Virginia Tech

Soil Genesis and Mined Land Reclamation

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Annual Monitoring Report for 2010 Calendar Year
Weanack Dredge Spoil Utilization

To: Raymond Jenkins, Virginia DEQ, Piedmont Regional Office

From: W. Lee Daniels and G. Richard Whittecar (Old Dominion Univ.)

Re: Weanack Ground & Surface Water Monitoring for VPA Permit No. VPA00579

Date: **February 22, 2011**

Cc: Mike Baker, PCC
Charles Carter, Weanack
Charles Saunders, Marshall Miller & Assoc.

This memorandum and associated maps, attachments and data sets comprise our Annual Monitoring Report for all work conducted in **calendar year 2010** for ground and surface water monitoring, hydrogeologic modeling and beneficial use study requirements for VPA Permit No. VPA00579 at Weanack Land LLP in Charles City County. The original monitoring plan submitted to DEQ by American Land Concepts (ALC) in November, 2000, focused on the Woodrow Wilson Bridge (WWB) sediment utilization area (Fig. 1). This approved monitoring plan served as the basis for our protocols and designs through mid 2004. On September 7, 2004, Virginia DEQ approved a modification to the monitoring plan as outlined below that reduced the number of water quality sampling points and frequency. Subsequently, in June 2005, DEQ approved further modifications to the permit and monitoring requirements to allow placement of a new source of dredge materials (Earle Naval Weapons Station - Earle) into a separate utilization basin as shown in Fig. 2. In July of 2005, modifications to the Operations and Maintenance Manual and Monitoring Plans for both utilization areas were approved by DEQ.

In 2006, permit coordination and liaison responsibilities for this permit were transferred from ALC to Marshall Miller & Associates (MMA) who we have worked with closely over the past four years. Virginia Tech and Old Dominion University (ODU) continue to serve as subcontractors to Weanack Land LLP to carry out monitoring and research as specified in the approved plans. In 2010, additional dredge materials (Approximately 69,000 cubic yards) from the Cheatham Annex on the York River were deposited over the surface of the Earle Basin as described below. This report includes data and analyses relative to both utilization areas (WWB and Earle+Cheatham) in 2010 plus an overall assessment of site hydrologic conditions for both basins as detailed later.

Over the 2010 monitoring year we continued limited monitoring of a project installed by Science Applications International Corporation (SAIC) and the Norfolk District of the U.S. Army Corps of Engineers. This project is a small (35 x 120 feet) dredge sediment field experiment adjacent to the

Earle Basin that is knows and the Landfarm Pilot Study (LPS). The SAIC/LPS study plan was approved on 7/25/07 to assess the ability of surfactants plus an added microbial consortium to degrade moderately contaminated (with PAH's) sediments from the nearby Appomattox River. A separate and detailed report on that project has presumably been submitted to DEQ by SAIC. In the fall of 2010, we sampled the soils within the LPS experimental cells and analyzed them for PAH's and those data are presented later in this report.

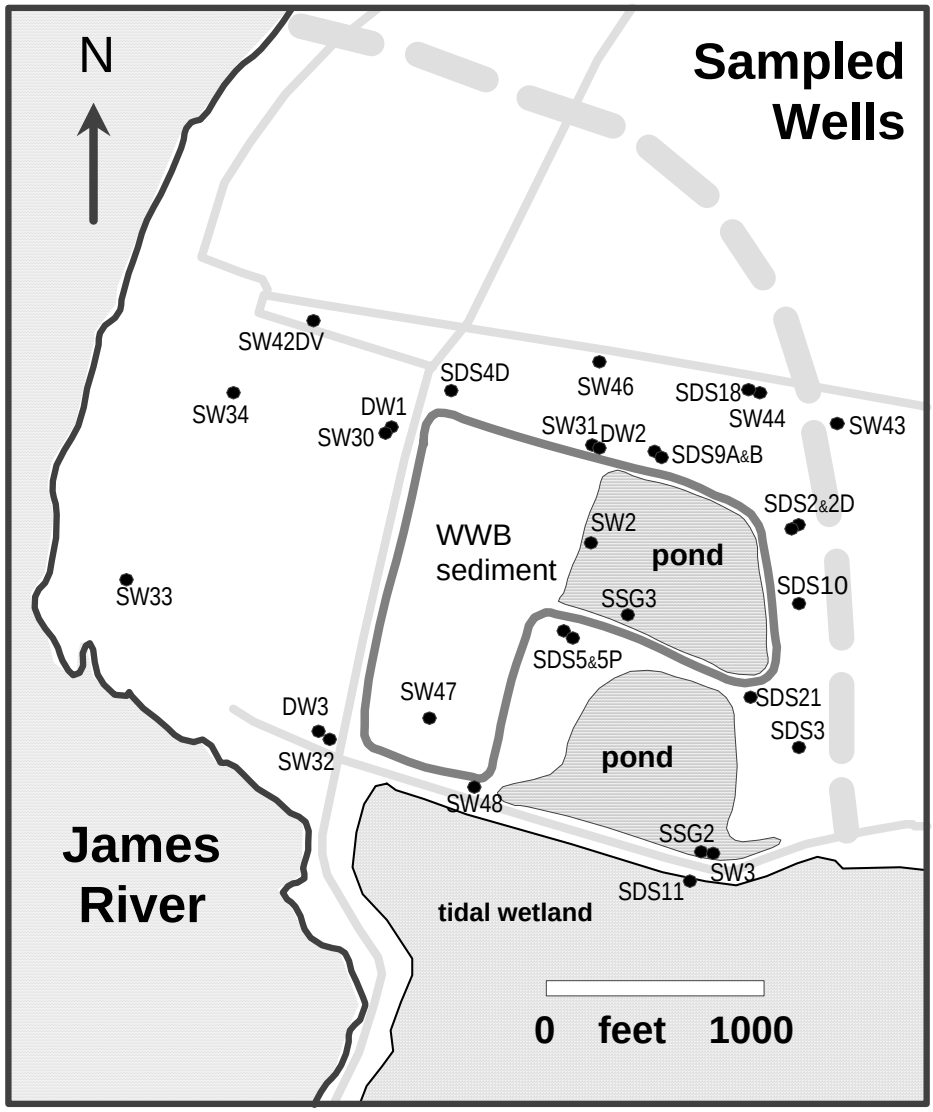


Figure 1. Map of basin location and monitoring wells around the Woodrow Wilson Bridge (WWB) sediments discussed in this report. The Shirley Plantation drinking well (SP) in the NW corner of the map area was also sampled but is not shown. The dashed line corresponds to a local terrace scarp which defines the base of older river sediments to the West. Please note that this map shows all wells installed over time around the WWB basin. Monitoring locations are detailed below.

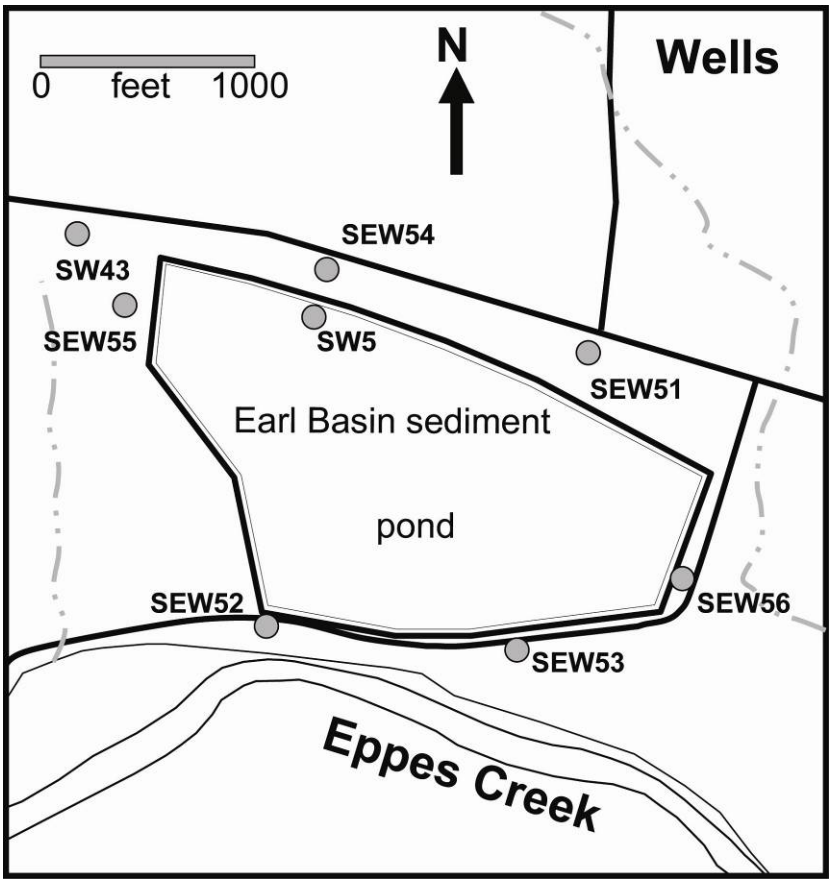


Figure 2. Map of basin location and monitoring wells sampled around the Earle sediment basin as discussed in this report. The WWB basin lies to west, across the ephemeral drain shown running south towards Eppes Creek. FYI: The LPS project is located to the southeast of well SEW 51 and approximately 50 feet uphill from the original edge of sediments deposited into this basin. Another monitoring well (SEW 57) is not shown on this figure but lies just downgradient from the LPS cells very close to the NE corner of the Earle pond boundary.

Finally, in 2010 we also installed another monitored dredge sediment experiment with potentially acid-forming materials from the Maryland Ports Authority (MPA) Cox Creek facility near Baltimore. This experiment is located directly adjacent (east) to the LPS experiment within the Earle Basin permit area. Details on the monitoring regime and results from this experiment are also discussed later in this report.

Water Quality Monitoring Methods

WWB Monitoring Locations

Under the approved 9/7/04 monitoring plan revision for WWB, we reduced our routine monitoring frequency for temperature, pH, EC, and DOC to quarterly (Jan/Apr/July/Oct). Furthermore, our detailed water quality sampling locations were modified from all wells available on-site to a minimum of the six specified below. These locations and labels were further clarified via Email and

memo interactions with DEQ over the summer of 2006 and were also detailed in an O&M Manual revision submittal (Oct. 2009) by Marshall Miller & Associates

Upgradient ground-water wells: **SDS 3 and SW 43**

Downgradient ground-water wells**: SW 30 and SW 31**

Surface water: **SW2** has been sampled over time from the continuous water body present within the dikes (SSG3 is the staff gage reading in that pond). The old mining slimes pond to the south of the WWB basin has been dry for the vast majority of sampling dates since 2005, and therefore reporting on that location (SSG 2/SW 3) was discontinued.

Owner's drinking well: **SP-well** (reported with Earle array in this report)

The locations specified above were sampled for detailed "partial suite" of water quality analyses in October of 2010 as set forth in Table 6 of the revised O&M Manual.

Earle Monitoring Locations

Procedures and rationale for the location, installation and sampling of the primary water quality monitoring points for the Earle Basin were included in the 2005 permit revision materials, the 2006 annual report and the October 2009 revisions to the O&M Manual. The following set of locations (see Fig. 2) was used for "partial suite" sampling and analysis in October of 2010.

Upgradient ground-water wells: **SEW 51 and SEW 54**

Downgradient ground-water wells: **SEW 52 and SW 53**

Surface water: **SW 5** is sampled from within the Earle Basin ponded portion as shown in Fig. 2.

In addition to the detailed sampling events described above, we conducted routine quarterly monitoring (Jan/Apr/July/Oct) of wells around the WWB and Earle Basin sites for water level, pH, conductivity, temperature, and DOC.

Inbound Dredge Spoil Testing

Over the summer of 2010, approximately 69,000 cubic yards (*in situ*) from the U.S. Navy Cheatham Annex facility near Yorktown were placed at Weanack into the Earle Basin. We reviewed the properties of the materials against our dredge spoil quality template in 2009 and confirmed that based on in situ sampling, the materials were suitable for upland placement at Weanack. Following approval by DEQ, the materials were barged from Cheatham to Port Tobacco at Weanack and placed hydraulically over the pre-existing Earle Basin sediments.

We cooperated with the dredging contractor (Cashman) to ensure that composite samples were obtained for every 30,000 yards of material excavated and that appropriate splits of those samples were shipped to our lab (Virginia Tech) for potential acidity testing and to Air, Water and Soil Laboratories (AWS) in Richmond for the required "sediment full suite" testing. A total of 27 barges were loaded and moved to Weanack and two separate composite samples were provided to both labs by Cashman. The Virginia Tech data for potential acidity as determined by the peroxide oxidation technique (PPA) and the AWS data are presented in Attachment 1.

The potential acidity data (Attachment 1) indicate that while the Cheatham materials will be expected to be slightly acid forming with time, they are within the normal range of liming (e.g. 1 to 5 tons per acre furrow slice or 1000 dry tons) of agricultural soils. Examination of the AWS full suite data (Attachment 1) indicates no exceedances of our inbound sediment quality criteria. The only elevated parameters are sodium and chloride as expected with saline source materials.

Hydrogeologic Analyses and Results for 2010

Well Maintenance and Hydrogeologic Analyses

Virginia Tech and ODU maintained the well sites around the existing basin containing the Woodrow Wilson Bridge (WWB) and Earle Basin sediments. We conducted routine quarterly monitoring (Jan/Apr/July/Oct) of wells and ponds around the WWB and Earle Basin sites for water levels, pH, conductivity, temperature, and DOC. We collected water samples at the WWB site and the Earle Basin for a "partial suite" of analyses in October 2010.

Water flow analyses for the two basins are combined on one map (Figure 3) due to the close proximity of the basins. This more comprehensive view gives a larger perspective of the relationships of water flow through this topographically and stratigraphically complex setting.

Woodrow Wilson Bridge site

After dropping through 2009 to a record low (8.7 feet) by October, water levels in the pond inside of the WWB berm (measured at SSG3) rose more than 2 feet by April before dropping about one foot by October. Pond levels are maintained by a combination of direct precipitation and groundwater inflow from the sediment mound deposited in the western end of the disposal area. Water levels in most monitoring wells rose and fell in same general pattern throughout the year. These changes reflect strong recharge during the winter of 2009-10, as well as seasonal evaporation.

Analyses of water flow direction for the WWB disposal site shown in Figure 3 indicate no important change in flow directions from previous analyses, despite the general lowering of the water table system due to the drought. As is usual, minor changes were observed over time and over short distances. Shallow wells and wells close to storm water drainage ditches proved to be the most responsive to rainfall events, being the most likely to rise after one of the few rain

showers. The close relationship between the shape of the berm and groundwater contours reflects the permeable connection between the fill sediments, the pond, and surrounding aquifer. Variations in hydraulic conductivity of these permeable sediments over short distances cause the locally steep gradients in the water table.

Earle Basin site

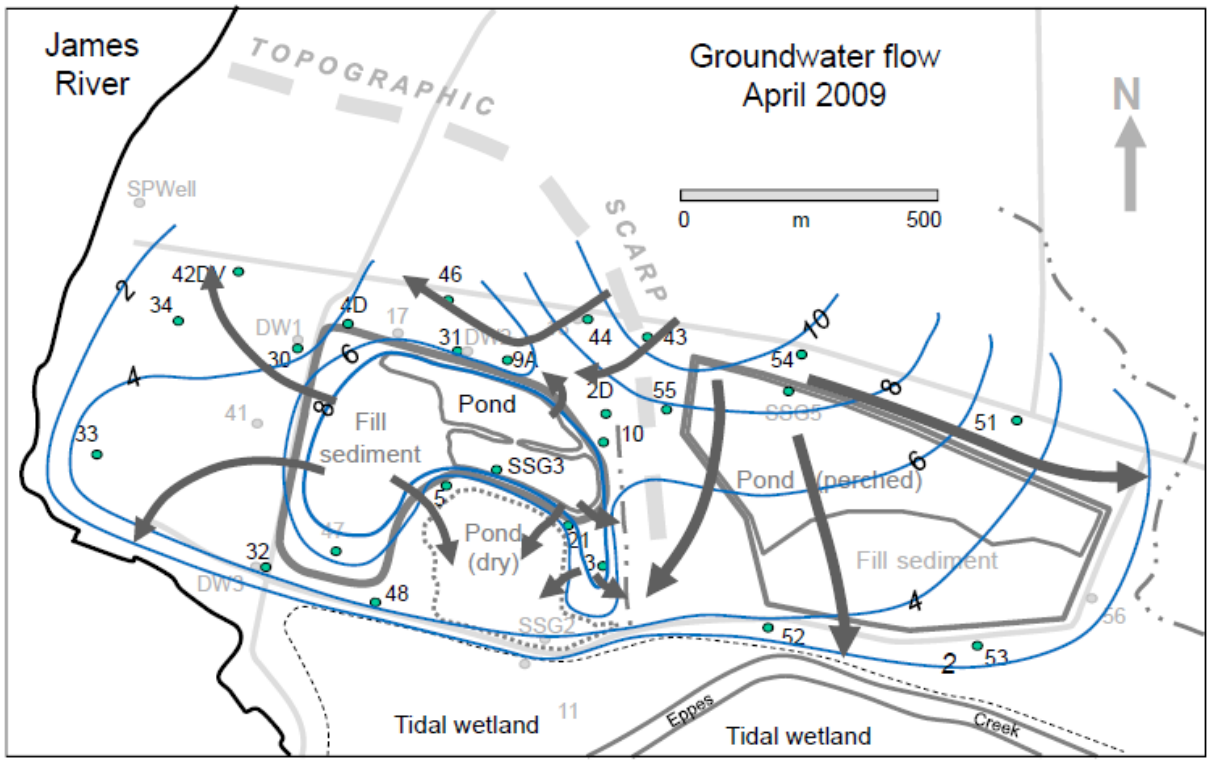
The groundwater flow analyses of the Earle Basin site (Figure 3) also show no important change in flow directions from previous analyses. Overall, water levels in the pond inside of the berm (measured at SSG5) rebounded from their lows in October 2009 to 26.2 feet by January 2010; except for a summertime decline of a couple of feet, measured water levels remained relatively constant. Water levels in monitoring wells indicate disposal pond water does not influence the groundwater flow patterns surrounding the Earle Basin sediments in any measurable way. The clay-rich substrate across the floor of the basin, purposefully compacted and smeared to reduce its permeability, effectively retains most basin water. The gentle ground water ridge that lies several meters below the level of the pond existed before the sediment basin was constructed and our data do not indicate that it has changed in any important way due to the filling of the basin.

The water pH and conductivity readings for the monitoring wells around the Earle Basin are values typical for groundwater in this hydrogeologic setting. The water in the Earle Basin sediment retention basin is brackish, reflecting the pore water quality of the estuarine sediments placed in the basin. Fluctuations in pH and EC values during the year also reflect the influence of rainfall events within a few days of sampling times, as well as the dry conditions during much of the year.

The one exception is that the conductivity values for SEW53 - the down-gradient monitoring well closest to the disposal area – continued to increase during 2010. From July 2007 to October 2010 it has risen from relatively stable values of approximately 300 μS to 2460 μS. This trend suggests that seepage water from the basin has reached that monitoring well site. This conclusion is supported by the elevated chloride levels at this location as discussed later in the water quality results section. Water quality readings in the other down-gradient well (SEW 52) are still within the range of values common in aquifer water in this study area.

Due to the disparity in conductivity between the two downgradient wells (SEW 52 and 53), we (via a contractor) are currently conducting an electromagnetic survey study of the shallow groundwater surface in an attempt to determine the extent of potentially elevated conductivity in local groundwater. Once that effort is completed, we will install at least one additional groundwater monitoring well to better document downgradient water quality. Once that well is developed, we will sample all three downgradient wells again and run a limited suite of parameters (pH, EC, DOC, Na, Cl, etc.) to better establish the nature and extent of the salinity migration.

Figure 3. Ground water flow around the disposal site for the Woodrow Wilson Bridge sediments (western disposal basin) and the Earle Basin sediments (eastern disposal basin). Wells are marked with the number of their label; wells and ponds marked with grey labels were not used in the analysis of flow on this day (04/30/09). Contours show the shape of the water table surface and are in feet elevation. Grey lines denote roads, creeks, and the compacted sediment berms that contain the disposal sediment. The large dashed line notes location of a distinct scarp between a higher terrace that underlies the Earle Basin and the lower terrace that underlies the Woodrow Wilson Bridge sediment disposal site.



Detailed Water Quality Results for 2010

As described earlier, the monitoring wells around the WWB and Earle Basins were sampled quarterly in 2010 for water level, pH, EC and DOC and for "partial suite analyses" in October. The full data sets for all monitoring are presented in Attachment 2.

Woodrow Wilson Bridge Basin

Water quality results for the October 2010 "partial suite" analyses are presented in Attachment 2. Other than the somewhat elevated iron and sulfate levels seen in several up- and down-gradient wells due to native sulfide oxidation in the Shirley Formation (as discussed in previous reports), no significant water quality degradation or change is noted. The drinking well at the Shirley

house (SP well) is also sampled per the WWB monitoring protocol. Those data are included with the Earle data set in this report due to the fact that we analyzed them for the more complete set of parameters associated with the Earle partial suite requirements.

Earle Basin

The water pH, conductivity and DOC levels (Attachment 2) for the monitoring wells around the Earle Basin continue to be typical for groundwater in this hydrogeologic setting. The water in the Earle sediment retention basin is brackish, reflecting the pore water quality of the estuarine sediments placed in the basin. This was also amplified over the summer of 2010 by the addition of the saline source Cheatham sediments within the basin. Fluctuations in pH and EC values during the year also reflect the influence of rainfall events within a few days of sampling times, as well as the dry and hot conditions during much of the summer.

The one exception is that the conductivity values for SEW53 - the down-gradient monitoring well closest (~ 75 feet) to the disposal area – continued to increase during 2010 as noted earlier. The observed Cl levels in well SEW 53 (823 mg/L) are above the secondary drinking water standard (250 mg/L) and continued to rise above the October 2009 levels (378 mg/L).

Several of the up- and downgradient wells for the Earle also exhibited moderate levels of iron and sulfate which we believe are due to similar oxidation of sulfides in deeper strata as discussed in previous years' reports.

LPS Study Plots

In 2010, we maintained the vegetation on the LPS cells via periodic mowing and allowed to the PAH contaminated Appomattox River sediments to continue in situ degradation. In December, we took composite soil/sediment samples from the four half-cell locations (East and West; vegetated on non) and submitted them to AWS for low-level PAH analysis. Those data are reported in Attachment 3 and indicate that while there has been little further degradation of Benzo(a)pyrene over the past two years, the other major PAH of concern, Dibenzo(a,h)anthracene, has been degraded to levels below detection.

In March of 2010, we extracted water from the zero tension lysimeters below the two main cells (East - A and West - B) with the following results:

	pH	EC*	NO_3-N	Ortho-P	NH_4-N
LPS East (1 and 2 in Attach. 3:	4.60	1.00	98.5	0.38	0.035
LSP West (3 and 4 in Attach. 3):	4.72	0.32	16.8	0.14	0.058

*mmhos/cm; N and P reported in mg/L

These data indicate that issues with the large amounts of fertilizer-N that were added to drive microbial bioremediation persist to some extent as noted in earlier reports. We will continue to monitor this experiment for at least the next six nine months.

MPA Study Plots

A research paper detailing our work and monitoring on the MPA experiment is included in Attachment 4. This paper is currently under anonymous referee review and will be presented at the 2011 National Meetings of the American Society for Mining and Reclamation in Bismarck ND in June. Overall, our findings confirm that we do need to be concerned about the importation of net acid-forming dredge materials into an upland environment. While our results do indicate that we can successfully predict how much agricultural lime will need to be bulk-blended with these materials, it is also clear that the acid neutralization process will generate significant amounts of sulfate salts that will amplify salinity-related revegetation limitations for some period of time. The levels of Fe and Mn leaching below the MPA sediments as captured in our zero-tension lysimeters are also of concern.

Our permit requires that the leachates from the MPA cells are captured in a holding tank and treated to limit Fe and Mn before release over the surface of the Earle Basin sediments. In late November of 2010, we collected a water sample from the holding tank and determined the following properties:

Total Al: 5.3 ppm
Total Fe: 0.04 ppm
Total Mn: 77.8 ppm
Total S: 900.6 ppm
EC: 4.18 mmhos cm^{-1}
pH: 4.68

These data indicated to us that Fe did not appear to be an issue with this leachate and that if we raised the pH of the solution to > 8.5 prior to release that Mn would be precipitated as well. On January 31, 2011, under our direction, Mr. Charles Carter added lime to the 3100 gallon storage tank below the MPA plots until he was able to confirm (via pH test strips) that the pH was stabilized between 8.5 and 9.0 and then released the treated water into the surface of the Earle Basin.

Soil Formation/Beneficial Use Conversion Studies

Vegetation Establishment on Amended Saline Dredge Materials

In 2009, per our monitoring agreement with DEQ, we installed a replicated revegetation experiment on the Earle Basin sediments as described below. The Earle sediments are much higher in soluble salts than those in the WWB basin due to their marine origin. Thus, our primary goal in this new research effort is to determine the best ways of amending and converting them into usable agricultural soils. This work is designed and supervised by Dr. Abbey Wick who is working with us as a post-doctoral Research Associate.

Crop establishment on the Earle Basin sediments is challenging not only because of soluble salt influences on plant establishment and growth, but also because of adverse physical properties (e.g. high silt and lack of structure) of the dredge material. There are two "active" approaches feasible to the situation at Weanack, where use of locally available soil resources is highly desirable. The first is the addition of a topsoil cap (approximately 20 cm) from nearby topsoil stockpiles and berms.

This will provide a growth medium suitable for root development of a cover crop followed by succeeding annual crops or perennial vegetation. The second solution is to utilize stockpiled sand dredged from the James River channel and mix this material with the surface of the Earle dredge material to achieve 15-30% sand by volume. Salt leaching from the surface of the dredge material and macroporosity would be improved by this approach. A more "passive" approach is simple surface tillage of the existing sediments.

Overall Project Objectives:

-To evaluate the influences of: (1) a topsoil cap over the Earle Basin dredge material vs. (2) sand incorporation into existing Earle Basin dredge material on cover crop establishment followed by annual crops or perennial vegetation .

-To evaluate the effects of additions of: (1) compost + N + P fertilizer and (2) standard N + P fertilizer applications on each soil treatment via split plot applications on cover crop establishment and succeeding annual crops or perennial vegetation.

Last year's Annual Report contained significant details on the overall procedures utilized to install and monitor this experiment. A detailed scientific paper detailing our results to date is included in Attachment 5. This paper is currently under anonymous refereed review and will be presented at the 2011 National Meetings of the American Society for Mining and Reclamation in Bismarck ND in June.

We intend to continue managing and documenting this experiment over the next several years, but we need to determine whether or not sediments+water from the 2010 Cheatham event have affected any of the plots. At this point in time, preliminary soil sampling around the lower edges of the experiment indicates that this is not an issue.

Overall Monitoring Summary

Our overall long-term conclusion remains that the WWB materials appear benign with respect to potential ground- or surface water degradation. We have yet to detect any significant contaminants in inbound dredge spoils, dewatered dredge soils, or water samples in and around the disposal/utilization area. The elevated levels of iron and sulfate observed in 2007 through 2009 remain in several wells, but do not appear to be related to dredge placement activities.

The surface of the Earle Basin is now dominated by the recent addition of 69,000 yards of fresh saline source dredge materials from the Cheatham Annex at Yorktown. These materials were extensively tested as they were shipped to Weanack and are low in potential contaminants relative to our established dredge material quality screening criteria. The Earle+Cheatham materials differ from the WWB dredge sediments in that they contain a much higher inbound salt load, are slightly higher in total heavy metals, and do contain detectable levels of certain organics (PAHs) as discussed in previous reports. Future soil and water quality monitoring efforts will be focused on these parameters to determine net degradation, attenuation, or any potential for movement with time.

It does appear that bulk soluble salts (particularly Cl) from this basin have migrated a relatively short distance to one of the downgradient wells (SEW 53). The ponded water within the Earle Basin remains high in salts (Cl and SO_4), but the pH of both the surrounding reclaimed sediments and surface declined as expected until the Cheatham materials arrived in mid-summer of 2010.

Despite their initially saline nature, dewatered Earle basin sediments have been converted to support conventional agricultural cropping practices and their near-surface pH and salinity levels are dropping over time. The Woodrow Wilson Bridge sediments continue to be cropped by the local farmer and produce yields typical of surrounding prime farmlands.

Acknowledgments

We deeply appreciate the continuing support of Mr. Charles Carter of Weanack/Shirley and Mr. Mike Baker of Potomac Crossing Consultants/Woodrow Wilson Bridge Project in our efforts. The assistance in the field of Julie Burger, Nick Haus, Marjorie Howren, Steve Nagle, W.T. Price, Emmett Rafferty, Wesley Powell, Matt Richardson, Dani Morgan-Smith, Tanique Rush, and Abbey Wick was also essential to our continuing efforts. The sediment and water data sets contained herein were compiled by Kathryn Haering and Sue Brown. Finally, thanks to Chee Saunders of Marshall Miller & Associates for coordination of permit monitoring requirements and to Carmela Tombes of Air, Water & Soil Labs in Richmond for assistance with the waters quality analyses.

ATTACHMENT 1

Inbound Cheatham Sediment Analyses

Potential Peroxide Acidity (PPA) by Va Tech

PPA results = Tons $CaCO_3$/1,000 Tons material

Date	Sample ID	PPA
7/22/2010	Scow #1	1.12
	Scow #2	1.77
	Scow #3	1.45
	Scow #4	1.05
	Scow #5	1.56
	Scow #6	1.31
	Scow #7	1.72
	Scow #8	2.76
	Scow #9	1.25
	Scow #10	1.07
7/29/2010	Scow #11	1.88
	Scow #12	0.91
	Scow #13	5.79
	Scow #14	4.14
	Scow #15	2.44
	Scow #16	2.10
8/5/2010	Scow #17	1.43
	Scow #19	1.46
	Scow #20	5.74
	Scow #21	1.20
	Scow #22	3.06
	Scow #23	1.72
	Scow #24	1.27
	Scow #25	1.39
	Scow #26	2.58
	Scow #27	1.46

Weanack Sediment **Sample ID: SCOW 1-16**
Cheatham Barge Composite **Date: 7/29/10**

Parameter	Methods	Units	Test Results	Reporting Limit

Chloride	EPA300.0/R2.1	mg/kg	8580	120
Cyanide	SM18/4500-CN E	mg/kg	<2.4	2.4
Nitrate	Calculated	mg/kg	<24	24
Nitrate+Nitrite	SM18/4500-NO3 F	mg/kg	<24	24
Nitrite	SM18/4500-NO2 B	mg/kg	<4.8	4.8
Phosphorus, Ortho	SM18/4500-P E	mg/kg	12.6	9.6
Sulfate	EPA300.0/R2.1	mg/kg	668	120
Sulfide	SW9030B	mg/kg	429	120
TKN	EPA351.2/R2.0	mg/kg	429	120
Total Organic Carbon (TOC)	SW9060A	mg/kg	14,100	479
2,3,7,8-TCDD	EPA 1613B	pg/g	<1.00	1.00
Asbestos	EPA 600/M4-B2-020	%	<1%	1%

Weanack Sediment **Sample ID: SCOW 1-16**
Cheatham Barge Composite **Date: 7/29/10**

Metals

Parameter	Methods	Units	Test Results	Reporting Limit
Aluminum	SW6010C	mg/kg	7500	5.99
Antimony		mg/kg	<12	12
Arsenic		mg/kg	6.17	1.2
Barium		mg/kg	23.2	1.2
Beryllium		mg/kg	2.71	1.2
Cadmium		mg/kg	<1.2	1.2
Calcium		mg/kg	1550	5.99
Chromium		mg/kg	20.9	1.2
Copper		mg/kg	10.6	1.2
Iron		mg/kg	18,900	1.2
Lead		mg/kg	13.8	1.2
Magnesium		mg/kg	4260	1.2
Nickel		mg/kg	10.7	1.2
Potassium		mg/kg	2930	24
Selenium		mg/kg	<5.99	5.99
Silver		mg/kg	<1.2	1.2
Sodium		mg/kg	9,980	24
Thallium		mg/kg	<5.99	5.99
Zinc		mg/kg	70.5	1.2
Mercury	EPA 7471B	mg/kg	0.127	0.022

Weanack Sediment **Sample ID: SCOW 1-16**
Cheatham Barge Composite **Date: 7/29/10**

Pesticides & PCBs

Parameter	Methods	Units	Test Results	Reporting Limit
2,4-D	EPA 8151A	µg/kg	<12	12
2,4,5-TP (Silvex)		µg/kg	<12	12
2,4,5-T		µg/kg	<12	12
Dinoseb		µg/kg	<12	12
Pentachlorophenol		µg/kg	<12	12
PCB as Aroclor 1016	SW8082	mg/kg	<0.2	0.2
PCB as Aroclor 1221		mg/kg	<0.2	0.2
PCB as Aroclor 1232		mg/kg	<0.2	0.2
PCB as Aroclor 1242		mg/kg	<0.2	0.2
PCB as Aroclor 1248		mg/kg	<0.2	0.2
4,4'-DDD	SW8081A	µg/kg	<14.4	14.4
4,4'-DDE		µg/kg	<9.58	9.58
4,4'-DDT		µg/kg	<958	958
Aldrin		µg/kg	<4.79	4.79
alpha-BHC		µg/kg	<4.79	4.79
beta-BHC		µg/kg	<4.79	4.79
Chlordane		µg/kg	<95.8	95.8
delta-BHC		µg/kg	<9.58	9.58
Dieldrin		µg/kg	<9.58	9.58
Endosulfan I		µg/kg	<9.58	9.58
Endosulfan II		µg/kg	<14.4	14.4
Endosulfan sulfate		µg/kg	<4.79	4.79
Endrin		µg/kg	<9.58	9.58
Endrin aldehyde		µg/kg	<19.2	19.2
gamma-BHC (Lindane)		µg/kg	<4.79	4.79
Heptachlor		µg/kg	<4.79	4.79
Heptachlor epoxide		µg/kg	<95.8	95.8
Methoxychlor		µg/kg	<9580	9580
Toxaphene		µg/kg	<95.8	95.8

Weanack Sediment **Sample ID: SCOW 1-16**
Cheatham Barge Composite **Date: 7/29/10**

Semi-volatile Organics

Parameter	Methods	Units	Test Results	Reporting Limit
Benzoic acid	SW8270D	µg/kg	<1200	1200
4-Chloro-3-methylphenol		µg/kg	<1200	1200
2-Chlorophenol		µg/kg	<1200	1200
m.p.-Cresols		µg/kg	<1200	1200
o-Cresol		µg/kg	<1200	1200
Cresols, Total		µg/kg	<1200	1200
2,4-Dichlorophenol		µg/kg	<1200	1200
2,6-Dichlorophenol		µg/kg	<1200	1200
2,4-Dimethylphenol		µg/kg	<1200	1200
4,6-Dinitro-2-methylphenol		µg/kg	<1200	1200
2,4-Dinitrophenol		µg/kg	<1200	1200
Ethyl methanesulfonate		µg/kg	<1200	1200
Methyl methanesulfonate		µg/kg	<1200	1200
2-Nitrophenol		µg/kg	<1200	1200
4-Nitrophenol		µg/kg	<1200	1200
Pentachlorophenol		µg/kg	<1200	1200
Phenol		µg/kg	<1200	1200
2,3,4,6-Tetracholophenol		µg/kg	<1200	1200
2,4,5-Trichlorophenol		µg/kg	<1200	1200
2,4,6-Trichlorophenol		µg/kg	<1200	1200
Acenaphthene		µg/kg	<24	24
Acenaphthylene		µg/kg	<24	24
Anthracene		µg/kg	<24	24
Azobenzene		µg/kg	<1200	1200
Benzo(a)anthracene		µg/kg	34.9	24
Benzo(b)fluoranthene		µg/kg	77.7	24
Benzo(k)fluoranthene		µg/kg	26.3	24
Benzo(g,h,i)perylene		µg/kg	<24	24
Benzo(a)pyrene		µg/kg	43.3	24
4-Bromophenyl phenyl ether		µg/kg	<1200	1200
Butyl benzyl phthalate		µg/kg	<1200	1200
bis (2-Chloroethoxy) methane		µg/kg	<1200	1200
bis (2-Chloroethyl) ether		µg/kg	<1200	1200
bis (2-Chloroisopropyl) ether		µg/kg	<1200	1200
2-Chloronaphthalene		µg/kg	<1200	1200
4-Chlorophenyl phenyl ether		µg/kg	<1200	1200
Chrysene		µg/kg	48.7	24

Weanack Sediment **Sample ID: SCOW 1-16**

Cheatham Barge Composite **Date: 7/29/10**

Semi-volatile Organics, continued

Parameter	Methods	Units	Test Results	Reporting Limit
Dibenz (a,h) anthracene	SW8270D	µg/kg	<1200	1200
Di-n-butyl phthalate		µg/kg	<1200	1200
1,2-Dichlorobenzene		µg/kg	<1200	1200
1,3-Dichlorobenzene		µg/kg	<1200	1200
1,4-Dichlorobenzene		µg/kg	<1200	1200
Diethyl phthalate		µg/kg	<1200	1200
Dimethyl phthalate		µg/kg	<1200	1200
2,4-Dinitrotoluene		µg/kg	<1200	1200
2,6-Dinitrotoluene		µg/kg	<1200	1200
Di-n-octyl phthalate		µg/kg	<1200	1200
bis (2-Ethylhexyl) phthalate		µg/kg	<1200	1200
Fluoranthene		µg/kg	106	24
Fluorene		µg/kg	<24	24
Hexachlorobenzene		µg/kg	<1200	1200
Hexachlorobutadiene		µg/kg	<1200	1200
Hexachlorocyclopentadiene		µg/kg	<1200	1200
Hexachloroethane		µg/kg	<1200	1200
Indeno (1,2,3-cd) pyrene		µg/kg	<24	24
Isophorone		µg/kg	<1200	1200
Naphthalene		µg/kg	12	12
Nitrobenzene		µg/kg	<1200	1200
N-Nitrosodimethylamine		µg/kg	<1200	1200
N-Nitrosodiphenylamine		µg/kg	<1200	1200
N-Nitrosodi-N-propylamine		µg/kg	<1200	1200
Phenanthrene		µg/kg	107	24
Pyrene		µg/kg	118	24
Pyridine		µg/kg	<1200	1200
1,2,4-Trichlorobenzene		µg/kg	<1200	1200
Benzidine		µg/kg	<1200	1200
3,3-Dichlorobenzidine		µg/kg	<1200	1200
Aniline		µg/kg	<1200	1200
Benzyl alcohol		µg/kg	<1200	1200
4-Chloroaniline		µg/kg	<1200	1200
Dibenzofuran		µg/kg	<1200	1200
2-Methylnaphthalene		µg/kg	<1200	1200
2-Nitroaniline		µg/kg	<1200	1200
3-Nitroaniline		µg/kg	<1200	1200
4-Nitroaniline		µg/kg	<1200	1200

Weanack Sediment **Sample ID: SCOW 1-16**

Cheatham Barge Composite **Date: 7/29/10**

Semi-volatile Organics, continued

Parameter	Methods	Units	Test Results	Reporting Limit
Acetophenone	SW8270D	µg/kg	<1200	1200
4-Aminobiphenyl		µg/kg	<1200	1200
1-Chloronaphthalene		µg/kg	<1200	1200
Dibenz (a,j) acridine		µg/kg	<1200	1200
p-Dimethylaminoazobenzene		µg/kg	<1200	1200
7.12-Dimethylbenz(a) anthracene		µg/kg	<1200	1200
Diphenylamine		µg/kg	<1200	1200
3-Methylcholanthrene		µg/kg	<1200	1200
1-Naphthylamine		µg/kg	<1200	1200
2-Naphthylamine		µg/kg	<1200	1200
N-Nitrosodi-N-butylamine		µg/kg	<1200	1200
N-Nitrosopiperidine		µg/kg	<1200	1200
Pentachlorobenzene		µg/kg	<1200	1200
Pentachloronitrobenzene		µg/kg	<1200	1200
Phenacetin		µg/kg	<1200	1200
Proamide		µg/kg	<1200	1200
1,2,4,5-Tetrachlorobenzene		µg/kg	<1200	1200

Weanack Sediment Sample ID: SCOW 17-27
Cheatham Barge Composite Date: 8/6/10

Parameter	Methods	Units	Test Results	Reporting Limit
Chloride	EPA300.0/R2.1	mg/kg	18,800	137
Cyanide	SM18/4500-CN E	mg/kg	<2.74	2.74
Nitrate	Calculated	mg/kg	<27.4	27.4
Nitrate+Nitrite	SM18/4500-NO3 F	mg/kg	<27.4	27.4
Nitrite	SM18/4500-NO2 B	mg/kg	<5.5	5.5
Phosphorus, Ortho	SM18/4500-P E	mg/kg	20.6	5.5
Sulfate	EPA300.0/R2.1	mg/kg	<137	137
Sulfide	SW9030B	mg/kg	692	137
TKN	EPA351.2/R2.0	mg/kg	3090	68.6
Total Organic Carbon (TOC)	SW9060A	mg/kg	18,100	549
2,3,7,8-TCDD	EPA 1613B	pg/g	<1.08	1.08
Asbestos	EPA 600/M4-B2-020	%	<1%	1%

Weanack Sediment **Sample ID: SCDW 17-27**
Cheatham Barge Composite **Date: 8/6/10**

Metals

Parameter	Methods	Units	Test Results	Reporting Limit
Aluminum	SW6010C	mg/kg	17,300	6.86
Antimony		mg/kg	<13.7	13.7
Arsenic		mg/kg	12.9	1.37
Barium		mg/kg	54.4	1.37
Beryllium		mg/kg	<1.37	1.37
Cadmium		mg/kg	2.26	1.37
Calcium		mg/kg	3540	6.86
Chromium		mg/kg	51.9	1.37
Copper		mg/kg	19.4	1.37
Iron		mg/kg	37,100	1.37
Lead		mg/kg	27.4	1.37
Magnesium		mg/kg	8360	1.37
Nickel		mg/kg	22.2	1.37
Potassium		mg/kg	4130	27.4
Selenium		mg/kg	<6.86	6.86
Silver		mg/kg	<1.37	1.37
Sodium		mg/kg	13,300	27.4
Thallium		mg/kg	<6.86	6.86
Mercury	EPA 7471B	mg/kg	0.127	0.022

Weanack Sediment **Sample ID: SCOW 17-27**
Cheatham Barge Composite **Date: 8/6/10**

Pesticides & PCBs

Parameter	Methods	Units	Test Results	Reporting Limit
2,4-D	EPA 8151A	µg/kg	<13.7	13.7
2,4,5-TP (Silvex)		µg/kg	<13.7	13.7
2,4,5-T		µg/kg	<13.7	13.7
Dinoseb		µg/kg	<13.7	13.7
Pentachlorophenol		µg/kg	<13.7	13.7
PCB as Aroclor 1016	SW8082	mg/kg	<0.3	0.3
PCB as Aroclor 1221		mg/kg	<0.3	0.3
PCB as Aroclor 1232		mg/kg	<0.3	0.3
PCB as Aroclor 1242		mg/kg	<0.3	0.3
PCB as Aroclor 1248		mg/kg	<0.3	0.3
4,4'-DDD	SW8081A	µg/kg	<16.5	16.5
4,4'-DDE		µg/kg	<11	11
4,4'-DDT*		µg/kg	<220	220
Aldrin		µg/kg	<5.49	5.49
alpha-BHC		µg/kg	<5.49	5.49
beta-BHC		µg/kg	<5.49	5.49
Chlordane		µg/kg	<110	110
delta-BHC		µg/kg	<11	11
Dieldrin		µg/kg	<11	11
Endosulfan I		µg/kg	<11	11
Endosulfan II		µg/kg	<16.5	16.5
Endosulfan sulfate		µg/kg	<5.49	5.49
Endrin		µg/kg	<11	11
Endrin aldehyde		µg/kg	<22	22
gamma-BHC (Lindane)		µg/kg	<5.49	5.49
Heptachlor		µg/kg	<5.49	5.49
Heptachlor epoxide		µg/kg	<110	110
Methoxychlor*		µg/kg	<220	220
Toxaphene		µg/kg	<4390	4390

*Reporting limit for this compound elevated due to matrix interference

Weanack Sediment **Sample ID: SCOW 17-27**
Cheatham Barge Composite **Date: 8/6/10**
Semi-volatile Organics

Parameter	Methods	Units	Test Results	Reporting Limit
Benzoic acid	SW8270D	µg/kg	<1370	1370
4-Chloro-3-methylphenol		µg/kg	<1370	1370
2-Chlorophenol		µg/kg	<1370	1370
m.p.-Cresols		µg/kg	<1370	1370
o-Cresol		µg/kg	<1370	1370
Cresols, Total		µg/kg	<1370	1370
2,4-Dichlorophenol		µg/kg	<1370	1370
2,6-Dichlorophenol		µg/kg	<1370	1370
2,4-Dimethylphenol		µg/kg	<1370	1370
4,6-Dinitro-2-methylphenol		µg/kg	<1370	1370
2,4-Dinitrophenol		µg/kg	<1370	1370
Ethyl methanesulfonate		µg/kg	<1370	1370
Methyl methanesulfonate		µg/kg	<1370	1370
2-Nitrophenol		µg/kg	<1370	1370
4-Nitrophenol		µg/kg	<1370	1370
Pentachlorophenol		µg/kg	<1370	1370
Phenol		µg/kg	<1370	1370
2,3,4,6-Tetracholophenol		µg/kg	<1370	1370
2,4,5-Trichlorophenol		µg/kg	<1370	1370
2,4,6-Trichlorophenol		µg/kg	<1370	1370
Acenaphthene		µg/kg	<27.4	27.4
Acenaphthylene		µg/kg	<27.4	27.4
Anthracene		µg/kg	<27.4	27.4
Azobenzene		µg/kg	<1370	1370
Benzo(a)anthracene		µg/kg	36.9	27.4
Benzo(b)fluoranthene		µg/kg	53.8	27.4
Benzo(k)fluoranthene		µg/kg	<27.4	27.4
Benzo(g,h,i)perylene		µg/kg	<27.4	27.4
Benzo(a)pyrene		µg/kg	<27.4	27.4
4-Bromophenyl phenyl ether		µg/kg	<1370	1370
Butyl benzyl phthalate		µg/kg	<1370	1370
bis (2-Chloroethoxy) methane		µg/kg	<1370	1370
bis (2-Chloroethyl) ether		µg/kg	<1370	1370
bis (2-Chloroisopropyl) ether		µg/kg	<1370	1370
2-Chloronaphthalene		µg/kg	<1370	1370
4-Chlorophenyl phenyl ether		µg/kg	<1370	1370
Chrysene		µg/kg	34.9	27.4

Weanack Sediment **Sample ID: SCOW 17-27**
Cheatham Barge Composite **Date: 8/6/10**

Semi-volatile Organics, continued

Parameter	Methods	Units	Test Results	Reporting Limit
Dibenz (a,h) anthracene	SW8270D	µg/kg	<27.4	27.4
Di-n-butyl phthalate		µg/kg	<1370	1370
1,2-Dichlorobenzene		µg/kg	<1370	1370
1,3-Dichlorobenzene		µg/kg	<1370	1370
1,4-Dichlorobenzene		µg/kg	<1370	1370
Diethyl phthalate		µg/kg	<1370	1370
Dimethyl phthalate		µg/kg	<1370	1370
2,4-Dinitrotoluene		µg/kg	<1370	1370
2,6-Dinitrotoluene		µg/kg	<1370	1370
Di-n-octyl phthalate		µg/kg	<1370	1370
bis (2-Ethylhexyl) phthalate		µg/kg	<1370	1370
Fluoranthene		µg/kg	55.1	27.4
Fluorene		µg/kg	<27.4	27.4
Hexachlorobenzene		µg/kg	<1370	1370
Hexachlorobutadiene		µg/kg	<1370	1370
Hexachlorocyclopentadiene		µg/kg	<1370	1370
Hexachloroethane		µg/kg	<1370	1370
Indeno (1,2,3-cd) pyrene		µg/kg	<27.4	27.4
Isophorone		µg/kg	<1370	1370
Naphthalene		µg/kg	<13.7	13.7
Nitrobenzene		µg/kg	<1370	1370
N-Nitrosodimethylamine		µg/kg	<1370	1370
N-Nitrosodiphenylamine		µg/kg	<1370	1370
N-Nitrosodi-N-propylamine		µg/kg	<1370	1370
Phenanthrene		µg/kg	28.2	27.4
Pyrene		µg/kg	55.1	27.4
Pyridine		µg/kg	<1370	1370
1,2,4-Trichlorobenzene		µg/kg	<1370	1370
Benzidine		µg/kg	<1370	1370
3,3-Dichlorobenzidine		µg/kg	<1370	1370
Aniline		µg/kg	<1370	1370
Benzyl alcohol		µg/kg	<1370	1370
4-Chloroaniline		µg/kg	<1370	1370
Dibenzofuran		µg/kg	<1370	1370
2-Methylnaphthalene		µg/kg	<1370	1370
2-Nitroaniline		µg/kg	<1370	1370
3-Nitroaniline		µg/kg	<1370	1370
4-Nitroaniline		µg/kg	<1370	1370

Weanack Sediment **Sample ID: SCDW 17-27**
Cheatham Barge Composite **Date: 8/6/10**

Semi-volatile Organics, continued

Parameter	Methods	Units	Test Results	Reporting Limit
Acetophenone	SW8270D	µg/kg	<1370	1370
4-Aminobiphenyl		µg/kg	<1370	1370
1-Chloronaphthalene		µg/kg	<1370	1370
Dibenz (a,j) acridine		µg/kg	<1370	1370
p-Dimethylaminoazobenzene		µg/kg	<1370	1370
7.12-Dimethylbenz(a) anthracene		µg/kg	<1370	1370
Diphenylamine		µg/kg	<1370	1370
3-Methylcholanthrene		µg/kg	<1370	1370
1-Naphthylamine		µg/kg	<1370	1370
2-Naphthylamine		µg/kg	<1370	1370
N-Nitrosodi-N-butylamine		µg/kg	<1370	1370
N-Nitrosopiperidine		µg/kg	<1370	1370
Pentachlorobenzene		µg/kg	<1370	1370
Pentachloronitrobenzene		µg/kg	<1370	1370
Phenacetin		µg/kg	<1370	1370
Proamide		µg/kg	<1370	1370
1,2,4,5-Tetrachlorobenzene		µg/kg	<1370	1370

ATTACHMENT 2

Detailed Water Quality Analyses

Woodrow Wilson Bridge Water Partial Suite

Parameter	Method	Sample Date: / Well ID:	Detection Limits	Units	10/12/2010 SW30 Results	10/12/2010 SW31 Results	10/12/2010 SW43 Results	10/12/2010 SDS3 Results	10/12 SW Res
Aluminum	SW-6010c		0.05	mg/l	<0.05	<0.05	33	7.56	2.(
Antimony	EPA200.9/R2.2		0.005	mg/l	<0.005	<0.005	<0.005	<0.005	<0.(
Arsenic	EPA200.7/R4.4		0.01	mg/l	<0.01	<0.01	0.0109	<0.01	<0
Beryllium	EPA200.7/R4.4		0.01	mg/l	<0.01	<0.01	<0.01	<0.01	<0
Cadmium	EPA200.7/R4.4		0.01	mg/l	<0.01	<0.01	<0.01	<0.01	<0
Chromium	EPA200.7/R4.4		0.01	mg/l	<0.01	<0.01	0.0538	<0.01	<0
Copper	EPA200.7/R4.4		0.01	mg/l	<0.01	<0.01	0.0183	<0.01	<0
Iron	SW-6010C		0.01	mg/l	0.1744	0.0868	59.9	21.2	5.(
Lead	EPA200.7/R4.4		0.01	mg/l	<0.01	<0.01	0.0312	0.0142	0.0
Mercury	EPA245.1/R3.0		0.0002	mg/l	<0.0002	<0.0002	<0.0002	<0.0002	<0.(
Nickel	EPA200.7/R4.4		0.01	mg/l	<0.01	<0.01	0.0319	0.0104	<0
Selenium	EPA200.9/R2.2		0.003	mg/l	<0.003	<0.003	0.003	<0.003	<0.(
Silver	EPA200.7/R4.4		0.01	mg/l	<0.01	<0.01	<0.01	0.01	<0
Thallium	EPA200.9/R2.2		0.002	mg/l	<0.002	<0.002	<0.002	<0.002	<0.(
Zinc	EPA200.7/R4.4		0.01	mg/l	0.0114	<0.01	0.154	0.01	0.2
Cyanide	Keleda-01		0.01	mg/l	<0.01	<0.01	<0.01	<0.01	<(
Nitrate+Nitrite	DM28/4500/NO3 F		0.1	mg/l	0.3	4.4	2.2	<0.01	<(
Phosphorus Ortho	SM18/4500-P E		0.01	mg/l	0.03	0.03	0.05	0.01	0.(
Sulfate	EPA300.0/R2.1		2	mg/l	199	79.7	29.1	1	12
Sulfide	SW9030B M		1	mg/l	<10	<1	<1	<1	<
TKN	EPA351/2/R2.0		0.2	mg/l	1.7	0.4	2.4	4	2.
Total Organic Carbon	SW9060		1	mg/l	4.8	1.2	2.1	13.1	17

Earle Water Partial Suite

Parameter	Method	Sample Date: / Well ID:	Detection Limits	Units	10/12/2010 SP Well Results	10/12/2010 SEW 51 Results	10/12/2010 SEW 52 Results	10/12/2010 SEW 53 Results	10/12/2010 SEW 54 Results	10/12/2010 SW5 Results
Aluminum	SW-6010c		0.05	mg/l	<0.5	<0.5	24.7	3.11	15	2.68
Antimony	EPA200.9/R2.2		0.005	mg/l	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Arsenic	EPA200.7/R4.4		0.01	mg/l	<0.1	<0.01	<0.1	<0.01	<0.01	<0.01
Beryllium	EPA200.7/R4.4		0.01	mg/l	<0.1	<0.01	<0.1	<0.01	<0.01	<0.01
Cadmium	EPA200.7/R4.4		0.01	mg/l	<0.1	<0.01	<0.1	<0.01	<0.01	<0.01
Chromium	EPA200.7/R4.4		0.01	mg/l	<0.1	<0.01	0.0394	<0.01	0.0211	<0.01
Copper	EPA200.7/R4.4		0.01	mg/l	0.0819	<0.01	0.0263	<0.01	0.0156	0.0125
Iron	SW-6010C		0.01	mg/l	0.011	0.0153	33	5.19	20.6	4.65
Lead	EPA200.7/R4.4		0.01	mg/l	<0.01	<0.01	0.0237	<0.01	0.0287	<0.01
Mercury	EPA245.1/R3.0		0.0002	mg/l	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Nickel	EPA200.7/R4.4		0.01	mg/l	<0.01	<0.01	0.0382	0.0435	0.0176	0.0113
Selenium	EPA200.9/R2.2		0.003	mg/l	<0.003	<0.003	0.0035	<0.003	<0.003	<0.003
Silver	EPA200.7/R4.4		0.01	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Thallium	EPA200.9/R2.2		0.002	mg/l	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Zinc	EPA200.7/R4.4		0.01	mg/l	0.0424	<0.01	0.1535	0.0821	0.0923	0.05
Cyanide	Keleda-01		0.01	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate+Nitrite	DM28/4500/NO3 F		0.1	mg/l	<0.1	9.2	2.8	7.4	10	<0.1
Phosphorus Ortho	SM18/4500-P E		0.01	mg/l	0.35	0.04	0.8	0.07	0.05	0.39
Sulfate	EPA300.0/R2.1		1	mg/l	12.1	13.9	29.3	14.3	11.9	783
Sulfide	SW9030B M		1	mg/l	<1	<1	<1	<1	<1	<1
TKN	EPA351/2/R2.0		0.2	mg/l	1.1	<0.2	2.3	1.5	0.9	8.9
Total Organic Carbon	SW9060		1	mg/l	<1	<1	2.8	1.6	2.3	6.2
4, 4-DDT	SW8081A		0.01	µg/l	<0.01	<0.01	0.01	<0.1	<0.01	<0.01
gamma-BHC (Lindane)	SW8081A		0.02	µg/l	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Phenol	SW8270D		10	µg/l	<10	<10	<10	<10	<10	<10
Chloride	EPA300.0/R2.1		1	mg/l	18.6	14.1	22.5	823	22.7	2590

Water levels in monitoring wells - 2010

	----Water level (feet above sea level) ----			
Well ID	**1/6/2010**	**04/08/10**	**7/16/2010**	**10/12/10**
SDS 2	11.93	11.02	8.39	7.26
SDS 2D	5.52	6.12	4.25	3.67
SDS 3	8.98	8.43	6.16	6.51
SDS 4D	7.84	6.58	2.45	dry
SDS 5	6.02	5.1	dry	3.49
SDS 5P	5.7	5.34	2.14	3.86
SDS 9A	5.72	6.06	4.12	dry
SDS 9B	4.73	5.05	dry	dry
SDS 10	7.94	7.7	5.17	4.53
SDS 11	na	na	na	na
SDS 18	15.87	14.03	7.39	14.5
SDS 21	8.03	7.53	5.03	na
SW 30	4.25	4.29	3.12	2.84
SW 31	4.67	4.85	3.46	2.68
SW 32	3.28	4.08	3.35	3.45
SW 33	6.07	4.94	1.07	1.3
SW 34	3.81	3.84	2.75	2.49
SSG 2	dry	dry	dry	dry
SSG 3	11.04	12.29	10.57	10.14
SW42DV	3.34	na	2.33	2.07
SW43	11.18	11.75	11.47	11.03
SW44	8.93	9.08	6.97	6.06
SW46	5.83	6.82	4.32	3.87
SW47	na	na	na	na
SW48	5.19	5.13	dry	3.69
SEW51	4.94	6.14	5.86	5.19
SEW52	4.57	6.14	2.73	1.9
SEW53	2.5	2.3	2.68	2.23
SEW54	9.94	9.9	9.65	9.13
SEW55	7.68	7.7	7.39	6.71
SEW56	na	na	na	7.84
SSG5	26.2	26.17	23.55	25.8

na=not available

pH of water in monitoring wells - 2010

	---- pH ----			
Well ID	**1/6/10**	**4/28/10**	**7/16/10**	**10/12/10**
SDS 3	5.63	5.94	5.83	5.78
SW 30	5.8	5.77	5.96	5.9
SW 31	5.66	5.54	5.62	5.42
SW43	5.3	5.28	5.35	5.4
SW3(@SSG 2)	dry	dry	dry	dry
SW2(@SSG 3)	7.37	7.05	7.76	8.92
SP Well*	6.56	7.59	7.13	7.54
SEW51	5.3	5.11	5.17	5.07
SEW52	5.33	5.5	5.46	5.34
SEW53	5.0	5.02	5.1	5.02
SEW54	5.21	5.33	5.5	5.75
SW5(@SSG5)	8.26	8.29	9.82	9.05

*SP Well water taken from tap of new bathroom starting 10/2010

EC of water in monitoring wells - 2010

	---- EC (µS/cm) ----			
Well ID	**1/6/10**	**4/28/10**	**7/16/10**	**10/12/10**
SDS 3	245	261	192	300
SW 30	1203	1210	1105	1118
SW 31	589	649	643	386
SW43	180	166	134	157
SW3(@SSG 2)	dry	dry	dry	dry
SW2(@SSG 3)	682	680	497	459
SP Well*	452	471	453	461
SEW51	202	196	178	173
SEW52	229	148	240	250
SEW53	1650	1803	1955	2460
SEW54	290	191	255	227
SW5(@SSG5)	4790	3440	7990	9330

*SP Well water taken from tap of new bathroom starting 10/2010

Temperature of water in monitoring wells - 2010

	---- Temperature °C ----			
Well ID	**1/6/10**	**4/28/10**	**7/16/10**	**10/12/10**
SDS 3	7.6	13.8	22.4	26.4
SW 30	13.9	15.4	19.4	20.6
SW 31	15.2	15.1	17.5	21
SW43	13.4	14.6	17	24.8
SW3(@SSG 2)	dry	dry	dry	dry
SW2(@SSG 3)	2	19.7	36.1	28.5
SP Well*	4.2	16.4	29	22.5
SEW51	11.6	15.8	18	20.9
SEW52	11.5	14.7	19	21.6
SEW53	10.9	15.6	17.8	20.4
SEW54	10	16	18.6	28.2
SW5(@SSG5)	2.9	18.6	33.5	27.7

*SP Well water taken from tap of new bathroom starting 10/2010

Dissolved organic carbon (DOC) in monitoring wells - 2010

	---- DOC (ppm) ----			
Well ID	**Jan 2010**	**Apr 2010**	**Jul 2010**	**Oct 2010**
SDS 3	6.76	10.7	2.97	5.13
SW 30	3.85	9.531	6.01	5.683
SW 31	7.01	6.413	2.70	1.787
SW 43	7.15	6.250	1.25	1.64
SW 2	11.22	17.83	11.74	13.95
SP Well	5.096	4.323	3.556	1.129
SEW 51	6.31	4.861	1.43	0.85
SEW 52	8.25	5.456	3.03	2.798
SEW 53	6.35	9.405	2.56	1.874
SEW 54	4.55	5.133	1.30	1.212
SW 5	13.70	18.77	24.86	23.48

ATTACHMENT 3

LPS Sediment PAH Data for 2010

ATTACHMENT 4

MPA Results Paper

UPLAND PLACEMENT AND MANAGEMENT OF ACID-FORMING DREDGE MATERIALS

A.F. Wick[2], W.L. Daniels, Z.W. Orndorff, and C.H. Carter III

Abstract: Harbor and ship channel maintenance dredging by the Maryland Port Administration (MPA) has historically presented a dredge disposal and utilization challenge due to metals and the potential acidity of their sediments. Post-placement low pH (<4.0) has been problematic for vegetation establishment and also reduces the pH of water moving through or over the sediment disposal or utilization facility. To determine best management practices for one material (Cox Creek; H_2O_2 potential acidity - PPA = - 10 Mg CCE per 1000 Mg material; Total S = 1.31%; CCE = 7.13%) proposed for upland placement, we conducted lab and field experiments. In the lab, a series of liming rates (0.00, 0.50, 0.75, 1.00, and 1.25x of required lime additions as CCE) were subjected to 32 wet-dry cycles. The pH of the 0.00x liming rate treatment remained between 4.10 to 4.20 throughout the experiment, while the effects of the various liming rates on bulk sediment pH were not evident until after four wet-dry cycles were completed. The lack of development of pH lower than 4.10 was unexpected. Based on the PPA results, we predicted the pH of the unlimed treatment to drop below 4.0 over more extended periods of time. By the end of the experiment, the 1.25x liming rate sediment pH was 6.22 and the 0.50x pH was 5.11. Salinity of the material is clearly an additional issue. The EC of the 0.00x liming rate increased from 5.9 dS m^{-1} at the start of the experiment to 7.9 dS m^{-1}, while the 1.25x rate EC increased from 7.0 to 8.9 dS m^{-1}, presumably due to sulfate release. In the field, two lime application methods were tested (bulk blending and layering) against an unlimed control treatment. Three zero-tension lysimeters were installed under each plot to monitor pH and EC of leachates. First-year results indicate that the pH of both the bulk-blended lime and layered treatments remained between 4.4 and 5.5 after four sampling events. The unlimed control pH was slightly lower, between 4.2 and 4.5. The EC of the leachate samples (6 to 17 dS m^{-1}) again indicates an issue with soluble salts across all treatments. The salts initially originate from entrained chlorides, but are enhanced by sulfates over time as sulfides react and are neutralized. Thus, managing these materials for plant growth and water quality in an upland environment will not only be limited by pH, but we will also need to develop strategies for leaching soluble salts and predicting their ground- and surface water impacts. The PPA technique for estimating potential acidity was superior to a more conventional acid-base-accounting technique based on Total-S and CCE determinations.

Additional Key Words: acidity, dredging, potential peroxide acidity, salinity

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Introduction

Maintenance of navigational channels from the Baltimore Harbor to the mouth of the Patapsco River by the Maryland Port Administration (MPA) produces approximately 765,000 cubic meters of material per year with an additional 380,000 cubic meters per year for modifications to channels (Jackson, 2010). As of April 2010, the MPA used three existing locations for placement of dredge material, including the Poplar Island, the Cox Creek and the Masonville Storage Facilities with the recent closure of Hart Miller Island. Poplar Island is a restoration project for an eroding shoreline, with the capacity to hold 23.3 million cubic meters, while Cox Creek and Masonville Storage facilities are primarily holding cells for 16 million cubic meters of material (Jackson, 2010). Historically, MPA facilities have encountered periodic management problems with acidic runoff and leachates from emplacement of sulfidic materials. An additional operational goal of the Cox Creek Facility is to be a source of dredged material for beneficial re-use projects. Hart Miller Island was a restoration project to create shore bird habitat which reached capacity at 76.5 million cubic meters of material in December of 2009. The days are numbered as to when the remaining three facilities will reach capacity and alternative placement locations are needed (within 40 years at the current dredging rates). Therefore, MPA is making an effort to identify alternative placement locations as well as beneficial re-use options, especially for the Cox Creek material. One location which has been identified for upland placement of dredge material followed by beneficial re-use is the Shirley Plantation in Charles City, VA (managed by Weanack LLP; capacity 1.5 million cubic meters). This location has a history of conversion of dredge sediments to productive agricultural uses (Daniels et al., 2007).

Locating storage facilities is only one facet to understanding the long-term management needs of the MPA maintenance dredge material from the Cox Creek Facility. This sediments' depositional history and mineralogy has created an additional management issue primarily due to the potential acidity (from sulfides) of the sediment. Once the material is dredged and exposed to oxygen, pyrite within the sediment reacts with oxygen and water to produce sulfuric acid which reduces the pH of the sediment. Low pH material ($\leq$4.0) can be problematic for vegetation establishment, genesis of soil structure and can drastically reduce the pH of water moving through the sediment. Drainage and runoff waters from oxidizing sulfidic sediments (Orndorff et al., 2008) and coal mine spoils (Skousen et al., 2002) are usually enriched in Fe, Mn and other metals and post major risks to local groundwater and receiving streams. Due to these combined risk, careful planning and pilot field

studies need to be conducted to determine appropriate treatment and reclamation strategies, best management practices and to ensure compliance local and state permit requirements.

Remediation solutions and best management practices for the MPA materials are currently being evaluated at the Shirley Plantation/Weanack research facility. First, the Cox Creek material was fully characterized (i.e. heavy metals, pesticides, organics, nutrients, potential acidity, salinity, pH and particle size). Second, based upon those results, necessary amendments and/or remedial treatments were determined to stabilize the materials for upland use. An upland placement pilot study was designed and installed which is being monitored for soil and water quality. Our material characterization and first-year monitoring results are reported here. . Our primary objectives are to: (1) measure the effects of two liming procedures (e.g. blending vs. layering) on acid production and associated soil and water quality parameters and (2) document the effects of sulfide oxidation and lime application on water quality immediately below the emplaced dredge sediments.

Materials and Methods

Study Sites and Field Sampling

Approximately 150 cubic meters of maintenance dredge from the Cox Creek Facility was transported to Port Tobacco, Weanack, Charles City, VA via truck in November of 2009 (Fig. 1). The material was placed onto pavement and immediately covered with a tarp to limit water/rainfall additions and oxidation. Five representative samples were collected in January of 2010 and analyzed for soil properties necessary to determine a management strategy (i.e. dredge sediment characterization). As described below, we determined that these materials (as received) would require a net liming rate of 12.5 Mg $CaCO_3$ per 1000 Mg which was 125% of their predicted acid-forming potential. We also decided to test two alternative lime management strategies, bulk blending vs. layering lime with the sediment.

Figure 1. Maryland Port Administration, Cox Creek Facility dredge material being placed at Port Tobacco, Shirley Plantation, Charles City, VA, in November of 2009. The materials were immediately covered with a tarp to limit rainfall additions and oxidation.

By May 2010, three research cells (4.5 x 8 m) were constructed to test the two different lime addition treatments (bulk-blend and layered) with respect to an untreated control (Fig. 2). The research cells, engineered by Marshall Miller and Associates, have a compacted clay liner and controlled drainage to a collection tank for excess water moving through the Cox Creek material. Zero-tension lysimeters (3 per cell) were also installed for sampling of any saturated flow that passes the interface of treated sediment and the compacted soil liner. At Port Tobacco, the Cox Creek material was separated into three piles for plot monitoring plot construction in May and June, 2010. The first pile was for placement in the west research cell as the control (no lime). The next pile was bulk-blended with 381 kg of pelletized agricultural lime based on its assumed potential acidity using a Komatsu 750 and hauled to the middle research cell. The bucket on the equipment was rinsed to avoid cross contamination during loading. The third pile was hauled to the east research cell in lifts (17 cubic meters), with 127 kg of lime placed between each lift. A total of three lifts were placed in the research cell (in the sequence from bottom to surface: dredge material - lime - dredge material - lime- dredge material - lime). The surface of each plot was roto-tilled (starting with the control,

again to avoid cross contamination) and hydroseeded (with mulch and fertilizer) to *Setaria italica* (German millet) at a rate of 44 kg ha^{-1} (Fig. 3).

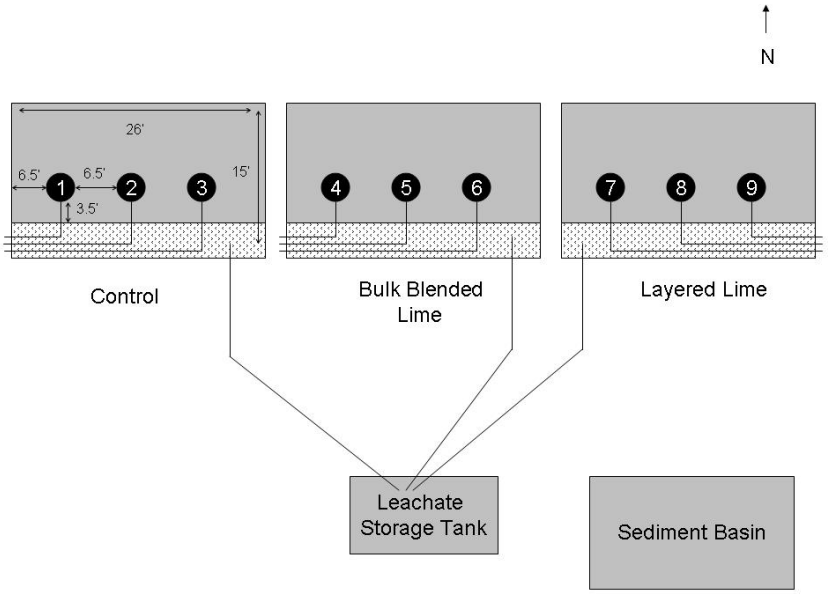

Figure 2. Schematic diagram for lysimeter locations within each treated (control, bulk blended lime and layered lime) cell at the Maryland Port Administration/Cox Creek dredge material study, Shirley Plantation, Charles City, VA.

Figure 3. Research cells for the Maryland Port Administration/Cox Creek dredge material study at the Shirley Plantation, Charles City, VA.

In June, 2010, the first lysimeter samples were collected and analyzed (as described below). A low pH was observed in cells containing lime additions (Table 1; similar the control), therefore in September, 2010, all three cells were roto-tilled and an additional 20 kg of lime was tilled into the surface 15 cm of the blend and layered plots to assist revegetation. Fertilizer (90 kg N and 224 kg P ha^{-1}) were also roto-tilled into all three cells at this time. Plots were then seeded to a diverse assemblage of acid-tolerant species utilized for direct seeding of acid-forming coal wastes (Daniels and Stewart, 2000) at a (combined seeding rate of 112 kg ha^{-1}. These species included, *Eragrostis curvula* (weeping lovegrass), *Festuca arundinacea* 'bronson' (tall fescue), *Festuca brevipila* 'stonehenge' (hard fescue), *Lotus corniculatus* 'norecen' with inoculant (birdsfoot trefoil), *Lespedeza cuneata* with inoculant (lespedeza), and *Secale cereale* (grain rye). Plots were mulched with straw post-seeding and berms around the cells were again stabilized with erosion control matting. The zero-tension lysimeters have been sampled three times (September, November and December, 2010) since the additional lime incorporation.

Dredge Sediment Characterization

There were two separate sampling dates, January 2010 (pre-plot installation) and June 2010 (post-plot installation). Acid-producing potential (PPA) was determined using a modified H_2O_2 oxidation method based on Barnhisel and Harrison (1976) and O'Shay et al. (1990) as recently documented for use on Coastal Plain sediments by Orndorff et al. (2008). To approximate a more conventional approach to acid-base-accounting we also determined calcium carbonate equivalent (CCE; AOAC, 2002) on samples collected from both sample dates. Total sulfur, EC and pH were only conducted on January, 2010 samples. Total sulfur analysis was determined on a ground sample (<53 μm) with a Leco S632 analyzer. Electrical conductivity (EC) and pH were determined on a saturated paste extract with an Oakton con 100 series EC probe (Vernon Hills, IL) and a Fisher Scientific Accumet Basic pH meter with a glass electrode (Pittsburgh, PA).

Leachate Analyses

Leachates from the lysimeters were analyzed for EC and pH using the same techniques described above. Leachate samples were filtered through a 0.45 μm mixed cellulose filter and analyzed for Al, Fe, Mn and S using a Thermo Elemental ICAP 61E equipped with a TJA-300 autosampler.

Lab Experiment

Because of the variability in PPA and CCE results observed between the January and June 2010 samples, a wet-dry lime equilibration experiment was also conducted in the lab to test the effects of various liming rates (0.00, 0.50, 0.75, 1.00 and 1.25% of the anticipated liming rate of 12.5 Mg $CaCO_3$ per 1000 Mg of material) on soil EC and pH over a series of wet-dry cycles for material directly removed from the control field cell. Each treatment was wetted to field capacity and dried in a 65˚C oven to constitute one wet-dry cycle. After four cycles, 40 g of each sample was removed and a 1:1 soil:DI water mixture was prepared. Electrical conductivity and pH analyses were conducted on each extract as described above. Samples were again wetted and dried for four more cycles and again tested for EC and pH. This was completed for a total of 32 cycles.

Statistical Analyses

One way analysis of variance was used to determine differences among treatments followed by t-tests for separation of means for both the field and lab experiments (SigmaPlot, 2008). Statistical analyses were accomplished at $P<0.05$.

Results and Discussion

Dredge Sediment Characterization

An average liming rate of 10.6 Mg $CaCO_3$ per 1000 Mg material was determined on the January 2010 samples via the PPA method which was significantly ($P<0.10$) higher than the June 2010 values (9.04 Mg $CaCO_3$ per 1000 Mg material). Calcium carbonate equivalency values were also higher on the January 2010 sample (7.13%) vs. the June 2010 samples (2.54%; $P<0.05$). Total-S in the January 2010 samples averaged 1.31% and the saturated paste pH was 7.80 and the EC was 10.38 dS m^{-1}. If we make conservative assumptions that the original total-S in January 2010 was all pyritic, the maximum potential acidity (MaxPA) of this material in January was approximately - 41 Mg CCE per 1000 Mg of sediment. Similarly, if we assume that our lab determined CCE approximated the actual neutralization potential (NP), the material contained approximately +71 Mg per thousand NP, and thus had a net surplus of +30 Mg CCE per thousand Mg and a Max PA/NP

ratio of 1.73. Thus, under common assumptions of the conventional acid-base-accounting approach, this material would not be expected to be net acid-forming over time (Skousen et al., 2002).
By looking at the combined leachate plus sediment data from June 2010, it is clear that a significant component of the total-S in this material was highly reactive as the bulk sediment and leachate pH dropped from 7.8 in January into the low 4.0's by June. This appears to have occurred in-situ within the sediment stockpile over that six month period, but may have been accelerated by the mixing and oxidation involved with building the treatment cells in May and June. Similarly, the CCE of the bulk sediment appeared to decrease from 7.13% to 2.54% which may have been due to internal neutralization reactions or perhaps sampling error due to the presence of numerous carbonate bearing shells in the sediments. Based on our experience with other mid-Atlantic region sediments, we actually expected this material to produce soil:water pH values < 4.0, but that did not occur here. Presumably, the significant carbonate content of this sediment is sufficient to keep the pH buffered above 4.0, but not reactive or soluble enough to quickly neutralize the acidity and keep the pH any higher.

Surprisingly, the PPA values determined in June (- 9.04 Mg CCE demand per 1000 Mg) were still similar to those determined in January (- 10.6 Mg CCE), indicating that a significant portion of the sulfidic-S either had not reacted yet, or that large amounts of total acidity reaction products remained entrained in the sediments that subsequently influenced the final titration step of the PPA procedures. As mentioned earlier, a conventional acid-base-accounting interpretation of this material would not have predicted it to be acid-forming due to the abundance of CCE inferred NP values over MaxPA. However, much of the CCE in this material is contained in larger (> 1 cm) shells and shell fragments which more than likely are not reactive under field conditions but are accounted for in the CCE procedure due to the grinding employed. In this instance, the PPA prediction that the material would be net acid-forming was correct, but the large amount of CCE that these materials contain was keeping the pH just above 4.0 despite the apparent high reactivity of the sulfidic components.

Leachate

Leachate pH was similar across sampling dates for the control treatment (ranging from 4.16 to 4.46) and increased significantly with time for the bulk-blended treatment (4.43 to 5.53; Fig. 4abc). The Layered treatment leachate pH showed a gradual increase (4.98 to 5.41), although this was not

significant. This difference against the control and the bulk-blended treatment may be due to the presence of a layer of lime immediately under the bottom of the emplaced sediment and immediately around and above the lysimeter. Across treatments, the pH of leachate samples collected in December was significantly lower in the control vs. both lime amended treatments. Leachate EC declined significantly for all treatments, from 13.0 to 6.4 dS m^{-1} for the control, 12.8 to 6.6 dS m^{-1} for the blend and 16.7 to 9.5 dS m^{-1} for the layer treatment (Fig. 4def), presumably due to net Cl^- leaching from the saline source sediments since the total-S component of the leachates did not decline significantly (Table 1). The EC of the leachates was significantly higher for all sample dates in the layered-lime treatment.

Aluminum, Fe, Mn and S concentrations for the leachate samples collected were similar across all sample dates for the control (Table 1). Aluminum and Mn decreased with sample date for the bulk-blended treatment, while Fe and S remained similar. Leachates collected from the control were generally higher in Al and Fe relative to the limed treatments, while Mn and S were consistently higher in the layered treatment relative to the other two. Manganese and S concentrations were lower in the bulk-blended treatment than the layered, while for most sample dates, Al and Fe were similar.

Lab Equilibration Experiment

As expected the pH of the MPA/Cox Creek material was low (approx. 4.0) in the 0% treatment relative to the limed treatments (Fig. 5) and remained low throughout the experiment. The effect of lime additions was first observed after four wet-dry cycles with significant increases in pH with increased additions of lime. These differences were consistent throughout the experiment with the greatest separation of values observed after 24 wet-dry cycles. Trends in EC were not as clear as pH; however, there was an interesting increase in EC observed in the control treatment after 20 wet-dry cycles.

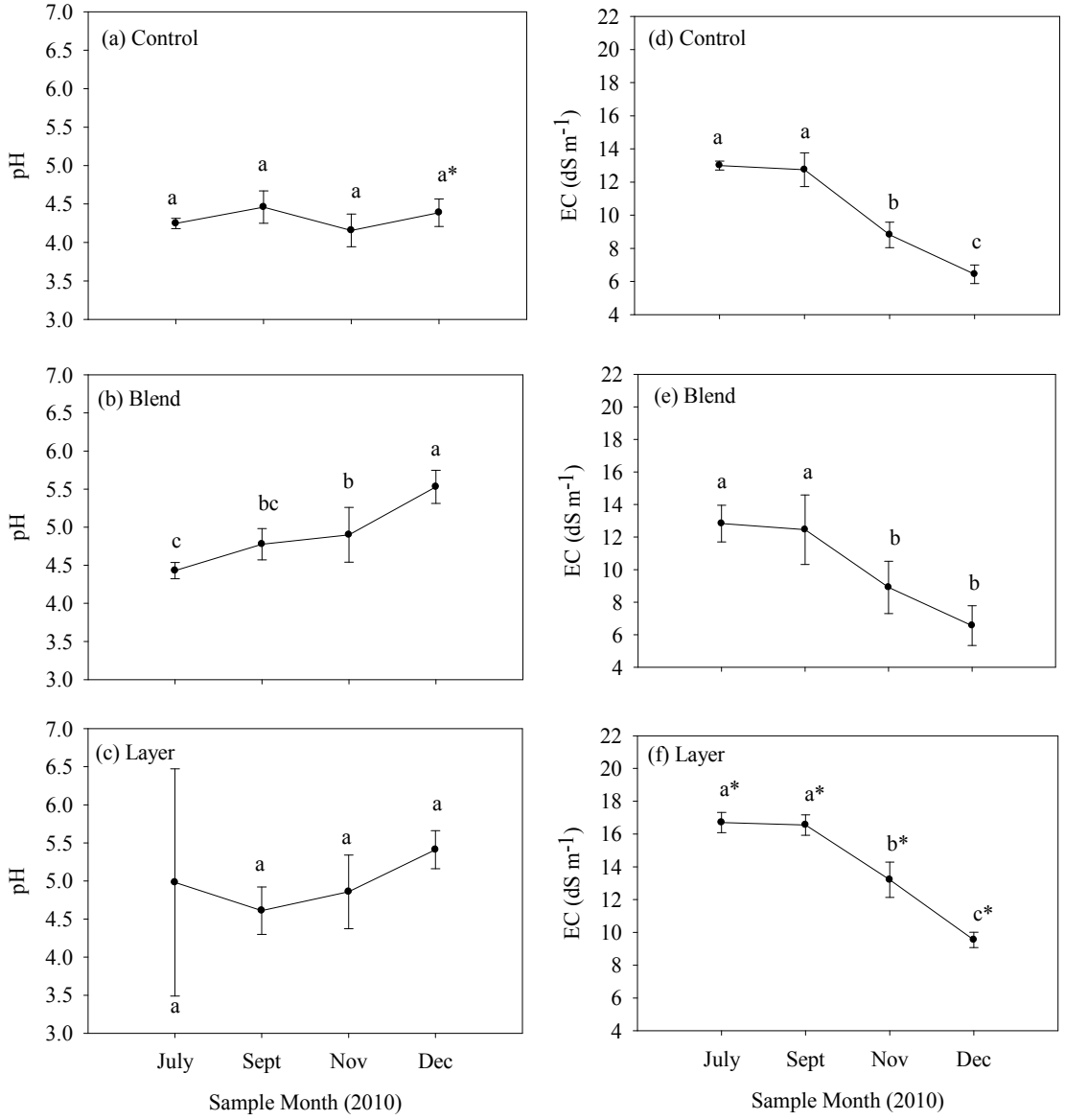

Figure 4. Maryland Port Administration/Cox Creek dredge sediment cell leachate pH and electrical conductivity (EC) for three different treatments: control (a, d), bulk blended lime (b, e) and layered lime (c, f). Different letters indicate significant differences among sample month in 2010 within each treatment and asterisk indicates a significant different among treatments within each sample month at the $p<0.05$ level. Bars indicate standard deviation.

Table 1. Maryland Port Administration/Cox Creek dredge sediment cell leachate Al, Fe, Mn and S concentrations for treatments (control, blended and layered). Lower case letters indicate significant differences among dates within a specific treatment and upper case letters indicate significant differences among treatments within a specific date for each element at the $p<0.05$ level.

Element/Date	Treatment		
	Control	Blended	Layered
		mg L^{-1}	
Al			
7/15/10	11.50 a, A	7.15 a, B	3.27 a, C
9/10/10	1.83 a, A	1.07 b, A	1.02 b, A
11/11/10	4.20 a, A	0.40 b, B	0.40 b, B
12/15/10	10.30 a, A	0.10 b, A	0.30 b, A
Fe			
7/15/10	8.9 b, A	23.1 a, A	71.4 a, A
9/10/10	79.4 a, A	81.4 a, A	153.8 a, A
11/11/10	13.0 b, B	30.4 a, B	170.3 a, A
12/15/10	2.4 b, A	21.3 a, A	133.7 a, A
Mn			
7/15/10	182.5 a, B	146.8 a, C	301.7 a, A
9/10/10	149.6 a, B	116.1 ab, B	249.2 ab, A
11/11/10	155.0 a, B	105.2 b, B	230.3 b, A
12/15/10	178.5 a, A	97.1 b, B	191.2 b, A
S			
7/15/10	2199 a, B	2226 a, B	2921 a, A
9/10/10	1935 a, B	2025 a, B	2703 a, A
11/11/10	1830 a, B	1964 a, B	2673 a, A
12/15/10	1936 a, B	1948 a, B	2462 a, A

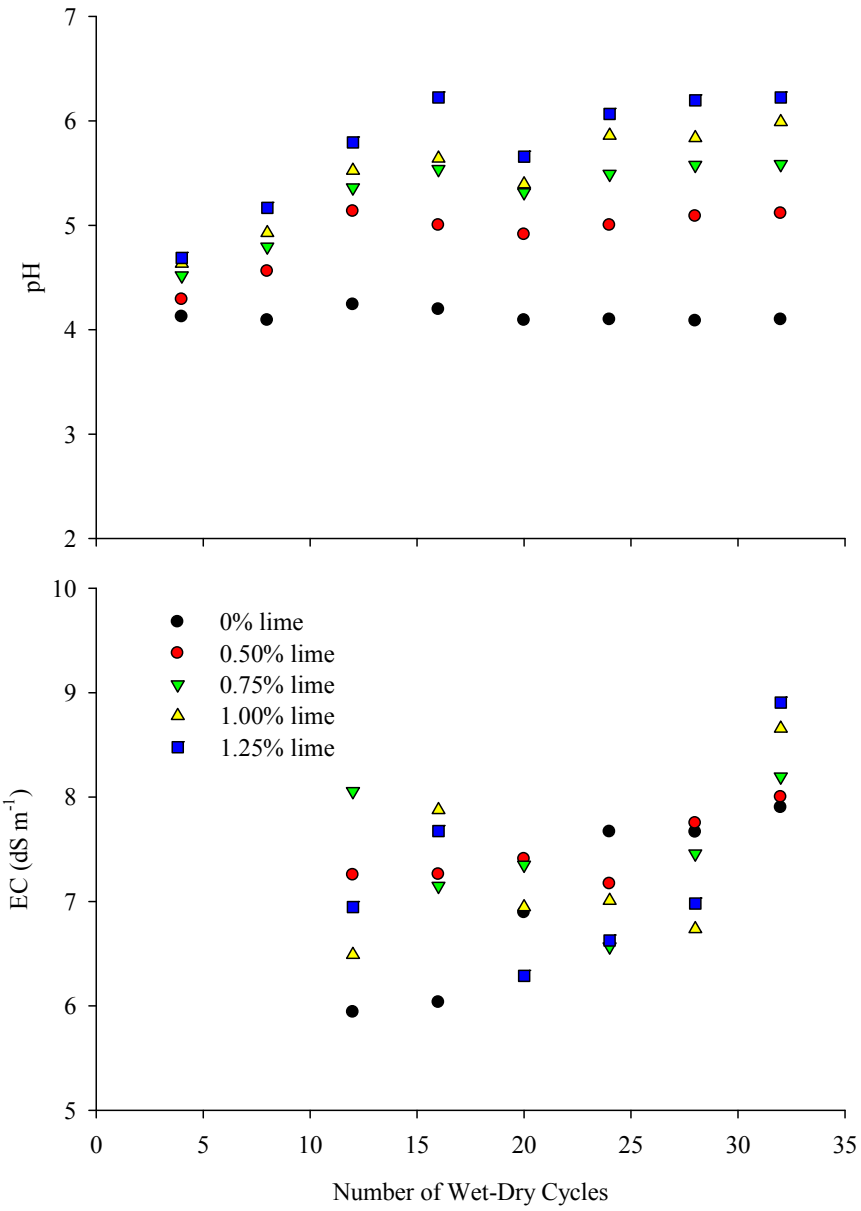

Figure 5. Soil pH and electrical conductivity (EC) for a series of wet-dry cycles conducted on lime treated (0, 0.5, 0.75, 1.0, 1.25% dry weight of calcium carbonate equivalent) Maryland Port Administration/Cox Creek dredge material.

In the 0% treatment, pH remained unchanged throughout the experiment (Table 2), while there were significant increases in pH with number of wet-dry cycles for lime treatments at all rates. The highest pH was achieved with the 1.25% CCE rates which was also approximately 125% of PPA

determined CCE field addition rate. Electrical conductivity increased with the number of wet-dry cycles for all treatments, except the 0.50 and 0.75% of CCE treatments.

Table 2. Soil pH and electrical conductivity (EC) for a series of wet-dry cycles conducted on lime treated (0, 0.5, 0.75, 1.0, 1.25% of calcium carbonate equivalent) Maryland Port Administration/Cox Creek dredge material. Lower case letters indicate significant differences within treatment across the number of wet-dry cycles at the $p<0.05$ level. Standard deviation in parentheses.

Number of Cycles	pH				
	Treatment (% of CCE)				
	0.00%	0.50%	0.75%	1.00%	1.25%
4	4.12 (0.1) a	4.29 (0.1) c	4.51 (0.1) d	4.63 (0.0) e	4.69 (0.1) d
8	4.09 (0.1) a	4.56 (0.1) bc	4.79 (0.1) c	4.93 (0.1) d	5.17 (0.1) c
12	4.24 (0.1) a	5.13 (0.6) a	5.36 (0.1) b	5.52 (0.4) c	5.79 (0.2) b
16	4.19 (0.0) a	5.00 (0.2) a	5.54 (0.1) a	5.64 (0.1) bc	6.22 (0.0) a
20	4.09 (0.1) a	4.91 (0.2) ab	5.31 (0.1) b	5.39 (0.1) c	5.66 (0.0) b
24	4.10 (0.0) a	5.00 (0.1) a	5.49 (0.1) ab	5.86 (0.2) ab	6.07 (0.1) a
28	4.08 (0.0) a	5.09 (0.1) a	5.58 (0.0) a	5.84 (0.0) ab	6.20 (0.1) a
32	4.10 (0.0) a	5.11 (0.1) a	5.58 (0.0) a	5.99 (0.0) a	6.22 (0.1) a

Number of Cycles	EC ($dS\ m^{-1}$)				
	Treatment (% of CCE)				
	0.00%	0.50%	0.75%	1.00%	1.25%
4	NA	NA	NA	NA	NA
8	NA	NA	NA	NA	NA
12	5.94 (0.2) b	7.25 (0.5) a	8.05 (0.3) a	6.49 (1) c	6.95 (0.4) bc
16	6.03 (0.6) b	7.26 (0.9) a	7.15 (1) a	7.88 (0.7) ab	7.67 (1) b
20	6.89 (0.9) ab	7.41 (1) a	7.35 (0.5) a	6.95 (0.2) bc	6.29 (0.7) c
24	7.67 (1) a	7.17 (0.5) a	6.57 (0.3) a	7.01 (0.1) bc	6.63 (0.7) bc
28	7.66 (0.5) a	7.75 (0.5) a	7.46 (0.6) a	6.74 (0.2) c	6.98 (0.5) bc
32	7.90 (0.8) a	8.00 (0.6) a	8.19 (0.1) a	8.65 (0.4) a	8.90 (0.5) a

Summary and Conclusions

While not shown here, the two revegetation efforts on the surface of the field experimental cells both failed regardless of the fact that: (1) we added a moderate amount of additional surface-incorporated lime to the two limed treatments, (2) used a proven acid/salt tolerant seeding mix with a combination of fiber and straw mulch. Field visual evidence points to excessive salts and possibly high surface temperatures (this material is gray/black) as being the primary reasons for revegetation failure. It is clear that between the times these materials were sampled in January vs. June of 2010 that a significant portion of their sulfides oxidized, dropping pH from near 8.0 to just above 4.0, while the measured CCE appeared to drop from 7.1 to 2.5%, presumably due to carbonate neutralization of the acid-sulfate weathering products. The fact that the PPA values remained close to original estimates indicate that some portion of the sulfides remain in reduced form or that we have problems with the application of that technique to these carbonate rich materials. Regardless, it is important to point out that the PPA technique did predict these materials to be significantly acid-forming while a more conventional approach to acid-base-accounting did not.

Once placed and lime-treated in the field, these materials did show a gradual and consistent liming response. A similar response was observed in the laboratory wet/dry incubation studies that confirmed that the necessary liming rate predicted by the PPA technique was appropriate and should be effective over an extended period of time at offsetting sulfide oxidation. It does appear that bulk blending the lime is more effective than layered approaches, but more time will be needed to adequately address this alternative. Regardless, the bulk sediment and leachate EC of these materials remains high due to sulfates produced internally even though the originally entrained Cl salts do appear to leach relatively quickly.

Thus, over long periods of time, it appears that while the potential acidity in these materials can be successfully neutralized via addition of appropriate rates of agricultural limestone, that revegetation efforts will be hindered by soluble salt effects which will not diminish until after the sediment's sulfides have been completely neutralized and the bulk solution sulfates leach away. The net groundwater effects of the combined leaching of Cl + sulfates will need to be addressed.

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References Cited

AOAC International. 2002. Official methods of analysis of AOAC International 17th Ed. AOAC International, Gaithersburg, MD, USA, Official Method 955.01.

Barnhisel, R.I., and J. Harrison. 1976. Estimating lime requirement by a modified hydrogen peroxide potential acidity method. Unpublished method for KY Agric. Exp. Stn., Soil Testing Lab., Lexington, KY.

Daniels, W.L. and B.R. Stewart. 2000. Reclamation of Appalachian coal refuse disposal areas. p 433-460 *In:* R.I. Barnhisel et al. (Eds.). Reclamation of Drastically Disturbed Lands. American Soc. of Agron. Monograph #41, Madison WI.

Daniels, W.L., Whittecar, G.R. and Carter, C.H. 2007. Conversion of Potomac River dredge sediments to productive agricultural soils. p. 183-199 In: R.I. Barnhisel (ed.), Proc., 2007 Nat. Meeting Amer. Soc. Mining and Reclamation, Gillette WY, June 2-7, 2007. Published by ASMR, 3134 Montavesta Rd., Lexington, KY, 40502, 980 p.

Jackson, N.M. 2010. Island Dreams: Successful End of Dredging Project Celebrates at Hart Miller Island. Pp. 24-28. In The Helen Delich Bentley Port of Baltimore Magazine. Media Two Publishers, Baltimore, MD.

Orndorff Z. W., W. L. Daniels, D. Fanning. 2008. Reclamation of disturbed sulfidic Coastal

Plain sediments using lime-stabilized biosolids. J. Environ. Quality 37:1447-1455.

O'Shay, T., L.R. Hossner, and J.B. Dixon. 1990. A modified hydrogen peroxide method for determination of potential acidity in pyritic overburden. J. Environ. Qual. 19:778-782.

Skousen, J., J. Simmons, L.M. Mcdonald and P. Ziemkiewicz. 2002. Acid base accounting to predict post-mining drainage quality on surface mines. J. Environ. Qual. 31: 2034-2044.

ATTACHMENT 5

Earle Sediment Revegetation Results Paper

SOIL DEVELOPMENT AND VEGETATION ESTABLISHMENT ON AMENDED SALINE DREDGE SEDIMENTS[1]

A.F. Wick[2], W.L. Daniels and C.H. Carter III

Abstract: Crop establishment on saline-source fine textured dredge sediments is challenging due to the adverse physical properties of the material (e.g. fine texture and lack of structure) and short-term salinity. Two approaches to improve crop establishment and soil properties on dredge sediments were tested: (1) a topsoil cap plus fertilizer (approximately 20 cm; TS), and (2) incorporation of 30% sand by volume into the surface plus fertilizer (30%S). Each treatment was compared to a Control where only fertilizer was added based on soil fertility testing. A greenhouse study was initiated prior to the installation of field experimental plots. In the greenhouse study, German millet (*Setaria Italica* L.) yields and average plant height from highest to lowest were: Control > TS > 30%S after three months. Large aggregation (250-8000 μm) was highest on the Control (68-70% total soil) followed by the TS (56%) and 30%S (48%) treatments; however, salinity was also higher on the Control treatment vs. the other two. The field experiment was installed in the spring of 2009 with an additional compost treatment added to the plots in splits. Plots were seeded to German millet in May 2009 and no-till drilled to *Triticum aestivum* (winter wheat) in October 2009. Weed control and a second application of N fertilizer in the spring of 2010 were impossible due to extremely wet soil conditions; therefore, only total biomass (wheat+weeds) data are presented for 2010. Millet yields (4381 kg ha^{-1}) and total biomass (4318 kg ha^{-1}) were higher on the 30%S treatments followed by the Control and TS treatments (1517 kg millet ha^{-1} and 3363 kg biomass ha^{-1}, respectively). Large aggregation was higher in the Control (70-80% total soil) than the 30%S (40-60%) and TS (20-30%) treatments in 2009 and 2010. Salinity declined with time across all treatments with suitable levels for crop production attained in the amended plots (30%S and TS). Compost additions stimulated microbial biomass and soil C concentrations, but did not significantly increase crop yields or aggregate formation relative to the non-compost treatment. Overall, yields and soil salinity were significantly improved when 30% sand by volume was incorporated into the dredge sediment, making this a feasible remediation strategy in the short-term, provided it is cost-effective.

Additional Key Words: macroaggregate, microaggregate, organic matter, soil quality

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Introduction

The US Army Corps of Engineers maintain over 20,000 km of waterways across the USA, requiring the dredging of almost 300 million cubic meters of material on an annual basis (USACE, 2003). Depending on the properties and contamination levels of the dredged sediments, as well as logistical and economical constraints, the material is either handled via placement in open water or a confined upland disposal facility or sighted for beneficial use. There are three general categories for beneficial use: (1) engineered uses, (2) agricultural and product use, and (3) environmental enhancement. Some examples of options within each category include; habitat development, aquaculture, beach nourishment, recreation, agriculture, mine reclamation, shoreline stabilization, and industrial use/construction (Brandon and Price, 2007). As the capacities of the confined upland disposal facilities are reached, more material is now being considered for beneficial use.

Weanack Land LLLP, located around Shirley Plantation in Charles City VA, has a history of accepting dredge materials for beneficial use (primarily agricultural and mine land reclamation uses). Management issues associated with each dredge material accepted at this facility are increasingly complex, i.e. the first sediments accepted (Woodrow Wilson Bridge Project) were fresh-water in origin and very low in contaminant levels, the second group of sediments accepted (Earle Naval Weapons Station, NJ) were slightly contaminated with organics and came from a saline environment, and the current work is oriented towards accepting and remediating moderately contaminated or acid forming materials (Maryland Port Administration and Appomattox River to name a few). Though crop establishment on the Woodrow Wilson Bridge sediments was achieved within two years (Daniels et al., 2007), crop establishment on the Earle Naval Weapons Station sediments has been more difficult. Challenges result from the soluble salt influences on crop establishment as well as adverse physical properties of the material (e.g. high silt and lack of structure).

There are two “active” approaches feasible to this situation, where use of locally available soil resources is highly desirable. The first is the addition of a topsoil cap (approximately 20 cm) from nearby topsoil stockpiles and berms, providing a growth medium suitable for root development of a cover crop followed by succeeding annual crops or perennial vegetation. The second solution is to utilize stockpiled sand dredged from the nearby James River channel and mix this material with the surface of the Earle dredge material to achieve 30% sand by volume. Salt leaching from the surface of the dredge material and macroporosity would be improved by this approach. A more

"passive" approach is tillage of the existing sediments. Additionally, the application of compost could improve both biologic and physical soil properties above that of fertilizer applications. Organic amendments are a feasible way to stimulate microbial communities and to provide organic material which acts as a nucleus for aggregate formation (Six et al., 1998). An active microbial community secretes polysaccharides into the soil facilitating aggregate formation and transforms organic nutrients into inorganic forms more available for plant uptake. Aggregation improves soil physical properties by increasing the ratio of interconnected macro- to micropores for root development, gas exchange and water flow in addition to regulating biotic activity through the slow release of organic matter for microbial utilization via aggregate turnover (Hillel, 1982; Essington, 2004; Coleman et al., 2004). Through time, an aggregated soil rich in soil nutrients capable of supporting row crops should develop.

The objectives of this experiment were: (1) to evaluate the main treatment effects of a topsoil cap over the Earle Basin dredge material vs. sand incorporation into existing Earle Basin dredge material on cover crop establishment followed by annual crops or perennial vegetation, (2) to evaluate the secondary effects of additions of a compost + N + P fertilizer treatment and a standard N + P fertilizer applications to each main treatment via split plot applications on cover crop establishment and succeeding annual crops or perennial vegetation and (3) to identify soil chemical (soluble salts and pH), physical (aggregation and organic matter) and biological (microbial biomass) responses to the soil amendments and vegetation establishment.

Materials and Methods

Shirley Plantation is located on the James River in Charles City County, VA (39 km southwest of Richmond). Around the edges of the main plantation property, Weanack Land LLLP manages dredge sediments from navigational waterways in upland containment basins created from degraded farmland and abandoned gravel mining pits (Figure 1). In 2004, a clay lined containment basin approximately 25 ha in size was created to hold marine dredge material from Earle Naval Weapons Station. The sediments were derived from marine environment (original sediment:water EC>25 dS m^{-1}). The slurried dredge material was hydraulically pumped using a closed loop system into the basin over a period of six months. Approximately 300,000 m^3 of saline, uncontaminated material

were pumped into the basin in total. Over a three year time period, the material had gone through extensive dewatering; however, the basin was still devoid of vegetation. By 2009, the Earle Naval Weapons Basin showed indications of natural invasion of surrounding plant species (mostly weedy).

The final management goal for this basin is return to farmland, which will only be possible once the sediments are well drained enough to support large farm equipment and the salinity is reduced in the rooting zone to tolerance levels acceptable for specific crops [i.e. *Zea mays* (corn), *Triticum sp.* (wheat), *Glycine max* (soybeans)].

Image: Google Earth, 2130m

Figure 1. Aerial view of the Shirley Plantation and Weanack land holdings in Charles City, VA. Field study was conducted on the southeast corner of the Earle Naval Weapons Basin.

There were two components to this study; a preliminary study conducted in the greenhouse to test the effects of each treatment on German millet (*Setaria Italica* L.) establishment in a controlled setting followed by a fully replicated field experiment. Experimental designs for each will be discussed in detail below.

Greenhouse Experiment

A greenhouse experiment was initiated in March of 2009 to test the effects of three treatments on German millet establishment before field plots were installed. Treatments included: (1) Earle dredge material + N + P + lime, (2) Earle dredge material + 30% sand by volume + N + P + lime, and (3) Earle dredge material covered with 5 cm of topsoil material (20 cm not added due to the small size of the pots). Treatments were assembled and placed in plastic lined pots (15 cm in diameter) at equal weights. Nitrogen fertilizer was applied to all pots in splits (rate of 25 mg kg^{-1} at initial seeding and 25 mg kg^{-1} after plant establishment) as ammonium nitrate; phosphorous fertilizer (triple superphosphate) was also applied at a rate of 100 mg kg^{-1} prior to seeding. Calcium hydroxide was applied (0.1% dry weight) to increase the pH prior to seeding on all treatments.

Each treatment was replicated four times and was also added to two pots lined with paper filters to determine 90% container capacity for watering on a weight basis. Pots were seeded with German millet (0.75 g per pot) and vented plastic wrap was used to cover the pots during germination. Plants were thinned to 10 plants per pot once established (30 days). The pots were monitored and watered on a daily basis. German millet establishment was evaluated weekly on each treatment via plant height and at peak biomass the pots were harvested and the biomass dried and weighed.

Study Site Installation and Field Sampling

After preliminary sampling to test the variability in dredge sediment properties (EC, pH and fertility), plot locations were flagged in the southeast corner of the Earle Naval Weapons Basin (Figure 2). Two samples were collected and composited from each plot from the 0-5 and 5-20 cm depths prior to treatment installation in mid-April of 2009 (referred to as "pre-install" in the results section; collected on 4-16-09). Main treatments consisted of: (1) a loamy topsoil cap of 20 cm, tilled (TS), (2) 30% sand by volume tilled into the surface 20 cm of dredge material (30%S) and (3) the existing dredge sediment surface, tilled (Control). Each main treatment was replicated four times in a completely randomized design with plot sizes 15x15 m. Splits of: (1) compost (78.4 Mg ha^{-1}) and (2) non-compost were randomly assigned within each plot and plots were tilled in an east-west direction to avoid contamination across splits. Soil samples were again collected from the 0-5 and 5-20 cm depths prior to seeding and fertilizing (referred to as "post-install" in the results section; collected on 5-13-09) to better represent microbial and aggregate dynamics at time zero.

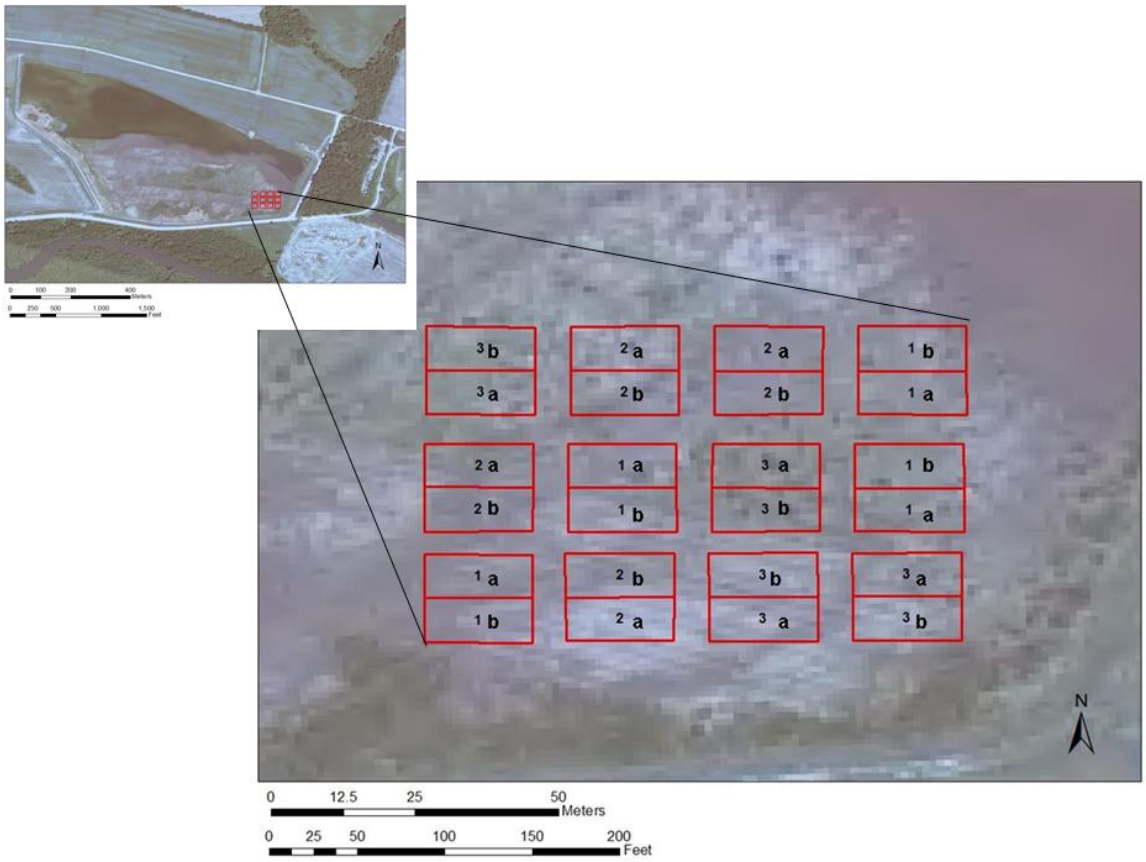

Figure 2. Location and treatments of the experiment on the Earle Naval Weapons Basin at the Shirley Plantation, Charles City, VA. Treatment type indicated by number (1: topsoil, 2: sand, 3: Earle). Compost split indicated by letter (a: no compost, b: compost).

Figure 3. Installation of main treatments at the Earle Soil Amendment Crop Plot Experiment, Charles City, VA. Photo taken from southeast corner of plots.

After plot installation and a second soil sampling, the area was hydro-seeded to German millet at a rate of 22.4 kg ha^{-1} with N (40 mg N kg^{-1}) and P (200 mg P kg^{-1}) fertilizer applications (as a combination of di-ammonium phosphate and triple super phosphate) and lime (300 kg ha^{-1}; 0.1% dry rate). Millet yields were determined at peak biomass with three randomly assigned clip plots per split. Within two of the three clip plot locations, soil samples were collected and composited for the 0-5 cm depth and again for the 5-20 cm depth (referred to as "millet" in the results section). Remaining millet on the plots was cut with three passes and raked from the plots. Plots were then no-till drill seeded into winter wheat (*Triticum aestivum)* and fertilized with 45 kg N ha^{-1} and 45 kg P ha^{-1} as a combination of di-ammonium phosphate and triple super phosphate. Due to difficulties in plot access (i.e. an extremely wet winter, making dredge material very soft), the plots did not receive any additional N fertilizer applications or weed control as would be necessary for effective management. Total above-ground biomass and soil samples were collected from the plots in June of

2010 using the same method as for the previous year's sampling (referred to as "wheat" in the results section). Bulk density samples were also collected from the field plots in 2010 using a standard core sampler.

Sample Preparation

Vegetation samples were separated into specific vegetation groups (i.e. millet and "other" in 2009 and "total" in 2010), dried at 55˚C in a force air oven and weighed. Soil samples were split into thirds; one third air dried and sieved to 2 mm for general soil analyses, one third air dried and sieved to 8 mm for aggregate analyses and one third refrigerated and moist sieved to 8 mm for microbial analyses.

Soil Analyses

Soils from both the greenhouse and field experiment were analyzed for saturated paste soluble salt concentrations (electrical conductivity - EC), pH, physical soil properties (via water stable aggregate size distributions - large and small macroaggregates and microaggregates), organic matter (using whole soil and aggregate carbon (C) as a proxy for OM), and microbial activity (using microbial biomass C). Samples from the greenhouse experiment were also analyzed for root biomass and length. An Oakton con 100 series EC probe (Vernon Hills, IL) and a Fisher Scientific Accumet Basic pH meter with a glass electrode (Pittsburgh, PA) were used for analyses. Water stable aggregate size distribution of soil was determined using a wet sieving protocol described by Six et al. (1998) on all 8 mm sieved samples. Aggregate sizes were corrected for sand according to Denef et al. (2001) for clarity when comparing across plots of different soil textures. Samples were powder ground (<53 μm) and analyzed for total C (and total N; however total N results will not be presented, only used to determine C:N ratios) via dry combustion (Elementar CNS analyzer, Hannau, Germany). Concentrations for each aggregate sample were calculated on a sand free basis (Elliot et al., 1991) and bulk density values were used to convert concentrations (mg kg^{-1}) into pools (Mg ha^{-1}) for the samples collected in July of 2010. Field moist samples were analyzed for microbial biomass C using a chloroform fumigation-extraction method (Kc = 0.38; Coleman et al., 2004; von Luetzow et al., 2007) followed by analysis using a Sievers 900 total organic C analyzer (Boulder, CO). Root analyses were conducted on volumetric cores collected from the center of each pot in the greenhouse experiment. These cores were slaked overnight and roots were washed and collected on a 2 mm

sieve. Root length was then determined using the WinRhizo program. Root samples were then dried in a 55˚C oven and weighed to determine biomass.

Statistical Analyses

One way analysis of variance was used to determine differences among treatments followed by t-tests for separation of means (SigmaPlot, 2008). Statistical analyses were accomplished at $P<0.05$ or $P<0.10$ where specified.

Results

Greenhouse Study

German millet establishment in the greenhouse study was consistent across all treatments. Aboveground biomass production was highest on the Control and TS treatments after three months of growth (Table 1; Fig. 4).

Table 1. Plant height and biomass at harvest data for German millet grown on various treatments (Control, 30% sand by volume added (30%S), and topsoil cap (TS)) applied to the Earle Basin dredge materials in a greenhouse experiment. Significant differences are shown across treatments by date with different letters ($P<0.05$).

Treatment	Plant Height				Biomass
	cm				g per pot
	4/12/2009	5/17/2009	6/18/2009	7/16/2009	7/17/2009
Control	8.61 b	35.1 a	42.7 a	51.1 a	14.9 a
30%S	14.7 a	34.0 a	38.2 a	44.8 a	9.20 b
TS	13.5 a	32.9 a	41.8 a	50.6 a	15.0 a

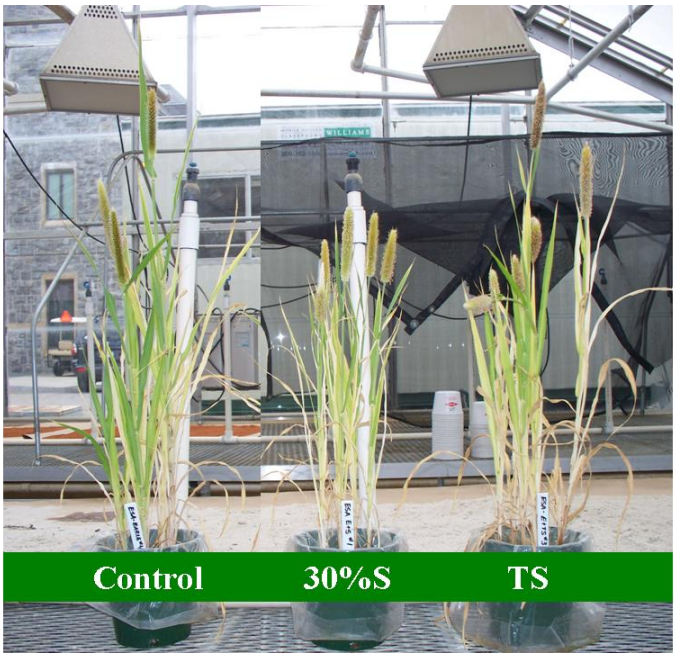

Figure 4. German millet establishment after 3 months on Control, 30% sand (30%S) and topsoil (TS) treatments.

Electrical conductivity was significantly higher in the TS vs. the Control and 30%S treatments (Table 2). Soil pH was significantly higher in the TS treatment than the Control and 30%S treatments. Large macroaggregate proportions were highest in the Control treatment (0.32 g g^{-1}), while small macroaggregates dominated the 30%S treatment. The TS treatment has a similar distribution of all aggregate size classes (0.21, 0.36, and 0.21 for large- and small macroaggregates and microaggregates, respectively). Root biomass was highest on the TS treatment, followed by the 30%S and Control treatments; however, root length among the treatments was similar.

Table 2. Soil electrical conductivity (EC), pH, large macroaggregates (2000-8000 μm), small macroaggregates (250-2000 μm), microaggregates (53-250 μm), microbial biomass carbon (MBC), root biomass and root length for various treatments (Control, 30% sand by volume added (30%S), and topsoil cap (TS)) applied to the Earle Basin dredge materials. Results presented were from lab analyses conducted following German millet harvest in a greenhouse experiment. Significant differences are shown across treatments with different letters ($P<0.05$).

Treatment	EC	pH	2000-8000 μm	250-2000 μm	53-250 μm	MBC	Root Biomass	Root Length
	$dS\ m^{-1}$			$g\ g^{-1}$			$kg\ ha^{-1}$	cm
Control	9.79 a	6.16 b	0.32 a	0.38 a	0.07 b	18.05 a	198.8 b	355.9 a
30%S	8.87 b	5.94 b	0.21 b	0.26 b	0.05 c	15.44 a	239.7 ab	321.7 a
TS	7.68 c	6.95 a	0.21 b	0.35 a	0.17 a	16.97 a	383.1 a	443.9 a

In general, macroaggregate (250-8000 μm) C concentrations were higher in the Control and 30%S compared to the TS treatment (Fig. 5a), while microaggregate C concentrations were higher in the TS relative to other treatments. Carbon pools (on a Mg ha^{-1} basis) were higher for all aggregate size classes for the TS than other treatments (Fig. 5b).

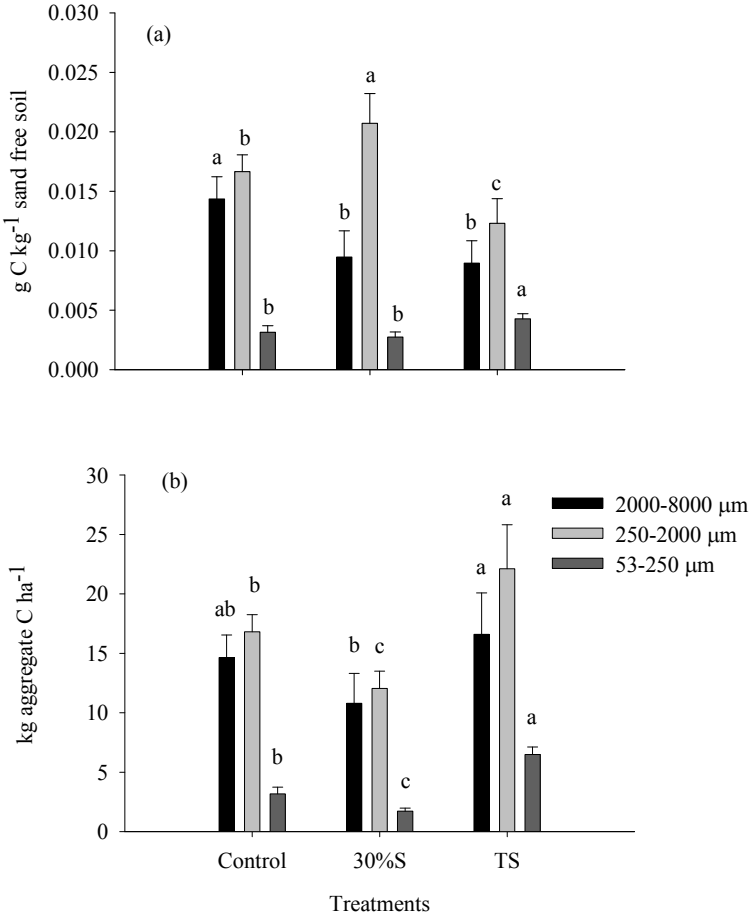

Figure 5. Aggregate carbon (C) concentrations (a) and pool sizes (b) for treatments (Control, 30% sand by volume added (30%S), and topsoil cap (TS)) applied to the Earle Basin dredge materials. Results presented were from lab analyses conducted following German millet harvest in a greenhouse experiment. Significant differences are shown across treatments with different letters ($P<0.05$).

Field Experiment

Vegetation biomass was similar across all treatments when a compost material was incorporated into the soil (Table 3). Without compost, differences among treatments were apparent. The 30%S treatment had significantly higher biomass production than the TS treatment, with the Control

treatment biomass similar to all treatments. Under wheat/mixed vegetation, both the Control and 30%S treatments had higher production than the TS treatment. The addition of compost significantly increased total biomass production in 2010 compared to non-compost plots for the TS treatment. The opposite was observed for the 30%S treatment, where non-compost plots exhibited higher productivity than composted plots within this treatment.

Table 3. Plant biomass for 2009 German millet, other species (invasive) and total as well as 2010 total biomass grown on various treatments (Control, 30% sand by volume added (30%S), and topsoil cap (TS)) applied to the Earle Basin dredge materials. Significant differences are shown across treatments with different letters ($P<0.10$) and an asterisk indicates significant differences within treatment among compost/non-compost splits.

Treatment	2009			2010
	German millet	Other	Total	Total
	kg ha^{-1}			
	Compost			
Control	3455 a	612.3 a	4067 a	4007 a
30%S	2751 a	893.0 a	3644 a	4302 a
TS	2547 a	828.2 a	3375 a	3897 a*
	Non-compost			
Control	3276 ab	1052 a	4328 ab	4121 a
30%S	4382 a	987.0 a	5369 a*	4319 a
TS	1517 b	1467 a*	2984 b	3364 b

Soil EC was generally lower for the 30%S and TS treatments regardless of compost additions once vegetation was established on the plots (Table 4). There was a consistent decline in EC for all treatments as the plots were seeded to millet and then into wheat; eventually dropping to levels below the threshold for negative yield effects of most agricultural crops (e.g. 4.0 dS m^{-1}; Singer and Munns, 2006; Sparks, 2003). Soil pH was consistently lower on Control and 30%S treatments than the TS in the 5-20 cm depths across all sampling times regardless of compost additions. In the surface soils (0-5 cm), pH did not follow consistent trends with treatment (Table 4). Though time, pH generally increased across all treatments. Compost additions generally did not influence soil pH in either depth of all treatments.

Table 4. Soil electrical conductivity (EC) and pH for treatments (Control, 30% sand by volume added (30%S), and topsoil cap (TS)) applied to the Earle Basin dredge materials. Significant differences are shown across treatments with lower-case letters ($P<0.05$), upper-case letters indicate a change across dates within treatment and an asterisk indicates significant differences within treatment among compost/non-compost splits.

Treatment/Date	**Compost (0-5 cm)**		**Non-compost (0-5 cm)**	
	EC	pH	EC	pH
	dS m^{-1}		dS m^{-1}	
Pre-Install (4/16/09)				
Control	7.67 a, A	4.59 a, C	4.47 a, A	4.91 a, B
30% Sand	6.18 a, A	4.31 a, B	6.28 a, A	4.79 a, A
Topsoil	4.73 a, A	4.90 a, C	3.14 a, A	4.89 a, C
Millet (9/7/09)				
Control	3.36 a, B	5.65 b, B	3.24 a, A	5.32 a, B
30% Sand	1.32 b, B	5.99 ab, A	1.92 b, B	5.50 a, A
Topsoil	1.15 b, A	6.21 a, B	0.846 b, B	6.25 a, B
Wheat (6/22/10)				
Control	2.74 a, B	6.74 ab, A*	2.72 a, A	5.98 b, A
30% Sand	1.62 b, B	6.60 b, A	2.23 a, B	6.39 b, A
Topsoil	0.995 b, A	7.71 a, A	1.35 b, B	7.24 a, A
	Compost (5-20 cm)		**Non-compost (5-20 cm)**	
Pre-Install (4/16/09)				
Control	6.64 a, A	4.77 a, B	4.23 a, A	5.24 a, A
30% Sand	5.14 a, A	5.42 a, B	4.15 a, A	5.35 a, A
Topsoil	4.01 a, A	5.79 a, B	3.34 a, A	5.25 a, C
Millet (9/7/09)				
Control	3.28 a, B	5.71 b, A	3.88 a, A	5.17 b, A
30% Sand	1.75 b, B	5.80 b, B	2.42 a, A	5.36 b, B
Topsoil	0.900 b, B	6.34 a, B	1.73 a, B	6.30 a, B
Wheat (6/22/10)				
Control	3.49 a, B	6.39 b, A	3.22 a, A	5.70 b, A
30% Sand	2.07 ab, B	6.59 b, A	2.47 a, A	6.55 b, A
Topsoil	1.24 b, B	7.41 a, A	1.08 b, B	7.07 a, A

Soil macroaggregation (250-8000 μm) was consistently higher for the Control treatment than the 30%S and TS treatments, across both depths and regardless of compost additions (Table 5). There was no indication that the addition of compost improved soil aggregation for any treatment. After plot installation, macroaggregation significantly decreased in the 30%S and TS treatments and did

not recover to pre-disturbance level. Microaggregates are significantly higher in the TS treatment, due to the difference in soil textures and type of material.

Macroaggregate C was consistently higher for the Control treatment relative to the other two treatments (Table 6). Once wheat was established on the plots, there was a clear separation among all treatments, with- and without compost, for macroaggregate C concentrations. Carbon concentrations for both size classes were similar after compost was added to the plots and within two years, the effects of the compost additions within the aggregate size classes were diminished by the main treatments (sand and topsoil) to the plots. The only treatment consistently gaining C under the different plantings of millet and wheat was the Control treatment. When comparing the concentrations observed under wheat to the post-installation concentrations, there was a 20 to 45 g C kg^{-1} reduction in concentrations under the 30%S treatment in the macroaggregate fraction in the compost amended splits. The Control and TS treatments both gained C by 2 to 10 g C kg^{-1} soil. In the non-compost plots, both the 30%S and TS treatment concentrations were reduced between plot installation and wheat establishment, while the C in the Control treatment increased in the 0-5 cm depth only. Microaggregate C concentrations increased for all treatments, again when compost was added to the plots, and decreased between plot installation and wheat establishment for the TS treatment only in plots not receiving compost.

Carbon:N ratios can provide insight into the rates at which organic substrates are being utilized by microbial communities in the soil. After compost additions to the plots, C:N ratios were approximately 25:1 to 15:1 in the surface soils of the amended plots (30%S and TS) and were consistently 15:1 in the surface and subsoil of the Control plots pre- and post-compost additions. In non-compost plots, C:N ratios were between 9 and 12:1 across all treatments at all sampling times.

Table 5. Soil aggregation for treatments (Control, 30% sand by volume added (30%S), and topsoil cap (TS)) applied to the Earle Basin dredge materials. Significant differences are shown across treatments with lower-case letters, upper-case letters indicate a change across dates within treatment and an asterisk indicates significant differences within treatment among compost/non-compost splits (P<0.10).

Treatment/Date	**Compost (0-5 cm)**		**Non-compost (0-5 cm)**	
	250-8000 µm	53-250 µm	250-8000 µm	53-250 µm
	g aggregate g^{-1} soil			
Pre-Install (4/16/09)				
Control	0.76 a, AB	0.11 a, A	0.80 a, A	0.09 a, A
30%S	0.73 a, A	0.10 a, A	0.76 a, A	0.10 a, A
TS	0.76 a, AB	0.08 a, C	0.77 a, A	0.11 a, C
Post-Install (5/13/09)				
Control	0.79 a, A	0.06 b, B	0.83 a, A	0.04 b, B
30%S	0.49 b, B	0.05 b, C	0.58 b, B	0.03 b, B
TS	0.29 c, B	0.33 a, A	0.22 c, B	0.43 a, A
Millet (9/7/09)				
Control	0.69 a, B	0.07 b, B*	0.72 a, B	0.05 b, B
30%S	0.48 b, B	0.06 b, BC	0.48 b, B	0.06 b, A
TS	0.27 c, B	0.32 a, A	0.23 c, B	0.37 a, B
Wheat (6/22/10)				
Control	0.77 a, A	0.07 b, B	0.81 a, A*	0.06 b, AB
30%S	0.47 b, B	0.07 b, B	0.51 b, B	0.06 b, A
TS	0.32 c, B*	0.23 a, B	0.22 c, B	0.43 a, A
	Compost (5-20 cm)		**Non-compost (5-20 cm)**	
Pre-Install (4/16/09)				
Control	0.81 a, A	0.07 a, A	0.77 a, A	0.04 a, BC
30%S	0.74 a, A	0.04 a, A	0.76 a, A	0.05 a, A
TS	0.75 a, A	0.06 a, C	0.78 a, A	0.04 a, BC
Post-Install (5/13/09)				
Control	0.78 a, A	0.04 b, A	0.80 a, A	0.02 b, C
30%S	0.53 b, B	0.01 b, A	0.57 b, B	0.02 b, A
TS	0.29 c, B	0.34 a, A	0.23 c, B	0.38 a, A
Millet (9/7/09)				
Control	0.63 a, A	0.06 b, A	0.64 a, B	0.06 b, B
30%S	0.39 b, B	0.11 b, A	0.47 b, C	0.06 b, A
TS	0.22 c, C	0.36 a, A	0.26 c, B	0.32 a, A
Wheat (6/22/10)				
Control	0.76 a, A	0.07 b, A	0.74 a, A	0.08 b, A
30%S	0.49 b, B	0.07 b, A	0.48 b, BC	0.07 b, A
TS	0.34 c, B*	0.19 a, B	0.18 c, B	0.27 a, A*

Table 6. Soil aggregate carbon for treatments (Control, 30% sand by volume added (30%S), and topsoil cap (TS)) applied to the Earle Basin dredge materials. Significant differences are shown across treatments with lower-case letters, upper-case letters indicate a change across dates within treatment and an asterisk indicates significant differences within treatment among compost/non-compost splits (P<0.10).

Treatment/Date	**Compost (0-5 cm)**		**Non-compost (0-5 cm)**	
	250-8000 µm	53-250 µm	250-8000 µm	53-250 µm
	g C kg^{-1} soil			
Pre-Install (4/16/09)				
Control	35.3 a, B	5.02 a, A	39.9 a, BC	4.33 a, A
30%S	33.4 a, A	4.40 a, AB	35.2 a, A	4.61 a, A
TS	35.7 a, A	3.78 a, C	37.3 a, A	5.21 a, A
Post-Install (5/13/09)				
Control	68.1 a, A*	4.70 a, A*	40.8 a, B	2.01 b, C
30%S	89.9 a, A*	3.08 a, BC*	23.6 b, B	0.760 c , C
TS	32.9 a, A*	4.58 a, BC	9.62 c, B	3.92 a, B
Millet (9/7/09)				
Control	65.0 a, A*	5.47 a, A*	47.0 a, A	2.42 b, BC
30%S	44.0 b, A*	2.78 b, C	22.9 b, B	2.34 b, B
TS	32.2 b, A	5.34 a, AB	14.5 b, B	4.20 a, B
Wheat (6/22/10)				
Control	70.2 a, A*	6.88 a, A*	36.4 a, C	3.53 a, AB
30%S	45.2 b, A*	4.65 a, A*	21.7 b, B	2.73 a, B
TS	29.4 c, A*	5.83 a, A*	7.64 c, B	2.66 a, C
	Compost (5-20 cm)		**Non-compost (5-20 cm)**	
Pre-Install (4/16/09)				
Control	36.2 a, B	2.90 a, B	33.5 a, BC	1.65 a, C
30%S	32.9 a, B	1.54 a, C	34.8 a, A	1.95 a, A
TS	33.7 a, A	2.42 a, B	36.0 a, A	1.93 a, B
Post-Install (5/13/09)				
Control	64.2 a, A*	2.91 ab, B*	39.6 a, A	1.11 b, C
30%S	61.7 a, A*	2.40 b, B*	22.9 b, B	0.704 b, A
TS	26.4 b, B*	4.55 a, B	7.45 c, BC	3.55 a, A
Millet (9/7/09)				
Control	45.9 a, B*	4.22 ab, B*	30.9 a, C	2.62 b, B
30%S	31.5 ab, B	3.27 b, AB	23.8 b, B	2.36 b, A
TS	19.7 b, C*	4.60 a, B*	10.8 c, B	3.60 a, A
Wheat (6/22/10)				
Control	66.4 a, A*	6.11 a, A*	37.0 a, AB	4.02 a, A
30%S	39.7 b, AB*	3.51 b, A*	17.6 b, C	2.15 b, A
TS	34.4 b, A*	5.95 a, A*	3.97 c, C	2.33 b, B

When converting soil C concentrations to pool sizes using bulk density values, there was a clear difference in the treatment effects (Fig. 6). The Control treatment contained the most C followed by the 30%S treatment and then the TS treatment. The effects of compost additions to the plots were evident after two years of vegetation growth, especially in the 5-20 cm depth. The effects of compost addition were also observed in the microbial community (microbial biomass C) when the plots were seeded to wheat, by increasing C concentrations in this pool by 20 g C kg^{-1} soil (data not shown); however, there were no differences among treatments for microbial biomass.

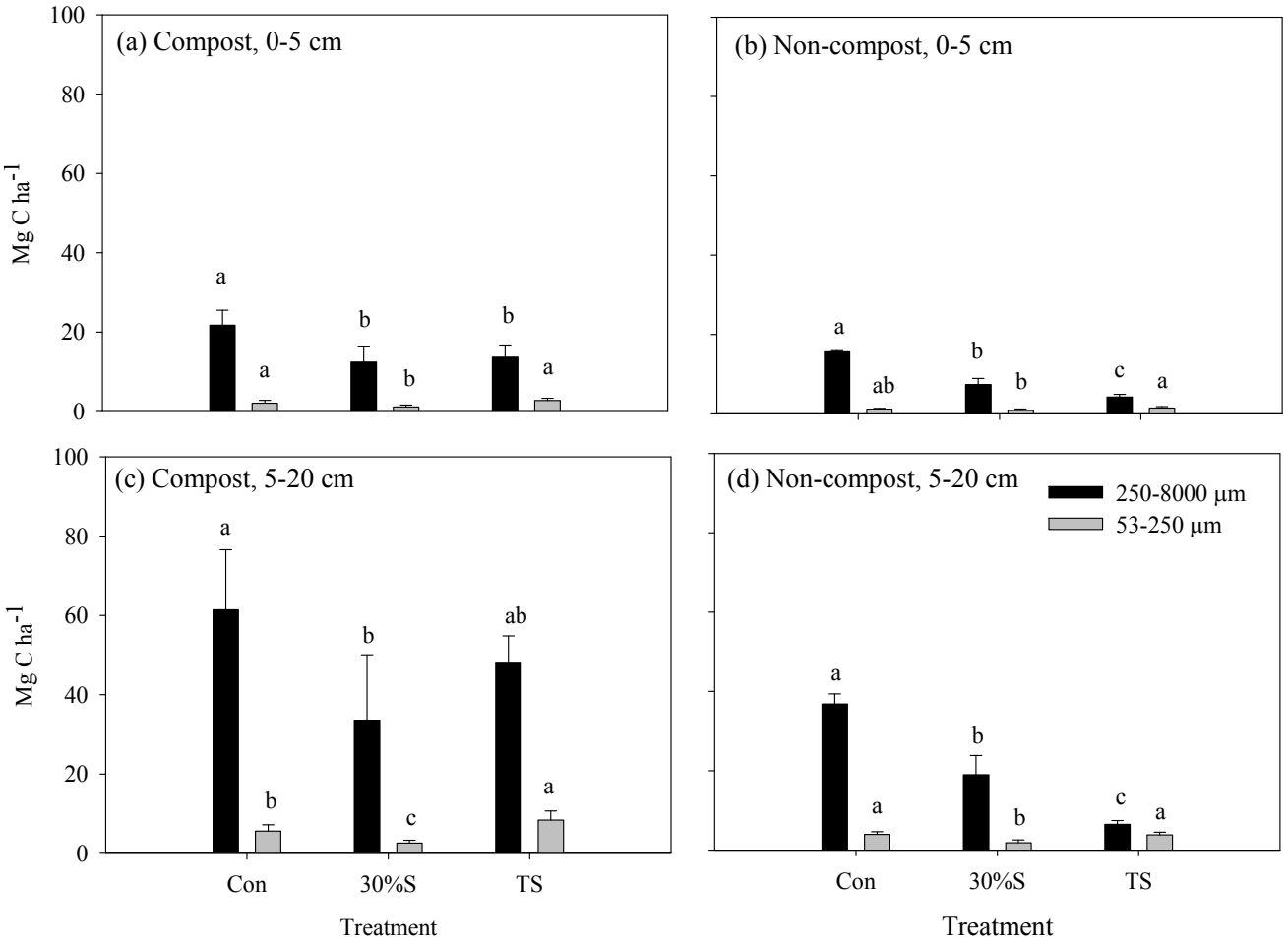

Figure 6. Carbon pool sizes under wheat/mix crop (6/22/10) for treatments (Control, 30% sand by volume added (30%S), and topsoil cap (TS)) applied to the Earle Basin dredge materials. Significant differences are shown across each treatment with lower-case letters ($P<0.10$). Error bars indicate standard deviations.

Discussion

Conversion of saline dredge materials in an upland containment basin into crop production is a challenging process because of: (1) adverse chemical properties (salinity), (2) lack of physical soil structure to provide paths for roots and habitat for microbes, as well as (3) a deficit in fresh, labile organic material in the dredge sediments. Assessment, manipulation, management and monitoring of these soil properties to improve conditions for crop production are necessary for a complete understanding of this dynamic system. Although there are many instances where dredge material has been beneficially reused, amending marine dredge material for agricultural production with continued monitoring and research is quite unique (Lee, 2001; Darmody and Marlin, 2002; Darmody et al., 2004; Daniels et al., 2007).

For the greenhouse component of this study, millet aboveground biomass was higher on the Control and TS treatments than the 30%S treatment, while belowground root biomass was highest on the TS treatment, followed by the 30%S and then the Control treatments. In evaluation of just the vegetation in the greenhouse experiment, the TS treatment would appear to be the most beneficial amendment for the establishment of a cover crop. In the field, millet biomass was highest on the 30%S plots relative to the other two treatments, with the TS treatment having the lowest millet and wheat production. As for soil properties, macroaggregation and C concentrations were higher on the Control than the amended soils for both the greenhouse and field experiments, but EC was also high on the Control treatment relative to the other two treatments. A high presence of soluble salts affects the ability of plants to obtain water from the soil (Sparks, 2003) and would negatively impact the establishment of crops less tolerant to saline/sodic soils than millet (i.e. the EC threshold where corn yields are reduced is ~ 1.7; Sparks, 2003). Though high aggregation and C indicate desirable soil properties for soil development and crop establishment (Jastrow and Miller, 1998; Six et al., 1998), the issues associated with salinity outweigh the benefits of aggregation and OM.

One of the goals with the incorporation of sand into the surface of the dredge material was to enhance salt leaching from the surface to zones below the rooting zone, via creation of macropores. This goal was successfully attained, although at the cost of loss of aggregation and OM accumulation. A major sand component in soils can reduce the stability of aggregates, making them

more dependent upon the tensile strength of fungal hyphae (Degens et al., 1996) than other electrostatic forces and microbial polysaccharides. The addition of a topsoil cap was also successful for creating a "low salt" rooting zone, but again, the physical soil properties and C concentrations were reduced relative to the Control treatment. The TS cap also brought in weedy species (i.e. *Sorghum halepense*, i.e. Johnson grass), exhibited surface crusting early in the experiment and was highly compacted by the equipment during plot construction. Biologically, the amended and Control treatments were similar; however, the composition of these communities could differ greatly based on the salinity of the soils as well as the microbial habitats created by soil aggregates (Coleman et al., 2004).

It also appears as if aggregation in these soils (amended or un-amended) relies up on cation bridging as a primary mechanism of aggregate formation and OM stabilization. An abundance of exchangeable calcium in this material (data not reported) greatly enhanced the aggregation in the Control plots, while dilution or reduction/leaching of these cations in amended soils led to lower aggregation (Six et al., 2004). However, the addition of compost material did not enhance aggregation in the short-term by serving as a nucleus for microbial activity and thus aggregate formation, the effects of organic amendments on calcium dominated soils has been observed in the long-term (Baldock et al., 1994). Other than the slight increase in microbial activity and some differences observed in vegetation production, the cost associated with hauling compost to the site did not prove to be beneficial in the short-term. Over the longer term, this relationship might change.

At this point, it is difficult to identify the ideal treatment, especially since a "weed-free", adequately fertilized (i.e. with N, based on soil fertility testing) crop has not been successfully established on these plots. These results point out that management issues associated with crop establishment on dredge sediments (Daniels et al., 2007), especially those of marine origin, are just as important as the optimization of soil properties. For example, the inability to access the plots for fertilizer applications or weed control because of rising water within the fully contained basin over the winter months influenced the wheat production and low bearing strength of dredge materials. The rising water within the basin also brought salts into the rooting zone, again reducing crop establishment and production. Thus, there are several dynamics that need to be considered when converting

dredge material into agricultural production. Optimization of management strategies and soil properties are two approaches for successful agricultural production on these marginal soils.

Conclusions

The short-term results presented in this study point towards the incorporation of sand into this material as being a feasible method for crop establishment and salinity reduction. It is possible that the addition of less sand would create a balance between aggregate formation, C accumulation and controlling salinity issues, while still producing high vegetation yields. The effects of the compost additions also might be realized in the long-term. It is clear that an additional year of management and a successful crop yield would assist in our selection of a best management practice for this specific type of dredge material.

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References Cited

Baldock, J.A., M. Aoyanna, J.M. Oades, and C.D. Grant. 1994. Structural amelioration of a South Australia red-brown earth using calcium and organic amendments. Aust. J. Soil Res. 32:571-594.

Brandon, D.L. and R.A. Price. 2007. Summary of available guidance and best practices for determining suitability of dredged material for beneficial uses. U.S. Army Corps of Engineers, Engineer Research and Development Center, ERDC/EL TR-07-27.

Coleman, D.C., D.A. Crossley, Jr., and P.F. Hendrix. 2004. Fundamentals of Soil Ecology (2nd ed.). New York: Elsevier Press.

Daniels, W.L., G. R. Whittecar, and C.H. Carter III. 2007. Conversion of Potomac River dredge sediments to productive agricultural soils. American Society of Mining and Reclamation meeting, June 2-7, Gillette, WY. Published by ASMR, 3134 Montevesta Rd., Lexington, KY 40502.

Darmody, R.G. and J.C. Marlin. 2002. Sediments and sediment-derived soils in Illinois: pedological and agronomic assessment. Env. Mon. and Assess. 77:209-227.

Darmody, R.G., J.C. Marilin, J. Talbott, R.A. Green, E.F. Brewer and C. Stohr. 2004. Dredged Illinois River sediments: Plant growth and metal uptake. J. Env. Qual. 33:458-464.

Degens, B.P., G.P. Sparling, and L.K. Abbott. 1996. Increasing the length of hyphae in a sand soil increases the amount of water stable aggregates. Appl. Soil Ecol.: 149-159.

Denef, K., J. Six, H. Bossuyt, S.D. Frey, E.T. Elliott, R. Merckx, and K. Paustian. 2001. Influence of dry-wet cycles on the interrelationship between aggregate, particulate organic matter, and microbial community dynamics. Soil Biology and Biochemistry 33, 1599-1611.

Elliott, E.T., C.A. Palm, D.A. Ruess, and C.A. Monz. 1991. Organic matter contained in soil aggregates from a tropical chronosequence: correction for sand and light fraction. Agriculture. Ecosystems & Environment 34:443–451.

Essington, M.E. 2004. Soil and Water Chemistry: An Integrative Approach. CRC Press, Boca Raton.

Hillel, D. 1982. Introduction to Soil Physics. Academic Press, San Diego, 364 pp.

Jastrow, J.D., and R.M. Miller. 1998. Soil aggregate stabilization and carbon sequestration. P. 207-233. In: R. Lal, J.M. Kimble, R.F. Follett, and B.A. Stewart (Ed.), Soil Processes and the Carbon Cycle, CRC Press, Boca Raton, FL.

Lee, C.R. 2001. Manufactured soil field demonstrations on brownfields and abandoned minelands, DOER Technical Notes Collection (ERDC TN-DOER-C25), U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/dots/doer

SigmaPlot. 2008. Version 11.0, A division of Systat, San Jose, CA.

Singer, M.J., D.N. Munns. 2006. Soils: An Introduction. Pearson Education, Inc., Upper Saddle River, NJ.

Sparks, D.L. 2003. Environmental Soil Chemistry. 2nd ed. Academic Press, Amsterdam.

Six, J., E.T. Elliott, K. Paustian, and J.W. Doran. 1998. Aggregation and soil organic matter accumulation in cultivated and native grassland soils. Soil Sci. Soc. Am. J. 62:1367-1376.

U.S. Army Corps of Engineers. 2003. "Evaluation of dredged material proposed for disposal at island, nearshore, or upland confined disposal facilities - Testing Manual," Technical Report ERDC/EL TR-03-1, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

von Luetzow, M., I. Koegel-Knabner, K. Ekschmitt, H. Flessa, G. Guggenberger, E. Matzner, and B. Marschner. 2007. SOM fractionation methods: Relevance to functional pools and to stabilization mechanisms. Soil Biology and Biochemistry 39:2183-2207.