CONVERSION OF POTOMAC RIVER DREDGE SEDIMENTS TO PRODUCTIVE AGRICULTURAL SOILS[1]

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Abstract. River channel and harbor dredging activities in the eastern USA generate hundreds of millions of yards of dredge materials annually with very little used beneficially. The Woodrow Wilson Bridge project across the Potomac River at Washington D.C. generated in excess of 450,000 m^3 of silt loam, high pH, low salt dredge materials. The materials were barged to Shirley Plantation on the James River in Charles City Co. Virginia, and placed into an upland utilization area atop a previously reclaimed sand and gravel mine. The strongly reduced inbound sediments were very low in sulfides, pesticides, and other contaminants. The materials were dewatered, treated with varying rates of yardwaste compost and planted to wheat (*Triticum vulgare*) in the fall of 2001 and corn (*Zea mays)* in 2002 and 2003. Winter wheat yields in 2001 were similar to local agricultural lands despite animal damage and less than ideal establishment conditions. Average corn yields in 2002 were greater than long-term county prime farmland yields in a severe drought year (2002) and equaled county averages in a wet year (2003). Soil pit and auger observations revealed significant oxidation and formation of a deep Ap-AC-C profiles with coarse prismatic structure within two years after placement. Overall, the chemical and physical properties of these materials are equal or superior to the best topsoils in the region, supporting federal initiatives to utilize suitable dredge materials in upland environments whenever possible.

Additional Key Words: Sand and gravel mining, oxidation, water quality, beneficial use.

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Introduction and Background

River and harbor dredging activities generate hundreds of millions of cubic meters of dredge materials in the eastern USA annually, and disposal options are becoming increasing limited and expensive. While sediments from certain sites are heavily contaminated (USEPA, 2005), much dredge material is quite suitable for placement into upland environments for conversion to topsoiling materials for mining and other disturbed sites (Darmody and Marlin, 2002; Darmody et al., 2004; Lee, 2001). The basic chemical and physical properties of these dredge sediments vary widely based on their depositional environment and watershed characteristics and history. For example, exposure and weathering of highly sulfidic dredge sediments produces extremely acid soil conditions and metal release (Fanning and Fanning, 1989), while any materials removed from marine or brackish environments will necessarily contain entrained salts and Na that will need to be leached before conversion into viable topsoiling materials. Similarly, dredge materials that are too high in fine silt+clay and organic matter may be difficult to handle, place and till in an upland environment. However, large volumes of non-sulfidic potentially suitable materials are routinely dredged and disposed of annually, and the federal interagency National Dredging Team (USEPA, 2003) has placed a high priority on moving suitable materials to upland beneficial use environments rather than disposal impoundments.

The Woodrow Wilson Bridge Dredge Materials Project

The construction of the Woodrow Wilson Bridge (WWB) replacement spans across the Potomac River just south of Washington D.C. excavated approximately 450,000 m^3 of freshwater tidal dredge sediments between 2000 and 2005. The sediments included a mixture of deeper Holocene deposits and recent post-settlement deposition. Extensive pre-excavation testing indicated that the sediments were very low in organic contaminants and metals, relatively low in organic matter and loam to silt loam in texture. A summary of inorganic constituents is presented in Table 1, and all pesticides, herbicides, and anthropogenic organic compounds were either non-detectable or well below United States Environmental Protection Agency (USEPA) Region III Risk Based Criteria (USEPA, 2006) for residential soils.

Weanack Land Limited Partners (Weanack) worked cooperatively with Virginia Tech, Old Dominion University, and Potomac Crossing Consultants (http://www.wilsonbridge.com/ea-ConDredgeDisposal.htm) to develop an upland beneficial use permit structure to use these materials to construct an agricultural soil landscape on a former sand and gravel mine adjacent to Shirley Plantation (Fig. 1). The majority of materials were moved by barge to Weanack in 2000 and 2001 and then off-loaded at its port facility with a clamshell loader into haulers. The materials were then placed into the 20 ha utilization cell (Fig. 2) and allowed to dewater and consolidate. The majority of materials was placed with haulers, had the consistency of raw cake dough, and flowed laterally for several m after placement. The upland utilization cell was on a former sand & gravel mine that had been in a mix of reclaimed agricultural and scrub forest land use. Mine spoils were cut out to enlarge the capacity of the area and the cut spoils were used to construct a 3 to 6 m berm/dike as required by permit conditions around the facility to avoid any loss of sediment or water to surface waters during operations (See Figs. 1 and 2). Additional materials were transported in later years and hydraulically pumped into lower reaches of the area.

This paper describes our collaborative studies on hydrologic impacts and conversion of dredge sediments to agricultural soils. Our overall program objectives were (1) to develop a viable approach for establishing productive agricultural systems on these sediments, and (2) to monitor changes in local hydrology, water quality and soil quality over time.

Table 1. Characteristics of WWB sediments based upon pre-dredge analyses (n = 12). Values given are for total analysis following appropriate digestion. ND = Not detected.

Parameter	**Units**	**Average**
Aluminum	mg/Kg	13,767
Antimony	mg/Kg	2.5
Arsenic	mg/Kg	3.9
Beryllium	mg/Kg	1.15
Cadmium	mg/Kg	0.73
Chromium	mg/Kg	36
Copper	mg/Kg	42.9
Iron	mg/Kg	30,619
Lead	mg/Kg	42
Magnesium	mg/Kg	5,219
Nickel	mg/Kg	28.7
Selenium	mg/Kg	25
Zinc	mg/Kg	198
Total Cyanide	mg/Kg	0.23
Dioxin	µg/Kg	0.01
Total Sulfur	%	1.0
Total Phosphorus	%	0.22
Total Nitrate & Nitrite	mg/Kg	5.1
Ammonia	mg/Kg	323
Total Kjeldahl Nitrogen	mg/Kg	405
Total Organic Carbon	%	1.8
OIL & GREASE	mg/Kg	500
PHENOLS	mg/Kg	ND
VOCs	µg/Kg	ND
PESTICIDES	mg/Kg	ND
PCBs	mg/Kg	ND
TRIBUTYLTIN	µg/Kg	5.36

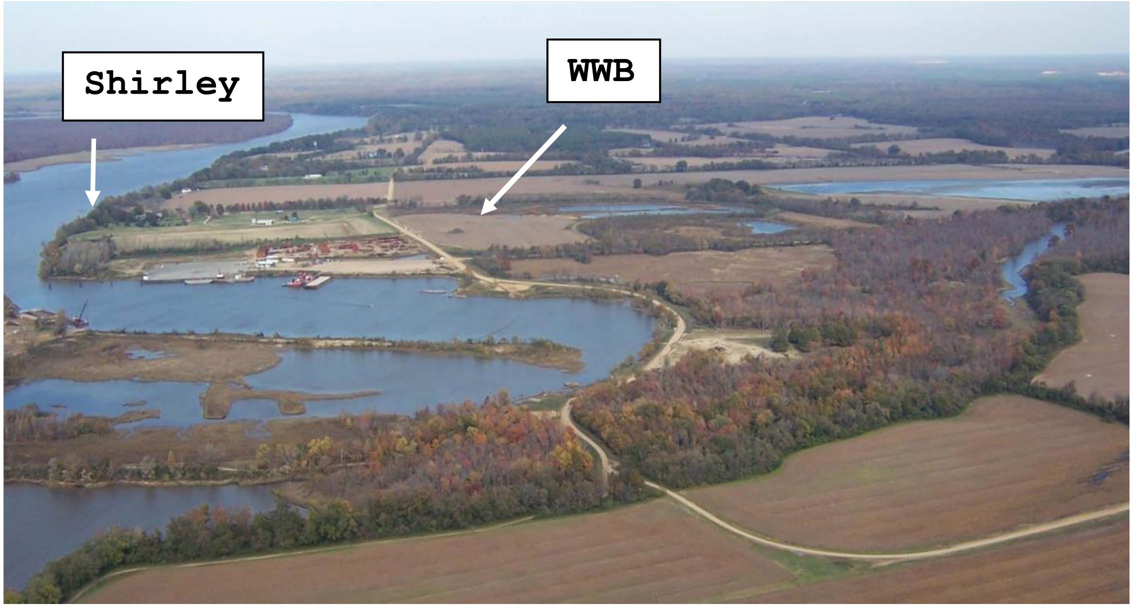

Figure 1. Overview of WWB dredge materials utilization area on Weanack property adjacent to Shirley Plantation. The dredge materials were transported by barge to the port facility shown in the middle of the photograph. James River is to the left. Agricultural lands in foreground and background are prime farmland (Pamunkey series; Typic Hapludalfs). Weanack is located in Charles City County, approximately 30 km SW of Richmond.

Figure 2. Reduced dredge materials being placed in December 2000. Picture was taken atop enclosing dike looking NW with Shirley Plantation house in background. Agricultural experiments were installed in August 2001 in area immediately to the left of this photograph.

Methods and Materials

Geologic and Groundwater Flow Analyses:

In 2000 and 2001 we bored over 30 shallow and deep wells for the purpose of logging geologic conditions and establishing a hydrologic and a water quality monitoring network. By 2002, we had installed 34 monitoring wells in the surficial aquifer; several more sites were used during the initial stages of the project but were destroyed by construction activity. Seven sets of nested piezometers were installed with well points above and below aquitards at key locations. Four ponds in (2) and around (2) the dredge placement area were also monitored using staff gages. Groundwater flow directions were inferred from water table contours derived from the water level data collected in monitoring wells. Several wells were not used in constructing the flow maps shown in figures because they reflect water levels in small water table lenses perched above the most extensive surficial aquifer system.

Field Revegetation Experiments:

By the summer of 2001, an area just to the south of well SW 47 (see Fig. 3) had dewatered and cured sufficiently for the installation of an agricultural amendment experiment. On August 16, 2001, a bushhog was used to knock down the vegetation in the general area. On September 11, 2001, we installed an experimental area 70 m X 35m with a 3 m buffer area around the plots. This location was chosen due to uniformity of dredge material conditions, relatively well-drained landscape position, and adjacency to the external dike haul road. A large composite soil sample (see Table 2 below) was taken from the area to quantify the chemical properties of the partially oxidized dredge Materials. On September 25, 2001, we used a common agricultural disk on the plot area to break up the clods and dessication cracks caused by the dry-down of the dredge Materials. On October 2, we returned to apply 60 kg/ha of triple super phosphate (0-45-0) over the entire block with a spinner spreader. Following this, we incorporated the material and further broke up the clods and cracks in the dredge Materials and prepared our seedbed with a Rotera^{tm} tiller with a rolling basket pulled behind (Fig. 4). On October 3, winter wheat (*Triticum vulgare*) was broadcast seeded over the area with a spinner spreader. We used 40 kg/ha of common winter wheat as a cover crop for the area. On October 24, we returned to the site to top-dress with 25 kg/ha urea (46-0-0).

Table 2. Initial soil test results from bulk composite surface dredge soil samples. These data represent the un-amended properties of the freshly deposited oxidizing materials taken in August of 2001.

pH	P	K	Ca	Mg	Zn	Mn	Cu	Fe	B
	-------------mg/kg dilute acid (Mehlich I) extractable--------------								
6.9	21	55	2808	198	50	126	8.6	300	0.6

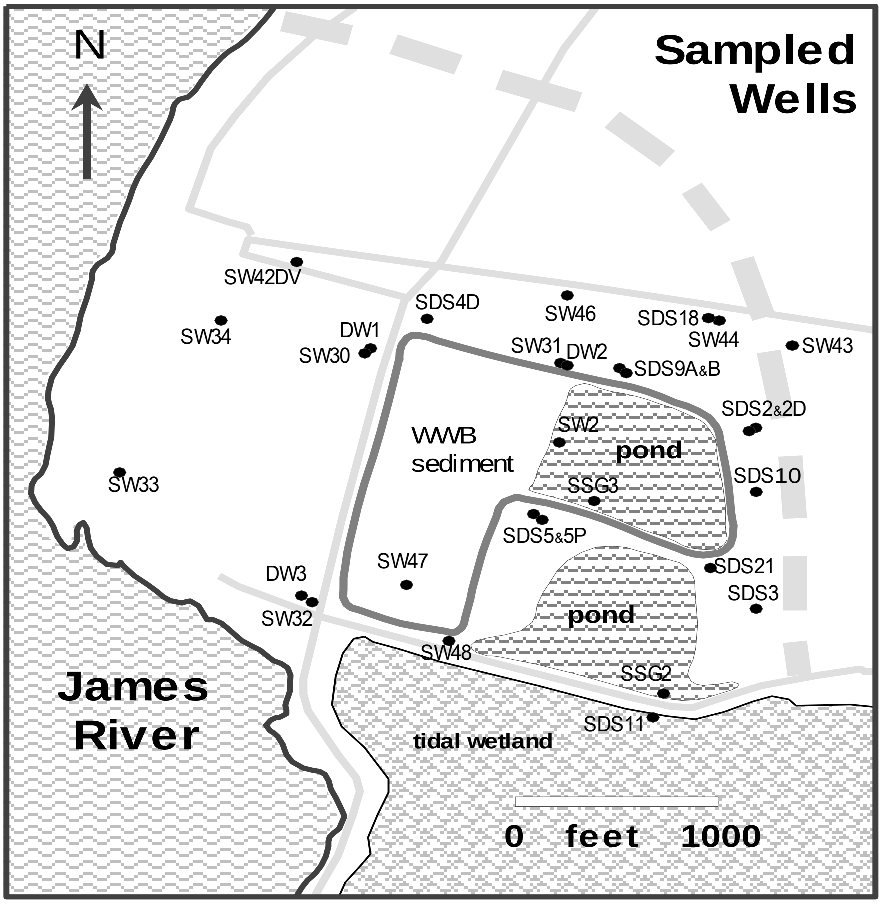

Figure 3. Detail map of WWB sediment utilization area and selected water sampling locations. Dashed line represents higher elevation terrace to north and east. Scale is in feet. Solid line is the external dike.

On February 5, 2002, we top-dressed nitrogen (50 kg/ha as UAN – Urea Ammonium Nitrate soln.) on the wheat in the entire experimental area. On March 26, 2002, we split the research block into two areas. On the area to be maintained and harvested for wheat, we applied a second application of 12 L of 30 % UAN. Fertilizer was applied on the split to be converted to corn at 50 kg/ha of 0-0-60 - potash, 100 kg/ha 0-46-0 - triple super phosphate, and 50 kg/ha 34-0-0 - ammonium nitrate. Yardwaste compost was spread on April 16, 2002 (Fig. 5). Compost was obtained from Grind-all Incorporated (Richmond VA) and spread at 0, 25, 50, 100 and 150 dry tons per acre (0, 56, 112, 224 and 336 Mg/ha) into each 3 x 5 m plot (with 3 m alleys). The design was completely randomized with four replications. The area was then disked to incorporate the compost, herbicides and fertilizers. Corn (*Zea Mays*) was planted (variety MA9140YG) on April 17, 2002 (Fig. 6). The mature wheat stand was harvested on June 20, 2002 with a plot combine (see Fig. 7). Corn was harvested on September 9, 2002. A similar approach was taken to establish corn in 2003. The crop was planted on April 23, 2002, and on May 20, 2003, we applied 80 kg/ha acre of P_2O_5 and 50 kg/ha per acre of K_2O with a hand held spinner spreader over the top of the emergent corn. In an effort to determine the inherent N supplying ability of the compost amended dredge soils, no N fertilizer was added in 2003. Plots were harvested on September 19, 2003. Crop yields were analyzed by ANOVA followed by Fishers LSD when the overall F was significant $p < 0.05$.

Figure 4. Row crop experimental area ready for seeding to wheat in October of 2001.

Figure 5. Application of 336 Mg/ha compost into high rate plots.

Figure 6. Row crop plots ready for seeding in April of 2002.

Figure 7. Wheat harvest in June of 2002.

Soil Observations

Back-hoe pits and soil augers were used to observe and log soil morphology at various times in the summers of 2002 and 2003. In June of 2005, we transect sampled the dry and arable portions of the WWB sediments as shown in Fig. 8. The soils were sampled with a 9 cm diameter bucket auger to a depth of 150 cm. Basic soil horizonation, color, structure and rooting were carefully described before bulk samples were taken of the 15 cm plow layer and the deeper, least weathered sediments at 150 cm. The soils were transported to our laboratories and analyzed for particle size analysis by sieving/pipette and dilute double-acid (Mehlich I) extractable nutrients and metals.

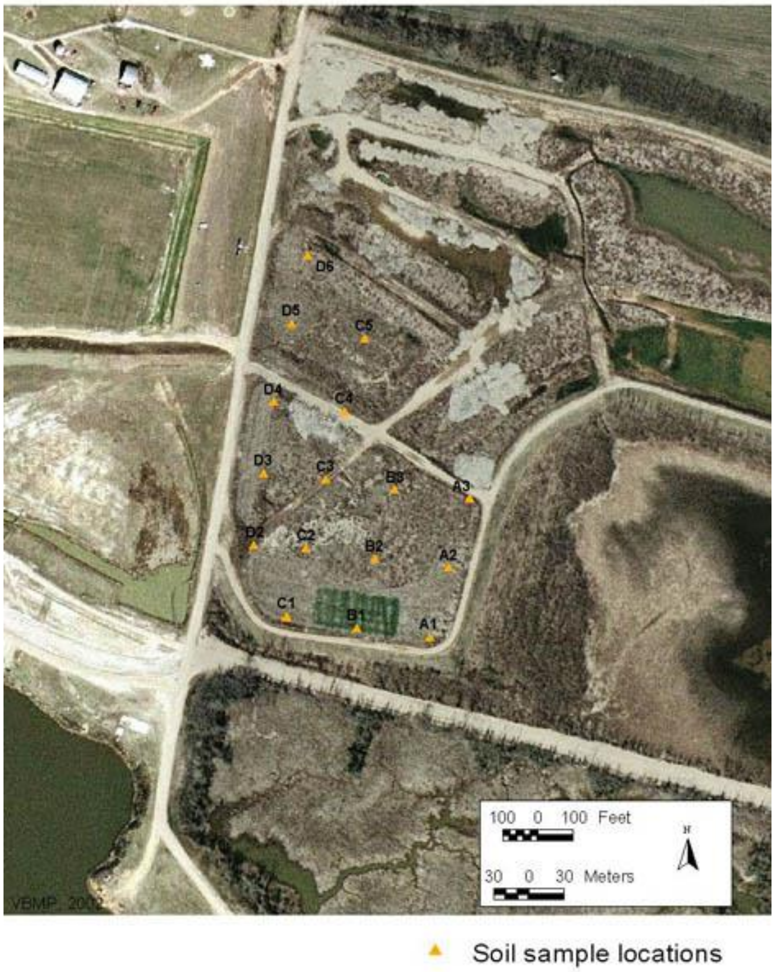

Figure 8. Soil boring and sampling locations in agricultural area of WWB basin in June of 2005. This photograph was taken in 2002 and the original row-crop experimental area can be seen at point B1.

Results and Discussion

Hydrogeologic Conditions

Overall, results from these hydrogeologic studies indicate that the study area has a very complex pattern of aquifers and aquitards (Table 3). The complexity stems from the history of cut-and-fill related to the sand-and-gravel mining at this site and the history of stream incision and valley-infilling caused by Pleistocene sea level fluctuations. At least six different geologic units play a significant role in controlling the flow of groundwater through this site (unit names from Mixon et al., 1989; McFarland, 1997)

Table 3. Description of geologic conditions at WWB utilization area based upon multiple drill cores logged in 2000 and 2001.

Hydrostratigraphic Unit	**Description**
Mining Fill	Mine spoils placed into older abandoned mine excavation. Commonly 5 – 8 m thick overlying fine-grained, compact Aquia beds beneath sediment disposal site. *Mixed member*: poorly sorted mixture of gravel, sand, silt, and clay; deposited by dumping; mostly under N half of refilled mine sites *Stratified member*: stratified sands and mud deposited in a lake from W to E; mostly under the S end and immediately to the W of the refilled mine site
Kennon Formation	Fining upward stream deposit (gravelly sand to silty clay) dominated by thick clay-rich beds; 3 – 5 m thick; fills small recent valleys carved into Tabb Formation beds.
Tabb Formation	Fining upward stream deposit (cobble beds to silty clay) dominated by cobbles and gravelly sand; 4 – 7 m thick; carpets large valley carved by the James River; forms broad terrace surface 15-20 feet elevation
Shirley Formation	Sand and gravel deposit (7+ m thick) with fine grained cap (3 m thick); forms broad terrace at approximately 10 – 13 m elevation, and terrace remnant beneath Shirley Plantation manor house
Nanjemoy-Marlboro unit	Compact glauconitic confining bed; encountered beneath Tabb Fm and Mining Fill
Aquia-Potomac units	Layered gravelly aquifers and confining beds (45+ m thick); noted in drill cuttings

Groundwater flow comes from rainfall soaking into the aquifers and from lateral flow from higher ground, particularly the surface aquifers of the Shirley Formation east of the study area. Before construction of the bermed area and addition of the sediment fill, flow passed beneath the bermed area and drained into the high permeability gravels of the Tabb Formation. Several examples of higher-than-expected water levels have been found in different monitoring wells, some of which have led to confusing preliminary interpretations of groundwater flow pattern in the shallow aquifer. Most of these "perched" readings were found in wells placed in the Kennon Formation alluvium and in portions of the Mining Fill.

During 2002, low rainfall during the winter, spring and summer lowered water levels and generated relatively little groundwater movement across the site. Following the heavy rains of fall 2002, water levels rose within the bermed area creating a hydraulic mound. Because of severe regional summer drought conditions, the December 2002 data are presented (Fig. 9). This analysis of the water levels indicates that groundwater radiates in all directions from the disposal site into ponds and into the very coarse Tabb Formation aquifer. Depending upon the distance, sediment permeability and hydraulic gradient present along the flow path taken, water draining from the sediment disposal area may take as little as one year to more than a decade to reach surface water sources. Hydrologic analyses in subsequent years (Daniels and Whittecar, 2004) revealed similar “water table mounding” effects, particularly during the winter months.

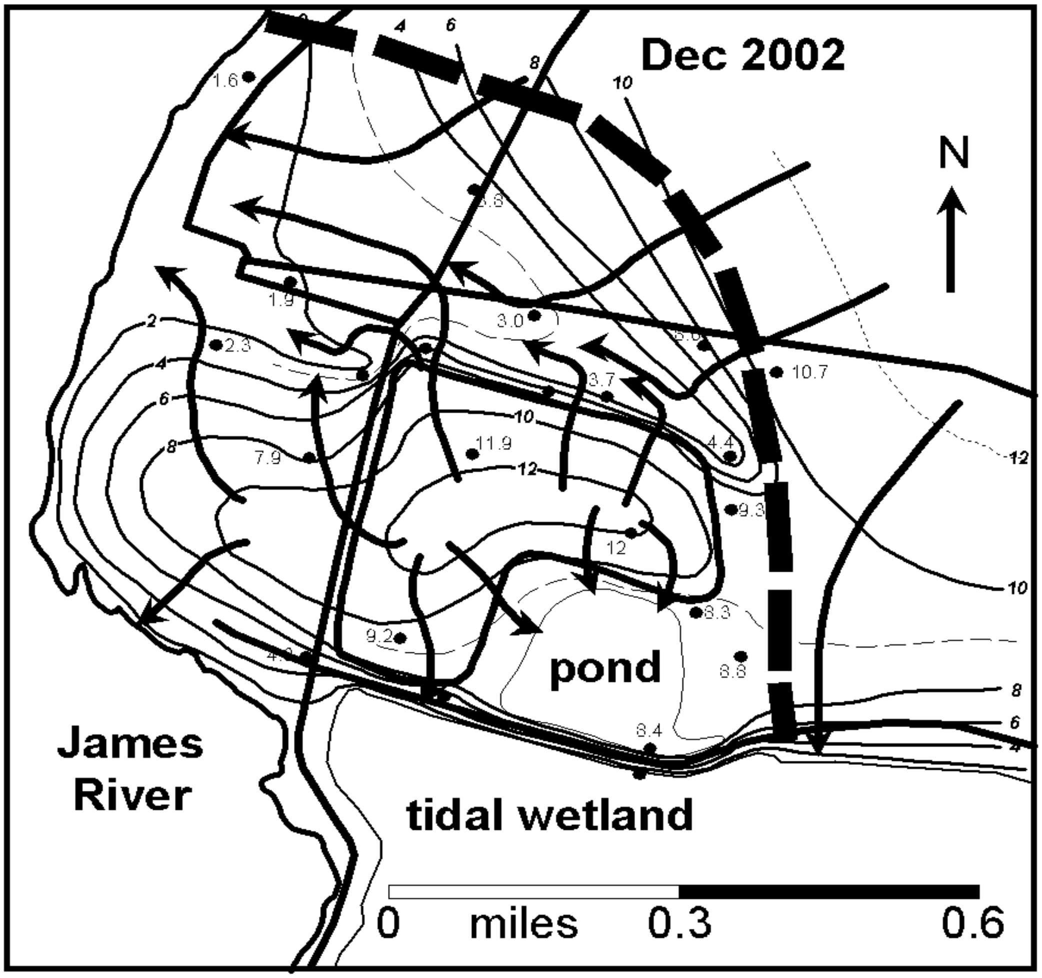

Figure 9. Groundwater elevations in surficial (unconfined) aquifer system at Weanack disposal site, December 14, 2002. Contours are in feet elevation. Arrows indicate the expected direction of seepage through the aquifer system.

Per permit requirements (Virginia Pollution Abatement – VPA), a rigorous baseline water quality study was performed in 2000 and detailed analyses (for most Safe Drinking Water Act constituents) of two upgradient and two downgradient wells have been performed on four occasions since placement. The surface water pond within the utilization area (Fig. 3) and the drinking well at Shirley Plantation are also sampled. To date, no effects of dredge placement have been observed on ground- or surface water quality (Daniels and Whittecar, 2004; 2006). Nitrate-N has been observed above drinking water standards (10 mg/L) on several occasions within the ponded area and at moderate levels (< 10 mg/L) in several upgradient ground water wells. The ephemeral high levels observed in the pond were attributed to revegetation of the dikes while the groundwater effects are clearly due to intensive local agricultural practices.

Over the initial 2001 and 2002 monitoring years, we did not observe any toxicity or "plant growth related" problems with these materials in the laboratory or field setting. Over the 2001 growing season, the entire surface of the dewatered sediments supported a lush vegetative cover which was a combination of seeded (buckwheat) and invasive native vegetation (smartweed and Johnson grass). As discussed below, this soil/sediment material has no apparent plant growth limiting properties.

Compost Amendment Rate Study Results:

Wheat and corn yields from the experimental plots are presented in Tables 4 and 5. The wheat yields were low relative to what would be expected from a well-managed agricultural enterprise. However, as noted above, wildlife damage (mainly via deer bedding and goose grazing) was extensive. Initial establishment was also hampered by high weed pressures necessitating extensive herbicide use and tillage on the low bearing strength dredge materials. Taking these combined factors into account, the observed wheat yields were reasonable, and no-soil related productivity or management limitations were noted.

Simply put, the corn yields recorded on the dredge materials in 2002 were outstanding. This region suffered a severe regional drought in 2002, although a few summer thunderstorms did provide adequate moisture at critical times for ear filling and grain development. Overall establishment and emergence was good and the corn established a full canopy by mid-July, effectively smothering weed competition. By early August, the corn plants within the plot area were over 2.5 m tall with 2 to 3 ears of corn per stalk. Apparently, the corn was able to root down through the dewatering dredge materials (through the deep desiccation cracks discussed later) to tap into the wetter dredge materials at depth. This coupled with the very favorable chemical conditions of these materials led to high yields. While corn grain yield did appear to increase with compost loading rate up to 112 Mg/ha, within-plot variability was high, and no significant compost rate effects were noted. However, even the control (0 compost) treatment yields were well above any 2002 yields on surrounding farms that we queried. In fact, a large percentage of corn planted in Charles City County suffered such protracted drought damage in 2002 that it was not harvested. After harvest, the standing crop residues were removed and the plots were disked.

Table 4. Wheat yield estimated on 4 random strips on June 20 2002 at Shirley Plantation/Weanack.

Strip ID Number		---- Wheat Yield ----	
		bu/A	kg/ha
SDS-1	30	36	1944
SDS-2	35	34	1836
SDS-3	36	24	1296
SDS-4	31	29	1566

Table 5. Corn yield in September 2002 and 2003 at Shirley Plantation/Weanack.

Treatment Compost Mg/ha	2002 Yield bu/A	2002 Yield kg/ha	2003 Yield bu/A	2003 Yield kg/ha
Check	187 a*	13,090	105 a	7350
56	226 a	15,820	113 a	7910
112	230 a	16,100	113 a	7910
224	197 a	13,790	117 a	8190
336	209 a	14,630	70 b	4900

*****Yields followed by different letters are significantly different at $p \leq 0.05$).

In contrast to 2002, 2003 was an exceedingly wet year, and we believe that contributed to overall yields being lower than the high yields observed in 2002 (Table 5). However, the intermediate compost rate plots still yielded in excess of 110 bushels per acre (7800 kg/ha; Fig. 10), consistent with state average corn yields in eastern Virginia for undisturbed soils. It is also important to note that we added no N-fertilizer to these plots, even though the heavy crop the preceding year certainly extracted large amounts of plant available N. Nitrogen availability is generally the major predictor of corn yield when rainfall is not limited, so we are quite impressed by this overall yield response, particularly from the 0 compost control plots. The lower yield at the highest compost loading rate was most likely related to excess moisture holding in the very large amount of organic matter added.

The fully dewatered portion (W and SW; Figs. 2 and 8) of the dredge utilization area was disked for weed control in the spring of 2005 and planted to corn by Weanack's contract farmer. Using conventional management and inputs, the farmer estimated 2005 average corn yield at approximately 180 bushels per acre. Long-term regional averages on prime farmland soils are 160 to 180 bushels per acre (according to the USDA/Virginia Dept. of Agric. Statistical Reports). No management limitations were noted. 2006 corn yields were 193 bushels per acre which slightly exceeded yields (180 to 195 bu/ac) on adjoining native soils.

Figure 10. Corn crop on experimental plots ready for harvest in late summer of 2003. The double fence was erected to keep animals (raccoons and deer) out of plots. Biomass and yield in 2003 were much lower than in 2002, but still equal to or above adjacent farmlands.

Soil Genesis and Agricultural Soil Properties:

The fresh dredge materials were approximately 35 to 45% solids when placed in 2000 through 2002 and were highly reduced and anaerobic (Fig. 2). Over the course of one year, however, the materials stabilized and settled to some extent, and deep polygonal cracking was observed. The polygons were initially 20 to 50 cm in diameter at the surface, the cracks were 2 to 8 cm wide, and > 25 cm deep by the summer of 2002. Auger observations in the fall of 2002 indicated that the material was oxidized along cracks to a depth of > 50 cm, but reduced materials within polygon/prism centers were observed at 25 cm (Fig. 11). We excavated several soil pits adjacent to the cropping experiment discussed above in 2002 and 2003, and observed a continuation of the surface oxidation and horizon forming processes. The surface layer was clearly becoming more uniformly oxidized with time (Fig. 12), and the surface became better aggregated in comparison with the very coarse polygonal cracking patterns observed in 2001. The oxidized surface layer still possessed very coarse prismatic primary structure (Fig. 13), but the surface Ap horizon was moderate fine and medium subangular blocky and granular. We described overall Ap-AC-Cg1-Cg2 horizon morphology in these two year-old soils. Auger observations with depth revealed that relatively unconsolidated "soupy" materials occurred at 2.0 m+ that were still strongly reduced and low chroma. Total subsidence of the research plot area is estimated to be 10 to 15% (of originally placed 5 to 7 m of dredge) to date, and further settlement is expected once these deeper layers dewater and consolidate fully.

In June 2005, we sampled the stable portion of the dredge fills with an auger on a grid as shown in Fig. 8. Properties of three typical profiles from this sampling are presented in Table 6. The particle size analysis data reinforce the positive physical quality of these materials as discussed earlier. The average soil texture was silt loam with a few samples falling into loam and silty clay loam classes. The surface horizons were well aggregated while deeper structural development was primarily from the large downward developing polygonal prisms discussed earlier. The depth of oxidation varied considerably, but most soils showed browner oxidized colors (7.5 YR 5/3 to 5/4) to a depth of at least 50 cm. Most of the deeper horizons were still bluish gray (10B 5.1) in color. Despite the significant oxidation of reduced Fe and Mn species, the pH of the surface layers has remained > 6.8 at all locations and averaged > 7.2. The inbound dredge sediments had an average calcium carbonate equivalence of > 2.5% and were very low in sulfides, so this outcome was expected. In a parallel study, Tang et al. (2004) reported that trace levels (ug/L) of several metals of concern could potentially become soluble as these materials oxidize, but we have not seen any evidence of such release in repeated analyses of surface and ground-waters at the site.

Table 6. WWB Soil Analyses from June 2005, three years after placement. Particle size analysis via sieve + pipette; nutrients and metals via Mehlich I.

Sample Location	B-3	B-3	B-4	B-4	C-1	C-1
Depth (cm)	0-15	150	0-15	150	0-15	150
Total % Sand	16	23	26	73	35	37
Total % Silt	64	52	58	18	51	49
Total % Clay	20	25	16	9	14	14
Textural Class	SIL	SIL	SIL	SL	SIL	SIL/L
Soil Test (mg/kg for Nutrients & Metals)						
pH	7.55	7.10	7.52	6.96	6.94	7.27
P	9	10	8	19	30	24
K	43	83	82	43	247	45
Ca	3176	1865	3356	757	2076	2226
Mg	198	162	197	73	198	151
Zn	18	17	16	6.2	33	39
Mn	73	143	75	72	74	69
Cu	3.8	6.6	3.1	3.4	6.7	9.2
Fe	106	319	83	192	153	262
B	0.8	0.5	0.7	0.2	0.6	0.5


4 23 2003

Figure 11. Prismatic subsoil aggregate pulled from approximately 35 cm deep in the soil. Note the distinct oxidation of both the surface soil under the aggregate and the oxidation rind around the aggregate itself. The inbound dredge material was all initially the dark bluish black color seen at the center of the aggregate.

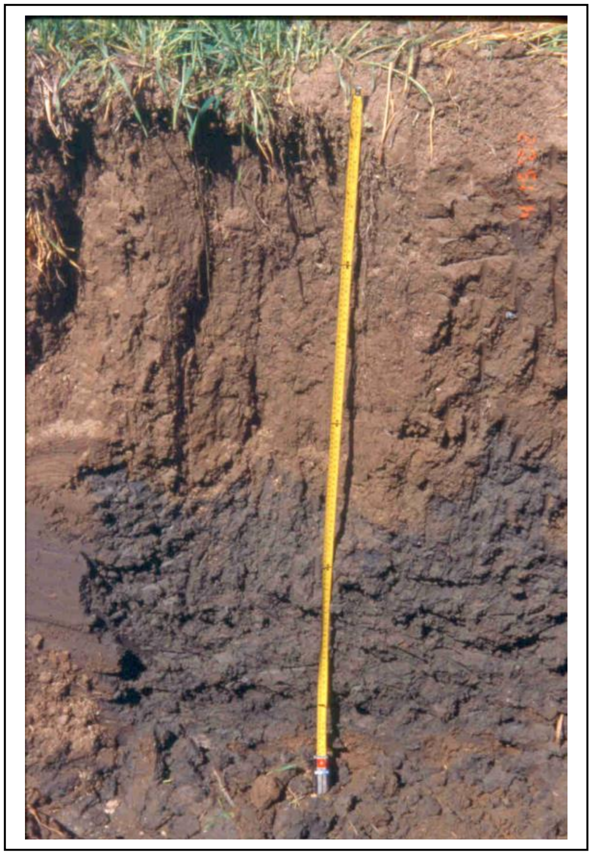


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Figure 12. Profile of oxidizing dredge soil in April 2002, less than 18 months after placement.

Figure 13. Very coarse prism breaking out of profile seen at left. Interiors of these prisms were still reduced and gray below 30 cm.

Conclusions

Based upon these documented chemical, physical and morphological properties, and the combined 2002 and 2003 yield data, we are convinced that these newly deposited "dredge soils" may be as productive as natural soils in the region. From a narrow standpoint of bulk soil chemical properties and fertility, these newly developed soils are outstanding and actually superior to most native agricultural soils. The pH of the surface soil ranges from 6.8 to 7.4, despite over five years of oxidation and weathering. Extractable cations (Ca, Mg and K) are very high, extractable P is moderate, as are levels of essential micronutrients such as Zn and Mn. While the construction and placement of these dredge materials within a diked area has created a local groundwater high and altered the local groundwater flow regime to some extent, we believe that this effect will be ephemeral once the materials completely dewater and the enclosing dikes are removed. No water quality effects of the dredge placement have been observed.

The surface layers of these materials oxidized, dewatered, cracked and stabilized rapidly to allow conversion to agricultural production within two years after placement. Within two years, Ap-AC-Cg horizon morphology developed with at least 50 cm of oxidation down into the reduced layers at depth. Taken together, these findings clearly support the utilization of suitable dredge materials for conversion to upland agricultural soils or as potential topsoil substitutes in mining and urban environments. These findings also support the overall objectives of the National Dredge Task Force and the related findings of Darmody et al. (2004).

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