Passaic River Erosion Testing and Core Collection: Field Report and Data Summary

Subcontract No. KC-ACE2002-31

Final Report To:

Malcolm Pirnie, Inc.
104 Corporate Park Drive
White Plains, New York 10602

March 2006

Michael Owens, Jeffrey C. Cornwell, Steven E. Suttles,
and Patrick Dickhudt

Chesapeake Biogeochemical Associates

Introduction

Under subcontract KC-ACE2002-31, Chesapeake Biogeochemical Associates collected cores for erosion experiments and radionuclide analysis for the Lower Passaic River Restoration Project, a joint study being conducted by the U.S. Environmental Protection Agency (EPA), U.S. Army Corps of Engineers (USACE) and New Jersey Department of Transportation. The major emphasis of this program was the determination of Gust microcosm erosion rates using the exact approach used in Dr. Larry Sanford's research laboratory at the University of Maryland Center for Environmental Science (Sanford and Maa 2001). In addition, we collected cores for other project purposes including: surficial (0.0-0.5 cm) sediments for Malcolm Pirnie for radionuclides analysis, water column properties using Conductivity-Temperature-Depth (CTD), Laser In Situ Scattering Transmissiometer (LISST) and optical backscatter sensor (OBS) for Malcolm Pirnie, and sediment cores for the USACE "Sedflume" experiments (Borrowman et al., 2006). Field descriptions of sediment cores collected for other project purposes are provided in Appendix A. Results of measurements unrelated to Gust Microcosm experiments were provided to Malcolm Pirnie and are not presented in this report. All field work was carried out from May 16-20, 2005.

This document reports the field sampling carried out in the program and presents a graphical data summary of our erosion experiments.

Field Sampling Activities

Field activities conducted include collection of three types of core samples, and water column measurements as follows:

- Cores for the analysis of radionuclides (for Malcolm Pirnie)
- Cores for the analysis of sediment erosion (for USACE testing via Sedflume)
- Cores for near-surface erosion (for Chesapeake Biogeochemical Associates testing via Gust Microcosm)
- Water column measurements using LISST/CTD/OBS (for Malcolm Pirnie)

We used a plastic box corer, identical in design to the Ocean Instruments PBC-100 **(http://www.oceaninstruments.com/products/box_corers/pbc_100.html),** to collect undisturbed surface sediments for all radionuclide samples collected in this project. Box cores were subcored into PVC core liners (4" ID) and extruded from the bottom to collect the top 0.5cm of sediment. Three replicate cores were sampled from each site and pooled into one sampling container.

Sedflume cores were collected with a pole mounted piston corer modified to accept the USACE erosion core tubes. This device worked exceptionally at all sites except where hard bottom was encountered containing large stone or very coarse sand. In most cases, we had good penetration of the piston corer and collected sediment in excess of 40 cm.

Sample locations

The sample locations are identified in Table 1 and Figure 1. In a few cases we found the sediment at the predetermined sample locations unsuitable for coring with our box corer or our pole mounted piston corer. Site #9 was located very near a gas pipeline and was relocated about 20m downstream near the center of the channel. This relocation was unsuitable for coring due to hard bottom substrate and the site was relocated 25m toward the north side of the river in an area with soft bottom deposits. The sediment in proximity to site 10 was not suitable for coring because of a layer of very fluid mud overlying a coarse sand layer. This situation prevented suitable penetration of the box corer or the piston corer and caused the sediment to wash out of the corer upon retrieval. We found the sediment in the region of the river located near sites 5, 6, and 7 to be patchy, ranging from hard substrate to fluid mud. Site 5 was relocated upstream of the original position near the south shore of the river. Site 6 and 7 were sampled close to their original positions for sedflume cores but the very fluid nature of the mud at these two sites prevented the collection of radionuclide cores with the box corer. The remaining sampling locations were found to be well suited for all types of coring.

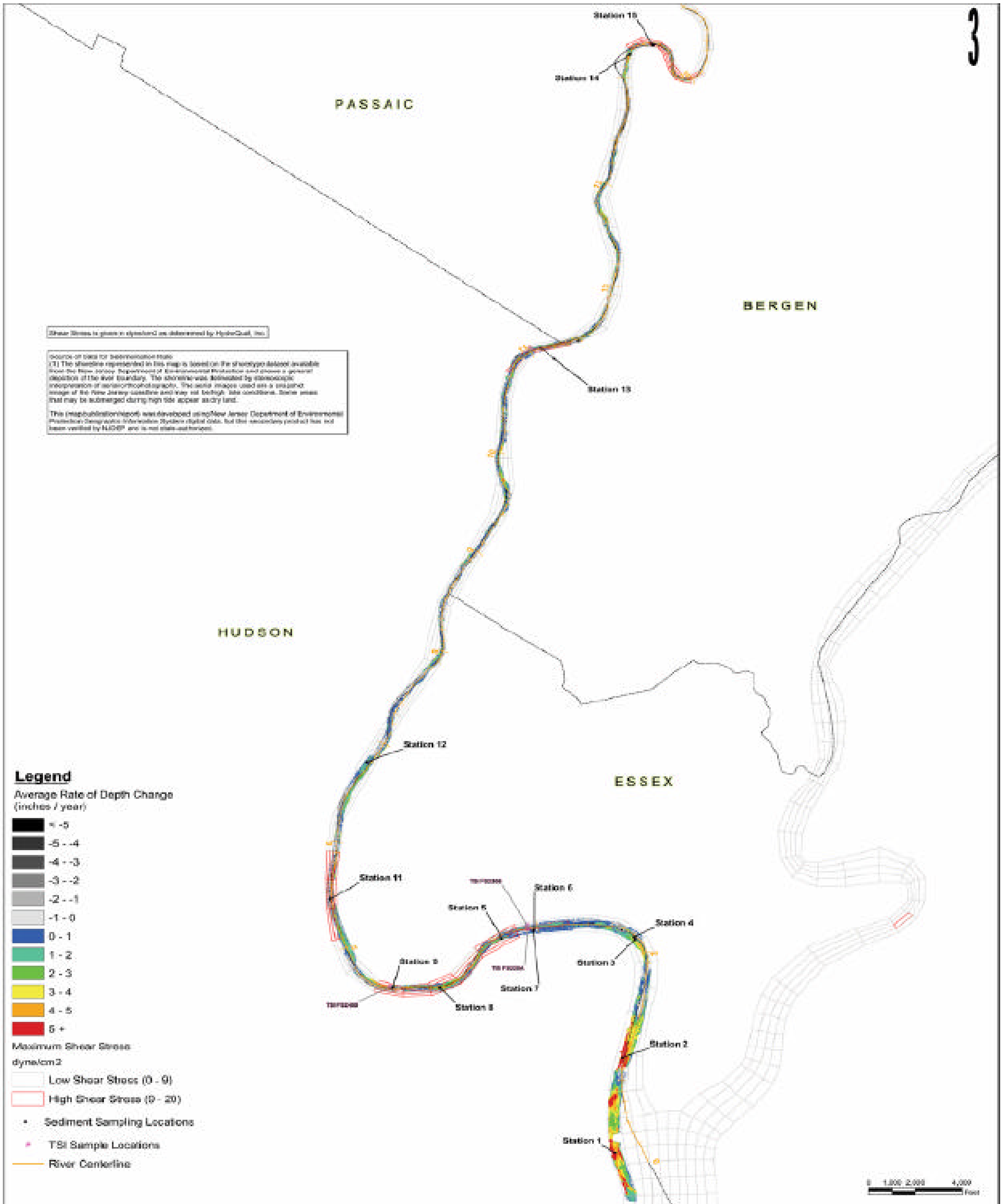
Final Comments on Coring in the Passaic River

The core collection was successful, but parts of it were extremely difficult. The need for undisturbed cores for Sedflume studies, Gust erosion studies, and surficial radionuclides presented a considerable challenge. We were very pleased at the performance of our improvised 4” piston corer; the cores we supplied to USACE were undisturbed and of more than sufficient length. Box coring would not have worked for this sediment collection. The radionuclide sampling and Gust microcosm sampling required an intact interface and most cores were collected with our box corer. This corer is very light and penetration in circumstances with coarse grained sediment required repositioning at a number of stations. In the end, we can not identify light coring gear that would work better for these studies; only a large ship box corer would have the penetrating power to sample the most difficult sites. Such large vessels would have difficulty working in such a narrow river with so many unattended bridges. While box coring was much more difficult than we initially envisioned, we are pleased with the overall results.

Table 1 - Station locations, sampling times, and water depths for sites sampled May 16-20, 2005. The "X" designates that sample was collected.

Station	Date Time	Location	Depth (m)	Sedflume	Nuclides
1	05/17/2005 1400	N40.71175 W74.12208	8.2	X	X
2	05/17/2005 1630	N40.72441 W74.12088	5.5	X	X
3	5/18/2005 1215	N40.740198 W74.11885	2.4	X	X
4	05/18/2005 0940	N40.74055 W74.11895	3.6	X	
5	05/18/2005 1213	N40.74040 W74.13931	1.8	X	X
6	05/19/2005 1236	N40.74156 W74.13439	3.1	X	
7	05/19/2005 1250	N40.74142 W74.13454	2.1	X	
8	05/18/2005 1400	N40.73387 W7414894	5.5	X	X
9	05/17/2005 1548	N40.73400 W74.15616	2.1	X	
11	05/18/2005 1630	N40.74577 W74.16591	5.2	X	X*
12	05/19/2005 1236	N40.76400 W74.16010	3.1	X	X
13	05/17/2005 1024	N40.81793 W74.13080	1.5	X	
14	05/17/2005 1024	N40.85859 W74.11892	1.3	X	
15	05/20/2005 1236	N40.85983 W74.11538	1.8	X	X**

* Sampled on 05/19/2005 at 1700 hours
** Replicate sample collected



MALCOLM PIRNIE

Figure 1 - LOWER PASSAIC RESTORATION PROJECT SITE LOCATION FOR SEDIMENT EROSION EXPERIMENTS AND MAXIMUM SHEAR STRESS

MAY 2005

Results of Erosion Experiments

This section presents sediment erodibility results from 6 sites (12 cores) as measured with a Gust erosion microcosm system. Cores were collected between May 16, 2005 and May 19, 2005 in the Passaic River, NJ (see Table 2). Erodibility measurements were conducted within a few hours of core collection to minimize core disturbance and consolidation. Results reported include: erodible mass (kg m^{-2}), critical shear stress, τ_c, for erosion (Pa), and erosion rate constant M (kg s^{-1} Pa^{-1} m^{-2}) for each core. Plots of these results are provided as Figures 2 through 8. Pictures of the Gust erosion microcosm system are depicted in Appendix B of this report.

Undisturbed 10 cm cores were collected at each study site using either a piston push corer (shallow water) or by subsampling from a small box corer. Each core was extruded until the sediment surface was 10 cm from the top of core tube and was then carefully transported by boat to the warehouse space. Erodibility measurements were conducted for each core using a Gust erosion microcosm system (Gust and Mueller, 1997). This system simultaneously measured the erodibility of 2 undisturbed 10 cm sediment cores collected from each study site. A series of seven 20 minute long steps, each with a consecutively increasing shear stress (0.01 Pa, 0.05 Pa, 0.1 Pa, 0.15 Pa, 0.2 Pa, 0.3 Pa, 0.45 Pa), was applied to the sediment surface within these cores by a rotating disc with central suction. The shear stress generated by the rotating disc with central suction was previously calibrated in the laboratory using hot film sensors. The effluent of this system, containing the eroded sediment, was passed through a turbidimeter and collected. The collected effluent water samples were filtered and weighed to determine the actual mass eroded during each step as well as a calibration for the turbidimeter for each step. The calibrated turbidimeter data provided a time series of suspended sediment concentration for each step. Erosion rate (E) was subsequently calculated as the product of pumping rate and suspended sediment concentration.

Data was analyzed using the erosion formulation of Sanford and Maa (2001). This erosion formulation uses a linear erosion rate expression with depth-varying critical stress to describe unlimited (type 2) and limited erosion (type 1), with erosion behavior depending on the rate of increase in critical stress relative to the rate of change of bottom shear stress. This erosion formulation assumes an exponentially decreasing erosion rate for each step (equation 1). Based on this assumption, the erosion rate time series was extrapolated to determine the total erodible mass for each applied shear stress. Using the applied shear stress (τ_b) and total erodible mass, a profile of critical shear stress for erosion was generated. From this profile, the excess shear stress (τ_b - τ_c) at the beginning of the step was determined. The initial erosion rate for each step was then divided by the excess shear stress to calculate the erosion rate constant, M (equation 2). The calculation of M uses observed erosion rates and the actual excess applied shear stress from the erodibility measurements. As a result, values for M could only be calculated for the eroded mass values observed during the erodibility measurements. M values could not be calculated for the extrapolated total erodible mass for each step. Thus, there is not a corresponding M value for all critical stress and erodible mass values.

$$E(t) = E_0 e^{-l\,t} \quad (1)$$

$$\boldsymbol{M} = \frac{\boldsymbol{E_0}}{(t_b - t_{c0})} \quad (2)$$

Table 2 - Locations and station information for 6 sites where cores were collected for erodibilty testing using the Gust erosion microcosm system.

Station	Exp	Cores	Date	Time[EDT]	Latitude	Longitude	depth[m]
9	1	1,2	5/16/2005	15:48	40.73400 N	74.15616 W	2.1
13	2	3,4	5/17/2005	10:24	40.81793 N	74.13080 W	1.5
1	3	5,6	5/17/2005	14:00	40.71175 N	74.12208 W	8.2
3	4	7,8	5/18/2005	12:15	40.74020 N	74.11885 W	2.4
6	5	9,10	5/19/2005	12:36	40.74156 N	74.13439 W	3.1
5	6	11,12	5/19/2005	13:45	40.74040 N	74.13931 W	1.8

Note: The coring location at station 9 was 160 meters east of the originally specified station location; this was necessary because of the sediment conditions and inability to core at the original site locations. It was necessary to adjust some of the other stations due to sediment conditions encountered in the field. In all cases the coordinates shown here should be used as the sample locations.

All Experiments

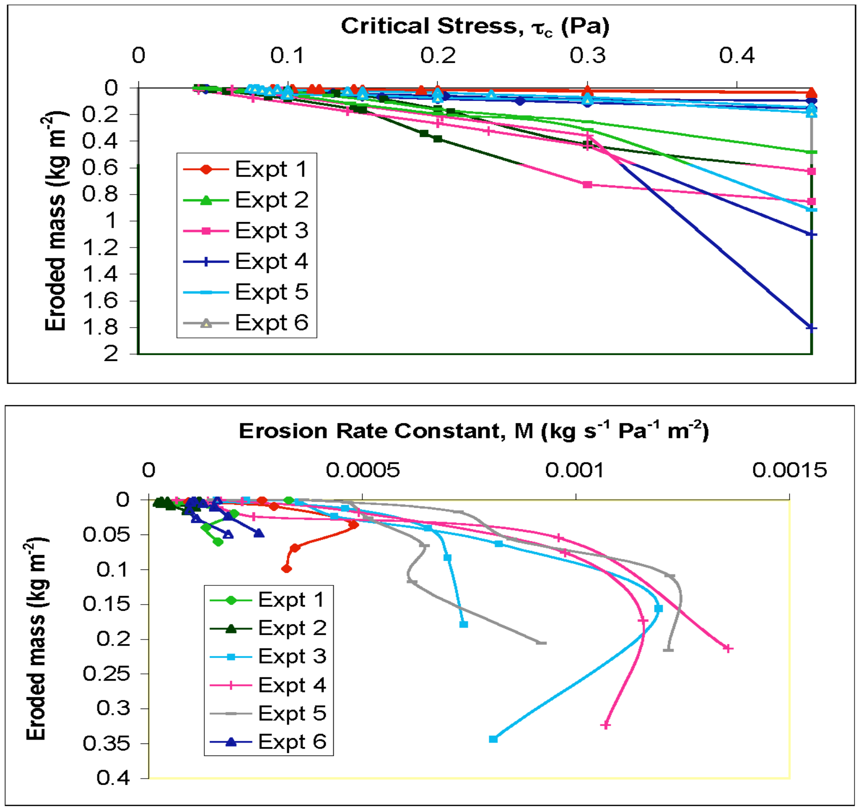
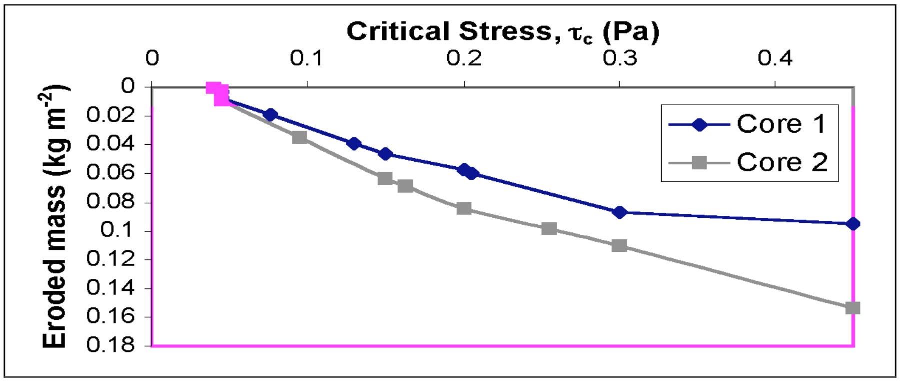


Figure 2- Plot of all 12 cores, from 6 experiments, that were tested using the Gust erosion microcosm system from 10 cm cores collected at 6 sites in the Passaic River, NJ. Upper panel shows profiles of critical stress (τ_c) versus eroded mass which is a measure of depth into sediment bed. Lower panel shows erosion rate constant, M, values for all cores. All units are in MKS (meters-kilograms-second) system.

Experiment 1



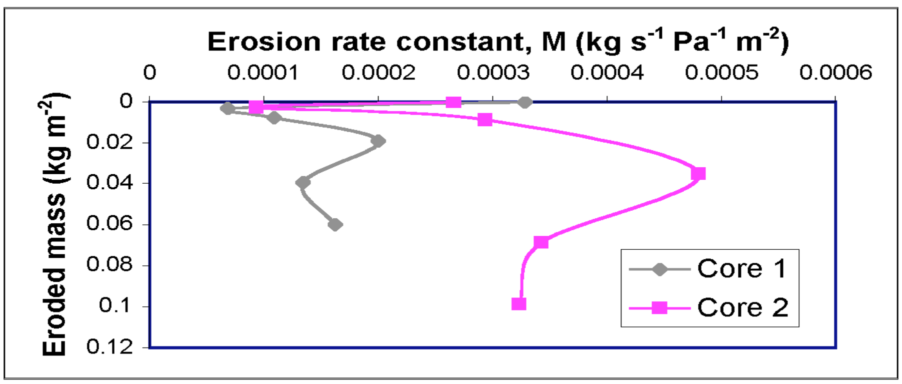
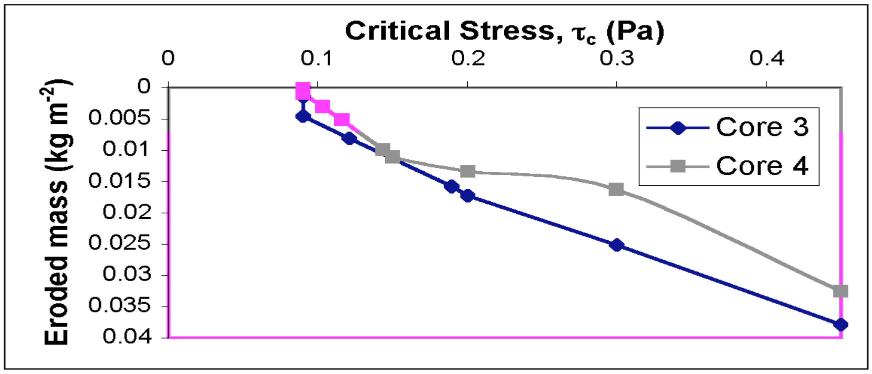


Figure 3 - Critical stress and erosion rate constant profiles for experiment 1, cores 1 and 2. These cores were collected and eroded on May 16, 2005. The cores were taken in the vicinity of station 9, in a water depth of 2.1 meters. See table 1 and figure 1 for additional information.

Experiment 2



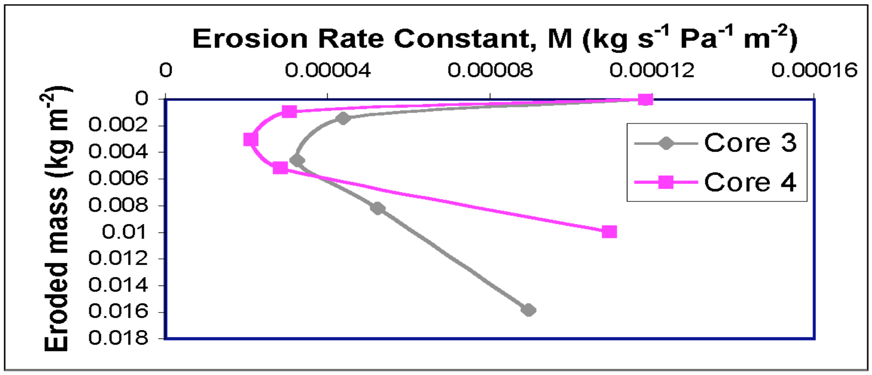


Figure 4 - Critical stress and erosion rate constant profiles for experiment 2, cores 3 and 4. These cores were collected and eroded on May 17, 2005. The cores were taken in the vicinity of station 13, in a water depth of 1.5 meters. See table 1 and figure 1 for additional information.

Experiment 3

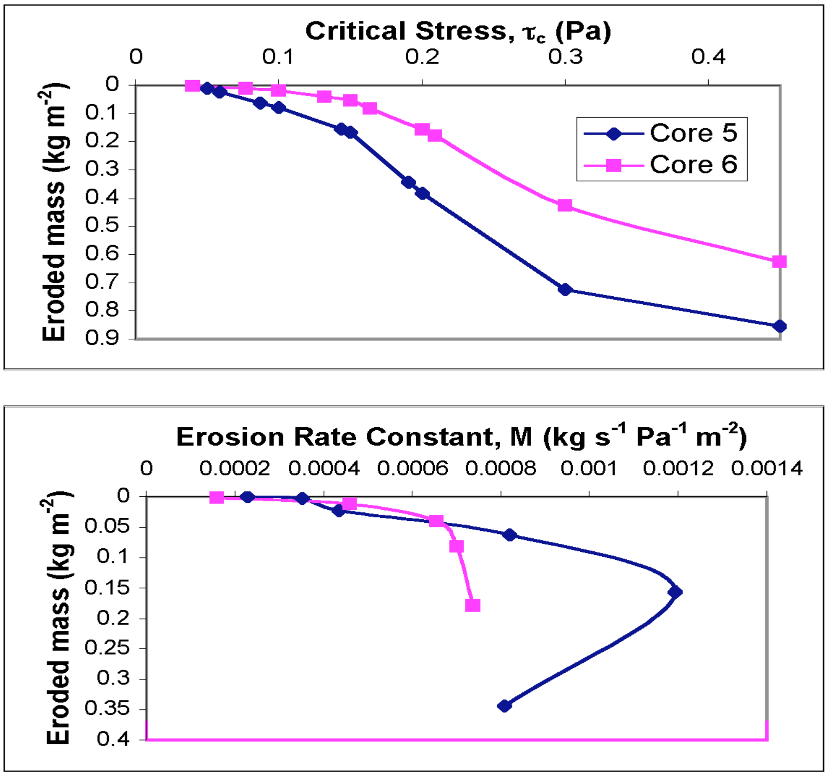


Figure 5 - Critical stress and erosion rate constant profiles for experiment 3, cores 5 and 6. These cores were collected and eroded on May 17, 2005. The cores were taken in the vicinity of station 1, in a water depth of 8.2 meters. See table 1 and figure 1 for additional information.

Experiment 4

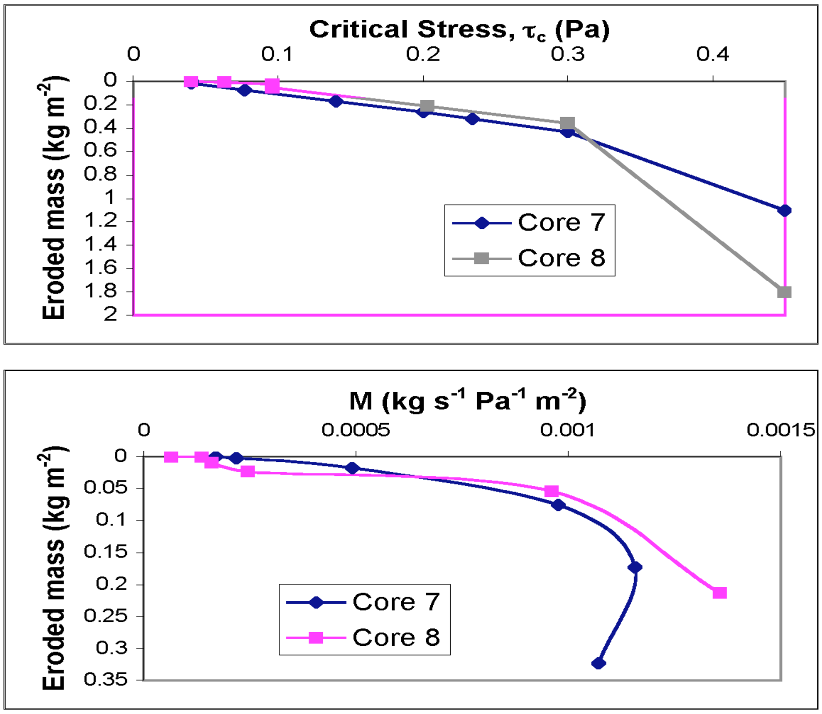
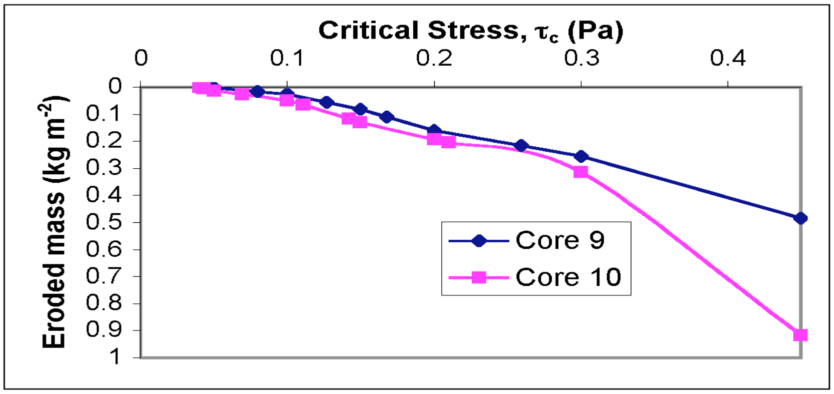


Figure 6 - Critical stress and erosion rate constant profiles for experiment 4, cores 7 and 8. These cores were collected and eroded on May 18, 2005. The cores were taken in the vicinity of station 3, in a water depth of 2.4 meters. See table 1 and figure 1 for additional information.

Experiment 5



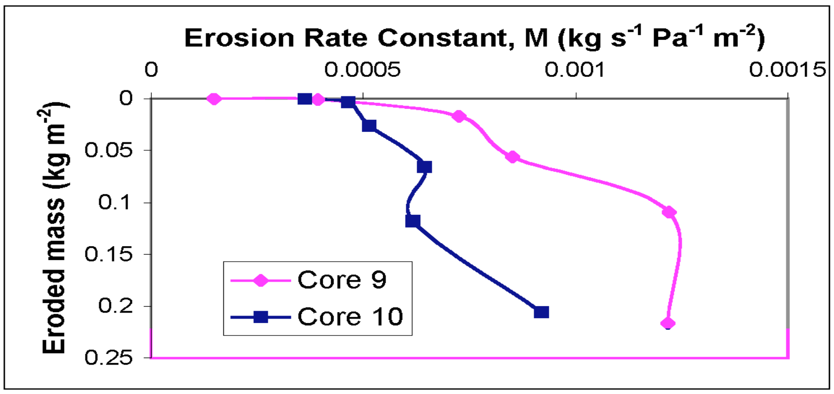


Figure 7- Critical stress and erosion rate constant profiles for experiment 5, cores 9 and 10. These cores were collected and eroded on May 19, 2005. The cores were taken in the vicinity of station 6, in a water depth of 3.1 meters. See table 1 and figure 1 for additional information.

Experiment 6

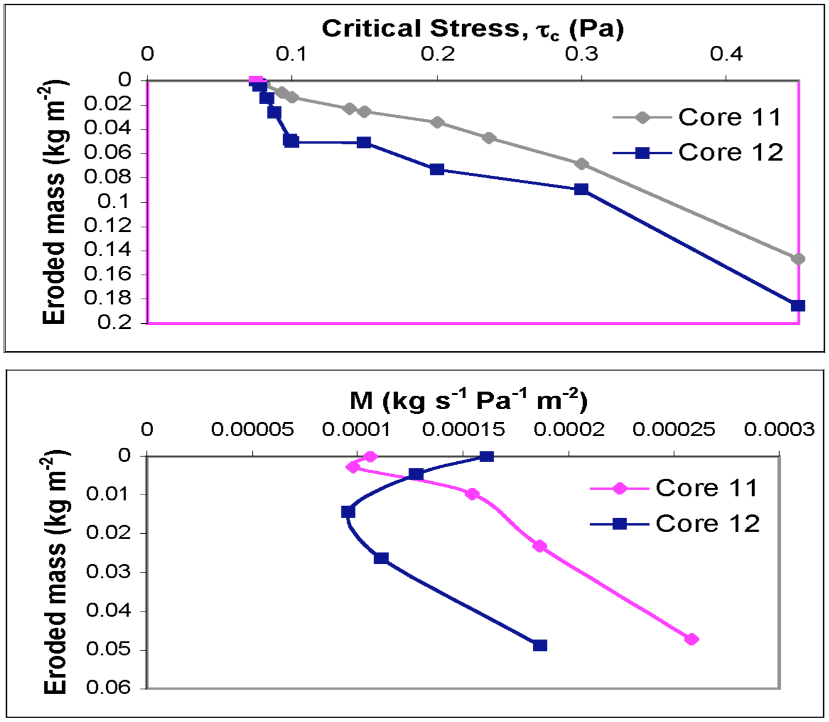


Figure 8 - Critical stress and erosion rate constant profiles for experiment 6, cores 11 and 12. These cores were collected and eroded on May 19, 2005. The cores were taken in the vicinity of station 5, in a water depth of 1.8 meters. See table 1 and figure 1 for additional information.

Results of the Calibration of LISST/CTD/OBS to Water Column TSS

During the sediment core collection, observations of water column particle size distribution were made using from a Laser In-Situ Scattering Transmissometry (LISST) instrument. In addition, observations of water column temperature and salinity were made using from a CTD. Total suspended solids (TSS) were calculated from both the LISST transmissometry and an optical backscatter sensor attached to the CTD by calibrating the readings to collected water samples that were analyzed for TSS in the laboratory. The LISST and CTD were joined together by their protective cages and were lowered through the water column as a package at 14 stations on the Passaic River between May 16, 2005 and May 20, 2005, at sites where sediment cores were being collected for erosion testing. These data were collected for Malcolm Pirnie for other project purposes. This report presents the results of the calibration of these instruments to water column TSS.

Water column profiles using an SBE 19 CTD and a LISST 100-c particle size analyzer were made in the Passaic River at 14 stations where sediment cores were collected for erosion testing. The CTD and LISST were attached together and lowered through the water column as a single instrument package from an 18' CBA research vessel that was used on the project. At a number of sites the coring operation required relocation in the vicinity of the designated site and requiring a couple of hours to get suitable cores. This time lag offset some CTD/LISST cast by 2 hours or more from the time cores were sampled. The CTD/LISST cast at station 9 was 160 meters west of the coring location because the coring location was relocated due to sediment conditions and inability to core at the original site locations where the CTD/LISST cast was taken. The CTD/LISST station information is given in Table 3.

Both the CTD and LISST logged each cast internally at a sampling rate of 1 scan per second (1 hz). All casts were downloaded to a laptop computer at the end of the field work. The CTD data were initially processed with the SeaBird Data processing software 'SBE Data Processing, version 5.25' to convert the hexadecimal raw data files into engineering units. The converted files were quality controlled to remove all points where the instrument was out of the water or had obviously hit the bottom and created a disturbance in the water column. For calibration of the OBS-3 turbidity data to TSS 11 water samples were collected in the field and the TSS was measured in the laboratory using standard methods with GF/F 0.7 micron filters. A regression of OBS turbidity (NTU, 20 point average) and TSS (milligrams per liter) from the bottle samples gave a calibration of NTU to TSS of;

$$TSS,[mg\ L^{-1}] = 1.6404*OBS\_NTU + 4.1168; \text{ with an } R^2 = 0.9258$$

This equation was used to calculate OBS-TSS values.

The LISST data was first processed with the LISST-SOP, version 4.40 by Sequoia Scientific, to determine the sample numbers of the beginning and ending of each cast and the sample numbers of the 20 samples centered around the water sample collections for TSS calibrations. Afterwards a MatLab routine that was originally provided by Sequoia and since modified by others was used to extract the data for each TSS calibration sample. The calibrations were compiled and the LISST transmission value (tau) was calibrated to the TSS of the samples using a logarithmic fit. The calibration was found to be;

$$TSS = -91.259 \text{Ln}(tau) - 8.9868; \quad R^2 = 0.7545$$

Table 3 - Station information for CTD/LISST measurements.

Station	Date	Time[EDT]	Latitude	Longitude	depth[m]
009	5/16/2005	13:59	40.73402 N	74.15805 W	7.3
013	5/17/2005	11:30	40.81793 N	74.13080 W	1.5
001	5/17/2005	15:10	40.71175 N	74.12208 W	7.6
002	5/17/2005	15:38	40.72441 N	74.12008 W	5.5
014	5/17/2005	18:42	40.85859 N	74.11892 W	1.1
004	5/18/2005	9:39	40.74055 N	74.11895 W	3.9
003	5/18/2005	10:11	40.74020 N	74.11885 W	1.4
005	5/18/2005	12:13	40.74040 N	74.13931 W	1.6
008	5/18/2005	14:15	40.73387 N	74.14894 W	5.3
011	5/18/2005	17:36	40.74577 N	74.16591 W	5.5
006	5/19/2005	12:40	40.74156 N	74.13439 W	2.7
007	5/19/2005	12:51	40.74142 N	74.13454 W	2
012	5/19/2005	17:24	40.76400 N	74.16010 W	2.7
015	5/20/2005	10:13	40.85983 N	74.11538 W	1.8

References:

Borrowman, T.D., Smith, E.R., Gailani, J.Z., Caviness, L. 2006. "Draft Erodibility Study of Passaic River Sediments", Project Report, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Gust, G. and V. Mueller (1997). Interfacial hydrodynamics and entrainment functions of currently used erosion devices. Cohesive Sediments. N. Burt, W. R. Parker and J. Watts. New York, John Wiley and Sons: 149-174.

Sanford, L. P. and J. P.-Y. Maa (2001). "A unified erosion formulation for fine sediments." Marine Geology 179(1-2): 9-23.

Appendix A: Field Descriptions of Sediment Cores Collected for Other Project Purposes

Site 1 - Collected May 17, 2005 in 8.2 meters of water. Box corer was deployed and was successful in retrieving 25-30cm of sediment. Sediment was very fine-grained and flocculent at the surface. No visual change in grain size apparent down to 30 cm.

Site 2 – Collected May 17, 2005 in 5.5 meters of water. Box corer was deployed and was successful in retrieving 20-30cm of sediment. Sediments were very fine grained and similar to station 1 with no visual down core change in grain size observed.

Site 3 - Collected May 18, 2005 in 2.4 meters of water. Box corer was deployed and was successful in retrieving 15-25cm of sediment. Fine-grained sediment with some leafy detritus mixed in. Sediments were fine grained down to 25 cm with no visual change in grain size.

Site 5 – Collected May 18, 2005 in 1.8 meters of water. Box corer was deployed and was successful in retrieving 15-20cm of sediment. Fine grained sediment with some sand mixed in. Sediments had no visual change in grain size down core.

Site 8 - Collected May 18, 2005 in 5.5 meters of water. Box corer was deployed and was successful in retrieving 20-30cm of sediment. Sediments were fine-grained and consistent in grain size down core with some leaf detritus mixed in.

Site 11 - Collected May 18, 2005 in 5.2 meters of water. Box corer was deployed and was successful in retrieving 25-35cm of sediment. Very fine grained sediment consistently down to 35cm in the core. No visual change in grain size.

Site 12 - Collected May 19, 2005 in 3.1 meters of water. Box corer was deployed and was successful in retrieving 20-30cm of sediment. Sediments were fine-grained at surface but appeared to have a mixture of sand and fine-grained material at depth.

Site 15 - Collected May 20, 2005 in 1.8 meters of water. Box corer would not penetrate at this site. Pole corer was used to collect sediment cores to a depth of 20-25cm. Very fine surface sediment down to about 2-3 centimeters and then a very distinct change to mostly sand down to 15 centimeters. Below the sand layer there appeared to be another fine-grained layer of sediment that was black and had the aroma of hydrocarbons.

Appendix B: Pictures of the Gust erosion microcosm system