Lateral Spillways and Weirs, Storage Areas, and SA Connections Workshop Solution

Tasks

1. **Run and Evaluate the Existing Conditions**

    a. Run the existing plan.

    b. Analysis the results including the bridge overtopping.

2. **Develop Storage Areas, Lateral Structures, and Storage Area Connections**

    b. Construct storage areas for Site 1 and 2.

Storage areas were drawn over Site 1 and 2 utilizing the **Storage Area** button in the **Tools** row of the **Geometric Data** editor. The storage areas were named **Upstream SA** and **Downstream SA**, denoted their location on the schematic.

The data was entered in the **Geometric Data Editor** by selecting the **Storage Area** button, located in the **Editors** column. The **Area Times Depth Method** was selected for both storage areas. The **Upstream SA** minimum elevation was set to **209 ft** and the area to **80 acres**. The **Downstream SA** minimum elevation was set to **207 ft** and the area to **85 acres**.

    c. In the **Unsteady Flow Data** editor set the initial water surface elevations of the storage areas.

In the editor the **Initial Conditions** tab was selected and the elevations were set to **209 ft** and **207 ft** for the upstream and downstream storage areas, respectively. These elevations are the minimum elevations of both storage areas, thus the storage areas are dry at the beginning of simulation.

    d. Connect the storage areas to each other with a storage area connection. The connection should consist of a weir and culvert.

The connection was drawn utilizing the "**SA/2D Conn.**" tool found in the **Geometric Data Editor**, located in the **Tools** row. By beginning the connection within the upstream storage area and ended the connection in the downstream storage area the connection is linked to these two storage areas. The connection was named **SA Transfer**.

The connection editor was opened with the "**SA/2D Conn.**" button on the **Geometric Data** editor, located in the **Editors** column. By selecting this option Figure 1 was displayed. The option to "**Compute flow each time step**" was selected.

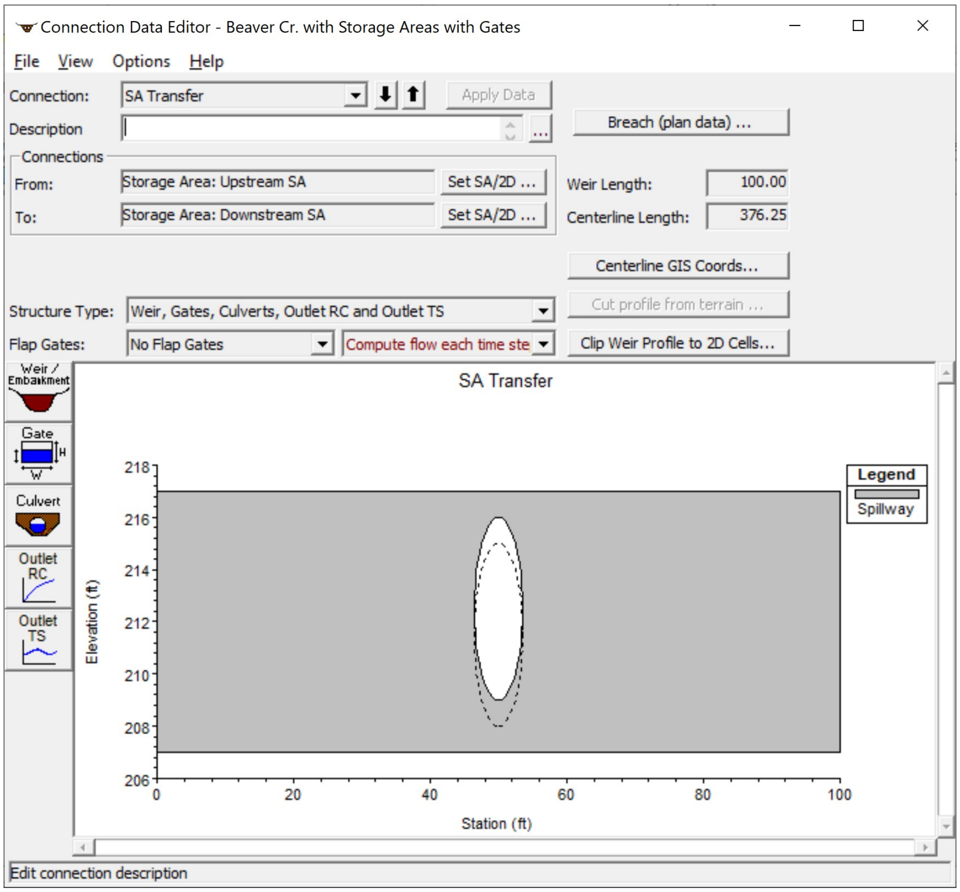


Figure 1. SA/2D Connection editor.

From this editor the **Weir/Embankment** tool was selected. Data was entered for the weir geometry, as shown in Figure 2.

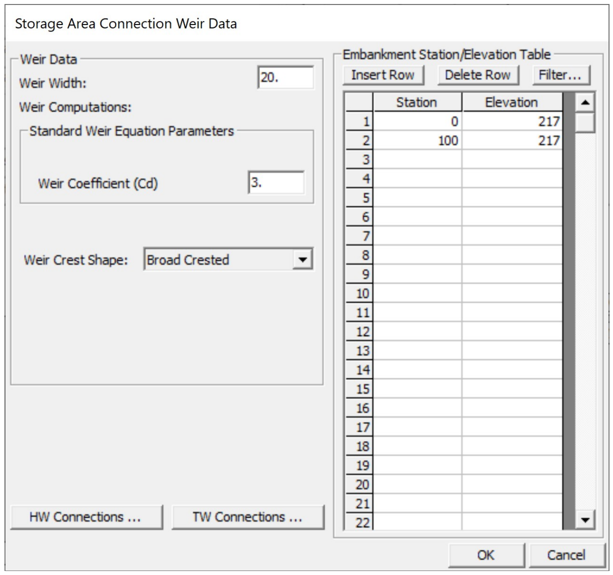


Figure 2. Storage Area Connection Weir Data editor.

After editing the weir, the **Culvert** tool was selected from the **SA Conn Data Editor**. Data was entered for a single culvert as shown in Figure 3.

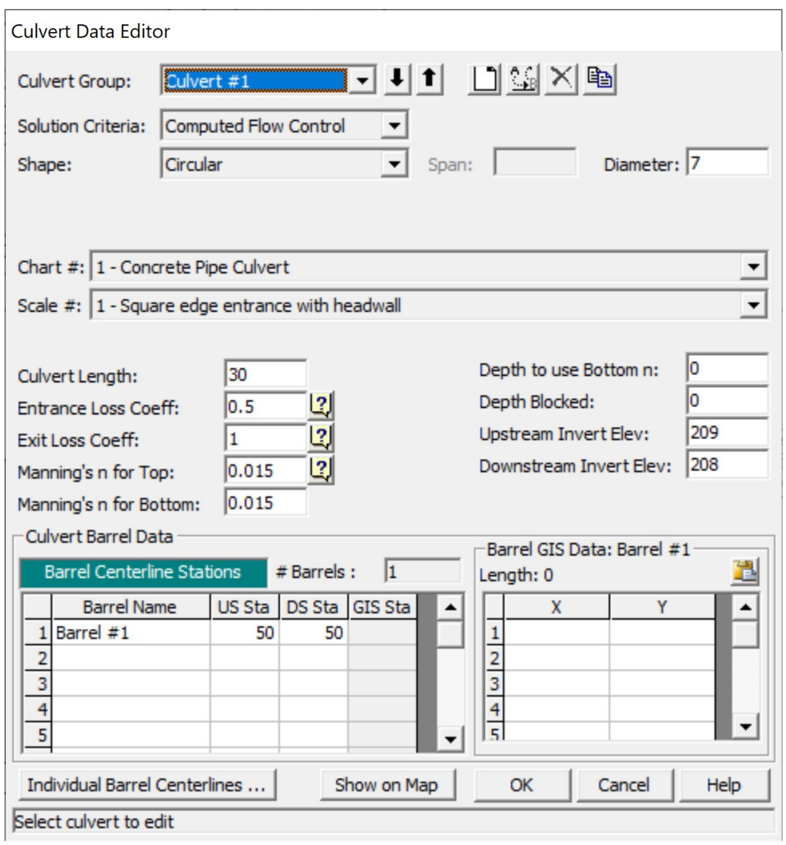
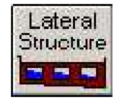


Figure 3. Culvert Data Editor.

e. Connect the two storage areas to the reach via lateral structures.

The lateral structures were added using the lateral weir tool found in the **Geometric Data Editor**, located in the "Editors" section. After pressing this button the **Lateral Structure Editor** shown in Figure 4 is displayed.



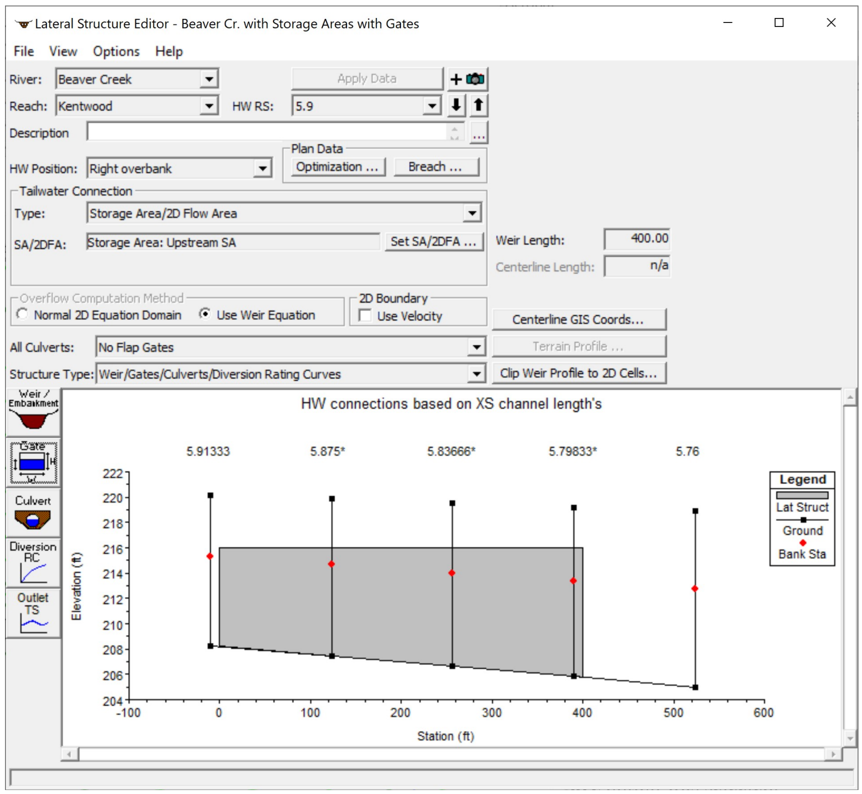


Figure 4. Lateral Structure Editor.

Under the **Options** menu **Add a Lateral Structure** option was selected. The River Station was entered as 5.9. Next, the **Weir/Embankment** button was selected. The dimensions of the lateral weir were entered as shown in Figure 5. The weir was connected to SA Upstream by selecting the **Set SA** button and choosing "SA Upstream."

The same method was used to add the second lateral weir at River Station 5.570. The dimensions of this weir are shown in Figure 6. After completing the geometry, the file was saved and the unsteady flow simulation was run.

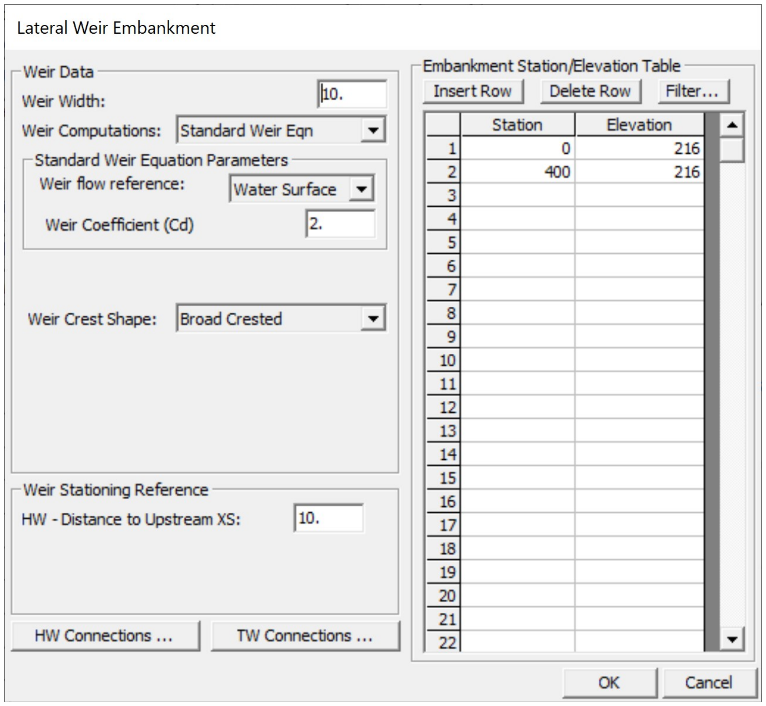


Figure 5 Lateral Weir Located at RS 5.9.

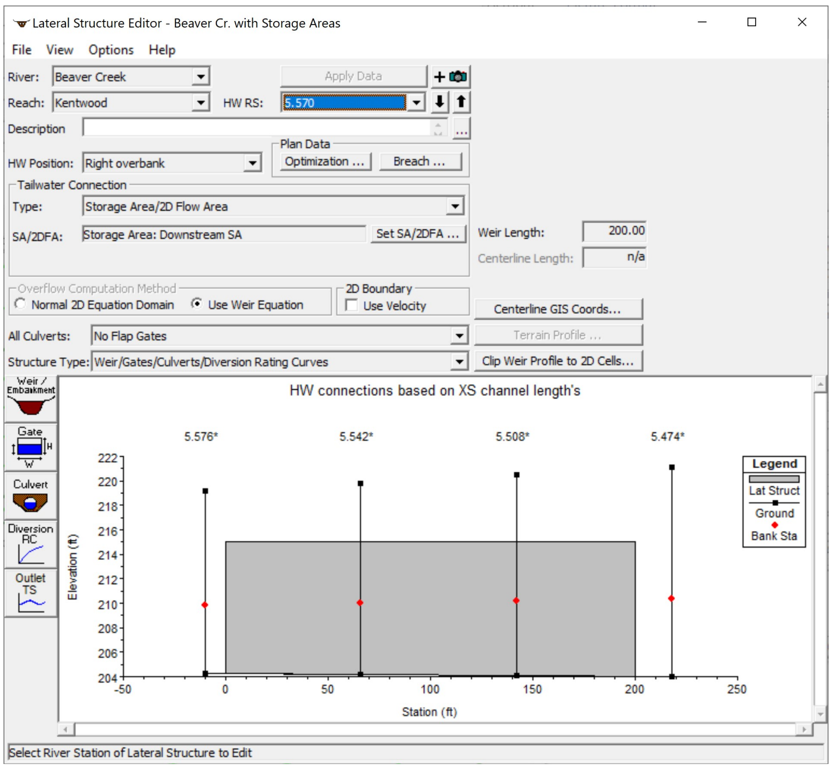


Figure 6 Lateral Weir Located at RS 5.570.

f. Save a new plan and run it

In the **Unsteady Flow Analysis** editor**,** a new plan with the name “Storage Areas and Lateral Structures” and the short ID “SA and LS.” was saved. The simulation was then run.

g. View output and adjust geometry until the bridge is not overtopped.

Figure 7 displays the profile plot with the maximum water surface profile displayed. From this plot it can be seen that the maximum profile does not overtop the bridge for the given geometry.

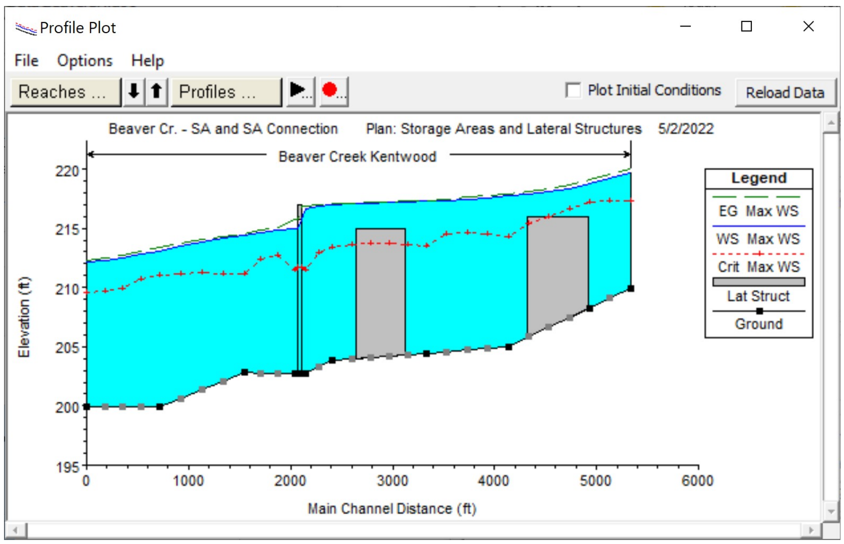


Figure 7. Profile Plot of Maximum Water Surface Profile.

Additionally, Figure 8 displays the **Profile Output Table** for the **Bridge Only**. Under the **Options** menu **Profiles** was selected, and every time step was selected. The data shows that there was no weir flow.

Profile Output Table - Bridge Only

HEC-RAS Plan: SA and LS River: Beaver Creek Reach: Kentwood

Reach	River Sta	Profile	E.G. US. (ft)	Min El Prs (ft)	BR Open Area (sq ft)	Prs O WS (ft)	Q Total (cfs)	Min El Weir Flow (ft)	Q Weir (cfs)	Delta EG (ft)	BR Sluice Coef
Kentwood	5.4	22MAY1974 0000	209.60	215.70	1600.36		515.19	216.94		0.02	
Kentwood	5.4	22MAY1974 0200	210.60	215.70	1600.36		1187.86	216.94		0.05	
Kentwood	5.4	22MAY1974 0400	212.41	215.70	1600.36		3392.17	216.94		0.16	
Kentwood	5.4	22MAY1974 0600	214.12	215.70	1600.36		6411.12	216.94		0.34	
Kentwood	5.4	22MAY1974 0800	215.29	215.70	1600.36		8854.04	216.94		0.48	
Kentwood	5.4	22MAY1974 1000	215.96	215.70	1600.36		10418.05	216.94		0.55	
Kentwood	5.4	22MAY1974 1200	216.37	215.70	1600.36	216.53	10843.24	216.94		1.21	0.37
Kentwood	5.4	22MAY1974 1400	216.86	215.70	1600.36	216.63	11337.71	216.94		1.10	0.38
Kentwood	5.4	22MAY1974 1600	216.19	215.70	1600.36	216.51	10679.60	216.94		1.25	0.36
Kentwood	5.4	22MAY1974 1800	215.23	215.70	1600.36		8620.90	216.94		0.45	
Kentwood	5.4	22MAY1974 2000	213.44	215.70	1600.36		4941.72	216.94		0.24	
Kentwood	5.4	22MAY1974 2200	211.46	215.70	1600.36		1956.40	216.94		0.08	
Kentwood	5.4	23MAY1974 0000	210.01	215.70	1600.36		728.76	216.94		0.03	
Kentwood	5.4	23MAY1974 0200	209.42	215.70	1600.36		448.16	216.94		0.01	

Upstream energy grade elevation at bridge or culvert (specific to that opening, not necessarily the weighted average).

Figure 8. Profile Output Table for Bridge Only.

3. **Place Gates on the Downstream Lateral Structure**

b. Construct the gates along the downstream lateral weir.

From the **Lateral Structure Data Editor** the downstream lateral weir at RS 5.570 was selected. Next, the **Gate** button was selected. Figure 9 displays the data entered for the gates. Ten gates were entered; each gate is 4 feet apart. After entering all gate information the geometry file was saved as "Beaver Cr. with Gates."

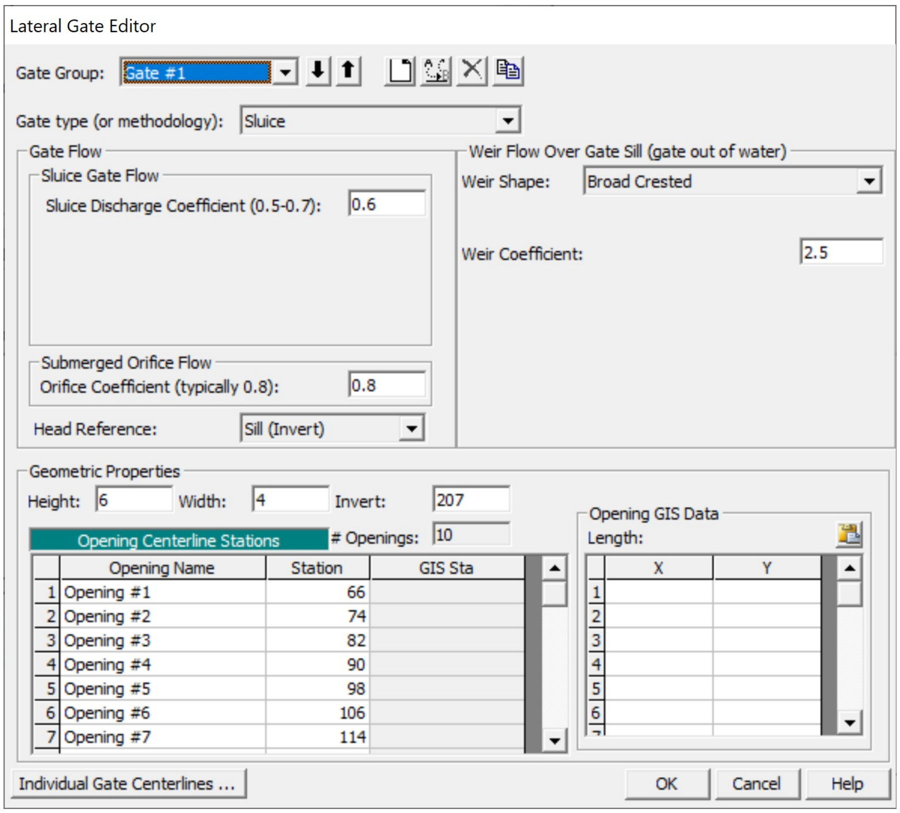


Figure 9. Lateral Gate Editor.

c. In the **Unsteady Flow Data Editor** develop a time series of operation for the gates that will release the water in the downstream storage area after the flood wave.

In the **Unsteady Data** editor RS 5.570 was selected and then the **Add a Boundary Location** button was depressed. A time series was developed that opened the gates after the flood wave had passed. After entering the times series information the unsteady flow file was saved as "Unsteady Flow with Gates." Figure 10 displays a plot of the time series for gate openings.

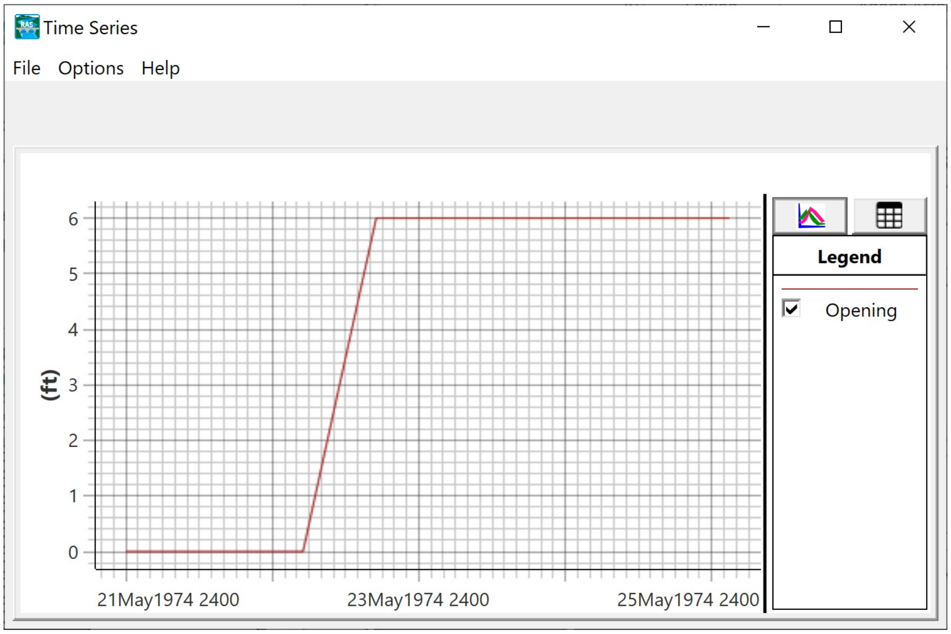


Figure 10. Times Series of Gate Openings.

d. Save a new plan for Task 2 with the new geometry and unsteady flow files and then proceed with the simulation.

In the **Unsteady Flow Analysis Window,** a new plan with the name "Storage Areas and LS with Gates" and the short ID "SA and LS with Gates" was saved. The simulation was then run.

Questions

1. Did your design meet the requirement to prevent weir flow over the highway bridge?

As shown in Figures 7 and 8 the design met the requirement to prevent weir flow over the highway bridge. Pressure flow did occur during the simulation but the bridge was never overtopped.

2. When did the maximum flowrate occur in the storage areas? What was the maximum stage of both storage areas? What was the maximum flowrate between the two storage areas? What was the maximum flowrate over the lateral structure located at River Station 5.9?

Figure 11 and 12 display the ***Stage and Flow Hydrographs*** *for the upstream and downstream storage areas. As seen from the figures, the maximum flow occurred in the upstream storage area on the May 22nd, 1974 at 1200 hours (~1845 cfs).*

The maximum flow in the downstream storage area occurred on May 22nd, 1974 at around 1400 hours (~1976 cfs). The maximum stages of the storage areas were 218.14 ft and 216.5 ft for upstream and downstream, respectively.

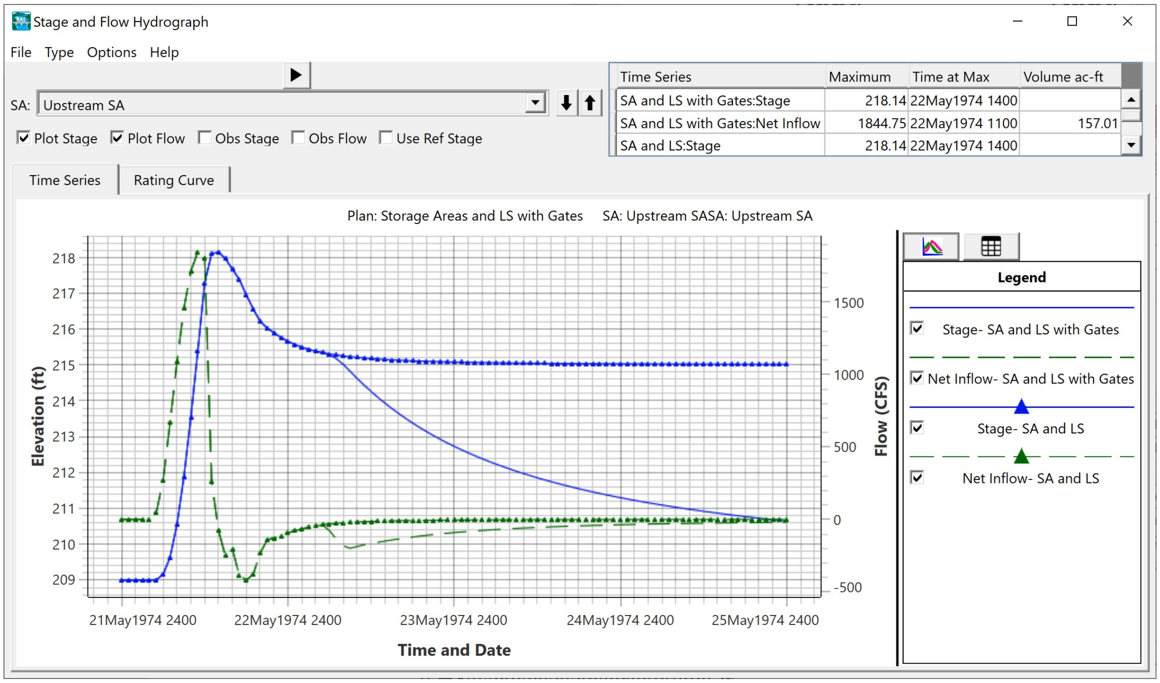


Figure 11. Upstream Storage Area.

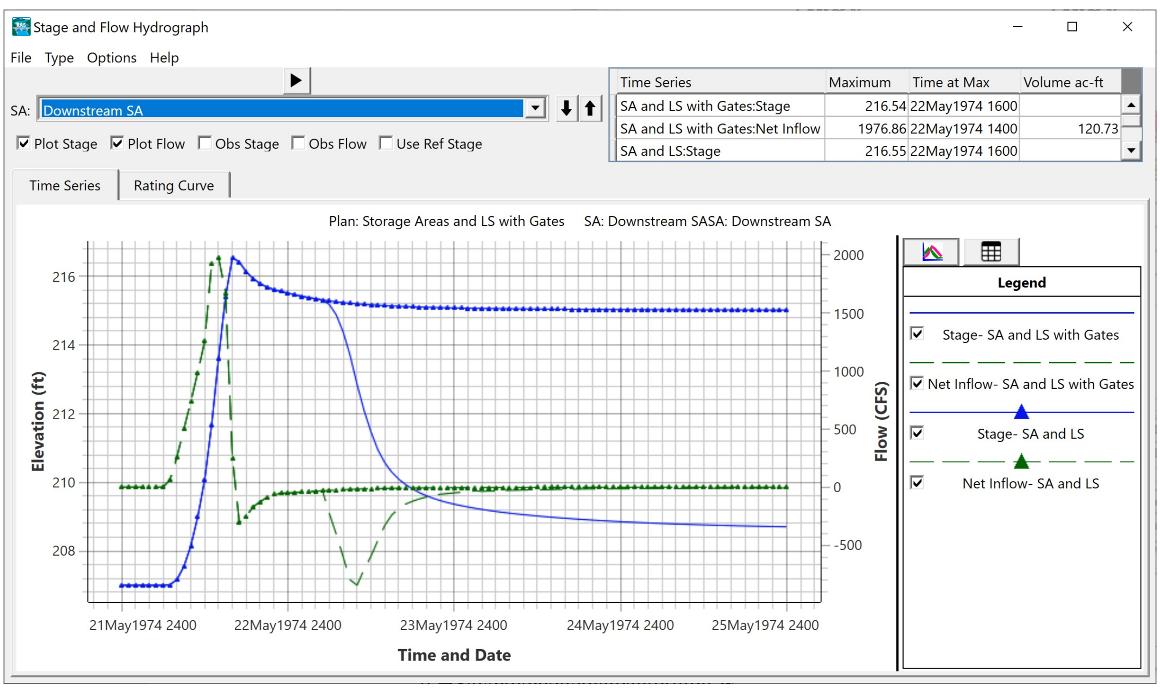


Figure 12. Downstream Storage Area.

The maximum flow between the two storage areas can be viewed from the ***Stage and Flow Hydrograph*** *of the hydraulic connection, as shown in Figure 13. The maximum flowrate was about* ***760 cfs****.*

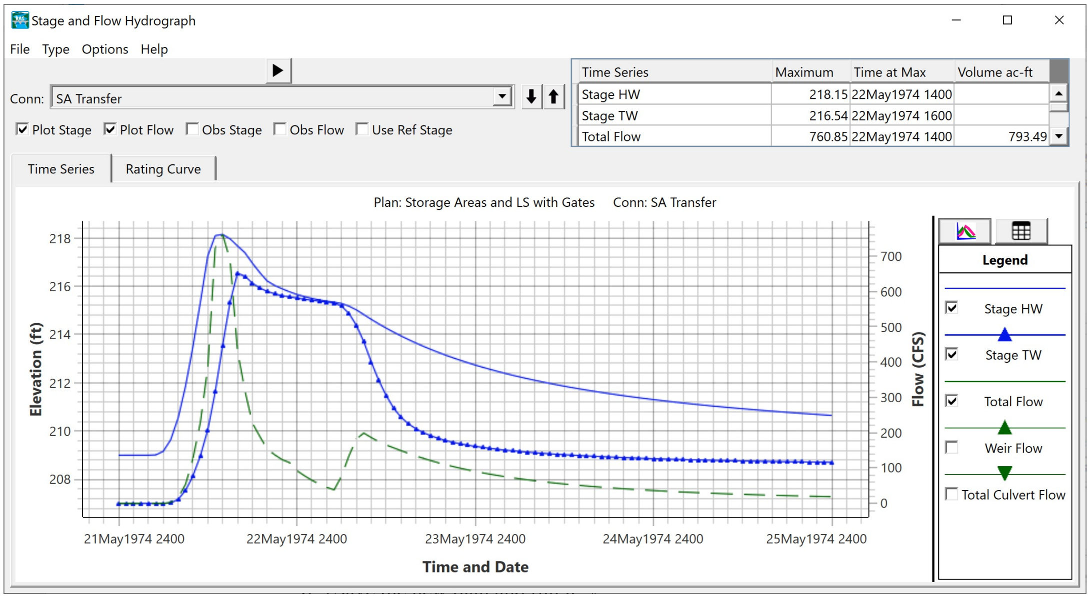


Figure 13 Storage Area Connection.

The maximum flow over the lateral weir can be found by examining the ***Stage and Flow Hydrograph*** *plot of the lateral weir located at River Station 5.9, as shown in Figure 14. This figure can display the flow and stage information for headwater upstream and downstream of the lateral weir. Additionally, the figure can display flow and stage information for tailwater of the lateral weir (flow entering or leaving the storage area). To make the figure easier to read, only the flow information is included. As seen on the figure, the maximum flow over the weir (flow leaving) is about 2,200 cfs.*

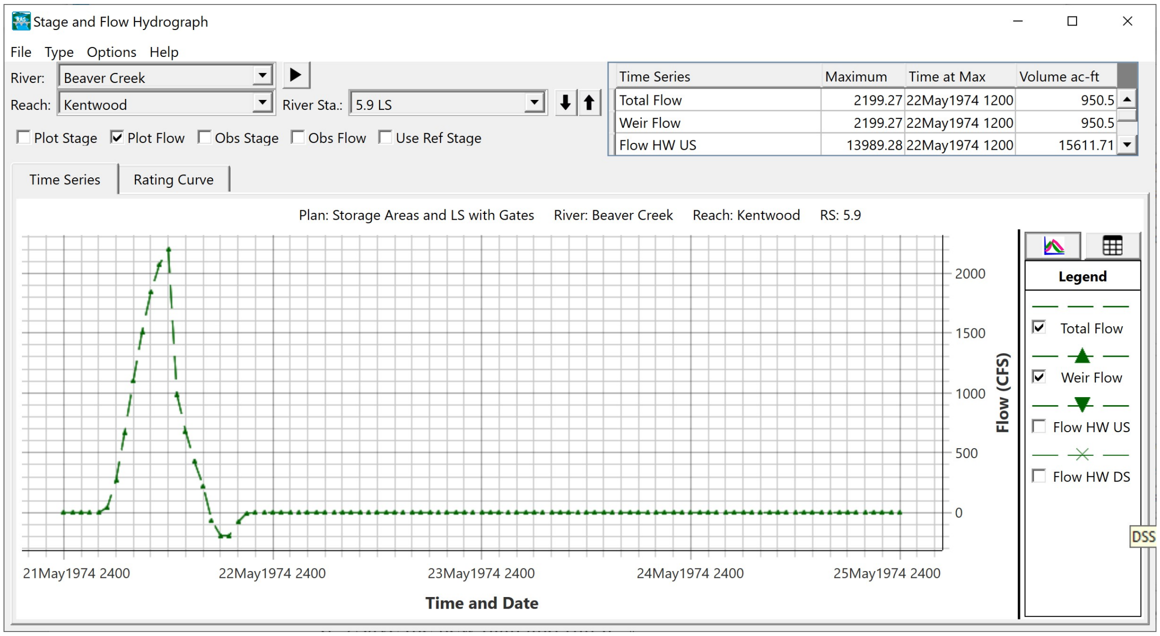


Figure 14. Lateral Structure at River Station 5.9.

3. How did the stage and flow hydrographs change from when the gates were added? Did any numerical oscillations occur in the stage and flow hydrographs? If so, how can these oscillations be smoothed?

Figure 15 displays the downstream storage area before and after the control gates were added.

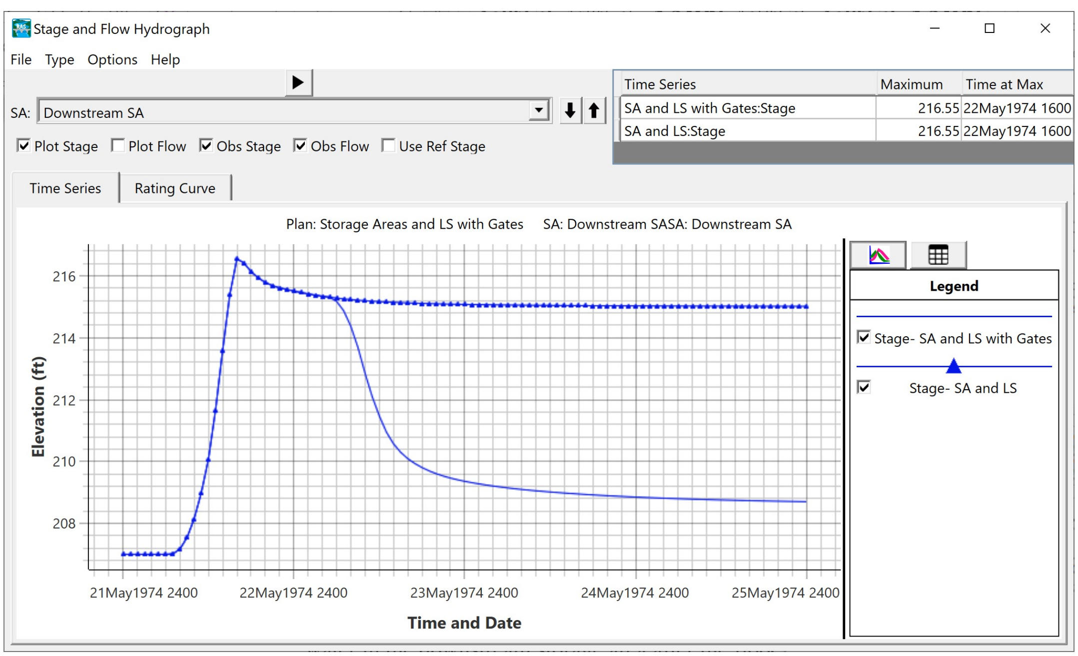


Figure 15. Downstream Storage Area With and Without Gates.

Numerical oscillations can be observed, particularly in the downstream storage area hydrograph when the water surface elevations of the two storage areas approach each other (see circle on Figure 12). Oscillations become more prevalent and pronounced at coarse time steps (e.g.>30 seconds). Some oscillations can be smoothed by using a smaller time step, lowering the ***Storage Area Elevation Tolerance*** *and raising the* ***Weir Flow Submergence Decay Exponent****. These tolerance factors are found in the* ***Unsteady Flow Analysis Window*** *under the* ***Options*** *menu, under* ***Calculation Options and Tolerances…*** *For further discussion on these calculation options can be found in the HEC-RAS User's Manual.*

4. What is another alternative, besides off-stream storage areas, to keep the bridge from being overtopped?

The bridge could be designed with multiple openings besides the main channel to pass larger flows. Multiple culverts could be placed along the bridge.