GOVERNMENT OF THE BAHAMAS
MINISTRY OF WORKS & TRANSPORT

NASSAU HARBOUR
PORT IMPROVEMENT PROJECT

PRELIMINARY ENGINEERING REPORT

SEPTEMBER 2008

COX & SHAL CONSULTANTS

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PORT IMPROVEMENT PROJECT

PRELIMINARY ENGINEERING REPORT

1.0 INTRODUCTION

The number of people taking cruise vacations continues to grow at a rapid rate, resulting in the need for a greater number of cruise ships. As new ships are built, they are becoming increasingly larger. A number of ships currently being built are post-Panamax size, meaning that they are too large to pass through the Panama Canal.

These "new-build" ships will be delivered over the next few years with the first arriving for active service in the fall of 2009. The cruise lines have advised that the existing Nassau Harbour Turning Basin and Approach Channel are not adequate for the safe entry of the new-build ships and for some of the larger newer ships recently put into service. These new ships have replaced smaller ships that called on Nassau on a regular basis, resulting in a reduction in the number of cruise ships and passengers arriving in Nassau over the past few years.

Tourism is extremely important to the economy of the Bahamas and cruise ship arrivals contribute significantly to tourism revenue. Therefore, Government has made it a priority to reverse this downturn in cruise ship and passenger arrivals by making improvements to the Harbour their highest priority.

In response to a formal Request For Proposal, Cox & SHAL submitted a proposed to Government for the design and contract administration of the Nassau Harbour Port Improvement Project. Because of Cox & SHAL's extensive Bahamian experience and in particular, their experience with Nassau Harbour, Cox & SHAL were awarded the design contract.

For execution of the Project, Cox & SHAL have assembled a team of subconsultants, each of which are specialists in their respective fields.

Baird Associates, Ottawa	Coastal Engineers
Blue Engineering, Nassau	Environmental Impact
Hydrographic Consultants, Houston	Hydrographic Surveys
Trow International	Geotechnical Investigation

Key individuals within the Ministry of Works and Transport are also an important part of the Project Team.

This Report describes the site investigations carried out as a necessary starting point for Project execution, the establishment of dredge limits acceptable to Port users and the alternative types of mooring dolphins considered leading to firm recommendations to Government for final design of the Project. This Report also establishes construction priorities to meet scheduling demands.

2.0 Executive Summary

The number of cruise ship passenger arrivals has decreased in recent years because some of the cruise lines have withdrawn smaller ships from service and replaced them newer, larger liners. The cruise line companies have advised that some of these replacement vessels currently in service are unable to safely enter Nassau Harbour.

In addition, even larger cruise vessels are in the process of being built with the first of these, Royal Caribbean Cruises' Oasis of the Seas, scheduled to be commissioned in the fall of 2009. Vessel size is significantly larger, especially the beam of this vessel. Dimensions of the Oasis of the Seas:

	Metres	**Feet**
Length Overall	360	1,181
Beam	47.0	154
Draft	9.3	30.5

Overview

The recent reduction in cruise ship passenger arrivals represents a serious setback to the Bahamian economy which will be compounded if the soon to be commissioned new-build ships cannot be accommodated.

Tourism is extremely important to the economy of the Bahamas and cruise ship arrivals contribute significantly to tourism revenue. Therefore, Government has made it a priority to reverse this downturn in cruise passenger arrivals by making improvements to the Harbour the highest priority. Improvements identified include:

- Increasing the length of the Turning Basin;
- Widening the outer portion of the Approach Channel;
- Installing new mooring dolphins to increase the length of the Centre and North Piers;
- Upgrades to the existing bollards on the Centre and North Piers (not part of this Project).

The volume of dredged material is 2.0 million cubic yards, which includes an allowance for overdredging. Government recognize that the dredged material, consisting of sand and broken up coral rock, is a valuable resource and wish to stockpile as much of this material as possible for use elsewhere. However, the stockpile must be located within approximately one mile of the dredge location to maintain dredge efficiency and keep the dredging cost reasonable. The logical stockpile location is the unused space on Arawak Cay.

Existing space available on Arawak Cay will accommodate 600,000 cubic yards of dredged material. Therefore, there was a need to identify a location for placement of the 1.4 million cubic yards of excess material. Since there is no existing land area available within reasonable pumping distance, Cox & SHAL together with Government came to the conclusion that an area needed to be reclaimed from the sea to create the necessary stockpile area.

Three options were considered:

Alternative A1: A westward expansion of Arawak Cay;
Alternative A2: Filling south of Arawak Cay to join with New Providence;
Alternative A3: Creating a new island 3,000 feet west of Arawak Cay.

Trucking the material to an offsite location as the material is deposited was also considered; however, this is not a practical solution since the material will be very wet when deposited and needs time to dry out. A trucking operation could not keep up with the deposition of 10,000 cubic yards per day of wet material, the rate necessary to meet the fall 2009 completion date.

The other alternative of depositing the material as part of the Bay Street Redevelopment is also not viable because relocation of the Bay Street shipping to Arawak Cay cannot be accomplished in time to meet the Port Improvement Project Schedule.

After due consideration, Government approved the westward extension of Arawak Cay as the means of receiving the excess dredged material. Government also agreed that the containment structure necessary to receive this material will be built of steel sheet piling, similar to that used for the existing Arawak Cay.

The extension of Arawak Cay is being treated as a separate project and the various issues such as environmental impact associated with the extension to Arawak Cay are not part of this Report other than sizing the extension to accommodate the excess dredged material.

Calculations indicate that Arawak Cay should be extended 1,000 feet, with 900,000 cubic yards used to build the extension, allowing the stockpiling of an additional 500,000 cubic yards. This results in a total volume of stockpiled material of 1.1 million cubic yards available for use elsewhere. Currently, Government's intention is to use much of this material in connection with the planned redevelopment of Bay Street immediately east of Prince George Wharf. A number of alternatives are being considered, all of which require the use of fill to build northward into the Harbour.

As noted, Bay Street redevelopment cannot proceed until the shipping operations located along Bay Street are relocated. Currently, Government are planning to move the Bay Street shipping operations to Arawak Cay. With the addition of new dockwalls to the existing landform together with alongside dredging, this will meet shipping needs over a time frame of twenty to thirty years. Thereafter, the north and west ends of the Arawak Cay extension can be dredged to provide for future needs.

Project Schedule

The current Project Schedule shows receipt of Tenders by the end of November 2008 followed by a Tender Evaluation and the activities necessary to meet Tender’s Board requirements, with a Port Improvement Project Contract award by the end of January 2009.

Because there are limited number of high capacity dredges available throughout the world, all of which are engaged on other work, it is anticipated that dredge mobilization will be up to 2.5 months with start of work by mid April 2009 provided that the current schedule is maintained. With an average daily dredge production of 10,000 cubic yards per day, Project completion is estimated as mid December, 2009.

The Oasis of the Seas is scheduled to call in November 2009. This vessel can still be accommodated if the Turning Basin and Mooring Dolphins are completed before the end of

November, with the remainder of the work following. Even with a modest late start, this should still be achievable.

The Arawak Cay Extension has been considered as a separate project, making use of a second contractor. Tenders should be received by the end of January and the contract awarded by the middle of March 2009. Comparing this schedule to the Port Improvement Project Schedule, work on the Arawak Cay containment structure will start one month before arrival of the dredge.

With 600,000 cubic yards of stockpile available on existing Arawak Cay and assuming a daily production rate of 10,000 cubic yards, it will be a further two months before dredged material deposition will begin within the extension to Arawak Cay.

By that time, the Arawak Cay contractor will have two parallel containment walls in place along most of the length of the extension. A silt curtain can be installed between the ends of these two sheet pile walls to provide the necessary containment of turbidity until the final west wall of the extension is completed. Thereafter, the dredging contractor will manage the dredged material placement to first fill the containment structure and then to build the stockpile on top of the extension.

Cruise Line Input

Various meetings were held with representatives of the cruise industry. At their recommendation, Government commissioned a Simulation Study which modelled the Nassau Harbour entry and exit of the Oasis of the Seas and the Carnival Conquest. The Simulation Study was based on the harbour improvements proposed at the outset of the Project. Following completion of the Simulation study and the addition of a few very minor modifications to dredge limits, representatives of the cruise industry agreed that they would be able to call on Nassau with their new-build ships following completion of the Port Improvement Project based on the dredge limits being proposed.

Site Investigations

A number of site investigations were carried out to determine the characteristics of the site.

- The Hydrographic Survey established water depths relative to Mean Low Water Springs (MLWS), allowing the volume of dredging to be calculated.

- The Geotechnical Investigation included the drilling of 18 boreholes, which were sampled and tested to determine the strength of the rock to be dredged.

- The Coastal Engineering Study established a design wave height for East Breakwater repairs and determined that the current dredging will not be detrimental to the Western Esplanade beach.

- The Environmental Impact Assessment established turbidity criteria that must be met during dredging activities.

Contractor Prequalification

Government decided that contractors tendering on this Project should be prequalified to ensure that they had the experience and equipment with sufficient capacity to execute this Project within the time required. Prequalification submissions were received and reviewed and short list of seven qualified contractors was established. This included a mix of contractors from the U.S. and Europe which should result in healthy competition

Mooring Dolphin Alternatives

A number of Mooring Dolphin alternatives were considered as described in Section 10.0. Alternative 2 as shown in the sketch included in Section 10.0 was recommended, in large part because it was preferred by the cruise lines as compared to the other prime alternative using inclined piles which presented an obstruction and hazard to cruise ships finding themselves out of position.

East Breakwater Repairs

Baird have considerable experience in the design of breakwaters. In their Coastal Engineering Report, they strongly recommended that the design of repairs to the East Breakwater should not proceed without first conducting a physical hydraulic model study. Because this is their area of expertise, Cox & SHAL support their recommendation and feel that it would be a mistake to proceed without the recommended study.

Cox & SHAL have therefore recommended to Government that the physical hydraulic model study be carried out. Since the Port Improvement Project will be going out to tender very shortly, there is insufficient time to authorize and conduct the study and then to carry out a proper design of the repairs. Therefore, Cox & SHAL have recommended that the repairs to the East Breakwater be deferred and removed from the current Port Improvement Project.

Cost Estimates

Preliminary Engineering cost estimates have been included in Section 12.0. Summarizing:

Port Improvement Project	$ 35.0 million
Arawak Cay Extension	$ 21.5 million
Total Estimated Cost	$ 56.5 million

Recommendations

Recommendations are given in Section 13.0 of the Report.

3.0 Recent History of Nassau Harbour

The following is intended to provide a brief background to the prominent features of Nassau Harbour beginning with the construction of the southerly most pier in the 1930's, know as Prince George Wharf. This prominent feature on the Nassau waterfront was named after Prince George who later became King George after the abdication of Edward VII.

Following completion, this pier was used by both passenger liners and cargo vessels. Most of the cargo of the day was palletized break-bulk cargo, which was handled ashore by fork lifts which transported cargo to storage inside two transit sheds built on the pier. The west transit/cargo shed still exists in more or less its original condition. This steel frame structure was built using rivets as fasteners rather than the bolts and welds used in today's construction. The east shed has been converted into the cruise passenger Welcoming Centre. Prior to and following construction of the Prince George Wharf, private shipping entities created their own docking facilities to handle cargo along the East Bay Street waterfront.

In the mid 1960's, Frederick Snare Corporation of New York were hired to design and construct the Centre Pier which was know as the Passenger Pier at the time, since trans Atlantic travel by ship was still common. We believe that this was intended to separate passenger liners and passengers from cargo ships and cargo handling operations at the original southerly pier. The project also included a large amount of dredging to provide a Turning Basin and access to the new pier. The size of the turning basin was increased from 800 to 1,500 feet, with it's northerly limit extending to within 50 feet of Paradise Island. The dredged depth was increased from 25 to 36.5 feet relative to Mean Low Water Springs (MLWS).

Arawak Cay was created as a location to dispose of the dredged material. Since the dredged material would be subject to erosion in the open sea, a steel sheet pile containment structure was constructed to contain the material and control turbidity. The steel sheet piling was capped by a concrete cope beam extending down below the water surface.

This same project also included the construction of the East and West Breakwaters. Prior to proceeding with final design and construction, Frederick Snare made arrangements with the U.S. Corps of Engineers to conduct a physical hydraulic model study of wave conditions to aid in establishing the configuration of the east and west breakwaters and the location of Arawak Cay. These physical hydraulic model studies are described in greater detail in Section 5.0, Existing Breakwaters. One of the interesting outcomes of these investigations resulted in Arawak Cay being located 630 feet west of its originally intended location.

Another interesting fact associated with this mid sixties project is the location of the Queen's Warehouse, erected on the east end of Arawak Cay. We believe that original construction drawings identify this structure as the Passenger Hall. Based on anecdotal information, this building, intended to handle passengers at the upper level and baggage and some cargo on the lower level, was supposed to be located on the Centre Pier, known as the Passenger Pier at the time.

For whatever reason, when the prefabricated steel structure components arrived by ship in Nassau, it was discovered that the building was too wide to be located on the Centre Pier. This led to the decision being made to erect it on the east end of Arawak Cay for use as the Queen's Warehouse for storage of bonded cargo. In this location it was inaccessible to ships because of draft restrictions and bonded cargo had to be trucked to this location. This eventually proved to be impractical. Efforts

were made to use this building for other purposes; however, it has eventually fallen into a state of gross disrepair, as shown in Photo 1 of Appendix A.

Shortly after the mid 1960's expansion of Harbour facilities, most palletized break-bulk cargo gave way to containerized cargo, both roll on/roll off and lift on /lift off, which gravitated towards the cargo handling operations that had been established by the private entities on Bay Street east of Prince George Wharf.

During this period, trans Atlantic travel by passenger vessel gave way to air travel and "passenger" vessels became "cruise" vessels, offering holiday cruises to many of the islands within the Caribbean. The cruise line industry grew rapidly and, with Nassau often the first stop on the itinerary, cruise ship arrivals became a very important component of Bahamas tourism and the economy of the Bahamas.

By the mid eighties it was obvious that the Harbour needed to be expanded to accommodate the growing number of cruise ships which were also becoming larger, with the newer ships being 800 to 900 feet long at the time. Balfour Beatty, a United Kingdom based contractor with a newly established branch office located in Miami were awarded a design/build contract to construct the North Pier and enlarge the Turning Basin and portions of the Approach Channel by dredging. This extensive project also included the widening of Woodes Rogers Walk, east and west extensions to Potter's Cay, a new dock at Morgan's Bluff in North Andros, a new dock at Governors Harbour in Eleuthera and smaller mail boat docks at Morgan's Bluff, North Andros and Georgetown, Exuma.

SHAL Consulting Engineers were Balfour Beatty's civil and marine consulting engineers responsible for the design of all of these structures. George V. Cox & Company was also involved in some of the buildings and civil works included in the project.

Some of the dredged material was used for the widening of Woodes Rogers Walk and for filling the "Plaza" area where the taxis park today. The majority of the dredged material was stockpiled on Arawak Cay and used by Government as construction material for a number of Government projects. Remnants of some of the stockpiled dredged material are still evident today as shown in Photo 2 of Appendix A. This extensive project was completed in 1990.

On October 31, 1991, the entire Nassau waterfront was subjected to some exceptionally large swells (as opposed to waves) originating from the North Atlantic due to the convergence of two very large storms, which became known as the Perfect Storm, as in the film. This caused a breach in the east breakwater where it connects with the bare rock at the very westerly end of Paradise Island. This breach still exists today, allowing the entry of wave energy and, to a minor degree, affects the direction of tidal currents. The wave energy is disruptive to the container handling operations which, due to the increase in volume of container traffic over the last number of years, have expanded and become established on the north east corner of Arawak Cay (Photo 3, Appendix A).

Nassau Harbour once again needs expansion. The current Nassau Harbour Port Improvement Project involves dredging to enlarge the Turing Basin and to widen the outer portion of the Approach Channel to accommodate the larger new-build ships coming on stream in the Fall of 2009.

The current Project also includes the installation of two new mooring dolphins located 300 feet from both ends of the North Pier and a third mooring dolphin located a similar distance from the west end of the Centre Pier.

4.0 Project Overview and Schedule

Improvements are necessary to Nassau Harbour to satisfy the concerns of the cruise line industry. The target for completion of these improvements is the fall of 2009 to suit the arrival of the first of the very large new-build ships.

Government have also established the redevelopment of East Bay Street as one of their top priorities. Relocation of the Bay Street shipping and associated trucking is the necessary first step in redevelopment of Bay Street and the implementation of the proposed extension of the water's edge pedestrian promenade from Woodes Rogers Walk westward all the way to Malcolm Park.

Rather than relocating shipping to South West Bay near Clifton Pier as recently studied, Government intend to relocate the Bay Street shipping to Arawak Cay, which already has a significant cargo handling operation at its north east corner.

4.1 Project Overview

The number of cruise ship passenger arrivals has decreased in recent years because some of the cruise lines have withdrawn smaller ships from service and replaced them newer, larger liners. The cruise line companies have advised that some of these replacement vessels currently in service are unable to safely enter Nassau Harbour. Spending by cruise ship passengers is an important component of the tourism industry. Therefore, the reduction in cruise ship passenger arrivals represents a serious setback to the Bahamian economy.

In addition, even larger cruise vessels are in the process of being built with the first of these, Royal Caribbean Cruises' Oasis of the Seas, scheduled to be commissioned in the fall of 2009. Vessel size is significantly larger, especially the width or beam of this vessel. Dimensions of the Oasis of the Seas:

	Metres	**Feet**
Length Overall	360	1,181
Beam	47.0	154
Draft	9.3	30.5

Norwegian Cruise Line will also have a new vessel coming into service in 2010 with dimensions:

Length Overall	329	1,079
Beam	40.6	133
Draft	8.7	28.5

These new vessels and similar sized larger vessels currently being built cannot safely call at Nassau Harbour with its existing configuration. The cruise lines have identified the following problem areas.

- Inadequate Turning Basin and Approach Channel

- Too great a ship overhang on the existing piers
- Inadequate line pull capacity on existing bollards

This Port Improvement Project will address the first two problems by increasing the length of the Turning Basin, widening the outer end of the Approach Channel and by the installation of three new mooring dolphins at the piers to increase the effective length of the North and Centre Piers. The upgrade to bollard capacity is being implemented as a separate project by another department within the Ministry of Works and Transport.

A description of the dredging is given in Section 9.0, Dredging and Dredged Material Stockpiles and a description of the mooring dolphins in given in Section 10.0, Mooring Dolphin Alternatives. Of note, because a significant amount of the material to be dredged consists of coral rock, and because of the quantity involved and the tight schedule, a high capacity cutter suction dredge must be used to pump the dredged material to the disposal or stockpile area.

The volume of dredged material is 2.0 million cubic yards, which includes an allowance for overdredging which is a common element of a dredging project. Government recognize that the dredged material, consisting of sand and broken up coral rock, is a valuable resource and wish to stockpile as much of this material as possible for use elsewhere. However, the stockpile must be located within approximately one mile of the dredge location to maintain dredge efficiency and keep the dredging cost reasonable. The logical stockpile location is the unused space on Arawak Cay.

Calculations indicate that if the stockpile were fifteen feet high, existing space available on Arawak Cay will accommodate 600,000 cubic yards of dredged material. Therefore, it was necessary to identify a location for placement of the 1.4 million cubic yards of excess material. With the built up nature of the surrounding area, there is no existing land area available within reasonable pumping distance to stockpile the excess material.

Consideration was given to trucking the material to an offsite location as the material was deposited. However, this is not a practical solution since the material will be very wet when deposited and needs time to dry out and, to meet the new-build arrival schedule, the material will be deposited at a rate of 10,000 cubic yards per day. A trucking operation could not keep up with that daily volume, especially taking into consideration the wet nature of the material.

Cox & SHAL together with Government came to the conclusion that an area needed to be reclaimed from the sea to create the necessary stockpile area. Cox & SHAL developed three alternative plans for creating the stockpile platform:

Alternative A1: A westward expansion of Arawak Cay;

Alternative A2: Filling south of Arawak Cay to join with New Providence;

Alternative A3: Creating a new island 3,000 feet west of Arawak Cay.

A fourth alternative, depositing the material east of Prince George Wharf as part of Government's planned redevelopment of Bay Street was also briefly considered; however, based on scheduling requirements, this is not a practical alternative since the redevelopment cannot proceed until after the Bay Street shipping is relocated. This cannot be achieved in time to meet the Port Improvement Project schedule.

There were obvious cost, logistical and environmental concerns with Alternatives A2 and A3 and Cox & SHAL recommended that Government proceed with Alternative A1. Government staff agreed and supported this recommendation which, after due consideration, was approved by Cabinet, subject to the necessary site investigations being carried out including an Environmental Impact Assessment.

A large volume of dredged material cannot be deposited directly into the sea without creating turbidity problems and being subject to erosion due to waves and current. Therefore, a containment structure must be constructed as part of the deposition process. Government have agreed that steel sheet piling will be used, similar to the original construction of Arawak Cay.

The Arawak Cay site investigations, consisting of the EIA, hydrographic survey, geotechnical investigation and coastal engineering study are scheduled to start shortly. The extension of Arawak Cay is being treated as a separate project and the various issues such as environmental impact associated with the extension to Arawak Cay are not part of this Report other than sizing it to accommodate the excess dredged material.

Using water depth information available from the hydrographic chart and based on the approach of providing the minimal extension possible while maximizing the amount able to be stockpiled, calculations indicate that a 1,000 foot extension will require 900,000 cubic yards to build and will allow the stockpiling of 500,000 cubic yards. These two volumes together with the 600,000 cubic yards on existing Arawak Cay accommodate the total dredged material volume of 2.0 million cubic yards.

This results in a total volume of stockpiled material of 1.1 million cubic yards available for use elsewhere. Currently, Government's intention is to use much of this material in connection with the planned redevelopment of Bay Street immediately east of Prince George Wharf, extending from the Port Department building as far as Malcolm Park. Several alternative types of development have been suggested, all of which require the use of fill to build northward into the Harbour. The redevelopment plan to be adopted is still very much a work in progress.

As noted, Bay Street redevelopment cannot proceed until the shipping operations located along Bay Street are relocated. A few years ago, studies were carried out with a view to relocating the Bay Street shipping to South West Bay near Clifton Pier, on a site between the BEC generating station and the Kalik Brewery. This site required dredging and the removal of an elevated piece of land, adding to the cost which reportedly ranged between $ 200 and $ 400 million.

Currently, Government are planning to move the Bay Street shipping operations to Arawak Cay. Initially, the existing dockwall on the north side will have to be extended westward and this new bulkhead dredged to a depth of 30 to 32 feet. Eventually, a new berth would be added to the east end of the Cay by squaring off the rounded shape with a new bulkhead wall. Dredging would be required in this area as well adding to the amount of material available for use on other civil works.

These modifications are intended to be sufficient to meet cargo demands within a planned time frame of twenty to thirty years. Thereafter, the 1,000 foot long extension to Arawak Cay can be used to further expand cargo handling operations. To allow for the long term growth of cargo handling operations, we recommend that the north and west bulkhead walls be designed to accommodate future dredging to allow berthing facilities to be extended to those locations in the future.

The new construction required to prepare Arawak Cay to accommodate relocation of the Bay Street shipping will take place concurrently with the work being carried out for the Port Improvement Project.

As seen from the above, the three projects: Port Improvement Project, Arawak Cay Shipping Operation and the Bay Street Redevelopment are very much inter-related.

4.2 Project Schedule

Two Project Schedules have been developed as included on the following pages.

Port Improvement Project
Arawak Cay Extension

The Port Improvement Project Schedule shows activities starting in June 2008 and shows the site investigations completed and the results submitted to Ministry of Works and Transport (MOWT) for review.

As agreed during meetings with MOWT staff, the tendering phase is separated into two stages, the first being the issuance of Pre-Tender Dredging Documents to Prequalified Contractors to allow them a start on evaluating their dredging techniques and pricing. The second stage involves the issuance of the completed Tender Documents consisting of final drawings, Specifications and Contract Documents.

The schedule shows receipt of Tenders from short listed contractors (see Section 8.0, Contractor Prequalification) at the end of November 2008 followed by Tender Evaluation and Contract Award activities to suit Ministry of Finance Tender's Board requirements. Assuming that the schedule is maintained as shown, the Port Improvement Project Contract will be awarded by the end of January 2009.

Because there are limited number of high capacity dredges available throughout the world, all of which are engaged on other work, we anticipate a dredge mobilization of about two and one half months to allow for a dredge with the required capacity to become available from another job. Travel time from a probable distant location is also a factor.

If the mobilization can be achieved as shown, dredging would start in mid April 2009. As noted, we anticipate that daily dredge production will average 10,000 cubic yards per day. This results in an estimated completion of dredging as of mid December, 2009.

Large portions of Arawak Cay are currently overgrown with Casuarina trees and shrubs. It is recommended that MOWT engage a local contractor to clear the site prior to the start of dredging and construction of the dredged material containment berms. Clearance work should be complete prior to award of the dredging contract.

If the Contract is awarded later than shown or the dredge requires a longer mobilization period, completion of the entire project will be later than the scheduled November 2009 arrival of Royal Caribbean Cruises' new-build, the Oasis of the Seas. In that event, the following contingency plan is in place.

NASSAU HARBOUR PORT IMPROVEMENT PROJECT

PROJECT SCHEDULE

Revised September 12, 2008

		2008																						2009																							
PHASE	**TASK**	**JUNE**						**JULY**						**AUG**						**SEPT**						**OCT**						**NOV**						**DEC**						**JAN**					
PH I	**PRELIMINARY ENGINEERING**																																															
1.1	Project start-up (April)																																															
1.2	Cruise Lines (April, May)																																															
1.3	Simulation Study Report																																															
1.4	Prelim. Engineering Evaluation																																															
1.5	Prelim. Engineering Report																																															
1.6	Ministry Review																																															
1.7	Final Report																																															
PH 2	**SITE INVESTIGATIONS**																																															
	Hydrographic Survey																																															
2.1	Mobilize (April)																																															
2.2	Hydrographic Survey (May)																																															
2.3	Topo Survey Shoreline (May)																																															
2.4	Process Deliverables																																															
	Geotechnical Investigation																																															
2.5	Mobilization (May)																																															
2.6	Field Work																																															
2.7	Lab Testing																																															
2.8	Analysis & Report																																															
	Environmental																																															
2.9	Environmental Start-Up (May)																																															
2.10	Fieldwork																																															
2.11	Chemical/Biological Testing																																															
2.12	Env. Analysis & Reporting																																															
2.13	Permit Assistance																																															
	Coastal Engineering																																															
2.14	Wave Climate (May)																																															
2.15	Near Shore Wave Modeling																																															
2.16	Beach Assessment																																															
2.17	Coastal Engineering Report																																															
PH 3	**DESIGN, DOCS & TENDERING**																																															
3.1	Prequalification																																															
	Advertise																																																
	Receive																																																
	Evaluate																																																
	Shortlist																																																
3.2	Final Design & Documents																																															
	Dredging																																																
	Structures																																															
3.3	Ministry Review																																															
3.4	Pre-Tender Cost Estimate																																															
3.5	Tendering																																															
	Issue Pre-Tender Dredging Docs																																															
	Issue Complete Tender																																															
	Tender Evaluation																																																
	Contract Award																																																
PH 4	**CONTRACT ADMIN / REVIEW**																																															
	Construction Mobilization																																																
	Construction	8 Mo.						Dec 15/09																																									
4.1	Contract Administration	9 Mo.																																															
4.2	Resident Review	8 Mo.																																															

In discussions with representatives of the cruise lines, they advised that their priorities were as follows:

- Lengthening the Turning Basin
- Construction of the west Mooring Dolphins
- Widen the Approach Channel
- Dredge north of the North Pier

The Tender Documents will be prepared to ensure that the Contractor carries out the work in sequence according to these priorities. The cruise lines have advised that the larger vessels including the Oasis of the Seas will be able to access Nassau Harbour following completion of the Turning Basin and installation of the west dolphins.

Therefore, if for whatever reason the construction is not totally complete, work will have progressed to the point where the two critical elements noted above have been completed by November 2009, allowing the scheduled access by the first of the new-build ships.

The Arawak Cay Extension Project Schedule has been set up based on this being a separate project, making use of a second contractor. This schedule shows activities starting in July 2008 and assumes Government authorization to proceed with site investigations by the middle of September.

Assuming that this is achieved, Tenders should be received by the end of January and the contract awarded by the middle of March 2009. It is assumed that another contractor will carry out this Contract, although the Port Improvement Project tenderers will probably bid on the Arawak Cay Extension project as well. Comparing the two schedules, work on the Arawak Cay containment structure will start one month before arrival of the dredge.

With 600,000 cubic yards of stockpile available on existing Arawak Cay and assuming a daily production rate of 10,000 cubic yards, it will be a further two months before dredged material deposition will begin within the extension to Arawak Cay.

By that time, the Arawak Cay contractor will have two parallel containment walls in place along most of the length of the extension. A silt curtain can be installed between the ends of these two sheet pile walls to provide the necessary containment of turbidity until the final west wall of the extension is completed. Thereafter, the dredging contractor will manage the dredged material placement to first fill the containment structure and then to build the stockpile on top of the extension.

ARAWAK CAY EXTENSION

PROJECT SCHEDULE

Revised September 12, 2008

		2008																						2009											
PHASE	**ACTIVITY**	**JULY**				**AUG**				**SEPT**				**OCT**				**NOV**				**DEC**				**JAN**				**FEB**				**MAR**			
PH 5	**ARAWAK CAY**																																		
	SITE INVESTIGATIONS																																		
5.1	Obtain Quotations																																		
5.2	Authorize																																		
5.3	Geotechnical																																		
	Drilling																																		
	Testing																																		
	Report																																		
5.4	Hydrographic Survey																																		
	Mobilize																																		
	Survey																																		
	Process & Drawings																																		
5.5	Coastal Engineering																																		
	Wave Climate																																		
	Nearshore Waves																																		
	Beach Assessment																																		
	Report																																		
5.6	Environmental																																		
	Fieldwork																																		
	Impact Assessment																																		
	Report																																		
	Permit Assistance																																		
PH 6	**DESIGN, DOCS &**																																		
6.1	Final Design & Documents																																		
6.2	Ministry Review																																		
6.3	Tendering																																		
6.4	Tender Evaluation																																		
6.5	Contract Award																																		

5.0 Existing Breakwaters

On accessing archived files from our involvement in the 1988-90 Harbour expansion, SHAL were fortunate to locate two reports prepared by the U.S. Corp of Engineers, Waterways Experiment Station in Vicksburg, Mississippi. These reports were prepared at the request of Frederick Snare Corporation, Engineers and Contractors of New York as part of their mid 1960's design/build project to dredge Nassau Harbour, create Arawak Cay, construct the east and west breakwaters and construct what is now the Centre Pier.

These studies were commissioned prior to start of final design of the breakwaters to assist in establishing the most effective length and orientation of the east and west breakwaters and to assist in establishing design parameters for slope protection on the breakwaters.

The first of these Corps of Engineers reports is titled "Technical Report No.2 – 696, Selection of Optimum Plan for Improvements in Nassau Harbor, Nassau, New Providence, Bahamas, Hydraulic Model Investigation," dated October 1965. This involved a physical hydraulic model study of the proposed improvements superimposed on the Nassau Harbour features existing at the time.

A 1:100 scale model was constructed at the Vicksburg Mississippi laboratory. This was a quite comprehensive exercise with model construction taking place between November 1963 and May 1964, with wave testing carried out between May and December 1964. It was a further ten months before the report was finalized.

Historically, a number of different water level datums have been used in the past. The Datum used for these reports and the construction in the 1960's was the Shattuck Scale which is an exceptionally low datum. With the concurrence of the cruise line industry, subsequent construction has be related to Mean Low Water Springs (MLWS) which is a more realistic datum when considering navigation requirements. MLWS is 1.5 feet higher than the Shattuck Datum. All references in this section of the Report have been converted from the Shattuck Datum to MLWS. All other references to elevations and water depths throughout this Report are also referenced to MLWS.

Tests involved the use of a wave generator which modelled the effects of a 18 foot design wave, taking into consideration near shore bottom conditions just outside of the Harbour. The breakwaters were originally intended to be vertical wall structures, built using two parallel rows of steel sheet pile walls filled with dredged material and capped with a concrete deck. Because of the considerable dynamic impact force imposed by the incoming design waves, it was proposed that energy absorbing slope protection be provided on both the seaward and Harbour sides of the breakwaters, the latter because of anticipated wave overtopping.

One of the conclusions reached as a result of the wave model tests was that the energy absorptive structures required were so large that they encased the proposed double walled steel sheet pile structure, making it redundant. Thus, steel sheet piling was not used for breakwater construction.

SHAL were also fortunate to find in their archives photocopies of the Frederick Snare Corporation drawings showing details of the east and west breakwater construction. Unfortunately, the quality of these photocopies is very poor and they cannot be reproduced in this Report.

Like many other islands in the Caribbean, New Providence has very poor quality rock when subjected to wet/dry cycles and repeated wave impact. Therefore, the breakwater design was based on using much harder imported rock in shallow areas and very large precast concrete armour units

in deeper water and at the head of the breakwaters. The type of concrete unit used in this case is known as a tribar.

At the West Breakwater starting point on the east edge of Silver Cay, imported 2 to 6 ton armour stone was used as the cover layer. Further east, 10 ton concrete tribar units were used, increasing to 19 tons for the final 300 feet and head of the West Breakwater (Photo 5, Appendix A).

At the East Breakwater, 35.5 ton tribar units were installed at the head and outer 300 feet, decreasing to 19 ton units at the central section. The western tip of Paradise Island consists of a low outcrop of rock two to four feet above MLWS. The breakwater extended eastward over this low rock outcrop until the rock elevation increased to 12 feet. Two parallel shallow trenches about five feet wide were cut into the crest of the outcrop and this portion of the breakwater was constructed using imported 2 to 6 tons boulders keyed into these trenches.

This section of the East Breakwater was the weakest since it was constructed using the smallest sized armour units, in this case imported armour stone. It is likely that this section of breakwater failed first during the 1991 Perfect Storm exposing the edge of the 19 ton tribars immediately to the west, causing these to unravel and fail progressively on their exposed flank. A dive inspection was carried out by the Defence Force on behalf of the Port Department to assist the Project Team in assessing the situation at the East Breakwater. The divers reported that the seabed over the entire area opposite the rock outcrop and on both sides of breach was covered with broken pieces of tribar units (Photo 6, Appendix A).

The second report by the Corps of Engineers Vicksburg Experimental Waterways Station was titled "Stability of Rubble Mound Breakwaters, Nassau Harbour, Nassau, New Providence, Bahamas," October 1965. This investigation was also conducted at the request of the Frederick Snare Corporation.

A series of tests were conducted using scaled armour units consisting of quadripods, tetrapods and tribar armour units. These scale model tests were conducted in a wave flume which was instrumented to measure wave pressures on the originally proposed steel sheet pile wall forming the core of the breakwater. Observations were also made of the stability of various sizes of armour units when subjected to prototype waves with periods of 7 to 11 seconds and heights between 10 and 18 feet.

Separate tests simulated waves on the main body or trunk of the breakwater and on the conical breakwater head. Only the West Breakwater was modelled; however, the data obtained was judged to be suitable for use in the design of the East Breakwater as well.

The West Breakwater was located along the spine of a submerged coral reef that extended from Silver Cay towards the western tip of Paradise Island. The East Breakwater covered the rock outcrop portion of the western tip of Paradise Island and curved to the north running down the side of the reef. Thus, the breakwater was founded on bare bedrock, which in this case appears to have been smooth surfaced.

This condition was incorporated into the wave flume model study. Under certain wave conditions, the outer slope layer on the seaward side failed by sliding on the smooth surface. Additional tests were conducted with the lower levels of the outer face keyed into a V-shaped trench. Tests confirmed that this would be successful in preventing sliding failure of the outer layer units. During testing, it was recognized that a V-shaped trench would be impractical and costly to build; therefore, dimensions for a rectangular trench were established.

Of note, the breakwater construction drawings show a rectangular trench being required on both sides of the West Breakwater; however, similar trenches were not shown as a requirement for the East Breakwater. Undoubtedly, this was another contributing factor to the eventual failure of a portion of the East Breakwater.

6.0 Cruise Line Input and Simulation Study

An initial meeting was held with cruise line representatives at the Port Department offices in Nassau on March 25, 2008. The following Government agencies, organizations and cruise lines were represented.

- Port Department
- Nassau Harbour Pilots
- Ministry of Works and Transport
- Ministry of Tourism
- Florida-Caribbean Cruise Association (FCCA)
- Royal Caribbean Cruises Ltd.
- Norwegian Cruise Line
- Celebrity Cruises
- Cox & SHAL Consultants

The Port Department provided introductory comments regarding the Project and stressed that Government has given this Project the highest priority. The intent of the Project is to allow the next generation of large cruise ships to safely use the Harbour. Port improvements include dredging to provide improvements to the Turning Basin and the Approach Channel and the installation of new mooring dolphins to extend the effective length of the Centre and North Piers.

Participants were advised that the scheduled completion of the Project is the fall of 2009, intended to coincide with the start of the 2009 winter season and the arrival of some of the larger new-build cruise ships. Contractors will be required to carry out the work with minimal disruption to cruise ship use of the Harbour.

A second more technically oriented meeting was held with cruise line representatives at the Royal Caribbean Cruise offices in Miami on April 8, 2008 with the following represented.

- Florida-Caribbean Cruise Association (FCCA)
- Royal Caribbean Cruises Ltd.
- Norwegian Cruise Line
- Celebrity Cruises
- Carnival Cruise Lines
- Disney Cruise Line
- Ministry of Works and Transport
- Ministry of Tourism
- Cox & SHAL Consultants

During this meeting, Cox & SHAL presented preliminary drawings showing the existing Approach Channel and Turning Basin and the new dredge limits being proposed. These were very similar to Figure 1 and 2 included in Appendix B.

At the outset of the Project, the Port Department had proposed the removal of the outer 300 feet of the West Breakwater to improve access to the Harbour. Cox & SHAL recommended against this since this would increase the amount of wave energy entering the Harbour which in turn would:

- Disrupt existing cargo handling operations at Arawak Cay

- Provide even greater disruption to the new container berth being considered by the Arawak Cay Development Company at the east end of Arawak Cay, intended to allow removal of cargo handling operations from Bay Street

- Threaten the stability of the West Esplanade beach, potentially leading to significant erosion

Following discussion, it was agreed that the existing west breakwater would remain in place if the outer end of the Approach Channel were widened.

The proposed dredge limits shown on the preliminary drawing circulated at the meeting were discussed at length. Cox & SHAL described how the toe of the breakwater slope protection is keyed into a trench cut into the bedrock to maintain stability of the precast concrete armour units. Because of this, it is not possible to widen the existing 600 foot channel width without destroying the restraint provided by the shoulder of this trench and undermining the breakwater.

Following discussion, the following was agreed:

- The triangular shape of the Approach Channel dredge cut adjacent to the west breakwater will be retained and widened at its outer end to allow a wider approach angle to ships while still outside the breakwaters.

- It was agreed that the following would be acceptable dredged depths (MLWS):

Entrance Channel	40 feet
Turning Basin	38 "
Alongside Berths	38 "

- It was agreed that dredging priority to suit cruise ship operations should be:

  Turning Basin first
  Entrance Channel second
  North berth dredging last

- Because the new west mooring dolphins will decrease the size of the present Turning Basin, it was agreed that the Turning Basin should be completed prior to the installation of these dolphins.

The cruise lines requested that the bollard and fender configuration on the existing piers be improved to suit the new-build ships. MOWT advised that another department within the Ministry have hired another consultant to design the necessary improvements.

During the meeting, the following was established relative to the use of the Centre and North Piers.

- With the addition of the two new north mooring dolphins, the north side of the outer pier could be used by two cruise ships at the same time provided that neither of them

are new-builds. It would not be safe for the east ship to leave berth with the west ship still at berth.

- It is likely that the Genesis Class of vessels (Oasis of the Seas) would not use the north berth since this is considered a difficult berth to access due to north east winds and there is a concern that they would be exposed to a potential mishap caused by passing ship traffic.

- Based on the dimensions of the majority of current ships, the remaining berths could only be used by one cruise ship.

- With the addition of the two west mooring dolphins, both sides of the Middle Pier and the south side of the North Pier could be used by new-builds.

All of the cruise line representatives strongly recommended that a ship simulation study be commissioned by Government to analyze the proposed new dredge limits and installation of mooring dolphins. This has become common practice when existing ports are planning improvements. Star Center of Dania Florida was recommended since they have modelled Nassau Harbour in the past and they already have modelling characteristics for the Genesis Class and many of the ships currently calling at Nassau. They recommended that two types of ships be simulated:

- Genesis Class with azipod propulsion

- The largest conventional fixed pitch cruise ship within their database

Cruise ship representatives made the following additional suggestions/comments:

- A new range line should be established on the centreline of the new approach channel

- Damaged buoys should be reinstated promptly

- Bollards should be located to provide 30 metre headlines at the bow and stern

- End of pier bollards should be located near the centre line of the pier

- Two bollards should be provided where ships berth end on to each other, one bollard for each ship

- Bollard design loads for non new-build ships should be 150 to 200 tons

- Entry to the Harbour with 10 foot wave conditions is considered acceptable provided that wind conditions are not severe

As suggested during this meeting, Cox & SHAL requested a proposal from the STAR Center of Dania Florida, a company specializing in maritime training and research and one that also specializes in ship simulation studies. A proposal was submitted by STAR Center and accepted by Government.

The simulation was based on the new dredge limits shown in Figure 2 of Appendix B and the addition of the three new Mooring Dolphins. The following are a number of excerpts from STAR Center's July 2, 2008 Report "Nassau Harbour Evaluation 2008."

> "Simulator testing was conducted on May 10 and 11, 2008 at the RTM STAR Center in Dania Beach, Florida. Tests were conducted using STAR Center's full mission bridge shiphandling simulator that features a 360 degree out-of-window view and realistic wheelhouse navigation and control equipment."

In keeping with recommendations during the April 8, 2008 cruise line meeting, two ships were simulated: Oasis of the Seas with an azipod propulsion and the Carnival Conquest with a fixed propulsion system.

> "Two senior Nassau pilots participated in the testing by controlling the simulated cruise ships from the simulator wheelhouse just as they would in actual practice. The Pilots also provided their professional opinion regarding the most relevant conditions to be tested, and the accuracy and realism of the simulation models.
>
> Representatives of cruise lines with interest in Nassau as a port-of-call attended one, or both of the two day sessions. Cruise lines represented were Carnival, Celebrity, Disney, Norwegian Cruise Line and Royal Caribbean. Also in attendance were pilots from Nassau, various Nassau Port Officials and Engineers, including representatives for the engineering firm Cox & SHAL. The observers and pilots participated in debriefings and roundtable discussions that helped to direct the focus of the simulation exercises.
>
> All tests were conducted in unrestricted visibility during daylight hours. The focus was on extreme operational conditions of wind therefore, tests were conducted with the wind ranging up to 35 knots. In most cases, wind from the prevailing easterly direction was simulated. Wind from western quadrants was also tested because the Pilots noted that a wind from the west, while rare, can at times pose a challenge to the Pilots.
>
> The simulator automatically recorded the vessel's trajectory, heading, speed and information relating to control settings and the resultant forces acting on the vessel for archiving purposes. In addition, track plots were generated after each run. These were used in debriefing the shiphandler immediately after completing a run and for reporting results."

Photos showing the realism of the simulation exercise are included as Photos 7 and 8, Appendix A. A total of ten test runs were conducted for the Carnival Conquest and eight test runs for the Oasis of the Seas. Sample track plots are included in Appendix C. STAR Center reported the following under the heading Conclusions.

> "There are no recommendations for enhancements to the dredging/widening plan as modeled on the simulator. The widened and deepened Nassau entrance channel and "turning area" accommodated the Carnival Conquest and larger Oasis of the Seas without observed problems in winds ranging up to 35 knots. The only identified potential enhancement, from a navigational perspective, is to the visual aids to navigation as discussed below. The ships easily accessed the berths that were assigned/tested and the mooring dolphins did not interfere with the ships when manoeuvring in the turning basin."

During the simulation exercise, Cox & SHAL had an opportunity to explore design details with the Port Department and cruise line representatives, all of whom were cruise ship captains. The following additional information was obtained relevant to the Project.

- There would be an improvement if the north east mooring dolphin and catwalk were moved towards the south edge of the north pier and if the south dredging limit at this location were increased slightly to allow the stern of the vessel to swing when leaving the berth. This was based on a suggestion provided by the Port Department. This has subsequently been incorporated into the dredge plan.

- Port Department also asked that the dredge limit on the north side of the channel adjacent to the east breakwater gap be altered to eliminate the sharp corner at this location. This has also been added to the dredge plan.

- Port Department advised that the range line markers will be relocated to place them on the centreline of the new Approach Channel.

- Cruise lines advised that maintenance dredging is required alongside all existing berths to remove siltation and debris which includes lost fenders.

- Alternative types of mooring dolphin pile support systems were discussed including a combination of vertical and batter piles as compared to much larger diameter vertical piles only. Cruise line representatives do not favour batter piles because they extend beyond the edge of the dolphin pile cap below water and represent a potential hazard to vessels.

- Cruise line representatives recommended that corner fenders be installed on the corners of the mooring dolphins as a precaution to prevent damage to ships if unintentional contact is made. Cox & SHAL agreed that this would be beneficial provided that it is clear to all that these are mooring dolphins as opposed to breasting dolphins and therefore have less capacity to resist horizontal forces. The fenders will act to absorb some energy; however, if an inadvertent contact exceeded 300 tons, there is a risk of damage to the mooring dolphin. Cox & SHAL also recommended that the sides of the dolphins be labelled with wording similar to: "No Contact, Mooring Lines Only".

- Cruise line representatives advised that they will secure three forward lines to the mooring dolphin and asked that four bollards be provided to accommodate one ship on each side of the pier.

- Cruise line representatives again advised that dredging priority should be the Turning Basin first (before dolphin installation), the Approach Channel next (during good weather during the summer months) and then the north east slip.

- Cruise line representatives agreed that it would be possible to have the mooring dolphin construction barge located within the 100 foot wide projection of the Centre and North Piers with ships moored on both sides. They suggested that, for safety's sake, it may be necessary to have a tug on stand-by.

- RCC do not favour the north side of the North Pier because the north channel will be used by cargo vessels passing to deliver containers to cargo operations on Bay Street east of Prince

George wharf. They are concerned that a mishap may lead to a collision with their ship. When advised that this traffic will be relocated to Arawak Cay within a few years, they said they would re-evaluate their position at that time.

Immediately following completion of the simulation exercise, the Project Team consisting of Ministry of Works and Transport and Cox & SHAL personnel had a meeting with Royal Caribbean Cruises and Celebrity Cruises at RCC's offices on May 12, 2008. A second meeting was held on the same day with Norwegian Cruise Lines at their offices. The purpose of these meetings was to gain immediate feedback from the major cruise lines which had participated in the simulation exercise.

A number of things were discussed; however, the outcome was that both NCL and RCC advised that they are comfortable with the new dredge limits being proposed and with the new mooring dolphins and that these improvements will suit their upcoming new-builds.

7.0 Site Investigations

It was necessary to commission a number of site investigations to determine the characteristics of the site with respect to water depths, soils conditions, wind and wave conditions and the impact that the Project would have on the environment. The following investigations have been carried out.

Hydrographic Survey
Geotechnical Investigation
Coastal Engineering Study
Environmental Impact Assessment
Underwater Inspection of the East Breakwater

These investigations were commissioned in April and the fieldwork started shortly afterwards.

7.1 Hydrographic Survey

Since dredging is a major component of the Project, it was necessary to establish existing water depths by means of a hydrographic survey. This was carried out by Hydrographic Consultants Ltd (HCL) of Houston over the period of April 23 to May 2, 2008.

The survey was conducted using the single beam – high frequency (200 KHz) technique. Survey cross-sections were taken at 50 foot intervals perpendicular to all existing channel slopes and covering the breadth of the proposed areas to be dredged. Sounding lines were run at 100 foot intervals within the existing turning basin and channel where dredging is not required. All surveys conducted complied with the standards outlined by U.S. Army Corps of Engineers for CLASS I, dredge payment, hydrographic surveys.

The survey employed Real Time Kinematic (RTK) technology for both the horizontal positioning and determining heave for the portion of the survey outside of the breakwater. RTK technology was also utilized for the acquisition of topographic data along the shorelines of Paradise Island and for the Western Esplanade Beach.

The equipment employed for the hydrographic survey was as follows:

Positioning Equipment

RTK Base Station	–	Trimble 5700
RTK Backpack Rover	–	Trimble SPS 770 (Topographic Survey Work)
RTK Boat Receiver	–	Trimble SPS 751Max (Vessel Positioning)
Echo Sounder	–	Odom CVM (200KHz – 3 degree)
Tide Gauge	–	Onset pressure gauge with 2nd gauge for atmospheric reduction.
Heave	–	Heave for outside work provided by vessel RTK (Trimble SPS751 Max**)**

The following relates to the Datum used for the survey.

1. The horizontal datum for the survey data was UTM Zone 18N – WGS 84 ellipsoid with the units being International Feet.

2. The vertical datum for the survey was Mean Low Water Springs (MLWS). All bathymetric data was reduced by the tidal data collected such that all data shown on the AutoCAD drawings is relative to 0.0 MLWS. Reduced copies of the drawings showing water depth data acquired are included in Appendix D.

For volume computations, all the survey data was used to develop a surface model of the harbour. Using the surface model, volume computations were then performed using the Digital Terrain Model (DTM) method. The DTM method for volumes is a computation based on a surface to surface difference within a bounded area.

For the volume calculations for this Project, the quantities were based on the difference between the surface model from the survey data against the surface model of the design prism. This volume method does not provide for a station by station volume by cross-section, the average-end-area method; rather, the DTM method provides a complete volume for each bounded area, incorporating all dredge elements.

7.2 Geotechnical Investigation

The Geotechnical Investigation included the drilling of a number of boreholes within the Harbour in the areas to be dredged and at each of the three new mooring dolphin locations. This was necessary to identify the type of material to be dredged, whether sand or coral rock, establish the level of interface between the rock and the overlying sand and the nature of the rock, whether hard or soft and whether jointed or solid.

A total of 15 boreholes were drilled within the Harbour and 3 in the Approach Channel within the area to be widened. A plan of the borehole locations and copies of the Borehole Logs are included as Appendix E.

A split barrel sampler was used through the upper sand layers down to the interface with rock. In all cases the top surface of the rock was soft and sampling was continued using the split barrel sampler (with blow counts) and this was continued until it was determined that the rock was competent enough to be cored. At that level boreholes were advanced by coring with HQ3 wire line triple tube core barrels.

Boreholes extended to five feet below the dredge grade: - 43 feet within the Harbour and – 45 feet in the Approach Channel. The three boreholes located at the Mooring Dolphins extended to – 100 feet in an effort to establish a competent bearing strata for piles.

The Geotechnical Consultant, Trow International, retained Toney Drilling of Miami to carry out the drilling and sampling using a jack up barge as shown in Photo 4, Appendix A. Fieldwork was carried out over the period May 22 to June 9, 2008. International dredging contractors known to be interested in the Project were invited to send representatives (usually geologists) to view the drilling

procedures carried out and to view the samples obtained first hand. A total of four dredging contractors took advantage of this opportunity.

Samples were tested at Trow's Toronto area laboratory and the compressive strengths of the rock cores was established by Unconfined Compression Tests and Point Load Tests. Test results are shown in Trow's Table 5: Bedrock Core Test Results, reproduced on the next page. Note that during the drilling process, much of the rock crumbled and could not be cored; therefore, only the more competent rock which was capable of being cored and retained was able to be tested. Therefore the test results are indicative of the more competent of the material to be dredged.

Generally, the upper layers of rock throughout most of the Harbour above the dredge limit has been tested with compressive strengths of 15 to 138 tons per square foot (210 to 1,900 psi). However, the rock on the north side of the Turning Basin near the west end of Paradise Island was tested at 36 to 375 tons per square foot (500 to 5,200 psi) and the rock at the widening of the Approach Channel tested at 36 to 600 tons per square foot (500 to 8,300 psi). These test results indicate that dredging of most of the Harbour will be relatively easy except in these two areas which will be more difficult.

Following testing, to assist with the Project schedule and to allow early distribution of soil properties to dredging contractors, it was decided that Trow would issue two reports. The first dealt with dredging activities and was titled "Geotechnical Investigation, Part 1 Dredging, Nassau Harbour Port Improvement Project," August 8, 2008.

The second report dealing with design issues and soils properties associated with the three mooring dolphins was titled "Geotechnical Investigation, Part 2 Mooring Dolphins, Nassau Harbour Port Improvement Project, "September, 2008.

Table 5: Bedrock Core Test Results

Sample Number	Elevation (ft)	Unit Weight (pcf)	Moisture Content (%)	Point Load Test Results (kPa)				Unconfined Compression Strength (U/C) (tsf) from				
				U/A	U/L	S/A	S/L	U/A	U/L	S/A	S/L	U/C Test
BH 2-1	-74.9	127.5	8									98
BH 2-2	-88.9	136.2		3197	924			401	116			138
BH 2-3	-95.8	157.7	1.5									627
BH 2-4	-98.6	142.8										195
BH 3-1	-19.4		14.1	219	239	225	152	21	23	21	14.3	
BH 3-2	-24.8	113.7										33
BH 4-1	-72.1	133.9	7.2	1108	0	1199	2176	139	0	150	273	137
BH 4-2	-87.6	135.7										176
BH 4-3	-92.1	155.8	1.4	4282	2186	5912	4121	536	274	741	516	549
BH 4-4	-93.8	154.6		4368	2306	2998	3926	547	289	376	492	631
BH 5-1	-68.1	121.4	8.2									75
BH 5-2		130.2										194
BH 5-3	-90.8	134.3	2.1	1119	2548	2783	3022	140	319	349	379	153
BH 8-1	-20.9	111.4										30
BH 8-2	-27.6	111.9	2.9									23
BH 8-3	-22.9	114.3		209	0			21	0			
BH 9-1	-23.1	105			575	176	192		54	16.5	18	28
BH 9-2	-30.1	108.5	13.1									37
BH 10-1	-21.2	132.3										137
BH 10-2	-22.3	105.5	13.8									24
BH 11-1	-20.8	133.3			408	343	476		39	33	45	71
BH 11-2	-35.3	120.7	7.2		2401		1163		225		108	
BH 11-3	-38.1	122.7			834		1102		79	104		
BH 12-1	-29.6	122.4	11.1									63
BH 12-2	-45	74.1			1478		155		138		14.5	25
BH 13-1	-27.1	131.4	12.1				833				79	125
BH 13-2	-35.4	118.9										41
BH 13-3	-42.8	121.5	1.4		3945		2818		371		264	
BH 14-1	-18.7	124.4			394				37			72
BH 14-2	-30	133.1										75
BH 14-3	-39.2	118			883		1242		83		117	
BH 14-4	-41.2	107.9	3.6		1119		1773		106		167	
BH 15-1	-19.6	129.4										80
BH 15-2	-28.5	121.9	8.2		1153	2153	1602		108	203	151	102
BH 16-1	-25.5	152.6		1713	420	6332	1674	46	41	595	158	228
BH 16-2	-35.2	101.9	7.8		286		164		27		15.4	
BH 16-3	-40.3	110.9										63
BH 18-1	-30.8	122.3	11.7		1215	1156	1164		114	109	109	131
BH 18-2	-34.7	122.3			375	1156	1003		35	109	95	33
BH 18-3	-42.9		1.9		796		1363		75		128	

Notes:

1. Moisture Content is for samples that were soaked for at least 24 hours in artificial saltwater.
2. For the Point Load Test results, testing was carried out on bedrock cores, as follows:
   - U/A Unsoaked/Axial (Vertical)
   - U/L Unsoaked/Lateral (Horizontal)
   - S/A Soaked in Artificial Seawater for at least 24 hours/Axial (Vertical)
   - S/L Soaked in Artificial Seawater for at least 24 hours/Lateral (Horizontal)
3. Point load test results multiplied by 9 above El. -58 feet and by 12 below El. -58 feet to estimate Unconfined Compression Strength.
4. Unconfined Compression Tests, Unsoaked Point Load Tests and Unit Weight determinations were carried out on the samples as received in the laboratory.

7.3 Coastal Engineering Study

A comprehensive Coastal Engineering Study was carried out by Baird Associates of Ottawa. The purpose of this study was to establish a design wave height at the East Breakwater and to determine whether the dredging to enlarge the Harbour and widen the Approach Channel would negatively impact the stability of the Western Esplanade Beach.

Offshore deep water wave conditions were established for both non hurricane and hurricane conditions. These waves were transformed into near shore wave conditions based on water depths shown on hydrographic charts and the hydrographic survey data obtained for this Project by Hydrographic Consultants Ltd. Numerical modelling was used throughout including their investigation.

Baird's analysis was documented in their Report "Wave Climate and Dredging Impacts, Nassau Harbour Port Improvement Project", August 7, 2008. Their analysis indicated that the dredging will have minimal impact on the stability of the Western Esplanade Beach which in reality consists of five separate beaches separated by five groynes, most of which are protective structures for storm outfalls. Groyne 1 is the most westerly groyne and is not part of a storm outfall. Baird have labelled the Beaches A to E starting from the west end adjacent to Arawak Cay at Groyne 1. Quoting from Baird's Report:

> ".....It is expected that the beach will change in subtle ways, but will not undergo any major changes under non-hurricane waves. This is particularly the case as the existing groyne structures will continue to anchor the beaches through preventing alongside movement of sand. The region immediately west of Groyne 2 in Beach A is presently a narrow beach suffering erosion. Numerical results indicate a reduction in wave height in front of this beach. It is likely that slightly smaller waves in this area may be helpful for the beach if sand is supplied/added to this site in the future. It is expected that Beach B may realign slightly to face a more westerly direction; however, this change will likely be very small and may be in the order of a few degrees. No significant changes are expected in the alignment of Beaches C to E."

With respect to hurricane generated waves, Baird say:

> "The erosion at the ordinary waterline (0.0 m CD) is approximately 1.5 m and 2.0 m erosion for the existing and dredged conditions, respectively. It is possible that the actual erosion rates would be less than the predicted values because of the existence of coarse sediments. Coarser sediment in a sand mixture tend to expose themselves and armour the bed, resulting in less transport of sediment compared to the case of uniform sand. Nevertheless, slightly more erosion of the beach is expected under dredged conditions. In either case, the eroded material is predicted to stay in the vicinity of the shoreline (in waters shallower than 1 m) and, therefore, is likely to come back to the beach under the action of long-period swells.
>
> In summary, beaches in Nassau Harbour are dynamic as they respond to different swell events and tropical storm events. The changes that are expected to occur due to the dredging will likely remain within the natural variation that occurs along these beaches."

In their recommendations, Baird recommend that a beach profile monitoring program be set up immediately before the start of dredging to allow any change in beach profile to become evident during and after dredging.

The Study also indicated that under certain weather conditions, proposed new dredging will allow the entry of a greater amount of wave energy into the Harbour, resulting in an increase in wave height at the cruise piers. Baird advise that this could be problematic if mooring conditions are currently "borderline" at the cruise piers. On checking with the Port Department, they advise that they currently do not experience adverse wave conditions at the cruise piers. Therefore, we do not believe that there will be adverse impacts on mooring as a result of the proposed dredging and recommend that conditions be monitored following completion of dredging.

With respect to the East Breakwater, based on their analysis, Baird provided a design wave height in the order of 6.5 metres (21 feet). Baird have considerable expertise in the design of breakwaters and they strongly recommended that design of repairs to the East Breakwater should not proceed without the benefit of a physical hydraulic model study first being carried out. This is discussed in greater detail in Section 11.0, East Breakwater Repairs.

7.4 Environmental Impact Assessment

The Environmental Impact Assessment (EIA) of this Project has been carried out by Blue Engineering of Nassau. At the very outset of the Project, Blue Engineering conducted meetings with staff at the BEST Commission and the Department of Environmental Health, both within the newly created Ministry of the Environment. Early discussions with these agencies was intended to ensure that the EIA addressed their requirements.

Major environmental concerns relate to the impacts of the dredging on the marine environment including the turbidity caused by the dredging operation and the turbidity created by discharge of water at the dredge discharge pipe. Another environmental concern relates to the impact of the dredging on the stability of the Western Esplanade Beach. This latter concern has been addressed in detail by the Coastal Engineering Study, described in the preceding section. Blue Engineering were finalizing their report at the time of issuing this Preliminary Engineering Report.

7.5 East Breakwater Underwater Inspection

The Port Department made arrangements with the Defence Force Dive Team to conduct an underwater inspection of the area of the breach in the East Breakwater. This was carried out by the divers making observations over a number of days on transects perpendicular to the failed section of the breakwater and perpendicular to the low rock outcrop forming the western tip of Paradise Island.

The Dive Team was accompanied by a Cox & SHAL engineer who took notes, recording divers observations which included water depths along the transects. Following the fieldwork, Cox & SHAL made tidal adjustments to the water depths to relate them to MLWS and are in the process of establishing cross sections along each of the transects. This information will be extremely useful in assessing conditions at the breach in the East Breakwater.

The divers reported that most of the dislodged concrete units have been broken up into small pieces, scattered throughout the area of the breach.

8.0 Contractor Prequalification

Because of the specialized type of construction involved in the construction of the high capacity mooring dolphins and the need to complete a large quantity of dredging in a short period of time to meet the fall 2009 arrival of the new-build cruise ships, Government decided that contractors tendering on this Project should be prequalified to ensure that they were capable of performing the work within the time required.

The prequalification process was based on the capacity of the dredge equipment available for the Project, experience with similar projects, the experience of supervising personnel and the equipment available to construct the mooring dolphins.

A Prequalification Notice was advertised in the local press starting on May 29, 2008. Proponents were asked to register their interest by completing and submitting a Prequalification Document prepared jointly by MOWT and Cox & SHAL for this purpose. The Prequalification Notice and Prequalification Document was also emailed to a number of large European and U.S. contractors known to specialize in dredging projects.

Within Part B of the Prequalification Document forwarded to interested contractors, proponents were advised that the following Prequalification Rating Criteria would apply.

Dredge(s) availability and capacity for the Project	35 %
Experience on similar type and demand of work	25 %
Financial capability	20 %
Experience of supervising personnel	10 %
Other equipment available for the Project	10 %
	100 %

Dredge capacity was given the highest percentage rating since achieving Government's intended completion date of the fall of 2009 is highly dependent on the production capacity of the dredging equipment. To achieve this date, contractors would need equipment capable of dredging coral rock at an average rate of 10,000 cubic yards per day.

If a proponent's equipment was capable of only 2,000 cubic yards per day which is typical of many smaller dredges, they should not be eligible to tender on this Project and therefore, they would not score highly. This together with the other next higher percentages (Experience and Financial Capability) was intended to result in the proponent without the proper equipment, experience and financial capability failing to prequalify.

Since the Project also includes structural components including three new mooring dolphins, contractors must have access to floating equipment consisting of crane barges which differ from the cutter suction dredge required for the dredging work. Therefore, the Other Equipment criteria was intended to cover identification of that type of equipment in their Prequalification submission.

As of the closing date and time of 10:00 a.m. on July 1, 2008, the Tenders Board had received nine submissions. A submission made by Jan de Nul from Belgium was received on July 3, 2008, two days late. Jan de Nul advised that the late delivery was the fault of their courier company, TNT Express of Luxembourg, and requested that their submission be allowed. However, the Tender's Board advised that their submission could not be considered.

Copies of the nine submissions received on time were forwarded to the Ministry of Works and Transport and these were distributed to members of the Evaluation Committee, consisting of members of the Consulting Team and the Ministry of Works and Transport.

On initial review of the submissions, it was noted that two submissions were made by "sister companies" owned by the same parent company. These companies were Misener Marine, known for their extensive experience with marine structures in the Caribbean including the Bahamas, and Subacqueous Services, a dredging company from Jacksonville, Florida. Their submissions indicated that they would work together on this Project. Therefore, these two companies were evaluated on the basis of their combined resources, experience and financial capabilities.

Each of the Committee members conducted their own independent review and evaluation of the submissions received and each completed a Rating Sheet. The ratings were then averaged. Average ratings varied between 16 and 94 percent. Because Equipment is especially important to maintain the Project Schedule, as well as Related Experience and Financial Capability, a cut off point of 60 percent was established. Those failing to reach this percentage would not prequalify.

Based on this criterion, it was recommended that the following seven entities be added to the short list for this Project.

Company	Origin	Average %
Boskalis	Netherlands	90.7
Dredging International	Belgium	90.7
Great Lakes Dredge and Dock	United States	88.3
Manson Construction	United States	75.3
Misener Marine/Subacqueous	United States	71.0
Van Oord	Netherlands	94.3
Weeks Marine	United States	77.0

Cox & SHAL prepared a "Prequalification of Contractors, Evaluation Report", submitted under cover letter dated August 5, 2008, recommending that the contractors listed above be added to the Tenderers Short List for this Project. MOWT and the Tender's Board accepted this recommendation.

It was noted in the Evaluation Report that the mix of a near equal number of contractors from both the U.S. and Europe will be beneficial in maintaining healthy competition during the tendering stage. To encourage Bahamian input during execution of the Project, it was also suggested that local contractors should be advised of those contractors being short listed, and they should be encouraged to contact those contractors during the tendering stage to offer their services as subcontractors.

9.0 Dredging and Dredged Material Stockpiles

9.1 Dredging Operations

As identified by the Geotechnical boreholes drilled within the Harbour, the material to be dredged consists of a layer of sand between zero to fourteen feet thick, overlying coral rock. In most places the sand layer is two to four feet thick. The borehole plan and borehole logs are included as Appendix E.

Very few rock cores could be obtained at the east end of the Harbour and south of the Turning Basin because of the softness of the rock. Cores that were taken in these two locations had compressive strengths of 210 to 1,900 pounds per square inch (psi). Note that during the drilling process, much of the rock crumbled and solid cores could not be retrieved; therefore, only the more competent rock capable of being cored and retained was able to be tested. Therefore the test results are indicative of the more competent of the material to be dredged.

The rock cores taken on the north side of the Turning Basin near the west end of Paradise Island had compressive strengths of 500 to 5,200 psi and the rock at the widening of the Approach Channel tested between 500 to 8,300 psi. These combined test results indicate that dredging of most of the Harbour will be relatively easy except in these two areas, which will be more difficult.

The limits of the existing Turning Basin and Approach Channel are shown in Figure 1 in Appendix B. Currently the Turning Basin is circular in shape with a diameter of 1,700 feet. The new dredge limits are shown in Figure 2. The new dredging limits will maintain the Turning Basin width at 1,700 feet and increase its length to 3,000 feet, taking into account the 300 foot encroachment of the new mooring dolphins into the existing Turning Basin.

The existing width of the Approach Channel will remain at 600 feet between the East and West Breakwaters since widening cannot be carried out at this location without undermining the toe of the breakwaters. Further offshore, the width is being increased from 600 to 950 feet.

Existing water depths within the previously dredged areas vary between 39 and 43 feet. Depths within the new areas to be dredged vary between 8 and 22 feet. Note that all water depths are referenced to Mean Low Water Springs (MLWS).

Dredge depths between the existing and new dredge limits will be 38 feet within the Harbour and 40 feet within the Approach Channel, allowing a greater depth for vessel entry under wave action. Drawings 2, 3 and 4 of Appendix B show the dredge limits superimposed on the hydrographic survey plans showing existing water depths.

The hydrographic survey provided detailed water depth information over the new and previously dredged areas. Based on the existing water depths, the volume of material to be dredged to grade is 1.9 million cubic yards. This includes the volume on the 1:1 slopes at the edges of the dredge limits. Over dredging is typical with any dredging project. Based on an assumed average of one foot of over dredging, the actual volume is estimated at 2.0 million cubic yards.

With the type of material within Nassau Harbour and with this quantity of material, a cutter suction dredge is required. Very simply, this consists of floating equipment equipped with a very powerful pump and a cutter head mounted on the end of a "ladder" which is lowered down into the water. The cutterhead is very large with rotating teeth which cut and loosen the material. The pump sucks up

the loosened material and transports it by pipeline to the disposal or stockpile area. Generally, the pipeline conveys 10 percent solids and 90 percent water. At the discharge end of the pipe, deposition of the solids is dependent on the weight of individual particles of material, with the coarser material settling closest to the pipe and the finest settling the furthest away. The finest particles will stay in suspension for a period of time. The following is an excerpt from Trow's Geotechnical Report.

> "It is expected that the solids will settle to the bottom of a 10 to 20 feet deep stilling pond within 24 hours and that the turbidity of the water will be such that it will meet U.S. Corps of Engineers criteria for disposal offshore within 1 to 2 days. If this does not occur, there are a number of remedies that may be considered, including but not limited to filtering through geotextiles and flocculation of the effluent."

The contractor will be required to meet turbidity levels identified in the Environmental Impact Assessment Report.

An important factor is the distance between the dredge and the location of the pipeline discharge. The greater the length of pipeline, the lower the rate of production and the higher the cost. As a rule of thumb, the pipeline length should not exceed 6,000 feet for the majority of the dredging. Otherwise an intermediate booster pump may be required, adding to the cost.

Dredging production is a particularly important aspect of this Project. Cutter suction dredges generally work 24 hours a day; however, maintenance and downtime due to repairs, pipeline moves and pipeline blockages results in an efficiency rate of 60 to 75 percent. To meet the scheduled arrival of new-build cruise ships in the fall of 2009, and assuming a dredge start in April 2009, current planning requires that the 2.0 million cubic yards of dredging be completed within seven months. This requires a dredge with an average production rate of 10,000 cubic yards per day. This will likely require a dredge with a 27 to 30 inch discharge pipe.

9.2 Dredged Material Stockpiles

The material to be dredged is considered a valuable resource, suitable for use as fill for land reclamation and as construction material for civil works throughout New Providence.

Arawak Cay was used to stockpile dredged material during the dredging that was carried out in 1989. The material stockpiled at that time was removed over a number of years on Government civil works projects. Since that time, large sections of Arawak Cay have become occupied by commercial operations, the largest being the container handling operation at the east end of Arawak Cay. Other operations include the water reservoirs, aggregate storage, asphalt plant and contractors storage yard. If dredged material were placed within containment berms over the entire area left available on Arawak Cay to a height of 15 feet, this would accommodate 600,000 cubic yards. There was a need to find a location to stockpile the remaining 1.4 million cubic yards.

As discussed in Section 4.0, Project Overview and Schedule, Cox & SHAL presented Government with a number of options involving land reclamation to provide for storage of the remaining material. When considering the construction logistics involved and relative costs, Cox & SHAL recommended the alternative involving the westward extension of Arawak Cay. After due consideration, Government accepted that recommendation.

Using water depth information available from the hydrographic chart and based on the approach of providing the minimal extension possible while maximizing the amount able to be stockpiled, calculations indicate that a 1,000 foot extension will require 900,000 cubic yards to build and will allow the stockpiling of 500,000 cubic yards. These two volumes together with the 600,000 cubic yards on existing Arawak Cay accommodate the total dredged material volume of 2.0 million cubic yards.

Note that a separate set of site investigations will be required in connection with the westward extension of Arawak Cay. These include:

Hydrographic Survey
Geotechnical Investigation
Coastal Engineering Study
Environmental Impact Assessment

These investigations will determine site conditions and identify whether steps need to be taken to mitigate any environment impact. Since site investigations have not yet been authorized by Government, to maintain the Port Improvement Project Schedule, the extension of Arawak Cay will be dealt with as a separate project at a later date with respect to obtaining the necessary approvals from the regulatory agencies.

Deposition of a large volume of dredged material directly into the sea without some sort of containment would create turbidity problems. It would also be subject to erosion over time due to waves and current. Therefore, a containment structure must be constructed as part of the deposition process. Government have agreed that steel sheet piling will be used, similar to the original construction of Arawak Cay. This will likely be built by a second contractor as a separate project in advance of the arrival of the cutter suction dredge.

The dredging contractor will first build containment berms on the perimeter of the area available on Arawak Cay for stockpiling. The first 600,000 cubic yards of material will be deposited within these containment berms and will be managed using shore based equipment. This will include using the dried out portions of the dredged material to increase the height of the berms as dredging progresses.

Since ninety percent of the material dredged will be water, the contractor will manage the return of this water to sea using stilling basins to allow finer particles to drop out prior to discharge to sea. The Contract Documents will require the Contractor to use silt curtains at the point of discharge to sea to further protect against turbidity. Similar techniques will be used when discharging material into the containment structure on the extension to Arawak Cay. Monitoring of turbidity at both the dredge itself and the discharge of excess water to sea will be monitored as outlined in the Environmental Impact Assessment Report.

10.0 Mooring Dolphin Alternatives

Three mooring dolphins will be installed to effectively increase the length of the Centre and North piers, each of them located 300 feet from the end of the existing piers. The two westerly dolphins are located on the centreline of the piers. The north east dolphin is located south of the centreline of the pier to provide for additional dredging to allow the stern of the ship to swing slightly when leaving the north berth. All three dolphins are connected to the piers by three foot wide walkways.

These structures are mooring dolphins rather than breasting dolphins. Each dolphin will be designed to resist ships line pulls and will have a total capacity of 300 tons. As requested by the cruise lines, each dolphin will support four bollards, each of which will have an individual capacity of 200 tons.

These structures are not intended to be breasting dolphins and will not be designed to resist the forces imposed by a vessel berthing on this structure. However, as a precaution and as requested by the cruise lines, corner fenders will be provided in the event that a ship accidentally contacts the dolphin. These fenders will act to protect both the ship and dolphin. If the force applied exceeds 300 tons, this may result in damage to the dolphin; however, it is unlikely that this will happen.

Because these dolphins are located in up to 43 feet of water, a substantial structure is required to resist the design forces. The type of piles used is also highly dependent on the type of seabed material present for use as the foundation for the structure, in this case, relatively soft limerock. This lends itself to the use of open ended pipe piles being driven into the bedrock. A number of different types of structures have been investigated by means of preliminary engineering design calculations. These include:

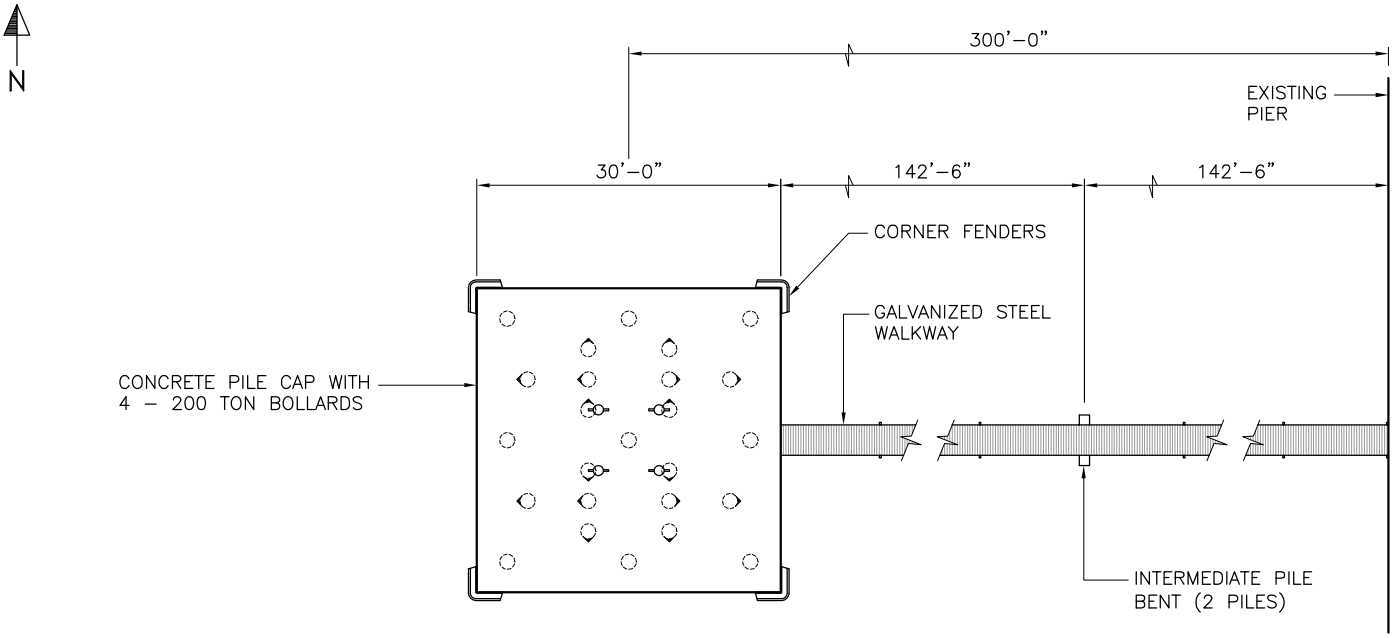
- Concrete pile cap supported by a combination of vertical and batter (inclined) piles
- Concrete pile cap supported by larger sized vertical piles only, either steel or concrete piles
- Circular steel sheet pile cell with concrete cap

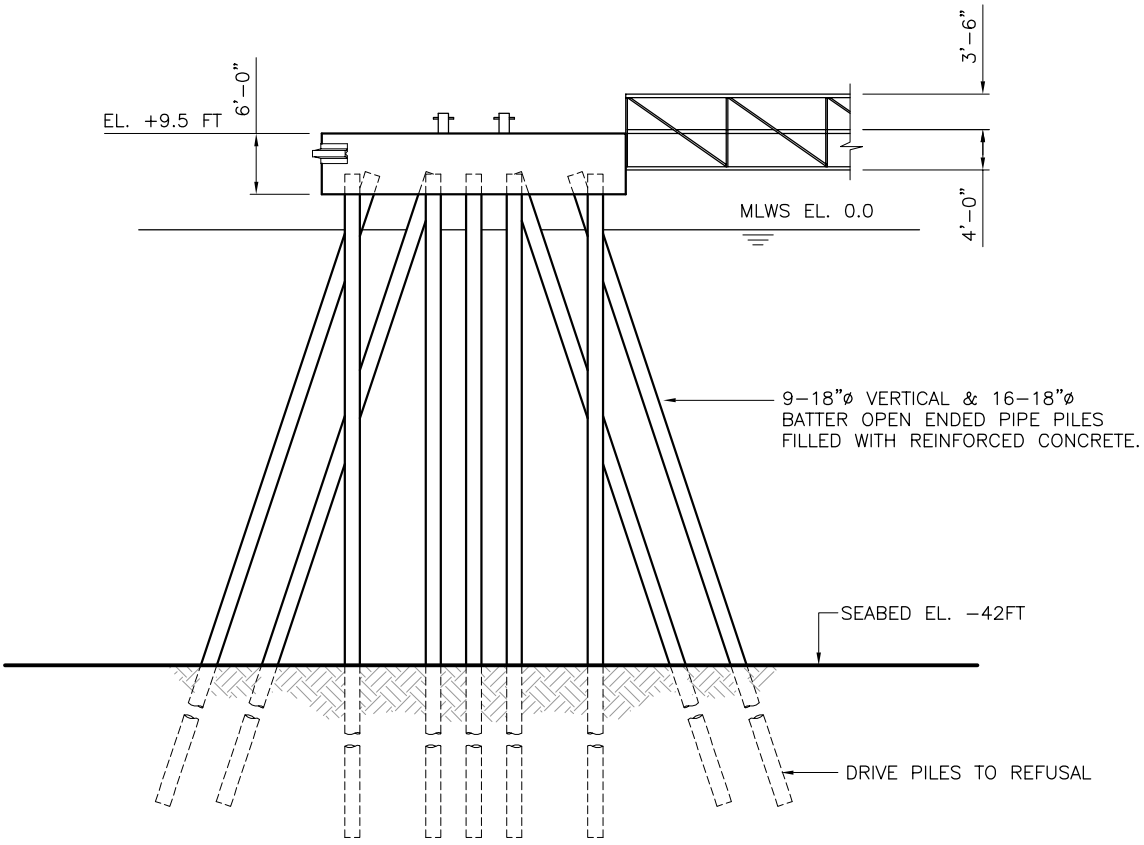
Plans and cross sections of these types are shown in the sketches included on the following pages.

Alternative 1: Combined Vertical and Batter Piles

This type of structure is designed with the piles resisting design forces in compression or tension without bending. This allows piles to be somewhat smaller in size. This approach results in relatively high tensile forces being applied to the batter piles; however, with the type of seabed material found within Nassau Harbour, tensile resistance on steel piles is low. To overcome this, tension capacity in batter piles would need to be increased by drilling and grouting high strength rocks anchors which would extend well beyond the pile tip at Elevation minus 86 feet. This presents a problem since the geotechnical investigation indicates that the competent material at this level, suitable for providing a bond between the rock anchor grout and the rock, is only ten feet thick and then becomes very weak below this level. Therefore, the required tensile capacity may not be achievable.

Piles would be epoxy coated and filled with concrete to resist corrosion. The wall thickness of the pipe is increased to provide a sacrificial corrosion allowance to allow for the eventual decrease in effectiveness of the epoxy coating.





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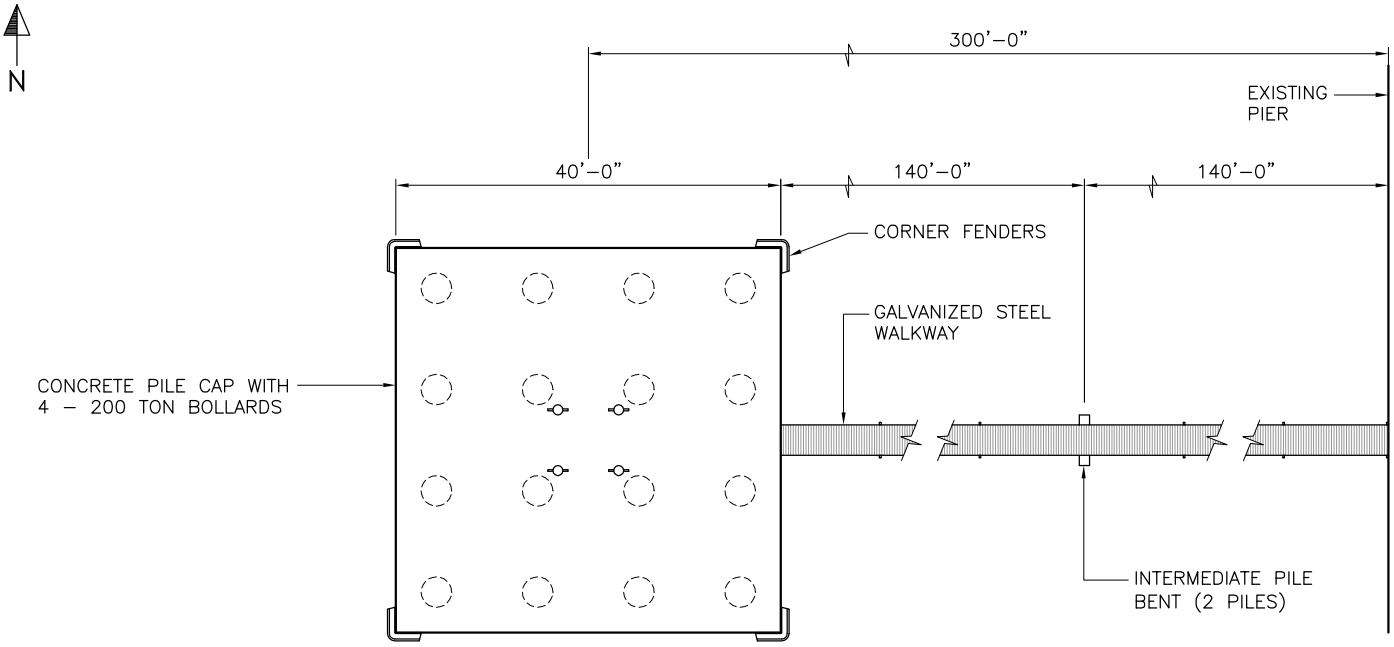
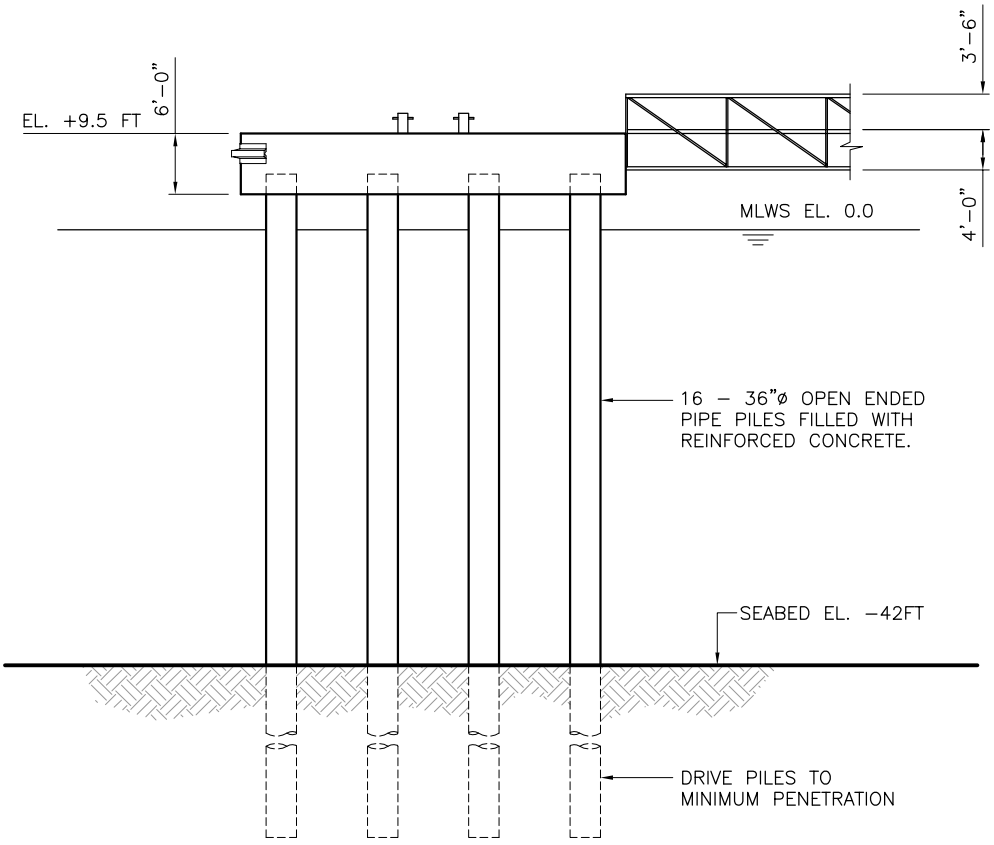
MOORING DOLPHIN ALTERNATIVE 1





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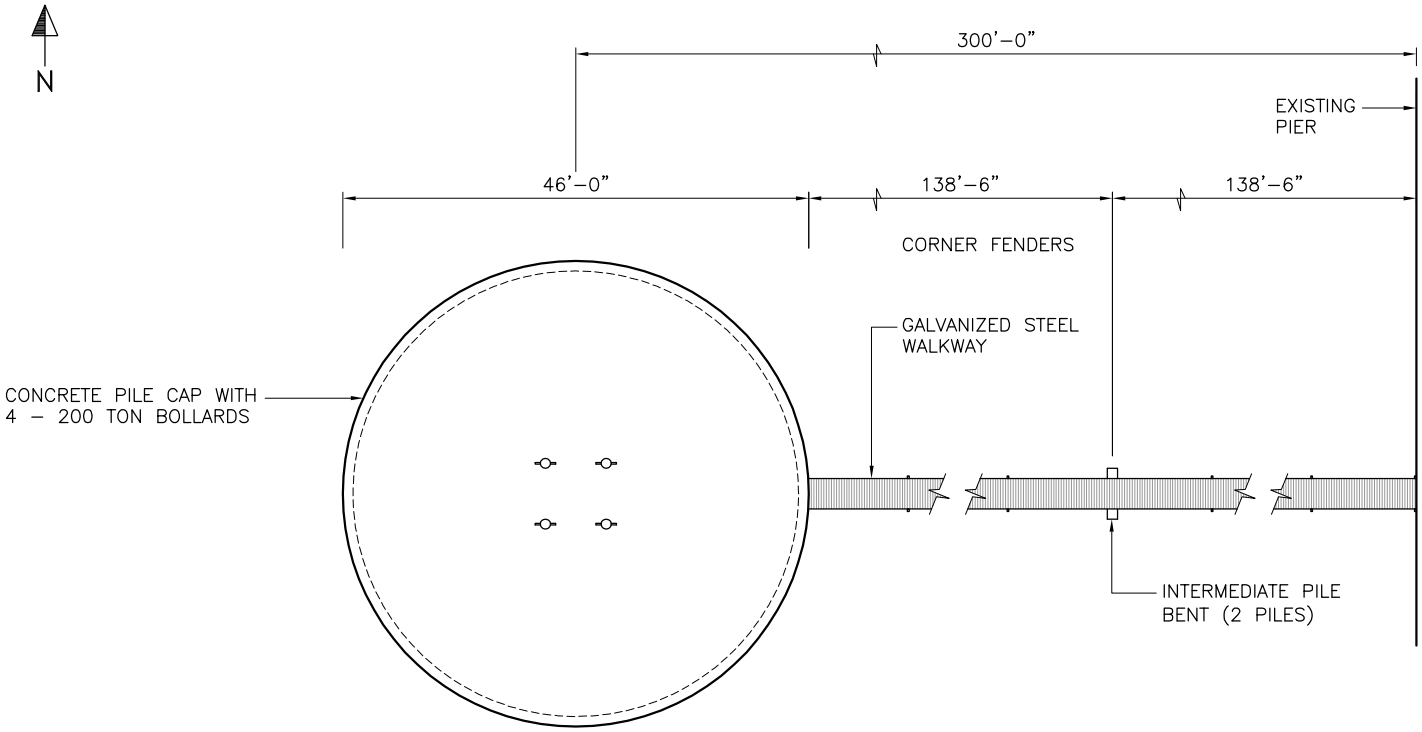
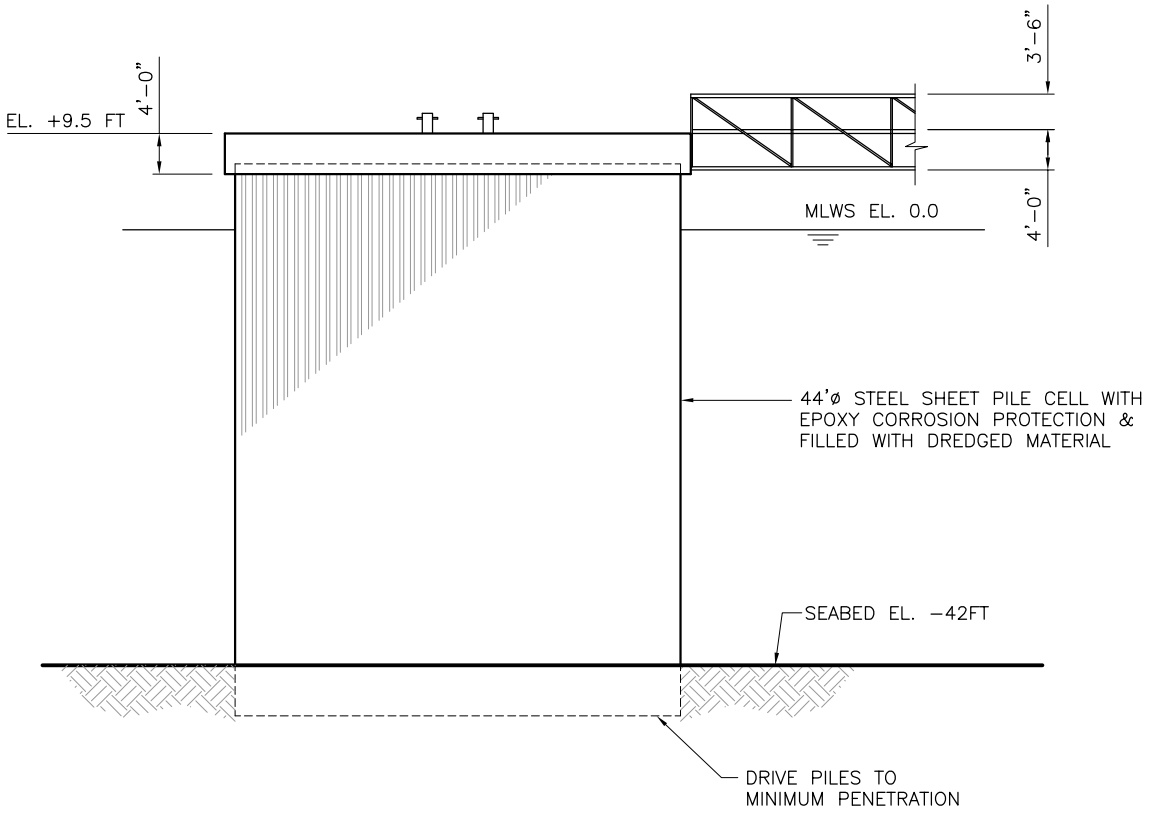
MOORING DOLPHIN ALTERNATIVE 2





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MOORING DOLPHIN ALTERNATIVE 3

This design has the potential to result in a slightly lower cost structure. However, it has the disadvantage that the rock anchor tensile capacity may not be achieved and, the batter piles protrude underwater beyond the edge of the structure. In discussing this with the cruise lines, they were concerned that this would present a hazard to cruise ships in the event of a cruise ship finding itself out of alignment with the pier breasting face. This hazard is compounded by the fact that this obstruction is below water and not visible.

Alternative 2: Vertical Piles

This type of structure (Figure 10.2) resists design forces with the piles acting in bending as vertical cantilevers extending upwards from the seabed. Axial compression and tension loads are minimal; therefore, grouted rock anchors are not required. Because the dolphins are located in 43 feet of water, this results in the need for large diameter piles. Two types of piles have been considered.

- The first makes use of open ended steel pipes piles driven into the bedrock as shown in the Alternative 2 sketch. Piles would be epoxy coated with an increased wall thickness as a corrosion allowance and would be filled with reinforced concrete. Sixteen 36 inch diameter piles would be required to resist design forces.

- The second type of pile involved the use of open ended 54 inch prestressed hollow concrete piles with a five inch wall thickness. These piles cannot be driven into the bedrock and would have to be set into slightly oversized pre-augured holes with the space between the hole and pile filled with tremie (underwater) grout. However, analysis indicated that these piles would be overstressed because of the depth of water at the dolphins locations. Therefore, use of the prestressed concrete piles was discarded as a viable option.

This alternative of making use of large diameter open ended steel pipe piles has the advantage that rock anchors are not required and the piles do not extend beyond the face of the pile cap.

Alternative 3: Steel Sheet Pile Cell

This is a gravity type of structure which resists design forces by virtue of its weight. This type of structure consists of a ring of low profile sheet piles with interlock connections forming a closed circular shaped cell. The structure is filled with dredged material and topped with a heavy reinforced concrete cap. Piles are epoxy coated and the pile wall thickness includes a corrosion allowance. The advantage to this type of structure is that, because it is a gravity structure, it is more resistant to a potential overload condition, including an accidental impact by a vessel.

The disadvantage of this type of structure is it vulnerability to damage during construction. During construction, individual piles have to be lifted high in the air to allow threading onto the adjacent pile on the circular arc. At this stage, none of the previously threaded piles have been driven since this is an operation that is performed once all of the piles have been threaded to form a complete closed circle. During this procedure, this partially constructed structure is extremely flimsy and is subject to damage due to waves. This procedure is also subject to difficulties due to currents which can be as high as two knots as a result of tidal flow. This has the potential to increase the cost of this type of structure since contractors will probably include a contingency allowance in the event that problems are experienced.

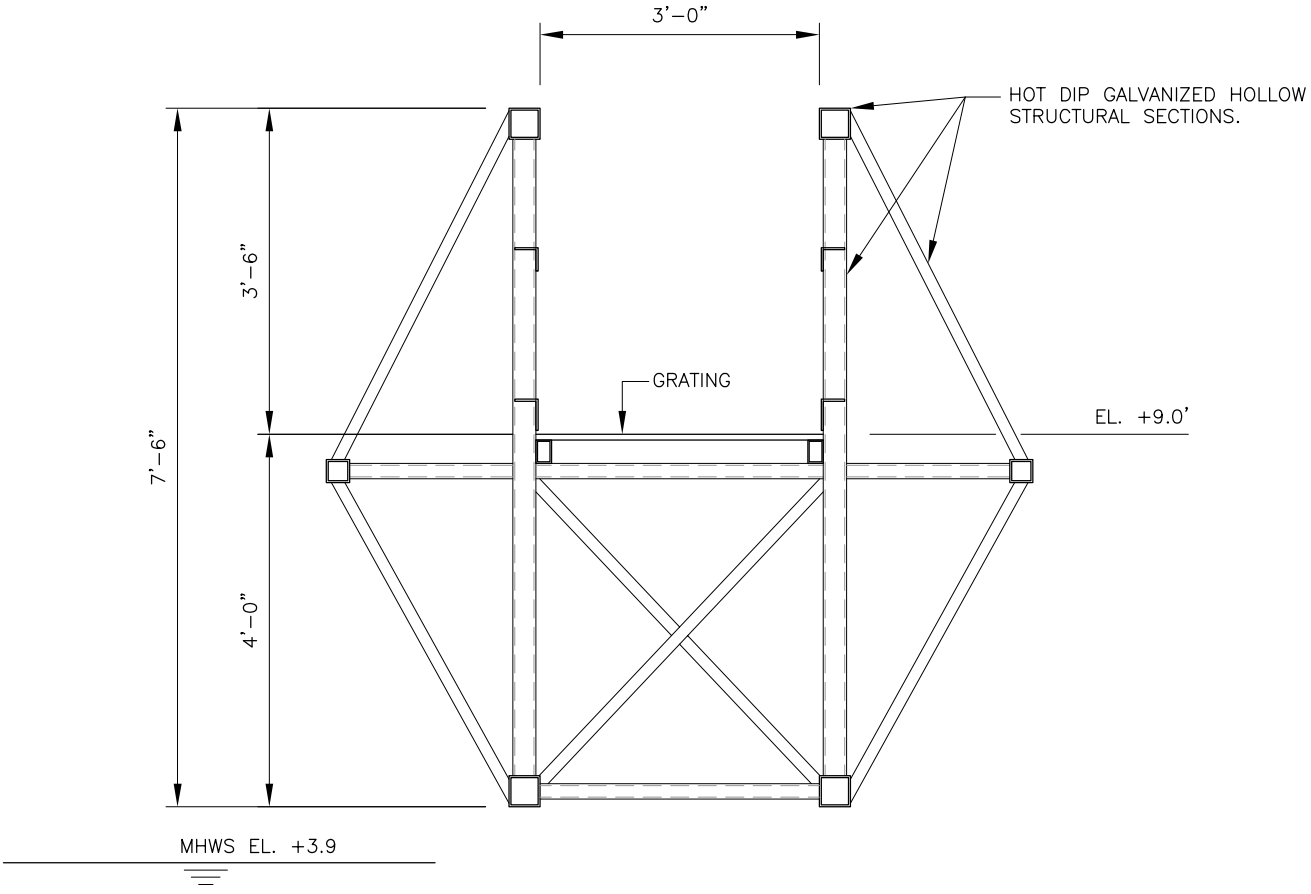
When considering the relative costs of each of these alternatives, their constructability and long term durability, we favour and recommend the vertical pipe pile Alternative 2. As noted in Section 12.0, Cost Estimates, the cost of the Alternative 2 type of structure is comparable to Alternative 1; however, it does not have the disadvantages associated with Alternative 1.

Connecting Walkways

A cross section of the "catwalk" connecting the dolphin to the end of the existing pier is shown in the sketch on the following page. This is a through-truss type of walkway capable of spanning 140 feet to the mid point between the edge of the dolphin pile cap and the end of the existing pier. This requires an intermediate pile support between the dolphin and the end of the existing pier, consisting of a concrete pile cap supported by four 20 inch diameter pipe piles filled with concrete.

The entire walkway is hot dipped galvanized as part of the fabrication process prior to final assembly of spliced segments. The frame of the entire walkway structure is built of welded hollow structural sections which support a grated walkway. The top chord of the truss is smooth topped in the event that lines have to be walked out to the dolphin.

The walkway will be fabricated with a camber so that when set in place, the deflection caused by the dead load of the structure will produce a level structure.



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WALKWAY SECTION

11.0 East Breakwater Repairs

As described in Section 5.0, Existing Breakwaters, in the mid 1960's the U.S. Corps of Engineers carried out two physical hydraulic model studies at their Vicksburg Mississippi hydraulic lab to aid in the design of the East and West Breakwaters. The breakwaters were constructed using imported armour stone in shallow areas and very large precast concrete armour units known as tribars in deeper water and at the head of the breakwaters.

The total length of the East Breakwater is about 600 feet with the eastern 130 feet supported by a low rock outcrop at the western tip of Paradise Island. The head and outer 300 feet are protected by 35.5 ton tribar units, decreasing to 19 ton units at the central section which is about 150 feet long. Two to six ton imported boulders were installed on the easterly 130 feet of the breakwater on top of the low rock outcrop at the tip of Paradise Island. These were keyed into two parallel shallow trenches about five feet wide.

On October 31, 1991, the entire Nassau waterfront was subjected to some exceptionally large swells originating from the North Atlantic due to the convergence of two very large storms, which became known as the Perfect Storm, as in the film. This caused the wash out of all of the boulders on the rock outcrop and created a breach about 150 feet long along the central section which was protected by the 19 ton tribars. Some of these units are visible in shallow water immediately south of the breach. However, as reported by the divers, most of these concrete units have been broken up into small pieces, scattered throughout the area of the breach.

Photo 9 in Appendix A shows the two parallel toe trenches on the lower portion of the rock outcrop constructed to hold the toe of the 2 to 6 ton imported rock, the breach in the breakwater and some of the 19 ton tribars swept to the south of the breach. These units represent a very small number of units dislodged, with the majority of them broken into small pieces as reported by the divers. Photo 10 shows a few remaining tribars and imported rock at the upper level of the Paradise Island rock outcrop, nearest the lighthouse.

Our coastal engineering subconsultant, Baird Associates, were retained to establish nearshore and in-Harbour wave characteristics to determine whether the proposed new dredging would impact the Western Esplanade beaches. They found that there would be no significant impact as a result of the dredging. They were also asked to provide a design wave for repairs to the East Breakwater. As part of that work, they were provided with details of the original construction as well as the original U.S. Corps of Engineers reports. They also made use of the hydrographic survey data in the area provided by Hydrographic Consultants Ltd.

Baird are in the forefront of coastal engineering technology with particular expertise in the design of breakwaters. Following their assessment of the situation, in Appendix A of their Report, they very strongly recommended that the design of repairs to the East Breakwater should not proceed without first conducting a physical hydraulic model study. They advise that conditions at the East Breakwater are very complicated and cannot be properly modelled using numerical models. Complications include the shape of the East breakwater relative to bottom contours, which because of its concave shape tends to focus wave energy, something that numerical models cannot accurately predict. They are also concerned about how the new armour units would mesh with the remaining existing 19 ton tribars remaining in the central section, many of them spread out and scattered as compared to their original installation.

Because this their area of expertise, Cox & SHAL cannot ignore Baird's recommendation. We therefore support their recommendation and feel that it would be a mistake to proceed without the benefit of a physical hydraulic model study. Cox & SHAL have therefore recommended to Government that the physical hydraulic model study be carried out. This would have to go to Cabinet for approval and the study itself will take a number of months to complete. Since the Port Improvement Project will be going out to tender very shortly, there is insufficient time to authorize and conduct the study and then to carry out a proper design of the repairs. Therefore, Cox & SHAL have recommended that the repairs to the East Breakwater be deferred and removed from the current Port Improvement Project. This should not present a problem to cruise ship operations since the Nassau Harbour Pilots have advised that the current breach does not seriously affect navigation of the cruise ships.

13.0 Recommendations

Based on the results of the site investigations, input from the cruise line industry including the Simulation Study, various discussions with Government staff and our own analysis of conditions affecting the Project, we offer the following recommendations.

1. Dredge limits should be to the limits shown on Drawings 2, 3 and 4 of Appendix B, which were confirmed as being acceptable during the Cruise Ship Simulation Study and subsequently agreed to by the major cruise lines.

2. Dredge depths should be 38 feet within the Harbour and 40 feet within the Approach Channel as agreed to by the cruise lines.

3. Tender Documents should require the contractor to give sequential priority to the following project elements as recommended by the cruise lines:

   Dredge the Turning Basin
   Install Mooring Dolphins
   Dredge the Approach Channel
   Dredge north of the North Pier

4. The design of the Mooring Dolphins should be based on the use of large diameter vertical piles as preferred by the cruise line captains, rather than using a combination of vertical and batter piles which introduce a potential obstruction to cruise ships out of position. This type of dolphin is shown as Alternative 2 in Section 10.0 of the Report.

5. As recommended by representatives of the cruise lines, each mooring dolphin should support four 200 ton bollards to provide for new-build bow and stern lines. Corner fenders should be provided in the event that there is an unintentional contact by a cruise ship finding itself out of position.

6. Since the existing space available on Arawak Cay can only stockpile 600,000 cubic yards of dredged material, Arawak Cay should be extended 1,000 feet to the west to allow the receipt of the additional 1.4 million cubic yards of material. This provides space for an additional stockpile of 500,000 cubic yards available for use.

7. To allow the 1,000 foot Arawak Cay extension to be used for future berthing and cargo handling operations, it is recommended that the north and west sides of the extension be designed and constructed to allow for future dredging to a 32 foot depth.

8. Large portions of Arawak Cay are currently overgrown with Casuarina trees and shrubs. It is recommended that MOWT engage a local contractor to clear the site prior to the start of dredging and construction of the dredged material containment berms. Clearance work should be complete prior to award of the dredging contract.

9. As recommended by Baird in their Coastal Engineering Report, a physical hydraulic model study should be conducted to determine the most technically feasible and cost effective method of repairing the East Breakwater.

10. Since the Project Schedule does not allow sufficient time to authorize and carry out this physical hydraulic model study, Tender Documents should be issued without the East Breakwater repairs included, the design of which should be deferred until the results of the physical hydraulic model study are available.

11. As recommended by Baird in their Coastal Engineering Report, a beach profile monitoring program should be set up immediately before the start of dredging to allow any change in beach profile to become evident during and after dredging.