Particle Tracking Model Data Analysis Tools – Part 2: Capabilities in SMS

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PURPOSE: A number of new analysis methods and tools have been added to the Surface-water Modeling System (SMS) to facilitate the interpretation and understanding of the Particle Tracking Model (PTM) output. These new SMS interface capabilities described in the companion Part 1 Technical Note (TN), were designed to help users simulate particle transport processes in dredging and coastal projects that are concerned about dredged material fate, dispersion, sediment pathways, constituent transport, settling, deposition, mixing, and resuspension of sediment processes. These new data analysis tools are demonstrated for a Case Study in this Part 2 TN.

BACKGROUND: Demirbilek et al. (2012) provide descriptions of new analysis methods and associated tools that have been recently added to the PTM interface in the SMS. Additional information about the PTM is available from earlier publications. The analysis methods and tools are designed for post-processing the PTM solutions, allowing users to convert the Lagrangian pathways to Eulerian datasets at discrete locations. This Part 2 TN demonstrates the application of these analysis methods for a hypothetical example problem and discusses model results. The new analysis capabilities of the PTM have been implemented in the Graphical User Interface (GUI) of the PTM available in SMS 11.0 and higher versions (Zundel 2011). In the Part 3 Note (in preparation), a step-by-step user guide will describe the usage of new tools implemented in the SMS interface of the PTM.

This TN describes how to apply the new analysis tools in projects and help users to facilitate correct interpretation of the PTM output in engineering works. For the given example application, it has been assumed that there are concerns about the fate of resuspended sediment during a dredging operation, and also the deposition and suspended sediment concentration in environmentally sensitive areas.

EXAMPLE PROBLEM: In this hypothetical case study, the bathymetry for the area and hydrodynamic modeling solution files used in the PTM simulations were taken from a real world site with fictitious names. The site's name was changed because hypothetical environmental concerns have been introduced to investigate a range of issues that users may encounter in their own projects. The goal is to illustrate the latest PTM data analysis tools introduced in the Part 1 companion TN without disclosing sensitive issues specific to a project. For this purpose, we assume the concern is about potential impacts of dredging on Bridges Harbor shown in Figure 1. Further, we assume a plan exists to deepen the entrance channel to improve economics of the Bridges Harbor, a deep-draft coastal port, that requires dredging the channel from its present -45ft design depth to -55ft to allow for larger vessels (higher tonnage and with deeper draft) to bring in more goods and products to the port to increase its import/export commerce capacity. We assumed the approach channel to the port is 15,000 m long and the dredging reach (shown in green) is

900 m long and 150 m wide. One of the major concerns is related to the dredging activity which will be performed near three environmentally sensitive areas shown in Figure 1: coral reef (blue), submerged aquatic vegetation (SAV) (red), and fish passage (yellow). Another fictitious nature of this project is the study of the fish passage for the nonexistent "tropical salmonid". We addressed it in this simulation by creating a tropical salmonid only for the purpose to illustrate how such a purely hypothetical issue could be investigated with the PTM. In this application, there are clearly competing interests and concerns in terms of maintaining a navigation channel while protecting sensitive resources from potential impacts of sediment transport (bedload and resuspension).
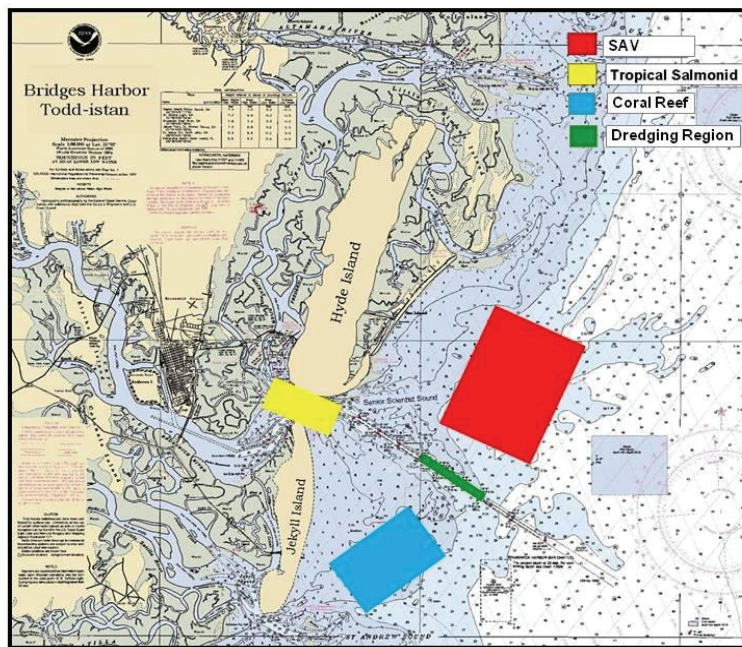

Figure 1. Map of Bridges Harbor region with SAV (red),
tropical salmonid passage (yellow), coral reef (blue),
and dredging region (green).

The PTM simulations conducted provide estimates of the potential exposure caused by nearby dredging activities in the project study area. Placement of dredged material was not addressed, but assumed to be further offshore from the open water placement sites. In these simulations, we used a hopper dredge for dredging to address an additional issue concerning the effect of allowing for overflow from the hopper dredge and the intentional dredging spill of the fine-grained sediment. As the hopper fills, excess water is allowed to spill out of the hopper that contains fine-grain sediments, which may not be of concern for dredging operations whereas coarser materials can be a major issue. The overflow would allow more sediment per dredging cycle to be dredged before the placement occurs, reducing the total dredging time and the cost of dredging. However, with the overflow of the hopper permitted, fine sediment is released back into the water column, potentially increasing suspended sediment concentration and deposition on the sea bed. The PTM simulations were performed for the hopper dredging cycles without overflow as well as with 30-minutes of overflow. Analysis, using the previously described PTM/SMS data analysis tools, aids in determining estimates of the suspended sediment

concentration and sediment deposition in the areas of interest. Additional information about the specifics of the PTM simulation follows.

Details of Simulation

Although dredging occurs only during the first three days, fourteen day PTM simulations are performed to allow ample time for post-dredging transport and deposition to take place. The PTM input for this project is only outlined here because previous documentations describe details of inputs. Present focus is on interpretation of modeling results obtained by applying recently developed data analysis methods and tools. It suffices to note that the PTM requires grid/bathymetry data, hydrodynamic flow fields, sediment source definitions, native sediment data, and computational modeling details. For this work the bathymetry and hydrodynamic data were extracted from an ADCIRC simulation, and the native sediment data were mapped onto the grid based on sediment core samples taken in the area. The PTM was run in full 3-D mode. The dredged material removed from the entrance channel is composed of approximately 80 percent sand and 20 percent silt and clay. For the PTM simulation, the sediment was separated into two major classes based on the analysis of sediment distribution data shown in Table 1, with sands representing the coarser material and fines the combination of the silt and clay class size materials.

Table 1. Grain size distribution.		
Size class	D50	Standard Deviation
Sand	0.235	0.525
Fines	0.065	0.724

PTM Simulation Results

New data analysis tools were applied to the PTM solutions and results for the particle pathways, concentration maps, and deposition maps are presented here to help identify potential risk to the environmentally critical areas. The particles positions are shown after 1 day, 2 days, 3 days, and 7 days of simulation for a no overflow case (Figure 2) and a 30-minute overflow case (Figure 3). Each particle represents a mass of sediment. Quantitative information for concentration and deposition is difficult to extract from the visuals and will be determined using the data analysis tools. However, from the particle positions, the pathways for sediment transport can be determined. A qualitative analysis of the data shows that sediment is not transported in the direction of the coral reef area (shown in blue) during dredging or after. This observation indicates that for the dredging operation as simulated, the coral would have little to no exposure to the dredging materials, and consequently the risk due to dredging operations is virtually non-existing. Panels (a) through (d) in Figure 2 and Figure 3 indicate that both the salmonid crossing and submerged aquatic vegetation areas experience a comparatively greater sediment transport within their respective areas for both no overflow and 30 minutes hopper overflow scenarios. As expected, larger amounts of sediment can be seen for the overflow case in the areas of the salmonid and the SAV because of additional sediment released during the overflow period. The coral reef region remains free of sediment, and this suggests that the transport pathways remain consistent and is dominated by the hydrodynamic conditions.
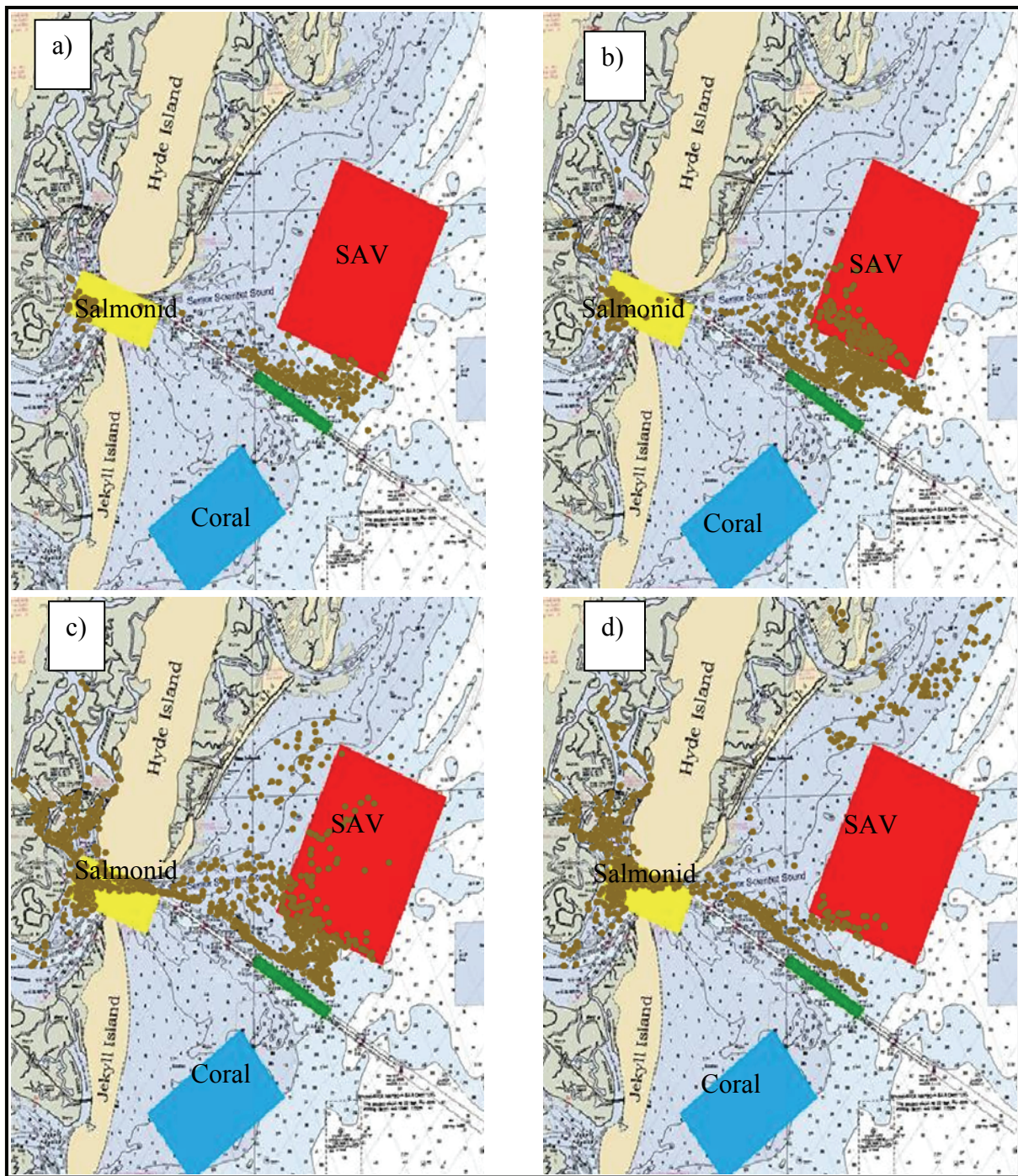
Figure 2. Particle positions shown for the Case Study: a) 1 day, b) 2 days, c) 3 days, and d) 7 days after dredging begins for a hopper dredge with no overflow.
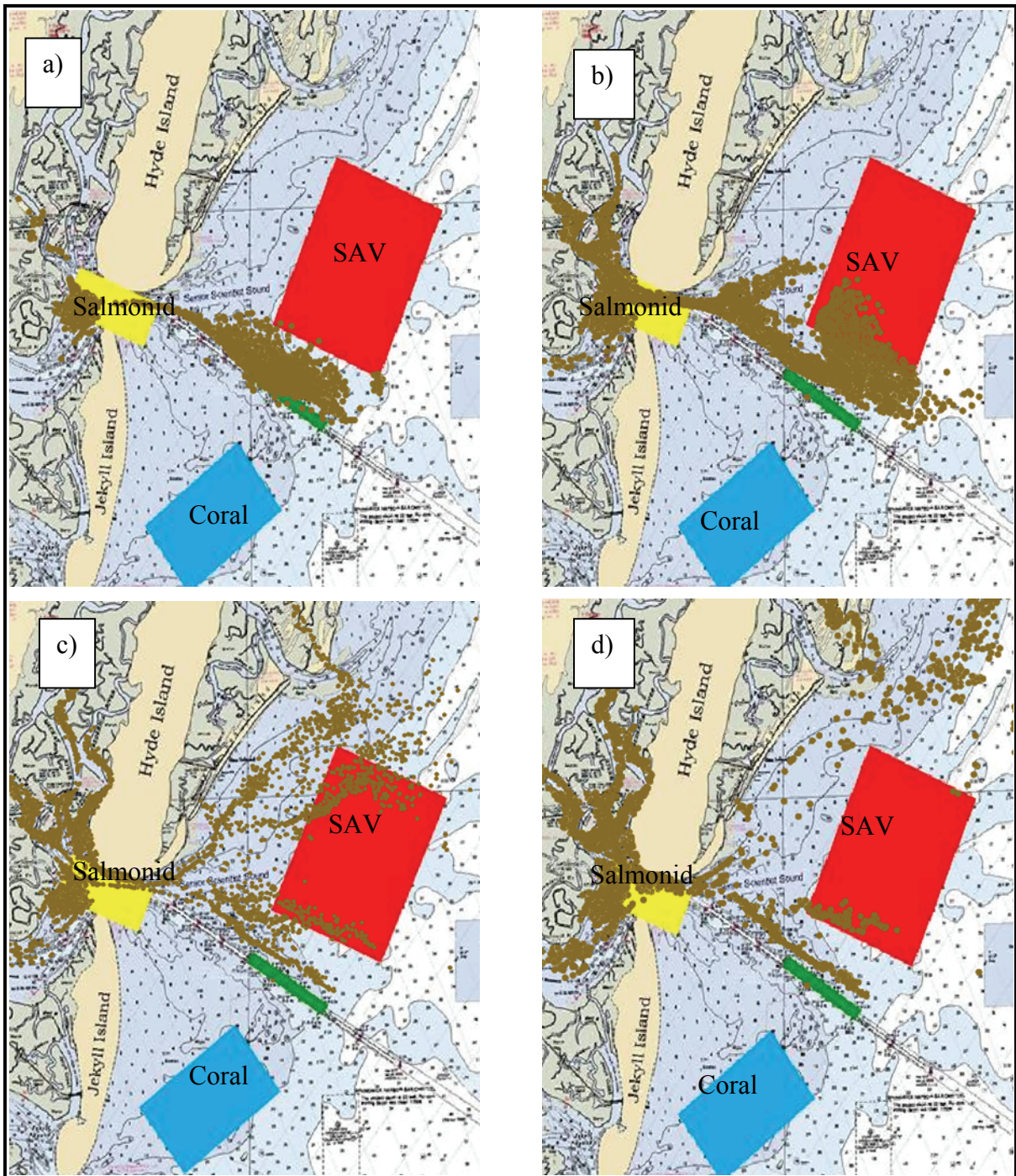
Figure 3. Particle positions for the Case Study: a) 1 day, b) 2 days, c) 3 days, and d) 7 days after dredging begins for a hopper dredge with 30 minutes of overflow.

SMS has the ability to display particle colors based on additional data such as the state (e.g., the particles deposited or in suspension) or the grain size. Examples of these displays can be found in Lackey and Smith (2008), and Lackey et al (2009). This information can help to determine where sediment is depositing, and what type of sediment (fine grain or coarse sands for example)

is being transported to which area. In addition, if there are multiple dredging sources, particles can be color coded based on each source which can also help determine the origin of the deposited sediment. In this example simulation, because it is evident based on the particle position output that sediment is depositing and re-suspending in the critical areas, the priority is to determine sedimentation and suspended sediment concentration in those areas.

In the next sections, maps and time series of concentration and deposition will be shown which were developed utilizing the Compute Grid Datasets option from SMS. The grid region (Figure 4) is 5500m x 14100m. There are 20 grid cells along the shoreline and 50 grid cells in the offshore direction. As mentioned in the Part 1 TN, grid resolution impacts quantitative results. It is recommended that the user perform grid sensitivity studies for each project.
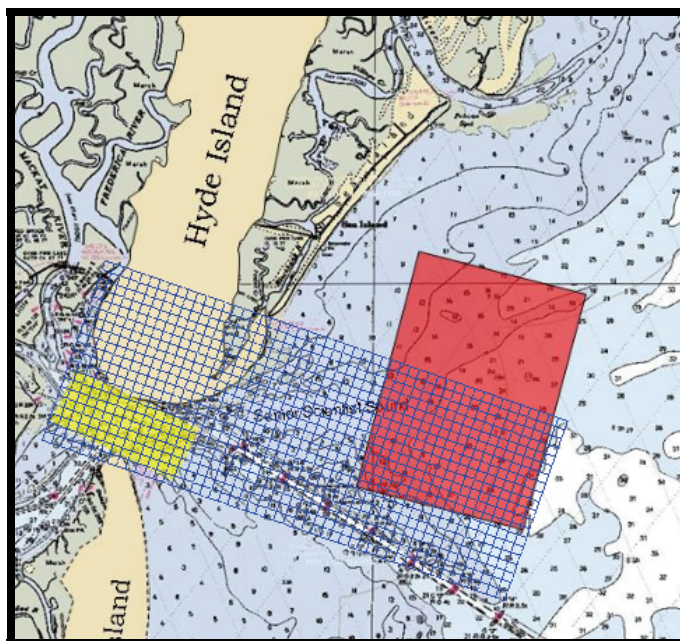

Figure 4.   Computational grid for data analysis maps.

Based on the particle pathways of the results, although there was more sediment transported, the sediment was primarily transported along the same pathways, independent of overflow. Because overflow conditions are economically preferable, the subsequent exposure assessment will focus on the 30 minute overflow conditions. If final results show that overflow conditions are above critical levels, non overflow conditions could be reconsidered. For the tropical salmonid passing, suspended sediment concentration is extremely important. For this reason, the data analysis grid (Figure 4) specifically included this area (shown in yellow) and has been extended beyond the yellow box to determine the extent of the nonzero values of sediment concentration. The area in question was defined to enclose the majority of particle positions. For these simulations concentration is highly variable both spatially and temporally. Figure 5 shows contours of suspended sediment concentration (kg/m^3) at approximately day 3 for overflow conditions. This snap shot in time was taken during a period when some of the largest concentrations of suspended sediment existed. Values range from 0.0 to 0.025 kg/m^3 (25mg/l) for the overflow conditions. The largest levels, near 0.025 kg/m^3, are indicated by the red contours. Note that these areas are small

in comparison to the total area considered. It is important to consider that this is an instantaneous snap shot in time which is sometimes not as important as the duration of concentration levels. To view temporal changes, a time series of concentration can be utilized. The time series of concentration extracted at one of the points where the largest values of suspended sediment concentration are found is shown in Figure 6.
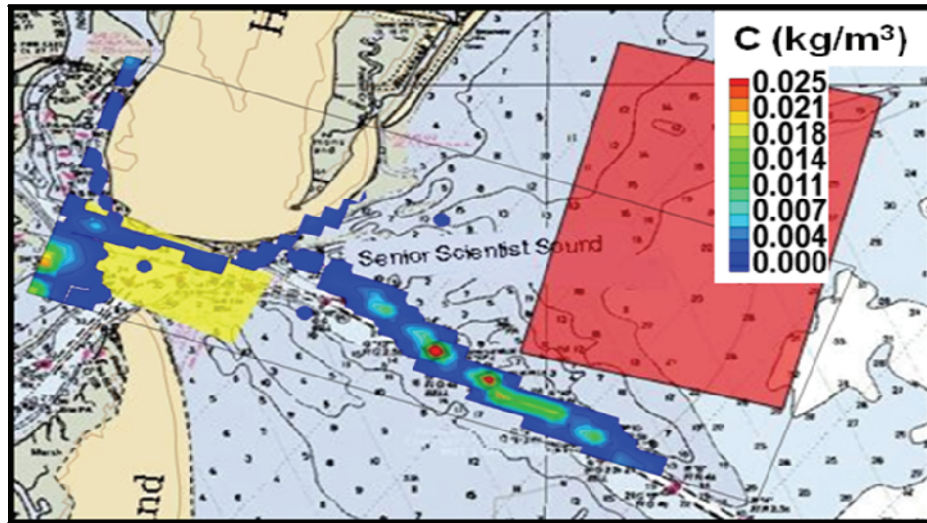

Figure 5.   Suspended sediment concentration contours shown on the data analysis grid during day three.
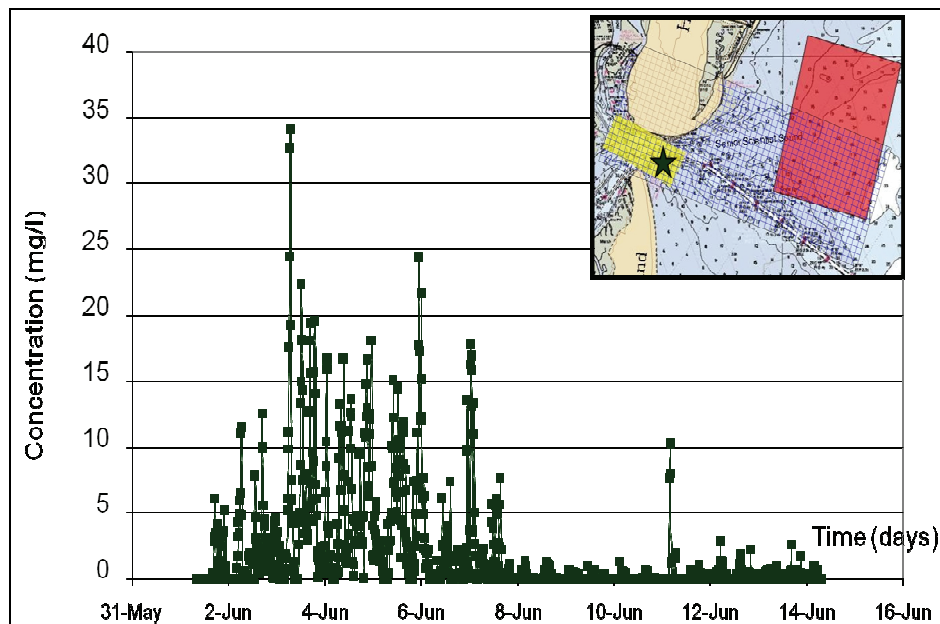

Figure 6.   Time series of concentration at a point (marked by the star in the upper schematic).

The following observations were made from Figure 6. The time series shows the maximum value of concentration is approximately 35 mg/l. However this appears at a single instance over the time series and it can generally be said that values remain less than 25 mg/l. In addition the largest values are clustered during the first few days when dredging occurs. After that, sediment concentrations quickly decrease which suggests sediment in this area either quickly deposits or is transported out of the area rapidly. After day five, most concentrations remain below 2 mg/l. However a spike appears around day 10. This represents sediment that had deposited but was resuspended and quickly passed through the area. The results of suspended sediment concentration can be converted to NTU and then to light attenuation values if needed. In addition to total concentration in an area which is determined by calculating the mass of sediment per volume of water in a grid cell, sometimes an assessment of vertical distribution of concentrations is important. In the case of a fish passage, for example, it is possible that the fish may swim in the upper or lower portion of the water column. Therefore, the risk may be different depending on the vertical distribution of the sediment concentration. Figure 7 shows a vertical cross section at the fish passage (shown in yellow). A black line is drawn in the accompanying schematic which shows the location of the cross section. In the vertical cross section, the largest concentrations are within the middle of the water column and to the side of the channel.
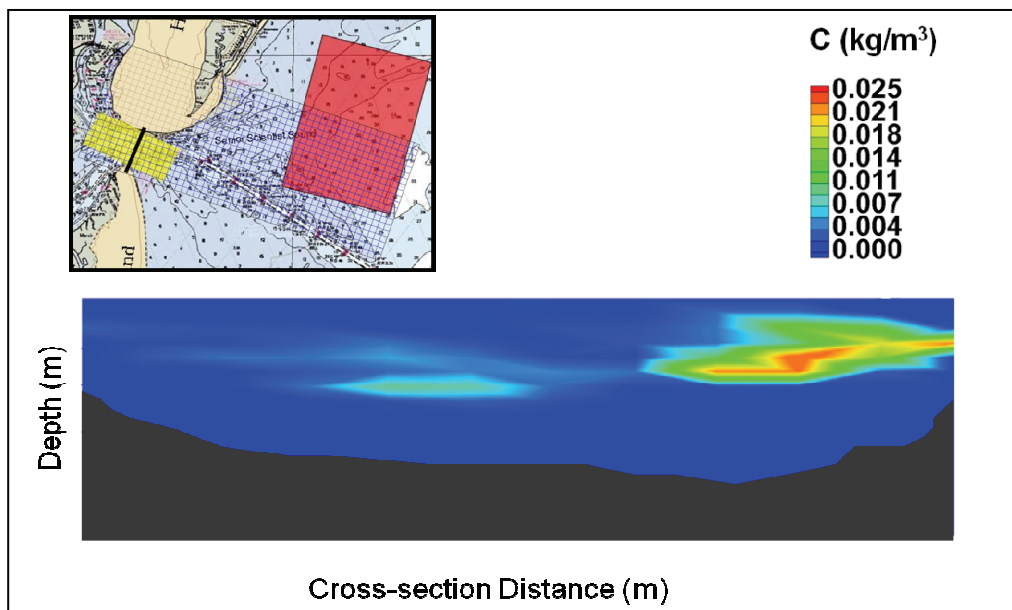

Figure 7.   Cross section of suspended sediment concentration contours (marked by line shown in upper schematic) during day three.

A snap shot of deposition contours during day three is displayed in Figure 8. Values shown range from 0.0 to 0.025m. Most of the deposition occurs in channel or in the harbor. It should be remembered that in-harbor deposition will not impact the salmonid where exposure pathways are within the water column. Therefore the focus for deposition occurs in the SAV habitat. Some deposition does occur within in the SAV habitat. Due to resuspension, deposition values are time dependent. Similar to the concentration analysis, a time series of deposition was extracted from the data analysis grid (see Figure 9). Deposition generally increases with time at this position, though at certain periods it can be seen that some sediment is resuspended and transported away giving rise to a decrease in deposition. Soon after dredging ends (around June 5th) the sediment deposition values at this position levels off at approximately 0.065mm.
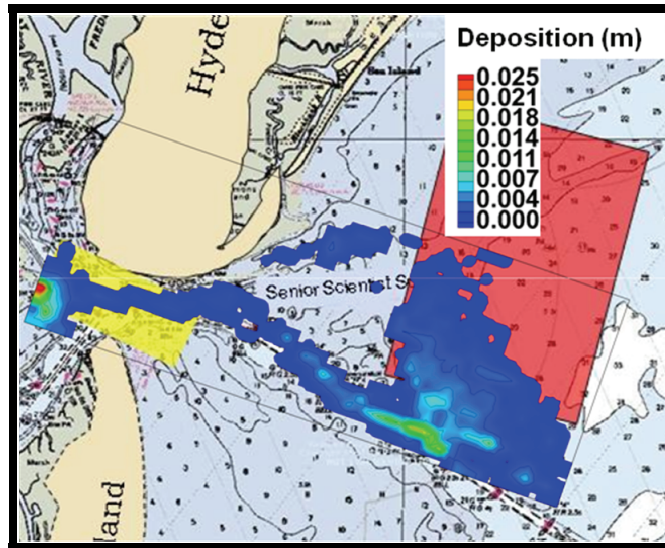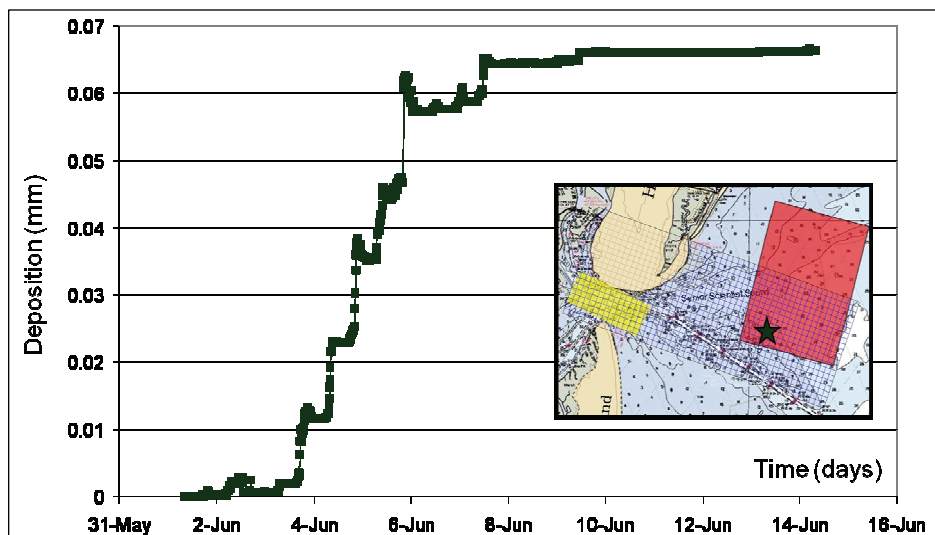
Figure 8. Contours of deposition during day three.

Figure 9. Time series of deposition at a point (marked by star shown in schematic).

CONCLUSIONS: A case study is presented dealing with a hypothetical dredging operation of a channel in Bridges Harbor and its potential consequences that require prediction of exposure of resuspended sediment caused by dredging. For the hopper dredged utilized, both overflow and non overflow conditions were considered to investigate environmental concerns on nearby coral reefs, submerged aquatic vegetation, and a salmonid fish passage. Analyses were done for particle positions and maps of concentration and deposition, and the results showed no pathways of exposure to the coral reef. Because pathways were qualitatively similar for both the overflow and non-overflow case, the overflow conditions were the focus of the data analysis maps. It was determined that suspended solids move into the salmonid migration pathway but only cover a portion of the channel cross section. Deposition occurs over the southern half of the SAV. Dredge-

induced turbidity moves out of the region after approximately two weeks. Concentration and deposition patterns are shown to be dynamic. This example problem illustrates data analysis tools for PTM developed to operate with the model's SMS interface. The user-friendly interface allows for an efficient data analysis for predicting the transport of sediment in open water.

ADDITIONAL INFORMATION: This Technical Note was written under the Dredging Operations and Environmental Research Program (DOER) by Dr. Zeki Demirbilek (*Zeki.Demirbilek@ usace.army.mil*, Tel: 601-634-2834, Fax: 601-634-3433), and Tahirih Lackey (Tahirih.C.Lackey@usace.army.mil), of the U.S. Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL); and Dr. Alan Zundel (*azundel@aquaveo.com*) of the Aquaveo, LLC & Brigham Young University.

This DOERTN should be referenced as follows:

> Demirbilek, Z., T.C. Lackey, and A. K. Zundel. 2012. *Particle Tracking Model Data Analysis Tools in the SMS—Part 2: Case Study.* DOER Technical Notes Collection. ERDC TN-DOER-D16. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

This DOER-TN and files for the examples may be downloaded from *http://chl.wes.army.mil/ library/publications/chetn/* and *http://xmswiki.com/*.

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Lackey, T.C. and Smith, S. J (2008) "Application of the Particle Tracking Model To Predict the fate of Dredged Suspended Sediment at the Willamette River" Proceedings Western Dredging Association Twenty-Eighth Annual Technical Conference, St. Louis, MO.,USA

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