

# Trouble Shooting Workshop Solution

## Task 1

As seen in Figure 1, the water surface computed for Beaver Creek is unstable, and eventually the errors become very large and the water surface bounces up and down erratically.

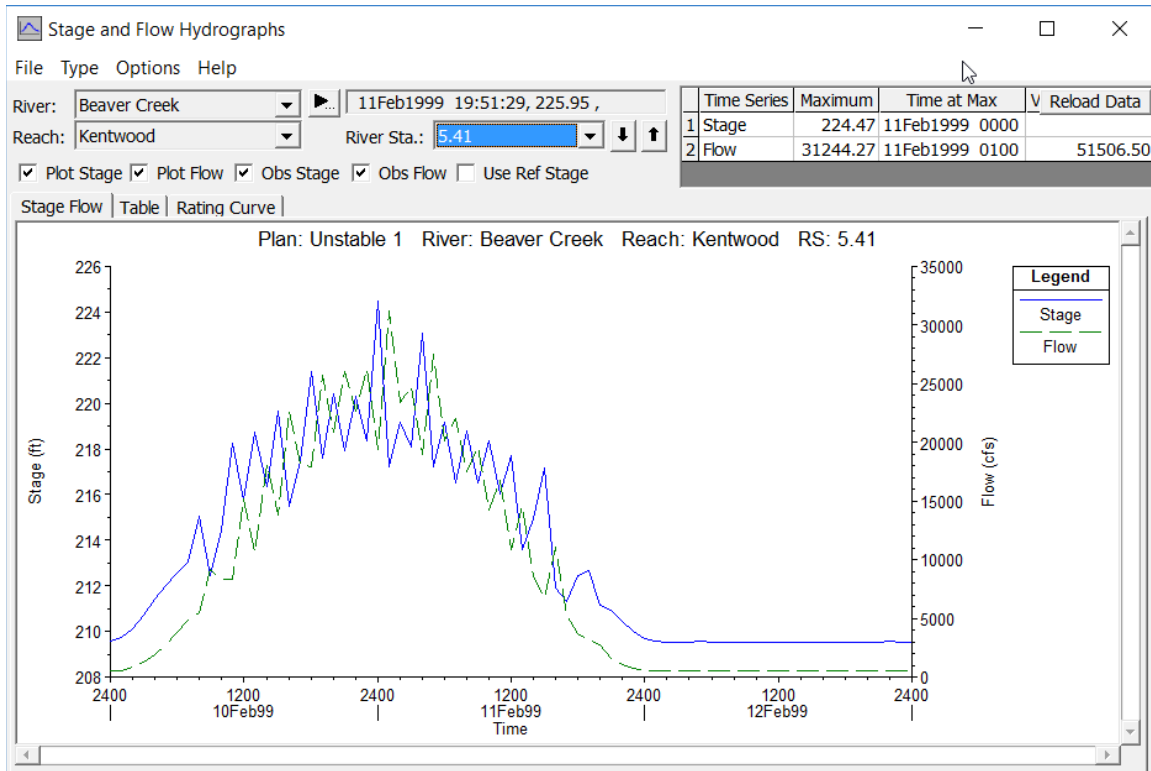
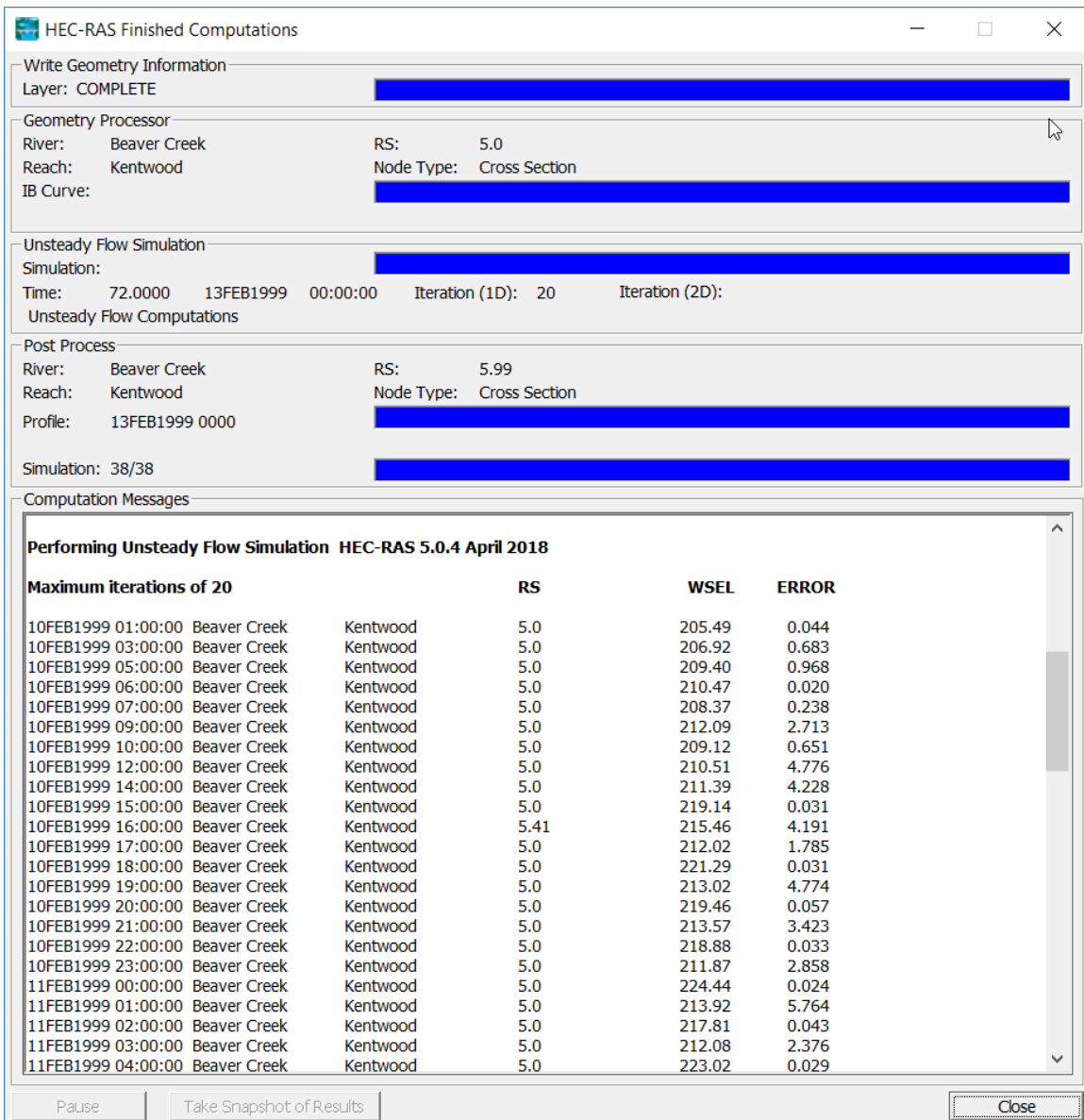


Figure 1 Profile Plot of Progressing Instability

## Questions

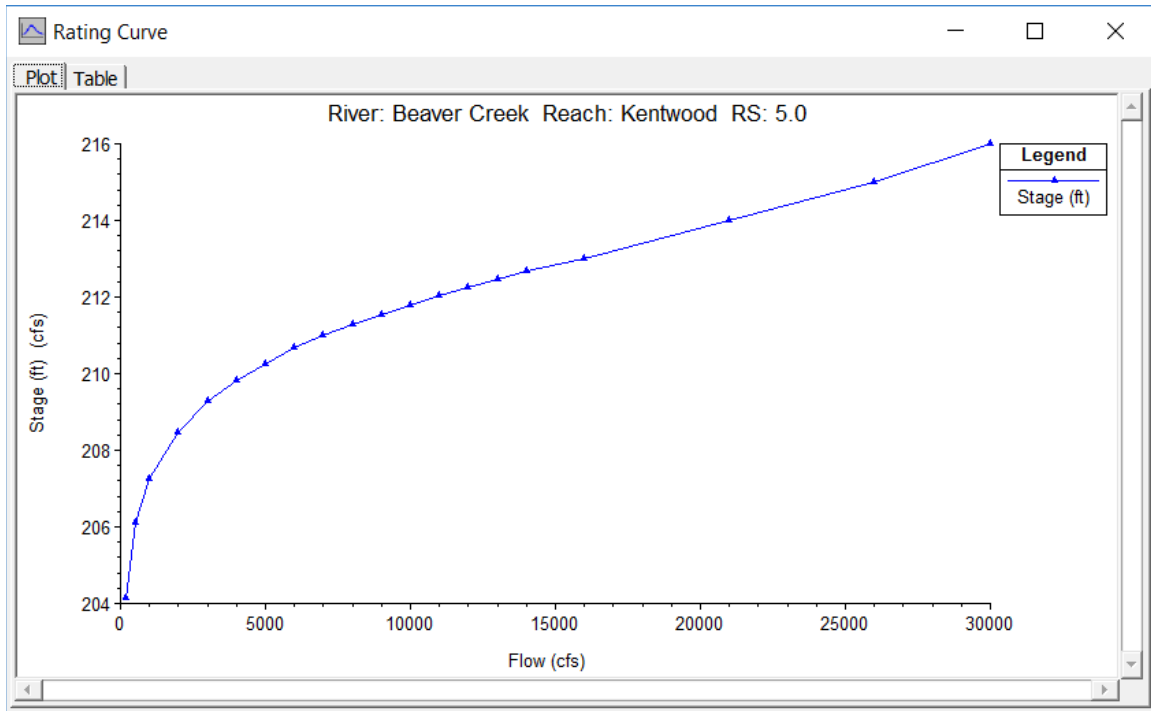
**At what time step and at what location did the program begin to go unstable?**

The computational messages on the HEC-RAS Hydraulic Computations window showed some minor instability at the very first time step. However, there was no significant instability until 0300 on 10FEB1999, at which time the computational error was up to 0.681 feet. From there things just got worse, and the errors grew very large. The location of the largest errors was shown as cross section 5.0.



**Figure 2 Detailed Computational Messages**

Since the instability is occurring near the downstream end of the model, the user should examine the downstream boundary condition first. This particular data set has a rating curve at the downstream boundary. Figure 3 displays a plot of the rating curve. The plot shows a smooth continuously increasing rating curve. Most likely, the rating curve is not creating the instability.



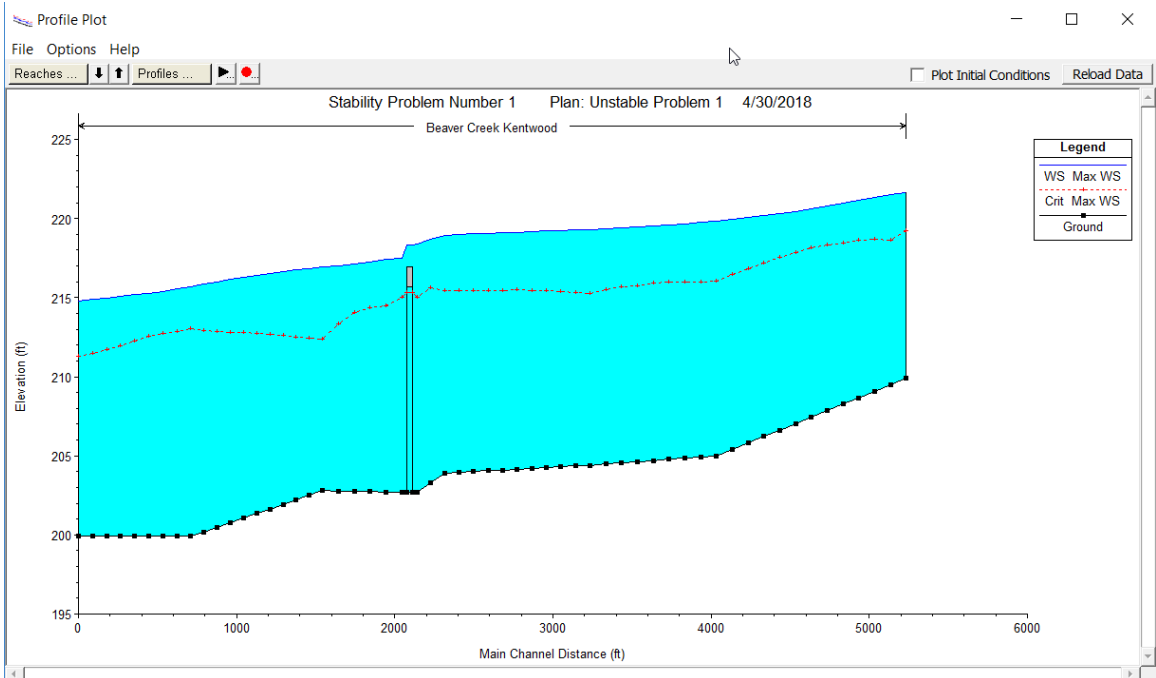
**Figure 3 Downstream Boundary**

**What caused the instability?**

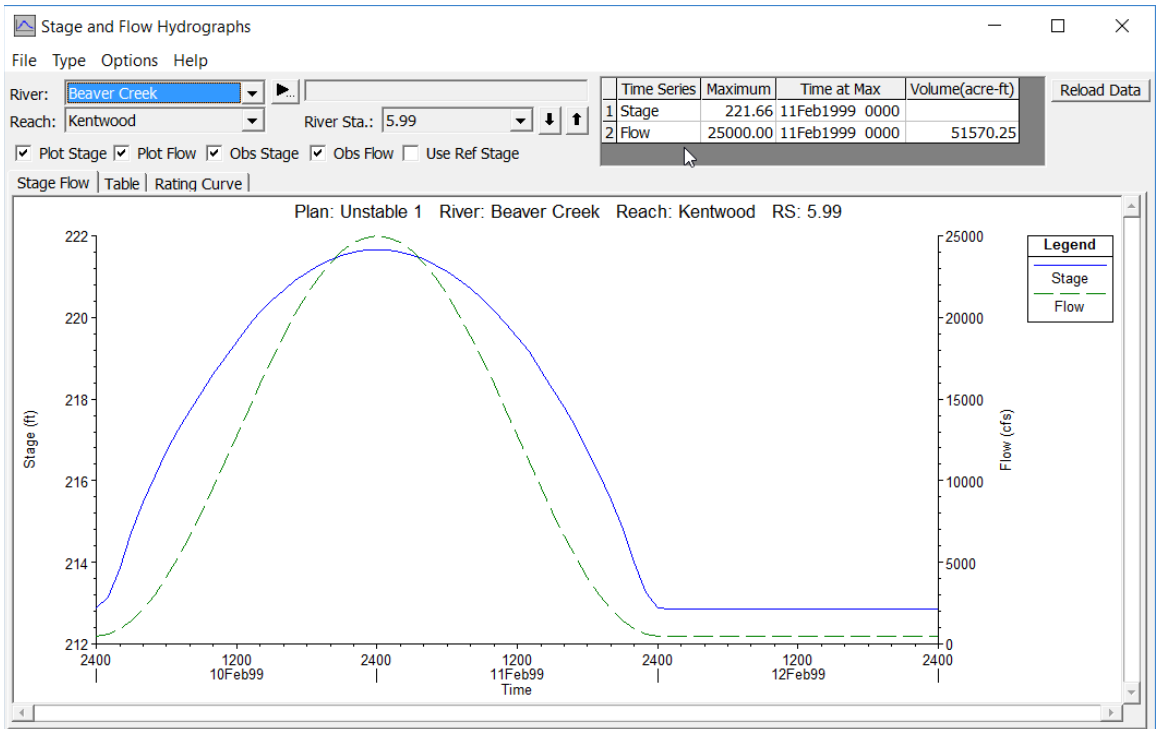
Upon further review of the data, no problems were found with the geometry or boundary conditions. In the **Unsteady Flow Analysis Window**, the computation interval is set at one hour. This is an extremely large time interval for the computations. The upstream boundary condition for this simulation is a rapidly rising flow hydrograph. The one hour interval cannot capture the rapid change in flow with time and causes the instability.

**If you were able to fix the instability, how was this achieved?**

The computation interval was lowered to five minutes and the simulation was run. As seen in Figures 4 and 5, the change produced a stable simulation.



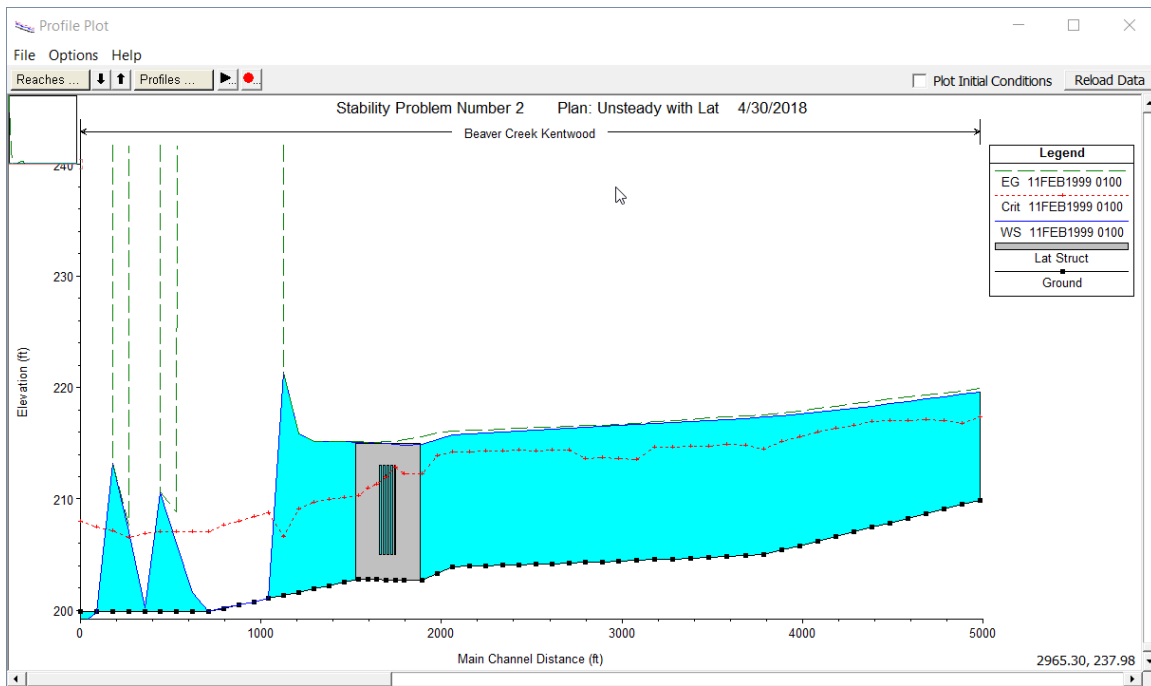
**Figure 4 Maximum Water Surface Profile with a Computation Interval of 5 Minutes**



**Figure 5 Hydrograph Plot with Computation Interval at 5 Minutes**

## Task 2

The simulation was run and the **Profile Plot** was examined. The animation tool was used to progress through the time steps. The animation shows that the program went completely unstable at the time step on 10FEB1999 at 2400. This is shortly after the gates were opened on time 2000. Figure 6 shows the profile just after the model went unstable.



**Figure 6. Instability Occurring on the Profile Plot**

## Questions

**At what time step and at what location did the program begin to go unstable?**

Reviewing the output shows that the model begins to go unstable just after the gates are opened, around 10FEB1999 21:15. The location of the instability is at multiple locations downstream of the location of the lateral structure with the gates. After analyzing the output, it was noticed that the flow going through the gates is highly unstable from one time step to the next. It is difficult to tell at exactly what time step the program became unstable, but there is definitely a problem right when the gates open up.

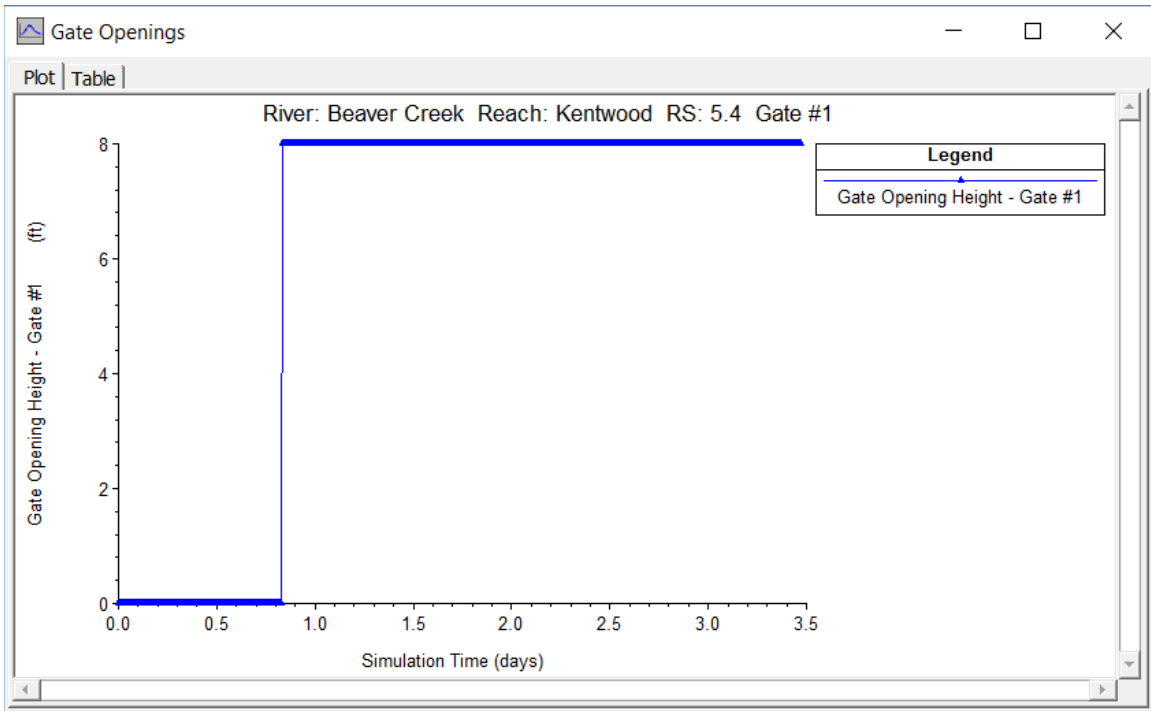
## What caused the instability?

Figure 7 displays the tabular output for the Lateral Structure hydrograph plot just after the gates were opened. As seen on the figure, the flowrate through the gates went from 0.0 cfs to 5311 cfs in one time step (5 min.). This is a large change in flow leaving the reach between time steps. Also notice that the total flow in the river upstream of the gates just before they opened was around 12930 cfs. The 5320 cfs going through the gates is around 41% of the total flow in the river. This is a tremendous percentage of the flow to take out of the channel in 5 minutes. The rapid change in flow is most likely the cause of the instability in the solution.

Date	Stage HW US	Stage HW DS	Stage TW	Flow HW US	Flow HW DS	Flow Leaving	Weir Flow (includes breach overflow)	Gate Flow - Gate #1	Gate Open - Gate #1
	INST-VAL Feet	INST-VAL Feet	INST-VAL Feet	INST-VAL cfs	INST-VAL cfs	INST-VAL cfs	INST-VAL cfs	INST-VAL cfs	INST-VAL Feet
13 10Feb1999 1200	213.41	213.02	205.00	6969.81	6925.62	0.00	0.00	0.00	0.00
14 10Feb1999 1300	213.71	213.32	205.00	7866.72	7824.35	0.00	0.00	0.00	0.00
15 10Feb1999 1400	213.99	213.59	205.00	8740.40	8699.80	0.00	0.00	0.00	0.00
16 10Feb1999 1500	214.24	213.85	205.00	9589.71	9550.41	0.00	0.00	0.00	0.00
17 10Feb1999 1600	214.47	214.07	205.00	10401.43	10364.69	0.00	0.00	0.00	0.00
18 10Feb1999 1700	214.68	214.28	205.00	11154.29	11120.32	0.00	0.00	0.00	0.00
19 10Feb1999 1800	214.85	214.46	205.00	11845.23	11815.40	0.00	0.00	0.00	0.00
20 10Feb1999 1900	215.00	214.60	205.00	12452.36	12426.31	0.00	0.00	0.00	0.00
21 10Feb1999 2000	214.62	214.30	205.06	14071.97	10108.06	5320.44	0.00	5320.44	8.00
22 10Feb1999 2100	214.08	213.68	205.81	13399.57	8932.93	4475.42	0.00	4475.42	8.00
23 10Feb1999 2200	215.45	215.49	206.61	11852.30	3994.37	6542.02	322.27	6219.76	8.00
24 10Feb1999 2300	217.68	217.72	208.08	12977.75	1118.10	11630.29	4771.21	6859.08	8.00
25 10Feb1999 2400	217.24	217.28	209.94	12075.46	1118.12	10400.08	3659.92	6740.16	8.00
26 11Feb1999 0100	214.60	214.63	211.05	13818.51	7020.13	5579.31	0.00	5579.31	8.00
27 11Feb1999 0200	217.46	217.50	212.58	11988.69	532.04	10999.48	4199.89	6799.59	8.00
28 11Feb1999 0300	215.88	215.91	213.48	11214.35	4529.75	5058.73	896.75	4161.98	8.00
29 11Feb1999 0400	216.52	216.33	214.61	18222.92	16272.78	5212.44	1786.03	3426.41	8.00
30 11Feb1999 0500	215.25	215.14	214.84	12070.73	9223.10	1506.32	73.09	1433.22	8.00
31 11Feb1999 0600	217.51	217.52	215.71	11625.41	4154.15	7743.33	4297.96	3445.37	8.00
32 11Feb1999 0700	219.73	223.20	215.98	-4562.80	-34146.01	24140.39	16884.04	7256.35	8.00
33 11Feb1999 0800	204.09	212.53	215.63	24.09	-1473.23	-4026.26	-538.37	-3487.89	8.00
34 11Feb1999 0900	215.11	215.11	215.17	-135.50	363.53	-679.05	-74.34	-604.71	8.00
35 11Feb1999 1000	219.58	219.62	215.81	23412.38	10240.17	16335.41	10648.43	5686.98	8.00
36 11Feb1999 1100	217.50	217.49	217.42	10903.28	7744.02	3476.78	2769.21	707.57	8.00
37 11Feb1999 1200	217.20	216.88	217.56	11460.98	19904.64	-6184.22	-4377.04	-1807.18	8.00
38 11Feb1999 1300	216.04	215.69	216.69	9882.23	16084.80	-4692.62	-2381.67	-2310.95	8.00
39 11Feb1999 1400	215.30	214.96	216.47	7256.57	12595.47	-4864.48	-1931.40	-2933.07	8.00

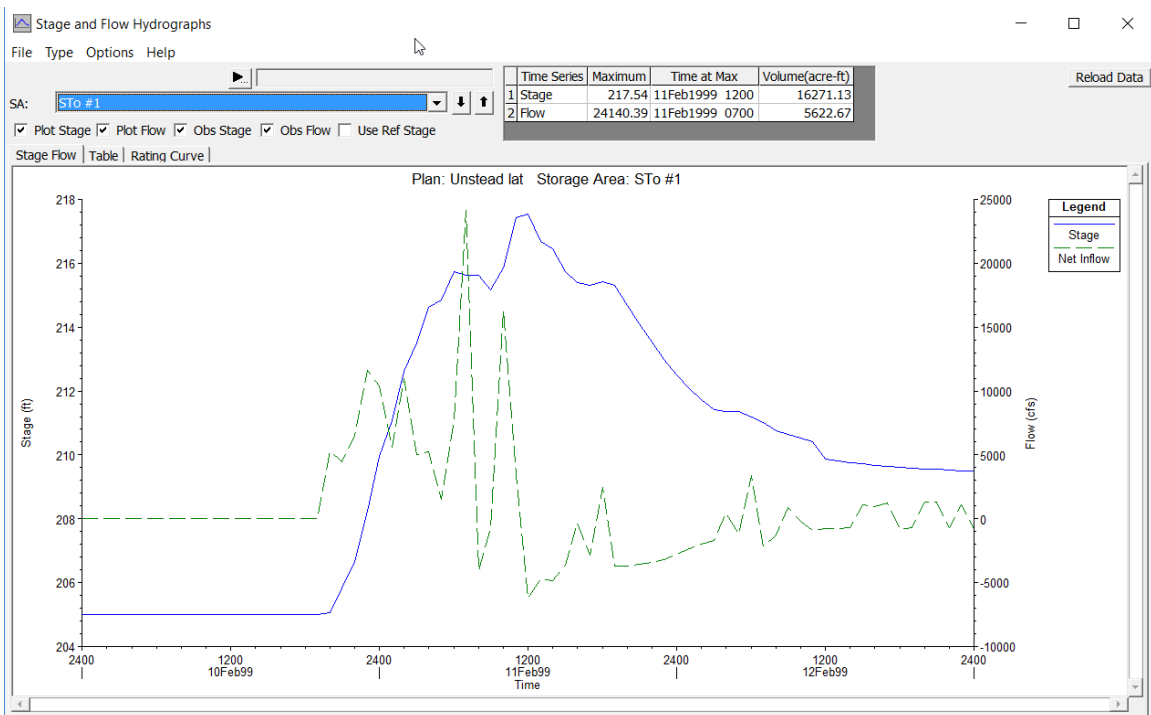
Figure 7 Detailed Output

Under the **Unsteady Flow Data Window** the **Time Series of Gate Openings** was examined. As can be seen on Figure 8, the gates are rapidly opened (5 minute interval). The rapid opening of the gates is the cause of the rapid increase in flow, which in turn caused the instability.



**Figure 8 Plot of Gate Opening**

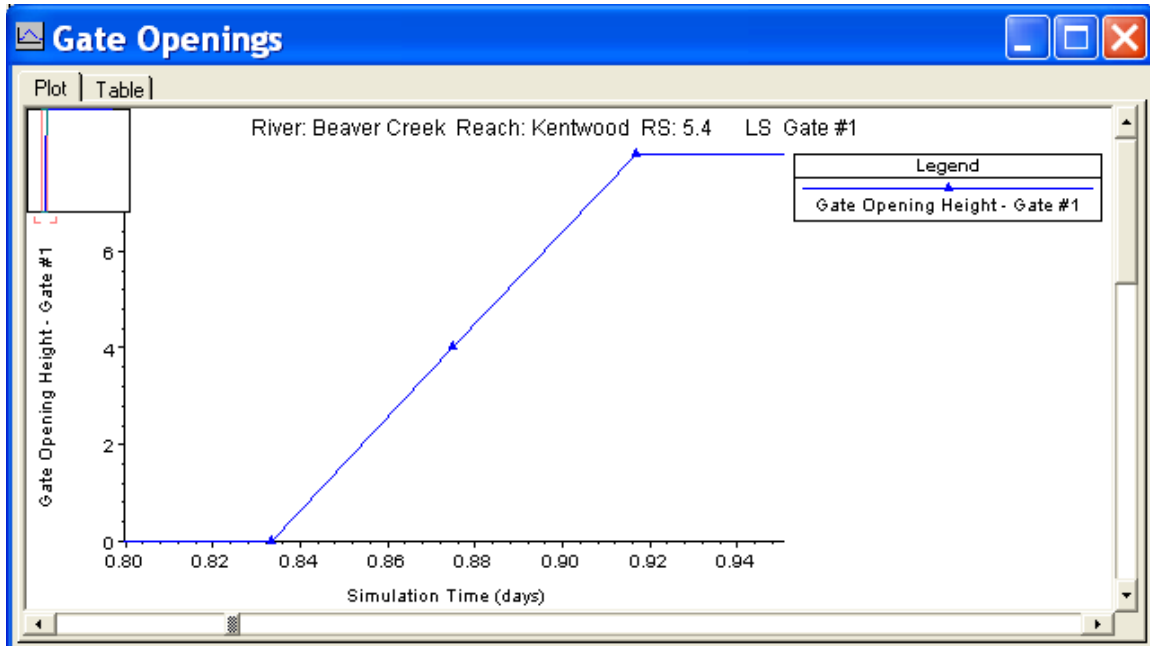
Figure 9 displays the **Stage and Flow Hydrograph** of the storage area for the unstable simulation. The sudden spike in flow that occurred when the gates were opened caused the instability. Shortly after that the flow went negative to a very high amount.



**Figure 9 Stage and Flow of Storage Area for Unstable Simulation**

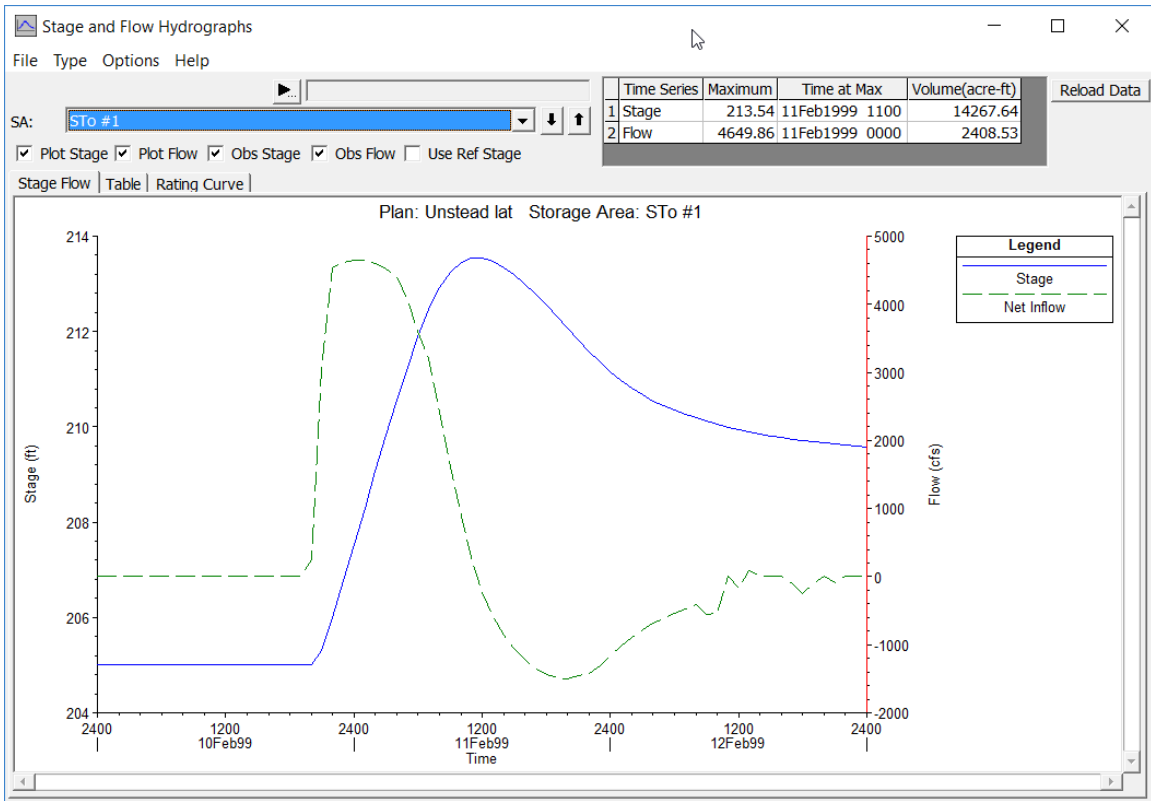
**If you were able to fix the instability, how was this achieved?**

The time series of gate openings was adjusted in the **Unsteady Flow Data Window**. As seen in Figure 10, the gates were opened over a 2 hour period of time. Additionally, the “Gate Flow Submergence Decay Exponents” were changed from 1.0 to 3.0 under the “Computational Options and Tolerances” window.



**Figure 10 Plot of Slower Gate Opening**

Figure 11 displays the **Stage and Flow Hydrograph** of the storage area for the stable simulation. By opening the gates at a slower rate the rapid change in flow leaving the reach was decreased. This prevented instabilities in the simulation. Another solution would have been to reduce the time step. However, you were asked not to do that for this problem.



**Figure 11 Stage and Flow of Storage Area for Stable Simulation**

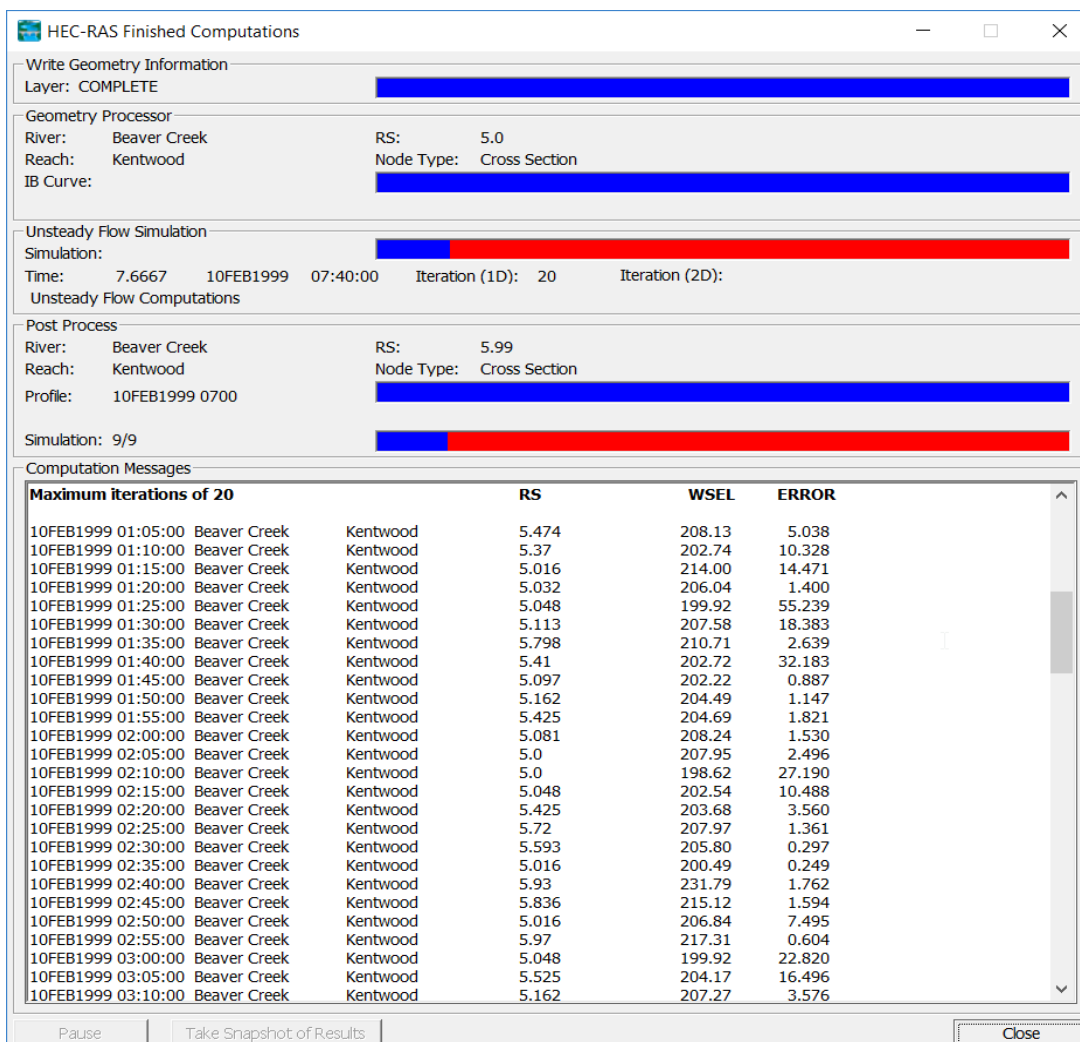
## Task 3

Examining the animation of the **Profile Plot** and reviewing the computational messages on the “HEC-RAS Hydraulic Computations” window, showed that the program crashed near the beginning of the simulation. The detailed output was examined to determine exactly when the instability occurred.

## Questions

**At what time step and at what location did the program begin to go unstable?**

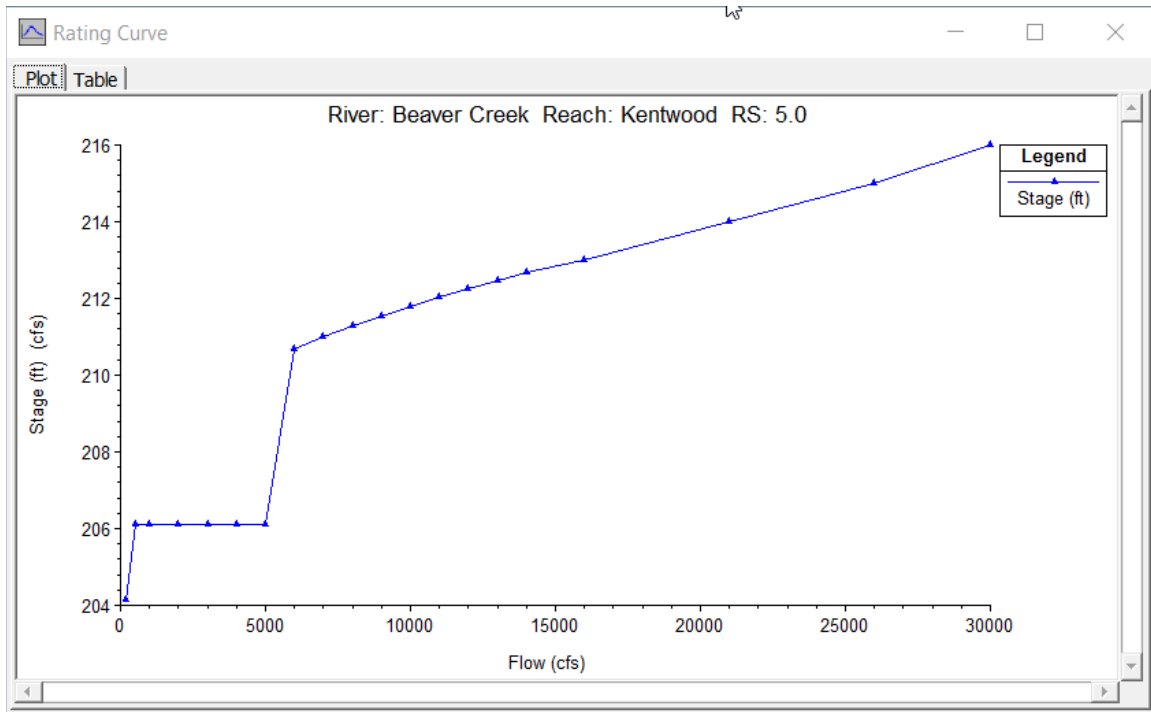
The computational messages were reviewed from the Unsteady Flow Computational Messages window, as shown in Figure 12. The model began to go unstable near the downstream end of the model at time 10FEB1999 01:05:00.



**Figure 12 Unsteady Flow Computational Window**

## What caused the instability?

Since the instability is occurring at the cross sections near the downstream end of the model, the user should examine the downstream boundary condition. This particular data set has a rating curve at the downstream boundary. Figure 13 displays a plot of the rating curve.

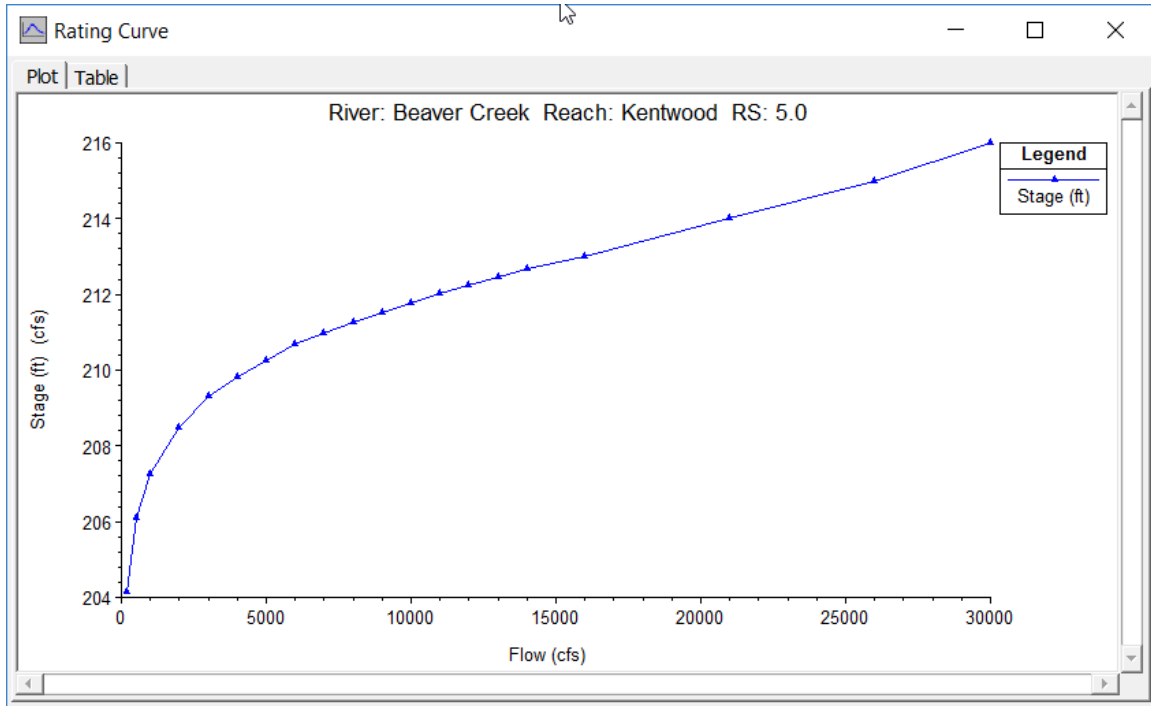


**Figure 13 Downstream Boundary Condition**

As seen in the plot, there is an area of discontinuity in the rating curve. This discontinuity causes a large difference in the water surface slopes at lower flows. The program goes unstable because of large differences in the derivatives caused by the large differences in the water surface slopes.

**If you were able to fix the instability, how was this achieved?**

To correct the problem the rating curve was adjusted to produce a smooth, continuous increase in flow versus stage. Figure 14 displays the adjusted rating curve that produced a stable simulation.



**Figure 14 Adjusted Rating Curve Producing Stability**

## Task 4

The **Profile Plot** for this example shows a dramatic change in water surface slope occurring at River Station 7.0, which is at the upstream end of a significant drop in the channel.

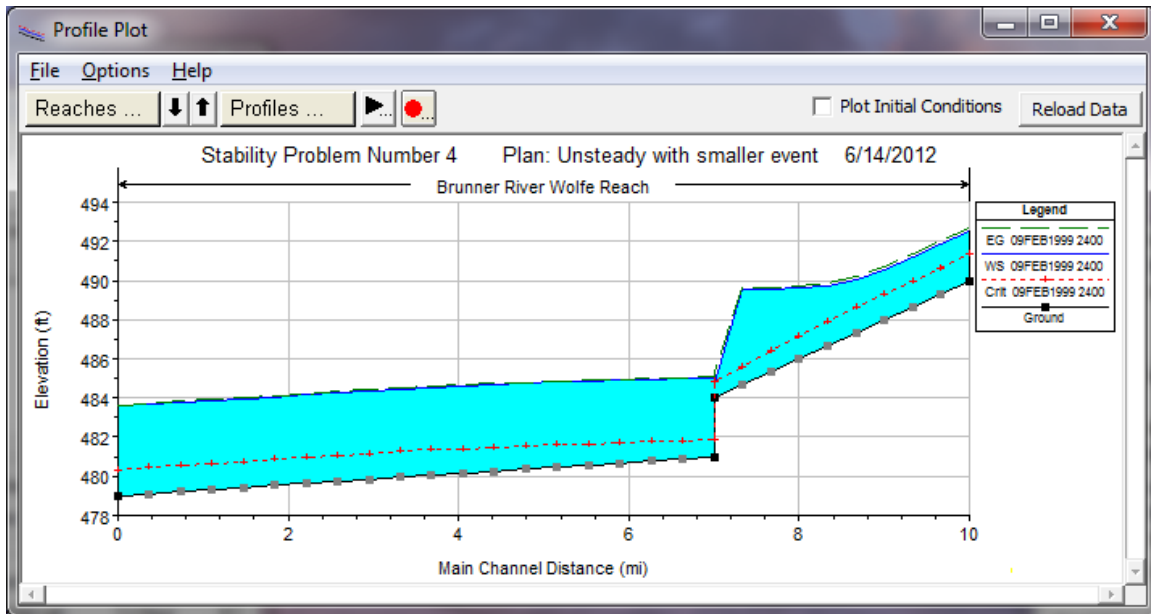


Figure 15 Profile Plot of Instability

## Questions

**At what time step and at what location did the program begin to go unstable?**

Examining the animation of the **Profile Plot** shows that the program went unstable where the slope of the reach dramatically changes, River Station 7.0. Figure 15 displays the **Profile Plot** illustrating the instability. The instability occurs at the beginning of the simulation and progressively became larger.

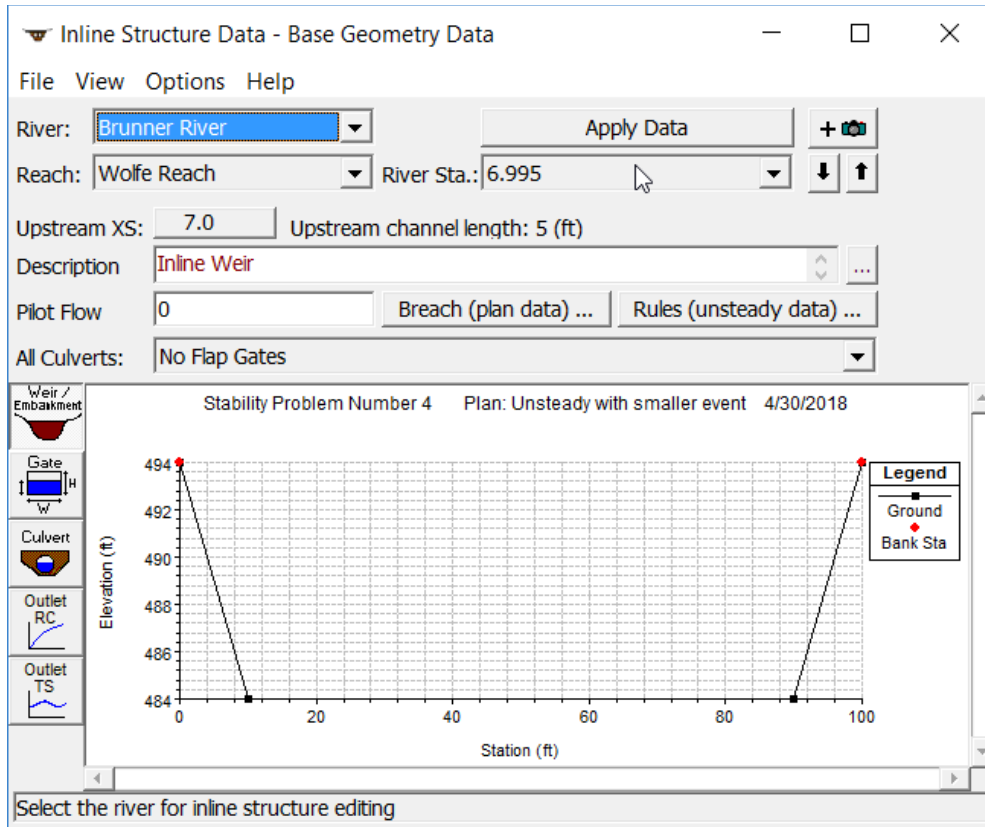
### **What caused the instability?**

As seen on Figure 15, the water surface profile goes to critical depth where the slope of the reach changes. When HEC-RAS is run in its default mode (non-mixed flow regime), it is limited to subcritical flow for unsteady flow simulations.

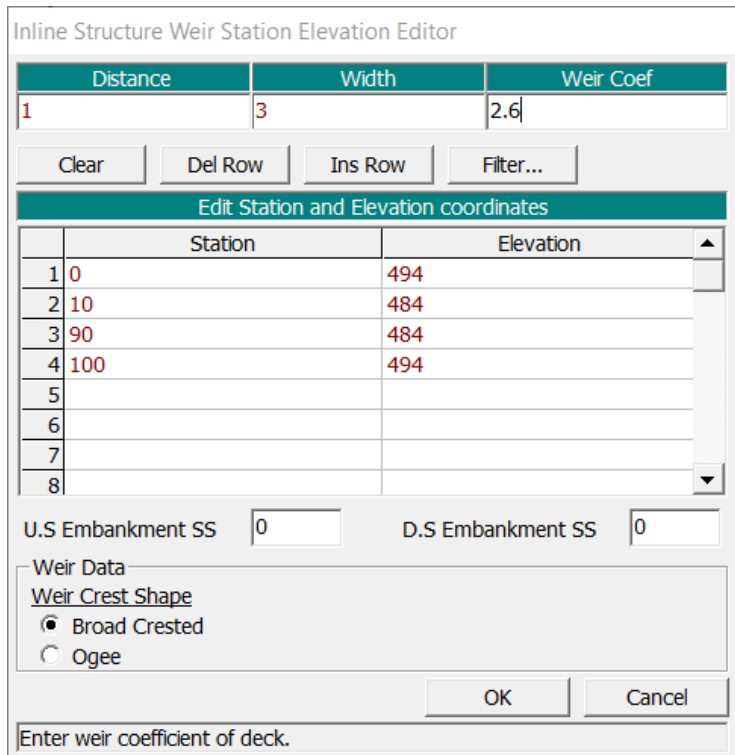
### **If you were able to fix the instability, how was this achieved?**

There are three or four possible solutions for this problem. The first involves examining the base flow from the input hydrograph. The simulation with the instability had a base flow and initial condition of 700 cfs. This low flow allows the water surface to pass through critical depth. One solution is to increase the base flow and initial flow to a value that does not pass through critical depth (i.e. high enough base flow to submerge the drop). A value of 1000 cfs was set and the simulation was re-run. This adjustment to the hydrograph and initial conditions provided a stable simulation.

Second, the change in slope could be modeled as an inline weir. An inline weir was added just downstream of the change in slope at River Station 6.995. Figure 15 displays the cross section view of the inline weir. Figure 16 and 17 display the dimensions of the inline weir.



**Figure 16 Plot of Inline Weir**

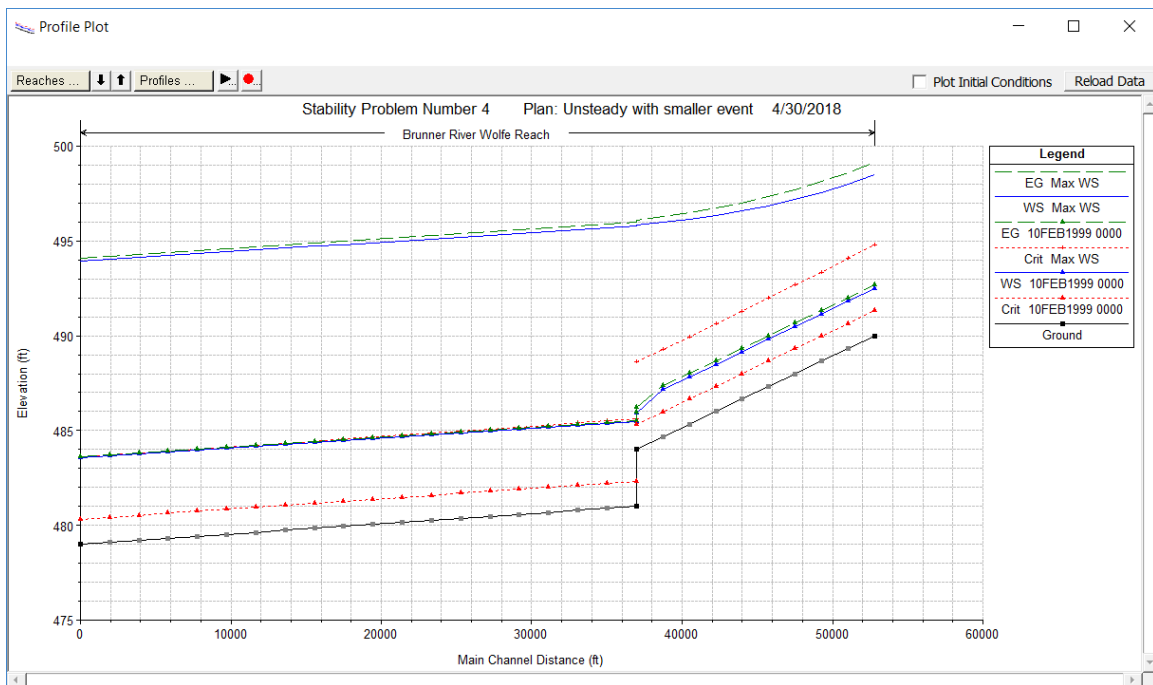


**Figure 17 Dimensions of Inline Weir**

Notice that the inline weir has the same dimensions as the cross section. Thus, the placement of the inline weir at this cross section does not impede the flow in any manner. The purpose of placing the inline weir at this point is to provide stability in the model. The solution of the continuity and momentum equations are causing the instability at the point where the slope dramatically changes. With the inline weir in place, RAS uses a weir flow equation instead of the unsteady flow equations for the solution over the drop. This solution allows the program to get a subcritical water surface both upstream and downstream of the drop. The flow transition is handled by the weir equation and is not modeled directly.

The third solution to this problem would be to turn on the mixed flow regime option. With this option turned on the program automatically reduces the magnitude of the inertial terms in the momentum equation when the Froude number starts to get close to 1.0. This feature allows the program to solve for the water surface passing through critical depth, and then going into a hydraulic jump.

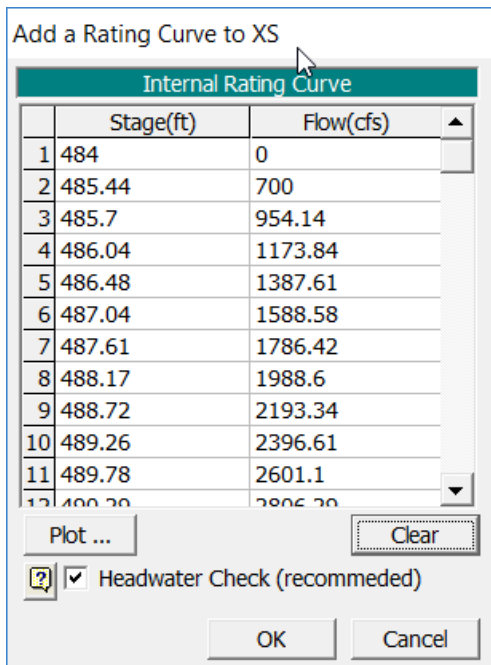
All three of these methods were tried on this data set and they worked. The resulting profiles are shown in Figure 18. The lower profile is at the base flow of 700 cfs, and the upper profile is the maximum profile.



**Figure 18. Resulting profiles from mixed flow regime run.**

The last possible solution to this problem would be to put a Rating Curve into the cross section at the top of the drop. By adding a rating curve to this cross section, the program does not calculate the water surface with the continuity and momentum equations at this

location. Instead it simply gets the water surface from the rating curve. Shown in Figure 19 is the rating curve editor, which is selected from the **Options** menu of the Cross Section editor.



**Figure 19. Rating Curve Editor for Cross Sections.**

As shown in Figure 19, the user enters Stage vs. Flow from low to high in order to bound all possible flows that may occur during a run. There is also an option called “Headwater Check”. This option looks at the water surface downstream of this cross section, and if the water surface downstream is greater than what is coming from the rating curve, then the downstream water surface is applied to the cross section with the rating curve. This allows for downstream water surface elevations to affect the cross section with the rating curve do to high tailwater elevations. In general, this should be turned on.