2D Sediment Options and Boundary Conditions

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Alex Sánchez, PhD

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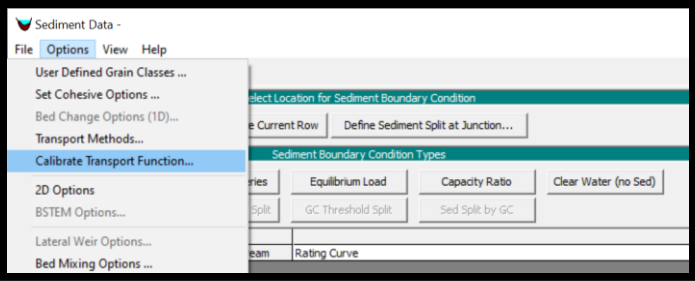
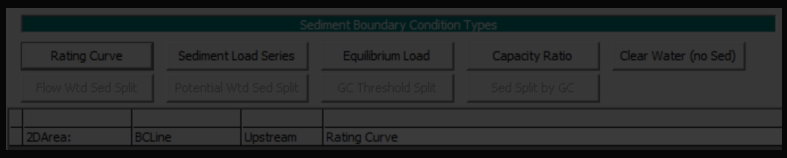
Topics

Sediment Options Menu



Boundary Condition Options



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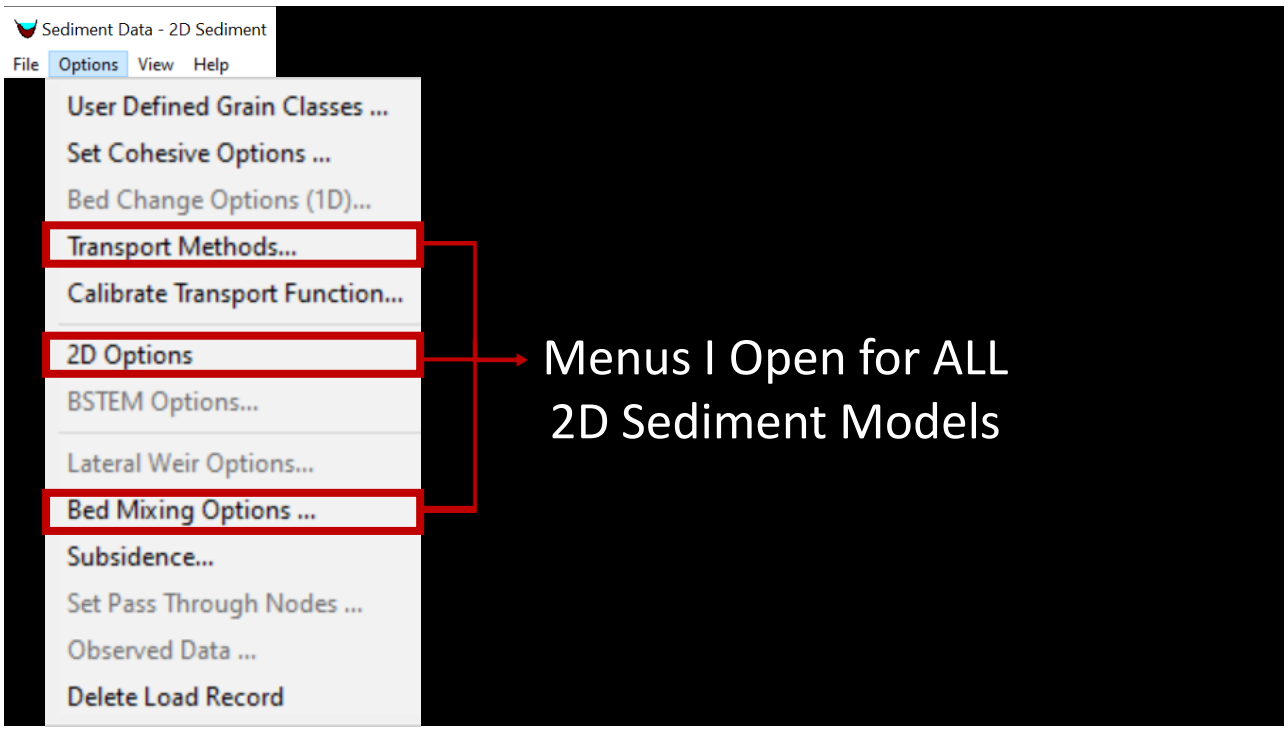

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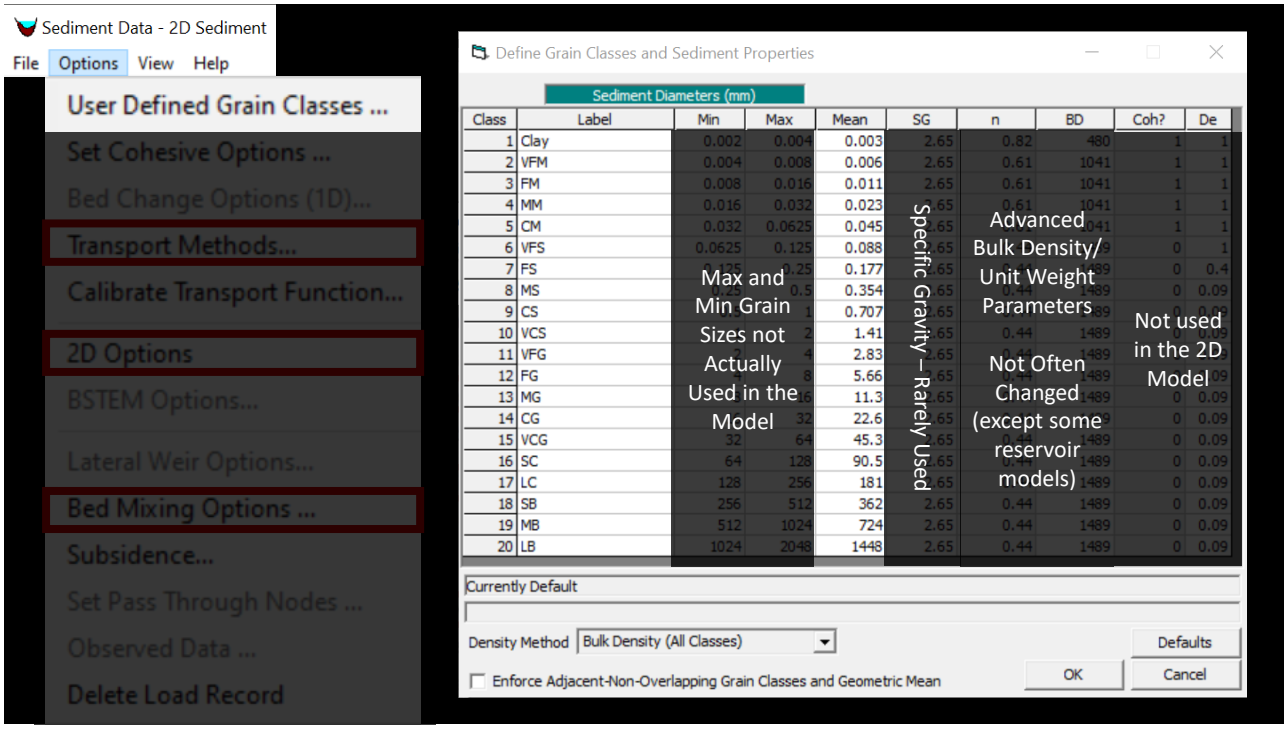
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Define Grain Classes and Sediment Properties
Sediment Diameters (mm)
Class
Label
Min
Max
Mean
SG
n
BD
Coh?
De
1 Clay 0.002 0.004 0.003 2.65 0.82 480 1 1
2 VFM 0.004 0.008 0.006 2.65 0.61 1041 1 1
3 FM 0.008 0.016 0.011 2.65 0.61 1041 1 1
4 MM 0.016 0.032 0.023 2.65 0.61 1041 1 1
5 CM 0.032 0.0625 0.045 2.65 0.61 1041 1 1
6 VFS 0.0625 0.125 0.088 2.65 0.61 1041 0 1
7 FS 0.125 0.25 0.177 2.65 0.44 1489 0 0.4
8 MS 0.25 0.5 0.354 2.65 0.44 1489 0 0.09
9 CS 0.5 1 0.707 2.65 0.44 1489 0 0.09
10 VCS 1 2 1.41 2.65 0.44 1489 0 0.09
11 VFG 2 4 2.83 2.65 0.44 1489 0 0.09
12 FG 4 8 5.66 2.65 0.44 1489 0 0.09
13 MG 8 16 11.3 2.65 0.44 1489 0 0.09
14 CG 16 32 22.6 2.65 0.44 1489 0 0.09
15 VCG 32 64 45.3 2.65 0.44 1489 0 0.09
16 SC 64 128 90.5 2.65 0.44 1489 0 0.09
17 LC 128 256 181 2.65 0.44 1489 0 0.09
18 SB 256 512 362 2.65 0.44 1489 0 0.09
19 MB 512 1024 724 2.65 0.44 1489 0 0.09
20 LB 1024 2048 1448 2.65 0.44 1489 0 0.09
Max and Min Grain Sizes not Actually Used in the Model
Specific Gravity – Rarely Used
Advanced Bulk Density/ Unit Weight Parameters
Not Often Changed (except some reservoir models)
Not used in the 2D Model
Currently Default
Density Method
Bulk Density (All Classes)
Defaults
Enforce Adjacent-Non-Overlapping Grain Classes and Geometric Mean
OK
Cancel

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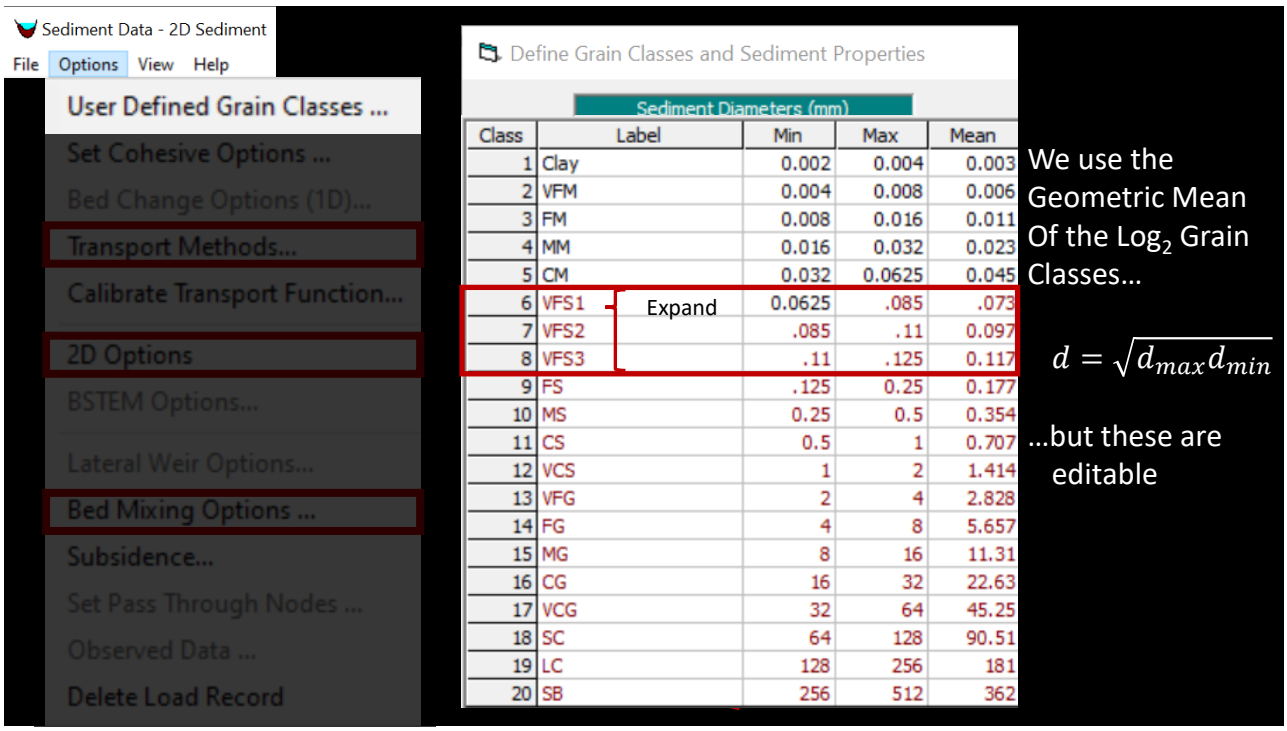
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Define Grain Classes and Sediment Properties
Sediment Diameters (mm)
Class
Label
Min
Max
Mean
1 Clay 0.002 0.004 0.003
2 VFM 0.004 0.008 0.006
3 FM 0.008 0.016 0.011
4 MM 0.016 0.032 0.023
5 CM 0.032 0.0625 0.045
6 VFS1 0.0625 .085 .073
7 VFS2 .085 .11 0.097
8 VFS3 .11 .125 0.117
9 FS .125 0.25 0.177
10 MS 0.25 0.5 0.354
11 CS 0.5 1 0.707
12 VCS 1 2 1.414
13 VFG 2 4 2.828
14 FG 4 8 5.657
15 MG 8 16 11.31
16 CG 16 32 22.63
17 VCG 32 64 45.25
18 SC 64 128 90.51
19 LC 128 256 181
20 SB 256 512 362
Expand
We use the Geometric Mean Of the Log2 Grain Classes…
$d = \sqrt{d_{max} d_{min}}$
…but these are editable

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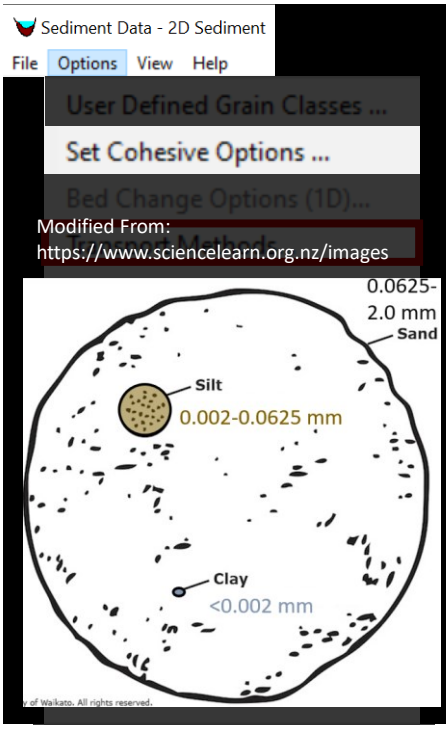

Define Grain Classes and Sediment Properties

		Sediment Diameters (mm)		
Class	Label	Min	Max	Mean
1	Clay	0.002	0.004	0.003
2	VFM	0.004	0.008	0.006
3	FM	0.008	0.016	0.011
4	MM	0.016	0.032	0.023
5	CM	0.032	0.0625	0.045
6	VFS	0.0625	0.125	0.088
7	FS	0.125	0.25	0.177
8	MS	0.25	0.5	0.354
9	CS	0.5	1	0.707
10	VCS	1	2	1.41
11	VFG	2	4	2.83
12	FG	4	8	5.66
13	MG	8	16	11.3
14	CG	16	32	22.6
15	VCG	32	64	45.3
16	SC	64	128	90.5
17	LC	128	256	181
18	SB	256	512	362
19	MB	512	1024	724
20	LB	1024	2048	1448

Applies to the first five grain classes:
Sand and Silt
<625 microns or
<0.0625 mm
In default grain classes

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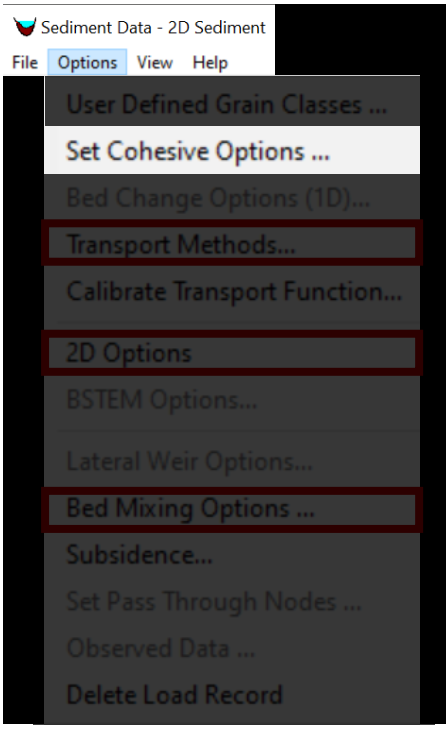
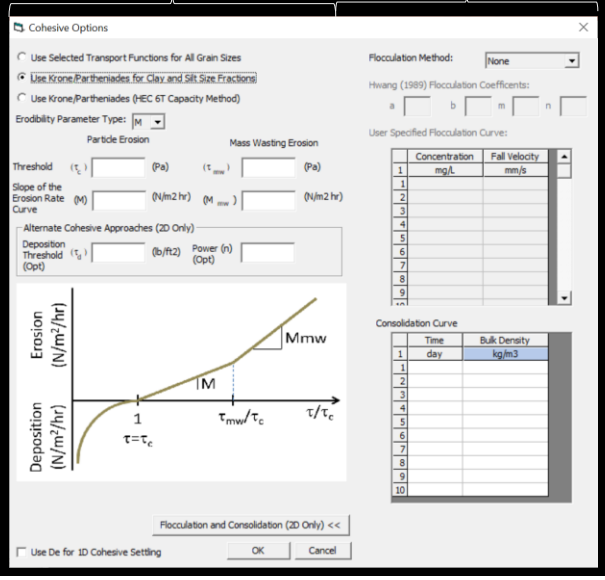


$$E = k_d(\tau_b - \tau_c)$$

Excess Shear Erodibility Model

2D-Specific Methods



Flocculation (2 Methods) Consolidation

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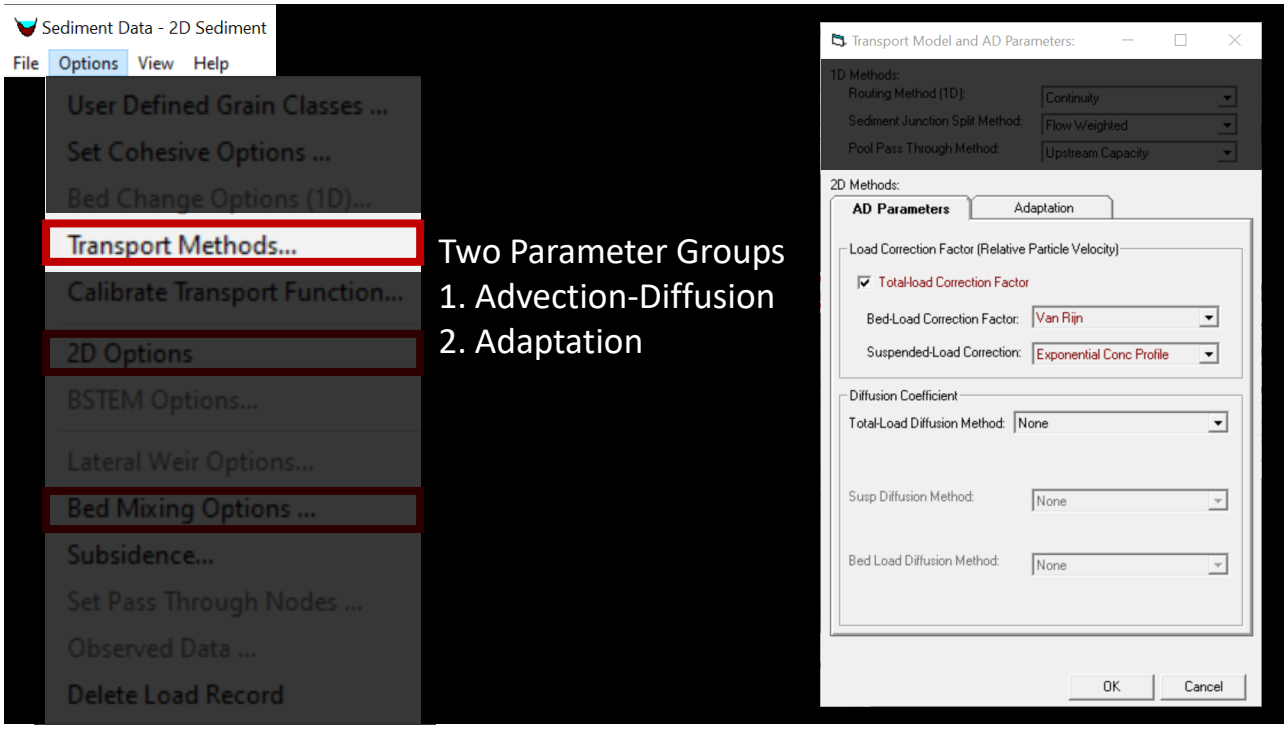

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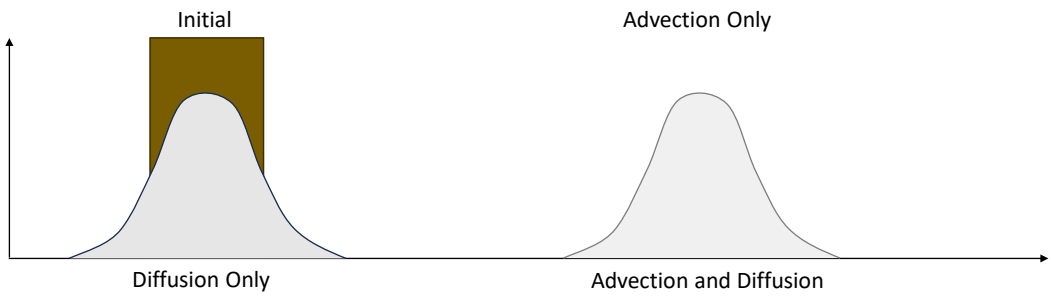
Governing Sediment Equations

- Total-load Transport Equation

$$\frac{\partial}{\partial t}\left(\frac{hC_{tk}}{\beta_{tk}}\right) + \nabla \cdot (h\mathbf{U}C_{tk}) = \nabla \cdot (\varepsilon_{tk} h \nabla C_{tk}) + E_{tk} - D_{tk}$$

Advection Diffusion



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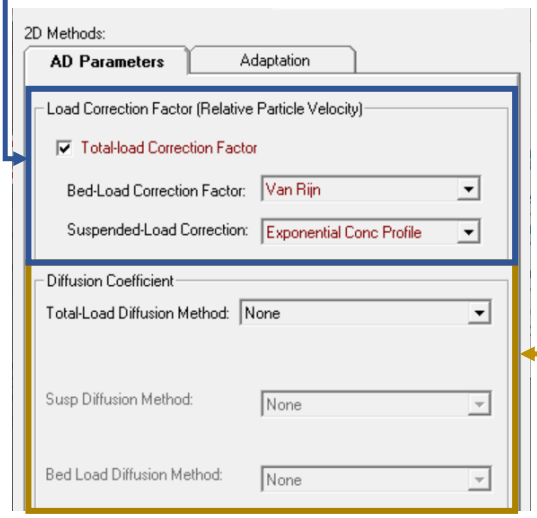
$$\frac{\partial}{\partial t}\left(\frac{hC_{tk}}{\beta_{tk}}\right) + \nabla \cdot (h\mathbf{U}C_{tk}) = \nabla \cdot (\varepsilon_{tk} h \nabla C_{tk}) + E_{tk} - D_{tk}$$

Advection

Diffusion

Load Correction Factor (Relative Particle Velocity)



Diffusion Coefficient

Not Commonly Adjusted

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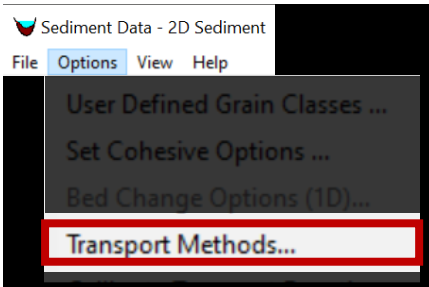


The Adaptation Length affects the non-equilibrium erosion and deposition rate.

Guidance is 1 to 2X the cell size. (downstream direction)

Increasing Adaptation Length approaches an equilibrium model, increases deposition and erosion, leads to stronger blue-red.

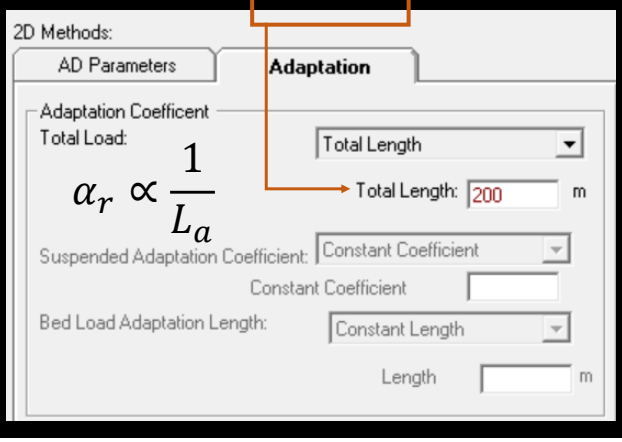
↑ Adaptation Length ↓ Bed Change
↑ Adaptation Length Smooths Results
↑ Adaptation Length ↑ Stability

The Bed Change Equation

Deposition Erosion

$$\rho_{sk}(1-\phi_b)\left(\frac{\partial z_b}{\partial t}\right)_k = D_{tk} - E_{tk} + \nabla \cdot (\kappa_{bk}|q_{bk}|\nabla z_b)$$

$$D - E = \alpha_c \omega_s C - \alpha_c \omega_s C_*$$



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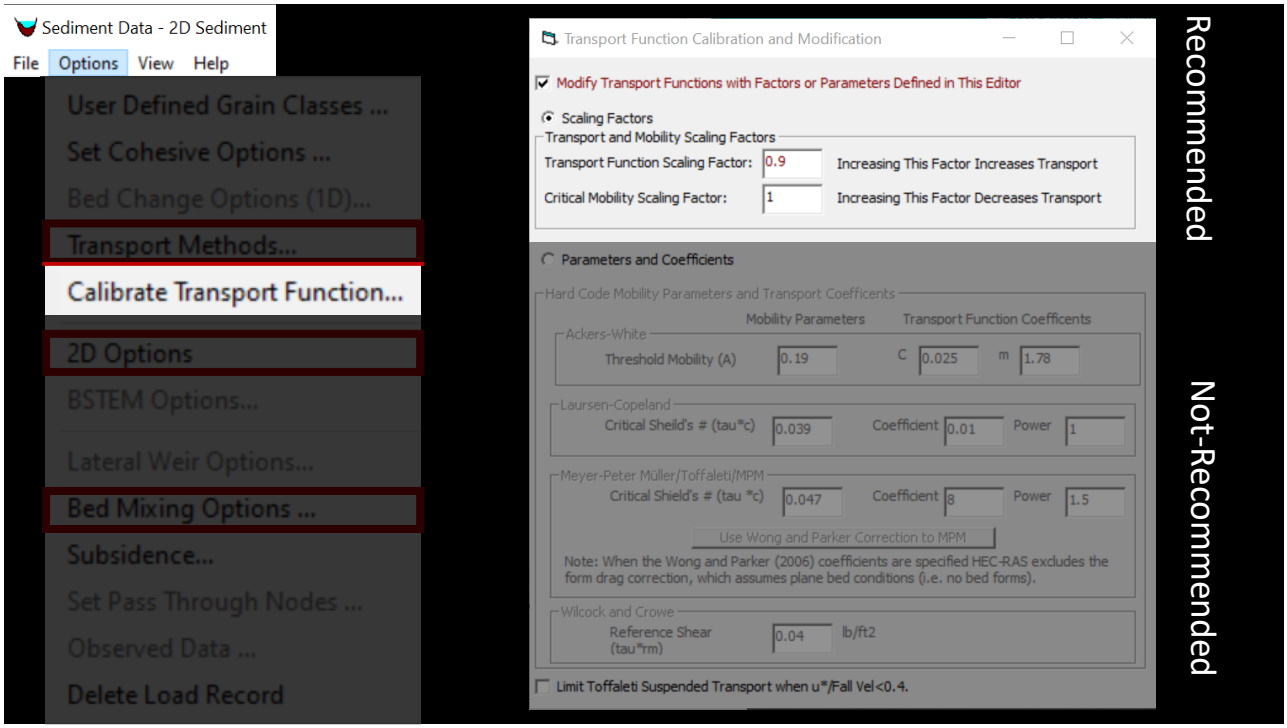
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Transport Function Calibration and Modification
Modify Transport Functions with Factors or Parameters Defined in This Editor
Scaling Factors
Transport and Mobility Scaling Factors
Transport Function Scaling Factor: 0.9
Increasing This Factor Increases Transport
Critical Mobility Scaling Factor: 1
Increasing This Factor Decreases Transport
Parameters and Coefficients
Hard Code Mobility Parameters and Transport Coefficents
Mobility Parameters
Transport Function Coefficents
Ackers-White
Threshold Mobility (A) 0.19
C 0.025
m 1.78
Laursen-Copeland
Critical Sheild's # (tau*c) 0.039
Coefficient 0.01
Power 1
Meyer-Peter Müller/Toffaleti/MPM
Critical Shield's # (tau *c) 0.047
Coefficient 8
Power 1.5
Use Wong and Parker Correction to MPM
Note: When the Wong and Parker (2006) coefficients are specified HEC-RAS excludes the form drag correction, which assumes plane bed conditions (i.e. no bed forms).
Wilcock and Crowe
Reference Shear (tau*rm) 0.04 lb/ft2
Limit Toffaleti Suspended Transport when u*/Fall Vel<0.4.
Recommended
Not-Recommended

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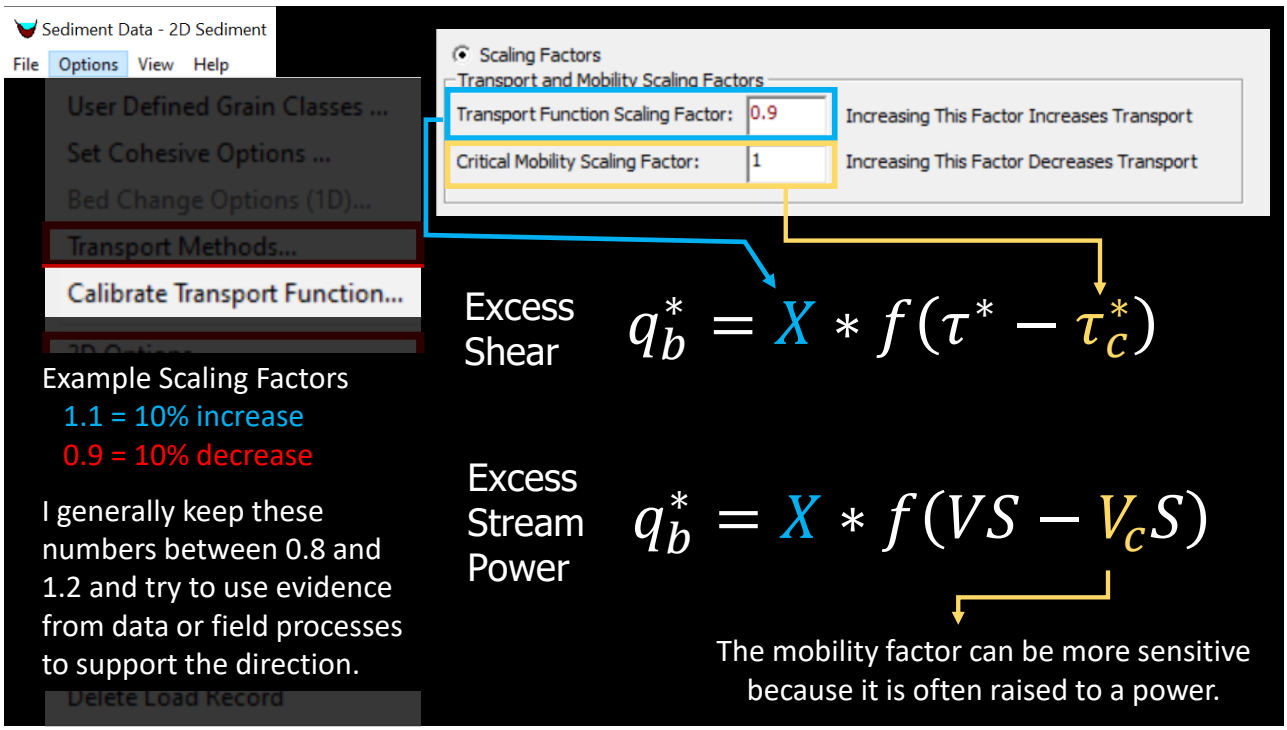
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Transport and Mobility Scaling Factors
Transport Function Scaling Factor: 0.9
Increasing This Factor Increases Transport
Critical Mobility Scaling Factor: 1
Increasing This Factor Decreases Transport
Example Scaling Factors
1.1 = 10% increase
0.9 = 10% decrease
I generally keep these numbers between 0.8 and 1.2 and try to use evidence from data or field processes to support the direction.
Excess Shear
$q_b^* = X * f(\tau^* - \tau_c^*)$
Excess Stream Power
$q_b^* = X * f(VS - V_cS)$
The mobility factor can be more sensitive because it is often raised to a power.

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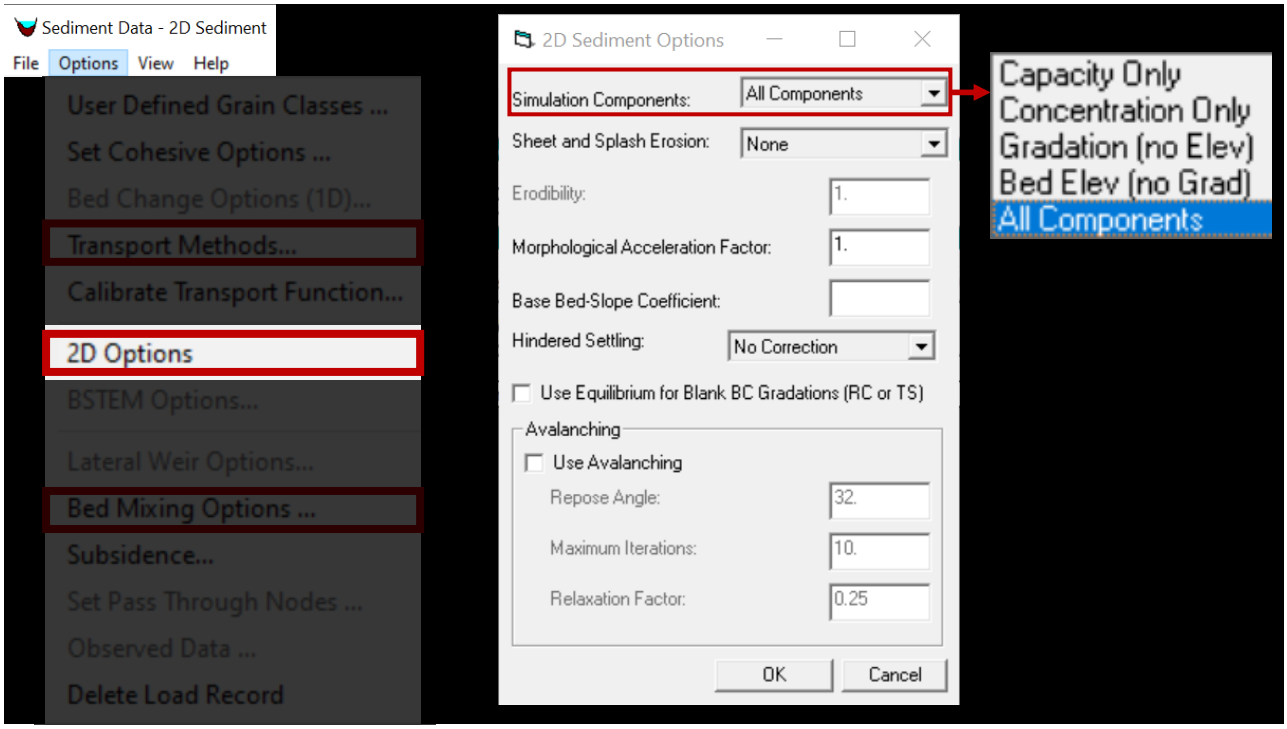
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2D Sediment Options
Simulation Components:
All Components
Sheet and Splash Erosion:
None
Erodibility:
1.
Morphological Acceleration Factor:
1.
Base Bed-Slope Coefficient:
Hindered Settling:
No Correction
Use Equilibrium for Blank BC Gradations (RC or TS)
Avalanching
Use Avalanching
Repose Angle:
32.
Maximum Iterations:
10.
Relaxation Factor:
0.25
OK
Cancel
Capacity Only
Concentration Only
Gradation (no Elev)
Bed Elev (no Grad)
All Components

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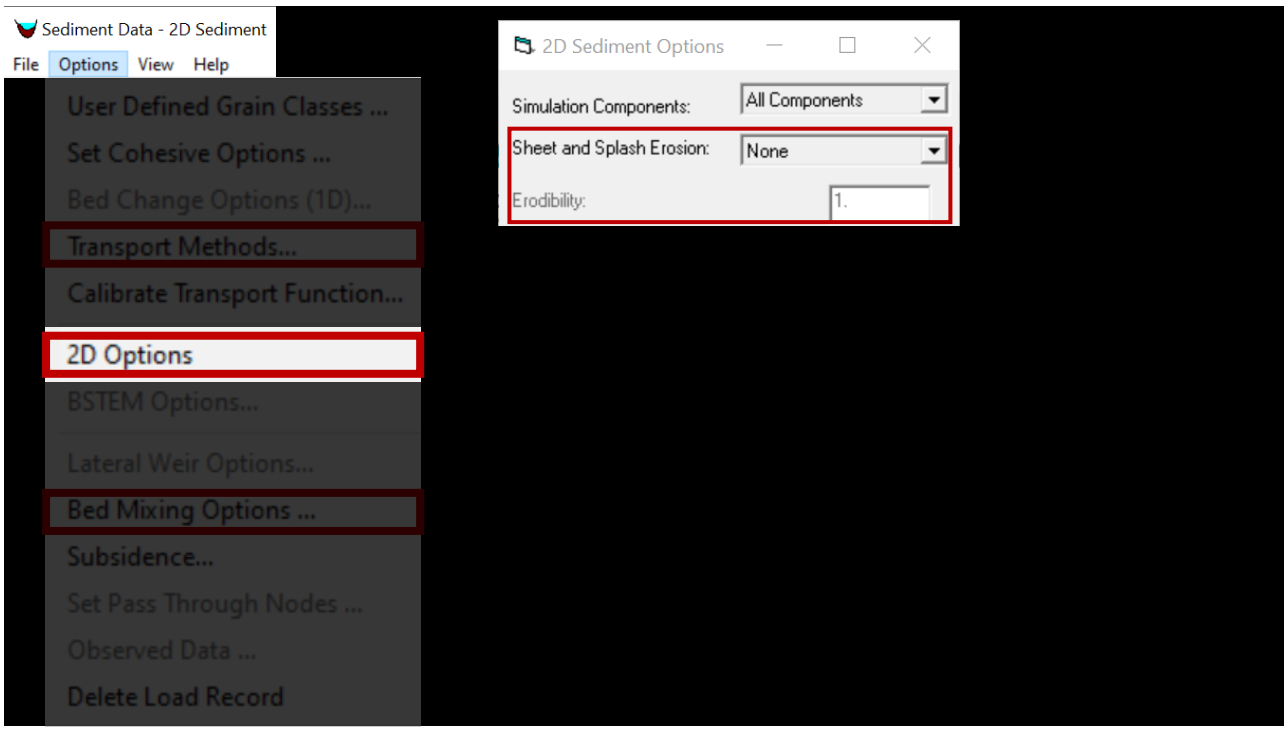
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Simulation Components:
All Components
Sheet and Splash Erosion:
None
Erodibility:
1.

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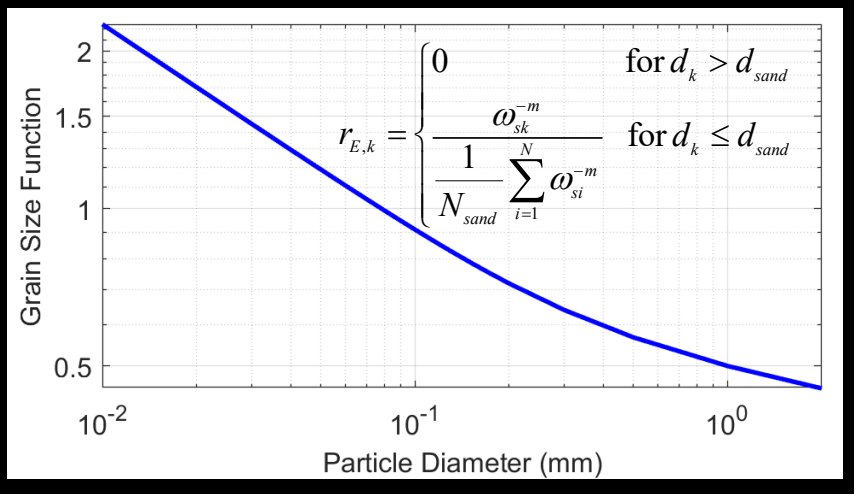
Sheet and Splash Erosion

- Based on Wei et al. (2009)
  - Extended to multiple grain sizes and limited for intense rain
  - Applied to hydraulically dry areas of cells
- No rill dynamics
  - Sediment instantly reaches wet portion of cell



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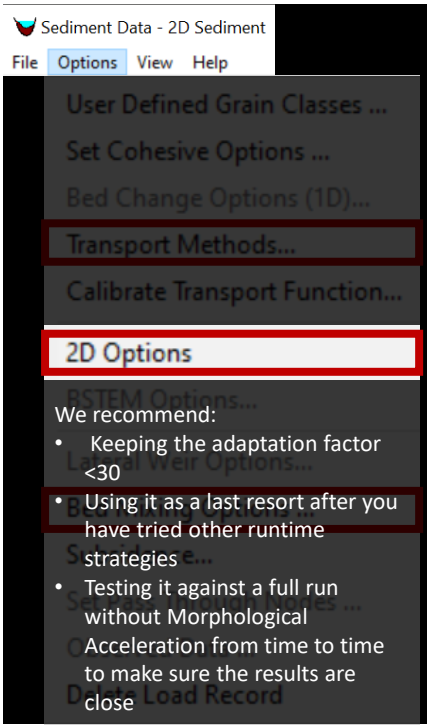
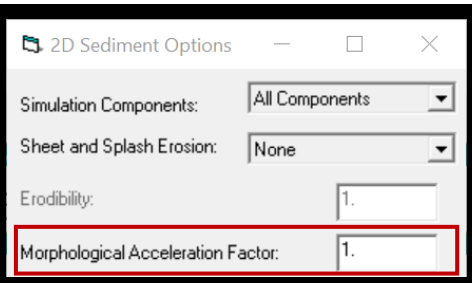
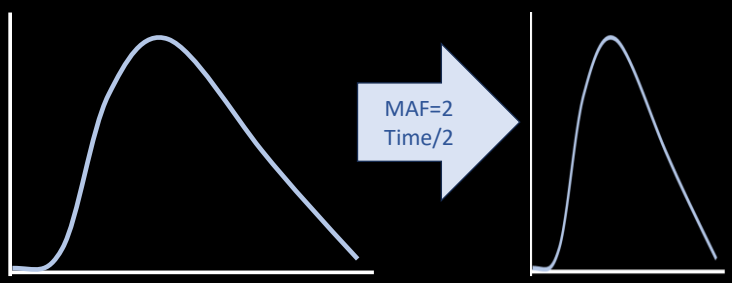


We recommend:

- Keeping the adaptation factor <30
- Using it as a last resort after you have tried other runtime strategies
- Testing it against a full run without Morphological Acceleration from time to time to make sure the results are close



Because sediment change is accelerated, you must compress time by compressing your hydrograph.



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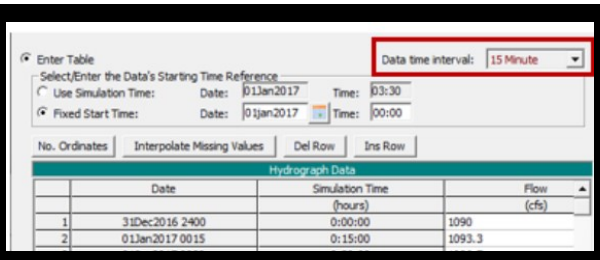

New Data Time Interval = Original Data Time Interval / Morphological Acceleration Factor

Accelerate bed change by 15X → Reduce Flow Increment from 15 to 1 min

Morphological Acceleration Factor: 15 Data time interval: 1 Minute

Accelerate bed change by 5X → Reduce Flow Increment from 15 to 3 min

Morphological Acceleration Factor: 5 Data time interval: 3 Minute

Accelerate bed change by 3X → Reduce Flow Increment from 15 to 5 min

Morphological Acceleration Factor: 3 Data time interval: 5 Minute

Choose an MAF that divides well into your original data time interval.

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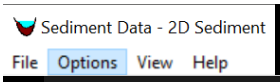
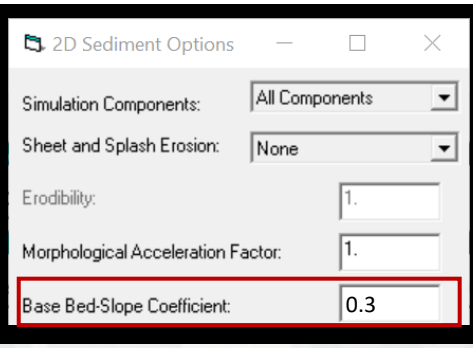


The slope correction is essentially a diffusion term for bed change.

↑ Slope Coefficient smooths erosion-deposition (e.g. red-blue patching)

2D Options

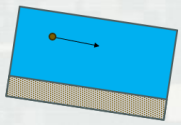
Recommended Range: 0.0-0.5



Governing Sediment Equations

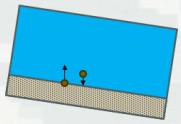
- Total-load Transport Equation

$$\frac{\partial}{\partial t}\left(\frac{hC_{tk}}{\beta_{tk}}\right) + \nabla \cdot (h\mathbf{U}C_{tk}) = \nabla \cdot (\varepsilon_{tk} h \nabla C_{tk}) + E_{tk} - D_{tk}$$



- Bed Change Equation

$$\rho_{sk}(1-\phi_b)\left(\frac{\partial z_b}{\partial t}\right)_k = D_{tk} - E_{tk} + \nabla \cdot (\kappa_{bk}|q_{bk}|\nabla z_b)$$



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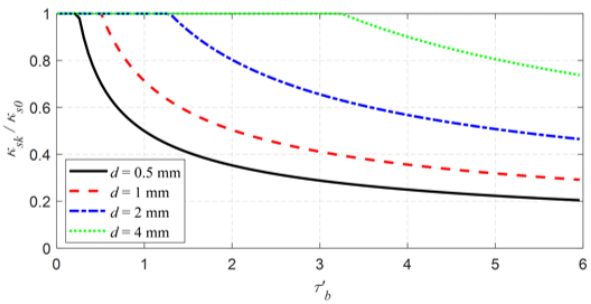
The Bed Change Equation

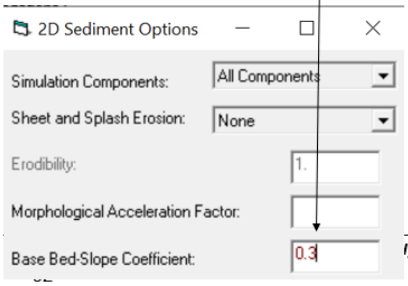
$$\rho_{sk}(1-\phi_b)\left(\frac{\partial z_b}{\partial t}\right)_k = D_{tk} - E_{tk} + \nabla\cdot(\kappa_{bk}|q_{bk}|\nabla z_b)$$

Bed Change | Deposition | Erosion | Slope Correction



$$\kappa_{bk} = \kappa_{b0}\sqrt{\frac{\tau_{crk0}}{\max(\tau'_b, \tau_{crk0})}}$$

$$\kappa_{b0} \approx 0.1 - 0.5$$



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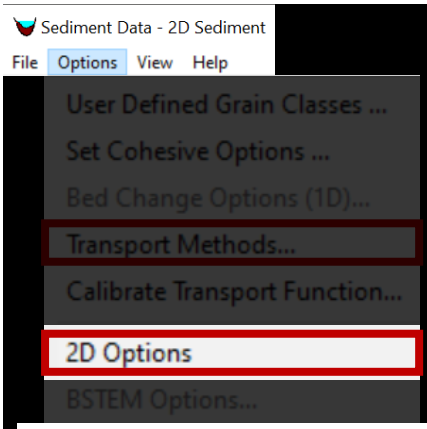

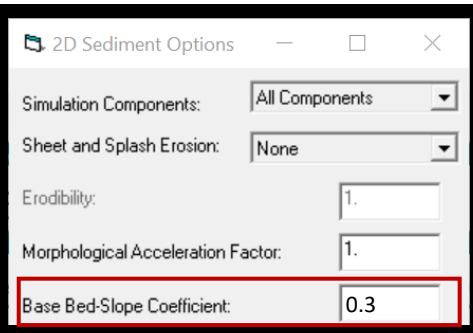

The Bed Change Equation

$$\rho_{sk}(1-\phi_b)\left(\frac{\partial z_b}{\partial t}\right)_k = D_{tk} - E_{tk} + \nabla\cdot(\kappa_{bk}|q_{bk}|\nabla z_b)$$

Bed Change | Deposition | Erosion | Slope Correction

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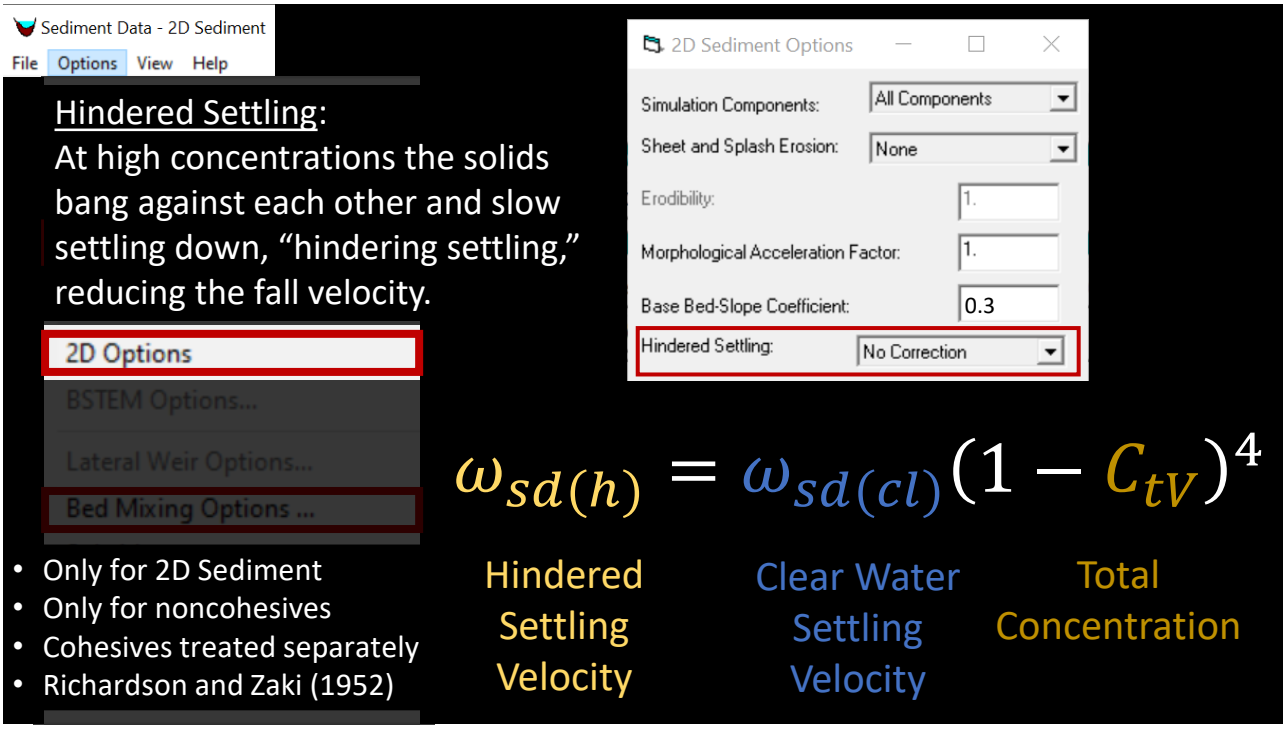

Hindered Settling:
At high concentrations the solids bang against each other and slow settling down, "hindering settling," reducing the fall velocity.

- Only for 2D Sediment
- Only for noncohesives
- Cohesives treated separately
- Richardson and Zaki (1952)

$$\omega_{sd(h)} = \omega_{sd(cl)}(1 - C_{tV})^4$$

Hindered Settling Velocity

Clear Water Settling Velocity

Total Concentration

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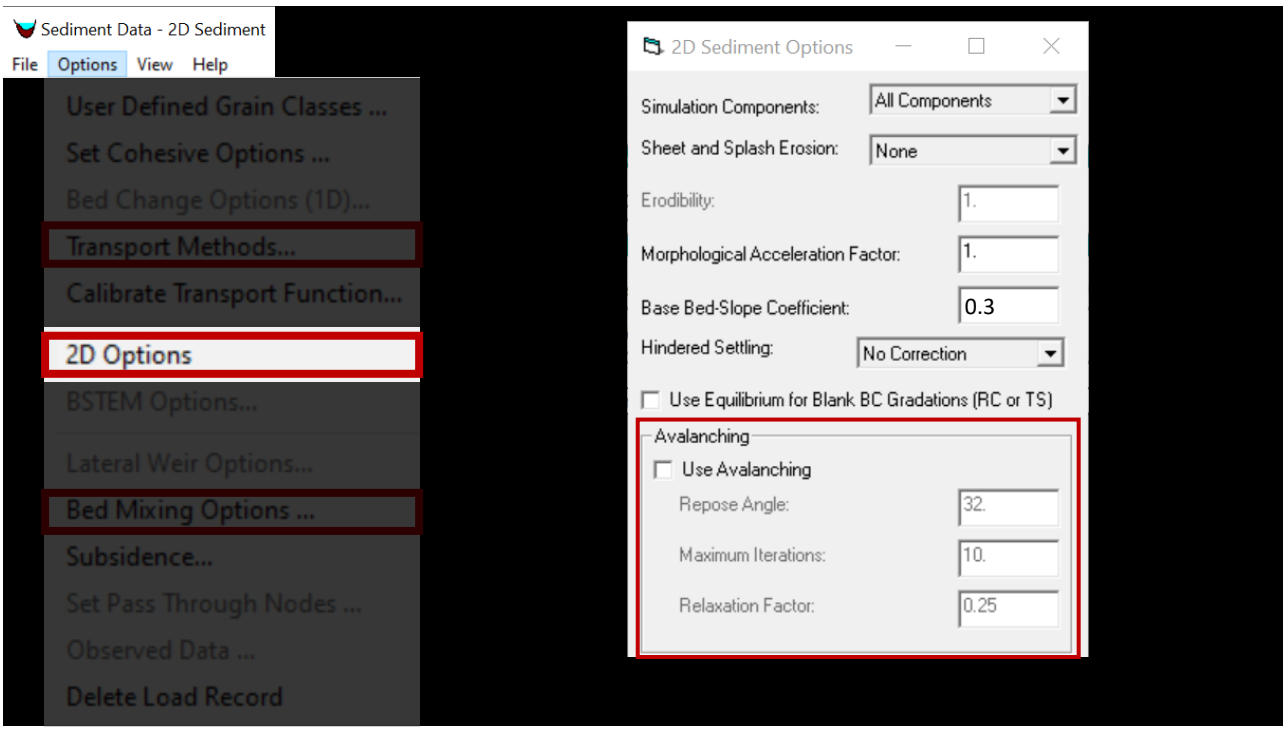

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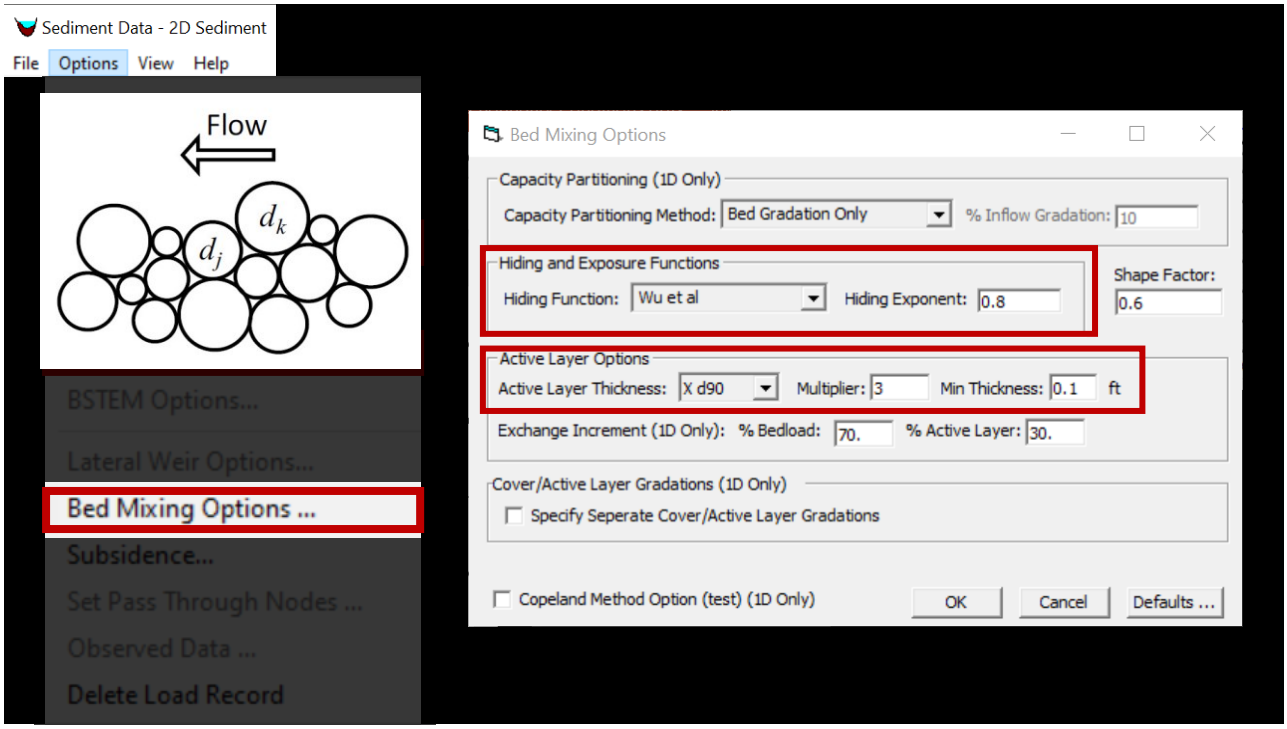

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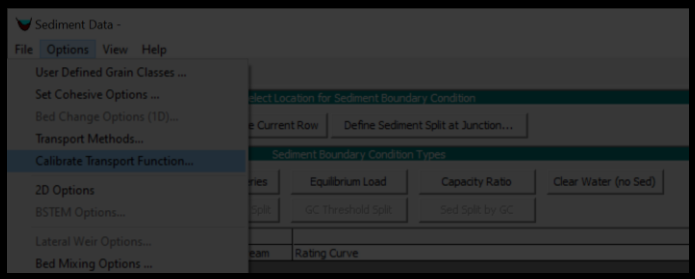
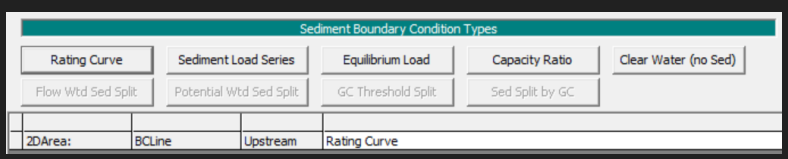
Topics

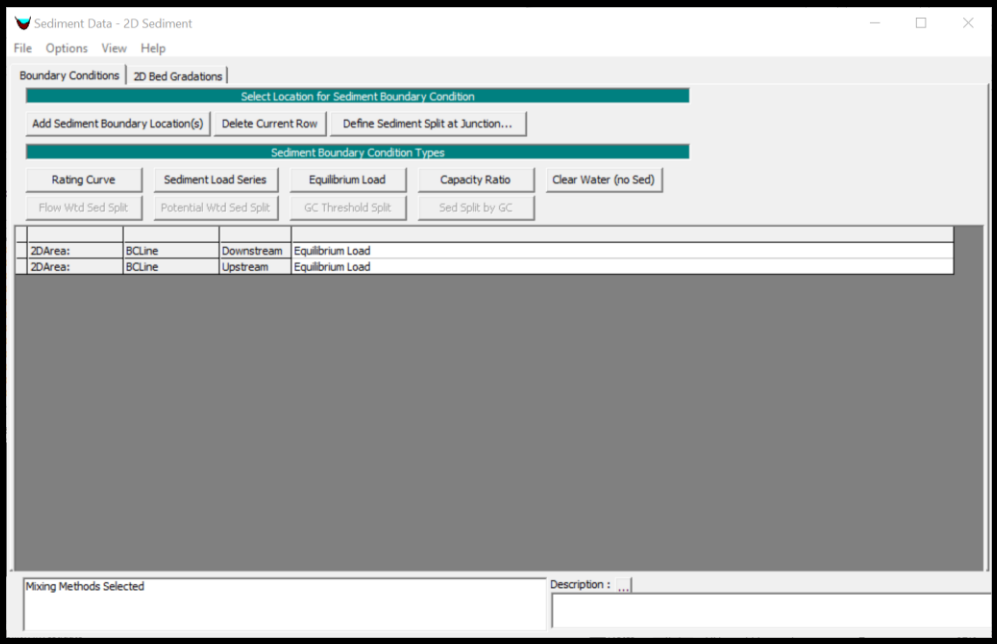
Sediment Options Menu



Boundary Condition Options

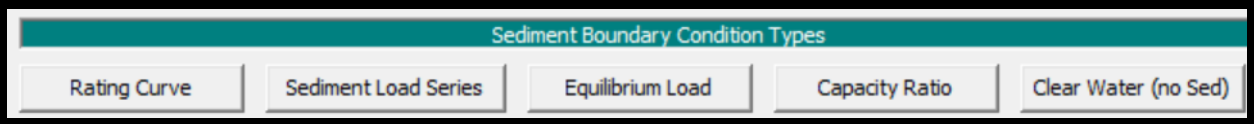


26



27

Upstream Boundary Conditions



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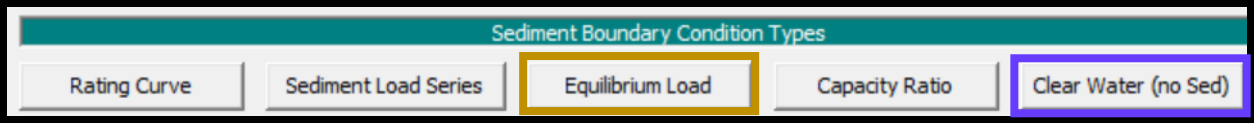
Upstream Boundary Conditions



Computes sediment capacity across boundary condition and introduces the load into the boundary cells equal to the capacity.

- Should keep the cells at the boundary condition stable.
- Cannot compute wash load.
- Problematic at actively changing transects.
- VERY sensitive to bed gradation at the cell centers which can be extremely uncertain.

Brings in no sediment. Can erode upstream cells if they are not coarse enough.

Let's start with the easiest two

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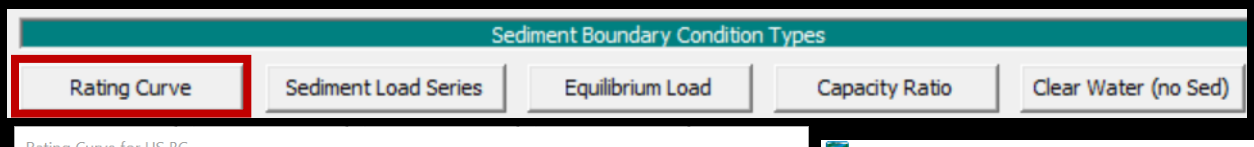
Upstream Boundary Conditions

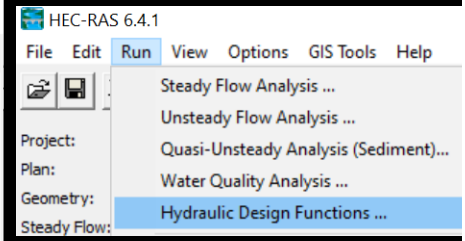


Rating Curve for US BC

Number of flow-load points: 3 sets ≤3

	Flow (cfs)	100	30000	200000
	Total Load (tons/day)	3.5	2100	105000
1	Clay (0.002-0.004)	20	20	15
2	VFM (0.004-0.008)	12	12	10
3	FM (0.008-0.016)	12	12	10
4	MM (0.016-0.032)	12	12	10
5	CM (0.032-0.0625)	12	12	10
6	VFS (0.0625-0.125)	12	12	10
7	FS (0.125-0.25)	20	20	30
8	MS (0.25-0.5)			
9	CS (0.5-1)			
10	VCS (1-2)			
11	VFG (2-4)			
12	FG (4-8)			
13	MG (8-16)			
14	CG (16-32)			
15	VCG (32-64)			
16	SC (64-128)			

Define Diversion Load ◉ Load ○ Concentration | Conc<-->Load | Plot ... | OK | Cancel



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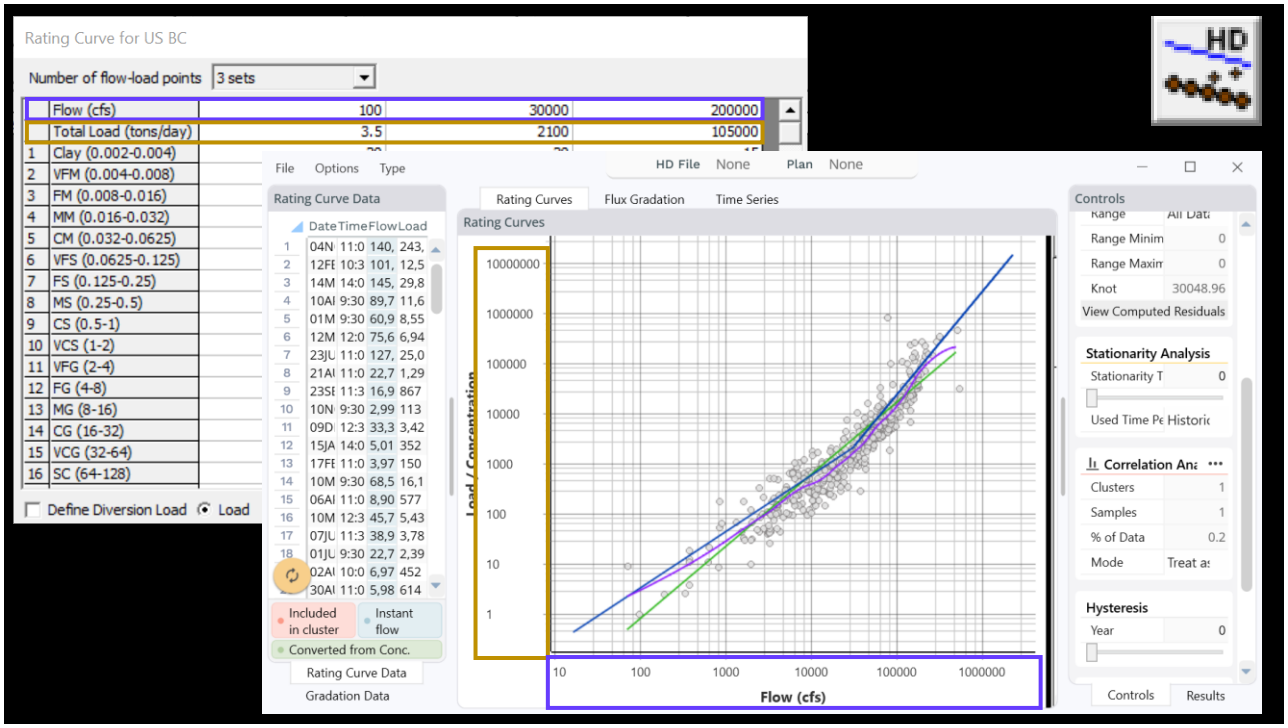

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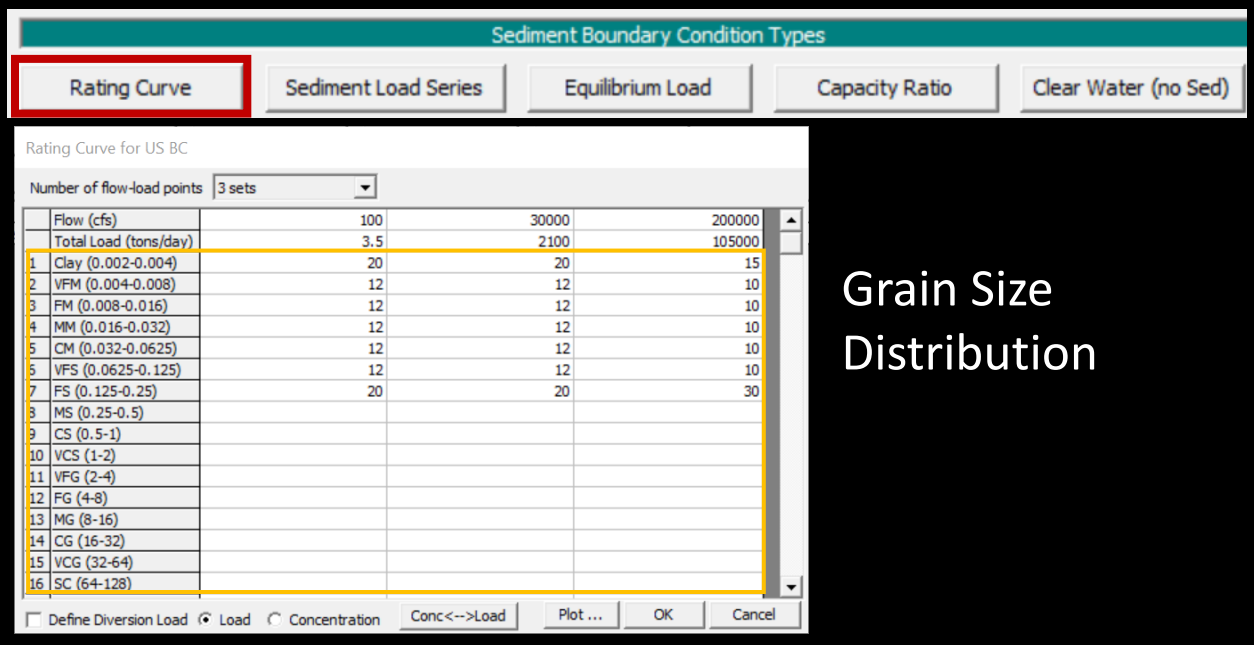
Upstream Boundary Conditions



Grain Size Distribution

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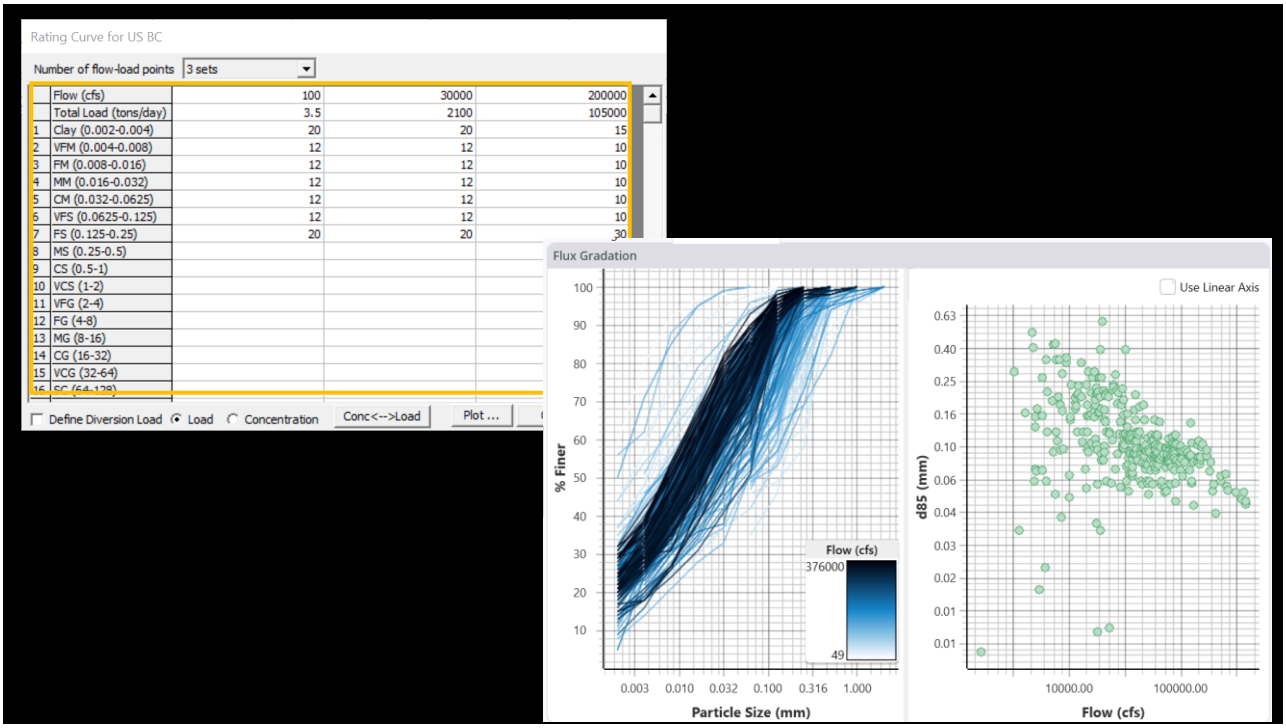

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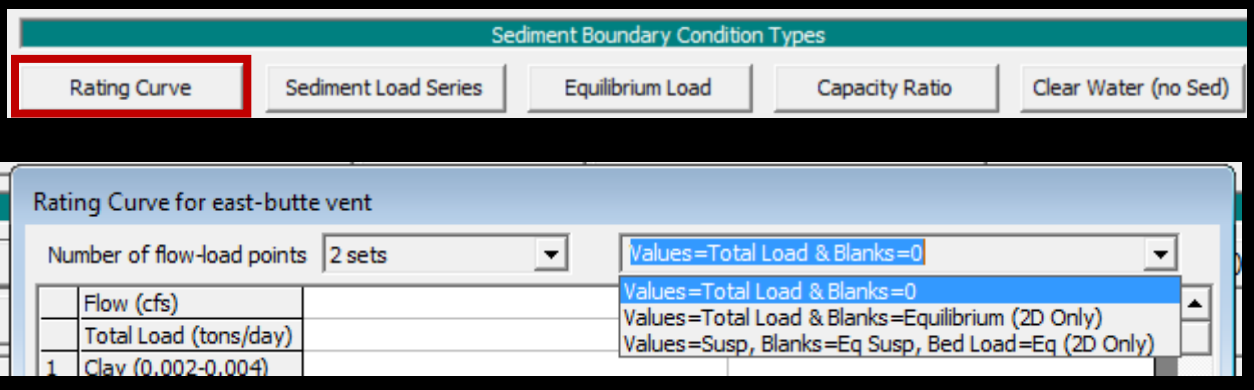
Upstream Boundary Conditions



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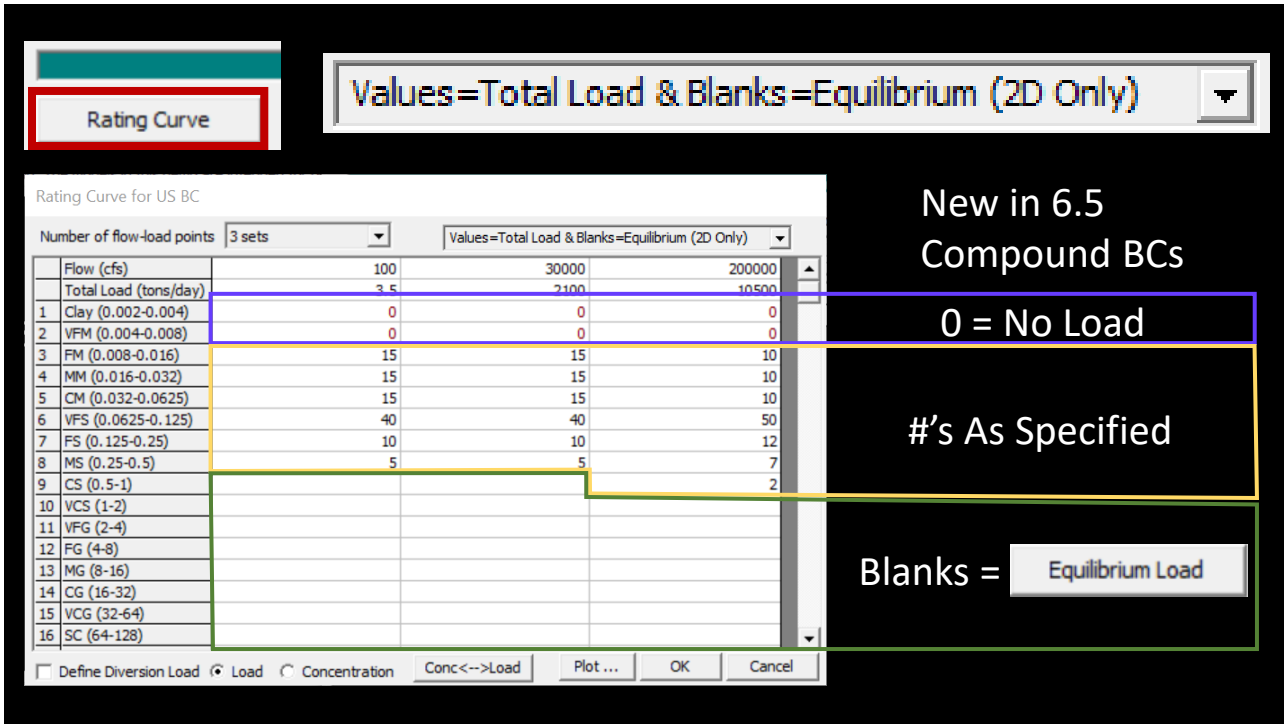

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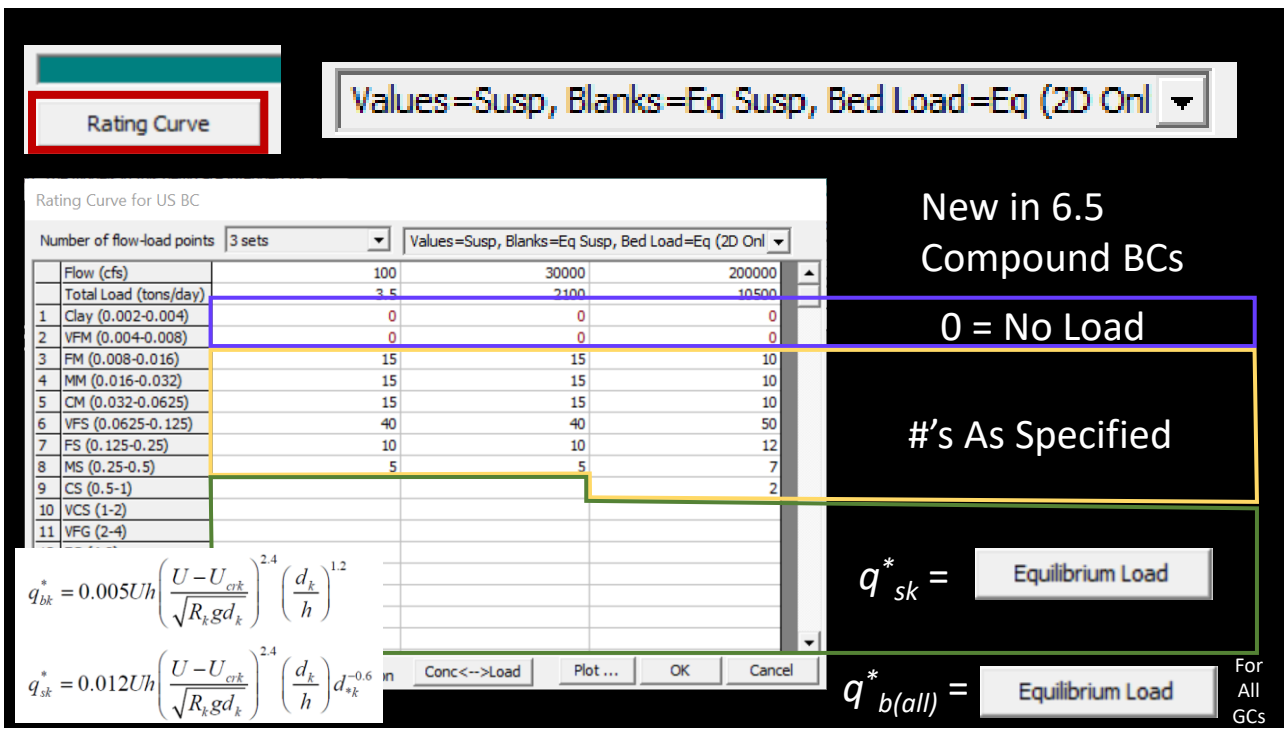
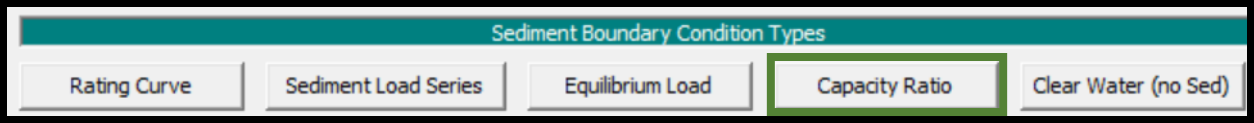


$$q_{bk}^{*} = 0.005Uh\left(\frac{U-U_{crk}}{\sqrt{R_k g d_k}}\right)^{2.4}\left(\frac{d_k}{h}\right)^{1.2}$$

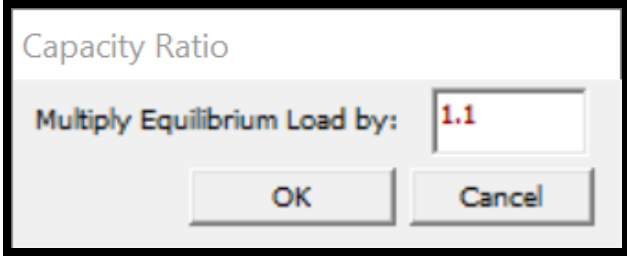
$$q_{sk}^{*} = 0.012Uh\left(\frac{U-U_{crk}}{\sqrt{R_k g d_k}}\right)^{2.4}\left(\frac{d_k}{h}\right)d_{*k}^{-0.6}$$

36

Upstream Boundary Conditions



10% Overloaded



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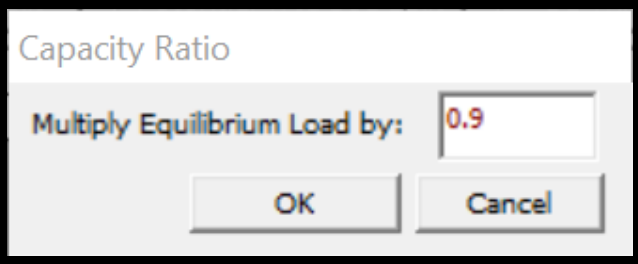

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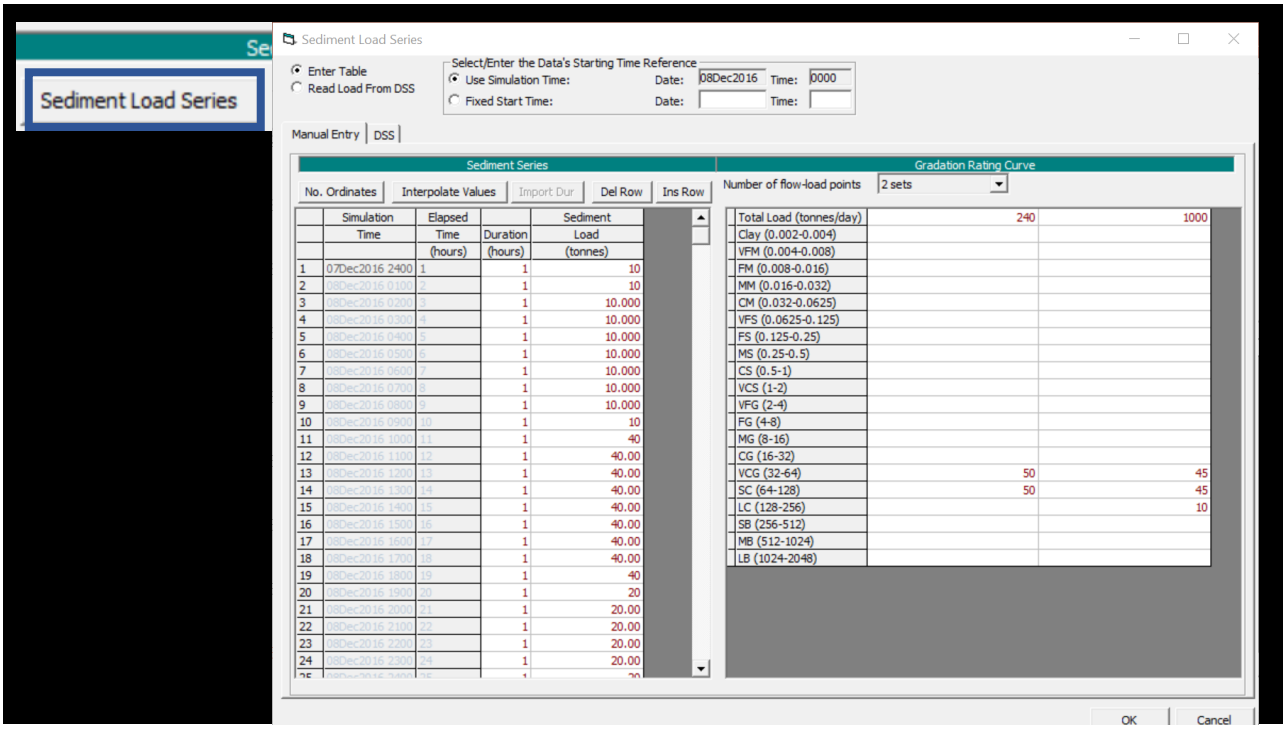

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