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U.S. Army Corps of Engineers
Portland District

John Day Tailrace MASS2 Hydraulic Modeling

Memorandum for Record

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1 Introduction

Recent biological results for the Juvenile Bypass System at John Day Lock and Dam (Figure 1.1) have raised concerns about the hydraulic conditions that are created in the tailrace under different project operations. The Juvenile Bypass System water enters the John Day tailrace at the outfall location shown in Figure 1.1. To address these concerns, the US Army Corps of Engineers (USACE), Portland District (CENWP) Hydraulic Design recommended the use of MASS2 (Richmond and Perkins (1999)), a two-dimensional depth-averaged computational fluid dynamics model to simulate the hydraulic conditions under different operational scenarios. Because Pacific Northwest National Laboratory (PNNL)[1] used MASS2 to model the entire system, including the John Day tailrace, during the Dissolved Gas Abatement Study on the Lower Columbia and Lower Snake Rivers, the Laboratory was selected to update the MASS2 model of the John Day tailrace. The updated model included the most recent bathymetry, had increased resolution in certain areas as specified by CENWP, and had the downstream extent of the model truncated at river mile 212 to reduce simulation run times. This MASS2 model was then transferred to CENWP for their personnel to do a large number of production runs. This document discusses the development of the truncated MASS2 model, the development of downstream boundary conditions for that model, and some scenarios run by PNNL.

[1] Pacific Northwest National Laboratory is operated by Battelle for the U.S. Department of Energy.

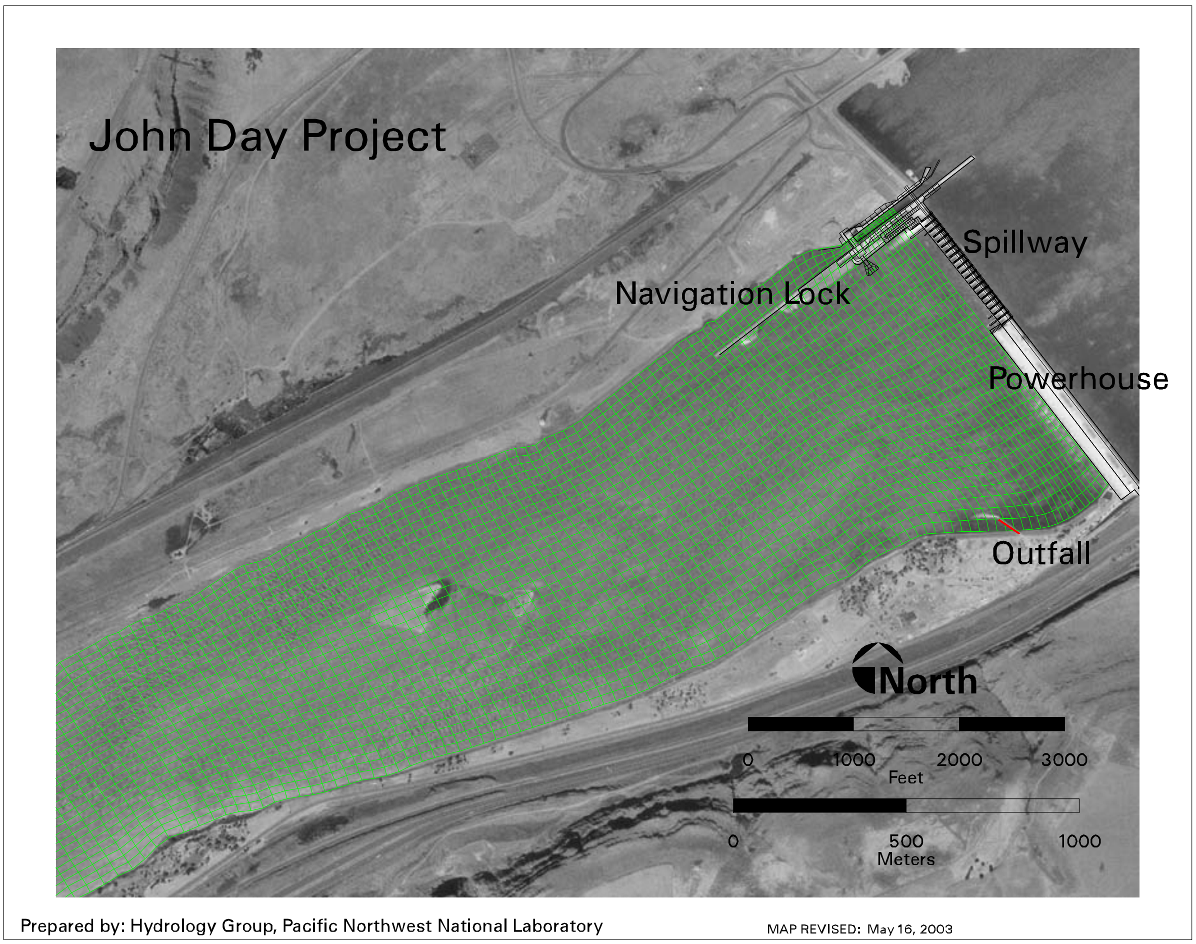

Figure 1.1: John Day Project and its features.

2 Methods

Previous studies by PNNL for the Dissolved Gas Abatement Study (DGAS) led to the development and application of MASS2, a depth-averaged computational fluid dynamics model (Richmond and Perkins (1999)). MASS2 was used to simulate flow, temperature, and dissolved gas transport through the lower Columbia and Snake Rivers. To incorporate recent bathymetric survey data and better analyze tailrace flow conditions below the John Day Project, it was necessary to revise the computational grids to simulate smaller spatial scales and to include areas closer to the project than were included previously. The grid used for the Dissolved Gas Abatement Study had an average cell size of about 12,300 ft^2. For this study, the cell size near the powerhouse was reduced to about 7800 ft^2 and the computational mesh extended closer to the powerhouse and spillway.

2.1 MASS2 Model Components

Several steps were required to develop the new computational grid and determine appropriate downstream boundary conditions. These included the following:

- A new bathymetric surface was created for the area downstream of the John Day Project. Survey data from the 1999 detailed survey were used near the project.
- A MASS2 computational mesh was created of the tailrace for the extent and resolution specified by CENWP. The new bathymetric surface was used to determine the river bottom elevation of the computational nodes.
- The MASS1 model was set up and run for The Dalles pool from the John Day tailrace to The Dalles Dam. Results were used to determine the stage/discharge relationship for the downstream end of the MASS2 model domain as a function of flow from the John Day Project and the forebay water surface elevation at The Dalles.
- The updated MASS2 model (Linux ^{TM} and Windows ® executables) and stage/discharge relationship were transferred to CENWP for their use in performing additional production runs.

River Bathymetry A high-resolution survey of bathymetric data was conducted in 1999. These data were combined with older data used in the Dissolved Gas Abatement Study. The older data were derived from NOAA charts and previous surveys, and hand-drawn contours (Figure 2.1) and used to create a new bathymetric surface in Arc/Info. The point data from the September 1999 survey (Contract DACW57-98-D-0001) were provided to PNNL by CENWP. The files used were silting (multi-beam data), jd-area-a, jd-area-c, jd-area-d, jd-area-e, and jd-tail-shore (non-silting data are single-beam data).

Mesh Creation The mesh was created in Gridgen (Steinbrenner and Chawner (1995)) using shorelines as the exterior boundaries. The mesh extends downstream to river mile 212. The mesh was then overlaid on an orthophoto to determine if the mesh adequately represented the river (see Figure 2.2), included the desired areas, and followed the navigation lock features (see Figure 1.1).

Some adjustments were made to include the shallow area just downstream of the outfall. The mapping between the cells and the spillway bays, and the cells and the powerhouse turbines were determined (Figures 2.3 and 2.4). The contoured bathymetry from the MASS2 mesh is shown in Figure 2.5.

New MASS2 Features and Their Implications Several new features have been added to MASS2[1]. One feature is the ability to have wetting and drying of cells. With this new feature, it is no longer necessary to have separate blocks around all potentially emergent features in the river channel. Instead, the mesh was created from shoreline to shoreline, and island emergence and shore areas becoming emergent are simulated in the numerical model. Other new features allow the specification of walls that follow the gridlines and the exclusion of cells altogether from the computations. These features simplify the meshing and blocking of complex areas. Figure 1.1 shows the computational mesh near the John Day Project, and Figure 2.2 shows the overall extent of the computational domain. For the simulations, a wall was included that extended the length of the navigation lock, and the cells that coincided with the thicker portion of the navigation lock wall, the fish ladder, and the upper navigation lock were excluded from the model.

Model Parameters Model parameters were based on those used for previous MASS2 models in this area. The time step was 30 seconds, eddy viscosity was 0.20001, and a Manning's n of 0.027 was used.

[1]2003 report, under preparation, Battelle Pacific Northwest Division, Richland, Washington

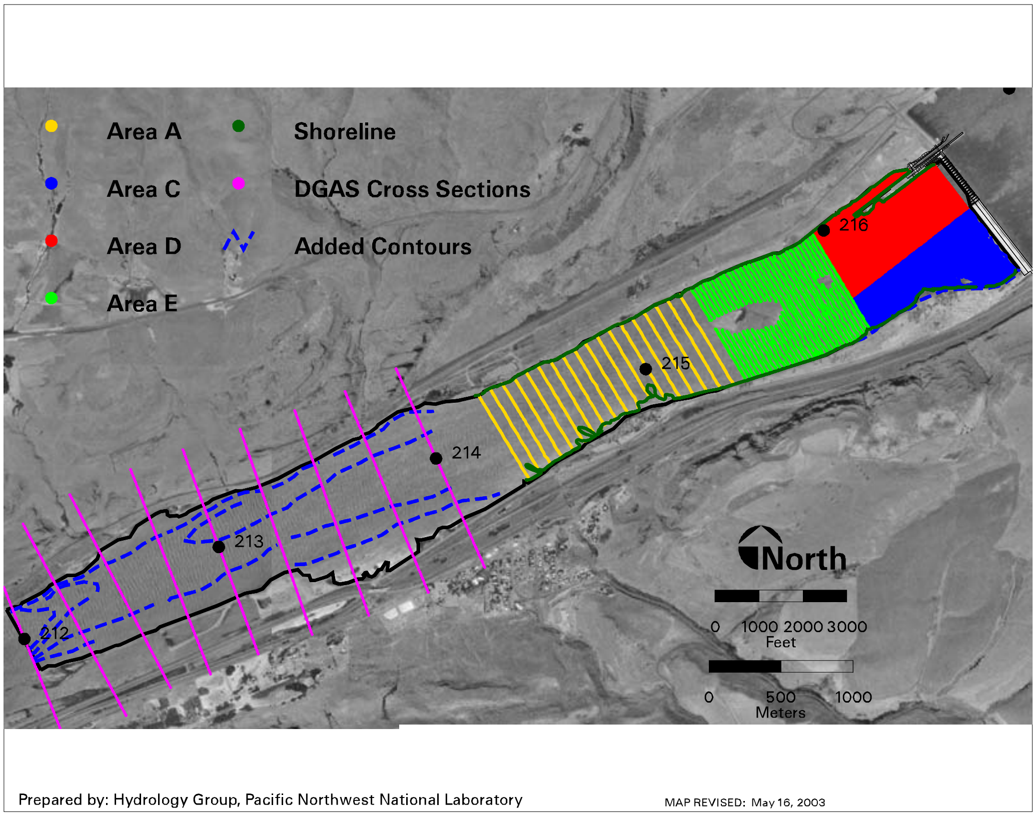

Figure 2.1: Survey and other data used to create the bathymetric surface for the area below the John Day Project. DGAS stands for Dissolved Gas Abatement Study.

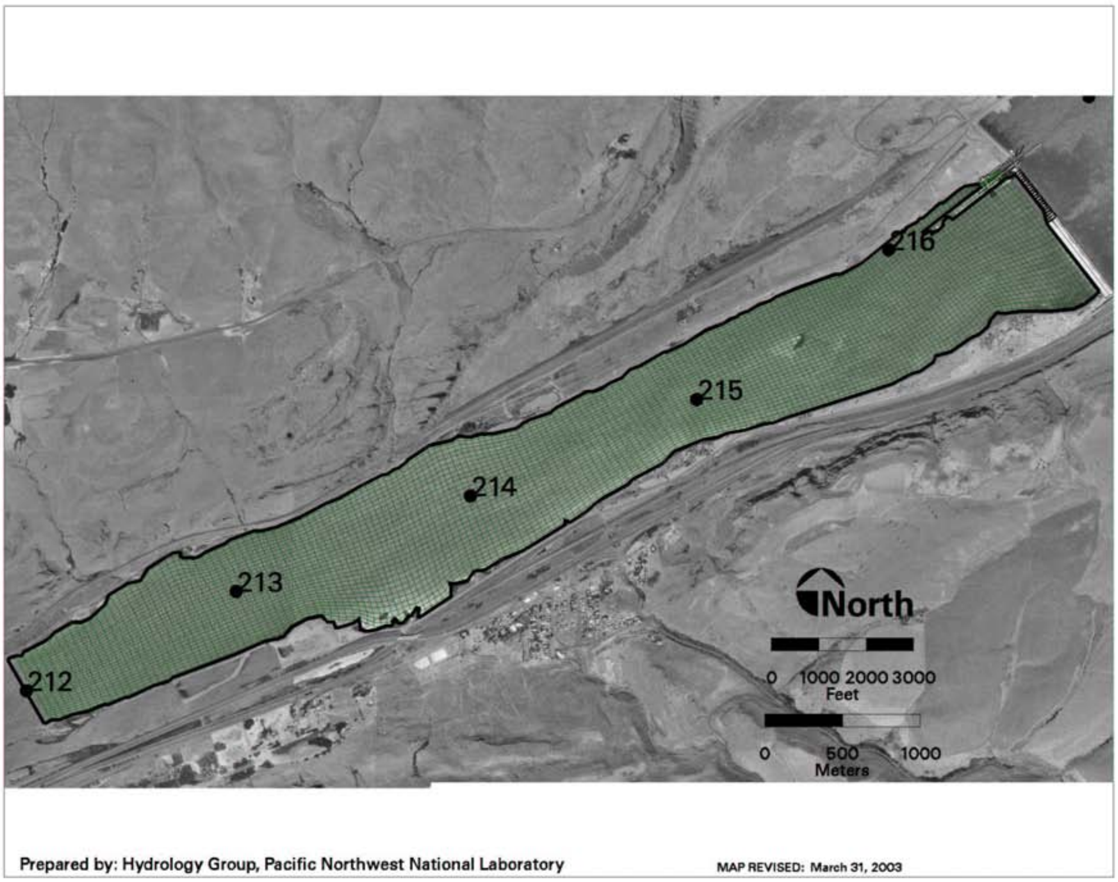

Figure 2.2: Extent of the computational domain for the MASS2 model of the John Day Project tailrace.

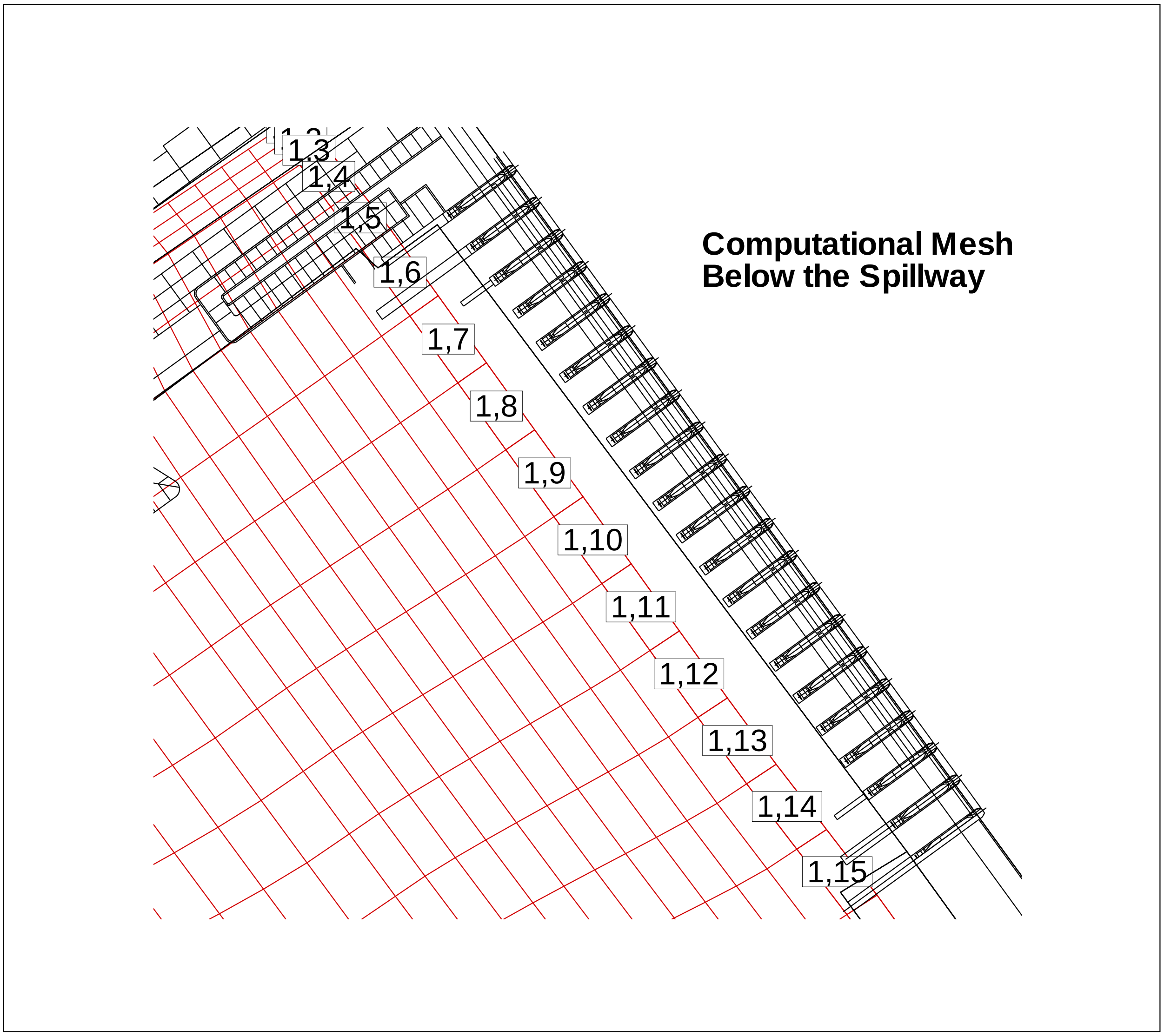

Figure 2.3: Computational mesh and cell numbering near the John Day spillway.

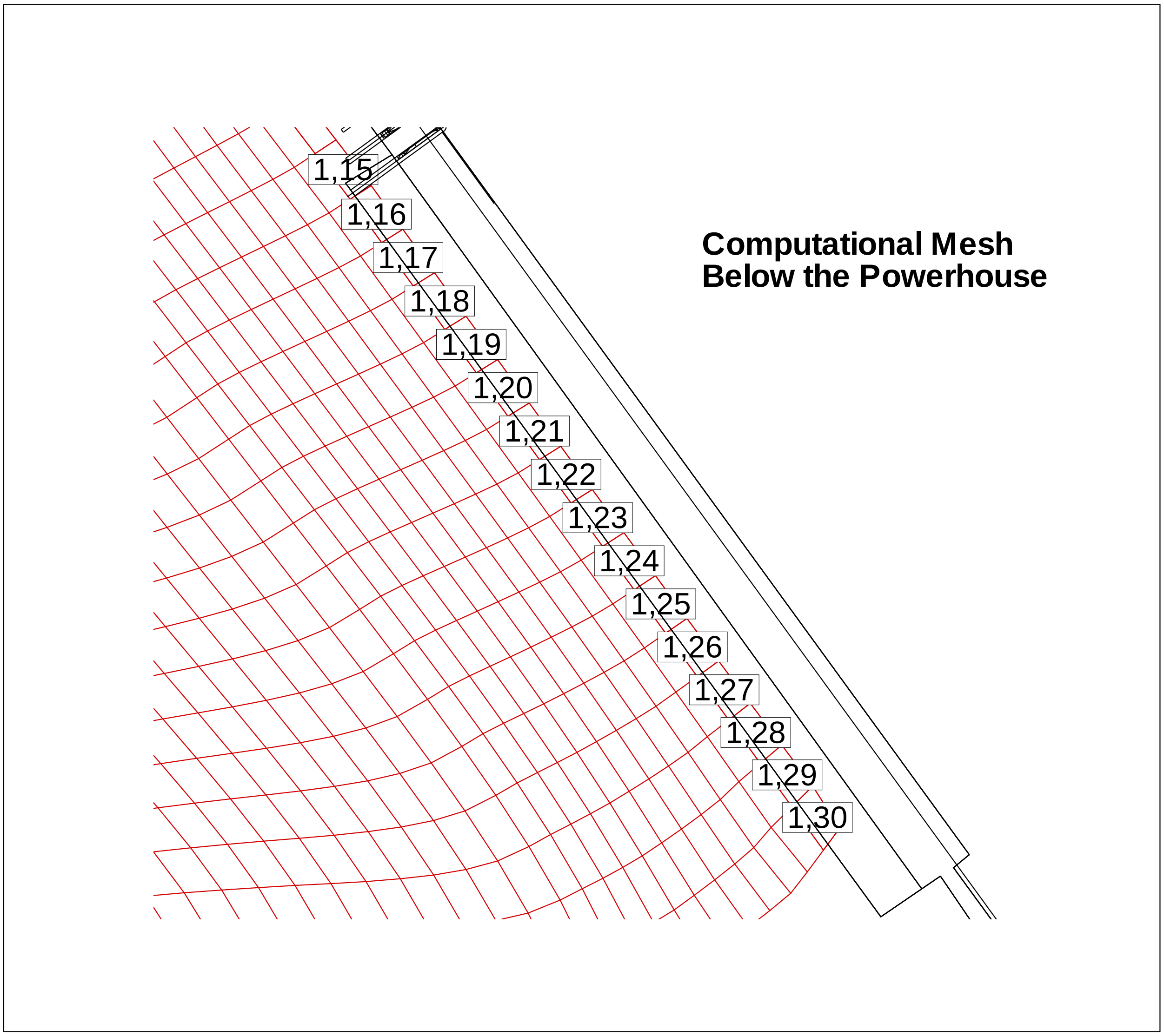

Figure 2.4: Computational mesh and cell numbering near the John Day powerhouse.

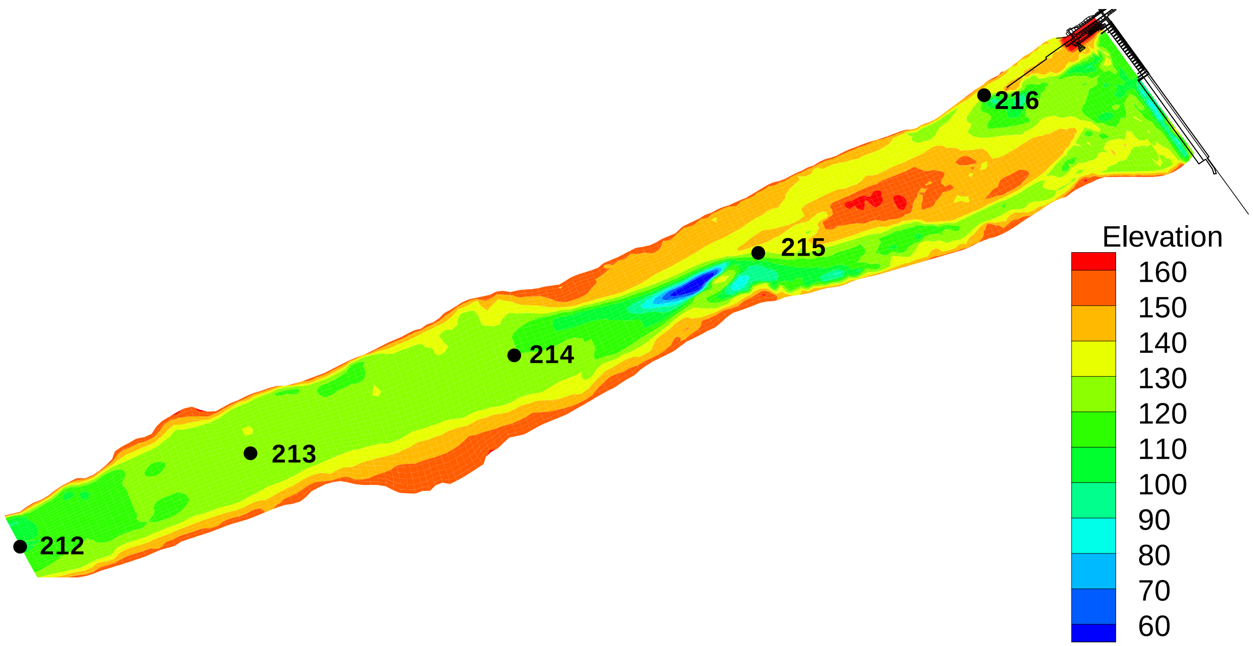

Figure 2.5: Bathymetric surface in the John Day tailrace.

2.2 Configuration and Use of MASS1 for Downstream Boundary Condition

Downstream boundary conditions for water elevations (stage) were derived using MASS1, a one-dimensional unsteady river model. MASS1 was configured and run as described in Appendix F of Richmond et al. (2000) but for flow only. This was an existing configuration, although only the river between John Day and The Dalles Projects was simulated rather than the whole lower Columbia River. The MASS1 model was run for steady flows from 50,000 cfs to 500,000 cfs for forebay elevations at The Dalles from 156 to 160 ft. The water surface elevation at the downstream end of the MASS2 model was extracted from these simulations and used to develop a stage/discharge relationship. These data, shown graphically in the results, were used to determine an appropriate downstream stage for the range of operations simulated.

3 Results

3.1 MASS1 Results

The MASS1 results were tabulated and represented graphically (Figure 3.1). These results were used to estimate the downstream stage for the MASS2 model runs for a range of flows from the John Day Project and for a given range of forebay elevations at The Dalles Project.

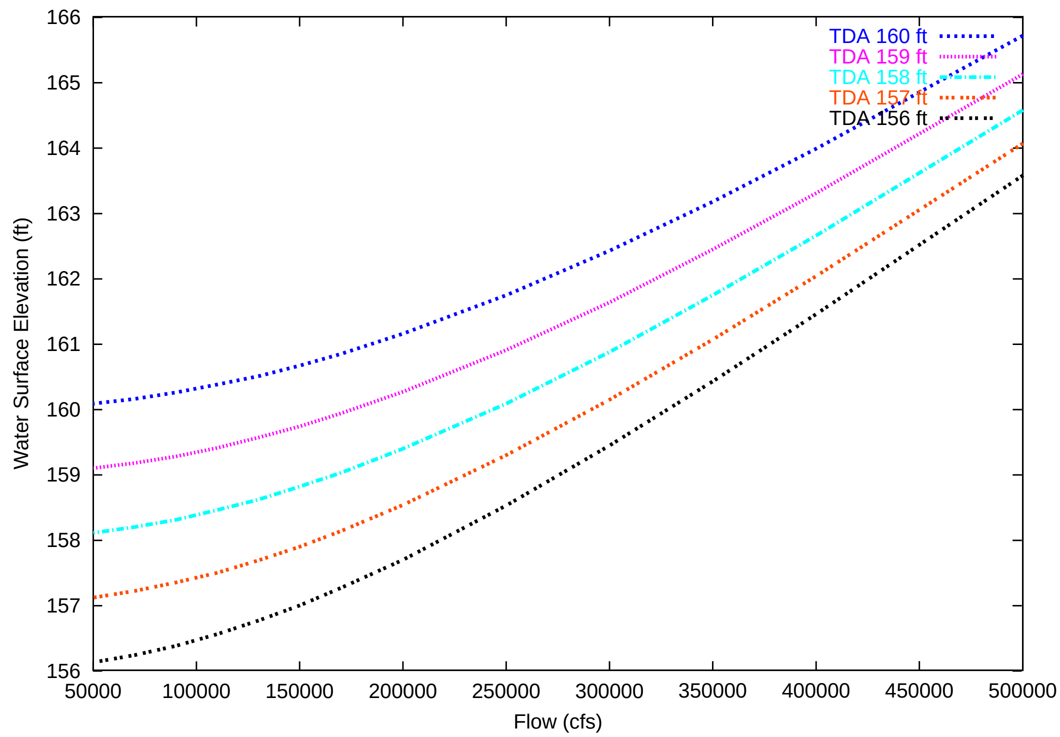

Figure 3.1: Stage at the downstream extent of the new MASS2 model as a function of river discharge and forebay elevation at The Dalles Dam (TDA).

3.2 MASS2 Validation

Although no additional validation was required, a steady-state simulation corresponding to the flow conditions during the June 1996 transecting acoustic doppler current profiler (ADCP) surveys were run as a check of the new model configuration. Transecting ADCP data are collected by a boat motoring across the river rather than from a vessel trying to maintain a constant position. Although transecting ADCP data are a much less accurate measure of velocity than on-station, time-averaged measurements, these were the validation data available. It was shown in the forebay of the Bonneville Project that on-station measurements of about 6 minutes were needed for the mean velocity to stabilize (ENSR (2000)). Consequently, the transecting ADCP data are a snapshot, rather than representative of the mean flow. For the Dissolved Gas Abatement Study (Richmond and Perkins (1999)), these ADCP measurements were depth averaged so that a mean velocity vector resulted. During this period, powerhouse flow was 326.8 kcfs, and the spillway flow was 90 kcfs. The simulation results (Figure 3.2) were very similar to those reported in Richmond and Perkins (1999). The velocity magnitude, as indicated by arrow length in Figure 3.2, is similar for both sets of measurements; however, near the powerhouse the direction is biased. In the numerical model, the flow from the powerhouse was distributed evenly across the powerhouse as no information was available on the distribution of flow through the turbine units of the powerhouse. This difference in direction could be a product of the distribution of flow through the powerhouse during the ADCP collection period. A more extensive comparison of the velocities was not made given the overall quality of transecting ADCP measurements.

3.3 MASS2 Simulations

Although there were no specified runs for the John Day tailrace, several scenarios were run to ensure that the simulated flow patterns were reasonable, the wall and cells that were not included in the model did not have flow, and that the dredge spoil island and shallow area near the outfall emerged for scenarios with a lower downstream stage.

Simulations were run for total river flows of 100, 200, 300, and 400 kcfs with no spill, 30 percent spill, and 100 percent spill. The downstream elevation for these flows was 158.4, 159.39, 160.87, and 162.65 ft, respectively. These downstream water surface elevations were taken from the rating curve developed with MASS1. Figures 3.3 through 3.8 show the results for these scenarios. These figures show the dredge spoil island emergent at 100 and 200 kcfs although it becomes inundated at flows of about 300 kcfs. For cases in which the flow through the project was not distributed between the spillway and powerhouse (i.e., all spill or no spill), areas of recirculation developed below the powerhouse during the all-spill cases and below the spillway in the no-spill cases. Figures 3.9 and 3.10 show the flows and some stream trace in the recirculation zones for the 300-kcfs cases for the all-spill and no-spill cases.

3.4 Limitations of Two-Dimensional Models

Although MASS2 adequately simulated the general pattern of velocities downstream of the John Day Dam, two-dimensional depth-averaged models such as MASS2 assume that velocity and water quality constituents do not significantly vary vertically through the water column. Areas where vertical variations could be significant commonly include zones of rapidly changing bathymetry or at inflow zones where the flow is limited to a portion of the water column (e.g., immediately downstream of turbine draft tubes and spillways with deflectors). Simulation results in these areas represent depth-averaged velocities and may under- or over-estimate the actual velocities. For the simulations reported here, results closer than 500 ft to the dam should be viewed with caution. In these areas a three-dimensional free-surface model, for example FLOW3D, would provide a better representation of the velocity distribution.

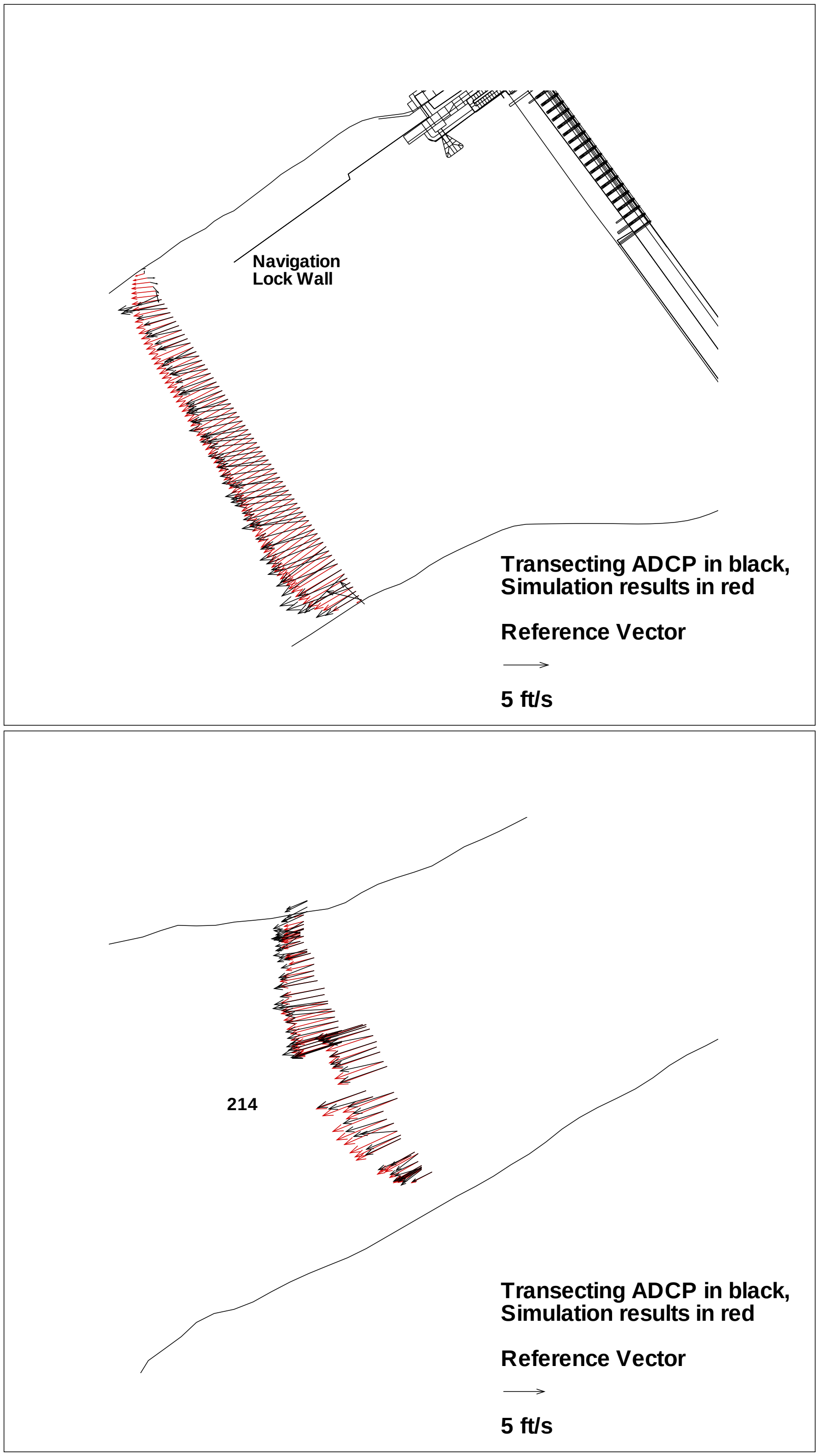

Figure 3.2: Comparison of MASS2 simulation results and June 1996 transecting acoustic doppler current profiler measurements near the John Day Project and at river mile 214.

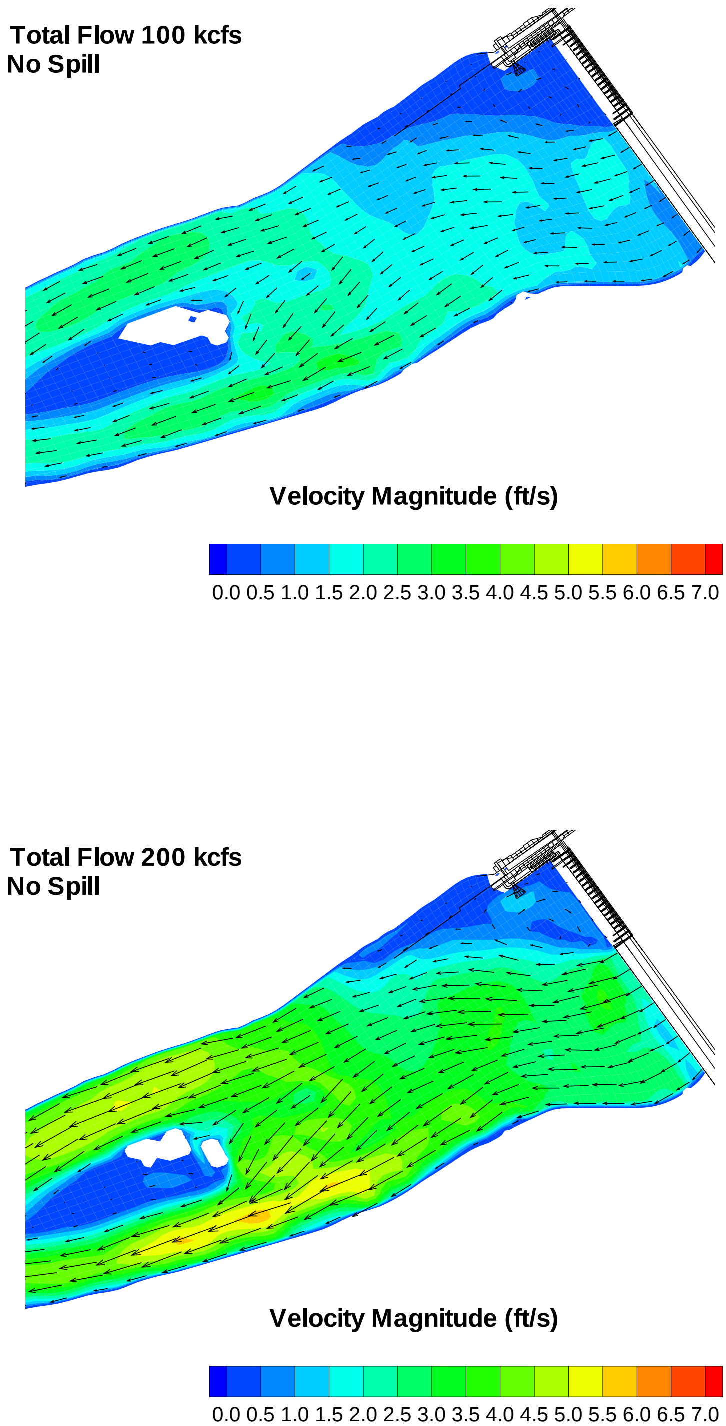

Figure 3.3: Model results for the no-spill scenarios for 100 and 200 kcfs total river flow. North is to the top of the page.

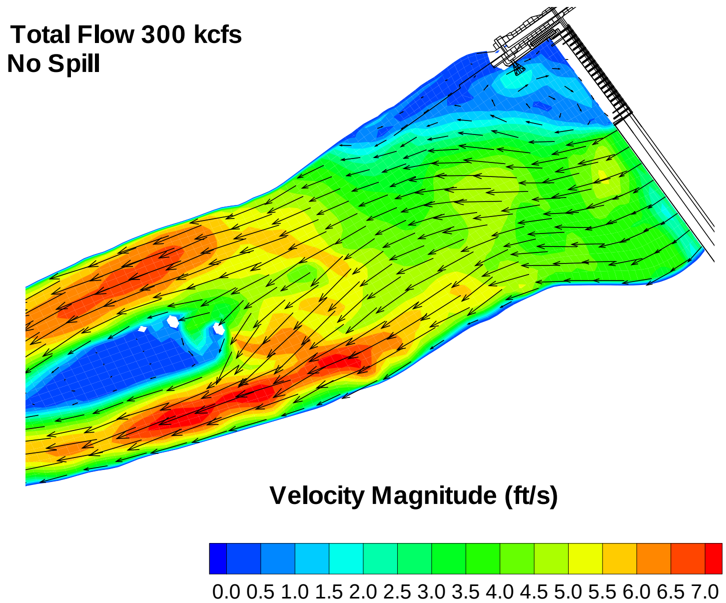

Figure 3.4: Model results for the no-spill scenarios for 300 kcfs total river flow. The scenario with 400 kcfs through the powerhouse is not shown as it is beyond the powerhouse capacity. North is to the top of the page.

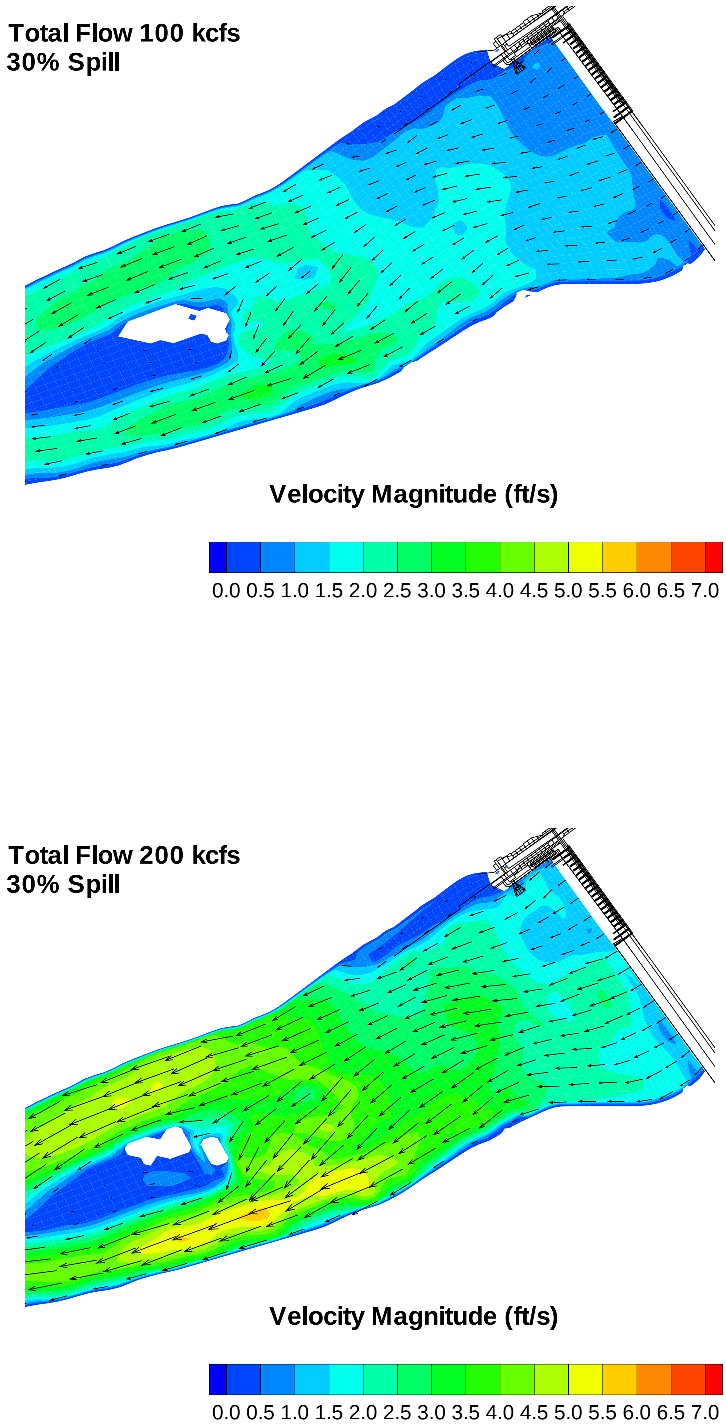

Figure 3.5: Model results for the 30 percent spill scenarios for 100 and 200 kcfs total river flow. North is to the top of the page.

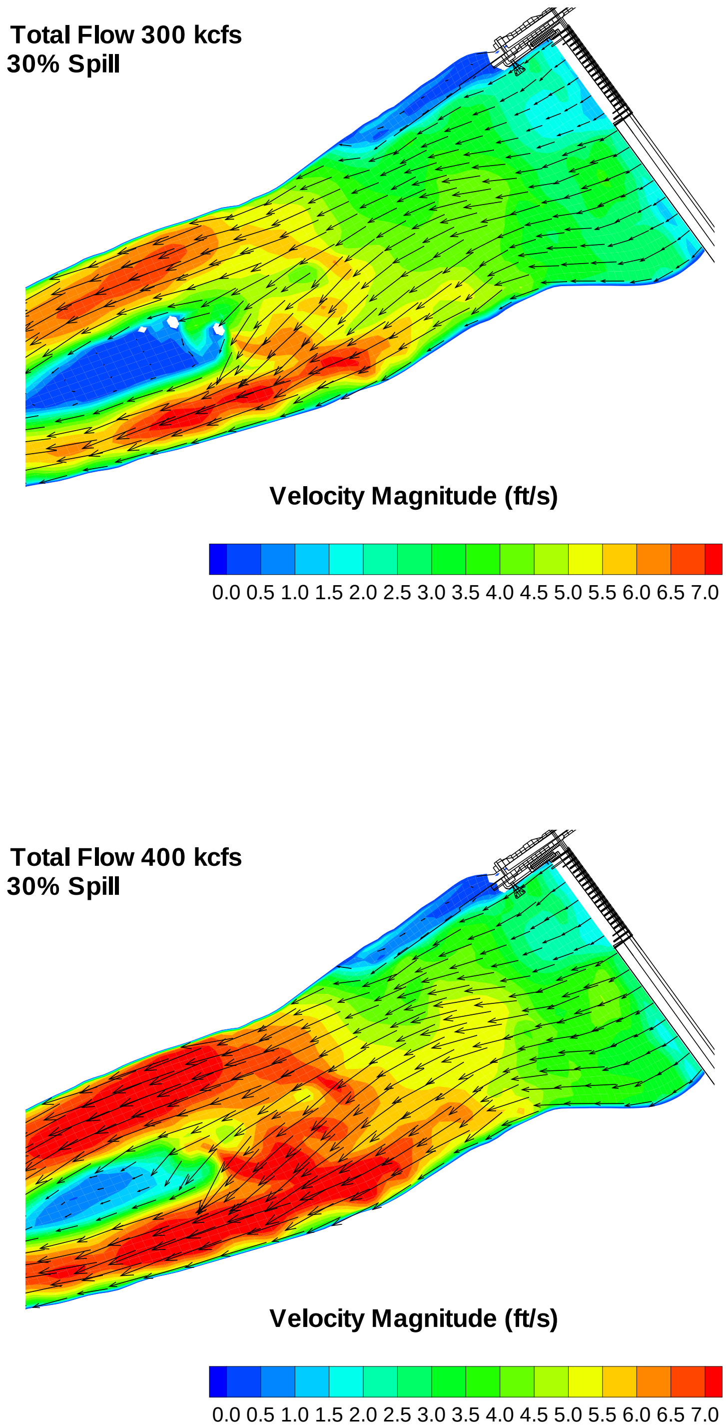

Figure 3.6: Model results for the 30 percent spill scenarios for 300 and 400 kcfs total river flow. North is to the top of the page.

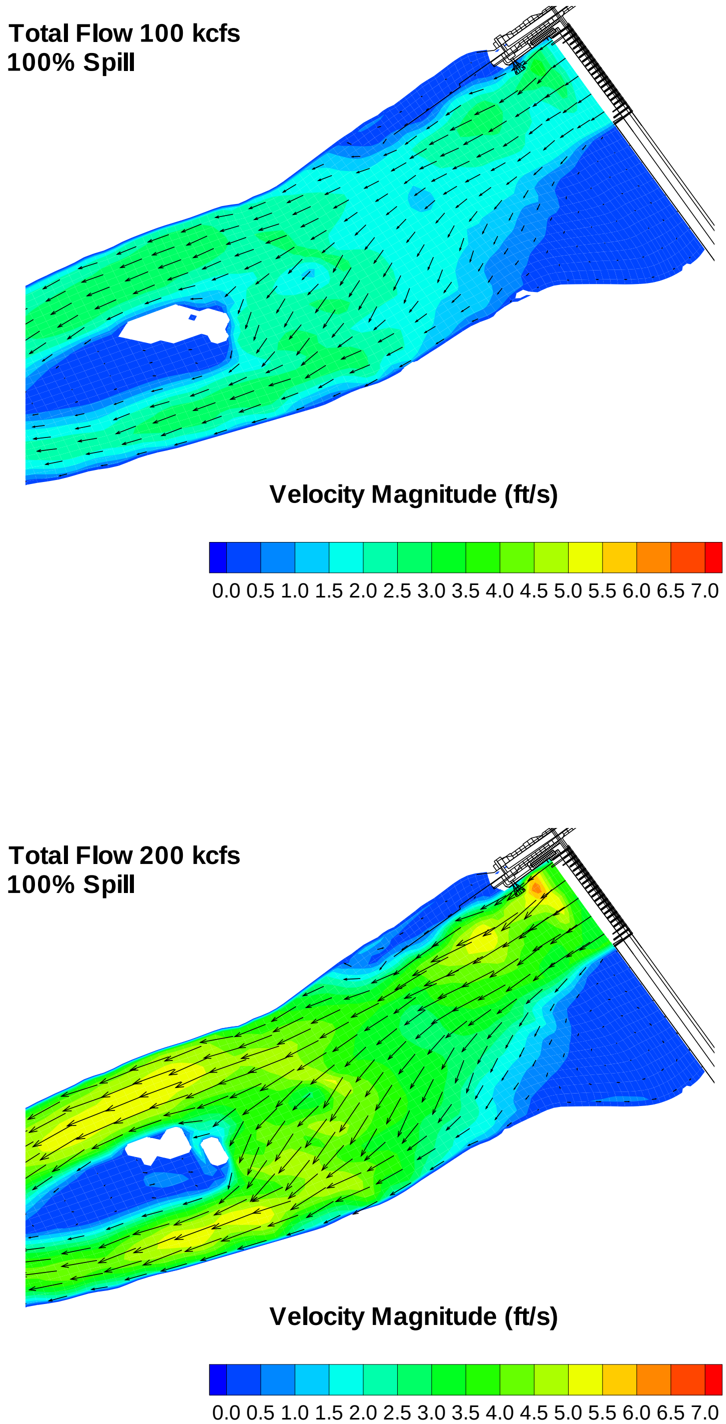

Figure 3.7: Model results for the 100 percent spill scenarios for 100 and 200 kcfs total river flow. North is to the top of the page.

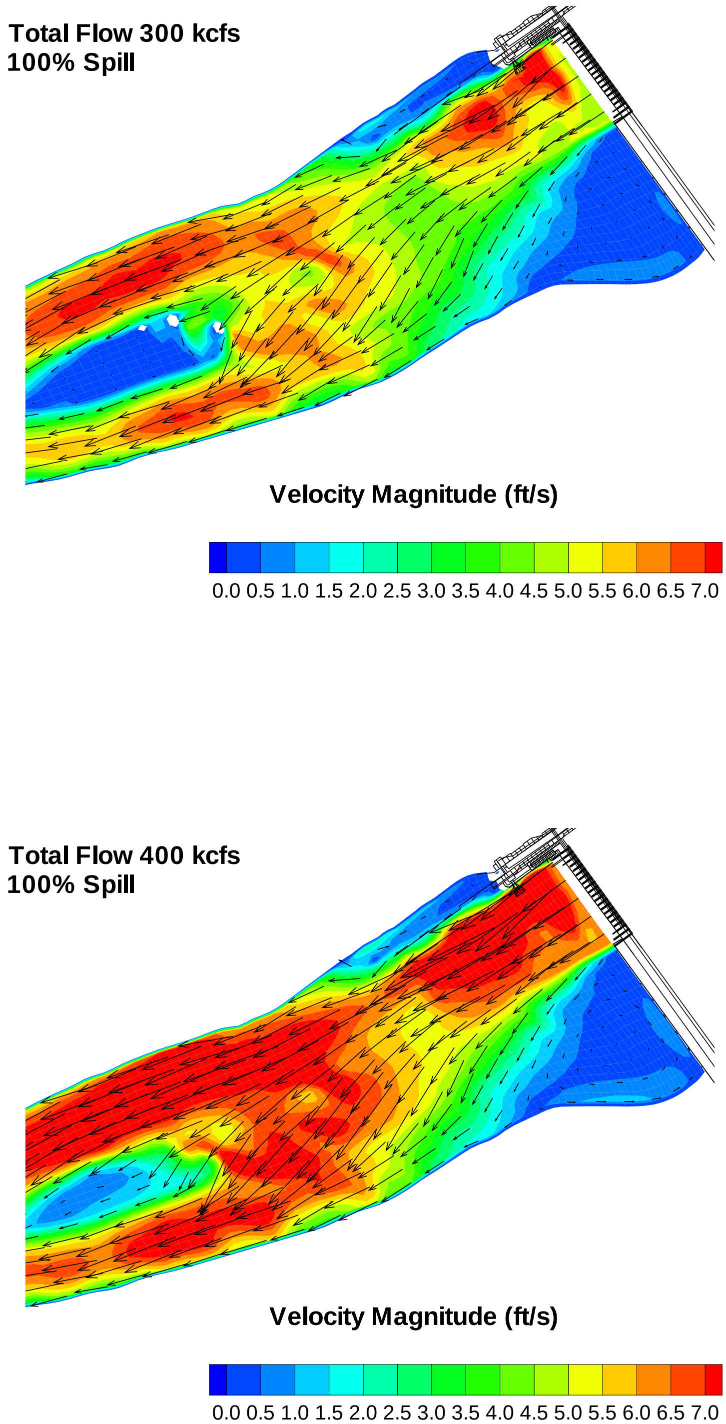

Figure 3.8: Model results for the 100 percent spill scenarios for 300 and 400 kcfs total river flow. North is to the top of the page.

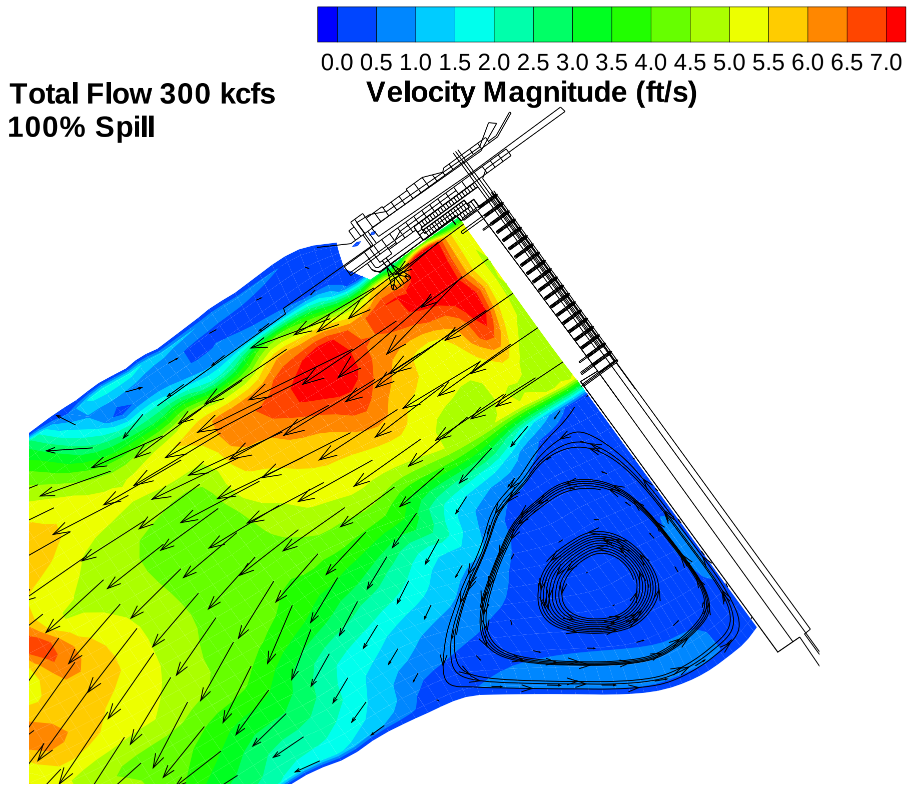

Figure 3.9: Stream traces showing the recirculation zone below the powerhouse for the 300 kcfs total river flow with all flow passing through the spillway. North is to the top of the page.

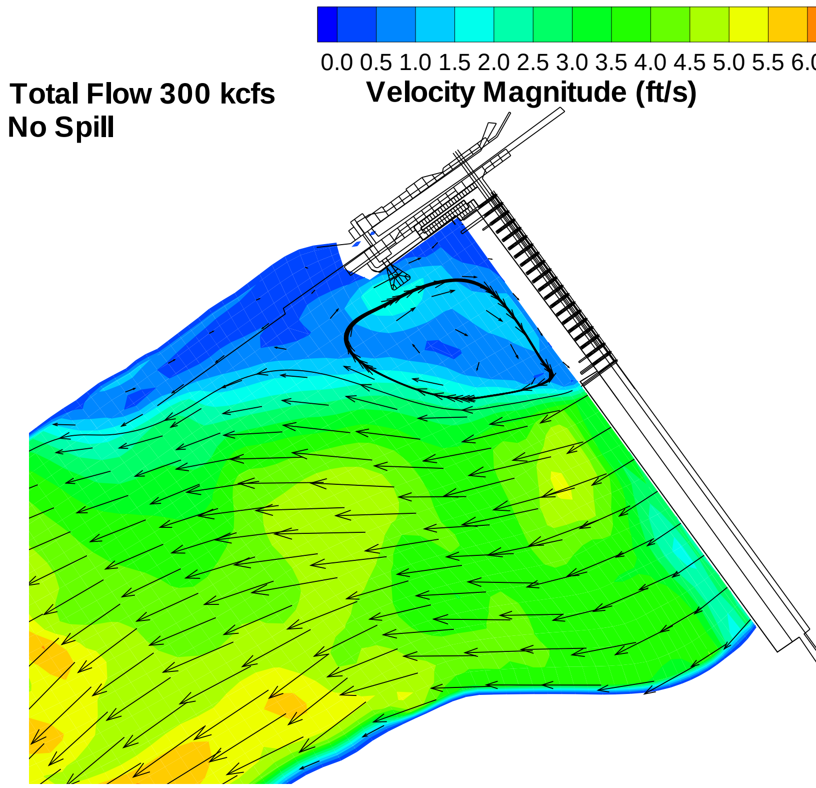

Figure 3.10: Stream traces showing the recirculation zone below the spillway for the 300 kcfs total river flow with all flow passing through the powerhouse. North is to the top of the page.

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