Dam Breach Modeling

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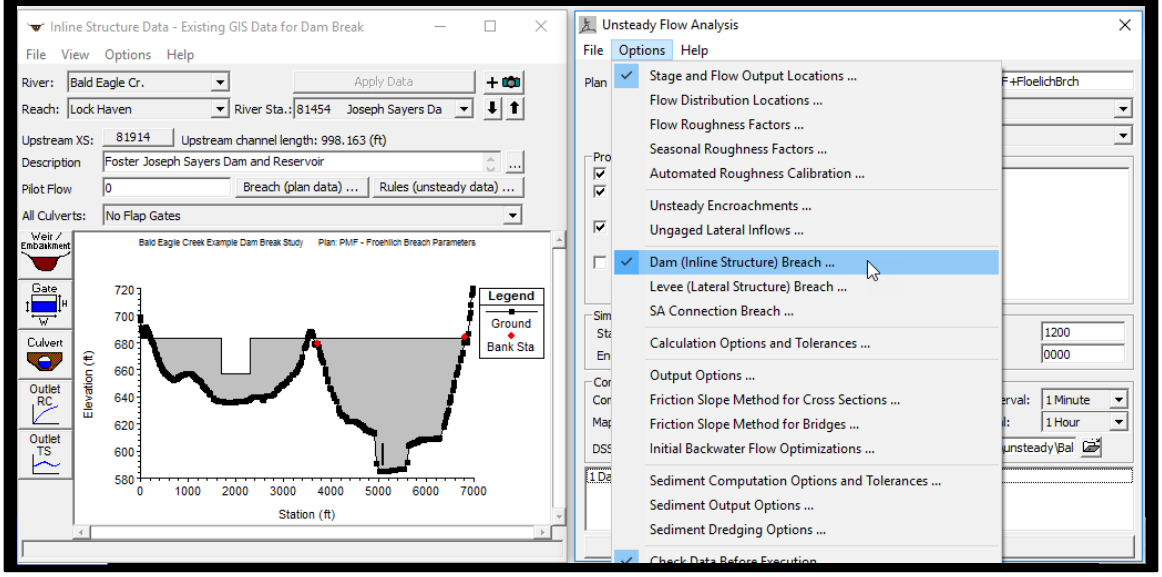
Dam & Levee Breach



A dam breach can be performed on an inline weir and a levee breach can be performed on a lateral weir. The breach editor can be accessed from either the unsteady flow analysis editor or by clicking the breach button on the inline or lateral weir editor. It is usually more convenient to just click on the button on the appropriate geometry editor, but the user should keep in mind that breach information is stored with the plan data not the geometry data. For instance, to compare a "breached" with a "not breached" run, the project should have two plans, but they can (and usually should) have the same geometry.

The dam breach data (next slide) is as follows:

Breach This Structure - This check box is used to decide if the program will perform the breach or not. This box was added to allow the user to turn certain breaches on or off, without loosing the user entered breach information.

Breach Method – User Entered Data is the default type of breach where growth is based on user entered time. Simplified Physical grows the breach based on the velocity through the breach.

Center Station - The centerline stationing of the final breach.

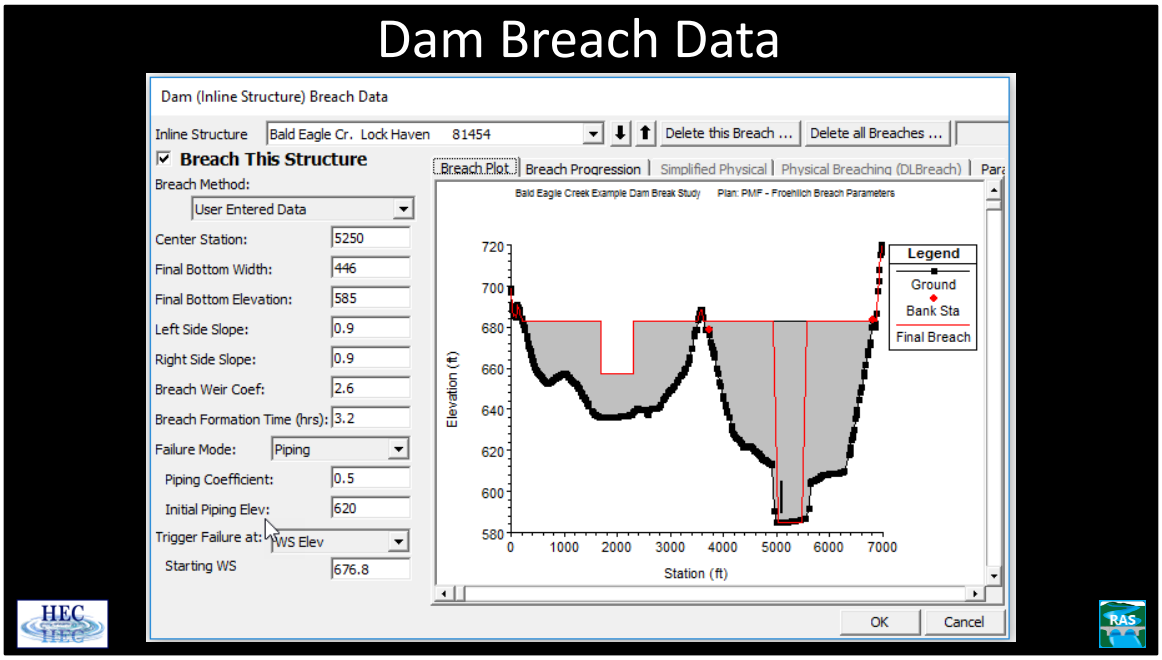
Final Bottom Width - The bottom width of the breach at its maximum size.

Final Bottom Elevation - The elevation of the bottom of the breach after it has been fully developed.

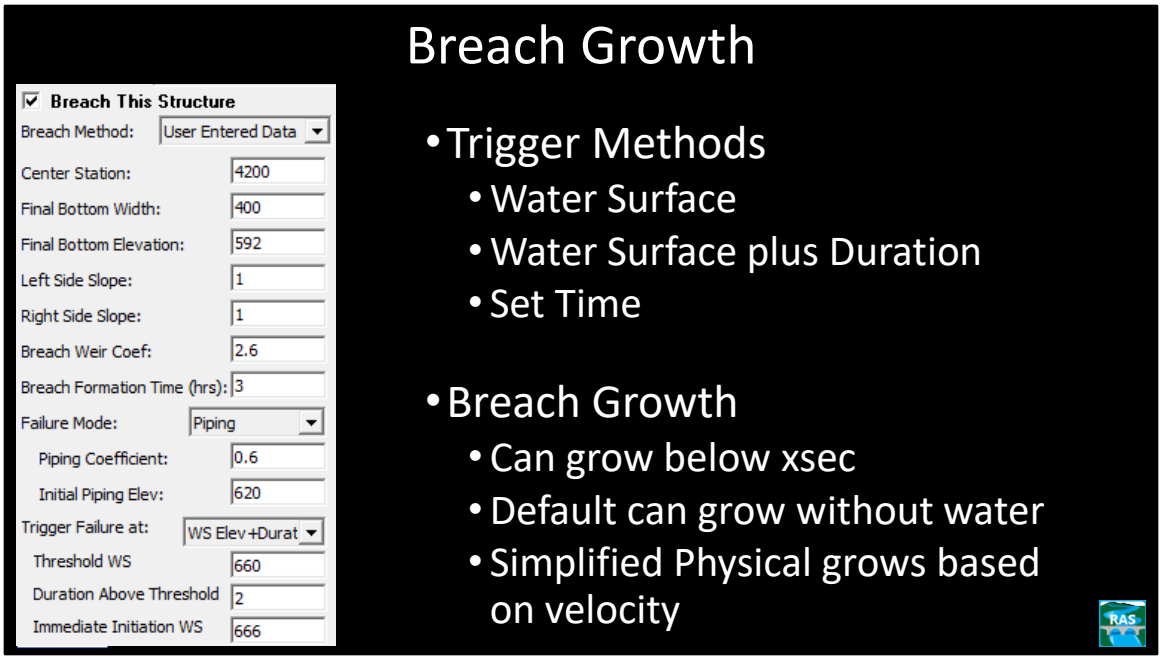
Left Side Slope - This is the left side slope of the trapezoidal breach.

Right Side Slope - This is the right side slope of the trapezoidal breach.

Dam Breach Data

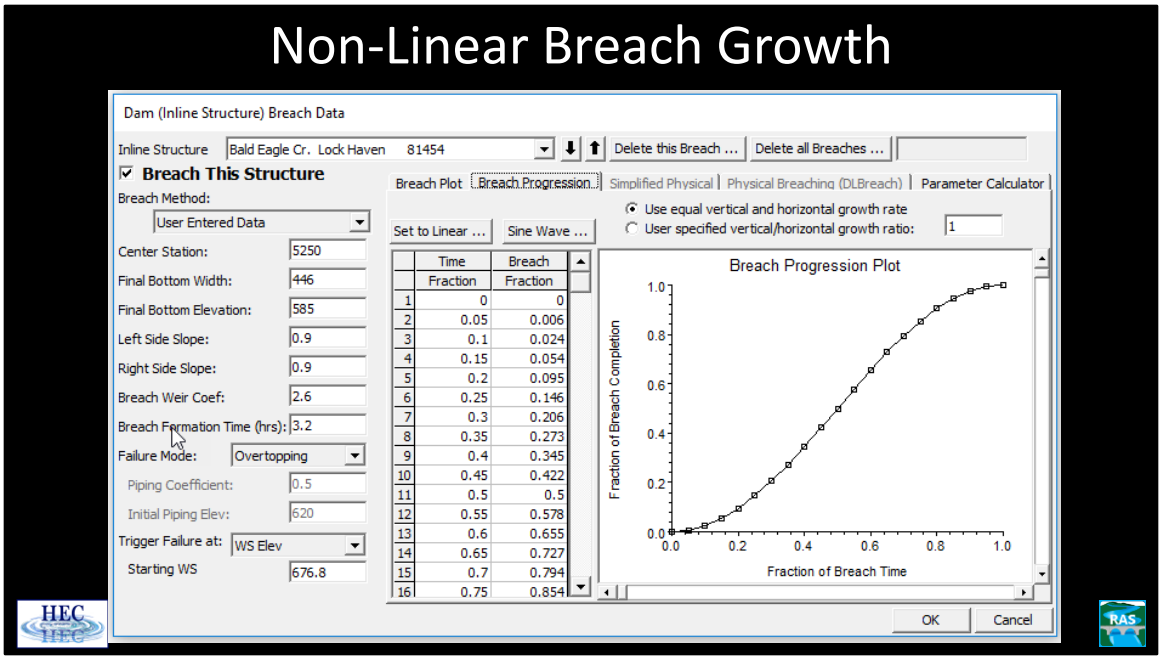


Breach Weir Coef - The weir coefficient to be used for the flow through the breach.
Breach Formation Time (hrs) - The breach development time in hours.
Failure Mode - This option allows the user to choose between two different failure modes, an Overtopping failure and a Piping failure.
Piping Coefficient - If a piping failure mode is selected, the user must enter a piping coefficient.
Initial Piping Elev. - If a piping failure mode is selected, the user must enter an initial piping elevation.
Trigger Failure At - This field is used to select one of three trigger methods for initiating the breach. The three trigger methods are a water surface elevation, a specific time and date, and a water surface elevation plus a duration.
Starting WS - If the user selects water surface elevation for the failure trigger mode, then this field must be entered. This field represents the water surface elevation at which the breach should begin to occur.
Start Date - If the user selects a starting date and time as the failure trigger mode, then this field must be entered. This field is used to enter the date at which the breach will begin to occur.
Start Time - If the user selects a starting date and time as the failure trigger mode, then this field must be entered. This field is used to enter the time at which the breach will begin to occur.



Threshold WS - If the user selects water surface elevation plus duration for the failure trigger mode, then this field must be entered. This field represents the water surface elevation at which the duration is triggered ("the clock starts ticking").
Duration above threshold - If the user selects water surface elevation plus duration for the failure trigger mode, then this field must be entered. This field is used to enter the amount of time that the water surface must be above the threshold for the breach to begin. In the above example, if the water surface is higher than 660 feet for 2 hours, then the breach will be triggered.
Immediate initiation WS - If the user selects water surface elevation plus duration for the failure trigger mode, then this field must be entered. This field is used to enter a water surface at which the breach will immediately begin to occur (regardless of the amount of time).
Note: For the User Entered Breach, once the breach has been triggered, it will continue to grow even if the water surface drops below the invert of the breach. The breach will reach its maximum size, based on the formation time, regardless of the hydraulics. The original cross section shape does not limit the maximum size of the breach. The breach will reach the full size as entered by the user (and outlined in red on the plot) even if this is below (or past the edge) of the cross section.

Non-Linear Breach Growth



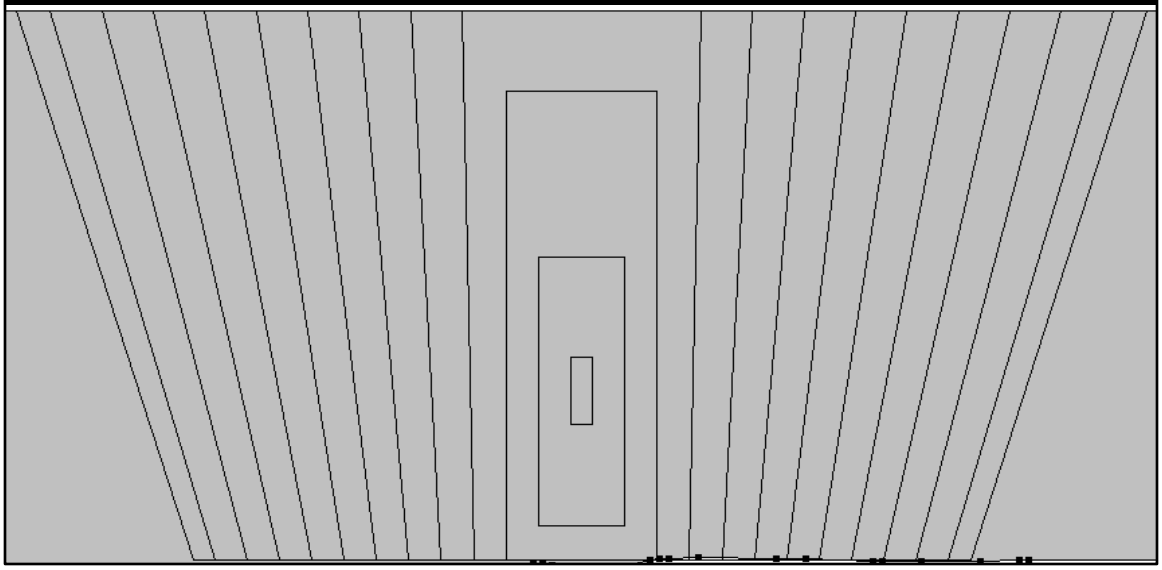
By clicking on the **Breach Progression** button, the above editor will be shown. By default, the breach growth is assumed to be linear from start to maximum size (Full Formation Time). However, a non-linear breach growth curve can be entered. This is done by entering a Time Fraction (from zero to 1.0) and a Breach Fraction (from zero to 1.0). The user-entered data is plotted in the graphic next to the table. The breach progression curve is then used during the breach formation time to adjust the growth rate of the breach.

In addition to adjusting the curve in order to have a more realistic breach growth, the curve can sometimes be used in order to improve stability. If the program is having stability problems during part of the breach growth, the rate of growth during that time can be reduced by adjusting the curve.

By default, the breach grows at the same rate in the vertical and horizontal direction.

This can be changed by specifying the ratio of the vertical growth rate to the horizontal.

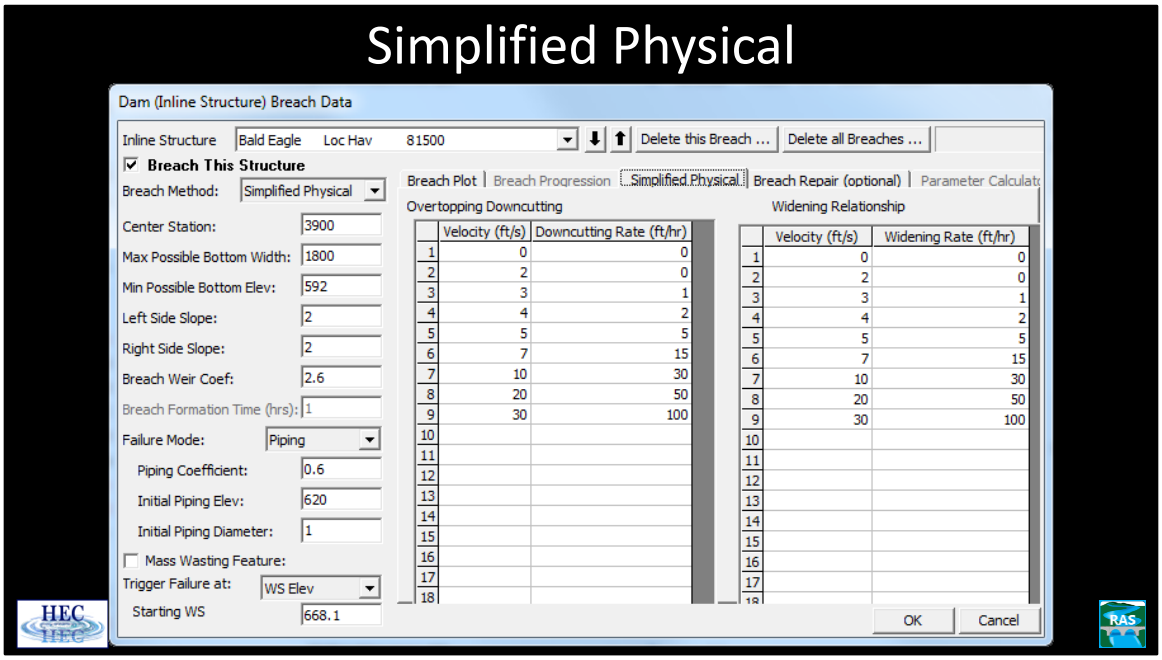
Breach Growth Geometry



A piping breach starts out as a point—at the centerline station and elevation as specified by the user. Its growth is modeled as a rectangle.

When the top of the piping breach is greater than the water surface, it is assumed that the levee sluffs and the breach is modeled as an open breach. The side slopes are gradually increased until they reach the user specified values.

Simplified Physical



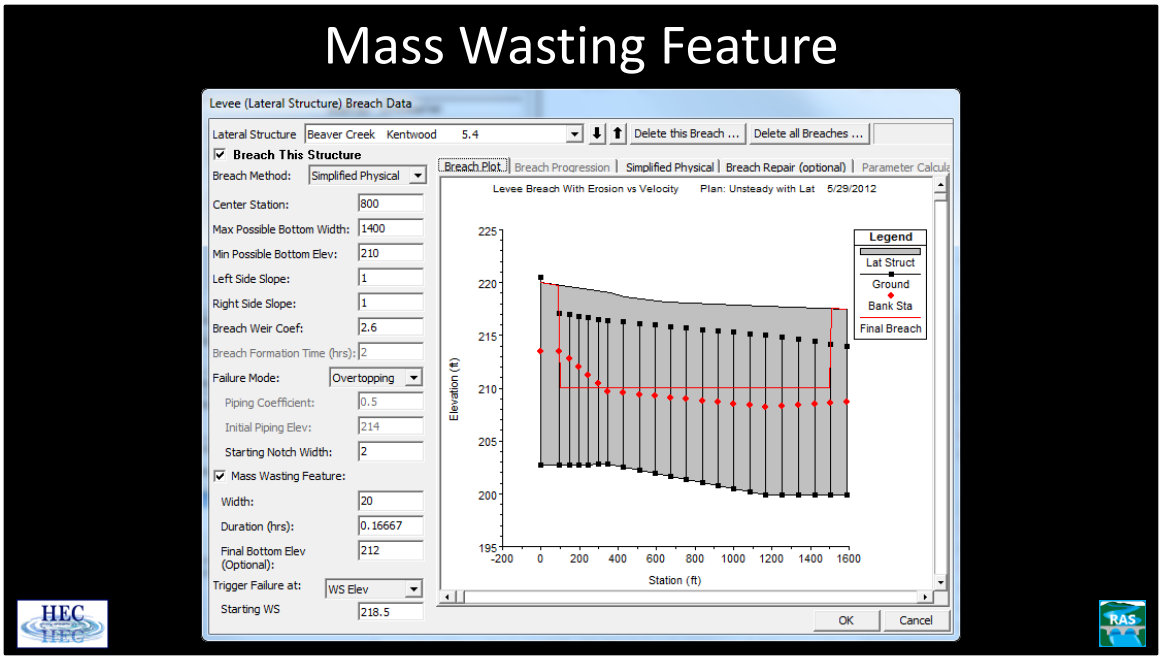
Simplified Physical is an alternate Breach Method where the breach growth is based on the velocity through the breach. Selecting this method [slightly] changes the left side of the editor. The bottom width and bottom elevation are now maximum values. Since growth is based on velocity, these maximums may or may not be reached.

From the **Breach Method** pull down menu, select Simplified Physical and then clicking on the **Simplified Physical** button displays the table where the user must enter the velocity versus downcutting rate and velocity versus widening rate. There is currently little guidance on what these values should be, but it is hoped that further analysis of historical failures will provide more information in the future.

Since the breach growth is based on velocity, the user must enter an initial breach size (in order for there to be flow to create a velocity). For the Piping breach, this is the initial diameter. (Note: it actually starts as a square.) For an overtopping breach, this is an initial width. (The flow over this specific part of the weir is used to compute the velocity).

Note: This breach method requires an actual flow over/through the breach to grow. It is possible to specify a trigger (such as starting time) when the water surface is too low to produce any breach flow/growth.

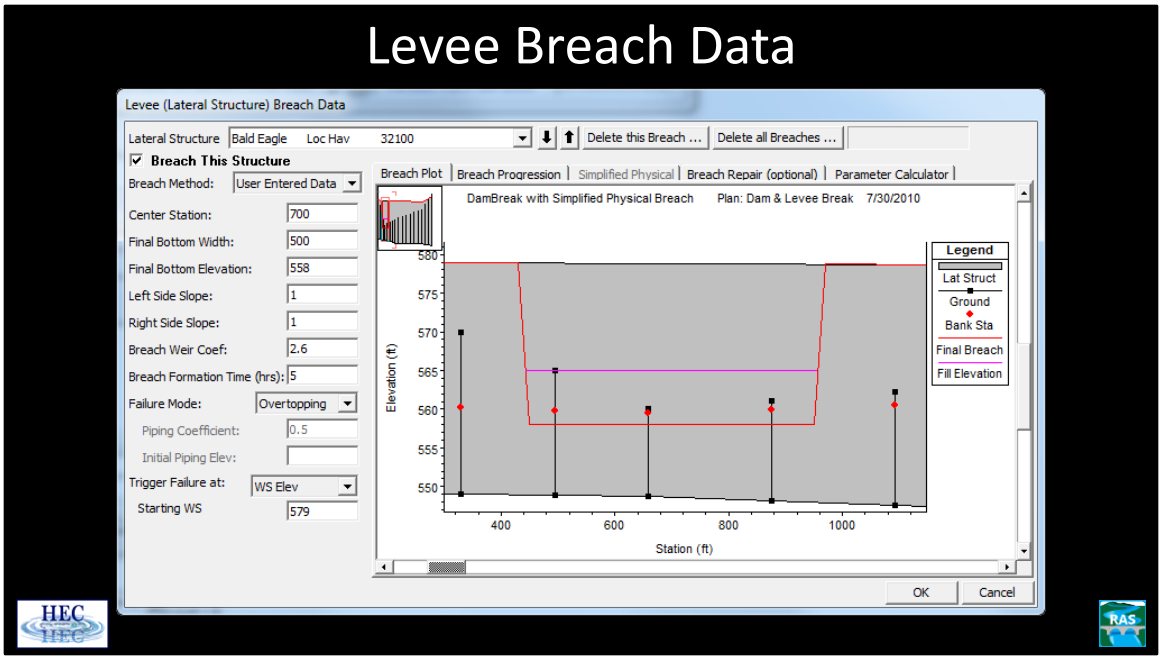
Mass Wasting Feature



The mass Wasting option allows the user to specify an initial breach growth. This feature is particularly intended to be used when a section of levee quickly gives way and then the levee [more slowly] continues to erode horizontally.

A width, time, and optional bottom elevation must be entered. (If the bottom elevation is left blank then the program will use the Maximum Possible Bottom Elevation that was entered above). The breach will grow to the width and bottom elevation in the time specified. As with the User Entered Data breach method, this part of the breach formation can grow without any actual flow. (This can be a useful option if the levee "blows out" without being overtopped.) Once the specified duration has been reached, further growth (if any) will be based on velocity versus downcutting/widening table.

Levee Breach Data



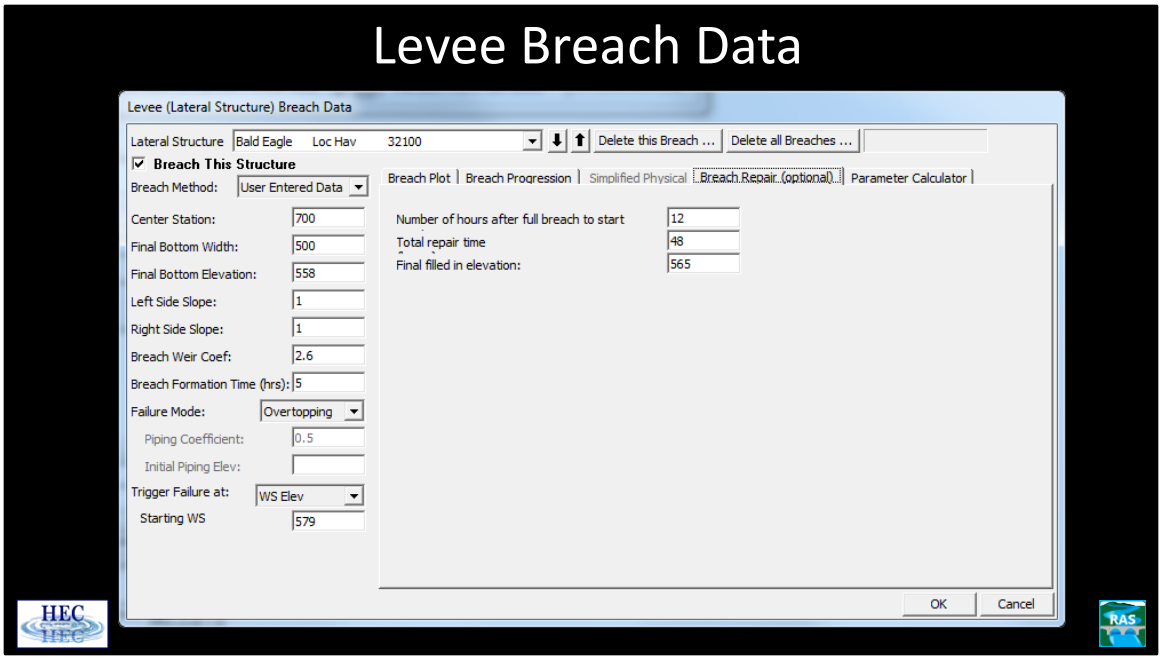
This option is very similar to the Dam Break option described previously. The only difference is that the breaching is performed on a levee. The options and data entered to describe the breach is the same as a Dam Break.

In order to use this option, the user must first define the levee as a lateral weir within HEC-RAS. The lateral weir profile is used to describe the top of the levee along the stream both at and between the cross sections. Second, a weir coefficient is entered for calculating the flow that may go overtop of the levee if the water surface gets high enough. Entering breach data for the levee can be accomplished from the lateral weir editor or from the **Levee (lateral weir) Breach** option from the unsteady flow simulation window. The levee breaching data is stored as part of the unsteady flow plan file, just as it is for a dam break. When the levee breach option is selected, a breach editor will appear as shown above.

The information entered in the fields is the same as for a Dam Break.

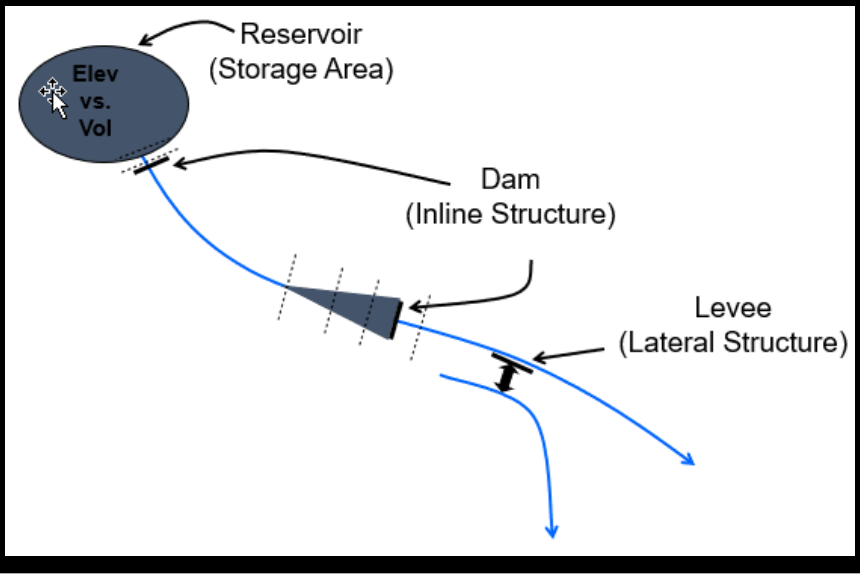
A levee breach can grow vertically below the level of the original cross section. However, (and unlike a dam breach) it cannot grow horizontally past the edge of the original lateral weir. Again, the red outline will show the final shape of the breach.

Levee Breach Data



A levee repair option is available by clicking on the **Breach Repair** button. Enter the number of hours after, the breach has fully formed, that the repair is to start. The total time for repair to take place and the elevation that the breach is repaired to. The elevation that the breach is repaired to is shown on the levee breach schematic (previous slide).

HEC-RAS Breach Locations

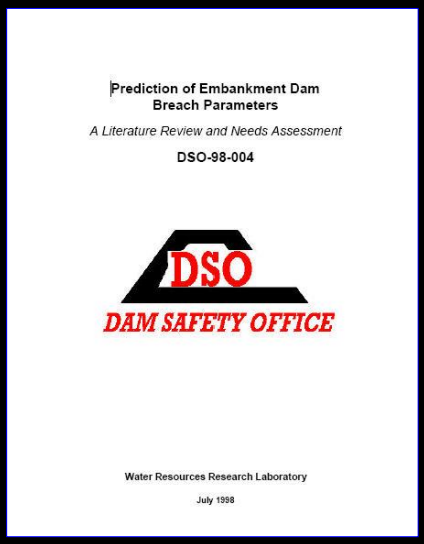


The formation of a breach can be simulated in two types of structures: inline and lateral. The parameters and hydraulic computations for the breaches are the same.
A reservoir is usually modeled as "inline"; that is, its geometry is described with cross sections. This allows dynamic routing of the flood wave through the reservoir. Alternatively, the reservoir can be described as a "storage area" for which the geometry is described by an elevation-volume relationship. Level-pool hydrologic routing within the reservoir is done for this situation. (See Goodell[1])
There must be at least two cross sections between the storage area and the dam. The first cross section is associated with the storage area and the second is associated with the inline structure that represents the dam. These two cross sections should be large, "reservoir-sized" cross sections.
A lateral structure may be a levee that overtops and does not fail, or possibly fails (depending on user input data). The levee is connected to a neighboring reach or storage area.

[1]Goodell, Christopher R. "Dam Break Modeling for Tandem Reservoirs – a Case Study using HEC-RAS and HEC-HMS," Presented at the ASCE World Water & Environmental Resources Congress 2005, EWRI, Anchorage, AK, 15-19 May 2005.

Estimating Dam Break Parameters

- USBR Dam Safety Research Report!
- Froehlich (1995b)
  - Earth dams
- MacDonald and Langridge-Monopolis
  - Earth dams
- Van Thun and Gillette (1990)
- Breach



Determining the size and growth rate for breaches is a very inexact science. The Bureau of Reclamation's "Dam Safety Research Report," offers an excellent literature review of the subject (available online).

MacDonald and Langridge-Monopolis developed best-fit and envelope curves for both breach parameters and peak outflow from breached, earthfill dams as a function of a breach formation factor.

Froehlich developed a best-fit regression equation for peak flow based on a breach formation factor.

Breach is a physically based model that uses sediment transport equations.

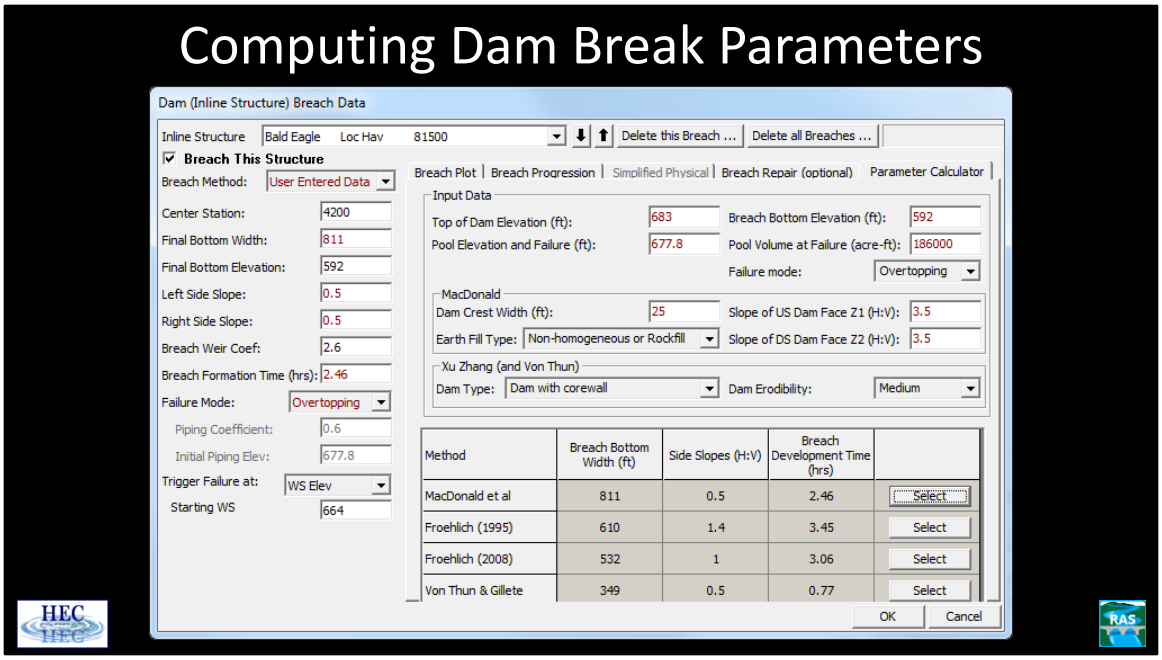
The use of several different procedures, to get a range of values, is generally recommended.

Reference:
Water Resources Research Laboratory, "Prediction of Embankment Dam Breach Parameters", Dam Safety Office, Bureau of Reclamation, 1998.

Reference for breach parameters:

Wahl, Tony L., "Prediction of Embankment Dam Breach Parameters – A Literature Review and Needs Assessment," DSO-98-004, Dam Safety Research Report, U.S. Department of the Interior, Bureau of Reclamation, Dam Safety Office, July 1998.
(http://www.usbr.gov/pmts/hydraulics_lab/pubs/PAP/PAP-0735.DSO-98-004.pdfhttp://www.usbr.gov/pmts/hydraulics_lab/pubs/PAP/PAP-0735.DSO-98-004.pdf)

Computing Dam Break Parameters



The dam break parameters can be computed by clicking on the **Parameter Calculator** button, entering the input data, and then choosing a method by clicking on the appropriate **Select** button. When the **Select** button is clicked, the program will enter the information automatically.

The previous parameter information will be overwritten!

Before using the Parameter Calculator, it is recommended that the user review the given methods in order to understand exactly what each method requires for the input and which methods would be most appropriate for the given dam break.

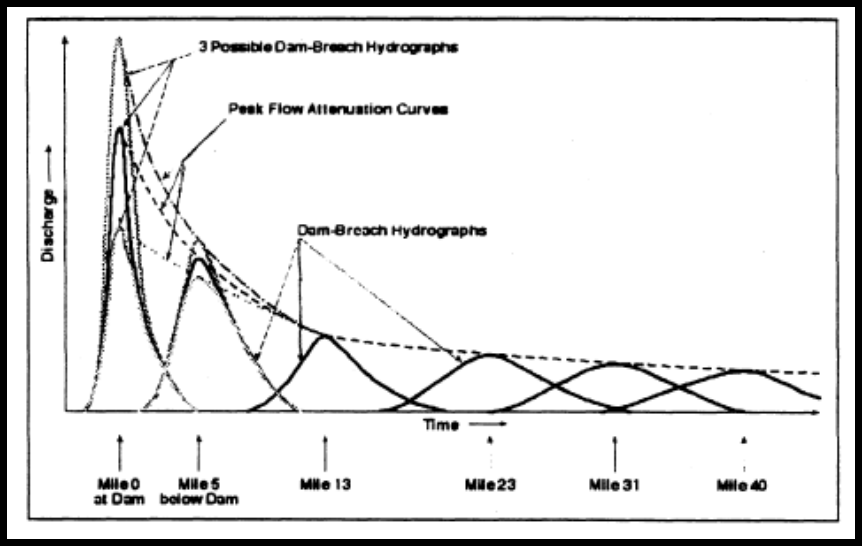
Castle Lake Example

	Width	Time	Peak Q
Breach	480	0.25	1,180,000
Froehlich	305	0.36	761,300
M and L-M	25	0.50	147,600

The above example is taken from a study HEC did on a debris avalanche dam that formed after the eruption of Mount St. Helens.

The MacDonald and Langridge-Monopolis equations probably do not give the most appropriate results for this situation, since their data did not include any landslide or debris blockage dams. However, even on a more typical embankment dam, breach parameters can vary considerably between different methodologies.

Dambreak Floodwave Progression



How important the breach parameters are depend largely on how far downstream from the dam the study area is located. At the toe of the dam, the computed peak flow often varies wildly within the assumed limits of the breach parameters. However, as the study area is moved downstream, the breach parameters have less and less effect on the flow hydrograph. There are two main reasons for this. First, the total volume of water in each of the different hydrographs is basically the same (being the stored water behind the dam). Second, as the hydrographs move downstream, a sharp hydrograph will attenuate much more quickly than a flat hydrograph. Hydrographs from different assumed breach parameters can converge to produce the same peak flow (and for that matter, the same rise and fall) in a surprisingly quick distance. In the above example (Fread), the hydrographs have substantially converged within five miles and are indistinguishable by mile 13. It is still recommended that the user perform a sensitivity analysis on the breach parameters for all dam break studies.

Levee breaches in general and dam breaks in particular have rapidly varying water surfaces and flows. Because of this, a small time step is required to maintain stability and accuracy. Often on the order of a few seconds for a dam break problem. (See next slide).

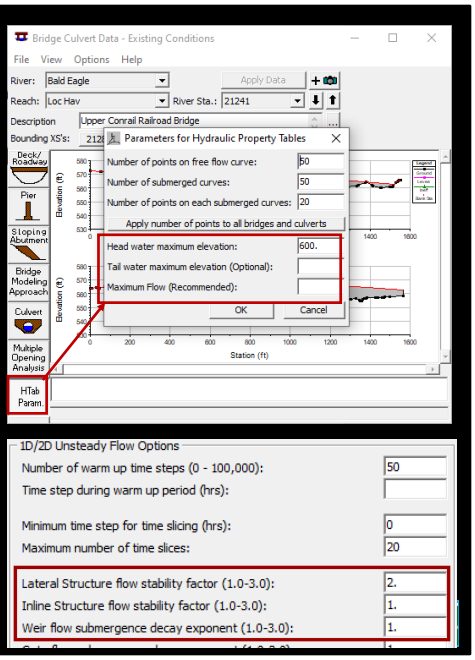
Dam & Levee Breach Considerations

- Small Time Step – Important!
  - XS Spacing DS of Dam Breach (Courant <1.0)
- Increased Manning's n values just downstream of Dam (Jarrett for steep)
- "Critical" vs. "Total" Breach Time
- Non-Linear Growth usually more accurate
  - adjust, if needed

Cross sections that are spaced too far apart below a dam break can cause stability and accuracy problems. However, the Courant condition should be kept close to or less than one (e.g., if the velocity is 20 feet/second and a ten second time step is being used, the cross section spacing should be no closer than around 200 feet).
Dam breaks are usually associated with large amount of sediment, debris and turbulence. The Manning's n value should be increased (particularly at cross sections near the dam) to account for these affects. For dams on steep streams, consider Jarrett's equation.
The reported breach time, especially for piping initiated breaches, often includes a significant period of time when the flow is, relatively speaking, a trickle. This time should not be included in the "Critical Breach Time" unless the user makes appropriate adjustments to the non-linear growth time.

Dam & Levee Breach Stability

- Set Stability Factors
- Modify Bridge/Culvert curves
  - Increase max elevations/flow on Htab!
  - Consider energy bridge method
  - Other changes as needed
- Mixed Flow On (only if needed)
- Modified Puls (only if needed)



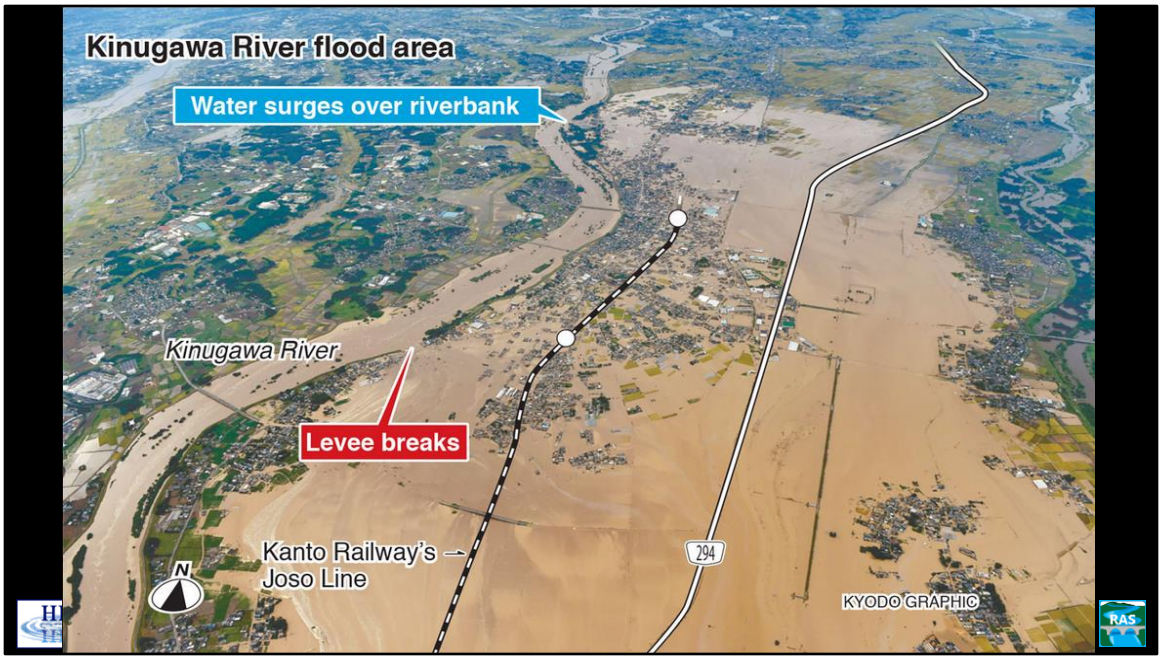
Increasing the inline/lateral structure flow stability factors to the maximum value of 3 can significantly improve stability.

Make sure the Htab parameters (head water maximum and optional tailwater and flow) for any bridges and culverts downstream of the dam break are set high enough!

Bridge and culvert curves can also be a source of instability. The energy method may be a better approach for highly submerged bridges than pressure/weir. If a given bridge/culvert is still causing problems, it may be possible to model the bridge/culvert as a normal cross section. For a bridge/culvert, a “lid” can be added to represent the top of the opening and the deck.

If the dam break has stability problems, turning the mixed flow option on may help (it may help even if the flow is not going supercritical). This may reduce the accuracy of the water surfaces, particularly immediately downstream of the dam. However, this error is usually very minor compared with the error caused by the unknowns in the breach parameters.

If all else fails, use the modified puls method downstream of the dam. The modified puls region should not continue any further downstream than needed (this may take experimentation).



From:

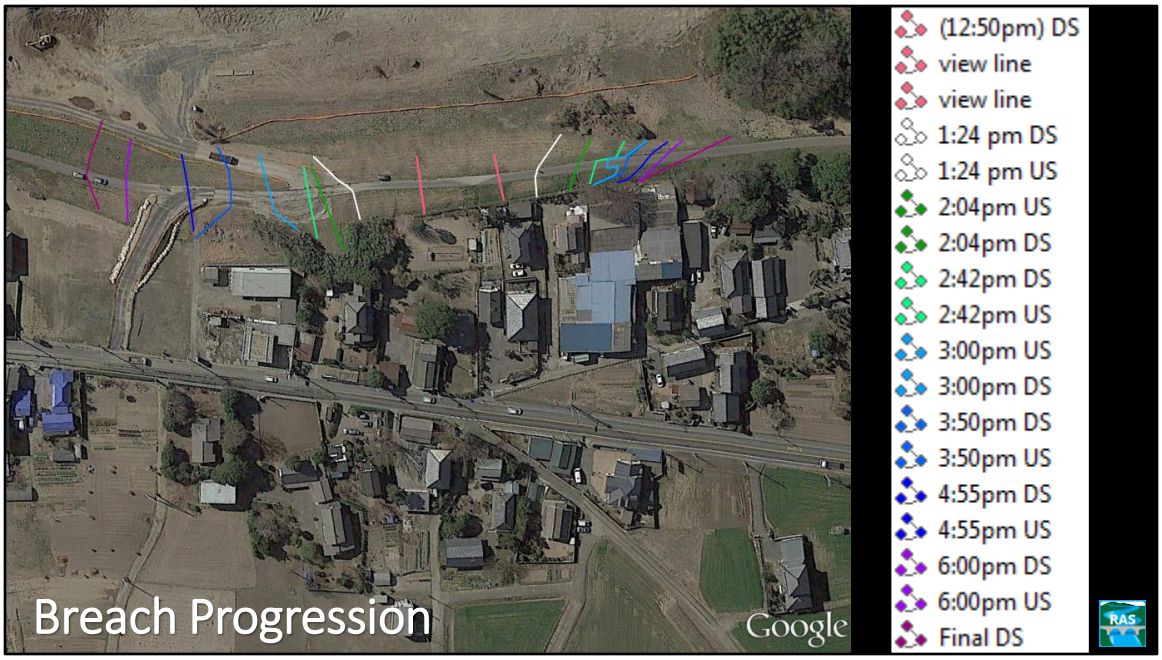
Kinugawa River Levee - Joso, Japan Levee Breach & Consequences

10 September 2015

Paul Risher, PE, M.ASCE

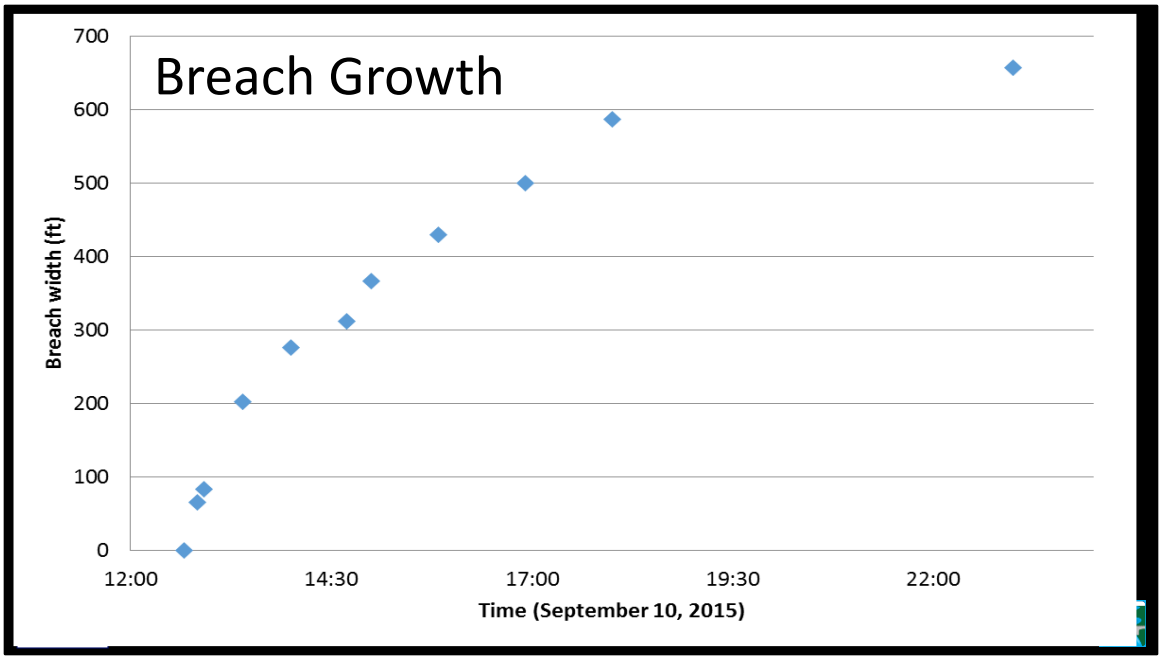
9/10 11:46頃
21k
H25/10/17
21k
Original Condition

大雨で鬼怒川（手前）の堤防が決壊し、住宅地に流れ込む大量の水＝１０日午後１時２４分、茨城県常総市（共同通信社ヘリから）

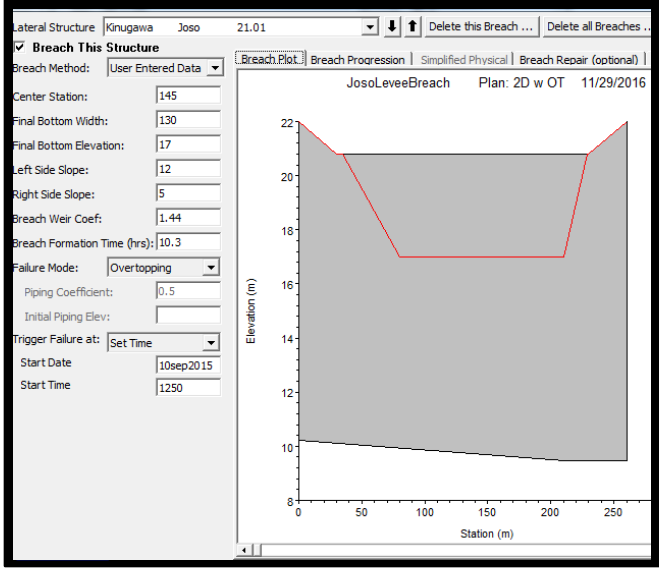


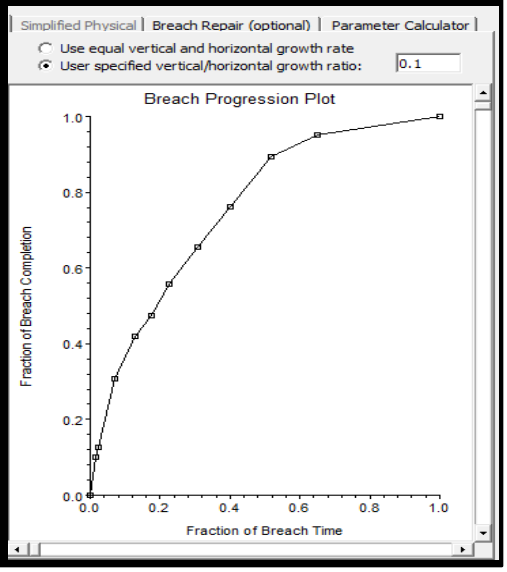
10 hours for a full breach.
3 trends observed: 1 rapid downcutting and widening. 2. Full depth widening. 3. recession flow (no driving head).

Trend observed in multiple levee breaches.

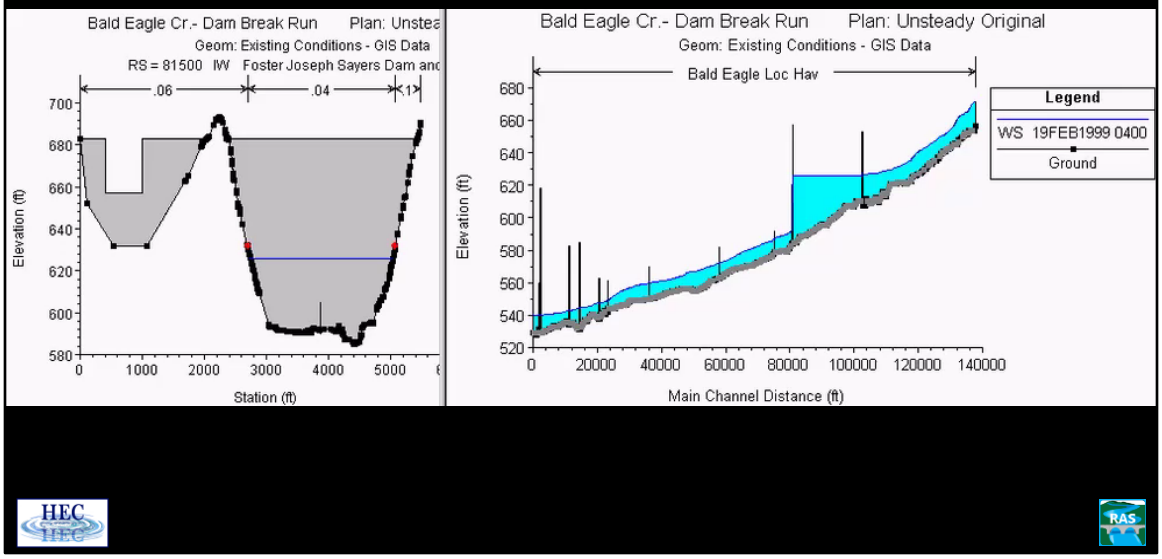

Breach Growth
Breach width (ft)
700
600
500
400
300
200
100
0
12:00
14:30
17:00
19:30
22:00
Time (September 10, 2015)

Lateral Structure Breaching





Example



Getting a dam breach model to be stable can be tricky. However, it is usually possible with enough adjusting. While close cross sections and small time steps usually work best, there are occasions when very short cross section spacing and tiny time steps can make stability worse. Trying a range of parameters is suggested.

Under the animation option in HEC-RAS, an animation of the profile plot or the cross section plot can be written out as an AVI.

As a final note on dam breaching, Dr. Gee and Gary Brunner have submitted a paper for publication, “Dam Break Flood Routing using HEC-RAS and NWS-FLDWAV.” In it, they conclude that the computed breach outflow hydrograph is similar for the two models. The discrepancy being mostly due to the interpretation and approximation of the river geometry.