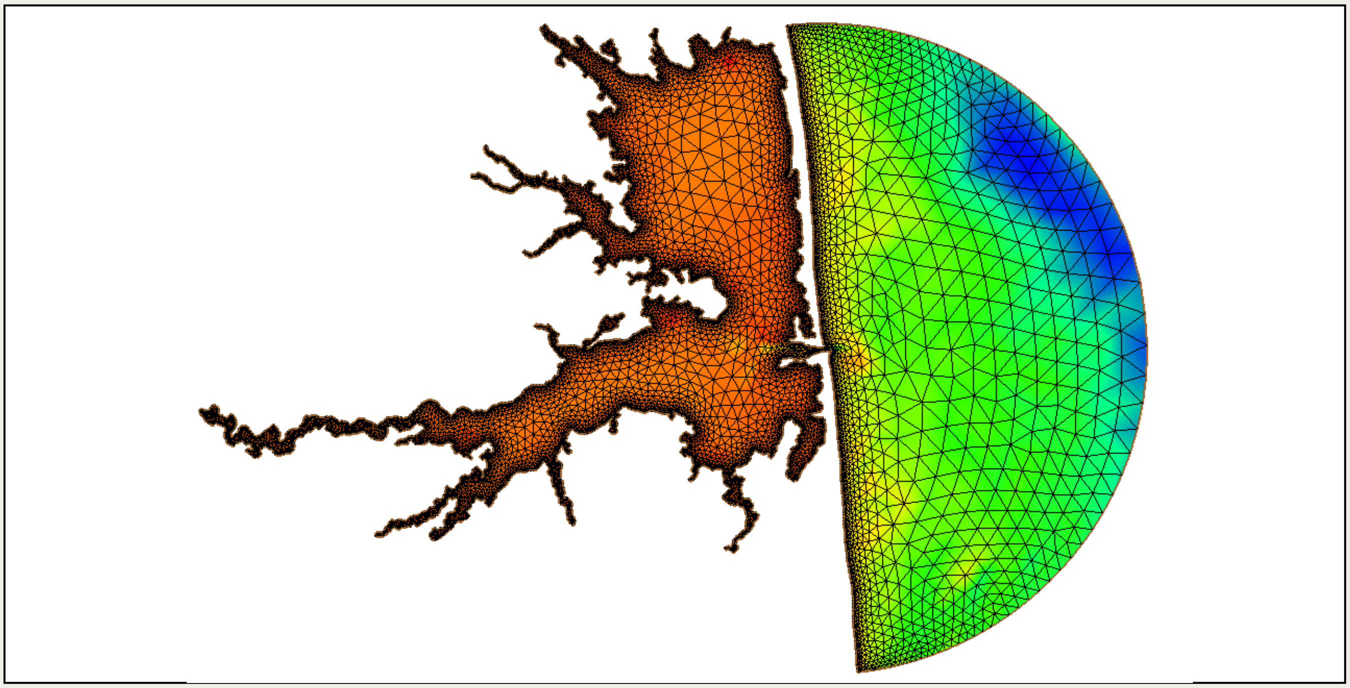
SMS 14.0 Tutorial

ADCIRC Simulation



Objectives

This tutorial demonstrates how to set up and run an ADCIRC simulation given a mesh. This includes specifying model parameters, model boundary condition locations and types, and the tidal forcing functions.

Prerequisite Tutorials

- Overview
- Map Module
- Raster
- Background Data
- Simulation Domain
- Mesh Generation
- Mesh Quality

Required Components

- SMS Core

Time

- 15–20 minutes

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1 Introduction

This exercise illustrates how to set up and execute an ADCIRC Simulation in the Surface-water Modeling System (SMS) when a mesh has already been generated.

This exercise utilizes data from the region around Indian River Inlet located on Delmarva Peninsula along the Maryland coast between Delaware Bay and Chesapeake Bay.

2 Getting Started

Start by importing a project file containing an existing mesh:

1. Launch the SMS application.
2. From the *Menu* bar, select the *File* | **Open…** menu option to bring up the *Open* dialog.
3. Navigate to the *Exercises/Indian River* folder.
4. From the *Files of type* drop-down menu, select “Project Files (*.sms)”.
5. Select the “IR_checked_mesh.sms” file.
6. Click the **Open** button to import the project and exit the *Open* dialog.

The initial project should appear similar to Figure 1.

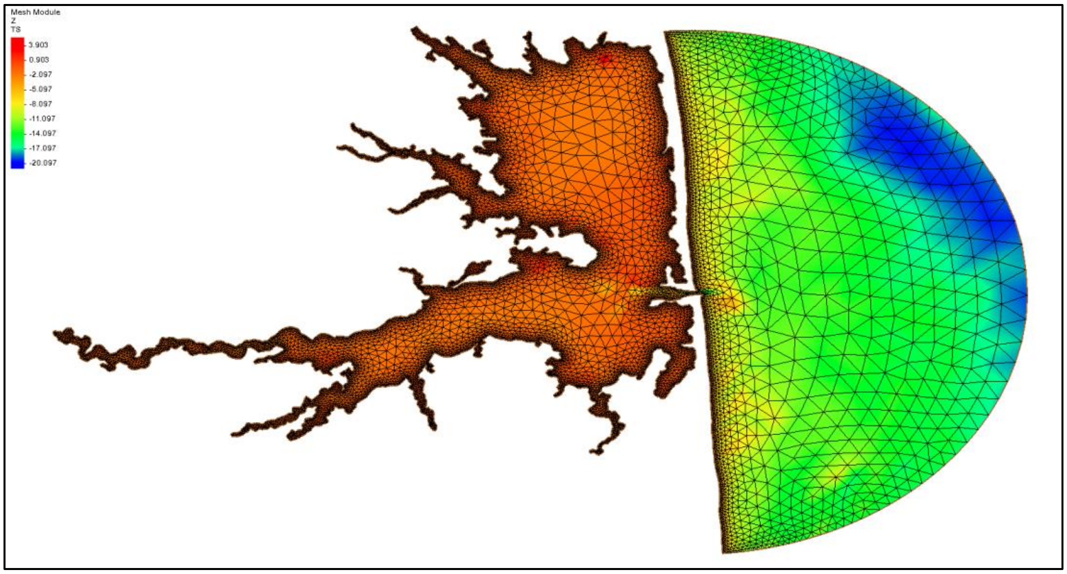

Figure 1: Initial Project

3 Reviewing the Projection

ADCIRC simulations of real-world locations are normally executed in geographic coordinates. The mesh in this project was defined in rectilinear (State Plane) space, so the mesh should be reprojected at this time. To do this:

1. In the *Project Explorer,* right-click on the "constant pave 50-1000m" mesh and select the *Projection* | **Reproject…** context menu item. A warning dialog will appear.
2. Acknowledge the warning about reprojection by clicking the **Yes** button. The *Reproject Object* dialog opens.
3. The default reprojection in SMS is to reproject an object into the display projection. This is what we want to do here, so accept all default values.
4. Click the **OK** button to close the *Reproject Object* dialog and perform the reprojection.

4 Defining the Simulation

SMS uses an approach referred to as "simulation-based modeling". This means that attributes and components for a numerical simulation are combined explicitly into a "simulation". A simulation is created as a separate entity in the *Project Explorer.* This allows components to be reused in multiple simulations, resulting in a more efficient process.

An ADCIRC simulation includes a mesh, boundary conditions, model parameters and potentially other components such as tides and meteorological conditions.

4.1 Creating a Simulation

To create an ADCIRC simulation:

1. In the white space of the *Project Explorer,* right-click and select the *New Simulation* | **ADCIRC** context menu item. This creates a new simulation named " Sim".
2. Right-click on the " Sim" simulation, select the **Rename** context menu item, and rename it to "Tide".

4.2 Setting Model Parameters

The ADCIRC run parameters include many options and variables which ADCIRC reads from a control file (fort.15). These parameters include hot start options, model timing, numerical settings, and output control.

A full description of all of these parameters is outside of the scope of this exercise. They can be examined in the ADCIRC documentation at www.adcirc.org.

To set up the ADCIRC simulation parameters:

1. In the *Project Explorer,* right-click on the " Tide" simulation and select the **Model Control…** context menu item to open the *ADCIRC Model Control* dialog.
2. Select the *General parameters* tab:
   a. In the *Simulation description* section, for the *Project title,* enter "Indian River Tides 9/10/2010-9/12/2010".
   b. For the *Run ID,* enter "version 53"
   c. In the *Coordinates* section, change the *Coriolis option:* to "Variable". This instructs ADCIRC to use the coordinates of the mesh to compute the influence of Coriolis forces.
   d. Leave all the other general parameters as the default settings. Refer to the ADCIRC documentation for descriptions of each parameter.
3. Select the *Model formulation* tab:
   a. Leave *Model type – IM* as the default "Barotropic 2DDI".
   b. In the *Nonlinear terms* section, set the *Finite amplitude terms* to "With wetting/drying".
   c. For the *Minimum depth,* enter "0.05".
   d. For the *Minimum vel (m/s),* enter "0.02".
   e. Turn on the *Advective terms – NOLICA* checkbox.
   f. In the *Generalized wave continuity equation – GWCE* section, set the *Weighting factor* to be "Pure primitive equation: TAU0 specified".
   g. For the *Tau0* value, enter "0.005".
   h. Set the *Solver message level* to be "Fatal". Scroll down, if necessary.
4. Select the *Timing* tab:
   a. Set the *Interpolation reference date* to "9/10/2010 12:00 am" (0.0 hours on September 10, 2010). This date refers to a date used by the interface to extract tidal or meteorological values from other data sources for use in a simulation.
   b. In the *Timing* section, for the *Time step (seconds),* enter "4.0".

   c. For the *Length of run (days),* enter “3”. Normal simulations last for several days up to a full lunar month, but we’ll use a much lower duration in the interest of time.
   d. In the Ramp Options – NRAMP section, set the Number of hyperbolic tangent spin up ramps to be “1”.
   e. For the *Duration (days): General ramp*, enter “1.0”.

5. Select the *Output* tab. We will set default options that will be applied to both elevation and velocity. On the *Default line:*
   a. Leave the *Output format* as the default of “NetCDF”.
   b. For the *Start (days),* enter “0.0”. With a running simulation this would be “1.0” so the solution would only be created after the ramp period, but this allows us to view solutions during the ramp.
   c. For the *End (days),* enter “30”. This will tell ADCIRC to create output to the end of the 3-day simulation. We’ve set it to the maximum duration we expect to use in this model so that if the model is run for a longer duration later output will still be written to the end of the run.
   d. For the *Increment (min),* enter “30.0”.
6. Select the *Wind* tab in the *ADCIRC Model Control* dialog.
   a. Verify that the *NWS = 0 – No wind* drop-down menu item is selected. The *Wind* tab allows the user to specify what winds are to be used by ADCIRC. In this exercise we are not using wind.
7. Click the **OK** button to exit the *ADCIRC Model Control* dialog.

4.3 Saving the Project

It is good practice to save frequently.

1. From the *Menu* bar, select the *File* | **Save As…** menu item.
2. Navigate to the Extra Exercises/Indian River/work folder.
3. For the *File name*, enter “IR_tides.sms”.
4. Click the **OK** button to save the file and close the *Save As* dialog.

4.4 Adding the Mesh to the Simulation

An ADCIRC simulation requires a mesh. To add the mesh to the simulation:

1. Drag the “ constant pave 50-1000m” mesh from the top of the tree in the *Project Explorer* down to the “ Tide” simulation until a line appears below the simulation name. When the line appears, drop the mesh. (Alternatively, right-click on the mesh and select “Apply to | ADCIRC Simulations -> Tide”.)

This links the mesh to the ADCIRC simulation.

An entry appears below the simulation that looks like the mesh. The icon includes an arrow indicating that this is not an independent mesh, but rather a link to the mesh in the *Mesh Data* section of the project.

5 Defining the Boundary Conditions

An ADCIRC simulation requires that the modeler define the boundary conditions for all the nodes around the edge of the domain. This can easily be assigned by creating arcs that wrap around the domain boundary. These arcs could follow the boundary exactly, but don't need to be precise because SMS will snap the boundary arcs to match the mesh boundary.

This simulation will only contain two boundary conditions. One will specify that the coastline should be treated as a mainland boundary. The other will specify that the semi-circular boundary will be treated as ocean.

5.1 Creating the BC Coverage

The first step in defining the boundary locations is to create the boundary condition coverage. To do this:

1. In the *Project Explorer*, right-click on the " Map Data" entry in the data tree and select the *New Coverage* context menu item to open the *New Coverage* dialog.
2. Under the *Coverage Type* section, select *Models* | *ADCIRC* | **Boundary Conditions** as the type.
3. For the *Coverage Name*, enter "Tidal BC to snap".
4. Click the **OK** button to exit the *New Coverage* dialog and create the coverage.

5.2 Coastline

We now require an arc that will tell ADCIRC what portion of the domain to treat as mainland. ADCIRC treats this as a closed boundary (no flow). To do this:

1. From the *Dynamic Tool* bar, select the **Create Feature Arc** tool.
2. In the *Graphic Window,* create an arc that starts near one end of the coastline, wraps around the bay and ends near the other coastline end as shown in Figure 2. The order is not important, nor is the number of vertices. It should start near the "corners" where the coast intersects with the ocean. We will check this later.

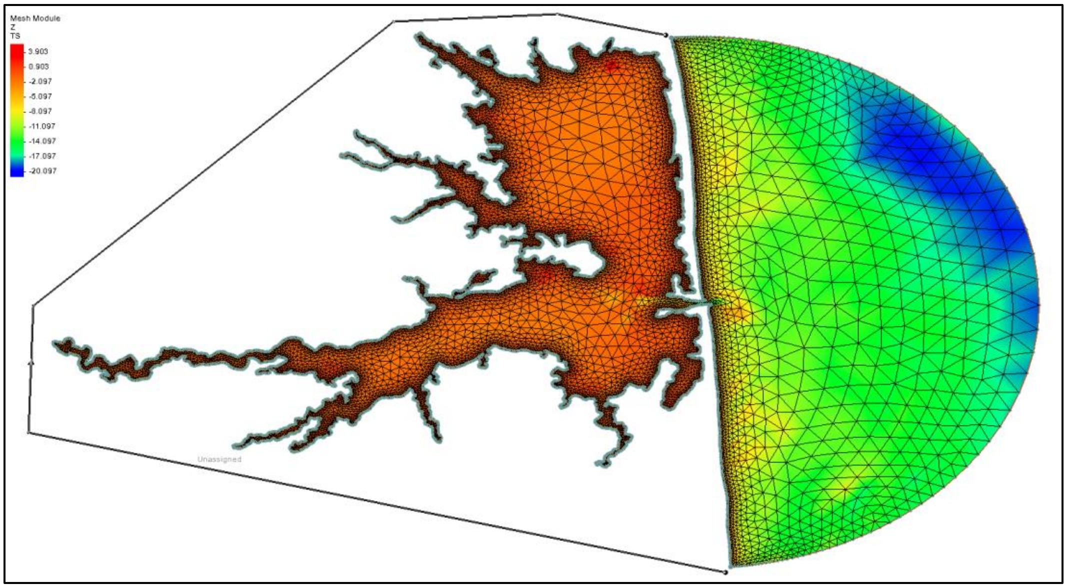

Figure 2: The Mainland/coastline Arc

3. From the *Dynamic Tool* bar, select the **Select Feature Arc** tool.
4. In the *Graphic Window*, select the new arc and double-click to open the *Assign Linear BC* dialog.
5. Set the *Linear boundary condition option* to “Mainland”. The default *modify* will be “Natural”.
6. Click the **OK** button to close the *Assign Linear BC* dialog and make the assignment.

The label near the arc will change from “Unassigned” to “Mainland” indicating the assignment has been made.

5.3 Tidal Boundary

We now require an arc that will tell ADCIRC what portion of the domain to treat as ocean. ADCIRC will force a water level at all nodes on this portion of the domain and allow flow to enter and leave the domain between these nodes. To do this:

1. From the *Dynamic Tool* bar, select the **Create Feature Arc** tool.
2. In the *Graphic Window,* create an arc that starts near one end of the coastline, wraps around the ocean portion of the domain and ends near the other coastline end as shown in Figure 2. It is a good idea to make the ends of this arc snap to the ends of the arc created in the previous section. Again, the order is not important, nor is the number of vertices.

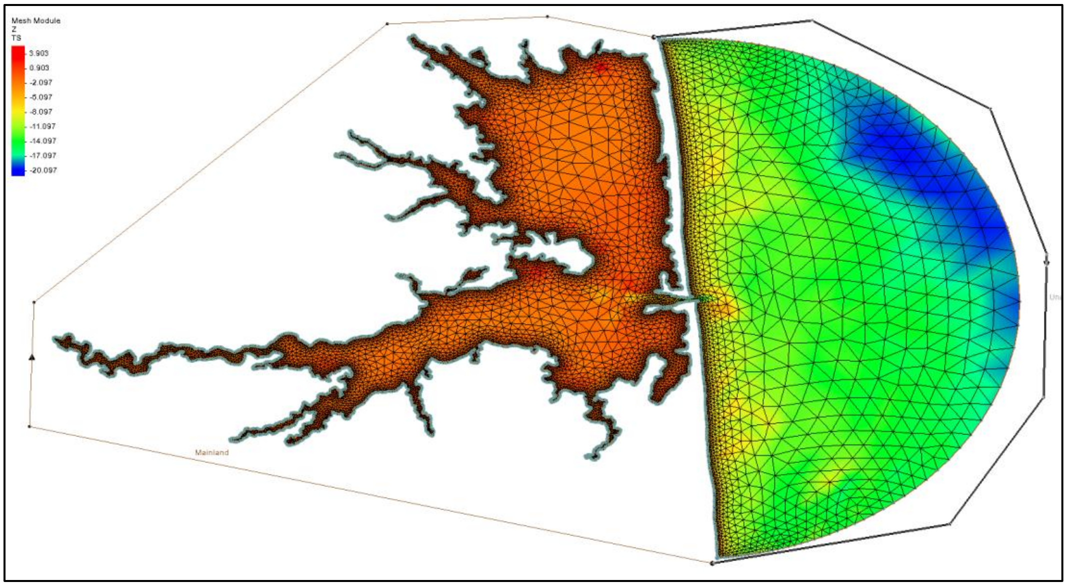

Figure 3: The Ocean Arc

3. From the *Dynamic Tool* bar, select the **Select Feature Arc** tool.
4. In the *Graphic Window,* select the new arc and double-click to open the *Assign Linear BC* dialog.
5. Set the *Linear boundary condition options* to “Ocean”.
6. Click the **OK** button to close the *Assign Linear BC* dialog and make the assignment.

The label near the arc will change from “Unassigned” to “Ocean” indicating the assignment has been made.

5.4 Adding the Boundary Conditions to the Simulation

To associate this ADCIRC boundary conditions coverage with the simulation, the mesh must first be included in the simulation. That is why the mesh was added to the simulation in the previous section. This is because the boundary condition locations will be snapped onto the mesh. To do this:

1. In the *Project Explorer,* right-click on the “ Tidal BC to snap” coverage and select the *Apply to* | **ADCIRC Simulations** → **Tide** context menu item.

An entry appears below the “ Tide” simulation labeled “ Tidal BC to snap (applied)”.

2. Toggle off the display of both the “ constant pave 50-1000m” mesh and the “ Tidal BC to snap” coverage. This will leave just the applied boundary conditions visible.
3. Right-click on the “ Tidal BC to snap (applied)” simulation entry and select the **Display Options…** context menu item to open the *Display Options* dialog.
4. In the *Ocean* line of the table , click on the button in the *color/style* column (it should have a thin blue line) to open the *Line Attributes* dialog.
5. Change the *Width* variable in the *Line Attributes* dialog to 3. This will make the ocean boundary thick and obviously different from the mainland boundary.

6. Click the **OK** button to close the *Line Attributes* dialog.
7. Click the **OK** button to close the *Display Options* dialog.

The display should now look something like Figure 4. Note that SMS has snapped the approximate arcs to the exact mesh boundary. Check to make sure that the applied ocean arc goes right up to the coast but does not wrap around to include other points on the coast. If the snapping is not correct, you can edit the "Tidal BC to snap" coverage and reapply the boundary condition coverage to the simulation.

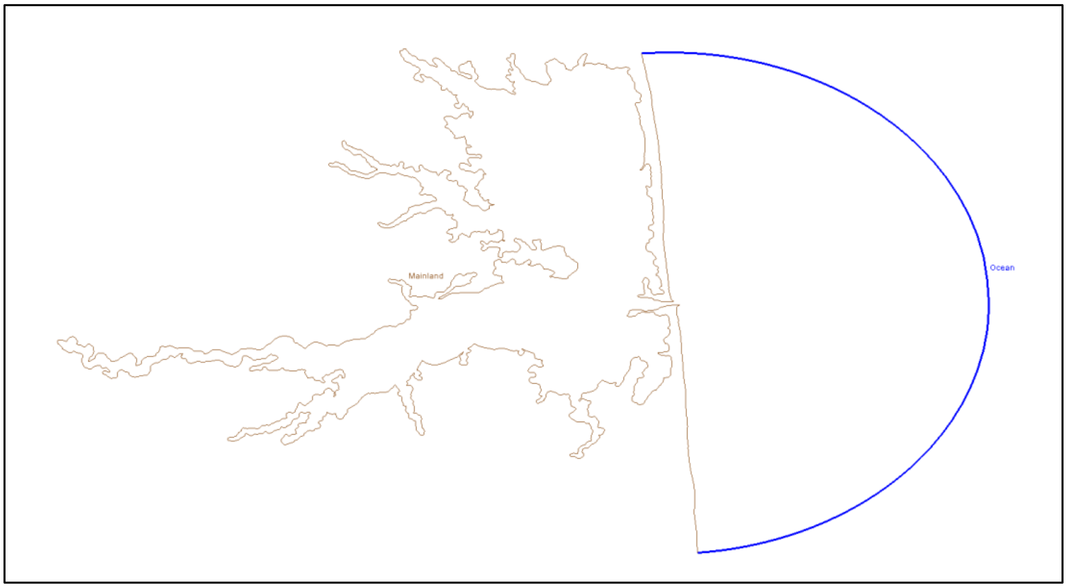

Figure 4: The Applied Ocean Boundary Condition Display

You can right click on the "Tidal BC to snap (applied)" entry and select *Boundary Conditions …* to view the table of the nodes for each boundary condition types. This information will be saved into the fort.14 file which contains the geometry for the simulation.

5.5 Other Possible Boundaries

These are all of the boundary conditions for this simulation. In more complex simulations you would could also define arcs representing:

- Islands.
- Rivers.
- Levees that flow out of the domain.
- Levees that are internal to the domain.

An alternative to creating the arcs interactively in an approximate fashion as demonstrated here, you could also create arcs from the boundary of the mesh using the right-click command on the mesh to *Convert* | *Mesh -> Map*. This can be helpful if the boundary is complex, such as a domain that contains many islands.

6 Specifying the Tidal Forcing

Many ADCIRC simulations use tidal constituents to drive water levels on ocean boundaries. The user can define which tidal constituents should be used and where the definition should come from. A tidal database is commonly used to do this.

SMS includes interfaces to the LeProvost, ADCIRC2015, FES2014, TPX08 and TPX09 databases. The latter three are licensed products and must be installed as instructed in the XMSWiki. The first two are free and if needed, SMS will download them via an internet connection. For this tutorial we will use the LeProvost tidal database (default). The user also has an option to define custom constituents.

6.1 Defining the Tidal Component

To create a tidal constituent component:

1. In the blank space of the *Project Explorer,* right-click and select the *New Simulation* | **Tidal Constituents** context menu item. This creates a new set of tidal constituents named " Sim".
2. Right-click on the " Sim" Tidal Constituents Simulation, select the **Rename** context menu item*,* and enter "LeProvost - Major".
3. Right-click on the " LeProvost - Major" simulation and select the **Edit constituents...** context menu item to open the *Tidal Constituents* dialog.
4. For the *Reference time,* enter "9/10/2010 12:00 AM".
5. Click on the **Select Major** button to select the major constituents. The *Tidal Constituents* should now look similar to Figure 5.

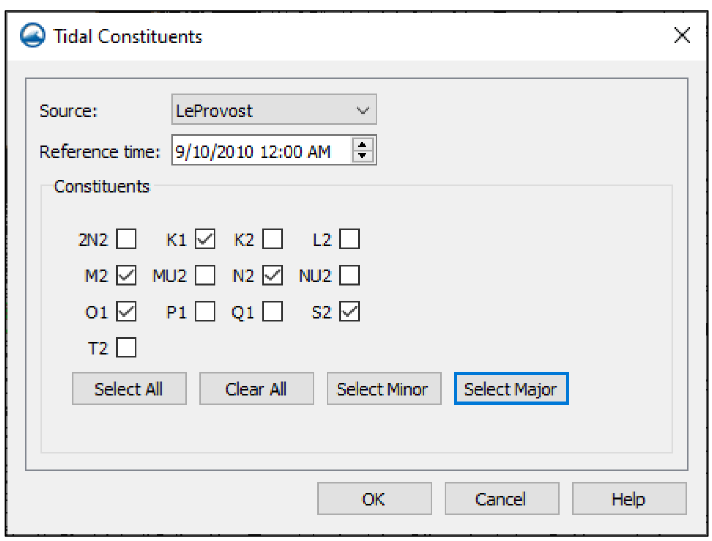

Figure 5: The Tidal Constituents Dialog Filled In

6. Click the **OK** button to exit the *Tidal Constituents* dialog.

6.2 Applying Tidal Forcing to the Simulation

To apply the tidal constituents that ADCIRC will use to the simulation, the boundary conditions coverage must be applied to the simulation. This is because the boundary condition coverage defines which nodal locations will have tidal forcing applied.

To apply the tidal component to the simulation:

1. In the *Project Explorer,* right-click on the " LeProvost - Major" component and select the *Apply to | ADCIRC Simulations* → **Tide** context menu item. SMS maps all of the tides to the ocean nodes in the simulation. This extracts the constituent values from the specified database.
2. A dialog appears reporting on the process of applying the tidal constituents to the simulation. If no errors are encountered, this dialog will automatically close and the " LeProvost – Major (applied)" entry appears in the simulation.

Right clicking on the "LeProvost - Major (applied)" object in the simulation and selecting *Tidal Constituents* brings up a table of constituents in this simulation. Each constituent and the phase/amplitude at each ocean node in the mesh can be viewed and edited here. This information will be saved in the fort.15 file for the simulation.

7 Running ADCIRC

The simulation is now ready to be run. To start the run:

1. In the *Project Explorer,* right-click on the " Tide" simulation and select **Save Project, Simulation and Run** to run ADCIRC.

This command does the following:

- Save all the work done so far into the SMS project files
- Export the fort.14 and fort.15 files for the "Tide" simulation into its own folder below the SMS simulation folder
- Launch the *Simulation Run Queue* and starts the "Tide" simulation. Progress of the simulation can be monitored in the Simulation Run Queue.

This run is set to simulate 3 days (518,400 seconds) of simulation with a 1.0 day (24 hour) ramp. The time step was specified as 4.0 seconds, so the simulation will include 129,600-time steps (1 days * 24 hours/day * 3600 seconds/hour * 0.25 time steps/second). Output will be saved for each point on the mesh every 30 minutes of simulation time from 0 hours to 24 hours (48 total output periods).

This run simulates a short period for multiple reasons. First, the compute time required for longer runs makes it impractical for a short tutorial. Second, it is very common for an ADCIRC simulation to require "tuning" to attain a stable solution. This run should take less than 5 minutes to terminate.

⚠ NOTE: This simulation run will fail. This failure is by design to show what happens when an unstable simulation run diverges out of bounds.

It actually diverges (fails) at about 18% (0.18 * 3 days = 0.55 days). However, since the option was set to save output from the start of the simulation, we can review the output.

2. In the *Simulation Run Queue* dialog, click on the **Close** button. This will load the solution in the *Project Explorer*.

8 Notes on the ADCIRC Run

This section contains a few additional notes on running *ADCIRC*. Presently, *ADCIRC* uses a specific naming convention for its input and output files. Therefore, before an *ADCIRC* run can start, the basic input files must be present in the working directory in your operating system, which *SMS* does automatically. *SMS* exports the active mesh to a simulation folder and names it “*fort.14*”. It also exports the control parameters into a control file in the same folder and names it “*fort.15*.”

Once an *ADCIRC* run has been completed, there will be several newly created folders and files under the working directory, in this case *Exercises/Indian River,* including:

- “*fort.63.nc”* (global elevation) – water level at each node in mesh.
- “*fort.64.nc”* (global velocity) – velocity at each node in mesh.

Other output that can be turned on based on parameters include:

- “*fort.61”* (monitor point elevation) – water level at specified locations.
- “*fort.62”* (monitor point velocity) – velocity at specified locations.
- “*fort.5*”* (harmonic output) – amplitude and phase values for each constituent in the harmonic analysis.
- “*fort.7*”* (meteorologic output) –wind magnitudes and velocities as well as atmospheric pressure datasets.

ADCIRC creates observation station output files if observation stations of the appropriate types exist in a simulation. Refer to the model control dialog or the ADCIRC web page for more information.

As mentioned above, if the time duration of this run is extended to multiple days, it illustrates a very common behavior for ADCIRC simulations, that is, it goes unstable. The *Run Queue* will show a message from the engine saying something like:

```
TIME STEP =   22072     ITERATIONS =   20     TIME =  0.44144000E+05
  ELMAX = 3.3017E+003 AT NODE       672
  SPEEDMAX =  2.9221E+002 AT NODE       594
  ** ERROR: Elevation.gt.ErrorElev, ADCIRC stopping. **
```

This message indicates that the water level or velocity at a specific node has become unreasonably large and ADCIRC terminated the run.

The nodes identified in the message often identify areas where there are issues in the mesh. These include (but are not limited to):

- Elements with bad geometry (flat or too much elevation change).
- Insufficient resolution.
- Courant condition violations (elements too small for specified time step).
- Flat elements.
- Elements with too large a variation in elevation.

We will discuss the methods of addressing these issues in later tutorials.

9 Conclusion

- This concludes the “ADCIRC Simulation” exercise. Several features have been demonstrated including:
- Creating an ADCIRC simulation.
- Creating boundary condition coverages and assigning types.
- Applying boundary conditions to a simulation.
- Creating a tidal component.
- Applying tidal constituents to a simulation.
- Saving and running an ADCIRC simulation.

If time permits, you may wish to review the other parameters in the model control dialog for ADCIRC and refer to the ADCIRC documentation.