

Bank-Stability and Toe-Erosion Model

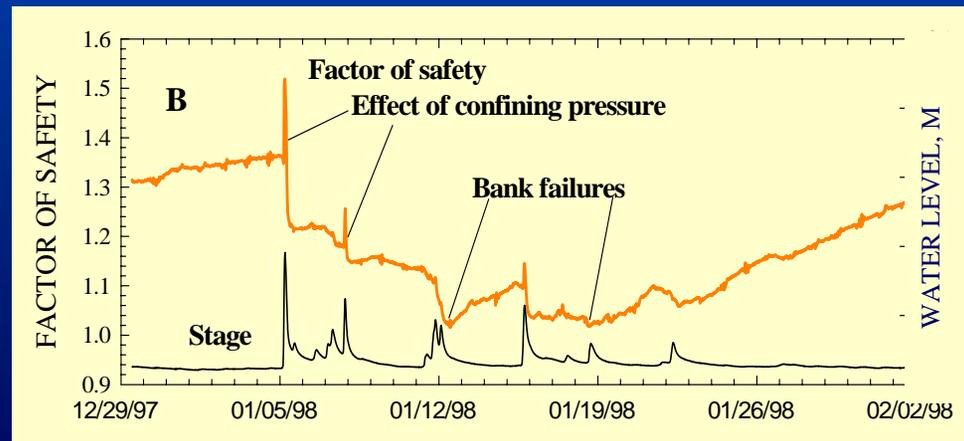
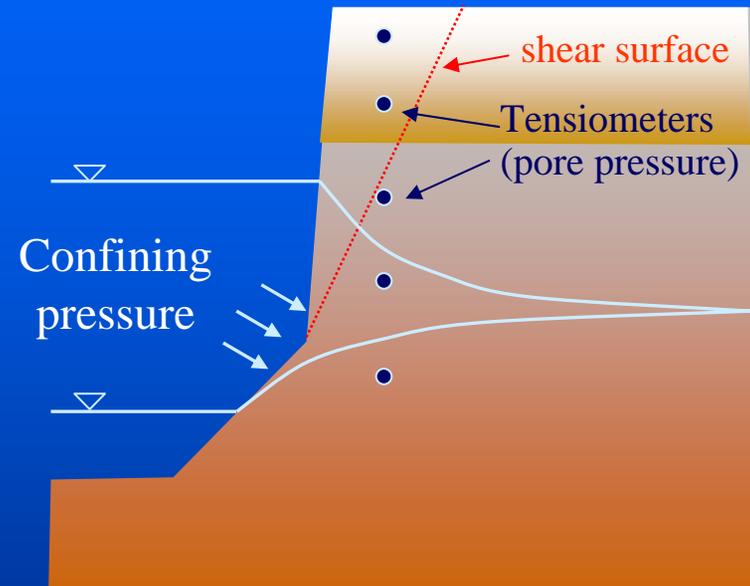
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Bank-Stability Model Version 5.0

- 2-D wedge- and cantilever-failures
- Tension cracks
- Search routine for failures
- Hydraulic toe erosion
- Complex bank geometries
- Positive and negative pore-water pressures
- Confining pressure from flow
- Incorporates layers of different strength
- Vegetation effects: RipRoot
- Inputs: γ_s , c' , ϕ' , ϕ^b , h , u_w , k , τ_c



Web Address

<http://www.ars.usda.gov/Research/docs.htm?docid=5044>

Model Structure

- **Introduction page:** provides general background
- **Technical Background page:** provides equations for stability analysis including positive and negative pore-water pressures, effects of vegetation, and the toe-erosion algorithm.
- **Model Use and FAQ page:** provides methodology for application of model features including hints for working with bank geometry, selecting the shear surface, soil layers, pore-water pressure/water table, vegetation, and the toe-erosion algorithm.

Model Structure (cont'd)

- **Input Geometry page:** Enter coordinates for bank profile, soil layer thickness, and flow parameters..
- **Bank Material page:** Enter bank-material properties (geotechnical and hydraulic)
- **Bank Vegetation and Protection page:** Run root reinforcement (RipRoot) model and to input default values of bank and toe protection.
- **Bank Model Output page:** Enter water-table depth and obtain results.

Model Structure (cont'd)

- **Toe Model Output page:** Run shear stress macro and obtain toe-erosion results.
- **Unit Converter page:** Imperial (English) to metric units

Modeling Steps

- Model the current bank profile by first evaluating the effect of hydraulic erosion at the bank toe.
- Take the resulting new profile and run this in the bank-stability model to see if the eroded bank is stable.
- Investigate the effects of water-table elevation, stage, tension cracks, vegetation, and toe protection.

Operational Steps

1. Open Excel file “BSTEM-5.0”
2. Click on “Enable Macros”...to “Introduction” sheet

Introduction Sheet

Bank Stability and Toe Erosion Model

Static Version 5.0

Bank Stability Model

The Bank Stability Model combines three limit equilibrium-method models that calculate Factor of Safety (F_s) for multi-layer streambanks. The methods simulated are horizontal layers (Simon *et al.*, 2000), vertical slices with tension crack (Morgenstern and Price, 1965) and cantilever failures (Thorne and Tovey, 1981). The model can easily be adapted to incorporate the effects of geotextiles or other bank stabilization measures that affect soil strength.

The model accounts for the strength of up to five soil layers, the effect of pore-water pressure (both positive and negative (matric suction)), confining pressure due to streamflow and soil reinforcement and surcharge due to vegetation.

Input the bank coordinates (**Input Geometry**) and run the geometry macro to set up the bank profile, then input your soil types, vegetation cover and water table or pore-water pressures (**Bank Material, Bank Vegetation and Protection** and **Bank Model Output**) to find F_s .

The bank is said to be 'stable' if F_s is greater than 1.3, to provide a safety margin for uncertain or variable data. Banks with a F_s value between 1.0 and 1.3 are said to be 'conditionally stable', i.e. stable but with little safety margin. Slopes with an F_s value less than 1.0 are unstable.

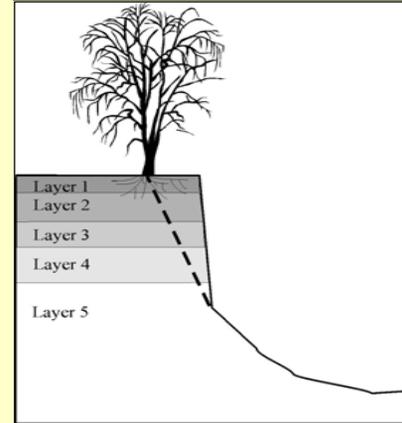
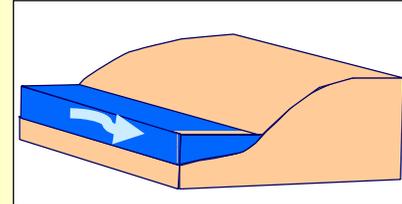
This version of the model assumes hydrostatic conditions below the water table, and a linear interpolation of matric suction above the water table (unless the user's own pore-water pressure data are used).

The model can either use estimated input data where no field data are available or as a first pass solution, or can be set to run using your own data. Your own data can be added to white boxes. Don't change values in yellow boxes - they are output.

Bank Toe Erosion Model

The Bank Toe Erosion Model can be used as a tool for making reasonably informed estimates of hydraulic erosion of the bank and bank toe by hydraulic shear stress. The model is primarily intended for use in studies where bank toe erosion threatens bank stability. The effects of erosion protection on the bank and toe can be incorporated to show the effects of erosion control measures.

The model estimates boundary shear stress from channel geometry, and considers critical shear stress and erodibility of two separate zones with potentially different materials: the bank and bank toe; the bed elevation is assumed to be fixed. This is because the model assumes that erosion is not transport limited and does not incorporate, in any way, the simulation of sediment transport.



Operational Steps

1. **Open Excel file “BSTEM-5.0”**
2. **Click on “Enable Macros”...to “Introduction” sheet**
3. **Click on “Input Geometry” sheet**

Input Geometry Sheet

Input bank geometry and flow conditions

Work through all 4 sections then hit the "Run Bank Geometry Macro" button.

- 1) Select **EITHER** Option A or Option B for Bank Profile and enter the data in the relevant box-cells in the alternative option are ignored in the simulation and may be left blank if desired.
 - 2) Enter bank material layer thicknesses (if bank is all one material it helps to divide it into several layers).
 - 3) If bank is submerged then select the appropriate channel flow elevation to include confining pressure and calculate erosion amount; otherwise set to an elevation below the bank toe.
- To ensure bank profile is correct you can view it by clicking the **View Bank Geometry** button.

Option A - Draw a detailed bank profile using the boxes below

Option A

Point	Station (m)	Elevation (m)	Top of toe?
A			<input type="checkbox"/>
B			<input type="checkbox"/>
C			<input type="checkbox"/>
D			<input type="checkbox"/>
E			<input type="checkbox"/>
F			<input type="checkbox"/>
G			<input type="checkbox"/>
H			<input type="checkbox"/>
I			<input type="checkbox"/>
J			<input type="checkbox"/>
K			<input type="checkbox"/>
L			<input type="checkbox"/>
M			<input type="checkbox"/>
N			<input type="checkbox"/>
O			<input type="checkbox"/>
P			<input type="checkbox"/>
Q			<input type="checkbox"/>
R			<input type="checkbox"/>
S			<input type="checkbox"/>
T			<input type="checkbox"/>
U			<input type="checkbox"/>
V			<input type="checkbox"/>
W			<input type="checkbox"/>

Shear emergence elev

Shear surface angle

Option B - Enter a bank height and angle, the model will generate a bank profile

Option B

a) Input bank height (m)

b) Input bank angle (°)

c) Input bank toe length (m)

d) Input bank toe angle (°)

Input shear surface angle

Bank layer thickness (m)

Layer	Thickness (m)	Elevation of layer base (m)
Layer 1	<input type="text" value="5.00"/>	5.00
Layer 2	<input type="text" value="5.00"/>	5.00
Layer 3	<input type="text" value="5.00"/>	5.00
Layer 4	<input type="text" value="5.00"/>	5.00
Layer 5	<input type="text" value="5.00"/>	5.00

Parallel layers, starting from point B

Top Layer

Bottom Layer

Channel parameters

Input reach length (m)

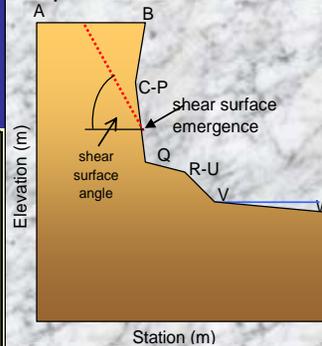
Input reach slope (m/m)

Input concentration (kg/kg)

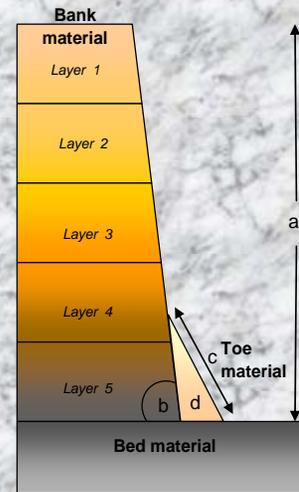
Input elevation of flow (m)

Input duration of flow (hrs)

Definition of points used in bank profile



- A - bank top: place beyond start of shear surface
- B - bank edge
- C-P - breaks of slope on bank (if no breaks of slope place as intermediary points)
- Q - top of bank toe
- R-U - breaks of slope on bank toe (if no breaks of slope then insert as intermediary points)
- V - base of bank toe
- W - end point (typically mid point of channel)



Notes:
Bank profile may overhang.
If the bank profile is fully populated, the shear surface emergence point should be anywhere between points B and Q.
The shear surface emergence point must not be on a horizontal section - the elevation of this point must be unique or an error message will display.

View Bank Geometry

Run Bank Geometry Macro

Operational Steps

1. **Open Excel file “BSTEM-5.0”**
2. **Click on “Enable Macros”...to “Introduction” sheet**
3. **Click on “Input Geometry” sheet**
4. **Select EITHER Option *A* or Option *B* for bank geometry and input geometry data. For this first example select Option *B*.**

Input Geometry Sheet

Input bank geometry and flow conditions

Work through all 4 sections then hit the "Run Bank Geometry Macro" button.

- 1) Select EITHER Option A or Option B for Bank Profile and enter the data in the relevant box-cells in the alternative option are ignored in the simulation and may be left blank if desired.
- 2) Enter bank material layer thicknesses (if bank is all one material it helps to divide it into several layers).
- 3) If bank is submerged then select the appropriate channel flow elevation to include confining pressure and calculate erosion amount; otherwise set to an elevation below the bank toe.

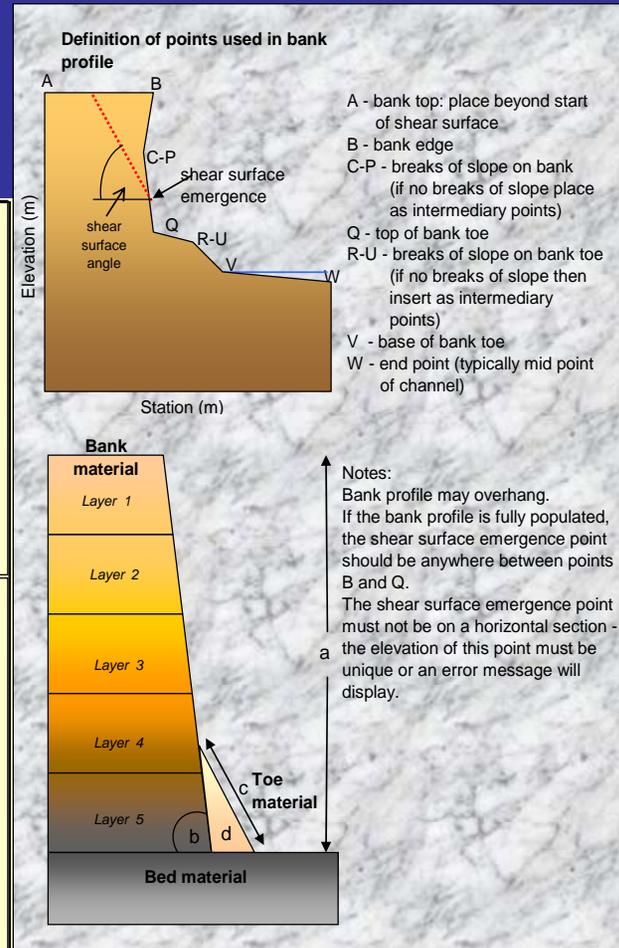
To ensure bank profile is correct you can view it by clicking the **View Bank Geometry** button.

Option A - Draw a detailed bank profile using the boxes below <input type="radio"/> Option A				Option B - Enter a bank height and angle, the model will generate a bank profile <input checked="" type="radio"/> Option B			
Point	Station (m)	Elevation (m)	Top of toe?				
A			<input type="checkbox"/>	a) Input bank height (m) <input type="text" value="3.0"/>			
B			<input type="checkbox"/>	b) Input bank angle (°) <input type="text" value="85.0"/>			
C			<input type="checkbox"/>	c) Input bank toe length (m) <input type="text" value="1.0"/>			
D			<input type="checkbox"/>	d) Input bank toe angle (°) <input type="text" value="25.0"/>			
E			<input type="checkbox"/>	Input shear surface angle <input type="text"/>			
F			<input type="checkbox"/>				
G			<input type="checkbox"/>				
H			<input type="checkbox"/>				
I			<input type="checkbox"/>				
J			<input type="checkbox"/>				
K			<input type="checkbox"/>				
L			<input type="checkbox"/>				
M			<input type="checkbox"/>				
N			<input type="checkbox"/>				
O			<input type="checkbox"/>				
P			<input type="checkbox"/>				
Q			<input type="checkbox"/>				
R			<input type="checkbox"/>				
S			<input type="checkbox"/>				
T			<input type="checkbox"/>				
U			<input type="checkbox"/>				
V			<input type="checkbox"/>				
W			<input type="checkbox"/>				
Shear emergence elev				<input type="text"/>			
Shear surface angle				<input type="text"/>			

Bank layer thickness (m)		
	Elevation of layer base (m)	
Layer 1	Top Layer	
<input type="text"/>	5.00	
Layer 2	<input type="text"/>	5.00
Layer 3	<input type="text"/>	5.00
Layer 4	<input type="text"/>	5.00
Layer 5	<input type="text"/>	5.00
	Bottom Layer	

Parallel layers, starting from point B

Channel parameters	
<input type="text"/>	Input reach length (m)
<input type="text"/>	Input reach slope (m/m)
<input type="text"/>	Input concentration (kg/kg)
<input type="text"/>	Input elevation of flow (m)
<input type="text"/>	Input duration of flow (hrs)



View Bank Geometry

Run Bank Geometry Macro

Starting with Option B

Option B - Enter a bank height and angle, the model will generate a bank profile

Option B

a) Input bank height (m)

b) Input bank angle (°)

c) Input bank toe length (m)

d) Input bank toe angle (°)

Input shear surface angle

Select: Option B

- **5m high bank**
- **85 degree angle**
- **1m toe length**
- **25 degree toe angle**

If you don't know failure-plane angle, search routine will solve for it.

Operational Steps

1. **Open Excel file “BSTEM-5.0”**
2. **Click on “Enable Macros”...to “Introduction” sheet**
3. **Click on “Input Geometry” sheet**
4. **Select EITHER Option *A* or Option *B* to input bank geometry**
5. **Enter Bank-layer Thickness**

Enter Bank Layer Thickness

Input bank geometry and flow conditions

Work through all 4 sections then hit the "Run Bank Geometry Macro" button.

- 1) Select EITHER Option A or Option B for Bank Profile and enter the data in the relevant box- cells in the alternative option are ignored in the simulation and may be left blank if desired.
- 2) Enter bank material layer thicknesses (if bank is all one material it helps to divide it into several layers).
- 3) If bank is submerged then select the appropriate channel flow elevation to include confining pressure and calculate erosion amount; otherwise set to an elevation below the bank toe.

To ensure bank profile is correct you can view it by clicking the **View Bank Geometry** button.

Option A - Draw a detailed bank profile using the boxes below

Option A

Point	Station (m)	Elevation (m)	Top of toe?
A			<input type="checkbox"/>
B			<input type="checkbox"/>
C			<input type="checkbox"/>
D			<input type="checkbox"/>
E			<input type="checkbox"/>
F			<input type="checkbox"/>
G			<input type="checkbox"/>
H			<input type="checkbox"/>
I			<input type="checkbox"/>
J			<input type="checkbox"/>
K			<input type="checkbox"/>
L			<input type="checkbox"/>
M			<input type="checkbox"/>
N			<input type="checkbox"/>
O			<input type="checkbox"/>
P			<input type="checkbox"/>
Q			<input type="checkbox"/>
R			<input type="checkbox"/>
S			<input type="checkbox"/>
T			<input type="checkbox"/>
U			<input type="checkbox"/>
V			<input type="checkbox"/>
W			<input type="checkbox"/>

Shear emergence elev

Shear surface angle

Option B - Enter a bank height and angle, the model will generate a bank profile

Option B

a) Input bank height (m)

b) Input bank angle (°)

c) Input bank toe length (m)

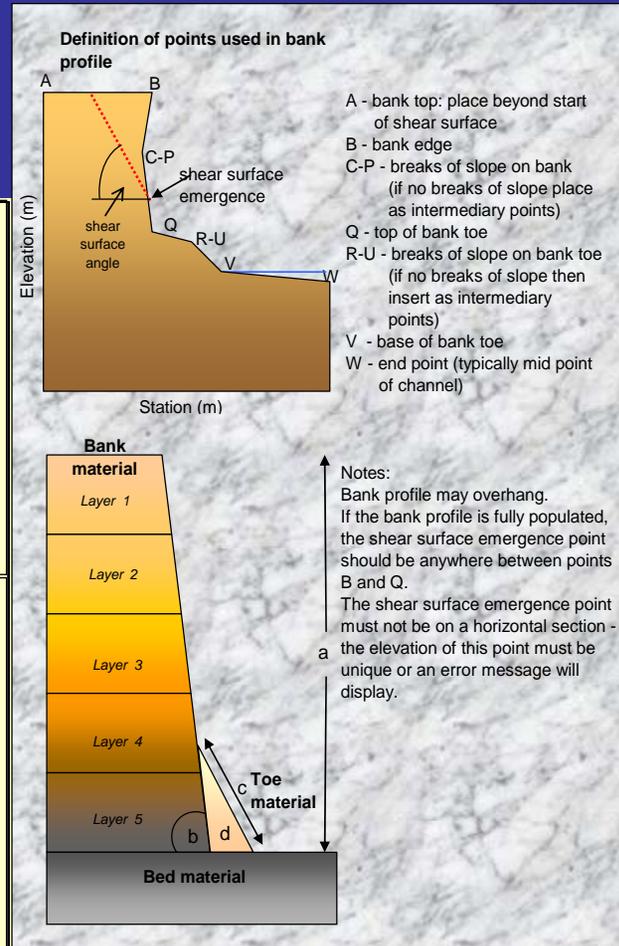
d) Input bank toe angle (°)

Input shear surface angle

Bank layer thickness (m)

Layer	Thickness (m)	Elevation of layer base (m)
Layer 1	<input type="text" value="5.00"/>	5.00
Layer 2	<input type="text" value="5.00"/>	5.00
Layer 3	<input type="text" value="5.00"/>	5.00
Layer 4	<input type="text" value="5.00"/>	5.00
Layer 5	<input type="text" value="5.00"/>	5.00

Parallel layers, starting from point B



Channel parameters

Input reach length (m)

Input reach slope (m/m)

Input concentration (kg/kg)

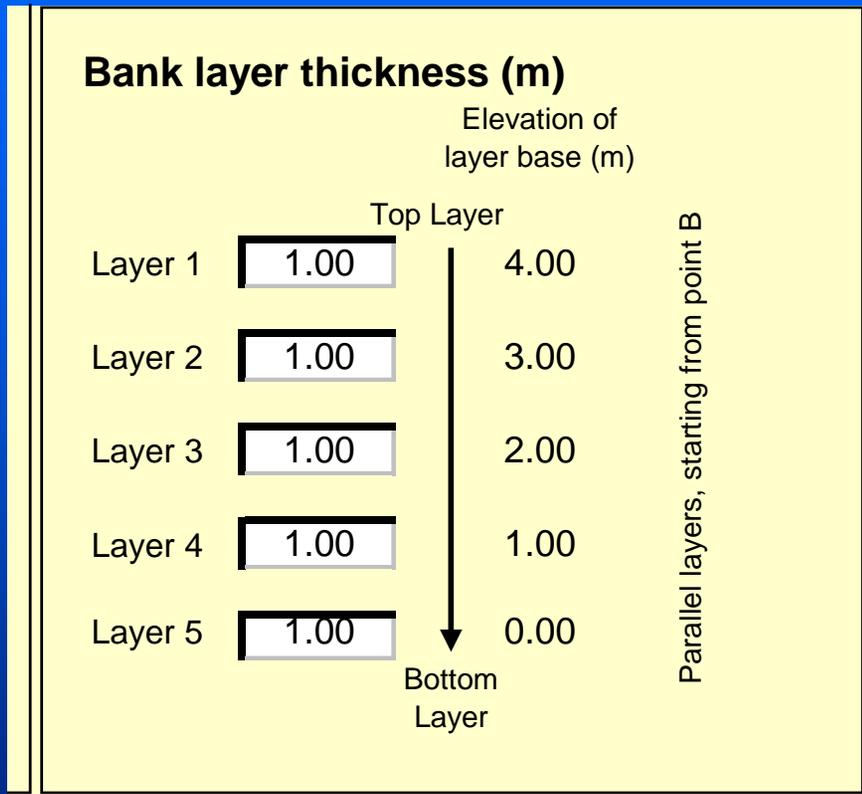
Input elevation of flow (m)

Input duration of flow (hrs)

View Bank Geometry

Run Bank Geometry Macro

Enter Bank Layer Thickness: Detail



**For this example,
enter 1m thicknesses
for all five layers**

Layer 5 should (but does not have to) end at or below the base of the bank toe. Therefore, the basal elevation of layer 5 should be equal to or less than the elevation of point V (base of bank toe) if Option A is selected or 0 (zero) if Option B is selected.

Operational Steps

1. **Open Excel file “BSTEM-5.0”**
2. **Click on “Enable Macros”...to “Introduction” sheet**
3. **Click on “Input Geometry” sheet**
4. **Select EITHER Option A or Option B to input bank geometry**
5. **Enter bank-layer thickness**
6. **Enter channel and flow parameters, and check cross section inputs:**
 - a. **View Geometry**
 - b. **Bank Geometry Macro**

Channel and Flow Parameters

Input bank geometry and flow conditions

Work through all 4 sections then hit the "Run Bank Geometry Macro" button.

- 1) Select EITHER Option A or Option B for Bank Profile and enter the data in the relevant box- cells in the alternative option are ignored in the simulation and may be left blank if desired.
 - 2) Enter bank material layer thicknesses (if bank is all one material it helps to divide it into several layers).
 - 3) If bank is submerged then select the appropriate channel flow elevation to include confining pressure and calculate erosion amount; otherwise set to an elevation below the bank toe.
- To ensure bank profile is correct you can view it by clicking the **View Bank Geometry** button.

Option A - Draw a detailed bank profile using the boxes below

Option A

Point	Station (m)	Elevation (m)	Top of toe?
A	0.00	5.00	<input type="checkbox"/>
B	10.79	5.00	<input type="checkbox"/>
C	10.82	4.69	<input type="checkbox"/>
D	10.84	4.39	<input type="checkbox"/>
E	10.87	4.08	<input type="checkbox"/>
F	10.90	3.78	<input type="checkbox"/>
G	10.92	3.47	<input type="checkbox"/>
H	10.95	3.17	<input type="checkbox"/>
I	10.98	2.86	<input type="checkbox"/>
J	11.00	2.56	<input type="checkbox"/>
K	11.03	2.25	<input type="checkbox"/>
L	11.06	1.95	<input type="checkbox"/>
M	11.08	1.64	<input type="checkbox"/>
N	11.11	1.34	<input type="checkbox"/>
O	11.14	1.03	<input type="checkbox"/>
P	11.16	0.73	<input type="checkbox"/>
Q	11.19	0.42	<input checked="" type="checkbox"/>
R	11.37	0.34	<input type="checkbox"/>
S	11.55	0.25	<input type="checkbox"/>
T	11.74	0.17	<input type="checkbox"/>
U	11.92	0.08	<input type="checkbox"/>
V	12.10	0.00	<input type="checkbox"/>
W	13.10	0.00	<input type="checkbox"/>

Shear emergence elev

Shear surface angle

Option B - Enter a bank height and angle, the model will generate a bank profile

Option B

a) Input bank height (m)

b) Input bank angle (°)

c) Input bank toe length (m)

d) Input bank toe angle (°)

0.84524

Input shear surface angle

Bank layer thickness (m)

Layer	Thickness (m)	Elevation of layer base (m)
Top Layer		
Layer 1	<input type="text" value="1.00"/>	4.00
Layer 2	<input type="text" value="1.00"/>	3.00
Layer 3	<input type="text" value="1.00"/>	2.00
Layer 4	<input type="text" value="1.00"/>	1.00
Layer 5	<input type="text" value="1.00"/>	0.00
Bottom Layer		

Parallel layers, starting from point B

Channel parameters

Input reach length (m)

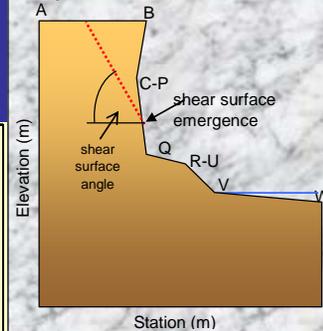
Input reach slope (m/m)

Input concentration (kg/kg)

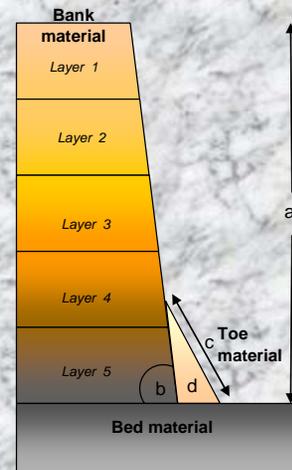
Input elevation of flow (m)

Input duration of flow (hrs)

Definition of points used in bank profile



- A - bank top: place beyond start of shear surface
- B - bank edge
- C-P - breaks of slope on bank (if no breaks of slope place as intermediary points)
- Q - top of bank toe
- R-U - breaks of slope on bank toe (if no breaks of slope then insert as intermediary points)
- V - base of bank toe
- W - end point (typically mid point of channel)



Notes:
Bank profile may overhang.
If the bank profile is fully populated, the shear surface emergence point should be anywhere between points B and Q.
The shear surface emergence point must not be on a horizontal section - the elevation of this point must be unique or an error message will display.

View Bank Geometry

Run Bank Geometry Macro

Channel and Flow Parameters: Detail

Channel and flow parameters

<input type="text" value="100"/>	Input reach length (m)
<input type="text" value="0.0035"/>	Input reach slope (m/m)
<input type="text"/>	Input concentration (kg/kg)
<input type="text" value="2.00"/>	Input elevation of flow (m)
<input type="text" value="12"/>	Input duration of flow (hrs)

Input the above values for this example

Check Cross Section Inputs I: (View Geometry)

Input bank geometry and flow conditions

Work through all 4 sections then hit the "Run Bank Geometry Macro" button.

- 1) Select EITHER Option A or Option B for Bank Profile and enter the data in the relevant box-cells in the alternative option are ignored in the simulation and may be left blank if desired.
 - 2) Enter bank material layer thicknesses (if bank is all one material it helps to divide it into several layers).
 - 3) If bank is submerged then select the appropriate channel flow elevation to include confining pressure and calculate erosion amount; otherwise set to an elevation below the bank toe.
- To ensure bank profile is correct you can view it by clicking the **View Bank Geometry** button.

Option A - Draw a detailed bank profile using the boxes below

Option A

Point	Station (m)	Elevation (m)	Top of toe?
A	0.00	5.00	<input type="checkbox"/>
B	10.79	5.00	<input type="checkbox"/>
C	10.82	4.69	<input type="checkbox"/>
D	10.84	4.39	<input type="checkbox"/>
E	10.87	4.08	<input type="checkbox"/>
F	10.90	3.78	<input type="checkbox"/>
G	10.92	3.47	<input type="checkbox"/>
H	10.95	3.17	<input type="checkbox"/>
I	10.98	2.86	<input type="checkbox"/>
J	11.00	2.56	<input type="checkbox"/>
K	11.03	2.25	<input type="checkbox"/>
L	11.06	1.95	<input type="checkbox"/>
M	11.08	1.64	<input type="checkbox"/>
N	11.11	1.34	<input type="checkbox"/>
O	11.14	1.03	<input type="checkbox"/>
P	11.16	0.73	<input type="checkbox"/>
Q	11.19	0.42	<input checked="" type="checkbox"/>
R	11.37	0.34	<input type="checkbox"/>
S	11.55	0.25	<input type="checkbox"/>
T	11.74	0.17	<input type="checkbox"/>
U	11.92	0.08	<input type="checkbox"/>
V	12.10	0.00	<input type="checkbox"/>
W	13.10	0.00	<input type="checkbox"/>

Shear emergence elev

Shear surface angle

Option B - Enter a bank height and angle, the model will generate a bank profile

Option B

a) Input bank height (m)

b) Input bank angle (°)

c) Input bank toe length (m)

d) Input bank toe angle (°)

0.84524

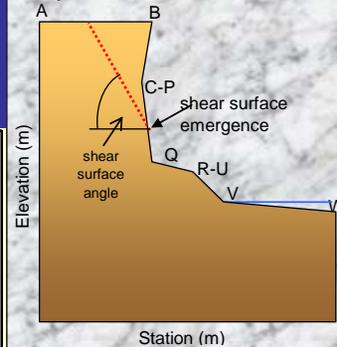
Input shear surface angle

Bank layer thickness (m)

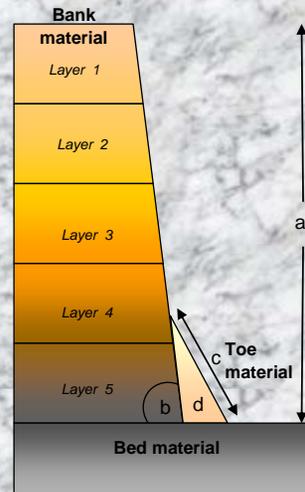
Layer	Thickness (m)	Elevation of layer base (m)
Layer 1	<input type="text" value="1.00"/>	4.00
Layer 2	<input type="text" value="1.00"/>	3.00
Layer 3	<input type="text" value="1.00"/>	2.00
Layer 4	<input type="text" value="1.00"/>	1.00
Layer 5	<input type="text" value="1.00"/>	0.00

Parallel layers, starting from point B

Definition of points used in bank profile



- A - bank top: place beyond start of shear surface
- B - bank edge
- C-P - breaks of slope on bank (if no breaks of slope place as intermediary points)
- Q - top of bank toe
- R-U - breaks of slope on bank toe (if no breaks of slope then insert as intermediary points)
- V - base of bank toe
- W - end point (typically mid point of channel)



Notes:
Bank profile may overhang.
If the bank profile is fully populated, the shear surface emergence point should be anywhere between points B and Q.
The shear surface emergence point must not be on a horizontal section - the elevation of this point must be unique or an error message will display.

Channel and flow parameters

- Input reach length (m)
- Input reach slope (m/m)
- Input concentration (kg/kg)
- Input elevation of flow (m)
- Input duration of flow (hrs)

View Bank Geometry

Run Bank Geometry Macro

View of Input Cross Section

Input bank geometry and flow conditions

Work through all 4 sections then hit the "Run Bank Geometry Macro" button.

- 1) Select EITHER Option A or Option B for Bank Profile and enter the data in the relevant box- cells in the alternative option are ignored in the simulation and may be left blank if desired.
 - 2) Enter bank material layer thicknesses (if bank is all one material it helps to divide it into several layers).
 - 3) If bank is submerged then select the appropriate channel flow elevation to include confining pressure and calculate erosion amount; otherwise set to an elevation below the bank toe.
- To ensure bank profile is correct you can view it by clicking the **View Bank Geometry** button.

Option A - Draw a detailed bank profile using the boxes below

Option A

Point	Station (m)	Elevation (m)	Top of toe?
A			<input type="checkbox"/>
B			<input type="checkbox"/>
C			<input type="checkbox"/>
D			<input type="checkbox"/>
E			<input type="checkbox"/>
F			<input type="checkbox"/>
G			<input type="checkbox"/>
H			<input type="checkbox"/>
I			<input type="checkbox"/>
J			<input type="checkbox"/>
K			<input type="checkbox"/>
L			<input type="checkbox"/>
M			<input type="checkbox"/>
N			<input type="checkbox"/>
O			<input type="checkbox"/>
P			<input type="checkbox"/>
Q			<input type="checkbox"/>
R			<input type="checkbox"/>
S			<input type="checkbox"/>
T			<input type="checkbox"/>
U			<input type="checkbox"/>
V			<input type="checkbox"/>
W			<input checked="" type="checkbox"/>

Shear emergence elev

Shear surface angle

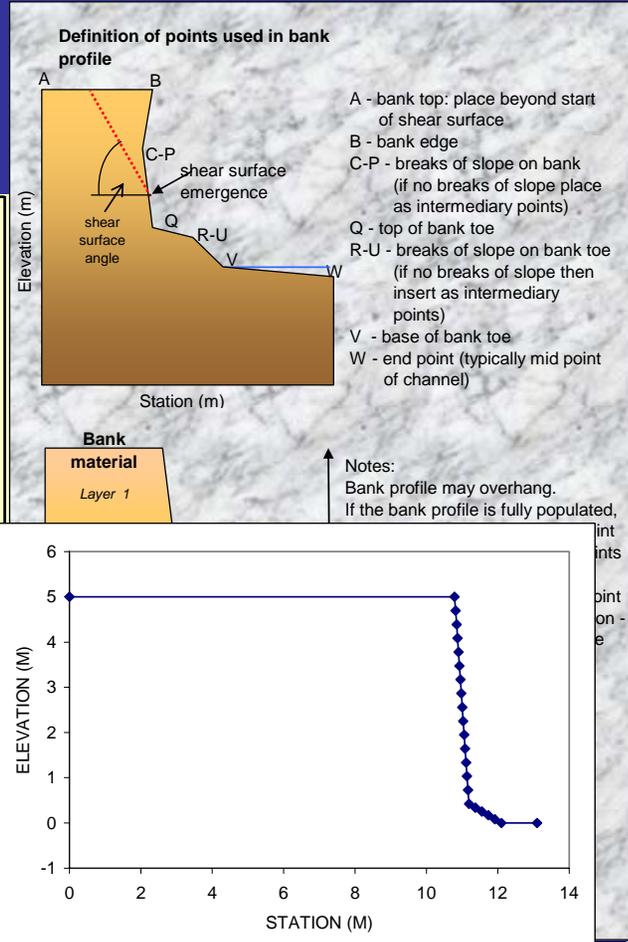
Option B - Enter a bank height and angle, the model will generate a bank profile

- Option B
- a) Input bank height (m)
- b) Input bank angle (°)
- c) Input bank toe length (m)
- d) Input bank toe angle (°)
- 0.84524
- Input shear surface angle

Bank layer thickness (m)

Layer	Thickness (m)	Elevation of layer base (m)
Top Layer		
Layer 1	<input type="text" value="1.00"/>	4.00
Layer 2	<input type="text" value="1.00"/>	3.00
Layer 3	<input type="text" value="1.00"/>	2.00
Layer 4	<input type="text" value="1.00"/>	1.00
Layer 5	<input type="text" value="1.00"/>	0.00
Bottom Layer		

Parallel layers, starting from point B



Channel and flow parameters

- Input reach length (m)
- Input reach slope (m/m)
- Input concentration (kg/kg)
- Input elevation of flow (m)
- Input duration of flow (hrs)

View Bank Geometry

Run Bank Geometry Macro

Check Cross Section Inputs: II (Geometry Macro)

Input bank geometry and flow conditions

Work through all 4 sections then hit the "Run Bank Geometry Macro" button.

- 1) Select EITHER Option A or Option B for Bank Profile and enter the data in the relevant box-cells in the alternative option are ignored in the simulation and may be left blank if desired.
 - 2) Enter bank material layer thicknesses (if bank is all one material it helps to divide it into several layers).
 - 3) If bank is submerged then select the appropriate channel flow elevation to include confining pressure and calculate erosion amount; otherwise set to an elevation below the bank toe.
- To ensure bank profile is correct you can view it by clicking the **View Bank Geometry** button.

Option A - Draw a detailed bank profile using the boxes below

Option A

Point	Station (m)	Elevation (m)	Top of toe?
A	0.00	5.00	
B	10.79	5.00	
C	10.82	4.69	<input type="checkbox"/>
D	10.84	4.39	<input type="checkbox"/>
E	10.87	4.08	<input type="checkbox"/>
F	10.90	3.78	<input type="checkbox"/>
G	10.92	3.47	<input type="checkbox"/>
H	10.95	3.17	<input type="checkbox"/>
I	10.98	2.86	<input type="checkbox"/>
J	11.00	2.56	<input type="checkbox"/>
K	11.03	2.25	<input type="checkbox"/>
L	11.06	1.95	<input type="checkbox"/>
M	11.08	1.64	<input type="checkbox"/>
N	11.11	1.34	<input type="checkbox"/>
O	11.14	1.03	<input type="checkbox"/>
P	11.16	0.73	<input type="checkbox"/>
Q	11.19	0.42	<input checked="" type="checkbox"/>
R	11.37	0.34	<input type="checkbox"/>
S	11.55	0.25	<input type="checkbox"/>
T	11.74	0.17	<input type="checkbox"/>
U	11.92	0.08	<input type="checkbox"/>
V	12.10	0.00	<input type="checkbox"/>
W	13.10	0.00	<input type="checkbox"/>

Shear emergence elev

Shear surface angle

Option B - Enter a bank height and angle, the model will generate a bank profile

Option B

a) Input bank height (m)

b) Input bank angle (°)

c) Input bank toe length (m)

d) Input bank toe angle (°)

0.84524

Input shear surface angle

Bank layer thickness (m)

Layer	Thickness (m)	Elevation of layer base (m)
Layer 1	<input type="text" value="1.00"/>	4.00
Layer 2	<input type="text" value="1.00"/>	3.00
Layer 3	<input type="text" value="1.00"/>	2.00
Layer 4	<input type="text" value="1.00"/>	1.00
Layer 5	<input type="text" value="1.00"/>	0.00

Parallel layers, starting from point B

Channel and flow parameters

Input reach length (m)

Input reach slope (m/m)

Input concentration (kg/kg)

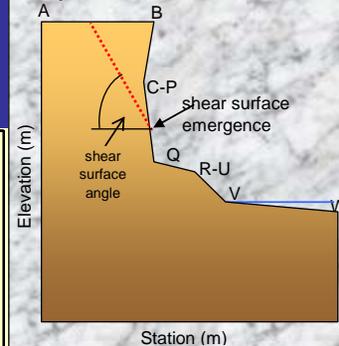
Input elevation of flow (m)

Input duration of flow (hrs)

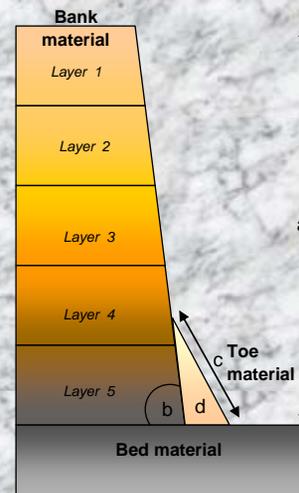
View Bank Geometry

Run Bank Geometry Macro

Definition of points used in bank profile



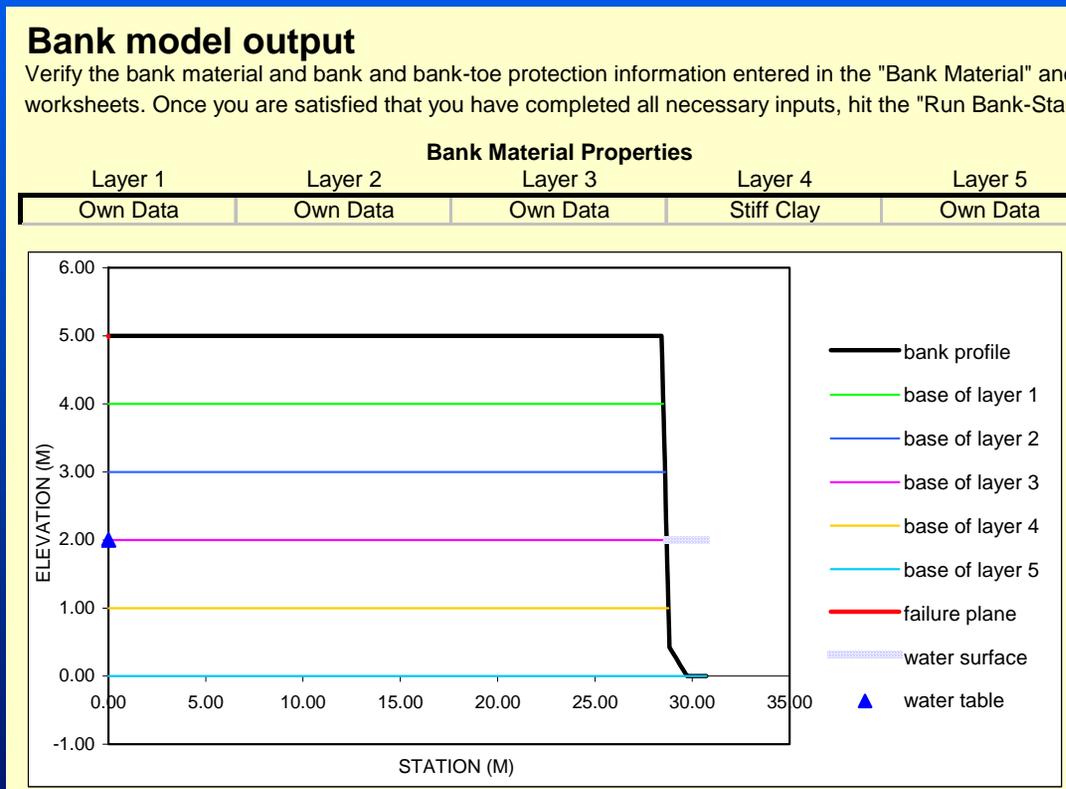
- A - bank top: place beyond start of shear surface
- B - bank edge
- C-P - breaks of slope on bank (if no breaks of slope place as intermediary points)
- Q - top of bank toe
- R-U - breaks of slope on bank toe (if no breaks of slope then insert as intermediary points)
- V - base of bank toe
- W - end point (typically mid point of channel)



Notes:
Bank profile may overhang.
If the bank profile is fully populated, the shear surface emergence point should be anywhere between points B and Q.
The shear surface emergence point must not be on a horizontal section - the elevation of this point must be unique or an error message will display.

Check Geometry and Flow Level

1. Model will direct you to the Bank Material sheet
2. Click on Bank Model Output sheet



Operational Steps

1. **Open Excel file “BSTEM-5.0”**
2. **Click on “Enable Macros”...to “Introduction” sheet**
3. **Click on “Input Geometry” sheet**
4. **Select EITHER Option A or Option B to input bank geometry**
5. **Enter Bank-layer Thickness**
6. **Enter channel and flow parameters**
7. **Enter Bank-material Properties: Click on “Bank Material” sheet**

Select Bank Materials by Layer

Select material types (or select "own data" and add values below)

Bank Material					Bank Toe Material
Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	
Moderate soft clay ▼	Moderate soft clay ▼	Moderate silt ▼	Erodible silt ▼	Moderate silt ▼	Own data ▼

Select bank materials by layer from drop down boxes. For this case:

Layer 1 = Moderate soft clay,

Layer 2 = Moderate soft clay,

Layer 3 = Moderate silt,

Layer 4 = Erodible silt,

Layer 5 = Moderate silt,

Bank Toe Material = Own data

Selecting Bank Materials

Select material types (or select "own data" and add values below)

Bank Material: Layer 1 (Erodible silt), Layer 2 (Moderate silt), Layer 3 (Moderate silt), Layer 4 (Erodible silt), Layer 5 (Moderate silt)
 Bank Toe Material: Own data

Bank and bank-toe material data tables.

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white boxes.

Material Descriptors			Bank Model Input Data			
Bank material type	Description	Mean grain size, D_{50} (m)	Friction angle ϕ' (degrees)	Cohesion c' (kPa)	Saturated unit weight (kN/m^3)	ϕ^b (degrees)
1	Boulders	0.512	42.0	0.0	20.0	5.0
2	Cobbles	0.128	42.0	0.0	20.0	5.0
3	Gravel	0.0113	36.0	0.0	20.0	5.0
4a and 4b	Angular sand	0.00035	36.0	0.0	18.0	15.0
5a and 5b	Rounded sand	0.00035	27.0	0.0	18.0	15.0
6a, 6b and 6c	Silt	-	25.0	5.0	18.0	15.0
7a, 7b and 7c	Soft clay	-	30.0	10.0	16.0	15.0
8a, 8b and 8c	Stiff clay	-	10.0	15.0	18.0	15.0
9	Own data layer 1					
	Own data layer 2					
	Own data layer 3					
	Own data layer 4					
	Own data layer 5					
	Own data Bank Toe					

COMING
JANUARY
2009!

Toe Model Input Data	
τ_c (Pa)	k (cm ³ /Ns)
498	0.004
124	0.009
11.0	0.030
Coarse (0.71 mm) or Fine (0.18 mm)	
Erodible (0.100 Pa), Moderate (5.00 Pa), or Resistant (50.0 Pa)	
2.00	0.071

Need to know the critical shear stress (τ_c) ?
 Input non-cohesive particle diameter (mm)
 Critical Shear Stress τ_c (Pa)

Need to know the erodibility coefficient (k) ?
 Input critical shear stress τ_c (Pa)
 Erodibility Coefficient (cm³/Ns)

Input value (2.00) and hit enter

Need to know the erodibility coefficient (k) ?
 Input critical shear stress τ_c (Pa)
 Erodibility Coefficient (cm³/Ns)

Enter values (2.00 and 0.071)

Operational Steps

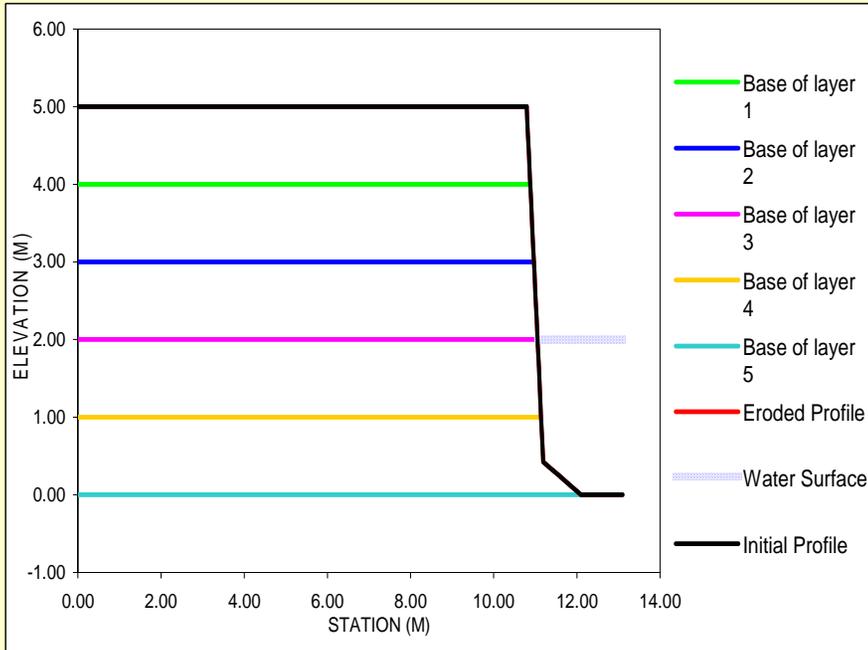
1. **Open Excel file “BSTEM-5.0”**
2. **Click on “Enable Macros”...to “Introduction” sheet**
3. **Click on “Input Geometry” sheet**
4. **Select EITHER Option A or Option B to input bank geometry**
5. **Enter Bank-layer Thickness**
6. **Enter channel and flow parameters**
7. **Enter Bank-material Properties: Click on “Bank Material” sheet**
8. **Select “Toe Model Output” sheet and Click on “Run Toe-Erosion Model”**

Toe Model Output Sheet

Toe Model Output

Verify the bank material and bank and bank-toe protection information entered in the "Bank Material" and "Bank Vegetation and Protection" worksheets. Once you are satisfied that you have completed all necessary inputs, hit the "Run Toe-Erosion Model" button (Center Right of this page).

Bank Material					Bank Toe Material	
Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Material	
Moderate cohesive	Moderate cohesive	Moderate cohesive	Erodible cohesive	Moderate cohesive	Own data	Material
5.00	5.00	5.00	0.10	5.00	2.00	Critical shear stress (Pa)
0.045	0.045	0.045	0.316	0.045	0.071	Erodibility Coefficient (cm ³ /Ns)

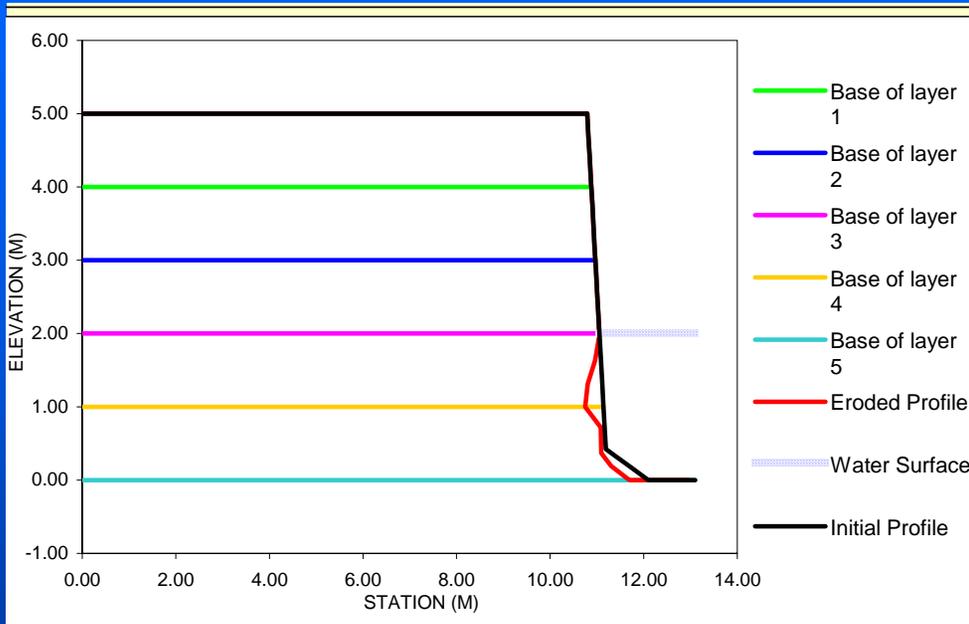


Run Toe-Erosion Model

Average applied boundary shear stress	<input type="text"/>	Pa
Maximum Lateral Retreat	0.000	cm
Eroded Area - Bank	0.000	m ²
Eroded Area - Bank Toe	0.000	m ²
Eroded Area - Bed	0.000	m ²
Eroded Area - Total	0.000	m ²

Export New (Eroded) Profile into Model

Results of Toe-Erosion Model



Run Toe-Erosion Model

Average applied boundary shear stress

41.780 Pa

Maximum Lateral Retreat

0.000 cm

Eroded Area - Bank

0.300 m²

Eroded Area - Bank Toe

0.133 m²

Eroded Area - Bed

0.000 m²

Eroded Area - Total

0.433 m²

Export New (Eroded) Profile into Model

Click this button to export eroded profile to Option A in "Input Geometry" worksheet

Operational Steps

1. **Open Excel file “BSTEM-5.0”**
2. **Click on “Enable Macros”...to “Introduction” sheet**
3. **Click on “Input Geometry” sheet**
4. **Select EITHER Option A or Option B to input bank geometry**
5. **Enter Bank-layer Thickness**
6. **Enter channel and flow parameters**
7. **Enter Bank-material Properties: Click on “Bank Material” sheet**
8. **Select “Toe Model Output” sheet and Click on “Run Toe-Erosion Model”**
9. **Export Coordinates to Model (Returned to “Input Geometry” sheet)**

Profile Exported into Option A

(Model Directs you to “Input Geometry” sheet)

Check profile (View Geometry) and select top of bank toe

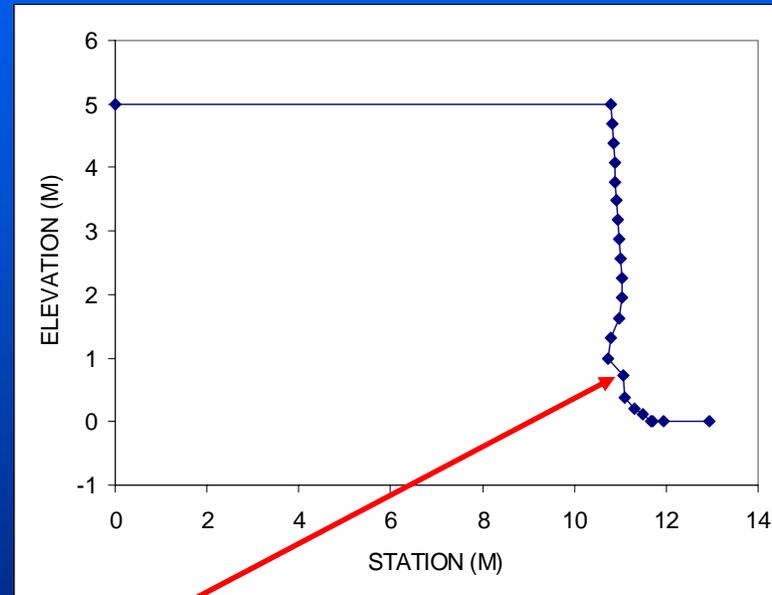
Option A - Draw a detailed bank profile using the boxes below

Option A

Point	Station (m)	Elevation (m)	Top of toe?
A	0.00	5.00	
B	10.79	5.00	
C	10.82	4.69	<input type="checkbox"/>
D	10.84	4.39	<input type="checkbox"/>
E	10.87	4.08	<input type="checkbox"/>
F	10.90	3.78	<input type="checkbox"/>
G	10.92	3.47	<input type="checkbox"/>
H	10.95	3.17	<input type="checkbox"/>
I	10.98	2.86	<input type="checkbox"/>
J	11.00	2.56	<input type="checkbox"/>
K	11.03	2.25	<input type="checkbox"/>
L	11.04	1.95	<input type="checkbox"/>
M	10.96	1.63	<input type="checkbox"/>
N	10.81	1.31	<input type="checkbox"/>
O	10.75	1.00	<input type="checkbox"/>
P	11.08	0.72	<input type="checkbox"/>
Q	11.09	0.37	<input checked="" type="checkbox"/>
R	11.31	0.19	
S	11.48	0.10	
T	11.66	0.02	
U	11.72	0.00	
V	11.95	0.00	
W	12.96	0.00	

Shear emergence elev

Shear surface angle



For this case select Point Q

Either: (1) Select shear emergence elevation and shear angle or (2) **leave blank for search routine**

Operational Steps

1. **Open Excel file “BSTEM-5.0”**
2. **Click on “Enable Macros”...to “Introduction” sheet**
3. **Click on “Input Geometry” sheet**
4. **Select EITHER Option A or Option B to input bank geometry**
5. **Enter Bank-layer Thickness**
6. **Enter channel and flow parameters**
7. **Enter Bank-material Properties: Click on “Bank Material” sheet**
8. **Select “Toe Model Output” sheet and Click on “Run Toe-Erosion Model”**
9. **Export Coordinates to Model (Returned to “Input Geometry” sheet)**
10. **Run “Bank Geometry Macro” and Click on “Bank Model Output” sheet; Set water-table depth and Click “Run Bank Stability Model”**

Data for Pore-Water Pressure

In “Bank Model Output” worksheet

Water table depth (m) below bank top

 Use water table
 Input own pore pressures (kPa)

Own Pore Pressures	kPa	Pore Pressure From Water Table
<input type="text"/>	Layer 1	<input type="text" value="-24.52"/>
<input type="text"/>	Layer 2	<input type="text" value="-14.71"/>
<input type="text"/>	Layer 3	<input type="text" value="-4.90"/>
<input type="text"/>	Layer 4	<input type="text" value="4.90"/>
<input type="text"/>	Layer 5	<input type="text" value="14.71"/>

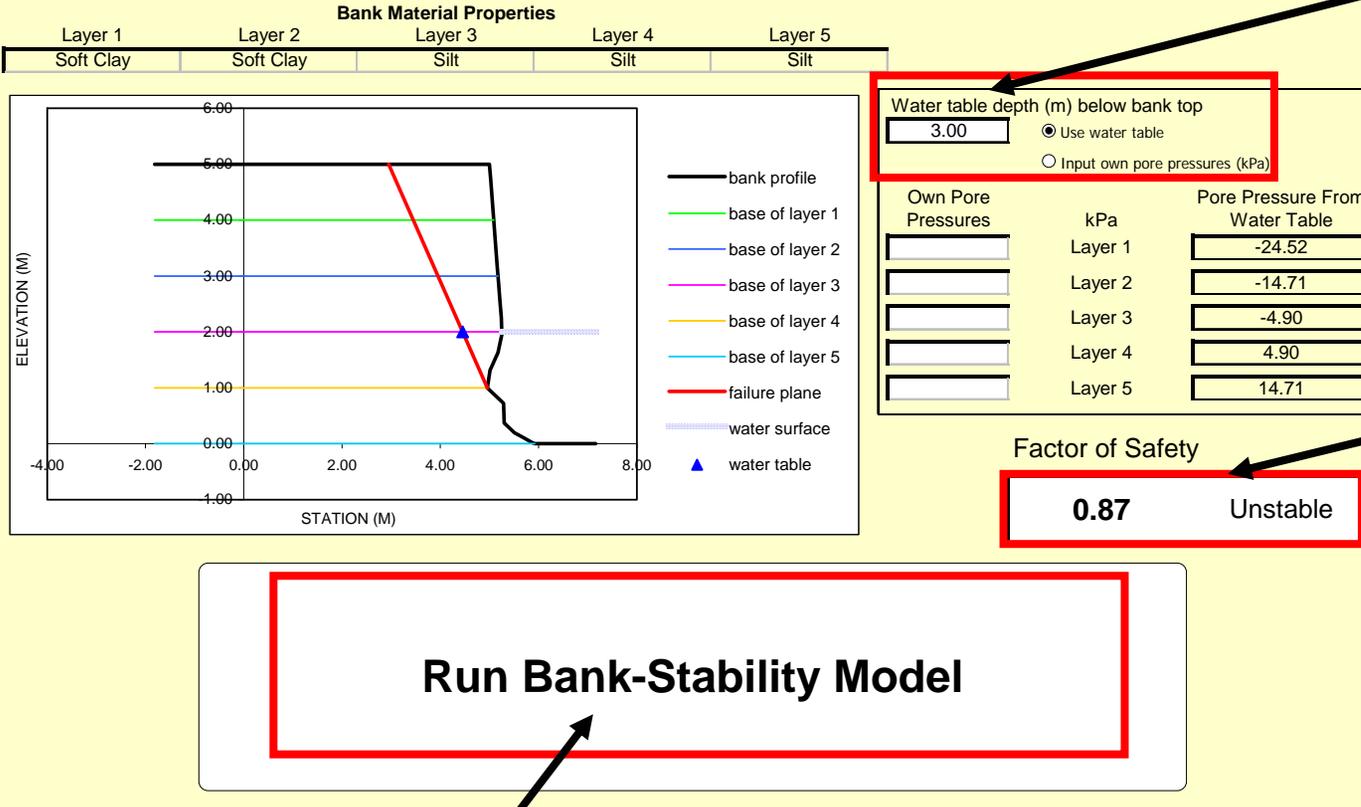
Or

In this case select option to use water table depth, and enter a value of 3.0m below the bank top

Bank Model Output: No Tension Crack

Bank model output

Verify the bank material and bank and bank-toe protection information entered in the "Bank Material" and "Bank Vegetation and Protection" worksheets. Once you are satisfied that you have completed all necessary inputs, hit the "Run Bank-Stability Model" button.



Set water-table depth to 3.0 m

Bank is Unstable

$$F_s < 1.0$$

Click "Run Bank-Stability Model"

Bank Model Output: Specific Results

Failure plane from search routine

Shear emergence elevation

Shear surface angle used

Export New (Failed) Profile into Model

Failure dimensions (loading)

Failure width	2.05	m
Failure volume	468	m ³
Sediment loading	813163	kg
Constituent load	0	kg

Save your file under a different name

Operational Steps

1. **Open Excel file “BSTEM-5.0”**
2. **Click on “Enable Macros”...to “Introduction” sheet**
3. **Click on “Input Geometry” sheet**
4. **Select EITHER Option A or Option B to input bank geometry**
5. **Enter Bank-layer Thickness**
6. **Enter channel and flow parameters**
7. **Enter Bank-material Properties: Click on “Bank Material” sheet**
8. **Select “Toe Model Output” sheet and Click on “Run Toe-Erosion Model”**
9. **Export Coordinates to Model (Returned to “Input Geometry” sheet)**
10. **Run “Bank Geometry Macro” and Click on “Bank Model Output” sheet; Set water-table depth and Click “Run Bank Stability Model”**
11. **Save file under different name**

How can you make this bank more stable or more unstable?

Try experimenting with the following parameters to get a feel for the model:

- Water surface elevation (Input Geometry Sheet)
- Shear angle (Input Geometry Sheet)
- Water table height (Bank Model Output sheet)
- Bank material types (Bank Model Output sheet)

We'll work with the effects of vegetation later...

Operational Steps

1. **Open Excel file “BSTEM-5.0”**
2. **Click on “Enable Macros”...to “Introduction” sheet**
3. **Click on “Input Geometry” sheet**
4. **Select EITHER Option A or Option B to input bank geometry**
5. **Enter Bank-layer Thickness**
6. **Enter channel and flow parameters**
7. **Enter Bank-material Properties: Click on “Bank Material” sheet**
8. **Select “Toe Model Output” sheet and Click on “Run Toe-Erosion Model”**
9. **Export Coordinates to Model (Returned to “Input Geometry” sheet)**
10. **Run “Bank Geometry Macro” and Click on “Bank Model Output” sheet; Set water-table depth and Click “Run Bank Stability Model”**
11. **Save file under different name**
12. **Open file and Click on “Bank Vegetation and Protection” sheet**

Incorporating Vegetation Effects and other Protection

Simulate the mechanical effects of bank top vegetation on bank stability using a root-reinforcement model

RipRoot (Pollen and Simon, 2005) is a global load-sharing fiber-bundle model. It explicitly simulates both the snapping of roots and the slipping of roots through the soil matrix, by determining the minimum applied load required to either break each root or pull each root out of the soil matrix. As the strength of each root is removed from the fiber bundle, the load is redistributed to the remaining roots according to the ratio of the diameter of each root to the sum of the diameters of all the intact roots. RipRoot builds on earlier work by Waldron (1977), Wu *et al.* (1979) and Waldron and Dakessian (1981).

RipRoot requires the user to first select either a species from a drop-down box, which then activates root tensile strength- diameter curves measured by USDA-ARS-NSL scientists, or the user may enter their own root tensile strength- diameter relation. The user must then decide whether to use growth curves that use the age of the plant to predict the total number of roots and root diameter histograms derived separately for woody vegetation and grasses or to enter their own root-diameter data. Finally, the user needs to enter the percentage of the study reach that is composed of the selected species.

After it has run, the model outputs a tab-delimited list of the species entered by the user, a tab-delimited list of the percent contribution of each of those species to the assemblage and the estimated increase in cohesion afforded by the roots associated with the assemblage.

**Run
Root-Reinforcement
Model**

Root-Reinforcement Model Output

**List of Species
Percent of Assemblage**

Added cohesion due to roots, c_r

Select bank and bank-toe protection (or select "own data" and add values below)

Protection	
Bank Protection	Bank Toe Protection
No protection ▼	No protection ▼

Bank and bank-toe protection data table

These are the default parameters used in the model. Changing the values or descriptions will change the values used when selecting soil types from the list boxes above. Add your own data using the white box.

Bank and Bank-Toe Protection Descriptors		
Protection type	Description	Permissible shear stress (Pa)
1	No protection	-
2	Coir fiber	108
3	Geotextile (synthetic)	144
4	Jute net	22
5	Large Woody Debris	192
6	Live fascine	100
7	Plant cuttings	17
8	Rip Rap (D_{50} 0.256 m)	204
9	-	-
10	-	-
11	-	-
12	-	-
13	Own Data	<input style="width: 50px;" type="text"/>

Root Reinforcement: RipRoot

(from measured data)

Bank and Toe Protection

(from literature values)

Operational Steps

1. **Open Excel file “BSTEM-5.0”**
2. **Click on “Enable Macros”...to “Introduction” sheet**
3. **Click on “Input Geometry” sheet**
4. **Select EITHER Option A or Option B to input bank geometry**
5. **Enter Bank-layer Thickness**
6. **Enter channel and flow parameters**
7. **Enter Bank-material Properties: Click on “Bank Material” sheet**
8. **Select “Toe Model Output” sheet and Click on “Run Toe-Erosion Model”**
9. **Export Coordinates to Model (Returned to “Input Geometry” sheet)**
10. **Run “Bank Geometry Macro” and Click on “Bank Model Output” sheet; Set water-table depth and Click “Run Bank Stability Model”**
11. **Save file under different name**
12. **Open file and Click on “Bank Vegetation and Protection” sheet**
13. **Click “Run Root-Reinforcement Model”**

Root Reinforcement using RipRoot

Simulate the mechanical effects of bank top vegetation on bank stability using a root-reinforcement model

RipRoot (Pollen and Simon, 2005) is a global load-sharing fiber-bundle model. It explicitly simulates both the snapping of roots and the slipping of roots through the soil matrix, by determining the minimum applied load required to either break each root or pull each root out of the soil matrix. As the strength of each root is removed from the fiber bundle, the load is redistributed to the remaining roots according to the ratio of the diameter of each root to the sum of the diameters of all the intact roots. RipRoot builds on earlier work by Waldron (1977), Wu *et al.* (1979) and Waldron and Dakessian (1981).

RipRoot requires the user to first select either a species from a drop-down box, which then activates root tensile strength- diameter curves measured by USDA-ARS-NSL scientists, or the user may enter their own root tensile strength- diameter relation. The user must then decide whether to use growth curves that use the age of the plant to predict the total number of roots and root diameter histograms derived separately for woody vegetation and grasses or to enter their own root-diameter data. Finally, the user needs to enter the percentage of the study reach that is composed of the selected species.

After it has run, the model outputs a tab-delimited list of the species entered by the user, a tab-delimited list of the percent contribution of each of those species to the assemblage and the estimated increase in cohesion afforded by the roots associated with the assemblage.

**Run
Root-Reinforcement
Model**

Root-Reinforcement Model Output

List of Species
Percent of Assemblage

Added cohesion due to roots, c_r

RipRoot

1. Select the species

2. Select the method to determine the distribution of root diameters

- Specify plant age and percent contribution to assemblage
- Input the number of roots in each of seven size classes

Footnotes:
* Uses mean growth curve for woody vegetation to estimate root numbers (Pollen-Bankhead and Simon, 2008)
+ Uses growth curve for Alamo Switch Grass to estimate root numbers
\$ Growth curve is a result of combining data from stands of Eastern and Western Cottonwoods

Root Reinforcement using RipRoot

RipRoot ✕

1. Select the species

2. Select the method to determine the distribution of root diameters

Specify plant age and percent contribution to assemblage years %

Input the number of roots in each of seven size classes

You have assembled 100 % of your assemblage

Footnotes:
* Uses mean growth curve for woody vegetation to estimate root numbers (Pollen-Bankhead and Simon, 2008)
+ Uses growth curve for Alamo Switch Grass to estimate root numbers
\$ Growth curve is a result of combining data from stands of Eastern and Western Cottonwoods

Simple Case: 1 species

1. Select “Meadow, Wet”
2. Enter age and percent contribution to stand
3. Click when finished

RipRoot: Results

Microsoft Excel - BSTEM-5.0.xls

File Edit View Insert Format Tools Data Window Help Adobe PDF

Arial 14

6.87790020937641

2 Simulate the mechanical effects of bank top vegetation on bank stability using a root-reinforcement model

3

4 RipRoot (Pollen and Simon, 2005) is a global load-sharing fiber-bundle model. It explicitly simulates both the snapping of roots and the slipping of roots through the soil matrix, by determining the minimum applied load required to either break each root or pull each root out of the soil matrix. As the strength of each root is removed from the fiber bundle, the load is redistributed to the remaining roots according to the ratio of the diameter of each root to the sum of the diameters of all the intact roots. RipRoot builds on earlier work by Waldron (1977), Wu et al. (1979) and Waldron and Dakessian (1981).

5 RipRoot requires the user to first select either a species from a drop-down box, which then activates root tensile strength- diameter curves measured by USDA-ARS-NSL scientists, or the user may enter their own root tensile strength- diameter relation. The user must then decide whether to use growth curves that use the age of the plant to predict the total number of roots and root diameter histograms derived separately for woody vegetation and grasses or to enter their own root-diameter data. Finally, the user needs to enter the percentage of the study reach that is composed of the selected species.

6 After it has run, the model outputs a tab-delimited list of the species entered by the user, a tab-delimited list of the percent contribution of each of those species to the assemblage and the estimated increase in cohesion afforded by the roots associated with the assemblage.

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Operational Steps

1. **Open Excel file “BSTEM-5.0”**
2. **Click on “Enable Macros”...to “Introduction” sheet**
3. **Click on “Input Geometry” sheet**
4. **Select EITHER Option A or Option B to input bank geometry**
5. **Enter Bank-layer Thickness**
6. **Enter channel and flow parameters**
7. **Enter Bank-material Properties: Click on “Bank Material” sheet**
8. **Select “Toe Model Output” sheet and Click on “Run Toe-Erosion Model”**
9. **Export Coordinates to Model (Returned to “Input Geometry” sheet)**
10. **Run “Bank Geometry Macro” and Click on “Bank Model Output” sheet; Set water-table depth and Click “Run Bank Stability Model”**
11. **Save file under different name**
12. **Open file and Click on “Bank Vegetation and Protection” sheet**
13. **Click “Run Root-Reinforcement Model”**
14. **Return to “Bank Model Output” sheet**

Still Unstable with Vegetation

Bank model output

Verify the bank material and bank and bank-toe protection information entered in the "Bank Material" and "Bank Vegetation and Protection" worksheets. Once you are satisfied that you have completed all necessary inputs, hit the "Run Bank-Stability Model" button.

Bank Material Properties

Layer 1	Layer 2	Layer 3	Layer 4	Layer 5
Soft Clay	Soft Clay	Silt	Silt	Silt

The graph plots ELEVATION (M) on the y-axis (from -1.00 to 6.00) against STATION (M) on the x-axis (from -4.00 to 8.00). It shows a black bank profile, horizontal lines for the base of each layer (Layer 1 to 5), a red failure plane, a blue water table, and a grey water surface. A legend on the right identifies these elements.

Water table depth (m) below bank top
 Use water table
 Input own pore pressures (kPa)

Own Pore Pressures	kPa	Pore Pressure From Water Table
<input type="text"/>	Layer 1	<input type="text" value="-24.52"/>
<input type="text"/>	Layer 2	<input type="text" value="-14.71"/>
<input type="text"/>	Layer 3	<input type="text" value="-4.90"/>
<input type="text"/>	Layer 4	<input type="text" value="4.90"/>
<input type="text"/>	Layer 5	<input type="text" value="14.71"/>

Factor of Safety

0.99	Unstable
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Run Bank-Stability Model

Revised strength and F_s calculated automatically

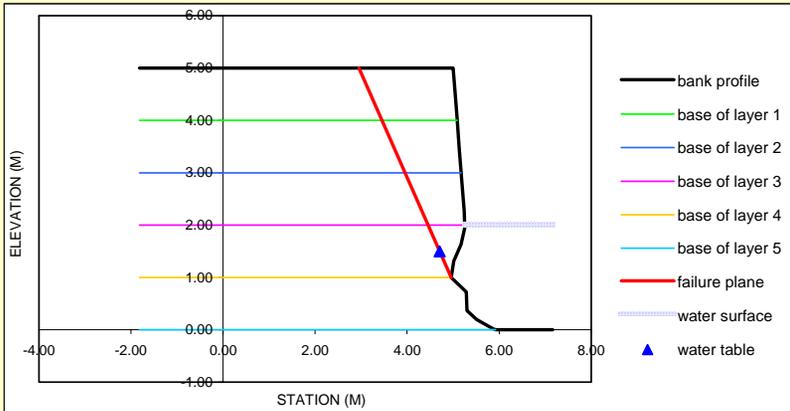
Conditionally Stable with Lower Water Table

Bank model output

Verify the bank material and bank and bank-toe protection information entered in the "Bank Material" and "Bank Vegetation and Protection" worksheets. Once you are satisfied that you have completed all necessary inputs, hit the "Run Bank-Stability Model" button.

Bank Material Properties

Layer 1	Layer 2	Layer 3	Layer 4	Layer 5
Soft Clay	Soft Clay	Silt	Silt	Silt



Water table depth (m) below bank top

Use water table
 Input own pore pressures (kPa)

Own Pore Pressures	kPa	Pore Pressure From Water Table
<input type="text"/>	Layer 1	-29.42
<input type="text"/>	Layer 2	-19.61
<input type="text"/>	Layer 3	-9.81
<input type="text"/>	Layer 4	0.00
<input type="text"/>	Layer 5	9.81

Factor of Safety

1.11

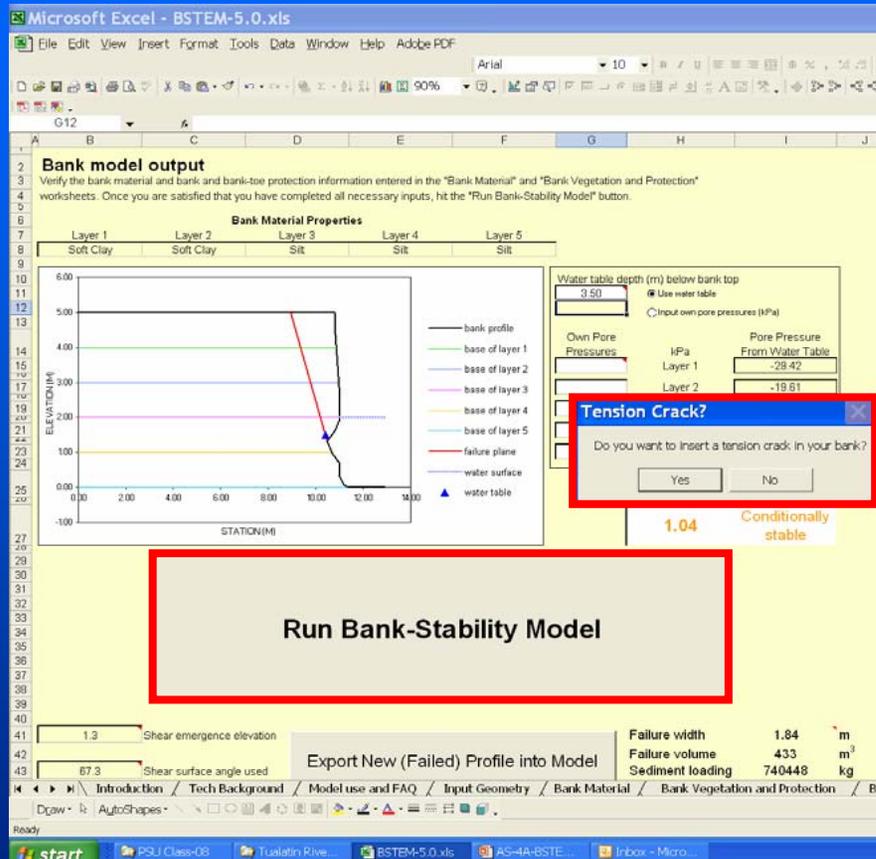
Conditionally stable

Change water-table depth to 3.5 m

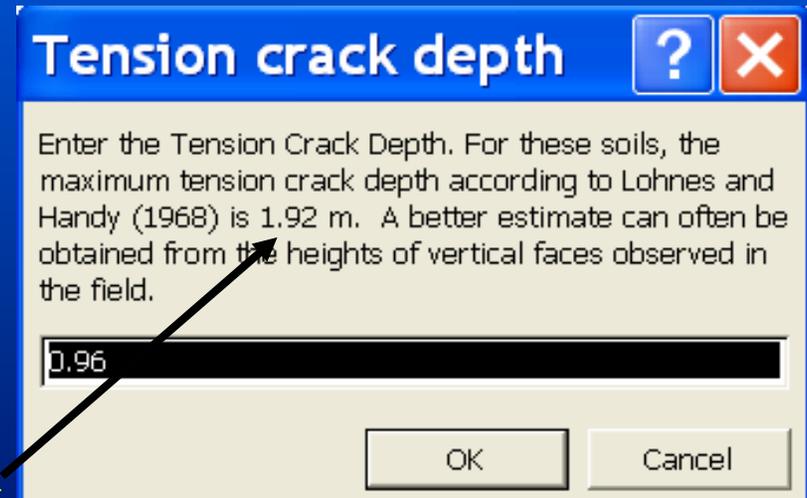
Run Bank-Stability Model

Revised pore-water pressures and F_s calculated automatically

Further Simulations...Tension Cracks



1. Click "Run-Bank Stability Model"
2. Click "Yes" for tension crack
3. Enter depth of tension crack



Maximum based on cohesion and unit weight

We often use $\frac{1}{2}$ the value or observed vertical-face heights

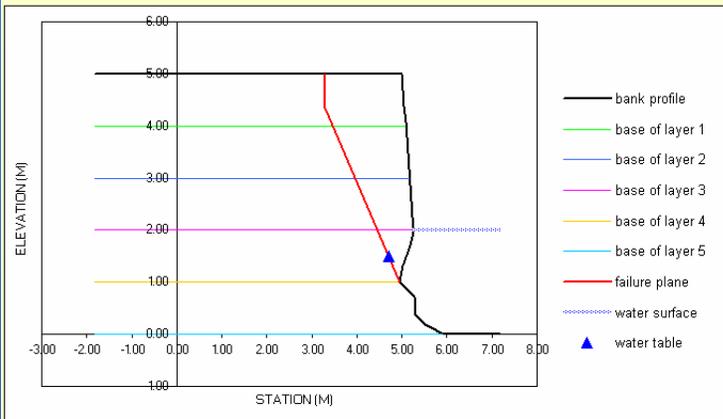
Results with Tension Crack

Bank model output

Verify the bank material and bank and bank-toe protection information entered in the "Bank Material" and "Bank Vegetation and Protection" worksheets. Once you are satisfied that you have completed all necessary inputs, hit the "Run Bank-Stability Model" button.

Bank Material Properties

Layer 1	Layer 2	Layer 3	Layer 4	Layer 5
Soft Clay	Soft Clay	Silt	Silt	Silt



Water table depth (m) below bank top
3.50 Use water table Input own pore pressures (kPa)

Own Pore Pressures	kPa	Pore Pressure From Water Table
	Layer 1	-29.42
	Layer 2	-19.61

Horizontal Layer Factor of Safety

The Fs with no tension crack is 1.11.

0.79 Unstable

Run Bank-Stability Model

1.0	Shear emergence elevation	<input type="button" value="Export New (Failed) Profile into Model"/>	Failure width	1.71	m
63.4	Shear surface angle used		Failure volume	457	m ³
			Sediment loading	781362	kg

Model use and FAQ / Input Geometry / Bank Material / Bank Vegetation and Protection / **Bank Model Output** / Toe Model Output

$$F_s = 0.79$$

Bank is unstable again due to loss of strength along upper part of failure plane.

Bank-Toe Protection

1. Re-open BSTEM-5.0.xls
2. Select “Input Geometry sheet”
3. Select Option B
4. Input these values:
5. Input channel and flow parameters
6. Click “Run Bank Geometry Macro”
7. Open “Bank Material” sheet
8. Select “Moderate silt” for all layers
9. Select “Toe Model Output” sheet
10. Click “Run Toe-Erosion Model”

Option B - Enter a bank height and angle, the model will generate a bank profile

Option B

a) Input bank height (m)

b) Input bank angle (°)

c) Input bank toe length (m)

d) Input bank toe angle (°)

Input shear surface angle

Channel and flow parameters

Input reach length (m)

Input reach slope (m/m)

Input concentration (kg/kg)

Input elevation of flow (m)

Input duration of flow (hrs)

Toe Erosion without Protection

Toe Model Output

Verify the bank material and bank and bank-toe protection information entered in the "Bank Material" and "Bank Vegetation and Protection" worksheets. Once you are satisfied that you have completed all necessary inputs, hit the "Run Toe-Erosion Model" button (Center Right of this page).

Bank Material					Bank Toe Material		
Layer 1	Layer 2	Layer 3	Layer 4	Layer 5		Material	
Moderate cohesive							
5.00	5.00	5.00	5.00	5.00	5.00	Critical shear stress (Pa)	
0.045	0.045	0.045	0.045	0.045	0.045	Erodibility Coefficient (cm ³ /Ns)	

Run Toe-Erosion Model

Average applied boundary shear stress	52.200	Pa
Maximum Lateral Retreat	0.000	cm
Eroded Area - Bank	0.202	m ²
Eroded Area - Bank Toe	0.421	m ²
Eroded Area - Bed	0.000	m ²
Eroded Area - Total	0.622	m ²

Export New (Eroded) Profile into Model

Toe Erosion = 0.62 m²

Bank-Toe Protection

1. Re-open BSTEM-5.0.xls
2. Select “Input Geometry sheet”
3. Select Option B
4. Input these values:
5. Input channel and flow parameters
6. Click “Run Bank Geometry Macro”
7. Open “Bank Material” sheet
8. Select “Moderate silt” for all layers
9. Select “Toe Model Output” sheet
10. Click “Run Toe-Erosion Model” and notate
11. Select “Bank Material” sheet and select boulders for layer 5 and toe material
12. Select “Toe Model Output” sheet and click “Run Toe-Erosion Model”

Option B - Enter a bank height and angle, the model will generate a bank profile

Option B

a) Input bank height (m)

b) Input bank angle (°)

c) Input bank toe length (m)

d) Input bank toe angle (°)

Input shear surface angle

Channel and flow parameters

Input reach length (m)

Input reach slope (m/m)

Input concentration (kg/kg)

Input elevation of flow (m)

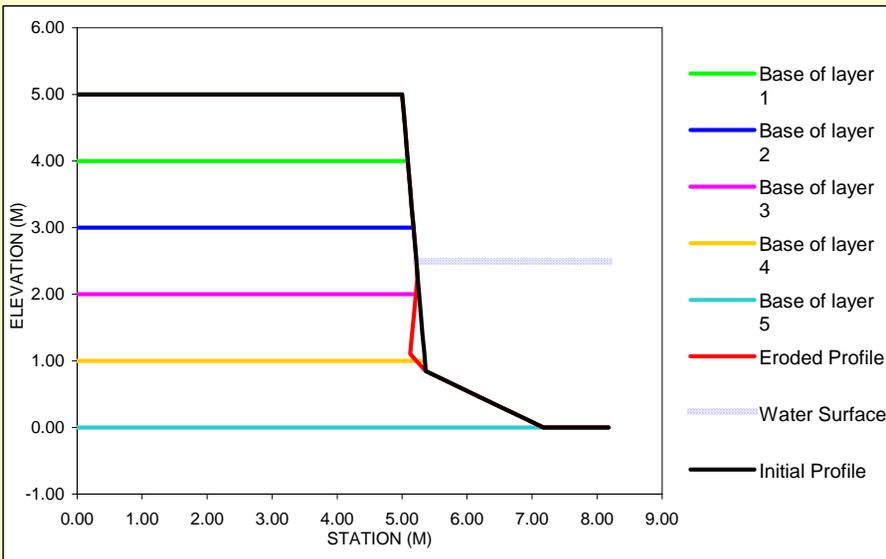
Input duration of flow (hrs)

Toe Erosion with Protection

Toe Model Output

Verify the bank material and bank and bank-toe protection information entered in the "Bank Material" and "Bank Vegetation and Protection" worksheets. Once you are satisfied that you have completed all necessary inputs, hit the "Run Toe-Erosion Model" button (Center Right of this page).

Bank Material					Bank Toe Material		
Layer 1	Layer 2	Layer 3	Layer 4	Layer 5			
Moderate cohesive	Moderate cohesive	Moderate cohesive	Moderate cohesive	Boulders	Boulders	Material	
5.00	5.00	5.00	5.00	497.66	497.66	Critical shear stress (Pa)	
0.045	0.045	0.045	0.045	0.004	0.004	Erodibility Coefficient (cm ³ /Ns)	



Run Toe-Erosion Model

Average applied boundary shear stress	52.200	Pa
Maximum Lateral Retreat	0.000	cm
Eroded Area - Bank	0.154	m ²
Eroded Area - Bank Toe	0.000	m ²
Eroded Area - Bed	0.000	m ²
Eroded Area - Total	0.154	m ²

Export New (Eroded) Profile into Model

Toe Erosion = 0.15 m²

Distinguish Between Hydraulic and Geotechnical Bank Protection

- Toe armoring
rock, LWD, live vegetation,
fiberschines
- Bank face armoring
mattresses, vertical bundles,
geotextiles

Hydraulic
Protection

- Bank reinforcement
pole and post plantings,
bank top vegetation, brush
layers, drainage

Geotechnical
Protection

Distinguish Between Hydraulic and Geotechnical Bank Protection

- Hydraulic protection reduces the available boundary hydraulic shear stress and increases the shear resistance to particle detachment

Hydraulic
Protection

- Geotechnical protection increases soil shear strength and decreases driving forces

Geotechnical
Protection