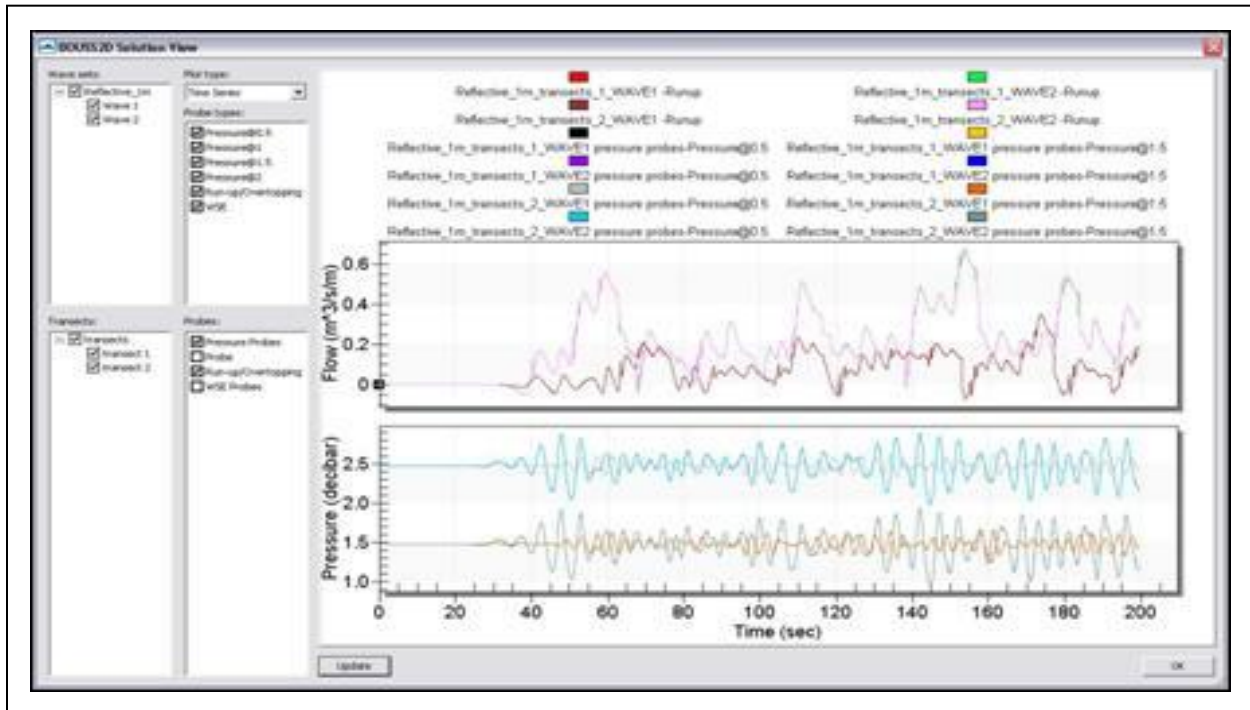


SMS 12.1 Tutorial

Runup/Overtopping Analysis



Objectives

This tutorial illustrates the mechanics for using the “Runup/Overtopping Simulation” interface, a tool incorporated into the Surface-water Modeling System (SMS). This tool utilizes Boussinesq analysis in the BOUSS2D numerical engine.

Prerequisites

- Overview Tutorial

Requirements

- Model
- Map Module
- Cartesian Grid Module
- Scatter Module

Time

- 45-60 minutes

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1 Introduction

The “Runup/Overtopping Simulation” interface is a tool incorporated into the Surface-water Modeling System (SMS). It performs analysis on one dimensional profiles to determine wave characteristics, the extent of runup, and the quantity of overtopping along those profiles for specified wave conditions. Boussinesq analysis is completed using the BOUSS-2D numerical engine.

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 the simulation.
3. Create transects. These can be in a single coverage or in multiple coverages if there are enough to be grouped.
4. Create wave makers.
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

2 Getting Started

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 scatter set for use in a runup/overtopping simulation.

To begin this tutorial:

1. Select *File* | **Open...** to bring up the *Open* dialog.
2. In the *data files* directory, select the file “reflective_beach.sms”. This project contains a scattered dataset representing a simple reflective beach profile.
3. Click on the **Open** button to open the file and close the *Open* dialog.

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 using *Display* | *View* | **Oblique**.

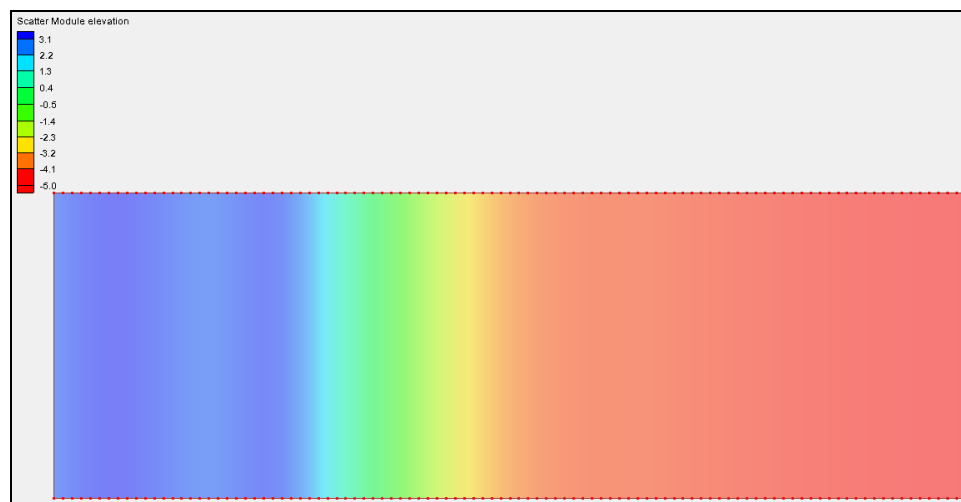


Figure 1 Initial view upon opening the project file

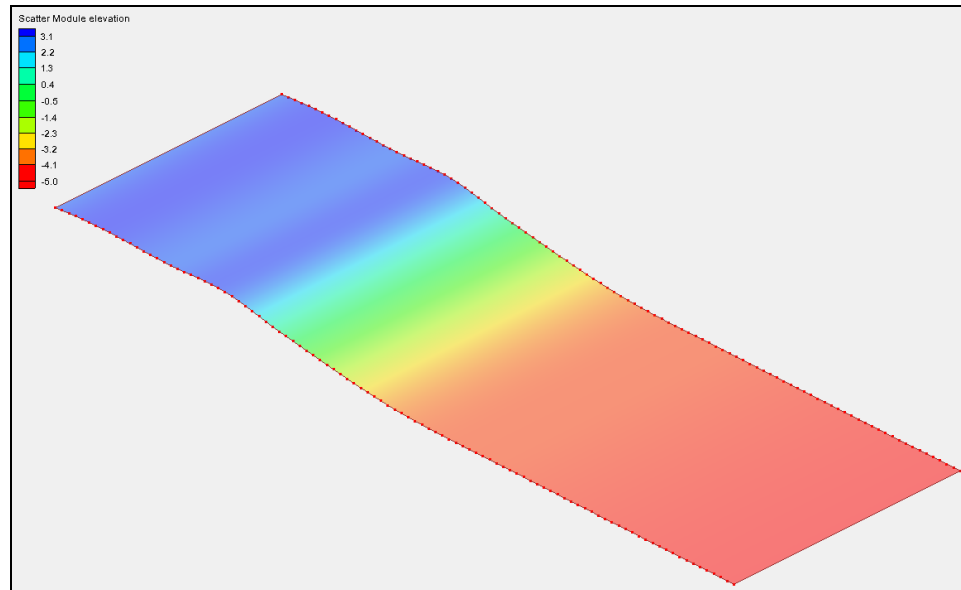


Figure 2 Oblique view of the project

3 Setting Up the Simulation

Many of the interfaces in SMS consist of data gathering dialogs and formatting routines to drive a specific numerical engine. These interfaces primarily 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 is not based on a single geometric entity. Instead, create the components of the simulation and link them together. The components and simulation can be created in any order.

3.1 Runup Simulation

SMS manages the runup simulations with a separate entry in the Project Explorer. A runup/overtopping simulation links many components together. These components are each represented by feature 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.

Begin the process of creating a simulation by doing the following:

1. Right-click in the Project Explorer and select *New Simulation* | **BOUSS Runup/Overtopping** to bring up the *New Runup/Overtopping Simulation* dialog (Figure 3). This dialog controls which coverages will be created.

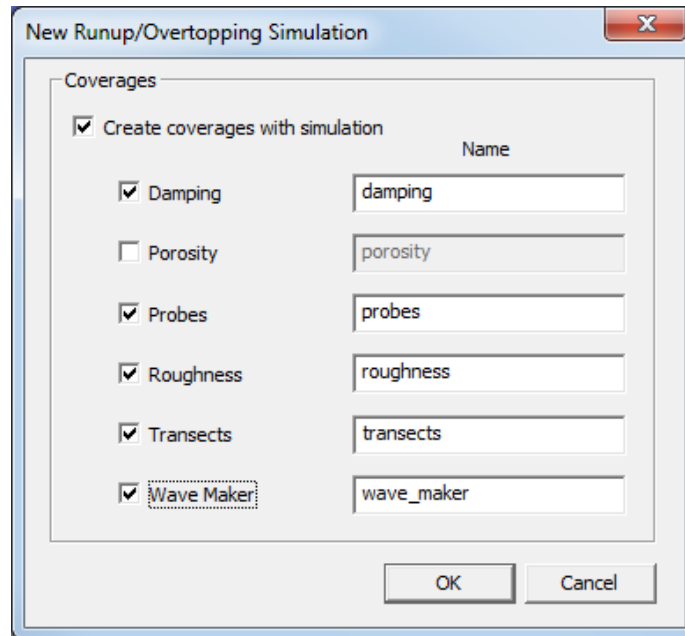


Figure 3 New Runup/Overtopping Simulation dialog

2. Toggle on Create coverages with simulation.
3. Toggle on all options except *Porosity* (see Figure 3). Leave the default name for each option.
4. Click **OK** to exit New Runup/Overtopping Simulation dialog.

The Project Explorer now includes a “Runup/Overtopping” folder. This entry includes a folder named “Simulations”. In that folder, one new simulation named “Sim” has been created.

5. Right-click on “Sim” and select **Rename**.
6. Enter “Reflective_01” as the name and press the *Enter* key to set the name.

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:

- Spatially variable damping stored in the “damping” coverage.
- Probes stored in the “probes” coverage.
- Spatially variable roughness stored in the “roughness” coverage.
- Profile locations stored in the “transects” coverage.
- Wave maker locations stored in the “wave_maker” coverage.

3.2 Linking Other Coverages

If coverages have been defined before creating the simulation, or if importing/creating additional coverages after the simulation has been defined, simply drag and drop these coverages into the simulation.

3.3 Specifying Simulation Properties

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

To set these:

1. Right-click on the “Reflective_01” simulation and select **Model Control** to bring up the *Runup/Overtopping Model Control* dialog.
2. Enter “Reflective profile runup/overtopping test case” as the Project title.
3. Click **OK** to close the *Runup/Overtopping Model Control* dialog.

The model parameters will be revisited after the other components of the simulation are defined.



4 Geometric Parameters

The principal geometric input for a runup/overtopping simulation are the transects where the calculations take place.

4.1 Transect Locations

SMS defines transects as “arcs in a transect coverage”. A simulation references one or more such coverages. When the simulation above was created, it also instructed SMS to create one transect coverage. The next step is to create a couple of transect arcs to define profile locations.

To do this:

1. Select the “transects” coverage to make it active.
2. **Frame**  the project.
3. Using the **Create Feature Arc**  tool, create a profile arc near the top of the scatter set, starting from deep water and ending in shallow water or land, as in Figure 4. Make certain the transect nodes are inside the scatter set area.
4. Create a second profile arc in a similar fashion near the bottom of the project.

The nodes can be moved around after creation if a specific location is desired. This model runs in 1D mode, so while the profile should be fairly straight, it can be curved.

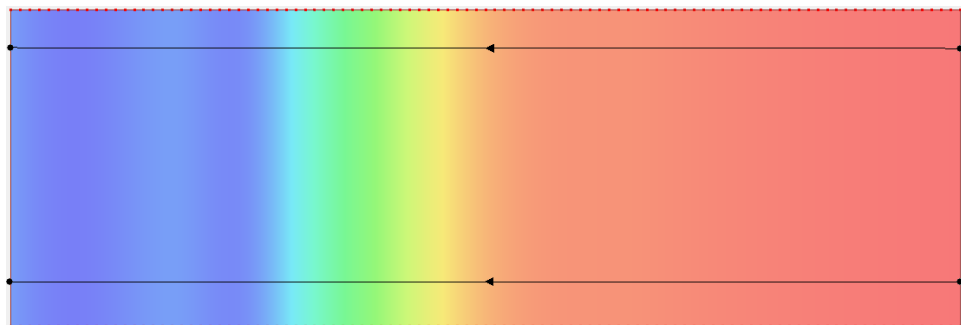


Figure 4 Geometry with two profile arcs created, with deep water on the right

4.2 Transect Elevations

The arc location defines the position of the transect. The elevation must be extracted from the underlying scatter set by doing the following:

5. Right-click on the “transects” coverage and select **Extract elevations** to bring up the *Interpolation* dialog.
1. Select “elevation” from the tree in the *Scatter Set To Interpolate From* section.
2. Click **OK** to extract the transect elevations and close the *Interpolation* dialog.
3. Right-click on the “Reflective_01” simulation and select **View transects profile...** to bring up the *Reflective_01 Transects* dialog appears (Figure 5).

A list of transect arcs appears in the *Transect arc* section on the lower left side. Selecting a transect displays its profile in the *Profile* section on the right of the dialog.

4. Click **OK** to close the *Reflective_01 Transects* dialog.

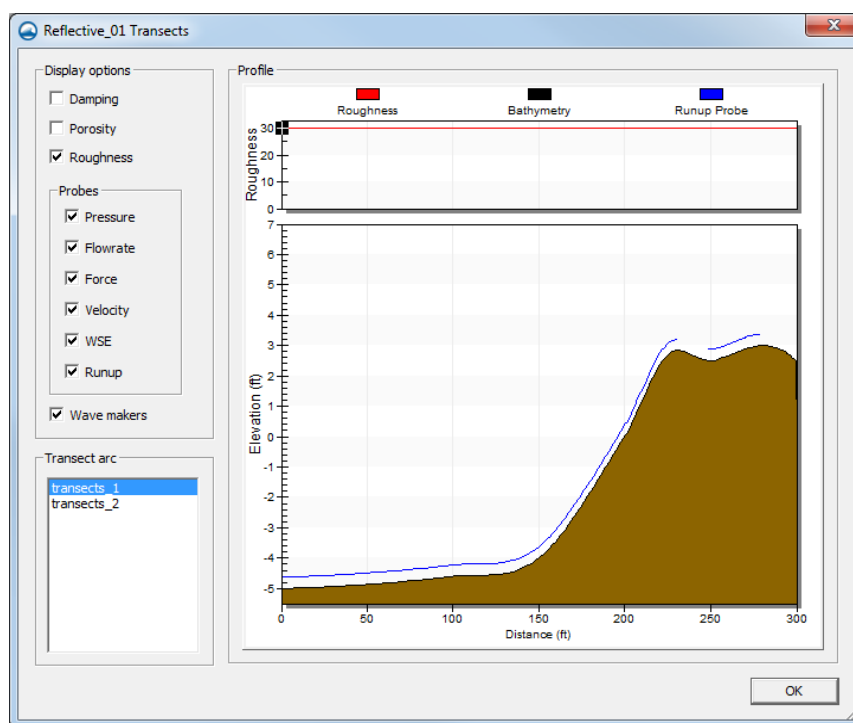


Figure 5 The Reflective_01 Transects dialog

4.3 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 wave maker. 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.

First, inactive coverages need to be visible to make this part easier to do.

1. Select *Display* | **Display Options** to bring up the *Display Options* dialog.

2. Select “Map” from the list on the left.
3. Toggle on Inactive coverage.
4. Click **OK** to close the *Display Options* dialog.

To set the wave maker position:

1. Select the “wave_maker” coverage to make it active.
2. Using the **Create Arc**  tool, click out arc crossing the two transect arcs at the deep end of the scatter set to define the wave maker location, as in Figure 6.

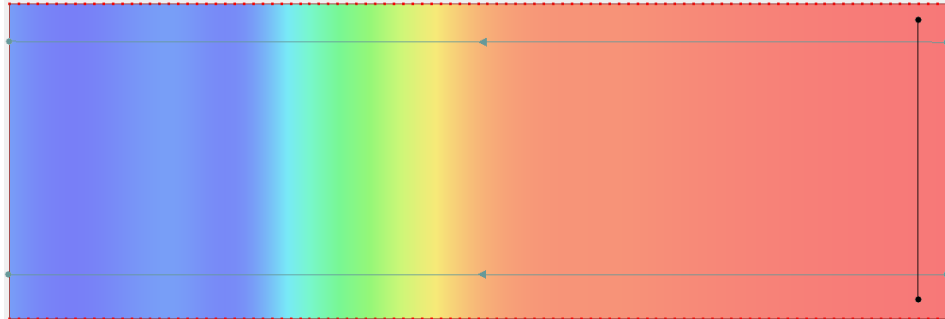


Figure 6 Location of wave maker arc, with transect arcs grayed out

With the wave maker position defined:

3. Right-click on the “Reflective_01” simulation and select **View transects profile...** to bring up the *Reflective_01 Transects* dialog (Figure 7).
4. Notice the blue arrow that marks the wave maker. Once done viewing the transect information, click **OK** to close the *Reflective_01 Transects* dialog.

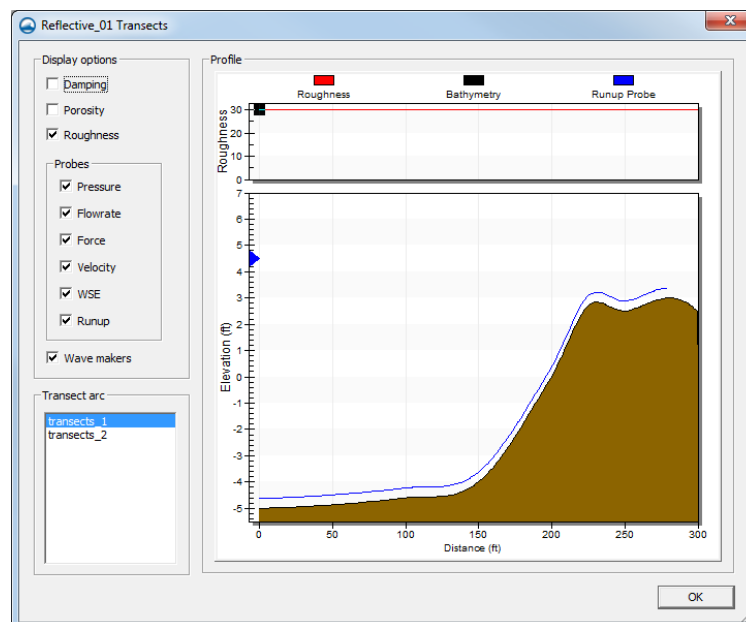



Figure 7 Wave maker marked by blue arrow

4.4 Wave Maker Attributes

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. Using the **Select Feature Arc**  tool, select the wave maker arc.
2. Right-click and select **Attributes...** to bring up the *BOUSS-2D Wave Generator Properties* dialog.
3. In the *Wave Simulation Parameters* section, select “Irregular Unidirectional” from the *Type* drop-down.
4. In the *Spectral Parameters* section, click the **Add** button to add a second wave case for comparison. As many cases as desired can be added.
5. Set the case parameters as follows:


	Wave 1	Wave 2
Sig. Wave Height (m)	0.5	1.0
Peak Wave Period (s)	3.5	5.0
Gamma (3.3)	3.3	3.3
Min. Wave Period (s)	2.31	2.31
Min. Wave Period (25.0) (s)	25.0	25.0
Tidal Offset (m)	0.0	0.0
Storm Duration (s)	0.0	0.0
Rescale Spectrum? (Yes)	Yes	Yes

- Click **OK** to close the BOUSS-2D Wave Generator Properties dialog.

4.5 Roughness Zones

The bottom roughness in coastal areas can impact the conveyance of waves as they progress towards the shore. This phenomenon can be simulated in the runup/overtopping simulation using a roughness zone.

To specify this for one of the transects:

- Select the “roughness” coverage to make it active.
- Using the **Create Feature Arc**  tool, click out a polygon enclosing an area with different roughness, as shown in Figure 8. This may represent a vegetated region.

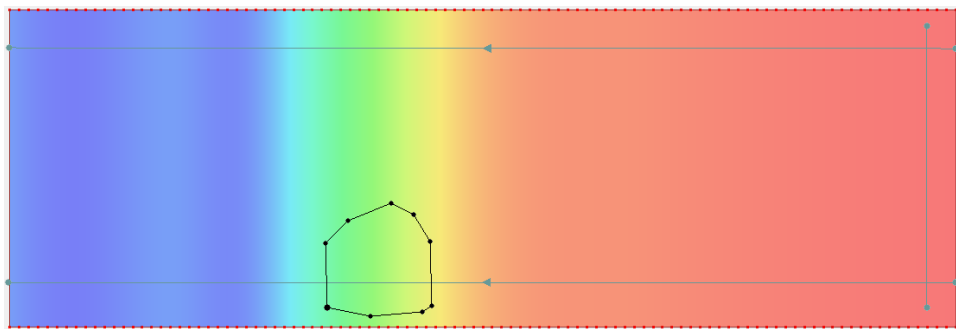



Figure 8 Area with different roughness

- Select *Feature Objects* | **Build Polygons**.
- Using the **Select Polygon**  tool, double-click in the roughness zone to bring up the *Roughness* dialog.
- In the *Chezy coefficient* area, enter “50.0”.
- Click **OK** to close the *Roughness* dialog.

This is a higher value than the default, 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:

- Right-click on the “Reflective_01” and select **View transects profile...** to bring up the *Reflective_01 Transects* dialog.
- In the *Transect arc* section, select “transect_2” and note the plot along the top of the *Profile* section showing the changing Chezy roughness value (Figure 9).
- When done viewing the information, click **OK** to close the *Reflective_01 Transects* dialog.

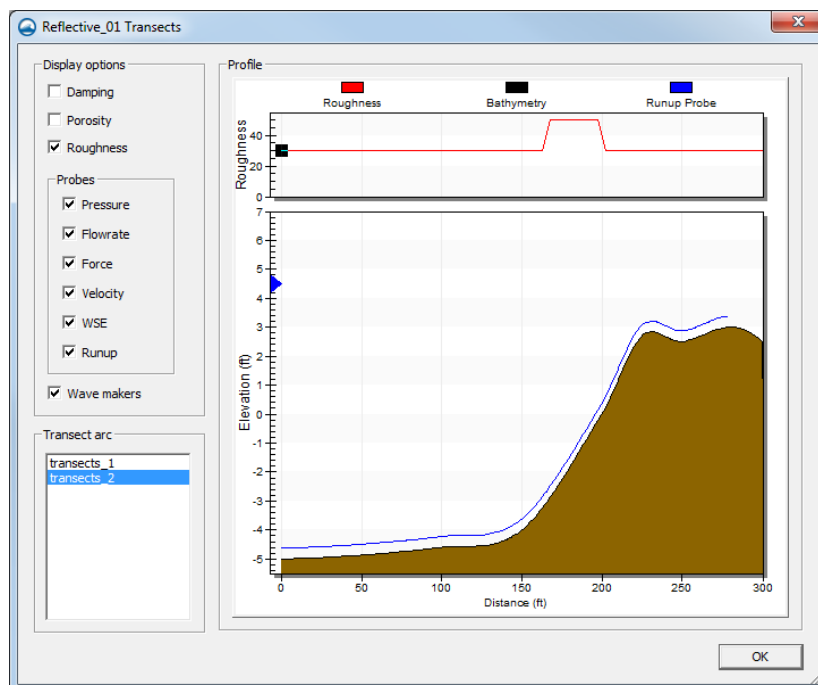


Figure 9 Changing roughness along transect_2

4.6 Damping Zones

In this 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 by specifying 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.

5 Autogenerated Probes

The Boussinesq 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 autogenerated and manually placed.

First, autogenerate some probes by doing the following:

1. Right-click on the “probes” coverage and select **Properties...** to bring up the *Probe Rules* dialog.

The *Auto-create runup probes* toggle at the top of the dialog is checked. This tells SMS to create runup probes along the transect.

2. Click on the **Add** button to generate a set of probes and do the following:
 - Enter “WSE Probes” in the *Name* field.
 - Enter “-1.0” in the *Elev. (m)* field.

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 location point is chosen based on the option selected from the *Closest to* drop-down (the default here is “Wavemaker”).

- Toggle on *WSE*.
3. Click on the **Add** button to generate another set of probes and do the following:
 - Enter “Pressure Probes” in the *Name* field.
 - Enter “-3.0” in the *Elev. (m)* field.
 - Toggle on *Pressure*.
 - Click the **Define** button to the right of the pressure toggle to bring up the *Pressure Heights* dialog.
 - In the first row below *Height above Seabed (m)*, enter “0.5” and press the *Tab* key.
 - Enter “1.5” in row 2.
 - Click **OK** to close the *Pressure Heights* dialog.
 4. Click **OK** to close the *Probe Rules* dialog.

The probes can be viewed in the transect profile:

5. Right-click on the “Reflective_01” and select **View transects profile** to bring up the *Reflective_01 Transects* dialog.

Note the triangle and cross symbols illustrating the locations of the water surface and pressure probes (Figure 10). These are placed on all the transects in the simulation at points that match the rules defined for the probes.

The blue line running along the transect shows 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 m^3/s that flows to the right of the runup probe. The runup value is meaningless if the overtopping value is not zero.

- When done viewing the information, click **OK** to close the *Reflective_01 Transects* dialog.

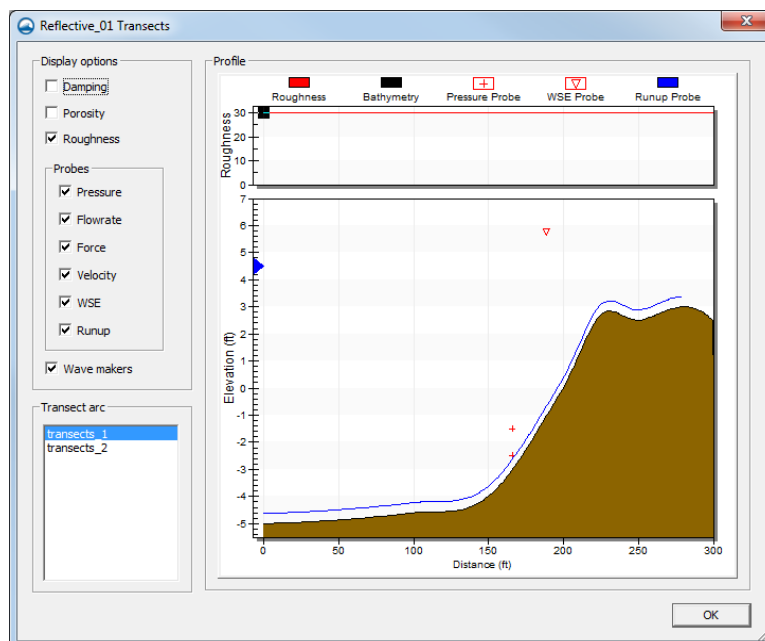



Figure 10 Pressure probes and WSE probes with transects

6 Manually Placed Probes

In addition to the autogenerated probes, some projects require specifically positioned probes at areas of interest. For example, a reef or manmade submerged breakwater may exist inside of the domain and the project 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:

- Select the “probes” coverage to make it active.
- Using the **Create Feature Arc**  tool, create an arc in the area where the manually place probe is desired, as shown in Figure 11.

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.

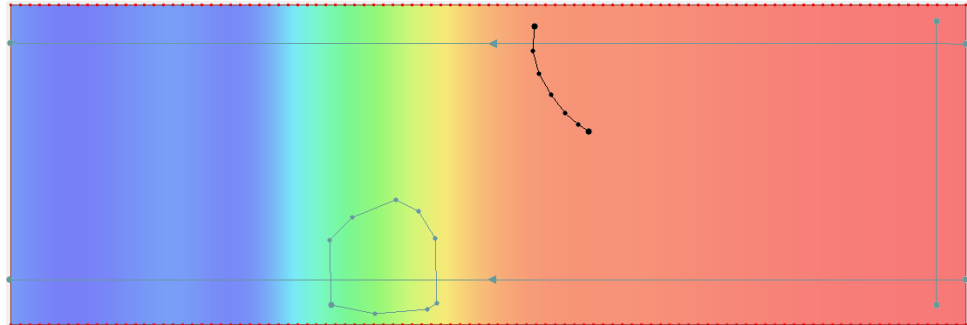



Figure 11 Arc for a reef or buoy probe, crossing the upper transect

3. Using the **Select Feature Arc**  tool, select the new probe arc.
4. Right-click on the probe arc and select **Attributes...** to bring up the *Arc Attributes* dialog (Figure 12).
5. Toggle on *Probe*, *WSE*, and *Pressure*.
6. In the first row below *Height above Seabed (m)*, enter “1.0” and press the *Tab* key.
7. Enter “2.0” in row 2.
8. Click **OK** to close the *Arc Attributes* dialog.

These probes are visible in the transect profile just as the autogenerated probes were.

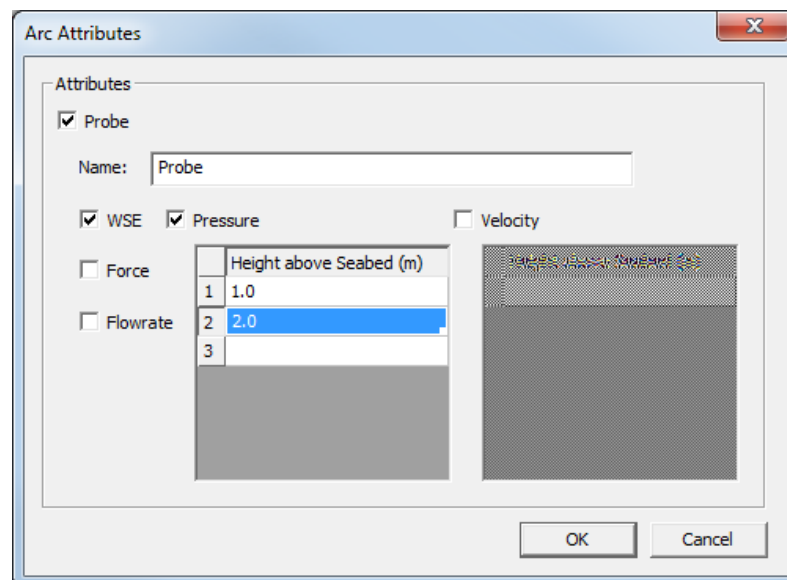


Figure 12 Arc Attributes dialog

7 Previewing Profiles

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

1. Select the “transects” coverage to make it active.

- Using the **Select Feature Arc** tool, right-click on one of the transect arcs and select **Attributes...** to bring up the *XY Series Editor* dialog (Figure 13).

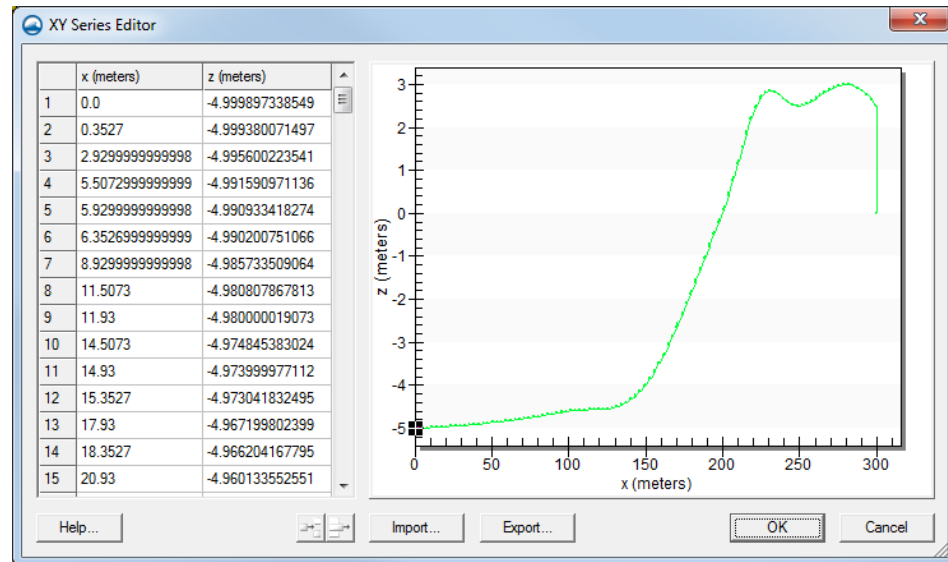


Figure 13 The XYZ Series Editor dialog showing information from one transect

The data in this dialog can be selected from this spread sheet and pasted to another program (for example, into a spreadsheet program). It may also be exported using the **Export** button.

Extreme care should be used if these values are edited. The *x (meters)* values correspond to distances along the arc. If these values are edited, the coordinates along the arc are no longer consisted with the geometric placement on the arc. In extreme cases change the *z (meters)* values, but it is recommended that the geometry of the transects come from a scatter set.

- Click **OK** to exit the *XY Series Editor* dialog.

8 Model Control

Before defining the transects, the name of the project was specified in the model control dialog. This was only to introduce the method of setting model parameters. Now that the transects and wave makers are defined, the model parameters can be specified.

To specify the model parameters, do the following:

- Right-click on the simulation and select **Model Control** to bring up the *Runup/Overtopping Model Control* dialog.
- Enter “Reflective profile runup/overtopping test case – 1m” for the *Project title*.
- In the *Grid Information* section, enter “1.0” in the *Cell size (dx)* field.
- In the Output Options section, under Animation output, toggle on Output WSE, Output velocity, and Override defaults.
- Set the following:
 - *Begin output* as “100.0” sec.

- *End output* to “150.0” sec.
 - *Step* to “5.0” sec.
6. Click **OK** to exit the Runup/Overtopping Model Control dialog.

The *End output* has to be set to less than the duration time of the simulation (which is 199.57 sec in this case). To obtain duration time, run the simulation once before overriding defaults. A file with a “*.par” extension will be generated for each simulation run. Using a text editor such as Notepad, view the PAR file and scroll down to find the Duration time.

9 Saving the Project Data and Running the Analysis

Before running the simulation, it is recommended to save the project:

1. Select *File* | **Save Project** to save all the changes made to the coverages and simulation.
2. Right-click on the “Reflective_01” simulation and select **Export Runup/overtopping files**.


The exported files are viewable in the *data files/Bouss2D* folder. Within this folder, SMS saves each runup/overtopping simulation in a separate folder. In this example, there is only one. The folders bear the name of the simulation, so there should be a folder named “Reflective_01” or whatever name was given to the simulation.

Inside that folder is a PAR file for each transect/wave condition pair defined. There should be four PAR files in the 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...** to bring up the *BOUSS Runup/Overtopping Reflective_01* dialog.
4. The dialog box will instruct to click on a bar in the dialog to start the process. The process may take several minutes, and all bars should change to green once completed. The information section at the bottom of the dialog will show “PROCESS FINISHED” and the **Abort** button will change to an **Exit** button.
5. Click the **Exit** button to close the *BOUSS Runup/Overtopping Reflective_01* dialog.

10 Viewing Results

After the run is complete, review the solutions created by the Boussinesq model using the Plot Wizard in SMS:

1. Click on the **Plot Wizard**  icon to bring up the *Plot Wizard – Step 1 of 2* dialog.
2. Select *Runup/Overtopping Solution* from the list on the left side of the *Plot Type* section.
3. Click **Finish** to close the *Plot Wizard – Step 1 of 2* dialog and open the *BOUSS2D Solution View* dialog.

10.1 BOUSS2D Solution Views

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 by doing the following:

1. In the *Wave sets* section, toggle on *Wave 1* and *Wave 2* under “Reflective_01”.
2. From the *Plot Type* drop-down, select “Profile”.
3. Select the desired transect in the *Transects* section.
4. Toggle on the desired datasets in the *Dataset types* section.
5. Click the **Update** button.

Figure 14 shows the solution profile plots for Transect 1 for both wave cases for all dataset types.

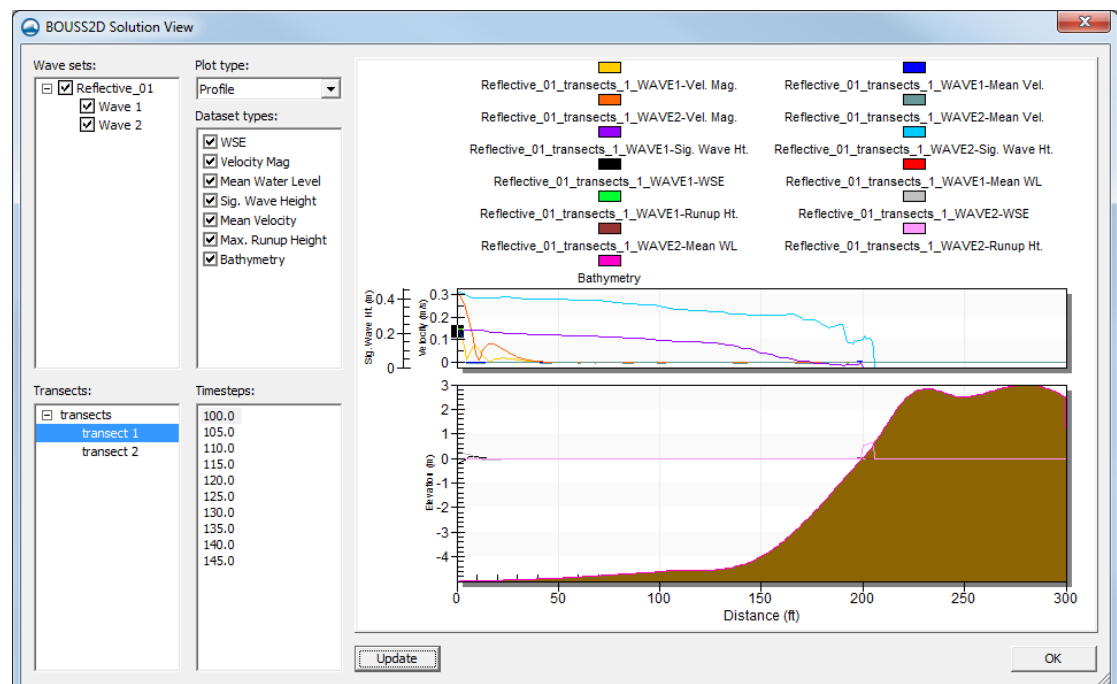


Figure 14 Profile plots for Transect 1 and both waves

10.2 Time Series Plots

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

To view this data:

1. In the *BOUSS2D Solution View* dialog, in the *Plot type* section, select “Time Series” from the drop-down.
2. In the *Transects* section, toggle on both transects.
3. In the *Probes types* section, toggle on *Pressure @0.5* and *Runup/Overtopping*.
4. In the *Probes* section, toggle on *Pressure Probes* and *Runup/Overtopping*.
5. Click the **Update** button. Figure 15 shows how these plots appear.
6. Experiment with changing the options in this dialog to see how different data appear.
7. Click **OK** when done to close the *BOUSS2D Solution View* dialog.

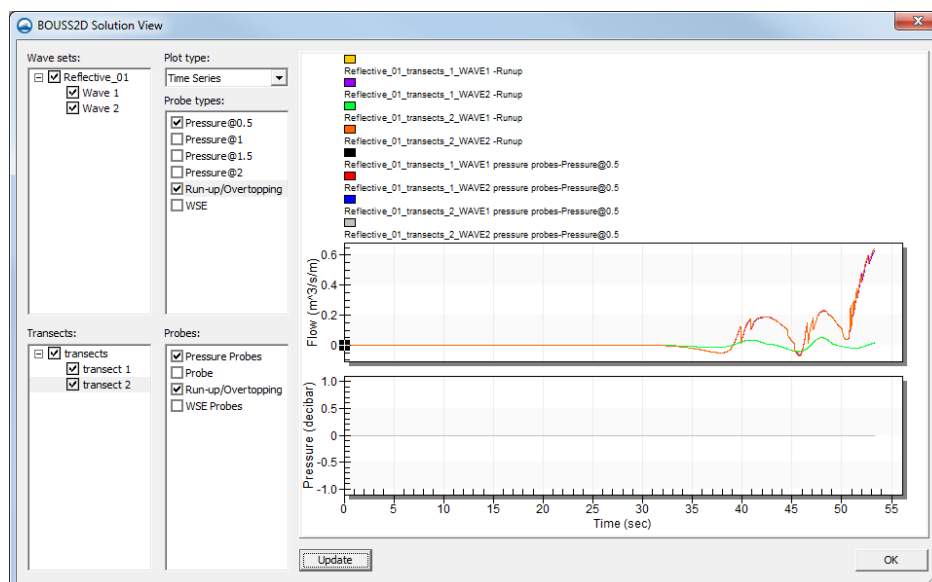


Figure 15 Time Series plots with two probes selected

11 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** to bring up the *Statistics* dialog.
2. Experiment by selecting different options from the *Type* drop-down.

The “ETA Time Series Statistics” display the following for each wave cases for each transect (in this 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:

- H_{av} – Average value of all wave heights.
- $H_{1/3}$ – Percentage of wave heights exceeded by 1/3 of the peaks.
- $H_{1/10}$ – Percentage of wave heights exceeded by 1/10 of the peaks.
- H_{max} – Maximum value of all wave heights.
- T_{av} – Average period.
- $T_{1/3}$ – Period exceeded by 1/3 of the wave peaks.
- $T_{1/10}$ – 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:

- R_{max} – Maximum value of all peaks,
- $R_{2\%}$ – Value exceeded by 2% of peaks.
- $R_{10\%}$ – Value exceeded by 10% of peaks.
- $R_{33\%}$ – Value exceeded by 1/3 of peaks.
- R_{mean} – Average of all peaks.

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

3. Click **OK** to close the *Statistics* dialog when done.

12 Conclusion

This concludes the *Runup/Overtopping* tutorial. Continue experimenting and exploring different options, or quit the program.