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Evaluation of Water Temperature Regimes in the Snake River using Transect Measurements and the RBM10 Model

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Introduction

In order to evaluate impacts to the temperature of the mainstem Columbia and Snake rivers, EPA Region 10 has developed a dynamic, one-dimensional heat budget model (RBM10) of the basin. While EPA continues to apply RBM10 using long-term records (tributary inflows/temperatures, meteorology, etc.) to evaluate temperature variability over time, this report focuses on detailed monitoring information collected by the Columbia River Inter-Tribal Fish Commission (CRITFC) and Fisheries and Aquatic Sciences in the early 1990s at 18 locations in the Snake River (Karr et al, 1998). This data is used to evaluate questions about the underlying assumptions and performance of the RBM10 model, including:

(1) Does available data support the assumption, inherent in one-dimensional temperature analysis, that cross-sectionally averaged temperatures are uniformly transferred through dams?

(2) To what extent do surface temperatures deviate from the cross-sectional average temperature, and are these deviations influenced by flow augmentation from Dworshak reservoir?

(3) How do RBM10 model simulations compare to measured cross-sectionally averaged temperature of the Snake River?

(4) How do RBM10 model simulations compare to measured temperatures under the dynamic conditions associated with flow augmentation from Dworshak reservoir?

Transect Measurements

Long term monitoring of temperature has been conducted since the construction of the Snake River dams, but temperature measurements have been taken at single, fixed depths in the vicinity of the dams (e.g, forebays, tailraces, and scroll cases). Evaluation of the performance of one-dimensional models has been hampered somewhat by the absence of transect data (Yearsley 2001, Cope 2001). The transect data from the CRITFC study offers an opportunity to evaluate model performance against more specific measures of cross-sectional average temperature.

The data used for these evaluations were collected over the periods July 23-October 15, 1991, and July 1-October 22, 1992. Transect measurements were collected during the summer at 14 stations in the lower Snake River and four stations in the Clearwater River (see Table 1). The distance between each Snake River station is approximately 10 miles, with some adjusted distances based on dam locations. Measurements were collected at varying time intervals ranging from one day to several days between samples.

At each transect, temperature was measured at three locations (1/4, ½, and 3/4 river width) and at four depths (surface,1/3 river depth,2/3 river depth, and near bottom). For this analysis, rectangular cross sections around each sampling point were assumed and the area-weighted average temperature was calculated for both the entire cross-section and the surface layer.

Technical Evaluations

Heat Transfer at Dams

As discussed above, EPA is simulating Snake River temperatures using a one-dimensional model. The model simulates cross-sectional average temperatures, and its use implies an assumption that the energy upstream of a dam is uniformly transferred downstream. This assumption appears reasonable when assessing run-of-river reservoirs, which release all of the upstream flow through their control structures. Nevertheless, given that there is some stratification in the water impounded behind the dam, and that the dam intakes structures can draw water from the reservoir preferentially from a particular elevation, it is reasonable to question whether net heat is stored behind the dams. Another way to frame the question is ask if "short-circuiting" of cold water through the lower waters of an impoundment can be observed.

If net heat storage is occurring behind the dams, one would expect to see higher cross-sectional average temperatures at locations upstream of a particular dam, compared to average temperatures downstream of the same dam. Graphical comparisons of upstream and downstream temperatures at two dams (Lower Granite and Lower Monumental) for 1992 are shown in Figures 1A and 1B. The data do not indicate a pattern of consistently higher temperatures above the dams, except for the period from July 21 to August 6 at Lower Granite. This was the two weeks following the July 19 cessation of flow augmentation from Dworshak Dam.

The difference in cross-sectional average temperature for each sampling day was calculated at upstream and downstream locations around each dam for 1991 and 1992 data sets. The results are shown in Tables 2A and 2B. Since the difference is calculated as the upstream temperature subtracted from the downstream temperature, net heat storage behind a dam would be indicated by a negative difference. The 1992 comparisons indicate minor negative differences (less than -0.4 °C) between upstream and downstream monitoring locations at Lower Granite, Little Goose, and Lower Monumental dams over the sampling period. Data for the vicinity of Ice Harbor Dam data indicate at small positive difference, indicating higher temperatures below the dam than above the dam. The 1991 comparisons show higher temperatures below the dams than above the dams with the exception of Lower Granite (mean difference of -0.18 °C). For both years and all dam locations, the standard deviation of the upstream/downstream differences is greater than the absolute value of the mean difference. Thus, it appears that significant short-circuiting of cold water (and associated heat storage behind dams) is not a consistent feature in the Snake River.

Stratification

While the Snake River is amenable to use of a one-dimensional model based on the above evaluation of uniform downstream heat transfer, the model will provide only the cross-sectional average temperature of the river. It will not provide information on lateral and vertical temperature variations in the river. In particular, thermal stratification due to surface heating will not be estimated. The transect data can be used to compute and compare cross-sectional average temperatures to the surface temperatures. This provides a comparison between model outputs (cross-sectionally averaged temperatures) and associated surface temperatures for the summer months.

For the transect data collected in the summer of 1991 and 1992, the differences between cross-sectional average temperature and surface temperature are provided in Tables 3A and 3B. As would be expected, stratification in the nearest downstream stations from the dams is lower than in the reservoirs just upstream of the dams. The mean difference in 1991 for these stations ranged from 0.08 °C to 0.26 °C. For the stations closest to the dam forebays, Ice Harbor in 1991 had the highest mean (1.22 °C) and maximum (4.3 °C) stratification of the four reservoirs, while Lower Monumental had the lowest mean (0.96 °C) and maximum (3.2 °C). For the 1992 data, Lower Granite had the highest mean (1.65 °C) and maximum (4.5 °C) stratification of the four reservoirs, while Lower Monumental again had the lowest mean (0.96 °C) and maximum (3.2 °C).

A time series view of the changes over time at Lower Granite Dam in 1992 indicates that stratification is greater during flow augmentation periods than other periods (Figure 2A). The highest stratification occurred during periods of flow augmentation in July and September, while stratification was lower when augmentation ceased in August. Vertical temperature profiles near Lower Granite Dam (Station 5) indicate that reductions in temperature in response to Dworshak releases are more dramatic in deeper waters than at the surface (Figures 2B through 2D). Also, the temperature at depth corresponds to the calculated mixed temperature at the confluence of the Snake and Clearwater rivers.

Comparison of RBM10 Simulations and Transect Measurements

In recent years, EPA has used the RBM10 model to generate predictions of water temperatures that would result from a variety of flow conditions, meteorological conditions, and flow augmentation operations at Dworshak Reservoir in Idaho. To compare RBM10 simulations to measured temperatures, RBM10 was run using measured temperatures at the upstream model boundaries; then simulated downstream temperatures were compared to measured cross-sectional average temperatures. Since flow augmentation was conducted at Dworshak in 1992, this comparison provides insights on the ability of the model to simulate cold water fronts and changes in flow over short time-scales.

Upstream transect temperatures, collected in the Clearwater, North Fork Clearwater, and Snake Rivers, were used as boundary condition inputs to the model. Since samples were not collected every day over the study period, linear interpolation was used to estimate temperatures between sampling days. Aside from these upstream boundary temperature inputs, all other model inputs and assumptions were similar to those described in EPA's documentation for the RBM10 model (EPA, 2001).

Graphical presentations of the model outputs and measured temperatures at selected transect sampling locations in the Snake River are shown in Figures 3A through 3H. For the upstream stations, the flows from Dworshak Reservoir are included for comparison to temperature patterns. For one of the dams (Lower Granite), the forebay and tailrace data for this 1992 period is also displayed for comparison to the nearest transect sampling locations (Stations 5 and 6).

A qualitative review of the graphical comparisons indicates that the model is successful in simulating both the magnitude and temporal patterns in the Clearwater River and the Snake River (river mile 130) above Lower Granite reservoir. The same can be said of stations in the reservoir (stations 4 and 5), except some of the temperature effects of the three periods of flow augmentation from Dworshak appear to be shifted to later days in the model simulations. This is quite evident in the Station 6 outputs, and the pattern shift is also apparent at downstream transect stations. Also, at the locations downstream of Lower Granite dam, the simulated patterns of cooling in response to Dworshak releases are more distinct in the RBM10 simulations than in the measured temperatures. This suggests that longitudinal dispersion, which is not currently included in the model, may be an important process in the actual river system.

A quantitative comparison of the differences between simulated and measured values at four transect locations is presented in Table 4. The mean difference in simulated and measured values for the summer 1992 period is low, indicating that the bias between simulated and measured values is low. While the differences are small, it can be noted that they increase in the downstream direction. The range of differences is relatively high, as would be expected when time of arrival of sharp cold fronts is different in simulations and measurements.

Simulating Cold Water Fronts

There are a number of potential problems associated with simulation of abrupt changes in the system such as the release of cold water fronts from Dworshak Reservoir into the Clearwater River and subsequently the Snake River. One potential problem for any Eulerian (fixed-grid) model run in a dynamic mode, particularly in advection-dominated systems, is error due to numerical dispersion. Numerical dispersion occurs when high-frequency inputs at a model boundary are erroneously propagated to downstream model cells by the advection scheme of the model.

RBM10 employs a mixed Lagrangian-Eulerian advection scheme (Reverse Particle Tracking). Within this hybrid scheme, RBM10 employs a second-order polynomial estimation of segment temperatures. These features reduce, but do not eliminate, numerical dispersion associated with abruptly changing inflows. Numerical dispersion would tend to both reduce the peak and advance a cold water front ahead of the advected inflow. This would result in a simulated cold front reaching a downstream river location faster (and lower in magnitude) in the model than in the measurements.

Another feature of RBM10 that affects its simulation of flow augmentation is its hydrodynamic scheme. The model employs a constant elevation, continuity-based algorithm to calculate the river velocity, under the assumption that flows are gradually varied in the system. Good model performance during normal flow conditions indicates that this is a reasonable assumption; however, flow augmentation episodes create a more complex hydrodynamic regime that is not simulated by the model. For example, the abrupt change in the river geometry created by the abrupt release of flows from Dworshak would create a dynamic wave, which would affect velocities as it moved downstream. This feature, and the complex velocity patterns it would create, are not simulated in the model. Rather, the continuity function in the model would instantaneously adjust all velocities downstream in response to the change at the upstream boundary of the model. This would result in a simulated cold front reaching a downstream river location slightly faster in the model than in observations when flow increased abruptly at the boundary.

Finally, the Dworshak releases one-dimensional RBM10 model would not capture the complexities of a gravity flow (also termed a density flow) resulting from cold Clearwater River flows plunging under the warmer, impounded waters of Lower Granite reservoir. Since density underflows move at a higher velocity than the river as a whole, this would result in a cold front reaching a downstream location slower in the model than in observations.

To aid in evaluating the cold water fronts and performance of the model, longitudinal profiles of the Snake River temperature (simulated and measured) from river mile 140 to 100 were constructed for each transect sampling date in 1992. Based on a qualitative review of these figures and Figures 3A through 3H, it appears that numerical dispersion is not a significant problem in the RBM10 model. This is evident in the results for the mouth of the Clearwater River (Figure 3A) and Snake River 20 miles upstream from Lower Granite dam (Figure 3B), which indicate a good matching of both the timing and magnitude of cold water flows moving downstream from Dworshak dam. The results for downstream locations, however, indicate that the time of arrival of the cold front is later in the model than in the measurements, particularly for the highest flow augmentation spike in mid-July (see longitudinal profiles for the period around 7/23/92 and 9/17/92). This suggests that in order to more accurately capture the time of arrival of the cold front downstream, model constructs that capture the flow and density conditions occurring in the actual system would be needed. For a one-dimensional model, these conditions may be represented more accurately by incorporating longitudinal dispersion into the model. Finally, it appears that while the travel times are shifted, the magnitude of the temperature changes from the Dworshak releases appear comparable in the simulations and measurements.

Conclusions

Based on the evaluation of transect data from 1991 and 1992, the following can be concluded:

(1) Small differences in cross-sectionally averaged temperatures above and below each of the dams indicate that the dams transfer heat downstream rather than store heat. This lends support to the use of one-dimensional temperature model for the lower Snake River and other large rivers with run-of-the-river dams.

(2) Thermal stratification in the four Snake River reservoirs, measured as the mean difference between surface temperatures and cross-sectionally average temperatures, ranged from 0.97 °C at Lower Monumental Dam to 1.22 °C at Ice Harbor Dam over the summer 1991 transect record. They ranged from 0.96 °C at Lower Monumental Dam to 1.65 °C at Lower Granite Dam over the summer 1992 transect record.

(3) Stratification occurs throughout the summer months in the four reservoirs, and flow augmentation appears to increase stratification.

(4) The mean difference between simulated and measured temperatures over the summer 1992 period at four transect locations ranged from -0.25 °C to 0.20 °C.

(5) The time of arrival of cold water from Dworshak releases tends to be longer in the simulations than in the measurements beginning at the Lower Granite forebay station. This may be caused by elevated velocities in a gravity-underflow of cold water from the mixed Snake and Clearwater rivers during flow augmentation, which is not simulated in the RBM10 model.

(6) The timing and magnitude of cold water fronts suggests that errors associated with numerical dispersion and continuity-based hydrodynamics in RBM10 are minor.

(7) Incorporation of longitudinal dispersion in RBM10 may improve accuracy in the timing and magnitude of cold water fronts.

References

Yearsley, J. An Outline of a Monitoring Program for Estimating the State of Water Temperature In the Columbia and Snake Rivers, EPA Region 10. 2001.

Cope, B., et al. Site Visits to Six Dams on the Columbia and Snake Rivers, EPA Region 10, Memorandum to the file dated 4/18/2001.

Karr, Fryer, and Mundy. Snake River Water Temperature Control Project. Phase II. Methods for managing and monitoring water temperatures in relation to salmon in the lower Snake River. May 21, 1998.

EPA Region 10. Application of a 1-D Heat Budget Model to the Columbia River System. May, 2001.

Table 1: Station Locations

Station	Description	River Mile	Dam Mile
1A	N.F. Clearwater	1.3	
2A	Clearwater abv N.F.	41.5	
3A	Clearwater blw N.F.	39.5	
1	Snake abv Clearwater	140.5	
2	Clearwater mouth	0.8	
3	Lower Granite Reservoir	129.5	
4	Lower Granite Reservoir	119.5	
5	Lower Granite Reservoir	110.5	
	Dam		107.6
6	Little Goose Reservoir	101.0	
7	Little Goose Reservoir	91.5	
8	Little Goose Reservoir	80.5	
	Dam		70.0
9	Lower Monumental Reservior	65.0	
10	Lower Monumental Reservior	57.5	
11	Lower Monumental Reservior	44.0	
	Dam		41.7
12	Ice Harbor Reservoir	35.5	
13	Ice Harbor Reservoir	25.0	
14	Ice Harbor Reservoir	15.5	
	Dam		9.6
15	Snake River blw Ice Harbor	5.0	

Map 1 : Study Area (from Karr et al, 1992)

Figure 1. Map of the Lower Snake River Basin showing the major hydroelectric dams, and the location of water temperature monitoring transects. Symbols used in this report for dams are DWR, Dworshak Dam; LWG, Lower Granite Dam; LGS, Little Goose Dam; LMN, Lower Monumental Dam; IHR, Ice Harbor Dam.

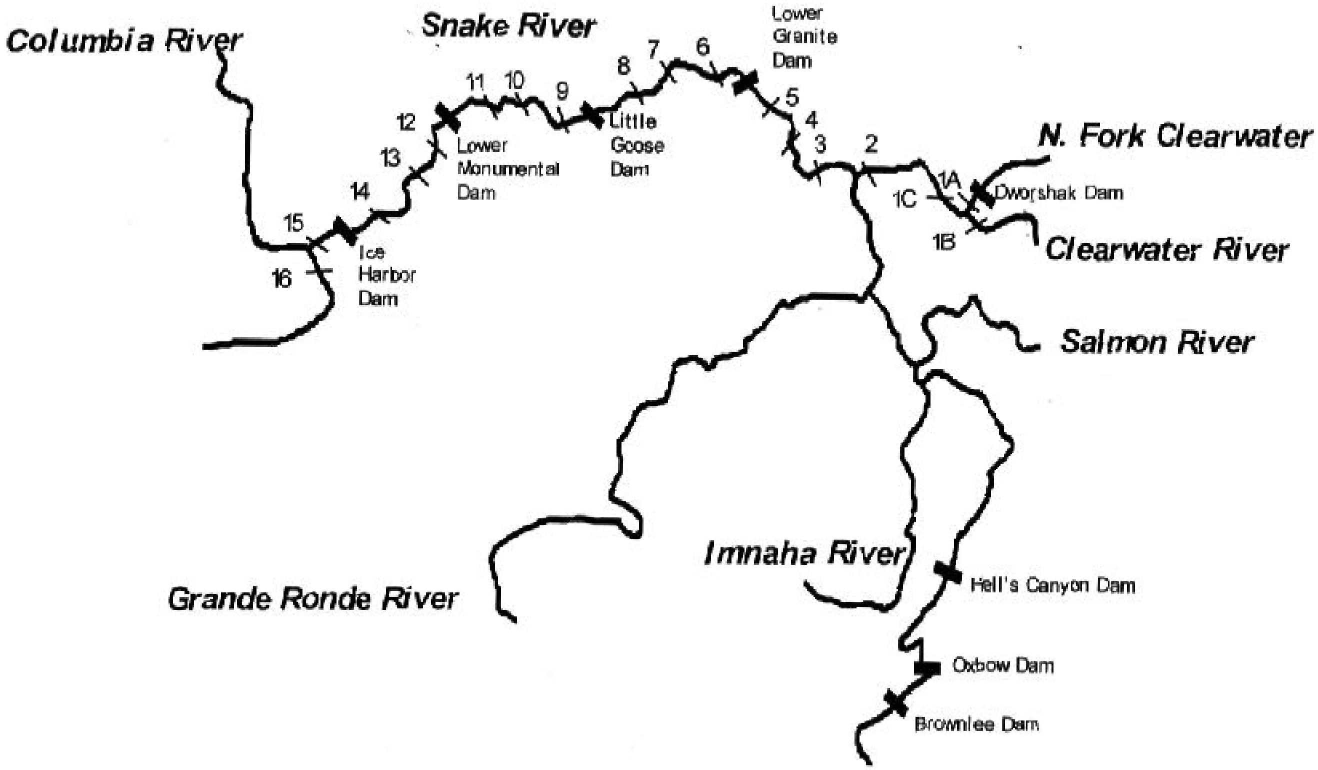


Table 2A: Comparisons of Average Temperatures Above/Below Snake River Dams (1991 Transects)

Dam	Stations	Mean Temperature Difference (deg C) [downstream-upstream]	Max	Min	Std Dev
Lower Granite	5,6	-0.18	0.60	-2.20	0.59
Little Goose	8,9	0.12	1.00	-1.00	0.53
L. Monumental	11,12	0.12	1.20	-0.60	0.38
Ice Harbor	14,15	0.22	0.90	-0.90	0.41

Table 2B: Comparisons of Average Temperatures Above/Below Snake River Dams (1992 Transects)

Dam	Stations	Mean Temperature Difference (deg C) [downstream-upstream]	Max	Min	Std Dev
Lower Granite	5,6	-0.38	0.80	-1.90	0.59
Little Goose	8,9	-0.39	1.00	-2.50	0.84
L. Monumental	11,12	-0.09	0.70	-0.70	0.36
Ice Harbor	14,15	0.23	1.10	-0.40	0.33

Table 3A: Comparison of Average Temperatures and Surface Temperatures Above and Below Dams (1991 Transects)

Station	Mean Temperature Difference (deg C) [surface-average]	Max	Min	Std Dev
5	1.13	3.90	0.00	0.98
6	0.17	0.60	0.00	0.17
8	1.07	2.60	0.10	0.71
9	0.26	1.30	0.00	0.28
11	0.97	2.70	0.10	0.64
12	0.24	1.70	0.00	0.39
14	1.22	4.30	0.10	1.14
15	0.08	0.40	0.00	0.10

Table 3B: Comparison of Average Temperatures and Surface Temperatures Above and Below Dams (1992 Transects)

Station	Mean Temperature Difference (deg C) [surface-average]	Max	Min	Std Dev
5	1.65	4.50	0.00	1.10
6	0.15	0.60	-0.10	0.19
8	1.14	3.90	0.00	1.10
9	0.40	3.40	0.00	0.66
11	0.96	3.20	0.10	0.77
12	0.30	1.40	0.00	0.33
14	1.40	3.50	0.00	1.08
15	0.09	0.30	0.00	0.10

Table 4: Difference Between Simulated and Measured 1992 Temperatures

Location	Station	River Mile	Mean Temperature Difference (deg C) [measured-simulated]	Max (deg C)	Min (deg C)	Std Dev
Clearwater River	2	0.8	-0.25	4.20	-5.50	1.97
Snake River	3	130	-0.02	3.20	-1.50	0.96
Snake River	6	101	0.14	4.80	-2.80	1.67
Snake River	9	65	0.20	2.20	-2.10	1.17

Figure 1A: Average Temperatures Above and Below Lower Granite Dam
(July 1 - October 22, 1992)

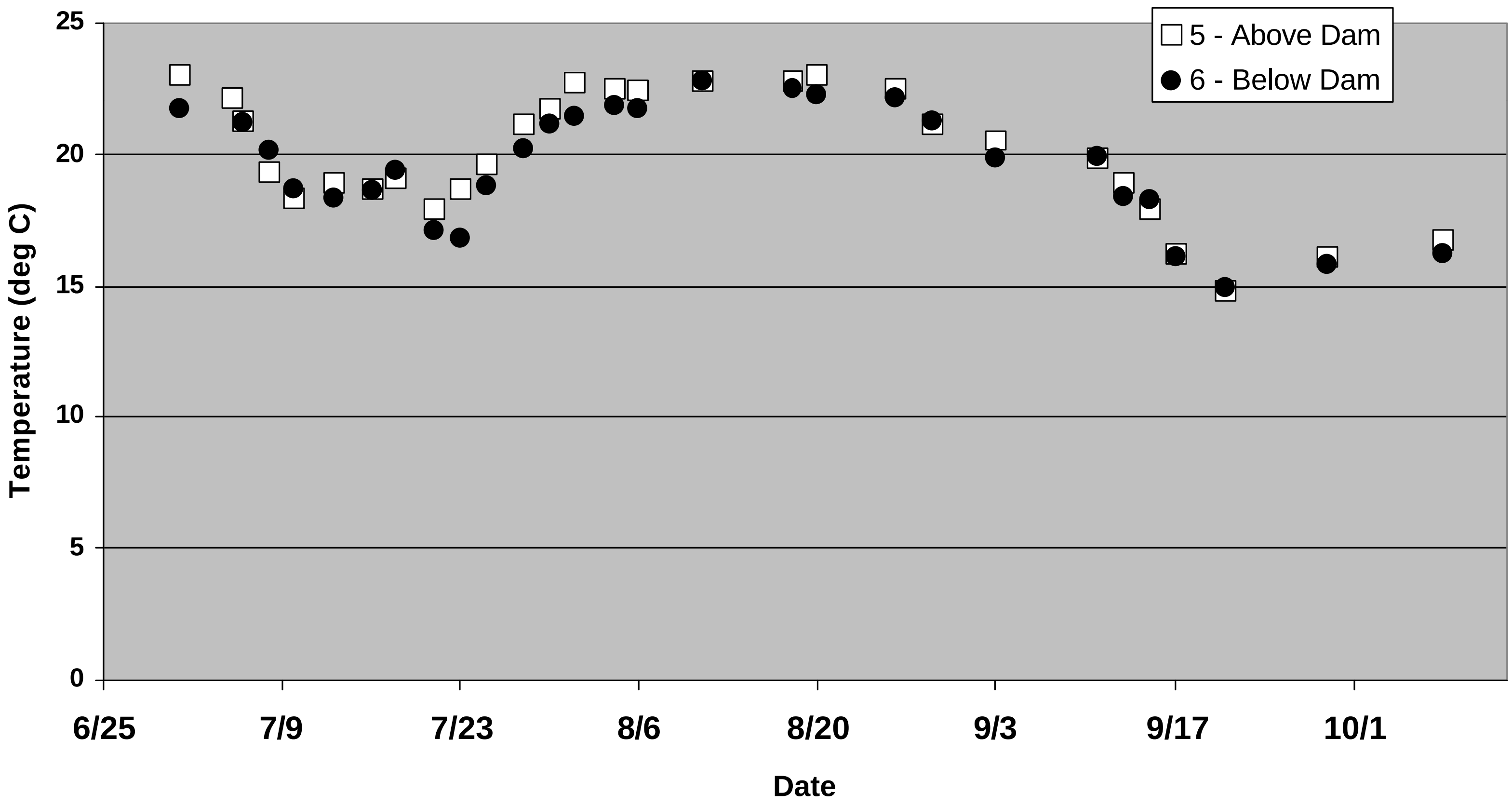
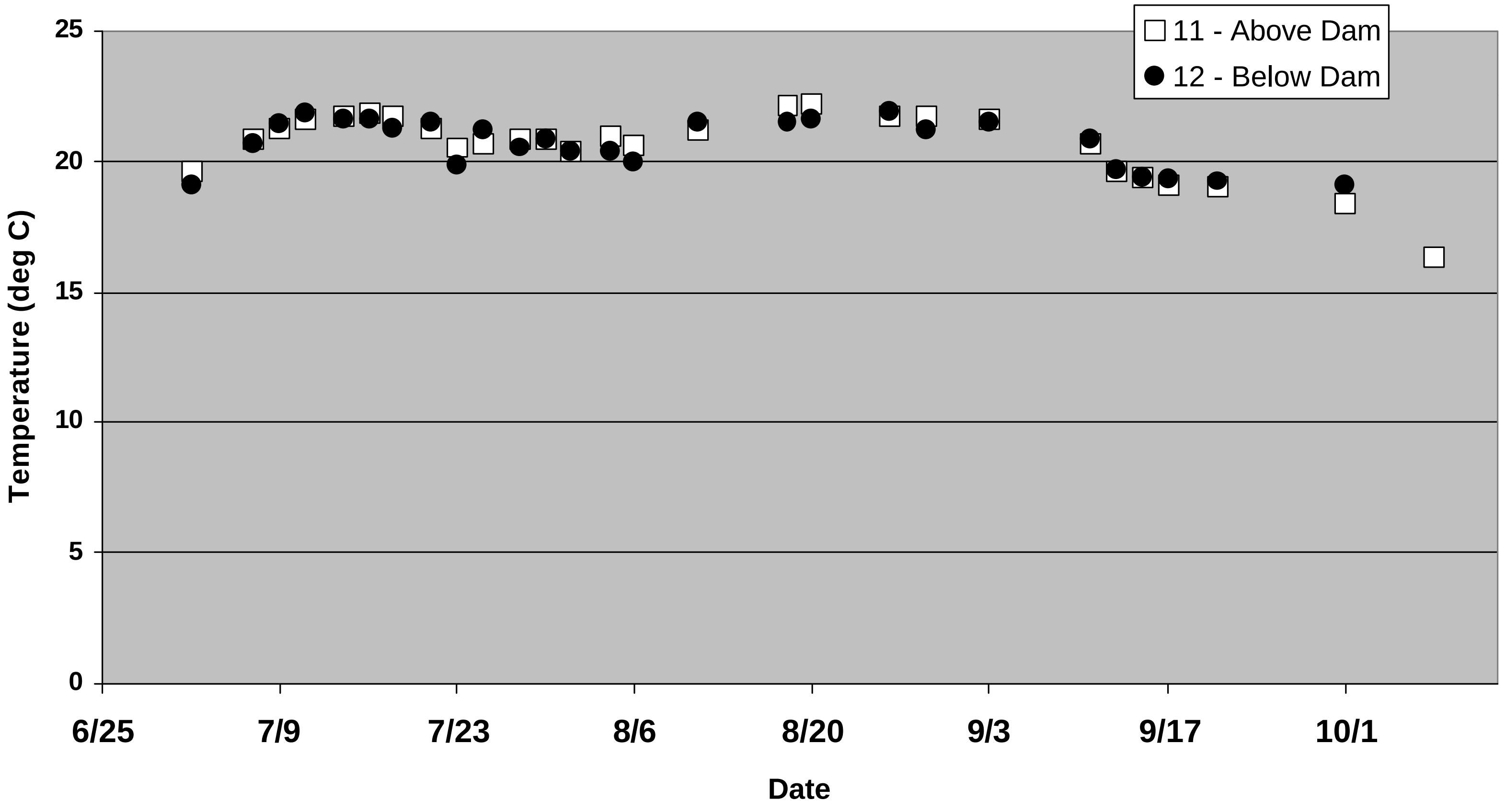


Figure 1B: Average Temperatures Above and Below L. Monumental Dam
(July 1 - October 22, 1992)



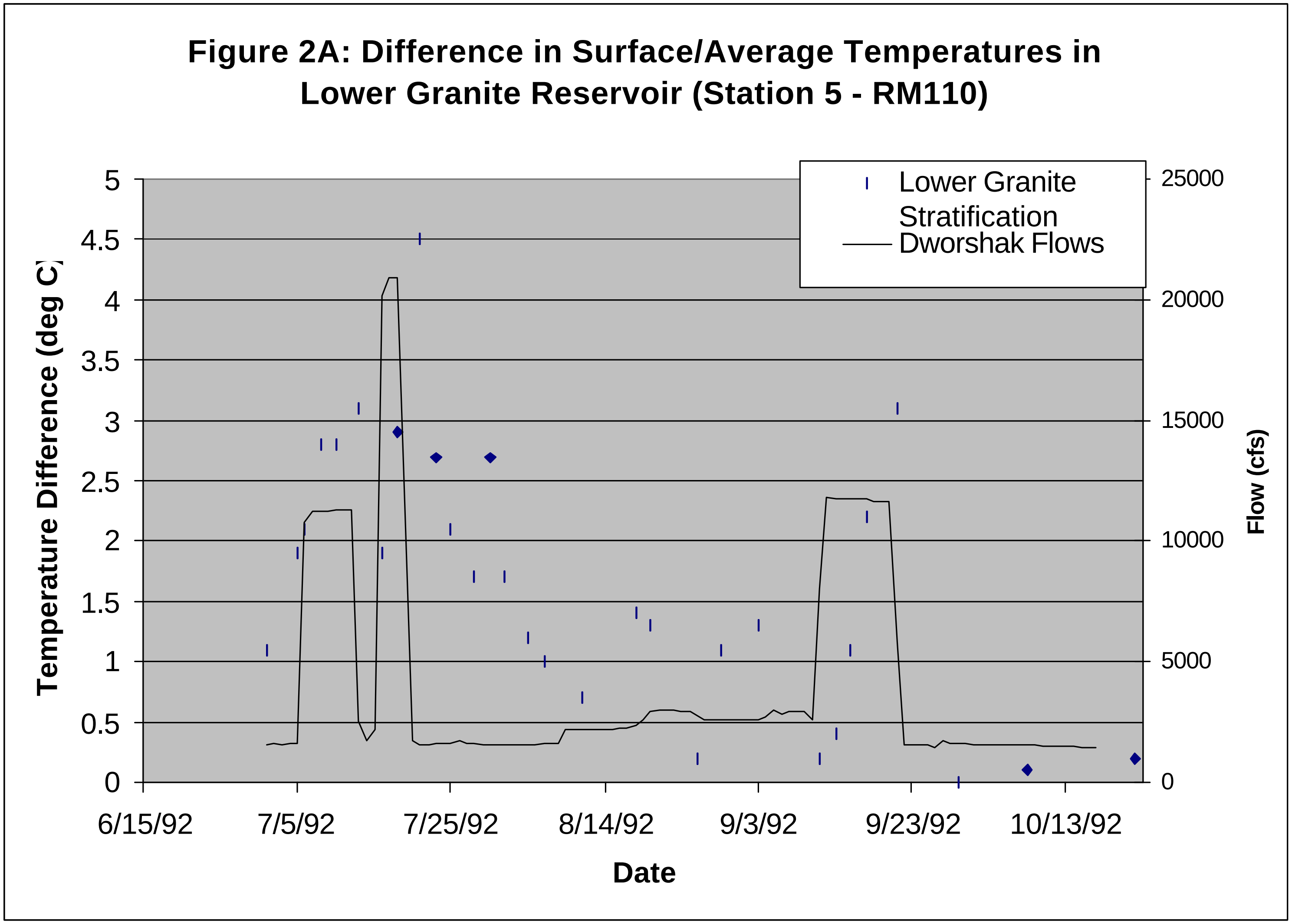


Figure 2A: Difference in Surface/Average Temperatures in Lower Granite Reservoir (Station 5 - RM110)
Lower Granite Stratification
Dworshak Flows
Temperature Difference (deg C)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Flow (cfs)
25000
20000
15000
10000
5000
0
6/15/92
7/5/92
7/25/92
8/14/92
9/3/92
9/23/92
10/13/92
Date

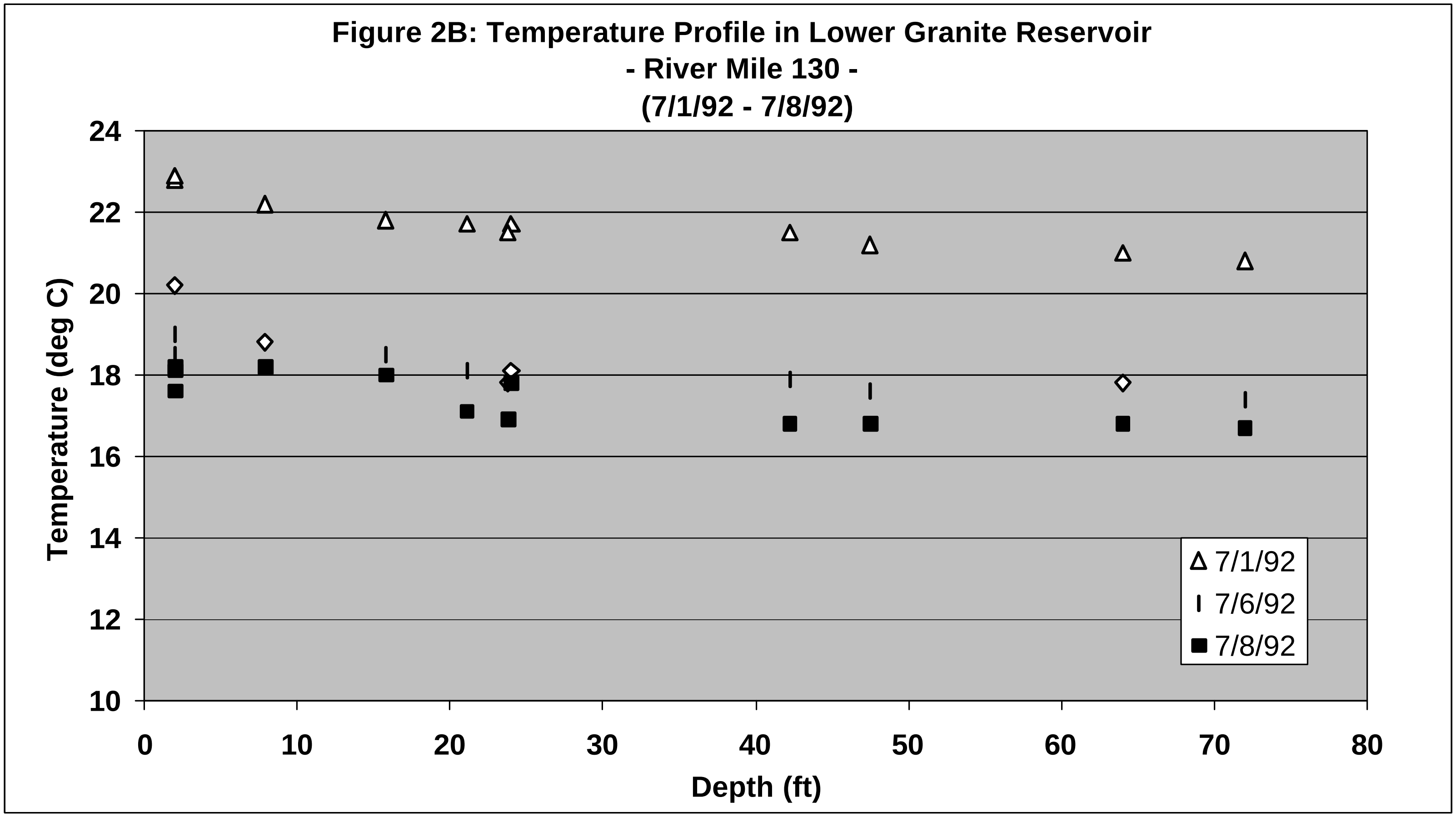


Figure 2B: Temperature Profile in Lower Granite Reservoir
- River Mile 130 -
(7/1/92 - 7/8/92)

Flow-weighted temperature at confluence of Snake and Clearwater rivers

Date	Temperature
7/1/92	20.2
7/6/92	17.1
7/8/92	17.6

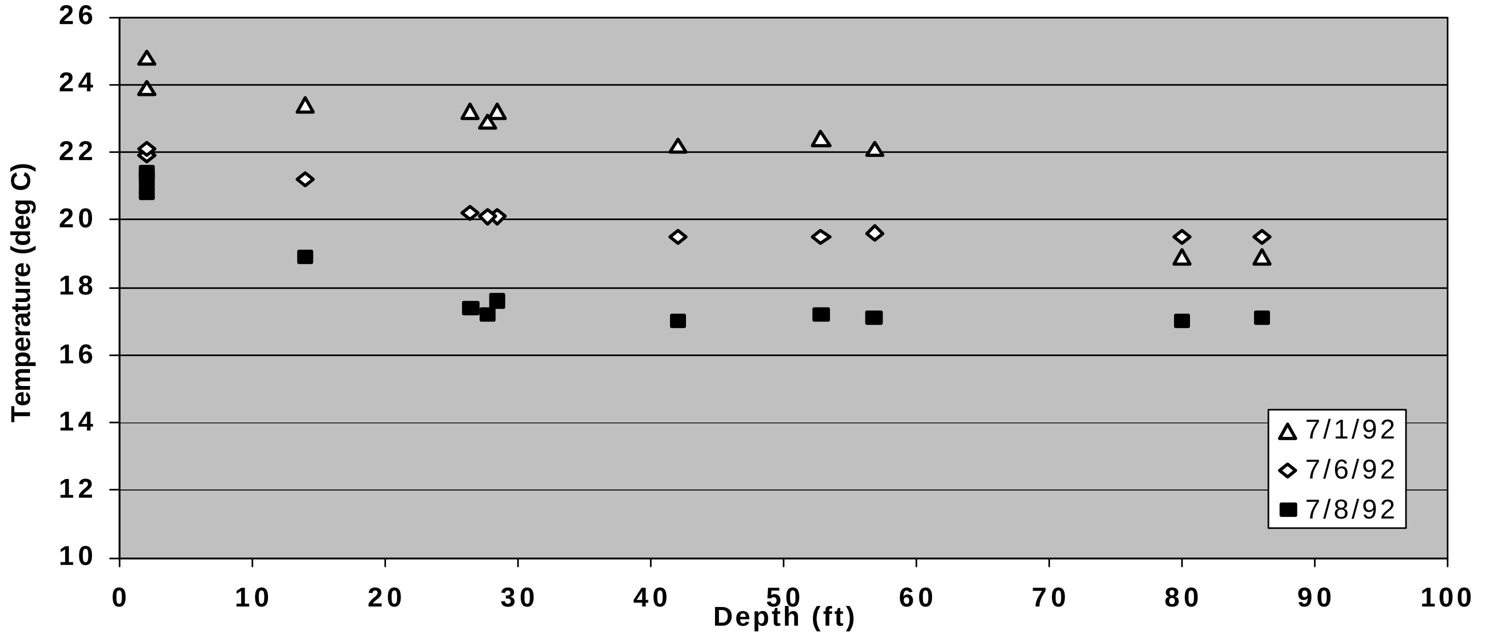


Figure 2C: Temperature Profile in Lower Granite Reservoir
- River Mile 120 -
(7/1/92 - 7/8/92)

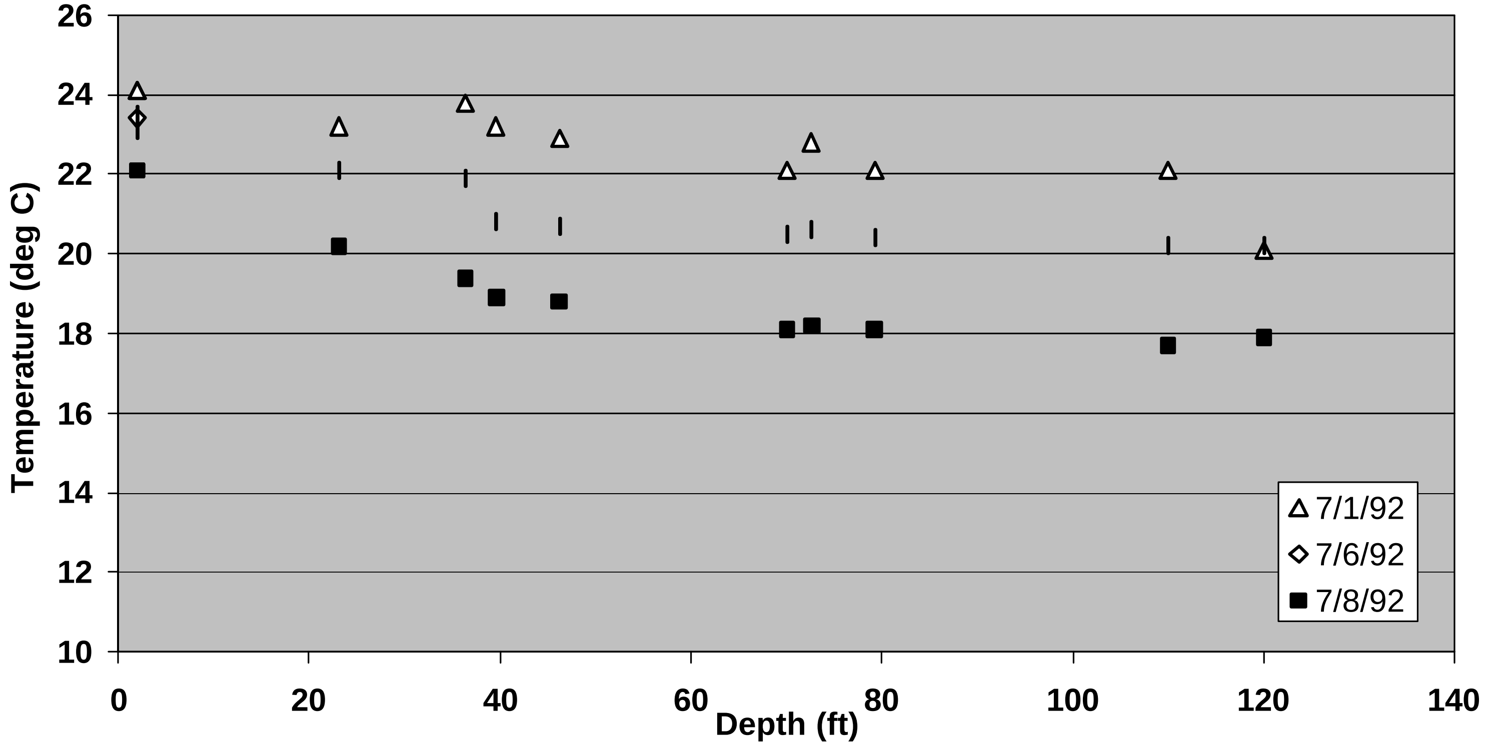
Flow-weighted temperature at confluence of Snake and Clearwater rivers

Date	Temperature
7/1/92	20.2
7/6/92	17.1
7/8/92	17.6

Upstream flow-weighted temperature during augmentation period

	clearwater		snake		mixed temperature
	T (deg C)	Flow (cfs)	T (deg C)	Flow (cfs)	
7/1/92	20.3	5820	20.2	16100	**20.2**
7/6/92	13.4	15500	19.2	26800	**17.1**
7/8/92	14	16800	19.8	26800	**17.6**

Figure 2D: Temperature Profile in Lower Granite Reservoir
- River Mile 110 -
(7/1/92 - 7/8/92)



Flow-weighted temperature at confluence of Snake and Clearwater rivers

Date	Temperature
7/1/92	20.2
7/6/92	17.1
7/8/92	17.6

Figure 3A: Clearwater River at Mouth - 1992

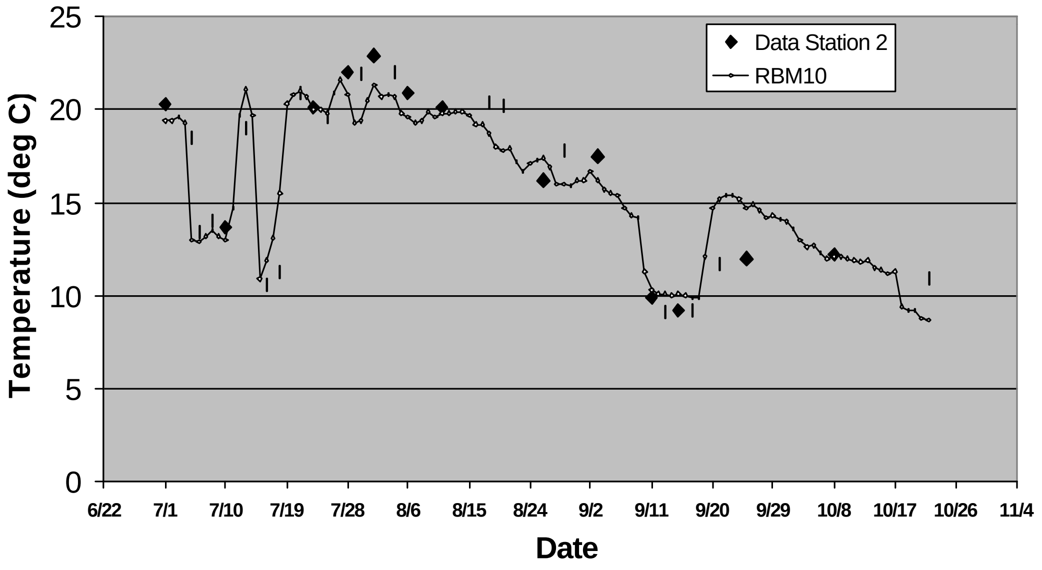


Figure 3B: Snake River (RM 130) - 1992

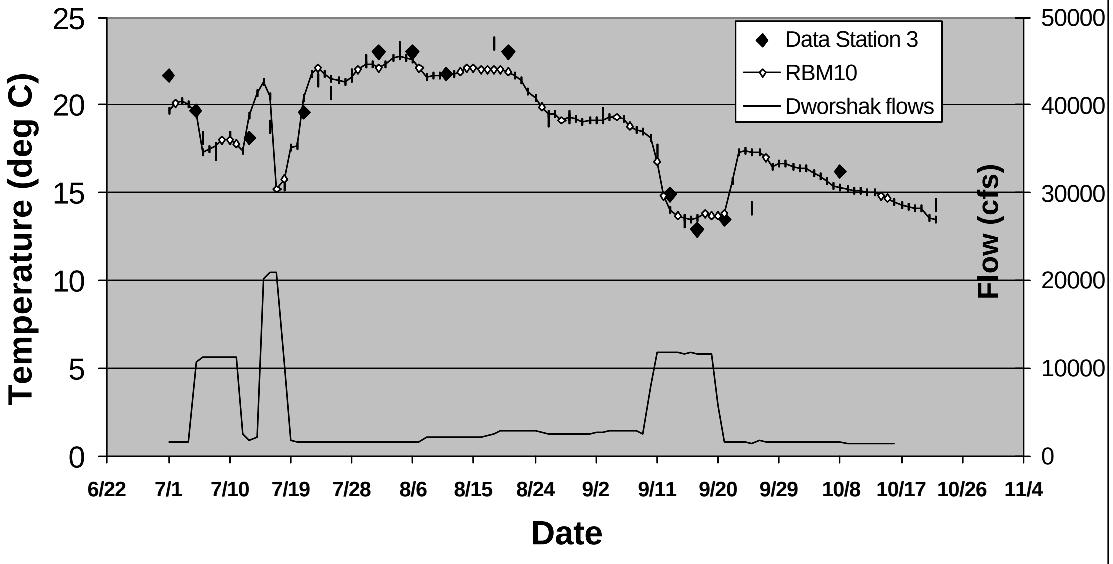


Figure 3C: Lower Granite Pool (RM 111) - 1992

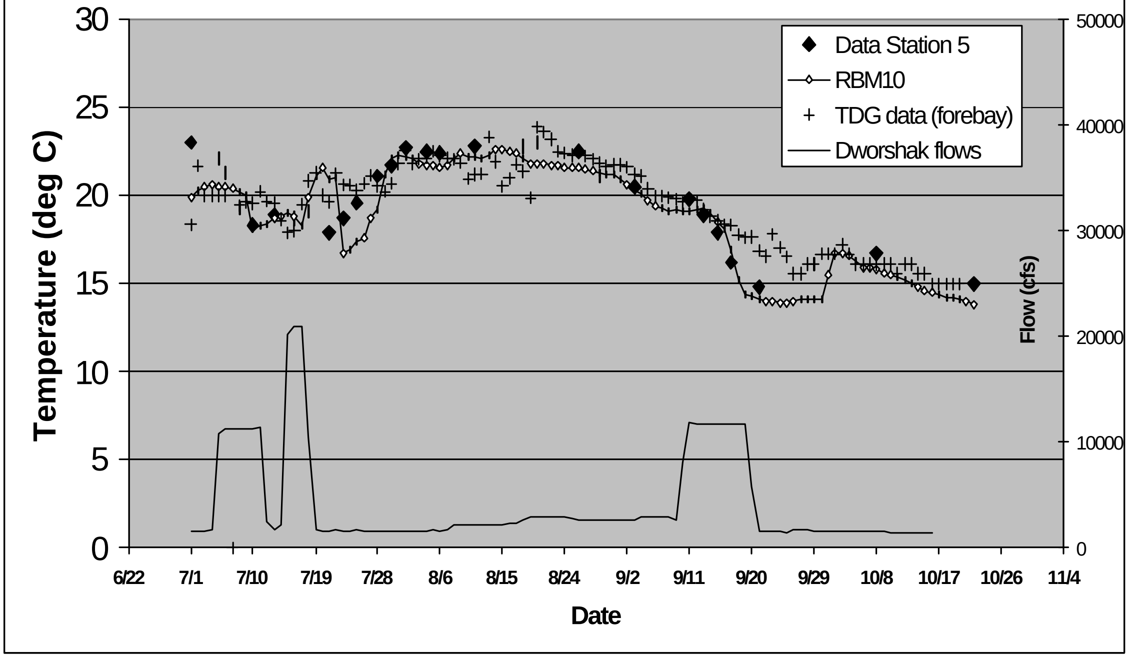


Figure 3D: Lower Granite Tailrace - 1992

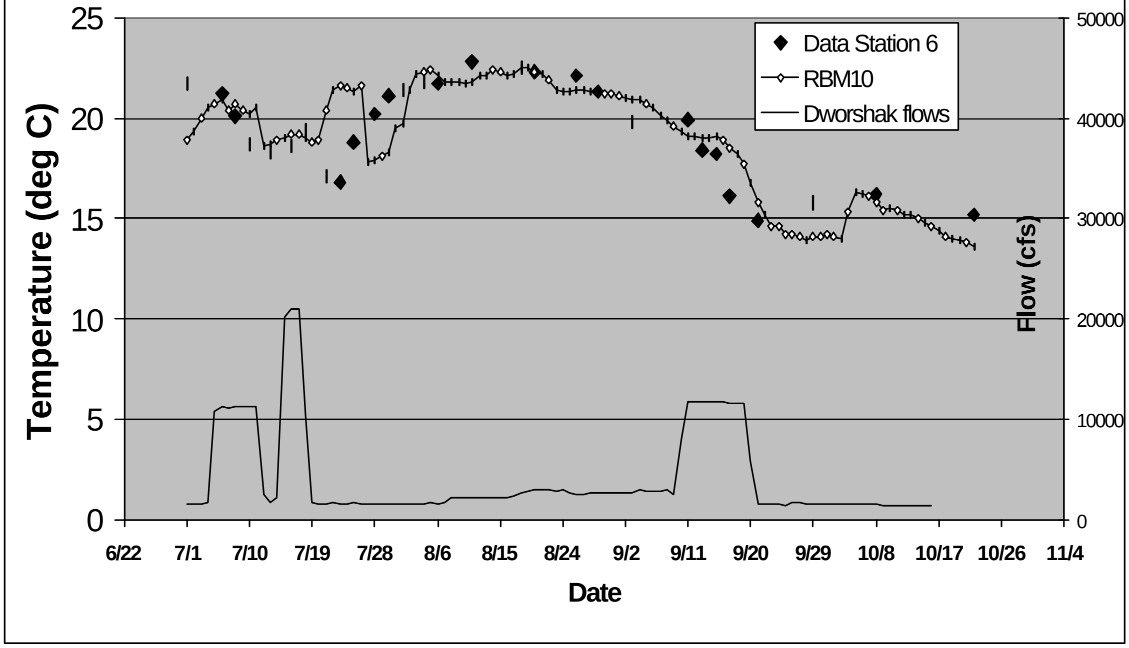


Figure 3E: Little Goose Forebay (RM80) - 1992

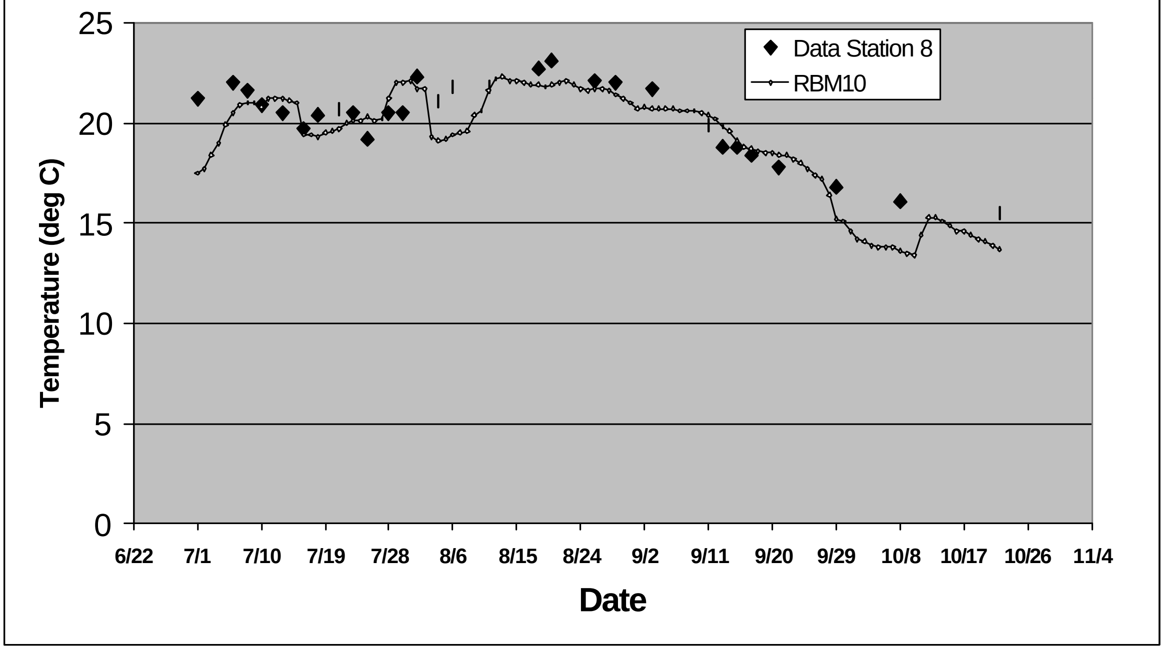


Figure 3F: Little Goose Tailrace (RM65) - 1992

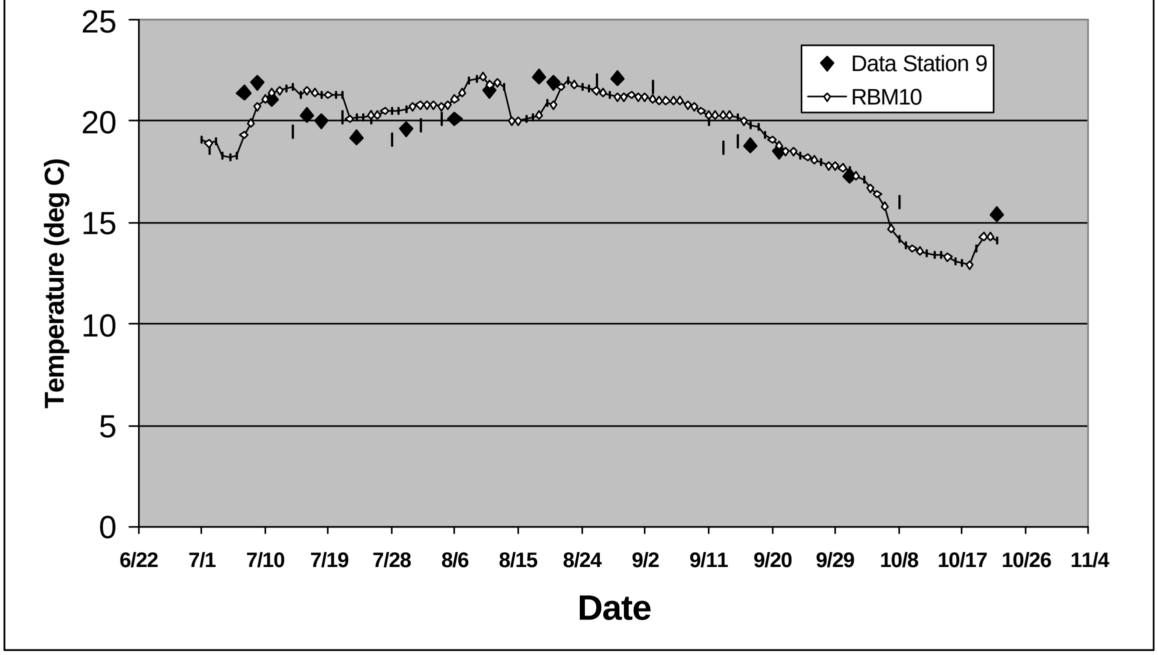


Figure 3G: L. Monumental Forebay (RM 44) - 1992

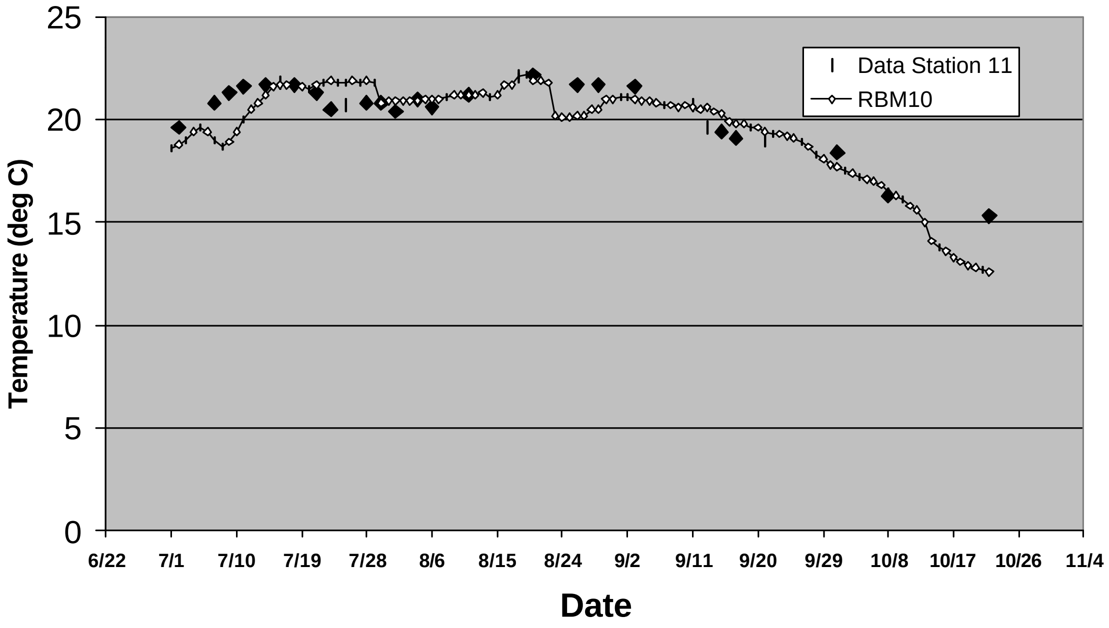
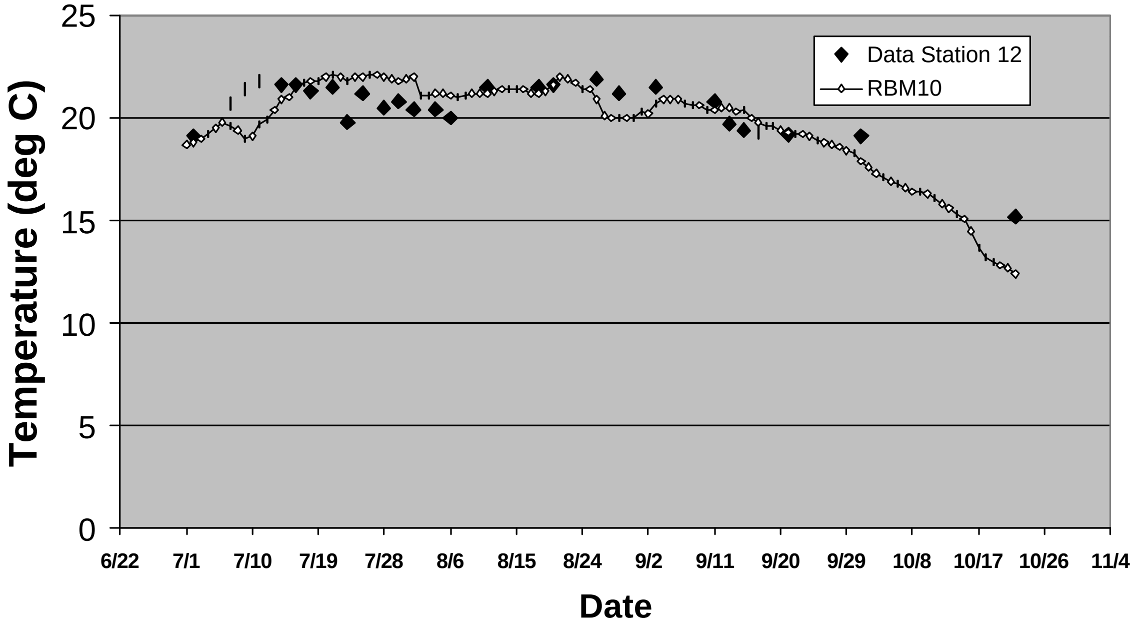
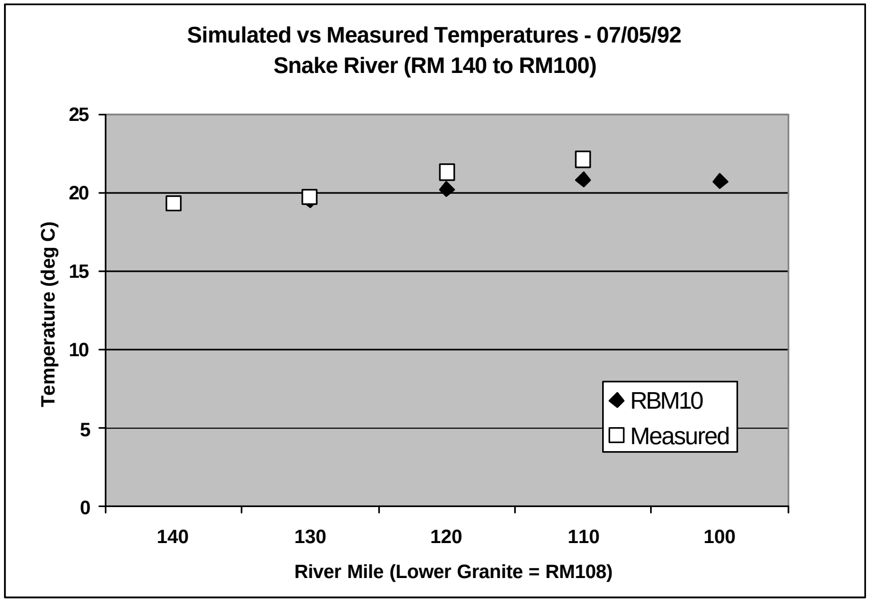
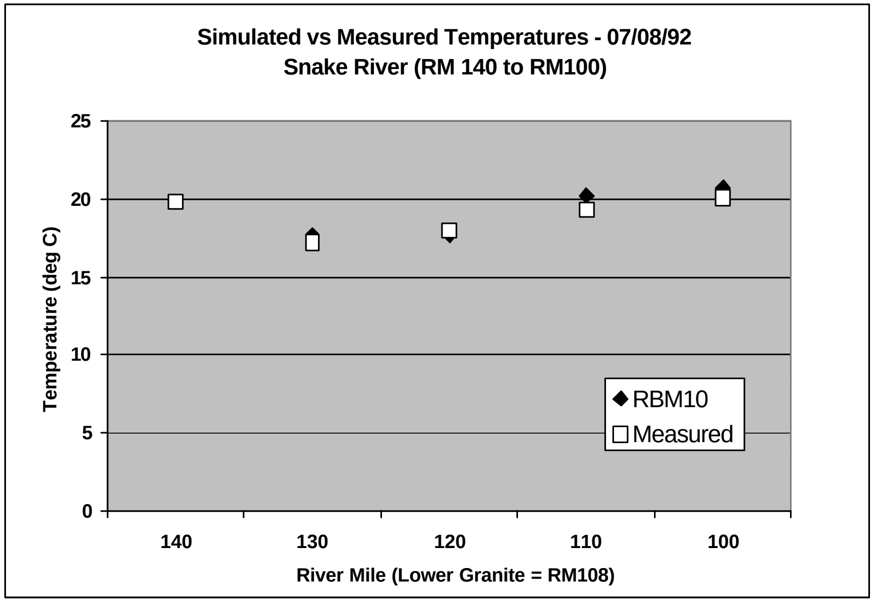
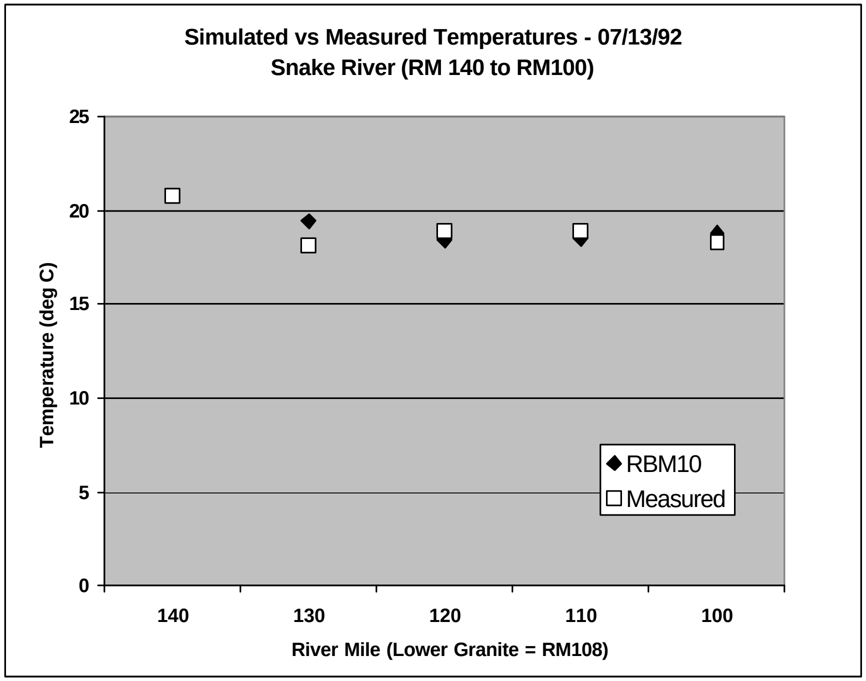


Figure 3H: L. Monumental Tailrace (RM 36) - 1992




Simulated vs Measured Temperatures - 07/05/92
Snake River (RM 140 to RM100)


Simulated vs Measured Temperatures - 07/08/92
Snake River (RM 140 to RM100)


Simulated vs Measured Temperatures - 07/13/92
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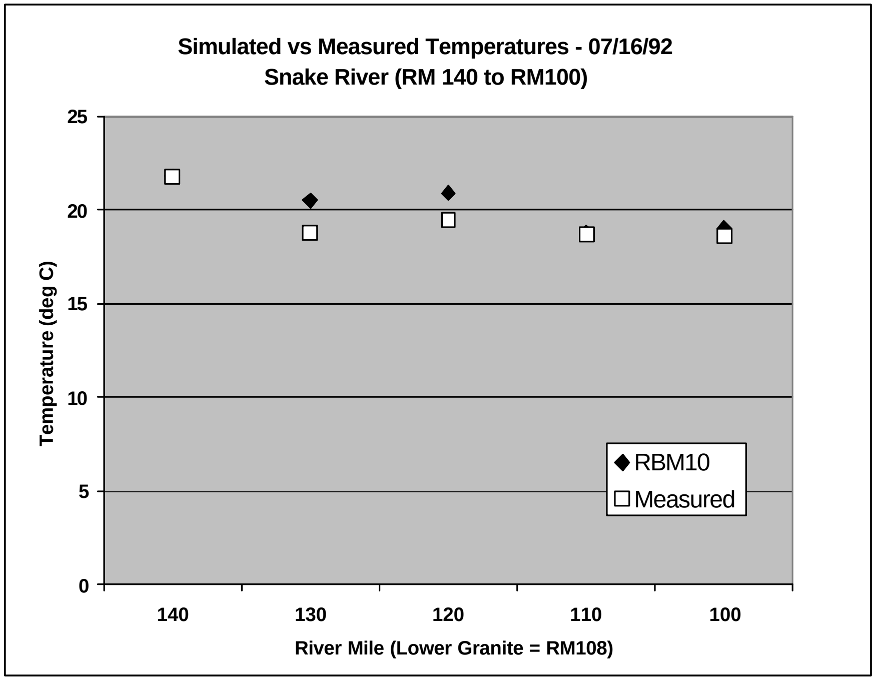
Simulated vs Measured Temperatures - 07/16/92
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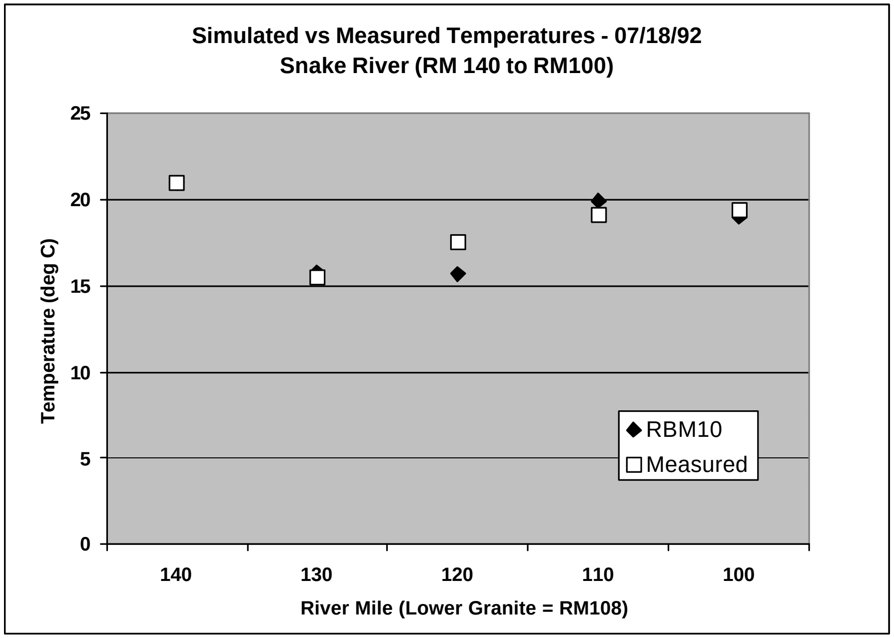
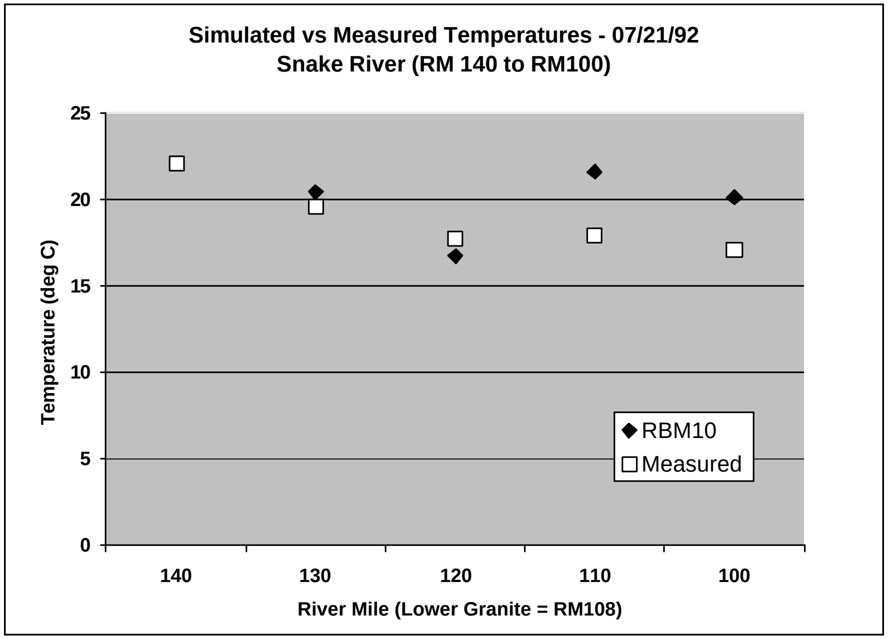
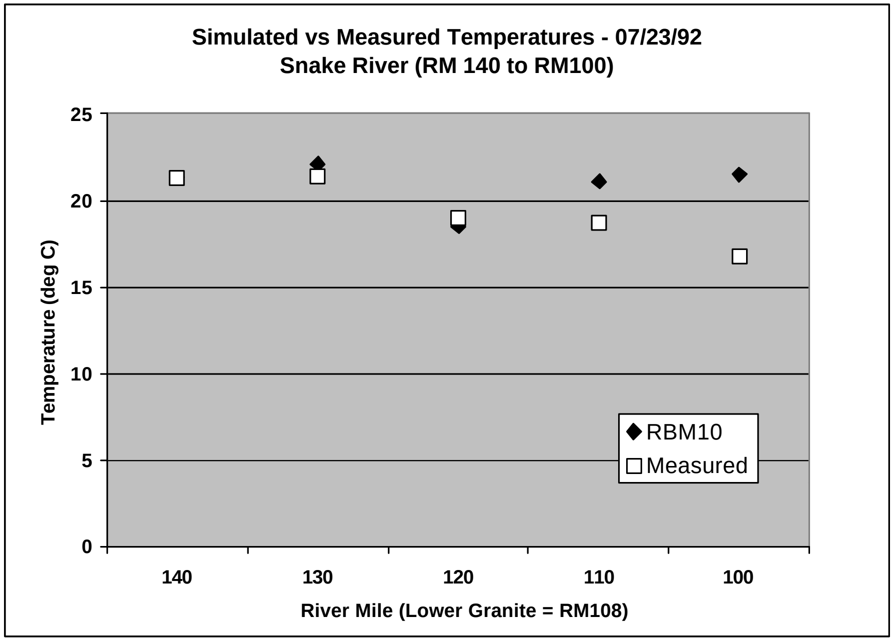
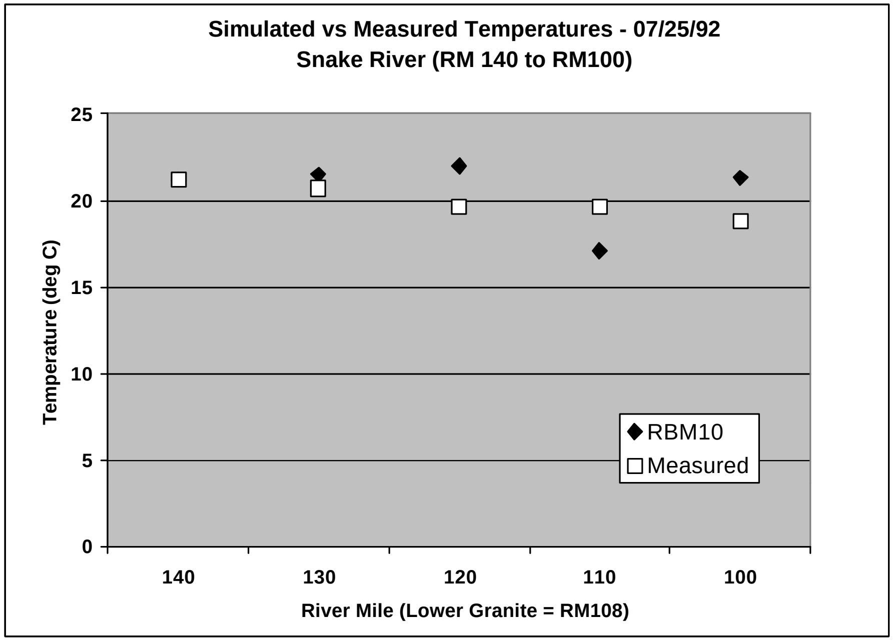
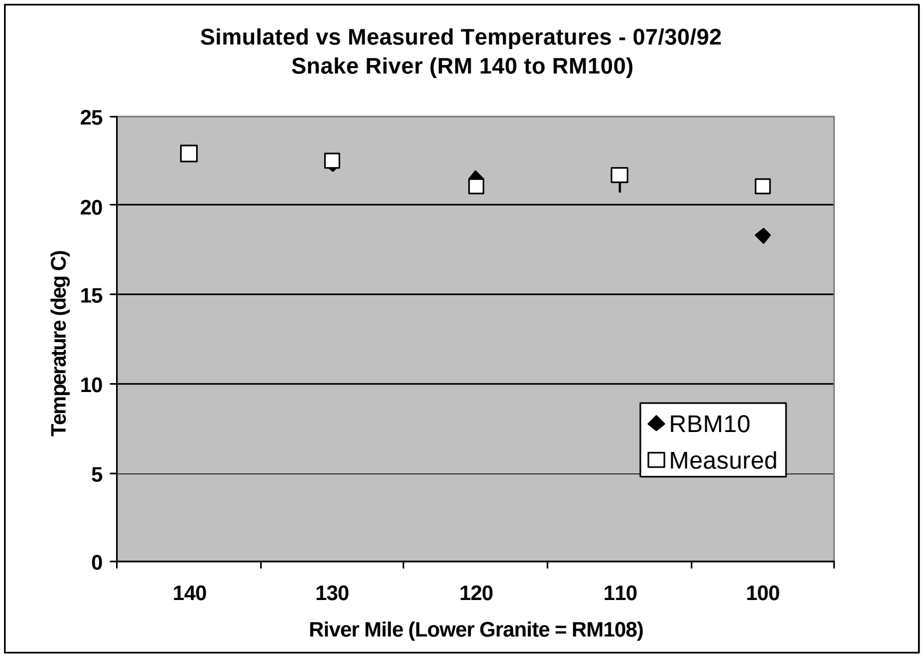
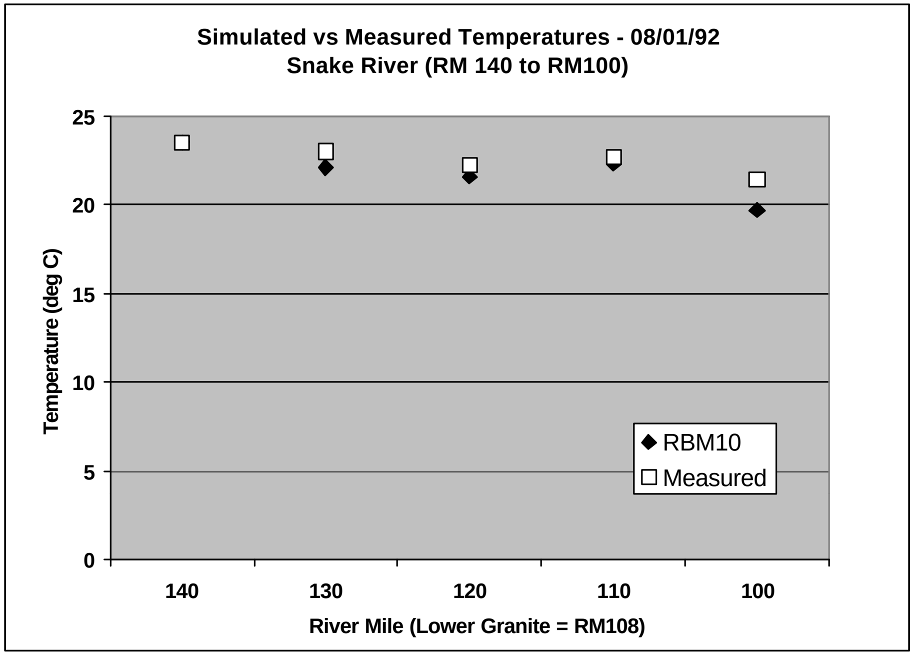

Simulated vs Measured Temperatures - 07/18/92
Snake River (RM 140 to RM100)

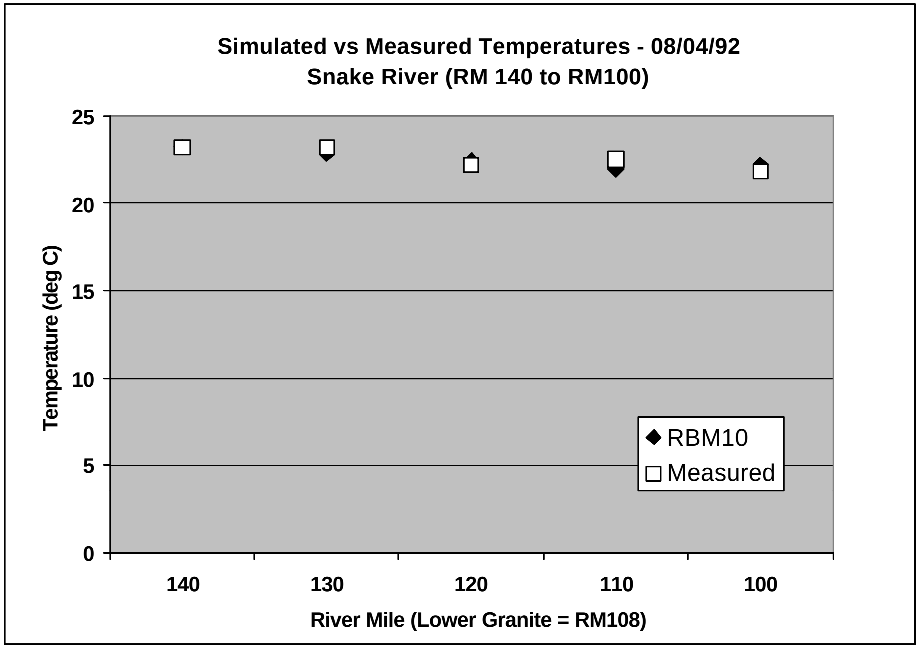

Simulated vs Measured Temperatures - 07/21/92
Snake River (RM 140 to RM100)

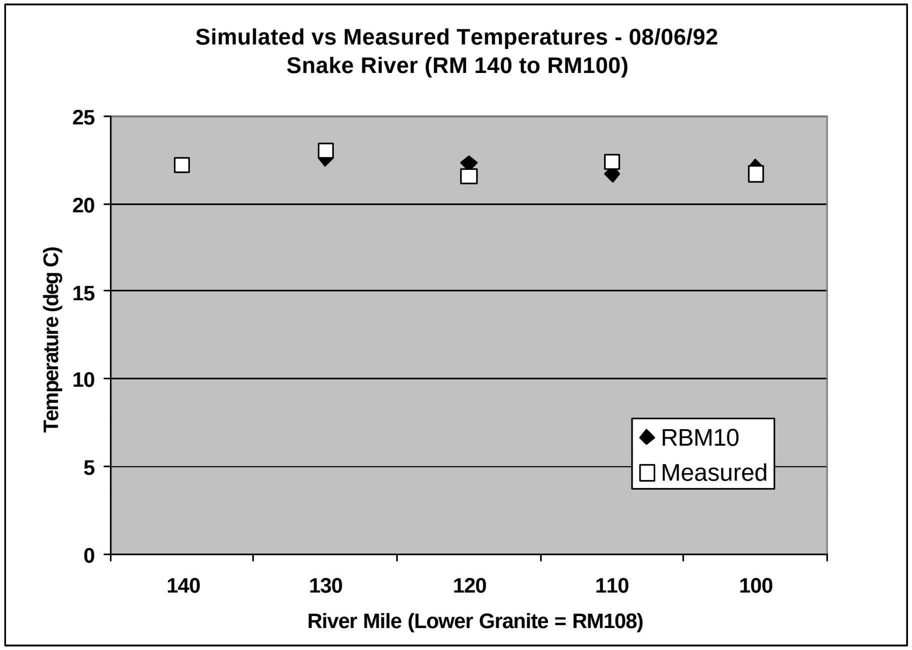

Simulated vs Measured Temperatures - 07/23/92
Snake River (RM 140 to RM100)

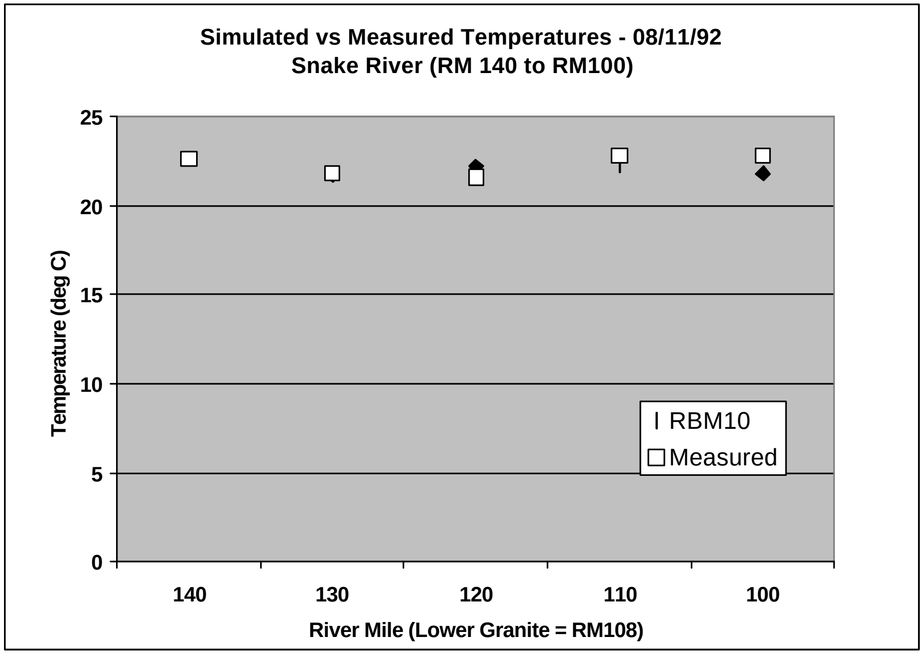

Simulated vs Measured Temperatures - 07/25/92
Snake River (RM 140 to RM100)

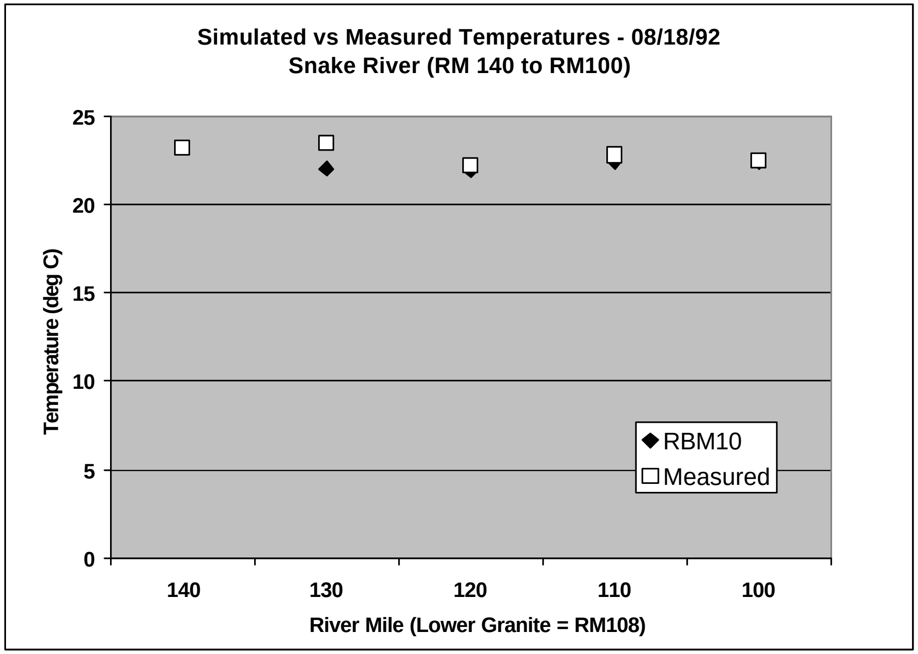

Simulated vs Measured Temperatures - 07/30/92
Snake River (RM 140 to RM100)
Temperature (deg C)
25
20
15
10
5
0
140
130
120
110
100
River Mile (Lower Granite = RM108)
◆ RBM10
☐ Measured

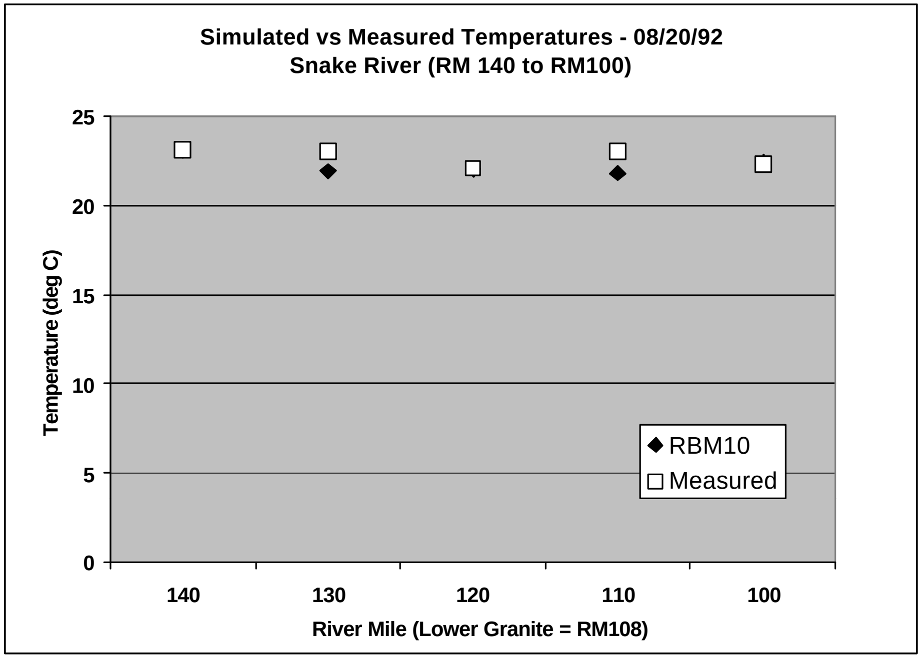

Simulated vs Measured Temperatures - 08/01/92
Snake River (RM 140 to RM100)
Temperature (deg C)
25
20
15
10
5
0
140
130
120
110
100
River Mile (Lower Granite = RM108)
◆ RBM10
☐ Measured

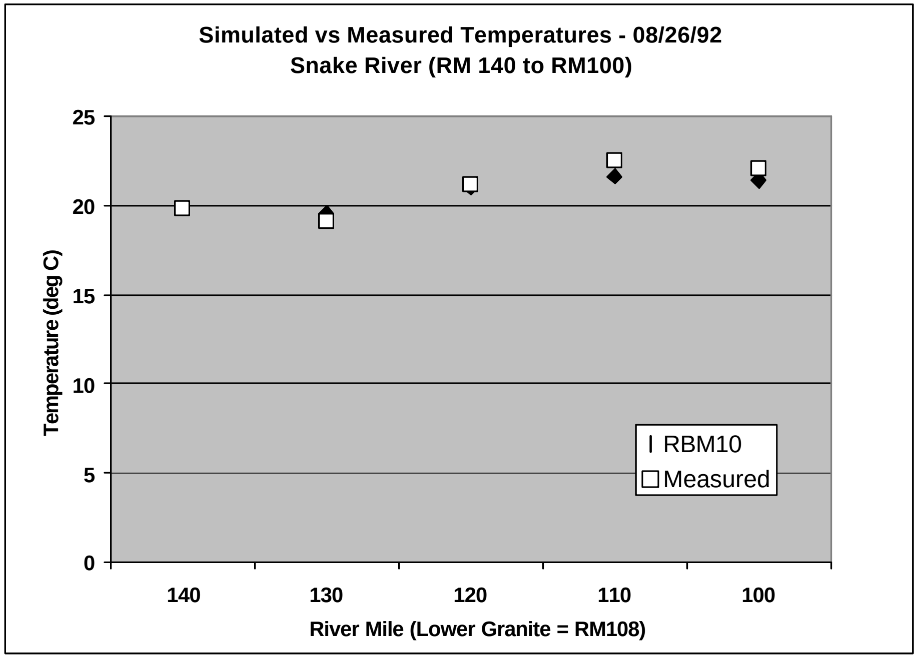

Simulated vs Measured Temperatures - 08/04/92
Snake River (RM 140 to RM100)
Temperature (deg C)
25
20
15
10
5
0
140
130
120
110
100
River Mile (Lower Granite = RM108)
◆ RBM10
☐ Measured

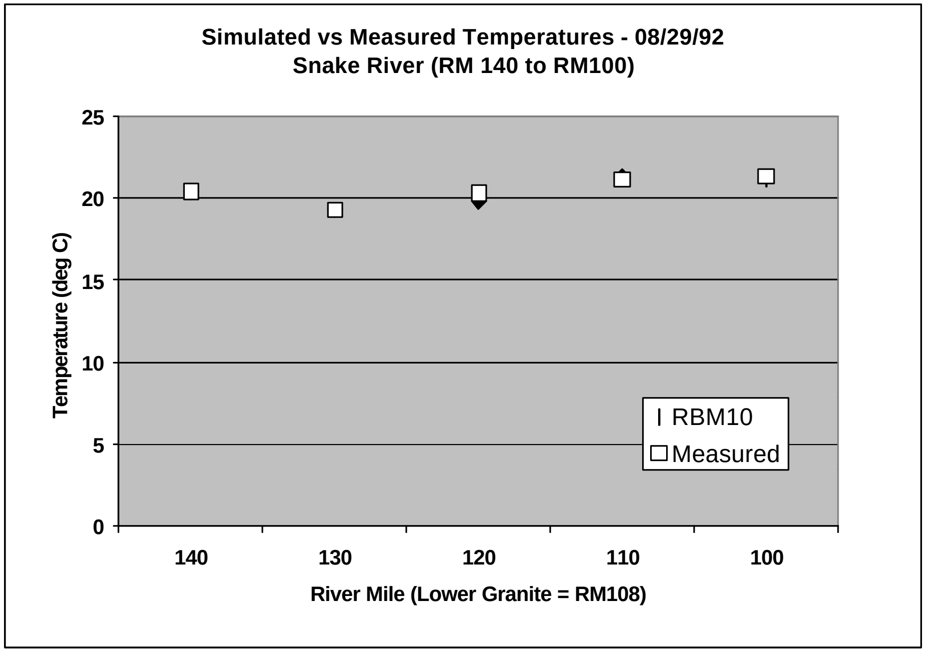

Simulated vs Measured Temperatures - 08/06/92
Snake River (RM 140 to RM100)
Temperature (deg C)
25
20
15
10
5
0
140
130
120
110
100
River Mile (Lower Granite = RM108)
◆ RBM10
☐ Measured

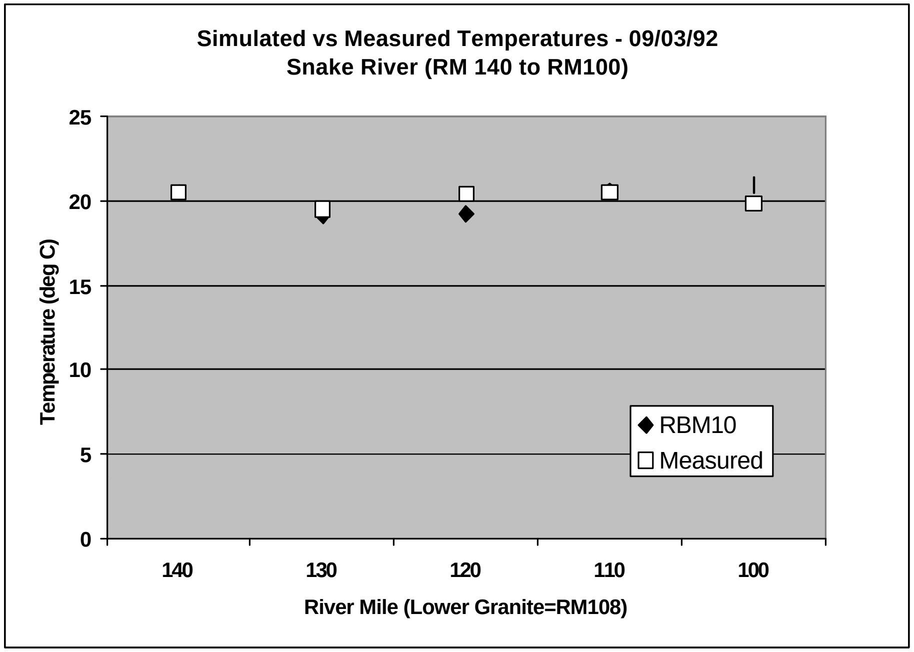

Simulated vs Measured Temperatures - 08/11/92
Snake River (RM 140 to RM100)
Temperature (deg C)
25
20
15
10
5
0
140
130
120
110
100
River Mile (Lower Granite = RM108)
I RBM10
☐ Measured

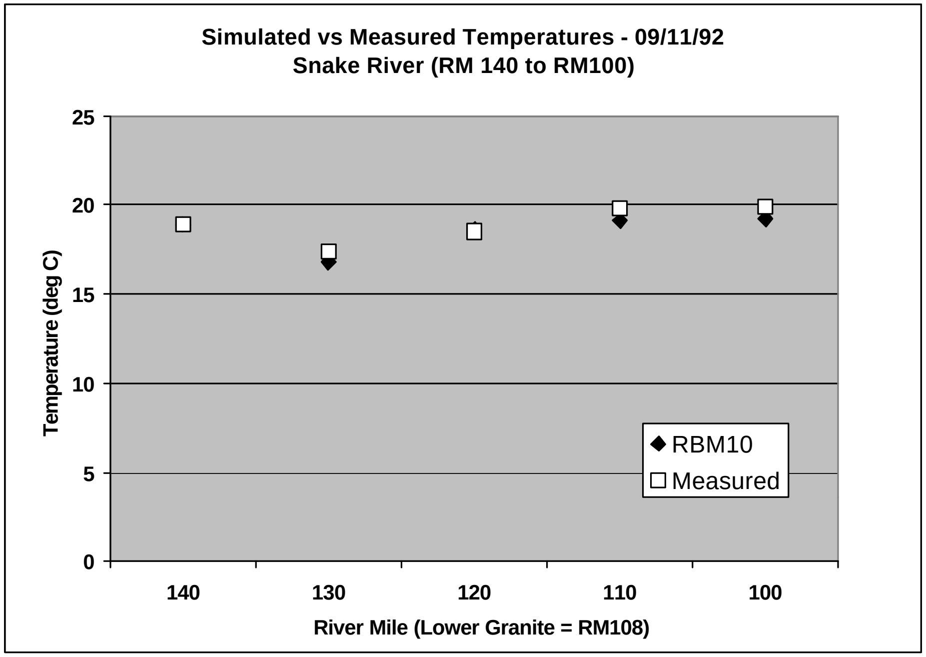

Simulated vs Measured Temperatures - 08/18/92
Snake River (RM 140 to RM100)
Temperature (deg C)
25
20
15
10
5
0
140
130
120
110
100
River Mile (Lower Granite = RM108)
◆ RBM10
☐ Measured

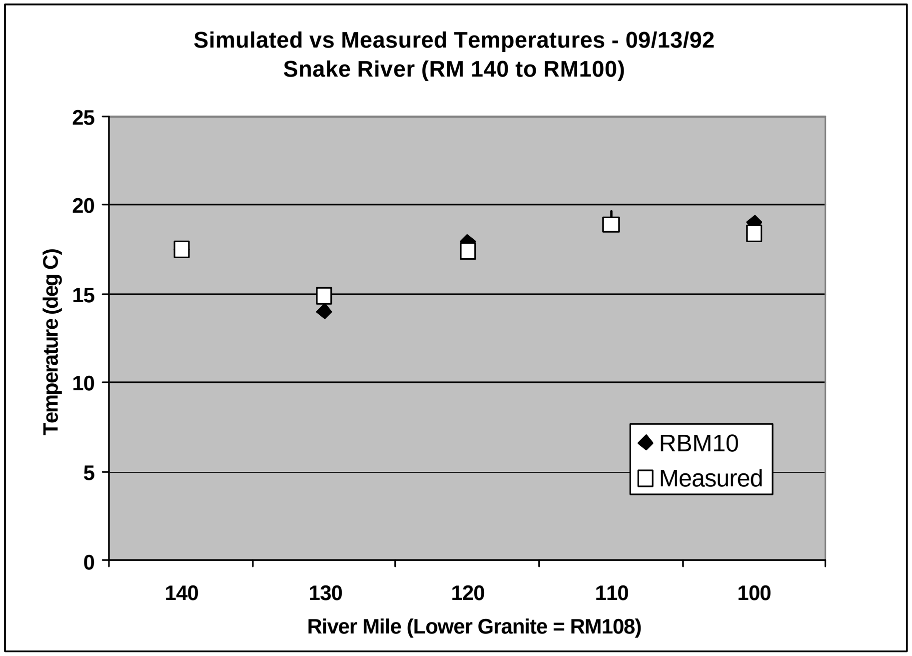

Simulated vs Measured Temperatures - 08/20/92
Snake River (RM 140 to RM100)
Temperature (deg C)
25
20
15
10
5
0
140
130
120
110
100
River Mile (Lower Granite = RM108)
◆ RBM10
☐ Measured

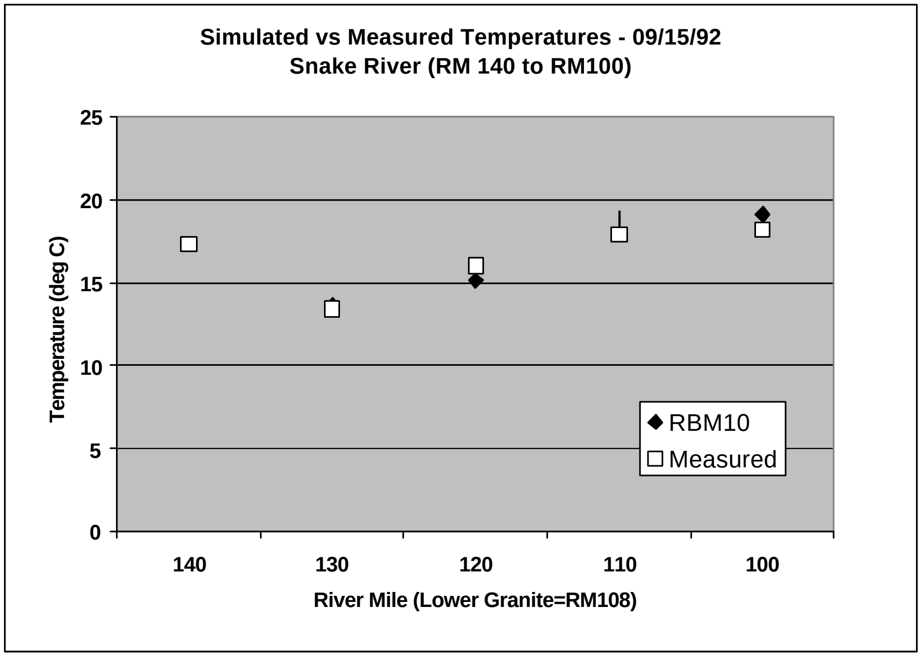

Simulated vs Measured Temperatures - 08/26/92
Snake River (RM 140 to RM100)
Temperature (deg C)
25
20
15
10
5
0
140
130
120
110
100
River Mile (Lower Granite = RM108)
I RBM10
☐ Measured

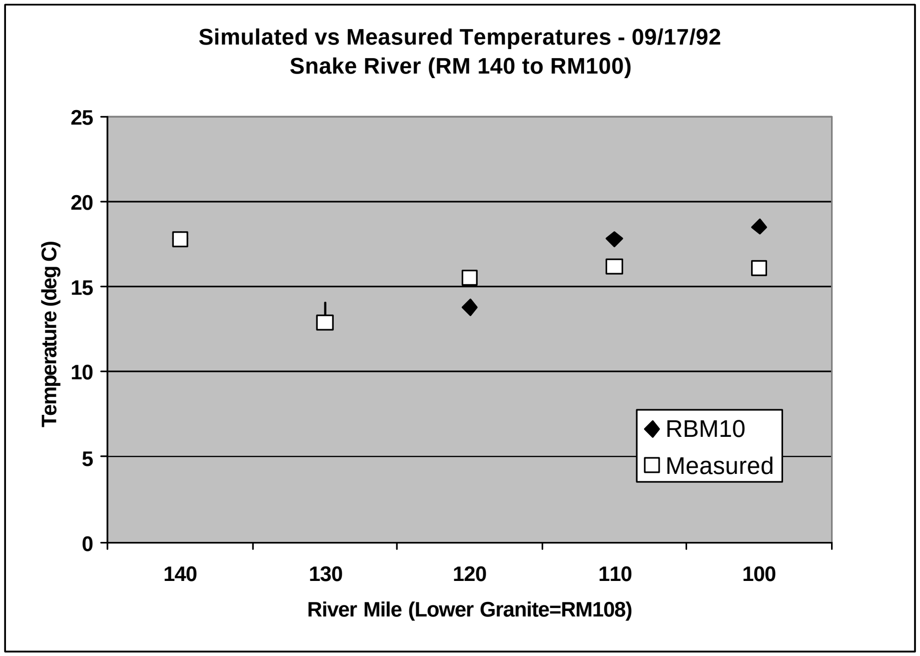

Simulated vs Measured Temperatures - 08/29/92
Snake River (RM 140 to RM100)

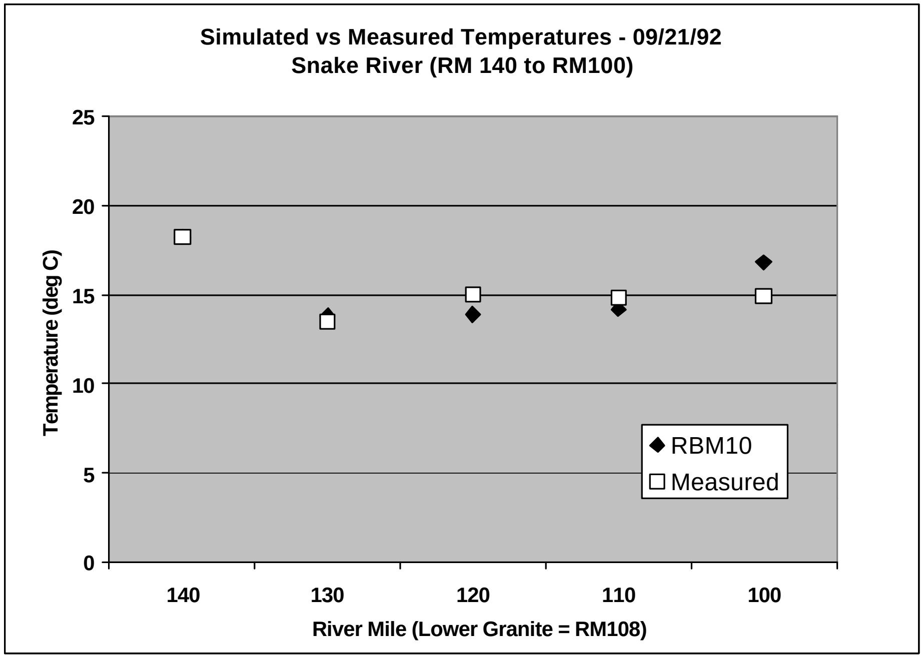

Simulated vs Measured Temperatures - 09/03/92
Snake River (RM 140 to RM100)

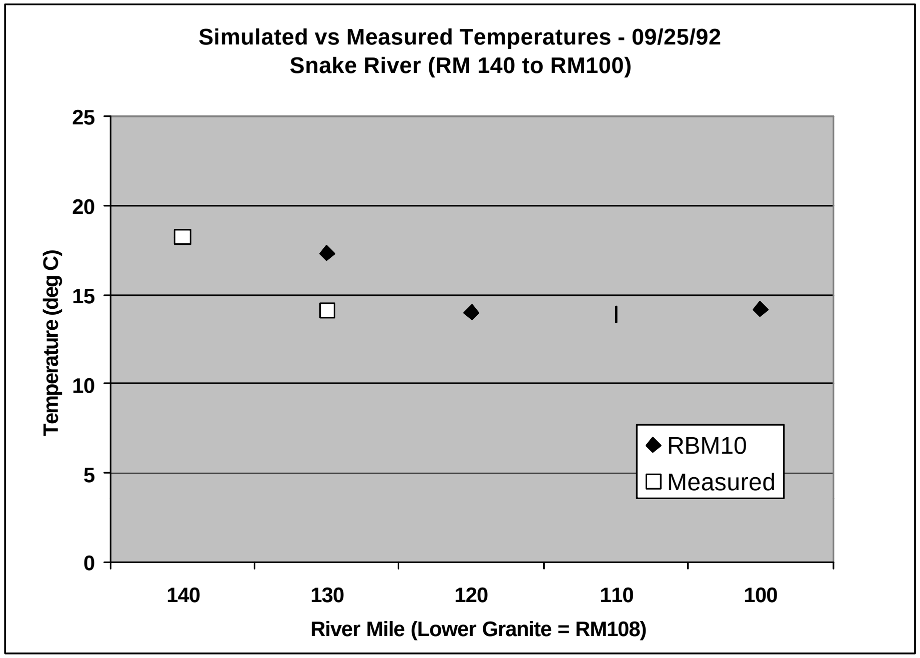

Simulated vs Measured Temperatures - 09/11/92
Snake River (RM 140 to RM100)

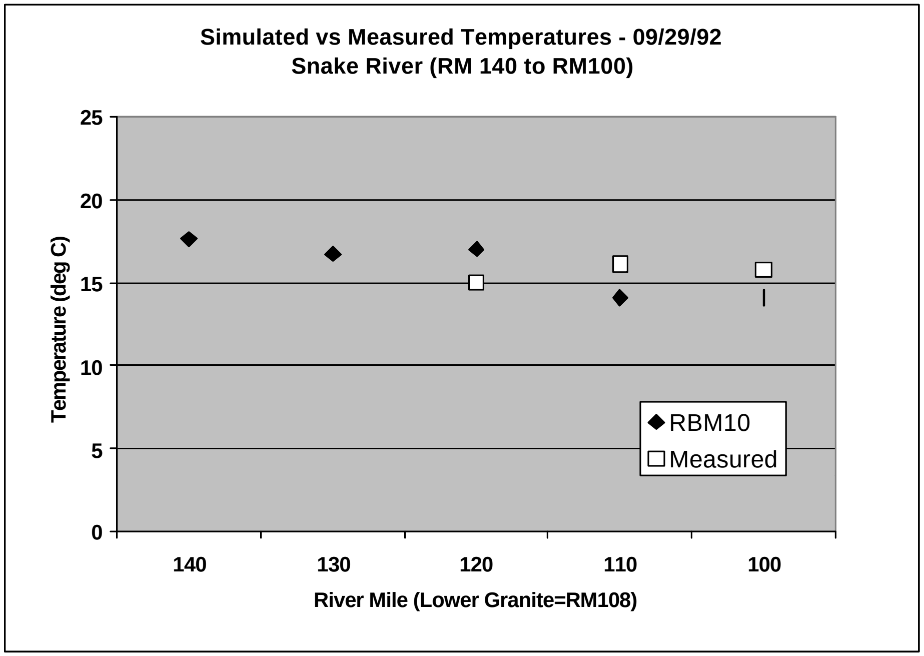

Simulated vs Measured Temperatures - 09/13/92
Snake River (RM 140 to RM100)

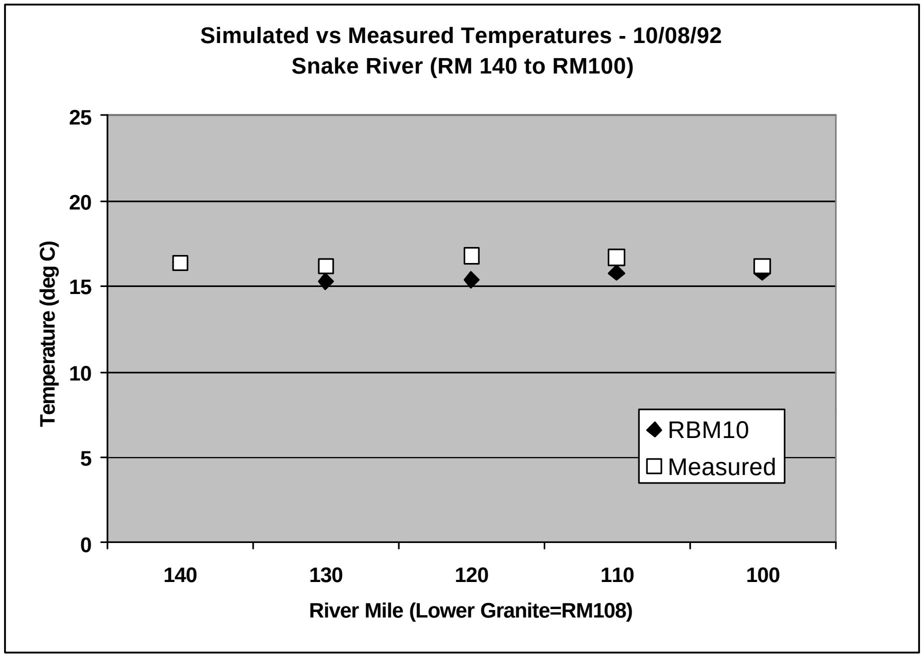

Simulated vs Measured Temperatures - 09/15/92
Snake River (RM 140 to RM100)
Temperature (deg C)
25
20
15
10
5
0
140
130
120
110
100
River Mile (Lower Granite=RM108)
◆ RBM10
☐ Measured

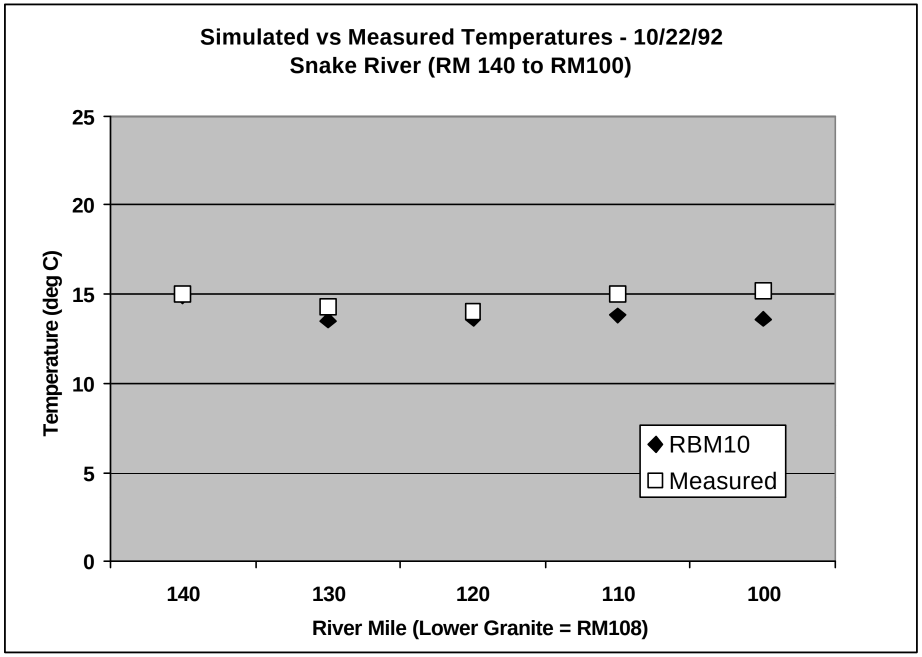

Simulated vs Measured Temperatures - 09/17/92
Snake River (RM 140 to RM100)
Temperature (deg C)
25
20
15
10
5
0
140
130
120
110
100
River Mile (Lower Granite=RM108)
◆ RBM10
☐ Measured


Simulated vs Measured Temperatures - 09/21/92
Snake River (RM 140 to RM100)
Temperature (deg C)
25
20
15
10
5
0
140
130
120
110
100
River Mile (Lower Granite = RM108)
◆ RBM10
☐ Measured


Simulated vs Measured Temperatures - 09/25/92
Snake River (RM 140 to RM100)
Temperature (deg C)
25
20
15
10
5
0
140
130
120
110
100
River Mile (Lower Granite = RM108)
◆ RBM10
☐ Measured


Simulated vs Measured Temperatures - 09/29/92
Snake River (RM 140 to RM100)
Temperature (deg C)
0
5
10
15
20
25
140
130
120
110
100
River Mile (Lower Granite=RM108)
◆ RBM10
☐ Measured


Simulated vs Measured Temperatures - 10/08/92
Snake River (RM 140 to RM100)
Temperature (deg C)
0
5
10
15
20
25
140
130
120
110
100
River Mile (Lower Granite=RM108)
◆ RBM10
☐ Measured


Simulated vs Measured Temperatures - 10/22/92
Snake River (RM 140 to RM100)
Temperature (deg C)
0
5
10
15
20
25
140
130
120
110
100
River Mile (Lower Granite = RM108)
◆ RBM10
☐ Measured