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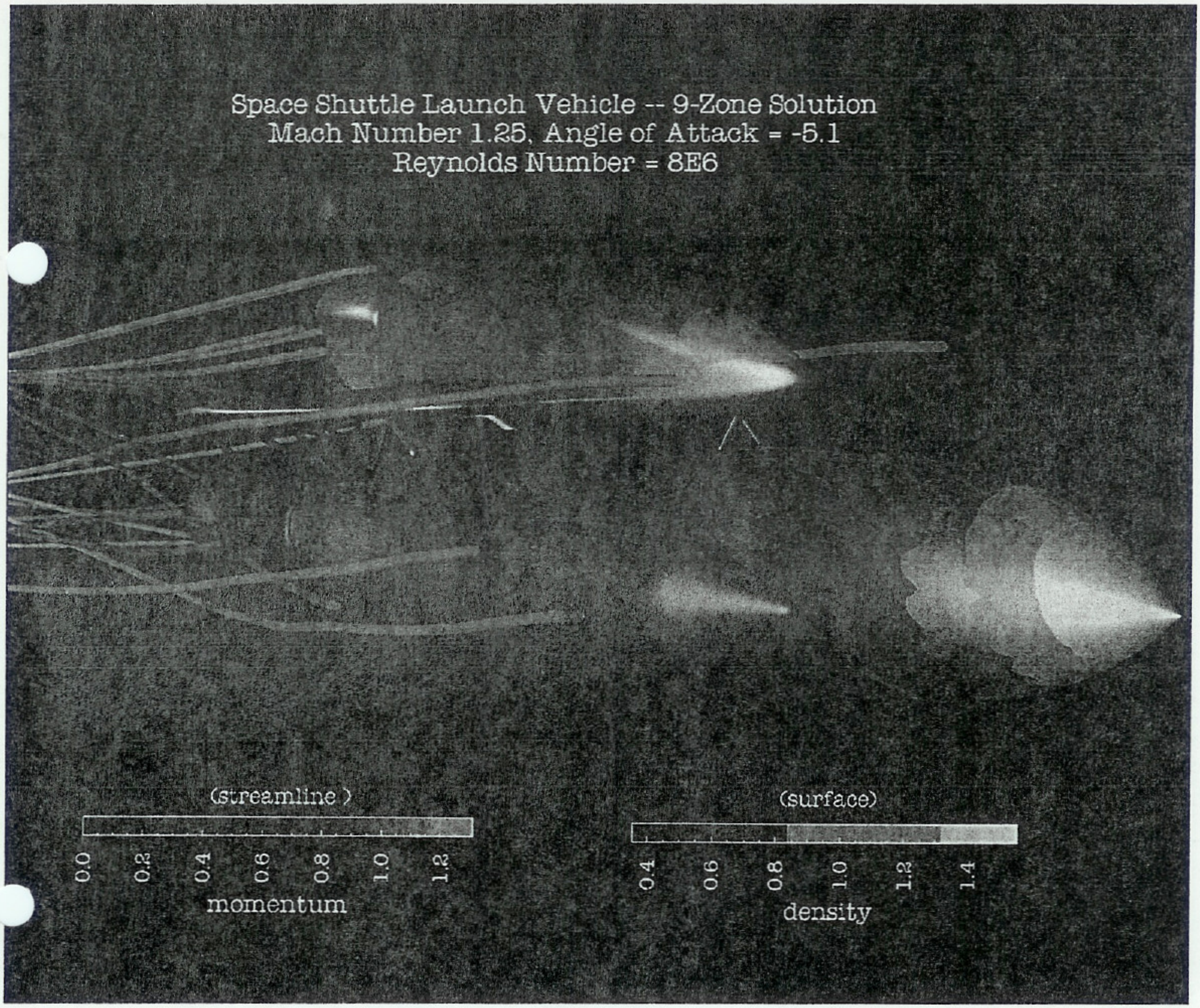

Three-Dimensional Visualization of Sediment Chemistry in the New York Harbor

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Introduction

Shipping channels become filled with sediment over time and need to be dredged periodically in order to keep the waterways open. Ships need at least forty feet of depth to navigate safely; the dredging required to maintain this depth generates an annual volume of five million cubic yards of sediment for disposal. These dredged sediments can be dumped in the open sea if they are uncontaminated, but the disposal of contaminated sediments presents a problem. Aquatic sediments consist of fine- to coarse-grain minerals and organic particles that are found at the bottom of lakes, rivers, bays, estuaries, and oceans. Chemicals that attach themselves to these sediments are easily transferred to a variety of aquatic organisms. 15% of the sediments in the New York Harbor have been found to be toxic, and 8% has been found to be highly toxic. This high concentration of sediment contaminants in the New York Harbor has prevented regular maintenance dredging of shipping channels, thus adversely affecting the economic viability of the port. Consequently, the Environmental Protection Agency and the U.S. Army Corps of Engineers have been charged with selecting technologies to decontaminate the Harbor's sediments, resulting in the New York/New Jersey Harbor Contaminated Sediment Decontamination Technologies Demonstration Project.

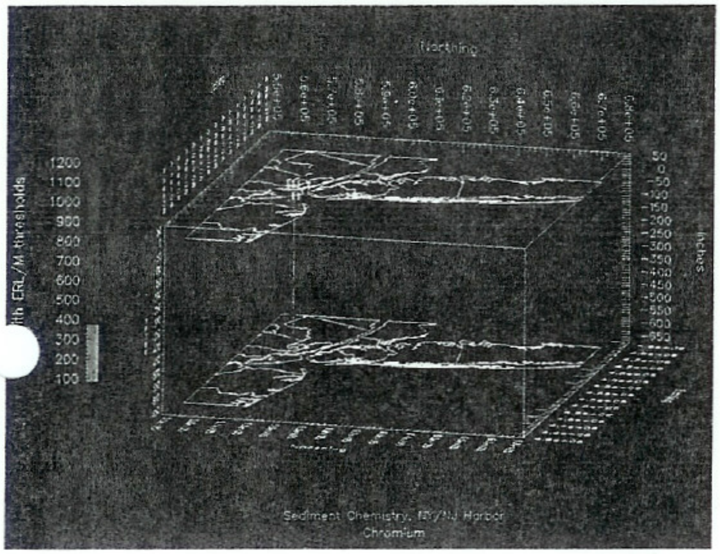

Figure 1.

Knowing the contaminant levels of an areas sediments prior to dredging can save large amounts of time and money. Engineers would not need to test sediments as they were dredged in order to know which sediments could be ocean-dumped and which sediments need decontamination. Visualization of sediment contaminant data is a powerful way to gain the knowledge necessary to dredge and dispose of sediments cost-effectively. Hence, one of the tasks in the decontamination project is "Three-Dimensional Visualization of Harbor Sediments," which is being carried out by Rensselaer Polytechnic Institute using IBM Data Explorer. These visualizations use core data from the Maxus Corporation's Superfund site on the lower Passaic River in Newark, New Jersey. Collecting core data involves using a vertical hollow tube to grab a column of sediments starting on the harbor floor and going down to a given depth, perhaps ten feet. The sample is then partitioned at regular intervals of several feet, and the sediments within each partition are mixed to create a homogeneous sample. The homogeneous samples are then tested for contaminant concentrations and physical parameters such as grain size. The results of the sample testing are organized into three-dimensional data points; each one contains horizontal Universal Transverse Mercatur (UTM) coordinates to locate the core in the XY plane, a vertical coordinate in inches or feet to indicate the depth below the Harbor floor of the homogeneous sample, and the values for the contaminant levels and physical parameters. In this article, the word "sample" refers to one of the homogeneous segments of the core.

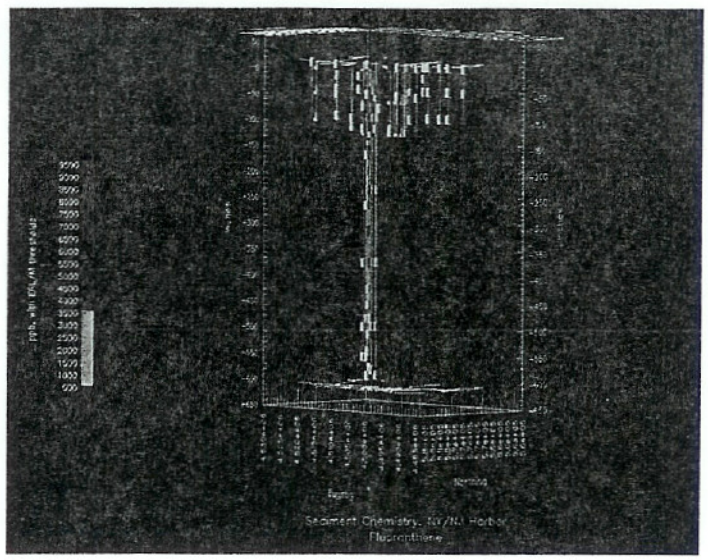

Figure 2.

Sediment Visualization

The full-scale visualization plans for the Harbor are intended to illustrate both sediment chemistry and sediment toxicity, as well as to provide a visual summary of the probability of adverse biological effects. Sediment

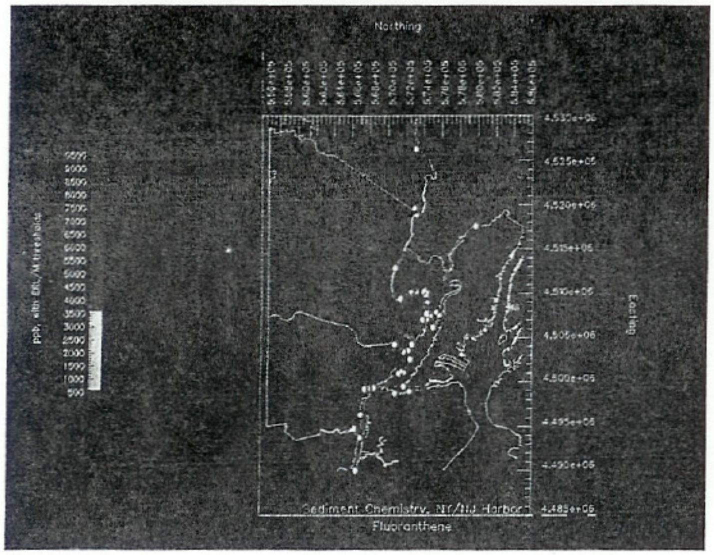

Figure 3.

chemistry visualizations show sediment concentrations of a single contaminant for a given region. They highlight the locations which exceed reference values (i.e., concentrations of contaminants high enough that adverse biological effects are anticipated) for specific chemicals. Sediment toxicity visualizations show percent survival rates of a particular organism in a given location. The summary visualizations shows the probability of adverse biological effects in a given area, based on both sediment chemistry and sediment toxicity data. They would help detect hot spots, that is, areas which have high toxicity or exceed acceptable reference values for any contaminant. Another type of summary visualization can show which locations exceed reference values for an entire class of chemicals, all PAHs, for example.

The illustrations in this article are from sediment chemistry visualizations. The contaminants that have been visualized include heavy metals, PCBs, PAHs, dioxins, and pesticides. The National Oceanic and Atmospheric Administration (NOAA) has developed sediment assessment guidelines that include reference values for contaminant concentrations. The reference values used in these visualizations are NOAA's Effects Range Low (ERL) and Effects Range Medium (ERM). Using these two reference values creates three ranges of interest: values below ERL, values between ERL and ERM, and values above ERM. Samples from each range are mapped to a different color. Figure 1 shows a three-dimensional view of the concentrations of chromium. The over- and underlaid Harbor shoreline maps make it easy to see from what part of the Harbor the cores were obtained. In many cases, however, the data are so dense that an enlarged view is required in order to make visual sense of the data. A user of Data Explorer can easily zoom in on an area of interest; however, these visualizations were designed to be displayed through a World Wide Web browser, thus precluding that type of interaction. Therefore, several images from each program were exported to GIF files, each providing a different perspective on the data. Figure 2 shows a close-up view of a more densely sampled contaminant, fluoranthene. Displaying non-interactive images in this fashion often requires the generation of additional reference images. Two reference images commonly used in this project were the top-down perspective (see Figure 3), which shows the planar location of each fluoranthene core as well as the concentrations of the uppermost layer of samples, and the full Harbor map (see Figure 4), which shows the general location of the sample data within the Harbor. These visualizations can be viewed on-line at: ***http://www.vlsc.rpi.edu/locker/69/000469/dx/harbor.www/harbor.html.***

Visualization Design

The design of the visualization is intended to mimic the visual appearance of a core. Each sample within a core is represented by a colored cylinder located in three-space by UTM coordinates on the X and Y axes and by inches on the Z axis. The color represents the concentration of a single contaminant found at a given depth. As mentioned earlier, the concentrations have been categorized by their relative location above, below, or between

Figure 4.

the reference values. Blue samples have a concentration below ERL, yellow samples have a concentration between ERL and ERM, and red samples have a concentration above ERM. All of the samples in a single core are connected by a thin gold line. An enhanced version of the three-dimensional visualization replaces the three solid colors with three ranges of colors (see Figure 5). Here, samples with a concentration below ERL run from dark blue to light blue, depending on their relative values. Samples with a concentration between ERL and ERM run from yellow to orange, and samples with a concentration above ERM run from magenta to red. This color scheme still permits instant identification of which range each sample belongs to, but it also allows for comparison of samples within a range.

Technical Challenges

Creating these visualizations presented a number of programming challenges. Because the values on the X and Y axes (in UTM) were several orders of magnitude larger than the values on the Z axis (in inches), it was necessary to scale up the Z axis so that it would be an appropriate size relative to the X and Y axes. Scaling of

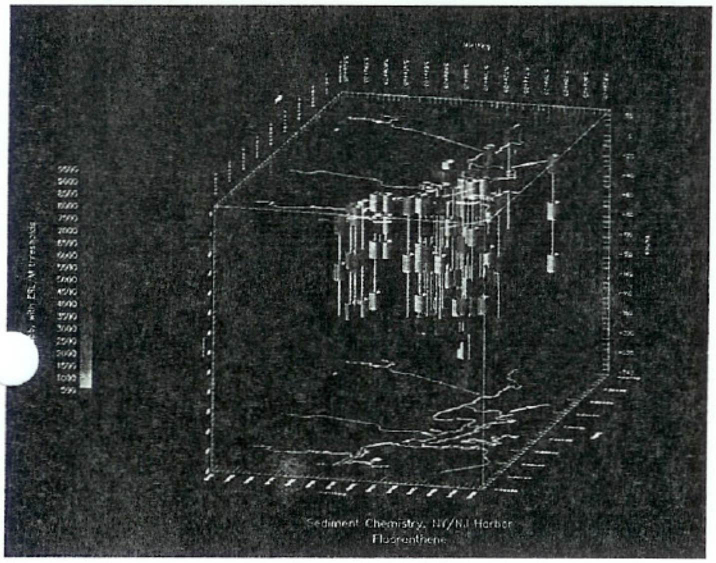

Figure 5.

this type must precede the final *Collect* module (if one is used) in order to avoid inaccurate axis labels. Another problem that surfaced was that any three-dimensional glyphs being used with axis scaling of this type will explode in the direction of the axis being magnified. This problem can be resolved by using an additional *Scale* module to flatten those glyphs by the inverse of the factor by which the axis was magnified. Creating the cylinder glyphs required several steps. A cylinder-shaped template for the glyph-type was first created with *Grid, Tube,* and *Refine* modules and then piped into the type input of another *Glyph* module. After being scaled appropriately, the cylinder glyph was ready for color-mapping. The three-dimensional image needs to be capable of showing not only the three-dimensional representation of the data, but also, after rotation, the two-dimensional top-down view of the X-Y plane, with circular or spherical glyphs showing the locations of cores. Because the tube-capping features is not functional in the DX version used for this visualization (2.5), a sphere, scaled in the same manner as the cylinders, was placed in the center of each cylinder-glyph to provide the visual effect of a cap.

To create the lines that connect all of the samples in a single core, the Z coordinate value was isolated and passed to the data field of a *Glyph* module. Using the Z coordinate value as the glyph's data input caused a tubular line to be constructed that runs from the sample location up along the Z axis to the surface. The lines for samples in the same core are superimposed on one another and the appearance is one of a single line connecting all of the samples in the core.

Future Work

Future work with sediment visualizations includes incorporating modeling into the visualizations. Two types of models are being investigated: the first is an interpolative model that would allow the generation of continuous data from discrete data, and the second is a predictive model that incorporates sediment transport models and predicts how harbor sediment contaminant concentrations will change over a period of years. Using continuous data would permit an estimation of sediment volumes, an important piece of information for the decontamination project. A user shell will be developed that permits the visualization of remodeled data on the fly. In addition, the *Pick* module will be used to identify the coordinates and data values for any given sample.

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