TEXAS COASTAL GEOLOGICAL DREDGING VS. GEOTECHNICAL DREDGING:
CAN WE ANTICIPATE THE FUTURE?

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ABSTRACT

How much do we really know about our new Texas dredged material? The expansion of the maritime commerce and the position of Texas ports in the international markets will force expansion in our waterways and navigation channels. The Post-Panamax adaptation and the deepening and widening initiatives will require major dredging and the potential of beneficial use of dredge material (BUDM) practices on new “geological sediments”. The Texas sedimentary environments are the results of the sea level inundation during the last 7,000 years. The description of these sediments have already been incorporated into the Texas Coastal Sediment Geo Database (TxSed) and have connected engineers, geoscientists, academic groups and geotechnical experts, all after one simple goal: To understand the natural geographical distribution of our dredging materials. This presentation talks specifically about the geological evolution of the Texas upper coast and how geology is connected to Regional Sediment Management Plans based on the history of the depositional environments. The present bay environments were converted from fluvial dominated landscapes to coastal dominated environments. Geologic maps from the University of Texas, Bureau of Economic Geology may now be used to anticipate the dredging needs, equipment, and sediment management practices to be used for the expansion of the navigation channels. Specific examples of key dredging spots along some navigation channels will be presented under the perspective of geologic and geomorphic processes, which have the intention of facilitating the work of the dredging industry. Concepts such as building with nature and using natural sediment transport processes will also be discussed as part of the dredging maintenance process.

Keywords: Geomorphology, geology, regional sediment management, dredging, planning.

Introduction.

The Texas bays and Gulf coast inlets are some of the most dredged areas for navigation purposes in the US. Just from the 1850s through 1993, at least 260 million cubic yards (CY) of sediments have been excavated or dredged in Galveston Bay for the federally maintained navigation channels managed by the USACE (Ward 1993). These dredged material, do not include private or state navigation and restoration projects.

In many instances, the dredge material (here after sediments for the geologic perspective) ended up in Dredged Material Placement Areas (DMPA or PAs) next to the navigation channels or in Ocean Dredged Material Disposal Sites (ODMDS) in the Gulf of Mexico. Just for Galveston Bay, about 27,000 acres of PAs were created since World War II (Ward 1993). Although the data on Beneficial Use of Dredged Material (BUDM) is unknown due to lack of records, it is estimated that a very small volume of the sediments that have been dredged in Texas navigation channels were used for BUDM projects.

For this study, we are using the Texas upper coast and specifically Galveston Bay (GB) as examples of how geological and geomorphological processes can enhance the planning of future dredging projects.

For the new phases of “dredging projects” coming to Texas for the expansions of navigation channels or for the protection of the Gulf Intracoastal Waterway (GIWW), the geological history of the sediments and deposits located below the modern channel depths will be very important. This information is key in the planning and execution of deepening and widening projects. This presentation addresses the importance of the geologic and geomorphological processes in the perspective of planning for new navigation channels and for the expansion of dredging projects mainly in the Texas Upper coast. The presentation shows an example of how the understanding of geological information and geomorphological process can contribute to long term navigation planning.
Geology of the Texas Upper Coast and New Dredge Material.

The geologic and geophysical records collected by the Texas coastal programs (Anderson 2007), show that the Texas barrier islands and bays are on top of the paleo-River system deposits (Brazos, Trinity and Sabine Rivers) or the areas called the “Beaumont Formation or Beaumont clays”. Beaumont Formation or Beaumont clays correspond to hard clays deposited more than 60,000 years ago. The coastal conditions as we see them today started their development between 18,000 to ~5,300 years BP, with the regression of the sea level occurring in steps. For example, for Galveston Island close to 7,700 years BP, the barrier shoreline system was located approximately 55 km offshore (Rodriguez et al. 2004). According to these data, it took about 1,400 years for the barrier island to migrate to its present location.

As in other bays of the Texas coast, the paleo-Trinity River channel created the embayment that formed Galveston Bay when the sea level inundated its alluvial plain. The eastern tip of Galveston Island, Bolivar Roads inlet, and the southern tip of Bolivar Peninsula is on top of the paleo-Trinity River valley. The geological profile of the Trinity valley (Anderson 2007) shows a fluvial system at the base of the incised channel, which was covered later by an estuarine system, when sea level was rising and flooding Galveston and Trinity Bay. The estuarine system was then covered in the last few thousand years by a sandy coastal barrier island system (Anderson 2007).

The geologic processes for the Brazos River delta were different from the Trinity River in the last 8,000 years BP. While the incised channel of the Trinity valley was getting filled, the Brazos River delta channels were migrating along the coast and flooding part of WGB, mainly on the modern west side. Between 6,000 to 4,000 years BP, one of the channels known now as Big Slough, was located along the western boundary of WGB. At that time, the delta reached its most eastern path observed today, which included the channel that formerly occupied the San Luis Pass inlet channel (Anderson 2007).

This information connected to the evolution of our coastal systems is very relevant for the planning of dredging projects. The vertical and horizontal distribution of geologic sediments in time means that the materials deposited on the coast in the last few thousand years are very diverse. There is a specific distribution of hard and soft deposits as well as the presence of hard clays, very soft clays and loose sands. Different geotechnical investigations can be saved if the geologic conditions are known in advance, Dredging plans will have to consider the presence of these materials. Knowing the sedimentary geology, the industry can anticipate a lot of the major planning and engineering issues associated with dredging.

Texas Sediment Inventories.

An important tool to predict future dredging challenged is the new Texas Coastal Sediment Geodatabase (TxSed). TxSed is a geospatial sediment geodatabase that has combined the geotechnical and geological cores available on the Texas coast. More than 12,000 cores and grab samples have been incorporated into a database that shows the geology and geotechnical conditions of the sediments in the Texas bays (http://gisweb.glo.texas.gov/txsd/index.html). The database allows to have a good idea of the challenges that future navigation projects may have. That includes new navigation challenges or the expansion of pre-existing channels. The concept of TxSed was developed by Dr. Juan Moya and Dr. Daniel Gao (GLO) and is the results of the cooperation of the state of Texas and academic institutions such as Rice University, Texas A&M University, the Bureau of Economic Geology and the US Army Corps of Engineers and its partners.

Rapid Sedimentation due to Coastal Processes.

Rapid sedimentation occurs on navigation channels due to long- and short-term water circulation in the bays and estuaries and to catastrophic events such as major storms. Storm surges can overtop the barrier islands and impact the navigations channels. Bolivar Peninsula was overtopped by Hurricane Ike in 2008 and left the sandy deposits of the Gulf of Mexico dispersed in a wide area in East Galveston Bay. A large amount of sediment covered the GIIW and the north and south side of East Galveston Bay. Data collected before and after Hurricane Ike on East Galveston Bay shows fast deposition of sandy and organic sediments with thickness up to 4 ft. Data presented here shows that these sediments buried productive habitats including fish and oysters reefs which are in the process of recovery in Galveston Bay.
Long-Term Sedimentation due to Coastal Processes.

Long term sedimentation can be also identified based on geologic patterns. For example, in 2012 using shallow sedimentary cores in West Galveston Bay, Moya et al., (2012) compared the bay bottom sediments with the grab samples collected in 1984 by the University of Texas, Bureau of Economic Geology (Fisher et al. 1972). The distribution of the core and grab samples collected under the new sediment data were located strategically to estimate the thickness of the sedimentary units and to identify the changes between 1985 and 2012. Several areas identified where dramatic changes in the grain size where observed due to erosion or accumulation processes. Lack of new sediments above the hard clays was interpreted as an indicator of specific circulation processes that produce no recent deposition or have induced erosion.

When the sedimentary history was combined with the interpretation of the 2D ADCIRC circulation model, several areas were identified as fast depositional spots, where some of them consisted of some segments of navigation channels. This comparison helped to understand the most recent sediment transport patterns and the potential “hot spots for dredging”.

The Geology of Major Navigation Channels.

Going to deeper and wider channels will require dredging new material on geological deposits and modifications to the natural system are expected to occur. For example, the development of the Port of Houston navigation channel, in addition to numerous oil and gas refineries and chemical plants in the GB area, caused modifications to coastal processes after the construction of the channel itself, as well as breakwaters, jetties, and various other hard structures as protection measures for navigation safety and to protect these industries. The demand for expansion of the maritime industry is expecting to expand the volume of traffic by bringing larger ships on deeper and wider channels, which will require more dredging and sediment management related projects.

Since submerged habitats are now part or are connected with some of the dredged material placement areas (DMPAs), the expansion of the DMPAs will also require environmental considerations to accommodate the new habitats that will populate the new areas. In other cases, habitat mitigation projects will also develop new conditions for the impacts to these habitats.

From the perspective of the dredging industry, several geotechnical conditions are expected to be found in the new geologic materials during the deepening and widening of the upper coast navigation channels:

**Hard Clays.**
Typical of the Beaumont Formation and normally used for DMPA levee material. This formation is the base of all the coastal deposits in the Texas Upper Coast.

**Main Paleo River Channel Deposits.**
These materials may include gravel, sands, silts and clays.

**Secondary Paleo-Creek Channel Deposits.**
These materials tend to be very fine in the order of clay and silt and also are soft and easy to dredge. These materials tend to be very organic.

**Reworked or In Situ Barrier Island Deposits.**
These consist of clean fine sands of the modern barrier islands or from ancient barrier islands before the Holocene.

**Early Stages of the Estuarine Deposits.**
These materials are also a combination of sands, silts and clays and tend to have high contents of shells material.

**Active Estuarine Bay Deposits.**
These materials tend to be associated with the high energy of the bay circulation processes. These deposits tend to be on the top of the bay bottom and can include very shelly materials as well as sands, silts and clays.

**Flood Delta Inlet Deposits.**
These materials tend to be sandy in nature and very loose, some big pockets of shells may be also included.

**Fine Clays and Silts on Navigation Channels.**
This is called the “maintenance material” by the dredging industry. The sediments consist mainly from the suspended silts and clays that are observed day by day in the Texas bays.

**The State of the Gulf Intracoastal Waterway.**
The Gulf Intracoastal Waterway (GIWW) is a 1,100-mile-long, shallow-draft, man-made, protected waterway that connects ports along the Gulf of Mexico from St. Marks, Florida, to Brownsville, Texas. As the nation’s third busiest inland waterway (Kruse et. al., 2014), the GIWW is an essential component of the nation’s transportation network. In addition to the economic benefits derived from the cargo carried on the GIWW, traffic on the waterway reduces highway and rail congestion and also decreases maintenance costs and extends the life of these systems. In addition, water transportation is the most fuel-efficient mode of transportation and produces the least emissions per ton of cargo carried. Additionally, many of the cargoes moved on water are hazardous materials and maritime vessels provide the safest mode for their movement.

The Texas GIWW is one of the most highly utilized corridors in the U.S. inland waterway commerce network. The Texas portion of the GIWW covers 379 miles of Texas’s coastline, links together 11 deep-draft ports and 13 shallow-draft channels, and handles 67 percent of all traffic on the entire GIWW. Texas’s coastwise maritime trade plays a key role in managing congestion and reduces the need to build new transportation infrastructure.

In 2012, the Lone Star State ranked second in the nation in total waterborne tonnage transported, with 486 million tons (or 21 percent) of the total U.S. maritime freight volume on both deep and shallow-draft waterways (Kruse et. al., 2014).

The GIWW is a federally maintained channel with authorized dimensions of 125 feet wide and 12 feet deep. U.S. Army Corps of Engineers (Corps) is responsible for maintaining the GIWW but limited federal funding has prevented the Corps from maintaining the authorized dimensions. The net result of improperly maintaining the GIWW is costly shipping inefficiencies for Texas businesses, lost revenue, as well as lost economic opportunity for the State.

**Future of the GIWW.**
The Texas Department of Transportation (TxDOT) is committed to providing safe and reliable transportation solutions for Texas and is fully developing all aspects of the intermodal transportation system.

The mission of TxDOT’s Maritime Division is to promote the development of high-value growth in Texas’ maritime system. The division supports development and intermodal connectivity of Texas ports, waterways and marine infrastructure and operations. It also works to incorporate port and waterway initiatives into TxDOT’s overall transportation system planning. Additionally, the division helps maintain and increase the use of the Gulf Intracoastal Waterway (GIWW) and promote waterborne transportation as a means of maintaining Texas’ economic competitiveness.

TxDOT was named the official non-federal sponsor for the GIWW in the 1975 Texas Coastal Waterway Act, now codified as Transportation Code, Chapter 51. The non-federal sponsor’s duties include the provision of lands, easements, rights of way, relocations, and necessary disposal areas for the placement of material from maintenance and operation of the GIWW. As part of a 50-year GIWW dredged material management plan, there are over 200 designated disposal areas along the GIWW in Texas. In addition to designated disposal areas, TxDOT is actively involved in regional sediment management (RSM). Proper management of sediments can reduce the need for dredging, help maintain channel dimensions, and increase water quality. One form of RSM is the beneficial use of dredge material (BUDM). BUDM will utilize dredged material to revitalize sediment starved environments such as marshes, beaches, and eroding shorelines in lieu of placing the material in disposal areas that have limited capacity.

As the demand for more waterborne transportation capacity increases waterways and ship channels will need to be deepened and widened, creating a challenge for placement of dredged material that is compounded by coastal development expansion. More innovative solutions for management of dredge material and placement are imperative.
The GIWW continues to face challenges due to the coastal process and the impacts of navigation on the channels. The challenges can be divided into three categories:

**The Shoaling of the Navigation Channel.**

The shoaling of the navigation channel will increase as traffic and other coastal processes increase. GIWW has identified traditional hot spots for maintenance and some future spots that will require new projects and placement areas.

**The Loss of Existing Dredge Material Placement Areas.**

The dredge material placement areas along the GIWW requires maintenance and many of them are out of capacity and are subject to strong erosion. Specific areas face the entire disappearance of the placement areas due to intense erosion coming from the navigation channels and form the bays fetches.

**Identification of New Placement Areas.**

The shoaling processes are becoming more active and intense on many of the Texas bays. This demand for more placement areas brings the challenge of locating new placement areas, which may include new placement areas in the bays as well as on land.

**Conclusion.**

The understanding of the geological and geomorphological processes occurring on the Texas coast may facilitate the planning of future navigation projects as well as their maintenance. The mentioned information if used correctly, will support the will expansion of our waterways and navigation channels to support the maritime commerce and the position of Texas ports in the international markets. The deepening and widening initiatives will require major dredging and the potential of beneficial use of dredge material (BUDM) practices on new "geological sediments". The understanding of the origin and dynamics of the coastal sediments benefits engineers, geoscientists, academic groups and geotechnical experts. Understanding geology and geomorphology means understanding the natural geographical distribution of our dredging materials. Concepts such as building with nature and using natural sediment transport processes will be key in the future for the maintenance of our navigation channels.

**References.**


