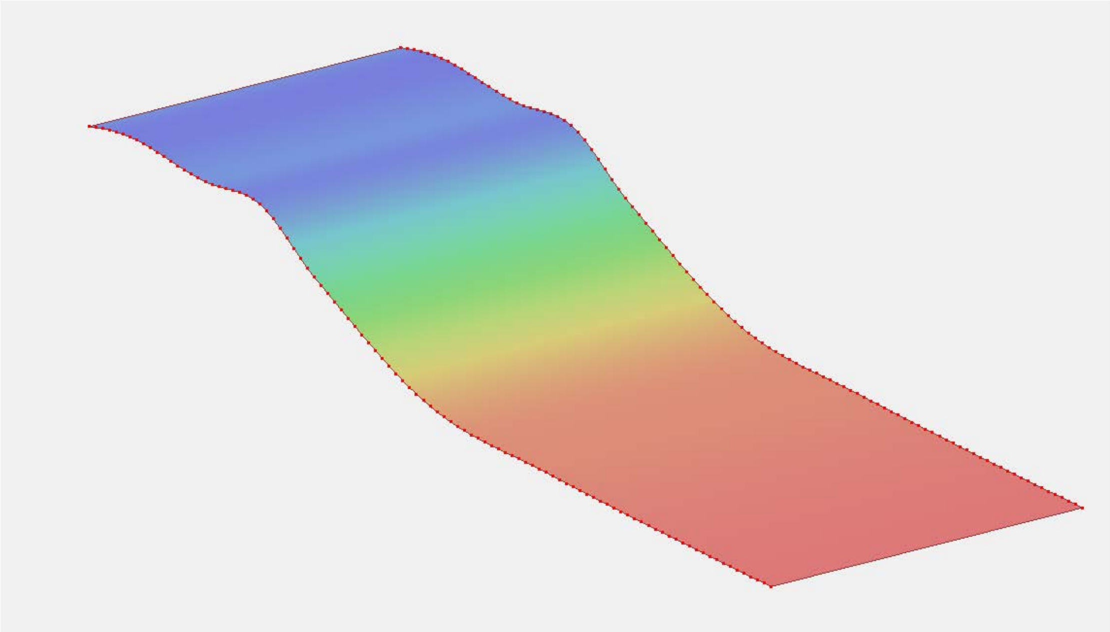
v. 11.1

SMS 11.1 Tutorial

Runup/Overtopping Analysis in SMS



Objectives

This tutorial illustrates the mechanics for using a tool incorporated into the Surface-water Modeling System (SMS) referred to as a "Runup/Overtopping Simulation" interface. This tool performs analysis on one-dimensional profiles to determine wave characteristics and the extent of runup and quantity of overtopping along those profiles for specified wave conditions. The utility utilizes Boussinesq analysis in the BOUSS2D numerical engine.

Prerequisites

- BOUSS2D Tutorial
- Overview Tutorial

Requirements

- BOUSS2D
- Scatter Module
- Map Module

Time

- 60-75 minutes

Applications

Sample applications for this interface include:

- Determining the extent of wave induced flooding. This includes both spatial extents and quantity of water.
- Design of flood protection structures

A set of typical steps for this type of analysis includes:

1. Load bathymetry as a scatter set in SMS.
2. Define simulation
3. Create transects(s). These can be in a single coverage or in multiple coverages if there are enough to be grouped.
4. Create wave maker(s).
5. Create spatially varied roughness zones, damping regions and porosity zones as needed.
6. Create probes. These can be geometrically placed or autogenerated.
7. Save files and run numeric analysis
8. View individual profile results and run statistical analysis

Load bathymetry

The most common application of this tool bases the profiles on some underlying geometric surface (usually representing the sea floor) represented as a scatter set. Multiple sources can be loaded into SMS. However, they must be converted to a scattered data set for use in a runup/overtopping simulation. To begin this tutorial:

1. Click on the *File |Open..* command and select "reflective_beach.sms". This project contains a scattered data set representing a simple reflective beach profile. (The project file sets up display settings and projection to be consistent.) The resulting display should appear as shown in Figure 1. Figure 2 shows the profile shape.

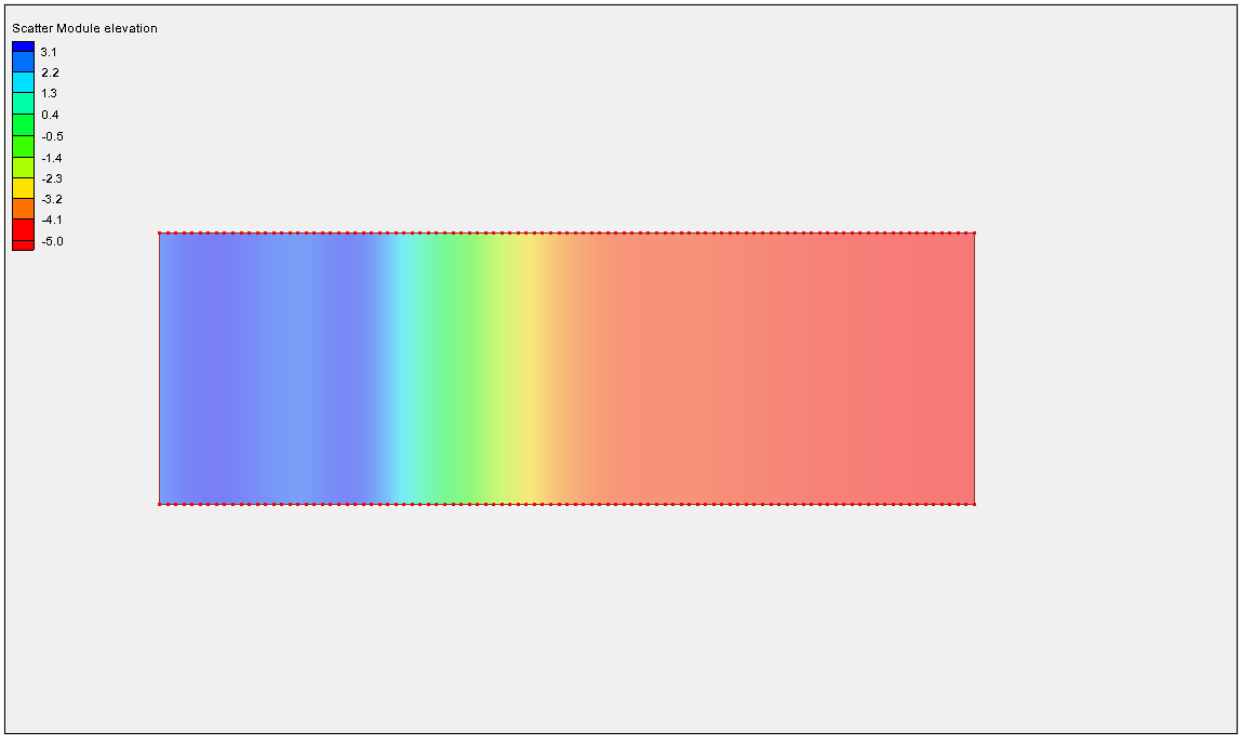


Figure 1 Dataset representing underlying geometry.

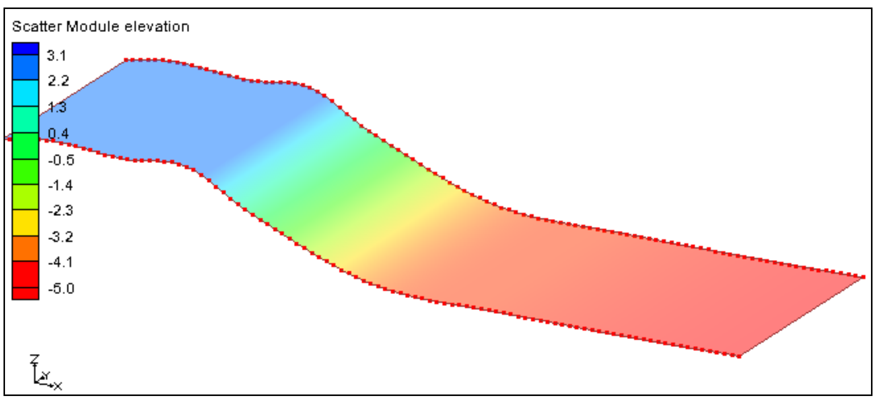


Figure 2 Oblique view of the reflective beach profile.

Setting up the Simulation

Many of the interfaces in SMS consist of data gathering dialogs and formatting routines to drive a specific numerical engine. Primarily these interfaces process a single geometric entity such as a grid, and format model parameters for a single instance of a numerical model analyzing conditions on that grid.

In the case of the "Runup/Overtopping Simulation", the system can analyze multiple profiles for multiple wave cases in a single simulation. In addition, the interface includes statistical analysis tools to evaluate this suite of cases in a post processing mode. Since the simulation links to multiple geometric entities (multiple profiles) and multiple boundary condition sets (wave cases), a simulation of necessity is not based on a single geometric entity. Instead, the user creates the components of the simulation and links them together. The components and simulation can be created in any order.

Runup simulation

SMS manages the runup simulations with a separate entry in the Project Explorer (data tree). For this example, we will begin the process by creating this entry, which is referred to as a "BOUSS Runup/Overtopping Simulation". To do this:

1. Right click in the project explorer. In the pop up menu which appears select "New Simulation | BOUSS Runup/Overtopping".

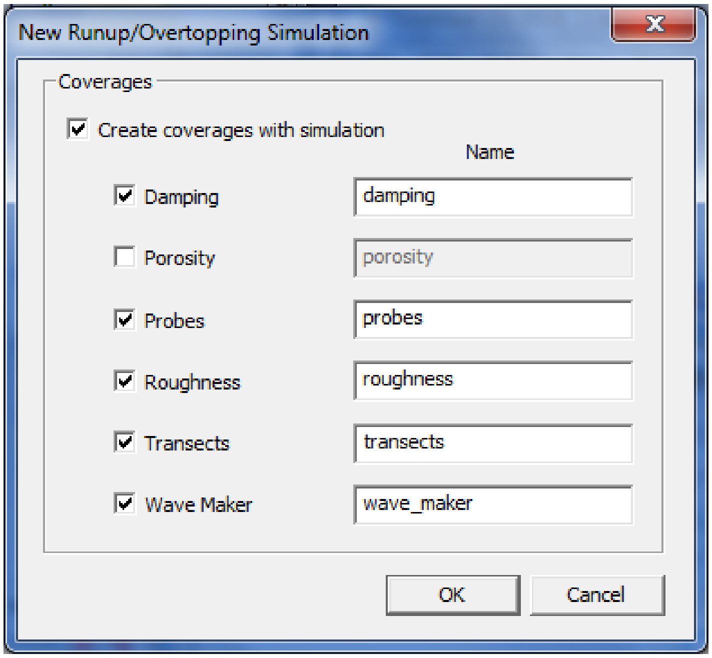


Figure 3 New Simulation dialog with coverage flags selected.

2. The "New Runup/Overtopping Simulation" dialog (Figure 3) appears. A runup/overtopping simulation links many components together. These components are each represented by GIS objects (arcs and polygons) in one or more coverages. If these are not defined when the simulation is created, SMS can create place holders as the simulation is initialized. This dialog controls which coverages will be created.
    - Check the box labeled "Create coverages with simulation".
    - Now with the other toggles enabled, check all the options except "Porosity".
    - Click "OK" to exit the dialog.

The project explorer now includes an entry for "Runup/Overtopping". This entry includes a folder named "Simulations". In that folder one new simulation named "Sim" has been created.

3. Right click on "Sim" and select "Rename". Change the name of the simulation to "Reflective_01". (You can name your simulations anything you want.)

The newly created simulation already includes links to five different coverages. These coverages were created in the “Map Data” section of the project explorer and stored in the “Bouss” folder in that section. These include:

- Profile locations: stored in the transects coverage.
- Wave maker location(s): stored in the wave_maker coverage.
- Probes: stored in the probes coverage.
- Spatially variable damping: stored in the damping coverage.
- Spatially variable roughness: stored in the roughness coverage.

Linking other coverages

If you define coverages before you create the simulation, or import/create additional coverages after the simulation has been defined, simply drag and drop these coverages into the simulation.

Specifying simulation properties

The simulation also controls the numeric model control parameters for all the transects and wave cases in the simulation. To set these:

1. Right click on the simulation and select “Model Control”. The dialog appears.
2. Set the project title to “Reflective profile runup/overtopping test case”.
3. Click “OK”. We’ll come back and revisit the model parameters after the other components of the simulation are defined.

Geometric parameters

The principal geometric input for a runup/overtopping simulation is the transect(s) where the calculations will take place.

Transect locations

SMS defines transects as arc(s) in a transect coverage. A simulation references one or more such coverages. When you created the simulation above, you also instructed SMS to create one transect coverage. Now we will create a couple of transect arcs to define profile locations.

To do this:

1. Select the “transects” coverage.

4. Select the “create arc”  tool.

5. Click on the offshore region on the right to define the beginning of the profile. Terminate the arc near shore or up on the beach. Profile should go from deep water to shallow water/land. (See Figure 4).

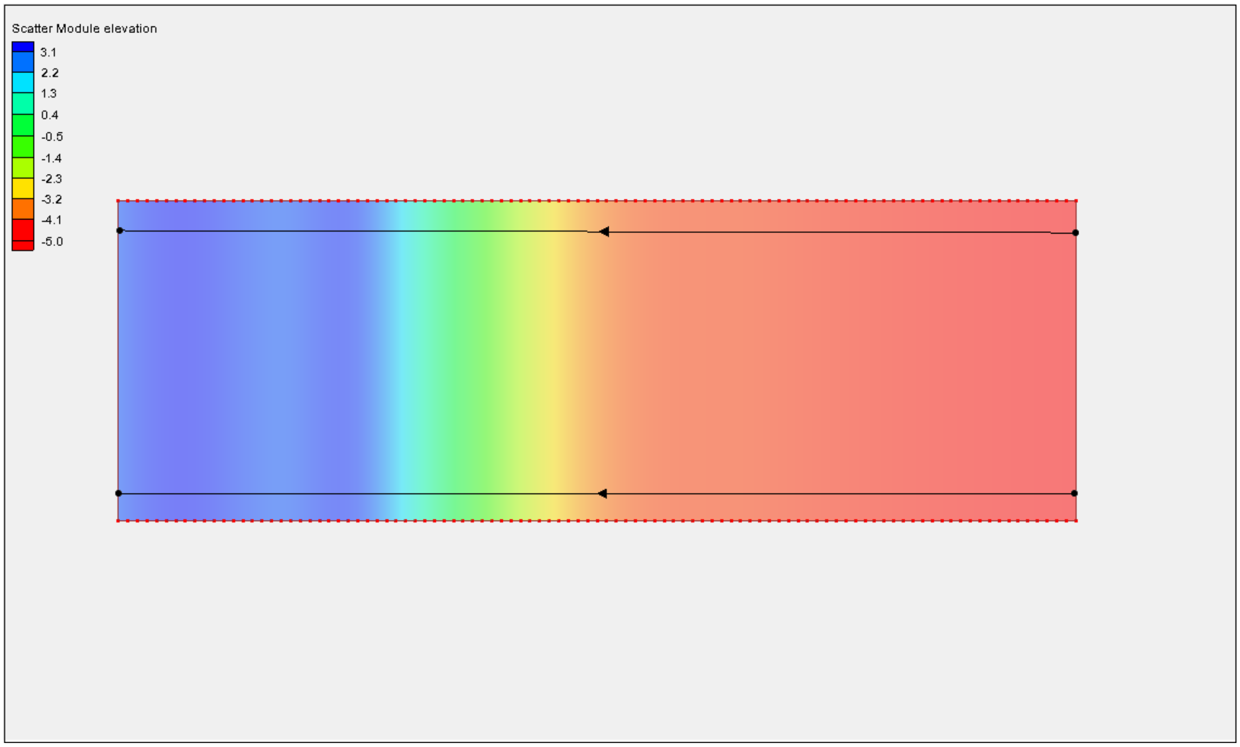


Figure 4 Geometry with two profile arcs created.

6. Create a second profile arc in a similar fashion.

The nodes can be moved around after creation if a specific location is desired. The model runs in 1D mode, so to be totally true to the assumptions of the model, the profile should be fairly straight, but can be curved.

Transect elevations

The arc location defines the position of the transect. The elevation must be extracted from the underlying scatter set. To do this:

1. Right click on the "transects" coverage and select "Extract elevations". The standard SMS interpolation dialog appears listing the scatter sets loaded into SMS. This currently should just show the "reflective_beach (active)" scattered data set.
2. Click the "OK" button to extract the transect elevations.
3. Right click on the "Reflective_01" simulation and select "View transects profile…". The transect preview dialog appears (Figure 5). This dialog includes a list of the transects on the lower left side. As you select a transect, its profile is displayed in the preview window.

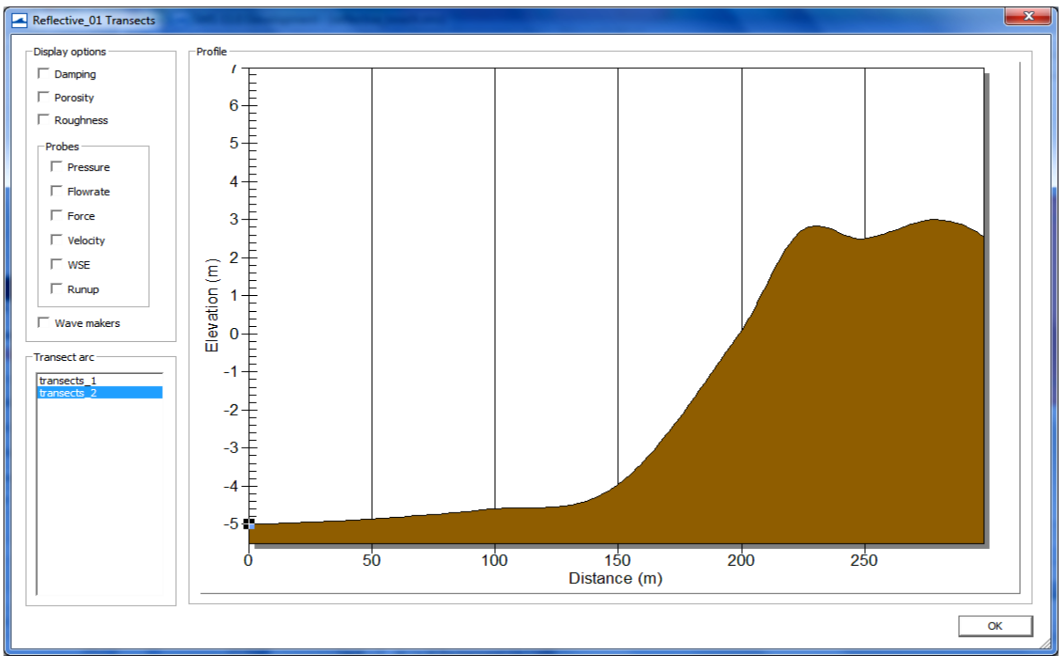


Figure 5 Transect preview.

Wave maker positions

SMS defines a wave maker as an arc in a wave_maker coverage. The intersection of this arc with a transect arc defines the location of the wavemaker. Each transect arc should only intersect a single wave maker at a single location. Multiple wave makers in a 1D analysis is not recommended. Since a single wave maker arc can cross multiple transects, wave conditions can be specified for one wave maker and applied to multiple times.

To do this:

1. Select the wave_maker coverage.

2. Select the "create arc"  tool.
3. Click out an arc crossing the profiles in the offshore region to define the wave maker location. (see Figure 6)

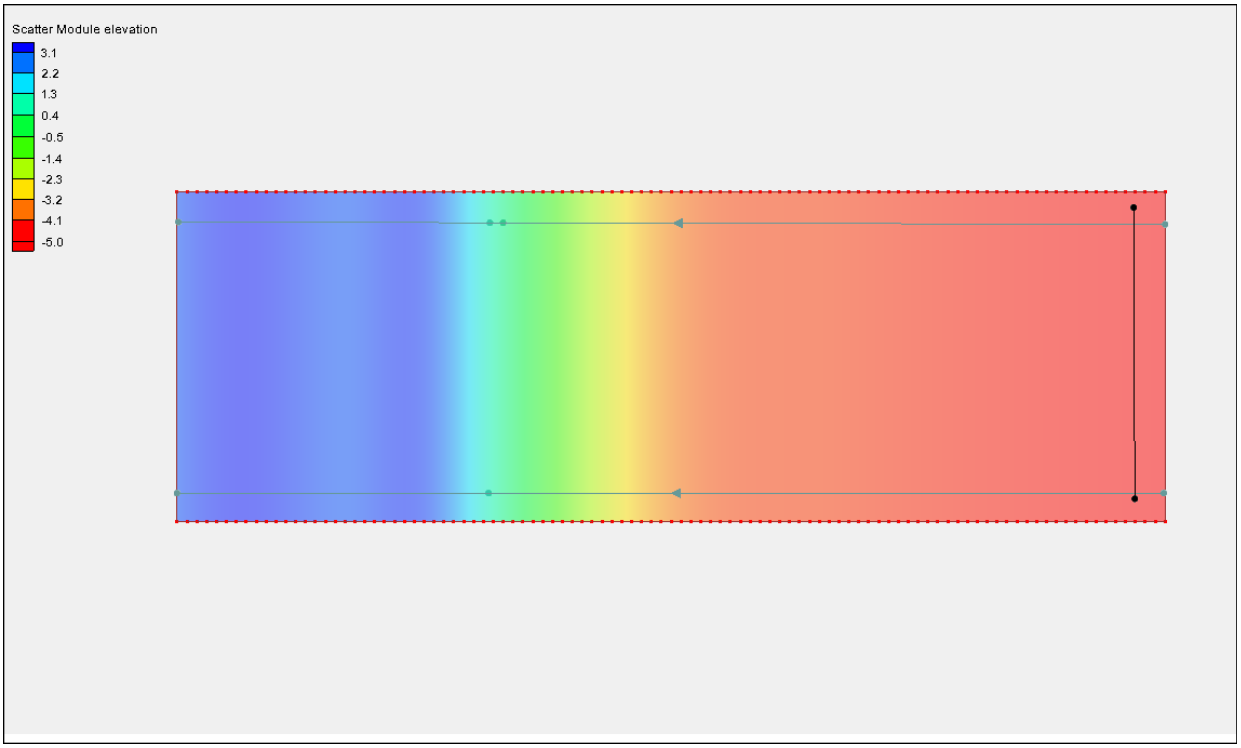


Figure 6 Wave maker arc.

With the wave maker position defined:

4. Right click on the "Reflective_01" and select "View transects profile. Note the display of the location of the wave maker as a blue arrow.

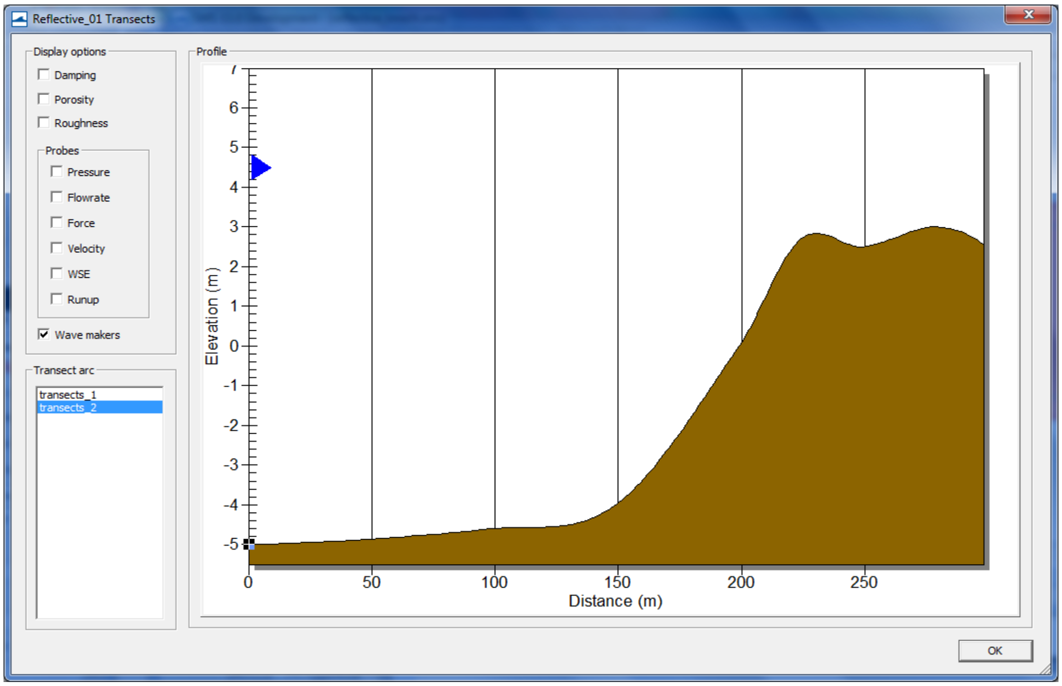


Figure 7 Transect with wave maker.

Wave maker attributes

The arc position defines the position of the wave maker. The arc attributes define the wave conditions to be considered. SMS allows multiple wave conditions at each wave maker location. All wave makers in a simulation must have the same number of wave cases. To define the wave conditions:

1. Select the "select arc"  tool.
2. Right click on the wave maker arc and select "Attributes…". The wave generator properties attributes dialog appears (Figure 8). (This is the same dialog used to define wave makers for the 2D applications of the Boussinesq model. The directional options are disabled in this case.)

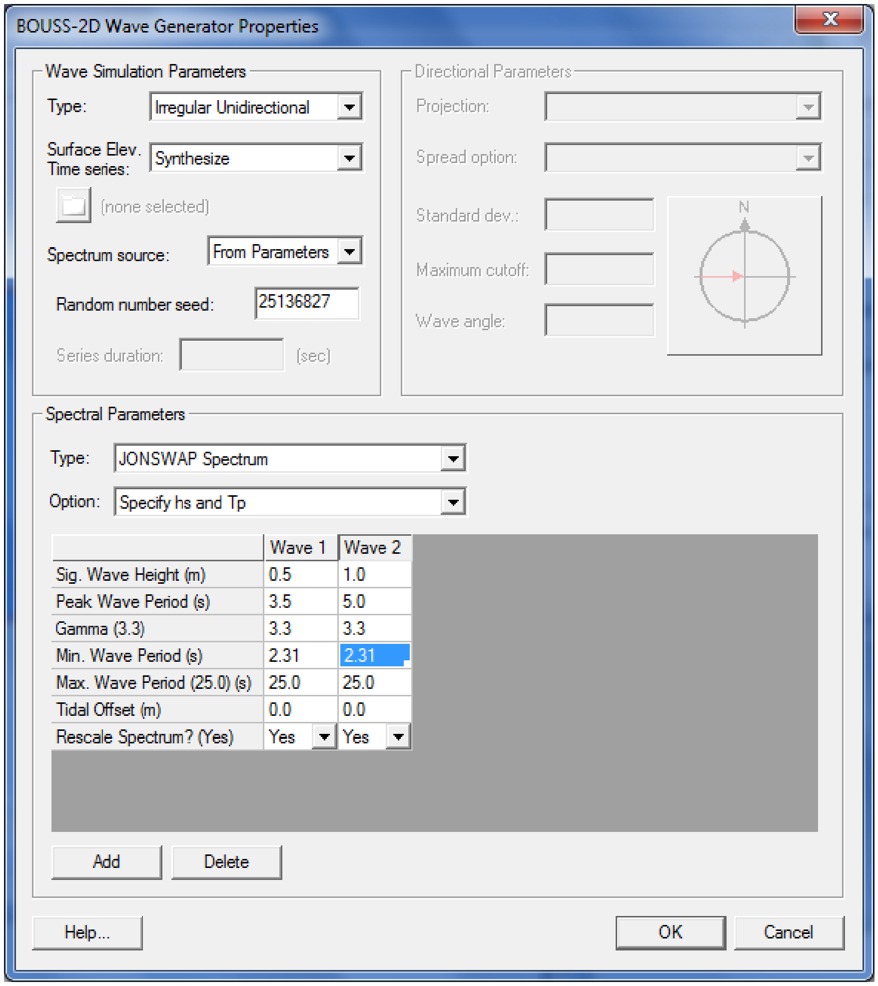


Figure 8 Wave maker properties.

3. Change the "Type" to "Irregular Unidirectional".
4. Click on the "Add" button to define a second wave case to compare. (You can define as many cases as desired in applications.) Set the case parameters as shown in the figure. This will show two different wave heights.

Roughness zones

The bottom roughness in coastal areas can impact the conveyance of waves as the progress to the shore. This phenomenon can be simulated in the runup/overtopping simulation using a roughness zone. To specify this for one of our transects:

1. Select the roughness coverage.
2. Select the “create arc”  tool.
3. Click out a polygon enclosing an area with different roughness as shown in Figure 9. This may represent a vegetated region.

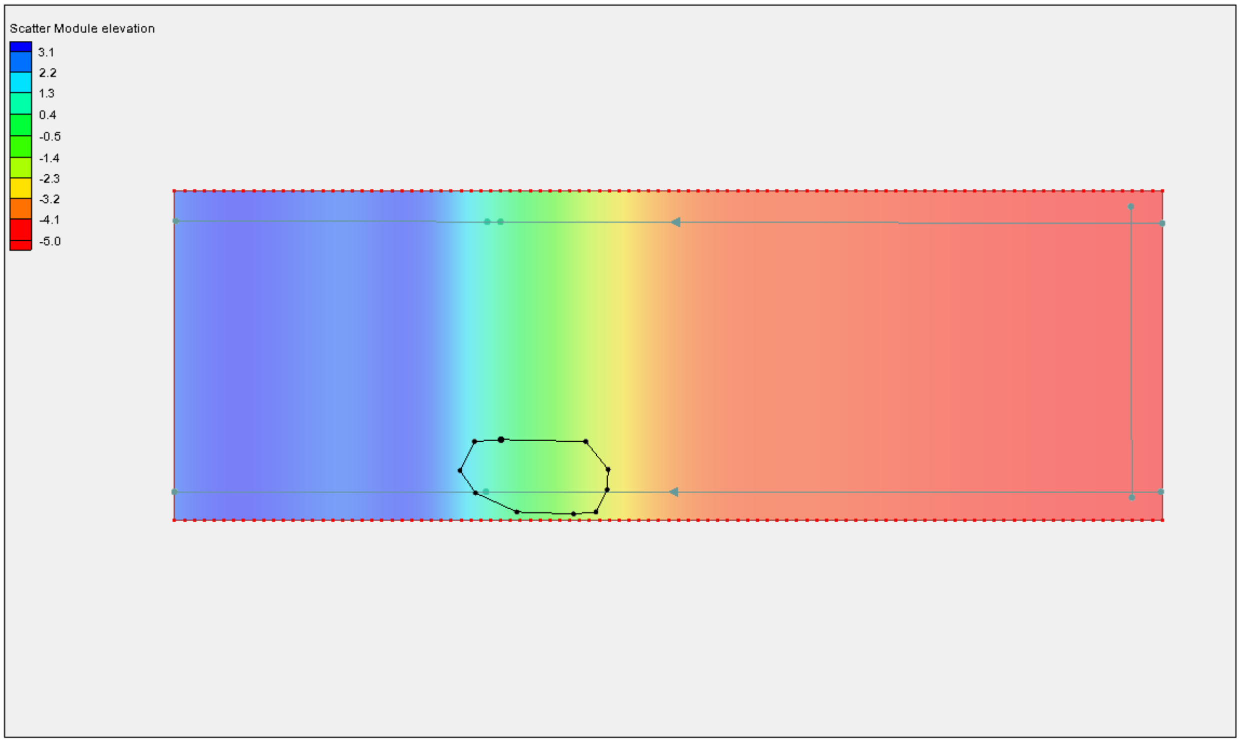


Figure 9 Roughness zone.

4. Select *Feature Objects* | *Build Polygons* to tell SMS that the zones are defined. SMS will create a polygon associated with each zone.
5. Click on the “select polygon”  tool.
6. Double click in roughness zone to bring up the dialog. Assign a Chezy roughness value of 50.0 and click “OK”. The default roughness value is 30, so this represents an area with more resistance to the flow.

The roughness zone can also be displayed in the transect profile. To see this:

1. Right click on the “Reflective_01” and select “View transects profile.
2. Select “transect_2” and note the plot along the top showing the changing Chezy roughness value.

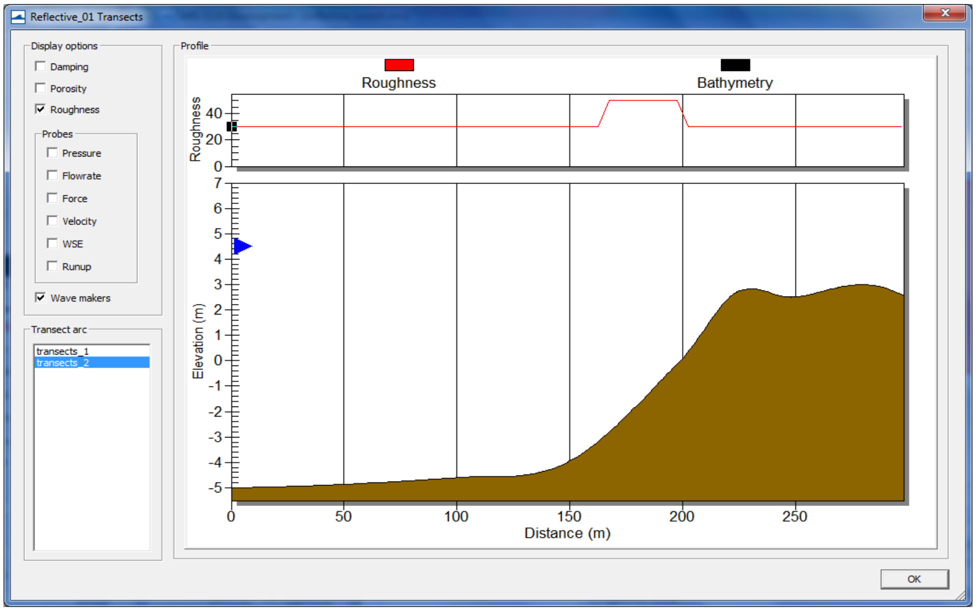


Figure 10 Transect with roughness zone.

Damping zones

In our example, there are no damping zones. However, if damping zones are desired, they can be added by creating arcs in the damping coverage. These arcs operate just as their counterparts in the 2D model work. The user specifies a damping width and coefficient. Any computational cell within the specified width from the arc is impacted by the damping coefficient. The coefficient decreases linearly as the distance from the arc increases.

Auto-generated probes

The BOUSS2D model has the option to output several data quantities at every cell in the domain. This includes the transient wave height and phase, the wave direction, and the energy dissipation at that cell due to breaking. However, since a grid can be very large, the size of the global output grows too large for outputting data at high temporal resolutions. Instead, small time ranges can be saved, or data can be extracted at specified locations at the high temporal frequency. These locations are called probes.

The model supports saving the following data at specified probe locations:

- Elevation.

- Velocity (at a specified distance from the sea floor).
- Pressure (at a specified distance from the sea floor).
- Force on a vertical face.
- Flowrate through the probe.

The model also supports a linear probe called a "Runup/Overtopping" probe. This type of probe is defined by a line rather than a single point.

SMS supports two methods of defining probes, including auto generated and manually placed. First we will autogenerate some probes. To do this:

1. Right click on the "probes" coverage and select "Properties…". The "Probe Rules" dialog appears.
2. Note that the "Auto-create runup probes" toggle at the top of the dialog is clicked. This tells SMS to create runup probes along the transect.
3. Click on the "Add" button to generate a set of probes.
   - Change the "Name" to "WSE Probes"
   - Set the "Elev. (m)" to -1.0. This tells SMS to position the probe at the location where the bathymetry is 1 meter below the datum. If multiple points match this description on a transect, the point closest to the wave maker is selected based on the "Closest to:" setting.
   - Toggle on the "WSE" toggle.
4. Click on the "Add" button again.
   - Change the "Name" to "Pressure Probes"
   - Set the "Elev. (m)" to -3.0.
   - Toggle on the "Pressure" toggle.
   - Click the "Define" button to the right of the pressure toggle. In the "Pressure Elevations" dialog that appears, enter an elevation of 0.5. This will cause another row to appear in the spread sheet. Enter 1.5 in that row.
5. Click "OK" two times to exit the dialogs.

SMS also displays in the transect profile. To see this:

- Right click on the "Reflective_01" and select "View transects profile.
- Note the triangle and cross symbols illustrating the locations of the water surface and pressure probes. These are placed on all the transects in the simulation at points that match the rules defined for the probes.

- Also note the blue line running along the transect. This line displays the extents of the runup probe. Since there are no abrupt structures or barriers in this profile, a single probe covers the entire profile. The model outputs two quantities along this probe. The first is the position of the water/land interface at each time snap. The second is the amount of overtopping flow (cubic meters/second/meter) that flows to the right of the runup probe. (Note: the runup value is meaningless if the overtopping value is not zero.)

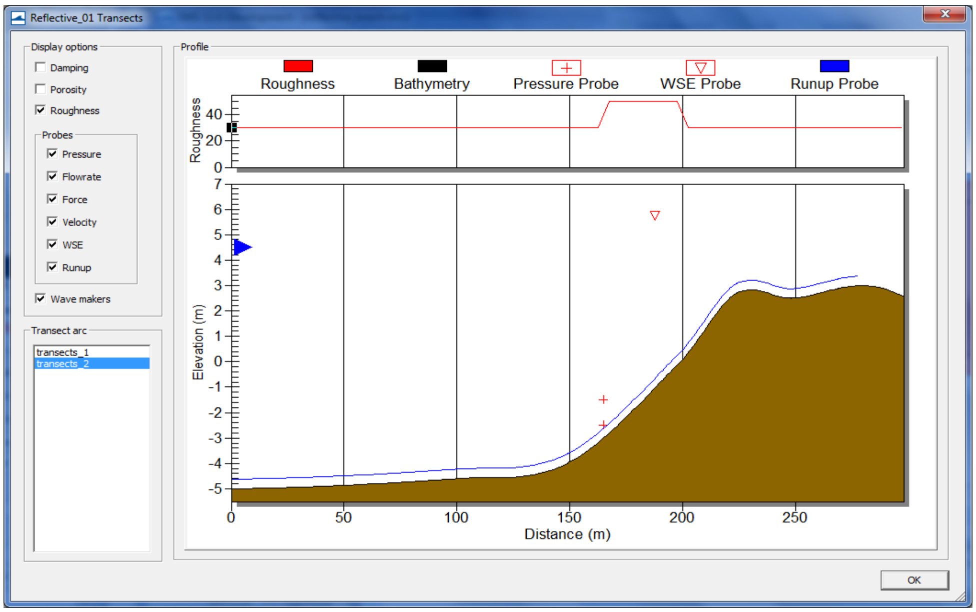


Figure 11 Transect with roughness zone.

Manually placed probes

In addition to the auto generated probes, the user may wish to specifically position probes at areas of interest. For example, a reef or manmade submerged breakwater may exist inside of the domain and the user is particularly interested in the impacts of that feature on the waves. A probe may also be placed to correspond to the location of a physical buoy in the domain. These manually placed probes are positioned in the following manner:

1. Select the probes coverage.
2. Select the "create arc"  tool.

3. Click out an arc in the area where the manually place probe is desired. This could be along a feature such as a reef. If the feature is really just a point, such as a buoy, create a short arc through the buoy location. SMS will create probes for each transect which intersects this arc.

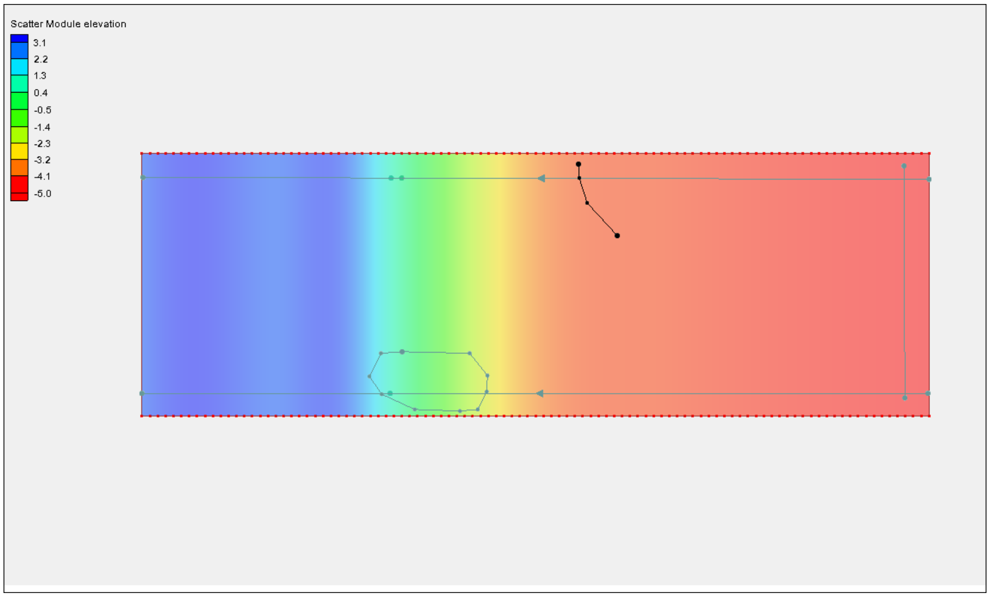


Figure 12 Manually placed probe location.

4. Select the "select arc"  tool.
5. Right click on the probe arc and select "Attributes…" (or double click) to bring up the attributes dialog.
6. Turn on the probe toggle, the "WSE" toggle, and the "Pressure" toggle and enter elevations as shown in Figure 13.

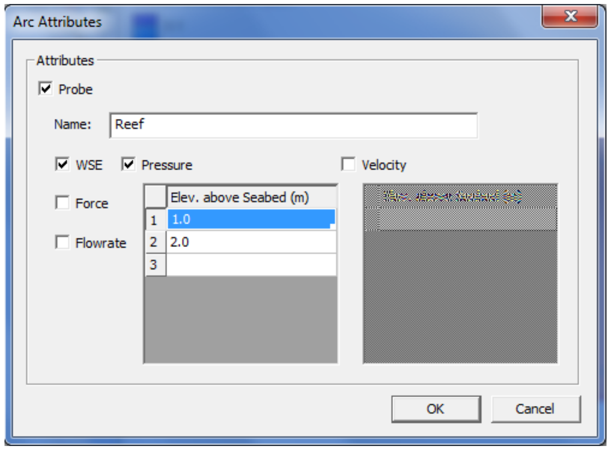


Figure 13 Attributes of manually placed probe.

These probes are visible in the transect profile just as the auto-generated probes were.

Previewing Profiles

In addition to previewing the transects as illustrated in the previous sections, the interface allows the user to review the coordinate values of the points on the transect. To do this:

1. Select the transects coverage.
2. Select the "select arc"  tool.
3. Right click on the transect arc and select "Attributes…" (or double click) to bring up the attributes dialog (Figure 14). The data can be selected from this spread sheet and pasted to another program. It may also be exported using the export button. (Extreme care should be used if these values are edited. The "x" value corresponds to a distance along the arc. If these values are edited, the coordinates along the arc are no longer consistent with the geometric placement on the arc. In extreme cases, you may change the "z" values, but it is recommended that the geometry of the transects come from a scatter set.)
4. Click "OK" to exit the dialog.

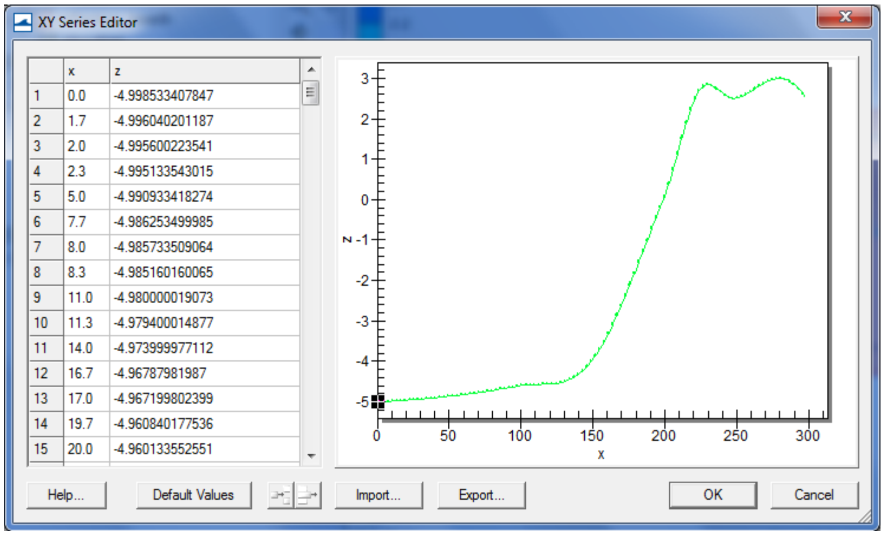


Figure 14   Transect attributes – the raw data.

Model control

Before we defined the transects, we went into the model control dialog and specified the name of the project. This was only to introduce you to the method of setting model parameters. Now that we have transects and wave makers defined, we can specify the model parameters.

1. Right click on the simulation and select "Model Control". The dialog appears.
2. Change the Project title to 'Reflective profile runup / overtopping test case – 1m.
3. Change the Cell size under Grid information to 1.0 m.
4. Notice that the constant Chezy coefficient is set to 30.0 as previously mentioned.
5. Under Output Options, select the following for Animation output:
   - Output WSE.
   - Output velocity.
   - Toggle on Override defaults and make the following changes
     - Begin output to 50.0 sec.
     - End output to 150.0 sec. The End output has to be set to less than the duration time of the simulation which in this case is 199.57 sec. To obtain duration time, make sure to run the simulation once before

overriding defaults. A file with a .par extension for each scenario will be generated during that run. Open one of the files using a text editing software such as Notepad and scroll down to find the Duration time.

- Step to 2.0 sec.

6. Click “OK” to exit the dialog.

Saving the project data and running the analysis

We are now ready to perform the analysis. It is a good idea to save your project before you do this.

1. Select File | Save Project. This saves all the changes you have made to the coverages and simulation.

If you right click on the “Reflective_01” simulation, a popup menu appears. The last three commands in this menu are options to save the model specific input files for the runup computations. One command just saves the files. This allows you to look at the data before launching the model. It also allows you to move those files to another machine for distributed computing. The second command saves the files and launches the BOUSS2D engine for each transect/wave condition pair. In this example we have two transects and two wave conditions so we have four total simulations to run. The third option saves the SMS project, then saves the model specific files, and then launches the numeric engine.

2. Right click on the simulation and select “Export Runup/overtopping files”. If you then open a file browser from your windows desktop, you can see that SMS created a “Bouss2D” folder in the same location your project was saved. Inside this folder SMS saves another folder for each runup/overtopping simulation. In this example there is only one. The folders bear the name of the simulation, so you should see a folder named “Reflective_01” or whatever name you gave the simulation. Inside that folder you will see a “par” file for each transect/wave condition pair you defined. There should be four in your folder. SMS also saves a set of grid files for each transect and a batch file to run all of these cases.

3. Right click on the simulation and select “Launch Runup/overtopping …”. SMS brings up a model wrapper and starts launching processes. Four processes are launched at a time. Once a set of four is complete, the system launches four more until all are complete.

Viewing results

After the run is complete, you can review the solutions created by BOUSS2D using the plot wizard in SMS.

1. Click on the plot wizard icon .
2. When the wizard appears (Figure 15), choose the "Runup/Overtopping Solution" option and click "Finish".

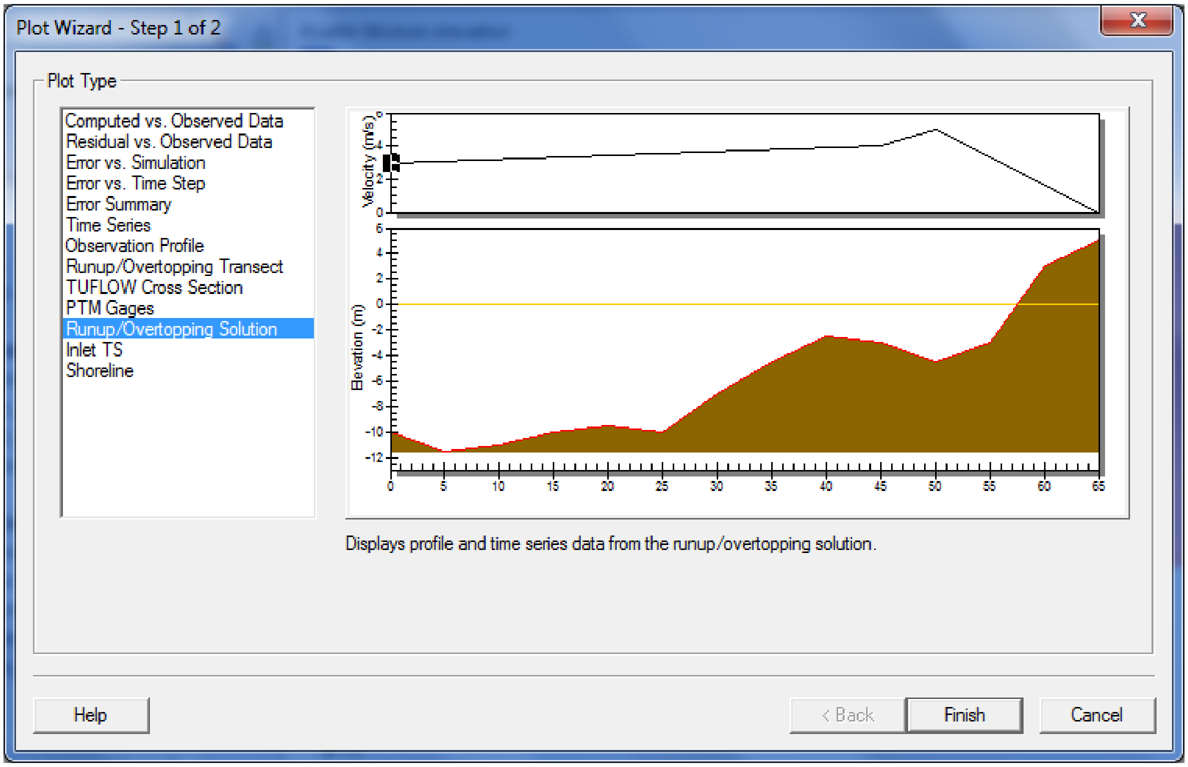


Figure 15 Step 1 of plot wizard to view Runup/Overtopping results.

The plot dialog appears.

Profile plots

This view is used to display the bathymetry with the following datasets if they were turned on in the model control:

- WSE
- Velocity magnitude

- Mean water level
- Significant wave height
- Mean velocity
- Maximum runup height

The data for multiple wave sets can be viewed for a single transect at the same time.

1. Toggle on the wave sets under 'Reflective_01'.
2. In the plot type, select "Profile".
3. Select the transect you want under Transects.
4. Select the data set(s) you want under Dataset types.
5. Click the update button. Figure 16 shows the solution profile plots for Transect 1 for both wave cases for all Dataset types.

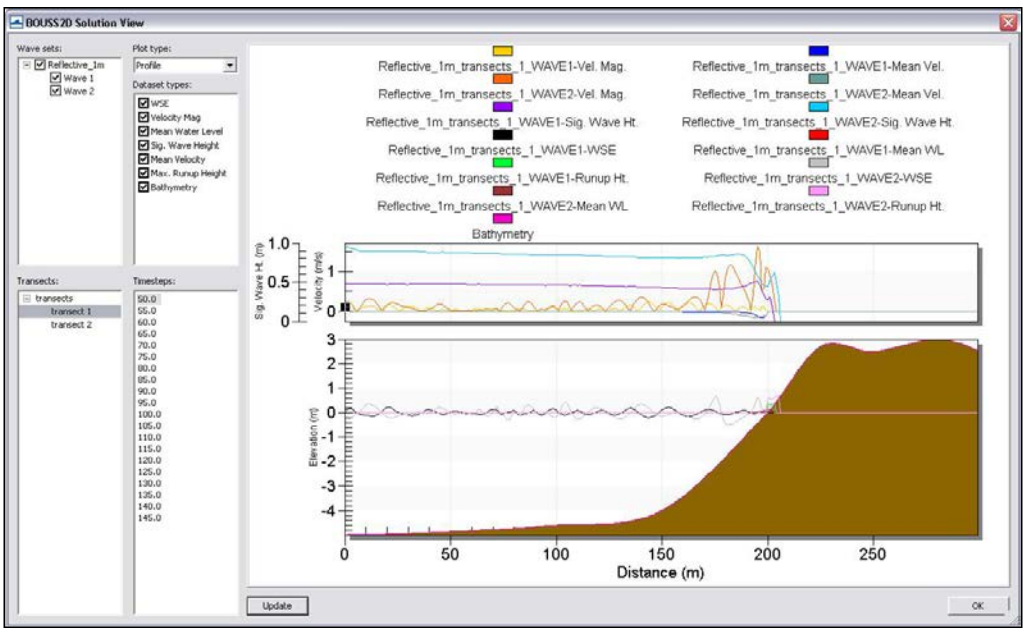


Figure 16 Bouss2D Runup / Overtopping Solution View.

Time series plots:

The Time series view displays the probe data from the simulation. In this view, you can display the data for any combination of transects, wave cases, and probes.

1. In the plot type, select “Time Series”.
2. Choose the transect(s).
3. Choose the probe set(s).
4. Choose the probe type(s).
5. Click the update button.
6. Click OK when finished looking through the data.
7. Figure 17 shows the Time Series plot in the BOUSS2D Solution View.

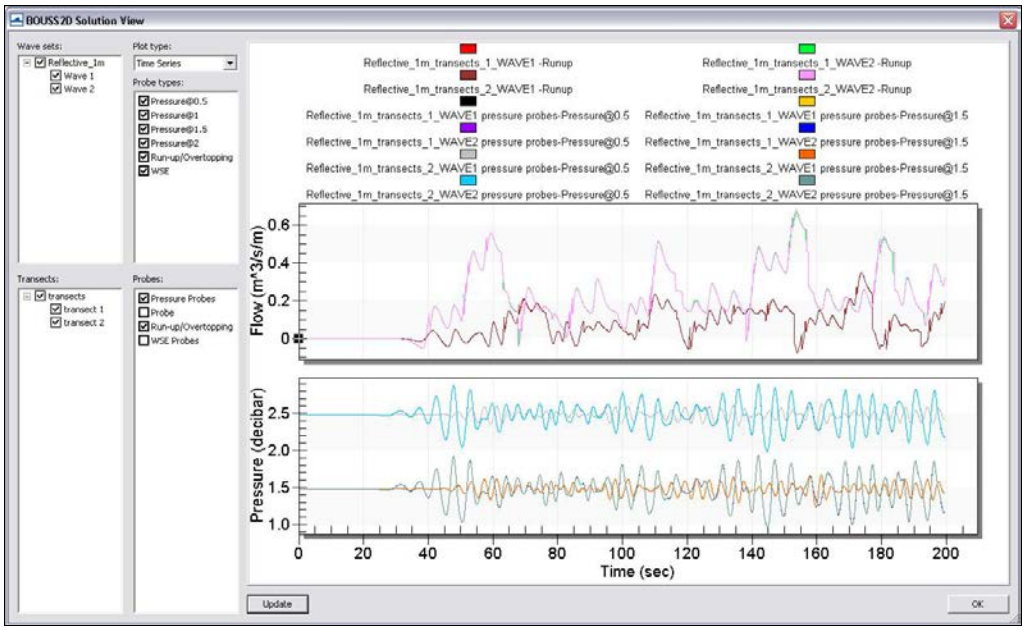


Figure 17 BOUSS2D Solution View – Time Series Plot

Statistical Analysis

After the simulation run, Statistics will be available for velocity, pressure, force, and water surface elevation probes on each transect.

To obtain the statistics,

1. Right-click on the simulation and select ‘Statistics’ from the menu. The statistics dialog will appear.

The ETA time series statistics display the following for each wave cases for each transect (in our case, there will be 6 scenarios):

- Minimum – the minimum value in the time series
- Maximum – the maximum value in the time series
- Mean – the mean value for the time series
- Standard Deviation – the standard deviation for the time series

The ‘ETA Zero-Crossing’ option displays:

- HAV – Average value of all wave heights.
- H13 – Percentage of wave heights exceeded by 1/3 of the peaks.
- H10 – Percentage of wave heights exceeded by 1/10 of the peaks.
- HMAX – Maximum value of all wave heights.
- TAV – Average period.
- T13 – Period exceeded by 1/3 of the wave peaks.
- T10 – Period exceeded by 1/10 of the wave peaks.

The ‘Runup Statistics’ show the highest water surface elevation where cells were dry before simulation and became wet after runup / overtopping. This statistics option displays:

- RMAX – Maximum value of all peaks,
- R2 – Value exceeded by 2% of peaks.
- R10 – Value exceeded by 10% of peaks.
- R33 – Value exceeded by 1/3 of peaks.
- RMEAN – Average of all peaks.

The ‘Pressure Time Series’ shows the values that were recorded by the different probes.

Conclusion

At this point, you can close SMS or investigate Runup / Overtopping module some more.

This concludes the Runup / Overtopping tutorial.