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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 2: Lower Granite 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 2 of the report series summarizes the development and application of a two-dimensional depth-averaged hydrodynamic and water quality model (MASS2) to the Lower Granite Reservoir of the Lower Snake River system.

Acknowledgements

Significant editorial and technical contributions were made by the following Battelle staff: Lyle Hibler of the Marine Sciences Group and Kurt Recknagle of the Fluid Dynamics Group, Russ Moursund of the Ecology Group, and Christa Knudson of the Hydrology Group.

Thanks to Rick Emmert, Tom Carlson, Kim Fodrea, and Joe Carroll of the USACE for their assistance in this project.

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Two-Dimensional Hydrodynamic, Water Quality, and Fish Exposure Modeling of the Columbia and Snake Rivers. Part 2: Lower Granite 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 2 of the report series describes the application of the model to the Lower Granite Pool of the Snake and Clearwater Rivers. The modeled domain encompasses the following region:

- Lower Granite Dam, at Snake rivermile (RM) 107
- Clearwater River, at about Clearwater RM 0.9
- Snake River, at Snake RM 141.8

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

A two-dimensional-depth averaged hydrodynamics and transport model has been developed and applied to the part of the Snake and Clearwater Rivers that form the Lower Granite 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 Granite 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.

Hydrodynamics were verified using Spring 1997 Acoustic Doppler Current Profiler (ADCP) data. Dissolved gas and temperature verification used the Spring 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 Granite pool is shown in Figure 1. Larger scale maps of the model grid near the Snake/Clearwater confluence and Lower Granite dam boundaries are shown in Figure 2 and Figure 3. Figure 2 also shows the locations of cross-sections iof the one-dimensional flow model used to predict flows at the Clearwater and Snake river model boundaries (see Appendix B). Note that some 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).

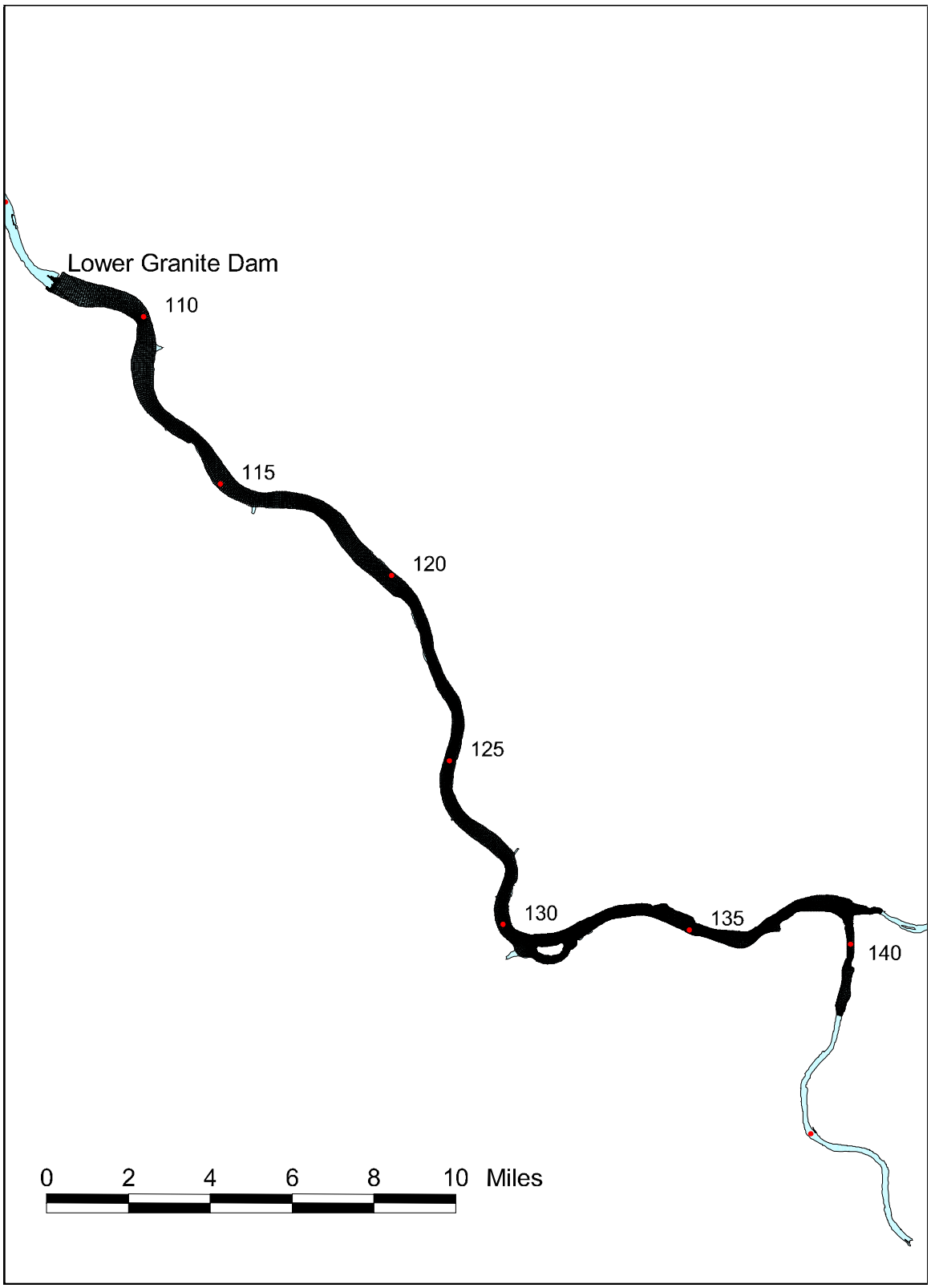

Figure 1. Model grid for Lower Granite pool.

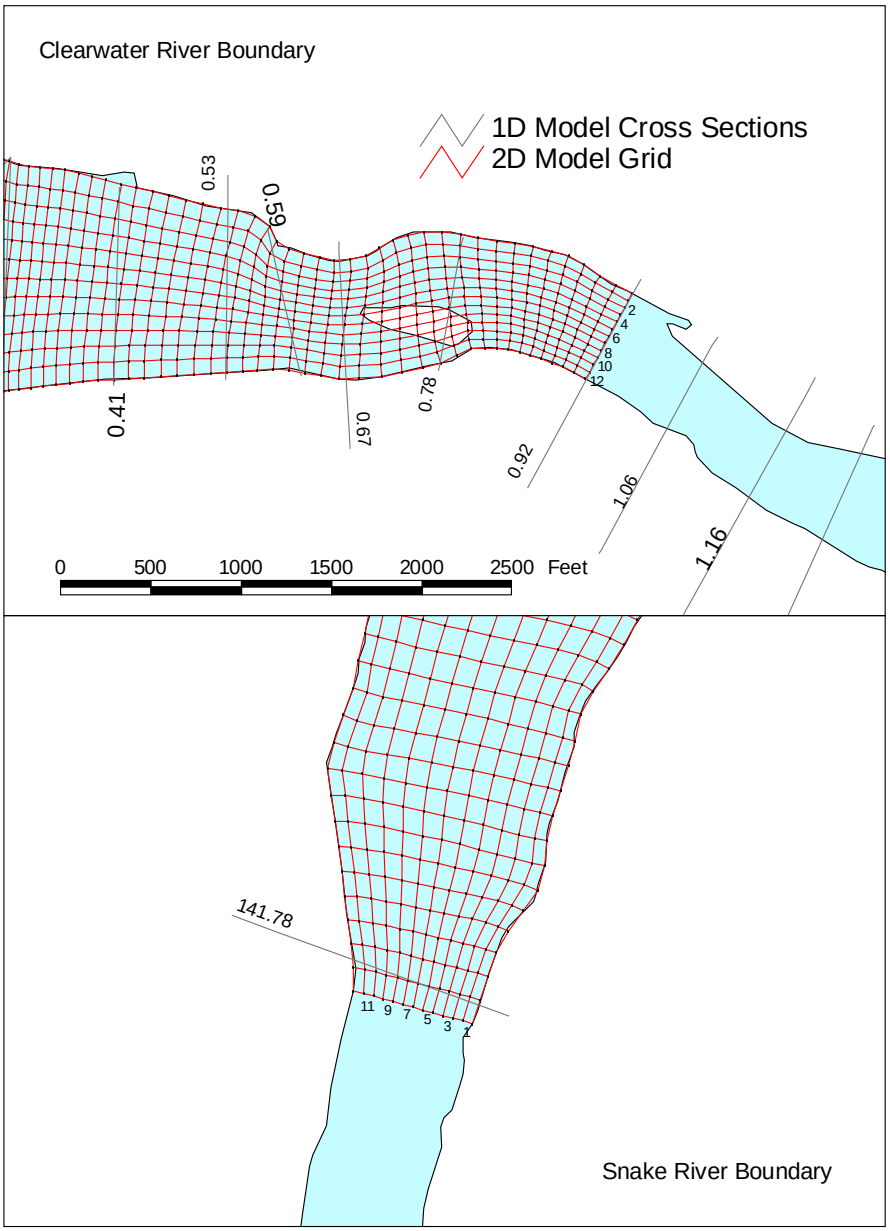

Figure 2. Model grid boundaries on the Snake and Clearwater rivers.

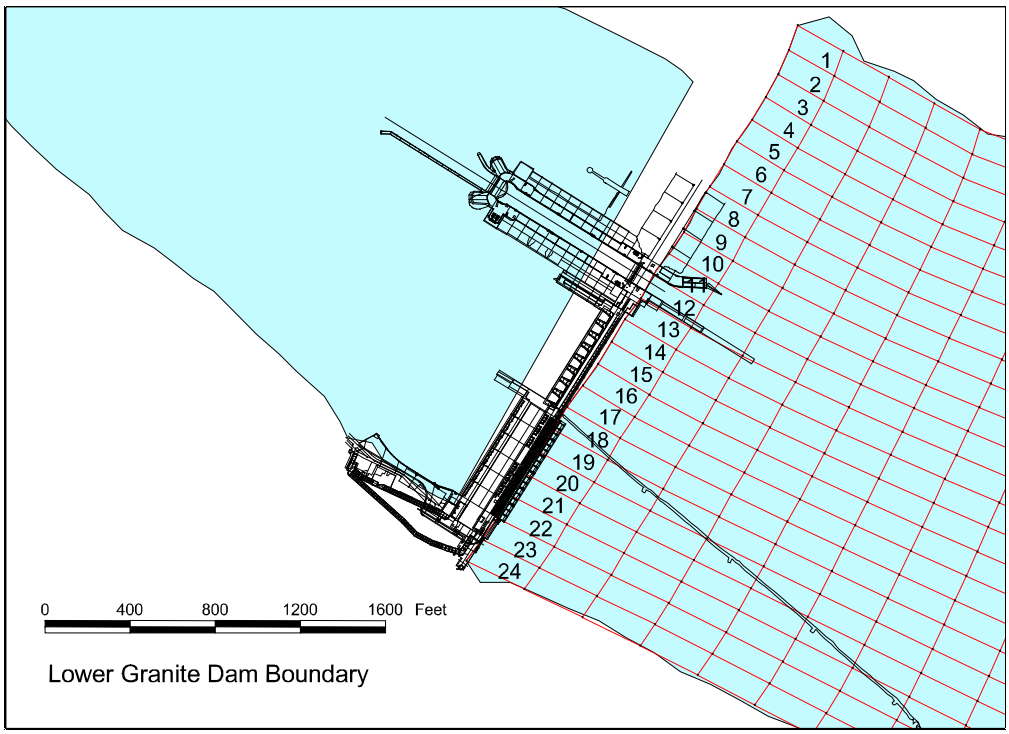

Figure 3. Model grid boundary at Lower Granite dam.

1.2 Boundary Conditions

Upstream boundary flows were established using a one-dimensional model that used measured flows from USGS gages on the Snake River at Anatone (USGS Station 13334300) and the Clearwater River at Orofino (USGS Station 13340000). Recorded discharges from Dworshak dam were also used.

1.3 Hydrodynamics Calibration and Verification

Measured stages in the pool were not available, so calibration of Manning's n was not possible. A value of 0.029 was chosen as representative.

ADCP velocity measurements were available for the study period. Due to instrumentation problems the 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. Simulated and observed velocities comparisons are shown below Figure 4 in through Figure 12.

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 ft^2/s.

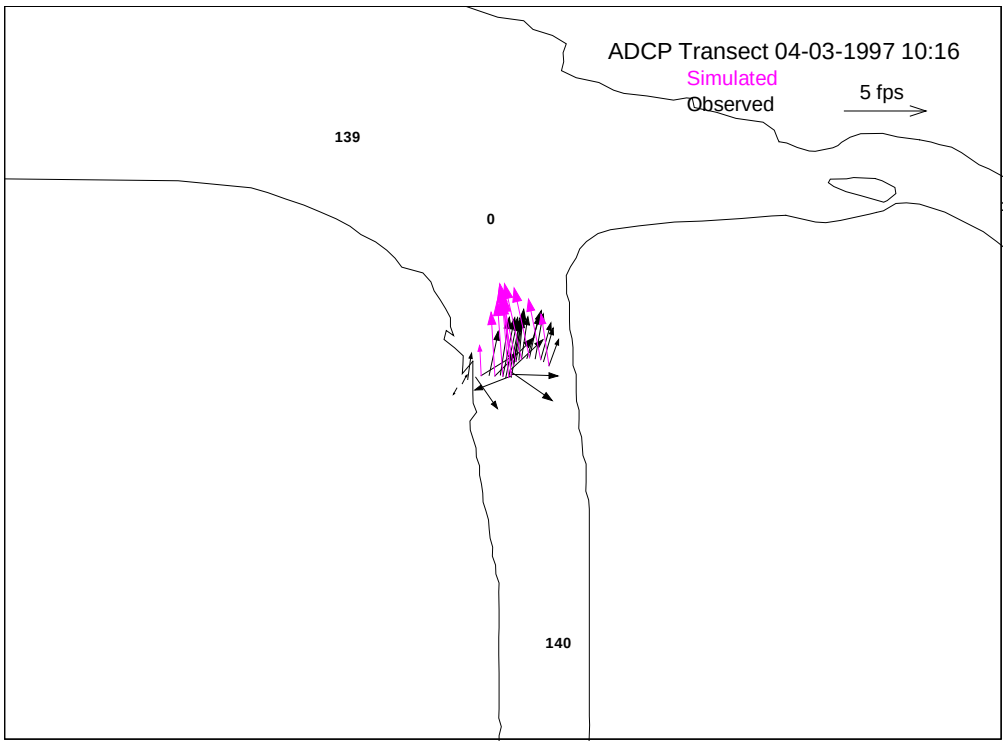

Figure 4. Simulated and observed depth-averaged velocities near the Snake/Clearwater confluence April 3, 1997.

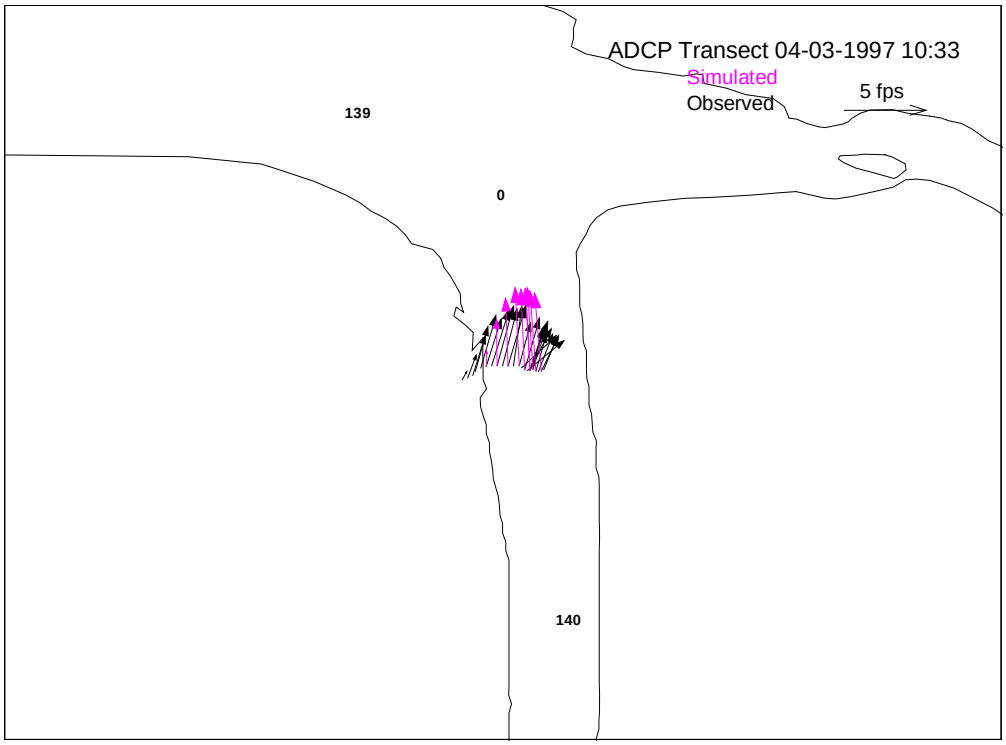

Figure 5. Simulated and observed depth-averaged velocities near the Snake/Clearwater confluence April 3, 1997.

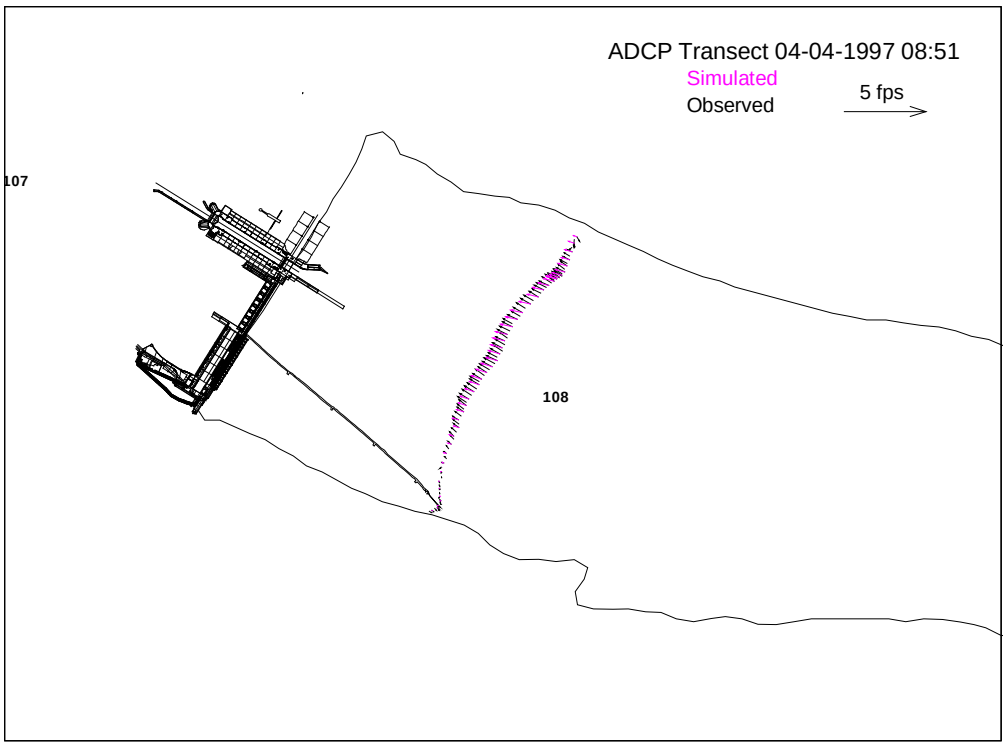

Figure 6. Simulated and observed depth-averaged velocities near Lower Granite dam April 4, 1997.

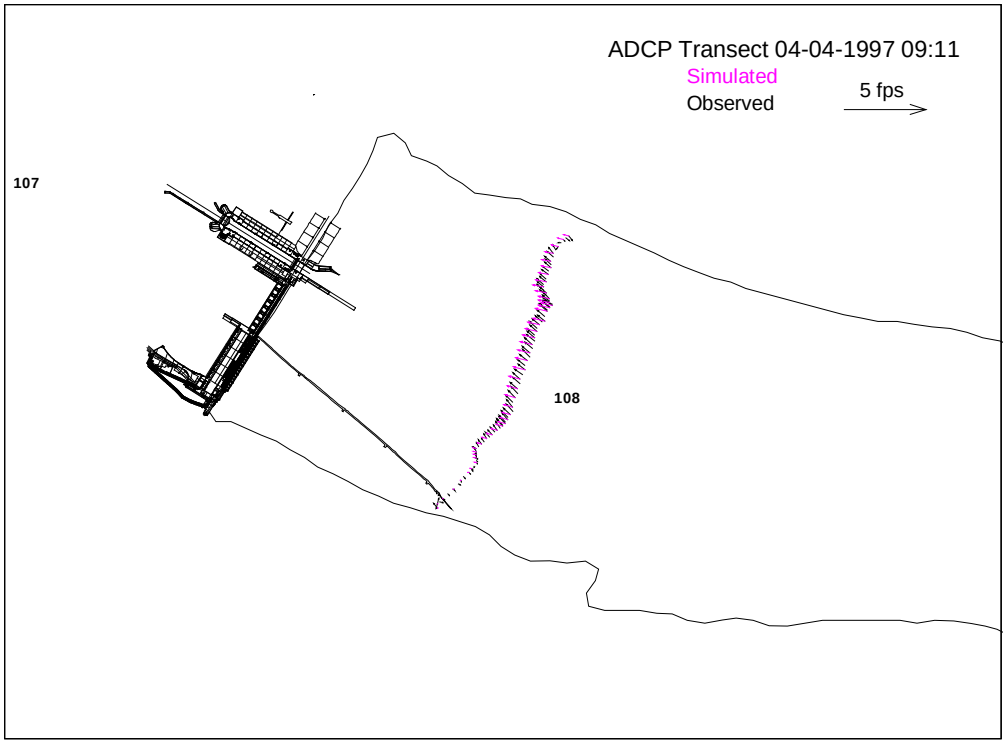

Figure 7. Simulated and observed depth-averaged velocities near Lower Granite dam April 4, 1997.

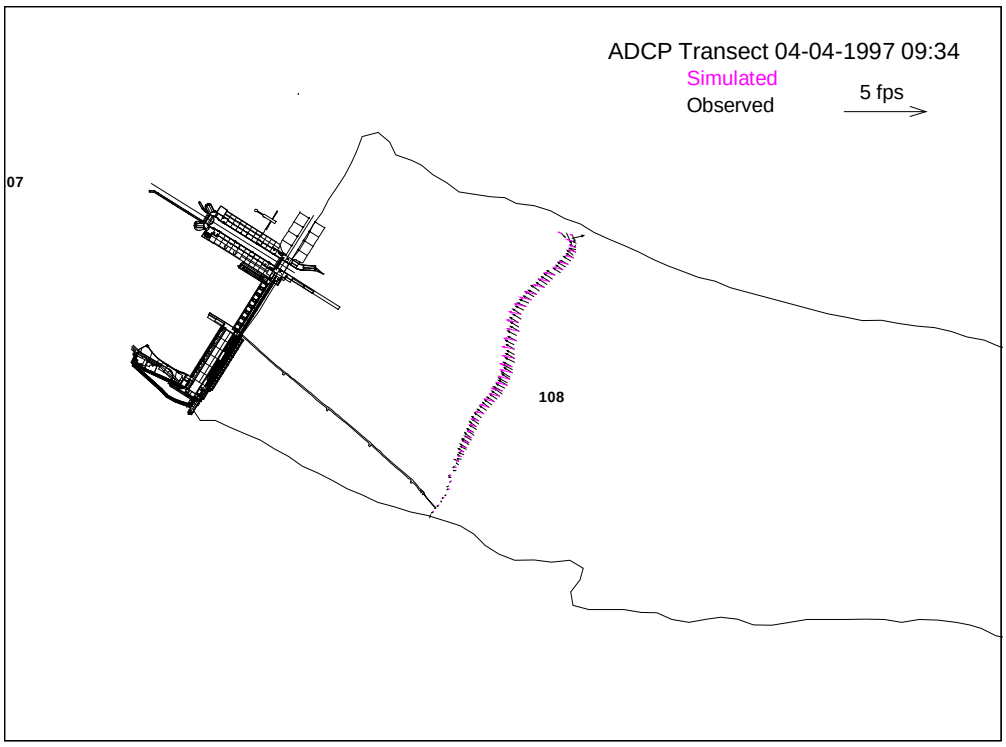

Figure 8. Simulated and observed depth-averaged velocities near Lower Granite dam April 4, 1997.

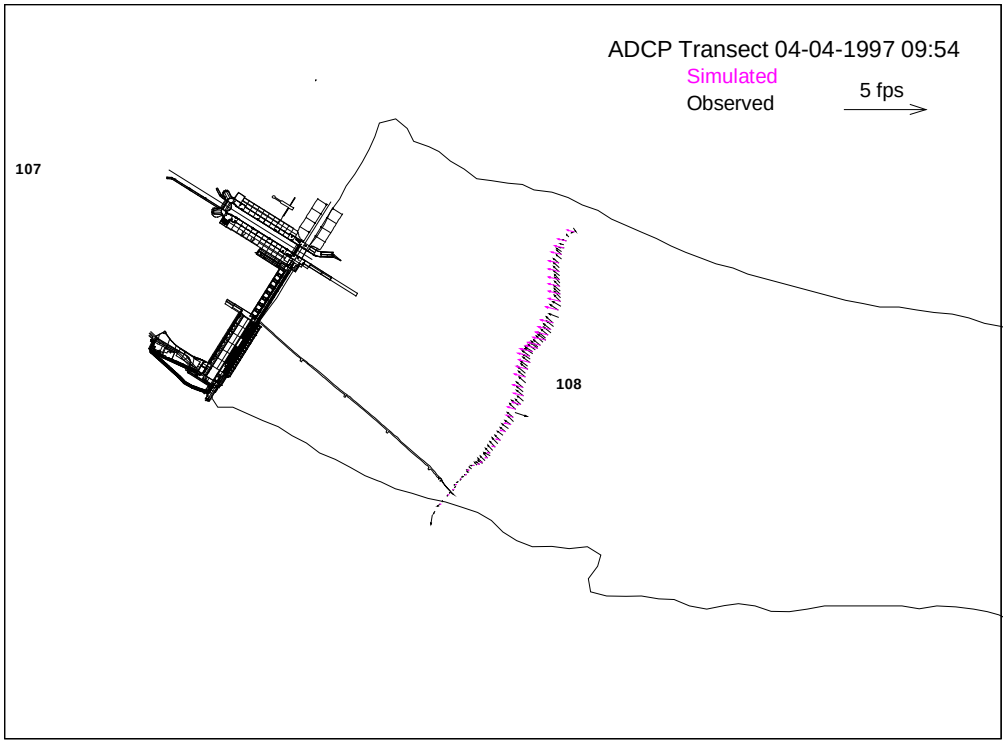

Figure 9. Simulated and observed depth-averaged velocities near Lower Granite dam April 4, 1997.

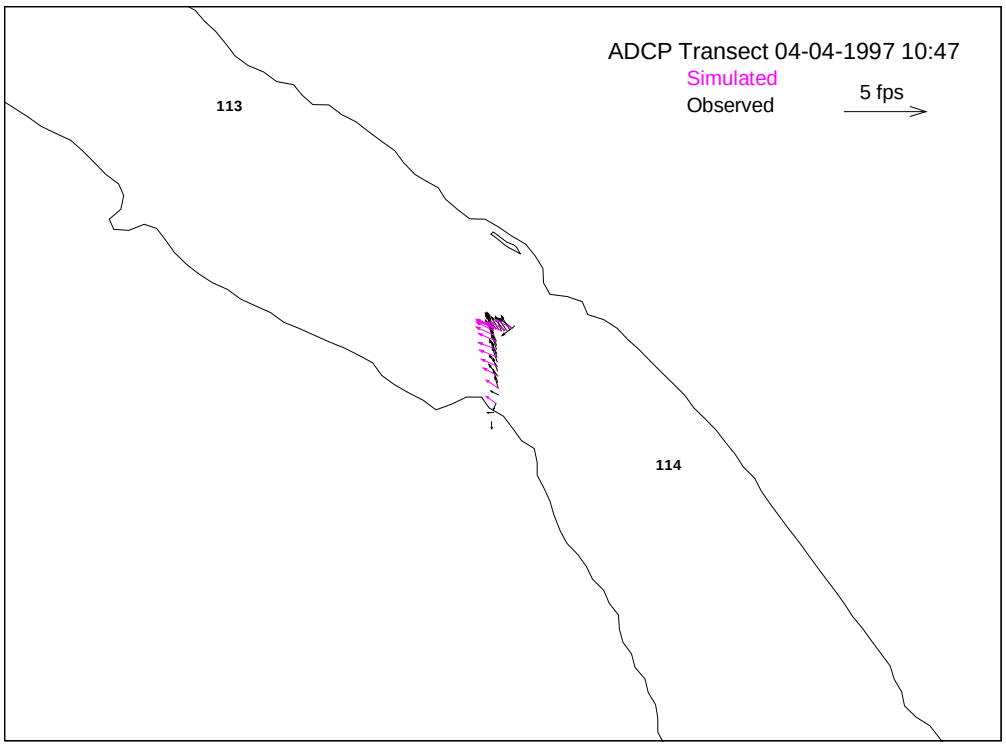

Figure 10. Simulated and observed depth-averaged velocities near Snake river mile 114 April 4, 1997.

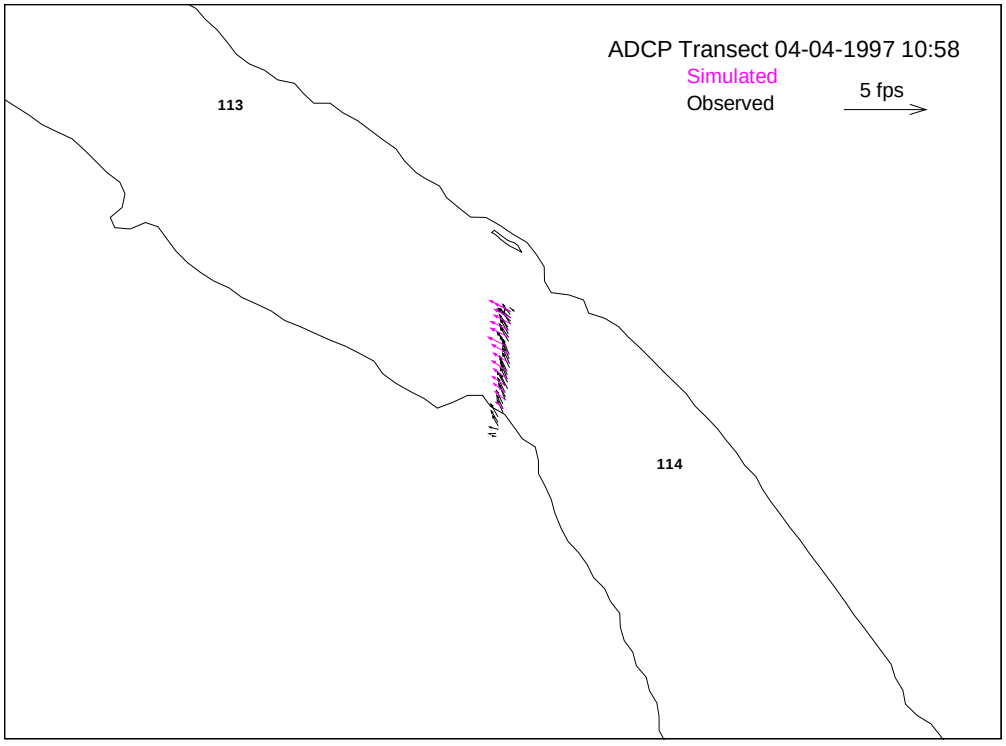

Figure 11. Simulated and observed depth-averaged velocities near Snake river mile 114 April 4, 1997.

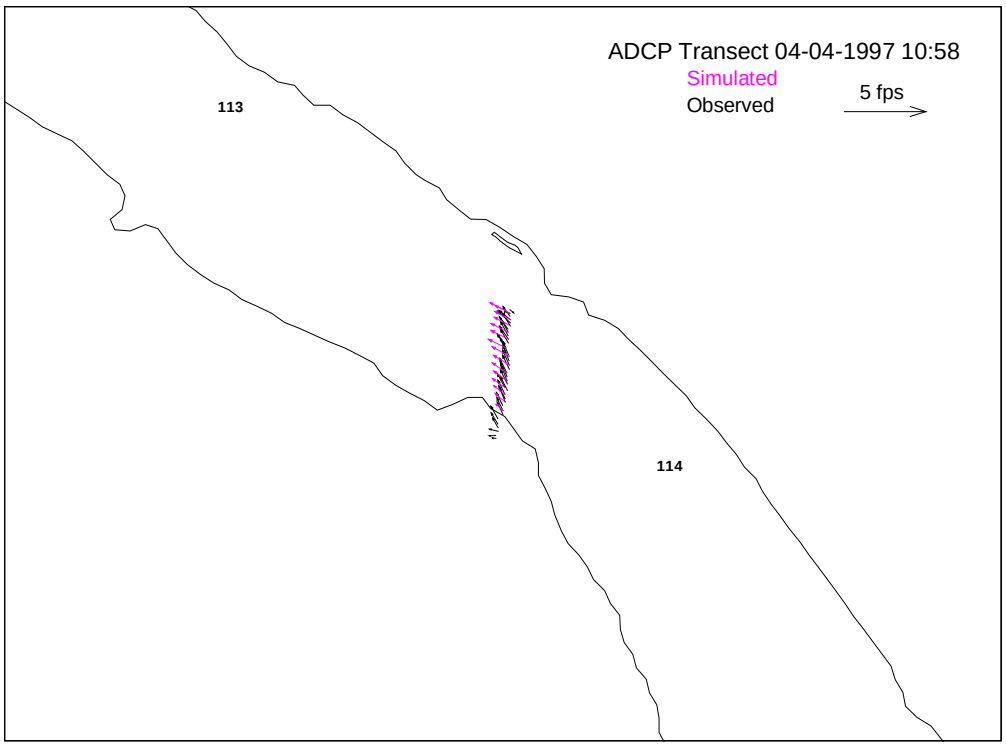

Figure 12. Simulated and observed depth-averaged velocities near Snake river mile 114 April 4, 1997.

1.3.1 Simulated spatial velocity distribution during the Spring 1997 study.

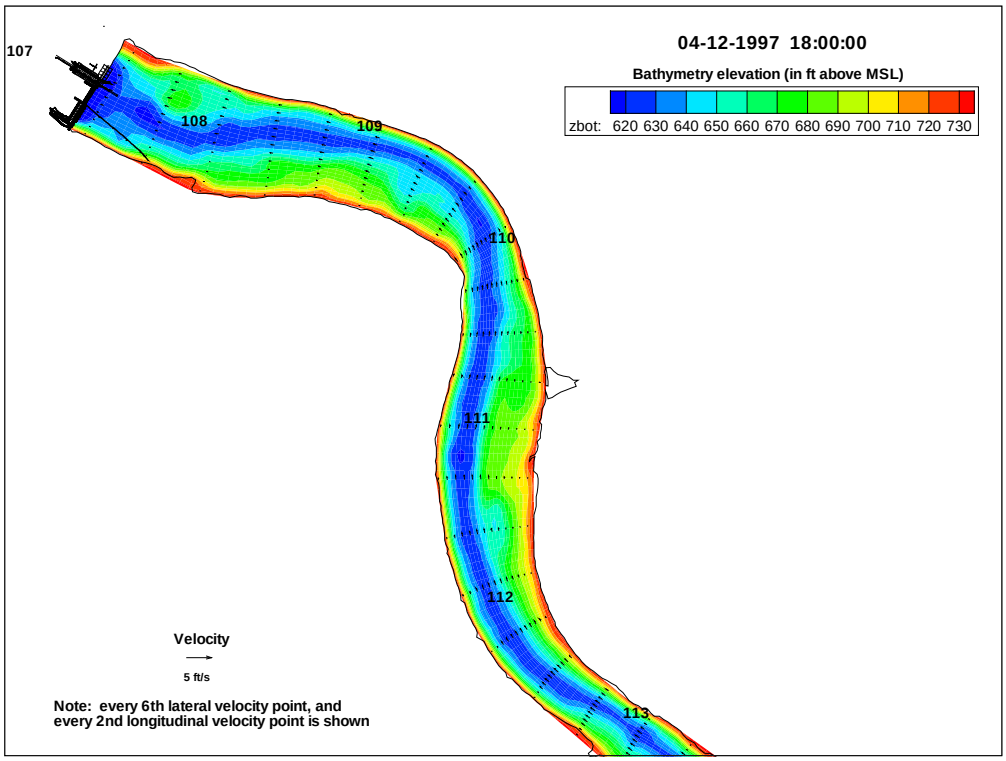

Figure 13. Spatial velocity distribution during the Spring 1997 study.

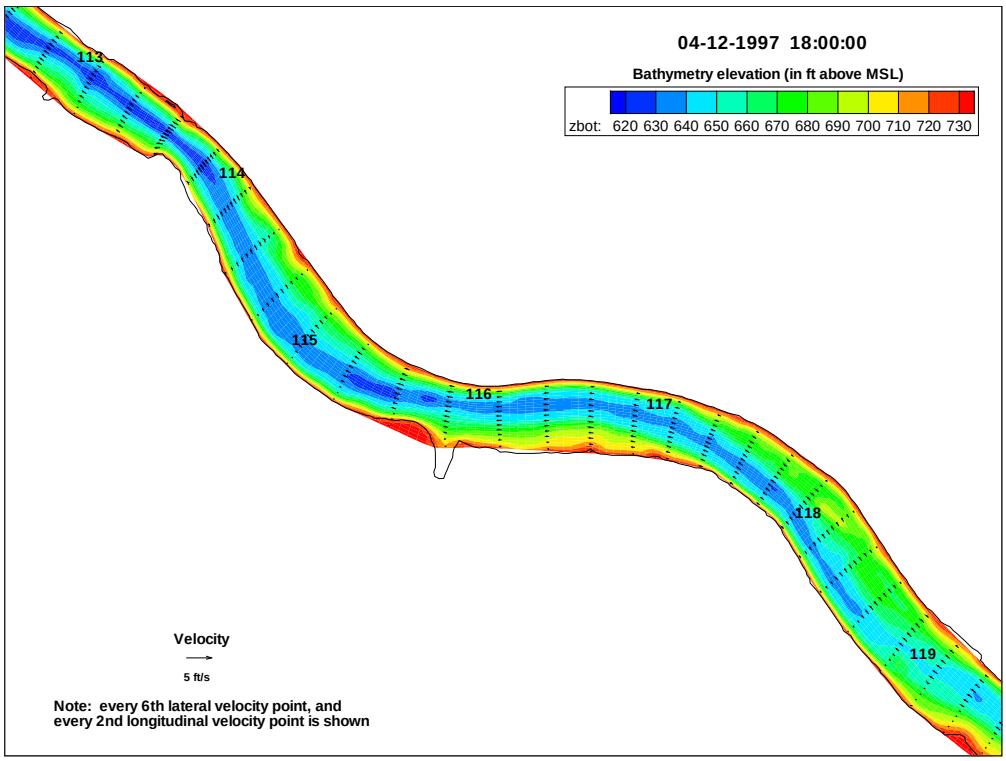

Figure 14. Spatial velocity distribution during the Spring 1997 study.

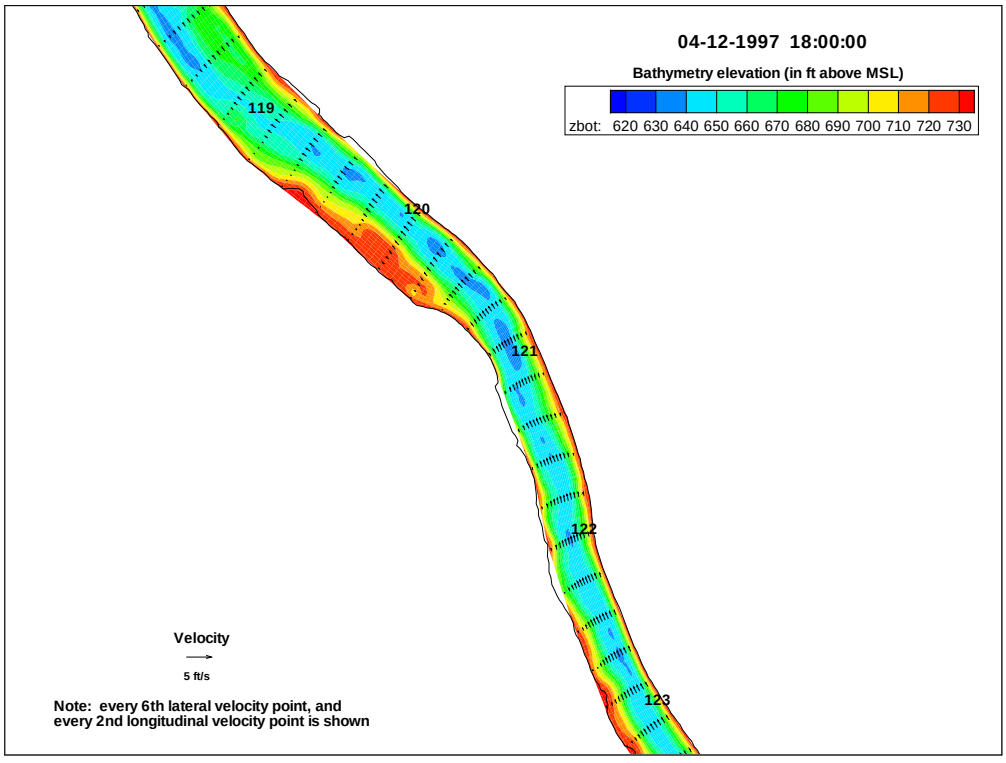

Figure 15. Spatial velocity distribution during the Spring 1997 study.

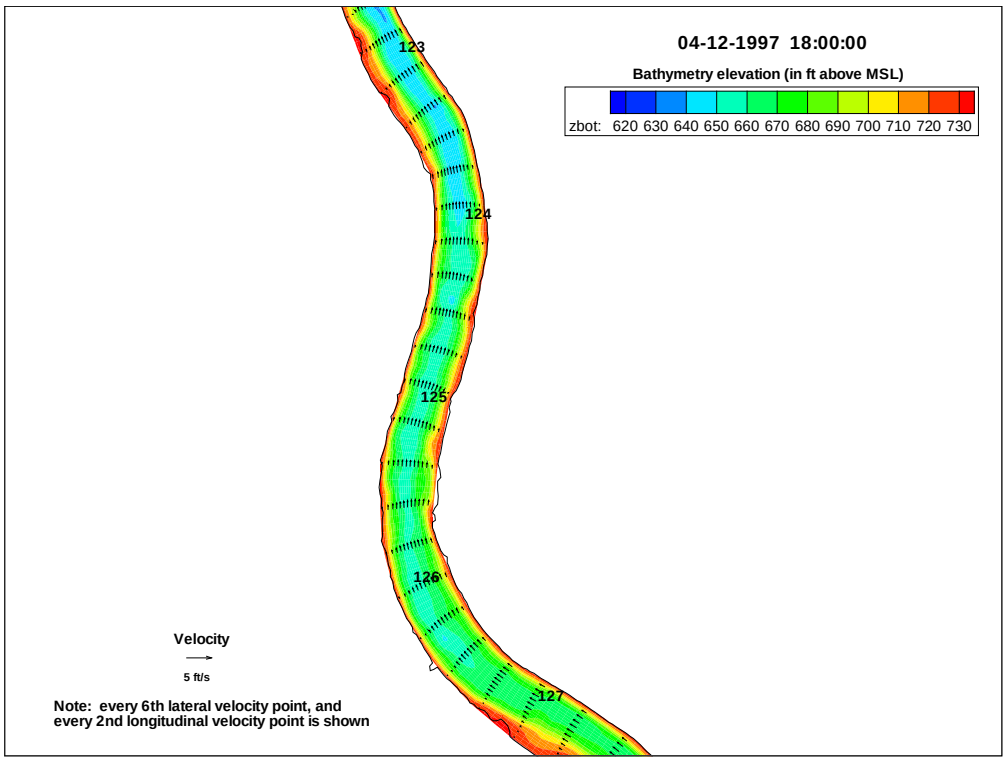

Figure 16. Spatial velocity distribution during the Spring 1997 study.

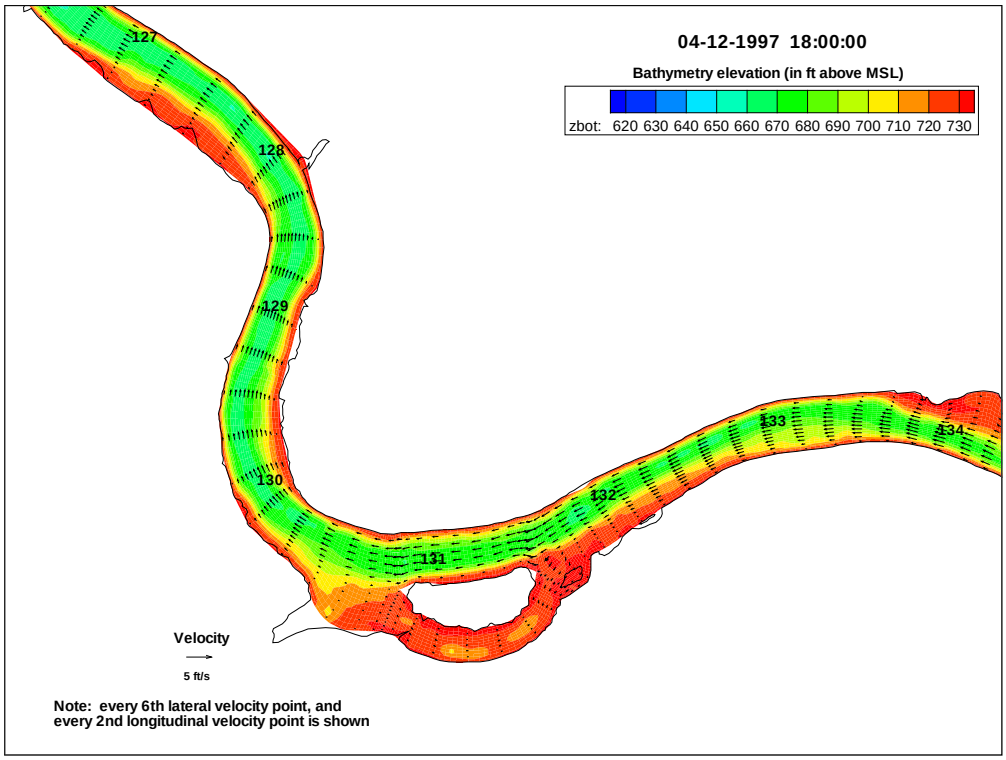

Figure 17. Spatial velocity distribution during the Spring 1997 study.

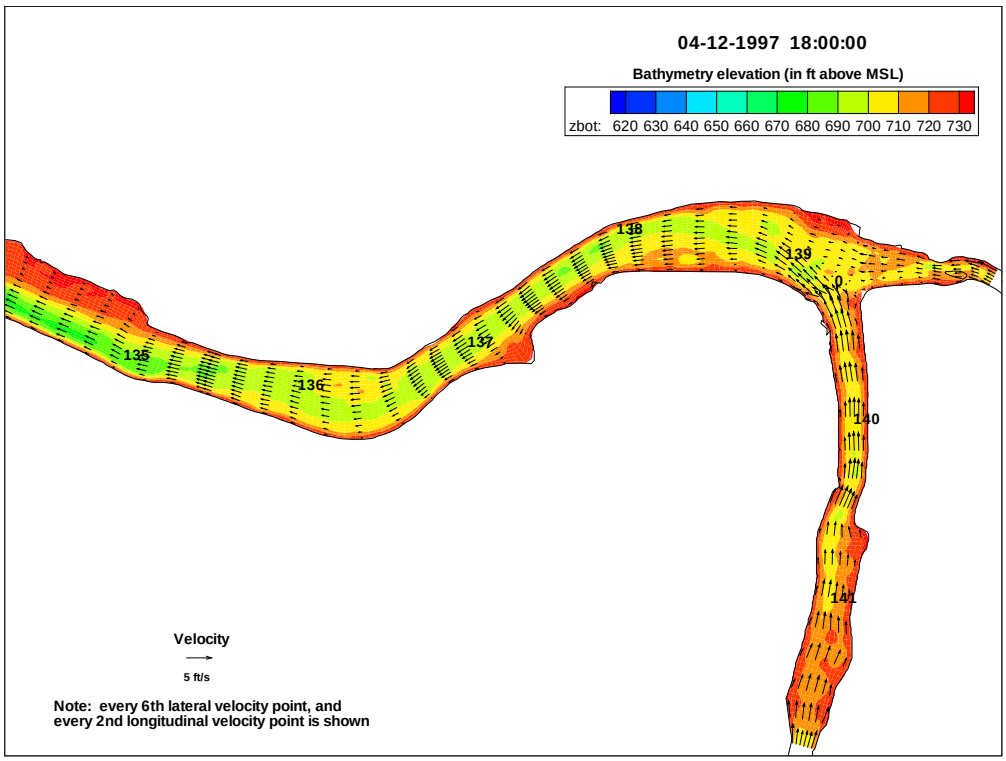

Figure 18. Spatial velocity distribution during the Spring 1997 study.

1.4 Water Quality Calibration and Verification

1.4.1 1997 Spring Simulation

Comparisons between field measurements and simulations are shown in the figures below. Statistics on the comparisons between measured and simulated temperatures and totol dissolved gas are also presented.

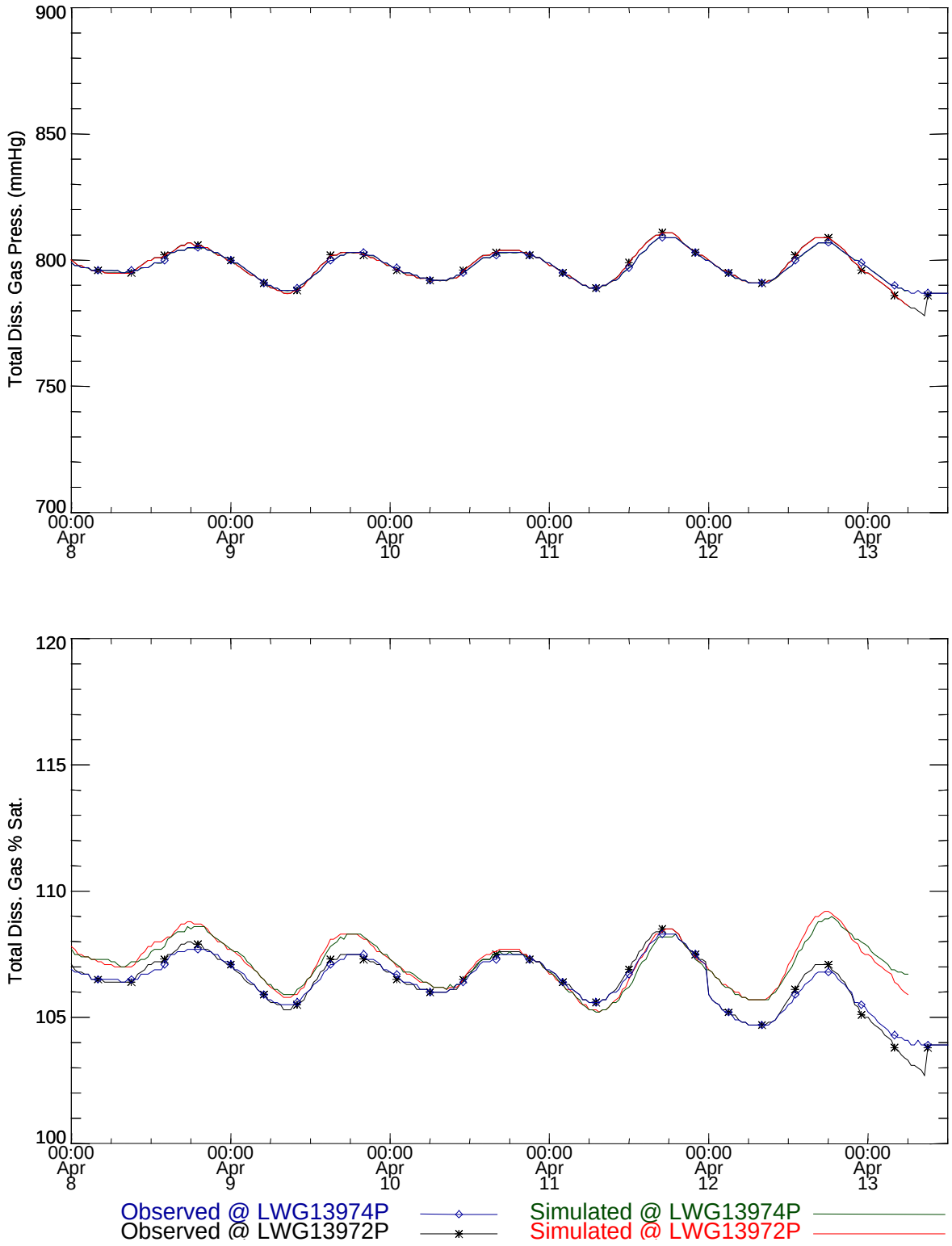

Figure 19. Temperature and total dissolved gas time series near Snake River mile 139.7 for the Spring 1997 pool study.

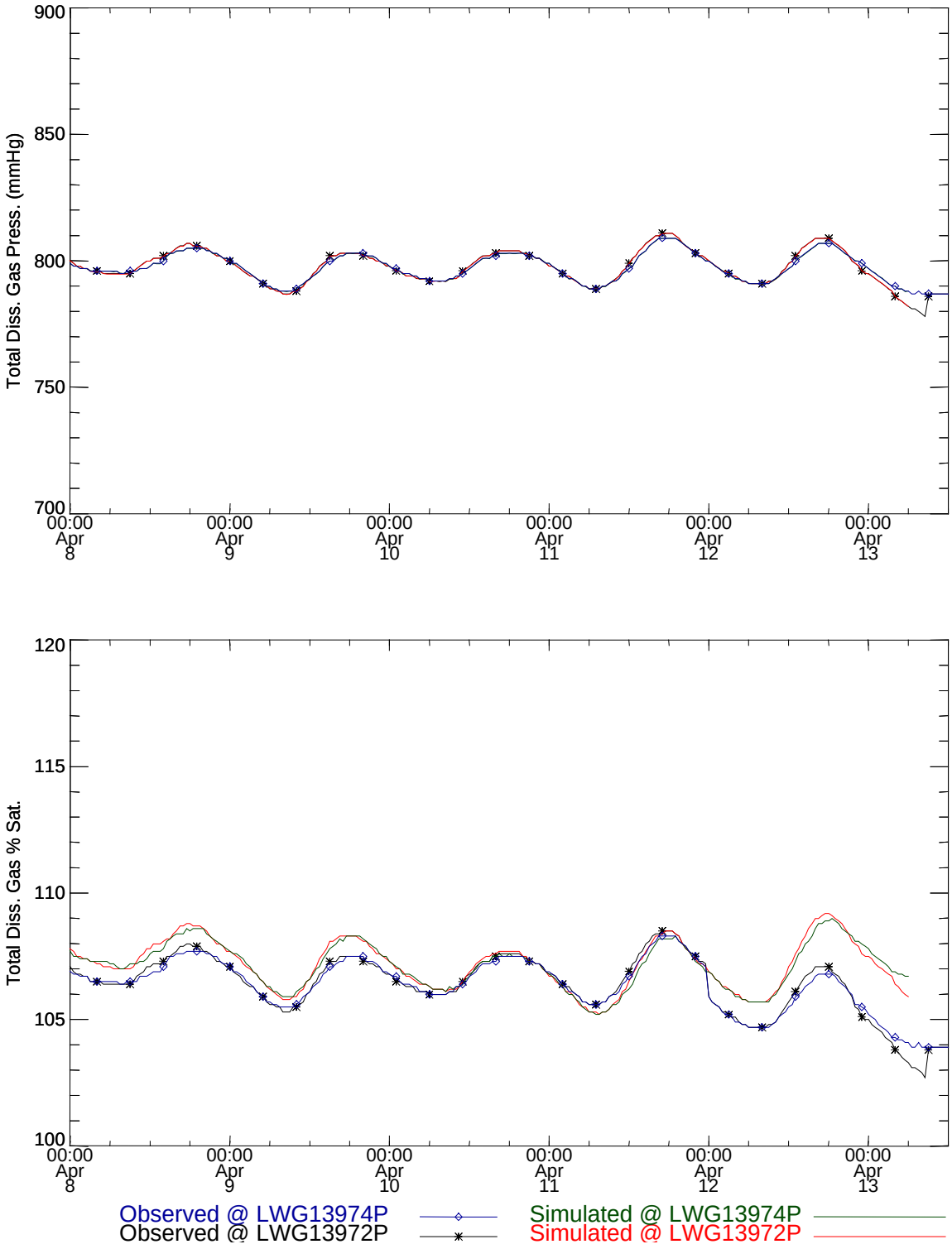

Figure 20. Total dissolved gas pressure and saturation time series near Snake River mile 139.7 for the Spring 1997 pool study.

Table 1. Statistical summary of measurements and simulations at river mile 139.7 during the Spring 1997 pool study.

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
LWG13972P	8.86	8.8	0.25	0.25	0.07
LWG13974P	8.82	8.78	0.24	0.24	0.07
Concentration					
LWG13972P	33.29	33.25	0.25	0.25	0.06
LWG13974P	33.31	33.26	0.23	0.22	0.07
Gas Pressure					
LWG13972P	798.01	797.96	6.17	6.16	0.11
LWG13974P	797.76	797.72	5.39	5.38	0.1
% Saturation					
LWG13972P	106.5	107.17	1.04	0.96	1.02
LWG13974P	106.46	107.13	0.94	0.9	1.02

Table 2. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at rivermile 139.7 for the Spring 1997 study

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
LWG13972P	100	100	100	100
LWG13974P	100	100	100	100

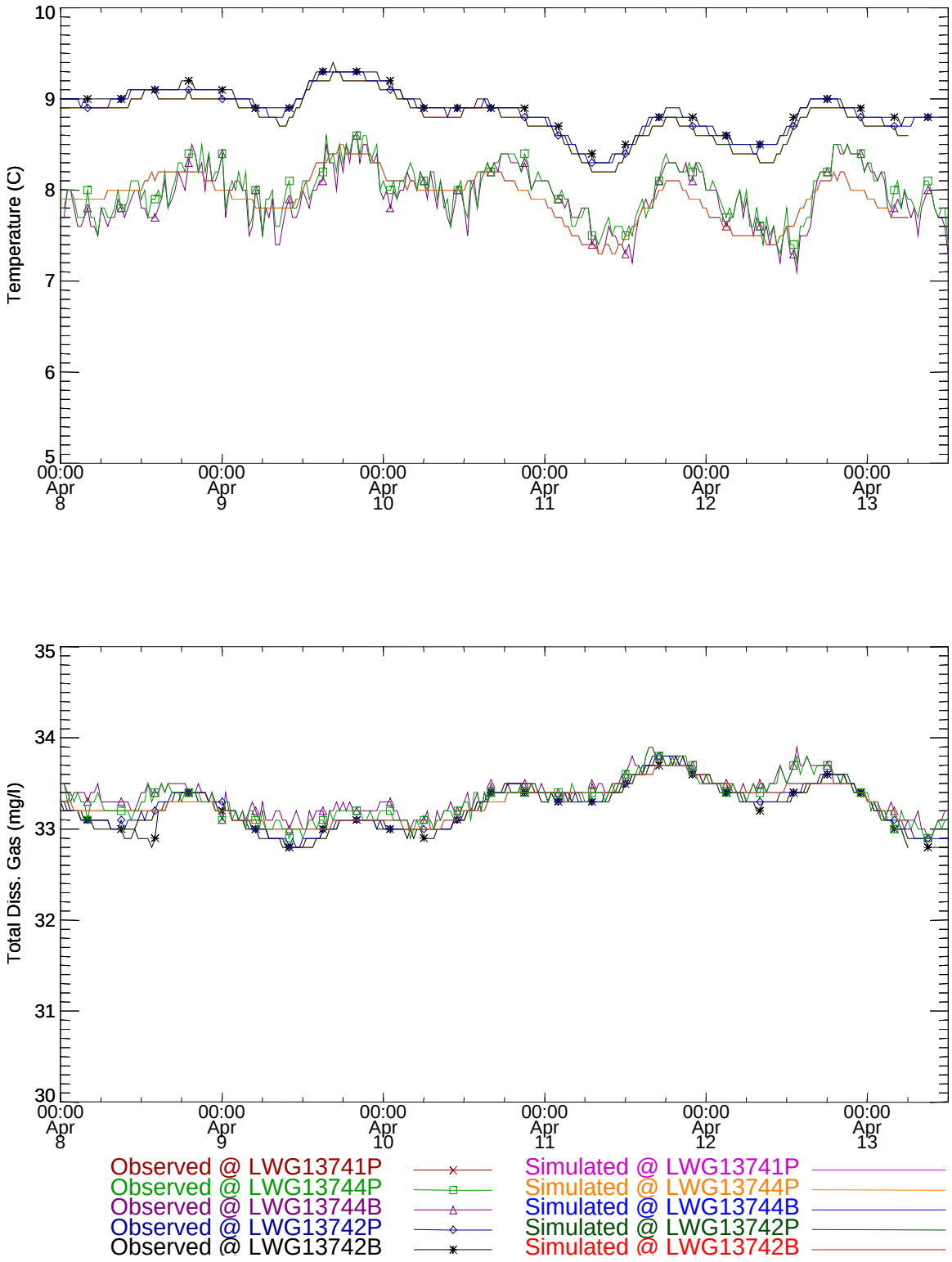

Figure 21. Temperature and total dissolved gas time series near Snake River mile 137.4 for the Spring 1997 pool study.

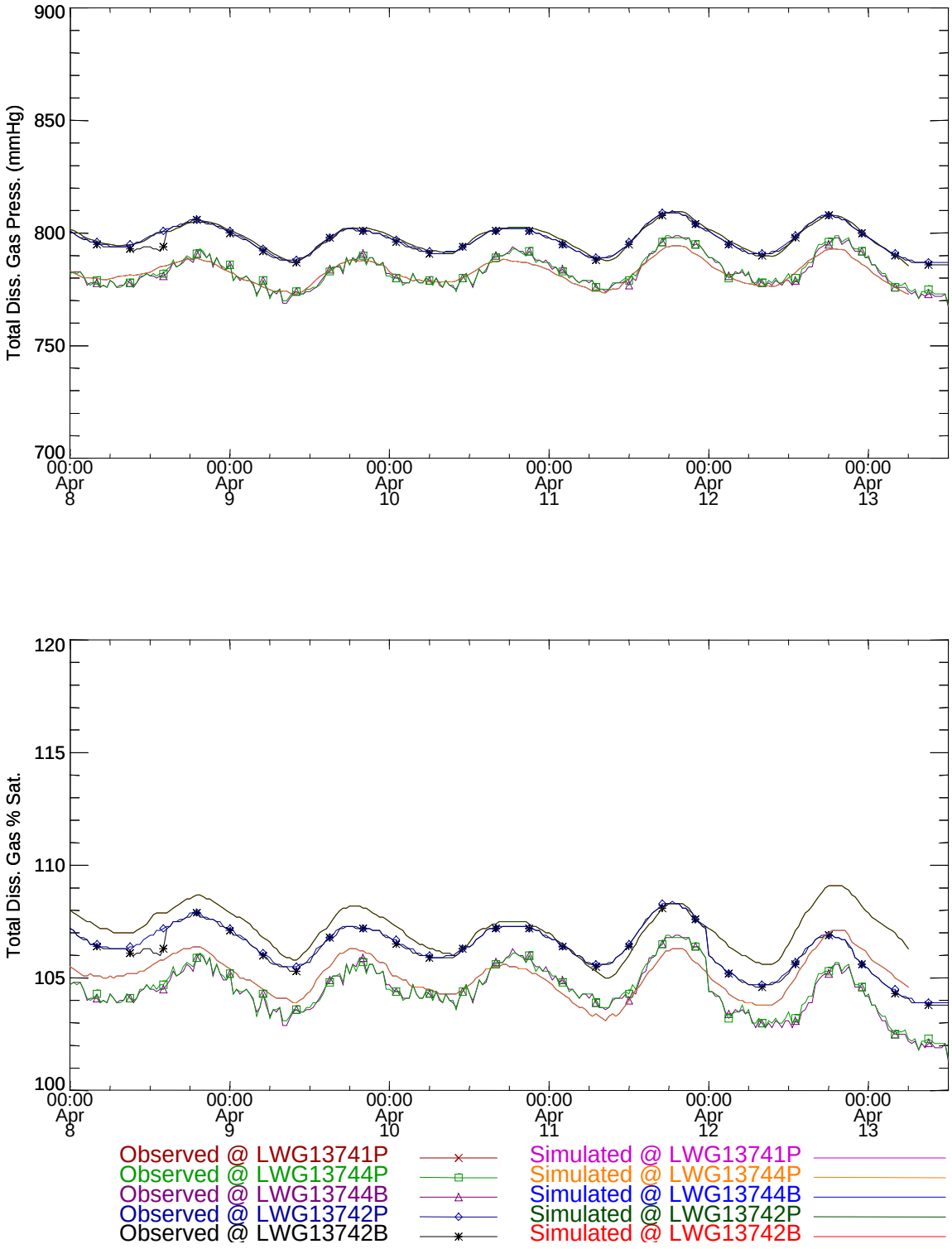

Figure 22. Total dissolved gas pressure and saturation time series near Snake River mile 137.4 for the Spring 1997 pool study.

Table 3. Statistical summary of measurements and simulations at river mile 137.4 during the Spring 1997 pool study.

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
LWG13742B	8.89	8.79	0.24	0.25	0.11
LWG13742P	8.86	8.79	0.24	0.25	0.09
LWG13744B	7.94	7.92	0.31	0.27	0.23
LWG13744P	8	7.92	0.29	0.27	0.22
Concentration					
LWG13742B	33.24	33.26	0.24	0.24	0.07
LWG13742P	33.27	33.26	0.23	0.24	0.05
LWG13744B	33.38	33.29	0.2	0.19	0.13
LWG13744P	33.34	33.29	0.22	0.19	0.1
Gas Pressure					
LWG13742B	797.18	797.9	5.67	5.68	1.5
LWG13742P	797.66	797.9	5.55	5.68	1
LWG13744B	783.21	782.66	6.79	5.36	2.82
LWG13744P	783.49	782.66	6.73	5.36	2.84
% Saturation					
LWG13742B	106.39	107.16	0.93	0.94	1.09
LWG13742P	106.45	107.16	0.93	0.94	1.04
LWG13744B	104.53	105.11	1.01	0.89	1.01
LWG13744P	104.57	105.11	0.98	0.89	0.96

Table 4. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at rivermile 134.7 for the Spring 1997 study.

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
LWG13742B	100	100	100	100
LWG13742P	100	100	100	100
LWG13744B	100	100	100	100
LWG13744P	100	100	100	100

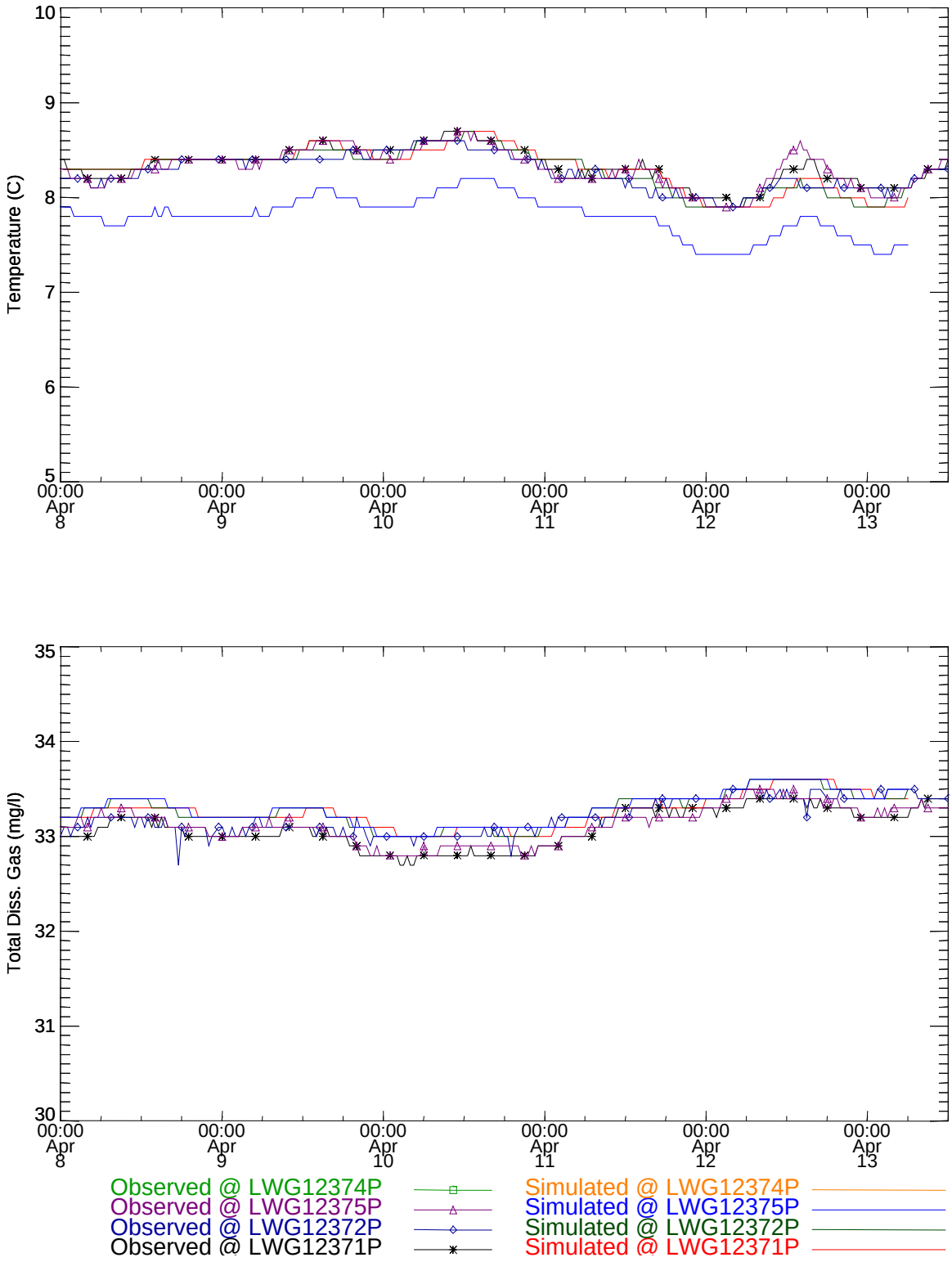

Figure 23. Temperature and total dissolved gas time series near Snake River mile 123.7 for the Spring 1997 pool study.

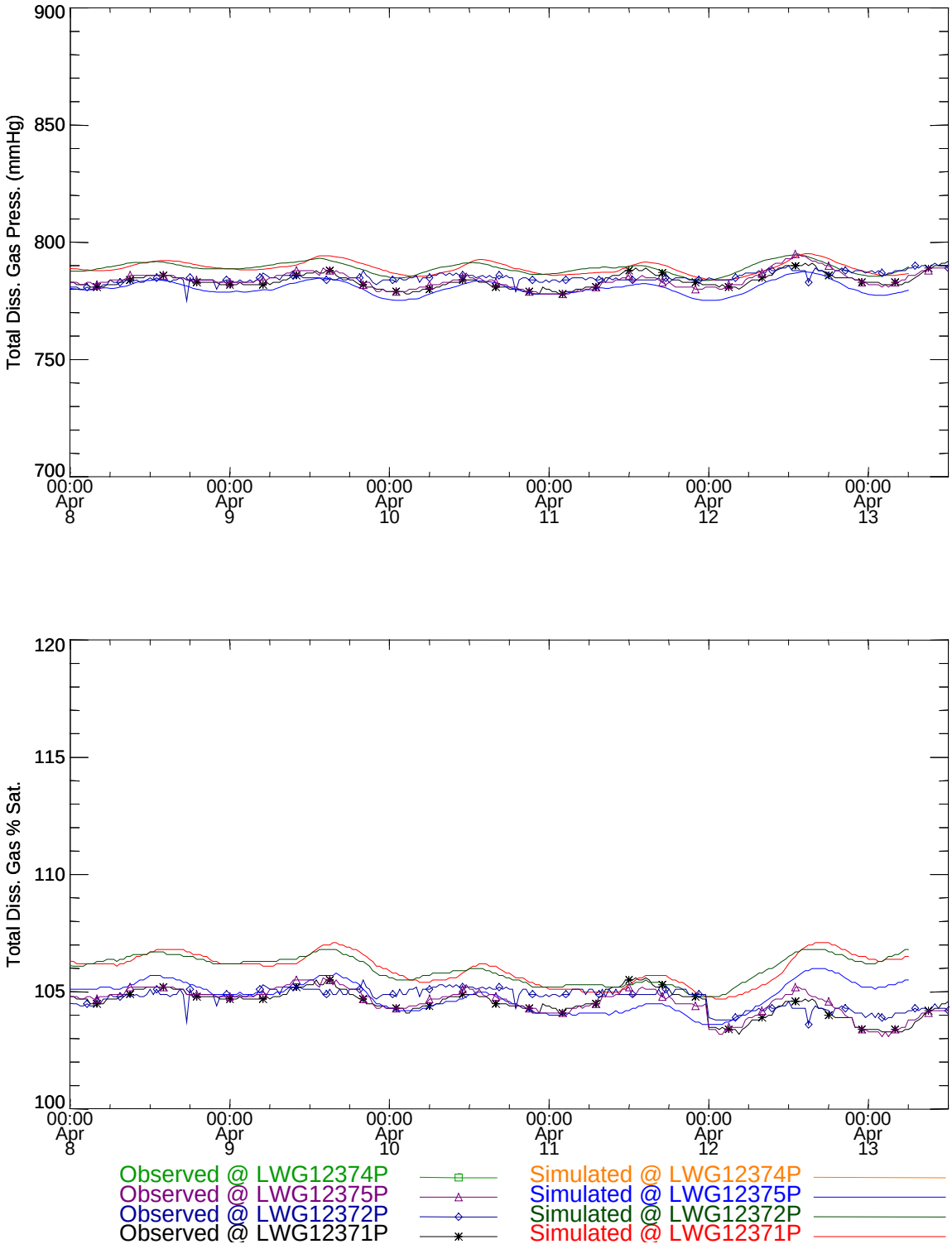

Figure 24. Total dissolved gas pressure and saturation time series near Snake River mile 123.7 for the Spring 1997 pool study.

Table 5. Statistical summary of measurements and simulations at river mile 123.7 during the Spring 1997 pool study.

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
LWG12371P	8.33	8.3	0.19	0.23	0.1
LWG12372P	8.27	8.29	0.19	0.22	0.09
LWG12375P	8.31	7.8	0.2	0.21	0.52
Concentration					
LWG12371P	33.08	33.26	0.2	0.17	0.2
LWG12372P	33.19	33.28	0.18	0.18	0.13
LWG12375P	33.12	33.29	0.19	0.17	0.18
Gas Pressure					
LWG12371P	783.34	789.05	2.93	2.67	6.1
LWG12372P	784.88	789.03	2	2.46	4.97
LWG12375P	783.85	780.51	3.48	2.85	3.76
% Saturation					
LWG12371P	104.55	105.97	0.57	0.66	1.61
LWG12372P	104.75	105.97	0.41	0.58	1.42
LWG12375P	104.62	104.82	0.57	0.62	0.68

Table 6. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at rivermile 123.7 for the Spring 1997 study.

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
LWG12371P	100	100	100	100
LWG12372P	100	100	100	100
LWG12375P	100	100	100	100

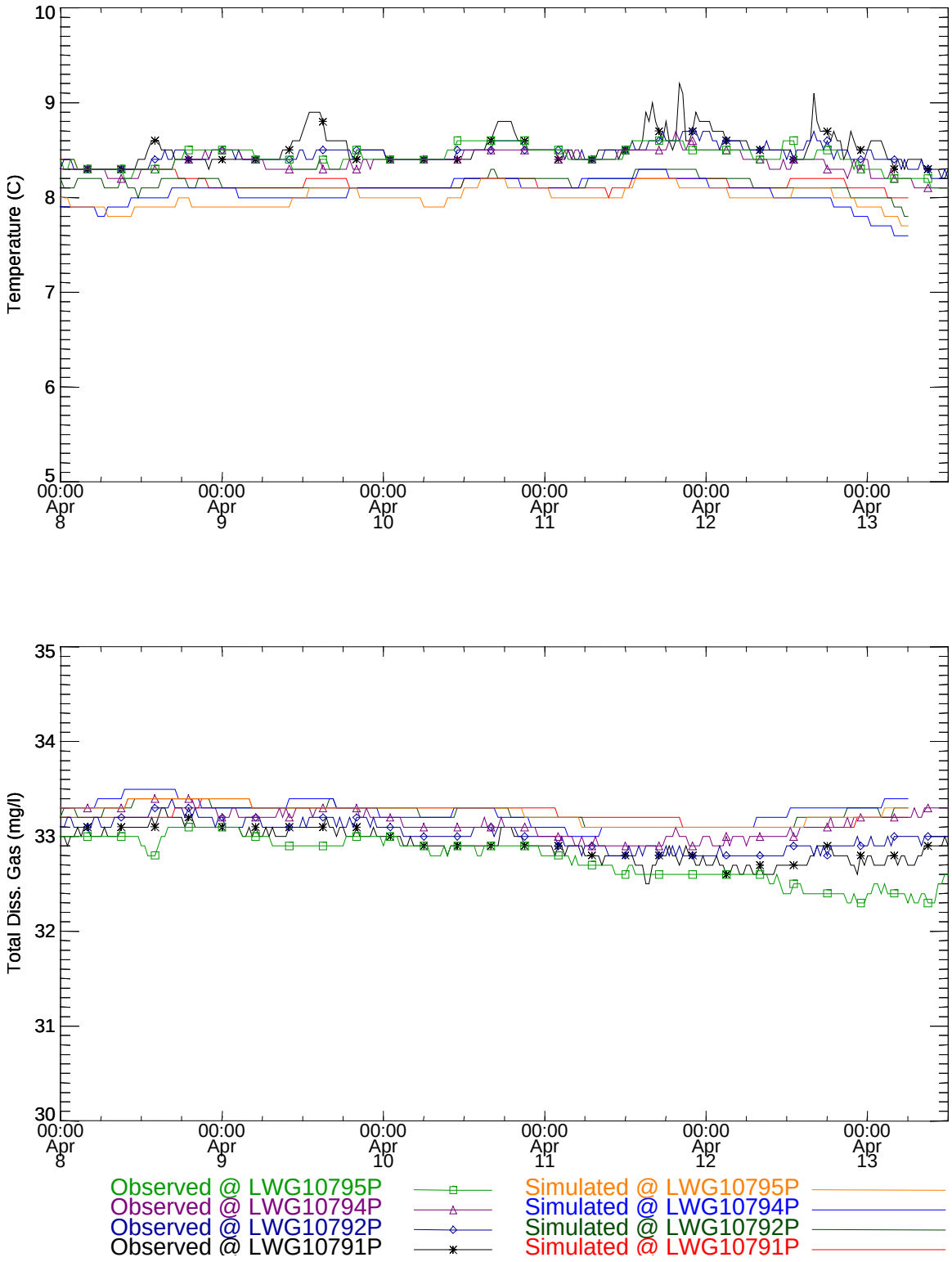

Figure 25. Temperature and total dissolved gas time series near Snake River mile 107.9 for the Spring 1997 pool study.

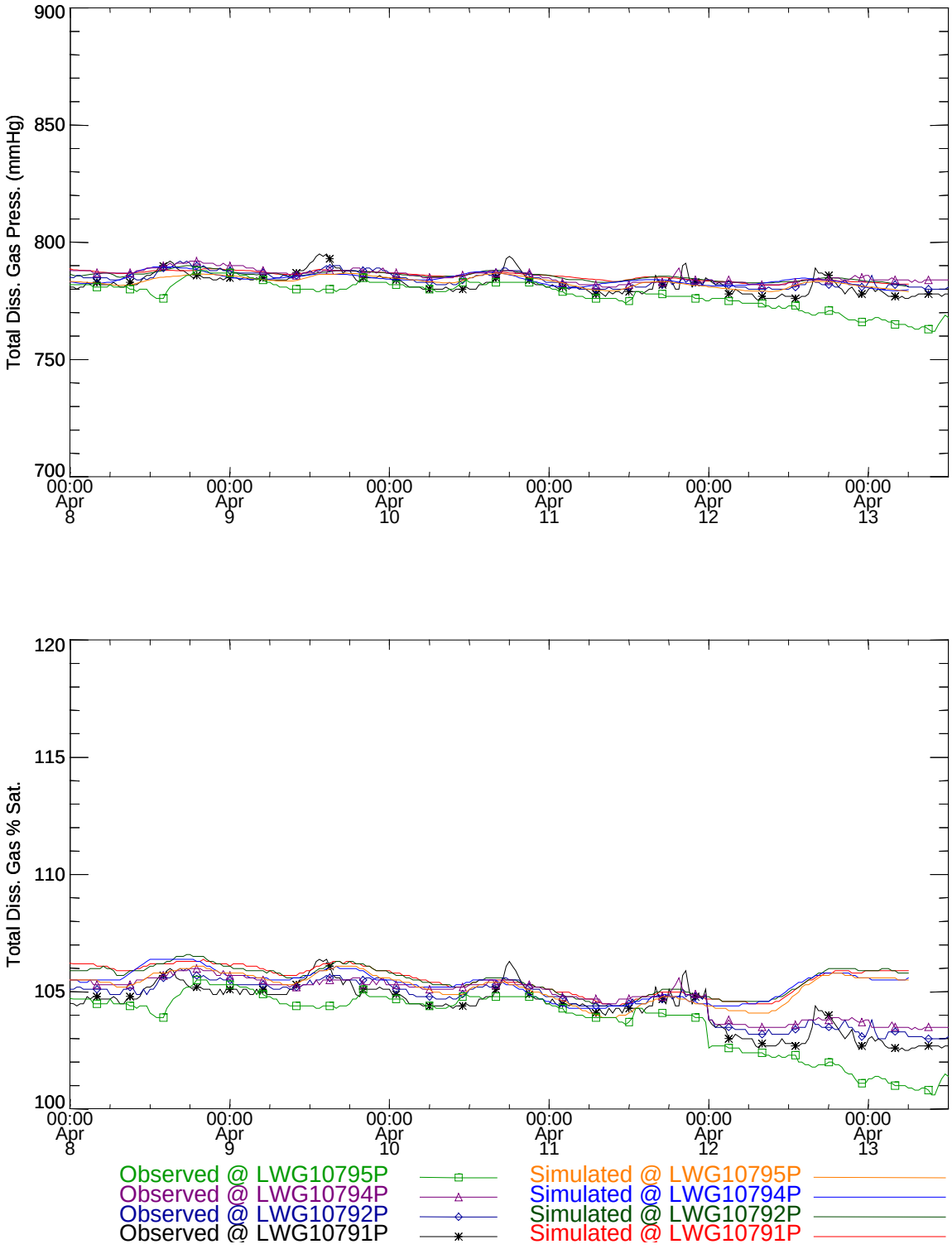

Figure 26. Total dissolved gas pressure and saturation time series near Snake River mile 107.9 for the Spring 1997 pool study.

Table 7. Statistical summary of measurements and simulations at river mile 107.9 during the Spring 1997 pool study.

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
LWG10791P	8.51	8.16	0.16	0.08	0.39
LWG10792P	8.47	8.14	0.1	0.08	0.34
LWG10794P	8.39	8.05	0.1	0.14	0.35
LWG10795P	8.43	8	0.11	0.11	0.44
Concentration					
LWG10791P	32.91	33.23	0.17	0.09	0.34
LWG10792P	33.02	33.24	0.15	0.1	0.24
LWG10794P	33.14	33.25	0.15	0.13	0.13
LWG10795P	32.78	33.25	0.23	0.1	0.49
Gas Pressure					
LWG10791P	782.7	785.72	4.2	2.04	4.38
LWG10792P	784.39	785.63	3.05	1.92	2
LWG10794P	785.87	784.19	2.66	2.35	2.58
LWG10795P	778.41	783.23	5.48	2.24	6.38
% Saturation					
LWG10791P	104.47	105.52	0.94	0.59	1.37
LWG10792P	104.69	105.51	0.82	0.58	1.11
LWG10794P	104.88	105.31	0.76	0.59	0.84
LWG10795P	103.89	105.19	1.2	0.61	1.78

Table 8. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at rivermile 107.9 for the Spring 1997 study.

Station	1.00 C	1.00 mg/l	38.00 mmHg	5.00% Sat.
LWG10791P	100	100	100	100
LWG10792P	100	100	100	100
LWG10794P	100	100	100	100
LWG10795P	100	100	100	100

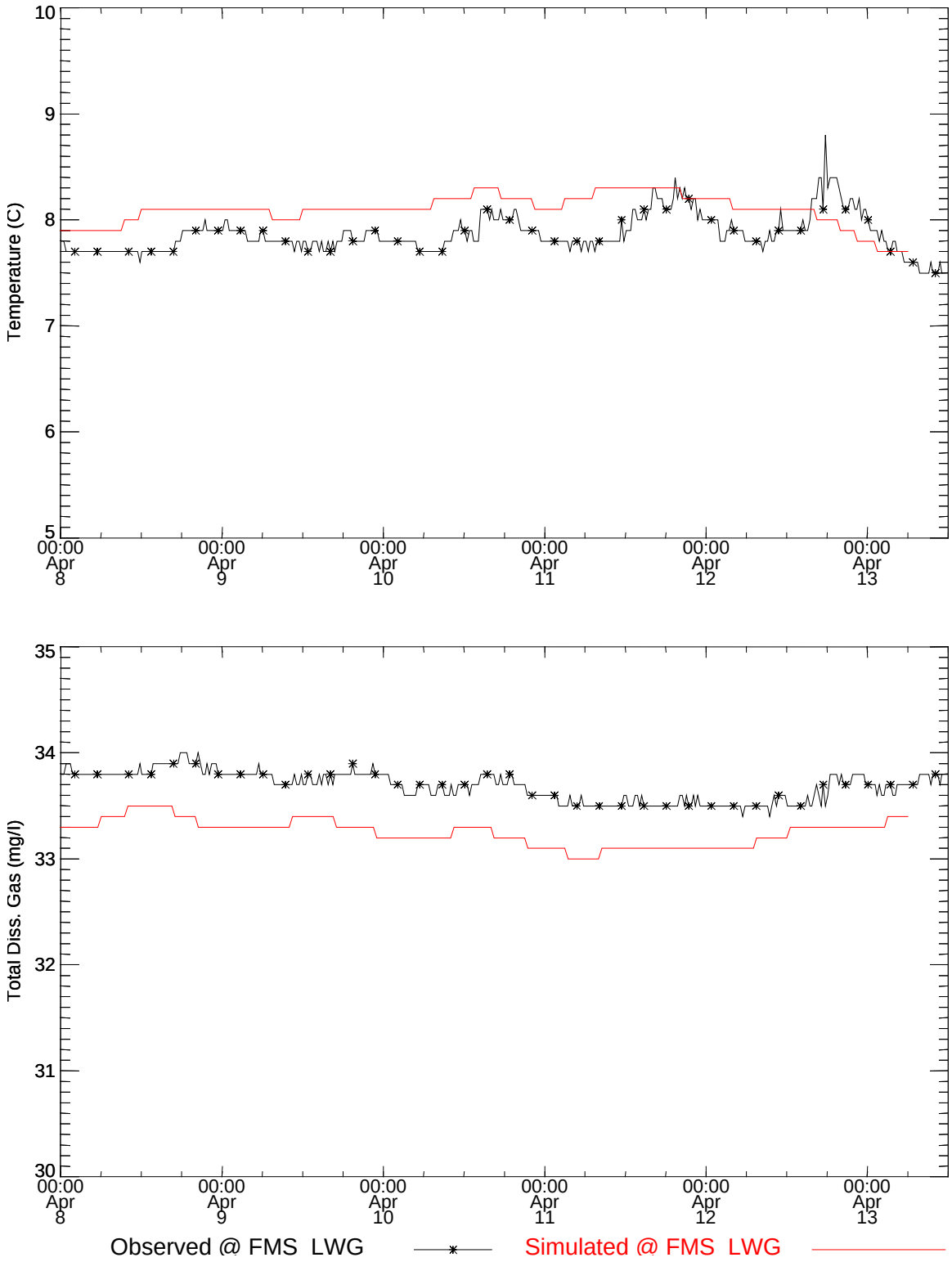

Figure 27. Temperature and total dissolved gas time concentration series at the LWG fixed monitor for the Spring 1997 pool study.

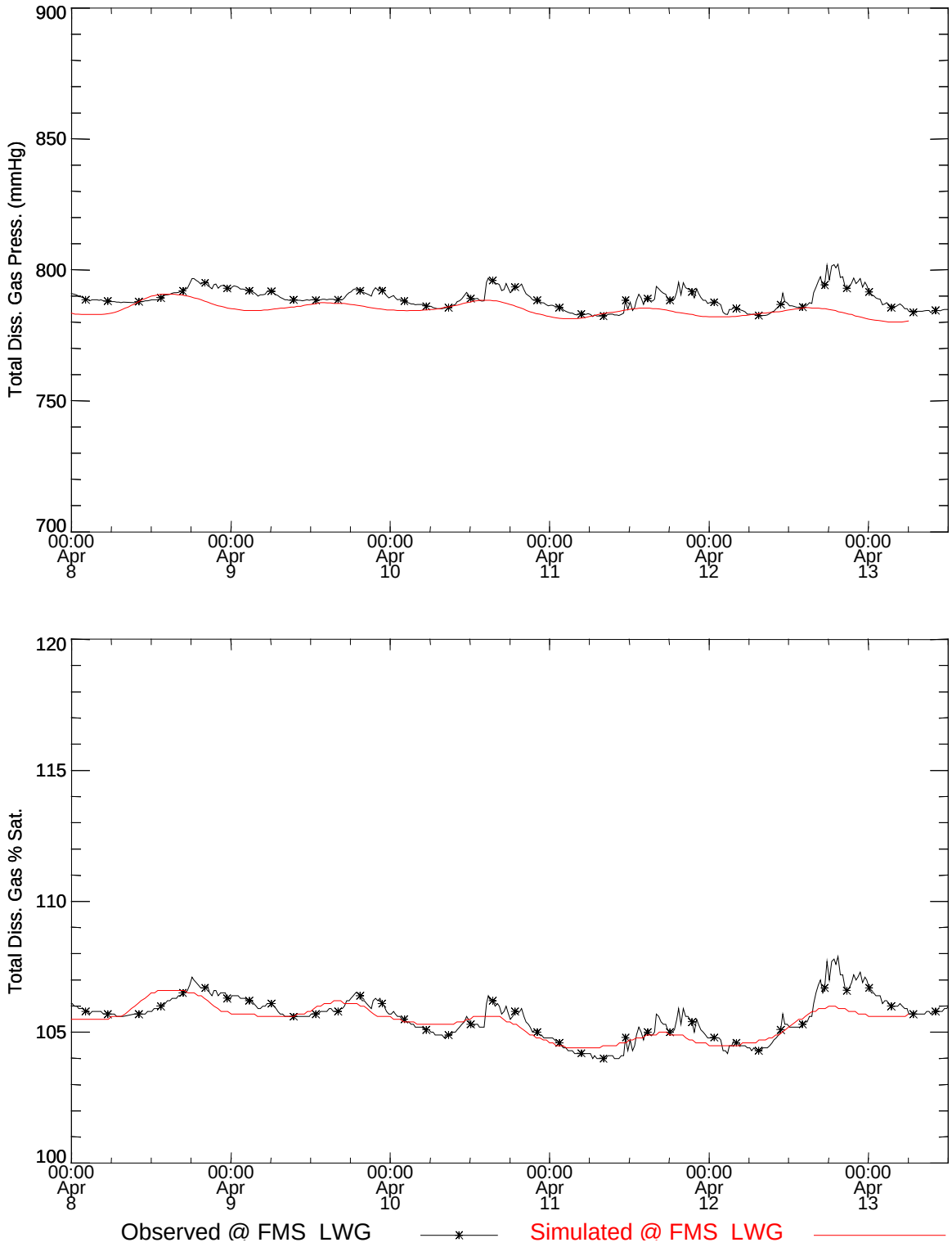

Figure 28. Total dissolved gas pressure and saturation time concentration series at the LWG fixed monitor for the Spring 1997 pool study.

Table 9. Statistical summary of measurements and simulations at fixed monitor LWG during the Spring 1997 pool study

Station	Measured Ave.	Simulated Ave.	Measured Std.Dev	Simulated Std.Dev.	RMS Error
Temperature					
FMS_LWG	7.88	8.09	0.17	0.14	0.29
Concentration					
FMS_LWG	33.68	33.25	0.14	0.12	0.44
Gas Pressure					
FMS_LWG	789.17	784.88	3.81	2.41	5.65
% Saturation					
FMS_LWG	105.57	105.41	0.8	0.59	0.49

Table 10. Percentage of time during the simulation where the computed value is within the given variance compared to the measurements at fixed monitor LWG for the Spring 1997 study.

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

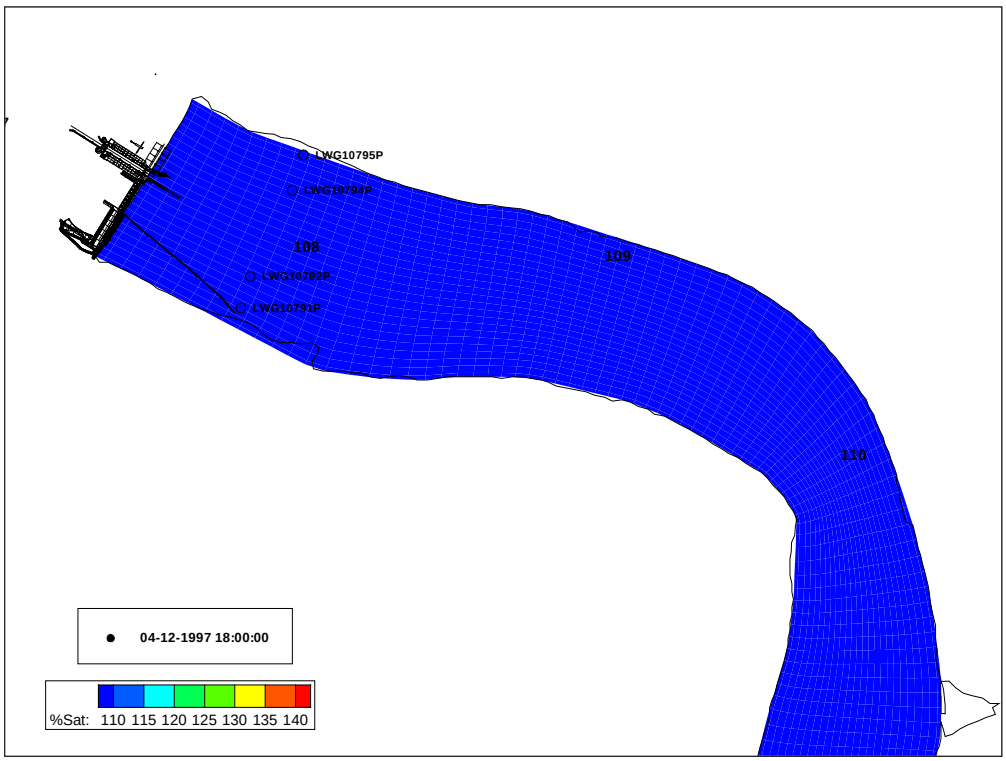

Figure 29. Spatial distribution of dissolved gas near Snake river mile 108 during the Spring 1997 study period.

2 References

Cunningham, L., 1993. Technical Exhibit G: Prediction of Erosion and Sediment Transport. In*: Columbia River System Operation Review, Final Environmental Impact Statement, Appendix M: Water Quality*. DOE/EIS-0170, SOR Interagency Team, P.O. Box 2988, Portland, Oregon, November 1995.

Gordon, J.L., B.J. Evans, and E.M. Perry, 1995. *Lower Granite GIS Data Description and Collection Guidelines.* PNL-10889. Pacific Northwest National Laboratory, Richland, Washington.

National Oceanic and Atmospheric Administration (NOAA), 1990. *Snake River: Lake Bryan.* Nautical Chart 18547, 7th Ed., National Ocean Service, Riverdale, Maryland.

Richmond, M.C., W.A. Perkins, and T.D. Scheibe. 1998. *Two-Dimensional Hydrodynamic, Water Quality, and Fish Exposure Modeling of the Columbia and Snake Rivers. Part 1: Summary and Model Formulation*. Draft Final Report submitted to U.S. Army Corps of Engineers, Walla Walla District. Battelle Pacific Northwest Division, Richland, Washington.

Steinbrenner J.P., and J.R. Chawner, 1995. *The GRIDGEN Version 9 Multiple Block Grid Generation Software*. MDA Engineering, Inc., Arlington, Texas.

U.S. Geological Survey (USGS), 1995. *Metadata for 1-degree Digital Elevation Models.* [online report]. Available Online URL: http://nsdi.usgs.gov/ File: nsdi/wais/maps/dem1deg.HTML.

Appendix A. Lower Granite Pool Data Sources

A.1 Bathymetry

Bathymetric data for the Columbia River was gathered from the various sources shown in Table 11. The primary source was a set of contours developed by Gordon, et al. (1995). These were supplemented with dense surveys and digitized NOAA charts (NOAA, 1990) in the Lower Granite dam tailrace, and with sedimentation range surveys near the confluence of the Clearwater and Snake rivers (Cunningham, 1993). 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 Granite pool is shown in Figure 30. Once the surface was produced, it was "sampled" at the necessary grid locations to produce the bathymetry required by the hydrodynamic model grid.

Table 11. Columbia River bathymetry data sets used to create the Ice Harbor pool bathymetric surface. Listed figure numbers refer to the map which shows the survey location(s).

Bathymetric Data Set	Source	Survey Date	Approximate Rivermile Start	Approximate Rivermile End
Lower Granite Dam Tailrace (Figure 32)	Julie Davin (Walla Walla)	1992	106.4	107.5
Lower Granite Dam Sedimentation Ranges (Figure 32)	Les Cunningham (Walla Walla)	1987	101.8	107.2
Lower Granite Pool Sedimentation Ranges (Figure 31)	Les Cunningham (Walla Walla)	1996	101.8	107.2
NOAA Navigation Charts (Figure 32)	Battelle	unknown	0.0	107.2

Figure 30. Color representation of Lower Granite pool bathymetric surface.

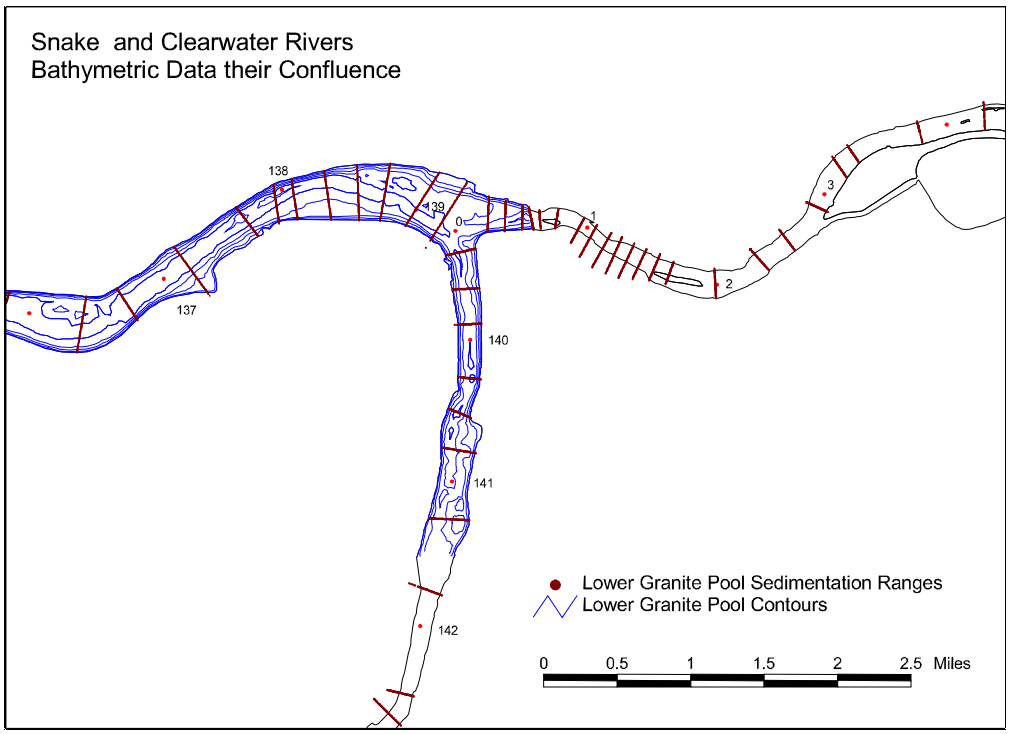

Figure 31. Bathymetric data near Snake/Clearwater confluence.

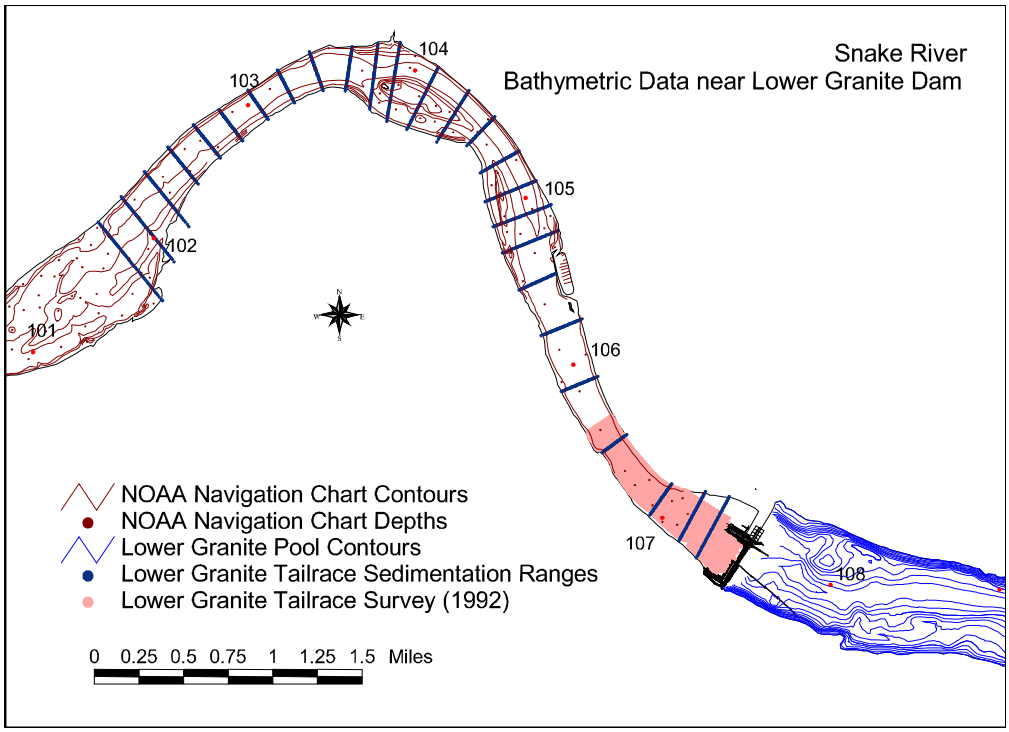

Figure 32. Bathymetric data near Lower Granite dam.

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 Granite pool area are shown in Figure 34. 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 John Day dam model boundary.

The dissolved gas pool studies performed in Lower Granite Pool to date are shown in Table 12 and their durations are shown graphically in Figure 33. During these studies water temperature and TDG pressures were measured at several locations within Lower Granite 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.

Table 12. Dates of dissolved gas field studies in Lower Granite pool.

STUDY SET	Start	End
LWG LGS LMN SPR 97	4/2/97 11:00:00 AM	4/16/97 11:00:00 AM

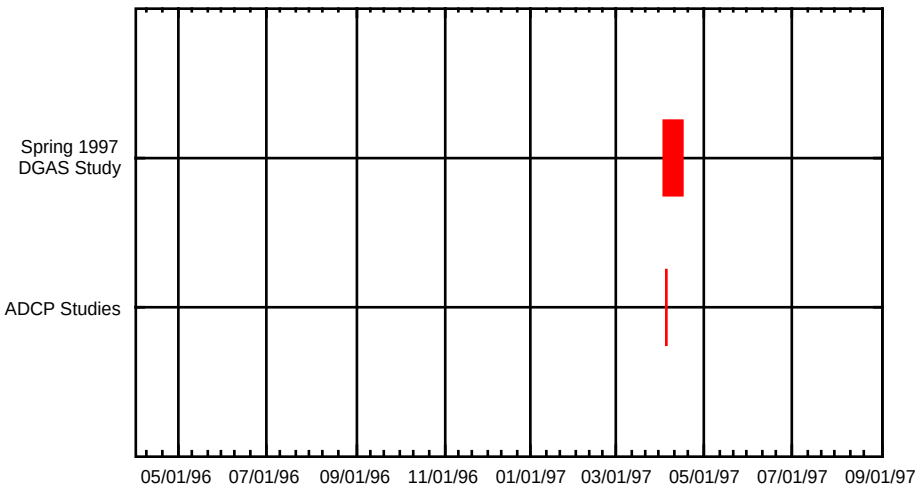

Figure 33. Dates and durations of dissolved gas and ADCP velocity studies in Lower Granite Pool

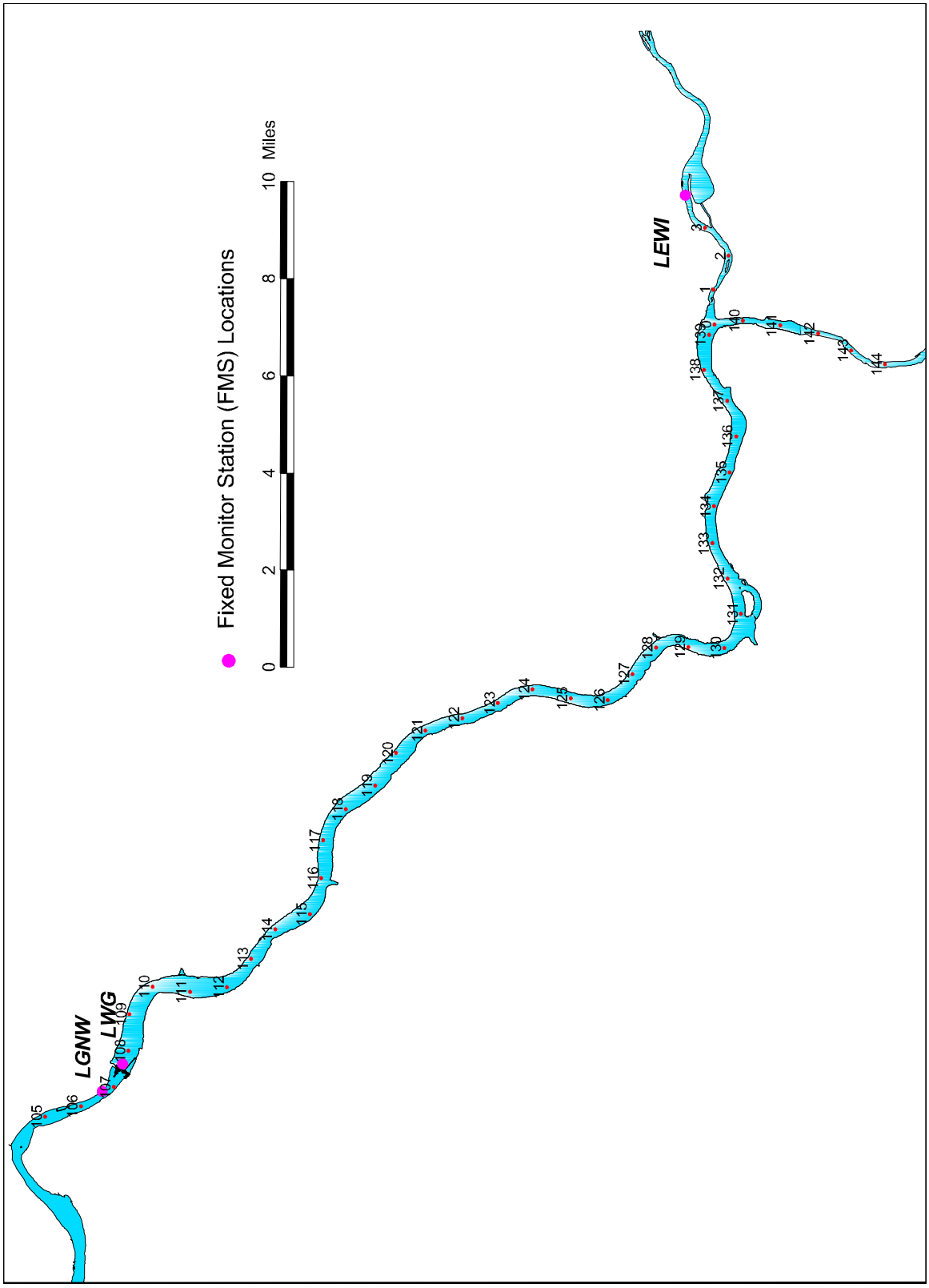

Figure 34. FMS locations in and around Lower Granite pool.

A.2.2 ADCP Velocity Measurements

As shown in Figure 33, velocity measurements were taken using ADCP (Acoustic Doppler Current Profiler) instruments during two of the dissolved gas pool studies: Spring 1996 and Summer 1997. The ADCP data was obtained from the DGAS team FTP server, `limnos.wes.army.mil`, in the file `/data3/dgas/database/ADCP data/97ADCP.zip`, dated July 15, 1998. Figure 35 through Figure 37 show the measurements made as small arrows.

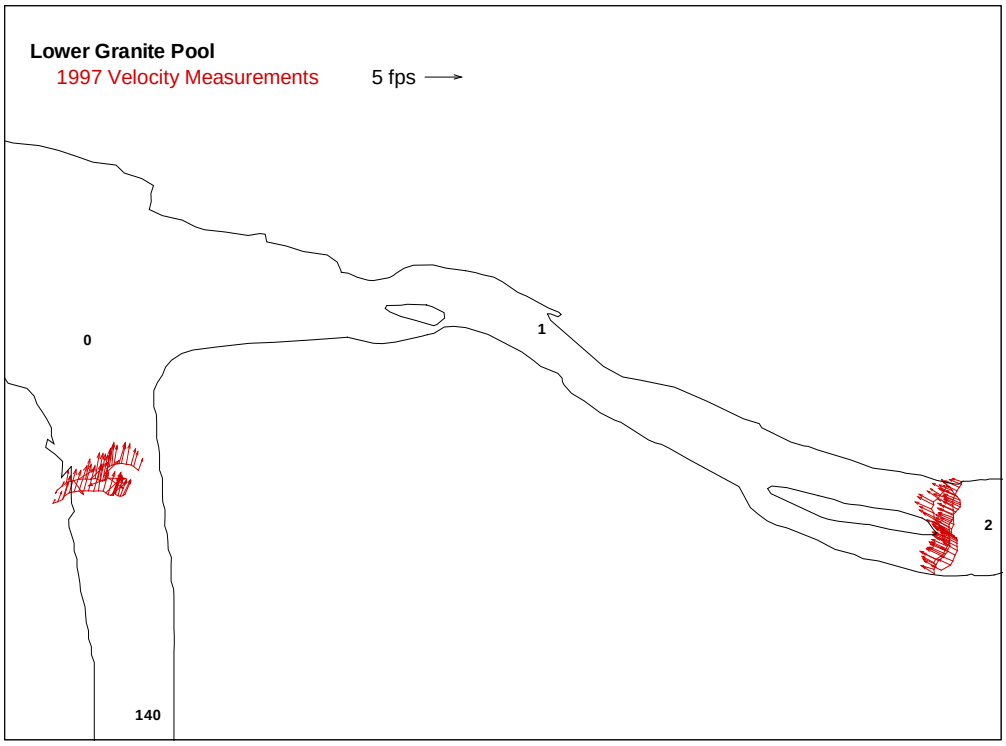

Figure 35. Lower Granite pool ADCP velocity measurements near the confluence of the Snake and Clearwater rivers.

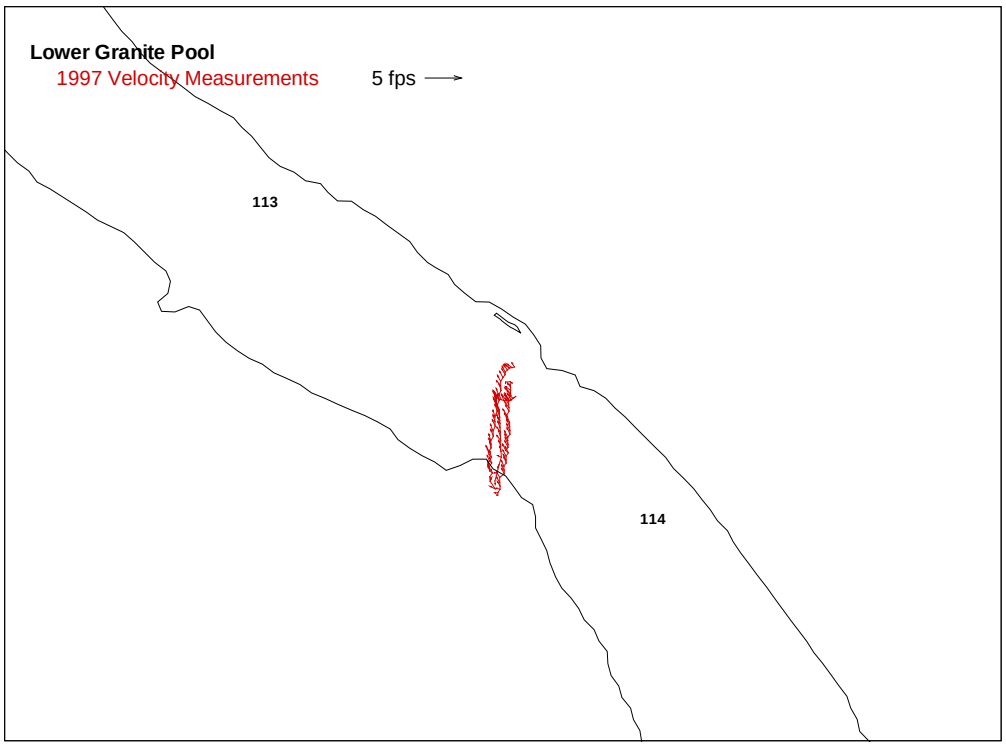

Figure 36. Lower Granite pool ADCP velocity measurements near Snake river mile 114.

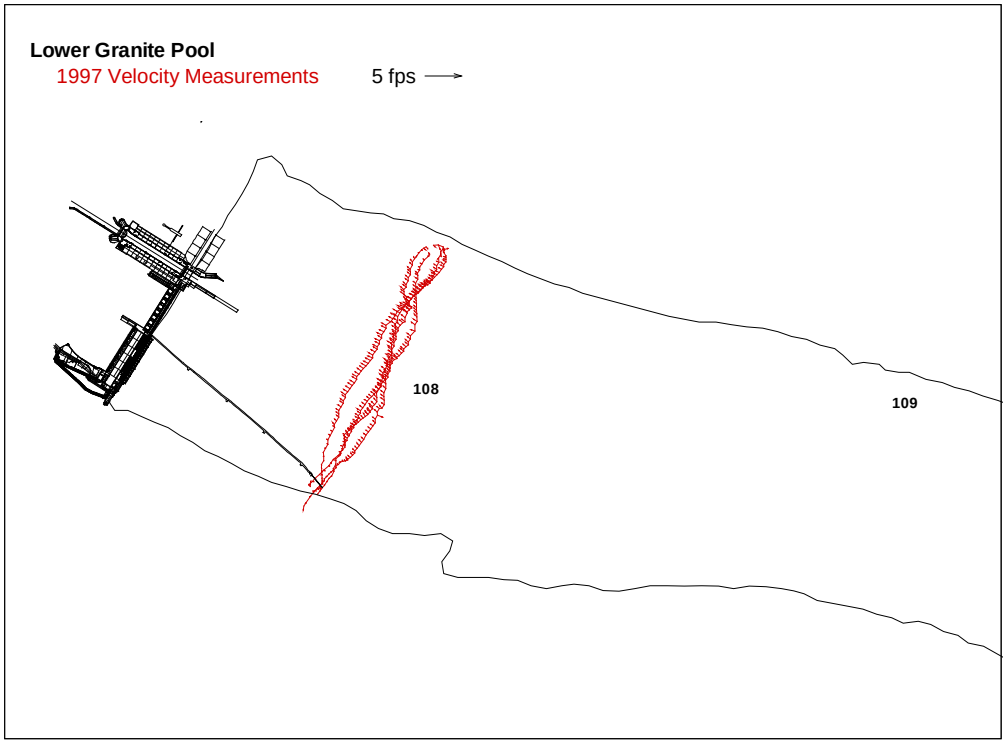

Figure 37. Lower Granite pool ADCP velocity measurements near Lower Granite dam.

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 August 25, 1998. The CHROMS operations data provided hourly aggregate spill and powerhouse flows and forebay and tailwater stages.

A.2.4 Snake and Clearwater River Data

Provisional hourly flow and temperature data was obtained from the USGS for the Snake River at Anatone (USGS Station 13334300) and the Clearwater River at Orofino (USGS Station 13340000).

A.2.5 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 June 11, 1998.

Appendix B. Spring 1997 Lower Granite Pool Study

B.1 Dissolved Gas Data

The Spring 1997 Lower Granite pool dissolved gas study started on April 2 and ended on April 16. A total of 17 water quality monitors were used. These stations, and their records, are listed in Table 13. Station locations are shown in Figure 38. TDG pressure was not recorded by stations LWG12374P and LWG13741P during the study period.

Table 13. Dissolved gas monitor stations, and their records, used during the Spring 1997 study period.

Station	Start Time	End Time	Temperature Records	Pressure Records
LWG12375P	4/2/97 11:00:00 PM	4/14/97 12:00:00 PM	555	555
LWG00184P	4/2/97 11:00:00 PM	4/14/97 12:00:00 PM	555	555
LWG10791P	4/2/97 11:00:00 PM	4/14/97 12:00:00 PM	555	555
LWG10792P	4/2/97 11:00:00 PM	4/14/97 12:00:00 PM	555	555
LWG10794P	4/2/97 11:00:00 PM	4/14/97 11:30:00 AM	554	554
LWG10795P	4/2/97 11:00:00 PM	4/14/97 12:00:00 PM	555	555
LWG12371P	4/2/97 11:00:00 PM	4/14/97 12:00:00 PM	555	555
LWG00182P	4/2/97 11:00:00 PM	4/14/97 12:00:00 PM	555	555
LWG12374P	4/2/97 11:00:00 PM	4/14/97 12:00:00 PM	555	0
LWG13974P	4/2/97 11:00:00 PM	4/14/97 12:00:00 PM	555	555
LWG13741P	4/2/97 11:00:00 PM	4/14/97 12:00:00 PM	555	0
LWG13742B	4/2/97 11:00:00 PM	4/14/97 12:00:00 PM	555	555
LWG13742P	4/2/97 11:00:00 PM	4/14/97 12:00:00 PM	555	555
LWG13744B	4/2/97 11:00:00 PM	4/14/97 12:00:00 PM	555	555
LWG13744P	4/2/97 11:00:00 PM	4/14/97 12:00:00 PM	555	555
LWG13972P	4/2/97 11:00:00 PM	4/14/97 12:00:00 PM	555	555
LWG12372P	4/2/97 11:00:00 PM	4/16/97 9:00:00 AM	645	538

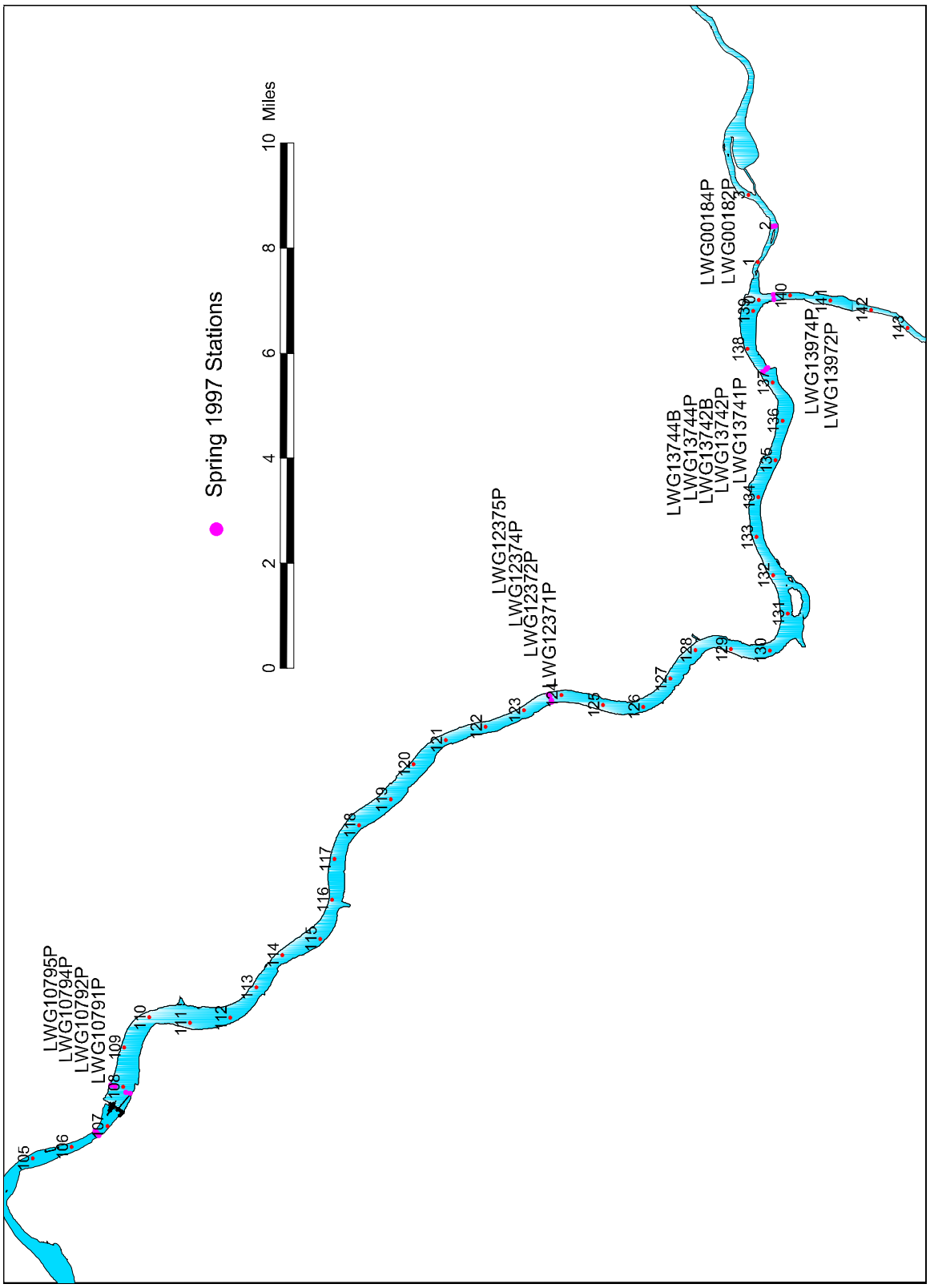

Figure 38. Dissolved gas monitor locations during the Spring 1997 study.

B.2 Velocity Data

Velocity measurements were made along a total of 12 transects in Lower Granite Pool during the Spring 1997 study period. The transects are summarized in Table 14. Supplied measurement locations are shown in Figure 39.

Table 14. Summary of ADCP transects made during the Spring 1997 study period.

	Average		
Date Label	Velocity	Depth	Number of Measurements
04-03-1997 09:08	2.1	15.5	27
04-03-1997 09:20	2.1	15.6	27
04-03-1997 09:38	2.2	15.8	26
04-03-1997 10:16	2.7	30.9	27
04-03-1997 10:33	2.8	32.5	25
04-04-1997 08:51	0.5	86.0	90
04-04-1997 09:11	0.4	83.4	93
04-04-1997 09:34	0.4	85.2	90
04-04-1997 09:54	0.4	86.0	88
04-04-1997 10:47	0.9	97.6	34
04-04-1997 10:58	0.8	95.8	36
04-04-1997 11:07	0.9	98.0	35

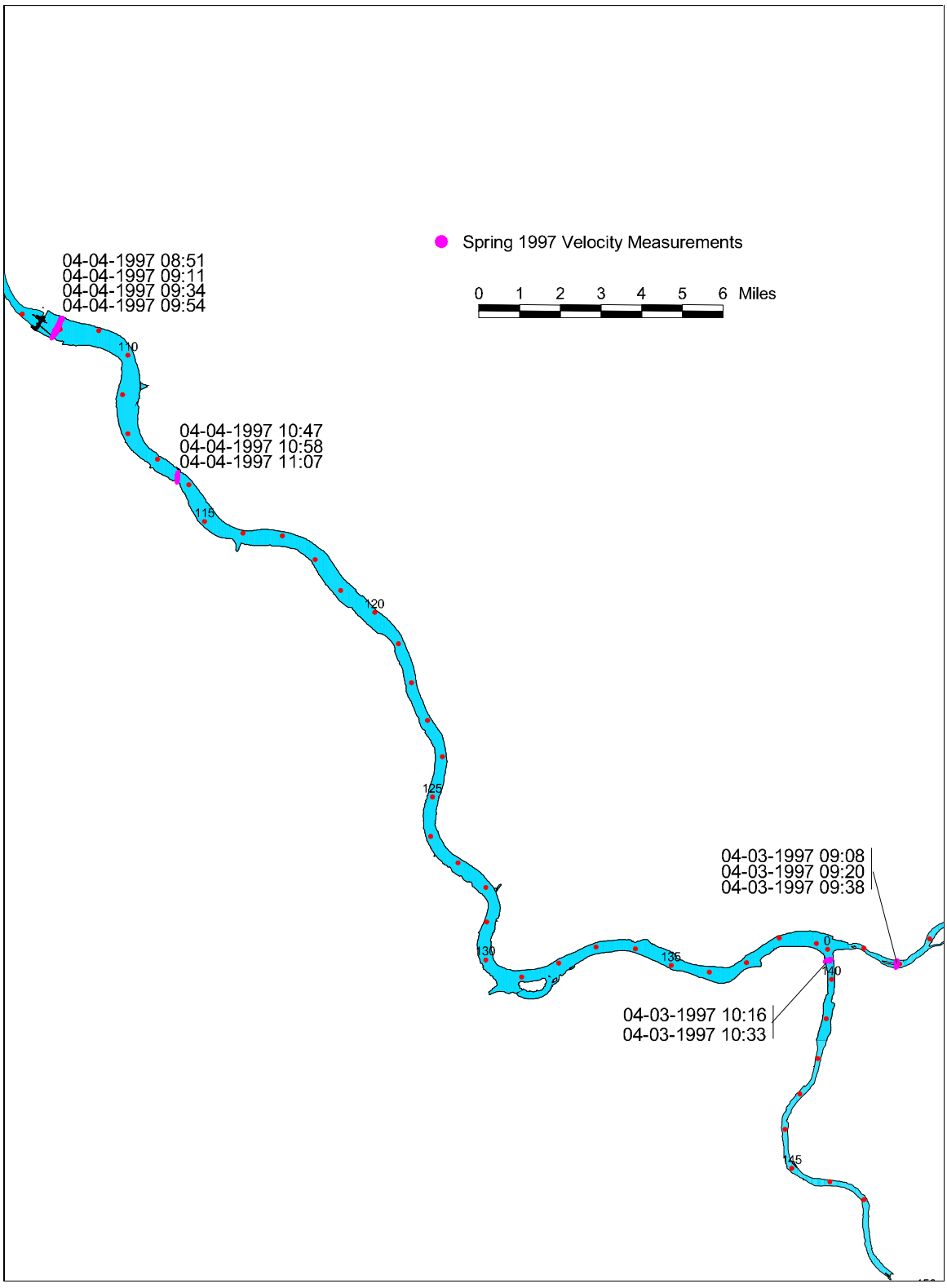

Figure 39. Locations of ADCP velocity measurements during the Spring 1997 study period.

B.3 Clearwater and Snake River Model Boundaries

B.3.1 Flow

Discharge at the Clearwater and Snake model boundaries was estimated using a one-dimensional hydrodynamic model. The model used flows from the North Fork of the Clearwater at Dworshak dam (Figure 40), Clearwater River at Orifino (USGS gage #13340000, Figure 41) and Snake River at Anatone (USGS gage #13334300, Figure 42). The one-dimensional model also used forebay elevation at Lower Granite dam (Figure 51). Flows predicted by the one-dimensional model at Snake river mile 141.78 (Figure 43) and Clearwater river mile 0.92 (Figure 44) were used as boundary conditions for the two-dimensional model.

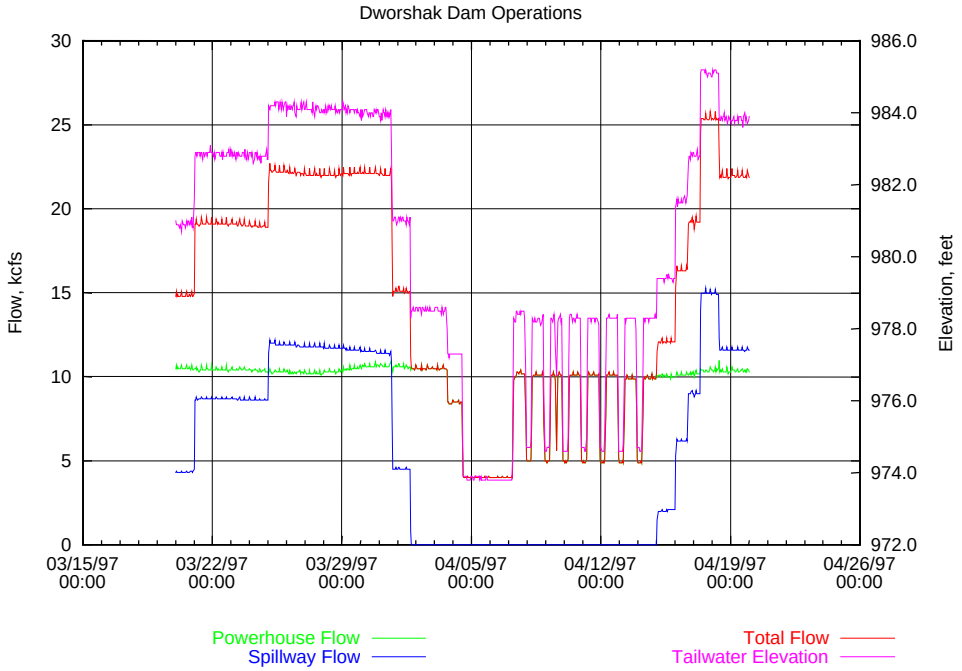

Figure 40. Dworshak dam operations during the Spring 1997 study period.

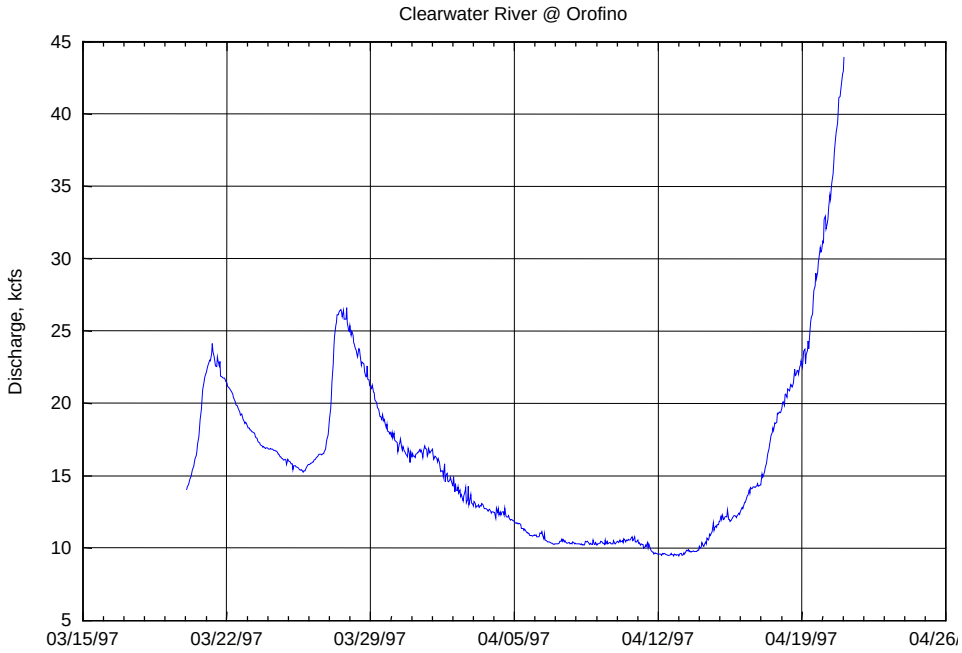

Figure 41. Clearwater River flow at Orofino, Idaho during the Spring 1997 study period.

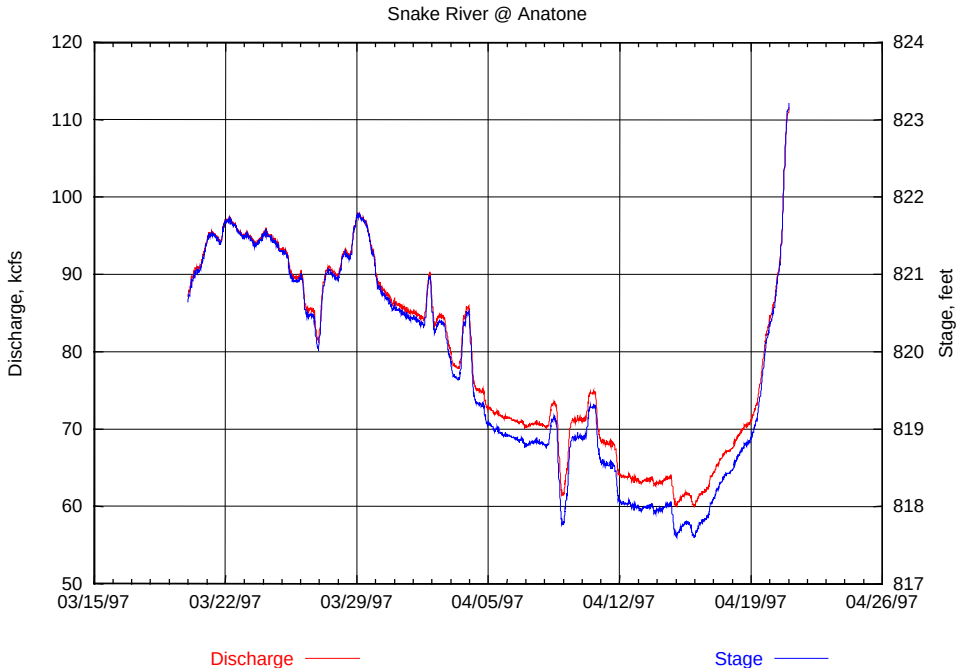

Figure 42. Snake River flow and stage at Anatone, Washington during the Spring 1997 study period.

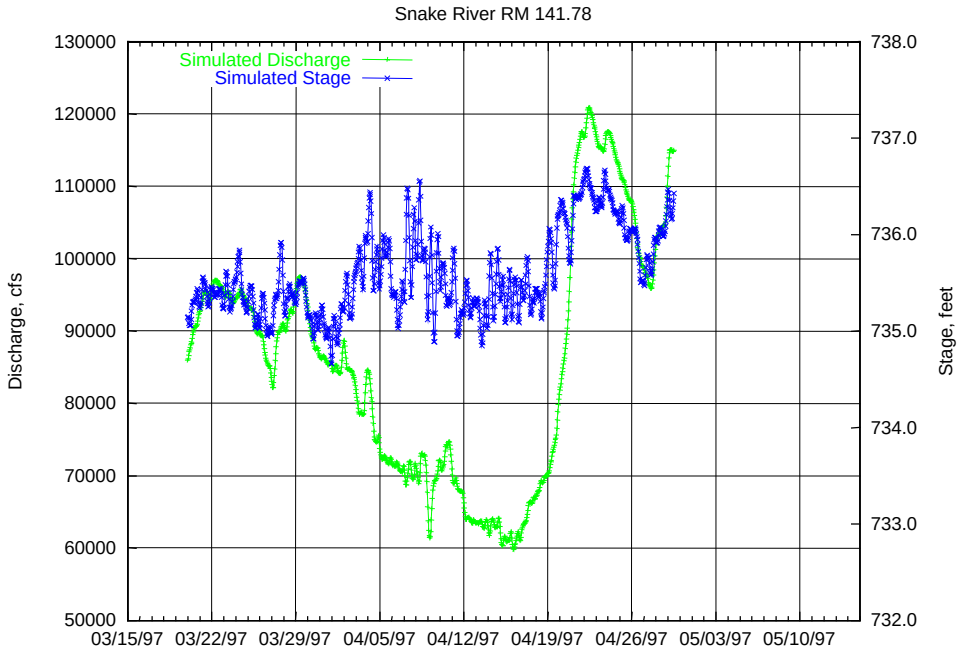

Figure 43. Simulated discharge and stage at Snake river mile 141.78, the Snake river model bounary, during the Spring 1997 study period.

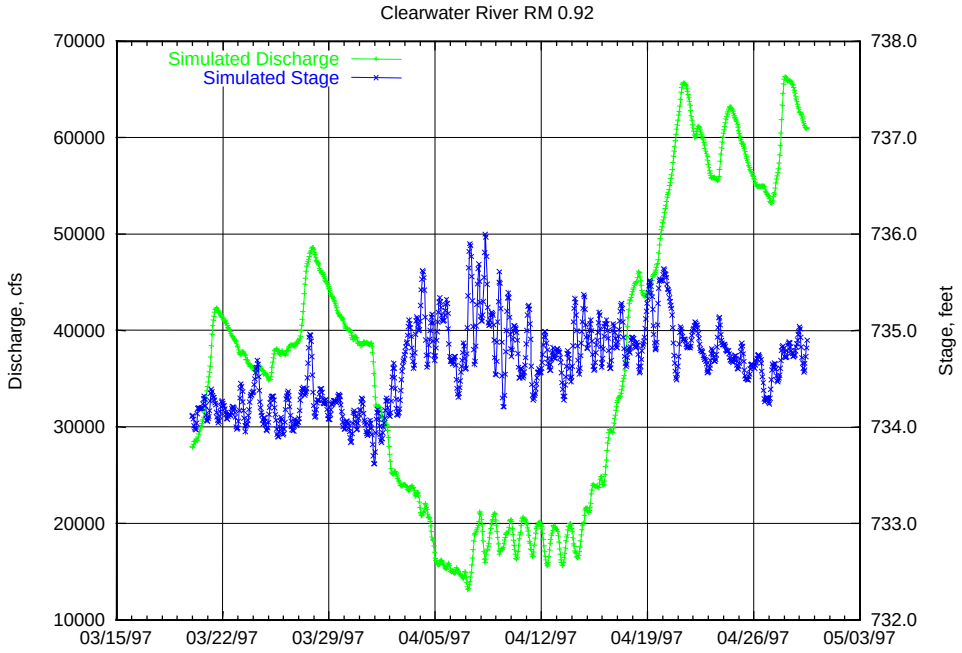

Figure 44. Simulated discharge and stage at Clearwater river mile 0.92, the Clearwater river model boundary, during the Spring 1997 study period.

B.3.2 Clearwater River Water Quality

During the Spring 1997 study period, Clearwater river temperature and TDG pressure were measured at two locations near river mile 1.8 using temporary monitors: LWG00182P and LWG00184P. These were located approximately one mile upstream of the model boundary. The temperatures and pressures measured by these monitors are shown in Figure 48 and Figure 49, respectively. These were used to compute TDG concentrations, shown in Figure 50. These temperatures and concentrations were applied as Clearwater river boundary conditions, with station LWG00184P applied to cells 1 through 6 and LWG00182P to cells 7 through 6 (see Figure 2).

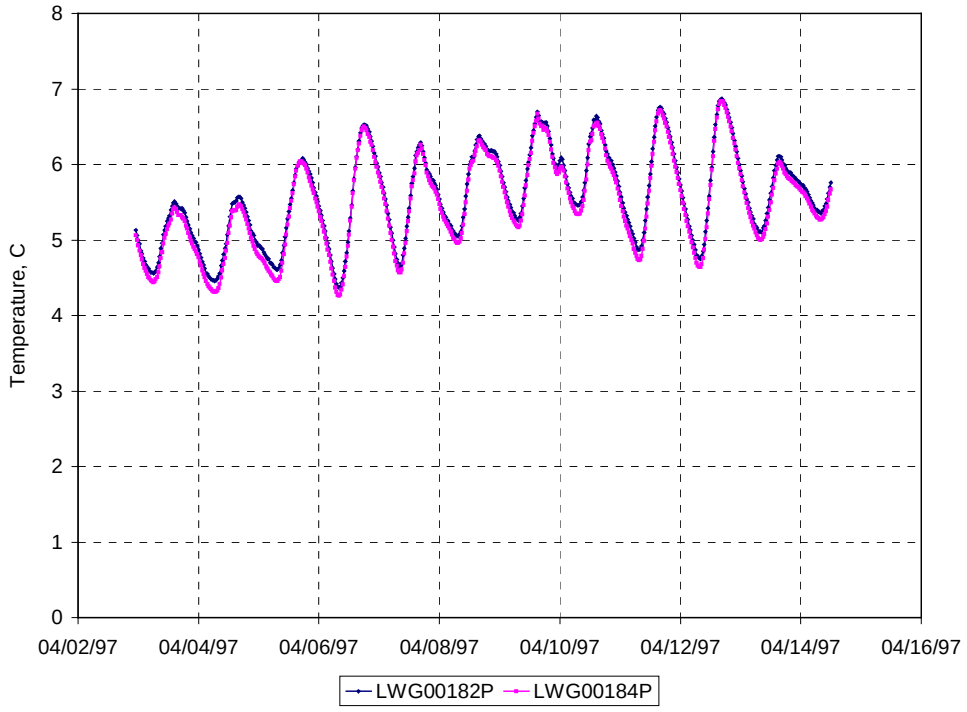

Figure 45. Water temperatures measured by temporary monitors in the Clearwater River near Lewiston during the Spring 1997 study period.

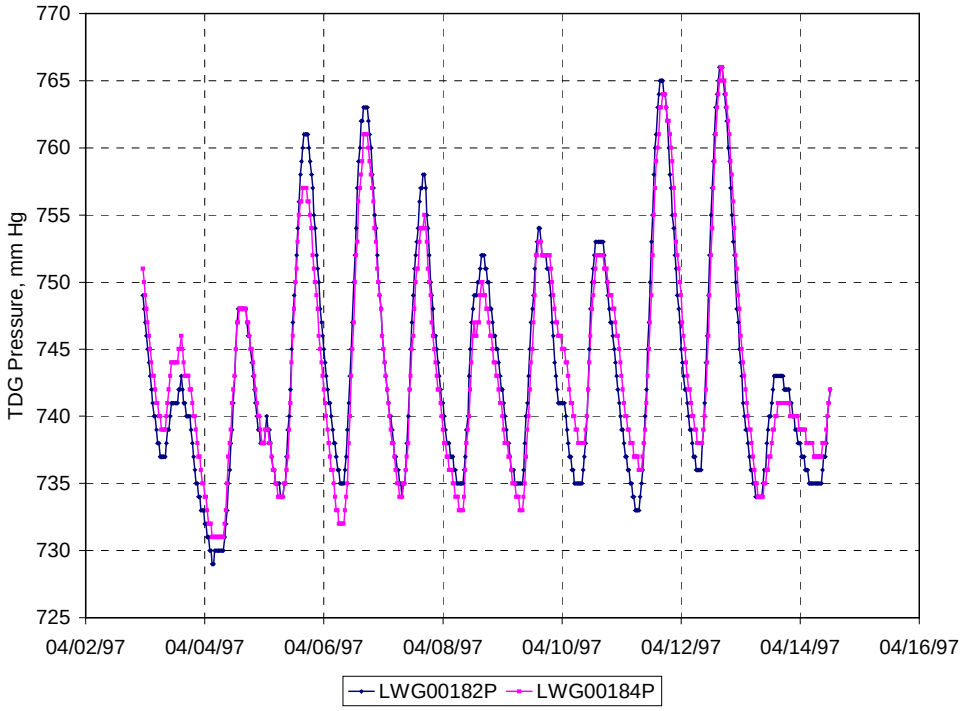

Figure 46. TDG pressures measured by temporary monitors in the Clearwater River near Lewiston during the Spring 1997 study period.

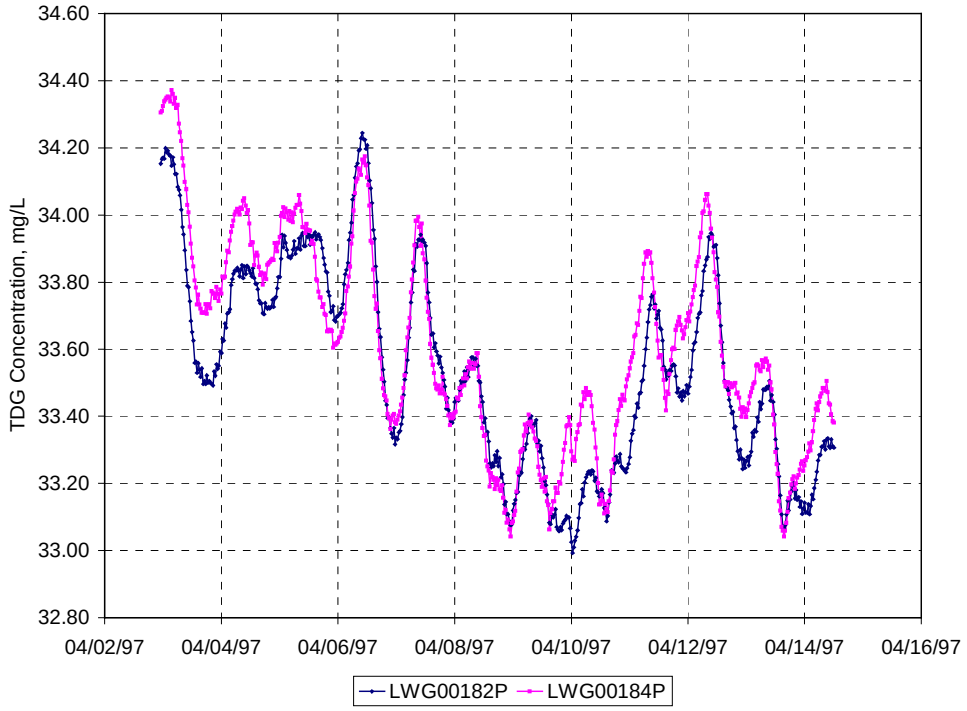

Figure 47. TDG concentrations in the Clearwater River near Lewiston computed using temporary monitor temperatures and pressures during the Spring 1997 study period.

B.3.3 Snake River Water Quality

Snake river temperature and TDG pressure were also measured at two locations, LWG13972P and LWG13974P, near Snake river mile 139.7. This is approximately two miles downstream of the model boundary. The temperatures and pressures measured by these monitors are shown in Figure 48 and Figure 49, respectively. These were used to compute TDG concentrations, shown in Figure 50. These temperatures and concentrations were applied as Snake river boundary conditions, with station LWG13974P applied to cells 1 through 6 and LWG13972P to cells 7 through 6 (see Figure 2).

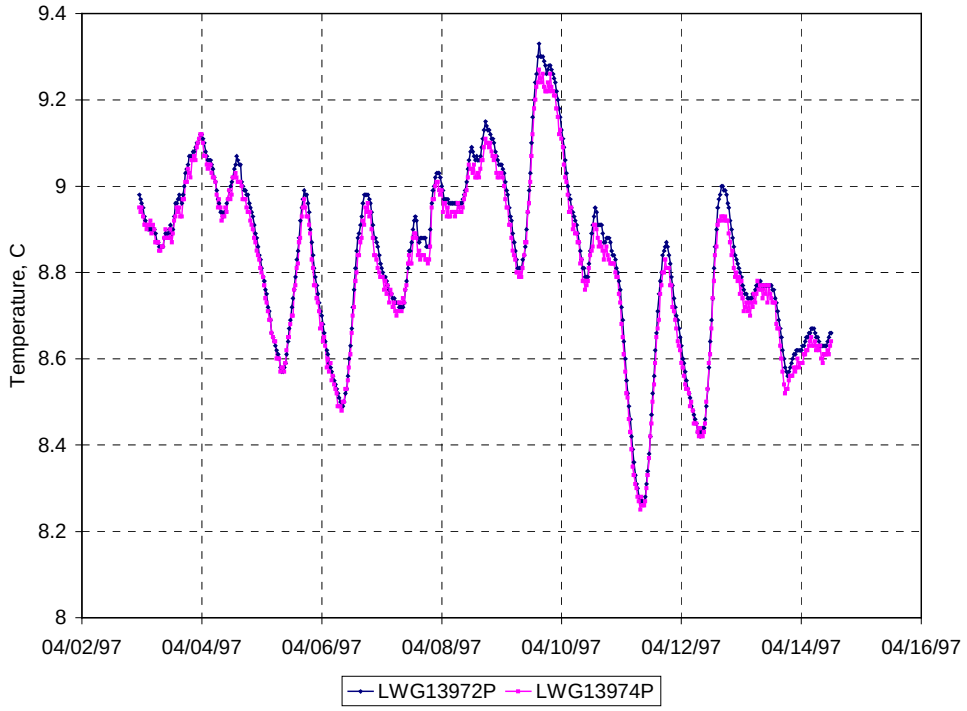

Figure 48. Water temperatures measured by temporary monitors in the Snake River above Lewiston during the Spring 1997 study period.

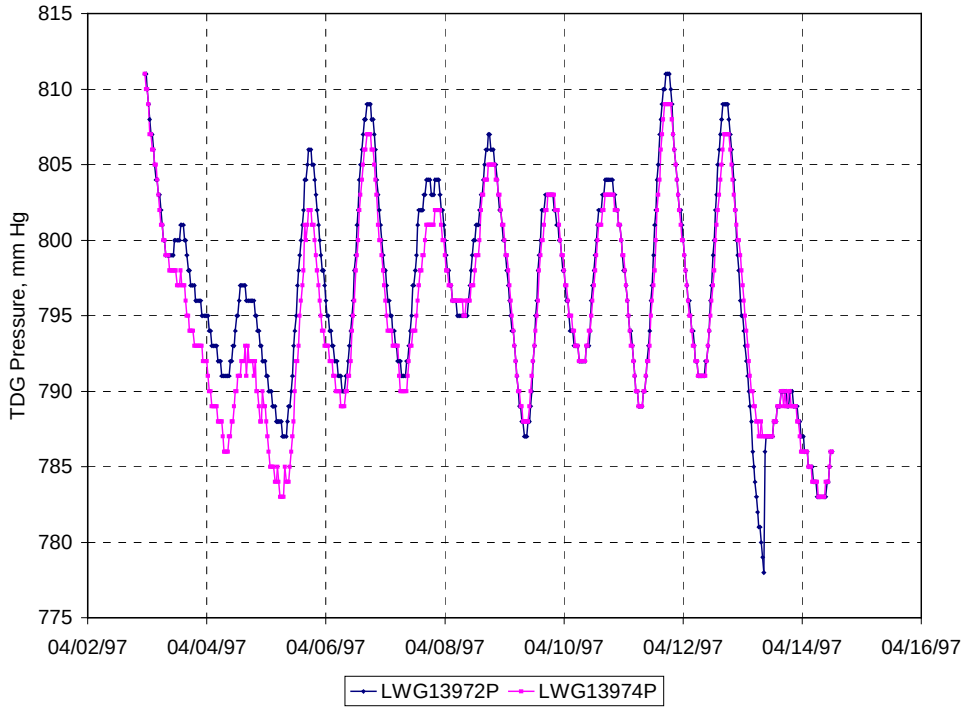

Figure 49. TDG pressures measured by temporary monitors in the Snake River above Lewiston during the Spring 1997 study period.

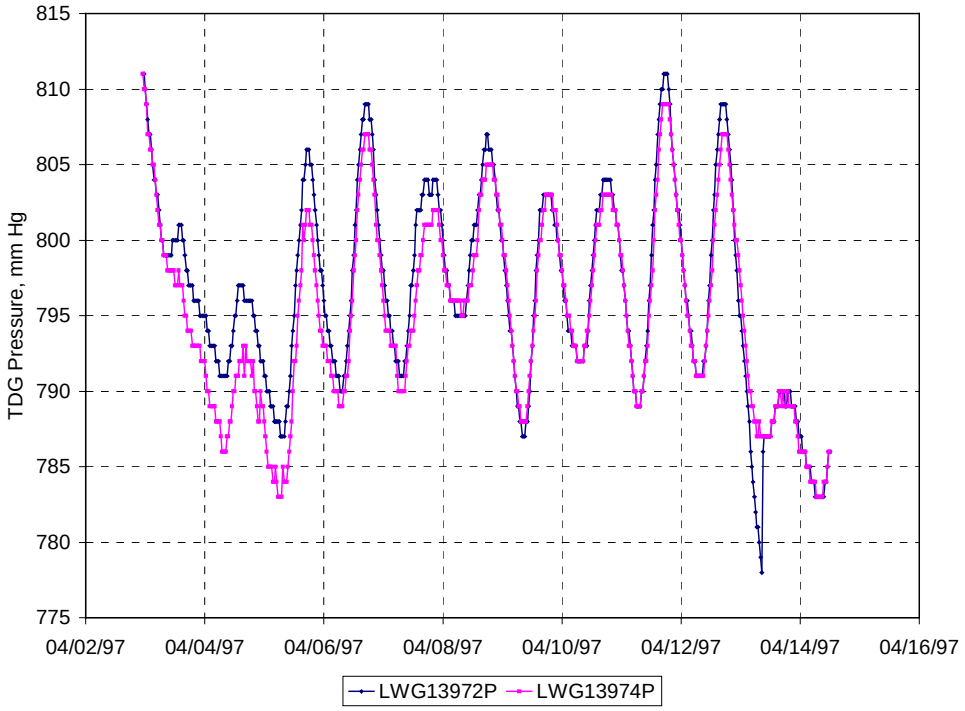

Figure 50. TDG concentrations in the Snake River above Lewiston computed using temporary monitor temperatures and pressures during the Spring 1997 study period.

B.4 Lower Granite Dam Operations

Figure 51 shows Lower Granite dam operations during the Spring 1997 study period.

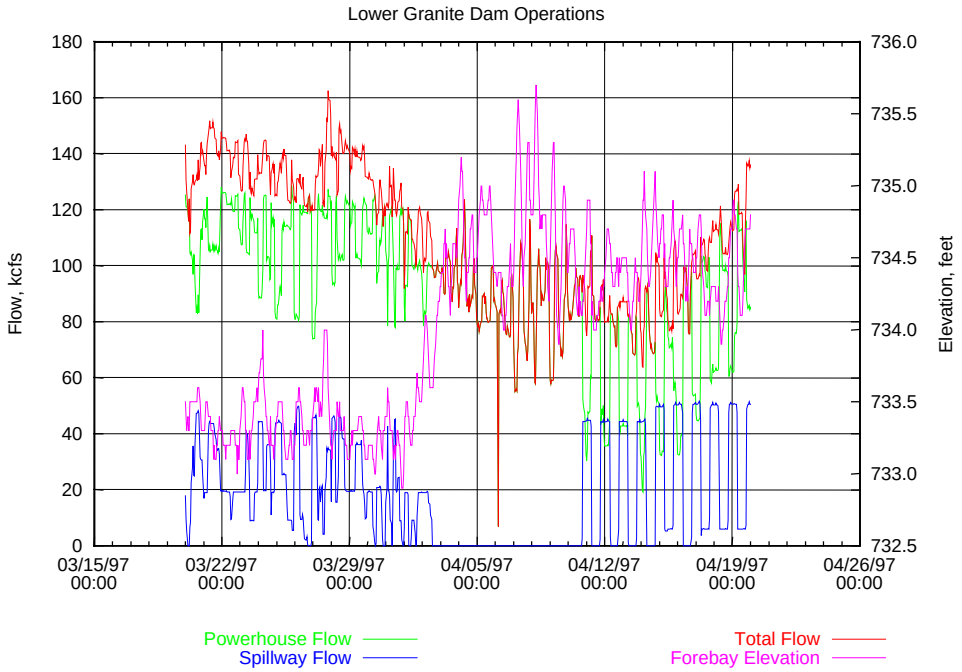

Figure 51. Lower Granite dam operations during the Spring 1997 study.

B.5 Weather

Atmospheric conditions were considered constant over the entire pool. Lewiston, Idaho, air and dew point temperature (Figure 52) and wind speed (Figure 53) were used from the NWS weather database. Barometric pressure (also shown in Figure 52), measured at the LEWI FMS, was considered to apply over the entire modeled area. Measured short-wave radiation was available from the WeatherPak database for a most of the time during the Spring 1997 study. That record was extended by estimating total incoming radiation using NWS Lewiston dew point and cloud cover data. Cloud cover was assumed to be zero (clear skies) if cloud cover data was missing from the Lewiston record. Net incoming solar radiation based both on the estimated total solar radiation is shown in Figure 54.

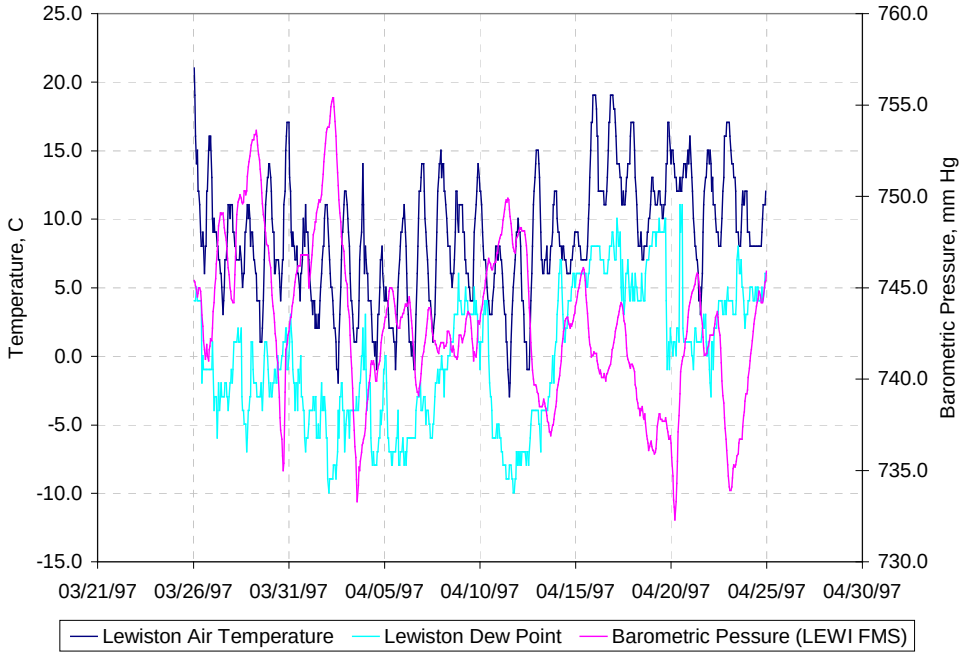

Figure 52. Air temperature, dew point, and barometric pressure used during the Spring 1997 study period.

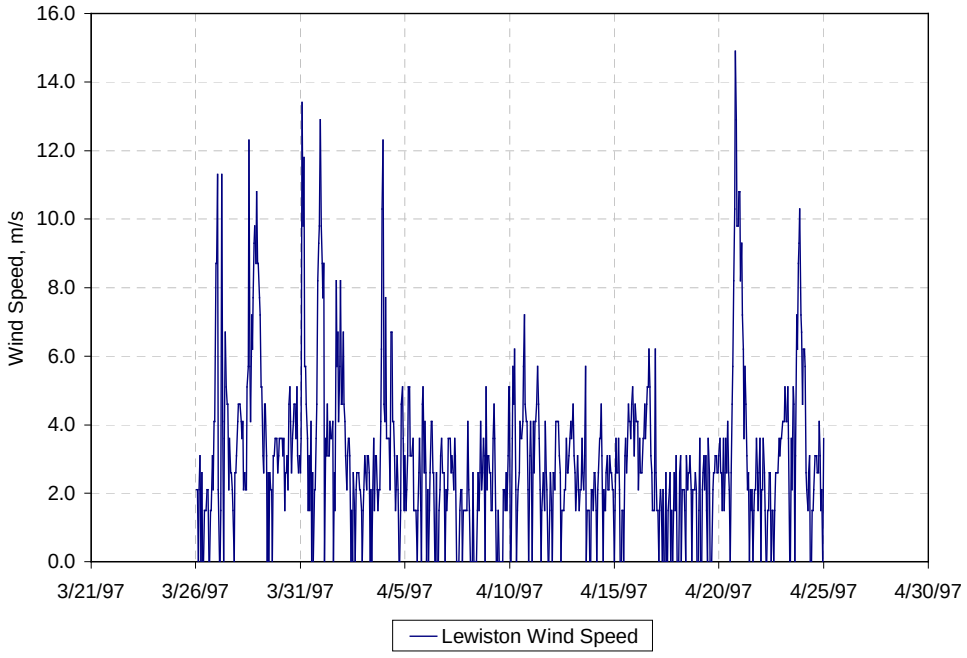

Figure 53. Wind speed used during the Spring 1997 study period.

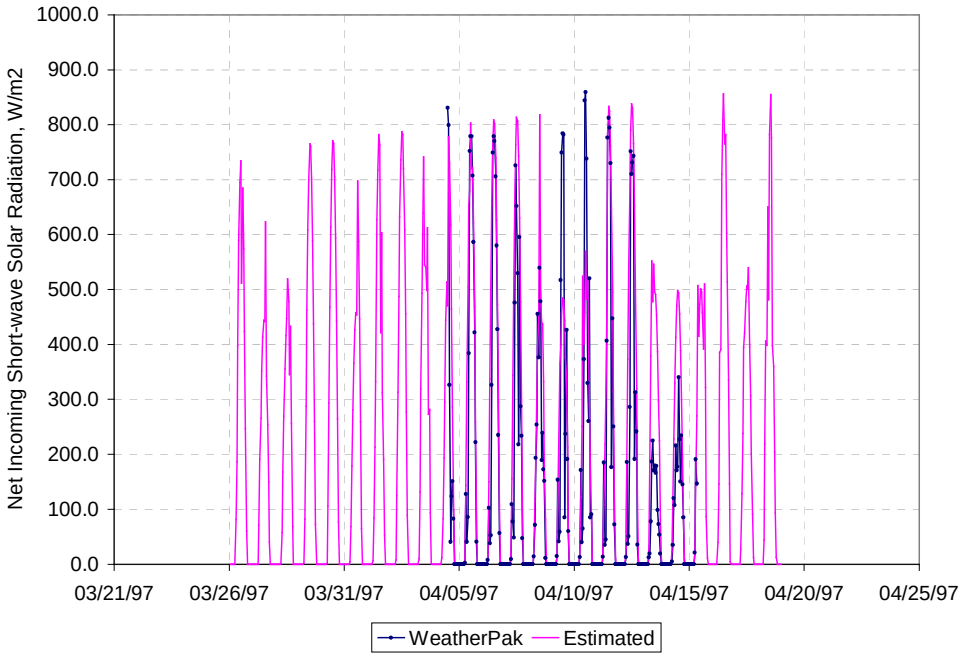

Figure 54. Net incoming short-wave solar radiation based estimated total radiation used during the Spring 1997 study period