10. Hands On: Particle Tracking Model in the CMS (CMS-PTM)

10.1 CMS-PTM Setup

The CMS is an integrated wave, current, sediment transport, and morphology change model for coastal and inlet applications (Buttolph et al. 2006; Lin et al. 2008) that was developed by the Coastal Inlets Research Program (CIRP). The Particle Tracking Model (PTM) was developed jointly by CIRP and the Dredging Operations and Engineering Research (DOER) program as a tool to compute the fate and pathways of sediments and other waterborne particulates in coastal engineering and dredging operations (MacDonald et al. 2006; Demirbilek et al. 2008). CMS-PTM is implemented in the SMS (Aquaveo 2010), which is a graphical user interface utility for PCs as developed by the U.S. Army Corps of Engineers (USACE).

The CMS calculates water levels, currents and waves through the coupling of a hydrodynamic model, CMS-Flow and a wave spectral model, CMS-Wave. CMS-Flow is driven by time-dependent water surface elevation at the offshore open boundaries, and wind forcing over the surface boundary. Directional wave data for input to CMS-Wave are available from the National Data Buoy Center (NDBC, http://www.ndbc.noaa.gov) or Coastal Data Information Program (CDIP, http://cdip.ucsd.edu). The wave conditions are specified at the seaward boundaries.

The step by step CMS-PTM setup is demonstrated through a nearshore sediment placement pilot study at Noyo, CA.

Noyo Harbor and Noyo River are located on the northern California coast. Every year about 30,000-40,000 cy of beach-quality sediment is dredged from the Noyo River Federal Navigation Channel. The USACE San Francisco District (SPN) and the Coastal and Hydraulics Laboratory (CHL), U.S. Army Engineer Research and Development Center are presently collaborating with the Noyo Harbor District and stakeholders in a pilot study to investigate a potential candidate site for nearshore placement of dredged sediment. Upland disposal sites used in the past will soon be exceeded. The pilot study proposes a dispersive nearshore site 3 to 8 miles north of Noyo Bay along the northern California coast (Figure 10.1.1).

The CMS and CMS-PTM are applied to simulate sediment transport for combined waves and currents under various ambient conditions and project alternatives. The model results will provide the technical information necessary to evaluate a demonstration site that is economically feasible for the optimum sediment placement location.

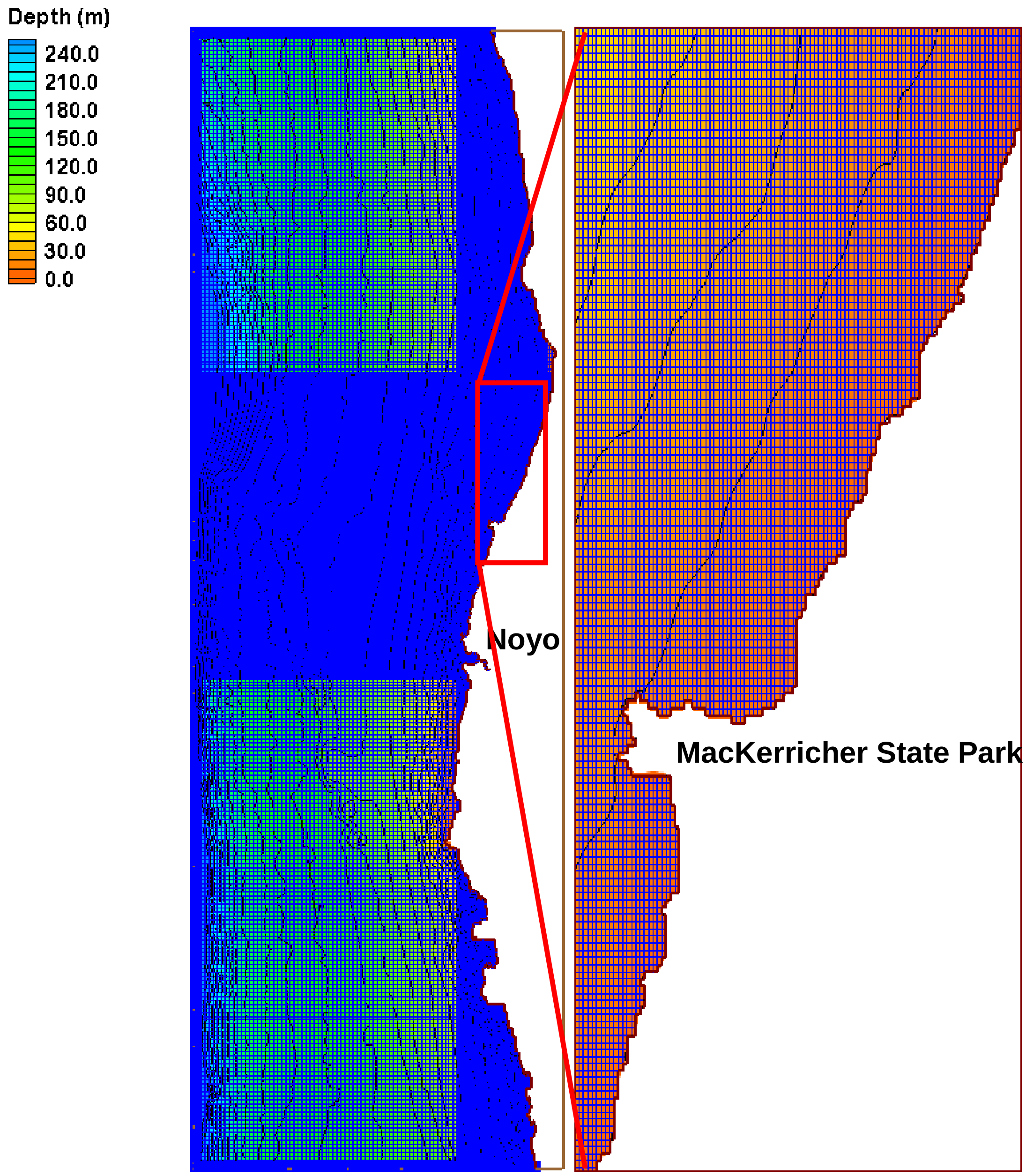


Figure 10.1.1. CMS domain, grid, and bathymetry.

CMS-Flow requires three input files and CMS-Wave requires six input files that can developed through the SMS. Each CMS-Flow and CMS-Wave simulations will generate its own output file (Figure 10.1.2).

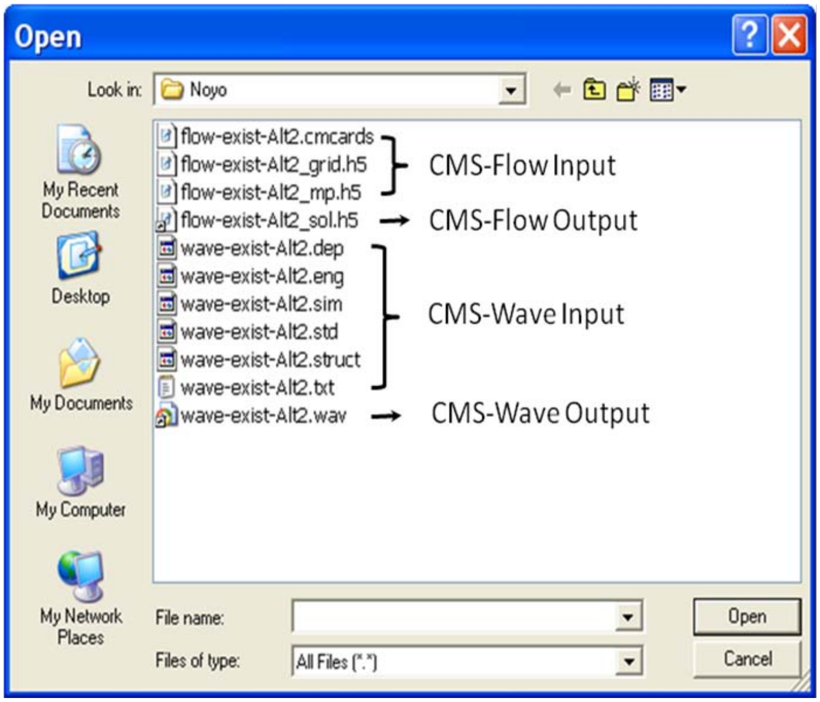


Figure 10.1.2. CMS files.

The CMS-Flow input and output files are required, while the CMS-Wave output files are optional for setting up a CMS-PTM simulation. After loading the required hydrodynamic and/or wave files, users can follow the steps below to set up the CMS-PTM simulation for the Noyo application.

- Native Sediment Dataset

  CMS-PTM requires spatially varying native bed sediment data specified as datasets, including the grain size information of d35, d50, and d90 for each cell, in the CMS-Flow grid.

  1. Select and open the CMS-Flow control file, flow-exist-Alt2.cmcards (Figure 10.1.2),
  2. Choose *Data* | *Data Calculator* in the CMS-Flow menu,
  3. Name the first dataset, d35, in *Output data set name* and specify a constant value, 0.1 mm in *Calculator*,
  4. Click *Compute* to generate the dataset,
  5. Repeat steps 3) and 4) to generate the datasets for d50 and d90 (Figure 10.1.3), (for the Noyo simulation, d50=0.2 mm and d90=0.4 mm),
  6. Click *Done* to exit *Data Calculator*,

7. Highlight the datasets, d35, d50, and d90, right-click, and select *Export* (Figure 10.1.4),

8. Select *XMDF file* in *File Type*, check *All time steps* in *Time Steps*, and click *Filename* to save the file NativeSediments.h5 in the present working folder.

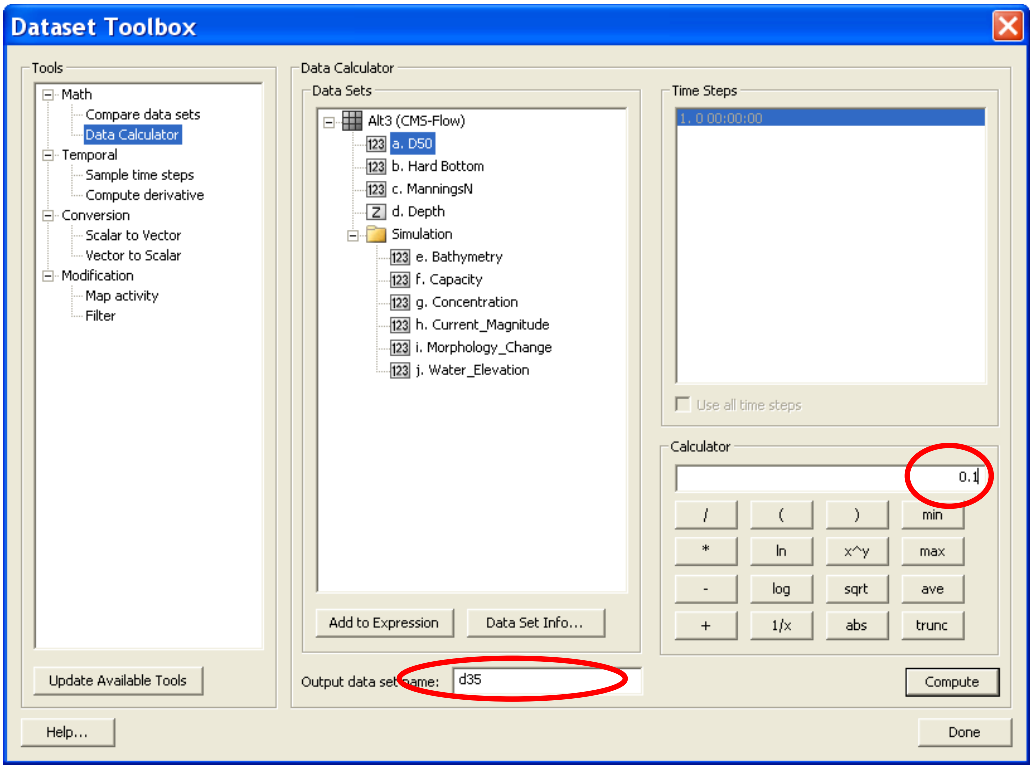


Figure 10.1.3. Generate the datasets, d35, d50, and d90.

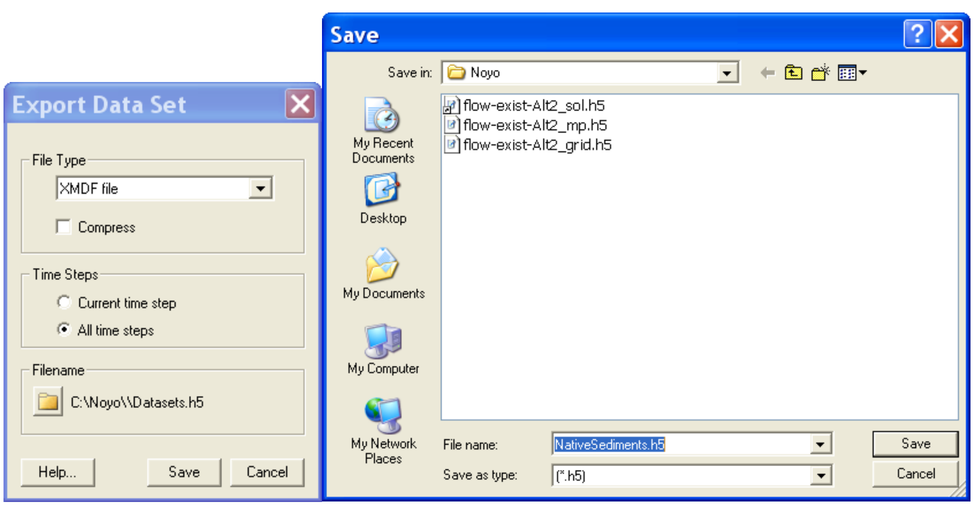
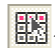


Figure 10.1.4. Generate the native sediment file.

- Land-water Interface Boundary Strings

CMS-PTM requires specifications of both open and closed boundaries. Open boundaries are specified in CMS-Flow so closed boundaries need to be added for CMS-PTM (future versions of SMS will automatically generate the closed boundaries). The steps to perform this task are described as follows:

1. Choose *Cellstring | Generate Along Boundary* (this step will generate redundant boundary strings overlapped with existing strings along open boundaries) (Figure 10.1.5),
2. Choose the *Select Cellstring*  tool and select *Land boundary* along the open boundary,
3. Right click and choose *Delete* (Figure 10.1.5),
4. Repeat steps 2) and 3) to delete other *Land boundary* cellstrings overlapped with existing open boundaries if more than one open boundaries exist in CMS-Flow,
5. Save the project.

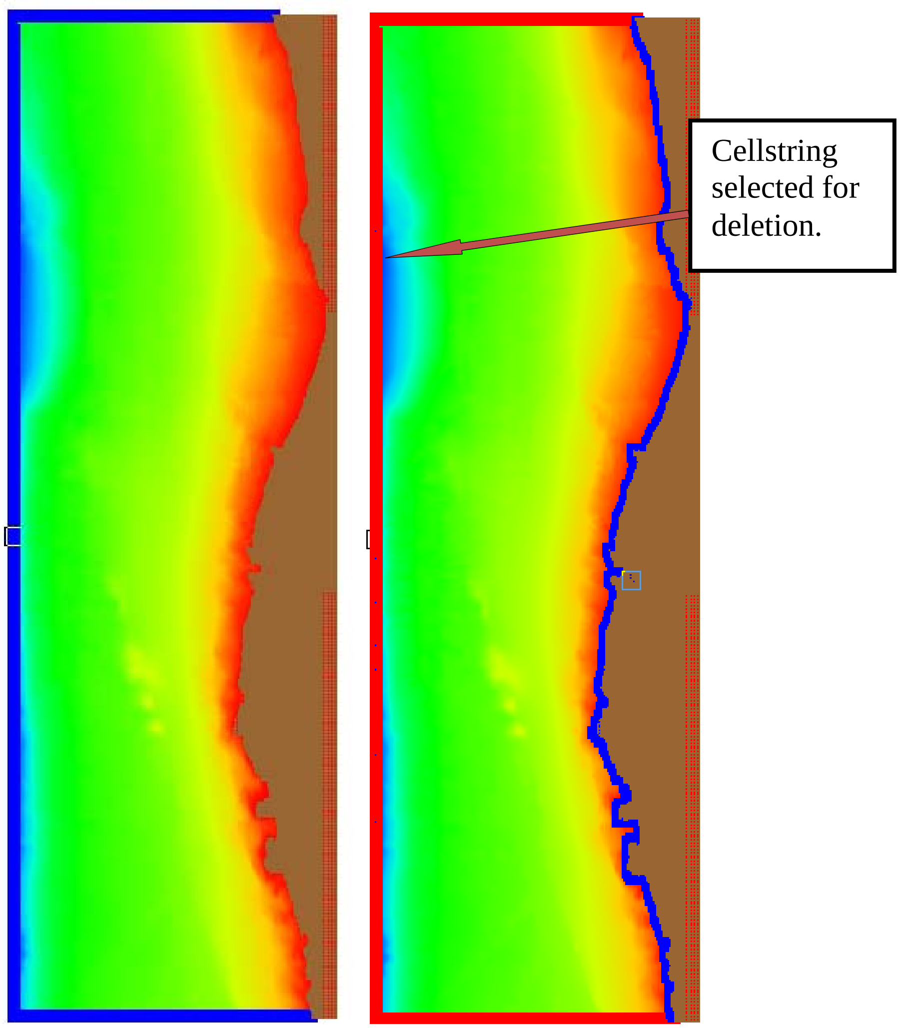


Figure 10.1.5. Generate the boundary cellstrings.

- Sediment Sources

1. Switch to *Map Module* by clicking the icon ,
2. Right click *default coverage* and choose *Type* | *Models* | *PTM* after generating the rectangular area for the sediment release (Figure 10.1.6),
3. Choose the *Select Feature Polygon* icon and click on the area source,
4. Right-click the polygon, select *Attributes*, and *Feature Object Attributes* will pop up,
5. Select *Horizontal Polygon Source* in the *Type* (Figure 10.1.7),
6. Specify *Date/Time* for the particle release, *Parcel Mass (kg)*, released mass *Rate (kg/m^2/s)*, and *Median Grain Size (mm)* of released particles (Figure 10.1.7),
7. Save the area source specification as a map file.

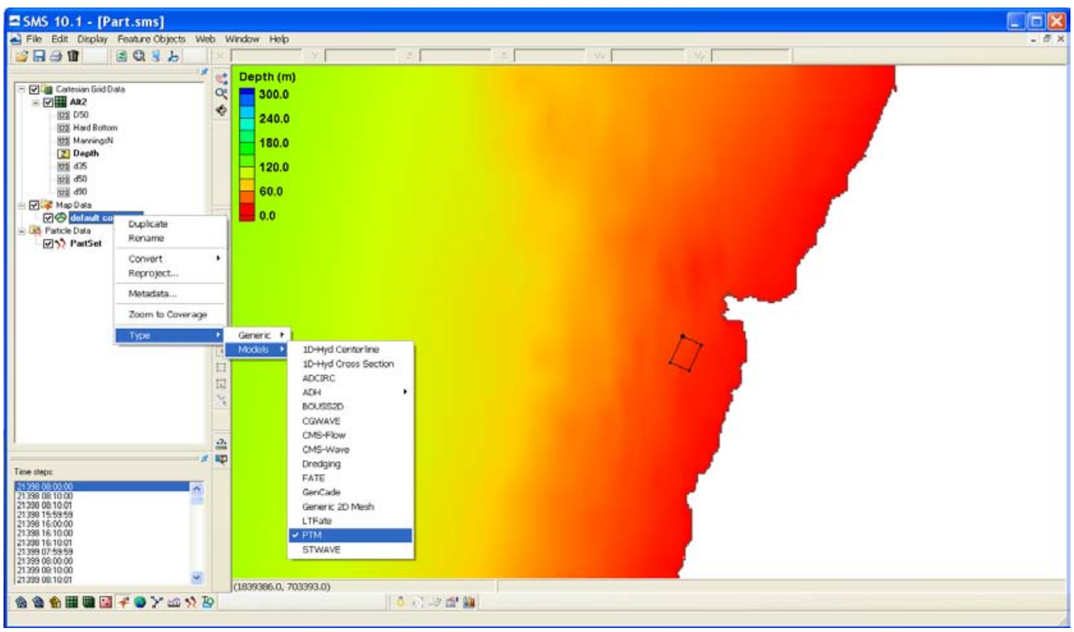
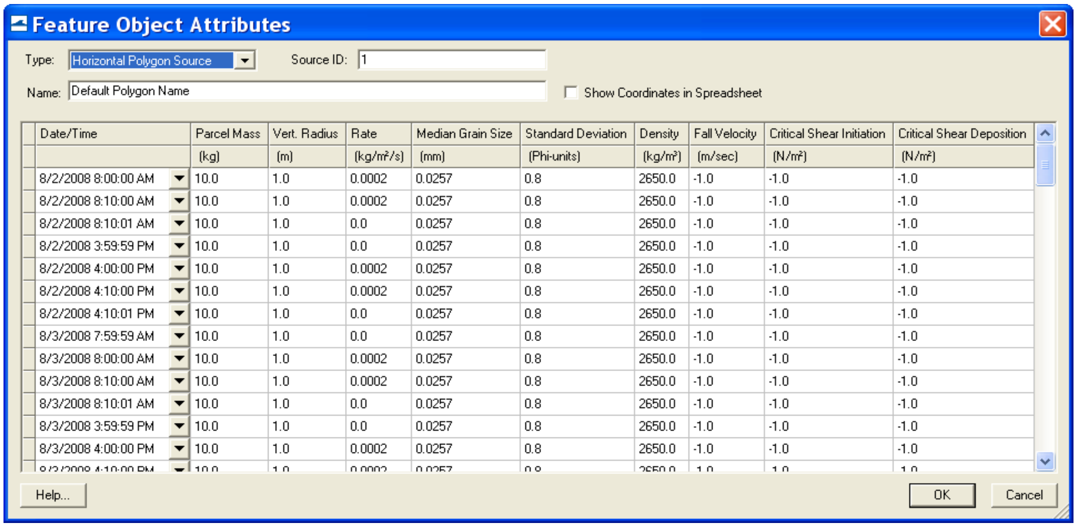


Figure 10.1.6. Link source file to CMS-PTM.



Feature Object Attributes

Type: Horizontal Polygon Source Source ID: 1

Name: Default Polygon Name ☐ Show Coordinates in Spreadsheet

Date/Time	Parcel Mass (kg)	Vert. Radius (m)	Rate (kg/m²/s)	Median Grain Size (mm)	Standard Deviation (Phi-units)	Density (kg/m³)	Fall Velocity (m/sec)	Critical Shear Initiation (N/m²)	Critical Shear Deposition (N/m²)
8/2/2008 8:00:00 AM	10.0	1.0	0.0002	0.0257	0.8	2650.0	-1.0	-1.0	-1.0
8/2/2008 8:10:00 AM	10.0	1.0	0.0002	0.0257	0.8	2650.0	-1.0	-1.0	-1.0
8/2/2008 8:10:01 AM	10.0	1.0	0.0	0.0257	0.8	2650.0	-1.0	-1.0	-1.0
8/2/2008 3:59:59 PM	10.0	1.0	0.0	0.0257	0.8	2650.0	-1.0	-1.0	-1.0
8/2/2008 4:00:00 PM	10.0	1.0	0.0002	0.0257	0.8	2650.0	-1.0	-1.0	-1.0
8/2/2008 4:10:00 PM	10.0	1.0	0.0002	0.0257	0.8	2650.0	-1.0	-1.0	-1.0
8/2/2008 4:10:01 PM	10.0	1.0	0.0	0.0257	0.8	2650.0	-1.0	-1.0	-1.0
8/3/2008 7:59:59 AM	10.0	1.0	0.0	0.0257	0.8	2650.0	-1.0	-1.0	-1.0
8/3/2008 8:00:00 AM	10.0	1.0	0.0002	0.0257	0.8	2650.0	-1.0	-1.0	-1.0
8/3/2008 8:10:00 AM	10.0	1.0	0.0002	0.0257	0.8	2650.0	-1.0	-1.0	-1.0
8/3/2008 8:10:01 AM	10.0	1.0	0.0	0.0257	0.8	2650.0	-1.0	-1.0	-1.0
8/3/2008 3:59:59 PM	10.0	1.0	0.0	0.0257	0.8	2650.0	-1.0	-1.0	-1.0
8/3/2008 4:00:00 PM	10.0	1.0	0.0002	0.0257	0.8	2650.0	-1.0	-1.0	-1.0

Help... OK Cancel

Figure 10.1.7. Define particle release scenario from the area source.

- CMS-PTM Setup

  After the hydrodynamic data, native sediment data, source file, and boundary cellstrings are generated, users can follow steps below to specify the CMS-PTM parameters and set up the CMS-PTM simulation.

  1. Switch to *Particle Module* by clicking the icon ,
  2. Choose *PTM* | *New Simulation*,
  3. Choose *PTM* | *Model Control*.

- Simulation Time (Figure 10.1.8)

  1. Specify the starting time of the completed CMS-Flow simulation in *Hydrodynamics*,
  2. Specify the starting and ending times of a CMS-PTM run in *Simulation*,
  3. Specify the time step for the CMS-PTM simulation and the output time interval in *Particle Output*,
  4. Specify how often to update the sediment parameters and the hydrodynamic variables.

  The starting time of CMS-Wave and the time step for the wave forcing update need to be specified if waves are included in the simulation and selected in the *Files* page.

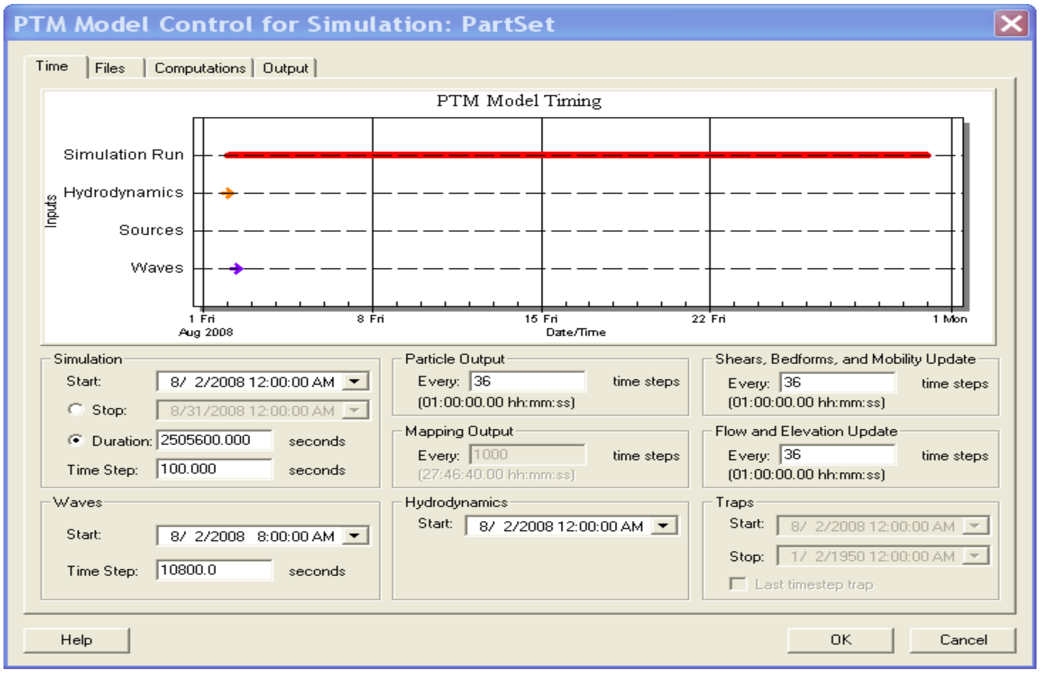
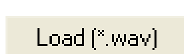


Figure 10.1.8. CMS-PTM model control pages (*Time*).

- Links to hydrodynamic and sediment data (Figure 10.1.9)

  1. Click *Select paths* under *XMDF Path* and set *Alt2/Datasets/Depth* for *Depth Path*,
  2. Select the CMS solution file, flow-exist-alt2_sol.h5, in the working folder for *Hydrodynamics*,
  3. Set *Simulation/Current_Velocity* for *Velocity*, and *Simulation/Water_Elevation* for *Water surface elevation*,
  4. Select *default coverage* in *Sediment source* and name part.source in *Select filename*,
  5. Select *create when model is run* in *Neighbor* and name part.neighbors in *Select filename*,
  6. Include *Waves and breaking* by selecting *CMS-Wave* and click *options* to obtain wave input for CMS-PTM (Figure 10.1.10),
  7. Click the icon  to browse the working folder and to link the wave simulation file, wave-exist-Alt2.sim, under *Parent Grid Geometry* | *CMS simulation file*,
  8. Click the icon 

 to link the wave input file, wave-exist-Alt2.wav, under *Parent Grid Solution Data*,

9. Specify *Number of Spectra in file*,

10. Click *OK* to complete the specifications of the page.

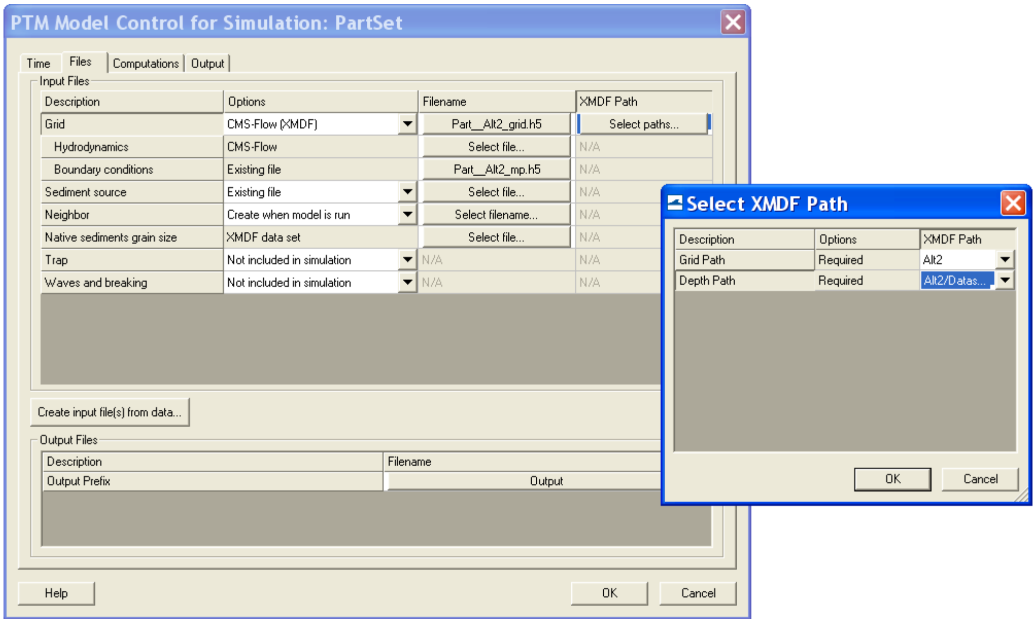


Figure 10.1.9. CMS-PTM model control pages (*Files*).

Because the wave simulation is included in CMS-PTM, it is necessary to return to the previous (*Time*) page to specify the *Start* time and *Time Step* under *Waves* (Figure 10.1.8).

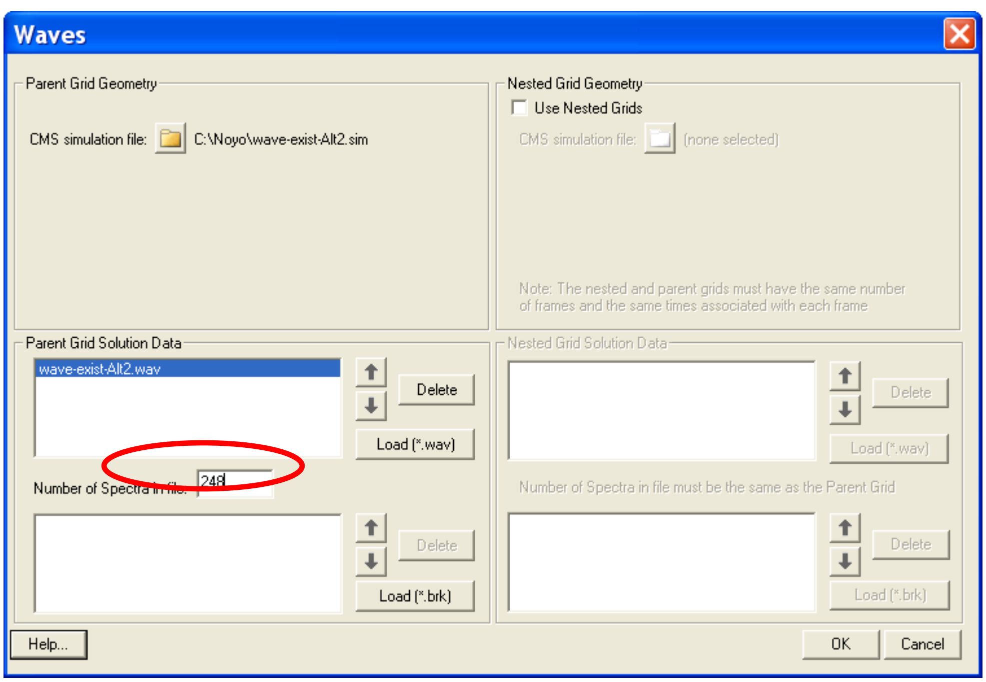


Figure 10.1.10. Specifications of wave input.

- Computation Parameters and Output

  Most of the options in the *Computations* page are default for this Noyo application except that the 3D mode is selected (Figure 10.1.11). In the *Output* page (Figure 10.1.12), *Print default keywords* is selected in *File Output*, and *Source* and *State* are selected in *Particle Output*.

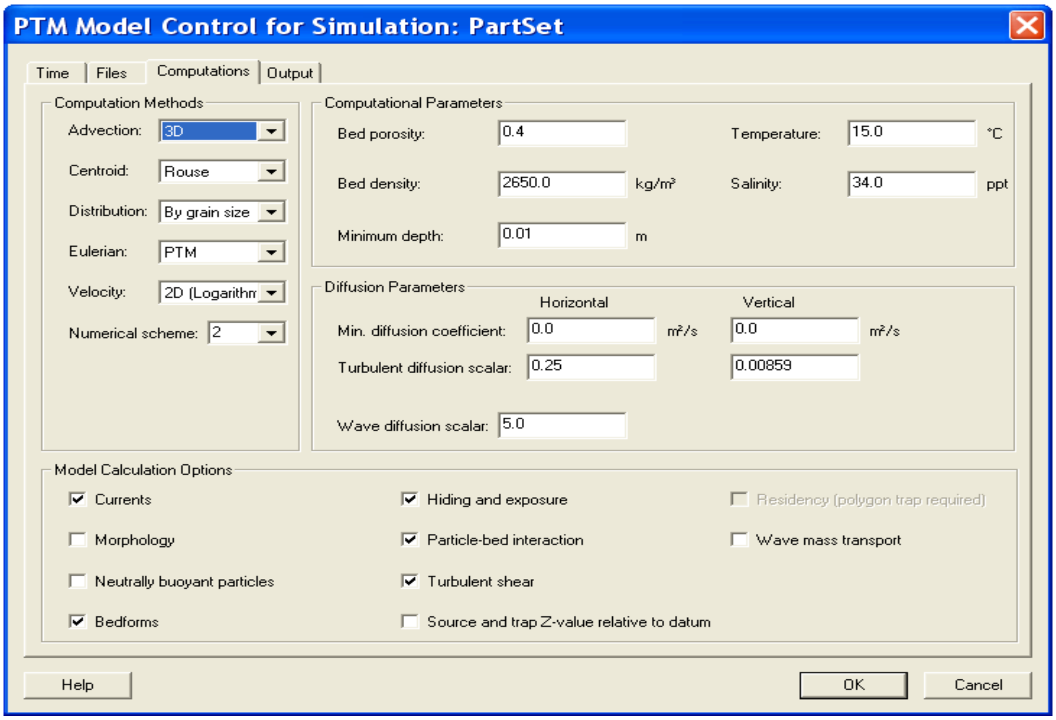


Figure 10.1.11. Specification of CMS-PTM parameters.

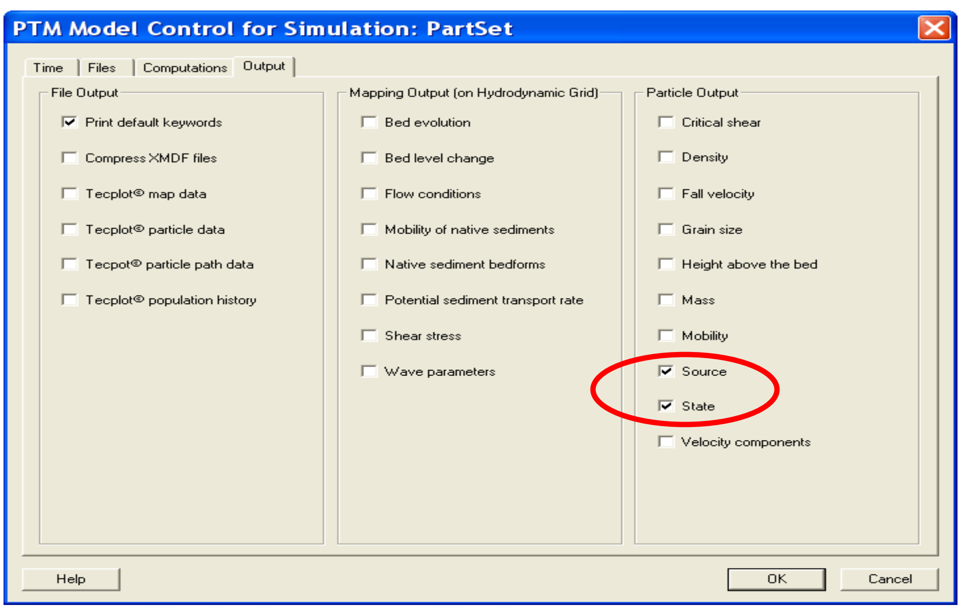


Figure 10.1.12. Selections of CMS-PTM output.

10.2 CMS-PTM Results

As described in the previous sections for the Noyo application, CMS-PTM was designed to investigate the fate and transport of dredged materials under combined influence of waves and currents from proposed placement sites.

The placement site, a rectangular area of 86,600 yd^2, is located about 4 miles north of Noyo Harbor near MacKerricher State Park. The CMS-PTM simulation is for August 1 – 30, 2008. In this application, clay materials were released at a level of 1 m above the ocean bottom at a rate of twice daily for 12 days. Each release lasted 10 minutes to mimic the barge placement operation. Figures 10.2.1 and 10.2.2 show the snapshot of calculated clay particle distributions at the end of the release (day 12) and the end of simulation (day 30), respectively. The simulation shows clay particles either follow the waves propagating towards shore or move southward driven by the northerly wind in this summer period. A good portion of the fine sediments can transport around Noyo Bay to the model's south boundary and some out of the model domain through the simulation. At the end of simulation, about 65% of released clay particles are considered "dead" (Figure 10.2.3), which are either permanently buried at the sea bed or moved out of the model domain. The silt and clay particle tracking results are documented in the "output.txt" file (see Figure 10.2.3) and are summarized in Figure 10.2.4 at the end of the Noyo simulations.

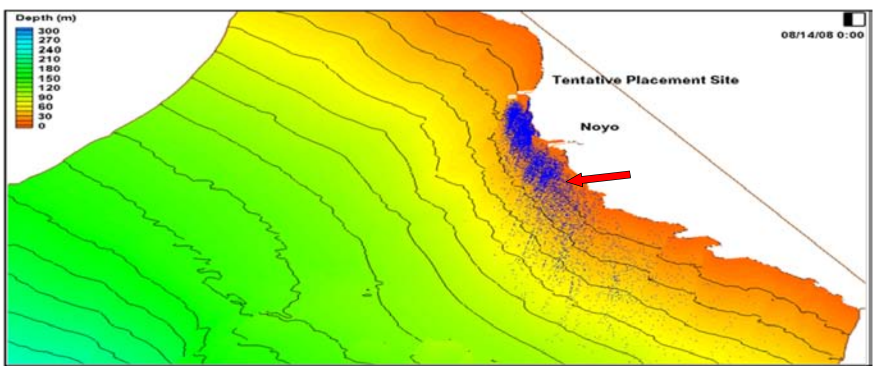


Figure 10.2.1. An oblique view of calculated clay particle distribution at the end of the release (day 12). The white square indicates the release area.

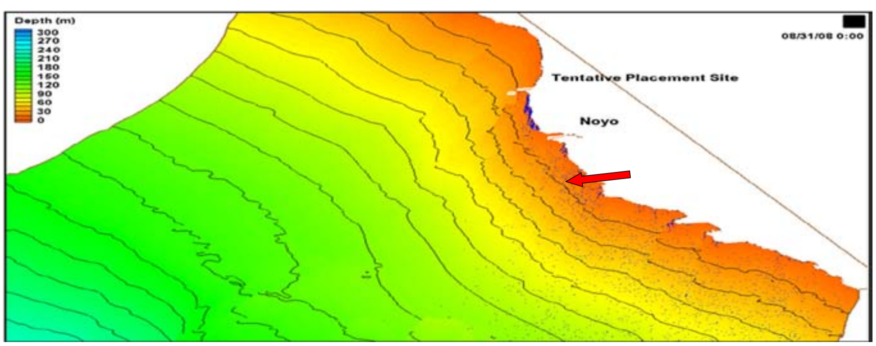
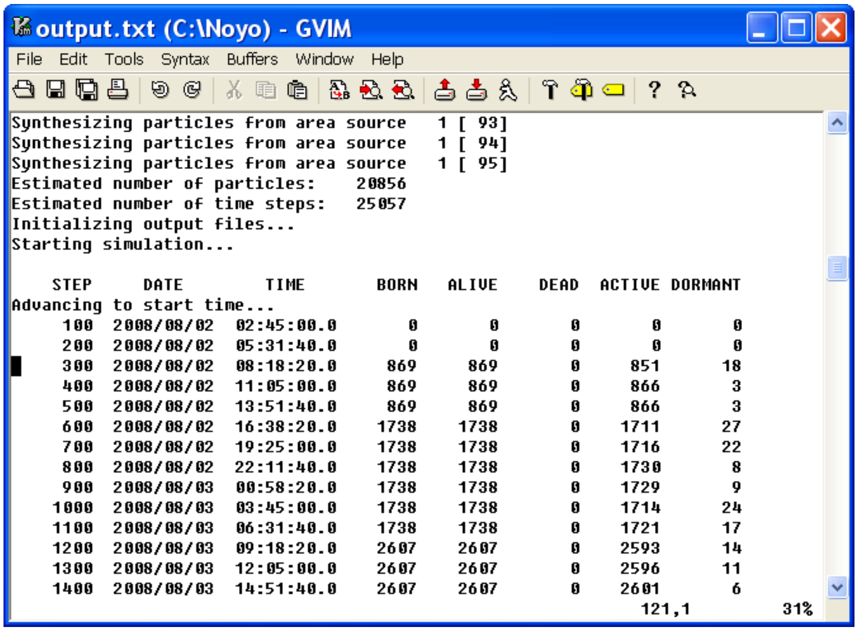


Figure 10.2.2. An oblique view of calculated clay particle distribution at the end of the simulation (day 30). The white square indicates the release area.



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output.txt (C:\Noyo) - GVIM
File  Edit  Tools  Syntax  Buffers  Window  Help
Synthesizing particles from area source    1 [ 93]
Synthesizing particles from area source    1 [ 94]
Synthesizing particles from area source    1 [ 95]
Estimated number of particles:     20856
Estimated number of time steps:    25057
Initializing output files...
Starting simulation...

    STEP     DATE         TIME        BORN    ALIVE     DEAD   ACTIVE  DORMANT
Advancing to start time...
     100  2008/08/02  02:45:00.0        0        0        0        0        0
     200  2008/08/02  05:31:40.0        0        0        0        0        0
     300  2008/08/02  08:18:20.0      869      869        0      851       18
     400  2008/08/02  11:05:00.0      869      869        0      866        3
     500  2008/08/02  13:51:40.0      869      869        0      866        3
     600  2008/08/02  16:38:20.0     1738     1738        0     1711       27
     700  2008/08/02  19:25:00.0     1738     1738        0     1716       22
     800  2008/08/02  22:11:40.0     1738     1738        0     1730        8
     900  2008/08/03  00:58:20.0     1738     1738        0     1729        9
    1000  2008/08/03  03:45:00.0     1738     1738        0     1714       24
    1100  2008/08/03  06:31:40.0     1738     1738        0     1721       17
    1200  2008/08/03  09:18:20.0     2607     2607        0     2593       14
    1300  2008/08/03  12:05:00.0     2607     2607        0     2596       11
    1400  2008/08/03  14:51:40.0     2607     2607        0     2601        6
                                                             121,1          31%
```

Figure 10.2.3. Intermediate output of CMS-PTM.

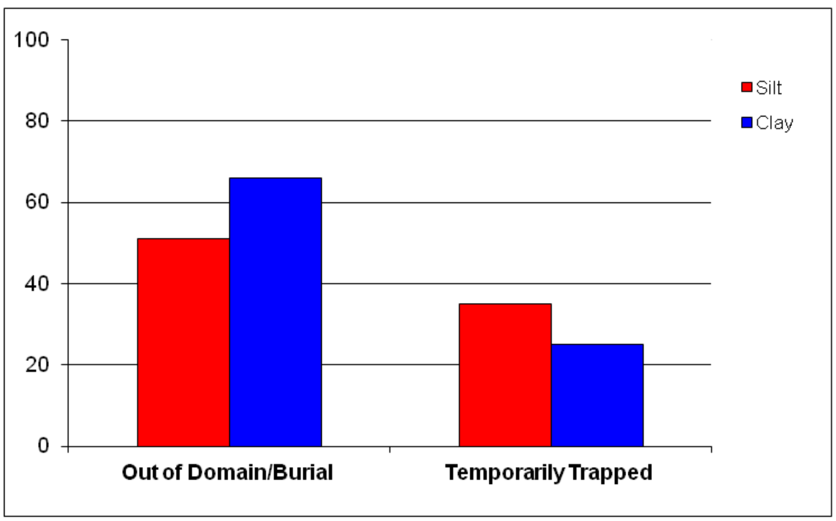

Figure 10.2.4. Particle tracking results after the 30-day simulation.