EEDP-03-3
June 1987

Environmental Effects of Dredging
Technical Notes

FIELD VERIFICATION OF THE ESTUARINE PLANT BIOASSAY PROCEDURE

PURPOSE: This note summarizes results of field testing and verification of plant bioassay procedures developed under the Long-Term Effects of Dredging Operations (LEDO) Program. The verification work was conducted as part of the Interagency Field Verification of Testing and Predictive Methodologies for Dredged Material Disposal Alternatives, called the Field Verification Program (FVP).

BACKGROUND: The FVP is a multiyear research project initiated in 1982. The objectives of the program are to field test and verify laboratory predictive methods for assessing the effects of disposal of contaminated dredged material and to evaluate findings of these objectives for aquatic, intertidal (wetland creation), and confined upland disposal alternatives.

ADDITIONAL INFORMATION OR QUESTIONS: Contact the author, Dr. Bobby L. Folsom, Jr. (601) 634-3720 (FTS 542-3720), or the EEDP Program Manager, Dr. Robert M. Engler (601) 634-3624 (FTS 542-3624).

The FVP used contaminated sediment dredged from a project in Black Rock Harbor (BRH), Bridgeport, Conn. Use of a single highly contaminated dredged material afforded a unique opportunity to evaluate results of disposal under three different disposal alternatives: open water, intertidal (wetland), and upland.

Upland and wetland sites were designed to meet surface area, elevation, and operational requirements for FVP contaminant mobility studies. Designs for sedimentation and storage followed recently developed Corps procedures, and the resulting site performance fulfilled design objectives. Provisions were made to ensure that essentially the same dredged material was placed in the open-water, upland, and wetland sites. The upland and wetland sites, constructed within protected areas using conventional construction techniques, were filled hydraulically from barges. The filling operation provided conditions typical of confined dredged material disposal operations. Following filling, the weirs at both sites were managed to allow free drainage of

US Army Engineer Waterways Experiment Station, Environmental Laboratory
PO Box 631, Vicksburg, Mississippi 39180-0631

surface water as the fill stabilized through consolidation. Within approximately 9 months, the upland and wetland substrates had stabilized at the desired surface elevations.

Prior to dredging, sediment samples were collected from 25 locations along the BRH channel. These samples were mixed together into a composite sample to simulate the mixing that usually occurs during confined disposal. The composite material was used in laboratory tests to predict uptake of selected metals by plants grown in the wetland creation site and the upland confined disposal site.

The estuarine plant bioassay procedure was used in the laboratory to evaluate heavy metals uptake from BRH sediment. The estuarine index plants *Spartina alterniflora* and *Sporobolus virginicus* were grown on the sediment and then were analyzed for selected metals. Sediment samples were subjected to total and Diethylenetriaminepentacetic acid (DTPA) metal extraction (Lee, Folsom, and Bates 1983). Some of the other factors known to affect plant uptake of heavy metals were also determined. These included organic matter, wet-dry pH and calcium carbonate equivalent, salinity, etc.

Chemical analysis of the BRH sediment (Table 1) indicated that the sediment would eventually become extremely acidic (dry pH < wet pH) and highly saline upon air-drying (high electrical conductivity); thus, under upland disposal conditions, the dredged material would become a harsh environment for

Table 1

Selected Physical and Chemical Parameters of Black Rock Harbor Sediment

Organic matter, %	19.5
Salinity, parts per thousand	28.0
Electrical conductivity, dS/m	35.7
$CaCo_3$ equivalent, %	0.9
pH wet	7.6
pH reconstituted air-dried	6.6
Oil and grease, mg/g	17.5
Total sulfur, %	1.3

plants to survive. Previous investigations*,** involving similarly acidic saline sediments have shown that growth of the index plants on such sediments is possible only if the sediments are rinsed with freshwater to remove salt and are limed to increase pH.

Total metal content (Table 2) of the BRH sediment was relatively high;

Table 2

Total Acid Digestible and DTPA Extractable Concentrations ($\mu g/g$) of Selected Metals in Black Rock Harbor Sediment

Heavy Metal	Total Acid Digestible Original Sediment	DTPA Extractable: Original Sediment, Flooded	DTPA Extractable: Original Sediment, Upland	DTPA Extractable: Washed Sediment, Upland
Zn	1370	344	962	925
Cd	23.3	0.02	28.7	26.6
Cu	2860	0.15	387	262
Ni	203	2.46	66.9	77.0
Cr	1403	0.10	0.83	1.29
Pb	399	0.06	16.3	10.1

the copper content was extremely high (Folsom, Lee, and Bates 1981). The data show that air-drying resulted in increased DTPA-extractable metals. Washing the sediment before air-drying had little or no effect on DTPA metal extractability. Based on results of the DTPA extractions, one could predict that plant uptake of metals in the field would be greater from the air-dried upland disposed sediment than from the flooded wetland disposed sediment. The chemical data from the laboratory portion of the plant bioassay would indicate that *S. alterniflora* and *S. virginicus* should grow under anticipated wetland conditions, but under upland conditions the plants would not grow especially well and would accumulate excessive levels of heavy metals.

* B. L. Folsom, Jr. 1982a. "Heavy Metal Content of *Spartina alterniflora* from the Texas City Prototype Marsh on the Texas City Dike," Memorandum for Record, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

** B. L. Folsom, Jr. 1982b. "Heavy Metal Content of *Spartina alterniflora* from Pawtuxet Cove, Rhode Island," Memorandum for Record, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

As expected from the chemical analyses of BRH sediment (Tables 1 and 2), *S. alterniflora* and *S. virginicus* did not grow well in the laboratory in the original unwashed air-dried (upland) sediment: only one plant of one replicate survived. The elevated heavy metal content of the surviving plants (*S. alterniflora* - Table 3, *S. virginicus* - Table 4, Folsom and Lee 1985) could be explained by the reduced plant growth. Plants grown in washed sediment under an upland condition grew better than those grown in the unwashed sediment under upland condition. However, heavy metal content of plants grown in the oxidized washed sediment was much greater than that of plants grown in sediment under flooded condition. This same effect was observed by Folsom and Lee (1981a, b) when freshwater plants were grown in freshwater sediments under both flooded and upland disposal environments. Apparently, once estuarine sediment is washed free of excess salt and plant growth occurs, the air-drying process results in increased plant availability of metals. Removing excess salt from sediment by washing relates to natural salt leaching from rainfall, and therefore washing can be used in an estuarine plant bioassay to estimate contaminant mobility into plants growing on estuarine dredged material in upland disposal sites.

Table 3

Plant Content (mg/g) of Selected Metals in Leaf Tissue of *S. alterniflora* Grown in Sediment from Black Rock Harbor

Heavy Metal	Greenhouse: Original Sediment: Flooded	Greenhouse: Original Sediment: Upland*	Greenhouse: Washed Sediment: Upland	Field: Wetland (Flooded)	Field: Upland: Upland
Zn	14.1 (1.26)**	219	35.5 (26.5)	19.2 (7.05)	No survival
Cd	0.04 (0.01)	0.91	0.10 (0.08)	0.41 (0)	
Cu	15.2 (1.39)	18.7	85.7 (98.2)	6.55 (5.55)	
Ni	1.62 (0.39)	‡	4.50 (3.33)	21.9 (0.67)	
Cr	18.8 (1.16)	0.93	97.2 (103)	7.97 (5.49)	
Pb	0.28 (0.42)	1.53	2.79 (3.66)	0.83 (0.89)	

* Only one replicate supported plant growth.
** Number in parentheses is ±1 standard deviation.
‡ Not analyzed.

Table 4

Plant Content (mg/g) of Selected Metals in Leaf Tissue of *S. virginicus* Grown in Sediment from Black Rock Harbor

Heavy Metal	Greenhouse			Field	
	Original Sediment		Washed Sediment	Wetland	Upland
	Flooded	Upland	Upland	(Flooded)	Upland
Zn	27.0 (5.9)*	65.0 (38.1)	90.8 (54.0)	No survival	66.0 (18.1)
Cd	0.86 (0.86)	0.68 (0.46)	1.34 (0.59)		2.22 (1.11)
Cu	<0.025 (0)	<0.025 (0)	<0.025 (0)		19.8 (4.00)
Ni	7.90 (1.97)	58.8 (46.1)	19.9 (20.0)		5.38 (0.93)
Cr	31.4 (12.3)	610 (720)	187 (189)		7.64 (1.52)
Pb	<0.013 (0)	<0.013 (0)	<0.013 (0)		1.56 (0.47)

* Number in parentheses is ±1 standard deviation.

The wetland site was planted with *S. alterniflora* and *S. virginicus* after laboratory evaluations were completed and construction of the confined disposal sites was accomplished. Plant growth was poor during the first year of the project. *S. alterniflora* survived from the first year to the second year, but good growth and subsequent propagation did not occur until the second year. *S. virginicus* did not survive in the wetland site. Low survival and poor growth of both *S. alterniflora* and *S. virginicus* could have been due to a combination of a late planting in the fall followed by an early frost and the extremely low oxidation-reduction potential of the dredged material since the water level was not sufficiently low to allow complete drainage at low tide. Plant tissue of surviving *S. alterniflora* was sampled and analyzed for selected metals. Heavy metal content in plant tissue of field-grown *S. alterniflora* was in general agreement with that predicted from the greenhouse data (Table 3).

Plant death in the upland site was very strongly predicted from the chemical data and results of the greenhouse portion of the plant bioassay. An in situ plant bioassay was attempted at the FVP upland site, but no plants survived. Since prediction of plant death was so strong, *S. alterniflora* was not planted in the upland site. However, *S. virginicus* should have survived, based on the greenhouse prediction, if the acidic condition were corrected by addition of lime. *S. virginicus* was subsequently planted in limed rototilled dredged material. These plants survived and developed normally. Heavy metal uptake by *S. virginicus* showed mixed results (Table 4). Zinc and cadmium contents in the field-grown plants were relatively close to values observed in the laboratory. Laboratory test results indicated plant contents of zinc and cadmium would be elevated; field results showed they were elevated. Copper and lead contents in laboratory-grown plants were much lower than field-grown plants. Chromium and nickel contents in laboratory plants were much higher than in field-grown plants.

The overall conclusion from this study was that the estuarine plant bioassay procedure predicted growth and contaminant mobility under wetland conditions and the initial growth under upland conditions. The longer term effects of aging and salt leaching from the upland portion and an appropriate index plant to predict contaminant uptake were not successfully verified and require further research.

References

Folsom, B. L., Jr., and Lee, C. R. 1981a. "Zinc and Cadmium Uptake by the Freshwater Marsh Plant *Cyperus esculentus* Grown in Contaminated Sediments Under Reduced (Flooded) and Oxidized (Upland) Disposal Conditions," Journal of Plant Nutrition, 3:233-244.

Folsom, B. L., Jr., and Lee, C. R. 1981b. "Development of a Plant Bioassay for Determining Toxic Metal Uptake from Dredged and/or Fill Material," Proceedings International Conference, Heavy Metals in the Environment, Amsterdam, The Netherlands, pp. 417-420.

Folsom, B. L., Jr., and Lee, C. R. 1985. "Plant Bioassay of Dredged Material," Environmental Effects of Dredging, Technical Note EEDP-02-1, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Folsom, B. L., Jr., Lee, C. R., and Bates, D. J. 1981. "Influence of Disposal Environment on Availability and Plant Uptake of Heavy Metals in Dredged Material," Technical Report EL-81-12, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Lee, C. R., Folsom, B. L., Jr., and Bates, D. J. 1983. "Prediction of Plant Uptake of Toxic Metals Using a Modified DTPA Extraction," The Science of the Total Environment, 28:191-202.