LEAF ERICKSON

LOCAL SEDIMENT MANAGEMENT AT LEEWARD-GOING-THROUGH IN PROVIDENCIALES, TURKS AND CAICOS

ABSTRACT

Dredged material was transferred from the borrow site to the beach via a pipeline cutter suction dredger. Approximately 260,000 m^3 of material was taken from the borrow area and placed on the beach. Survey transects were used to ensure complete sediment removal. The same transects continue being used to determine shoal evolution and migration. The project significantly widened and improved the severely eroded Emerald Beach shoreline by the placement of approximately 240,000 m^3 of high quality sand. The immediate post-construction survey data for the beach profiles was scheduled to be resurveyed 6 months following the initial construction project, or in February 2005. This new information will be compared to the immediate post-construction survey data to determine the shoreline change rates and the volumetric change rates.

A physical and biological monitoring plan for the Emerald Beach Sand Replenishment Project has been implemented to measure and evaluate the physical and biological systems within the nearshore coastal areas surrounding Leeward-Going-Through. The purpose of the post-Project monitoring studies are to evaluate the Project's overall performance and to determine the long-term beneficial and/or adverse impacts of the Project on the coastal environment. The results of the measured changes will be used to determine if erosion amelioration measures and mitigation is required.

Water Cay, immediately north of Little Water Cay and connected by Donna Cut, was planned for development requiring an access channel be dredged to move construction equipment onshore. An environmental impact statement and construction drawings were developed to satisfy outline planning needs while in depth site investigations were conducted finalizing channel alignment and sediment containment location. Sediment analysis indicated beach compatible sand and beach nourishment was planned. Recognition of the local interests regarding the property owner rights, government planning interests, marine environment, dredge contractor, and client all were found to be essential to effective project management.

The author wishes to thank Billy L. Edge of Texas A&M University and Karyn M. Erickson of Erickson Consulting Engineers of Sarasota, Florida for their collaboration and support. This paper was presented at WEDA XXV, New Orleans, Louisiana, USA in June 2005 and appears in the conference Proceedings. It is reprinted in a slightly revised form with permission.

INTRODUCTION

Coastal beach nourishment is essential to maintain the economic viability of island tourism. The Turks and Caicos Islands of the British West Indies are located southeast of the Bahamas and north of Hispaniola (Figure 1). The economy of this island nation has been primarily based on tourism and recognized as an international destination with enough travel to support regular direct air service from Miami twice daily, Charlotte twice daily, New York twice weekly, and London twice weekly. In addition, the exportation of conch and spiny lobster provides a significant portion of their economy which is greatly supported by the high quality marine environment surrounding these islands. Understandably, a central concern of their government was their quality coastal systems.

Above, Figure 2. Leeward-Going-Through and Emerald Beach.

Figure 3. Dredger in operation with beach fill and Leeward-Going-Through in the background.

Proper maintenance is essential to protect them as one of their most valuable natural resources.

The quality of the local environment has been exceptional and provides for world class snorkeling, diving, fishing, and beach recreation. The island chain rises from deep water on all sides by several thousand feet with some of the Caribbean's best wall diving experiences with many coastal areas protected by national parks. Providenciales is approximately 18 miles long by 10 miles wide with approximately 38 square miles in land area. The islands were governed for many years by the British, initially through the Bahamas from Nassau, producing primarily salt for the English empire. They are now a protected territory of the United Kingdom. The following article details the activities conducted during the summer of 2004. While employed by Erickson Consulting Engineers, Inc. three projects were conducted, each representing a separately distinct stage and type of a coastal engineering project.

Emerald Beach

A coastal nourishment project was constructed on the Emerald Beach region of Providenciales (Figure 2). The project involved both the Department of Environment and Coastal Resources and the Planning Department for approval of the removal of sediments from a near-shore shoal and then the subsequent placement onto the adjacent coastline for a nourishment project in order to replenish eroded sediments. Over time, strong storm events and shoal evolution changed the tidal flow regime in the vicinity of Leeward-going-through and Donna Cut.

The initial project size was designed for approximately 240,000 cubic yards of sand but an extension permit was approved for an increase of the project size to 265,000 cubic yards to accommodate an extension of the beach fill, including two adjoining homeowners, to a natural rock feature.

During construction, the additional clients required more private agreements between them as property owners than approval of design changes from the Planning Department. Thus work was delayed on the extension of the project to two adjacent property owners. Once final approval was granted for the extension, beach fill placement was relatively uneventful for a project of that scale.

The measurement of fill through pre- and post-dredge surveys presented some problems while working with a sluggish local business that seemed unable to operate at the same rate as those accomplished by both the contractor and engineering firm.

Figure 1. Map of Central Caribbean

IADC AWARD 2005 PRESENTED AT WEDA XXV NEW ORLEANS, LOUISIANA, USA JUNE 19-22 2005

In 2005 the IADC Award was presented to Mr. Leaf Erickson, an Associate Engineer at Erickson Consulting Engineers, Sarasota, Florida, USA in charge of project development and site management for coastal projects in North Carolina, South Carolina, Florida, and the Caribbean. He has a ME in Coastal Engineering from Texas A&M University, College Station, TX and a BS in Environmental Engineering from the University of Florida, Gainesville, FL.

Each year at selected conferences, the International Association of Dredging Companies grants awards for the best papers written by younger authors. In each case the Paper Committee is asked to recommend a prizewinner whose paper makes a significant contribution to the literature on dredging and related fields. The purpose of the IADC Award programme is "to stimulate the promotion of new ideas and encourage younger men and women in the dredging industry". The winner of an IADC Award receives Euros 1000 and a certificate of recognition and the paper may then be published in *Terra et Aqua*.

Leaf Erickson receives the IADC Award for young authors from IADC Secretary General Constantijn Dolmans (right).

Government

All dredging related projects in the Turks and Caicos involved the Department of the Environment and Coastal Resources when within national parks, Maritime Department when within navigable waters, and Planning Department for any upland sediment placement. Each group had its own interests in the project and the impact it would have on their respective jurisdictions.

The Department of the Environment and Coastal Resources primarily showed concerns over water quality, impacts on adjacent ecosystems, and protection of protected species, as well as many others. The Maritime Department was largely concerned with the proper marking of navigational channels as well as the presence of any remaining features within the borrow area that could pose an obstruction to navigation, during and after construction. The Planning Department was needed to confirm that property changes did not interfere with any zoning restrictions, property rights, or adjacent homeowner's rights. Each organization had the authority to stop construction at any time, if there were concerns of permit violations.

The skill to enforce these violations did vary in part as related to the education levels of the government officials, ranging from high school to university levels, but an independent specialist was brought in from the U.S. since none existed or were available on island, at the time. To receive permits, environmental assessments were first conducted privately by the engineering firm for review and confirmation by the special inspector.

The prevalence of marine life in local culture has lead to a dolphin becoming a national ambassador to the environment. JoJo the dolphin has come to be recognised as the vague touristy symbol but he also represents a deep local connection to the environment (Figure 4). JoJo began life wild and, through his own will, choose to interact with humans. His local reputation of curiosity was soon

Figure 4. JoJo the Dolphin, Ambassador to the environment.

understood by both the local dredge supervisor and engineer's site representative. Initially, JoJo showed intense interest with all that went on with the dredger, from following the anchors as they were moved and mimicking the cutter head while in operation. This caused great concern but, very little could realistically be done. In the end, JoJo eventually lost interest and visited the site sporadically, primarily only as the dredger warmed up in the mornings.

OUTLINE OF WORK

While serving as and engineer's site representative, in the Turks & Caicos B.W.I. from June to August of 2004, tasks associated with being a site investigator, ACAD draftsman, and survey crewmember, among many others were performed. The site investigation on South Caicos shows the initiation of work with a general site assessment; Water Cay represented the permitting process of a dredge and fill project; and Emerald Beach gave a comprehensive experience at managing a coastal engineering construction project. These activities show both the diversity and various stages of coastal engineering projects.

The beaches that make up Grace Bay are regarded as some of the Caribbean's most valuable resort properties, on which both Club Med and Beaches own resort property. This section of Providenciales, comparatively developed for an island of its size, has been well recognized by investors.

All remaining properties have been purchased along these beaches and developments have begun or are reaching completion. Immediately to the east of these properties is Emerald Beach which comprises the easternmost end of Providenciales.
A tidally influenced channel, Leeward-Going-Through, that divides Little Water Cay from Providenciales, had significantly eroded shorelines. Since the closing of Donna Cut, the erosion along this length of shoreline has been extensive, threatening several homes and other structures.
Other areas of Grace Bay have also been experiencing similar erosion problems without direct influence by significant tidal flows, so proper determination of causes was essential to an effectively engineered solution (Figure 5).

EMERALD BEACH

The dominant cause of sediment transport from Emerald Beach was Leeward-Going-Through which has a relatively high tidal flow that dominates the movement of local sediments. During severe storm events, closing nearby Donna Cut, and natural ebb shoal evolution, the tidal flows from Leeward-Going-Through and Donna Cut were combined resulting in more scour and erosion between the Emerald Beach shoreline and the western end of the Little Water Cay (Figure 6). This channel has been historically stable but, as mentioned, strong storm events and subsequent changes in the local tidal flow patterns resulted in severe erosion along the adjacent shorelines. The erosion threatened many homeowners with losses in property and structures. Before nourishment, some sections of beach became seawalls, were divided by geotextile groins, and dead trees.

Monitoring

The project involved monitoring and management of both environment and contractor. Ecosystems surrounding the project area required careful planning as well as monitoring during the project to ensure no excessive impacts were caused by dredging activities. Turbidity was monitored at several locations and biologic transects were regularly surveyed to help keep a record and to protect the environment (Figure 7). Daily reports were produced by the engineer's site representative, contractor, and dredge captain to help keep track of daily activities, making a record to reference if miscommunications occur.

Proper management of the contractor was found to help reduce and eliminate many unnecessary impacts to the environment. A good working relationship was helpful to resolve both minor and major issues experienced during the construction process.

Figure 6. Emerald Beach erosion before dredging facing north (above) and south (below).

Water Quality

Turbidity monitoring, government field approvals and permit compliance were the most significant areas of concern regarding water quality (Figure 8). The government required turbidity measurements twice daily and any time a significant plume developed, measurements beyond the established mixing zones of twenty-nine nephelometric turbidity units above background would have placed the project in violation of the permit requirements. Global positioning was used to determine all sampling locations relative to the discharge and dredge as they progressed through the borrow and fill areas, respectively. Turbidity as it is related to most dredging projects, especially one operating inside of a marine national park was a

Figure 5. Donna Cut closed from the east.

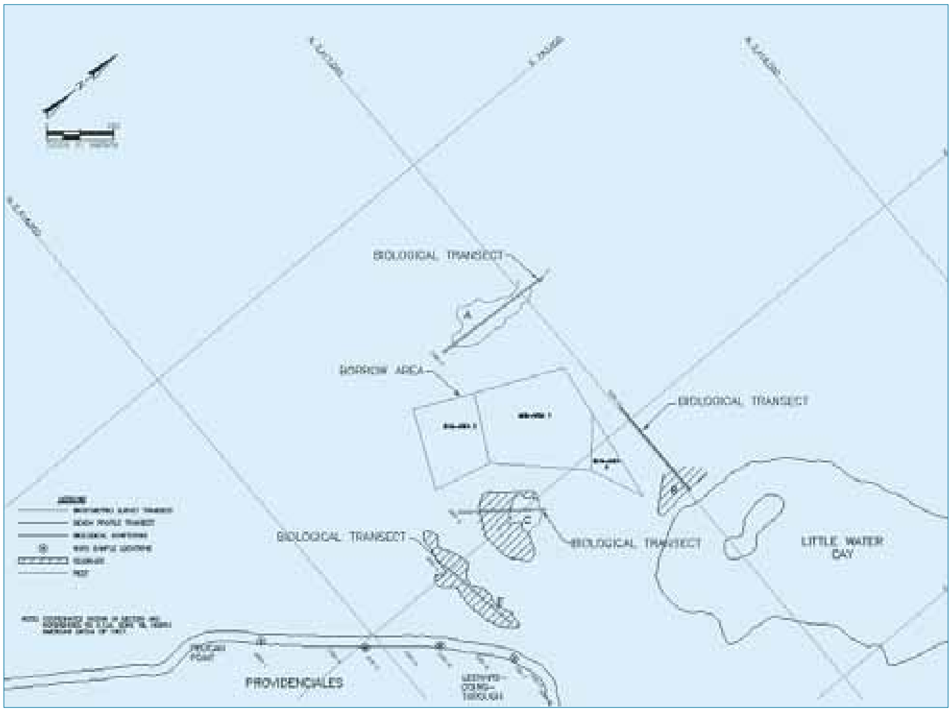


Figure 7. Biologic monitoring transect locations.

primary environmental concern but, did not present any major problems during the project. All plumes developed dissipated within the distances required by the permitted monitoring plan.

As with most regulatory agencies, the local government representative felt that this project could and should be done without any impact to the environment whatsoever. Possibly there would be some siltation resulting from turbidity, but that would pass once the construction was completed. As an employee of an engineering firm, discussing problems during the construction of a project before they occur is important, but over-speculation can impart doubt for no productive reason and possibly impart unfounded concerns.

Biologic

Slight siltation was documented during regular monitoring intervals, but no major problems occurred for the first half of the project. Eventually, the high tidal currents caused the anchoring system of the pipeline to fail, allowing it to drag across a portion of a densely populated and productive patch reef. Repairs and compensation were made for the damages to the marine environment by the contractor (Figure 9), but once the anchor system was doubled in strength, no further problems occurred with pipeline movement.

The efforts of reattaching coral and sponges was found to be quite difficult for some of the same reason the pipeline damaged the coral in the first place, tidal currents were quite strong and anchoring them to the bottom proved difficult at best. To resolve the issue of the pipeline dragging, the anchoring system strength was doubled by using four additional twelve and six ton anchors.
Once repositioned, dragging was no longer a problem with the pipeline, but at times the heavy currents would kink the pipeline like a garden hose. This could have been very damaging for the dredge as well as

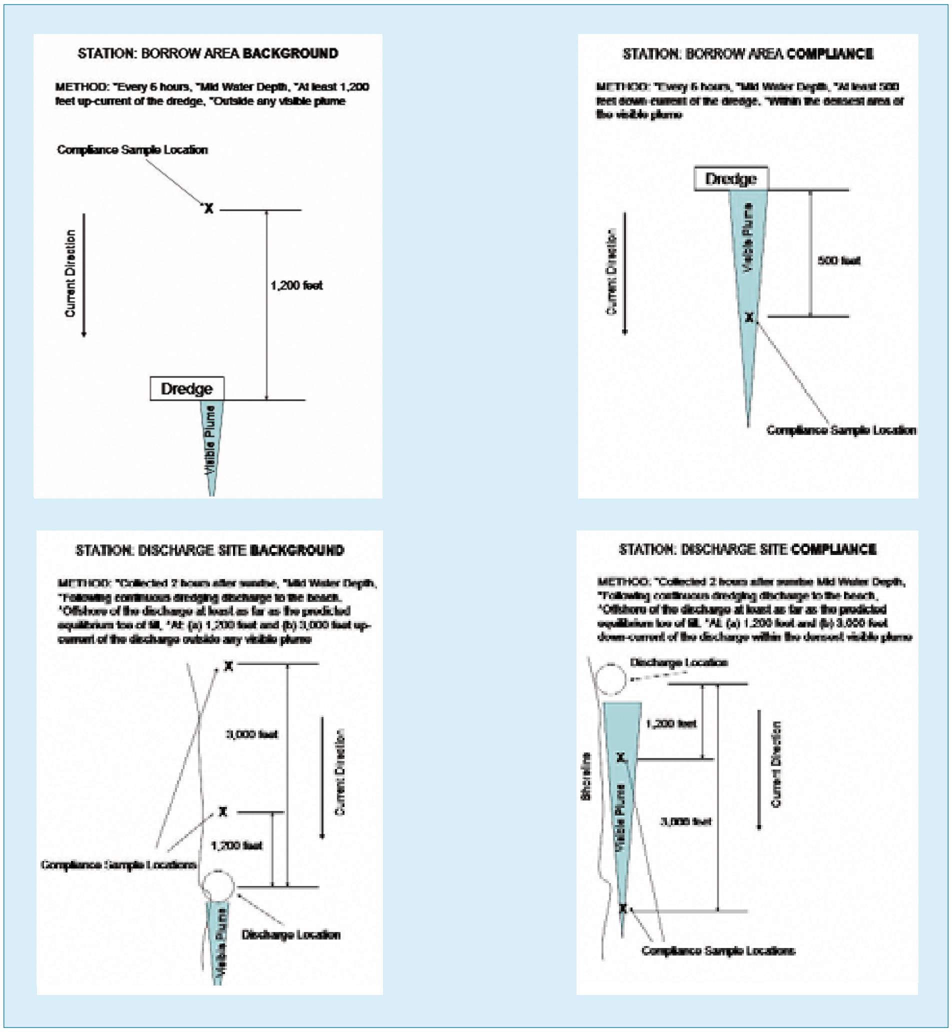


Figure 8. Monitoring locations.

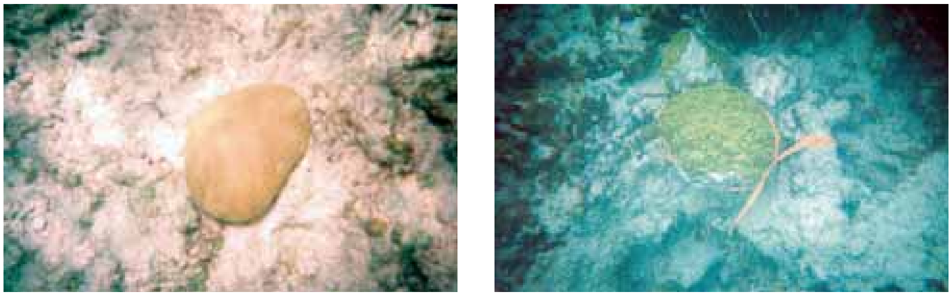


Figure 9. Reattached mustard coral (left) and brain coral (right).

the pipeline but, no breaks in the pipeline occurred or pressure related damages were experienced by the dredger.

Construction

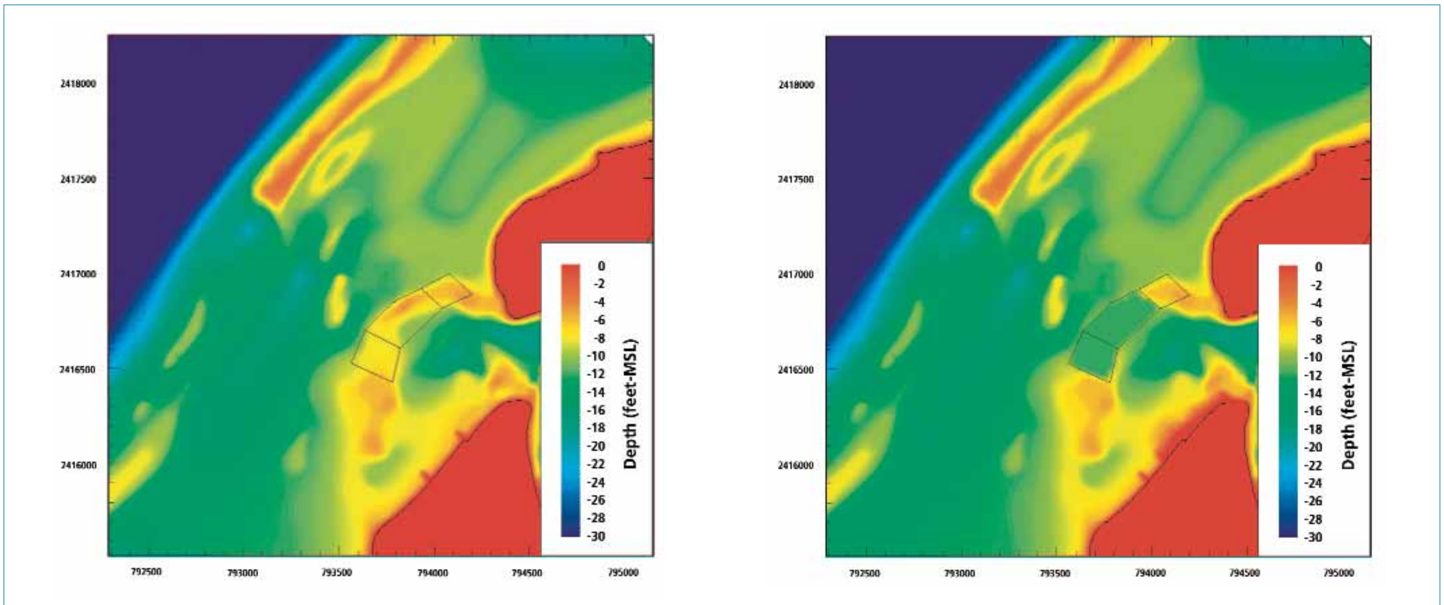
Many complex logistical, managerial, and administrative tasks were experienced. Weekly construction meetings, daily site inspections, dredge inspections, and pipeline location monitoring, all were involved during the supervision of daily progress. Working with a construction contractor was interesting. Essentially both the local supervising contractor and the engineer's site representative work to help the project progress along properly as far as the project sponsor, construction firm, and government are concerned, while minimizing costs to their respective organizations. While serving as the site engineer it was found that having a good personal relationship with the local supervising contractor helped greatly during everyday operations. At times, it made dealing with small problems easier in some ways and large problems more awkward in others. Both representatives do their best to prevent any difficulties but, on a project of this scale much can happen. All things concerned, the project went quite well and set an example for beach nourishment projects in the Turks and Caicos islands.

Proper oversight of a construction project was found to be heavily detail oriented. The continuous movement of construction supplies and equipment during the project required attention for proper customs, engineering, and environmental clearance, not to mention delivery from local transport and freight companies. Primarily, proper monitoring of the construction was to ensure the design was properly constructed and the client was comfortable as work progressed. Local bathymetry was used to model tidal flows before and after dredging. The removal of sediments would allow for a more direct flow pattern and navigational channel.

The new channel would provide a direct route for both tidal flows and local marine access to Leeward-Going-Through.
The survey transects used to determine the before dredging bathymetry will be resurveyed after construction and used to ensure complete sediment removal (Figure 10). The same transects will continue being used to determine shoal evolution and migration for the remaining monitoring surveys. These surveys will be used to help determine the beach fill performance over the design life. The renourishment interval will be determined with these monitoring surveys but, with the borrow area sand almost identical to the beach fill the erosion will be primarily determined by the local flow regime.

The stability of the beach fill will be assessed during a series of monitoring studies to be conducted during the years after construction completion (Figure 11). The need for a rock groin at the eastern most end of the beach fill area was recognized and initially engineered for but, the need became evident from both the

Figure 10. Before dredging survey (left) and after dredging modelled bathymetry (right.)



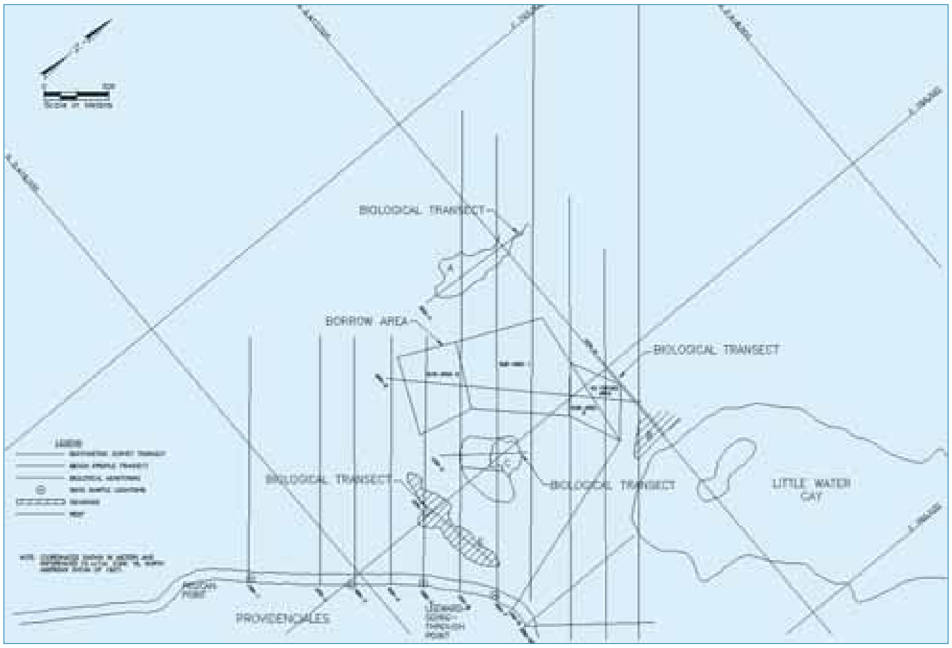


Figure 11. Construction survey monitoring transects.

speed of the tidal current as well as the location of the beach fill. Before project completion, small sand bars have grown into larger bars in the vicinity on the ebb tidal shoal from sediments eroded off the easternmost beach fill templates. The extension work to the initial project was a brief lesson in the many aspects associated with getting a coastal project permitted. The legal hassling was mind boggling, but the most decisive part of the situation was that the clients were more driven by egos at times than by the financial cost of construction alternatives.

Extension work

The originally permitted design included an option for extending the fill one homeowner property to the west, as is common for adjacent properties in many coastal projects. Interest was shown by the property owner beyond the designed extension to the west for beach fill, if permitting could be achieved. As this was not an option on the originally permitted design, permitting was needed and was quickly received with the same standard conditions as before. This required re-documentation of many formal standard public and legal notices (Figure 12).

Groin design

An angled T-head design was chosen for both the groins, with the head remaining above water, but allowing the seaward portion of the trunk to emerge and submerge with the tides. The groin for the eastern end of the project is being permitted and has been understood by the property owner as needed to avoid excessive erosion. A groin was also designed; the groin at the western end of the original extension design will be constructed if erosion requires greater end containment. The extension of sand placement to the nearby rock headland could give a natural closure feature that could eliminate the need for the groin because the rock headland would fill the same engineered purpose of the groin containing the sediment.

WATER CAY

A resort development was planned for the island of Water Cay. The investors had been organized and construction of an access channel needed to be completed in order to begin any development of the property. Channel depth was to be sufficient in order to bring barges to shore and have enough area for maneuvering in a turning basin, allowing vessels to depart safely.
Locally, fill dirt is expensive and all sediments excavated during the dredging project are sought to be confined in an upland containment area, to help in later site grading and development (Figure 13).

Channel design

The channel was designed deep enough for an 8-foot depth to remain at low tide, allowing for relatively deep draft vessels to safely navigate to shore. Three to one side slopes are chosen for the channel to limit slope avalanche failure and to help provide ease of construction for an oversized dredger on site. The dredger did allow for greater flexibility in placement of the containment area because of the higher pumping capacity associated with the equipment. The channel was designed to be longer than necessary in order to cross areas of beach quality sediments on the

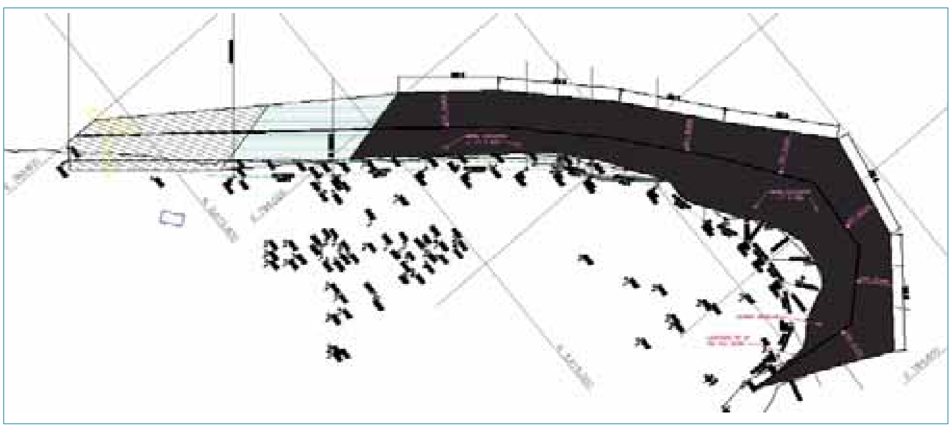


Figure 12. Extension of beach fill for two homeowners to the west.

Figure 13. Aerial view of Donna Cut with Water Cay in the background.

backside of a closed inlet, to help limit the overall impact to the ecosystem by crossing fewer seagrass beds, and for safer navigation because of smaller turns for vessels while during approach and departure (Figure 14).

Environmental impacts from the removal of sediments were limited, the loss of sea grass was noticeable, and the impact from turbidity was minimal, but with no hard-bottom impacts, permitting approval was achieved. The design was developed such that the landward end of the channel was placed on the western side of the small cove in order to minimize impacts to the mangrove wetlands to the east. The lack of hard-bottom habitat and by being adjacent to turbidity tolerant ecosystems, made environmental impacts relatively minimal. This helped greatly with permit approval considering the high quality of the local marine environment and being within a national park.

Material Placement

In the short term, the process began with an engineering overview of the project and initial approval for the outline planning stage of the project. A large upland containment area with earthen dikes was designed to contain all sediments and associated overwash from channel dredging. The volume was difficult to estimate, but from vibracores taken in the area sediment depths, a general estimation was made. A maximum dike height of 15 feet was established by the planning department in order for the fill to remain concealed behind a ridge when viewed from offshore, near the neighboring fringe reef. With an approximation for the area needed, the aerials of the property were consulted and initial locations were established. An environmental assessment of the upland impacts were made by an independent specialist which caused the final location to be moved inland of a freshwater marsh, relatively rare for the Caribbean, that contained plants designated as protected. Functionally, their marsh and wetlands areas are treated much like counterparts in the United States. After the areas of concern were designated, the site was briefly reviewed, by both the engineer's site representative and the contractor, for final containment area placement and estimation of land clearing and dike building needs (Figure 15).

The placement of all beach quality sand will be made to a section of beach fill designed for nourishment of the shoreline adjacent to the areas deepened by the dredging. Due to the relatively protected nature of this beach from storms, wind and wave impacts are limited. The relative stability of the fill placement was considered stable enough and would be unlikely to reenter the channel.

Figure 14. Water Cay Project layout showing channel alignment and bathymetry.

Permitting

The engineer's site representative was responsible for the creation and production of the drawings for the outlined planning permit. The particulars of producing documents required some effort in America, but when on island it is a struggle to accomplish even the most basic of business related tasks. Developing the construction drawings in AutoCAD was relatively normal even with the rush.
For example, printing plotted documents was an interesting process because large format plotters, suitable for producing construction drawing sets, are rare on Caribbean islands and all the usual expected last minute revisions including one that required a rush to the firm to produce a revised drawing and to then to the planning office with the new sheets and a stapler. Interesting situation but, needed for the quick approval from permitting.

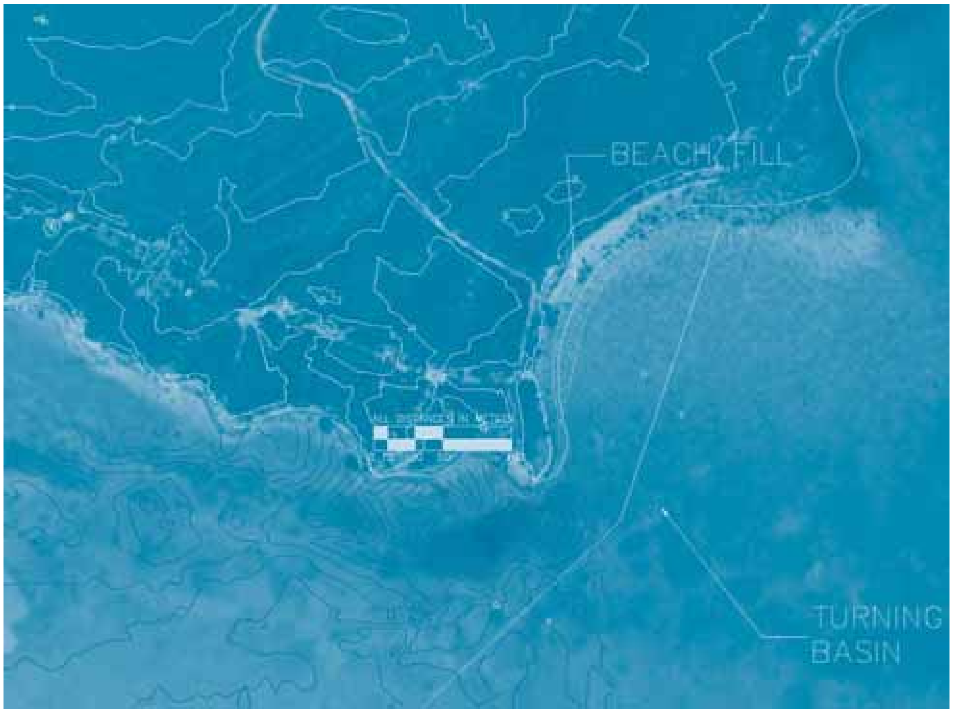


Figure 15. Water Cay beach fill, turning basin, and containment area.

Conclusions

Contractual delays between homeowners pushed the construction of the access channel to the spring but, because the project was essentially permitted in time and the dredging company wanted to overhaul the dredger, no mobilization and demobilization costs were incurred for the dredger to leave the project area for regularly scheduled maintenance and to return later completing the work in the spring of 2005. This represents the heart of field operations. Many tasks at a field office included rush work, but sometimes it turned out there was no need for the work or the rush. Constant attention to the contractor, project site, local workers, and officials is a must for the best working relationship with all involved in the project.

LOCAL LOGISTICS

Working on islands, especially in the Caribbean, requires the patience and understanding that can make normal schedules impossible. In short, 'island time' is a state of mind held in part or whole by many Caribbean islanders. The best way to describe 'island time' is by a short exchange learned from a Bahamian. I asked, "What time is it?" and he replied "It's Tuesday". What is not done today will probably get done tomorrow, can at times, be a good description of island life.
This work ethic caused only a few delays and problems, but eventually had to be figured into working deadlines. This caused increased friction with the contractor for precise and timely pay volume calculations from pre- and post- dredge surveys. Transportation issues also presented themselves that reflected this type of working relationship.

Customs

The transfer of materials and equipment was delayed initially for some items because customs declarations and shipping manifests were not prepared early enough to receive pre-approval for clearance.
This was resolved later in the project by proper notification. All shipments, arriving or departing, were well documented in advance to accommodate for the need of earlier notification. The disorganization of the customs storage facility caused a couple of brief delays. Paperwork for emptied fuel containers did not accompany some shipments leaving the island and were delayed but this did not significantly affect the dredging progress.

Government

The local government required an intimate relationship in order to acquire quick assessment of permitting requests. There is a thirty-day public notice of all planning permits and notification of all adjacent property owners to show openness of all development activities (Figure 16).
The weekly construction meetings provided the most common interaction with the government officials. These meetings showed that, regardless of the location, the governing agencies were aware of their points of concern, openly and directly discussing them during the course of these meetings. Regular surveys, turbidity testing, and site management were required and regularly reviewed by the Department of the Environment and Coastal Resources and as well as its special inspector.
The Planning Department had little objections to the property improvements and subsequently granted permitting approval.

Surveyors

The local survey firm worked reasonably satisfactorily throughout the first half of the project on Emerald Beach. Later, excessive delays were experienced as a result of problems with both conducting surveys and data reduction. A concern arose from the vague nature of the reasoning and cause for the delays and was enough to give formal notice of concern. At times, the contractor and surveyor had disagreements about survey methods, which did not help an already difficult situation. Directing the contractor to interact through the Engineer's site representative did help some, but it was decided to not rehire the survey firm for future needs.
Working at any coastal engineering project site tends, by nature, to be in a more remote location than many other engineering professions, but when the projects are on an island in the middle of the Caribbean, running on 'island time', things can become challenging.
Remote and isolated from the rest of the world, islands are, by nature, difficult to deal with logistically but complications of using a local survey company, freight delivery company, and local contractors show that regardless of having all the proper tools and supplies on hand, it still can be difficult to get the human element to bring a task to completion.

CONCLUSIONS

Permitting
Construction permit drawing development and permit condition compliance were required for the approval of detailed site preparation. Dealing with permits was a primary focus for any coastal engineering project. The particulars of the way that drawings and reports were organized was important to giving a clear idea of what was intended for construction and how to accomplish it within permit, environmental, and planning requirements. Knowing the issues of interest for the government was helpful and almost essential in receiving quick construction approval on projects of that scale.

Monitoring
Regular, accountable, and reliable environmental monitoring was required for all projects in the waters surrounding the Turks and Caicos Islands, but being within a national marine wildlife refuge caused great attention and occasional spot checks of both methods and results. The mixing zones allowed by the permit were large enough to allow all unwanted turbidity to settle out of the water column. The global positioning that was used to help determine sampling locations ensured proper monitoring as construction progressed.

Local logistics
Initial site investigations, detailed field studies, surveying and construction all require operating remotely from the home office, infrastructure, and executive oversight. These constraints and liberties require focused and hardworking individuals able to handle the complex and diverse aspects of logistics, planning, and completion of tasks producing accurate data to help in the engineered solution. Proper benchmarking, site designation, and data recording allowed for data with enough precision to properly represent the site conditions.

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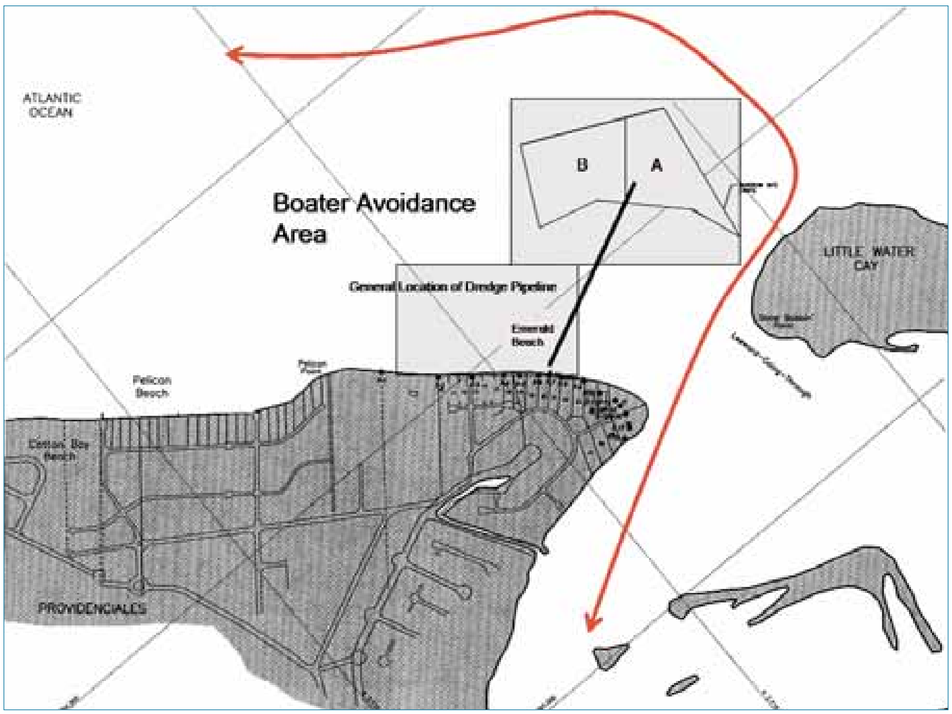

Figure 16. Government required public notice.