2D Sediment Workshop

1 Objective

In this workshop, you will use HEC-RAS to setup a simple 2D sediment simulation.

2 Introduction

The workshop is based on a series of laboratory experiments conducted by Weise (2002). The experiments were designed to study contraction scour and expansion deposition of nonuniformly sized sediment. The experiment consists of a 16.5-m long rectangular flume with a variable with between 0.5 m and 1 m. The straight side of the flume is a smooth glass while the curved side with rough concrete. The initial bed had a 20-cm layer of fine gravel with a 5.5 mm mean diameter and geometric standard deviation 1.47. The upstream flow was 0.15 m³/s and the downstream water depth was 0.312 m. The experiment duration was 125 min.

3 Workshop Instructions

3.1 Open the RAS Project

The HEC-RAS project is named Weise.prj and should be contained in a folder names 2D Sediment Workshop.

3.2 Geometry

The workshop already contains a terrain, computational mesh, boundary condition lines and Manning's n layer. The grid resolution utilized for this workshop is relatively coarse but is utilized for computational efficiency. It is always recommended to start with a coarse grid resolution to get the model running and narrow down on the model parameters and settings, and then increase the model resolution before doing production runs. Sediment transport has a lot of options and parameters to calibrate, so being able to speed up the initial exploratory calibration runs is very useful. Once the calibration options and parameters have been narrowed down, the resolution can be increased to finalize the calibration and do the validation runs. For this model, Manning's polygons have been defined in order to specify different roughness coefficients for the flume walls. The roughness is utilized in the hydrodynamic model at faces while in sediment at cells. Because the model only uses a single value extracted from the cell centroids and face centers, it is important the Manning's polygons extend into the first cell/face right next to the walls.

File Project Tools Help					
Selected Layer: Boundary Condition Lines	•		🔜 🗷 🖏 \land 🐂 🕅 .	Max Min 4	
	Â	💟 斥 り ୯ 🍌 🏛 Tools 🗸	?	Editing: 'Boundary Condition Lines'	
Mesh Points Breaklines Refinement Regions					
B- Dridges/Culverts B- Inline Structures B- Lateral Structures					
SA/2D Connections Pump Stations Generative Condition Lines Statistic Condition Rests	-				
Reference Points Reference Lines					
Manning's n Infiltration					

3.3 Flow Data

Open the Unsteady Flow editor $\widehat{\mathbf{M}}$. The boundary condition lines have already been defined as Upstream and Downstream.

	Select Location in table then select Boundary Condition Type					
	River	Reach	RS	Boundary Condition		
	•					
St	orage/2D Flow A	reas		Boundary Condition		
1	2DArea BCLi	ine: Downstream				
2	2DArea BCLi	ine: Upstream				

Click on the **Downstream** BCLine and select

Stage Hydrograph

Set a constant downstream stage at 0.312 m

(Note: you can set a constant downstream stage by repeating the stage – or flow in the next step – in the time series.)

It is usually best practice in 2D modeling to **Use Initial Stage** with a downstream stage boundary condition. Vertical Stage (recommended)

Click on **Upstream** BCLine and select Flow Hydrograph

Set the flow to 0.15 m3/s

Also set the **EG Slope** to 0.001 for distributing flow along BC Line and select **TW Check**.

EG Slope for distribut	0.001	V TW Check		
	Plot Data		ОК	Cancel

It is not necessary to set the initial water surface since the model will use the downstream stage to initialize the model.

Save As and give it a name (e.g. "2D Sediment")

3.4 Sediment Data

3.4.1 Define Bed Gradation Polygon in Mapper

Before you define sediment data, it is useful to define the spatial distribution of your bed gradations in Mapper (so you can populate them with gradation data in the sediment editor).

Open Mapper, and Right Click on Map Layers. Select Create a New RAS Layer→Sediment Bed Material Layer.

Features Points Polygons Profile Lines Polygons Profile Lines Polygons Profile Lines Polygons Profile Lines Polygons Polygons	kshop 🥕				
⊡. Mannings_r 🐌	Add Web Imagery				
⊡ ✓ Terrains	Reference Layers	•			
۱	Create a New RAS Layer	•		Land Cover Layer	1
*	Add an Existing RAS Layer	•		Soils Layer	
×	Manage Geometry Associatio	ons		Sediment Bed Material Layer	
1 Profile Lines migrated to f	Profile Lines under the F		16	Infiltration Layer From Land Cover / Soils Layers Infiltration Layer From Shapefile Elevation Point Layer Calculated Layer	•

You can press **No** to the question about spatial reference system.

This editor was developed to import layer data from raster or shape files.

But we are just going to draw a singly polygon, so you will press the **Create Empty** button.

Press the folder if you want to change the name to something other than the default "Sediment Bed Material."

Filename: d:\\Sediment Bed M	aterial.hdf	<u> </u>
ons can be added later	Create Empty	Cancel

Expand the Association Editor that comes up until you can see the **Sediment Bed Material Layer** dropdown menu.

Select the empty Sediment Bed Material layer you just created.

Mar	nage Layer A	Associations					×
	Type	RAS Geometry Layers	Terrain Terrain With Walls On	Manning's n	Infiltration	% Impervious	Sediment Bed Material Layer
	cicomeny	20 Scament Workarop			(None)	(None)	(None) Sediment Bed Material

Start editing the Classification Polygons in this new layer, choose the draw tool 🧭, and draw a polygon around the mesh.

Give the Polygon a **Classification Name** (e.g. "Bed Gradation").

Geometries H 2D Sediment Workshop			
Event Conditions			
Results			
🖃 🔽 Map Layers	•		•
🗄 🔲 Mannings_n			
🗄 🗹 Sediment Bed Material			
Classification Polygons		Ref Classifications	×
Terrains			
Terrain_With_Walls_0p01m		Classification Name: Bed Gradation	_
1 Profile Lines migrated to Profile Lines under the F		ОК	Cancel

Stop Editing 🧕 and save the classification.

Associate this Bed Material Classification with the geometry file by right clicking on the Geometries tree node and selecting Manage Geometry Association.

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		Туре	RAS Geometry Layers	Terrain	Manning's n	Infiltration	% Impervious	Sediment Bed Material Layer		
🖻 🗹 Map L		Geometry	2D Sediment Workshop	Terrain_With_Walls_0p 💌	Mannings_n 💌	(None) 💌	(None) 💌	(None)		
								(None) Sediment Bed Material		
⊽ Тептаі ⊽ Те								Close		
			1							1

Warning Current versions of RAS have a glitch that can make this step difficult.

The Layer Association Manager opens too small so you cannot see or scroll to the Sediment Bed Material Layer. Drag the right edge to expand the editor and see the last column or make the column headers thinner until you see all the columns.

М	lanage Layer A	ssociations					×	
	Туре	RAS Geometry Layers	Terrain	Manning's n	Infiltration		% Impervious	
	Geometry	2D Sediment Workshop	Terrain_With_Walls_0	p 💌 (None)	▼ (None)	-	(None)	
	Results	sim	Terrain_With_Walls_0	p 💌 (None)	(None)		(None)	

Then the Sediment Bed Material Layer selection does not always save.

Reopen the Geometry Association Manager to make sure if it is selected.

If it isn't – reselect it, and then click on the Terrain drop down.

Reselecting the current terrain should get it to save.

3.4.2 Basic Options

Open Sediment Data editor by clicking on the icon \searrow from the main RAS window.

This window opens to the **Boundary Conditions** Tab, click on **2D Bed Gradations** to start there.

👿 Sediment Data			
File Options View	Help		
Boundary Conditions 2	D Bed Gradations		
Transport Function:	Wu	-	Define/Edit Bed Gradation
Sorting Method:	Active Layer	-	
E HALL I AN ALL I	Souleby	-	Define Layers (2D)

Set the **Transport Function** to **Wu**, the **Sorting Method** to **Active Layer**, and the **Fall Velocity Method** to **Soulsby** as shown in the screenshot below.

Notes: The only **Sorting Method** supported by the 2D sediment model is the **Active Layer**. Choosing any other sorting method will default back to the **Active Layer** method.

3.4.3 Bed Gradation

From the Sediment Data editor press	Define/Edit Bed Gradation	
		•

Create a new **Bed Gradation** by pressing the "New" button **D**. Give it a name (e.g. "Nonuniform"). Enter the gradation information as shown in the figure below.

Since the grain size distribution is moderately well sorted, the fractions are contained within only two grain classes. This is relative few. One of the improvements which could be done to the model is to specify User-defined grain classes with more resolution in the range utilized in the experiment, so that more grain classes are utilized.



3.4.4 Transport Method Options

From the Sediment Data editor, click on Options | Transport Methods...

▼ Sediment Data - Weis sed					
File	Options	View	Help		
Bou	User Defined Grain Classes				
	Set	Cohesiv	e Options		
	Bed Change Options (1D)				
	Transport Methods				

Under AD Parameters, set the Load Correction Factor Options.

2D Methods: AD Parameters Ero	sion Parameters
Load Correction Factor	
Total-load Correction Fac	stor
Bed-Load Correction Facto	ır: 🛛 Van Rijn-Wu 💽
Suspended-Load Correctio	n: Exponential Conc Profile 💽

In the **Adaptation Coefficient** section, set the **Total-load** method to **Total Length** and specify a value in the editor of 0.2 m as shown in the screenshot below.

🖏 Transport Model and	AD Parameters:	_		\times
1D Routing Method:	Continuity			•
2D Advection-Diffusion Met	hods:			
Adaptation Coefficent				
Total Load:	Total Len	igth		•
	Total	Length: 🛛	0.2	m
Suspended Adaptation Co	efficient: Constant	Coef		-
	Constant Coefficier	nt 🗍		
Bed Load Adaptation Leng	gth: Constar	nt Length		-
	L	ength		ft

Click on **OK**, and save your changes in the **Sediment Data** editor.

3.4.5 2D Sediment Options

In the **Sediment Data** editor lick on the menu **Options | 2D Options** as shown in the screenshot below.

∀s	ediment [Data - 2[D Sediment		
File	Options	View	Help		
Initia	Use	r Define	d Grain Classes		
	Set	Cohesiv	e Options		
	Bed Change Options				
	Bed	Bed Change Options (New)			
	Transport Methods				
<u>R</u>	R Calibrate Transport Function				
	2D (Options			

An editor called **2D Sediment Method** will appear. This windows contains only 2D specific sediment options.

In order to speed up the simulation, a **Morphologic Acceleration Factor** of 12.5 will be used. Since the experiment duration is 125 min, the equivalent computational time representing 125 min of simulated bed change is computed as 125 min / 12.5 = 10 min. In general, it is not recommended to use Morphologic Acceleration Factors larger than 20 or 30.

🗅. 2D Sediment Options	_		\times
Simulation Components:	All Comp	onents	•
Sheet and Splash Erosion:	None		•
Erodibility:		1.	
Morphological Acceleration I	Factor:	12.5	
Base Bed-Slope Coefficient:			
Hindered Settling:	No Correc	tion	-
Avalanching			
🔲 Use Avalanching			
Repose Angle:		32.	
Maximum Iterations:		10.	
Relaxation Factor:		0.25	

3.4.6 Bed Mixing Options

From the **Sediment Data** editor click on the menu **Options | Bed Mixing Options**.

∀ s	ediment D	Jata - 2D Sediment
File	Options	View Help
	Use Set Bed Trar Cali	r Defined Grain Classes Cohesive Options Change Options I Change Options (New) nsport Methods ibrate Transport Function
-	2D (Nor BST Late	Options n Newtonian EM Options eral Weir Options
	веа	wixing options

In the **Hiding Functions** section, set the **Hiding Function** to **Wu et al.** the **Hiding Exponent** to 0.6 as shown in the snapshot below.

🛱. Bed Mixing Options —		\times
Capacity Partitioning (1D Only) Capacity Partitioning Method: Bed Gradation Only	n: 10	_
Hiding Functions (Beta for 1D) Hiding Function: Wu et al ✓ Hiding Exponent: 0.6	Shape F	actor:
Active Layer Options Active Layer Thickness: X d90 Multiplier: 3 Min Thickness: 0.5 Exchange Increment (1D Only): % Bedload: 70. % Active Layer: 30.	m	
Cover/Active Layer Gradations (1D Only)		
Copeland Method Option (test) (1D Only) OK Cancel	Defa	ults

Click on **OK**, to exit the editor and save your changes.

3.4.7 Sediment Boundary Conditions

From the **Sediment Data** editor, select the **Boundary Conditions** tab. The interface automatically searches for boundary condition lines where sediment data could be needed and list them in the table.

By default, any boundaries left unspecified are equilibrium boundary conditions, but this option may also be specified by first select the white entry space and then selecting the **Equilibrium Load** option (see snapshot below).

🤟 Sediment Data			_	\times
File Options View Help				
Initial Conditions and Transport Parameters Boundary Con	itions USDA-ARS Bank Stability and Toe Erosion Mode	el (BSTEM) 2D Bed Gradations		
Select Locatio	for Sediment Boundary Condition			
Add Sediment Boundary Location(s) Delete Current Ro	V Define Sediment Split at Junction			
Sedimer	t Boundary Condition Types			
Rating Curve Sediment Load Series E	uilibrium Load Capacity Ratio Clear V	Vater (no Sed)		
Flow Wtd Sed Split Potential Wtd Sed Split GC	Threshold Split Sed Split by GC			
2DArea:2DArea BCLine Downstream Equ	librium Load			
Mixing Methods Selected	Descri	iption :		
	, J			

3.4.8 Select Initial Bed Gradations

Next, select the bed gradations associated with each manning's region. Open the 2D Sediment Tab. This will populate a row for each Manning's n region in your geometry file. This project only has one (base n). Click on the field next to it. You will get a drop down menu including all of the bed gradations (again, just one in this case) that you defined in Step 3.4.2.

<u>Note</u>: You may have to close the sediment file and open it if you do not see the "Bed Material Type." If you still don't see it, make sure the classification polygon saved and that the mapper association is correct.

💙 Sediment Data - Sed	-	×
File Options View Help		
Boundary Conditions 2D Bed Gradations		
Transport Function: Wu Image: Wu Sorting Method: Active Layer Image: Wu Define Edit Bed Gradation		
Fall Velocity Method: Soulsby		
Bed Material Type Gradation		
1 Bed Gradation Nonuniform		-
Non-erodible surface		
Nonuniform		

3.5 Unsteady Flow Analysis

From the main HEC-RAS editor, open the **Unsteady Flow Analysis** editor by clicking on

Click on the menu **File** | **Save**, and give the plan a name and **Short ID**.

In the section **Programs to Run**, select the checkboxes for **Geometry Preprocessor**, **Unsteady Flow Simulation**, and **Sediment**.

Utilize today's date for starting and ending dates. Start the simulation at 00:00 hours. The experiment duration is 125 min. However, since a morphologic acceleration factor of 12.5 is used, the total simulation duration should be 125 min / 12.5 = 10 min.

」 Unsteady Flow Analysis

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File	Options	нер	
Plan:	2D Sedime	ent	

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lan:	J2D Sediment	Short ID: 2D Sedin	ient
	Geometry File:	2D Sediment Workshop	-
	Unsteady Flow File:	2D sediment	-
	Sediment File:	2D sediment	-

Programs to Run Plan Description Image: Comparison of the second seco	< v
Simulation Time Window Starting Date: 08Dec2016 Ending Date: 08Dec2016 Computation Settings Computation Interval: 0.2 Second	000 020 nute 💌
Mapping Output Interval: 30 Second Detailed Output Interval: Image: C:\Users\q0hecsag\Documents\Projects\Classes_St Louis Project DSS Filename: C:\Users\q0hecsag\Documents\Projects\Classes_St Louis C:\Users\q0hecsag\Documents\Projects\Classes_St Louis C:\Users\q0hecsag\Documents\Projects\Classes_St Louis	iute

3.5.9 Flow Computation Options and Tolerances

In the **Unsteady Flow Data** editor, make the following changes to the **Options**→**Computation Options and Tolerances** for the **2D Flow Area**.

Because this dataset is a small scale laboratory dataset, the water surface and volume tolerances should be reduced.

It is important to change the governing equations to the SWE. Use either the ELM or EM solvers.

The other critical thing which the user should turn on is turbulence modeling.

The calibrated turbulence coefficients are provided below.

Since this is a relatively small dataset with only \sim 2700 cells, there is better to use a small number of cores less or equal to 4 and not the default option of using all of the cores.

Using too many cores can easily make this dataset run slower than with fewer cores.

HEC-RAS Unsteady Computation Options and Tolerances				
General 2D Flow Options 1D/2D Options	Advanced Time Step Control 1D Mixed Flow Opti	ons		
Use Coriolis Effects (not used with Diffusion Wave equation)				
Parameter	(Default)	2DArea		
1 Theta (0.5-1.0)	1	1		
2 Theta Warmup (0.5-1.0)	1	1		
3 Water Surface Tolerance [max=0.06](m)	0.01	0.001		
4 Volume Tolerance (m)	0.01	0.001		
5 Maximum Iterations	20	20		
6 Equation Set	Diffusion Wave	SWE-ELM (original/faster)		
7 Initial Conditions Time (hrs)		0.03		
8 Initial Conditions Ramp Up Fraction (0-1)	0.1	0.5		
9 Number of Time Slices (Integer Value)	1	1		
10 Turbulence Model	None	Conservative		
11 Longitudinal Mixing Coefficient	0.3	0.3		
12 Transverse Mixing Coefficient	0,1	0.1		
13 Smagorinsky Coefficient	0.05	0.05		
14 Boundary Condition Volume Check				
15 Latitude for Coriolis (-90 to 90)				
16 Solver Cores	All Available	2 Cores		
17 Matrix Solver	PARDISO (Direct)	PARDISO (Direct)		
18 Convergence Tolerance	0.00001	0.00001		
19 Minimum Iterations	3	5		
20 Maximum Iterations	30	30		
21 Restart Iteration	10	10		
22 Relaxation Factor	1.3	1.3		
23 SOR Preconditioner Iterations	10	10		
		OK Cancel Defaults		

3.5.10 Sediment Computation Options and Tolerances

In the **Unsteady Flow Analysis** editor, select the menu **Options** | **Sediment Computation Options and Tolerances**.

Sediment Computation Options and Tolerances	N
Sediment Output Options	47
Sediment Dredging Options	

On the **General** tab, set the **Sediment Computation Multiplier** to **5X** the hydraulic time step.

On the **2D Computational Options** tab set the **Advection Scheme** to upwind.

We often change the **Sediment Matrix Solver** to speed models up, but we will leave it for this short model.

Most models leave the **Concentration Max Error and Concentration RSM Error** default, but because this is a flume model we will reduce these to **0.000001**.

Layer thickness sets your vertical computational intervals. The defaults are set for a river. So we need to reduce these for a flume to **Initial=0.05m**, **Min=0.005m**, and **Max=0.2m**.

HEC-RAS Sediment Computation Options and Tolerances	HEC-RAS Sediment Computation Options and Tolerances
General 2D Computational Options	General 2D Computational Options
1D Computational Options Bed exchange iterations per time step (SPI) 10 10 10 10 10 10 10 10 10 10 10 10 10	Advection Scheme: Upwind
Min XS change before recomputation of hydraulics (ft): 0.02	Implicit Sediment Weighting Factor: 1.
Perform Volume Error Check/Carry Over: Transport Energy Slope Method: Downwind	Outer Loop Convergence Parameter: Maximum # of Iterations: 5
Sediment Computation Multiplier: 5 X the hydraulic time step	Concentration Max Abs Error (mg/L): 0.000001 Concentration RMS Error (mg/L): 0.000001
Concentration (2D Only): (days) Gradation: (days)	Grain Class % Max Abs Error: 0.001
Bathymetry: (days)	Computational Sediment Layer Parameters Layer Thickness (Optional):
Bed Roughness Predictor: None	Initial (m) 0.1 Min (m) 0.05 Max (m) 0.2 # of Computational Layers (Optional): 5
Select Reaches to Average Bed Roughness Predictors	Subgrid Subcell Erosion Method: Constant Subcell Deposition Method : Veneer Max Subgrid Regions (Optional): 1 Max Subgrid Length Scale (Optional):
Defaults Cancel OK Show XS Weights >>	Defaults Cancel OK Show XS Weights >>

3.5.11 Sediment Output Options

3.6 Run the Model

Go back to the Unsteady Flow Analysis window and click on the compute button. The model should start running and finish within a few minutes.

3.7 Open the Computation Log File

The computation log file contains detailed information on the model setup and variable statistics during the simulation. This file is very important to look at when running sediment. It contains detailed information on the sediment model setup, initial and boundary conditions which should be checked to make sure everything is correction.

3.8 View Results in RAS Mapper

Open **RAS Mapper** from the main HEC-RAS menu by clicking on . Expand the **Results** node and select the 2D area you just ran. Turn on the computational mesh.

To add a 2D sediment output variable, right-click on the 2D area and select the menu **Add New RAS Results Map Layer**.





Adjust the **Color Ramp** and for the dataset so that it can be visualized well in **RAS Mapper**.

Below is an example of the computed bed change with a red-white-blue color ramp with lower and upper limits set to -0.1 m and 0.1 m, respectively.



Try adding other 2D variables from both the **Sediment Bed** and **Sediment Transport Output Blocks**.

3.8.12 Plot Time Series





3.8.13 Plot Profile



W – 2D Sediment Transport



Bed Change on 'Centerline'



Experiment with other results like Concentration.

Add "Depth" under the Hydraulics Results. Compare it to the "Variable Depth" results. How are they different?