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Proposed Cruise Berthing Facility, Grand Cayman

Environmental and Engineering Consultancy Services
Environmental Statement - Draft

June 2, 2015
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Proposed Cruise Berthing Facility, Grand Cayman

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Environmental Statement - Draft

Prepared for

Ministry of District Administration Tourism & Transport and The Port Authority of the Cayman Islands

Prepared by

W.F. Baird & Associates Coastal Engineers Ltd.

Smith Warner International Ltd. and TEM Network Ltd.

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APPENDIX O - BUSINESS DISTRICT IMPACT ASSESSMENT
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APPENDIX Q - RIAM - SUMMARY OF METHODOLOGY

LIST OF ACRONYMS

AGRRA	Atlantic and Gulf Rapid Reef Assessment
Baird	W.F. Baird & Associates Coastal Engineers Ltd.
CBF	Cruise Berthing Facility
CIG	Cayman Islands Government
DOE	CIG Department of Environment
EAB	CIG Environmental Advisory Board
EIA	Environmental Impact Assessment
ES	Environmental Statement
GTH	George Town Harbour
GTRP	George Town Revitalization Program
IMO	International Maritime Organization
MM	Mott MacDonald
MMM	MMM Group Ltd.
MPA	Marine Protected Area
MSL	Mean Sea Level
NGO	Non-Governmental Organization
NOAA	U.S. National Ocean and Atmospheric Administration
NRA	National Roads Authority of Cayman Islands
RIAM	Rapid Impact Assessment Matrix
OBC	Outline Business Case (PricewaterhouseCoopers, October 2013)
ORIA	Owen Roberts International Airport
PACI	Port Authority of the Cayman Islands
PTB	CIG Public Transport Board
PwC	PricewaterhouseCoopers
RFP	Request for Proposals
SC	CIG Project Steering Committee
SOC	Strategic Outline Case (CIG Project Steering Committee, April 2013)
SWI	Smith Warner International Ltd.
TEMN	Technological & Environmental Network Ltd.
ToR	Final EIA Terms of Reference
WHO	World Health Organization
7MB	Seven Mile Beach

MEASUREMENT UNITS

Where possible, all measurements are given in imperial units with metric conversions of these units shown in brackets following. The only exception to this is certain scientific measurements, such as suspended sediment concentration, in which use of metric units is customary. The following are typical imperial to metric conversions employed.

- Length: 1 foot = 0.3048 metres
- Volume: 1 cubic yard = 0.7646 cubic metres
- Area: 1 acre = 0.405 hectare
- Nautical Distance: 1 nautical mile = 1.852 km
- Nautical Speed: 1 knot = 0.5144 metres/second
- Terrestrial Distance: 1 mile = 1.609 km
- Terrestrial Speed: 1 mile per hour = 0.4470 metres/second

REPORTING CONVENTIONS

- All time is Local (Eastern Standard Time) unless otherwise stated
- All directions clockwise relative to True North
- Wind direction is the direction from which the wind blows
- Wave direction is the direction from which the waves propagate
- Current direction is the direction to which the currents are moving
- Vertical datum: Grand Cayman Vertical Datum 1954 (GCVD 1954)

SECTION II – ENVIRONMENTAL STATEMENT

1.0 INTRODUCTION

1.1 Project Background

Grand Cayman is one of the few islands in the Caribbean where cruise ships must still tender their passengers ashore. In order to improve the safety and quality of the passenger experience, and maintain market share, the Cayman Islands Government (CIG) is considering the development of a new cruise berthing facility in George Town Harbour, on the west coast of Grand Cayman Island.

This project has a long history, with numerous studies undertaken by various groups dating back to 1994. Most recently, the CIG has overseen the completion of the following studies: Strategic Outline Case (CIG Project Steering Committee, April 2013); Concept Study (Mott MacDonald, October 2013); and Outline Business Case (PricewaterhouseCoopers, October 2013).

1.2 Scope of EIA Study

The scope of the Environmental Impact Assessment study is defined in the "Final EIA Terms of Reference" (ToR) prepared for the CIG by Mott McDonald in December 2013. This comprehensive document defines specific requirements for each of the following considerations:

- Consultation (stakeholders and public);
- Analysis of alternatives;
- Natural hazards assessment;
- Geology and soils;
- Coastal processes;
- Sediment transport and water quality;
- Storm water;
- Air quality and greenhouse gas emissions;
- Noise and vibration;
- ~~Terrestrial ecology~~ (this task was subsequently eliminated from the scope of work);
- Marine ecology;
- Cultural heritage;
- Vehicular and pedestrian traffic;
- Cruise and cargo operations;
- Socio-economic impact assessment;
- Business district impact assessment (incorporated into socio-economic impact assessment);
- Landscape and visual impact assessment.

Further, the ToR noted that the potential impacts of climate change were to be integral to the EIA, including consideration of both adaptation and mitigation measures.

In May 2014, the CIG retained W.F. Baird & Associates Coastal Engineers Ltd. (Baird), in association with Smith Warner International Ltd. (SWI), to undertake environmental and engineering studies for the proposed cruise berthing facility. The resulting Environmental Impact Assessment study is now complete, and is documented in this Environmental Statement (ES).

The overall scope of the environmental studies included the following key tasks:

- Definition of baseline site and environmental design conditions;
- Assessment of benthic habitat and marine ecology;
- Modeling and analyses of coastal processes, sediment transport and water quality;
- Development and assessment of alternative project layouts;
- Identification and assessment of anticipated environmental impacts and socio-economic impacts related to project development;
- Identification and assessment of possible mitigation measures to reduce negative impacts.
- Preparation of Environmental Statement summarizing the results of the EIA, including technical appendices for each EIA consideration listed above, as well as an Environmental Management Plan for the project.

1.3 Overview of Study Methodology

1.3.1 CIG Direction and Participation

As noted above, the present study was designed to be responsive to the "Final EIA Terms of Reference" prepared for the CIG by Mott McDonald in December 2013. CIG direction to and participation in the study has been provided by the CIG's Project Steering Committee (SC) and Environmental Advisory Board (EAB), including regular email and telephone conversations between key members of the CIG and Baird project teams, intermittent teleconferences on key technical matters, and review of progress and interim reports.

Interim reports were submitted by the Baird team on June 27, 2014 (Interim Report 1, IR1) and August 1, 2014 (Interim Report 2, IR2). Various other progress reports were also submitted to the SC and EAB over the course of the study. Interim presentations were made to the Ministers of Environment, Planning and Tourism on July 4, 2014 and September 9, 2014; the Minister of Finance and several representatives from the PACI Board of Directors were also present at the latter meeting.

1.3.2 Stakeholder Engagement Plan and Public Consultation Process

The EIA study included a comprehensive stakeholder engagement plan and public consultation process. This included online and in-person surveys with local business stakeholders and

households, as well as meetings and discussions with representatives from various industry groups, various CIG Departments and Authorities, and local Non-Governmental Organizations (NGOs). The stakeholder engagement plan and public consultation process is presented in Chapter 6 and in Appendix 1.

1.3.3 Assessment of Baseline Conditions

The EIA study included a comprehensive assessment of baseline conditions for fifteen different considerations identified in the Final EIA Terms of Reference (MM, 2013), as required to allow an assessment of the potential impacts of the proposed project on each of these considerations. The assessment of baseline conditions included collection and review of information and data available from previous studies, collection and analysis of additional field data (refer to Appendix 2), and modeling and analysis of various processes under existing conditions. Chapters 8 to 22 present a summary of baseline conditions for each of the EIA considerations, while more detailed information is provided in the Appendices.

1.3.4 Development and Assessment of Alternatives

The EIA study included a review of studies and concepts previously completed by others for new cruise berthing facilities in George Town Harbour, and at other locations around Grand Cayman. In addition, starting with the project layout developed in the Concept Study (MM, 2013) and adopted in the Outline Business Case (PwC, 2013), a number of additional alternatives were developed and assessed, leading to the development of a refined project layout that provides improved functionality (for both cruise and cargo operations) and a significant reduction in environmental impacts as compared to the OBC layout, with only a marginal increase (10%) in capital cost. Chapter 7 and Appendix A present further information on the review of previous alternatives and the development of the refined project layout undertaken as part of the EIA study.

1.3.5 Assessment of Project Impacts

The construction and operation of a cruise berthing facility in George Town Harbour will result in various impacts on the natural environment, as well as the socio-economic fabric of George Town, Grand Cayman and the Cayman Islands. These impacts may be positive or negative and temporary/short term or permanent/long term. In addition, their likelihood of occurrence and their significance (i.e. minor, moderate or severe) range from highly predictable to highly uncertain. Furthermore, the effects of climate change have been considered in assessing the impacts of the project on the environment, and vice-versa.

The EIA study included a comprehensive assessment of potential impacts for each of the fifteen different considerations identified in the Final EIA Terms of Reference (MM, 2013), including consideration of climate change. A wide range in assessment methodologies was utilized, including field work, desktop assessments and empirical and numerical modeling, as well as prior experience with similar projects. Chapters 8 to 22 present a summary of the assessment of project impacts for each of the EIA considerations, while more detailed information is provided in the Appendices.

1.3.6 Rapid Impact Assessment Method

The Rapid Impact Assessment Matrix (RIAM) method was developed by the Danish Hydraulics Institute to address concerns related to subjectivity that is generally inherent in Environmental Impact Assessments (EIA). The RIAM method is based on the fact that certain criteria are common to all impact assessments; by scaling these criteria, it becomes possible to record the values of the assessments made. The criteria are divided into two general groups, as follows:

A. Those which individually are important in their impact; and

B. Those which are collectively important.

The Rapid Impact Assessment Matrix (RIAM) method is based on a standard definition of the important assessment criteria as well as the means by which semi-quantitative values for each of these criteria can be collated to provide an accurate and independent score for each condition. The impacts of project activities are evaluated against various environmental components. For each component, a score (using the defined criteria) is determined; this score provides a measure of the impact expected from the component. The value ascribed to each of these groups of criteria is determined by the use of a series of simple formulae. These formulae allow the scores for the individual components to be determined on a defined basis.

Environmental Components
The RIAM method requires specific assessment components to be defined through a process of scoping. The components are then grouped into four categories, as follows:

- Physical/chemical
- Biological / ecological
- Sociological / cultural
- Economic / operational

Assessment Criteria
Five assessment criteria are incorporated in the RIAM method, as summarized below:

Group A

- *Importance of Condition (A1)* - the importance is assessed against the spatial boundaries or human interests it will affect
- *Magnitude of Change/Effect (A2)* - a measure of the scale of benefit or dis-benefit of an impact or a condition

Group B

- *Permanence (B1)* - defines whether a condition is temporary or permanent; it is a measure of the temporal status of the condition.
- *Reversibility (B2)* - defines whether the condition can be changed, and is a measure of the control over the effect of the condition (it is different than permanence).

- *Cumulative (B3)* - measure of whether the effect will have a single direct impact or whether there will be a cumulative effect over time, or a synergistic effect with other conditions. This criterion judges the sustainability of a condition (again, it is different than permanence).

The RIAM method has been applied to relevant EIA tasks to "quantify" anticipated project impacts, as well as proposed mitigation measures, for the following situations:

- Existing (Baseline) Conditions
- Dredging and Reclamation Phase
- Construction (Post Dredging) Phase
- Operation Phase

The results of the application of the RIAM method to the various EIA tasks are summarized in tables and graphs at the end of each EIA task chapter in the Environmental Statement, while additional information on the RIAM methodology is provided in Appendix Q.

1.3.7 Study Documentation

This draft report presents the results of the environmental studies, and is organized as follows:

- **Section I – Non-Technical Summary**

- **Section II – Environmental Statement**
  - Chapter 1 - Introduction
  - Chapter 2 - Project Need and Policy Context
  - Chapter 3 - Project Objectives and Key Constraints
  - Chapter 4 - Project Site and Physical and Environmental Constraints
  - Chapter 5 - Proposed Project and Overview of Concerns
  - Chapter 6 - Stakeholder Engagement and Public Consultation
  - Chapter 7 - Task A - Summary Analysis of Alternatives
  - Chapter 8 - Task B - Natural Hazards Assessment
  - Chapter 9 - Task C - Geology and Soils
  - Chapter 10 - Task D.1 - Coastal Processes – Waves and Sediment Transport
  - Chapter 11 - Task D.2 - Coastal Processes – Hydrodynamics and Dredge Plumes
  - Chapter 12 - Task E - Sediment and Water Quality
  - Chapter 13 - Task F - Storm Water
  - Chapter 14 - Task G - Air Quality and Greenhouse Gas Emissions
  - Chapter 15 - Task H - Noise and Vibration
  - ~~Task I - Terrestrial Ecology~~ - this task was deleted from EIA scope of work

- Chapter 16 - Task J - Marine Ecology
- Chapter 17 - Task K - Cultural Heritage
- Chapter 18 - Task L - Vehicular and Pedestrian Traffic
- Chapter 19 - Task M - Cruise and Cargo Operations
- Chapter 20 - Task N - Socio-Economic Impact Assessment
- ~~Chapter 21 - Task O - Business District Impact Assessment~~ - incorporated in Chapter 20
- Chapter 22 - Task P - Landscape and Visual Impact Assessment

- **Section III - Environmental Management Plan** – not included in this draft

- **Section IV - Technical Appendices**

  - Appendix 0 - Final EIA Terms of Reference (MM, 2013)
  - Appendix 1 - Stakeholder Engagement and Public Consultation
  - Appendix 2 - Field Data Collection Program

  - Appendix A - Alternatives Assessment
  - Appendix B.1 - Natural Hazards Assessment
  - Appendix B.2 - Climate Change Risk Assessment
  - ~~Appendix C - Geology and Soils~~ - no appendix required
  - Appendix D.1 - Coastal Processes - Waves and Sediment Transport
  - Appendix D.2 - Coastal Processes - Hydrodynamics and Dredge Plumes
  - Appendix D.3 - Sediment Re-Suspension by Cruise Ships
  - Appendix E - Sediment and Water Quality
  - Appendix F - Storm Water
  - Appendix G - Air Quality and Greenhouse Gas Emissions
  - Appendix H - Noise and Vibration
  - ~~Appendix I - Terrestrial Ecology~~ - this task was deleted from EIA scope of work
  - Appendix J.1 - Marine Ecology
  - Appendix J.2 - Marine Resource Valuation
  - ~~Appendix K - Cultural Heritage~~ - no appendix required
  - Appendix L - Vehicular and Pedestrian Traffic
  - Appendix M - Cruise and Cargo Operations
  - Appendix N - Socio-Economic Impact Assessment
  - ~~Appendix O - Business District Impact Assessment~~ - incorporated in Appendix N
  - ~~Appendix P - Unused~~
  - Appendix Q - Rapid Impact Assessment Matrix (RIAM) - Summary of Methodology

2.0 PROJECT NEED AND POLICY CONTEXT

2.1 Project Need

Tourism is an important component of the Cayman Islands economy, representing 24% of the Gross Domestic Product and providing significant employment and entrepreneurial opportunities for residents (Strategic Outline Case, 2013). Approximately 85% of these visitors to the island arrive by sea, predominantly by cruise ship. It has been noted that in recent years Cayman has been gradually losing market share in the Caribbean tourism region. Based on feedback from the cruise industry, it was identified in the SOC that this declining trend is likely to continue unless a berthing facility is constructed to facilitate the movement of passengers to and from the cruise ships.

Presently, cruise ship passengers arriving at Grand Cayman are transferred ashore by means of small craft ("tendering"). As noted in the OBC, while the existing tendering service at GTH is rated very highly in the industry, tendering itself is considered to be a "high-risk, negative passenger experience by cruise lines and passengers alike". Another important consideration is that, due to inefficiencies associated with tendering, visitors may have to wait for long periods to come off the ships, and also have to queue and return to their vessels at a much earlier time than if berthing facilities were available. This limits the time that passengers have available to enjoy and experience the Cayman Islands.

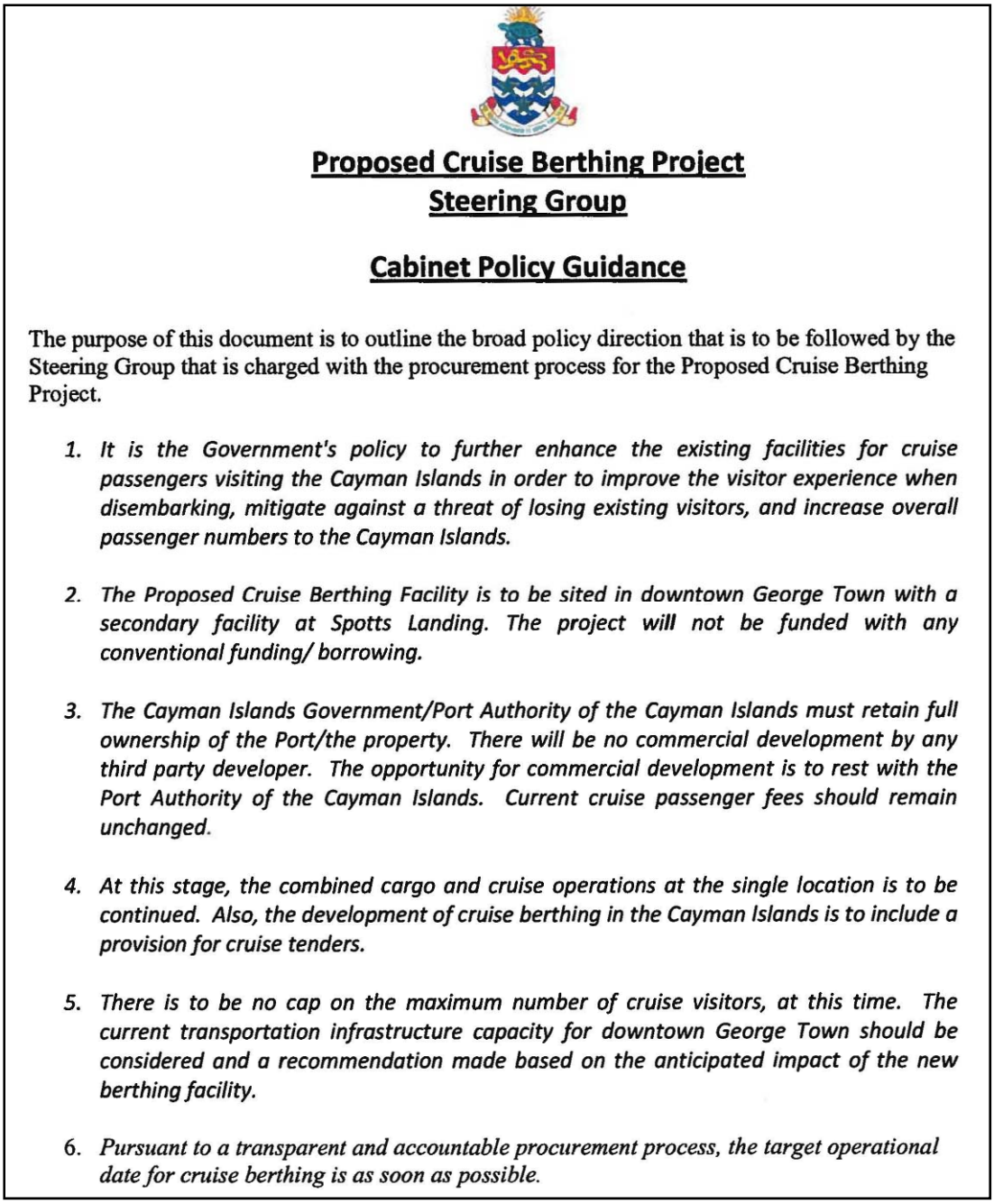
Other jurisdictions in the Caribbean region have developed dedicated cruise berthing facilities in order to capture a greater share of cruise tourism, and to meet the needs of larger vessels, such as the relatively new Oasis and Quantum class vessels. Due to their size, these larger vessels are not well suited for tendering operations. Grand Cayman is one of the few remaining major cruise destinations without berthing facilities (OBC, 2013).

Available information suggests the potential for the declining trend in cruise traffic and market share to continue, with resultant impacts on the tourism sector and economy of the Cayman Islands, unless significant investment is made in port infrastructure improvements. The CIG expects that the proposed cruise berthing facility at George Town Harbour will strategically place the Cayman Islands in an enhanced position to maintain and /or increase its share of the growing cruise market in the Caribbean region.

2.2 Planning History and Policy Context

2.2.1 Introduction

As noted earlier, the idea of a cruise berthing facility in George Town Harbour has a long history, with numerous studies undertaken by various groups dating back to 1994. On March 5, 2013, the CIG issued a policy directive for the development of cruise berthing facilities in George Town, as well as the enhancement of existing facilities at Spotts Landing. A copy of this document is presented in **Figure 2.1**.



Proposed Cruise Berthing Project
Steering Group

Cabinet Policy Guidance

The purpose of this document is to outline the broad policy direction that is to be followed by the Steering Group that is charged with the procurement process for the Proposed Cruise Berthing Project.

1. *It is the Government's policy to further enhance the existing facilities for cruise passengers visiting the Cayman Islands in order to improve the visitor experience when disembarking, mitigate against a threat of losing existing visitors, and increase overall passenger numbers to the Cayman Islands.*

2. *The Proposed Cruise Berthing Facility is to be sited in downtown George Town with a secondary facility at Spotts Landing. The project will not be funded with any conventional funding/ borrowing.*

3. *The Cayman Islands Government/Port Authority of the Cayman Islands must retain full ownership of the Port/the property. There will be no commercial development by any third party developer. The opportunity for commercial development is to rest with the Port Authority of the Cayman Islands. Current cruise passenger fees should remain unchanged.*

4. *At this stage, the combined cargo and cruise operations at the single location is to be continued. Also, the development of cruise berthing in the Cayman Islands is to include a provision for cruise tenders.*

5. *There is to be no cap on the maximum number of cruise visitors, at this time. The current transportation infrastructure capacity for downtown George Town should be considered and a recommendation made based on the anticipated impact of the new berthing facility.*

6. *Pursuant to a transparent and accountable procurement process, the target operational date for cruise berthing is as soon as possible.*

Figure 2.1 – CIG Cabinet Policy Guidance (March 5, 2013)

The CIG appointed a Steering Committee to oversee various processes required to further consider/develop the project proposal. The Steering Committee has since overseen the completion of the following studies:

- Strategic Outline Case (CIG Project Steering Committee, April 2013);
- Concept Study (Mott MacDonald, October 2013);
- Outline Business Case (PricewaterhouseCoopers, October 2013).

In early 2014, the CIG authorized the present Environmental Impact Assessment study, which represents the next step in the planning of the proposed project.

The Strategic Outline Case (SOC) presents the strategic aims and policy objectives for the proposed project, including the project need, objectives and constraints. Key information as presented in the SOC is summarized below.

2.2.2 Strategic Aims and Policy Objectives

The CIG's 2013-14 Strategic Policy Statement listed 19 Broad Outcome Goals. Under Broad Outcome Goal No. 2, the CIG outlined its support for "*the development of new cruise ship berthing facilities in the Cayman Islands.*"

This policy was reaffirmed with a more specific directive "*to further enhance the existing facilities for cruise passengers visiting the Cayman Islands in order to improve the visitor experience when disembarking, mitigate against the threat of further loss in cruise market share, and increase overall passenger numbers to the Cayman Islands.*"

The SOC noted the following benefits of the project:

- *The change from tendering to berthing will enhance the cruise visitor experience, better facilitate the embarkation and disembarkation of larger vessels, improve the competitiveness of the Cayman Islands Tourism product and further improve the island's reputation as a destination of choice.*
- *The development of berthing facilities is an important growth strategy for the Cayman Islands.*
- *Visitors who remain on the island for longer periods have more opportunity to spend in the local economy.*

Finally, the SOC noted that the proposed project is supported by key stakeholders, including the Chamber of Commerce, Port Authority of the Cayman Islands, Cayman Tourism Association, downtown merchants, the cruise lines, local attractions and the transport industry.

2.2.3 Relevant CIG Policy Documents and Guidance

Cayman Islands Government policy and guidance documents relevant to the proposed development include:

- The CIG Development and Planning Laws (http://www.planning.gov.ky/HTML_BODY/FOI/FOI_Laws_And_Regs.htm)
- The CIG Development and Planning Regulations (http://www.planning.gov.ky/HTML_BODY/FOI/FOI_Laws_And_Regs.htm)
- The Draft National Conservation Law 2013
- The National Tourism Management Plan (2009 to 2013)
- The National Biodiversity Action Plan 2009

- Coastal Works Policies
- The Draft Climate Change Policy (2011)

3.0 PROJECT OBJECTIVES AND KEY CONSTRAINTS

3.1 Project Objectives

As noted in the SOC, the overall objectives of the proposed project are as follows:

- Provide the infrastructure necessary to facilitate the safe and efficient disembarkation and embarkation of passengers from larger cruise ships;
- Increase the number of cruise ships which call at Grand Cayman;
- Provide additional tourism opportunities, industry jobs and benefits to local merchants by improving the competitiveness of the Cayman Islands cruise product.
- Conduct the project in an open and transparent manner, consistent with international best practices, and in accordance with the Public Management and Finance Law (PMFL, 2012 revision) to ensure value for money.

3.2 Key Constraints

As noted in the SOC, the following points highlight key constraints that must be considered in the planning and implementation of the proposed project:

- ***Impact on Cargo Operations:*** The planning, design and construction of the proposed project must consider the port's cargo operations, and must limit impacts on these operations, as the port is the lifeline for the island (i.e. all goods arrive through the port).
- ***Domestic Infrastructure:*** Consideration must be given to the physical capacity of the infrastructure in the downtown area of George Town to accommodate the higher influx of cruise passengers associated with the proposed facility.
- ***Natural Environment:*** The Cayman Islands includes marine assets/resources that provide significant environmental, cultural, social and economic value. Of particular importance to this project are healthy coral reefs, marine ecology and ship wrecks (*Balboa* and *Cali*) within George Town Harbour, Seven Mile Beach to the North, Hog Sty Bay to the South and various cultural assets in central George Town. As well, it is noted that the project is located within the confines of a designated Marine Park. The marine environment must be protected to the extent possible throughout project construction and operation. A central aim of the project is to deliver the necessary infrastructure while protecting the environment. Appropriate consultation and input is required throughout the key phases of the project, including the Department of Environment, and the local community as key stakeholders.

4.0 PROJECT SITE, EXISTING FACILITIES AND KEY CONSTRAINTS

4.1 Project Site

The RFP for the study indicates that the proposed cruise berthing facility (CBF), if developed, will be located in George Town Harbour (GTH). This project site is specifically identified in a document issued by the CIG to guide the Steering Committee in the procurement process (planning, design and construction) for the proposed cruise berthing project (CIG Cabinet Policy Guidance, dated March 5, 2013).

GTH is located on the west coast of Grand Cayman Island, adjacent to the central business district of George Town, and to the south of Seven Mile Beach, as shown **in Figures 4.1 and 4.2.**



Figure 4.1 – Site Location - Grand Cayman Island (Source: Google Earth)



Figure 4.2 – Site Overview – George Town Harbour (Source: IRG Ltd)

Grand Cayman is a popular port-of-call in the Caribbean. Cruise ships calling at George Town anchor offshore and ferry their passengers to and from the shore using tenders, or shuttle boats. With George Town Harbour being the centre of both cruise and cargo operations for Grand Cayman, and the facilities located immediately adjacent to downtown George Town, the harbour can be busy and congested.

The Cayman Islands are regarded among the best destination for scuba diving and snorkeling in the Caribbean, mostly because of the water clarity, diverse coral and fish, and the proximity and ease of access to the thriving underwater reefs. The reef system in George Town Harbour is generally in better condition than most other reef systems around the Caribbean, and have been a long-time favourite for local dive operators, who benefit from the proximity of such a unique resource. The reefs themselves, as well as the associated flora and fauna, are of great ecological, commercial and cultural significance. The aesthetic and economic value of the George Town Harbour reef system is important given the area's local and international reputation as a desirable dive site. The location and aesthetic quality of these reefs makes them one of the few places where "interesting reef dives" can be accessed directly from shore without the need to use a boat. Dive sites such as Soto's Reef and Eden Rock offer a maze of gullies and tunnels in shallow water that are a great attraction to tourists and locals alike. For the cruise ship passengers, the harbour reefs offer a site that can be viewed from glass bottom boats, or by snorkeling and diving at the site.

The following sub-sections provide a summary of existing port facilities in GTH, the natural environment surrounding the project site, and key site considerations and constraints that must be considered in the planning and development of the proposed CBF.

4.2 Existing Port Facilities

This section provides a summary of existing port facilities in GTH. Chapter 19 and Appendix M provide additional detail on the existing cruise and cargo facilities and operations, and the anticipated impact of the development of the proposed CBF on these operations.

The existing port facilities are located on a small land reclamation area that serves both cruise and cargo operations, and includes the following facilities (refer to **Figure 4.3**):

- Land reclamation area – approximately six acres, with vertical perimeter walls (including steel sheet pile bulkhead and gravity block wall construction);
- Cargo facilities - south dock/pier, west wall and RO/RO ramp;
- Cruise facilities - four offshore anchorages/moorings (shown in **Figure 4.4**), with tenders providing service to three landing facilities (main tender pier and Royal Watler terminal at north end of land reclamation area, and North and South terminals in Hog Sty Bay). Port Authority of the Cayman Islands (PACI) data shows that up to seven cruise vessel arrivals have occurred in the past although 95% of the time there are four or fewer cruise ships at port. Vessels not on anchorage are required to stay offshore under engine power.



Figure 4.3 – Existing Harbour Facilities (Source: CIG Department of Lands & Surveys)

The land reclamation area supports both cruise and cargo operations. Spatial constraints and safety concerns are such that cruise and cargo operations cannot occur together. As such, cruise operations prevail through the day, with cargo operations taking place through the night. In addition, spatial constraints at the site led to the development of an inland port facility, with the GTH site being used only to offload cargo (containers, general cargo and bulk materials) for subsequent transport to the inland site. These constraints severely limit the capacity of cargo handling operations at the GTH site, with future growth in imports expected to exceed the capacity of the existing facilities within 10 to 20 years (refer to Chapter 19 and Appendix M).

The existing tender operation is well-established but can be subject to strong winds and heavy seas (particularly during Nor'westers), resulting in the intermittent relocation of cruise operations to Spotts Landing and/or missed calls (refer to Chapter 19 and Appendix M).

As per the Terms of Reference, the focus of the present study is to assess alternatives for, and the environmental and socio-economic impacts associated with, the development of a cruise berthing facility (CBF) to replace the existing tender operation. However, given the spatial constraints at the George Town Harbour site, as well as the critical importance of the cargo port to the economy of the Cayman Islands, consideration was also given to various options to improve/expand the existing cargo facilities at this site.

4.3 Key Site Considerations and Constraints for the Project

Figure 4.4 and the following bullet points highlight key site conditions of particular relevance to the proposed project:

- Existing harbour and port areas are already congested with cruise/tender and cargo operations, as well as recreational/water sports activities (diving, snorkeling, etc.)
- Proximity to George Town's central business district;
- Proximity to Seven Mile Beach;
- Shallow nearshore area (generally less than 60 ft);
- Proximity to very deep water ("The Wall");
- Presence of significant and healthy coral reefs and thriving marine ecosystem;
- Presence of two historic ship wrecks (*Balbao* and *Cali*);
- Variable subsurface conditions (calcareous sediment with varying degree of cementation);
- Exposure to Nor'westers though the fall and winter months;
- Potential exposure to severe hurricanes and earthquakes.

These site conditions present a number of important considerations and constraints with respect to the development of a cruise berthing facility at this site, including:

- The top of "The Wall" (~ 60 ft depth) represents a practical limit for the project footprint (construction beyond this depth pushes the limits of technical and economic feasibility).
- Dredging of the nearshore area will be required to create sufficient depths for large cruise ships, which have drafts of 28 to 33 ft. There are a number of potential impacts associated with dredging, as noted below:
  - In the absence of a coral relocation program, approximately 6 hectares of coral reef substrate located within the dredging and land reclamation area footprints will be destroyed. In addition, the project will result in a loss of "connectivity" between the reefs to the North and South of the project, with associated impacts on marine life.
  - Elevated turbidity and sedimentation levels will occur during dredging and construction. Similarly, project operations (cruise ship traffic) will result in some level of sediment re-suspension, turbidity and sedimentation. Elevated turbidity levels will put additional stress on the adjacent coral reefs and impact existing/ongoing watersports activities in the George Town Harbour area.
  - Although some of the dredged material will be used as fill for the land reclamation area, material will need to be disposed offshore through direct pumping or barge dumping. The disposed material will also result in a turbidity plume.
  - Dredging may result localized increases, or decreases, in wave exposure along the shoreline of George Town; this will depend upon the dredging footprint, as well as the wave conditions.
  - The dredged basin may create a "sediment trap," with the potential requirement for maintenance dredging.
- The presence of calcareous sediments (in particular, uncertainty regarding the extent and strength of cemented materials) is an important consideration with respect to the design and cost of the project, with potential impacts on dredging methods and pile design.
- The exposure of the berths to Nor'westers will result in a certain amount of operational "downtime" (i.e. when wave action causes vessel motions in excess of safe operating limits);
- The potential exposure to a severe hurricane or earthquake will be a critical consideration in the design of the marine structures and land reclamation works. Inadequate design could result in significant damage to the facilities, and an extended period of downtime when cruise ships cannot call at Grand Cayman.
- Given the proximity of the cruise berthing facility to the central business district of George Town, there is potential for increased vehicular and pedestrian conflicts

These factors were critical considerations in the completion of the environmental impact assessment for the proposed CBF, including the development and assessment of alternative layouts.



Figure 4.4 – Overview of Key Site Conditions and Constraints

5.0 PROPOSED PROJECT AND OVERVIEW OF CONCERNS

5.1 Summary of Functional/Design Requirements

As summarized in Chapter 2, the Strategic Outline Case (CIG, 2013) and Outline Business Case (PwC, 2013) describe the strategic aims, overall objectives and constraints related to the implementation of the proposed project. These requirements, and other project principles, have been confirmed and further developed/refined through subsequent discussions with PwC and the CIG, as reported in PwC's (2015) Presentation to Cabinet.

The following bullet points highlight key functional/design requirements for the proposed cruise berthing facility which are of particular relevance to the present EIA study:

- The only feasible location for the proposed CBF is in George Town Harbour;
- Two piers/four berths are required, and both piers must be constructed together;
- Two berths must be able to accommodate Oasis class vessels;
- Design and construction must limit negative impacts on the natural environment;
- The facility must be designed to resist/withstand Nor'westers and hurricanes.
- The facility must allow for continuing cargo operations by PACI.

These functional/design requirements were critical considerations in the development and assessment of alternatives for the proposed project, as summarized in Chapter 7 and Appendix A of this report.

5.2 Proposed Project

5.2.1 Project Design Overview

The EIA study led to the development of a final concept layout for the proposed cruise berthing facility that provides a balance between functional and cost considerations, with reduced environmental impacts as compared to the project layout presented in the Outline Business Case (PwC, 2013). The final concept layout is shown in **Figure 5.1**, and includes the following key elements:

- Dredging of berth pockets for the cruise vessels to depths of 35 feet and 36.5 feet relative to Chart Datum at the south and north sides of the port, respectively. The total dredge volume will be approximately 333,000 yd^3 (255,000 m^3).
- Two piers with berths for four large cruise ships (two suitable for *Oasis* class vessels). The piers have nominal lengths of 1000 ft (305 m) and a width of 60 ft (18 m). The pier structure will likely consist of a concrete deck supported by concrete piles with a bent spacing of

approximately 30 ft (9 m). There are a total of 366 piles in the conceptual design, each 3 ft (1 m) in diameter and an approximate length of 120 ft (37 m). The piles will be driven, socketed and anchored into the seabed. Each bent will be made up of a cast-in-place concrete cap with pre-cast concrete deck panels spanning between bents. A cast-in-place wear surface will be constructed on top of the deck panels. The piers have an elevation of +10 ft (+3 m) relative to GCVD54 National Datum.

- The berthing fenders will be fastened to the pile caps, and be located at 60 ft (18 m) intervals.
- Mooring dolphins (three at North pier; two at South pier) are proposed at the outer end of the piers. The dolphins will be constructed of 10 foot diameter steel monopiles, each 140 ft (43 m) long and driven, socketed and anchored into the underlying seabed.
- Approximately 7.7 acres (3.1 ha) of new land will be created using approximately 164,000 yd^3 (125,000 m^3) of the dredged materials. The remainder of the dredged materials (174,000 yd^3, 133,000 m^3) will be disposed of offshore. The perimeter of the reclamation area will consist of a vertical bulkhead wall composed of a continuous pipe piles, topped with a concrete cap. The top of the cap is anticipated to have an elevation of +10 ft/+3 m (GCVD54 Datum). The piles have been assumed to have a length of approximately 100 ft (30 m).
- The dredged material in the reclamation will be contained by means of a rock fill containment dike located landwards of the bulkhead wall. A continuous pipe pile anchor wall will be located within the dike material and tied to the bulkhead wall by means of tie rod walers.
- A 460 ft (140 m) quay wall for smaller cruise ships and RO/RO vessels will be constructed, along with a 250 ft (76 m) extension to north tender dock and a 310 ft (95 m) extension to south cargo dock.
- A new RO/RO ramp will be built in the centre of the reclamation area (between the piers) with a width of approximately 75 ft (23 m).
- Basic landside improvements will consist of a flood protection wall, site grading/drainage and basic servicing.
- The outer edge of the reclamation area will consist of a 75 ft (23 m) wide concrete promenade to provide access to the piers by the cruise ship passengers and support crew.
- In the conceptual design, a large portion of the reclamation area will be sloped seawards for direct drainage of stormwater into the sea, while the remainder will slope eastward to a stormwater drain. The drain discharges to the sea at the northern and southern edges of the reclamation area.

Two of the existing vessel anchorage points nearest the project site will be removed. After construction, the port will be able to accommodate four vessels at berth and two vessels at anchorage. When more than six cruise ships arrive at Grand Cayman (the presently occurs approximately 10 to 15 days per year), the additional vessels will need to remain under engine offshore.

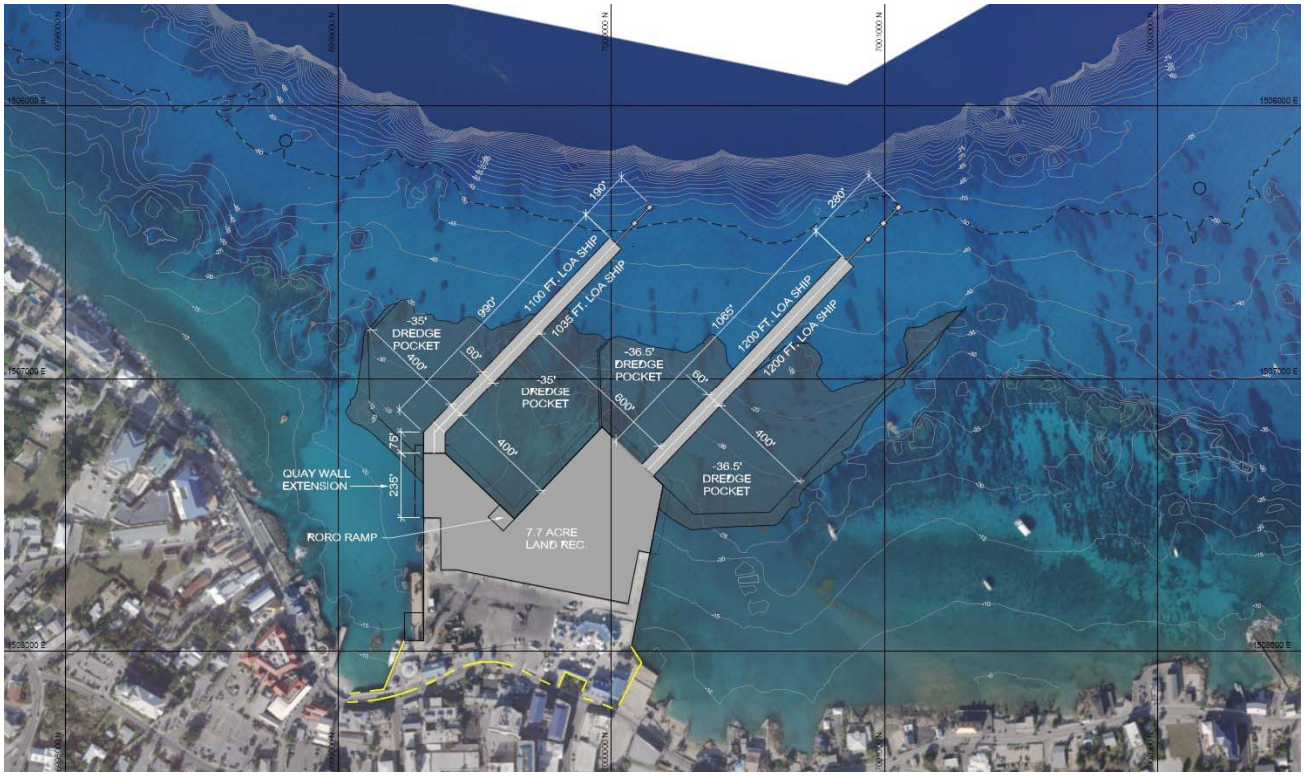


Figure 5.1 - Final Concept Layout

A "design" passenger volume of 14,300 passengers per day was assumed for the proposed facility for the purposes of the EIA study. This value represents the estimated "85% exceedance level" during the cruise season (it will be exceeded on very busy days - nominally 15% of the time). The estimate is based on a review of passenger volume data from PACI for the past five years (total of 1.4 to 1.6M cruise passengers per year from 2010 to 2014), and assumes 30% growth in passenger volumes over the project life. It is noted that the OBC (PwC, 2013) considered "baseline" and "optimistic" growth rates of 1-3%/year, corresponding to 20-60% growth over a 20 year period, with a cap at 2.3M passengers per year. The maximum capacity for arriving passengers will be dependent upon the planning and design of landside infrastructure and facilities, which is beyond the scope of the EIA study.

5.2.2 Dredging

Regarding potential environmental impacts, many of the concerns relate to the proposed dredging and land reclamation works, the estimated quantities of which are summarized below:

- Total project footprint ~ 32.5 acres (13.2 ha), including:
  - Dredging footprint ~ 23.0 acres (9.3 ha);
  - Land reclamation footprint ~ 7.7 acres (3.1 ha);

  - Pier footprints (beyond dredging) ~ 1.8 acres (0.7 ha)
- Dredging volume ~ 333,000 yd^3 (255,000 m^3)
- Dredge disposal volume ~174,000 yd^3 (133,000 m^3)
- Dredge fill placed in the reclamation area ~164,000 yd^3 (125,000 m^3)

Based on a review of available information regarding the subsurface conditions, it is anticipated that either hydraulic or mechanical dredging may be feasible for this project. Hydraulic dredging would likely be undertaken using a large cutter suction dredge (CSD), while mechanical dredging would likely be undertaken using a large backhoe dredge (BHD). Figure 5.2 presents photographs of a CSD and BHD.

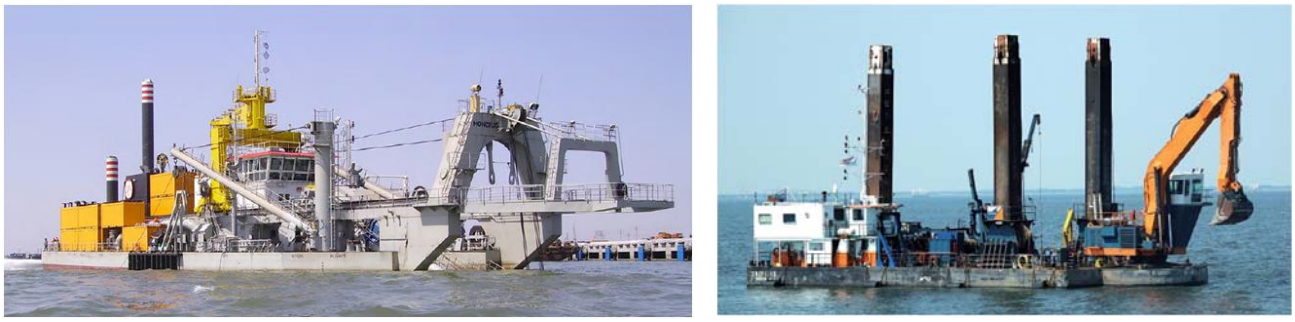


Figure 5.2 Cutter Suction Dredge [left] and Backhoe Dredge [right]

A cutter suction dredge is a dredge that has a large rotating cutter head that is lowered to the seabed to loosen the sediment. The sediment and seawater is then sucked up by means of a suction inlet pipe adjacent to the cutter head, and the resulting slurry is pumped to the reclamation area or disposal site. Hydraulic dredging with a CSD is a relatively fast operation, but generates large volumes of water (dredge slurry may be 5-25% solids, depending on the nature of the material being dredged). The estimated duration of a CSD operation for this project is in the order of 4 to 6 weeks. The primary sources of turbidity created by a CSD are the cutter head on the seabed and suspended sediment in the process water discharged from the reclamation area.

Mechanical dredging involves the use of a clam shell or bucket that is lowered to the seabed to "grab" the soils. The material is then lifted through the water column and placed into a barge for transport to/disposal at the reclamation area or offshore disposal site. Mechanical dredging is generally slower then hydraulic dredging (estimated duration in the order of 12 to 16 weeks for this project), but does not generate large volumes of water. The primary source of turbidity is at the dredge itself, as the bucket is pulled up through the water column.

Discussions with several dredging companies have indicated that a mechanical dredging operation would likely be employed for this project given the volume and type of material to be dredged. In addition, the environmental impacts associated with dredging are expected to be less with a mechanical dredging operation. As such, mechanical dredging is recommended for this project.

Regardless of the dredging method and equipment adopted, best practice generally involves the use of real time monitoring and adaptive management techniques to minimize turbidity and sedimentation associated with dredging, reclamation and disposal operations. Proposed turbidity and sedimentation thresholds have been developed and are included in the draft Environmental Management Plan (EMP), which is included as Section III of the Environmental Statement. Should monitoring detect turbidity or sedimentation levels in excess of the specified threshold conditions, the Contractor would be required to adjust, modify or cease operations.

Finally, it is noted that the absence of a comprehensive subsurface investigation at the project site represents an uncertainty with respect to the size and type of dredge required. Additional subsurface investigations are recommended to address this uncertainty.

5.2.3 Dredged Material Disposal

As noted previously, the excess volume is estimated to be in the order of 174,000 cubic yards (133,000 cubic metres). Various options may be feasible for the disposal of excess dredged material, including disposal/dumping at an offshore location or disposal at an onshore location.

Empirical calculations and numerical model simulations were completed to assess the anticipated characteristics of turbidity plumes associated with dredging and land reclamation works under the following scenarios:

- Turbidity generated by dredge (CSD or BHD);
- Turbidity generated by overflow of CSD process water from land reclamation area;
- Turbidity generated by offshore disposal (pipeline or barge) beyond "The Wall".

These results are summarized in Chapter 11 and Appendix D.2 of the Environmental Statement.

Onshore disposal would be more complicated and expensive than offshore disposal, but could provide the opportunity to process the material for sale as fill in the future. Onshore disposal is more likely to be a viable option with a mechanical dredging operation than with a hydraulic dredging operation (dealing with the huge volumes of water generated by a CSD would be a particular challenge. The CIG has identified several onshore sites in reasonable proximity to the project site that may be available to allow processing of the dredged materials.

The processing operation would require the construction of a containment dike to allow settlement and dewatering of the sediment. In addition, a suitable discharge path for the discharge water to return to the sea would be required. For a hydraulic dredging operation, the slurry would be pumped via a large diameter pipeline to the disposal site (with various challenges associated with road crossings, etc.). For a mechanical dredging operation, multiple handling of the dredged material (dredge bucket → barge →shore → truck → disposal site) would be required, with significant truck traffic through George Town.

5.3 Overview of Environmental Concerns

The following bullet points highlight key environmental concerns identified in previous studies, and through the stakeholder engagement and public consultation process completed for the EIA:

- Damage/destruction of coral reefs and associated marine habitat/ecology;
- Increased wave action and flooding along the George Town waterfront;
- Requirement for ongoing maintenance dredging due to sedimentation;
- Impacts on (in particular, erosion of) Seven Mile Beach;
- Increased turbidity due to project construction and operations, and impact on coral reefs and marine habitat/ecology;
- Increased pollution (spills, runoff, emissions, noise) and associated degradation of natural environment.

These key environmental concerns (and others) have been addressed as part of the EIA.

5.4 Overview of Socio-Economic Concerns

The following bullet points highlight key socio-economic concerns identified in previous studies, and through the stakeholder engagement and public consultation process completed for the EIA:

- Reduction/loss of tender boat operations;
- Loss of business for snorkel, dive and water sports operators during construction;
- Reduction in quality of snorkelling and diving experience due to reduced water quality and coral reef health, and associated loss of business;
- Disruption to cruise and cargo operations during construction;
- Increase in pedestrian and vehicular traffic on Harbour Drive and in central George Town;
- Resources required to support growth in cruise traffic.

These key socio-economic concerns (and others) have been addressed as part of the EIA.

6.0 STAKEHOLDER ENGAGEMENT AND PUBLIC CONSULTATION

6.1 Introduction

The Environmental Impact Assessment study included a comprehensive stakeholder engagement and public consultation process. Stakeholder consultations were undertaken to ascertain awareness of the proposed project, perceptions on the potential impacts on communities/groups, socio-economic, cultural/heritage landscape and the natural environment. A summary of this process, and the perceptions of stakeholders, are presented below. Additional information is provided in **Appendix 1**.

6.2 Methodology

Interviews and surveys were the main methods used in consultations. Questionnaires were administered to the several stakeholder groups identified in **Table 6.1**. Households were used to determine overall sample size for the general public as it allows for a greater level of participation from a wider cross-section of residents. Households were targeted across all Grand Cayman (regional level) with representative sample size based on population distribution by district. The local study area which includes areas within 1.2 miles (2km) of the project site and the wider George Town District accounted for the largest sample size. In addition to the general public, key stakeholder interviews were conducted with government and non-government stakeholders.

Table 6.1 Stakeholder groups engaged in consultations

Stakeholder Group	Description of Stakeholders	Number of Participants
General Public	Households George Town (167); West Bay (64); Bodden Town (60); North Side (9); East End (8)	308
Business Stakeholders	Tender boat operators (Captains and Linesmen)	12
	George Town Business Operators	16
	Water Sports operators (Independent)	11
	Transportation service providers	5
	George Town Dive Shops	9
Industry Groups	Chamber of Commerce	62
	Land & Sea Cooperative	1
	Cruise Lines (Carnival, Disney, Norwegian and Royal)	4
Cayman Islands Government	Port Authority of the Cayman Islands (PACI)	1
	National Roads Authority (NRA)	1
	Department of Tourism	1
	Department of Planning	1
	Cayman Islands National Museum	1
Non-government Organizations	Cayman National Trust	1
	Cayman Eco	1

Questionnaires customized to each stakeholder group and consisting of closed and open-ended questions were used in surveys and as interview guides. Stakeholder consultations were ongoing between June and December 2014. The following tasks were undertaken:

- Survey of business stakeholders in George Town were June 19 -24, 2014;
- Survey of households were conducted on weekends of June 28 to July 27, 2014;
- Online survey of selected business stakeholders was July 16-24, 2014;
- Chamber of Commerce administered an online survey to its membership September 15-19, 2014;
- Meetings with cruise industry representatives were October 16-28, 2014;
- Survey of selected watersport operators on direct use economic valuation of George Town Harbour Reef was December 1-16, 2014.

Option A, the preferred layout identified in the OBC (PwC, 2013) and the Final EIA Terms of Reference (MM, 2013), was used for all stakeholder consultations except for consultations with the cruise lines. Three concepts were shared with cruise lines (Concepts A, B and C).

A public meeting reporting the preliminary findings of the EIA and soliciting comments from the public (to be held on June 9, 2014) will be also be incorporated in the consultation process prior to the production of the final ES. Feedback from the Steering Committee (SC) and Environmental Advisory Board (EAB), the CIG bodiess overseeing the engineering and environmental studies, will also be incorporated during the review and public consultation process. The SC is chaired by the Ministry of Tourism, while the EAB is chaired by the Department of Environment.

6.3 Stakeholder Perceptions

6.3.1 Selected Government Agencies

All CIG stakeholders engaged identified the potential macro-economic benefits from increased taxes as a result of increased numbers of cruise visitors because of the project. It was also noted that additional "spin-off" benefits are also likely. Opportunity to develop other attractions and for increased time for land-based activities with non-boat tendering for visitors to disembark from ships were also identified as potential benefits.

A PACI representative noted that the project is the preferred option of cruise lines calling in the Cayman Islands as the pier is considered safer for passengers than the current practice of tendering.

CIG stakeholders' concerns were related to departmental and agency capability to meet the increasing demands on existing resources. PACI noted that while the organisation can likely handle small incremental changes, in the long-term it will become increasingly difficult and

expensive to handle the increased capacity. NRA noted that financial resources to improve the capacity of roadways will be required.

The Department of Tourism expressed concern about overexploitation of the Cayman Island's limited resources and added strain on tourism infrastructure and attractions.

Key project considerations noted by CIG stakeholders include the following:

- Need for long-term strategic plan in order for cargo and cruise operations to safely co-exist. Present night-time operations for cargo can safely continue to co-exist with cruise for the next 10-12 years, however, planning for beyond is needed. Refer to Appendix M (Cruise and Cargo Report) for additional information.
- Need to acquire additional human and financial resources for security purposes, tugs, marine pilots, etc.
- Insurance coverage will be required for new berthing facilities. Currently insurance coverage is presumed a liability of tender operations.
- Measures to deal with potential conflicts during peak periods of traffic, including tourist related traffic, especially on days when ships stay at berth later than usual. Refer to Appendix L (Traffic and Congestion Report) for additional information.
- Increased security and access by emergency services (police, fire, etc.) to an area congested with people will be needed.
- Funding to increase capacity of road networks and other land-side development including infrastructural capacity, site functionality, security, street/road capacity, wastewater and solid waste management
- Construction risks should be managed in such a way that they do not have long-term impacts on the environment.
- Concern was expressed about the potential for dredging and other construction related activities to alter the marine environment and the impact on coastal resources, especially Seven Mile Beach, the reefs .e.g. Cheeseburger Reef; air and water quality; and ship wreck sites.

6.3.2 Non-Government Organizations (NGOs)

Representatives of the Cayman National Trust and Cayman Eco were interviewed. The Cayman National Trust is a charity organisation that promotes the historic and environmental preservation of Caymanian resources and the establishment of protected areas. Cayman Eco is a clearing house for environmental information. The Cayman National Trust identified the following potential positive impacts of the proposed project:

- Likely increase in business activities for transportation groups/associations;

- Port will be able to generate revenues through landing fees;
- Opportunity for the government to negotiate closing down of on-ship restaurants for specified periods to facilitate more spending on island.

Concerns about the project identified by the NGOs are:

- Increase in the volume of persons and likely conflicts;
- Likely to be very limited benefits to locals. It was felt that people should be made aware of who will lose and who will gain as funding constraints are likely to determine who gets greater benefits;
- Possibility for increasing crime and other social ills;
- If cruise visitors can walk on and off easily from ship, they will spend less in Cayman. Most persons will go back on ship to eat as it is free and Cayman is expensive;
- There is a clear absence of a sustainable business plan; the project is more of a 'build, people will come' approach;
- Cruise ship benefits or expected outcomes may not materialize;
- Existing infrastructure is inadequate to support expected changes;
- There is no comprehensive development plan to address infrastructure deficiencies, e.g. there will be safety concerns as pedestrian facilities are inadequate. Similarly tourists do not have a keen sense of safety when using roadways and, as such, motorists are faced with challenges associated with safety;
- The project represents a sacrifice of high-end tourism for low-end tourism....dive operators need more stay over tourist/visitors. They contribute more financially to the economy;
- Tenders will lose jobs, who will offer them new jobs or adequate compensation?
- Security is currently lacking at the port, and with increased port traffic how will movement be managed to ensure no one is put at risk? What measures are being put in place to ensure security?
- The destruction and loss of heritage sites and reefs (e.g. Cheeseburger Reef). This will negatively impact visitor experience. It was felt that tourists come to the Cayman Islands because of its natural resources, therefore destruction and depletion of these resources over time will result in loss of visitors;
- Changes in water flow will reduce water quality;
- Wave action will impact deposition and erosion, likely destroying coastal features;
- Berthing is likely to increase siltation, smothering reefs, killing coastal resources and wildlife;
- It was felt that alternative sites should be examined;

- The balance between cruise ship demands and returns should be properly examined as the environmental impacts and other resultant impacts, e.g. crime and loss of culture can far outweigh immediate economic benefits;
- This project represents a sort of 'love them and leave them' approach. Cruise ship operators have very high demands, however if attractions and resources become compromised, they will simply take their business elsewhere.

6.3.3 Industry Groups

A representative of the Land & Sea Cooperative (LSC) was interviewed. The Land & Sea Cooperative is an umbrella organisation for local service/tour operators. The LSC identified potential positive impacts similar to other stakeholders, including:

- Improved facilities for visitors and reduced waiting times;
- Increased competitiveness for Cayman as a viable cruise ship destination;
- More economic growth for Cayman and all interested stakeholders, including business groups, service providers, etc.

Concerns and potential negative impacts that were identified by LSC were also consistent with the views of NGOs and CIG stakeholders. Other comments/concerns identified by LSC include:

- The proposed location is not suitable as the impact from wave action on the facilities and George Town are not being properly considered. It is believed that storm surges have the potential to cause widespread flooding and destruction in George Town and that deepening of the seafloor through dredging, will allow for larger surges to develop, causing more expansive destruction;
- How will dredging and construction affect Seven Mile Beach? Changes in wave direction (littoral drift) can cause deposition and removal of sediments affecting the coastline;
- Loss of dive spots is a major impact on diving community and Caymanian heritage;
- Loss of dive spots/wrecks/ reefs will be a loss of income for dive operators and potential loss of cruise revenues, as tourists come to the Cayman Islands for diving;
- How will safety of divers be addressed during the operational phase of the project? Ships and divers operating within the same harbour will undoubtedly pose a conflict and will pose threats to the safety of divers and visitors who wish to dive;
- There is potential for increase in crime, and possible tourist harassment due to limited local benefits;
- If cruise operators are major investors in project, it may take a very long time for locals to see any benefits at all, as the cruise operators must first be repaid for their investments;
- Tenders will lose jobs;

- Project is a conflict with cargo operations. How will cargo and normal cruise business operate with construction plans? Who will absorb costs for delays, loss of revenues?
- Capacity to manage the new facility does not currently exist; what measures will be put in place to address capacity issues on and offsite?
- There are four main tourist attractions on the island. These facilities cannot support the proposed volumes from the cruise ship and therefore new attractions will be needed;
- Increased conflict between cruise visitors and overnight visitors. Overnight guests have complained that they do not enjoy the attractions when cruise ships are in port as the attractions are over-crowded and there is overloading of attractions; they do not get to truly enjoy the experience, they say;
- Current road infrastructure is inadequate to handle existing traffic loads and pedestrians. What measures will be put in place to address the increased volumes expected with more cruise ships?
- New berthing facilities will likely result in tourists spending less time and money on the island as they are able to walk on and off the ship easily. This will create a backlash on the local economy as fewer businesses will generate revenue. Spin-off impacts could be quite adverse;
- Department of Tourism needs dedicated department for cruise ship tourism to allow for capitalisation of the marine culture of Cayman. There is a deliberate approach in looking at high-end versus low-end tourism, which is not good for the economy. Value needs to be placed on all types of tourist and tourism products.

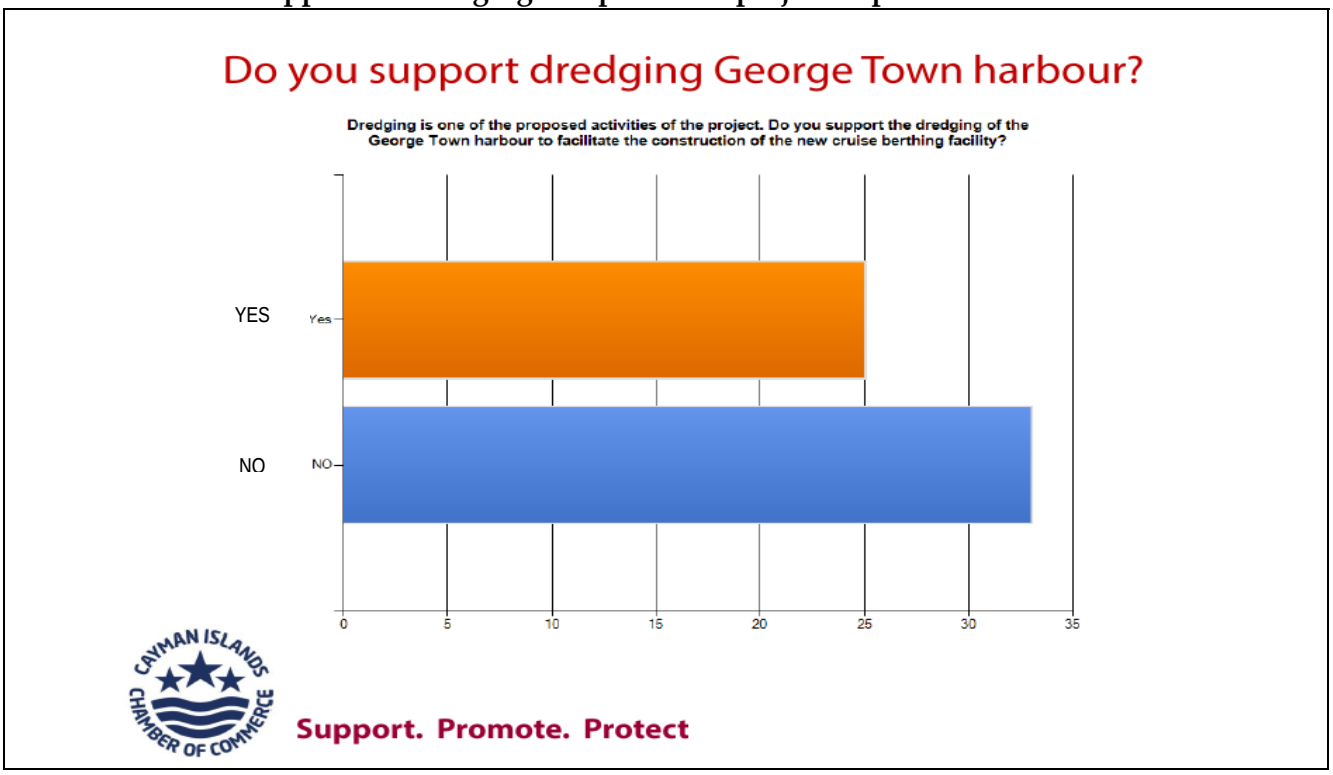
Another industry group that participated in stakeholder consultations was the Cayman Islands Chamber of Commerce (CoC). The CoC is a non-profit organization that exists to support, promote and protect Cayman businesses and the wider community. In an effort to present the perspectives of its membership, the Chamber of Commerce prepared and distributed a 17- question survey to its member on September 15 to October 31, 2015. The survey was distributed to 645 main contacts of Chamber member businesses and organizations across all industry sectors. A total of 62 valid responses were reportedly received and tabulated. The Chamber shared the aggregate results with the SIA team. It should be noted that the results reflect the views of participating CoC members and should not be regarded as the overall view of the Chamber's council or staff.

Member businesses/organizations that participated in the CoC's survey belong to a range of industries (including the financial services, retail, transportation, construction, hotel/resort, restaurant, health care, wholesale and manufacturing) and sizes (5-100 employees). The large majority of the surveys were completed by top level managers in participating member businesses/organizations. Thirty two percent (32%) of participants reported using/and or conducting business at the GTH port facilities. A third of them reportedly import/export goods for business. Others operate tours from the GTH port facility; conduct recreational/leisure activities on the waterfront; are employed at businesses operating from the cruise terminal facilities; and

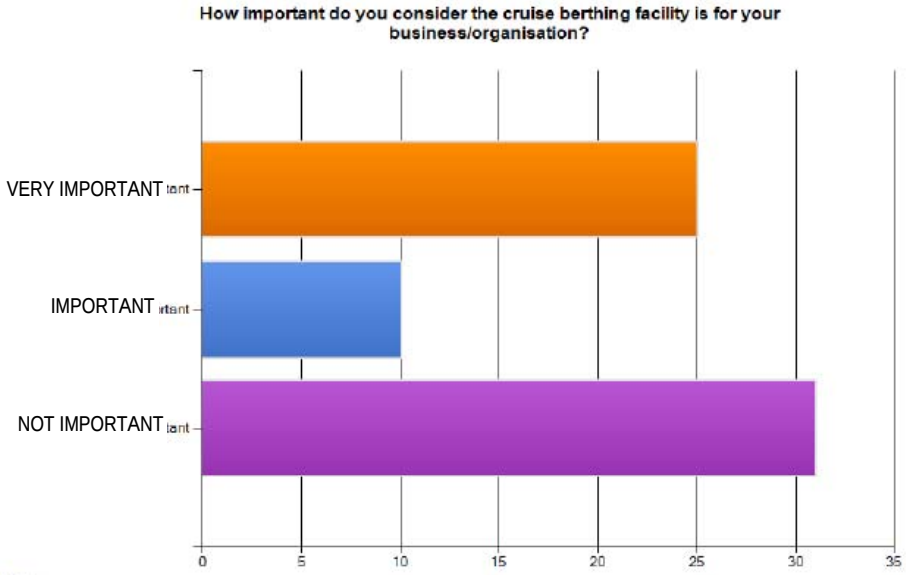
occasionally clear personal goods. Over two thirds of the businesses/organizations were located in George Town. One third of businesses/organisations reported that the present level of services and facilities now offered at the cargo/cruise port to be inadequate and have experienced problems dealing with the cargo/cruise terminal. The main issues identified were traffic, inadequate parking, delays, poor customer service, overcrowding and inadequate infrastructure and facilities. Refer to additional details in Appendix 1.

Perceptions of the project are summarized in **Table 6.2**. Participants were asked about their support for dredging of the GTH to facilitate the construction of the cruise berthing facility and the importance of the project to their business and the Cayman Island's economy. Of the 58 participants that responded to the question on dredging, 60% did not support dredging of the GTH. Fifty three percent (53%) of respondents thought the project was important/very important to their business/organization while 67% believed that the project was important/very important to the Cayman Island's economy.

Table 6.2 Support for dredging and perceived project importance of CoC members

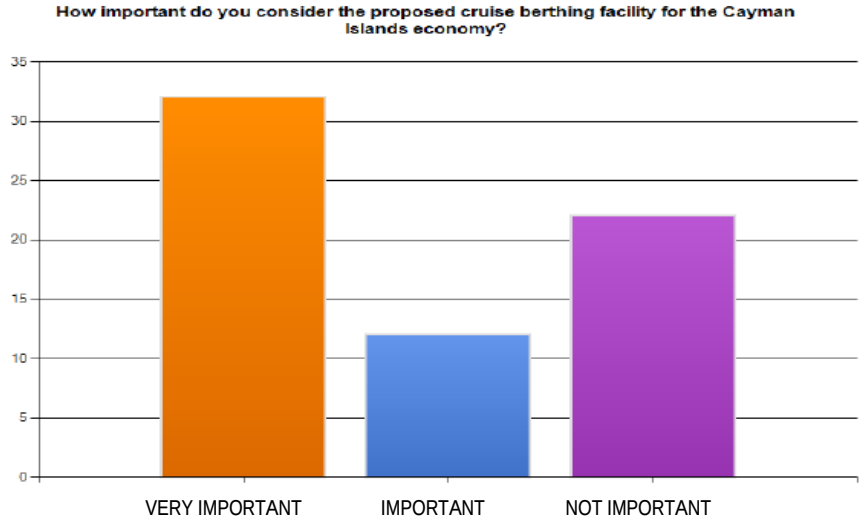


How important is cruise berthing to your business?



Support. Promote. Protect

How important is cruise berthing for the economy?



Support. Promote. Protect

General comments on the project from CoC members were both positive and negative and were consistent with those of other stakeholders. Negative comments were related to potential environmental impacts and related loss of income and livelihoods. It is also believed that without the project, local businesses will not be able to survive for much longer. Potential strain on existing resources, the capital investment required for the construction and operations, as well as supporting developments were also perceived as negative impacts. Positive comments were related to macro and micro economic benefits and the potential for better strategic position in the wider cruise tourism market.

6.3.4 Downtown George Town Business Community

Two groups within the downtown George Town area were included in consultations. The first group is made up of marine commercial entities. Nine marine commercial entities (dive, water excursion businesses) operating within the GTH participated in a survey that was administered in December 2014. The purpose of the survey was to obtain information on the potential economic impacts of the project on this group as a result of dredging the GTH. The second was the land-side commercial entities (including retail, souvenir retailer, jewelry retailer, attraction, the National Museum, and restaurant). Interviews were conducted with representatives of 15 businesses within 0.6 miles (1.0km) of the project site.

Results show that the marine commercial group was less in favour of the proposed project than the land-side commercial group.

The marine commercial group categorized six reef systems in the GTH as being among the best in the country (**Table 6.3**). These reef systems are located either within the proposed dredge footprint or immediately adjacent to the project construction zone.

Table 6.3 Best dive sights identified by George Town dive shops

George Town Dive Shops (n=9)			
Best in Island Dive Sites	**# of Respondents**	**% of Respondents**	**Located within GTH**
Eden Rock	4	44%	✓
Devil's Grotto	3	33%	✓
Turtle Reef	3	33%	
Cheeseburger/Soto's Reef	2	22%	✓
Sunset House	2	22%	
North and East sides of Cayman	2	22%	
Balboa Wreck	2	22%	✓
North Wall	1	11%	
Cali Wreck	1	11%	✓
Orange Canton	1	11%	
West side of Cayman	1	11%	Includes GTH

6.3.4.1 Perceived Project Impacts on Dive Shops

All nine entities believe that the construction of the project would impact their business. Seven eight percent (78%) indicate that they do not support dredging the harbour for construction of the piers, while one supports dredging "where necessary and kept to a minimum so less damage to our environment." Eight believed that the dredging would impact their business while one replied "don't think it will." The main dredging and project construction impacts identified are summarized in **Table 6.4**. Comments are summarized in **Table 6.5**.

Table 6.4 Perceived impact of dredging and project construction on dive shops

Impact of Dredging – GTH Dive Shops (n=9)		
Impact of Dredging/Construction of Project on Business	**# of Respondents**	**% of Respondents**
Destroy ecosystems and diminish/damage marine wildlife	4	44%
Poor Water Visibility due to silt and sediment	3	33%
May have to change dive sites (based on access and water quality)	3	33%
May put us out of business	3	33%
Significant disruption in business	3	33%
Pollution	2	22%
Construction traffic	2	22%
100% of business impacted on short term	2	22%
Construction Noise	1	11%
Longer travel to alternate dive sites	1	11%
Lower revenue and higher/enormous costs	1	11%
Significant disruption in courses, the main revenue earning activity	1	11%
Unable to operate in short term due to poor visibility	1	11%
Long term poor visibility as inclement weather stir up disturbed sediments	1	11%
Corals will be smothered	1	11%
Immediate, short term impact	1	11%
Long-term impact to dive businesses depending on extent of dredging	1	11%
Short-term may cause hiccups	1	11%
Long-term better for island	1	11%

Table 6.5 Comments from dive shops regarding project

Comments on Project by GTH Dive Shops (n=9)		
Comments	**# of Respondents**	**% of Respondents**
Cayman Islands tourism will grow from air arrivals	1	11%
Cruise pier is likely to bring minimal increase in passenger numbers and/or spend	2	22%
Air arrivals have more time and (broadly speaking) more money to spend	1	11%
Country's primary tourism focus should be on the airport and hotel	2	22%
Existing infrastructure (roads, waste, attractions, etc.) inadequate to handle increased cruise passenger arrivals	1	11%
Focus should be on low volume, high income air arrivals	1	11%
Our business uses Cheeseburger/Soto Reef over 90% of the time, removal will make diving at current location impossible	1	11%
Propeller wash from entering/departing ships will almost certainly make diving impossible in locations immediately north of the pier e.g. in the vicinity of Lobster Pot	1	11%
Strongly opposed as our location will not facilitate diving if dredging occurs	1	11%
Choose a deeper site as sand will likely refill dredged areas and in future this will require further dredging	1	11%
George Town is avoided on cruise days due to crowds. If streets are pedestrianised when cruise ships are in port how do we cater to the needs of overnight visitors?	1	11%
The tourism industry depends on diving. All the new hotels being built will need good dive sites and some of the better ones will be lost by this project	1	11%
Construction may hinder the very product we offer to cruise visitors	1	11%
Long-term impact to all tourism industry including retail shops in town	1	11%
The unknowns of dredging or building a dock are too many	1	11%
More and more customers are seeking the unique and less crowded destinations. The dock will put Cayman at the same level as other islands hence we may lose our character as a different island. Construction in George Town and other areas has started us down that path. Cayman Islands will be no different from St. Thomas, St. Martin or any other island destination.	1	11%
Should look at the environmental impact of tender operators going back and forth in addition to dredging impact	1	11%

6.3.4.2 Project Awareness and Perceived Impacts among GT land-side commercial stakeholders

Ninety three (93%) percent of respondents believes that the project is important-very important to the Cayman Islands and all thought it was important-very important to their business. Sixty

percent (60%) of the businesses indicated that they support dredging of GTH to facilitate construction of the piers while 20% do not support dredging (**Figure 6.1**). The main reasons given for supporting dredging were the level of importance of the project, which was related to the importance of the tourism sector and the direct and indirect income anticipated for businesses and the government. Environmental destruction or damage was the reason for not supporting dredging.

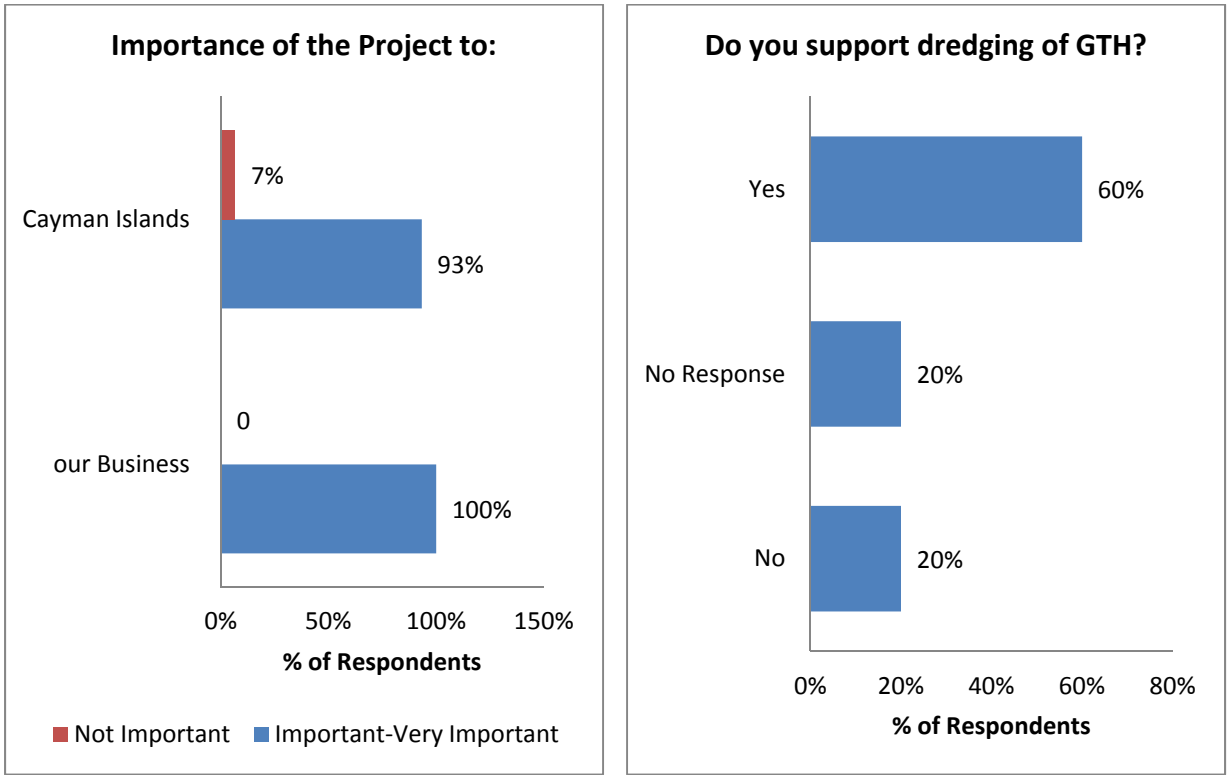


Figure 6.1 Views on the importance of the proposed project & support for dredging among GTH businesses interviewed

6.3.4.3 Perceived Project Impacts among GT Land-Side Commercial Stakeholders

During Construction

Participants were asked how they thought the project would impact selected environmental, socio-economic and cultural heritage receptors during and post construction. Responses are summarized in **Table 6.6** and **Table 6.7**. There was an average non-response rate of 53% for this question. Based on the receptors identified by the highest percentage of participants, perceived positive impacts during the construction phase of the project tend to be economic in nature, related to business and job opportunities. These include local job opportunities, local businesses and the Cayman economy. Participants thought both residents of Caymanian and Non-Caymanian status would be positively impacted during construction. Perceived negative impacts during construction were environmental receptors including coral reefs/coastal resources, noise levels in George Town and water quality, watersports and artisanal fishing. Participants believed that cruise tourism, cargo

operations and tender operations would also be negatively impacted. It was, however, felt that overnight tourism would not be affected. As it relates to cultural heritage, participants believed that ship wrecks would be negatively impacted but that buildings and monuments would not be impacted. Traffic and visual aesthetics were other negative impacts identified.

Table 6.6 Perceived impacts during construction (GT land-side commercial businesses)

During Construction Impacts (n=15)				
	Positively %	**Negatively %**	**No Effect %**	**Not Sure / Non-Response %**
Water quality		27	20	53
Coral Reefs/coastal resources		40	13	47
Noise Levels in George Town	7	47	7	40
Water Sports (Fishing, Diving, etc.)		40	13	47
Artisanal fishermen		47	13	40
Cruise tourism	2	20	13	53
Overnight tourism	7	13	33	47
Tenderers		40	7	53
Cargo operations	7	27	7	60
Job opportunities (locals)	53			47
Local businesses	40	7	7	47
Cayman's economy	47	7		47
Caymanians	40	13		47
Non-Caymanians	40	7	7	47
Visual aesthetics		27	20	53
Traffic	7	47		47
Ship wrecks		33	7	60
Heritage sites (monuments, buildings)		20	33	47

During Operations

Water sports, cruise tourism, cargo operations, visual aesthetics and cultural heritage receptors are believed to be positively impacted during the post-construction phase of the project as opposed to negatively impacted during the construction phase. It is believed that water quality and corals/coastal resources will continue to be negatively impacted as will traffic. The perception of the impact on tender operators was evenly split between positive and negative among participants.

Table 6.7 Perceived impacts post construction/operations (GT land-side commercial businesses)

Post Construction/Operations Impacts (n=15)				
	Positively %	**Negatively %**	**No Effect %**	**Not Sure / Non-Response %**
Water quality		33	13	53
Coral reefs/coastal resources		30	20	60
Noise levels in George Town	7	7	40	47
Water sports (Fishing, Diving, etc.)	33	13	7	47
Artisanal fishermen	13	20	7	60
Cruise tourism	47			53
Overnight tourism	7	7	33	53
Tenderers	20	20		60
Cargo operations	27	7	7	60
Job opportunities (locals)	53			47
Local businesses	47	7		47
Cayman's economy	47	7		47
Caymanians	47	7		47
Non-Caymanians	47	7		47
Visual aesthetics	27	7	13	53
Traffic	7	27	13	53
Ship wrecks	20	7	13	53
Heritage Sites (monuments, buildings)	20	7	13	60

Eighty percent (80%) of the GT business stakeholders believe that the project will impact their business. Increased sales/business from increased number of cruise passengers coming on land was the most prevalent response. One participant noted that the project will have positive long-term impacts on their business, while another noted that the dredging will impact cultural heritage sites.

6.3.5 Tender Operators

Structured interviews were conducted with 12 tender boat captains and linesmen in June 2014. In total 48 persons are employed by CMS' tender services operations. Each boat has a captain and two linesmen onboard. The operators interviewed have been with the company for an average of six years. Almost 60% of tender operators interviewed thought the level of service at the cruise terminal is currently adequate while 33% thought that they were inadequate. One person did not respond to this question. The main reasons given for considering the facilities inadequate were:

- Lack of shelter for visitors;
- Insufficient number of bathrooms;
- Long length of time it takes visitors to get on and off tender boats;
- Inadequate security to safeguard passengers;
- Lack of "proper information" for visitors.

Perceptions on improvements needed at the facility were:

- "Better docking facilities" and better access to and from ships for visitors;
- Shelter from the sun;
- A digital information monitor to provide information to visitors;
- Improved communication among all stakeholders as it relates to the arrival and departure of the ships was also recommended.

Approximately 27% of respondents noted that the goods available to tourist were too expensive and that they deter spending.

6.3.5.1 Perceived Project Impacts among Tender Operators

Sixty seven percent (67%) of respondents believed that dredging will destroy marine life and ecosystems and that this will make the area less attractive to tourists. One noted that if the environment will be destroyed, "it is not worth it." Others believe that divers' safety will be at risk.

Seventy five percent (75%) of participating tender operators believe that the proposed project is not very important (**Figure 6.2**). They believe that "the benefits of the project are uncertain and that if the attractions will be destroyed, then the trade-offs are not worth it." They also noted that they will lose their jobs. The remaining 25% believed that the project will generate revenues and create job opportunities.

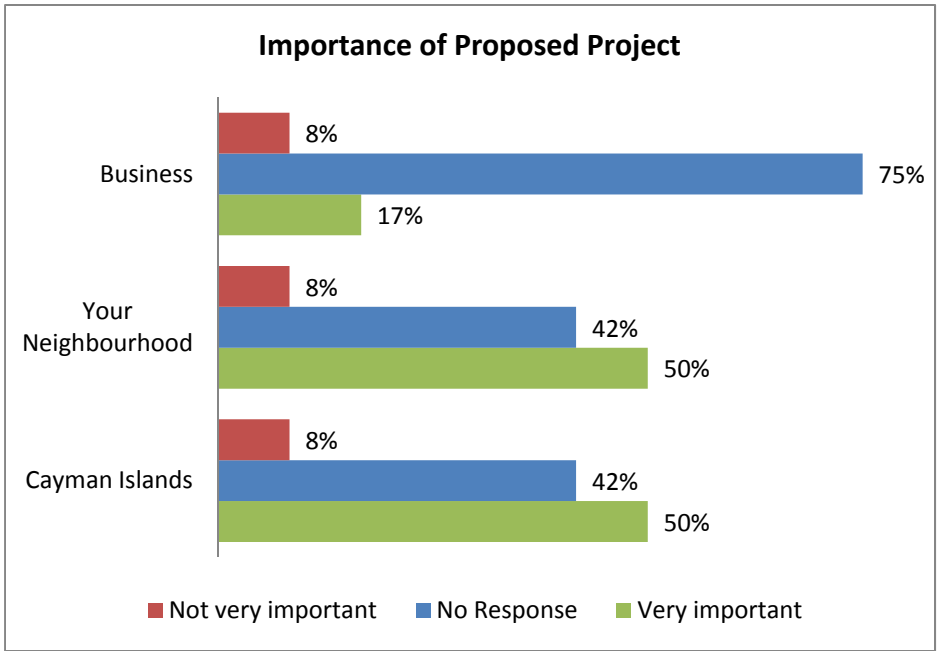


Figure 6.2 Views on the importance of the proposed project (Tender Operators)

When asked what measures should be put in place to mitigate negative impacts on the group, the following were the responses:

- One third of tender operators thought that their management company CMS should ensure all workers are placed in full-time jobs before fully pulling their services;
- Eight percent suggested compensation packages or assistance with obtaining alternative employment opportunities;
- One respondent thought that it "would be good if the company would still offer services" after CMS withdraw theirs.

The withdrawal of tender services has the potential for income losses for employees of US$557,000-787,000 per annum based on a 2:1 ratio of captains to linesmen.

Estimated direct financial losses to the owners of the tender business resulting from the loss of US$5.25 per manifested passenger are estimated at an average of US$5 million per year. This is based on reports that approximately 70% of landed cruise passengers in the past five years used local tendering services to get to and from ships.

6.3.6 Transportation Services (Tour Bus) Operators

6.3.6.1 Profile and Baseline

Five tour bus operators were interviewed on site at the cruise facility while they were awaiting the arrival of a cruise ship in June 2014. There were four males and one female. All except one were over 50 years old and had been operating for over 20 years. Operators provide services at other locations, including Spots for cruise ships in bad weather, hotels and the airport. One reported having a trade and business license to operate.

Four owned their buses while one was company-owned. Dolphin Discovery, Island Tours, Botanical Gardens, Sting Ray City, dive sites, Turtle Farm, Seven Mile Beach, Morgan's Harbour and Captain Boat were identified as the most popular destinations. They average four trips per day with 15-29 passengers.

Two operators felt that the infrastructure at the existing cruise terminal is inadequate to meet the needs of all interest groups. It was also noted that the alternative location at Spots was also inadequate. Parking, aesthetics, poor drainage in visitor areas during rainfall periods, and concerns about the safety of visitors with the overlap with the cargo sections of the port for boarding ground transportation were identified as deficiencies.

Two issues affecting the group are inadequate space for tour buses and competition from budget tour bus operators. It is believed that improved waiting facilities are needed at the port.

6.3.6.2 Project Awareness and Impacts

All respondents were aware of the proposed project, the main source of information being the media. Two were in favour of dredging but stated that they "are hoping it does not result in damage of other places especially Seven Mile Beach." One person did not support dredging noting that it *"may damage the marine environment."*

Three operators believe the project is very important to the Cayman Islands as *"cruise ships have said the island needs a pier and if this is not provided they will pull their services; we need the business."* One commented that they were in support of *"a more efficient and safe movement of visitors."*

Three operators provided the following comments on the impact to their sector:

- *"Very important, potential for increased revenues and visitors"*
- *"Very important as the various tour operators (e.g., Websters, Reliable, Tropicana and Majestic) will benefit"*
- *"Very important as all operators will get equal opportunity to earn money"*

General comments on the project included:

- *"There needs to be regulation put in place that prevents cruise ship operators from having direct say in the way pier projects are managed. They can give their requirements for safe docking of their vessels, but should not guide the process.*
- *Purpose of a terminal is that when bad weather takes place cruise ships can still safely dock. This project does nothing to change the current problem of bad weather and ships being unable to dock.*
- *South Sound is a better alternative and more persons would benefit as tourists will need to be bussed into Georgetown.*
- *There is need for a port, just not in this location, however not sure where is most suited. South Sound is a much safer harbour.*
- *Not in full support of this project, but Caymanians need this dock.*
- *Cheese Burger is a very important reef and is worth saving."*

6.3.7 Cruise Lines

Meetings were held with four cruise lines in October 2014. Records from three meetings were reviewed for their views on the proposed project design options and potential impacts. The concept layouts (Concepts A, B and C) presented to the cruise lines are discussed in Appendix A. Opinions provided by the various cruise lines are summarized below.

6.3.7.1 Cruise Line #1:

Comments were provided on the designs based on functionality and "commercial equivalence" of the proposed piers. It was noted that the two piers should be functional and have the same widths. Cruise Line #1 highlighted that "they would not invest in a project that they did not approve, nor would they make calls to such a project." Reference was made to a 2006 proposal that was prepared and submitted through a collaborative effort with cruise lines and the CIG.

A larger land area for reclamation was recommended by Cruise Line #1. The representatives argued that a larger land area would enable "more efficient landside operations for the cruise berthing facility." [Note: the cruise lines reviewed concept layouts that had smaller land reclamation areas (2 to 3.5 acres; 0.8 to 1.4 ha) than exists in the preferred concept (7.7 acres; 3.1 ha)]

The aging trend of passengers and increasing numbers with mobility issues were highlighted as issues to consider.

Comments on potential environmental impacts and mitigation of negative impacts were based on Cruise Line #1's experience. No evidence was provided at the time of the meeting. Coral relocation was cited as a feasible strategy that Cruise Line #1 has been engaged in for over 20 years with a success rate of 70-80%. Focus on live organisms, not rocks, was suggested.

It was noted that similar projects did not have long-term impacts from layers of fines (silt and sediments) from dredging as ship traffic will dissipate them once operations started.

6.3.7.2 Cruise Line #2:

Cruise Line #2 expressed frustration on the lack of progress over the past seven years since the last proposal. It was noted that their largest ship currently has to sail past George Town as the capacity of the existing facilities cannot support the ship. Layout designs that included piers that were too long and/or varied in performance levels and were considered unsuitable. It was recommended that the selected option should include potential to accommodate larger ships in the future. This cruise line expressed interest in financing and building a single pier design, but would consider financing two piers with measures to recoup costs from other users.

Additional comments/suggestions were provided on the technical designs and requirements based on various fleet types, weather conditions, space requirements for screening, etc.

A larger land area was proposed to accommodate terminal facilities. [Note: as indicated previously the cruise lines reviewed concept layouts with smaller reclamation areas that the preferred concept.]

The representatives noted that change in tendering services will result in increased rate of disembarkation, and associated impacts on landside services such as buses and taxis. Alternative models of transportation to meet the changed functional needs such as water taxis in addition to landside transportation were recommended.

6.3.7.3 Cruise Line #3

Similar to the others, Cruise Line #3 highlighted the functional and navigational requirements based on their fleet. Passenger walk was also an issue pointed out. Cruise Line #3 acknowledged the environmental issues associated with the project but highlighted that the design minimizing environmental impact is similar to one of their least successful locations, based on the length of passenger walk and pier width to cost ratio for people movers. It was also noted that the navigation aspects would need to be modelled to prove functionality.

Cruise Line #3 also raised questions on landside development and tender operators.

6.3.7.4 Cruise Line #4

Cruise line No. 4 expressed considerable interest in the project, but did not provide any significant technical feedback.

6.3.8 General Public (Households)

A total of 308 households were surveyed. All 308 surveys were completed resulting in a 100% response rate. Response rates for specific questions or parts of questions however varied.

6.3.8.1 General Profile of Participating Households

Fifty percent (50%) of respondents to the household surveys were female. Some 86% of respondents were between the ages of 19 and 59 years. The 40-49 age group accounted for the largest proportion at 30% followed by the 30-39 age group which accounted for 20% of respondents. Eleven percent (11%) of respondents belongs to the 60 years and over age group, the smallest age group represented among respondents.

College/university was the highest level of education attained for 32% of respondents, consistent with national educational levels of the labour force. Close to 28% indicated that they had post-secondary skills training while 32% had up to high school level education. Post-secondary levels were higher than the 20% national average while high school level was lower than the 39% national average. Some 6% of respondents attained up to primary level education while 1% indicated other.

6.3.8.2 Household Characteristics

The average household size among respondents was six persons, higher than local, regional and national averages. Thirty six percent (36%) of responding households were of sizes consistent with the national, local and regional averages of two and three, respectively. Over 90% had three or fewer children in their households and 55% had two or less adults.

Thirty four percent (34%) of respondents indicated that they currently reside in George Town (**Figure 6.3**). Some 22% reside in West Bay while 14% reside in Bodden Town and 5% in Prospect. Almost 60% of households had resided at their current residences for 12 years or less. Close to 24% have been residing in their homes for 13-26 years while 10% have resided there for over 26 years. Almost 55% of households reported owning their homes while 37% rent or lease their homes (**Table 6.8**).

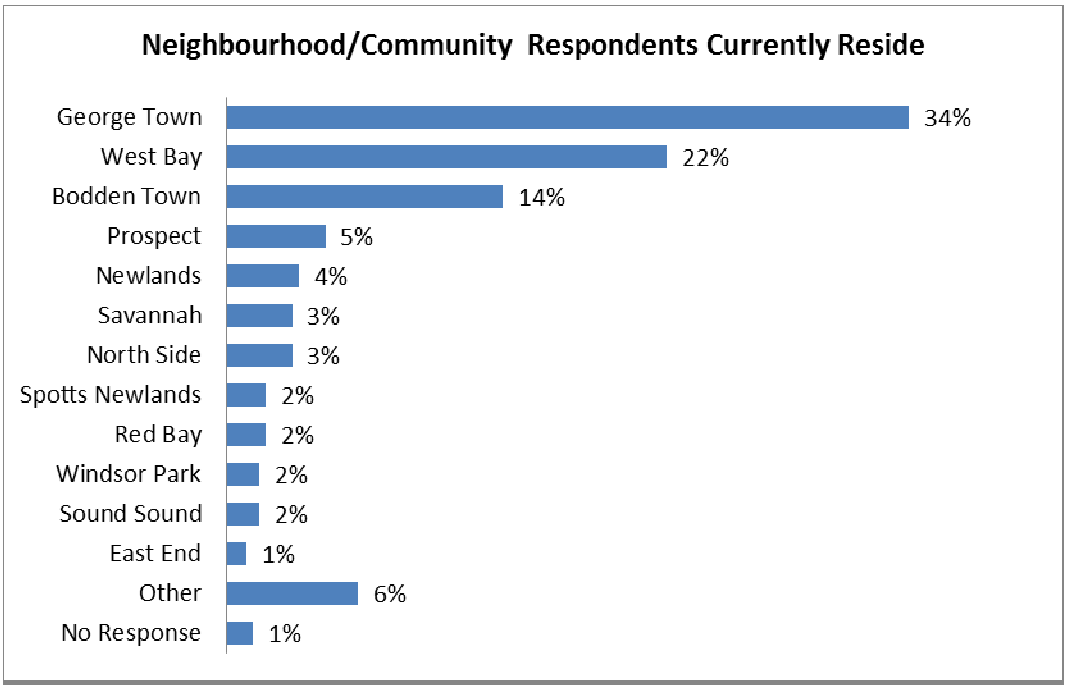


Figure 6.3 Neighbourhood/community where respondents currently reside

Table 6.8 Housing tenure among households

Housing Tenure among Households			
Dwelling Tenure	**Frequency**	**Percent**	**Cumulative Percent**
Own	169	54.9	55
Rent	113	36.7	92
Other	16	5.2	97
No Response	9	2.9	99.7
Don't know	1	0.3	100.0
Total	308	100.0	

Household-specific modes of transportation were also included in the survey. The data shows that 80% of households used private vehicles as their main mode of transportation. Ten percent (10%) travelled by bus, 4% walked and 3% cycled.

6.3.8.3 Economic Activities of Households

Employment

Eighty two percent (82%) of participants reported that they are employed. Of those employed, 83% have full-time employment while 5% worked part-time and 10% were self-employed (**Table 6.9**). **Table 6.10** summarizes the occupational level of respondents. It shows that 30% of respondents belong to the skilled/trade/technical/clerical/sales occupational level group. Fourteen percent (14%) belonged to the professional/large business owner/manager occupational level.

Four percent (4%) reported being unemployed, a rate that is two percentage points less than the national unemployment rate. Five percent reported being retired; three percent are students; and one percent housewives.

Table 6.9 Employment status of employed respondents (households)

Employment Status of Employed Respondents (Households)			
	Frequency	Percent	Cumulative Percent
Full-time	211	83	83
Self-employed	25	10	93
Part-time	13	5	98
Other	4	2	100
Total	253	100	

Table 6.10 Occupational skill level of respondents (households)

Occupational Skill level of Respondents (Households)			
	Frequency	Percent	Cumulative Percent
Unskilled/Labourer/Domestic	23	7	7
Semi-skilled/machine operators	17	6	13
Skilled/trade/technical/clerical/sales	93	30	43
Small farmer/micro-business owner	21	7	50
Small business owner/Manager/Administrator	19	6	56
Medium business owner/Manager/Semi-professional/ Large Farmer	12	4	60
Professional/ Large business owner/Manager	44	14	74
Unemployed/Housewife/Student/Retired	42	14	88
Other	28	9	97
No Response	9	3	100
Total	308	100	

Income

Approximately 80% of participants responded to the question on monthly income. The data shows that the lowest (< CI$799 and highest > $7,200) income categories each accounted for 5% of respondents (**Figure 6.4**{a}). Almost 50% earned between CI$2,400 and $4,799 per month. The >CI$3,200-$4,799 income category accounted for the largest proportion of respondents (18%). This was followed by the $2,400-$3,199 (16%) and $1,600-$2,399 (15%) categories.

Sixteen percent of all participating households reported having additional income other than employment. Rent, family, business, jobs and pension were among the main sources reported [**Figure 6.4** {b})

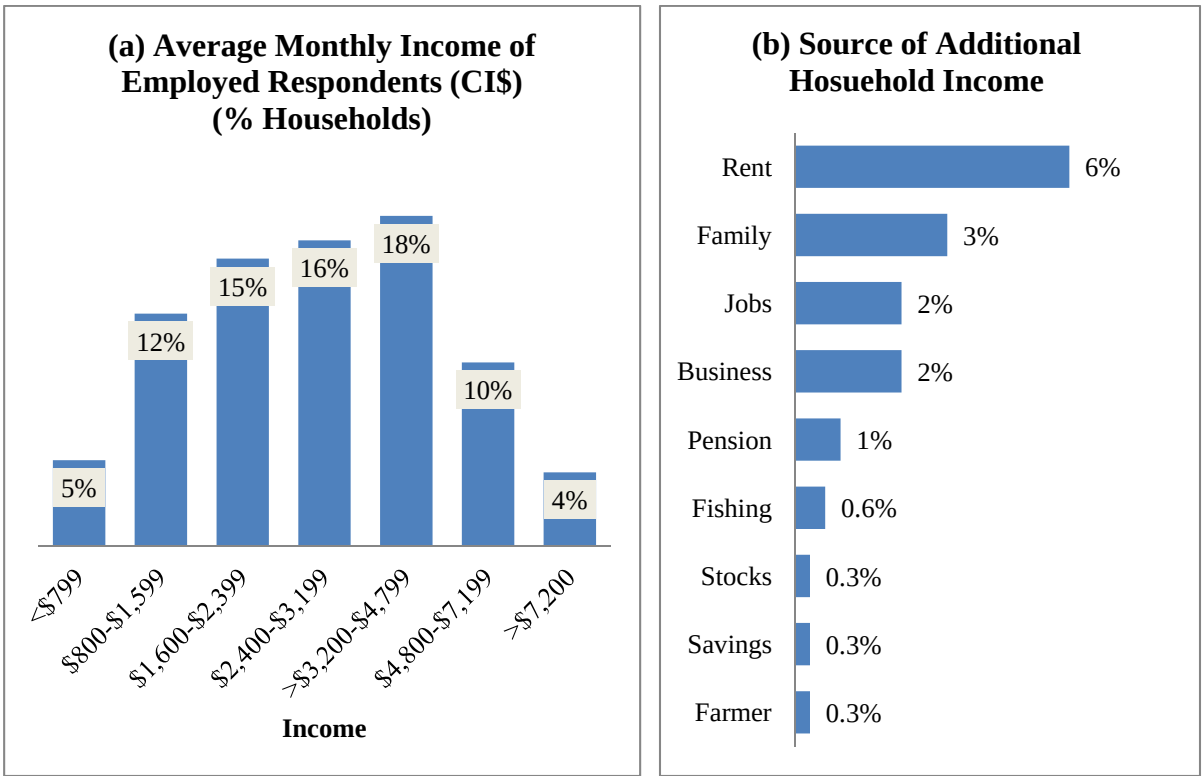


Figure 6.4 (a) Average monthly household income (b) main source of additional household income (CI$)

6.3.8.4 Community Development: Projects, People and Citizen Involvement

Information on community development and social linkages was obtained through household survey respondents' expressed appreciation for their neighbourhoods and participation in community activities. The quiet/peaceful nature of the neighbourhood was the characteristic with the highest number of respondents (**Table 6.11**). This was followed by access to services and place of work, which 21% of respondents indicated. Community cohesion (friendly people), safe and secure accounted for 14% and 11%, respectively while 10% valued the natural and cultural resources and aesthetics.

Table 6.11 Neighbourhood characteristics valued and appreciated by households

Neighbourhood Characteristics Valued and Appreciated by Households	
	Percent
Quiet/Peaceful	43%
Access to services/amenities/business/work	21%
Community Cohesion	14%
Safe/Secure/Privacy	11%
Nature/Beauty/Natural & Cultural Resources	10%
Other	2%

Households reported engaging in a range of recreational activities in their neighbourhoods (**Table 6.12**). Sporting activities including soccer/football, walking, and basketball at parks, stadiums and community centres, were most common. The beach and water sports activities including diving and sailing were also popular. Some heritage sites and attractions named by household respondents included Turtle Farm, Dolphin Cove, Hell, Rum Point, Botanical Garden, Smith Cove, Town Hall, and the auto museum.

Table 6.12 Recreational Activities of Households

Recreational activities of Households (n=308)		
Recreation Activity	Frequency	Percent
Parks & sports	126	41%
Beach	38	12%
Botanical gardens/attractions	26	8%
Church	20	6%
Restaurants, shopping, movies, etc.	9	3%
Water sports (sailing, diving, etc.)	8	3%

The main areas identified for improvements within the neighbourhoods of the SIA study are included in **Table 6.13**. Roads and drainage/flood control were the most common area of improvement that was identified by households. This was followed by community facilities and youth activities, community policing and the need for pedestrian-friendly improvements such as street lights, speed bumps and sidewalks.

Table 6.13 Desired neigbourhood improvements (households)

Desired Neighbourhood Improvements among Households (n=308)		
	Frequency	**Percent**
Roads & drainage	65	22%
Community facilities, youth activities (sports, parks, etc.)	58	19%
Community policing	26	9%
Street lighting/sidewalks/speed bumps	17	6%
Housing and lower rent	9	3%
Jobs/opportunities for Caymanians and Non-Caymanians	7	2%
Waste (garbage) management	6	2%
Mosquito control	5	2%
Awareness of wildlife and preservation	2	1%
Better maintained public launch ramps and docks & coastal improvements	2	1%
Bus service	2	1%

Neighbourhood/protection watch, area committees, home owners/strata associations, Red Cross and youth club were some organizations identified within the neighbourhoods in the SIA study area. However, on average less than 10% of households reported having membership in these

organizations. Voluntary organizations contribute to the communities through the provision of assistance to persons in need, including for food, training and spiritual support. Disaster relief, "keeping each other safe" and community counselling were other roles mentioned.

6.3.8.5 Natural Resource Use of Households

Community members reported using marine/coastal and terrestrial (land) natural resources in their communities. Approximately 98% believed that marine/coastal resources are important/very important while 94% believed terrestrial resources are important/very important (**Table 6.14**). Almost 70% of respondents reported using these resources (**Table 6.15**). Marine/coastal resources are mainly beaches, coral reefs and fishing grounds.

Table 6.14 Importance of natural resources (households)

Importance of Natural Resources						
	Important/ Very Important		Not Important		Don't Know/ No Response	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Marine/coastal	302	98	1	0.3	2	1
Terrestrial	288	94	11	4	5	2

Table 6.15 Utilization of natural resources (households)

Utilization of Natural Resources			
	Frequency	Percent	Cumulative Percent
No	88	29	29
No response	7	2	31
Yes	213	69	100
Total	308	100	

Natural resources are used for domestic, commercial and recreational purposes. Recreational use was the most common use among respondents accounting for 52% of total respondents (**Table 6.16**). Only 1% of households surveyed use resources for commercial purposes. Recreational uses of marine/coastal resources are mainly swimming, diving, sailing and water sports (refer to **Table 6.12**). Terrestrial resources such as the geologic outcrop at Hell, the Botanical Gardens, the Mastic Reserve and Barkers are attractions for site seeing.

Table 6.16 Purpose for use of natural resources (households)

Purpose for Use of Natural Resources		
	Frequency	**Percent**
Commercial	4	1.3
Domestic	78	25
Recreational	161	52

Note: Percentages will not total 100 as multiple responses were given

Natural Resources and Pollution Threats

An estimated 38% of respondents indicated that pollution threats exist within their communities (**Figure 6.5**). Pollution on land was identified by 13% of respondents. Water pollution was noted by 8%, another 2% noted air pollution while less than 1% noted noise pollution. Another 12% of respondents reported the existence of multiple threats. The main sources of pollution threats identified included:

- Land pollution: mainly from community members, improper disposal of garbage and the presence of the waste dump/landfill;
- Water pollution: boats and cars (oil/fuel leaks), development, improper garbage disposal, tourists and community members;
- Air pollution: emissions from cars and boats, community members and the waste landfill;
- Noise pollution: community members.

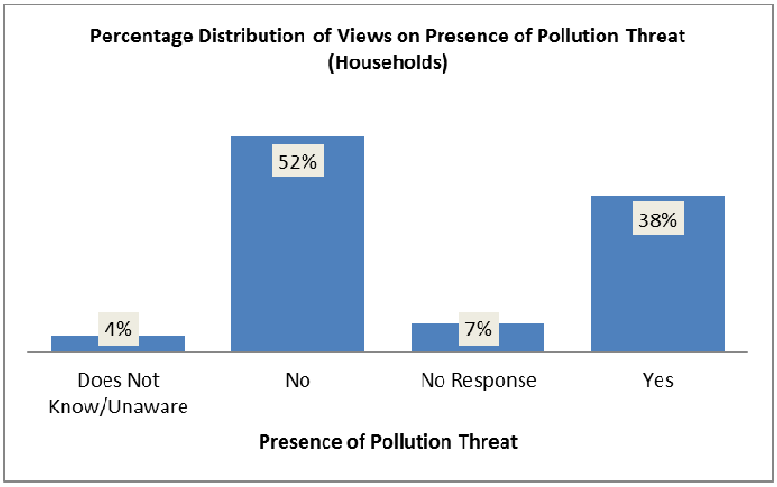


Figure 6.5 Percentage distribution of views on presence of pollution threat (households)

6.3.8.6 Household Project Awareness and Perceived Impacts

Almost 90% of households surveyed are aware of the proposed project (**Figure 6.6**(a)). The most common source of information on the project was the media (newspaper, television and radio). Other sources included community members (word of mouth) and the elected official, i.e., councillor. Over 85% of households believe that the project is important to very important to the Cayman Islands compared with 7% who believe that it is not important (**Figure 6.6** (b)). Less than 1% was not sure while 5% did not respond. When asked about importance to the neighbourhood where they live, 45% believe the project is important/very important while 23% felt that it was not important. Those unsure and did not respond represented 1% and 30% of households surveyed, respectively.

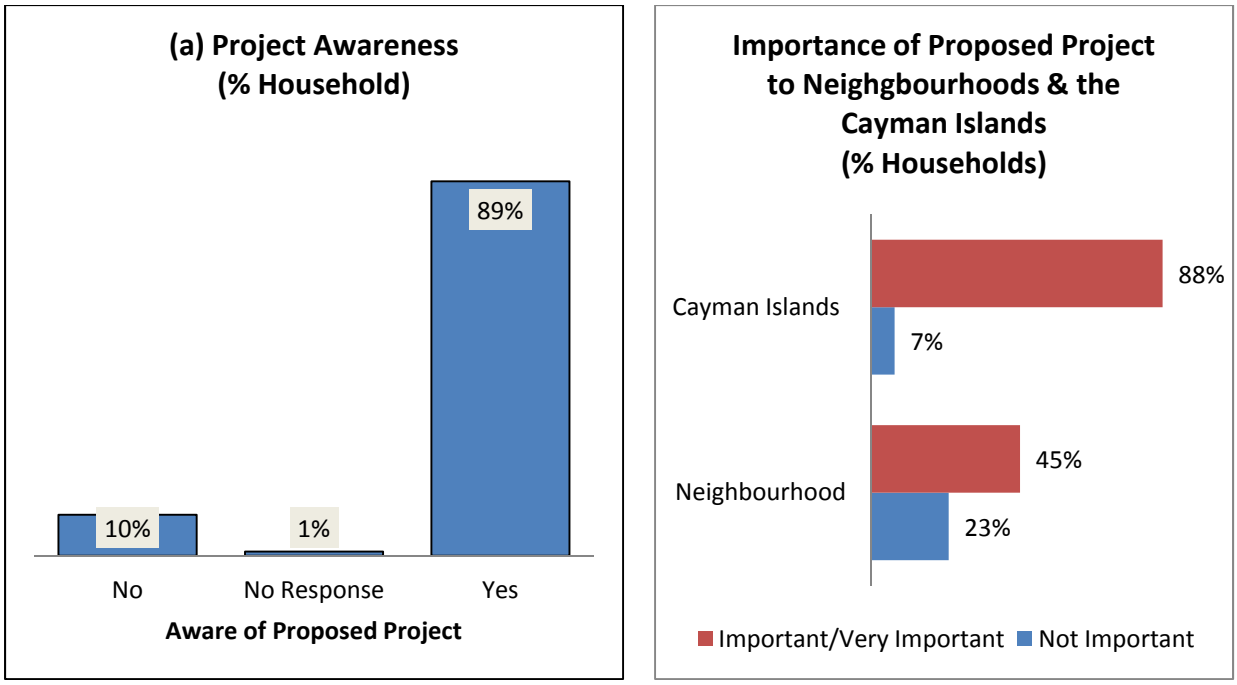


Figure 6.6 (a) Percent Distribution of Project Awareness (b) Importance of Project to Neighbourhood and Cayman Islands (% Households)

6.3.8.7 Project Impacts

During Construction Impacts

Participants were asked how they thought the project would impact selected environmental and socio-economic receptors during and post-construction of the project. Responses are summarized in **Table 6.17** and **Table 6.18**. Response rates for this question were very high (over 90%). Based on the receptors identified by the highest percentage of participants, perceived positive impacts during the construction phase of the project tend to be economic in nature, related to business and job opportunities. These include local job opportunities, local businesses and the Cayman economy. Participants thought both residents of Caymanian and Non-Caymanian status would be positively impacted during construction.

Perceived negative impacts during construction were environmental receptors and groups that rely on the environment for livelihoods. These include water quality, coral reefs/coastal resources, noise levels in George Town, water sports and artisanal fishing. Participants believed that cruise tourism, cargo operations and tender operations would also be negatively impacted, as would be visual aesthetics and traffic. It was however felt that overnight tourism would not be affected. As it relates to cultural heritage, participants believed that ship wrecks would be negatively impacted but that land-based heritage assets (buildings and monuments) would not be impacted.

Based on averages, impacts during construction were negative (37%) compared with 30% positive and 24% no effect. On average, only 3% of respondents were unsure of impacts.

Table 6.17 Percent distribution of households' views on impacts during construction

During Construction Impacts – % Households (n=308)						
% Pre	Positively	Negatively	No Effect	No Response	Not Sure	Total
Water quality	5	61	24	6	3	100
Coral reefs/coastal resources	8	72	14	3	3	100
Noise levels in George Town	9	57	27	5	3	100
Water sports (fishing, diving, etc.)	11	57	23	6	3	100
Artisanal fishermen	11	46	32	8	3	100
Cruise tourism	29	42	20	6	3	100
Overnight tourism	23	11	57	6	3	100
Tenderers	21	46	23	7	3	100
Cargo operations	23	38	28	8	3	100
Job opportunities (locals)	77	6	12	3	3	100
Local businesses	58	17	16	7	3	100
Cayman's economy	70	11	12	4	3	100
Caymanians	67	11	13	6	3	100
Non-Caymanians	51	12	26	8	3	100
Visual aesthetics	23	43	24	7	3	100
Traffic	14	66	14	3	3	100
Ship wrecks	13	46	29	7	5	100
Heritage Sites (monuments, buildings)	19	32	38	6	4	100

Post-Construction/Operational Impacts

There were some shifts in the views on impacts in the post-construction/operational phase of the proposed project, compared with those expressed for the construction phase (Table 6.18). Overall impacts were believed to be more positive than negative averaging 42% and 21% respectively. A number of receptors that were believed to be negatively impacted during the construction phase were thought to no longer be impacted post-construction. These included water quality, noise levels, water sports, and artisanal fishermen with the change being marginal for artisanal fishermen. Cruise tourism, cargo operations and visual aesthetics are believed to be more positively impacted post-construction while there is a slight (2%) shift in the percentage believing that overnight tourism would be positively impacted versus not impacted. Respondents believe that coral/coastal resources, traffic, tender operators and ship wrecks would continue to be negatively impacted during the post-construction/operational phase of the project.

Table 6.18 Percent distribution of households views on impacts post-construction

Post Construction/Operations Impacts – % Households (n=308)						
% Post	Positively	Negatively	No Effect	No Response	Not Sure	Total
Water quality	11	34	42	9	4	100
Coral reefs/coastal resources	10	51	27	9	4	100
Noise levels in George Town	16	25	47	9	3	100
Water sports (fishing, diving, etc.)	29	28	30	9	3	100
Artisanal fishermen	21	31	33	11	4	100
Cruise tourism	73	5	12	7	3	100
Overnight tourism	42	6	40	8	4	100
Tenderers	26	51	11	9	3	100
Cargo operations	50	10	29	8	3	100
Job opportunities (locals)	69	6	12	9	3	100
Local businesses	76	3	9	9	3	100
Cayman's economy	79	4	6	8	3	100
Caymanians	71	7	10	8	3	100
Non-Caymanians	60	7	20	9	3	100
Visual aesthetics	52	12	21	11	4	100
Traffic	24	48	14	11	4	100
Ship wrecks	17	36	32	10	5	100
Heritage Sites (monuments, buildings)	28	21	39	9	3	100

Other positive and negative impacts to their neighbourhoods and the Cayman Islands identified by respondents are summarized in **Table 6.19.**

Table 6.19 Other project impacts identified by households surveyed

Other Impacts – Households (n=308)	
Negative	**Positive**
Environment (12%)	
- Impact to marine life especially coral reefs - Loss of coastline protection - Disruption in sediment transport to seven mile beach - Beach erosion - Bigger waves and storm surges - Noise	
Infrastructure (7%)	Infrastructure
- Traffic - "Island is too small to handle large increase in number of visitors" - Over-development - Pollution - Structural damage from blasting	- Improved access to land for cruise tourist; improved visitor experience; more efficient visitor processing (6%) - Facelift to George Town waterfront; community boost (2%)
Economic (4%)	Economic
- High cost - Increased debt - Employment loss (tender operators) - Loss of tourism from "dead reefs" - Impact on stay-over tourists - Competitiveness of island will decline	- Increase number of tourists (20%) - Economic growth (20%) - Employment opportunities including youth (16%) - Increase revenue and incomes (10%) - Boost in local businesses (6%)
Cultural (1%)	
- Loss and damage of heritage sites - Structural impact from blasting	

Direct Impacts

Participants were asked for their view on the potential for the proposed project to have any direct impacts on them and their households. Thirty seven percent (37%) believed that the project may have direct benefits to them while 60% believed that it would not (**Figure 6.7**). Direct benefits were largely due to potential employment, business opportunities, and improved earnings.

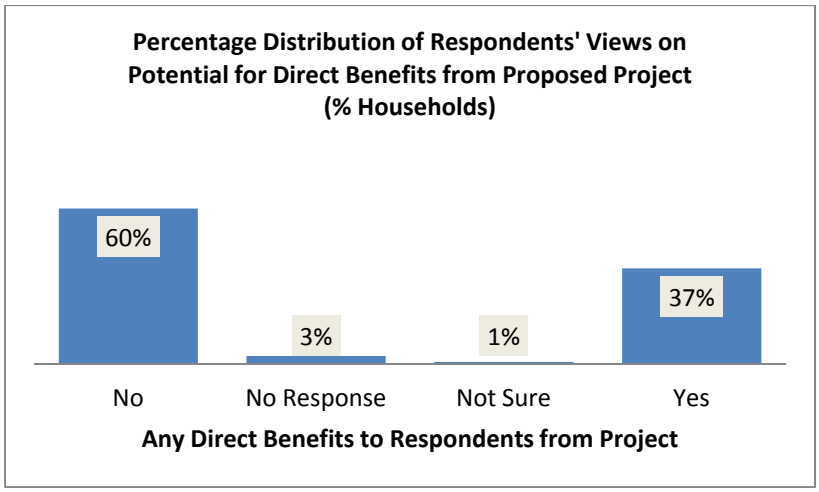


Figure 6.7 Percent distribution of respondents' view of direct impacts from project (% households)

Another potential direct impact relates to respondents' visit to the CBD. An estimated 35% believed that the proposed project would not impact their visits to downtown George Town. Almost 30% cited increased traffic and congestion, which may cause delays. Less than 10% noted that they would change the days and time when they visit the area. Others felt they had no choice.

General Comments about Proposed Projects from Households Surveyed

Comments from this stakeholder group were mainly positive, however there were some concerns noted. Several themes could be ascertained from the comments:

One theme was a sense of urgency for the project, tied to the potential socioeconomic benefits that may be derived from the project. The following comments reflect this theme:

- *"A well needed facility."*
- *"Should have been built 20 yrs. ago. Positive move."*
- *"The country needs this project to get started now."*
- *"Should be completed sooner than later although the airport expansion should be a higher priority."*
- *"This would be better because most of the cruise ships are pulling out because the tourists can't get off."*
- *"Times have changed and we need a better system so things can get better for us."*

Other comments were concerned about opportunities being available for locals:

- *"Caymanians should get a piece."*
- *"Hope it brings jobs for Caymanians."*

A third theme is related to concerns about the location:

- *"Does not necessarily need to be in George Town. Cruise terminal should be away from people trying to do business in George Town."*
- *"Rather not be in town, relocated."*
- *"Can't it be done somewhere else?"*

A fourth theme is a potential for negative environmental impacts and the need to explore alternatives to mitigate risks:

- *"Can't it be done without dredging?"*
- *"I like the floating pier. Less ecological damages and unique for Cayman are huge plus."*
- *"The cost and efficiency of the floating dock proposal must be seriously considered in order to preserve our coral reefs and integrity."*
- *"Have any serious consideration been given to a floating deck construction?"*
- *"It is not necessary. We have thriving tourism and healthy marine life. Why sacrifice for money?"*

A fifth theme related to the fourth is the view that stay-over tourism should be prioritized over cruise tourism and improving the town:

- *"The airport is more important."*
- *"I would place airport development as the #1 priority for the Cayman Islands at this moment."*
- *"We don't need any cruise berthing piers. We need to shut off vehicle access there and spend money improving the town's image."*

Still other comments express concern about *"the upkeep of the facility such as upkeep cost,"* while others would like additional information before forming an opinion:

- *"More information is needed. This is a big project with many options for both construction and operation."*
- *"Would like more info to be easily accessible, perhaps official website."*

6.4 Summary of Stakeholders' Perceived Impacts

6.4.1 Construction

Public perception of project impacts during construction is mainly negative. Stakeholders believe that environmental receptors and groups who are vulnerable due to their dependence on the environment will be negatively impacted. The proportion that viewed construction impacts as negative is higher than those citing positive impacts during construction. Positive impacts identified during construction were jobs and value added to the economy. The main potential negative impacts are:

- Destruction/damage of the marine environment (coral reefs and ecosystems);
- Pollution (water, air, noise);
- Loss of tender boat operations (loss of service to cruise visitors; loss of jobs and income and benefits to employees);
- Decline in dive operations due to poor water quality;
- Loss of business for dive and water sports businesses;
- Disruption in cruise ships calling in GTH due to dredging and construction activities.

6.4.2 Operations

Stakeholder perception of impacts during operations is generally more positive than negative for non-maritime businesses and households. At the household level, job opportunities, local business opportunities and boost to the local and the national economy were identified during stakeholder engagement.

Long-term environmental impacts, loss of livelihoods, jobs and business for groups such as dive shops, and tender operators were some negative impacts identified.

There will be need for budgetary resources for infrastructural and other planning and development projects that will be needed to support the expected growth in visitor arrivals. This will have negative effects on CIG Departments and other agencies with limited resources.

6.5 Mitigation of Stakeholder Impacts

Communication with stakeholders and the general public on the potential negative and positive impacts of the proposed project will be very important:

- There were some views that there is insufficient information available on the full scope and potential impacts and benefits of the project.

- Given the socio-economic and socio-cultural significance of the sea to the Cayman Islands, and the potential for negative impacts, it is critical that alternative scenarios (with, without, alternate locations, etc.) be presented in a clear and concise way that is understandable to the public and stakeholders.

- A justification for the preferred option and mitigation strategy is also recommended.

Several themes that that should be addressed in consultation that emerged from stakeholder consultations are:

- The perception that the project is needed for socio-economic gains and the sense of urgency and some level of frustration with the lengthy decision-making process;

- The fear that the benefits derived from the project will not go to locals and those of Caymanian status;

- The location of the proposed project; its suitability given current practices in bad weather;

- The negative environmental impacts associated with the project;

- The perceived potential negative impact on stay-over tourism visiting the downtown George Town area;

- Resources required for constructing and operating the facility, and the source of funding;

- The sources for funding required for the supporting development required e.g. George Town redevelopment, traffic and pedestrian infrastructure, etc.;

- Should the project proceed, a grievance mechanism will need to be developed at the appropriate juncture;

- See other measures in the Task N: Socio-economic Chapter.

7.0 TASK A - SUMMARY ANALYSIS OF ALTERNATIVES

7.1 Introduction

The "Final EIA Terms of Reference" (MM, 2013) required a discussion of alternatives that have been previously considered for the development of cruise facilities within George Town Harbour, and also at other locations around Grand Cayman Island. The following section provides a summary and discussion of alternatives previously developed/considered by others, including the preferred project layout developed in Concept Study (MM, 2013) and incorporated in the Terms of Reference for the EIA, and culminating in a new layout developed by the Baird team as part of this study.

The new layout developed was the result of a comprehensive effort to develop a refined project layout that would provide a balance between functional and cost considerations, with reduced environmental impacts as compared to the project layout incorporated in the Outline Business Case (PwC, 2013). This effort is summarized in **Appendix A**.

7.2 Previous Studies Related to Alternative Project Sites

The "Master Port Development Plan" study undertaken for PACI by PBSJ (1994) included a review and assessment of various sites around Grand Cayman Island for improved cruise and cargo port facilities. **Figure 7.1**, which has been extracted from the PBSJ (1994) study, presents a number of sites that were under consideration.

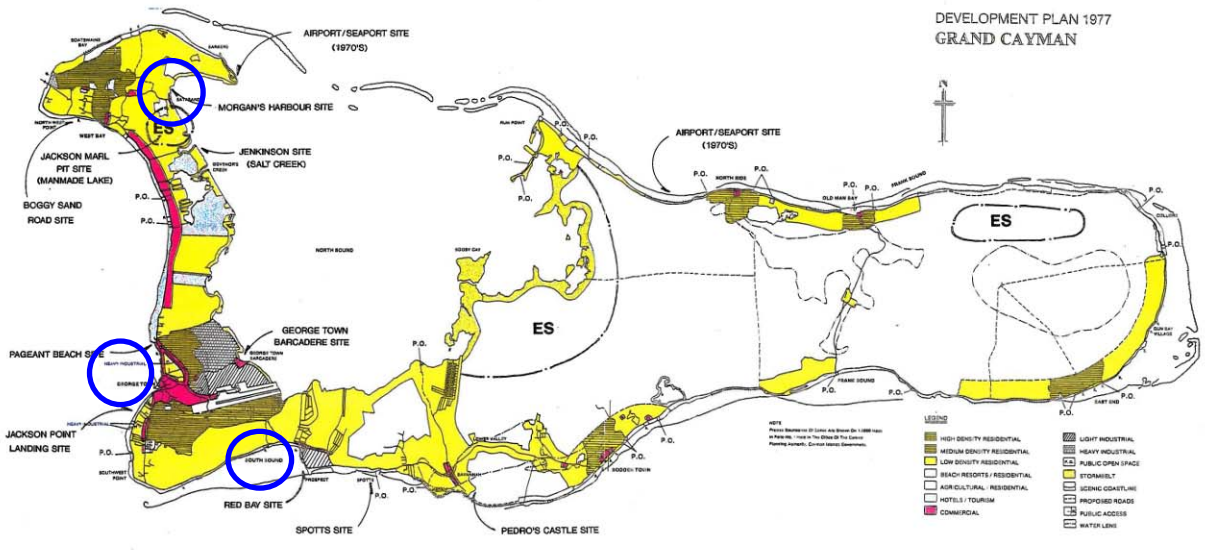


Figure 7.1 Alternative Project Sites Considered in Previous Studies (Source: PBSJ, 1994)

The PBSJ (1994) study assessed a number of potential port development sites in five "sectors" around the island, including:

- Sector One - George Town (Jackson Point, Pageant Beach);
- Sector Two - West Bay;
- Sector Three - North Sound (Morgan's Harbour, Barcadere);
- Sector Four - South Sound (Red Bay, Spotts Landing);
- Sector Five - Bodden Town.

PBSJ and PACI eliminated a number of these sites due to concerns related to site exposure, safe navigation, dredging volume, environmental impacts, distance from George Town and/or distance from the Cargo Distribution Centre (CDC). Three specific sites were selected for further consideration, including Morgan's Harbour (North Sound), Red Bay (South Sound) and George Town Harbour; these sites are highlighted on **Figure 7.1**. Conceptual layouts for combined cruise and cargo ports were developed for these three locations, with several alternatives developed for the GTH site.

PBSJ and PACI concluded that that GTH was the preferred location for the port for the following reasons:

- Substantially lower dredging volumes in GTH (~ 550 to 600K cy) as compared to Morgan's Harbour (~ 13.8M cy) and Red Bay (~ 6.3M cy);
- Reduced infrastructure requirements and costs (marine and landside);
- Reduced environmental impacts;
- Proximity to business district and CDC.

The PBSJ (1994) study resulted in the identification of a preferred layout for a combined cruise and cargo port in GTH. This layout is presented in the following section, along with other layouts for port improvements in GTH subsequently developed by others.

More recently, there has been some interest in the potential development of a cruise berthing facility at Red Bay, located in South Sound, to the west of Spotts Landing (refer to **Figure 7.2**, and to *www.caymancruiseport.com*). The primary advantages of this site are that it is sheltered from Nor'Westers, it would separate cruise and cargo operations, and it would reduce congestion in George Town. The primary disadvantages of this site are the extensive dredging required (in the order of 11M cubic yards, including dredging through the shallow fringing reef), the distance to George Town, and the proximity to upscale residential development.



Figure 7.2 Schematic Layout of Red Bay Cruise Berthing Facility (Source: CIG, 2015)

As noted earlier in this report, the CIG has adopted George Town Harbour as the preferred location for the development of the proposed cruise berthing facility. The scope of work for the present EIA study did not include an evaluation of alternative sites for the proposed cruise berthing facility. That being said, the Baird team has reviewed the available information related to the potential development of a cruise berthing facility at other locations on Grand Cayman Island, and agrees with the selection of George Town Harbour as the preferred site. The basis for this opinion is as follows:

- The natural environment of George Town Harbour has already been compromised by years of shipping and port related activity;
- It is likely that significantly greater dredging will be required, with increased environmental impacts, should the CBF be developed in another location.
- It is likely that the capital cost associated with the development of a CBF will be significantly lower in GTH than at other locations around the island;
- The proximity of GTH to the George Town business district is perceived to be a significant advantage to both cruise passengers and local merchants.

7.3 Previous Studies for CBF in George Town Harbour

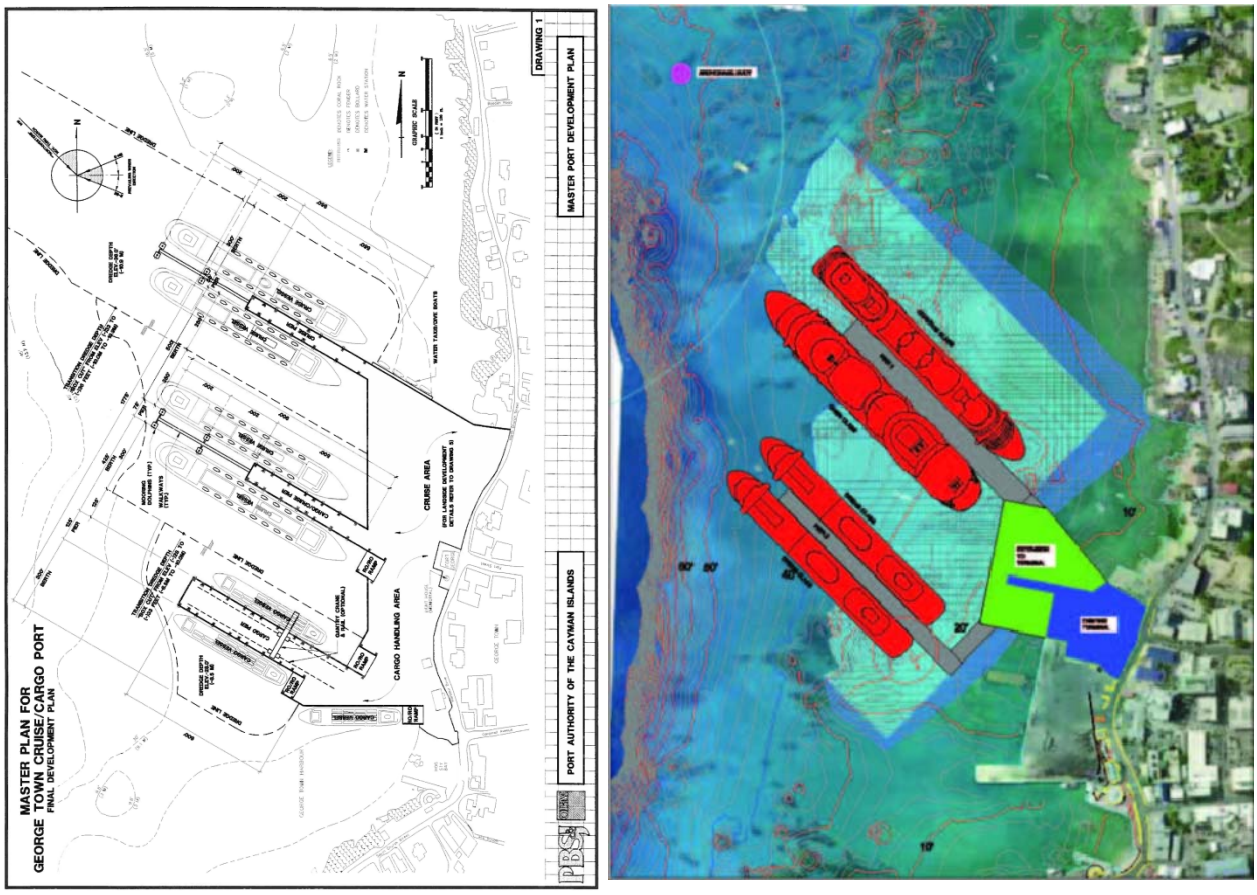
Subsequent to the PBSJ (1994) study, a number of studies have been undertaken by various groups regarding the development of a cruise berthing facility in George Town Harbour. The following list highlights studies that the project team was aware of:

- PBSJ (1994) – concept layout for cruise berthing facility and expanded cargo port;
- CH2MHill (2006) – concept layout for cruise berthing facility;
- Atlantic Star (2008) – private proposal for cruise berthing facility and new cargo port;
- Moffatt & Nichol (2009) - EIA for cargo port expansion;
- Decco/CD Howe/DHI (2010) – private proposal for cruise berthing facility and expanded cargo port;
- GLF/Halcrow (2011) – private proposal for cruise berthing facility;
- CHEC/AECOM (2012) – private proposal for cruise berthing facility and expanded cargo port;
- PwC/MM (2013) – Concept Study and Outline Business Case for new cruise facility.
- Balboa Cruise Terminal (2013) – Application for a proposed cruise berthing facility located to the north of the existing port facility.

Figure 7.3 presents the recommended layouts developed in the PBSJ (1994) and PwC/MM (2013) studies. Anecdotal information was also available regarding some of the other concept layouts developed by others.

The following bullet points highlight key points of interest regarding the previous concepts developed by others:

- Many of the concepts are generally similar, with two new piers for cruise ships, nearshore dredging and an expanded land area. The PBSJ (1994) and Altlantic Star (2008) proposals incorporate significant expansion of the cargo port (a third pier). The Balboa (2013) concept was located to the north of and separate from the existing cargo port.
- The similarity of the concepts reflects the significant constraints to the development of a cruise berthing facility at this site (i.e. proximity to "The Wall," proximity to coral reefs to the North and South).
- All of the concepts utilize a WNW-NW pier orientation; this is generally aligned with Nor'Westers, and is anticipated to result in the least downtime for ships at berth).
- Some of the concepts incorporate a sheltered small craft harbour basin on the North side.
- All of the concepts retain or extend the South cargo pier.
- All of the concepts retain the existing RO/RO ramp.



PBSJ (1994) **MM/PwC (2013)**

Figure 7.3 Concept Layouts Developed in Previous Studies

It is noted that retaining access to the existing RO/RO ramp for cargo vessels requires that the cruise ship piers be located some distance to the north of the South cargo pier. This, along with a WNW-NW orientation of the cruise ship piers, results in the dredged basin extending into the coral reefs to the North of the project site. This issue was an important consideration in the development and assessment of alternative layouts undertaken as part of the present study, as discussed further in Chapter 7.5 and Appendix A.

7.4 Floating Pier Concept

During the course of the present study, an independent proponent proposed a floating pier concept for the cruise berthing facility (refer to *www.cruisetogeorgetown.com*), as illustrated in **Figure 7.4.** At the request of the CIG, Baird undertook a preliminary technical review of the floating pier concept.



Figure 7.4 Schematic Rendering of Floating Pier Concept
(*Source:* www.caymancompass.com, *31Oct14*)

Baird's review (which is included in Appendix A) concluded that the proposed floating pier concept provides a number of potential significant benefits as compared to a fixed pier concept, including reduced environmental impacts (i.e. elimination of dredging, and reduced damage to corals), as well as a reduced duration of on-site construction activities and the associated reduction in impacts (disruption) to existing businesses and operations. However, Baird identified a number of significant technical challenges to address in the design of such a facility that do not appear to have been addressed by the proponent. In particular, Baird questions the ability to develop a sufficiently robust mooring system given the significant water depths into which the floating piers would extend. Further, the proposed concept is unique, and without precedent, for a site exposed to hurricane waves. Based upon the information available at this time regarding the floating pier concept, Baird has concerns about the technical feasibility of this concept.

7.5 Review of Options in Outline Business Case (PwC, 2013)

7.5.1 Status Quo (Do Nothing)

The Strategic Outline Case (CIG, 2013) and Outline Business Case (PwC, 2013) both discuss a Status Quo (Do Nothing) option, as summarized below:

- Cruise ships moor offshore of George Town;
- Tenders shuttle cruise passengers between the cruise ships and the landside terminals;
- Cargo operations continue at the site;
- Spotts Landing is used as a backup, particularly during Nor'Westers.

This option was rejected in the OBC (PwC, 2013), as it does not resolve any of the issues which Cayman's cruise industry is presently facing.

The "do nothing" scenario was used as a baseline for the assessment of alternatives in the EIA.

7.5.2 Improved Status Quo

The Strategic Outline Case (CIG, 2013) and Outline Business Case (PwC, 2013) both discuss an Improved Status Quo option, including "some improvements" to enhance tendering facilities and cargo operations at George Town, and site improvements at Spotts Landing. The OBC (PwC, 2013) retained this option for further consideration, noting that "it is a low cost solution which does provide some level of improvement should all berthing solutions be judged unaffordable or otherwise undesirable."

The proposed improvements are not specified in the SOC (CIG, 2013) or OBC (PwC, 2013) documents. However, it is understood that PACI is considering limited landside improvements at George Town, including raising the Royal Watler Pier, and installing a new security facility to screen passengers from Oasis class vessels (these vessels do not have onboard screening capability).

As noted in earlier, the existing tender operation is susceptible to the weather, in particular wave action associated with Nor'westers. These conditions result in missed calls approximately 4% of the time (based on PACI records from 2010-2014), with relocation of the cruise ships and tender operations to Spotts Landing another 4% of the time. The landside improvements described above are unlikely improve this situation. Rather, a sheltered landing facility (requiring a breakwater) would be necessary to reduce the frequency of missed and relocated calls. However, even with a sheltered landing facility, the tender operation would remain susceptible to wind and wave action at the cruise ships, with associated safety concerns. It is also noted that the largest vessels prefer to avoid tender operations due to the large number of passengers on board (> 4,000).

It is important to note that a tendering operation does provide some resiliency in terms of port operations following a severe hurricane event as compared to the use of fixed berths. It is possible that a cruise berthing facility may be damaged during a hurricane, thereby preventing berth usage until repairs have been carried out. Vessel tendering may be able to resume in a relatively short period of time following the hurricane, as occurred after Hurricane Ivan in 2004.

7.5.3 Proposed Cruise Berthing Facility (MM Option 7D)

The Concept Study undertaken by MM (2013) included the development and assessment of alternative concepts for the proposed cruise berthing facility. In general, five different layout concepts were considered (each with one and two pier variants), with a wide range in pier locations and orientations, with dredging as required to accommodate the design vessels and a small land reclamation area. The MM (2013) report includes a concise summary of key project constraints considered in the development of the alternative layouts, a comparative assessment of the different

layouts (advantages, disadvantages and relative construction costs), and a matrix-based ranking of each alternative under various criteria, leading to the identification of MM Option 7D (two piers and small reclamation area) as the recommended concept (best overall ranking).

MM Option 7D is shown in **Figure 7.5**. Key elements of the proposed project include two finger piers (with four berths for large cruise ships), dredging and land reclamation works, and limited onshore improvements. This project layout was incorporated into the Outline Business Case, completed for the CIG by PricewaterhouseCoopers (PwC, 2013), and the Terms of Reference for the EIA.

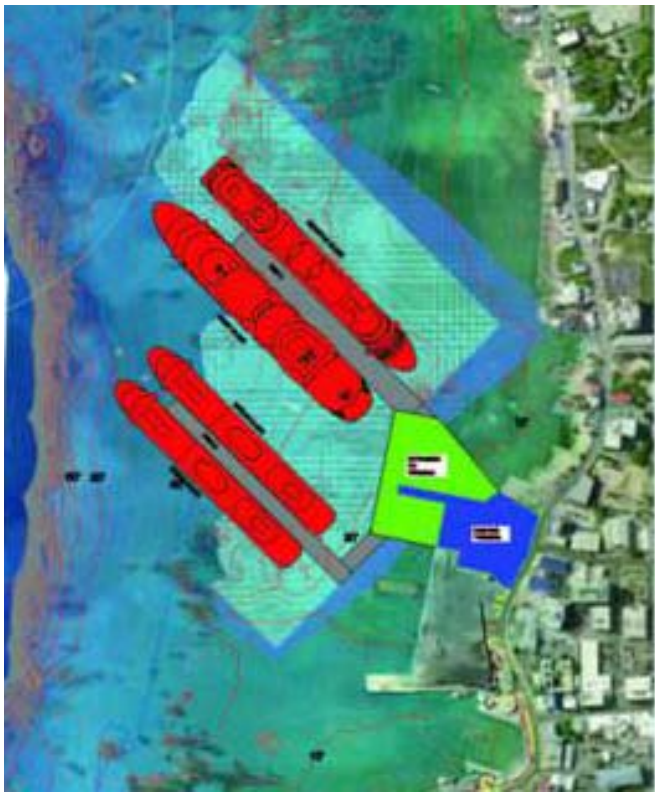


Figure 7.5 OBC Preferred Project Layout (MM, 2013)

The project constraints and ranking criteria utilized by MM (2013) in their development and assessment of the alternative concepts were reasonable. Further, MM Option 7D is considered to be the best alternative of those considered by MM (2013). However, the Baird team's review identified two key limitations in the prior studies, and two potential "big picture" issues with MM Option 7D, each of which may have an important effect on the overall project layout, functionality/cost and/or environmental impacts, as summarized below:

1. Facility downtime - the risk of downtime associated with wave-induced motions of cruise ships moored at the piers was not estimated;

2. Sedimentation - the risk of sedimentation in the dredged basin, and the associated requirement for future maintenance dredging, was not estimated;
3. Cut/fill balance - the dredge volume is much greater than the fill volume, therefore requiring disposal of a significant volume of dredged material;
4. Impact on coral - the location of the northern dredged basin overlays a significant area of coral reef.

7.6 Current Study

7.6.1 Development and Assessment of Additional Alternatives

The limitations and issues noted above have been assessed as part of the EIA study, and were considered in the development of additional layout alternatives for the proposed project. Specifically, EIA study included the following tasks:

1. Numerical model simulations of moored ship response were undertaken to assess the influence of pier orientation on facility downtime;
2. Numerical model simulations of coastal processes were undertaken to estimate the potential for sedimentation in the dredged basin (as well as potential impacts on adjacent shorelines, including Seven Mile Beach);
3. Alternative project layouts were developed to reduce the discrepancy between cut and fill, including various options with reduced dredging and/or larger land reclamation areas;
4. Alternative project layouts were developed to reduce the overlap of the project footprint on coral reefs.

Ultimately, the spatial extent and volume of dredging, and the potential requirement for offshore disposal of excess dredged materials, were deemed to be critical considerations with respect to the anticipated impacts of project construction on the natural environment. As such, a number of alternative layouts were developed to minimize the spatial extent and volume of dredging, to achieve a cut/fill balance and to eliminate the requirement for offshore disposal. In addition, consideration was given to potential beneficial uses for dredged materials, such as:

- Additional land reclamation at the project site, or elsewhere;
- Beach fill/nourishment along Seven Mile Beach, or elsewhere;
- Process/stockpile for use as fill elsewhere.

Finally, alternative design and construction methods were assessed for major project elements, including dredging and disposal methods and structural design concepts for the piers and shoreline protect structures.

Appendix A provides a comprehensive summary of the development and assessment of alternatives undertaken as part of the EIA study. This effort resulted in the development of a refined concept layout for the proposed cruise berthing facility, as summarized in the next section.

7.6.2 Optimized EIA Layout

The development and assessment of alternatives undertaken as part of the EIA study (refer to Appendix A) culminated in the optimized EIA layout presented in **Figure 7.6**.

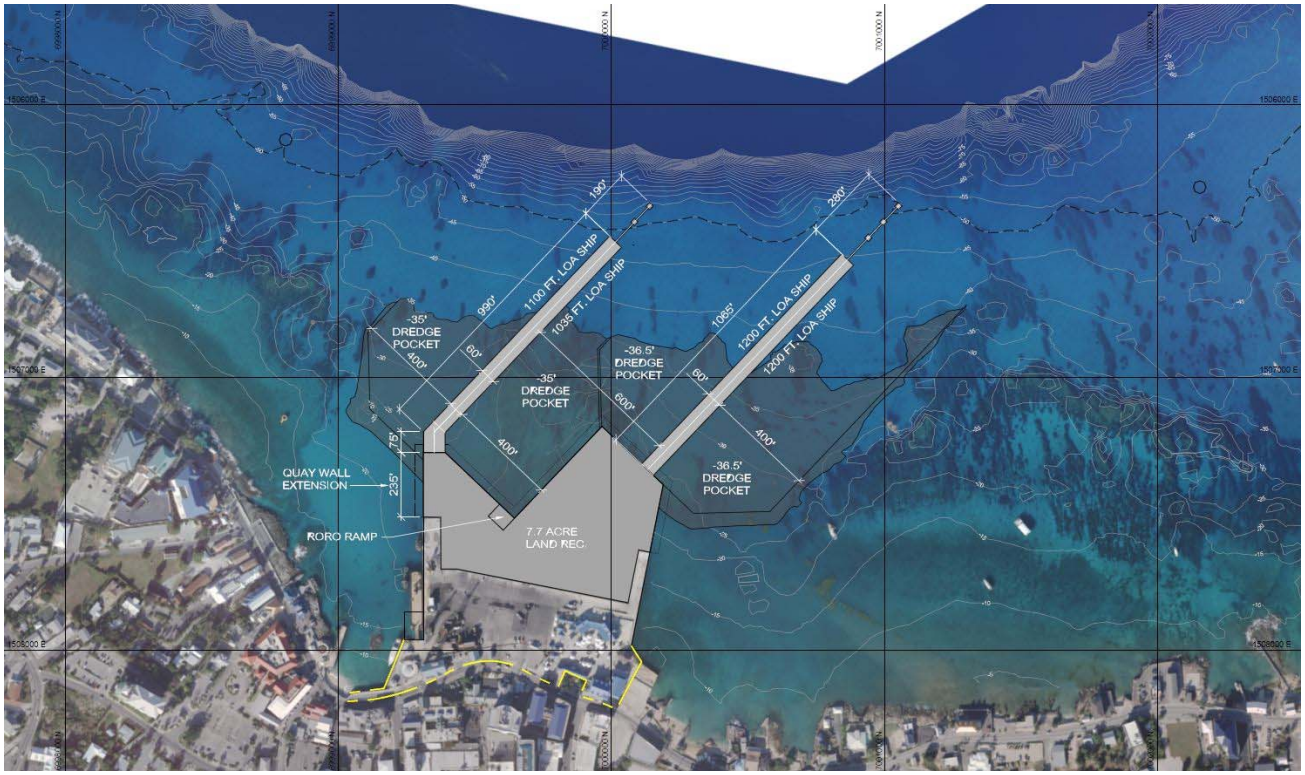


Figure 7.6 Optimized EIA Layout

The optimized EIA layout provides improved functionality (for both cruise and cargo operations) and a significant reduction in environmental impacts as compared to the OBC layout. **Table 7.1** quantifies the specific improvements of the optimized EIA layout developed by the Baird team as compared to the OBC layout, while Figure 7.7 provides a comparison of the two layouts.

Table 7.1 - Comparison of OBC and Final Concept Layouts

Description	Original (OBC)	Final (Baird)	% Change
Parameters Related to Functionality			
Land Reclamation Area (acres)	3.5	7.7	+120%
RW Tender Dock (ft)	350 ft	600 ft	+71%
South Cargo Dock (ft)	450 ft	760 ft	+69%
Parameters Related to Environmental Impacts			
Total Project Footprint (acres)	41.4	32.5	-22%
Dredge Footprint (acres)	37.4	23.0	-39%
Dredge Volume (cy)	728,000	333,000	-54%
Disposal Volume (cy)	608,000	174,000	-71%
Direct Impact on Reefs (acres)	20.0	12.4	-38%



Figure 7.7 Comparison of OBC Layout (top) and Optimized EIA Layout (bottom)

8.0 TASK B - NATURAL HAZARDS ASSESSMENT

8.1 Introduction

The Cayman Islands are vulnerable to a number of natural hazards, including hurricanes, earthquakes and tsunamis. A review and assessment of these natural hazards has been undertaken in order to understand the potential risks and implications of each on the proposed project. Hurricanes, earthquakes and tsunamis have the potential to cause severe damage to the project, as well as other infrastructure on the island, possibly resulting in an extended period of time when the project is non-functional (i.e. during repair/reconstruction efforts). The loss of cruise ship traffic over an extended period of time would have significant impacts on the economy of the Cayman Islands. As such, it is important that the planning and design of the project consider the extreme conditions associated with natural hazards. The natural hazard assessment is summarized in this chapter; more complete information may be found in **Appendix B.1**.

Adding to the natural hazards are the effects of climate change, with increasing air temperatures, changing precipitation patterns, growing frequency and intensity of extreme events and sea level rise expected over the life of the facility. Climate change effects do not have the same potentially devastating impacts on the project, but are an important consideration in the planning and design of the project. The proposed infrastructure must resilient to such future changes. A site-specific investigation of climate change effects was carried out, and is briefly summarized in this chapter. More details may be found in **Appendix B.2**.

8.2 Assessment Methodology

A detailed investigation of natural hazards was carried out as part of the EIA, and is documented in Appendix B.1. This investigation involved the completion of the following activities:

- *Hurricane-Generated Winds and Waves:* The available records of measured hurricane-generated wind and waves in the Cayman Islands are very limited. To overcome this limitation, a statistical analysis of tropical events occurring within 160 nautical miles (300 km) of Grand Cayman was completed. The frequency distribution from this analysis was subsequently used to develop parameters describing 500 random synthetic hurricanes that could affect the project site. Monte Carlo simulations were then conducted using a wave model, and maximum wind and wave conditions were estimated at the project site. These data were then entered into a statistical extreme value analysis to determine extreme wind and wave conditions by return period.

- *Hurricane-Generated Storm Surge*: In similar fashion, hurricane-induced storm surge due to wind and atmospheric pressure setup were estimated for each of the 500 synthetic storms using a two-dimensional hydrodynamic model, MIKE21.

- *Seismic Hazard*: An assessment of seismic hazard in Grand Cayman was conducted by means of a review of technical literature, Building Codes and international databases.

- *Tsunami Hazard*: An assessment of tsunami hazard was carried out by means of a review of technical literature and international databases of coastal seismic activity and historical tsunami inundation.

- *Climate Change*: The Climate Studies Group at the University of West Indies, Mona, was commissioned to undertake a site-specific investigation of climate change effects, as given in Appendix B.2. This investigation focused on four specific parameters: air temperature, rainfall, sea levels and hurricanes. It made use of dynamical downscaling provided by the PRECIS regional climate model, extracting data for the Cayman Islands.

8.3 Baseline Conditions

8.3.1 Hurricane-Generated Wind, Waves and Surge

Grand Cayman is subject to the passage of hurricanes during the months of May to November, with approximately one hurricane or tropical storm passage per year on average within 160 nautical miles of the George Town Harbour (GTH) area. As such, hurricanes are one of the most significant natural hazards that the proposed project will be subject to.

One of the most severe events to affect Grand Cayman was Hurricane Ivan in 2004 (**Figure 8.1**), with devastating consequences. Total loses exceeded CI$2.8 billion. Sustained wind speeds exceeding 115 knots resulted in extensive structural damage to old, poorly designed buildings; however, much of the economic loss resulted from water damage due to precipitation and storm surge. Hurricane Ivan dumped 16.5 inches of rain on Grand Cayman in a matter of hours, overwhelming drainage systems. It was estimated that over 70% of the island was flooded during this storm.

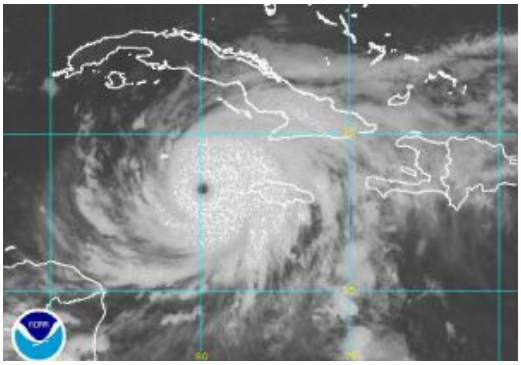


Figure 8.1 Hurricane Ivan [Source: US NOAA]

Hurricane Ivan passed on a track south and west of Grand Cayman. Due to the anti-clockwise wind fields that surround a hurricane, this mean that the island was exposed to severe winds from directions that varied from northeast to southeast during the storm passage. Numerical modelling of wave conditions during Hurricane Ivan was carried out using the second generation WAVAD model, as developed by the U.S. Army Corps of Engineers. This modelling showed that offshore waves during the hurricane peaked at 11 metres (significant wave height, Hs), but the direction of the waves resulted in significant sheltering at GTH, and much smaller waves at the project site. The maximum significant wave height at the site was estimated at 4 metres, but this occurred after the

storm had passed the island, not during the period when the island experienced the most severe winds.

The most significant storm surge inundation occurred in the North and South Sounds due to the easterly wind directions, not in the GTH area where winds were primarily blowing offshore.

As noted previously, a Monte Carlo analysis of extreme hurricane-generated wind, wave and surge conditions at the project site was conducted in this study**. Table 8.1** summarizes the estimated maximum wind speeds by return. Also shown is the variation in maximum wind speed by averaging interval, ranging from sustained (10-minute average) to gust (30-second average) speeds.

Table 8.1 Estimated Maximum Wind Speeds by Return Period and Averaging Period

	Wind Speed (knots)		
Return Period	10-min Average	1-min Average	30-sec Gust
10	50	56	69
20	62	69	86
50	76	84	105
75	81	90	112
100	85	95	118
200	94	105	130
400	103	114	142
1000	114	126	157

Table 8.2 provides a summary of the estimated maximum wave heights in deep water to the West of Grand Cayman Island ("offshore"), as well as in a water depth of approximately 115 ft at a location just west of the project site ("nearshore"). An estimate of storm site at the site is also included. Due to the shallow nearshore shelf in the GTH, storm surge effects tend to be dominated by pressure setup, not wind setup.

Table 8.2 Estimated Maximum Wave Heights and Storm Surge by Return Period

Return Period	Offshore Hm0 (ft)	Nearshore Hm0 (ft)	Surge (ft)
10	21.7	6.9	0.2
25	28.5	9.6	0.4
50	34.1	11.7	0.6
75	37.4	12.9	0.7
100	40.0	13.8	0.8
200	45.9	15.9	0.9
400	52.2	18.0	1.1

8.3.2 Earthquakes

Earthquakes can pose a significant risk to both property and human life. Violent horizontal and vertical ground shaking carries the potential to damage and collapse structures, particularly if they were under-designed or inadequately detailed for seismic response. Earthquakes can also cause geotechnical failures such as liquefaction and slope destabilization, among others.

The Cayman Islands are located just north of the Oriente Fracture Zone, which is an active fault line roughly following the northern edge of the Cayman Trough. Earthquakes are relatively common in this region, but there is significant uncertainty regarding the level of seismic hazard to which the Cayman Islands are exposed. The Cayman Islands Building Code (1999) suggests a peak ground acceleration (PGA) of 2.0 m/s^2 (approximately 20% of gravity, 0.2*g) based on a 2% probability of exceedance in 50 years (2,475 year return period event); this is representative of a low to moderate hazard. In contrast, a recent interpretation of data compiled through the Global Seismic Hazard Assessment Program (GSHAP, 1999) by the United States Geological Survey (USGS, 2015), suggests a PGA of 6.8 m/s^2 (0.7*g) for the same return period event; this is representative of a high to very high hazard. However, the credibility of the GSHAP data (upon which the USGS estimate is based) has been challenged by some researchers (Kossobokov and Nekrasova, 2012).

The most significant earthquake to impact the Cayman Islands in recent history occurred in December 2004, just a few months after Hurricane Ivan. This event had a magnitude of 6.8 (Richter Scale), with its epicenter located 22 miles northwest of George Town, and caused minor damage on Grand Cayman. A less severe event (magnitude 5.9) occurred in January 2010, and also caused only minor damage. This event was only one week after the magnitude 7.0 earthquake which caused widespread damage in Haiti (where the quality of design/construction is generally lower).

8.3.3 Tsunamis

A tsunami is a series of long period ocean waves generated by an underwater disturbance such as a landslide, earthquake or volcano. In deep water, tsunami waves do not have large height but as the waves slow down in shallow waters adjacent to the coastline, the wave height may increase significantly. As has been witnessed in recent catastrophic events in the Indian and Pacific Oceans, tsunamis can cause widespread destruction and loss of life.

The Caribbean is geologically active, with earthquakes and volcanoes being relatively common occurrences. Generally, tsunamis have been acknowledged as a relatively minor natural hazard in the Caribbean (e.g. Lander et al., 2002), but the potential for a destructive event does exist, particularly in the northern and eastern Caribbean. Lander et al. (2002) identified 33 possible tsunamis (an average of one every three years) over the last century. The last destructive tsunami in the Caribbean of any consequence occurred in August 1946, and was the result of a magnitude 8.1 earthquake that affected the Dominican Republic. This event was formed by a seafloor disturbance about 65 km offshore, and resulted in waves exceeding 15 feet in height.

Tsunamis in the Caribbean can be generated by four different sources:

- *Tele-tsunamis*: These are tsunamis originating more than 600 miles (1000 km) from the Caribbean. There are only two known tele-tsunamis that have affected the Caribbean, occurring in 1755 and 1761 and originating along the Portugal coastline.

- *Landslide-Generated Tsunamis*: These are events typically triggered by earthquakes, but not in all cases. Such tsunamis generally result in local damage over a relatively small area, and can occur with very little warning.

- *Volcanic Tsunamis*: Volcanoes can generate tsunamis by various means, and have been observed historically due to eruptions of Mount Soufriere in Saint Vincent and Nevis Peak in Nevis.

- *Tectonic Tsunamis*: Tectonic activity is one of the most common sources of tsunamis in the Caribbean, and typically occurs the subduction zones of the tectonic plates. Several very large earthquakes have occurred along the boundary of the North American and Caribbean plates, but a series of active faults stretching from the west of Jamaica to Central America, just south of the Cayman Islands, also represents a possible tsunami threat.

A search of the US National Geophysical Data Center (NGDC) tsunami database did not reveal any observations of historical tsunami events or tsunami run-up observations in the Cayman Islands.

Overall, the risk of a large tsunami impacting Grand Cayman and George Town Harbour seems very low. In addition, it is noted that the relatively narrow coastal shelf around the Cayman Islands, and the steep dropoff to very deep water, would limit the height of a tsunami wave that could potentially impact the shoreline.

8.4 Impact Assessment

8.4.1 Project Impacts - Hurricanes

Hurricanes can result in a variety of impacts on the proposed facilities, both during construction and operation, including:

- Extreme loads on the pier structures, and uplift on the pier deck, leading to damage;
- Increased wave and surge action along adjacent shorelines;
- Flooding of the reclamation area due to wave overtopping, storm surge and/or heavy rainfall, with damage to landside infrastructure (buildings and facilities);
- Runoff could result in pollution, turbidity and sedimentation in the nearshore area;

- Sedimentation of the dredged basin, resulting in reduced water depths;
- Wave reflection from the land reclamation area, resulting in scour/erosion of the seabed;
- Wind damage to landside infrastructure (buildings and facilities).

During construction, such impacts can potentially result in significant delays and possible ancillary damage (for example, a barge sinking on a coral reef). In the operational phase, such impacts could result in extended periods of missed calls and lost revenue. Reduced water depths may result in lost calls by the deepest draft (largest) vessels. In addition, hurricane-generated waves and currents could result in damage to transplanted corals and/or benthic habitat.

An assessment of the project impacts on nearshore wave and water levels for hurricane conditions was made using MIKE 21 HD+SW. Working in a coupled mode, the model included wave set-up, which is the localized increase in water level that takes place during the wave breaking process. Input wave conditions were based on the 50 year hurricane event described earlier. The statistics used to develop these conditions incorporated climate change considerations. The simulations examined the range of different wave directions that could affect the site; the worst-case directions were found to be from 247 and 270 degrees respectively. **Figure 8.2** and **Figure 8.3** show the model results for water levels and wave heights for the existing and proposed conditions for waves from 270 degrees (results from 247 degrees were similar).

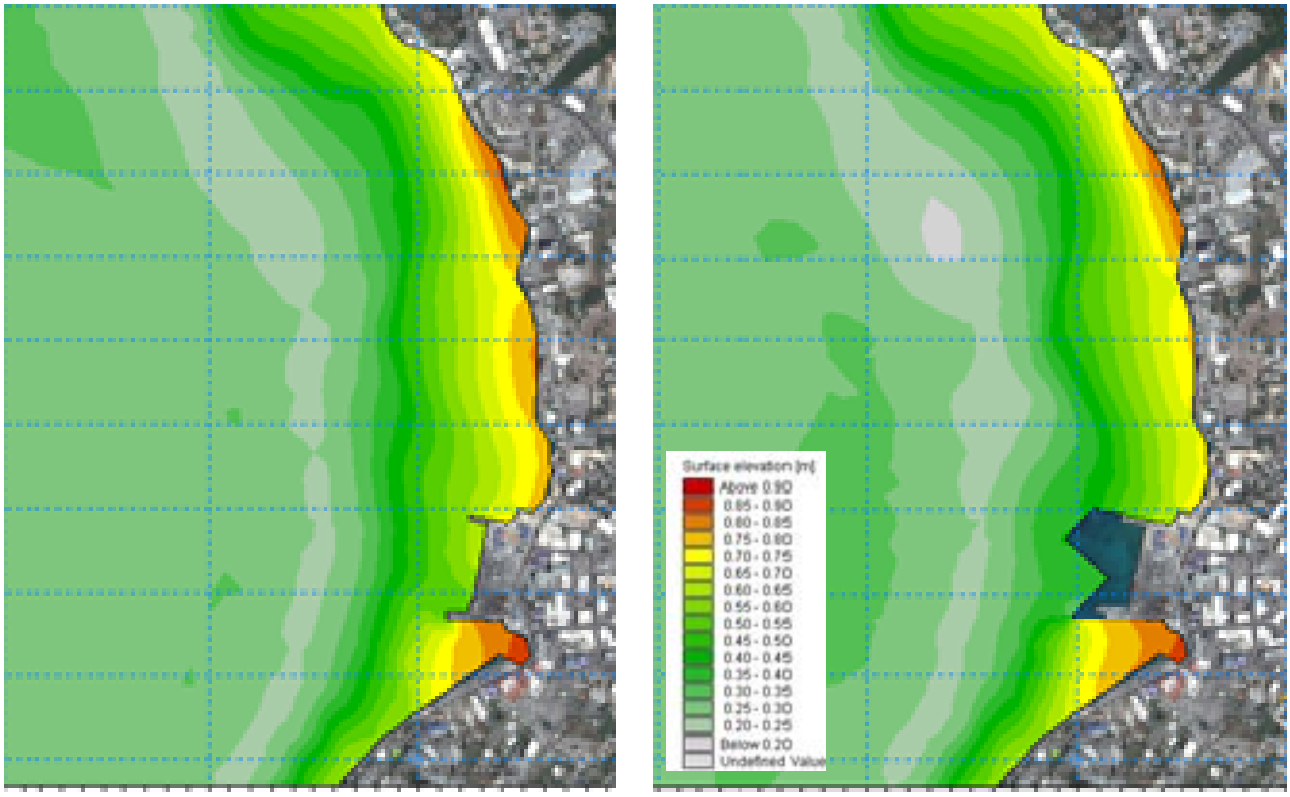


Figure 8.2 Storm Surge Heights for 50 yr Hurricane from 270° - Existing (left) and Proposed (right)

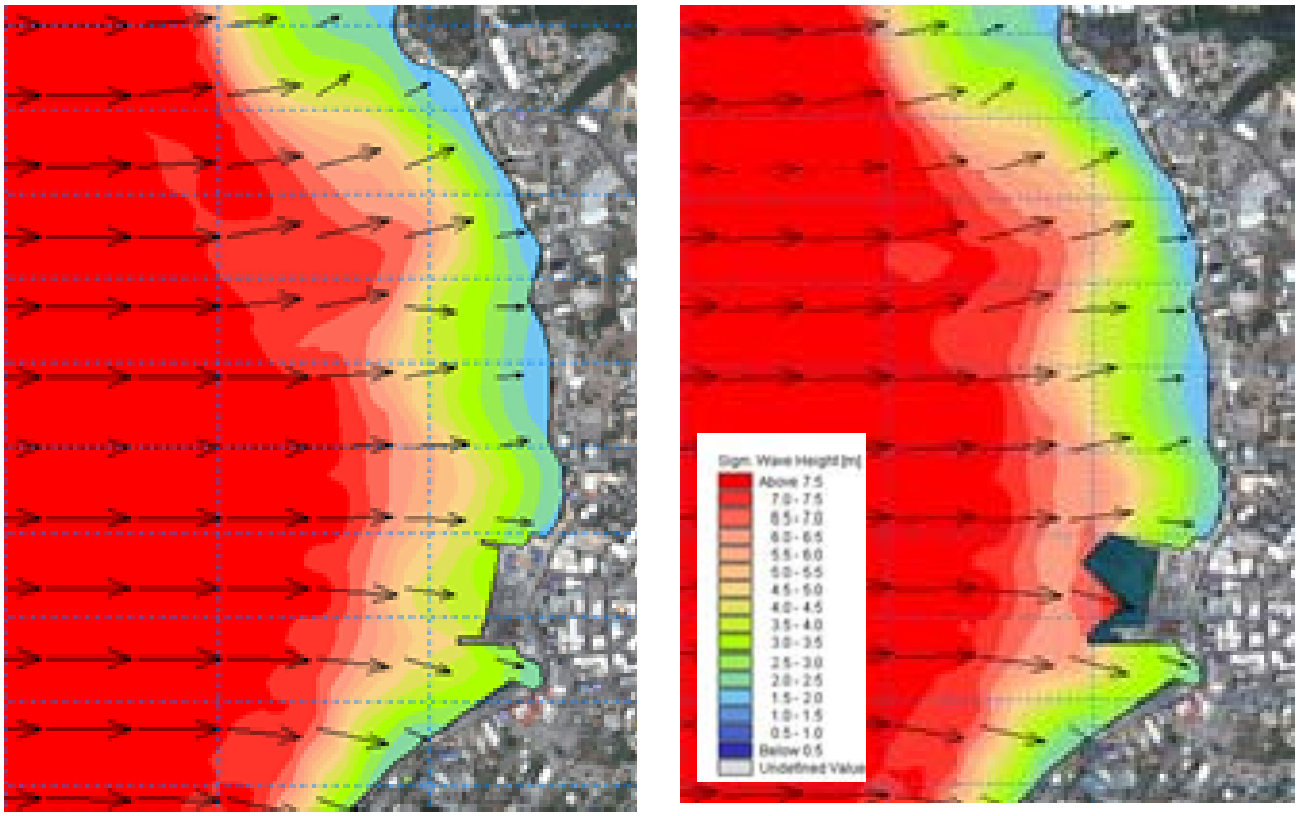


Figure 8.3 Significant Wave Height for 50 year Hurricane from 270° - Existing (left) and Proposed (right)

The results presented in **Figure 8.2** indicate that the storm surge values are marginally reduced under proposed conditions. The results in **Figure 8.3** indicate localized increases in wave height due to the effects of wave reflection from the vertical walls around the new land reclamation area. The increase in wave heights appears to be limited to the area offshore the land reclamation area, and is not widespread. In contrast, wave heights along the shorelines both North and South of the CBF do not appear to be significantly impacted by the development.

It is noted that the analysis presented above does not include wave run-up and overtopping. The results of more detailed analyses describing flooding and inundation due to waves are provided in Chapter 10 and Appendix D.1. These more detailed results demonstrate that the proposed works will not increase wave heights at the shoreline, nor increase flooding and inundation.

The issue of sedimentation in the dredged basin is also discussed in Chapter 10 and Appendix D.1.

8.4.2 Project Impacts – Earthquakes and Tsunamis

Seismic activity can also have a significant impact on the proposed facilities. A severe earthquake may have two primary impacts:

- Direct damage to port structures, such as piers, and land-based facilities due to dynamic loading.
- Liquefaction of soils within the port or reclamation area leading to geotechnical failure and structural damage. Liquefaction occurs when a saturated or partially saturated soil is subjected to dynamic loading, causing the soil to lose shear resistance and behave like a liquid.

Tsunamis are a relatively low risk as compared to these other natural hazards, but could potentially occur. As with hurricane waves, there is risk of overtopping and flooding of the reclamation area, with the potential for damage to landside infrastructure, and possible loss of life. It is noted that, unlike hurricane and surge events, there may be limited warning for a tsunami, and people may be on the piers or land reclamation area during a tsunami wave impact. Another risk with a tsunami may be if a ship is at berth when the tsunami wave strikes, as there is significant potential for the ship to break free of its moorings and possibly strike another vessel or run aground.

8.4.3 Climate Change Impacts

As noted in the CIG draft Climate Change Policy (2011), small island developing states, such as the Cayman Islands, are particularly vulnerable to the effects of future climate change. Climate change effects do not have the same potentially devastating impacts on the cruise berthing facility, but are certainly an important consideration in its planning and design. Specifically, increasing air temperatures, changing precipitation patterns, increasing frequency and intensity of extreme storm events and sea level rise are expected over the life of the facility. The design and construction of the project must be resilient to such future changes.

For this study, a site-specific investigation of climate change was carried out for Grand Cayman by the Climate Studies Group at University of West Indies, Mona (refer to Appendix B.2). The following trends and projections were estimated for the Cayman Islands:

- *Air Temperatures*: A projected increase of 0.6° to 5.9° F (0.34° to 3.26° Celsius) in mean, minimum and maximum temperatures over the 50-year life of the facility. This increase in air temperature would also result in an increase in sea temperatures.
- *Rainfall*: A general drying trend in annual rainfall will occur. There may be 10% less summer rainfall by the time period 2061-2080. The extreme rainfall indices generally suggest more intense but fewer rainfall events.
- *Sea Levels*: Caribbean sea level changes are near the global mean. Analyses of trends in historical data show an average increase of 3.2 mm/year between 1993 and 2010. Mean sea

level is expected to rise in the order 0.17 to 0.38 m by the years 2046 to 2065 (approaching the end of the design life of the facilities), relative to 1986-2005 levels. The mean sea level increase across all scenarios over the next 50 years is 0.26 m.

- *Hurricanes*: There will be no change in the overall frequency of hurricanes, but a shift towards stronger storms by the end of the century with maximum wind speed increases of 2% to 11%. A 20% to 30% increase in rainfall rates for the hurricane inner core is estimated with a small increase (10%) at distances of 200 km or greater from the hurricane core.

Climate change can potentially have a number of impacts on the operational aspects of the proposed facilities, including:

- Sea level rise resulting in increased potential for overtopping of the reclamation area and higher hydrodynamic loads on the primary structures.
- Increased hurricane intensity may lead to a variety of impacts including increased hydrodynamic loading of the facility structures, uplift forces on the piers, seabed scour around piles, sediment infilling of the dredged basin and overtopping/flooding of the reclamation area.
- Increased intensity of precipitation events potentially overwhelming the stormwater drainage and resulting in site flooding.
- Increased sea temperatures with resulting impacts on the coral reefs and benthic community, as discussed in the marine ecology report.

8.5 Proposed Mitigation Measures

8.5.1 Construction Impact Mitigation

Recommended approaches to natural hazard mitigation during construction include the following:

- Appropriate contractor planning and preparation, taking into account the risks associated with hurricanes, surge and seismicity. In particular, significant exposure of partially completed works should not occur during the hurricane season.
- A Disaster Management Plan should be developed by the Contractor in advance of construction. Ports of refuge and moorings for marine-based construction (such as dredges, barges and tugs) during hurricane events should be identified in advance. The contractor should utilize a hurricane forecasting service in order to support decision-making.

8.5.2 Operational Impact Mitigation

Hurricanes

Potential actions to mitigate hurricane hazard during operations are primarily related to appropriate design of the marine facilities, including:

- Final design of piers, dolphins and shoreline structures to resist hurricane conditions, with due consideration of climate change effects. This may include "controlled failure" of the deck if the design event is exceeded in order to maintain some level of functionality during repairs.
- Comprehensive investigations of wave-structure interaction during the final design phase, including possible physical model and computational fluid dynamics investigations to define extreme loading on the pier structures.
- Appropriate design of shoreline and flood protection systems at the land reclamation area to consider extreme wave loads, severe wave overtopping and extreme rainfall during hurricanes. The storm drainage system should consider the potential for hurricane inundation.
- Possible over-dredging of the port basin to accommodate sedimentation during a severe hurricane.
- Maintenance dredging immediately following a severe hurricane.
- Evaluation of scour potential at pier pile supports and implementation of scour protection, if required.
- Implementation of scour protection at the base of sheet pile walls.

Storm Surge

The primary mitigation against storm surge effects is appropriate design of shoreline and flood protection systems at the land reclamation area, taking into account future sea level rise.

Seismicity

Mitigation for seismic hazard should include:

- Comprehensive subsurface investigations, including completion of a Probabilistic Seismic Hazard Assessment (PSHA), to quantify seismic hazard and that incorporates recent earthquake data and employs current assessment methods.
- Final design of major structures to accommodate and resist extreme seismic loads.

The potential for soil liquefaction at the site due to earthquake needs to be examined in detail during project design. Typical approaches to mitigate liquefaction effects include the following:

- Utilization of free draining "structural fill" with high shear resistance, such as coarse gravel, will provide a denser state upon placement below water, and will reduce the likelihood of elevated pore water pressures during an earthquake, thereby reducing the risk of liquefaction.

- Ground improvements that densify soils (e.g. surcharging, dynamic compaction, vibroflotation, etc.) and/or dissipate pore-water pressures (e.g. stone columns) may be considered.
- Lengthening piles to found them in deeper, more competent strata may alleviate liquefaction induced bearing failures and/or settlement.

Tsunamis

Potential mitigation for tsunami impacts include:

- Undertaking a detailed tsunami hazard assessment to quantify risk, and define the potential magnitude of a tsunami wave.
- Final design of the port structures to resist the hydrodynamic loads associated with a tsunami.
- Design of shoreline and flood protection system around the reclamation area to accommodate wave overtopping during a tsunami.

Overall Port Operations

An overall Disaster Management Plan could be developed for the port that provides guidance in the event of any natural or anthropogenic hazards during the course of construction and operation. Linkages to a tsunami warning system as well as hurricane forecasting system could be developed. It is noted that a Tsunami Guideline Plan for Operators of Caribbean Ports was developed in 2011 through the support of various US agencies.

8.5.3 Climate Change

The primary mitigation for climate change effects is to appropriately design the marine structures to accommodate (or be adaptable to accommodate) these future effects, particularly sea level rise, increased intensity of storms, and increased intensity of rainfall events. This includes, in particular, the design of the pier substructure and superstructure system, the design of shoreline protection structures around the land reclamation area, the elevation of the land reclamation area and the stormwater drainage system.

9.0 TASK C - GEOLOGY AND SOILS

9.1 Introduction

Subsurface conditions (i.e. geology and soils) are a key consideration in the planning and design of any coastal engineering or marine infrastructure project. Considering the proposed cruise berthing facility, subsurface conditions may have an important impact on the project layout, structural design, potential impacts of development on the natural environment, and construction means, methods and costs. This Chapter provides a summary on these topics.

9.2 Assessment Methodology

A review of the available information regarding the regional geology of the Cayman Islands, and the subsurface conditions at the project site, was undertaken. This information was used to identify potential issues for project development associated with subsurface conditions. In general, the key issues are related to project design, construction, and environmental impacts. In particular, the nature of the geology and soils can influence the dredging and spoil disposal methodologies.

There is uncertainty related to the existing soils information and mitigation of the key issues will require comprehensive site-specific subsurface investigations. These investigations may result in future refinement of the EIA.

9.3 Baseline Conditions

9.3.1 Overview of Regional Geology

The Cayman Islands consist of three islands in the Western Caribbean, including Grand Cayman, Cayman Brac and Little Cayman (refer to **Figure 9.1**). The islands are outcrops of the Cayman Ridge, a submarine mountain range that extends from the southeast end of Cuba across the Caribbean Sea towards Belize. The Cayman Trough is located to the south, and is the deepest part of the Caribbean Sea, with water depths in excess of four miles.

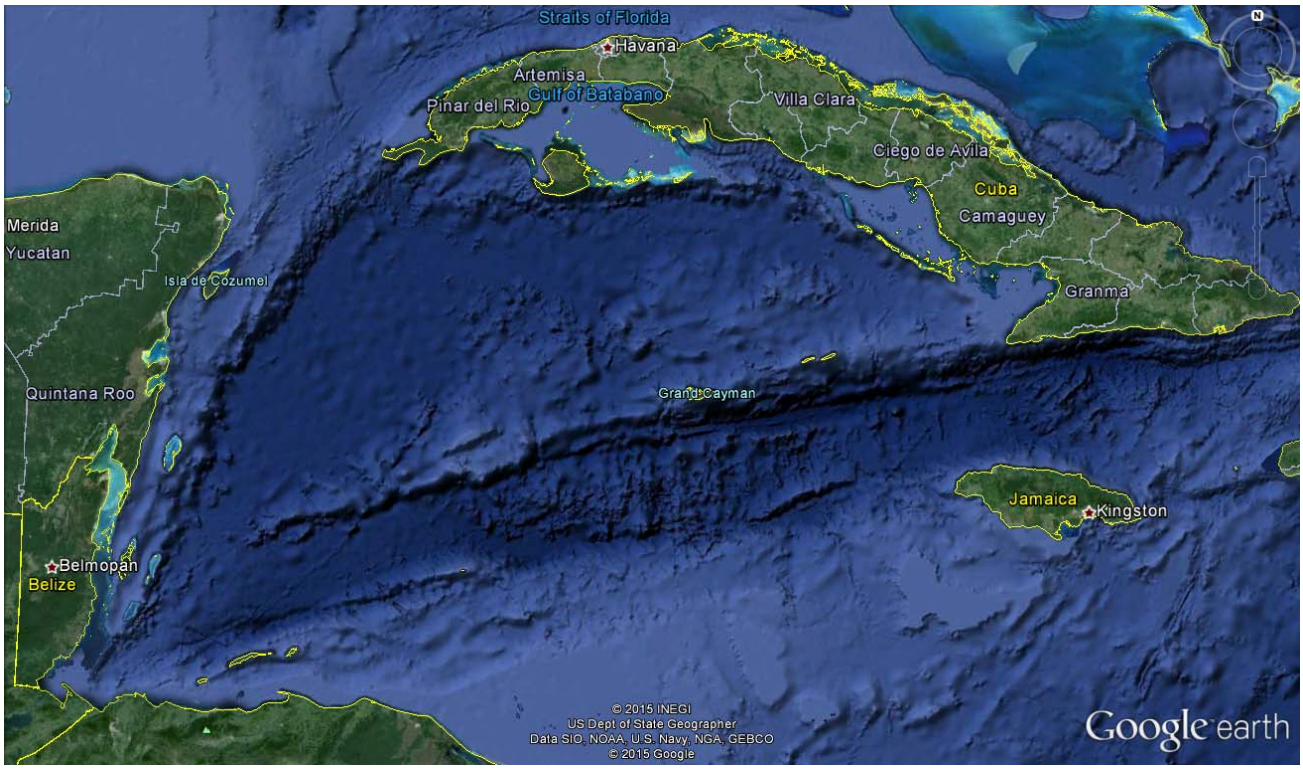


Figure 9.1 Location Plan – Cayman Islands (Source: Google Earth)

Grand Cayman is the largest of the three islands (76 square miles), and is located is located at 19°18'N, 81°16'W, approximately 150 miles south of Cuba and 180 miles west of Jamaica. It is an irregularly shaped island, oriented east-west with a length of approximately 22 miles and a maximum width of about 8 miles. The island has limited topographical relief, with the highest point about 60 feet above mean sea level. The proposed cruise berthing facility will be located in George Town Harbour (refer to Figure 9.2), which is located in an embayment on the west side of the island. George Town Harbour is located between Seven Mile Beach to the North and Southwest Point to the South.



Figure 9.2 Project Location - Grand Cayman Island

The Cayman Ridge has formed over geologic time due to the interaction between the North American and Caribbean tectonic plates. The Cayman Islands are individually uplifted fault blocks that were forced upward due to the frictional forces on the North American/Caribbean tectonic plate margin. The following summary of the geology of the Cayman Islands is taken from http://www.cayman.com.ky/geography-geology:

> *"The Cayman Islands are formed of two distinct formations of calcareous rock. The older limestone, called bluff limestone, was formed in the Oligocene-Miocene period, about 30 million years ago. This limestone forms the central core of each island. It is a dense karst limestone. Surrounding this bluff limestone core is a coastal limestone terrace called "ironshore". Ironshore is a formation of consolidated coral, mollusk shells and marl with some limestone. It was formed about 120,000 years ago in the Pleistocene period. The Pleistocene period was marked by a series of ice ages. After the last ice age, the sea level began to rise slowly from a level about 400 feet below present sea level."*

Due to the porous nature of the limestones along with the lack of topographical relief, there are no rivers or streams on any of the Cayman Islands. The lack of sediment runoff results in extremely clear waters around the islands. The excellent water quality contributes to the health of the coral reefs which surround the islands, making the Cayman Islands one of the most popular snorkeling and scuba diving areas in the world.

9.3.2 Subsurface Conditions at the Project Site

9.3.2.1 Summary of Available Information

The CIG provided Baird with copies of reports available from three previous geotechnical investigations undertaken in George Town Harbour, including:

- Fugro & McClelland Marine Geosciences, Inc. (1996);
- Kaderabek & Barreiro Consultants, Inc. (1999); and
- Ardaman & Associates, Inc. (2001).

In addition, the CIG provided a report by Mott MacDonald (2014) that gives a review and summary of these three subsurface investigations.

The three geotechnical investigations listed above included a total of 24 boreholes (BHs) around George Town Harbour, including 20 in the nearshore area (water depths of 13 to 30 ft) and four further offshore, near "The Wall" (water depths of 48 to 60 ft). The BH locations are shown in **Figure 9.3**; the nearshore BHs were advanced to depths ranging from 6 to 60 ft below the seabed, while the offshore BHs were advanced to a depth of 75 ft below the seabed. **Figure 9.4** presents a compilation of BH logs along three nearshore transects identified by the yellow lines shown in **Figure 9.3**. These transects generally fall within the footprint of the proposed dredging and land reclamation works.

As part of the present EIA study, a series of jet probes were undertaken around George Town Harbour and along Seven Mile Beach in order to estimate the depth of loose sediment cover over hard material. The jet probe locations and "refusal depths" (i.e. thickness of loose sediment cover) in George Town Harbour are shown in **Figure 9.5**.

The EIA study also included the collection and laboratory testing of grab samples of surface sediments to assess the physical and chemical characteristics of the sediments. Grain size distribution tests (GSD) were undertaken on nine samples (most located along Seven Mile Beach), while tests to assess the presence/level of various contaminants were undertaken on four samples in George Town Harbour. The sediment sample locations in George Town Harbour are shown in **Figure 9.5**.

The following sections summarize the available subsurface information at the project site, focusing on results of particular relevance to the proposed project. Additional information on the jet probes and physical characteristics of the sediments is provided in Appendix 1, while additional information on the chemical characteristics of the sediments is provided in Chapter 12 and Appendix E.

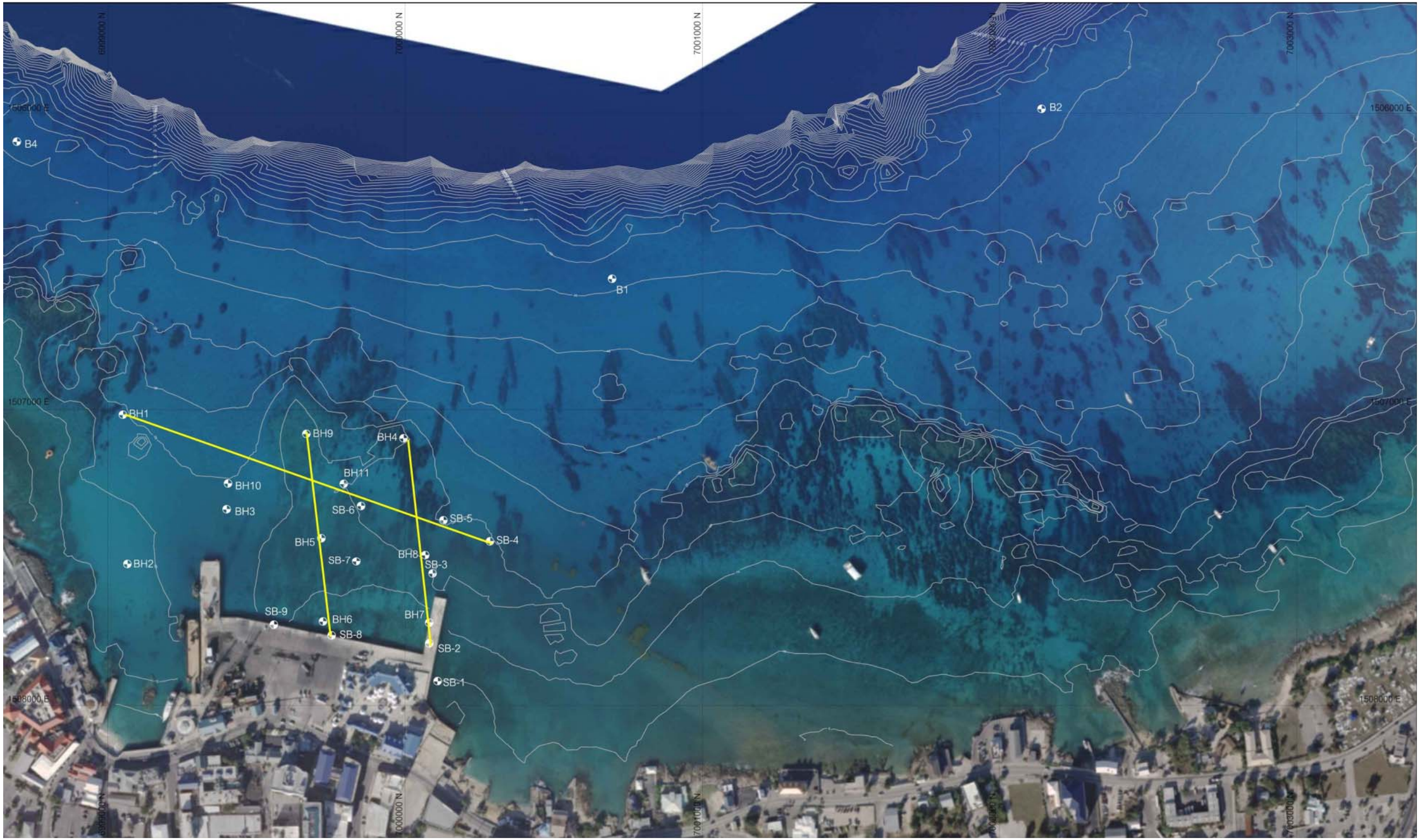


Figure 9.3 – Borehole Locations from Previous Studies

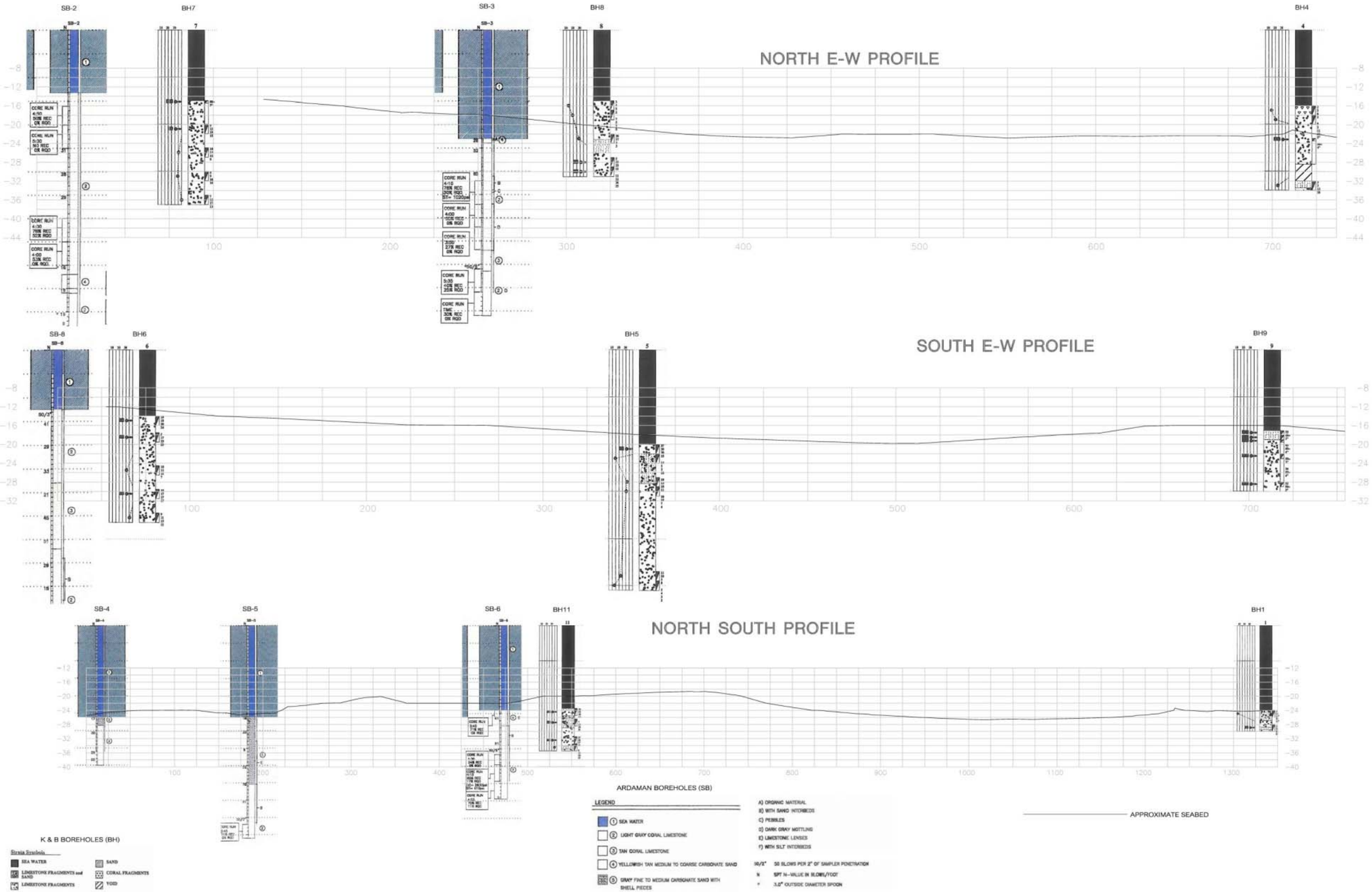


Figure 9.4 – Borehole Logs from Previous Studies along Selected Nearshore Transects

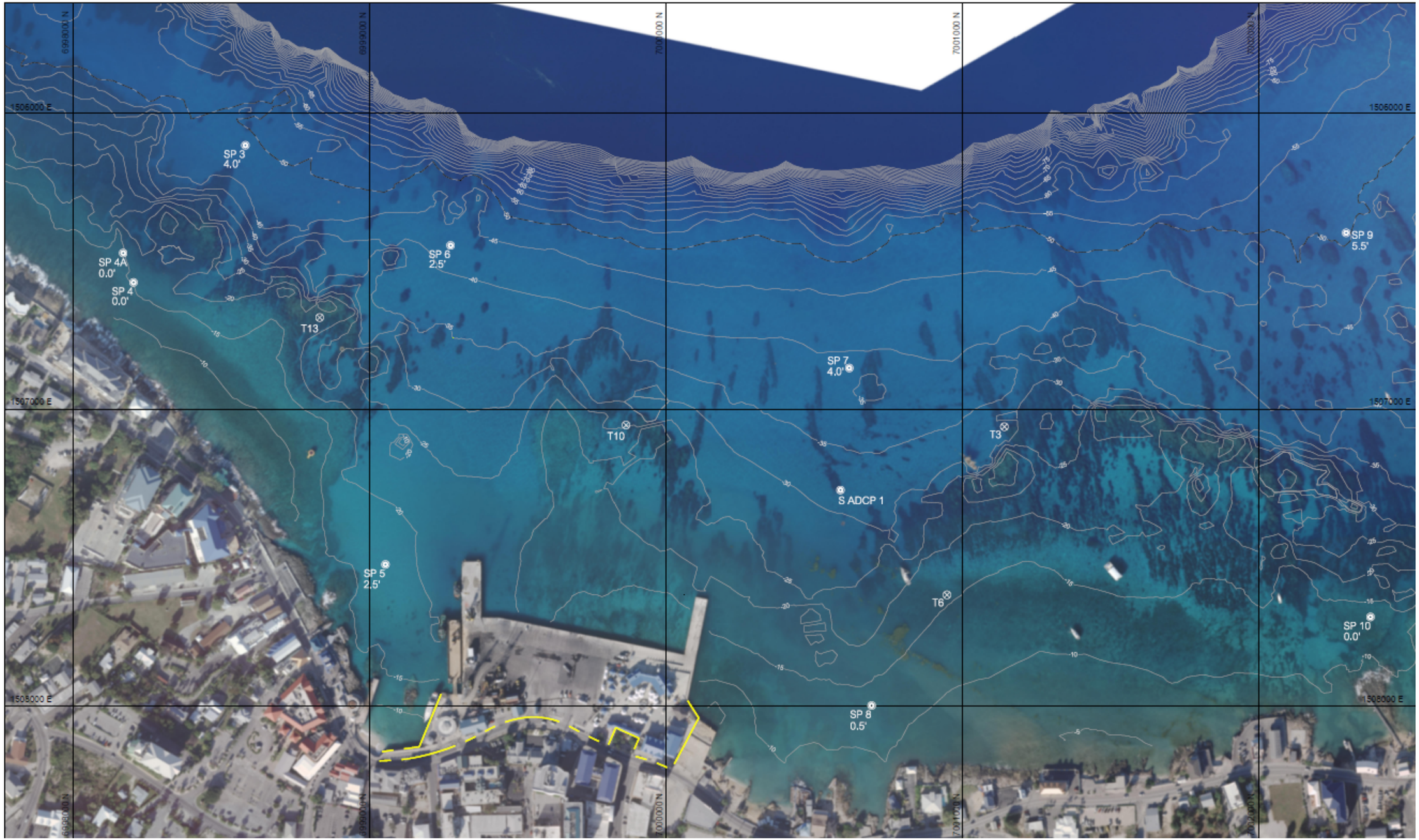


Figure 9.5 – Jet Probe Locations/Refusal Depths and Surface Sediment Grab Sample Locations

9.3.2.2 Physical Characteristics of Soils

Based on the results of previous geotechnical investigations at the site, the subsurface materials consist of calcareous sediments and rock, including loose granular material as well as cemented "rock" materials (i.e. limestone or calcarenite). The available information is insufficient to define the spatial extent and thickness of loose versus cemented material within the project footprint. Further, Mott MacDonald (2014) raised concerns regarding the accuracy of the samples recovered and tested by K&B (1999) and A&A (2001), suggesting that some of the results may have been compromised by the drilling and sampling methods used (i.e. loose limestone fragments may have been generated by drilling and sampling in cemented materials).

Table 9.1 presents a summary of the subsurface materials encountered in seven nearshore boreholes that were located within (or in close proximity to) the footprint of the proposed dredging and land reclamation works. Six of these boreholes (BH-1, 4, 5, 9, 10, 11) were conducted by Kaderabek & Barreiro Consultants in 1999, with the seventh (SB-4) by Ardaman & Associates in 2001. The borehole locations are shown in **Figure 9.3**; the borehole logs are included in the original study reports. The depths in the table are referenced to mean sea level (as noted later in this report, the proposed dredge depths range from -35.0 ft to -36.5 ft).

Table 9.1 – Summary of Subsurface Materials Encountered within Project Footprint

BH Location	Water Depth (ft)	BH Log Soil Description (all depths referenced to water level)
BH-1	24	Limestone fragments to -28.5ft, then 1ft of sand with limestone fragments below; BH terminated at -30ft.
BH-4	16	Limestone fragments overlain by 2ft of coral fragments; 3.5ft void below the limestone, then 2ft thickness of fine to medium sand; BH terminated at -34ft.
BH-5	20	2ft of limestone fragments overlying 6ft of limestone fragments and sand, then limestone fragments to BH termination at -51ft.
BH-9	17	2ft of fine to medium sand (with limestone fragments) overlying limestone fragments; BH terminated at -30ft.
BH-10	29	Fine to medium sand with some shell fragments to -43ft; BH terminated at -60ft.
BH-11	23.5	0.5ft of fine to medium sand over 1.5ft of limestone fragments, then 3ft of limestone fragments and sand, then limestone fragments to -34ft; BH terminated at -35.5ft.
SB-4	26	2ft of fine to medium sand over light gray coral limestone; BH terminated at -40ft.

The following sub-sections present a summary of the physical characteristics of the loose and cemented materials encountered at the project site based on the information presented in the prior geotechnical investigation reports.

Characteristics of Loose Granular Sediments

The earlier studies by K&B (1999) and A&A (2001) included grain size distribution (GSD) tests for 11 loose granular samples within the project footprint. These samples had median grain sizes (D_{50}) ranging from 0.5 to 10.8 mm, and fines content (silt and clay sized particles) ranging from 3% to

22% (with a median value of 7.4%). Details of the GSDs for the individual samples are provided in **Table 9.2**.

Table 9.2 – Loose Sediment Samples – Results of Grain Size Distribution Tests

Borehole No.	Sample Depth Rel. Water Level(ft)	Description	Grain Size (mm)			Composition		
			D85	D50	D15	%Gravel	%Sand	%Fines
BH-1	24-26	coraline limestone & sand	23.2	10.8	0.186	60.4	32.2	7.4
BH-1	28-30	sand and limestone	19.1	1.64	0.0851	38.2	48.1	13.7
BH-4	18-20	Limestone Fragments	23	9.16	0.225	56.3	36.3	7.4
BH-4	32-34	Sand w limestone frags.	2.26	0.606	0.201	10.7	82.5	6.8
BH-5	22-24	Limestone Fragments	15.1	3.26	-	45.0	32.7	22.3
BH-5	27-29	limestone & sand	28.1	8.77	0.378	60.1	31.1	8.8
BH-9	18-20	Sand & limestone	13.5	1.36	-	34.9	46.3	18.8
BH-10	38-40	Sand w limestone frags.	28.8	0.84	0.184	26.2	67.1	6.7
BH-10	29-31	fine to medium sand	1.23	0.536	0.226	0.8	96.0	3.2
BH-11	23-25	Sand w limestone frags.	18.8	0.801	0.203	29.8	64.0	6.2
BH-11	26-28	Sand w limestone frags.	13.3	1.1	0.137	36.4	52.3	11.3

GSD tests were also undertaken by Fugro (1996) on nine granular samples retrieved from the offshore BHs. These samples showed similar characteristics to those noted above, with D_{50}'s ranging from 0.2 to 2 mm, and fines content ranging from 1 to 21%.

Characteristics of Cemented Materials

For cemented materials, K&B (1999) and A&A (2001) completed uniaxial compressive strength (UCS) tests on five core samples collected from within the project footprint. These five tests gave UCS values ranging from 420 to 2,830 psi (average ~ 1,165 psi). A&A (2001) also completed split-tensile strength (STS) tests on three core samples collected from within the project footprint. These three tests gave STS values ranging from 150 to 1,020 psi (average ~ 595 psi).

Fugro (1996) did UCS tests on nine samples collected from the offshore BHs. These nine tests gave UCS values ranging from 290 to 3,575 psi (average of 1,555 psi).

9.3.3 Chemical Characteristics of Soils

As noted above, the subsurface materials at the project site consist of calcareous sediments and rock. For example, calcium carbonate tests completed by Fugro (1996) on three samples collected from the offshore BHs showed $CaCO_3$ content ranging from 94 to 97%.

Regarding sediment quality (i.e. presence of contaminants), sediment samples were obtained from four locations within the proposed development area and analyzed for a range of trace metals and organic compounds. The results of the laboratory tests are summarized below:

- Arsenic (As), Lead (Pb), Mercury (Hg) and Tin (Sn) were below the test detection levels (<0.002 ppm for Mercury and <1 ppm for all others).

- Copper (Cu), Nickel (Ni), Vanadium (V) and Zinc (Zn) returned positive results for all sediment samples, but levels were well below the guideline values.
- TPH and PCB's were undetected.

Additional information on the sediment quality testing and results is provided in Chapter 12 and Appendix E of the Environmental Statement.

9.3.4 Summary of Baseline Conditions

The available information provides a general indication of the composition and nature of the subsurface materials at the project site. However, the available information is insufficient to define the spatial extent and thickness of loose versus cemented material within the project footprint. This issue is further complicated by concerns related to the accuracy of the samples recovered and tested by K&B (1999) and A&A (2001), as there is evidence to suggest that some of the results may have been compromised by the drilling and sampling methods used (i.e. limestone fragments may be generated by drilling and sampling in cemented materials). Based on prior experience in similar materials at other sites, significant variations in material characteristics may occur, including a range in strength due to varying degrees of cementation, and the possibility of large voids.

The uncertainty in subsurface conditions represents an important risk to the project at this time. Better definition of the complex and variable subsurface conditions is required to assess several key design and cost issues, and to limit the risk of a claim for "changed conditions" during construction.

Based on review of available information on subsurface conditions, the following bullet points highlight the key findings of particular relevance to the proposed project:

- The subsurface conditions include an intermittent presence and varying thickness of loose calcareous sediments over calcarenite or limestone (i.e. cemented calcareous sediments);
- The loose sediments are generally gravel and sand, with median grain sizes (D_{50}) ranging from 0.2 to 10 mm and fines content (silt and clay sized particles) ranging from 1 to 22%;
- The degree of cementation and strength of the cemented materials varies (uniaxial compressive strength, UCS ~ 300 to 3,600 psi; split-tensile strength, STS ~ 150 to 1,000 psi).
- The seabed sediments are "clean," and are expected to be suitable for use as fill or for open water disposal without any special treatment (additional information on sediment quality is provided in Chapter 12 and Appendix E).
- The existing boreholes do not extend to anticipated embedment depth of piled structures.

9.4 Impact Assessment

9.4.1 Project Impacts

Development of the proposed cruise berthing facility will include nearshore dredging and land reclamation works, as well as the construction of two cruise ship piers (anticiapted to be open, pile-supported structures) and shoreline protection structures around the land reclamation area (anticipated to be vertical bulkhead wall, though a sloping rubble mound revetment is possible). With respect to the impacts of project development on subsurface conditions, the primary issue is disturbance of the seabed materials and the generation of turbidity and sedimentation, first by dredging and construction works, and subsequently by project operations (prop wash associated with cruise ship berthing and de-berthing at the piers). Other issues include the dewatering of dredged material placed within the reclamation area, disposal of the excess water to the sea, and the offshore disposal of dredged sediments. These issues are addressed in Chapters 11 and 16, and in Appendices D.2, D.3 and J.

As noted above, the subsurface conditions are a critical consideration in the design, construction and cost of the project. However, due to limitations in the available subsurface information, additional subsurface investigations are required to support detailed design development for the proposed project. In particular, more reliable information is required to support an assessment of the following key issues:

- Extent of loose sediment over cemented materials, and strength of cemented materials;
- Selection of dredging equipment, and associated production rates and costs;
- Ability to drive piles, and assessment of alternative methods to provide tensile capacity to resist wave extreme uplift loads on piers;
- Seismic risk, in particular for land reclamation area (liquefaction potential).

9.4.2 Climate Change Impacts

The potential effects of climate change are not expected to have any direct impacts on soils and geology, or the design of the project to address issues associated with subsurface conditions.

9.5 Proposed Mitigation Measures

In order to address limitations in the available subsurface information, and provide critical information on key design, constructability and cost issues for the project, a comprehensive site-specific subsurface investigation is required. The scope for work for the required investigations should include geophysical and geotechnical investigations, and a probabilistic seismic hazard assessment.

10.0 TASK D.1 - COASTAL PROCESSES - WAVES & SEDIMENT TRANSPORT

10.1 Introduction

The primary objective of this program was to assess and quantify baseline wave and sediment transport characteristics along this shoreline, in order to evaluate changes to these parameters that might result from the proposed development. Key issues raised by stakeholders included the following:

- Potential for negative impacts to Seven Mile Beach which might result from the proposed project;
- Potential for increased wave action in George Town Harbour and flooding along Harbour Drive and in George Town which might result from the proposed project;
- Potential for infilling of the proposed dredged basin and associated requirement for intermittent maintenance dredging, with associated disruptions to activities in the harbour.

This report discusses the meteorological and oceanographic conditions at the project site (i.e. tides, wind and wave climate) and the associated sediment transport processes; additional details may be found in Appendix D.1. Nearshore hydrodynamics (currents) and dredge plumes are discussed in Chapter 11.0.

10.2 Assessment Methodology

10.2.1 Metocean Data Collection

A number of metocean parameters were required to be collected in order to facilitate the assessment and modelling of waves and sediments offshore GTH and environs. In addition, as well as bathymetric data, a number of other primary input boundary conditions had to be quantified in order to support the coastal process modelling and, hence, predictions regarding impact of development scenarios. These included tides, currents, winds and wave conditions. While global ocean wave and tide models provided boundary input values for use in numerical modelling, it was very important that some level of model validation or calibration be undertaken. Local measurements of waves, currents and tidal conditions therefore provided an effective means of validating the numerical models in the vicinity of the project area.

The wave data collected under this project included a number of Nor'Wester (swell) events that were used in the validation process. The model predictions (validation) for these events were very good, giving confidence in the impact prediction results. It is also noted that small, non-swell wave events were captured during the wave collection and these were under-predicted by the model. Minimal or no sediment transport and sedimentation occurs however, under these low energy waves, so the model validation and its subsequent use were geared primarily to the simulation of swell events and the movement of sediment under these waves.

10.2.1.1 Bathymetry

Bathymetry data from a number of sources was obtained so as to have a good representation of the seabed and shoreline topography. A boat-based bathymetric survey using an echo-sounder and GPS device was carried out in June of 2014 in the nearshore of the project site to obtain water depth profile data. The methodology consisted of a boat based traverse of the nearshore zone, utilising a series of tracks running from deep water (approximately 160 ft water depth) in towards the shoreline. Horizontal positioning was measured using GPS equipment, and an ODOM EchoTrac CV100 single-beam echo sounder provided the water depth information along the tracks.

The area surveyed measured approximately 2.1 miles north-south and 0.75 miles east-west. Track lines were run perpendicular to the shore at a spacing of 500-650 ft, giving a total track length of approximately 15 miles. Water depths were collected at two second intervals, which for the boat speed used equated to a horizontal spacing of approximately 10 to 15 ft. The bathymetry of the GTH is shown Figure 10.1. Data files giving *x, y, z* bathymetric points were supplied to the DoE under separate cover.

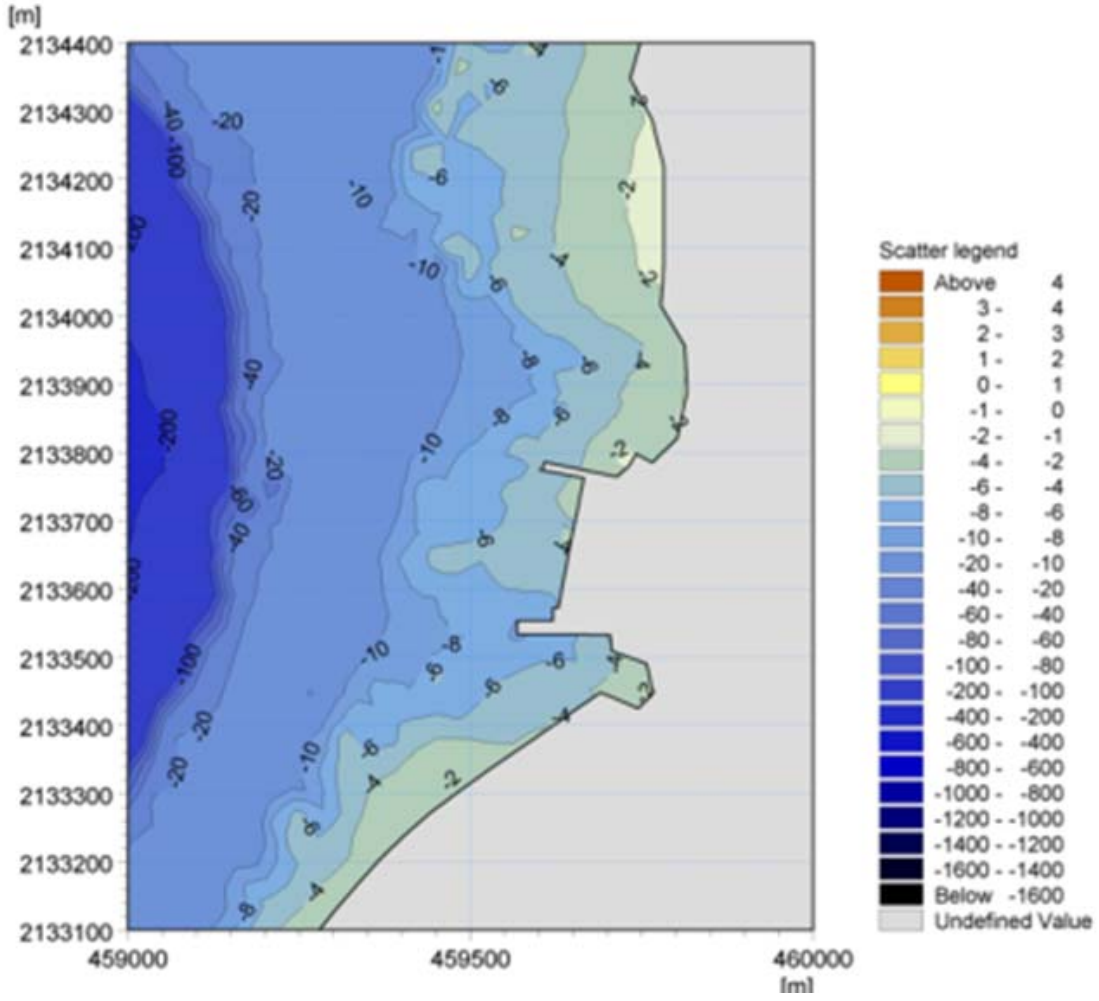


Figure 10.1 – Bathymetry in George Town Harbour

10.2.1.2 Waves, Currents and Tide Measurements

The instruments used in the wave, current and tide data collection program were Acoustic Doppler Current Profilers (ADCP's). In order to improve the reliability of the numerical model predictions and gain a more in-depth understanding of the coastal processes prevailing off the west coast of Grand Cayman, three instruments were deployed in the nearshore of the study area, located so as to achieve good spatial coverage within this area. The locations selected were:

- Offshore of SMB (North ADCP);
- Offshore of the GTH (South ADCP); and
- South of GTH (AWAC).

A fourth instrument, Quartermaster, was deployed in deeper water (850ft), however that instrument was used primarily to investigate deep water current patterns and upwelling trends, rather than for other measurement purposes. The locations of these instruments are shown in

Figure 10.2.

Wave, current and tide measurements for the North and South ADCP's started in June 2014 and continued through April 2015 (additional data incorporated as Appendix D1 to this report). These instruments provided day-to-day measurements of wave conditions through the summer (June to September 2014) and winter (October 2014 to April 2015) seasons. The AWAC was deployed in June 2014 and retrieved in August 2014. The Quartermaster was deployed in July 2014 and retrieved in August 2014. The schedule of deployment is shown in **Table 10.1**.

Table 10.1 Instrument recovery and deployments from start of data collection program

Instrument	*Deployment No.*	*Deployment Period*	*Deployment Location*	*Deployment Depth (ft)*
AWAC	1	9 Jun – 21 Aug 2014	19.2881 N, -81.39218 E	65
South ADCP	1	10 Jun – 22 Jul 2014	19.2975 N, -81.38626 E	30
	2	24 Jul – 14 Sep 2014		
	3	14 Oct – 5 Nov 2014		
	4	12 Nov -30 Dec 2014		
	5	31 Dec 2014 – 24 Apr 2015		
North ADCP	1	10 Jun – 22 Jul 2014	19.3445 N, -81.39142 E	50
	2	5 Aug – 9 Sep 2014		
	3	4 Oct – 11 Nov 2014		
	4	12 Nov – 30 Dec 2014		
	5	31 Dec 2014 – 24 Apr 2015		



Figure 10.2 - Deployment locations for Wave and Current Measurements

10.2.1.3 Tides

Tidal data was collected in tandem with the wave and current measurements at the AWAC (south of GTH), South ADCP (offshore the Port) and North ADCP (offshore Seven Mile Beach) instruments, as shown in Figure 10.2 The tidal data collection period spanned from June 2014 to early April 2015.

10.2.1.4 Winds

Winds were not measured under this programme, rather data were obtained from a number of sources. These included thirty-five (35) years of wind measurements from the Owen Roberts International Airport in Grand Cayman. These measurements span from 1980 – 2014, and yielded information on occurrence frequency of wind speed by direction. In addition, historical wind measurement data at the Government Administrative Building were obtained.

Second, a Climate Forecast System Reanalysis (CFSR) product was accessed. This is a global, high resolution, coupled atmosphere-ocean-land surface-sea system that is designed to provide the best estimate of the state of these coupled domains over the period of interest. The CFSR data includes (1) coupling of atmosphere and ocean processes during the generation of a 6 hour guess field, (2) an interactive sea-ice model where applicable, and (3) assimilation of satellite radiances. The CFSR global atmosphere resolution is ~38 km (24 miles). The global ocean is resolved at 0.25° at the equator, extending to a global resolution of 0.5° beyond the tropics.

10.2.2 Coastal Process Modelling

Numerical modelling techniques were used to gain an understanding of the baseline coastal processes that are in evidence along the shoreline of Grand Cayman. Waves, currents and sediments all interact to affect shoreline morphology, and to produce changes such as erosion or accretion. Wave conditions that are suitable for input to numerical modelling are available from global ocean wave models. Several such global models exist and are generally maintained, operated and archived by government entities such as the National Oceanic and Atmospheric Administration (NOAA), the United States (US) Navy, the United Kingdom Meteorological Office (UKMO), and some specialist private sector firms that service the offshore oil industry.

These deep water wave models are usually applied on spatial scales (grid increments) larger than 10km and outside the surf zone. As a result, the models are not at a sufficiently detailed scale to provide accurate nearshore wave data for islands as small as Cayman. The nearshore wave climate for this project was therefore developed using the output from an offshore wave hindcast undertaken by Baird. The model archived wave parameters included wave height, period and direction as well as the wind speed and direction. Model output was provided every three hours covering the period from 1980 to 2014.

The numerical model used to evaluate the nearshore conditions, MIKE 21, relies on a flexible computational mesh (

Figure 10.3) to compute the waves and hydrodynamics. The flexible mesh is ideal for nearshore wave computations as it facilitates the modelling of large complex areas that, at the same time, require detailed resolution of smaller features. The mesh describes the spatial relationship between all the computation points, and is principally governed by the water depth. The main source of wave energy is from the wind, and the primary wave energy sinks include dissipation through wave breaking, white-capping, and bottom friction.

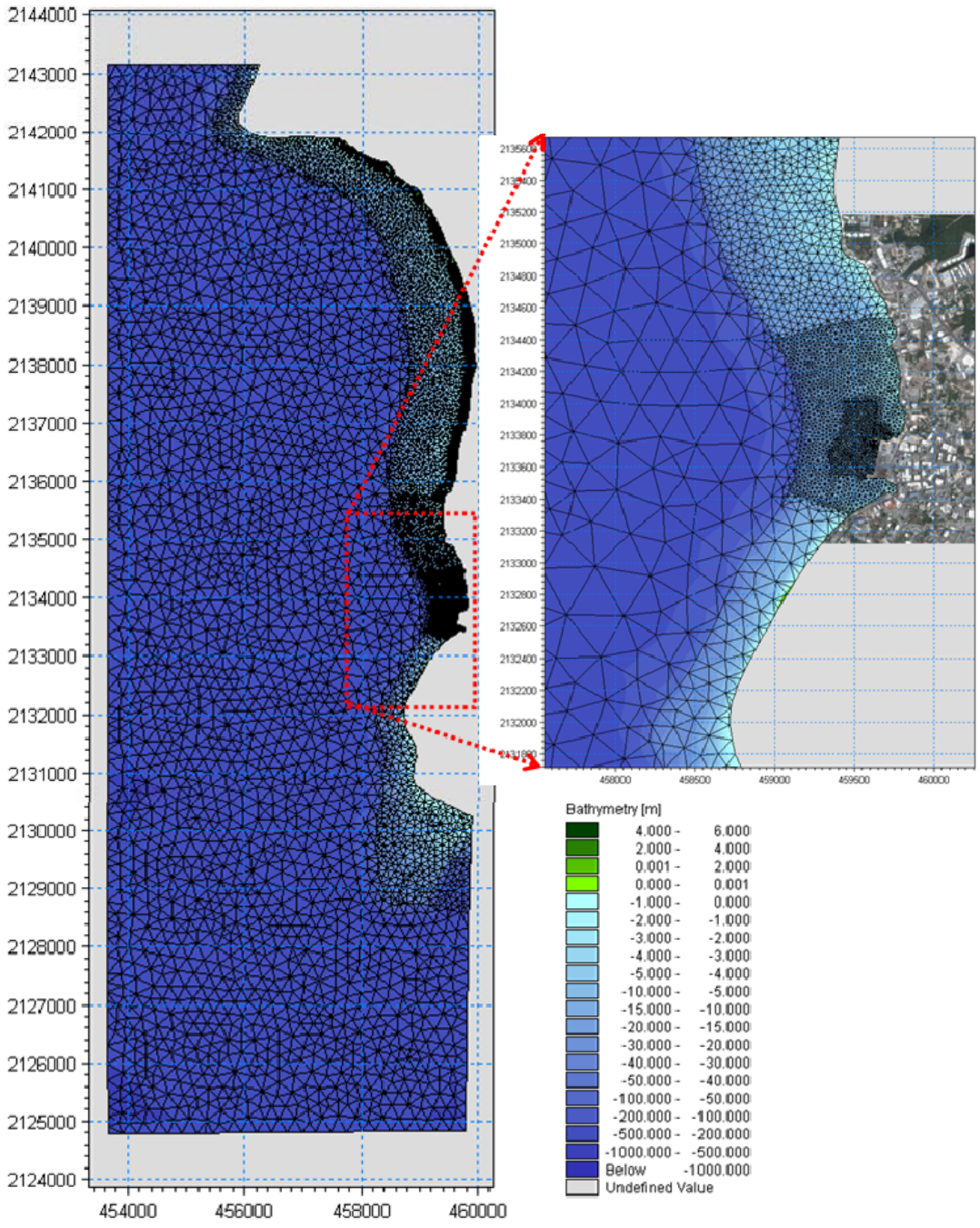


Figure 10.3 - MIKE 21 Flexible Mesh Used to Estimate Nearshore Wave Climate at Project Site

10.3 Baseline Conditions

10.3.1 Baseline - Metocean Conditions

A comprehensive understanding of metocean conditions and nearshore hydrodynamics is critical to the development and assessment of alternatives for the project, including the potential impacts of the project on the natural environment (in particular, sediment transport and water quality), as well

as the potential impacts of these natural environment conditions on the functional performance of the proposed facility. Extensive field measurements and modeling of metocean conditions and nearshore hydrodynamics were undertaken to define the range in conditions which may occur at the project site. An overview summary of these conditions is presented below for the metocean conditions. Details of hydrodynamic conditions are presented in Chapter 11 of the Environmental Statement. In addition, more detailed information on the field measurements and modeling of metocean conditions and nearshore hydrodynamics is provided in Appendices 2, D.1 and D.2 of this report.

10.3.1.1 Wind Climate

Long-term statistical summaries of the (1980-2014) wind climate from the Owen Roberts International Airport are presented in **Figure 10.4** for the summer (May - October) and winter (November - April) seasons. These figures depict the frequency of occurrence of wind speed by direction, and clearly show the predominant E-NE Trade Winds. The wind speeds are seen to be generally stronger during the winter months. Over the 35 year period of record, the average wind speed during the winter is approximately 11 knots. A wind speed of 23 knots is exceeded approximately 5% of the time during the winter. In addition, wind speeds of up to 40 knots may occur during Nor'westers.

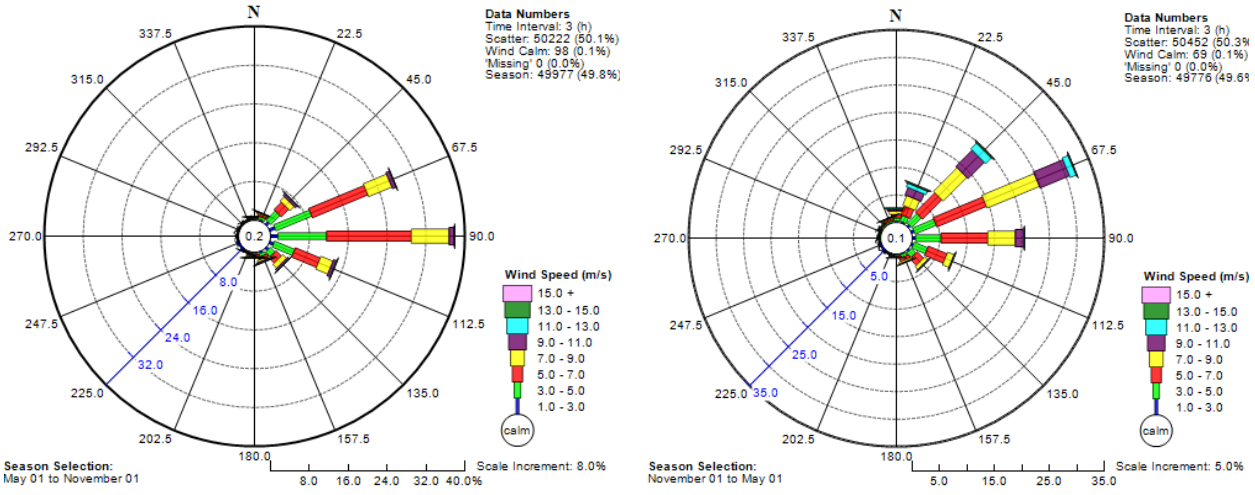


Figure 10.4 - Wind Roses (1980 – 2014, ORIA)

10.3.1.2 Wave Climate

With respect to the wave climate, GTH is located on the west (lee) side of Grand Cayman Island, and is therefore sheltered from waves associated with the prevailing NE Trade Winds. However, GTH is exposed to "Nor'westers" during the winter months. These events, which may arise suddenly, are characterized by strong winds (up to 40 knots) and rough wave conditions that

approach GTH from the NW, and are typically accompanied by thunderstorms and heavy rain. Nor'westers typically occur several times each winter, and may last for up to several days. These events are problematic for the existing tender operation, resulting in the relocation of the cruise ships and tender operations to a more sheltered location (remote from George Town) on the South Shore (Spott's Landing), as well as missed calls (refer to additional discussion on this topic in Appendix M). These events may also cause overtopping of the port area and flooding along Harbour Drive.

Figure 10.5 below shows the occurrence of wave action and extensive overtopping in GTH during a typical Nor'wester.



Figure 10.5 - Wave Action in GTH During Typical Nor'wester

Comprehensive investigations were undertaken to define the wind and wave climate at the project site, including the development of a long-term (1980 – 2014) wind-wave hindcast database in deep water surrounding Grand Cayman, and numerical modeling of shallow water wave transformations as the waves propagate towards the site. The MIKE 21 spectral wave model (SW) used for modelling of nearshore wave conditions was run in a semi-stationary mode, with time varying inputs of deep water wave parameters that were taken from Baird's offshore wave model and applied to the boundaries of the model domain (see **Figure 10.6**). The time-series wave boundary conditions included the integrated spectral parameters Hs, Tp and mean direction. The corresponding wind speeds and directions were applied over the entire model domain. Tidal amplitude variations, which generally vary less than 0.7 ft, and tidal currents, were not included in the simulation. The MIKE21 output time series were computed and extracted in the nearshore zone of the project site. The wind and wave climates were validated against available measurements, including satellite observations, NOAA buoys in the region, and site specific measurements collected as part of this study. The available measured data provided a reasonable dataset for such validations.

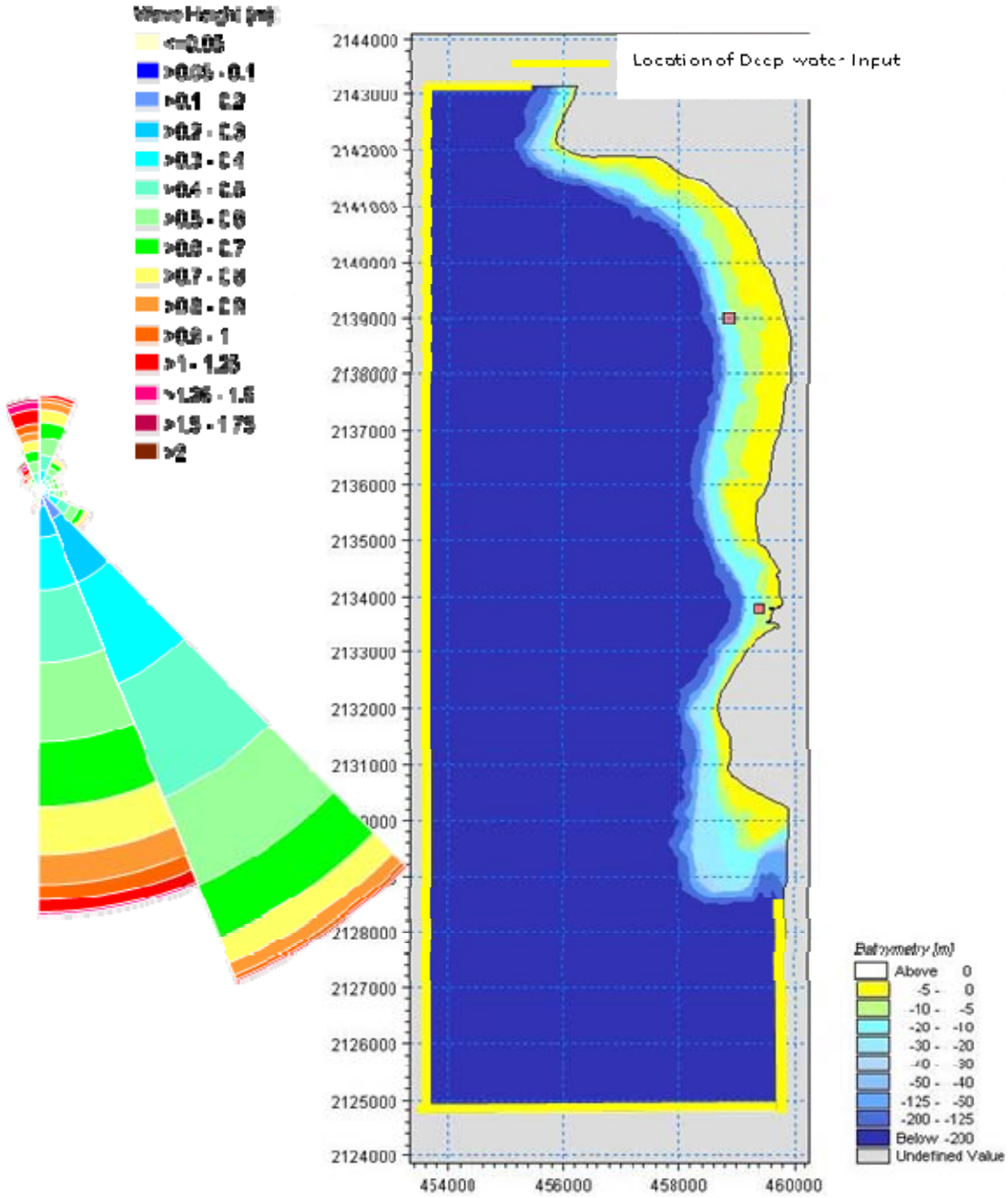
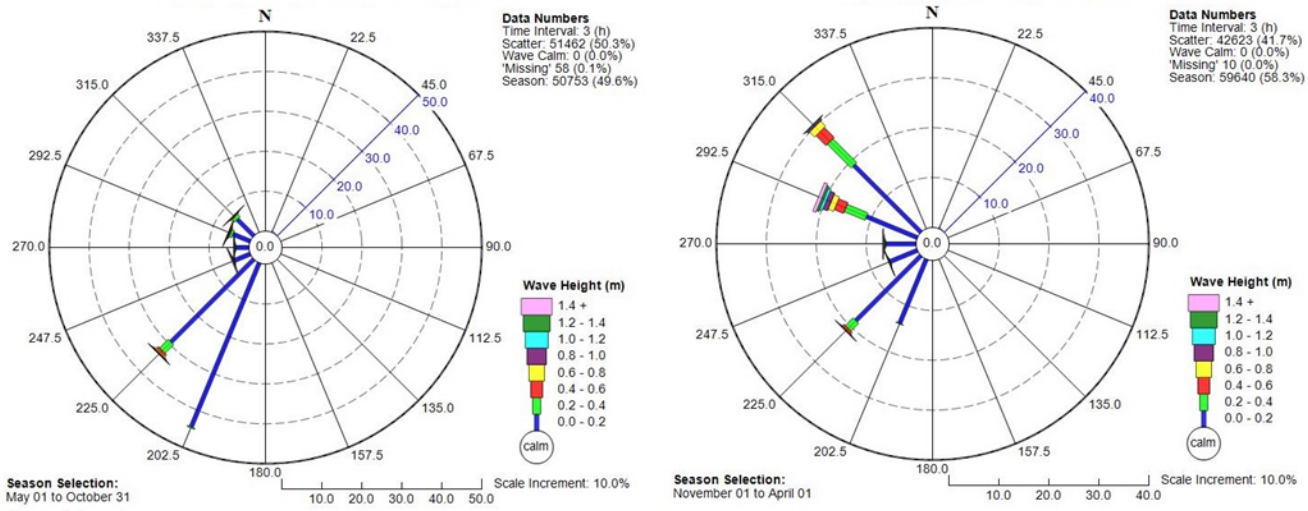


Figure 10.6 - Deep Water Wave Data Input from Offshore Wave Model

Statistical summaries of the wave climate in GTH for the summer and winter seasons obtained from the wind-wave hindcast are presented in **Figure 10.7**. The wave roses show a strong seasonal effect, with SW waves predominant in the summer months and NW waves predominant in the winter months. The average wave conditions in GTH during the summer are Hs ~ 0.3 ft (significant wave height) and Tp ~ 7 s (peak wave period). The average wave conditions in GTH increase to Hs ~ 0.6 ft and Tp ~ 7 s during the winter. During Nor'westers, the wave conditions in GTH may reach Hs ~ 5-10 ft and Tp ~ 6-9 s. More detailed information on the wind and wave climate, including the frequency of occurrence and severity of Nor'westers, is provided in Appendix D.1.



Summer (May – October) **Winter (April – November)**

Figure 10.7 - GTH Wave Roses (1980 – 2014)

10.3.1.3 Tides

The tidal range in GTH is relatively small (spring tidal range of approximately 0.7 ft). The range of water levels that were recorded for the instruments are shown in **Table 10.2** below.

Table 10.2 Instrument recovery and deployments from start of data collection program

	Highest High Tide ft (m) during the period of measurement	Lowest Low tide ft (m) during the period of measurement
AWAC	0.83 (0.25)	-0.97 (-0.30)
South ADCP	1.44 (0.44)	-1.13 (-0.34)
North ADCP	1.40 (0.43)	-1.20 (-0.37)

10.3.2 Baseline – Measured Waves

Representation of the measured wave data in the form of wave roses reveals a very distinct seasonality to the wave climate (see

Figure 10.8), which matches very well the results from the long-term wind wave hindcast presented above. During the period from June to September, the majority of the wave energy comes from the SW quadrant. Between November and December, the majority of the wave energy is from the NW quadrant. Overall however, the results indicate that while a general trend can be depicted during the summer and winter periods, the wave directional distribution remains quite complex in the nearshore of the project site.

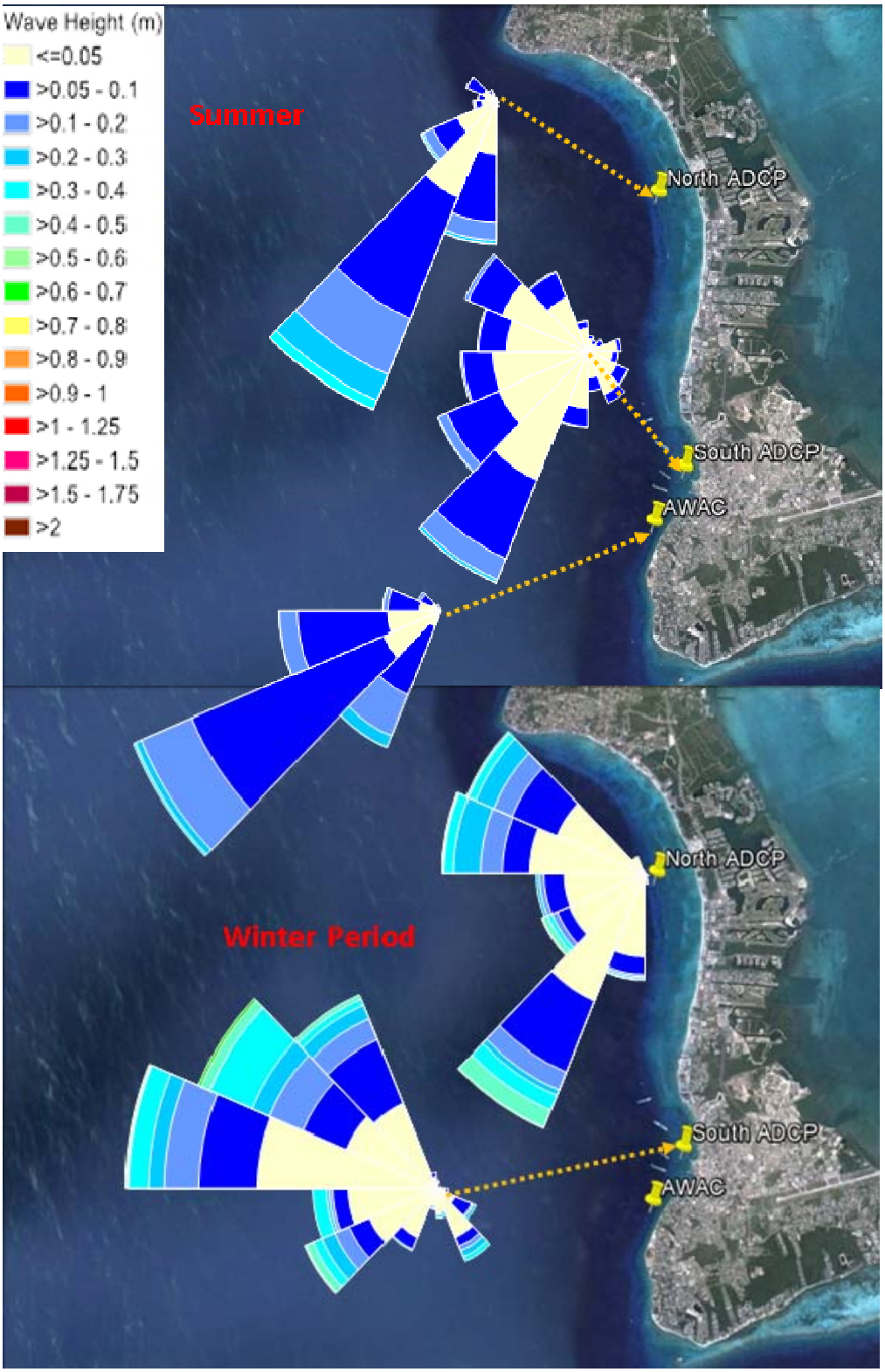


Figure 10.8 - Directional Distributions of Measured Waves During Summer (top) and Winter (bottom)

10.3.2 Baseline Conditions – Sediment Transport

10.3.2.1 Methods and Techniques

A number of methods and techniques were utilised to define the characteristics of sediment transport along the west coast of Grand Cayman, both qualitatively and quantitatively. These included:

- 1-D and 2-D sediment transport modelling along this coastline;
- Bed level change analysis;
- Google Earth observations and analysis;
- Beach planform data analysis (data from Lands & Surveys)
- Beach profile analysis (Lands & Surveys data); and
- Beach width analysis specific to the Marriott Hotel.

The information generated from these various techniques provides an important baseline against which the potential impacts of the project can be assessed. These include impacts on the stability of Seven Mile Beach (7MB), and the potential (or not) for sedimentation of the dredged basin and the requirement for maintenance dredging.

Appendix D includes additional detail on the methodologies and results, including the following:

- Appendix D-1 – Waves and Sediment Transport
- Appendix D-2 – Hydrodynamics and Dredge Plumes

10.3.2.2 Summary of Littoral System

The various data sources gave differing insights; however, in summary, the following can be said about the littoral system along the West coast of Grand Cayman Island:

- The supply of sediment to the West coast of Grand Cayman is relatively low, with only limited amounts of sand being transported around SW Point into the GTH area, and around NW Point into the 7MB area. Coral reefs along the west coast also supply sand to the local nearshore system.
- The sand on 7MB is likely brought there from the north shore of Grand Cayman. It is not hastily renewed and should be treated as a precious resource.
- Coral reefs around the island are the primary source of sediment to the nearshore region. A significant portion of these sediments may be lost offshore (over "The Wall") during storm events. In addition, the rate of replenishment from this source is quite low.

- 7MB acts as a "closed" system most of the time, with sand moving to the north in the summer and to the south in the winter. Some sand also appears to move in a cross-shore direction.
- Three "bands" of sediment in movement have been identified. The first is on the shoreline itself (swash zone - yellow), where most of the sand in this system moves; the second is a nearshore band that is approximately 150 to 300 ft from the shoreline (green); and the third is a wide band located about 3300 ft from shore (blue). Sand movement in this outer layer however is of the order of 100 times less than at the shoreline (**Figure 10.9**).
- The shoreline sediment pathway does not usually move or connect beyond the southern headland of 7MB, and so does not have a direct pathway to GTH. This is also mostly true for the nearshore pathway.
- The offshore pathway comes in close to shore in the vicinity of the port and it is this pathway that over time has fed the port area with sand deposits. The low rate of movement and deposition from this pathway explains why the port has not required dredging for some time.
- During storms and energetic Nor'westers, the surf zone widens and suspended sediment may leak around the south headland into the area north of the port. The same does not appear to happen from the south to the north, further confirming the fact that sediment processes at Seven Mile Beach are not fed from the port area.



Figure 10.9 - Sediment Transport Pathways Along 7MB

- Sediment transport along 7MB tends to be from South to North during the summer and from North to South during the winter. As a result, SMB shows seasonal trends in beach width, with the North end of the beach being wider in the summer, and the South end of the beach being wider in the winter.
- A review of beach monitoring data available over the past ten years shows that SMB is subject to natural fluctuations in beach width in the order of 30-60 ft (see **Figure 10.10**).
- Individual storms may result in significant changes in the beach width (up to 60 ft). Beach recovery following a severe storm (such as Hurricane Ivan) can take up to three to five years.



Figure 10.10 - Typical Variations in Shoreline Position along Seven Mile Beach (derived from Lands & Surveys beach planform database, 2003-2014)

10.4 Impact Assessment

The following sections summarize the impacts of project development on nearshore wave conditions and sediment transport. The impacts of the project on sediment and water quality are presented in Chapters 11 and 12.

10.4.1 Project Impacts

10.4.1.1 Impact on Nearshore Wave Climate (NW and SW Swells)

The nearshore wave model was used to simulate the impacts on the nearshore wave climate that could be expected to occur as a result of the development of the proposed cruise berthing facility. The estimated ten year wave event was selected for the purpose of this assessment.

Figure 10.11 presents the wave height patterns in the vicinity of GTH for the ten year storm event from the NW with the existing configuration and with the proposed project in place. The comparison shows that north of the port, the wave patterns are almost identical. South of the port, the wave patterns are similar, but the wave heights are smaller in Hog Sty Bay with the proposed

works in place. This is not surprising, as the proposed works provide additional shelter to Hog Sty Bay from NW wave events. Seaward (west of the port), the wave heights increase due to the effects of wave reflection off the expanded land reclamation area, with a band of increased wave heights extending out into deeper water. It is noted that wave reflection occurs from the existing land reclamation area as well, and can create problems for the tender operation, particularly when using the Royal Watler Pier. Wave reflections are not anticipated to be a problem for large cruise ships, but could be a problem for smaller vessels (tender boats, etc.).

Figure 10.12 presents a similar comparison for the ten year storm event approaching from the SW. As expected, the wave conditions to the north of the new facility are reduced due to the sheltering effect of the land reclamation area. There is a localized increase in wave energy to the south of the new facility; however, the wave conditions within Hog Sty Bay are not significantly increased. As for the NW storm, there is also evidence of increased wave action seaward (west) of the port due to the effects of wave reflection; however, the increase is less than for the NW waves.

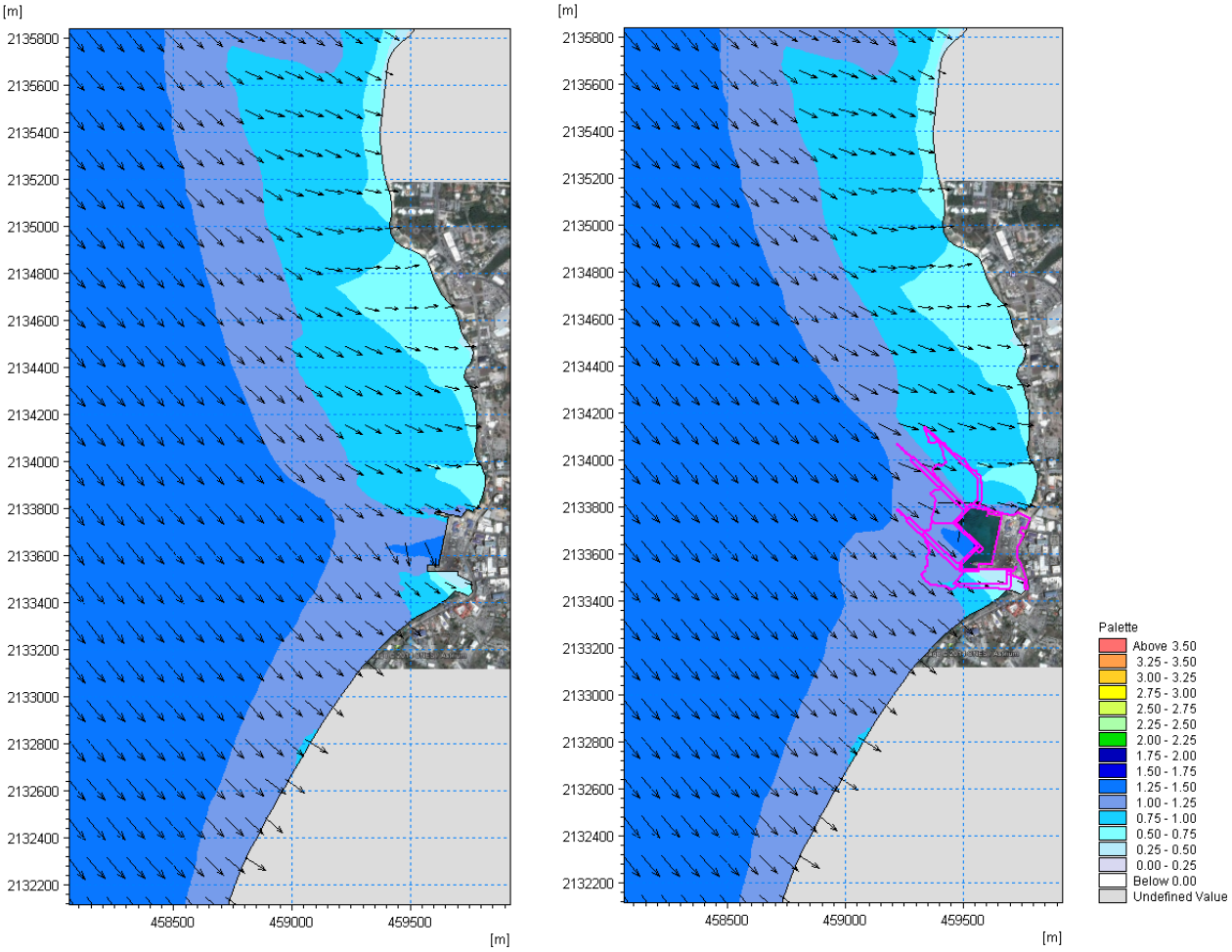


Figure 10.11 - NW Storm – Existing Conditions (L) and Proposed Project (R)

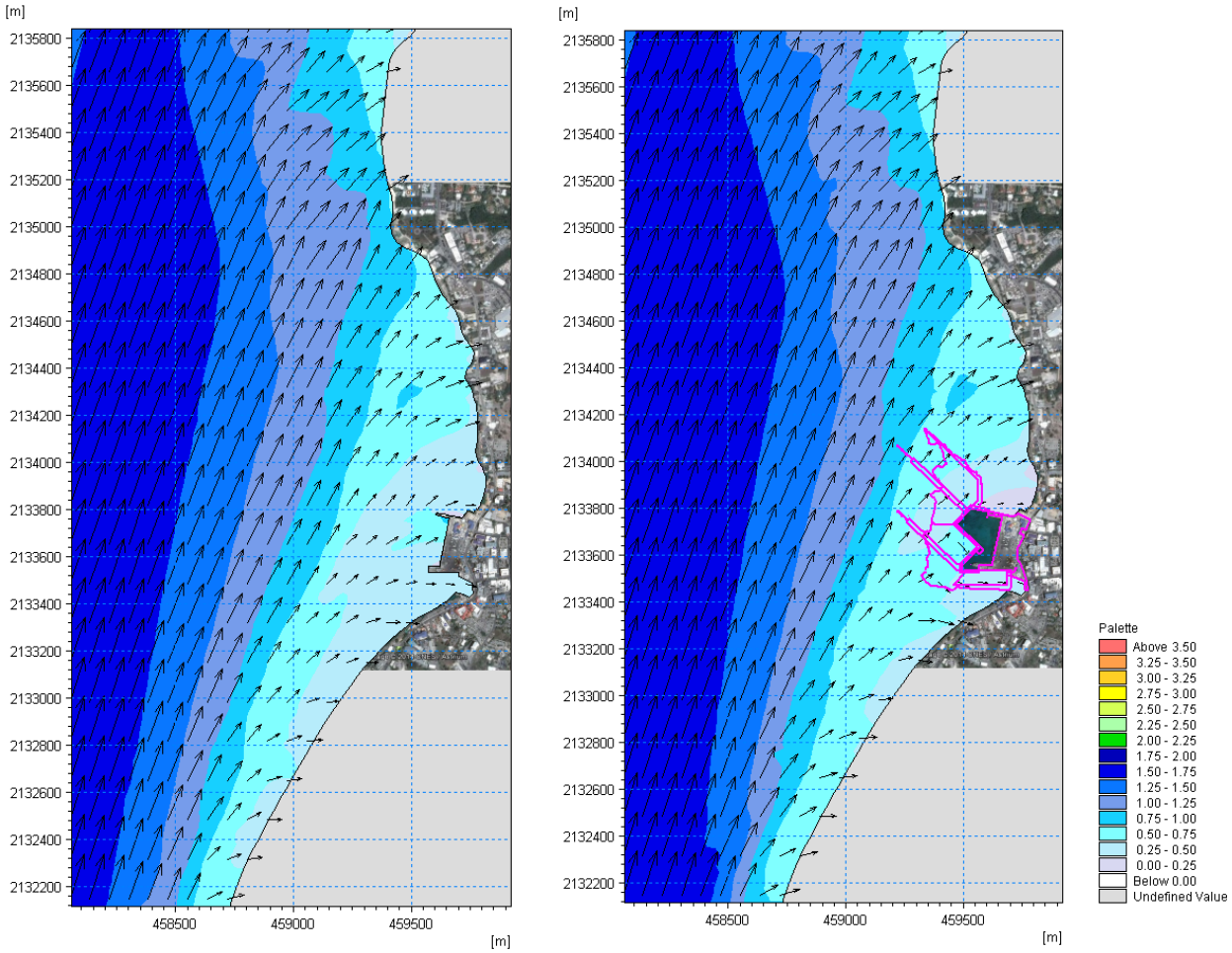


Figure 10.12 - SW Storm – Existing Conditions (L) and Proposed Project (R)

10.4.1.2 Impact on Flooding Risk from Hurricane Waves

This analysis included wave overtopping for both the existing (baseline) and proposed Option C. In this way the flooding conditions at the project site and surrounding George Town area resulting from the 1 in 50-year hurricane wave conditions could be accurately assessed.

For the existing condition, flooding of up to 10ft is observed at the port while values up to 10ft and 12ft are observed respectively to the north and south of the port. With the proposed Option C in place there is an increase in the flooding level up to 15ft, however this increase is limited to the area of the land reclamation only and is not widespread. South and north of the port, the flood levels with the proposed Option C remain similar with maximum predicted being at 12ft to the south and 10ft to the north. Also for Option C, in the land space where the existing port now occupies, there is a very slight increase in flooding. All flooding elevations are given relative to MSL. The flood risk predictions are shown in **Figure 10.13**.

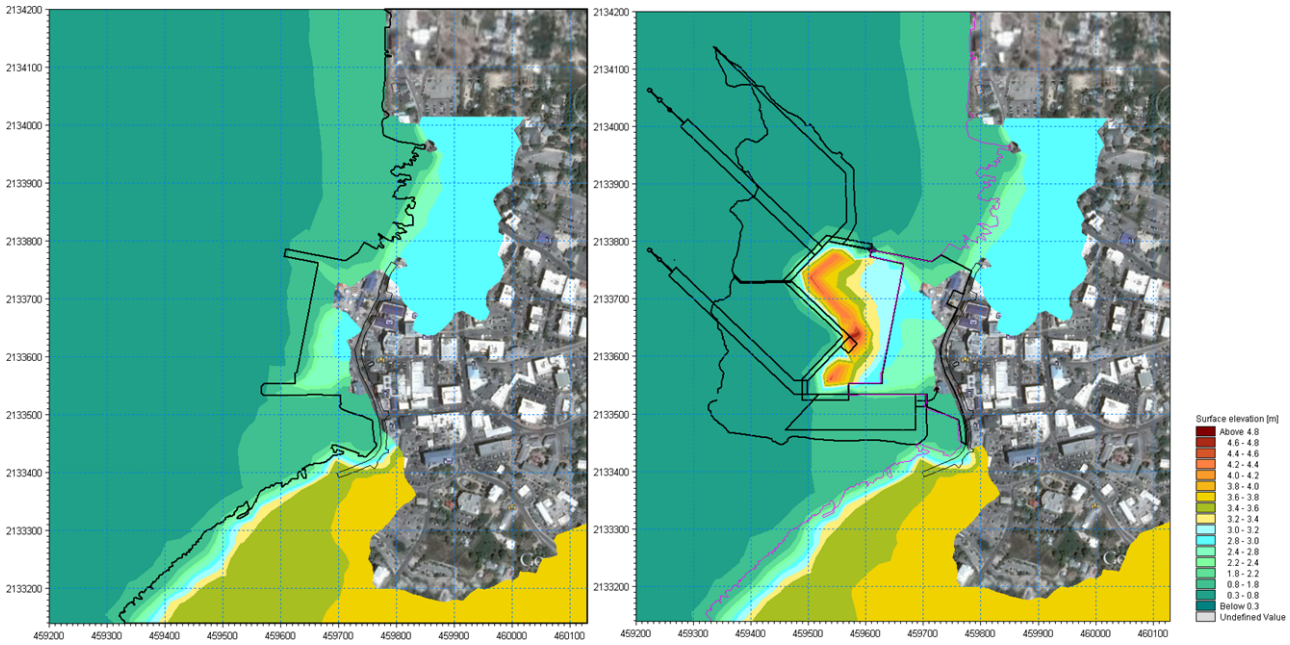


Figure 10.13 - SW Storm – Existing Conditions (L) and Proposed Project (R)

10.4.1.3 Impacts on Sediment Pathways

Figure 10.14 presents a plot of the sediment transport total load for a NW swell event and reveals the direction of sediment transport along the west Grand Cayman shoreline. For the existing scenario, the wave induced currents move south along the shoreline and go around the existing port. These currents appear to become much smaller in magnitude south of the port. Transport rates above 10 $m^3/s/m$ appear in pockets that hug the shoreline. For the proposed alternative, there is an observed significant change in current velocities in the immediate area of the port, in that the currents become much less. The area of dredging therefore becomes an area of decreased total load transport.

For the SW swell (**Figure 10.15**), the total load direction is northward along the shoreline. However, in the vicinity of the port, load rates drop to below 1 $m^3/s/m$. For the proposed alternative, the total load velocities appear to be increased slightly in the vicinity of the port. Further, there appears to be a small increase in total load magnitudes. As with all of the plots for this wave direction, the reef feature to the north of the port appears to have a significant effect on the total load patterns.

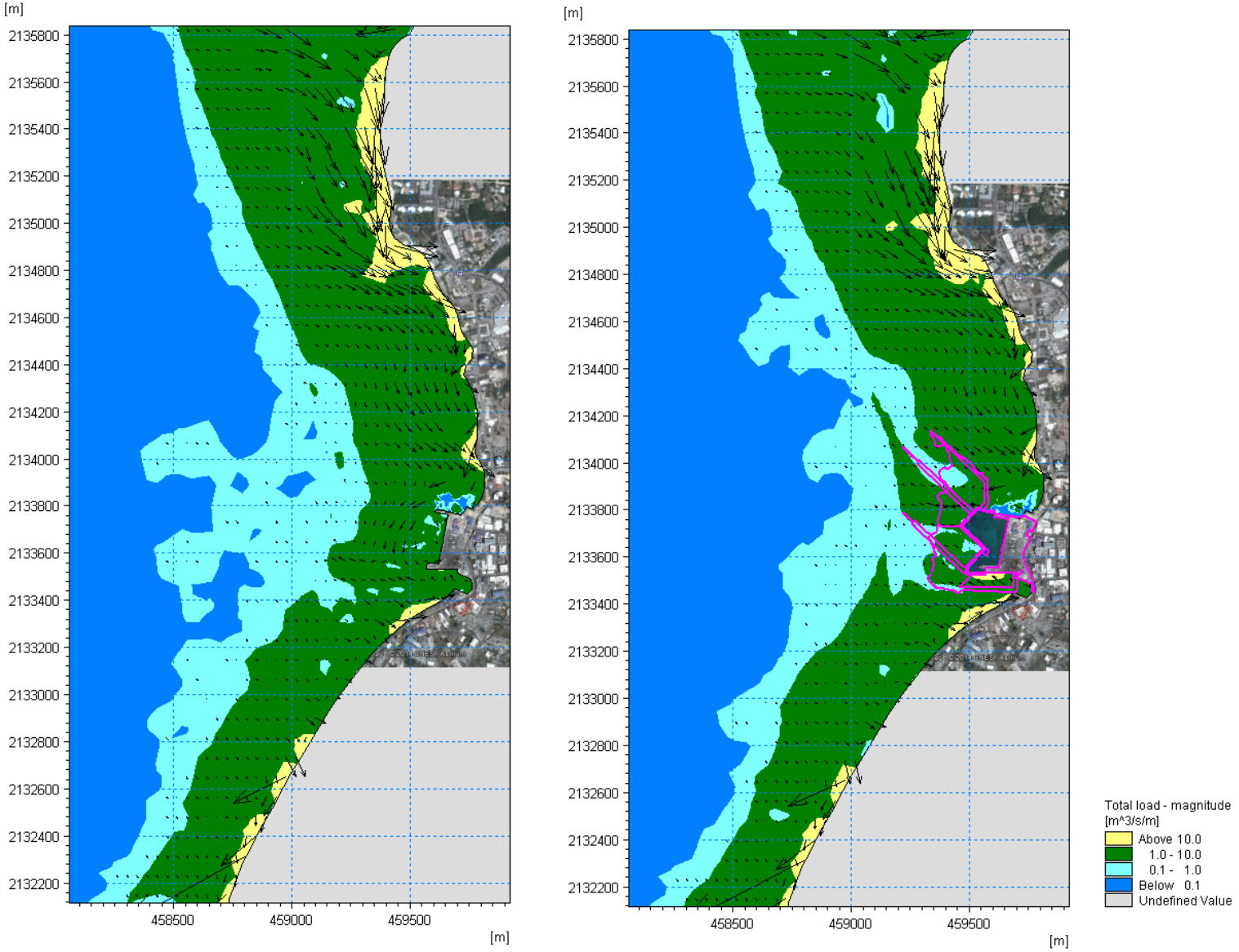


Figure 10.14 - Total Load Pathways for GTH: NW Swell – Existing (L); Proposed (R)

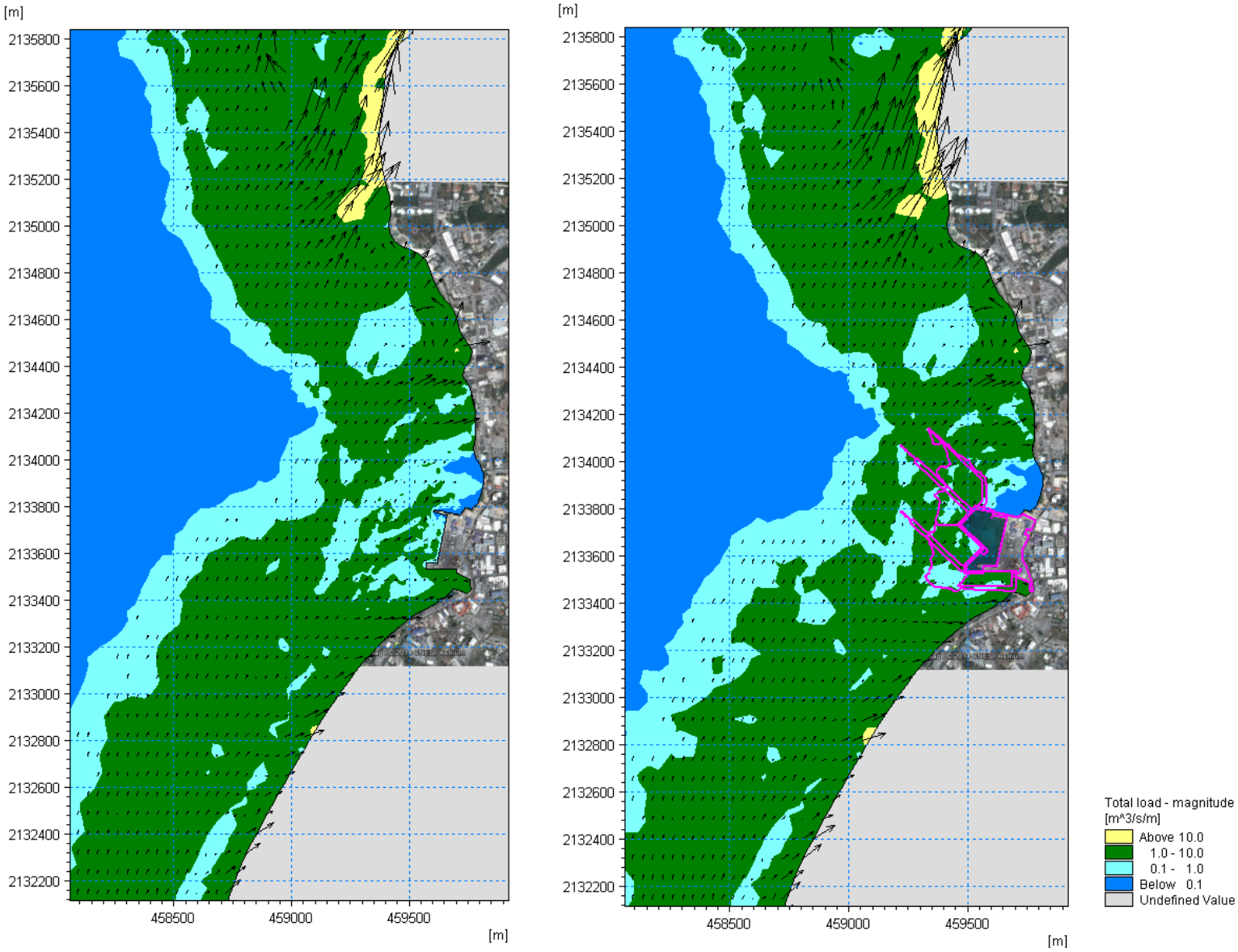


Figure 10.15 - Total Load Pathways for GTH: SW Swell – Existing (L); Proposed (R)

10.4.1.4 Impacts on Erosion and Deposition in GTH – Typical Conditions

The accumulated sediment transport for the year 2014 is plotted in

Figure 10.16 for existing conditions and for the proposed project. The results indicate various areas of erosion and deposition for existing conditions and following the implementation of the proposed option. For the proposed project, alternating bands of erosion and deposition are predicted to occur within the dredged area; this pattern is attributed to the redistribution of sediment in response to changes in wave patterns, in particular wave reflections from the new land reclamation area. The deposition and erosion patterns in the surrounding area remain generally unchanged, with the exception of a small zone of deposition predicted to occur offshore the south dredge pocket.

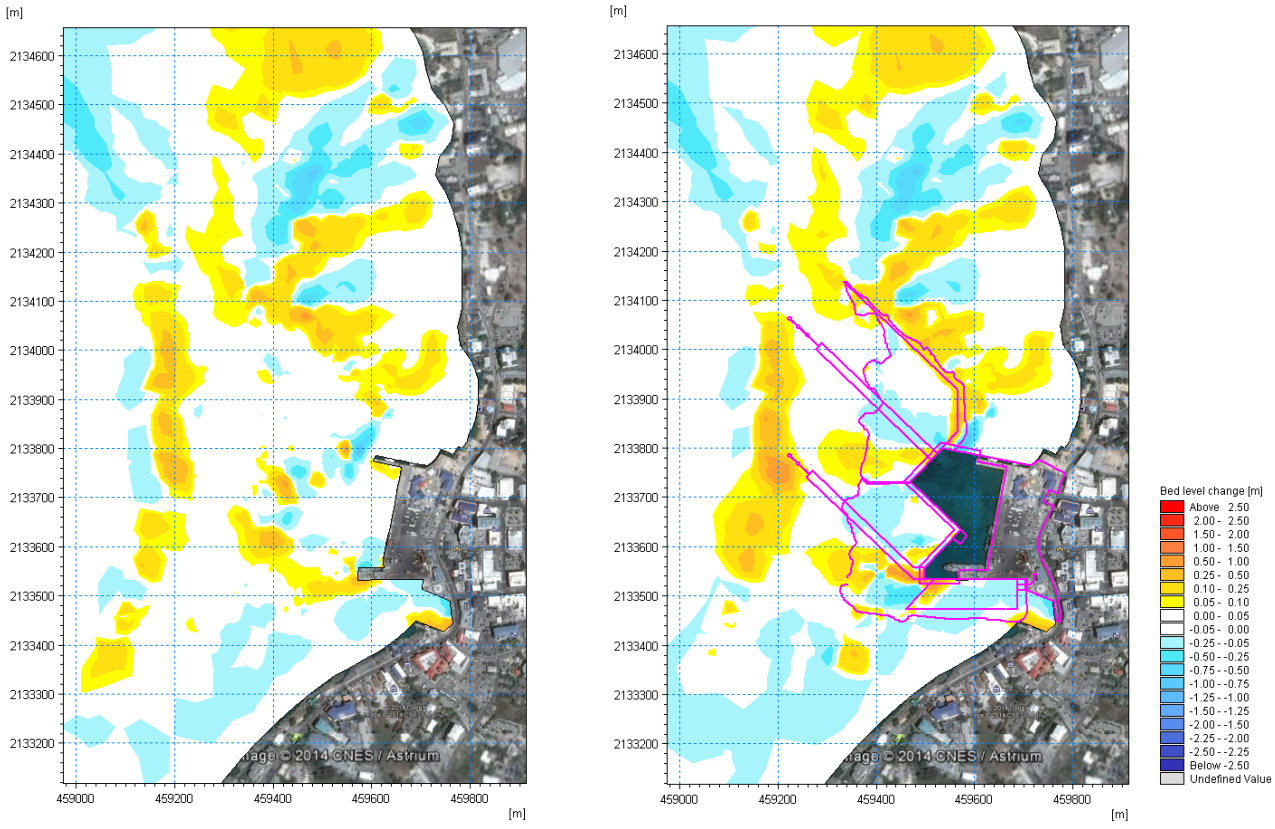


Figure 10.16 - Erosion/Deposition Patterns in GTH – Typical Conditions (2014) – Existing (L); Proposed (R)

To gain more insight into erosion and deposition within the dredged area, the volume of sediment transported into the dredged area was computed. The results indicate that there will be very little deposition within the dredged area under typical conditions. However, there is a risk of sedimentation in the dredged area during hurricanes, as discussed in the next section.

10.4.1.5 Impacts on Erosion and Deposition in GTH – Hurricane Conditions

Numerical model simulations of waves, surges and sediment transport patterns were completed for Hurricane Ivan (2004) and Hurricane Fox (1952). In general, the results showed that Hurricane Fox had a greater impact on George Town Harbour and the west coast of Grand Cayman due to its storm track, whereas Hurricane Ivan had a greater impact on the south coast. Considering this information, Hurricane Fox was chosen for the analysis of sedimentation for the proposed project.

The resulting accumulated sediment transport after the passage of Hurricane Fox is plotted in **Figure 10.17** for existing conditions and for the proposed project. For the proposed project, the model results indicate a total of approximately 3,000 yd^3 of deposition within the dredged area, with the majority of the deposition predicted to occur along the side slopes, in particular on the south side of the dredged basin (sedimentation depths in the order of 1 to 5 ft).

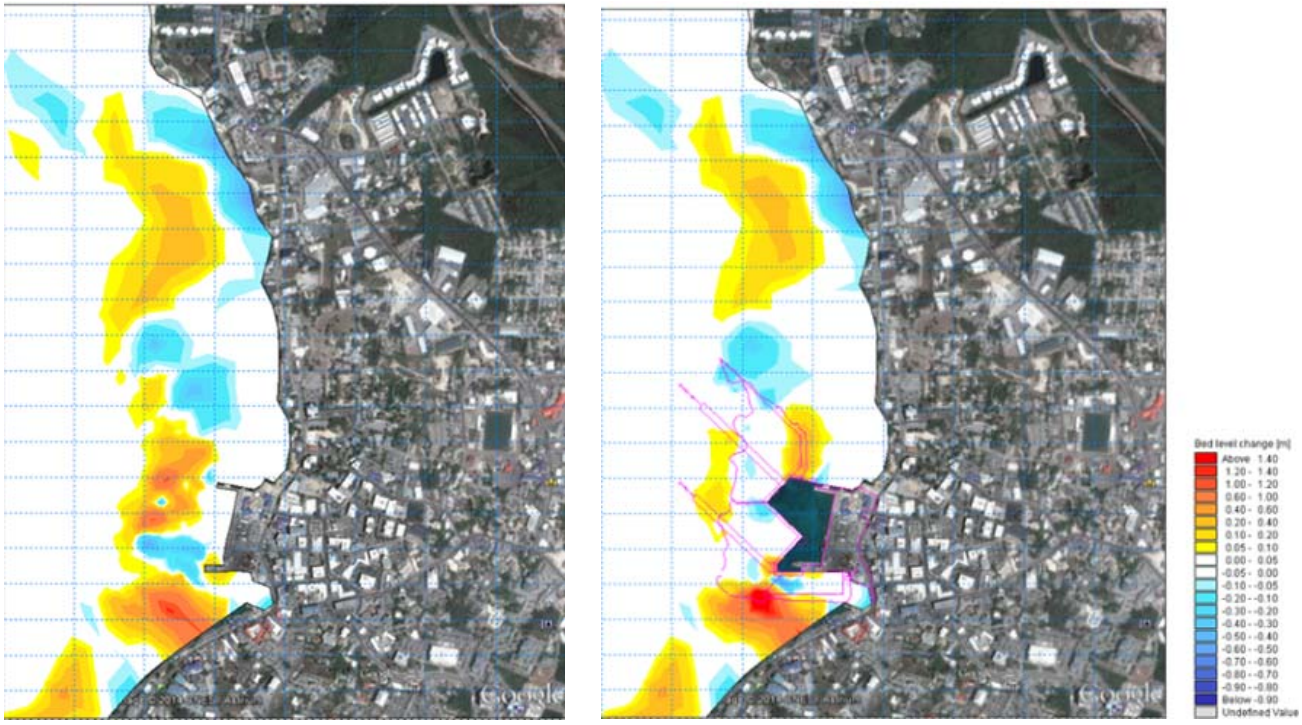


Figure 10.17 – Erosion/Deposition Patterns in GTH - Hurricane Fox (1952) – Existing (L); Proposed (R)

It is noted that sedimentation rates, volumes and depths will vary depending upon the proximity (track) and severity (intensity) of the hurricane. It is therefore possible that maintenance dredging may be required to restore the design dredge depths following the passage of a severe hurricane that impacts the west coast of Grand Cayman.

10.4.1.6 Impacts on Sediment Transport Rates – Swell Events

Figure 10.18 presents a plot of the sediment transport rates in GTH for a NW swell event (Nor'Wester) under existing and proposed conditions. Under existing conditions, the wave induced currents and sediment transport are directed south along the shoreline and go around the existing port. These currents appear to become much smaller in magnitude south of the port. Transport rates above 10 $m^3/s/m$ appear in localized areas along the shoreline. With the proposed project in place, there are significant changes in sediment transport vectors in the immediate area of the port; specifically, the sediment transport is no longer deflected around the port structures, but now moves partially into the dredged area, with the dredged area becoming an area of decreased sediment transport.

For SW swell events, the sediment transport is directed northward. However, in the vicinity of the port, the transport rates drop below 1 $m^3/s/m$ (very low transport). With the proposed project in place, the sediment transport rates appear to be increased very slightly in the vicinity of the port. One point of note here is a reef feature north of the port that bifurcates the sediment movement, causing strengthening to the north and to the south of the feature. Another point of note is that the pathway of sediment for SW waves does not go through the port, indicating that the proposed development will be isolated from the natural headland at the south end of Seven Mile Beach.

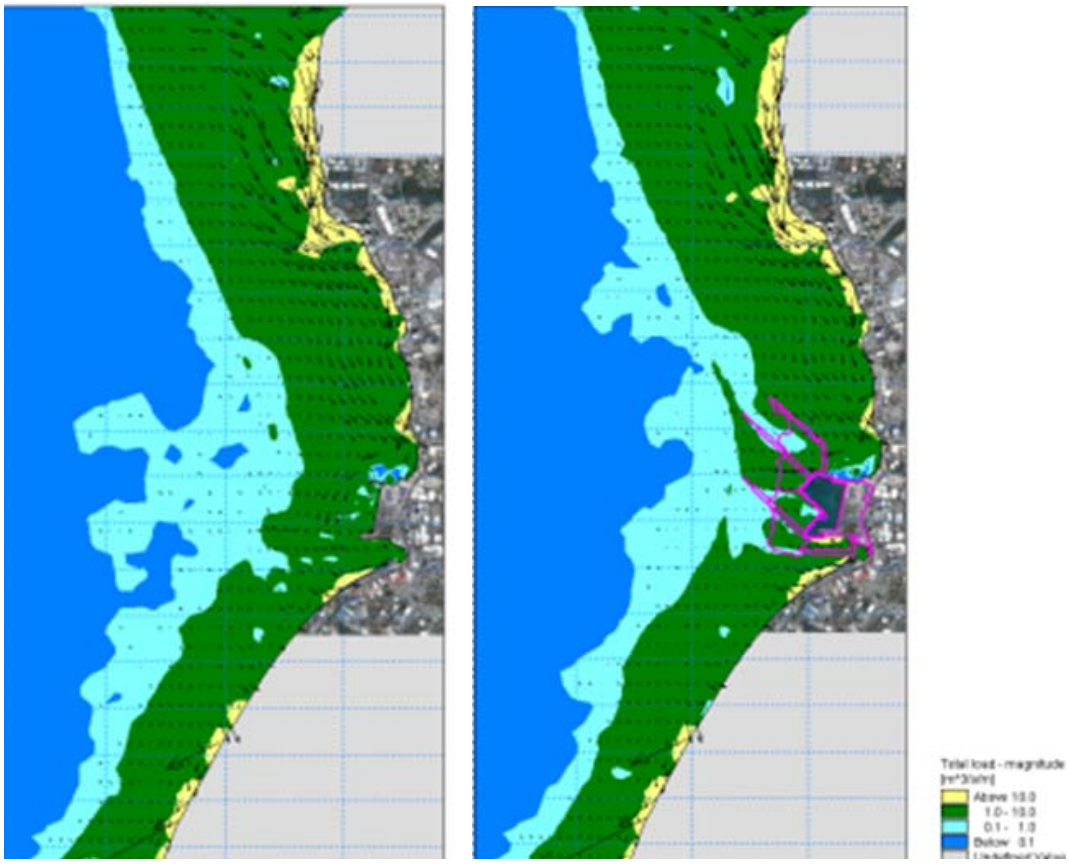


Figure 10.18 – Sediment Transport Rates in GTH - NW Swell – Existing (L); Proposed (R)

10.4.1.7 Impacts on Sediment Transport Rates – Hurricane Fox

Figure 10.19 presents a plot of the sediment transport rates in GTH at the peak of Hurricane Fox (1952) under existing and proposed conditions. In both cases, the wave induced currents and sediment transport are directed towards the north. With the proposed project in place, these currents appear to become slightly higher in magnitude along the outer edge of the dredge pocket. There is no significant change in current velocities in the immediate area of the port, in that the current pathways remain the same in both shape and intensity.

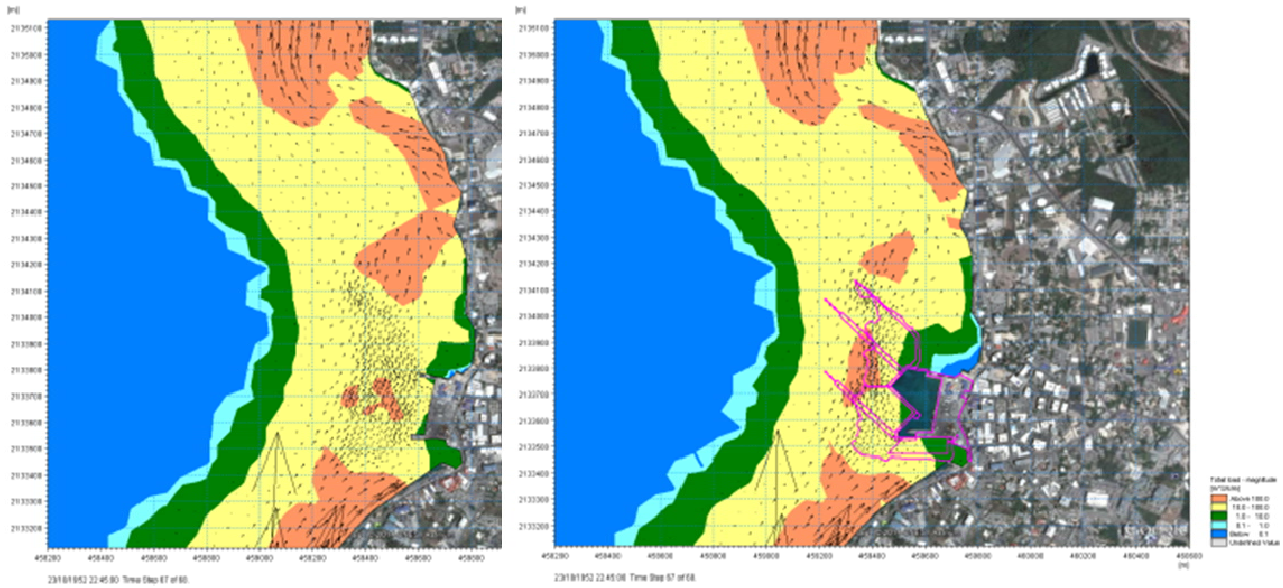


Figure 10.19 – Sediment Transport Rates in GTH - Hurricane Fox (1952) – Existing (L); Proposed (R)

10.5 Climate Change Impacts – Flooding from Hurricane Waves

The Climate Change Assessment suggests that Mean Sea Level (MSL) will increase by 1 to 3 ft by 2100. The predicted increase in MSL will increase water depths in the vicinity of GTH and this may affect flooding in the vicinity of the port area. An assessment of the impacts on nearshore water levels under the 1 in 50-year hurricane condition was made using MIKE 21 HD+SW. The statistics used to develop these conditions incorporated climate change considerations. In addition analysis included overtopping for both the existing and proposed conditions.

Figure 10.20 (on the following page) compares the maximum flooding for both existing and proposed conditions; these results assuming a MSL increase of 2.7 ft to account for climate change.

For the existing conditions, flood levels of up to 10 ft are observed at the port, while flood levels up to 10 ft and 13 ft are observed to the north and south of the port respectively. With the proposed project in place, there is a localized increase in flood level up to 15 ft within the project footprint; however, this increase is limited to the outer portion of the land reclamation area, outside the

proposed wave/flood barrier. South and north of the proposed project, the flooding levels remain similar to existing conditions.. It is noted that inland flooding from an event of this severity would be extensive, and would occur with or without the project in place. With the proposed project in place, there is a slight reduction in flooding of the land area immediately east of the port.

In conclusion, the project is not expected to have a significant impact on flooding along the adjacent shorelines or in George Town.

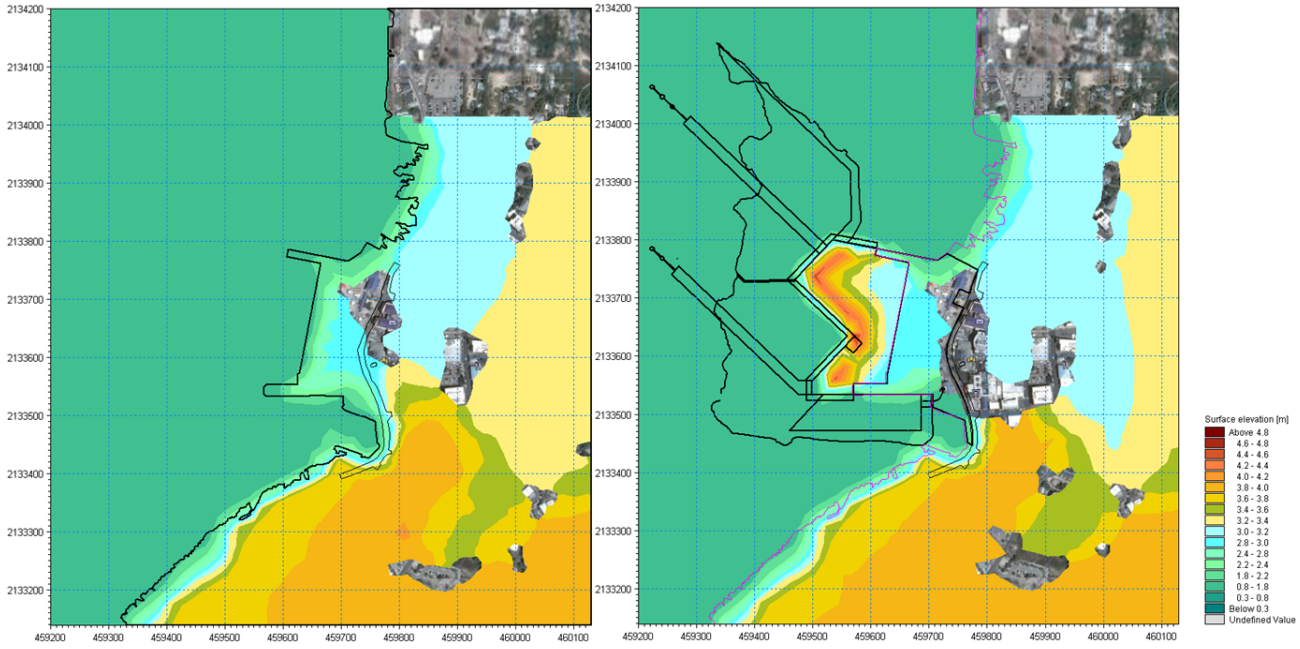


Figure 10.20 – Flood Levels for 50-year Hurricane with SLR = 2.7 ft - Existing (left) and Proposed (right)

10.6 Summary of Impacts

The following points emerge from the modeling and analyses of waves and sediment transport:

- Historically, 7MB has been subject to large variations in beach width; these variations are a natural response to seasonal and long term variations in the wave climate.
- 7MB appears to be supplied by sand coming around the northwest corner of the island, with the sand being sourced from the nearshore/fringing reefs along this shoreline. .
- There is no apparent sediment transport linkage between GTH and SMB; therefore, the proposed project is not expected to have any impact on 7MB. Fluctuations in the beach width will continue, but the proposed project will not cause any changes in erosion or deposition patterns along 7MB.
- Under non-hurricane conditions, very minimal sediment infilling is expected in the dredged basin. During hurricanes, some sedimentation may occur, with the potential requirement for maintenance dredging following as severe event in order to restore the design depths.

- No large scale changes to the prevailing sediment transport patterns are expected as a result of the proposed project.
- The project will result in localized changes in wave conditions in GTH; however, the project will not increase storm surge in GTH or flooding along the shoreline or in George Town.

A summary of the anticipated project-related impacts is presented in Table 10.3. The impacts have been split into the construction and operation phases, and have been assessed in terms of direct, indirect, secondary; cumulative; short-term, medium term and long-term; permanent, temporary; positive, negative.

10.7 RIAM Summary of Anticipated Project Impacts and Proposed Mitigation Measures

The RIAM summary for waves and sediment transport is presented along with the RIAM summary for hydrodynamics and dredge plumes in Chapter 11.6.

Table 10.3 Summary of Anticipated Project Impacts – Waves and Sediment Transport

SUMMARY OF IMPACTS	*Direct*	*Indirect*	*Secondary*	*Cumulative*	*Short-Term*	*Med-Term*	*Long-Term*	*Permanent*	*Temporary*	*Positive*	*Negative*
Construction											
Impact on sediment deposition patterns	◆			◆	◆				◆		◆
Impact on wave patterns	◆				◆				◆	◆	
Potential for localised scour		◆		◆		◆			◆		◆
Potential for localised deposition	◆			◆		◆		◆			◆
Impact on drainage patterns from stockpiles		◆		◆		◆			◆		◆
Operation											
Impact on wave patterns from Swell events											
Reduction in wave reflection from quay wall - NW Swell			◆				◆	◆		◆	
Sheltering to shoreline north of port - SW Swell	◆						◆	◆		◆	
Increase in wave action in Hog Sty Bay - NW Swell	◆						◆	◆			◆
Impact on wave patterns from Hurricane events											
No flood risk increase north and south of the port											
Reduction in flood risk I area of existing port		◆					◆	◆		◆	
Changes to deposition/erosion patterns											
Small deposition in middle and south pockets - Annual	◆			◆		◆			◆		◆
Small deposition in north dredge pocket - Hurricane	◆			◆	◆				◆		◆
Impacts on littoral drift											
Reduction in total load transport - NW Swell	◆			◆			◆	◆			◆
Increase in total load transport - SW Swell	◆			◆			◆	◆		◆	
Increase in total load transport at dredge pockets - Hurricane	◆				◆				◆	◆	
Climate Change Impacts											
Strom surge values are reduced		◆					◆	◆		◆	
Wave heights increased offshore quay wall	◆					◆		◆			◆
No change in flooding risk from climate change effects											

11.0 TASK D.2 - COASTAL PROCESSES – HYDRODYNAMICS & DREDGE PLUMES

11.1 Introduction

Following on from the discussions of waves and sediment transport in Chapter 10, this chapter describes the investigations and impacts of the following processes at the project site:

- Hydrodynamics: nearshore currents (flow patterns and magnitude).
- Dredge plumes: the creation of suspended sediment plumes during the dredging, land reclamation and disposal process, including at the dredger itself and at the discharge locations (land reclamation area or disposal site).
- Sediment re-suspension: This is the re-suspension of seabed sediments associated with vessel traffic, particularly propeller/thruster generated flows during berthing and de-berthing.

Additional details may be found in **Appendix D.2**.

11.2 Assessment Methodology

Due to the complexity of current patterns in the vicinity of George Town, the assessment methodology involved the use of a nearshore hydrodynamic computer model. This computer model was driven using boundary conditions that were obtained from a global ocean circulation model. The nearshore hydrodynamic model was initially validated using measured currents and then baseline conditions were simulated. The proposed modifications to the seabed and shoreline conditions that would arise from construction of the cruise berthing facility were implemented within the model, which was then re-run with the same boundary values to establish the proposed conditions. Comparisons were then made between the model output for the baseline conditions and the proposed conditions.

In order to assess the dredge plume impacts, use was also made of the nearshore hydrodynamic computer model. In this case, simulations of the likely dredging operations were made within the computer model. Due to uncertainties in many of the input conditions, such as the dredge spoil characteristics, a range of likely input values was used that would encompass the uncertainties.

The ability to accurately predict/quantify sediment re-suspension and turbidity plumes associated with vessel operations is limited by the complexity of the processes involved. That being said, the following tasks have been undertaken to assess the potential for impacts associated with this process over the operational life of the project:

- Empirical and numerical modeling of key processes, including propeller/thruster generated flows, sediment mobilization and entrainment;

- Literature review of experience at similar facilities; and
- Identification of possible mitigation measures to limit impacts.

11.2.1 The Numerical Model

The modelling software used in this study was MIKE 21 and MIKE 3. Developed by Danish Hydraulic Institute, this suite is a modular system that includes Hydrodynamic (HD), Transport (TR) and Sand Transport (ST) modules. These were used to simulate currents (HD), turbidity (TR) and sedimentation rates (ST).

- HD, the hydrodynamic modelling system, is based on the numerical solution of the two/three-dimensional incompressible Reynolds averaged Navier-Stokes equations. The model consists of continuity, momentum, temperature, salinity and density equations.

- The TR module simulates the spreading and fate of dissolved or suspended substances in an aquatic environment under the influence of the fluid transport and associated dispersion processes. The substance may be of any kind, conservative or non- conservative, inorganic or organic.

- The ST module is used for the calculation of sediment transport capacity and related initial rates of bed level changes for non- cohesive sediment (sand) due to currents or combined waves-currents.

A flexible mesh (FM) approach has been used, which is based on an unstructured grid to describe the bathymetry and uses a cell-centred finite volume solution technique. In the horizontal plane, an unstructured triangular grid is employed while a structured mesh is used in the vertical domain. Due to the irregular grid and variable resolution, the FM is well suited for modelling large complex areas that, at the same time, require detailed resolution, as in the case at GTH.

Figure 11.1 shows the flexible mesh which has grid resolution ranging from 3.1 mile (5 km) element sizes in deep water down to 131ft (40m) element sizes at GTH.

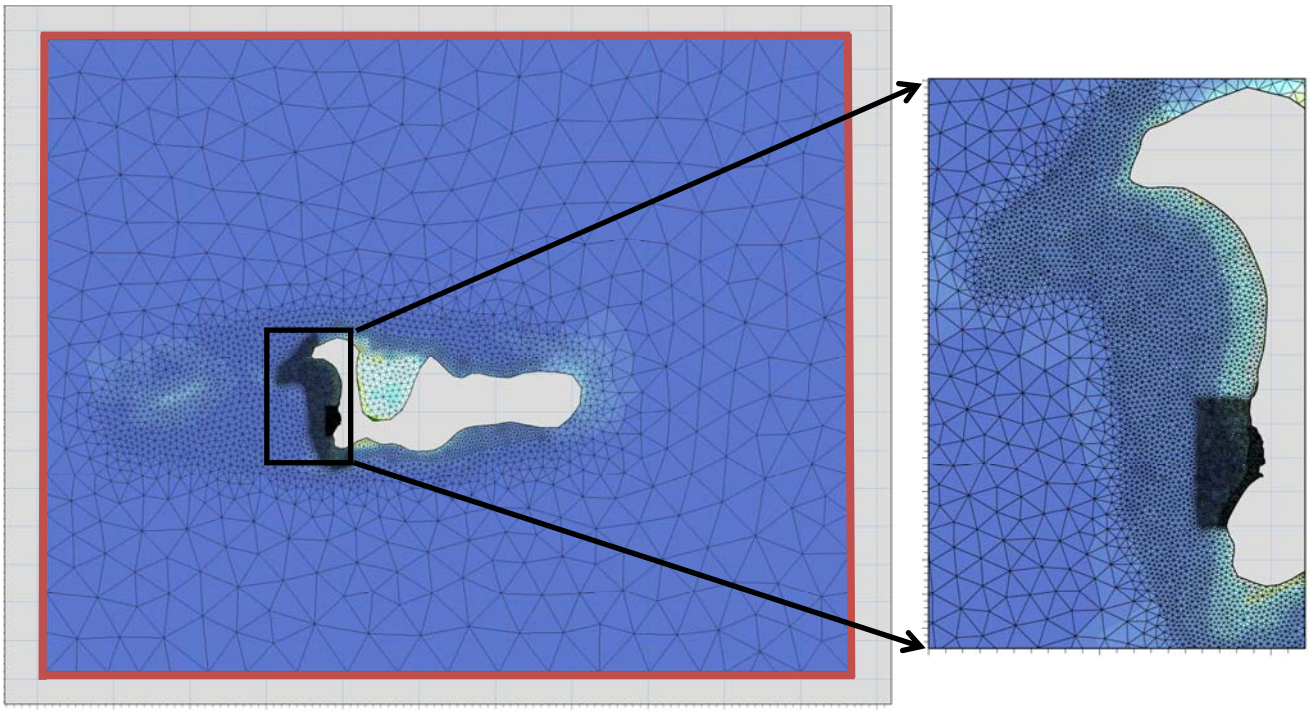


Figure 11.1 Hydrodynamic model domain with GTH detail inset. Orange lines represent input boundaries

11.3 Baseline Conditions

11.3.1 Hydrodynamics

Baseline hydrodynamic conditions were established using a combination of analyses of direct measurements and of output from the numerical model. Currents were measured at four locations as part of these investigations, as shown in **Figure 11.2** to **Figure 11.5**. Three instruments (North ADCP, South ADCP, and AWAC) were situated on the nearshore shelf (32.8-65.6ft) [10-20m], while the Quartermaster was located in a depth of 853ft (260m).

Results of the current measurements generally indicate a circulation system that is dominated by weak currents (<1.31 ft/s) [<0.4 m/s] that run parallel to the local contours. On closer analysis, the actual current patterns often appear to be quite complex and influenced by nearby large-scale oceanic circulation patterns. Tidal influences on the hydrodynamic currents were relatively weak.

Concurrent measurements at the three instruments located adjacent to GTH were analysed to identify six dominant flow regimes as shown in **Figure 11.6**. These regimes exist for 81% of the time, with the remaining time occupied in transition or other patterns. In a system where the currents are controlled by changing tide heights, one would expect simple flow regimes (flow to the north, and flow to the south) to dominate. For GTH, the most prevalent flow regime was found to be "divergent", where currents north of GHT flow north and south of GTH flow south, suggesting the presence of an onshore current.

Due to the presence of onshore currents, an assessment of upwelling was undertaken using the water temperature measurements. This assessment did not find significant upwelling events either during the monitoring period for this study or in previous measurement campaigns.

11.3.2 Turbidity Levels

Sampling during the dry and wet season indicated that turbidity levels ranged from <1 to 4 NTU. However, it was noted that two samples were collected in GTH by the DOE in November 2014 during a Nor'Wester which measured turbidity levels ranging from 14-16 mg/L. Turbidity baseline conditions are further detailed in Chapter 12.

The complexity of the current patterns along the western shoreline of Grand Cayman necessitated the use of a 3D hydrodynamic model driven with boundary conditions derived from a large-scale oceanic model (the HYCOM model). Boundary inputs included tidal heights, oceanic currents, and variations in temperature and salinity. An example of the oceanic current input used to drive the 3D hydrodynamic model is shown below in **Figure 11.7**.

The nearshore 3D hydrodynamic model was validated against the measured current data. The model produced all of the observed regime flows and predicted these flow patterns for 62% of the time compared to 81% for the measured data. The model appears to have over-predicted the occurrence of convergent flow and under-predict that for divergent flow. Similarly, the model over-predicts the occurrence of flow to the north, and under-predicts that for flow to the south. Finally, the model under predicts the occurrence of shear flow conditions in both north and south directions as shown in **Figure 11.8**.

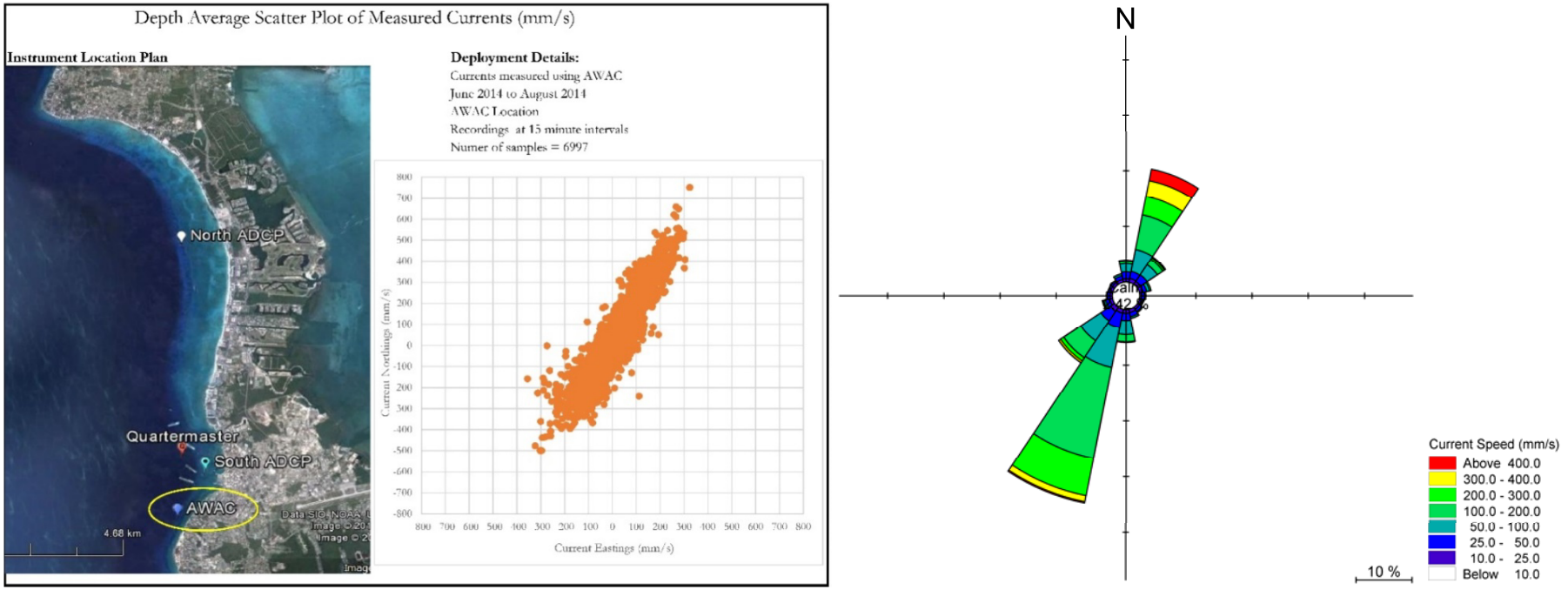
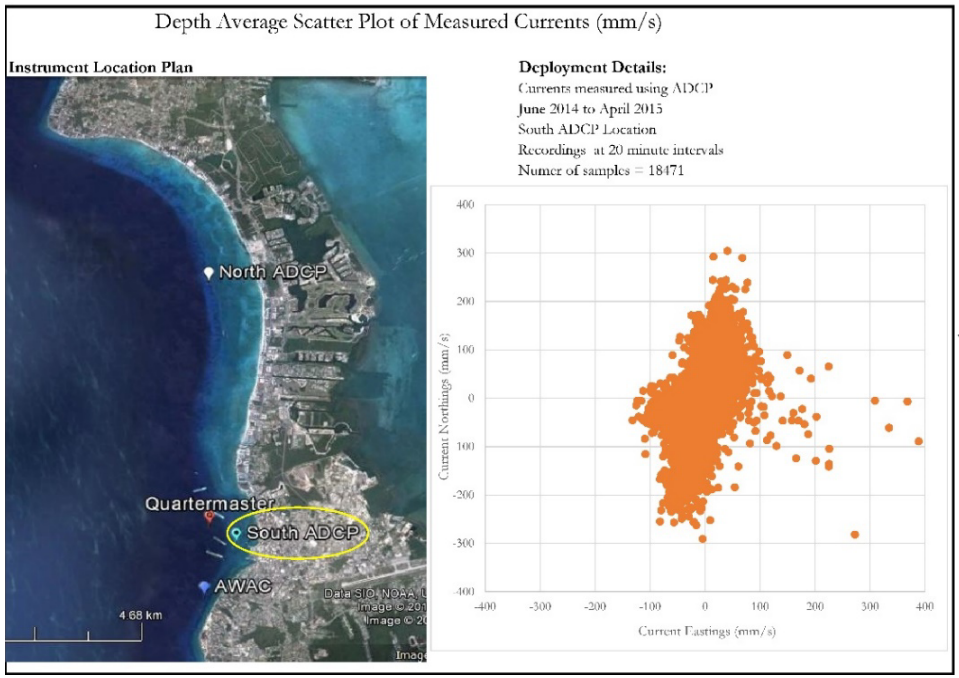


Figure 11.2 Scatter plot of measured currents (left) and current rose (right) at the AWAC location for the deployment period



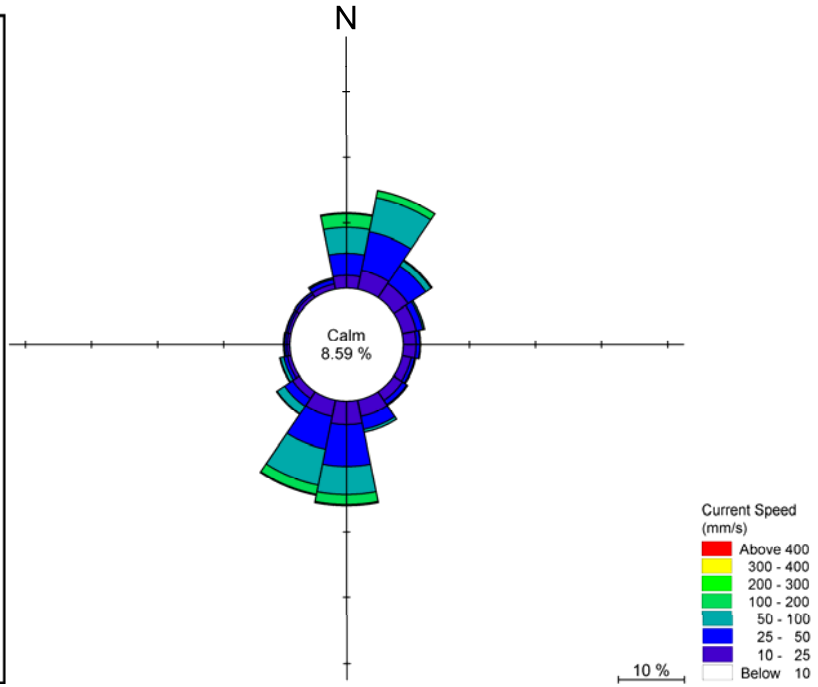


Figure 11.3 Scatter plot of measured currents (left) and current rose (right) at the South ADCP location for the deployment period

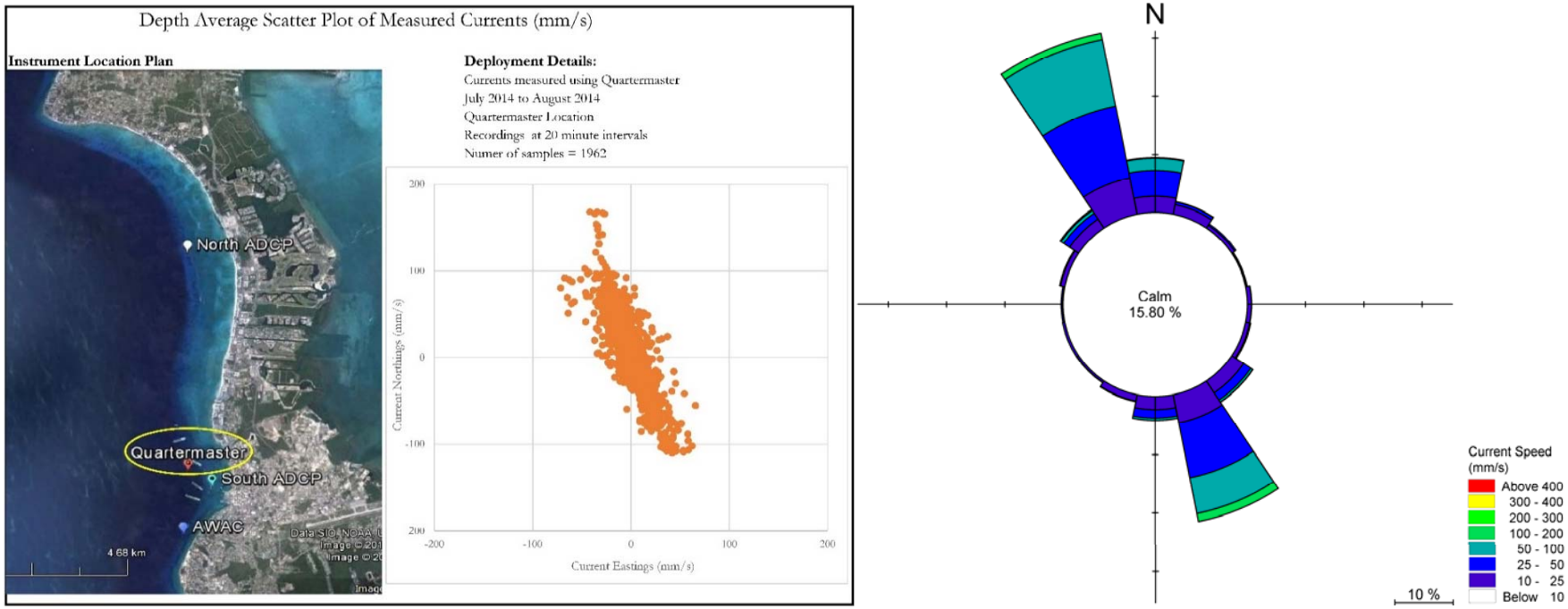


Figure 11.4 Scatter plot of measured currents (left) and current rose (right) at the Quartermaster location for the deployment period

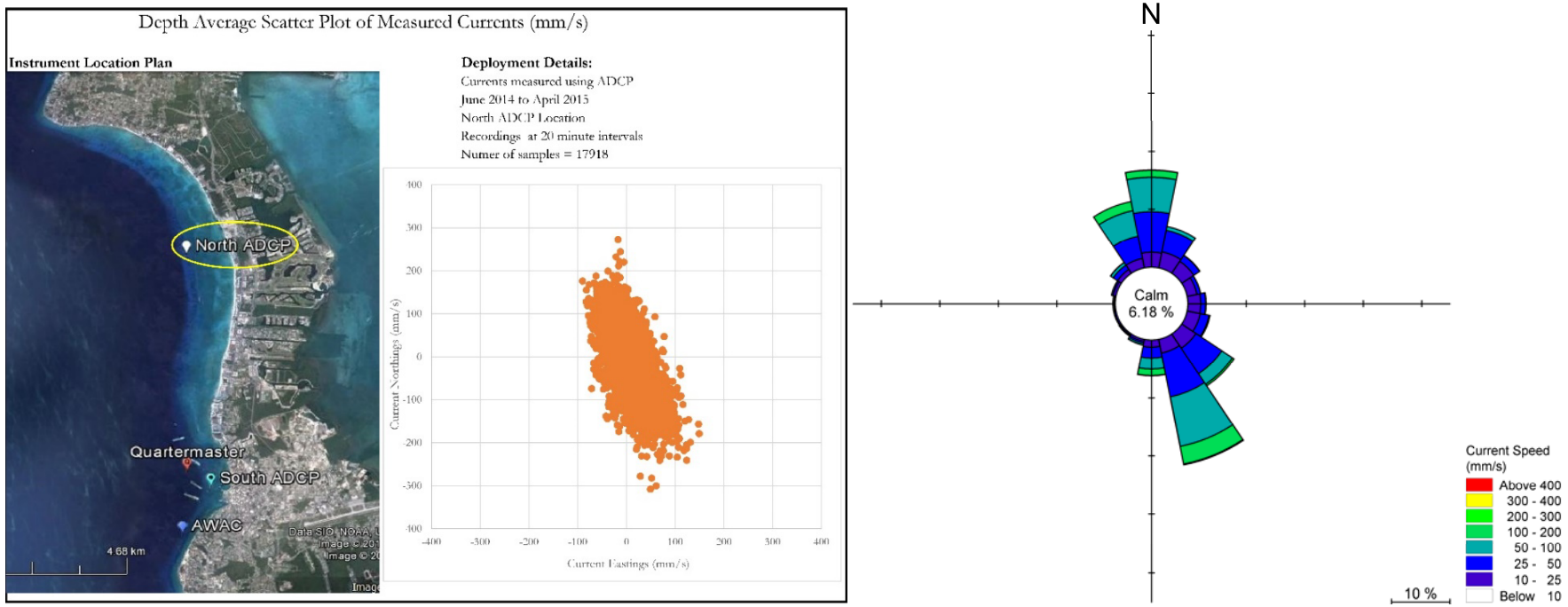


Figure 11.5 Scatter plot of measured currents (left) and current rose (right) at the North ADCP location for the deployment period

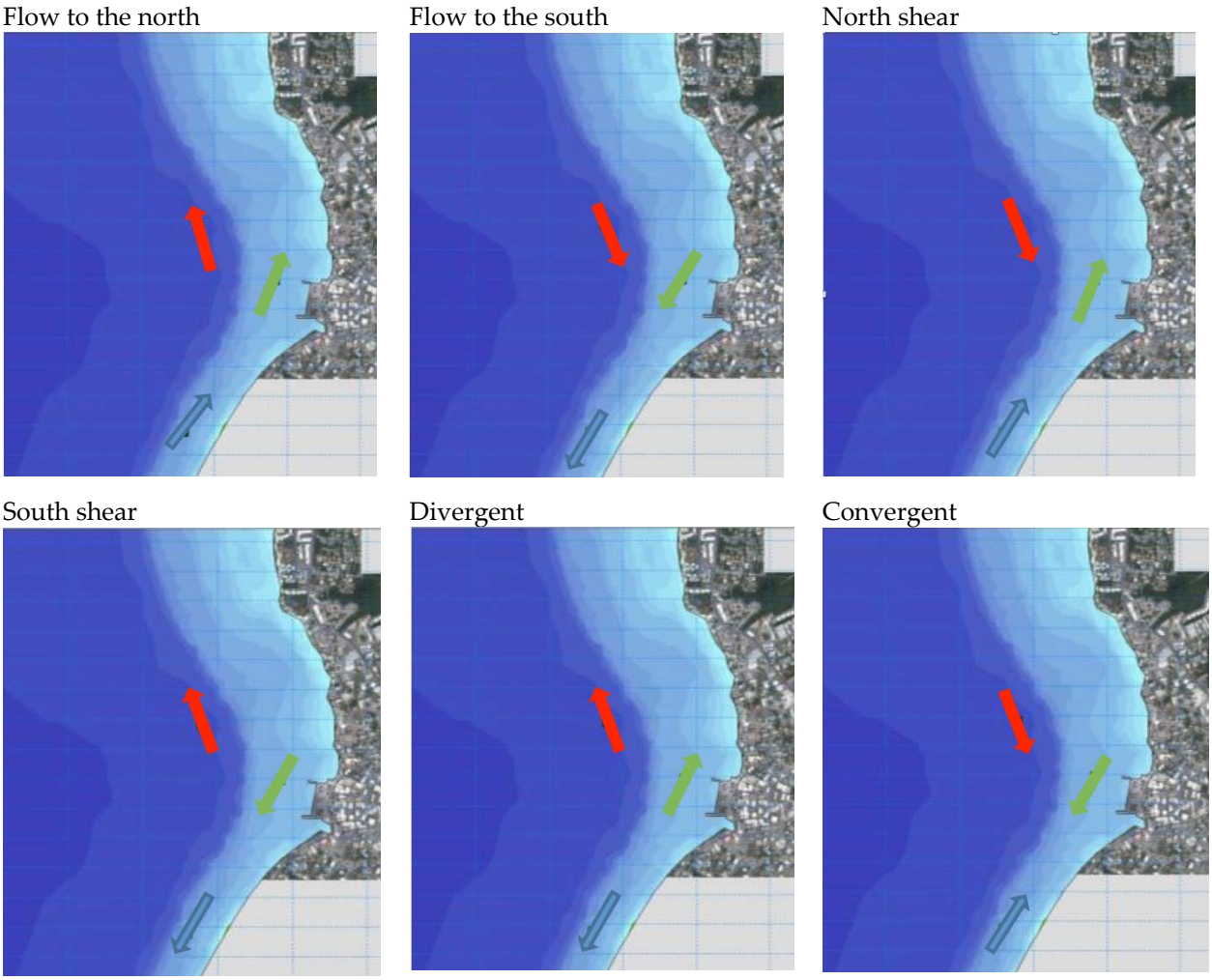


Figure 11.6 Flow regimes occurring at GTH

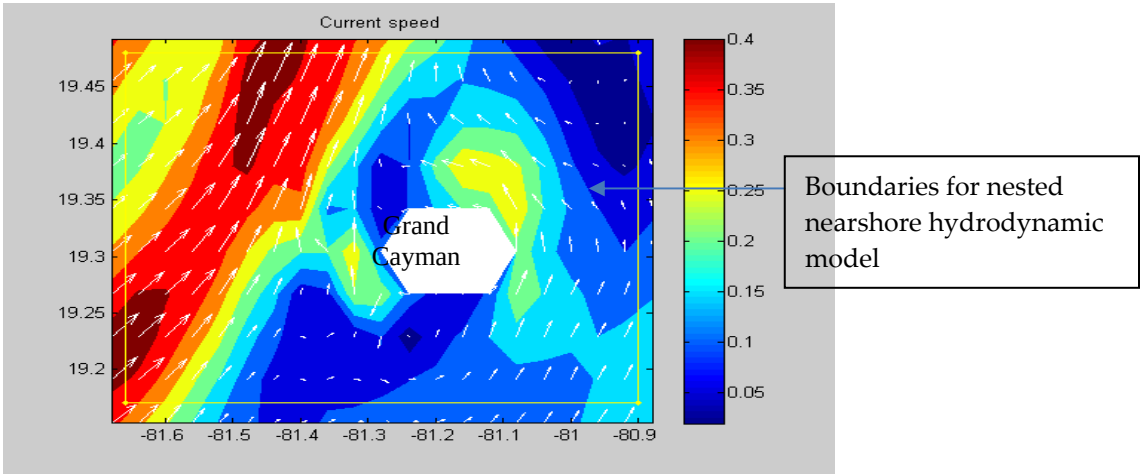


Figure 11.7 HYCOM oceanic circulation model used to drive nearshore 3D hydrodynamic model

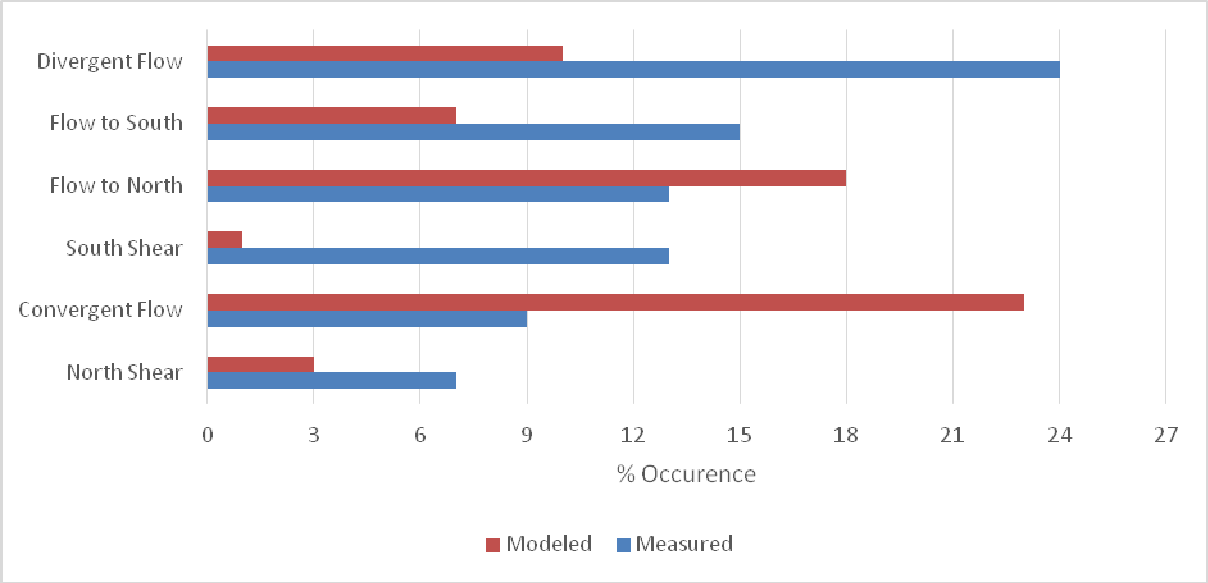


Figure 11.8 Bar chart comparing occurrence of measured and modelled flow regimes

Figure 11.9 and **Figure 11.10** show the northing and easting current component box plot comparison between measured and modelled at the current meter locations. The box plot provides a visual representation of the current statistics. The centre line of the box represents the median current, and the lower and upper box limits are the lower and upper quartiles. The bars above and below the box represent the maximum and minimum values. The box plots allows for a visual assessment of the statistical distribution of the current components.

The modelled northing median and quartile currents, which is the dominant flow axis, seems to be quite well matched at the AWAC and Quartermaster locations. At the South ADCP, the model appears to have a north flowing bias. The modelled and measured range of currents appears to be quite well matched, suggesting that the model is representing the peak current speeds.

The easting box plot comparison shows that the median and quartile currents are well matched for the Quartermaster and South ADCP (Oct/Nov) simulation period. For the AWAC and South ADCP (Jul/Aug) the model appears to have an onshore bias that was not measured.

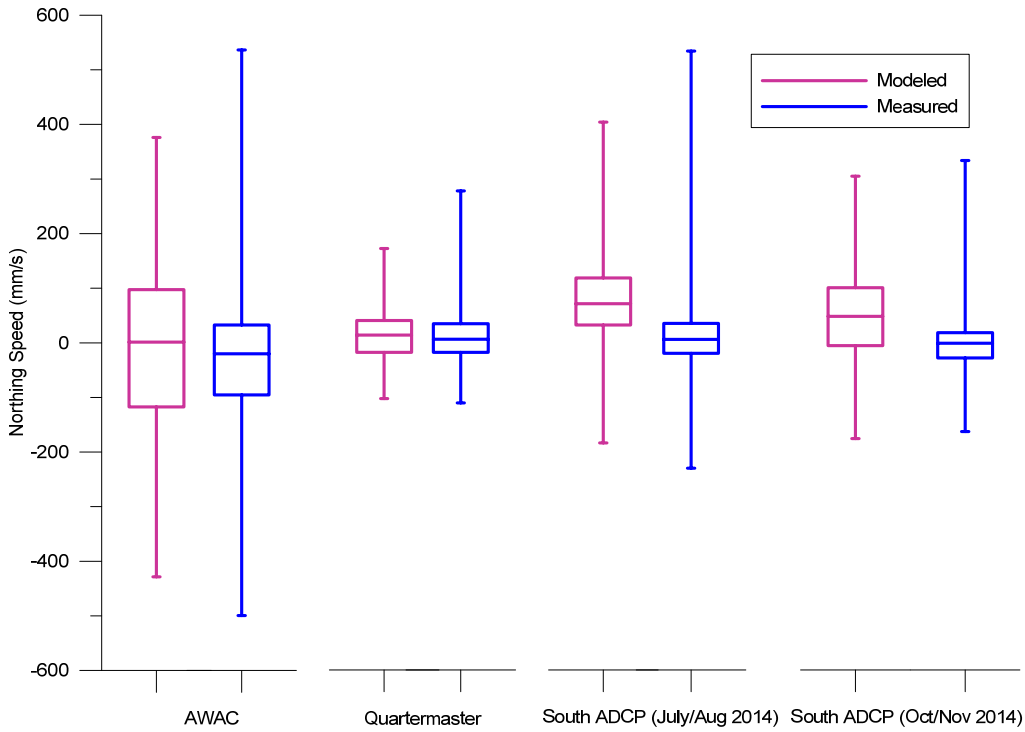


Figure 11.9 Box plot comparison of measured and modelled Northing current speeds at current measurement locations

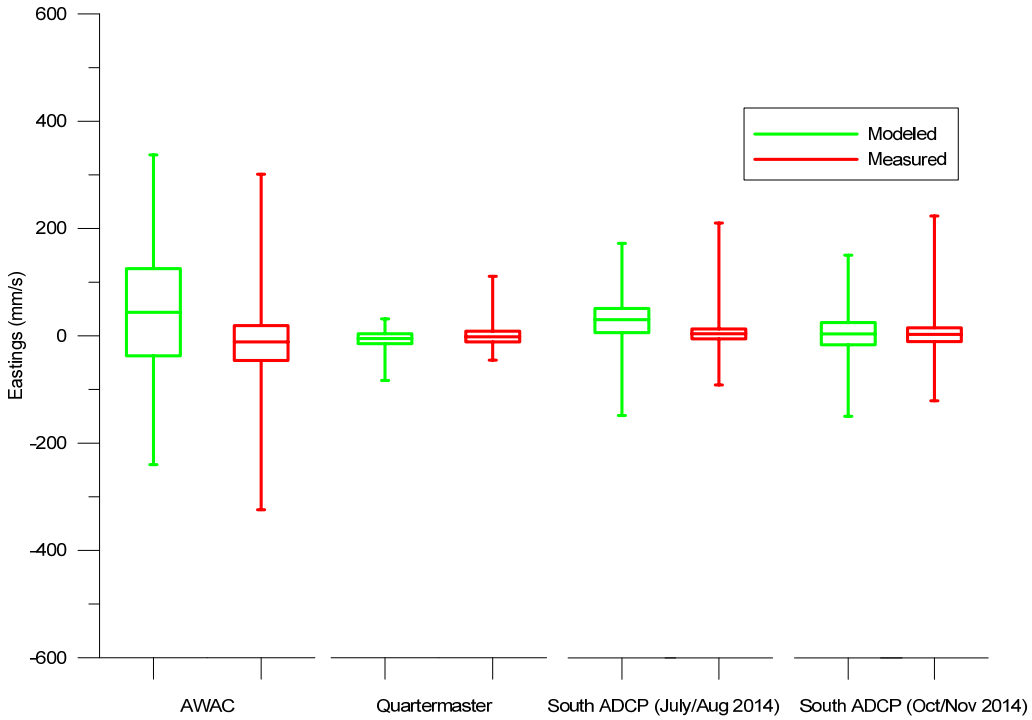


Figure 11.10 Box plot comparison of measured and modelled Easting current speeds at current measurement locations

11.3.3 Sediment Re-Suspension

At this time, vessel traffic to and from the existing port is limited to cargo ships, tenders and other smaller vessels. Cruise ships presently anchor at one of four offshore mooring points; on busy days (i.e. greater than four cruise ships), the additional vessels remain on power in offshore locations.

Anecdotal evidence indicates that turbidity plumes are generated with the arrival or departure of cargo ships and tenders when they apply power in shallow water areas adjacent to the quay walls. These turbidity plumes are relatively short-lived. In addition, anecdotal evidence as well as drogue tracking measurements undertaken by the DoE, indicates that the use of thrusters by cruise ships moored offshore may generate large scale gyres within George Town Harbour.

11.4 Impact Assessment

The assessment of impacts looked at several different aspects under the category of hydrodynamics and dredge plumes. The following impacts were examined:

- Direct impacts on current patterns at GTH and in the adjacent areas caused by the new water depths and shoreline positions resulting from the construction of the CBF,
- Direct impacts on current patterns at GHT and in the adjacent areas resulting from cruise ships being at berth in the new CBF,
- Dredge plume formation resulting from dredging at the CFB, and
- Dredge plume formation resulting from disposal of the dredge spoil.

For the assessment of impacts on current patterns from the new CBF and from the cruise ships at berth, the nearshore hydrodynamic model was adjusted to represent both the existing conditions and Option C. This was achieved by modifying the land boundary to represent the new land reclamation area, and modifying the water depths within the area of where dredging will be undertaken. The nearshore hydrodynamic model was then run using the same boundary input values and the resulting current patterns were analysed to determine changes. A similar approach was adopted for the situation when cruise ships are at berth. It must be noted that these simulations over-estimate the impact of the cruise ships as the simulations included the ships at berth for the entire simulation period. In reality the ships will berth and depart, occupying the berths less than 12 hours per day and not every day during the year.

For the assessment of dredge plume formation several different scenarios were examined including:

- Use of a backhoe dredge (BHD) to deepen the berthing areas;
- Use of a cutter-suction dredge (CSD) to deepen the berthing areas;
- Offshore disposal of the dredge spoil using an outfall pipeline at three different locations;

- Disposal of the dredge spoil offshore using split-hull hopper barges; and
- Overflow of sediment laden waters from the land reclamation area.

11.4.1 Project Impacts

11.4.1.1 Impacts on Current Patterns

The deepening of the nearshore and relocation of the shoreline resulting from the CBF, and the berthing of cruise ships at the CBF both have significant impacts on the nearshore circulation patterns within the confines of the facility. At the three evaluation points within the facility, the percent of calm currents (<0.03 ft/s, or < 0.01m/s) increased as a result of the CBF. Adjacent areas, within 660ft (200m) of the CBF, have noticeable changes to the current patterns, including a decrease in the average current speeds and an increase in calm conditions. No significant changes in current patterns were noted at locations 0.75 mile (1.2 km) north and 0.6 mile (1.0 km) south of the CBF (refer to **Table 11.1**).

Table 11.1 Percent calm current speeds (<0.03 ft/s) at various points within and surrounding CBF

	Within CFB	Adjacent 660 ft	0.6 – 0.75 mi North/South	
Existing	15-26	12-25	11.8	5.5
CFB	19-52	16-24	12.1	5.2
CFB with ships at berth	46-70	29-46	11.1	4.5

In addition to increasing the occurrence of calms, the implementation of the CBF and having cruise ships at berth affects the maximum currents, as shown in **Figure 11.11**. The impact on the maximum currents of the CBF compared to the existing is limited to the immediate area of the CBF. However, when cruise ships are at berth, the maximum currents are reduced beyond the immediate area.

These impacts on ambient current patterns may have direct or indirect impacts on the marine ecology in the vicinity of GTH and the findings have been incorporated in assessment of impacts described in Task J.

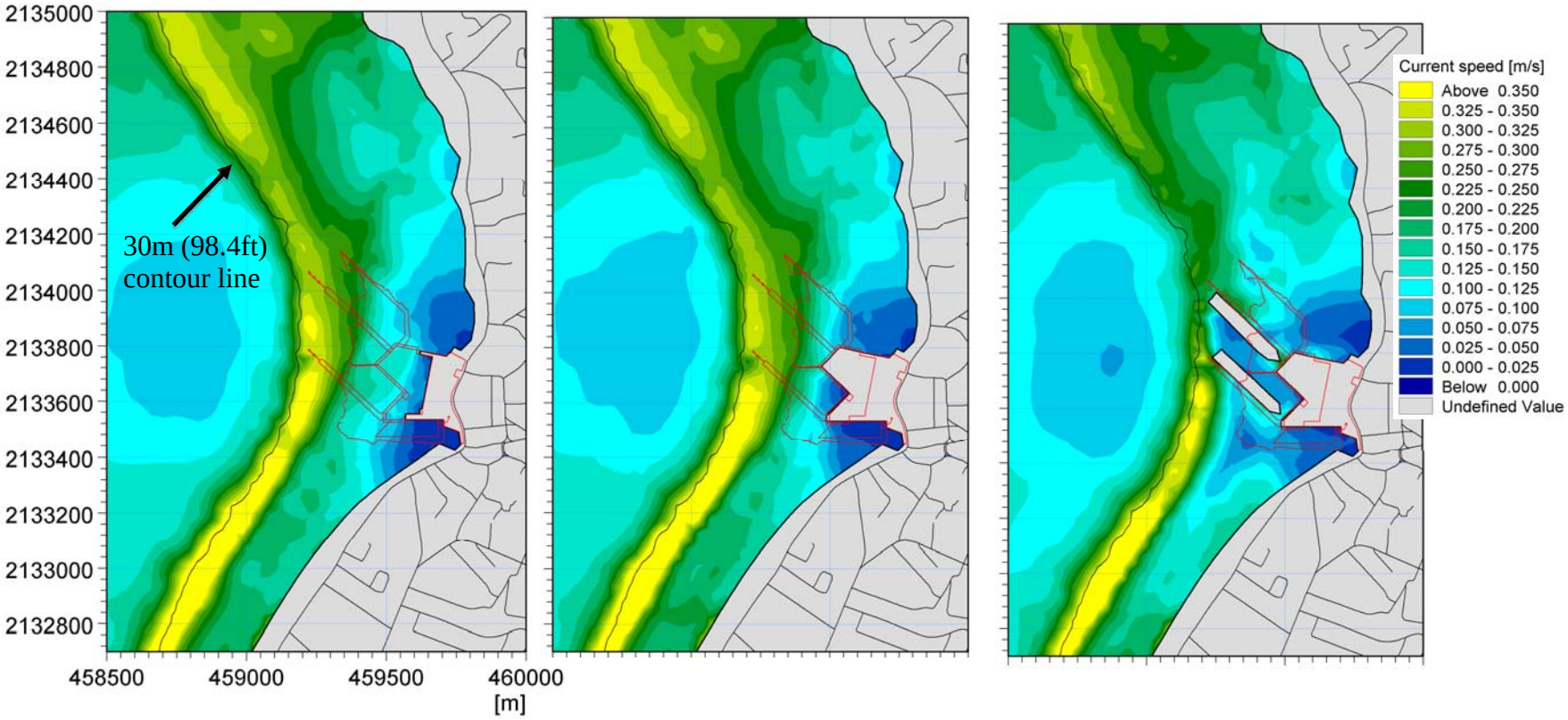


Figure 11.11 Comparison of maximum current speeds for existing (left), Option C (centre), and with ships at berth (right)

11.4.1.2 Dredging Impacts

The creation of the new CBF will require deepening of the nearshore area. This will be accomplished by dredging the seabed. Option C will require the removal of 333,000 yd^3 and the disposal of 174,000 yd^3, with the remaining material being used as fill for the land reclamation.

As noted earlier, dredging for this project may be done using a hydraulic dredge (cutter suction dredge, CSD) or a mechanical dredge (BHD). The duration of the dredging operation will be dependent upon the type and size of dredge that is used. It is expected that hydraulic dredging with a CSD will take 4-6 weeks to complete, whereas mechanical dredging with a BHD will take 12-16 weeks to complete. Based on discussions with several dredging contractors, a mechanical dredging operation is considered to be more likely due to the volume of dredging required and the size of the land reclamation area.

Regardless of the dredging method adopted by the contractor, dredging will result in the creation of a suspended sediment (turbidity) plume due to the seabed disturbance created by the dredging operation.. The plume will have elevated turbidity levels and will also result in sediment settling on the seabed outside the dredge area. The spreading and settling of the suspended sediments have been evaluated using the nearshore hydrodynamic model. In order to address uncertainty regarding the exact nature of the material to be excavated and the dredge production rate, a range of suspended sediment concentrations has been considered in the modeling efforts, as discussed below.

A literature review of similar dredging projects (McLellan, et al, 19891, Johnson and Pachure, 19992) suggests that typical BHD operations result in a mass loss of 1-2% of the dredge material. Based on a reasonable pace of dredging using appropriate equipment, this has been converted to lower and upper mass loss rates of 0.22 and 1.1 lb/s (0.1 and 0.5 kg/s). This material will be lost through the water column as the bucket is lifted from the seabed; this effect has been simulated in the model simulations for the BHD operation.

For a CSD operation, the plume is generated at the seabed adjacent to the cutterhead. Available information for CSD operations of a similar nature indicates that the sediment concentration at the cutterhead generally does not exceed 300 mg/L. This source term was used as the basis for the model simulations of the CSD operation.

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[1] McLellan, T.N, Havis, R.N, Hayes, D.F, and Raymond, G.L., 1989. "Field Studies of Sediment Resuspension Characteristics of Selected Dredges", *Technical Note (HL-89-9), U.S. Army Hydraulics Laboratory, Vicksburg, M.S.*

[2] Johnson, B. H., and Pachure, T. M. (1999). "Estimating dredging sediment resuspension sources," *DOER Technical Notes Collection* (TN DOER-E6). U.S. Army Engineer Research and Development Center, Vicksburg, MS. *www.wes.army.mil/el/dots/doer*

The dredging operations were simulated using a 30-day period at three different locations within the dredge area. The results were combined to create an overall 90-day simulation period. Suspended sediment concentrations in mg/L were computed every 30 minutes and these results were analysed to determine the maximum concentrations, as shown in

Figure 11.12. In addition, a 24-hour rolling mean was computed to represent the 24-hour maximum concentration (see

Figure 11.13). An additional presentation of the model output was created using the percent exceedance format. This shows the percent of time that the suspended sediment concentration exceeds 20 mg/L (see

Figure 11.14). At the end of the simulation period, the deposition of silt on the seabed was determined and this was converted to a sedimentation rate, expressed in mg/cm^2/d (see

Figure 11.15).

Turbidity threshold values for low (< 10mg/L), medium (10 - 20mg/L) and high (> 20mg/L) impact zones correspond to marine biological threshold values discussed in Chapter 16 / Task J – Marine Ecology, which ranks the relative sensitivity of corals according to their response to different levels of turbidity (mg/L) and sedimentation rates (mg/cm2/day).

As shown in Figure 11.12, the model simulations of both dredging methods (BHD and CSD) identify the potential for high turbidity levels (> 20 mg/L) to extend well beyond the dredged basin. The model data were post-processed to provide a "rolling" 24-hour average; these data (Figure 11.13) also show high turbidity levels (> 20 mg/L) extending beyond the project footprint, but the spatial extent of the plume is reduced significantly. There were only minor differences between the BHD upper mass loss rate and the CSD; the BHD lower mass loss rate produces a noticeably smaller plume.

An evaluation of the 24-hour maximum plume concentration results indicates the occurrence of zones of extremely high (> 150mg/L) turbidity only for the high productivity BHD and CSD within 330 ft (100m) and 250 ft (75m) respectively.

Both dredging methods (BHD and CSD) also resulted in high sedimentation rates (>20 mg/cm^2/d) that extend beyond the CBF. There were only minor differences in the extent of the impacted area for the different dredging methods.

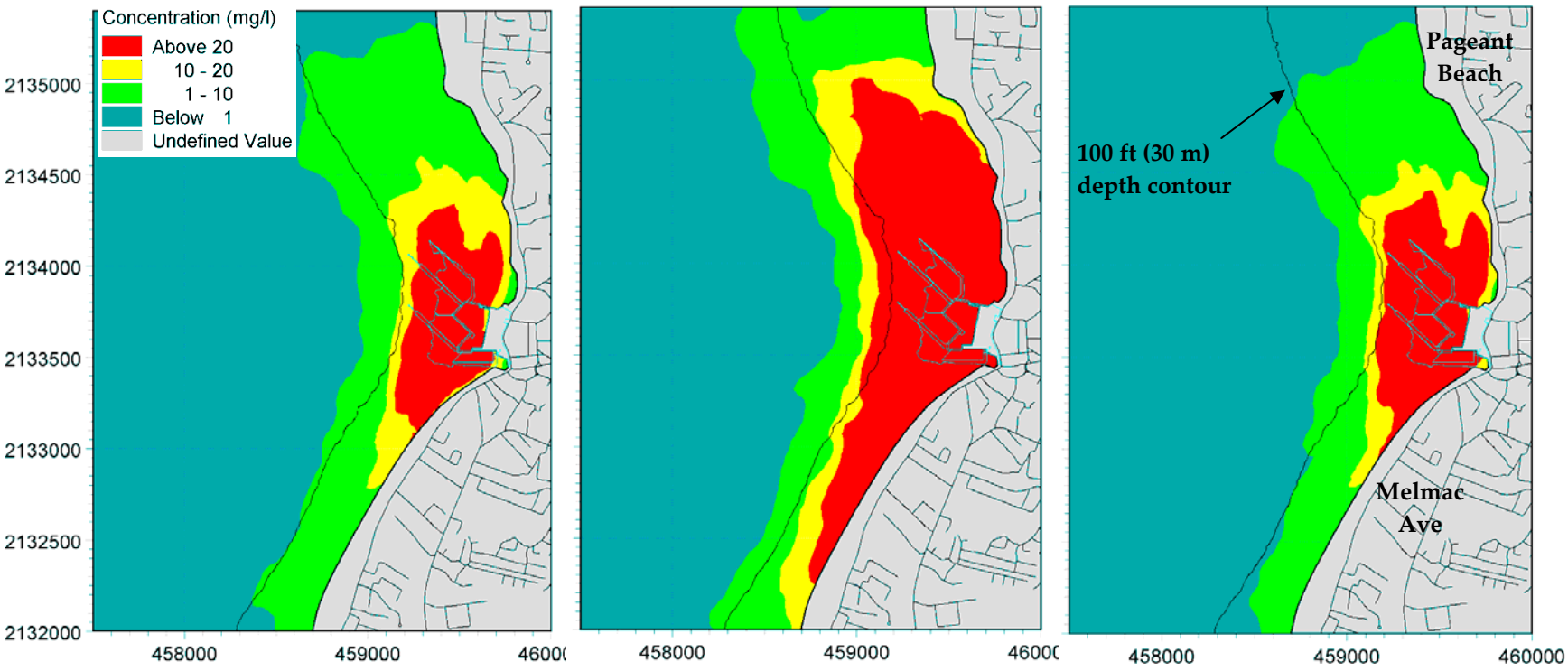


Figure 11.12 Maximum suspended sediment concentration at seabed for lower rate BHD (left), upper rate BHD (centre) and CSD (right)

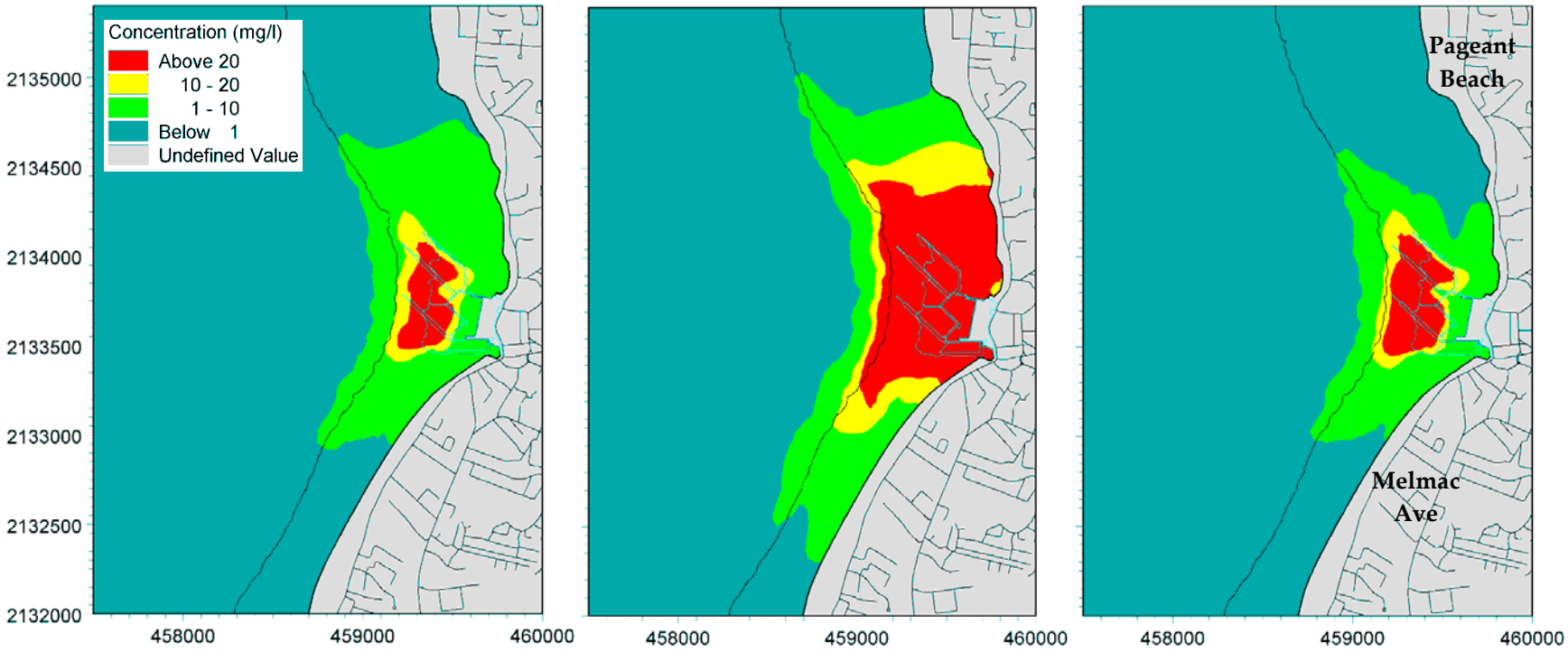


Figure 11.13 24-hour maximum suspended sediment concentration at seabed for lower rate BHD (left), upper rate BHD (centre) and CSD (right)

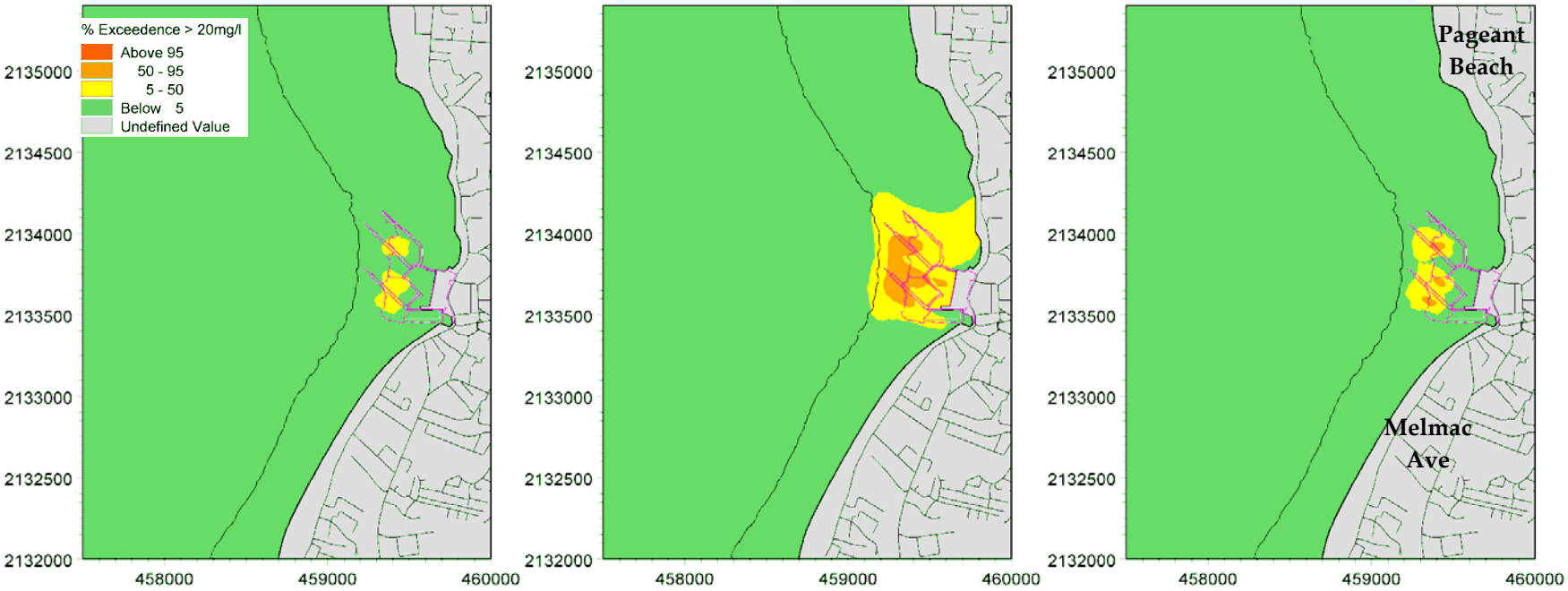


Figure 11.14 Percent exceedance of high suspended sediment concentration (20 mg/L) for lower rate BHD (left), upper rate BHD (centre) and CSD (right)

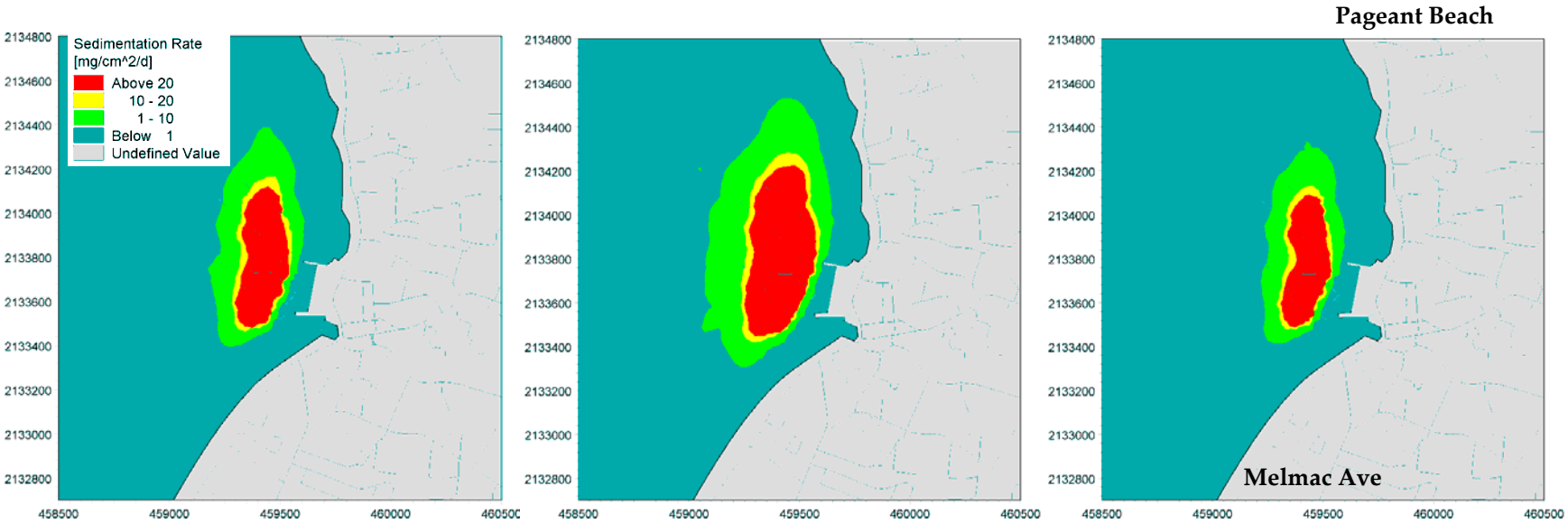


Figure 11.15 Sedimentation rate for lower rate BHD (left), upper rate BHD (centre) and CSD (right)

The extent and magnitude of these dredge plumes and impact zones form an important part of the marine ecological impact assessment (Task J).

11.4.1.3 Disposal Impacts

Three different methods of disposal were investigated to determine the impacts:

- Offshore disposal using a pipeline;
- Offshore disposal using a split-hull hopper barge; and
- Overflow from the land reclamation.

The impacts of these different disposal methods were evaluated using the nearshore hydrodynamic model. However the pipeline and split-hull barge methods also required an assessment of the process of initial dilution using CORMIX and STFATE.

For the pipeline disposal, which may describe a either fixed pipeline or pumping out of a hopper dredge, it was assumed that the dredge spoil would enter the sea below the surface. The slurry enters the water as a jet and entrains the surrounding water. This process mixes and carries the warmer surface water down with the sediment-laden jet. Eventually the downward motion of the jet slows at which point it becomes a plume, which is then modeled using the nearshore hydrodynamic model. Investigations of the initial dilution using CORMIX revealed the creation of a plume 262-492ft (80-150m) below the surface, with an upper initial suspended sediment concentration of approximately 300 mg/L.

STFATE was used to model the initial dilution of dredge spoil dumped from a split-hull barge. In this case, the barge carries the dredge slurry offshore to the dumping area and opens the hoppers dumping the material. The initial mixing process is similar to the pipeline, however, the rapid dumping rate results in a large plume extending approximately 1082ft (330m) down from the surface. Within this plume, the suspended sediment concentration was estimated to be 50 mg/L.

Using the results of the initial dilution models (CORMIX and STFATE), the nearshore hydrodynamic model was employed to determine how these plumes would spread and dilute. The results indicate that the areas of high turbidity impact (>20 mg/L) are quite small and concentrated around the disposal area. Lower impact levels (>1 mg/L) extend further and for the subsurface pipeline discharge this plume remains trapped below the surface and does not return to the shoreline (

Figure 11.16).

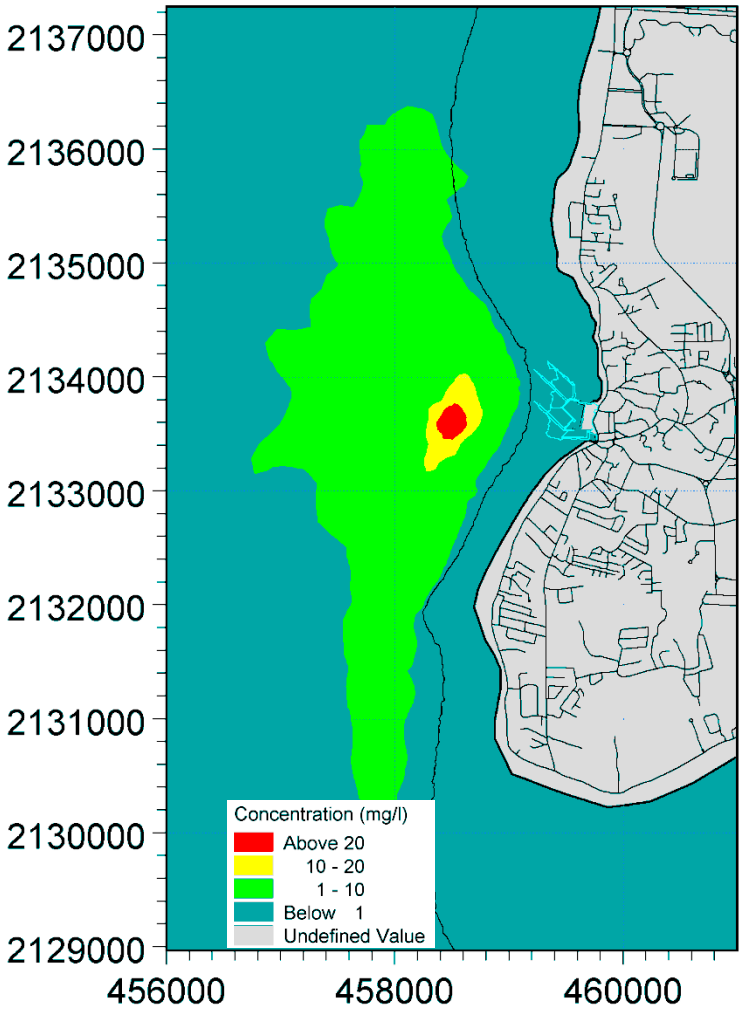


Figure 11.16 Maximum turbidity for pipeline discharge (in sub-surface layer)

For the split-hull hopper barge plume, the lower impact level (1-10 mg/L) maximum concentration extends to the shoreline for disposal points 0.62, 1.24 and 1.86 miles (1, 2, and 3 km) from the shore. It should be noted that the larger area of high impact (>20 mg/L) at the disposal locations for the 1.24 and 1.86 miles (2 and 3 km) reflects the coarser model resolution in those areas (

Figure 11.17).

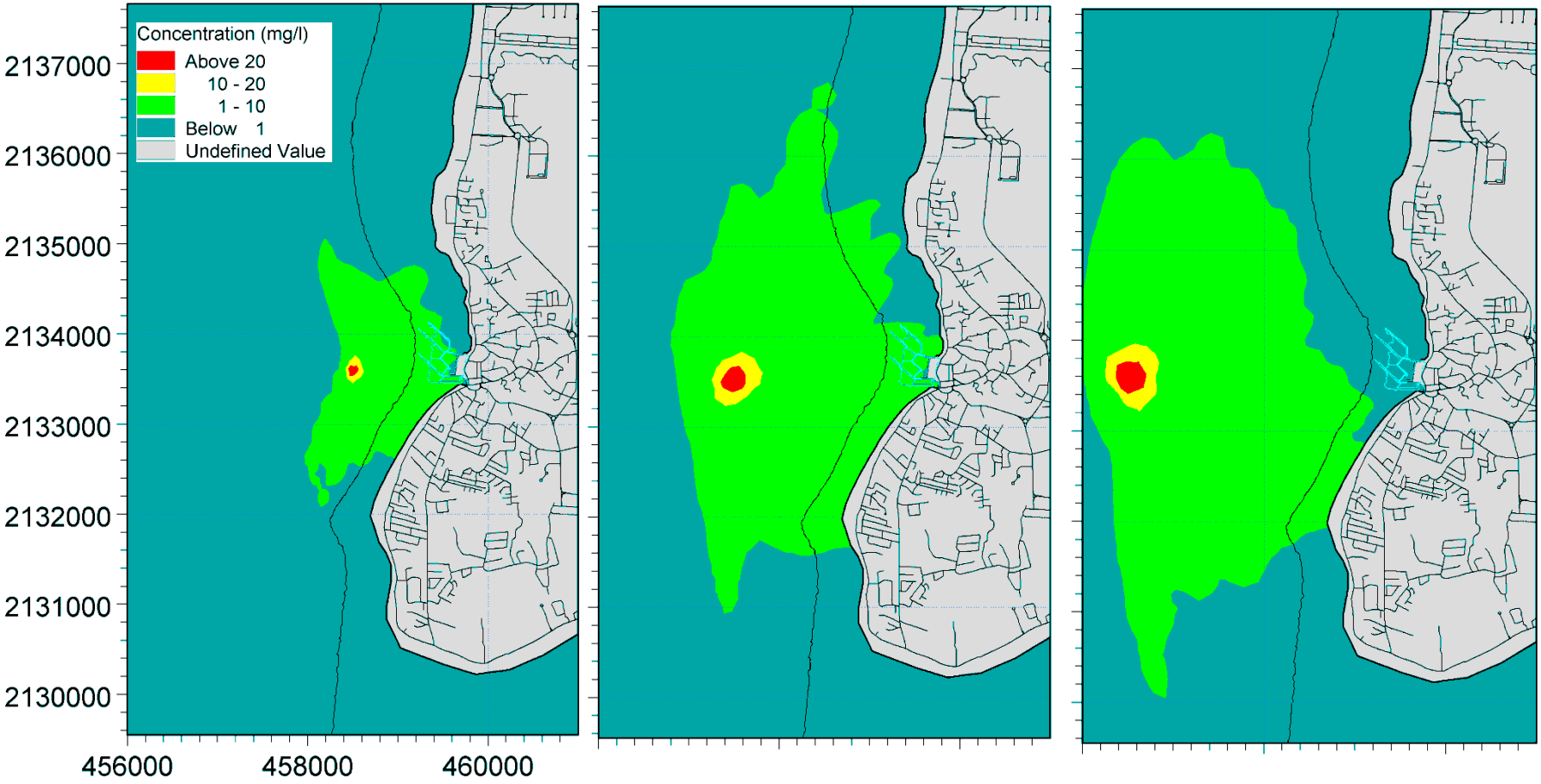


Figure 11.17 Maximum surface suspended sediment concentration for split-hull barge disposal at 1 km (left), 2 km (centre) and 3 km (right)

Overflow discharge was simulated using the nearshore hydrodynamic model. The simulations revealed that areas of high turbidity impacts (>20 mg/L) would be produced by a low (50 mg/L) and high (250 mg/L) effluent concentration. This range of suspended sediment concentrations was developed based on the dredge material composition as well as the available area for settling ponds to be created. The results indicate that the area affected by high turbidity impacts (>20 mg/L) are generally smaller and overlap the areas that would already be impacted by either the BHD or CSD operations. It should be mentioned that the BHD is not expected to result in significant overflow discharge, as the water content will be much lower, compared to the CSD slurry.

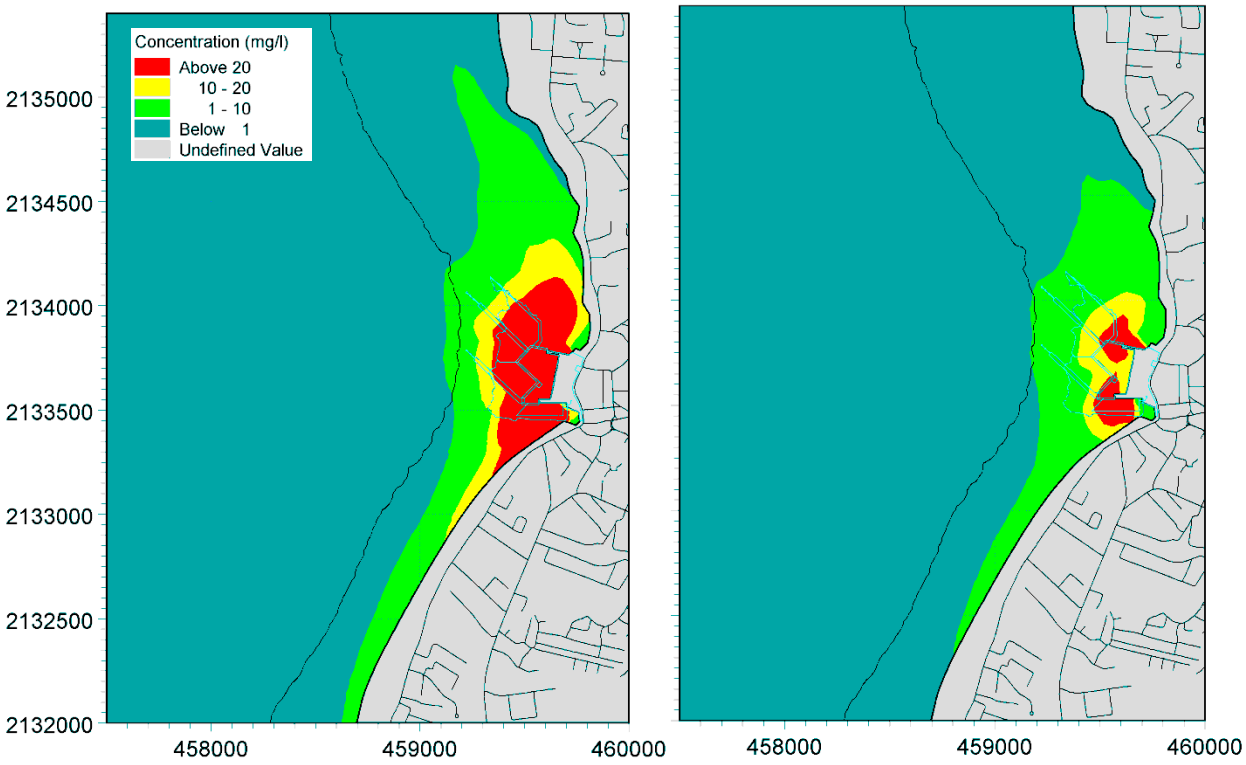


Figure 11.18 Maximum turbidity plot for overflow discharge at land reclamation. High concentration (left), Low Concentration (right)

11.4.1.4 Sediment Re-Suspension Impacts

The construction of the proposed facility will include nearshore dredging to allow large cruise ships to berth alongside the new piers. The extent and depth of the dredged area will be limited to that necessary to allow safe navigation of the largest cruise ships expected to use the facility, as defined through discussions with the cruise lines and review of published design guidelines (PIANC, 2014; ROM, 1999; Thoresen, 2010).

The sediment re-suspension process is illustrated in **Figure 11.19**, with the spinning propeller generating a high velocity, turbulent flow field that dissipates with distance from the propeller ("prop wash"). Interaction of the prop wash with loose sediments on the seabed may be sufficient to mobilize, suspend and entrain these sediments, with finer sediments being more prone to this "re-suspension" process, and the associated development of a turbidity plume. The presence of confining structures (such as a solid quay wall) may exacerbate the process.

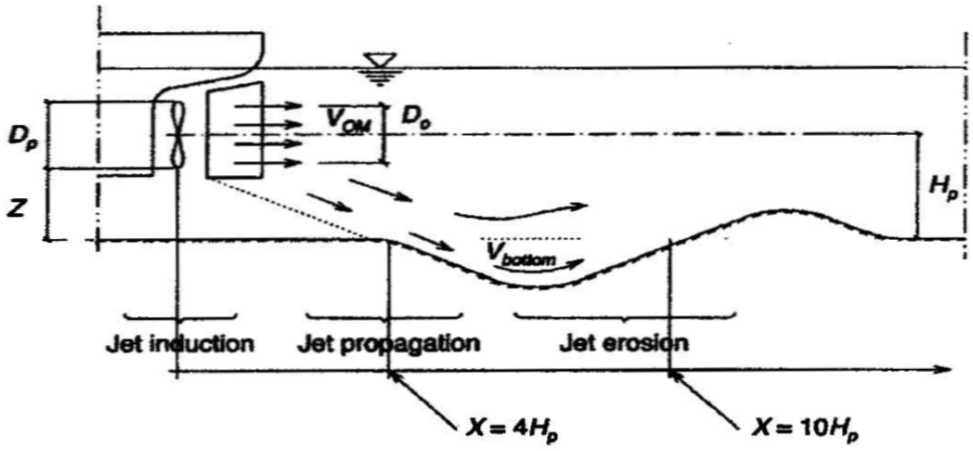


Figure 11.19 Schematic Illustration of Prop Wash (Source: PIANC, 1997)

The primary uncertainty in estimating the occurrence, frequency and extent of turbidity plumes is the sediment entrainment process. While tools are available to estimate the flow field generated by propellers and thrusters, and the initiation of motion of seabed sediments, it is not yet possible to reliably quantify sediment entrainment and plume generation.

Empirical Estimates of Flow Field and Initiation of Motion of Seabed Sediments

Published empirical methods (EAU, 1996; PIANC, 1997) were used to estimate the flow field generated by cruise ship propellers and thrusters, and the initiation of motion of seabed sediments.

Figure 11.20 presents a summary of the results for typical cruise ships anticipated to call at George Town based on the dredge depth of 35ft. These results indicate that very fine sand (0.074mm) may be mobilized up to about 825ft from the main propellers (at 50% power), and up to about 340ft from the bow thrusters (at 100% power). Finer sediments may be mobilized at greater distances.

A review of existing borehole data for GTH in the vicinity of the proposed dredged basin showed that the loose sediments were relatively coarse (median grain size, D_{50} typically in the order of 0.2-2mm) with an average of 7.4% fines (silt and clay sized particles, with D < 0.074 mm). However, it is noted that dredging in cemented materials may generate fines.

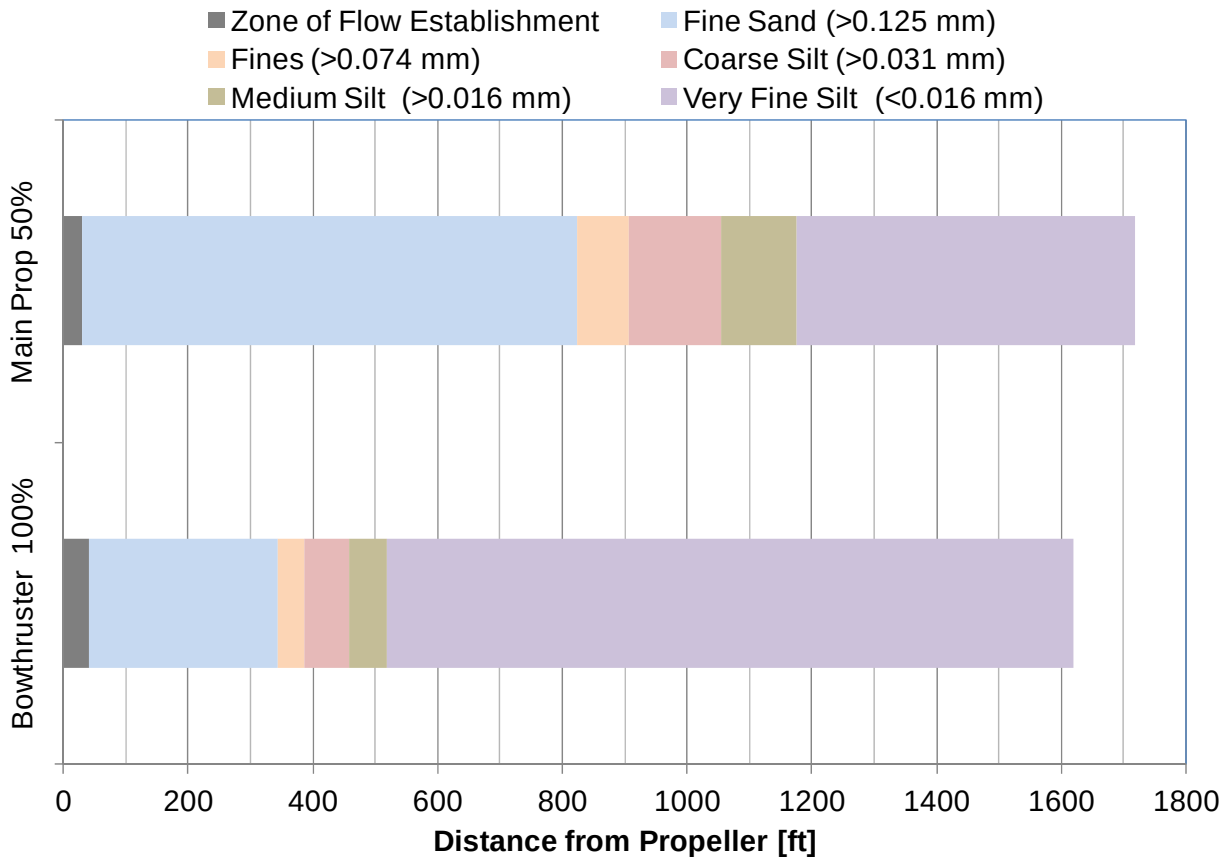


Figure 11.20 Estimated mobilization of seabed sediments by prop wash (35ft water depth)

The input parameters used in these calculations are summarized below:

- 35ft water depth (based on design dredge depth and low tide)
- Typical vessel characteristics
    - Length (LOA) ~ 1,000ft
    - Beam (B) ~ 122ft
    - Draft (d) ~ 27ft
    - Gross registered tonnage (GRT) ~ 90,000 to 140,000t
- Main propellers - 19ft diameter, non-ducted, shaft 23ft above the seabed, 50% power
- Bow thrusters - 6ft diameter, ducted, with shaft 20ft above the seabed, 100% power

The propeller and thruster details used in the calculations are based on a review of information for several vessels in the size range noted above. Larger vessels (with larger propellers and more power) may call at Grand Cayman, but relatively infrequently. The power application levels used in the calculations are based on discussions with Captains and published design

guidance. Higher power levels are possible, but are typically only used in extreme or emergency conditions.

For comparison purposes, Baird estimated the wave conditions required for initiation of motion of sediments in a water depth of 35 ft. These calculations indicate that medium-coarse silt will be mobilized at this depth by wave height/period combinations in excess of 3 ft/6-8 s. Referring to the metocean report (Appendix D.1), these conditions are estimated to occur, on average, approximately 1% of the time, and would generally be associated with Nor'westers. Typical (less severe) wave conditions do generate turbidity plumes, but only in very shallow water (i.e. in the surf/breaking zone). This information indicates that initiation of motion of the seabed sediments does not necessarily result in sediment entrainment through the water column and the development of a turbidity plume. Hence, initiation of motion of the sediment is not directly indicative of the generation of a turbidity plume.

Numerical Modeling of Sediment Re-Suspension and Turbidity Plumes

A three-dimensional hydrodynamic and sediment transport model (MISED, an in-house model developed by Baird) was used to estimate the generation and dispersal of turbidity plumes caused by cruise ships berthing/de-berthing at the proposed facility. The processes-based model simulates the hydrodynamic flow field (including ambient nearshore currents, as well as the turbulent jet flow produced by propeller/thruster action), the mobilization/entrainment of seabed sediments, and the dispersion of the suspended sediment (i.e. the turbidity plume) around the project site. Key model input assumptions are summarized below:

- Typical vessel size and propulsion system details as summarized in preceding section;
- Seabed sediments include 7.4% fines (average for sediment samples in the project area);
- Propellers and thrusters operated for 15 minute duration (50% power for main props, 100% power for thrusters);
- Typical northerly flowing nearshore current with average speed of 0.6 ft/s.

Figure 11.21 (on the next page) presents "snapshots" of qualitative results from the MISED model simulations for a turbidity plume generated by the bow thrusters (100% power for 15 minutes) of a vessel berthed bow-in on the north side of the north pier. **Figure 11.22** (also on the next page) presents similar results for a turbidity plume generated by the main propellers (50% power for 15 minutes) of a vessel berthed stern-in at the same location.

The MISED model appears to provide a reasonable simulation of the turbidity plume associated with the sediment re-suspension process. However, it is important to note that the model has not been calibrated or validated for this application. Given the complexity of the processes involved (i.e. turbulent flows generated by ships' thrusters and propellers, and resulting mobilization/entrainment of seabed sediments), there is considerable uncertainty in the model results, including the severity, spatial extent and duration of the resulting turbidity plumes. A

field observation/measurement program of turbidity plumes generated by existing operations (i.e. cargo ships at the south cargo dock) could be undertaken to provide a better understanding of sediment re-suspension at the project site, and calibration data for the model.

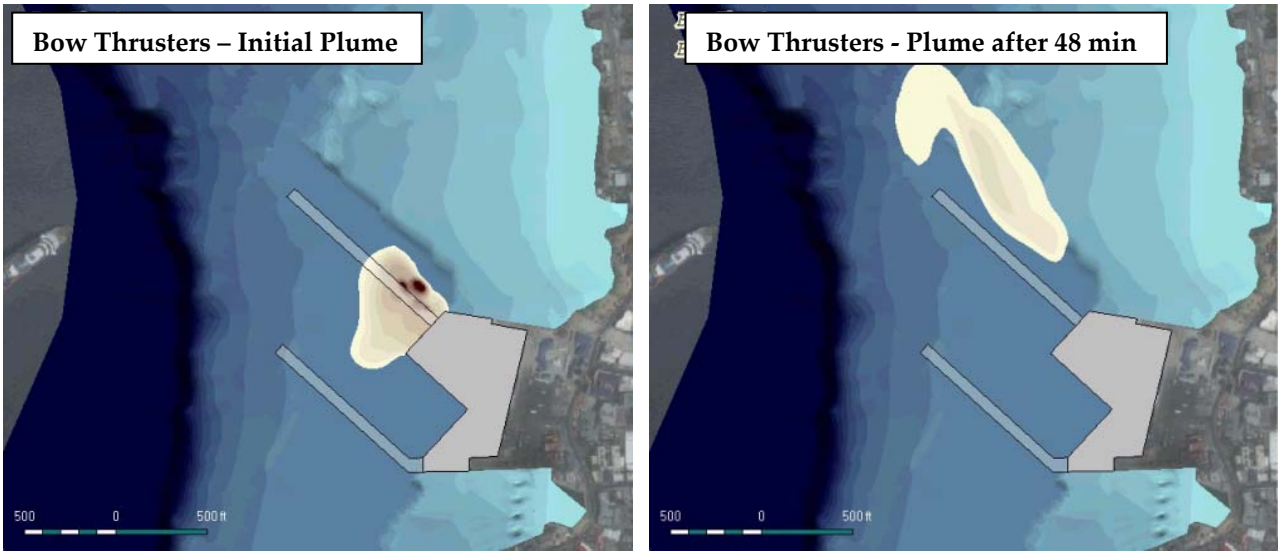


Figure 11.21 Estimated Turbidity Plume due to Bow Thrusters - Vessel Berthed Bow-In at North Pier

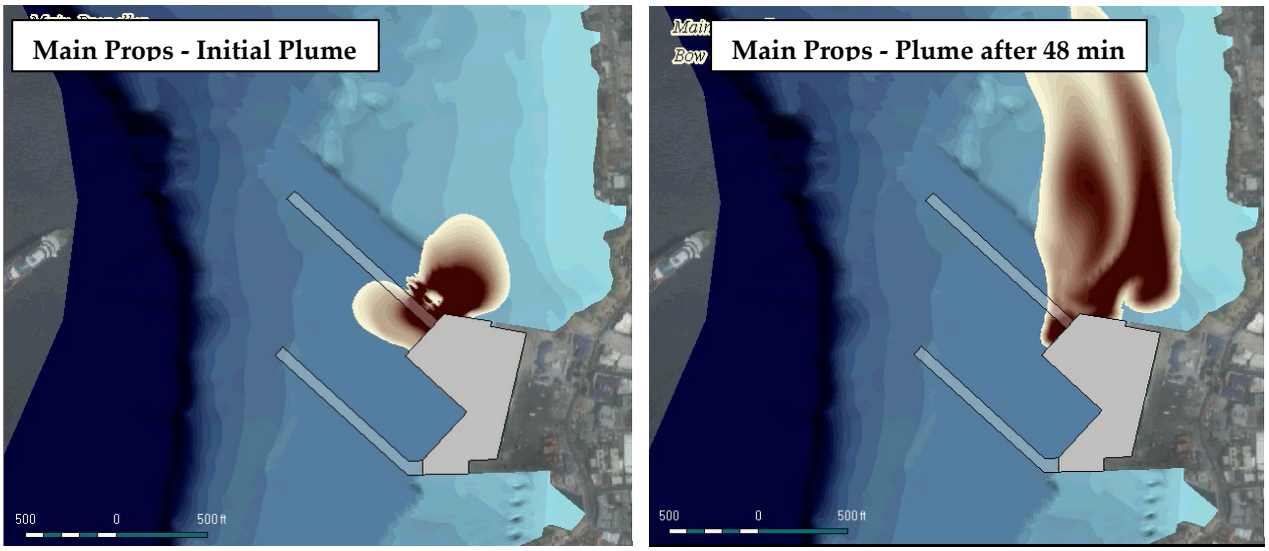


Figure 11.22 Estimated Turbidity Plume due to Main Props - Vessel Berthed Stern-In at North Pier

Review of the MISED model results leads to the following conclusions regarding sediment re-suspension by cruise ships:

- Suspended sediment concentrations may exceed 100 mg/L in localized areas for short periods of time (as noted above, there is considerable uncertainty in these values);
- Elevated turbidity levels over the adjacent reefs may persist for tens of minutes;
- Sediment entrainment does not occur for coarser materials (i.e. sands and gravels), as these materials rapidly fall out of suspension;
- Sediment entrainment, and the severity of turbidity plumes, decreases as the proportion of fines in the bottom sediment decreases;
- Sediment entrainment, and the severity of turbidity plumes, decreases as the water depth increases.

Literature Review/Experience at Similar Facilities

A literature review was undertaken to identify other cruise ship facilities where sediment re-suspension and turbidity plumes have been identified as an issue of concern. A number of relevant papers were identified and reviewed (Gelinas et al, 2013; Jones, 2011; Thomas J. Murray & Associates, Inc., 2005). Specific sites where this process has been identified as a concern, and have been subject to study, include Bermuda, Key West and Venice. It is noted that the relevant characteristics of these three sites are very different from the George Town site, as follows:

- Projects are located in shallow, sheltered areas;
- Projects include long, dredged approach channels with bends/turns that require significant ship power application;
- Shallow water depths and high percentages of fine sediments adjacent to the dredged channels.

These factors result in a significantly greater potential for sediment re-suspension at these sites as compared to George Town Harbour.

In addition, Baird recently completed a review of turbidity plumes associated with cruise ship operations in the existing Port of Bridgetown in Barbados. Key points of relevance are summarized below:

- Sediment re-suspension is not a significant issue in the existing port, despite limited under keel clearance for large cruise ships and the presences of fine grained sediments;
- Turbidity plumes associated with vessel operations are generally localized, and typically dissipate within 20 minutes;
- Localized turbidity levels may reach 10-60 NTU, versus background levels of 3-4 NTU;
- Turbidity plumes are more prevalent with departures than arrivals;

- More severe turbidity plumes are associated with more complicated maneuvers, which require increased power application.

Considering the characteristics of the Bridgetown site, the risk of sediment re-suspension is considered to be lower in George Town Harbour due to following factors:

- Coarser seabed sediments;
- Open pier structures (versus closed quay walls);
- Simpler vessel maneuvers (requiring less power).

Summary of Sediment Re-Suspension Impacts

The information presented herein (and in Appendix D.3) indicates that there is a potential for cruise ship operations at the proposed cruise berthing facility to result in sediment re-suspension and turbidity plumes. Due to the complex nature of the processes involved, in particular uncertainty related to quantifying the sediment entrainment process, it is not possible to systematically estimate the frequency of occurrence, extent or severity of turbidity plumes.

Comparison of relevant characteristics at the project site to those at other cruise ship facilities where sediment re-suspension is an issue indicates that the risk of sediment re-suspension is significantly lower at the George Town Harbour site. In particular, the coarser seabed sediments and limited extent of shallow water approaches to the site reduce the risk of sediment re-suspension events and associated turbidity plumes. However, the proximity of the dredged berthing area to coral reefs to the north and south warrant consideration of measures to mitigate the risk of sediment res-suspension and turbidity plumes associated with project operations. Potential mitigation measures are discussed at the end of this section.

It is important to note that frequency and extent of sediment re-suspension due to vessel traffic is expected to reduce with time. Specifically, as finer materials are displaced/dispersed by effects of wave action and propeller wash, the seabed sediments will become coarser and less susceptible to entrainment.

11.4.2 Climate Change Impacts

The Climate Change Assessment suggests that Mean Sea Level (MSL) will increase by 0.85-2.7ft (0.26 to 0.82m) by the year 2100. The predicted increase in MSL will increase water depths in the vicinity of GTH and this may affect the nearshore current patterns, which were found to be influenced by tides and the nearby oceanic circulation. The nearshore hydrodynamic model was used to assess the changes to the current patterns resulting only from an increase in MSL. As the climate change impacts on oceanic circulation patterns are poorly understood, attempts to model these factors were not made. **Figure 11.23** compares the maximum current speeds for Option C at present water levels and assuming a MSL increase of 2.7ft (0.82m). The results

indicate a slight increase in the maximum current speeds; however, the overall effect is limited to the immediate surroundings of the CBF and is considered to be quite small.

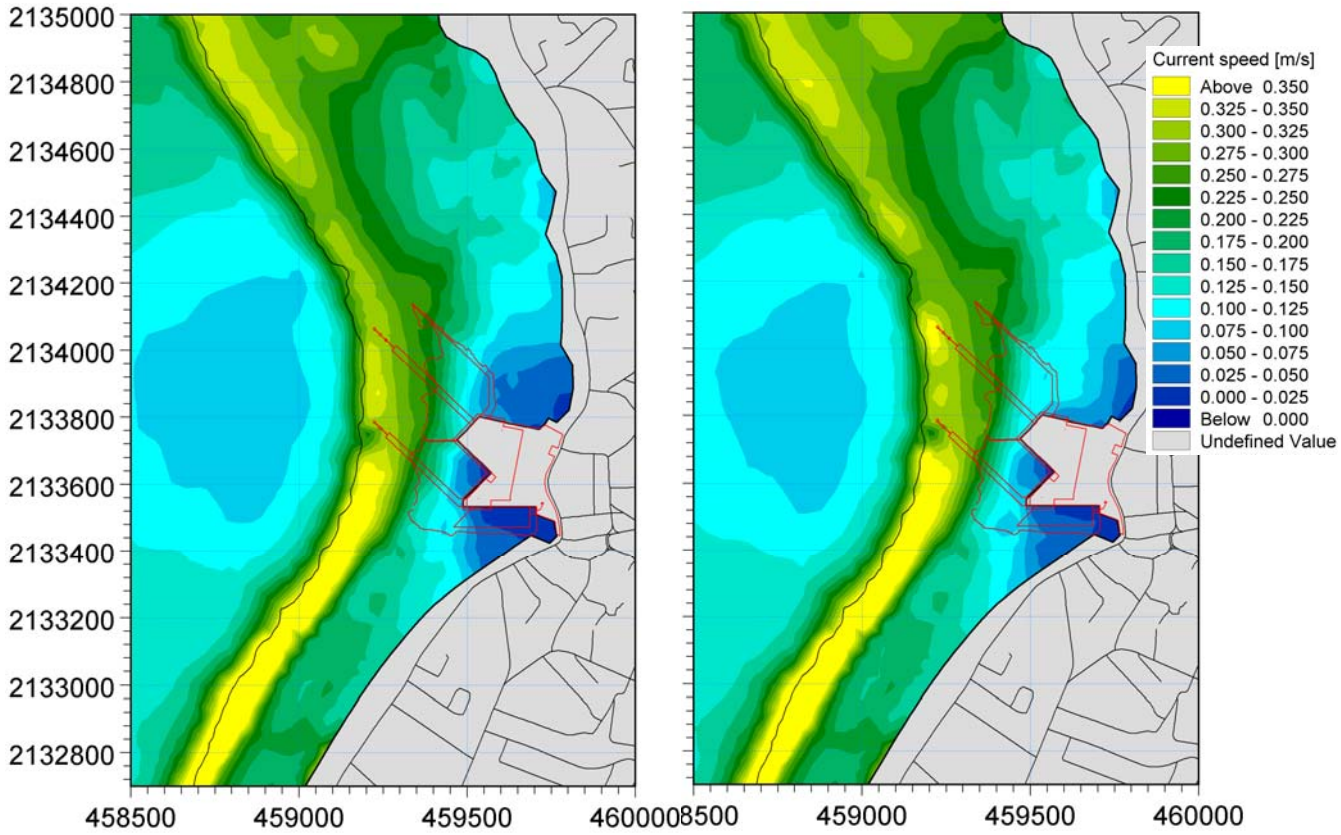


Figure 11.23 Comparison of maximum currents for Option C using MSL (left), and MSL+2.7ft (right)

The effects of climate change are not expected to have a significant impact on the sediment re-suspension process, or the frequency/extent/severity of the associated turbidity plumes and sedimentation.

11.5 Summary of Impacts

Using the hydrodynamic model that was validated from measured currents, an assessment of the impacts on current patterns has been made. In addition, the HD model has been used in conjunction with the Transport (TR) model and Sediment Transport (ST) module to determine the extent and magnitude of the area surrounding the port that may be affected by elevated turbidity levels and increased sedimentation. Various aspects of the dredging operation have been investigated, including:

- The use of both backhoe and cutter suction dredges to remove material;
- Offshore disposal through a pipeline;
- Offshore disposal using a split hull hopper barge;

- Placement of dredged fill materials within a containment berm surrounding the land reclamation area, with overflow of excess water back into the sea;
- The impacts on nearshore current patterns resulting from the post-construction shoreline and seabed configurations.

This impact assessment has revealed the following findings:

- For turbidity impacts, these were categorized as low, medium and high impacts and correspond to suspended sediment concentrations of <10 mg/L, 10-20 mg/L and >20 mg/L.
- For sedimentation rates, low, medium and high impacts correspond to <10 mg/cm^2/d, 10-20 gm/cm^2/d and >20 mg/cm^2/d.
- The BHD operation simulated two mass-loss rates of 0.1 and 0.5 kg/s, corresponding to low-productivity and high-productivity scenarios. The deployment of turbidity barriers was not simulated, but the low-productivity rate would be representative of the deployment of turbidity barriers for a high-productivity scenario.
- The BHD high-productivity operation generates a maximum plume of high impact that extends 3,280ft (1000m) north and 4,590ft (1400m) south of the dredge operations. The plume reaches the shoreline and extends seaward 1,640ft (500m).
- The BHD high-productivity operation generates a 24-hour maximum plume of high impact that extends 1,640ft (500m) north and 1,310ft (400m) south of the dredge operations. The plume reaches the shoreline and extends seaward 660ft (200m).
- The BHD low-productivity (or deployed turbidity barrier) operation generates a maximum plume of high impacts that extends 1,310ft (400m) north and 1,970ft (600m) south of the dredge options. The plume also reaches the shoreline and extends seaward 660ft (200m).
- The BHD low-productivity (or deployed turbidity barrier) operation generates a 24-hour maximum plume of high impacts that extends to an approximately 490ft (150m) radius of the dredge options. The plume also reaches slightly further at the seabed compared to the surface.
- A 50% exceedance plume, meaning that up to 50% of the time the concentration exceeds the high impact level, was found to occur within approximately 330ft (100m) of the dredge operation for the low-productivity operation. For the high-productivity scenario, this plume reaches the shoreline and for the bottom layer it extends 980ft (300m) offshore.
- Sedimentation rates exceeding the high impact value were found to extend approximately 980ft (300m) beyond the dredge site for the high-productivity scenario and 660ft (200m) for the low-productivity scenario.

- The cutter-suction dredge operation was found to produce a slightly smaller impact zone than the low-productivity BHD for both the turbidity and sedimentation criteria. The impact zone is also limited to the bottom layer for the cutter-suction dredge.
- The offshore disposal operations examined pipeline and barge disposal. The initial mixing was modeled using CORMIX for the pipeline and STFATE for the barge disposal.
- The pipeline disposal results in a plume of suspended sediments, while the remainder of the material, including sand and cobble/chunks, descends rapidly to the seabed.
- The plume from the pipeline disposal descends below the surface where its downward motion eventually stops. This depth ranges between -260 and -460ft (-80 and -140m) from the surface. This offshore plume of elevated turbidity levels exceeds the high impact value, but will be diluted under ambient current action. This plume measured approximately 980ft (300m) in diameter. The lower limit of concern (1 mg/L) remained offshore.
- The hopper discharge was simulated using STFATE, which predicted a convective descent of the dredge spoil to a depth of 980ft (300m), more than twice the depth of the pipeline disposal. The concentration within this plume is lower, however because it is spread throughout the water column, when disposed 3,300ft (1 km) from the shoreline, portions of the plume (at the minimum impact level) reach the shoreline.
- The hopper discharge will result in very small changes to the seabed elevation (1-7cm) for each load that is dumped.
- When disposed 1.25 miles (2 km) from the shoreline, the minimum impact zone also reaches the shoreline.
- Using the 1.8 miles (3 km) discharge point for the hopper dredge, the minimum impact zone only makes minimal contact with the shoreline.
- Overflow discharge from the land reclamation was simulated using high and low concentration scenarios. Results for the maximum concentration suggest a highly impacted area extending 980ft (300m) to the north and 660ft (200m) to the south for the high concentration overflow discharge. For the 24-hour maximum concentration, the area of high impact is quite similar to the maximum concentration. The low concentration overflow creates a smaller highly impacted zone with a radius extending approximately 330ft (100m) from the discharge point.
- The assessment of impacts on ambient currents in the vicinity of the port has revealed that approximately 3,300ft (1 km) north and south of the port the effects of the proposed CBF will not be felt. Further, at Eden Rock, little or no change in current patterns is observed. The primary impact on the ambient current patterns is observed in the mid and south dredge pockets, where current velocities and frequencies of occurrence are significantly reduced. In the north dredge pocket, the currents to the NE are reduced and those to the SW are increased. At Soto's Reef, the major change predicted is a reduction in the SSE currents and an increase in the South currents.

- The assessment of impacts on ambient currents in the vicinity of the port has revealed that when cruise ships will be at berth, current speeds will be reduced. At comparison points approximately 3,300ft (1 km) north and south of the port the effects of the proposed CBF will not be felt. At Eden Rock, the presence of the cruise ship reduces current speeds and alters their direction, while significantly increasing the percentage of time experiencing calms (<1 cm/s). Within the dredge pocket, currents are reduced significantly. At Soto's Reef, the major change predicted is a reduction in the overall currents and an increase in the south-west currents.
- Climate change impacts were assessed using the nearshore hydrodynamic model taking into consideration a rise in mean sea level of 2.7ft (0.82m). Results indicate a small increase in localized maximum current speeds in the vicinity of the CBF.

The impacts listed above have been related to the various potential impacts identified in the ToR. Impacts were grouped in terms of their occurrence in the construction or operational phase. In addition, an assessment of the type of impact, duration and permanence has been undertaken, with the results summarized in Table 11.2 on the following page. Detailed numerical modelling has been undertaken for most of the impacts identified in the ToR, whereas others have been estimated.

Table 11.2 Summary of Anticipated Project Impacts - Hydrodynamics and Dredge Plumes

SUMMARY OF IMPACTS	*Modelled*	*Direct*	*Indirect*	*Secondary*	*Cumulative*	*Short-Term*	*Med-Term*	*Long-Term*	*Permanent*	*Temporary*	*Positive*	*Negative*
Construction Phase												
Impact of dredging on water clarity in GTH (effect on water sports businesses, aesthetic views)	◆	◆			◆	◆				◆		◆
Impact of reclamation discharges on water clarity in GTH (effect on water sports businesses, aesthetic views)	◆	◆			◆	◆				◆		◆
Impact of dredge material disposal on water clarity (marine related businesses)	◆		◆		◆	◆				◆		◆
Impact of large construction vessels on current flow patterns				◆			◆			◆		◆
Potential for pollution from construction equipment to be transported to adjacent areas			◆		◆		◆			◆		◆
Impact of construction related equipment on current patterns during general construction			◆				◆			◆		◆
Operational Phase												
Potential for polluting discharges from vessels: bilge pumping; propeller wash; refuelling and storage; spillage		◆			◆			◆		◆		◆
Impact of structures on current patterns	◆		◆					◆	◆			◆
Impacts from extreme weather events and climate change	◆		◆			◆			◆		◆	

11.6 Proposed Mitigation Measures

11.6.1 Construction Phase

Based on the results of the EIA, it is recommended that a mechanical dredging operation be used for the project. Specifically, based on the results of model simulations of turbidity plumes for both mechanical (BHD) and hydraulic (CSD) operations, as well as discussions with several dredgers, it is anticipated that the overall impact of dredging on the surrounding marine environment (i.e. coral reefs and aquatic habitat) will be less with a BHD. In particular, mechanical dredging is slower, easier to control and does not generate the huge volumes of sediment laden water that a CSD does. This latter factor is a particular challenge for a hydraulic dredging operation for the proposed project due to the small size of the land reclamation area, which effectively limits the "retention time" available for the solids to fall out of suspension before the excess water returns to the sea.

The model simulations for the BHD demonstrate that the impact of a high productivity operation is greater than a low productivity operation, although the overall duration of impact also needs to considered. Given the extent of the turbidity plume created by BHD with a mass-loss rate of 0.5 kg/s, it may be necessary to limit the size and type of dredge that is used.

Turbidity barriers (silt curtains) should be deployed around active dredging operations. Best management practice (BMP) guidelines[3] suggest that turbidity barriers can be deployed in calm areas where wave action is limited and currents are less than 1 - 1½ knots (0.6 to 0.9 m/s). Observed and modeled current speeds were typically much less than these limits in the vicinity of the dredge area. Further, the wave climate at the project site is generally mild, other than intermittent Nor'Westers that occur during the winter, and hurricanes. Turbidity barriers should be deployed from the surface to within 1-2ft (0.3 to 0.6 m) of the seabed, and must be anchored at multiple points. Correctly deployed and maintained, turbidity barriers can be more than 80% effective in containing sediment-laden waters.

A containment dike around the land reclamation area should be constructed prior to dredging such that the dredged materials are fully contained as they are placed. The design of the containment dike should incorporate features to prevent the loss of sediment through the structure, and to maximize the "retention time", thereby limiting the suspended sediment concentration in the excess water that returns to the sea. In addition, a silt curtain should be deployed at the discharge/outlet of the land reclamation area to limit the spatial extent of the turbidity plume.

Excess dredged materials should be dumped in large water depths (> 1000 feet) more than 1.25 miles west (offshore) of the project site in order to limit the impacts of the disposal operation on the nearshore environment. Onshore disposal of excess dredged materials may be a viable alternative, particularly for a mechanical dredging operation, and could provide the opportunity to process the

[3] Francingues, N. R., and Palermo, M. R. (2005). "Silt curtains as a dredging project management practice," DOER Technical Notes Collection (ERDC TN-DOER-E21). U.S. Army Engineer Research and Development Center, Vicksburg, MS.

material for sale as fill in the future. However, onshore disposal would require the identification, acquisition and preparation of a suitable site to allow processing (dewatering) of the excess dredged materials.

Regardless of the dredging and disposal methods adopted by the Contractor, real time monitoring and adaptive management techniques should be implemented in order to minimize turbidity and sedimentation associated with dredging, reclamation and disposal operations. Proposed turbidity and sedimentation thresholds have been developed and are included in the draft Environmental Management Plan (EMP), which is included as Section III of the Environmental Statement. Should monitoring detect turbidity or sedimentation levels in excess of the specified threshold conditions, the Contractor would be required to adjust, modify or cease operations.

The EMP also includes numerous other measures to limit the impacts of other construction activities on the surrounding environment.

11.6.2 Operation Phase

The impact of the CBF on ambient current patterns is limited to the area immediately surrounding the facility, with the impact being greater when ships are at berth. As such, project impacts on current patterns can be mitigated by limiting the duration that large cruise vessels remain at berth to daytime hours only (as is presently the case), thereby allowing the current patterns to re-establish through the night.

One or more of the following measures could be incorporated into the design of the project in order to reduce the risk of sediment re-suspension associated with cruise ship traffic:

Project Design/Construction

- Overdredge berthing area
- Vacuum berthing area after primary dredging to remove fines
- Install seabed stabilization measures in critical areas of berthing area

Project Operations

- Limit vessel approach speeds to the minimum necessary for safe handling of the vessel
- Limit power application at berth to the minimum necessary for safe handling of the vessel
- Require “bow-in” berthing unless conditions dictate otherwise (this puts the more powerful and larger main propellers in deeper water)

11.7 RIAM Summary of Anticipated Project Impacts and Proposed Mitigation Measures

As noted in Chapter 1.3.6, the Rapid Impact Assessment Matrix (RIAM) method has been used to "quantify" the anticipated impacts of project construction, operation and mitigation measures.

Table 11.3 and Figure 11.22 provide a summary of the RIAM scoring for specific impacts related to waves, sediment transport, hydrodynamics and dredge plumes (as discussed in Chapters 10 and 11), including scores for each of the following project phases:

- Existing (baseline) conditions
- Dredging and reclamation phase
- Construction (post-dredging) phase
- Operational phase

Proposed mitigation measures for specific impacts are highlighted in the green cells in Table 11.3, with the RIAM method applied both without and with these mitigation measures.

Chapter 1.3.6 provides an overview of the various RIAM scoring criteria (A1, A2, B1, B2 and B3) and the methodology used to derive the Environmental Score (ES) and associated Range Value (RV) for each specific impact. The Range Values are summarized as follows:

- N: Neutral (no change/impact)
- A to E: Positive change/impact (A is slight positive...E is major positive)
- -A to –E: Negative change/impact (-A is slight negative...E is major negative)

Additional information on the RIAM methodology is provided in Appendix Q.

Table 11.3 Detailed RIAM Scoring for Waves, Sediment Transport, Hydrodynamics and Dredge Plumes

PHASE	IMPACTS SCORED WITH NO MITIGATION	Spatial Importance (0 to 4)	Magnitude of change/effect (-3 to + 3)	Permanence (1 to 3)	Reversibility (1 to 3)	Cumulative (1 to 3)			IMPACTS SCORED WITH MITIGATION	Spatial Importance (0 to 4)	Magnitude of change/effect (-3 to + 3)	Permanence (1 to 3)	Reversibility (1 to 3)	Cumulative (1 to 3)	*ES with mitigation*	*RV With Mitigation*
		A1	A2	B1	B2	B3	ES	RV		A1	A2	B1	B2	B3	ES	RV
EXISTING CONDITIONS	**Hydrodynamics/Dredge Plumes**															
	Changes to the local current patterns from ships at anchor	1	-1	3	3	3	-9	-A		1	-1	3	3	3	-9	-A
	Waves and Sediments															
	Effects of prop wash (resuspension of sediments)	1	-1	2	2	3	-7	-A		1	-1	2	2	3	-7	-A
	Deposition of silt and fine sediments within the port over time	1	-1	2	2	3	-7	-A		1	-1	2	2	3	-7	-A
	Changes to the wave patterns in the form of reflection from the quay wall	1	-1	3	1	1	-5	-A		1	-1	3	1	1	-5	-A
DREDGING & RECLAMATION PHASE	**Hydrodynamics/Dredge Plumes**															
	Changes to the local current patterns from construction vessels	1	-1	2	2	3	-7	-A		1	-1	2	2	3	-7	-A
	Impact of dredging on water clarity in GTH	3	-3	2	2	2	-54	-D	Install turbidity barriers to contain plume	3	-2	2	2	2	-36	-D
	Impact of reclamation discharges on water clarity in GTH	3	-3	2	2	2	-54	-D	Construct berms to contain runoff	3	-2	2	2	2	-36	-D
	Impact of dredge material disposal on water clarity	2	-3	2	2	2	-36	-D	If piped, discharge shoud be not closer than 1km to shore. If a hopper is used, then discharge point must be not closer than 3km from shore	2	-2	2	2	2	-24	-C
	Potential for pollution from construction equipment to be transported to adjacent areas	1	-2	2	2	2	-12	-B	Install turbidity barriers to contain plume	1	-1	2	2	2	-6	-A
	Waves and Sediments															
	Impact on sediment deposition patterns	1	0	2	2	2	0	N		1	0	2	2	2	0	N
	Wash-out of sediments from stockpiles; Diversion of normal drainage patterns by stockpiles	1	-2	1	1	1	-6	-A	Install bunds/berms barriers and also turbidity barriers to contain plumes	1	-1	1	1	1	-3	-A
CONSTRUCTION - POST DREDGING	**Hydrodynamics/Dredge Plumes**															
	Changes to the local current patterns from construction vessels	1	-1	2	2	1	-5	-A		1	-1	2	2	1	-5	-A
	Potential for pollution from construction equipment to be transported to adjacent areas	1	-2	2	2	2	-12	-B	Install turbidity barriers to contain plume	1	-1	2	2	2	-6	-A
	Waves and Sediments															
	Impact on sediment deposition patterns	1	0	2	2	2	0	N		1	0	2	2	2	0	N
	Impact on wave patterns	1	-1	2	2	2	-6	-A		1	-1	2	2	2	-6	-A
	Potential for localised scour	1	-1	2	2	2	-6	-A		1	-1	2	2	2	-6	-A
	Potential for localised deposition	1	-1	2	2	2	-6	-A		1	-1	2	2	2	-6	-A
	Wash-out of sediments from stockpiles; Diversion of normal drainage patterns by stockpiles	1	-2	1	1	1	-6	-A	Install bunds/berms barriers and also turbidity barriers to contain plumes	1	-1	1	1	1	-3	-A
OPERATIONAL	**Hydrodynamics/Dredge Plumes**															
	Changes to the local current patterns from ships at berth	1	-2	3	2	1	-12	-B		1	-2	3	2	1	-12	-B
	Potential for polluting discharges from vessels: bilge pumping; propellar wash; spillage	1	-2	2	2	2	-12	-B	Port must have Oil Spill Management and Containment capability and also Waste Management capability	1	-1	2	2	2	-6	-A
	Impacts from extreme weather events and climate change	3	-3	1	1	1	-27	-C		3	-3	1	1	1	-27	-C
	Impacts from cruise operations (e.g. turbulence, maintenance dredging)	2	-2	3	2	3	-32	-C		2	-2	3	2	3	-32	-C
	Waves and Sediments															
	Effects of prop wash (e.g. resuspension of sediments)	1	-2	2	2	3	-14	-B	Limit vessel approach and departure speeds; vessels should not be allowed to moor stern in	1	-1	2	2	3	-7	-A
	Deposition of silt and fine sediments within the port over time	2	-2	2	3	3	-32	-C	Vacuum dredging of seabed to remove fines	2	-1	2	3	3	-16	-B
	Impact on wave patterns from Swell events	2	-2	2	2	2	-24	-C	Localised reduction of flooding by constructing a Concrete Wave Wall	2	-1	2	2	2	-12	-B
	Impact on wave patterns from Hurricane events	3	-3	2	2	2	-54	-D		3	-3	2	2	2	-54	-D
	Changes to deposition/erosion patterns	2	-2	2	2	2	-24	-C		2	-2	2	2	2	-24	-C
	Impacts on littoral drift	2	-1	2	2	2	-12	-B		2	-1	2	2	2	-12	-B
	Climate Change Impacts	2	-1	2	2	2	-12	-B		2	-1	2	2	2	-12	-B

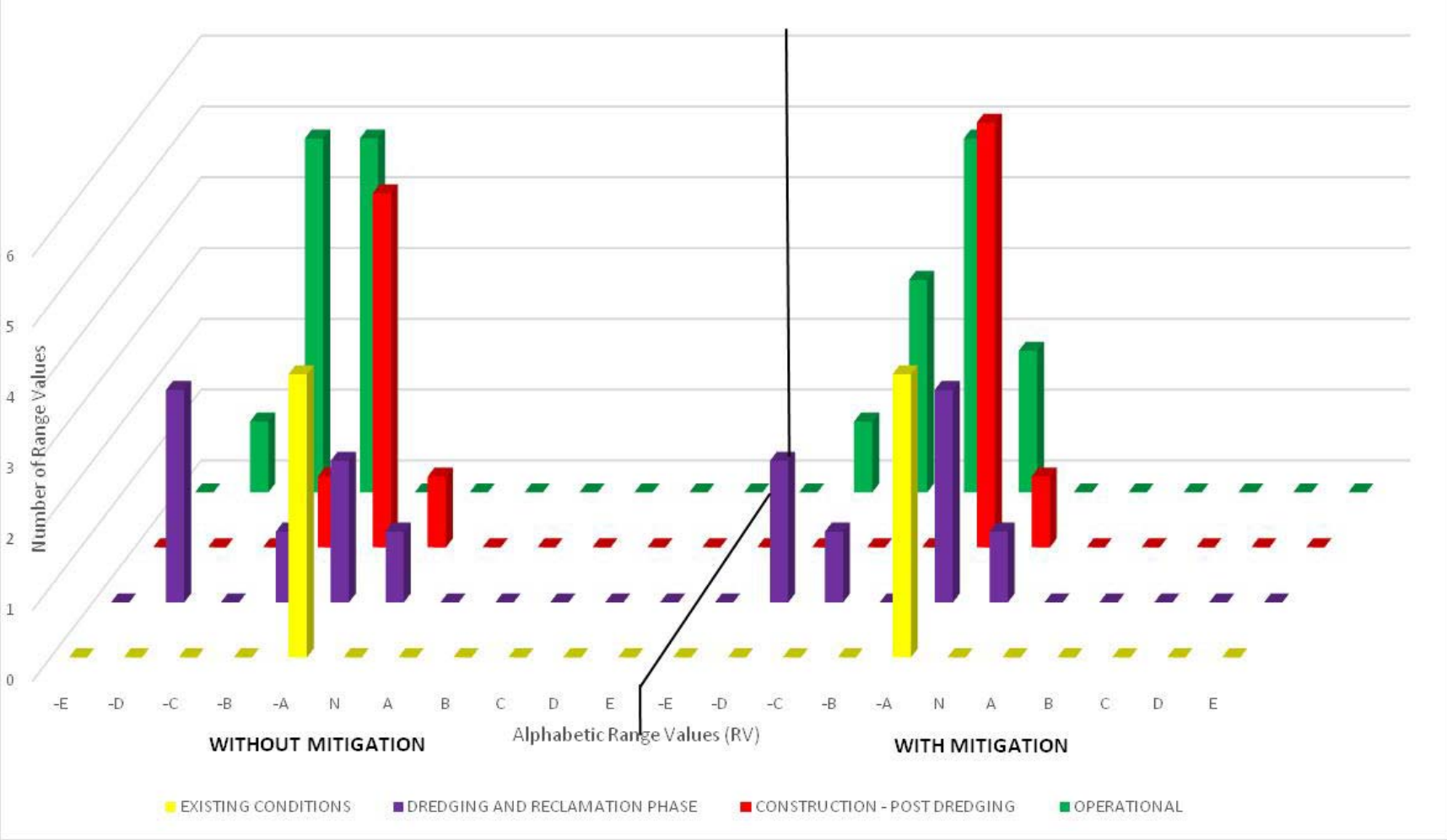


Figure 11.22 Summary RIAM Scoring for Waves, Sediment Transport, Hydrodynamics and Dredge Plumes

12.0 TASK E - SEDIMENT AND WATER QUALITY

One of the requirements of the EIA is to determine the chemical characteristics of the sediment that will be dredged, including grain size, main inorganic pollutants, likely heavy metals and synthetic organic pollutants. With regard to water quality, the EIA must:

- Establish baseline levels in coastal waters for salinity, temperature, turbidity, dissolved oxygen, concentration of chemical parameters (PAHs, nutrients, chlorophyll "A", BOD, suspended solids etc.);
- Review data previously collected by the Department of Environment;
- Evaluate the impact of dredged sediment on water quality using water quality parameters selected for establishing the baseline;
- Assess impacts of the proposed project on site water quality, such as the potential influence on any existing shoreline discharges or outfalls.

The assessment is based on a comparison of baseline levels with established criteria and standards from the United States Environmental Protection Agency (USEPA), Environment Canada, Jamaica, and the National Oceanic and Atmospheric Administration (NOAA).

Additional detail may be found in **Appendix E**.

12.1 Assessment Methodology

Sediment sampling was done using a 2" PVC pipe pushed manually into the substrate to a depth of 2m. Due to substrate compaction, the pipe was set at a slight angle to vertical to facilitate manual insertion. The entire sample was recovered and treated as a composite. A sample aliquot of approximately 0.5kg (1.1 lb) was then taken for analysis of the selected heavy metals at each site. Another portion of approximately 0.5kg (wet weight, 1.1 lb) was used for preparation of an elutriate by mixing with water from the sampling site, agitating while aerating, and filtering. The filtrate/elutriate was subsequently analysed for a range of trace metals. Sampling sites are shown at **Figure 12.1**.

Baseline water quality data in George Town Harbour (GTH) was assessed through a review of intermittent data collected by the Department of Environment (DoE) since 2000. Additional samples were collected by the project team at four locations within the anticipated area of impact in June (dry season) and October (wet season). The baseline water quality conditions were assessed in terms of basic parameters (dissolved oxygen, salinity, temperature and turbidity), trace metals and organic compounds.



Figure 12.1 Water quality/sediment sampling sites

12.2 Baseline Conditions

12.2.1 Water Quality

The following points highlight the key results (additional details are included in Appendix E):

- For the dry season sampling, dissolved oxygen (DO) levels were generally better than 98% saturation in the morning, dropping to 97% in the afternoon. For the wet season sampling, there was a bigger deficit, with DO values of 86-90% saturation in the morning, and 90-95% in the afternoon. In general, DO levels were slightly lower at the bottom of the water column. On all occasions, DO levels were better than the USEPA criteria for marine waters.
- Salinity was in the narrow band of 34.7-35.3 ppt for all sampling occasions (wet/dry seasons and morning/afternoon).
- For the dry season sampling, turbidity levels were < 1 to 1 NTU. For the wet season sampling, turbidity levels were < 1 to 4 NTU. Three samples collected in GTH by the DoE during a Nor'Wester in November 2014 (ST7, ST8 and ST9) registered turbidity levels of 14-16 NTU (see **Figure 12.1**). The DoE sites were systematically selected based on their

proximity to TEMN's sampling sites. None of DoE's sites were however close enough to T10 to compare that data.

- For the dry season, the water temperature was 28.8-28.9oC in the morning, and slightly cooler in the afternoon (28.3-29.1oC). For the wet season, the water temperature was 29.3-29.5oC in the morning, and slightly higher in the afternoon (29.6-29.8oC).
- For the dry season, pH was in the range of 7.87-8.03, while for the wet season the range was 8.04-8.16. In both cases, pH levels were slightly higher in the afternoon.
- Average nutrient levels (Nitrates and Phosphorous) for all sites were determined to be 0.004mg/L for nitrates and .023mg/L for phosphorous. Though these nitrate levels were determined to be below the NEPA interim marine ambient standards for coastal waters, reactive phosphate/ortho-phosphate (o-PO4) was higher than the NEPA interim standard. This value for o-PO4 represented an increase in orders of magnitude over levels determined by the Cayman Islands DoE in 2000.
- The trace metals (As, Cr, Cu, Pb, Hg, Ni, Sn, V) were well within USEPA and World Health Organization (WHO) criteria for marine waters. Polychlorinated biphenyls (PCBs) and poly-aromatic hydrocarbons (PAHs) were below the test detection limits (TDL < 0.5 ppb and 0.1 ppb respectively). Total petroleum hydrocarbons (TPH) as petroleum range organics were undetected at a test detection limit of 0.2 mg/L. There are no visible outfalls to the George Town Harbour. Stormwater reaches the marine as a non-point source in the form of over-wash.

Based on the results of this assessment, an expanded turbidity monitoring program was recommended by the study team and approved by the CIG. The program includes the deployment of two turbidity sensors in GTH for a period of four months. The objective of the additional water quality monitoring is to better define elevated turbidity levels that occur in GTH under existing conditions (due to storms and vessel traffic). This information will be used to develop threshold criteria for turbidity, to be included in the Environmental Management Plan for the project. The results of this measurement program will be included as an addendum to this document.

12.2.2 Sediment Quality

Sediment samples obtained from four locations within the proposed development area were analysed for a range of trace metals and organic compounds. The results of the laboratory tests are summarised below:

- Analyses conducted on sediment samples returned trace metals levels that were well within the guideline values and in some cases below the test detection limit.
- Arsenic (As), lead (Pb) and tin (Sn) were below the test detection limits of 0.9mg/kg, 0.1mg/kg and 0.5mg/kg respectively. The test detection limits were comfortably below the guideline values for these parameters (50mg/kg, 47mg/kg and 8mg/kg respectively).

- Chromium was in the range 3.49mg/kg to 5.30mg/kg for all sites sampled. The highest concentration was determined from sediment samples taken at T6 (Cali NW) while the lowest concentration was detected in sediment taken from T10 (Balboa NE). At T3 (Harbour NW), sediment levels of Cr were 4.08mg/kg while at T13 (Harbour S), Cr in sediment was 4.15mg/kg.
- Copper (Cu) concentration was in the range 12-13.5mg/kg for all sediment samples. Copper was highest (13.5mg/kg) for sediment taken from T6 (Cali NW) and lowest in sediment from T3 (Harbour S). For T10 (Balboa NE) and T13 (Harbour S) copper in sediment was 12.7mg/kg and 13.4mg/kg respectively. These levels were an order of magnitude below the Environment Canada guideline value of 160mg/kg.
- Mercury (Hg) was in the range 0.0030-0.006mg/kg. These levels were three orders of magnitude below the Environment Canada guideline value.
- Nickel (Ni) concentrations were in the range 0.63-0.82mg/kg for all sediment samples. These results were well within the NOAA guideline value of 21mg/kg.
- Vanadium (V) concentrations were in the narrow range 3-4mg/kg for all sediment samples. These levels were well below reported background levels. No specific criteria or guideline levels were found for this parameter.
- Total petroleum hydrocarbon (TPH) and polychlorinated biphenyls (PCB's) were not detected in any samples.

12.3 Impact Assessment

12.3.1 Present Impacts

Present water quality is good with all parameters returning values within USEPA limits. There is a concern that the increase in nutrient levels determined by this EIA relative to that determined by DoE in 2014 could indicate a trending up of nutrient levels, particularly phosphate. The levels determined for this study are, however, well within the NEPA interim ambient marine standards for protection of coral reefs; low chlorophyll levels support this.

Despite the evidence of phosphate levels that seem to be trending upwards, these results generally indicate only mild impacts from land-based and marine activity. There is an opportunity at present to address the trending up of phosphorous through the adoption of appropriate policies and regulations.

It is likely that the primary sources of phosphate pollution in the George Town area will be fertilizers used for landscaping, stormwater run-off, and the soaps and detergents used in domestic and commercial applications. Phosphates are often used as either sodium tripolyphosphate (dry detergents) or sodium/potassium phosphates (liquid detergents) (Knud-Hansen, 1994). These phosphates, acting as builders, are capable of tying up calcium, magnesium, iron and manganese ions, thereby improving overall washing performance (Duthie, 1972). The addition of these builders

are particularly necessary in hard water: without builders, manufacturers would have to add more surfactants, which are more expensive. Phosphate detergents are generally safe to use, and are minimally toxic. The major drawback is that secondary wastewater treatment removes only a small percentage of phosphorus from the influent, and a considerable amount of phosphorus is therefore released to the environment. The impact of phosphate on the marine environment and its role in leading to algal blooms (eutrophication) and the associated problems are well established (USEPA, 1971).

12.3.2 Project Impacts

Construction Phase

Based on the levels of trace metals and organics returned by the analyses, sediments to be dredged from the seabed for the proposed CBF are considered clean and suitable for open water disposal and/or disposal on land.

Expected impacts to water quality impacts during construction include:

- High turbidity levels from dredging – This impact will be temporary and short term as turbidity will return to normal after cessation of dredging;
- Possible leaching of copper from dredged sediment - This impact will be short term and temporary for the duration of the disposal of dredged sediment, as leached copper will tend to be precipitated in the sediment in slightly alkaline marine conditions;
- Possible contamination due to minor spills/releases from equipment associated with the dredging and construction – This impact will be short term/temporary as spills will be subjected to weathering and can also be cleaned up;
- Site runoff can be sediment laden in the event of heavy rainfall during construction before completion of hard surfaces - This will be a temporary/short term impact.

Operational Phase

Expected impacts to water quality impacts during operation include:

- Increased risk of pollution from marine sources as the amount of visiting vessels increase. This could lead to:
    - Possible releases of fuel and bilge discharges – This will be a long term impact associated with shipping activities in the harbour;
    - Increased propeller wash from increased marine traffic leading to increased turbidity - This impact will be ongoing/long term.

12.3.3 Climate Change Impacts

The impact of climate change on water quality will be mainly associated with expected temperature rise and increased severity of rainfall events. Anticipated impacts include:

- Increased temperatures leading to reduction in dissolved oxygen levels as saturation level of DO in water is inversely related to temperature. This impact will be long term, as the increase in temperature is inevitable and is a global concern;
- The increased severity of rainfall events is predicted to result in a lowering of salinity levels. This could in fact cause a slight increase in dissolved oxygen as this parameter is more soluble in fresh water; This impact would be temporary and primarily associated with (less frequent) episodes of severe rainfall;
- Increased fresh water input could lead to increased nutrients reaching the marine environment in over-wash and possible drainage from land. This impact would also be associated with episodes of heavy rainfall but residual impacts from nutrients could be significant if levels lead to eutrophication and associated secondary impacts (algal blooms, increased BOD and reduced DO (temporary).

12.4 Mitigation

Increases in turbidity levels associated with dredging can be mitigated through the effective deployment of silt screens. Silt screens (also called silt or turbidity curtains) have been designated a "best management practice (BMP)" by the Corps of Engineers (Francingues and Palermo, 2005). Available information indicates that turbidity levels outside a silt screen are 80-90% lower than levels within the enclosure or up-current of the screen enclosure (JBF Scientific, 1978).

Mitigation of TPH contamination can be achieved by focusing on prevention and abatement. This could be effected by strict adherence to MARPOL and emergency/contingency planning in relation to fuels and other hazardous materials.

Arresting the escalation of phosphate levels in coastal waters is essential to controlling unwanted phenomena such as algal blooms (eutrophication) and associated deleterious effects. Policies and regulations to achieve this may involve a consideration of all, or a combination of, the following:

- Ban the use of phosphate detergents. Such a ban would require time for a framework to be put in place and implemented, and to effectively screen imports to ensure importation of only phosphate-free soaps and detergents;
- Implement a permitting process to selectively allow importation of phosphate-containing detergents. Switzerland, for example, bans phosphates in washing powder, but still allows phosphates in washing-up liquid and dishwasher powder though it sets a limit of 2.5 grams per washing cycle;

- Institute a threshold concentration for phosphate in detergent; and
- Offer incentives/disincentives to discourage the use of phosphate-containing detergents and fertilisers.

Immediate actions to heighten public awareness of this potential problem could revolve around implementing a public education program targeting likely users of phosphate-containing detergents and fertilisers. This would likely engender buy-in to future actions geared at controlling levels of phosphate in the environment due to anthropogenic activity. A more aware public can prompt a greater level of self-regulation, leading to a reduction in demand for phosphate-containing materials, thus enhancing the chances of successful implementation of the relevant policies and regulations.

12.5 RIAM Summary of Anticipated Project Impacts and Proposed Mitigation Measures

As noted in Chapter 1.3.6, the Rapid Impact Assessment Matrix (RIAM) method has been used to "quantify" the anticipated impacts of project construction, operation and mitigation measures. Table 12.1 and Figure 12.2 provide a summary of the RIAM scoring for specific impacts related to sediment and water quality, including scores for each of the following project phases:

- Existing (baseline) conditions
- Dredging and reclamation phase
- Construction (post-dredging) phase
- Operational phase

Proposed mitigation measures for specific impacts are highlighted in the green cells in Table 12.1, with the RIAM method applied both without and with these mitigation measures.

Chapter 1.3.6 provides an overview of the various RIAM scoring criteria (A1, A2, B1, B2 and B3) and the methodology used to derive the Environmental Score (ES) and associated Range Value (RV) for each specific impact. The Range Values are summarized as follows:

- N: Neutral (no change/impact)
- A to E: Positive change/impact (A is slight positive...E is major positive)
- -A to –E: Negative change/impact (-A is slight negative...E is major negative)

Additional information on the RIAM methodology is provided in Appendix Q.

Table 12.1 Detailed RIAM Scoring for Sediment and Water Quality

PHASE	IMPACTS SCORED WITH NO MITIGATION	Spatial Importance (0 to 4)	Magnitude of change/effect (-3 to + 3)	Permanence (1 to 3)	Reversibility (1 to 3)	Cumulative (1 to 3)			IMPACTS SCORED WITH MITIGATION	Spatial Importance (0 to 4)	Magnitude of change/effect (-3 to + 3)	Permanence (1 to 3)	Reversibility (1 to 3)	Cumulative (1 to 3)	*ES with mitigation*	*RV With Mitigation*
		A1	A2	B1	B2	B3	ES	RV		A1	A2	B1	B2	B3	ES	RV
EXISTING CONDITIONS	**Marine**															
	Disolved Oxygen (DO) - Low organic pollution; no algal blooms	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Water Clarity [Suspended Solids/Turbidity (TSS/TUR)] - Good water clarity	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Petroleum Hydrocarbons (TPH) - Below test detection limits	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Toxic Pollutants [Heavy Metals] - Well within USEPA criteria levels	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Organics (PAHs, PCBs) - Below test detection limits	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Nutrients (N/P) - Nitrates and reactive phosphates are both within marine criteria for coral reefs; but reactive phosphates has shown an appreciable increase over the last 14 years	3	-1	2	2	3	-21	-C	Promote reduced phosphate usage through regulation of imports of phosphate containing detergents and fertilizers; Enhanced public education and awareness	3	0	3	3	2	0	N
	Salininty - Typical of ocean water levels	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Stormwater															
	Oil and Grease (O/G) - Water discharged to soak-away pits	3	0	1	1	1	0	N		3	0	1	1	1	0	N
	Flow/Nutrients - to marine waters and salinity reduction	3	0	1	1	1	0	N		3	0	1	1	1	0	N
DREDGING AND RECLAMATION PHASE	**Marine**															
	Disolved Oxygen (DO) - Low organic pollution; no algal blooms	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Reduction in Water Clarity [Suspended Solids/Turbidity (TSS/TUR)]	2	-2	2	2	2	-24	-C		2	-2	2	2	2	-24	-C
	Petroleum Hydrocarbons (TPH) - Below test detection limits	2	-1	2	1	2	-10	-B	Observe MARPOL Convention, Oil Spill Contingency Planning	2	0	1	1	1	0	N
	Toxic Pollutants Heavy Metals: Sediment levels well within USEPA criteria levels However, Possible leaching of copper from dredged sediment;	2	-1	2	2	1	-10	-B		2	-1	2	2	1	-10	-B
	Organics (PAHs, PCBs) - Below test detection limits	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Nutrients (N/P) - Nitrates and reactive phosphates are both within marine criteria for coral reefs; but reactive phosphates has shown an appreciable increase over the last 14 years	3	-1	2	2	3	-21	-C		3	-1	2	2	3	-21	-C
	Salininty - Typical of ocean water levels	3	0	1	1	1	0	N		3	0	1	1	1	0	N
	Stormwater	3	0	1	1	1	0	N		3	0	1	1	1	0	N
	Oil and Grease (O/G) - Water discharged to soak-away pits	3	0	1	1	1	0	N		3	0	1	1	1	0	N
	Flow/Nutrients - to marine waters and salinity reduction	1	0	1	1	1	0	N		1	0	1	1	1	0	N
CONSTRUCTION - POST DREDGING	**Marine**															
	Disolved Oxygen (DO) - Low organic pollution; no algal blooms	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Water Clarity [Suspended Solids/Turbidity (TSS/TUR)] - Good water clarity	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Petroleum Hydrocarbons (TPH) - Below test detection limits	2	0	1	1	1	0	N	Observe MARPOL Convention, Oil Spill Contingency Planning	2	0	1	1	1	0	N
	Toxic Pollutants [Heavy Metals] - Well within USEPA criteria levels	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Organics (PAHs, PCBs) - Below test detection limits	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Nutrients (N/P) - Nitrates and reactive phosphates are both within marine criteria for coral reefs; but reactive phosphates has shown an appreciable increase over the last 14 years	3	-1	2	2	3	-21	-C		3	-1	2	2	3	-21	-C
	Salininty - Typical of ocean water levels	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Stormwater															
	Oil and Grease (O/G) - Storm water pick-up of contaminants from soiled hard surfaces	1	-1	2	2	2	-6	-A	Utilise best practice with respect to servicing and maintenance of vehicles and fuel transfers; Spill contingency planning.	1	0	1	1	1	0	N
	Flow/Nutrients - Increased hard surface leads to increase fresh water runoff; Possible elevated sediment in site run off.	1	-1	2	2	2	-6	-A	Plan construction actuvities to prevent coinciding with rainy season, Use only non phosphate cleaners.	1	0	1	1	1	0	N
OPERATIONAL	**Marine**															
	Disolved Oxygen (DO) - Possible release of untreated bilge could cause temporary elevation in organic pollution;	2	-1	2	2	2	-12	-B	Strict adherence to MARPOL; All vessels to be fitted with oil monitoring equipment for bilge discharge.	2	0	1	1	1	0	N
	Water Clarity [Suspended Solids/Turbidity (TSS/TUR)] - Reduction in water clarity with increased ship traffic	2	-2	2	3	2	-28	-C	Use of tug boats to position vessels	2	-1	2	3	2	-14	-B
	Petroleum Hydrocarbons (TPH) - Increased risk of oil spills	2	-2	2	3	2	-28	-C	Strict adherence to MARPOL; Contingency planning	2	-1	2	3	2	-14	-B
	Toxic Pollutants [Heavy Metals] - Well within USEPA criteria levels	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Organics (PAHs, PCBs) - Below test detection limits	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Nutrients (N/P) - Nitrates and reactive phosphates are both within marine criteria for coral reefs; but reactive phosphates has shown an appreciable increase over the last 14 years	3	-1	2	2	3	-21	-C	Promote reduced phosphate usage through regulation of imports of phosphate containing detergents and fertilizers; Enhanced public education and awareness	3	0	3	3	2	0	N
	Salininty - Typical of ocean water levels	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Stormwater															
	Oil and Grease (O/G) - Storm water pick-up of contaminants from soiled hard surfaces	1	-1	2	2	2	-6	-A	Utilise best practice with respect to servicing and maintenance of vehicles and fuel transfers; Spill contingency planning.	1	0	1	1	1	0	N
	Flow/Nutrients - Increased hard surface leads to increase fresh water runoff; Solid waste in storm water run off.	1	-1	2	2	2	-6	-A	Proper containment of solid waste; Harvesting of storm water run off	1	1	1	1	1	3	A

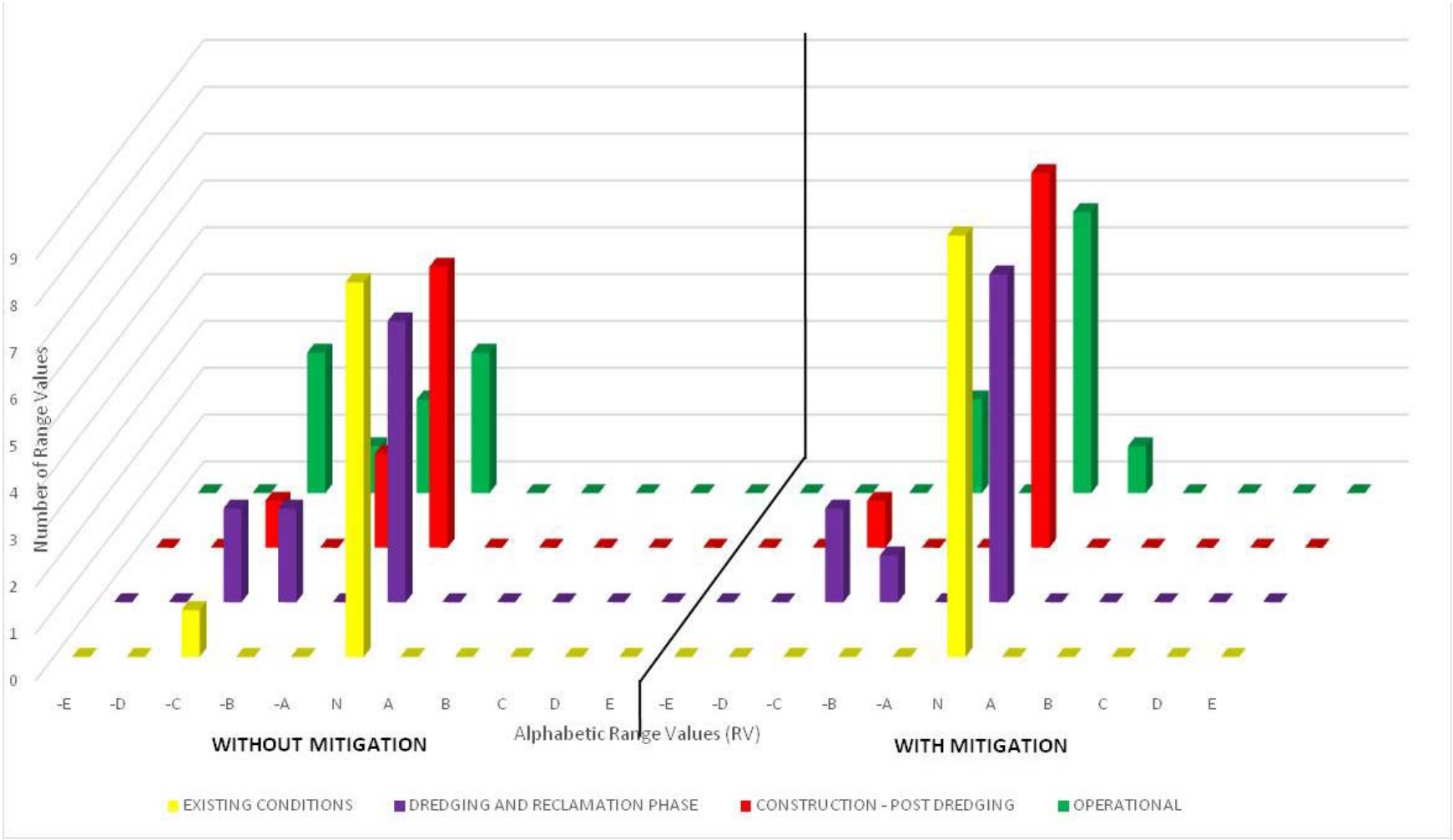


Figure 12.2 Summary RIAM Scoring for Sediment and Water Quality

13.0 TASK F - STORM WATER

13.1 Introduction

The proposed reclamation area will add 7.7 acres of land area to the existing port area. This will essentially double the rainfall catchment area for the port. Work was carried out to develop a drainage master plan for the project that would help to mitigate adverse flooding impacts to the port and surrounding environs. The drainage master plan was developed for the final project layout developed as part of the EIA study.

The drainage master plan for the project site was developed with three key objectives in mind:

1. The reclaimed area should not increase the vulnerability of the rest of the port, or its immediate environs, to flooding. In this case, flooding may come from rainfall or wave overtopping.
2. The use of sink wells, which is a standard practice in Cayman, should be maximized. This would allow typical day-to-day rainfall to be stored and drained into the ground. Such an approach would reduce focused surface flow into the harbour from the proposed drainage channel, thereby reducing possible sustained impacts on the marine environment.
3. The plan should consider potential changes in rainfall intensity or frequency due to climate change.

Additional details may be found in **Appendix F**.

13.1.1 Background Hydrology

The rainy season of the Cayman Islands spans from May to November, with May to June and September to October typically being the wettest months. The dry season spans from December to April. Rainfall is generally from either tropical thunderstorms (usually in the summer months) or localized events resulting from the evaporation of water in the central mangroves of the main island[4].

Flooding from rainfall has not been a major hazard in Grand Cayman. However, some low-lying areas do flood moderately after heavy rainfall events. For example, there were flash floods in August 2012 when there was reportedly 4.5 inches of rainfall over a short period. The total annual rainfall averages 56.4 inches, with October maintaining the highest average of 8.55 inches over a 30-year period (1971-2000). March is the driest month, with an average of around 1.36 inches of rainfall.[5] During the 30-year period from 1983 to 2013, the maximum total daily rainfall for a

[4] Preliminary Vulnerability Assessment of Grand Cayman by NDAC, 2009.
[5] Cayman Islands National Weather Service

particular year ranged from 3 inches in 2007 to 19.4 inches in 2004 (during Hurricane Ivan). The average maximum daily rainfall over this 30-year period was 8.1 inches.

The island is formed largely of limestone outcroppings with little soil. Two types of limestone form most of the surface: bluff limestone, formed about 30 million years ago; and iron shore, a substance created about 120,000 years ago, combining limestone with coral, mollusk shell, and marl.[6] The relatively high porosity of the limestone causes most rain to be quickly absorbed. Rainfall is therefore typically a relatively minor hazard for the island.

A more frequent cause of flooding along the George Town coastline is waves, whether from tropical storms or Nor'westers. Wave overtopping onto the port lands and Harbour Drive occasionally occurs, making this area unusable. The proposed project is not likely to have adverse impacts on this particular issue, as discussed in Chapter 10 and Appendix D. The focus of this chapter is storm water, and the development of a drainage master plan for the project site to address potential flooding from heavy rainfall.

13.1.2 Local Storm Water Guidelines

The CIG Ministry of Planning issued Storm Water Management guidelines for the Cayman Islands, prepared by the National Roads Authority (NRA- Revised June 2006). The following guidelines from this document are of particular relevance to this project:

- The storm water management system should be designed to include storm water runoff produced from a rainfall intensity of 2 inches per hour for one hour of duration upon completion of the project;
- Ensure that surrounding properties that are lower and nearby public roadways are not subject to storm water runoff from the site;
- The drainage master plan (DMP) shall show general drainage direction and finished floor elevations, showing a comprehensive drainage plan for the completed project. The DMP must also contain the following:
    - Pre- and post-development run-off direction arrows
    - Location, type, and size of existing and proposed drainage conveyance systems
    - Existing and proposed runoff flows
    - Location of any on-site or nearby existing drainage channels
    - Existing drainage runoff rates
    - Proposed run-off calculations
    - Sizing calculations for storm water facilities

[6] Alonso-Zarza and Jones, 2007

- Contributing drainage area (on and off-site)
- Storage capacity
- Outlet configuration

13.2 Assessment Methodology

A survey plan of the existing port, as well as a digital elevation model (DEM) for George Town was provided by the CIG (Department of Lands and Surveys). These data were merged with additional topographic survey data collected as part of this study.

The primary objective of the drainage master plan is to ensure the new land reclamation area does not contribute to increased flooding of the existing port area, and a concept drain plan was developed to meet this specific objective. This concept proposes a box-drain along the entire north-to-south length of the proposed new land reclamation area. Discharges are proposed at both ends of the drain into the sea. The drain would slope from its midpoint to the north and to the south discharge points. The drain would capture flow from both the new land reclamation area and the existing port area. Assuming the drain is appropriately sized, the primary objective will be achieved.

Sizing of the drain involved a typical hydrologic and hydraulic analysis, including selecting the design rain fall intensity, delineating an appropriate catchment area, determining run-off over this catchment area and finally determining the adequate drain size to convey the run-off to the discharge points. A conservative approach was adopted with respect to the existing port, with the assumption that none of the run-off from the existing port area would be captured in the existing drains. This approach was adopted, as these drains currently discharge into sink wells; in the event of an intense rainfall, the capacity of the sink wells may not be adequate to alleviate overflow from the existing drains.

The analysis carried out was as follows:

1. Delineate the catchment area for the project site based on contour maps of the project area and George Town.
2. Analyze records of 24-hour rainfall activity for the Cayman Islands measured at several gauge stations to determine the 2, 5, 10, 25, 50 and 100-year events.
3. Derive the one-hour rainfall intensity from appropriate rainfall distribution curves.
4. Carry out a hydraulic run-off analysis using Civil-3D to determine the drain dimensions.
5. Based on the flow rates in the drain, assess water quality impacts to the surrounding marine environment for the new development.

13.3 Baseline Conditions

Figure 13.1 shows the topography of the existing dock area merged with the proposed expansion plan for the project. This survey shows that the existing port lands are around 7-9 ft above mean sea level (MSL). Harbour Drive and the adjoining roadways are at elevations in the order of +10 to +11ft above MSL. The south cargo dock is at approximately + 8 ft above MSL, while the north (Royal Watler) tender pier is at approximately +4 ft above MSL. Considering the existing grades, the port area generally drains towards the sea.



Figure 13.1 Existing site topography and proposed new land reclamation area

The existing storm water drainage at the site consists of two sections of grated box-drains, one 65 ft long and the other 500 ft long, as well as two individual manholes with a number of sink wells. These drains should capture any flow from Harbour Drive onto the port area. The box-drains discharge into sink wells, and are not directly connected to the sea. They are located towards the southern end of the port, directly in front of the access gates and guard house. The existing drains are shown in **Figure 13.2.**



Figure 13.2 Location of existing drains and likely drainage paths

13.4 Impact Assessment

Table 13.1 summarises potential storm water impact and mitigation strategies offered by the proposed drainage master plan. The potential impacts of project development on storm water are discussed in further detail in this section.

Table 13.1 Potential storm water impacts and mitigation offered by drainage master plan

Potential Storm Water Impacts	Mitigation by Drainage Master Plan
Inadequate drainage of the development, leading to flood damage or interruption to operations.	The proposed drain is designed to capture run-off from both the existing and proposed port areas. The drain has a freeboard of 8 inches at peak flow during the 25-year design rainfall event. T his design event is double the NRA's recommended design event.
An increase in storm water discharge, leading to increased flooding of neighbouring properties.	The additional land reclamation area will drain into the proposed box-drain or directly into the sea. Discharge from the drain goes directly into the sea and does not interfere with neighbouring drains.
Damage to existing drainage infrastructure and subsequent flooding of neighbouring properties or infrastructure	The Environmental Management Plan specifies that construction activities should not damage or block existing drainage pathways.
Blockage of existing overland drainage routes or the diversion of additional runoff towards existing properties.	The proposed drain does not interfere with existing drainage routes or pathways.

13.4.1 Project Impacts

The primary potential adverse impact of the proposed development as it relates to storm water is that the new land reclamation area will (nominally) double the surface runoff as compared to the existing port area. The additional area introduces a greater surface area for collection of contaminants that will eventually be washed into the sea. During heavy rainfall events, when the sink wells cannot adequately accommodate the runoff, there will be point flows into the sea at the points of discharge. Any contaminants (grease, oils, mud, etc.) washed from the surface of the port area may be discharged into the sea at outlets on the north and south side of the project.

A grating cover over the drain will prevent large debris from entering the drain. Further, the sink wells are intended to capture the runoff and its contaminants during light showers. The sink wells will also capture contaminants washed off the surface at the start of heavier rainfall events. During heavy showers, after the sink wells exceed their capacity to collect run-off, the drain will discharge to the sea.

The impact on nearshore water quality was estimated using the numerical model MIKE 21 (this model is discussed in more detail in Chapters 10 and 11). The objective of the present modeling exercise was to evaluate the difference between the impacts of storm water run-off on the marine environment for the existing facility and the proposed new facility (including the drain). The fundamental difference between existing and proposed conditions is that while the existing scenario involves mostly surface run-off from the port, the new developed has two focused-point discharges.

Figure 13.3 shows the assumed discharge locations for existing and proposed conditions, as well as four water quality "sample points," two near coral reefs and two near the shorelines to the north and south of the project site. For existing conditions, the 25-year run-off discharge was distributed equally between four points around the existing port area. For proposed conditions, the 25-year run-off discharge was split between the two drain outlet locations on the north and south sides of the project.

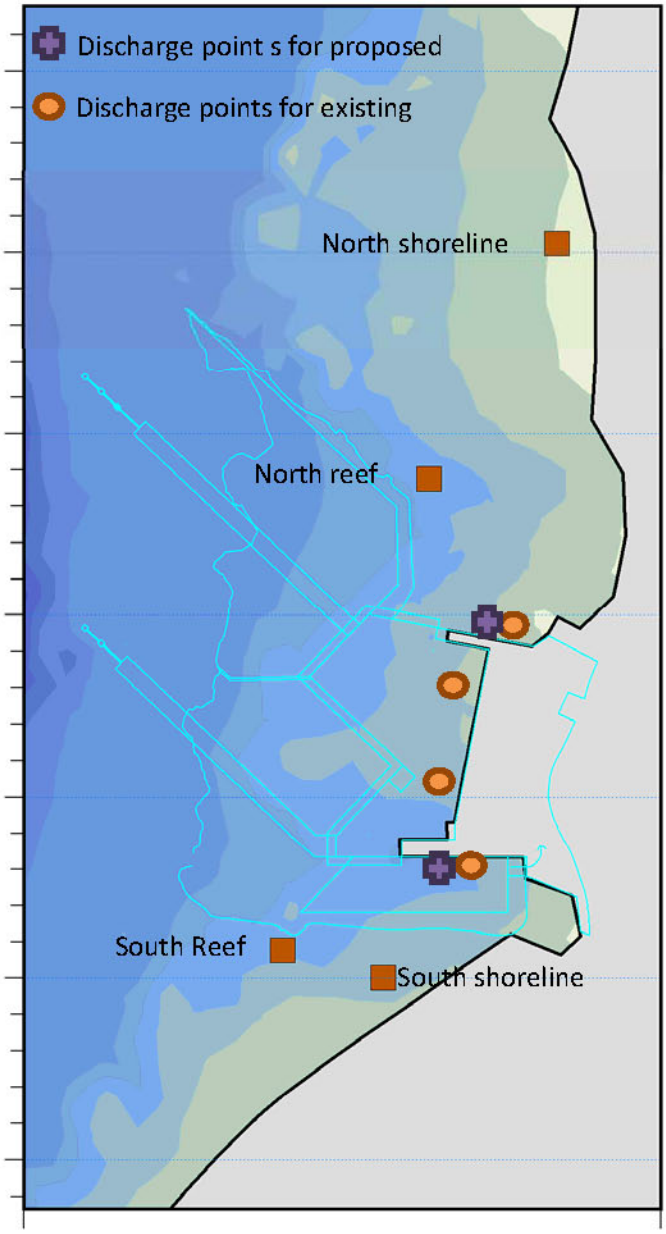


Figure 13.3 MIKE 21 Storm water runoff model discharge and sampling points for existing and proposed conditions

Figure 13.4 compares salinity between existing and proposed conditions (referred to as Option C in the figure) at the four sampling points. Salinity was used as an indicator parameter for several reasons: i)the sink holes are likely to collect initial concentrations of pollutants that are washed into the drains; ii) low sustained salinity can adversely impact corals; iii) fresh water correlates well with temperature changes.

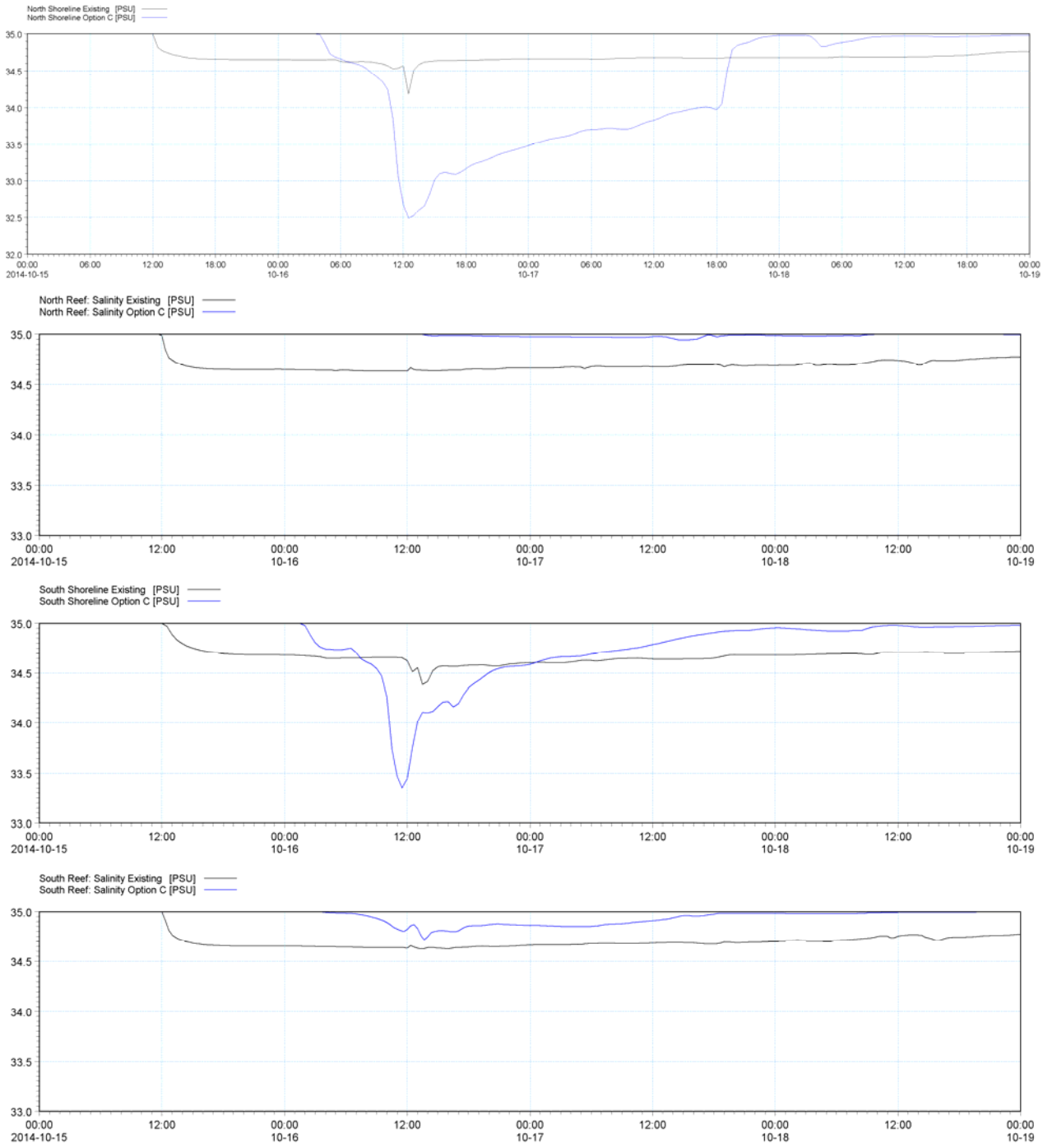


Figure 13.4 Salinity variation at sampling points for existing and proposed conditions (25-year event)

The results indicate that the proposed drainage system will reduce salinity at the sampling points along the shoreline but not at those near the coral reefs. With the focused run-off from the drain outlets at the north and south sides of the project, the freshwater discharge plume extends further along the shoreline than what happens under existing conditions. As a result, there is a 3-6% decrease in salinity at the two nearshore locations, with this decrease occurring over a period of 12-18 hours.

Based on the model results, it is anticipated that during the 25-year rainfall event, the proposed project (including the drainage master plan described herein) will cause 3-6% lower salinity along the shoreline over a period of 12-18 hours as compared to existing conditions. The impact on coral reefs located farther offshore will be less.

13.4.2 Climate Change Impacts

The climate change analysis carried out for this project by the Climate Studies Group of the University of West Indies (refer to Appendix B.1) includes the following summary of historical and current rainfall activity for Grand Cayman:

- Significant year-to-year variability exists in the record due to the influence of phenomenon like the El Nino Southern Oscillation (ENSO).
- The inter-annual signal is the dominant contributor to variability.
- There is a slight upward trend, likely due to an upswing in the decadal signal.
- The trend suggests more intense but slightly fewer rain events.

Regarding the impact of climate change on rainfall, the UWI report notes the following:

- Based on model predictions, there are only small changes in annual rainfall through the 2080s. A drying trend sets in toward the end of the century with up to 11% less total rainfall for the most severe Representative Concentration Pathway (RCP) scenario suggested by the Global Climate Models (GCMs).
- Changes in summer rainfall will be greater than the annual change. The drying trend will set in earlier with up to 3% less rainfall by 2021-2040, 6% less rainfall by 2041-2060, 10% less rainfall by 2061-2080 and 17% less rainfall by 2081-2100.
- Changes in rainfall are consistent with projections for the rest of the Caribbean. There is strong agreement across models that there will be more variability in rainfall activity in the future than variations observed in the historical data.
- The extreme rainfall indices generally suggest more intense but fewer events.

The projected increased intensity of rainfall suggests that the drainage system should be designed to accommodate larger flows. Considering this, the 25-year event is proposed for design. Based on

the analyses undertaken for this study, the 25-year rainfall event has an intensity of 4 inches in 1 hour. This is twice the NRA recommendation of 2 inches of rainfall in one hour.

13.5 Proposed Mitigation Measures

Increased runoff from the new land reclamation area has been mitigated by the development of a concept level storm water drainage master plan for the site. The storm water drainage master plan has been developed to prevent any negative impacts on existing drainage paths/patterns/systems.

Figure 13.5 and **Figure 13.6** present a preliminary site grading/drainage plan and conceptual design details (drain profile and sections) respectively. Key features built into the proposed storm water drainage master plan are as follows:

- The drainage system is proposed to be designed for a 25-year rainfall event. Typically, the 5-year event is used for municipal drainage, while the 50 to 100-year event is used for major storm water channels. For this project, considering the importance of continued operation throughout the cruise (winter) season, and the projected increase in rainfall intensity due to climate change, the 25-year event is recommended for the design of the drainage system. The rainfall intensity of this event is double that recommended for design by the NRA.
- A grated box-drain is proposed along the intersection of the existing port area and the new land reclamation area; the top of this drain will match the elevation of the existing port area.
- Storm water from the existing port area will flow into the new drain. The new land reclamation area be divided by a north-to-south "ridgeline"; storm water from west of this ridgeline will flow west and into the sea, while storm water from east of this ridgeline will flow east and into the drainage channel.
- Vehicular and pedestrian access will be required across the drain; stainless steel grating is recommended.
- The invert of the box-drain will slope to the sea north and south of its midpoint, with discharges at the north and south sides of the project.

The proposed storm water drainage master plan is designed to capture flow from the existing and new land reclamation areas, and will reduce the vulnerability of the existing port area to flooding. To further mitigate possible adverse impacts on nearshore water quality associated with runoff, the following additional measures are recommended:

- Sink wells are recommended within the drain to minimize low flow discharge into the sea. During light showers, the sink wells will be able to capture any flow in the drain, similar to what now happens with the existing drainage system.
- Sink wells are also recommended in the area west of the ridgeline. These sink wells will further reduce the predicted minimal impacts of fresh water on corals in the marine environment.

- The sink wells will collect sediment and pollutants washed off the ground surface in the early stages of a rainfall. Although the ambient water table is relatively high (i.e. sea level), the low flows from light showers are expected to be absorbed quickly given the anticipated permeability of the fill materials in the land reclamation area.
- Sediment traps are proposed at both ends of the drain. These are expected to slow and collect the runoff from light showers to allow sediments and debris to drop out. These traps can be cleaned through routine maintenance programs. Sink wells have also been proposed within these traps to avoid issues with standing water.

In addition, the land side master plan and design development process for the project should include consideration of the following features:

- Provide a wave/flood wall around the exposed perimeter of the land reclamation area (as shown in **Figure 13.5**) to limit site flooding due to wave overtopping during severe storms.
- Where possible, use pervious surface treatments to reduce surface runoff, particularly during light showers. However, the outer perimeter of the new land reclamation area will require a robust hardscape surface treatment to resist damage from severe wave overtopping during storms.

Based on the proposed storm water drainage master plan described above, a hydraulic analysis was carried out to size the drain. The concept plan and key assumptions incorporated in the modeling are summarized below:

- The proposed drain runs north to south along the intersection of the existing port and the proposed new land reclamation area.
- The catchment area for the new drain includes a portion of the new land reclamation area (see next bullet point) and the existing port lands, and extends inland to a location east of Harbour Drive where the land reaches its highest point.
- The new land reclamation area will slope up to a north to south ridgeline. While the final elevations of the new area will be determined later in the design process, reasonable assumptions were made for the purpose of the drainage calculations. Specifically, a +10ft elevation was assumed at the seaward (west) edge of the area, with the land sloping up to the proposed ridgeline at +11 ft. The land then slopes down towards the drain. As such, only the rainfall captured to the east of the ridgeline will flow to the drain. Water captured to the west of the ridge line (due to rainfall or wave overtopping) will flow back to the sea.
- The drain flows in north and south from its mid-point and discharges into the sea.
- The presence/capacity of existing drains in the area were ignored.

With this concept, a run-off analysis was carried out using Civil 3D. The 25-year design rainfall intensity of 4 inches in one hour was modeled. The results show that an open channel drain, 30 inches deep by 36 inches wide, will provide a freeboard of 8 inches at maximum flow (i.e. there will

be 8 inches of excess capacity from the top of water level to the top of the drain). The estimated maximum flow rate in the drain is approximately 50 cubic feet per second.

A preliminary site grading/drainage plan and conceptual drain details are provided in **Figure 13.5** and **Figure 13.6** respectively. Additional features of the concept drainage design are as follows:

- The invert of the drain slopes at a grade of 0.5%;
- 8-inch diameter sink wells are proposed at intervals along the drain to lowest low water level;
- Silt traps are proposed at both ends of the drain. The silt traps have been designed to slow flow and allow sediments to drop out of suspension. Sink wells are also in the silt traps to avoid any post-runoff settlement of water;
- A stainless steel grating is proposed to cover the drain; and
- Intermittent drain crossings, including 30 ft wide vehicle crossing and 8 ft wide walkways.

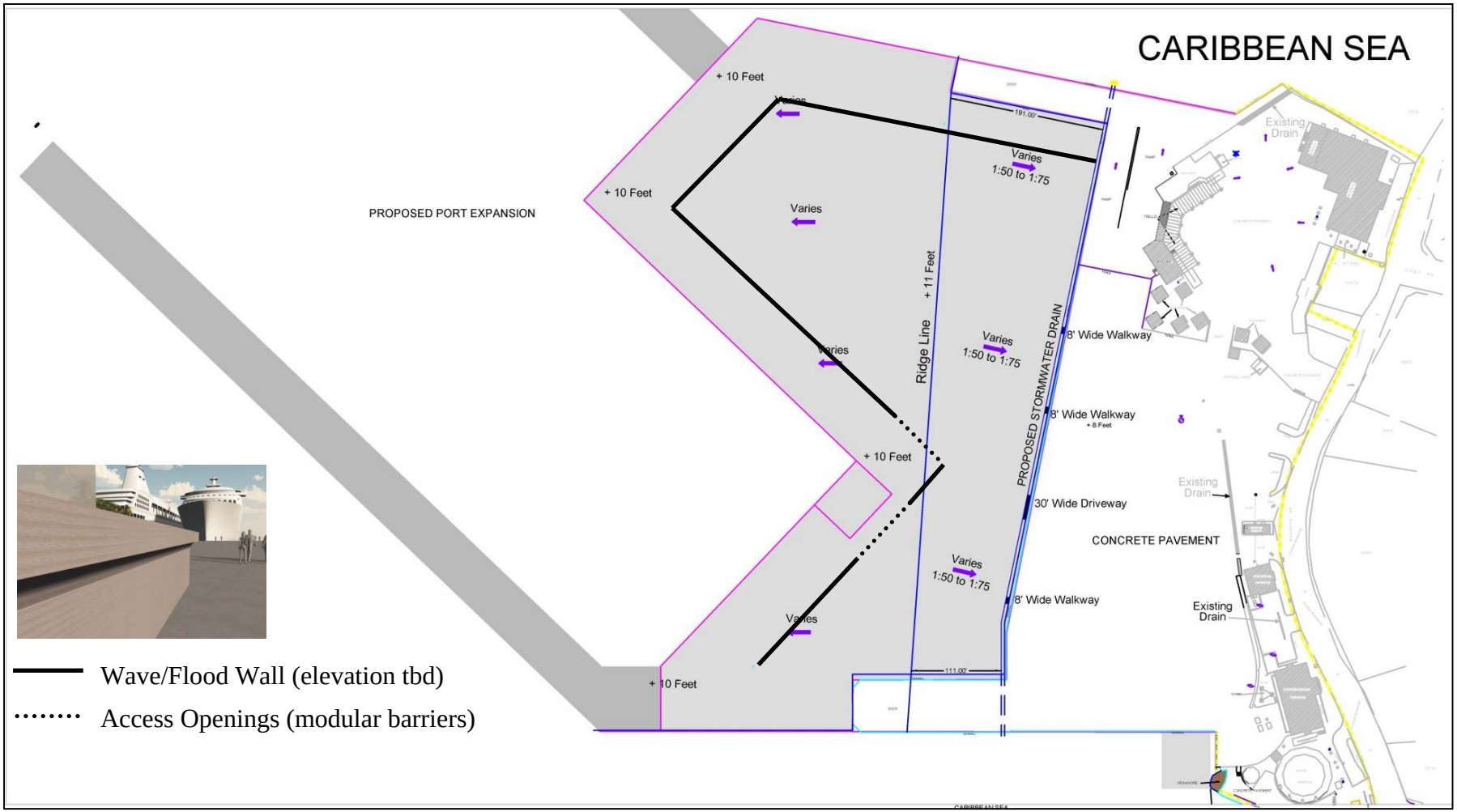


Figure 13.5 Proposed storm water drainage master plan and wave/flood wall

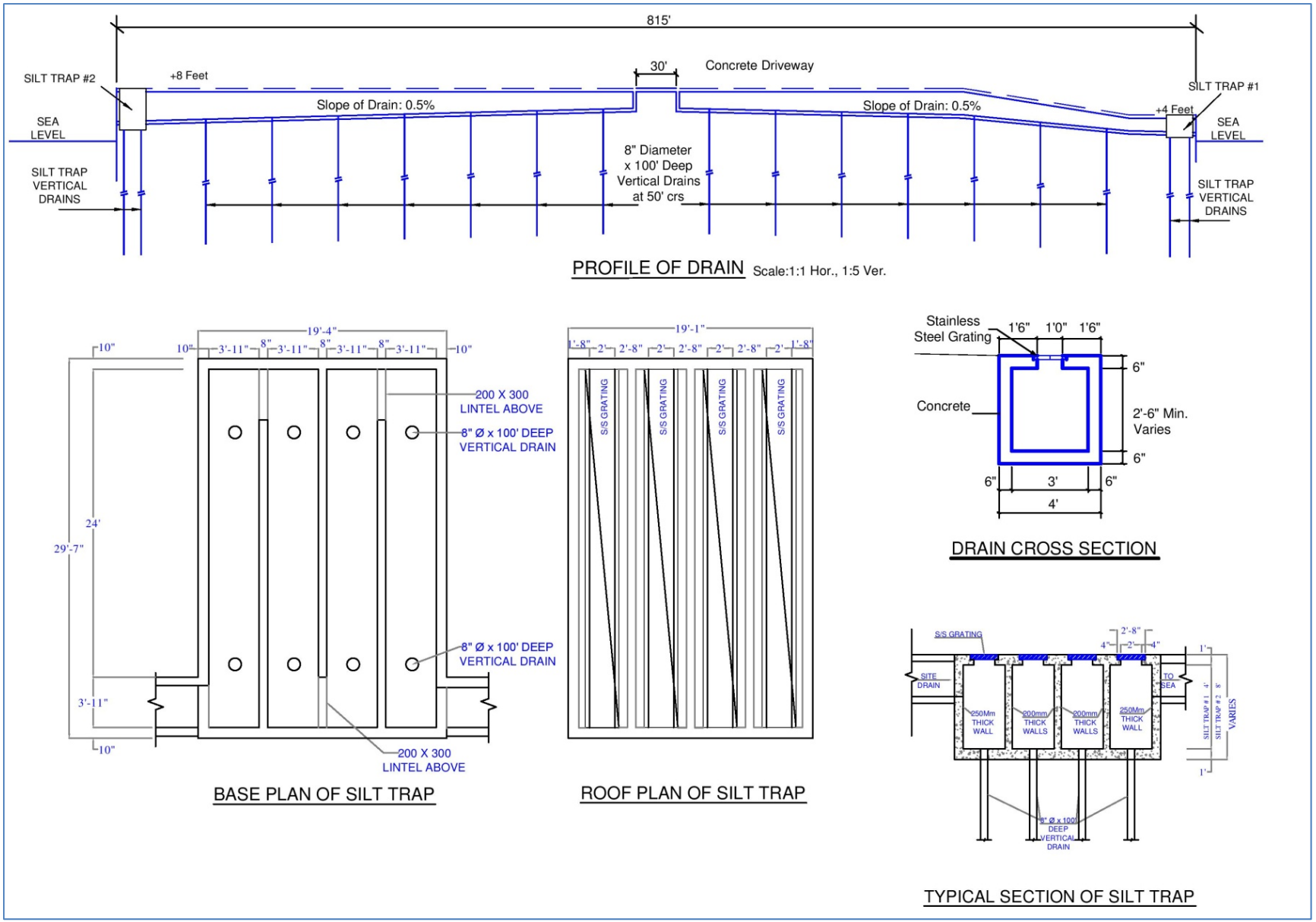


Figure 13.6 Concept design of proposed drain and sediment traps

14.0 TASK G - AIR QUALITY AND GREENHOUSE GAS EMISSIONS

14.1 Introduction

The Terms of Reference (TOR) calls for focus on certain pollutants: nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and the finer size fraction of airborne particles (PM_{10}). The TOR also calls for quantification of Greenhouse Gas emissions (GHGs) focusing on carbon dioxide (CO_2). Together, in this assessment, these four substances are termed compounds of potential concern (COPC).

Specific TOR requirements include the following:

- An assessment of the construction and operation phase for the expanded berthing terminal to determine possible effects of the development on air quality and greenhouse gas emissions;
- Carrying out a three month survey for nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) using passive sampling devices (PSDs);
- Dispersion modeling to quantify impacts at sensitive onshore receptors if the assessment concludes that the project is expected to result in significant air quality effects.

As indicated in the TOR, "The Cayman Islands has not adopted numerical standards for ambient air quality. There are a range of standards applied in countries such as the United Kingdom and the United States. Those that apply to the UK (for England), for NO_2 and SO_2, are presented in **Table 14.1.**

Table 14.1 UK Ambient Air Quality Standards (AAQS)

Pollutant	Averaging Period	Concentration (µg/m³)
Nitrogen Dioxide (NO_2)	1-hour	200
	Annual	40
Sulfur Dioxide (SO_2)	15 minute	266
	1-hour	350
	24-hour	125

14.2 Assessment Methodology

An assessment of the operation phase for the expanded berthing terminal was conducted as the initial phase to determine possible effects of the development on air quality and greenhouse gas emissions during construction and operation of the development. For air emission assessment purposes, sources have been divided into three groupings of relevance to this EIA:

- Development construction-related sources: cargo ships, dredgers, on-land construction equipment and construction-site dust emissions.
- Marine sources – (i) ocean-going vessels, consisting largely of cruise ships and cargo ships, and, (ii) harbour craft, consisting of tender craft, pilot boats, pleasure craft, etc. Cargo vessel traffic will also contribute to emissions but is not included in this assessment.
- Land sources – On-road vehicular emissions consisting of road dust and vehicle exhaust emissions from trucks, buses, taxis, etc.

This initial assessment involved a review of the expected change in nature, and location of emissions of NO_2, SO_2, PM_{10} and CO_2 from shipping activities, as well as on-road sources, as a result of the proposed changes to the berthing terminal. The emissions due to the proposed changes at the berthing terminal were compared with a baseline scenario that assumed no expansion of the berthing terminal. Following this review, recommendations are made as to the need for dispersion modelling to assess whether or not the changes are likely to cause significant air quality effects at coastal sensitive receptors (residences, hospitals, hotels, etc.).

14.2.1 Meteorology

Meteorological data was collected from the National Climatic Data Center (NCDC) Integrated Surface Database (ISD) for Owen Roberts International Airport. Data was collected for the five year time period leading up to the start of the air quality assessment (June 20, 2009 to June 19, 2014).

14.2.2 Air Quality

A three month survey for nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) was carried out using Ogawa passive sampling devices (PSDs) as called for in the TOR. The objective of the air monitoring program was to determine an initial indication of background (baseline) levels of target contaminants. The sampling period for each set of PSDs encompassed a two week period, and therefore included weekends. Therefore, the sampling period would account for all periods of activity for a typical week and resultant emission variability.

The Ontario (Canada) Ministry of the Environment (MOE) document entitled "Operations Manual for Air Quality Monitoring in Ontario" (March 2008, PIBS 6687e) provides guidance on how to deal with the analysis of non-continuous data when values are less than the analytical method detection limits (MDLs). MDL is the smallest measurable amount, above which the risk of a false positive is 1%, or above which the confidence level is 99%. According to this MOE document, "for the purposes of performing statistical analyses (e.g., means, etc.) and in keeping with a commonly accepted practice, a value of half the MDL must be substituted for concentrations less than the MDL". This methodology was adopted for estimating background values using the measurements taken during the 2014 field campaign when samples were below the MDL.

The Ontario Ministry of the Environment also provides guidance on converting between averaging periods in their guidance document entitled "Procedure for Preparing an Emission Summary and Dispersion Modelling Report", dated March 2009 (ESDM Procedure Document).Using this guidance, the two week samples can be converted to the averaging times of the air quality standards listed in **Table 14.1**.

14.2.3 Sampling Locations

Seven sites were established within a 1.25 mile radius of the Royal Watler Cruise Terminal, with an eighth site at the Terminal, to capture representative background based on current land-use and taking into consideration features of the local terrain and prevailing winds. Sites were chosen based on accessibility, security reasons (e.g. 24-hr security to prevent vandalism of sample collectors), and proximity to sensitive receptors (e.g. Site ID 2 and 4). The location of the sites also ensured an almost complete coverage of all dominant wind directions. In general, samplers were placed within 50 ft of a driveway/road in order to capture one of the main sources of pollution (automotive traffic) in the project area. The monitoring site locations are shown in **Figure 14.1**. Note that one site (Bolas Engineering offices) was sampled in duplicate for quality assurance.

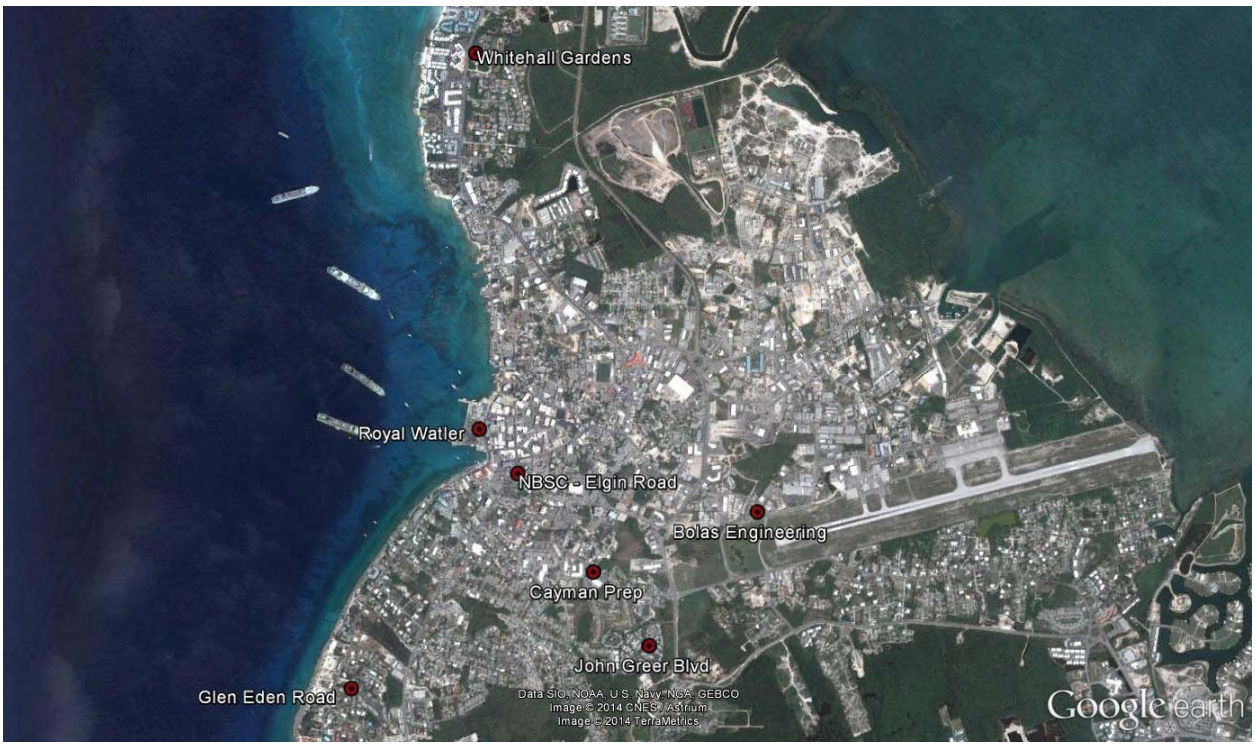


Figure 14.1- Air Quality Sampling Locations

14.2.4 Shipping Impacts

To calculate emissions from each vessel, information is required on engine configuration and ship activities while in the domain of interest. For the purposes of this comparative study emissions will be estimated based on an operating scenario developed by the EIA team in consultation with the

CIG. A common 24-hour basis is chosen for all COPC, as this is a common time period for cruise liner calls at Georgetown. In general, an EIA typically requires that impact assessments be conducted on a worst-case basis. However, for this study, the EIA team and CIG agreed to complete the air quality assessment based on a "typical busy day".

The two classes of marine vessels that will be most affected by the development are cruise ships and harbour craft, as discussed below.

14.2.4.1 Cruise Ships

Under the No Development scenario (as at present), that we were asked to analyze, four cruise ships anchor at designated anchors points (numbered 1 – 4) which are aligned N-S approximately 650 m NW of the current docks. Occasionally, up to three additional cruise ships have remained "on-engine offshore", located approximately 1500 m NW of the current docks, over a day (based on historical data supplied by PACI). However, these vessels were not included in this analysis.

Figure 14.2 provides an exampleof cruise ships moored at the offshore anchorages.

Under the Development scenario provided to us, all four ships will move dockside, and therefore operate closer to on-shore sensitive receptors. Two offshore anchor points will be eliminated; therefore, two additional ships will be accommodated at those anchor points. Therefore the total number of cruise ships present will increase to six under the provided development scenario.



Figure 14.2 - Cruise Ships Anchored off George Town (Source: Google Earth, Mar. 10, 2014)

The *Carnival Dream* (a *Dream* Class vessel) was provided as representative of all four ships under the No Development scenario and four of the six ships under the Development scenario. The Carnival Dream possesses engines totaling 75,600 kW maximum power. The *Allure of the Seas* (an *Oasis* class vessel, the largest in existence) was provided as representing the remaining two of the six ships under the Development scenario. The Allure of the Seas possesses engines totaling 97,020 kW maximum power. No information was available on whether these engines were main or auxiliary engines; hence, they were assumed all main. Emission factors for COPC were referenced from US EPA (2009) "Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories" based on the assumed use of RO fuel and the assumption that engines were medium speed (130 – 1,400 RPM).

The total ocean-side domain boundary extends a radius of approximately 30 miles from George Town. It is assumed that any onboard garbage incinerators do not operate within the domain. Ship activities while in the domain were based upon assumed time-in-mode estimates; while in the domain each ship was assumed to spend 1.5 hours at full cruise speed, 1.5 hours in RSZ mode, 1 hour maneuvering and eight hours hoteling. As shore power is currently not provided, and not envisaged as part of the development, no "cold ironing" (ship powered from shore) is assumed. Thus, a total of 12 hours of ship/engine activity was assumed while each ship was in the domain, per 24 hour period; no overnighting of cruise ships was assumed.

14.2.4.2 Harbour Craft

There are a variety of different harbour craft that currently frequent George Town Harbour including tenders, dive boats, and private recreational boats. Of specific interest are the CMS tender fleet which consist of 16 vessels and are expected to be impacted significantly by the proposed berthing facility. The US EPA (2009) Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories were used to prepare an estimate of the emissions associated with the tender operation under both existing and possible future scenarios.

The CMS tender fleet consists of 12 large tenders and 4 smaller tenders. We have assumed a large tender has engines totaling 800HP while small tenders are 400HP and they operate eight hours a day with emission factors obtained from EPA (2009). During operations it was assumed they spend 30% of their time in-transit (under 90% power), and 70% of their time loading/unloading (under 20% power) to give a weighted average load factor of 41%.

Under the No Development scenario, four *Dream* Class vessels are anchored offshore and all require tender services. All 16 tenders are assumed to be in operation on this day.

Under the future Development scenario, any days with four or fewer cruise ships in port (this currently occurs over 90% of the time), there will be no emission associated with tendering as the ships are expected to use the berthing facility. This represents a 100% decrease in tender emissions over 90% of the year.

We have also considered a scenario with six ships calling in Cayman where two *Dream* Class vessels are anchored offshore and require tender services, while two *Dream* and two *Oasis* class vessels are berthed at the piers. Under this scenario, ten large tenders were assumed to be in operation. The assumption of ten tenders for two ships was based upon CMS records indicating that when Carnival's *Magic* (*Dream* Class vessel) and Royal Caribbean's *Freedom of the Seas* (comparable to *Dream* Class) were in port, there were five tenders deployed for each ship. This estimate is conservative, as it is unlikely there will be ten large tenders available if the proposed berthing facility is constructed.

14.2.5 Road Dust Emissions

The US EPA AP-42 Chapter 13.2.1 for Paved Roads[7] was used to determine dust emissions in the PM_{10} size fraction. The required input information for road surface silt loading and the average weight of vehicles travelling the road were assumed for this assessment. The assumption for silt was the maximum ubiquitous baseline default value from AP-42, which is $0.6 g/m^2$. In order to determine an average weight of vehicles travelling the road, the vehicle km travelled in the onshore domain was used to determine an approximate weighted average, based on the assumed vehicle fleet. The vehicle fleet is estimated to consist of 2-wheeled and 3-wheeled vehicles, passenger vehicles, taxis, buses and trucks.

14.2.6 Tail-Pipe Emissions

In order to determine traffic vehicular exhaust emissions of NO_2, SO_2, CO_2, and PM_{10}, the International Vehicle Emissions model (IVE model) was used.[8] The IVE model was designed to provide flexibility in emission modelling for countries outside of the USA and Europe, who have their own emission projection models. The vehicular technologies outside of the USA and Europe may differ significantly from those jurisdictions and the IVE model helps to account for those differences. The IVE model domain used for this study is shown in

Figure 14.3.

[7]US EPA. AP 42, Fifth Edition, Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, January 2011. http://www.epa.gov/ttnchie1/ap42/

[8]IVE Team. (published 2008, May). IVE Model Users Manual Version 2.0.International Vehicle Emissions Model.Retrieved September 10, 2013, from http://www.issrc.org/ive/.



Figure 14.3 - Area Used to Simulate Vehicular Traffic Emissions

In order to determine emission estimates, IVE requires input information on driving behavior (e.g. amount of driving, driving patterns, and air conditioning use) and environmental conditions (e.g. altitude, temperature and relative humidity) for a specific area. Additionally, information on maintenance programs in force, the number of vehicle starts in an area (vehicle "start-ups") and the distribution of engine resting times is required. Information on fuel quality, type, contaminants and additives added to the fuel are also required as inputs to the IVE model. Estimates for these data inputs were made based on information provided by TEMN, IVE model guidance and default data available within the IVE model.

For the emission estimates with the development in place, it was assumed that only the taxi fleet and bus fleet would be affected as these two vehicle types would increase if passenger numbers arriving to the terminal station increases. The affect was an assumed increase by 10% in vehicle activity for these two classes of vehicles. This assumed increase was based on information from

other Caribbean jurisdictions that experienced port facility upgrades and witnessed an approximate 10% increase in cruise ship passenger arrivals following those facility upgrades.[9]

14.3 Baseline Conditions

14.3.1 Meteorology

Analysis of the five year meteorological data set indicated that the predominant winds in the Cayman Islands are easterlies, with components ranging from south easterly to northeasterly (see wind rose in **Figure 14.4**). Calm winds are considered winds below 0.5 m/s, which is the lowest measureable threshold at Owen Roberts International Airport, and represent periods of calm; these occurred 0.18% of the time over the five year period considered.

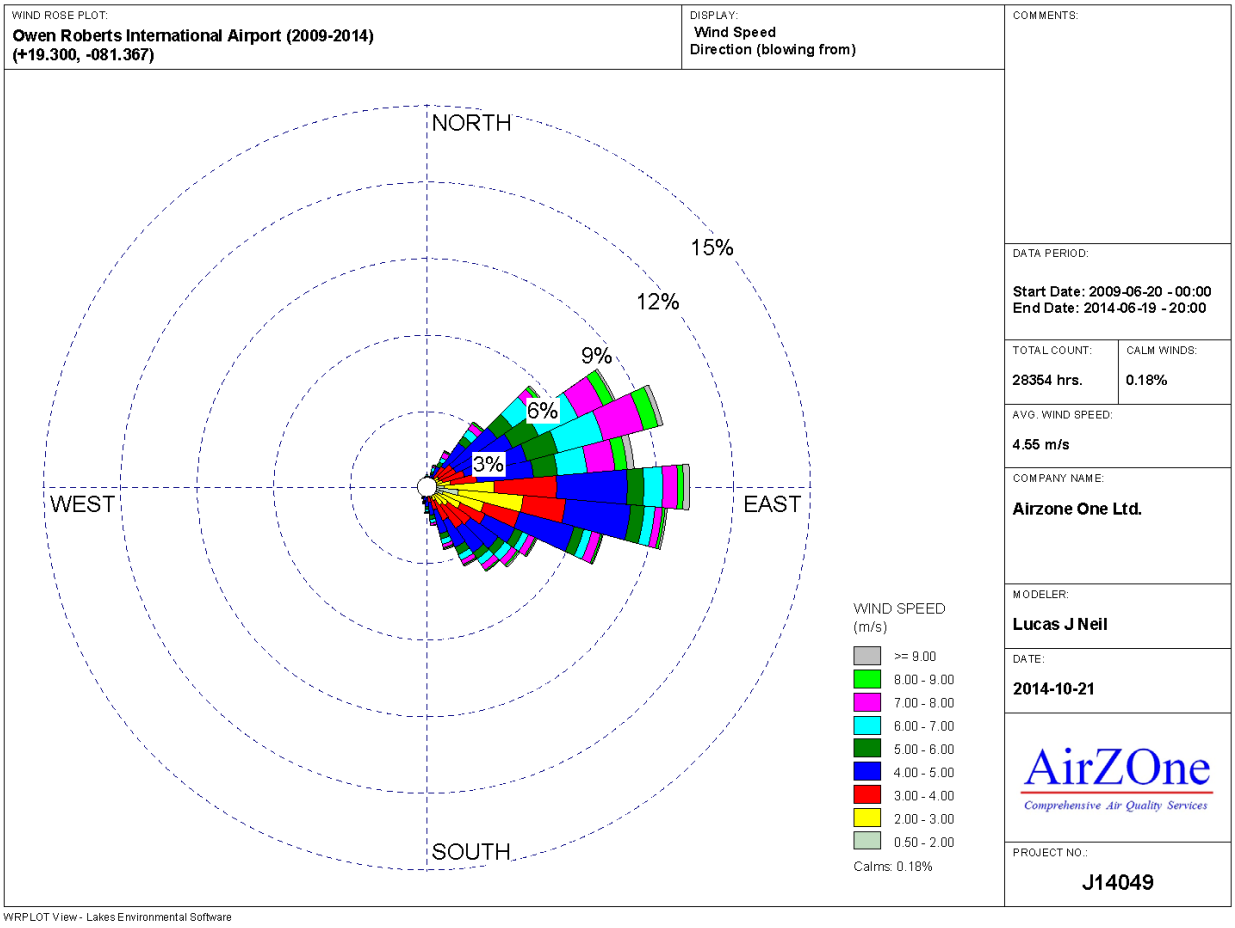


Figure 14.4 - Cayman Island Wind Rose
(Owen Roberts International Airport, 2009 – 2014)

[9] http://www.onecaribbean.org/statistics/latest-tourism-statistics-tables/, http://www.onecaribbean.org/wp-content/uploads/Lattab2011UpdatedApril2013.pdf

Table 14.2 provides a summary of relevant meteorological parameters for all sampling periods Note that parameters provided in **Table 14.2** are measured at Owen Roberts International Airport, which is approximately 1.5 miles to east of the project site and the monitoring locations.

Table 14.2 Meteorological Parameters for Sampling Period

Start Date	End Date	Temperature (°C)			24 hr Precipitation (mm)		Wind Speed (m/s)	
		Min	Max	Avg	Max	Avg	Max	Avg
20-Jun-14	04-Jul-14	25.0	32.2	29.4	0.00	0.00	6.71	3.34
04-Jul-14	18-Jul-14	26.1	32.2	30.0	0.51	0.08	7.15	3.58
18-Jul-14	01-Aug-14	26.1	32.8	30.4	0.25	0.02	7.15	3.22
01-Aug-14	15-Aug-14	25.0	32.8	29.6	7.11	0.90	6.26	2.60
15-Aug-14	01-Sep-14	25.0	32.8	30.1	6.10	0.78	8.05	3.81
01-Sep-14	16-Sep-14	25.0	32.2	29.2	22.1	3.44	11.2	4.37

14.3.2 Nitrogen Dioxide

A summary of the NO_2 results for the entire sampling campaign for each site is summarized in **Table 14.3** based on six 2-week samples. The detection limit for two week NO_2 samples is 0.30 µg/m3. From the table, it is clear that the Whitehall sampling location experienced lowerNO_2 values than all other sites. It is also evident from the table that the other seven sites experienced similar levels of NO_2 during the sampling campaign. These results most likely reflect the fact that Sites 2 through 8 are located within 2km of each other, while Site 1 is located 2 km north of the other sampling sites (see **Figure 14.1**). Based on local meteorology, Sites 2 through 8 are likely influenced by the same upwind sources. Site 1, however, is further north and would appear to be subject to different wind sources. Site 1 is just off the main road in a residential area and is on the grounds (front yard) of a residence adjacent to an empty lot that borders the main road. This would suggest that Site 1 may be less influenced by the direct emissions of NO_2 from the main road than the other sites, which are more closely located to traffic emission sources.

Table 14.3 Summary of NO_2 Results

Site No.	Location	NO_2 (µg/m3)		
		Min	Max	Avg
1	Whitehall	4.3	10	6.0
2	NBSC – Elgin Road	12	20	16
3	Royal Watler	16	24	20
4	Cayman Prep	12	19	16
6i	Bolas Eng 1	1.3	35	17
6ii	Bolas Eng 2	11	22	17
7	Glen Eden Road	6.8	26	12
8	John Greer Blvd	6.3	22	10

14.3.3 Sulfur Dioxide

A summary of the SO_2 results for the entire sampling campaign for each site is provided in **Table 14.4** based on six 2-week samples. The detection limit for two week SO_2 samples is 0.67 µg/m3 ("BDL" indicates sample values were below detection limit). From the table, it is clear that the Whitehall sampling location experienced higher SO_2 values than all other sites. It is also evident from the table that the other seven sites experienced similar levels of SO_2 during the sampling campaign. These results reflect the findings for NO_2 and reinforce the conclusion that Site 1 is influence by different sources than Sites 2 through 8.

Table 14.4 Summary of SO_2 Results

Site No.	Location	SO_2 (µg/m3)		
		Min	Max	Avg
1	Whitehall	2.2	4.0	3.1
2	NBSC – Elgin Road	BDL	1.5	0.73
3	Royal Watler	BDL	1.3	0.86
4	Cayman Prep	BDL	1.0	0.62
6i	Bolas Eng 1	BDL	0.90	0.51
6ii	Bolas Eng 2	BDL	1.3	0.76
7	Glen Eden Road	BDL	0.96	0.59

14.3.4 Comparison to Ambient Air Quality Standards

Using the ESDM Procedure Document conversion equations, the two week samples are converted to the averaging times of the air quality standards listed in **Table 14.1**. The results of the conversions are presented in **Table 14.5** and **Table 14.6**. The results suggest that the UK Ambient Air Quality Standards were not exceeded for both NO_2 and SO_2 during the sampling period. These results, however, are not absolutely conclusive as the levels for the shorter averaging times are estimates based on the measurements.

Table 14.5 NO_2 Results Converted to Air Quality Standard Averaging Times

Site No.	Location	NO_2 (µg/m³)			
		1-hour		Annual	
		Max	Avg	Max	Avg
UK AAQS		*200*		*40*	
1	Whitehall	50	30	3.9	2.4
2	NBSC – Elgin Road	104	82	8.2	6.5
3	Royal Watler	123	100	10	7.9
4	Cayman Prep	94	82	7.4	6.5
6i	Bolas Eng. 1	179	86	14	6.8
6ii	Bolas Eng. 2	113	86	8.9	6.7
7	Glen Eden Road	132	61	10	4.8
8	John Greer Blvd	113	53	8.9	4.2
MAX Value		***179***	***100***	***14***	***7.9***
% of UK AAQS		***89.5***	***50.0***	***35.0***	***19.8***

Table 14.6 SO_2 Results Converted to Air Quality Standard Averaging Times

Site No.	Location	SO_2 (µg/m³)					
		15 minute		1-hour		24-hour	
		Max	Avg	Max	Avg	Max	Aav
UK AAQS		*266*		*350*		*125*	
1	Whitehall	37	29	21	16	8.5	6.6
2	NBSC – Elgin Road	13	6.7	7.4	3.7	3.1	1.5
3	Royal Watler	12	7.9	6.8	4.4	2.8	1.8
4	Cayman Prep	9.5	5.7	5.3	3.2	2.2	1.3
6i	Bolas Eng. 1	8.2	4.6	4.6	2.6	1.9	1.1
6ii	Bolas Eng. 2	12	6.9	6.6	3.9	2.7	1.6
7	Glen Eden Road	8.7	5.4	4.9	3.0	2.0	1.2
8	John Greer Blvd	13	8.4	7.2	4.7	3.0	1.9
MAX Value		***37***	***29***	***21***	***16***	***8.5***	***6.6***
% of UK AAQS		***13.9***	***10.9***	***6.0***	***4.6***	***6.8***	***5.3***

14.4 Initial Emissions Assessment

The wind-rose plot presented in Figure 14.4 indicates that most emissions from the project site will be carried out to sea. However, this does not mean that there may not be significant impacts on local, on-shore, air quality caused by the development. It can be noted from the plot that there is a north-south element to the wind, which, when combined with the shape of the coastline at the harbour location, and increased emissions from both harbour and on-road activity due to the development, may cause local impacts in air quality on the timescales of the AAQS.

14.4.1 Changes in Air Emissions

14.4.1.1 No Development Scenario

Based on the assumption of four *Dream* Class cruise ships within the domain over 24 hours, as described above, emissions are estimated as follows: 7,881 kg NO_2, 7,906 kg SO_2, 1,098 kg PM_{10} and 474,784 kg CO_2 within a 24 hour period.

Under the No Development scenario, four *Dream* Class vessels are anchored offshore, and all require tender services. All 16 tenders are assumed to be in operation on this day. Emissions are estimated as follows: 276 kg NO_2, 36 kg SO_2, 8 kg PM_{10} and 19,011 kg CO_2 for the defined 24 hour period.

The combined results from the IVE model and paved roads assessment for each of the criteria air contaminants estimates emissions as follows: 23.3 kg NO_2, 4.03 kg SO_2, 366 kg PM_{10} and 23,873 kg CO_2 for the defined 24 hour period.

14.4.1.2 Development Scenario

Based on the assumption of two *Oasis* Class and four *Dream* class ships in the domain over 24 hours, as described above, emissions would increase to: 12,937 kg NO_2, 12,979 kg SO_2, 1,803 kg PM_{10} and 779,437 kg CO_2 within a 24 hour period.

Under the Development scenario, with six ships calling in Cayman, it is assumed that two *Dream* and two *Oasis* class vessels are berthed at the piers, while two *Dream* Class vessels are anchored offshore and require tender service. Under this scenario, ten large tenders were assumed to be in operation, and emissions were estimated to decrease to: 197 kg NO_2, 26 kg SO_2, 6 kg PM_{10} and 13,579 kg CO_2.

The combined results from the IVE model and paved roads assessment for each of the criteria air contaminants estimates emissions as follows: 24.6 kg NO_2, 4.22 kg SO_2, 384 kg PM_{10} and 25,069 kg CO_2 within a 24 hour period.

Table 14.7 Summary of Possible Emission Impacts

Parameter (kg/24 hr)	Source	No Development (4 Cruise Ships)	Development (6 Cruise Ships)	Relative Change
NO_2	Cruise Ships	7,881	12,937	64%
	Tenders	276	197	-29%
	Vehicles	23.3	24.6	5.6%
PM_{10}	Cruise Ships	1,098	1,803	64%
	Tenders	8	6	-29%
	Vehicles	366	384	4.9%
SO_2	Cruise Ships	7,906	12,979	64%
	Tenders	36	26	-29%
	Vehicles	4.03	4.22	4.7%
CO_2	Cruise Ships	474,784	779,437	64%
	Tenders	19,011	13,579	-29%
	Vehicles	23,873	25,069	5.0%

14.4.2 Overall Development Air Emission Changes

Under the existing and future development scenarios considered above, air emissions of COPCs from cruise ships are estimated to increase by approximately 64%, those from tenders are estimated to decrease by approximately 29%, and those from on-road vehicles are estimated increase by 5%.

In addition, but more importantly, offshore sources will change their general location to come closer to sensitive receptors onshore. The increased traffic along roadways may also increase exposure at sensitive receptors, as pollutant levels may be enhanced in street canyons.

The estimated cruise ship emissions are one to three orders of magnitude greater than the tender or vehicle traffic emissions. Hence, the anticipated decrease in tender emissions is not expected to significantly offset the increase in emissions from cruise vessels.

Furthermore, the assessment conducted here is not a worst-case scenario, as it does not account for the maximum number of vessels, and potentially the largest vessels, that can be accommodated by the existing and proposed facilities. An EIA typically requires impact assessments to be conducted on a worst-case basis. It is recommended that a worst-case scenario assessment be conducted for comparison with the "typical busy day" assessment conducted in this report.

14.4.3 Greenhouse Gas Emissions

The latest data on GHG emissions from the Cayman Islands was published in 2013 and covers emissions from 1990 to 2011 as part of the UK's reporting under the Kyoto Protocol. In 2011, the emissions accounted towards domestic transport were 0.18 $MtCO_2$. The results in Section 4.6.2 (on-road traffic emissions) can be converted to annual values of 0.0087 $MtCO_2$ for the No Development

scenario and a value of 0.0092 $MtCO_2$ for the Development scenario. This results in an increase of 0.28% over all transportation emissions.

The assessment of marine fleet activities suggests an increase of 64% in CO_2 emissions from cruise ships and a decrease of 29% in CO_2 emissions from harbour craft. As a result, this could significantly change the attributable CO_2 emissions for international travel, which already account for 13% of GHG emissions in the Cayman Islands.

However, there are a number of uncertainties in the emission estimates. Therefore, we recommend the collection of site-specific vessel and on-road data from Georgetown to provide a more accurate estimate of the impact on GHG emissions.

14.4.4 Recommendations

For estimating marine vessel emissions survey/data collection systems or time-limited surveys should be conducted to track and record vessel activity and characteristic data. This will allow emissions to be estimated on a more accurate, Georgetown-specific basis, especially for harbour craft. In tandem with this effort, more detailed ship-specific emission data should be collected (if available) from ship owners/operators to determine if the generic Entec emission factors are accurate for representative ships.

While it was not available at the time of writing, the on-road assessment should include a more accurate assessment of road emissions based on the results of the Traffic Impact Assessment.

COPC should include additional contaminants including very fine particulate matter ($PM_{2.5}$), carbon monoxide (CO), and hazardous air pollutants such as volatile organic compound (VOC) species and diesel particulate matter. These substances are common port emissions and have known health concerns (US EPA 2009) separate from the COPC assessed in this report.

Based on the significant increase in the emissions of COPCs predicted by this review, dispersion modelling is strongly recommended to predict levels at specific sensitive receptors. Information from the modelling will serve as a basis for the formulation of policy and strategies for effective management of ambient air quality.

As previously noted, there is a north-south element to the local wind, which, when combined with the shape of the coastline at the harbor location and increased emissions from both harbor and on-road activity, may cause local impacts in air quality on the timescales of the AAQS. The emission estimates provided describe emissions released at source into the entire domain; the effect on air quality at particular sensitive receptors can only be determined by dispersion modelling of all relevant emission sources, as an additional analysis step. Therefore, dispersion modelling is recommended along with expanded emissions estimations.

To support the recommended dispersion modeling, the emission inventory should be extended to all sources with common contaminants to allow an accurate estimate of changes in air quality levels due to the proposed development. This may include additional marine sources, such as cargo ships, but also additional land-based sources such as cargo handling equipment, on-road shipping trucks, etc. The emissions inventory should account for varying time basis according to the varying averaging period of each air quality guideline (ref. Table 3.4 in TOR).

Ultimately, a health/ecological risk assessment may also be required if dispersion modelling indicates that air quality guideline values are approached or breached.

14.5 Proposed Mitigation Measures

14.5.1 Construction Phase

In 2006 the Greater London (UK) Authority (GLA) with the London Councils produced "The Control of Dust and Emissions from Construction and Demolition: Best Practice Guidance" ("GLA Guidance Document"). This guidance document is widely referred to in assessments of construction impacts within London; however, the GLA Guidance Document is applicable to all general construction sites within England and around the world. The overarching aim of the GLA Guidance Document is the protection of public health by establishing best practices that are relevant and achievable.

The GLA Guidance Document outlines three principles that are central to the control strategies provided within its pages. They follow a hierarchy to control the emissions of dust and other emissions and reduce human exposure:

- Prevention
- Suppression
- Containment

While direct construction activities need to be considered, emissions from on-road vehicles associated with the construction site and on-site machinery (off-road emissions) must also be considered. This includes both static and non-road mobile machinery (NRMM). All on-site contractors will need to ensure that they follow best practicable means (BPM) at all time to minimize emissions of dust and other COPC. In general, the GLA Guidance Document provides the following BPMs that can be followed for various stages of the works.

Demolition Works

- Use water as a dust suppressant.
- Cutting equipment to use water as suppressant or suitable local extract ventilation.

- Use enclosed chutes and covered skips.
- Wrap building(s) to be demolished.

Construction Traffic

- All vehicles to switch off engines – no idling vehicles (apply, as practical, to dredging operations).
- Effective vehicle cleaning and specific fixed wheel washing on leaving site and damping down of haul routes.
- All loads entering and leaving site to be covered.
- No site runoff of water or mud.
- On-road vehicles to comply to set emission standards (as applicable in the Cayman Islands).
- All non-road mobile machinery (NRMM) to use ultra-low sulphur tax exempt diesel (ULSD) where available and be fitted with appropriate exhaust after-treatment.
- Minimize movement of construction traffic around site.
- Hard surfacing and effective cleaning of haul routes and appropriate vehicular speed limit around site.

Site Activities

- Minimize dust generating activities.
- Use water as dust suppressant where applicable.
- Cover, seed or fence stockpiles to prevent wind whipping.
- Re-vegetate earthworks and exposed areas.
- If applicable, ensure concrete crusher or concrete batcher has a permit to operate.

14.5.1.1 Monitoring During Construction

It is theoretically possible to estimate air emissions from construction operations. For example, the US EPA AP-42 Chapter 13.2.3.1 outlines emissions from heavy construction operations. However, the transitory nature of construction operations differentiates it from other contaminant sources (e.g. stationary industrial sources) with regards to estimation and control of emissions. Demolition and construction consists of a series of diverse activities, each with its own duration and frequency of operation, as well as potential for the emission of contaminants. For any single construction site, emissions will have a definable beginning and end (i.e. start and end of construction), but will vary significantly over various stages of the construction activity. This is quite different from industrial emission sources, where emissions are either relatively steady and/or follow a discernable cycle.

Due to the highly spatial and temporal nature of emissions from construction operations, a desktop emissions assessment of construction operations can result in highly inaccurate results, and may not reflect the true impact on human health and the environment. Therefore, rather than ignore construction operations completely (which still may cause significant adverse effects), a monitoring program is recommended to assess emissions during the construction phase of the berthing terminal expansion. The use of monitoring, conducted during demolition and construction activities, helps to ensure that the applied mitigation techniques effectively control contaminant emissions. This, in turn, helps to ensure that impacts to public health or on the surrounding environment are minimized.

In addition, it is recommended that a Dust and Air Quality Control Monitoring Plan be prepared prior to demolition and construction. This plan should include a description and rationale of the equipment to be used for the measurement primarily of PM_{10}, NO_2 and SO_2.

Finally, since little monitoring data for dust is available within the Cayman Island, a period of baseline monitoring is recommended prior to the start of construction activities (including any demolition or site clearance works). This monitoring should be conducted for sufficient time to collect meaningful data. This background data allows existing air quality to be defined more accurately, and, in conjunction with national and/or international air quality standards, can assist with the determination, as well as interpretation, of "trigger thresholds" of construction emissions.

14.5.2 Operation Phase

Detailed air pollutant modelling coupled with an air quality monitoring programme is recommended to inform local policy and regulation with regard to cruise shipping and their conduct while in port. Implementing the sulphur standards for shipping fuels that the International Maritime Organization (IMO) adopted in 2008 (Annex VI of MARPOL), is expected to significantly reduce impact from shipping on air quality. Globally, ships will have to cut their fuel's sulphur content to a maximum of 3.5% in 2012 and to 0.5% in 2020. Options for mitigation include a number of measures that would require cooperation of the cruise lines. These include:

- Scrubbers: a possible alternative to low sulphur fuels, they would cut emissions of SO_2 by 99% and considerably reduce emissions of other polluting particles, but there are still some concerns about the by-products they produce in the cleaning process.
- Internal engine modifications - such as water injection and exhaust gas recirculation: these are techniques to prevent NO_x production during the combustion process, and can abate NO_x emissions by 30 to 50%.
- Humid air motor: by adding water vapour to the combustion air, NO_x emissions could be cut by 70 to 85%.

- Selective catalytic reduction (SCR): a system to treat exhaust gases after their production but before they are actually emitted. SCR can cut NO_x by up to 95%. This is already used in some 500 ships worldwide and works better with low sulphur fuels.
- Gas engines: Ship engines can work with liquified natural gas (LNG) which doesn't contain sulphur and therefore has SO_2 emissions close to zero. Gas engines also dramatically reduce other PM emissions. Although easier to fit new ships with such engines, conversions have already taken place.
- Shore-side electricity: can be used while ships are at the port and could cut SO_2, NO_x and other PM emissions by up to 90%. It is not known if this is a technically or economically feasible solution for the proposed project (i.e. the existing power generating infrastructure on Grand Cayman Island may be insufficient to provide shore power to large cruise ships).

14.6 RIAM Summary of Anticipated Project Impacts and Proposed Mitigation Measures

As noted in Chapter 1.3.6, the Rapid Impact Assessment Matrix (RIAM) method has been used to "quantify" the anticipated impacts of project construction, operation and mitigation measures. Table 14.8 and Figure 14.5 provide a summary of the RIAM scoring for specific impacts related to air quality and greenhouse gas emissions, including scores for each of the following project phases:

- Existing (baseline) conditions
- Dredging and reclamation phase
- Construction (post-dredging) phase
- Operational phase

Proposed mitigation measures for specific impacts are highlighted in the green cells in Table 14.8, with the RIAM method applied both without and with these mitigation measures.

Chapter 1.3.6 provides an overview of the various RIAM scoring criteria (A1, A2, B1, B2 and B3) and the methodology used to derive the Environmental Score (ES) and associated Range Value (RV) for each specific impact. The Range Values are summarized as follows:

- N: Neutral (no change/impact)
- A to E: Positive change/impact (A is slight positive...E is major positive)
- -A to –E: Negative change/impact (-A is slight negative...E is major negative)

Additional information on the RIAM methodology is provided in Appendix Q.

Table 14.8 Detailed RIAM Scoring for Air Quality and Greenhouse Gas Emissions

PHASE	IMPACTS SCORED WITH NO MITIGATION	Spatial Importance (0 to 4)	Magnitude of change/effect (-3 to + 3)	Permanence (1 to 3)	Reversibility (1 to 3)	Cumulative (1 to 3)			IMPACTS SCORED WITH MITIGATION	Spatial Importance (0 to 4)	Magnitude of change/effect (-3 to + 3)	Permanence (1 to 3)	Reversibility (1 to 3)	Cumulative (1 to 3)	*ES with mitigation*	*RV With Mitigation*
		A1	A2	B1	B2	B3	ES	RV		A1	A2	B1	B2	B3	ES	RV
EXISTING CONDITIONS	**Ambient**															
	Sulphur Dioxide (SO2) - Acid forming gas; Source is emissions from automobiles, ships, power generation.	2	-1	2	2	1	-10	-B	Reduce dependence on fossil fuels; Use BACT for controlling emissions; Switch to alternative energy sources	2	0	1	1	1	0	N
	Nitrogen Oxides (NOx) - Acid forming gas; Source is emissions from automobiles, ships, power generation.	2	-2	2	2	3	-28	-C	Reduce dependence on fossil fuels; Use BACT for controlling emissions; Switch to alternative energy sources	2	-1	3	1	3	-14	-B
	Carbon Monoxide (CO) - From combustion; reacts in the atmosphere to form the greenhouse gas CO2; General meteorological conditions do not favour accumulation.	2	-2	2	2	3	-28	-C	Reduce dependence on fossil fuels; Switch to alternative energy sources	2	-1	2	2	1	-10	-B
	Dust as Total Suspended Particulates (TSP) - A nuisance and also a health hazard	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Volatile Organic Compounds (VOC's) - Traffic and power generation (burning of fossil fuels)	2	-2	2	2	3	-28	-D	Reduce dependence on fossil fuels; Switch to alternative energy sources	2	-1	1	1	1	-6	-A
	Carbon Dioxide (CO2)[Greenhouse Gas] - Traffic and power generation (burning of fossil fuels)	2	-2	2	2	3	-28	-D	Reduce dependence on fossil fuels; Switch to alternative energy sources	2	-1	1	1	3	-10	-B
	Occupational/Port Area															
	Volatile Organic Compounds (VOC's)	1	-1	2	2	3	-7	-A		1	-1	2	2	3	-7	-A
	Dust as Total Suspended Particulate (TSP)	1	0	1	1	1	0	N		1	0	1	1	1	0	N
DREDGING & RECLAMATION	**Ambient:**															
	Sulphur Dioxide (SO2) - Acid forming gas; Source is emissions from dredge, other heavy equipment, cruise and cargo ships, power generation.	2	-1	2	2	1	-10	-B	Reduce dependence on fossil fuels; Use BACT for controlling emissions; Switch to alternative energy sources	2	0	1	1	1	0	N
	Nitrogen Oxides (NOx) - Acid forming gas; Source is emissions from dredge, other heavy equipment cruise and cargo ships, power generation.	2	-2	2	2	3	-28	-C	Reduce dependence on fossil fuels; Use BACT for controlling emissions; Switch to alternative energy sources	2	-1	2	2	3	-14	-B
	Carbon Monoxide (CO) - From combustion; reacts in the atmosphere to form the greenhouse gas CO2; General meteorological conditions do not favour accumulation.	2	-1	2	2	3	-14	-B	Reduce dependence on fossil fuels; Switch to alternative energy sources	2	0	2	2	1	0	N
	Dust as Total Suspended Particulates (TSP) - A nuisance and also a health hazard	2	-2	2	2	2	-24	-C	Wetting, Control of speed limit; Covering trucks conveynig aggregate	2	-1	2	2	1	-10	-B
	Volatile Organic Compounds (VOC's) - Traffic and power generation (burning of fossil fuels)	2	-2	2	2	3	-28	-C	Reduce dependence on fossil fuels; Switch to alternative energy sources	2	-1	1	1	1	-6	-A
	Carbon Dioxide (CO2)[Greenhouse Gas] - Traffic and power generation (burning of fossil fuels)	2	-2	2	2	3	-28	-C	Reduce dependence on fossil fuels; Switch to alternative energy sources	2	-1	1	1	1	-6	-A
	Occupational/Port Area															
	Volatile Organic Compounds (VOC's)	1	-1	2	2	3	-7	-A		1	-1	2	2	3	-7	-A
	Dust as Total Suspended Particulate (TSP)	1	0	2	2	1	0	N		1	0	1	1	1	0	N
CONSTRUCTION -POST DREDGING	**Ambient:**															
	Sulphur Dioxide (SO2) - Vehicles and power generation emmissions; can contribute to acid rain	2	-1	2	2	1	-10	-B	Reduce dependence on fossil fuels; Use BACT for controlling emissions; Switch to alternative energy sources	2	0	1	1	1	0	N
	Nitrogen Oxides (NOx) - Vehicles and power generation emmissions; can contribute to acid rain	2	-2	2	2	3	-28	-C	Reduce dependence on fossil fuels; Use BACT for controlling emissions; Switch to alternative energy sources	2	-1	2	2	3	-14	-B
	Carbon Monoxide (CO) - Automotive	2	-2	2	2	3	-28	-C	Reduce dependence on fossil fuels; Switch to	2	-1	2	2	1	-10	-B
	Dust as Total Suspended Particulate (TSP) - A nuisance and also a health hazard	2	-2	2	2	2	-24	-C	Wetting, Control of speed limit; Covering trucks conveynig aggregate	2	-1	2	2	1	-10	-B
	Volatile Organic Compounds (VOC's) - Traffic and power generation (burning of fossil fuels)	2	-2	2	2	3	-28	-C	Reduce dependence on fossil fuels; Switch to alternative energy sources	2	-1	1	1	1	-6	-A
	Carbon Dioxide (CO2)[Greenhouse Gas] - Traffic and power generation (burning of fossil fuels)	2	-2	2	2	3	-28	-C	Reduce dependence on fossil fuels; Switch to alternative energy sources	2	-1	1	1	1	-6	-A
	Occupational/Port Area															
	Volatile Organic Compounds (VOC's)	1	-1	2	2	3	-7	-A		1	-1	2	2	3	-7	-A
	Dust as Total Suspended Particulate (TSP)	1	-2	2	2	1	-10	-B	Wetting, Control of speed limit; Covering trucks conveynig aggregate; Use of PPE.	1	-1	1	1	1	-3	-A
OPERATIONAL	**Ambient:**															
	Sulphur Dioxide (SO2) - Increased cruise ships and automobiles.	2	-1	2	2	1	-10	-B	Reduce dependence on fossil fuels; Use BACT for controlling emissions; Switch to alternative energy sources	2	0	1	1	1	0	N
	Nitrogen Oxides (NOx) - Vehicles and power generation emmissions; can contribute to acid rain	2	-2	2	2	3	-28	-C	Reduce dependence on fossil fuels; Use BACT for controlling emissions; Switch to alternative energy sources	2	-1	2	2	3	-14	-B
	Carbon Monoxide (CO) - Automotive emissions and power generation are main sources; reacts in the atmosphere to form the greenhouse gas CO2	2	-2	2	2	3	-28	-C	Reduce dependence on fossil fuels; Switch to alternative energy sources	2	-1	2	2	1	-10	-B
	Dust as Total Suspended Particulate (TSP) - A nuisance and also a health hazard	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Volatile Organic Compounds (VOC's) - Traffic and power generation (burning of fossil fuels)	2	-2	2	2	3	-28	-D	Reduce dependence on fossil fuels; Switch to alternative energy sources	2	-1	1	1	1	-6	-A
	Carbon Dioxide (CO2)[Greenhouse Gas] - Traffic and power generation (burning of fossil fuels)	2	-2	2	2	3	-28	-D	Reduce dependence on fossil fuels; Switch to alternative energy sources	2	-1	1	1	1	-6	-A
	Occupational/Port Area															
	Volatile Organic Compounds (VOC's)	1	-1	2	2	3	-7	-A		1	-1	2	2	3	-7	-A
	Dust as Total Suspended Particulate (TSP)	1	0	1	1	1	0	N		1	0	1	1	1	0	N

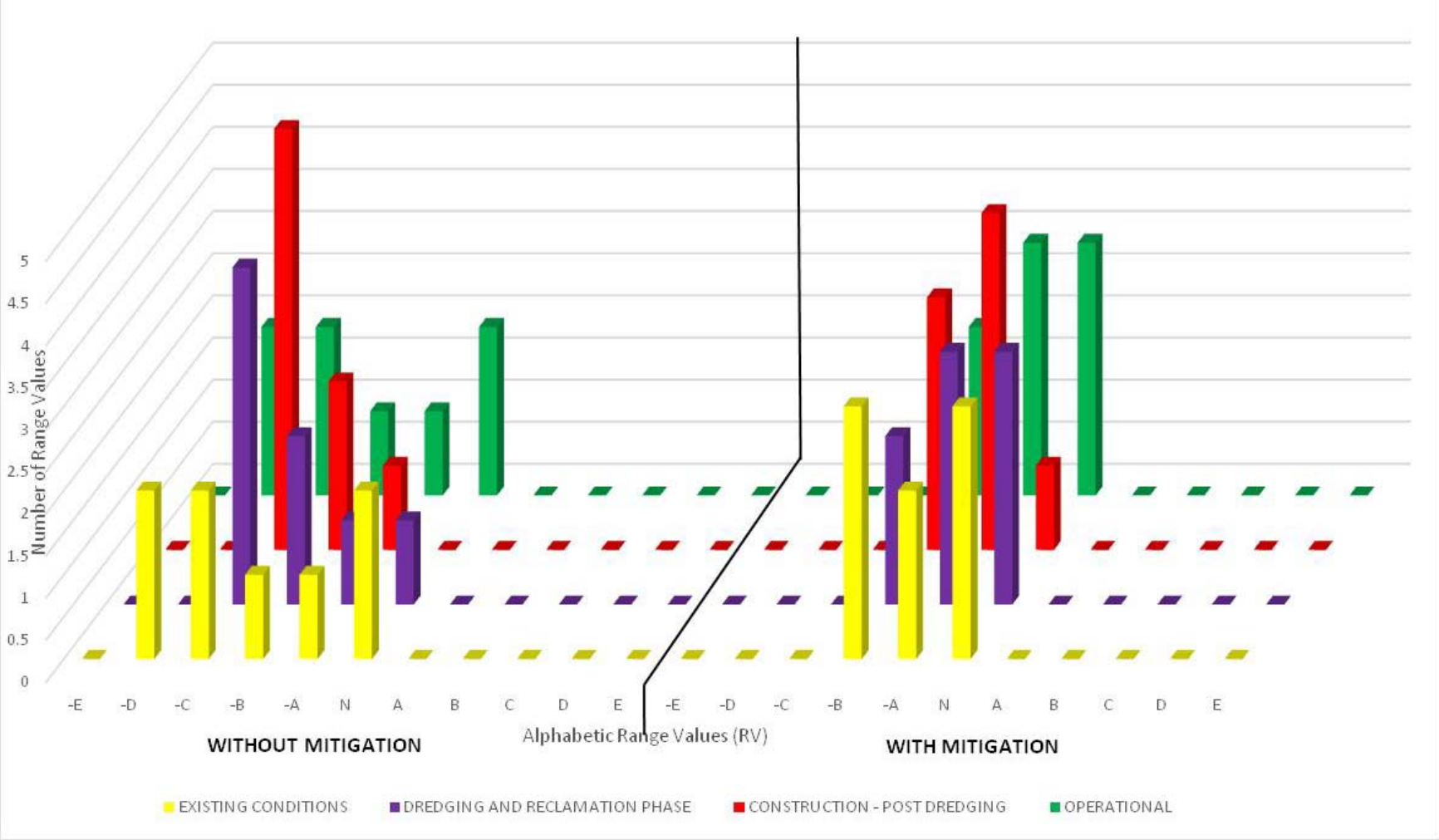


Figure 14.5 Summary RIAM Scoring for Air Quality and Greenhouse Gas Emissions

15.0 TASK H - NOISE AND VIBRATION

15.1 Introduction

The purpose of the noise and vibration assessment is to determine the significance of effects at receptors due to the expected magnitudes of impacts associated with the project. The significance of effect is dependent on both the sensitivity of the receptor and the magnitude of impact at the receptor. Onshore receptors in the vicinity of the proposed berthing facility include the following:

- Residential: private residential and hotels
- Commercial: restaurants, banks, retail, offices
- Institutional: public library, hospital

In keeping with the TOR, the assessment of noise and vibration was guided by standards and guidelines published by international organisations such as:

- International Finance Corporation (IFC)
- World Health Organisation (WHO)
- British Standard – 5228
- NOAA

The assessment of noise impacts was also guided by criteria relating to the sensitivity of the human ear and the fact that impacts of noise are very subjective. In addition, the nature of activities at a given site and its present context may influence the relative perception of a particular noise level change by the receptor community.

The proposed development site and environs is a relatively busy area and the port operates continuously, potentially making noise level changes seem less significant here than at a much more tranquil environment.

Noise criteria bear in mind the magnitude of the impact and significance of the effect. This process was also guided by the following facts:

- The human ear may detect noise levels changes as low as 1 dB under laboratory conditions, but a 3 dB change is generally the lowest change in environmental noise level that it is detectable.

- A 5 dB change may be clearly audible and because of the way that the human hearing mechanism works, a 10 dB change will generally be perceived as a doubling (or halving) of the noise in question.

Noise and vibration baseline measurement data may be found in **Appendix H**.

15.2 Assessment Methodology

The assessment was based on site visits and a survey of the existing noise environment, incorporating both qualitative assessment and quantitative measurement, supplemented by a desk-based assessment of potential future noise impacts arising from both the construction and operation of the upgraded port facilities. The assessment of potential impacts included consideration of off-site aspects associated with movements of construction-related traffic movements and subsequent movements of additional operational traffic on the public road network outside the port area.

Metrics employed in expressing noise data included:

- **LAeq**–Equivalent Continuous A-Weighted Sound Pressure Level
- **LA90** – Background Noise Level
- **LAmax**–Maximum Sound Level
- **SEL**– Sound equivalence level
- **DNL** – Day-Night Average Sound Pressure Level

The study area included the areas immediately adjacent to the port and extending out approximately 1640' (500 meters) to encompass other residential areas which may potentially be subject to noise impacts arising from the construction and operation phases of the proposed port development (refer to Figure 15.1).

The assessment was based on site visits and a survey of the existing noise environment, incorporating both qualitative assessment and quantitative measurement, supplemented by a desk-based assessment of potential future noise impacts arising from both the construction and operation of the upgraded port facilities. The assessment of potential impacts included consideration of off-site aspects associated with movements of construction-related traffic movements and subsequent movements of additional operational traffic on the public road network outside the port area.

15.2.1 Data Collection and Modelling

An attended noise measurement survey was conducted to generate baseline noise data during the period June 16 to 22, 2014. Source noise data for items of fixed and mobile construction equipment was obtained from existing sources including Annex C of British Standard (BS) 5228: Part 1: 2009.

The location of potentially noise sensitive receptors was determined in consultation with the team members based in Cayman, a review of information sources including land use maps and, aerial imagery and observations during a reconnaissance of the area of influence. Site locations are shown in Figure 15.1.



Figure 15.1 Noise Monitoring Locations

The noise measurement survey was conducted in accordance with current Best Practice methods using a UKAS calibrated, Cirrus Model CR:831B, Type 1 sound level meter, mounted on a tripod at a height of 4.2 ft(1.3 metres) above the ground and placed at least 11.5' (3.5 meters) from any walls or building facades. The meter was field-calibrated before and after each set of measurements. The measurements of existing noise levels were made during the week and weekend, for day and night time periods. The instrument was programmed to output hourly averages at each site over 24hrs.

15.2.2 Noise Modelling

The dhwaniPRO™ model was used to carry out the noise assessment. The dhwaniPRO™ model was developed to undertake construction, industrial and traffic noise propagation studies for which an environmental noise assessment may be required.

A variety of scenarios can be created quickly in dhwaniPRO™, allowing the determination of the impact of changing the source, layout and adding/removing the effects of shielding due to noise mitigation devices such as barriers. Additional details provided in Appendix H.

This assessment was conducted as follows:

Ambient noise readings collected from sampling points in George Town (
), were used to simulate noise impact based on the noise ratings of atypical array of equipment used in dredging and construction projects obtained from literature review (Table 15.1). Input data to the model also included building dimensions and locations in order to inform simulation of the "Barrier" effect that buildings have on sound wave;
Model output included both tabular and graphical representation of the results showing predicted noise levels associated with the construction phase. The results were compared with the local and international noise standards.

Table 15.1 Referenced Noise Values for Equipment and Operations

Construction Equipment Noise Emission Levels	
Equipment	**Typical Noise Level (dBA) 50 ft from Source**
Air Compressor	81
Backhoe	80
Concrete Mixer	85
Concrete Vibrator	76
Crane, Derrick	88
Generator	81
Grader	85
Jack Hammer	88
Loader	85
Paver	89
Pile Drive (Impact)	101
---"------ (Sonic)	96
Truck	88
Mechanical (Bucket) Dredge[1)]	124 (dist 500 ft)
Source: EPA 1971, Noise from Construction Equipment and Operations, Building Equipment and Home Appliances; [1)]Dickerson, C., Reine, K. J., and Clarke, D. G. (2001). "Characterization of underwater sounds produced by bucket dredging operations,"	

15.3 Baseline Conditions

The complete data collected from the ambient noise sampling exercise is summarized in Table 15.2 below. The standards for day time and night time noise values for the World Bank, International Finance Corporation (IFC) and the World Health Organization (WHO) are similar and makes for ease of comparison. The residential site, the school zone and the Elgin Road commercial site were monitored on week-days. Readings at the Royal Watler were taken on a week-end (Saturday to Sunday).

It can be concluded that the ambient noise standards have been exceeded in both the residential area of Whitehall Gardens and school zones. The major source of noise in the Whitehall Gardens

areas is traffic, which is evident in the decrease in the night time noise levels as traffic decreases, as well as decrease in other anthropogenic sources of noise. The school is located in the zone of influence of noise from the airport. The data from this assessment was placed in the modeling software, as the background ambient noise data.

Table 15.2 Summary of Ambient Noise Measurements and International Standards

Site ID	Location	UTME	UTMN	Lday (dBa)	WHO/IFC Standard (dBa)	Lnight (dBa)	WHO/IFC Standard (dBa)
N/AQ1	WHITEHALL GDNS	459716	2135690	62.6	55	53.05	45
N/AQ2	NBSC - ELGIN RD COMMERCIAL AREA	459942.	2133383.	59.16	70	53.22	70
N/AQ3	ROYAL WATLER	459730.	2133626.	65.7	70	61.2	70
N/AQ4	CAYMAN PREP	460358.	2132843.	67.0	55	66.7	45

15.3.1 Hall Gardens Site (N/AQ 1) – Residential Area by Main Road

At this site, the hourly Leq readings were in the range 49DB to 60dB to with an overall average of 55DB for the 24-Hr period (Table 16.2). The 24-Hr average was equal to the WHO Daytime Standard for a residential zone. The daytime noise level (Ld) of 57DB however was slightly higher than the daytime WHO guideline value of 55dB (Figure 15.2).

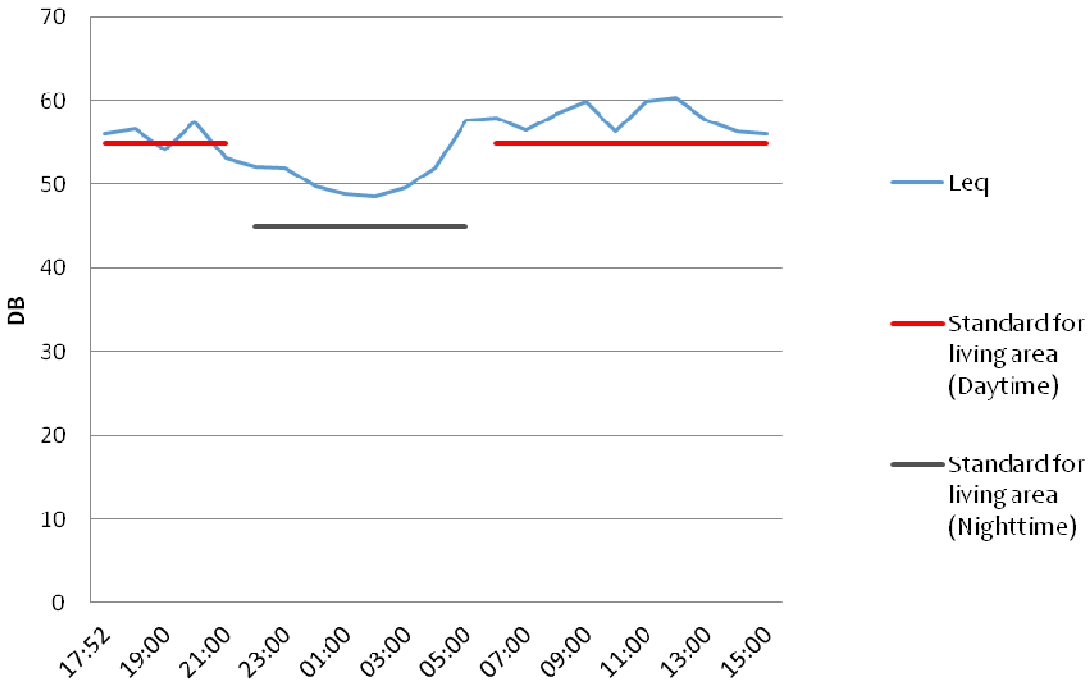


Figure 15.2 White Hall Gardens LAEQ vs WHO Day/Night Guideline Values

The level exceeded 90% of the time (L90 or background) was 50dB. Ln was determined to be 5dB higher than the guideline value for nighttime (45dB). These levels could be described as tolerable and would be further reduced indoors.

Sound exposure level was in the range 85dB to 114dB with the average being 97dB.

15.3.2 N/AQ2 – NBSC, Elgin Road

At this site,the hourly Leq readings were in the range 48dB to 69dB to with an overall average of 56dB. This average was within the WHO guideline for a commercial zone. The level exceeded 90% of the time (baseline) during the 24Hr sampling period was 50dB. The plot of LAEQ at Elgin Rd. vs the WHO guideline value is shown in Figure 15.3.

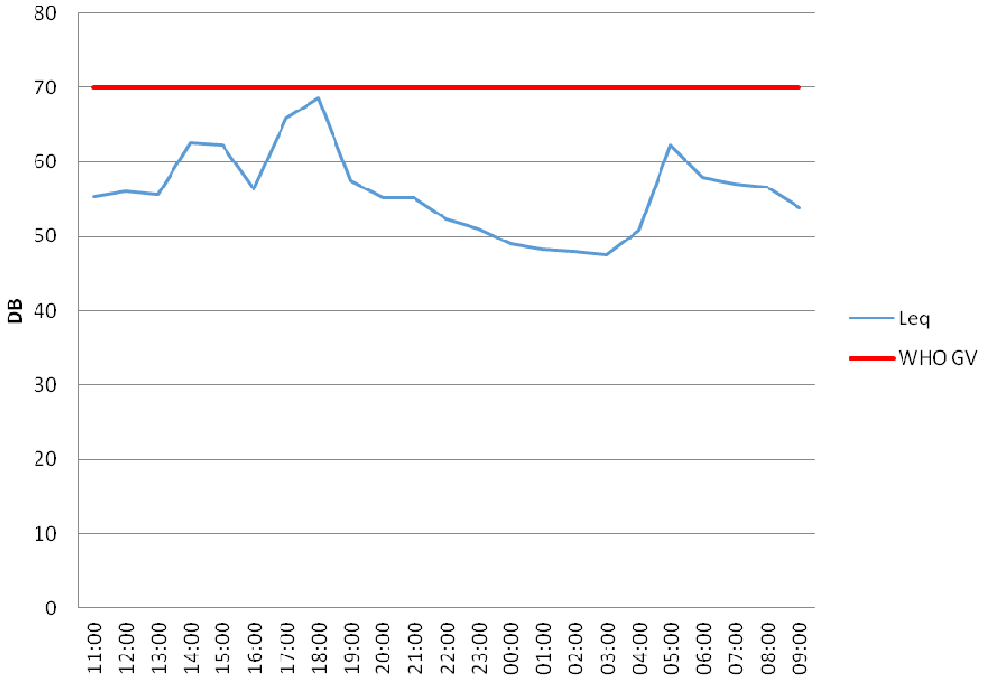


Figure 15.3 Elgin Road LAEQ vs WHO Value for Commerical Areas

15.3.3 N/AQ3 - Royal Watler

The plot of LAEQ at the Royal Watler vs the WHO guideline value for commercial areas is shown in Figure 15.4.

At this site, the hourlyLeq was in the range 58DB to 70dB with an overall average of 64dB. This average was within the WHO Standard for a commercial zone. The baseline level exceeded 90% of the time during the data collection period was 55dB.

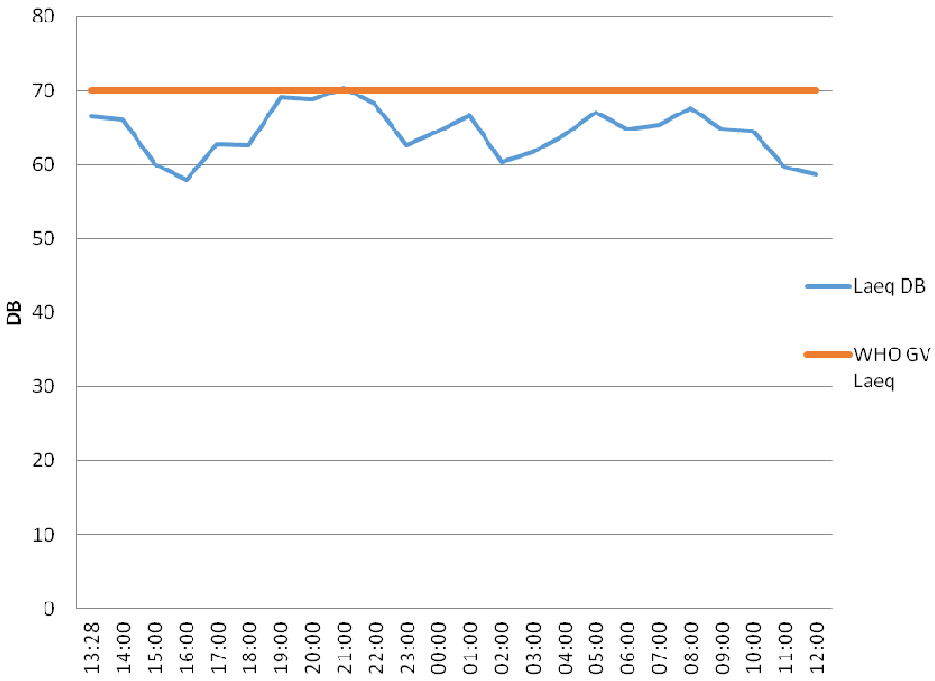


Figure 15.4 Royal WatlerLAEQ vs WHO Guideline Level

15.3.4 N/AQ4 - Cayman Prep

Noise characteristics data for the Cayman Prep site are summarised in Table 15.2. This site is affected by traffic and people sounds and is also in the flight path of the Owen Roberts International Airport (ORIA). Hourly Leq readings over the 24-Hr monitoring period were in the range 63dB to 76dB with an overall average of 69dB. These levels exceeded the 55DB WHO Standard for a school zone (Figure 15.5). The average baseline (L90) at this site was 50dB with a high of 59dB and a low of 40dB during the night time.

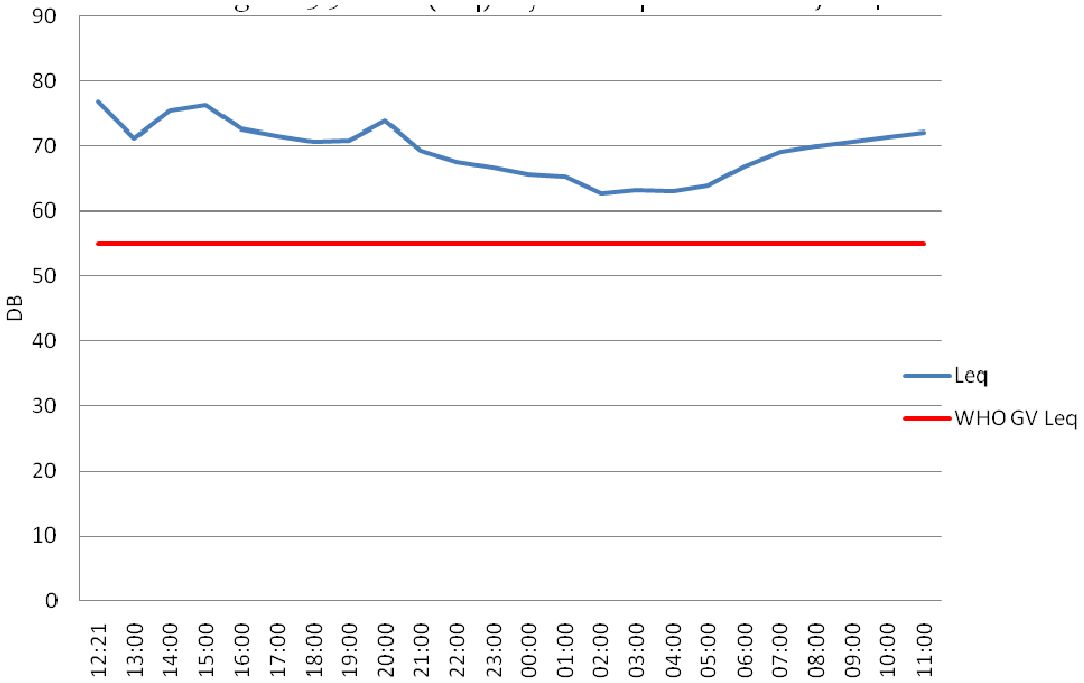


Figure 15.5 Noise (Leq) Cayman Prep June 20 to 21, 2014

15.4 Project Impact Assessment - Noise

15.4.1 Construction Phase Impacts on Onshore Receptors

Impact from noise is expected from dredging and construction activities and increased traffic movement. This is expected to mainly affect areas within 165 ft (50 m) of the port development site and residential areas along the corridor of movement of heavy duty equipment (largely trucks) going to and from the site. The main impact from the site is expected to be pile driving and the mechanical dredger which will have the potential to be an annoyance, possibly exceeding the WHO guideline value. The baseline study suggests that there could be some noise headroom (5dB) in the commercial area in the vicinity of the Royal Watler site, given that measured levels were lower than the 70dB WHO guideline level by 5dB. Pile driving close to shore will have an impact on noise levels as well as vibration.

Noise would be generated by the dredger as it transports material to the offshore disposal ground but the characteristics of this noise would be comparable to that generated by other vessels within the Harbour. Therefore, the movement of the dredger does not create a significant additional source of noise and it is not expected that there would be disturbance to the public due to noise generated by the activities of the dredger during disposal. No impact is envisaged as a result.

The results of the modelling runs are illustrated in Figure 15.6 and Figure 15.7, and are summarized in Table 15.3. Day time and night time runs were completed, to assess the change in noise impact over the 24 hours.

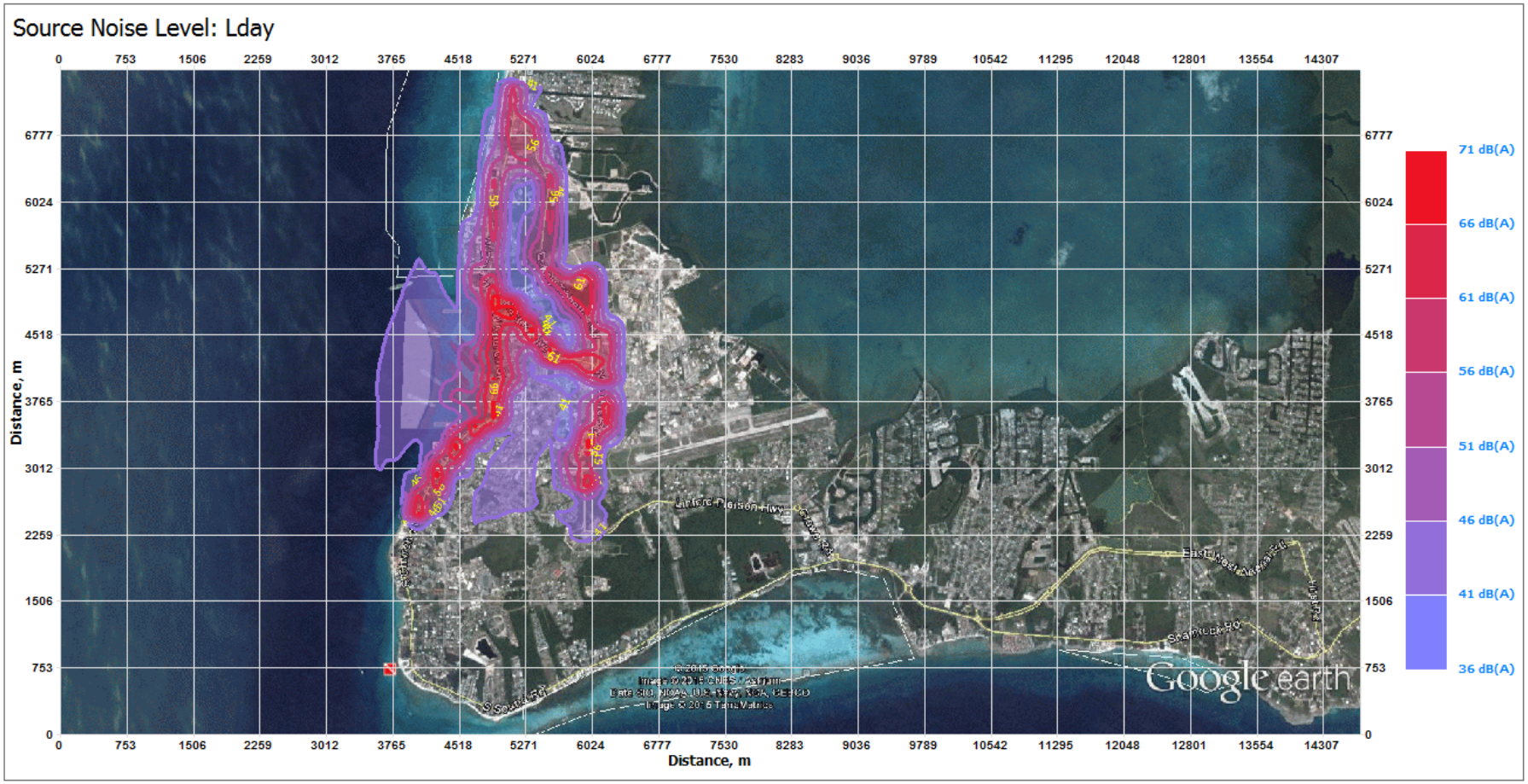


Figure 15.6 Noise Assessment for Daytime

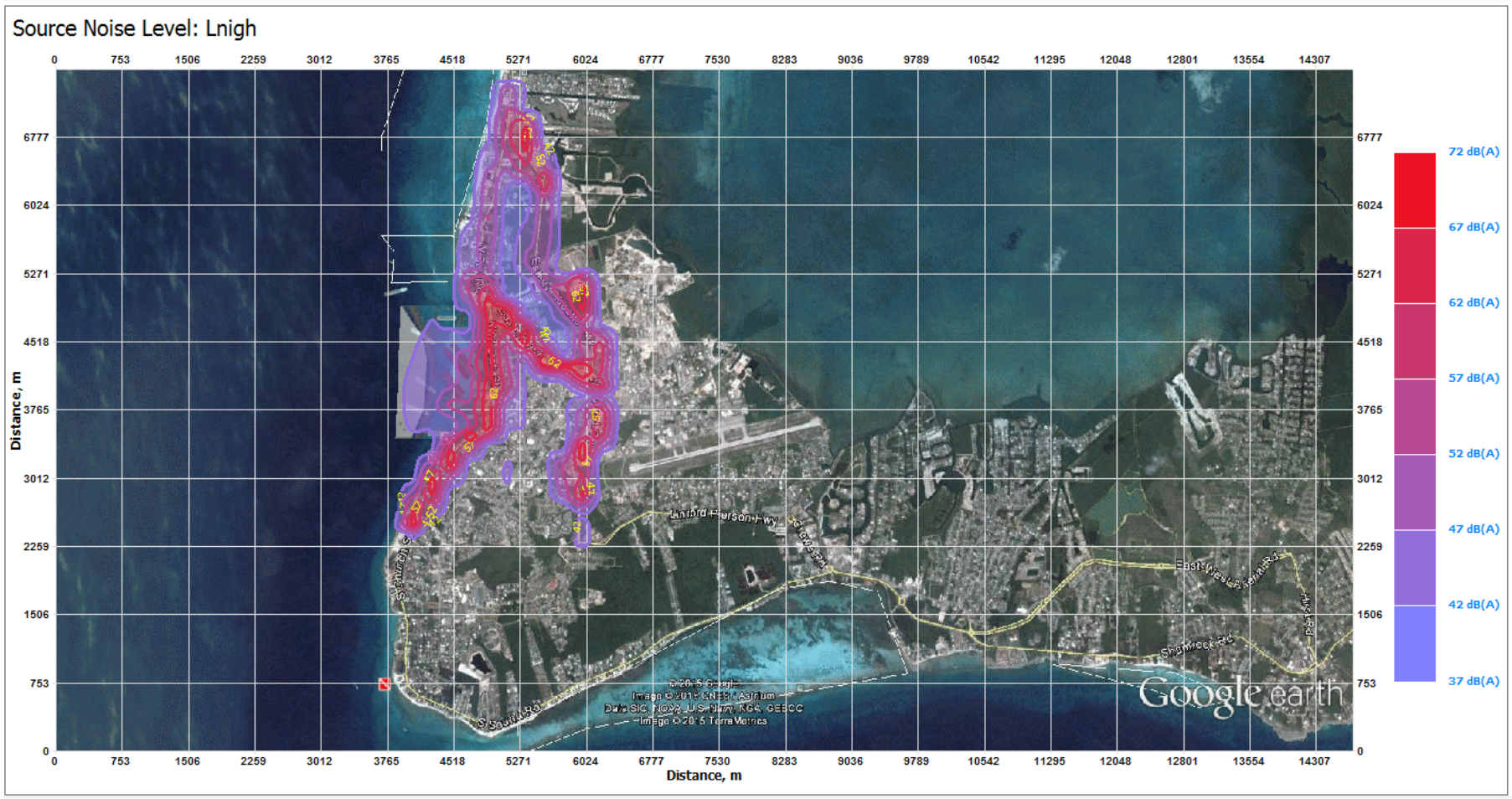


Figure 15.7 Noise Assessment for Night Time

Table 15.3 Results of Modelling Assessment at Monitoring Sites During Construction

SITE ID	LOCATION	Modelled readings		Noise Measured			
		Lday (dBa)	Lnight (dBa)	Lday (dBa)	WHO/IFC Standard Lday (dBa)	Lnight (dBa)	WHO/IFC standard Lnight (dBa)
N/AQ1	WHITEHALL GDNS	62	55	62.6	55	53.05	45
N/AQ2	NBSC - ELGIN RD COMMERCIAL AREA	61	55	59.16	70	53.22	70
N/AQ3	ROYAL WATLER	66	61	65.7	70	61.2	70
N/AQ4	CAYMAN PREP	67	67	67.0	55	66.7	45

A change in sound levels of less than 3 dB is imperceptible to the human ear. Any increase in sound levels that is less than 3dB was therefore deemed insignificant. As can be gathered from Table 15.3, no significant increase in sound levels greater than the measured sound level was predicted.

The Royal Watler site, which is the commercial area closest to the expected noise pollution sources, is predicted by the model to have no significant increase in sound levels from the proposed construction activities. This is not surprising, as most of the noise will be generated more than 330 ft (100 m) from the closest receptor. In addition, the noise levels from the construction equipment will also be subject to the influence of wind, which is generally blows from the east, thereby tending to push noise offshore from the site.

The 24 hr LAeq measured for the baseline conditions at the Royal Watler of 65.7dB compares to a predicted value of 66dB during dredging. For the Elgin Rd site, predicted level during dredging was 61dB compared to the baseline of 59.2dB. These levels compare to the WHO guideline value of 70dB for commercial/industrial zones. It should be noted however that these levels represent predicted averages and would not show transients or events of short duration.

Sensitive receptors falling within the highest predicted noise zone (62 - 67 dB) include the Elmslie United Church, which is located about 500 ft (150 m) to the SE of the site, and the Cayman Islands Law School and Public Library, which are located about 1000 ft (300 m) to the east.

In addition to 24 hour monitoring at the Royal Watler terminal over a weekend in June 2014 with no cruise ships present, monitoring was carried out on a weekday afternoon in June 2014 during a cruise ship visit. A comparison of the noise levels during the cruise ship visit with noise levels at a similar time during the weekend (without a cruise ship present) indicated no significant difference in the average noise levels. Specifically, the average noise level (LAeq) on the weekday afternoon with the cruise ship present was 63.3dB, as compared to the weekend afternoon (without a cruise ship present), when the average noise level (LAeq) was 62.6dB.

Pile Driving (Noise and Vibration)

Though not highlighted in the modeling, due to its sporadic nature, pile driving can represent an annoyance on land as well as in the marine environment. The repetitive sound on land can be regarded as an annoyance because of the expected daily occurrence. Sound pressure from marine pile driving depends to a great extent upon the size of the pile and the size of the hammer. There are, however, other factors that can cause large variations in measured sound pressures at a particular project site or from project site to project site. These factors include water depth, tidal conditions or currents, use/omission of sound attenuation systems and geotechnical conditions that determine how difficult it is to drive the pile (Illinworth & Rodkin 2007).

Incidences of structural damage from vibration impacts are not common. However, because humans can perceive vibrations of ≥ 0.01in/sec, or 1/100th the level at which structural damage could occur, it has been suggested that they extrapolate their sensitivity to a concern about the safety of their buildings (Marr 2012). For example, the sensitivity of structures and people to vibrations is summarized in Table 15.4.

Table 15.4 General Effects of Construction Vibration (source: Caltrans, 2004)

Effects	Peak Particle velocity (in/sec)	
	Transient Sources[1]	Continuous/Frequent Intermittent Sources[2]
Structure Type	0.12	0.08
Extremely Fragile historic buildings, ruins, ancient monuments	0.2	.01
Fragile buildings	0.5	0.25
Historic and some old buildings	0.5	0.3
Older residential structures	1.0	0.5
New residential structures	2.0	0.5
Modern industrial/commercial buildings		
Human Response		
Barely perceptible	0.04	0.01
Distinctly perceptible	0.25	0.3
Strongly perceptible	0.9	0.5
Severe	2.0	0.4

Notes:
1 Transient sources create a single isolated vibration event, such as blasting and drop balls.
2 Continuous/frequent intermittent sources include impact pile drivers, vibratory pile drivers, and vibratory compaction equipment.

Figure 15.8 indicates that structural damage may occur at distances in the order of 5 to 100 ft from the source of vibration (depending on the nature of the source), whereas people can perceive vibrations from the same sources at distances of 100 to 1000 ft.

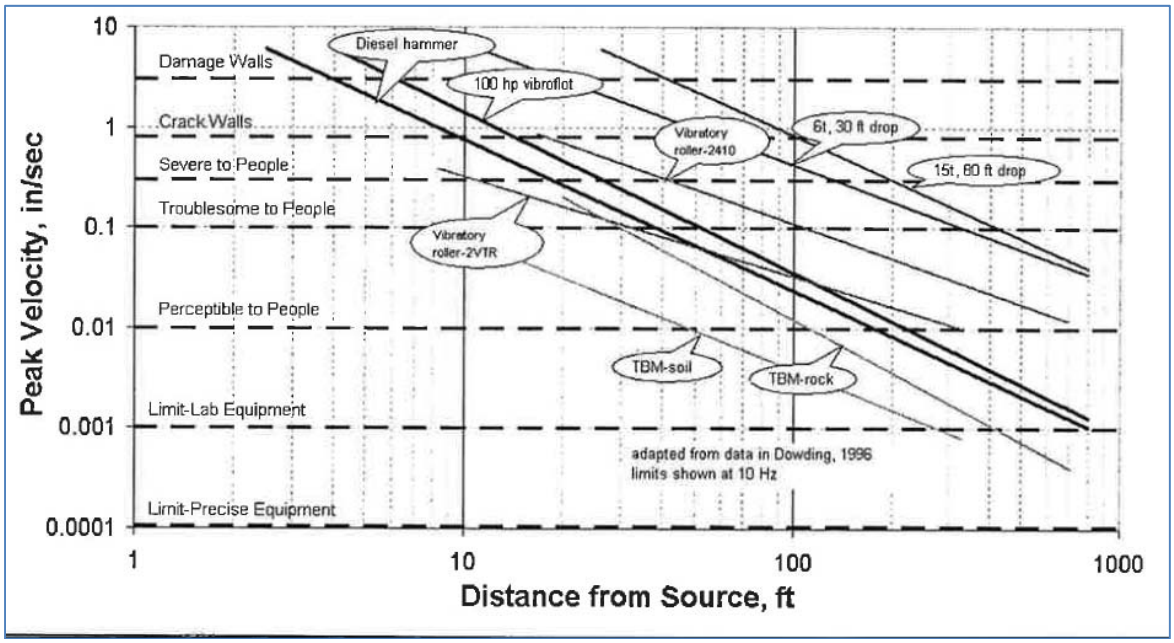


Figure 15.8 Human Concerns for Vibrations at Various Distances from Source (source: Marr, 2012)

Figure 15.9 summarizes noise data reported from various construction activities including two types of pile driving (impact and vibration). The data indicates that activities like pile driving could represent an annoyance within 300 ft of the source.

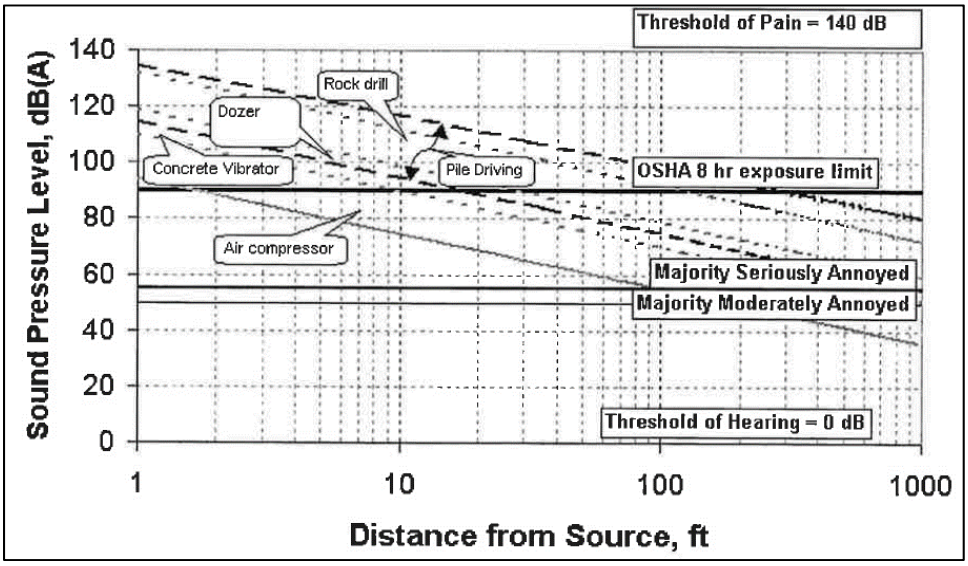


Figure 15.9 Typical Noise Data for Various Construction Activities (source: Marr, 2012)

Traffic Noise

Traffic noise predictions were done for during construction and post construction (operational phase) of the cruise ship development, with an expected 10% increase in traffic. The results are shown in Figure 15.10 and Figure 15.11. A maximum 1dB increase in sound levels is predicted, which is again an insignificant change in sound levels.

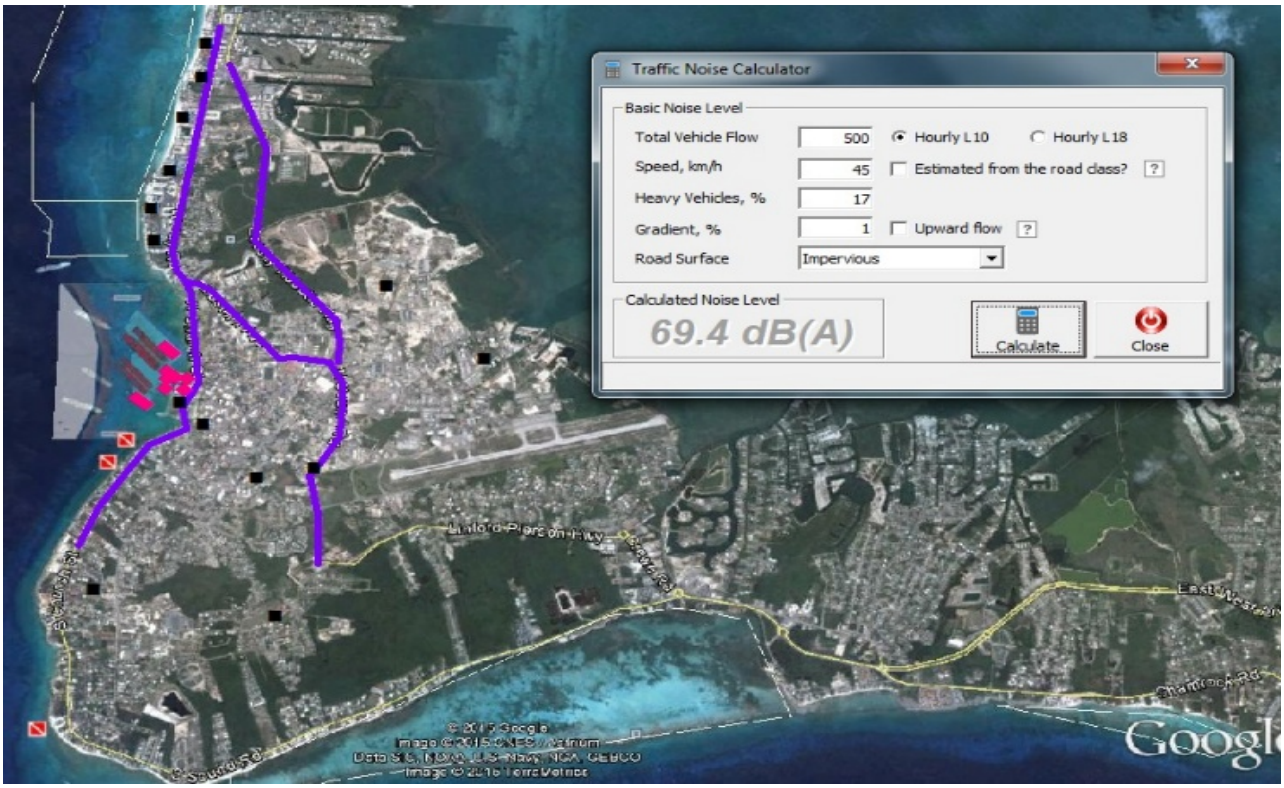


Figure 15.10 Traffic Noise Calculation During Project Construction

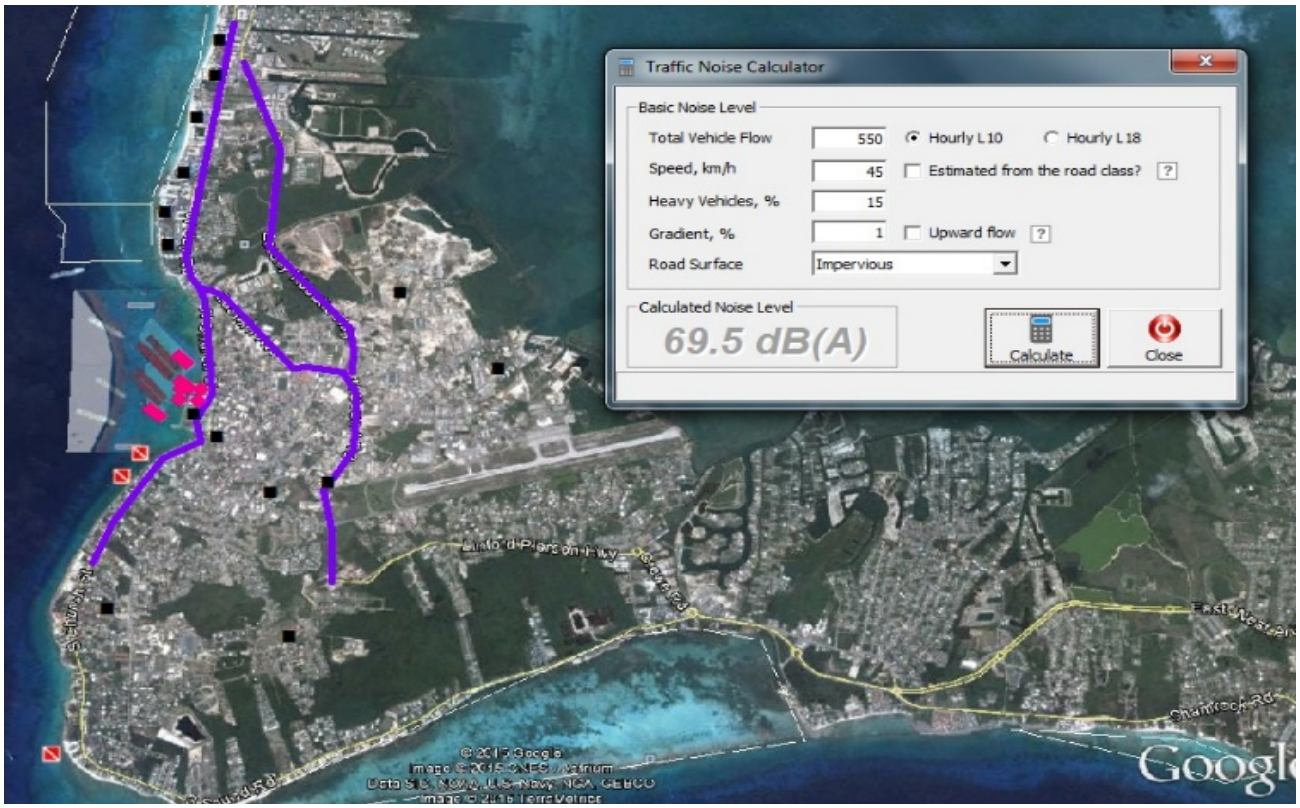


Figure 15.11 Traffic Noise Calculation During Project Operations

15.4.2 Operational Phase Impacts on Onshore Receptors

Potential sources of noise include ships at berth, land based equipment servicing the ship, passengers and plant in the terminal building, and road vehicles delivering goods or passengers to the ship. Available data from monitoring conducted over the first year of a recently developed cruise ship port facility has indicated that noise emissions are generally dominated by operation of the ships' engines and ventilation fans (PANSW 2014).

As noted earlier, a comparison of noise levels measured at the Royal Watler Terminal with and without a cruise ship moored offshore indicated no significant difference in the average noise levels. The cruise ships will be located closer to shore with the proposed cruise berthing facility, which will tend to increase onshore noise levels; however, this increase will be naturally mitigated, to some degree, by the prevailing easterly (offshore) winds.

15.4.3 Potential Impacts of Noise in the Marine Environment

Dredging is regarded as a medium impact activity being less noisy than seismic surveys, pile driving and sonar but louder than for example most shipping, offshore wind turbines and drilling (Hastings et al 2005). Potential human impacts of noise could include divers, snorkelers and other operating underwater in the vicinity. Impacts to humans will be in influenced by the fact that

water travels faster and for longer distances in water but the ear is less sensitive in that medium. Data exists which shows that human hearing underwater, with a 'wet' ear, is less sensitive than it is in air, and so sound underwater will produce less hearing damage, than airborne sound. This applies to divers where the auditory canal is filled with water, e.g. SCUBA divers and divers wearing band-masks (Anthony et al 2009).

15.4.3.1 Fish

Hearing structures among fish varies greatly, resulting indifferent auditory capabilities across species. Due to the higher compressibility of gas compared to water, the swim bladder responds to sound pressure fluctuations. Therefore, the perception of sound pressure is restricted to those fish species containing air-filled swim bladders. Fish without swim bladders are only sensitive to the particle motion component of the sound wave[10].

An assessment of impacts to fish in San Francisco Bay during a Pile Installation Demonstration Project (PIDP) indicated that there is mortality associate with exposure to pile driving sounds, with dead fish of several different species found to at least 164 feet (50 metres) from the pile being driven (Caltrans (2001). Increase in catch by over - flying gulls during pile driving, was also reported, further indicating fish mortality. Examination of dead/dying revealed bleeding and damage to the swim bladder. The extent of damage and mortality of caged fish was greater when the cages were closer to the source. Work done by Caltrans suggests that mortality could be reduced by the use of a bubble curtain.

15.4.3.2 Elasmobranchs and invertebrates

Hearing abilities among sharks have demonstrated highest sensitivity to low frequency sound (40 Hz - 800 Hz). Overall sensitivity however is reported to be poor compared to other taxa: Casper & Mann (2006). Some decapod crustaceans are able to detect and use sound in ways that are similar to detection and processing of acoustic stimuli in aquatic and terrestrial vertebrates (Popper *et al.* (2001)). Many aquatic decapod crustaceans are able to detect substrate vibration in order to obtain information on the location of mates, competitors or predators. However, the sensitivity of decapod crustaceans to particle motion and hydrodynamic stimuli is poor compared to fishes (Popper *et al.* 2001).

15.5 Project Impact Assessment - Vibration

15.5.1 Construction Phase Impacts

The effect of construction vibrations on surrounding buildings, sensitive devices and people in the urban environment is a significant consideration in implementing construction projects. Disruption of some businesses, possible structural damage and annoying people are the potential problems.

[10]Popper AN, Fay RR (1999).The Auditory Periphery in Fishes. In: Fay RR, Popper AN (eds) Comparative Hearing: Fish and Amphibians, p 43-100

The dynamic effect of construction vibrations on adjacent and remote structures depends on soil deposits at a site and susceptibility ratings of structures. It is possible that intolerable structure vibrations may be induced in close proximity to the driven piles. In addition, foundation settlements resulting from soil vibrations in loose soils may occur at various distances from the source.

The most prevalent and powerful sources of construction vibrations are pile driving, dynamic compaction and blasting. Blasting energy is much larger than the other sources of construction vibrations. However, blasting is not anticipated to be required for this project.

Ground vibrations generated by construction sources can be roughly separated into two categories: transient and steady-state vibrations. Pile driving would be considered a transient source. Noise emission levels from pile drivers can vary widely based on the type of driver, the type of pile (steel, concrete, wood), and the underlying ground conditions.

15.5.2 Operation Phase Impacts

The operation phase is not expected to result in any significant impacts on vibration.

15.6 Impacts Due to Climate Change

Climate change is not expected to have any direct influence on the potential effects of the project in terms of noise and vibration. This especially true when compared to the other aspects of the project. Though it is not possible to establish robust relationships between climate-sensitive factors and any corresponding changes in noise levels, or attribute sensitivities to specific aspects of the project some indirect effects could include:

- Noise attenuation with increasing temperature (this mainly affects high frequency);
- Increased noise from building services as more persons use air conditioning;
- Greater ingress of noise into households as greater temperatures force households to open up windows to impriove ventillation;
- Species communication could be affected as sound waves will not carry as far in warmer waters.

Furthermore, the influence of climate change is not expected to make a significant change to the assessment of impacts compared with the other aspects of the project design (e.g. the proximity of berthing facility to receptors).

15.7 Possible Mitigation Measures

Construction Phase
Mitigation measures to limit the impacts of noise and vibration during project construction may include the following:

- Working hours and conditions should be agreed with the local Authorities. In particular:
    - Limit pile driving to daylight hours when people are less affected by nuisance noise and vibration;
    - To the extent possible, avoid dredging the areas closest to land during the night.
- Take steps to reduce noise and vibration assocaited with pile driving to the extent that they are economically possible (i.e. use of quieter piling techniques, such as vibro-piling or pile-pressing, enclosure of the pile and ram by 'bellows').
- Undertake community liaison to keep affected parties engaged in the project and informed of progress and events through liaison with community representatives, community meeting, newsletters, project webpage (experience has shown that local residents may be tolerant of very high noise levels provided they have been forewarned of the occurrence of the activities, their reason and the potential duration, and are given details of a contact telephone number to call in the event of a perceived disturbance).
- Implement regulations to limit unnecessary noise, such as strict control of speed and no use of Jake brakes.
- Use noise shroud or curtains to reduce noise levels and limit the area within which people are moderately annoyed to ≤ 500 ft (150m).
- Conduct pre-construction damage survey on buildings within 500 ft (150m) of the area where piles will be driven.
- Measure noise and vibration at key locations within 330 ft (100m) of the proposed pile driving area. Use measured data in conjunction with baseline data to demonstrate that levels are below that which could cause harm/damage (note: baseline measurements of vibrations should be undertaken before construction starts).

Operation Phase
Mitigation measures to limit the impacts of noise and vibration during project operationns may include the following:

- Limit the use of cruise ships' main engines and ventilation fans when at berth.
- Procure plant and equipment for operations and maintenance with consideration given to its noise characteristics.
- Fit large diesel equipment with noise control kits.

- Fit site equipment with alternatives to standard reversing alarms (such as "squawker" alarms, flashing lights, video cameras, etc.).
- Conduct regular and effective maintenance of all stationary and mobile equipment, including noise mitigation features such as mufflers; as a minimum, plant and equipment should be inspected every six months, or in response to specific complaints.
- Provide staff and sub-contractors with noise and vibration awareness training (e.g. as part of general site induction and/or tool-box talks).
- Carry out noise monitoring to evaluate effectiveness of mitigation measures.

15.8 RIAM Summary of Anticipated Project Impacts and Proposed Mitigation Measures

As noted in Chapter 1.3.6, the Rapid Impact Assessment Matrix (RIAM) method has been used to "quantify" the anticipated impacts of project construction, operation and mitigation measures. Table 15.4 and Figure 15.12 provide a summary of the RIAM scoring for specific impacts related to noise and vibration, including scores for each of the following project phases:

- Existing (baseline) conditions
- Dredging and reclamation phase
- Construction (post-dredging) phase
- Operational phase

Proposed mitigation measures for specific impacts are highlighted in the green cells in Table 15.4, with the RIAM method applied both without and with these mitigation measures.

Chapter 1.3.6 provides an overview of the various RIAM scoring criteria (A1, A2, B1, B2 and B3) and the methodology used to derive the Environmental Score (ES) and associated Range Value (RV) for each specific impact. The Range Values are summarized as follows:

- N: Neutral (no change/impact)
- A to E: Positive change/impact (A is slight positive...E is major positive)
- -A to –E: Negative change/impact (-A is slight negative...E is major negative)

Additional information on the RIAM methodology is provided in Appendix Q.

Table 15.4 Detailed RIAM Scoring for Noise and Vibration

PHASE	IMPACTS SCORED WITH NO MITIGATION	Spatial Importance (0 to 4)	Magnitude of change/effect (-3 to + 3)	Permanence (1 to 3)	Reversibility (1 to 3)	Cumulative (1 to 3)			IMPACTS SCORED WITH MITIGATION	Spatial Importance (0 to 4)	Magnitude of change/effect (-3 to + 3)	Permanence (1 to 3)	Reversibility (1 to 3)	Cumulative (1 to 3)	*ES with mitigation*	*RV With Mitigation*
		A1	A2	B1	B2	B3	ES	RV		A1	A2	B1	B2	B3	ES	RV
EXISTING CONDITIONS	Traffic and background	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Effect of Vibration on Structures	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Effects of noise on Marine species	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Effects of noise on Diving/Snorkeling	2	0	1	1	1	0	N		2	0	1	1	1	0	N
DREDGING & RECLAMATION	Traffic and background	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Effect of Vibration on Structures	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Effects of noise on Sensitive Receptors on Land	2	-1	2	2	2	-12	-B		2	-1	2	2	2	-12	-B
	Effects of noise on Marine Species - Mainly from Pile driving	2	-2	2	2	1	-20	-C	Place hydro sound dampers on nets surrounding the pile drivers to absorb noise	2	-1	2	2	1	-10	-B
	Effects of noise on Diving/Snorkeling	3	-2	2	2	1	-30	-C	Place hydro sound dampers on nets surrounding the pile drivers to absorb noise	3	-1	2	2	1	-15	-B
CONSTRUCTION - POST DREDGING	Traffic and background	2	-1	1	1	1	-6	-A	Strict control of speed and no use of Jake Brake	2	0	1	1	1	0	N
	Effect of Vibration on Structures	2	-2	2	2	1	-20	-C	Pre construction damage survey within 5oo' (150m) of pile driver; Use of noise shroud or curtains	2	-1	2	2	1	-10	-B
	Effects of noise on Marine Species - Mainly from Pile driving	2	-2	1	1	1	-12	-B		2	-2	1	1	1	-12	-B
	Effects of noise on Diving/Snorkeling	2	-2	1	1	1	-12	-B		2	-2	1	1	1	-12	-B
OPERATIONAL	Traffic and background	2	-1	3	2	1	-12	-B		2	-1	3	2	1	-12	-B
	Effect of Vibration on Structures	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Effects of noise on Marine species	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Effects of noise on Diving/Snorkeling	2	0	1	1	1	0	N		2	0	1	1	1	0	N

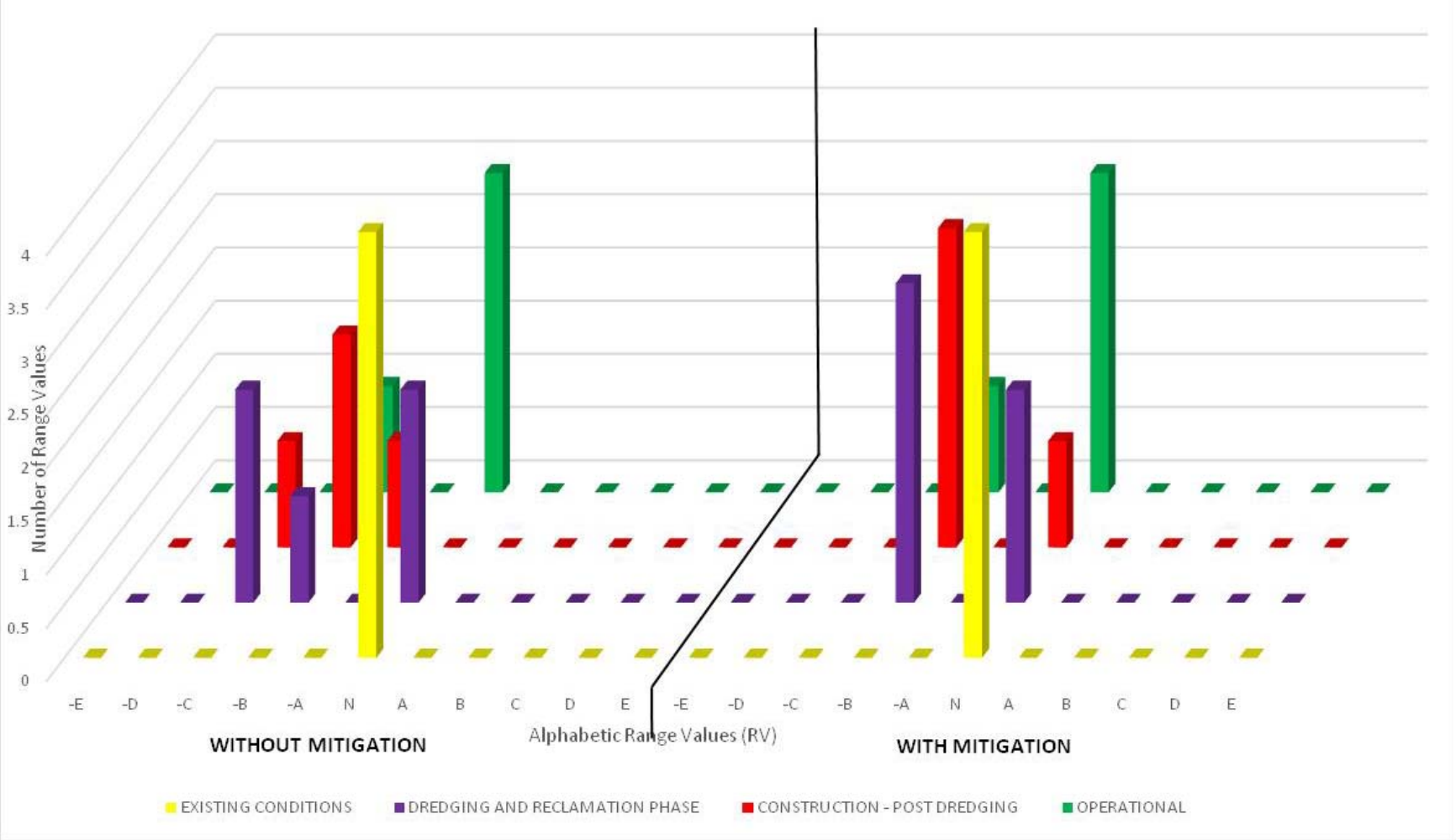


Figure 15.12 Summary RIAM Scoring for Noise and Vibration

16.0 MARINE ECOLOGY

16.1 Introduction

The EIA Terms of Reference identifies potential impacts of the proposed CBF on the marine environment during the construction and operational phases of the project. The list of potential impacts for the construction phase includes habitat loss, changes in water quality and seabed characteristics due to dredging, disruption of the benthic habitat due to contaminant release, disturbance due to noise and vibration, as well as accidental pollution events. For the operational phase of the project, potential impacts include habitat degradation and physical damage due to cruise ship traffic, changes in water quality, accidental pollution events and the potential for the introduction of invasive species. Appendix J.1 describes the baseline conditions of the marine environment and the associated coral reef community, and addresses the impacts of the development on these receptors and proposes mitigation measures.

Appendix J.1 provides additional information on the marine ecology of GTH, focusing on the coral reefs, which are so critical to the environmental and economic health of Grand Cayman.

Appendix J.2 includes a preliminary estimate of the economic value of the marine resources in GTH. The total estimated value of the 87 acres (35 hectares) of reefs ranges from US$23M to US$26M per year. This information has been factored into the socio-economic impact assessment for the project.

16.2 Assessment Methodology

Fourteen sampling stations were selected in GTH for the purpose of characterizing the benthic substrate, coral cover and recruitment (**Figure 16.1**). Fish census was also carried out at each station. The sampling sites were grouped into three distinct areas: a) Soto's reef, Balboa reefs, and Eden Rock.

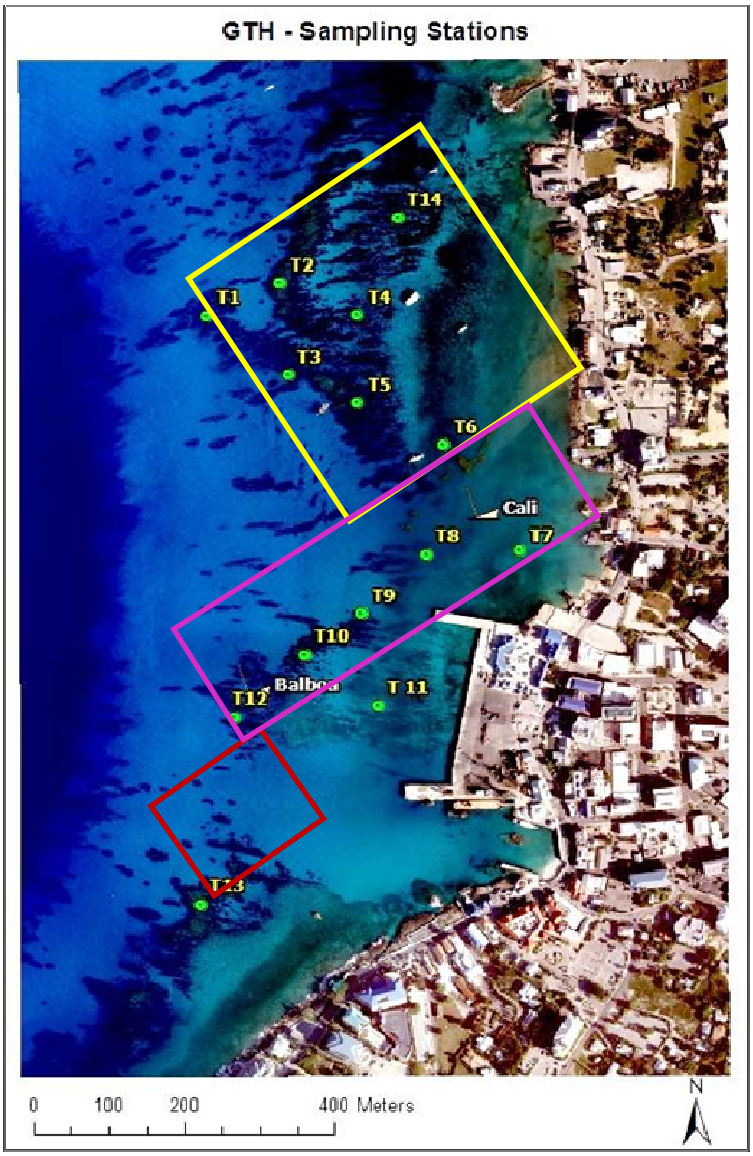


Figure 16.1 - Locations of sampling stations

16.2.1 Benthic substrate composition

A modified version of the AGRRA protocol (Lang et al. 2010) was used to assess the overall coral community structure in the vicinity of the project site. Four 33ft x 3ft (10m x 1m) transects were photographed at each site to record the benthic substrate composition, coral species abundance and diversity, coral status, and coral recruitment. Each transect comprised 10 photoquadrats, with each photoquadrat covering ~11ft^2 (~1m^2) of the coral substrate. Photoquadrats were analyzed using the Coral Point Count (CPCe v 3.6) image analysis software designed for enumerating benthic features (i.e. coral, algae, sponge, substrate type) (Kohler and Gill 2006). Coral colonies were classified according to genus species level, and the state of the colony, specifically disease, bleaching or mortality, recorded. Gorgonians were identified to genus level while sponges were differentiated into fleshy, encrusting, rope, tube and barrel sponges. Algae were grouped as macroalgae and coralline algae, and identified to genus level where possible.

16.2.2 Coral recruitment

Coral recruitment was assessed along each transect. A quadrat 10 in x 10 in (25cm x 25cm) was placed on the substratum, at 7ft (2m) intervals along the transect line; all scleractinian corals, up to 2in (4cm) in diameter, were enumerated and identified to the genus or species level.

16.2.3 Rugosity

Maximum reef relief, a proxy for rugosity, was measured along a 33ft (10m) section of each fish transect by laying a steel chain, also 33ft (10m) long, along the contours of the reef substrate. The rugosity index calculated as:

Equation 1 $C=1-d/L$

Where, d=horizontal distance covered by the chain that follows the contour of the reef, and

L= horizontal length of the fully extended 33ft (10m) chain (Faud 2010).

16.2.4 Fish community

A visual census (AGRRA) of the fish community was conducted in the same habitat as the benthic surveys. Fish were enumerated along 7ft x 99ft (2m x 30m) transects and identified to species level, and individual sizes estimated using a graduated T-bar. Other benthic organisms including urchins, conch and lobster were also enumerated when encountered along transects. The "Roving Diver Technique" (RDT) was used to record all species encountered, including rarer species that might not have been detected at the transect level.

16.3 Baseline Conditions

Grand Cayman has very few well-developed, shallow water, nearshore reefs; many of these are located in George Town Harbour (GTH) and form a unique marine ecosystem on the island (Lang and Land 1976). The unique aspect of the reef system in the harbour can be attributed to a combination of ecological and topographical factors. The high relief of the "spur and groove" formations converge into a network of grottos and tunnels that form a complex habitat supporting a diverse assemblage of stony and soft corals, sponges, and an equally diverse population of fish species.

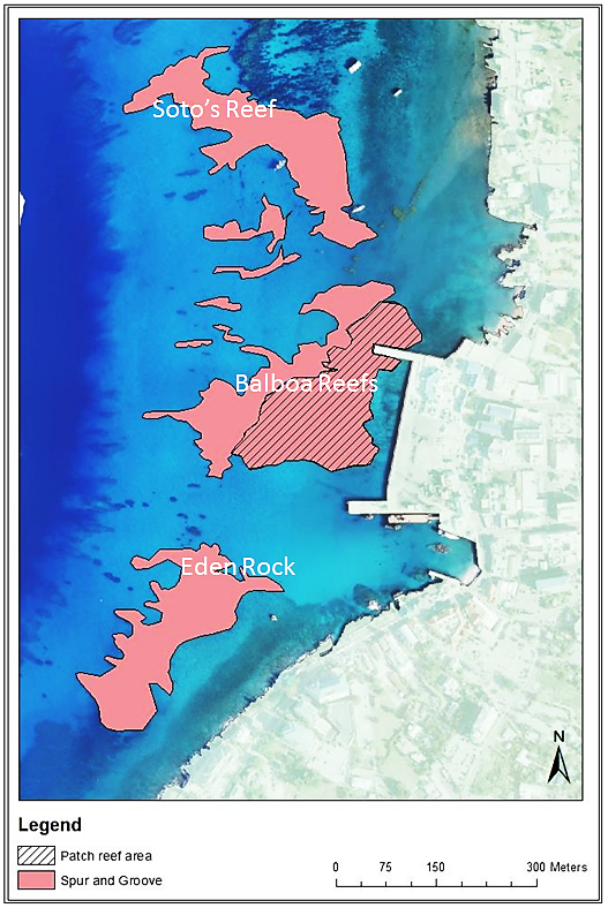
The clear harbour waters allow for the proliferation of healthy coral cover (recruitment, resilience), including the spotty recovery of *Acropora cervicornis* and *Acropora palmata* (found at one site), both listed as Critically Endangered on the IUCN Red List, and listed on Appendix II of CITES. The reef system, covering the area from "Soto's" Reefs located just north of the harbour to Eden Rock and Devil's Grotto to the south represent a significant proportion of the designated Marine Park Area (MPA) on the west side of the island. Although the reefs in the area do show signs of anthropogenic

stress resulting from harbour activities (e.g. cruise ship traffic and anchoring, tender traffic, tour boats, snorkeling/diving, coastal development), they are ecologically significant as a habitat due to their inherent structural complexity and functionality (e.g. nursery, refuge and foraging grounds). These reefs are considered to be in better shape relative to other reef systems found throughout the Caribbean. The MPA status affords some protection from overfishing.

16.3.1 Marine Habitat

As noted earlier, the marine habitat sampling sites in GTH were grouped into three areas (**Figure 16.2**):

- Soto's Reef;
- Balboa Reef;
- Eden Rock.



Reef Name	Surface Area (ha)	Surface Area (acres)
Soto's Reef (section)	3.5	8.7
Balboa Reefs(Spur and Groove)	2.9	7.2
Balboa Reefs(Patch reefs)	3.2	7.9
Eden Rock	3.0	7.4
Total Reef Area	**12.6**	**31.2**

Reef Type		
Spur and Groove	**(ha)**	**(acres)**
Total spur and groove surface area	**9.4**	**23.2**
Complex topography (gullies, tunnels)		
High relief spurs	2-7 m	
Coral cover variable	14-30 %	
• Hard coral species	26	
• Species threatened under ESA	6	

Mixed Patch Reef	**(ha)**	**(acres)**
Total mixed patch reef surface area	**3.2**	**7.9**
Patch reefs , hard pan substrate, sand		
Mixture of low relief patches	1-2 m	
Discontinuous coral cover	~10-14 %	

Figure 16.2 - Description of the three reef areas surveyed in GTH. Included are surface area estimations, description of reef type, and coral cover

16.3.1.1 Soto's (Cheeseburger) Reef Area

Soto's Reef (commonly referred to as Cheeseburger Reef) was represented by sampling sites T1, T2, T3, T4, T5, and T14. The segment of the reef that was surveyed covers an estimated 8 acres (31,394 m^2) (**Figure 16.3**). Additional sites, T6 and T7, were surveyed to examine the sandy substrate closer to shore. Located just north of George Town Harbour, Soto's Reefs is a topographically complex network of medium to well-developed spurs, ranging in height from 3-6.5ft (1-2m) to 16-26ft (5-8m). These spurs are found at a depth of 26-33ft (8-10m) and slope down to 150ft (45m) where they flatten out onto a sandy bottom. These reef formations are "honeycombed" with caverns, grottos, and winding tunnels that provide habitat for a vibrant coral reef community. In addition to healthy coral cover, the reef is teeming with large schools of fish, and frequent sightings of Hawksbill turtles and yellow rays. Reefs located closer inshore, (e.g. T5 and T14) show signs of stress with higher algal cover and the presence of *Lyngbia*, both indicators of localized eutrophication.

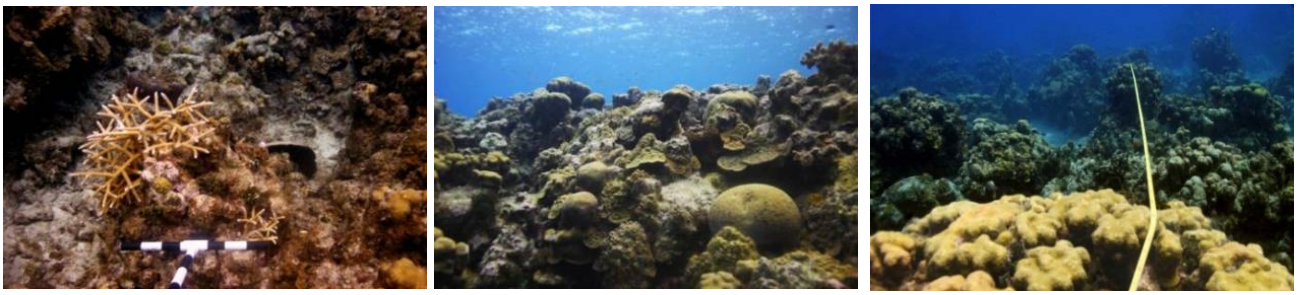


Figure 16.3 Reefscape along Soto's reef. Threatened species *A. cervicornis* and *O. annularis* found along well developed spurs.

16.3.1.2 Balboa Reefs

The "Balboa" Reef, which refers to the spurs located immediately in front of the terminal (within the proposed project dredge footprint), is represented by sites T8, T9, T10, T11, T12 and the wreck of the Balboa. These reefs cover an estimated ~15 acres (60, 375 m^2), including spur and groove and mixed patch reef areas. The hard substrate and patch reefs closer to shore (T11) give way to a more topographically complex reefscape. The T8 site, located near the northern pier and close to the wreck of the Cali, is a combination of patch reefs and low relief 7-10ft (2-3m) spurs. The overhangs and crevices are inhabited by juvenile fish, shrimp, lobster and urchin species (*Diadema, Echinometra*). The broken up hull of the Cali (**Figure 16.4**) lies near the port in 26-30ft (8-9 m) of water.



Figure 16.4 Wreck of the Cali. Near the wreck there is a large (~2m in diameter) *O. annularis* colony that will be destroyed during dredging operations. Relocating a colony of this size is likely not possible without causing extensive damage.

At stations T9 and T10 (**Figure 16.5**) reef topography becomes more diverse and complex, with 10-13ft (3-4m) high spurs and large coral heads, interspersed with patch reefs and longer, low elevation or younger spurs. *O. annularis* colonies are abundant but do show signs of stress from sedimentation and parrot fish bites. Similarly, the topography at T12 is a combination of spurs and scattered patch reefs with sand channels and sand flats. The notable difference compared to other sites is the abundance of gorgonians, sea rods and sea plumes, as well as the presence of healthy *Acropora* thickets, juvenile *Diadema* and Queen Conch.



Figure 16.5 Balboa Reefs are located immediately in front of the terminal and are all located within the dredge footprint. The diverse coral cover abundance of gorgonians and sponges support an equally diverse fish community.

Sitting at a depth of ~ 26-33ft (~8-10 m), the wreck of the Balboa is a popular dive site where fragments of this 375ft freighter are strewn across the sand flat (**Figure 16.6**). The metal pieces are encrusted with coral, sponge and gorgonians, plumes, sea whips and sea rods, and provide an ideal habitat for a variety of reef fish. Given its location in George Town Harbour, the area is an "oasis" in the midst of a barren sandy terrace. The area has high coral cover and supports a diverse reef community, including meadows of grooved-blade sea whips (*Pterogorgia* spp.) and a variety of fleshy sponges. The spurs and the pieces of the wreck provide habitat to large schools of Mahogany Snapper, a variety of parrot and other reef fish. The site can only be accessed safely by divers once the cruise ships have sailed and the local "Tender" traffic abates (after 6 pm).



Figure 16.6 Wreck of the Balboa lies within the dredge footprint. The wreckage serves as an artificial substrate for a variety of hard and soft corals.

16.3.1.3 Eden Rock

Eden Rock, a reef formation located to the south of the terminal represented by sampling site T13, covers an estimated 8 acres (30,281m²). Eden Rock (T13) is located immediately south from the proposed CBF and is a very diverse reef site (**Figure 16.7**). Reefs spurs form a network of tunnels, grottos and overhangs. Tarpon, bar jacks, various species of parrot fish, file fish, trigger fish and grouper are a common sight. The coral cover is healthy and diverse. What makes Eden Rock and the nearby Devil's Grotto so unique are the shallow coral canyons on top of the spurs that resemble shallow reef environments, whereas on the sides of the spurs, the reef community is reminiscent of deeper wall environments.



Figure 16.7 The well-developed spurs at Eden Rock create canyons that make this site a desirable dive site. The reef formation supports a diverse coral cover (29% cover) and a diverse community of fish

16.3.2 Benthic composition

The marine benthic assessment protocols entail quantifying and documenting the status of coral, specifically: a) the standing stocks and condition of functional indicator groups (e.g. corals, crustose coralline algae, macroalgae), b) fish populations (i.e. indicator of herbivory), c) other (e.g. *Diadema*, also an indicator of herbivory, d) water chemistry (i.e. nutrient levels). These measurements can reveal quantitative tipping-point levels beyond which resilience to undesirable phase shifts begins to become critically reduced (Hughes et al. 2010).

16.3.2.1 Coral Cover

The coral cover on George Town Harbour reefs was variable, ranging from 14% to 30%, with an average cover of 20% (SE+/-5.0) across all sites. The abundance of living coral was highest on Eden

rock and on reefs near the wreck of the Balboa, where the cover was 27% and 26%, respectively (**Figure 16.8**).

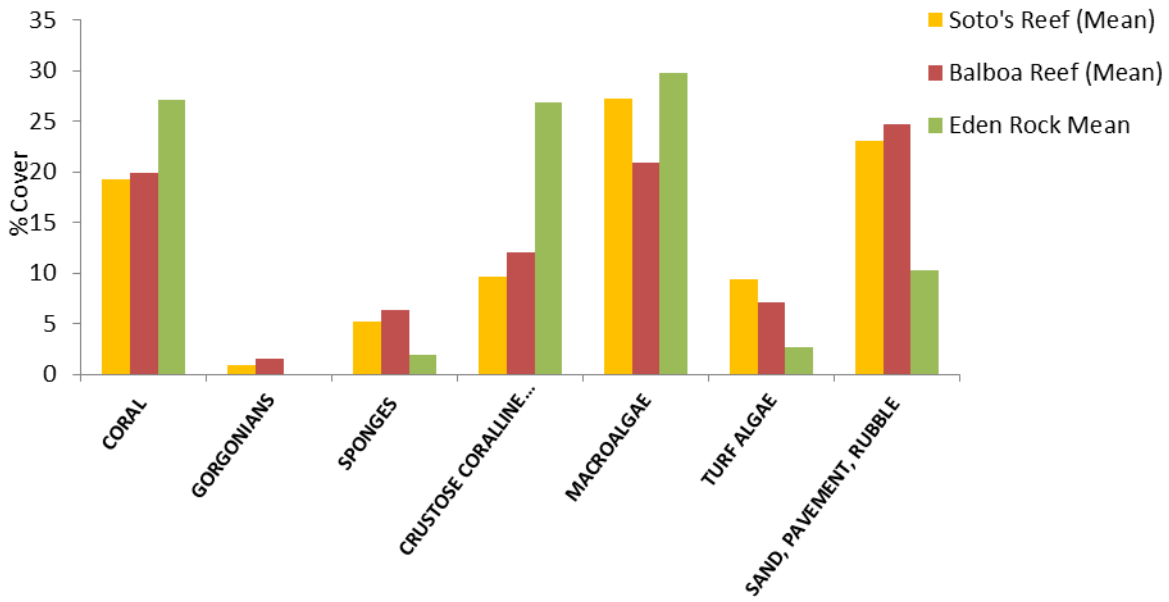


Figure 16.8 Percent cover contribution of key benthic components, including stony corals (live coral), gorgonians, sponges, algal functional groups (macroalgae, turf and crustose coralline algae), and substrate types (sand, pavement, rubble).

16.3.2.2 Algal cover

Crustose coralline algae (CCA) were found at all sites, most frequently encrusting bare substrate on the tops and sides of spurs. CCA cover was high (6-27%, mean cover, 12% +/- 2.8), supporting the notion of healthy herbivory in the area. Macroalgal cover on GTH reefs ranged from 15% (Balboa Reefs-T12) to 49% (Soto's Reef – T14), with a mean cover of 25% +/-7.2. Turf algae covered, on average, 8% of the substrate.

The prevalence of massive corals and calcareous coralline algae relative to the abundance of fleshy macroalgae and algal turfs indicates a healthy, spatially heterogeneous benthic community reflecting relatively low nutrient inputs and high herbivory (Littler and Littler 2006). On the GTH reefs, the coral and CCA cover represent, on average, 32% of the substrate cover relative to 33% by macroalgae and turf algae. This tenuous balance suggests that the top-down control exerted through herbivory is sufficient to offset bottom-up effects of existing nutrient levels. However, it also suggests that the existing steady state is close to the tipping point, beyond which rapid reef degradation can occur.

16.3.2.3 Coral Species

A total of 26 species of scleractinian and one genus of hydrozoan corals were identified in the GTH phototransects. The most prevalent species across all sites were *Orbicella annularis, Porites astreoides*

and *Agaricia agaricites* (**Figure 16.9**). These species accounted for 82% of live coral cover on Soto's Reef and 79% on the Balboa Reef. At Eden Rock, 84% of the live coral cover was attributed to *Orbicella annularis, Porites astreoides, Agaricia agaricites* and to *Orbicella faveolata* colonies. *Siderastrea* boulders were more abundant among patch reefs inshore, whereas *Diploria* colonies were scattered throughout the reefscape. *Acropora cervicornis* thickets were observed on low-lying reefs, especially around the Balboa. Eden Rock was the only site in the harbour where young *Acropora palmata* colonies were found. Eden Rock is a particularly healthy coral reef; as such, all measures should be taken to protect this area.

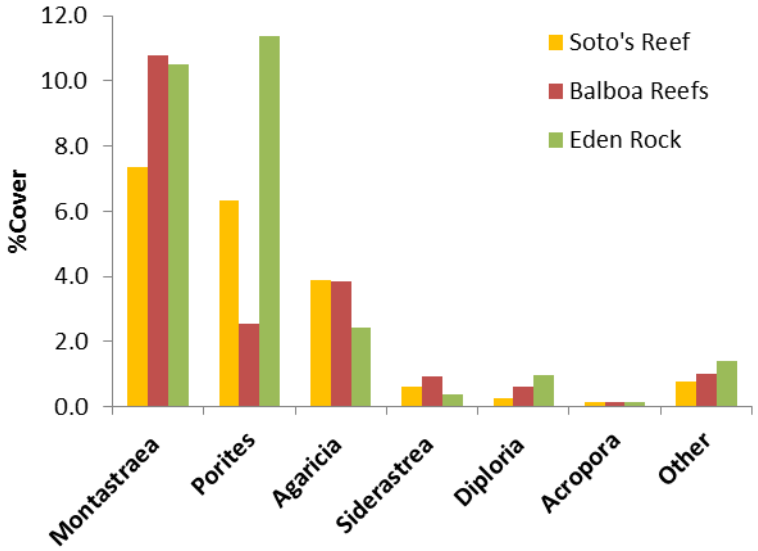


Figure 16.9 Percent cover contribution of dominant scleractinian corals found on Stoto's Reefs, Balboa Reefs and at Eden Rock

Coral mortality was highest at shallow sites closest to shore (i.e. 8.3% at T8, T9, and T11) as compared to 4.4% of the coral cover at T12 located in the vicinity of the Balboa wreck. Average mortality observed on Soto's Reef was 4.9%, compared to the 1.25% mortality observed on Eden Rock. Higher partial mortality (9.2%) observed on the nearshore reefs could be attributed to the re-suspension of sediments, runoff and nutrient loading, all of which can contribute to smothering of coral colonies.

16.3.2.4 Threatened coral species

In August 2014, NOAA listed twenty additional corals as threatened under the *Endangered Species Act*[11]; six of these species are found on GTH reefs (**Table 16.1**). While the announcement did not come with specific restrictions on harming these corals, either directly by harvesting them or indirectly by altering their habitat, it does bring to the forefront the imperative need for protection of these species.

[11] http://www.nmfs.noaa.gov/pr/species/invertebrates/corals.htm

Table 16.1 Coral species listed as threatened under the Endangered Species Act

Species Name	Soto's Reef	Balboa Reefs	Eden Rock
Acropora cervicornis (Staghorn)[2]	X	X	X
Acropora palmata (Elkhorn)[12]			X
Orbicella annularis	X	X	X
Orbicella faveolata	X	X	X
Orbicella franksi	X	X	X
Mycetophyllia ferox	X		

16.3.2.5 Coral Recruitment

A total of 240 quadrats (5 quadrats along the length of each 33 ft (10 m) transect) were sampled to estimate the abundance of coral recruits and juvenile corals (< 2 in, or <4 cm). The abundance was variable within and between sampling sites, ranging from 0 to 6 recruits per 10 in x 10 in (25 x25 cm) quadrat. Of the 12 species that were observed, *Agaricia agaricites* and *Porites astreoides* were most abundant recruits found at all the sites (**Figure 16.10**). Other species included *Siderastrea*, *Orbicella*, *Diploria* and *Stephanocoenia*. *Siderastrea* juveniles, which were most abundant on rocky substrate closer to shore (T11), whereas *F. fragum* juveniles were common at all sites.

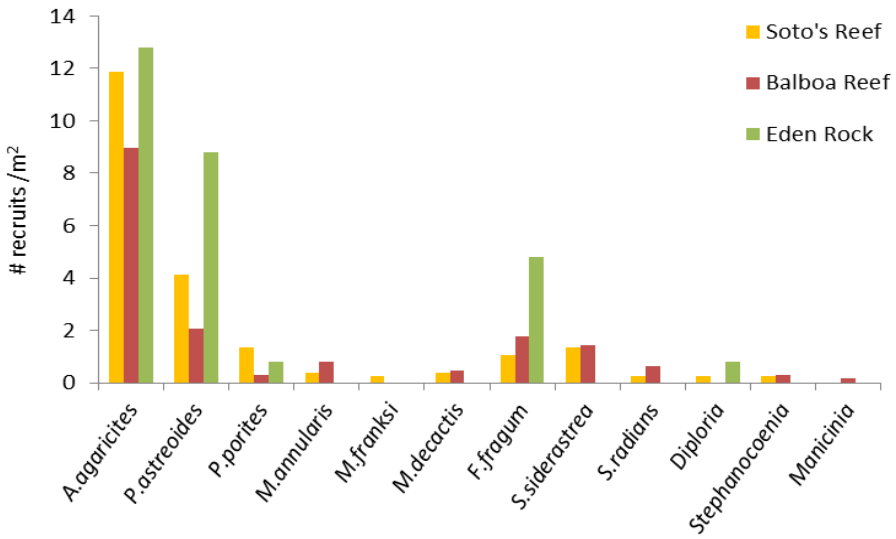


Figure 16.10 Estimated number of recruits per species, per unit area (#/m²) based on quadrats sampled along transects on Soto's Reefs, Balboa area reefs, and at Eden Rock

[12] *Acropora cervicornis* and *Acropora palmata*, are both listed as Critically Endangered on the IUCN Red List, and listed on Appendix II of CITES

16.3.2.6 Other Species

In addition to coral, other reef fauna encountered during surveys included gorgonians, sponges and fouling species such as the mat tunicates. Urchins, primarily rock boring urchin (*Echinometra lucunter*), and to a lesser extent *Diadema antillarum,* were present at all sites, but were underrepresented in the survey because of their hidden distribution. (Refer to Appendix J.1 for a complete list of other fauna observed during benthic surveys).

16.3.3 Fish Community Structure

A total of 11,705 fish and 99 species of fish were recorded across the three reef areas, with 5,612 at Soto's Reef, 5,008 at Balboa and 1,085 at Eden Rock (**Figure 16.11**). The majority of the fishes (86.3%) were found in the juvenile (<0.2 in; 2.4-4 in) (<0.5 cm; 6-10 cm) and intermediate phase (4.3- 8 in) (11-20 cm) size classes.

The average density of fish across all three sites was estimated at 2.17 fish/m^2, compared to the average value of 1.3 fish/m^2 reported by Bruckner (2010) for the Cayman Islands . There were differences between fish density numbers at each site: on Soto and Balboa reefs the densities were 2.7 and 3.1 fish/m^2 respectively, compared to 1/m^2 at Eden Rock (refer to Appendix J.1 for a summary of functional groups and size-class distribution of fish recorded in the survey).

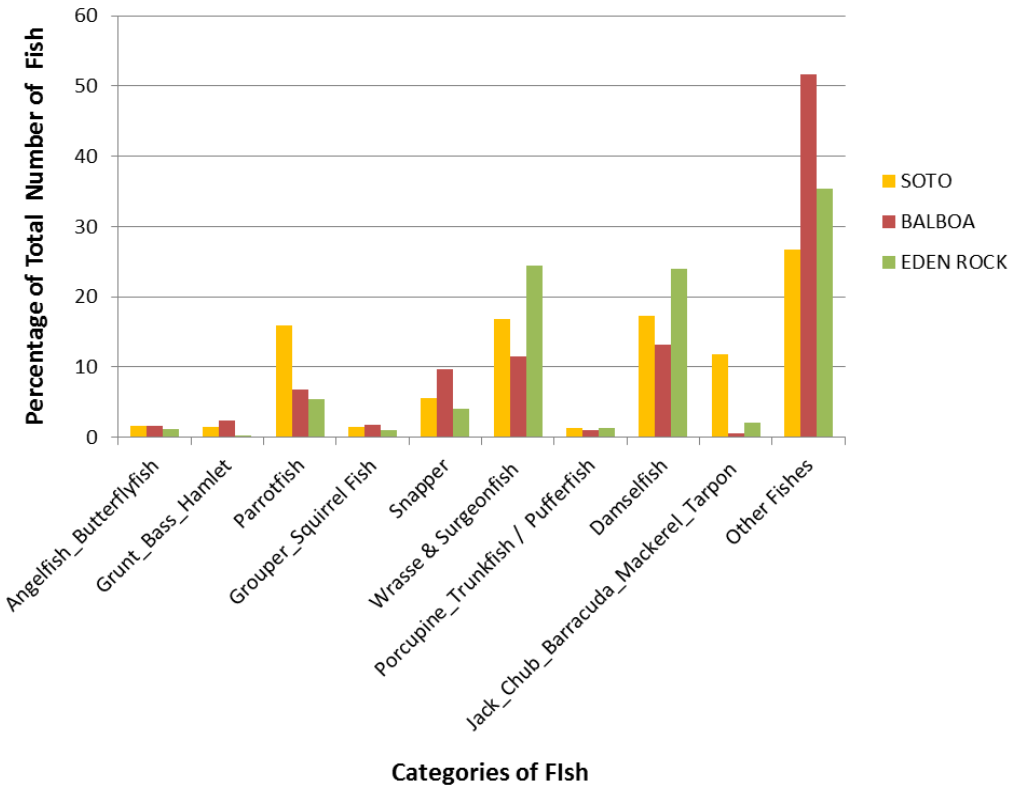


Figure 16.11 Relative abundance of fish /m^2 at the three reef sites as a % of the total number of fish

16.3.4 Rugosity

The physical structure of a coral reef habitat fundamentally influences its associated biodiversity and ecosystem function, with more complex habitats fostering species coexistence through niche partitioning and provision of refuges from predators and environmental stressors (Alvarez-Filip et al. 2009). The rugosity index is typically classified into three categories, low (≤0.170), moderate (0.170 ≤ 0.275) and high (>0.275) (Faud 2010). In GTH, rugosity values ranged from 0.18 to 0.79 across all transect sites. The average rugosity value at Soto's Reefs was 0.42 (SD +/- 0.1), 0.47 (SD +/- 0.09) for the reefs in the vicinity of the Balboa Reef, and 0.58 (SD +/- 0.2) at Eden rock. According to **Table 16.2**, average rugosity at all the sampling sites falls into the high rugosity value, except at T1 where the rugosity reflected a more moderate topography.

Table 16.2 Average rugosity index values for all transect sites sampled. The depth values reflect the maximum depth at each site and the recorded depth on top of spurs provides an estimate of spur heights

Site Name	Depth (Top of spur) (m)	Max Depth (m)	Average Rugosity Index
T1	5.5	7.6	0.27
T2	8.5	11.9	0.37
T3	4.6	7.6	0.51
T4	5.8	8.5	0.40
T5	4.6	9.1	0.47
T14	4.3	6.7	0.48
T8	6.1	7.6	0.50
T9	4.6	7.0	0.53
T10	4.0	7.6	0.47
T11	3.7	4.9	0.39
T12	4.6	7.6	0.47
T13	3.0	10.7	0.58

16.3.5 Marine Protected Area and Functional Connectivity

Marine Protected Areas (MPAs) in GTH contribute to the protection of biodiversity, the maintenance of natural species ranges, protection of unique, endemic, rare, and threatened species, and protection of areas essential for ecological processes (e.g. spawning and feeding grounds). Despite it being a multi-use area (i.e. port facility, mooring area, water-sport recreational area, marine park, etc.) the reefs in George Town Harbour show remarkable resilience.

The heterogeneous reefscape in GTH provides functional connectivity between the reefs north of Soto's Reef (i.e. 7 Mile Beach) with reef areas in the harbour and those south of the harbour. Functional connectivity describes the degree to which the reefscape characteristics enable or impede movement of fauna among reef patches within and between habitat areas (Taylor et al.

1993). Functional connectivity has important implications for the functioning of Marine Protected Areas on the island's west side because spatially clustered segments allow for ecological linkages, including migration of individuals during developmental stages as well as during diurnal migration of fauna between habitats (Mumby and Harborne 2006).

16.3.6 Economic Valuation of Goods and Services

Based on a preliminary resource valuation, the economic benefit derived from the 87 acres (35 hectares) of coral reefs that lie within the bounds of George Town Harbour has been estimated to be in the order of US$23- 26M/year (refer to Appendix J.2), or US$66-75/m^2/year. For comparison purposes, available information regarding the costs of coral damage and coral restoration efforts range from US$250-1,800/m^2

16.4 Impact Assessment

16.4.1 Ecological Assessment of Project Layouts

Several cruise berthing facility (CBF) design options were evaluated (**Table 16.3**). Damage to the reef is inevitable under all options; however the magnitude of the damage is variable. Option A has a dredge footprint of 49 acres (15 ha) of which 23 acres (7 ha) is reef area which would be directly impacted by dredging. Variants of Option B represent the "least impact" options with ~ 3 and 4 acres (~1.2 and 1.5 ha) of reef area to be affected by dredging and construction. Variants of Option B are favorable from an environmental perspective because they minimize direct damage to the reefs while preserving ecosystem functionality (**Figure 16.12**).

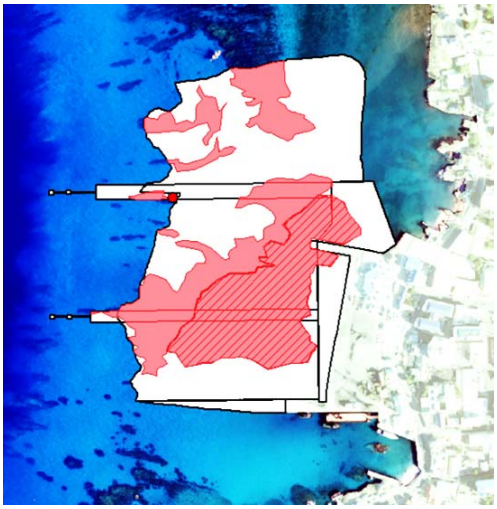
16.4.1.1 Impacts Option C

The dredging footprint for option C (**Figure 16.13**) is 32 acres (13 ha) and will impact ~15 acres (~6 ha) of reef area and the wreck of the Balboa (i.e. Balboa Reefs). Furthermore, it is estimated that an additional 15-17 acres (6-7 hectares) (orange), primarily reefs located within 660ft (~200m) of the project footprint, (i.e. Soto's Reef, Eden Rock and possibly Devil's Grotto) will be exposed to extended periods of lethal/sub-lethal sedimentation and turbidity (shading) during the dredging operations and to chronic sediment re-suspension during the operational phase; they are designated as high-impact zones (orange areas) where high coral mortality is likely. The encroachment of the dredge area onto Soto's Reef and onto Eden Rock is a serious concern. Dredging will not only cause direct damage to the reef formations in these areas, but it may also impede the implementation of mitigation measures (e.g. silt curtains may drift onto the reef spurs during moderate to rough reef conditions).

Table 16.3 Project layouts were analyzed to estimate the surface area of the reef substrate within the respective dredge footprints.

	% Coral Cover (Range)	OBC OptionMM7D	Option A	Option B Refined	Option B Shift NE	Option C Final
Dredge footprint **(ha)**	10-30%	17.3	15.3	1.5	1.2	12.6
Mixed patch reef **(ha)**	10-15%	3.2	3.5	0.7	0.7	3.2
Spur and groove **(ha)**	14-30%	5.1	3.8	0.9	0.5	2.8
Coral reef area in the dredge footprint (ha)	10-30%	**8.4**	**7.3**	**1.6**	**1.2**	**6**
High Impact Zone (ha)* Reef area located within ~200 m of the dredge footprint	14-30%	6-7	6-7	6-7	6-7	6-7
Dredge footprint **(acres)**		**42.8**	**37.8**	**3.7**	**3**	**31.2**
Coral reef area in the dredge footprint **(acres)**	10-30%	**19.8**	**18**	**3.9**	**3**	**14.8**
High Impact Zone **(acres)** Reef area located within ~200 m of the dredge footprint	**14-30%**	**15-17**	**15-17**	**15-17**	**15-17**	**15-17**
(%) of reef area dredged		64.6	56.2	12.3	9.2	46.2

** High Impact Zone : Based on plume model studies (refer to Chapter 11), it is estimated that an additional 6-7 hectares (orange), primarily reefs located within ~200m of the project footprint, (i.e. Soto's Reef, Eden Rock and possibly Devil's Grotto) will be subjected to extended periods of lethal/sub-lethal sedimentation and turbidity (shading) during the dredging and construction phases of the project and to chronic sediment re-suspension during the operational phase (Figure 16.13). High coral mortality is likely.*



- **Option A**

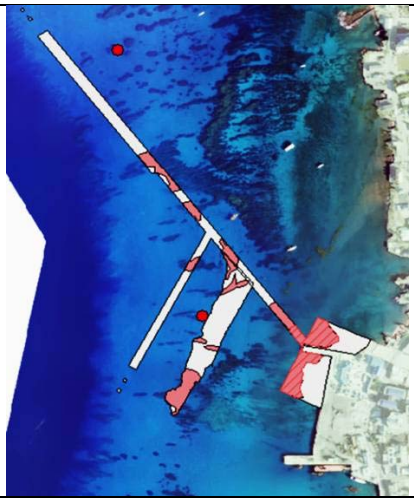
This option would destroy the Balboa Reef (T8-T12) and a segment of Soto's Reef. The reef area within the dredge footprint is a combination of low relief, fragmented patch reefs and high well developed spurs with healthy coral cover ranging from 13-29%. The required dredging would directly destroy 18 acres (72,324 m² or ~7ha) of the reef area as well as the wreck of the Balboa and the associated coral community, including extensive settlement by gorgonians and corals.

Given its proximity to the southern arm of the pier, deleterious effects can be expected for T13 (e.g. Eden Rock) during dredging (stress from sedimentation).The proximity of the northern arm of the pier to T1 poses a potential risk to the site from operation during rough (*north-westerly*) weather (e.g. mooring line failure). The proximity of Soto's Reef to the dredge footprint would expose the area to stress associated with chronic sedimentation and decreased water quality, both during construction and operational phases of the project.



- **Option B - Least Impact**

This layout represents the "least impact" option. The reef area within the dredge footprint covers 1.2 ha. This option would have the smallest dredging footprint, with the least direct damage to the reefs. The objective of this layout was to minimize direct damage to the reefs by reducing the need to dredge and by placing the piers away from the reefs, thereby further reducing the potential for direct damage. The pilings used to support the piers would not impact on the functional connectivity of the area. Option B (both variants), while minimising the amount of dredging relative to the other options, still require dredging that would destroy part of T12, a very healthy reef, the wreck of the Balboa and part of T10 (Option B-Refined). As with other options, the proximity of reef areas to any type of dredging and construction is of concern.



- **Option B Refined**

The reef area within the dredge footprint and under piers is estimated to cover approximately 1.5 ha. This option was one of the three that were presented to the cruise lines.

For Options B and B-Refined, coral relocation could be used to save the corals within the dredge footprint and to offset some of the damage caused by dredging and construction.

Figure 16.12 - Project layouts were analysed to estimate the reef substrate surface area within each of the dredge footprints

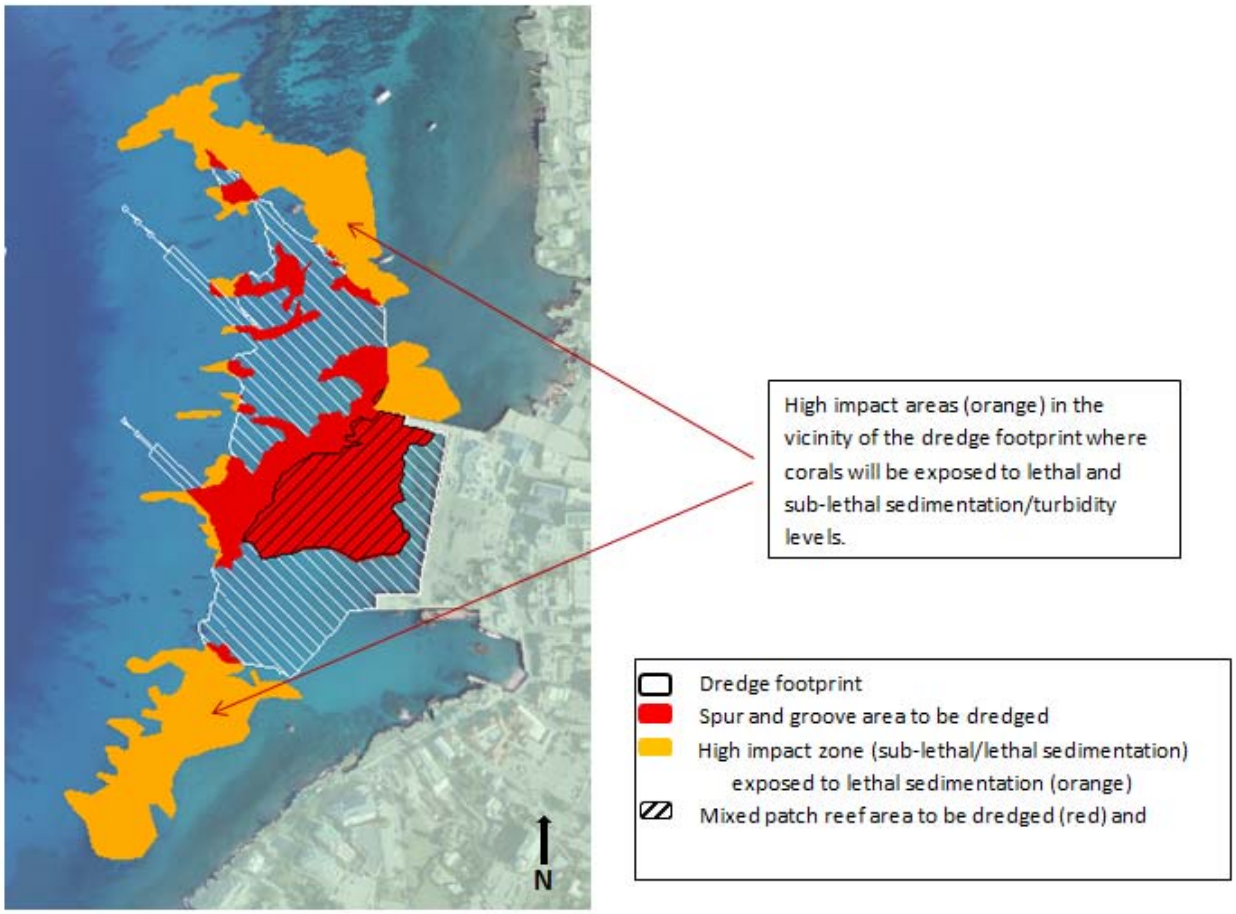


Figure 16.13 - Schematic of Option C representing the reef area that will be subject to direct and indirect impacts from dredging, landfill and resulting in increased turbidity and sedimentation. The high impact zone was based on dredge plume modelling described in Chapter 11

16.4.2 Assessment of Impacts-Dredging and Construction Phase

In accordance with the Terms of Reference, anticipated impacts within the project footprint are discussed for the various phases of the project's life cycle, including the following:

- Dredging phase
- Construction phase
- Operational phase
- Other impacts-Influence of climate change on marine ecology

16.4.3 Dredging Phase

Depending on the nature of the materials to be dredged, and the dredging equipment to be used, dredging may take 30-120 days to complete. The dredging footprint for the final layout (i.e. Option C) covers 32 acres (~13 ha) of marine substrate, of which 15 acres (~6 ha) or 48% of the dredge

footprint, is comprised of coral reef substrate (**Figure 16.14**). Dredging activities will result in physical and biological changes in the harbour, resulting in direct impacts within the project footprint and indirect impacts on adjacent reefs.



Figure 16.14 - GTH Option C dredge footprint covers 13 hectares of which 6 hectares are reef substrate

16.4.3.1 Turbidity and Sediment Dispersal

The sedimentation and turbidity impacts associated with the dredging operations are expected to have both short and long term negative impacts on nearby coral reefs. Specific environmental impacts of dredging include:

- Increased turbidity causing a decrease in light penetration and smothering of coral;
- Short-term decreases in dissolved oxygen levels due to excessive sedimentation;
- Dispersal of sediment from the dredge area onto nearby coral reefs (Refer to Chapter 11 and Appendix D.2);
- Release of contaminants from sediment and the ensuing uptake by fish and other biota (refer to Chapter 12 and Appendix E);
- Accidental leaks or spills of dredged materials from equipment during dredging.

In contrast to the short-term impacts from dredging activities, sedimentation and turbidity resulting from ship propellers and thrusters represents a likely chronic impact that could affect water quality in the long term due to repeated re-suspension of sediments. Flora and fauna,

particularly sessile organisms, would suffer under conditions that promoted chronic re-suspension of sediments.

16.4.3.2 Offshore Disposal

Disposal of dredge spoil may cause impacts similar to those associated with dredging. Impacts associated with offshore disposal of dredge material include turbidity in the water column, smothering of flora and fauna around the disposal site and the possible dispersal of the dredge spoil over a larger area. Inadvertent spills or seepage of dredge material over coral reefs during transit also present a potential impact (Refer to Chapter 11 and Appendix D.2).

16.4.3.3 Impacts of Dredging on Corals

The proposed dredging will destroy the Balboa Reef and will encroach on sections of Soto's Reef and Eden Rock. The following are expected immediate and delayed responses of corals to dredging and to increased turbidity and sedimentation resulting from dredging:

Coral loss due to dredging (Direct impact)

The most obvious and direct impact of dredging is the actual destruction of coral within the project footprint due to the digging/cutting action of the mechanical dredger.

Coral Loss due to increased turbidity and sedimentation (Indirect impact)

Excessive turbidity and sedimentation due to dredging represent a major stress on coral systems which can impact negatively on the long term resilience of the system. The decline of a reef system under sediment stress proceeds in a series of steps:

- Light attenuation due to water turbidity causes shifts in the coral community functioning;
- Direct deposition of sediment on coral heads results in a selective loss of coral species that are less tolerant to sediment loading;
- Increased potential for additional loss of coral cover and a shift in the dominance to species tolerant to high sedimentation;
- Dead coral areas become overgrown with an algal-sediment mat and the total available space for coral larvae attachment or asexual coral head expansion is reduced;
- There is a marked increase in the dominance of species tolerant to high sedimentation;
- Increased susceptibility to coral pathogens.

Photo-physiological stress and coral mortality (Indirect Impact)

Light attenuation is a significant sediment-related effect of dredging on corals, resulting in a decline in photosynthetic productivity. Photo-physiological stress occurs within hours of exposure to elevated suspended solids concentrations, and may lead to reduced fitness of coral colonies or even mortality if the stress persists.

Smothering and mucus production (Indirect Impact)

The capacity of coral colonies to withstand increased sedimentation depends on sediment type (fine or coarse) and the ability of the corals to clear their surfaces of sediments. Stresses due to the settling of particulate matter on coral surface relates to decreased levels of photosynthesis and the concurrent increase in energy costs associated with elevated rates of respiration due to excessive mucus production and ciliary action required to remove sediments from coral surfaces. While larger sand-sized particles are harder to remove, an accumulation of fine silt on coral surfaces over an extended period of time is likely to cause more damage.

Reduced coral fitness and reduced coral recruitment (Indirect Impact)

Delayed non-lethal effects of prolonged exposure to attenuating light conditions include decreased net productivity of corals, decreased skeletal growth, calcification and tissue regeneration (Meesters and Bak 1993), and decreased resistance to disease (Lesser 2007). The overall reduction in coral fitness due to turbid conditions can lead to delayed mortality of individual colonies, and to a subsequent decrease in coral abundance and diversity. Reduced growth rates can aggravate any injuries already present. Further, increased sediment input (either in suspension or as accumulating particles) can radically reduce larval recruitment and survival.

Bleaching and coral mortality (Indirect Impact)

Bleaching can occur in response to various stressors including prolonged exposure to increased turbidity and sedimentation. If increased turbidity and sedimentation are short-lived and the bleaching is not too severe, the affected corals may recover within several weeks or a few months. If, however, turbidity and sedimentation persist or become chronic, then coral mortality is likely.

Increased susceptibility to disease (Indirect Impact)

There is a direct link between sedimentation due to dredging and increased susceptibility to pathogens. Dredging near coral reefs significantly increases the frequency of diseases afflicting corals (Pollock et al. 2014).

16.4.3.4 Impacts of Dredging on Coral Reef Habitat

Anticipated impacts of dredging on the coral community in GTH will be both direct and indirect:

- Immediate loss of coral and loss of habitat within the project footprint (direct).
- The response of nearby coral reef communities to both transient and permanent impacts resulting from dredging and construction activities, and project operations (indirectly).

Loss of habitat and habitat complexity (Direct Impact)

In the context of the CBF, the proposed dredging and development of the cruise berthing facility will result in the immediate destruction of the coral reef habitat within the project footprint. Habitat loss and reduced ecological functionality are generally associated with drastic declines in overall abundance and diversity of marine organisms. Generally, the environmental changes associated with the destruction of natural habitats promote the colonization and proliferation of opportunistic species that benefit from disturbed conditions.

Loss of ecosystem functions provided by the habitat (Direct Impact)

Structurally complex habitats such as coral reefs provide a wide range of ecosystem functions to the environment (e.g. nursery grounds, food, refuge, sediment trapping, etc.) all of which contribute to the resilience of the system. Habitat loss implies the loss of these functions which would have negative effects on the productivity of individual species and communities, and possibly the survival of other species (i.e. lobster).

Habitat degradation of nearby reefs (Indirect Impact)

Port dredging and coastal development have negative effects on reef habitats within the project footprint, and carry with them an inherent risk of further ecosystem degradation from factors such as sediment re-suspension, increased water column turbidity, increased nutrient loading and risk of collision damage. The dredge plume models suggest that coral reef areas located within a 330-660ft (100-200m) of the dredging footprint will be under immediate threat from dredging and construction (refer to Chapter 11 and Appendix D.2). Specifically, these areas will be exposed to a gradient of stress due to continued exposure to increased turbidity and sedimentation during dredging, construction and operation of the project.

Loss of coral biodiversity (Direct and Indirect Impacts)

Elevated turbidity and sedimentation can have negative effects on species richness and abundance due to mortality, the subsequent reduction in coral cover and reduced coral recruitment (Rogers 1990). Elevated turbidity levels and sedimentation during dredging will affect highly susceptible coral species, such as *Orbicella* and *Acropora* species, which are listed as threatened under the Endangered Species Act. Other sessile and mobile species whose habitat range is within the affected area will also be subjected to sedimentation stress.

Loss of fish biodiversity (Indirect Impact)

The loss of architectural complexity due to post-dredging degradation of the GTH reefs may drive a decline in diversity of habitat specialists and compromise fisheries abundance and productivity (Graham et al. 2007). Excessive sedimentation can further alter the complex interactions between fish and their reef habitat. Declines in live coral cover and rugosity of the reef are associated with a reduction in both the number of fish species as well as in the abundance of fish. Sedimentation can also affect recruitment of other species.

Habitat fragmentation and loss of functional connectivity (Direct Impact)

Dredging of the GTH reefs will result in habitat fragmentation and will compromise the integrity of a network of reefs that connects the reefs north of Soto's Reef and south of Eden rock. The 565-660ft (500-600m) gap that will be created by dredging will negatively impact the functional connectivity of the area, with implications for fish and invertebrate migratory pathways as well as population dynamics. The destruction of fish habitat, spawning and feeding grounds, and the disruption of fish migration routes, represents a direct long-term negative impact to the fish community in the harbour.

Loss of habitat: Balboa (Direct impact)

Most of the development options presented call for dredging at the present location of the Balboa. Much of the surface of the wreck of the Balboa supports a healthy population of hard corals, Gorgonians and sponges which will be lost due to dredging and construction.

Loss of ecosystem goods and services (Direct and indirect impacts)

The Marine Resource Valuation Report (Appendix J.2) estimates the value of goods and services provided by the GTH reefs, as they stand now, and provides an estimate of expected economic losses due to dredging and reef degradation. Ecosystem degradation and the loss of biodiversity weaken ecosystem functioning and resilience, thereby compromising the ability of the system to continue supporting ecosystem-related goods and services for present and future generations (de Groot et al. 2012). The loss of architectural complexity on the reefs in GTH is likely to have serious long-term consequences on reef biodiversity, ecosystem functioning and associated environmental services, such as fisheries productivity, biodiversity and functional connectivity.

It is estimated that the loss of ecosystem goods and services would result in economic losses in the order of US$8-10.5M/yr (based on current spend rates) related to direct and indirect damage to marine ecosystem goods and services within GTH caused by the project, in particular due to the loss of coral reefs and associated business for local watersports operators, plus indirect impacts to employees' incomes and purchasing power. Assuming 1-3%/year growth in cruise passenger traffic over the 20 year life of the project (as per the OBC), this correspondes to an estimated economic loss in the order of US$120-200M (range in net present value assuming a 3.5% discount rate).

The estimated economic losses presented above represent the anticipated project-related impacts resulting from the direct loss of a natural resource (coral reefs) which is essential to the watersports industry in GTH, as well as the indirect impacts to employees' incomes and purchasing power. It is noted that the estimated economic losses are based on a preliminary marine resource valuation derived from current spend rates, and are subject to some uncertainty. Further analyses are required to adjust the estimated losses to reflect the Gross Value Added (GVA) to the overall economy of the Cayman Islands, and also to account for the anticipated diversion/displacement of businesses from within GTH to other locations and/or activities/attractions in George Town and around Grand Cayman Island. It is recommended that the OBC be updated to reflect these and other socio-economic impacts identified in the EIA.

16.4.4 Construction Phase Impacts

In addition to dredging and offshore disposal, several other aspects of the project's construction phase have been identified as having significant potential to impact the receiving environments in the vicinity of the project footprint:

- Land reclamation works (placement and dewatering of dredged materials);
- Installation of the pilings and construction of piers;
- Landside construction works.

16.4.4.1 Use of Dredge Material for Reclamation (Direct Impact)

As previously noted, elevated levels of suspended solids are likely to occur during dredging, as well as during transportation of the material to the reclamation and offshore disposal sites; this can be caused by overflow from barges or leakage from pipelines. Further, the use of dredge material for land reclamation raises concerns of additional sediment loading into harbour waters that could potentially spread over nearby reefs and add to the already high turbidity and sedimentation levels that the reefs will be exposed to during dredging. As noted later, these risks can be mitigated through appropriate design and careful planning of the works.

16.4.4.2 Dewatering of dredge material (Direct Impact)

Dewatering (i.e. the process of draining the water and fine sediments from transport barges and from land reclamation) has the potential to create turbidity plumes of suspended sediments in the water column, which could then settle onto the nearby reefs to smother the reef flora and fauna. The risk of containment structures (e.g. dikes/bunds) rupturing poses an additional threat to nearshore reef habitats from excessive volumes of sediment-laden dredge material (i.e. exceedance of sediment thresholds). As noted later, these risks can be mitigated through appropriate design and careful planning n of the works.

16.4.4.3 Installation of pilings and construction of piers

The construction of the piers on pilings has been chosen as least damaging design to the marine environment, however, there are several concerns, including potential impacts from the installation of the pilings using a vibratory pile driver rig:

- Damage from the placement of the anchors/spuds of the barge that holds the vibratory pile driver. Given the proximity of the project footprint to adjacent reefs, improper anchorage and the risk of grounding by the barge pose potential risks to the marine environment (e.g. damage to Soto's Reef).
- Potential negative effects of the sound/vibration produced during pile driving on marine fauna. Un-attenuated pile strikes can produce a sound pressure level around 180 dB RMS at a distance of 650 to 1000 feet (200–300 meters; California Department of Transportation 2009)[13]. Exposure to low levels of sound for a relatively long period of time, or exposure to higher levels of sound for shorter periods of time, may result in auditory tissue damage in fish, though recovery is generally possible within 24 hrs (Popper et al. 2005). Oscillations induced by high sound pressure levels can cause swim bladders in fishes to rupture (Hastings and Popper 2005). It is likely that most species of fish would swim away from an intense sound source, thereby decreasing exposure to sound; however, larvae and eggs of fish (and corals) are often at the mercy of currents or move very slowly.
- Damage to marine life, alteration of local currents and sediment fluxes.
- Structures constructed in the ocean may alter localized currents, resulting in settling out of sediments carried by currents. Water currents and sediment fluxes will change, resulting in increased sedimentation rates on nearby reefs, which may affect the marine flora and fauna in the area.
- Any construction activities near water, especially the pouring of concrete and placement of scaffolding, where the debris can be washed or swept into the water, can contribute to the degradation of adjacent reefs (i.e. Soto's Reef, Eden Rock, 7-Mile Beach, etc.).

16.4.4.4 Infrastructure construction (Direct Impacts)

The proposed development entails the construction of the cruise ship terminal, and associated onshore infrastructure. Impacts to the ecology of the area resulting from the activities associated with the proposed landside development may involve the following:

Change in drainage patterns and resulting impacts on marine ecology

The development of the port facilities and the onsite storage of building materials as well as modified drainage patterns have the potential to release larger volumes of sediment-laden water

[13] By comparison, large tankers and naval vessels produce up to 198 dB, depth sounders can produce up to 180 dB and even small boats with large outboard motors can produce sound pressure levels in excess of 175 dB (WSDOT 2006).

into sensitive nearshore habitats during heavy rains, especially during the construction phase (refer to Chapter 13). The resulting turbidity and sedimentation would negatively impact the inshore water quality and the associated flora and fauna. These issues have been considered in the development of the storm water drainage masterplan for the project (refer to Chapter 13).

Transportation and storage of construction materials

Use of uncovered trucks for transporting construction materials, as well as improper storage of materials, especially gravel, sand and cement at the construction site could cause inadvertent dispersal (dust, spillage and emissions) of materials during heavy rains or high wind conditions, with localized negative impacts on coastal waters; cement raises the pH of the surrounding seawater considerably (Stark 1955), so pier construction has the potential to affect the relatively well-developed coral communities that exist <1 km down-current of the construction site. Further, improper storage or handling of hazardous or flammable materials, including fuel, paints and solvents, could result in contamination and eventual leaching (or direct runoff) of these substances into the harbour waters.

16.4.4.5 Disposal of construction debris

Each phase of the development will produce solid waste, the disposal of which, if not managed properly, could have negative impacts on the site and the surrounding area. Construction materials, including concrete waste, wood, steel and packaging plastics could be dispersed and could end up blocking drainage channels or creating direct damage to nearshore flora/fauna if not disposed of at an approved disposal site.

16.4.4.6 Sewage and garbage disposal

Inadequate provision of portable restrooms and garbage dumpsters at the construction site can lead to unsanitary conditions. Resulting impacts would vary from unsightly littering of the site, fly and vermin infestations to increased nutrient loading of coastal areas.

16.4.5 Operational Phase

Operational project impacts arising from cruise ship traffic and increased use of the new port facilities may include:

16.4.5.1 Maintenance Dredging

While harbour dredging may be viewed as a short term impact, the possible need for maintenance dredging to remove accumulated sediment in the dredge pocket represents a possible future/ongoing impact that could expose the reef areas to intermittent stress from dredging-related turbidity and sedimentation (refer to Chapters 10 and 11, and Appendix D.2).

16.4.5.2 Increased turbidity and sedimentation

Increased exposure to repeated propeller wash will result in chronic increases in turbidity and re-suspension of sediments, which will contribute to ongoing degradation of nearby reefs. Potential damage from cruise ship groundings and the inherent risk of future accidents represent long-term threats and direct impact.

16.4.5.3 Ballast water and invasive species

Cruise ships rely on quantities of ballast water for vessel stabilization. Ballast water discharge is the leading source of non-native or invasive species that enter shallow marine waters.

16.4.5.4 Cruise ship sewage – black and grey water discharges

Cruise ship black water is typically more concentrated than land-based sewage and may contain bacteria, pathogens, diseases and viruses requiring treatment prior to its release. Grey water, which represents the largest proportion of liquid waste generated by cruise ships, includes drainage from dishwashers, showers, laundry, baths, galleys, and washbasins. It can contain pollutants such as faecal coliform, food waste, oil and grease, detergents, shampoos, cleaners, pesticides, heavy metals and, on some vessels, medical and dental wastes. Illegal or accidental discharge of ship sewage, black or grey water in Cayman waters or in GTH poses a direct threat to the marine flora and fauna.

16.4.5.5 Contaminated bilge water and accidental pollution events

Illegal or accidental discharge of bilge/ballast water (and contaminants) by cruise vessels in international or coastal waters, as well as oil spills resulting from collisions and groundings, represent a serious threat to pelagic and coastal marine life. Petroleum pollution is known to have adverse effects on coastal ecosystems and their associated inhabitants including marine mammals, sea birds, fish, plankton and other invertebrates. Exposure of marine flora and fauna to oil and contaminated bilge products poses a serious threat to the reef community in GTH.

16.4.5.6 Potential for vessel grounding during berthing

The operation of vessels closer inshore, especially during Nor'westers, presents a risk of ship collision or grounding (e.g. due to power or steering failure, mooring line breakage or pilot error). Ship groundings can potentially result in flattening of a reef section and destroying the benthic fauna in the impact area. Further damage to the marine environment can be expected from re-suspension of sediments during rescue or salvage operations, as well as from potential oil, fuel or bilge water spills. The inherent risk of future accidents (i.e. damage from cruise ship groundings) represents a long-term threat with potential for direct impacts to the reef habitat.

16.4.5.7 Impacts of increased tourism

Exceeding the carrying capacity of the marine environment has the potential to further degrade the marine environment that presently makes GTH an attractive tourist destination. Potential impacts from increased tourism on coastal ecosystems include:

- Overexploitation of reef resources;
- Damage to remaining coral reefs from divers and snorkelers:
- Potential for exceeding carrying capacity of alternate attraction sites;
- Inadequate landside facilities to deal with sewage and solid waste generated by increased tourist traffic;
- Additional demands on potable water;
- Wear and tear on the surrounding environment.

16.4.5.8 Cumulative effects

Impacts from the construction phase of the pier construction and the impacts from operations will permanently alter the ecological landscape of the area. While it is difficult to provide a full assessment of the magnitude of all potential impacts, it is important to note the significant potential for long-term negative cumulative effects. Some of these may include:

- Impact of severe storm events on the CBF. Destruction of all or part of the proposed facility during storms (i.e. high category hurricanes) could potentially generate large amounts of debris to nearby marine and coastal environments.
- Increased potential for pollution and nutrient loading of the marine environment from debris generated by increased numbers of tourists using the facility; debris will end up in the harbour waters where they pose a threat to marine fauna (e.g. birds and turtles ingesting or become entangled in plastic debris), or of being dispersed by currents to reef communities further away.

16.5 Influence of Climate Change on Marine Ecology

Predictions of continued increase in sea surface temperatures (SSTs), in combination with sea level rise (SLR), and increased frequency of severe storm events have the potential to amplify the impacts of localized anthropogenic stressors, and can combine synergistically to reduce local biodiversity and alter or eliminate important ecosystem functions.

Climate change has been linked to increases in coral diseases (Ruiz-Moreno et al. 2012) and reduced calcification due to ocean acidification (Hoegh-Guldberg et al. 2007). However, the main climate-

related threat to coral reefs is coral bleaching caused by abnormally high sea surface temperatures (SSTs) coupled with high solar radiation (Eakin et al. 2009).

Bleaching is a stress response characterized by the disruption of the coral-algal symbiosis due either to the degradation of algal pigments or to partial or complete expulsion of zooxanthellae from the coral host (Douglas 2003). Delayed, non-lethal effects of bleaching include diminished rates of skeletal growth, calcification and tissue regeneration (Mendes and Woodley 2002), impaired reproduction (Szmant and Gassman 1990), and decreased resistance to disease. Bleached colonies can recover after mild bleaching episodes, as temperatures return to their normal seasonal values (Charpentier 2014); however, prolonged bleaching can result in extensive coral mortality and even local extinction of thermally susceptible species (Glynn 1996).

Mitigating impacts of climate change is a challenge that calls on cooperation of the international community, but much can be done at the local level through conservation of coastal habitats and implementation of sustainable coastal development strategies that minimize damage to these ecosystems.

16.6 Proposed Mitigation Measures

The *National Biodiversity Action Plan* (NBAP) for the Cayman Islands (DaCosta-Cottam et al. 2009) lists habitat preservation as the "backbone" of the plan, in that "it carries with it the greatest potential for the preservation of the widest variety of species and functioning ecosystems". The most effective way to conserve ecosystem biodiversity is to prevent or avoid destruction, conversion or degradation of a habitats (IFC-GN6 2012; IFC-PS6 2012) .

The recommended mitigation strategies address project impacts from the view of:

- Compensating for habitat destruction through coral relocation and habitat restoration;
- Minimizing project impacts.

16.6.1 Mitigating loss of coral cover and coral habitat

Mitigation measures such as coral relocation are an expensive undertaking with uncertain results. While coral relocation programs can be successful under the right circumstances, it does not compensate in full for the loss resulting from dredging and should not be looked upon as an all-encompassing environmental restitution for replacing an established and complex habitat. In the case of coral reefs, habitat protection and conservation are valued above compensation. Once destroyed, coral restoration cannot replace the ecosystem functionality or the associated goods and services provided by these ecosystems. Similarly, mitigating the losses associated with the cultural services (tourism and culture) will come at a cost to the local population. For example, the relocation plan for the Balboa will be judged not only on the cost and the execution, but also on the

success of preserving the structure of the wreck along with the corals and other marine fauna that have colonized the wreck surfaces over the years.

16.6.2 Coral relocation and habitat restoration

A coral relocation project should be considered only after all least-damaging alternatives have been eliminated as viable options. The primary objective of a coral relocation program is to minimize the loss of coral destined for destruction due to dredging by relocating select colonies and other benthic components to a new site that resembles the donor site. The end goal is to replace the destroyed reef area and its functionality, to maximize the likelihood of survival of transplanted material, and to lay the foundation for restoring biodiversity at the recipient site.

One of the most challenging aspects of coral restoration is estimating the cost of material and operational costs associated with the various stages of the process. Some of the factors that determine the overall cost is the distance between the donor and recipient sites), the restoration and transplantation techniques (hydraulic tools vs hand tools), cost of labour (equipment and training) and availability of supporting infrastructure (boats, etc.) (Precht 2006).

The cost of coral relocation is highly variable. Based on previous coral restoration undertakings, the cost can range from ~US$23/ft^2 to ~$170/ft^2 (~US$250/m^2 to ~$1,800/m^2), with a median value around US$93/ft^2 (US$1,000/m^2). The median value based on published cases corresponds to the value recently estimated by the Department of Environment, in the case of anchor damage caused by the Carnival Magic cruise ship[14].

In the case of GTH reef relocation, there are two aspects of the project that will require special consideration in the design phase: 1) relocation of coral on spurs (larger spur segments); and 2) relocation of the wreck of the Balboa. The manner in which these are handled will greatly influence the overall cost of the coral relocation/restoration project in GTH.

It is important to note that a coral relocation program will not compensate for the loss of connectivity, the loss of the three dimensional reef structure and complexity, or the loss of habitat of associated flora and fauna that are not migratory in nature but are also an integral part of the existing ecosystem. Further, it is noted that corals within patch reef areas, with lower relief, are better suited for coral relocation than the more complex spur and groove formations. The objectives and scope of the coral relocation program requires further investigation; it is recommended that these investigations be undertaken as part of the design development process should the project proceed (Refer to Appendix J.1, Appendix 3).

[14] http://www.cayman27.com.ky/2014/11/27/putting-a-price-tag-on-carnival-magic-reef-damage

16.6.2.1 Mitigating loss of the Balboa

Much of the surface of this wreck supports an extensive benthic community including coral, gorgonians and sponges. Further investigation of the structural integrity of the wreck is recommended to assess the feasibility of relocating the wreck, which is a designated Archaeological Heritage site. The preferred method would involve the lifting and setting down of large sections of the wreck in order to preserve, as much as possible, the attached flora and fauna. Depending on the final location, relocating the Balboa could make it more accessible to the diving community.

16.6.3 Mitigating impacts of dredging and disposal of dredge material

The following are recommended mitigation measures aimed at minimizing sediment release and spread of the sediment plume onto reef areas adjacent to the dredge footprint:

16.6.3.1 Dredging equipment and minimizing sediment spill

The following recommendations are aimed at controlling the amount of dredge material released into the harbour waters and onto sensitive reef areas (i.e. sediment spill):

- Monitoring and maintaining the dredging equipment in a proper state of repair to prevent leakage from equipment, especially the hopper (transportation) barge;
- Dredging to a slightly greater depth than required to reduce the need for maintenance dredging;
- Minimizing sediment spill by controlling the production rate, and/or by using a closed grab dredge;
- Monitoring the turbidity on adjacent reefs to guide adaptive management of dredging operations;
- Placing turbidity barriers around the dredging areas, and if necessary, doubling up on the barriers.

16.6.3.2 Silt curtains

There is concern that given unpredictable changes in the current regimes (Refer to Chapter 11 and Appendix D.2) dredge plumes may be carried onto nearby reefs. Silt curtains can be deployed immediately between dredging area and adjacent coral reefs to limit the spread of silt plumes over the reef. Similarly, silt curtains, or more appropriate barriers, can be deployed around the land reclamation area to prevent sediments from spreading over nearby reefs. Factors to consider when using silt curtains include:

- The deployment of appropriately sized silt curtains such that the lower edge of the curtain extends deep enough into the water column to effectively minimize sediment transport;

- The use of double or overlapping silt curtains to contain sediment plumes within the dredge area;
- Alternative solutions to be considered: a) deploying silt skirt around the dredger, or b) use of air bubble screens.

16.6.3.3 Timing of dredging operations

In order to minimize the risk of exposure to concurrent stressors, dredging operations should be restricted to periods when the risk of additional (natural or anthropogenic) stress is minimal;

- No dredging during coral spawning season (September-October, March-April);
- No dredging during periods of elevated sea surface temperatures when corals are at risk of bleaching (~August to October);
- No dredging during storm events or when trade winds are strong or during the rainy season when large influxes of fresh water could move significant volumes of sediment-laden water from onshore into the harbour waters and onto the reefs.

16.6.3.4 Use of thresholds

Even if sub-lethal sedimentation and turbidity thresholds are maintained during dredging, the duration of dredging activities will influence the amount and extent of dredging-related mortality of coral and other fauna.

Establishing quantifiable species-specific tolerance limits to increased levels of turbidity and sedimentation can provide an indication of potential impacts of sedimentation levels on the coral reef environment (**Table 16.4**). These thresholds can be used as control parameters for triggering specific management strategies, such as reduced production rate or temporary cessation of dredging operations in response to threshold exceedance.

In general, corals are negatively impacted by sediment deposition rates greater than 10-20 mg/cm^2/day and TSS levels greater than 10 mg/L. Most coral reefs adapt to short periods of high sediment loading which can occur naturally during storm events. For example, considering limited turbidity measurements collected by the DoE in GTH during a Nor'Wester in November 2014, it is apparent that corals in GTH are exposed to suspended sediment concentrations in the order of 10-20 mg/L for durations of 1-3 days periodically during storm events, with sub-lethal effects.

Table 16.4 Response matrix (Erftemeijer et al. 2012) ranking the relative sensitivity of corals according to their type of response to different levels of turbidity (mg /l) and sedimentation rates (mg/cm2/day)

Response intensity	Turbidity level (mg/L)		Sedimentation rate (mg/cm²/day	
	<10	10-20	<10	10-20
No effect	Most species	Intermediate	Most species	Intermediate
Sublethal effects (minor) (reduced growth/calcification, mucus production	Sensitive	Sensitive	Sensitive	Intermediate
Sublethal effects (major) (bleaching, tissue damage)	Very sensitive	Sensitive	Sensitive	Sensitive
Lethal effects (partial mortality)	Very sensitive	Very sensitive	Very sensitive	Sensitive
Lethal effects (mass mortality)	Very sensitive	Very sensitive	Very sensitive	Very sensitive

Thresholds for the management of dredging operations are characterized by a relatively short duration of high concentration plumes (refer to Chapter 11 and Appendix D.2). Given the low background turbidity and sedimentation values reported for GTH, turbidity thresholds of 10 mg/L (rolling average over one week) and sedimentation rates of 10 mg/cm²/day (rolling average over one week) should trigger management responses to ensure the values are not exceeded over reef areas adjacent to the dredging works (refer to Environmental Management Plan).

16.6.3.5 Mitigating effects of increased levels of turbidity and sedimentation due to dredging

Monitoring during dredging works

To monitor the effects of dredging and construction on adjacent coral reefs, turbidity and sedimentation thresholds have been recommended for receiving waters (Refer to Appendix J.1). Baseline physical conditions, especially turbidity and sedimentation levels, have to be monitored for exceedance during dredging and construction phases in order to trigger adaptive management strategies, as may be required, to ensure compliance. The following environmental indicators will require regularly scheduled monitoring:

- Daily metocean conditions (wind, wave, currents)
- Turbidity (NTU) measurements using *in situ* real-time sensor installed on select spots on Soto's Reef and Eden Rock (daily);
- Sediment samples collected at permanent sedimentation stations (every 3 days);
- Coral condition - photo transects and coral tagging (time series observations);
- Direction of the plume (UAV aerial survey -daily);

- Monitor for equipment malfunction and accidental dredge spills.

Adaptive management strategies

- In case of equipment malfunction, immediate cessation of dredging operations until all malfunctions have been remedied;
- Cessation of dredging, or decreased dredging rate, or relocation of dredger to another area immediately if concentration and temporal thresholds are exceeded;
- Relocation/re-deployment of silt curtains;
- Containment of dredge spills and implementation of redundancy and/or back-up solutions to prevent silt plume from spreading over nearby reefs.

16.6.3.6 Mitigation of impacts from land disposal and use of dredge material for reclamation

Use of dredge material for land reclamation presents an additional source of sediment seepage into coastal waters. Implementation of appropriate containment measures, including dike/bund structures and silt curtains, is recommended to minimize the silt content in the water discharged from the reclamation area.

16.6.4 Mitigation of construction impacts

Silt curtains should be used for mitigating impacts during the installation of pilings, construction of the pier's concrete support system and the terminal. Any construction at or near the water's edge, or where debris can be washed or blown into the water, should be surrounded by silt screens, which must be installed before the work starts. Screens should also be placed around storage areas, to prevent waste from blowing away and to prevent sediment run-off into the sea. In addition to silt screens, Caymanian building guidelines require that storage areas for sand and soil, and all work areas, must be at least 20m away from the high water mark, and construction equipment must not be cleaned or washed within 50m of the high water mark.

16.6.4.1 Mitigating changing drainage patterns and resulting impacts on coastal habitats

- Maintaining storm water drainage systems/areas free of debris is required to minimize surface runoff into coastal waters.
- Proper storage and cover of construction materials within enclosures or containment berms is needed to prevent or limit sedimentation and blockage of drainage channels.
- Appropriate use of sediment traps/silt curtains should accompany all approved land reclamation activities along with proper removal and disposal of construction debris.

16.6.4.2 Mitigation of impacts from transportation and storage of construction materials

- Ensure all vehicles used for transporting building materials/debris to and from the site should be covered to minimize dust.
- Proper stockpiling of dust producing building materials such as sand or cement in low enclosures and covered, away from drainage areas where they could easily be dispersed by wind or washed away during heavy rains.

16.6.4.3 Mitigation of impacts from disposal of construction debris

It is essential for development plans to consider the carrying capacity of the existing infrastructure in GTH to ensure that appropriate facilities can meet local demands as well as increased demands during peak tourist season. The main objective is to ensure that the sewage treatment, garbage disposal facilities and associated services are capable of handling the increased demand and that there is no direct discharge of untreated effluent into the harbour.

- Development and implementation of a site waste management plan is required to ensure appropriate waste storage areas on the site, including the timely collection and removal of construction debris to an approved dump site.
- Adequate sanitation (chemical toilets or dry composting toilets), dumpsters and regular garbage collection and removal of sewage from the construction site are essential to keeping the construction site clean and pest-free.
- All measures must be taken to ensure that untreated sewage is not directed into the harbour waters.

16.6.5 Mitigation for operational impacts

16.6.5.1 Mitigation measures in relation to solid wastes

- Implement a waste management strategy for biodegradable and non-biodegradable waste including waste processing and disposal, to deal with increased waste resulting from cruise ship tourist visits.

16.6.5.2 Mitigating impacts from sewage

- Mitigation for dealing with increased demand on sewage processing plants includes the application of adequate treatment options (e.g. BESST - Biologically Engineered Single Sludge Treatment Technology) for dealing with effluents. These treatments reduce the levels of macro-nutrients, BOD substances and suspended solids to levels where they do not constitute a threat to human health, or a risk to the integrity of the environment.

16.6.5.3 Mitigating environmental impacts arising from cruise ship traffic

The CIG should enforce compliance with international and national regulatory legislating governing cruise ship operations in Caymanian waters, including consideration of the following:

- International Maritime Organization (IMO) is an established United Nations agency that sets standards and adopts regulations that apply to all vessels that operate internationally. IMO's most important objectives are to improve vessel safety and to prevent marine pollution (www.imo.org).
- The MARPOL Convention - The International Convention for the Prevention of Pollution from Ships (MARPOL) sets strict regulatory guidelines for the protection of the marine environment. Regulations covering the various sources of ship-generated pollution are contained in five annexes of the Convention. The annexes that govern cruise industry operations set standards to prevent pollution by oil, garbage and waste and should be used as minimal guidelines for minimizing the impact of cruise tourism at this destination.

It is recommended that the CIG develop "Environmental Guidelines" and establish a Memorandum of Understanding (MOU) with the cruise ship industry that defines specific environmental practices to be adopted, including:

- Monitoring for compliance with international (IMO) and enforcement of local laws and regulations pertaining to cruise ship waste management and operation while in waters off Grand Cayman.
- Mitigating cruise related environmental impacts by establishing regulations and enforceable laws, including regular monitoring for compliance and significant penalties for non-compliance.

16.6.5.4 Mitigating damage to marine ecology

Given that the berthing facility is located within the bounds of a Marine Park Area (MPA), consideration should be given to the concept of environmental compensation where a designated percentage of profits generated by the cruise industry are directed specifically to the support of coral reef restoration projects in the area. Vehicles for this process include the implementation of a regional port fee or head tax (apart from existing passenger taxes or dockage fees) to support local tourism and environmental restoration/mitigation projects.

- Compliance with regulations (Cruise Control, 200215) which specifically prohibit dumping ballast water inside the Exclusive Economic Zone (200 miles from shore) is essential for reducing the risk of introducing invasive species into coastal waters.

[15] Cruise Control: A Report on How Cruise Ships affect the marine environment. The Ocean Conservancy May 2002

16.6.5.5 Mitigation for sewage, bilge and black-grey water discharge

- Compliance with International Regulations which prohibit the discharge of untreated or inadequately treated sewage with a faecal coliform bacterial count greater than 200 MPN per 100 ml, or total suspended solids exceeding 150 mg/100 ml within three nautical miles of shore.
- Strict international and/or Cayman rules and regulations which require that filtered oily wastes (< 15 ppm oil contents) are discharged at least 12 nautical miles offshore along with "No discharge zones" three miles from the coast and explicit prohibition of the discharge of untreated sewage by cruise ships in Cayman waters is also desirable but difficult to monitor or enforce.
- On-board inspections and sampling of bilge water for compliance with stated national and international regulations.
- Requirements for cruise line companies to adopt and comply with MARPOL guidelines pertaining to solid waste disposal regulations should be continued while ensuring that portside waste reception facilities and waste management strategies are adequate to accommodate the waste generated by passengers while onshore. The provision of fee-based waste disposal services (i.e. services not covered by dockage fees) would assist in ensuring proper waste disposal.

16.7 RIAM Summary of Anticipated Project Impacts and Proposed Mitigation Measures

As noted in Chapter 1.3.6, the Rapid Impact Assessment Matrix (RIAM) method has been used to "quantify" the anticipated impacts of project construction, operation and mitigation measures. Table 16.5 and Figure 16.15 provide a summary of the RIAM scoring for specific impacts related to marine ecology, including scores for each of the following project phases:

- Existing (baseline) conditions
- Dredging and reclamation phase
- Construction (post-dredging) phase
- Operational phase

Proposed mitigation measures for specific impacts are highlighted in the green cells in Table 16.5, with the RIAM method applied both without and with these mitigation measures.

Chapter 1.3.6 provides an overview of the various RIAM scoring criteria (A1, A2, B1, B2 and B3) and the methodology used to derive the Environmental Score (ES) and associated Range Value (RV) for each specific impact. The Range Values are summarized as follows:

- N: Neutral (no change/impact)
- A to E: Positive change/impact (A is slight positive...E is major positive)
- -A to –E: Negative change/impact (-A is slight negative...E is major negative)

Additional information on the RIAM methodology is provided in Appendix Q.

Table 16.5 Detailed RIAM Scoring for Marine Ecology

PHASE	IMPACTS SCORED WITH NO MITIGATION	Spatial Importance (0 to 4)	Magnitude of change/effect (-3 to + 3)	Permanence (1 to 3)	Reversibility (1 to 3)	Cumulative (1 to 3)			IMPACTS SCORED WITH MITIGATION	Spatial Importance (0 to 4)	Magnitude of change/effect (-3 to + 3)	Permanence (1 to 3)	Reversibility (1 to 3)	Cumulative (1 to 3)	*ES with mitigation*	*RV With Mitigation*
		A1	A2	B1	B2	B3	ES	RV		A1	A2	B1	B2	B3	ES	RV
EXISTING CONDITIONS	Resuspension of Sediments - coral smothering/mortality (turbidity/ sedimentation due to tender traffic props	1	0	1	1	1	0	N	Reduce speed of tender traffic to reduce prop wash effect	1	1	1	1	1	3	A
	Coral bleaching/disease/reduced fitness/reduced recruitment	3	-1	1	1	1	-9	-A		3	-1	1	1	1	-9	-A
	Habitat degradation (turbidity due to cruise ship traffic, collision, anchor damage)	3	-1	1	1	1	-9	-A		3	-1	1	1	1	-9	-A
	Habitat destruction due to collision, anchor damage	2	-1	1	1	1	-6	-A		2	-1	1	1	1	-6	-A
	Invasive species (Lion fish)	3	-1	1	1	1	-9	-A		3	-1	1	1	1	-9	-A
	Accidental spills/releases (Bilge, Black and grey water)	2	-1	1	1	1	-6	-A		2	-1	1	1	1	-6	-A
DREDGING & RECLAMATION	Coral destruction (dredging)	3	-3	3	3	3	-81	-E	Coral relocation/ transplantation including reef substrate blocks	3	-2	3	3	3	-54	-D
	Coral smothering/mortality (Turbidity/ sedimentation plumes due to dredging)	2	-3	2	2	3	-42	-D	Silt curtains/air screen/berms/bunds	2	-2	2	1	2	-20	-C
	Coral bleaching/disease/reduced fitness/reduced recruitment	2	-2	2	2	3	-28	-C	Timing of dredging/construction operations (no dredging during spawning, high SST or storms)	2	-1	2	2	3	-14	-B
	Loss of biodiversity (Scleractinian coral) threatened corals, other fauna	3	-3	3	2	3	-72	-E	Seeded artificial reef structures	2	-2	3	2	3	-32	-C
	Loss of habitat and ecosystem functionality due to dredging	3	-3	3	2	3	-72	-E	Habitat restoration: Artificial reef structures or relocated reef substrate (boulders, Balboa)	2	-2	3	2	3	-32	-C
	Habitat degradation of nearby reefs due to turbidity and sedimentation	2	-2	2	2	3	-28	-C	Adaptive Management and Compliance with Turbidity/Sedimentation threshold limits (EMP)	2	-1	2	2	3	-14	-B
	Offshore dredge disposal (deep reefs)	2	-2	2	2	3	-28	-C	Adaptive Management -Monitoring direction of plume	2	-1	2	1	3	-12	-B
	Ship grounding, anchor damage (habitat destruction)	2	-3	3	3	1	-42	-D	Coral relocation/transplantation; Artificial reef structures; Relocated reef substrate	2	-2	3	1	1	-20	-C
	Accidental spills/releases (Oil, fuel,bilge, black and grey water)	2	-2	2	2	3	-28	-C	Monitoring and maintaining equipment /Emergency Spill Response Plan (EMP)	2	-1	2	2	3	-14	-B
CONSTRUCTION - POST DREDGING	Coral destruction (installating of pilings and pier construction)	3	-3	3	3	3	-81	-E	Coral relocation/ transplantation including reef substrate blocks	3	-2	3	1	3	-42	-D
	Coral smothering/mortality -turbidity/ sedimentation plumes from pier construction, piling installation, dewatering, resuspension of sediments (propwash)	2	-2	2	3	3	-32	-C	Silt curtains/air screen; Berms/bunds; Proper storage and covering of construction material.	2	-1	2	3	3	-16	-B
	Coral bleaching/disease/reduced fitness/reduced recruitment	2	-2	2	2	3	-28	-C		2	-1	2	2	3	-14	-B
	Loss of biodiversity (motile reef fauna)	3	-2	3	2	3	-48	-D		3	-2	3	2	3	-48	-D
	Continued habitat degradation and loss of ecosystem functionality	3	-2	2	2	3	-42	-D	Adaptive Management; Compliance with turbidity and sedimentation threshold limits; Timing of construction operations	3	-1	2	2	3	-21	-C
	Accidental spills/releases (Oil, fuel,bilge, black and grey water)	2	-2	2	2	3	-28	-C	Monitoring and maintaining equipment /Emergency Spill Response Plan (EMP)	2	-1	2	2	3	-14	-B
	Ship grounding, anchor damage (habitat destruction)	2	-3	3	3	2	-48	-D	Coral relocation/transplantation; Artificial reef structures; Relocated reef substrate	2	-2	3	3	2	-32	-C
OPERATIONAL	Continued degradation of habitat and diminished ecosystem functionality - continued bleaching, increased disease, reduced fitness, recruitment; habitat fragmentation	3	-1	3	2	3	-24	-C		3	-1	3	2	3	-24	-C
	Waste/sewage from Tourists	2	-2	2	2	3	-28	-C	Waste Management Plan	2	-1	2	2	3	-14	-B
	Maintenance dredging - Coral smothering/mortality due to turbidity/sedimentation plumes from dredging and resuspension of sediments (prop wash)	2	-2	3	2	3	-32	-C	Silt curtains/air screen	2	-1	3	2	3	-16	-B
	Invasive species	3	-1	1	1	1	-9	-A	Compliance with regulations (Cruise Control 200217) prohibiting dumping ballast water withing 200 EEZ	3	-1	1	1	1	-9	-A
	Accidental spills/releases (Bilge, Black and grey water)	2	-2	2	2	3	-28	-C	Emergency Spill Response Plan preparedness (EMP); Enforcement of cruise ship compliance with Cayman and MARPOL regulations	2	-1	2	2	3	-14	-B
	Ship grounding, anchor damage (habitat destruction)	2	-3	3	3	2	-48	-E	Coral relocation/transplantation; Artificial reef structures; Relocated reef substrate	2	-2	3	3	2	-32	-C
	Impacts of mass tourism - carrying capacity	3	-2	3	2	3	-48	-D	Scheduling of closed/restricted area use as part of Protected Area Management Plan	3	-1	3	2	3	-24	-C

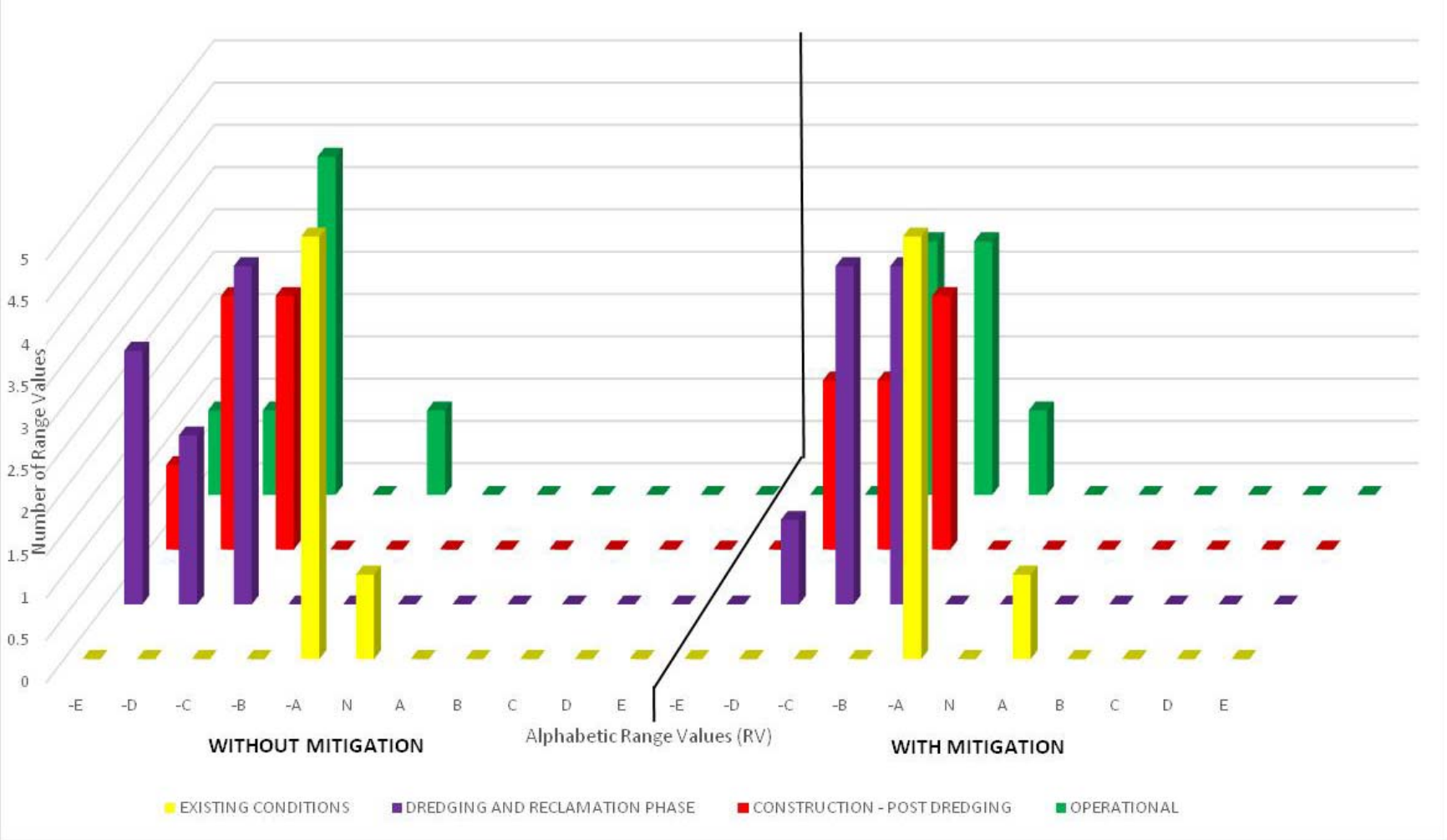


Figure 16.15 Summary RIAM Scoring for Marine Ecology

17.0 TASK K - CULTURAL HERITAGE

17.1 Introduction

The Cayman Islands has a rich natural and cultural heritage that is both marine and terrestrial in origin. The objective of this assessment was to describe the baseline archaeological and cultural heritage resources within the Socio-economic Impact Assessment (SIA) study area and to identify the potential impacts of the proposed project on these resources. The significance and severity of the effects was assessed for the construction and operational phases of the proposed project. Indirect, residual, cumulative and secondary impacts were also assessed and appropriate mitigation measures recommended.

17.2 Assessment Methodology

The impact assessment on cultural heritage assets was undertaken using mixed method research design requiring both primary and secondary data collection. Secondary data collection included review of documents, reports and other documented records to obtain baseline data. Primary data was collected through interviews with key stakeholders and through personal observations. A walking tour of the George Town historical sites was hosted by the Dr. M.E. Leshikar-Denton of the National Museum on June 20, 2014. An underwater observatory tour of the George Town Harbour, including the Wall, Balboa and Cali shipwrecks, and the reefs was hosted by Atlantis Submarine in August 2014. Additional primary data on stakeholder perception of resource importance and potential impacts was also gathered through surveys as well as structured and unstructured interviews.

The assessment focuses on resources within a 0.6 mile (1 km) radius of the project site. The importance and sensitivity of cultural heritage receptors is based on the importance of the resource to stakeholders from both a heritage perspective as well as a source of economic activity and livelihoods. Importance is ranked as high, medium and low. The magnitude of effects was determined by the predicted change in the existing baseline environment during the construction and operational phases of the proposed project. Magnitude of impact is categorized as high, moderate, low and negligible. The level of significance was based on the cross tabulation of the importance and magnitude of effect.

17.3 Baseline Conditions

The people of the Cayman Islands refer to their history and culture as being “tied to or founded upon the sea” (Cayman Islands Maritime Heritage Trail Partners, 2003; Craton, 2003). This heritage stems from the islands’ history of “turtlers” and “farmer-fishermen”, to the island’s favoured hideout and rendezvous for pirates and privateers in the 18th century; its evolution into a culture of shipbuilding, sailing and wreck trade; to today’s society with cruise and air tourism, beaches, diving,/scuba/snorkelling and underwater observatories. The Grand Cayman Maritime Trail

identifies five groups of cultural heritage sites within the study area namely, George Town Harbour Shipwrecks, Fort George, Maritime Architecture, Historic Hog Sty Bay and Shipbuilding heritage. A sixth group constitutes the monuments erected across the study area in honour of the men and women who were instrumental in the previous eras and in shaping the Cayman society.

17.3.1 George Town Harbour Shipwrecks

Two shipwrecks, the Balboa and the Cali, are located within the harbour (**Figure 17.1**). The ***Balboa*** was a Jamaican freighter that was wrecked while anchored in the harbour in a 1932 storm. The hull was reportedly subsequently broken up using dynamite in 1957 to reduce the threat to navigation. The Balboa is now a popular dive spot for tourists and was identified as one of the best dive sites in the Cayman Islands by local dive shops during recent surveys. The site is popular for night dives as daytime access is restricted to ensure safety during days when ships are in the harbour. In addition, the wreck has since been cemented to the seabed and surrounding reefs over time through natural processes, and has become a habitat for marine wildlife.

The ***Cali,*** also known as the Rice Wreck, was a rice cargo ship that ran ashore when it began to take on water in 1948. It is documented that salvaged rice from the wreck provided food for Caymanians and was also exported. The Cali wreck is also a popular dive site for tourists. Though less significant than the Balboa due to the separation of the hull from the wreck, the Cali is also habitat to marine life found within the harbour. The wrecks have been cemented into the seabed over time through natural processes, and have become a part of the marine environment. The wrecks have become artificial reefs and an extension of the natural reef system. Marine wildlife has been established on them. The direct use of the wrecks for economic activities (diving and snorkelling activities) and as habitat and reef renders the shipwrecks of significant use value.

Two other shipwrecks identified are the freighter ***Kirk Pride*** which sank in 1976 and currently rests on the Cayman Wall and the freighter ***Gamma***, which ran aground on the reef in 1980. Gamma was washed ashore and currently sits on a part of Seven Mile Beach, approximately two miles (3.2 km) from the project site.

All shipwrecks in the Cayman Islands are protected under the Abandoned Wreck Law (of 1966, 1997 Revision). The Abandoned Wreck Law makes all shipwrecks that have been on the seabed for more than 50 years the property of the Crown. The Law was reportedly enacted to ensure that the government receives a percentage of the value of articles recovered from shipwrecks and does not declare shipwrecks as cultural heritage sites (Leshikar-Denton, 2007). Historically shipwrecks have provided resources for the isolated Cayman Islands and, for example, many of the buildings in George Town were built using material from these shipwrecks.

The Balboa shipwreck is directly within the dredge footprint of the proposed project and will be impacted by the project. The Cali is within 275 yards (0.25 km) of the dredge footprint and is

expected to be indirectly affected while the Kirk Pride and Gamma are located more than 0.6 miles (1 km) from project activities and are not expected to be affected.



Figure 17.1 - George Town Harbour Shipwrecks (Balboa & Cali)
Source: Charpentier & Gayle, 2014

17.3.2 Previous Studies of the Balboa

The Balboa studies consisted of an underwater archaeological assessment conducted by Mid-Atlantic Technology and Environmental Research Inc. in 1992. A preliminary site map was developed; existing conditions of the wreckage site at the time and recommendations for mitigation measures were proposed based on their assessment and research. The studies noted that in 1932 a hurricane hit the Cayman Islands causing great damage and devastation to the islands' infrastructure. The Balboa was reportedly at anchor within Caymanian waters when it was affected by the 1932 hurricane causing it to sink. This resulted in the cargo spilling and washing ashore. In the aftermath of the hurricane, the cargo was reportedly used in rebuilding the islands' homes and rehabilitation of the infrastructure.

Explosives were reportedly used to destroy parts of the sunken ship to reduce navigational hazards. However, the main part of the ship is located in the midst of George Town Harbour. Since the recovery, the wreck site has been used as a tourist attraction, attracting visitors from several cruise ships annually. Interestingly, the studies stated that "no cargo or cultural artifacts have remained." The wreck is, however, considered a cultural artifact by Caymanians.

The Balboa studies described the Balboa as an attraction for thousands of visitors to the Cayman Islands annually. It found that the Balboa has no significant archaeological value but has significant historical and economic value to Caymanians including tourism interest groups. It was further noted that the 1932 hurricane was the feature that demanded and attracted greater public

attention and remembrance instead of the sunken ship. The use of materials for rebuilding George Town after the hurricane was also a point of interest.

The studies made recommendations for both research and mitigation in an effort to increase the importance of the Balboa and the wreckage site as well as the general area surrounding the site. The studies proposed several alternative courses of action to mitigate impacts on the Balboa from planned dredging including:

- Historical research should be conducted to determine more about the Balboa, (its crew, owner, materials) since it is of some historical importance to the Cayman Islands and especially because it was cargo from the ship that aided the rebuilding of homes and rehabilitation of infrastructure after the 1932 hurricane.
- In an effort to preserve the wreckage site, the Balboa should be left as is and re-routed or redesign the area for the turning basin that is proposed to avoid further impact on the site.
- The Balboa could be relocated to avoid and escape tourist traffic in that location. It makes it better for scuba diving that takes place daily throughout the area to access the ship and area. This would allow for greater importance to be given to the Balboa and its relevance to tourism in the Cayman Islands. Moreover, marine organisms can be preserved as a result of relocation.
- The current site could be recreated elsewhere by relocating and randomly dropping the pieces. This however, can create underwater hazards for divers.
- The wreckage could be completely removed to a salvage yard or landfill."

The studies concluded that "since the port expansion was necessary, option 1 was considered unfeasible because the wreckage lies in the proposed path of the expansion. Hence, options 2 – 4 were those likely to be considered with the associated costs."

No action was taken at the time and the same issues have resurfaced in this current environmental and engineering study for the cruise berthing facility. The stakeholder engagement and public consultation section will provide further insights into the historic and economic value of the Balboa and other ship wreck sites within GTH.

17.3.3 Fort George

Fort George is located at the south-west corner of the intersection of Fort Street and Harbour Drive, adjacent to the GTH Port. Rebuilt in 1780, the fort today hosts a World War II submarine lookout and a replica of three cannons (**Figure 17.2**). While there has been development to the seaward side of the fort, its location is accessible to the millions of visitors and residents walking along Harbour Drive and is a part of the walking tour offered by the National Museum. Fort George is separated from project activities by the existing Royal Watler Pier for cruise visitors. The site is not expected

to be directly affected but there is a plan to include the site in proposed future master planning for a cruise facility.



Source: Richards & Dwyer, 2014

Figure 17.2 - Fort George Historic Site

17.3.4 Maritime Architecture

The shipbuilding heritage of the Cayman Islands is said to be most evident today through its marine architecture. This is evident in the structure of downtown George Town including Elmslie Memorial Church, the National Museum, the George Town Central Post Office, Library and Town Hall **(Figure 17.3)**. The ceilings of these buildings (for example Elmslie Church), portray an inverted ship's hull and display the craftsmanship of Caymanian shipbuilders, while the Post Office is built to resemble the bow of a ship. Elmslie Memorial Church is located on the east side of Harbour Drive, adjacent to the GTH Port, while the other sites are located less than 0.3 miles (0.5 km) away. No direct impacts are expected on maritime architecture.

The National Museum of the Cayman Islands is located across from Hog Sty Bay. The building was originally constructed in the 1830's as the Courts Building and also served as the location of a lantern hoisted up a flagpole to serve as a beacon to homeward-bound sailors docking at Hog Sty Bay, and passing ships (Maritime Heritage Trail, 2003). Old Gaol is a part of the National Museum building and is hypothesized to have been storage for armaments and other military supplies.



Figure 17.3 Elmslie Memorial Church (exterior and interior); Cayman Islands Central Post Office and National Museum, Cayman Islands
Source: Richards & Dwyer, 2014; Google, 2015

17.3.5 Historic Hog Sty Bay

Historic Hog Sty Bay got its notoriety from being cited as "the only place of anchorage at the west end, abreast the hog sties and as a convenient place for wooding, watering and getting stock and refreshment in good weather" by British Navy surveyor George Gauld in 1773. In 1802, another sailor documented access to water supplied from wells close to shore. Today, Hog Sty Bay serves as a port and anchorage for local vessels, as well as visiting small crafts (**Figure 17.4**). It also serves as a swimming area for George Town residents as observed on a Sunday morning in June 2014. Evidence of the "wells near to the beach" documented in 1802 was discovered in the floor of a souvenir shop in Bayshore Mall, opposite Hog Sty Bay. The site, known as Step Well, was discovered in 2003 during the construction of the Bayshore Mall. Artifacts discovered in the well are also displayed in the mall.







View of GTH Port from Historic Hog Sty Bay (top left);
Swimmers observed in Hog Sty Bay, June 2014 (top right)
Historic Stepwell (bottom)

Figure 17.4 Historic Hog Sty Bay and Historic Stepwell
Source: Richards & Dwyer, 2014

17.3.6 Shipbuilding

The Maritime Heritage Trail Partners highlights the fact that the seafaring history of the Cayman Islands is also evident in many structures along the George Town waterfront. These structures include slipways and barcaderes along the George Town waterfront, both north and south of the GTH Port.

17.3.7 Monuments

There are numerous other historic sites within the SIA study area. It is believed that numerous archaeological artifacts lie throughout the George Town Harbour area and along its shores, especially given its rich history with shipwrecks, anchorages and shipbuilding activities.

In addition, there are numerous monuments with educational signs along the waterfront and throughout the downtown area. The monuments and architectural heritage sites are accessible to

visitors and residents as they walk around the town. Guided tours can be also arranged through the National Museum.

At the centre of Heroes Square, which is also the location of the library and Town Hall, is the national monument to the heroes and heroines of the Cayman Islands. It lists the names of men and women who contributed to the history and development of the Cayman Islands and fought in the World Wars.

17.4 Stakeholder Engagement & Perception

Stakeholder consultations were undertaken to ascertain perceptions on the potential impacts resulting from the project on their communities/groups, socio-economic status, cultural/heritage landscape and the natural environment. Views on cultural heritage resources/assets are summarized in the following sections.

17.4.1 George Town Businesses

17.4.1.1 Dive Shops

Nine dive shops were surveyed in December 2014. The Balboa and Cali shipwrecks were identified as being among the best dive sites in the Cayman Islands by participants. The Balboa was identified as the "best spot for night dives" and as a customer and staff favourite. The Cali was identified as suitable for skill sets ranging from beginners to experienced divers. The use of the shipwrecks as dive sites resulted in their inclusion in the economic valuation of the GTH reefs.

17.4.1.2 Down Town Businesses (mainly retail)

Interviews were also conducted with fifteen businesses (excluding dive shops) located in downtown George Town. In regards to cultural heritage assets, over 65% of GT business participants believe that the cultural heritage assets were important to very important to the Cayman Islands. Ship wrecks and monuments (67% each) ranked higher among participants than buildings and cultural assets (**Figure 17.5**). They also believe that any damage or loss to these cultural heritage assets would be significant to very significant for the Cayman Islands.

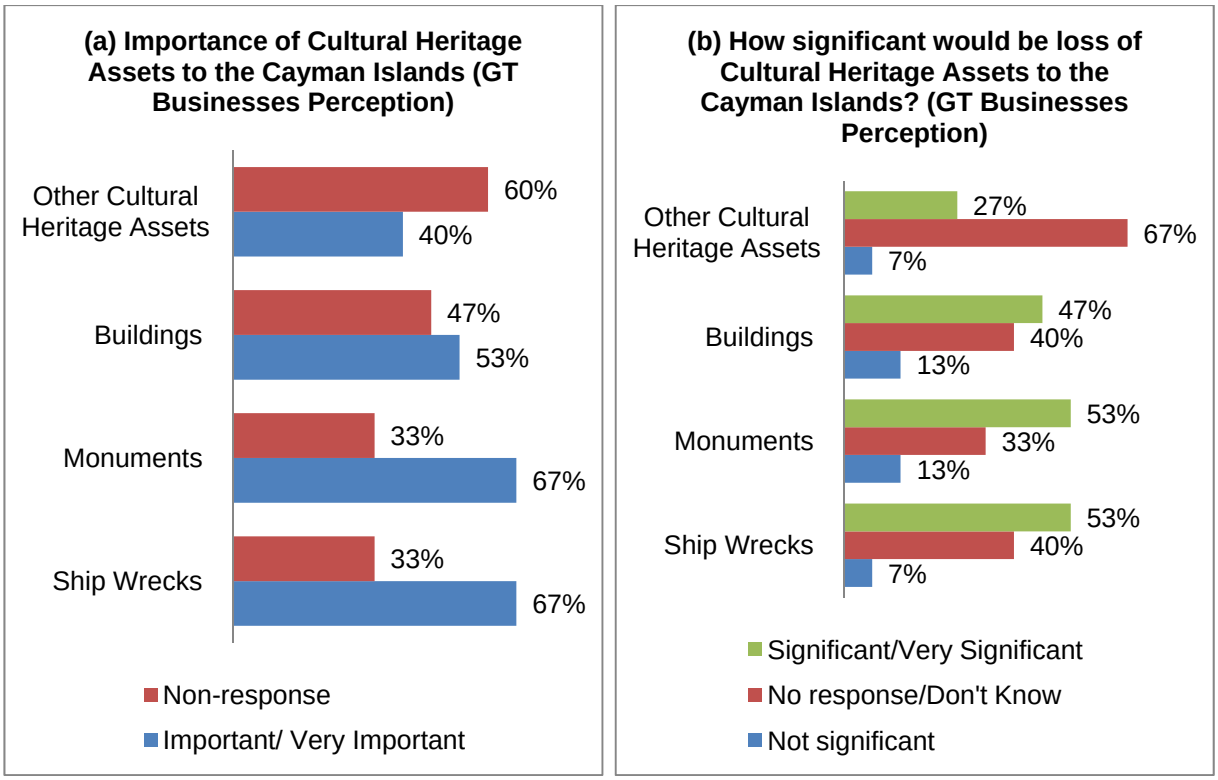


Figure 17.5 Percentage distribution of GT businesses' views on (a) the importance of cultural heritage resources and (b) the significance of loss or damage to the Cayman Islands

17.4.2 General Public (Households)

A total of 308 households across Grand Cayman were surveyed as part of the stakeholder consultation process. Household participants were also asked about their views on the cultural heritage assets of the Cayman Islands. A large proportion of respondents believe that the cultural heritage assets of the Cayman Islands are important/very important (**Figure 17.6**). Among the types of cultural assets mentioned, monuments had the highest proportion of respondents (91%) ranking them important/very important. Almost 90% believe buildings and ship wrecks are important/very important and 67% believe other heritage cultural assets are important/very important. Respondents were also asked to rank the significance of any loss or damage to the cultural heritage assets of the Cayman Islands. Consistent with their views of the importance of these assets, the large majority of respondents believe that any loss or damage would be considered as a significant/very significant loss to the country. For monuments, buildings and ship wrecks, over 80% of responds shared this view.

An estimated 1% of households identified loss and damage to cultural assets and structural impact from blasting as potential impacts of the proposed project. However, no blasting is expected in proposed project activities.

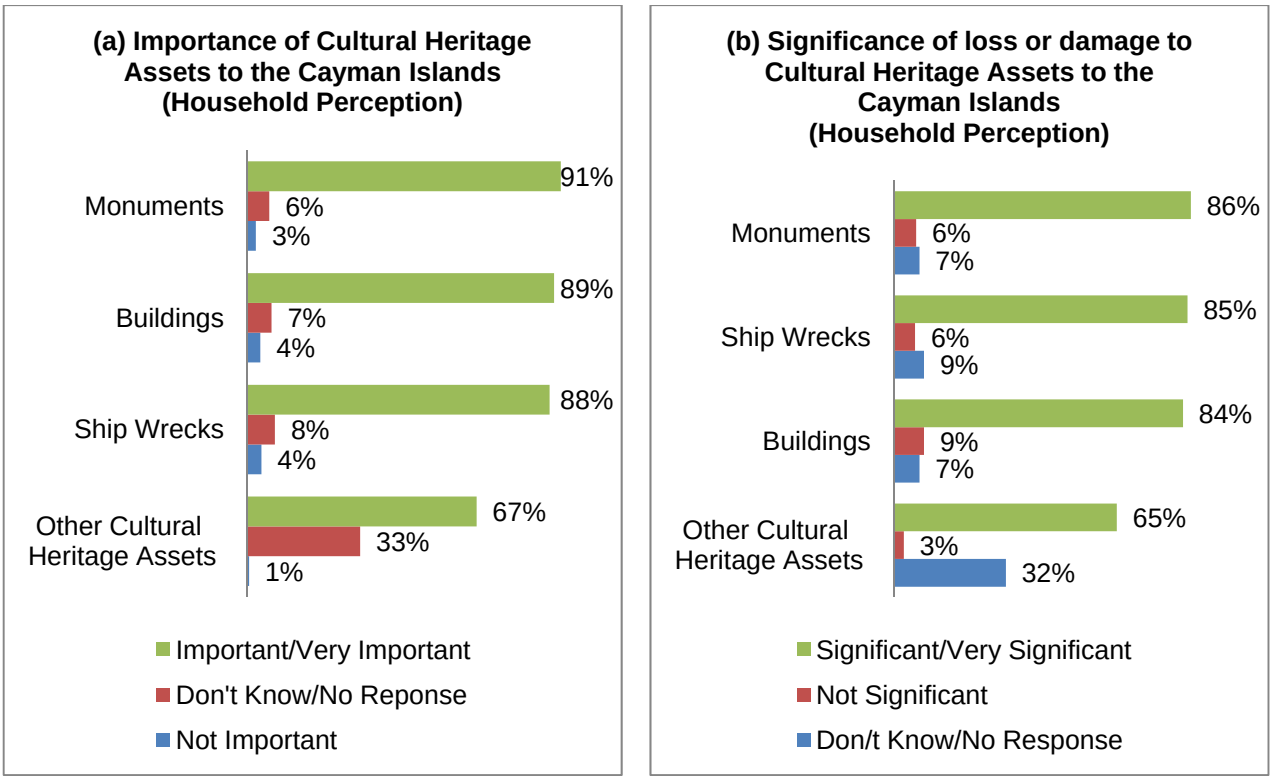


Figure 17.6 Percentage distribution of households' views on the (a) importance of cultural heritage resources and (b) the significance of loss or damage to the Cayman Islands

17.4.3 Perceived Construction and Operational Impacts

Views on potential impacts specific to the construction and operational phases of the proposed project were obtained from two stakeholder groups – downtown (non-diving) businesses and households. Participants were asked if they thought there would be positive, negative, or no impacts. The cultural heritage assets identified were also separated into "shipwrecks" and "other", based on the nature of the project and the location of the shipwrecks within the harbour. Analysis of results shows that construction impacts on shipwrecks were perceived as being mainly negative for both groups (36% of businesses and 46% of households). Seven percent (7%) of GT businesses and 29% of households believe there will be no impacts during this phase. Impacts on shipwrecks during the operational phase of the project were believed to be positive among 20% of downtown businesses while 13% believe there will be no effects. Seven percent (7%) thought that the impacts will continue to be negative post-construction. The majority of households thought that impacts on shipwrecks during construction would be negative (36%) or not impacted (32%) during the operational phase of the proposed project. Seventeen percent (17%) thought the impacts would be positive.

Construction impacts on other cultural heritage assets were believed to be negative among 20% of GT businesses but households were split between negative and no effect. An estimated 38% of households believe that there will be no effect on other cultural heritage assets, while 32% believed impacts will be negative. Impacts on other cultural heritage assets during the operational phase of

the proposed project are believed to be negative among 36% of households and 7% of GT businesses. An estimated 32% of households believe there will be no impact while 13% of GT businesses thought there would be no effects. **Table 17.1** to **Table 17.4** summarize perceived construction and operational phase impacts on cultural heritage.

Table 17.1 Perceived cultural heritage impacts during construction (GT Businesses)

During Construction Impacts (n=15)				
	Positively %	**Negatively %**	**No Effect %**	**Not Sure / Non-Response %**
Ship Wrecks		33	7	60
Heritage Sites (monuments, buildings)		20	33	47

Table 17.2 Perceived cultural heritage impacts post-construction/operational (GT Businesses)

Post Construction/Operations Impacts (n=15)				
	Positively %	**Negatively %**	**No Effect %**	**Not Sure / Non-Response %**
Ship Wrecks	20	7	13	53
Heritage Sites (monuments, buildings)	20	7	13	60

Table 17.3 Percent distribution of households' views on cultural heritage impacts during construction

During Construction Impacts – % Households (n=308)						
% Pre	Positively	Negatively	No Effect	No Response	Not Sure	Total
Ship Wrecks	13	46	29	7	5	100
Heritage Sites (monuments, buildings)	19	32	38	6	4	100

Table 17.4 Percent distribution of households' views on cultural heritage impacts post construction/operational

Post Construction/Operations Impacts – % Households (n=308)						
% Post	Positively	Negatively	No Effect	No Response	Not Sure	Total
Ship Wrecks	17	36	32	10	5	100
Heritage Sites (monuments, buildings)	28	21	39	9	3	100

17.5 Impact Assessment

Identification of cultural heritage receptors was based on the cultural heritage sites located within 0.6 miles (1 km) of proposed project activities. Stakeholder perception of value of worth was determined from public perception and protection by law. Significance of impact is related to

proximity to project activities. Given the strong stakeholder perception, the direct use of cultural heritage assets for economic activities (diving, snorkelling, sea observatory, guided tours, honouring contributors to the society, and the educational significance, etc.) the cultural heritage resources within the study area are considered of high importance.

17.5.1 Project Impacts

17.5.1.1 Construction Impacts

Shipwrecks

There are four shipwrecks located in the George Town area (Balboa, Cali, Gamma and Kirk Pride). The Balboa will be directly affected by the project, while the Cali may be indirectly affected; the other two shipwrecks are located outside the project's anticipated impact zone.

The Balboa shipwreck is located within the dredge footprint of the proposed project. It is expected that the wreck will be removed before dredging activities commence. This represents a significant (moderate to high) negative impact as the baseline conditions of the wreck will be significantly altered. The impact is potentially negative as there is a risk of damage to the structure during removal.

The Cali shipwreck is located less than 275 yards (0.25 km) from proposed project activities. This shipwreck is expected to be indirectly impacted by the dredge plumes. Marine wildlife on the Cali will also be negatively impacted by siltation. Impacts will be negative, moderate and long-term.

Residual impacts on shipwrecks would be negative for environmental receptors through disturbed/destroyed habitat and loss of life. This will be minor and potentially long-term.

Residual impacts have the potential for short-term economic impacts during the construction phase as the Balboa is being relocated. There will be loss of income and disruption in livelihoods. This impact is expected to be short-term.

Marine Architecture, Monuments and Shipbuilding

There is low potential for buildings and monuments to be structurally damaged during dredging activities. Those with compromised structural integrity are more sensitive to vibrations that might result from project activities during construction.

Hog Sty Bay

Access to Hog Sty Bay may be impacted during the construction phase of the project. Impact will be minor, negligible and short-term.

17.5.1.2 Operational Impacts

Cultural heritage impacts during the operational phase will be secondary and positive. Buildings and monuments will potentially generate income from guided tours to increased numbers of visitors. There is the potential to expand the inventory or cultural heritage artifacts.

The relocation of the Balboa shipwreck with successful relocation of corals and other marine life on shipwrecks has the potential for long-term positive economic impacts. The increased accessibility of the proposed relocation site will likely increase the number of dives and increase revenues for dive shops. This will be a long-term, positive and moderate impact. Currently, due to its location in the middle of an active and busy port, diving and access to the Balboa is restricted to nights and requires special permission from PACI.

Visual impacts from larger cargo vessels at berth and cruise ships closer to shore are expected. Refer to Task L: LVIA for details on visual impacts.

17.5.2 Climate Change Impacts

Climate change is not expected to have any significant impact on cultural heritage assets.

17.6 Proposed Mitigation Measures

Stakeholders generally believe that Grand Cayman's cultural assets are valuable and should be preserved.

17.6.1 Relocation of the Balboa

The proposal includes the mapping and removal of the wreck and rearranging it at a new location within the GTH. The new location should have no restrictions to access to the shipwreck, which will be an improvement over current restrictions to night diving. As highlighted in Task J: Marine Ecology Report, the Balboa supports an extensive population of marine life. To minimize the loss of marine life and preserve the structure, the relocation should be informed by in-depth structural data on the condition and integrity of the Balboa. This will identify the best methods for relocation. Previous studies such as the Balboa Studies and consultation with experts may be used to inform the need for further studies. Moving the structure in large elements will be required to preserve the wreck and the marine life it supports.

The relocation of the Balboa shipwreck with successful relocation of corals and other marine life on shipwrecks has the potential for long-term positive economic impacts. The increased accessibility of the proposed relocation site will likely increase the number of dives and increase revenues for dive shops. This will be a long-term, positive and moderate to high impact.

17.6.2 Access to Hog Sty Bay

Communication with stakeholders on the schedule of activities during the construction phase and operations will minimize any negative impacts to small vessels using Hog Sty Bay.

17.6.3 Socio-economic

There may be a need to compensate (monetary and non-monetary) those directly impacted by the relocation of the Balboa and reduced access to the Cali during construction activities. The proposed grievance mechanism in the Stakeholder Engagement and Public Consultation Report should be the mechanism through which this is addressed.

17.6.4 Public Perception

Continue communication with stakeholders and the general public on the potential impacts of the proposed project to cultural heritage assets and the measures that will be taken (not only proposed but those committed to by decision makers) to mitigate or cope with impacts. See the Stakeholder Engagement and Public Consultation for additional details.

17.7 Alternative Layout

An alternative layout design that avoids the shipwrecks would also avoid impact on the Balboa and other cultural heritage assets in the GTH. Assessment of multiple layout designs showed that the central location of the Balboa in relation to the port, options with the required functionality, performance and viable costs requires its relocation.

17.8 RIAM Summary of Anticipated Project Impacts and Proposed Mitigation Measures

As noted in Chapter 1.3.6, the Rapid Impact Assessment Matrix (RIAM) method has been used to "quantify" the anticipated impacts of project construction, operation and mitigation measures. Table 17.5 and Figure 17.7 provide a summary of the RIAM scoring for specific impacts related to cultural heritage and sociological factors, including scores for each of the following project phases:

- Existing (baseline) conditions
- Dredging and reclamation phase
- Construction (post-dredging) phase
- Operational phase

Proposed mitigation measures for specific impacts are highlighted in the green cells in Table 17.5, with the RIAM method applied both without and with these mitigation measures.

Chapter 1.3.6 provides an overview of the various RIAM scoring criteria (A1, A2, B1, B2 and B3) and the methodology used to derive the Environmental Score (ES) and associated Range Value (RV) for each specific impact. The Range Values are summarized as follows:

- N: Neutral (no change/impact)
- A to E: Positive change/impact (A is slight positive...E is major positive)
- -A to –E: Negative change/impact (-A is slight negative...E is major negative)

Additional information on the RIAM methodology is provided in Appendix Q.

Table 17.5 Detailed RIAM Scoring for Cultural Heritage and Sociological Factors

PHASE	IMPACTS SCORED WITH NO MITIGATION	Spatial Importance (0 to 4)	Magnitude of change/effect (-3 to + 3)	Permanence (1 to 3)	Reversibility (1 to 3)	Cumulative (1 to 3)			IMPACTS SCORED WITH MITIGATION	Spatial Importance (0 to 4)	Magnitude of change/effect (-3 to + 3)	Permanence (1 to 3)	Reversibility (1 to 3)	Cumulative (1 to 3)	*ES with mitigation*	*RV With Mitigation*
		A1	A2	B1	B2	B3	ES	RV		A1	A2	B1	B2	B3	ES	RV
EXISTING CONDITIONS	Community Development, Infrastructure & Social Services	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Public Perception (Socio-Economic, Socio-Cultural)	3	0	1	1	1	0	N		3	0	1	1	1	0	N
	Public Perception (Environment)	3	0	1	1	1	0	N		3	0	1	1	1	0	N
	Public Health & Safety	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Heritage/Historical Sites (Balboa Shipwreck)	3	0	1	1	1	0	N		3	0	1	1	1	0	N
	Heritage/Historical Sites (Other)	3	0	1	1	1	0	N		3	0	1	1	1	0	N
DREDGING & RECLAMATION PHASE	Community Development, Infrastructure & Social Services	2	-2	2	2	3	-28	-C	Continuous communication with stakeholders and the general public on schedule of project activities that may restrict/disrupt the public's access to and use of community resources. Continuous communication on project impacts (anticipated and unexpected) and measures that will be/are being taken to mitigate and cope with impacts.	2	-1	2	2	3	-14	-B
	Public Perception (Socio-Economic)	3	2	2	2	3	42	D		3	2	2	2	3	42	D
	Public Perception (Environment)	3	-3	2	3	3	-72	-E	Continuous communication with stakeholders and the public about impacts, mitigation plans, etc. Develop a grievance mechanism.	3	-2	2	3	3	-48	-D
	Public Health & Safety	2	-1	2	2	3	-14	-B	Monitor potential threats, notify the public and implement measures to reduce risk and impact	2	-1	2	2	3	-14	-B
	Heritage/Historical Sites (Balboa Shipwreck)	3	-3	2	2	3	-63	-D	Relocation of the Balboa with preservation of its structural integrity and the coral and other marine life it supports.	3	-2	2	2	3	-42	-D
	Heritage/Historical Sites (Other)	3	-2	2	2	3	-42	-D	Monitoring of cultural heritage sites (including the Cali wreck and buildings) to identify and adress uforseen impacts	3	-1	2	2	3	-21	-C
CONSTRUCTION - POST DREDGING	Community Development, Infrastructure & Social Services	2	-2	2	2	3	-28	-C	Continuous communication with stakeholders and the general public on schedule of project activities that may restrict/disrupt the public's access to and use of community resources. Continuous communication on project impacts (anticipated and unexpected) and measures that will be/are being taken to mitigate and cope with impacts.	2	-1	2	2	3	-14	-B
	Public Perception (Socio-Economic)	3	2	2	2	3	42	D		3	2	2	2	3	42	D
	Public Perception (Environment)	3	-3	2	3	3	-72	-E	Continuous communication with stakeholders and the public about impacts, mitigation plans, etc. Develop a grievance mechanism.	3	-2	2	3	3	-48	-D
	Public Health & Safety	2	-1	2	2	3	-14	-B	Monitor potential threats, notify the public; implement measures to reduce risk and impact, such as cordoning off construction work areas to maintain adequate buffer zones, etc.	2	0	2	2	3	0	N
	Heritage/Historical Sites (Balboa Shipwreck)	3	-3	2	2	3	-63	-D	Relocation of the Balboa with preservation of its structural integrity and the coral and other marine life it supports.	3	-2	2	2	3	-42	-D
	Heritage/Historical Sites (Other)	3	-2	2	2	3	-42	-D		3	-2	2	2	3	-42	-D
OPERATIONAL	Community Development, Infrastructure & Social Services	2	-3	3	1	3	-42	-D	Traffic and visitor management; Upgraded infrastructure. Access to GTH will be permanetly impacted by piers and is irreversible	2	3	3	1	3	42	D
	Public Perception (Socio-Economic)	3	3	1	1	3	45	D		3	3	1	1	3	45	D
	Public Perception (Environment)	3	-3	1	1	3	-45	-D	Reduce potential long-term environmental impact. Loss of reef and marine wildife may be irreversible	3	-2	1	1	3	-30	-C
	Public Health & Safety	2	2	3	1	3	28	C		2	2	3	1	3	28	C
	Heritage/Historical Sites (Balboa Shipwreck)	3	-3	3	2	3	-72	-E	Succesful relocation of Balboa and preservation of life form and structural integrity. Site is accessible to divers	3	-1	3	2	3	-24	-C
	Heritage/Historical Sites (Other)	3	1	1	1	3	15	B	Monitoring of cultural heritage sites (including the Cali wreck and buildings) to identify and adress uforseen impacts	3	1	1	1	3	15	B

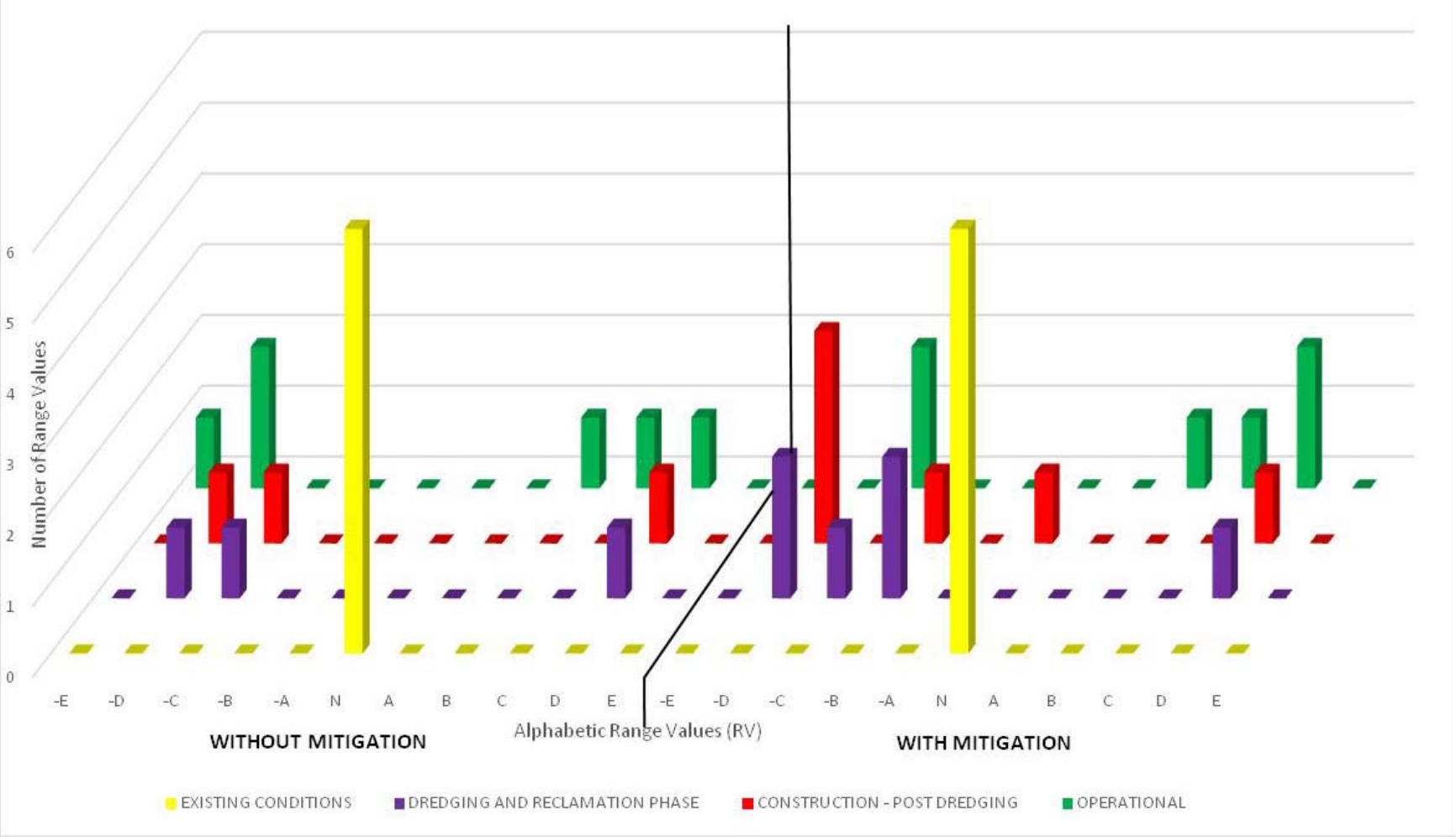


Figure 17.7 Summary RIAM Scoring for Cultural Heritage and Sociological Factors

18.0 TASK L - VEHICULAR AND PEDESTRIAN TRAFFIC

18.1 Introduction

A comprehensive vehicular and pedestrian traffic study was undertaken. This study included consultation with the National Roads Authority (NRA), the Ministry of Planning (in order to ensure coordination with ongoing efforts related to the George Town Revitalization Plan, GTRP) and the Public Transport Board (PTB). The key results of the traffic and pedestrian study are summarized below; a detailed technical report documenting the study is provided in Appendix L.

18.2 Assessment Methodology

The vehicular and pedestrian traffic study established a 2014 baseline of transportation conditions; the impact assessment was carried out assuming a ten year planning horizon (i.e. 2024). The assessment methodology consisted of collection/review of available background information and data and review/assessment of current conditions to establish baseline conditions and historical trends. This information was subsequently used to develop and calibrate a series of desktop and numerical models; the calibrated models were then used to analyze various growth and mitigation scenarios. Additional detail on specific tasks is provided below.

18.2.1 Background and Baseline Data Collection

- Collection of historical traffic records from the NRA, cruise ship data (number of calls and passengers) from PACI, tender traffic records from CMS, tour bus information from PTB, passenger disembarkation rates from RCCL;
- Measurement of traffic volumes, vehicle types, and turning movements at 32 different intersections in and around George Town;
- Measurement of cruise passenger queue times and vehicle travel times on days with and without cruise ships in Port;
- Measurement of parking utilization throughout George Town on days with and without cruise ships in Port.

18.2.2 Data Analysis and Numerical Modeling

- Focus on three impact areas: Harbour Drive, the Inner Cordon and the Outer Cordon;
- Desktop analysis of background and baseline data to establish historical and predicted future trends, including: pedestrian safety, level of service, vehicle traffic growth, pedestrian traffic growth, parking utilization, and various other parameters;
- Numerical modeling of baseline and future baseline conditions was conducted using VISTRO, VISSIM, and VISWALK;

- Evaluation of anticipated impacts of the cruise berthing facility included the NRA's Priority for road network improvements, the GTRP and other possible mitigation measures.

18.3 Baseline Conditions

18.3.1 Vehicle and Pedestrian Traffic Volumes

- Vehicle volumes along Harbour Drive are typically between 450-500 vehicles in the midday peak hour in each direction.
- As the number of cruise ships in port increases, the volume of pedestrians increases significantly; however, the volume of vehicular traffic on Harbour Drive and in George Town remains relatively constant.
- The intersection at Harbour Drive and Fort Street may have more than 2,500 pedestrians and vehicle movements per hour on cruise days (split approximately 50/50 between pedestrians and vehicles).
- The busiest time of day along Harbour Drive is midday (12:00 to 13:00). This is when the largest volume of cruise ship passengers is mixing with vehicular traffic on Harbour Drive.
- Tour buses and taxis account for about 100-200 vehicles per hour (both directions) on Harbour Drive, and typically move about half of the scheduled cruise passengers on a given day.
- Cycling and other modes of transport are minimal in George Town.
- Historical records (2008-2014) show that vehicle traffic volumes are generally declining in George Town; however, as per discussions with the NRA, a conservative "baseline" growth rate of 1% per year was adopted for vehicular traffic (this baseline growth is assumed to occur whether or not the CBF is constructed).
- For the purposes of this study, the baseline cruise passenger volume was established as 11,000 passengers/day. This volumes represents the 85th percentile, based on PACI records from 2010-2014 during the cruise season (Nov-Apr); an optimistic growth rate of 3% per year was adopted, as per the OBC (PwC, 2013) to give a future background volume of 14,300 passengers per day.

18.3.2 Travel Time along Harbour Drive

- Travel times along Harbour Drive increase significantly when ships are in port, from about 4 minutes without ships to over 7 minutes with ships in port (Mary Street to Shedden Road).
- Traffic delays along Harbour Drive are introduced due to the high number of conflicts between pedestrians and vehicles at intersections, as well as at uncontrolled pedestrian crosswalks and informal crossing locations.

18.3.3 Parking Utilization

- Parking utilization in George Town averages 60%, and primarily consists of private lots. Public on-street parking sees the highest utilization, with an average of 86%.
- The number of cruise ships in port has little effect on parking utilization.

18.4 Impact Assessment

This section presents a summary of the unmitigated impacts to be expected with the baseline growth in vehicular traffic in George Town (i.e. independent of the proposed CBF). Subsequently, the additional impacts that would be associated with the construction and operation of the CBF are presented. While unmitigated impacts may result in a net negative impact on traffic in George Town, potential mitigation measures that could be included as part of the CBF development may result in a net positive impact on traffic in George Town.

18.4.1 Project Impacts

18.4.1.1 Pedestrian Traffic

- The pedestrian level of service (LOS-C) along Harbour Drive, which is presently achieved approximately 70% of the time, will be reduced to approximately 30% of the time.
- The existing proportion of cruise passengers traveling east of Harbour Drive is about 6%; it is anticipated that improvements associated with the George Town Revitalization Plan (improvements to streetscapes, rest areas, greenery, wayfinding and sidewalk widening) may triple this.

18.4.1.2 Vehicle Traffic

- An increase in north and southbound travel times of 50 to 200% is expected by 2024.
- The NRA's Priority for road network improvements, will provide relief to mounting traffic pressures along the Harbour Drive corridor within the downtown core, but will have little effect on pedestrians.

18.4.1.3 Parking

- The demand for parking is expected to increase as a result of the expected increased in vehicle traffic volumes.

18.4.1.4 Construction Phase Impacts

- Civilian traffic and pedestrian volumes along Harbour Drive are expected to decrease as a result of traffic restrictions during construction.

- An increase in heavy vehicle traffic is expected in George Town. Construction traffic routes will be a function of the location of source of local construction materials (concrete and quarried stone) as well as staging and storage areas available to the Contractor; traffic issues will be an important consideration in the selection/approval of staging and storage areas.
- Delays are expected along Harbour Drive, and intermittent closures may be required.
- It is anticipated the Tower Lot will be used as a temporary staging area for tour bus operations; if so, this area will not be available to the regular clientele.
- The increased volume of heavy vehicles will lead to accelerated wear and tear of existing roadways.
- The potential for multiple construction projects associated with the GTRP, the NRA's priority for road network improvements, will increase pressure/congestion on the existing road network. Careful coordination amongst the projects and contractors will be required to minimize disruptions to local road users.

18.4.1.5 Operation Phase Impacts

- The rate of unloading passengers at the CBF is not expected to change significantly as compared to the existing tendering operation. However, the CBF is expected to result in a significant increase in overall pedestrian traffic levels in George Town.
- The additional vehicle traffic generated by the CBF is expected to be small compared to the baseline growth.
- Significant delays for vehicles travelling along Harbour Drive are expected as a result of the increased pedestrian traffic.
- The CBF is not anticipated to have a significant impact on the demand for parking in George Town.

18.4.2 Climate Change Impacts

Regarding landside traffic, the primary concern related to the impact of the proposed CBF on climate change is increased vehicle emissions that may result from increased vehicular traffic and/or increased traffic congestion/delays and vehicle idling. As noted above, the CBF is not expected to result in a significant increase in vehicular traffic; however, increased pedestrian traffic is expected to result in more congestion/delays along Harbour Drive. This issue can be address by various mitigation measures, as discussed in the next section.

18.5 Proposed Mitigation Measures

Various mitigation measures have been proposed by different parties (NRA, GTRP and the EIA study team) to improve traffic conditions in George Town for both pedestrians and vehicles. Some of these measures are specific to the CBF, while others are generally applicable regardless of

whether or not the CBF is constructed. A discussion of possible mitigation measures is presented below.

18.5.1 Construction Phase

A traffic management plan will be required during construction of the CBF in order to minimize the impacts of construction on pedestrian and vehicular traffic. The traffic management plan should be developed by the Contractor, in consultation with the CIG (NRA) and RCIPS. Key aspects of the traffic management plan may include the following:

- Temporary restrictions and alternative routes for pedestrians and vehicles to reduce traffic in/around the active construction area;
- Approved routes for construction traffic between key material sources (concrete plant and quarries), staging/storage areas and the project site;
- Time of day restrictions on construction traffic (for example, restrict heavy construction traffic to night, thereby limiting impacts on locals and cruise passengers during the day);
- Monitoring and maintenance plan to identify and repair damage to roads caused by construction traffic.

18.5.2 Operation Phase

The GTRP and the NRA's Priority for road network improvements will both play a significant role in mitigating issues associated with the anticipated increase in vehicular traffic, regardless of whether the CBF is constructed. As part of these plans, it is recommended that the CIG (Ministry of Planning and the NRA) incorporate and promote sustainable modes of transit, such as walking, cycling, car sharing and increased use of public transport.

The traffic and pedestrian study undertaken as part of the EIA has assessed measures proposed in the GTRP and NRA's Priority for road network improvements has also identified/assessed additional mitigation measures to provide increased priority for pedestrians, reductions in the number of vehicles in the downtown core, and increased levels of service for both pedestrians and vehicles. The various mitigation measures are discussed below.

18.5.2.1 Description of Vehicular and Pedestrian Traffic Mitigation Measures



- Optimization of the traffic signal function at Harbour and Fort would improve travel times and pedestrian level of service along Harbour Drive.
- Raised intersections and crosswalks improve pedestrian visibility and assist in promoting their priority among road user groups. Modelling of

these mitigation measures confirms reductions in future travel times and improved pedestrian level of service.

- The introduction of pedestrian priority options will improve vehicle flow without restricting vehicle access while significantly increasing the pedestrian experience. An analysis of corridor travel delays indicates an average north/south vehicle delay of 45s (20 hours total vehicle delay). Other network options and associated delays had higher vehicle delays and are further described below.
    - The **Full Pedestrianization** of Harbour Drive was assessed, but is not recommended (refer to Appendix L). . North/south traffic on Harbour Drive would need to be diverted to the road network, primarily the Mary-Fort-Edward corridor. In addition, Harbour Drive would still be required during the day for tour bus and other port traffic, and on nights and weekends for commercial traffic between the port and the CDC. The full pedestrianization of Harbour Drive would result in an average vehicle delay of 1½ minutes for northbound and southbound vehicles in the Mary-Fort- Goring corridor between Goring Avenue and Mary Street. This equates to 45 total vehicle delay hours. While this increase in average vehicle delay has been quantified during the midday peak hour, it could be expected that these delays would be spread across other hours of the day. This delay does not include turning movement or cross street delays.
    - Converting **Harbour Drive to one-way** (either northbound or southbound) was also assessed, but is not recommended (refer to Appendix L). For each of the one-way options additional modifications would be required to the downtown road network to improve the flow of southbound traffic including converting some existing one-way street to two-way, changes to intersection control lane arrangements and pedestrianizing some street blocks. In addition to introducing circuitous routings in the downtown the one-way options would have an increase in the average vehicle delay between 1½ minutes (northbound one-way) and 2½ (southbound one-way) or 38 hours and 61 hours of total vehicle delay for the northbound and southbound options respectively. Alternatively, a one-way couplet (i.e. northbound on Harbour Drive and southbound on Edward Street) would result in an average vehicle delay of 1 minute or 22 total vehicle hours while also adding circuitous routing.
- Passenger management features can be incorporated into the master plan for the reclaimed land area to effectively moderate the rate at which passengers reach Harbour Drive and George Town.
- Variable message signs may be used to inform and divert traffic away from the downtown core on peak volume days. For example, a sign informing drivers “Delays on Harbour Drive” would allow them to consider an alternate route before they have entered the downtown core.
- Providing clear cues and direction to all road users to promote pedestrian safety and mobility while minimizing crowding on sidewalks, intersection corners and crossings will lead to lower risk of conflicts.

- Although not included in the base layout for the CBF, a sheltered small craft harbour basin would reduce the volume of vehicular traffic entering and leaving the CBF, as marine based tours could be staged directly with boats and not require intermediate buses or taxis for transport.

18.5.2.2 Impact of Vehicular and Pedestrian Traffic Mitigation Measures

Despite an increase in traffic and pedestrian volumes, a 50% reduction in travel time and improved pedestrian experience may be achieved over existing conditions through the implementation of various mitigation measures. Referring to **Figure 18.1**, the model results for different mitigation measures are summarized below:

- Existing Baseline (blue): The model was calibrated to the measured (2014) travel times along Harbour Drive, with pedestrian LOS-C for 70% of the time.
- 2024 "Do Nothing" Scenario (red dash): Increase in north and southbound travel times by 50-200%, with pedestrian LOS-C reduced to 30% of the time.
- 2024 with NRA's Priority for road network improvements (red dotted): Reduces travel times by about 25% from "Do Nothing" Scenario, but remains about 50% higher than the Existing Baseline. No provision is made for pedestrians, so there is no significant change to pedestrian LOS with this option.
- 2024 with Pedestrian Priority (yellow): Reduces travel times an additional 10% from NRA's Priority for road network improvements (but still 40% above Existing Baseline), and increases pedestrian LOS-C to 70% of the time (same as Existing Baseline).
- 2024 with Expanded Pedestrian Priority (green): Reduces travel time by 50% from Existing Baseline, and increases pedestrian LOS-C to 80%.
- Further reductions in travel time and improvements to pedestrian LOS may be possible through narrowing of the roadway, removal of storage pockets, delineation of turning and driving lanes, and conversion to one-way operation on Fort Street (westbound) from Albert Panton to Harbour Drive.

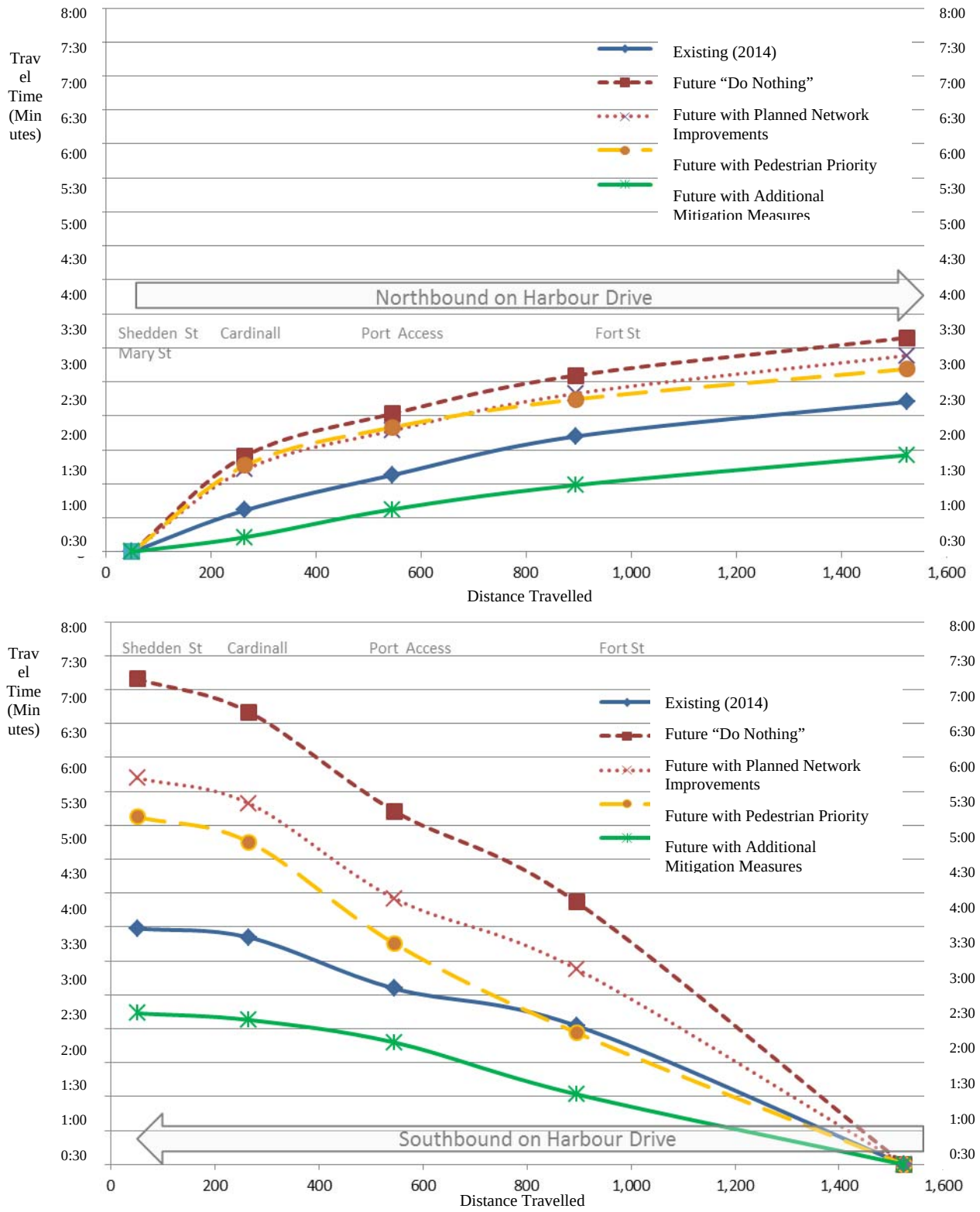


Figure 18.1 – Impact of Mitigation Measures on Travel Time on Harbour Drive

18.5.3 Parking Mitigation Measures

As noted earlier, private parking lots and public on-street parking presently have average utilization rates in the order of 60 and 86% respectively, with the presence of cruise ships in George Town not having a significant impact on parking. The following mitigation measures could be considered during the planning and design of the proposed CBF in order to increase parking capacity and/or reduce parking demand:

- Increased parking supply could be included as part of the master plan for the expanded land reclamation area;
- The addition of a sheltered small craft harbour basin would allow marine-based tours to be staged directly with boats, thereby reducing the demand for shuttle buses or taxis and the associated parking requirements for the CBF (note that a sheltered small craft harbour basin was not included in the EIA).

18.6 RIAM Summary of Anticipated Project Impacts and Proposed Mitigation Measures

As noted in Chapter 1.3.6, the Rapid Impact Assessment Matrix (RIAM) method has been used to "quantify" the anticipated impacts of project construction, operation and mitigation measures. Table 18.1 and Figure 18.2 provide a summary of the RIAM scoring for specific impacts related to vehicular and pedestrian traffic, including scores for each of the following project phases:

- Existing (baseline) conditions
- Dredging and reclamation phase
- Construction (post-dredging) phase
- Operational phase

Proposed mitigation measures for specific impacts are highlighted in the green cells in Table 18.1, with the RIAM method applied both without and with these mitigation measures.

Chapter 1.3.6 provides an overview of the various RIAM scoring criteria (A1, A2, B1, B2 and B3) and the methodology used to derive the Environmental Score (ES) and associated Range Value (RV) for each specific impact. The Range Values are summarized as follows:

- N: Neutral (no change/impact)
- A to E: Positive change/impact (A is slight positive...E is major positive)
- -A to –E: Negative change/impact (-A is slight negative...E is major negative)

Additional information on the RIAM methodology is provided in Appendix Q.

Table 18.1 Detailed RIAM Scoring for Vehicular and Pedestrian Traffic

PHASE	IMPACTS SCORED WITH NO MITIGATION	Spatial Importance (0 to 4)	Magnitude of change/effect (-3 to + 3)	Permanence (1 to 3)	Reversibility (1 to 3)	Cumulative (1 to 3)			IMPACTS SCORED WITH MITIGATION	Spatial Importance (0 to 4)	Magnitude of change/effect (-3 to + 3)	Permanence (1 to 3)	Reversibility (1 to 3)	Cumulative (1 to 3)	*ES with mitigation*	*RV With Mitigation*
		A1	A2	B1	B2	B3	ES	RV		A1	A2	B1	B2	B3	ES	RV
EXISTING CONDITIONS (with future growth)	Pedestrian Crowding: Reduced Pedestrian Level of Service	2	-1	3	3	3	-18	-B	Pedestrian priority improvements (traffic signal optimization, raised intersections, etc.)	2	1	2	2	3	14	B
	Increased Pedestrian traffic (future background traffic and GTRP)	2	-1	3	2	3	-16	-B	Pedestrian priority improvements (traffic signal optimization, raised intersections, etc.)	2	1	2	2	3	14	B
	Increased travel times along Harbour Drive	2	-2	3	3	3	-36	-D	NRA's priority for road network improvements; Pedestrian priority improvements (traffic signal optimization, raised intersections, etc.)	2	2	3	3	3	36	D
	Increased demand for Parking	1	-1	3	2	2	-7	-A		1	-1	3	2	2	-7	-A
DREDGING & RECLAMATION	Traffic Restrictions on Harbour Drive	2	-2	2	2	3	-28	-C	Traffic Management Plan (time of day restrictions, alternative routes, etc.)	2	-1	2	2	3	-14	-B
	Increased Heavy Vehicle Traffic	2	-2	2	2	3	-28	-C		2	-1	2	2	3	-14	-B
	Delays and intermittent closures of Harbour Drive	2	-1	2	2	3	-14	-B		2	-1	2	2	3	-14	-B
	Tower Lot used for Tour Bus Staging; Cruise passengers will need to cross Harbour Drive	2	-1	2	2	3	-14	-B	Control movement of passengers across Harbour Drive	2	-1	2	1	2	-10	-B
	Increased wear and tear of roadways	2	-1	2	2	3	-14	-B	Monitoring and maintenance plan to identify and repair damage	2	0	2	2	3	0	N
	Coordination of multiple projects (GTRP, NRA, CBF)	3	-1	2	2	2	-18	-B	N/A	3	-1	2	2	2	-18	-B
CONSTRUCTION - POST DREDGING	Traffic Restrictions on Harbour Drive	2	-2	2	2	3	-28	-C	Traffic Management Plan (time of day restrictions, alternative routes, etc.)	2	-1	2	2	3	-14	-B
	Increased Heavy Vehicle Traffic	2	-2	2	2	3	-28	-C		2	-1	2	2	3	-14	-B
	Delays and intermittent closures of Harbour Drive	2	-1	2	2	3	-14	-B		2	-1	2	2	3	-14	-B
	Tower Lot used for Tour Bus Staging; Cruise passengers will need to cross Harbour Drive	2	-1	2	2	3	-14	-B	Control movement of passengers across Harbour Drive	2	-1	2	1	2	-10	-B
	Increased wear and tear of roadways	2	-1	2	2	3	-14	-B	Monitoring and maintenance plan to identify and repair damage	2	0	2	2	3	0	N
	Coordination of multiple projects (GTRP, NRA, CBF)	3	-1	2	2	2	-18	-B	N/A	3	-1	2	2	2	-18	-B
OPERATIONAL	Pedestrian Crowding: Reduced Pedestrian Level of Service	2	-1	3	2	3	-16	-B	Pedestrian priority improvements (traffic signal optimization, raised intersections, etc.)	2	1	2	2	3	14	B
	Increased Pedestrian traffic (future background traffic and GTRP)	2	-1	3	2	3	-16	-B	Pedestrian priority improvements (traffic signal optimization, raised intersections, etc.)	2	1	2	2	3	14	B
	Increased travel times along Harbour Drive	2	0	3	3	3	0	N	NRA's priority for road network improvements; Pedestrian priority improvements (traffic signal optimization, raised intersections, etc.)	2	0	3	3	3	0	N
	Increased demand for Parking	1	0	3	2	2	0	N		1	0	3	2	2	0	N

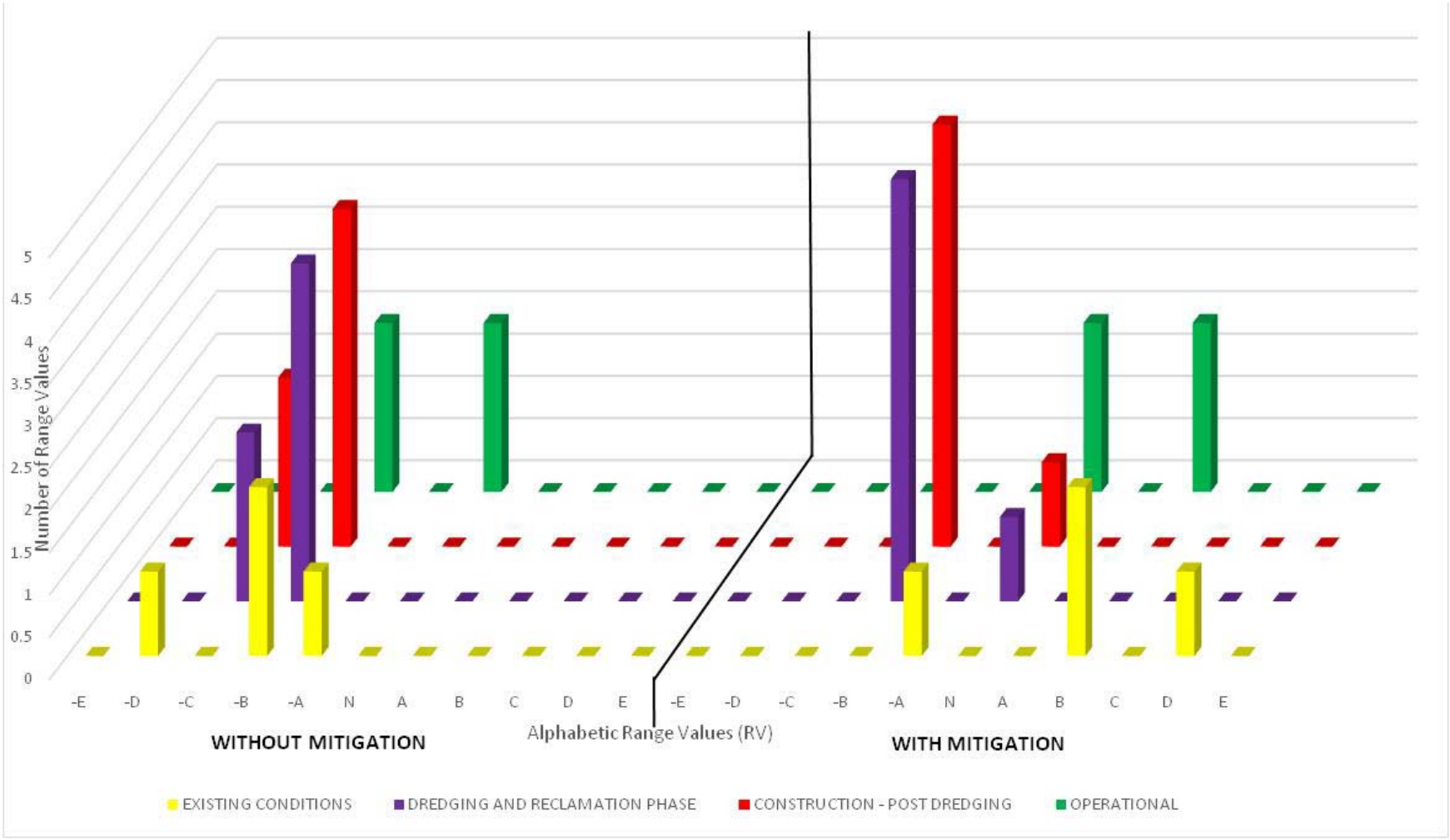


Figure 18.2 Summary RIAM Scoring for Vehicular and Pedestrian Traffic

19.0 TASK M - CRUISE AND CARGO OPERATIONS

19.1 Introduction

Task M included a review of existing cruise and cargo operations at George Town Harbour, and an assessment of the anticipated impacts of the development of the proposed cruise berthing facility (CBF) on these operations. This chapter presents a summary of baseline conditions for cruise and cargo operations at the existing facility, followed by a discussion of the anticipated impacts of the construction and operation of the proposed CBF on these operations. Finally, a number of mitigations measures to reduce adverse are presented.

19.2 Assessment Methodology

The assessment of cruise and cargo operations included the following key tasks:

- Collection, review and assessment of previous studies related to cruise and cargo operations in George Town Harbour;
- Collection, review and assessment of relevant historical data and information from various sources;
- Meetings and discussions with key stakeholders (including PACI, CMS, cruise lines) and other interested parties (West Indian Marine Group);
- Observation of cruise and cargo operations and visual inspection of infrastructure at existing port;
- Review of operations at other cruise berthing facilities in the Caribbean;
- Modeling and analyses of moored ship response and operational downtime due to wind and wave action.

The available information was assimilated to develop an understanding of existing cruise and cargo operations, as well as key opportunities and constraints related to the development of the proposed CBF. This information was used to guide the development of a refined project layout (refer to Chapter 7.6 and Appendix A), to identify potential impacts of development of the proposed CBF on cruise and cargo operations, and to identify possible mitigation measures to limit negative impacts.

19.3 Existing Data

The datasets listed in the Final EIA Terms of Reference (MM, Dec. 2013) were used as a starting point for data collection efforts for the EIA, as summarized below:

- *Obtain data from PACI for cruise vessels, passengers coming ashore, number of tender and tourist boats in operation*. These data were obtained from various sources including PACI, CMS, and the cruise lines.

- *Obtain passenger queuing data for departures/arrivals for shore excursion and queues for departure tendering.* Landside tender queuing data were collected as part of the traffic and pedestrian study (refer to Chapter 18 and Appendix L). Information about the queues on board the cruise ships was requested but not available.

- *Obtain data on the available shore excursions and their capacities to accommodate tourists.* Excursion owners and operators were typically reluctant to share detailed information on their operations. However, PACI and the Public Transport Board were able to provide some information, and questionnaires completed as part of the socio-economic impact assessment (refer to Chapter 20 and Appendix N) also provided some relevant information. Additional background information was also obtained from an economic valuation of the Cayman Turtle Farm completed by PwC (2013), as well as statistics from the Cayman Islands Department of Tourism.

- *Obtain data on existing demands for water, waste disposal, electricity and fuel from the port and cruise operations.* Currently, no provisioning or servicing is provided to large cruise ships. Small scale provisioning and waste disposal is provided to smaller cruise vessels, US Coast Guard and Navy vessels, and private vessels.

The datasets summarized in Table 19.1 were collected and reviewed as part of the EIA study.

Table 19.1 Summary of Data Coverage

Data	Data Coverage	Source	Notes
Scheduled and Historic Cruise calls in Cayman	2010-2014	PACI	
Historic Cargo data	1977-2013	PACI	
Tender Operations and loading rates	2011-2014	CMS	Intermittent days
Tender Queue Times	2014	Baird/MMM	Intermittent days
Caribbean Cruise Trends	2004-2014	Baird/OneCaribbean.org	
Shore Excursions	2013-2014	PTB/Baird/MMM/PwC/ SWI/Dept of Tourism	Tour Staging, CTF, etc
Existing Demand for Shore side services	2014	PACI, Cruise Lines	

19.4 Baseline Conditions

19.4.1 Port Infrastructure

The port facility in George Town Harbour serves both cruise and cargo operations, with both being essential to the economy of the Cayman Islands. The harbour area is congested with marine traffic (cruise, tender and cargo vessels, as well as recreational/water sport activities), particularly during the cruise season (November through April). Similarly, the landside port area (7.2 acres) and adjacent urban area of George Town are congested.

Figure 19.1 shows the locations of the major features of the existing facilities; the following pages highlight baseline conditions for cruise, tender and cargo operations, as well as recreational/water sport activities in George Town Harbour.



Figure 19.1 Existing Harbour Facilities (Source CIG Department of Lands and Surveys)

19.4.2 Baseline Conditions – Cruise Operations

19.4.2.1 Overall Cruise Operations

- Existing cruise facilities consist of four offshore anchorage/mooring locations, the Royal Watler (RW) pier and terminal (which accepts the majority of cruise passengers), the shared dock area for tour staging, and the North and South Terminals for tender handling on busy cruise days.
- When more than four ships call at George Town, the additional ships maintain position offshore using their engines.
- Anchored cruise ships frequently use their thrusters to adjust the orientation of the ship to reduce the wind exposure at the tender doors to facilitate passenger transfer to the tenders.
- PACI records (2010-2014) indicate a maximum of seven cruise vessels in one day, but that situation is rare (three occurrences in the past five years). In general (95% of the time), there are four or fewer cruise ships.
- Cruise ship sizes vary significantly; as such, the number of passengers rather than the number of ships is considered to be better indicator of the loading on the landside facilities. PACI have recorded peak passenger arrivals of over 20,000 pax/day; however, these are rare occurrences. As summarized in Table 19.2, PACI's records show that passenger arrivals are less than 11,000 pax/day 85% of the time during cruise season (i.e. passenger arrivals exceed 11,000 pax/day only 15% of the time).

Table 19.2 Summary of 85th Percentile Cruise Passenger Arrivals by Cruise Season

Cruise Season (Nov-Apr)	85th Percentile Pax Arrivals
2010/2011	10,760
2011/2012	11,991
2012/2013	11,108
2013/2014	10,296
Design Volume	11,000

- Tenders typically berth on the north side of the RW pier, as the south side is subject to significant wave reflection and wave agitation even under low to moderate wave conditions. The RW terminal is the primary terminal, and offers some landside amenities, including souvenir shops, restaurants, and bars. The North and South terminals are typically overflow terminals for busy days, and consist solely of a pier with a customs and immigration check point.
- The cruise facilities generally operate from 6 am to 6 pm (cargo operations generally occur overnight).
- The tender operation is susceptible to weather conditions (i.e. strong winds and rough seas, particularly during Nor'Westers). Over the past four years (2010-2014), approximately 4% of scheduled calls have been diverted to Spotts Landing (located in South Sound), with another 4% of missed calls (i.e. when the ships do not stop at Grand Cayman). On an annual basis, the total of diverted and missed calls varied from 5 to 15% over this four year period. Additional information on downtime is presented in Section 19.4.2.5.

- Passenger accessibility currently relies on ramps and stairs for loading/unloading at the tenders; this is challenging for elderly and disabled persons.
- Cruise passengers are currently dropped within 150 ft of the RW Terminal, which is approximately 300 ft from Harbour Drive. Hence, the total walking distance to Harbour Drive is approximately 450 ft.
- A study by BREA (2012) indicates that approximately 90% of cruise passengers disembark in Grand Cayman. Data collected as part of the traffic and pedestrian study (refer to Chapter 18 and Appendix L) indicate a peak of 60-70% of the passengers are ashore at the busiest time (early afternoon). The peak number ashore is lower than the disembarkation rate due to the distribution of disembarkation through the day (i.e. some passengers and crew come ashore in the afternoon, when the early morning passengers have already started to return to the ship).
- BREA (2012) reports that the overall passenger visit score at Grand Cayman is 7.9 out of 10. The highest rates are related to guided tours and the friendliness of locals, while the lowest ratings are related to prices, variety of shops, historic sites/museums and things to do.
- The Outline Business Case (PWC, 2013) indicates that cruise passenger traffic to Grand Cayman is expected to decline at a rate of 1-3%/year if a cruise berthing facility is not constructed (the OBC also indicates that cruise passenger traffic is expected to grow at a rate of 1-3%/year if a cruise berthing facility is constructed).

19.4.2.2 Tender Infrastructure

- The tender service is operated by Caribbean Marine Services (CMS). The CMS tender fleet consists of 12 large vessels (250 to 300 pax) and four small vessels (90 pax).
- There are three docks in George Town available for tender operations, including the RW pier, which is located on the north side of the port, and the North and South terminals which are located on the north and south sides of Hog Sty Bay respectively (i.e. on the south side of the port). The RW pier accepts the majority of tender and passenger arrivals.
- Depending on wind and wave conditions, the RW pier can accommodate 3-4 tenders, the North Terminal can accommodate 2 tenders and the South Terminal can accommodate 1-2 tenders.
- The tender operation is susceptible to the weather, particularly the strong winds and rough seas that occur during Nor'Westers. Overtopping of the RW pier, even on relatively calm days, can result in the requirement to move tender landings to the North and/or South Terminals. Under more severe conditions, cruise and tender operations are moved to Spotts Landing, in South Sound, or are cancelled altogether.
- On days when tenders are not required, they are moored at Sand Cay in South Sound (this is the nearest semi-sheltered anchorage available).

- PACI uses containers to provide separation between cruise and cargo areas when required, such as when the North Terminal is in use (refer to **Figure 19.2**).



Figure 19.2 Use of Containers to Contain Cruise Passengers at North Terminal

19.4.2.3 Tender Loading Rates

- Vessel loading records were available from CMS for the Carnival Glory (17 Dec, 2010), Carnival Valor (26 Apr, 2011 and Jan 03, 2012), Carnival Magic (18 Sept, 2014) and Freedom of the Seas (18 Sept, 2014).
- Typically, the first few tender loads of the day are full to capacity and load quickly (10-15 min), while remaining loads over the course of the day are subject to differing management strategies by the cruise ships. Some cruise ships prefer to hold tenders longer (30-45 min) and send full loads, whereas other cruise ships prefer to send more frequent loads (every 10-15 min) even if the tender is only partially full. Both strategies appear to move passengers at similar rates, but the shorter wait times with frequent rides are perceived as better by the passengers.
- CMS's tenders are estimated to be able to unload at the rate of 950 pax/hr/door. The total fleet capacity is estimated to be in the order of 4,500 to 6,500 pax/hr, assuming 40-50 minute round trip times. Poor weather conditions will reduce these rates.
- Self tenders are still used on some smaller cruise ships, but are typically being phased out and are not practical for use with the larger ships. Self tenders are typically smaller than the CMS tenders and require the ship to carry additional stairs/ramps to load/unload at the level of the ship doors. Self tendering is estimated to have a capacity of about 450pax/door/hour.

- Tender queue times are partially a function of varied passenger management strategies employed by different ships (more frequent partially full trips versus fewer full trips).

19.4.2.4 Cruise Market Trends

Over the past 20 years, the cruise industry has been the fastest growing sector of the world travel and tourism economy. The Caribbean region is the natural cruising ground for North Americans, and is the only area in the world that offers year-round cruising, albeit with a high season in the winter and a low season in the summer. Recently, the Caribbean cruise market has faced increasing competition from the rapidly growing European (Mediterranean) market; however, the Caribbean region continues to be the largest market sector in the cruise industry.

Table 19.3 presents cruise passenger arrival statistics for the Caribbean region and the Cayman Islands over the past decade (2004-2014). Growth in the Caribbean region has been strong over this period (average 2.5%/year growth); however, cruise passenger arrivals in the Cayman Islands have declined over this same period (average 0.4%/year decline).

Table 19.3 Caribbean versus Cayman growth over past decade (Source: OneCaribbean.org)

Destination	Cruise Passengers Arrivals (millions)											% Change (2004-2014)	% Change per annum
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014		
Cayman Islands	1.7	1.8	1.9	1.7	1.6	1.5	1.6	1.4	1.5	1.4	1.6	-5%	-0.4%
Caribbean	19.5	18.5	18.5	19.1	18.2	18.3	20.1	20.4	21.2	22.0	24.7	27%	2.5%

Considering the Cayman Islands, the peak in arrivals (1.9 M pax) experienced in 2006 is likely partially the result of hurricane damage to piers in Cozumel causing cruise traffic in the Western Caribbean to be redirected. Also, the recovery in 2014 (1.6 M pax, the highest since 2010) is attributed to a general upturn in the Caribbean cruise market.

Cayman's geographic location makes it a logical stop for ships travelling between Jamaica and Mexico, and historically George Town has ranked in the top five Caribbean ports in terms of passenger arrivals. Cayman's recent decline in passenger arrivals has been attributed to the lack of a cruise ship berthing facility (PwC, 2013).

The OBC (PwC, 2013) presents growth scenarios for cruise passenger traffic to the Cayman Islands without and with the proposed cruise berthing facility, as summarized in Table 19.4. The OBC growth scenarios have been plotted again historical records of passenger arrivals for the Cayman Islands, the Caribbean and Saint Maarten over the past decade (Figure 19.3, Figure 19.4, and Figure 19.5). Saint Maarten was chosen for comparison, as these data incorporate the impact of an upgrade to the Saint Maarten cruise berthing facility that was completed in 2009.

For the Cayman Islands, the historical data show a generally declining trend in passenger arrivals since 2004, with a peak in 2006 (associated with the diversion of traffic from Cozumel due to hurricane damage to their facilities) and a significant rebound in 2014 (attributed to general growth in the region). Considering the past decade (2004-14), the actual data fall around the OBC projections of -1%/yr ("expected") scenario without a new berthing facility.

For the Caribbean region, the historical data show no significant change in traffic between 2004 and 2010, with consistent positive growth since 2010, and particularly strong growth in 2014. The historical data show an average increase of approximately +1%/yr over the past decade, and +3%/yr over the past three years; these rates are generally consistent with the OBC projections for the scenario with a new cruise berthing facility.

Saint Maarten, which completed a major upgrade to their cruise berthing facility in 2009 (including a second pier and landside development), provides an interesting comparison. Prior to the upgrade, Saint Maarten was suffering from declining arrivals. In the first two years after the upgrade (2010-11), very high growth was experienced (note that a portion of this growth may have been a "rebound" to pre-construction levels, as traffic likely dropped during construction). Since 2011, the facility has registered an average growth rate of approximately +3%/yr; this growth rate is in line with the OBC's "optimistic" projection for the scenario with a new

Table 19.4 OBC Growth Scenarios (PwC, 2013)

OBC Growth Scenarios (PWC 2013)	Growth Per Annum
With berthing facility - optimistic	+3%
With berthing facility - expected	+1%
Without berthing facility - expected	-1%
Without berthing facility - pessimistic	-3%

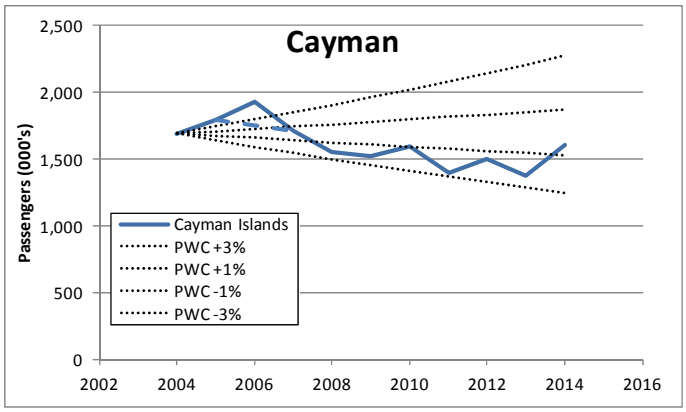


Figure 19.3 Passenger Growth in Cayman

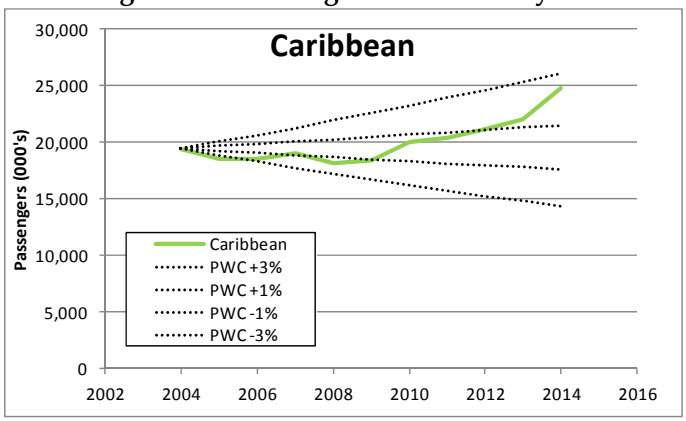


Figure 19.4 Passenger Growth in the Caribbean

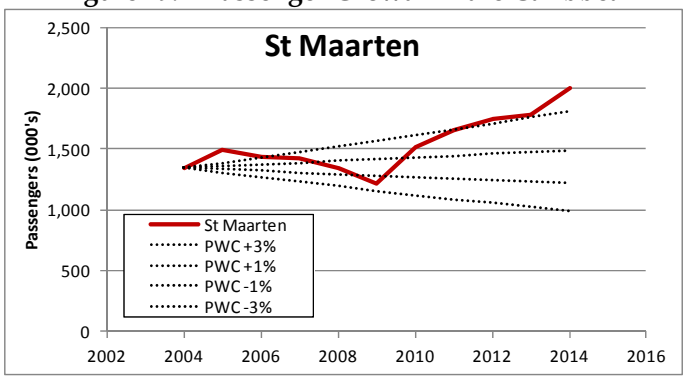


Figure 19.5 Passenger Growth in St Maarten

cruise berthing facility. Similar trends were also noted in data for Nassau, which completed an upgrade in 2009.

In summary, the anticipated growth rates presented in the OBC (PwC, 2013) appear to be reasonable based on a review of historical data in the region. In addition, upgraded cruise berthing facilities on other islands in the region have shown the ability to turn a declining trend into strong positive growth.

19.4.2.5 Operational Downtime

Downtime due to inclement weather (in particular, Nor'Westers) is an important factor to consider in the evaluation of passenger arrival numbers, as missed calls will reduce the number of passengers arriving in Grand Cayman. Downtime was included in a list of concerns identified by a coalition of local shop owners in an open letter to the Government regarding a previous version of the CBF (circa 2012).

Information on downtime was available from PACI for 2010-2014, as summarized in **Table 19.5.** These data indicate a total of 117 "missed calls" to Grand Cayman over this 5 year period with another 112 ships choosing to berth at the Spotts Landing facility (which is sheltered from Nor'Westers). Considering the variation from one year to the next, the total of missed and redirected calls represents between 5 and 15% of scheduled cruise ship arrivals to George Town.

Table 19.5 Summary of Missed Calls with Present Tender Operation (2010 – 2014)

Description	2010	2011	2012	2013	2014	Total
Total Scheduled	611	557	550	496	658	2,872
George Town*	520	519	516	471	617	2,328
Spotts	56	10	15	16	15	112
Missed	35	28	19	9	26	117
Total - Spotts + Missed						
Number of Calls	91	38	34	25	41	229
% of Calls	15%	7%	6%	5%	6%	8%

*Includes Royal Watler, North and South Terminals and Cargo Dock

Most of the missed and diverted calls occur during the winter cruise season (November to April), and are associated with Nor'Westers. Based on cross-referencing the dates of missed and diverted calls with hindcast wave data developed as part of the EIA study, as well as recorded wave data collected in George Town Harbour during the 2014-15 cruise season (refer to Chapter 10 and Appendix D.1), missed and diverted calls become significant when significant wave heights (Hs) in George Town Harbour approach 1.5 ft (approx 50% missed/diverted calls); when wave heights (Hs) in George Town Harbour exceed 3 ft, essentially 100% of the cruise ships miss their calls. This is primarily due to the inability of the tender operation to take place in rough seas.

CMS may cancel their tender operations in response to poor weather conditions, either actual or forecast. If the tender operations are cancelled, then the cruise ships are typically unable to unload. Discussion with CMS indicates that the limiting criteria is generally overtopping of the RW pier, rather than waves being too large for passenger transfer at the ship or pier. As such, a sheltered landing area in George Town Harbour would likely reduce the downtime associated with tendering.

When CMS observes rough conditions at the pier, or in response to a forecast for large waves (Hs > 5 ft, especially from the NW) at NOAA Buoy 42056, they will recommend to the cruise lines that tendering not occur on that day. For example, Figure 19.6 shows overtopping of the RW pier on October 17, 2011. Offshore wave conditions recorded at the NOAA Buoy were Hs = 7 ft from the ESE, while estimated wave conditions in George Town Harbour were Hs = 1 to 1.5 ft from the SW. This is an example of a relatively calm day when tendering was not possible (due to wave overtopping of the RW pier), and when the offshore trigger criteria was used to call off tendering.

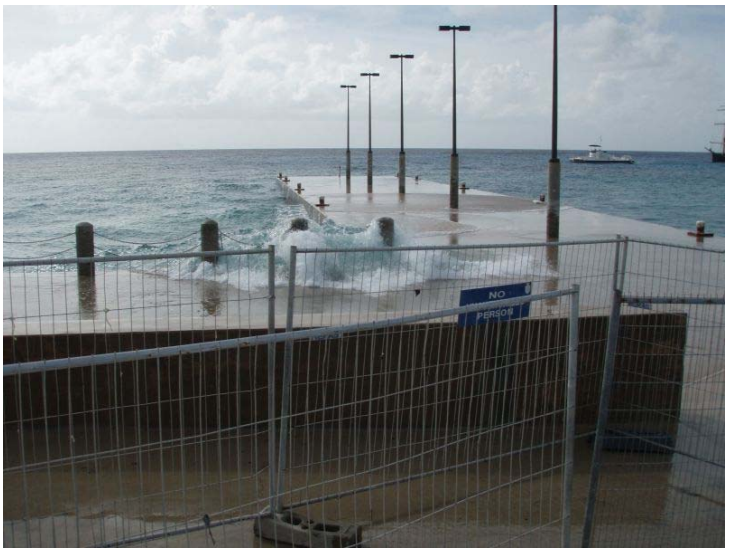


Figure 19.6 Overtopping of RW Pier on a "Calm" Day

The proposed cruise berthing facility will reduce downtime for cruise operations, as large cruise ships moored to the piers will be less susceptible to the effects of wave action than the much smaller tender vessels. The estimated downtime of cruise ships at the proposed cruise berthing facility is discussed Section 19.5.3.2 and Appendix M.2.

19.4.3 Baseline Conditions – Cargo Operations

19.4.3.1 General Cargo Operations

- Existing cargo facilities consist of the South cargo pier/dock, the RO/RO berth, the West dock wall, a shared staging area (7.2 acres) and the inland Cargo Distribution Centre (CDC), where cargo (predominantly containers) is stored/processed.
- There is a shared staging area between the cruise and cargo sides of the port. By day, this area is used as a tour bus staging area for cruise ship passengers, while by night it is used for cargo loading/offloading operations and temporary storage.
- The west dock wall, between the RW pier and the south cargo pier/dock, is used for miscellaneous activities, including temporary berthing of yachts and docking by smaller

commercial vessels and barges. Figure 19.1 and Figure 19.2 both show an aggregate barge using the west dock wall.

- Cargo operations typically take place from 6 pm to 5 am each day, with a 1 hour window (5 am to 6 am) allocated for cleaning the staging area before the cruise day starts.
- The draft alongside the south cargo pier/dock ranges from approximately 17 ft at the shoreward end to over 20 ft at the seaward end; PACI reports that no dredging has been undertaken since the facility was expanded in 2004.
- Typically, one or two crawler cranes are used to unload containers from the cargo ships, while forklifts are used for moving containers around the staging area, and for loading/unloading transport trucks. Containers are transported to the CDC for processing.
- The RO/RO berth is used primarily by RO/RO ships (approximately once per week) and bulk ships (cement and aggregate) and barges. The cement ship visits approximately once per month, and requires approximately 48 hours to offload its cargo, including the setup and removal of the onshore processing plant. RO/RO and aggregate operations occur more frequently, but are significantly quicker.
- Cargo ships calling at George Town are length and draft limited to about 500 TEU; this is a relatively small cargo vessel, even by Caribbean standards.
- The entire perimeter surrounding the existing land reclamation area consists of vertical bulkhead walls, predominantly of steel sheet pile construction. The vertical walls allow alongside berthing during calm conditions, but also lead to increased wave reflections and wave agitation during periods of wave action. It is understood that wave agitation causes frequent inconvenience to cargo operations and occasional damage to vessels using the port.
- A visual inspection of the various quay walls was conducted above and below water as part of the EIA study (refer to Appendix M.1). Although localized minor damage was observed, there were no areas that appeared to pose an immediate structural concern. However, if the development of the CBF includes long term use of the quay wall adjacent to the North Terminal, then rehabilitation/upgrade of this structure would be recommended.

19.4.3.2 Cargo Market Trends

Figure 19.7 presents a summary of PACI data for total cargo imports to the Cayman Islands since 1977. These data highlight an underlying trend of positive growth, averaging approximately 5%/year, as well as a distinct peak in cargo imports in 2005-2008. This peak was due to rebuilding efforts following Hurricane Ivan (2004), which caused substantial damage in the Cayman Islands. Since 2009, total cargo imports have remained below the projected long term trend line.

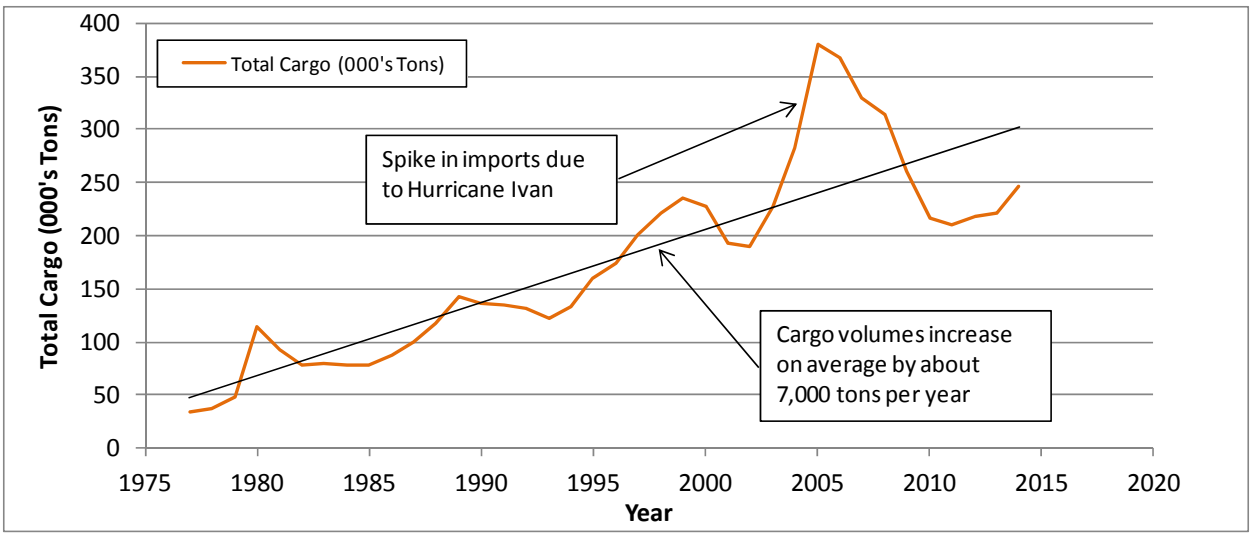


Figure 19.7 Growth in Total Cargo Volume in Grand Cayman

As noted earlier, cargo operations are restricted to 6pm-5am; furthermore, the size of the cargo ships is limited to approximately 500 TEU by the physical constraints of the existing facility (i.e. berth length and depth alongside), and therefore have not increased significantly over many years. As a result, without significant infrastructure improvements, the only way to increase the capacity of the existing port is to increase the number of days vessels are in port. However, retail market factors and competitive shipping forces determine the preferred arrival days for refrigerated container cargoes of perishable goods. As a result, arrival days for container ships are limited to certain days based on balancing the requirements of the US loading port, the Cayman unloading port (George Town) and the receiving requirements of the Cayman importers.

When the number of working days per year reaches 365 (i.e. the number of days without a ship in port reaches 0) the port will have reached its physical capacity, and expansion (or relocation) will be required to accommodate any additional growth. As such, the number of working days with ships in port, as well as the number of working days without ships in port, can be used to assess the excess capacity of the port. **Figure 19.8** presents historical PACI data for these two parameters from the past four decades (1977 to 2014). Projecting the historical trends for these two parameters suggests that the physical capacity of the port is expected to be exceeded between 2025 and 2035.

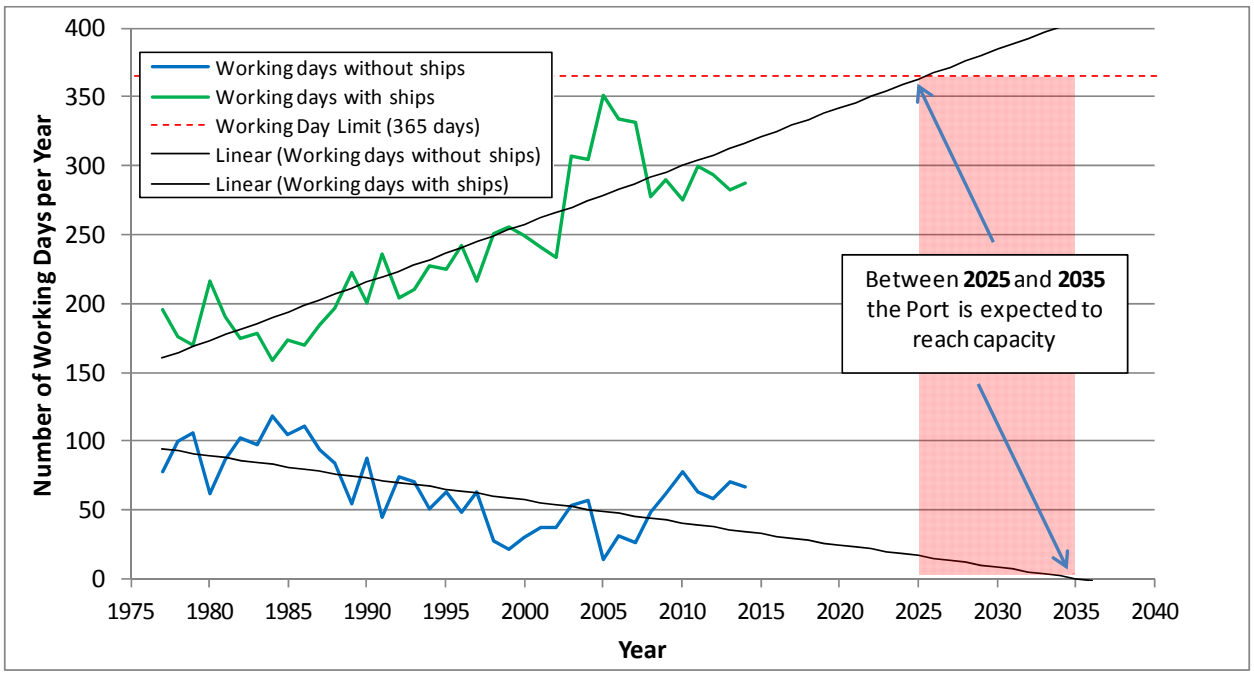


Figure 19.8 PACI Cargo Operations – Annual Working Days – Projection of Historical Data

Additional comments regarding the data in **Figure 19.8** and the capacity of the existing port are as follows:

- The green line represents the number of working days with ships in port; these data are well aligned with PACI's total cargo import data (**Figure 19.7**). Projection of these data to the physical maximum of 365 days per year suggests that the existing port will reach its capacity around 2025.
- The blue line represents the number of working days without ships in port. Projection of these data to the physical minimum of 0 days per year suggests that the existing port will reach its physical capacity around 2035.
- As the population and domestic consumption grows, the existing facility is unlikely to be able to handle a spike in imports such as that seen following Hurricane Ivan.
- Even assuming that port operations may be tweaked to increase the efficiency of operation, a new or expanded port facility is likely to be required in the relatively near future.

The requirement to build a new cargo port facility at another site would have huge implications in terms of the cost of the new facility and the potential for environmental damage. Increasing the capacity of the existing cargo facility in parallel with the construction of the proposed cruise berthing facility (as incorporated in the refined project layout assessed in the EIA) likely represents a much lower financial and environmental cost to the Cayman Islands.

19.4.3.3 Operational Downtime

PACI's historical records indicate that there are 5-13 days/yr (1.5-3.5% of the time) when cargo operations are not possible due to inclement weather conditions.

19.4.4 Baseline Conditions – Recreational and Water Sports Activities

- Numerous operators offer recreational activities within George Town Harbour, including snorkeling, diving, glass bottom boats, personal water craft rentals, etc. Fishing from a boat is not permitted, as GTH is located within a Marine Park.
- Snorkelling and diving generally takes place at the reefs located to the North and South of the main harbour area (Soto's/Cheeseburger Reef, Eden Rock, Devils Grotto), as well as the *Cali*. Night-time dives are also undertaken at the *Balboa* (day-time dives are not permitted due to vessel traffic over the *Balboa*).
- It is understood that no systematic management/control is provided for recreational and water sports activities within George Town Harbour. Further, no records of incidents/ accidents were available.
- The majority of George Town Harbour's recreational assets are located within walking distance of the port. Various other tourist attractions are located within George Town and around Grand Cayman Island.

19.4.5 Baseline Conditions - Carrying Capacity of Existing Landside Attractions

There is concern related to tourist activities in GTH that will be displaced during construction/ operation of the cruise berthing facility, and the capacity to accommodate them elsewhere. Operations that may be impacted include, but are not limited to, the Atlantis submarine, semi-submersible, glass bottom boats and snorkel/dive shops. Also, although not directly related to carrying capacity, it was noted that the proximity of the proposed cruise berthing facility to clear water, coral reefs and water sports (i.e. snorkeling, diving) is a significant attraction to Grand Cayman for cruise passengers. A reduction in the quality of this experience associated with the development of the proposed project could adversely impact this attraction, with important spinoff impacts on the local economy.

This section provides a high level review/assessment of the carrying capacity of a few key attractions and their ability to accommodate additional visitors. Other attractions exist but are typically relatively small volume and/or do not have readily available data on their typical and maximum operating capacities.

<u>Organized Tours</u>

- As noted earlier, a cruise passenger volume of 11,000 passengers/day (85% exceedance) was adopted for landside planning aspects of the EIA study.

- Data collected for the traffic and pedestrian study (refer to Chapter 18 and Appendix L) indicates that over 50% of manifested cruise passengers attended an organized tour. For example, on June 12, 2014, there were approx 11,000 cruise passengers with an estimated 6,000 participating in organized tours.
- Considering this information, 6,000 passenger/day has been adopted as the proxy design volume for orgainzed tours.

Cayman Turtle Farm (CTF)

- The CTF is located on the NW coast of Cayman, north of Seven Mile Beach.
- The CTF is located outside the direct impact zone of the proposed berthing facility, so no direct impacts are expected with respect to visitor capacity.
- The capacity is reported to be approximately 4000 visitors per day with a lagoon capacity of 2300 visitors.
- The Economic Impact Study of the Cayman Turtle Farm (PwC, 2013) states that " *even during the busiest tourism season, the CTF facility uses only a fraction of its overall capacity*", though it was noted that there are some bottlenecks, such as the restaurant, during very busy periods. This suggests that there is some capacity to accommodate additional visitors at this attraction.
- PwC (2013) indicate that the core advantages of the CTF include the following:
    - Unique offering: Along with Stingray City, the CTF represents a unique experience for tourists. This is particularly critical for the cruise industry, where passengers are offered very similar experiences at the various itinerary destinations, such as dolphinariums, water parks and shopping excursions.
    - High capacity and family value: Unlike many other attractions on Grand Cayman, the CTF has significant capacity, and also effectively targets the price-conscious family market.
- In 2007, the CTF entertained 351K visitors (328K cruise, 23K other), while in 2012 this number had dropped to 229K (163K cruise, 66K other). As such, the facility has been successful tested with > 100K more visitors a year; this represents a significant excess capacity for displaced visitors.
- The decrease in visitor numbers (2007-2012) to the CTF was attributed to higher ticket prices following its relocation in 2007.
- Overall, the CTF appears to be positioned to handle a significant increase in visitors with relatively little effort; however, some features (e.g. restaurant) may need to be upgraded.

Stingray City

- Stingray City is located on the NW side of North Sound.
- Stingray City is located outside the direct impact zone of the proposed berthing facility, so no direct impacts are expected with respect to visitor capacity.

- The DoE and PwC (2013) both indicate that Stingray City is currently operating near capacity, and therefore would not be able to accommodate a significant amount of displaced visitors.
- Limits are defined in the Marine Park Regulations and it is noted that operators require a Wildlife Interaction Zone (WIZ) license, although not all operators are licensed. New operators who want to go there would need to obtain a WIZ (direct cost to operator).

Seven Mile Beach (7MB)

- It is difficult to directly estimate the capacity of 7MB and it is understood that many of these visitors are stay over guests who are residing in one of the hotels located along 7MB.
- 7MB is located outside the direct impact zone of the proposed berthing facility so no direct effects are expected with respect to visitor capacity.
- It is expected that 7MB will have some ability to accommodate more cruise guests.

GTH Dive Shops

- The dive shops located in and around GTH were typically reluctant to share specific numbers related to their operations.
- Based upon the economic valuation of marine resources in GTH (refer to Ch.16 and Appendix J.2), approximately 5.6% of cruise passengers take a diving tour. This translates to around 600-650 visitors for the 11K/day design volume (85% exceedance).
- Some dive sites used by the GTH Dive Shops are located in or near to the direct impact zone of the proposed facility. As such, especially during construction, some dive sites may have limited access. It is expected that nearby alternative dive sites can be used with only a small degree of inconvenience to operators and visitors alike.
- The visitor volumes taking part in diving are relatively small compared to some of the other attractions; as such, it is expected that any displaced visitors during could be readily accommodated at other attractions.
- Relocation of the *Balboa* shipwreck to a new site that is accessible during the day has been proposed as a mitigation measure. This will increase the capacity of GTH dive shops by providing a new day-time dive site.

Queen Elizabeth II Botanic Park

- The QEII Botanic Park is estimated to have the following capacity
  - Visitor center and veranda (250)
  - Back veranda (125 seated)
  - Main lawn in the colour garden (300-400)

Pedro St. James

- Pedro St James is a relatively large venue estimated to have following capacity

- Grounds of the back lawn (2500 standing or 800 seated)
- Courtyard (300 standing, 125 seated)
- Theatre (60-65).

Cayman Craft Market

- The Cayman Craft Market is estimated to have a capacity of 300-400 visitors

Other

- The CIG noted that there are tourist excursion opportunities in the Eastern Districts (beaches, etc.), but the ability to realize these opportunities is presently limited by the lack of development/infrastructure and marketing

Summary of Carrying Capacity

The carrying capacity of some attractions (i.e. diving in George Town) is expected to decline in the short term, especially during construction, but these declines are expected to correspond to relatively small volumes of passengers which may easily be accommodated at some of the larger attractions (i.e. Cayman Turtle Farm). Most attractions are located well outside the direct impact zone of the proposed facility, and are not expected to have significant negative effects on their carrying capacity.

In addition to anticipated negative effects, there are some potential positive impacts on carrying capacity, such as the relocation of the *Balboa* shipwreck to a new location that allows daytime access for divers and snorkelers. Relocation of the *Balboa* is expected to significantly increase the number of diving/snorkeling tours that use this attraction.

19.4.6 Baseline Conditions – General Operations

19.4.6.1 Accessibility and Convenience

The tender queues are often cited as a major inconvenience and are a function of the existing infrastructure and the passenger management preferences of the individual cruise lines. A CBF is likely to increase the convenience of embarking/disembarking the cruise ships and reduce the queue lengths and the perception of queue wait times.

On the other hand, the current tender operations are convenient in that they deliver tourists directly into George Town, with minimal walking required to access tours, shopping, and dining areas. The walk from the tender drop off area at the RW pier to the RW Terminal is less than 150 ft, with another 300 ft walk to reach Harbour Drive.

19.4.6.2 Port Security

Current port security requirements comply with Level 1 of the International Ship and Port Facility Security Code (ISPS, IMO, 2004), and consist of entry and exit security checkpoints for passengers

and for vehicles. It is not anticipated that the security requirements will change significantly with the development of the proposed cruise berthing facility. Specific details will depend on the final master plan for the landside buildings and services, and may include separate security checkpoints at the end of each pier, as these are specifically required to accommodate *Oasis* class ships, as pre-clearance does not take place on board these ships

19.4.6.3 Public Rights of Way

Currently, it is understood that no systematic management/control is provided for recreational and water sports activities within George Town Harbour and further, no records of incidents/ accidents were available.

19.5 Impact Assessment

19.5.1 Project Impacts – Overview of Proposed New Port Infrastructure and Facilities

The proposed project will provide berths for four large cruise ships (at two piers), an extended cargo dock, two new RO/RO ramps (central and south), an extended tender dock (adjacent to the RW Terminal) and an increased land area (additional 7.7 acres) to serve both cruise and cargo operations. **Figure 19.9** and **Figure 19.10** present the overall project layout, and highlight key project features and anticipated landside traffic patterns related to cruise and cargo operations.

The anticipated impacts of the project on cruise, tender and cargo operations (marine and landside), as well as recreational/water sports activities are summarized on the following pages. Recommended mitigation measures are presented in Section 19.8.

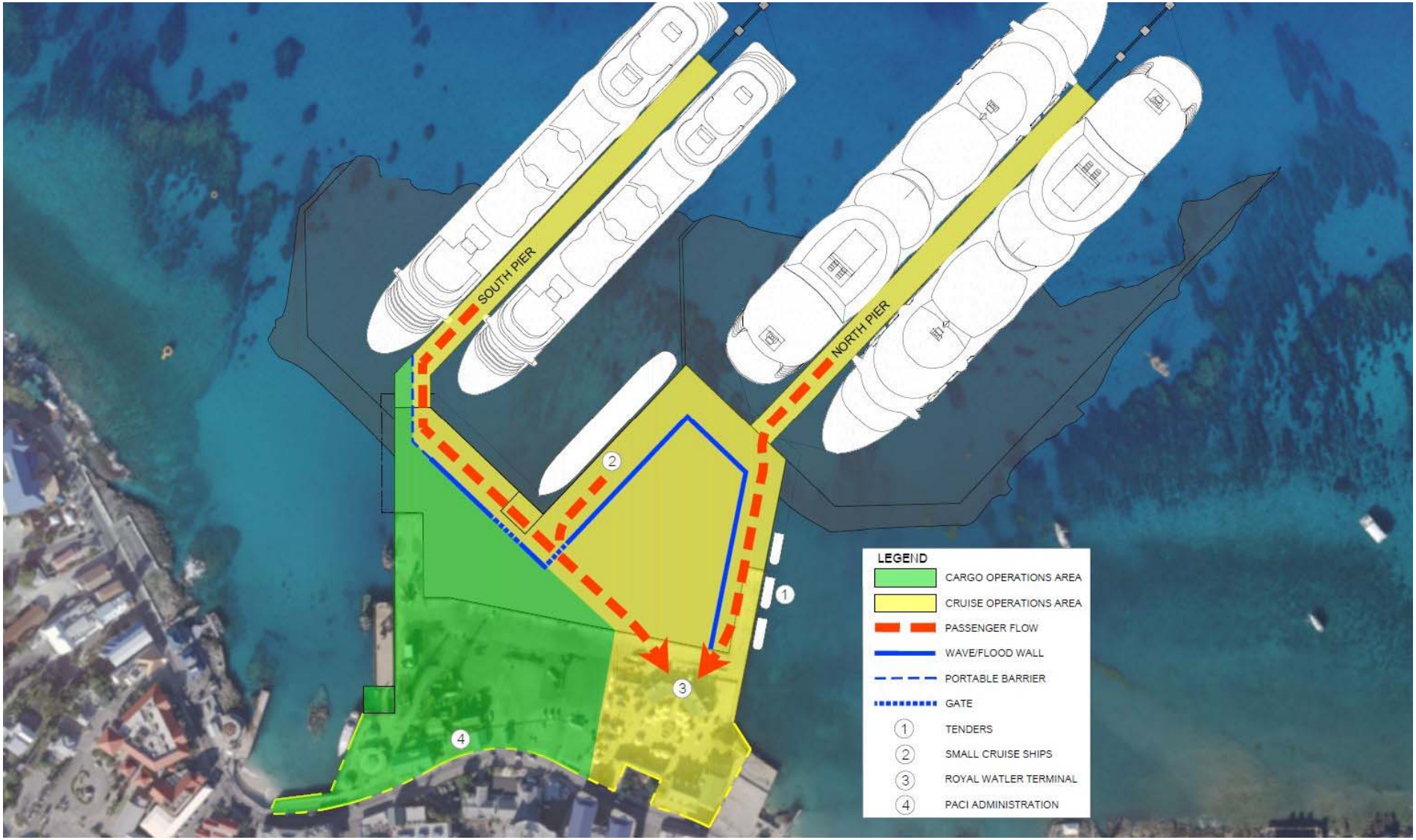


Figure 19.9 - Proposed Project Layout - Cruise Operations

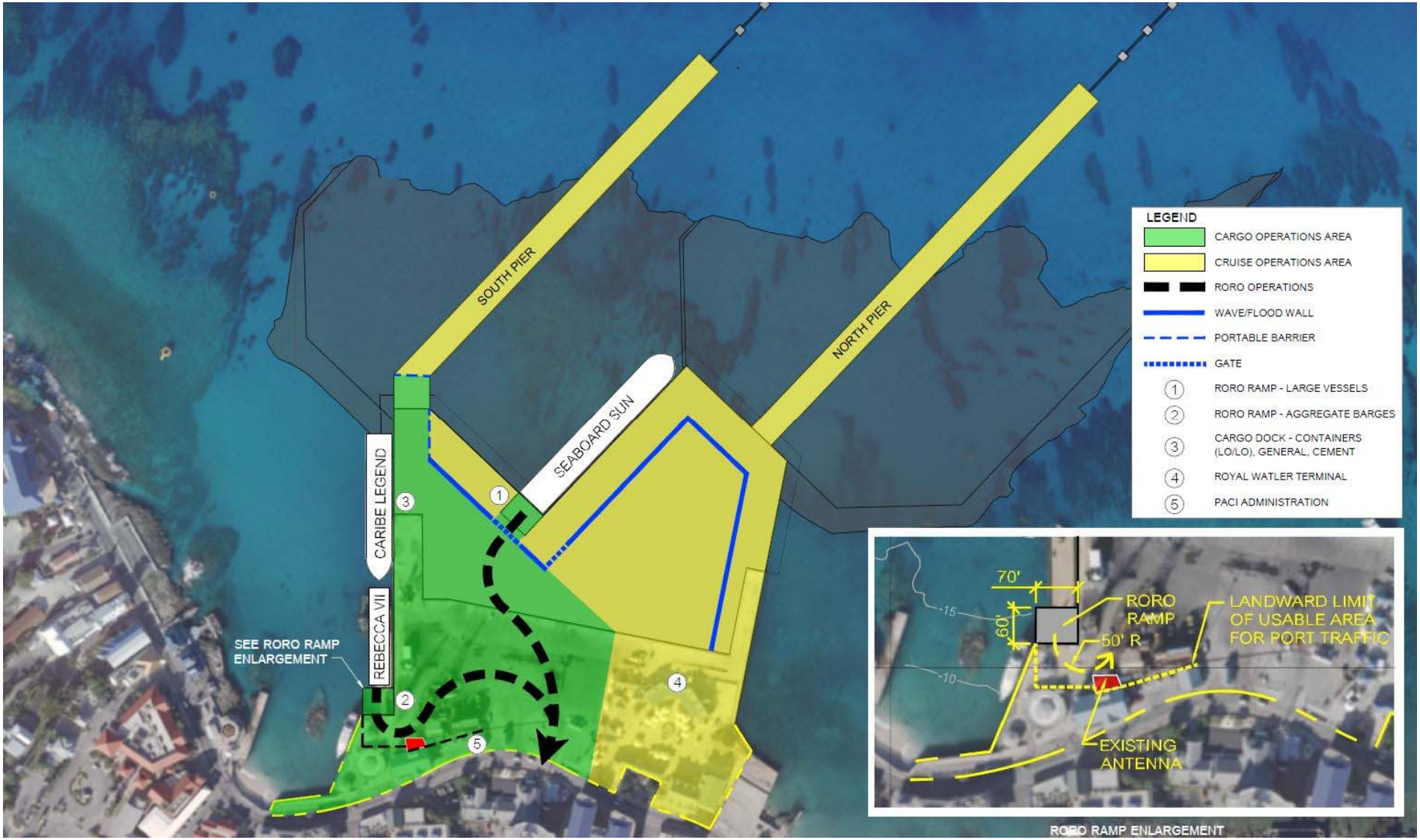


Figure 19.10 - Proposed Project Layout - Cargo Operations

19.5.2 Construction Phase Impacts

19.5.2.1 Cruise Operations

- During construction, cruise ships may not be able to anchor at the two middle anchorages. The duration of this restriction is not known at this time (it will depend on the Contractor's specific means and methods); however, this situation should not significantly affect vessel arrivals, as the vessels can remain on engine while waiting offshore as currently occurs when the four anchorages are full.
- Tender services will be required throughout construction.
- Tour staging will not be able to occur on the shared apron. The CIG has identified the Tower Site as a potential temporary tour staging area. This location would require a 600 ft walk from the RW terminal, or a 1,000-1,300 ft walk along Harbour Drive from the North and South terminals. Tour staging at Spotts Landing would be unaffected.

19.5.2.2 Tender Operations

- It is essential that arrangements be made to maintain tender operations throughout construction.
- The RW pier and terminal should remain generally available for tender operations, although intermittent closures may be required.
- The North and South terminals should remain generally available for tender operations, although intermittent closures may be required.
- Spotts Landing should remain generally available for tender operations, as it will be unaffected by the construction of the cruise berthing facility.

19.5.2.3 Cargo Operations

- Construction operations will interfere to some degree with both marine and landside cargo operations, with potential impacts on the safety and efficiency of operations.
- Cargo operations must be maintained throughout construction, including regular operations (i.e. containers, general, break-bulk, cement, aggregates, RO/RO), as well as construction specific operations (i.e. heavy equipment, construction materials, etc.).
- Careful planning and coordination of port and construction operations will be required to minimize the disruption to existing operations (refer to discussion of mitigation measures in Section 19.8).

19.5.2.4 Landside Operations

- The Contractor will require access to the site and staging/storage areas for their equipment, materials and operations. This will reduce the area available for cargo operations.

- Construction will generate waste materials, and will also increase the risk of spills.
- Construction will result in a risk of damage to existing structures and facilities.

19.5.2.5 Recreational and Water Sports

- Increased vessel traffic will increase the risk of marine incidents in GTH; temporary navigation aids will reduce the risk to marine operators.
- Dredging and construction activities will result in increased turbidity levels in GTH, with associated impacts on aesthetics, visibility and marine ecology (refer to Chapters 11 and 16, and Appendices D.2 and J). Approximately 6 acres of coral reef are located within the project footprint and will be lost; an additional 6-8 acres of coral will be exposed to elevated levels of turbidity and sedimentation during construction and operations, with the potential for long-term degradation of these reefs. Various mitigation measures are recommended to reduce these impacts (refer to Section 19.8).
- Access to specific areas in GTH may be restricted during construction, with potential loss of recreational opportunities for tourists and locals, and potential loss of revenues for operators (refer to Chapter 20 and Appendix N).
- The carrying capacity of the majority of the large attractions (including Cayman Turtle Farm, Stingray City, Seven Mile Beach) will not be directly affected by the proposed project. The Dive Shops in and around George Town will be affected, especially during construction. Dive shops may need to use alternative dive sites for their guests, and may suffer from a reduction in capacity due to longer travel times to these locations.
- Some of the major attractions have significant excess capacity (eg. Cayman Turtle Farm) to accommodate additional visitors should the demand arise.

19.5.3 Operation Phase Impacts

19.5.3.1 Cruise Operations

- Two anchorages will be lost, but a total of six ships can be accommodated at the four berths and remaining two anchorages. Additional vessels can wait on engine, as they do currently when all four anchorages are in use.
- As noted earlier, the design passenger for the existing facility was estimated as 11,000 pax/day volume (85th percentile during cruise season). This volume was increased to 14,300 pax/day to account for anticipated growth over the life of the facility (note: 30% growth corresponds to 10 years at 3%/yr, 15 years at 2%/yr or 30 years at 1%/yr).
- Berthing and de-berthing of large cruise ships will result in significantly increased turbidity levels in GTH, with associated impacts on aesthetics, visibility and marine ecology (refer to Chapters 11 and 16, and Appendices D.2 and J).
- Berthed cruise ships will be closer to George Town; the associated landscape and visual impacts are discussed in Chapter 22 and Appendix P.

- It is expected to take about two hours to berth four cruise ships at the proposed facility. As a result, it is expected that the majority of passengers will be off the first ship by the time the fourth ship is ready to start unloading. This staggered berthing will help to moderate the peak flow rate of passengers into George Town (with tendering, this staggered berthing is not required, and multiple cruise ships may start unloading at the same time).
- The maximum disembarkation rate per ship (berthed) is approximately 2,000 pax/hr, but tapers off quickly after the first hour. Due to staggered berthing (as noted above), the maximum combined disembarkation rate is likely to remain similar to the maximum possible with tender operations, which is in the order of 5,500-6,500 pax/hr.
- **Figure 19.11** illustrates two scenarios for passenger disembarkation rates, one with four Carnival *Magic* sized vessels at berth, and a second scenario with two Carnival *Magic* sized vessels and two Royal *Oasis* class vessels. The figure shows that passenger loading rates at the proposed cruise berthing facility are likely to fall within the range of passenger loading rates currently achieved by the tenders. **Table 19.6** shows the passenger unloading rates that were assumed for each scenario.

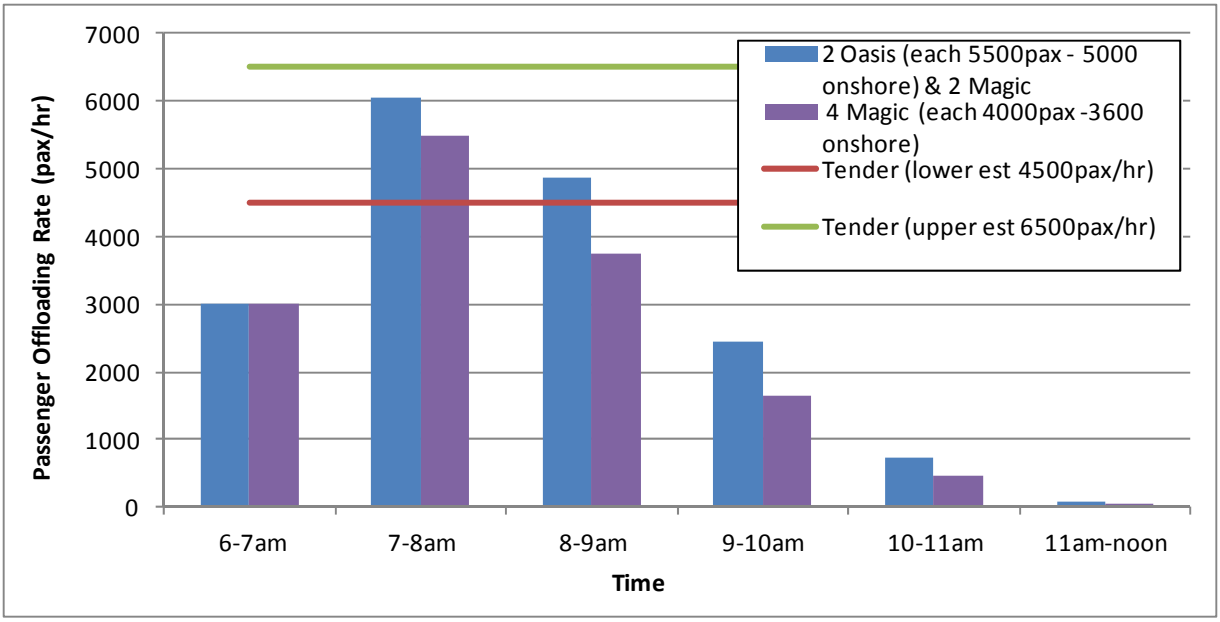


Figure 19.11 Possible Passenger Unloading Rate Scenarios

Table 19.6 Possible Passenger Unloading Rate Scenarios

Typical Vessel	Manifested Passengers	Pax Onshore	Disembarkation Rate (pax/hr)			
			Hour 1	Hour 2	Hour 3	Hour 4
Oasis	5500	5000	2000	1750	1000	250
Magic	4000	3600	2000	1000	500	100

- While the cruise berthing facility will allow passengers to disembark onto land directly from the ship, it will increase the travel distance to the terminal and George Town. The walk from

a cruise ship at berth to Harbour Drive will range from approximately 1,200 to 1,800 ft, as compared to approximately 450 ft with the existing tender operation. Travel assistance of some form may be required for elderly and disabled persons.

- Pilot boats and line handlers will likely be required for the new facility (PACI has advised that pilotage will likely be mandatory for cruise ships).
- Suitable tug assistance should be available to support older cruise vessels and in the event of emergencies (i.e. engine or steerage failure).
- The proposed cruise berthing facility will reduce downtime as compared to the existing tender operation, but will not eliminate it (refer to Section 19.5.3.2 and Appendix M.2 for more information on this topic).
- The increased passenger volumes expected with the CBF will put additional demand on landside infrastructure/facilities and services (refer to Chapter 20 and Appendix N), and will result in additional pedestrian traffic on Harbour Drive (refer to Chapter 18 and Appendix L).

19.5.3.2 Downtime of Cruise Ships

Numerical simulations of Moored Ship Response (MSR) and analyses to estimate operational downtime of the proposed cruise berthing facility were undertaken as part of the EIA study. Key results are summarized below, while more detailed information is provided in Appendix M.2.

- Under present conditions, cruise ships currently anchor offshore and are free to swing on the anchor, adjusting to prevailing wind and wave conditions. In some cases, the ships thrusters are used to hold position and/or to protect the tender loading doors from wind and wave action.
- With the new cruise berthing facility, the cruise ships will be (relatively rigidly) moored to the piers. Given the size of the cruise ships and the typical mooring arrangements, wave-induced motions of the vessels will be relatively small, with the passenger unloading/loading operations expected to be less sensitive to wind and wave action.
- Ideally, the piers should be aligned with the prevailing wind and wave directions. This is not possible at George Town, as the prevailing winds approach from the E-ENE and the prevailing waves approach from the NW (Nor'westers). The orientation of the piers to minimize downtime due to adverse weather conditions was a key consideration in developing a refined project layout for the proposed facility.
- Numerical model simulations of moored ship response (i.e. vessel motions and mooring loads caused by wind and wave action on the vessels) were used to identify the preferred pier orientation and to support the development of downtime estimates for the proposed cruise berthing facility.
- The model results indicate that the pier orientation should fall within the W to NW sector in order to minimize downtime due to moored ship response. Based on careful consideration

of various other site specific factors (i.e. location of coral reefs, dredging volumes, etc.), the final project concept adopted a NW pier orientation.

- Downtime estimates for the final project are summarized in **Table 19.7** for two ship sizes that are considered to be generally representative of the range in ships expected to call at the new facility. Downtime during the cruise berthing facility is estimated to range from 0 to 8% during the cruise season, as compared to 5-15% for the existing tender operation (i.e. missed and diverted calls).

Table 19.7 Summary of Estimated Downtime for Proposed CBF

Season	Cruise Season (Nov-Apr)		Off-Season (May-Oct)	
Ship Size (GRT)	**150,000 t**	**70,000t**	**150,000 t**	**70,000t**
Range in Downtime over 34 Years				
Days	0 - 9	0 - 14	0 - 4	0 - 7
%	0 - 5	0 - 8	0 - 2	0 - 4
Average Downtime over 34 Years				
Days	2.6	5.6	0.7	1.3
%	1.4	3.1	0.4	0.7

- The downtime estimates are based on numerical modeling of moored ship response, a 34 year hindcast database of wind and wave conditions at the project site, and estimated thresholds for allowable ship motions (refer to Appendix M.2 for additional details).
- Other observations of note:
    - Downtime is higher during the cruise season then during the off-season due to the prevailing weather conditions (i.e. Nor'Westerlers occur during the winter months)
    - There may be considerable variability in downtime from one year to the next due to natural variability in weather conditions
    - Larger vessels have lower downtime, but result in greater berthing and mooring loads.

19.5.3.3 Tender Operations

- Upon completion of the cruise berthing facility, tendering will only be required on busy days, when more than four ships call at George Town.
- The cruise berthing facility is expected to reduce tender business to approximately 5 to 15% of current levels.
- Tendering at the new facility is expected to take place primarily at the extended RW pier.

- The cruise berthing facility is not expected to change the operating limits of the tender operation, as it does not include a sheltered landing facility.

19.5.3.4 Cargo Operations

- The new facility is expected to significantly increase the port capacity. Primary storage will remain at the CDC.
- The cargo pier will be extended with the proposed facility so the outer end will be in deeper water. As such, larger container, cargo and RO/RO vessels may berth at the new facility, potentially reducing the number of individual ship calls that are required.
- The ability to accommodate larger vessels may not affect regularly scheduled deliveries such as perishable goods.
- Cargo operations are expected to remain a night-time activity (6 pm to 5 am).
- It is anticipated that downtime for cargo operations will be reduced due to additional sheltering from Nor'Westers along the South cargo dock.
- The transition between the South cruise per and South cargo dock, as well as the central location of the new RO/RO ramp, do not provide complete separation of cruise and cargo operations, but this can be addressed through landside planning and design (refer to Figure 19.3, and to mitigation measures in Section 19.8). It is noted that PACI's preference to retain the existing RO/RO ramp (as proposed in earlier studies) would require the cruise piers and dredge area to shift north, with a significant increase in dredging volume and impacts on the coral reefs to the North (i.e. as per the OBC layout).
- Cargo operations at the outer end of the South cargo dock/inner end of the South cruise pier, and RO/RO operations at the new (central) RO/RO ramp, will result in wear and tear on areas that are used for cruise passenger traffic; this issue can be addressed by various mitigation measures (refer to Section 19.8).

19.5.3.5 Landside Operations

- An increase in cruise and cargo traffic is anticipated over the life of the project, with increased demand on landside infrastructure/facilities and services (refer to Chapter 20 and Appendix N) and increased traffic on Harbour Drive (refer to Chapter 18 and Appendix L).
- The change from tendering to berthing will require changes to port security measures; these changes are not considered to be significant, and compliance with ISPS Level 1 code regulations and MARPOL standards are not expected to be an issue.
- Planning and design of new landside infrastructure/facilities and services is beyond the scope of the present study. It is understood that the CIG intends to develop a landside master plan for the expanded land reclamation area, including access to Harbour Drive.
- Commercial and cruise ship operations are currently governed by the MARPOL protocols, while Navy ships are not required to adhere to them. No significant changes are expected

with the introduction of the proposed cruise berthing facility. The Cayman Islands shipping registry and the DoE are the current authorities that monitor compliance with the MARPOL protocols. They conduct random spot checks on ships when they are anchored offshore. These spot checks may be conducted faster and more easily on ships berthed at the new facility, as there would be no requirement to travel to the ship by boat/tender.

19.5.3.6 Recreational and Water Sports

- Marine traffic patterns in GTH will change, with increased cruise ship traffic but significantly reduced tender traffic.
- Project operations will result in significantly increased turbidity levels in GTH and will reduce the quality of recreational experiences (snorkeling and diving) in GTH. These effects are discussed in more detail in the Marine Ecology section of the report (refer to Chapters 11 and 16, and Appendices D.2 and J). Various mitigation measures are recommended to reduce these impacts (refer to Section 19.8). In addition, it is noted that the impact of berthing/de-berthing operations on turbidity levels will likely decrease with time as the fines are flushed from the site.
- The ISPS Level 1 code (IMO, 2004) requires a 150 ft exclusion zone around cruise ships. While ships are at berth this exclusion zone will fall within the dredge area and the recreational exclusion zone will be taken as the further of the perimeter of the dredge area or 150ft from the hull of the ship. To allow for shipping manoeuvres (expected <1hr day) the exclusion zone will be measured as 150ft from the outer limits of the dredged berthing area.
- Permanent navigation aids will be required on the two piers and likely around the limits of the dredged berthing area. The markers on the edge of the dredged berthing area would serve to guide ships as they approach the facility, thus reducing the chance of accidental damage to the adjacent coral reefs. In addition, these markers would serve to warn swimmers and snorkelers from venturing into the cruise ship navigation area.
- Similar to the construction phase, the carrying capacity of the majority of the large attractions (including Cayman Turtle Farm, Stingray City, Seven Mile Beach) will not be directly affected by the proposed project. The Dive Shops in and around George Town will be affected, albeit less during operations. Dive shops may need to use alternative dive sites for their guests, and may suffer from a reduction in capacity due to longer travel times to these locations.
- Some of the major attractions have significant excess capacity (eg. Cayman Turtle Farm) to accommodate additional visitors should the demand arise.

19.5.3.7 Anticipated Impacts of Nearshore Berthing Operations

Propeller Induced Sediment Re-Suspension and Scour

Berthing and de-berthing of large cruise ships, in particular the flows induced by the action of the ships' propellers and thrusters, will result in sediment re-suspension and increased turbidity levels in GTH, with associated impacts on aesthetics, visibility and marine ecology (refer to Chapters 11

and 16, and Appendices D.2, D.3 and J). Various mitigation measures are proposed to reduce these impacts, as summarized in Section 19.8.

In addition, seabed scour may also result from the action of the main propellers and thrusters (as well also extreme wave action). Scour will be an important consideration in the detailed design of the piers and shoreline protection structures around the new land reclamation area.

Pollution from Ships

The current pollution from cruise ships is minimal, and no significant changes are anticipated with the new berthing facility. Refer to Chapter 12 for more details on Water Quality impacts.

Noise and Light Disturbance

Cruise operations occur during the daytime hours when the sun is up and there is considerable vehicular traffic in George Town, so impacts are expected to be minimal. Security and navigation lighting will be required on the piers, but this additional lighting is not anticipated to represent a significant increase over the existing lighting at the port. While there are few large beaches in the immediate vicinity of the port, turtle friendly lighting may be used on the piers to reduce potential impacts on these creatures. Chapter 15 provides additional detail on noise and vibration impacts.

19.6 Anticipated Impacts on Maritime Stakeholders

Cruise Passenger Interaction

As discussed earlier, the OBC (PwC, 2013) indicates that the proposed cruise berthing facility is expected to result in increased growth in cruise passenger arrivals. Associated impacts on tourism and local businesses have been assessed as part of a socio-economic impact assessment undertaken for the EIA (refer to Chapter 20 and Appendix N). No new types of tourism are currently planned as part of the proposed cruise berthing facility, but the opportunity does exist to include new facilities or tourist attractions as part of a follow-up master planning exercise. It is understood that the CIG intends to develop a landside master plan for the expanded land reclamation area, including access to Harbour Drive.

Support Services

With the implementation of a cruise berthing facility there will likely be an increased requirement for maritime support services, including pilots, line handlers and possibly tug services.

PACI has advised that pilotage will likely be mandatory for cruise ships using the new facility. In addition, it is expected that two teams of line handlers (one for each pier) will also be required for the new facility. Finally, it would be desirable to provide suitable tug assistance in the event of emergencies (i.e. engine or steerage failure).

Currently PACI do not own or operate any maritime support vessels. WI Marine and Thompson Shipping both own tugs; however, the Thompson Shipping tug is dedicated to barge operations between Grand Cayman and Cayman Brac, and would generally not be available to assist with

cruise or cargo operations. WI Marine and Bodden Shipping both employ pilots and pilot boats that would be suitable to assist with cruise operations.

Tendering

It is anticipated that the tender operation will reduce to less than 15% of the present operation upon the completion of the cruise berthing facility. It is understood that the viability of the existing tender operation may be questionable with such a significant reduction.

Public Rights of Way

Marine rights of way will be slightly affected by the development of the proposed cruise berthing facility. Marine traffic, such as water sports and dive operators, will be required to divert around the facility, including a 150 ft exclusion zone around the cruise ships. During berthing/de-berthing maneuvers, water sports vessels would have to wait until the cruise ship has cleared the berth before they proceed past the facility. Typically, the berthing/de-berthing maneuvers are quite rapid and only occur for a short period on mornings and afternoons. As such, they are not expected to cause any significant inconvenience to the small craft operators.

On the land side, various traffic management strategies were assessed as part of the traffic and pedestrian study section (refer to Ch. 18 of the ES and Appendix L). Rights of way will typically be maintained or enhanced by the proposed traffic management options. Diversion of a portion of vehicular traffic to alternate routes, as well as pedestrian priority options along Harbour Drive during cruise hours, are expected to reduce travel times for vehicles and improve the level of service for pedestrians. Further improvements in level of service may be realized through synergies with various improvements proposed as part of the George Town Revitalization Plan, as well as road network improvements proposed by the NRA.

19.7 Anticipated Requirements for Island Based Resources

Cayman is expected remain a port of call (not a home port) for the major cruise lines; as a result, no significant changes to provisioning are anticipated.

Cayman does not currently have the facilities to offer fuel to large cruise ships, and the infrastructure investment to provide this service would be substantial. In addition, some cruise lines have expressed their preference to refuel in Port Canaveral. As such, it is not expected that the cruise berthing facility will incorporate the ability to refuel large cruise ships. However, provision for a diesel fuel line to the RO/RO berth should be considered to serve small to medium sized vessels which are currently served by tanker trucks.

It is recommended that consideration be given to providing a potable water line to each berth to allow cruise ships to take on water. The water line could also be used to support emergency firefighting services.

Small scale provisioning of smaller private and commercial vessels could be provided at the new facility. An example of this is US Coast Guard vessels which visit Grand Cayman regularly and require provisioning with fuel, food, water, and waste disposal. Although provisioning of these vessels is not a specific objective of the cruise berthing facility, such an operation could provide additional revenue for PACI and local businesses. As such, it is recommended that this opportunity be considered during the development of the landside master plan.

Requirements for other land based infrastructure will depend on the outcome of the landside master planning exercise to be undertaken by the CIG.

19.7.1 Climate Change Impacts

The potential effects of climate change are not expected to have a direct impact on future cruise, tender or cargo operations. However, the CBF may result in a decrease in the Cayman Islands' contribution to climate change by reducing the energy used (and associated emissions discharged) by vessels, including cruise ships at berth (rather than remaining on power at the offshore anchorages) and significantly reduced tender traffic.

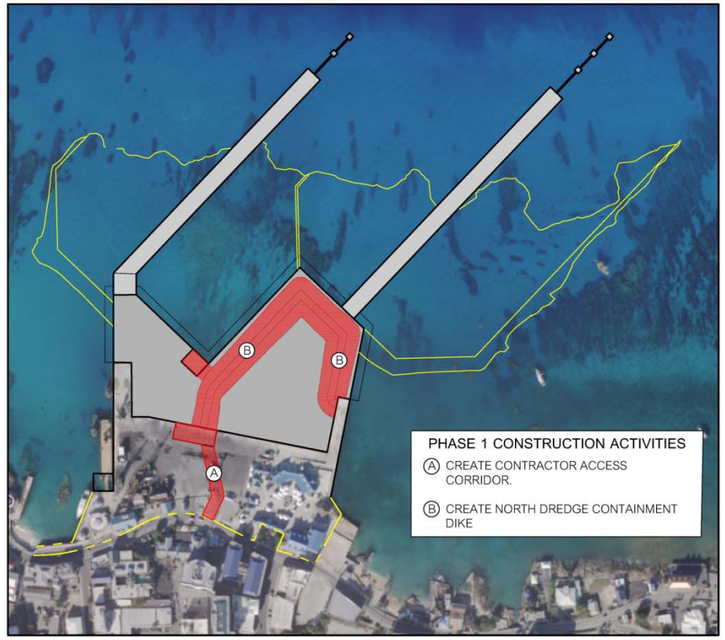
19.8 Proposed Mitigation Measures

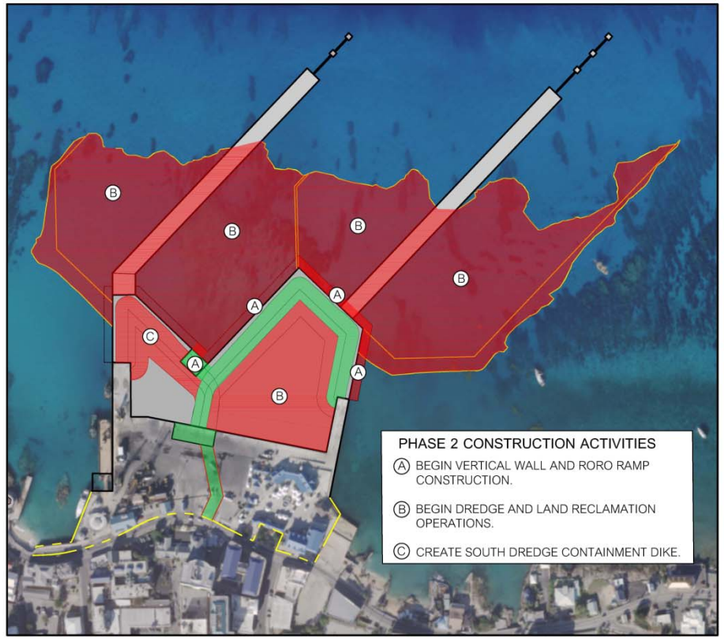
A number of mitigation measures are proposed to address potential negative impacts associated with the project. The various mitigation measures include elements related to project planning/design, dredging and construction methods and operations, as summarized below.

19.8.1 Project Planning/Design

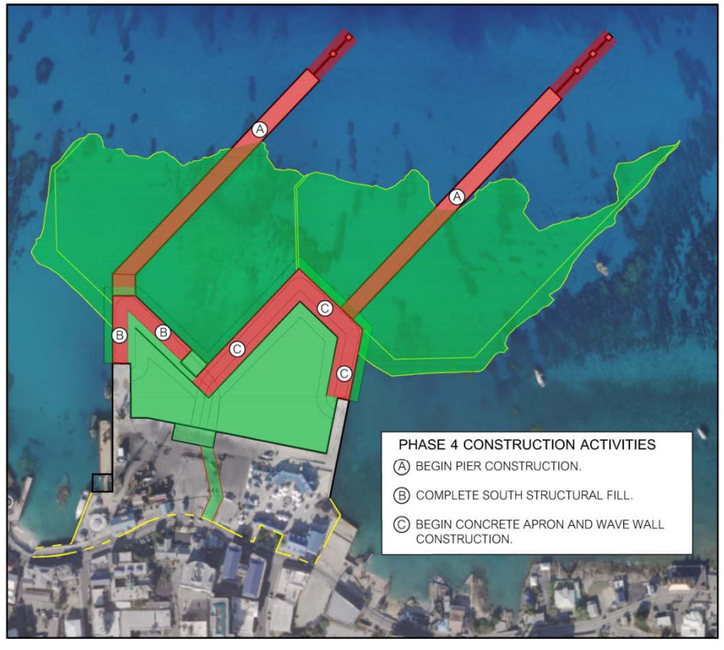
- Tender Dock – Retain existing RW dock elevation at +4 ft to accommodate self-tendering by smaller cruise ships, but construct extension at +8 ft to accommodate larger CMS tender vessels and reduce wave overtopping.
- South cargo dock/pier transition and new RO/RO ramp:
    - Robust surface treatment is required to minimize wear and tear (degradation) by cargo operations;
    - Movable barriers and/or gates are required to provide effective separation of cruise and cargo operations (refer to **Figure 19.9** and **Figure 19.10**).
- Relocation of *Balboa* – relocation of the wreck of the *Balboa* to a suitable location will allow increased (daytime) access to the wreck;
- Landside Master Plan – A basic site plan differentiating cruise and cargo areas, and incorporating a wave/flood wall to protect the site against wave overtopping and flooding, has been developed as part of this study (refer to Figures 19.3 and 19.4). The CIG should develop a landside master plan for the expanded land reclamation area. Key issues to be considered in the landside master plan include the following:

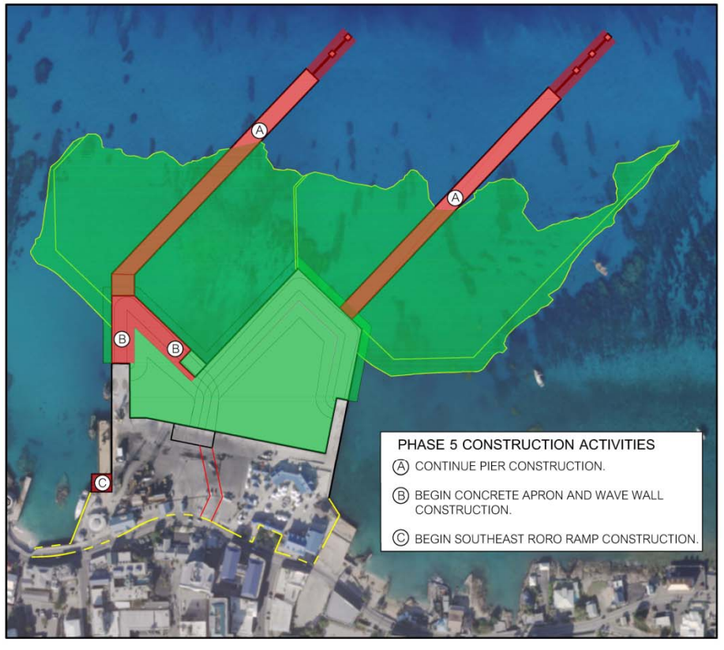
- Definition and layout of buildings (including upgrade or replacement of existing buildings), other facilities and amenities, and parking/staging/storage areas required to support progressive growth in both cruise and cargo operations;
- Effective separation of cruise and cargo operations, including safety and security requirements (ISPS and MARPOL);
- Openings in the wave/flood wall to meet operational requirements (i.e. vehicular and pedestrian access), and modular closures to be installed in anticipation of storm events;
- Site grading and drainage (refer to Chapter 13 and Appendix F);
- Services and utilities requirements for growing cruise and cargo operations (i.e. potable and fire water, power, telecommunications, fuel).
- It is anticipated that the tour staging experience at a new facility will be enhanced for both tourists and tour operators. It is expected that the master plan for the land reclamation area (not part of this study) will include a specific land area for tour staging with shaded waiting areas, benches, and perhaps a tour staging centre.
- There is an opportunity to create a marine based tour staging area so that water sports and dive operators may pick their guests up directly and potentially increase their tour capacity. This marine staging area would help to reduce the peak volumes of land based traffic, as the guests would not need to drive to their destination during the morning rush hour. The same guests could then be dropped into George Town upon their return, thereby giving them the opportunity to shop.
- Measures must be put in place to maintain tender operations during construction. The CIG should initiate discussions with CMS. Depending on the outcome of these discussions, it may be necessary to pursue alternatives (issue an RfP for tender services).
- A possible construction sequencing plan has been developed (refer to **Figure 19.12**), including access routes and staging/storage areas for the Contractor, in order to maintain cruise, tender and cargo operations throughout construction.
- Careful planning and coordination between PACI and the Contractor will be required to maintain safe and efficient cruise, tender and cargo operations (marine and landside).
- Notices to Mariners and temporary navigation aids will be required. Access to certain areas of GTH may be limited or restricted during construction.
- Careful planning and coordination and effective communication amongst PACI, the Contractor and recreational and water sports operators will be required.
- The Environmental Management Plan (refer to Section IV of the Environmental Statement) defines measures to be implemented by the Contractor to protect the natural environment within and around the project site.
- The Contract Documents should define requirements related to work area limits, time of day restrictions on operations, construction access routes and staging/storage areas, and protection of existing structures and facilities.











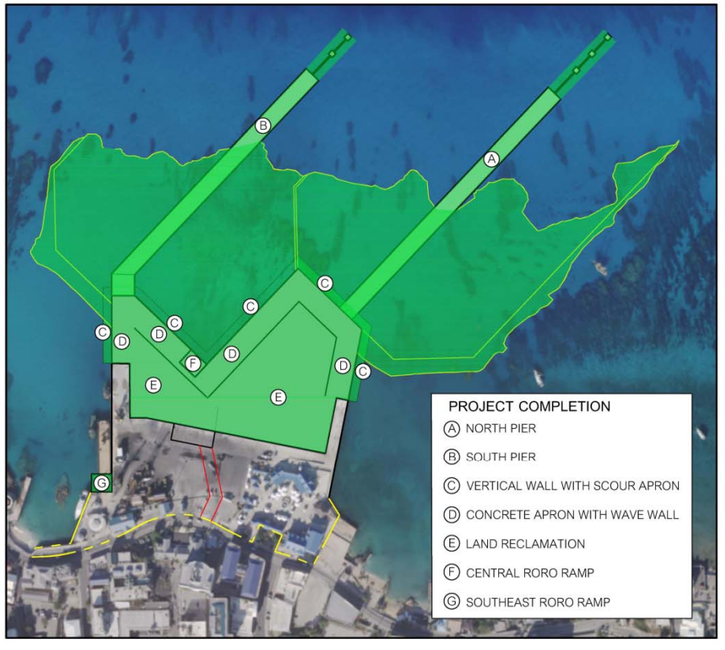


Figure 19.12 Possible Construction Sequencing Plan

19.8.2 Operation Phase

- Measures must be put in place to provide (reduced) tender operations following completion of the project. The CIG should initiate discussions with CMS. Depending on the outcome of these discussions, it may be necessary to pursue alternatives (issue an RfP for tender services).
- Suitable navigation aids will be required to support safe navigation;
- Suitable lighting will be required to meet safety and security requirements;.
- The longer walk from ship to shore may be challenging for disabled and elderly persons. The use of small transport vehicles should be considered to assist elderly and disabled passengers.
- As noted above, a landside master plan is required to guide the future development of the expanded land reclamation area. Building on the landside master plan, the CIG should prioritize landside improvements, with phased implementation to enhance the facility while maintaining safe and efficient operations.
- The CIG and/or PACI will need to obtain the additional resources necessary to operate the new facility, including:
    - Management, operational and administrative staff for marine and landside operations;
    - Suitable tug(s), pilot boats and crews and line handlers.
- Consideration should be given to replace outdated cargo handling equipment with more efficient equipment; in particular, the replacement of the crawler cranes with more rubber tired mobile cranes would result in improved efficiency of operations and reduced wear and tear (and associated maintenance requirements) on the dock surface.

19.9 RIAM Summary of Anticipated Project Impacts and Proposed Mitigation Measures

As noted in Chapter 1.3.6, the Rapid Impact Assessment Matrix (RIAM) method has been used to "quantify" the anticipated impacts of project construction, operation and mitigation measures. Table 19.8 and Figure 19.13 provide a summary of the RIAM scoring for specific impacts related to cruise and cargo operations, including scores for each of the following project phases:

- Existing (baseline) conditions
- Dredging and reclamation phase
- Construction (post-dredging) phase
- Operational phase

Proposed mitigation measures for specific impacts are highlighted in the green cells in Table 19.8, with the RIAM method applied both without and with these mitigation measures.

Chapter 1.3.6 provides an overview of the various RIAM scoring criteria (A1, A2, B1, B2 and B3) and the methodology used to derive the Environmental Score (ES) and associated Range Value (RV) for each specific impact. The Range Values are summarized as follows:

- N: Neutral (no change/impact)
- A to E: Positive change/impact (A is slight positive...E is major positive)
- -A to –E: Negative change/impact (-A is slight negative...E is major negative)

Additional information on the RIAM methodology is provided in Appendix Q.

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Table 19.8 Detailed RIAM Scoring for Cruise and Cargo Operations

PHASE	IMPACTS SCORED WITH NO MITIGATION	Spatial Importance (0 to 4)	Magnitude of change/effect (-3 to + 3)	Permanence (1 to 3)	Reversibility (1 to 3)	Cumulative (1 to 3)			IMPACTS SCORED WITH MITIGATION	Spatial Importance (0 to 4)	Magnitude of change/effect (-3 to + 3)	Permanence (1 to 3)	Reversibility (1 to 3)	Cumulative (1 to 3)	*ES with mitigation*	*RV With Mitigation*
		A1	A2	B1	B2	B3	ES	RV		A1	A2	B1	B2	B3	ES	RV
EXISTING CONDITIONS	Provision of four vessel anchorages	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Tender services continue	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	Existing cargo operations	3	0	1	1	1	0	N		3	0	1	1	1	0	N
	Existing Ro-Ro ramps	1	0	1	1	1	0	N		1	0	1	1	1	0	N
DREDGING & RECLAMATION	Intermittent loss of two anchorages	3	-1	2	2	2	-18	-B		3	-1	2	2	2	-18	-B
	Tender services may cease operations	3	-2	2	2	3	-42	-D		3	-2	2	2	3	-42	-D
	RW Pier will remain available	3	0	2	2	3	0	N		3	0	2	2	3	0	N
	North and South Terminals will remain available	3	0	2	2	3	0	N		3	0	2	2	3	0	N
	Delays to Cargo Operations	3	-1	2	2	3	-21	-C		3	-1	2	2	3	-21	-C
	Cargo Operations will be maintained during construction	3	0	2	2	3	0	N		3	0	2	2	3	0	N
	Construction staging will reduce Cargo areas	2	-1	2	2	3	-14	-B		2	-1	2	2	3	-14	-B
	Increased marine traffic and risk of accidents	1	-1	2	2	2	-6	-A	Navigation Aids, watersport planning	1	1	2	2	2	6	A
	Restricted access to certain areas	2	-1	2	2	2	-12	-B		2	-1	2	2	2	-12	-B
CONSTRUCTION - POST DREDGING	Intermittent loss of two anchorages	3	-1	2	2	2	-18	-B		3	-1	2	2	2	-18	-B
	Tender services may cease operations	3	-2	2	2	3	-42	-D		3	-2	2	2	3	-42	-D
	RW Pier will remain available	3	0	2	2	3	0	N		3	0	2	2	3	0	N
	North and South Terminals will remain available	3	0	2	2	3	0	N		3	0	2	2	3	0	N
	Delays to Cargo Operations	3	-1	2	2	3	-21	-C		3	-1	2	2	3	-21	-C
	Cargo Operations will be maintained during construction	3	0	2	2	3	0	N		3	0	2	2	3	0	N
	Construction staging will reduce Cargo areas	2	-1	2	2	3	-14	-B		2	-1	2	2	3	-14	-B
	Increased marine traffic and risk of accidents	1	-1	2	2	2	-6	-A	Navigation Aids, watersport planning	1	1	2	2	2	6	A
	Restricted access to certain areas	2	-1	2	2	2	-12	-B		2	-1	2	2	2	-12	-B
OPERATIONAL	***Cruise Operations***															
	Increased time onshore	3	1	3	2	3	24	C		3	1	3	2	3	24	C
	Increased walking distance to Harbour Drive	1	-1	3	2	3	-8	-A	Provide transport for elderly and disabled persons	1	0	3	2	3	0	N
	Pilot Boats Required	3	0	3	3	3	0	N		3	0	3	3	3	0	N
	Tugs required for certain vessels or emergency assistance	1	-2	3	3	3	-18	-B		1	-2	3	3	3	-18	-B
	Reduced weather related downtime of cruise ships	3	1	3	2	3	24	C		3	1	3	2	3	24	C
	Navigation closer to reefs	1	-1	3	3	3	-9	-A	Navigation Aids, watersport planning	1	1	2	2	2	6	A
	Daytime only operations (6am-6pm)	2	0	3	2	3	0	N		2	0	3	2	3	0	N
	Tender Operations															
	Reduced demand for Tender Services	1	1	3	2	3	8	A		1	1	3	2	3	8	A
	No change to weather related downtime of tenders	1	0	3	3	3	0	N		1	0	3	3	3	0	N
	Cargo Operations															
	Increased Port Capacity and longevity at present location	4	3	3	3	3	108	E		4	3	3	3	3	108	E
	Cargo operations expected to remain nocturnal (6pm-4am)	2	0	3	2	3	0	N		2	0	3	2	3	0	N
	Reduce weather related downtime of cargo ships	1	1	3	3	3	9	A		1	1	3	3	3	9	A
	New Ro-Ro ramps and improved functionalty	1	1	3	3	2	8	A		1	1	3	3	2	8	A
	Landside Operations															
	New infrastructure requirements	3	-1	3	3	3	-27	-C		3	-1	3	3	3	-27	-C
	Planning of new landside facilities	3	-2	3	2	3	-48	-D		3	-2	3	2	3	-48	-D
	Recreation and Watersports															
	Changes to marine traffic patterns	2	0	3	3	3	0	N		2	0	3	3	3	0	N

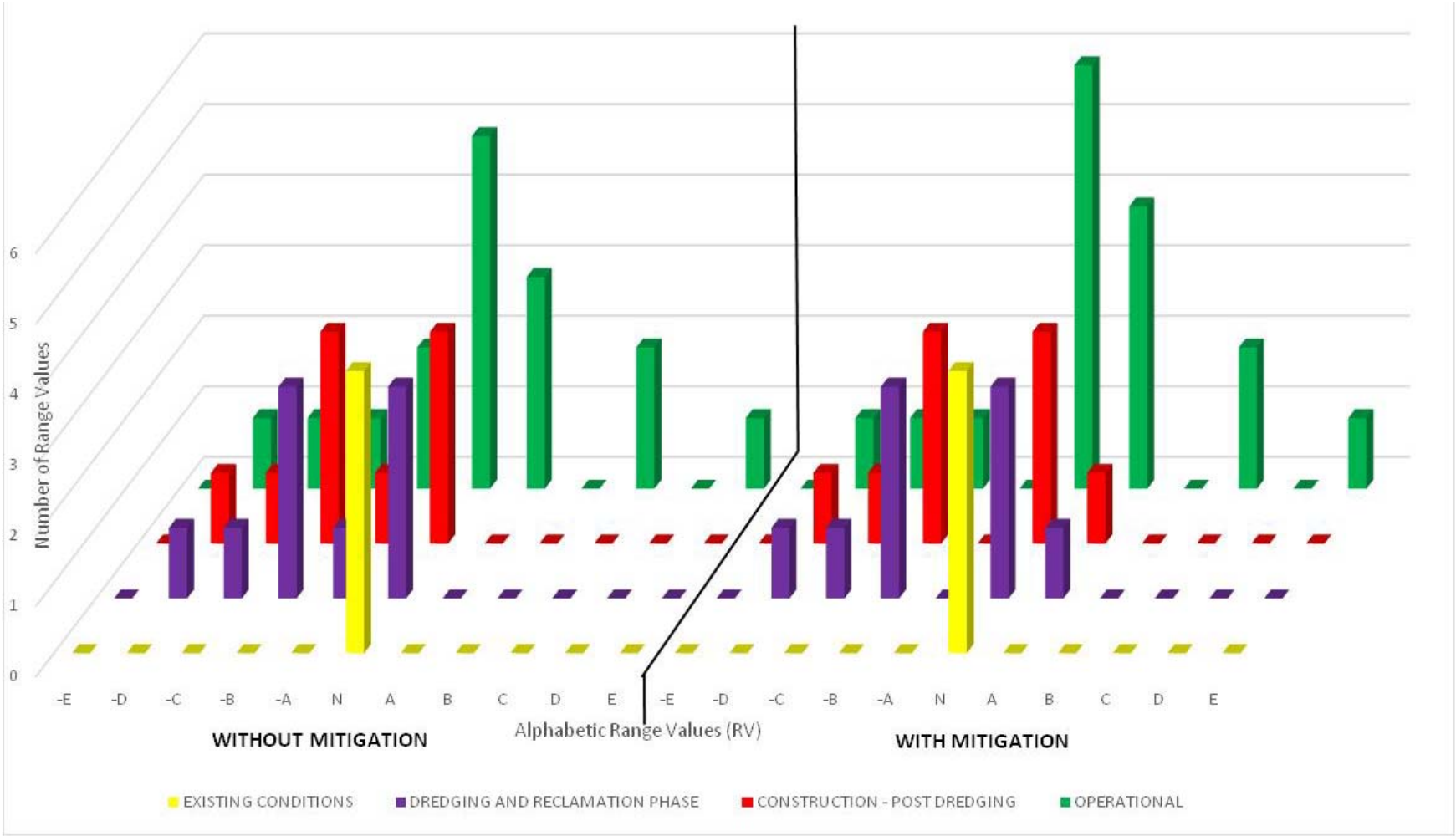


Figure 19.13 Summary RIAM Scoring for Cruise and Cargo Operations

20.0 TASK N - SOCIO-ECONOMIC IMPACT ASSESSMENT

20.1 Introduction

This Chapter presents the results of a socio-economic impact assessment (SEIA) undertaken as part of the EIA for the proposed cruise berthing facility. Specifically, the SEIA examines the socio-economic setting of the study area and identifies and assesses the potential social and economic impacts of the proposed cruise berthing facility. Additional details on the SEIA may be found in **Appendix N**. Related topics are discussed in other Chapters, including marine ecology (Chapter 16), cultural heritage (Chapter 17), vehicular and pedestrian traffic (Chapter 18), cruise and cargo operations (Chapter 19) and landscape and visual impacts (Chapter 22).

20.2 Assessment Methodology

The SIA study area consists of the project site – The George Town Port – and areas within a 1.2 mile (2 km) radius. The SIA approach is guided by *the International Association for Impact Assessment (IAIA),* which defined social impacts as "changes to people's way of life, culture, community, political systems, and environment, health and wellbeing, and personal and community property rights and perceptions of these changes" (IAIA, 2010). The approach is also guided by the *International Finance Corporation (IFC) Policy and Performance Standards on Social and Environmental Sustainability (PS)*. As such the assessment will address the management of environmental and social risks and impacts (PS1); labour and working conditions (PS2); community health, safety and security (PS4); land acquisition and involuntary resettlement (PS5); and cultural heritage (PS8).

The SIA included desktop research, observations and consultations with stakeholders. Data sources included census of population and housing, economic reports, and tourism, energy, water supply, and physical planning statistics from the Economic and Statistical Office (ESO) of the Government of the Cayman Islands. Other data sources included EIAs and other assessments that were previously conducted within the area and the results of stakeholder consultations.

Stakeholder consultations were undertaken to ascertain awareness of the proposed project, perceptions on the potential project impacts on communities/groups, socio-economic, cultural/heritage landscape and the natural environment. Interviews and surveys were the main methods used in consultations. See Stakeholder Engagement and Public Consultation Report for detailed methodology.

A public meeting reporting the preliminary findings of the EIA and soliciting comments from the public will be also be incorporated in the final SIA.

20.2.1 Limitations

Socio-economic data exists at the district level for Grand Cayman. This resulted in the description of the baseline and analysis of impacts at a zone wider than the 1.2 mile (2km) zone of influence identified.

20.3 Baseline Conditions

20.3.1 Description of the Study Area

20.3.1.1 SIA (Local) Study Area Description

The SIA study area consists of the project site – the George Town Port - and areas within a 1.2 mile (2 km) radius. George Town is located on the western shores of Grand Cayman, the largest of the three Cayman Islands (**Figure 20.1**). The city covers approximately 11square miles (29km^2) and is low-lying at 6.6-10 feet (2-3m) above sea level. George Town is the seat of the government and the center for the island territory's financial industry. George Town Harbour has the only port facility on the island and is the port of call for cargo and cruise ships. It is located in the city and is a locus of tourism activities. The district is the most populated across the territory, accounting for 50% of the total population.

The marine portion of the local study area extends over 1,655 feet (500m) into the George Town Harbour. The area is characterized by clear water and a system of well-developed, shallow water, nearshore reefs that support a healthy and diverse coral cover, sponges and population of fish species. The reef is described as having a high vertical relief of the "spur and groove" formation that creates a network of grottos and tunnels forming a complex and "unique" and marine ecosystem. The study area is located within the boundary of the Marine Park (see Task J: Marine Ecology Chapter for further details).

Grand Cayman

The regional study area is Grand Cayman, which is the largest of the three Cayman Islands and which has an area of approximately 75 square miles (196km^2). The island is irregular in shape forming a U-shape around a reef-protect lagoon in the north-western region. It is low-lying with the highest point being 60 feet (18m) above sea level. Grand Cayman is divided into five districts. West Bay is located in the north-western part of the island; at the south-western end is the George Town district, while Bodden Town District is immediately east of George Town. North Side District is east of Bodden Town and East End District is at the easternmost part of the island.

The Cayman Islands (Macro)

The Cayman Islands are located in the Caribbean Sea, 160 miles (257 km) south of Cuba, 167 miles (269 km) north-west of Jamaica and 460 miles (740 km) south of Miami. The Cayman Islands is comprised of three islands: Grand Cayman, Cayman Brac and Little Cayman. The Sister Islands – Cayman Brac and Little Cayman – are 81 miles (130 km) north-east of Grand Cayman and within

4.3 miles (7 km) of each other. Cayman Brac is approximately 14.7 square miles (38 km²) while Little Cayman is 10.8 square miles (28 km²) (Brunt & Davies, 1994). Tourism, banking, insurance, finance, and construction are important economic activities for the Cayman Islands.

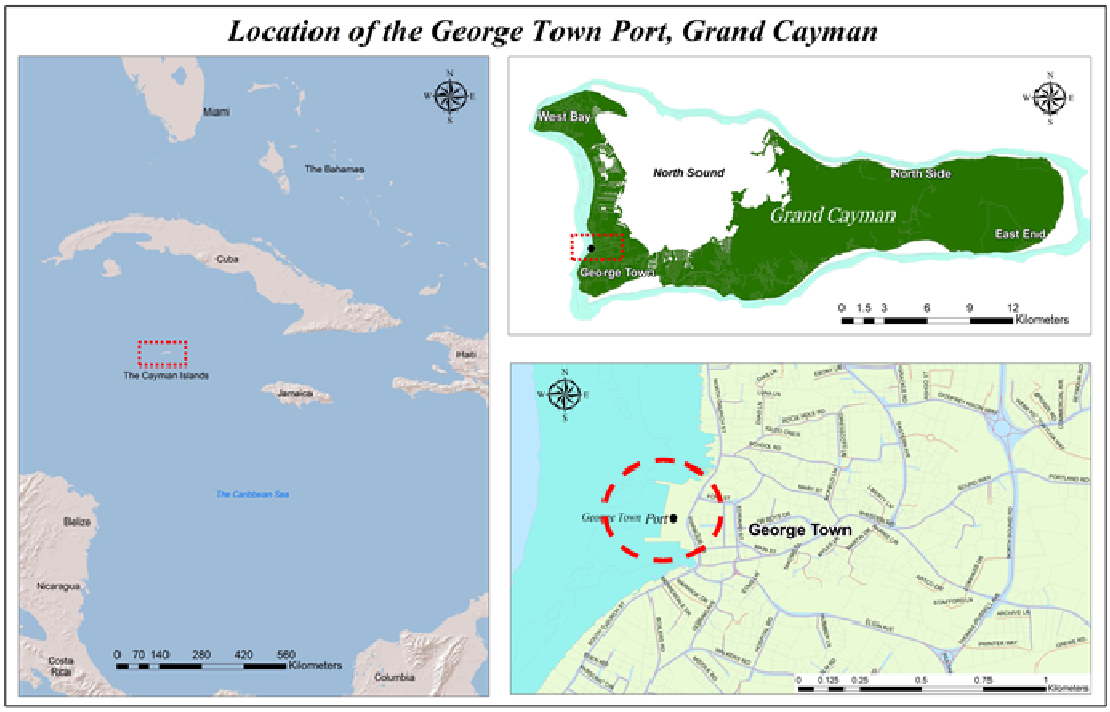


Figure 20.1- Local and regional study area

20.3.2 Population and Demography

20.3.2.1 Population

The population of the Cayman Islands was estimated at 55,691 at the end of 2013 with the Sister Islands accounting for 4% of the total (**Table 20.1**). While population has grown over the last decade the rate of growth has slowed from the rapid rates seen in the 1980's and 1990's (**Figure 20.2**).

The population of Grand Cayman was estimated at 53,368 at the end of 2013 with the SIA study area – George Town District - George Town District accounting for 53% of the total (ESO, 2014c).

Table 20.1 Population trends (1970 - 2013)

	Census Population					End of Year Population*		
	1970	1979	1989	1999	2010	2011	2012	2013
SIA Study Area (George Town)	3,812	7,617	12,921	20,626	28,089	28,334	28,955	28,423
Regional (Grand Cayman)	8,759	15,000	23,881	37,083	52,740	53,201	54,365	53,368
National (Cayman Islands)	10,068	16,677	25,355	39,020	55,036	55,517	56,732	55,691

2011-2013 represent year end population all others are census population
*2011 - 2013 population estimated based on proportion from last census

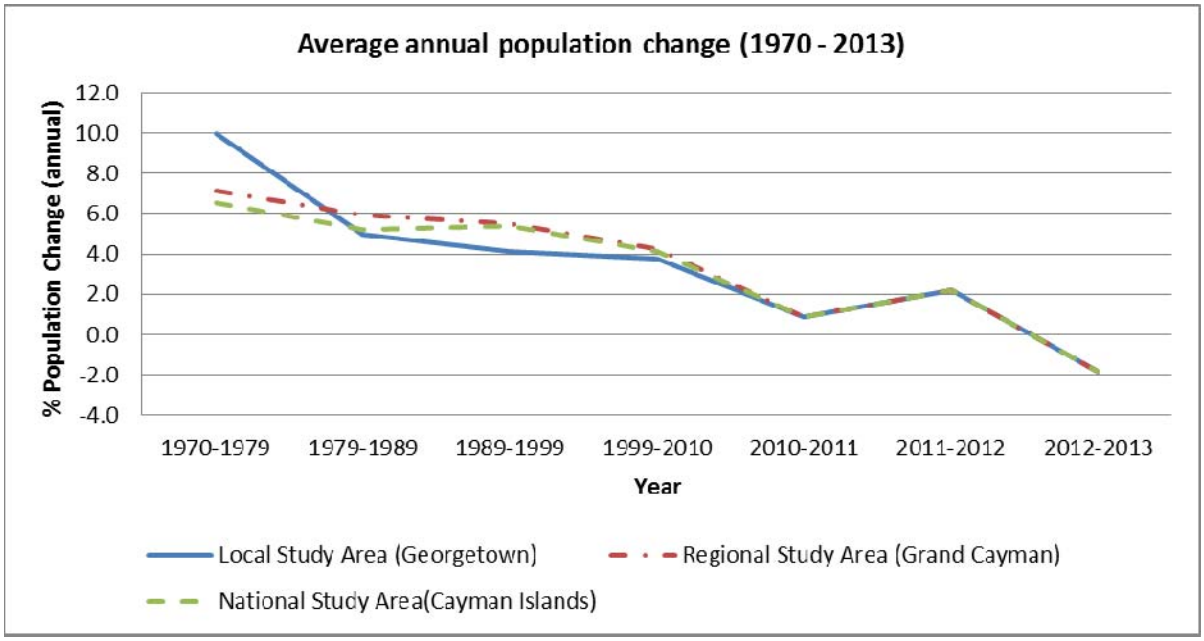


Figure 20.2 - Average annual population change (1970 - 2013)

There are no official population projections for the Cayman Islands currently, mainly due to the historically rapid growth rates and the high effects of net migration on the population of the island (ESO, 2009). However estimates based on historic growth rates suggest that the population of George Town will be between 20,161 and 55,366 by 2030.

20.3.2.2 Demography

The demographic profile is based on the 2010 population and housing census. Forty five percent (45%) of the population of the SIA study area are classifed as Caymanians while 55% are classified as Non-Caymanians (**Table 20.2**). The ratio of male to female in the SIA study area is 103 males to 100 females. This ratio is higher than the regional and national ratio of 98 males to every 100 females.

The age distribution shows that the SIA study area has 80% of its population in their productive years (age 15-80 years), 16% are under 15 years while less than 5% are over 65 years of age. The age

dependency ratio of the Cayman Islands was 38% in 2010 but has declined by seven percentage points to 31% in 2013.

Table 20.2 Status, sex and age distribution (2010 census)

Status, sex and age distribution (2010 census)						
	Local Study Area (George Town)		**Region (Grand Cayman)**		**National (Cayman Islands)**	
Status	#	%	#	%	#	%
Caymanian	12,640	45%	29,465	56%	22,565	44%
Non-Caymanian	15,449	55%	23,275	44%	28,178	56%
Sex						
# Males	14,253	51%	26,108	49%	27,219	50%
# Females	13,836	49%	26,632	51%	27,817	51%
Age-Group						
0-14 years	4,494	16%	9,658	18%	10,002	18%
15-64 years	22,471	80%	40,575	77%	42,229	77%
65+ years	1,124	4%	2,612	5%	2,910	5%

Source: (ESO, 2014c)

20.3.3 Housing

Appendix N provides a housing profile for the SIA study area and regional areas. Information is provided on household characteristics, housing tenure and dwelling types.

20.3.4 Municipal Services

Ninety five percent (95%) of households in the SIA study are served by city water obtained from treatment of rainwater and desalinization of groundwater. The main source of drinking water is bottled water, which is used by 77% of households.

Electricity is the main source of lighting for 99.5% of households in the all the Cayman Islands.

Public sewerage services are provided to portions of the SIA study area and adjoining district along the West Bay Road, by the WAC's West Bay Beach Sewer System. Areas not served by the public sewerage system are required by law to install onsite wastewater treatment systems. Septic tanks and aerobic treatment units are the systems approved by the Development Control arm of the WAC.

Public garbage collection services are provided to all the Cayman Islands by the Department of Environmental Health (DEH). The DEH collects residential and commercial waste as well as biomedical/infectious and hazardous waste. Waste is collected at least once per week. Waste disposal infrastructure includes three landfills (one on each island).

20.3.5 Social Services

20.3.5.1 Heath Services

Two hospitals are located within 0.6 miles (1 km) of project site - the principal health care facility of the country – the Cayman Islands Hospital and the independently owned and operated Chrissie Tomlinson Memorial Hospital. The area is also served by Health Services Authority (HSA) Health Centres. There are four doctors per 1,000 residents in the country and every resident is mandated to have health insurance under the Health Insurance Law (2013 Revision).

20.3.5.2 Educational Institutions

Appendix N provides an education profile for the SIA study area surrounding regions. Information is provided on educational institutional facilities at the early childhood, primary, secondary and tertiary levels (public and private). Information is also provided on the sex ratio and enrollment.

20.3.5.3 Police & Fire Services

The study area is served by the Royal Cayman Islands Police Service (RCIPC). RCIPC has five Basic Command Units with seven police stations and over 400 officers and support staff. The headquarters (George Town Police Station) is located on Elgin Street within 0.3 miles (0.5 km) of the project site. Police stations are also located in the other Districts of Grand Cayman and each of the Sister Islands.

The Cayman Islands Fire Service (CIFS) provides firefighting and rescue services to the study area and the country. There are three fire stations in Grand Cayman located in George Town, West Bay and Frank Sound. There is also one on each of the Sister Islands. Emergency (9-1-1) services are available across the country.

20.3.5.4 Telecommunications

Cell phones are the most common means of communication in all the Cayman Islands with between 97-98.8% of households reporting having cell phones within the local, regional and national study areas. Internet penetration is relatively high with 67% of households in the study area reported to have internet access. Access in the study is higher than the regional average of 59% and national average of 65%. On average, over 70% of households in the local, regional and national study areas reported ownership of computers, radio and television.

20.3.5.5 Transportation

Chapter 18 provides information on transportation services in the SIA study area. It provides information on existing and future transportation baseline pedestrian and traffic volumes,

pedestrian safety and mobility. Appendix N provides an overview of transportation services available within the SIA study area and surrounding regions.

Chapter 19 provides information on cruise and cargo operations.

20.4 Economic Activities

This section provides an economic profile of the Cayman Islands (macro) and SIA study area (micro). Further economic information is provided in Appendix N. Further information on the economic activities of households is provided Appendix 1.

20.4.1 Macro-Economic Overview

The Cayman Islands' economy is predominantly service-based, largely driven by the tourism and financial and insurance services sectors. Real Gross Domestic Product (GDP) of the Cayman Islands was CI $2.5 B (constant -2007- basic prices) in 2013 (ESO, 2014b).

The Service Producing Sector accounted for 95% of total GDP and employed 85% of the 36,070 persons in the employed labour force (80% of the total labour force) in the Cayman Islands (ESO, 2014d). The Goods Producing Sector accounted for 5% of total GDP in 2013. The construction industry was the largest contributor followed by manufacturing.

The heavy reliance on the service producing sector is largely due to the limited natural resource base beyond its coastal and marine (sand, sea, corals, reefs) and cultural resources. This contributes the country being a net importer with CI $775 million worth of merchandise imported in 2013.

This represented a 2% increase from CI $759 million in imports in 2012 and a 12% increase compared with CI $690 million in imports in 2010. The five-year annual average in imports is valued at CI $745 million. The country exported CI $25 million in merchandise in 2013. Exports grew by 49% compared with 2012 but more than doubled the CI $11 million exported in 2010. An average of CI $18 million in merchandise was exported over the past five years.

20.4.2 Sectoral Overview

20.4.2.1 Financial and Insurance Services

The Cayman Islands is recognized as one of the top ten banking centres globally. According to the Cayman Islands Monetary Authority (CIMA), the jurisdiction ranked 4th based on the value of liabilities booked through licensed banks in the jurisdiction and 6th based on the value of assets (CIMA, 2013). The main activities of the sector are banking, fiduciary (trusts and corporate services), insurance and investment and securities. The sector employs 10% of the employed labour force (9% of the total labour force) in 2013. See Appendix N for additional information.

20.4.2.2 Tourism

Tourism is the second largest contributor to the GDP of the Cayman Islands. While the national accounting statistics published by the ESO does not calculate the contributions of the industry as a whole, the importance is evident among the industries listed. In 2013 there were a total of 1.7 million visitors to the Cayman Islands (1.4 million by cruise and 345,400 by air).

Monthly air and cruise visitor arrivals exceed the local population throughout the year **(Figure 20.3**). This suggests that a large proportion of the economic activities (other than the obvious hotel and restaurants) support the tourism sector. Total visitor expenditure in 2013 was estimated at CI $496 million, an increase of 33% from CI $372M in 2012 (ESO, 2013). At CI $496 million in generated income, the tourism sector represents an estimated 14% of the CI $3.7B GDP at current (2013) basic prices.

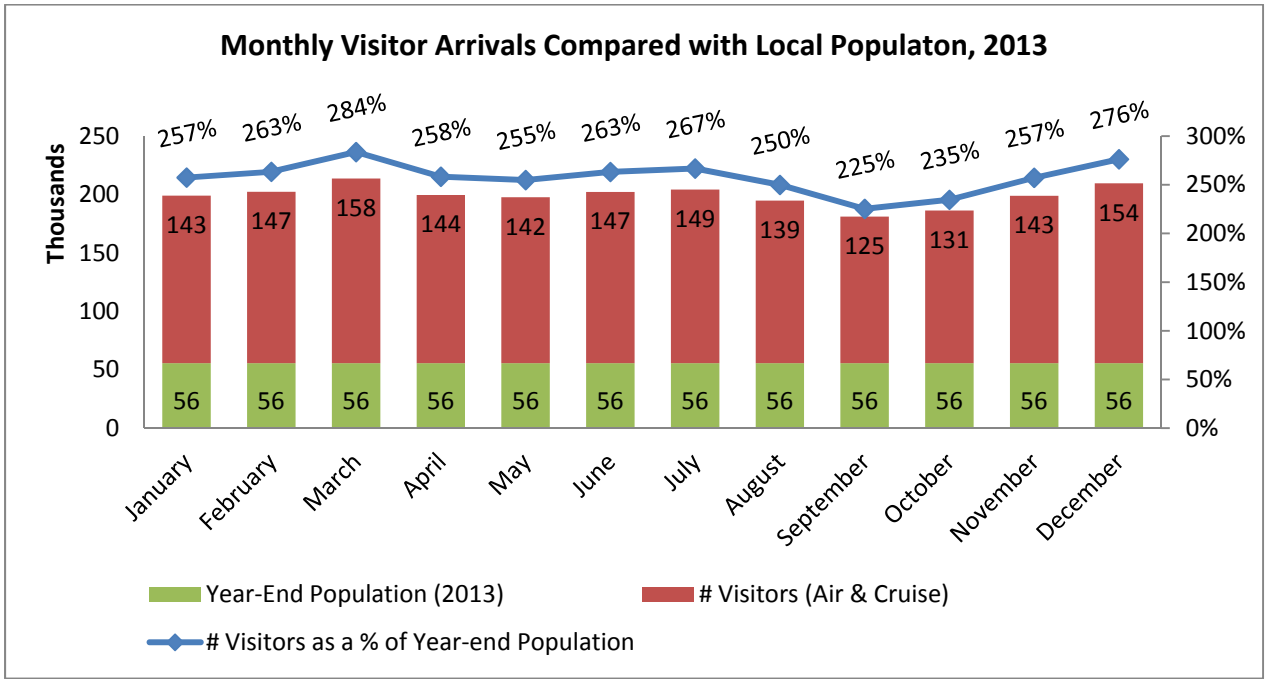


Figure 20.3 - Monthly visitor arrival compared with local population of the Cayman Islands, 2013

20.4.2.3 Cruise Tourism

Cruise visitor arrivals have fluctuated over the past 10 years but have followed a declining trend at an average annual rate of 4% since 2007. In 2006 there was an artificial increase due to the hurricane damage to piers in Cozumel, with Cayman accepting diverted traffic. Over the last five years annual cruise visitors totalled 1.4-1.6M with an average spend ranging from CI $67-137per day generating $85-187M per year (ESO, 2013).

20.4.2.4 Stay-over Tourism

Over the past five years annual air visitors totalled 272,000-345,000 with an average spend ranging from CI $ 129-241 per person per night and generating CI $225M-381M per year. Visitors were from the United States (77%), Europe (8%), Canada (7%), and the rest of the world (8%). The trend in visitors arriving by air has followed a general increasing trend over the past 10 years.

Over two thirds (72%) of the visitors in 2013 indicated that the purpose of their visit was recreation, while another 6% indicated diving. Seven percent (7%) were visiting family and friends (likely returning residents) while 6% visited on business.

Almost 50% of air visitors stayed in hotels and guesthouses while another 28% stayed in apartments or condominiums. An additional 4% indicated their accommodations as timeshare. Fifteen percent (15%) of visitors stayed in private homes.

20.4.3 Economic Indicators

20.4.3.1 Labour Force

The Cayman Islands has a labour force of 38,483 representing 83% of the working age population and split evenly between males and females. The unemployment rate is 6% with unemployment among males (7%) one percentage point higher than among females.

Approximately 50% of the labour force (19,317) is Caymanian while 19,165 are non-Caymanians. Participation among Caymanians is 76% and unemployment rate is 9%. There is a higher participation rate among non-Caymanians at 92% and lower unemployment rate of 3%. A total of 18,990 work permits were reported in 2013: Jamaica (40%), Philippines (13%), United Kingdom (9%), United States (7%) and Canada (5%) accounting for the largest proportions of the nationalities of persons with permits.

20.4.3.2 Training of the Labour Force

Seventy one percent (71%) of the 2013 labour force had training while 29% had no training. Some 72% of males were trained compared with 69% of females. Seventy five percent (75%) of non-Caymanians in the labour force had training indicating that permits were more likely to be issued to trained persons. Sixty six percent (66%) of Caymanians in the labour force had training.

Over 90% of the labour force attained education up to high school or higher. Thirty nine percent (39%) attained up to high school, while 33% and 20% attained college/university and post-secondary education, respectively.

20.4.3.3 Employment

Ninety four percent (94%) of the Cayman Islands labour force was employed in 2013. Professionals/technicians (32%) and service, shop and sales (20%) were the largest occupations while skilled agricultural & fishery (2%) had the smallest proportion of the employed labour force. Transportation and storage each employ 4% while arts, education and recreation employ 3%.

20.4.3.4 Micro-economic Overview (Business District)

The city (and district) of George Town is the main economic centre of the Cayman Islands. The study site and lands within a 0.6 miles (1km) radius are predominantly commercial, financial services, offices, restaurants and mobile food services. Commercial services include marine commercial activities geared towards tourism and transportation, general and neighbourhood commercial activities such as wholesale and retail (jewellery, supermarkets, apparel, duty free). There are also resort/residential activities along the coast south of the study site, which has both commercial (tourism) and residential activities.

At the regional or district level, light and heavy industries, including the airport, institutional and additional general and neighbourhood commercial activities are undertaken. Hotels, shops, recreation, restaurant and food services are concentrated to the north along the coast on West Bay.

Economic activities are undertaken in all districts in Grand Cayman; however the range of activities is less varied than within the zone of influence of the project. Tourism and related economic activities are highest in West Bay District, with the concentration along West Bay Road. An area of note within the West Bay District is the town of Camana Bay, which is located approximately 2.5 miles (4 km) north of the SIA study site. The development, which consists of 600 acres, is a relatively new high density mixed-use development said to be "an example of New Urbanism architecture" according to Cayman Shores Development Ltd. (CSDL, 2014). The development includes commercial offices, retail shops including duty free, restaurants, and a movie theatre, a school and a 75-foot tall observation tower that opened in 2009, in addition to residential buildings. The development was undertaken in phases after the acquisition of lands in 1995 according CSDL. The activities at Camana Bay rival those of the central business district of George Town.

A final indicator of economic activities is the status of planning approvals. In 2013, forty one (41) commercial, nine industrial, and two hotel expansions in Grand Cayman valued at CI $2.7 million were granted approval. In addition, permits obtained by the government, and for house and apartment/condominium valued at CI $1.8 million were also approved. While the data is not disaggregated by district, given its economic significance, it is highly probable that approvals were approved for activities within the SIA study area.

20.5 Stakeholder Consultation and Public Perception

Chapter 6 and Appendix 1 provide information on stakeholder consultation and public perception. It provides baseline socio-economic profile of stakeholders and their perception of the potential impacts of the proposed projects.

20.6 Estimated Economic Valuation of the George Town Harbour Reef System

20.6.1 Introduction

The George Town Harbour reefs are described as a "unique marine ecosystem" (Land and Land, 1976). The reef system is estimated to cover 35 hectares, is well-developed, is in shallow water, is nearshore and is characterised by clear water. These features are the reasons why the GTH reefs are considered among the best dive spots in the Cayman Islands. The reefs are among the main tourist attractions in George Town and Grand Cayman. In addition, the reefs' proximity to shore offers protection against storm waves and may play a role in protecting and maintaining the shoreline and sediment budget (volume of sand) in GTH. The reefs have historical significance in their connection to the historic shipwrecks and cultural heritage sites found there.

Two shipwrecks have become extensions of the reefs and have integrated into its ecosystem. Construction of the proposed cruise berthing facility in GTH will result in the destruction of corals within the project footprint, which will have ecological, cultural and economic impacts. The Cayman Islands' Department of Environment is currently undertaking a study with the specific goal of establishing the Total Economic Value (TEV) of the marine ecosystem services of the Cayman Islands. However, within the context of the EIA, a preliminary economic valuation of the ecosystems goods and services of the GTH reef system was done to provide an estimate of this value and an order of magnitude of the impacts. The detailed report is provided in Appendix J-2.

20.6.2 Method

The economic valuation methodology used was adopted from (Pagiola et. al. 2004 in Waite, Burke, & Gray, 2014). The methodology estimates total economic value as the cumulative value of use value derived from direct, indirect and future use of resource, and non-use value derived from the existence value placed on the resource by stakeholder perception (**Figure 20.4**). Direct use includes consumptive use (food) and non-consumptive use derived from cultural and tourism/recreational use. Indirect use involves services such as shoreline protection, regulating services and provisioning services. The scope of this estimate excludes future use. The reefs are located within a Marine Protected Area that is designated as a no-take zone hence consumptive use was also excluded from the estimates.

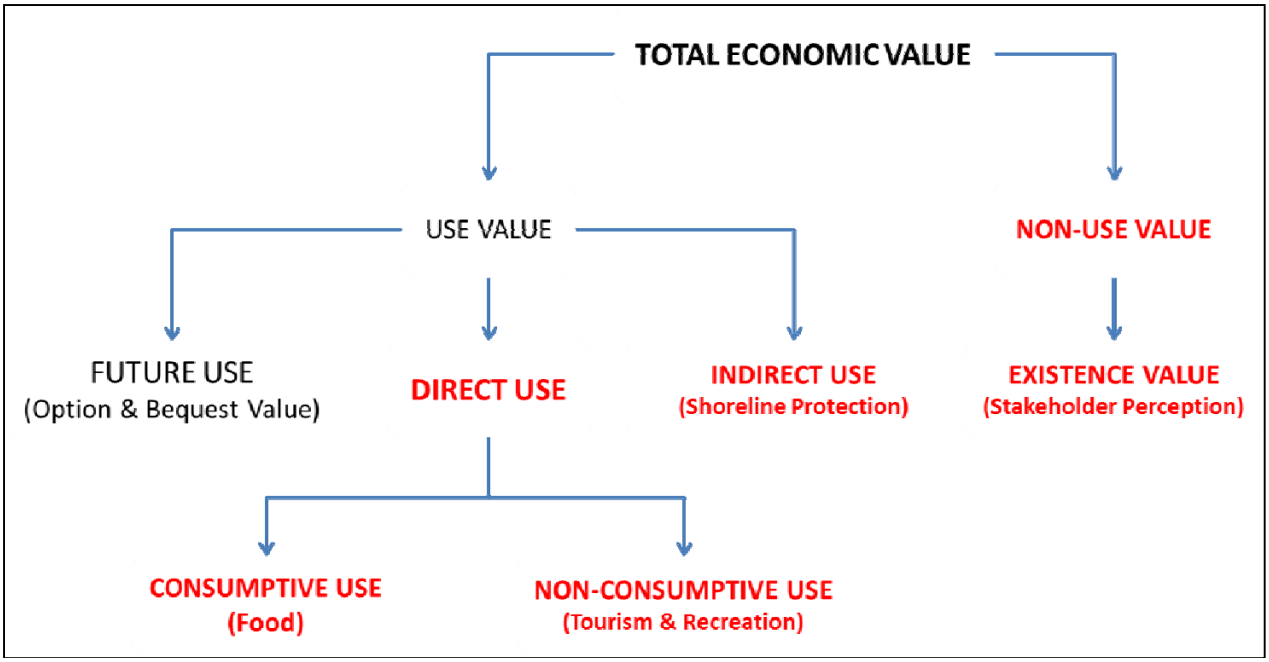


Figure 20.4 - Methodology for Total Economic Valuation of ecosystem goods and services
Source: (Waite et al., 2014) adopted from (Pagiola et. al. 2004)

20.6.3 Data Collection

Data collection was done through desktop research to obtain secondary data and surveys to obtain primary data. Secondary data was to determine indirect use since data on TEV for the Cayman Islands was not available. The DOE is currently undertaking a TEV for the resources of the country, however this was not completed at the time this report was prepared. Secondary data on tourism statistics published by the Economic and Statistics Office, Government of the Cayman Islands (ESO) was also used for non-consumptive direct use. Non-consumptive use was obtained through surveys of dive shops in George Town and the socio-economic and perception surveys of the general public and stakeholders. The dive shops provided data on direct use and associated revenues, while the other surveys provided importance value (qualitative).

The variation in values identified in the available literature resulted in the decision to estimate the economic value of the marine resources using three different approaches, as summarized below and presented in **Table 20.3**:

A. The first estimate uses cultural values calculated from tourism statistics published by the Economic and Statistics Office (ESO) of the Cayman Islands Government (refer to **Table 20.4**). All other values were adopted from literature.

B. The second estimate uses cultural values calculated from data generated in a survey of GTH dive shops conducted in December 2014 (refer to **Table 20.5**).

C. The third estimate uses a combination of cultural values from the GTH dive shop surveys and regulating services estimated by Smith Warner International Ltd.

Table 20.3 Total Estimated Economic Value of Ecosystem Goods & Services of GTH Reefs (US$/year)

Total Estimated Economic Value of Goods and Services of GTH Reefs (US$)			
Ecosystem Goods and Services	**Method A** Estimated Value GTH Reef Goods & Services (US$/year) (GTH reef area 35 ha)	**Method B** Estimated Value based on Survey of GTH Dive Shops (US$/year) (GTH reef area 35 ha)	**Method C** Estimated Value based on Survey of GTH Dive Shops and SWI Estimate for Regulating Services (US$/year) (GTH reef area 35 ha)
1.**Cultural services**	$19,629,891	$19,299,565	$19,299,565
2.**Provisioning services**	$29,610[1]	$29,610[1]	$29,610[1]
3.**Regulating services**	$6,001,730[2]	$6,001,730[2]	$3,139,240[4]
4.**Supporting services**	$567,350[3]	$567,350[3]	$567,350[3]
TOTAL ESTIMATED ECONOMIC VALUE PER YEAR FOR GEORGE TOWN HARBOUR (35 ha)	**$26,228,581**	**$25,898,255**	**$23,035,765**
ESTIMATED ECONOMIC VALUE PER YEAR PER HECTARE	$749,388	$739,950	$658,165

Notes:

- Provisioning services in estimated and actual values based on Bonaire valuation (MPA) US$846/ha/yr
- Regulating services in estimated and actual values based on deGroot et al 2012
- Supporting services in estimated and actual values based on deGroot et al 2012
- deGroot et al 2012 cultural services value excludes tourism estimates
- Regulating Services in actual values base on SW estimate for shoreline protection

Table 20.4 Estimated tourism (Cultural) value based on ESO Tourism Statistics (in US$)

Estimated tourism (Cultural) values based on ESO Tourism Statistics								
	Total Number of arrivals (2013)	% Number of tourists diving	% Number of air tourists diving in GTH	Direct Spend Value diving, snorkelling, boat, sub tours	Indirect spend value Cruise	Other spend Air	Total for GTH	Tourism Valuation/ha
Rates		5.6%	47%	$125	$86	$246		
Cruise	1,375,872	77,049		$9,631,104	$6,626,200		$16,257,304	
Air	345,385	19,342	9,091	$1,136,317		$2,236,271	$3,372,588	
Total	1,721,257	96,390		$10,767,421	$6,626,200		**$19,629,891**	$560,854

Table 20.5 Actual tourism (Cultural) values based on surveys of GTH dive shops (in US$)

Actual tourism (Cultural) values based on surveys of GTH dive stores							
	Total # of tourists reported by GTH dive shops	% tourists per group	Direct Spend Value diving, snorkelling, boat, sub tours	Indirect spend value Cruise	Other spend Air	Total for GTH	Tourism Valuation/ha
				$86	$246		
Air	38,700	47	$3,008,000		$9,513,234	$12,521,234	
Cruise	39,523	48	$3,072,000	$3,386,331		$6,458,331	
Local	4,117	5	$320,000			$320,000	
Total	82,340	100	$6,400,000	$3,386,331	$9,513,234	**$19,299,565**	$551,416

Notes:

- Average direct use cost: Average US$120; Median US$95
- Indirect spend value (cruise): US$86
- Indirect spend value (air): US$246

20.6.4 Estimated Economic Impact of Project on Marine Ecosystem Goods and Services

As noted in **Error! Reference source not found.**, the total estimated value of the goods and services provided by the marine resources in GTH (35 hectares of reefs) ranges from US$23M to US$26M per year. The associated estimated value per hectare is US$660K to US$750K per hectare per year.

The anticipated impact of the project on these goods and services was estimated based on a spatial analysis of the proposed project layout, specifically the extent of the reef areas to be directly or indirectly impacted by the construction and operation of the project, as summarized below:

- Direct impact zone (reef areas to be destroyed): 6 hectares
- High impact zone (reef areas to be impacted by construction and operations): 6-8 hectares

The resulting estimates of the impact of the project on the goods and services provided by the marine ecosystem in GTH is summarized in **Table 20.6**.

Table 20.6 Estimated Economic lmpact of Project on Marine Ecosystem Goods & Services

Estimated Economic Loss				
Description	Reef Area (ha)	**Method A** Estimated Value GTH Reef Goods & Services (US$M/year) (GTH reef area 35 ha)	**Method B** Estimated Value based on Survey of GTH Dive Shops (US$M/year) (GTH reef area 35 ha)	**Method C** Estimated Value based on Survey of GTH Dive Shops and SWI Estimate for Regulating Services (US$M/year) (GTH reef area 35 ha)
Direct impact zone – reef destruction	6	$4.5M/yr	$4.4M/yr	$3.9
High impact zone – reef stress and degradation	6-8	$4.5-6.0M/yr	$4.4-5.9	$3.9-5.3
Total Estimated Annual Loss (US$M/year)	**12-14**	**$9.0-10.5M/yr**	**$8.8-10.3M/yr**	**$7.8-9.2M/yr**

Based on this information, the estimated economic impact of the project on the goods and services provided by the marine ecosystem in GTH is in the order of US$7.8-10.5M/year. Approximately 40-50% of this value is due to the destruction of the reefs within the project footprint, while the remainder is associated with long-term degradation of the reefs to the North and South of the project that is expected due to elevated turbidity and sedimentation levels caused by project construction and operations.

These estimated economic losses are based on current spend rates, and are related to direct and indirect impacts on marine ecosystem goods and services within GTH caused by the project, in particular due to the loss of coral reefs and associated business for local watersports operators, plus indirect impacts to employees' incomes and purchasing power. Assuming 1-3%/year growth in cruise passenger traffic over the 20 year life of the project (as per the OBC), this corresponds to an estimated economic loss in the order of US$120-200M over the 20 year life of the project (range in net present value assuming a 3.5% discount rate). These estimates are based on a preliminary marine resource valuation, and are subject to some uncertainty. Also, these estimates do not consider the anticipated diversion/displacement of activities from within GTH to other locations and/or activities/attractions in George Town and around Grand Cayman Island.

Further analyses are required to adjust the estimated losses to reflect the Gross Value Added (GVA) to the overall economy of the Cayman Islands, and also to account for the anticipated diversion/displacement of businesses from within GTH to other locations and/or activities/attractions in George Town and around Grand Cayman Island. It is recommended that the OBC be updated to reflect these and other socio-economic impacts identified in the EIA.

20.6.5 Previous Baseline Studies

20.6.5.1 Strategic Outline Case

In light of the trend towards larger cruise ships being brought to the market, the CIG was concerned that the industry's continued growth and move towards larger vessels would result in gradual decline of the existing fleet of small vessels. This would negatively impact the Cayman Islands, which lack the capacity to accommodate these larger vessels. In addition, the necessity to tender passengers from ship to shore and back makes for a logistical challenge with the inclusion of these larger vessels. It was therefore decided that a larger berthing facility that could accommodate the larger vessels that have been dominating and are expected to continue to dominate the cruise ship industry.

A policy directive "to further enhance the existing facilities for cruise passengers visiting the Cayman Islands in order to improve visitor experience when disembarking, mitigate against further loss of cruise market share, and increase overall passenger numbers" was drafted. The project objectives were identified as:

- To provide the relevant infrastructure to better facilitate the efficient embarkation and disembarkation of passengers from larger cruise vessels in the Cayman Islands Ports. The construction of new berthing facilities will seek to achieve this objective.
- To provide additional tourism opportunities, industry jobs and benefits to local merchants while enhancing the competitiveness of the Cayman Islands Cruise tourism product by providing as good or better facilities than presently provided by competitors.

A Strategic Outline Case (SOC) was prepared by the CIG in April 2013 for this directive. The SOC identified financing; the political environment; project phasing; impact on cargo operations; domestic infrastructure; social environment; and the natural environment as constraints. Broad project costs and non-monetary costs were identified costs and risks. Initial perceived benefits included those to local construction industry; improved competitive positioning of Cayman in the region; increasing passenger volume and revenue; facilities that accommodate vessels not currently stopping in Grand Cayman; improved passenger experience; increasing percentage of passengers disembarking from cruise ships; longer time on shore for passengers; securing and potentially increasing the economic impact of cruise tourism. The SOC cited the BREA Report (discussed below) in its presentation of benefits. Risks outlined were financing, impact on the environment, impact from political environment, interaction with the social environment, impact of disaster and loss of tendering capabilities. The SOC highlighted the lack of existing budgetary provisions for the project.

20.6.5.2 Outline Business Cases

An Outline Business Case (OBC) was subsequently prepared by Price Waterhouse Coopers (PwC) and released in October 2013. PwC identified improved safety; reduced disembarkation delays; enhanced attractiveness of the Cayman Islands; increased disembarkation levels; attraction of larger ships to the island and securing long-term cruise tourism among the main drivers of the project. PwC's objectives included identifying value for money options, proposing a procurement strategy and project schedule, and identifying funding, accounting and management resources for the project. The process included review of eight project options and stakeholder consultations. A shortlist of options was identified and assessed for environmental impact, navigation, visual impact and degree of reclamation and dredging required. The selected preferred option was the two piers design being assessed in the EIA. An economic appraisal of the preferred option was undertaken to identify economic impacts. Both with (pier, no tendering, some self-tendering) and without (no berthing, tendering, self-tendering) cruise berthing facility were considered. Two impact flows were identified: one related to impacts on port operations and the other on the tourism economy. The economic analysis used Gross Value Added (GVA) and the total number of jobs (full time equivalent (FTE) to quantify impacts.

PwC further identified four impacts: 1) direct impacts from construction and operation of the cruise berthing facility; 2) indirect impacts primarily created by purchase of goods directly involved in construction and operations; 3) induced impacts or additional impact on the economy resulting from increased expenditure by employed workforce directly and indirectly by the cruise berthing facility; and 4) wider impacts through economic activities resulting from the cruise berthing facility such as increased tourism spending.

The results of the economic analysis are shown in **Table 20.7.** PwC found that the net benefit will be $245M, expressed as net present value over 20 years post-construction. Based on a total 50-year lifetime of the project, the NPV of the project is higher than $245M. When expressed in terms of

employment, they estimated net benefits at 491 man years of construction and 999 man years during operations.

Table 20.7 Net economic impact of cruise berthing facility (PwC Outline Business Case, October 2013)

Net impact of cruise berthing facility only (OBC)			
	(b) with cruise berthing facility	(a) without cruise berthing facility	Net Impact (a) – (b)
GVA (Net present value, $M)			
Direct	18	85	-67
Indirect & Induced	14	2	11
Wider	2,148	1,905	242
Tax Revenue	347	288	59
Total	**2,526**	**2,281**	**245**
Employment			
- Construction (man years)	491	-	491
- Operations (FTEs)	2,140 – 2,785	1,786 – 2,140	999 (in 2036)

PwC concluded that "projected passenger volumes are the key determinants of the economic impacts. The baseline was based on a 1% per annum growth and assumed corresponding 1% per annum decline without the cruise berthing facility. They further posited that at 3% growth with assumed corresponding 3% decline in the "without project scenario, would result in $1,196 M versus $245M."

A second conclusion drawn from the analysis was that increases in time spent ashore, largely due to eradicating the tendering delays, would increase tourist spend on tours and other goods and services. PwC also concluded that increased levels of disembarkation for both passengers and crew are significant contributions to the overall economic impacts estimated.

The analysis was noted to be based on data provided by the CIG and also on the *Economic Contribution of Cruise Tourism to the Destination Economics* prepared by BREA, September 2012. Uncertainties identified included those concerning very long-term economic analysis and the use of only partial infrastructure life cycle.

It is recommended that the OBC be updated to reflect the long-term economic impact of the loss of environmental goods and services resulting from the destruction and degradation of the GTH reefs. Based on current valuation of ecosystem goods and services provided by GTH reefs, the long-term economic losses resulting from the destruction and degradation of these reefs are estimated at US$120-200 million over the 20 year project life. These losses represent the net present value of the long-term fall-out resulting from the direct loss of a natural resource which is essential for the existing dive/water-sport industry in GTH, and also reflect the indirect impacts to employees' income and purchasing power. It is recognized that these values are based on a preliminary marine resource valuation based on current spend rates, and would have to be adjusted to reflect the Gross

Value Added (GVA) and take into account the possible diversion/displacement of businesses to other areas over time. While the spend value does not represent net benefits to the economy, it captures the magnitude of importance of the operations utilizing the GTH natural resources and the importance tourism has on the local economy within the 2km study area.

20.6.5.3 Economic Contribution of Cruise Tourism to the Destination Economics prepared by Business Research and Economic Advisors (BREA), September 2012.

Passenger and crew surveys were conducted on-board ships of the Florida Caribbean Cruise Association (FCCA) member cruise lines over a six-month period in an effort to collect data to assess the economic contribution of cruise tourism to destinations. The BREA report based its assessment for the Cayman Islands on hours spent ashore, expenditures, visitor satisfaction, likelihood of returning and demographic characteristics of passengers and crews. CIG Department of Tourism statistics were also used in the analysis. A total of 1,662 passenger surveys were completed. Key findings of the BREA report were:

- The report estimated that 90% of passengers and 37% of the crew disembarked and visited the Cayman Islands. Based on these rates, an estimated 1.44 million cruise visitors disembarked in the Cayman Islands in 2011/2012. Total generated cruise expenditures were US$157.7M ($206.24 per person). Approximately 56% of onshore visitors reported spending on food and beverage at restaurants and bars and shore excursions. The largest average spend were, however, on watches and jewellery followed by other purchases, clothing and shore-based excursions.
- Employment impacts were estimated at;
    - Direct economic contribution of 1,974 persons employed and US $36.7M in wages;
    - Total economic contribution of 3,547 persons employed and US $66.6M in wages.
- Overall passenger visit score was 7.9 out of 10 in the 2012 survey. When asked the degree to which the visit met expectations, the average score was 7.6. Likelihood of a return visit was however scored lower, at 5.5 out of 10. Guided tours, friendliness of residents, and 'informed of tours and activities' were the highest scored satisfaction variables. The lowest was overall prices, variety of shops, variety of things to do and historic sites/museums.
- The report highlighted that the US and Canada was the main source of passengers. The average age of respondents was 52 years with 26% being 65 years or older. Average household income was US$92,700 with over 32% reporting over US$100,000. Safety and difficulty of the aging passenger demographics was cited by cruise lines as a shortcoming of current baseline tender operations during consultations in October 2014. (See SEP for additional information on stakeholder consultation).

20.7 Impact Assessment

20.7.1 Project Impacts

20.7.1.1 Impacts during Construction (Positive)

Macro-economic: Construction of the proposed project will cost an estimated CI$150 million which will contribute to the GDP of the Cayman Islands. Sectors to be directly impacted include construction, mining and quarrying while indirect or secondary benefits will be in other sectors such as wholesale, retail and increased employment rates. This will be a direct, short-term impact.

Employment: The project will require administrative staff, labourers, divers, skilled tradesmen, project management, engineers, foremen and operators, among other positions. To the extent where local expertise is available, the labour force will benefit. There is no available estimate of the number of positions at this time. This will be a direct short-term impact. PwC estimated employment net benefits of 491 FTE (man years) during construction.

Materials: Local materials including aggregates, concrete work (pre-cast and cast-in-place) will be required, which will improve the contribution of the mining and quarrying and manufacturing sectors of the economy. Other materials such as additional quarried stone; rebar, structural steel, various other elements (bollards, fenders, mechanical equipment, instrumentation, etc.) and consumables (diesel, gas, drilling mud, etc.) may be imported. This will be a direct short-term impact.

Equipment: Equipment including cranes, excavators, pile drivers, drills/augers, trucks, generators, barges, tugs, support vessels, etc. will be required for the project. Although some construction equipment may be sourced locally, it is anticipated that the majority of the heavy/specialized construction equipment will for the proposed project will be imported. Impacts will be direct and short-term.

Micro-economic (George Town/Business District): The influx of construction workers in the downtown area may increase sales and revenues for some businesses, in particular food and beverage services and accommodation during the construction phase of the project.

Local residents within the District will also have employment opportunities from the project. Impacts will be indirect and short-term.

20.7.1.2 Construction Impacts (Negative)

Vehicular and Pedestrian Traffic: Traffic impacts will be temporary during construction and will be attributed to the movement of construction materials and additional staff on and off site. While construction activities will be undertaken on land, it is anticipated that personnel will be based at the port and materials will be transported through the port. Based on the number of trips required,

traffic impacts may be significant, given that the main access road is Harbour Drive, which is a main thoroughfare and which has high volumes of vehicles and local and tourist pedestrians. See Chapter 18 - Traffic and Pedestrian Report for additional information. Traffic impacts during construction will be direct and short-term.

Marine Traffic: Construction activities will increase the number of vessels in the harbour. This will potentially disrupt both cargo and cruise ships. There is also the increased potential for accidents and injuries. This impact is expected to be short-term and minor. Impacts on cruise and cargo operations are available in Chapter 19 – Cruise and Cargo Operations. Traffic impacts during construction will be direct and short-term.

Potential Resource Usage Conflicts: During the construction phase of the project, access to sites for diving, snorkelling, sea observatories and other water sports within the harbour will likely be prohibited or restricted to limited areas. This represents a direct short-term impact.

Displaced visitors will likely visit other attractions across the island. Increased visitors to these alternative natural resources and other attractions will increase pressure on these resources, some of which are fragile eco-tourism sites. There are concerns about the carrying capacity of these sites to accommodate increased numbers of visitors. This increases the potential for degradation of these sites. This will be an indirect moderate to long-term significant impact.

Reduction in Water Quality and Pollution of Coastal Resources: During construction, dredging, pile driving and other activities will increase turbidity in the water, causing reduction in water quality and visibility. This is due to an increase in suspended sediment from the disturbed sea floor and substrate (refer to Chapter 12 - Sediment Transport and Dredge Plume Modelling Report).

Declining water quality in the harbour will negatively impact diving and water sports/ excursions. Other businesses such as restaurants, especially those that allow patrons to swim, snorkel or dive while at their establishment will also be affected. Poor visibility and the destruction of marine wildlife will result in declining customer bases and revenues. An estimated valuation of dive services is included in the preliminary economic valuation.

There is also a threat to public health and safety of residents and visitors and potential health care implications. Reduction in water quality and pollution of coastal resources will be a short-term, direct impact.

Destruction and/or Damage of Marine Resources: There will be direct and indirect impacts on marine and coastal resources during the construction and operation of the project. Approximately 12-14 ha (~40%) of the reefs in GTH will be directly or indirectly impacted by the proposed dredge footprint; this includes 6 ha (17%) within the project footprint that will be destroyed. This will be a direct, long-term impact. A preliminary marine resource valuation was completed to estimate the economic losses associated with the destruction/damage to the marine resources in GTH. Project

construction is expected to result in a loss of marine ecosystem goods and services with a value in the order of US$4-4.5M/year. An additional US$4-6M/year of ecosystem goods and services may be impacted due to long-term degradation of the reefs adjacent to the project. As noted earlier, these values are based on current spend rates (not Gross Value Added), and do not account for the anticipated diversion/displacement of activities/business from within GTH to other locations and/or activities in George Town and around Grand Cayman Island.

Other marine wildlife including various fish species, sponges, etc. will also be destroyed. Water quality and connected and/or interdependent ecosystems will also be indirectly impacted.

Noise, Vibrations and Air Pollution: Construction activities will increase noise levels and air pollution in George Town. Dredging and driving piles will increase noise levels in the study area. No impact from vibration is expected.

Greenhouse gas emissions are also likely to increase with increases in construction equipment and boats and dust particulates. Air pollution represents health threats to people in the area, especially respiratory illnesses. See Chapters 14 and 15 for details on level of pollution. Noise and air pollution impacts are expected to be minor to moderate, direct and short-term.

Loss of Livelihoods/Incomes - Tender Operator: Tender operations are owned and operated by Caribbean Marine Services (CMS). CMS reports that the planned reduction in the use of tender boats will make the business no longer lucrative. As such they will cease all operations at the start of construction. This will decommission 16 tender boats and displace an estimated 40 tender operators (captains and line-men) in addition to mechanics who work on and service the boats. Loss in income is estimated at over CI $300,000/year and will affect upwards of 40 households.

Estimated direct financial losses to the owners of the tender business resulting from the loss of US$5.25 per manifested passenger are estimated at an average of US$5 million per year. This is based on reports that approximately 70% of landed cruise passengers in the past five years used local tendering services to get to and from ships. Assuming 1-3%/year growth in cruise passenger traffic over the 20 year life of the project (as per the OBC), this corresponds to an estimated economic loss in the order of US$77-92M over the life of the project (range in net present value assuming a 3.5% discount rate).

Secondary impacts will likely be felt in the transportation sector as this is the only company operating tender boats in the country. This will therefore impact cruise tourism during the construction period. Some cruise lines have “self-tendering” services. Other cruise lines may need to provide tender boat services to their passengers.

Impacts to tender operations will be long-term and direct. Impacts to the cruise tourism will be indirect and short-term.

Loss of Livelihoods/Incomes - Dive Shops & Water Sports/Excursion Operators: At least nine marine commercial establishments that offer dive/water sports/ excursions are located along the GTH waterfront and conduct their excursions within the harbour. There will be a loss of revenues to these businesses as many of them operate solely within the harbour. Estimated loss of revenue will be CI $6.4M/year (included in economic valuation of GTH reefs).

Employees will likely lose their jobs; this will have secondary effects on purchasing power, unemployment/employment rates, and standard of living. Impacts on establishments will be direct, while wider economic impact will be indirect.

Loss of Livelihoods/Incomes - Household Income and Quality of Life: Job loss, declining revenues for businesses and employees will lower household income, purchasing power and quality of life of impacted persons and their households. This impact will be indirect and moderate to long-term.

Cruise Tourism: During the construction phase, potential disruptions to cruise ships and withdrawal of tender services to transport cruise visitor ashore may result in declines in the number of ships calling and the number of cruise visitors. In addition, visitors with limited time ashore who would opt to do water activities in the George Town area will have to travel longer distances for those activities. Visitor experience during the construction phase will likely be lower than the baseline. This will have negative implications across other sectors of the local and national economy. Construction impacts will be direct and indirect impacts to cruise tourism and short-term.

Air Tourism: Stay-over visitors may opt to avoid downtown George Town during times of construction activities. Noise, air and lower aesthetic value of the sea may deter visitors, causing a decline in business in the area. Impacts on air visitors will be indirect and short-term.

Micro-economic (George Town) Tourism: George Town retail and wholesale businesses especially those heavily based on visitors may have declining sales in the short-term if the number of visitors to the area decline from the cumulative impacts described above. This is expected to be short-term.

Public Perception: Public perception of project impacts during construction was mainly negative. Stakeholders believe that environmental receptors and groups who are vulnerable due to their dependence on the environment will be negatively impacted. The proportion of stakeholders that believe the construction impacts of the project will be negative were higher than those citing positive benefits. Positive benefits identified were mainly from construction jobs and value added to the economy.

20.7.1.3 Impacts during Operational Phase (Positive)

Macro-economic (Grand Cayman and All Cayman Islands): The macro-economic impact during the operational phase of the proposed project is the main driving force of the project. It is a policy of the Cayman Islands Government to enhance the existing facilities for cruise passengers through the proposed project. It is expected that the berthing facility will *increase the capacity and efficiency of the port* to handle larger vessels with more passengers. This will potentially result in *increased revenue stream* from cruise tourism. Direct and indirect benefits will also result across the economy, which is largely dependent on tourism. There will be *employment and income opportunities*, higher and/or larger proportion of the population with disposable incomes and a higher standard of living.

There will be increased business opportunities for attractions such as the Turtle Farm, Dolphin Cove, Sting Ray City, among others across Grand Cayman. Tour companies and the transportation sector will also benefit.

Macro-economic impacts during operations are expected to be significant, long-term and positive. The PwC OBC estimated net benefits of between CI $245M and 999 FTE man years during the operational phase of the proposed berthing facility. Full time equivalent employment benefits were based at a 1% per annum growth in visitor volume. At 3% per annum increase in visitor volume the estimates were increased to CI$1,196M.

Micro-economic (George Town/Business District): There will be increased business opportunities in George Town during operations. Larger numbers of visitors will increase sales and revenues from cruise visitors. This will be a direct, positive and long-term impact. Non-marine commercial stakeholders in George Town reported sales of CI $1,992,000 per annum among seven respondents, 51% of which was attributed to cruise visitors. It is expected that revenues will increase. This will be a direct long-term impact.

Traffic: After construction the GTH will be able to accommodate larger ships along the deeper/longer berth. Assuming larger ships are used for cargo and cruises, fewer ship calls will be made and marine traffic/congestion will be reduced (See Chapter 17 for additional Traffic and Pedestrian impacts).

Stakeholder Perception: Stakeholder perception of impacts during operations is generally more positive than negative for non-maritime businesses and households. At the household level, job opportunities, local business opportunities and a boost to the local and national economy were identified during stakeholder engagement.

20.7.1.4 Impacts during Operations (Negative)

Traffic: Vehicular and pedestrian traffic in George Town is expected to increase during operations. An increased number of visitors who will be coming ashore in a shorter time than with current

tender boat transfers will descend on George Town en-mass. Chapter 17 - Traffic and Pedestrian Impact Assessment, estimates that the level of acceptable service (LOS) for pedestrians will decline and vehicular traffic volume will increase during operations, based on existing road infrastructure. This will be a negative, long-term and indirect impact of the proposed project.

Destruction of Marine and Coastal Resources: The presence of the pier during operations will have negative impacts on marine wildlife in its vicinity. Light penetration into the sea for photosynthesis will be blocked by the piers. See Chapter 16 - Marine Ecology for additional information. The loss of ecosystem goods and services will continue during operations. As previously discussed, the estimated value of this loss is US$8-10.5M/year.

Potential Resource Usage Conflicts: During operations, the piers will block the direct path of small crafts traversing the water of the harbour north and south of the port in either direction. This will result in longer trips and increased fuel costs. This includes dive and water sports/excursion vessels as well as private vessels entering and leaving Hog Sty Bay.

The presence of larger sized and potentially larger number of cruise vessels calling in the harbour will decrease access to residents and businesses conducting recreational activities in the harbour. The risk of accidents and injuries will also increase with the increasing size of vessels in the harbour and local vessels having to travel longer distances. This will be a negative, long-term and direct impact.

Larger numbers of visitors will increase pressure on other natural resources and attractions across the island. Attractions and sites may not have the capacity to accommodate larger numbers of visitors. This pressure may have negative impacts that undermine any potential economic gains. This will be a moderate to long-term, significant impact.

Community Development, Infrastructure & Social Services: During operations, increased resources will be required to cope with increased visitor volume. The NRA, PACI, and Planning Department among others, identified the need for funding to upgrade necessary infrastructure and social services such as the road infrastructure, insurance for the new facility, emergency services including health care and fire, in order to accommodate increased visitor and ship volumes. Community development, infrastructure and social services impacts will be indirect and long-term.

Micro-economic (George Town/Business District): During operations, dive and water sport/ excursion businesses that use the George Town Harbour will continue to decline from the long-term impact associated with the loss of coral reefs and ecosystems in the harbour. The estimated loss in income and revenues of CI $6.4M/year is attributable to the losses to the dive and water sports and excursion businesses in George Town. Specific sectors will likely decline within the business district. This represents both direct and indirect and long-term impact.

Public Perception (Air Tourism): The increased volume in cruise tourism may deter stay-over visitors from visiting George Town on days when ships call. Given that stay-over tourists spend more than three times that of cruise visitors, this has the potential to have significant, long-term negative impacts.

20.7.1.5 Climate Change Impacts

Climate change impacts will be as a result of increased greenhouse gas emissions from likely increases in construction equipment, boats and dust particles during construction (See Chapter 14). Climate change impacts will also result from impacts from stronger hurricanes and storm surges.

Potential risks exist during construction as well as during operations. In the long-term, there is also potential for indirect impact as a result of sea level rise. Rise in sea levels will exacerbate storm surges and flooding associated with stronger hurricanes. See Chapter 8 for additional information on *Natural Hazards Assessment* and recommended mitigation measures.

20.8 Proposed Mitigation Measures

Resource Conflict - During the construction phase of the proposed project, scheduling activities around existing activities within the study area will minimize traffic (vehicular and marine) and pedestrian impacts. Scheduling materials delivery during off-peak commute and visitor times will minimize the impacts on the community.

It is recommended that the increased pressure on other natural resources outside of the GTH due to restricted and/or prohibited access during construction as well as to accommodate larger numbers of visitors during operations, is quantified to assess the environmental, social and economic costs and benefits. Carrying capacity studies of alternative attractions are recommended to determine the potential impacts on those sites. This will inform strategies to control impacts to these sites to which operators would turn during construction as well as operations of the project.

Withdrawal of tender services - Alternative options for tendering should be explored as tendering will be required to maintain cruise operations during construction and for excess ships (> 4) during operations. Negotiations with CMS or procurement of new services (Request for Proposals) are two potential options for tender services.

Stakeholder Perception - Communication with stakeholders and the general public on the potential negative and positive impacts of the proposed project will be very important:

a. There were some views that there is insufficient information available on the full scope and potential impacts and benefits of the project.
b. Given the socio-economic and socio-cultural significance of the sea to the Cayman Islands and the potential for negative impacts, it is critical that alternative scenarios (with, without,

alternate locations, etc.) be presented in a clear and concise way that is understandable to the public and stakeholders.

c. A justification for preferred option and mitigation strategy is also recommended.

Loss of Livelihoods/Income - A program should be developed to mitigate livelihood impacts especially among vulnerable groups. The program should include a process for accurately identifying those directly impacted and work in a collaborative and inclusive manner to develop strategies to minimize socio-economic impacts. Consideration should be given to the need to compensate persons who will have income and revenue losses. Providing assistance with identifying and establishing alternative livelihoods and revenue streams should also be considered where needed. This may require skills training and professional development. A needs assessment will be required.

Successful relocation of the Balboa shipwreck to a location within the GTH with no restrictions to access, as is the current baseline case, will minimize the loss of revenues for GTH dive shops. At the current, access is restricted to night dives. Unrestricted access will increase the number of dives and revenue. A relocation plan informed by in-depth archaeological data on the condition and integrity of the Balboa including the Balboa Studies and expert opinions will be needed. It is important that stakeholders participate in the decision making process. The relocation plan for the Balboa will be judged not only on the cost and the execution, but also on the success of preserving the structure of the wreck along with the corals and other marine fauna that have colonized the wreck surfaces over the years.

Destruction and/or Damage to Marine Resources - Mitigation measures for environmental receptors (water quality, marine wildlife, etc.) are addressed in other Chapters of the EIA. Chapter 16 includes coral relocation; Chapter 12: Sediment and Water Quality; Chapter 14: Air Quality and Greenhouse Gas Emissions and Chapter 15: Noise and Vibration. H: Noise and Vibration.

Traffic - Traffic mitigation measures were shown to be able to reduce congestion and travel times to less than half of the baseline levels even with the increased tourist and local traffic. See Chapter 18: Traffic and Pedestrian for proposed mitigation for vehicular, pedestrian impacts.

20.9 RIAM Summary of Anticipated Project Impacts and Proposed Mitigation Measures

As noted in Chapter 1.3.6, the Rapid Impact Assessment Matrix (RIAM) method has been used to "quantify" the anticipated impacts of project construction, operation and mitigation measures. Table 20.8 and Figure 20.5 provide a summary of the RIAM scoring for specific impacts related to socio-economic impact assessment, which includes both the business district impact assessment and the landscape visual impact assessment.

The RIAM method was applied to score each of the following project phases:

- Existing (baseline) conditions
- Dredging and reclamation phase
- Construction (post-dredging) phase
- Operational phase

Proposed mitigation measures for specific impacts are highlighted in the green cells in Table 20.8, with the RIAM method applied both without and with these mitigation measures.

Chapter 1.3.6 provides an overview of the various RIAM scoring criteria (A1, A2, B1, B2 and B3) and the methodology used to derive the Environmental Score (ES) and associated Range Value (RV) for each specific impact. The Range Values are summarized as follows:

- N: Neutral (no change/impact)
- A to E: Positive change/impact (A is slight positive...E is major positive)
- -A to –E: Negative change/impact (-A is slight negative...E is major negative)

Additional information on the RIAM methodology is provided in Appendix Q.

Table 20.8 Detailed RIAM Scoring for Socio-Economic Impact Assessment (includes Business District Impact Assessment and Landscape Visual Impact Assessment)

PHASE	IMPACTS SCORED WITH NO MITIGATION	Spatial Importance (0 to 4)	Magnitude of change/effect (-3 to + 3)	Permanence (1 to 3)	Reversibility (1 to 3)	Cumulative (1 to 3)			IMPACTS SCORED WITH MITIGATION	Spatial Importance (0 to 4)	Magnitude of change/effect (-3 to + 3)	Permanence (1 to 3)	Reversibility (1 to 3)	Cumulative (1 to 3)	*ES with mitigation*	*RV With Mitigation*
		A1	A2	B1	B2	B3	ES	RV		A1	A2	B1	B2	B3	ES	RV
EXISTING CONDITIONS	Macro-economic (Cruise Tourism)	3	0	1	1	1	0	N		3	0	1	1	1	0	N
	Macro-economic (Employment and Income)	3	0	1	1	1	0	N		3	0	1	1	1	0	N
	Micro-economic (Business District)	3	0	1	1	1	0	N		3	0	1	1	1	0	N
	Water Sports/Dive Operators	3	0	1	1	1	0	N		3	0	1	1	1	0	N
	Tender Operators	3	0	1	1	1	0	N		3	0	1	1	1	0	N
	LVIA (Land Use)	2	0	1	1	1	0	N		2	0	1	1	1	0	N
	LVIA (Visual Aesthetics)	2	0	1	1	1	0	N		2	0	1	1	1	0	N
DREDGING & RECLAMATION	Macro-economic (Cruise Tourism)	3	-1	2	2	3	-42	-D	Alternative options for tendering cruise passengers Alternative attraction sites for restrictions in GTH Measures to minimize disruptions	3	-1	2	2	3	-21	-C
	Macro-economic (Employment and Income)	3	2	2	2	3	42	D		3	2	2	2	3	42	D
	Micro-economic (Business District)	3	-3	2	2	3	-63	-D	Implement measures to attract visitors downtown during construction to minimize loss of patronage.	3	-2	2	2	3	-42	-D
	Water Sports/Dive Operators (Reveunes; livelihoods)	3	-3	2	2	3	-63	-D	Alternative locations for dive operators using GTH Work with stakeholders to develop prgram to reduce livelihood impacts. This may include but not limited to insurance; skills training and alternative livelihood opportunities; and compensation for loss of income and revenues	3	-2	2	2	3	-42	-D
	Tender Operators (Revenues/Livelihoods	3	-3	3	2	3	-72	-E	Same as livelihoods program above	3	-2	3	2	3	-48	-D
	LVIA (Land Use)	2	0	1	1	3	0	N		2	0	1	1	3	0	N
	LVIA (Visual Aesthetics)	2	-2	2	2	3	-28	-C	Ongoing communication and involvement of stakeholders and the general public and buy-in will increase understanding of negative visual impacts during construction.	2	-2	2	2	3	-28	-C
CONSTRUCTION-POST DREDGING	Macro-economic (Cruise Tourism)	3	-1	2	2	3	-42	-D	Same as above	3	-1	2	2	3	-21	-C
	Macro-economic (Employment and Income)	3	2	2	2	3	42	D		3	2	2	2	3	42	D
	Micro-economic (Business District)	3	-3	2	2	3	-63	-D		3	-2	2	2	3	-42	-D
	Water Sports/Dive Operators	3	-3	2	2	3	-63	-D		3	-2	2	2	3	-42	-D
	Tender Operators	3	-3	3	2	3	-72	-E		3	-2	3	2	3	-48	-D
	LVIA (Land Use)	2	0	1	1	3	0	N		2	0	1	1	3	0	N
	LVIA (Visual Aesthetics)	2	-2	2	2	3	-28	-C		2	-2	2	2	3	-28	-C
OPERATIONAL	Macro-economic (Cruise Tourism)	3	3	3	1	3	63	D		3	3	3	1	3	63	D
	Macro-economic (Employment and Income)	3	3	3	1	3	63	D		3	3	3	1	3	63	D
	Micro-economic (Business District)	3	3	3	1	3	63	D		3	3	3	1	3	63	D
	Water Sports/Dive Operators (GTH)	3	-3	3	1	3	-63	-D	This is contingent on dive shops using alternative dives sites and increased visitor arrivals and longer time onshore for longer excursions; Also contingent on the successful relocation of the Balboa to a location with no restricted access. Assisting business operators in recouping losses through some means of compensation and/or alternative business opportunities (e.g., insurance, tax incentives; relocation assistance, etc.)	3	-1	3	1	3	-21	-C
	Tender Operators	3	-3	3	2	3	-72	-E	This is contingent on the successful implementation of a program that assits displaced employees in skills training and jobs	3	-1	3	1	3	-21	-C
	LVIA (Land Use)	2	2	3	1	3	28	C		2	2	3	1	3	28	C
	LVIA (Visual Aesthetics)	2	0	3	1	3	0	N	Less significant improvement for those who value the pristine view or the sea and not built landscape. View of the sea will be restricted to some along the coast and Harbour Drive.	2	0	3	1	3	0	N

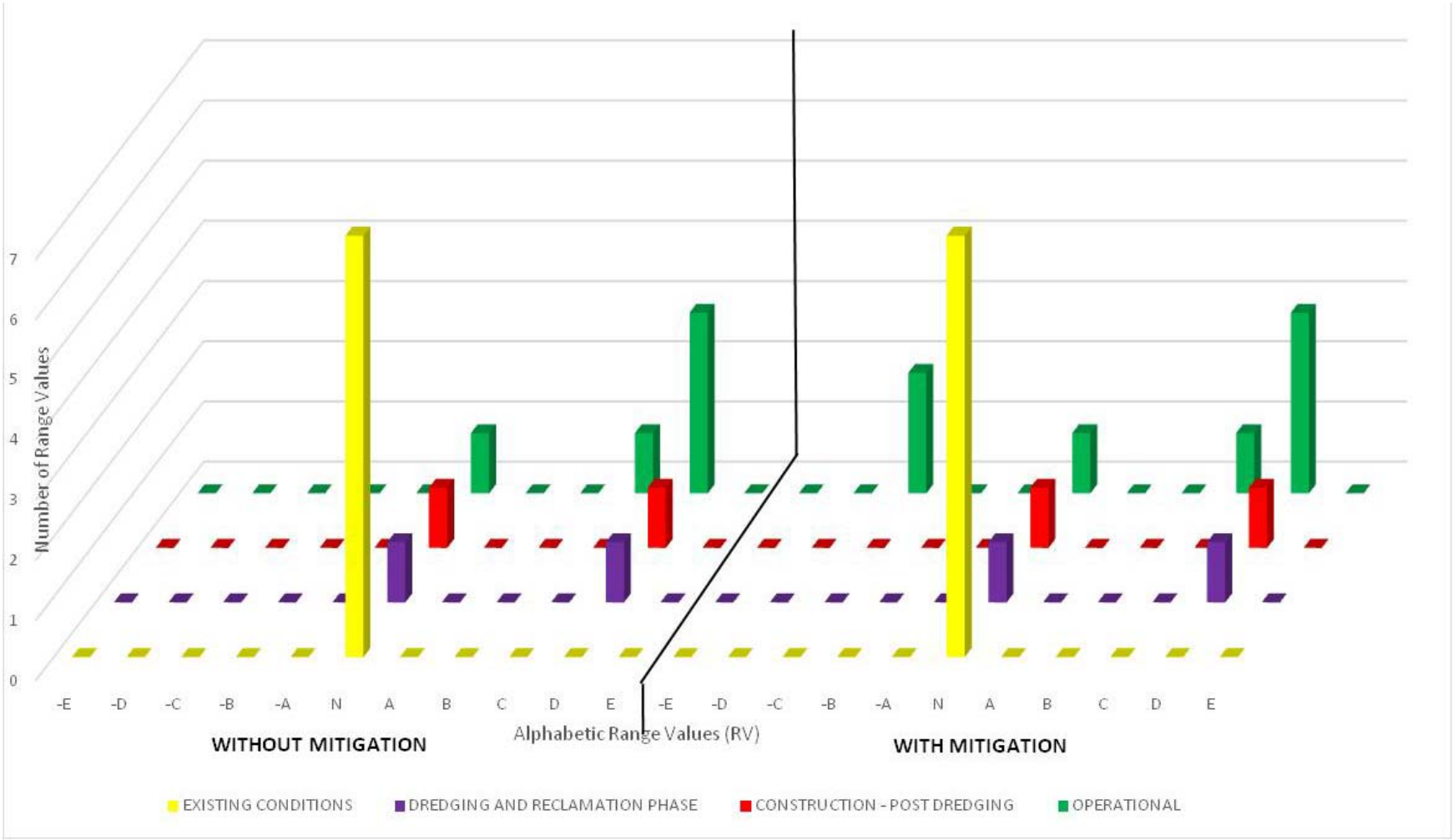


Figure 20.5 Summary RIAM Scoring for Socio-Economic Impact Assessment (includes Business District Impact Assessment and Landscape Visual Impact Assessment)

21.0 TASK O - BUSINESS DISTRICT IMPACT ASSESSMENT

The Business District Impact Assessment (including baseline conditions) is incorporated in the Socio-Economic Impact Assessment presented in Chapter 20 (and in **Appendix N**).

22.0 TASK P - LANDSCAPE AND VISUAL IMPACT ASSESSMENT

22.1 Introduction

The objective of this section is to provide an assessment of the visual impacts of the proposed Cruise Berthing Facility (CBF) on the George Town region and the greater Grand Cayman area. Through the use of spatial analysis tools, this assessment report has determined the visual impact of the proposed project at varying distances from the port and at predetermined observation points. The methodology, baseline conditions and results of the Landscape and Visual Impact Assessment (LVIA) are summarized below.

22.2 Assessment Methodology

This visual impact assessment was carried out primarily by means of Geographic Information System (GIS) analyses carried out on very detailed aerial images and GIS datasets for the George Town area. The ArcGIS 10.1 software package was utilized to create and analyze spatial representation of the George Town area.

A land use survey was carried out for 2,186 land parcels located within a two (2) kilometer radius of the project site, and a land use classification matrix was then developed to define the different land use classes to be recorded. Field maps were produced to display the land parcels, streets and points of interest within a two (2) kilometer buffer from the port. The field maps were used during the field investigation to record and verify the existing land uses observed. The collected land use (field) data was used to edit the land parcels shapefile obtained from the Department of Environment, and the data subsequently entered into ArcMap 10.1 and used to generate land use maps.

The spatial analysis tools (*Slope, Hillshade, Viewshed, Observer Points*) provided by ArcGIS were used to generate raster images that aided the assessment of the visual impacts of the CBF. A shapefile containing spot height information was obtained; this shapefile was converted to a raster image using the kriging interpolation method. The resulting raster image was used to generate Slope, Hillshade, Aspect, Observer Points and Viewshed images, which were analyzed in conjunction with the existing land uses in order to evaluate the level of impact that the CBF will have on the visual environment of George Town.

22.2.1 Assessment Criteria

The approach taken to determine the visual impact was based on two main factors;

- Visibility of the CBF from the predetermined Observer Points
- The ability of the landscape to absorb the changes that will result from the port expansion

Attributes used in this assessment are shown in Table 22.1. The approximate heights of the ships were entered into the attribute table for the specific viewing points, and used in generating the viewshed analysis. The results are, therefore, a representation of what is expected when the ships are at berth.

Table 22.1 Layers and attributes used in LVIA spatial analysis

Shapefiles & Attributes for Spatial Analysis	
Name/Type of Shape file	**Attribute (s)**
Contours	Elevation above sea level
Spot Heights	Elevation
Land Parcels	Land reference number
Building Heights	- Height at ground level - Height at roof level
Ship Heights	- 72m (RCCL Oasis) - 64m (RCCL Freedom) - 63m (CCL Conquest) - 66m (Disney Dream)
Base Imagery	
Berthing Terminal Design	
Coastline (Outline)	

22.2.2 Visibility

Visibility may be defined as a measure of the extent to which particular components of a project may be visible from surrounding areas. It is determined by the line of unobstructed sight and is influenced by topography, the presence of trees and buildings. If the project is not visible then there would be no impact. If it will only be seen by relatively few persons then the impact will be low; however, if the viewing population is large then the impact will also be large.

One criterion for determining level of visibility is:

- **High** – Where large numbers of people (90%) will view the project at a close distance on a frequent basis.
- **Moderate** – Where a medium number of persons (50%) will view the project over a medium distance and time.
- **Low**– Where a small amount of people (10%) will view the project in a short time period from far distances.

While the number of persons viewing the Port is an important factor to consider when evaluating the visual impact, this number will fluctuate and is difficult to measure accurately. Distance and the duration of view are more measurable and reliably quantify the level of impact. Table 22.2 summarizes distance and duration of view classification used in this assessment.

Table 22.2 Matrix to define Visibility Class used to determine the level of visual impact

Visibility Class	Period of View	Distance
High	More than 8 hours per day	Less than 0.5 Km
Medium	5 hours on average per day	0.5 Km – 1 Km
Low	Less than one (1) hour per day	Greater than 1 Km

22.2.3 Visual Absorption Capacity

This is a measure of the landscapes' ability to accommodate a development without creating significant visual contrast between the existing landscape and the proposed development. The ability of the landscape to accommodate a development is dependent on the nature of the existing physical environment, which is determined by the land form, land use and the character of existing developments.

There are no significant land form features within George Town and the landscape is significantly built up; therefore, the level of contrast between the CBF and the surrounding areas will not be significant. There is an existing port facility which has contributed to a very high visual absorption capacity.

22.3 Description of Existing Visual Environment

22.3.1 Land Form

Grand Cayman Island is generally flat with an average elevation of approximately 1.8 meters above sea level. The flat relief of the island gives it a low visual profile. There are no mountains or valleys, and the lands located on the western coast are of the highest elevation, with elevations gradually decreasing towards the east. George Town and George Town Harbour are slightly more elevated than the surrounding areas at elevations of 2 and 3 meters above sea level (see

Figure 22.1 Topography of George TownFigure 22.1 presents an overview of the topography (land elevations) in the George Town Area. The most significant land form feature within the area is the coast line and the fringing reef that surrounds the coast.

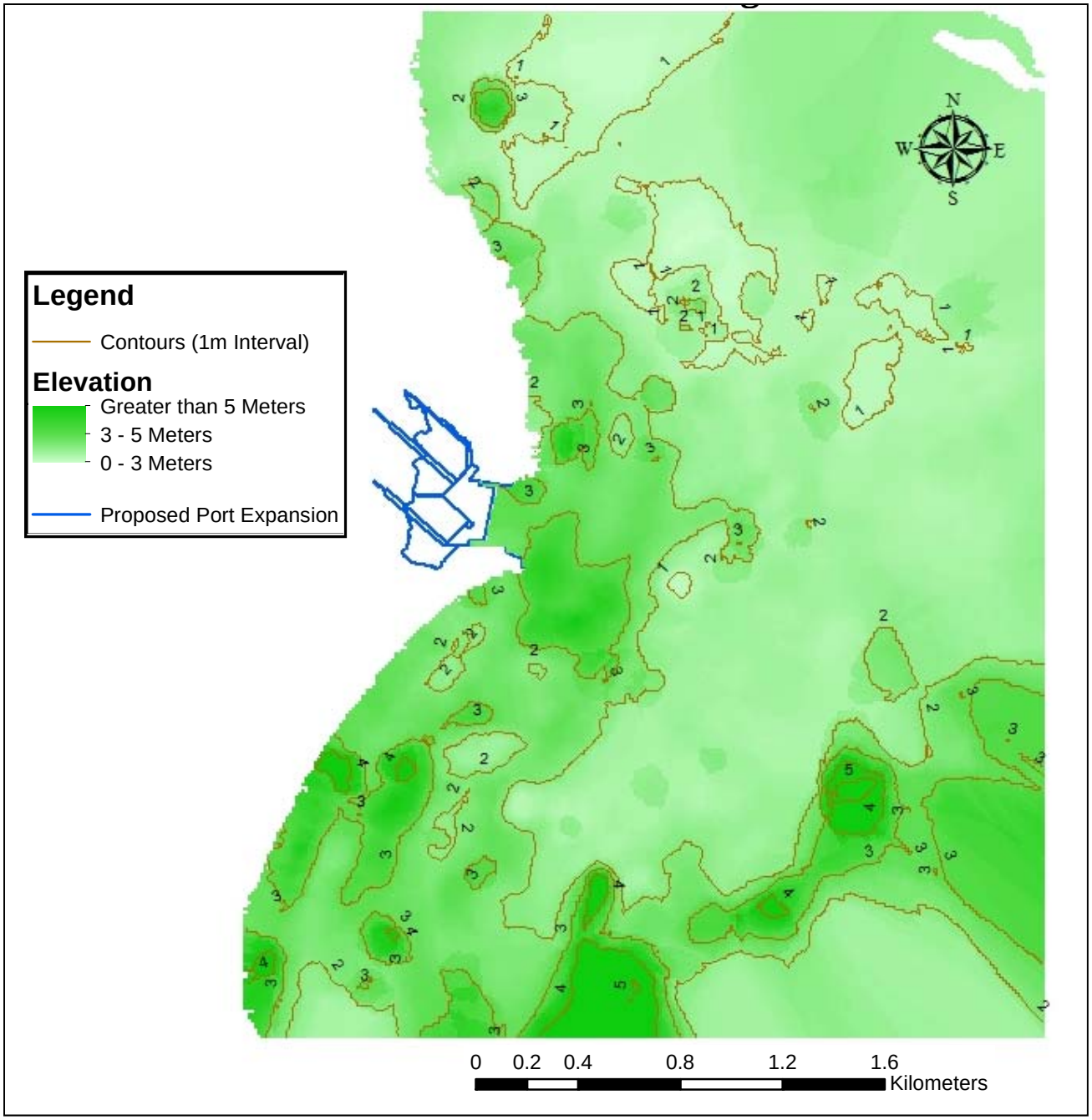


Figure 22.1 Topography of George Town (elevations above sea level)

22.3.2 Land Use

Land use data was collected for 2,186 land parcels within a two (2) kilometer radius of George Town Harbour. The primary land use within this radius is commercial, accounting for 55% of land parcels. Similarly, within the immediate vicinity of the port, the primary land use is also commercial (refer to **Figure 22.2**). Commercial activity is concentrated in the central business district of George Town; however, other commercial activities are dispersed throughout the region of interest. Of the parcels surveyed, residential activity accounted for 34%. Residential activities occur in clusters located mainly to the south and north of George Town. George Town being the capital city; is home to major government and administrative offices. These uses are classified as institutional, and occupy large tracts of land in George Town.

George Town has a significantly built landscape; the land use survey revealed that only 2% of the land parcels in George Town are vacant. Additionally, less than 4% of the lands are characterized as covered by shrubs. Approximately 95% of the lands in George Town can be classified as urban built-up area. The number of greenfield sites is very limited; therefore, future developments will result in modification of the existing urban fabric.

The nature of the land use pattern and building design and layout within the town limits visibility in a way that is described following. The commercial buildings, located closest to the coast, are on average significantly taller than the residential buildings located on the town's periphery. This effect is further compounded by the fact that the town center is more elevated than the lands located further inland. This result in taller buildings being built on more elevated lands; further limiting the visibility of the coast from the inland regions. The pattern of buildings within the town centre creates an obstruction to the visibility of the port.

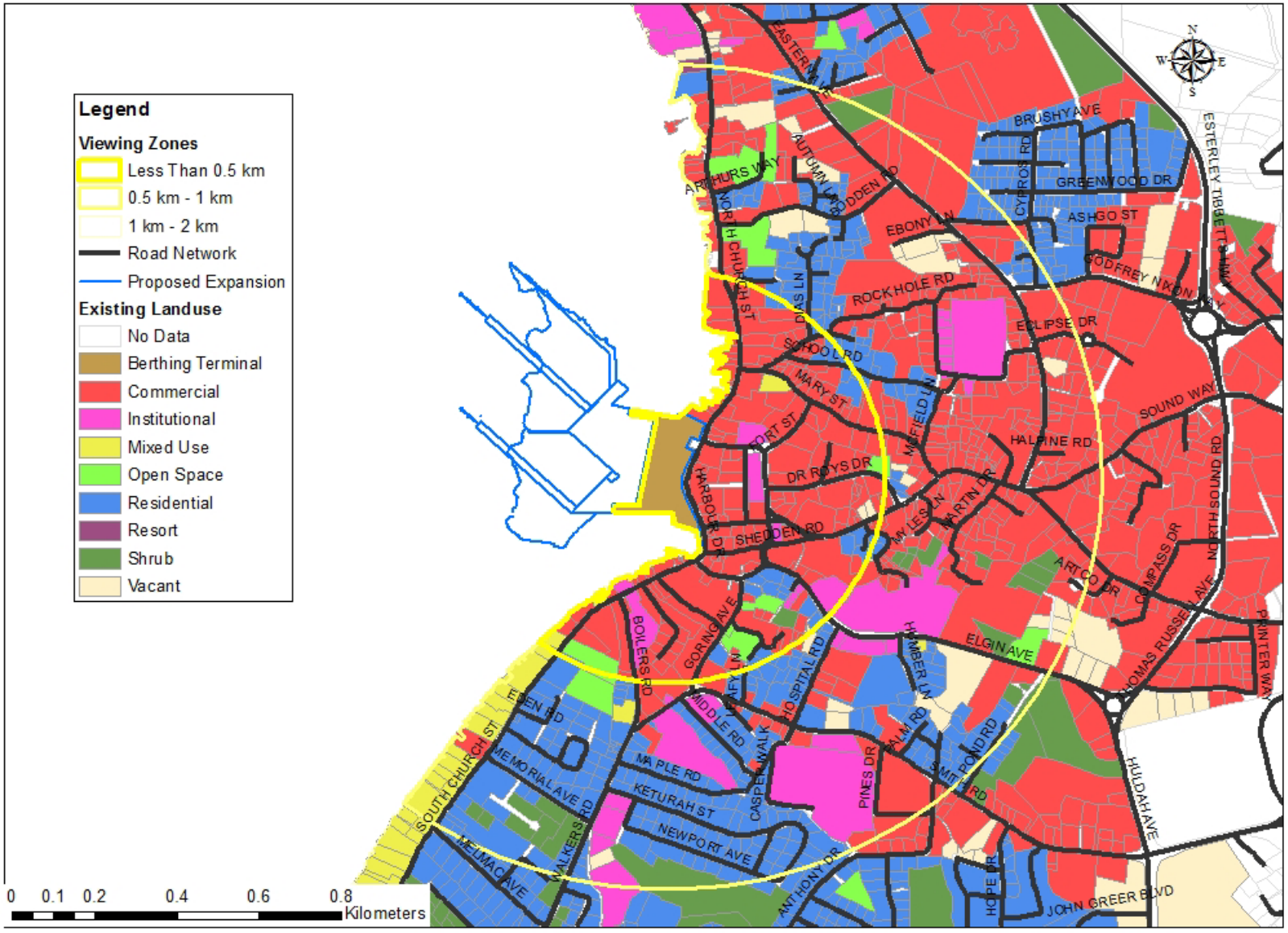


Figure 22.2 Existing Land use pattern within George Town

22.3.2.1 Building Heights

George Town, being the capital of Grand Cayman, has a significantly built environment. The buildings located within the Central Business District (CBD) are significantly larger in scale and height when compared to the buildings on the outskirts of the town. Building heights within George Town are between 9.4 meters and 35.7 meters while buildings on the outskirts range from 1.8 meters to 9.4 meters at roof level (see **Figure 22.3**). This represents a significant contrast between the building heights and scale within the town of George Town and the buildings located outside of the town.

The elevation of the land is a factor that also contributes to the contrast in building heights. George Town is relatively more elevated than surrounding areas. This further compounds the visual impact of the building layout pattern. The height, scale and layout of the buildings have created an obstruction to the view of the coastline by observers located further inland. In fact, the visibility of the coast is limited to the buildings adjacent to Harbour Drive.

The layout of the road networks has also contributed to reduced visibility of the coast and by extension the port. The main road, Harbour Drive, is located parallel to the coastline; this creates a barrier between the buildings and the waterfront and limits visibility of the Port to buildings located adjacent to Harbour Drive.

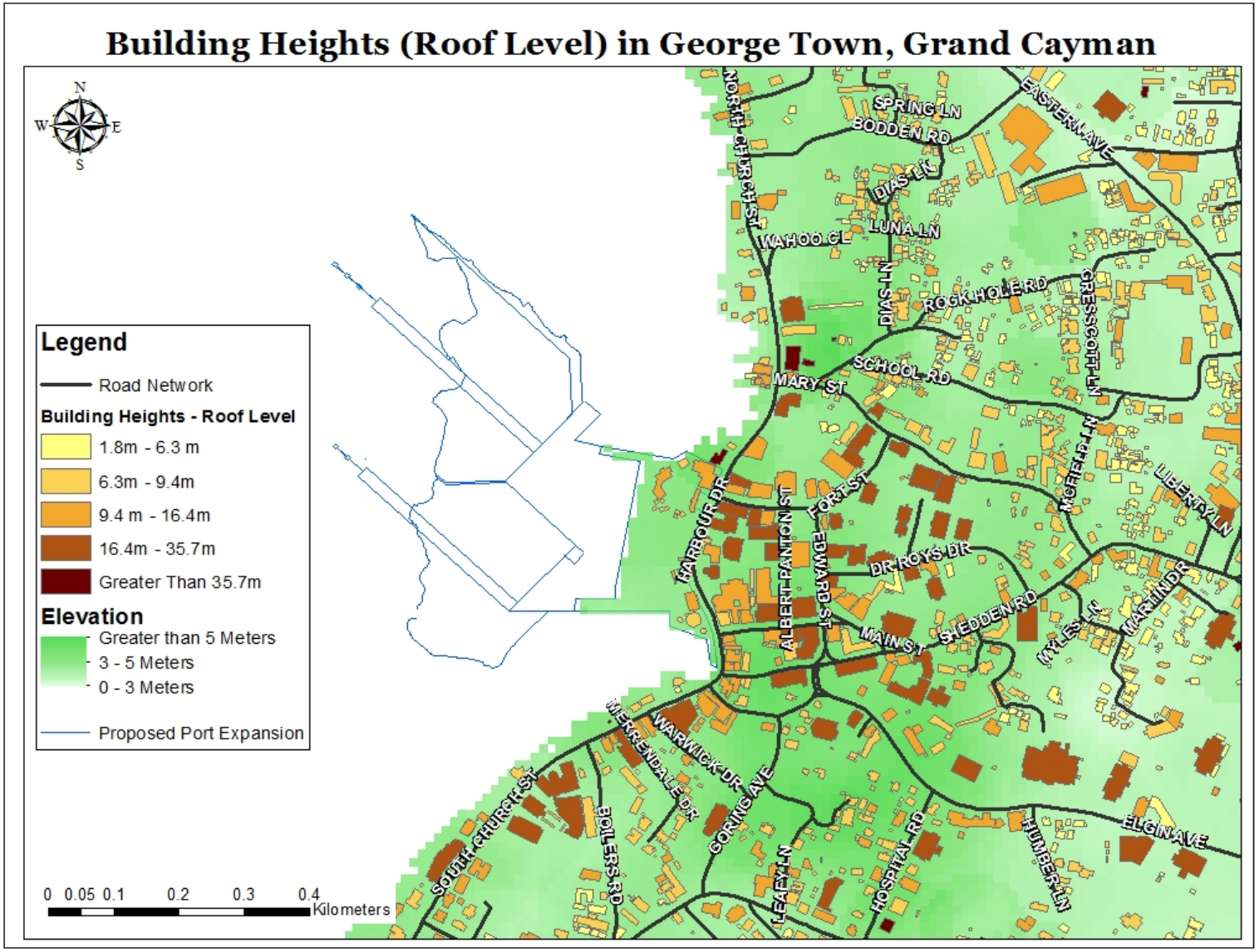


Figure 22.3 Building Heights at roof level and elevations above sea level of George Town, Grand Cayman

22.4 Visual Impact Assessment

22.4.1 Viewing Zones

In order to establish the potential visual impacts of the proposed Cruise Berthing Facility on the George Town area viewing zones were defined as the following:

1. Immediate vicinity (<0.5 km)
2. Local area (0.5 km – 1km)
3. Regional area (> 1 km)
4. View from the sea

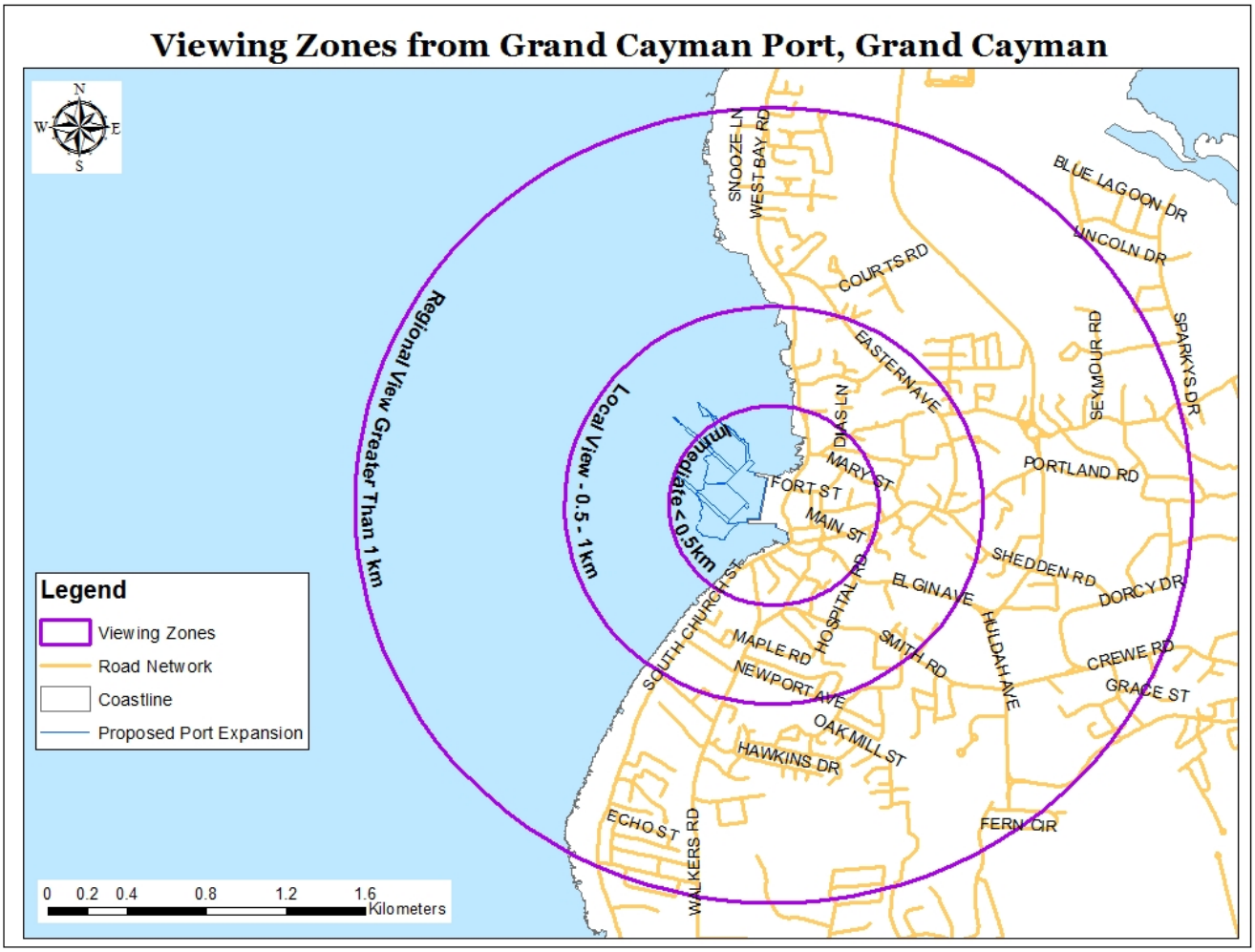


Figure 22.4 Viewing Zones from George Town Harbour

22.4.2 Viewshed Analysis

The aim of this assessment is to determine the level of visibility of the proposed Cruise Berthing Facility (CBF) from the surrounding areas. The Spatial Analysis extension provided by ArcGIS was utilized to analyze and assess the level of visibility of the proposed project. The Hillshade, Viewshed and Observer Point tools within ArcGIS were utilized to generate images to display the level of visibility of the port from the surrounding areas. The viewing zones represent 500km and 1km radius from the project site.

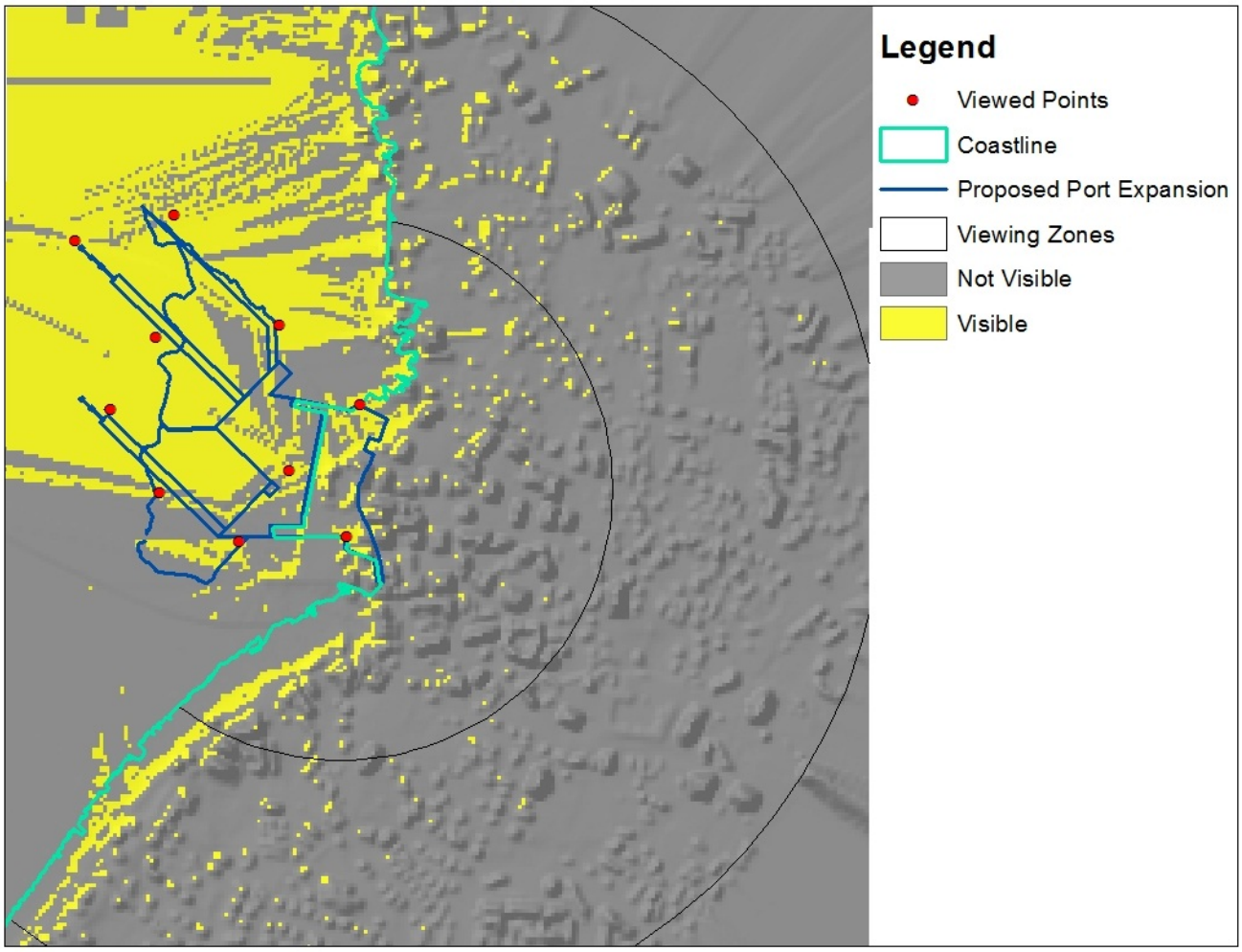


Figure 22.5 Viewshed illustrating the areas from which the CBF will be visible

The analysis shows that the CBF will be most visible from the sea (as illustrated in **Figure 22.5**); therefore, the greatest impact on views will be from the sea. On land, the greatest visual impact will occur within the immediate vicinity of the harbour and within the first 50 to 100m from the shoreline. Areas directly along the coastline and the town center, particularly along Harbour Drive, will be most impacted. The visibility of the CBF decreases landwards as the buildings located along the coastline creates an obstruction to the viewing plane.

22.4.3 Hillshade Analysis

Hillshade analysis shows the areas in which shadows will be cast. This can be used as a measure of obstruction to visibility. The areas that are highly shadowed represent the features that would create an obstruction to the views of areas that are less shadowed.

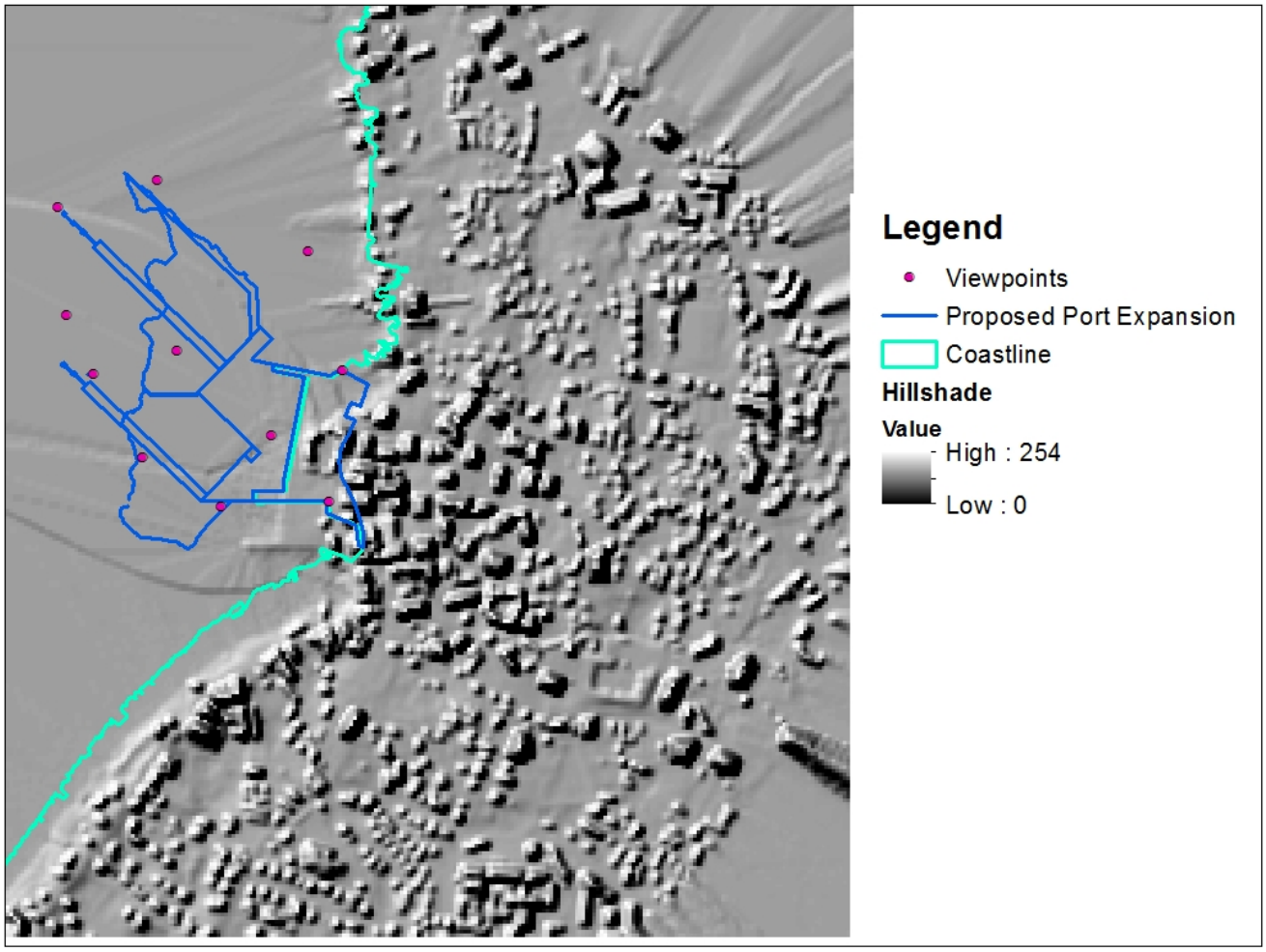


Figure 22.6 Hillshade analysis of the proposed George Town Port expansion

As can be seen in Figure 22.6, the areas closest to the existing port display the highest level of shadowing. George Town is located east of the port and with the rising of the sun, shadows are cast towards the port by the buildings along Harbour Drive and within the town of George Town. Figure 22.6 illustrates that the buildings along Harbour Drive and within George Town will create an obstruction to the views located outside the immediate vicinity of the port.

22.4.4 Visual Impact on Views in the Immediate Vicinity (Less than 0.5 km)

The greatest visual impact on land will occur within the immediate vicinity (less than 0.5 kilometers) due to proximity to the proposed CBF. This area is also the central business district of George Town, with land use within this zone primarily commercial and institutional. There is a small percentage of residential areas located on the periphery of this viewing zone. The population that utilizes this zone is present mostly during the day time, which is consistent with business hours. The frequency and number of viewers within this area are significantly higher; therefore the impact will be greatest in this zone.

Furthermore, the buildings within this viewing zone are taller and larger in scale than the buildings located in the 0.5 km to 1 km viewing zone. The viewing plane will, therefore, be obstructed by the larger buildings located in this zone, limiting visibility to places located further from the port.

The layout of the road network and land use pattern has resulted in a cluster of very tall buildings being concentrated parallel to the coastline. These buildings create an obstruction to the view of the port from the hinterlands as is illustrated in **Figure 22.7**.



Figure 22.7 Aerial view of George Town Port, Grand Cayman
Source: Cayman Island Government

22.4.4.1 Viewshed Analysis (< 0.5 km)

The Viewshed shows the areas from which the port will be visible. The areas shaded in yellow display the areas from which the CBF will be visible while the port will not be visible from areas shaded in grey.

As can be seen in **Figure 22.8**, the CBF will be most visible from areas within 50-100m inland from the coast to the north and south and within the immediate port vicinity. This is because the buildings located in this area create an obstruction to the view. The level of visual impact will be greatest in this zone because the visibility is greatest here.

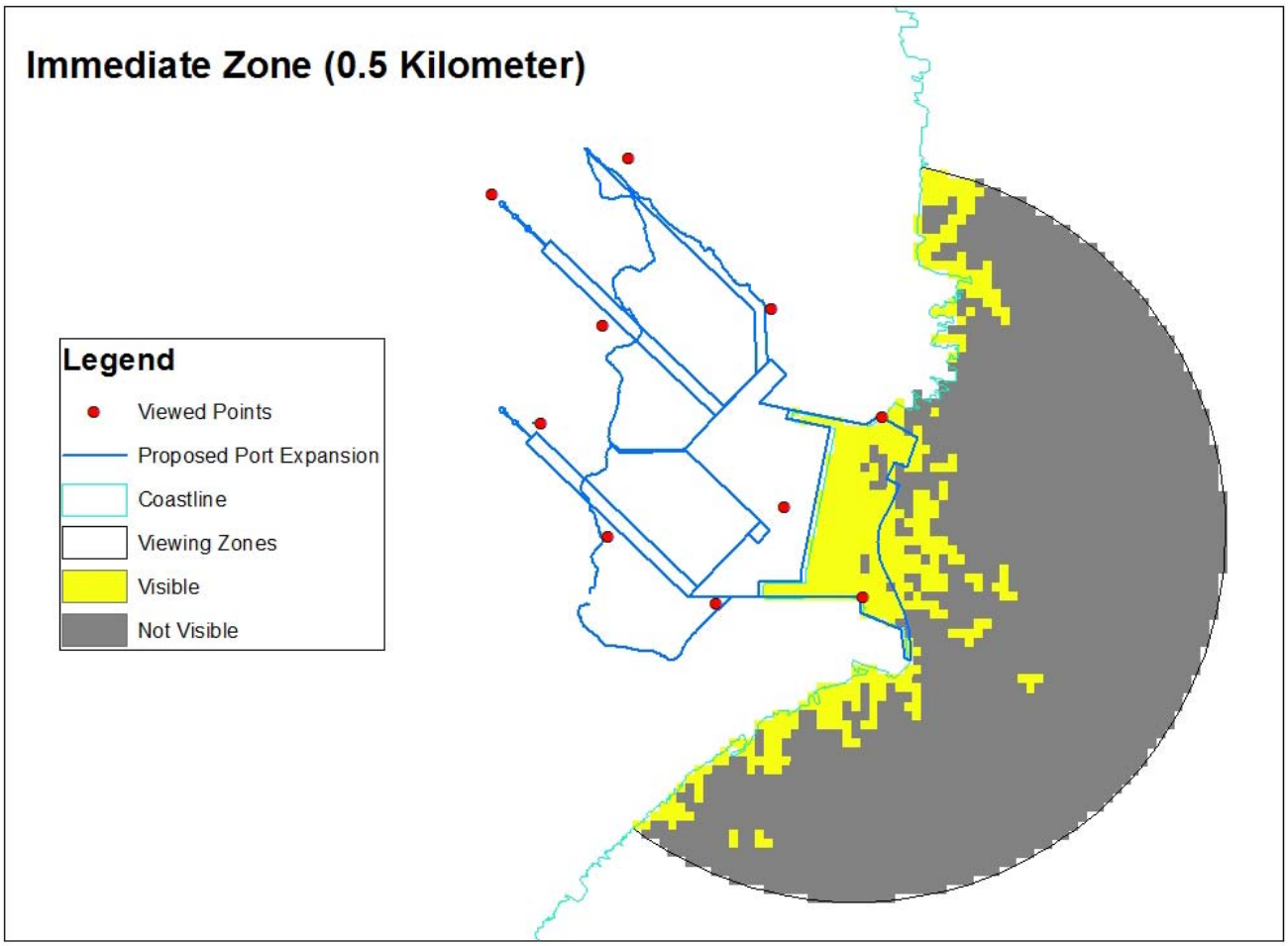


Figure 22.8 Viewshed showing the areas from which the Port will be visible within a 0.5 kilometer radius

22.4.4.2 Observer Points (<0.5 km)

Observer points show the area of the proposed CBF that will be visible to an observer at that particular point. Three (3) observer points were chosen along Harbour Drive: Margaritaville; Burger King; and Cayman Craft Market.

Immediate Views (Less than 0.5 km) Observer Point 1 - Margaretville

Observers standing at this location will be directly in front of the port and will be able to view most of the proposed CBF as is illustrated by the areas shaded in yellow in **Figure 22.9**. The visibility of the ships docked in the north berth pocket will be limited, as illustrated by the grey shades.

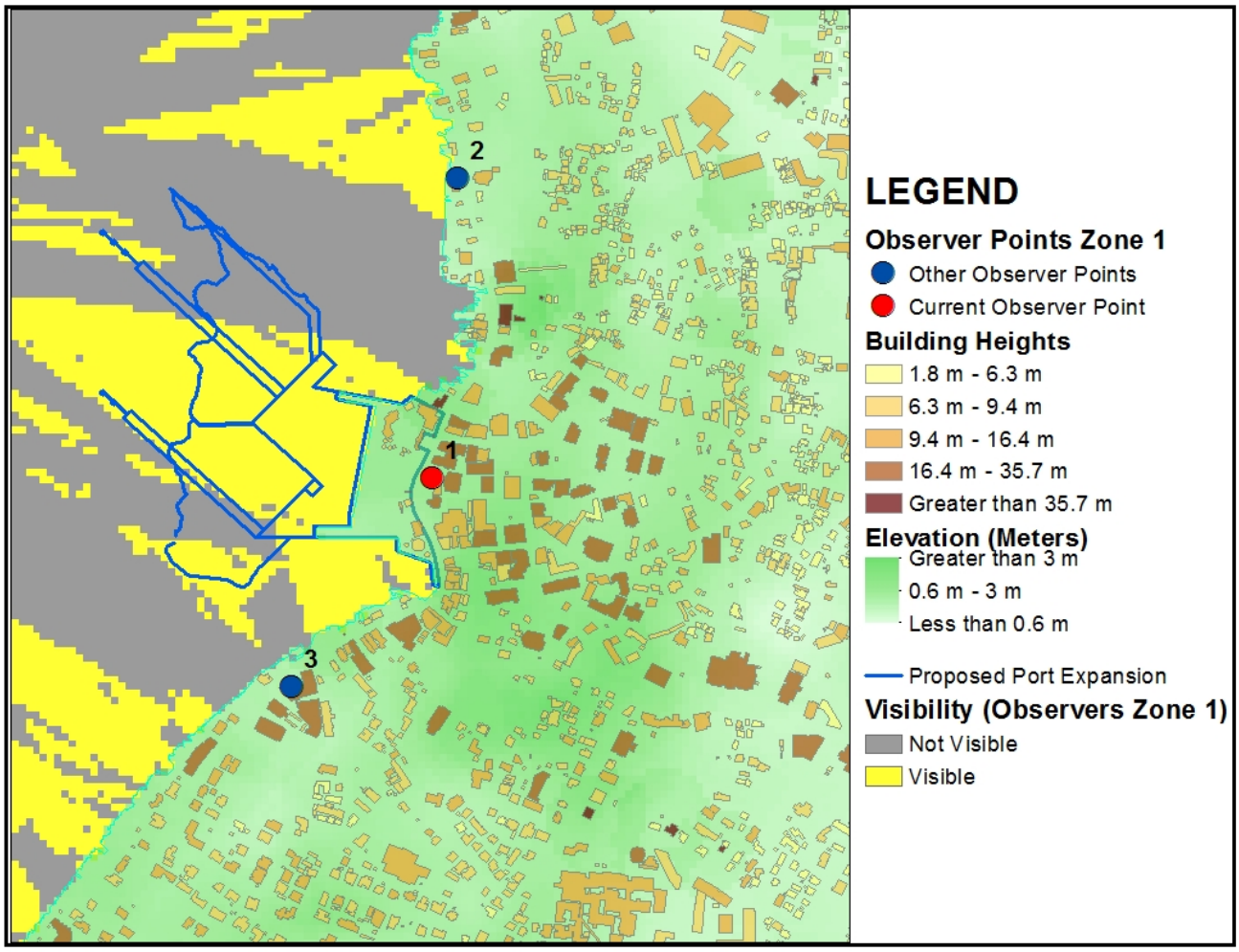


Figure 22.9 Areas visible to an Observer at Point 1: Margaritaville

Immediate Views (Less than 0.5 km) Observer Point 2 – Burger King

Observers standing at the Burger King location will be to the north of the port and will be able to view mostly the northern sections of the proposed CBF, as shown by the areas shaded in yellow in **Figure 22.10**. The visibility of the ships docked in the south berth pocket will be limited, as illustrated by the grey shades, only the seaward extent of these ships will be visible.

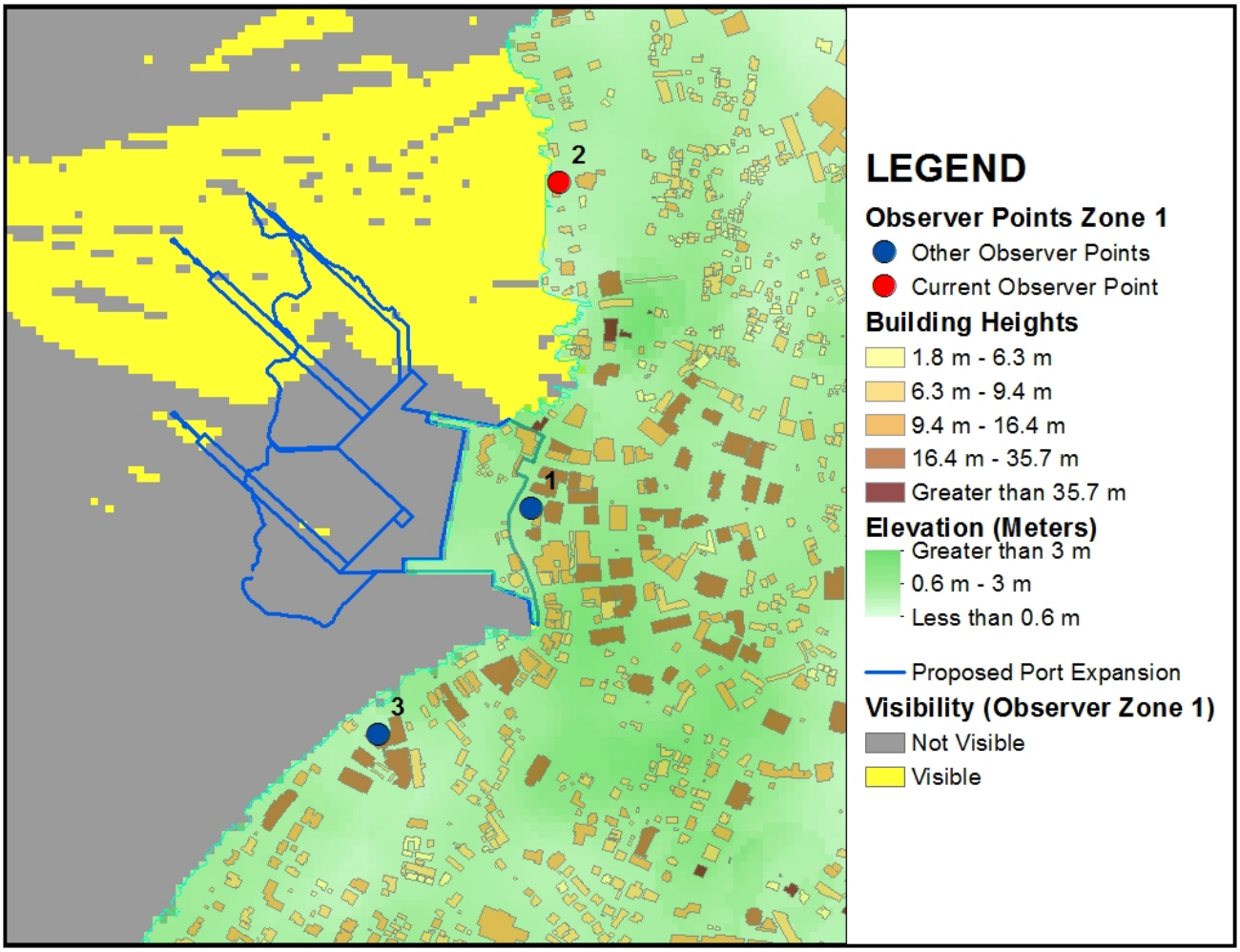


Figure 22.10 Areas visible to an Observer at Point 2: Burger King

Immediate Views (Less than 0.5 km) Observer Point 3 – Cayman Craft Market
Observers standing at the Craft Market location (Point 3) will be to the south of the port and on the opposite side of Harbour Drive. Only a small area of the proposed CBF will be visible from this point, as is illustrated by the areas shaded in yellow in **Figure 22.11**. The southernmost berthing area of the port and a small area to the north of the port will be visible to viewers at this location.

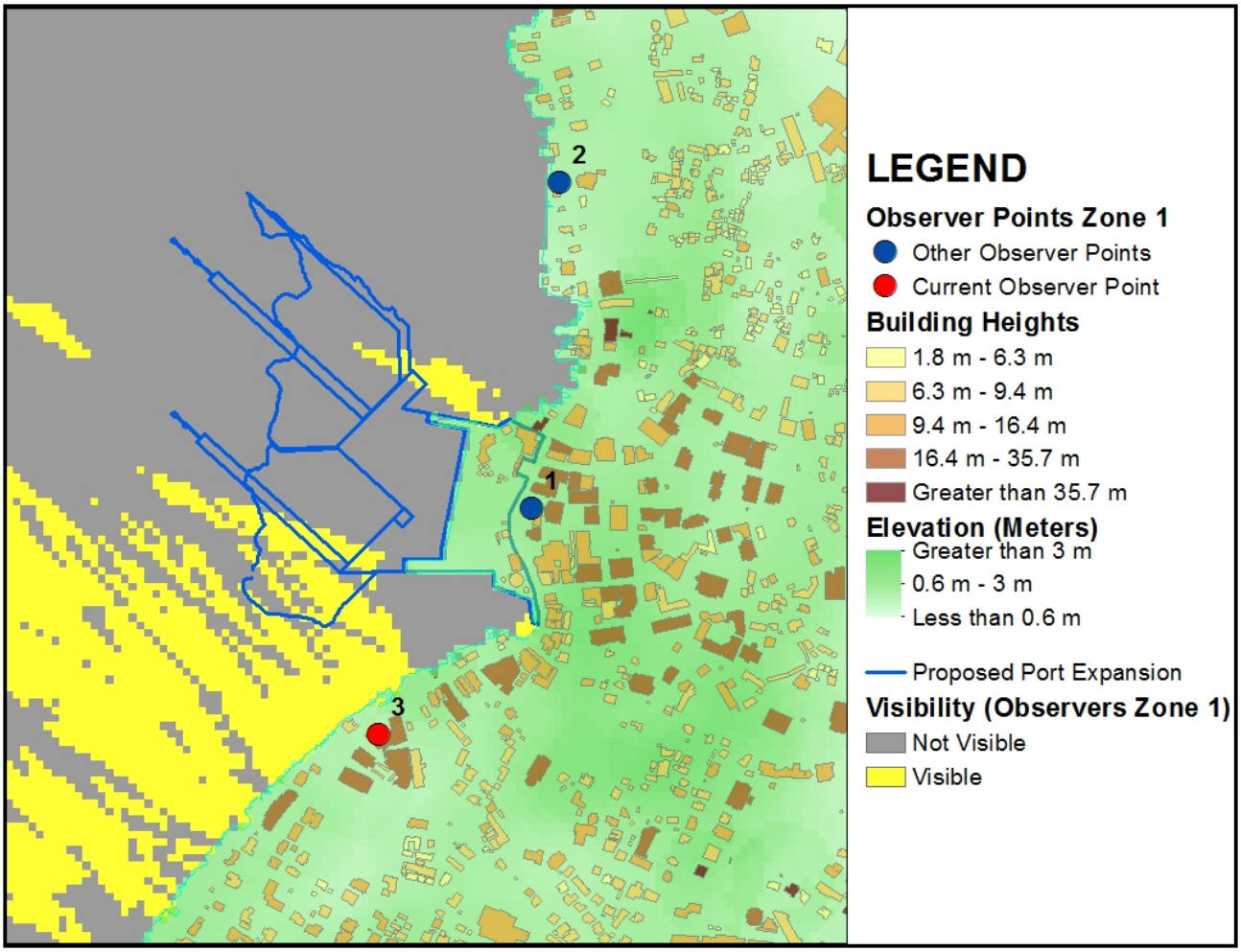


Figure 22.11 Areas visible to an Observer at Point 3: Cayman Craft Market

22.4.5 Visual Impact on Local Views (0.5 km – 1km)

22.4.5.1 Viewshed Analysis (0.5 km – 1km)

The level of impact within this viewing zone will be very low. Visibility of the proposed CBF is expected to have the least impact in this zone, as the view is obstructed by the taller and larger buildings that are located closest to the port. The generally flat nature of the landscape results in a very low viewing plane in this zone.

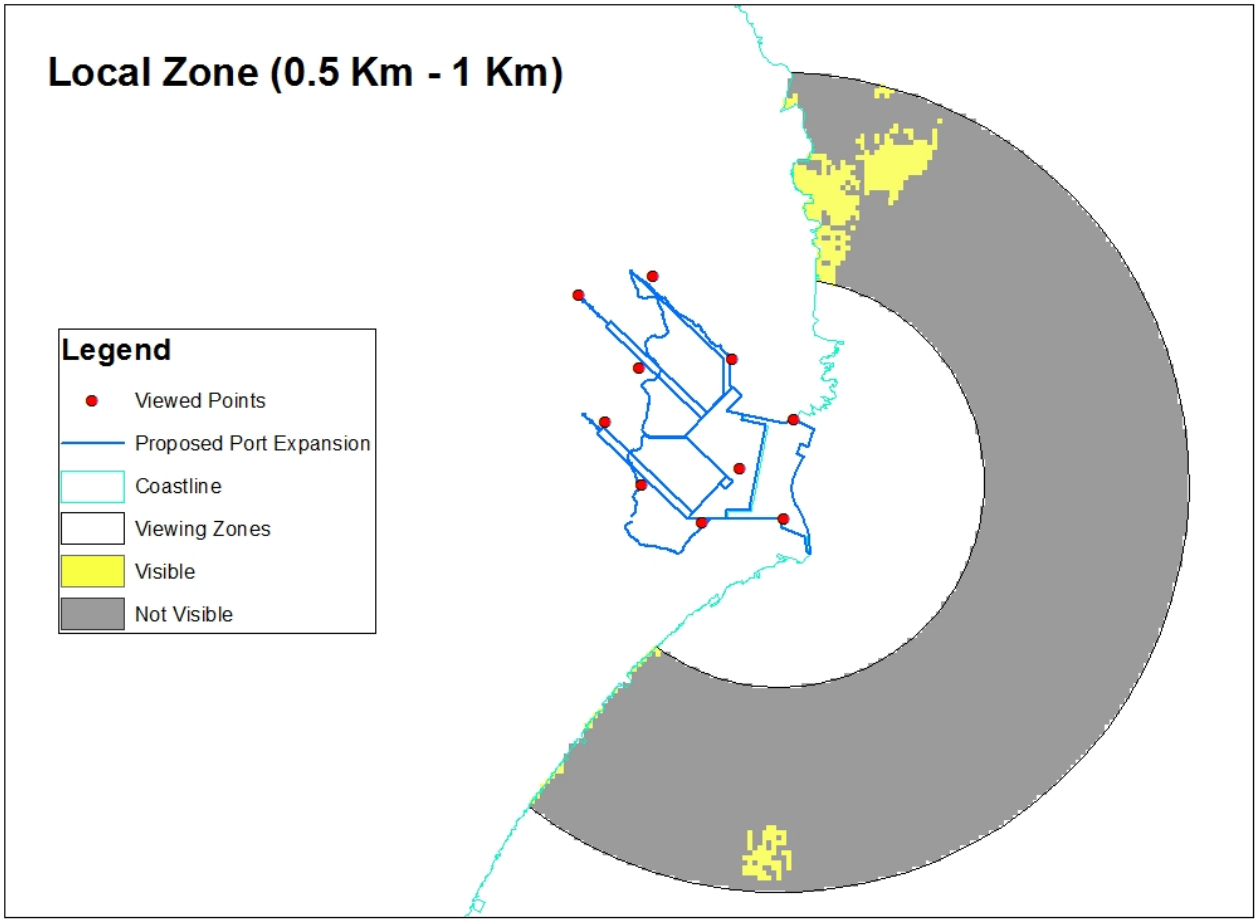


Figure 22.12 Viewshed showing the areas in which the Port will be visible at a distance of 0.5 kilometer to 1 kilometer

Figure 22.12 displays the Viewshed for distances of 0.5 km to 1 km from George Town Harbour. The yellow shaded areas on the image are those areas from which the proposed CBF will be visible. From the Viewshed, it can be seen that the impact of the CBF on the local views is greatest along the coastline and in the northern and southern sections where the lands are relatively more elevated; increasing visibility for taller buildings.

The CBF will not be visible from areas shaded in grey. The views from this area are obstructed by the taller and larger buildings that are located in the immediate vicinity of the port.

22.4.5.2 Observer Points Analysis (0.5 km – 1km)

Three (3) Observer Points were selected in this zone at locations where large populations are expected to be. These observer points include: Chrissie Tomlinson Memorial Hospital; Cricket Square; and Kirk Home Centre.

Local Views (0.5 km – 1 km) Observer Point 1 – Chrissie Tomlinson Memorial Hospital

Observers standing at Point 1 will be to the south of the port. Only a small area of the proposed CBF will be visible from this point, as is illustrated by the areas shaded in yellow in **Figure 22.13**. These areas include the southern berth pocket and the land reclamation area.

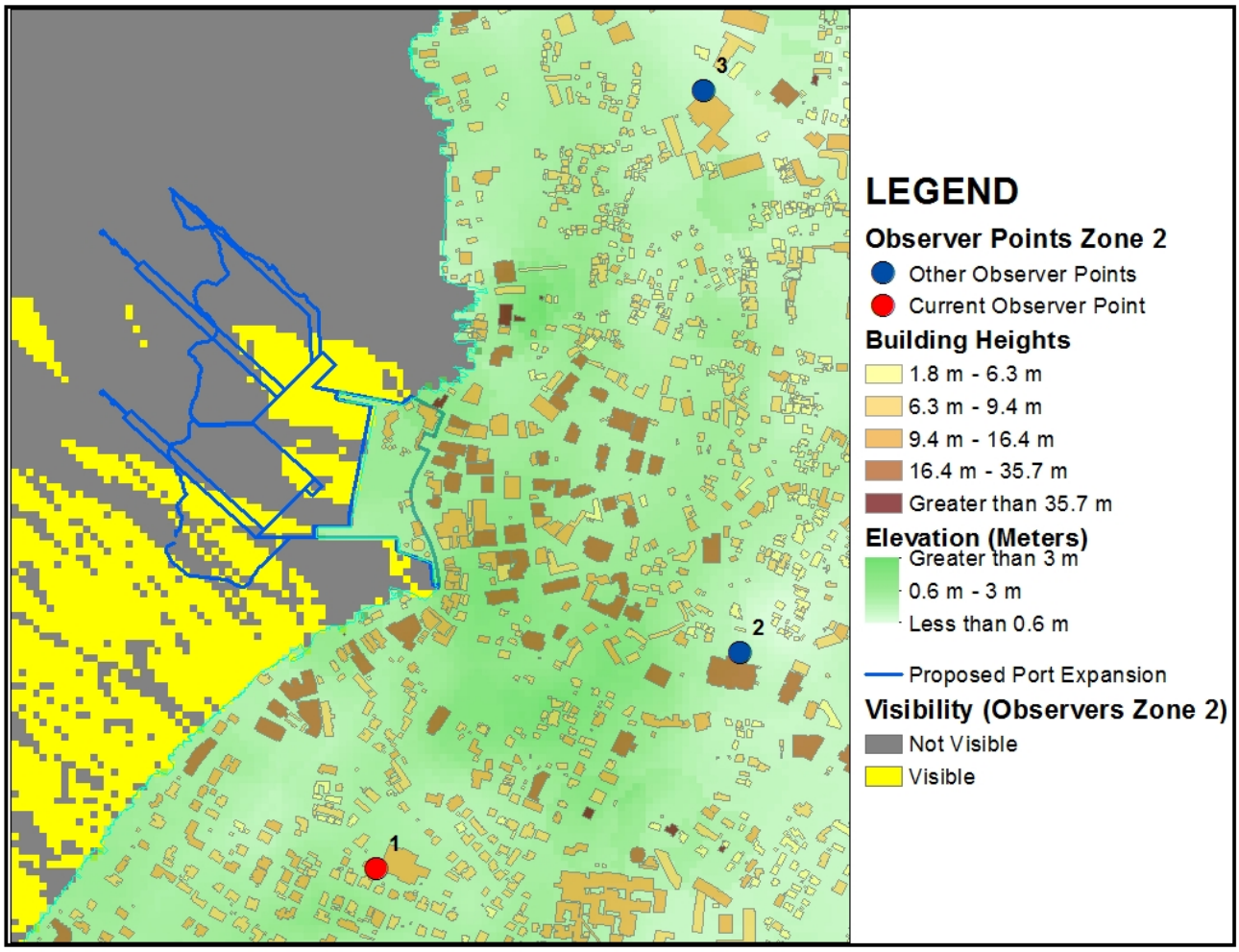


Figure 22.13 Areas visible to an Observer at Point 1: Chrissie Tomlinson Memorial Hospital

Local Views (0.5 km – 1 km) Observer Point 2 – Cricket Square:

Observers standing at Point 2 will be located to the southeast of the port. The Port will not be visible from this observation point, as is illustrated in **Figure 22.14** by the absence of yellow shading. The distance from the port, elevation of the adjacent lands and the obstruction caused by the buildings closest to the port are all factors contributing to the lack of visibility from this point. The proposed project will therefore have no visual impact on this observer point.

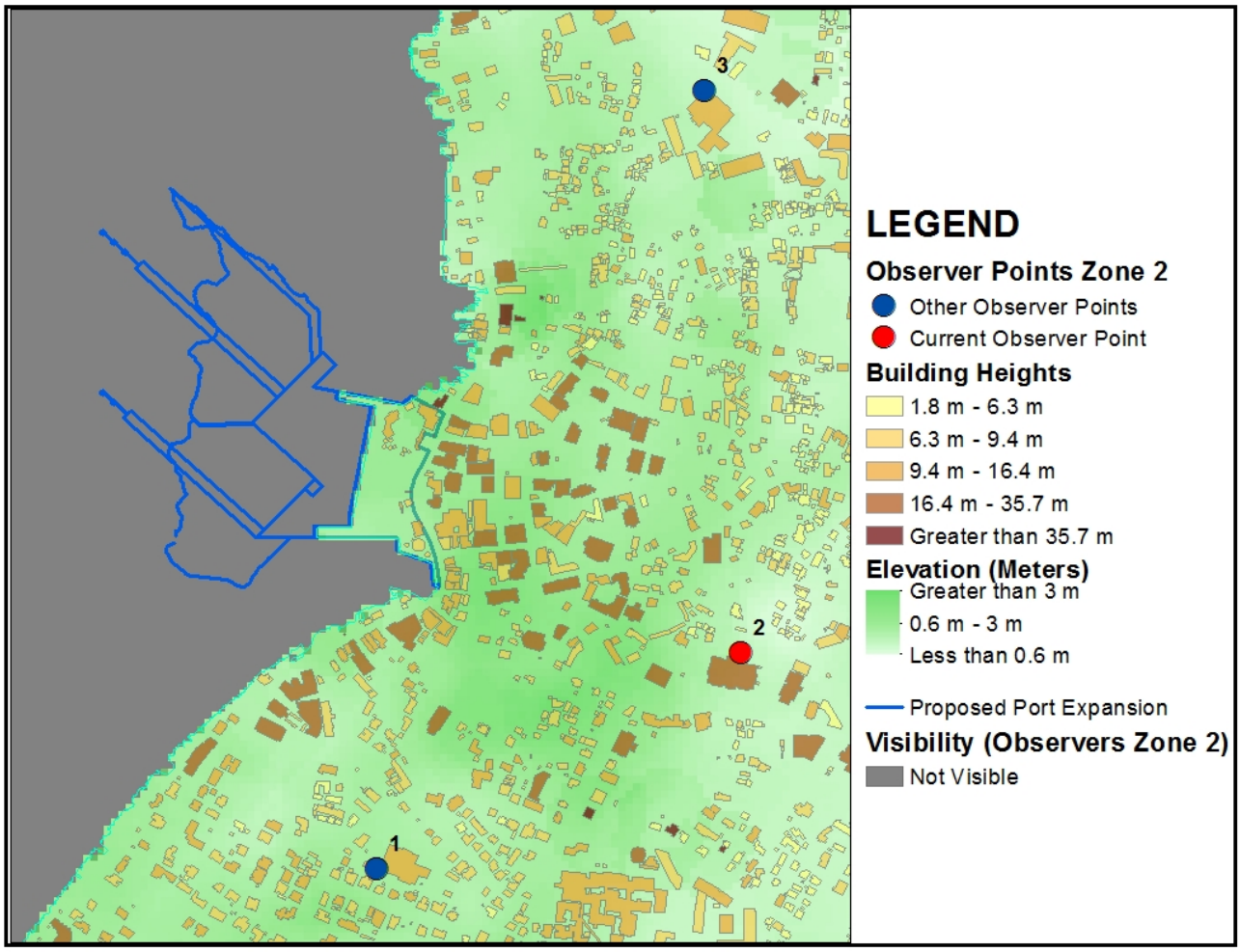


Figure 22.14 Areas visible to an Observer at Point 2: Cricket Square

Local Views (0.5 km – 1 km) Observer Point 3 – Kirk Home Center:

Observers standing at Point 3 will be located to the northeast of the port. The Port will not be visible from this observation point as is illustrated in **Figure 22.15**. The yellow shade at the north of the image shows the offshore areas that are visible from this observation point. Similar to observation point 2, the proposed project will have no visual impact on this observer point.

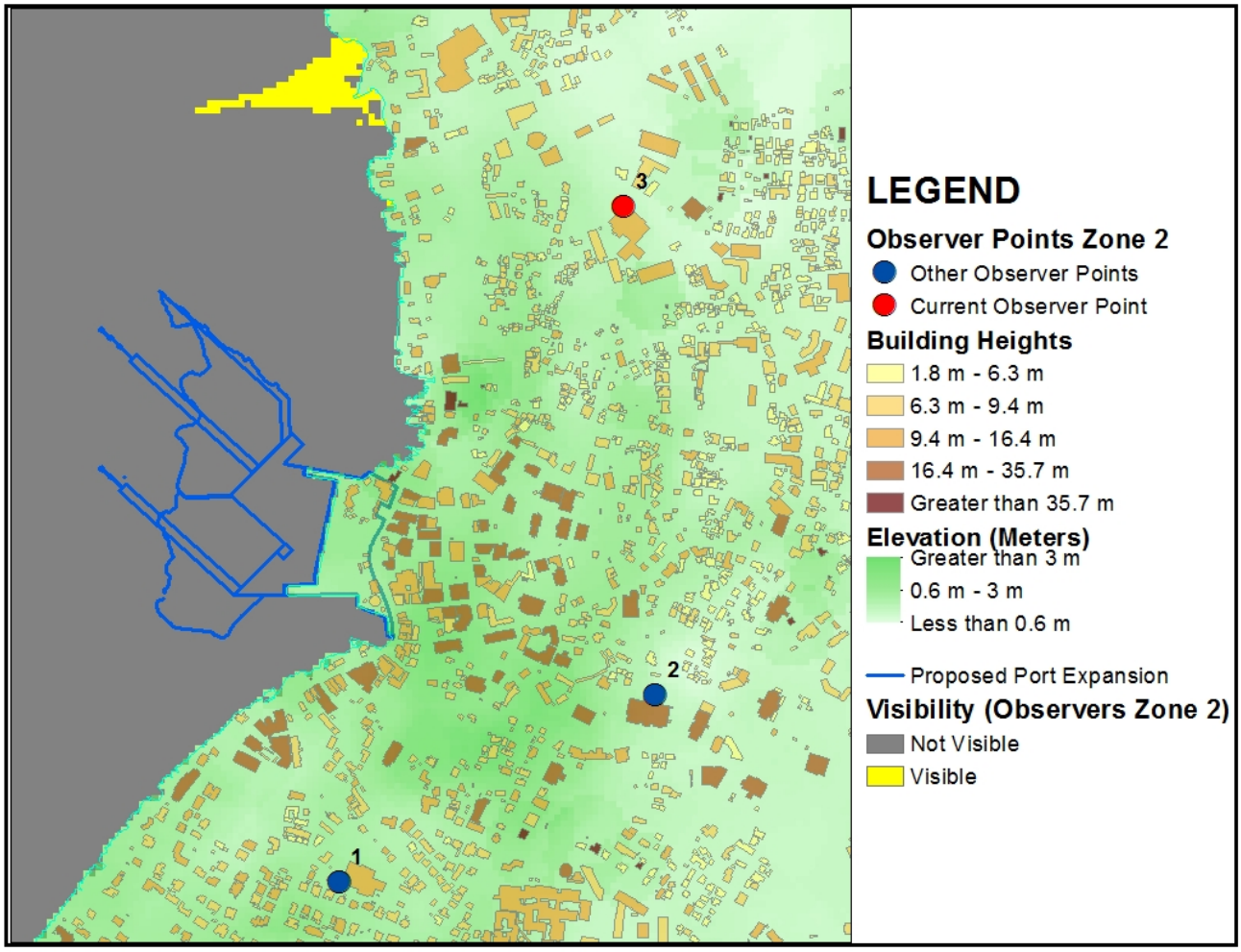


Figure 22.15 Areas visible to an Observer at Point 3: Kirk Home Center

22.4.6 Visual Impact on Regional Views (> 1 km)

The visual impact of the port within this viewing zone will be low, and from some areas the port will not be visible at all. Visibility is greater in the coastal areas of this zone than in the local zone despite the greater distances. The proposed CBF will be visible only to areas along the northwestern and southwestern coastal areas, as illustrated by the yellow shade. The angles at which these areas are located from the port have reduced obstruction from the built up area of the Town center.

Figure 22.16 presents the Viewshed analysis of areas located more than 1 km from the CBF. The areas shaded in grey illustrate the areas from which the port will not be visible. The port will not be visible from most places within this zone and as a result the level of impact will be quite low.

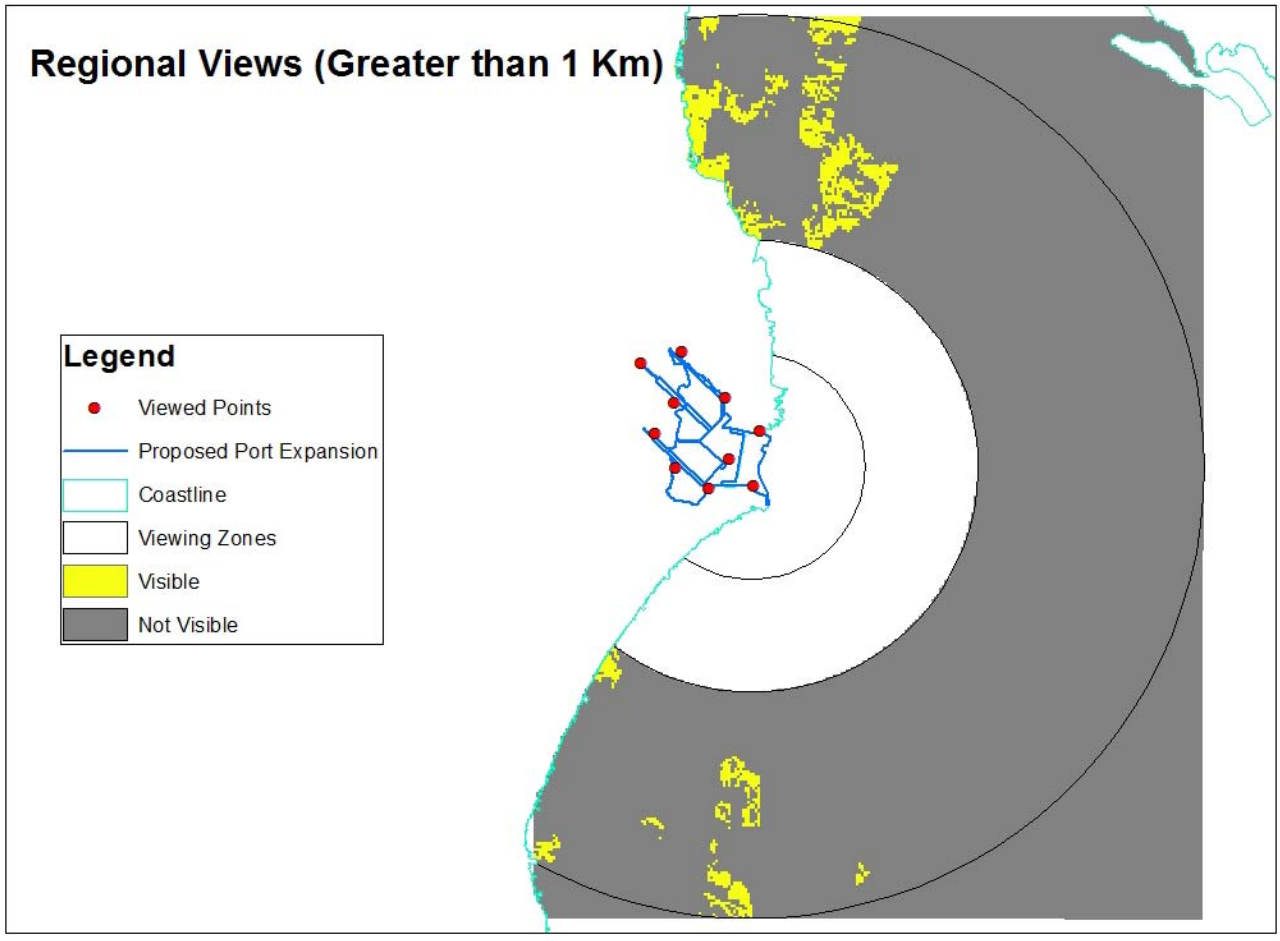


Figure 22.16 Viewshed showing areas from which the Port will be visible at a distance greater than 1 kilometer

22.4.6.1 Observer Points (> 1 km)

Observer points were chosen at locations of higher population density.

Regional Views (Greater than 1 km) Observer Point 1 – University College of the Cayman Islands

An observer at point 1 was selected to be located to the south of the port. A small section of the dock at the north of the new port area will be visible from this observation point; as illustrated by the yellow shades in **Figure 22.17**. The grey shades show the areas that will not be visible to an observer at point 1. The level of impact is expected to be very low from this observation point.

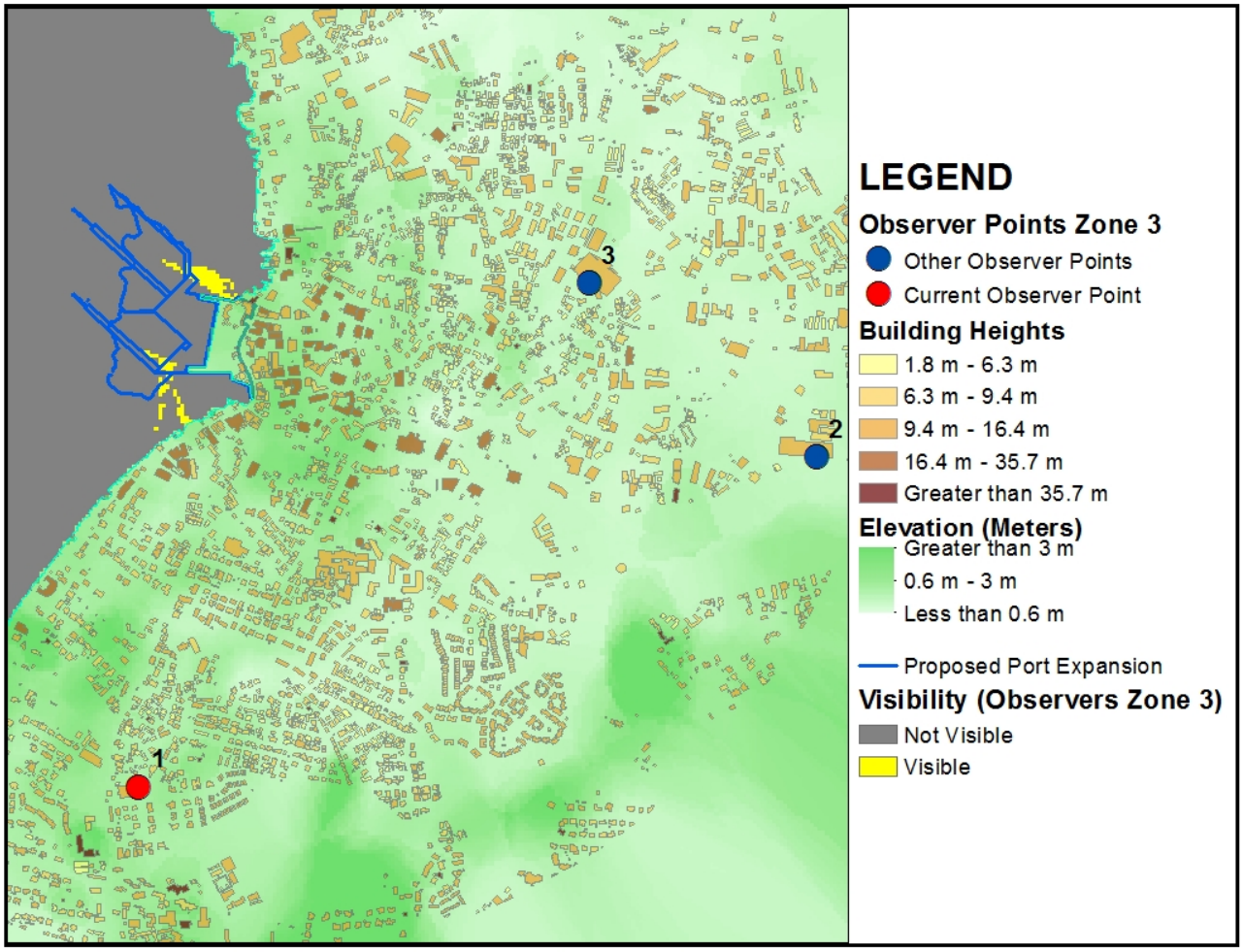


Figure 22.17 Areas visible to an Observer at Point 1: University College of the Cayman Islands

Regional Views (Greater than 1 km) Observer Point 2 – Foster's Food Fair

An observer at observation point 2 will be located to the east of the port. The area of visibility on the proposed CBF is very low from this observation point, as is illustrated by the yellow shade in **Figure 22.18**. Therefore, the visual impact on this observation point is also expected to be low or non-existent.

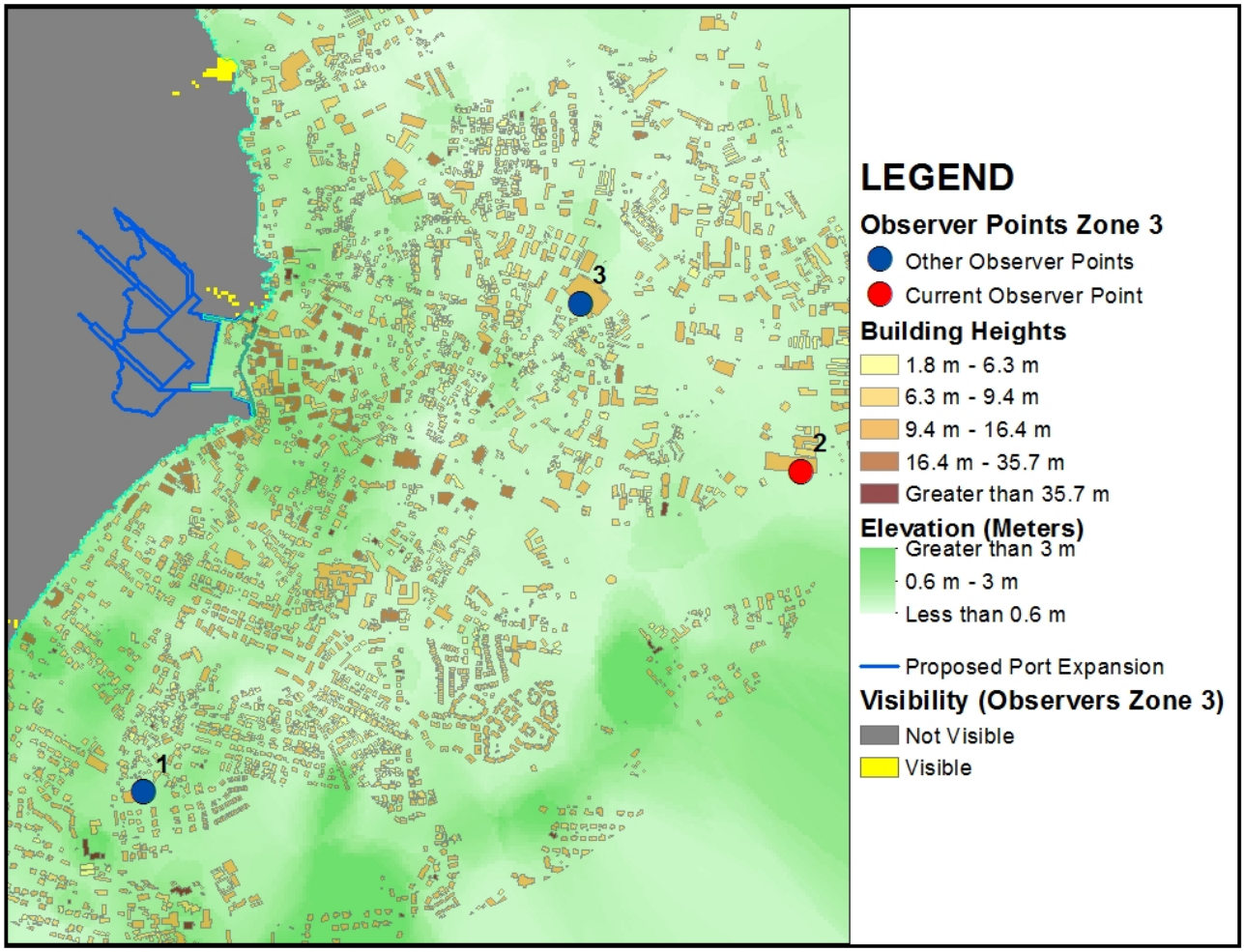


Figure 22.18 Areas visible to an Observer at Point 2: Fosters Food Fair

Regional Views (Greater than 1 km) Observer Point 3 – Arbutus Gallery

An observer at observation point 3 - Arbutus Gallery will be located to the north east of the port. The degree of visibility of the proposed CBF is also very low from this observation point, as is illustrated by the yellow shade in **Figure 22.19**. Therefore, the visual impact on this observation point is also expected to be low or non-existent.

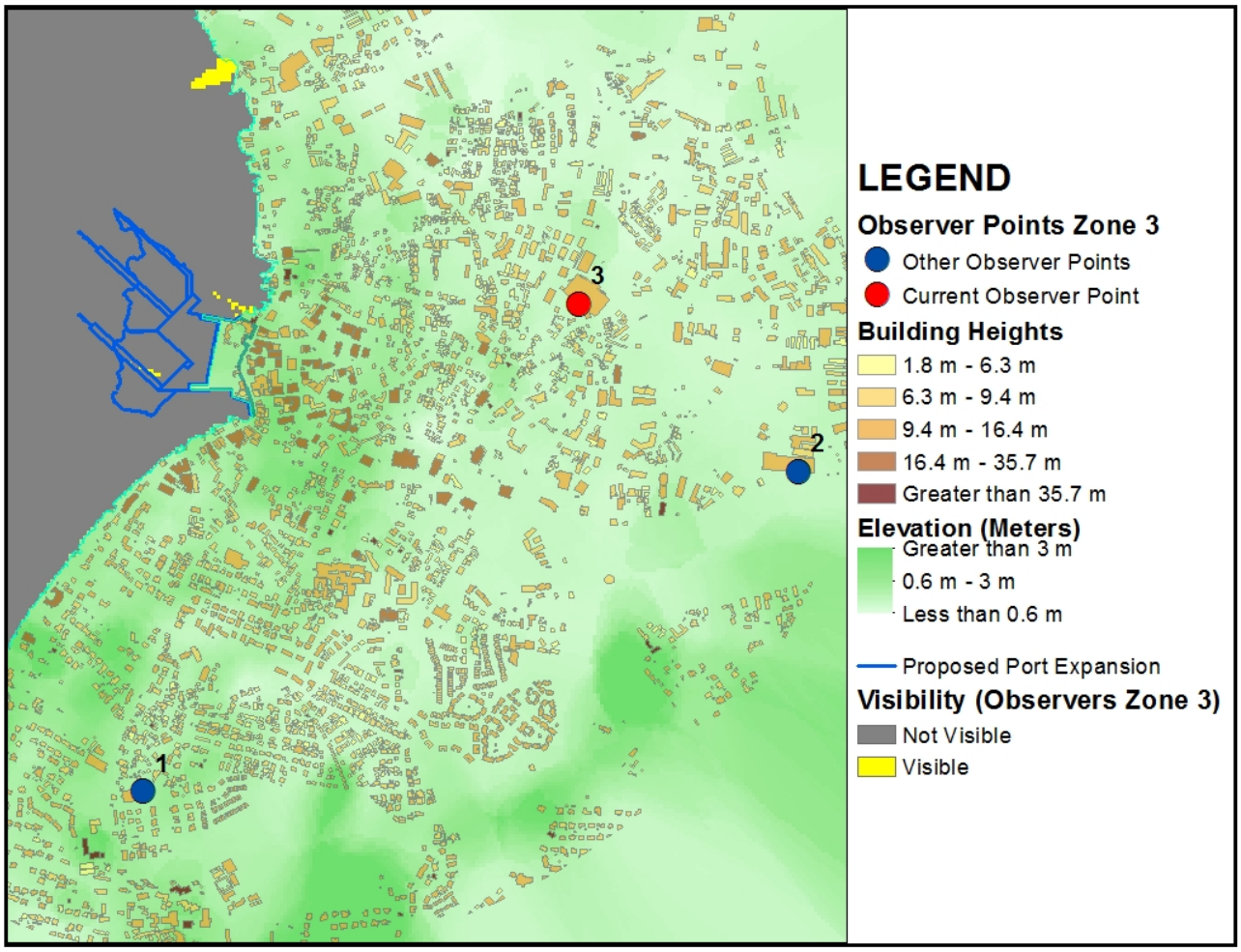


Figure 22.19 Areas visible to an Observer at Point 3: Arbutus Gallery

22.4.7 Visual Impact on Views from the Water

The proposed project will be visible from the ocean for a distance of over 1km and, thus, will have greatest visual impact on viewers from the sea due to the lack of obstructions.

Figure 22.20 displays the areas from which the CBF will be visible from the sea. The areas shaded in grey display the areas where some sections of the port will not be visible. Visibility in these areas is reduced by the design of the port.

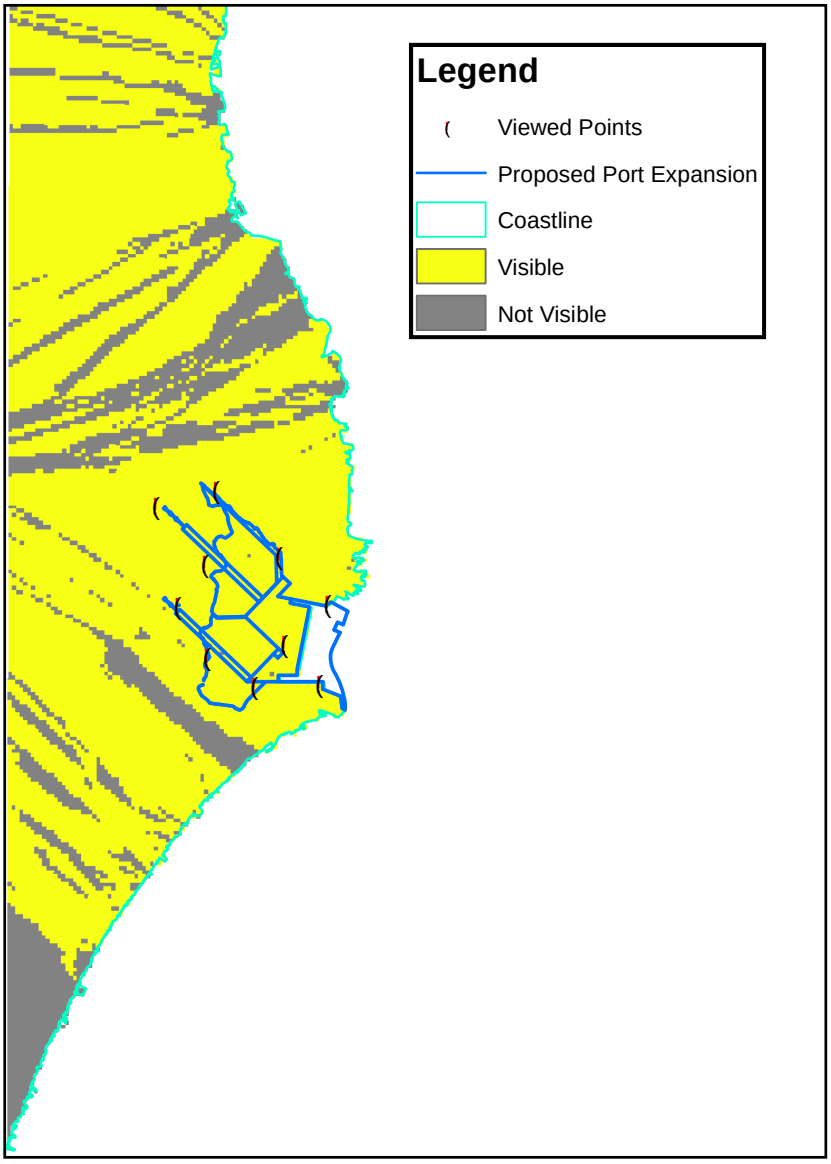


Figure 22.20 Viewshed showing the areas in which the Port will be visible from the sea

22.4.8 Visual Impact on Aerial Views

The Owen Roberts airport is located in close proximity to the port. The impact from the air is not expected to be significant. The view from above will be similar to the existing condition.

22.5 Summary of Impact Assessment

22.5.1 Visual Impact

The visual impact will be directly proportional to the visibility of the CBF. Those areas where the CBF will be fully visible will experience the greatest impact.

The largest visual impact will occur along the coastline and, particularly, along Harbour Drive (inland from the coast a distance of 50 to 100m) as these zones are located within close proximity to the port and have unobstructed views. Beyond this zone, the visibility impact will decrease with distance from the port due the obstruction created by the very large and tall buildings located along Harbour Drive.

The least visual impact will occur in areas located beyond a 0.5 kilometers distance from the CBF, except along the coastline, as a result of the obstruction created by the building patterns within George Town.

The overall visual impact of the port is not expected to be significant. The existing landscape is already significantly built and, therefore, the capacity to absorb the anticipated visual disturbance is very high. In addition, and of major significance, the visibility of the port from along the coastline is limited due to the obstructions created by the building and land use patterns within George Town. The Viewshed and observer point analyses have also confirmed that as expected, views from the sea will be most impacted because there are no obstructing features from this viewpoint.

22.5.1.1 Construction Impact

Impacts on aesthetics during construction will be negative, short-term and significant for areas along the coast and along Harbour Drive. The view of the sea will include construction and dredging equipment. Reduced water quality will also have a negative aesthetic impact of the clear water of the Harbour. Visibility of the marine landscape, especially for snorkeler and divers, will be negatively impacted.

22.5.1.2 Operations Impact

It is not anticipated that there will be a significant change to visibility as the proposed project will not bring the ships significantly closer to shore or more visible. The differences in visibility may be seen in renderings of cruise ships at anchorage/berth for four different viewpoints along the George Town shoreline, as shown in **Figure 22.21** to **Figure 22.24**.

The future development of the reclaimed land area with new facilities and site amenities is expected to have a long-term, positive and significant visual and aesthetic impact.

22.5.2 Land Use Impact

22.5.2.1 Construction Impact

Land use impacts during construction will be limited to activities at the existing Port facility. There will be no significant land use impacts during construction.

22.5.2.2 Operations Impact

Land use impacts during operations will be significant, long-term and positive. Capacity at both the cargo and cruise ports will be increased with the provision of increased land space.

The proposed project will include the reclamation of approximately 7.7 acres of land from the sea, thereby, increasing the land surface of George Town. The reclaimed land will be located in front of (seaward) the existing Port facilities and within an existing industrial land use zone. There are no plans to construct commercial retail buildings on the new lands, hence, there will be no competing uses with existing commercial land uses within the downtown George Town area, a concern that was expressed by stakeholders. However, the new land are provides the opportunity for the construction of modern cruise terminal facilities and other site amenities, which will have a positive impact on land use. In addition, the land value along the George Town waterfront is anticipated to increase.

22.5.3 Climate Change Impacts

Climate change is not anticipated to influence the visual impact of the project.

22.6 Proposed Mitigation Measures

Negative visual impacts are minor, short-term and limited to the first row of buildings on Harbour Drive and in the area > 1km from the site. Ongoing communication and involvement of stakeholders and the general public will increase understanding of negative visual impacts during construction.

22.7 RIAM Summary of Anticipated Project Impacts and Proposed Mitigation Measures

The application of the RIAM method to landscape and visual impacts is incorporated in the socio-economic impact assessment, which is presented in Chapter 20.9.



Figure 22.21 Rendering of Cruise Ships at Berth as viewed from Appleby Tower, George Town



Figure 22.22 Rendering of Cruise Ships at Berth as viewed from North Church Street, George Town (Burger King) [Existing, top; Proposed CBF, bottom]



Figure 22.23 Rendering of Cruise Ships at Berth as viewed from North Church Street, George Town (Fish Market) [Existing, top; Proposed CBF, bottom]



Figure 22.24 Rendering of Cruise Ships at Berth as viewed from South Church Street, George Town [Existing, top; Proposed CBF, bottom]

SECTION III - ENVIRONMENTAL MANAGEMENT PLAN

SECTION IV – APPENDICES

APPENDIX 0
FINAL EIA TERMS OF REFERENCE (MM, 2013)

APPENDIX 1
STAKHOLDER ENGAGEMENT AND PUBLIC CONSULATION

APPENDIX 2
FIELD DATA COLLECTION PROGRAM

APPENDIX A
SUMMARY ANALYSIS OF ALTERNATIVES

APPENDIX B.1
NATURAL HAZARD ASSESSMENT

APPENDIX B.2
CLIMATE CHANGE RISK ASSESSMENT

~~APPENDIX C~~
~~GEOLOGY AND SOILS~~
No appendix required

APPENDIX D.1
COASTAL PROCESSES – WAVES AND SEDIMENT TRANSPORT

APPENDIX D.2
COASTAL PROCESSES – HYDRODYNAMICS AND DREDGE PLUMES

APPENDIX D.3
SEDIMENT RE-SUSPENSION BY CRUISE SHIPS

APPENDIX E
SEDIMENT AND WATER QUALITY

APPENDIX F
STORM WATER

APPENDIX G
AIR QUALITY AND GREENHOUSE GAS EMISSIONS

APPENDIX H
NOISE AND VIBRATION

~~APPENDIX I~~
~~TERRESTRIAL ECOLOGY~~

This task was deleted from scope of work

APPENDIX J.1
MARINE ECOLOGY

APPENDIX J.2
MARINE ECOLOGY RESOURCE VALUATION

~~APPENDIX K~~
~~CULTURAL HERITAGE~~
No appendix required

APPENDIX L
TRAFFIC AND PEDESTRIAN STUDY

APPENDIX M
CRUISE AND CARGO OPERATIONS

APPENDIX N
SOCIO-ECONOMIC IMPACT ASSESSMENT

~~APPENDIX O~~
~~BUSINESS DISTRICT IMPACT ASSESSMENT~~

This task is incorporated in Appendix N - Socio-Economic Impact Assessment

~~APPENDIX P~~
~~LANDSCAPE AND VISUAL IMPACT ASSESSMENT~~
No appendix required