Smith and Bybee Lake Water Control Structure

DRAFT

Hydraulics Report

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INTRODUCTION

Parsons Brinckerhoff Quade and Douglas (PB) was retained by Ducks Unlimited (DU) to evaluate the hydraulic effects of the proposed water control structure dividing Smith and Bybee Lakes from the North Slough. DU provided a preliminary design of the structure proposed to replace the existing dam at the upstream end of the North Slough. PB has completed its task of modeling this design and providing criteria to operate the proposed structure. The main goals of this project were to evaluate flexibility and usability of the proposed water control structure and to estimate the maximum velocities in the North Slough after the construction of the proposed water control structure.

Model Background

The preliminary design of the proposed structure was evaluated by updating an existing CE-QUAL-W2 (W2) model of the Columbia Slough, North Slough, and Smith and Bybee Lakes system. W2 is a complex two-dimensional hydrodynamic computer model. The model predicts hydraulic and water quality parameters in longitudinal and vertical directions. The Columbia Slough-Smith and Bybee Lakes model was utilized for hydrodynamic information, the water quality parameters were not computed. The model was run using observed hydrology for a nine year time period, December 1988 to September 1997. The geometry of the model is broken down into cells with a fixed length in the upstream/downstream direction and specified width for each elevation range. For example, the portion of a cross-section from elevation –2 to 0 has an average width of 50 feet, the width from elevation 0 to +2 averages 100 feet, this methodology continues to the appropriate elevation range for each cell. A cross section of a representative cell is shown in Figure 1. The width of each elevation range remains constant over the length of the cell. The cells are linked together in a longitudinal direction to form segments that represent river reaches or lakes. The average widths and elevation ranges vary from cell to cell. Figure 2 shows the model's cell layout for the Lower Columbia Slough, North Slough, and Smith and Bybee Lakes.

Figure 1. Representative Cell Cross-Section

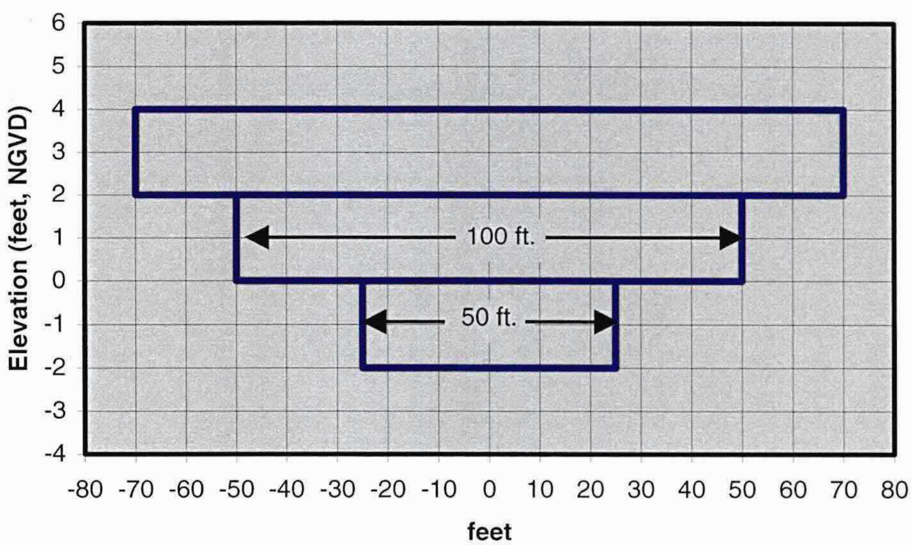
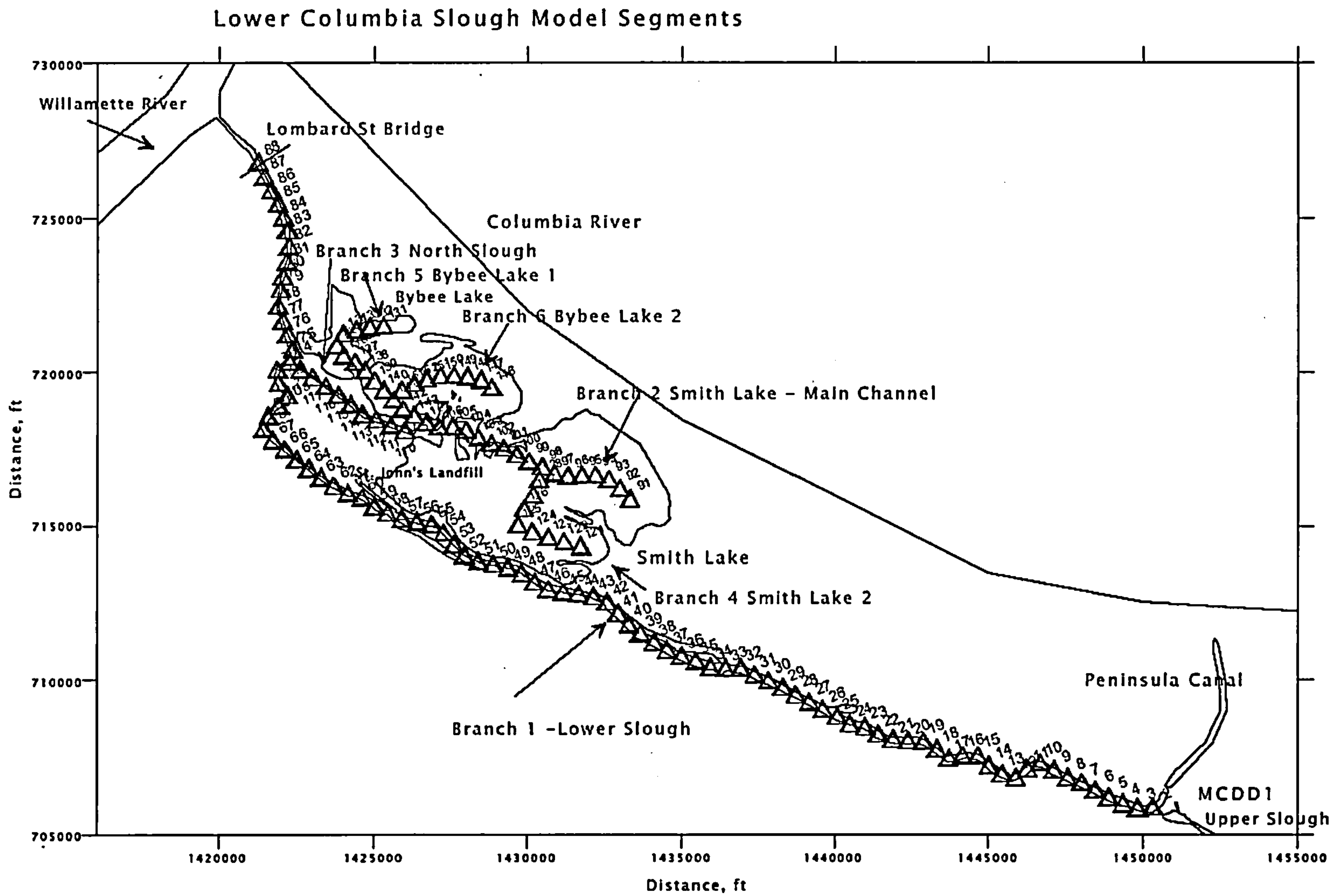


Figure 2. CE-QUAL-W2 Cell Layout

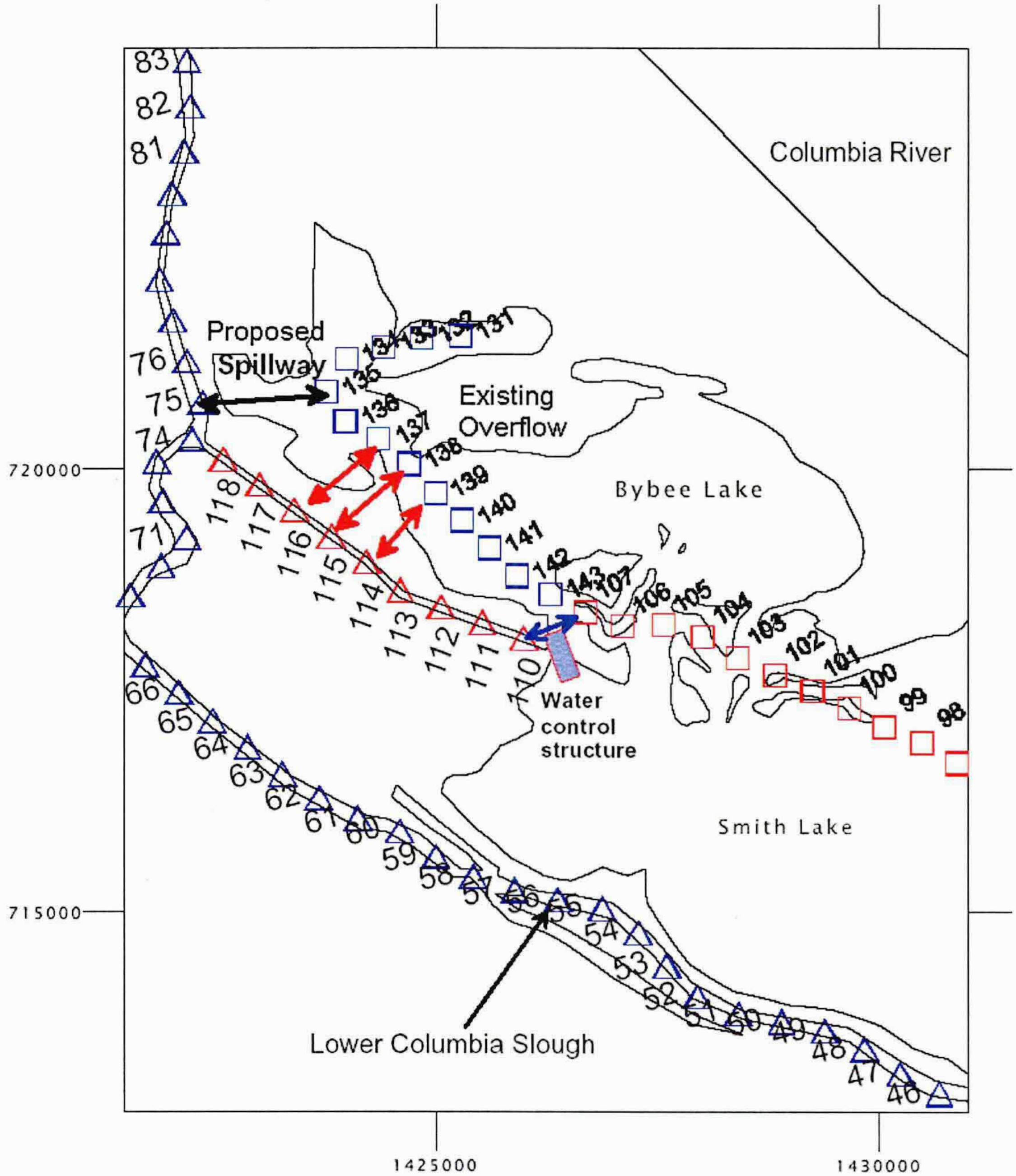


Dr. Scott Wells with Portland State University assisted PB by updating the existing W2 model. Dr. Wells converted the model from version 2 to version 3, incorporated an existing overflow from the North Slough to Bybee Lake, the proposed water control structure, and a spillway from Bybee Lake directly into the Columbia Slough.

METHODOLOGY

The model was updated to version 3 to take advantage of additional features including increased flexibility in modifying the model and the design of the proposed structure without re-compiling the model. The model layout around the North Slough is shown on Figure 3. This figure also shows the existing overflow, proposed spillway, and proposed water control structure incorporated into the model. The overflow area from the North Slough to Bybee Lake was not included in the W2, version 2 model. This overflow is existing, therefore it was included in the version 3 model. The overflow from the North Slough to Bybee Lake occurs from cells 116, 115, 114 to cells 137, 138, and 139 respectively. The invert elevation (approximate existing ground) of the overflow from cell 115 to 138 was set at 12 feet, NGVD the other two overflow cells were set at 14 feet, NGVD. The location of the existing overflow is shown on Figure 3.

Figure 3. Model Layout near the North Slough



An additional spillway was also added to the model, from cell 75 to 135, as shown on Figure 3. This spillway was proposed as part of the water control structure's construction. The invert elevation of the designed spillway was 12 feet, NGVD. The current design calls for an earthen spillway covered in native plantings.

The proposed water control structure design suggests using 3 box culverts with a stop-log system on the lake side of the structure to keep the water in the lakes from draining into the North Slough. The stop-log system will consist of channels on the outside of each weir that can hold flat boards stacked on top of each other to keep the lake at a controlled elevation or all of the stop-logs can be removed and the lakes can drain or fill naturally through the culverts. The invert elevation of the culverts will be 5.0 feet, NGVD. The stop-logs will be operated to raise or lower the lake elevation from 5 to 11 feet, NGVD in ½ foot increments. The culverts will be 10 ft. wide by 10 ft. high box culverts placed at the location of the existing dam.

Regulation Plan

The operation of the water control structure will be controlled by placing and removing stop-logs to artificially prolong high water surface elevations in the lakes. The base regulation plan was developed by PB and reviewed by DU and Metro. There were four operating goals used to develop the regulation plan:

1. Maintain free flow (no stop-logs in the structure) from August 15 until the first high water event of the season.
2. Place stop-logs in the structure as the water rises each winter, up to a maximum elevation of 11 feet, NGVD. As high water events fill the lakes, stop-logs will be placed in the structure to maximize the water level in the lakes after the North Slough water level recedes. Predicted high water peak elevations and site visits can be utilized to determine the ideal time to place the stop-logs in the structure.
3. After the first high water event of the season, the lake levels are held at 11 feet, NGVD (or as high as they can be filled) until June 15th.
4. The lake water surface elevation is slowly lowered from June 15 to August 15 each year. The stop-logs are removed at an approximate rate of one log (six inches) every five days.

This cycle is repeated each year and should be modified as necessary based on present knowledge, weather forecasts, and observed effects on vegetation and wildlife. Maximizing the water level in the lakes will require various techniques depending on the hydrology of a given year. If a high water event is predicted to peak at an elevation of at least 13 feet, NGVD it may be best to place all of the stop-logs in the structure before the peak of the flood event. This will minimize the velocities in the North Slough as the lakes will primarily be filled over the spillway and overflow area rather than through the water control structure. If a high water event is predicted to a peak at an elevation of less than 11 feet, NGVD, the highest water level of the lakes will be achieved if the stop-logs are not placed in the structure until the peak of the event, due to the fact that the lakes fill quicker if there are no stop-logs in the structure.

Model Scenarios

Model runs were completed for two regulation scenarios. The model geometry of both scenarios included the additional proposed spillway, the overflow area, and the proposed water control structure. The two model runs were labeled "lakes open" and "base case". The lakes open scenario includes all new geometric features but does not include any regulation, i.e., no stop-logs were placed in the structure for the entire 9-year model run. The base case scenario represented the regulation scenario described above, maintaining artificially high lake levels through mid June.

RESULTS

The model results are shown on Figures 4a through 4i. Each figure represents a calendar year and displays the water level in the North Slough and Bybee Lake and the velocity in the North Slough for the lakes open and base case scenarios. The water level at the upstream end of North Slough near the proposed water control structure is represented with a brown line. The Bybee Lake level for the base case scenario is represented with a dark blue line. The Bybee lake level for the lakes open scenario is represented with a light blue line. The maximum and minimum velocities are both included on the figures to represent the peak positive and negative flows. Positive flows represent discharge out of the lakes, negative flows represent discharge into the lakes. The dark green line on Figures 4a through 4i represents the maximum velocity at the upstream end of North Slough (near the proposed control structure) for the base case scenario. An example of peak positive flow is shown on Figure 4a, represented by the dark green line during the month of July, when stop-logs are being removed from the water control structure to lower the water level of the lakes. The purple lines on Figures 4a through 4i represents the maximum velocity at the downstream end of North Slough (near confluence of the North Slough with Columbia Slough). An example of peak negative flow is shown on Figure 4i, represented by the purple line at the beginning of February, when water was flowing into the lakes. The figures also show the stop-log elevations for the base case scenario represented with a black line. ✓

Table 1 shows the extreme velocities for each of the model's cells near the North Slough for the lakes open and base case scenarios. The extreme velocity is the greater of the maximum (positive or flow out of the lakes) and minimum (negative or flow into the lakes) velocities. Extreme negative velocities generally occur as flood events are beginning and the water level is rapidly rising, as shown on February 7, 1996 in Figure 4h. Reverse flow is important to report and can cause the same type of damage as normal or positive flow out of the lakes into the Columbia Slough.

Table 1. Extreme Velocities 1989-1997 (feet per second)

Cell Number	Lakes Open Scenario	Base Case Scenario	
North Slough			
110	-1.43	0.67	wcs
111	-1.22	0.72	
112	-1.33	-0.78	
113	-1.44	0.86	
114	-2.25	-1.39	overflow
115	-2.49	-1.54	
116	-3.05	-2.17	
117	-3.87	-2.84	
118	-2.37	-1.73	
Columbia Slough			
74	-2.14	-1.67	
75	-3.18	-2.46	spillway
76	-3.76	-2.92	
77	-4.64	-3.59	

A detailed statistical analysis was performed on the annual peak velocities of cells 77, 110, and 117. The 2, 5, and 10-year (50, 20, and 10 percent chance exceedance) peak velocities were computed for each of the cells for the lakes open and base case scenarios. The peak velocities were obtained by using the absolute value of the greatest extreme velocity, negative or positive. The statistics were performed on the absolute value of annual maximum velocities. The results are provided in Table 2.

Table 2. Predicted Maximum Velocities (feet per second)

Cell Number (Reoccurrence Interval)	Lakes Open Scenario	Base Case Scenario
77 (2-year)	3.14	3.12
77 (5-year)	3.69	3.39
77 (10-year)	4.19	3.54
110 (2-year)	0.76	0.52
110 (5-year)	1.13	0.61
110 (10-year)	1.44	0.67
117 (2-year)	1.17	1.01
117 (5-year)	2.22	1.79
117 (10-year)	3.46	2.65

CONCLUSIONS

The results of the modeling show that by operating the proposed water control structure, as outlined in this report, the maximum velocities observed in the North and Lower Columbia Sloughs will be reduced, compared to an un-regulated condition, based on the observed hydrology of December 1988 to September 1997.

The greatest velocities predicted by the model on the North Slough occurred at cell 117. The predicted velocities were –3.87 and –2.84 feet per second for the lakes open and base case scenario, respectively. These peak velocities occurred in early February 1996 as the flood on the Willamette River rapidly raised the water level in the North Slough and the lakes, as shown on Figure 4h. The model results indicate that the peak velocity of the base case regulation scenario compared to the lakes open scenario was reduced approximately one foot per second or 25% at cell 117 during the February 1996 flood.

SUMMARY

Based on the model results, the proposed water control structure and regulation plan effectively maintained the water level in the lakes on an annual basis while reducing velocities, compared to an un-regulated condition. Please note that a side effect of constructing and operating the structure was a reduction of the flow from the North Slough into the lakes, producing lower maximum water surface elevations in the lakes, depending on the hydrology of the year. This only occurs in low water years such as 1989, 1992, and 1994, when the water level in the North Slough does not maintain high water surface elevations long enough to fill the lakes to the desired elevation. This problem could be partially solved by installing additional culverts at the water control structure, allowing the lakes to fill quicker at lower elevations in the North Slough.

During an average water year, the proposed water control structure and regulation plan will effectively meet the main operating goals of: maintaining free flow through the water control structure from August 15 until the first storm of the season, keeping the lake water surface elevation at 11 feet, NGVD (or as high as possible) from the first storm of the season through June 15, and slowing lowering the lake levels from June 15 to August 15 a an approximate rate of ½ foot every five days.

Figure 4a. 1989 Model Results

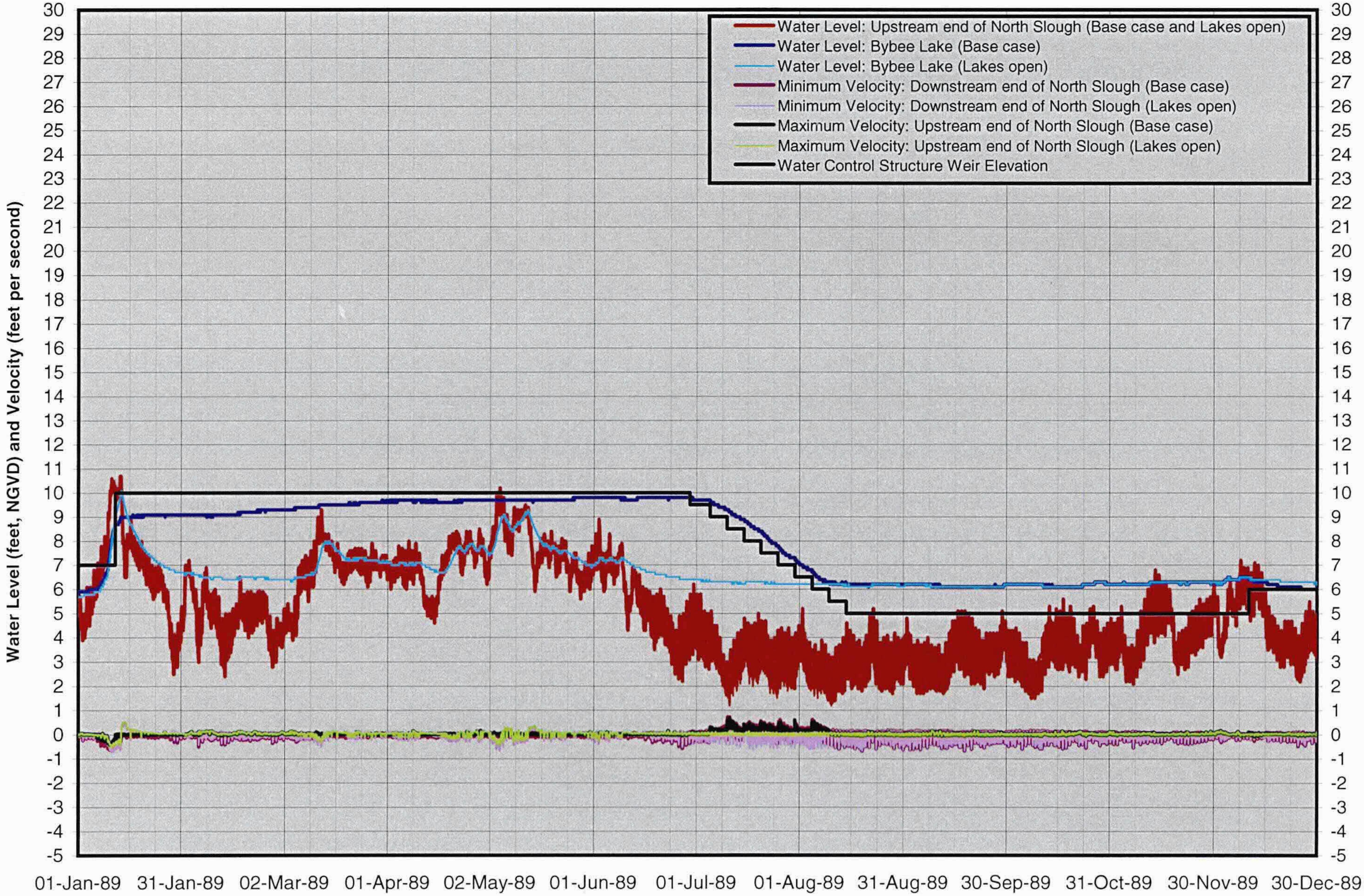


Figure 4b. 1990 Model Results

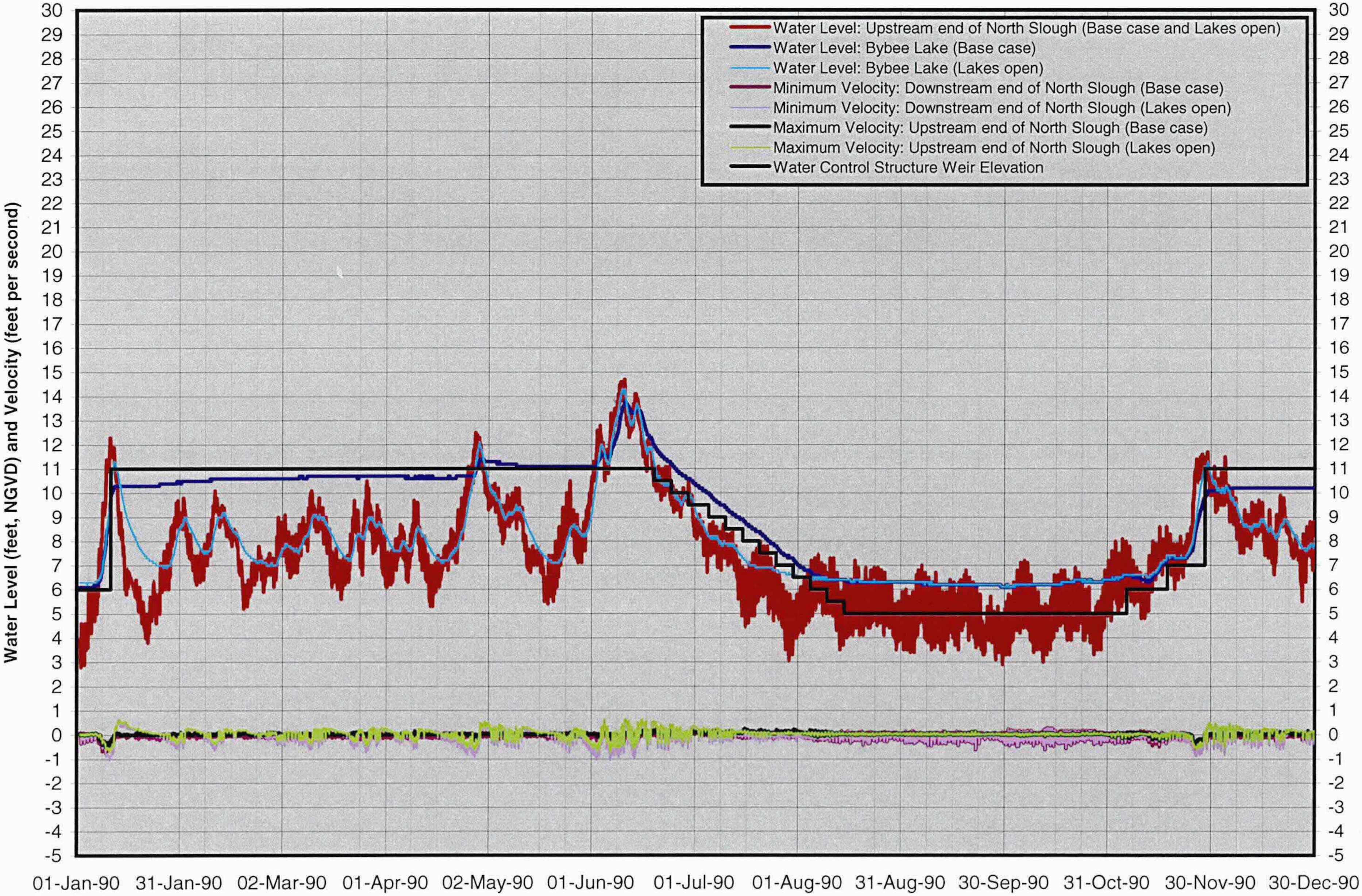


Figure 4c. 1991 Model Results

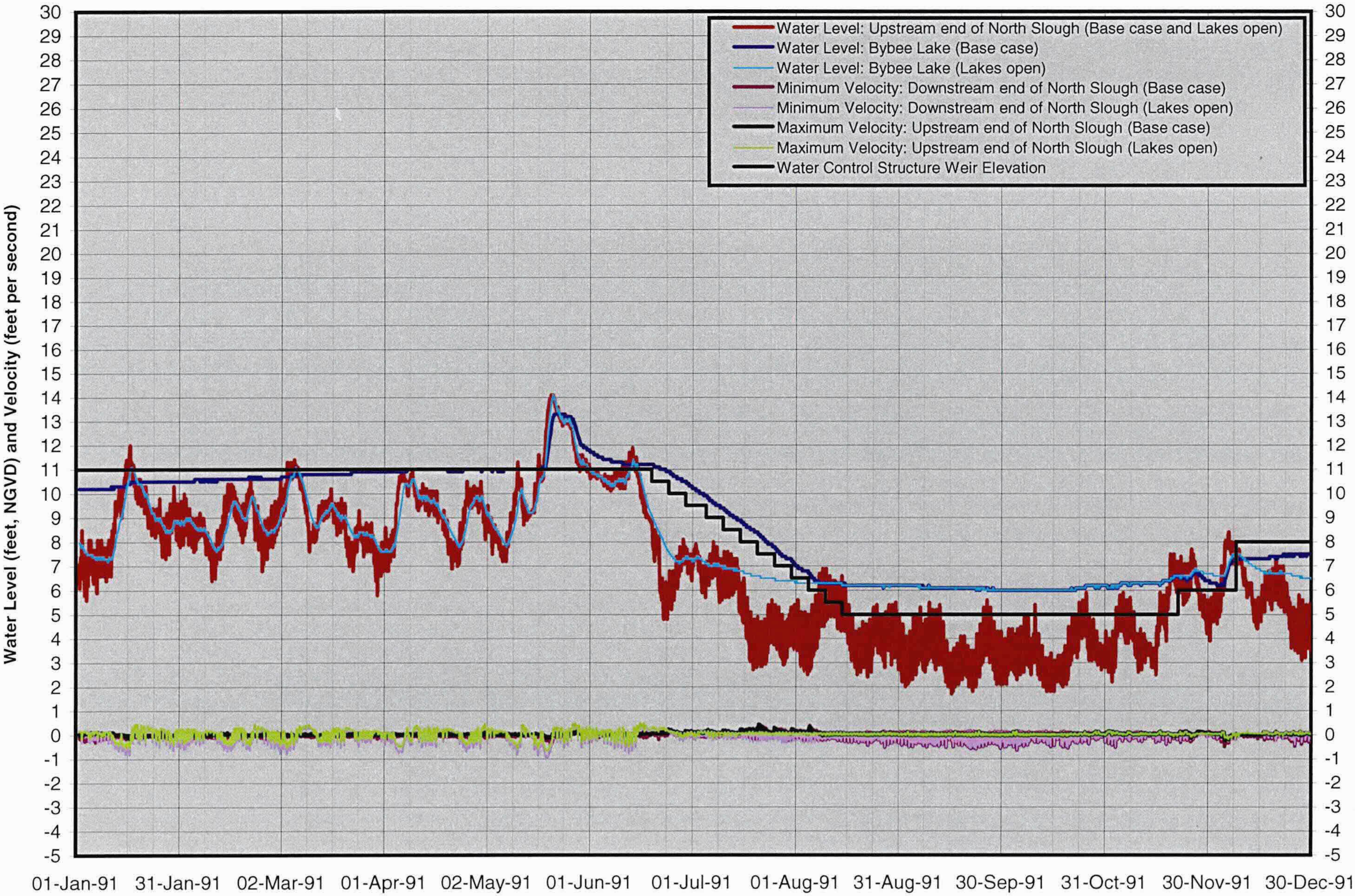


Figure 4d. 1992 Model Results

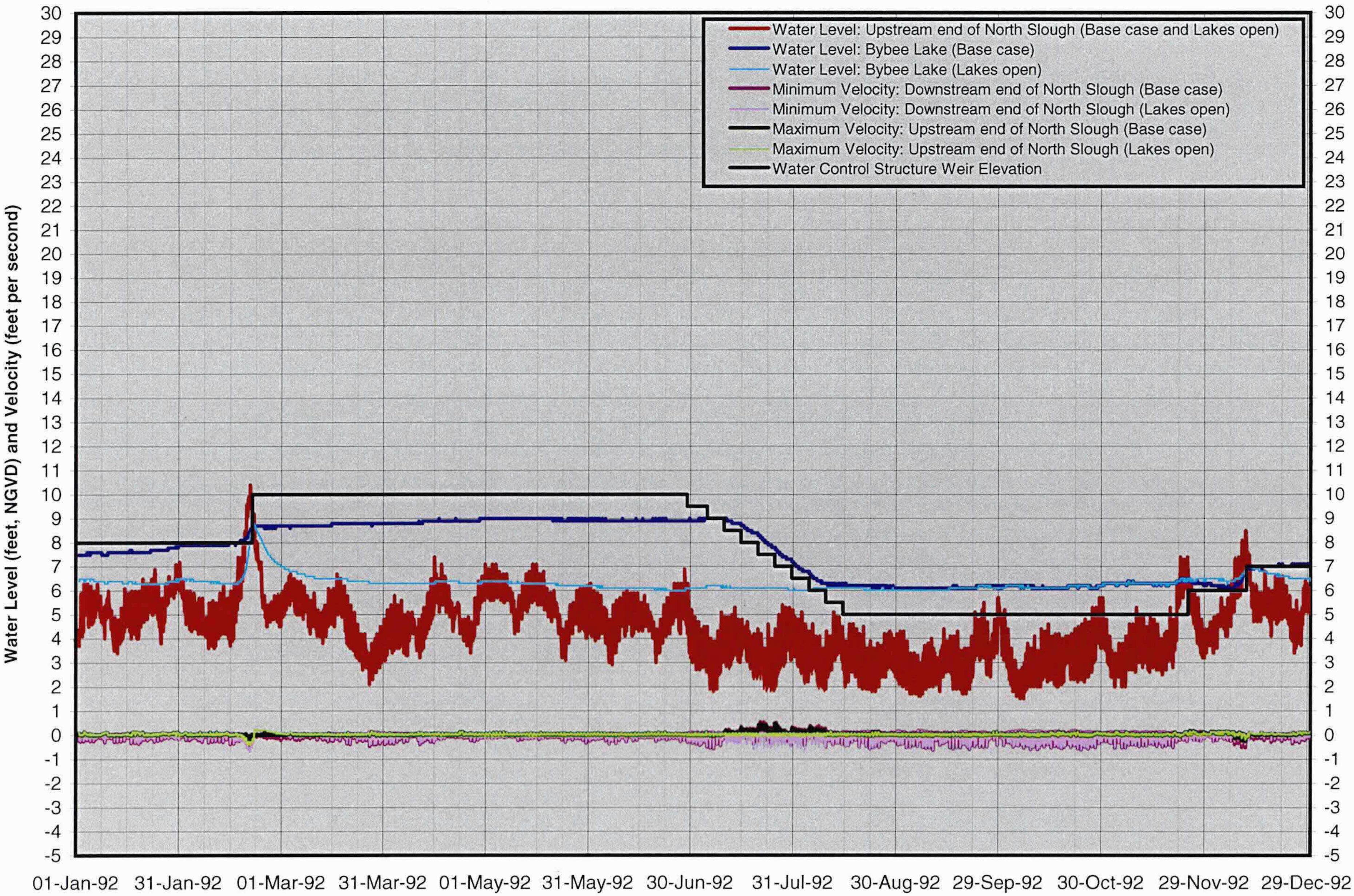


Figure 4e. 1993 Model Results

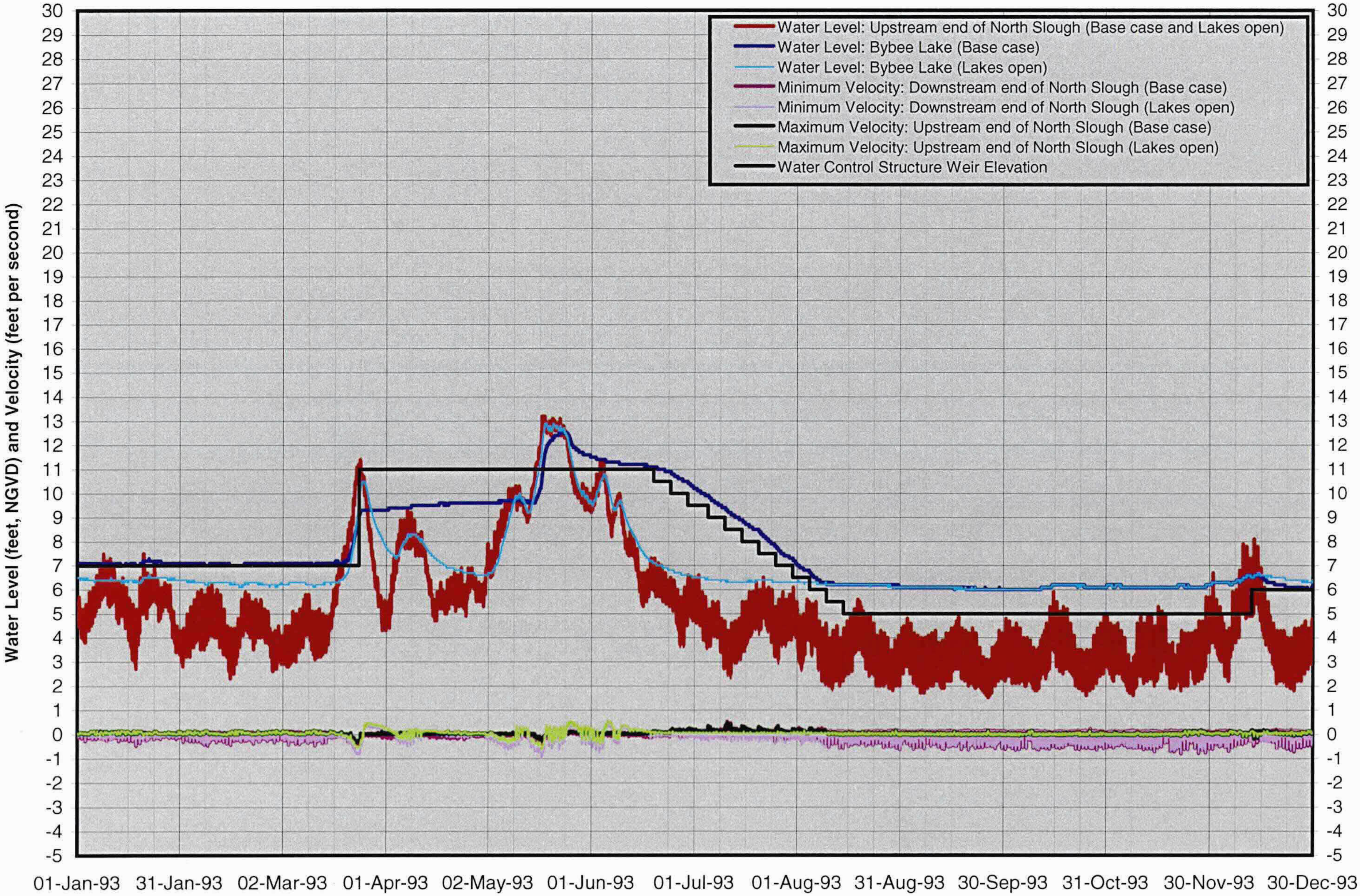


Figure 4f. 1994 Model Results

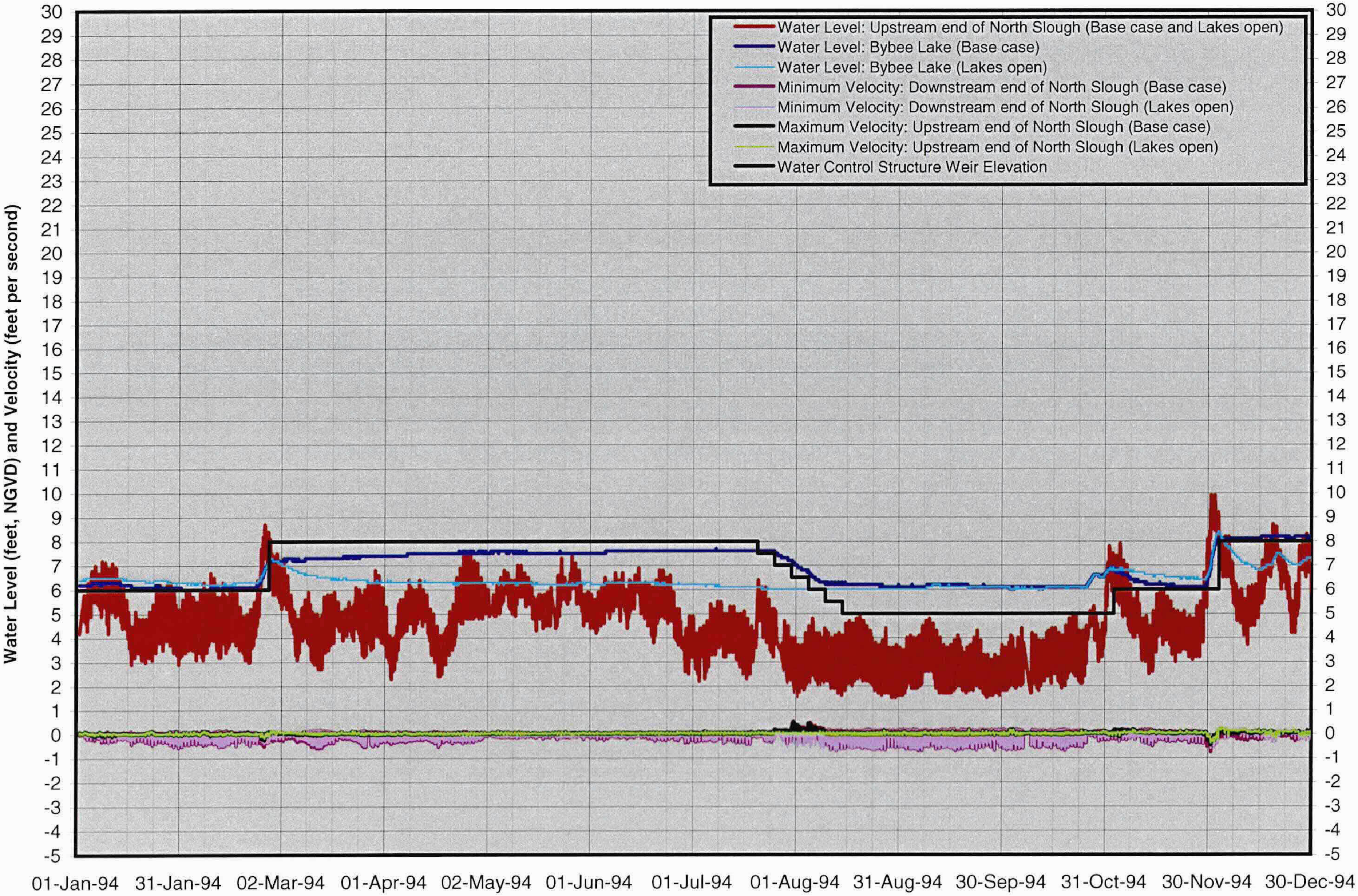


Figure 4g. 1995 Model Results

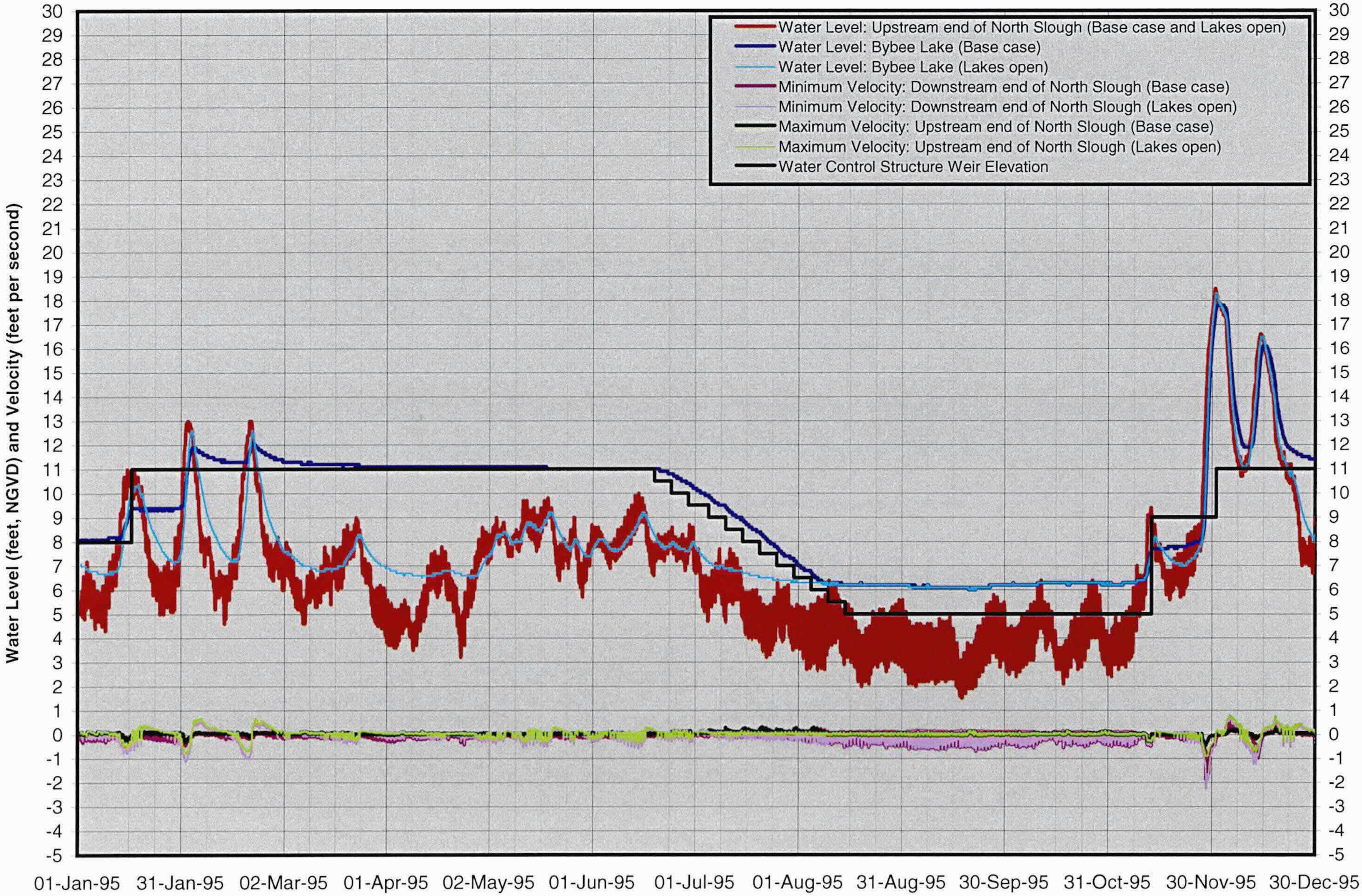


Figure 4h. 1996 Model Results

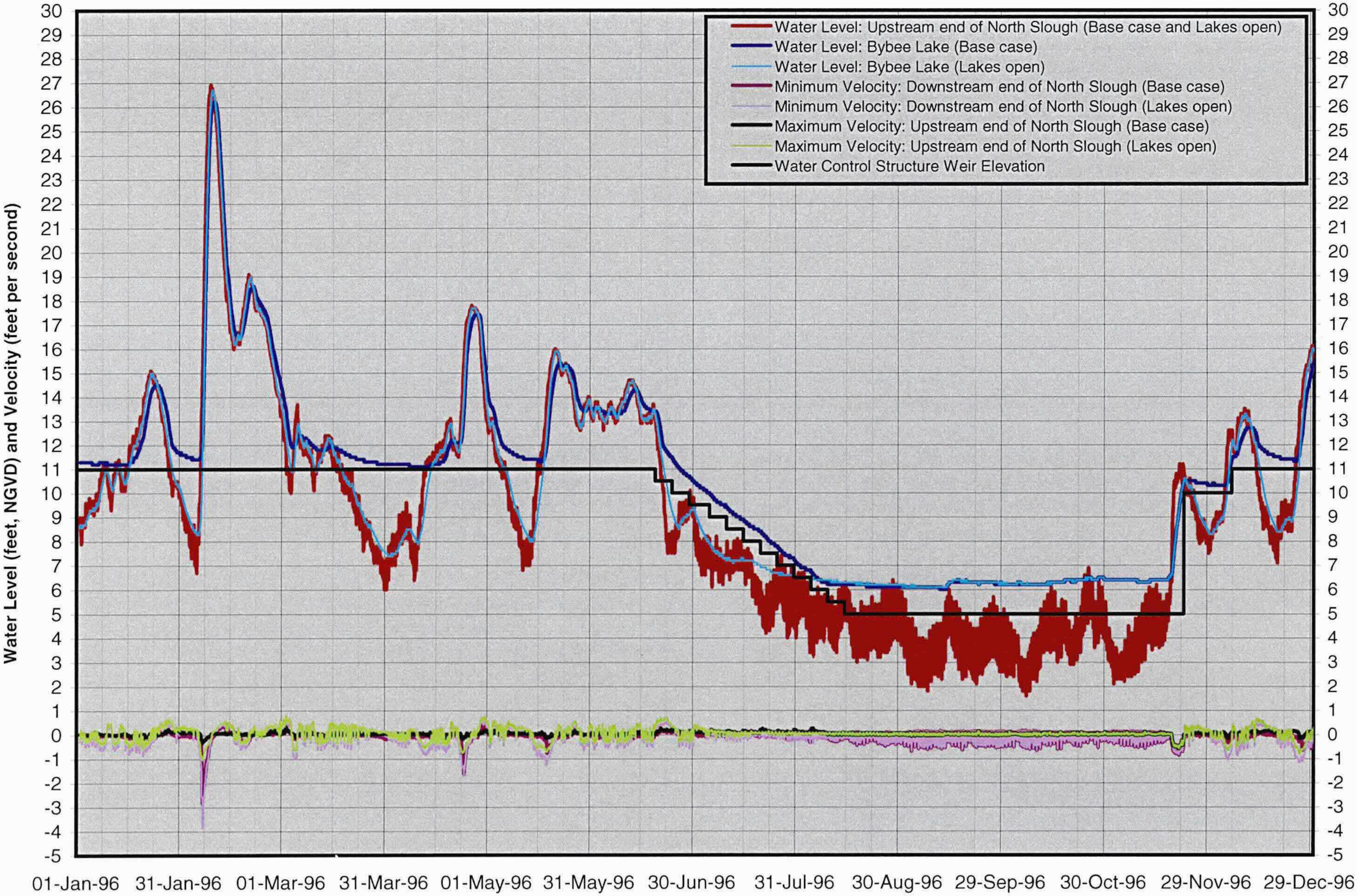


Figure 4i. 1997 Model Results