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The Use of Sediment Diversions in Fluvial Powered Wetland Restoration

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Natural fluvial energies can be used to restore degraded wetlands caused by the forces of erosion and subsidence . Sediment diversions work to redirect the flow of suspended sediment into these degraded areas. These diversions can operate in different magnitudes as dictated by the site. The monetary costs of all the diversions in respect to the amount of land restored is roughly equivalent but the ecological costs vary.

INTRODUCTION

In the estuary regions of the United States and other nations sediment control is being thought of as a tool to restore coastal wetlands threatened by excessive erosion and subsidence. The practice of sediment manipulation was taking place as early as the 17th century. French Acadians constructed dikes in order to reclaim salt marshes where the Petitcodiac River joins the Bay of Fundy (Luternaurer, 1995). Construction of dikes or diversions for marsh restoration is still a tool in modern estuary management.

The formation of coastal swamps and marsh lands is governed by two opposing processes, the depositional action of the river versus the erosive marine forces. Both of the forces are naturally occuring parts in a cycle of succession. When the fluvial forces predominate the deltaic region is considered to be active, ecosystems and land mass associated with coastal wetlands is increasing. When erosive forces are dominant, the deltaic region is considered to be abandoned, the land mass associated with coastal wetland is decreasing. The Pontchartrain, Breton Sound, and Mississippi River Delta basins are all shifting toward an abandoned state. The erosive forces in these regions are a combination of natural and anthropocentric processes. The suspended sediment load transported by the Mississippi River that feeds these regions has decreased from 1,576,000 tons per day in 1950 to about 219,000 tons in the late 1980's. This reduction is primarily due to the sediment trapping effects of upriver dam and reservoir formation. Despite the reduction, it has been predicted that there is currently enough suspended sediment to meet all of the restoration needs (Walling, 1995). In addition to the loss of 'natural' sediment volumes, channel construction for navigational and drainage uses has hastened the rate of erosion. The swamps and marshes located in these basins are rapidly loosing land to both subsidence and the erosive action of the marine waves and tides. By incorporating fluvial diversions into the present systems sedimentation is heightened due to a decreased flow rate. As sedimentation is increased, vegetation can return to marsh areas thus serving as a trapment. As the fluvial forces of sediment deposition become greater than that of erosion, the deltaic regions shift back from an abandoned state to an active one.

LARGE SCALE DIVERSIONS

The effects of a sediment diversion are dependent on the scale of the project. Regional scale projects in which barrier construction is designed to divert a large portion of the fluvial volumes is essentially an uncontrolled river diversion. These type of diversions have been proposed for the Mississippi River Delta, and Breton Sound basins. In Caernarvon, a gated structure with a capacity of 8,000 cfs (cubic feet per second) has been completed, and structures as big as 20,000 cfs and 30,000 cfs are being proposed for Breton Sound and Pontchartrain basins. The diversions proposed are projected to have a large scale effect, including large gains in emergent wetlands on the order of 10,000 - 50,000 acres over a period of centuries (Domingo, 1996). Construction of the structures used for diversions makes use of dredged materials collected from the navigational channels as part of the base on which wooden or steel poles are sunk and concrete is added. The diversions are ideally placed upriver from the targeted area in order to slow the fluvial currents as they reach the sites. By slowing the current, the sediment is allowed to settle at an increased rate. Placement of the structures too close or downstream of the targeted sites does little to slow currents, and in some cases actually accelerates them adding to the erosive forces (USACE, 1993). The details of placement remains a hotly researched topic, the size and angles of such structures is highly site dependent.

Large scale sediment diversions are not a tool for historic restorations of estuary conditions. Instead, they can cause major alterations and in some cases total replacements. Diversions in excess of 20,000 cfs alter sedimentation patterns enough to cause new deltaic formations. Along with the deltaic modifications, existing wetlands are altered or destroyed. As the deltaic region is modified, the surrounding wetlands change as well (Domingo, 1996). The degradation rates of current wetlands will be dependent on managed vegetation stock, the magnitude of the fluvial modification, marine penetration, and erosion.

SMALL SCALE DIVERSIONS:

Smaller scale diversions are used for site specific impacts rather than the regional influences of the larger scale diversions. They are designed to restore the natural fluvial forces in smaller sites rather than altering them on a larger scale. Principles of small diversions are the same as those involved in larger scale ones. Structures are built to slow fluvial currents thus allowing suspended sediments to settle out. Studies of mud and tidal flats have shown that there is a corresponding decrease in sediment suspension as flow velocities drop below 1.4 m/s (Walling, 1995). It follows that there is a decrease in flow rate with steeper angles of diversion. If additional transport of the sediment is needed the angle of the diversion should be decreased in order to conserve a portion of velocity. Specific rates of sedimentation with regard to time, velocity and distance can be derived from the equations of Krone (Amos, 1995).

When constructing dikes for use in small scale diversional projects special considerations are necessary. The foundation of the dike should consist of impermeable clay or bedrock. Seepage resulting from a porous base can result in the failure of a dike. The dike needs to be from 1 to 1.5 m in width. This will allow for a foot path involved in the maintenance of the structure. More sophisticated engineering may be needed for larger diversions (Hammer, 1996).

Another common method of construction of diversions is the extension of existing morphological features. In 1995, a project in Pontchartrain Basin of Louisiana, extended the downstream levees of dead end drainage canals. Over 140,000 recycled Christmas trees were sunk in the loose organic lattice on the floor of the canals and supported with parallel wood beams and wire fencing (Domingo, 1996). The recycled trees served as a trap for sediment accretion. Accretion in these areas varies from 15 cm to 4m. The entrapment of the suspended sediment has an additive effect with the diversions.

CREVASSES:

Crevasses connecting the river and shallow estuarine sites helps the restoration and creation of marsh areas. The creation of crevasses not only helps to rebuild the desired site but also helps to mimic natural meanders in a river with modified hydrology. Artificial flood levees and navigational channels increase the current velocity, the creation of crevasses serves to divert some of the water volume thus decreasing velocity. Crevasses can be built in to rectify a detrimental situation created through anthropomorphic modifications of the fluvial system. When artificial levees are built, marshlands are cutoff from the freshwater sediments and nutrients they had been receiving. A crevasse reconnects the marsh with the fluvial system allowing for a restoration of sediments lost to subsidence and providing a flood control outlet (USACE, 1995).

Determination of the rate of subsidence dictates the guidelines for construction of the crevasses. A higher rate of subsidence calls for bigger crevasses thus a larger volume of water and sediment. Larger crevasses are only different from smaller ones in terms of the width. The U.S. Army Corps of Engineers have determined that the depth of a crevasse is to kept above 8 feet, for flood control. The excavated material is to be disposed of in one of two ways: the material can be placed on the downstream edge of the crevasse, forming a small scale diversion to hasten fluvial diversion, or the material can be transported to the target site for deposition within the marsh system.

A successful example of marsh sedimentation through use of a crevasse is found in a modification done by the U.S. Army Corps of Engineers at the South Bend of the Mississippi River. A crevasse was formed through the excavation of 42,000 cubic yard of material, which was placed adjacent to the opening of the crevasse. The crevasse is 125 ft wide by 1,265 feet long with a depth varying uniformly from 8 feet. It has a flow rate of approximately 1,265 cfs, depositing nearly 6.5 acres per year. The construction of the crevasse was completed in 1995 and is projected to continue until the year 2001 depositing 33 acres to a marsh adjacent to the Pass a Loutre Waterfowl Management Area.

FEASIBILITY:

The premise for all three versions of sediment diversion techniques discussed in this paper are nearly identical with the only difference being the magnitude of each. A large scale technique is clearly the most expensive and risky in a variety of contexts. The construction of a major fluvial diversion can be expected to cost from $72,000,000 to $910,000,000 (Domingo, 1996). These figures do not take into account the possible short term losses of terrestrial and aquatic life due to habitat destruction. The possibility of gaining tens of thousand of acres of wetlands is tantalizing, but also very long term. Unfortunately success at this scale will not be realized by those implementing the project. Along with the large investment of capital, there needs to be a commitment from future generations of resource managers toward the continuance and monitoring of the project goals. At this time the costs and risks involved with large scale diversions make them impractical and more research is needed before widespread use becomes a viable option.

In contrast to the larger scale diversions the success of small scale sediment diversions, such as crevasses, is measurable within a shorter time frame. The costs of construction ranges from $100,000 to $500,000. The restorative results of the small scale diversions and crevasses are apparent within 5 to 25 years, and with continuous management effects can last for the lifetime of the system. Such rapid restorative values come at the cost of the total acreage deposited by the diversion. Usually only about 50 acres can be restored by a small scale diversion or crevasse (< 2,000 cfs).

Comparison between large scale diversions and small scale diversions + crevasses shows that the cost of each is proportionally equal. A large scale diversion restoring 10,000 acres at $100,000,000 has the same price per acre as a small scale diversion restoring 100 acres at $1,000,000 ($10,000 per acre).

SUMMARY:

The use of natural fluvial energies to transport sediment into restorations sites provides many benefits; 1)The sedimentation at the site will have a more natural dispersion pattern allowing for faster rehabilitation. 2)The continuous sedimentation will allow for the upkeep of the sites without further anthropocentric energy input. 3)The geological cycle of the whole deltaic region can shifted toward a more self sustaining state.

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