WRP Technical Note WG-RS-7.1
March 1997

Wetland Engineering in Coastal Louisiana: Mississippi River Delta Splays

PURPOSE: This technical note describes artificial delta splay cuts, one of several techniques being applied to marsh restoration, creation, and management in coastal Louisiana. Methods of engineering analysis available to aid in design and to evaluate the effectiveness of the technique are described.

BACKGROUND: The majority of the coastal region of Louisiana has been built from deltaic deposits of the Mississippi River, with the river changing its primary course numerous times over the past several thousand years. These long-term deltaic processes involve a natural growth and decay cycle for each subdelta. In recent years, major portions of coastal Louisiana have experienced significant declines in subaerial land as individual older deltaic deposits enter the decay portion of the deltaic cycle. The loss of coastal Louisiana wetlands has been dramatic for several decades, with 1,526 square miles (>3,950 km^2) of wetland lost over the period 1930-1990 (Boesch and others 1994). With 40 percent of the total coastal wetlands of the United States in Louisiana, those losses account for 40 percent of the U.S. losses of coastal wetlands. The current annual loss is approximately 65 km^2 per year (Boesch and others 1994).

The impact of man on the modern Mississippi River delta has been demonstrated over the past century. Cubit's Gap subdelta was initiated in 1862 when a flood enlarged a ditch dug by the daughters of Cubit, an oyster fisherman. A natural crevasse developed that evolved into a major subdelta. Such accidental experiences have inspired the utilization of delta crevasse splay cuts as a viable engineering technique in marsh management in the lower Mississippi River delta complex. That technique is the subject of this technical note.

DELTAIC PROCESSES: The natural deltaic process can be summarized as a series of characteristic events (LeBlanc 1989): rerouting of a river or major distributary channel, prodelta clay deposition, increased sand arrival, channel shoaling, channel bifurcation, subaerial land emergence, vegetative stabilization, channel incising, channel elongation, continued bifurcation, delta lobe migration, diminished channel capacity, channel rerouting, reduced sediment supply, subsidence, and loss of subaerial land. The process continues in another location. The overall Mississippi River delta has been created by a series of channel diversions, subdelta formations and subdelta decay. These processes occur at a variety of spatial and temporal scales (Kolb and Van Lopik 1966).

DELTA SPLAY CUTS: The use of delta crevasse splay cuts involves opportunistic channel rerouting to control the overall location of small-scale subdelta growth. The technique has been pioneered by the Louisiana Department of Natural Resources and the Louisiana Department of Wildlife and Fisheries in partnership with National Fish and Wildlife Foundation, North American Wetlands Conservation Act, and the U.S. Fish and Wildlife Service. The process is started by the excavation of a small crevasse channel through the natural levee of a large pass within the delta. Material from the excavation of the shallow channel is mounded along the side of the channel to provide further steering of the water and sediments as well as shelter from wave activity. The conceptual design is shown in Figure 1. The crevasse cut provides a pathway to open water with a favorable gradient in water surface. The depth of the cut varies from 15 ft (4.6 m) at the main pass to 2 ft (0.7 m) at the end of the channel cut. As the river discharge in the primary distributary channel increases, natural forces will favor the cut, which will naturally enlarge.

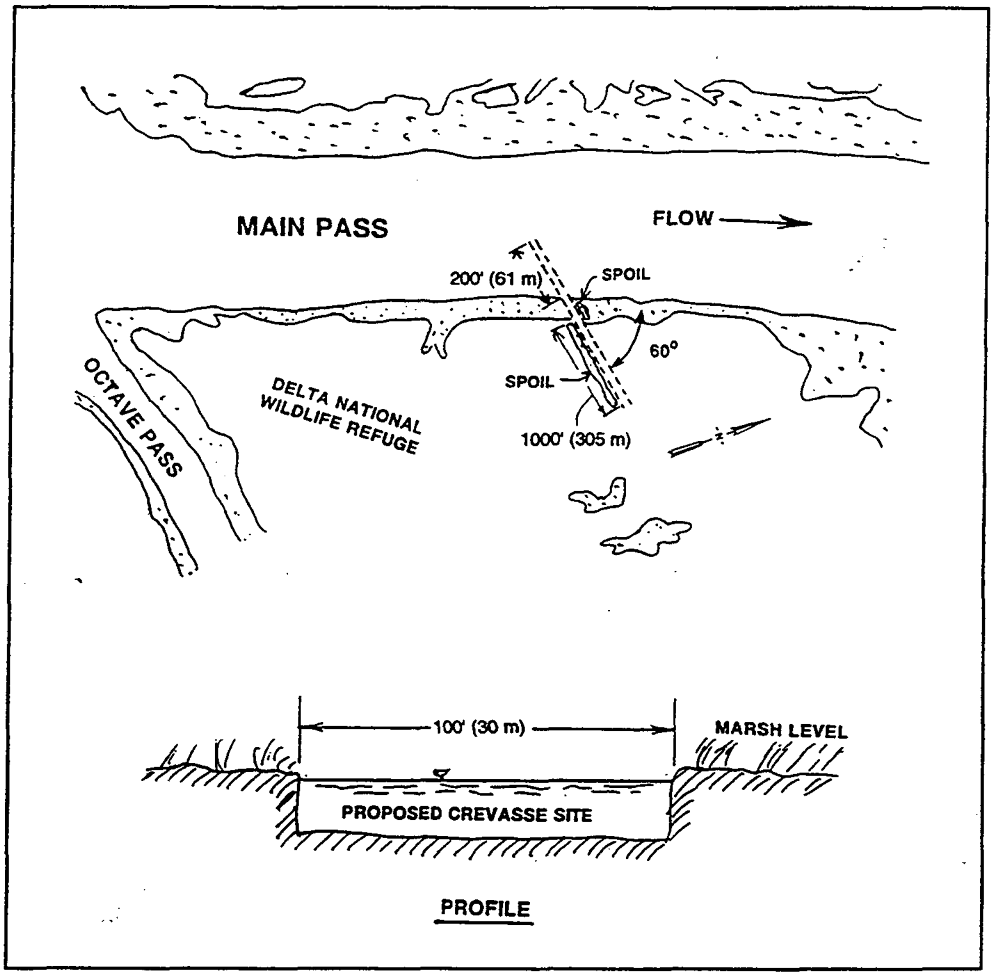

Figure 1. Example design of Delta splay cut

The enlarged crevasse cut begins to supply fresh water and sediment into the wetland selected for creation. The diversion develops a small subdelta covering several square miles. With time the subdelta splay develops its own series of distributary channels. As these channels elongate, the frictional resistance reduces the hydraulic efficiency of the channels, which will eventually close off naturally. The splay cut crevasses are expected to be active for about 5 years. After one delta splay has become ineffective at delivering sediment and water, another delta splay cut will be made in the delta. This activity can be maintained over a number of years, keeping several delta splays active at any time. The long-term plan for delta splay cuts is shown in Figure 2. The stability of the emerging delta splays is further enhanced by the construction of sediment fences. The plan is expected to create approximately 5,000 acres (20 km^2) over the next 50 years.

The number of active delta splay cuts is limited. The local enhancement of wetland creation cannot interfere with other deltaic activity in the delta. Excessive diversion of sediments and water would lead to loss of navigable depths in Southwest Pass because of the reduced sediment transport capacity in the main passes of the delta.

ENGINEERING ANALYSIS: The design of the cut involves determining the width, depth, length, and orientation of the cut. The channel should be designed to enhance natural erosion and enlargement of the

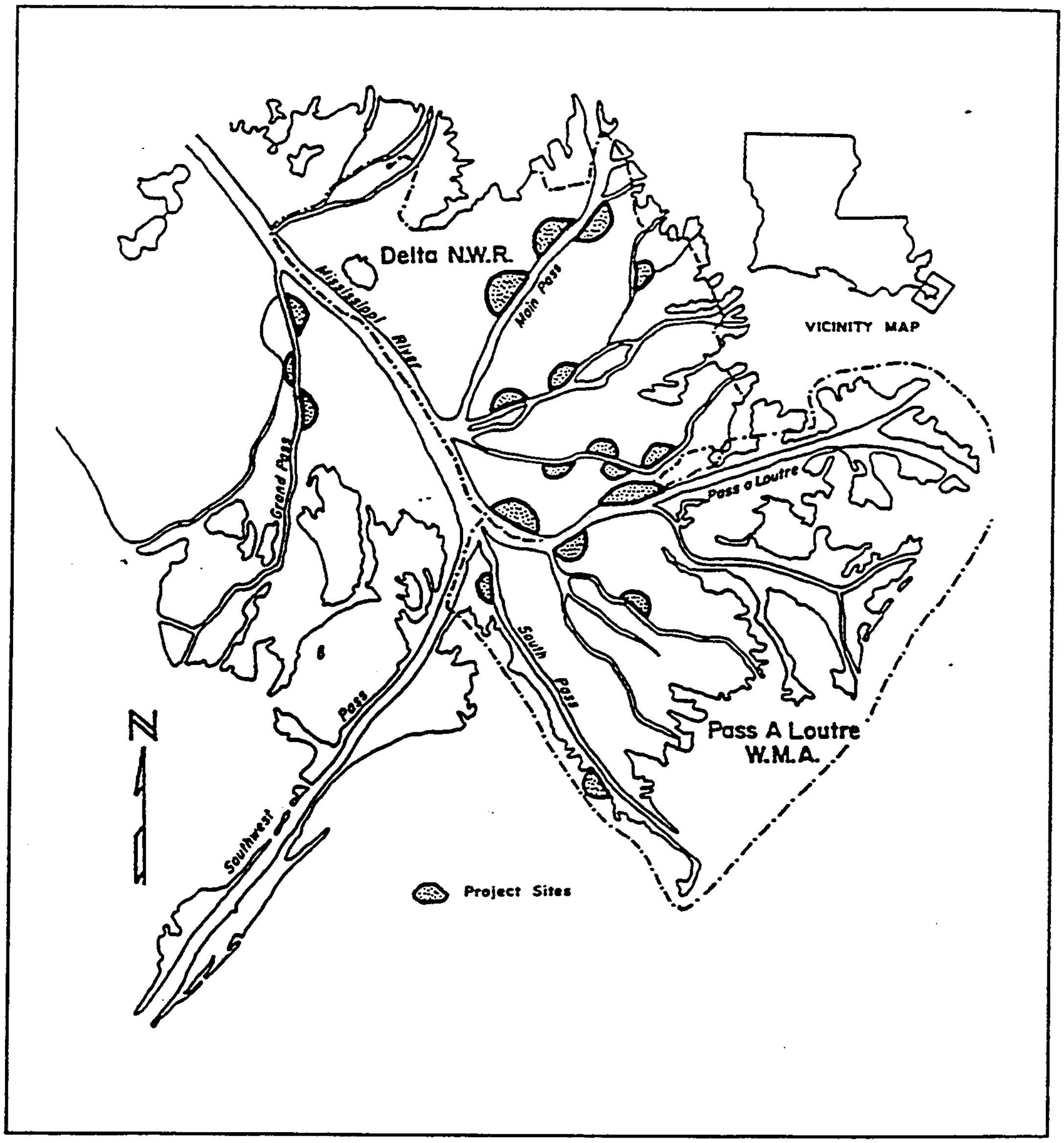

Figure 2. Delta splay cuts planned

cut, after which the natural deltaic processes will take over. The orientation of the cuts has been set to match the orientations of natural bifurcations within the delta, approximately 60 deg. The size of the cut can be designed based on hydraulic analysis of the flows through the original cut. The focus of the design is the shear stresses occurring in the crevasse relative to the erodibility of the sediments. The current velocity in the cut, V_c, can be estimated from application of the Bernoulli equation as

$$V_c = \left[\frac{2g\left(\Delta H + \frac{V_0^2}{2g} \right)}{\left(1 + h_e + h_f\right)} \right]^{1/2} \tag{1}$$

where

g = gravitational constant

ΔH = head difference across the cut

V_0 = main pass current

h_e, h_f = head loss coefficients for the entrance, exit, change in direction and friction

The current velocity in the main pass can be calculated from the discharge and geometry of the pass or is based on measurements. The design of the initial cut is incorporated in the head loss terms. The effective entrance and exit losses are reduced as the width of the cut is enlarged.

$$h_e = \frac{h_{e0}}{W}\left(1 + \frac{\alpha}{W}\right) + h_b \tag{2}$$

$$h_b = 0.001\ \theta \tag{3}$$

The frictional losses vary with the depth and length of the cut (Brater and King 1976).

$$h_f = \frac{29.1\ n^2 L}{D^{4/3}} \tag{4}$$

where W, D, and L are the width, depth, and length, of the cut, respectively, and n is the Manning's friction coefficient. The value of h_{e0} (Eq. 2) defines the overall smoothness of the basic cut through the bank line. The term α provides for the nonlinearity of the response with width of cut. The head loss associated with changing flow direction, h_b, is dependent on the overall change in direction, θ, expressed in degrees. For a crevasse cut at 60 deg, h_b would be 0.06, a loss factor applied to the velocity head.

The predicted velocity in the crevasse cut can then be used to estimate the bottom shear stress as

$$\tau_0 = \rho\ g\ \frac{n^2\ V_c^2}{(1.49)^2 D^{1/3}} \tag{5}$$

This shear stress is the stress immediately following the crevasse cut. This stress is then compared to the erosion resistance of the bank and bed material of the cut to determine at what flow level the cut will begin to enlarge. As the cut enlarges, the same analysis may be used to estimate the maximum size of the crevasse. The erosion resistance of the bed will define the flood level for which the crevasse will enlarge, given a fixed initial cut design. It may also define how long it will take to reach maximum dimensions. Therefore, it is critical to define the strength of the material in the flanks of the cut.

This analytical evaluation of the control section of the delta splay cut assumes that the cut does not dramatically change the hydraulic conditions in the parent distributary channel. That is, there is no significant reduction in the water surface elevation at the head of the cut because of the reduced discharge in the parent channel. If that assumption is invalid, a numerical analysis must be performed.

NUMERICAL MODEL: Deltaic marsh creation within the Mississippi Delta must be moderated to ensure that localized benefits will not cause loss of wetland in other portions of the delta because of shifting sediment supplies. The best means of evaluating the global deltaic integrity is through comprehensive numerical analysis. For this demonstration project a comprehensive numerical model of the Mississippi River delta was developed to illustrate the value of global evaluation. The model includes the entire delta (Figure 3) below Venice, LA. The modeling system TABS-MD, developed by the Corps of Engineers, was used (Thomas and McAnally 1990). The hydrodynamic model RMA-2 computes water levels and flows using a finite-element method to obtain an approximate solution to the Reynolds form of the Navier-Stokes equations.

The sediment transport model STUDH solves the convection-diffusion equation for total load transport with bed exchange using flow velocities and depths from RMA-2. RMA-2 was originally developed under contract by Resource Management Associates (RMA) of Suisun City, CA, and modified by the Waterways Experiment Station (WES) for use in the TABS-MD system. STUDH was jointly developed by WES and RMA. The modeling approach includes a method of describing the geometry of the wetlands statistically over subelemental spatial scales (Roig 1995). The technique, often referred to as marsh porosity by Corps modelers, allows for incorporation of the effects of the myriad of small tidal channels without their being explicitly resolved in the mesh.

The model was run for a range of river discharges and gulf levels to evaluate the response of the flow distributions to the distributary passes. Flow distributions to the major passes are presented for model and field observations (Copeland and Thomas 1992) in Figure 4. The current velocity patterns for the vicinity of Cubits Gap and the Head of Passes are shown in Figure 5. The response of the flow distribution in the numerical model to river discharge and gulf levels is shown in Figure 6 for Southwest Pass (at Head of Passes). The model provides a tool for evaluating the global effect of each of the delta splay cuts.

The hydrodynamic results were then used to drive the sediment transport model, STUDH, of the TABS-MD system to demonstrate the deposition patterns over the entire delta. An example of the suspended sediment field for a simulation of clay sediments with a river discharge below Venice of 500,000 cfs (14,160 m^3/sec) is shown in Figure 7. The associated deposition pattern for that flow is presented in Figure 8. The deposition patterns for the simulation show the majority of deposition occurring in the shallow back bay zones adjacent to the secondary distributary channels. The patterns show a lesser degree of deposition in the shallows near the primary bifurcations, with greater deposition near the ends of the main passes. This observation supports the placement of delta splay cuts closer to the upstream ends of each of the passes, as shown in Figure 2.

DELTA MANAGEMENT: The management of the sediment and water resources reaching Louisiana coastal wetlands requires the integration of field experience with a regional analysis. A complex relationship exists between natural deltaic activity and the activity of man. The tools described here provide a means for design and analysis of wetland creation and management activities. The numerical simulation of alternative locations for management efforts can lead to optimization of those resources.

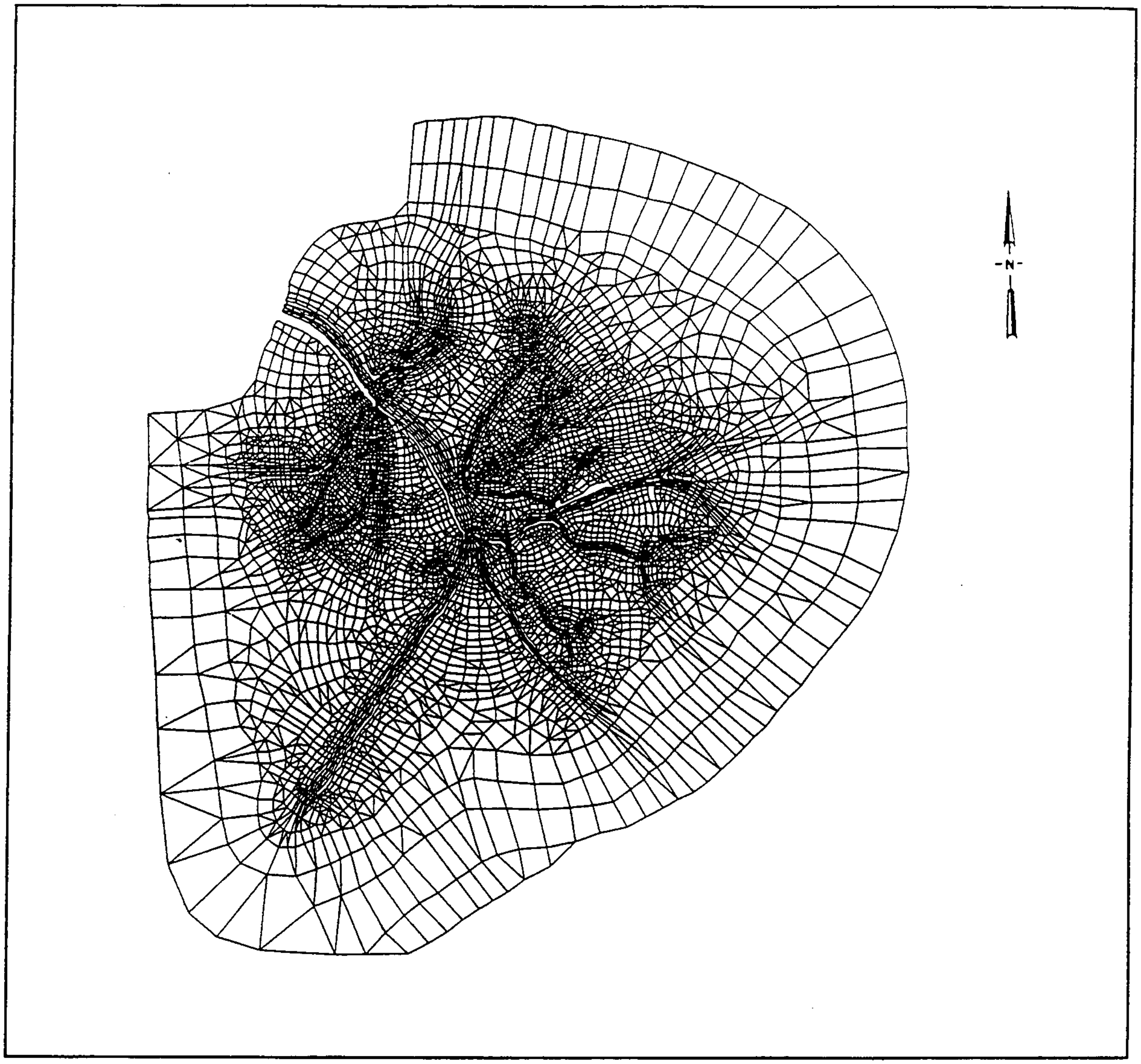

Figure 3. Computational mesh for numerical model

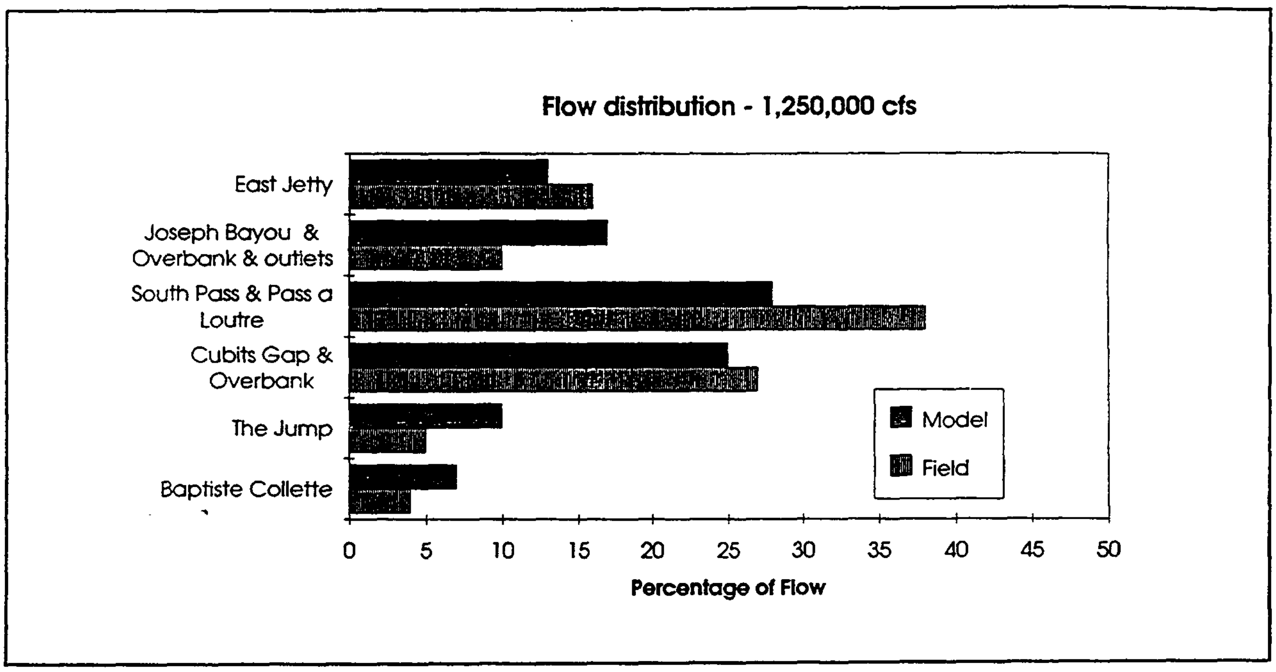

Figure 4. Comparison of model and observed flow distribution

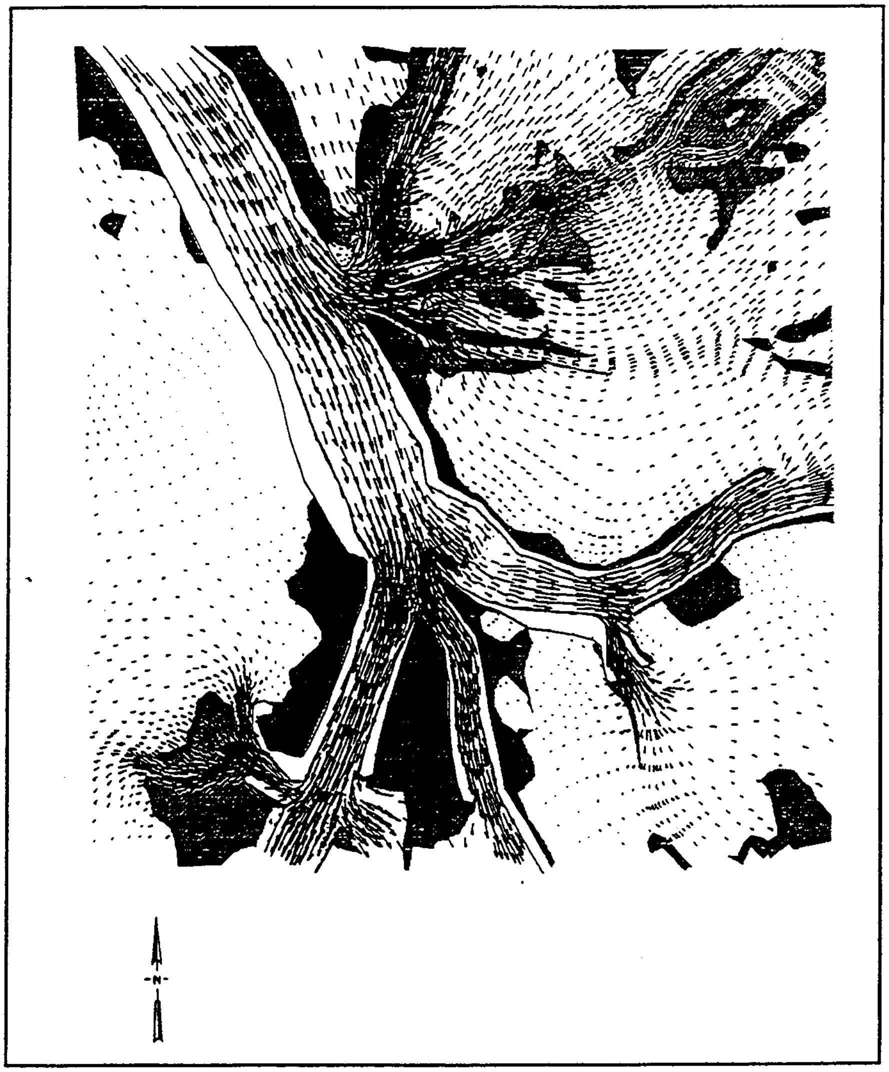

Figure 5. Current velocity patterns near Head of Passes

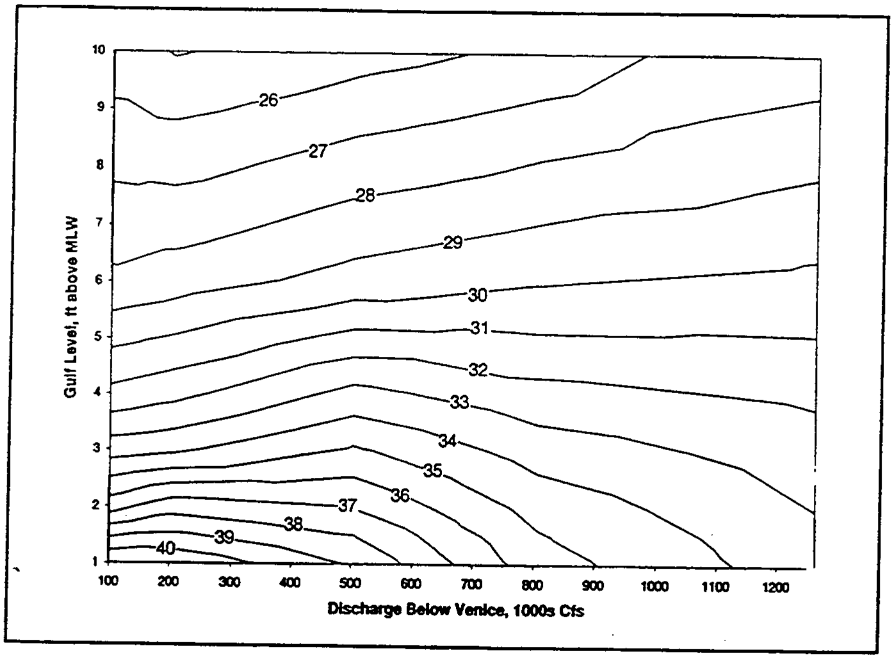

Figure 6. Percentage of flow at Venice entering Southwest Pass as a function of discharge and gulf level

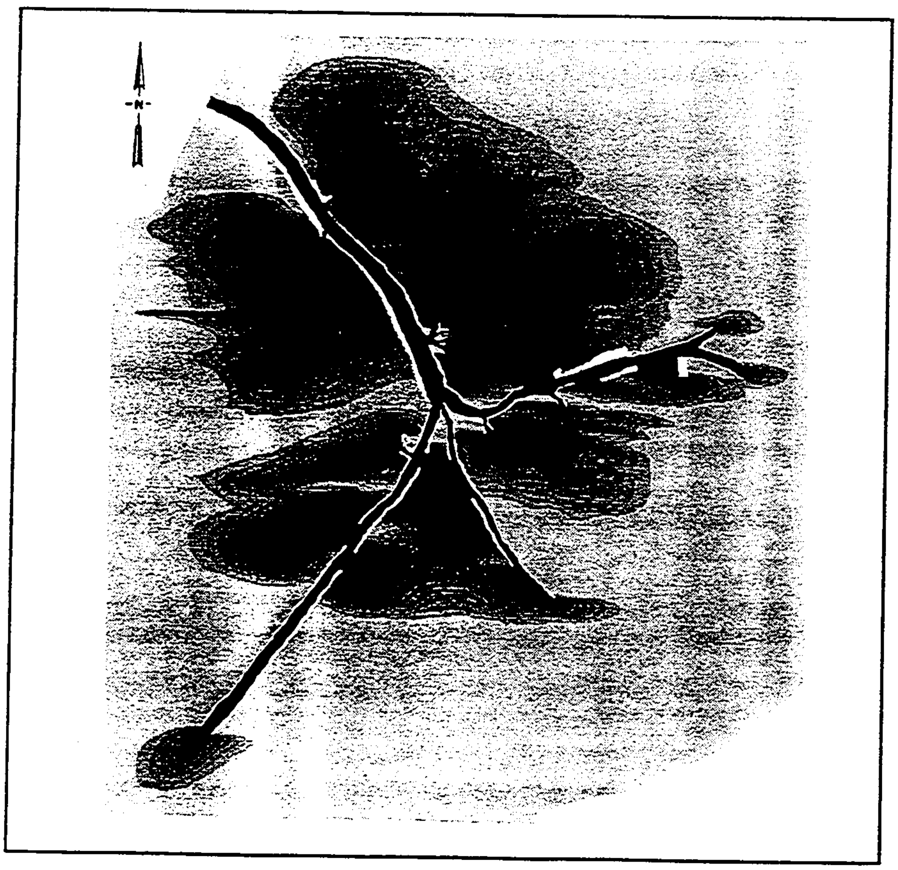

Figure 7. Sediment transport model concentration field

Figure 8. Deposition pattern from sediment transport model

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