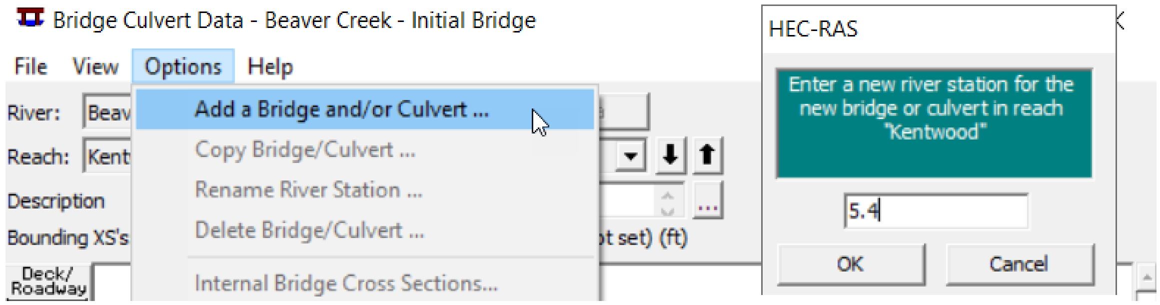
Modeling Bridges with Unsteady Flow

Solution

Enter Bridge Information

Add a new Bridge at **Station 5.4**.



Use the Bridge Design Editor to enter the deck and pier data.

- Road embankment is at a constant elevation of **216.93**ft.
- The bridge low chord is at elevation of **215.7 ft.**
- The bridge opening has vertical walls at cross section stationing **450** ft and **647** ft.
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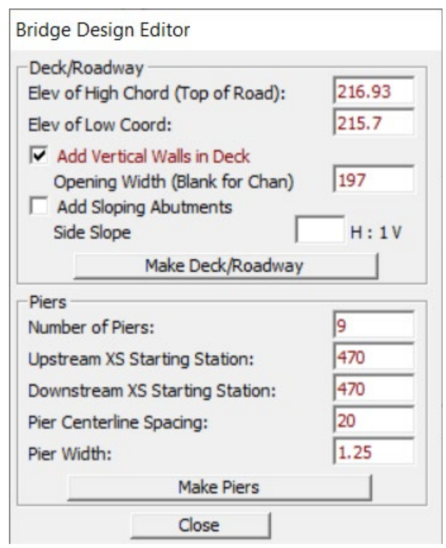
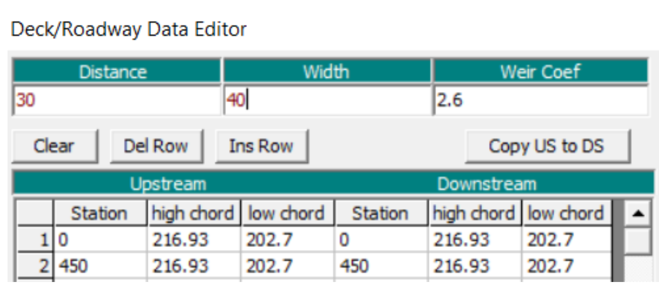
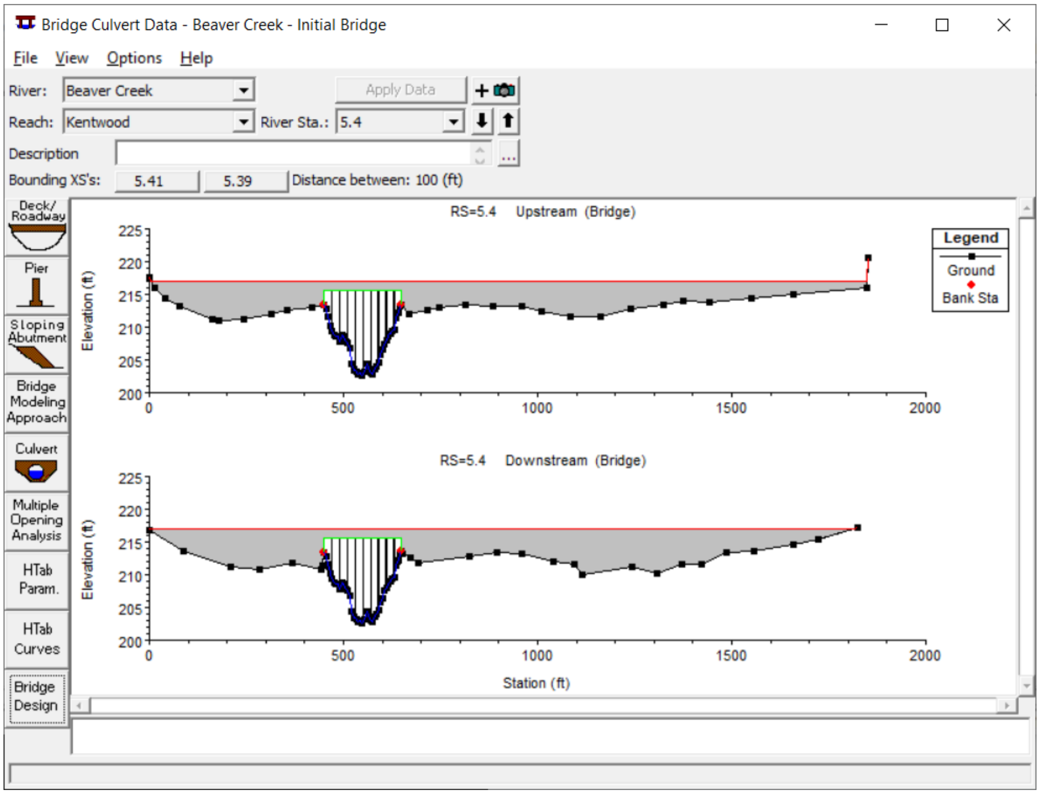
- The bridge has **9 piers**. The piers are **1.25** ft wide each and have a square nose. The piers are spaced **20** ft. apart on center, starting with the first pier at station **470** ft.



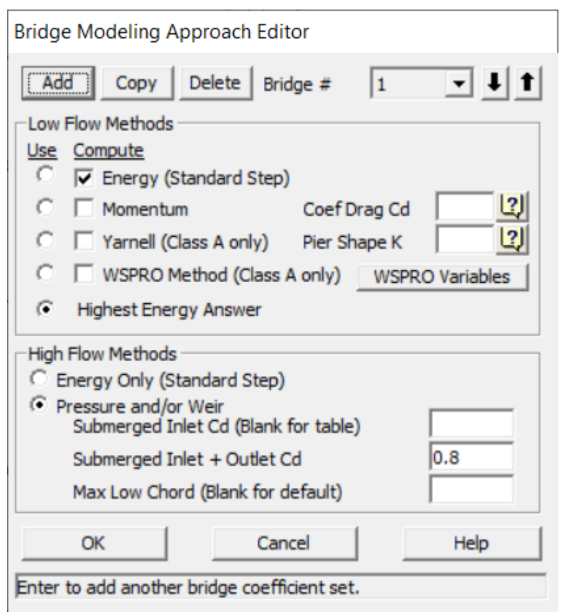
- The bridge deck is **40** ft wide, and the upstream side of the bridge deck is **30** ft from cross section immediately upstream of the bridge (section 5.41).





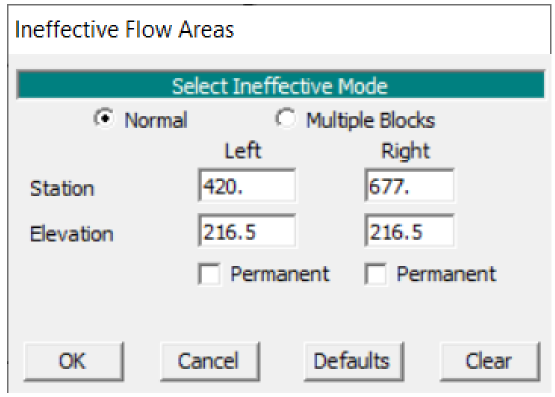
Select a Bridge Modeling Approach for both low and high flow.

Multiple methods can be used initially; however, a single method should be selected prior to unsteady flow modeling. Based on previous modeling with this data, the shown combination is the best choice for this bridge.



Enter the **Ineffective Flow Area** data for the bounding bridge cross sections

The initial model applied the Normal Ineffective Flow option, laterally offset from the abutment locations based on a rapid contraction and expansion of flow in the vicinity of the bridge. The elevation for the ineffective areas was set to just below the top of weir elevation.



Compute Steady Flow Profiles

The Bridge Comparison table shows that for the 1974 flood event the pressure/weir flow solution was used.

Profile Output Table - Bridge Comparison

HEC-RAS Plan: Steady River: Beaver Creek Reach: Kentwood

Reach	River Sta	Profile	E.G. US. (ft)	W.S. US. (ft)	BR Sel Method	Energy EG (ft)	Momen. EG (ft)	Yarnell EG (ft)	WSPRO EG (ft)	Prs O EG (ft)	Prs/Wr EG (ft)	Energy/W (ft)
Kentwood	5.4	PF 1	213.62	213.37	Energy only	213.62						
Kentwood	5.4	PF 2	216.79	216.36	Press Only	215.81				216.79		
Kentwood	5.4	1974 flood	217.31	217.17	Press/Weir	216.94				217.60	217.31	

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

The bridge only table shows weir flow for the third profile.

Profile Output Table - Bridge Only

HEC-RAS Plan: Steady 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	PF 1	213.62	215.70	1600.38		5000.00	216.94		0.21	
Kentwood	5.4	PF 2	216.79	215.70	1600.38	216.36	10000.00	216.94		1.42	0.34
Kentwood	5.4	1974 flood	217.31	215.70	1600.38		14000.00	216.94	1112.25	1.31	

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

Check the cross sections around the bridge. The Six XS Bridge table shows that there was a bit more overbank flow in the upstream of the bridge than downstream. This may be a result of the ineffective flow options being off upstream and turn on downstream. Also, the **overbank flow is much greater than weir flow**.

Profile Output Table - Six XS Bridge

File Options Std. Tables Locations Help

HEC-RAS Plan: Steady River: Beaver Creek Reach: Kentwood Profile: 1974 flood

Reach	River Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Crit W.S. (ft)	Frctn Loss (ft)	C & E Loss (ft)	Top Width (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Vel Chnl (ft/s)
Kentwood	5.44	1974 flood	217.52	217.41		0.20	0.01	1843.97	3719.94	4383.23	5896.83	4.18
Kentwood	5.41	1974 flood	217.31	217.17	212.25			1844.77	2102.79	7612.42	4284.79	3.81
Kentwood	5.4 BR U	1974 flood	217.30	217.17	212.52			1844.77	266.11	13004.25	694.10	7.89
Kentwood	5.4 BR D	1974 flood	217.30	217.17	212.52			1824.00	266.11	13004.24	694.10	7.89
Kentwood	5.39	1974 flood	216.00	215.74	212.28	0.23	0.06	1714.13	1874.00	8688.69	3437.32	5.06
Kentwood	5.3450*	1974 flood	215.71	215.58		0.23	0.00	1678.22	3130.06	4655.09	6214.85	4.36

Energy gradeline for given WSEL.

The ineffective area controlling elevation was set to 214.5' at the downstream section to allow overbank flow for the 1974 flood profile. Also, the overbank n values were doubled at the bounding sections to reduce overbank conveyance.

Looking at the bridge tables we find that there is still a lot of flow in the overbanks compared with the computed weir flow.

Profile Output Table - Six XS Bridge

File Options Std. Tables Locations Help

HEC-RAS Plan: Final Steady River: Beaver Creek Reach: Kentwood Profile: 1974 flood

Reach	River Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Crit W.S. (ft)	Frctn Loss (ft)	C & E Loss (ft)	Top Width (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Vel Chnl (ft/s)
Kentwood	5.44	1974 flood	217.64	217.50		0.25	0.00	1844.35	2137.27	4982.01	6880.72	4.71
Kentwood	5.41	1974 flood	217.38	217.23	212.25			1845.24	1140.96	8180.95	4678.09	4.07
Kentwood	5.4 BR U	1974 flood	217.38	217.23	212.52			1845.24	358.73	12705.14	936.13	7.66
Kentwood	5.4 BR D	1974 flood	217.38	217.23	212.52			1824.00	358.73	12705.14	936.13	7.66
Kentwood	5.39	1974 flood	216.18	215.89	212.26	0.27	0.07	1726.95	1025.42	9195.37	3779.21	5.27
Kentwood	5.3450*	1974 flood	215.85	215.69		0.31	0.00	1687.19	1759.68	5159.75	7080.58	4.77

Energy gradeline for given WSEL.

In order to reduce conveyance, we must dramatically increase the Manning's n values in the overbanks. An n value of 0.6 was used. This may be justified given the extremely thick trees in the overbank. Weir flow is much closer to the overbank flow.

Profile Output Table - Bridge Only

File Options Std. Tables Locations Help

HEC-RAS Plan: Final Steady River: Beaver Creek Reach: Kentwood Profile: 1974 flood

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	1974 flood	217.39	215.70	1600.36	217.23	14000.00	216.94	1492.69	1.07	0.40

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

Profile Output Table - Six XS Bridge

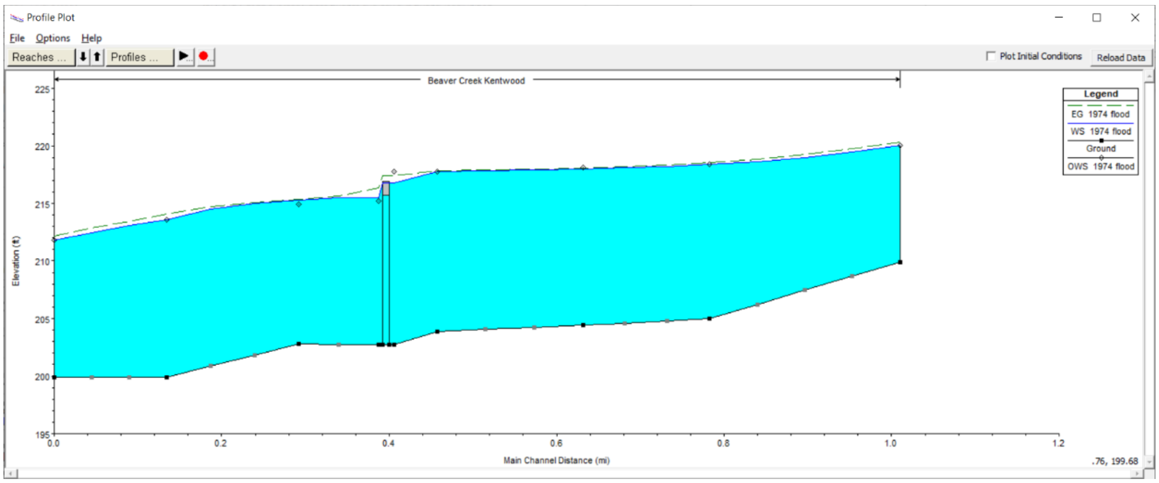
File Options Std. Tables Locations Help

HEC-RAS Plan: Final Steady River: Beaver Creek Reach: Kentwood Profile: 1974 flood

Reach	River Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Crit W.S. (ft)	Frctn Loss (ft)	C & E Loss (ft)	Top Width (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Vel Chnl (ft/s)
Kentwood	5.44	1974 flood	217.82	217.73		0.26	0.16	1845.42	3677.66	4162.94	6159.41	3.86
Kentwood	5.41	1974 flood	217.39	216.79	212.24			1841.40	509.72	12649.62	840.66	6.59
Kentwood	5.4 BR U	1974 flood	217.39	216.79	212.52				370.19	12669.36	966.07	7.92
Kentwood	5.4 BR D	1974 flood	217.39	216.79	212.52				370.19	12669.36	966.07	7.92
Kentwood	5.39	1974 flood	216.32	215.51	212.25	0.36	0.33	1693.56	429.04	12680.61	890.35	7.60
Kentwood	5.3450*	1974 flood	215.63	215.48		0.23	0.02	1670.79	3276.42	4754.07	5969.52	4.60

Energy gradeline for given WSEL.

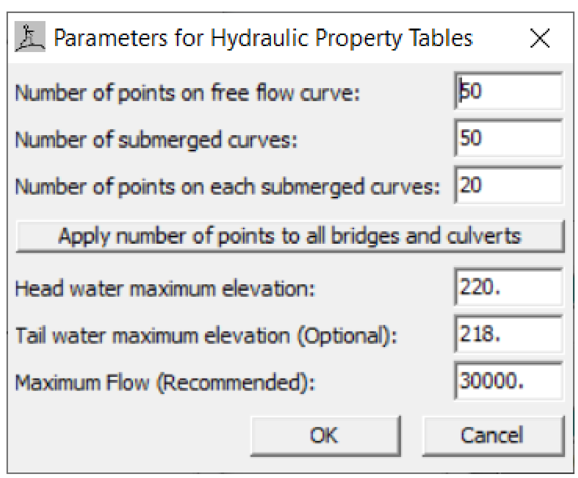
The model was rerun and checked against the observed data.



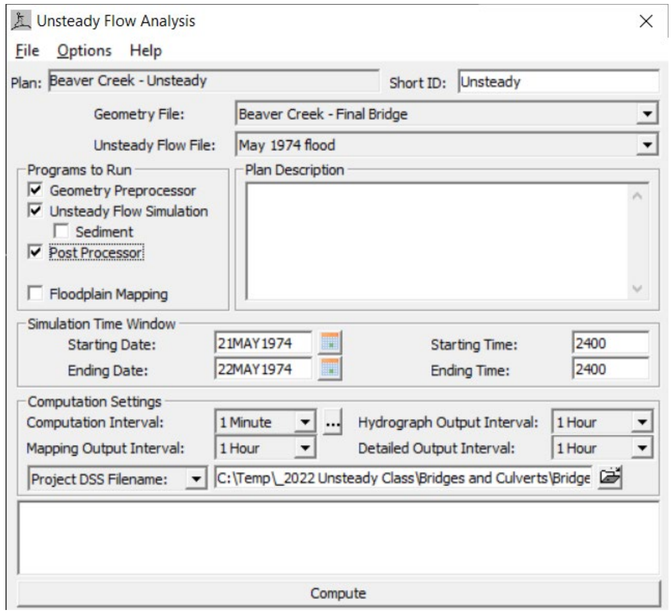
Unsteady Flow Simulation

HTAB parameters were set up for the flows the bridge.

The range of elevations for the processing of bridge data should exceed the expected range of flow and elevations. The tailwater and headwater elevations could be set one-foot higher than the values for the 1974 flood. Also, the maximum flow could be set to the maximum expected in future applications.

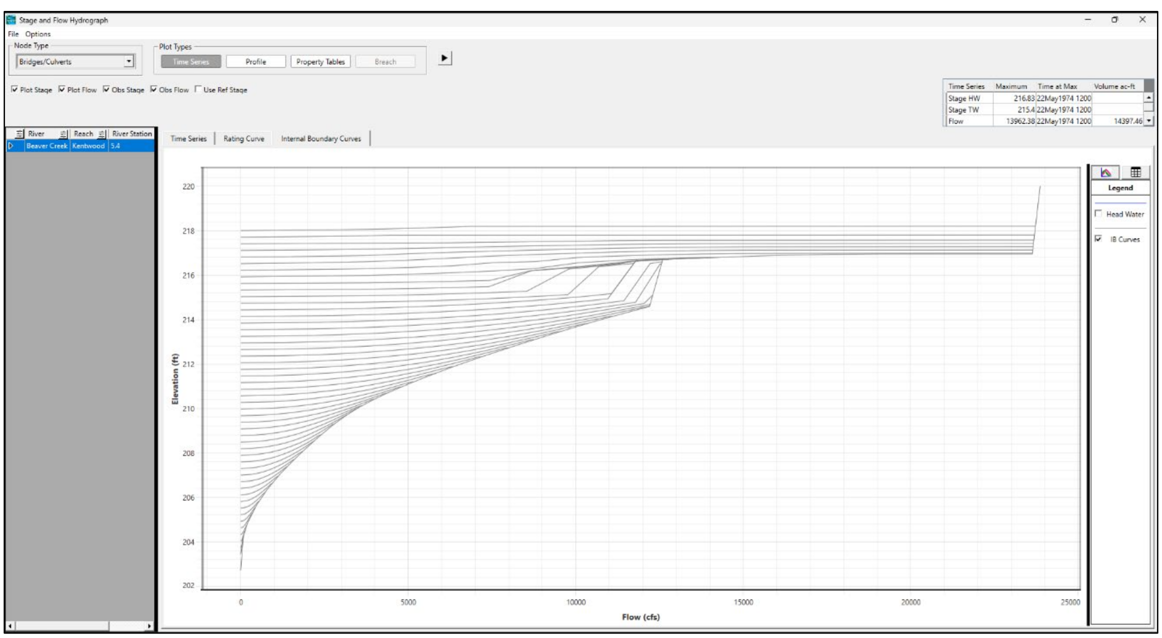


The unsteady flow simulation was set up for the May 1974 flood. A 1min time step was used.

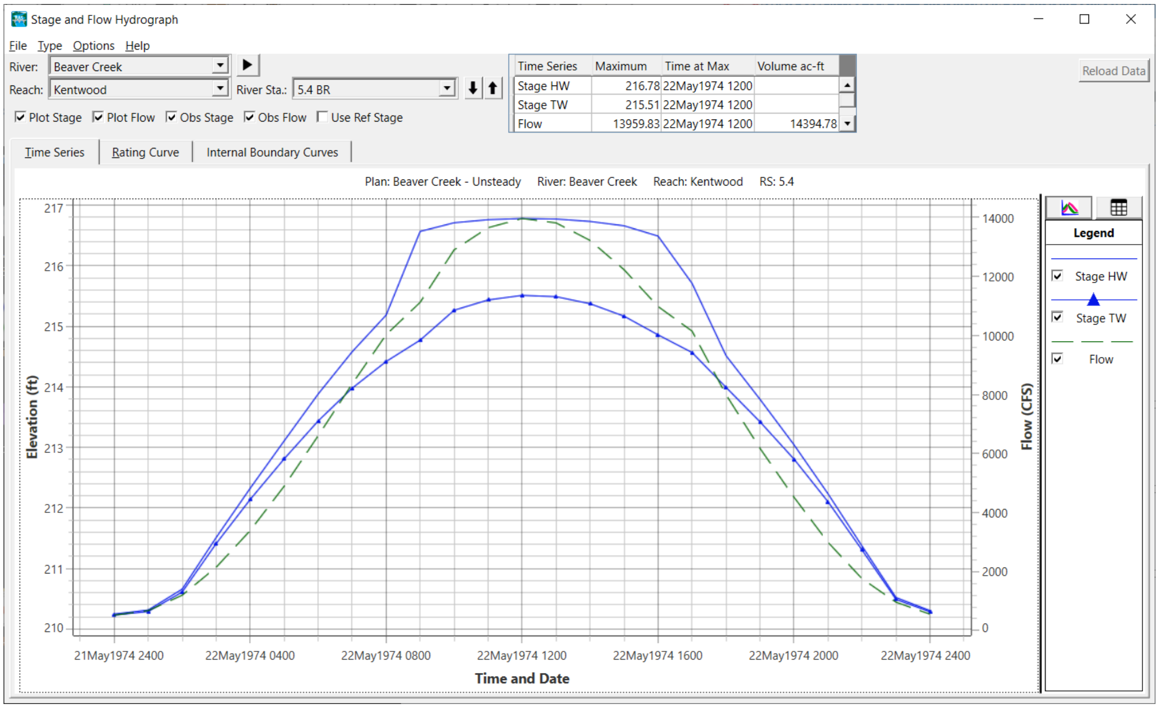


Review Unsteady Flow Results

The Hydraulic Properties Plot for the bridge is shown below. The family of curves looks reasonable, except for the zone around elevation 216, where it looks like we could have trouble. The low-chord elevation is 215.70, where pressure flow using the gate equation will begin. The sharp breaks for several curves reflect the upstream water surface elevation based on the gate equation, which is independent of tailwater. Solutions in that range may have difficulty.

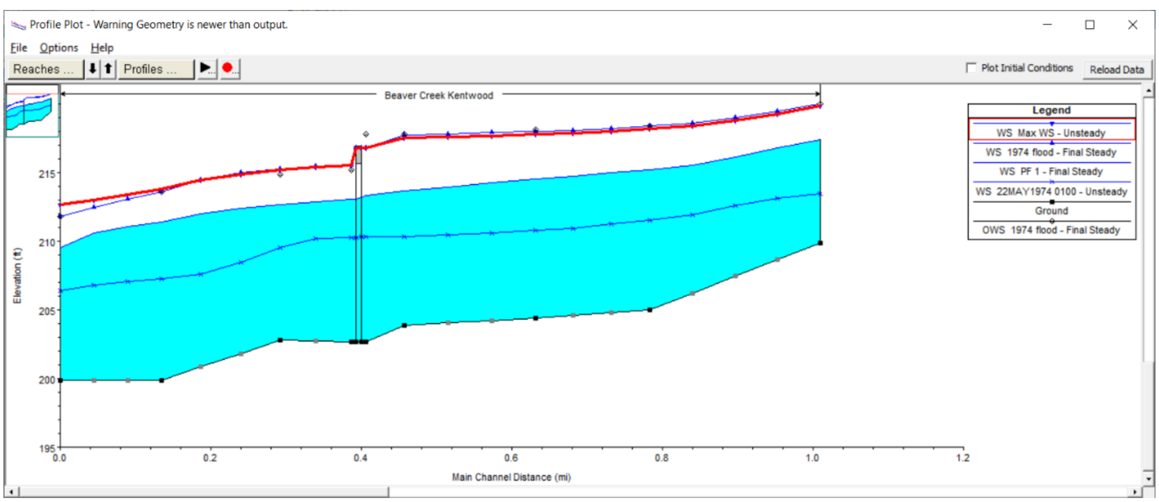


The stage and flow hydrograph plot, for the bridge solution, is shown below. Generally, the hydrographs appear reasonable up to the low-chord elevation. Then there is a break in the hydrographs as they hit the low chord and top of road for the bridge.



The ineffective flow areas around the bridge are turning off in unison.

The profile plot comparing the Max profile from the unsteady run is very close to the steady flow run for the 1974 event. The downstream stage is not in agreement with the steady flow solution. The unsteady run uses a rating curve with an elevation of 212.68’. The observed water surface elevation was 211.8’ per the USGS data.



Questions

How do your steady-flow results compare to the observed data? What methods did you use?

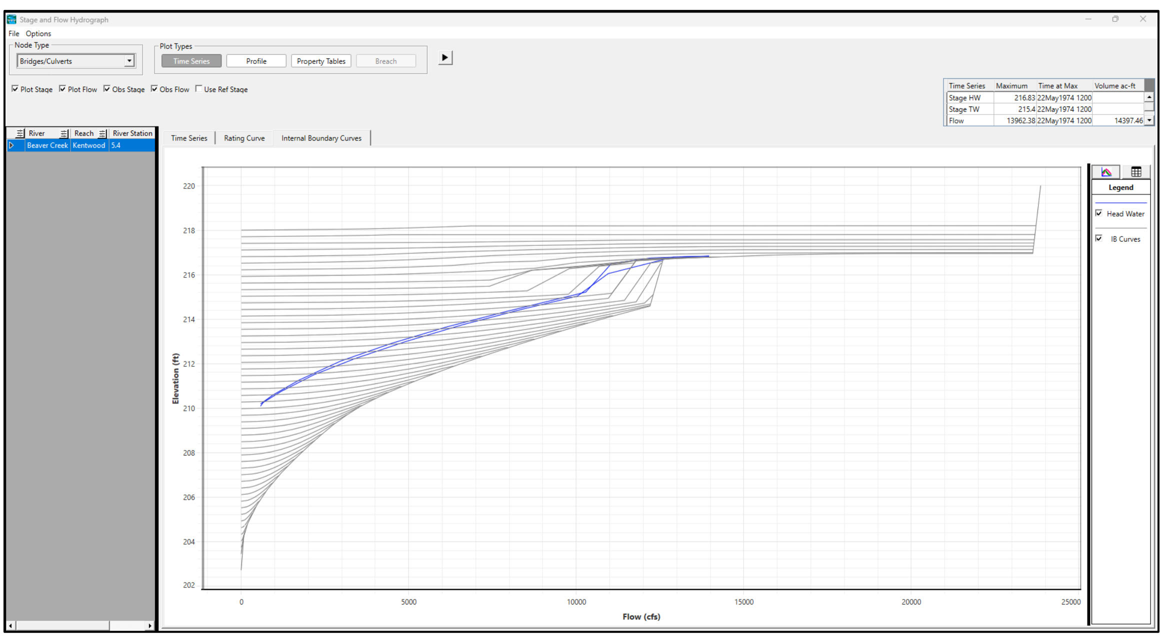
The final steady flow results looked good after significantly adjusting the Manning's n values very high to significantly reduce conveyance. This may well be appropriate given the large obstruction due to heavy trees and the bridge. The computed WSE is still low compared with the observed values. However, the observation could very well have been at the energy grade line – which would make sense near a bridge that the observation was not in the main channel but at the edge of the water.

What settings did you use for HTAB on bridge model processing?

The HTAB settings limited the tailwater and headwater to values above the 1974 flood. Also, the maximum flow was set to 30,000 – twice the 1974 peak. The number of curves were the default setting.

What changes did you make to the unsteady flow model, after you were satisfied with the steady flow solution?

The headwater stage hydrograph is a little ragged around the bridge deck. This can be expected when pressure and weir flow is present; however, it might be improved with a few adjustments. You can plot the solution track through the bridge rating, as shown in the Internal Boundary Curve below. The ragged zone is through the bridge when flow goes from using the energy solution to pressure flow with the gate equation.



If we were not satisfied with the internal boundary curves at the transition from the energy solution to the pressure solution, we could adjust the pressure coefficient to smooth out the flow transition. If a value of 0.40 was used a lower headwater would result from the same tailwater (at a given flow). A comparison of the results showed no significant improvement in the solution and was not used.

The Bridge Only table is shown below for profiles around the peak flow.

Profile Output Table - Bridge Only

File Options Std. Tables Locations Help

HEC-RAS Plan: Unsteady River: Beaver Creek Reach: Kentwood — Reload Data

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 0900	217.01	215.70	1600.36	216.48	10848.59	216.94	72.12	1.63	0.35
Kentwood	5.4	22MAY1974 1000	217.24	215.70	1600.36	216.91	12904.36	216.94	814.03	1.23	0.39
Kentwood	5.4	22MAY1974 1100	217.34	215.70	1600.36	217.12	13648.41	216.94	1278.59	1.12	0.39
Kentwood	5.4	22MAY1974 1200	217.39	215.70	1600.36	217.21	13959.84	216.94	1467.81	1.07	0.40
Kentwood	5.4	22MAY1974 1300	217.37	215.70	1600.36	217.16	13810.83	216.94	1380.16	1.08	0.40
Kentwood	5.4	22MAY1974 1400	217.28	215.70	1600.36	217.00	13216.70	216.94	1018.25	1.15	0.39
Kentwood	5.4	22MAY1974 1500	217.17	215.70	1600.36	216.73	12106.32	216.94	400.88	1.29	0.38
Kentwood	5.4	22MAY1974 1600	217.03	215.70	1600.36	216.52	10981.31	216.94		1.45	0.36
Kentwood	5.4	22MAY1974 1700	216.04	215.70	1600.36	216.39	10233.06	216.94		1.66	0.34

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

The weir flow values from post-processing can be compared to the flow transitions upstream and down from the bridge. The Six XS Bridge Table shows those results for the weir profiles, as shown below. Flow is conserved in the overbanks and overbank flow is comparable to the computed weir flow.

Profile Output Table - Six XS Bridge

File Options Std. Tables Locations Help

HEC-RAS Plan: Unsteady River: Beaver Creek Reach: Kentwood — Reload Data

Reach	River Sta	Profile	E.G. Elev (ft)	W.S. Elev (ft)	Crit W.S. (ft)	Frctn Loss (ft)	C & E Loss (ft)	Top Width (ft)	Q Left (cfs)	Q Channel (cfs)	Q Right (cfs)	Vel Chnl (ft/s)
Kentwood	5.44	22MAY1974 1100	217.55	217.46		0.36		1844.17	3625.03	4246.37	5793.38	4.03
Kentwood	5.44	22MAY1974 1200	217.59	217.50		0.37		1844.36	3699.17	4310.68	5955.13	4.08
Kentwood	5.44	22MAY1974 1300	217.57	217.48		0.36		1844.27	3659.42	4274.78	5871.12	4.05
Kentwood	5.41	22MAY1974 1100	217.34	216.76	212.13			1841.20	494.88	12340.12	813.41	6.44
Kentwood	5.41	22MAY1974 1200	217.39	216.78	212.23			1841.37	507.89	12614.81	837.14	6.57
Kentwood	5.41	22MAY1974 1300	217.37	216.77	212.18			1841.29	501.72	12483.15	825.96	6.51
Kentwood	5.4 BR U	22MAY1974 1100	217.34	216.76	212.41				312.06	12506.43	814.17	7.81
Kentwood	5.4 BR U	22MAY1974 1200	217.39	216.78	212.52				364.83	12651.75	952.08	7.91
Kentwood	5.4 BR U	22MAY1974 1300	217.37	216.77	212.46				339.53	12579.31	885.95	7.86
Kentwood	5.4 BR D	22MAY1974 1100	217.34	216.76	212.41				312.06	12506.43	814.17	7.81
Kentwood	5.4 BR D	22MAY1974 1200	217.39	216.78	212.50				364.83	12651.75	952.08	7.91
Kentwood	5.4 BR D	22MAY1974 1300	217.37	216.77	212.46				339.53	12579.31	885.95	7.86
Kentwood	5.39	22MAY1974 1100	216.23	215.44		0.43		1687.19	411.47	12386.77	850.17	7.49
Kentwood	5.39	22MAY1974 1200	216.32	215.51		0.43		1693.75	428.01	12643.48	888.35	7.57
Kentwood	5.39	22MAY1974 1300	216.29	215.49		0.43		1691.90	421.45	12515.75	873.63	7.52
Kentwood	5.3450*	22MAY1974 1100	215.47	215.32		0.24		1657.84	3194.46	4734.61	5703.96	4.67
Kentwood	5.3450*	22MAY1974 1200	215.54	215.39		0.24		1663.89	3268.01	4795.25	5891.56	4.69
Kentwood	5.3450*	22MAY1974 1300	215.52	215.37		0.24		1662.25	3235.94	4761.00	5818.78	4.66

Energy gradeline for given WSEL.

How did the unsteady-flow simulation compare to the steady-flow profile with 14,000 cfs?

A comparison plot is shown below for the Unsteady flow Max WSE and the 14,000 cfs steady flow. The profiles compare well, but in general, the unsteady flow profile is lower. We can expect the unsteady flow profile answer to be slightly lower because the unsteady flow solution does not use the contraction/expansion coefficients for computing energy losses. At the downstream boundary, it is evident that the unsteady solution started at a higher water surface elevation than the steady flow solution due to the use of a rating curve. (The lower two profiles are the third profile unsteady-flow profile from post processing and the first profile steady flow because the first and third profiles were selected for the two plans.)