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Thin Layer Placement of Dredged Material on Coastal Wetlands: A Review of the Technical and Scientific Literature

by Gary L. Ray

PURPOSE: Coastal wetlands in many areas are deteriorating due, in part, to sediment depletion, subsidence, and sea level rise. The purpose of this technical note is to review and synthesize the available scientific and technical literature concerning thin layer placement of dredged materials in wetlands to ameliorate these effects.

BACKGROUND: The stability of coastal wetlands is largely a function of the balance between sediment accretion, marsh subsidence, and sea-level rise (Mitsch and Gosselink 2000). In southern Louisiana, this balance has been upset by a variety of factors including control of the flow of the Mississippi River and construction of levees which act to restrict the supply of sediment, reduced freshwater inflow, and salt water intrusion due to construction of pipeline canals (Cahoon and Cowan 1987, 1988). As a result, Louisiana leads the United States in wetland loss, losing as much as 24 square miles each year (Louisiana Department of Natural Resources 2007). Extreme events such as hurricanes can result in even greater losses. For instance, the United States Geological Survey (USGS) estimates that as much as 217 square miles of coastal lands including marshes (Figure 1) were converted to open water following Hurricanes Katrina and Rita (USGS 2007).

Figure 1. Salt marsh vegetation (USACE photo).

One method of potentially slowing wetland loss is to artificially supply sediments to subsiding marshes. Techniques normally employed to move and distribute sediments are impractical in the unstable soils of wetlands, so new methods have been developed. The primary method is to deposit thin layers of sediment, usually by spraying a sediment slurry under high pressure over the marsh surface. The technique is essentially a modification of existing hydraulic dredging methods in which sediments are hydraulically dredged, liquefied, and then pumped through a high-pressure spray nozzle. Developed in Louisiana, it has since been performed on the Gulf and Atlantic coasts and shows promise for general application.

STUDIES OF THIN LAYER PLACEMENT: Studies of the effects of placing dredged materials on marshes originated with recognition that marshes are adapted to respond to natural processes, such as storms, which deposit wrack and sediments on the marsh surfaces. In one of the first studies of placement of dredged materials on marshes, Reimold et al. (1978) manually

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placed three types of dredged material (coarse sand, mixed sand and clay, and clay) at six thicknesses (8, 15, 23, 30, 61, and 91 cm) on replicated plots of natural, undisturbed marshes in Glynn County, Georgia. While this study was intended to test an alternative form of dredged material disposal, it provides important information on the response of marsh plants to dredged material overburden. Specifically, they reported that *Spartina alterniflora* stems can penetrate an overburden up to 23 cm deep regardless of the sediment type. Over a period of two growing seasons, plant growth was comparable to undisturbed reference marshes as long as overburden thicknesses were less than 23 cm; plots covered with 60 cm or more of dredged material did not recover.

Cahoon and Cowan (1987, 1988) provide the first description of the response of Louisiana coastal wetlands to thin-layer placement by high-pressure spraying. They examined sites at Lake Coquille and Terrebonne Parish Wetlands (Dog Lake) 14 months after placement. Sediments were deposited 10–15 cm deep and up to 70 m away from the water's edge at Dog Lake and 18-38 cm deep and up to 79 m from the water's edge at Lake Coquille. Fourteen months after placement, vegetation was still smothered at both sites; however, recolonization by typical salt marsh plant species was underway. The authors estimated it would take three years for full revegetation. Placement at two open-water sites dominated by floating cane was also examined but no evidence of placement could be detected. Cahoon and Cowan (1987, 1988) noted that although the results were promising, the lack of pre-placement elevation data limited interpretation of their data.

In an experimental study in Barataria Bay, Louisiana, DeLaune et al. (1990) manually added dredged material to salt marsh plots. Applied in two phases, sediments were initially deposited to result in thicknesses of 2–3 cm and 4–5 cm; after a second application of material, thicknesses were 4–6 cm and 8–10 cm. Addition of the sediment resulted in increases in above-ground biomass and density of *S. alterniflora* shoots in both treatments. In a related study, Pezeshki et al. (1992) found that leaf area, above-ground biomass, and culm regeneration were also significantly increased in areas receiving sediment additions; leaf conductance and transpiration rates were also higher in sediment-treated sites compared to untreated control sites.

A number of studies were implemented in the early 1990's under the Environmental Effects of Dredging Program (Wilber 1992a, 1992b, 1992c; Wilber et al. 1992; LaSalle 1992; USACE 1993). In Wilber (1992a) the basic concept of thin-layer placement was defined and its application as a beneficial use of dredged material was discussed. The term thin-layer placement itself has been used to describe thicknesses ranging from less than 0.5 in. to 3 ft, and in the context of both subtidal placement and marsh nourishment. Since the ecological impact of placement thickness differs among habitats, Wilber concluded that the best definition of thin layer placement would be placement of a thickness of dredged material that does not transform the receiving habitat's ecological functions. The chief purpose of several case studies following this work was to determine appropriate target thicknesses for wetlands. The first case study was that of LaSalle (1992) who revisited the Dog Lake and Lake Coquille sites originally sampled by Cahoon and Cowan (1987, 1988). By 1992 the placement site at Dog Lake was no longer distinguishable from nearby reference sites with regard to percent cover by the dominant plant species, *S. alterniflora*. *Salicornia virginica*, a subdominant, was most abundant at the placement site while *Distichilis spicata* and *Juncus roemerianus* were more abundant at the reference sites.

The placement site at Lake Coquille was also similar to the reference area except that it included several mounds covered with *Baccharis halimifolia* (LaSalle 1992).

A second case study was performed at Gull Rock, North Carolina (Wilber 1992b, 1992c). In 1981, maintenance dredged material was sprayed into oligohaline marshes along both sides of Landing Lake Canal and on an island site near the opening of the canal into Wysocking Bay. Marshes along the canal were covered to a depth of approximately 5 cm, whereas at the island site sediment depths averaged 10 cm. Sampled 10 years later, the canal marshes and two nearby reference sites were dominated by *J. roemerianus*. Elevation of the canal marsh disposal site was approximately 3 cm higher than that of the reference sites and aboveground biomass was 45 percent less than that of the reference sites. The island site was 10 cm higher than the reference sites and was dominated by *S. alterniflora*. Soil bulk density was lowest at the island site and soil organic content was lower at the disposal sites than either of the reference areas. Although the results are consistent with those expected from deposition of dredged material, the authors (Wilber 1992c, Wilber et al. 1992) point out that differences in elevation at the island site are also consistent with storm-related deposition and that the absence of pre-disposal information limited interpretation of the data.

Ford et al. (1999) were among the first to successfully incorporate pre-disposal monitoring in an evaluation of the impact of spray disposal (Figure 2) of dredged material. Sediments were pumped onto marshes near Venice, Louisiana, resulting in a thickness approximately 2.3 cm greater than pre-disposal elevations and a factor of 10 greater than natural accretion at simultaneously monitored reference sites. Vegetation was initially flattened at the disposal site, soil bulk density was increased, and soil organic content was lower than reference values. By the end of the first summer, vegetation at the disposal site had returned to an upright position and soil organic contents had increased, primarily as a response to plants colonizing the new sediment surface. The dredged materials were rapidly colonized by *S. alterniflora* and *Vigna luteola*, plant species also common at the reference site. One year after disposal there was no difference between the disposal and reference areas in the extent of marsh accretion, marsh elevation, soil bulk density and organic content, and vegetative dynamics.

Figure 2. Spray disposal of dredged material (photograph courtesy of Bob Blama, CENAB, USACE)

Mendelssohn and Kuhn (2003) examined 43 ha of rapidly subsiding marsh also in the vicinity of Venice, Louisiana, which received up to 60 cm of sediments from a hydraulic dredge pipeline spill. Two years after the spill they found that total vegetative cover, plant height, and plant biomass was higher at marshes that received dredged materials than at reference marshes. The degree of increase was a function of dredged material thickness, with layers greater than 30 cm having higher values than those less than 15 cm or 15-30 cm. There was no alteration of plant species composition; however, elevation and soil bulk density were higher especially at the sites with more than 30 cm of dredged material. These sites also had the highest sand content, while sites with lesser thicknesses of dredged material were predominantly silts and clays. The higher plant growth on dredged material sites was attributed to the increase in elevation, which reduced the depth of flooding and increased soil aeration. It was also believed that high nutrient concentrations in the dredged material spurred plant growth. Slocum et al. (2005) extended these observations a further seven years and reported that the growth spurt did not last through the third year after the spill; however, sites receiving moderate amounts of dredged material (5-12 cm) still had better vegetative growth and soil conditions than reference marshes by the end of the study.

Leonard et al. (2002) and Croft et al. (2006) performed a manipulative experiment in a *S. alterniflora* marsh on Masonboro Island, North Carolina. They examined both deteriorated (sparsely vegetated) and non-deteriorated (reference) plots as well as those where 0-10 cm of sandy dredged material had been manually applied. Marsh sediments were a mixture of fine sand and silts and clays, while the dredged material was predominantly medium sand. Deteriorated marsh plots were initially 20 cm lower than reference plots but increased by 8.5 cm after placement, while reference plots receiving sediment increased by 10 cm. Prior to sediment addition, stem densities were highest in the reference plots. At the beginning of the second summer after sediment application, mean stem density increased in all plots receiving sediment with the greatest increase occurring in the deteriorated marsh plots. By the end of the second summer, there was no longer a difference in stem density between deteriorated marsh and reference marsh plots. Plant height was unaffected by sediment additions. Marsh soils were generally sandier where sediments had been applied (particularly where thicker layers were added). Benthic microalgal biomass also tended to be higher where sediment had been placed on the plots. Benthic invertebrate populations were initially depressed by sediment placement, but quickly recovered in all plots.

In 2002 the Baltimore District, in cooperation with the U.S. Fish and Wildlife Service, employed high pressure spraying at the Blackwater Wildlife Refuge (Chesapeake Bay) to restore 3.2 ha (8 acres) of open water to intertidal wetland (Nemerson 2007). Material was pumped into containment areas surrounded by straw bale dams and into a pre-existing "pot-hole." Sites were allowed to settle and then planted. The sites are presently being monitored for elevation and plant growth.

The effects of sediment addition have been studied in freshwater wetlands as well, with regard to the potential impact of sediment loading resulting from storm runoff. Wang et al. (1994) reported that seed germination of cattail (*Typha X Glauca*) was inhibited at overburden depths of as little as 20 mm and seedling survivorship decreased in overburdens of 20 mm to 1 cm. Adult cattails were unaffected by addition of as much as 4 cm of sediment. Jurik et al. (1994) found that seedling emergence of common Midwestern wetland species including *Leersia oryzoides, Echinochloea crusgalli, Typha spp.* and *Carex spp.* was significantly inhibited by addition of as little as 25 mm of sediment. Combining both laboratory and field tests, Koning (2004) reported that in the lab, less than 2 cm of sediment had no effect on *Sagittaria latifola* growth, while addition of 2 cm of sediment resulted in increased above-ground biomass. There was no detectable effect on field plots, presumably due to the low level of sediment loading.

DISCUSSION: The distribution and abundance of wetland plant species are profoundly affected by sedimentation, elevation, and water level (Reed and Cahoon 1992, Mitsch and Gosselink 2000). In coastal areas, duration of inundation is especially important in controlling soil aeration and the exchange of phytotoxins such as hydrogen sulphide (Mendelssohn and McKee 1988). When the supply of sediment is interrupted or water levels are increased, the marsh begins to subside and the period of inundation increases, inhibiting plant growth and resulting in deterioration of the marsh. Artificially supplying sediments to compensate for declining sedimentation or reestablishing natural elevation levels has the potential to help restore damaged marshes as well as provide a beneficial use of dredged material.

Traditional methods of sediment application such as bucket dredging and low pressure spray disposal have limited physical range and tend to deposit materials in uneven layers made up of poorly mixed sediments. Cahoon and Cowan (1987) reported swaths of material 23 m wide and generally no more than 61 m from the water's edge deposited by dredging and low pressure spray disposal. Sediments were found in layers in excess of 30 cm thick and were often poorly mixed, with coarser fractions being found in distinct mounds. High-pressure spray disposal permits placement of a well-mixed slurry in uniform layers only a few centimeters thick over swaths 76 m wide and up to 91 m from the dredge site (Cahoon and Cowan 1987, 1988).

Spray disposal is capable of handling a variety of soil types ranging from sands to heavy clays and organic sediments. Its operation can be modified to target specific sites and avoid sensitive areas. Cahoon and Cowan (1987, 1988) report, that in their experience, water from the liquid slurry rapidly drains off, quickly leaving the deposited sediment without producing unusually high levels of turbidity.

Despite its superiority over traditional placement methods, high pressure spray disposal does have some significant limits. Shafer (2002) points out that site access is a primary consideration and that the receiving area must be close to a body of water deep enough to provide access for the dredging equipment. Although high pressure spraying has a greater physical range of disposal than traditional methods, placement is still limited to an area less than 100 m from the spray equipment (Cahoon and Cohen 1987, 1988). This limits the technique to marshes bordering relatively deep bodies of water unless access channels are cut into the receiving marsh. To be cost-effective, the dredging site should be relatively close to the placement area; however, if transport costs are not a limiting factor, it should be possible to barge or pump sediments over far greater distances.

Although the placement of materials can be controlled to a great extent by proper operation of the spray nozzle, the proximity of habitats sensitive to turbidity and sedimentation such as oyster beds or seagrass meadows should be a critical concern. For instance, seagrasses and other submerged aquatic vegetation are generally thought to be inhibited by suspended sediment concentrations above 15 mg/l (Chesapeake Bay Program 2000) and accumulation of as little as 1 mm of sediment can prevent oyster larvae from settling (Galtsoff 1964). For a review of dredging related impacts of suspended sediments on estuarine fish and shellfish, see Wilber and Clarke (2001).

Determining the appropriate thickness of material to apply is clearly a function of the habitat type as evidenced by the greater sensitivity of freshwater wetlands to sediment loading (e.g., Jurik et al. 1994). Negative impacts were found when only a few millimeters of sediment were applied to freshwater marshes, whereas coastal marshes are able to accommodate thicknesses measured in tens of centimeters (e.g., Mendelssohn and Kuhn (2003)). Calculating appropriate thickness requires an understanding not only of the desired or target elevations but also the nature of materials to be pumped and the extent of dewatering and subsequent compression. The precise nature of the receiving environment is also important to the success of a placement operation. Receiving marshes must have sufficient slope to ensure that water flows off the marsh and does not pond. Otherwise, existing marsh may be temporarily or permanently drowned. Marshes in areas of low tidal range may be more sensitive to placement thicknesses since relatively small changes in elevation can result in creation of upland rather than intertidal habitat. Care must also be taken in areas where there is a large tidal range or sites are exposed to wave action, since the sediments may be dispersed rather than deposited. This is an especially important consideration in open-water disposal (Shafer 2002).

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REFERENCES

Cahoon, D. R., and J. H. Cowan, Jr. 1987. *Spray disposal of dredged material in coastal Louisiana: Habitat impacts and regulatory policy implications*. Louisiana Sea Grant College Program. Baton Rouge, LA: Center for Wetlands Resources, Louisiana State University.

__________. 1988. Environmental impacts and regulatory policy implications spray disposal of dredged material in Louisiana wetlands. *Coastal Management* 16:341-362.

Chesapeake Bay Program. 2000. Chesapeake Bay submerged aquatic vegetation water quality and habitat-based requirements and restoration targets: A second technical synthesis. Annapolis, MD. Available online at http://www.chesapeakebay.net/pubs/sav/savreport.pdf

Croft, A. L., L. A. Leonard, T. Alphin, L. B. Cahoon, and M. Posey. 2006. The effects of thin layer sand renourishment on tidal marsh processes: Masonboro Island, North Carolina. *Estuaries and Coasts* 29:737-750.

DeLaune, R. D., S. R. Pezeshki, J. H. Pardue, J. H. Whitcomb, and W. H. Patrick. 1990. Some influences of sediment addition to a deteriorating salt marsh in the Mississippi River Deltaic Plain: A pilot study. *Journal of Coastal Research* 6:181-188.

Ford, M. A., D. R. Cahoon, and J. C. Lynch. 1999. Restoring marsh elevation in a rapidly subsiding salt marsh by thin-layer deposition of dredged material. *Ecological Engineering* 12:189-205.

Galtsoff, P. S. 1964. The American Oyster Gmelin. *Fishery Bulletin* 64:1-480.

Jurik, T. W., S.-C. Wang, and A. G. van der Valk. 1994. Effects of sediment load on seedling emergence from wetland seed banks. *Wetlands* 14:159-165.

Koning, C. I. 2004. Impacts of small amounts of sandy sediment on wetland soils and vegetation: Results from field and greenhouse studies. *Wetlands* 24:295-308.

LaSalle, M. W. 1992. *Effects of thin-layer disposal of dredged material in Louisiana coastal marshes* (Unpublished report). Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

Leonard, L., M. Posey, L. Cahoon, R. Laws, and T. Alphin. 2002. Sediment recycling: Marsh nourishment through dredged material disposal. Final Report to NOAA/UNH Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET). Available online at: http://people.uncw.edu/lynnl/Ciceetfinalreport.pdf

Louisiana Department of Natural Resources. 2007. Louisiana Coastal Facts. Factsheet. Louisiana Department of Natural Resources, Baton Rouge, LA. Available online at http://dnr.louisiana.gov/crm/coastalfacts.asp

Mendelssohn, I., and N. L. Kuhn. 2003. Sediment subsidy: effects on soil-plant responses in a rapidly submerging coastal salt marsh. *Ecological Engineering* 21:115-128.

Mendelssohn, I., and K. L. McKee. 1988. *Spartina alterniflora* die-back in Louisiana: Time course investigation of soil water-logging effects. *Journal of Ecology* 76:509-521.

Mitsch, W. J., and J. G. Gosselink. 2000. *Wetlands*. 3d ed. New York: John Wiley and Sons.

Nemerson, D. 2007. *Summary of monitoring data from 2003 wetland restorations at Blackwater National Wildlife Refuge*. Baltimore, MD: National Aquarium.

Pezeshki, S. R., R. D. DeLaune, and J. H. Pardue. 1992. Sediment addition and growth of *Spartina alterniflora* in deteriorating Louisiana Gulf Coast salt marshes. *Wetlands, Ecology and Management* 1:185-189.

Reed, D. J., and D. R. Cahoon. 1992. The relationship between marsh surface topography, hydroperiod, and growth of *Spartina alterniflora* in a deteriorating Louisiana salt marsh. *Journal of Coastal Research* 8:77-87.

Reimold, R. J., M. A. Hardisky, and P. C. Adams. 1978. *The effects of smothering a Spartina alterniflora salt marsh with dredged material*. Dredged Material Research Program Technical Report D-78-38. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

Shafer, D. 2002. Thin-layer placement. Chapter 9, In *Approaches to coastal wetland restoration: Northern Gulf of Mexico*, ed. R. E. Turner, and B. Streever. The Hague, Netherlands: SPB Academic Publishing.

Slocum, M. G., I. Mendelssohn, and N. L. Kuhn. 2005. Effects of sediment slurry enrichment on salt marsh rehabilitation: Plant and soil responses over seven years. *Estuaries* 28:519-528.

United States Army Corps of Engineers (USACE). 1993. *Managing dredged material via thin-layer disposal in coastal marshes*. EEDP Technical Notes Collection. EEDP-01-32. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

United States Geological Survey (USGS). 2007. USGS reports latest land change estimates for Louisiana coast. Available online at http://www.peoplelandandwater.gov/usgs/usgs_02-20-07_usgs-reports-latest.cfm

Wang, S.-C., T. W. Jurik, and A. G. van der Valk. 1994. Effects of sediment load on various stages in the life and death of cattail (*Typha X Glauca*). *Wetlands* 14: 166-173.

Wilber, P. 1992a. Thin-layer disposal: Concepts and terminology. Environmental Effects of Dredging Information Exchange Bulletin D-92-1. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

__________. 1992b. Thin-layer dredged material disposal in coastal marshes-case studies. In *Ports '92, Proceedings of the Conference. July 20-22 1992, Seattle, WA*. Washington, DC: Permanent International Association of Navigation Congresses.

__________. 1992c. Case studies of the thin-layer disposal of dredged material: Gull Rock, North Carolina. Environmental Effects of Dredging Technical Bulletin D-92-3. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

Wilber, D. H., and D. G. Clarke. 2001. Biological effects of suspended sediments: A review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. *North American Journal of Fisheries Management* 21:855-875.

Wilber, P., J. L. Luczkovitch, and D. B. Knowles. 1992. The long-term environmental effects of thin-layer disposal on a salt marsh, Lake Landing Canal, NC. In *Proceedings of the 25th Annual Dredging Seminar and WEDA XIII Annual Meeting. May 26-29, 1992, Mobile AL*. CDS Report No. 323. College Station, TX: Center for Dredging Studies, Texas A&M University.