EFFECTS OF AGITATION DREDGING IN SAVANNAH HARBOR

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ABSTRACT

Historically, tracking suspended sediment plumes resulting from dredging operations or passing container ships has been difficult due to the dynamic nature of suspended sediment transport. By using a new acoustic tracking technique, Applied Technology and Management (ATM) was able to accurately study a dredge plume from source to dissipation. While this study focused on dredging in Savannah Harbor, the method described can be applied to estimate suspended sediment concentrations resulting from fluvial erosion, offshore sediment disposal or runoff from disturbed uplands.

The Savannah Harbor is a high sedimentation environment that presents challenges for maintaining navigable depths on this fast-growing port. Agitation dredging has been used to maintain berths since at least 1932. In addition to agitation dredging, hydraulic cutterhead dredging with direct pipeline discharge is also currently permitted in the Harbor. Both methods utilize the tidal and river currents to flush the suspended sediments down the river. However, resource agency concerns over these dredging practices prompted a comprehensive study to evaluate environmental effects.

The data collection required three simultaneous efforts: water chemistry sampling, in situ water quality profiling, and monitoring the dredge plume. This last effort utilized SEDIVIEW, an acoustic Doppler post-processing software, to quantify total suspended solids (TSS) concentrations from the acoustic backscatter signal. Chemistry samples and in situ profiles were collected both upgradient and downgradient of the dredged material discharge to quantify released constituent concentrations and to measure changes to water quality (especially, dissolved oxygen). The fate of the suspended material was also modeled using SSFATE.

The results of this study addressed natural resource managers' concerns about suspended sediment and other water quality effects from agitation dredging. The final report includes complete discussions of water chemistry, sediment chemistry, suspended material, and dredge plume shape. Water quality changes were nearfield and brief in duration for both agitation dredging and passing container ships.

Keywords: Ships, berth maintenance, suspended sediments, plumes.

INTRODUCTION

The practice of dragging a weighted object along the bottom and using the natural river currents to move the sediments downriver goes back to ancient times. Herbich (1992) describes a practice used in the Indus River in early times where tree trunks were weighted with stones and dragged behind a boat to stir the accumulating mud back into suspension.

The practice has been an integral part of harbor maintenance in Savannah, Georgia for many years. Agitation dredging, performed by dragging with an I-beam (see Figure 1) or similar device behind a tug during ebb tide, was commenced in Savannah Harbor in 1932. Material is dragged (agitated) out of a slip or berth and dispersed downstream by the velocity of ebb tide, or pushed in or adjacent to the channel where it is swept downstream by currents. This type of maintenance dredging was found to be both economical and efficient since large amounts of material can be moved in a short period of time utilizing only a tugboat. An additional berth-maintenance technique that is also under scrutiny is overboard dredge disposal; where a cutterhead dredge releases dredged material just below the water line during ebb tide. This type of dredge disposal is therefore not technically overboard. As expected, dredged material can travel farther downstream when compared with I-Beam dragging.

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Agitation dredging has been essentially discontinued in recent decades because of its environmental impacts; although a few small studies concerning berth dredging in the Savannah River have generally concluded that impacts of agitation dredging are minor in nature and short-lived in duration. To address the ongoing concerns from resource managers involving agitation dredging, the US Army Corps of Engineers, Savannah District, commissioned ATM to evaluate the comprehensive environmental effects of agitation dredging. Study findings and recommendations addressed resource agency concerns over agitation dredging permit renewal. The three main goals of the study were to:

1. Determine aquatic resources in the river at risk from the effects of agitation dredging and conduct a literature review of published effects levels on these resources;
2. Conduct field studies to determine the level of temperature, DO, salinity, turbidity, and selected chemical parameters associated with the plume produced by agitation dredging, including relative effects in comparison to the background sediment levels; and
3. Determine the potential for effects on the identified aquatic resources from observed agitation dredging effects.

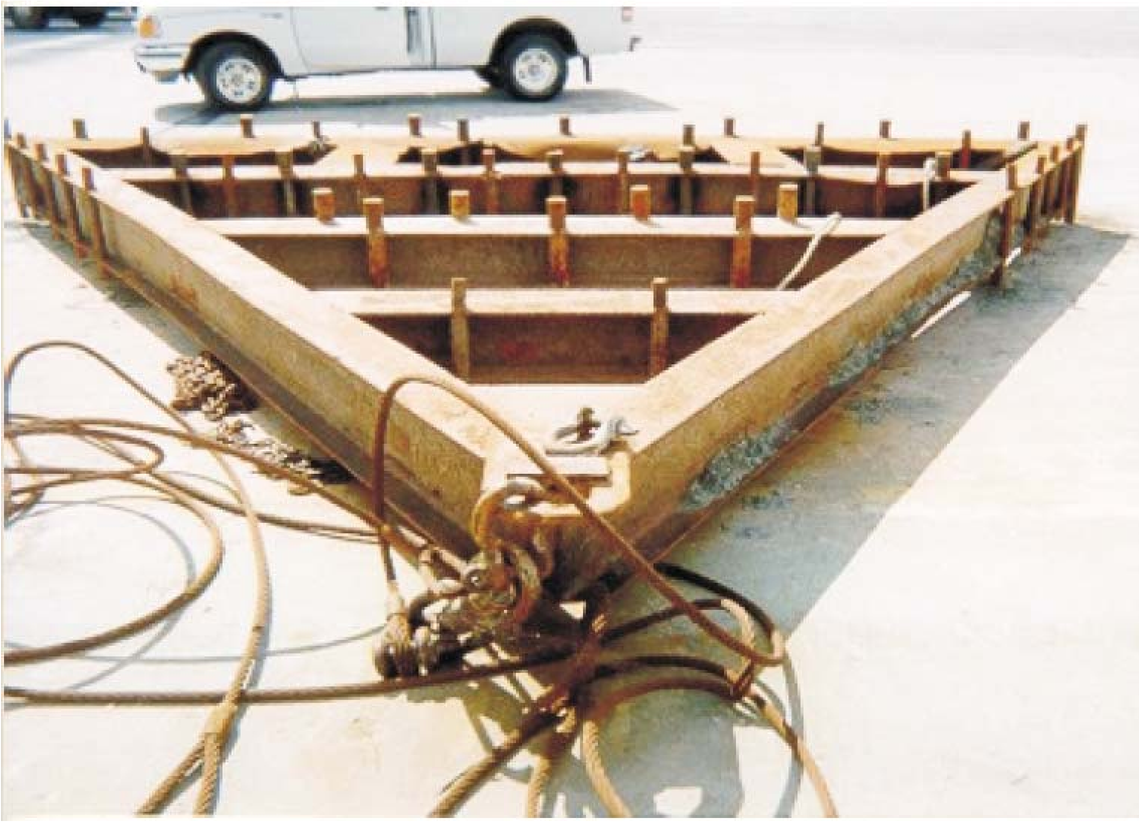

Figure 1. I-beam agitation dredge.

DATA COLLECTION

Parameters Evaluated

The types of data collected for the Agitation Dredge Evaluation (ADE) are listed below with descriptions of the parameters evaluated for each type of data. A location map of Savannah Harbor is presented in Figure 2.

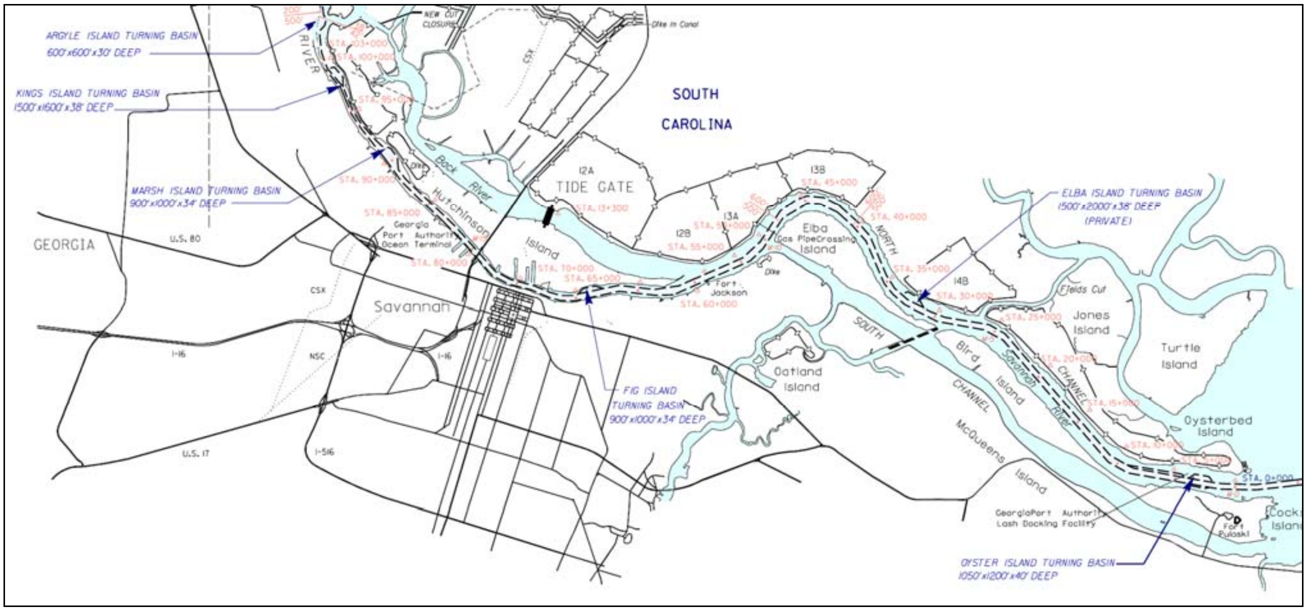

Figure 2. Savannah Harbor location map.

Continuous Water Quality Data: A Yellow Springs Instruments (YSI) Multi-parameter Water Quality Instrument was deployed at the USACE Engineers Depot Floating Dock. Parameters evaluated include water temperature (°C), specific conductance (mS/cm), salinity (ppt), turbidity (NTU), dissolved oxygen concentration (mg/L), dissolved oxygen percent saturation (%), pH and depth (m).

Berth Sediment Sampling: General Engineering Laboratory (GEL) tested sediment samples for a comprehensive list of compounds, including metals, pesticides, dioxins and furans, butyltins, polynuclear aromatic hydrocarbons (PAHs) and others.

Acoustic Doppler Current Profiler (ADCP) Transects: An ADCP was used to record acoustic backscatter data of the water column. Data files of each ADCP transect were recorded and later combined with total suspended solids (TSS) data using SEDIVIEW software.

Water Quality Profiles: A Yellow Springs Instruments (YSI) Multi-parameter Water Quality Instrument was used to profile the water column along the transect on either side and in the dredge plume resulting from agitation dredge operations. Similar to the Continuous Water Quality Deployment, parameters evaluated include water temperature (°C), specific conductance (mS/cm), salinity (ppt), turbidity (NTU), dissolved oxygen concentration (mg/L), dissolved oxygen percent saturation (%), pH and depth (m).

Sediment Plume Monitoring: Transect distances upriver and downriver from a dredge operation were dependent on the type of dredge operation. The location of the overboard disposal operation was determined by recording the position of the cutter head of Dredge Monitor. The discharge end of the disposal pipe is located at the aft section of Dredge Monitor on the port side. Example transect locations for the days of overboard disposal operation monitoring are shown in Figure 3. Perpendicular lines to the shore are first mapped before the data collection event begins using an onboard navigation program. The perpendicular mapped line was then offset 1000, 2000 and 3000 ft upstream from the cutter head position. Similarly the perpendicular line was offset downstream as much as 10,000 ft. I-beam dragging operations are continuously moving since the tug drags parallel to the bulkhead between an upstream and downstream boundary. Distances upriver and downriver are determined by the boundaries of the tug's track. The tug's path and transect locations for the I-Beam Monitoring Event are illustrated in Figure 4. Upriver distances are offset 1000, 2000, and 3000 ft from the upstream boundary and similarly offset from the downstream boundary. Transects are differentiated by "-" (negative sign) for transects upstream from dredging activity and "+" (positive sign) for transects downstream from dredging activity. The "0000" (zero) transect indicates that the monitoring line falls on the upstream or downstream boundary of dredging activity.

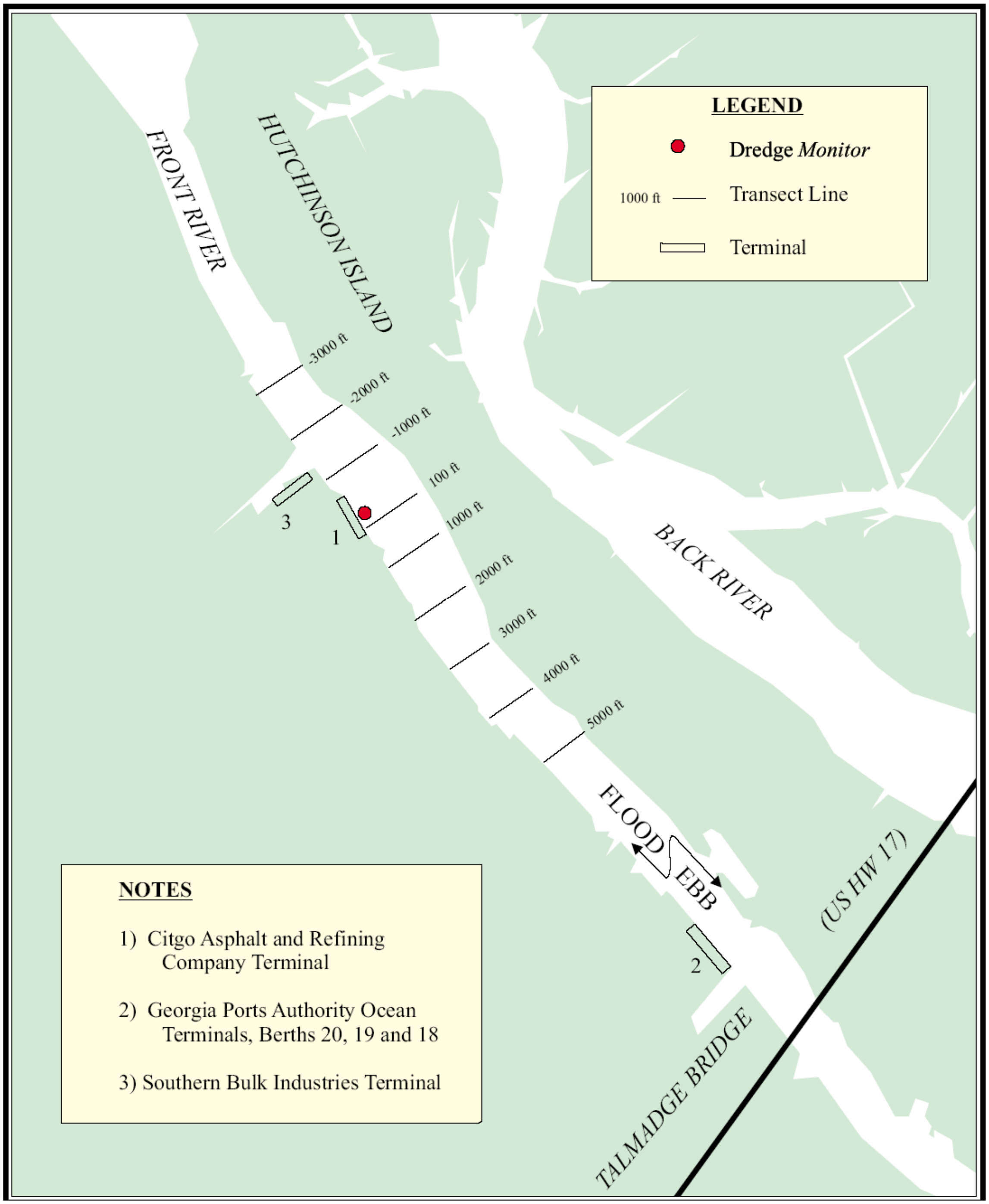

Figure 3. Transect locations and sampling stations for an overboard dredge disposal operation at the Citgo Terminal.

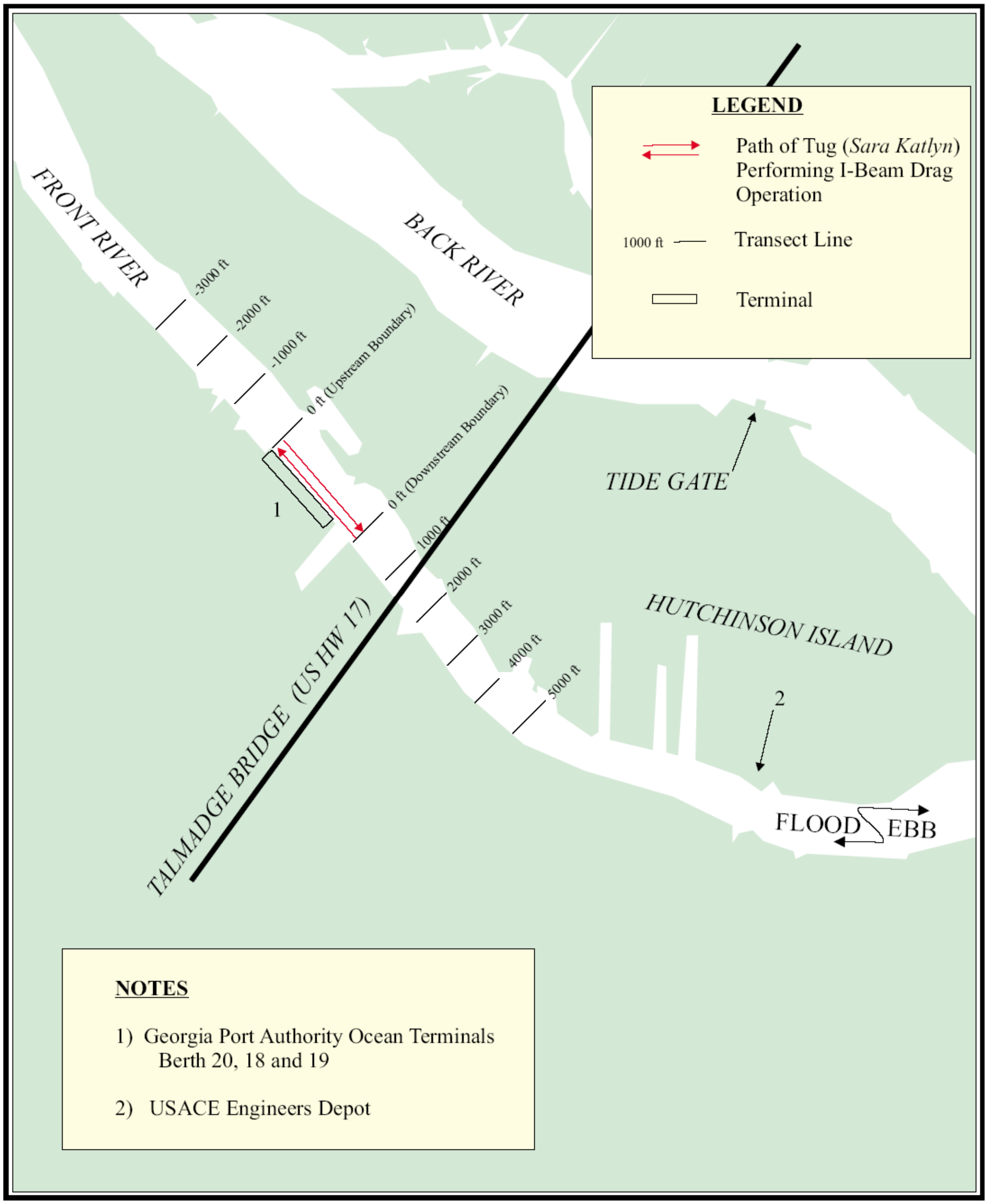

Figure 4. Transect location and sampling stations for I-Beam dragging operation at the GPA Ocean Terminal Berths 18, 19 and 20.

Table 1. Agitation dredge evaluation study monitoring locations and dates.

Type of Agitation Dredge Operation	Berth	River Mile
I-Beam Drag	GPA Ocean Terminals: 18, 19 and 20	15.1
Overboard Disposal	Citgo Terminal	16.9
Overboard Disposal	East Coast Terminals: 4 and 5	13.0
I-Beam Drag	GPA Ocean Terminals: Berth 13	15.0
Overboard Disposal	East Coast Terminals: Berth 4	13.0
I-Beam Drag	GPA Garden City Terminal: Berth 50 (Fuel Dock)	17.6

RESULTS

Post-processing of ADCP current data was performed using the SEDIVIEW program in conjunction with TSS data collected within the tracked dredge plume. Acoustic backscatter data was then interpreted to estimate the suspended sediment concentration of a dredge plume. SEDIVIEW produces a continuous two-dimensional picture of the suspended sediment concentrations, TSS, in the water column. An example presentation of the SEDIVIEW output is presented in Figure 5. The SEDIVIEW calibration method utilizes TSS grab samples at depth and profiling data to determine the accuracy of the suspended sediment estimate. Parameters to adjust for a successful calibration include acoustic signal interpretation constants and spreading corrections.

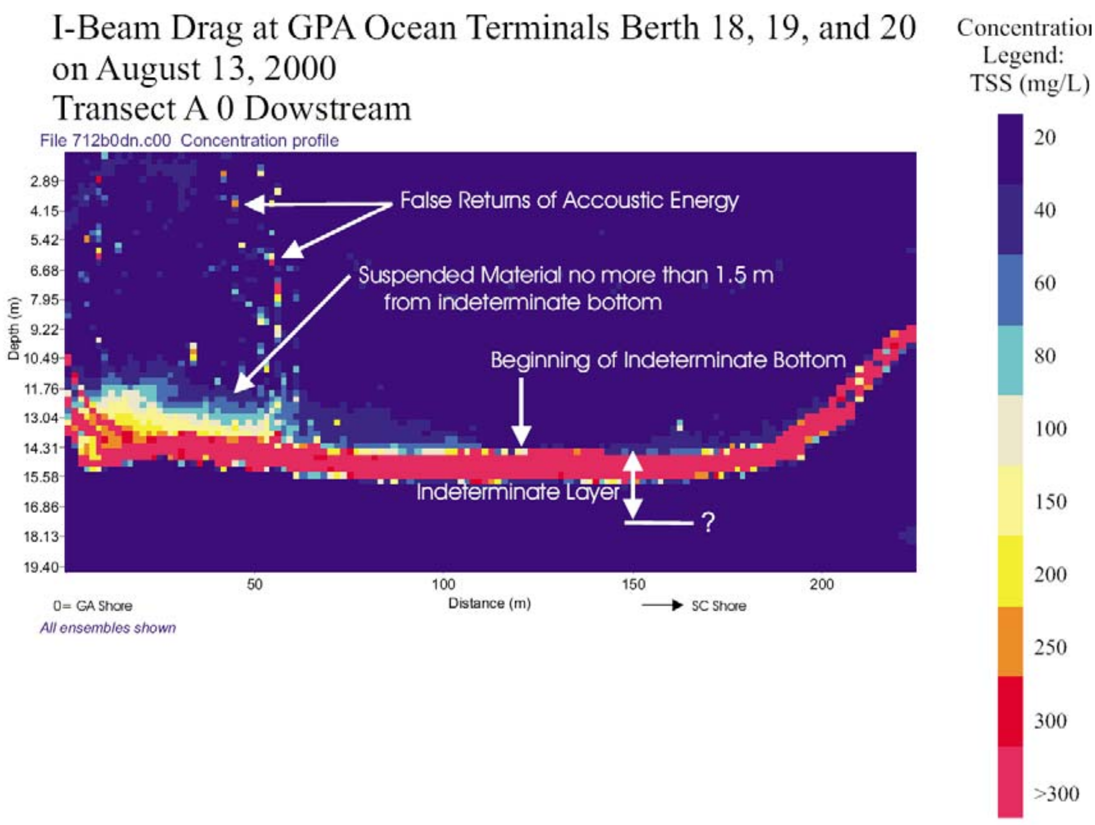

Figure 5. Example SEDIVIEW output plot of I-Beam dragging. This is a cross-section view of the river.

Characteristics of an I-Beam Drag Event

Based on the observations and SEDIVIEW outputs, suspended material created by I-Beam drag events is generally entrained no greater than three meters above the bottom for a maximum downstream distance of 2000 ft. The suspended sediment concentration does not appear to exceed 200 mg/L at the 0 ft transect, the transect location just downstream of the tug's path and where the highest concentrations of suspended material can be expected.

The amount of suspended material appears to vary depending on the direction of the current relative to the direction of the tug. When the tug is traveling with the current (downriver during the ebb tide), the maximum amount of suspended material is observed at the 0 ft Downstream transect only after the tugs starts to turn upriver into the current. This occurred because the tug was traveling faster than the ebb water velocity. ATM personnel altered the plume tracking methodology to capture the maximum pulse of material, thus the SEDIVIEW results presented in this report are worst-case predictions of the suspended sediment from either type of agitation dredge. After the tug turns from the downstream leg to the upstream leg of the drag path along a berth, the amount of suspended material reaching the 0 ft downstream line decreases to barely above background.

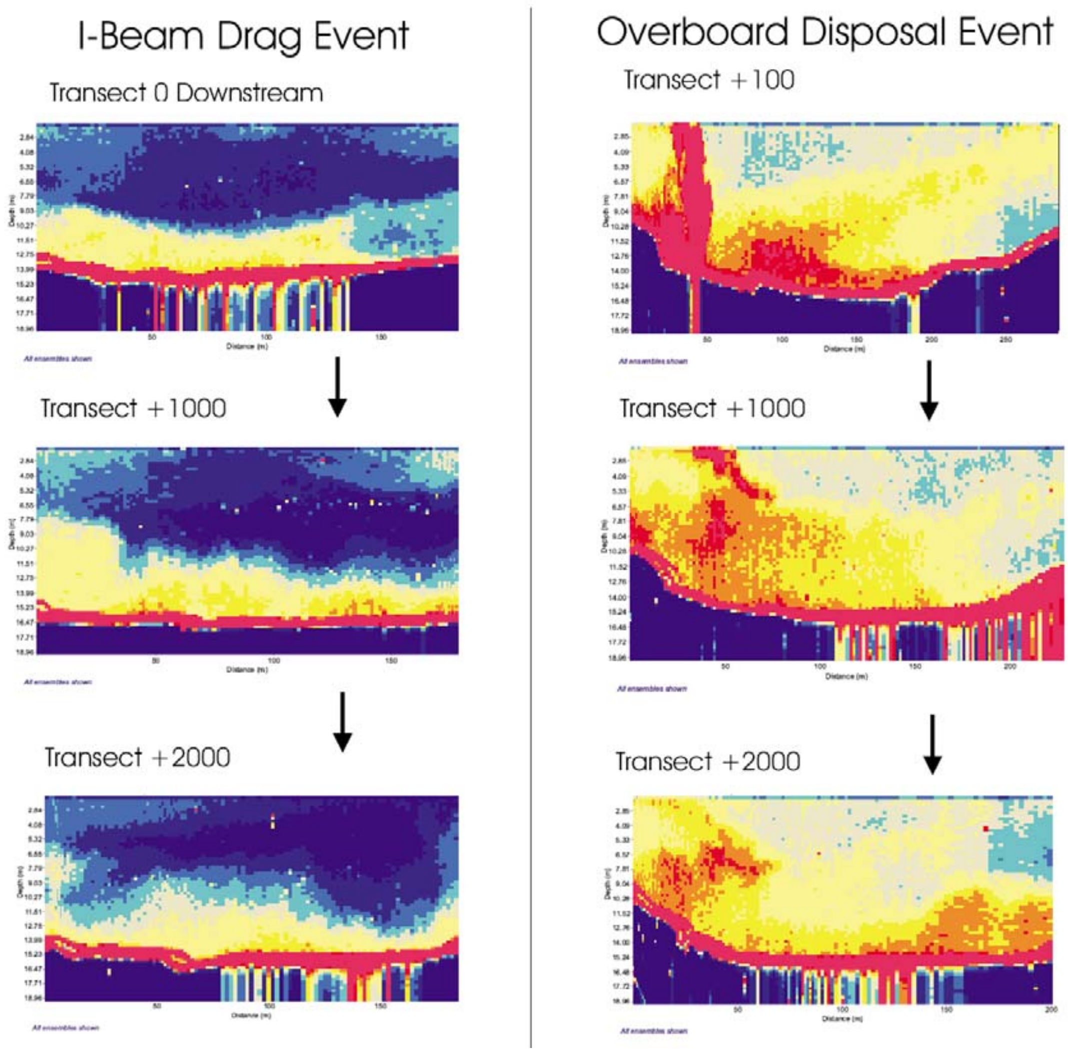

Figure 6. General characteristics of I-Beam and overboard disposal events.

Characteristics of an Overboard Disposal Operation

Based on observations and SEDIVIEW outputs, Overboard Disposal events were able to suspend material in the water column for a maximum downstream distance of 5000 ft. Maximum concentrations of suspended material occurred at the +100 ft transect, just downstream of the disposal pipe end and generally in the top three-quarters of the water column.

The combination of the mixing in the water column and the swinging of the dredge gives the plume a varying geometry relative to the shoreline. The location of the maximum concentrations, as high as 760 mg/L confirmed by TSS grab sample, directly corresponds to the location of the discharge pipe end. As the dredge discharge pipe was attached to the rear of Dredge Monitor near the spuds and thus swinging with the dredge as the cutter head was moved side-to-side, the maximum concentrations are continuously moving relative to the proximal shoreline. The concentrations observed at the +1000 and +2000 transects are significantly less than those observed at the +100 line due to spreading and dilution.

More dense material was also seen separating from the finer material at the +1000 ft and +2000 ft lines. The separation of material is evident by two distinct concentrations of material observed in the water column at these lines, a dense amount of material at the bottom half of the water column and a less dense amount of material suspended associated with the “salt wedge”. The “salt wedge” can be defined as the location in the water column where the vertical salinity gradient is the greatest, a location of the water column where the salinity rapidly increases over a small portion of the water column with the higher salinity (i.e., denser water) located near the bottom.

Material which is assumed to be the less coarse material remaining after the coarse material settled out at the +1000 and +2000 ft transect accounts for the suspended material observed at the maximum distance of 5000 ft downriver. The location of the less course suspended material in the water column is closely associated to the location of the “salt-wedge” in the water column.

Theoretically, the material leaving the discharge pipe should settle rapidly as a density current because the addition of solids to the background water increases density. Near the bottom, the courser-grained material should settle out and continued to transport more slowly along the riverbed while the now diluted fine-grained particles and colloids will continue to spread in the water and concentrations dilute as a function of distance from the discharge. However, the existence of the salinity stratification interrupts this process because the discharge entrains freshwater at the surface and becomes less dense as it moves down the water column. When the sediment plume encounters the relatively more dense “salt wedge”, the plume reduces its density as it sinks and spreads out “riding the wedge” downriver.

Comparison of the Amount of Agitation Dredge Material Suspended to Other Sources of Suspended Material

Data collection included both spring and fall monitoring events. Generally background concentrations of suspended material during the spring monitoring event were higher than background concentrations observed during the fall monitoring event. The fall event occurred during a neap tide (per the scope of work) when currents are smaller. During the spring events, SEDIVIEW outputs showed background concentrations of suspended sediment resulting from increased current velocity along the shallower channel slopes. For example, during periods of maximum current velocity, the area of the navigation channel slope and the downstream corner of Fig Island Turning Basin (see Figure 2) can apparently entrain a significant volume and concentration of suspended sediment in the water column. In general the concentration and volume of the sediment plume observed downstream of Fig Island Turning Basin was similar in concentration and volume to suspended sediment plumes observed +1000 ft downstream of agitation dredge events. The entrainment of suspended sediment in the water column in such a situation is assumed to be a result of significant friction between the moving water column and the river bottom due to channel and turning basin geometry.

While performing the spring and fall data collection events in Savannah Harbor, the ATM field crew had several opportunities to examine the effects of a passing ship as the Navigation Channel is regularly traveled by container ships moving upriver to GPA berths. After prop wash from accompanying tugs and the ship propeller dissipated (approximately 15 minutes), suspended sediment was observed in the bottom half of the water column. The concentration of the suspended material was equal to the concentrations observed from the I-Beam drag events at the +1000 ft transect. The SEDIVIEW output illustrating the effect of a passing ship is shown in Figure 7.

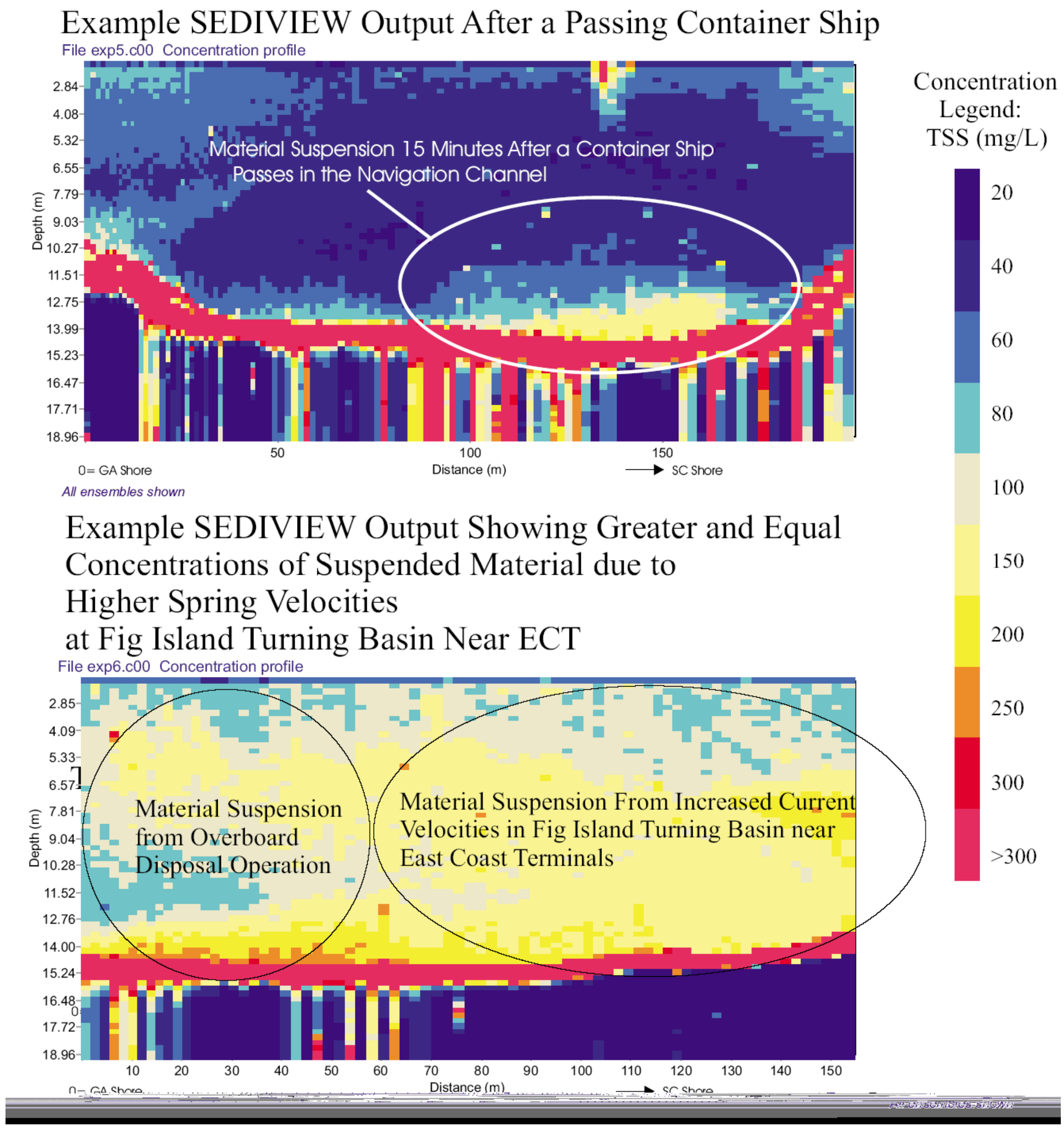

Figure 7. Example SEDIVIEW output showing containership plume (top) and a comparison of overboard disposal with strong river currents.

Sediment Quality

While monitoring for suspended sediments with the ADCP, ATM simultaneously collected total recoverable chemistry samples and performed water quality profiles. The ADCP data, water chemistry samples and water quality profiles were all collected along the same transects. Sediment samples were analyzed for metals, dioxins and furans, PCBs, PAHs, TOC, TPH, Tributyltin, and pesticides.

The data were coupled with ATM's three-dimensional hydrodynamic model of the lower Savannah River Estuary and imported to a Corps of Engineers model (SSFATE) to predict the concentration and fate of suspended sediments for any berth location in the Harbor. This model was also set up to track a conservative water contaminant released from the dredged material.

Copper, lead and zinc were found to exceed the NOAA and EPA designated "ER-M" (Effects Range Medium) and background soil concentrations while arsenic was found at levels above the ER-L (Effects Range Low). Selenium was also found at concentrations greater than background soil concentrations in several samples, but ER-L and ER-M values are not available for Selenium.

No significant dioxin or furan issues were encountered when the results of the sediment analysis were evaluated related to their potential for adverse effects. Based on the absence of any individual PCB Aroclors or congeners, it was also assumed that total PCBs were not present in concentrations exceeding its ER-L. All detected values were found below the ER-L threshold for each PAH parameter.

Although no ER-L or RE-M values are available for TOC, TPH or Tributyltin, no significant TPH or Tributyltin issues were encountered when the results of the sediment analysis were evaluated related to their potential for adverse effects. This conclusion is based on the comparison of the concentration of these parameters between the results of the berth sediment and the reference sample analytical results. Additionally, no significant pesticides issues were encountered when the results of the sediment analysis were evaluated related to their potential for adverse effects.

Water Quality

In addition to sediment quality testing, ATM compared the results of the water samples, dissolved oxygen measurements, sediment quality data, and concentrations of suspended sediments to applicable criteria to evaluate the potential environmental effects and water quality criteria violations.

Based on the review of the profiling data, a correlation of dissolved oxygen (DO) depletion to the presence of suspend material resulting from agitation dredge operations can cause short term and near field effects on dissolved oxygen. DO depressions as high as 2.8 mg/L, in an overboard disposal monitoring event, were recorded within 100 ft directly downstream of the disposal pipe. However two other observations need to be considered when discussing this data. First, the lowest DO concentrations observed downstream of the agitation dredge event were equal to or even worse than concentrations recorded in background profiles upstream of the agitation dredge activity. For example, near bottom profile data in an upstream turning basin showed DO concentrations less than 4.0 mg/L and the lowest concentration recorded downstream of the agitation dredge activity was 4.2 mg/L. Second, water quality instruments include a conductivity inversely proportional correction (higher the conductivity the lower the calculated DO concentration) when calculating dissolved oxygen concentrations. Therefore if overboard disposal introduces more conductivity into the water column, an effect on the calculated dissolved oxygen data could be experienced. In the case of the maximum DO depression of 2.8 mg/L mentioned above, the conductivity measured in the same location in the water column was on average 40% higher than background conductivity. DO concentration calculations are described in *Standard Methods for the Examination of Water and Wastewater*.

Overall, depressions in DO observed downstream of agitation dredge activity that could be attributed to the presence of suspended material, specifically mid-water column immediately downstream of the spring agitation dredge event monitoring, appear to be near field and brief in duration. It should be noted that no trends in DO depression directly resulting from I-Beam or overboard disposal operations could be identified for the fall event monitoring event. Trends in DO depression were directly attributable to overboard disposal operations during the spring monitoring event. Specifically, DO depressions downstream of the spring overboard disposal event were found 1000 ft downstream of the dredged material source. The observed depression in DO does not persist after overboard disposal operations cease.

AQUATIC RESOURCE ASSESSMENT

Potential Benthic Community Impacts

In general, dredging will remove, destabilize, and disturb any benthic invertebrate communities living in or directly downstream to the berths where dredging will occur. Physical and chemical characteristics and processes such as sediment size, organic composition, and deposition rate; and depth, turbidity, salinity and temperature range help determine which organisms live in these communities. Biological processes such as larval recruitment, competition, predation, and other ecological interactions also structure the community. Because soft sediment habitats are not as stable as those with hard bottoms for attachment, natural and anthropogenic disturbances play a large role in shaping the community composition.

Navigation channels generally support fauna characteristic of a disturbed area (Krenkel et al. 1976). Not many organisms can tolerate the constant disturbance that the berth basins experience from dredging, as well as propeller wash from vessels, sedimentation rates of a foot or more per month, and other impacts. As a result, the benthic community typically remains in an early successional stage. Succession in this community type depends upon established burrowing communities that aerate the otherwise anoxic sediments.

Agitation dredging removes benthic organisms and their habitat while releasing sediments that settle on communities in downstream areas of the navigation channel. The recovery speed of the benthic community depends on the availability of larvae for new settlement and other complex factors, but studies of other sites in Georgia, South Carolina, and Alabama indicate that the early successional stage community can recover within a few weeks to six months (Vittor et al., 2001, Clarke, D., and Miller-Way, T. 1992, Van Dolah et al. 1984).

In addition to the direct effects on the benthic community, agitation dredging can also temporarily lower dissolved oxygen, increase the total suspended solids in the water column, and release contaminants and decomposing organic materials formerly trapped in the sediments. The biological effect of these water quality changes depends upon exposure magnitude, frequency, and duration, as well as environmental parameters (mainly temperature and salinity), and species tolerance.

While no set criteria for TSS impacts exist for warm-water estuarine benthic communities, qualitative assessment should be based on how much the additional TSS exceeds normal background levels. Depending partially on rainfall, background TSS levels in the affected area range from 20 to 40 parts per million (mg/l). During dredging events, TSS levels may be raised to an average maximum of 350 mg/l above background concentrations, with worse case scenarios of 150 mg/l at 2000 feet downstream, and a one-time maximum of 800 mg/l 100 feet downstream. However, the sediment plume settles out of the water column rapidly. Within the navigation channel, this should have negligible impacts because resident species are accustomed to high levels of sedimentation and sudden high TSS from ship propellers, wakes, and other ongoing disturbances.

For the purposes of this discussion, observations were generalized into the following three points.

Dissolved oxygen:

DO depressions downstream of agitation dredge operations were recorded, however the effect was near field and short in duration. The maximum DO depression of 2.8 mg/L was observed 100 ft downstream of the overboard disposal operation during the spring monitoring event. The effect on DO is qualified as near field because the depression was less than 1.0 mg/L 1000 feet downstream of overboard disposal operation and indistinguishable 2000 feet downstream.

Low DO concentrations equal to or less than those resulting from overboard disposal operations were observed in background concentrations upstream of overboard disposal operations. Therefore, the background condition presently experienced by aquatic life is similar to observed conditions during agitation dredge operations.

Generally, DO depressions were observed in the lower half of the water column at 100- and 1000-foot downstream transects during the spring overboard disposal monitoring events. It should be noted that the standard in Georgia waters to support warm water aquatic life is a daily average of 5.0 mg/L, and no less than 4.0 mg/L, and the observed absolute values for DO at the 100 ft transect during the spring overboard disposal monitoring event did not drop below 4.0 mg/L. (Background concentrations for the fall monitoring events averaged below 3.0 mg/l. A special variance had to be obtained from Georgia Department of Natural Resources to conduct agitation dredging operations for the purposes of the fall event monitoring).

Total Suspended Sediments:

Sediment suspension resulting from I-Beam dragging results in a significantly less dense sediment plume than overboard disposal. Generally, suspended material does not move more than 3 meters off the river bottom, nor is it observed more than 2000 feet downstream. Sediment plumes resulting from overboard disposal operations are more dense and higher in the water column because the disposal pipe is secured to the back of the dredge and discharges less than 10 feet below the river's surface. More dense material falls out of suspension within 2000 feet while finer material can remain in suspension riding the vertical salinity stratification for as much as 5000 feet.

Water Chemistry Effects:

In some instances, downstream levels were equal to background concentrations directly upstream of agitation dredge activities. Water samples were evaluated from 3000 feet up and down-stream from agitation dredging at multiple transect locations. In each case elevated levels of almost all constituents occurred, but in some cases the levels were actually lower than background concentrations. However, none of these concentrations exceeded acute toxicity levels when calculated for dissolved metals. The evaluative criteria used in the water chemistry analysis were based on conservative thresholds and therefore should basically account for synergistic effects whether through proximity to exposure times or concentrations approaching critical levels.

MODELING

The suspended sediment fate model SSFATE was used to simulate the suspended sediment plume for dredging at a single site during neap and spring tide conditions. The purpose of the modeling was to demonstrate the variability in suspended sediment concentrations that are expected to occur during spring and neap tidal ranges.

The I-Beam dragging agitation dredging is not specifically included in the SSFATE model; however, the SSFATE model was used to simulate the suspended sediments plume by specifying a turbidity source similar to what is expected to occur during I-Beam dragging. The model is well suited to determine the transport and fate of the suspended sediments in the water column.

Sufficient data are not available to determine an appropriate value for the dredging rate for the I-Beam dragging, but the value of 150 cy/hr is in the “ballpark” since the predicted TSS concentrations are in a similar range as the measured values during I-Beam dragging events. Therefore, the magnitudes of the simulated TSS values have some high degree of uncertainty. However, the model results are still useful to evaluate the spatial distribution of the suspended sediments plume, the duration of the peak TSS concentrations at different locations and the relative effects of the spring and neap tidal ranges on the turbidity plumes.

The model results show the following:

- the high TSS plume is limited to the region near the river bottom during I-Beam dragging events;
- the periods of peak TSS concentrations at a given location occur over short periods of time (i.e., less than one hour);
- neap tide conditions results in greater spatial extent of high TSS concentrations (above ambient levels) than spring tide conditions; and
- the peak TSS levels generally occur when the currents reverse direction from ebbing to flood.

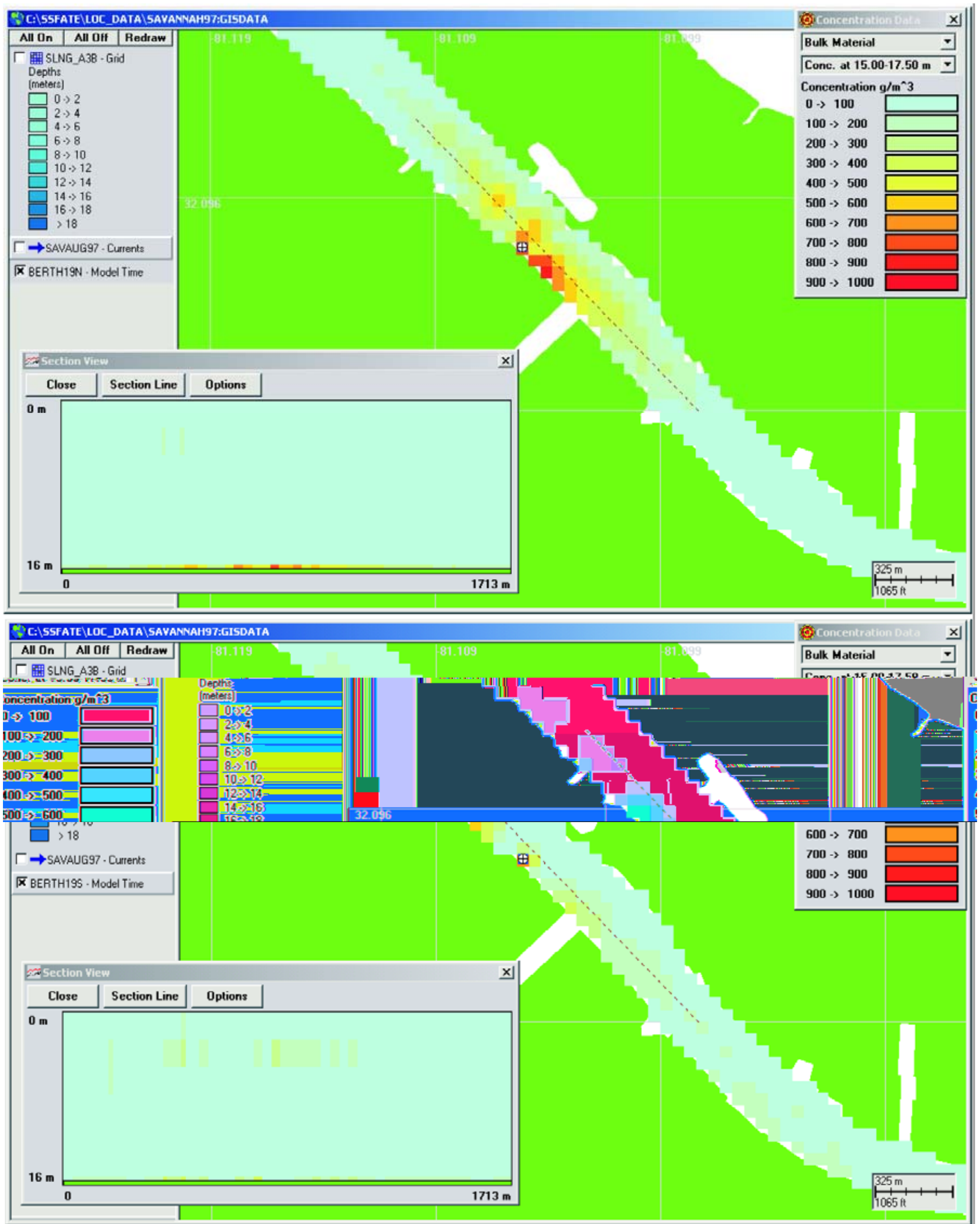

Figure 8. Example SSFATE model output.

CONCLUSIONS

While short-term water column effects of elevated TSS concentrations have been identified by this and previous studies, no unacceptable adverse effects have been identified by this study as a result of agitation dredging. Descriptions of the effects observed are summarized below:

- Contaminants detected downstream of the agitation dredge activity were determined to be below acute toxicity levels while in the water column. The highest concentrations of contaminants found in the water column were determined to occur for very brief durations.

- Water quality profiles taken downriver sometimes indicate that agitation dredge operations create a near field and brief DO depression. DO depressions downstream of agitation dredge operations were similar to concentrations observed in background profiles. Therefore, the DO depressions observed are within background fluctuations of near bottom DO already occurring.

- The lowest dissolved oxygen concentration measured for the fall and spring monitoring events were from the near bottom profile data. Occurrence of the lowest dissolved oxygen concentration were not consistently in the suspended sediment plume resulting from agitation dredge operations and in some cases were found in background transects performed during the monitoring event. A consistent near bottom depressed DO concentration was present in profiles performed around the Kings Island Turning Basin. Turbidity profile data indicate elevated levels of suspended material in the same water column location as the depressed DO concentration indicating the presence of a fluidized layer occurring in the harbor.

- The effects on water quality should only be discussed qualitatively for one event, location, and transect, because there are other confounding factors from other inputs (besides the dredging activity) and changes to the river system (river geometry and hydrodynamics) that are causing a concentration change between the background transect and the monitored transects irrespective of the dredging activity effect. Sometimes it appeared that minimal localized short-term DO depressions resulted from the activity and followed the densest part of the suspended sediment plume and other times DO increased downriver of the event (probably from vertical mixing of the water column by the tug or dredge or from air entrainment). Overall trends of the effect of resuspended sediments from agitation dredging on DO were not apparent. During some events monitored a depression was observed, but in others it appeared some increases were observed and in other cases a fluctuation between increases and decreases from comparable background concentration were observed. Seasonal variability, the presence of oxygen demanding substances in the sediments, the nature of the sediments, and the time that they have accumulated are all expected to affect oxygen demand.

- Effects from the presence of agitation dredged suspended material appear to be within the background variance presently occurring in Savannah Harbor for the seasons and conditions monitored. The conclusion, therefore, is that dissolved oxygen depression or increase, while observed in some cases, is generally not a significant effect of agitation dredging. Berth sediments should be evaluated individually for oxygen demand potential, especially during sensitive periods (like hot summer days) and in sensitive areas.

- During agitation dredging events, TSS levels may be raised up to 800 mg/L 100 feet downriver of the event, but the larger particles settle out of the water column rapidly and the fine particle concentrations dilute quickly. In the worst-case scenario observed, TSS levels were observed at only 150 mg/L 2000 feet downriver. Visual clarity can also be reduced significantly for a small portion of the river cross-section within 100 feet of the dredged material source as was evidenced by the turbidity data collected.

  These effects are however short-lived (a few minutes to hours), and resident species are accustomed to high levels of sediment resuspension from natural high-velocity semidiurnal tidal currents, passing ship and tug traffic, ship wakes, storm events and runoff in the Savannah River Basin, and other ongoing disturbances. During extended periods of increased sediment loading on the water column egg, larval, or small juvenile life stages may suffer some adverse impact. Considering the duration of exposure, season, life stage, volume of water body and percent of suitable aquatic habitat affected, there is not convincing evidence that agitation dredging activity as it is performed in the Savannah Harbor creates unacceptable adverse impacts on aquatic resources.

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