



**U.S. Army Corps of Engineers
Walla Walla District**

Two-Dimensional Hydrodynamic, Water Quality, and Fish Exposure Modeling of the Columbia and Snake Rivers.

Part 4: Lower Monumental Reservoir

FINAL REPORT

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Abstract

One of the major goals for the U.S. Army Corps of Engineers Dissolved Gas Abatement Study is to identify measures that could reduce levels of dissolved gas supersaturation in the Columbia and Snake Rivers caused by spillway discharges. Attaining this goal could contribute significantly to meeting water quality criteria and lowering gas bubble trauma in resident and migrating fish in these rivers. To achieve this goal, the Corps of Engineers is studying various operational and structural alternatives using field investigations and computational modeling tools to simulate the transport of dissolved gas in the river system.

Part 4 of the report series summarizes the development and application of a two-dimensional depth-averaged hydrodynamic and water quality model (MASS2) to the Lower Monumental Reservoir of the Lower Snake River system.

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Two-Dimensional Hydrodynamic, Water Quality, and Fish Exposure Modeling of the Columbia and Snake Rivers.

Part 4: Lower Monumental Reservoir

Under Biological Services Contract DACW68-96-D-0002, Delivery Order No. 8, Battelle, Pacific Northwest Division is developing and applying a two-dimensional hydrodynamic, transport model, and fish exposure model to the Lower Columbia and Snake River systems. This work is an element of the U.S. Army Corps of Engineers Dissolved Gas Abatement Program (DGAS).

Part 4 of the report series describes the application of the model to the Lower Monumental Pool of the Snake River. The modeled domain encompasses the following region:

- Little Goose Dam, at Snake rivermile (RM) 70
- Lower Monumental Dam, at Snake rivermile (RM) 40

1 Application of the Hydrodynamics and Water Quality Models to Lower Monumental Pool

A two-dimensional-depth averaged hydrodynamics and transport model has been developed and applied to the part of the Snake River that forms the Lower Monumental Dam pool. The model simulates time-varying distributions of the depth-averaged velocities, water temperature, and total dissolved gas. Further details concerning the model including the governing equations and solutions procedures are provided in Part 1 of the report series (Richmond, Perkins, and Scheibe, 1998).

The section discusses the general aspects of the application of the models to Lower Monumental Pool. The data used to assign the bathymetry and boundary conditions are described in Appendix A. Summaries of the field data in the calibration and verification simulations are provided in Appendix B through Appendix D.

Hydrodynamics were verified using Spring and Summer 1997 Acoustic Doppler Current Profiler (ADCP) data. Dissolved gas and temperature verification used the Spring 1996, Spring 1997, and Summer 1997 pool study data.

1.1 Model Grid

The computational grid was generated using the Gridgen 9.1 code. Gridgen 9.1 is software for the generation of 3D, multiple block, structured grids. The code was developed for NASA Ames Research Center (Steinbrenner and Chawner, 1995).

To create the grid, a data file containing discrete geographical locations that outline the river shoreline was imported to Gridgen. In Gridgen, curves containing the data points

were created and joined to enclose 2-dimensional flow regions. Grid spacing was set in each flow region and the grids were smoothed using the Gridgen elliptic solver. The elliptic solver was used to minimize grid twist and skew. The flow regions were then joined end to end in the downstream direction to make up the entire flow domain and the entire 2-dimensional grid was written to file. Once the grid was created bottom elevations in each cell were assigned using the bathymetric data and procedure described in Appendix A.

The model grid for Lower Monumental pool is shown in Figure 1. Larger scale maps of the model grid near the Little Goose dam and Lower Monumental dam boundaries are shown in Figure 2. Note that several small islands were not included in the model and these were replaced with bottom elevation approximately 2 ft below the low water surface elevation (the water is about 2 ft deep where the islands are).

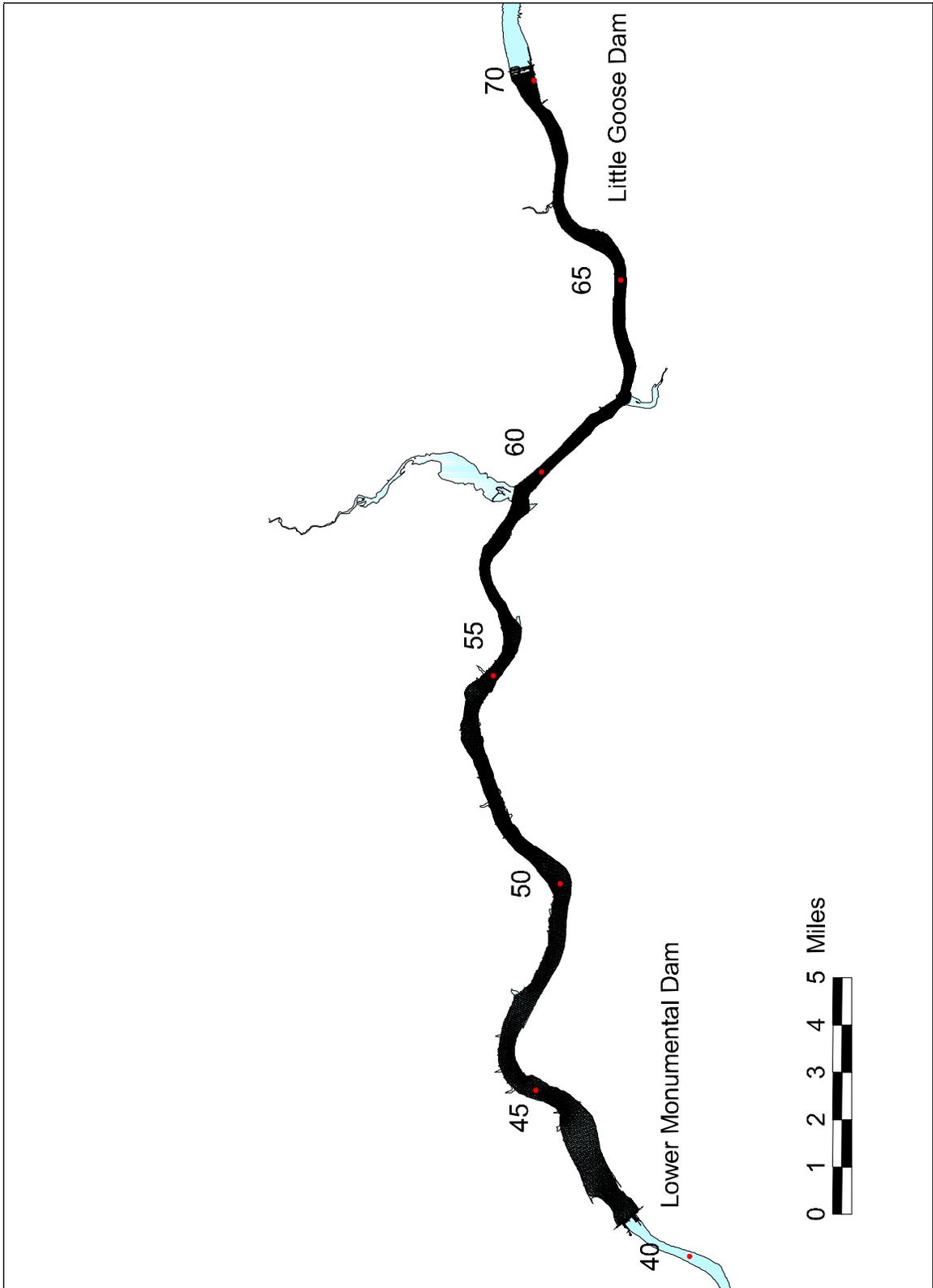


Figure 1. Model grid for Lower Monumental pool.

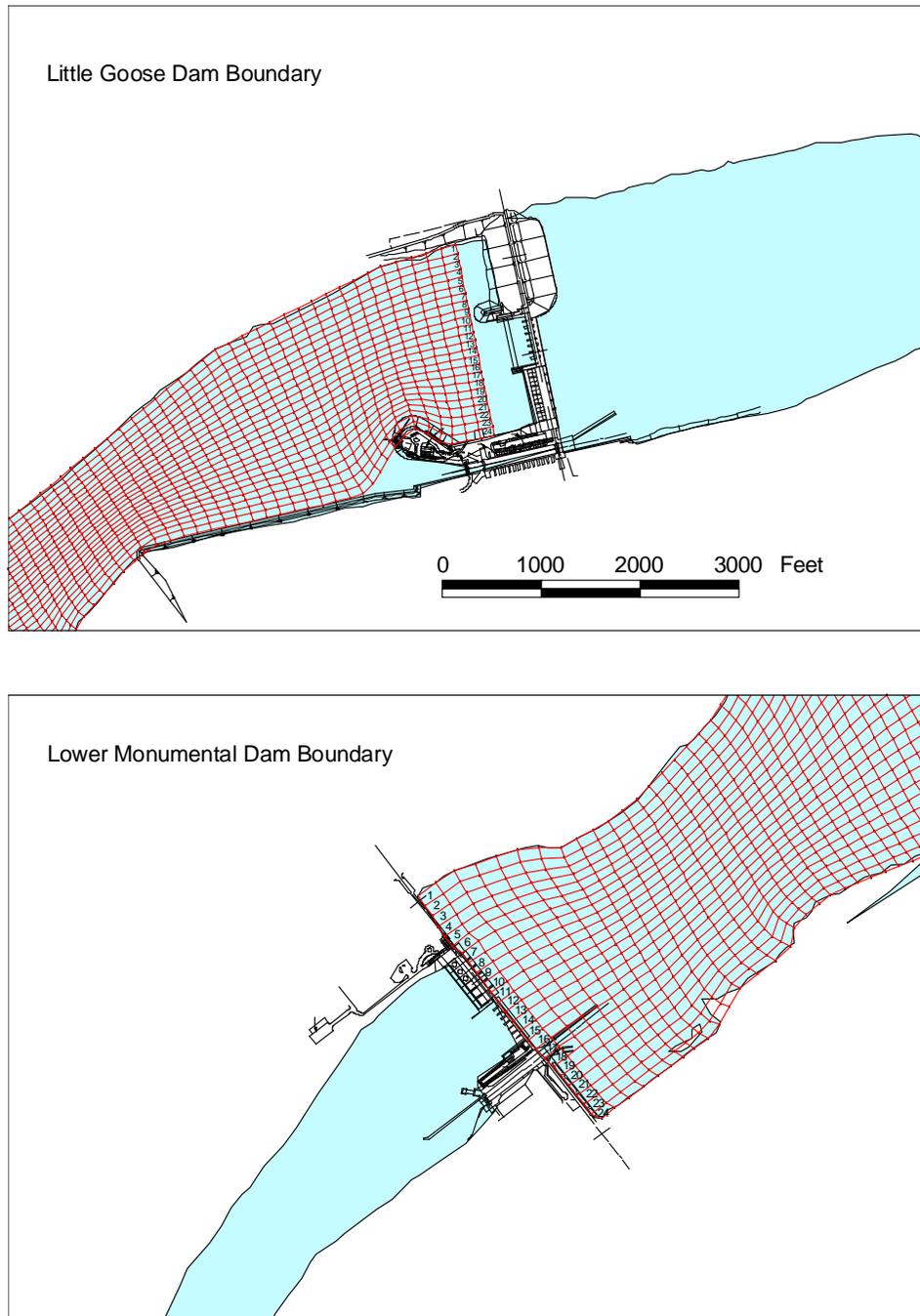


Figure 2. Model grid boundaries near Little Goose and Lower Monumental dams.

1.2 Boundary Conditions

1.2.1 Little Goose Dam Sourcing Function

Spillway TDG concentrations were estimated using the Little Goose dam TDG sourcing function presented by Schnieder and Wilhelms (1997):

$$S_s = 132 - 27.2 \exp(1.31 \times 10^{-5} Q_s) \quad (1)$$

where

S_s = TDG saturation of spillway flow, percent; and

Q_s = spillway flow, cfs.

Forebay temperatures and barometric pressures were used to compute concentration from the saturation estimated using equation (1).

1.3 Hydrodynamics Calibration and Verification

The model hydrodynamics were calibrated primarily using the Little Goose dam tailwater elevation gage. ADCP velocity measurements were available for both Little Goose pool study periods. Due to instrumentation problems the horizontal coordinates of the ADCP data were subject to uncertain errors. Therefore, at this time, use of the ADCP data was restricted to qualitative comparisons with the model simulations.

In all simulations in this report a time step of 50 seconds was used. The simulations also used constant longitudinal and lateral turbulent eddy viscosities of $0.2 \text{ ft}^2/\text{s}$.

1.3.1 Little Goose Tailwater

The first step in the calibration procedure was to select a spatially uniform value of the Manning roughness coefficient that would yield computed water surface elevations in satisfactory agreement with the Little Goose dam tailwater gage. The Spring 1997 pool study period was selected for calibration. Simulations were performed using Manning n values in the range of 0.021 to 0.029. Figure 3 compares the model simulation and measured tailwater elevation for a n -value of 0.024 which was chosen as the final parameter value to be used in the remainder of the Lower Monumental Pool simulations.

The selected-value of Manning's n was verified for the Spring 1996 and Summer 1997 study periods. The verification results are shown in Figure 4 and Figure 5.

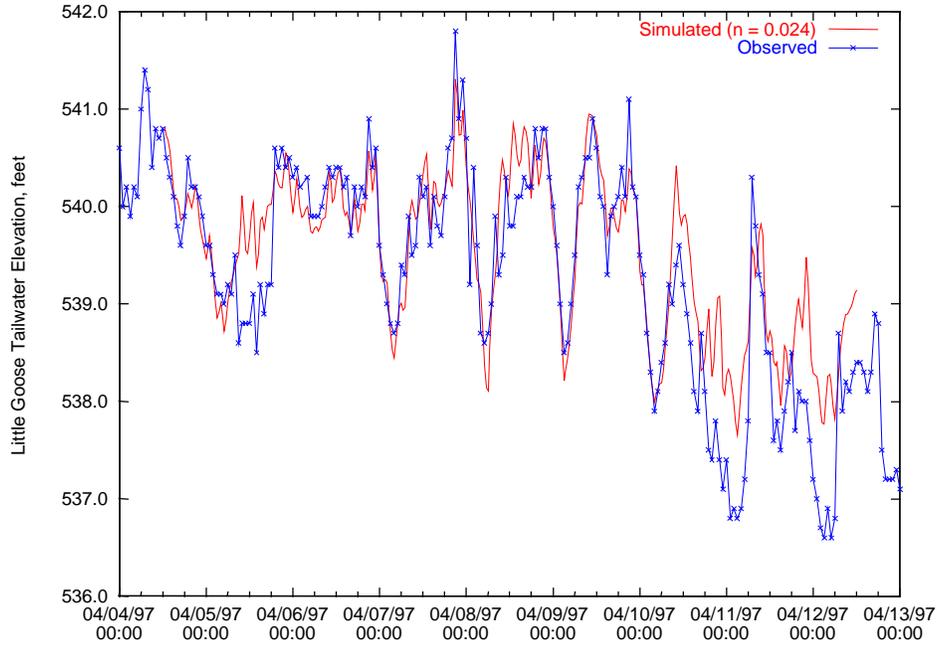


Figure 3. Comparison of simulated (Manning’s $n = 0.024$) and measured water surface elevation at the Little Goose dam tailwater gage during the Spring 1997 study period

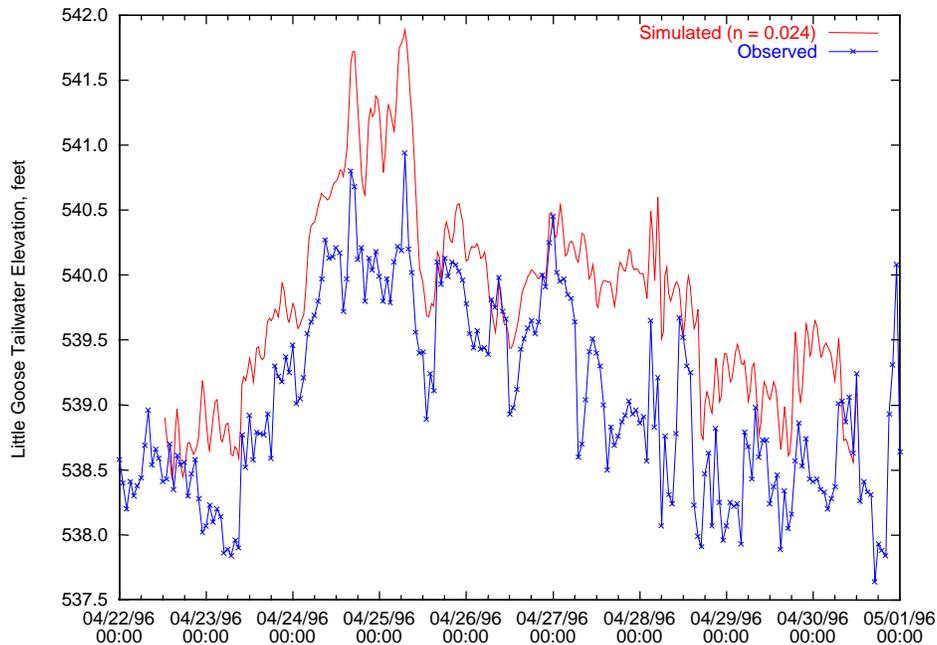


Figure 4. Comparison of simulated (Manning’s $n = 0.024$) and measured water surface elevation at the Little Goose dam tailwater gage during the Spring 1996 study period

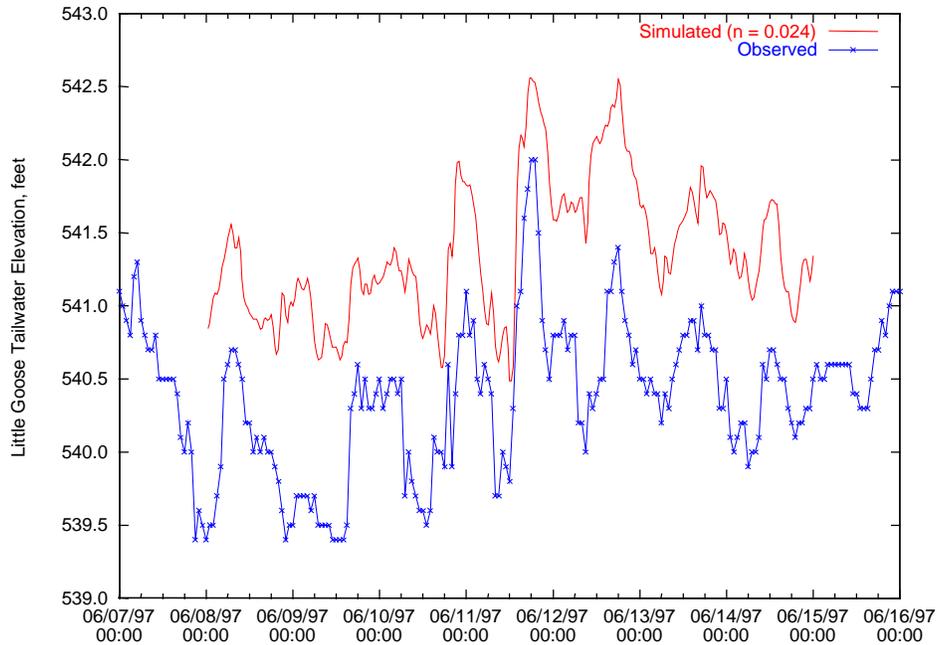


Figure 5. Comparison of simulated (Manning’s $n = 0.024$) and measured water surface elevation at the Little Goose dam tailwater gage during the Summer 1997 study period

1.3.2 Summer 1997 ADCP Data

Once the Manning n -value was selected, the model was run for the operational conditions that existed when the Summer 1997 ADCP measurements were performed. The Manning n value was not altered from the value of 0.024 selected from the tailwater calibration. Simulated velocities are compared to the depth-averaged ADCP data in Figure 6 through Figure 31.

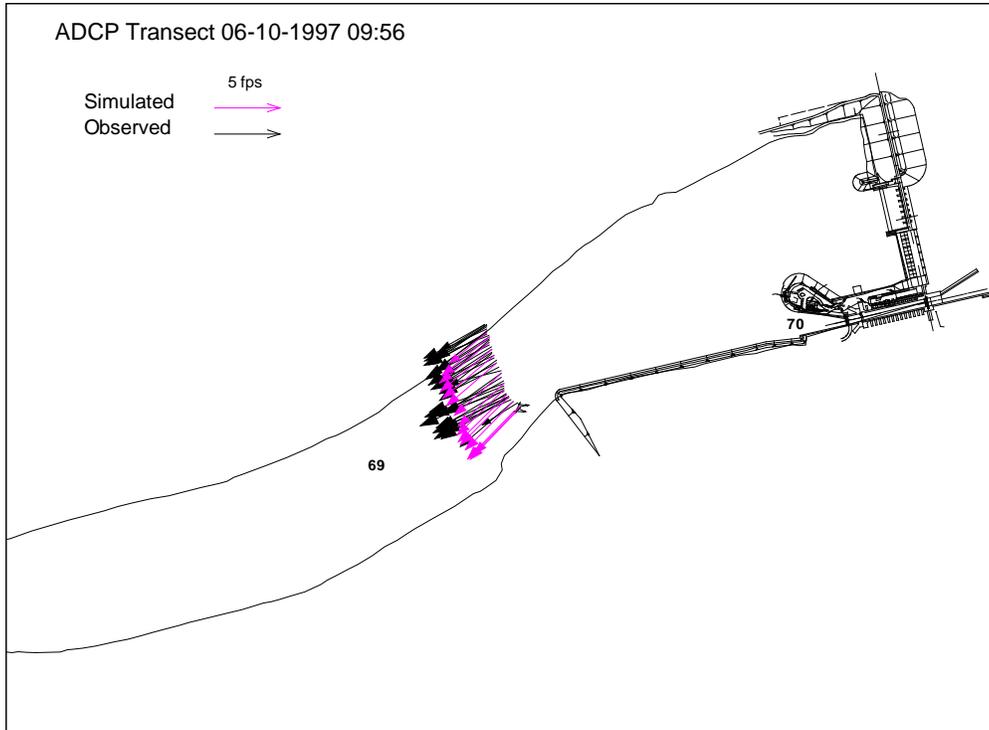


Figure 6. Simulated and observed depth-averaged velocities near Snake River Mile 69 on 6-10-1997.

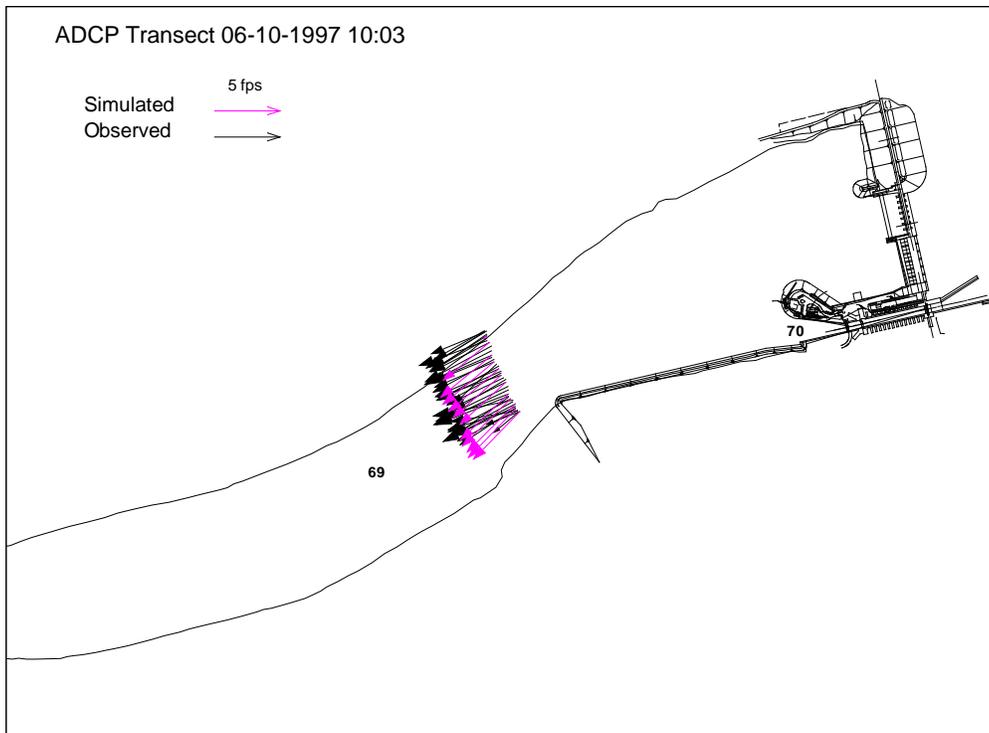


Figure 7. Simulated and observed depth-averaged velocities near Snake River Mile 69 on 6-10-1997.

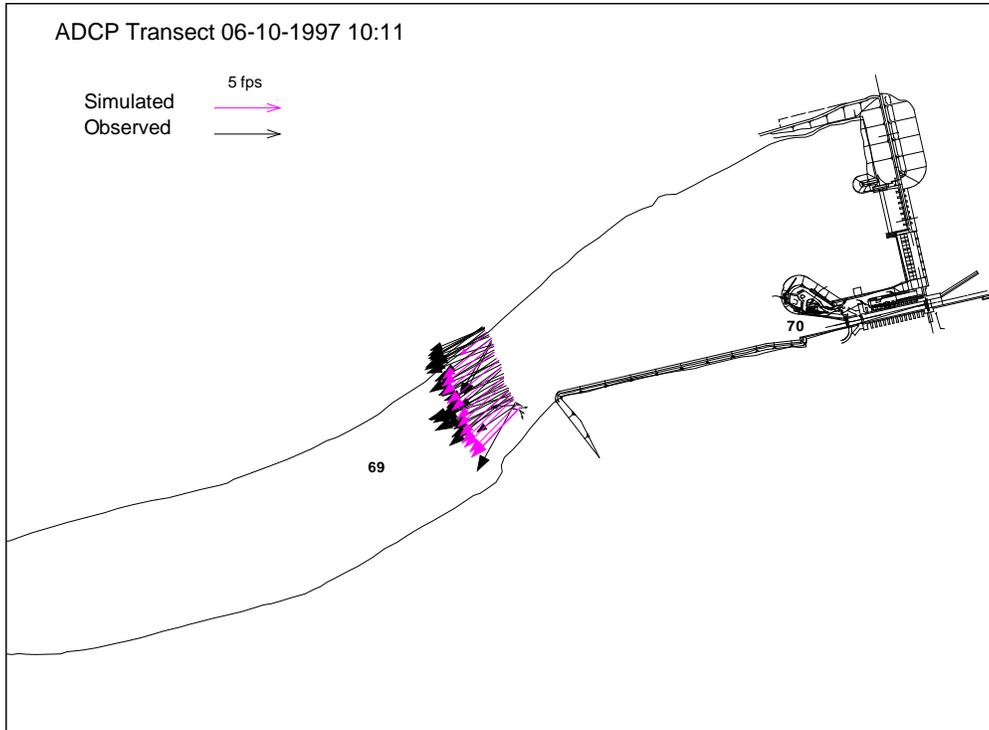


Figure 8. Simulated and observed depth-averaged velocities near Snake River Mile 69 on 6-10-1997.

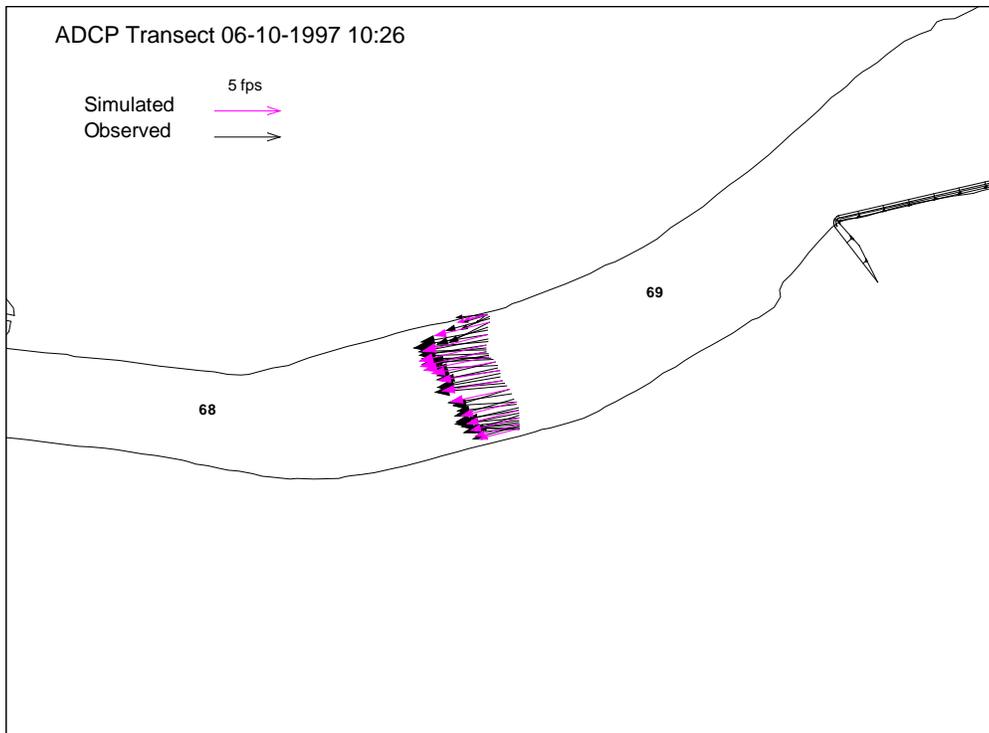


Figure 9. Simulated and observed depth-averaged velocities near Snake River Mile 68.5 on 6-10-1997.

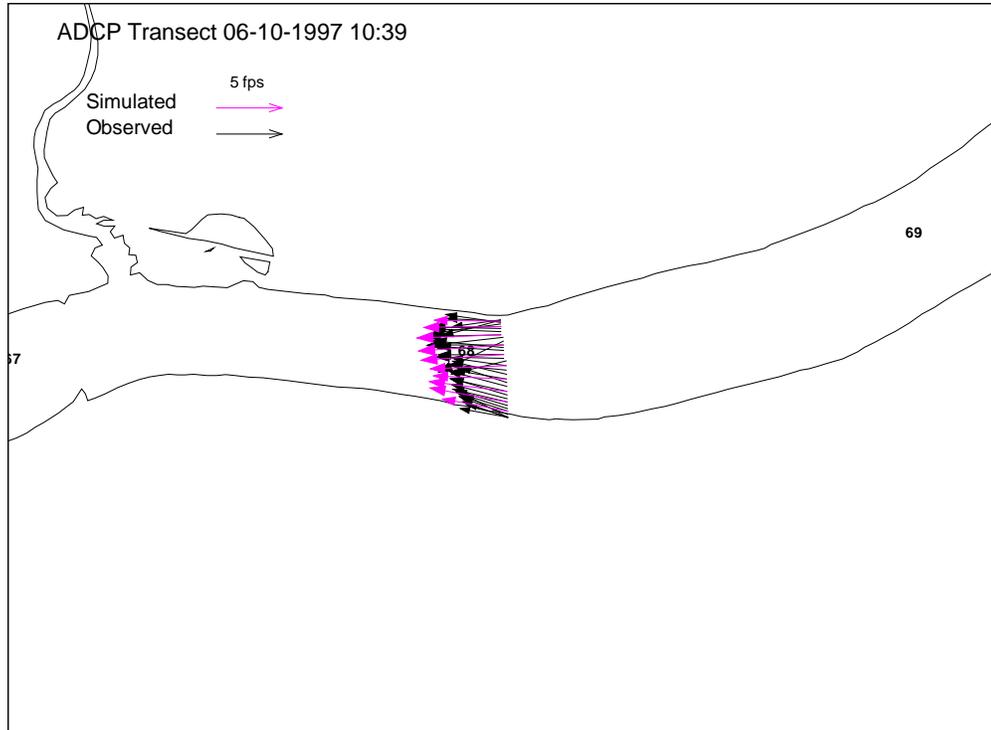


Figure 10. Simulated and observed depth-averaged velocities near Snake River Mile 68 on 6-10-1997.

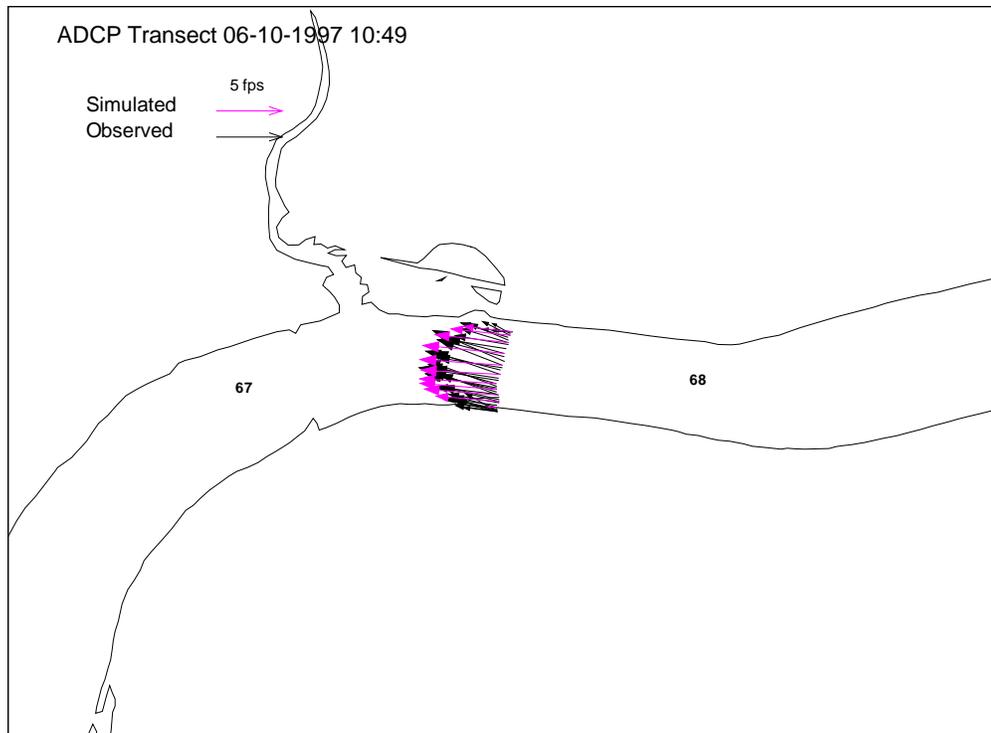


Figure 11. Simulated and observed depth-averaged velocities near Snake River Mile 67.5 on 6-10-1997.

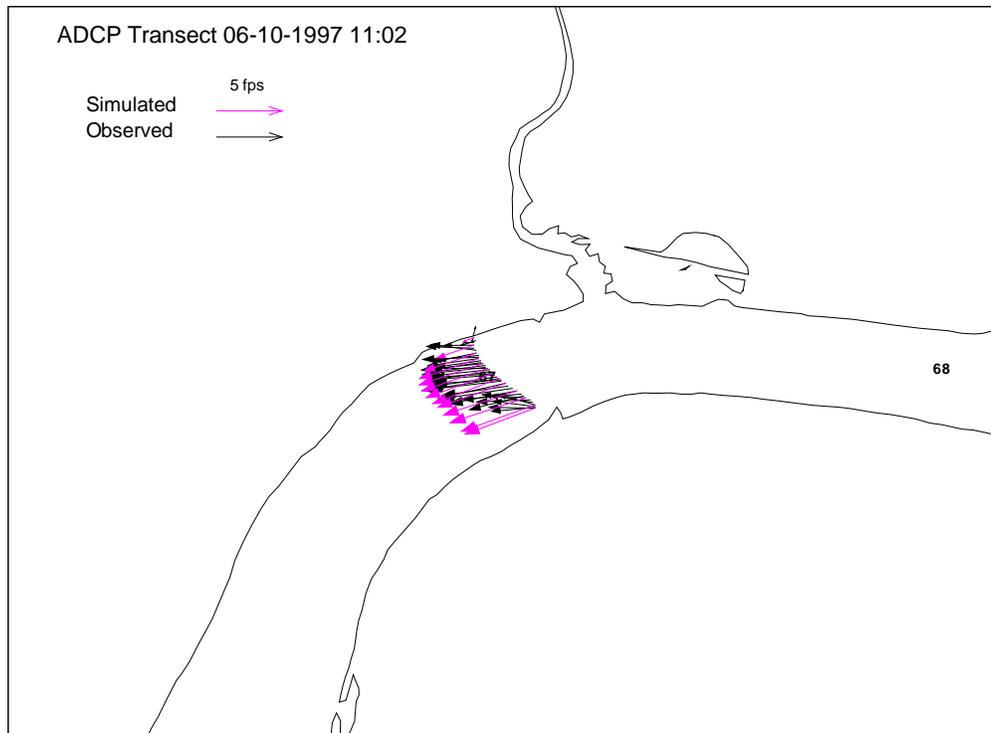


Figure 12. Simulated and observed depth-averaged velocities near Snake River Mile 67 on 6-10-1997.

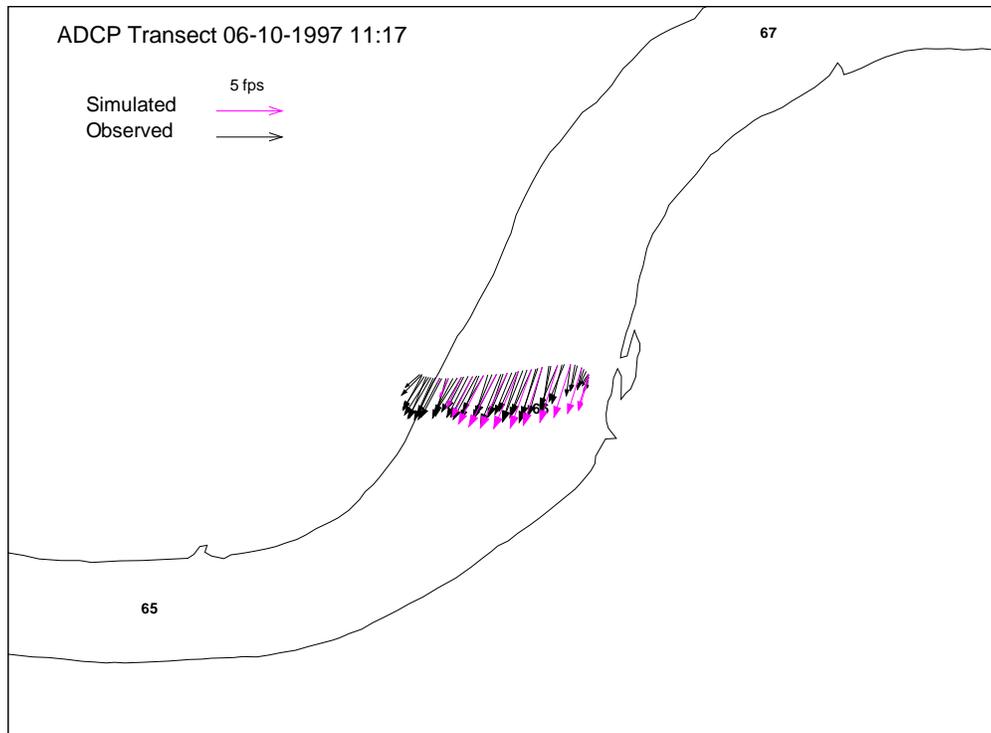


Figure 13. Simulated and observed depth-averaged velocities near Snake River Mile 66 on 6-10-1997.

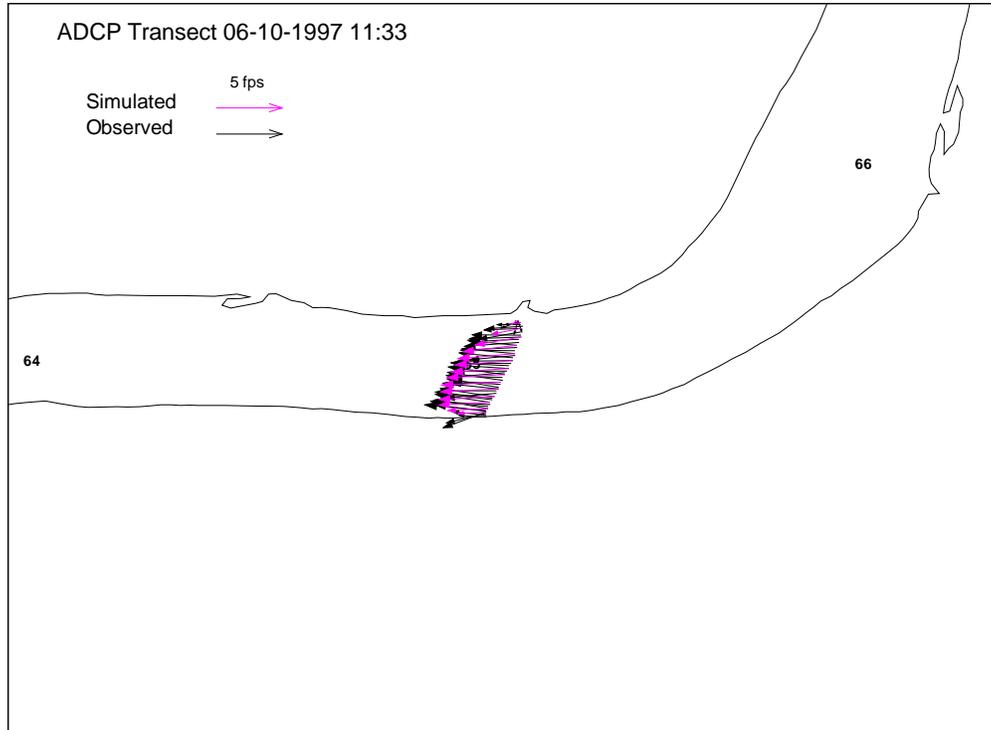


Figure 14. Simulated and observed depth-averaged velocities near Snake River Mile 65 on 6-10-1997.

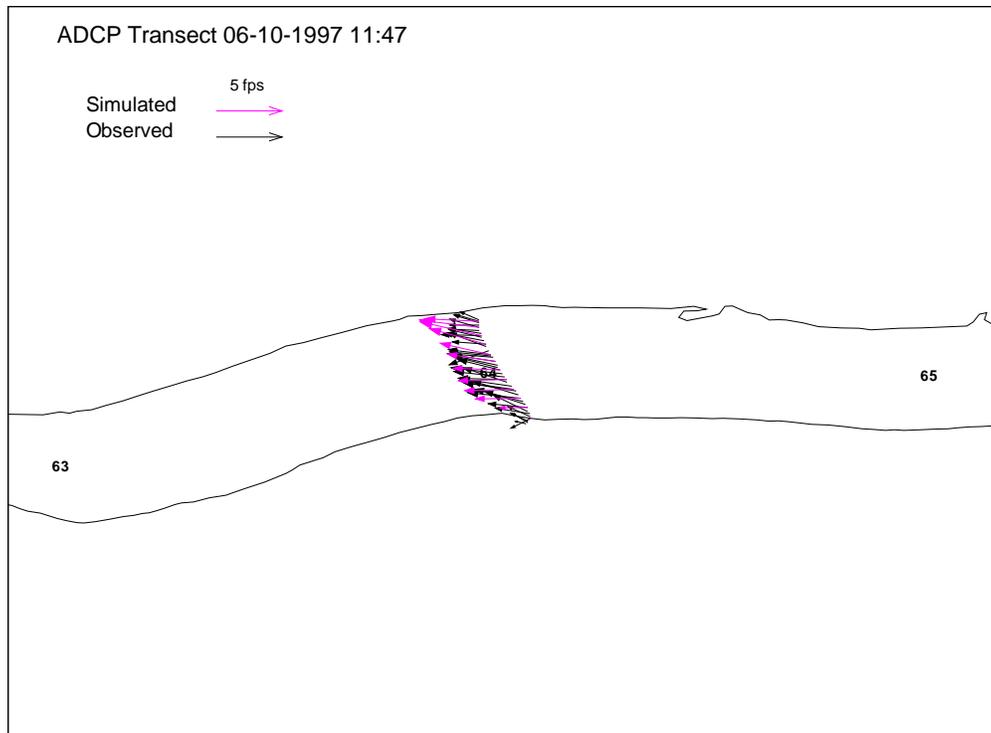


Figure 15. Simulated and observed depth-averaged velocities near Snake River Mile 64 on 6-10-1997.

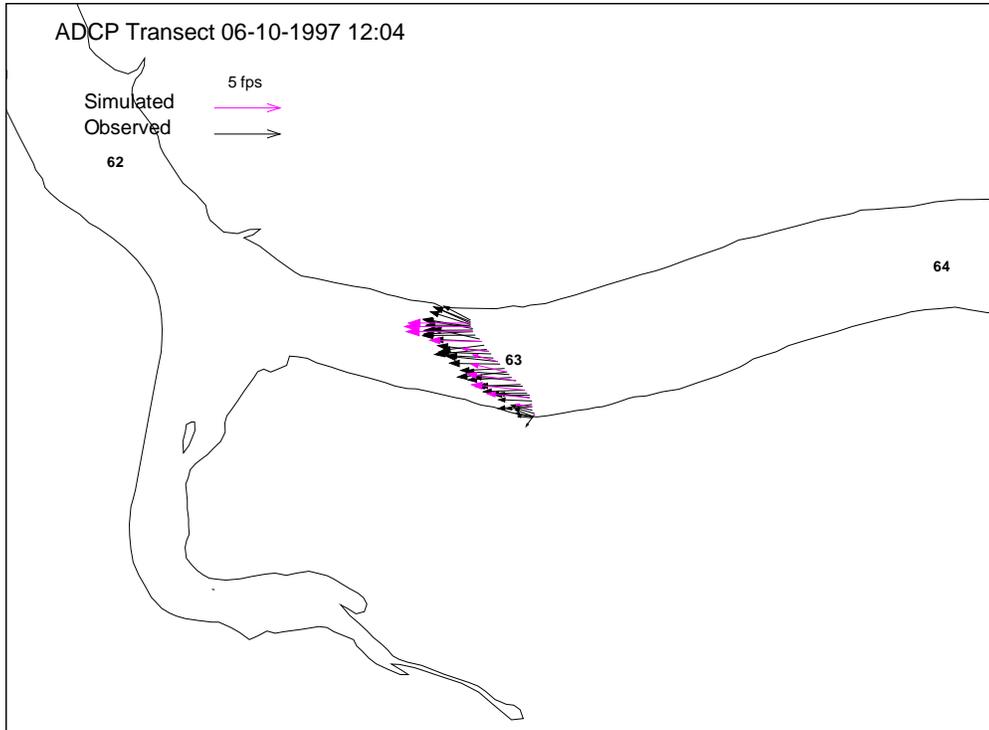


Figure 16. Simulated and observed depth-averaged velocities near Snake River Mile 63 on 6-10-1997.

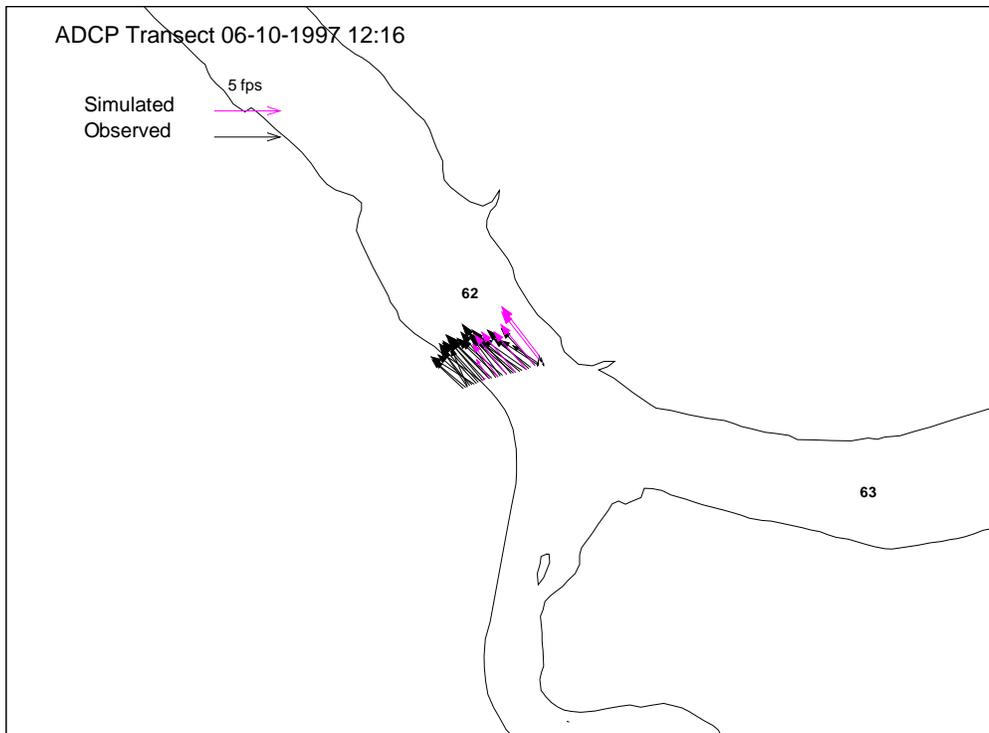


Figure 17. Simulated and observed depth-averaged velocities near Snake River Mile 62 on 6-10-1997.

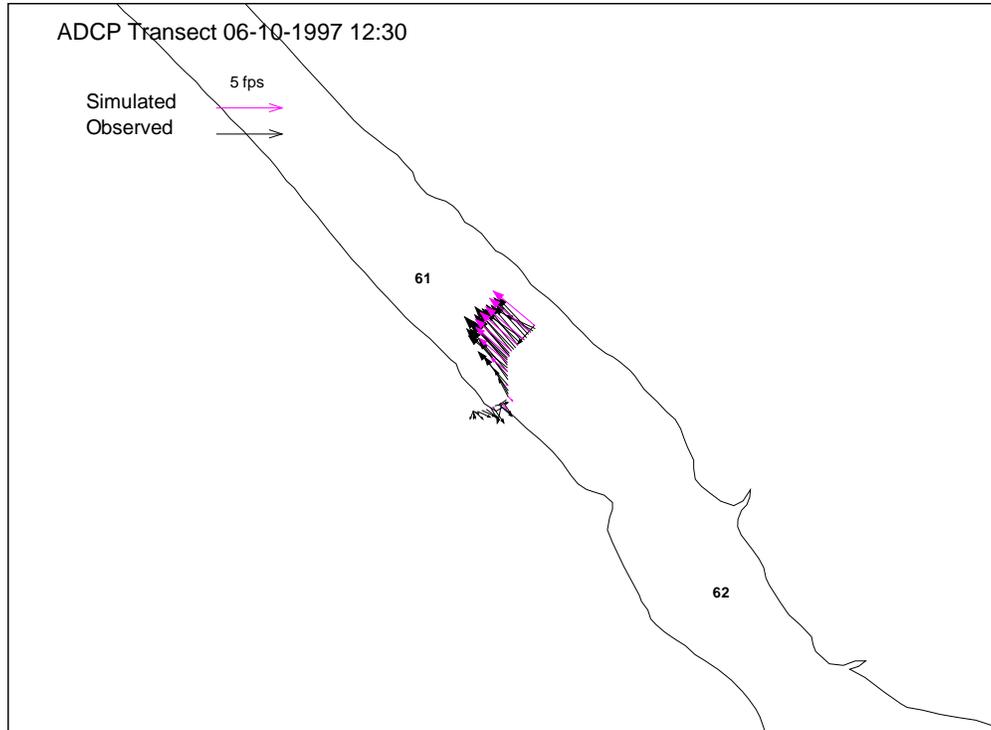


Figure 18. Simulated and observed depth-averaged velocities near Snake River Mile 61 on 6-10-1997.

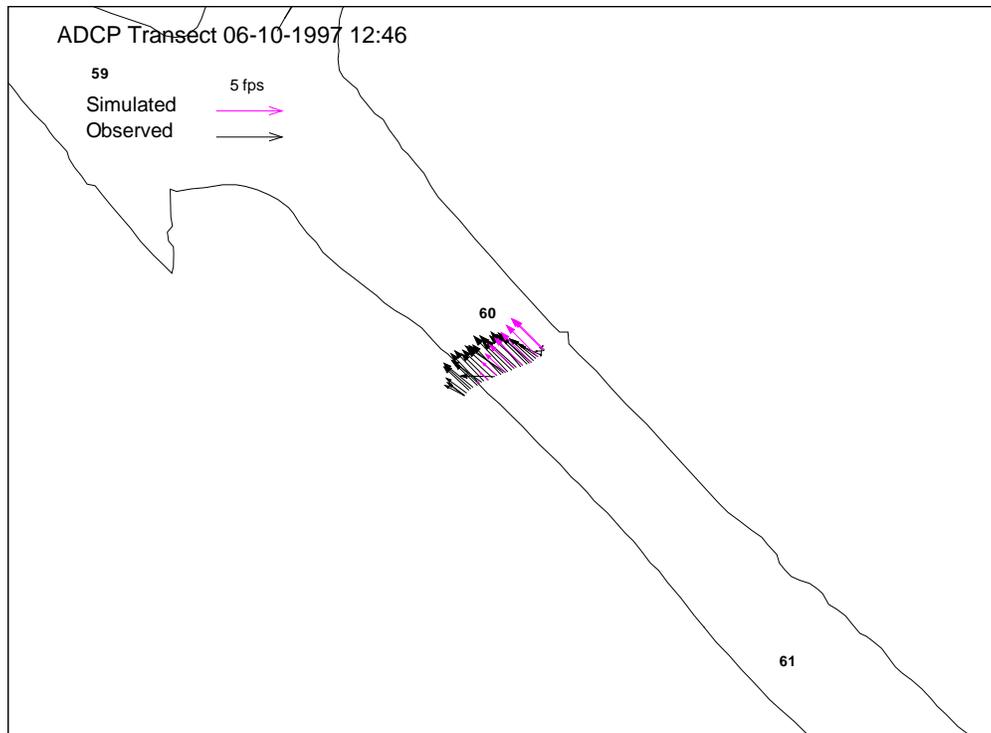


Figure 19. Simulated and observed depth-averaged velocities near Snake River Mile 60 on 6-10-1997.

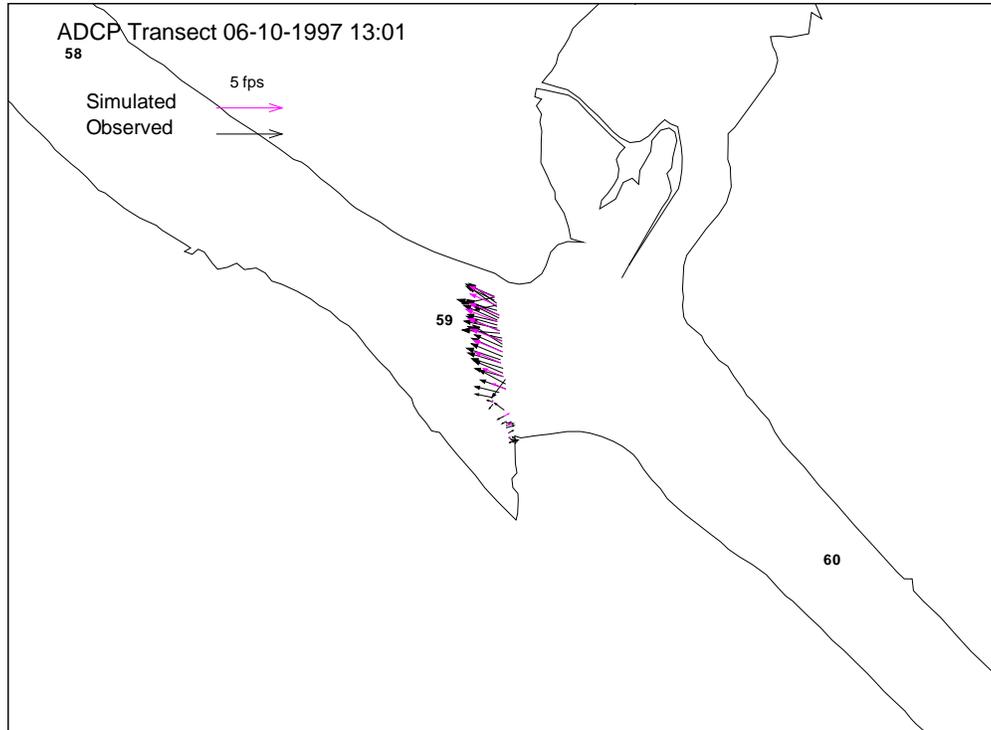


Figure 20. Simulated and observed depth-averaged velocities near Snake River Mile 59 on 6-10-1997.

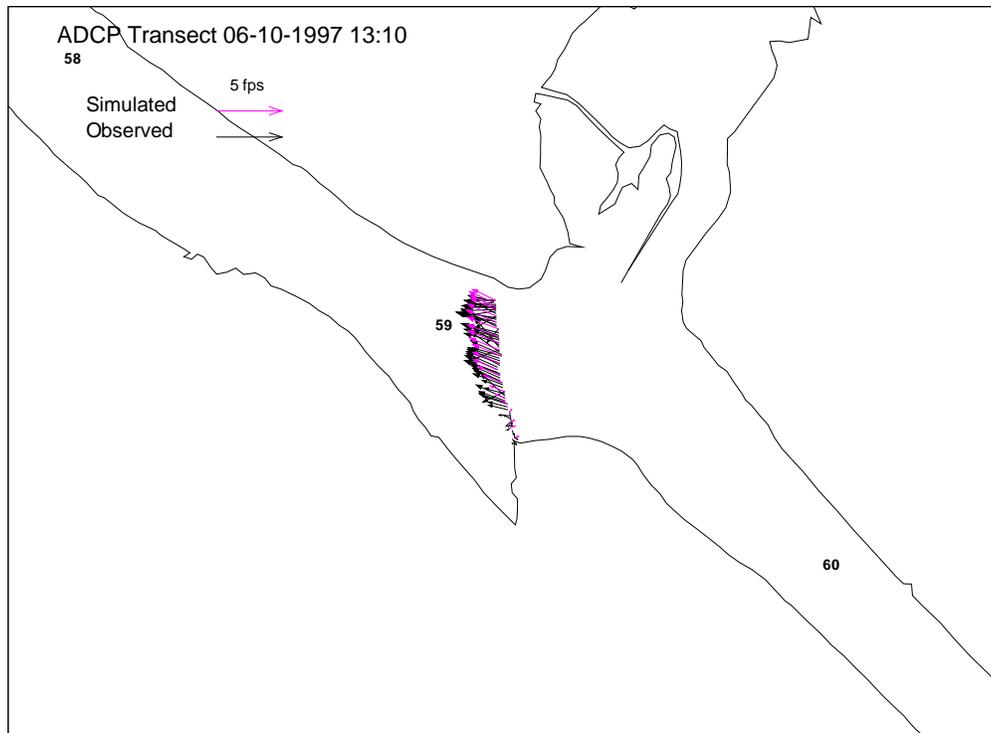


Figure 21. Simulated and observed depth-averaged velocities near Snake River Mile 59 on 6-10-1997.

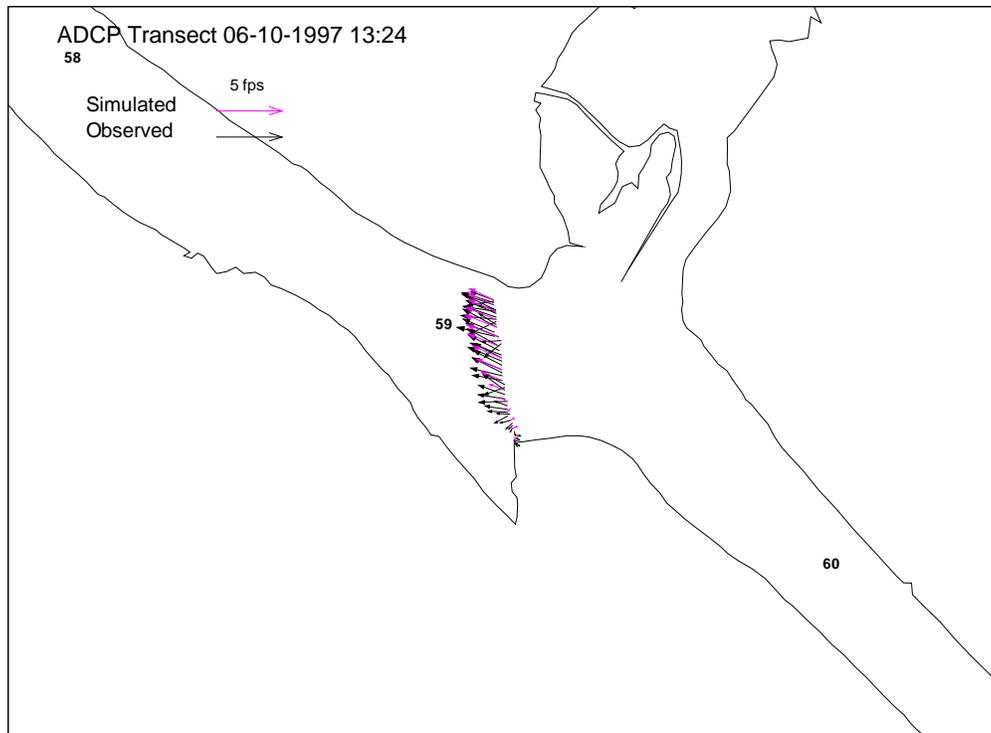


Figure 22. Simulated and observed depth-averaged velocities near Snake River Mile 59 on 6-10-1997.

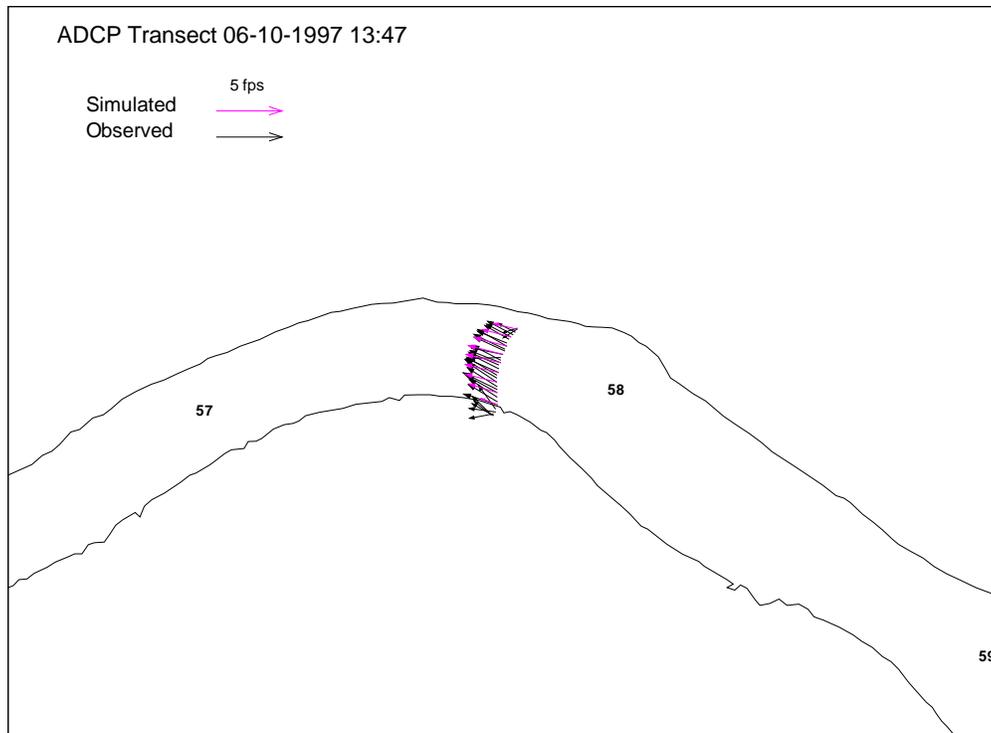


Figure 23. Simulated and observed depth-averaged velocities near Snake River Mile 58 on 6-10-1997.

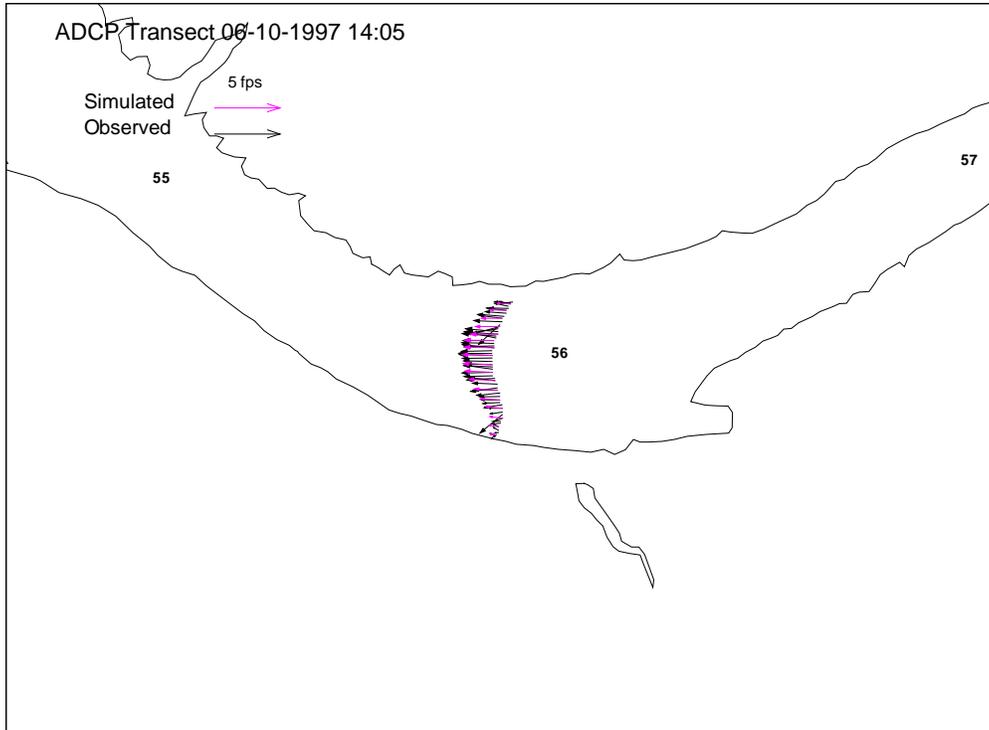


Figure 24. Simulated and observed depth-averaged velocities near Snake River Mile 56 on 6-10-1997.

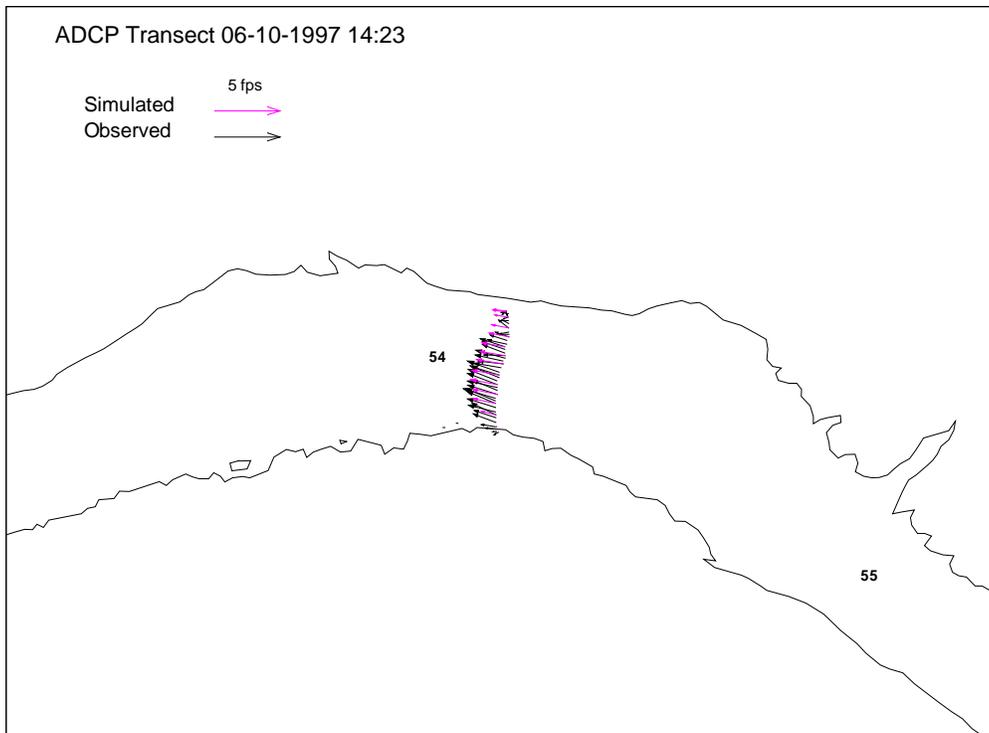


Figure 25. Simulated and observed depth-averaged velocities near Snake River Mile 54 on 6-10-1997.

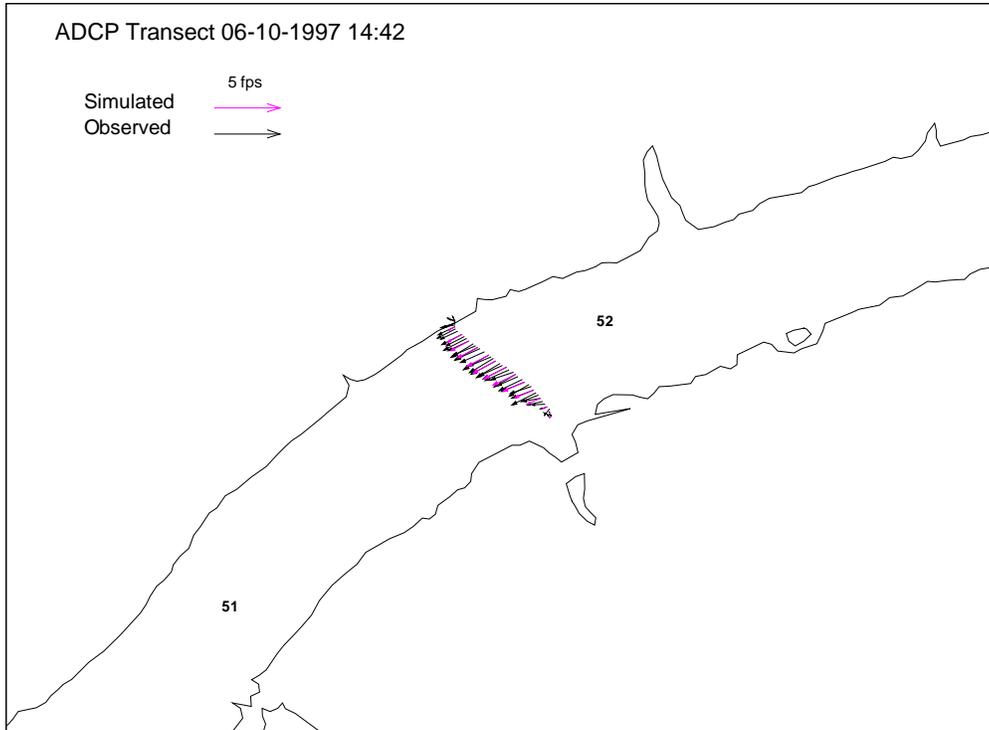


Figure 26. Simulated and observed depth-averaged velocities near Snake River Mile 52 on 6-10-1997.

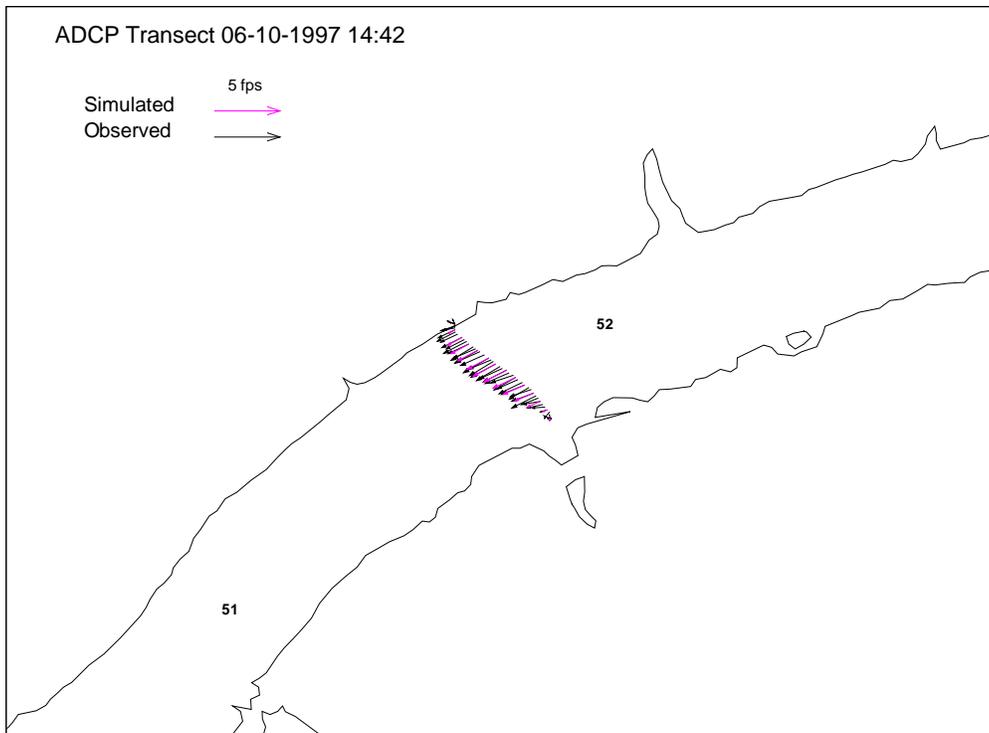


Figure 27. Simulated and observed depth-averaged velocities near Snake River Mile 52 on 6-10-1997.

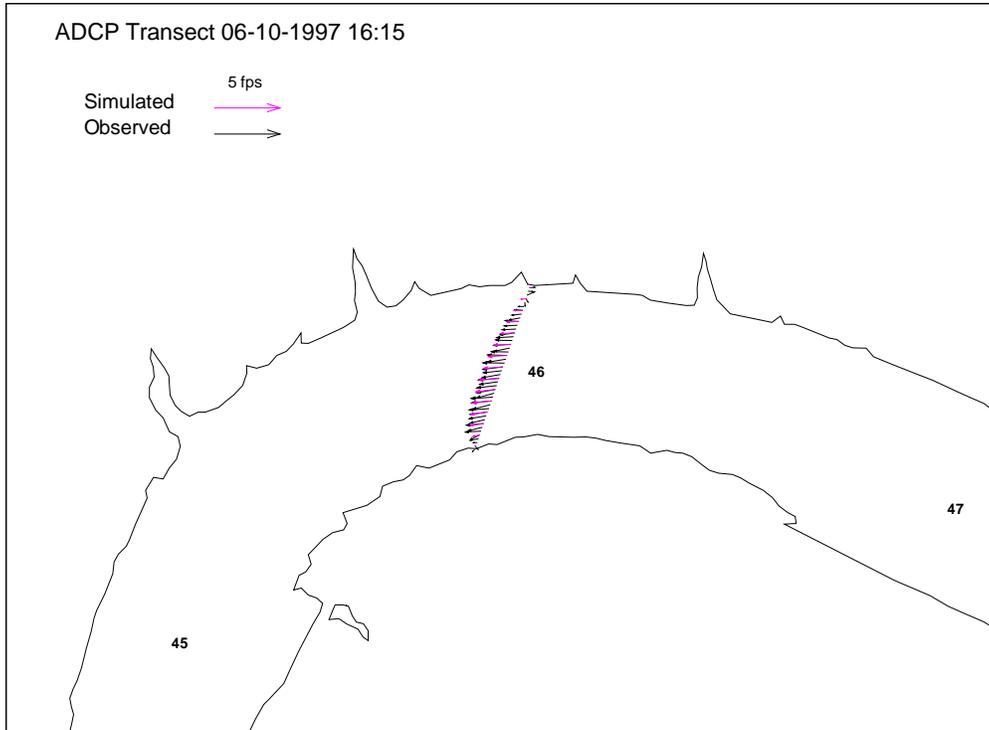


Figure 28. Simulated and observed depth-averaged velocities near Snake River Mile 46 on 6-10-1997.

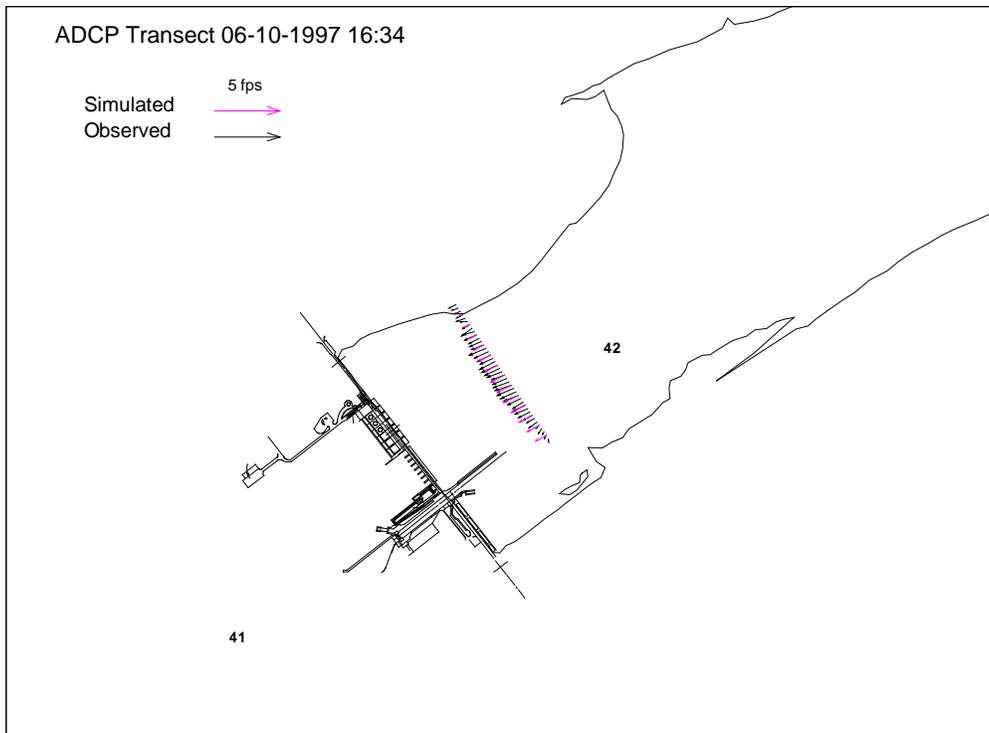


Figure 29. Simulated and observed depth-averaged velocities near Snake River Mile 42 on 6-10-1997.

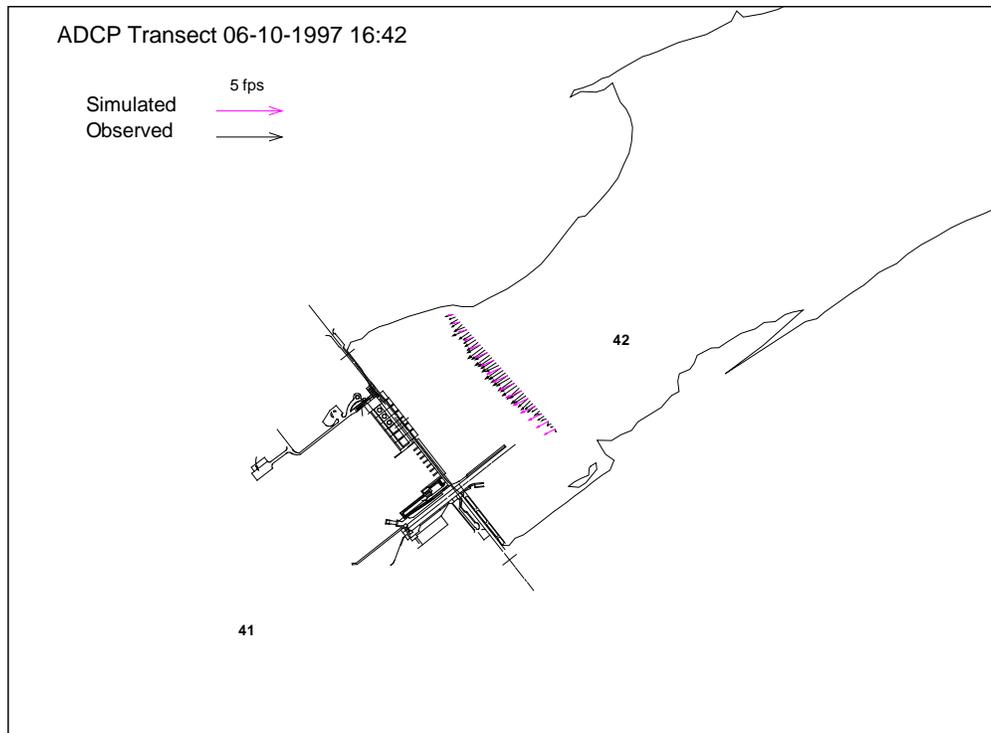


Figure 30. Simulated and observed depth-averaged velocities near Snake River Mile 42 on 6-10-1997.

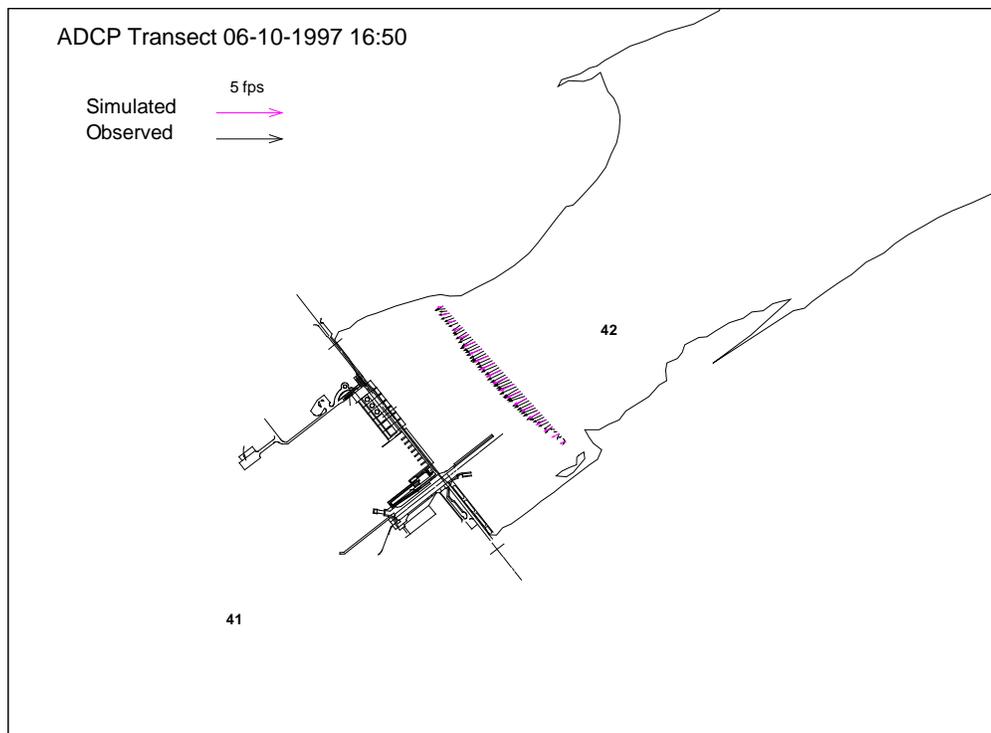


Figure 31. Simulated and observed depth-averaged velocities near Snake River Mile 42 on 6-10-1997.

1.3.3 Spring 1997 ADCP Data

As shown in Appendix A, ADCP velocity measurements for the Spring 1997 study period were in error. Comparisons between these measurements and simulated velocities were not made. Corrected ADCP have not been received as yet (December 1998).

1.3.4 Simulated spatial velocity distribution during the

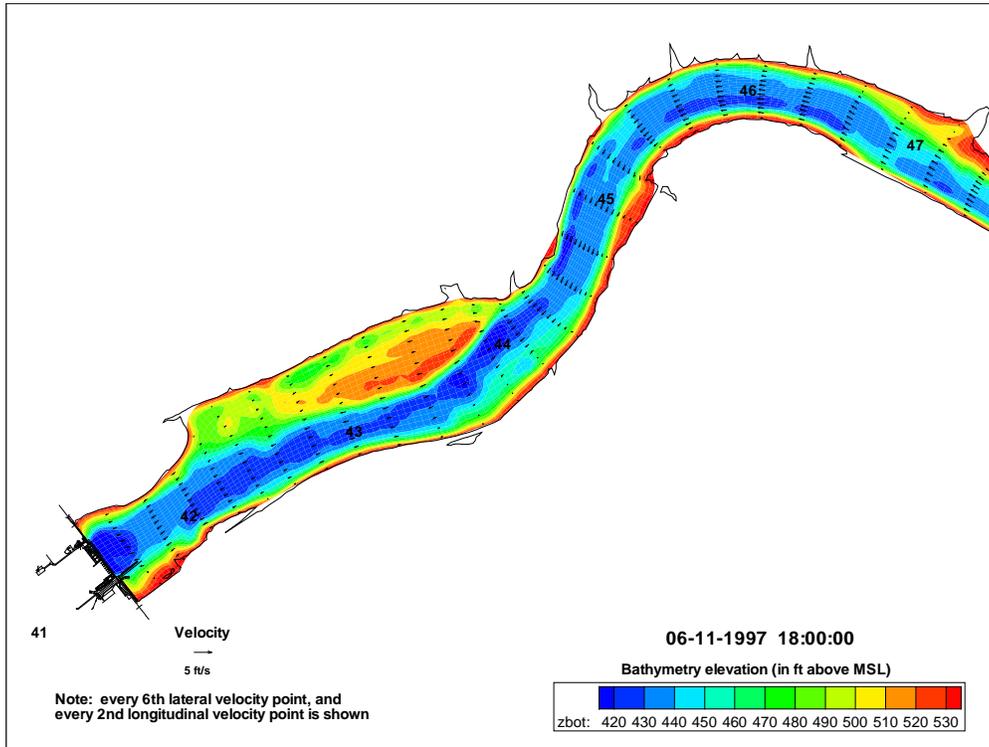


Figure 32. Spatial velocity distribution during the Summer 1997 study period.

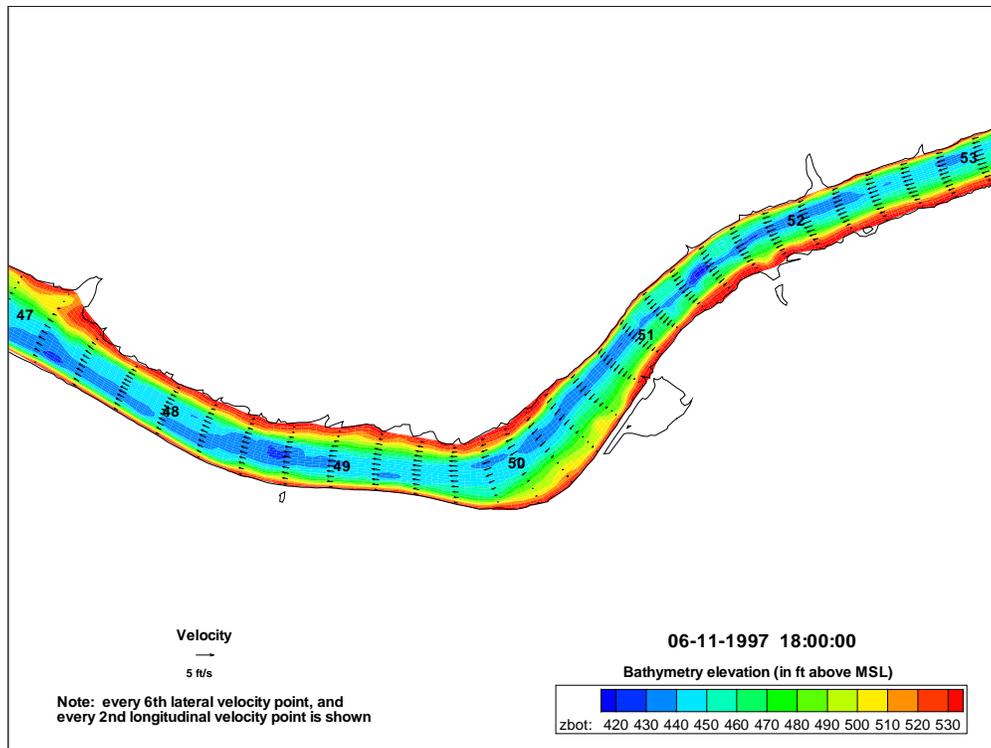


Figure 33. Spatial velocity distribution during the Summer 1997 study period.

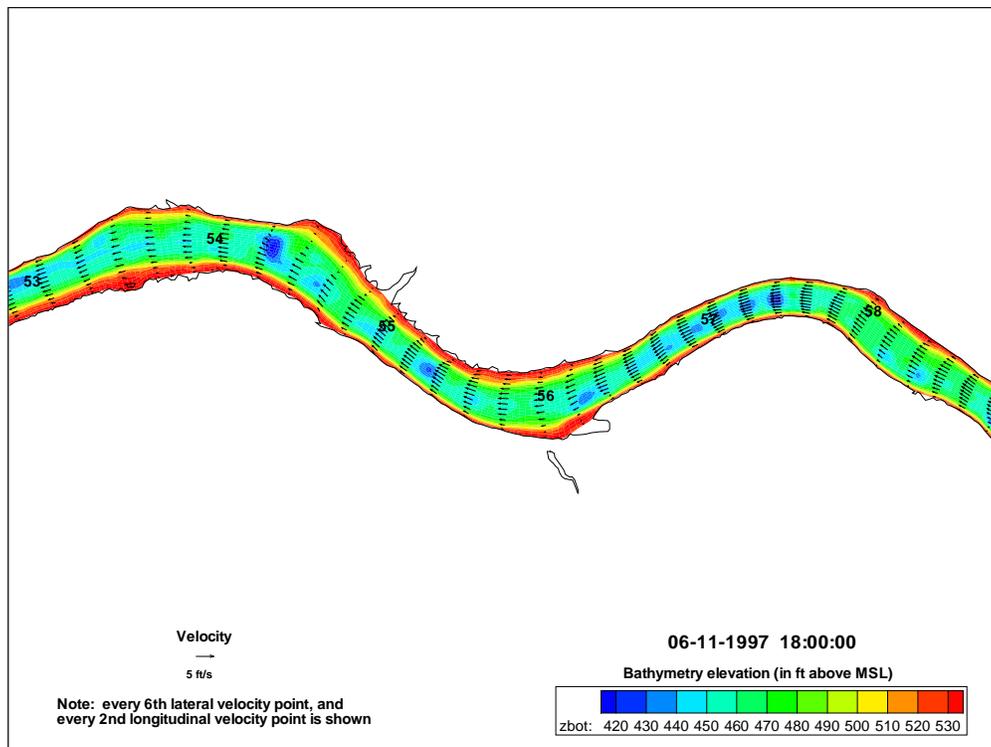


Figure 34. Spatial velocity distribution during the Summer 1997 study period.

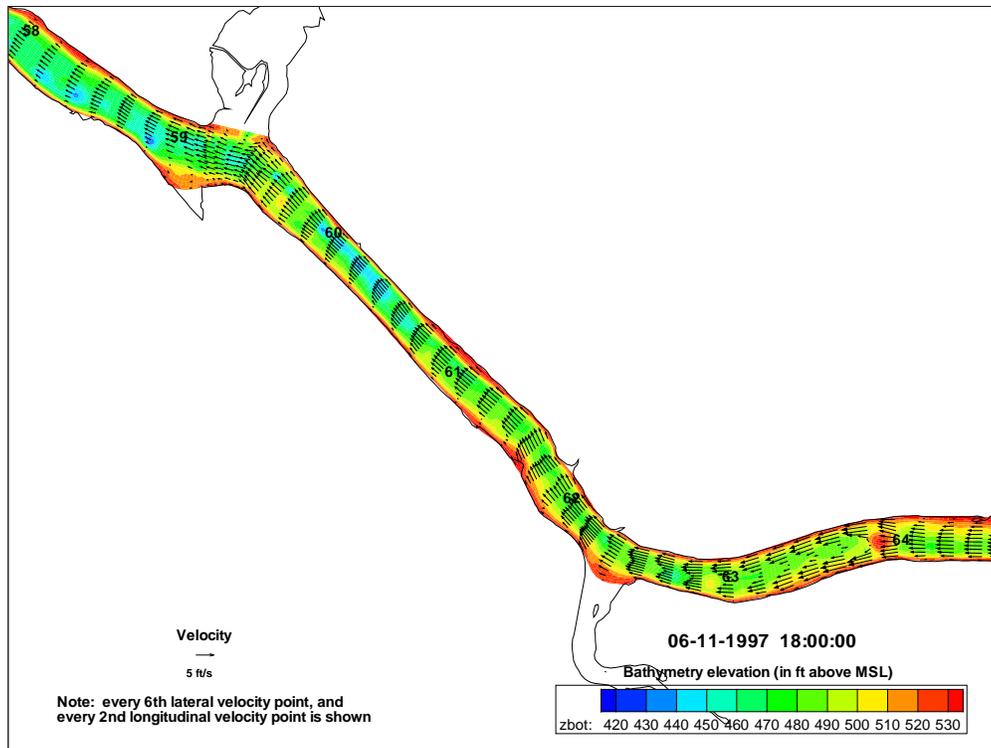


Figure 35. Spatial velocity distribution during the Summer 1997 study period.

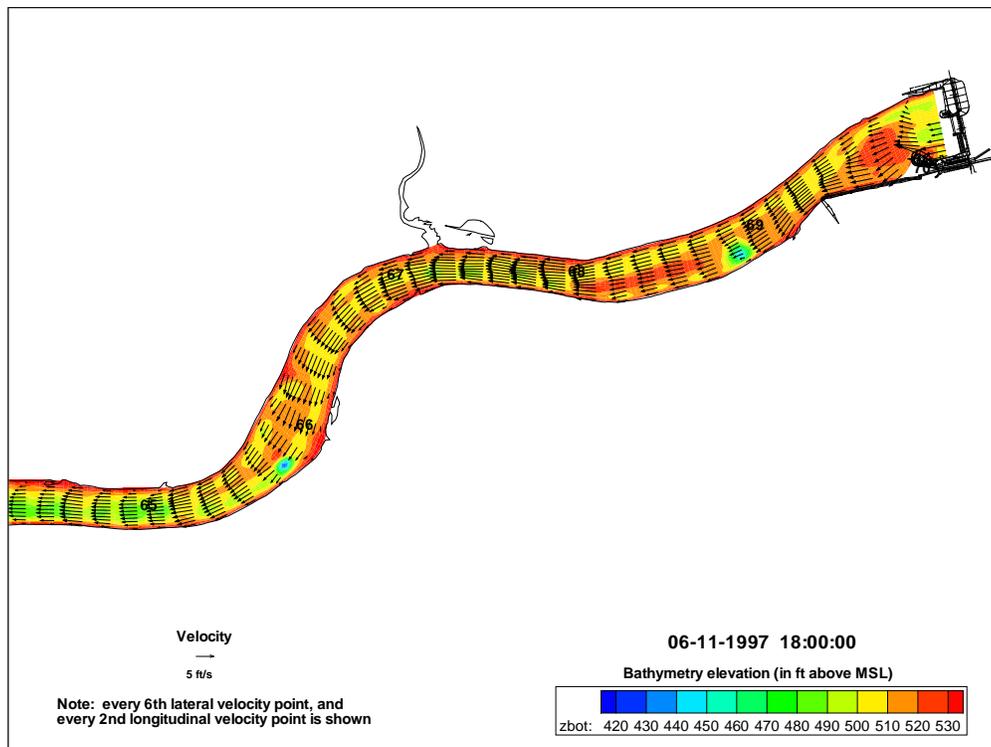


Figure 36. Spatial velocity distribution during the Summer 1997 study period.

1.4 Water Quality Calibration and Verification

1.4.1 1996 Spring Simulation

Boundary Conditions using Lower Granite Sourcing Function and Forebay FMS Data

Comparisons between the measurements and simulations using an upstream boundary condition developed from the empirical project gas sourcing function and the forebay FMS are shown in the figures below. Statistics on comparisons between measured and simulated temperatures and total dissolved gas are also presented. The case is denoted as FMS-BC in the figure and table captions.

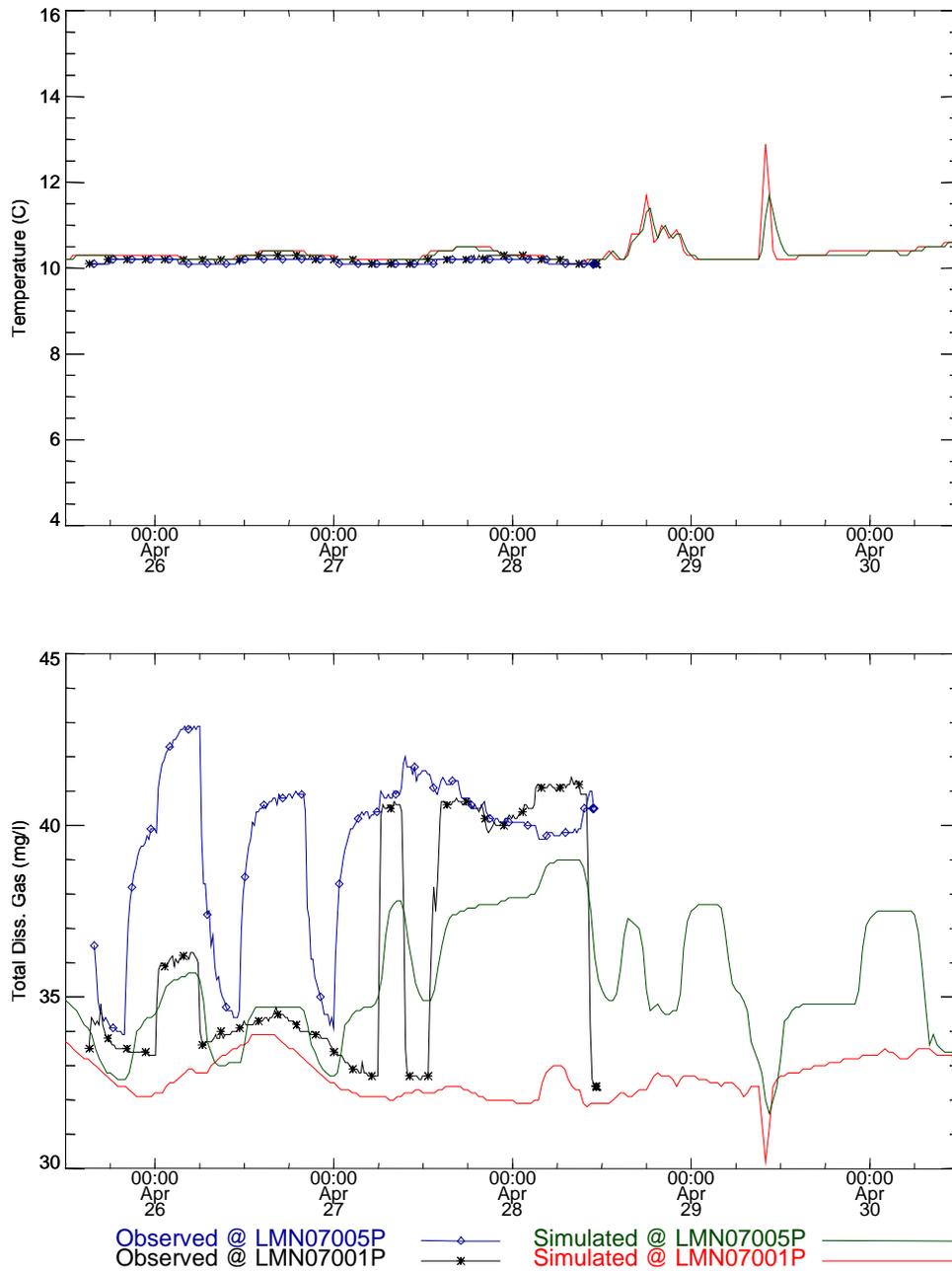


Figure 37. Temperature and total dissolved gas time series near Snake River Mile 70.0 for the Spring 1996 study (FMS-BC).

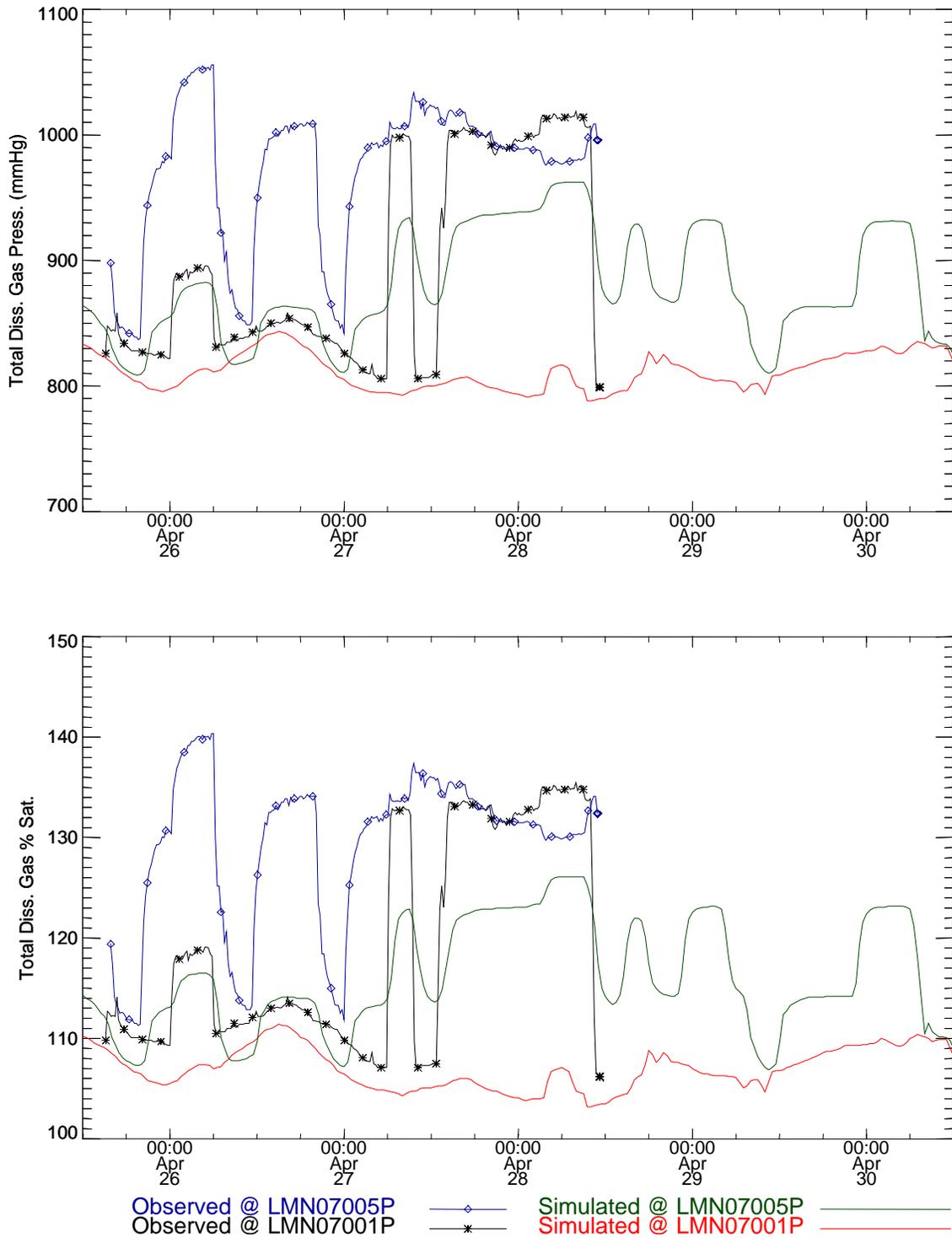


Figure 38. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 70.0 for the Spring 1996 study (FMS-BC).

Table 1. Statistical summary of measurements and simulations at River Mile 70.0 during the Spring 1996 study (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
LMN07001P	10.2	10.29	0.06	0.1	0.12
LMN07005P	10.15	10.25	0.05	0.1	0.13
Concentration					
LMN07001P	36.32	32.58	3.25	0.57	5.12
LMN07005P	39.43	35.54	2.4	1.97	4.36
Gas Pressure					
LMN07001P	896.76	808.14	79.57	14.38	122.92
LMN07005P	971.69	880.71	58.7	48.26	103
% Saturation					
LMN07001P	119.21	106.51	10.58	2.07	17.22
LMN07005P	129.17	116.06	7.8	5.97	14.53

Table 2. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at River Mile 70.0 for the Spring 1996 study (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
LMN07001P	100	36.67	54.07	54.07
LMN07005P	100	7.04	18.52	14.07

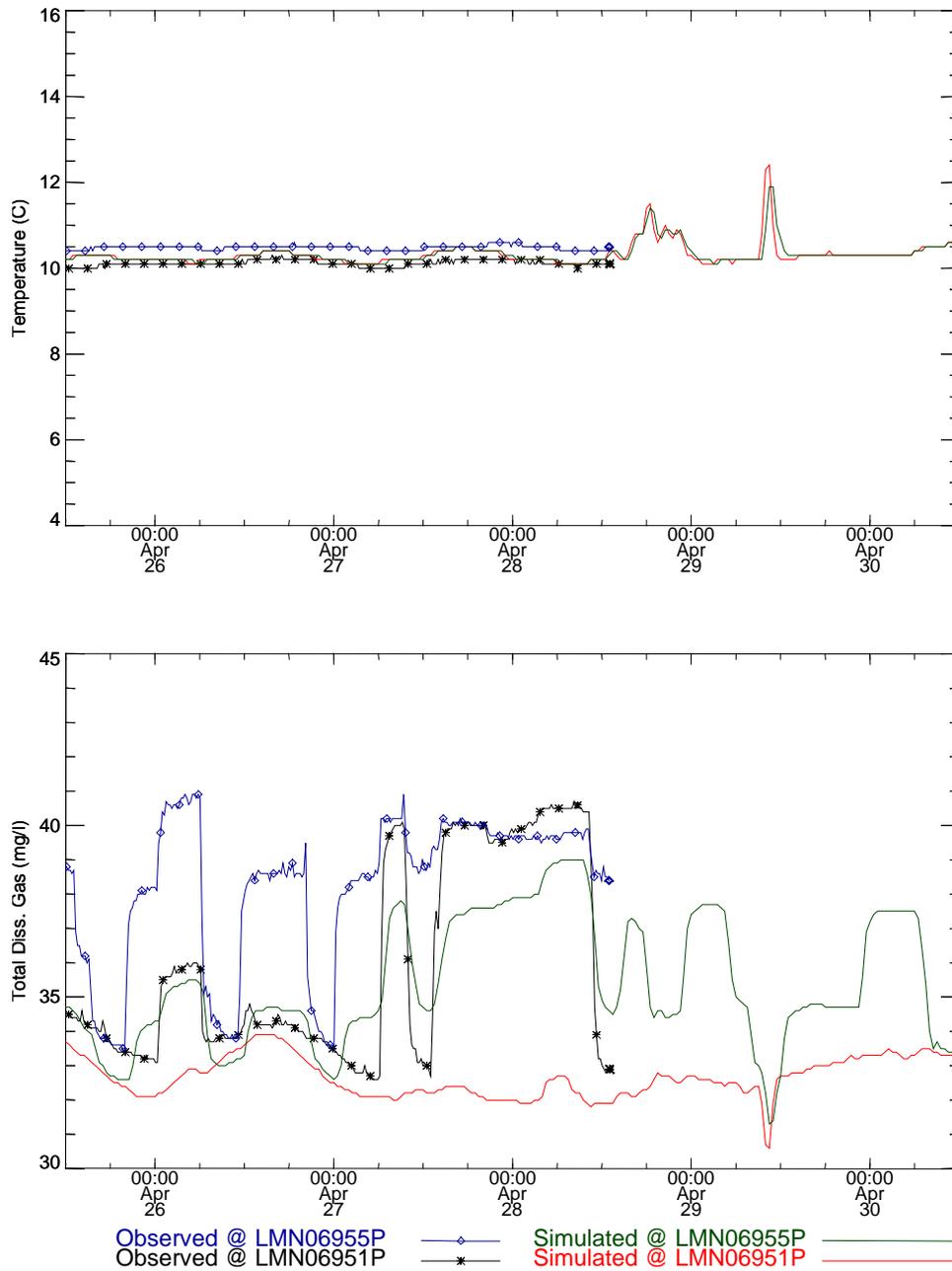


Figure 39. Temperature and total dissolved gas time series near Snake River Mile 069.5 for the Spring 1996 study (FMS-BC).

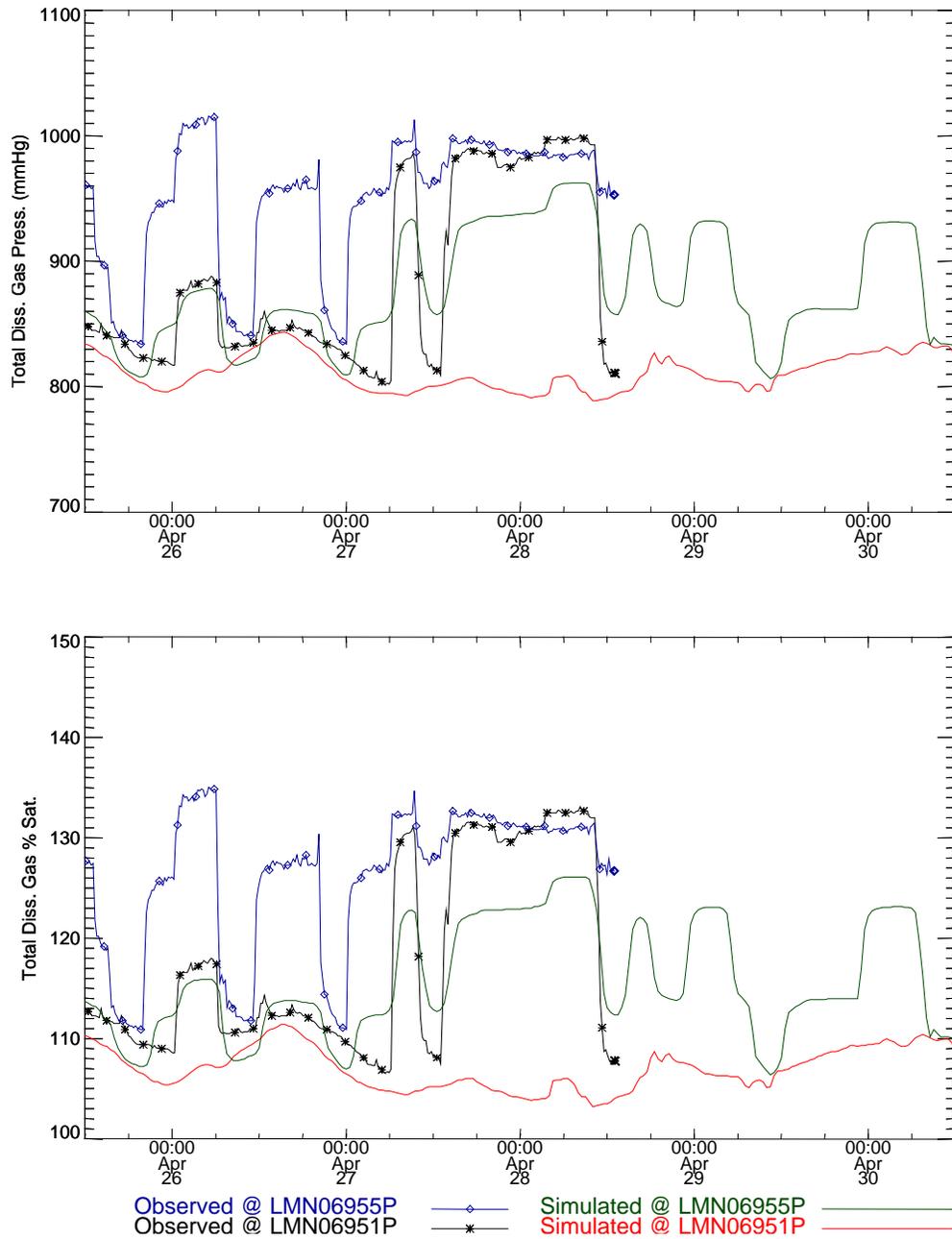


Figure 40. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 069.5 for the Spring 1996 study (FMS-BC).

Table 3. Statistical summary of measurements and simulations at River Mile 069.5 during the Spring 1996 study (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
LMN06951P	10.12	10.25	0.07	0.1	0.16
LMN06955P	10.48	10.25	0.05	0.1	0.25
Concentration					
LMN06951P	35.96	32.58	2.93	0.59	4.65
LMN06955P	38.21	35.39	2.19	1.95	3.2
Gas Pressure					
LMN06951P	886.3	808.27	71.81	14.8	110.57
LMN06955P	948.69	876.9	53.8	47.83	80.81
% Saturation					
LMN06951P	117.81	106.53	9.55	2.17	15.57
LMN06955P	126.11	115.56	7.15	5.92	11.59

Table 4. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at River Mile 070.0 for the Spring 1996 study (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
LMN06951P	100	41.18	56.06	55.02
LMN06955P	100	19.38	26.3	21.11

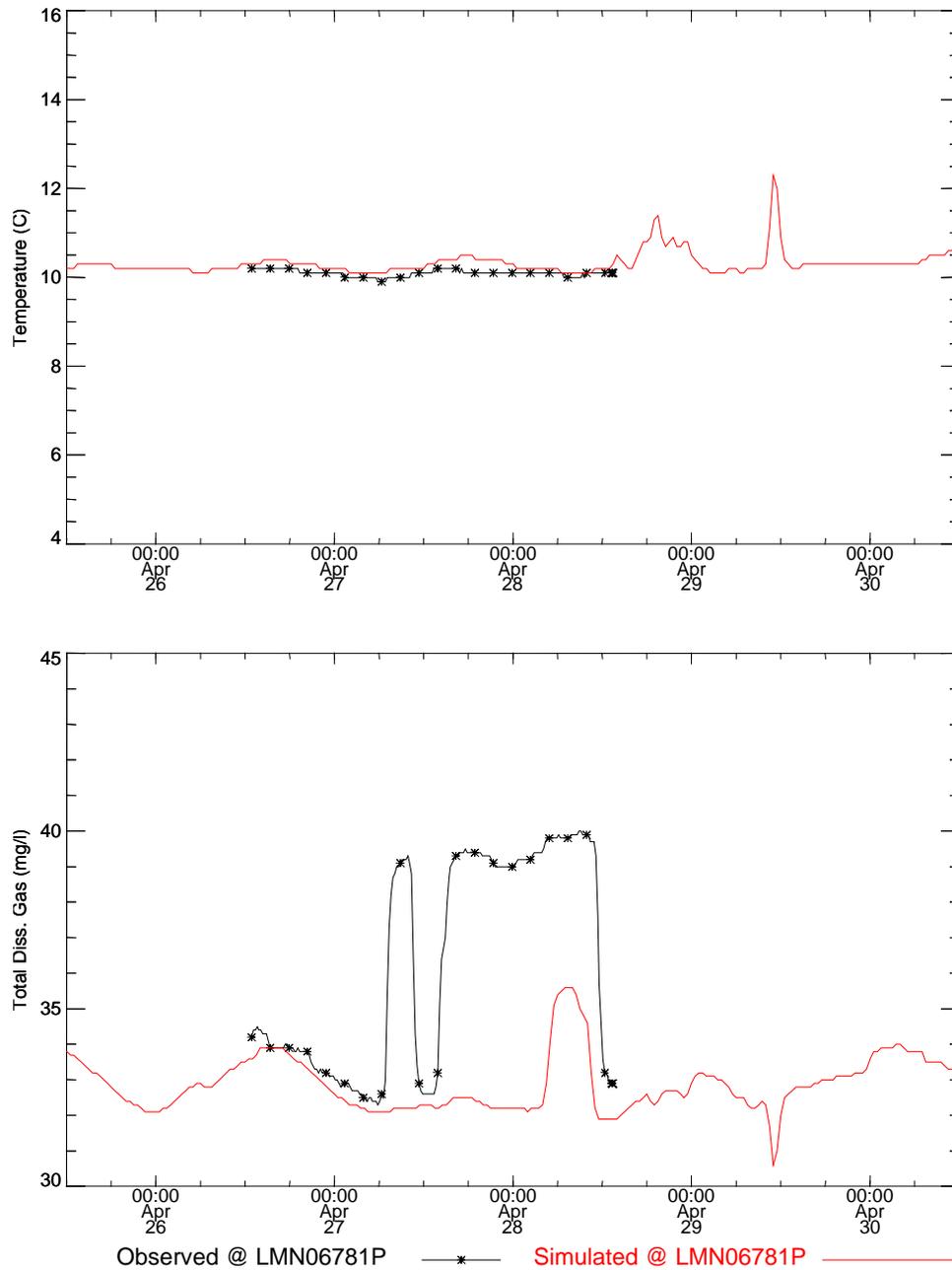


Figure 41. Temperature and total dissolved gas time series near Snake River Mile 067.8 for the Spring 1996 study (FMS-BC).

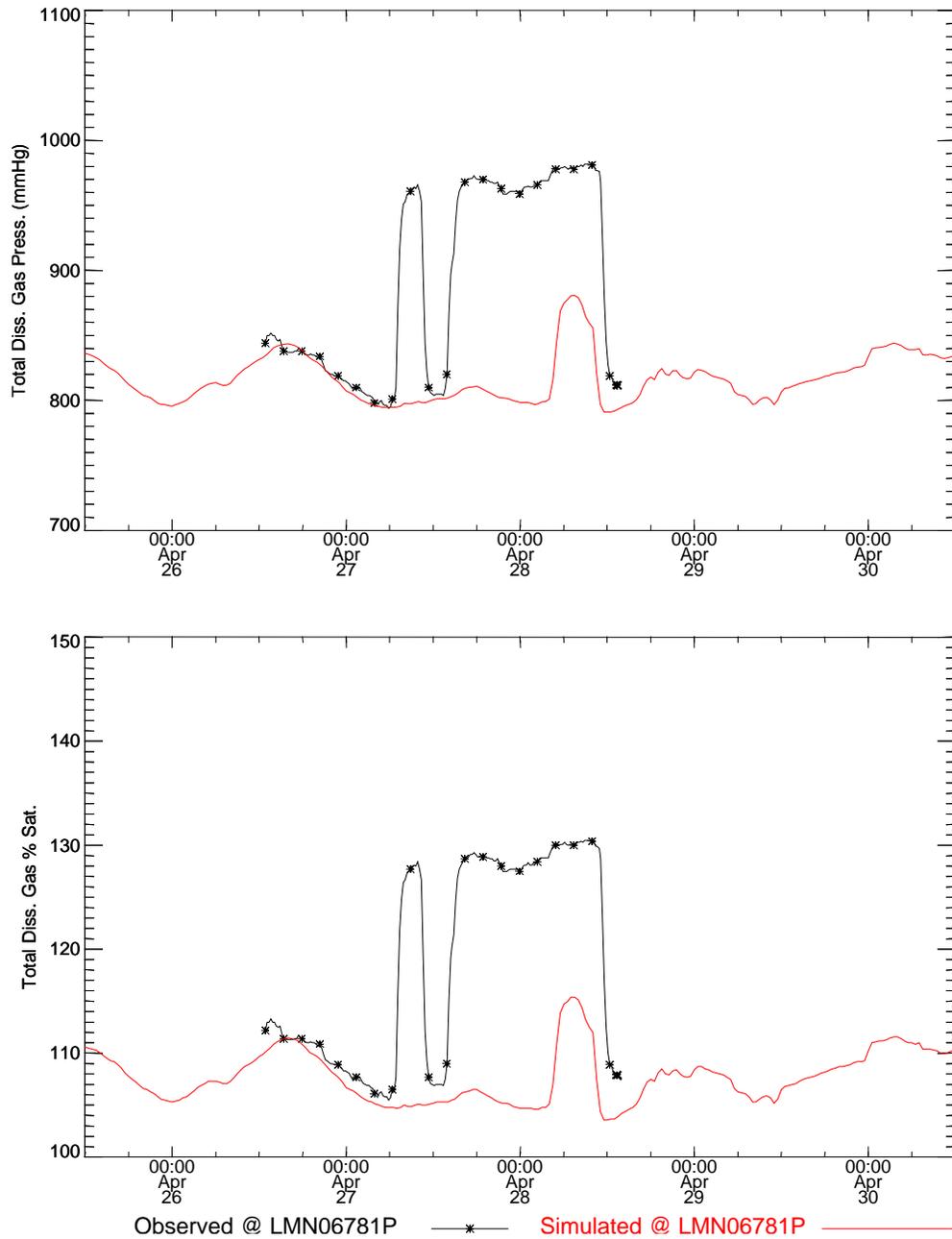


Figure 42. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 067.8 for the Spring 1996 study (FMS-BC).

Table 5. Statistical summary of measurements and simulations at River Mile 067.8 during the Spring 1996 study (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature LMN06781P	10.09	10.25	0.07	0.11	0.18
Concentration LMN06781P	36.33	32.87	3.01	1	4.56
Gas Pressure LMN06781P	894.6	815.59	73.4	24.12	107.11
% Saturation LMN06781P	118.91	107.3	9.75	3.18	15.25

Table 6. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at River Mile 067.8 for the Spring 1996 study (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
LMN06781P	100	43.08	46.67	45.64

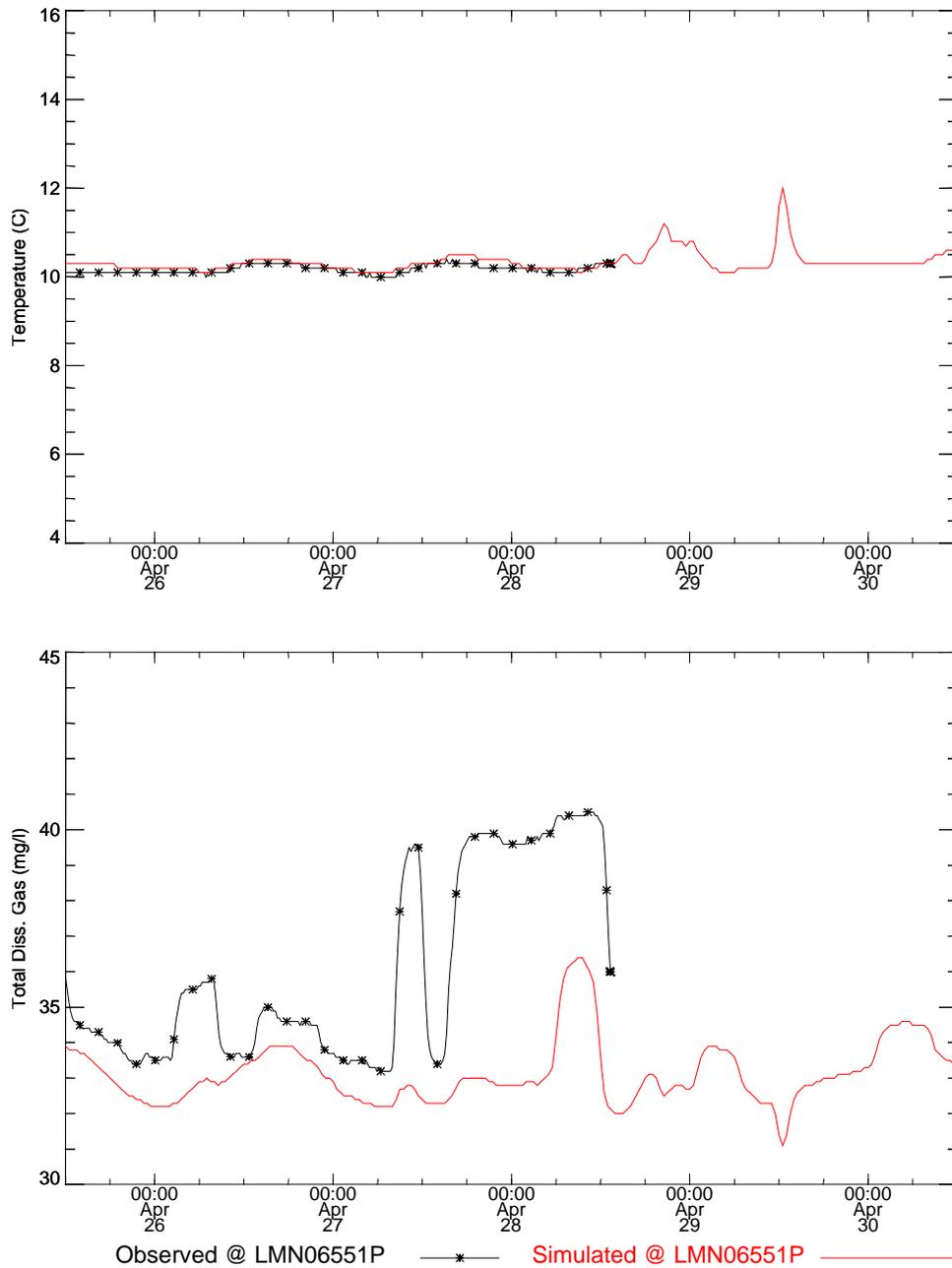


Figure 43. Temperature and total dissolved gas time series near Snake River Mile 065.5 for the Spring 1996 study (FMS-BC).

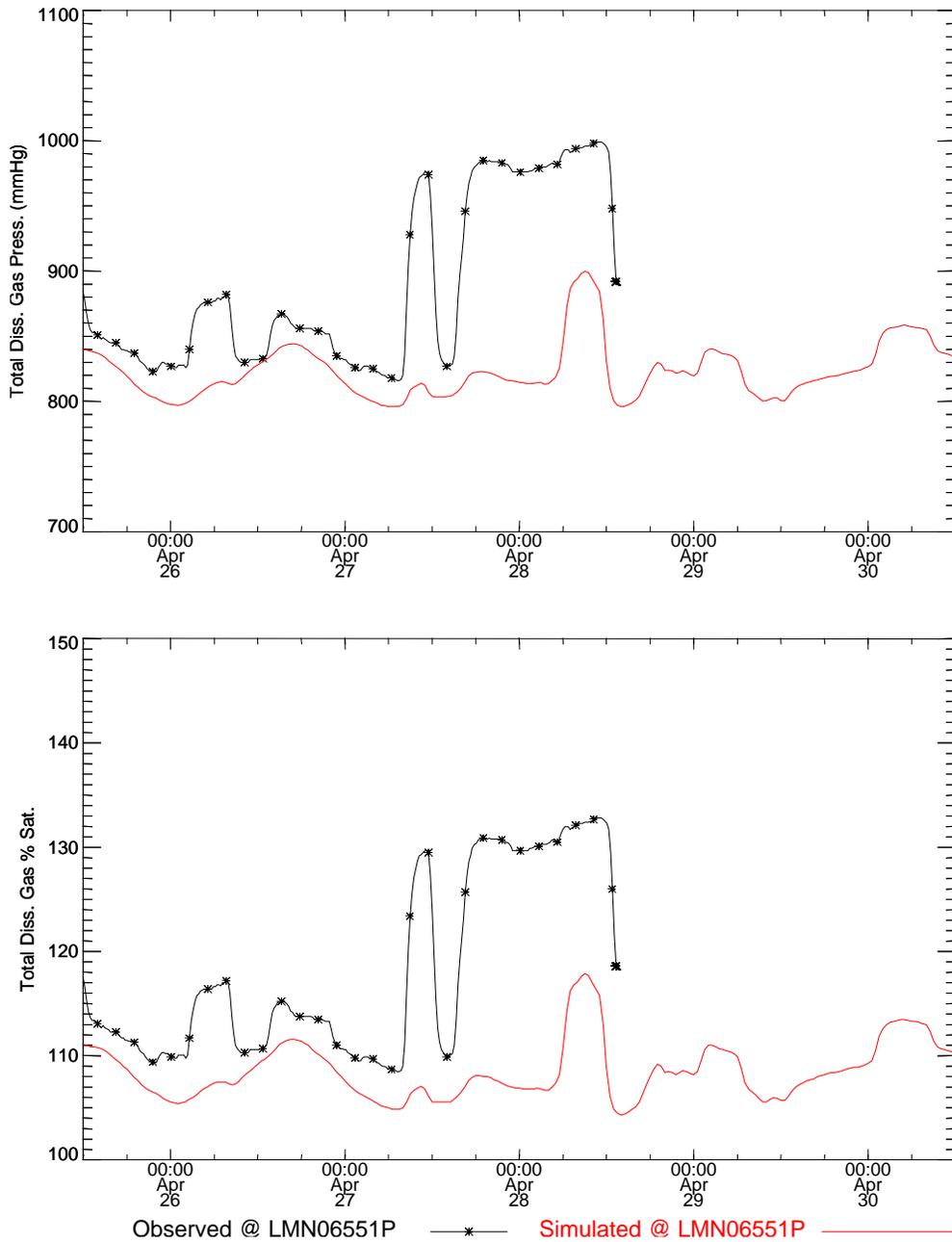


Figure 44. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 065.5 for the Spring 1996 study (FMS-BC).

Table 7. Statistical summary of measurements and simulations at River Mile 065.5 during the Spring 1996 study (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature LMN06551P	10.17	10.26	0.09	0.1	0.12
Concentration LMN06551P	36.03	33.13	2.7	0.95	3.79
Gas Pressure LMN06551P	889.09	821.84	66.37	23.11	89.87
% Saturation LMN06551P	118.18	108.31	8.82	2.93	12.88

Table 8. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at River Mile 070.0 for the Spring 1996 study (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
LMN06551P	100	29.66	54.83	53.79

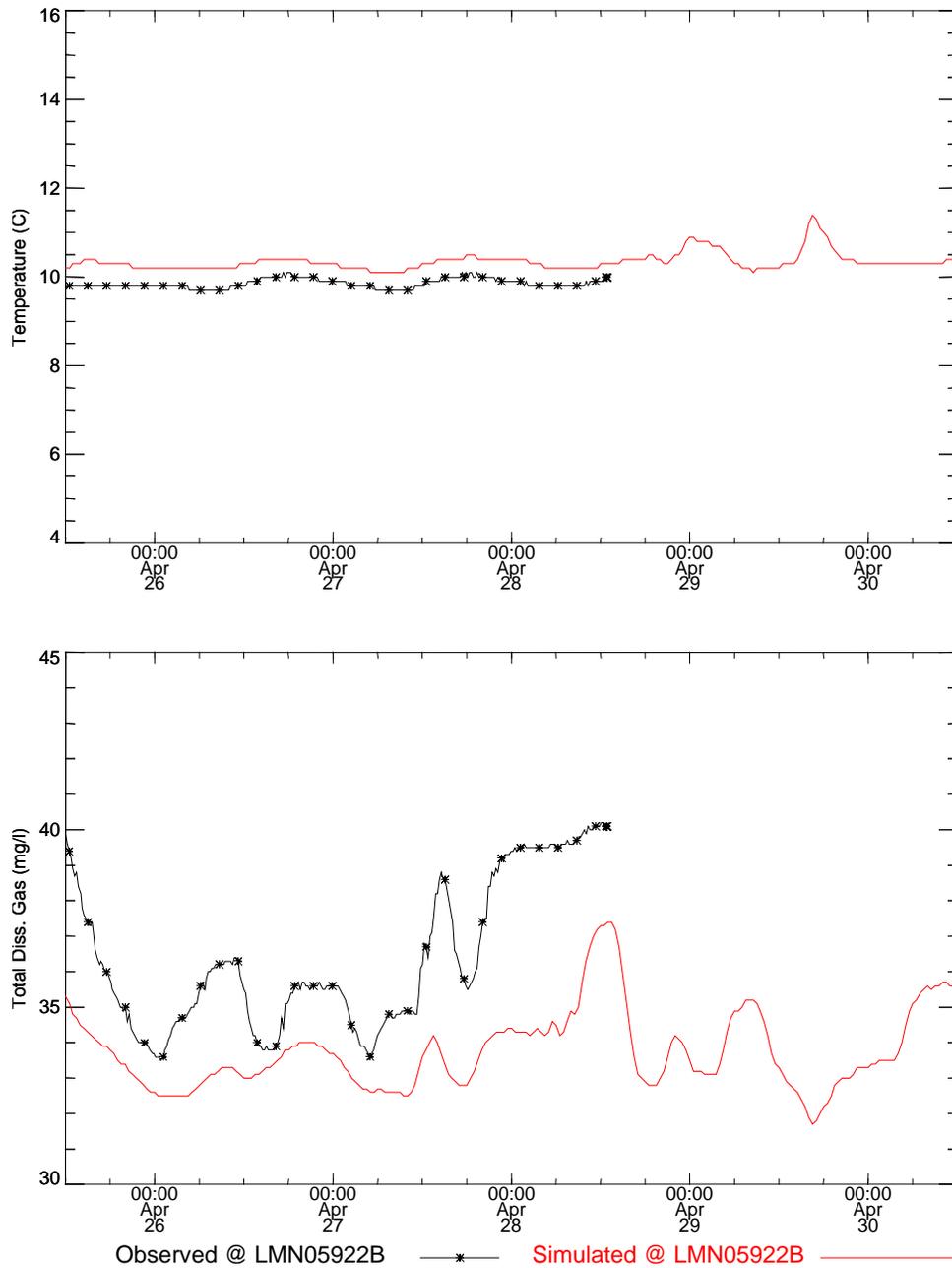


Figure 45. Temperature and total dissolved gas time series near Snake River Mile 059.2 for the Spring 1996 study (FMS-BC).

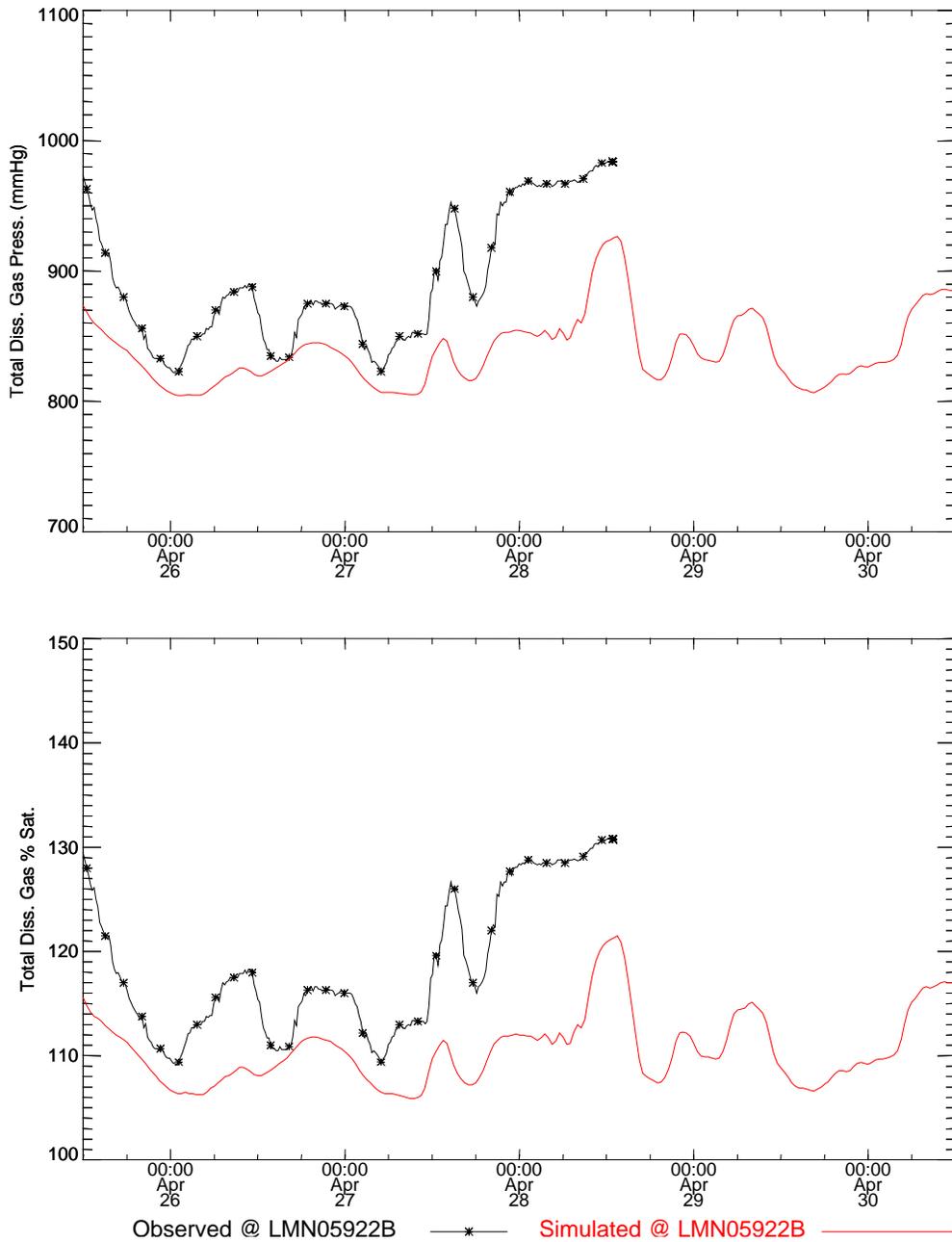


Figure 46. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 059.2 for the Spring 1996 study (FMS-BC).

Table 9. Statistical summary of measurements and simulations at River Mile 059.2 during the Spring 1996 study (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature LMN05922B	9.85	10.28	0.11	0.1	0.43
Concentration LMN05922B	36.38	33.65	2.07	1.01	3.06
Gas Pressure LMN05922B	891.32	834.94	50.57	25.19	65.57
% Saturation LMN05922B	118.48	110.04	6.72	3.15	9.7

Table 10. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at River Mile 059.2 for the Spring 1996 study (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
LMN05922B	100	5.56	35.76	31.25

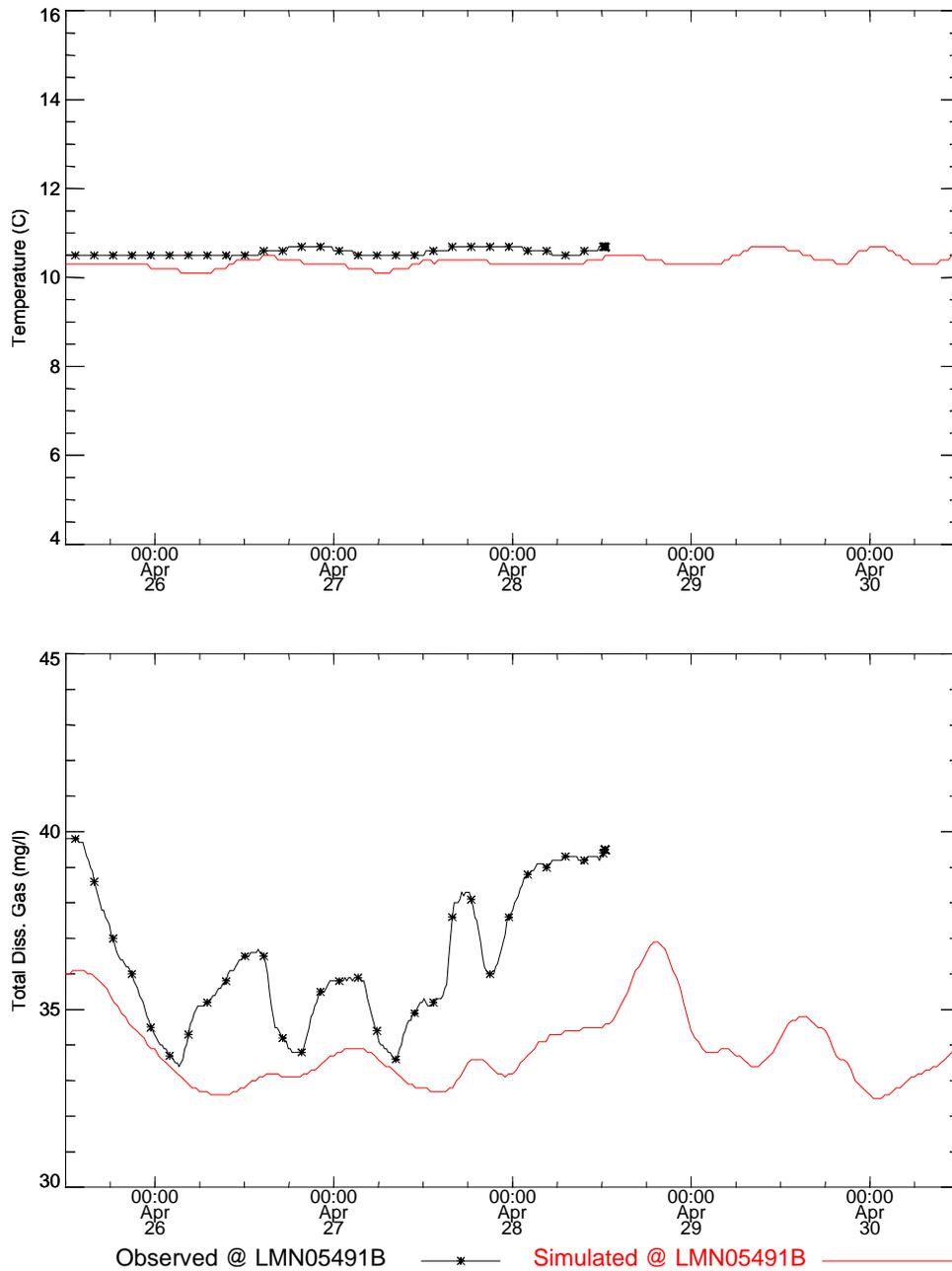


Figure 47. Temperature and total dissolved gas time series near Snake River Mile 054.9 for the Spring 1996 study (FMS-BC).

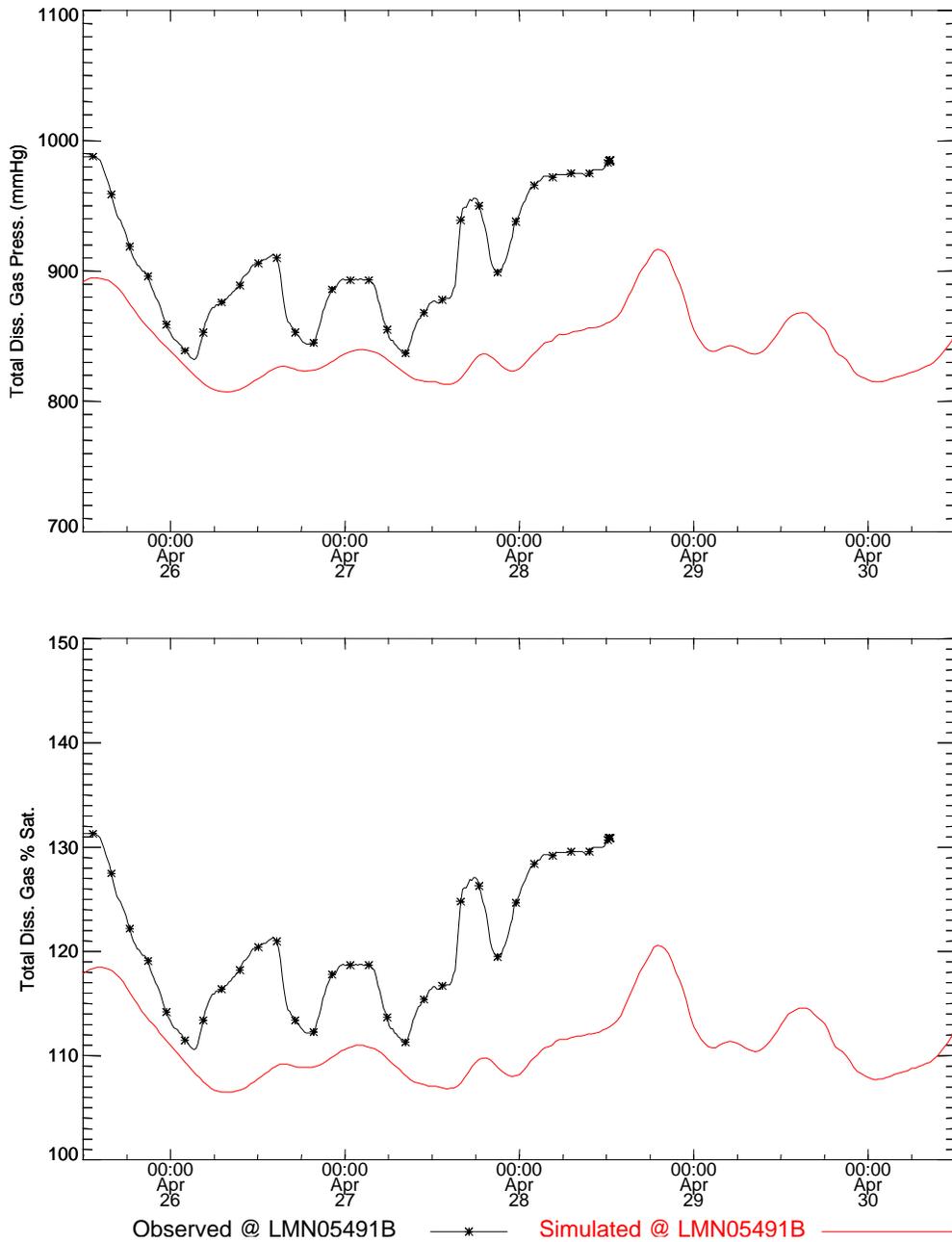


Figure 48. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 054.9 for the Spring 1996 study (FMS-BC).

Table 11. Statistical summary of measurements and simulations at River Mile 054.9 during the Spring 1996 study (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature LMN05491B	10.57	10.3	0.08	0.09	0.29
Concentration LMN05491B	36.37	33.7	1.89	0.91	3.07
Gas Pressure LMN05491B	905.48	836.44	46.69	22.29	78.37
% Saturation LMN05491B	120.36	110.25	6.2	3.09	11.39

Table 12. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at River Mile 054.9 for the Spring 1996 study (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
LMN05491B	100	17.77	23.69	20.91

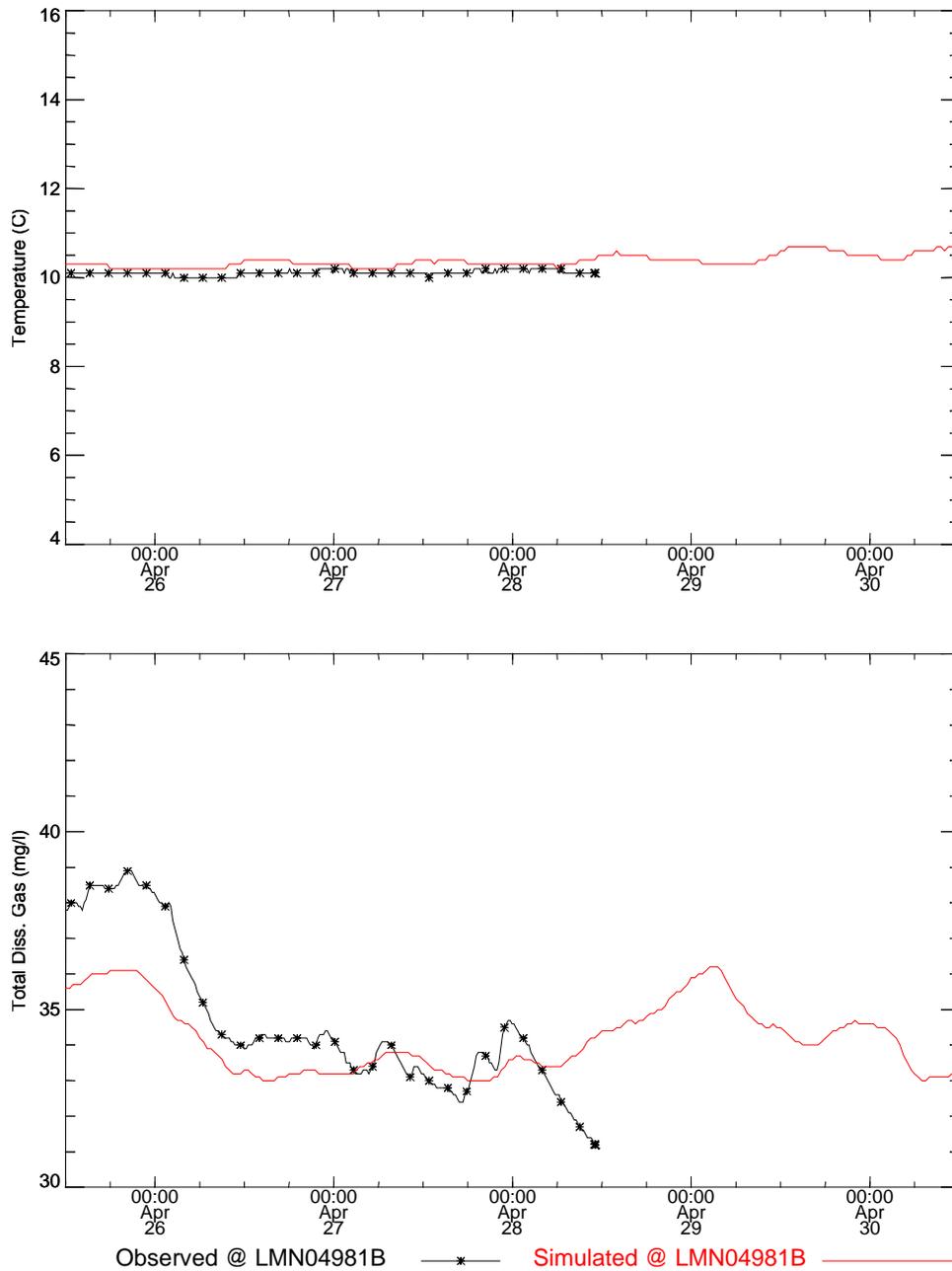


Figure 49. Temperature and total dissolved gas time series near Snake River Mile 049.8 for the Spring 1996 study (FMS-BC).

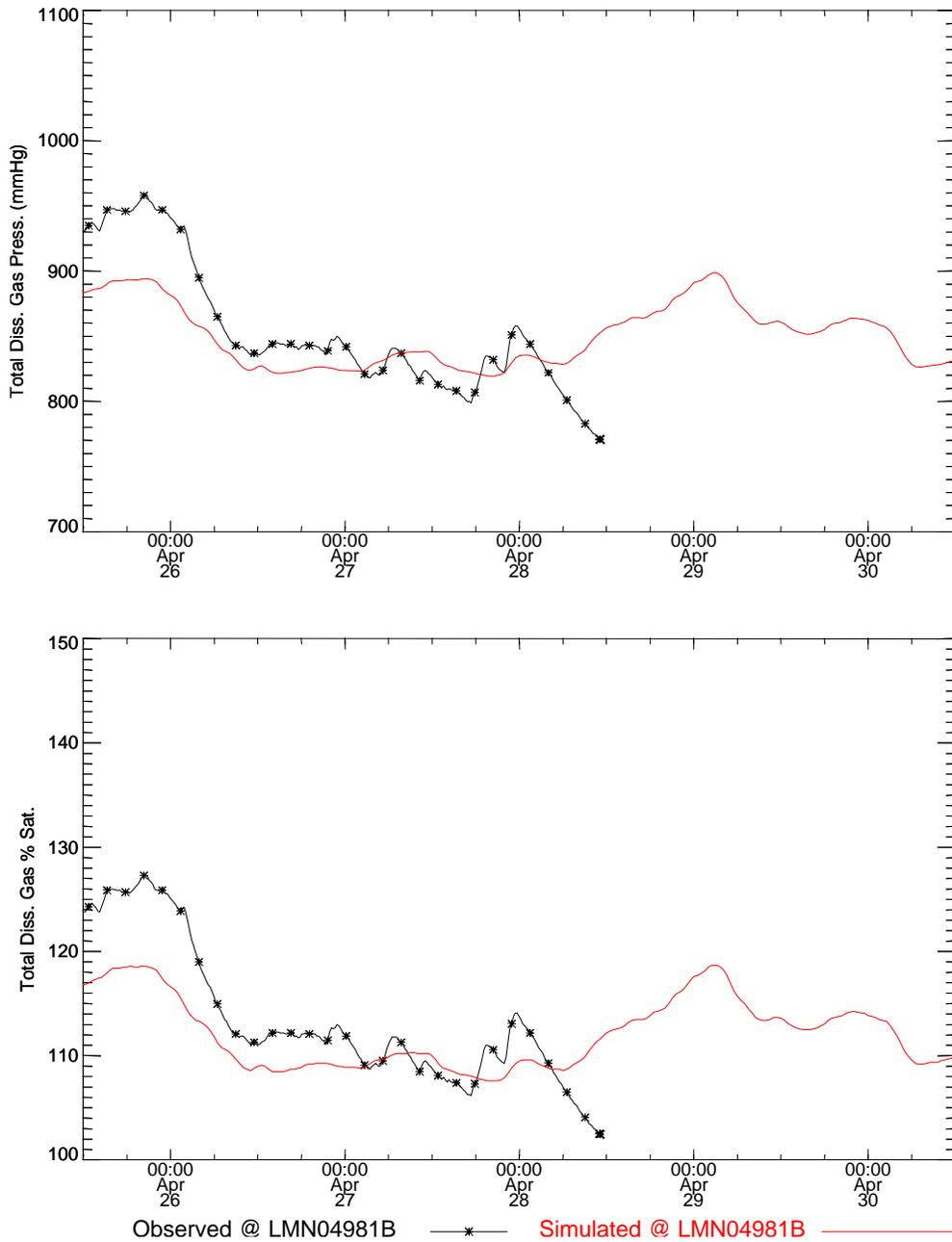


Figure 50. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 049.8 for the Spring 1996 study (FMS-BC).

Table 13. Statistical summary of measurements and simulations at River Mile 049.8 during the Spring 1996 study (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature LMN04981B	10.11	10.29	0.06	0.07	0.2
Concentration LMN04981B	34.66	33.95	2.07	1.01	1.44
Gas Pressure LMN04981B	854.49	842.54	50.09	24.28	33.09
% Saturation LMN04981B	113.59	111.07	6.66	3.49	4.53

Table 14. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at River Mile 049.8 for the Spring 1996 study (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
LMN04981B	100	57.3	72.6	73.31

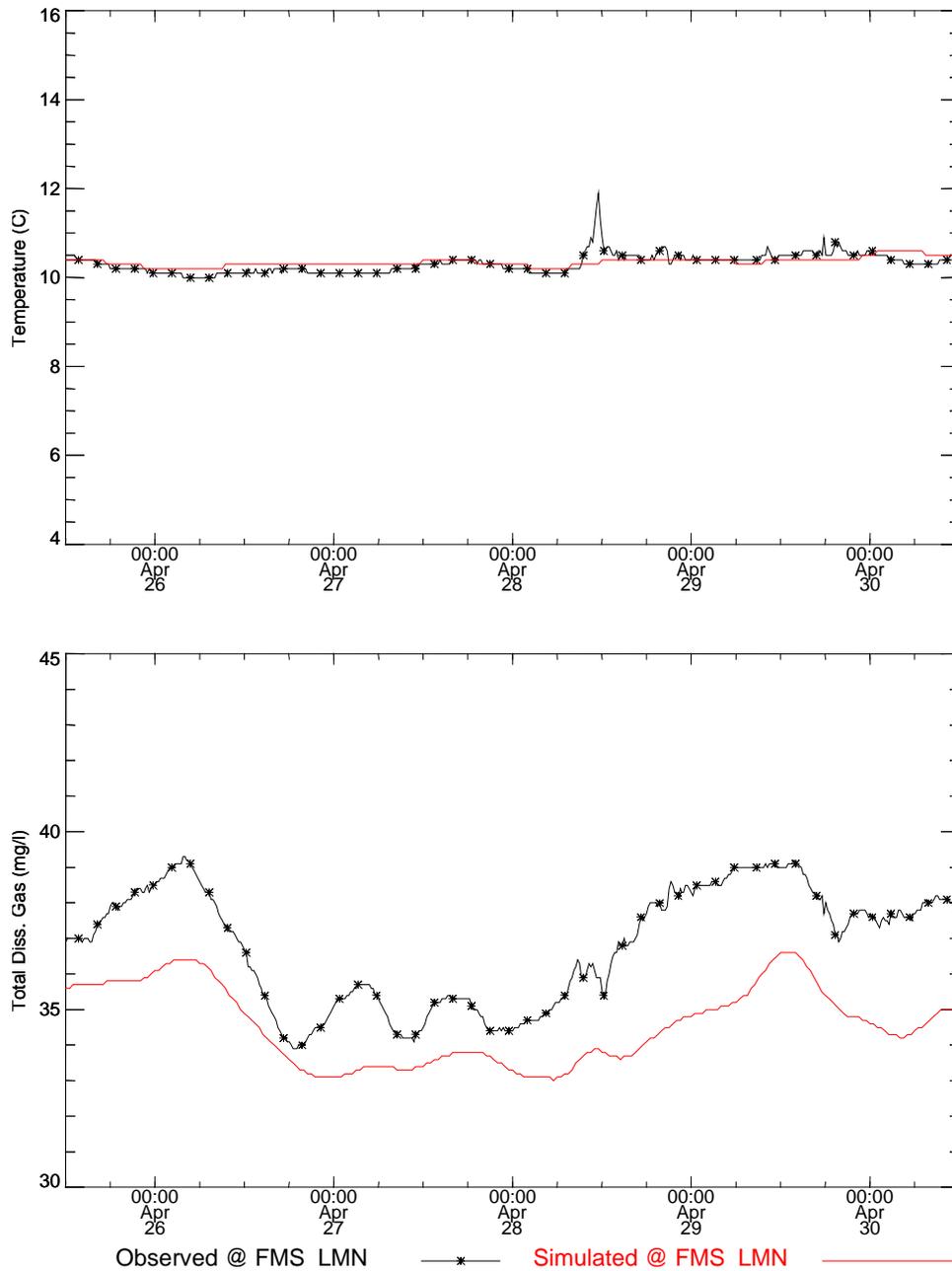


Figure 51. Temperature and total dissolved gas time series near fixed monitor LMN for the Spring 1996 study (FMS-BC).

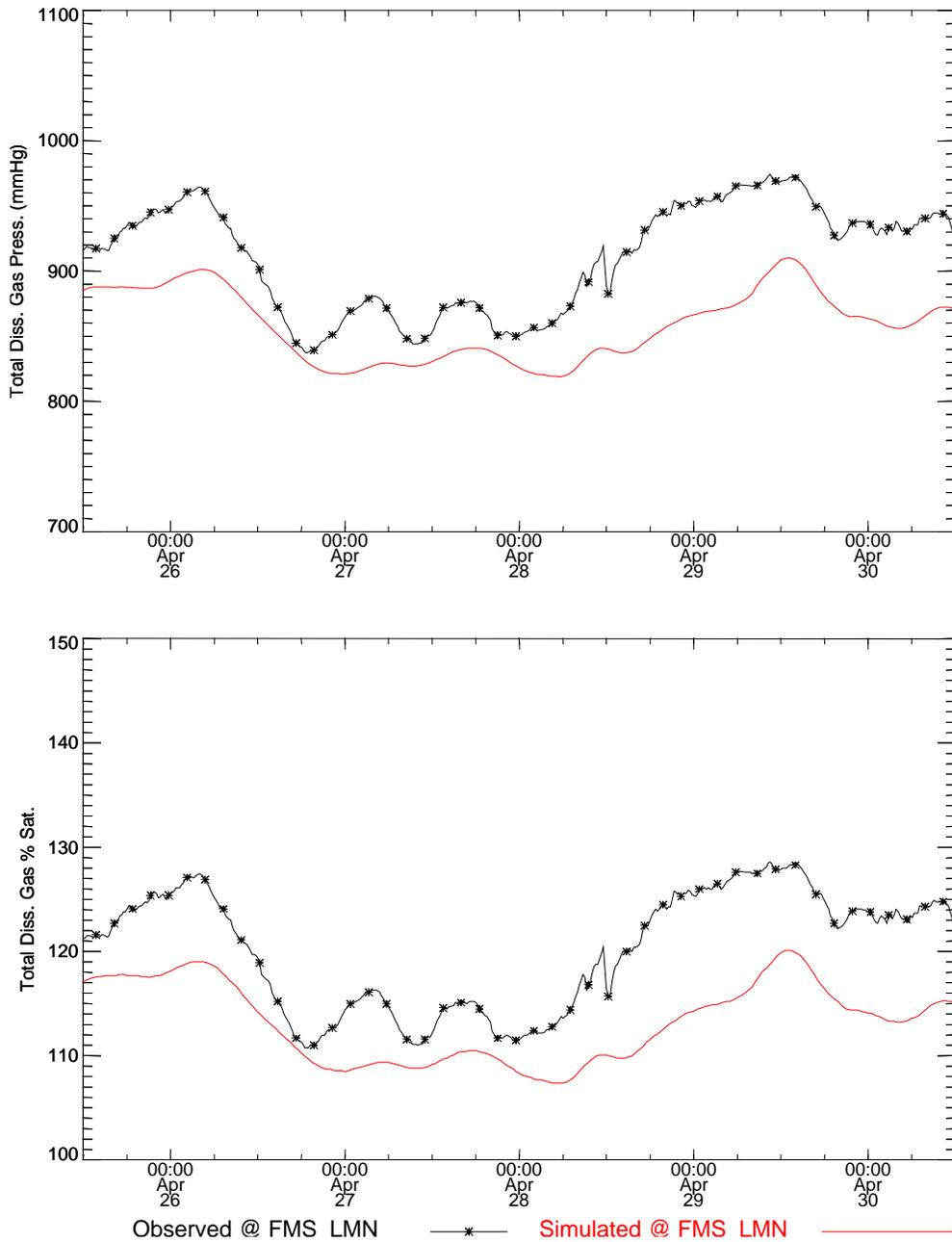


Figure 52. Total dissolved gas pressure and saturation time series comparisons near fixed monitor LMN for the Spring 1996 study (FMS-BC).

Table 15. Statistical summary of measurements and simulations at fixed monitor LMN during the Spring 1996 study (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_LMN	10.32	10.35	0.22	0.1	0.19
Concentration FMS_LMN	36.81	34.56	1.64	1.09	2.42
Gas Pressure FMS_LMN	911.04	858.49	41.29	26.77	57.2
% Saturation FMS_LMN	120.19	113.22	5.65	3.78	7.58

Table 16. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at fixed monitor LMN for the Spring 1996 study (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_LMN	99.59	10.79	31.54	31.95

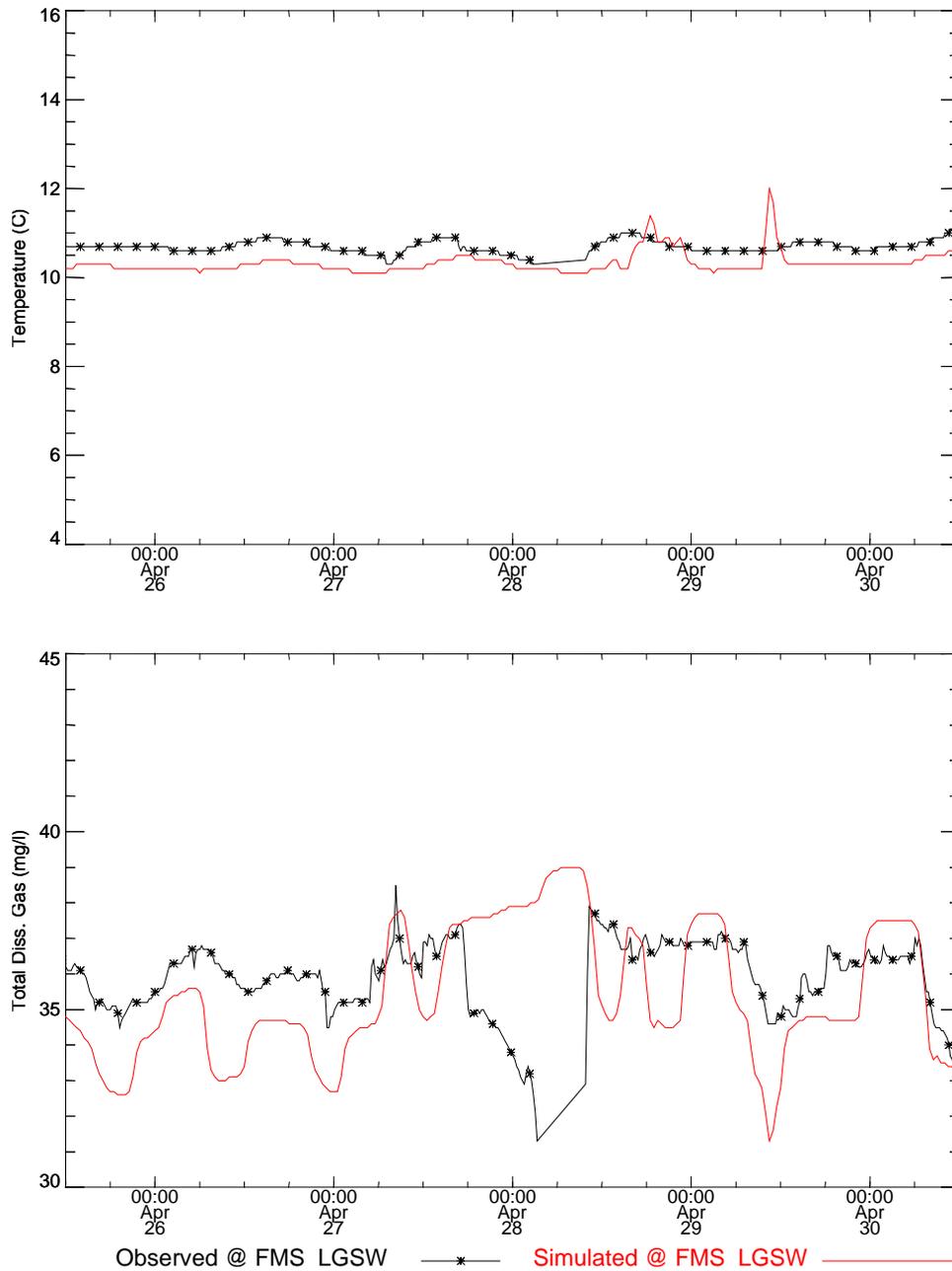


Figure 53. Temperature and total dissolved gas time series near fixed monitor LGSW for the Spring 1996 study (FMS-BC).

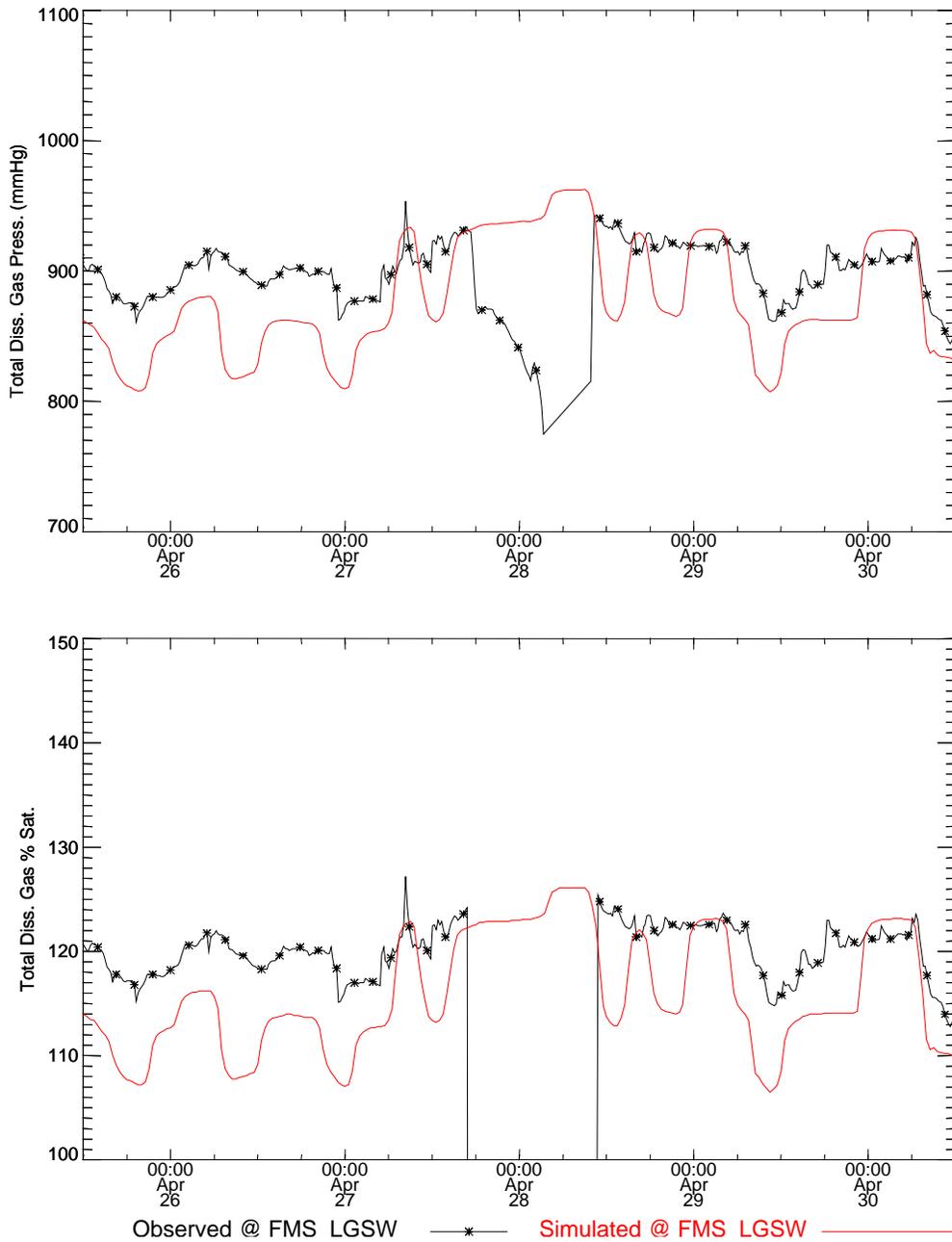


Figure 54. Total dissolved gas pressure and saturation time series comparisons near fixed monitor LGSW for the Spring 1996 study (FMS-BC).

Table 17. Statistical summary of measurements and simulations at fixed monitor LGSW during the Spring 1996 study (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_LGSW	10.68	10.33	0.16	0.24	0.43
Concentration FMS_LGSW	35.7	35.41	1.29	1.84	2.41
Gas Pressure FMS_LGSW	891.04	879.06	33.48	44.38	61.19
% Saturation FMS_LGSW	102.25	115.91	42.58	5.61	48

Table 18. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at fixed monitor LGSW for the Spring 1996 study (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_LGSW	99.17	35.27	46.06	32.78

Boundary Conditions using Temporary Monitored Field Data

Comparisons between the measurements and simulations using an upstream boundary condition developed from water temperatures and TDG pressures measured by temporary monitors are shown in the figures below. Statistics on comparisons between measured and simulated temperatures and total dissolved gas are also presented. The case is denoted as TM-BC in the figure and table captions.

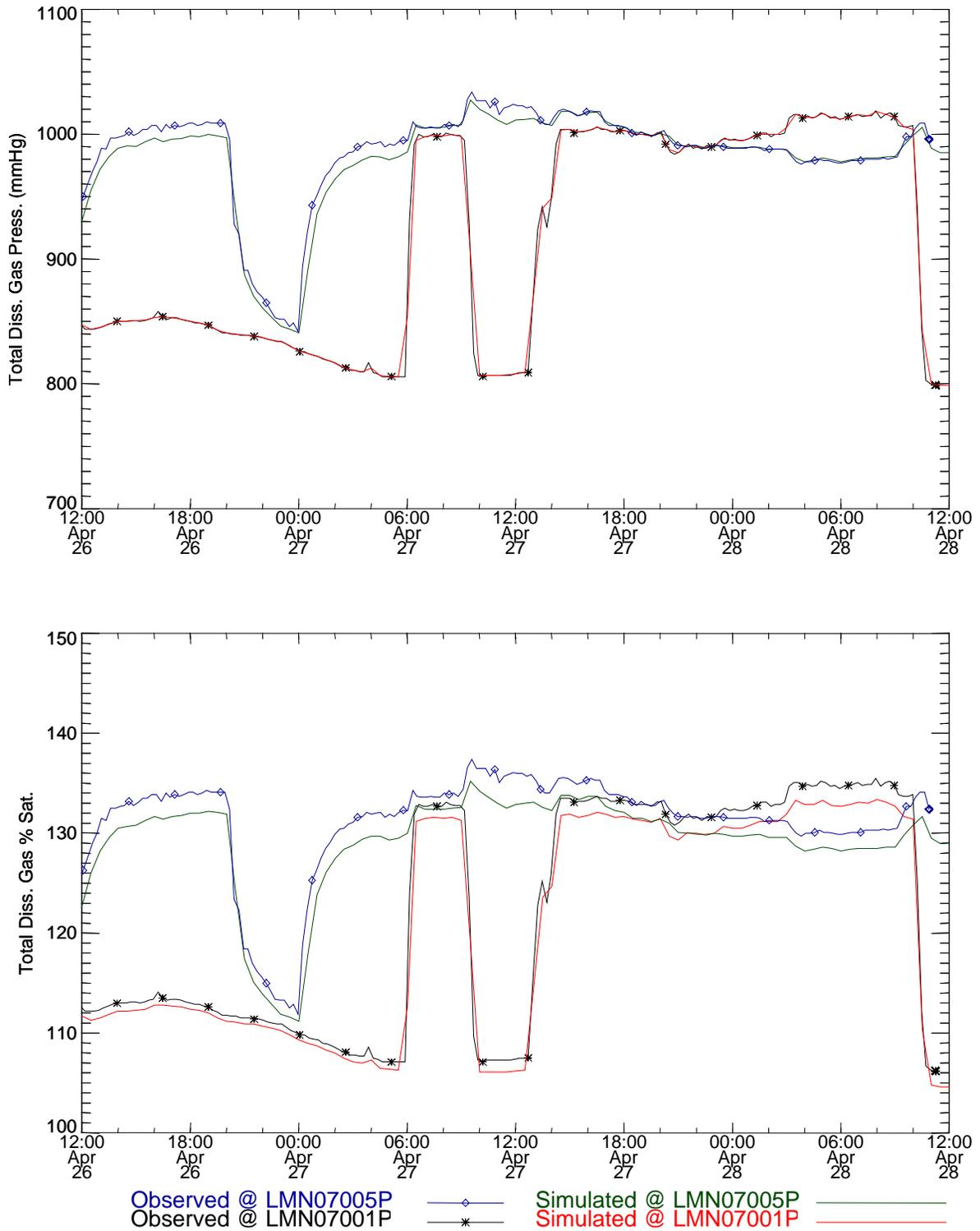


Figure 55. Temperature and total dissolved gas time series near Snake River Mile 070.0 for the Spring 1996 study (TM-BC).

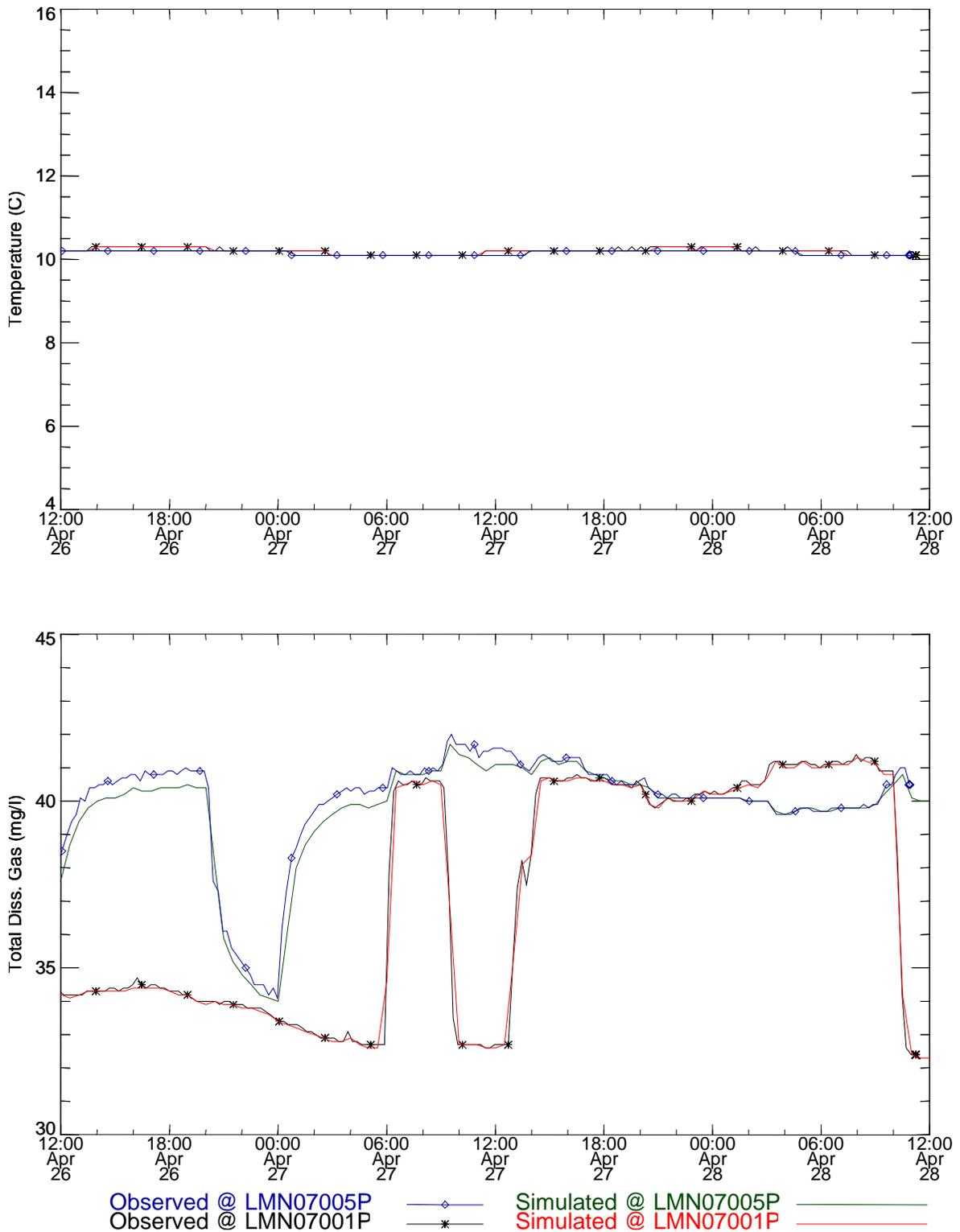


Figure 56. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 070.0 for the Spring 1996 study (TM-BC).

Table 19. Statistical summary of measurements and simulations at River Mile 070.0 during the Spring 1996 study (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
LMN07001P	10.2	10.2	0.07	0.07	0.02
LMN07005P	10.16	10.16	0.05	0.05	0
Concentration					
LMN07001P	37.18	37.14	3.51	3.46	0.3
LMN07005P	40.02	39.78	1.6	1.64	0.35
Gas Pressure					
LMN07001P	917.89	918	85.93	84.65	7.34
LMN07005P	986.25	981.42	38.83	39.95	7.94
% Saturation					
LMN07001P	122.02	120.78	11.43	10.83	1.65
LMN07005P	131.1	129.15	5.16	5.08	2.05

Table 20. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at River Mile 070.0 for the Spring 1996 study (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
LMN07001P	100	96.79	98.93	98.4
LMN07005P	100	98.4	100	100

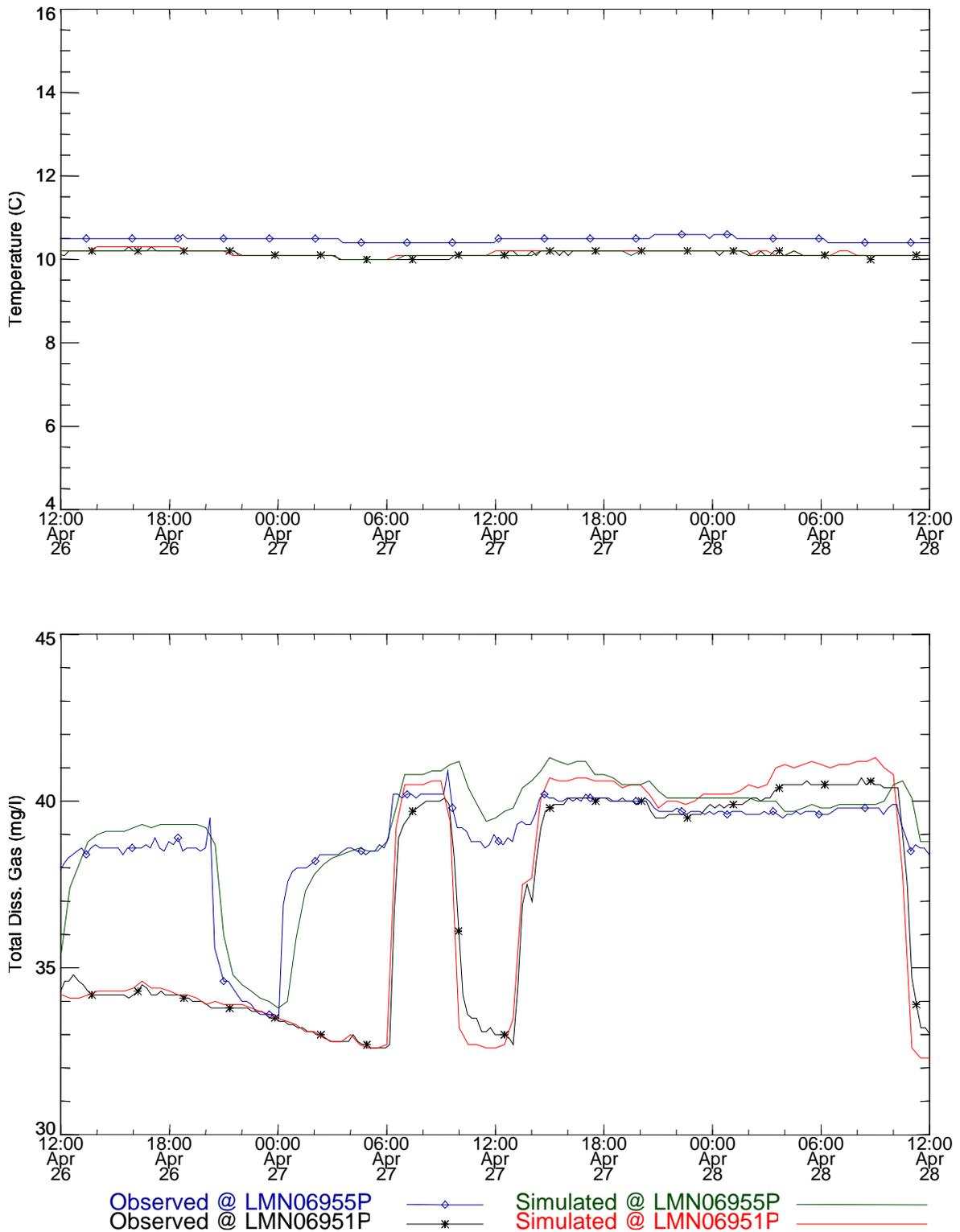


Figure 57. Temperature and total dissolved gas time series near Snake River Mile 069.5 for the Spring 1996 study (TM-BC).

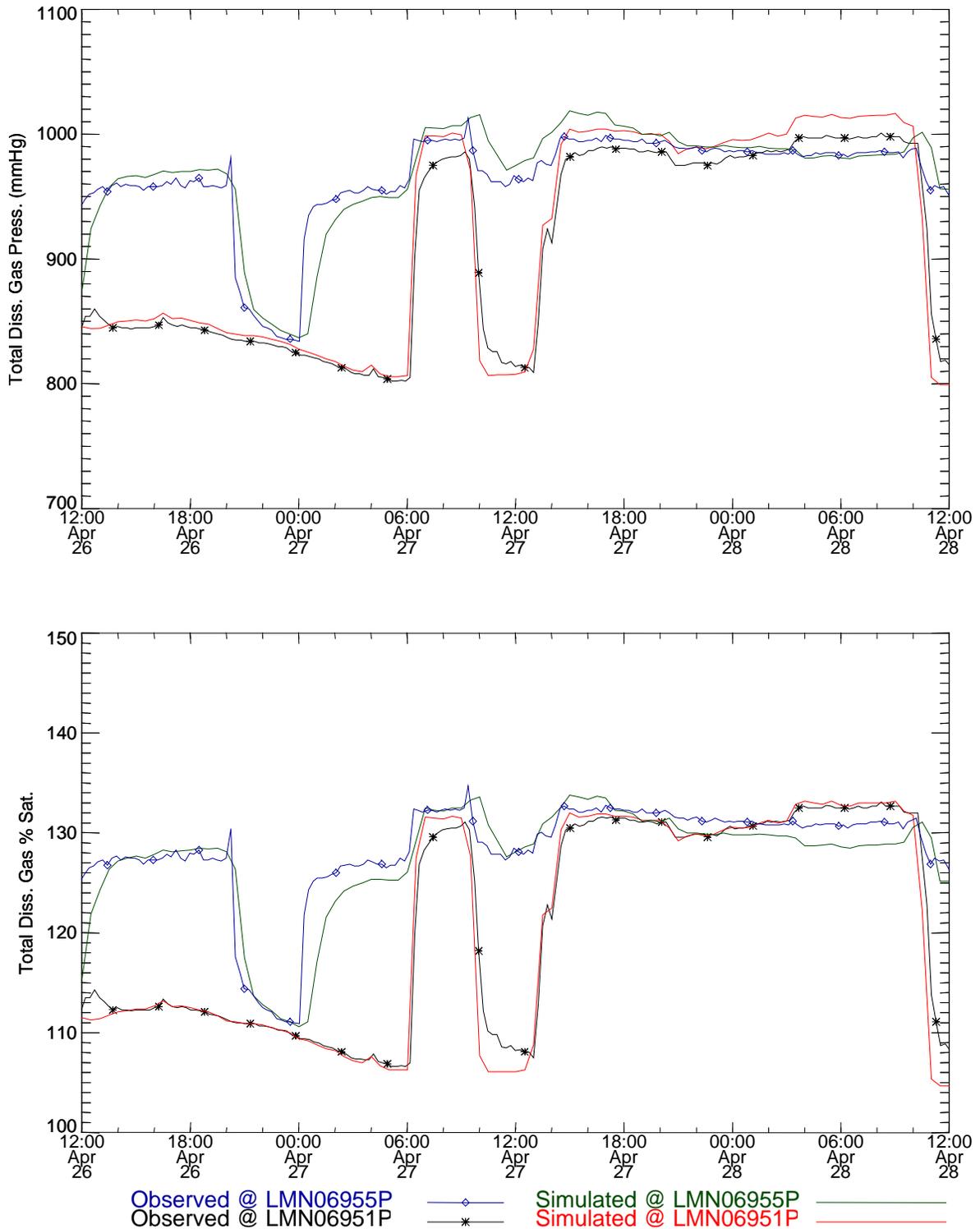


Figure 58. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 069.5 for the Spring 1996 study (TM-BC).

Table 21. Statistical summary of measurements and simulations at River Mile 069.5 during the Spring 1996 study (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
LMN06951P	10.13	10.16	0.07	0.07	0.05
LMN06955P	10.48	10.14	0.06	0.06	0.35
Concentration					
LMN06951P	36.9	37.1	3.17	3.47	0.61
LMN06955P	38.88	39.29	1.55	1.76	0.82
Gas Pressure					
LMN06951P	909.69	916.9	77.65	85.02	16.02
LMN06955P	965.25	969.42	37.94	43.02	18.08
% Saturation					
LMN06951P	120.92	120.63	10.32	10.89	1.87
LMN06955P	128.31	127.55	5.04	5.4	2.39

Table 22. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at River Mile 069.5 for the Spring 1996 study (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
LMN06951P	100	93.65	97.88	95.77
LMN06955P	100	83.6	95.77	95.24

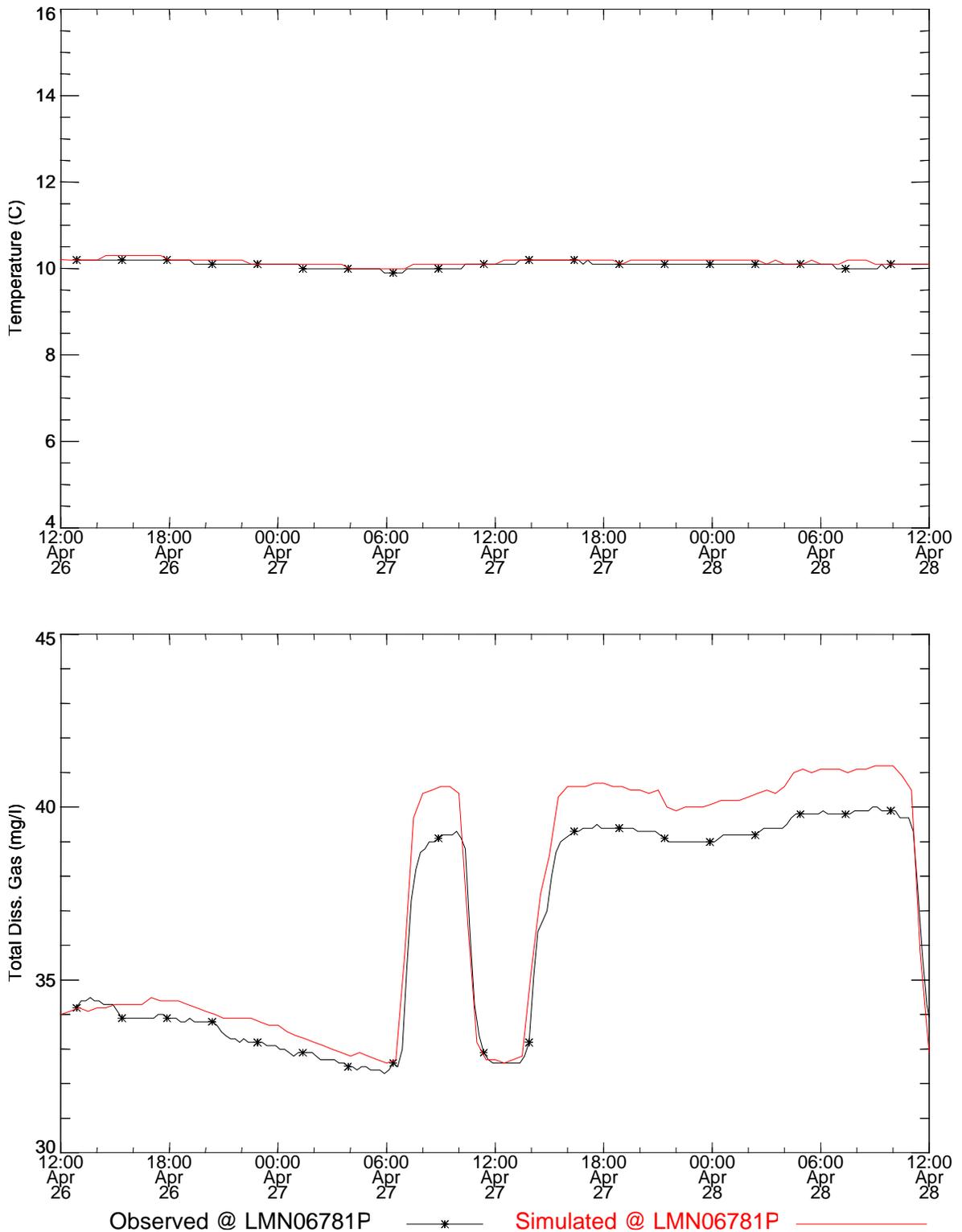


Figure 59. Temperature and total dissolved gas time series near Snake River Mile 067.8 for the Spring 1996 study (TM-BC).

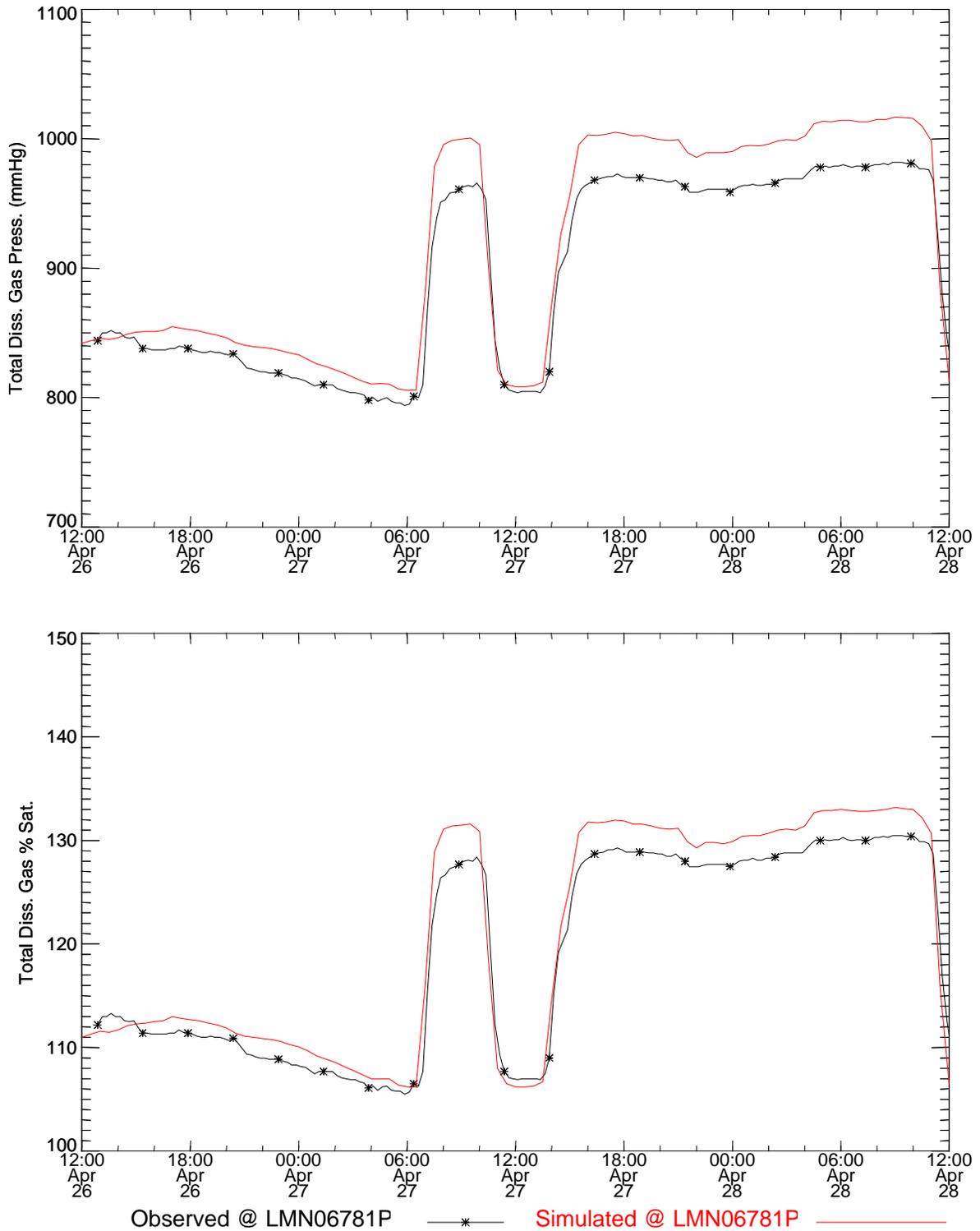


Figure 60. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 067.8 for the Spring 1996 study (TM-BC).

Table 23. Statistical summary of measurements and simulations at River Mile 067.8 during the Spring 1996 study (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature LMN06781P	10.09	10.16	0.07	0.07	0.08
Concentration LMN06781P	36.43	37.17	3.01	3.41	0.92
Gas Pressure LMN06781P	897.06	918.81	73.22	83.19	25.57
% Saturation LMN06781P	119.24	120.87	9.73	10.62	2.26

Table 24. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at River Mile 067.8 for the Spring 1996 study (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
LMN06781P	100	56.08	96.3	99.47

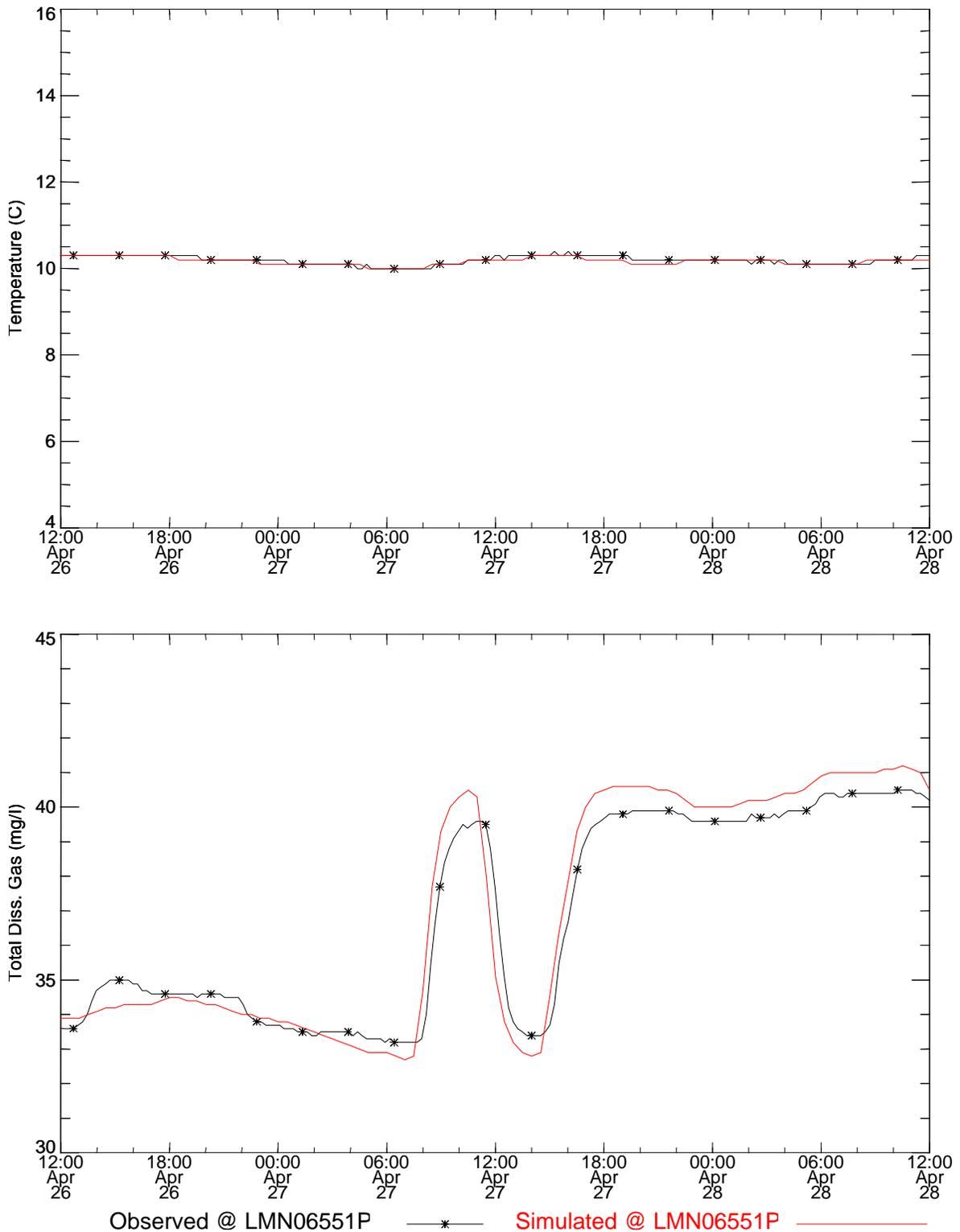


Figure 61. Temperature and total dissolved gas time series near Snake River Mile 065.5 for the Spring 1996 study (TM-BC).

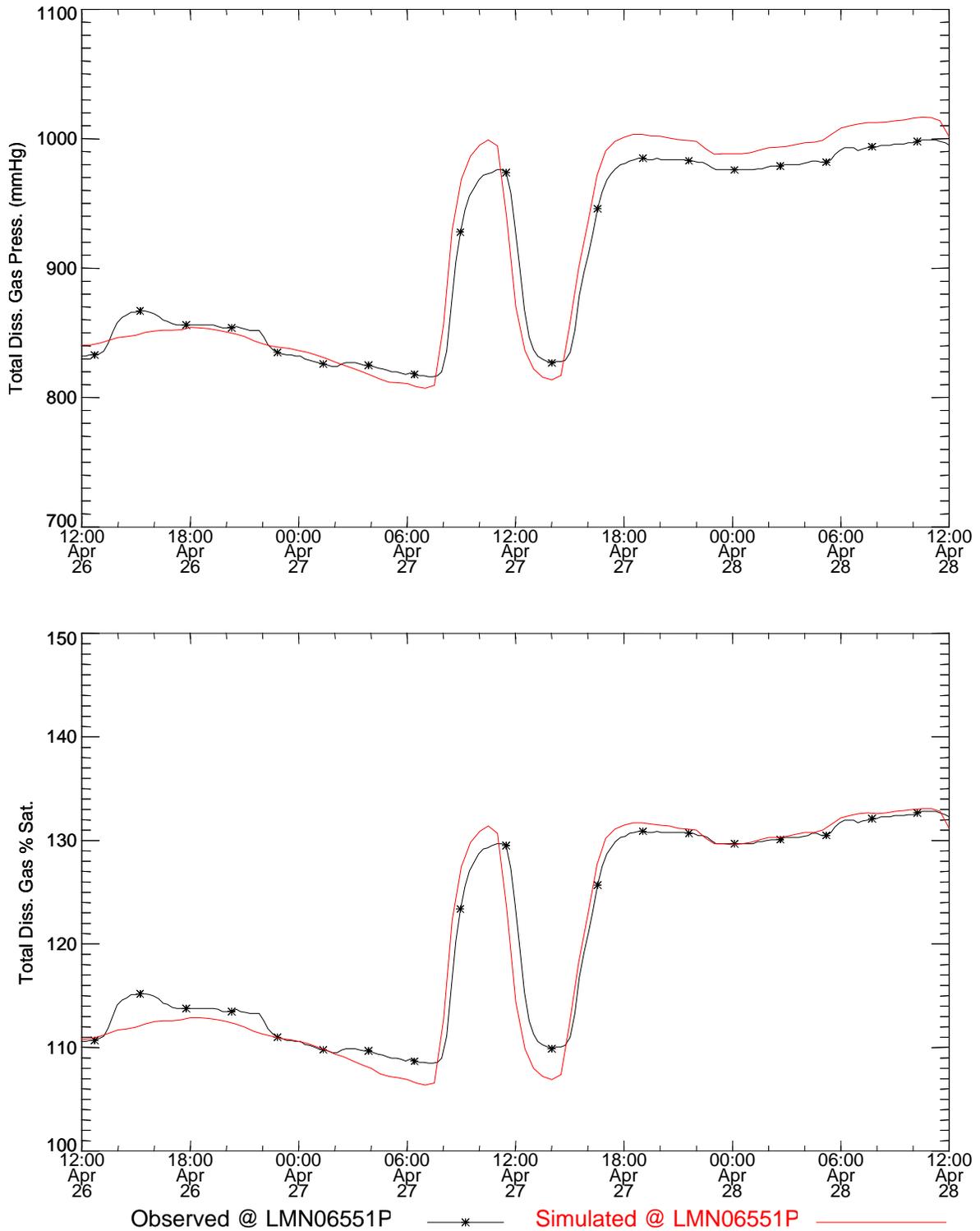


Figure 62. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 065.5 for the Spring 1996 study (TM-BC).

Table 25. Statistical summary of measurements and simulations at River Mile 065.5 during the Spring 1996 study (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature LMN06551P	10.19	10.17	0.1	0.08	0.05
Concentration LMN06551P	36.83	37.03	2.91	3.31	0.68
Gas Pressure LMN06551P	909	915.51	71.07	80.83	17.09
% Saturation LMN06551P	120.83	120.45	9.44	10.29	1.91

Table 26. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at River Mile 065.5 for the Spring 1996 study (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
LMN06551P	100	90.48	96.83	96.3

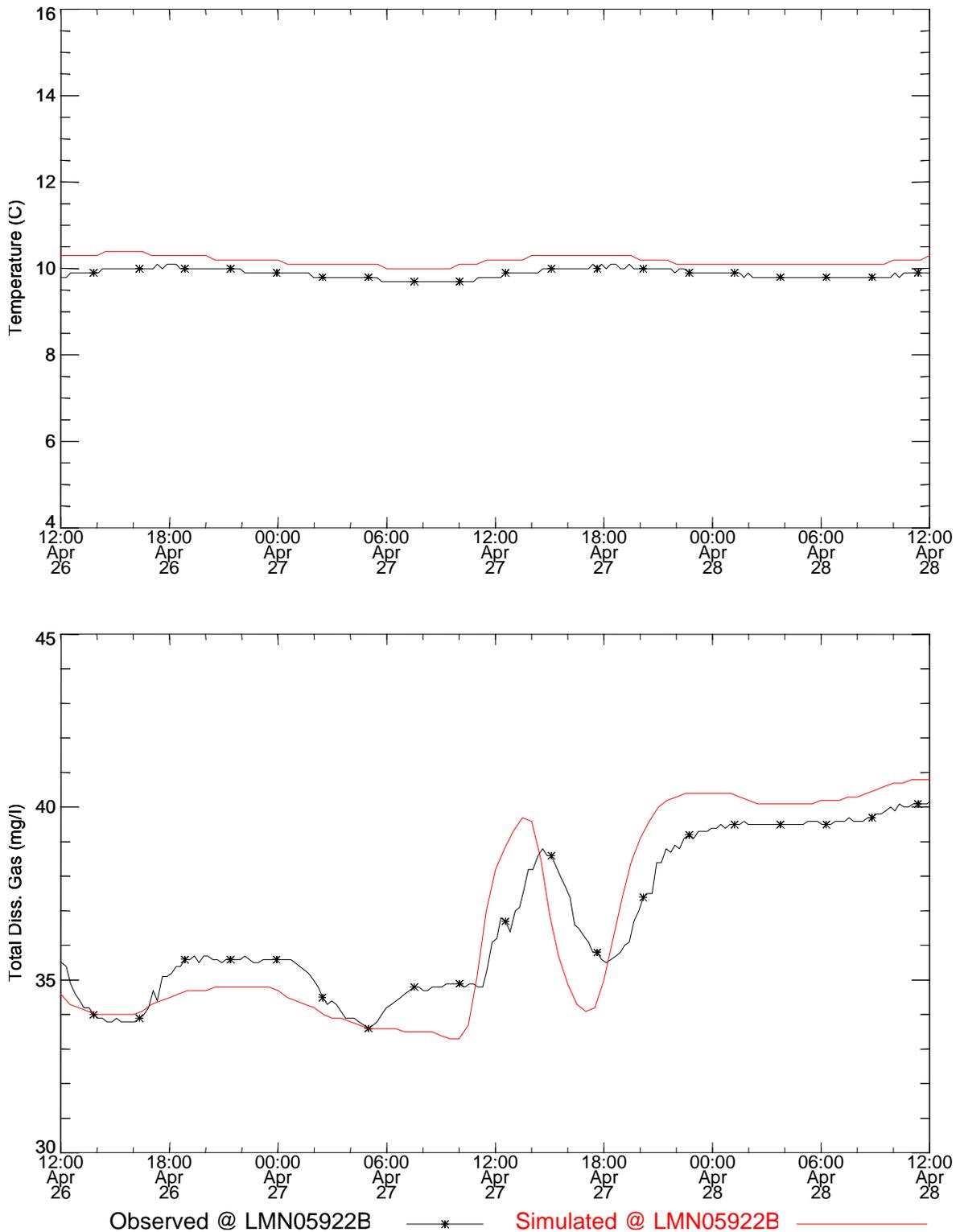


Figure 63. Temperature and total dissolved gas time series near Snake River Mile 059.2 for the Spring 1996 study (TM-BC).

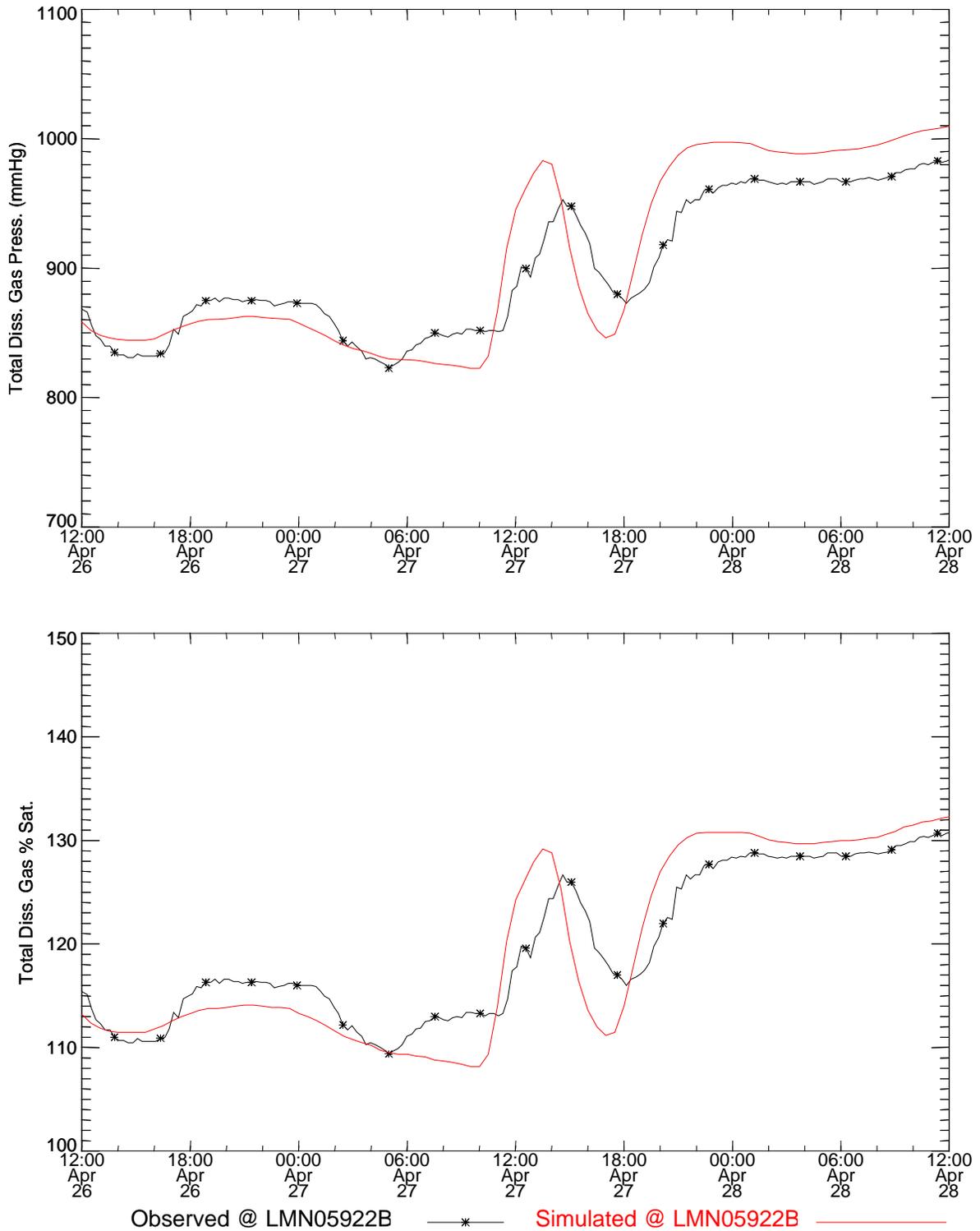


Figure 64. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 059.2 for the Spring 1996 study (TM-BC).

Table 27. Statistical summary of measurements and simulations at River Mile 059.2 during the Spring 1996 study (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature LMN05922B	9.89	10.18	0.11	0.11	0.3
Concentration LMN05922B	36.68	36.71	2.18	2.87	1.12
Gas Pressure LMN05922B	899.37	908.04	53.02	69.92	28.68
% Saturation LMN05922B	119.55	119.48	7.04	8.86	3.37

Table 28. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at River Mile 059.2 for the Spring 1996 study (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
LMN05922B	100	66.84	81.05	84.74

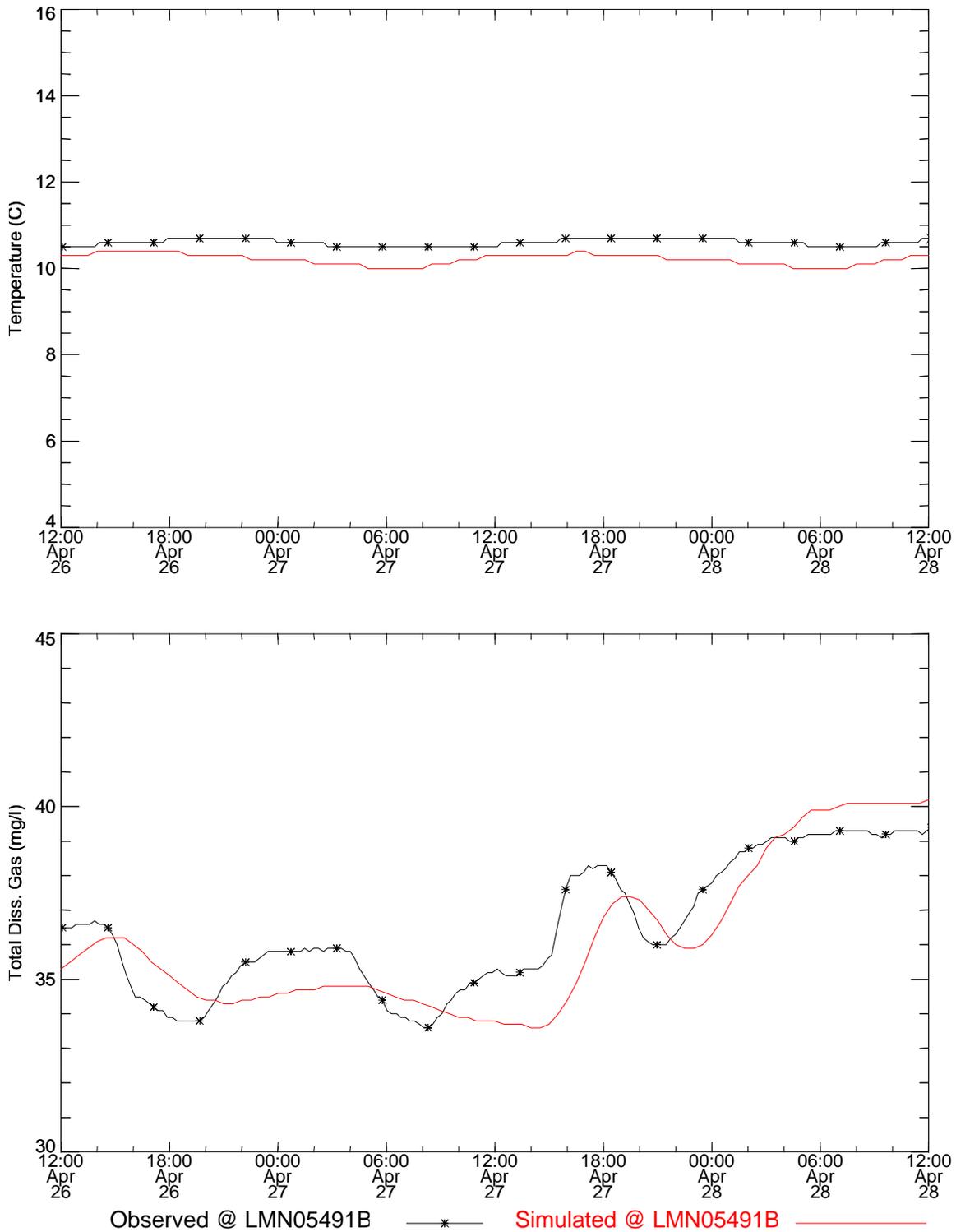


Figure 65. Temperature and total dissolved gas time series near Snake River Mile 054.9 for the Spring 1996 study (TM-BC).

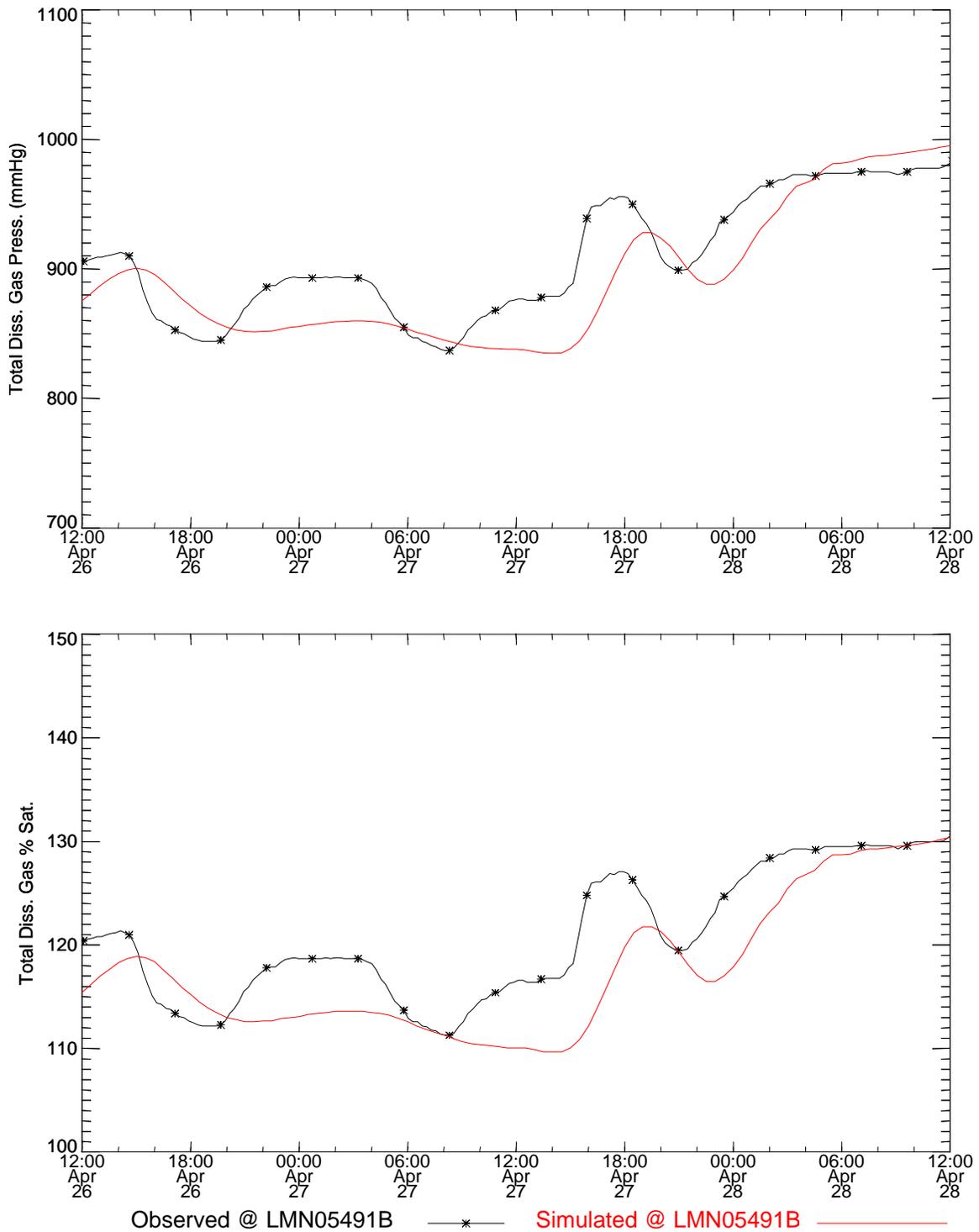


Figure 66

Figure 67. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 054.9 for the Spring 1996 study (TM-BC).

Table 29. Statistical summary of measurements and simulations at River Mile 054.9 during the Spring 1996 study (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature LMN05491B	10.6	10.21	0.08	0.12	0.41
Concentration LMN05491B	36.45	36.09	1.86	2.12	1.13
Gas Pressure LMN05491B	908.26	893.4	45.85	51.03	30.13
% Saturation LMN05491B	120.73	117.55	6.09	6.44	4.71

Table 30. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at River Mile 054.9 for the Spring 1996 study (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
LMN05491B	100	58.95	81.05	64.74

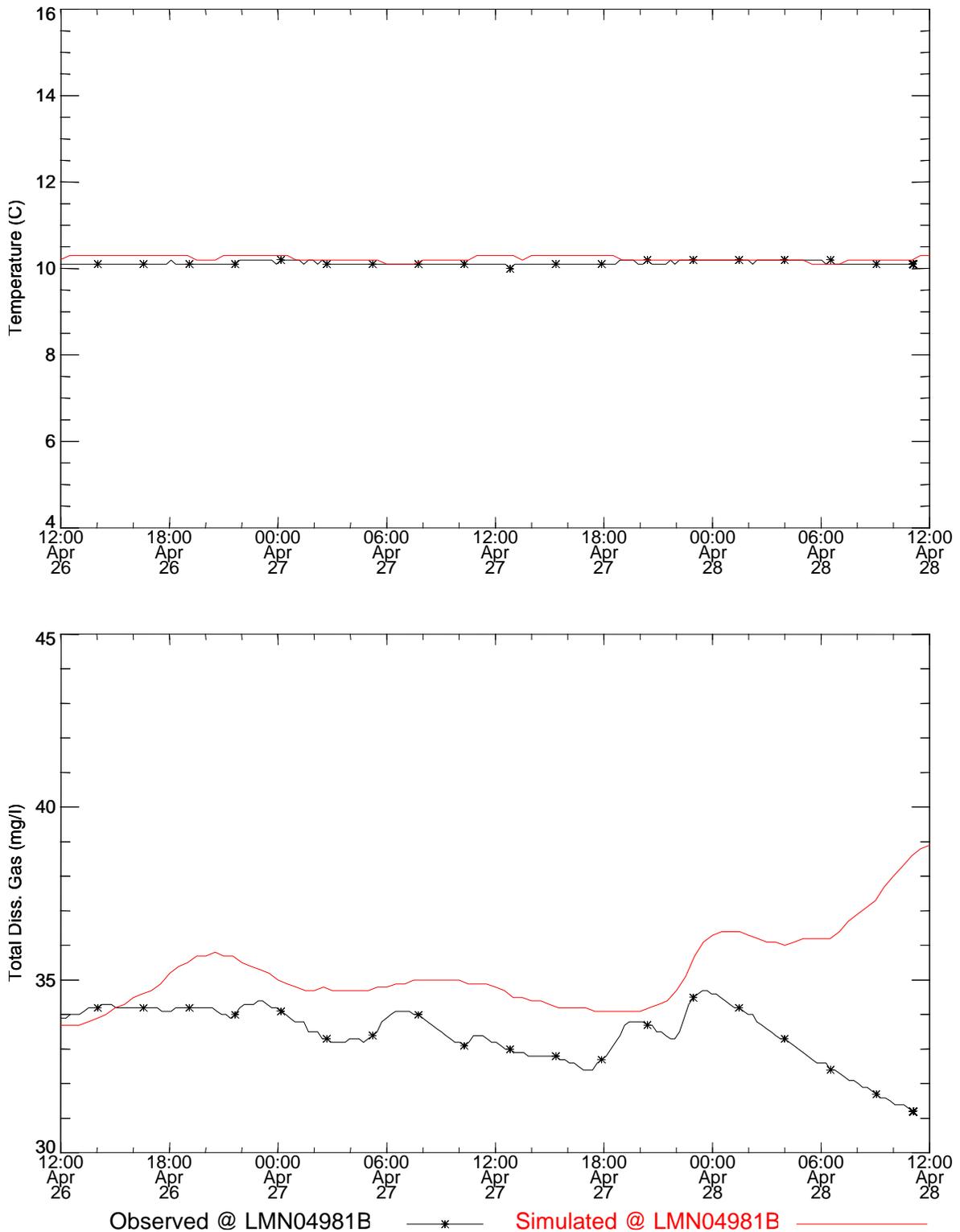


Figure 68. Temperature and total dissolved gas time series near Snake River Mile 049.8 for the Spring 1996 study (TM-BC).

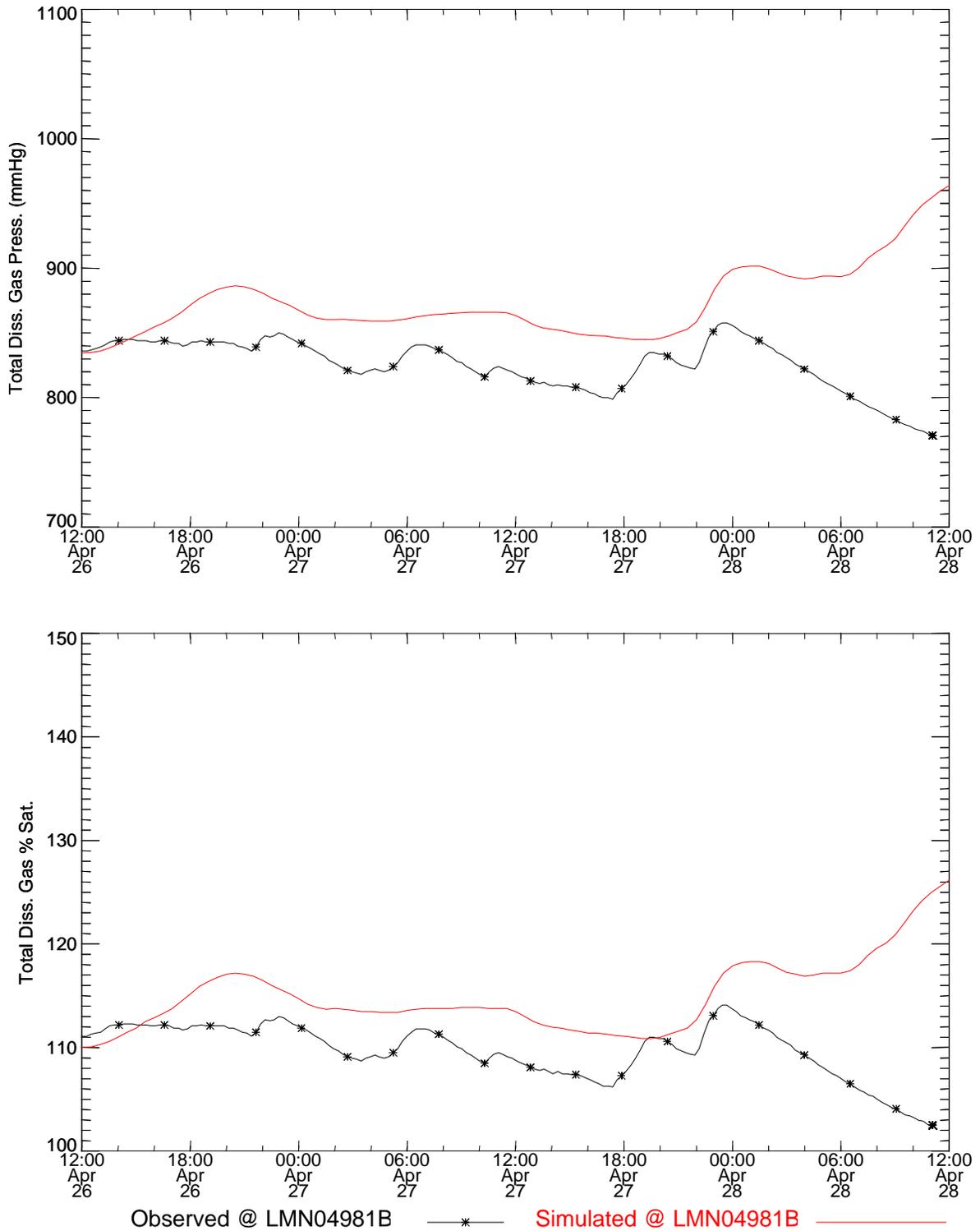


Figure 69. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 049.8 for the Spring 1996 study (TM-BC).

Table 31. Statistical summary of measurements and simulations at River Mile 049.8 during the Spring 1996 study (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature LMN04981B	10.13	10.23	0.05	0.06	0.13
Concentration LMN04981B	33.46	35.2	0.79	1.03	2.32
Gas Pressure LMN04981B	825.63	871.92	19.49	25.02	59.42
% Saturation LMN04981B	109.75	114.74	2.6	3.13	6.85

Table 32. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at River Mile 049.8 during the Spring 1996 study (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
LMN04981B	100	28.34	45.99	71.12

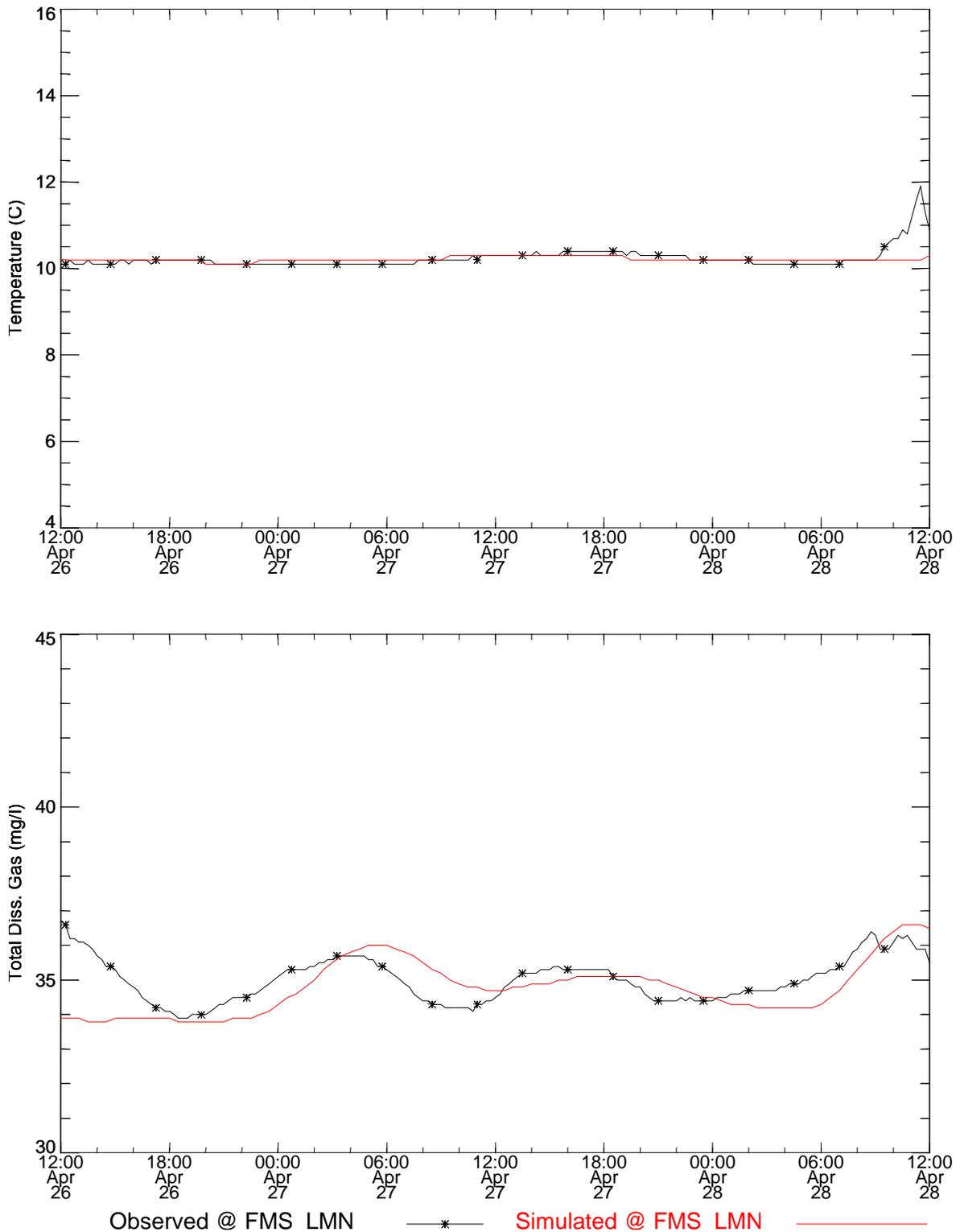


Figure 70. Temperature and total dissolved gas time series fixed monitor LMN for the Spring 1996 study (TM-BC).

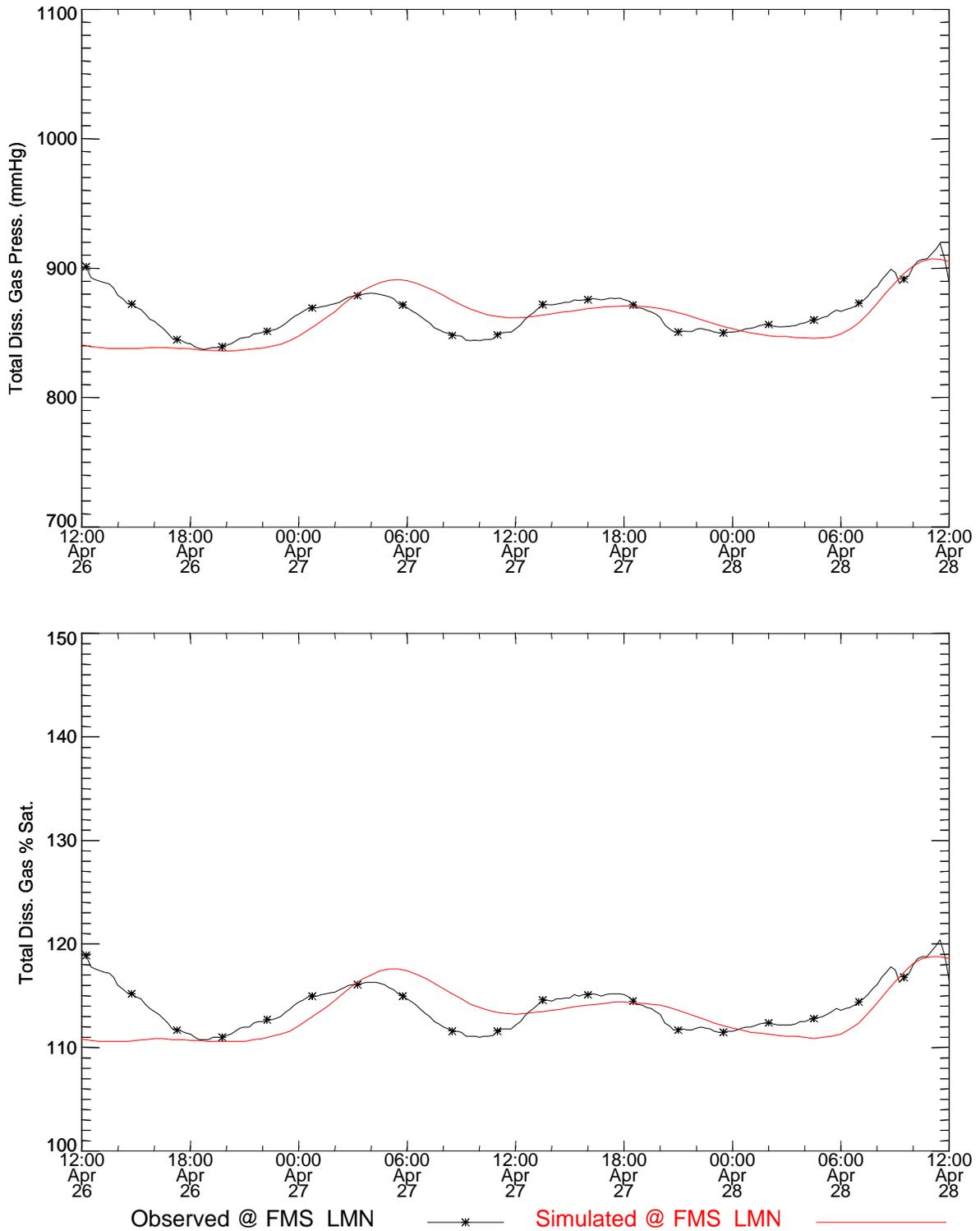


Figure 71. Total dissolved gas pressure and saturation time series comparisons near fixed monitor LMN for the Spring 1996 study (TM-BC).

Table 33. Statistical summary of measurements and simulations at fixed monitor LMN during the Spring 1996 study (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
FMS_LMN	10.24	10.22	0.25	0.05	0.24
Concentration					
FMS_LMN	35.01	34.78	0.63	0.77	0.78
Gas Pressure					
FMS_LMN	865.55	861.21	17.33	19.22	17.81
% Saturation					
FMS_LMN	113.92	113.33	2.2	2.38	2.35

Table 34. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at fixed monitor LMN during the Spring 1996 study (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_LMN	97.94	89.69	94.85	94.85

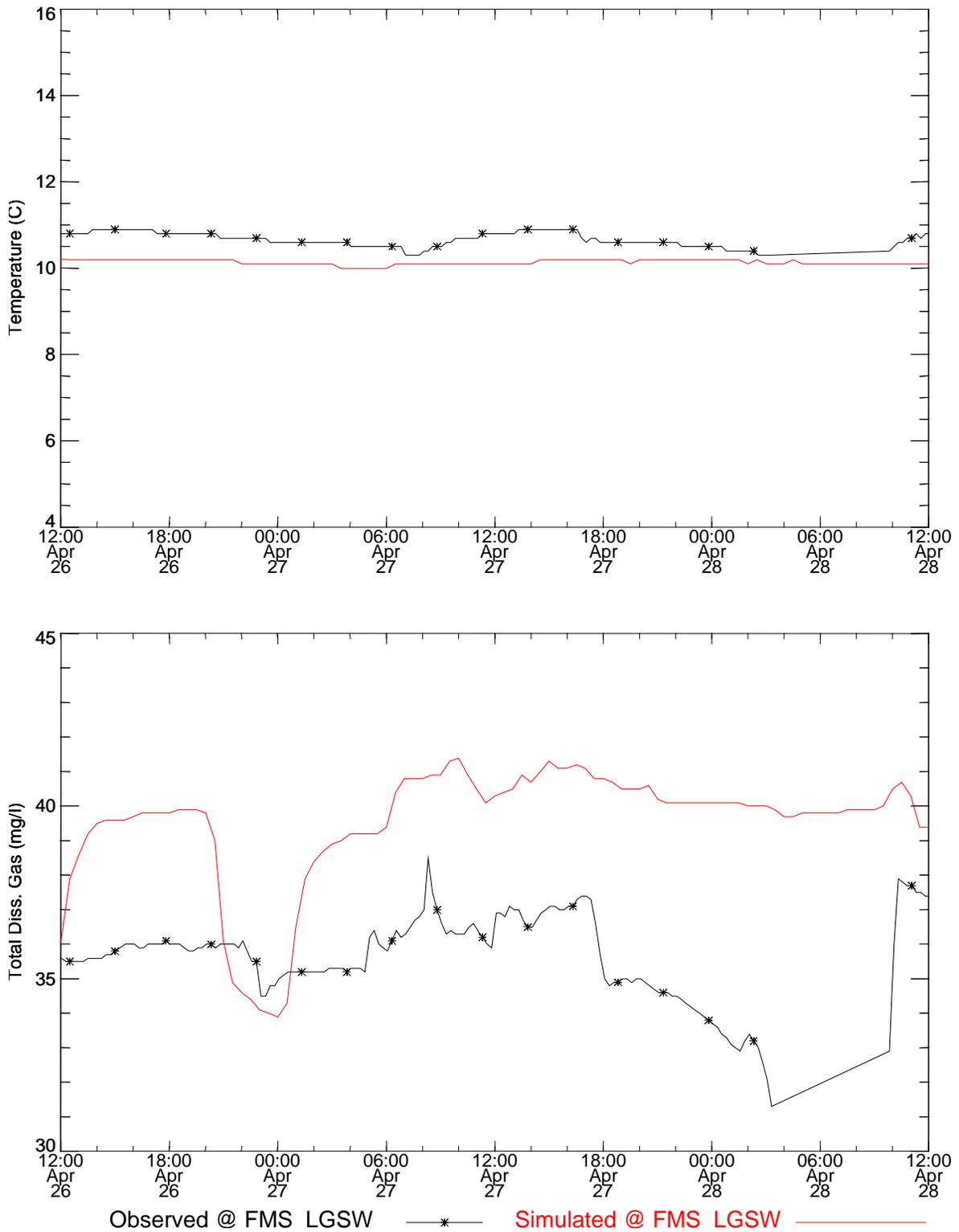


Figure 72. Temperature and total dissolved gas time series fixed monitor LGSW for the Spring 1996 study (TM-BC).

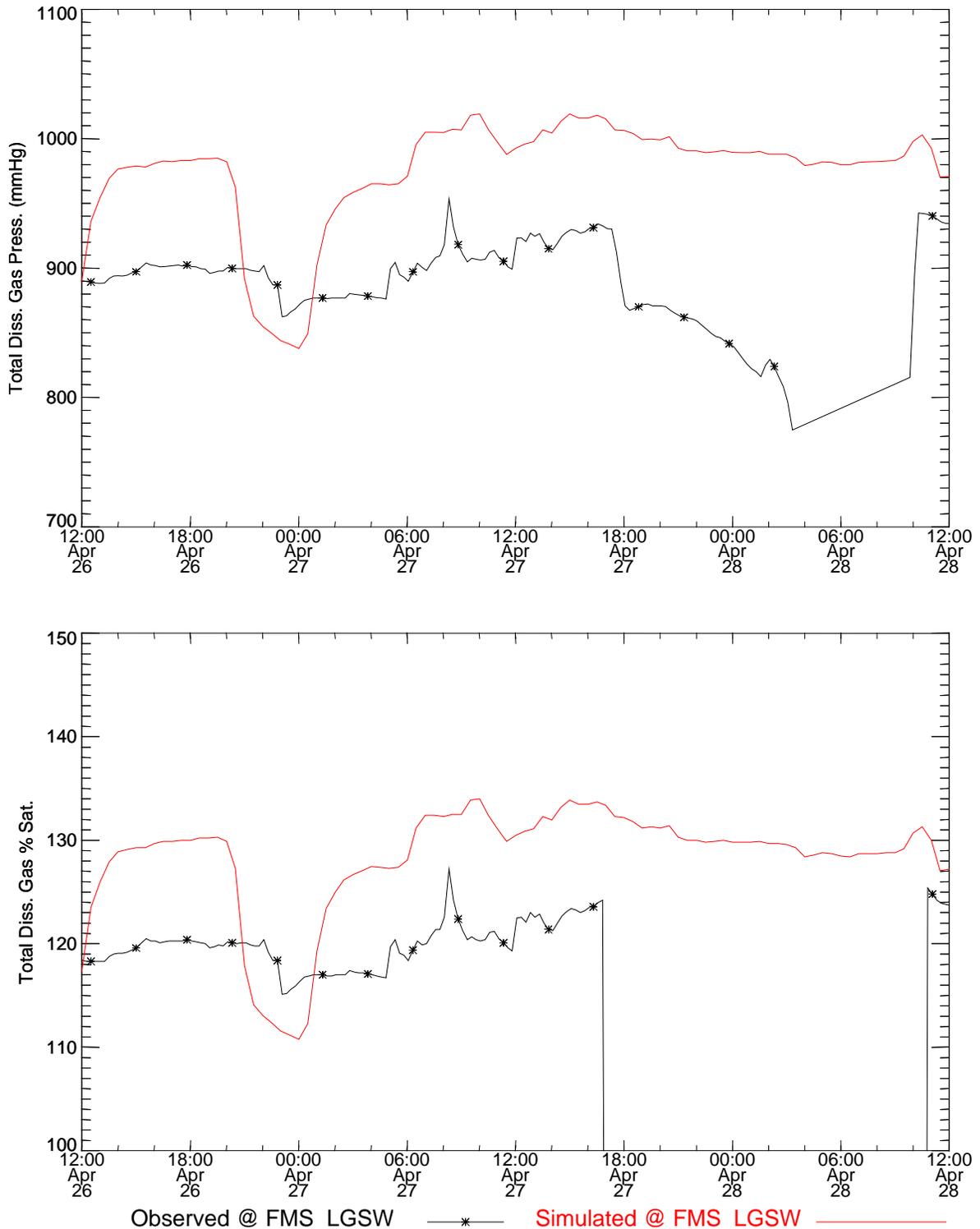


Figure 73. Total dissolved gas pressure and saturation time series comparisons near fixed monitor LGSW for the Spring 1996 study (TM-BC).

Table 35. Statistical summary of measurements and simulations at fixed monitor LGSW during the Spring 1996 study (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
FMS_LGSW	10.62	10.14	0.19	0.06	0.51
Concentration					
FMS_LGSW	35.19	39.5	1.64	1.73	4.88
Gas Pressure					
FMS_LGSW	877.34	974.58	43.19	42.24	113.44
% Saturation					
FMS_LGSW	75.82	128.24	57.66	5.34	78.99

Table 36. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at fixed monitor LGSW during the Spring 1996 study (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_LGSW	100	5.15	10.31	8.25

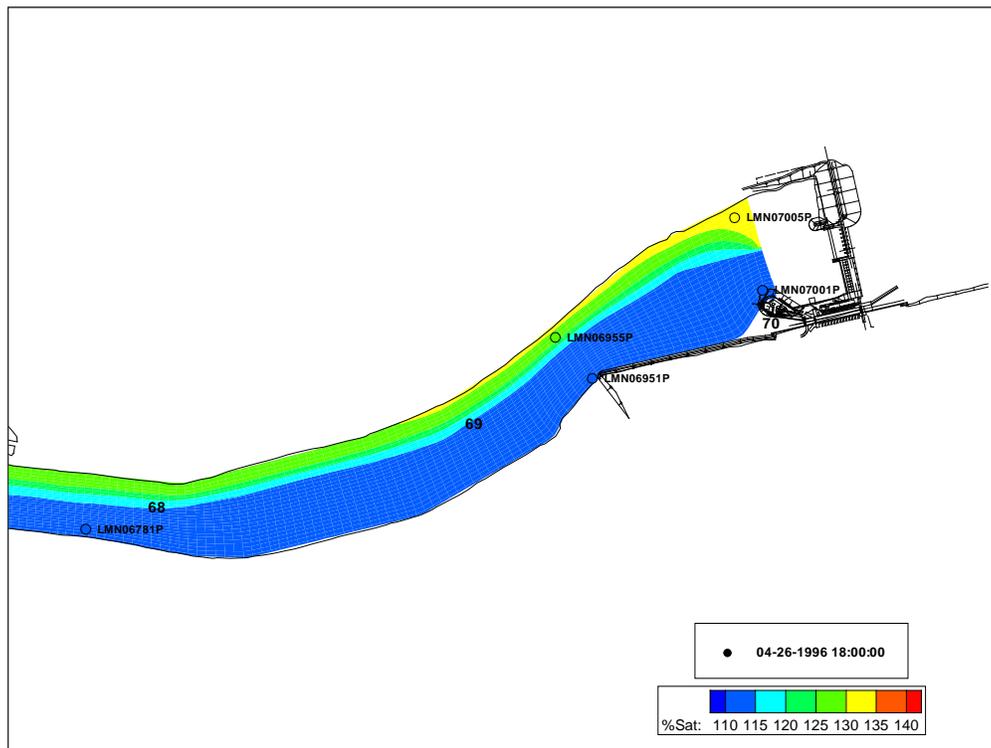


Figure 74. Spatial distribution of dissolved gas near Snake river mile 50 during the Spring 1996 study period.

1.4.2 Spring 1997 Simulation

Boundary Conditions using Lower Granite Sourcing Function and Forebay FMS Data

Comparisons between the measurements and simulations using an upstream boundary condition developed from the empirical project gas sourcing function and the forebay FMS are shown in the figures below. Statistics on comparisons between measured and simulated temperatures and total dissolved gas are also presented. The case is denoted as FMS-BC in the figure and table captions

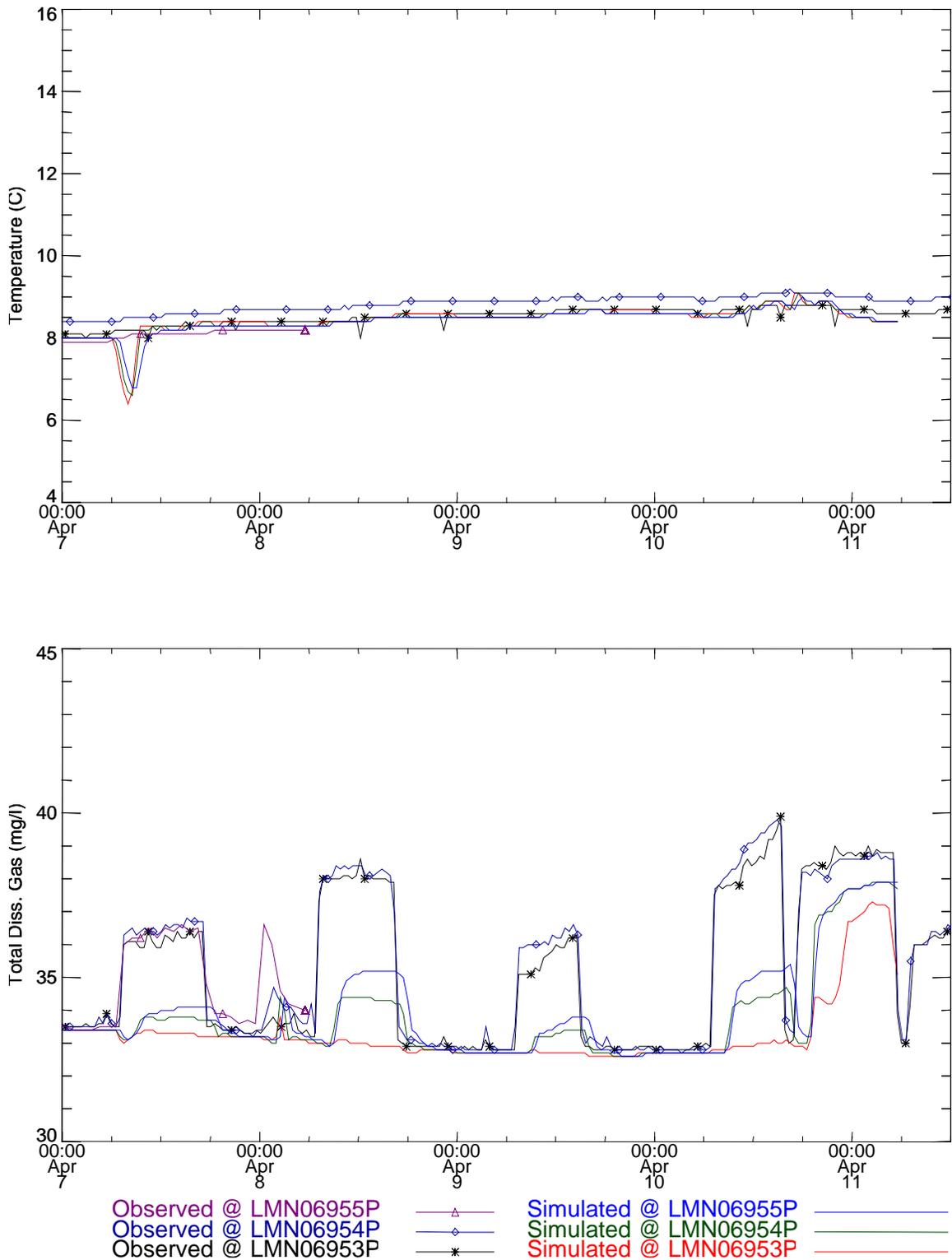


Figure 75. Temperature and total dissolved gas time series near Snake River Mile 069.5 for the Spring 1997 study (FMS-BC).

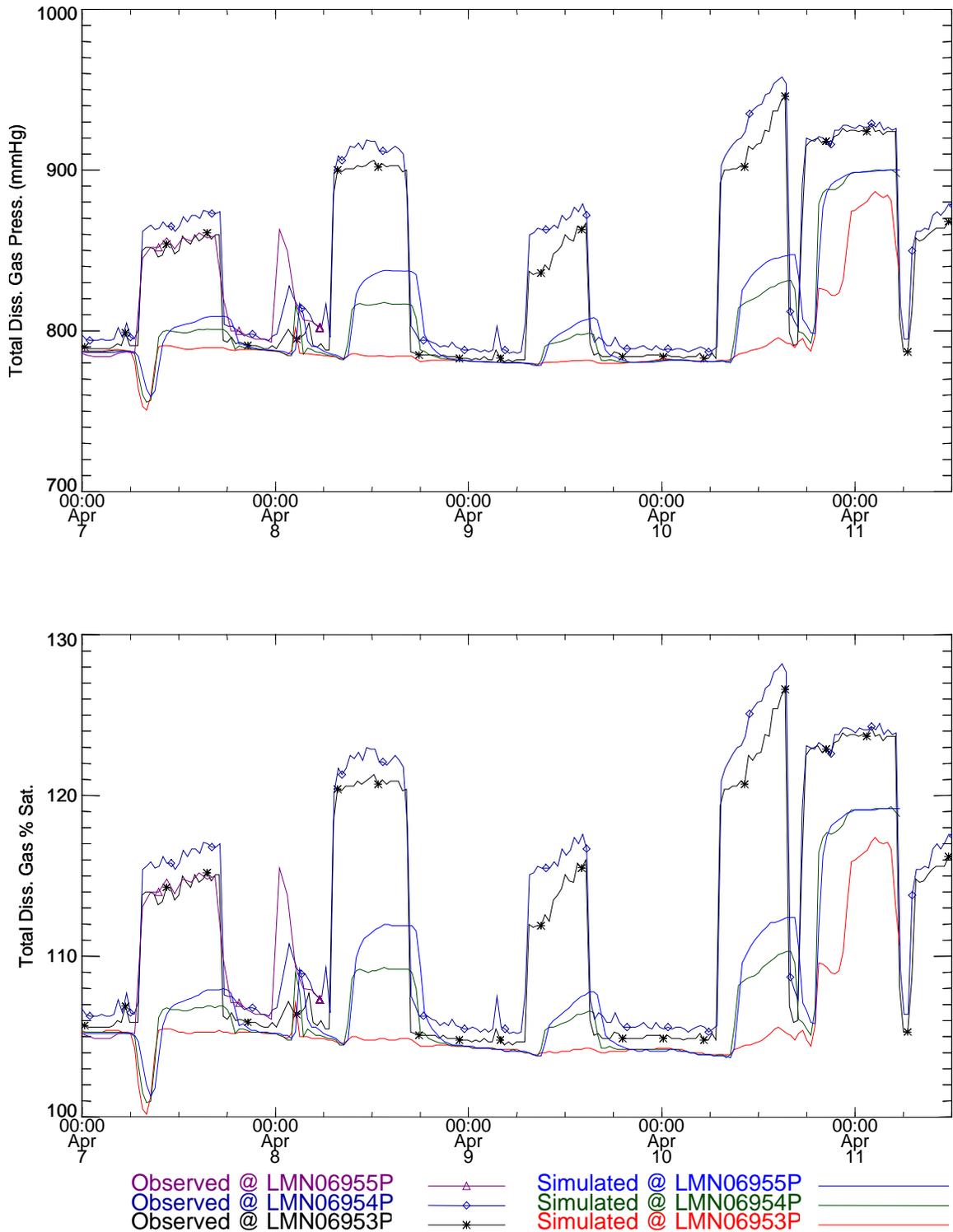


Figure 76. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 069.5 for the Spring 1997 study (FMS-BC).

Table 37. Statistical summary of measurements and simulations at River Mile 069.5 during the Spring 1997 study (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
LMN06953P	8.52	8.46	0.2	0.33	0.24
LMN06954P	8.83	8.44	0.2	0.32	0.44
LMN06955P	8.17	8.43	0.08	0.31	0.37
Concentration					
LMN06953P	35.17	33.26	2.31	1.02	2.78
LMN06954P	35.33	33.74	2.34	1.4	2.39
LMN06955P	34.24	33.92	0.78	1.45	1.69
Gas Pressure					
LMN06953P	836.17	791.76	55.1	24.47	64.96
LMN06954P	845.94	803.26	56.44	34.2	60.34
LMN06955P	807.18	807.28	17.99	35.52	41.19
% Saturation					
LMN06953P	111.92	105.53	7.38	3.04	9.09
LMN06954P	113.22	107.06	7.55	4.31	8.44
LMN06955P	108	107.59	2.41	4.5	5.3

Table 38. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at River Mile 069.5 during the Spring 1997 study (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
LMN06953P	98.04	51.47	52.45	51.96
LMN06954P	98.04	56.86	60.29	54.9
LMN06955P	99.02	36.27	73.53	76.96

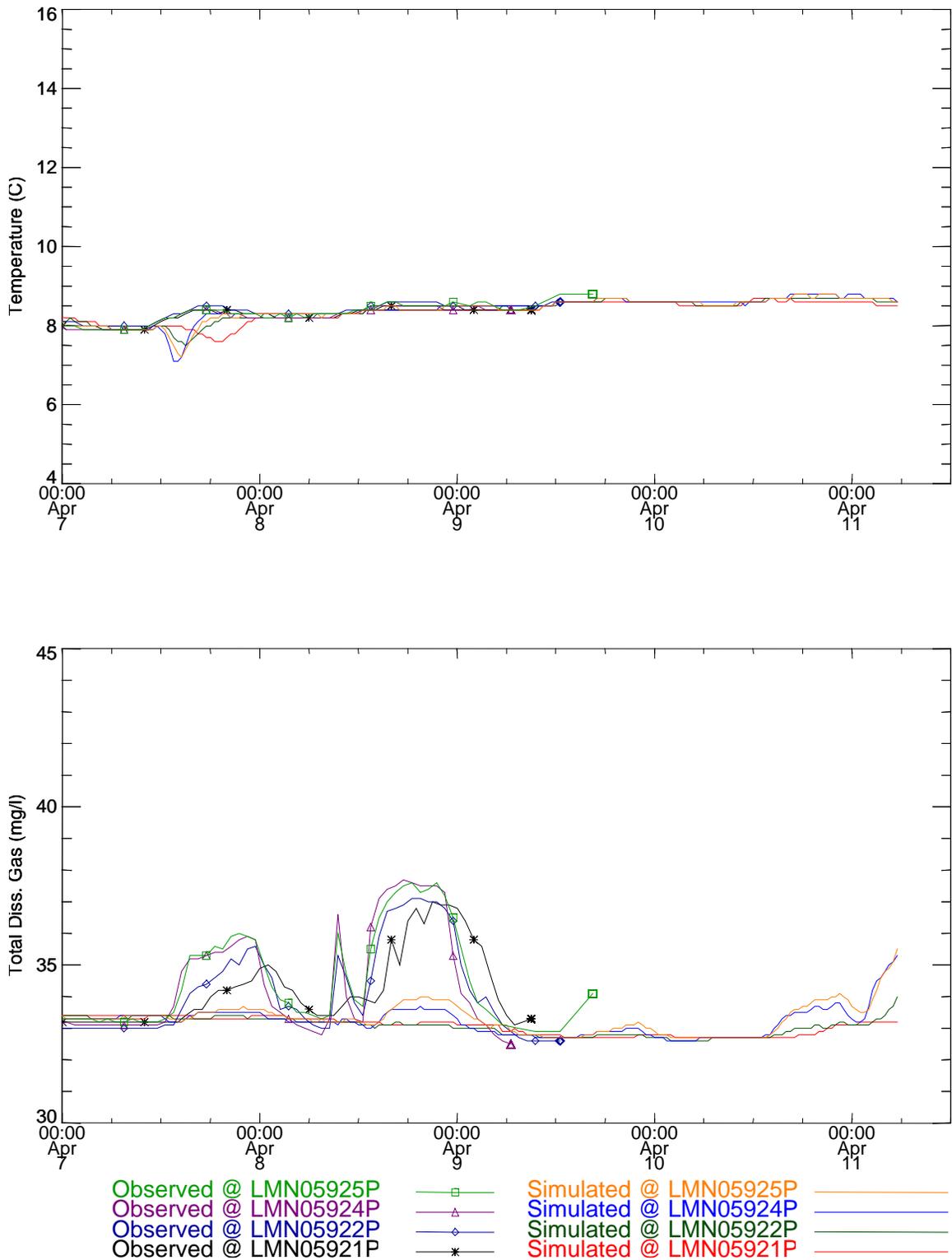


Figure 77. Temperature and total dissolved gas time series near Snake River Mile 059.2 for the Spring 1997 study (FMS-BC).

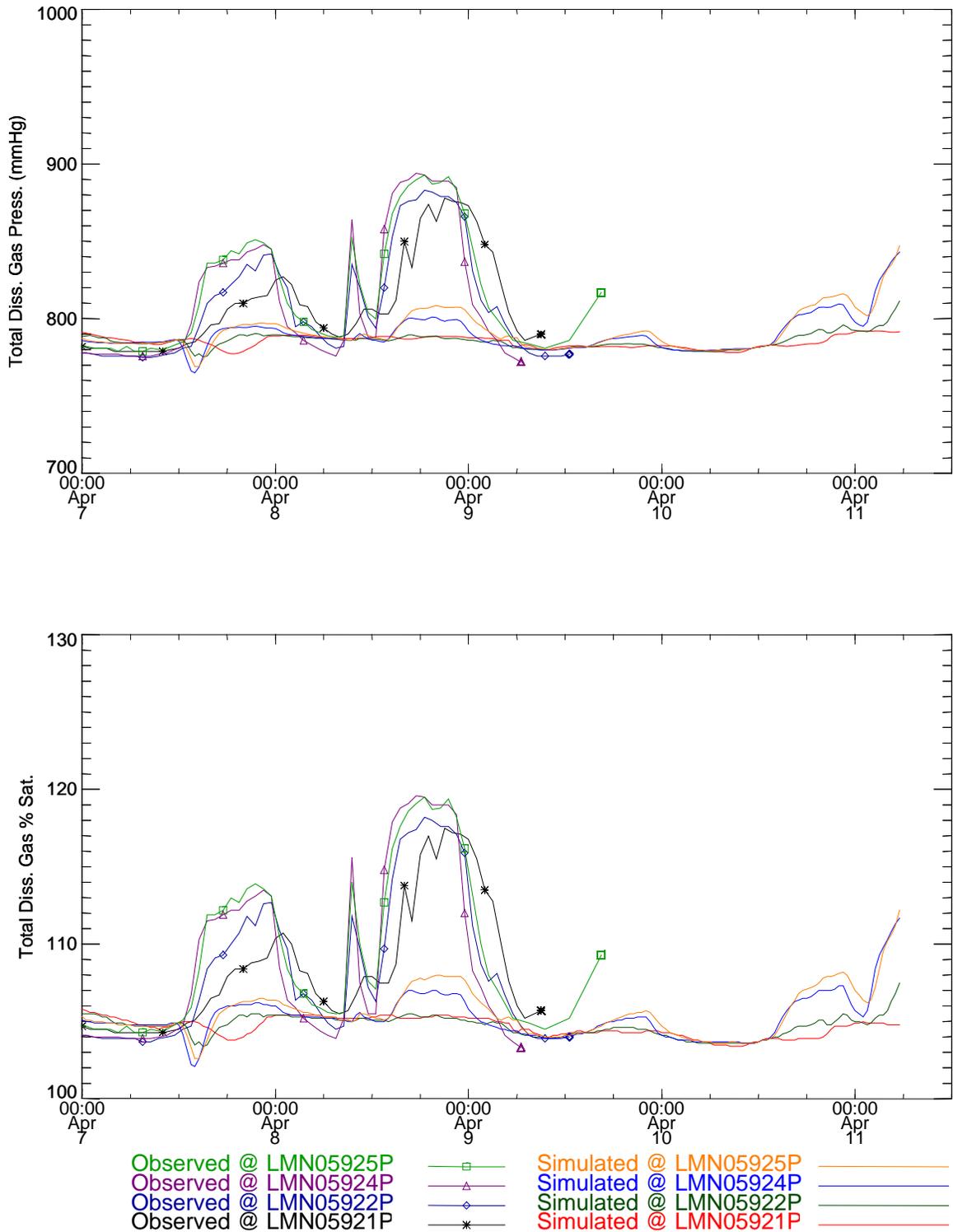


Figure 78. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 059.2 for the Spring 1997 study (FMS-BC).

Table 39. Statistical summary of measurements and simulations at River Mile 059.2 during the Spring 1997 study (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
LMN05921P	8.33	8.35	0.16	0.26	0.21
LMN05922P	8.46	8.38	0.19	0.27	0.19
LMN05924P	8.32	8.41	0.17	0.31	0.25
LMN05925P	8.51	8.4	0.29	0.3	0.21
Concentration					
LMN05921P	33.83	33.06	1.01	0.27	1.24
LMN05922P	33.53	33.05	1.32	0.27	1.35
LMN05924P	33.57	33.21	1.56	0.45	1.52
LMN05925P	34.32	33.3	1.19	0.48	1.49
Gas Pressure					
LMN05921P	801.2	785.08	24.66	3.78	28.78
LMN05922P	796.45	785.66	31.22	5.02	32.44
LMN05924P	795.18	789.73	36.81	11.5	36.84
LMN05925P	816.32	791.73	29	12.41	35.74
% Saturation					
LMN05921P	107.22	104.64	3.3	0.61	4.03
LMN05922P	106.6	104.72	4.17	0.66	4.37
LMN05924P	106.42	105.26	4.93	1.42	4.83
LMN05925P	109.24	105.53	3.88	1.55	5.03

Table 40. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at River Mile 059.2 during the Spring 1997 study (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat
LMN05921P	100	80.88	87.75	86.76
LMN05922P	100	76.47	83.33	81.86
LMN05924P	98.53	68.63	75	74.51
LMN05925P	99.51	53.43	77.94	64.71

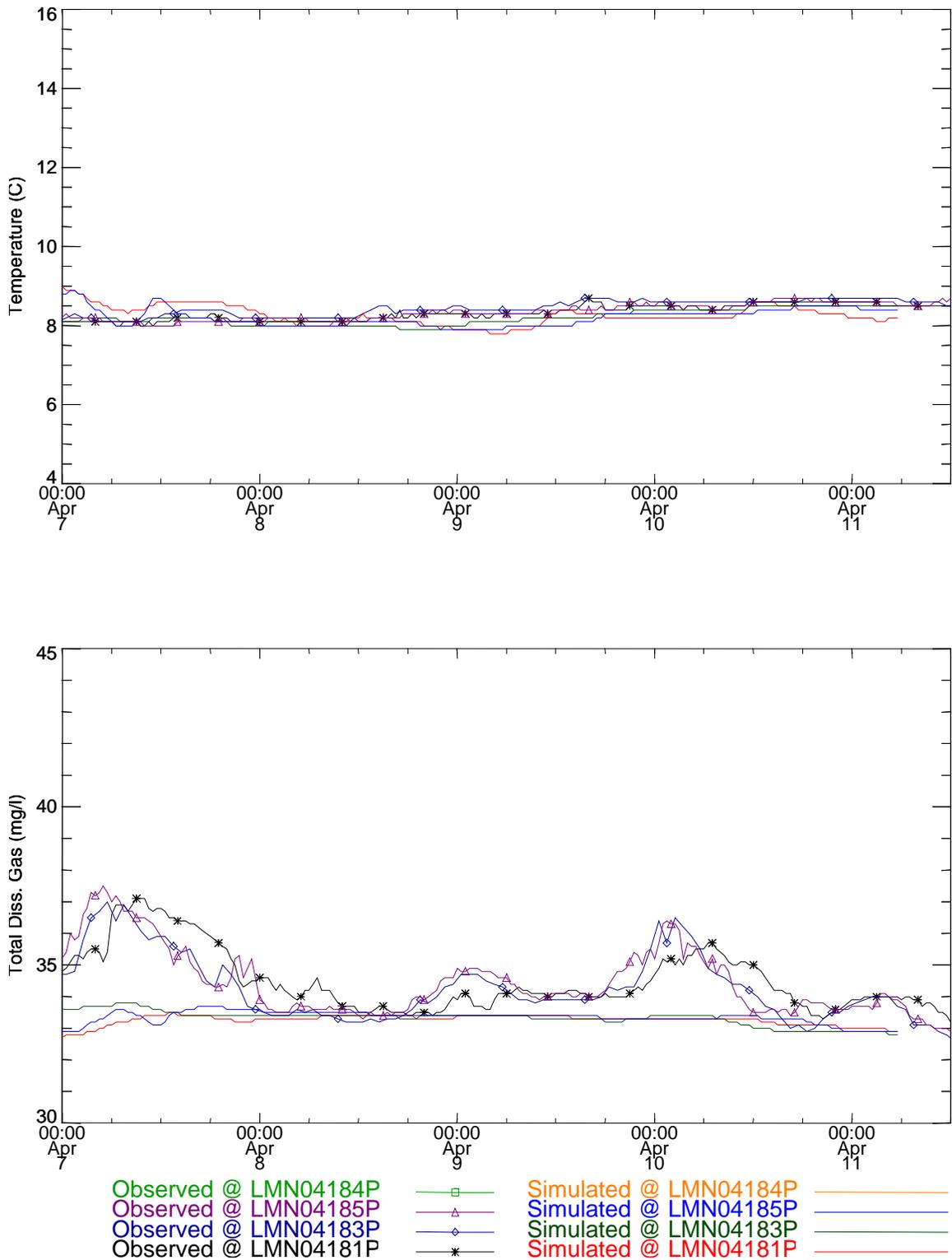


Figure 79. Temperature and total dissolved gas time series near Snake River Mile 041.8 for the Spring 1997 study (FMS-BC).

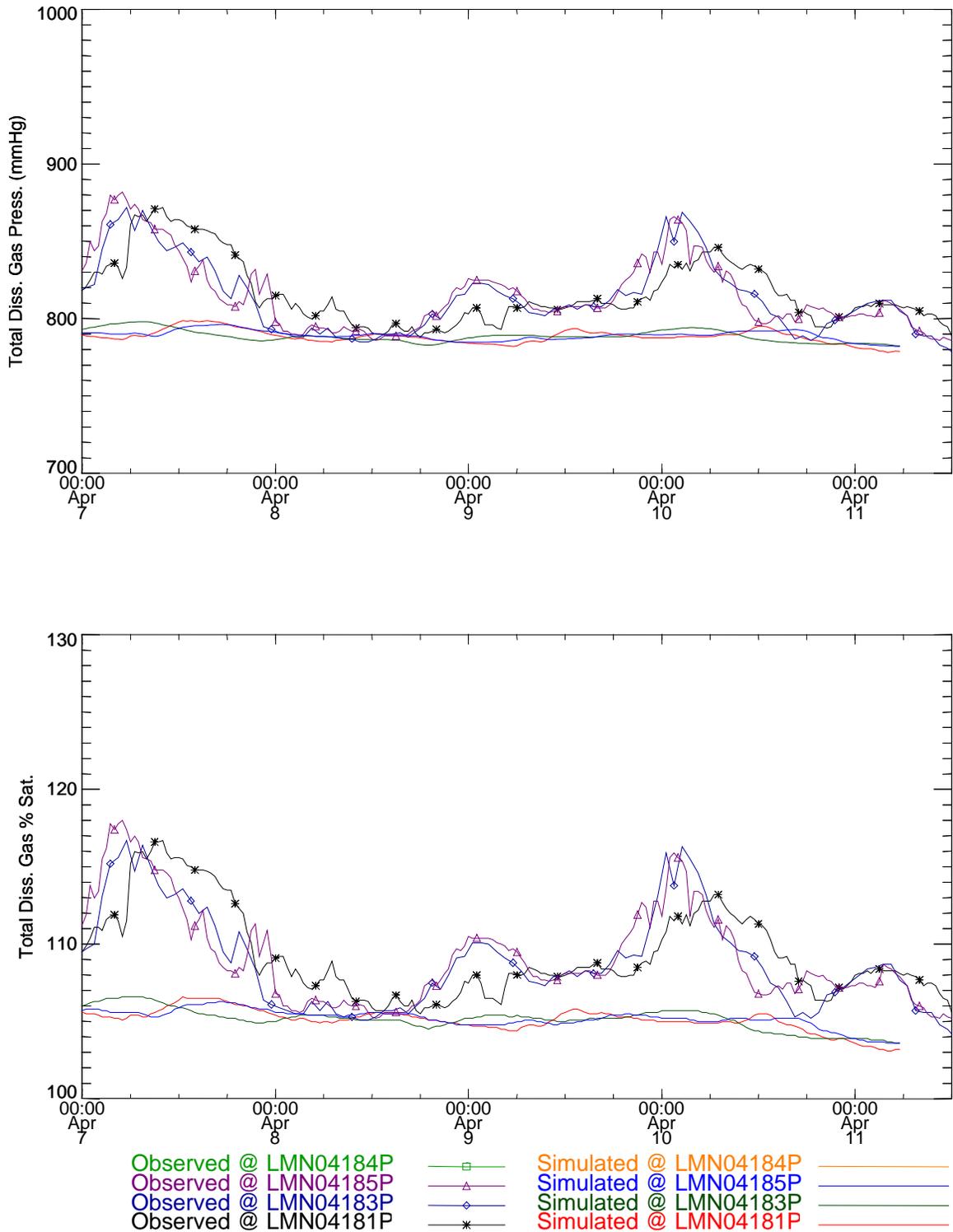


Figure 80. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 041.8 for the Spring 1997 study (FMS-BC).

Table 41. Statistical summary of measurements and simulations at River Mile 041.8 during the Spring 1997 study (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
LMN04181P	8.33	8.26	0.19	0.23	0.32
LMN04183P	8.45	8.24	0.19	0.19	0.26
LMN04185P	8.35	8.22	0.2	0.22	0.27
Concentration					
LMN04181P	34.51	33.24	0.97	0.18	1.59
LMN04183P	34.28	33.29	1.03	0.26	1.33
LMN04185P	34.46	33.32	1.05	0.22	1.55
Gas Pressure					
LMN04181P	816.82	787.93	21.34	4.79	34.51
LMN04183P	813.85	788.37	23.32	4.11	32.39
LMN04185P	816.14	788.86	23.5	3.51	35.54
% Saturation					
LMN04181P	109.31	104.99	2.86	0.83	5.02
LMN04183P	108.92	105.04	3.12	0.78	4.69
LMN04185P	109.22	105.11	3.15	0.67	5.09

Table 42. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at River Mile 041.8 during the Spring 1997 study (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat
LMN04181P	100	57.14	71.89	67.28
LMN04183P	100	58.99	77.88	74.65
LMN04185P	100	59.45	72.35	67.28

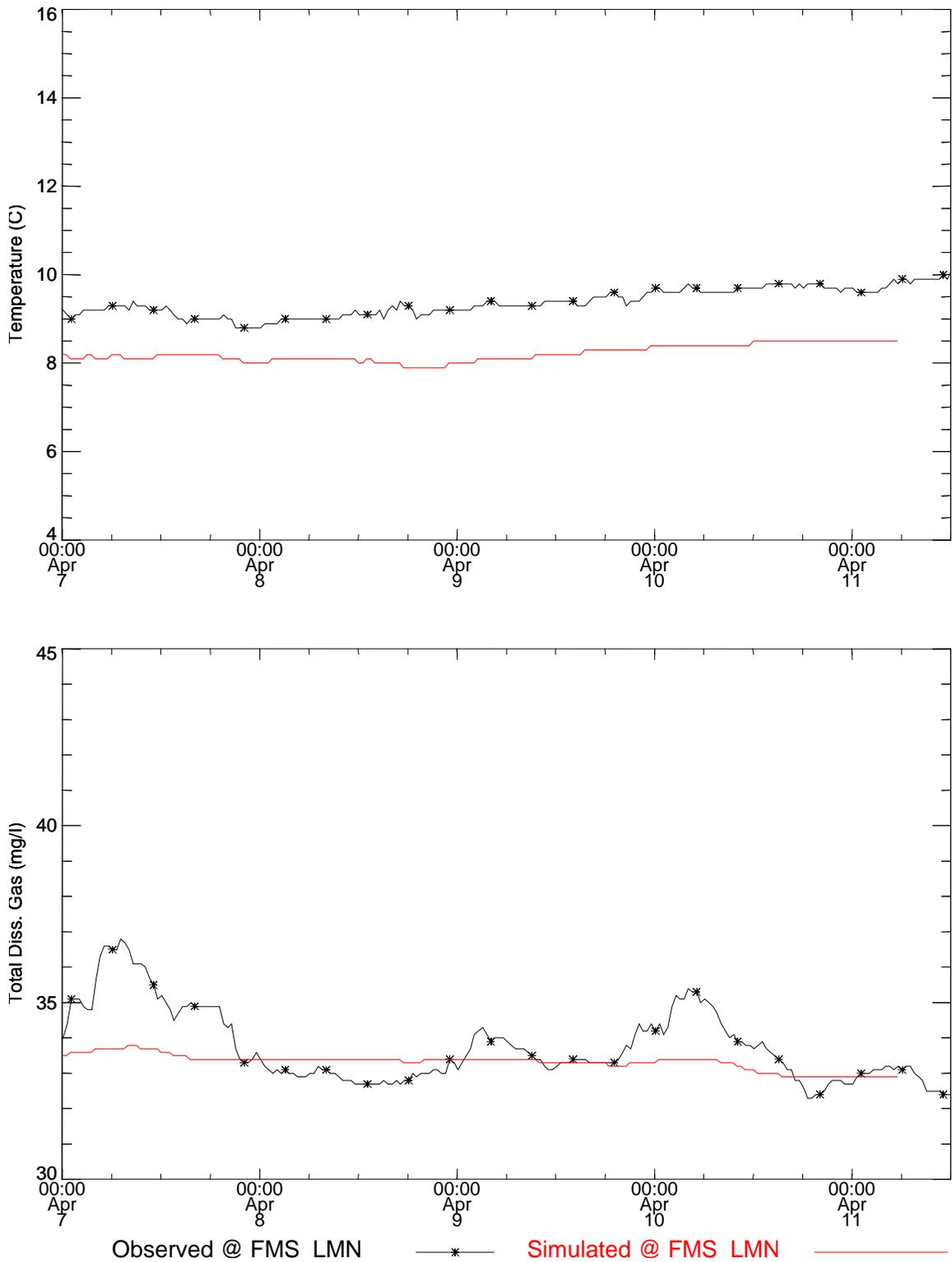


Figure 81. Temperature and total dissolved gas time series fixed monitor LMN for the Spring 1997 study (FMS-BC).

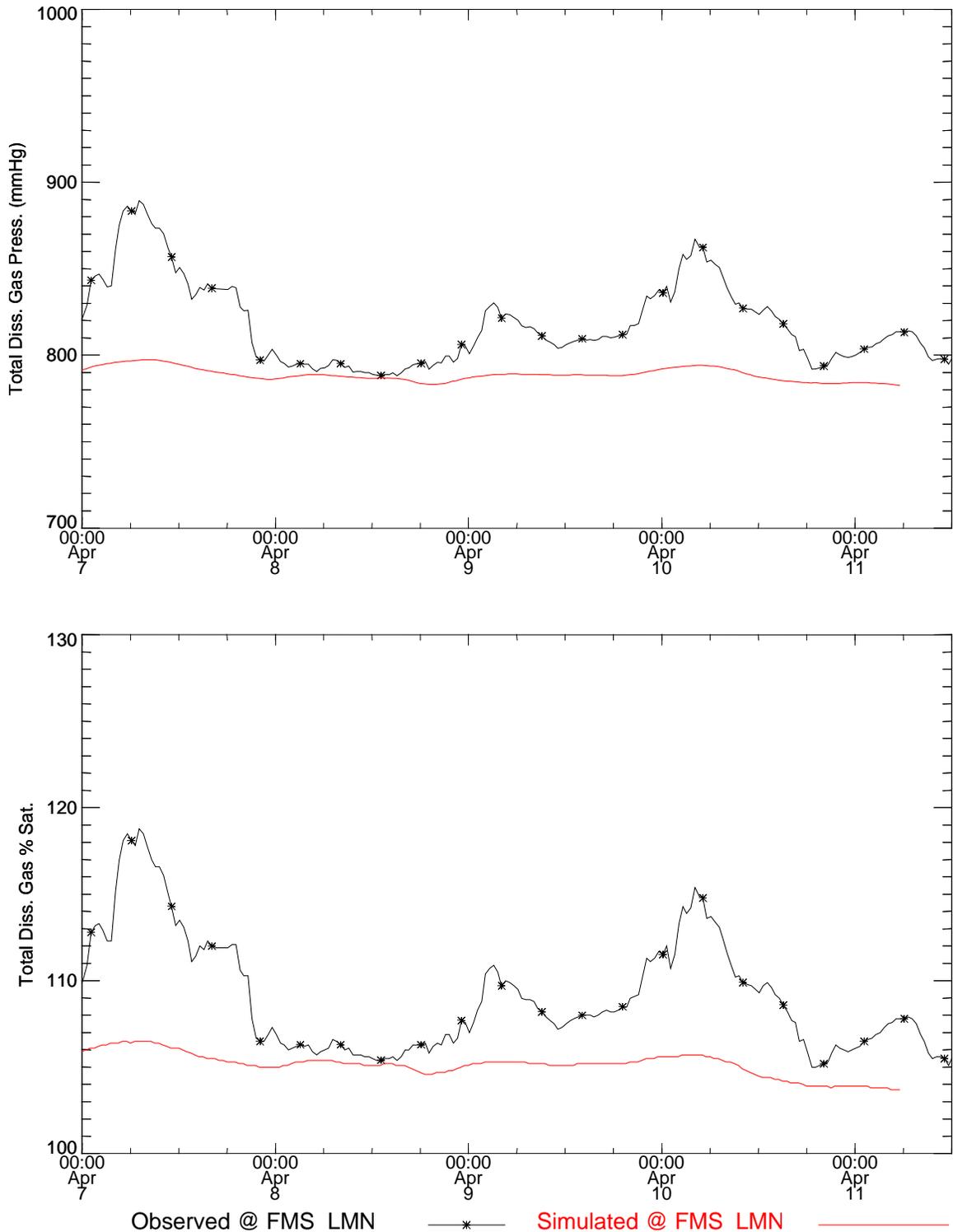


Figure 82. Total dissolved gas pressure and saturation time series comparisons near fixed monitor LMN for the Spring 1997 study (FMS-BC).

Table 43. Statistical summary of measurements and simulations at fixed monitor LMN during the Spring 1997 study (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_LMN	9.34	8.22	0.28	0.18	1.13
Concentration FMS_LMN	33.81	33.33	1.03	0.22	1.03
Gas Pressure FMS_LMN	819.36	788.83	24.9	3.8	37.44
% Saturation FMS_LMN	109.25	105.15	3.35	0.69	5.02

Table 44. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at fixed monitor LMN during the Spring 1997 study (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_LMN	26.96	74.02	65.2	64.22

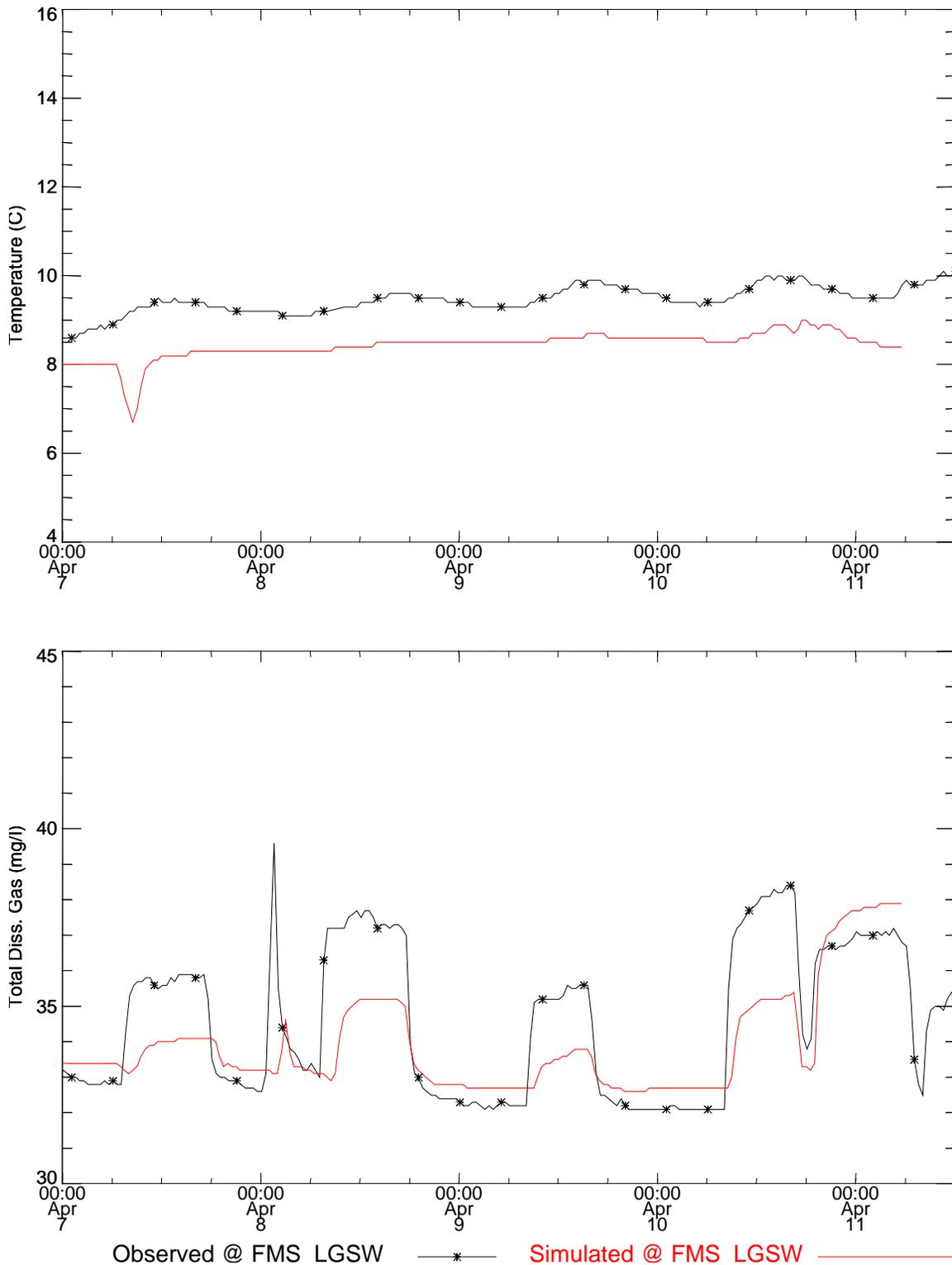


Figure 83. Temperature and total dissolved gas time series fixed monitor LGSW for the Spring 1997 study (FMS-BC).

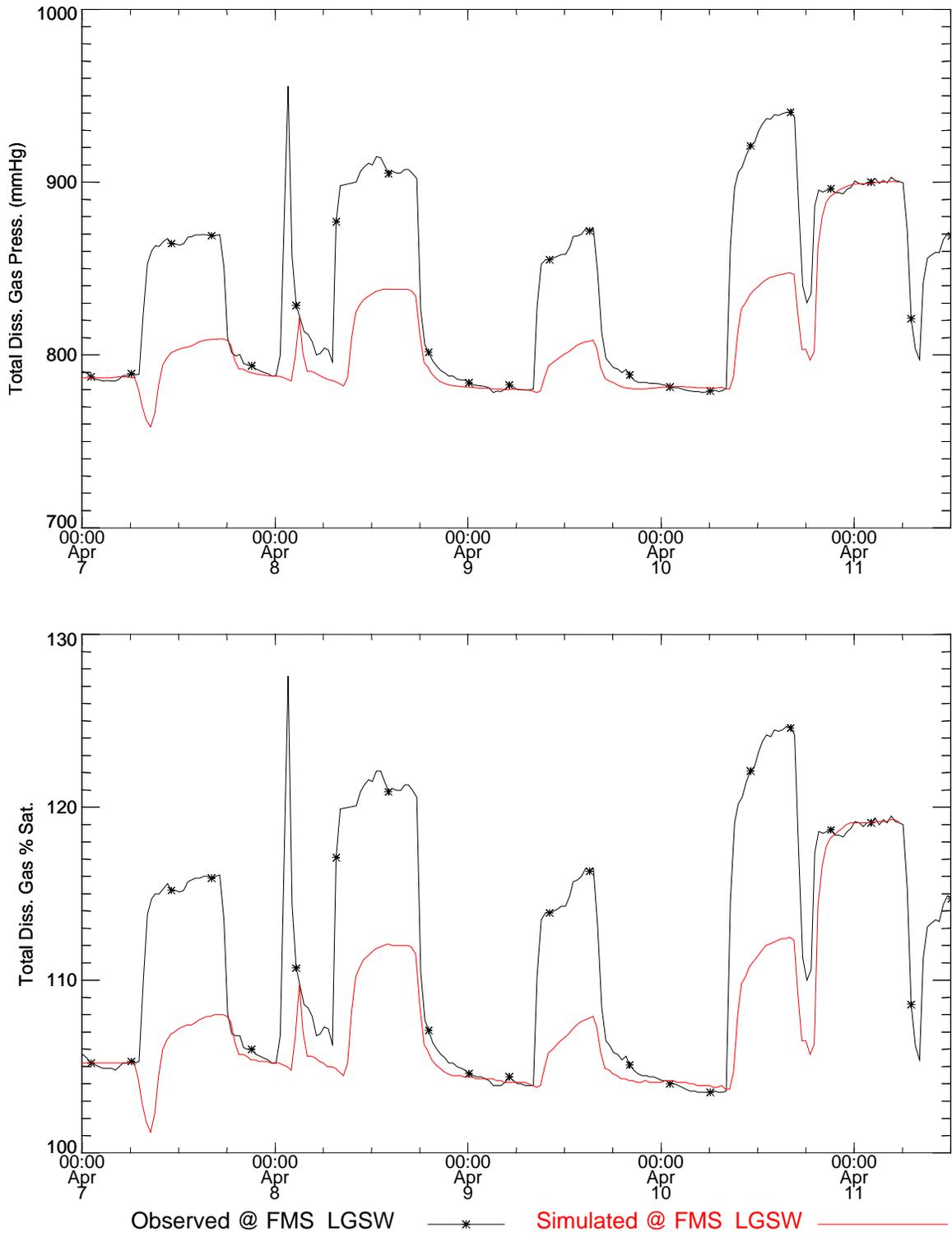


Figure 84. Total dissolved gas pressure and saturation time series comparisons near fixed monitor LGSW for the Spring 1997 study (FMS-BC).

Table 45. Statistical summary of measurements and simulations at fixed monitor LGSW during the Spring 1997 study (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_LGSW	9.43	8.43	0.29	0.31	1.03
Concentration FMS_LGSW	34.59	33.93	2.13	1.46	1.58
Gas Pressure FMS_LGSW	839.95	807.53	53.51	35.8	48.94
% Saturation FMS_LGSW	111.86	107.62	6.96	4.54	6.46

Table 46. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at fixed monitor LGSW during the Spring 1997 study (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_LGSW	65.69	60.29	60.29	60.29

Boundary Conditions using Temporary Monitored Field Data

Comparisons between the measurements and simulations using an upstream boundary condition developed from water temperatures and TDG pressures measured by temporary monitors are shown in the figures below. Statistics on comparisons between measured and simulated temperatures and total dissolved gas are also presented. The case is denoted as TM-BC in the figure and table captions.

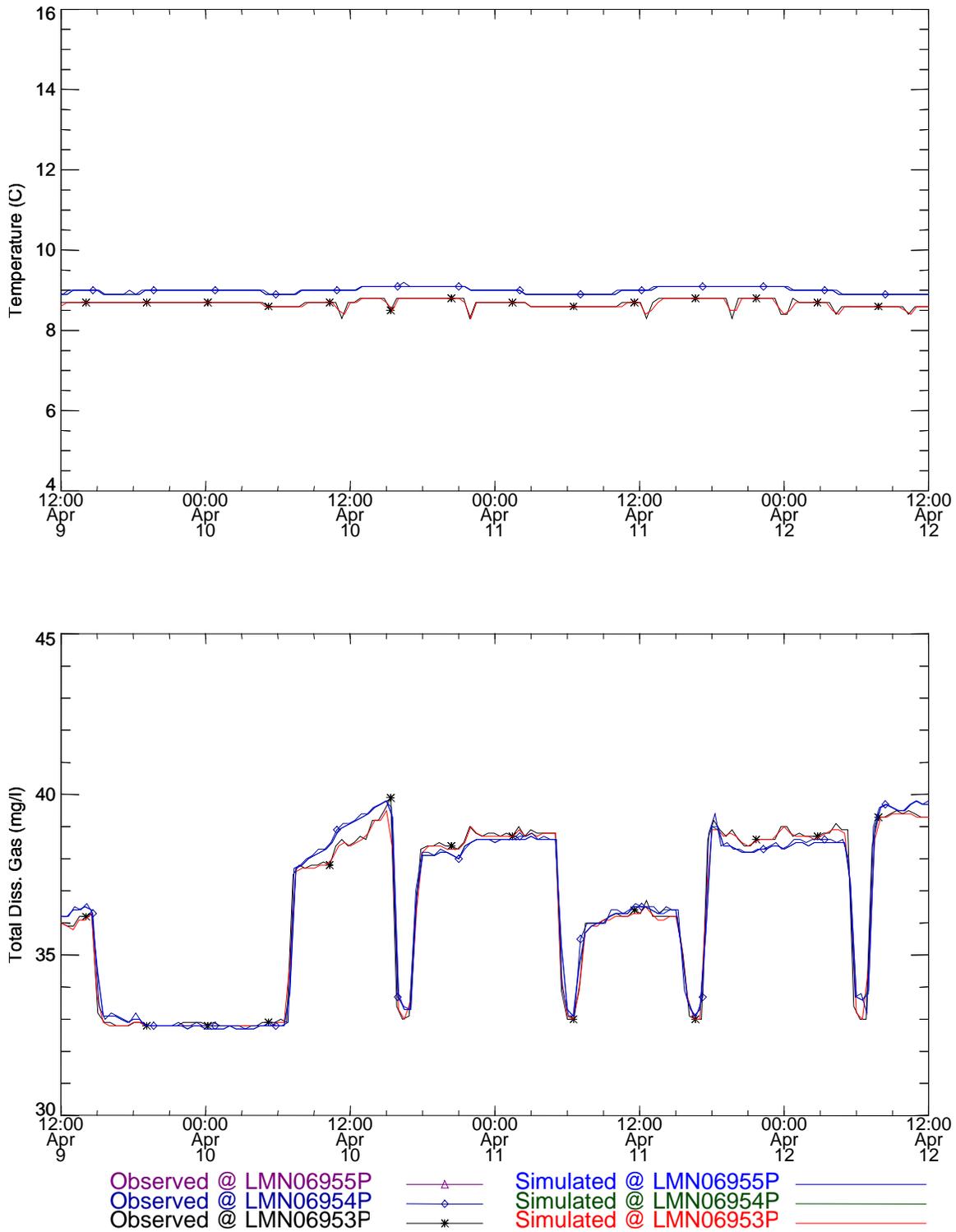


Figure 85. Temperature and total dissolved gas time series near Snake River Mile 069.5 for the Spring 1997 study (TM-BC).

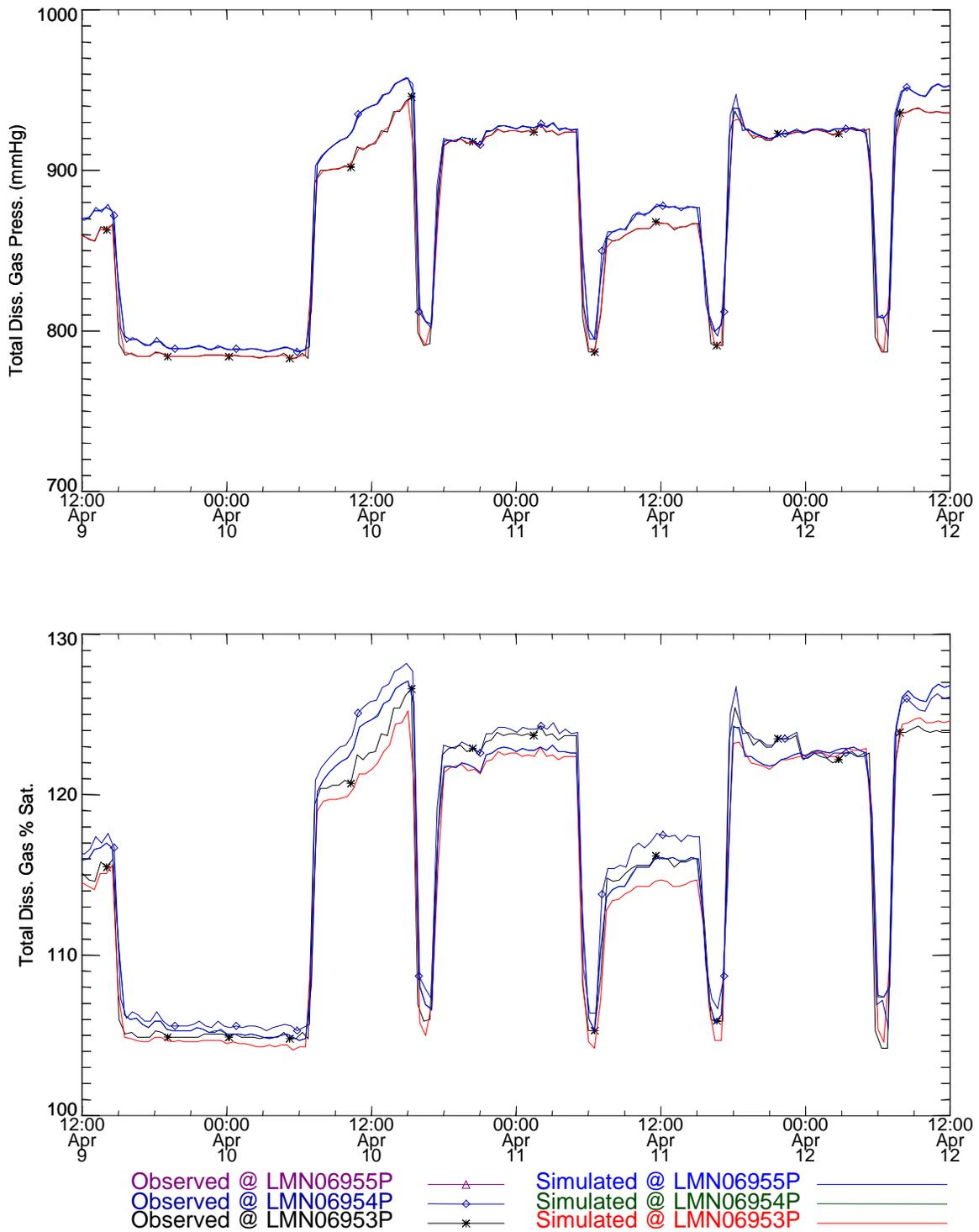


Figure 86. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 069.5 for the Spring 1997 study (TM-BC).

Table 47. Statistical summary of measurements and simulations at River Mile 069.5 during the Spring 1997 study (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
LMN06953P	8.68	8.67	0.09	0.1	0.03
LMN06954P	9	9	0.08	0.08	0.02
LMN06955P	8.2	9	0	0.08	0.8
Concentration					
LMN06953P	36.48	36.44	2.52	2.52	0.12
LMN06954P	36.54	36.49	2.5	2.51	0.13
LMN06955P	34	36.49	0	2.51	3.53
Gas Pressure					
LMN06953P	870.18	870.13	59.5	59.44	2.64
LMN06954P	877.9	877.78	59.78	59.92	2.74
LMN06955P	802	877.75	0	59.92	96.58
% Saturation					
LMN06953P	116.22	115.51	7.8	7.73	1.02
LMN06954P	117.26	116.52	7.84	7.8	1.03
LMN06955P	107.3	116.52	0	7.8	12.08

Table 48. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at River Mile 069.5 during the Spring 1997 study (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
LMN06953P	100	100	100	100
LMN06954P	100	100	100	100
LMN06955P	100	13.79	31.03	32.41

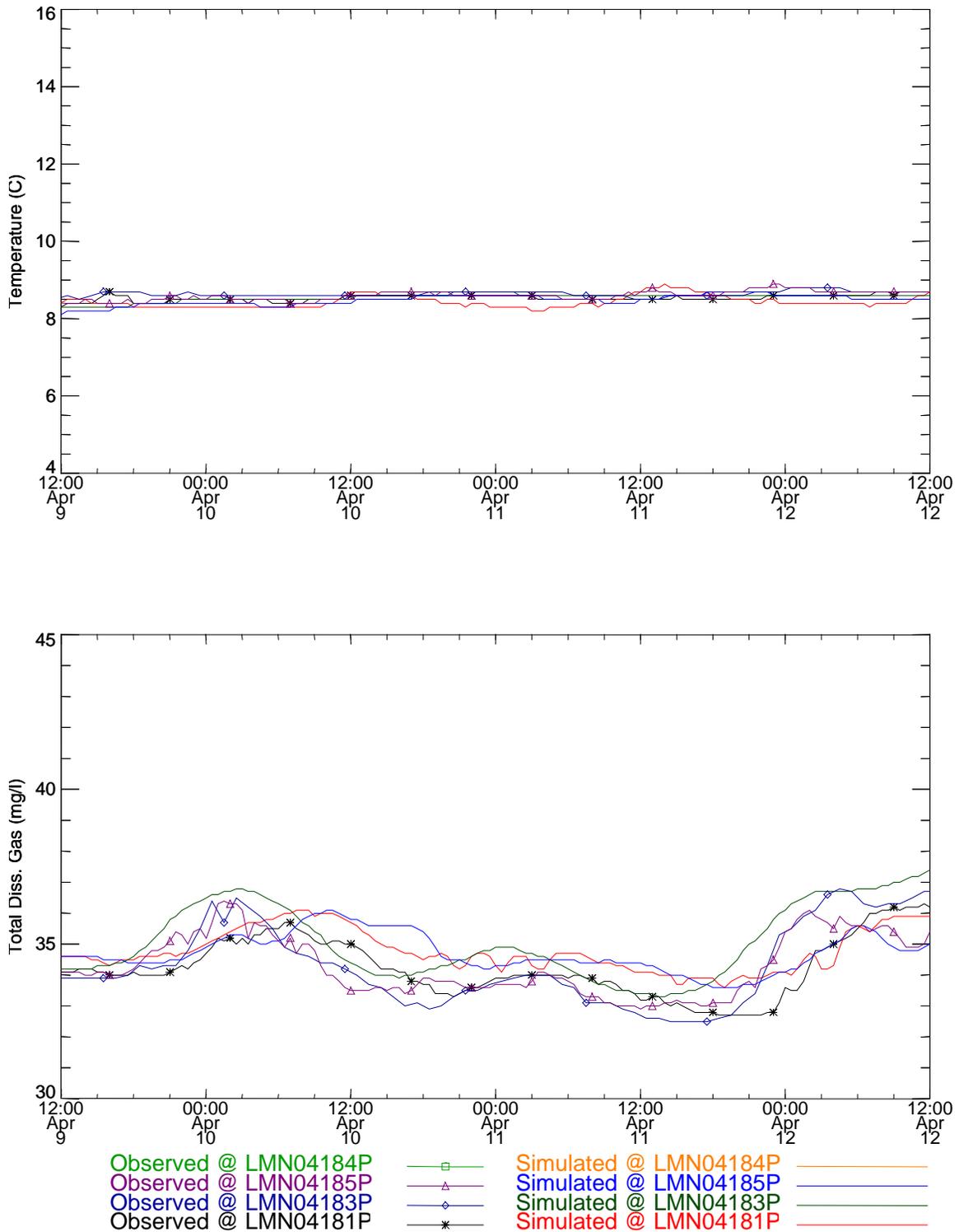


Figure 87. Temperature and total dissolved gas time series near Snake River Mile 041.8 for the Spring 1997 study (TM-BC).

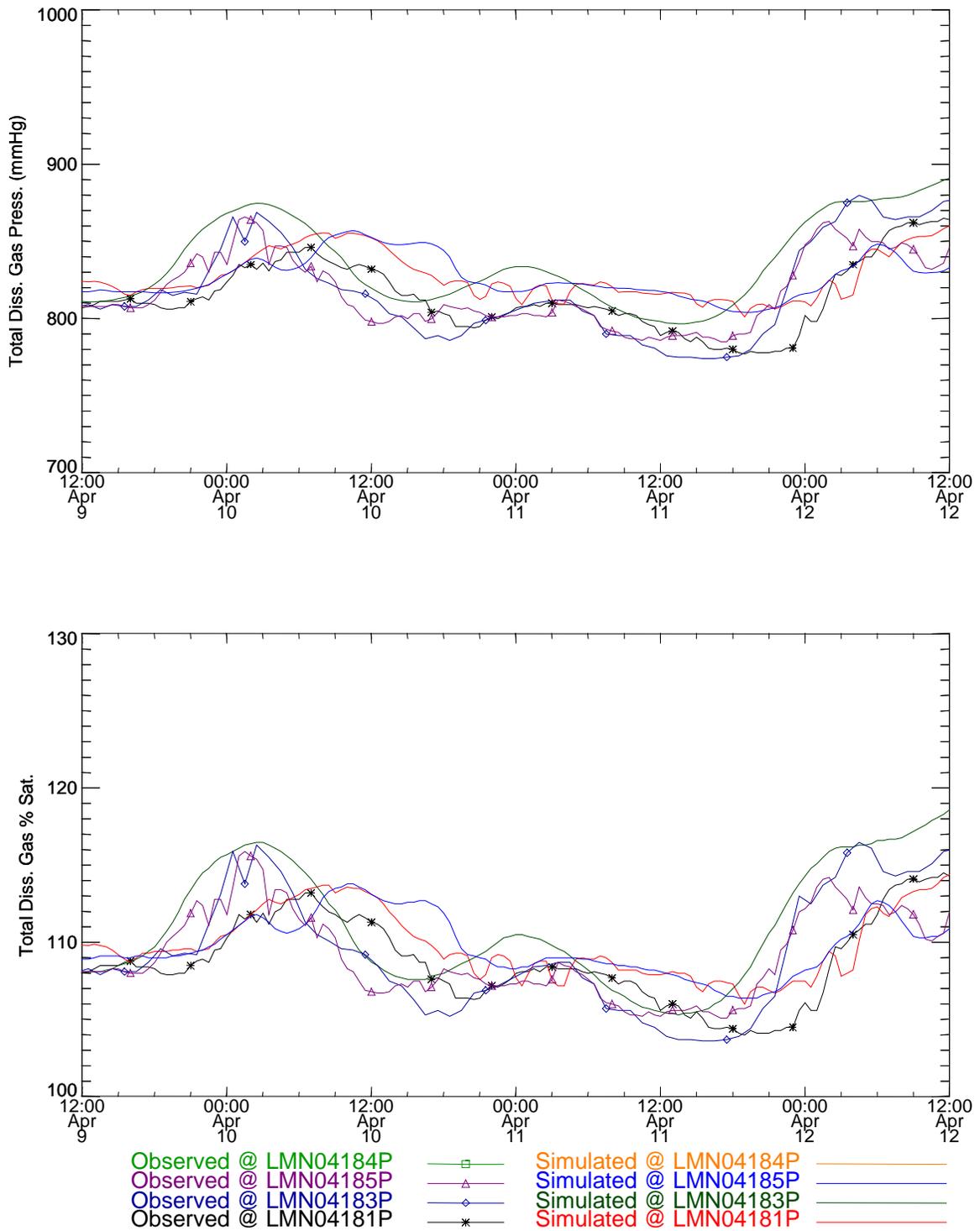


Figure 88. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 041.8 for the Spring 1997 study (TM-BC).

Table 49. Statistical summary of measurements and simulations at River Mile 041.8 during the Spring 1997 study (TM-BC).

Station	Measured	Simulated	Measured	Simulated	RMS
Temperature					
LMN04181P	8.54	8.44	0.08	0.15	0.19
LMN04183P	8.65	8.55	0.07	0.1	0.14
LMN04185P	8.6	8.49	0.12	0.13	0.15
Concentration					
LMN04181P	34.23	34.78	0.95	0.68	0.7
LMN04183P	34.3	35.08	1.3	1.2	0.87
LMN04185P	34.3	34.72	0.97	0.62	1.03
Gas Pressure					
LMN04181P	814.35	827.17	22.66	15.44	17.48
LMN04183P	818.18	836.44	31.27	28.02	20.87
LMN04185P	817.09	826.78	23.09	13.8	24.77
% Saturation					
LMN04181P	108.77	109.82	2.8	2.19	1.58
LMN04183P	109.28	111.05	3.85	3.86	2.13
LMN04185P	109.14	109.77	2.82	1.93	2.78

Table 50. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at River Mile 041.8 during the Spring 1997 study (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
LMN04181P	100	88.97	100	100
LMN04183P	100	73.79	95.86	100
LMN04185P	100	71.03	86.21	88.28

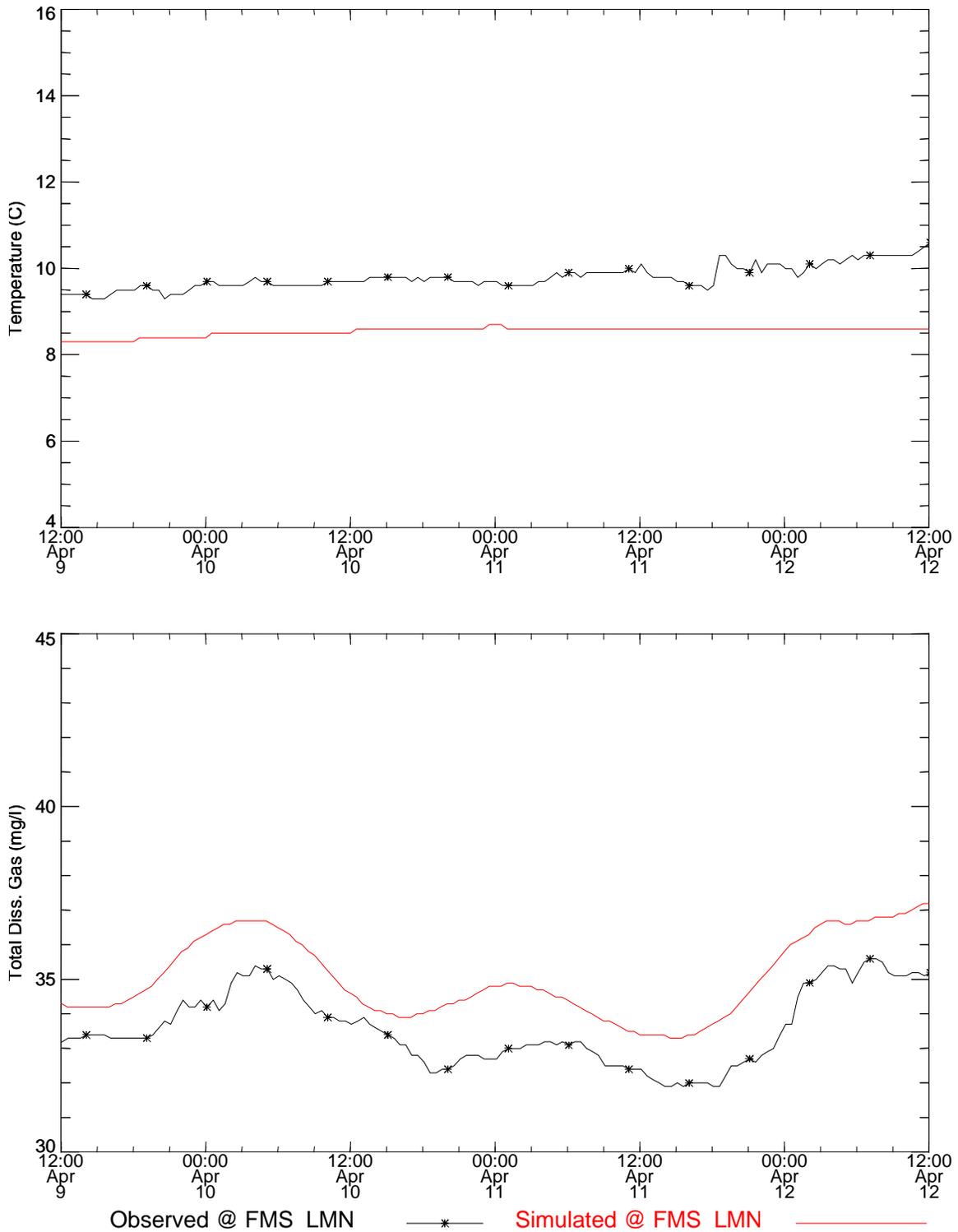


Figure 89. Temperature and total dissolved gas time series near fixed monitor LMN for the Spring 1997 study (TM-BC).

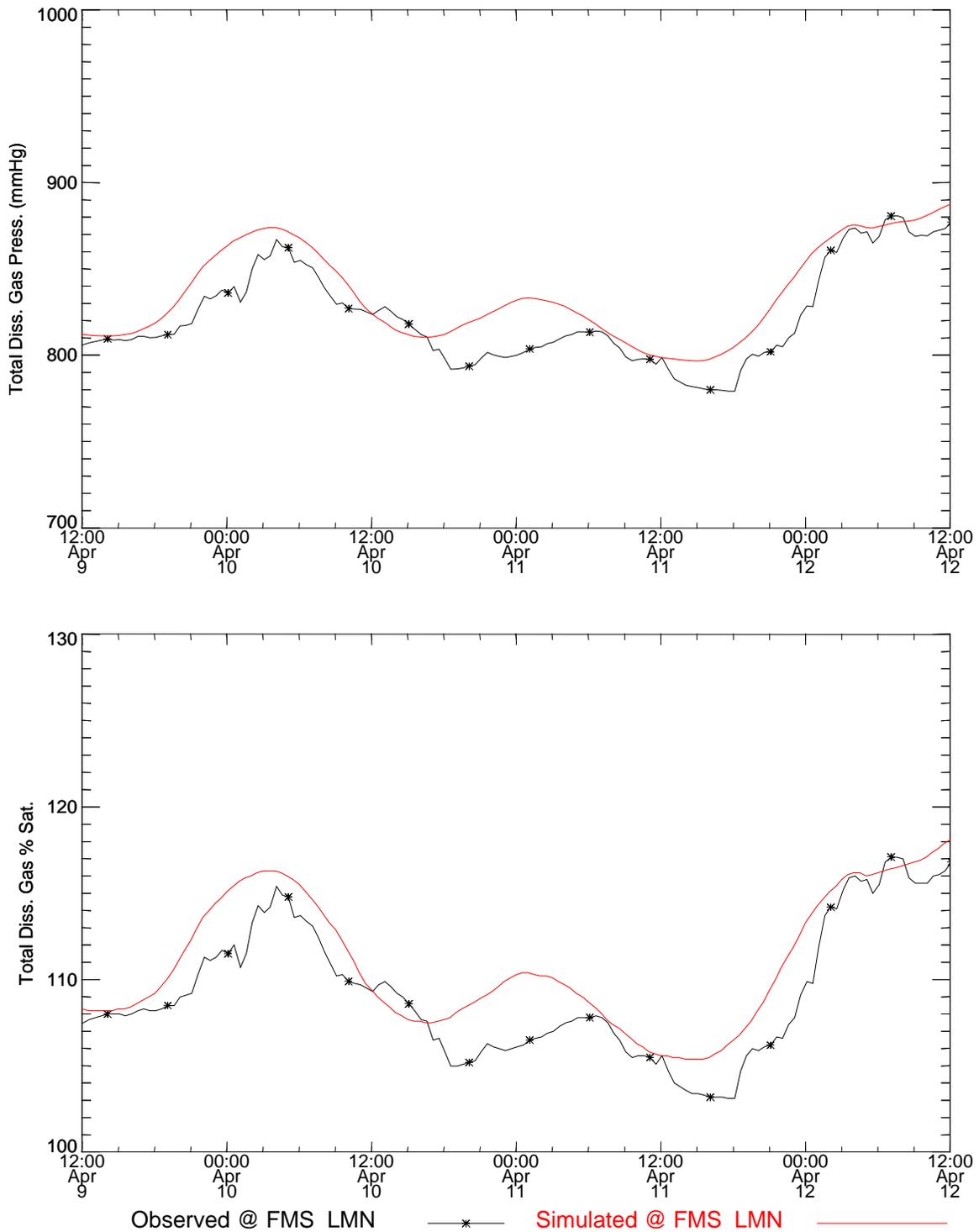


Figure 90. Total dissolved gas pressure and saturation time series comparisons near fixed monitor LMN for the Spring 1997 study (TM-BC).

Table 51. Statistical summary of measurements and simulations at fixed monitor LMN during the Spring 1997 study (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature FMS_LMN	9.79	8.54	0.27	0.1	1.27
Concentration FMS_LMN	33.58	35.03	1.07	1.16	1.51
Gas Pressure FMS_LMN	822.19	835.22	27.81	27.03	16.74
% Saturation FMS_LMN	109.2	110.89	3.85	3.74	2.2

Table 52. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at fixed monitor LMN during the Spring 1997 study (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_LMN	12.41	15.86	100	100

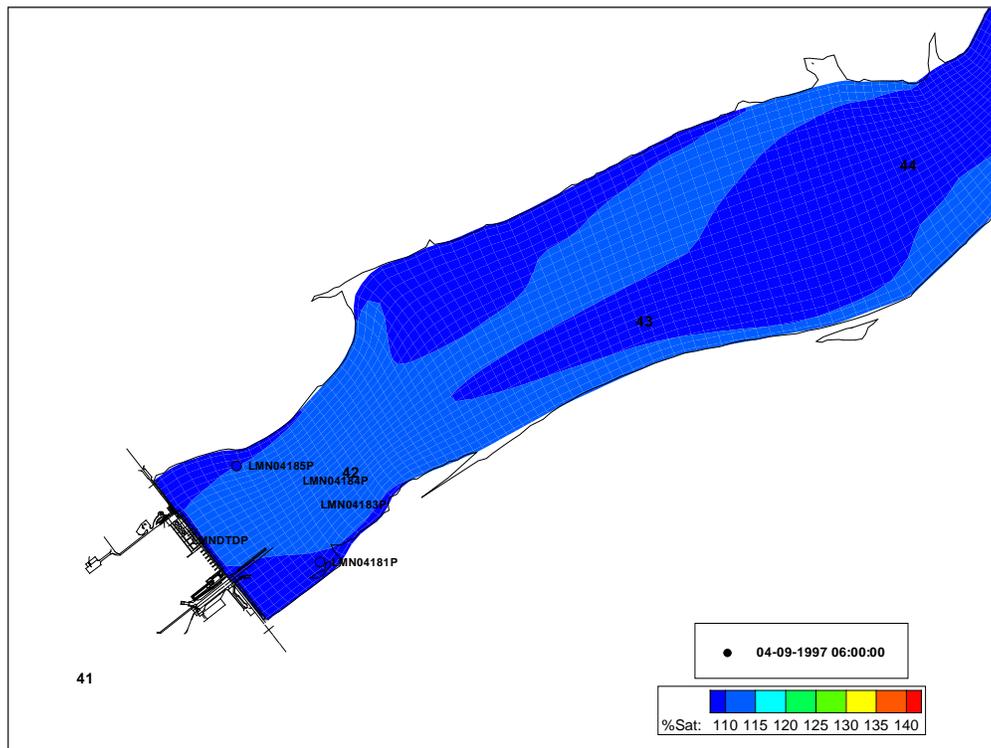


Figure 91. Spatial distribution of dissolved gas near Snake river mile 42 during the Spring 1997 study period.

1.4.3 1997 Summer Simulation

Boundary Conditions using Lower Granite Sourcing Function and Forebay FMS Data

Comparisons between the measurements and simulations using an upstream boundary condition developed from the empirical project gas sourcing function and the forebay FMS are shown in the figures below. Statistics on comparisons between measured and simulated temperatures and total dissolved gas are also presented. The case is denoted as FMS-BC in the figure and table captions.

The fixed monitor station LGSW had no dissolved gas data available for the Summer 1997 study period, so no graph is shown for that station.

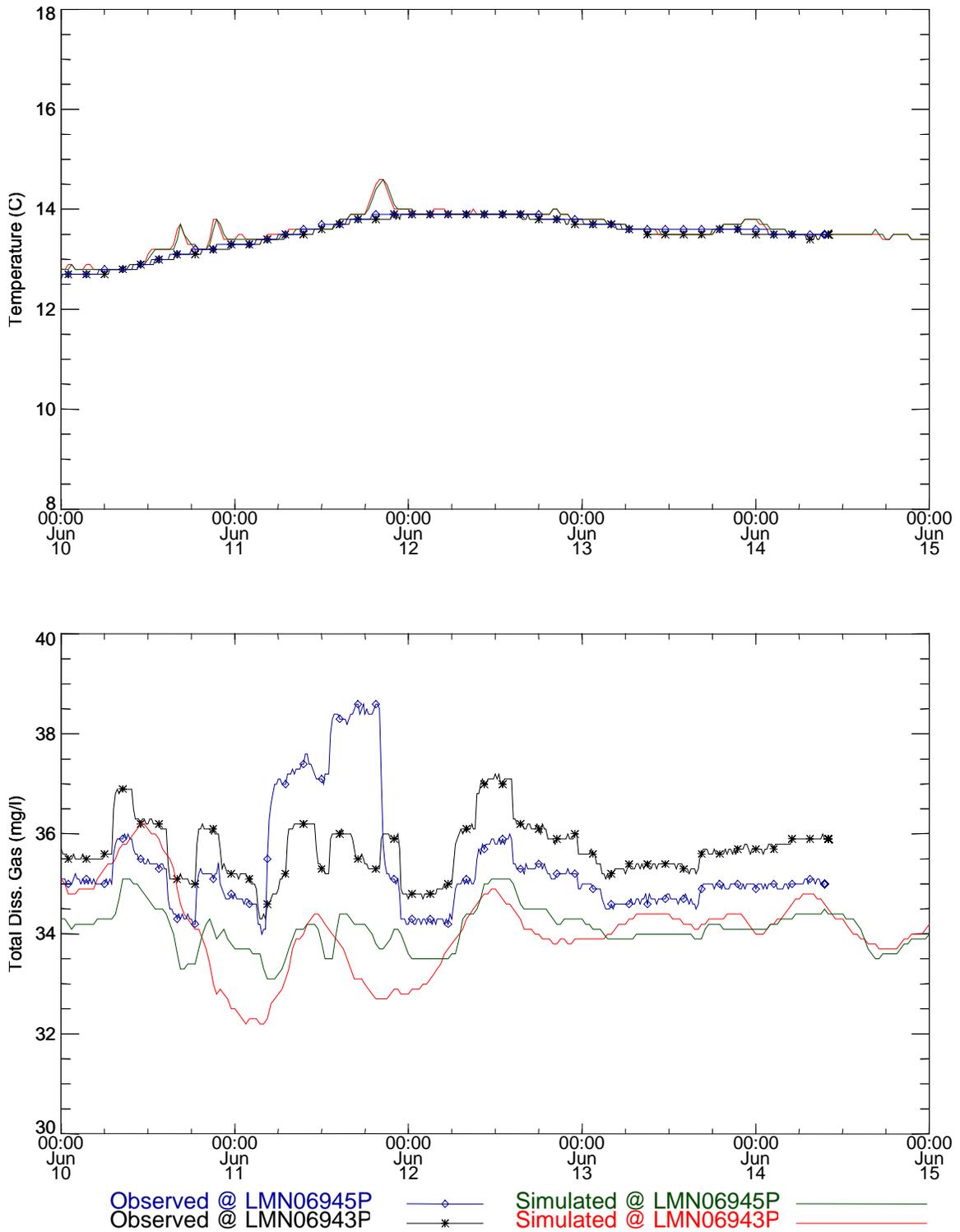


Figure 92. Temperature and total dissolved gas time series near Snake River Mile 069.4 for the Summer 1997 study (FMS-BC).

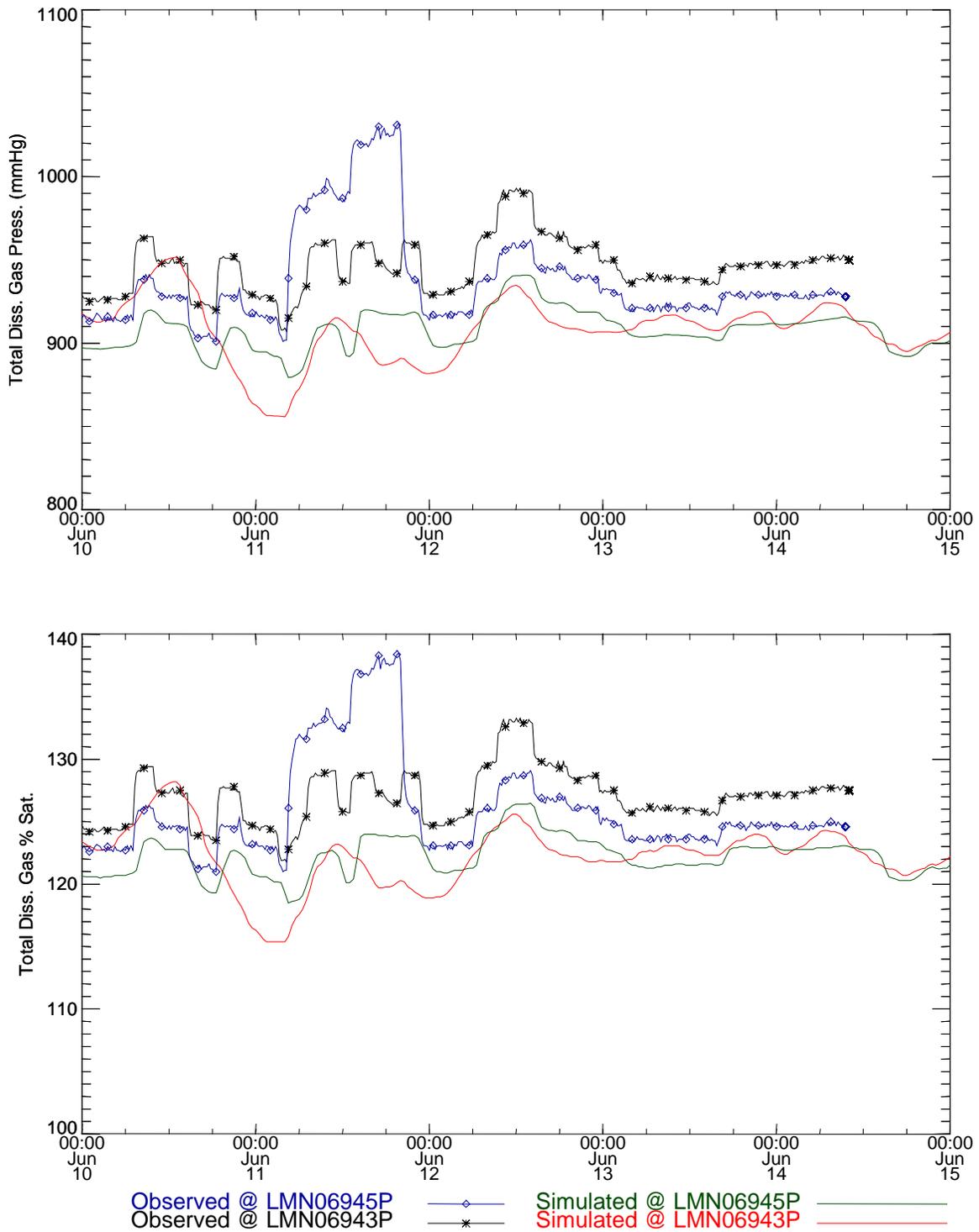


Figure 93. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 069.4 for the Summer 1997 study (FMS-BC).

Table 53. Statistical summary of measurements and simulations at River Mile 069.4 during the Summer 1997 study (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
LMN06943P	13.49	13.58	0.34	0.34	0.17
LMN06945P	13.52	13.57	0.33	0.35	0.14
Concentration					
LMN06943P	35.71	34.07	0.53	0.84	1.79
LMN06945P	35.33	34.09	1.02	0.42	1.62
Gas Pressure					
LMN06943P	946.49	907.42	15.38	19.15	43.33
LMN06945P	937.29	907.93	28.49	12	39.94
% Saturation					
LMN06943P	127.06	122.16	2.06	2.5	5.48
LMN06945P	125.83	122.23	3.83	1.57	5.08

Table 54. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at River Mile 069.4 during the Summer 1997 study (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
LMN06943P	100	20.75	46.06	48.13
LMN06945P	100	74.69	86.31	86.72

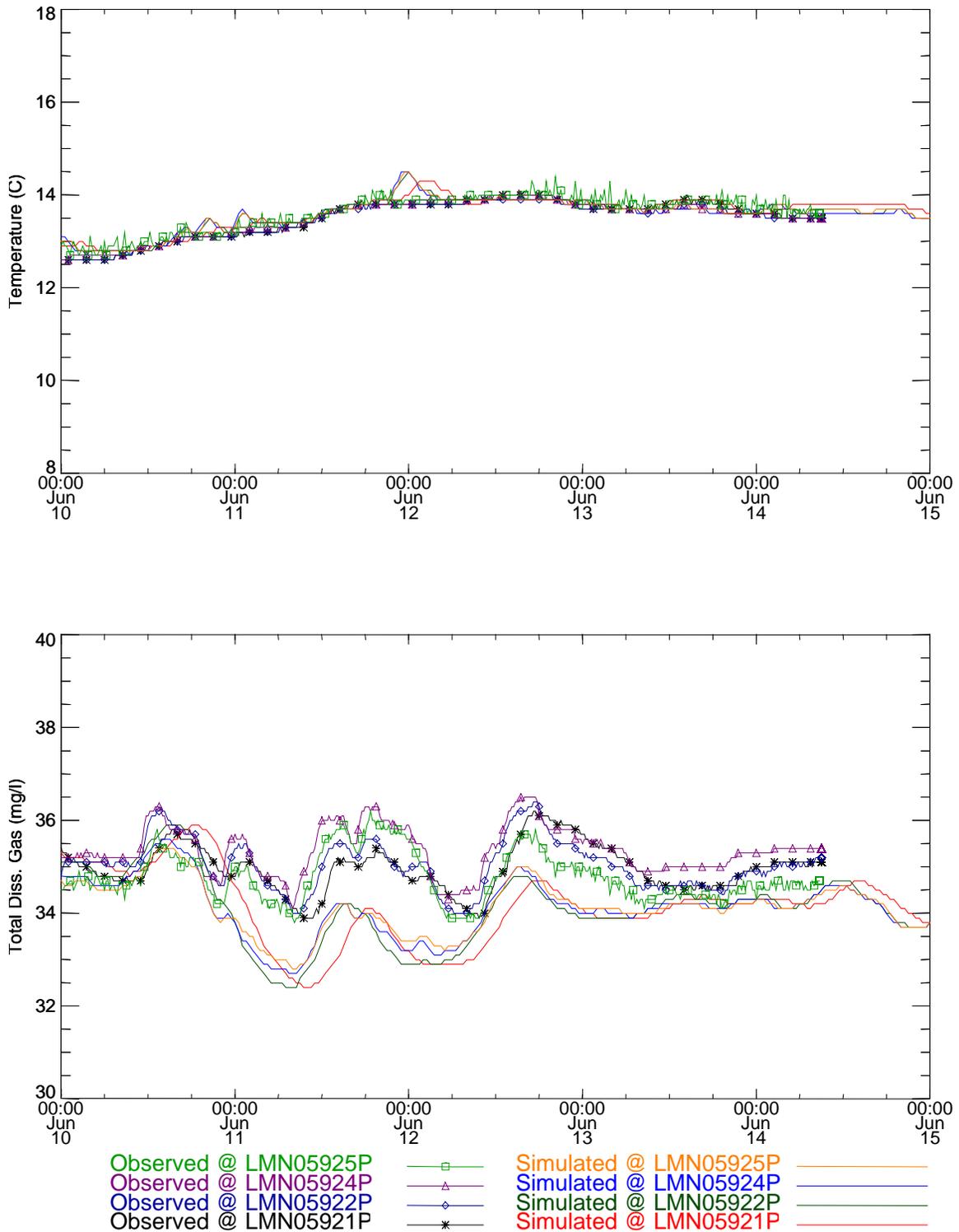


Figure 94 Temperature and total dissolved gas time series near Snake River Mile 059.2 the Summer 1997 study (FMS-BC).

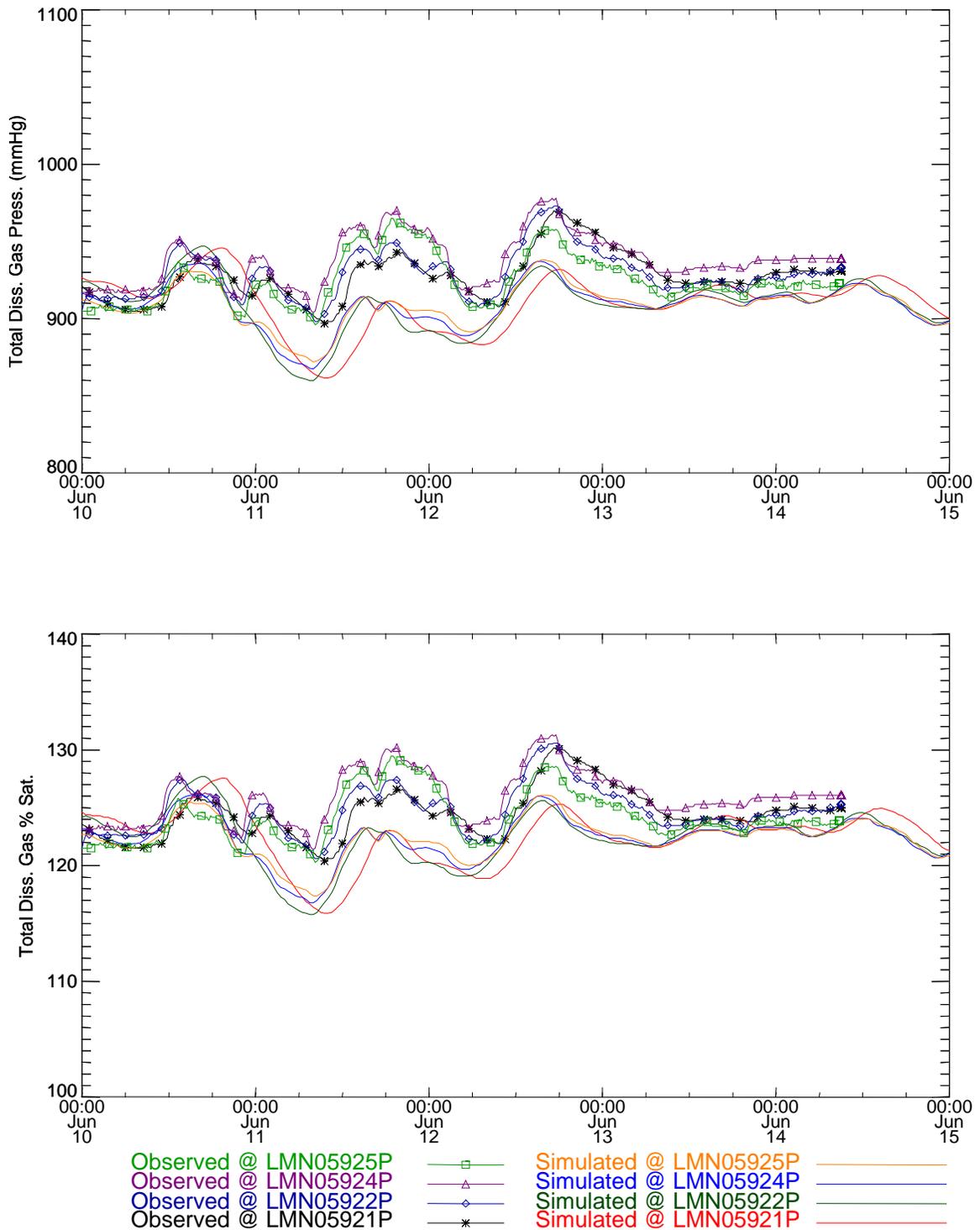


Figure 95. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 05.9.2 for the Summer 1997 study (FMS-BC).

Table 55. Statistical summary of measurements and simulations at River Mile 059.2 during the Summer 1997 study (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
LMN05921P	13.5	13.61	0.39	0.38	0.18
LMN05922P	13.48	13.59	0.37	0.36	0.17
LMN05924P	13.51	13.58	0.37	0.36	0.16
LMN05925P	13.62	13.59	0.37	0.36	0.17
Concentration					
LMN05921P	34.98	34.13	0.47	0.8	1.08
LMN05922P	35.07	34.1	0.5	0.78	1.16
LMN05924P	35.37	34.11	0.48	0.63	1.39
LMN05925P	34.77	34.11	0.49	0.55	0.89
Gas Pressure					
LMN05921P	928.02	909.98	14.61	18.02	25.11
LMN05922P	929.68	908.74	14.47	17.89	26.83
LMN05924P	938.44	908.66	15.21	14.49	33.31
LMN05925P	924.72	908.92	15.33	13.1	21.46
% Saturation					
LMN05921P	124.59	122.51	1.96	2.45	3.16
LMN05922P	124.81	122.34	1.94	2.4	3.34
LMN05924P	125.99	122.33	2.04	1.93	4.15
LMN05925P	124.14	122.37	2.05	1.74	2.6

Table 56. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at River Mile 069.5 during the Summer 1997 study (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
LMN05921P	100	57.26	92.53	94.61
LMN05922P	100	54.77	81.74	85.48
LMN05924P	100	42.32	68.46	73.03
LMN05925P	100	77.18	89.21	90.46

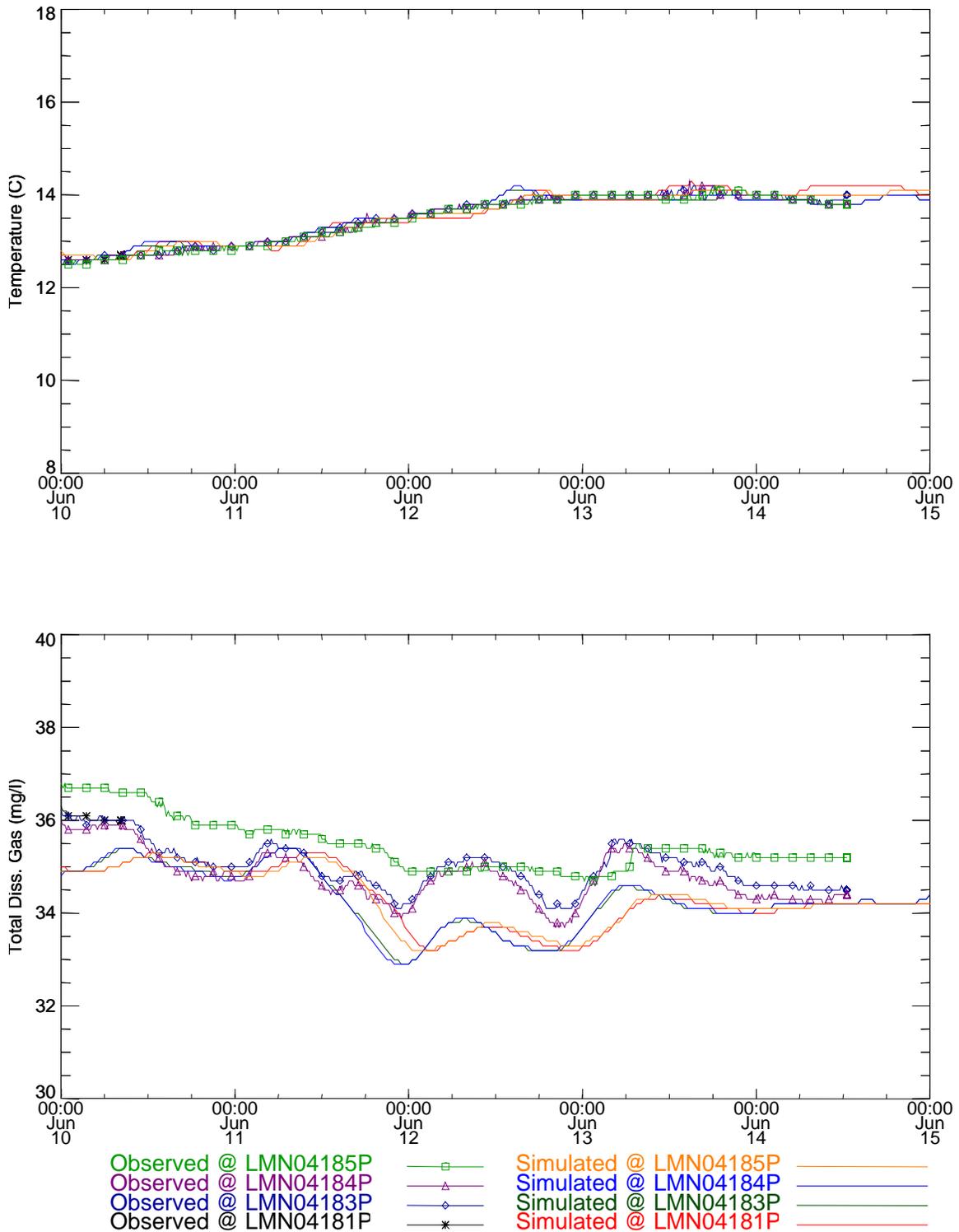


Figure 96 Temperature and total dissolved gas time series near Snake River Mile 041.8 for the Summer 1997 study (FMS-BC).

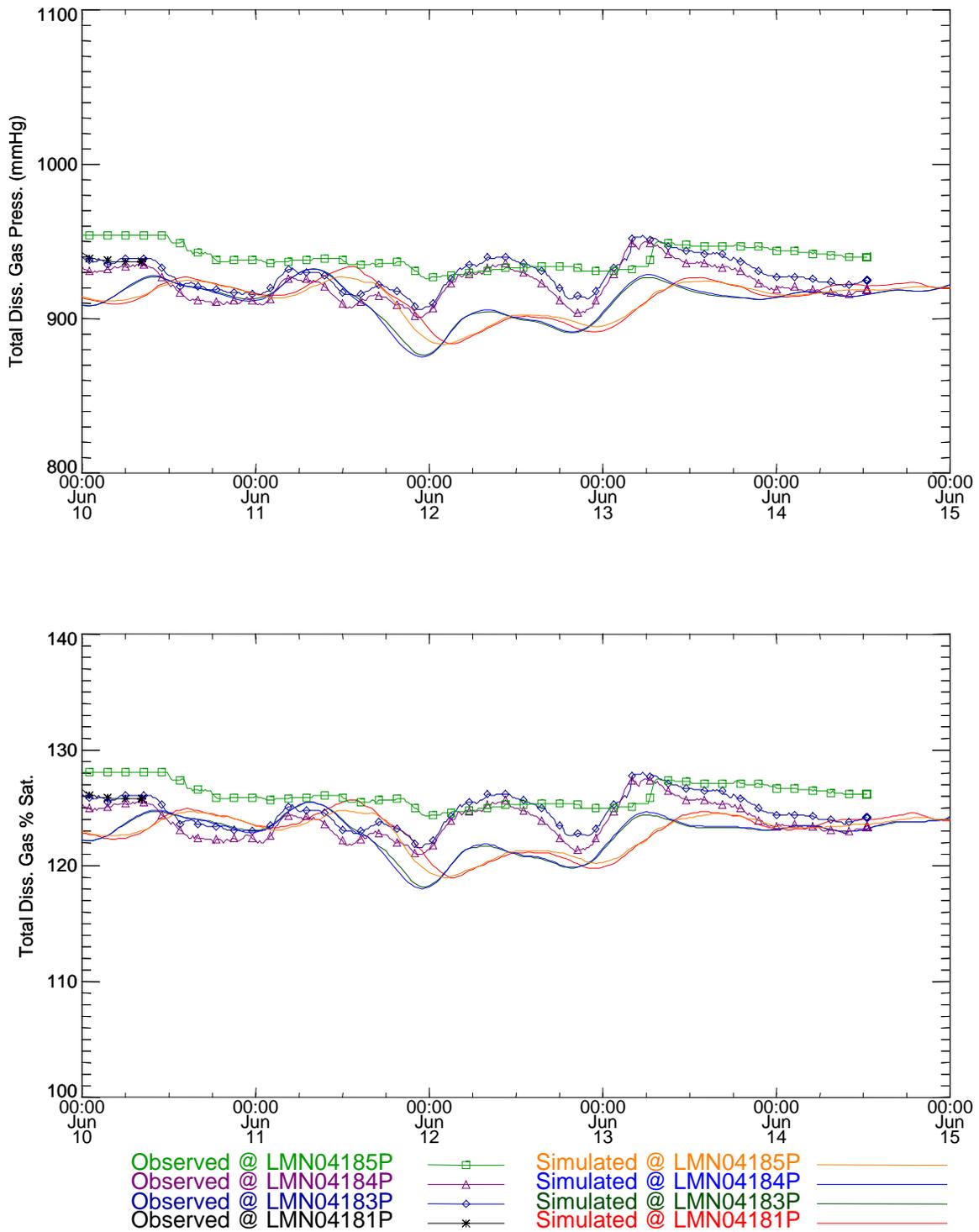


Figure 97. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 041.8 for the Summer 1997 study (FMS-BC).

Table 57. Statistical summary of measurements and simulations at River Mile 041.8 during the Summer 1997 study (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
LMN04181P	12.69	13.57	0.02	0.55	1.03
LMN04183P	13.55	13.53	0.52	0.47	0.11
LMN04184P	13.52	13.55	0.51	0.47	0.12
LMN04185P	13.49	13.54	0.51	0.51	0.13
Concentration					
LMN04181P	36	34.31	0.03	0.64	1.81
LMN04183P	34.97	34.27	0.5	0.66	0.83
LMN04184P	34.76	34.27	0.52	0.66	0.67
LMN04185P	35.45	34.3	0.54	0.62	1.2
Gas Pressure					
LMN04181P	937.07	913.58	0.51	12.21	26.48
LMN04183P	928.45	912.04	10.23	12.31	20.38
LMN04184P	922.36	912.05	10.89	12.69	16.05
LMN04185P	939.94	912.7	7.33	11.36	28.58
% Saturation					
LMN04181P	125.81	122.99	0.07	1.71	3.29
LMN04183P	124.64	122.79	1.38	1.64	2.51
LMN04184P	123.83	122.79	1.46	1.69	2.01
LMN04185P	126.19	122.88	0.99	1.58	3.54

Table 58. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at River Mile 041.8 during the Summer 1997 study (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
LMN04181P	50.62	23.24	83.4	84.65
LMN04183P	100	76.35	99.59	100
LMN04184P	100	83.4	100	100
LMN04185P	100	43.57	85.48	87.97

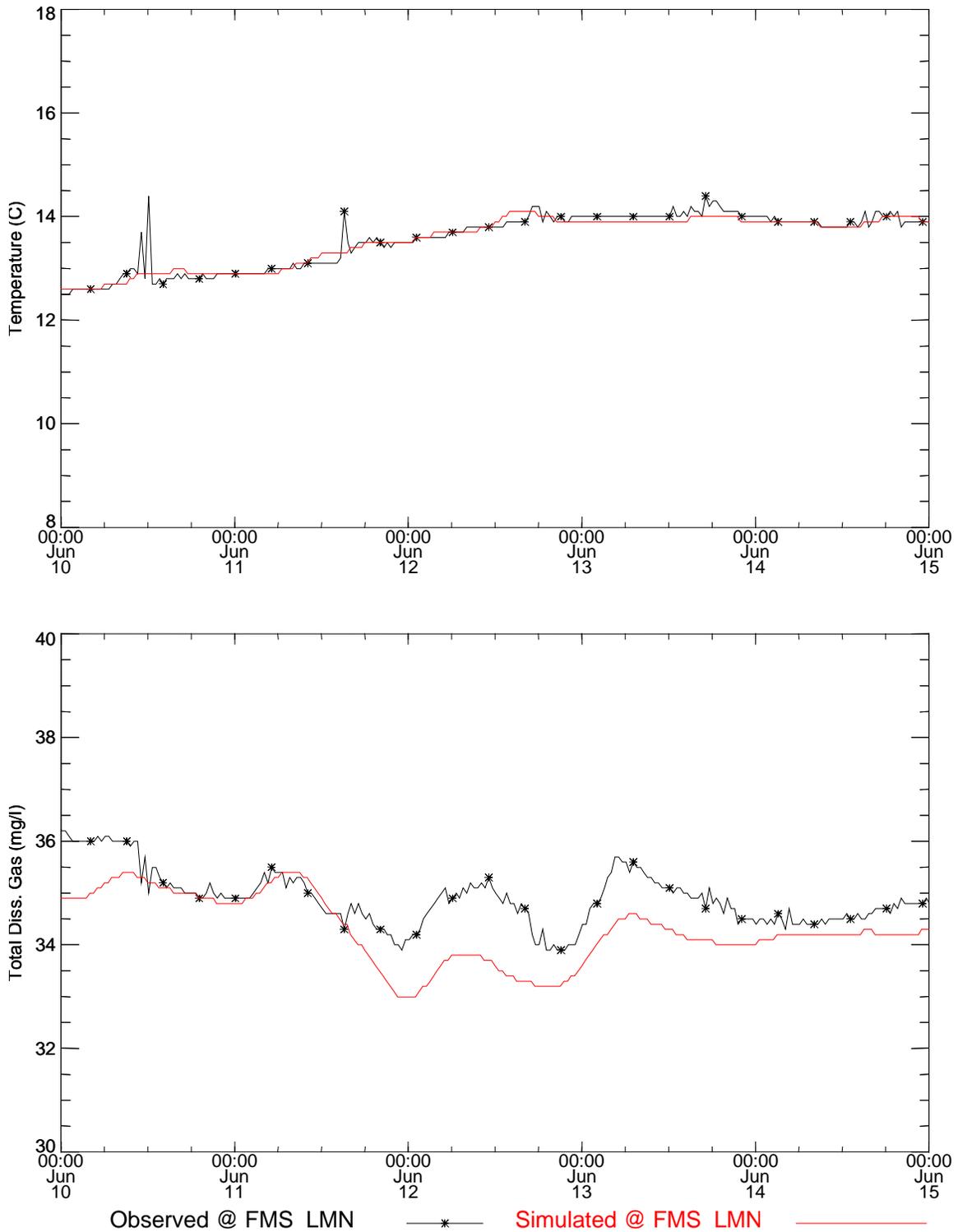


Figure 98 Temperature and total dissolved gas time series near fixed monitor LMN for the Summer 1997 study (FMS-BC).

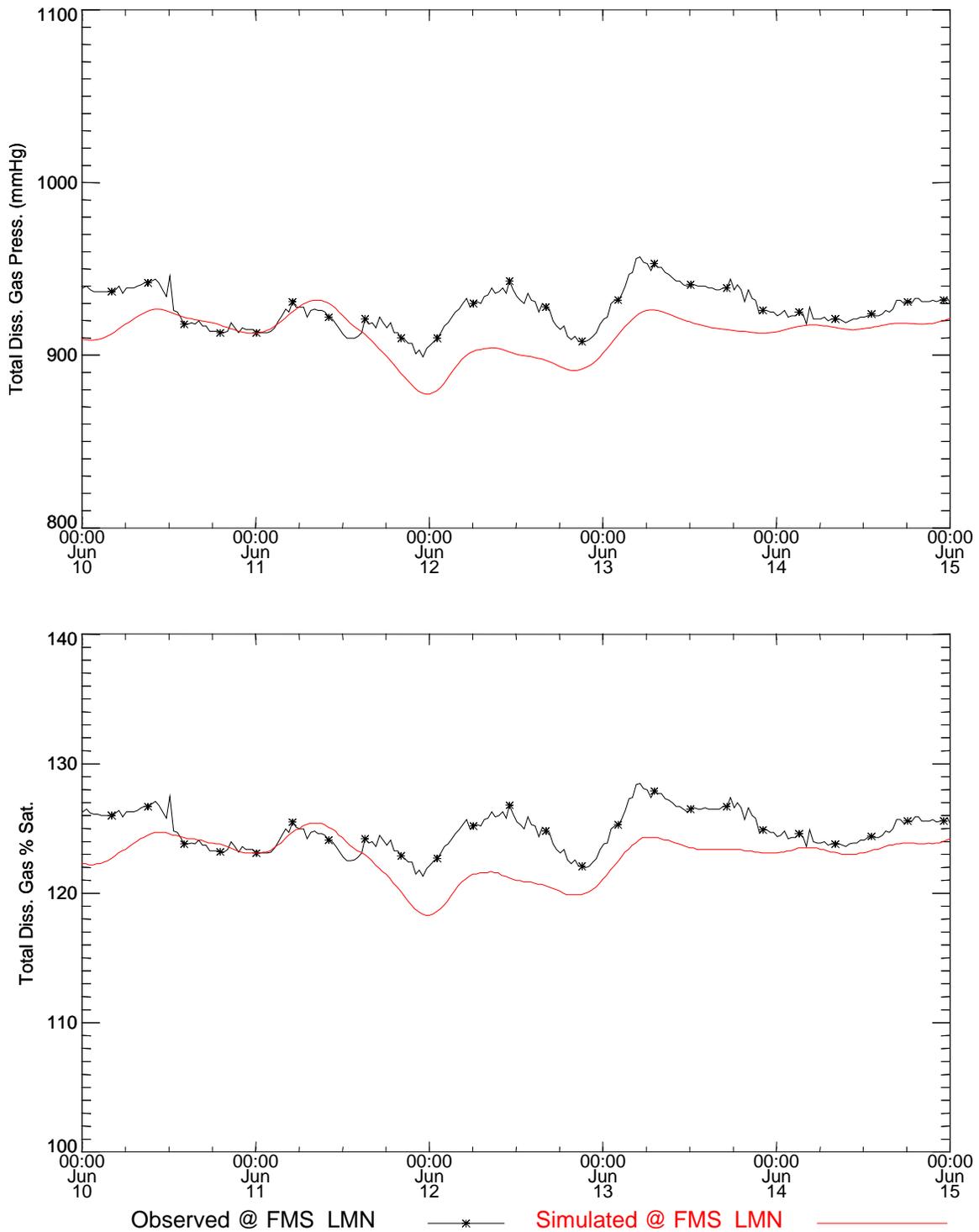


Figure 99. Total dissolved gas pressure and saturation time series comparisons near fixed monitor LMN for the Summer 1997 study (FMS-BC).

Table 59. Statistical summary of measurements and simulations at fixed monitor LMN during the Summer 1997 study (FMS-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
FMS_LMN	13.56	13.53	0.51	0.48	0.14
Concentration					
FMS_LMN	34.9	34.28	0.53	0.65	0.77
Gas Pressure					
FMS_LMN	926.82	912.07	11.64	12.16	19.15
% Saturation					
FMS_LMN	124.82	122.79	1.49	1.63	2.61

Table 60. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at fixed monitor LMN during the Summer 1997 study (FMS-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
FMS_LMN	99.59	79.25	99.59	99.17

Boundary Conditions using Temporary Monitored Field Data

Comparisons between the measurements and simulations using an upstream boundary condition developed from water temperatures and TDG pressures measured by temporary monitors are shown in the figures below. Statistics on comparisons between measured and simulated temperatures and total dissolved gas are also presented. The case is denoted as TM-BC in the figure and table captions.

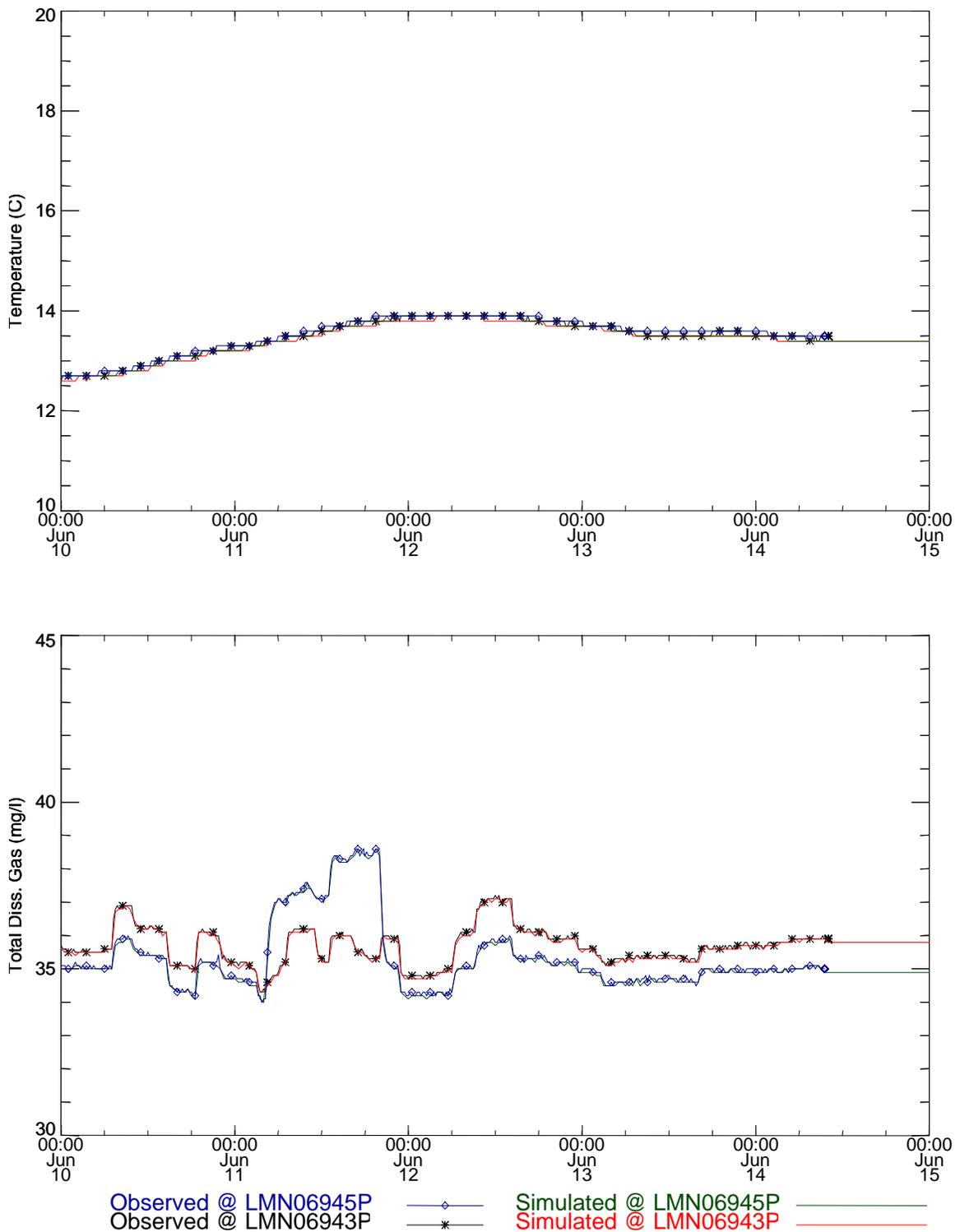


Figure 100 Temperature and total dissolved gas time series near Snake River Mile 069.4 for the Summer 1997 study (TM-BC).

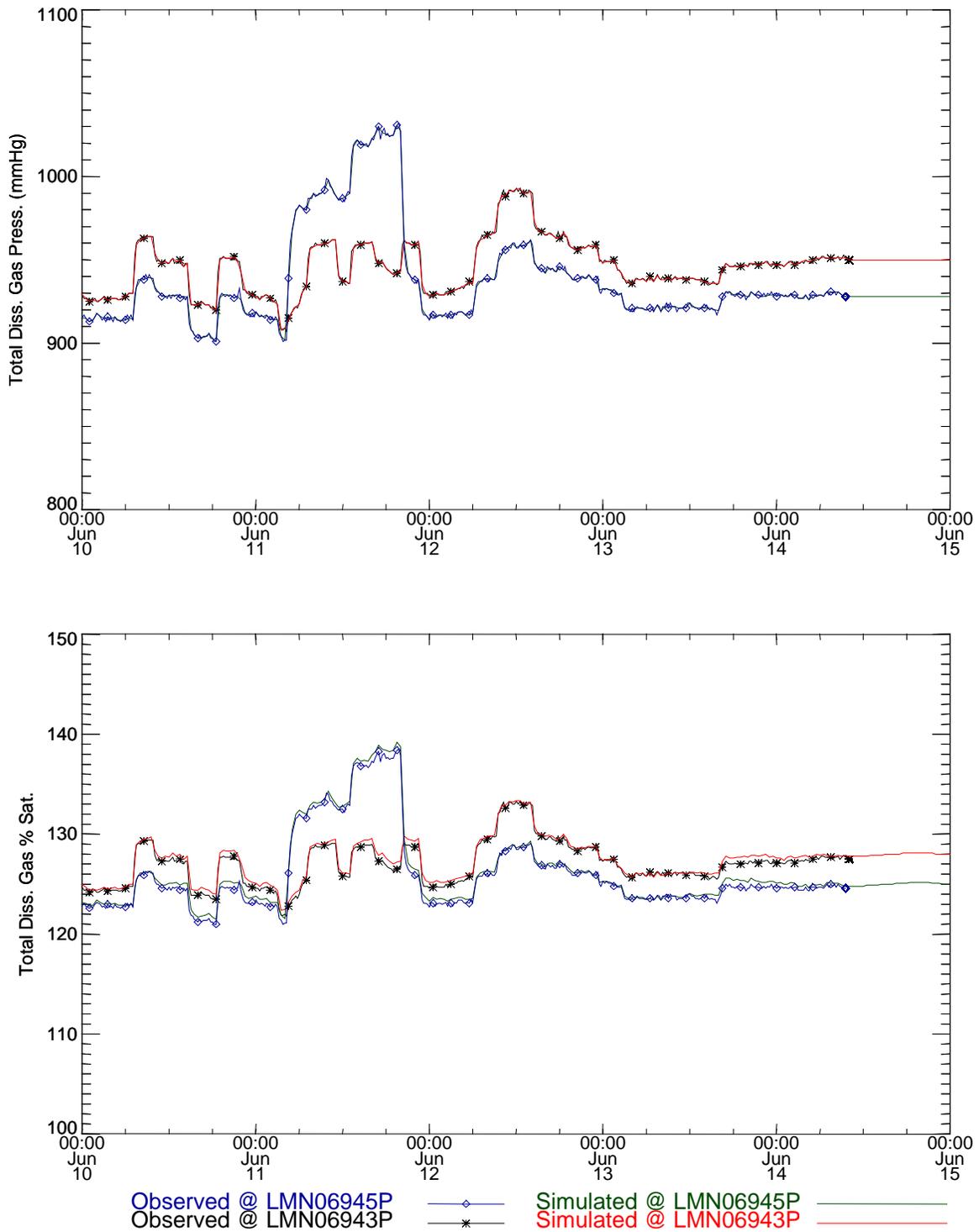


Figure 101. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 069.4 for the Summer 1997 study (TM-BC).

Table 61. Statistical summary of measurements and simulations at River Mile 069.4 during the Summer 1997 study (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
LMN06943P	13.49	13.43	0.34	0.34	0.07
LMN06945P	13.52	13.46	0.33	0.34	0.08
Concentration					
LMN06943P	35.71	35.66	0.53	0.53	0.07
LMN06945P	35.33	35.27	1.02	1.03	0.08
Gas Pressure					
LMN06943P	946.49	946.46	15.38	15.36	0.36
LMN06945P	937.29	937.25	28.49	28.46	0.47
% Saturation					
LMN06943P	127.06	127.42	2.06	2.04	0.41
LMN06945P	125.83	126.18	3.83	3.87	0.41

Table 62. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at River Mile 069.4 during the Summer 1997 study (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
LMN06943P	100	100	100	100
LMN06945P	100	100	100	100

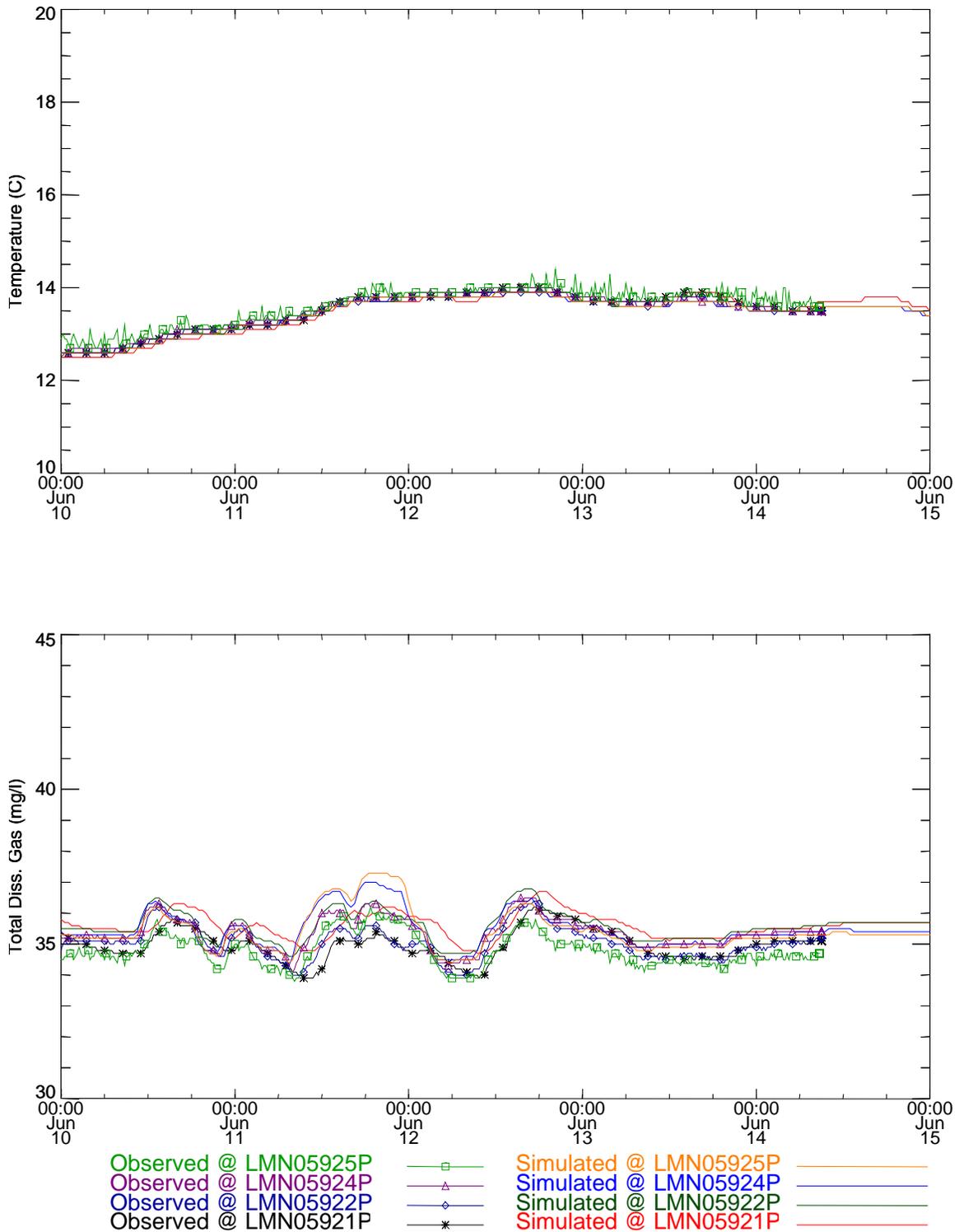


Figure 102 Temperature and total dissolved gas time series near Snake River Mile 059.2 for the Summer 1997 study (TM-BC).

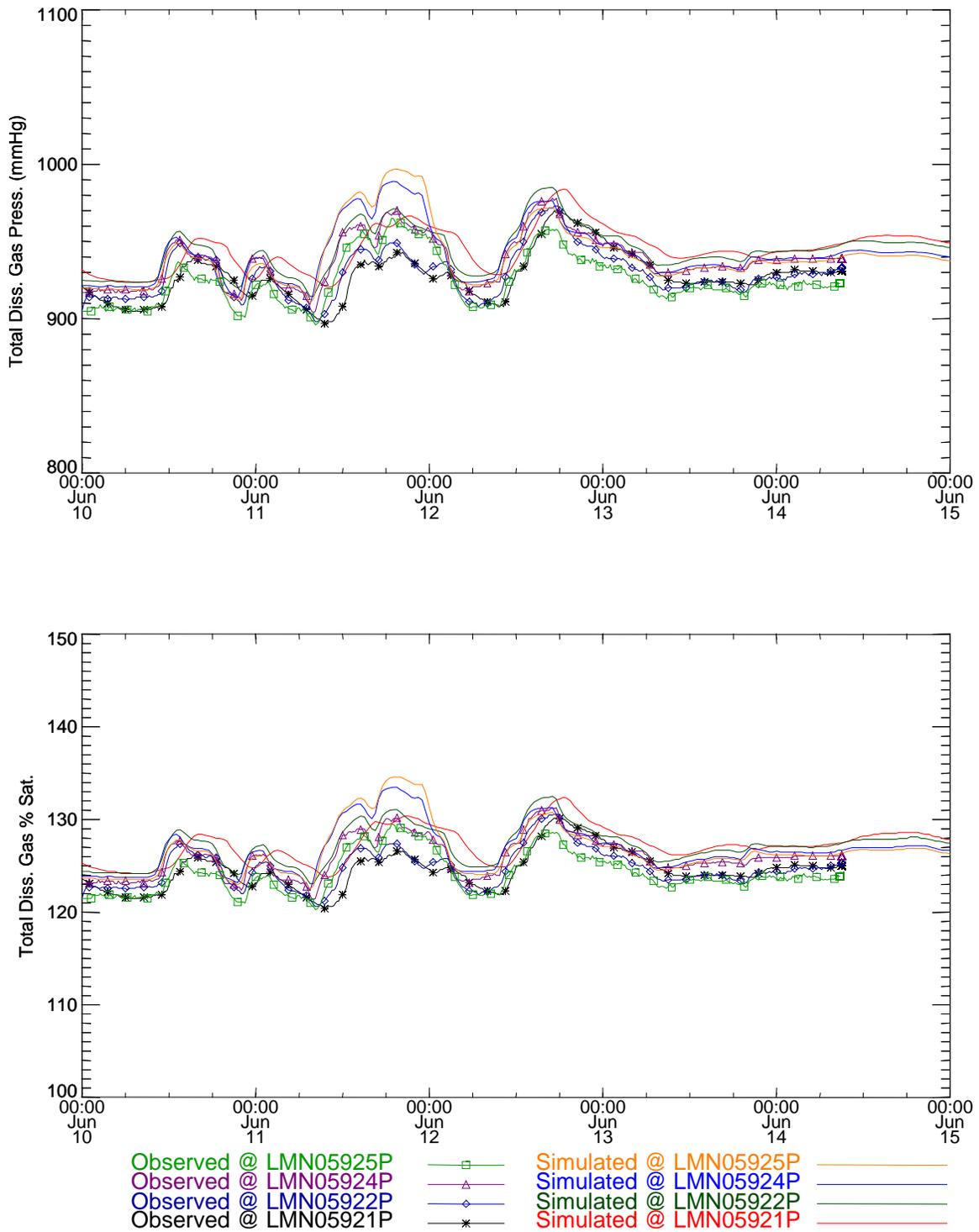


Figure 103. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 059.2 for the Summer 1997 study (TM-BC).

Table 63. Statistical summary of measurements and simulations at River Mile 059.2 during the Summer 1997 study (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
LMN05921P	13.5	13.47	0.39	0.42	0.12
LMN05922P	13.48	13.45	0.37	0.38	0.07
LMN05924P	13.51	13.46	0.37	0.37	0.09
LMN05925P	13.62	13.46	0.37	0.38	0.19
Concentration					
LMN05921P	34.98	35.59	0.47	0.41	0.64
LMN05922P	35.07	35.59	0.5	0.47	0.55
LMN05924P	35.37	35.48	0.48	0.58	0.28
LMN05925P	34.77	35.43	0.49	0.66	0.71
Gas Pressure					
LMN05921P	928.02	945.37	14.61	14.06	18.2
LMN05922P	929.68	944.83	14.47	14.93	15.93
LMN05924P	938.44	942.4	15.21	17.89	7.84
LMN05925P	924.72	941.32	15.33	19.78	18.15
% Saturation					
LMN05921P	124.59	127.27	1.96	1.92	2.82
LMN05922P	124.81	127.2	1.94	2.02	2.49
LMN05924P	125.99	126.87	2.04	2.44	1.33
LMN05925P	124.14	126.73	2.05	2.71	2.8

Table 64. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at River Mile 059.2 during the Summer 1997 study (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
LMN05921P	100	96.68	100	100
LMN05922P	100	100	100	100
LMN05924P	100	100	100	100
LMN05925P	100	90.04	98.34	93.78

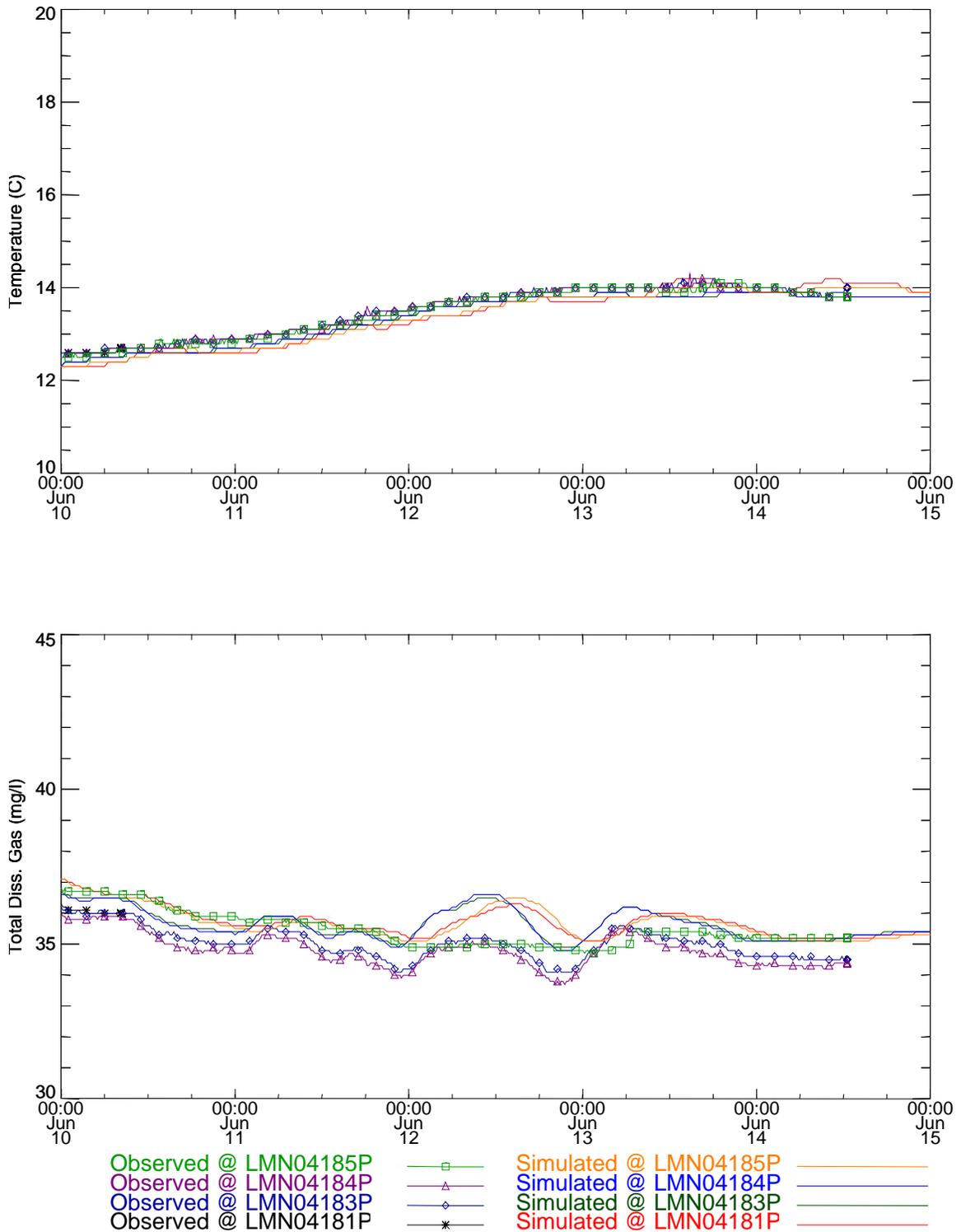


Figure 104 Temperature and total dissolved gas time series near Snake River Mile 041.8 for the Summer 1997 study (TM-BC).

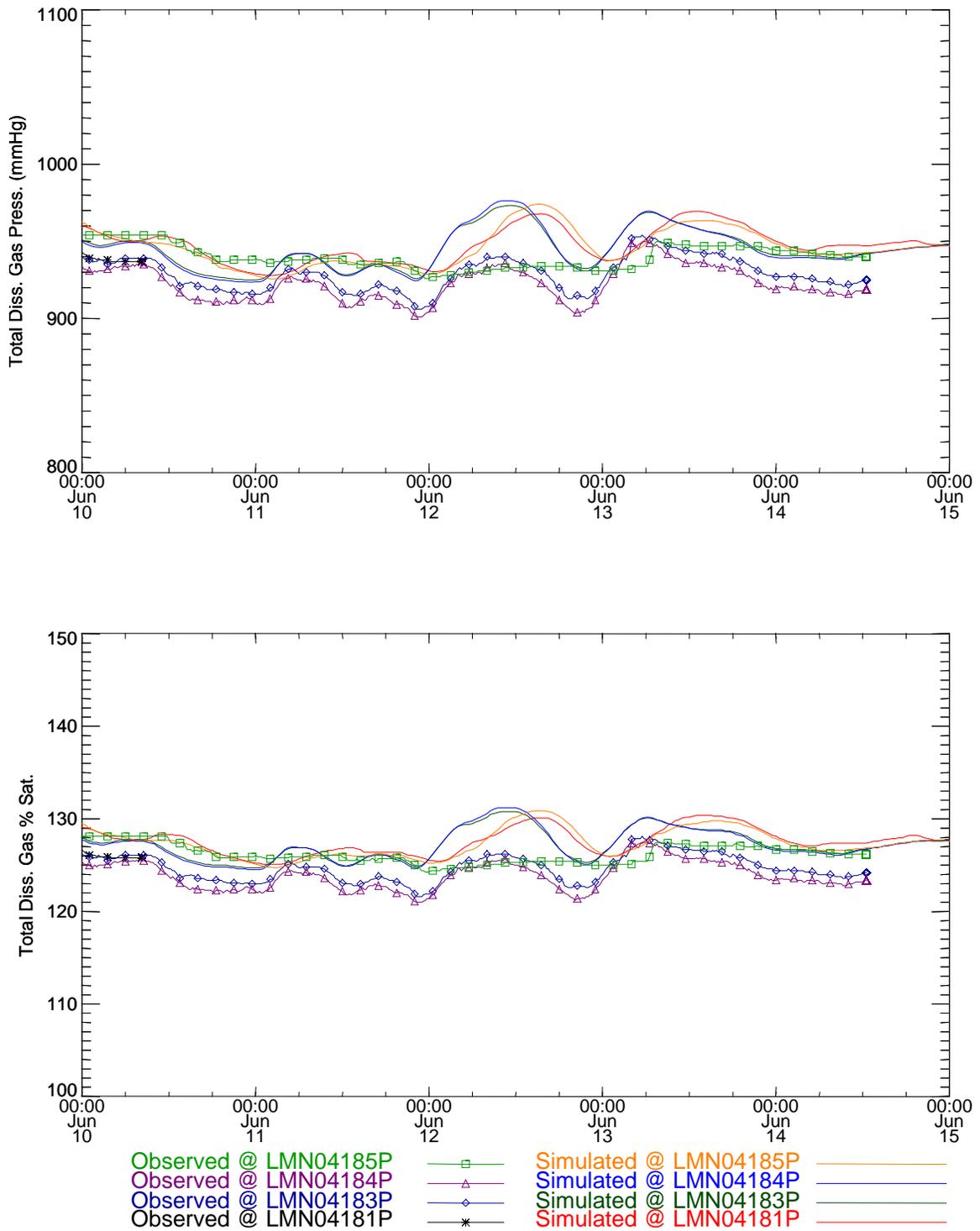


Figure 105. Total dissolved gas pressure and saturation time series comparisons near Snake River Mile 041.8 for the Summer 1997 study (TM-BC).

Table 65. Statistical summary of measurements and simulations at River Mile 041.8 during the Summer 1997 study (TM-BC).

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
LMN04181P	12.69	13.4	0.02	0.61	0.93
LMN04183P	13.55	13.38	0.52	0.53	0.18
LMN04184P	13.52	13.39	0.51	0.53	0.15
LMN04185P	13.49	13.38	0.51	0.59	0.18
Concentration					
LMN04181P	36	35.73	0.03	0.47	0.53
LMN04183P	34.97	35.65	0.5	0.47	0.72
LMN04184P	34.76	35.63	0.52	0.49	0.91
LMN04185P	35.45	35.68	0.54	0.51	0.5
Gas Pressure					
LMN04181P	937.07	947.65	0.51	11.09	15.28
LMN04183P	928.45	945.02	10.23	12.76	17.9
LMN04184P	922.36	944.61	10.89	13.65	23.52
LMN04185P	939.94	945.98	7.33	12.1	13.22
% Saturation					
LMN04181P	125.81	127.58	0.07	1.42	2.27
LMN04183P	124.64	127.23	1.38	1.62	2.73
LMN04184P	123.83	127.17	1.46	1.74	3.49
LMN04185P	126.19	127.36	0.99	1.55	1.91

Table 66. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at River Mile 0041.8 during the Summer 1997 study (TM-BC).

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat
LMN04181P	59.75	100	100	100
LMN04183P	100	90.04	100	100
LMN04184P	100	82.57	92.95	91.7
LMN04185P	100	91.7	96.68	95.44

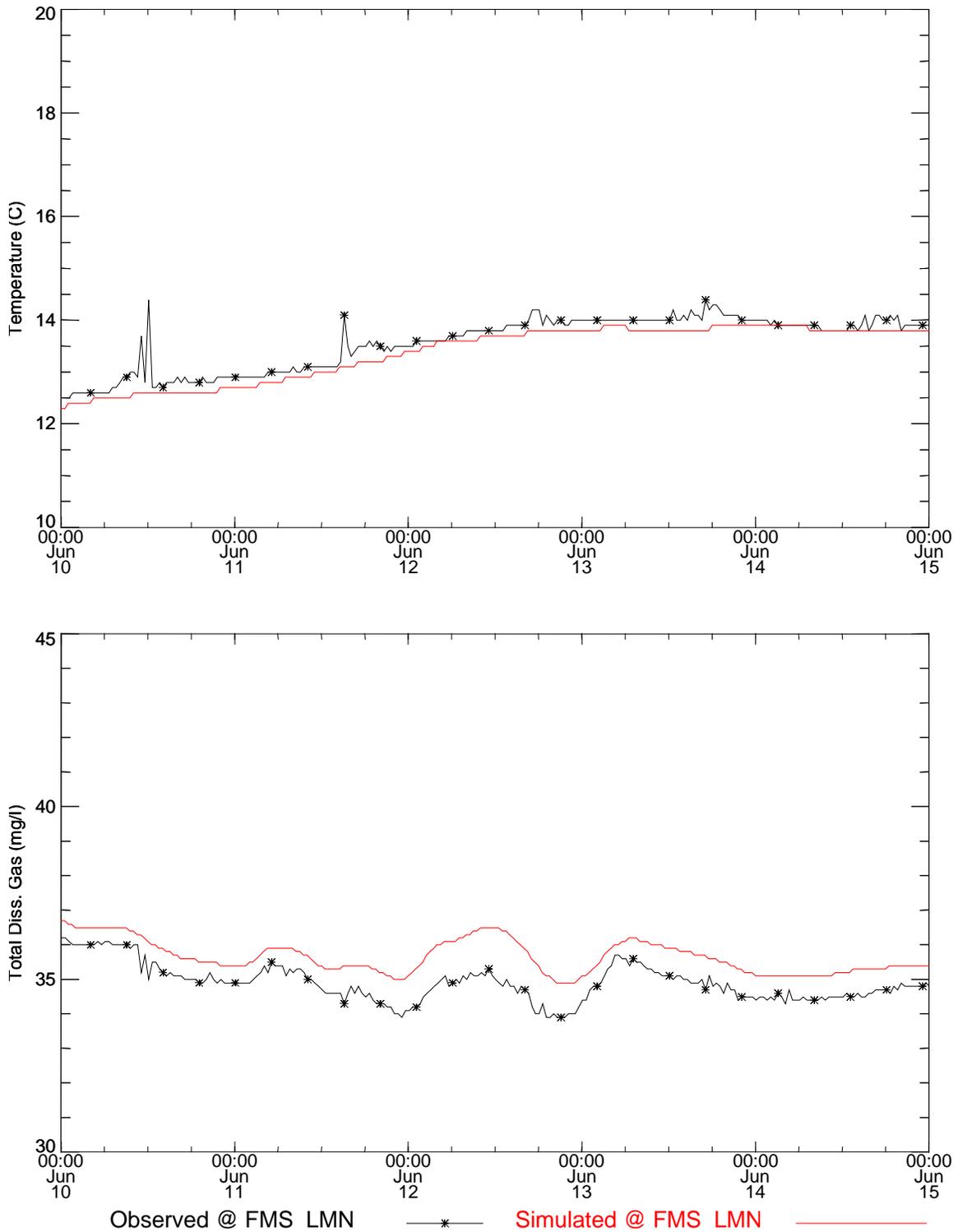


Figure 106 Temperature and total dissolved gas time series near fixed monitor LMN for the Summer 1997 study (TM-BC).

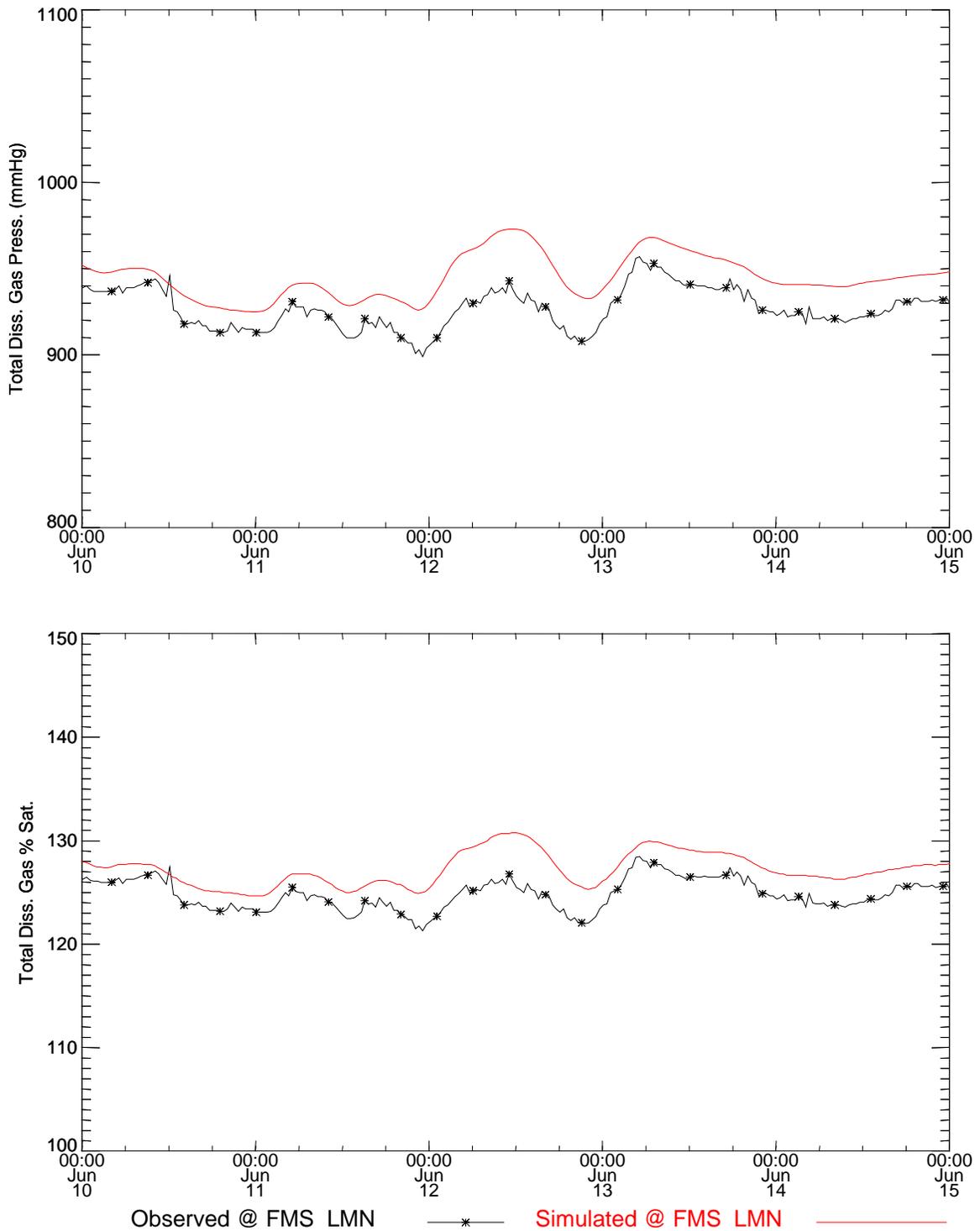


Figure 107. Total dissolved gas pressure and saturation time series comparisons near fixed monitor LMN for the Summer 1997 study (TM-BC).

2 References

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Appendix A. Lower Monumental Pool Data Sources

A.1 Bathymetry

Bathymetric data for the Columbia River was gathered from the various sources shown in Table 69. The primary data source was digitized NOAA navigation charts (NOAA, 1990a, 1990b, 1990c), which are rather coarse. These were supplemented with surveys in the Little Goose and Lower Monumental dam tailraces. USGS “1-degree” digital elevation data (USGS, 1995) was used to determine elevations on islands and along the shore. Using the Arc/Info® GIS software system, the data was converted to a consistent coordinate system and datum, and combined to build a triangular irregular network (TIN), which represented the river bottom and shore as a three-dimensional surface. The resulting surface for Lower Monumental pool is shown in Figure 109. Once the surface was produced, it was “sampled” at the necessary grid locations to produce the bathymetry required by the hydrodynamic model grid.

Table 69. Columbia River bathymetry data sets used to create the Lower Monumental pool bathymetric surface. Listed Figure numbers refers to the map which shows the survey location(s).

Bathymetric Data Set	Source	Survey Date	Approximate Rivermile	
			Start	End
Little Goose Dam Tailrace (Figure 110)	Julie Davin (Walla Walla)	1992	69.2	70.2
Lower Monumental Dam Tailrace (Figure 111)	Julie Davin (Walla Walla)	1992	40.4	41.5
NOAA Navigation Charts (Figure 110 and Figure 111)	Battelle	unknown	0.0	147.0

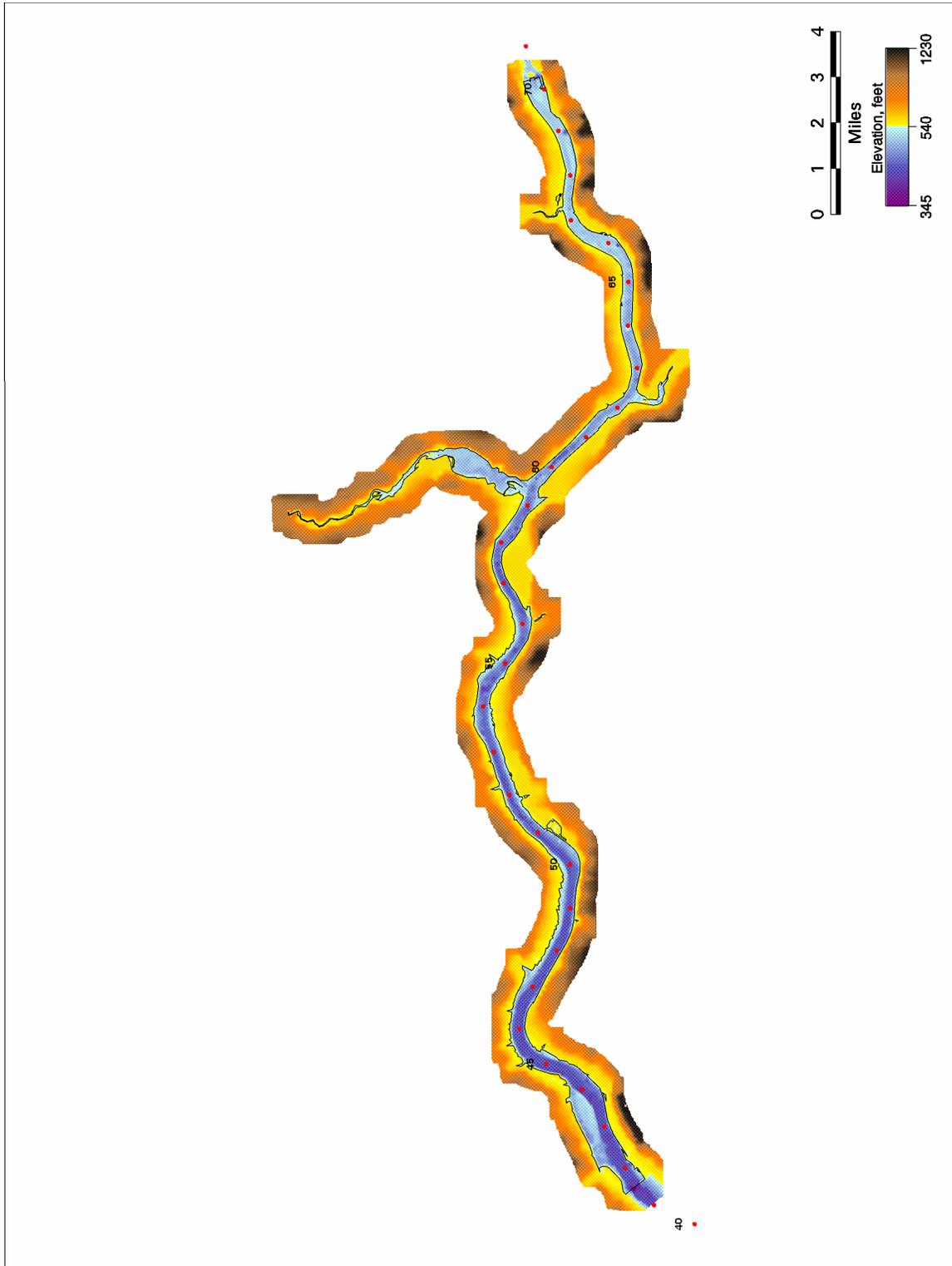


Figure 109. Color representation of Lower Monumental pool bathymetric surface.

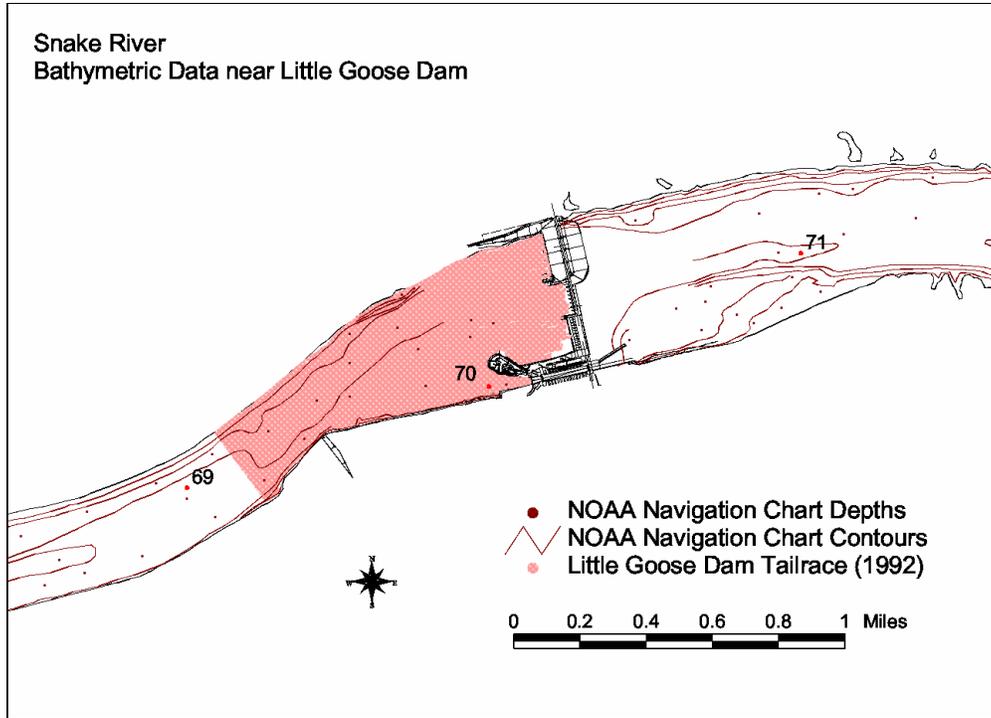


Figure 110. Bathymetric data near Little Goose Dam.

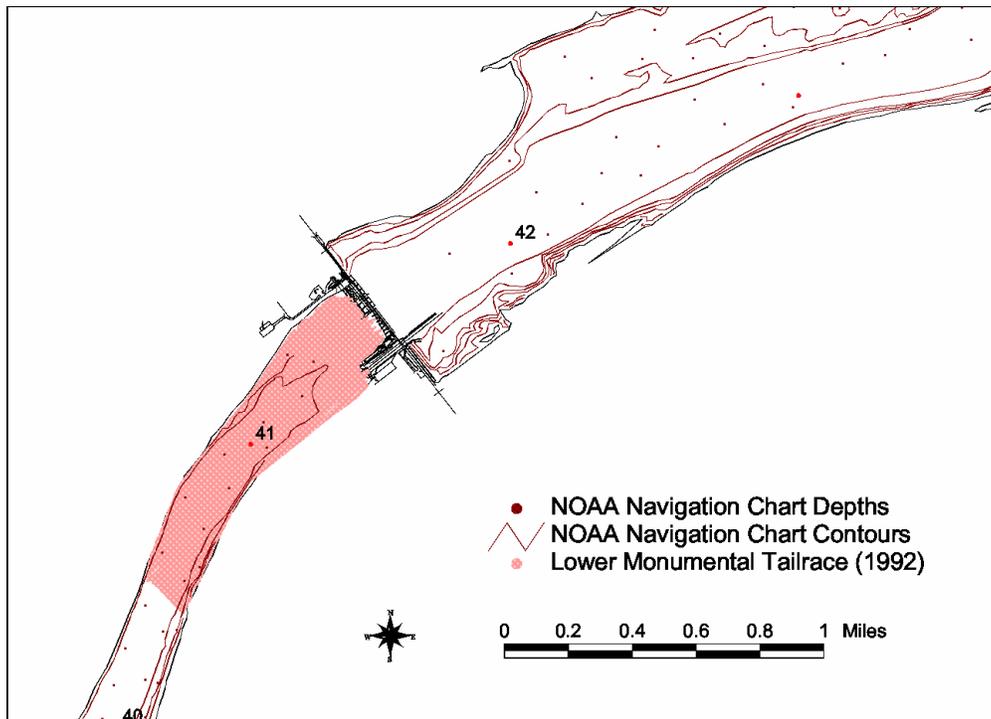


Figure 111. Bathymetric data near Lower Monumental dam.

A.2 Calibration/Verification Data Sources

A.2.1 Dissolved Gas Measurements

Dissolved gas measurements were available from two sources: permanent fixed monitors and dissolved gas pool studies which used temporary monitors. Fixed monitor stations (FMS) in Lower Monumental pool area are shown in Figure 112. The water quality data recorded by the FMS included total dissolved gas (TDG) pressure, barometric pressure, and temperature, and was obtained from the DGAS team ftp server, `limnos.wes.army.mil`, in the file `/data3/dgas/database/FMS_data/FMS_data.zip`, dated August 25, 1998. Fixed monitor data was used to establish temperature and TDG concentration in powerhouse flow at the Little Goose dam model boundary.

The dissolved gas pool studies performed in Lower Monumental Pool to date are shown in Table 70 and their durations are shown graphically in Figure 113. During these studies water temperature and TDG pressures were measured at several locations within Lower Monumental pool. These periods were used for model calibration and verification and are discussed individually below. The water quality data gathered during these studies was obtained from the DGAS team ftp server, `limnos.wes.army.mil`, in the file `/data3/dgas/database/field_data/field_data.zip`, dated August 25, 1998.

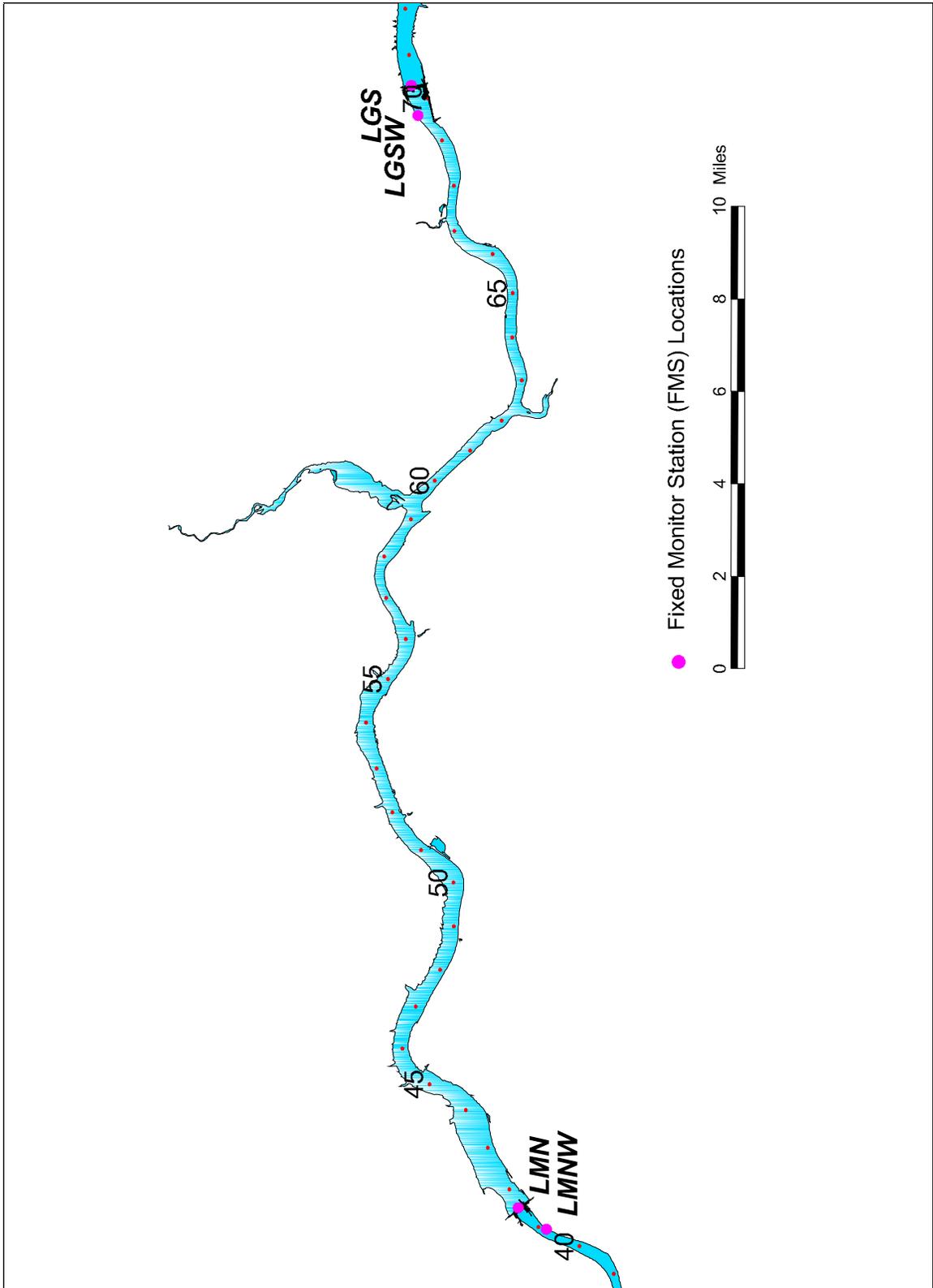


Figure 112. FMS locations in and around Lower Monumental pool.

Table 70. Dates of dissolved gas field studies in Lower Monumental pool.

STUDY SET	Start	End
LMN SPR 96	4/23/96 2:33:00 PM	4/28/96 2:15:00 PM
LWG LGS LMN SPR 97	4/2/97 11:00:00 AM	4/16/97 11:00:00 AM
LMN LGS SUM 97	6/4/97 8:03:00 AM	6/17/97 3:19:00 PM

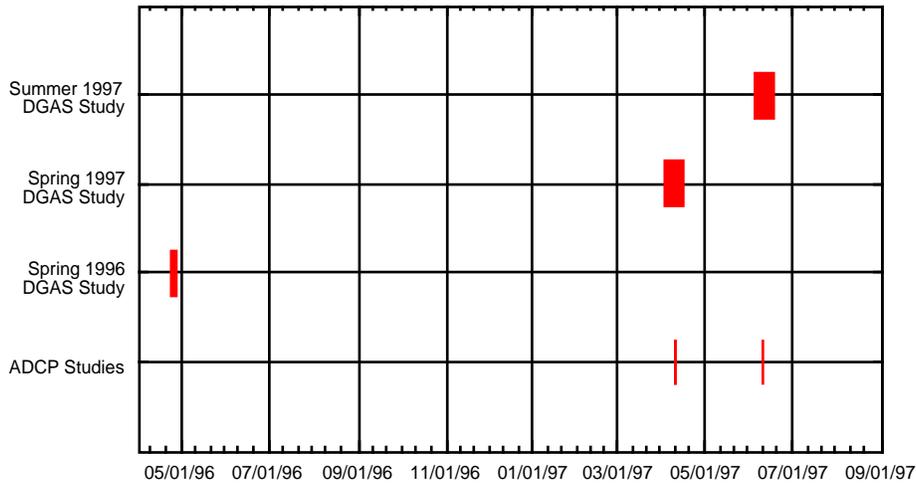


Figure 113. Dates and durations of dissolved gas and ADCP velocity studies in Lower Monumental Pool

A.2.2 ADCP Velocity Measurements

As shown in Figure 113, velocity measurements were taken using ADCP (Acoustic Doppler Current Profiler) instruments during two of the dissolved gas pool studies: Spring 1997 and Summer 1997. The ADCP data was obtained from the DGAS team FTP server, `limnos.wes.army.mil`, in the files `/data3/dgas/database/ADCP data/96ADCP.zip` and `/data3/dgas/database/ADCP data/97ADCP.zip`, dated April 10, 1998 and July 15, 1998, respectively. Figure 114 through Figure 121 show the measurements made as small arrows. The measurements were thinned for clarity in those figures: only one arrow in three was drawn. Measurements taken in the Spring 1997 period have obvious direction problems which have not been corrected at the time of writing. These measurements were not used for model calibration.

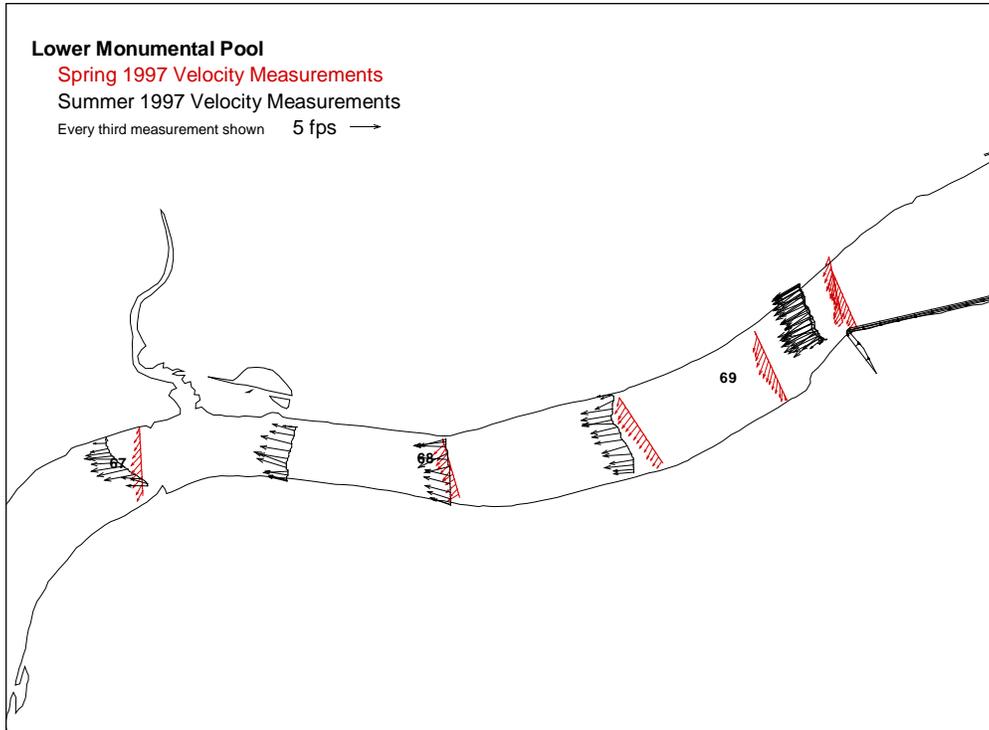


Figure 114. Lower Monumental pool ADCP velocity measurements near Little Goose dam.

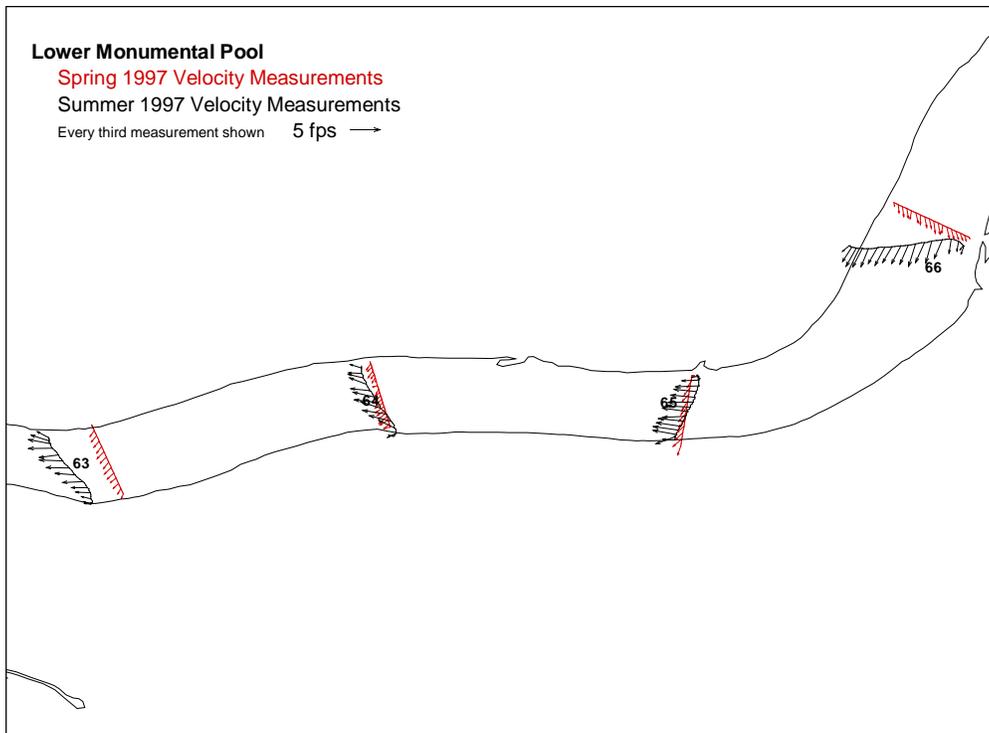


Figure 115. Lower Monumental pool ADCP velocity measurements near Little Goose dam.

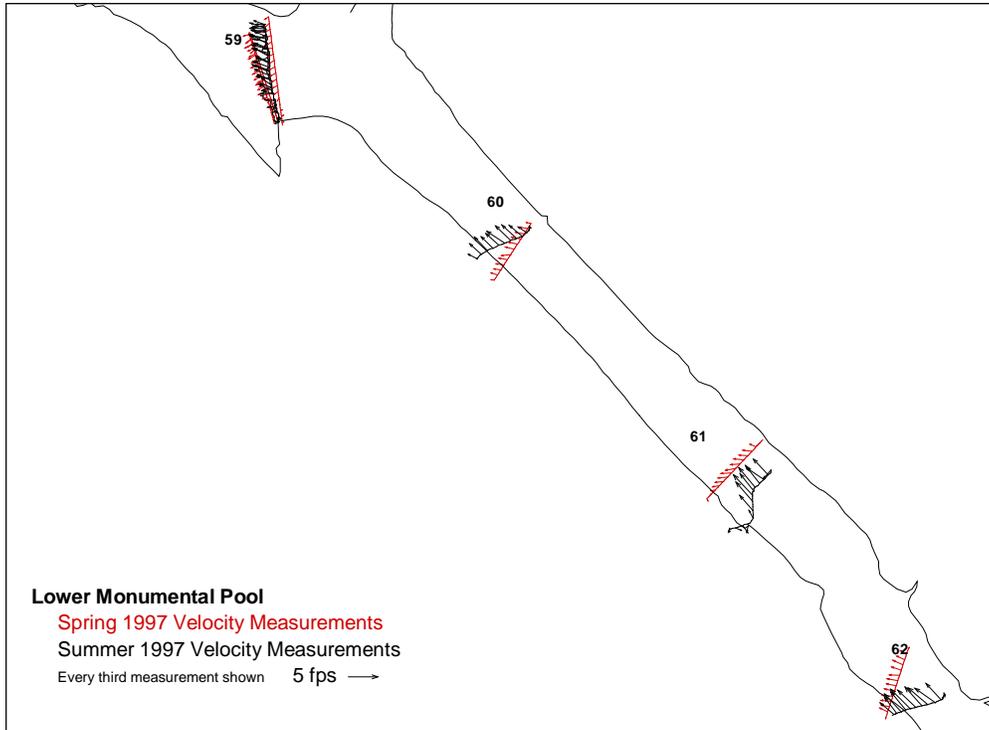


Figure 116. Lower Monumental pool ADCP velocity measurements near Little Goose dam.

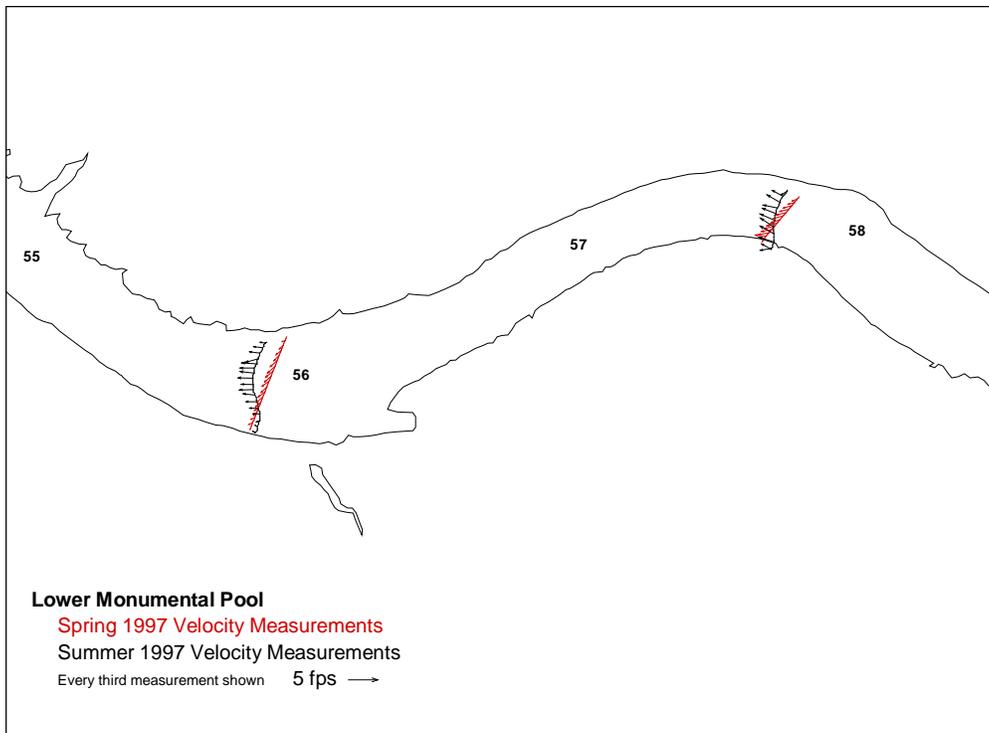


Figure 117. Lower Monumental pool ADCP velocity measurements near Little Goose dam.

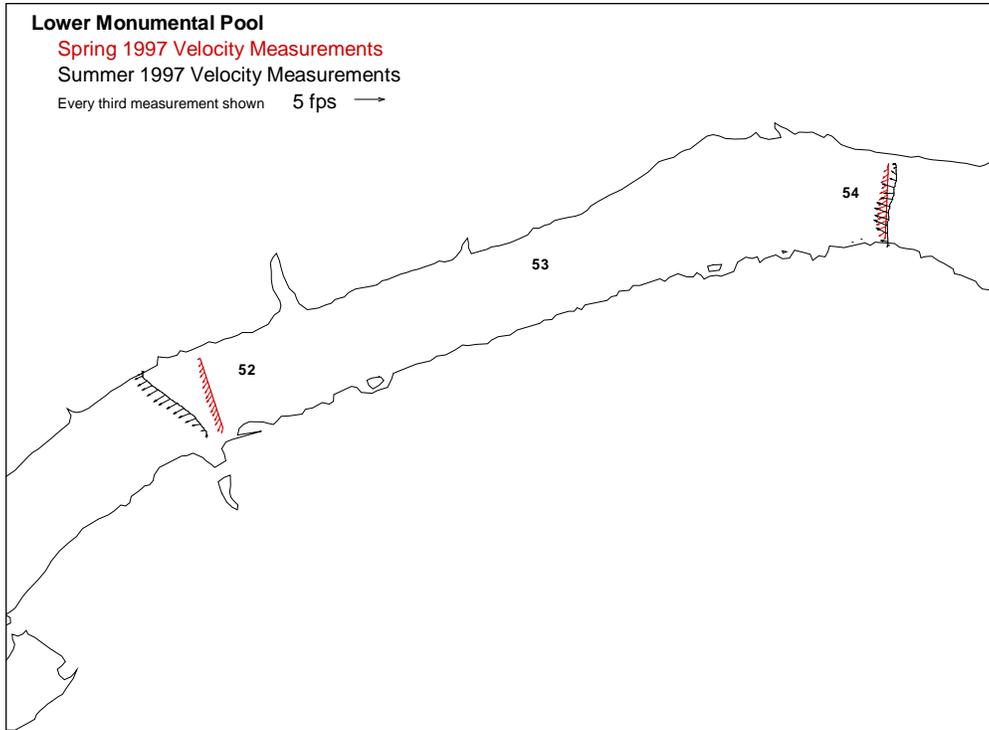


Figure 118. Lower Monumental pool ADCP velocity measurements near Little Goose dam.

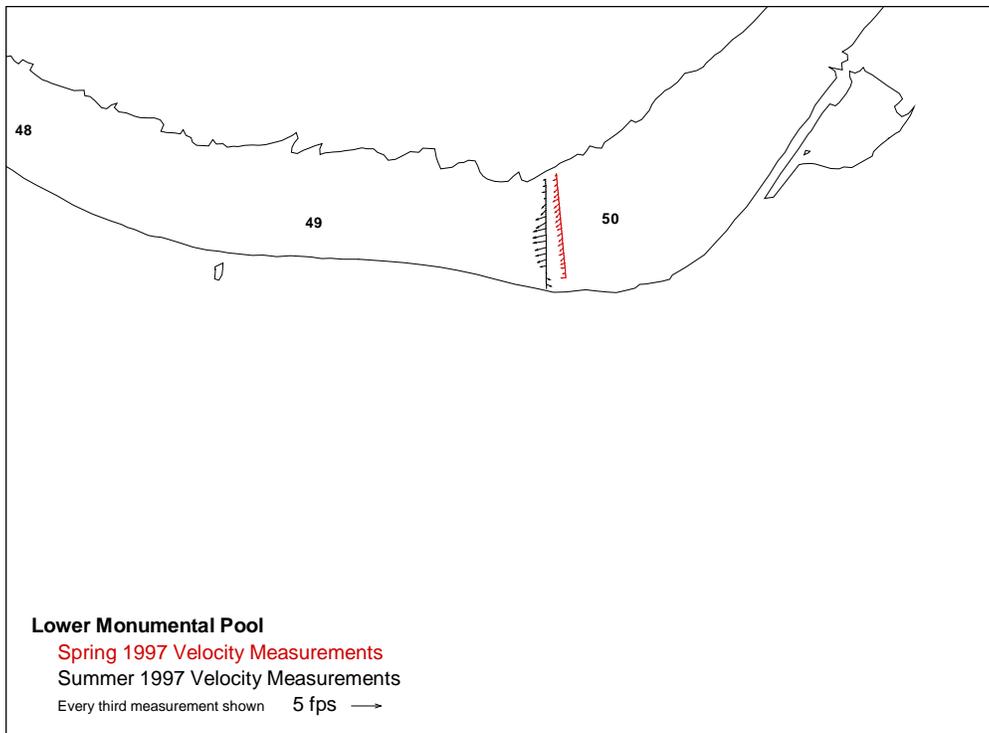


Figure 119. Lower Monumental pool ADCP velocity measurements near Little Goose dam.

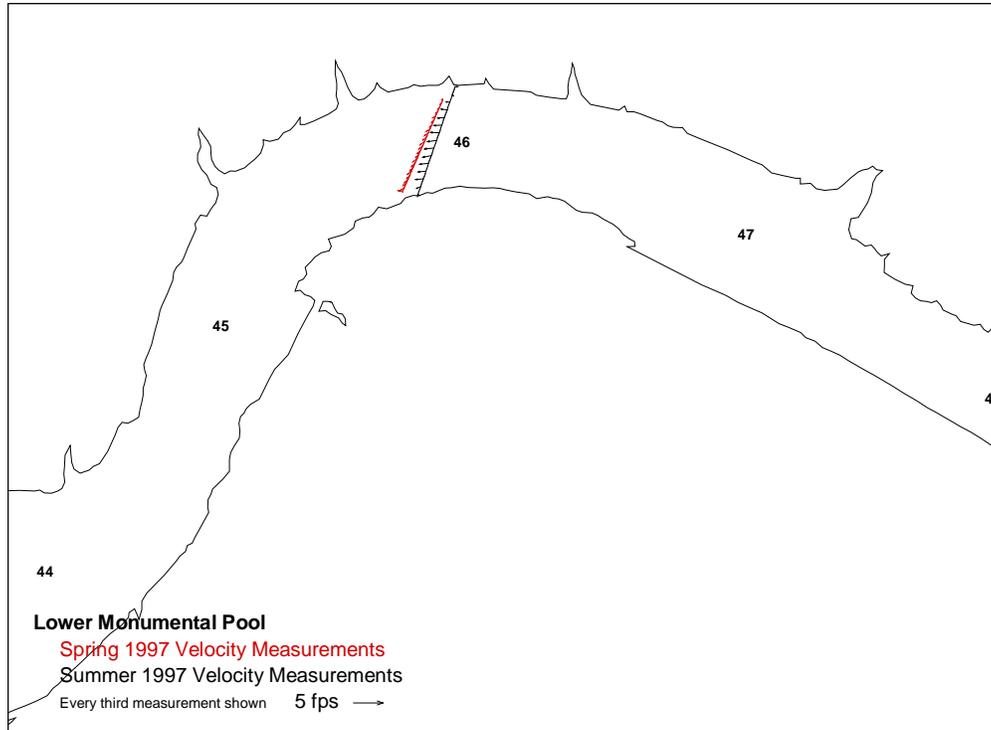


Figure 120. Lower Monumental pool ADCP velocity measurements near Little Goose dam.

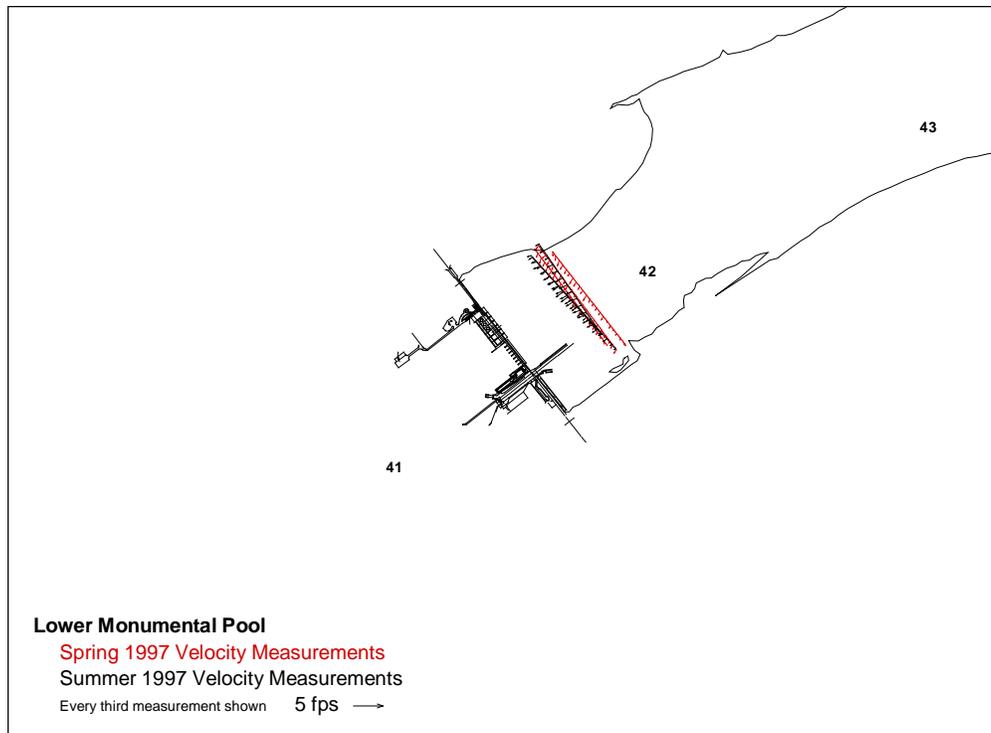


Figure 121. Lower Monumental pool ADCP velocity measurements near Lower Monumental dam.

A.2.3 Dam Operations Data

Dam operations data was used to establish model boundary conditions. Hourly CHROMS data was obtained from the DGAS team FTP server, limnos.wes.army.mil, in the file `/data3/dgas/database/ops_data/ops_data.zip`, dated April 8, 1998. The CHROMS operations data provided hourly aggregate spill and powerhouse flows and forebay and tailwater stages.

A.2.4 Weather Data

Weather data was obtained from two DGAS team databases: one containing data from National Weather Service (NWS) stations, the other from WeatherPak instrumentation used for short periods during the pool studies. Both NWS and WeatherPak data was obtained from the DGAS team FTP server, limnos.wes.army.mil, in the file `/data3/dgas/database/weather_data/weather_data.zip`, dated April 8, 1998.

Appendix B. Spring 1996 Lower Monumental Pool Study

B.1 Dissolved Gas Data

The Spring 1996 Lower Monumental pool study began on April 23 and ended on April 28. A total of 10 stations were used. These stations, and their records are listed in Table 71. Station locations are shown in Figure 122.

Table 71. Dissolved gas monitor stations, and their records, used during the Spring 1996 study period.

Station	Record Start	Record End	Temperature Records	Pressure Records
LMN06955P	4/23/96 2:33:00 PM	4/28/96 12:58:00 PM	469	469
LMN06951P	4/23/96 2:52:00 PM	4/28/96 1:02:00 PM	468	468
LMN06551P	4/23/96 4:22:00 PM	4/28/96 1:17:00 PM	463	463
LMN05922B	4/23/96 5:29:00 PM	4/28/96 12:52:00 PM	457	457
LMN05491B	4/23/96 6:17:00 PM	4/28/96 12:24:00 PM	452	452
LMN04981B	4/24/96 1:57:00 PM	4/28/96 11:05:00 AM	369	369
LMN?????	4/24/96 5:38:00 PM	4/28/96 2:15:00 PM	367	367
LMN07001P	4/25/96 3:10:00 PM	4/28/96 11:14:00 AM	270	270
LMN07005P	4/25/96 3:50:00 PM	4/28/96 10:53:00 AM	266	266
LMN06781P	4/26/96 12:52:00 PM	4/28/96 1:22:00 PM	195	195

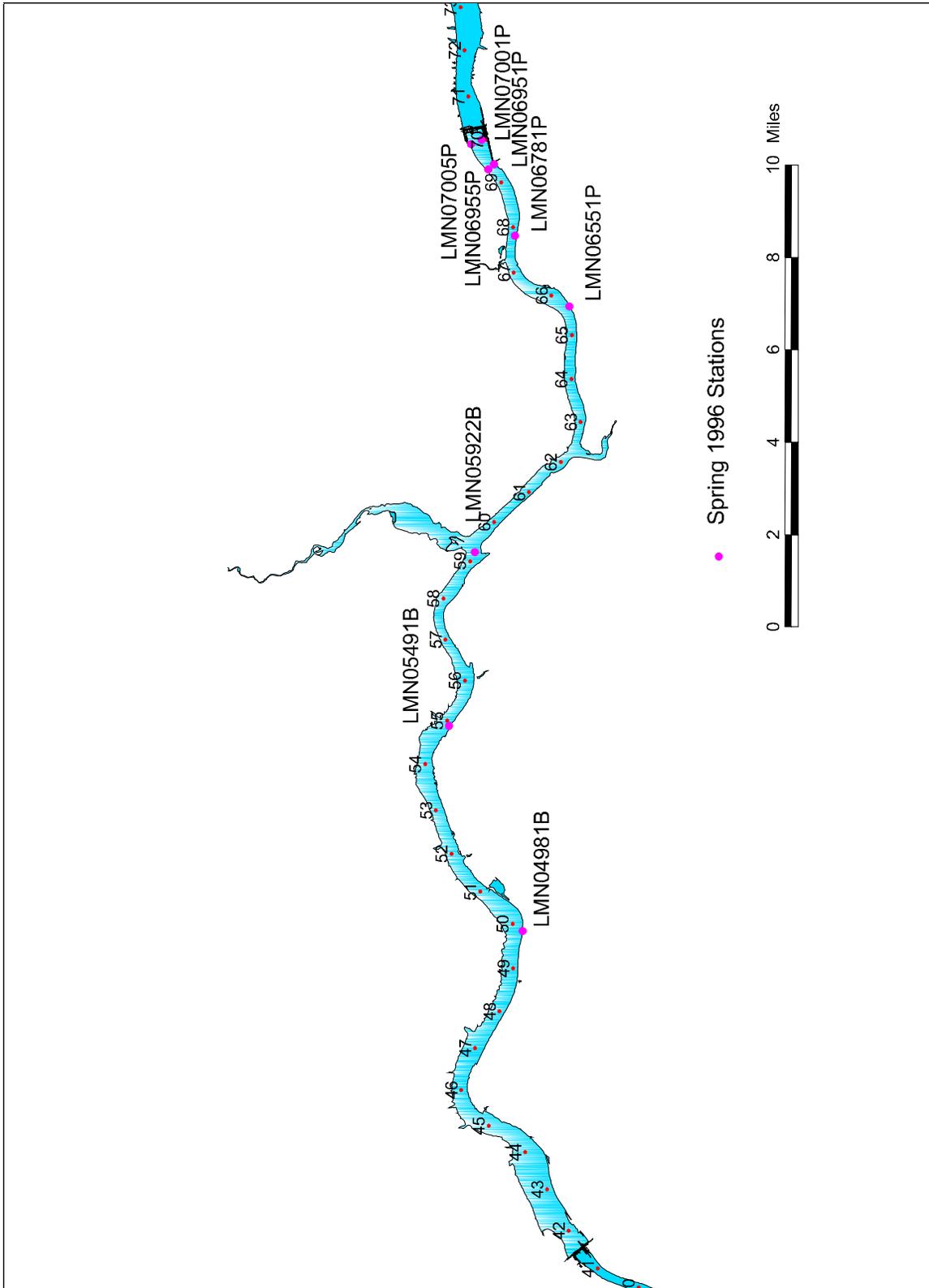


Figure 122. Dissolved gas monitor locations during the Spring 1996 study.

B.2 Velocity Data

No velocity measurements were made during the Spring 1996 study period.

B.3 Little Goose Dam Model Boundary

B.3.1 Dam Operations

CHROMS operations data was used to establish the flow at the Little Goose dam model boundary and stage at the Lower Monumental dam model boundary. This data provided hourly spillway flow and powerhouse flow. Hourly total spill and powerhouse flows for the Spring 1996 study period are shown in Figure 123. These flows were uniformly distributed across the corresponding part of the model grid.

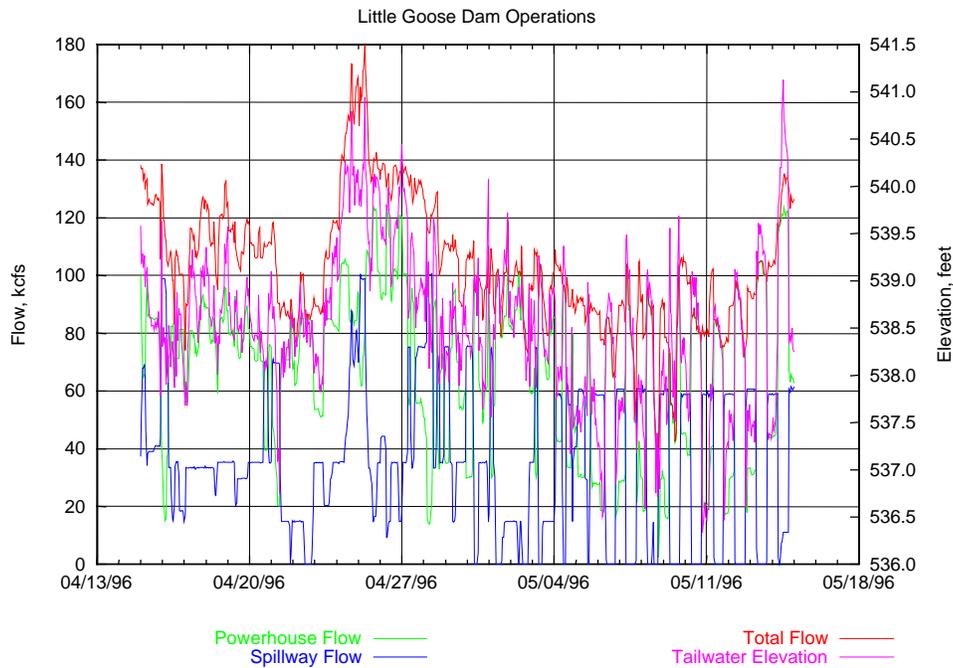


Figure 123. Little Goose dam operations during the Spring 1996 study.

B.3.2 Water Quality

Initially, data from the permanent fixed monitor located in the Little Goose dam forebay (station name "LGS") was used to establish temperature at the Little Goose dam boundary. Station data was taken from the FMS database. Temperature measured by the station (Figure 124) was used for both spillway and powerhouse flow. TDG pressures measured by the station (Figure 125) was used to compute TDG concentrations (Figure 126) for the power house flow. Spillway TDG gas pressures and concentrations (also shown in Figure 125 and Figure 126, respectively) were estimated using the TDG sourcing function for Little Goose dam.

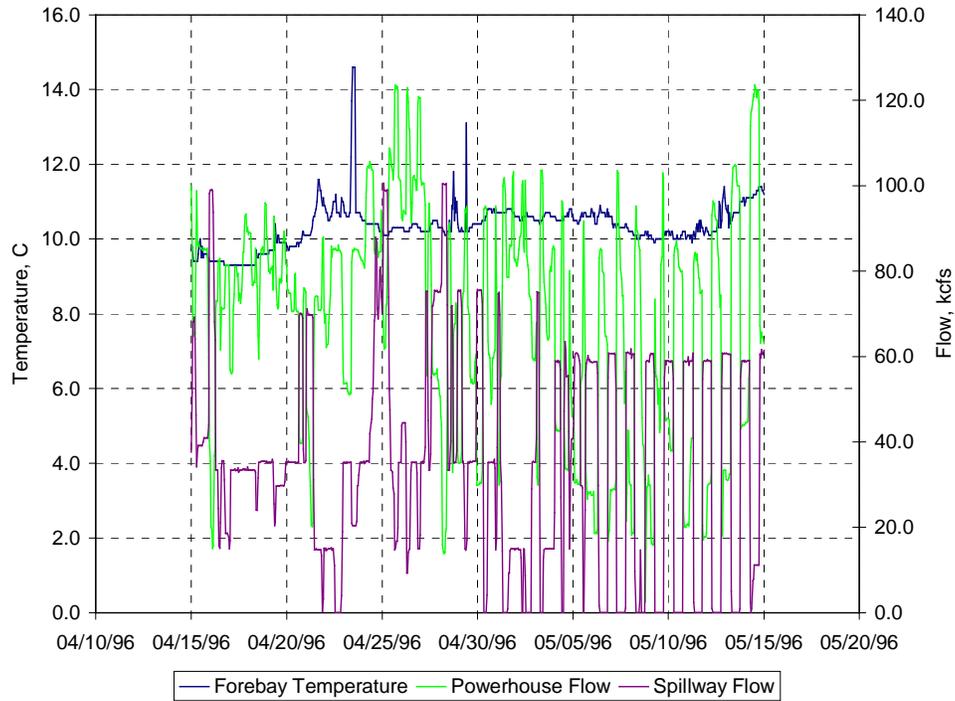


Figure 124. Little Goose forebay water temperature during the Spring 1996 study.

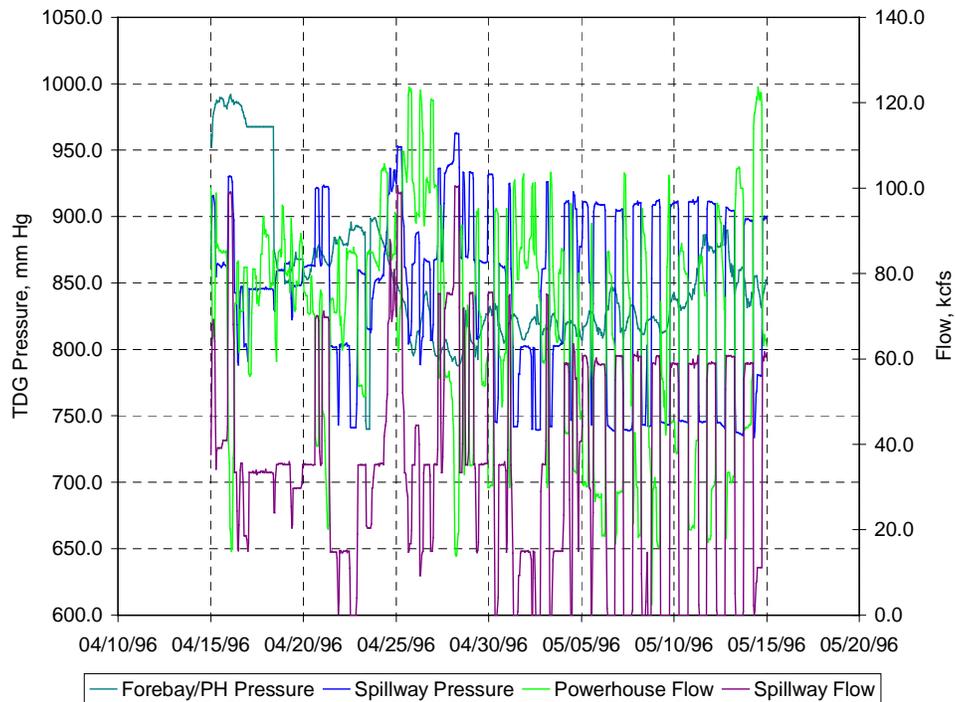


Figure 125. Little Goose forebay TDG pressure during the Spring 1996 study.

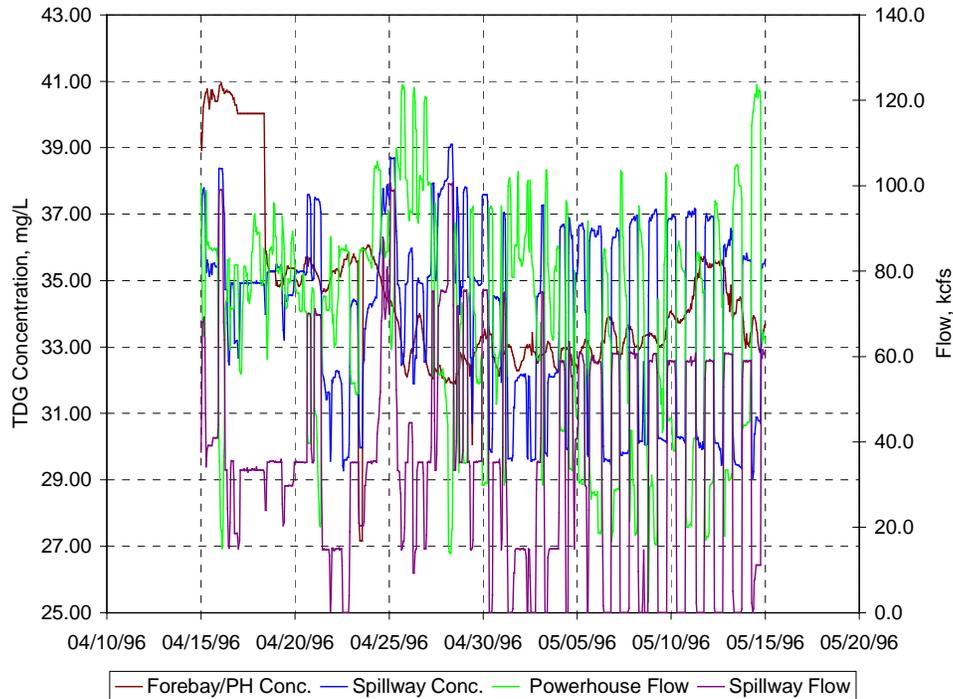


Figure 126. Computed TDG concentration in the John Day forebay during the Spring 1996 study period.

Model boundary temperature and dissolved gas concentrations were also established at the Little Goose dam boundary using the temporary pool study monitors. Two temporary monitors were located in the Little Goose tailrace during Spring 1996 study period, as shown in Figure 127. The temperatures and TDG pressures recorded by these monitors are shown in Figure 128 and Figure 129, respectively. TDG concentrations computed from the measured TDG pressures and temperatures are shown in Figure 130. The transport simulation boundary was established at grid row 7 of block 1 (shown in red in Figure 127). Temporary monitor TDG concentrations and temperatures as follows along the model grid:

- LMN07005P: columns 1 to 11; and
- LMN07001P: columns 12 to 24.

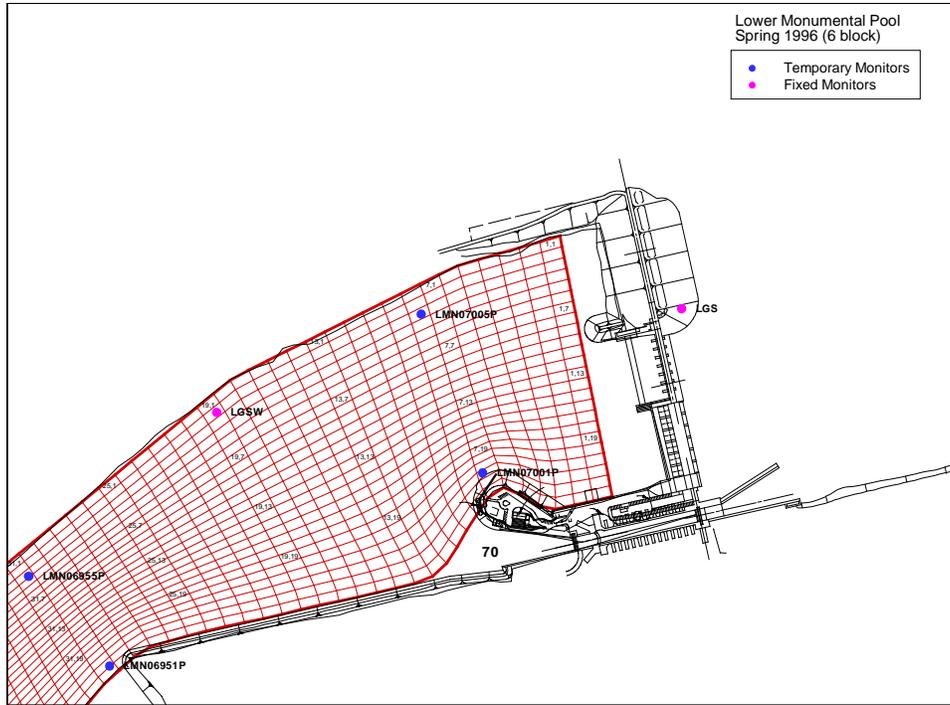


Figure 127. Locations, relative to the model grid, of upstream temporary monitors during the Spring 1996 study period.

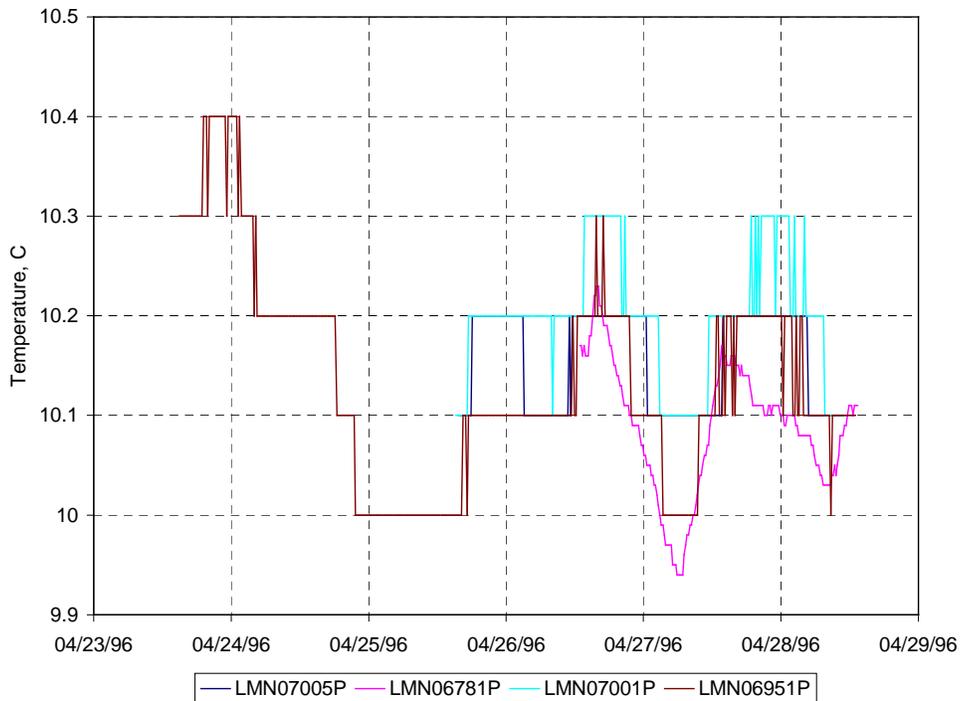


Figure 128. Temperatures measured by temporary monitors near Little Goose dam during the Spring 1996 study period.



Figure 129. TDG pressures measured by temporary monitors near Little Goose dam during the Spring 1996 study period.

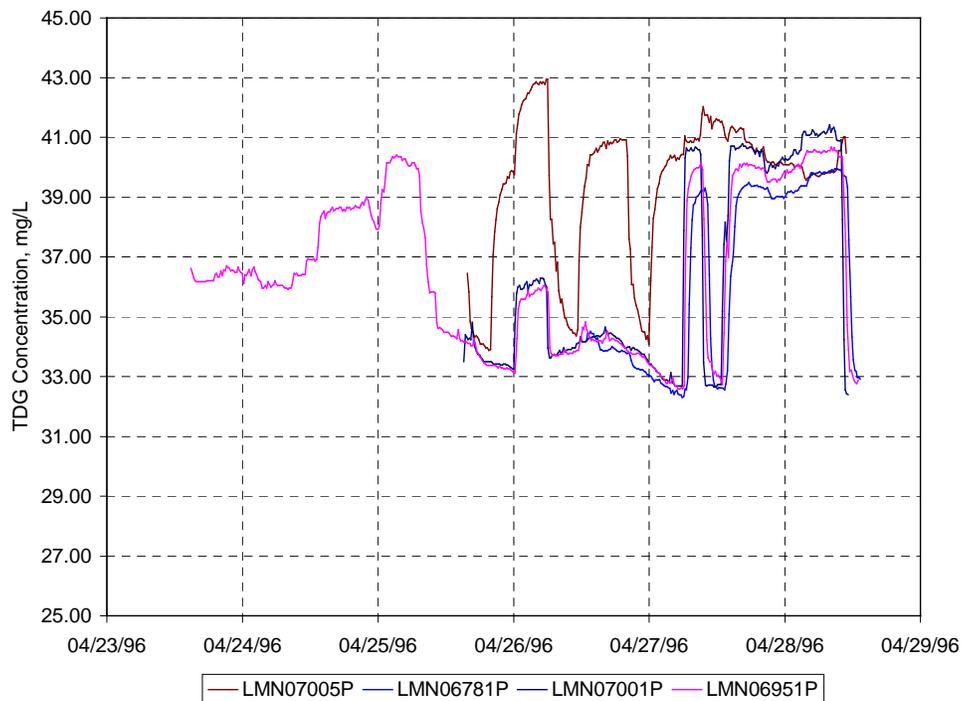


Figure 130. TDG concentrations computed from temporary monitor data near Little Goose dam during the Spring 1996 study period.

B.4 Lower Monumental Dam Boundary Operations

Forebay stage for Lower Monumental dam was obtained from hourly CHROMS operations data and is shown in Figure 131.

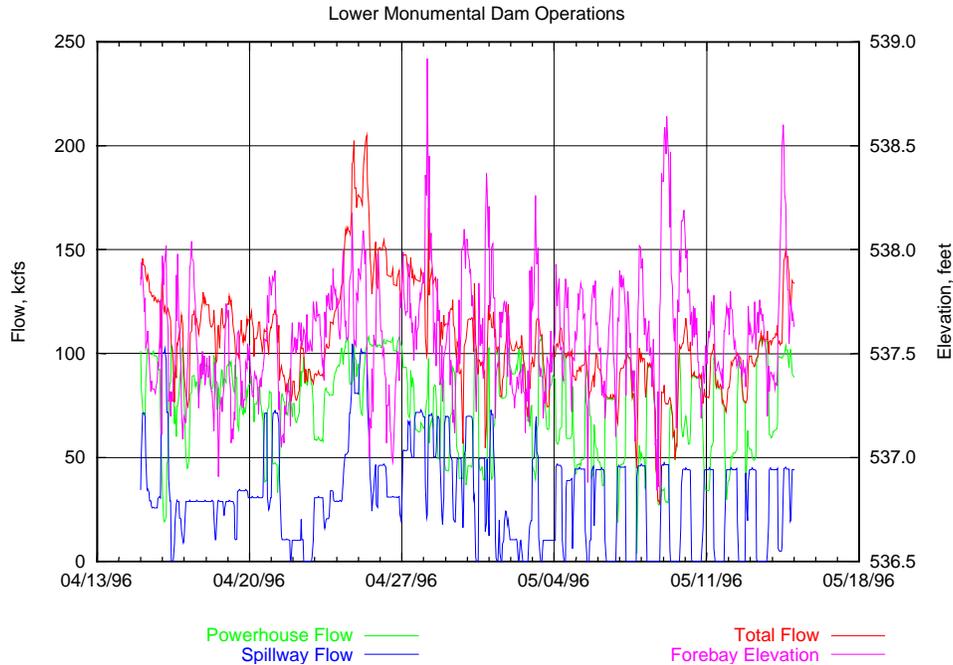


Figure 131. Lower Monumental dam operations during the Spring 1996 study.

B.5 Weather

Atmospheric conditions were considered constant over the entire pool. The Pasco, Washington, air and dew point temperature (Figure 132) and wind speed (Figure 133) were used from the NWS weather database. Barometric pressure measured by the LMN FMS (also shown in Figure 132) was considered to apply over the entire modeled area. Measured short-wave radiation was available from the WeatherPak database for part of the Spring 1996 study. The available radiation data was extended using NWS Lower Monumental dew point and cloud cover data. Net incoming solar radiation based both on the measured and estimated total solar radiation is shown in Figure 134.

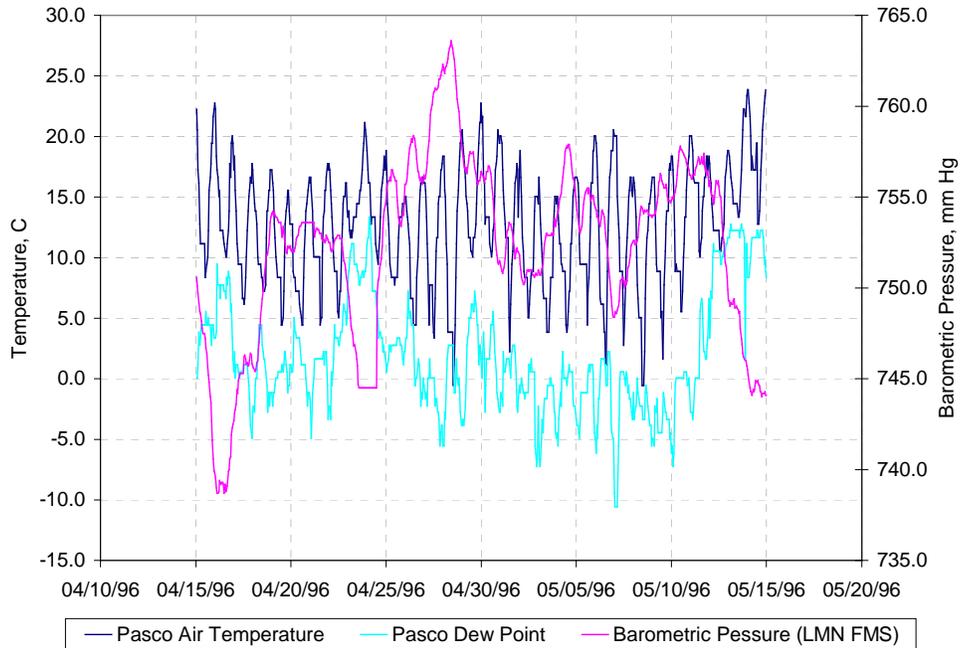


Figure 132. Air temperature, dew point, and barometric pressure used during the Spring 1996 study period.

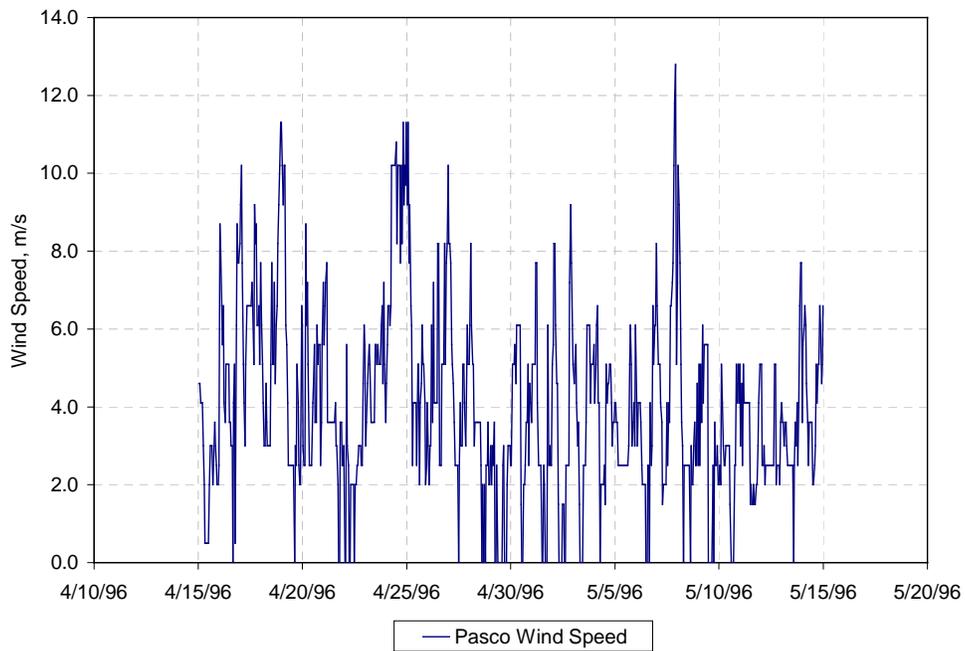


Figure 133. Wind speed used during the Spring 1996 study period.

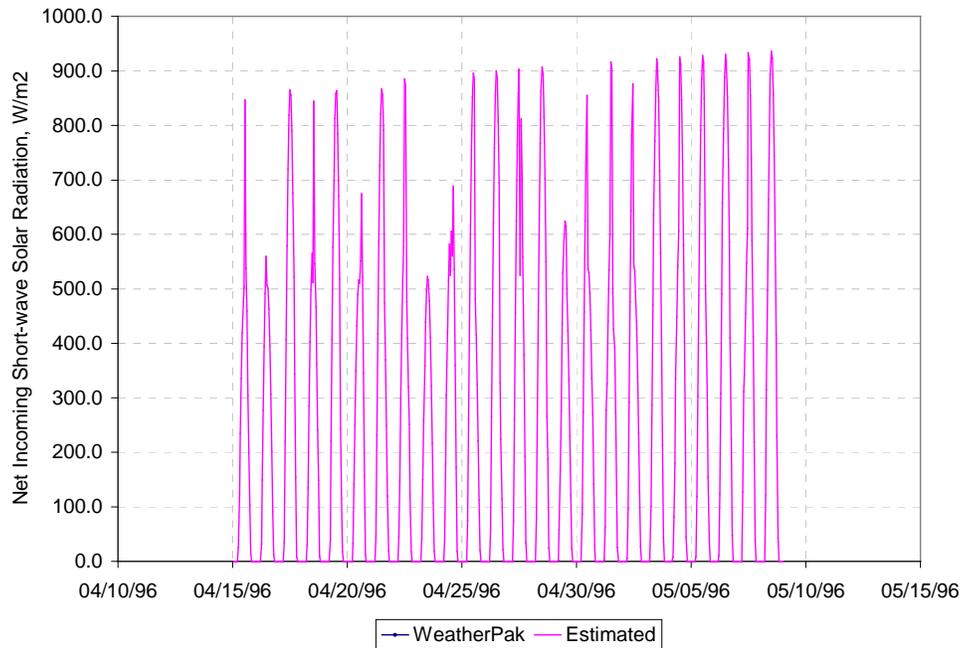


Figure 134. Net incoming short-wave solar radiation based on observed and estimated total radiation during the Spring 1996 study period.

Appendix C. Spring 1997 Lower Monumental Pool Study

C.1 Dissolved Gas Data

The Spring 1997 Lower Monumental pool dissolved gas study started on April 3 and ended on April 15. A total of 12 water quality monitors were used. These stations, and their records, are listed in Table 72. Station locations are shown in Figure 135. TDG pressure was not recorded at station LMN04184P.

Table 72. Dissolved gas monitor stations, and their records, used during the Spring 1997 study period.

Station	Record Start	Record End	Temperature Records	Pressure Records
LGSDTD1P	4/3/97 1:00:00 PM	4/13/97 3:00:00 PM	144	144
LMN05921P	4/3/97 4:00:00 PM	4/9/97 9:00:00 AM	137	137
LMN05925P	4/4/97 9:30:00 AM	4/9/97 4:30:00 PM	119	119
LMN05924P	4/4/97 9:30:00 AM	4/9/97 6:30:00 AM	118	118
LMN05922P	4/4/97 9:30:00 AM	4/9/97 12:30:00 PM	124	124
LMN06955P	4/4/97 11:30:00 AM	4/8/97 5:30:00 AM	91	91
LMN06953P	4/4/97 11:38:00 AM	4/15/97 7:08:00 AM	514	512
LMN06954P	4/4/97 12:13:00 PM	4/15/97 6:43:00 AM	512	510
LMN04183P	4/4/97 3:30:00 PM	4/15/97 7:30:00 AM	257	256
LMN04181P	4/4/97 3:30:00 PM	4/15/97 8:00:00 AM	514	513
LMN04185P	4/4/97 4:00:00 PM	4/15/97 8:00:00 AM	513	513
LMN04184P	4/4/97 4:30:00 PM	4/15/97 8:00:00 AM	512	0

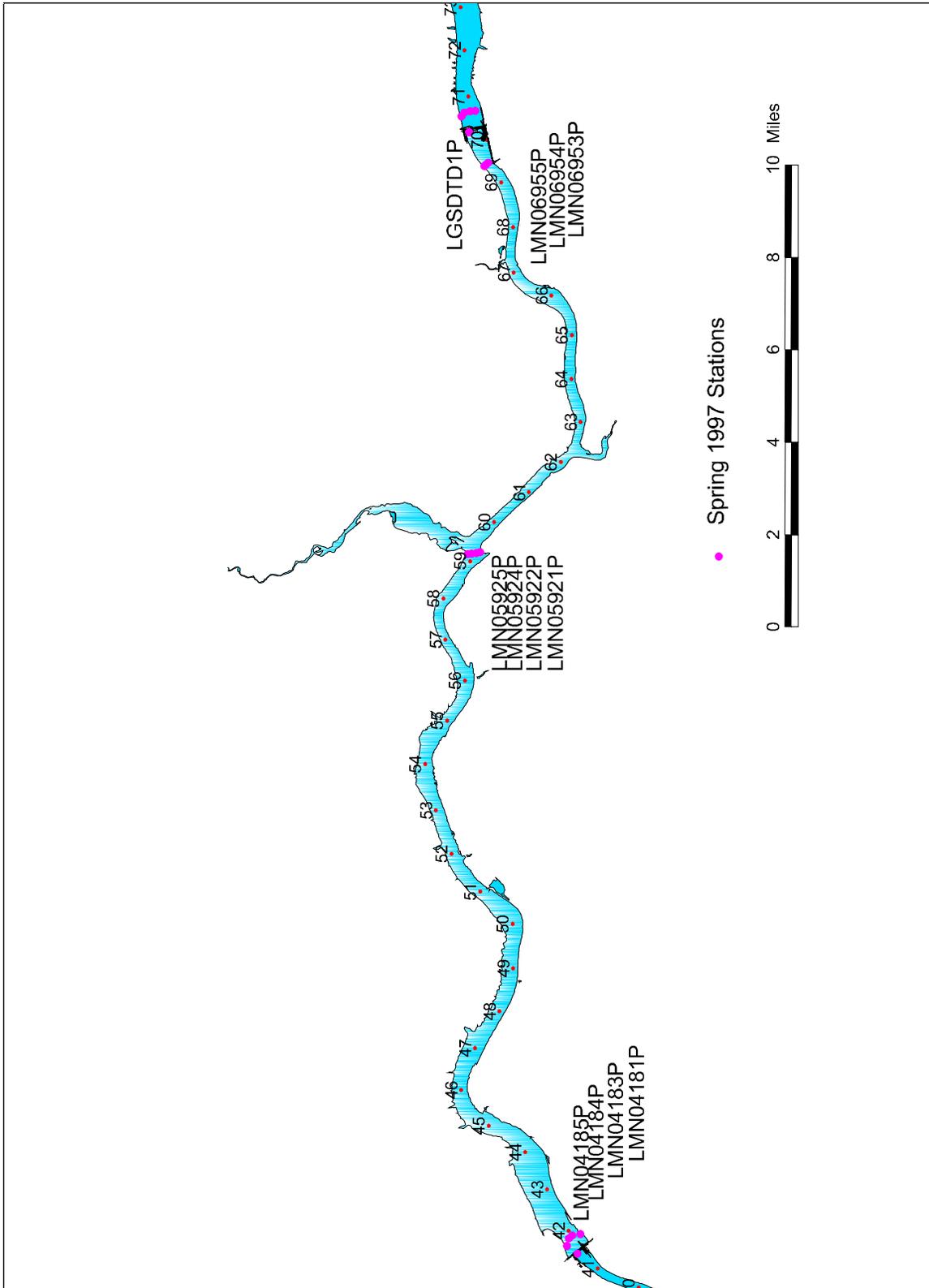


Figure 135. Dissolved gas monitor locations during the Spring 1997 study.

C.2 Velocity Data

Velocity measurements were made along a total of 25 transects during the Spring 1997 study period. The transects are summarized in Table 73. Supplied measurement locations are shown in Figure 136.

Table 73. Summary of ADCP transects made during the Spring 1997 study period.

Date Label	Average		Number of Measurements
	Velocity	Depth	
04-09-1997 12:47:00	2.1	28.9	42
04-09-1997 13:02:00	2.2	31.1	40
04-09-1997 13:31:00	2.3	27.5	43
04-09-1997 13:46:00	2.0	26.5	44
04-09-1997 14:02:00	2.1	30.2	36
04-09-1997 14:24:00	2.0	39.5	30
04-09-1997 14:46:00	1.5	30.7	52
04-09-1997 15:07:00	1.6	40.8	34
04-09-1997 15:27:00	1.2	39.5	57
04-09-1997 15:49:00	1.3	44.3	40
04-09-1997 16:12:00	1.5	48.0	40
04-09-1997 16:31:00	1.2	50.4	42
04-09-1997 16:50:00	1.3	59.4	34
04-09-1997 17:16:00	0.8	55.5	53
04-09-1997 17:30:00	0.9	55.2	53
04-09-1997 17:42:00	0.9	54.9	53
04-10-1997 08:33:00	0.5	82.1	66
04-10-1997 08:48:00	0.5	83.9	64
04-10-1997 09:01:00	0.5	84.6	67
04-10-1997 09:34:00	0.7	83.5	67
04-10-1997 10:01:00	0.7	67.8	64
04-10-1997 10:25:00	1.2	72.3	46
04-10-1997 10:44:00	1.2	68.8	44
04-10-1997 11:02:00	1.1	56.1	54
04-10-1997 11:23:00	1.5	65.0	39

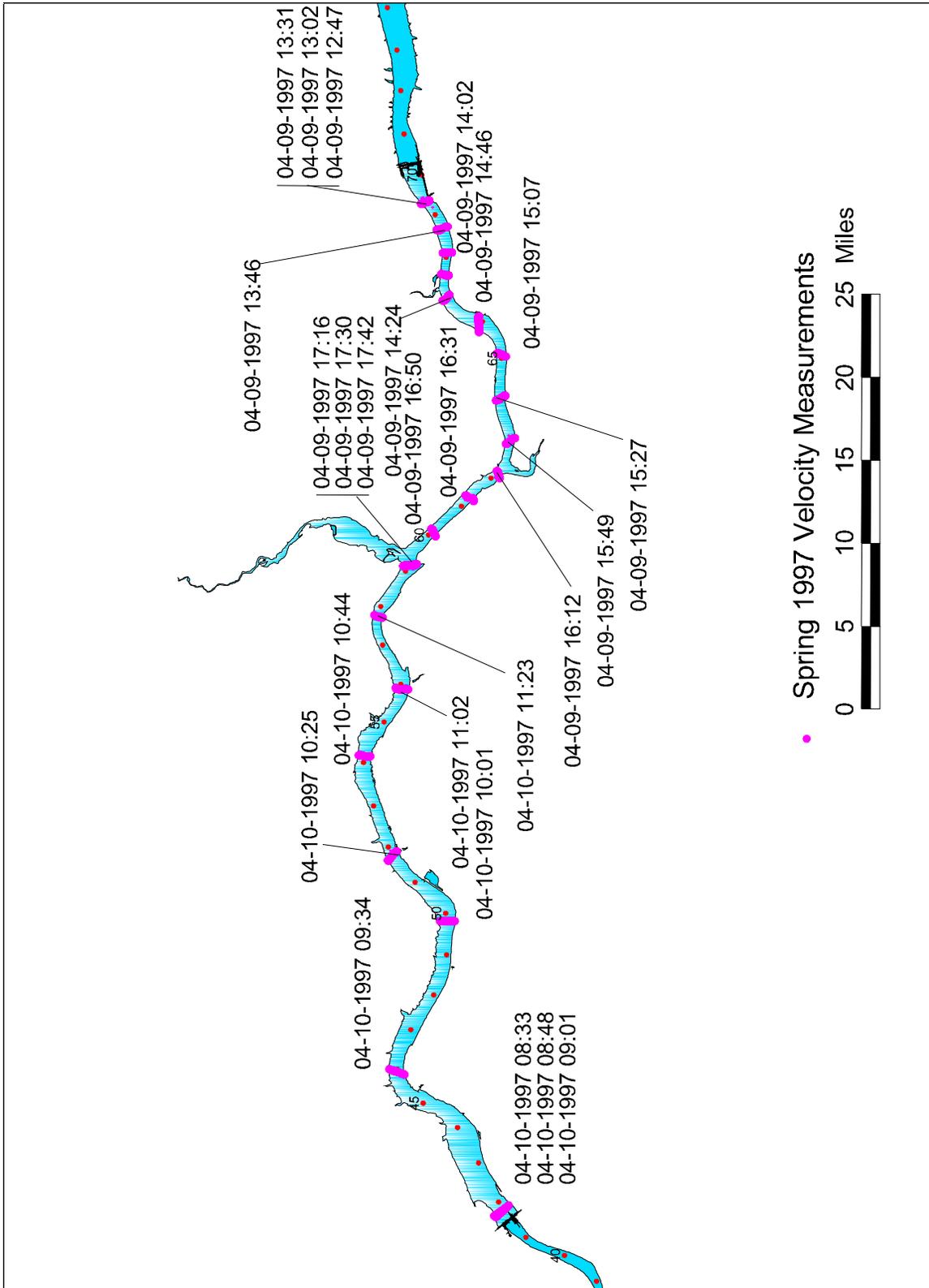


Figure 136. Locations of ADCP velocity measurements during the Spring 1997 study period.

C.3 Little Goose Dam Model Boundary

C.3.1 Dam Operations

CHROMS operations data was used to establish the flow at the Little Goose dam model boundary and stage at the Lower Monumental dam model boundary. This data provided hourly spillway flow and power house flow. Hourly total spill and powerhouse flows for the Spring 1997 study period are shown in Figure 137. These flows were uniformly distributed across the corresponding part of the model grid.

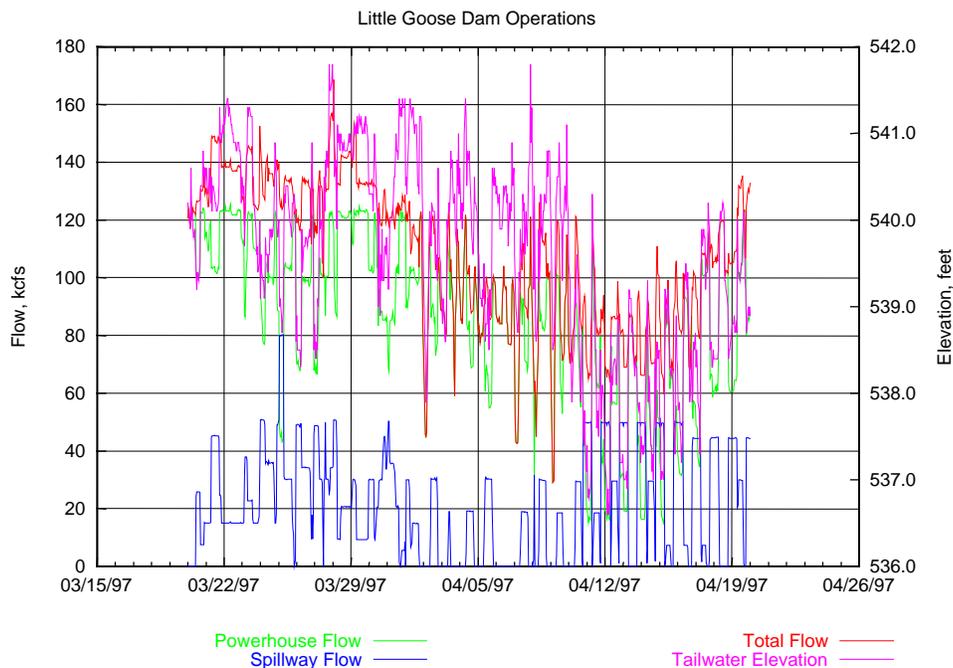


Figure 137. Little Goose dam operations during the Spring 1997 study.

C.3.2 Water Quality

Initially, data from the permanent fixed monitor located in the Little Goose dam forebay (station name "LGS") was used to establish temperature at the Little Goose dam boundary. Station data was taken from the FMS database. Temperature measured by the station (Figure 138) was used for both spillway and powerhouse flow. TDG pressures measured by the station (Figure 139) was used to compute TDG concentrations (Figure 140) for the power house flow. Spillway TDG gas pressures and concentrations (also shown in Figure 139 and Figure 140, respectively) were estimated using the TDG sourcing function for Little Goose dam.

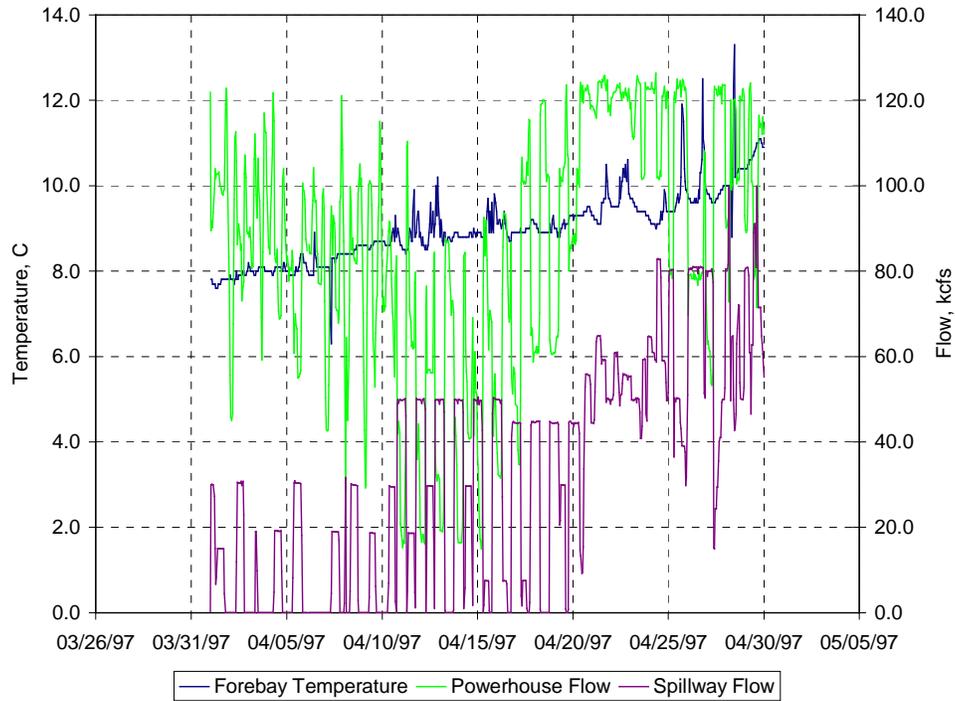


Figure 138. Little Goose forebay water temperature during the Spring 1997 study.

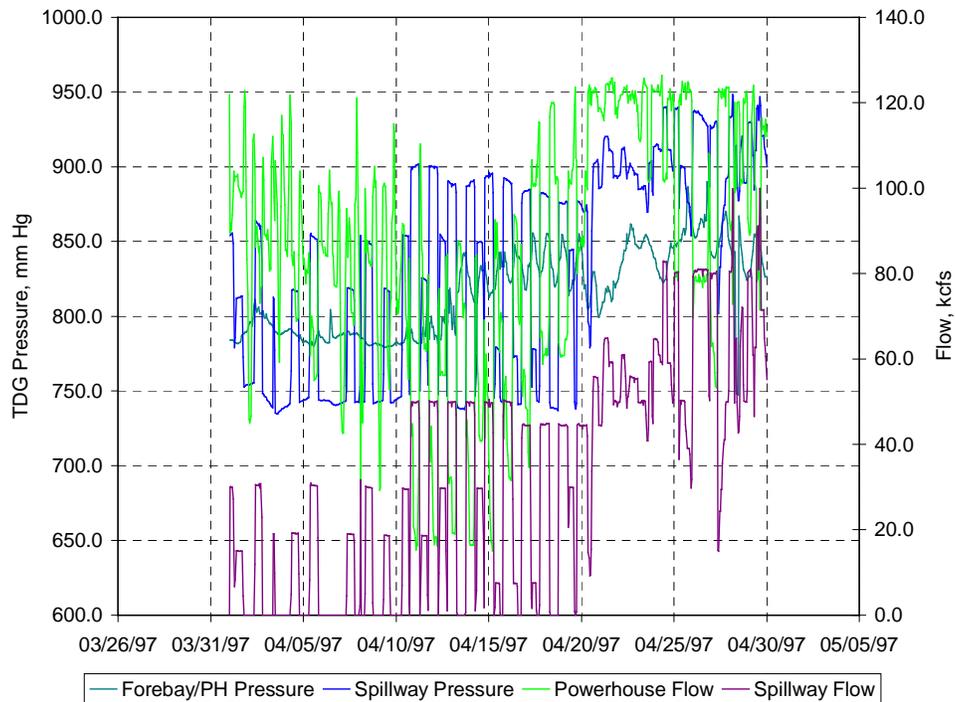


Figure 139. Little Goose forebay TDG pressure during the Spring 1997 study period.

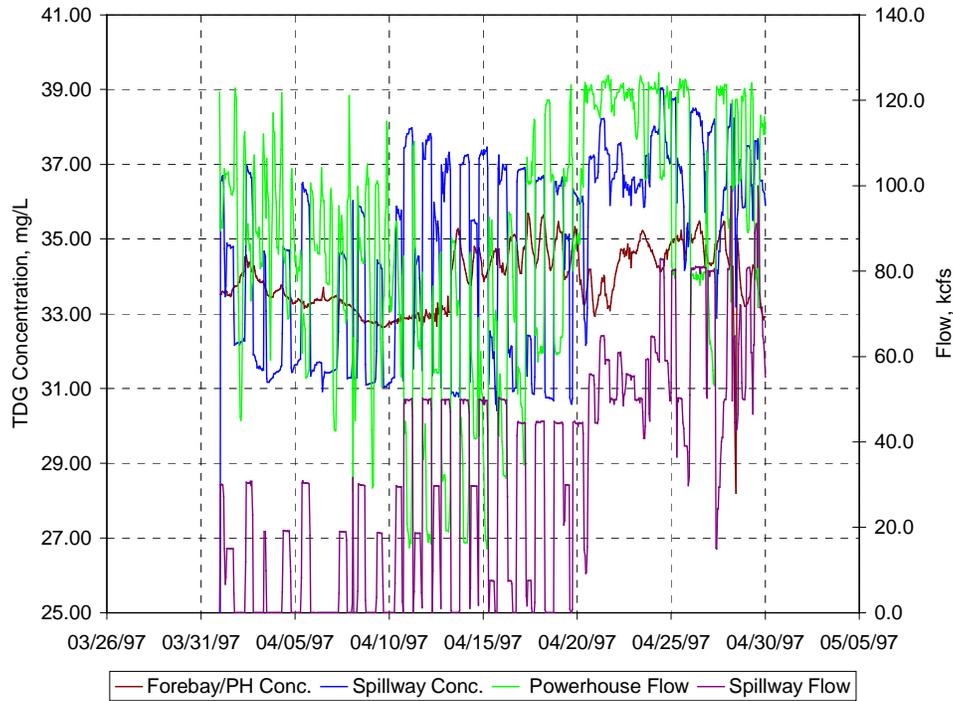


Figure 140. Computed TDG concentration in the Little Goose forebay during the Spring 1997 study.

Model boundary temperature and dissolved gas concentrations were also established at the Little Goose dam boundary using the temporary pool study monitors. Three temporary monitors were located in the Little Goose tailrace during Spring 1997 study period, as shown in Figure 141. The temperatures and TDG pressures recorded by these monitors are shown in Figure 142 and Figure 143, respectively. TDG concentrations computed from the measured TDG pressures and temperatures are shown in Figure 144. The transport simulation boundary was established at grid row 26 of block 1 (shown in red in Figure 141). Temporary monitor TDG concentrations and temperatures as follows along the model grid:

- LMN06954P: columns 1 to 10; and
- LMN06953P: columns 11 to 24.

Station LMN06955P was not used because of its short record.

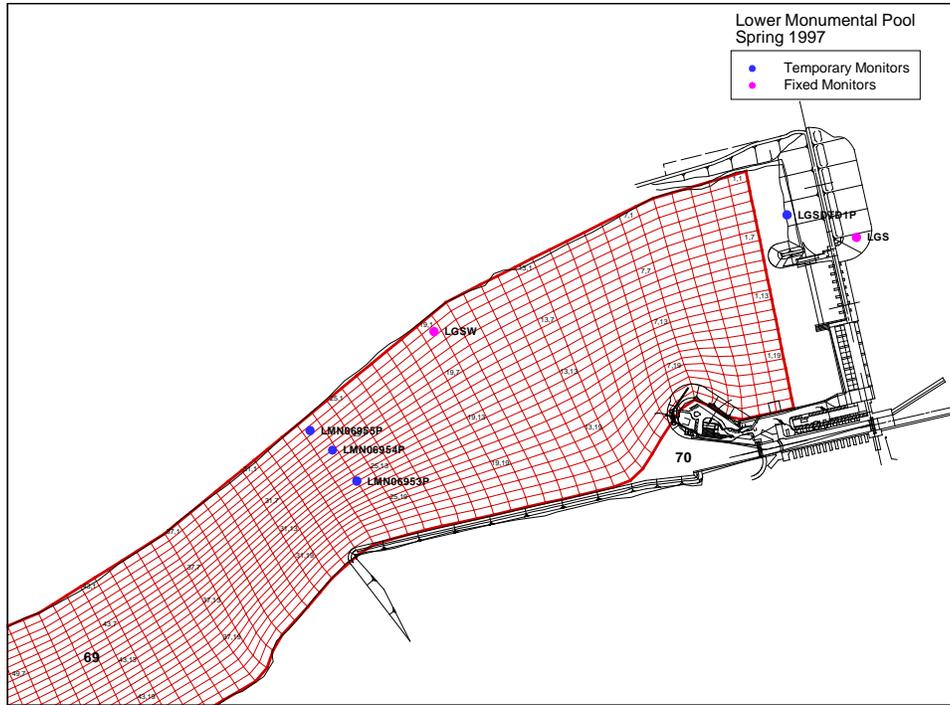


Figure 141. Locations, relative to the model grid, of upstream temporary monitors during the Spring 1997 study period.

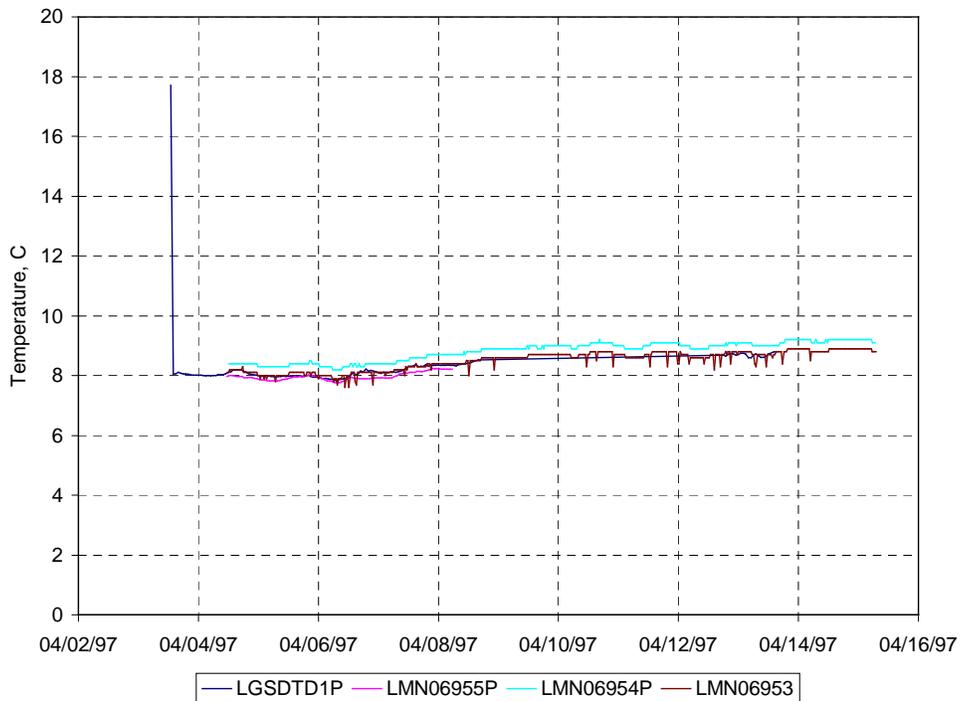


Figure 142. Temperatures measured by temporary monitors near Little Goose dam during the Spring 1997 study period.

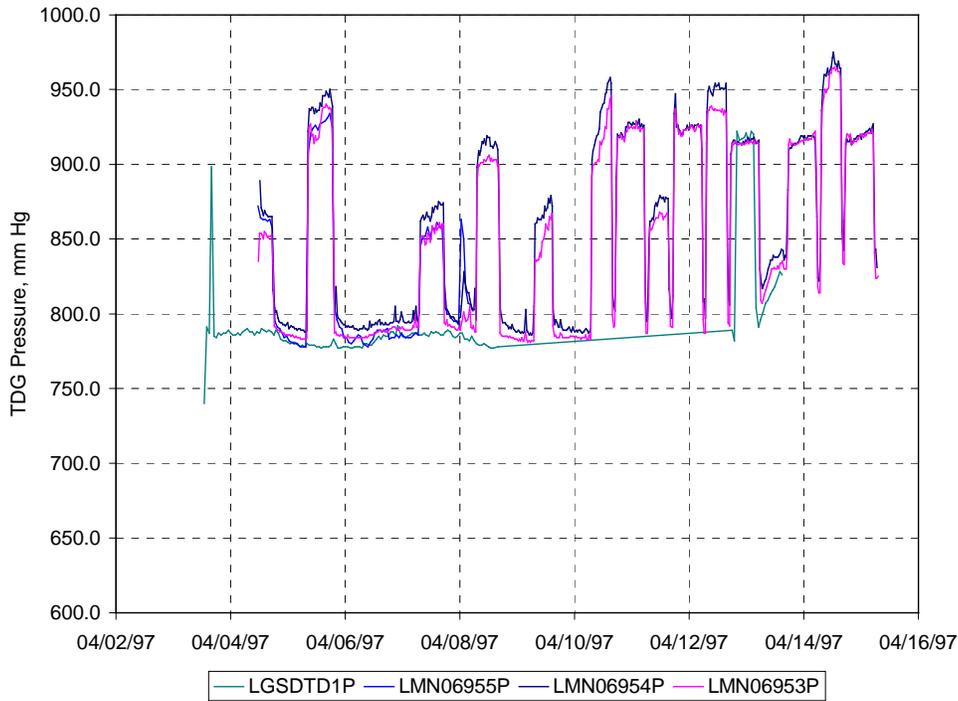


Figure 143. TDG pressures measured by temporary monitors near Little Goose dam during the Spring 1997 study period.

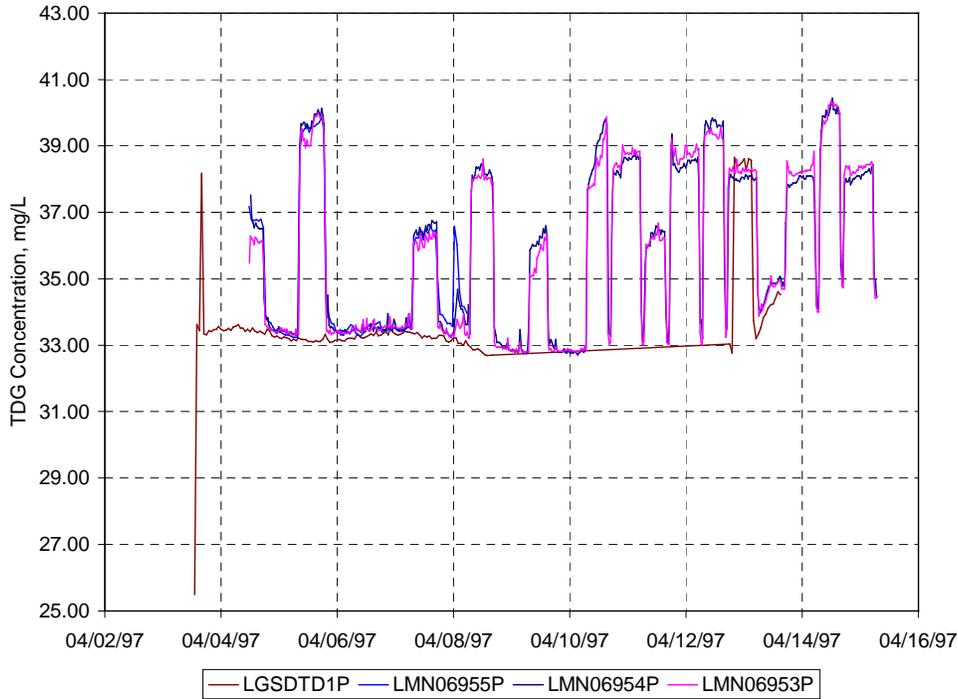


Figure 144. TDG concentrations computed from temporary monitor data near Little Goose dam during the Spring 1997 study period.

C.4 Lower Monumental Dam Boundary Operations

Forebay stage for Lower Monumental dam was obtained from hourly CHROMS operations data and is shown in Figure 145.

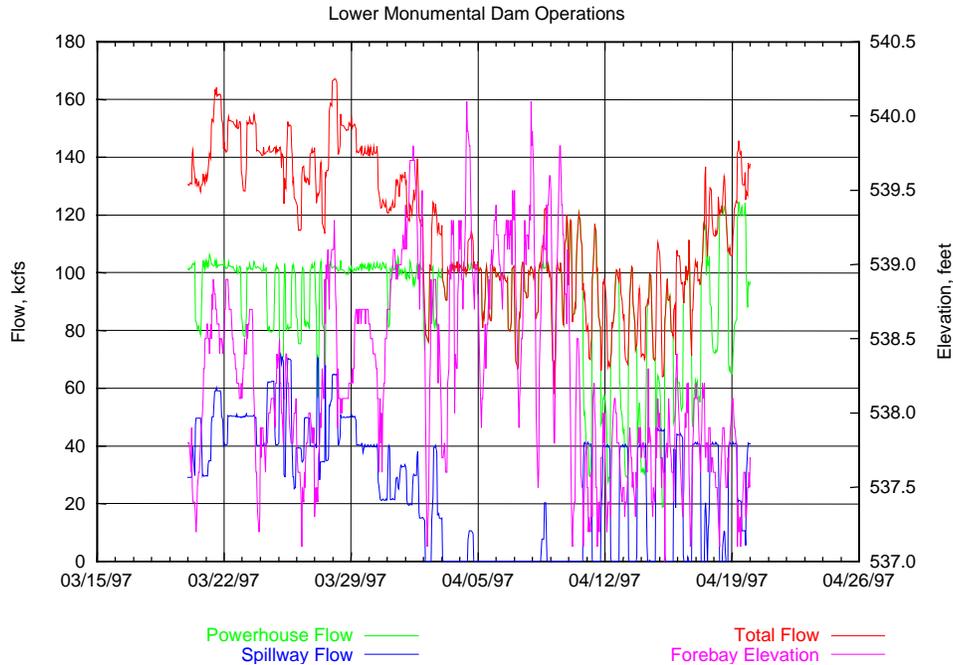


Figure 145. Lower Monumental dam operations during the Spring 1997 study period.

C.5 Weather

Atmospheric conditions were considered constant over the entire pool. The Pasco, Washington, air and dew point temperature (Figure 146) and wind speed (Figure 147) were used from the NWS weather database. Barometric pressure measured by the LMN FMS (also shown in Figure 146) was considered to apply over the entire modeled area. Measured short-wave radiation was available from the WeatherPak database for part of the Spring 1996 study. The available radiation data was extended using NWS Lower Monumental dew point and cloud cover data. Net incoming solar radiation based both on the measured and estimated total solar radiation is shown in Figure 148.

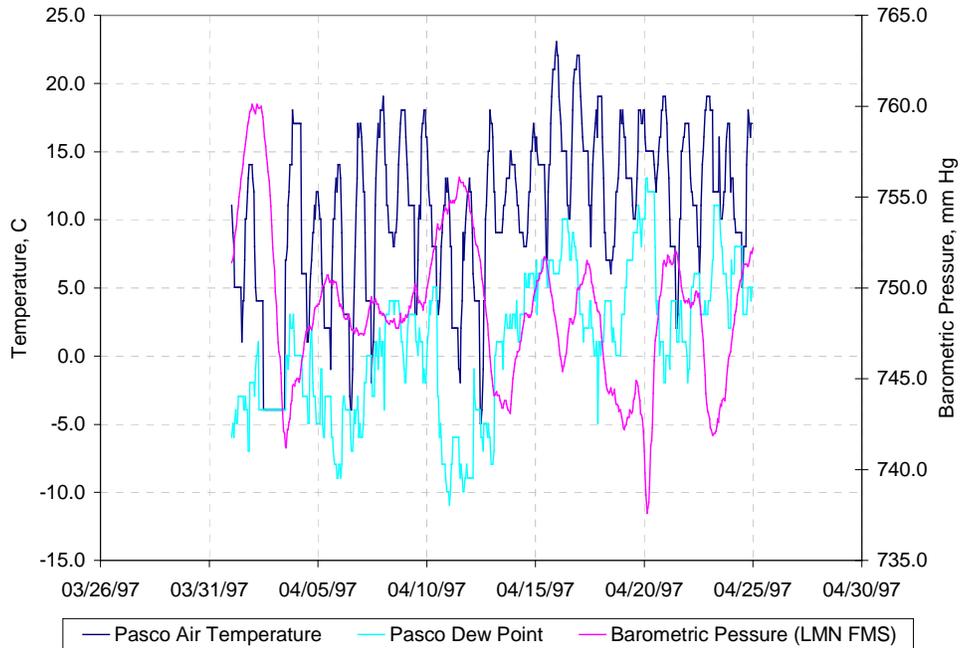


Figure 146. Air temperature, dew point, and barometric pressure used during the Spring 1997 study period.

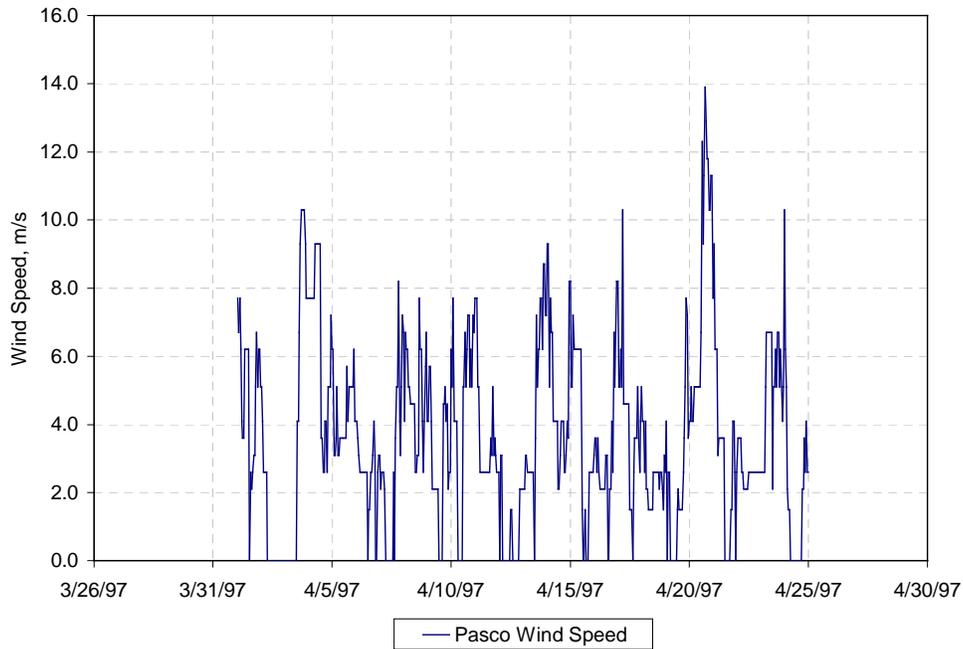


Figure 147. Wind speed used during the Spring 1997 study period.

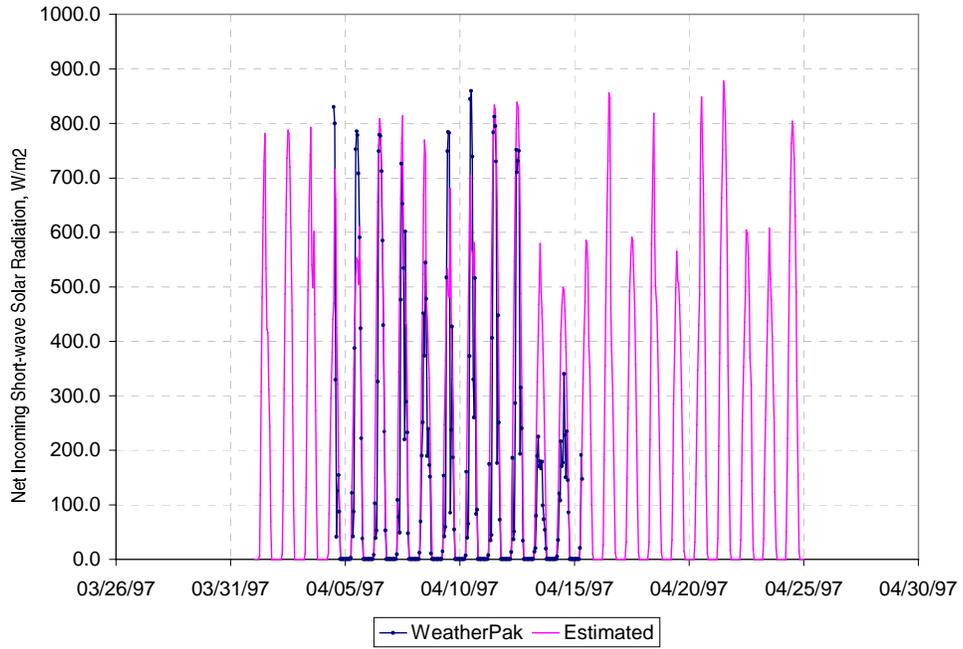


Figure 148. Net incoming short-wave solar radiation based on observed and estimated total radiation during the Spring 1997 study period.

Appendix D. Summer 1997 Lower Monumental Pool Study

D.1 Dissolved Gas Data

The Summer 1997 Lower Monumental pool dissolved gas study started on June 4 and ended on June 14. A total of 12 water quality monitors were used. These stations, and their records, are listed in Table 74. Station locations are shown in Figure 149.

Table 74. Dissolved gas monitor stations, and their records, used during the Summer 1997 study period.

Station	Record Start	Record End	Temperature Records	Pressure Records
LGSDTDP	6/4/97 8:03:00 AM	6/13/97 4:41:00 PM	869	858
LMNDTDP	6/6/97 12:00:00 PM	6/14/97 1:15:00 PM	774	528
LMN06945P	6/6/97 12:00:00 PM	6/14/97 9:30:00 AM	759	759
LMN06943P	6/6/97 12:00:00 PM	6/14/97 10:00:00 AM	761	761
LMN05925P	6/6/97 12:00:00 PM	6/14/97 8:45:00 AM	755	754
LMN05924P	6/6/97 12:00:00 PM	6/14/97 9:00:00 AM	757	757
LMN05922P	6/6/97 12:00:00 PM	6/14/97 9:00:00 AM	757	757
LMN05921P	6/6/97 12:00:00 PM	6/14/97 9:00:00 AM	757	757
LMN04185P	6/6/97 12:00:00 PM	6/14/97 12:30:00 PM	771	771
LMN04184P	6/6/97 12:00:00 PM	6/14/97 12:30:00 PM	771	771
LMN04183P	6/6/97 12:00:00 PM	6/14/97 12:30:00 PM	771	771
LMN04181P	6/6/97 12:00:00 PM	6/10/97 8:15:00 AM	368	368

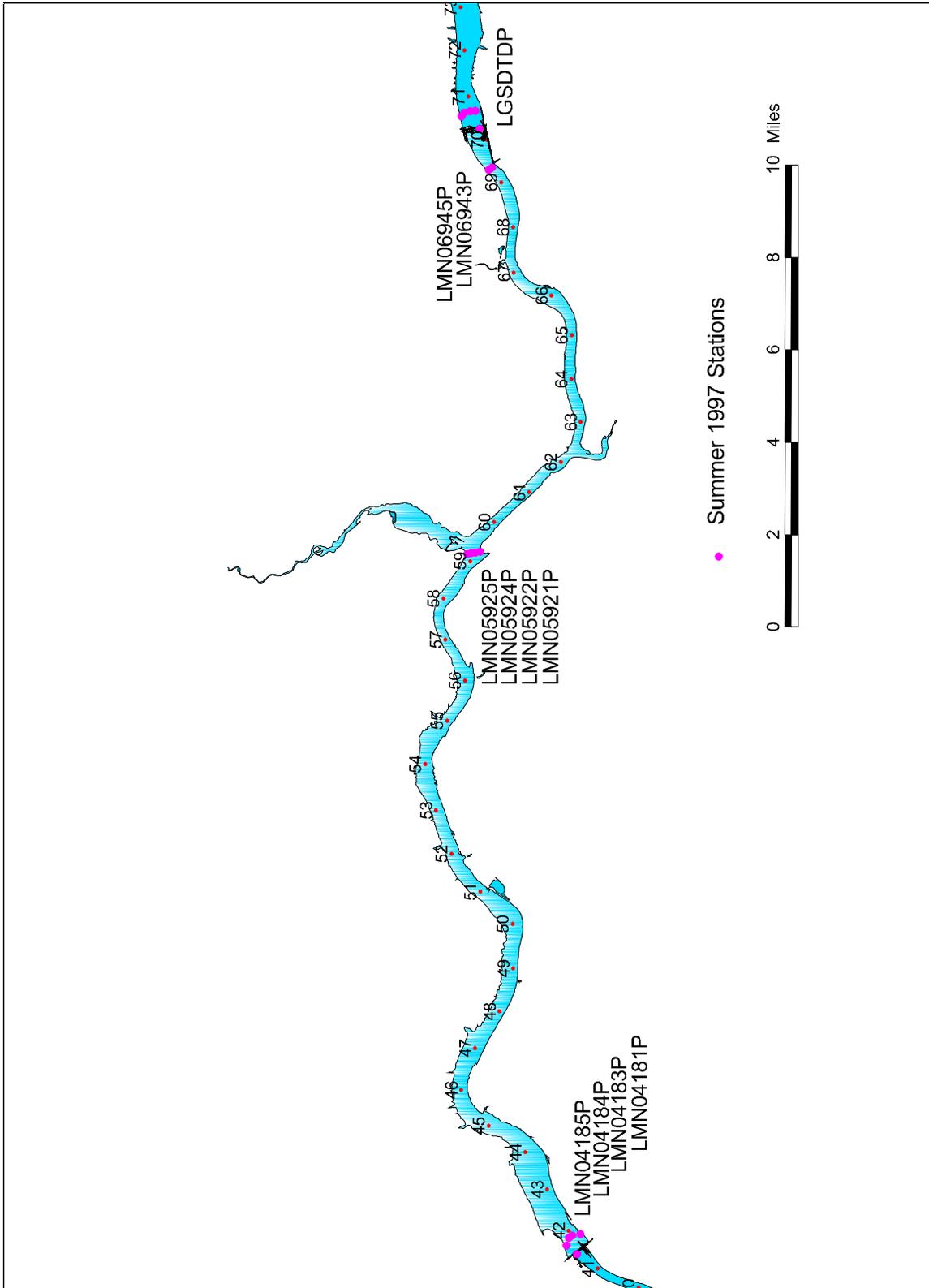


Figure 149. Dissolved gas monitor locations during the Summer 1997 study.

D.2 Velocity Data

Velocity measurements were made along a total of 26 transects during the Summer 1997 study period. The transects are summarized in Table 75. Supplied measurement locations are shown in Figure 150.

Table 75. Summary of ADCP transects made during the Summer 1997 study.

Date Label	Average		Number of Measurements
	Velocity	Depth	
06-10-1997 09:56:00	4.5	28.9	50
06-10-1997 10:03:00	5.1	30.0	40
06-10-1997 10:11:00	4.6	29.1	48
06-10-1997 10:26:00	4.2	24.7	47
06-10-1997 10:39:00	4.5	28.7	35
06-10-1997 10:49:00	4.0	33.7	40
06-10-1997 11:02:00	3.9	38.1	38
06-10-1997 11:17:00	3.0	27.0	52
06-10-1997 11:33:00	3.6	37.1	46
06-10-1997 11:47:00	2.9	42.0	39
06-10-1997 12:04:00	2.9	40.5	40
06-10-1997 12:16:00	3.5	43.7	35
06-10-1997 12:30:00	2.7	45.3	43
06-10-1997 12:46:00	2.4	50.4	36
06-10-1997 13:01:00	1.7	50.5	47
06-10-1997 13:10:00	2.0	53.4	66
06-10-1997 13:24:00	1.8	51.2	49
06-10-1997 13:47:00	2.3	62.2	32
06-10-1997 14:05:00	1.6	54.6	54
06-10-1997 14:23:00	1.5	60.5	44
06-10-1997 14:42:00	1.4	57.5	47
06-10-1997 15:56:00	1.2	61.1	54
06-10-1997 16:15:00	1.0	77.0	44
06-10-1997 16:34:00	0.9	77.2	41
06-10-1997 16:42:00	0.9	77.5	46
06-10-1997 16:50:00	0.9	81.1	58

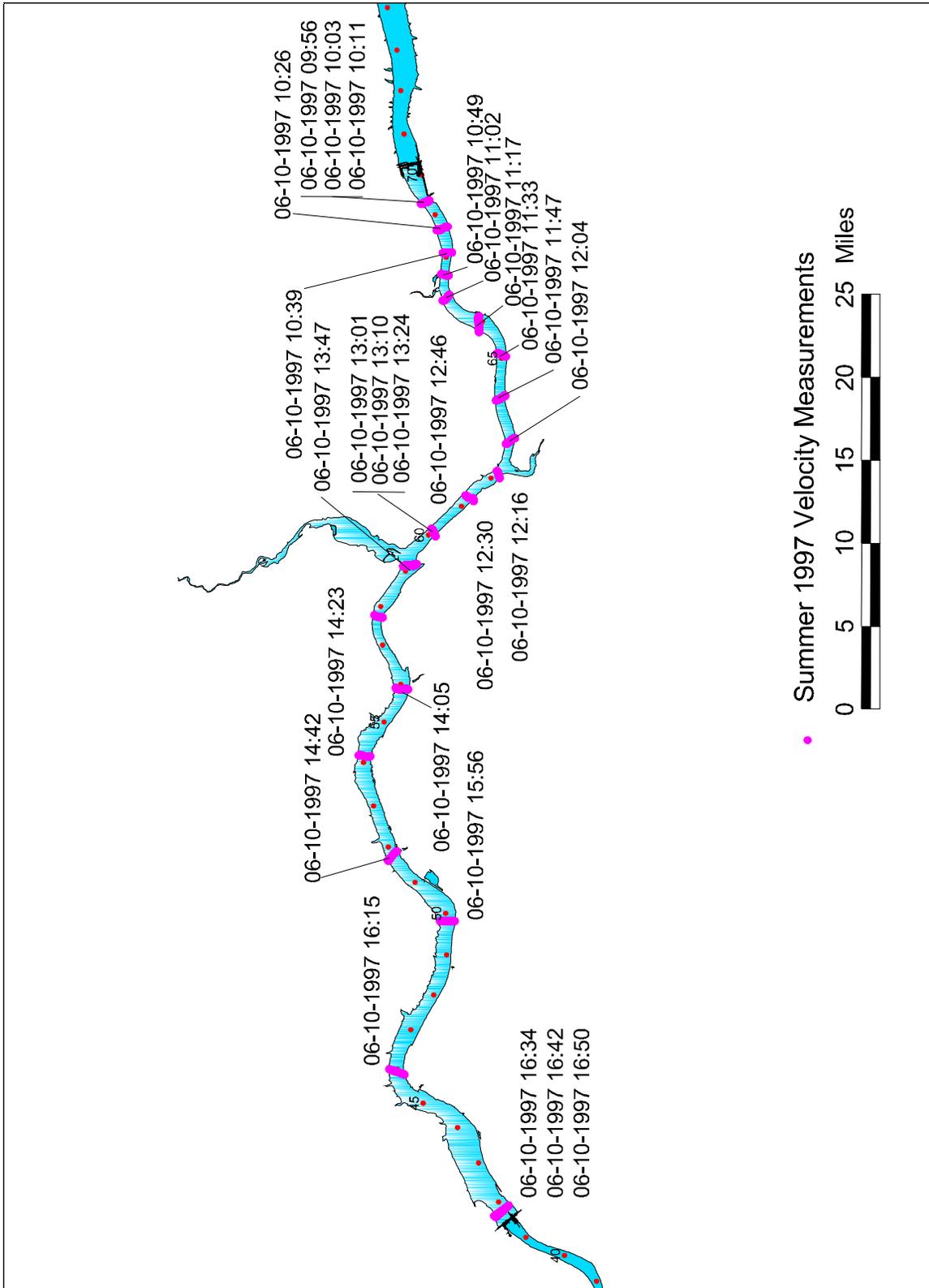


Figure 150. Locations of ADCP velocity measurements during the Summer 1997 study period.

D.3 Little Goose Dam Model Boundary

D.3.1 Dam Operations

CHROMS operations data was used to establish the flow at the Little Goose dam model boundary and stage at the Lower Monumental dam model boundary. This data provided hourly spillway flow and power house flow. Hourly total spill and powerhouse flows for the Summer 1997 study period are shown in Figure 151. These flows were uniformly distributed across the corresponding part of the model grid.

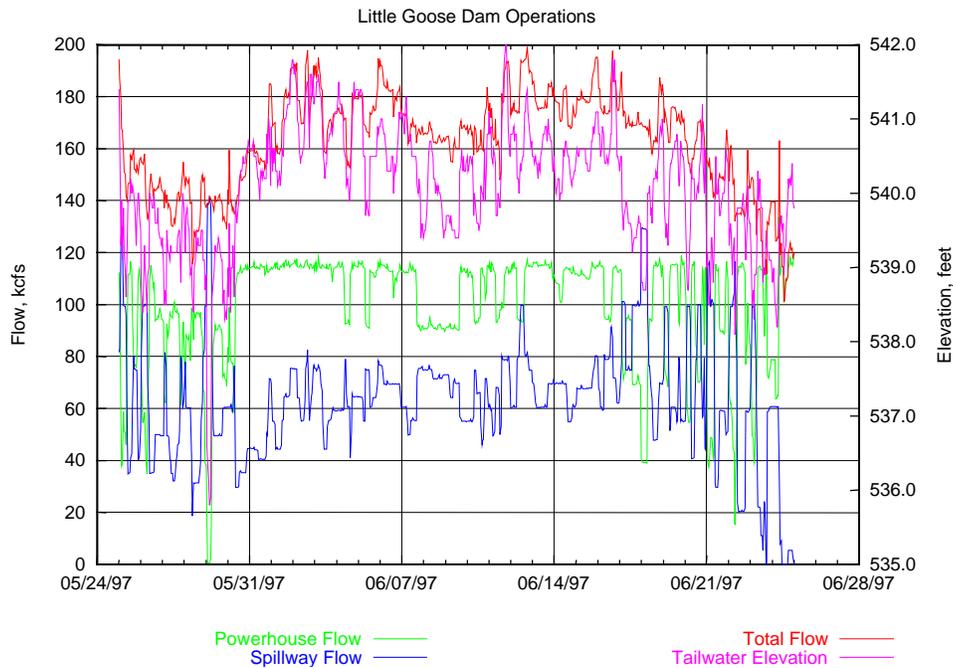


Figure 151. Little Goose dam operations during the Summer 1997 study.

D.3.2 Water Quality

Initially, data from the permanent fixed monitor located in the Little Goose dam forebay (station name "LGS") was used to establish temperature at the Little Goose dam boundary. Station data was taken from the FMS database. Temperature measured by the station (Figure 152) was used for both spillway and powerhouse flow. TDG pressures measured by the station (Figure 153) was used to compute TDG concentrations (Figure 154) for the power house flow. Spillway TDG gas pressures and concentrations (also shown in Figure 152 and Figure 153, respectively) were estimated using the TDG sourcing function for Little Goose dam.

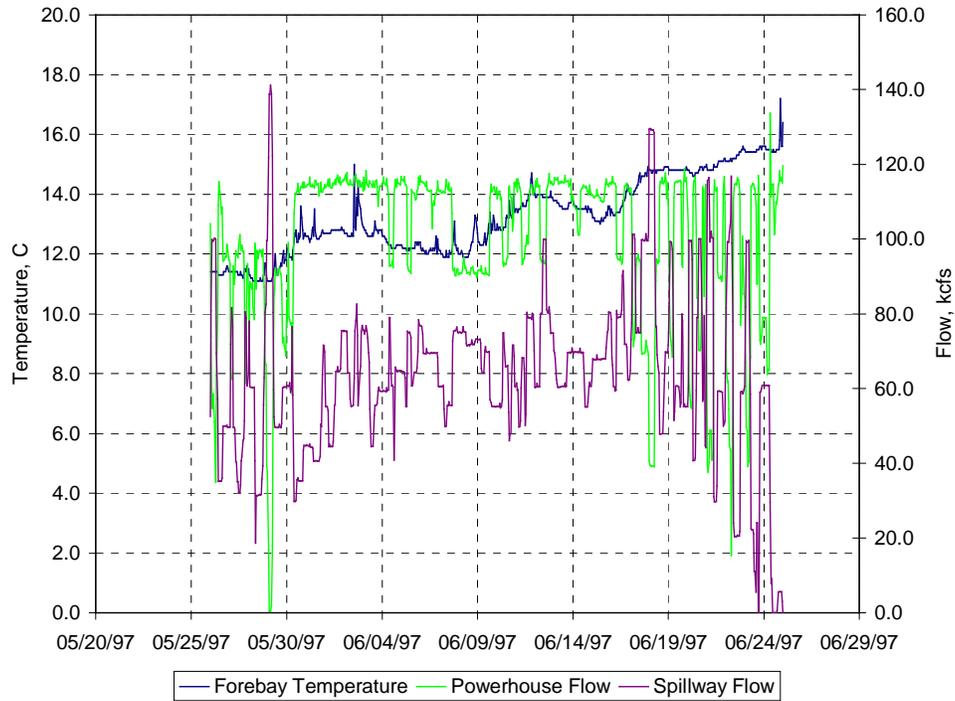


Figure 152. Little Goose forebay water temperature during the Summer 1997 study period.

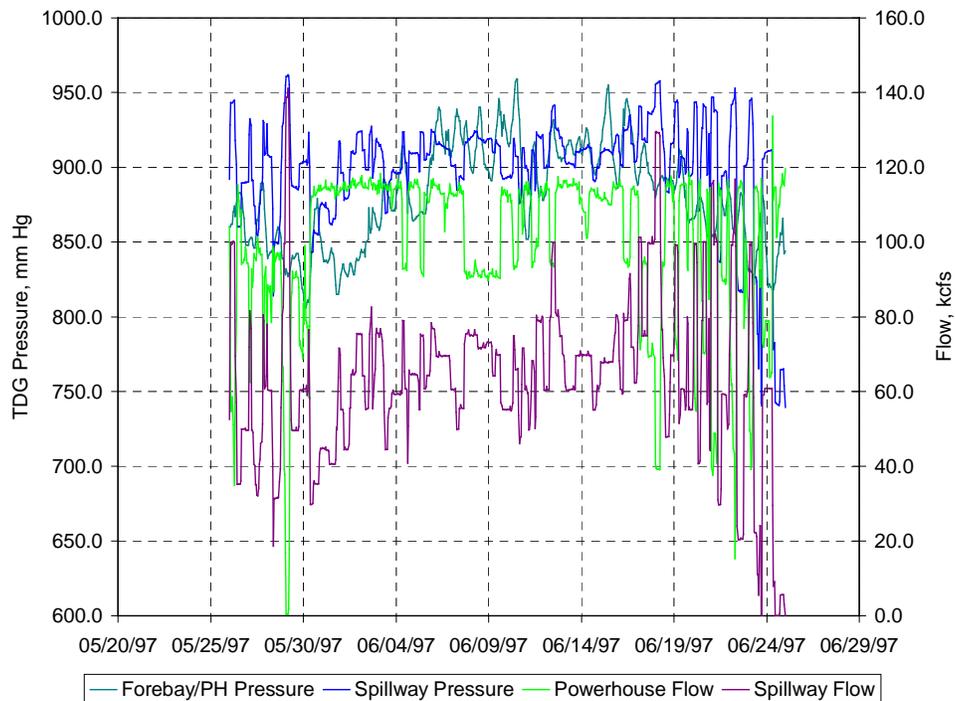


Figure 153. Little Goose forebay TDG pressure during the Summer 1997 study.

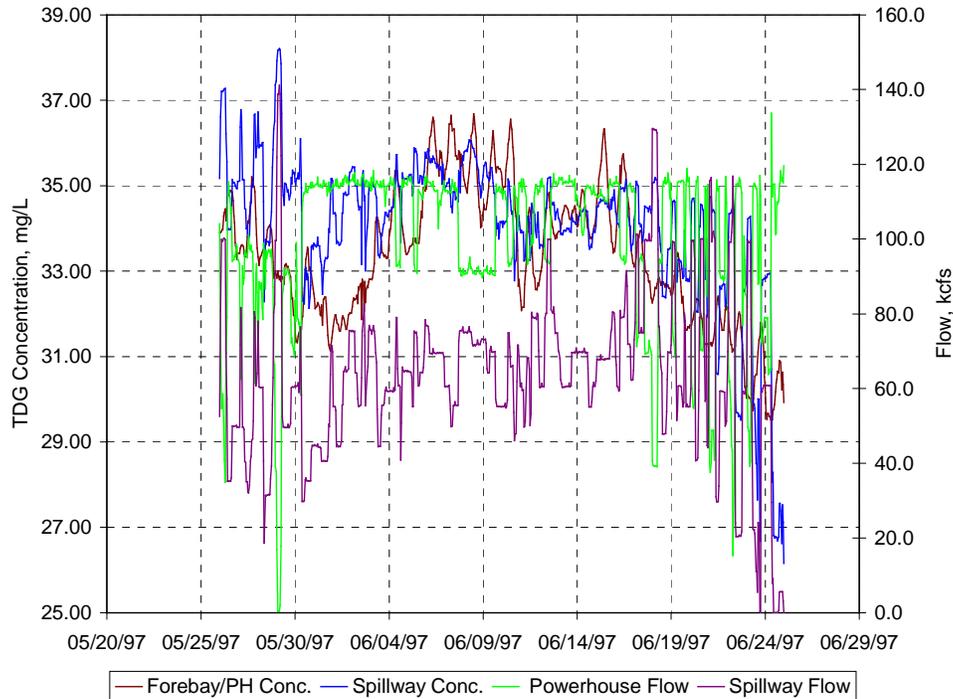


Figure 154. Computed TDG concentration in the Little Goose forebay during the Summer 1997 study.

Model boundary temperature and dissolved gas concentrations were also established at the Little Goose dam boundary using the temporary pool study monitors. Two temporary monitors were located in the Little Goose tailrace during Summer 1997 study period, as shown in Figure 155. The temperatures and TDG pressures recorded by these monitors are shown in Figure 156 and Figure 157, respectively. TDG concentrations computed from the measured TDG pressures and temperatures are shown in Figure 158. The transport simulation boundary was established at grid row 30 of block 1 (shown in red in Figure 155). Temporary monitor TDG concentrations and temperatures as follows along the model grid:

- LMN06945P: columns 1 to 9; and
- LMN06943P: columns 10 to 24.

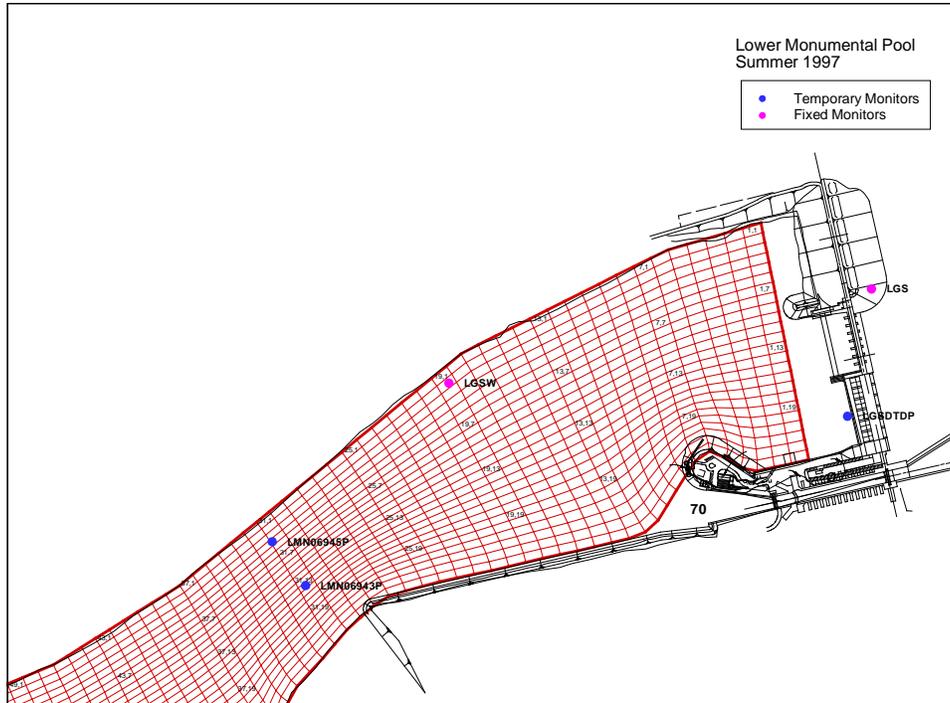


Figure 155. Locations, relative to the model grid, of upstream temporary monitors during the Summer 1997 study period.

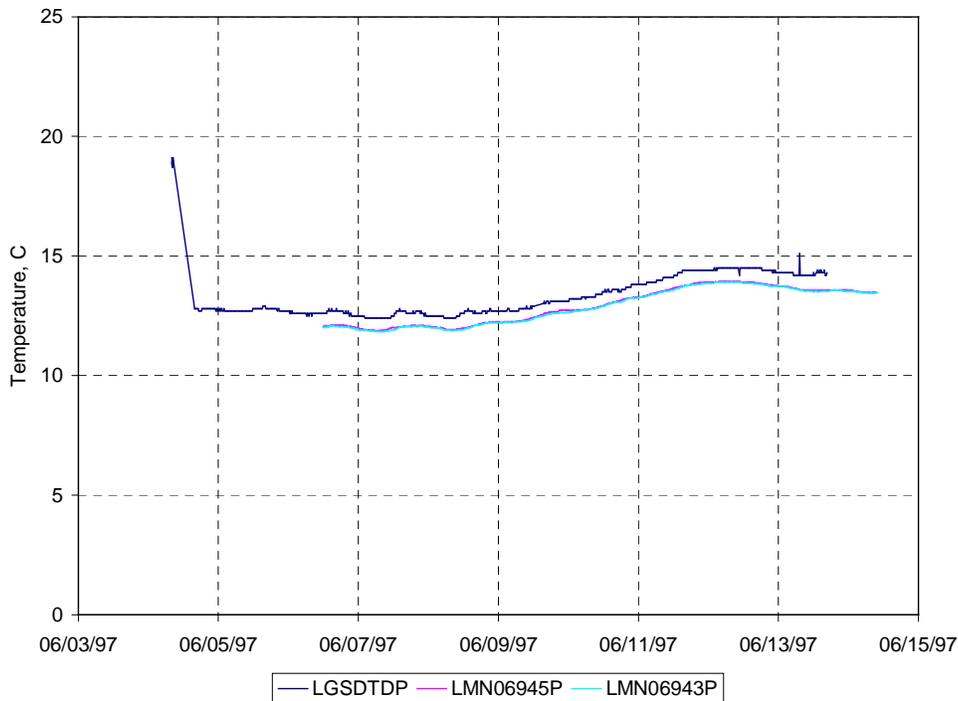


Figure 156. Temperatures measured by temporary monitors near Little Goose dam during the Summer 1997 study period.

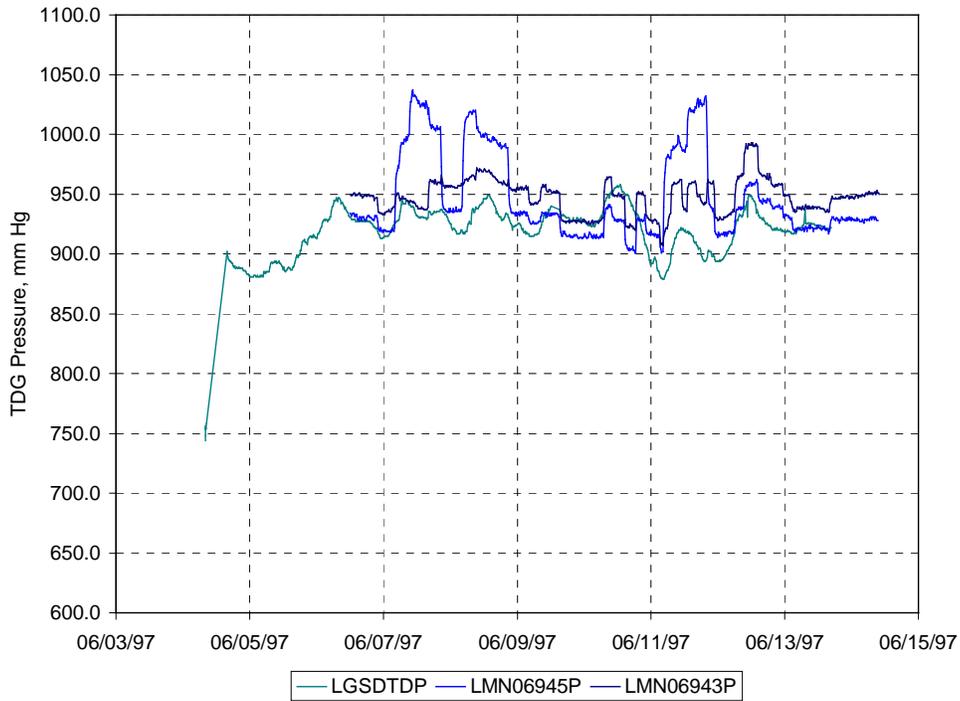


Figure 157. TDG pressures measured by temporary monitors near Little Goose dam during the Summer 1997 study period.

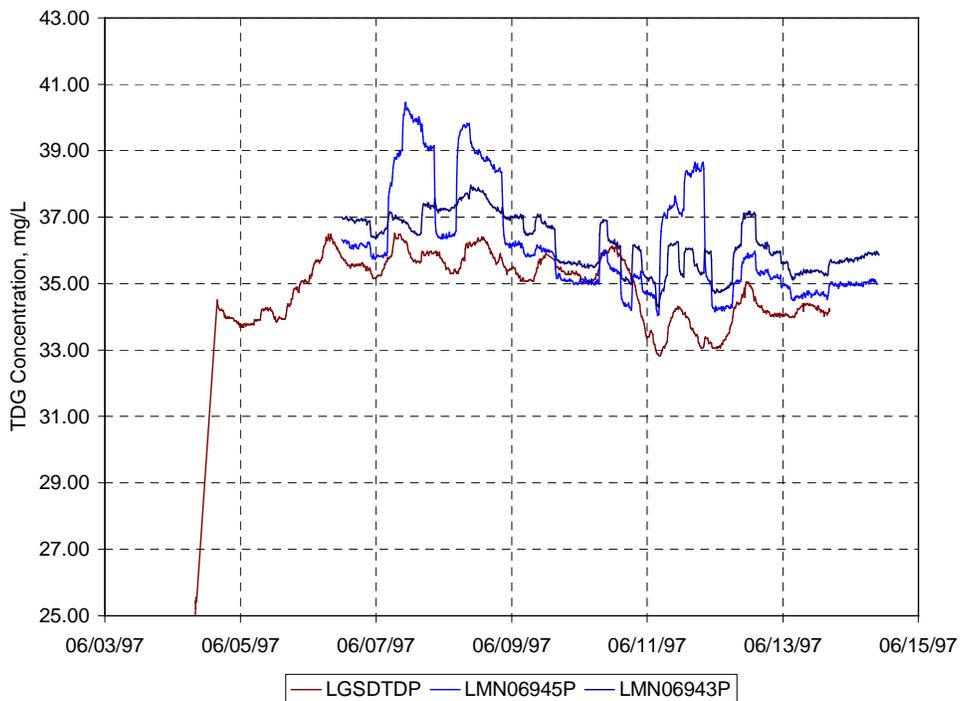


Figure 158. TDG concentrations computed from temporary monitor data near Little Goose dam during the Summer 1997 study period.

D.4 Lower Monumental Dam Boundary Operations

D.5 Weather

Atmospheric conditions were considered constant over the entire pool. The Pasco, Washington, air and dew point temperature (Figure 159) and wind speed (Figure 160) were used from the NWS weather database. Barometric pressure measured by the LMN FMS (also shown in Figure 159) was considered to apply over the entire modeled area. Measured short-wave radiation was available from the WeatherPak database for part of the Summer 1997 study. The available radiation data was extended using NWS Lower Monumental dew point and cloud cover data. Net incoming solar radiation based both on the measured and estimated total solar radiation is shown in Figure 161.

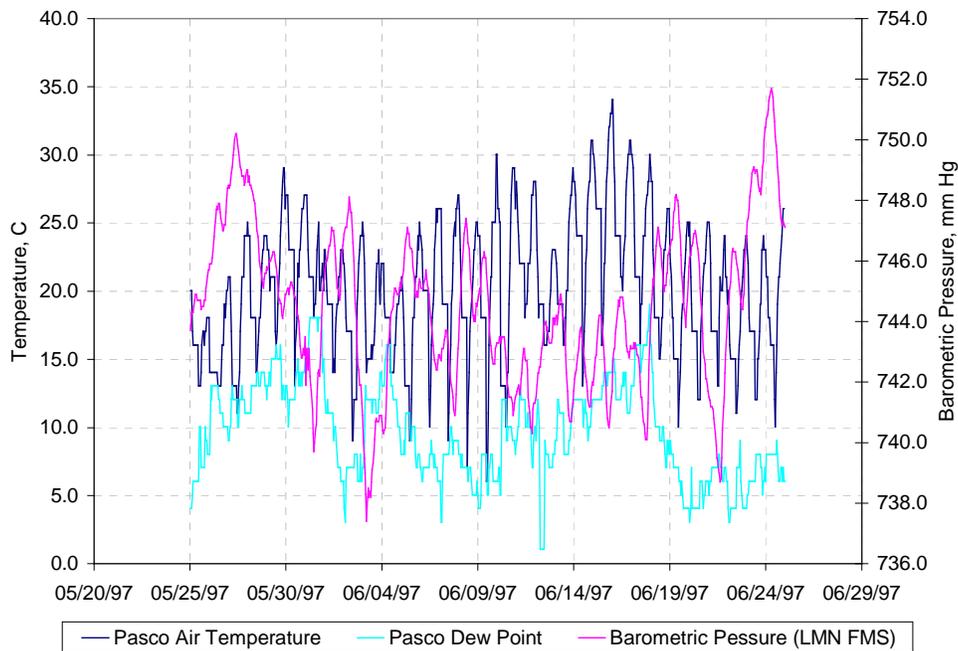


Figure 159. Air temperature, dew point, and barometric pressure used during the Summer 1997 study period.

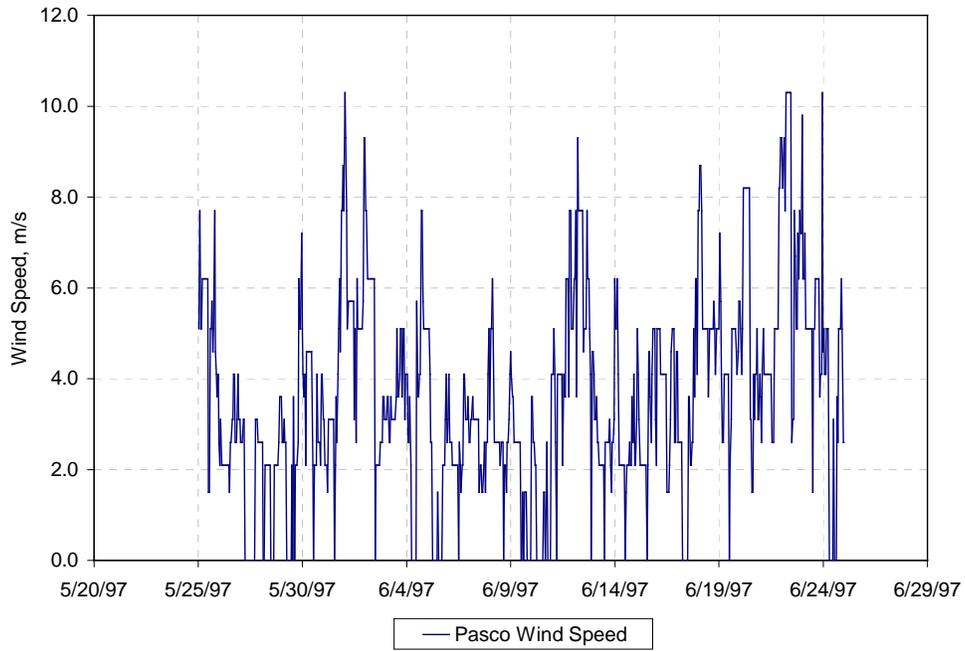


Figure 160. Wind speed used during the Summer 1997 study period.

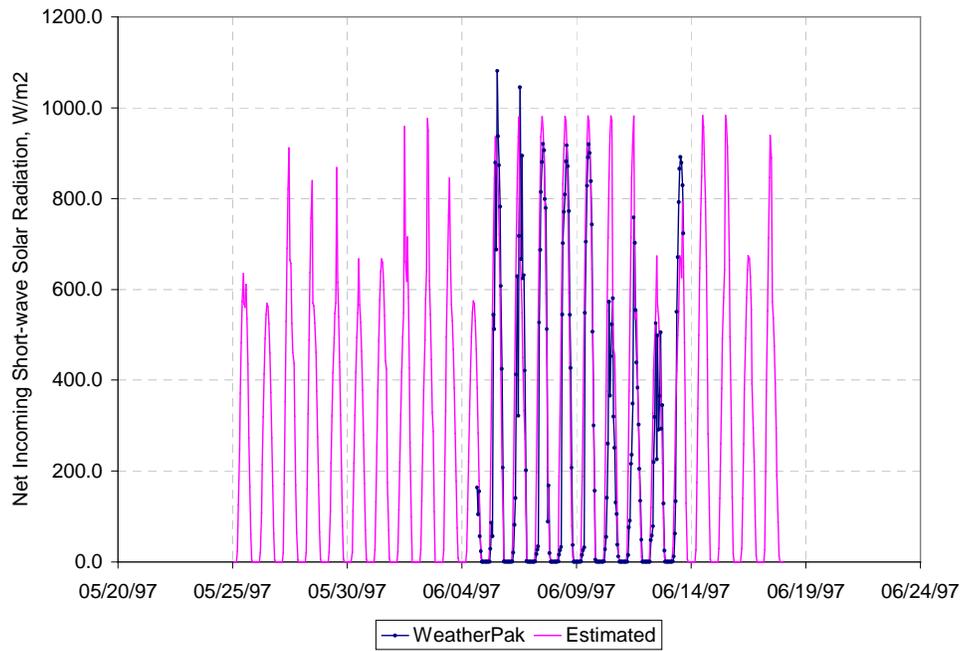


Figure 161. Net incoming short-wave solar radiation based on observed and estimated total radiation during the Summer 1997 study period.