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.



Weir Data	20.	Inser	t Row Dele	te Row	Filter
Weir Widul:			Station	Elevati	on l
weir computations.		1	0		217
-Standard Weir Equation Paramete	rs	2	100		217
		3			
Weir Coefficient (Cd)	3.	4			
• •		5			_
		6			_
		7			_
Weir Crest Shape: Broad Crester	d 👻	8			_
		9			
		10			- 10
		12			_
		12			
		14			
		15			
		16			
		17			
		18			
		19			
		20			
		21			

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.



Culvert Data Edit	tor				
Culvert Group:	Culvert #1		• I t		
Solution Criteria:	Computed Flow	v Control	•		
Shape:	Circular		▼ Spa	an: Diamet	er: 7
Chart #: 1 - Con	crete Pipe Culve	rt			-
Scale #: 1 - Squ	are edge entrand	e with h	eadwall		•
Culvert Length:	30			Depth to use Bottom n	0
Entrance Loss Co	eff: 0.5	2		Depth Blocked:	0
Exit Loss Coeff:	1	2		Upstream Invert Elev:	209
Manning's n for T	op: 0.015	2		Downstream Invert Ele	v: 208
Manning's n for B	ottom: 0.015				
Culvert Barrel Da	ata			Barrel GIS Data: Barre	#1
Barrel Center	line Stations	# Barrels	: 1	Length: 0	2
Barrel Na	ame US Sta	DS Sta	GIS Sta	X	Y
1 Barrel #1	50	50		1	
3				3	
4				4	
5					
Individual Barrel	Centerlines	S	how on Map	OK Cancel	Help
Select culvert to e	edit				

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.



♥ Lateral Structure Editor - Beaver	Cr. with Storage Areas with Gates		- 🗆 ×
River: Beaver Creek	Apply Data	- 100 	
Description	Plan Data		
Tailwater Connection			
Type: Storage Area/2D Flow A	ea	•	
SA/2DFA: Storage Area: Upstream	SASet SA/2DF	A] Weir Length: 400.00 Centerline Length: n/a	
Overflow Computation Method	se Weir Equation	Centerline GIS Coords	
All Culverts: No Flap Gates		▼ Terrain Profile	
Structure Type: Weir/Gates/Culverts/D	version Rating Curves	▼ Clip Weir Profile to 2D Cells	
Embaikment	HW connections based	on XS channel length's	-
5.9133	3 5.875* 5.83	66* 5.79833* 5.7	6
Culvert 220 218		Ī	Lat Struct Ground
Diversion RC 5 216- € 216- 5 214-	• •		Bank Sta
Outlet 5 212			†
210- 210-			
208			
206			-
-100 0	100 200	300 400 500	600
-	Station	(ft)	

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.

Weir Data	Embar	nkment Station/E	Elevation 1	Table
Weir Width:	Inse	rt Row Dele	ete Row	Filter
Weir Computations: Standard Weir Egn 🔻		Station	Eleva	tion
Standard Weir Equation Parameters	1	0 400		216 216
Weir Coefficient (Cd)	4			
Weir Crest Shape: Broad Crested 💌	6 7 8 9 10 11			
Weir Stationing Reference HW - Distance to Upstream XS: 10.	12 13 14 15 16 17 18 19			
HW Connections TW Connections	20 21 22			
			ОК	Cancel





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 Ta	able - Bridge Only I. Tables Locatio	ns Help							-	
		HEC-RA	S Plan: S	SA and LS	River: Bea	ver Creek	Reach:	Kentwood			Reload [
Reach	River Sta	Profile	E.G. US.	Min El Prs	BR Open Area	Prs O WS	Q Total	Min El Weir Flow	Q Weir	Delta EG	BR Sluice Coef
			(ft)	(ft)	(sq ft)	(ft)	(cfs)	(ft)	(cfs)	(ft)	
entwood	5.4	22MAY 1974 0000	209.60	215.70	1600.36		515.19	216.94		0.02	
entwood	5.4	22MAY 1974 0200	210.60	215.70	1600.36		1187.86	216.94		0.05	
entwood	5.4	22MAY 1974 0400	212.41	215.70	1600.36		3392.17	216.94		0.16	
entwood	5.4	22MAY 1974 0600	214.12	215.70	1600.36		6411.12	216.94		0.34	
entwood	5.4	22MAY 1974 0800	215.29	215.70	1600.36		8854.04	216.94		0.48	
entwood	5.4	22MAY 1974 1000	215.96	215.70	1600.36		10418.05	216.94		0.55	
entwood	5.4	22MAY1974 1200	216.37	215.70	1600.36	216.53	10843.24	216.94		1.21	0.37
entwood	5.4	22MAY1974 1400	216.86	215.70	1600.36	216.63	11337.71	216.94		1.10	0.38
entwood	5.4	22MAY1974 1600	216.19	215.70	1600.36	216.51	10679.60	216.94		1.25	0.36
entwood	5.4	22MAY1974 1800	215.23	215.70	1600.36		8620.90	216.94		0.45	
entwood	5.4	22MAY 1974 2000	213.44	215.70	1600.36		4941.72	216.94		0.24	
entwood	5.4	22MAY 1974 2200	211.46	215.70	1600.36		1956.40	216.94		0.08	
entwood	5.4	23MAY 1974 0000	210.01	215.70	1600.36		728.76	216.94		0.03	
entwood	54	23MAV1074 0200	200 42	215 70	1600 36		449 16	216 04		0.01	

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."

ate Group: Gate #1	ŢŢŢŢ	1 <u>64 × P</u>				
ate type (or methodology):	Sluice	•				
Gate Flow		Weir Flo	w Over Ga	ate Sill (gate ou	ut of water) -	
Sluice Gate Flow		Weir Sha	ne: Br	nad Crested	,	
Sluice Discharge Coefficient	(0.5-0.7): 0.6		per lo	oud created		
-						
		Weir Coe	efficient:			2.5
-Submerged Orifice Flow		_				
Orifice Coefficient (typically 0	0.8):					
	Cill (Taurant)	=				
nead Reference: ja	siii (Invert)	<u> </u>				
Constantia Descention						
Geometric Properties						
Height: 6 Width:	4 Invert:	207				
Height: 6 Width:	4 Invert:	207		pening GIS Da	ta	1
Height: 6 Width: Opening Centerline Stat	4 Invert:	207 gs: 10	-O Le	pening GIS Dai ength:	ta	<u></u>
Height: 6 Width: Opening Centerline Stat	4 Invert: tions # Opening Station	207 gs: 10 GIS Sta		pening GIS Dai ength: X	ta Y	
Height: 6 Width: Opening Centerline Stat Opening Name 1 Opening #1	4 Invert: tions # Opening Station 66	207 gs: 10 GIS Sta		pening GIS Dai ength: X	ta Y	
Height: 6 Width: Opening Centerline Stat Opening Name 1 Opening #1 2 Opening #2	4 Invert: tions # Opening Station 66 74	207 gs: 10 GIS Sta		pening GIS Dai ength: X	ta Y	
Height: 6 Width: Opening Centerline Stat Opening Name 1 Opening #1 2 Opening #2 3 Opening #3 4 Opening #4	4 Invert: tions # Opening 5tation 66 74 82	207 gs: 10 GIS Sta		pening GIS Dai ength: X	ta Y	
Opening Centerline Stat Opening Centerline Stat 0pening Centerline Stat 0pening 1 0pening #1 2 0pening #2 3 0pening #3 4 0pening #4	4 Invert: tions # Opening 66 74 82 90	207 Js: 10 GIS Sta		pening GIS Dai ength: X	ta Y	
Geometric Properties Height: 6 Width: Opening Centerline State 0pening Centerline State 1 Opening Mame 2 Opening #1 2 Opening #2 3 Opening #3 4 Opening #4 5 Opening #5	4 Invert: tions # Opening 66 74 82 90 90 90	207 Js: 10 GIS Sta		pening GIS Dat ength: X	Y Y	
Geometric Properties Height: 6 Width: Opening Centerline State 0pening Centerline State 1 Opening Mame 2 Opening #1 2 Opening #2 3 Opening #3 4 Opening #4 5 Opening #5 6 Opening #6 2 Opening #7	4 Invert: tions # Opening 66 74 82 90 98 106 114	207 Js: 10 GIS Sta	O Le 1 2 3 4 4 5 6	pening GIS Da Ingth: X	Y Y	
Height: 6 Width: Opening Centerline Stat Opening Name 1 Opening #1 2 Opening #2 3 Opening #3 4 Opening #4 5 Opening #5 6 Opening #6 7 Opening #7	4 Invert: tions # Opening Station 66 74 82 90 98 106 114	207 js: 10 GIS Sta	C Le	pening GIS Da ength: X	ta Y	

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 22^{nd} , 1974 at 1200 hours (~1845 cfs).

The maximum flow in the downstream storage area occurred on May 22^{nd} , 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 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.