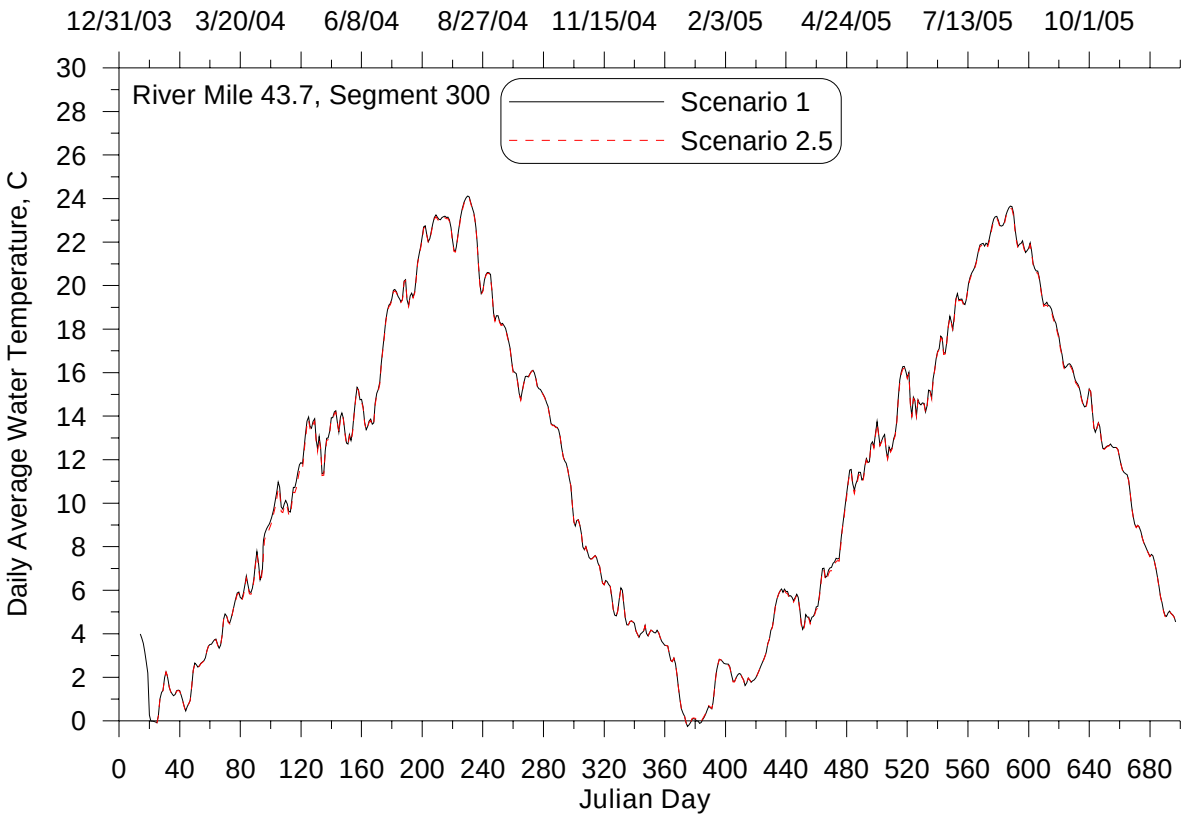

Figure 52. Comparison of segment 300 (RM 43.7) daily average water temperatures of the PNV temperatures for non-point sources scenario 2.5 and the existing conditions scenario 1.

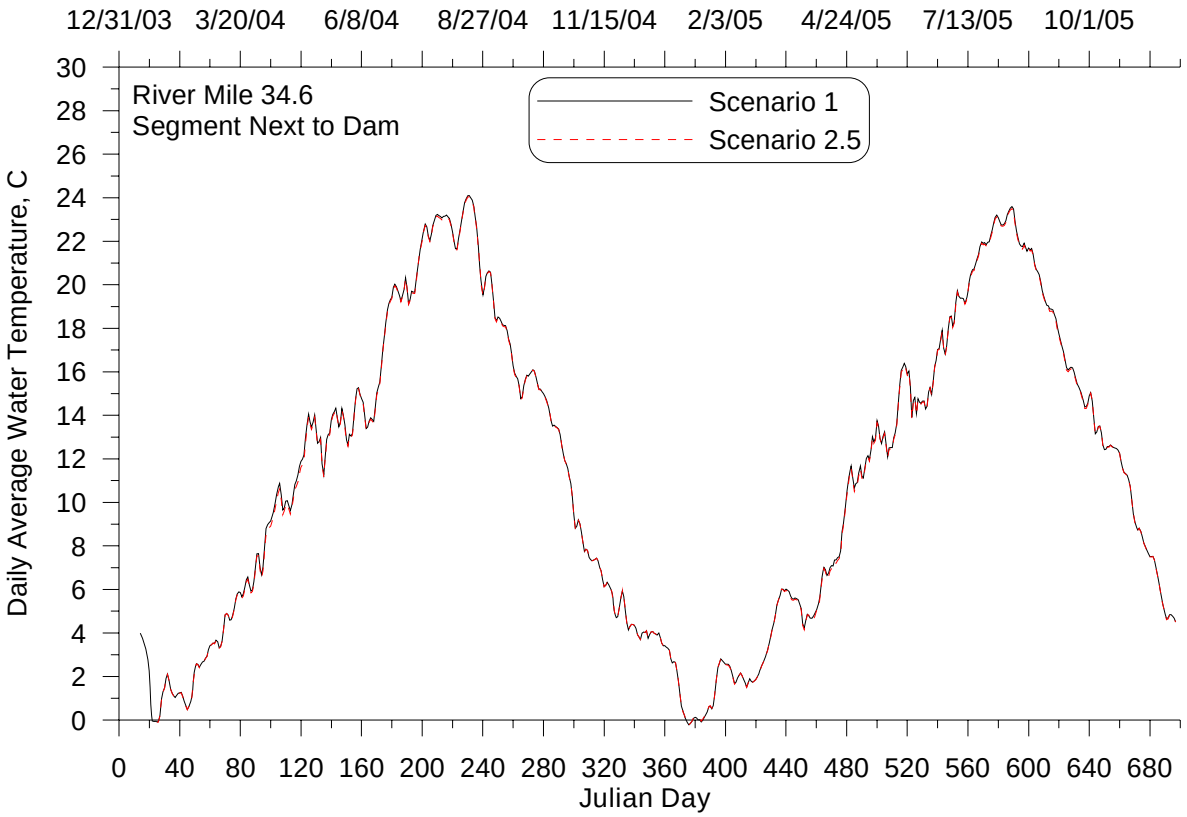

Figure 53. Comparison of model segment adjacent to Box Canyon Dam (segment 358) daily average water temperatures of the PNV temperatures for non-point sources scenario 2.5 and the existing conditions scenario 1 at RM 34.6.

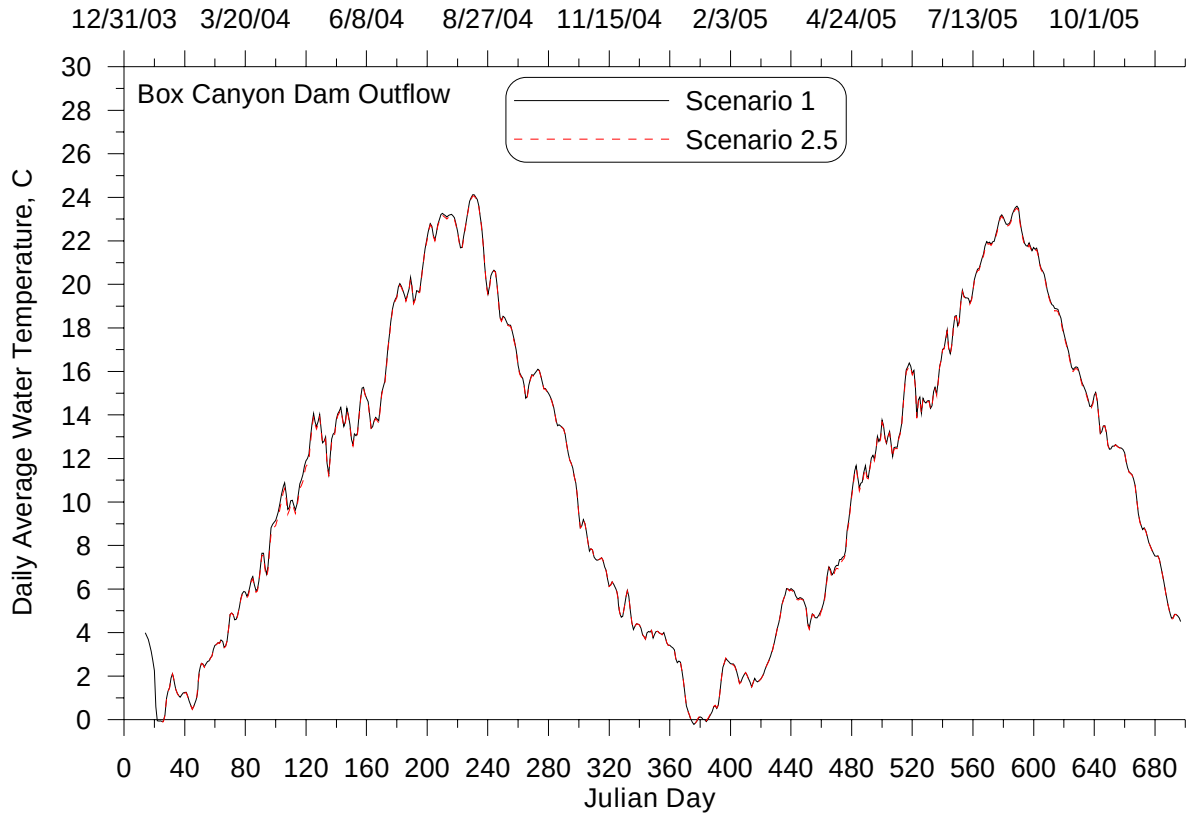

Figure 54. Comparison of Box Canyon Dam average daily outflow temperatures between the existing conditions scenario (1) and the PNV temperatures for tributaries scenario (2.5).

Table 11: Statistical significance in daily average temperature time series results between the Existing Conditions with the PNV temperatures for tributaries scenario (2.5) and Existing Conditions (1) Scenarios.

River Mile, Model Location	P-value	Result
River Mile 87.7 (Model Segment 17)	0.000	Model results between scenarios are the same, i.e. no difference
River Mile 72.4 (Model Segment 115)	0.000	Model results between scenarios are the same, i.e. no difference
River Mile 69.8 (Model Segment 132)	0.001	Model results between scenarios are the same, i.e. no difference
River Mile 63.7 (Model Segment 171)	0.114	Model results between scenarios are similar
River Mile 61.2 (Model Segment 187	0.110	Model results between scenarios are similar
River Mile 43.7 (Model Segment 300)	0.104	Model results between scenarios are similar
River Mile 34.6 (Model Segment next to dam site)	0.103	Model results between scenarios are similar
River Mile 34.5 (Box Canyon Dam Outlet)	0.103	Model results between scenarios are similar

Daily Maximum Temperatures

The daily maximum temperatures of the existing condition scenario 1 and the PNV temperatures for tributaries are plotted in Figure 55 through Figure 62. P value statistics for daily maximum temperature comparing scenario 2.5 and scenario 1 are listed in Table 12. The model predictions of the scenarios were very similar, and the P value statistics indicated that the scenario predictions were small.

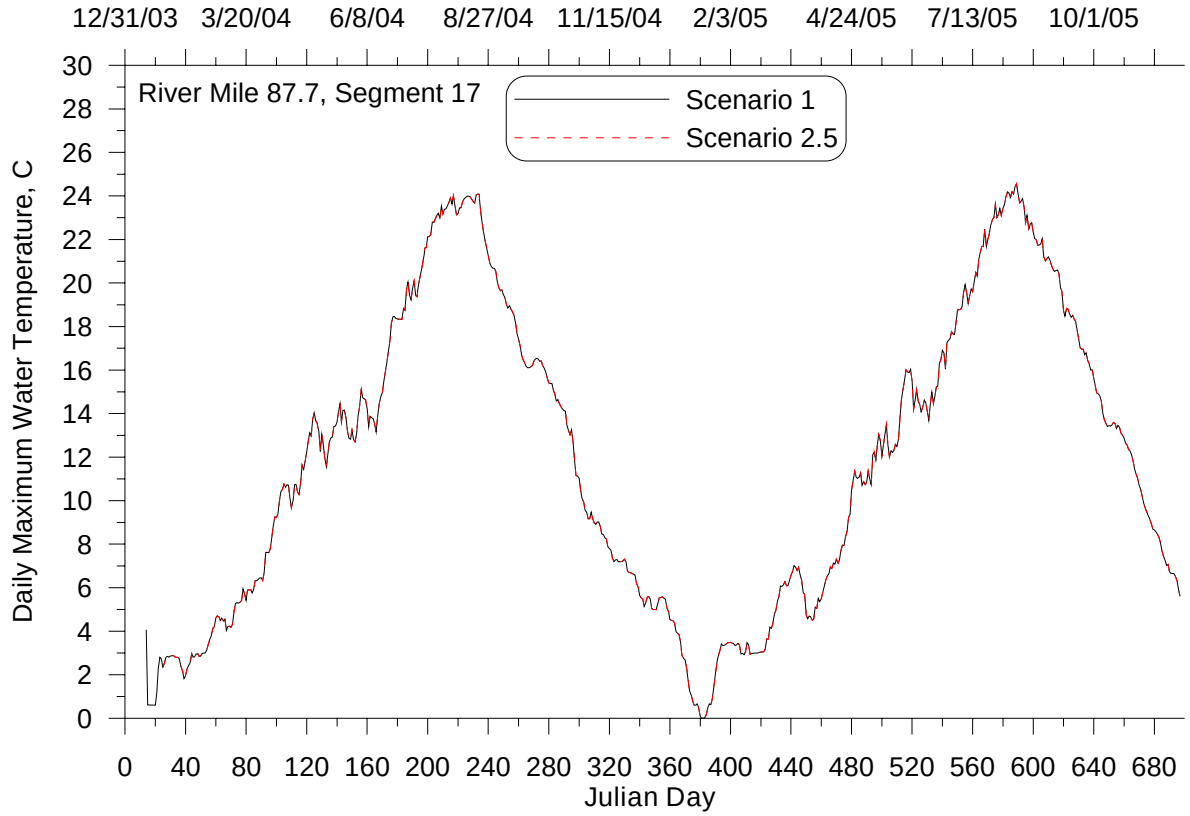

Figure 55. Comparison of segment 17 (RM 87.7) daily maximum water temperatures of the PNV temperatures for non-point sources scenario 2.5 and the existing conditions scenario 1.

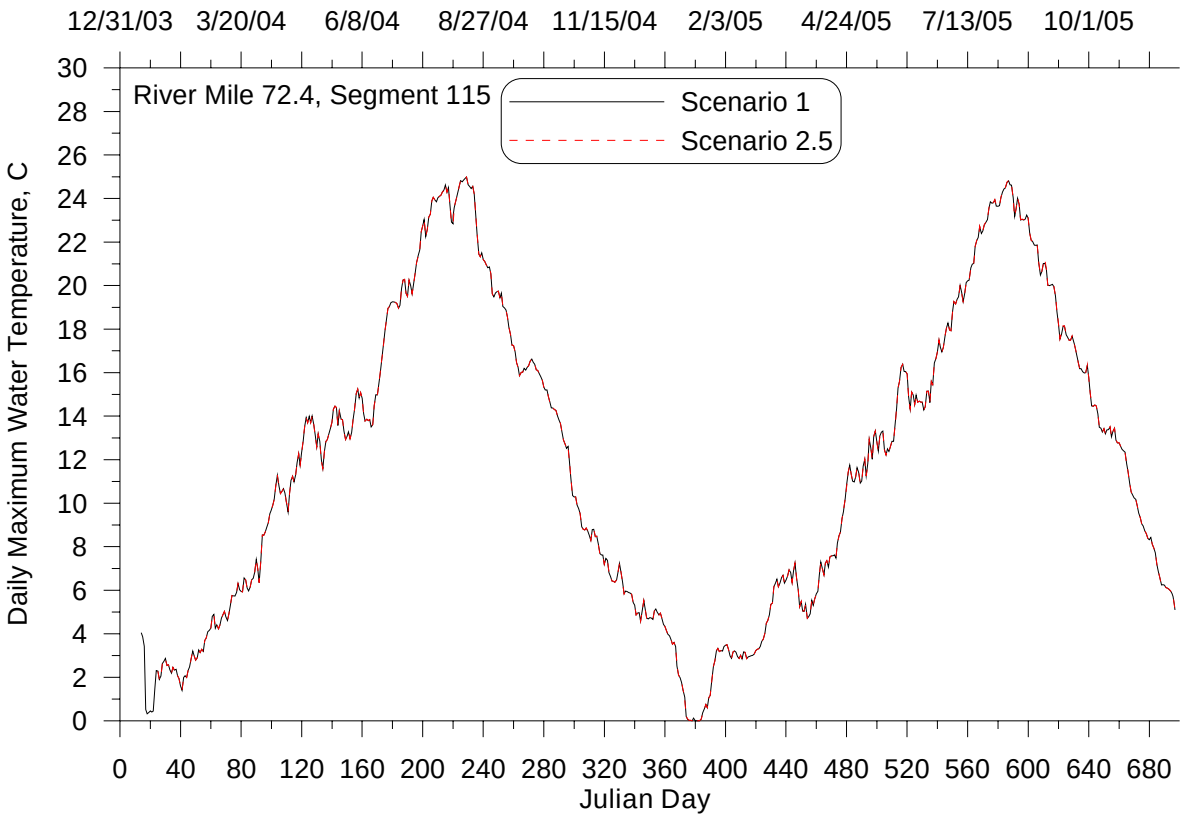

Figure 56. Comparison of segment 115 (RM 72.4) daily maximum water temperatures of the PNV temperatures for non-point sources scenario 2.5 and the existing conditions scenario 1.

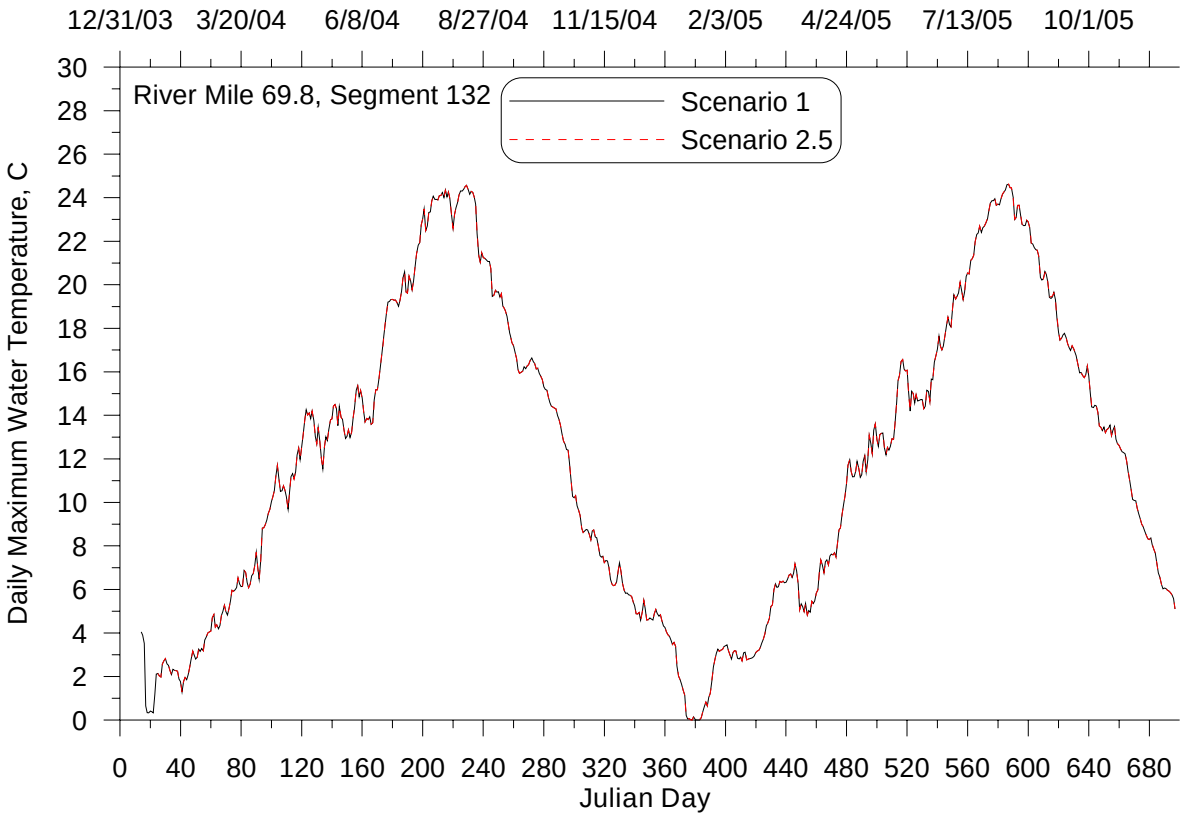

Figure 57. Comparison of segment 132 (RM 69.8) daily maximum water temperatures of the PNV temperatures for non-point sources scenario 2.5 and the existing conditions scenario 1.

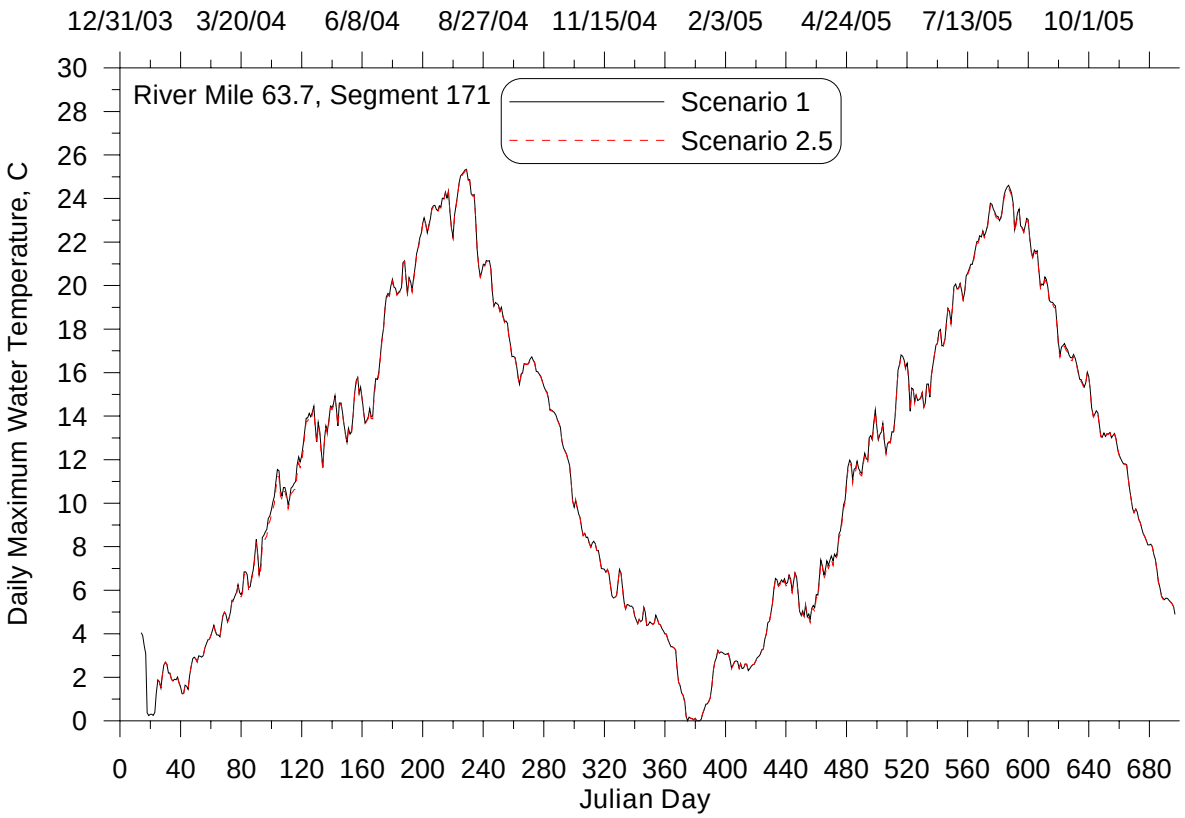

Figure 58. Comparison of segment 171 (RM 63.7) daily maximum water temperatures of the PNV temperatures for non-point sources scenario 2.5 and the existing conditions scenario 1.

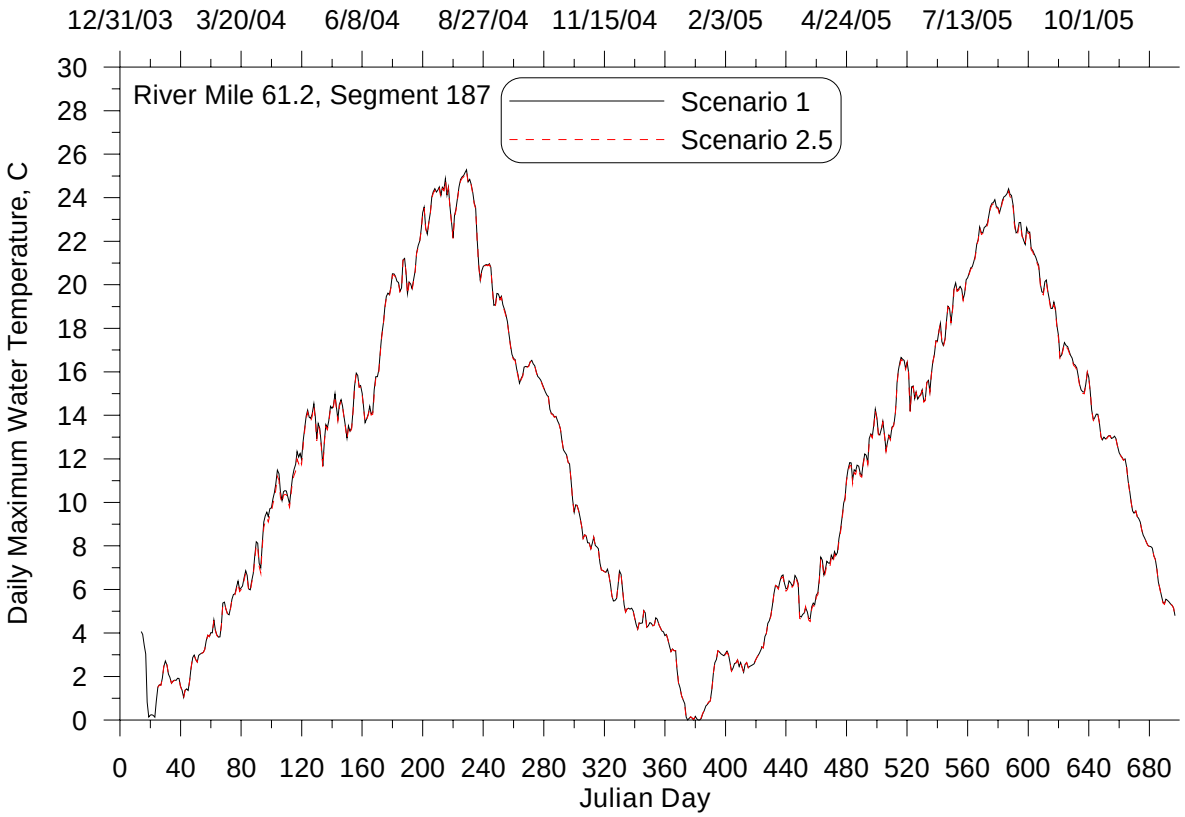

Figure 59. Comparison of segment 187 (RM 61.2) daily maximum water temperatures of the PNV temperatures for non-point sources scenario 2.5 and the existing conditions scenario 1.

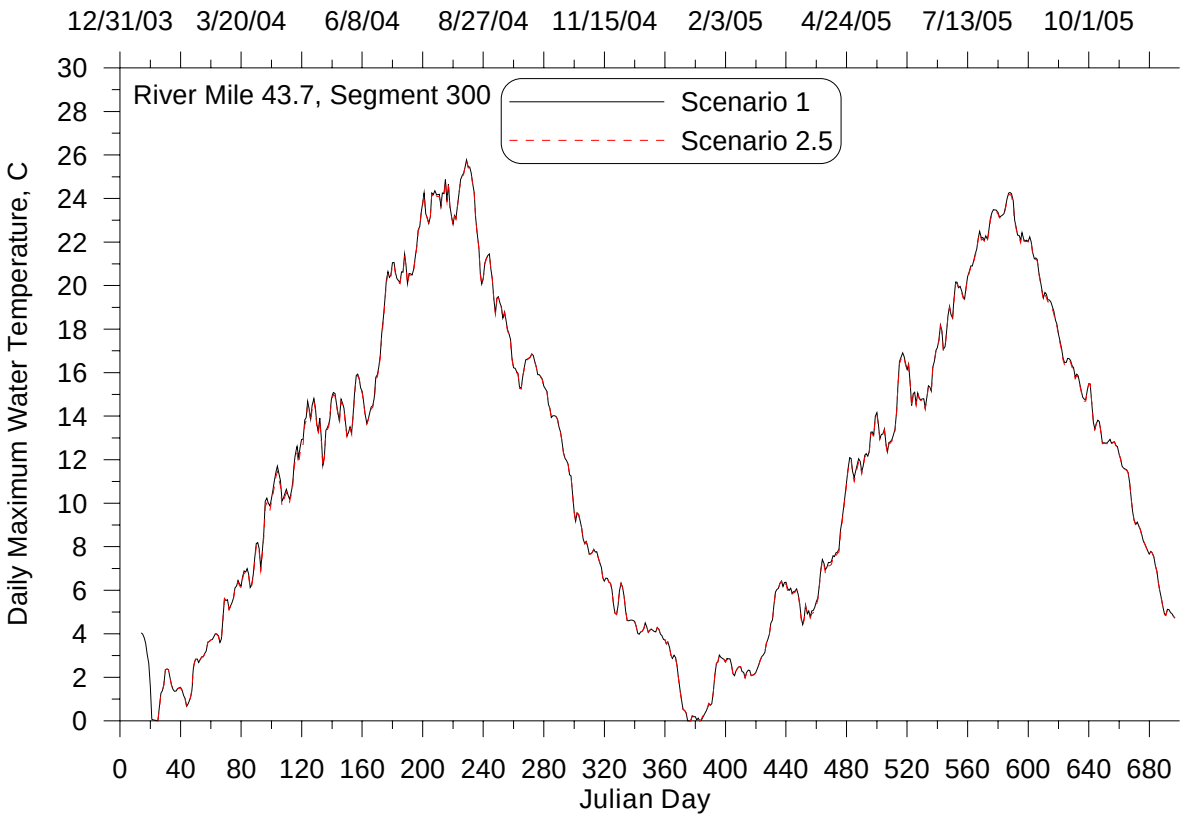

Figure 60. Comparison of segment 300 (RM 43.7) daily maximum water temperatures of the PNV temperatures for non-point sources scenario 2.5 and the existing conditions scenario 1.

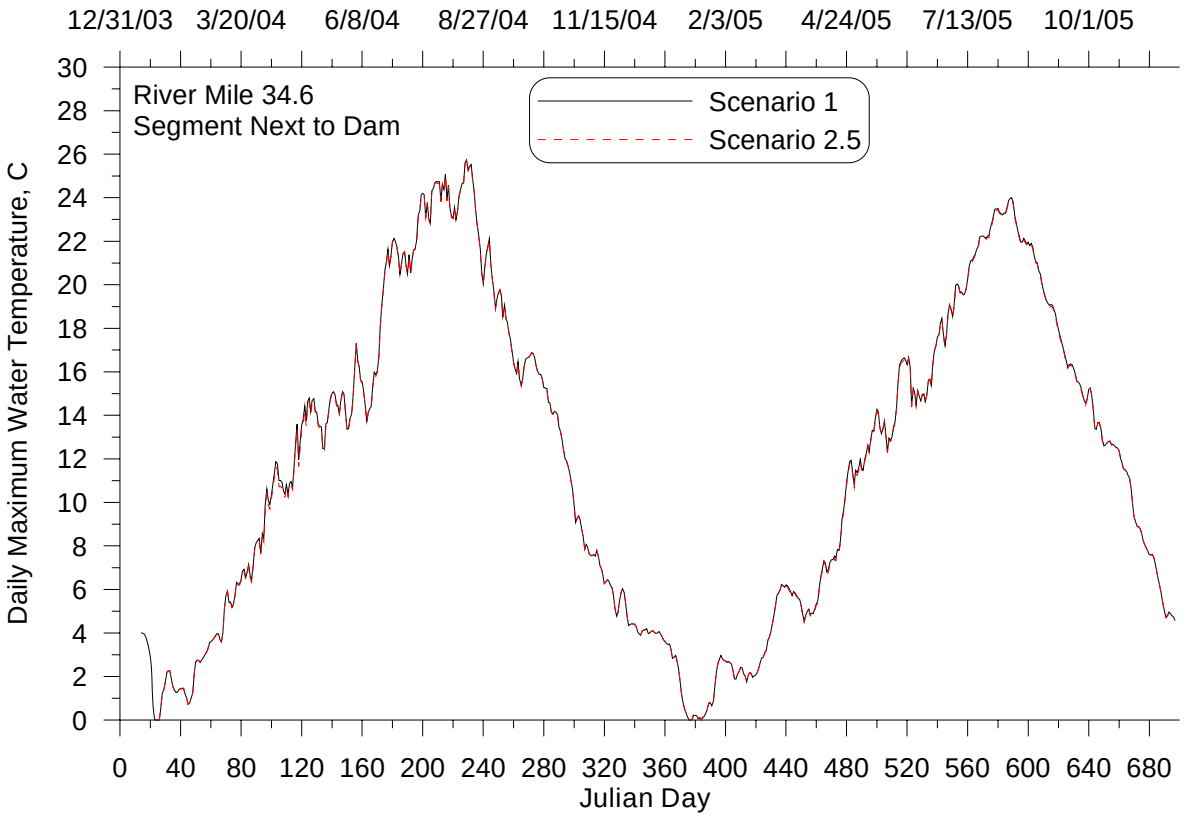

Figure 61. Comparison of model segment adjacent to Box Canyon Dam (segment 358) daily maximum water temperatures of the PNV temperatures for non-point sources scenario 2.5 and the existing conditions scenario 1 at RM 34.6.

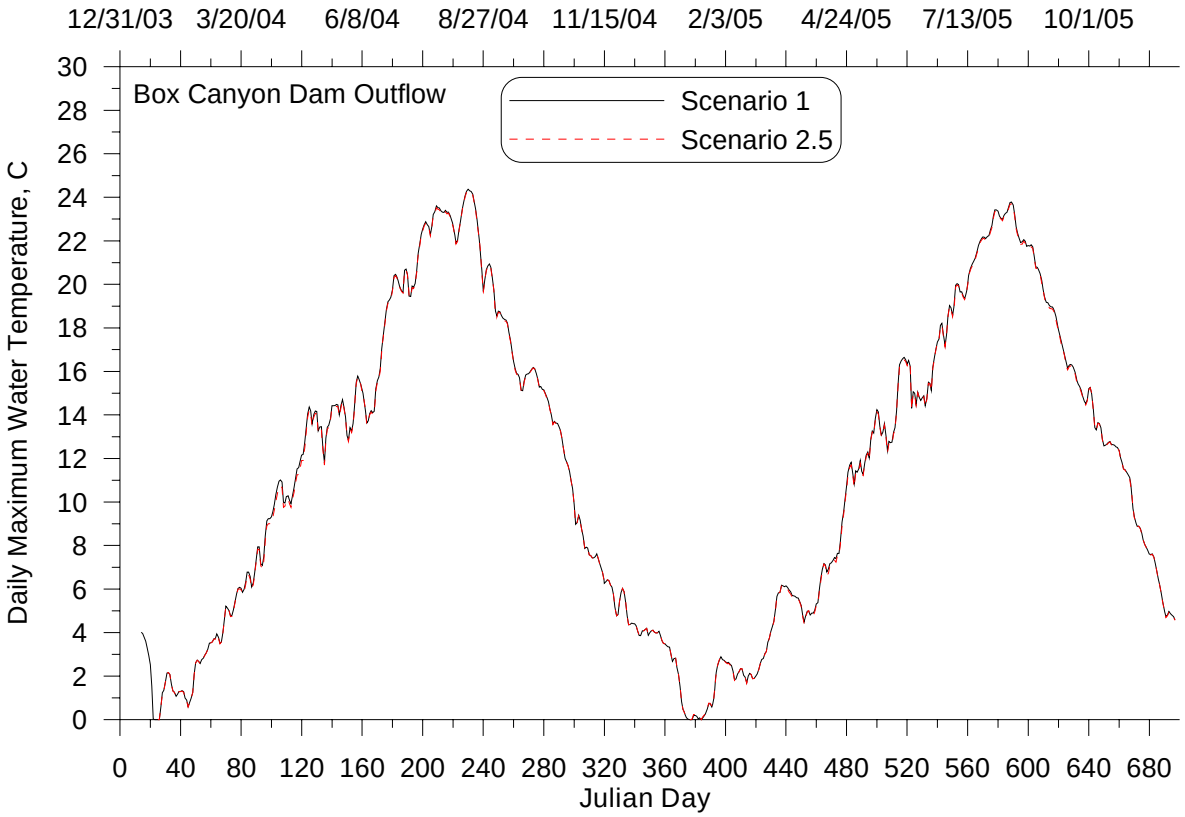

Figure 62. Comparison of Box Canyon Dam maximum daily outflow temperatures between the existing conditions scenario (1) and the PNV temperatures for tributaries scenario (2.5).

Table 12: Statistical significance in daily maximum time series results between the PNV temperatures for tributaries (2.5) and Existing Conditions (1) Scenarios.

River Mile, Model Location	P-value	Result
River Mile 87.7 (Model Segment 17)	0.000	Model results between scenarios are the same, i.e. no difference
River Mile 72.4 (Model Segment 115)	0.001	Model results between scenarios are the same, i.e. no difference
River Mile 69.8 (Model Segment 132)	0.000	Model results between scenarios are the same, i.e. no difference
River Mile 63.7 (Model Segment 171)	0.114	Model results between scenarios are similar
River Mile 61.2 (Model Segment 187	0.102	Model results between scenarios are similar
River Mile 43.7 (Model Segment 300)	0.099	Model results between scenarios are the same, i.e. no difference
River Mile 34.6 (Model Segment next to dam site)	0.094	Model results between scenarios are the same, i.e. no difference
River Mile 34.5 (Box Canyon Dam Outlet)	0.103	Model results between scenarios are similar

Longitudinal Profiles

The longitudinal profiles (May 7th and August 24th, 2004) of daily average temperature for the existing scenario 1 and the PNV temperatures for tributaries scenario 2.5 are plotted in Figure 63 and Figure 64. The longitudinal profiles of daily maximum temperature for these dates are plotted in Figure 65 and Figure 66. P value statistics comparing the similarity of the longitudinal profiles are listed in Table 13 and Table 14. The P values indicated that there was a difference between the scenarios for these dates. Scenario 2.5 predicted cooler temperatures, indicating that the cooler PNV temperatures of the tributaries resulted affected river temperatures.

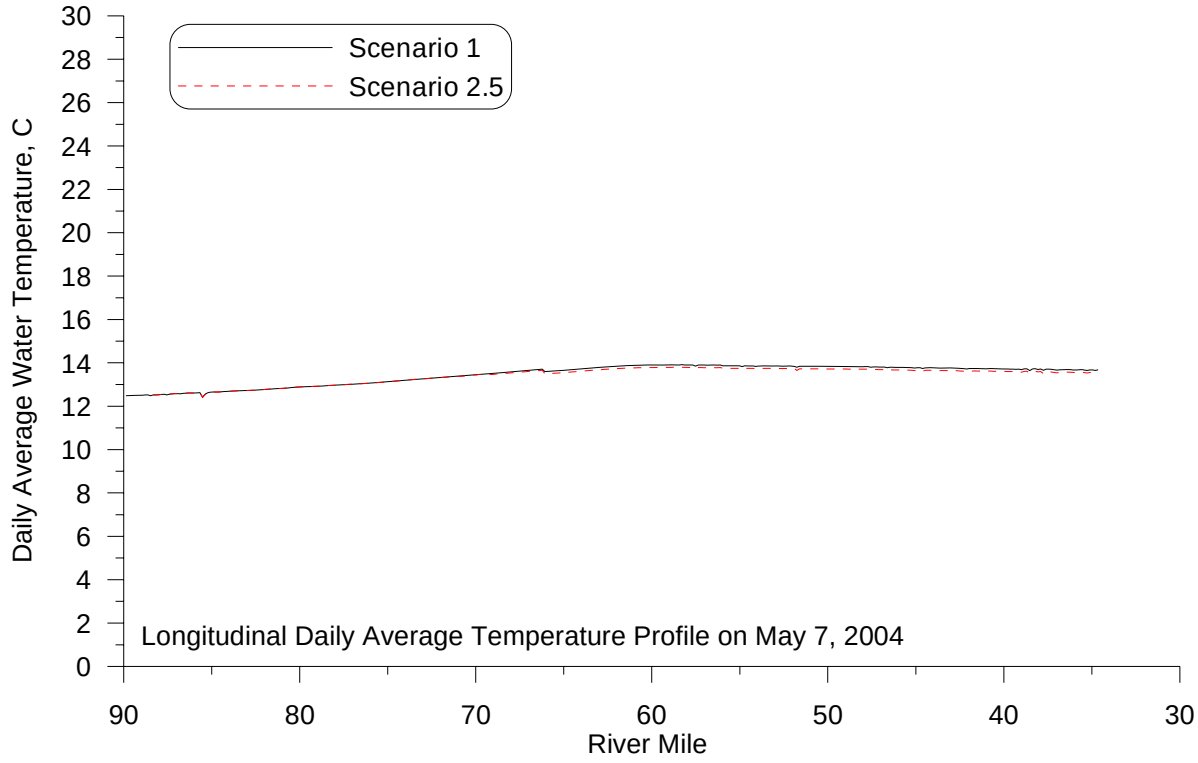

Figure 63. Comparison of longitudinal daily average temperature profile on May 7, 2004 between the PNV temperatures for tributaries scenario 2.5 and the existing conditions scenario 1.

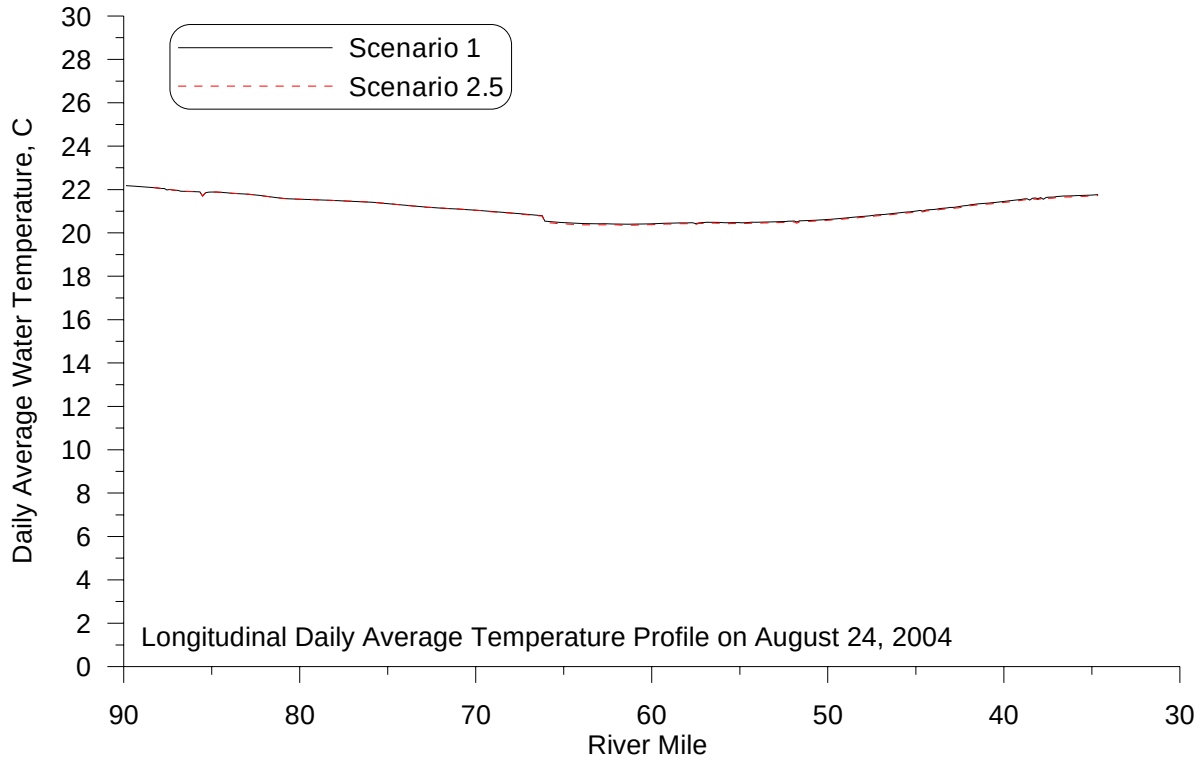

Figure 64. Comparison of longitudinal daily average temperature profile on August 24, 2004 between the PNV temperatures for tributaries scenario 2.5 and the existing conditions scenario 1.

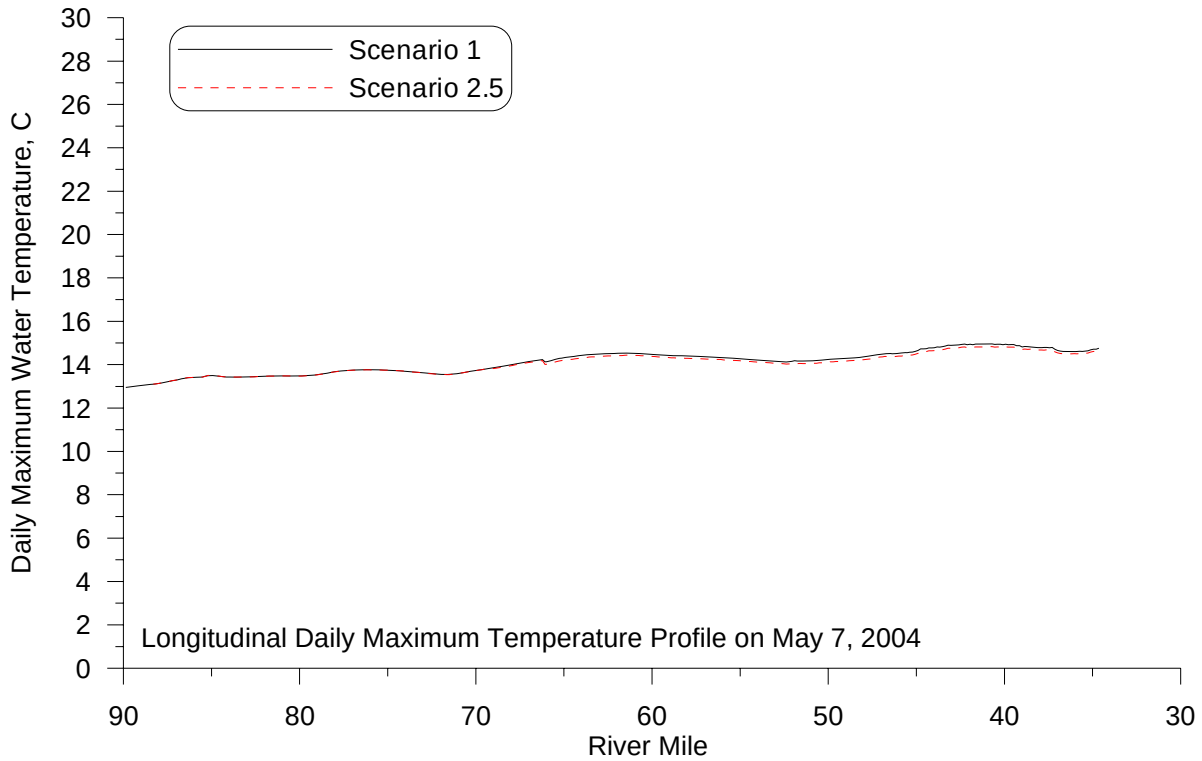

Figure 65. Comparison of longitudinal daily maximum temperature profile on May 7, 2004 between the PNV temperatures for tributaries scenario 2.5 and the existing conditions scenario 1.

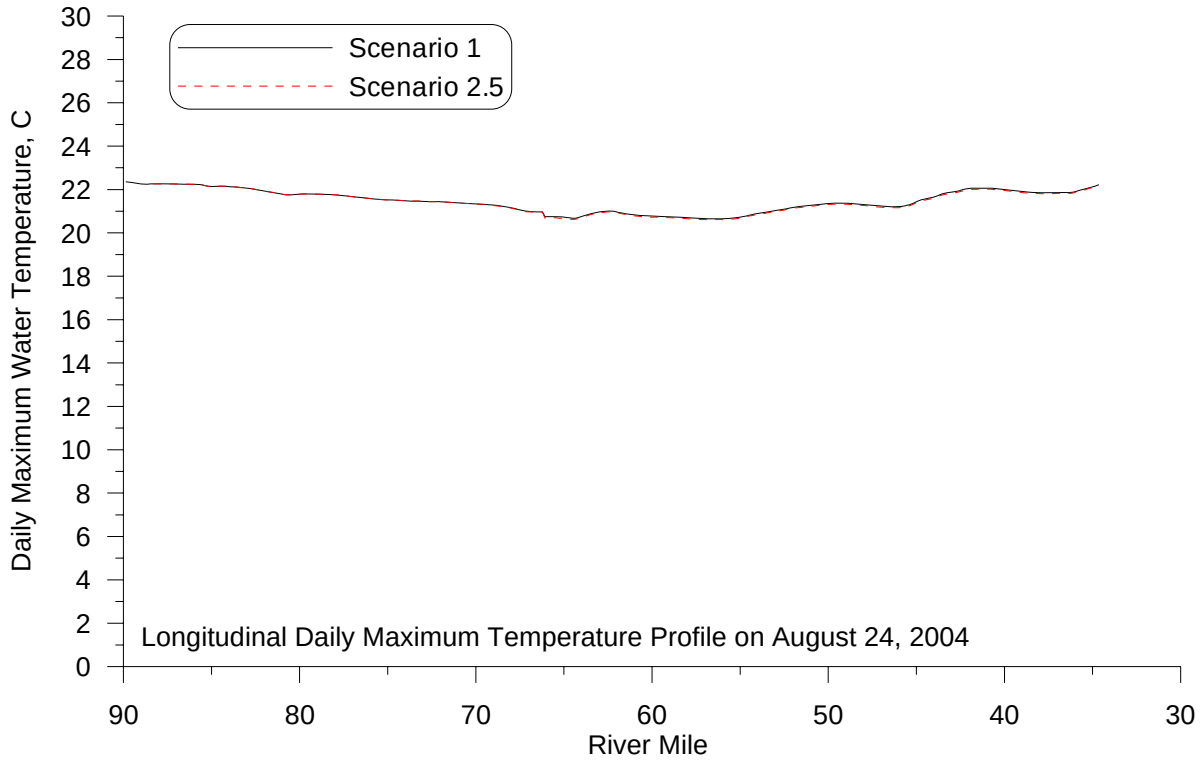

Figure 66. Comparison of longitudinal daily maximum temperature profile on August 24, 2004 between the PNV temperatures for tributaries scenario 2.5 and the existing conditions scenario 1.

Table 13: Statistical significance of daily average temperature in the longitudinal profiles on May 7th, 2004 and August 24th, 2004 between the PNV temperatures for tributaries (2.5) and Existing Conditions (1) Scenarios.

Scenario 1 and Scenario 2.5 Comparison	P-value	Result
May 7th daily average temperature	0.965	Model results between scenarios are not the same
August 24th daily average temperature	0.484	Model results between scenarios are not the same

Table 14: Statistical significance of daily maximum temperature in the longitudinal profiles on May 7th, 2004 and August 24th, 2004 between the PNV temperatures for tributaries (2.5) and Existing Conditions (1) Scenarios.

Scenario 1 and Scenario 2.5 Comparison	P-value	Result
May 7th daily maximum temperature	0.928	Model results between scenarios are not the same
August 24th daily maximum temperature	0.501	Model results between scenarios are not the same

Evaluation of Box Canyon Dam Compared to Natural Conditions

The cumulative thermal loading contributions to the Pend Oreille River from Box Canyon Dam are evaluated by comparing results from model scenario 3 (impounded with no point sources, no non-point sources, no Albeni Falls dam and potential natural vegetation) and scenario 8 (natural conditions with no point sources, no non-point sources, no dams and potential natural vegetation).

Time Series Plots

Daily Average Temperatures

Plotted in Figure 67 through Figure 74 are the daily average temperatures of the impounded scenario 3 and the natural conditions scenario 8. The P values comparing these simulations are listed in Table 15. The P value test indicated there was no difference between the scenarios in daily average temperature, but closer inspection shows that the unimpounded scenario 8 was warmer in the spring and cooler in the fall at sites closer to the dam.

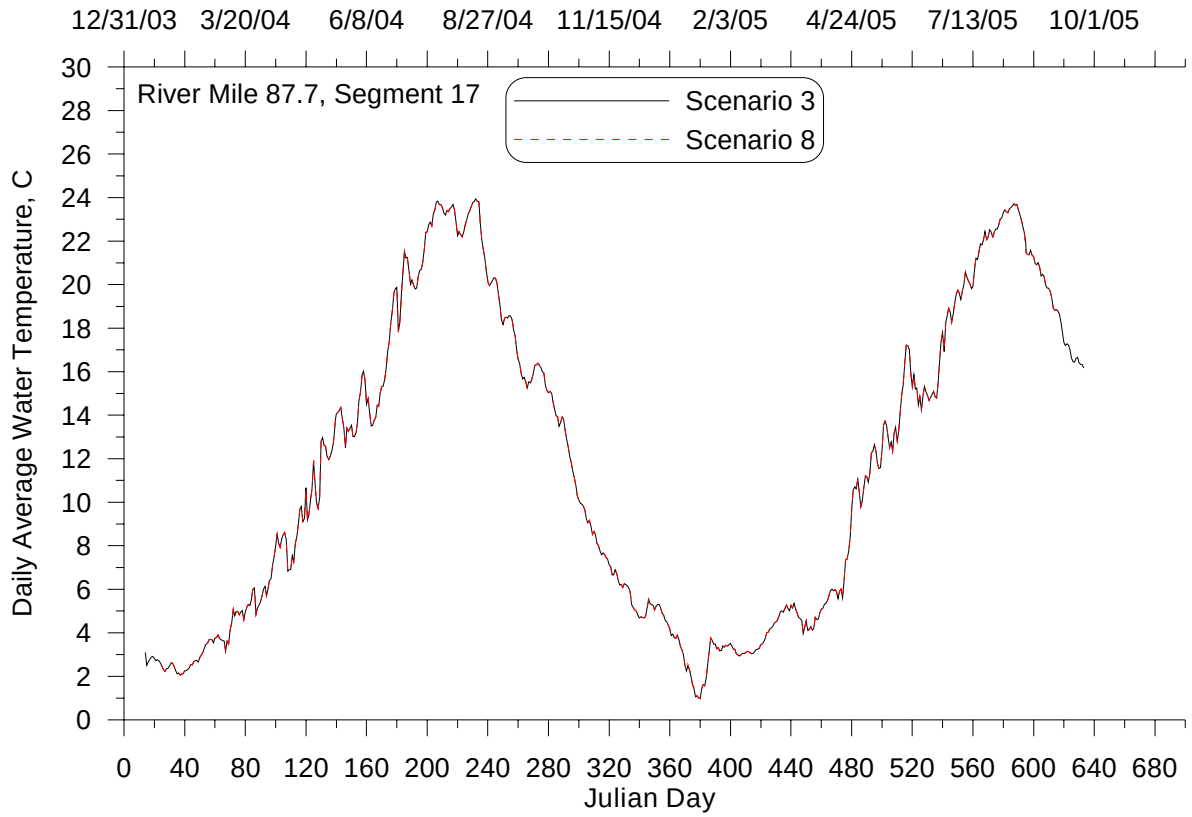

Figure 67. Comparison of segment 17 (RM 87.7) daily average water temperatures of the impounded scenario 3 and the natural conditions scenario 8.

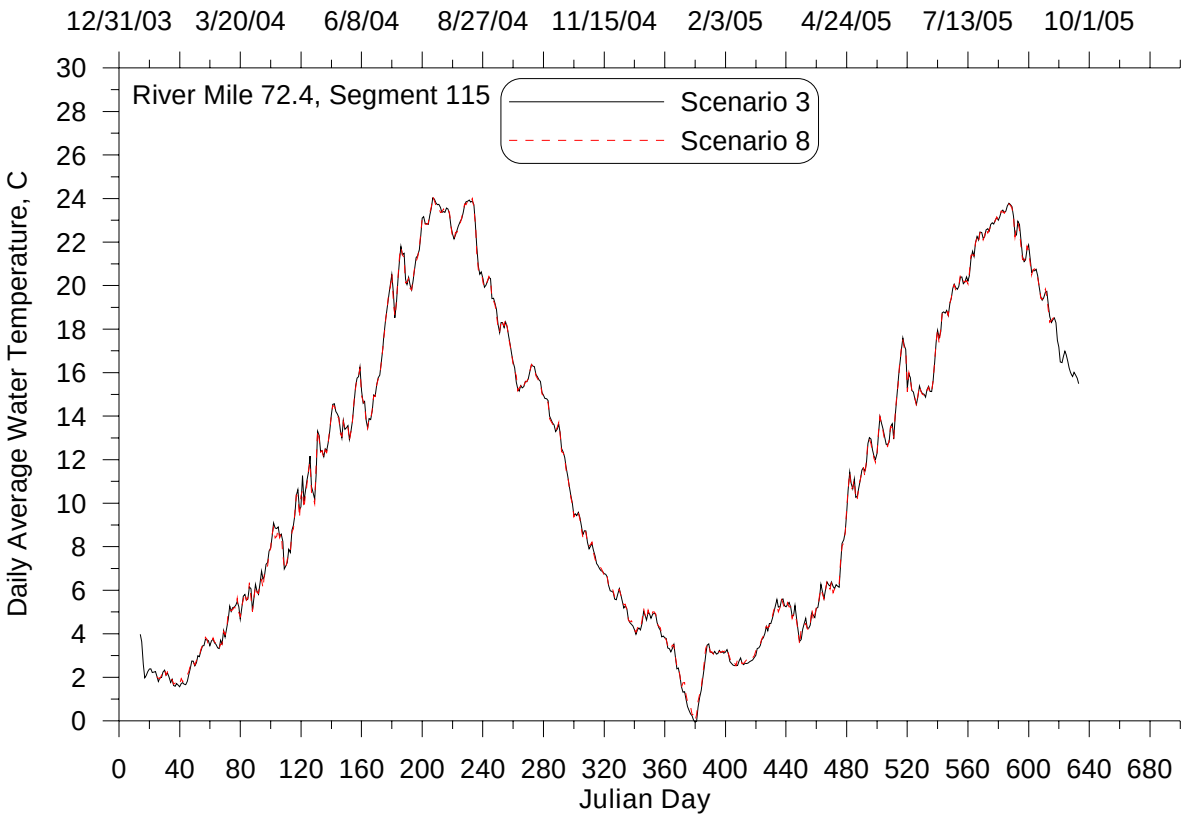

Figure 68. Comparison of segment 115 (RM 72.4) daily average water temperatures of the impounded scenario 3 and the natural conditions scenario 8.

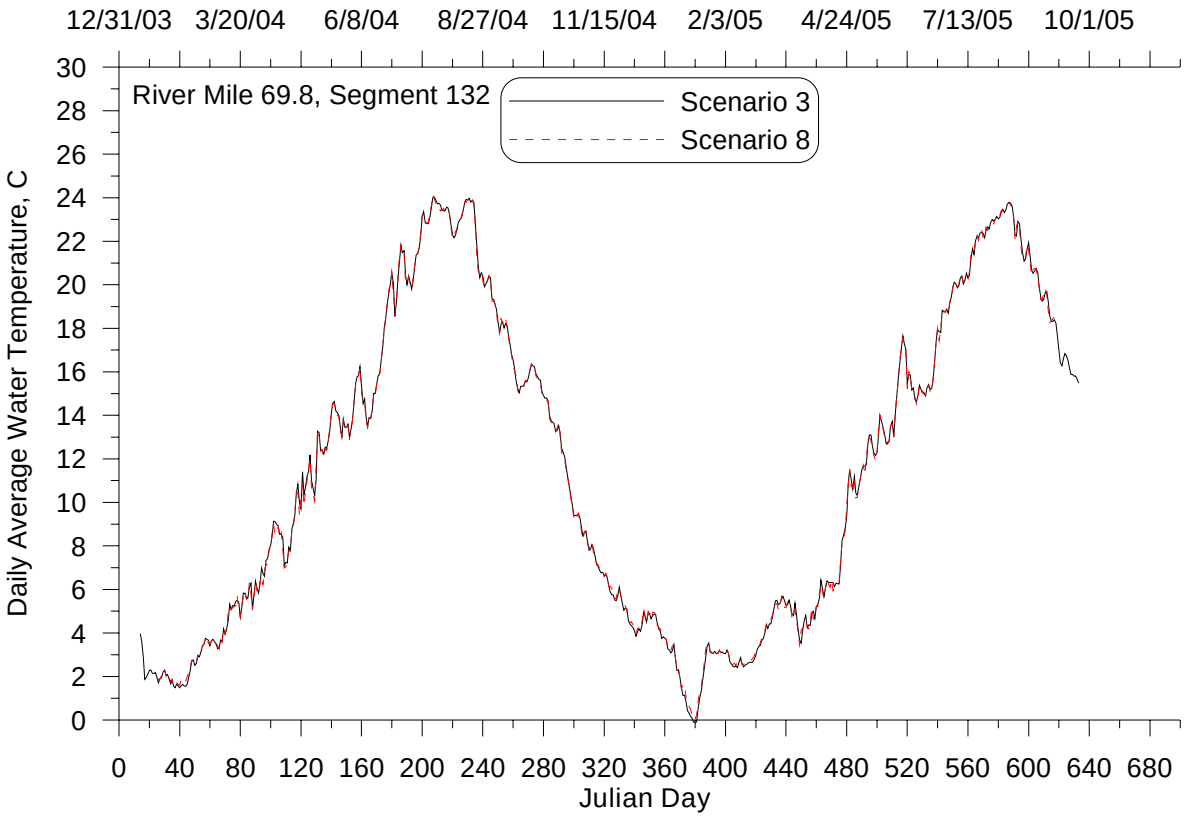

Figure 69. Comparison of segment 132 (RM 69.8) daily average water temperatures of the impounded scenario 3 and the natural conditions scenario 8.

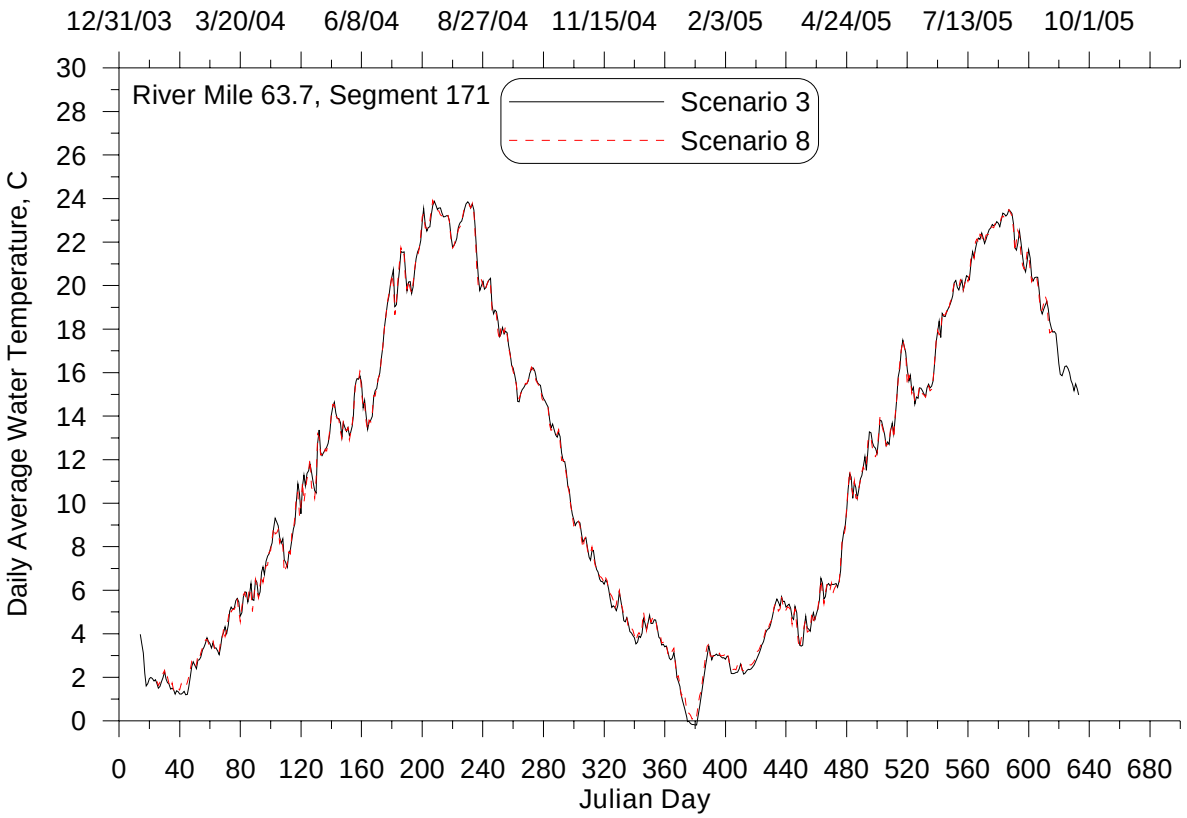

Figure 70. Comparison of segment 171 (RM 63.7) daily average water temperatures of the impounded scenario 3 and the natural conditions scenario 8.

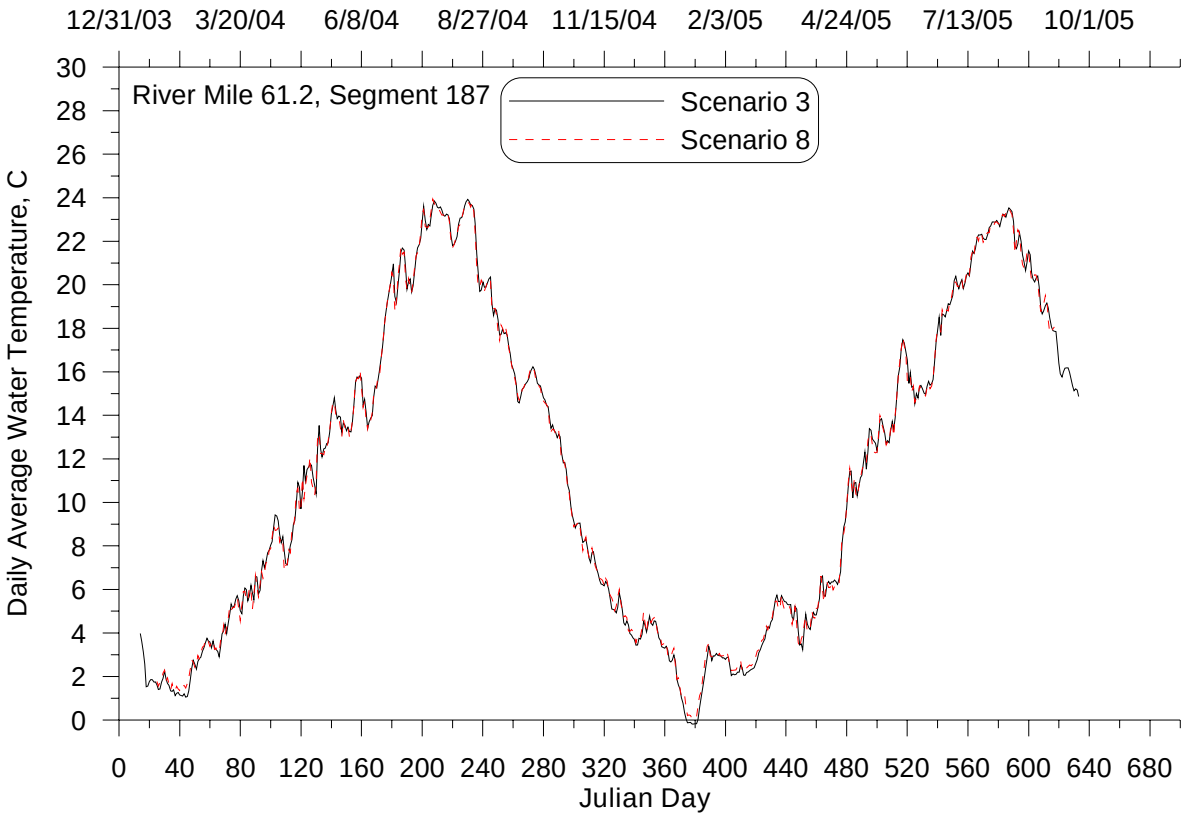

Figure 71. Comparison of segment 187 (RM 61.2) daily average water temperatures of the impounded scenario 3 and the natural conditions scenario 8.

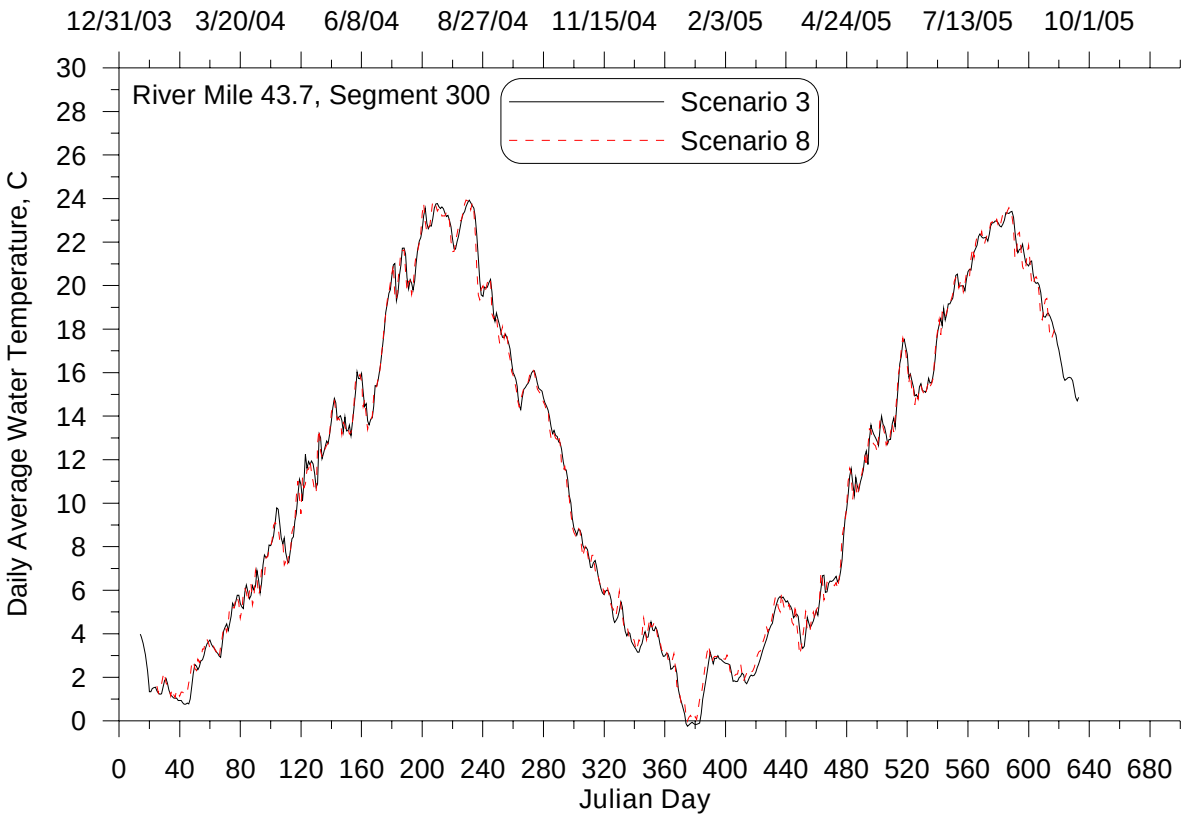

Figure 72. Comparison of segment 300 (RM 43.7) daily average water temperatures of the impounded scenario 3 and the natural conditions scenario 8.

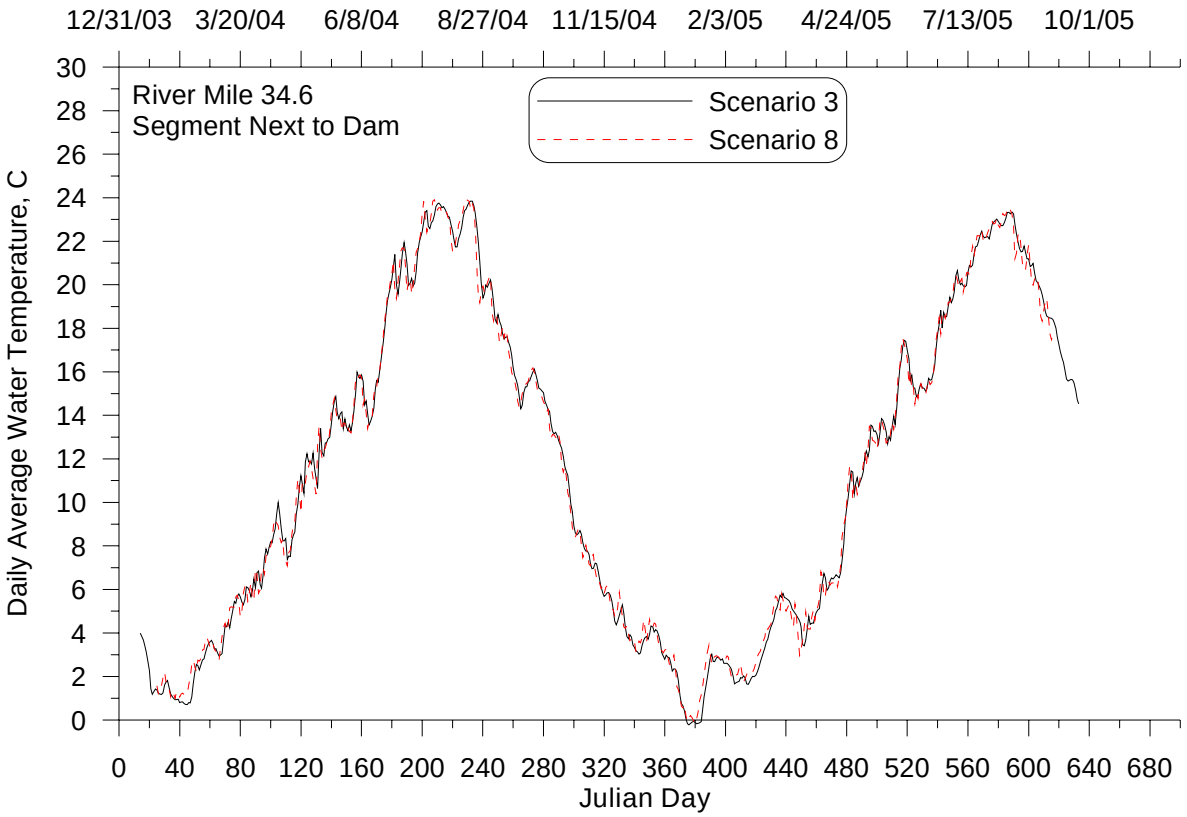

Figure 73. Comparison of model segment adjacent to Box Canyon Dam (segment 358 for impounded, segment 360 for unimpounded) daily average water temperatures of the impounded scenario 3 and the natural conditions scenario 8 at RM 34.6.

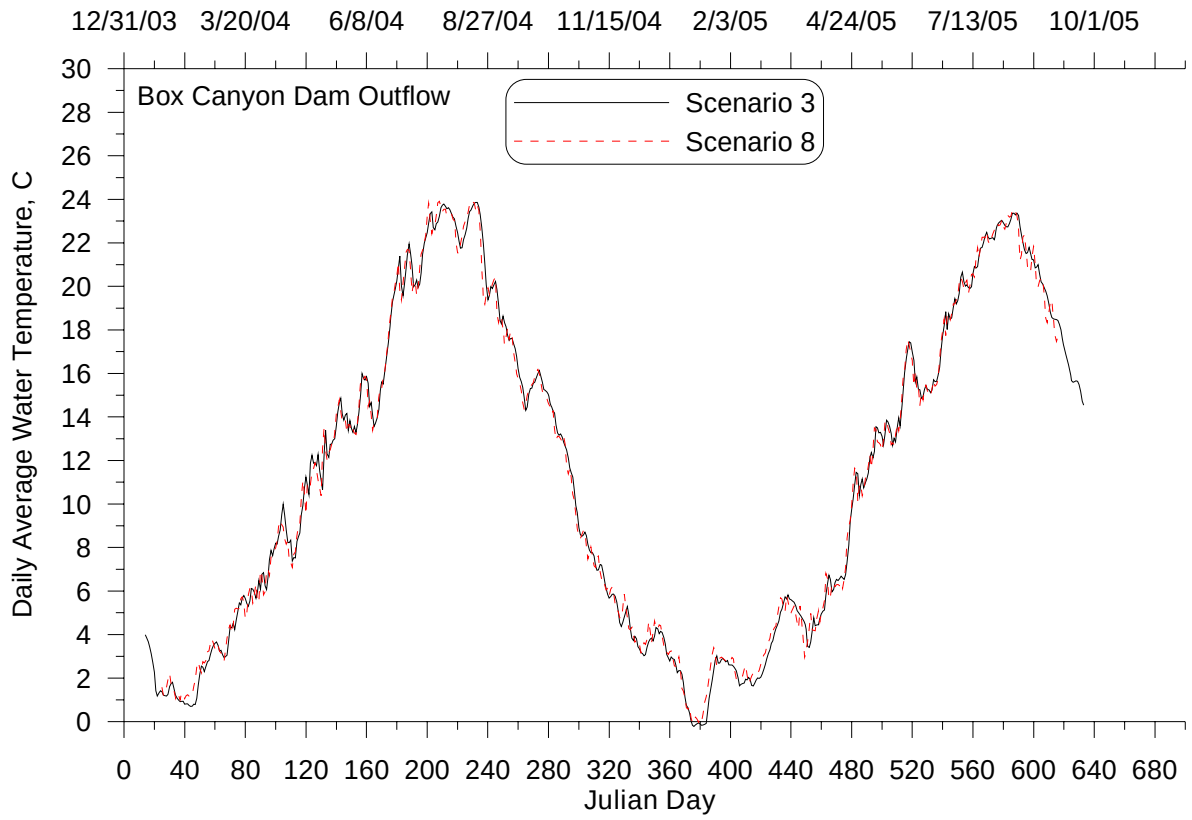

Figure 74. Comparison of Box Canyon Dam daily average outflow temperatures of the impounded scenario 3 and the natural conditions scenario 8.

Table 15: Statistical significance in daily average temperature time series results between the impounded scenario 3 and natural conditions scenario 8.

River Mile, Model Location	P-value	Result
River Mile 87.7 (Model Segment 17)	0.000	Model results between scenarios are the same, i.e. no difference
River Mile 72.4 (Model Segment 115)	0.011	Model results between scenarios are the same, i.e. no difference
River Mile 69.8 (Model Segment 132)	0.014	Model results between scenarios are the same, i.e. no difference
River Mile 63.7 (Model Segment 171)	0.011	Model results between scenarios are the same, i.e. no difference
River Mile 61.2 (Model Segment 187	0.010	Model results between scenarios are the same, i.e. no difference
River Mile 43.7 (Model Segment 300)	0.024	Model results between scenarios are the same, i.e. no difference
River Mile 34.6 (Model Segment next to dam site)	0.011	Model results between scenarios are the same, i.e. no difference
River Mile 34.5 (Box Canyon Dam Outlet)	0.002	Model results between scenarios are the same, i.e. no difference

Daily Maximum Temperatures

The daily maximum temperatures of the impounded scenario 3 and the natural conditions scenario 8 are shown in Figure 75 through Figure 82. Table 16 lists the P value statistics for daily maximum temperatures comparing scenario 3 and scenario 8. Scenario 3 and scenario 8 predicted statistically different daily maximums depending on location. The un-impounded scenario (8) predicted warmer or cooler temperatures depending on location. Near Box Canyon dam, the un-impounded scenario was actually cooler because the maximum temperatures of the impounded scenario 3 were enhanced by stratification. At the dam outflow however, the impounded scenario predicted cooler temperatures because the dam withdrawal removed water from different depths, including deeper layers where water was cooler.

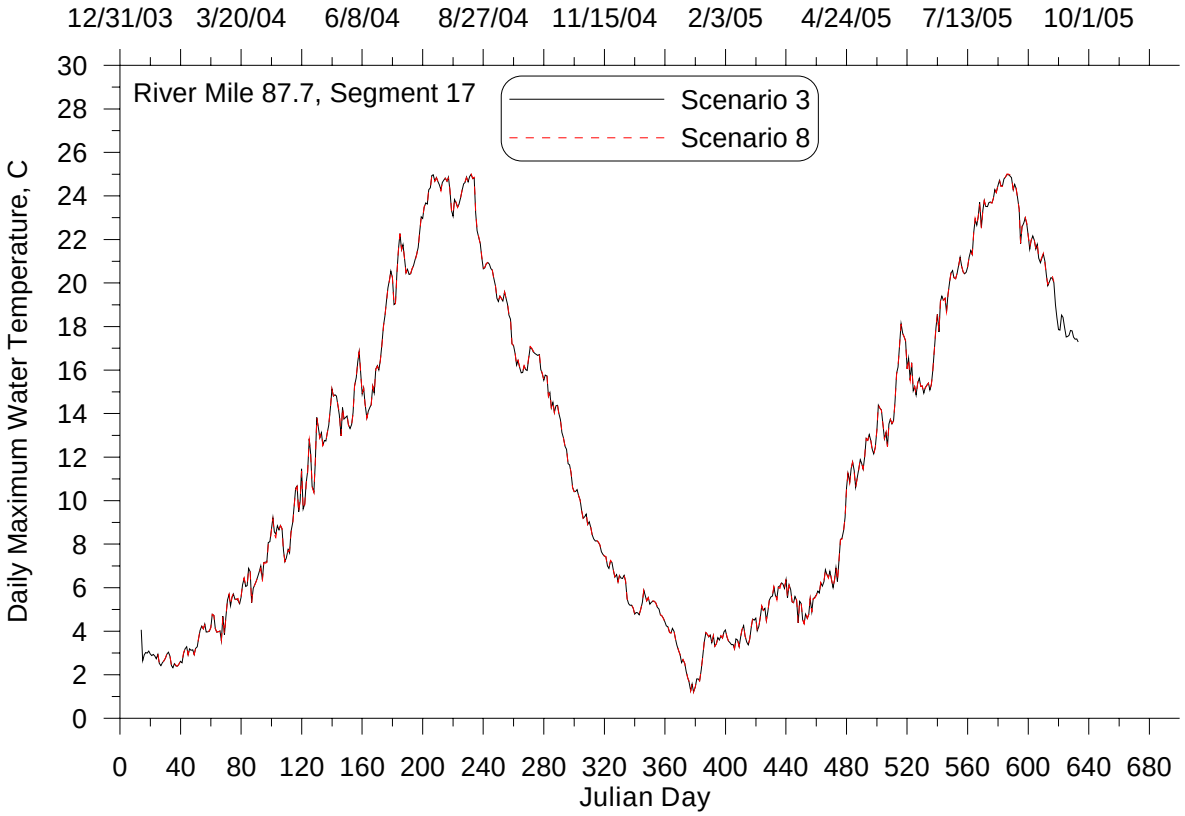

Figure 75. Comparison of segment 17 (RM 87.7) daily maximum water temperatures of the impounded scenario 3 and the natural conditions scenario 8.

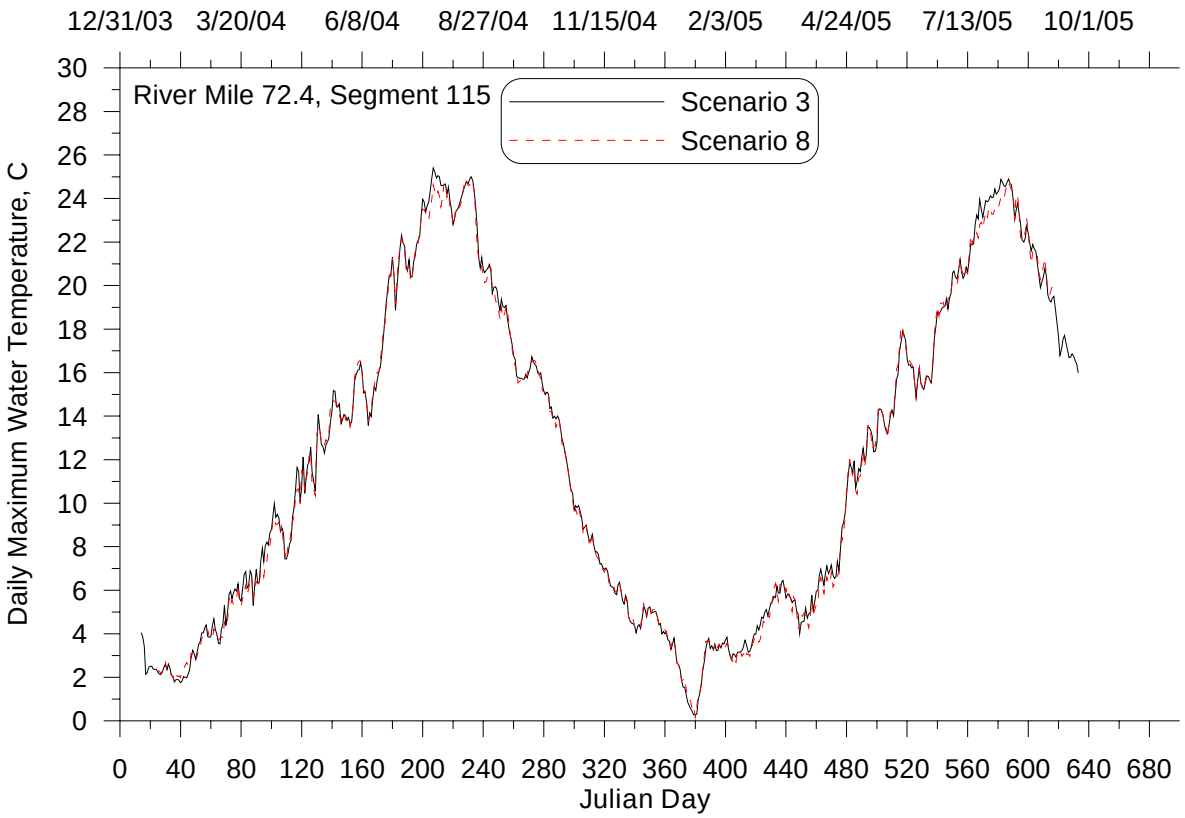

Figure 76. Comparison of segment 115 (RM 72.4) daily maximum water temperatures of the impounded scenario 3 and the natural conditions scenario 8.

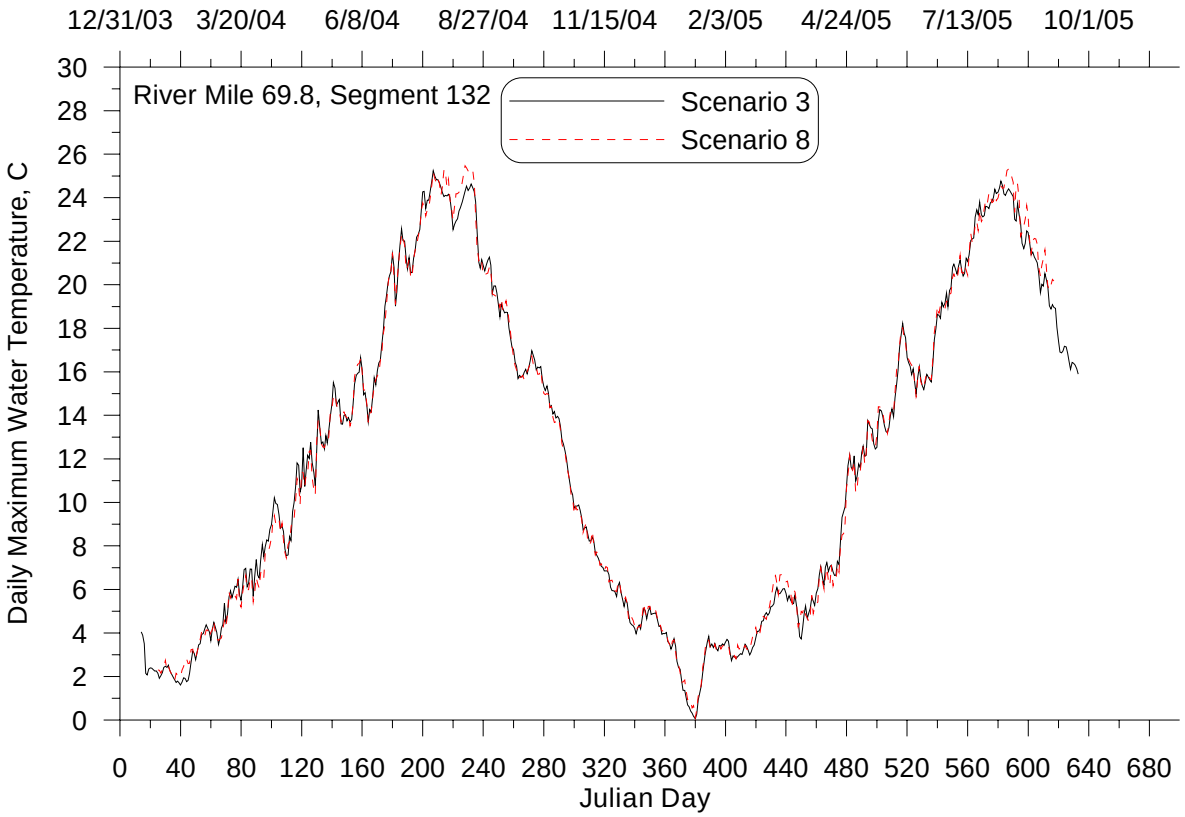

Figure 77. Comparison of segment 132 (RM 69.8) daily maximum water temperatures of the impounded scenario 3 and the natural conditions scenario 8.

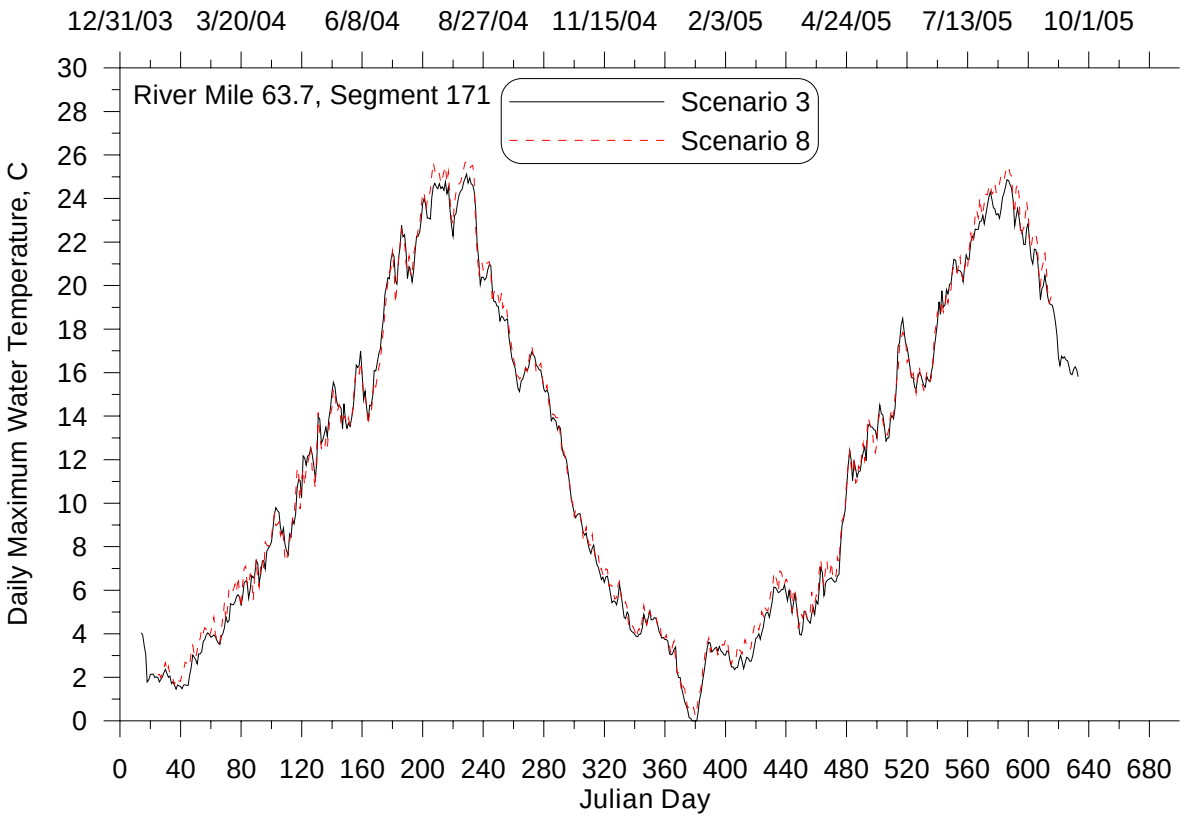

Figure 78. Comparison of segment 171 (RM 63.7) daily maximum water temperatures of the impounded scenario 3 and the natural conditions scenario 8.

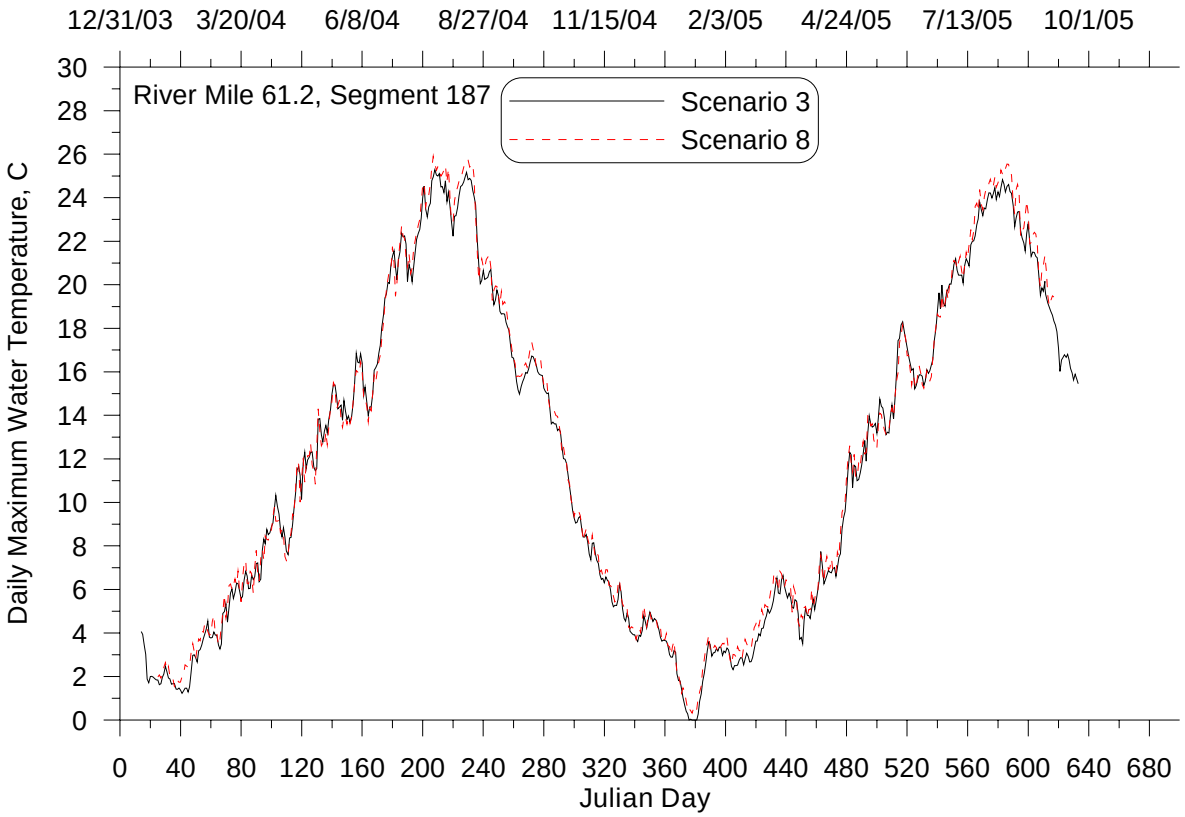

Figure 79. Comparison of segment 187 (RM 61.2) daily maximum water temperatures of the impounded scenario 3 and the natural conditions scenario 8.

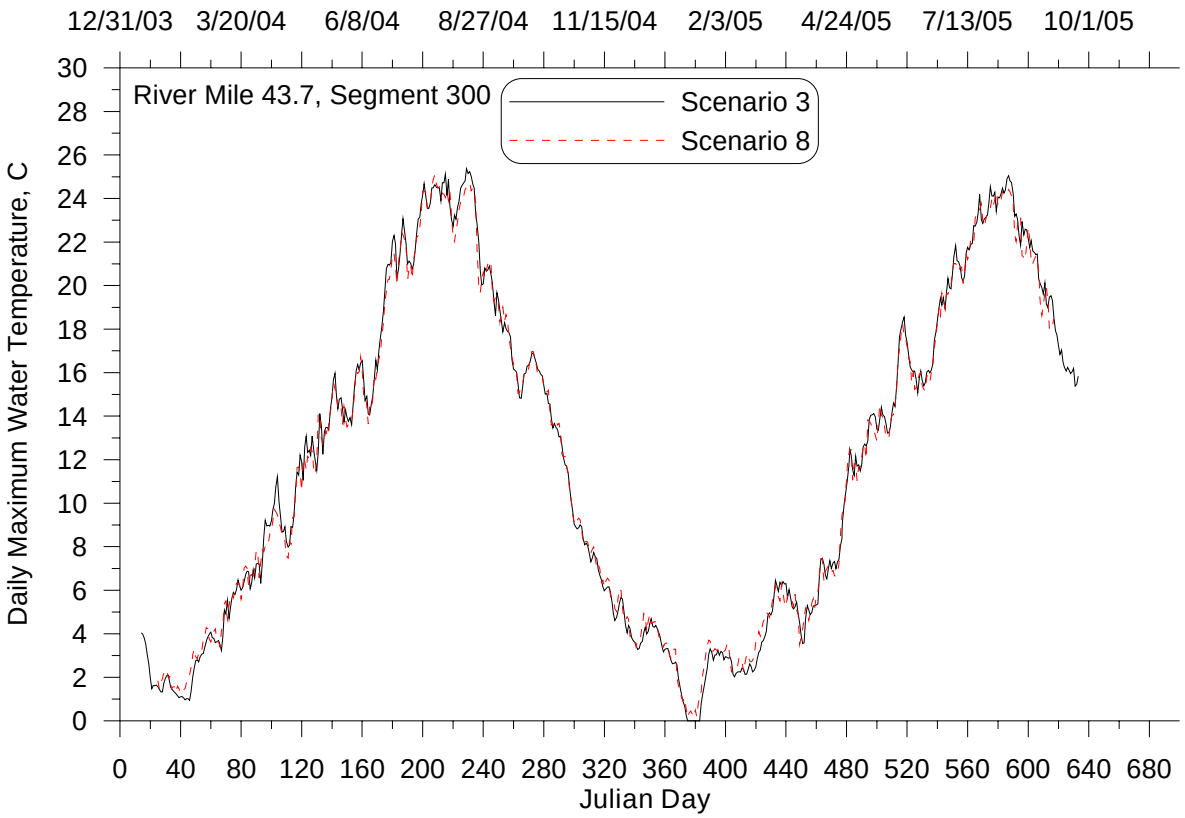

Figure 80. Comparison of segment 300 (RM 43.7) daily maximum water temperatures of the impounded scenario 3 and the natural conditions scenario 8.

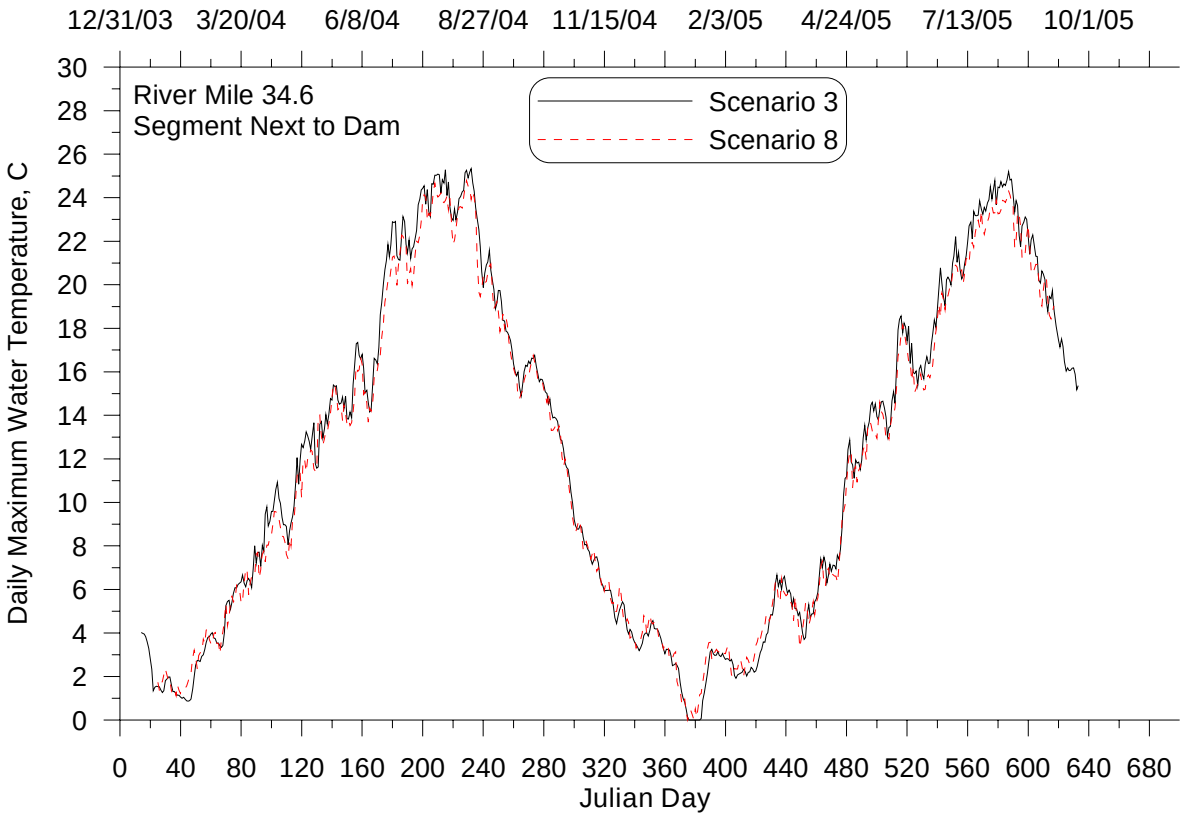

Figure 81. Comparison of model segment adjacent to Box Canyon Dam daily maximum water temperatures for the impounded scenario 3 and the natural conditions scenario 8 at RM 34.6.

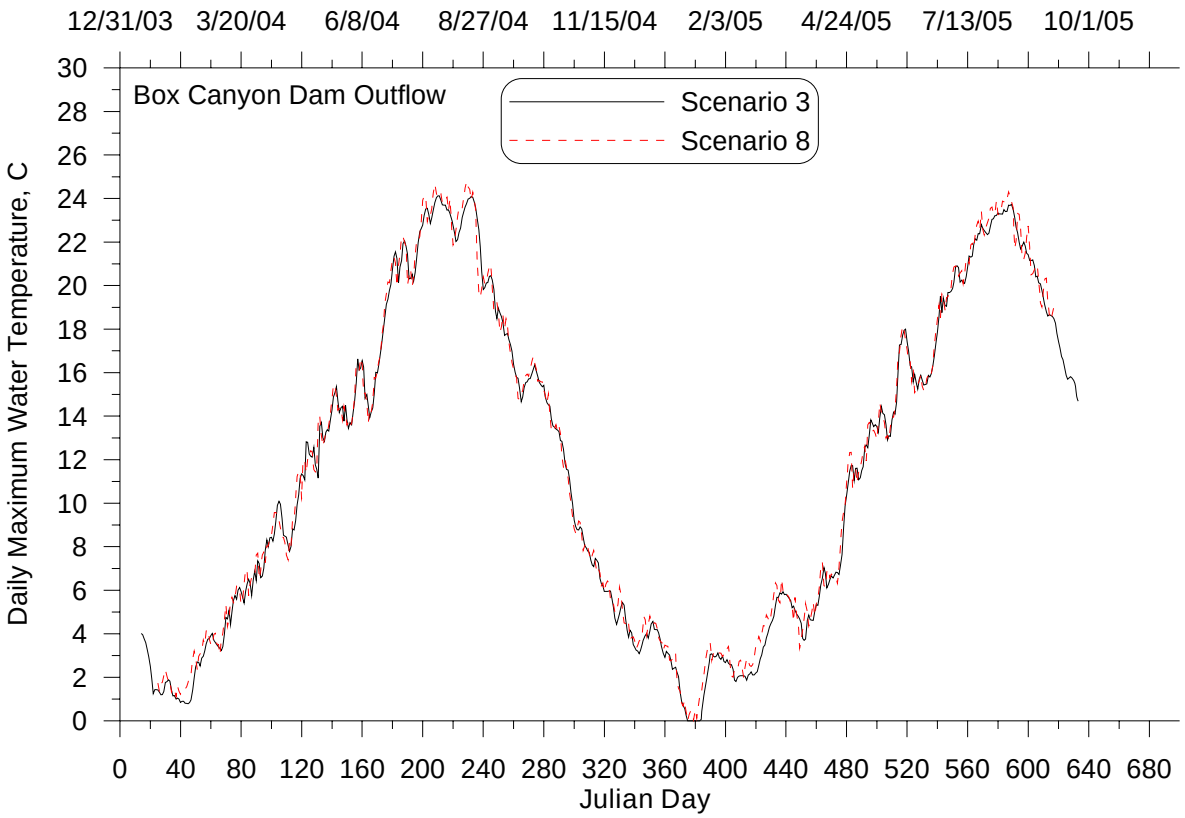

Figure 82. Comparison of Box Canyon Dam daily maximum outflow temperatures of the impounded scenario 3 and the natural conditions scenario 8.

Table 16: Statistical significance in daily maximum time series results between the impounded scenario 3 and the natural conditions scenario 8.

River Mile, Model Location	P-value	Result
River Mile 87.7 (Model Segment 17)	0.002	Model results between scenarios are the same, i.e. no difference
River Mile 72.4 (Model Segment 115)	0.160	Model results between scenarios are similar
River Mile 69.8 (Model Segment 132)	0.050	Model results between scenarios are the same, i.e. no difference
River Mile 63.7 (Model Segment 171)	0.382	Model results between scenarios are not the same
River Mile 61.2 (Model Segment 187	0.428	Model results between scenarios are not the same
River Mile 43.7 (Model Segment 300)	0.044	Model results between scenarios are the same, i.e. no difference
River Mile 34.6 (Model Segment next to dam site)	0.532	Model results between scenarios are not the same
River Mile 34.5 (Box Canyon Dam Outlet)	0.310	Model results between scenarios are not the same

Longitudinal Profiles

The longitudinal profile of daily average temperature of scenario 3 (impounded) and scenario 8 (natural conditions) are plotted in Figure 83 and Figure 84 for May 7 and August 24, 2004, respectively. Figure 85 and Figure 86 plot daily maximum temperature for those dates. The P value statistics for the longitudinal profiles comparing the scenarios are listed in Table 17 and Table 18, and they indicated that

the model predictions were different. The predicted daily maximum temperature of the impounded scenario 8 were warmer because near Box Canyon dam due to stratification resulting in warmer water near the surface.

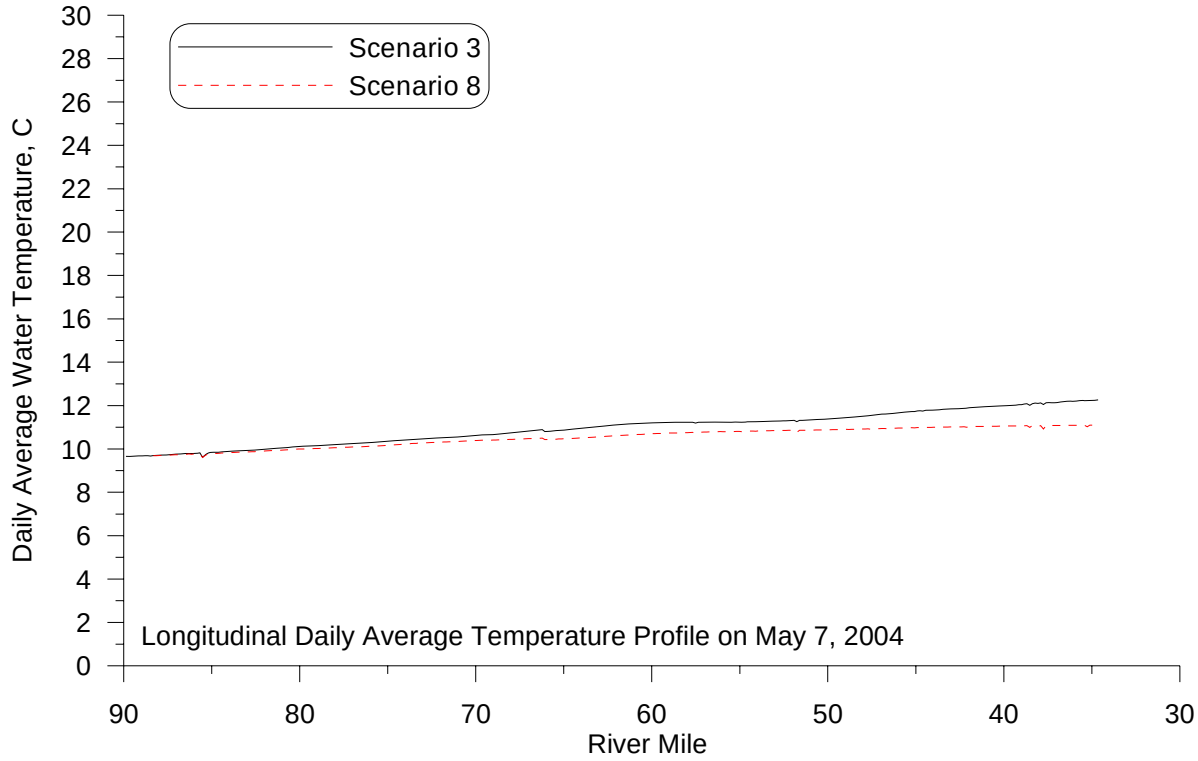

Figure 83. Comparison of longitudinal daily average temperature profile on May 7, 2004 between the impounded scenario 3 and the natural conditions scenario 8.

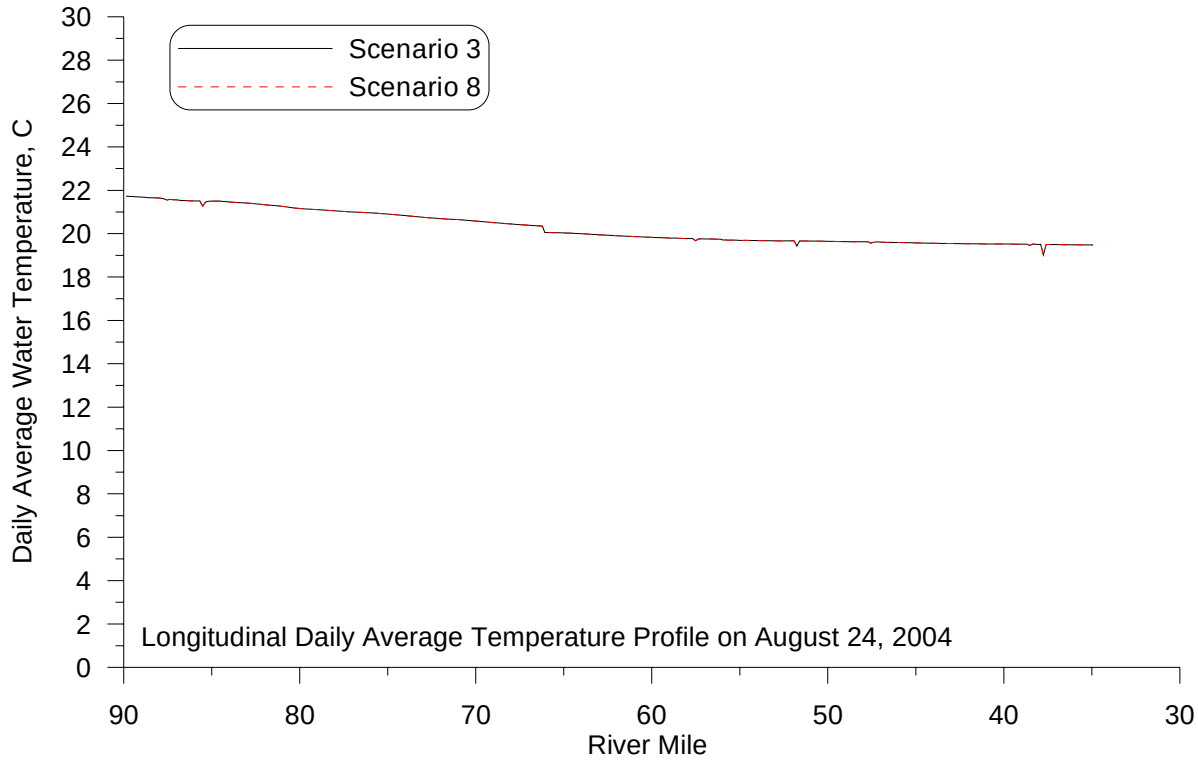

Figure 84. Comparison of longitudinal daily average temperature profile on August 24, 2004 between the impounded scenario 3 and the natural conditions scenario 8.

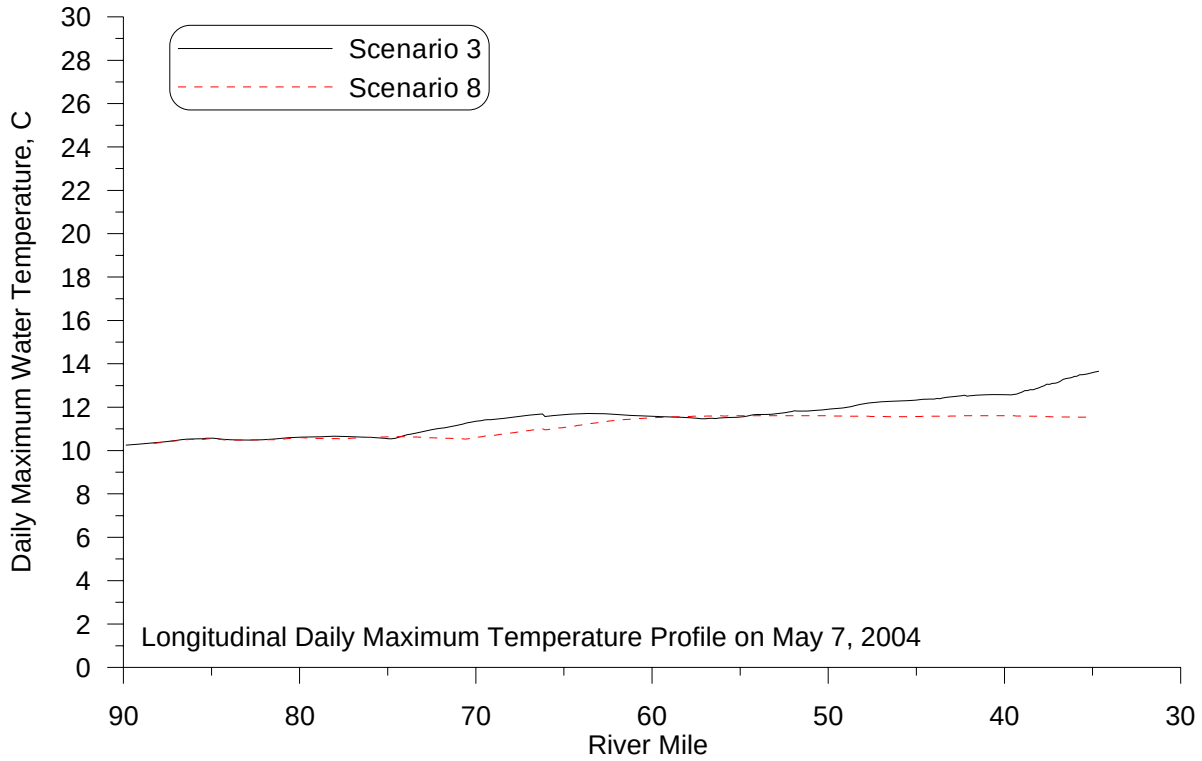

Figure 85. Comparison of longitudinal daily maximum temperature profile on May 7, 2004 between the impounded scenario 3 and the natural conditions scenario 8.

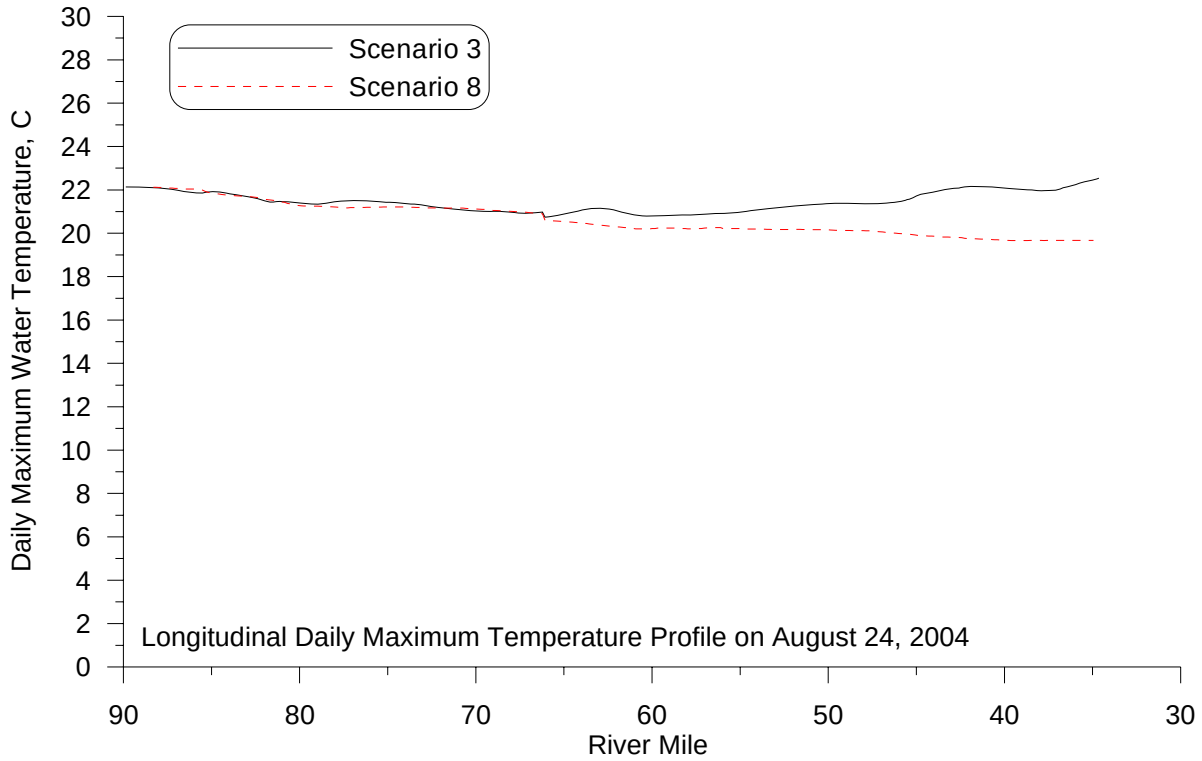

Figure 86. Comparison of longitudinal daily maximum temperature profile on August 24, 2004 between the impounded scenario 3 and the natural conditions scenario 8.

Table 17: Statistical significance of daily average temperature in the longitudinal profiles on May 7th, 2004 and August 24th, 2004 between the impounded (3) and natural conditions (8) Scenarios.

Scenario 3 and Scenario 8 Comparison	P-value	Result
May 7th daily average temperature	1.000	Model results between scenarios are not the same
August 24th daily average temperature	1.000	Model results between scenarios are not the same

Table 18: Statistical significance of daily maximum temperature in the longitudinal profiles on May 7th, 2004 and August 24th, 2004 between the impounded (3) and natural conditions (8) Scenarios.

Scenario 3 and Scenario 8 Comparison	P-value	Result
May 7th daily maximum temperature	1.000	Model results between scenarios are not the same
August 24th daily maximum temperature	1.000	Model results between scenarios are not the same

Evaluation of Box Canyon Dam Contributions

The influence of Box Canyon Dam to temperature on the Pend Oreille River was evaluated by comparing results from Model Scenario 4 to Existing Conditions (Scenario 1). Box Canyon Dam was removed for scenario 4. Flow rate and depth for the simulations were compared adjacent to the dam location (RM 34.6) and at RM 63.7. Predicted depths were shown in Figure 3 and Figure 4. Flows were plotted in Figure 5 and Figure 6.

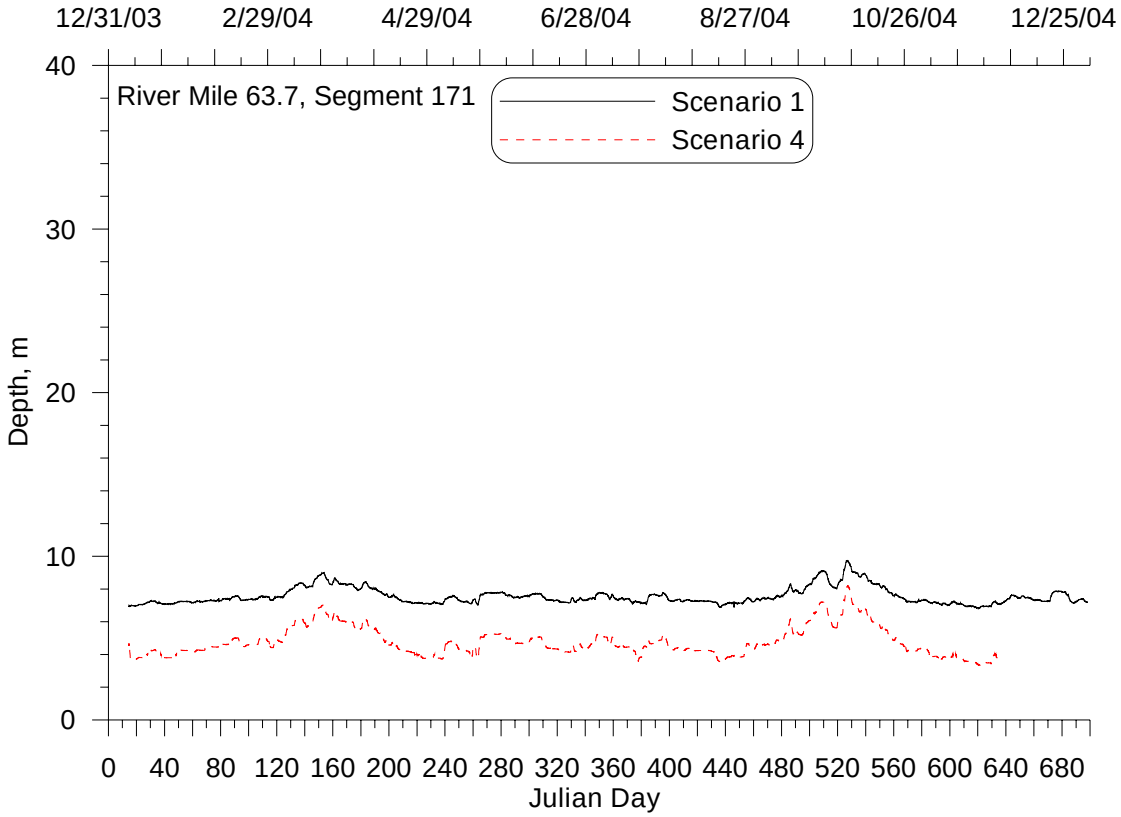

Figure 87. Comparison of model predicted depths for scenario 1 and scenario 4 at RM 63.7.

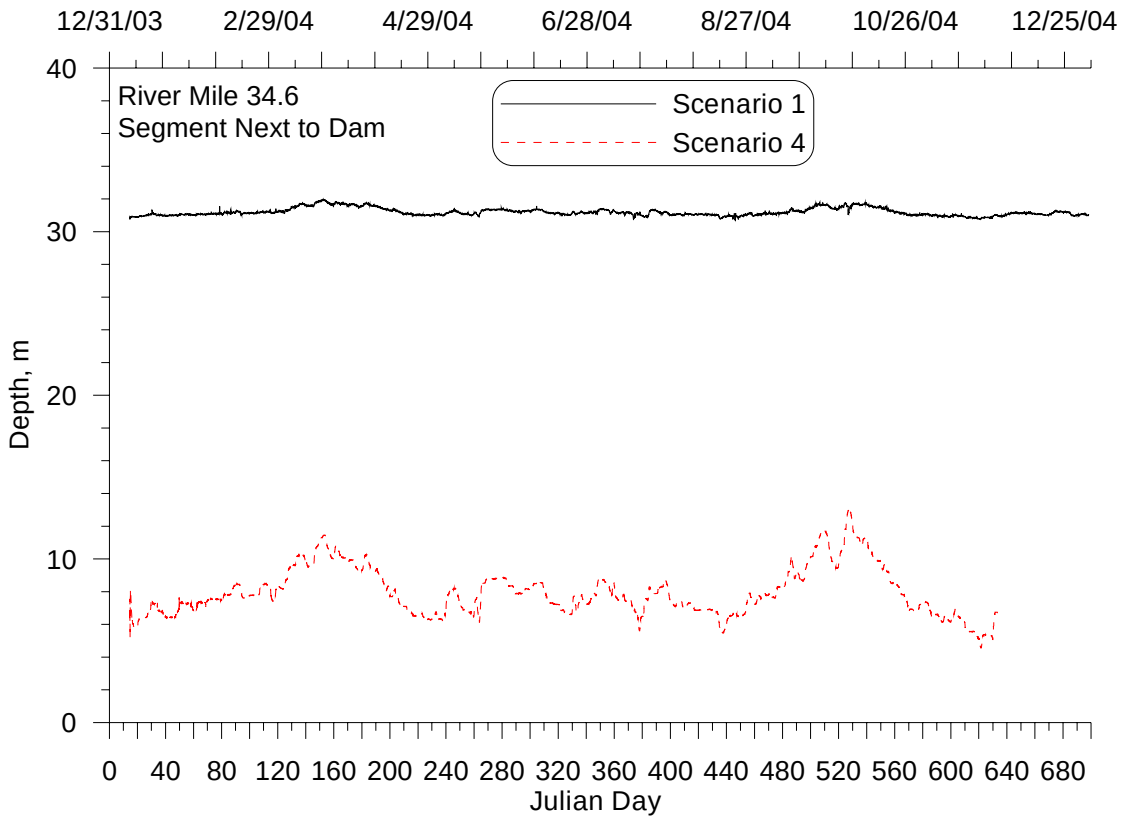

Figure 88. Comparison of model predicted depths for scenario 1 and scenario 8 at RM 34.6.

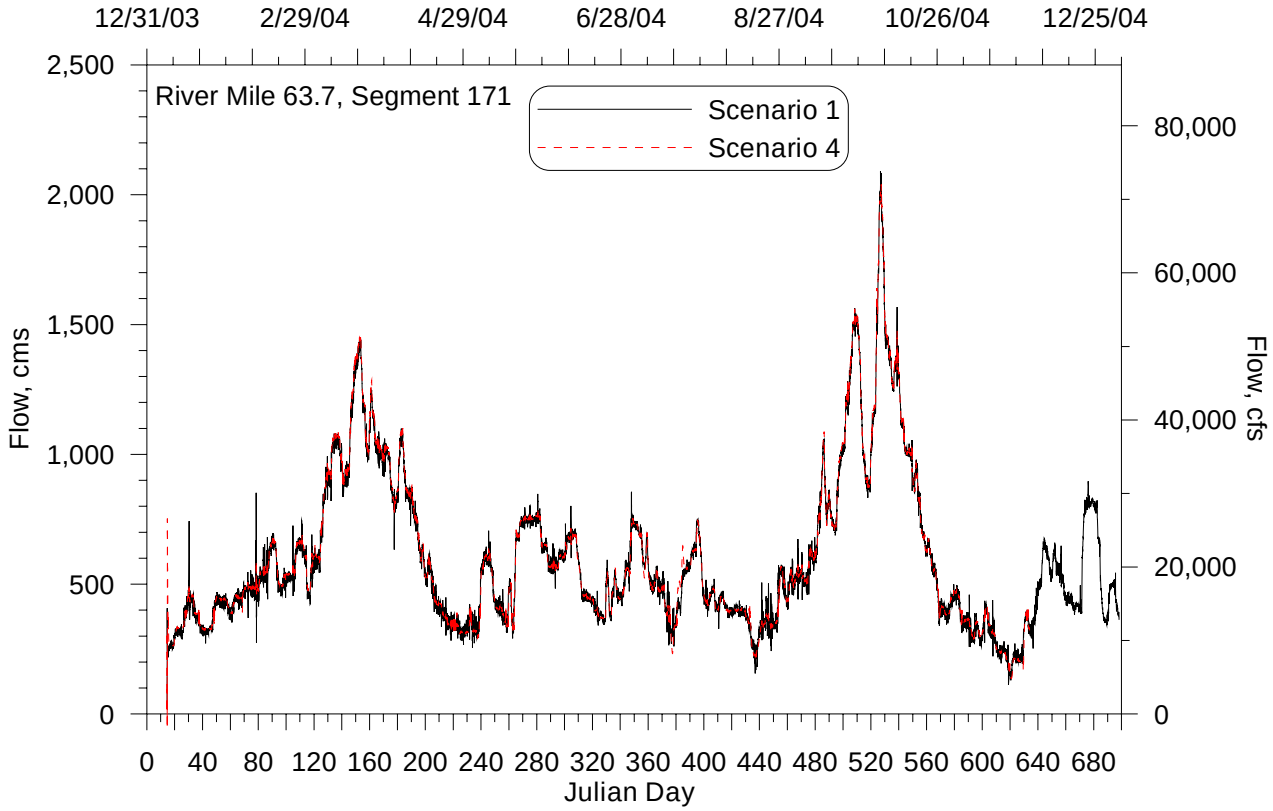

Figure 89. Comparison of model predicted flows for scenario 1 and scenario 8 at RM 63.7.

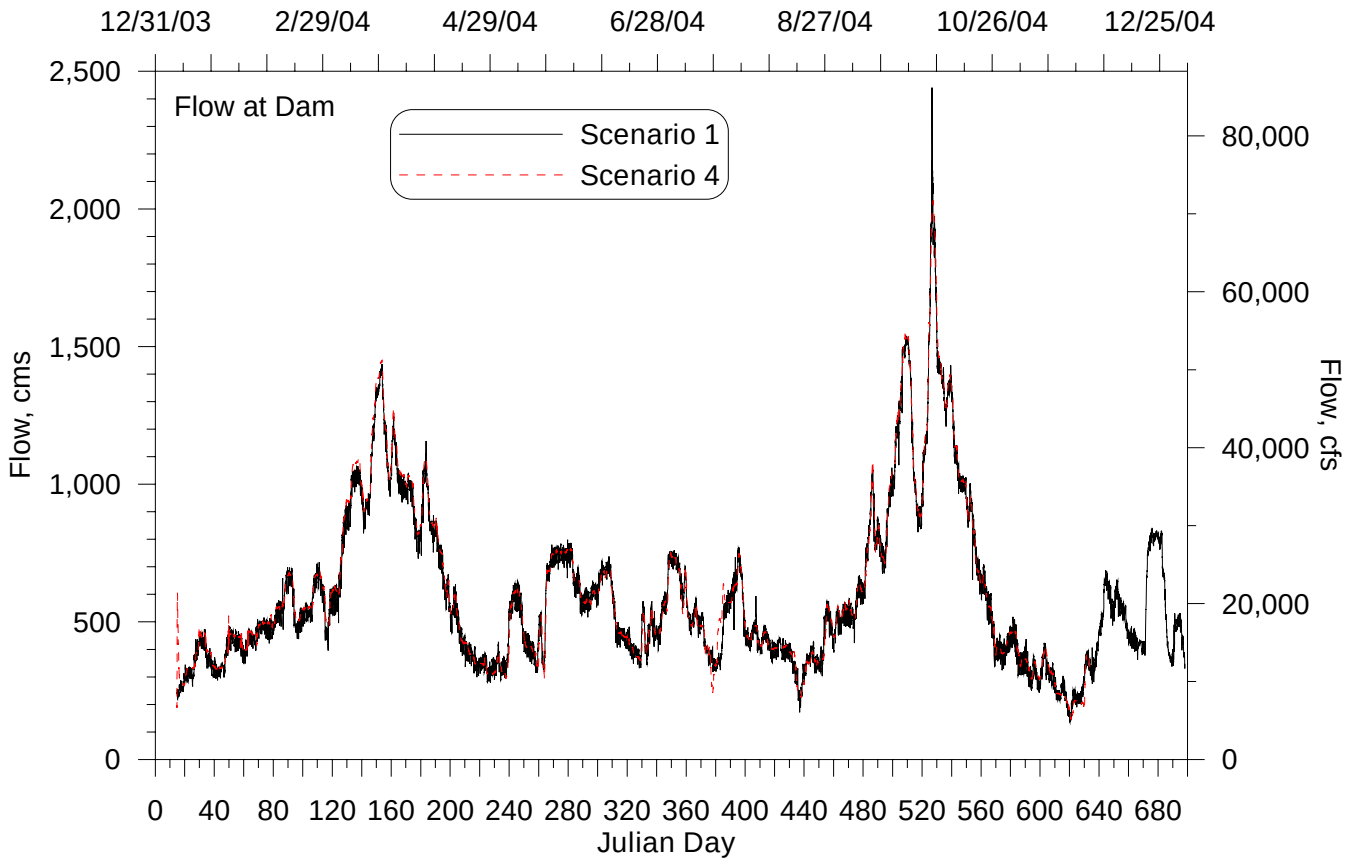

Figure 90. Comparison of model predicted flows for scenario 1 and scenario 8 at RM 34.6.

Time Series Plots

Daily Average Temperatures

Daily average temperatures of the existing conditions scenario 1 and the un-impounded scenario 4 are plotted in Figure 91 to Figure 98. The P value statistics of these scenarios for daily average temperature are listed in Table 19. The un-impounded scenario (4) predicted warmer temperatures in the summer and cooler temperatures in the fall. Scenario 1, with Box Canyon dam in place, responded more slowly to seasonal meteorological conditions.

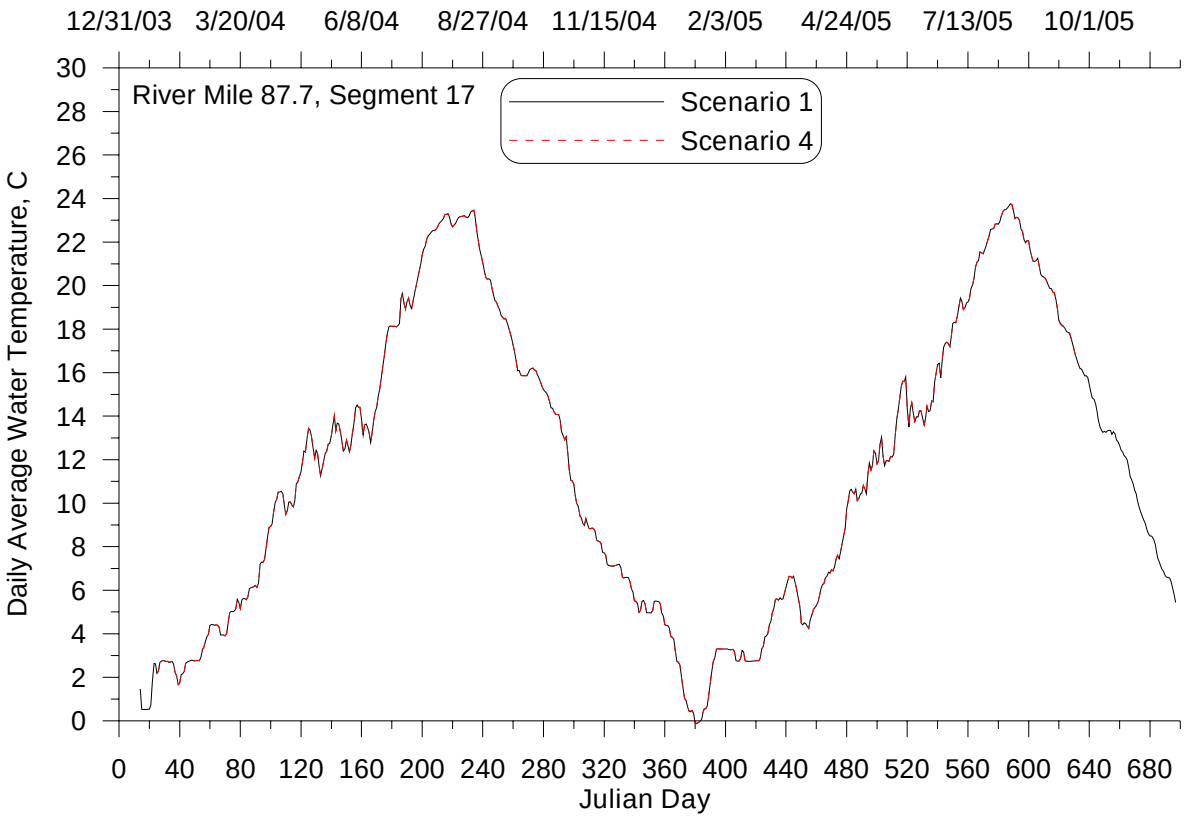

Figure 91. Comparison of segment 17 (RM 87.7) daily average water temperatures of the Box Canyon Dam removed scenario 4 and the existing conditions scenario 1.

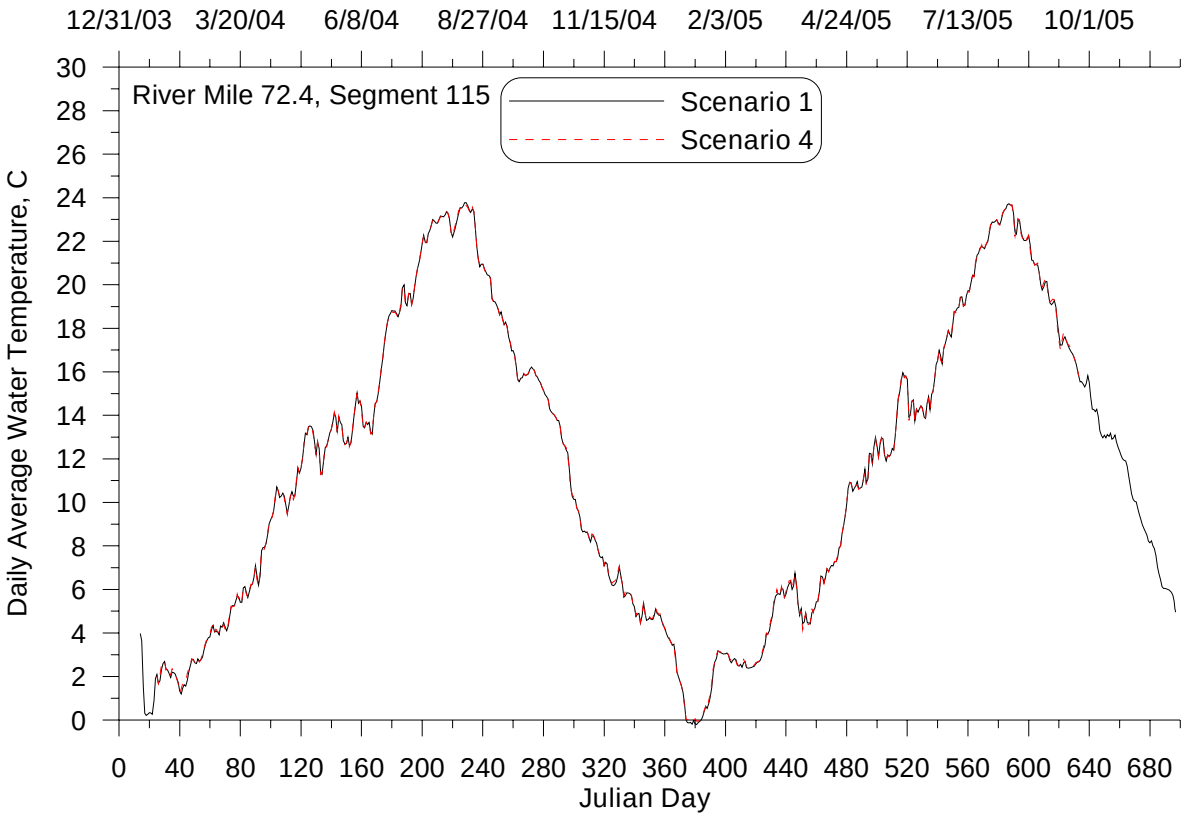

Figure 92. Comparison of segment 115 (RM 72.4) daily average water temperatures of the Box Canyon Dam removed scenario 4 and the existing conditions scenario 1.

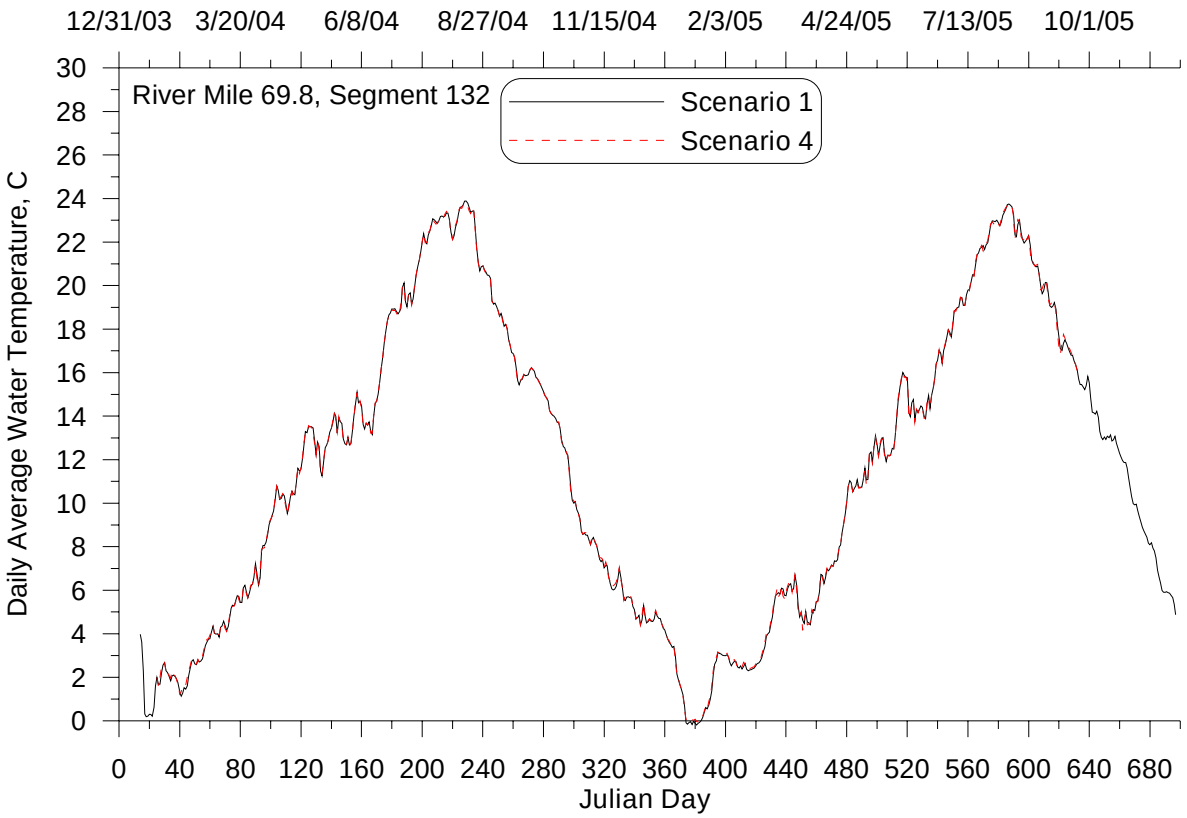

Figure 93. Comparison of segment 132 (RM 69.8) daily average water temperatures of the Box Canyon Dam removed scenario 4 and the existing conditions scenario 1.

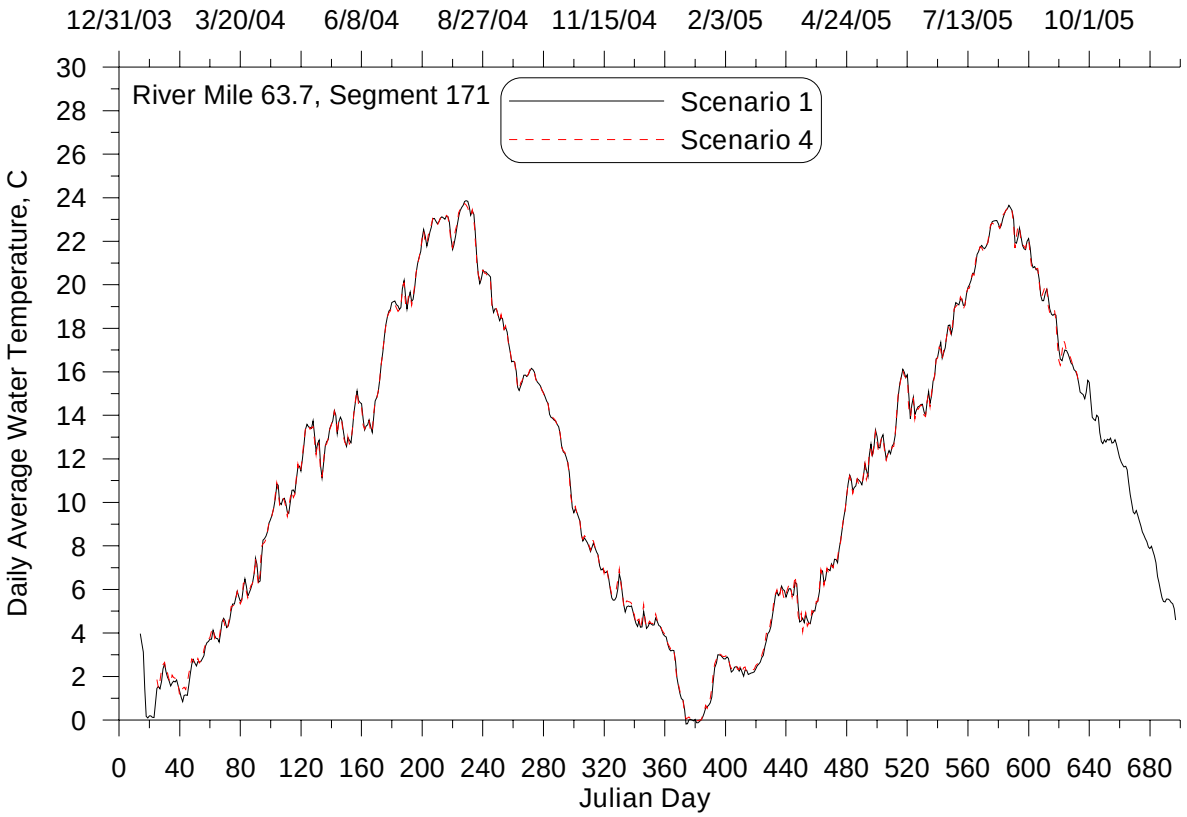

Figure 94. Comparison of segment 171 (RM 63.7) daily average water temperatures of the Box Canyon Dam removed scenario 4 and the existing conditions scenario 1.

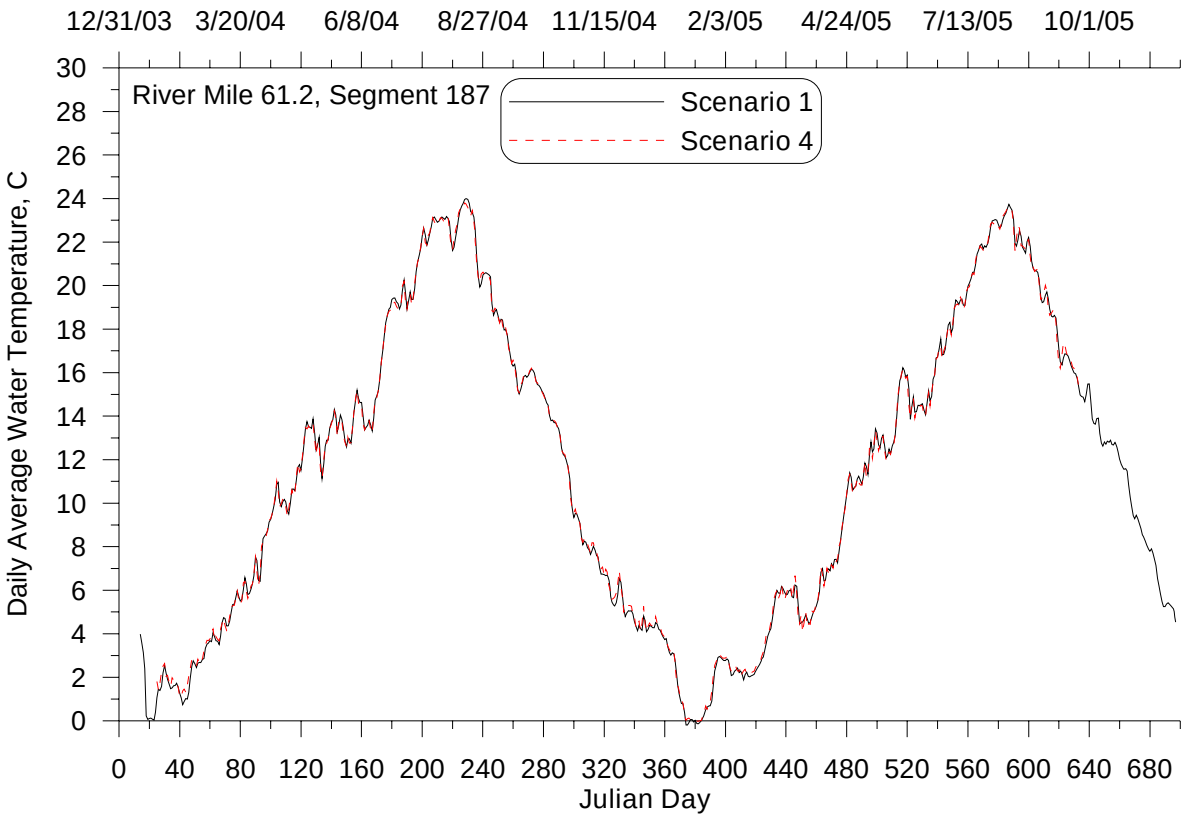

Figure 95. Comparison of segment 187 (RM 61.2) daily average water temperatures of the Box Canyon Dam removed scenario 4 and the existing conditions scenario 1.

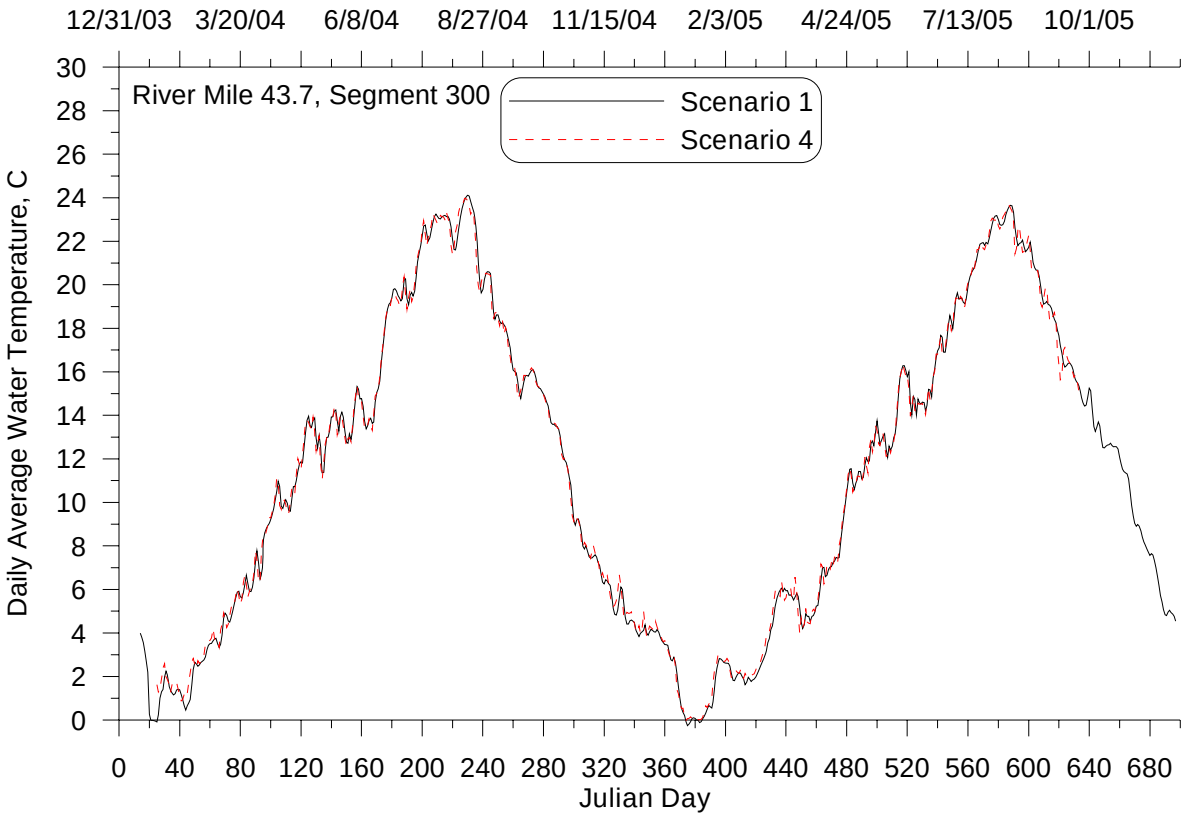

Figure 96. Comparison of segment 300 (RM 43.7) daily average water temperatures of the Box Canyon Dam removed scenario 4 and the existing conditions scenario 1.

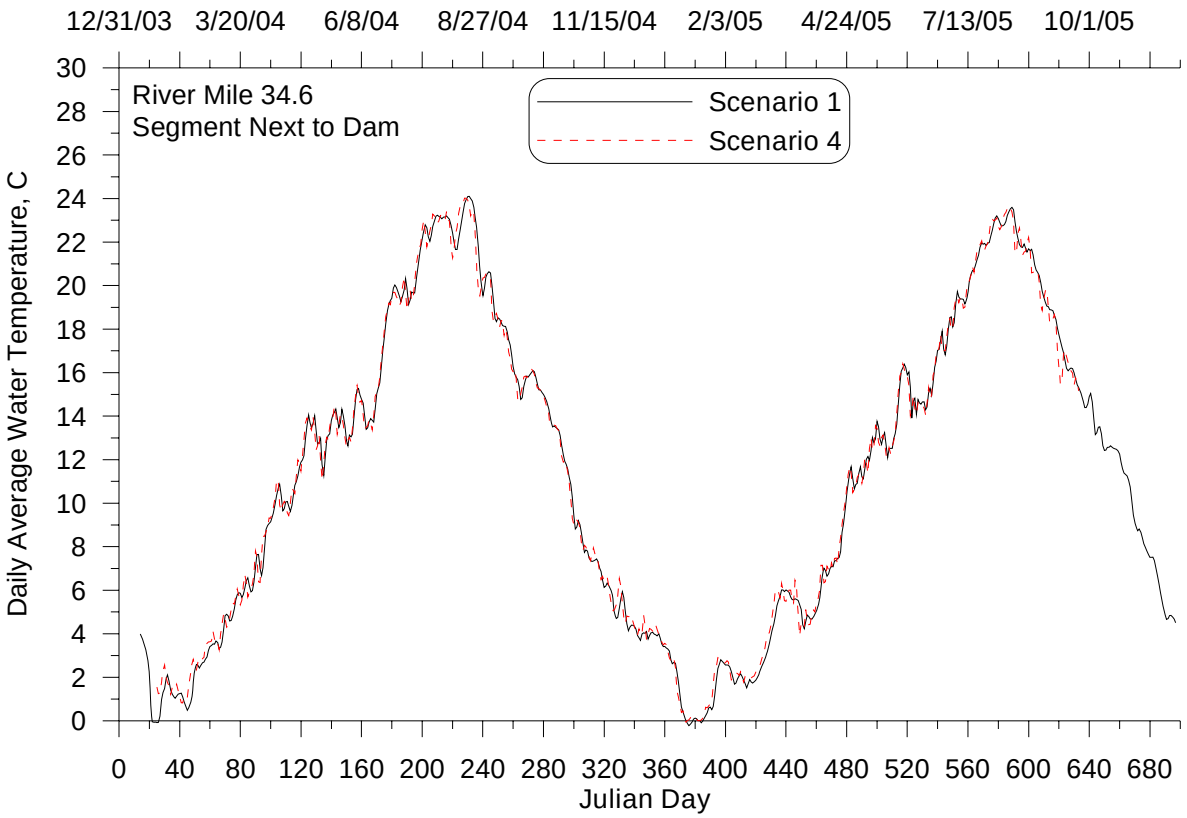

Figure 97. Comparison of model segment adjacent to Box Canyon Dam (segment 360) daily average water temperatures of the Box Canyon Dam removed scenario 4 and the existing conditions scenario 1 at RM 34.6.

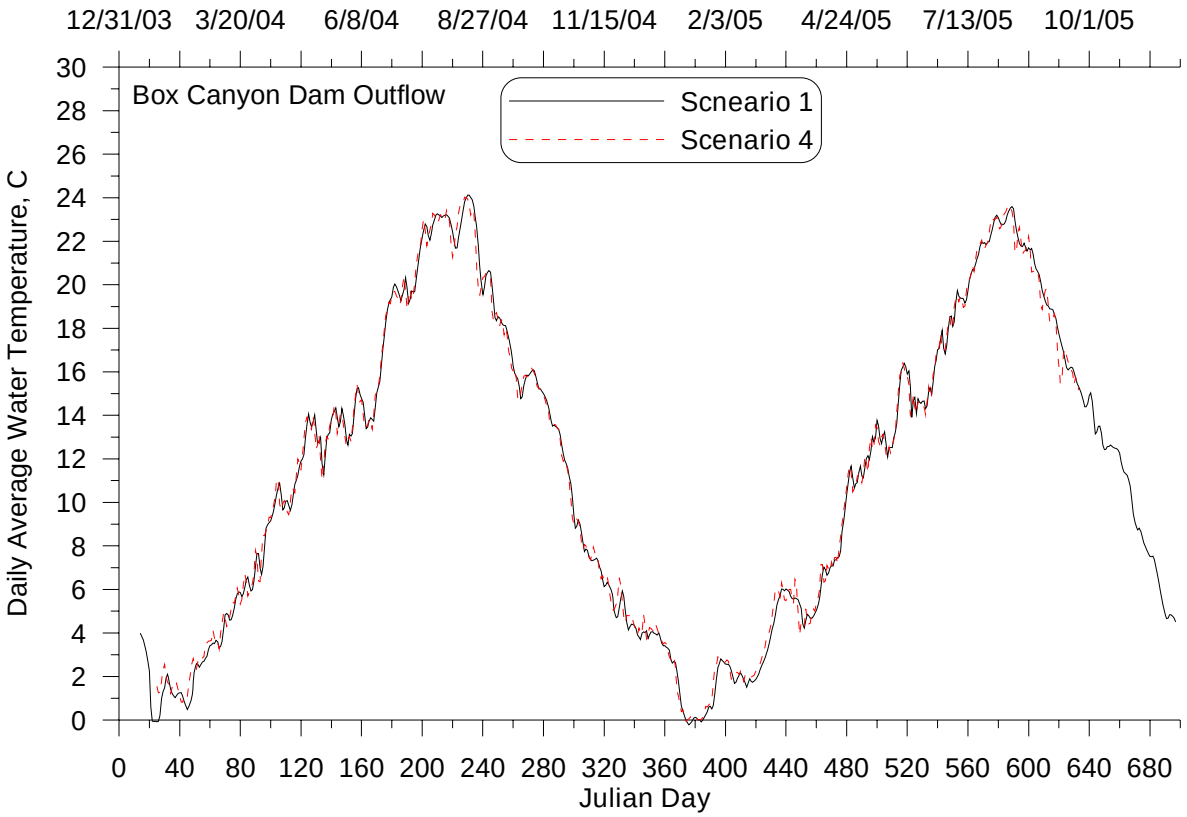

Figure 98. Comparison of Box Canyon Dam average daily outflow temperatures between the existing conditions scenario (1) and Scenario 4 (no Box Canyon Dam).

Table 19: Statistical significance in time series results between the No Box Canyon Dam (4) and Existing Conditions (1) Scenarios.

River Mile, Model Location	P-value	Result
River Mile 87.7 (Model Segment 17)	0.002	Model results between scenarios are the same, i.e. no difference
River Mile 72.4 (Model Segment 115)	0.024	Model results between scenarios are the same, i.e. no difference
River Mile 69.8 (Model Segment 132)	0.026	Model results between scenarios are the same, i.e. no difference
River Mile 63.7 (Model Segment 171)	0.034	Model results between scenarios are the same, i.e. no difference
River Mile 61.2 (Model Segment 187	0.036	Model results between scenarios are the same, i.e. no difference
River Mile 43.7 (Model Segment 300)	0.049	Model results between scenarios are the same, i.e. no difference
River Mile 34.6 (Model Segment next to dam site)	0.055	Model results between scenarios are the same, i.e. no difference
River Mile 34.5 (Box Canyon Dam Outlet)	0.049	Model results between scenarios are the same, i.e. no difference

Daily Maximum Temperatures

Figure 99 through Figure 106 show the daily average temperatures of the Box Canyon Dam removed scenario and the existing conditions scenario. The P value statistics for daily maximum temperature comparing these scenarios are listed in Table 20. Daily maximum temperatures of scenario 4 were greater because the un-impounded river was shallower resulting in larger daily temperature swings.

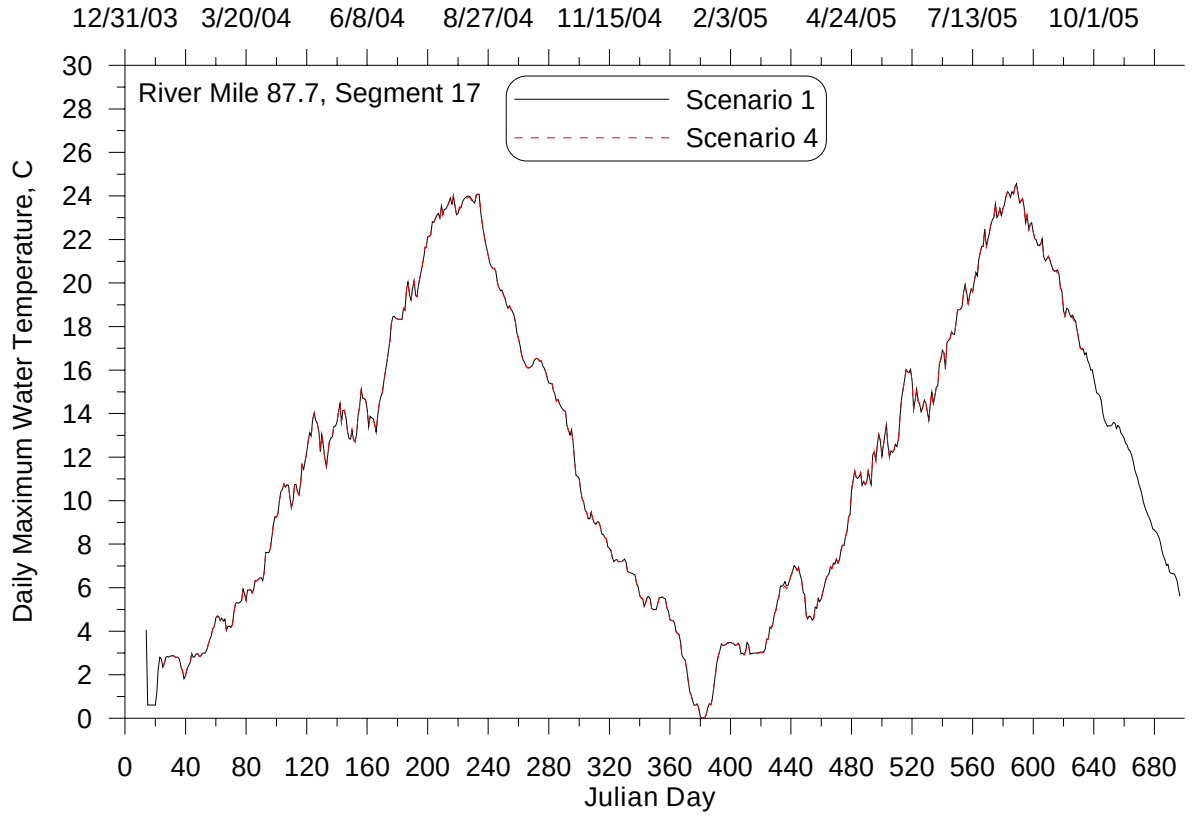

Figure 99. Comparison of segment 17 (RM 87.7) daily maximum water temperatures of the Box Canyon Dam removed scenario 4 and the existing conditions scenario 1.

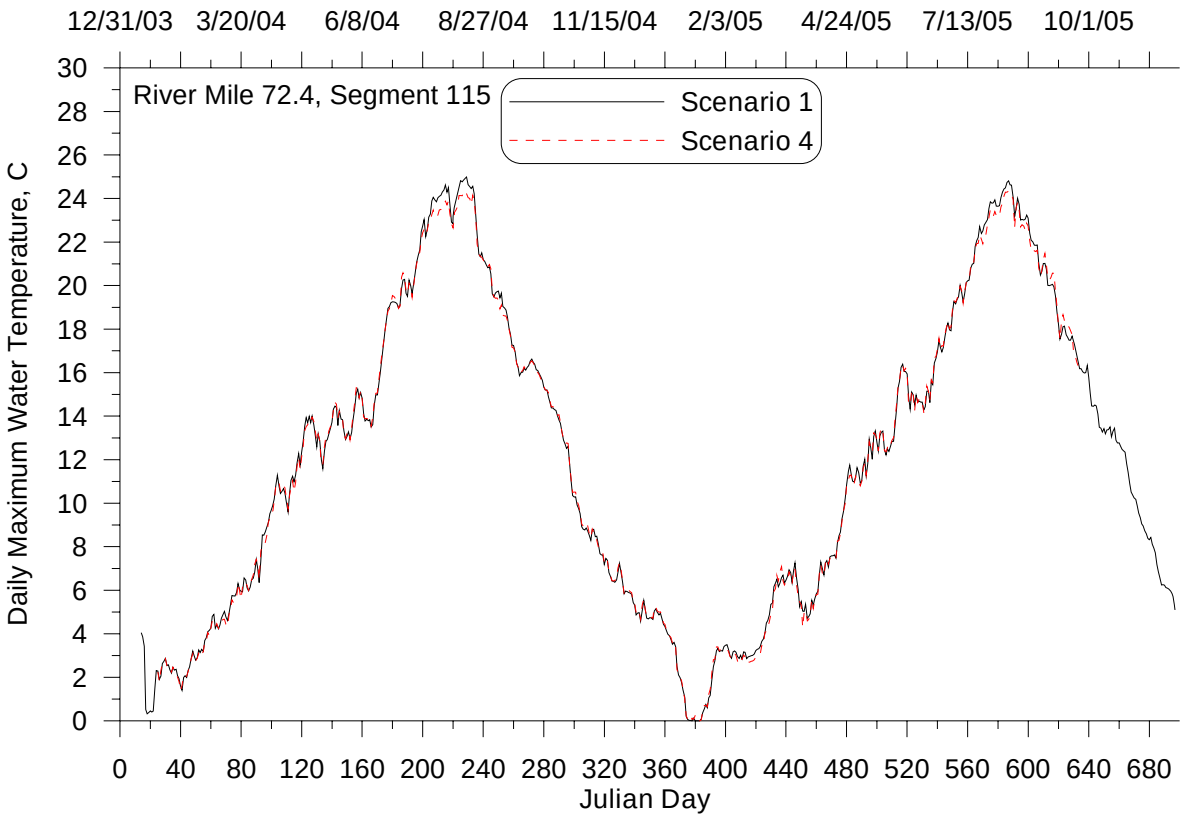

Figure 100. Comparison of segment 115 (RM 72.4) daily maximum water temperatures of the Box Canyon Dam removed scenario 4 and the existing conditions scenario 1.

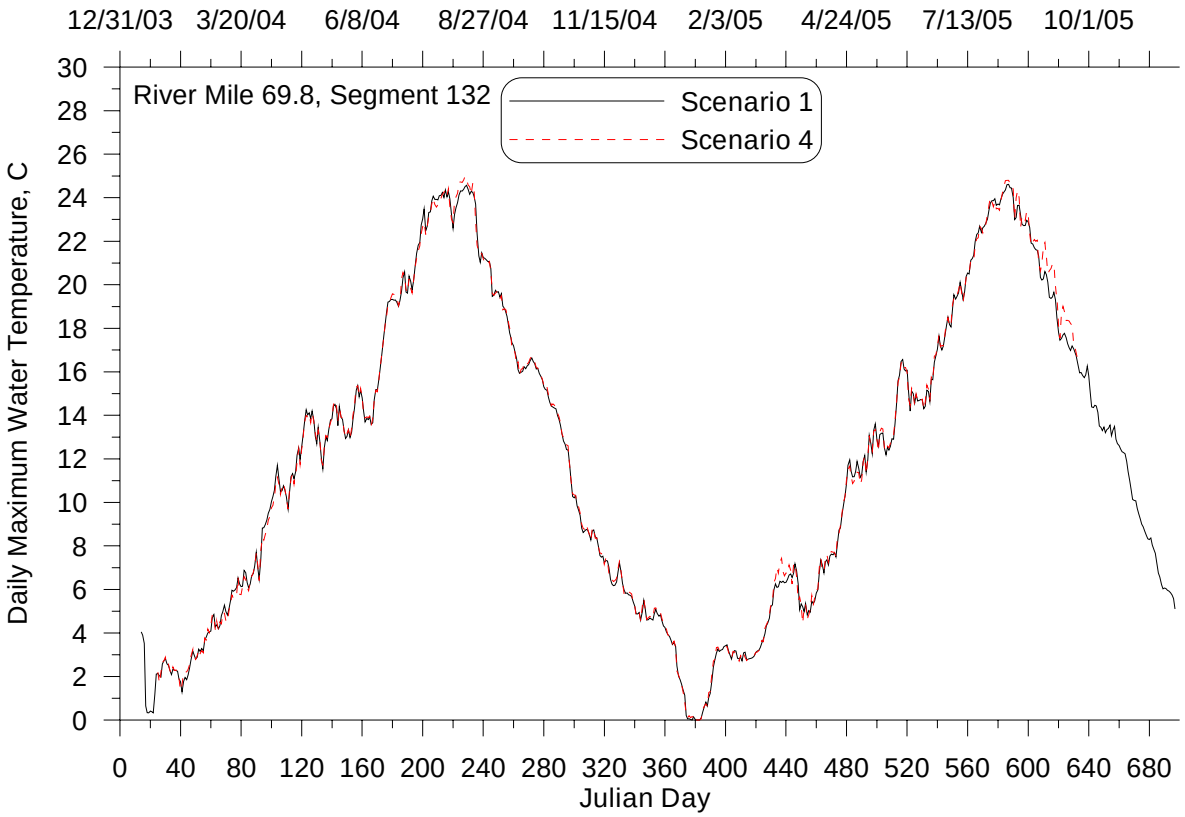

Figure 101. Comparison of segment 132 (RM 69.8) daily maximum water temperatures of the Box Canyon Dam removed scenario 4 and the existing conditions scenario 1.

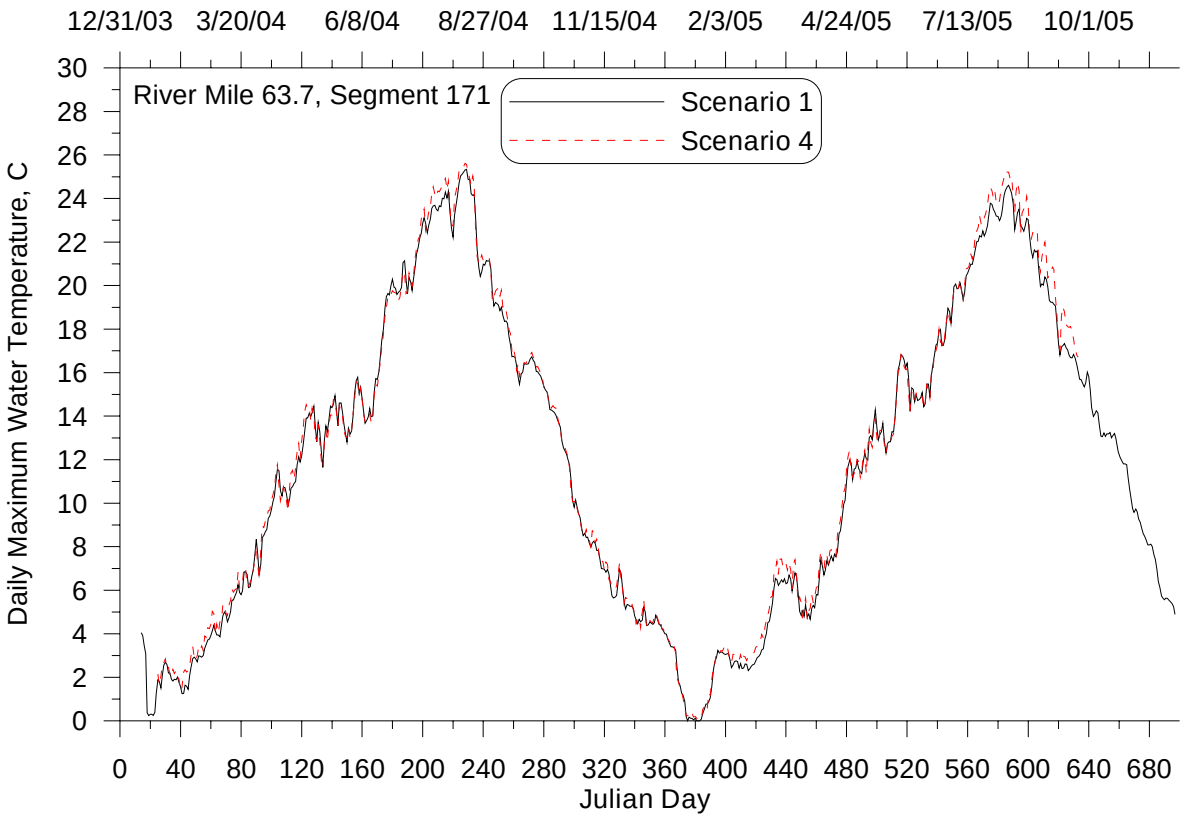

Figure 102. Comparison of segment 171 (RM 63.7) daily maximum water temperatures of the Box Canyon Dam removed scenario 4 and the existing conditions scenario 1.

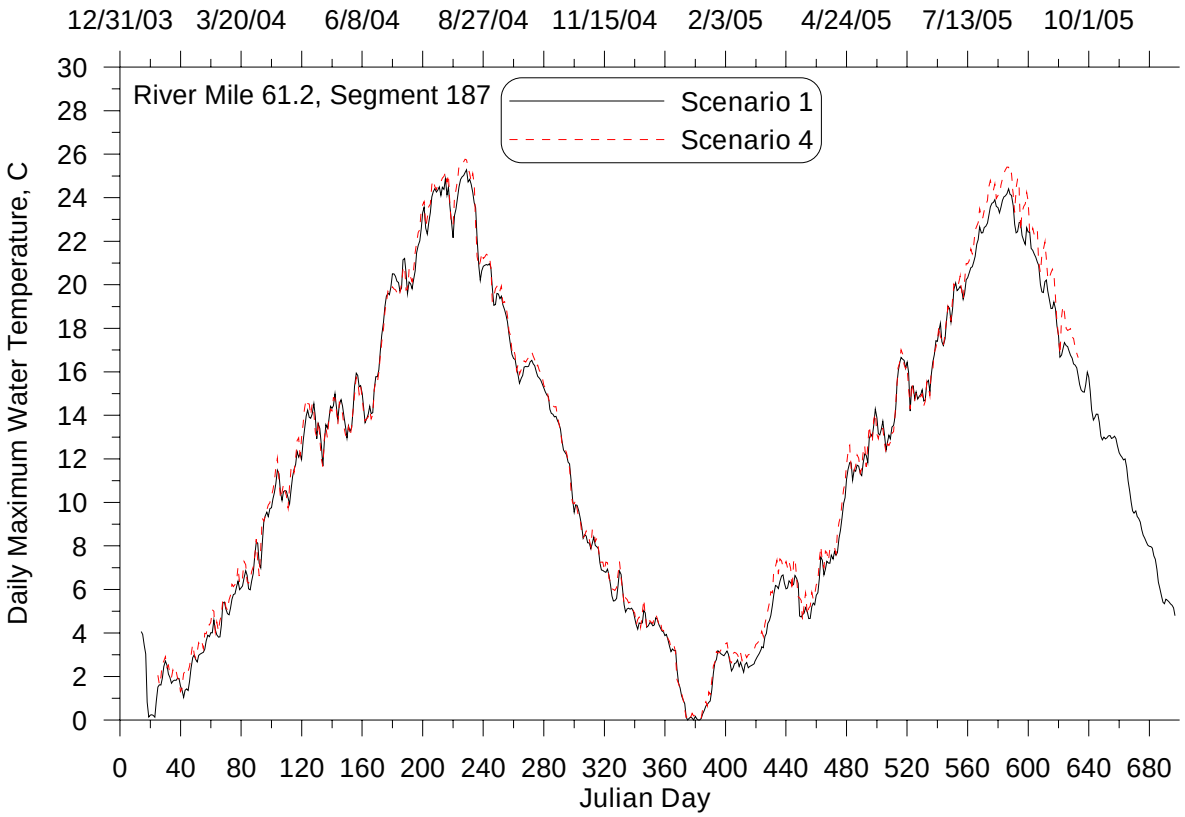

Figure 103. Comparison of segment 187 (RM 61.2) daily maximum water temperatures of the Box Canyon Dam removed scenario 4 and the existing conditions scenario 1.

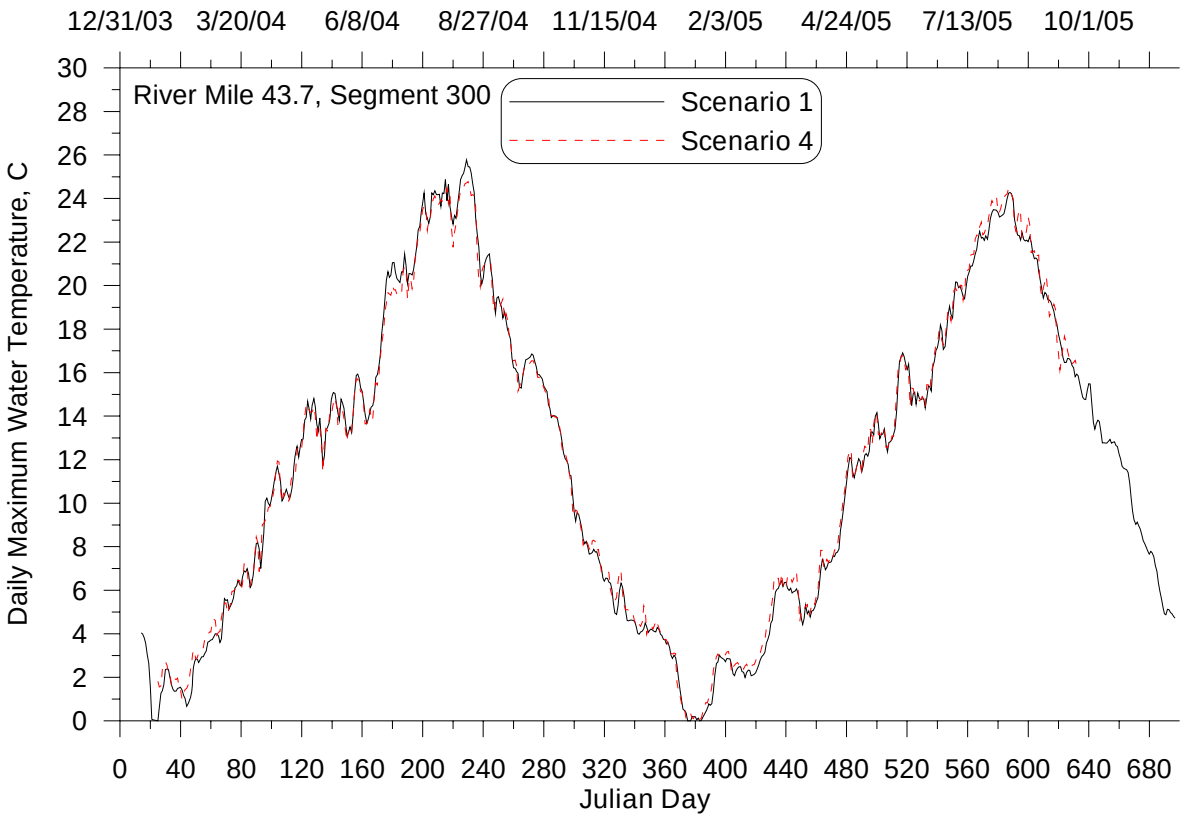

Figure 104. Comparison of segment 300 (RM 43.7) daily maximum water temperatures of the Box Canyon Dam removed scenario 4 and the existing conditions scenario 1.

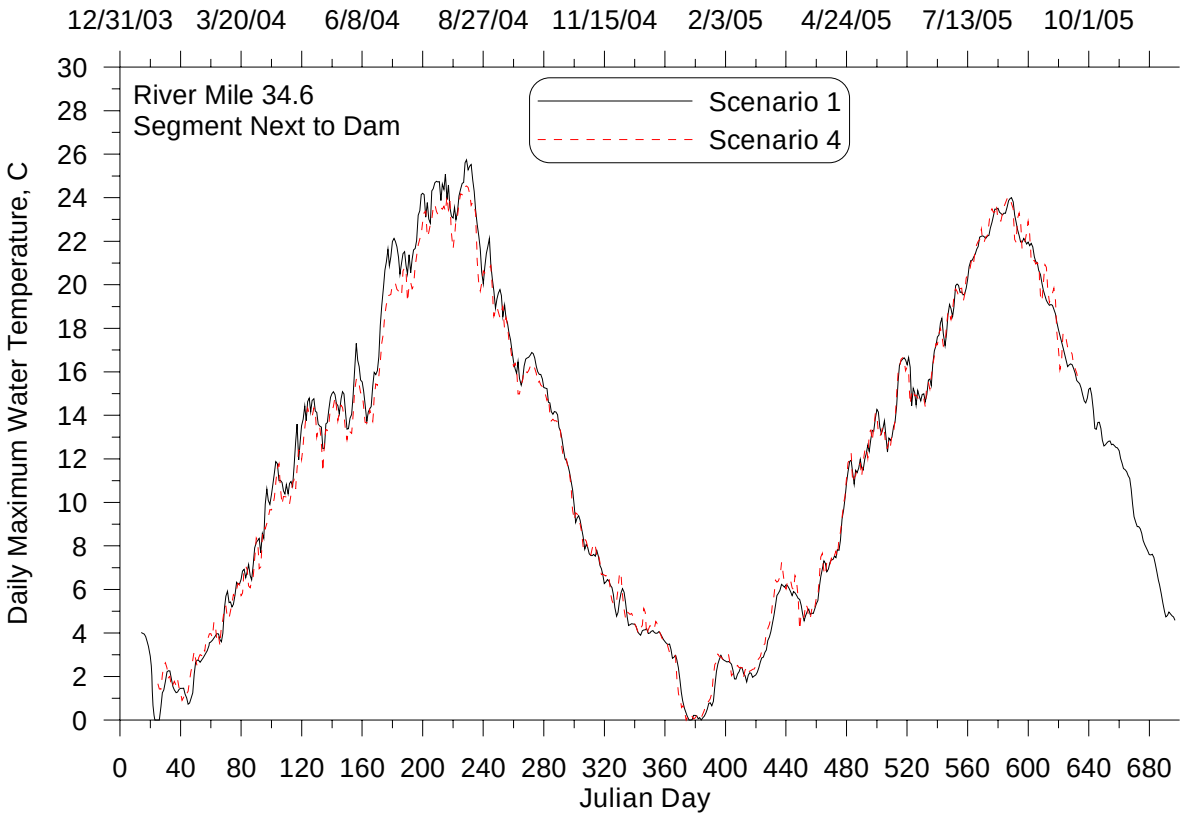

Figure 105. Comparison of model segment adjacent to Box Canyon Dam (segment 360) daily maximum water temperatures of the Box Canyon Dam removed scenario 4 and the existing conditions scenario 1 at RM 34.6.

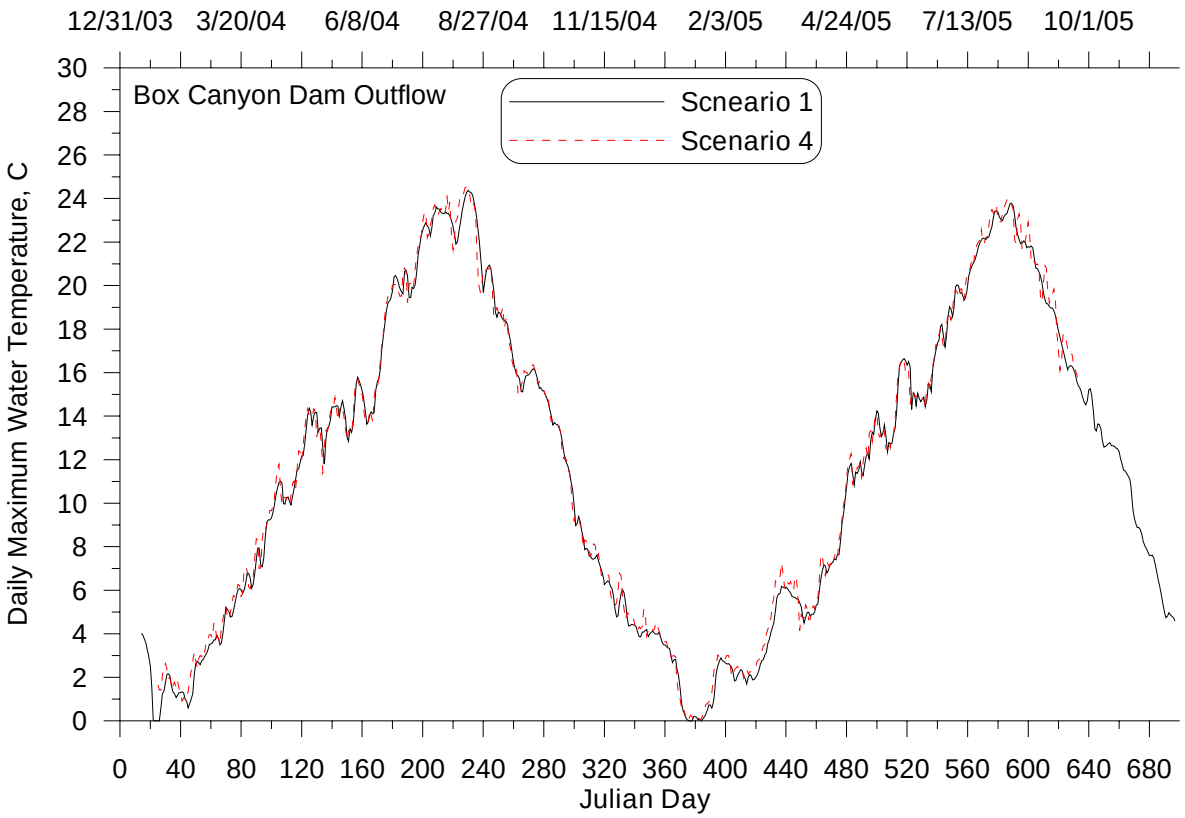

Figure 106. Comparison of Box Canyon Dam maximum daily outflow temperatures between the existing conditions scenario (1) and Scenario 4 (no Box Canyon Dam).

Table 20: Statistical significance in daily maximum time series results between the No Box Canyon Dam (4) and Existing Conditions (1) Scenarios.

River Mile, Model Location	P-value	Result
River Mile 87.7 (Model Segment 17)	0.006	Model results between scenarios are the same, i.e. no difference
River Mile 72.4 (Model Segment 115)	0.122	Model results between scenarios are similar
River Mile 69.8 (Model Segment 132)	0.073	Model results between scenarios are the same, i.e. no difference
River Mile 63.7 (Model Segment 171)	0.395	Model results between scenarios are not the same
River Mile 61.2 (Model Segment 187	0.520	Model results between scenarios are not the same
River Mile 43.7 (Model Segment 300)	0.129	Model results between scenarios are similar
River Mile 34.6 (Model Segment next to dam site)	0.347	Model results between scenarios are not the same
River Mile 34.5 (Box Canyon Dam Outlet)	0.255	Model results between scenarios have some similarities

Longitudinal Profiles

Longitudinal profiles of daily average temperature for the Box Canyon Dam removed scenario 4 and the existing conditions scenario 1 are shown in Figure 107 and Figure 108. Daily maximum temperature longitudinal profiles are plotted in Figure 109 and Figure 110. The P value statistics of the longitudinal

profiles are listed in Table 21 and Table 22. The longitudinal plots showed that the existing condition scenario predicted warmer temperatures on May 7 and August 24, 2004.

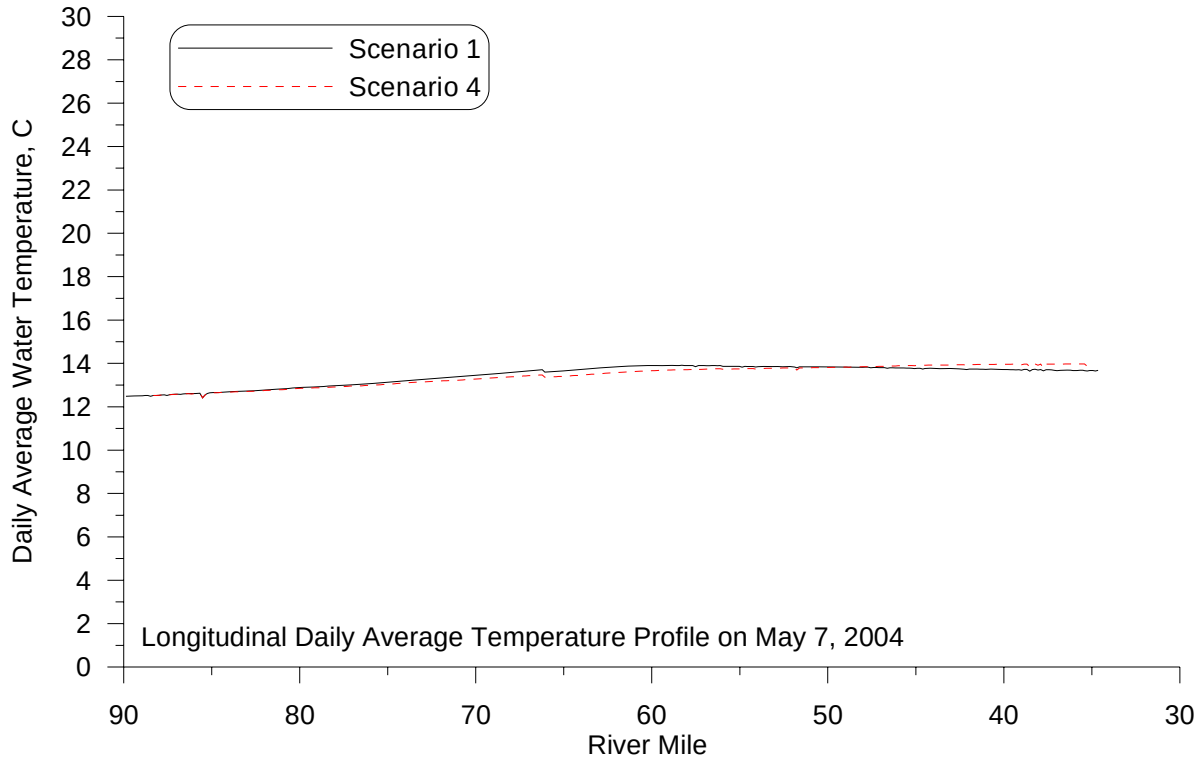

Figure 107. Comparison of longitudinal daily average temperature profile on May 7, 2004 between the Box Canyon removed scenario 4 and the existing conditions scenario 1.

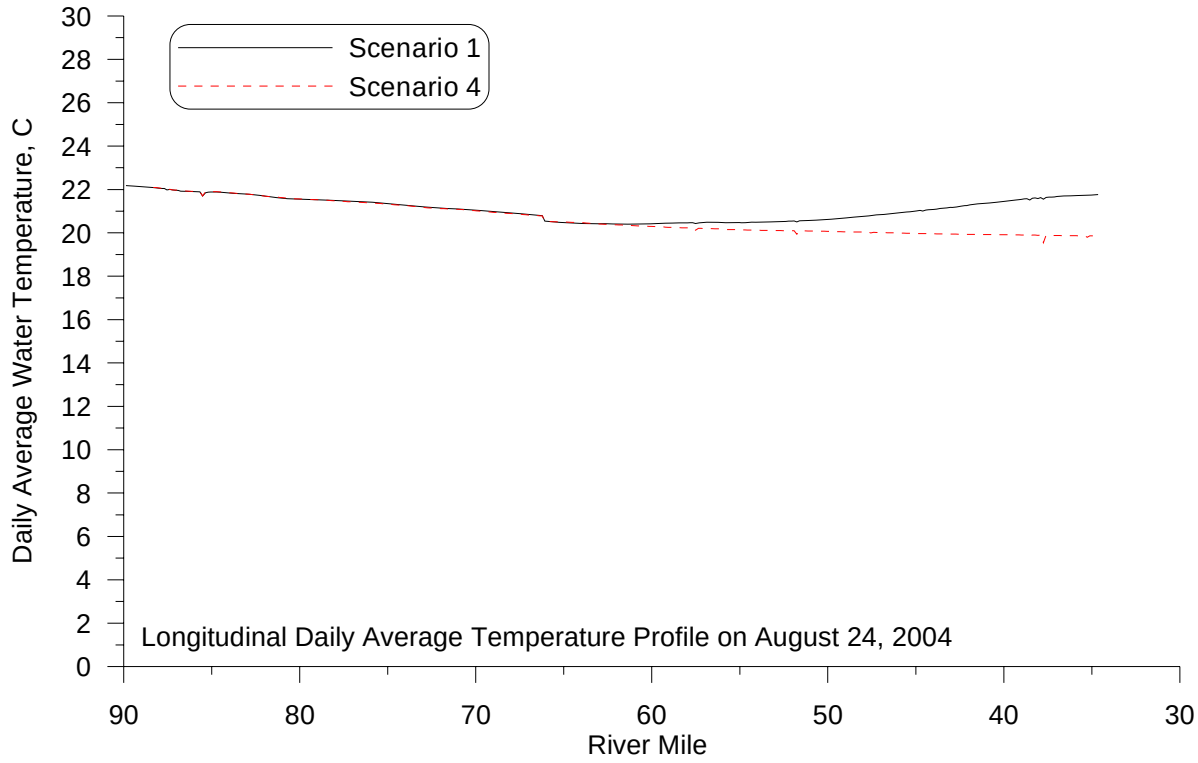

Figure 108. Comparison of longitudinal daily average temperature profile on August 24, 2004 between the Box Canyon removed scenario 4 and the existing conditions scenario 1.

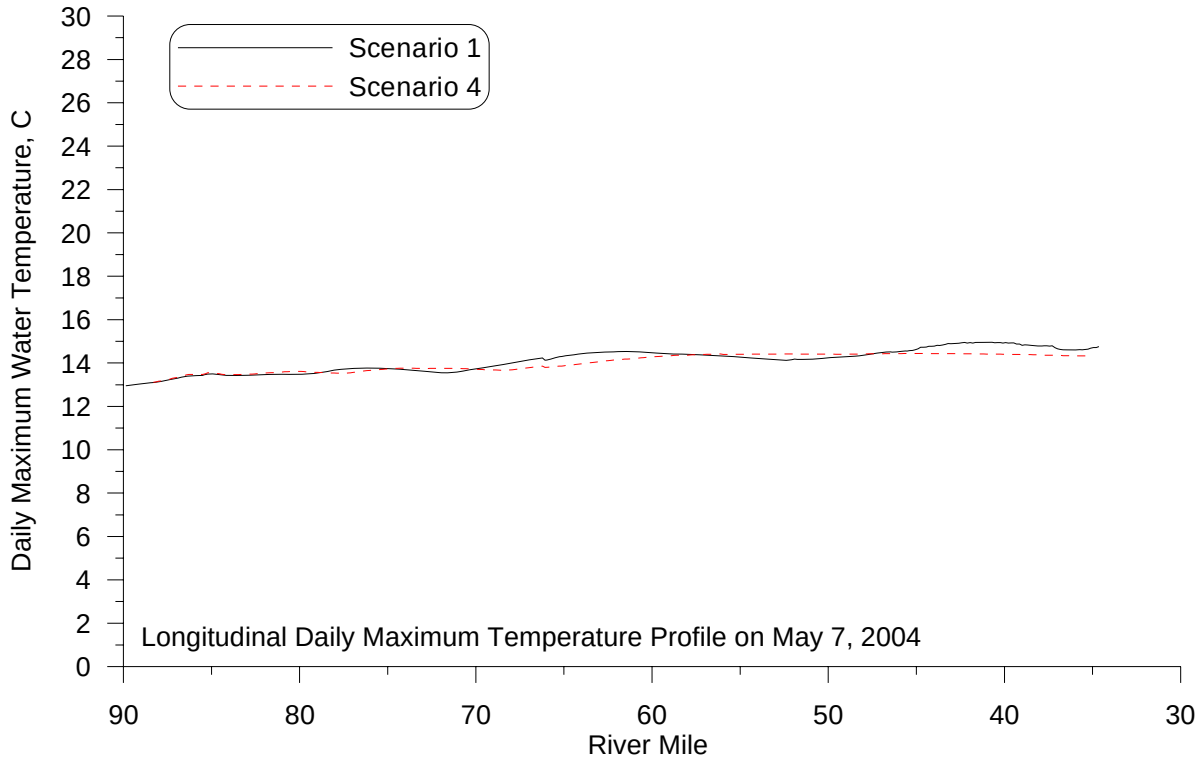

Figure 109. Comparison of longitudinal daily maximum temperature profile on May 7, 2004 between the Box Canyon removed scenario 4 and the existing conditions scenario 1.

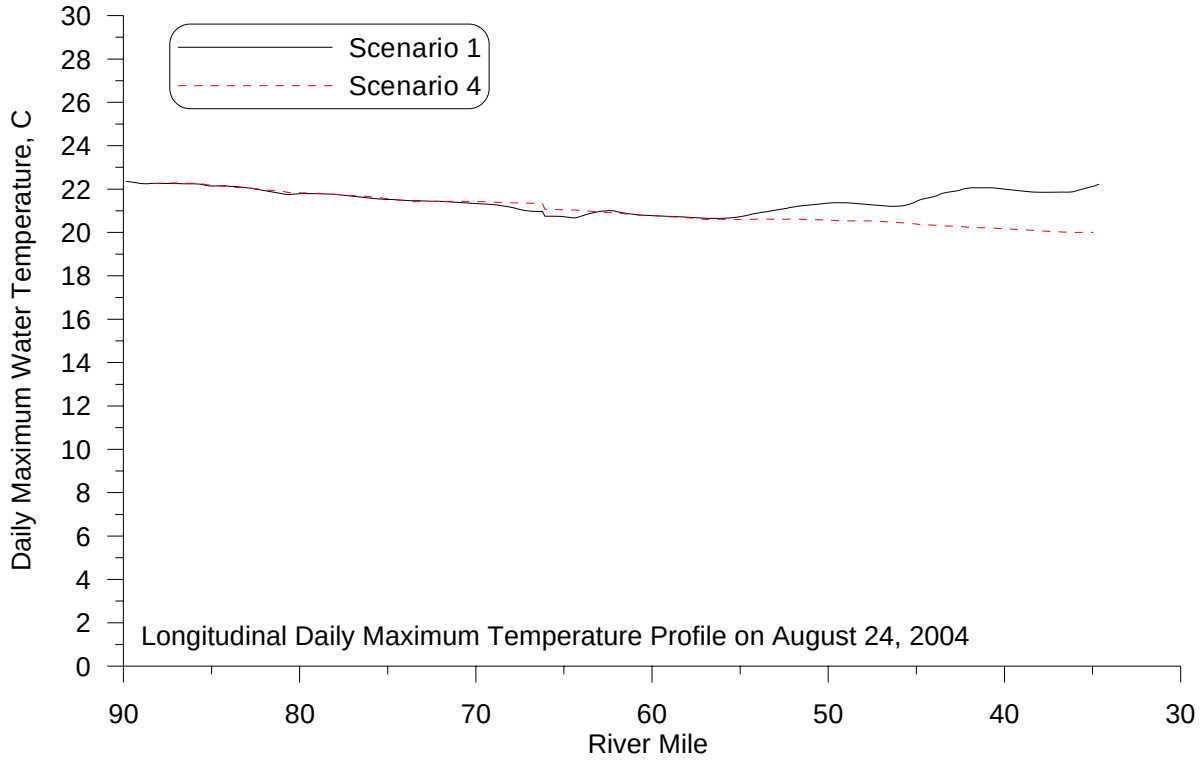

Figure 110. Comparison of longitudinal daily maximum temperature profile on August 24, 2004 between the Box Canyon removed scenario 4 and the existing conditions scenario 1.

Table 21: Statistical significance of daily average temperature in the longitudinal profiles on May 7th, 2004 and August 24th, 2004 between the Box Canyon dam removed (4) and Existing Conditions (1) Scenarios.

Scenario 1 and Scenario 4 Comparison	P-value	Result
May 7th daily average temperature	0.743	Model results between scenarios are not the same
August 24th daily average temperature	1.000	Model results between scenarios are not the same

Table 22: Statistical significance of daily maximum temperature in the longitudinal profiles on May 7th, 2004 and August 24th, 2004 between the Box Canyon dam removed scenario (4) and Existing Conditions (1) Scenarios.

Scenario 1 and Scenario 4 Comparison	P-value	Result
May 7th daily maximum temperature	0.997	Model results between scenarios are not the same
August 24th daily maximum temperature	1.000	Model results between scenarios are not the same

Evaluation of Vegetative Shade Contribution

The influence of vegetative shading on the Pend Oreille River to temperature was evaluated by comparing results from potential natural vegetation (PNV) Scenario 7 to Existing Conditions (Scenario 1).

Time Series Plots

Daily Average Temperatures

Daily average temperatures are compared for the existing scenario 1 and PNV scenario 7 in Figure 111 through Figure 118. The Box Canyon outflow temperatures were slightly cooler in the summer (Figure 118) for the PNV scenario. The P value statistics for these two scenarios are listed in Table 23. There were no significant statistical differences in daily average temperature between the existing conditions scenario and the PNV shading scenario.

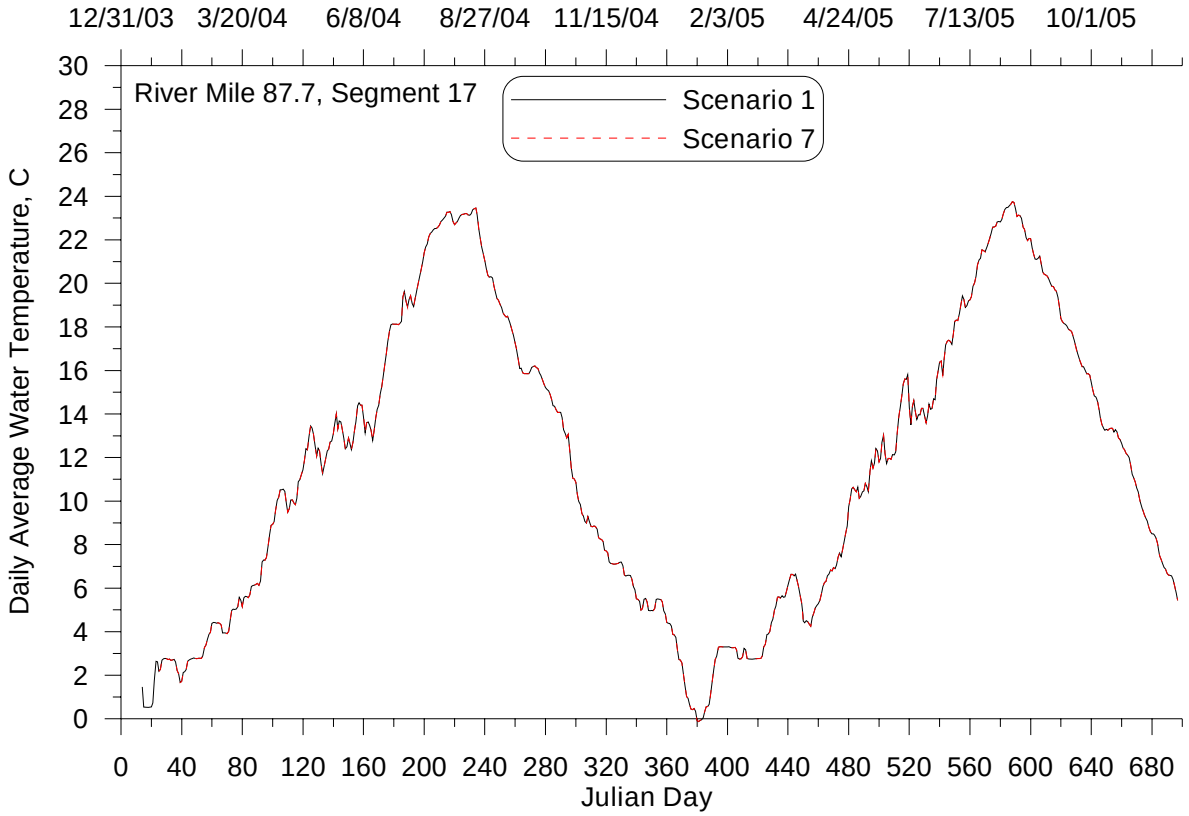

Figure 111. Comparison of segment 17 (RM 87.7) daily average water temperatures of the PNV shading scenario 7 and the existing conditions scenario 1.

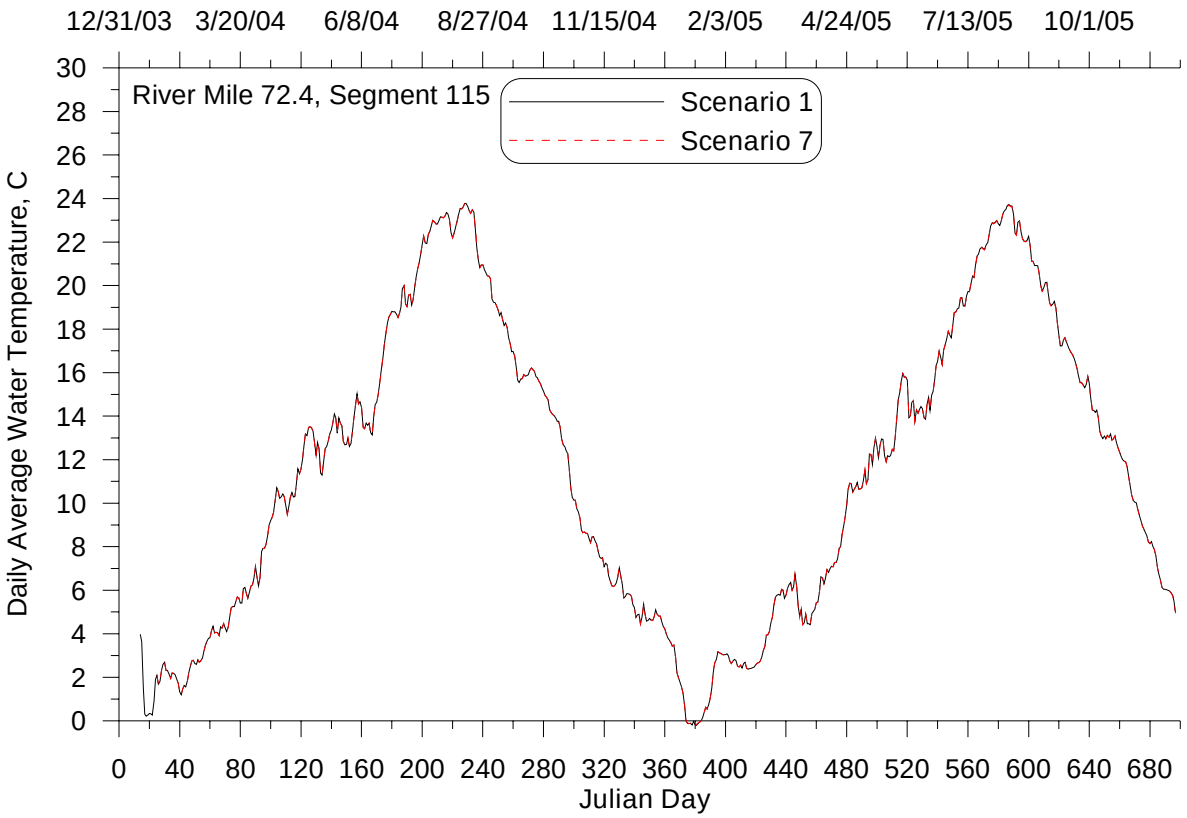

Figure 112. Comparison of segment 115 (RM 72.4) daily average water temperatures of the PNV shading scenario 7 and the existing conditions scenario 1.

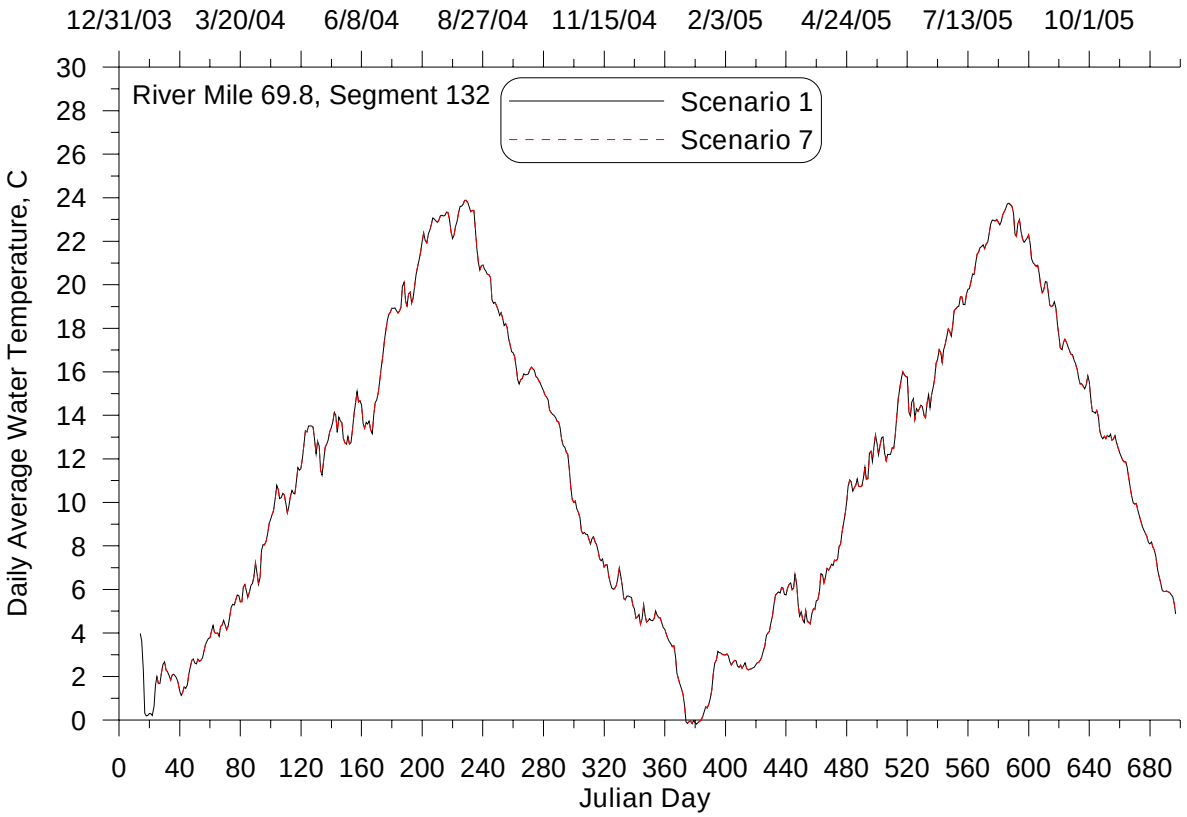

Figure 113. Comparison of segment 132 (RM 69.8) daily average water temperatures of the PNV shading scenario 7 and the existing conditions scenario 1.

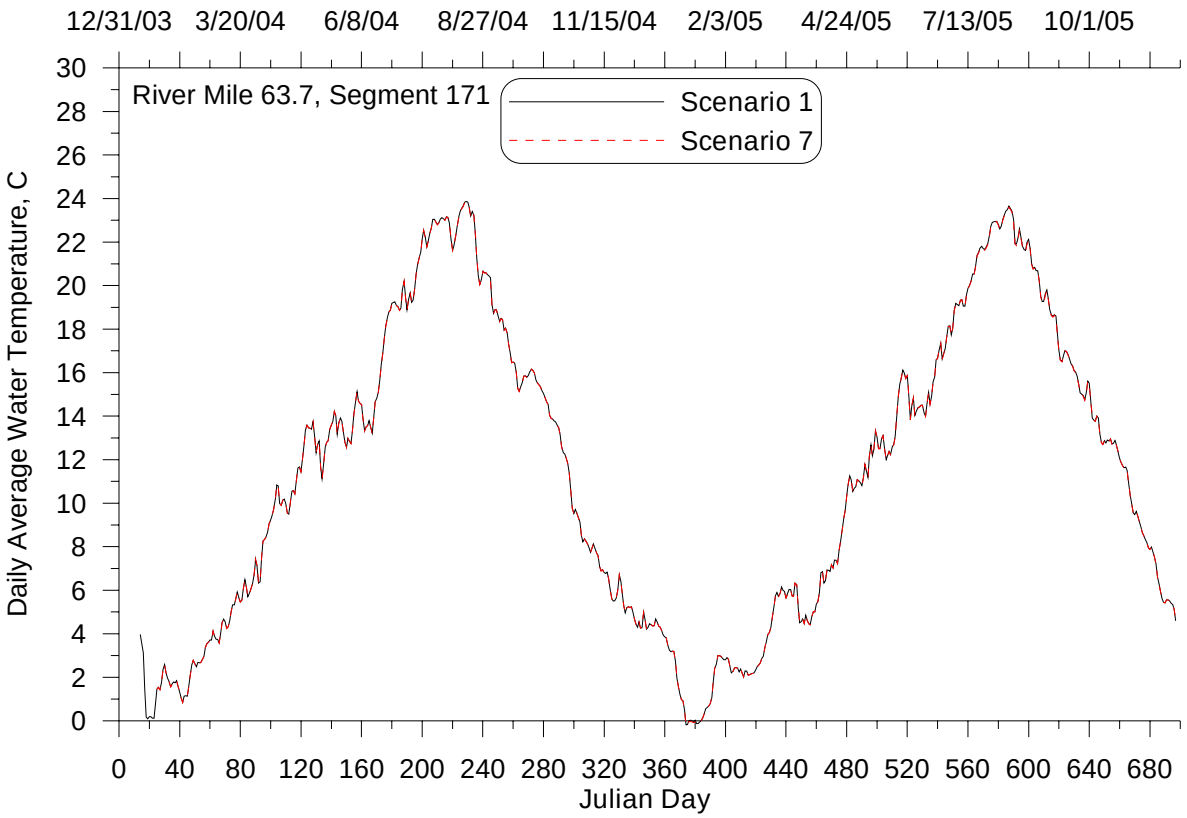

Figure 114. Comparison of segment 171 (RM 63.7) daily average water temperatures of the PNV shading scenario 7 and the existing conditions scenario 1.

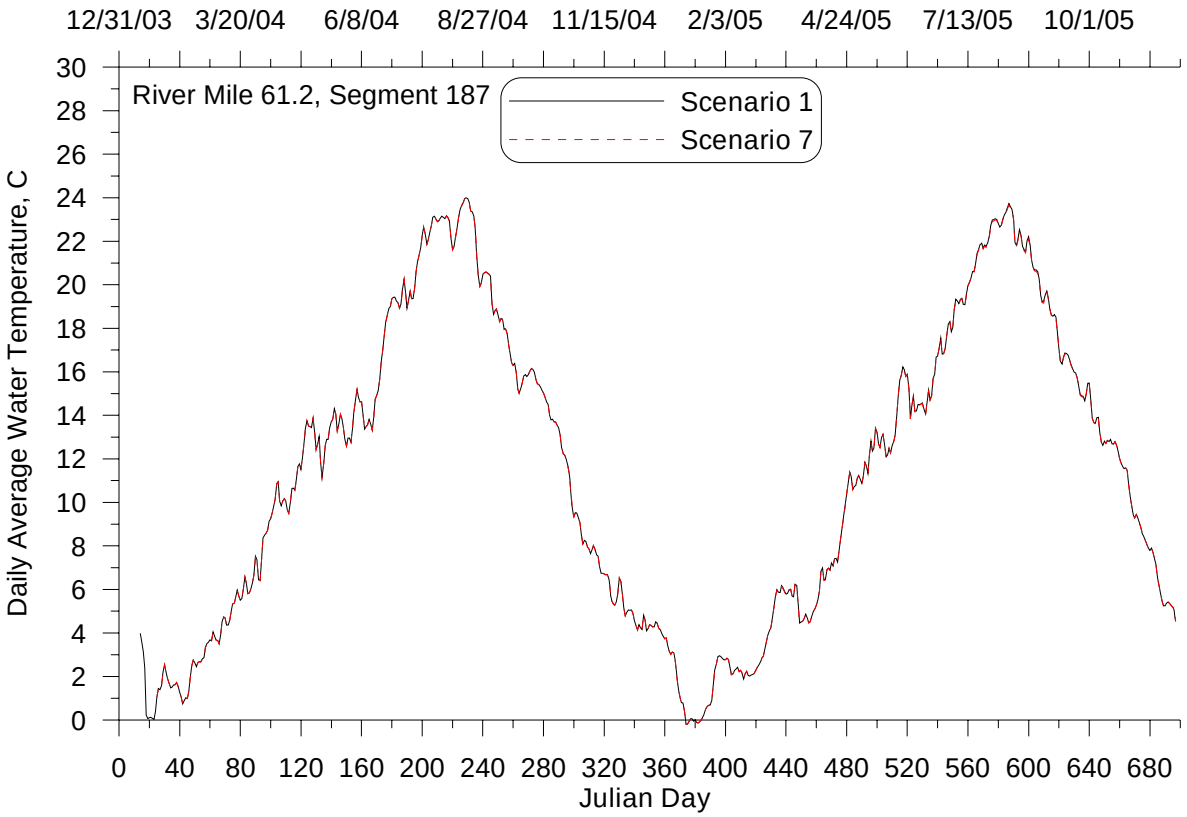

Figure 115. Comparison of segment 187 (RM 61.2) daily average water temperatures of the PNV shading scenario 7 and the existing conditions scenario 1.

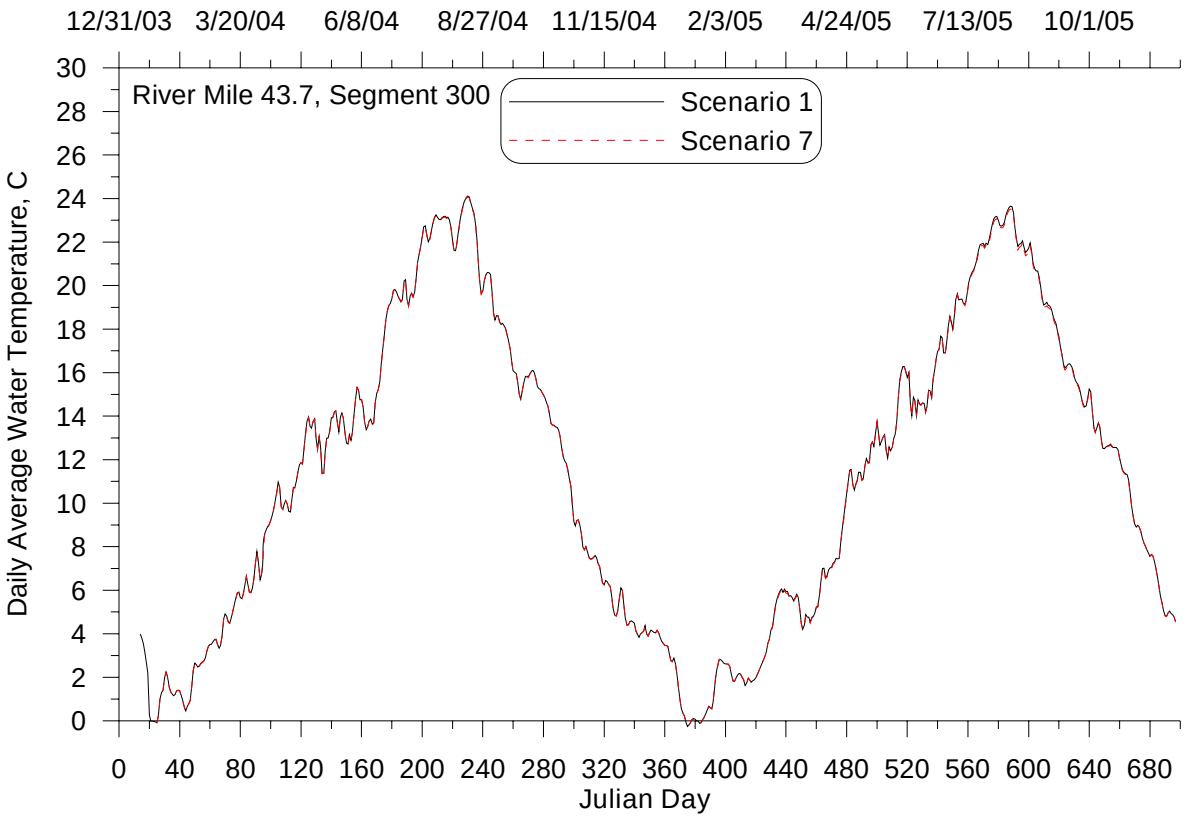

Figure 116. Comparison of segment 300 (RM 43.7) daily average water temperatures of the PNV shading scenario 7 and the existing conditions scenario 1.

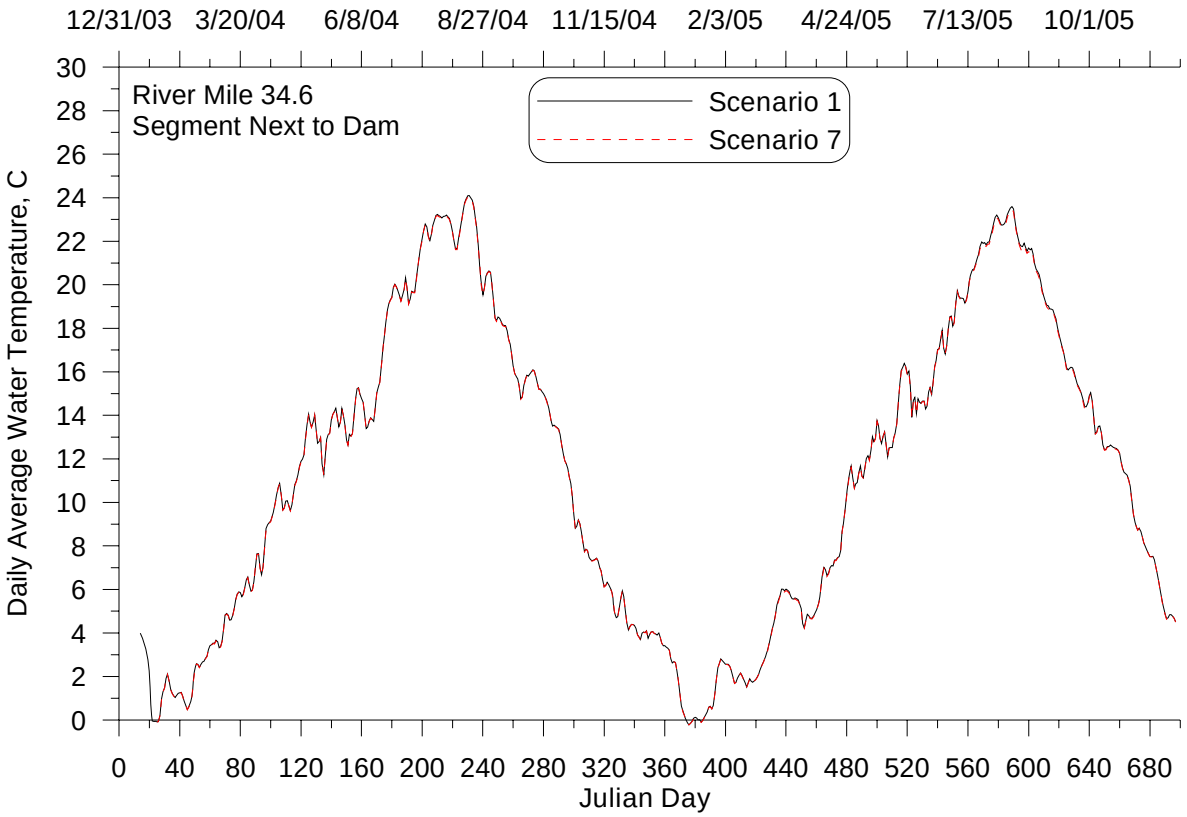

Figure 117. Comparison of model segment adjacent to Box Canyon Dam (segment 360) daily average water temperatures of the PNV shading scenario 7 and the existing conditions scenario 1 at RM 34.6.

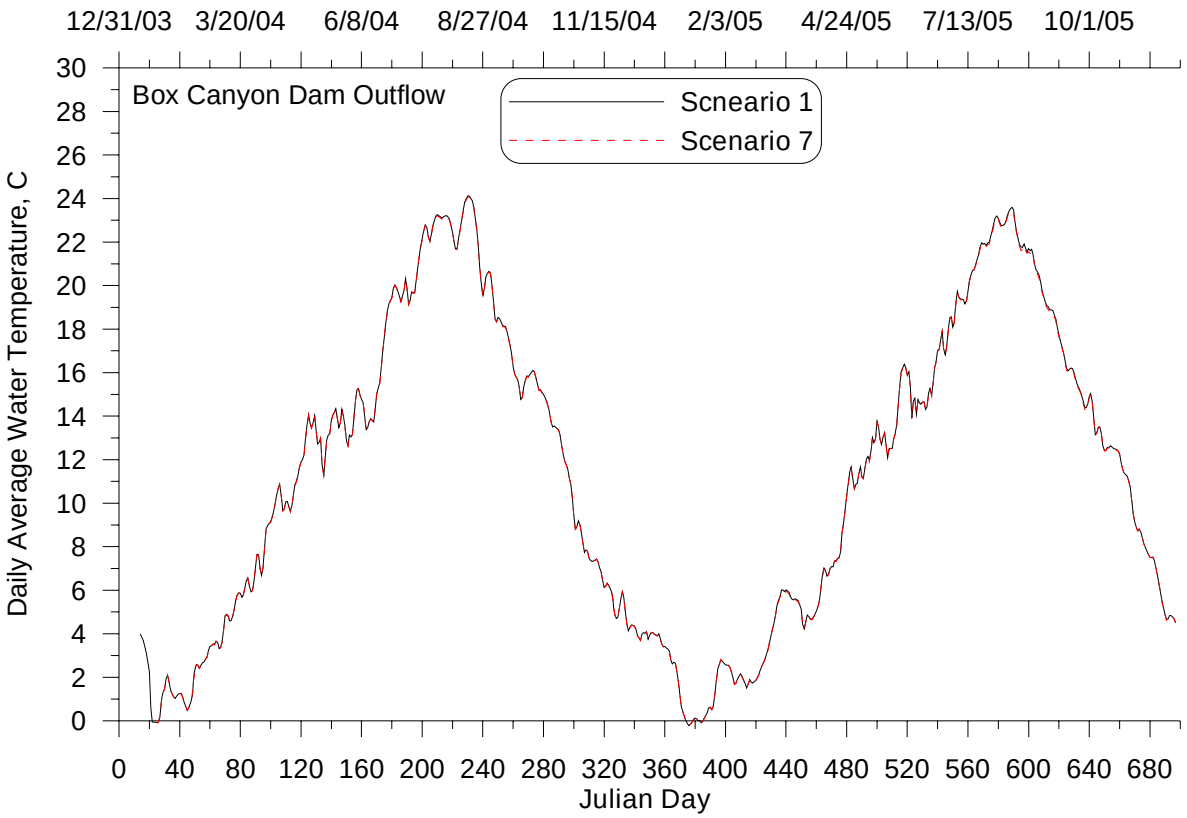

Figure 118. Comparison of Box Canyon Dam average daily outflow temperatures between the existing conditions scenario (1) and PNV shading scenario 7.

Table 23: Statistical significance in daily average time series results between the potential natural vegetation (7) and Existing Conditions (1) Scenarios.

River Mile, Model Location	P-value	Result
River Mile 87.7 (Model Segment 17)	0.003	Model results between scenarios are the same, i.e. no difference
River Mile 72.4 (Model Segment 115)	0.013	Model results between scenarios are the same, i.e. no difference
River Mile 69.8 (Model Segment 132)	0.017	Model results between scenarios are the same, i.e. no difference
River Mile 63.7 (Model Segment 171)	0.024	Model results between scenarios are the same, i.e. no difference
River Mile 61.2 (Model Segment 187	0.030	Model results between scenarios are the same, i.e. no difference
River Mile 43.7 (Model Segment 300)	0.062	Model results between scenarios are the same, i.e. no difference
River Mile 34.6 (Model Segment next to dam site)	0.062	Model results between scenarios are the same, i.e. no difference
River Mile 34.5 (Box Canyon Dam Outlet)	0.059	Model results between scenarios are the same, i.e. no difference

Daily Maximum Temperatures

Figure 119 through Figure 126 show the daily maximum temperatures of scenario 7 (PNV shading) and scenario 1 (existing conditions). The P value statistics for daily maximum temperature are listed in Table 24.

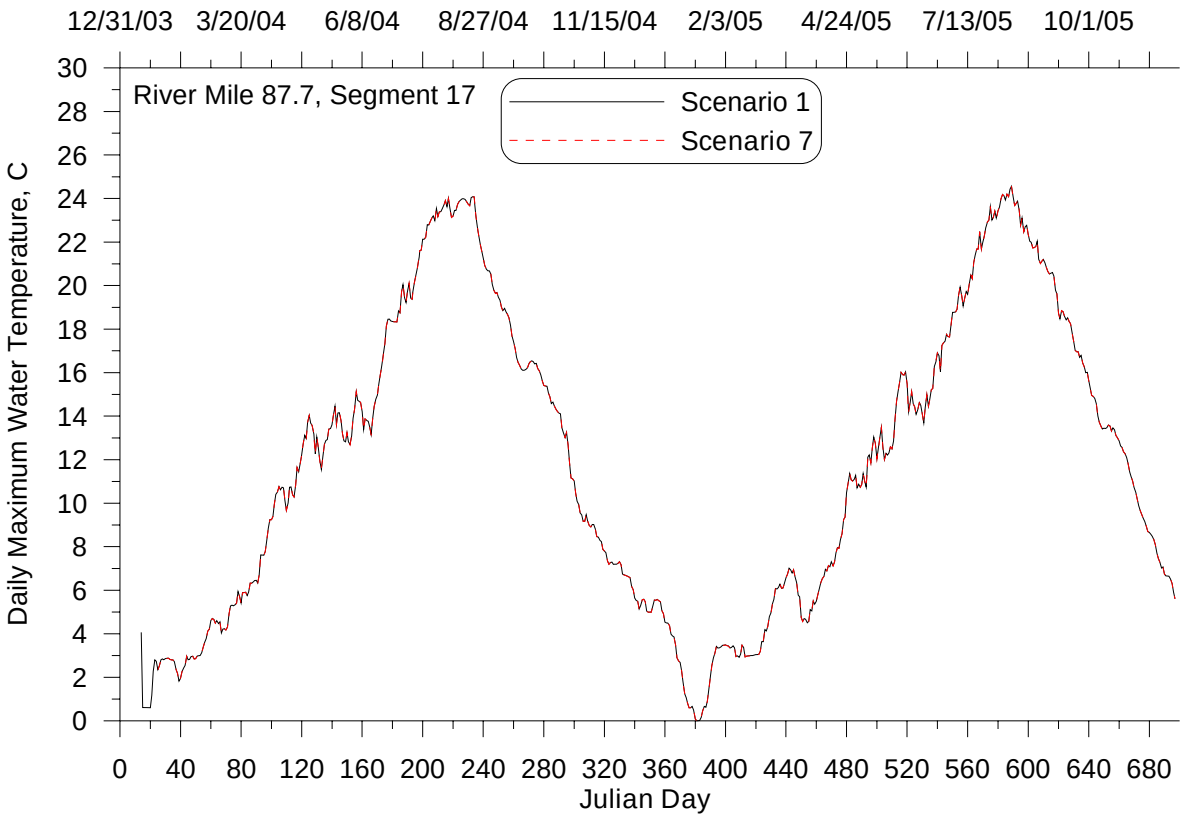

Figure 119. Comparison of segment 17 (RM 87.7) daily average water temperatures of the PNV shading scenario 7 and the existing conditions scenario 1.

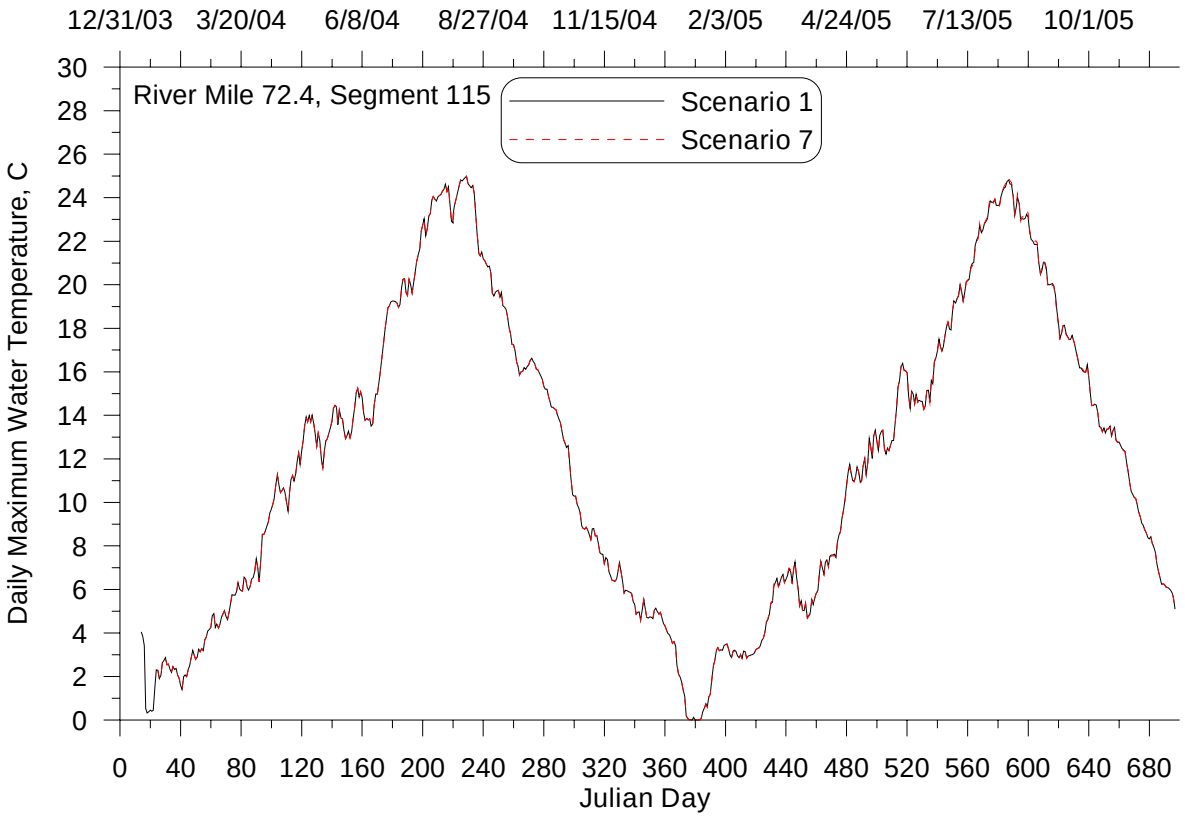

Figure 120. Comparison of segment 115 (RM 72.4) daily average water temperatures of the PNV shading scenario 7 and the existing conditions scenario 1.

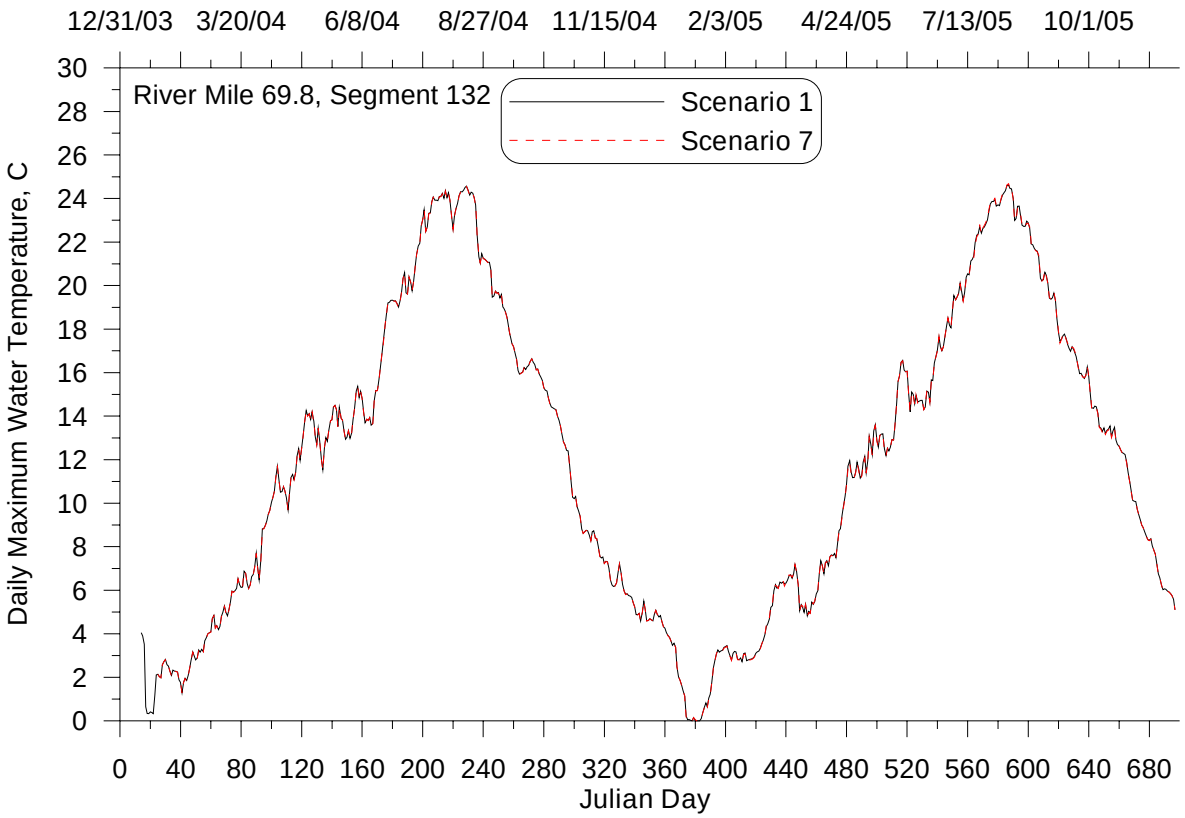

Figure 121. Comparison of segment 132 (RM 69.8) daily average water temperatures of the PNV shading scenario 7 and the existing conditions scenario 1.

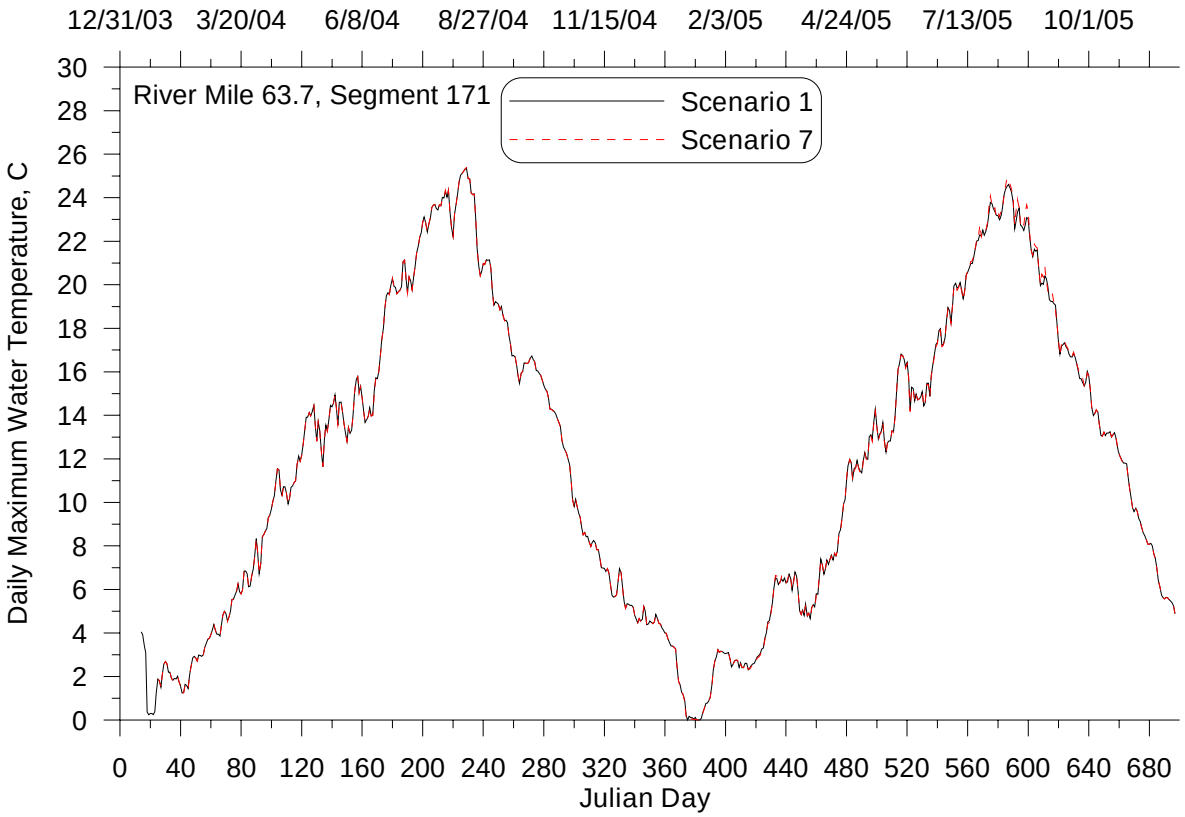

Figure 122. Comparison of segment 171 (RM 63.7) daily average water temperatures of the PNV shading scenario 7 and the existing conditions scenario 1.

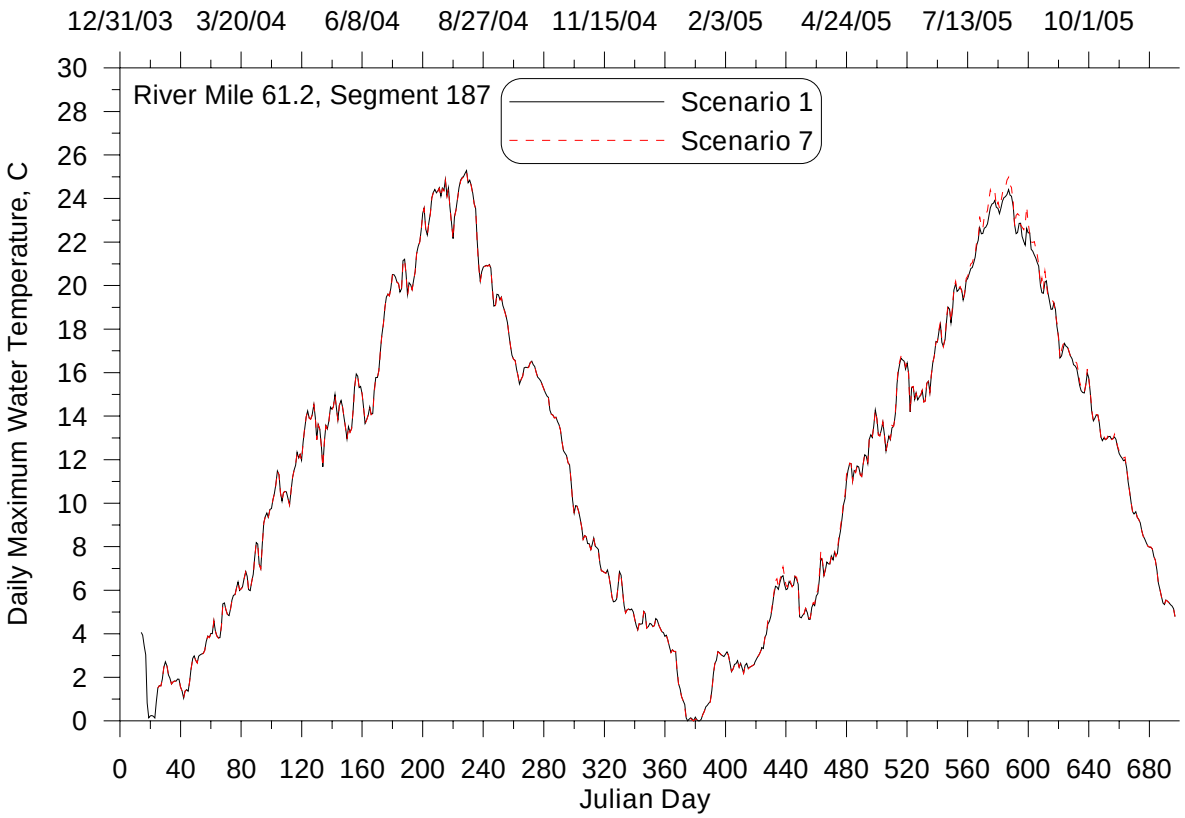

Figure 123. Comparison of segment 187 (RM 61.2) daily average water temperatures of the PNV shading scenario 7 and the existing conditions scenario 1.

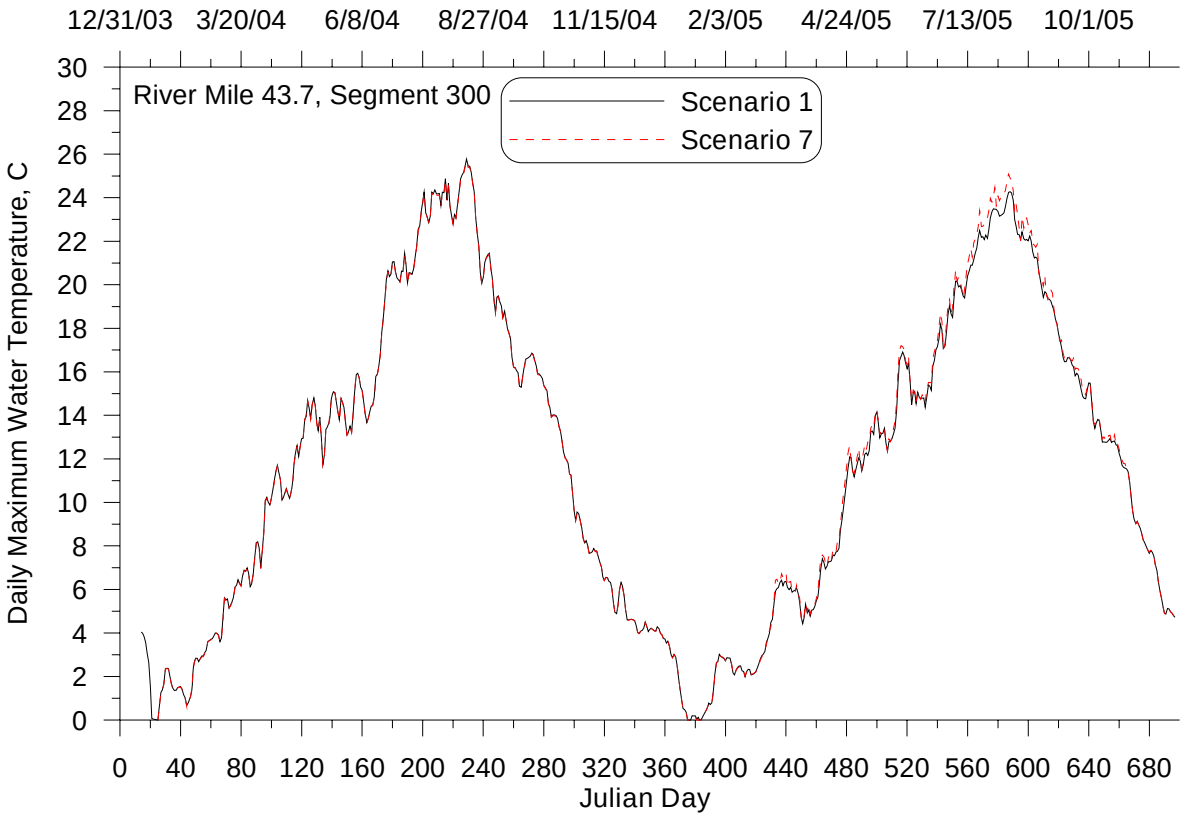

Figure 124. Comparison of segment 300 (RM 43.7) daily average water temperatures of the PNV shading scenario 7 and the existing conditions scenario 1.

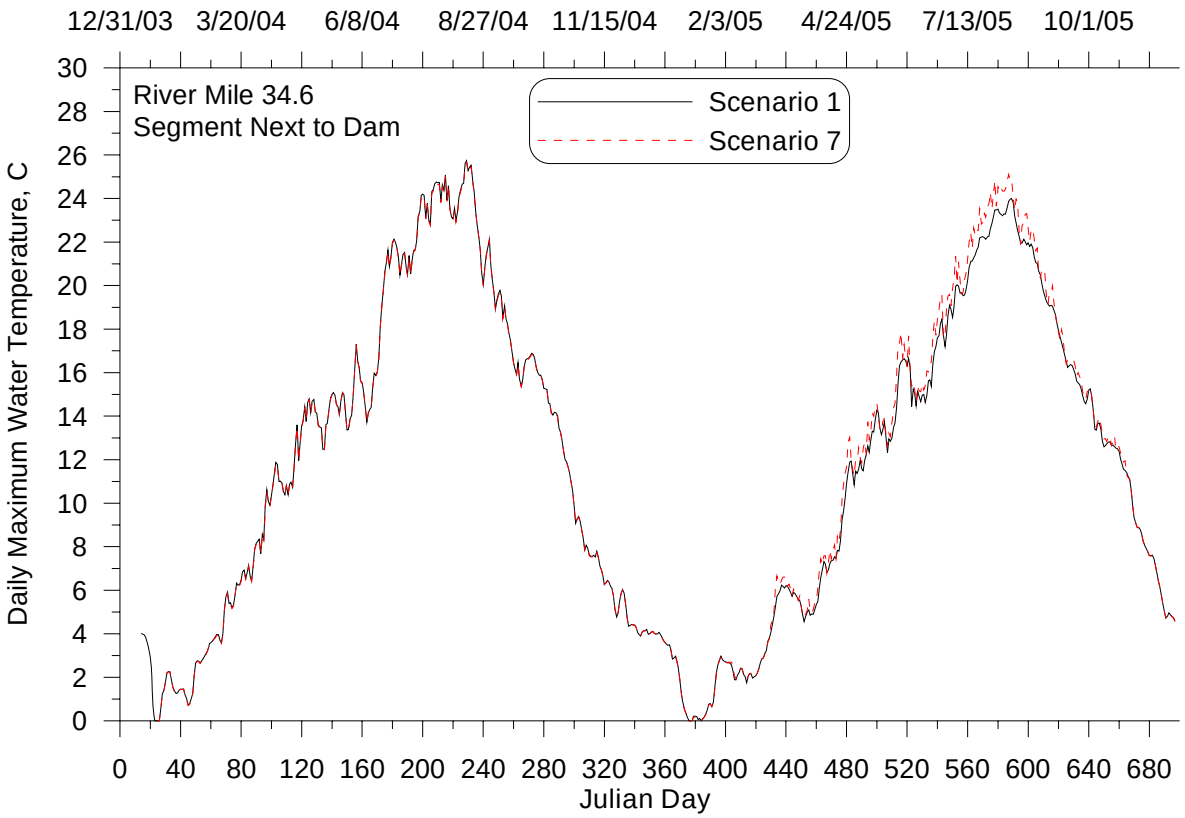

Figure 125. Comparison of model segment adjacent to Box Canyon Dam (segment 360) daily average water temperatures of the PNV shading scenario 7 and the existing conditions scenario 1 at RM 34.6.

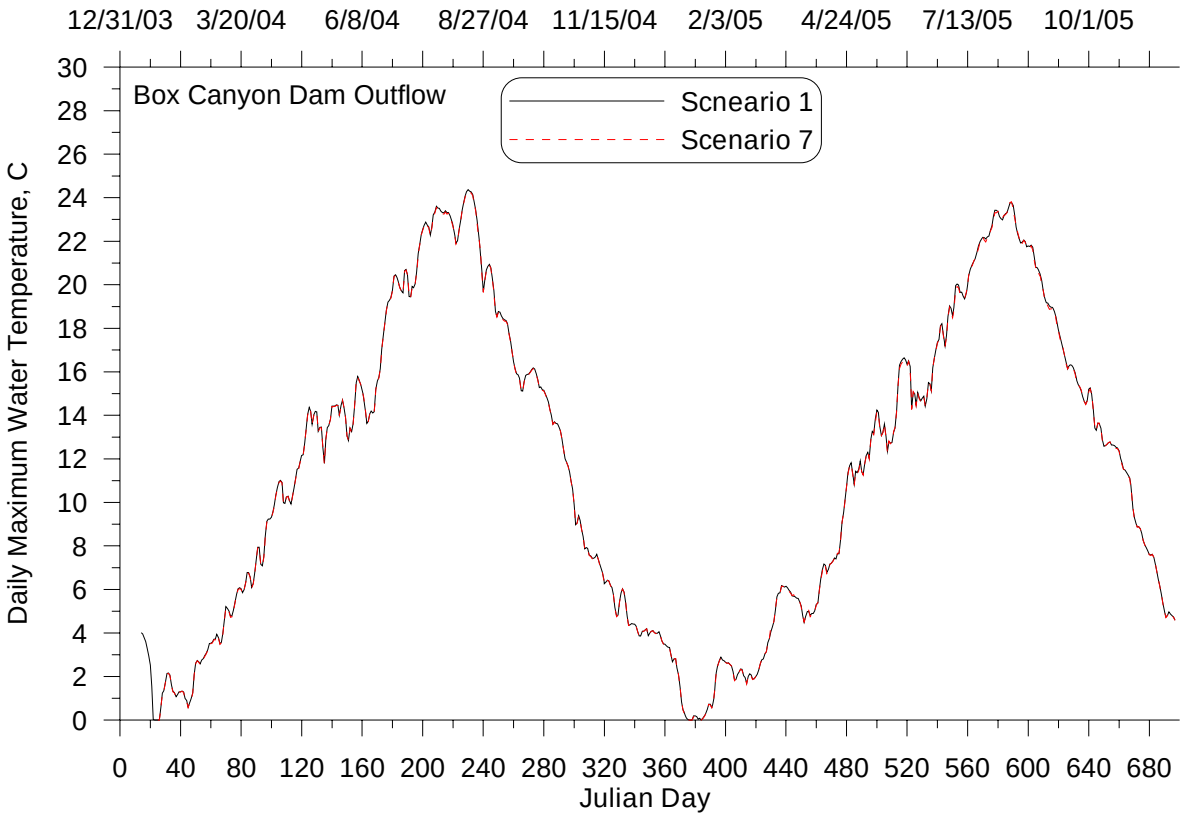

Figure 126. Comparison of Box Canyon Dam average daily outflow temperatures between the existing conditions scenario (1) and PNV shading scenario 7.

Table 24: Statistical significance in daily maximum time series results between the potential natural vegetation (7) and Existing Conditions (1) Scenarios.

River Mile, Model Location	P-value	Result
River Mile 87.7 (Model Segment 17)	0.006	Model results between scenarios are the same, i.e. no difference
River Mile 72.4 (Model Segment 115)	0.005	Model results between scenarios are the same, i.e. no difference
River Mile 69.8 (Model Segment 132)	0.016	Model results between scenarios are the same, i.e. no difference
River Mile 63.7 (Model Segment 171)	0.009	Model results between scenarios are the same, i.e. no difference
River Mile 61.2 (Model Segment 187	0.071	Model results between scenarios are the same, i.e. no difference
River Mile 43.7 (Model Segment 300)	0.157	Model results between scenarios are similar
River Mile 34.6 (Model Segment next to dam site)	0.300	Model results between scenarios have some similarities
River Mile 34.5 (Box Canyon Dam Outlet)	0.051	Model results between scenarios are the same, i.e. no difference

Longitudinal Profiles

Figure 127 and Figure 128 show the longitudinal daily average temperature profile for the PNV scenario 7 and the existing conditions scenario 1. The longitudinal daily maximum temperature profiles are plotted in Figure 129 and Figure 130. P value statistics for the longitudinal profiles are listed in Table 25 and Table 26. The longitudinal profile of the daily average temperature and daily maximum temperature for the PNV scenario were slightly cooler.

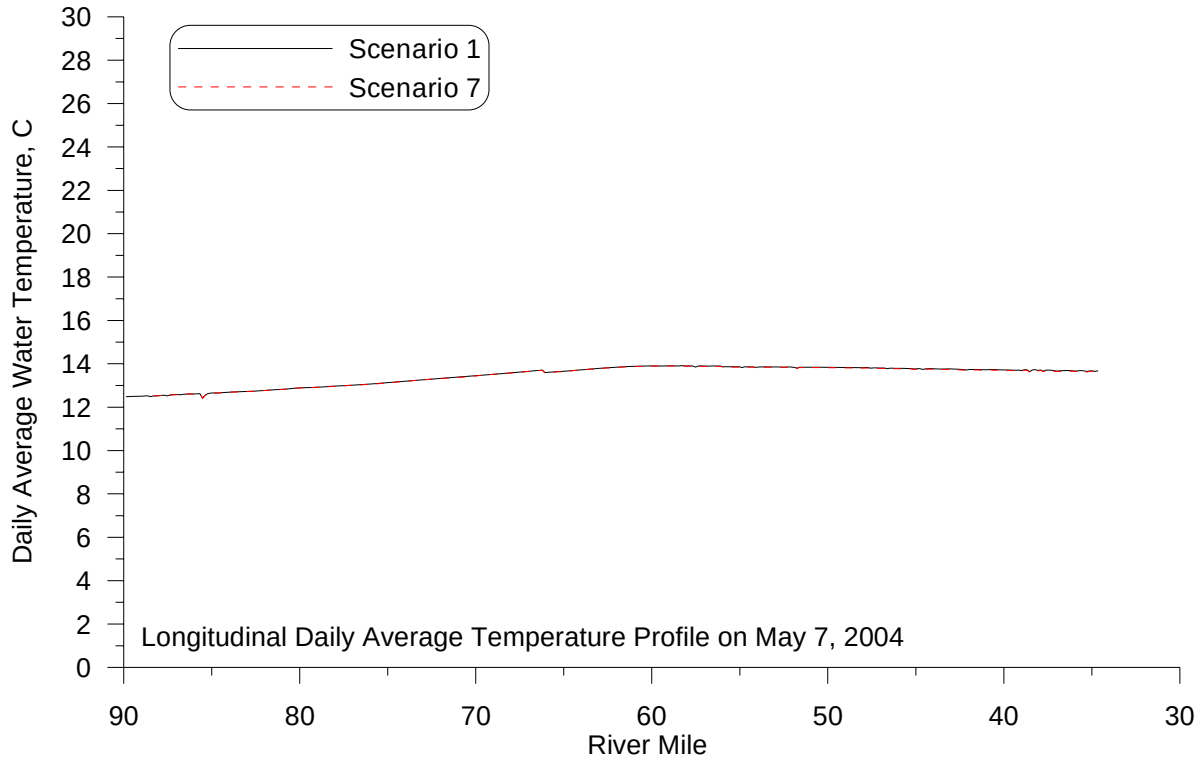

Figure 127. Comparison of longitudinal daily average temperature profile on May 7, 2004 between the PNV shading scenario 7 and the existing conditions scenario 1.

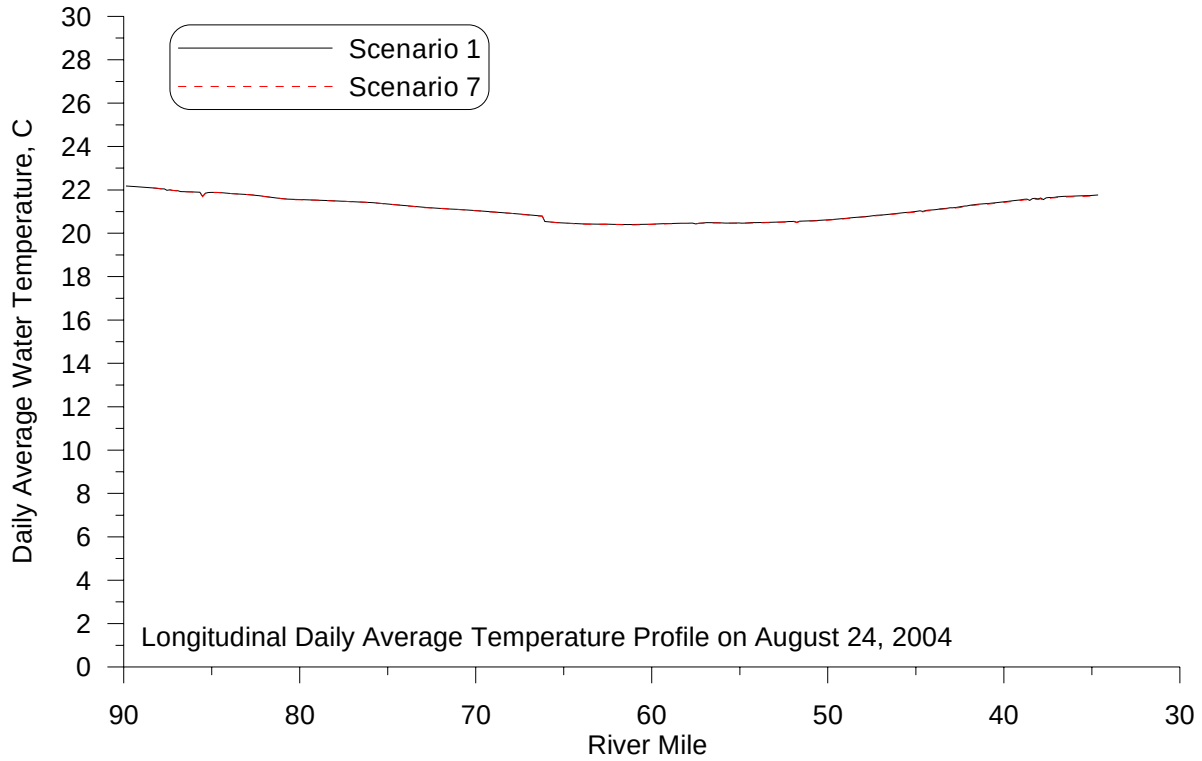

Figure 128. Comparison of longitudinal daily average temperature profile on August 24, 2004 between the PNV shading scenario 7 and the existing conditions scenario 1.

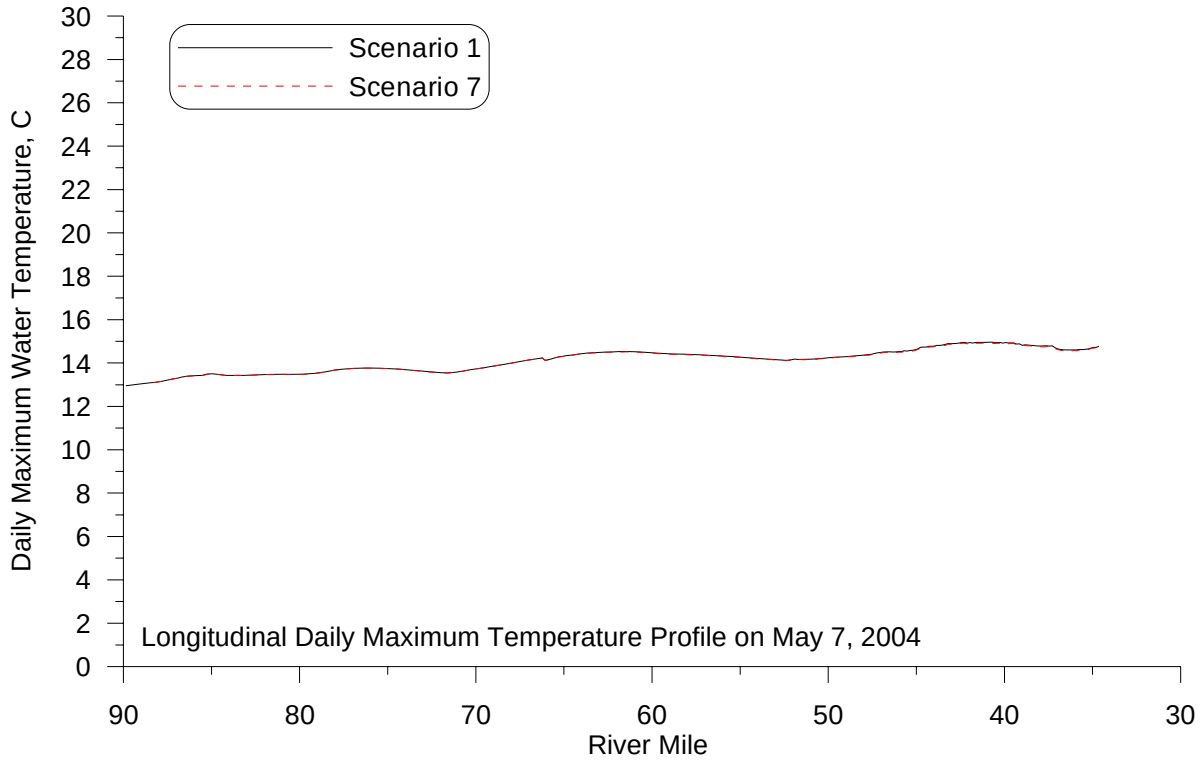

Figure 129. Comparison of longitudinal daily maximum temperature profile on May 7, 2004 between the PNV shading scenario 7 and the existing conditions scenario 1.

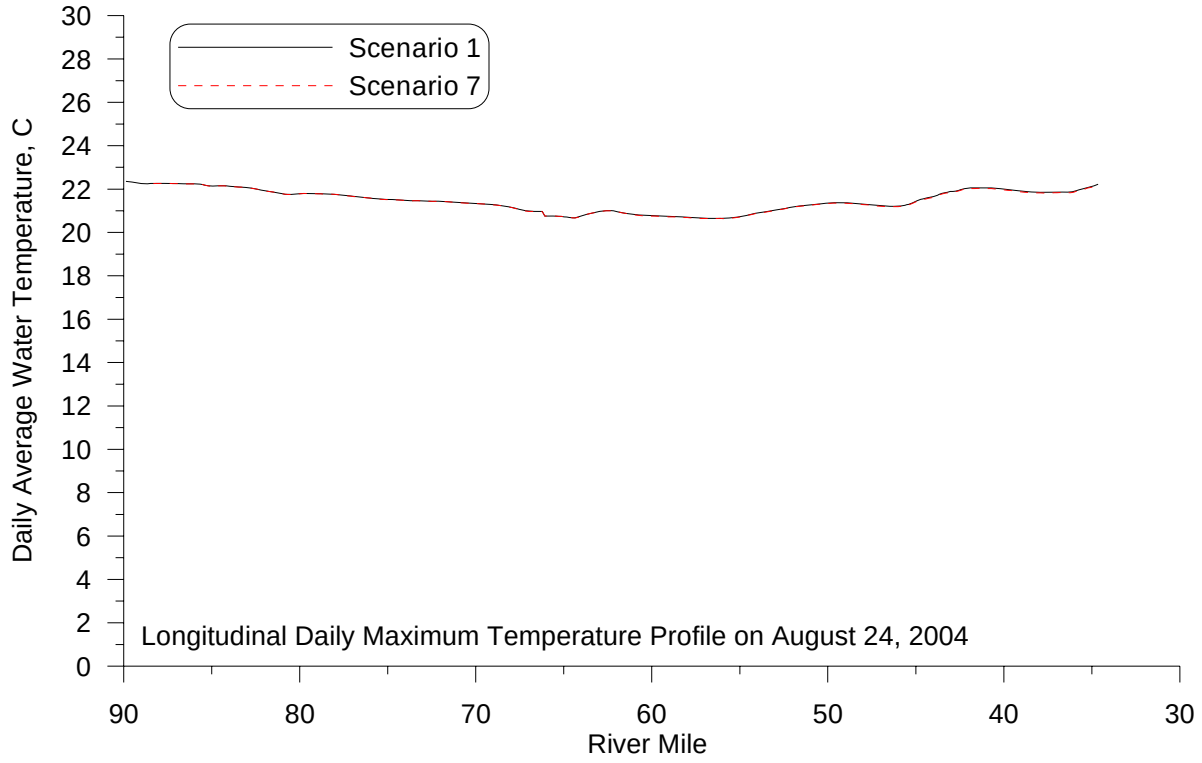

Figure 130. Comparison of longitudinal daily maximum temperature profile on August 24, 2004 between the PNV shading scenario 7 and the existing conditions scenario 1.

Table 25: Statistical significance of daily average temperature in the longitudinal profiles on May 7th, 2004 and August 24th, 2004 between the PNV shading (7) and Existing Conditions (1) Scenarios.

Scenario 1 and Scenario 7 Comparison	P-value	Result
May 7th daily average temperature	0.244	Model results between scenarios have some similarities
August 24th daily average temperature	0.233	Model results between scenarios have some similarities

Table 26: Statistical significance of daily maximum temperature in the longitudinal profiles on May 7th, 2004 and August 24th, 2004 between the PNV shading (7) and Existing Conditions (1) Scenarios.

Scenario 1 and Scenario 7 Comparison	P-value	Result
May 7th daily maximum temperature	0.286	Model results between scenarios have some similarities
August 24th daily maximum temperature	0.258	Model results between scenarios have some similarities

Evaluation of Upstream Conditions

The influence of Albeni Falls Dam to temperature on the Pend Oreille River was evaluated by comparing results from Model Scenario 7.5 to Existing Conditions (Scenario 1).

Time Series Plots

Daily Average Temperatures

The daily average temperatures of the no Albeni Falls Dam scenario 7.5 and the existing conditions scenario 1 are plotted in Figure 131 through Figure 138. Table 27 provides the daily average temperature P value statistics comparing these scenarios. The no Albeni Falls Dam scenario predicted warmer temperatures in the summer and cooler temperatures in the fall. These differences were not distinguished by the P value statistics, because the daily average temperatures of the scenarios even out.

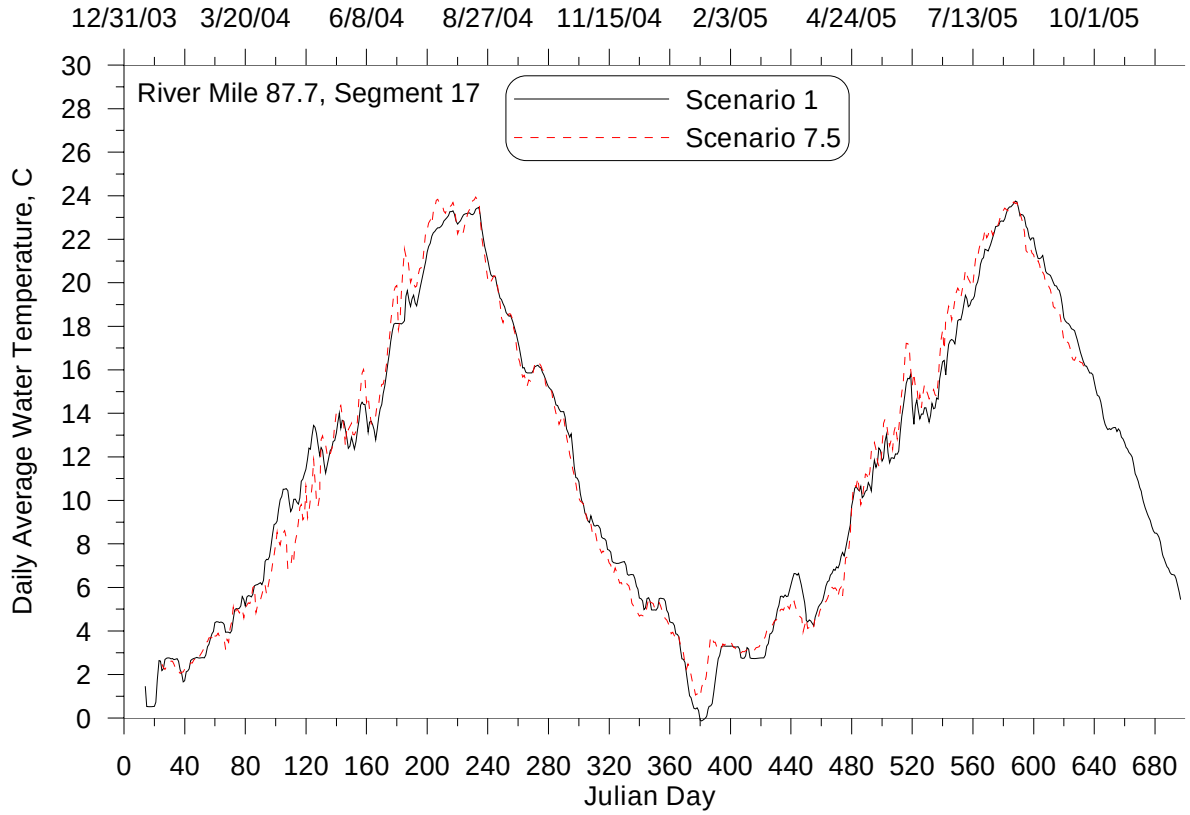

Figure 131. Comparison of segment 17 (RM 87.7) daily average water temperatures of the no Albeni Falls dam scenario 7.5 and the existing conditions scenario 1.

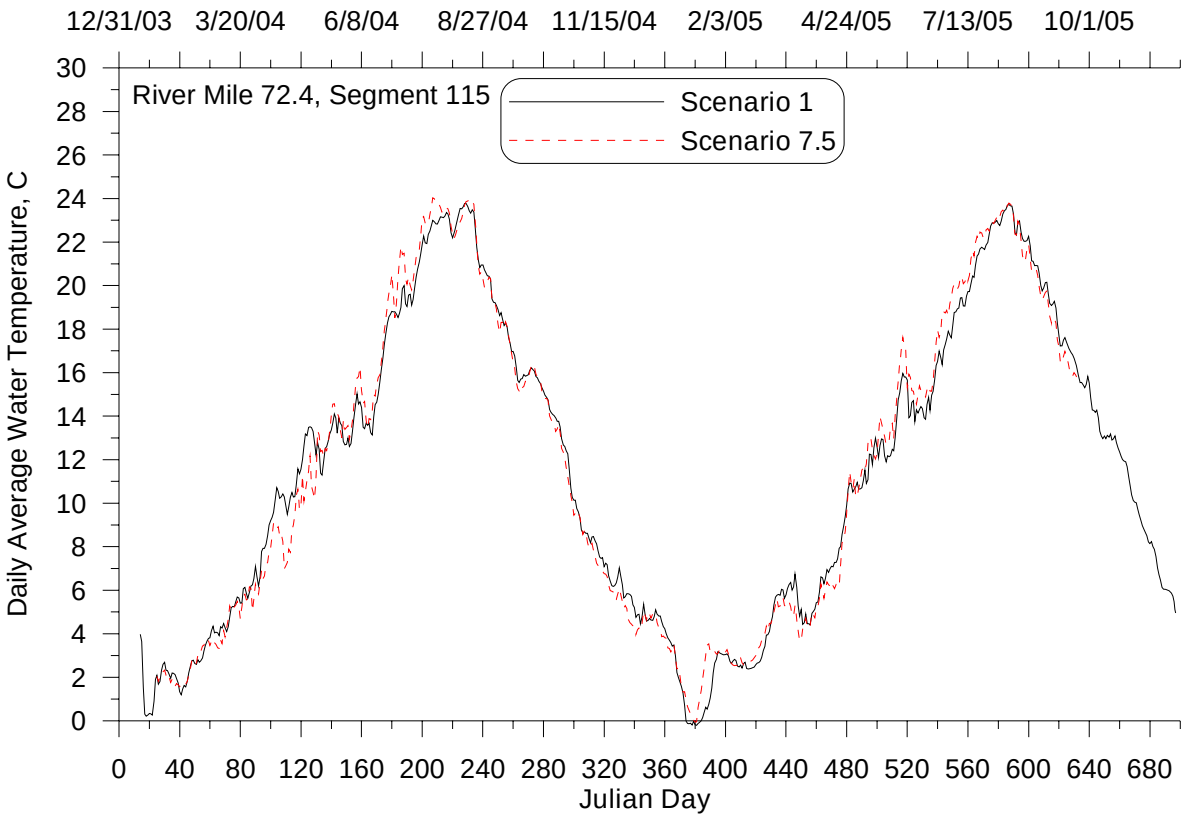

Figure 132. Comparison of segment 115 (RM 72.4) daily average water temperatures of the no Albeni Falls dam scenario 7.5 and the existing conditions scenario 1.

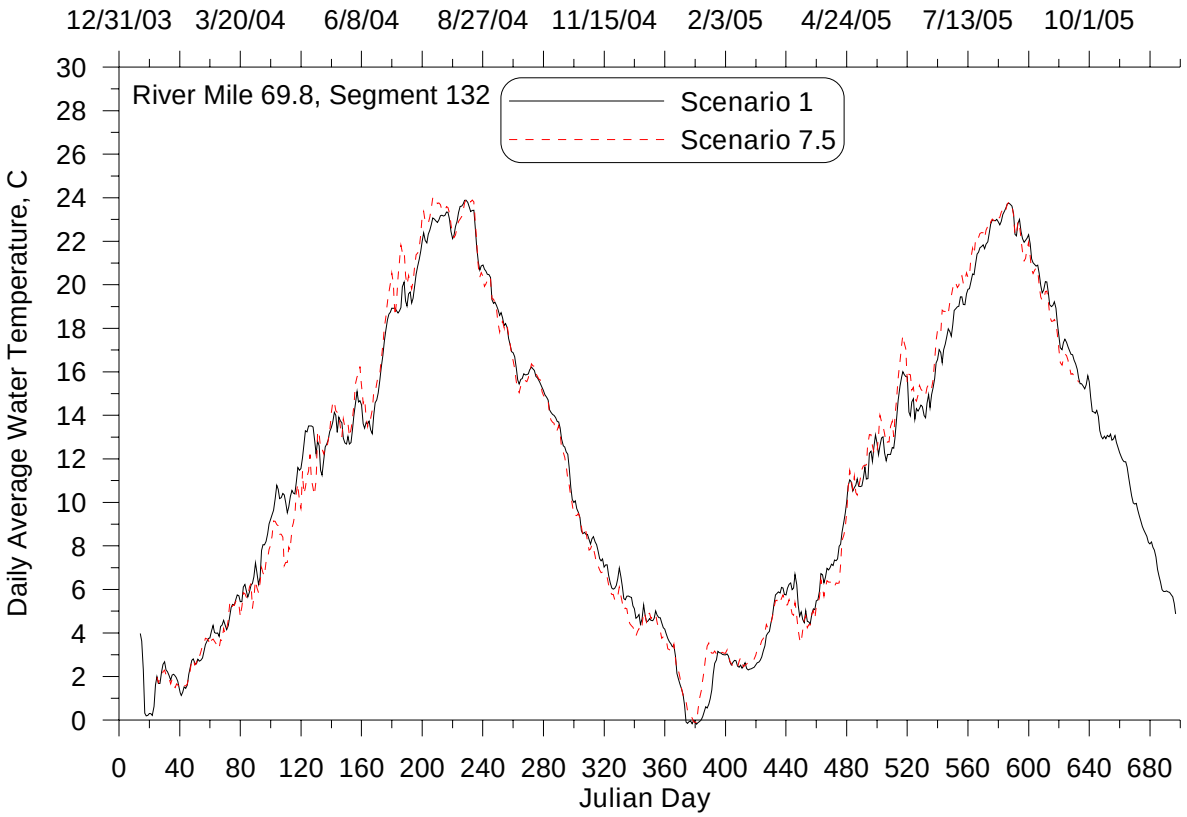

Figure 133. Comparison of segment 132 (RM 69.8) daily average water temperatures of the no Albeni Falls dam scenario 7.5 and the existing conditions scenario 1.

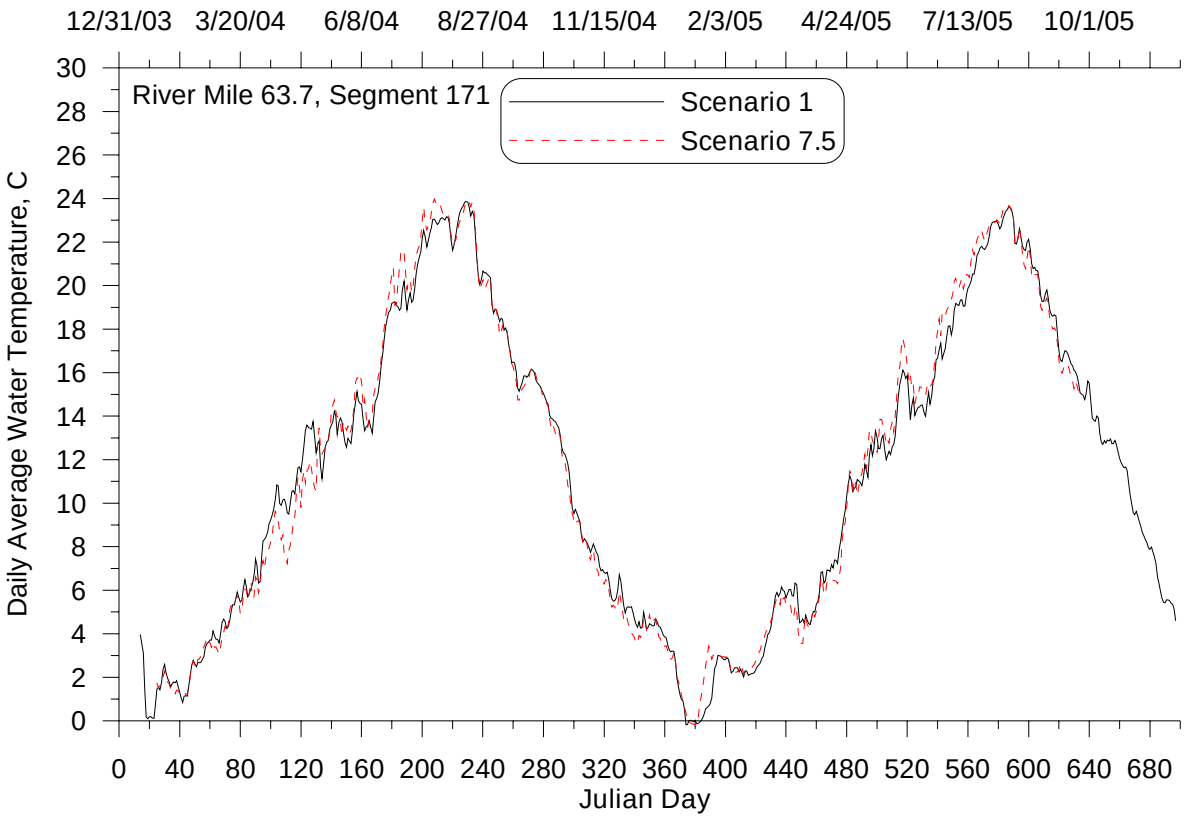

Figure 134. Comparison of segment 171 (RM 63.7) daily average water temperatures of the no Albeni Falls dam scenario 7.5 and the existing conditions scenario 1.

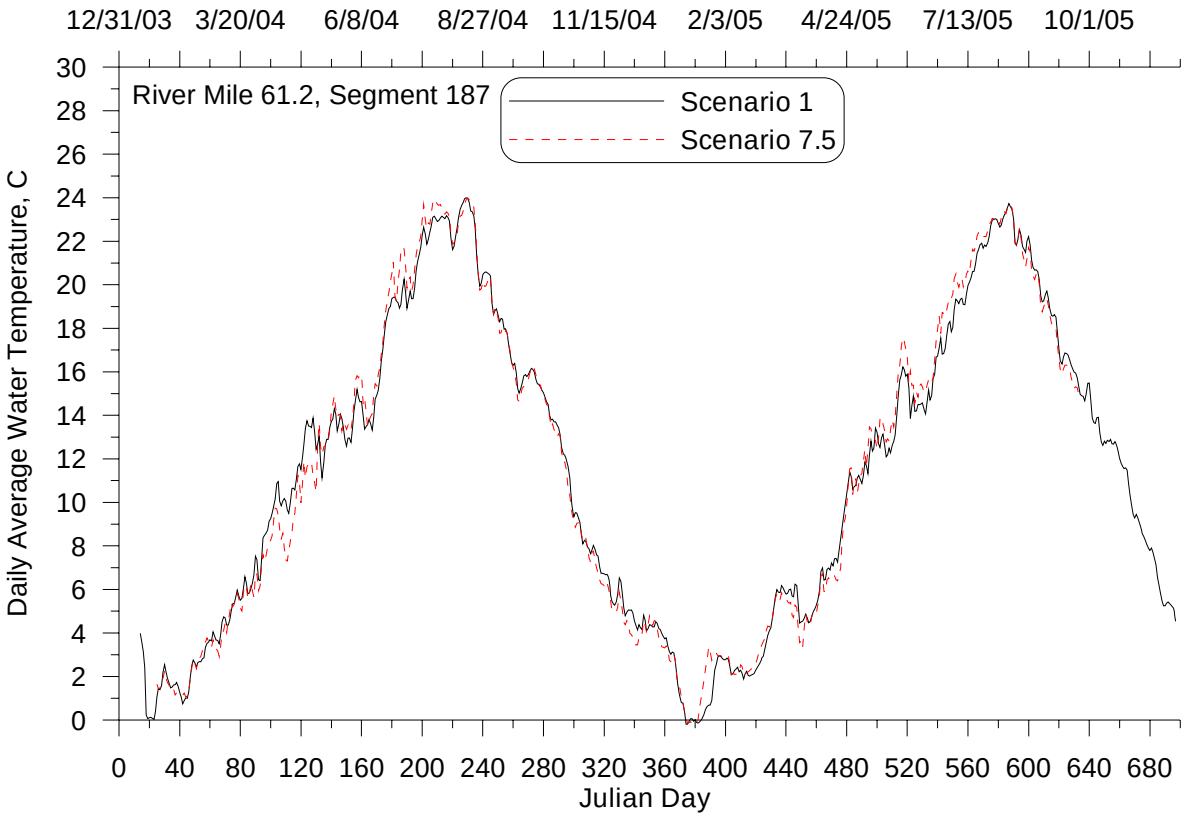

Figure 135. Comparison of segment 187 (RM 61.2) daily average water temperatures of the no Albeni Falls dam scenario 7.5 and the existing conditions scenario 1.

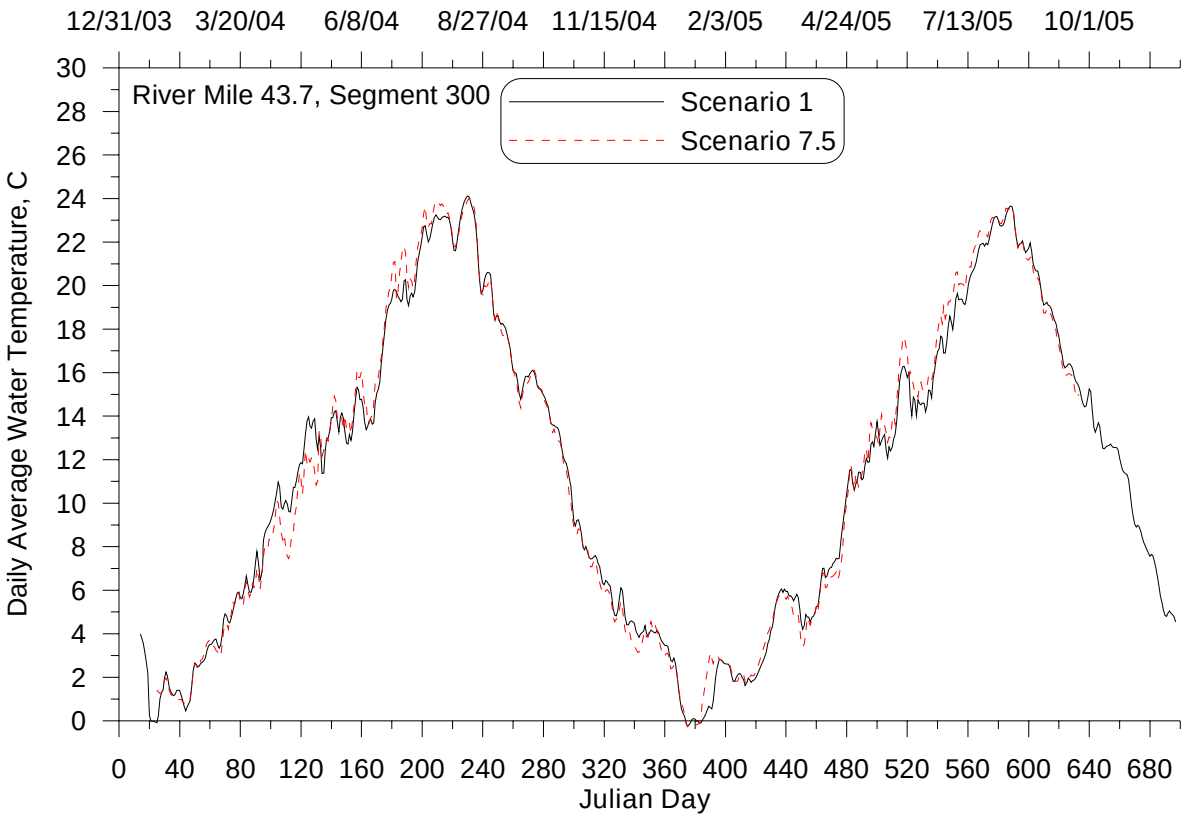

Figure 136. Comparison of segment 300 (RM 43.7) daily average water temperatures of the no Albeni Falls dam scenario 7.5 and the existing conditions scenario 1.

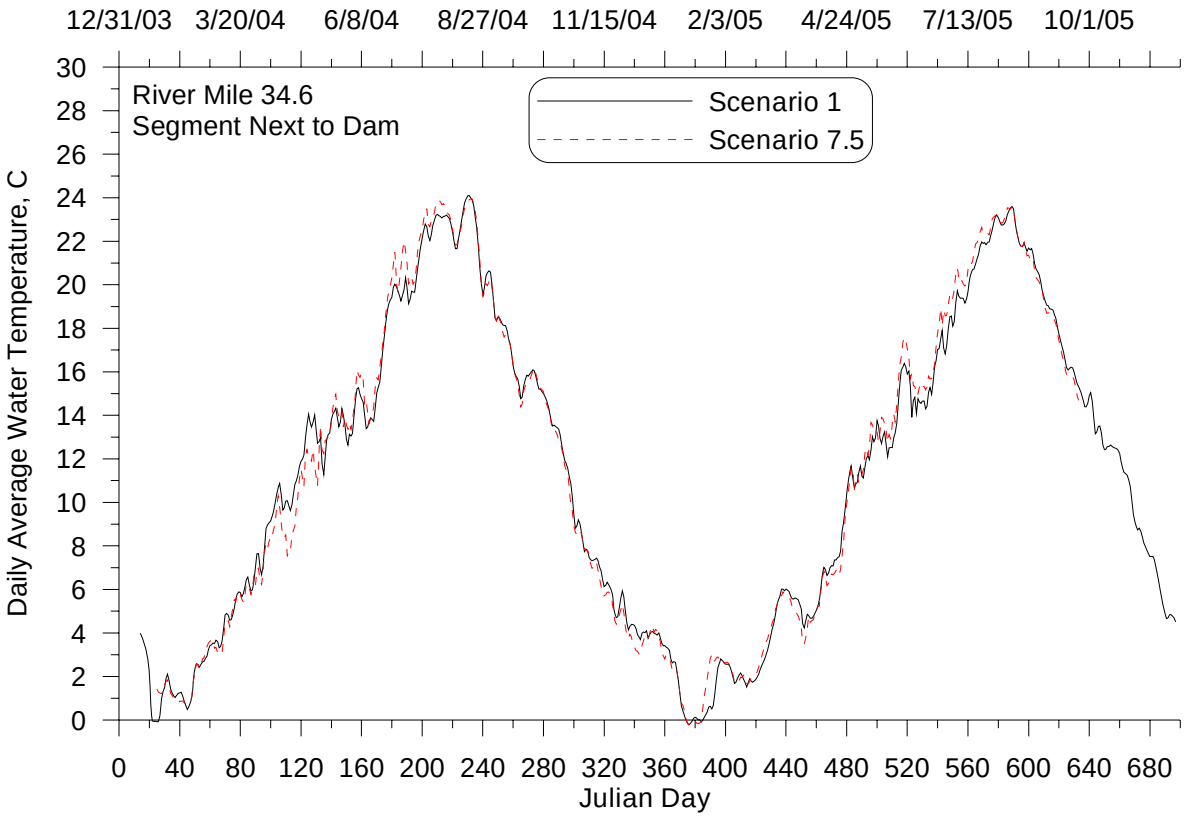

Figure 137. Comparison of model segment adjacent to Box Canyon Dam (segment 360) daily average water temperatures of the no Albeni Falls dam scenario 7.5 and the existing conditions scenario 1 at RM 34.6.

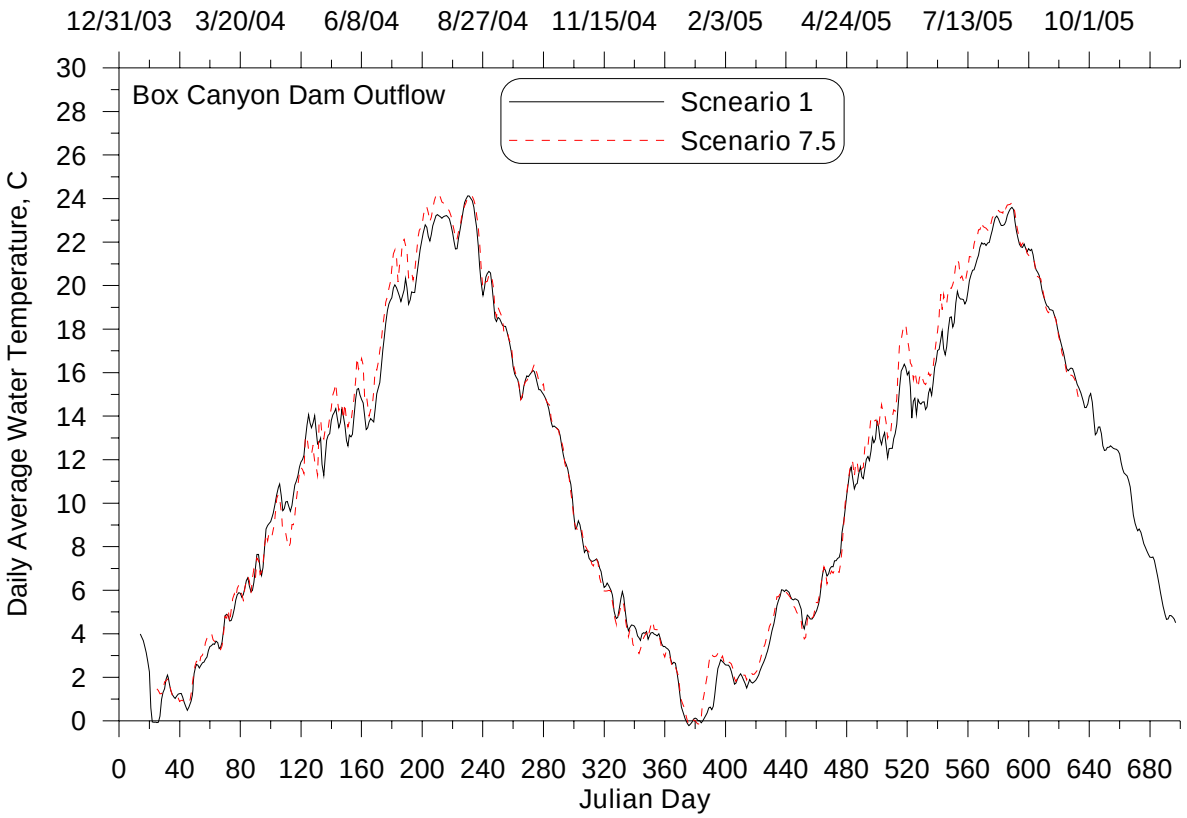

Figure 138. Comparison of Box Canyon Dam average daily outflow temperatures between the existing conditions scenario (1) and the no Albeni Falls dam Scenario 7.5.

Table 27: Statistical significance in daily average time series results between the no Albeni Falls dam (7.5) and Existing Conditions (1) Scenarios.

River Mile, Model Location	P-value	Result
River Mile 87.7 (Model Segment 17)	0.085	Model results between scenarios are the same, i.e. no difference
River Mile 72.4 (Model Segment 115)	0.085	Model results between scenarios are the same, i.e. no difference
River Mile 69.8 (Model Segment 132)	0.083	Model results between scenarios are the same, i.e. no difference
River Mile 63.7 (Model Segment 171)	0.086	Model results between scenarios are the same, i.e. no difference
River Mile 61.2 (Model Segment 187	0.086	Model results between scenarios are the same, i.e. no difference
River Mile 43.7 (Model Segment 300)	0.093	Model results between scenarios are the same, i.e. no difference
River Mile 34.6 (Model Segment next to dam site)	0.097	Model results between scenarios are the same, i.e. no difference
River Mile 34.5 (Box Canyon Dam Outlet)	0.097	Model results between scenarios are the same, i.e. no difference

Daily Maximum Temperatures

Figure 139 through Figure 146 compare the daily maximum temperatures of the no Albeni Falls Dam scenario 7.5 and the existing conditions scenario 1. The daily average maximum temperature P values statistics are listed in Table 28. Daily maximum temperatures of the no Albeni Falls Dam scenario were generally warmer, but were cooler during the spring and fall. Without Albeni Falls Dam, the river was shallower upstream and more responsive to short term meteorological conditions.

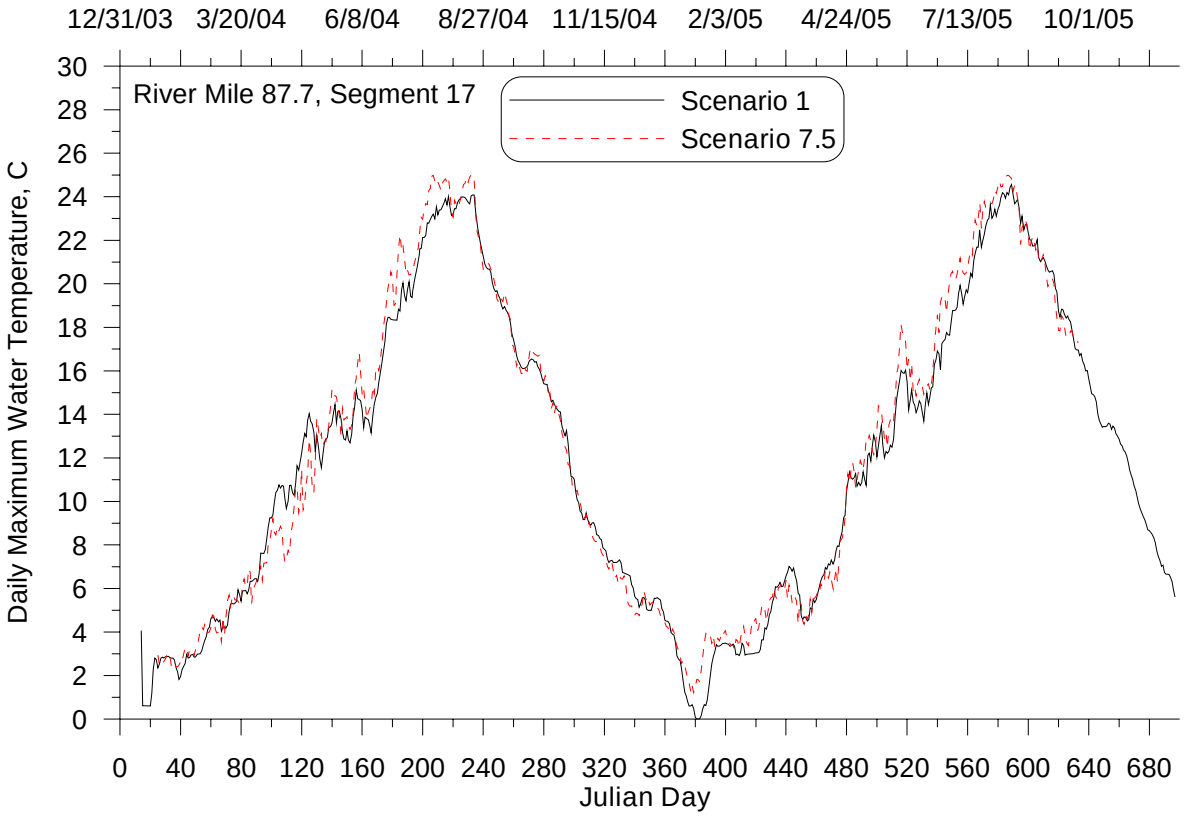

Figure 139. Comparison of segment 17 (RM 87.7) daily maximum water temperatures of the no Albeni Falls dam scenario 7.5 and the existing conditions scenario 1.

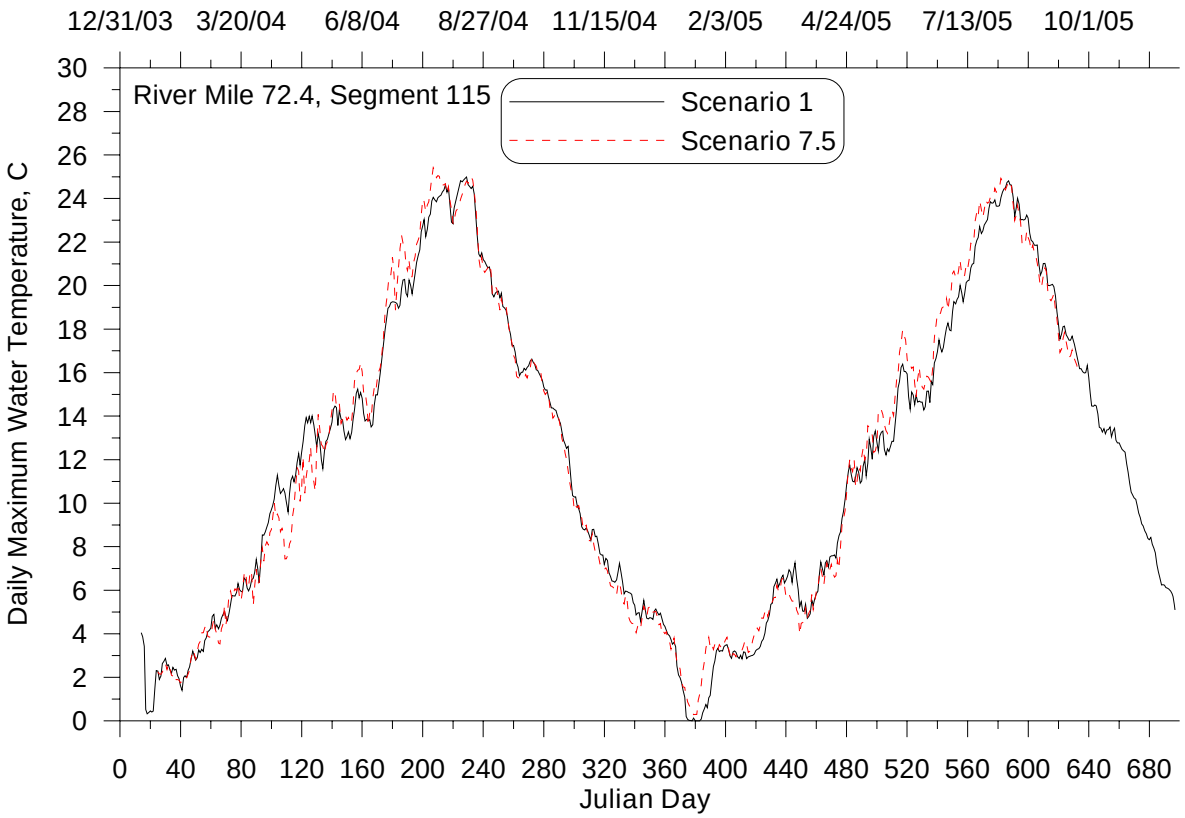

Figure 140. Comparison of segment 115 (RM 72.4) daily maximum water temperatures of the no Albeni Falls dam scenario 7.5 and the existing conditions scenario 1.

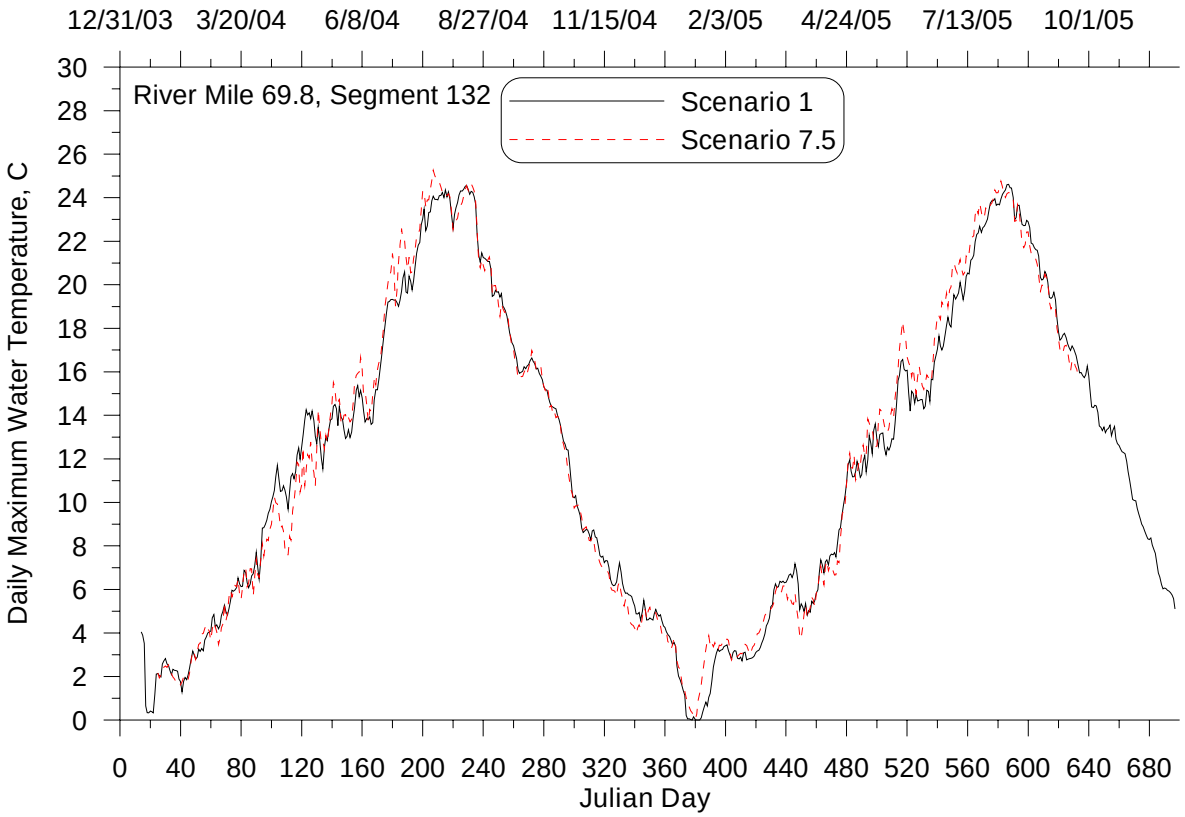

Figure 141. Comparison of segment 132 (RM 69.8) daily maximum water temperatures of the no Albeni Falls dam scenario 7.5 and the existing conditions scenario 1.

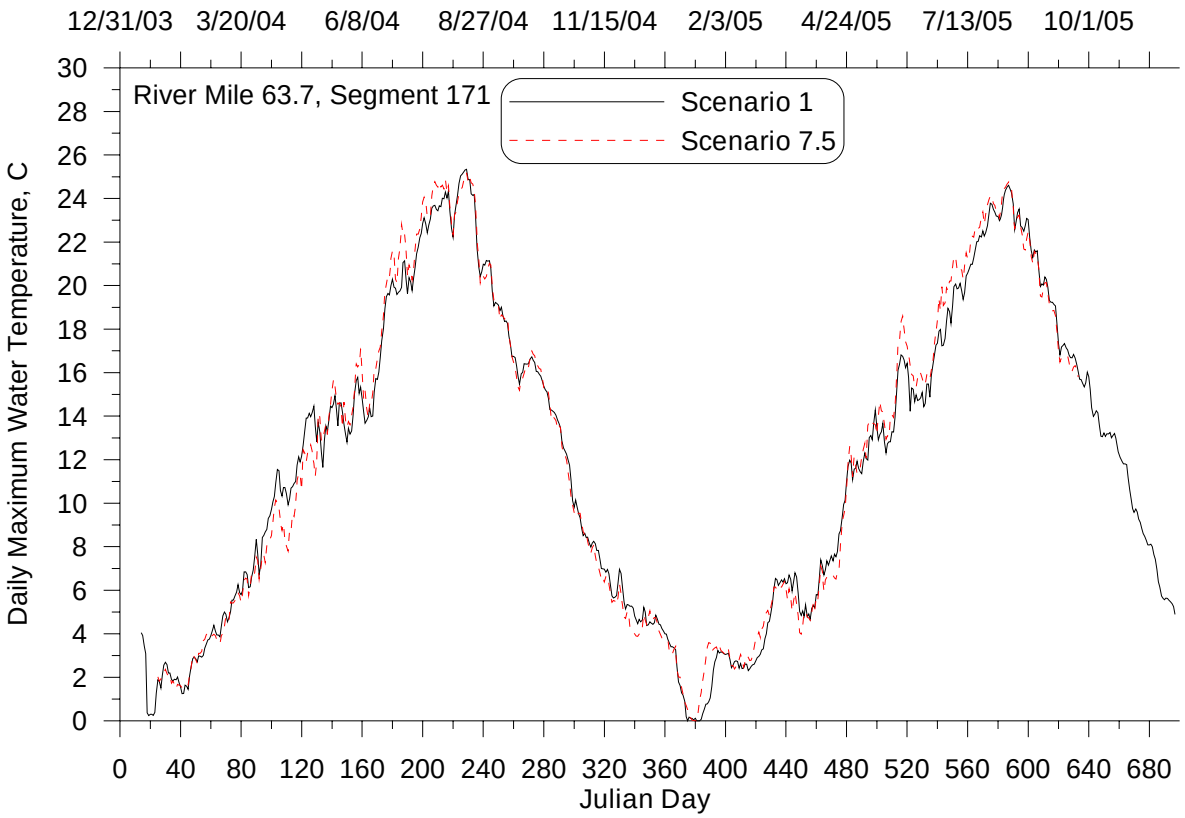

Figure 142. Comparison of segment 171 (RM 63.7) daily maximum water temperatures of the no Albeni Falls dam scenario 7.5 and the existing conditions scenario 1.

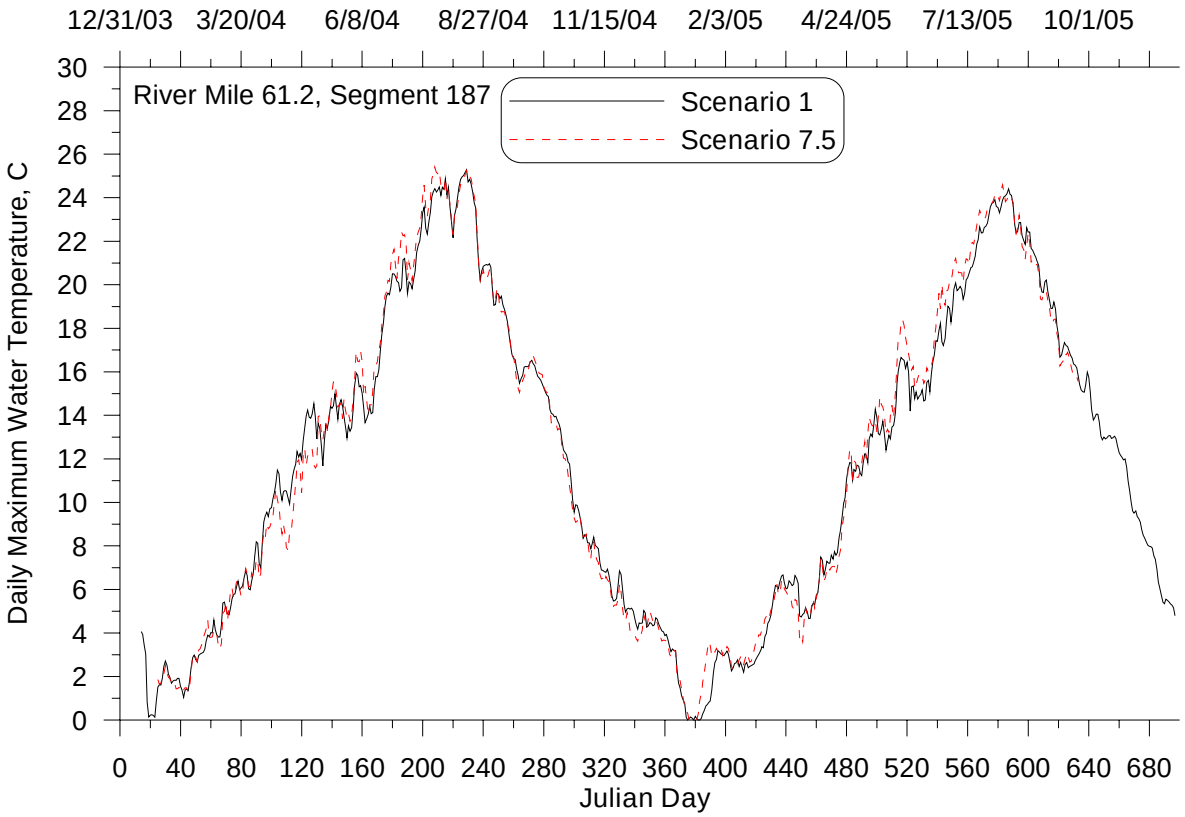

Figure 143. Comparison of segment 187 (RM 61.2) daily maximum water temperatures of the no Albeni Falls dam scenario 7.5 and the existing conditions scenario 1.

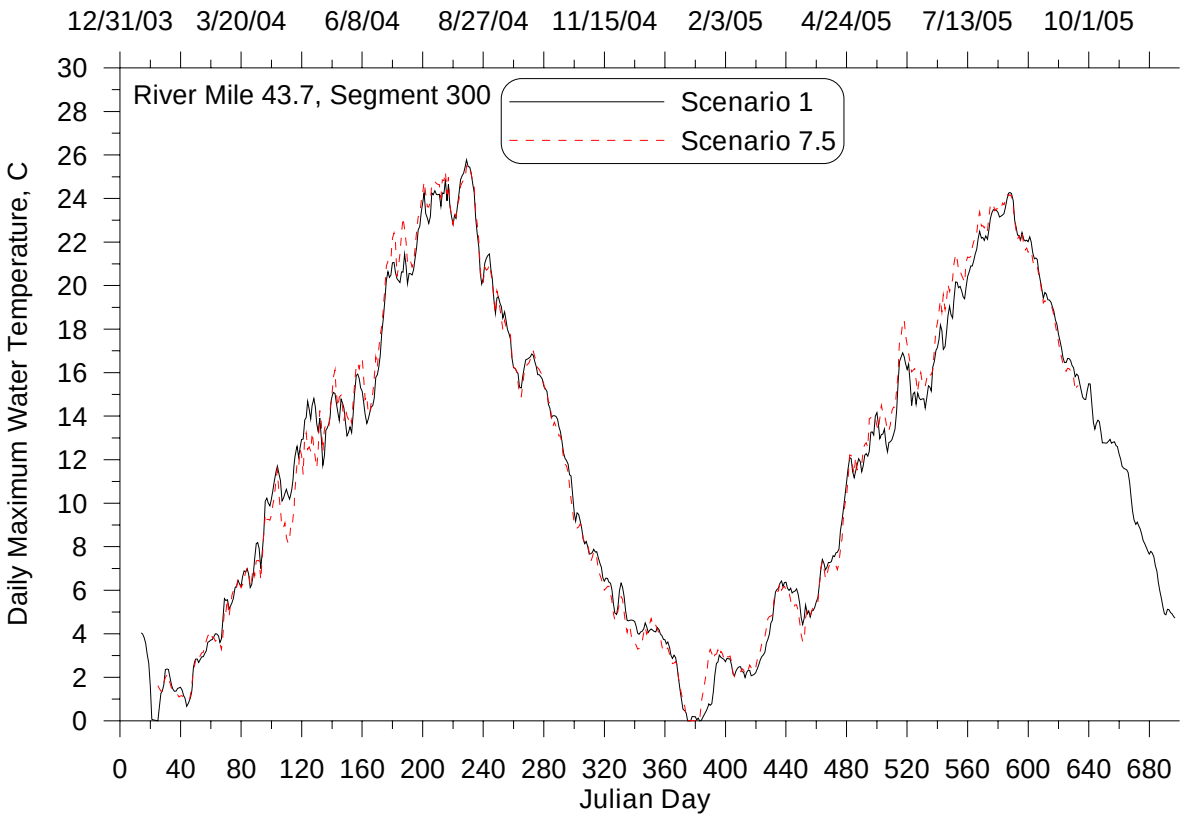

Figure 144. Comparison of segment 300 (RM 43.7) daily maximum water temperatures of the no Albeni Falls dam scenario 7.5 and the existing conditions scenario 1.

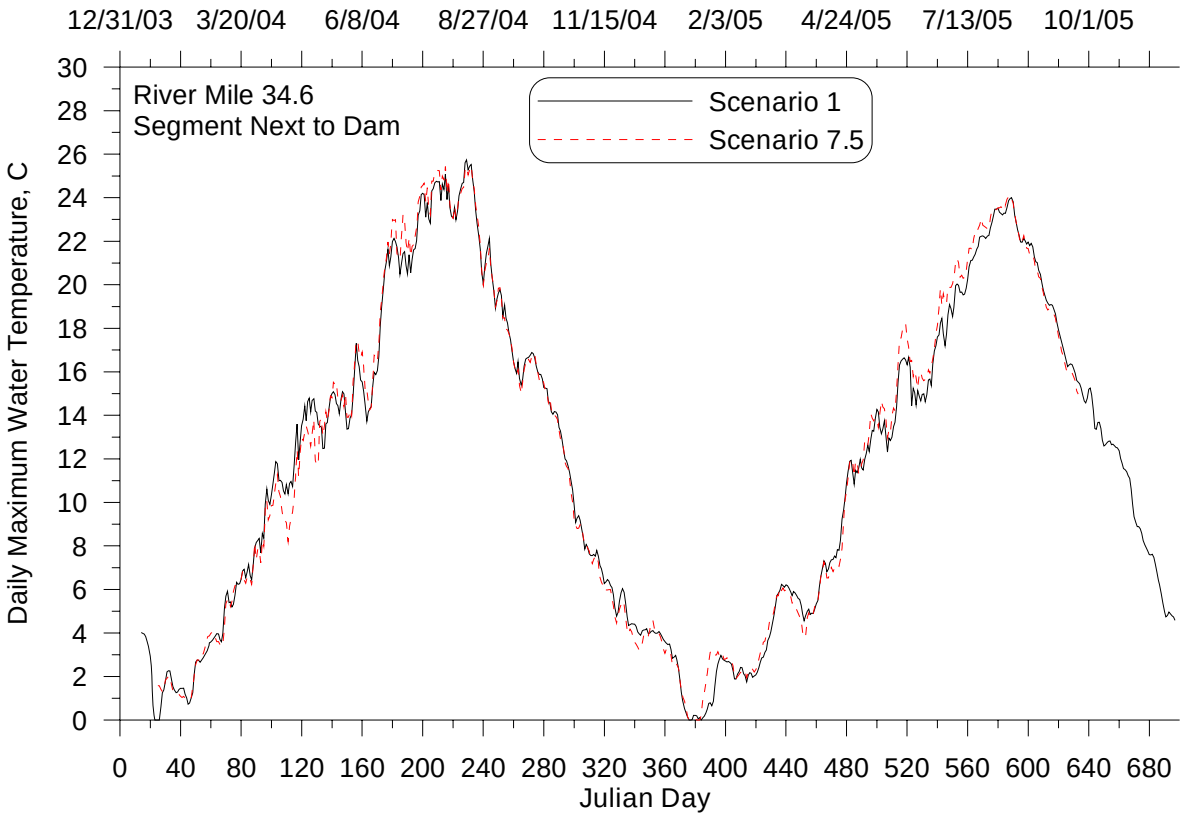

Figure 145. Comparison of model segment adjacent to Box Canyon Dam (segment 360) daily maximum water temperatures of the no Albeni Falls dam scenario 7.5 and the existing conditions scenario 1 at RM 34.6.

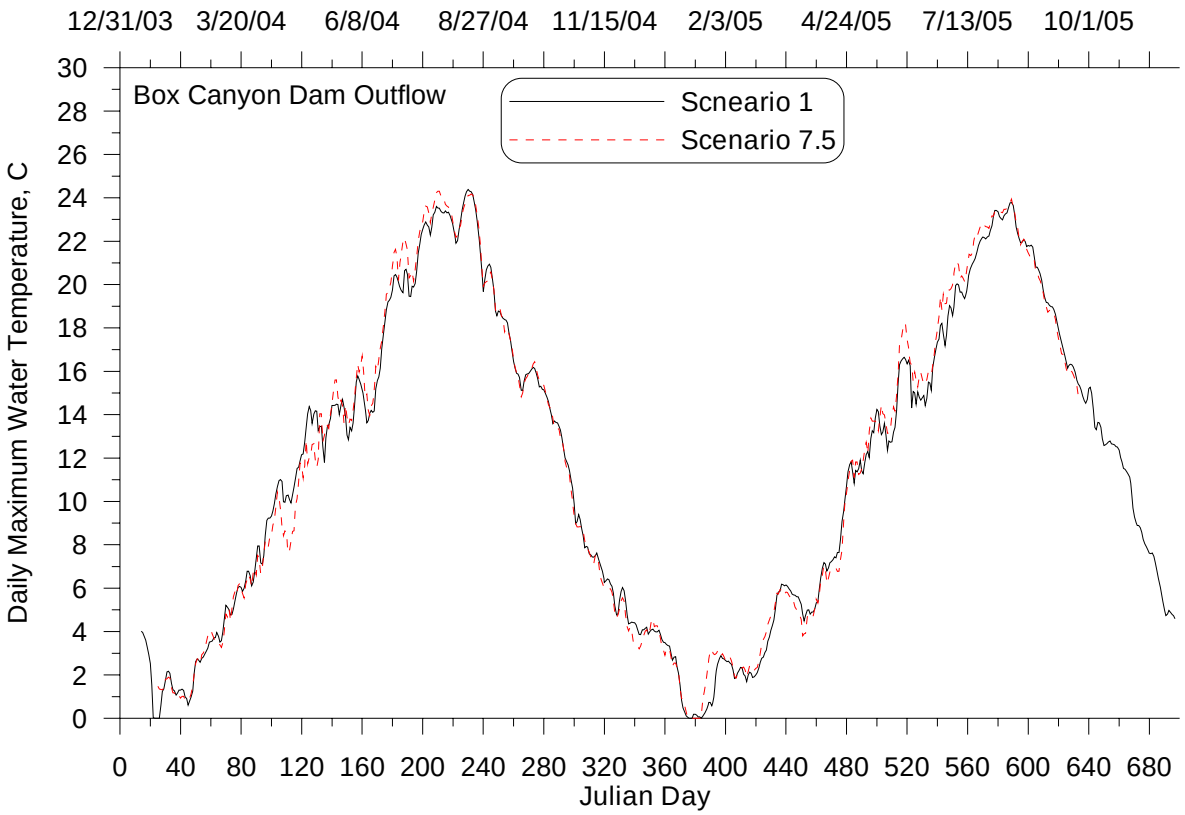

Figure 146. Comparison of Box Canyon Dam maximum daily outflow temperatures between the existing conditions scenario (1) and the no Albeni Falls dam Scenario 7.5.

Table 28: Statistical significance in daily maximum time series results between the no Albeni Falls dam (7.5) and Existing Conditions (1) Scenarios.

River Mile, Model Location	P-value	Result
River Mile 87.7 (Model Segment 17)	0.539	Model results between scenarios are not the same
River Mile 72.4 (Model Segment 115)	0.245	Model results between scenarios have some similarities
River Mile 69.8 (Model Segment 132)	0.221	Model results between scenarios have some similarities
River Mile 63.7 (Model Segment 171)	0.210	Model results between scenarios have some similarities
River Mile 61.2 (Model Segment 187	0.189	Model results between scenarios are similar
River Mile 43.7 (Model Segment 300)	0.180	Model results between scenarios are similar
River Mile 34.6 (Model Segment next to dam site)	0.148	Model results between scenarios are similar
River Mile 34.5 (Box Canyon Dam Outlet)	0.188	Model results between scenarios are similar

Longitudinal Profiles

The daily average temperature longitudinal profiles for May 7 and August 24, 2004, are compared in Figure 147 and Figure 148. Figure 149 and Figure 150 contain the daily maximum temperature profiles. Table 29 and Table 30 list the P value statistics of the longitudinal profiles. The longitudinal profiles of the scenarios differed. On May 7, the existing scenario was warmer than the no Albeni Falls Dam scenario. On August 24, the existing scenario was warmer near the upstream end of the reservoir, and cooler near the dam.

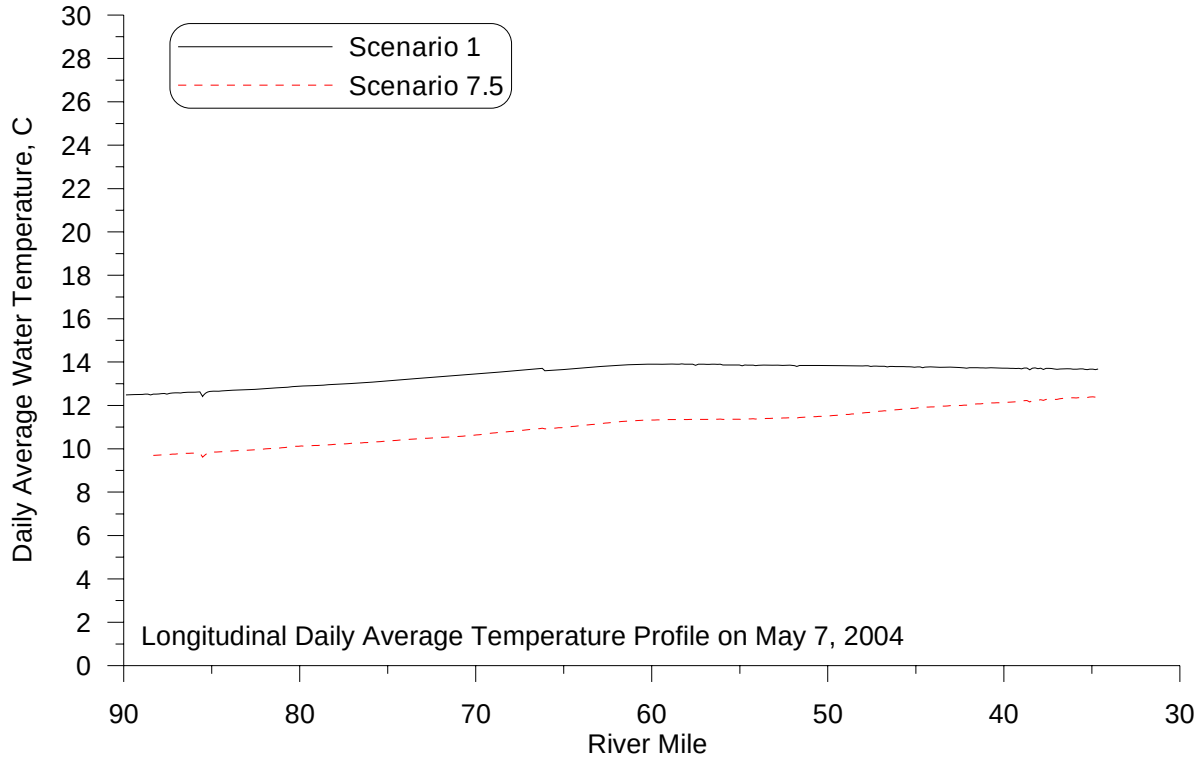

Figure 147. Comparison of longitudinal daily average temperature profile on May 7, 2004 between the No Albeni Falls dam scenario 7.5 and the existing conditions scenario 1.

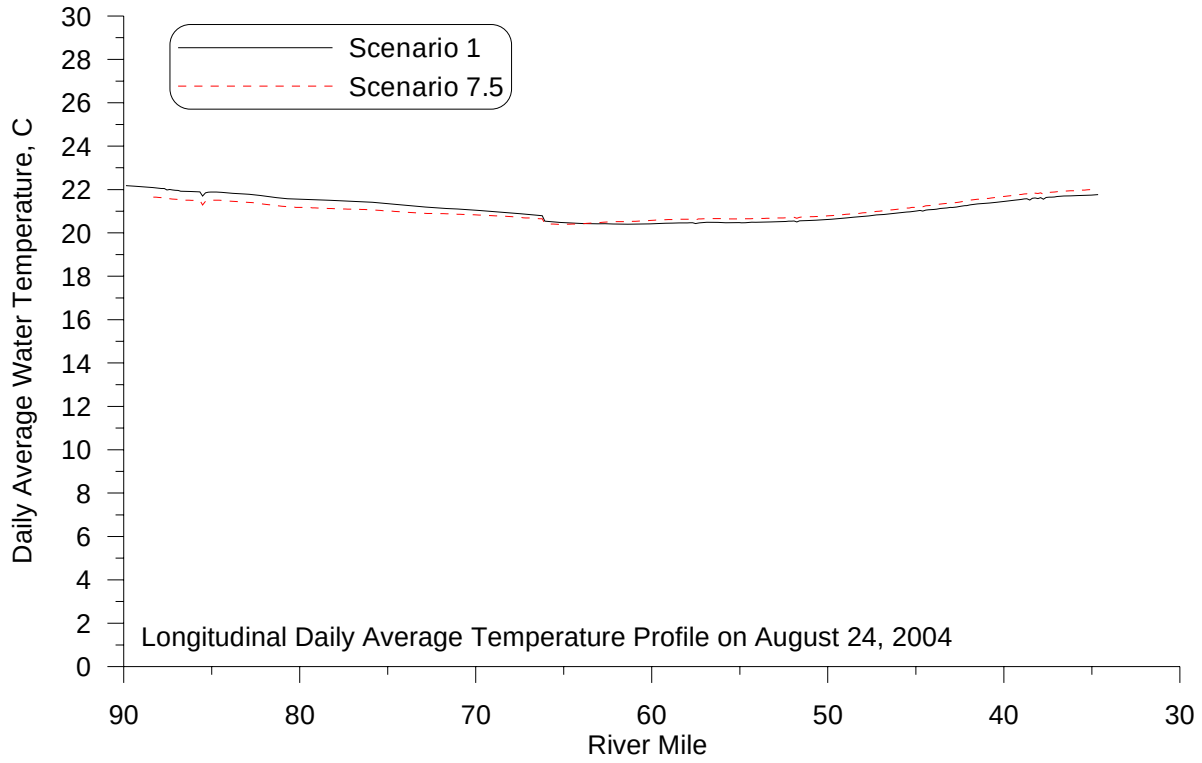

Figure 148. Comparison of longitudinal daily average temperature profile on August 24, 2004 between the No Albeni Falls dam scenario 7.5 and the existing conditions scenario 1.

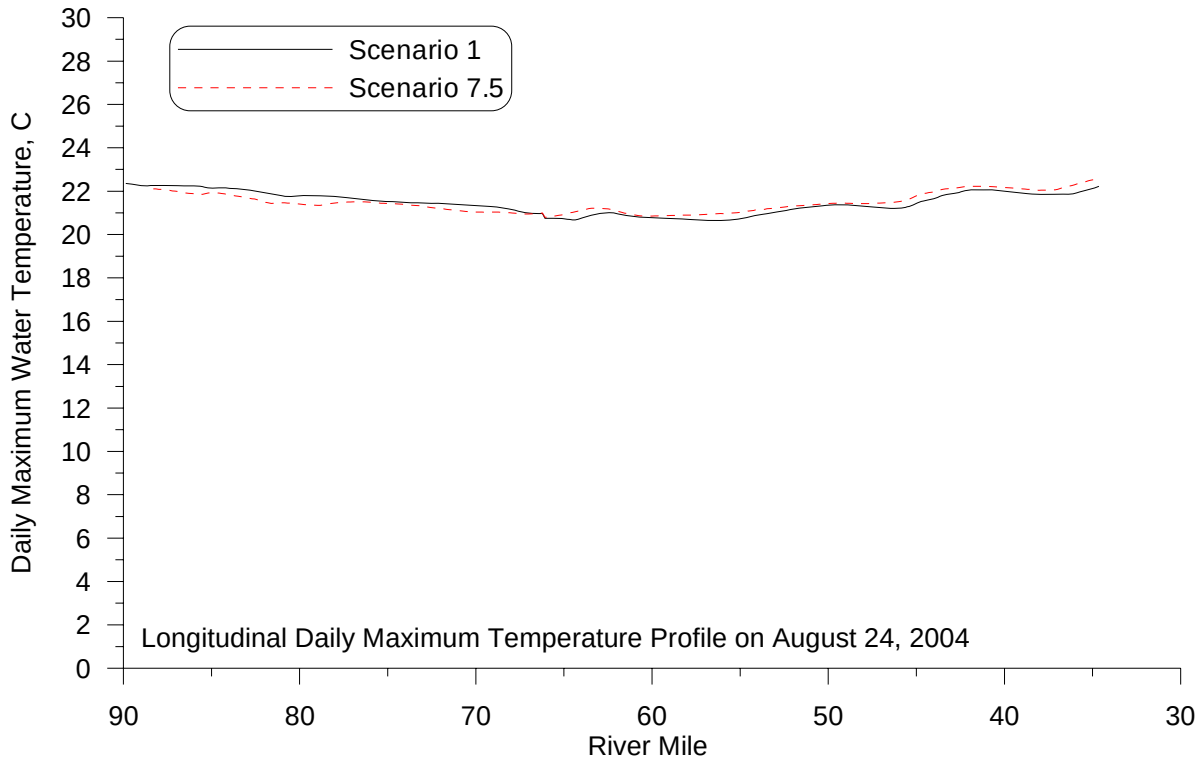

Figure 149. Comparison of longitudinal daily maximum temperature profile on May 7, 2004 between the No Albeni Falls dam scenario 7.5 and the existing conditions scenario 1.

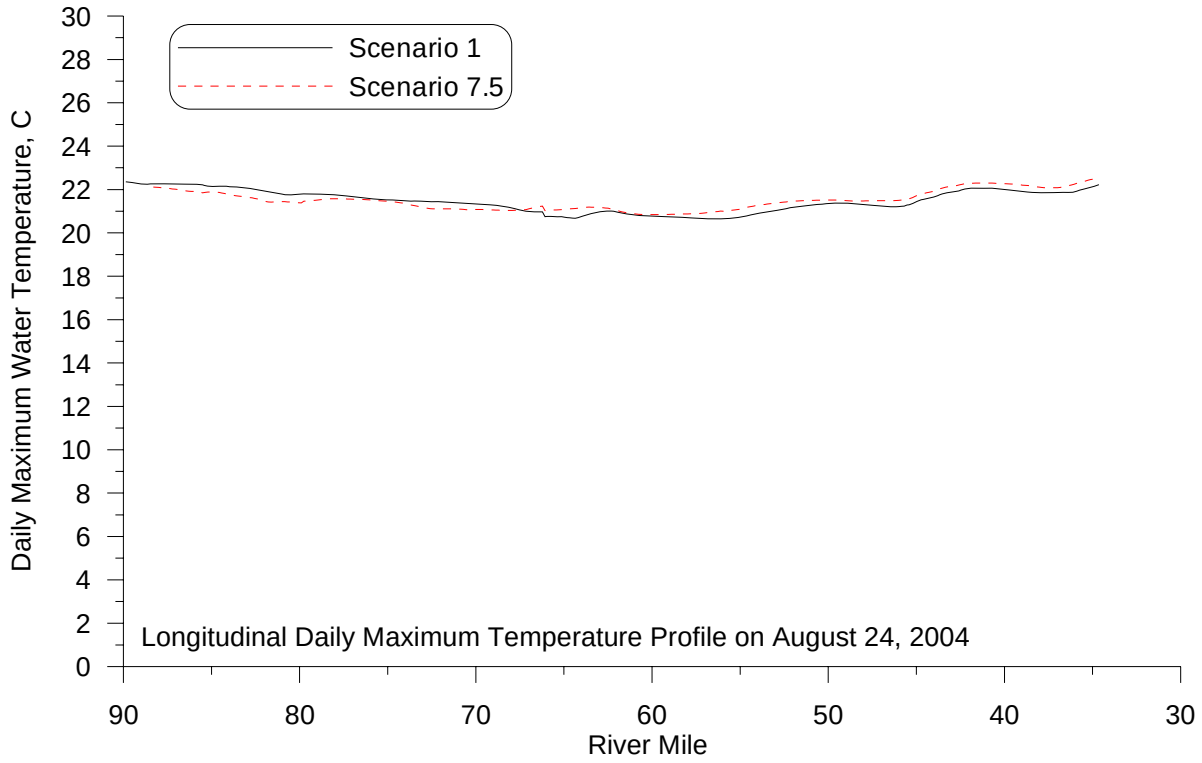

Figure 150. Comparison of longitudinal daily maximum temperature profile on August 24, 2004 between the no Albeni Falls dam scenario 7.5 and the existing conditions scenario 1.

Table 29: Statistical significance of daily average temperature in the longitudinal profiles on May 7th, 2004 and August 24th, 2004 between the no Albeni Falls dam (7.5) and Existing Conditions (1) Scenarios.

Scenario 1 and Scenario 7.5 Comparison	P-value	Result
May 7th daily average temperature	1.000	Model results between scenarios are not the same
August 24th daily average temperature	0.834	Model results between scenarios are not the same

Table 30: Statistical significance of daily maximum temperature in the longitudinal profiles on May 7th, 2004 and August 24th, 2004 between the no Albeni Falls dam (7.5) and Existing Conditions (1) Scenarios.

Scenario 1 and Scenario 7.5 Comparison	P-value	Result
May 7th daily maximum temperature	1.000	Model results between scenarios are not the same
August 24th daily maximum temperature	0.360	Model results between scenarios are not the same

Summary

Scenarios for the temperature TMDL were simulated using CE-QUAL-W2 Version 3.5 for the Pend Oreille River in Washington. The model scenarios were listed in Table 1. These results included analysis of daily averages and daily maximums at fixed locations and longitudinal plots at fixed times. The results of these individual comparisons are shown in each section of this report:

- Existing Conditions to Natural Conditions
- WLA/point source contributions
- Non-point source contributions
- Box Canyon Dam contribution relative to Natural Condition
- Box Canyon Dam contribution relative to existing condition
- Pend Oreille River Vegetative Shading
- Albeni Falls Dam

Statistics and graphical comparisons were made to assess impacts of the Box Canyon Dam, Albeni Falls Dam, bank shading, WLA and point sources, and non-point contributions to temperature in the Pend Oreille River, Washington. The results of the scenarios are summarized in Table 31.

Table 31. Summary of scenario comparison results.

Comparisons	Description	Results
Scenario 8 and Scenario 1	Existing Conditions to Natural Conditions	Temperatures of un-impounded scenario 8 generally warmer in summer, cooler in fall.
Scenario 2 and Scenario 1	WLA/point source contributions	There were no differences predicted in maximum daily temperature
Scenario 2.5 and Scenario 1	Non-point source contributions	Generally there were no temperature differences between scenarios, although the PNV shading for tributaries scenario 3 was slightly cooler on May 7 and August 24, 2004.
Scenario 3 and Scenario 8	Box Canyon Dam contribution relative to Natural Condition	The natural conditions scenario (8) predicted warmer (toward upstream) or cooler depending on location (toward dam site).
Scenario 4 and Scenario 1	Box Canyon Dam contribution relative to existing conditions	The un-impounded scenario (4) predicted warmer temperatures in the summer and cooler temperatures in the fall.
Scenario 7 and Scenario 1	Pend Oreille River Potential Natural Vegetative Shading contribution	Generally there were no temperature differences between scenarios, although the PNV scenario Box Canyon dam temperatures were slightly cooler

Comparisons	Description	Results
Scenario 7.5 and Scenario 1	Albeni Falls Dam contribution	Daily maximum temperatures of the no Albeni Falls scenario 7.5 are generally warmer than existing conditions, but can be cooler during the spring and fall.

Un-impounded conditions generally caused warmer temperatures in the summer, and cooler temperatures in the fall. Potential natural vegetation (PNV) shading (on the Pend Oreille or for the tributaries) only slightly affected water temperatures. Removal of the point sources did not affect river temperatures.