Ministry of Construction and Public Infrastructure

Environmental Impact Assessment Notes for Sh. Narudhoo Harbor Construction Project

Narudhoo, Miladhun-madulu Uthuru-buri, Maldives

January 2008

Prepared by

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For the Ministry of Construction and Public Infrastructure (MCPI)

Consultant's Declaration

I certify that statements made in this Environmental Impact Assessment study are true, complete and correct.

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Signature

Date: 17 January 2008

Environmental Impact Assessment Note for Sh. Narudhoo Harbor Construction Project

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1 Summary

This impact note deals with the construction of a harbor at Narudhoo in Shaiyani Atoll.

1. The implementing agency for this project is Ministry of Construction and Public Infrastructure (MCPI). The project was awarded to Aima Construction Private Limited.

2. The proposed site for the project on the eastern side of the Island appears to be the most appropriate location for the harbor development taking into account environment, construction feasibility and economics of the proposed development. There is apparently a justifiable need to sacrifice a portion of land (with vegetation) from the Island to make the mouth of the entrance channel safe, the keep the harbor basin calm and to prolong the life the breakwaters.

3. Baseline environmental condition at the project site indicated that the coral cover around the harbor basin area was very low. The coastal vegetation around the proposed harbor area was also typical and does not represent any specific preservation value.

4. Significant environmental impacts are predicted for the proposed development project. But these are short term impacts (e.g. sedimentation). These impacts can be mitigated through proposed environmental impact mitigation measures.

2 Introduction

2.1 Purpose of this EIA Note

This impact note presents the findings of an Environmental Impact Assessment (EIA) for the construction of Narudhoo harbor. This project was granted a special permission by the Ministry of Environment, Water and Energy (MEEW) to prepare only an impact note rather than a full scale EIA report. The Ministry of Construction and Public Infrastructure (MCPI) is required to obtain approval from the MEEW prior to the implementation of the project.

2.2 Tasks carried out in this impact study

These tasks were conducted in this study:

1) Description of the Project – A short description of the overall project, project locations and areas selected for development was discussed.

2) Description of the existing environment – The physical and ecological setting of the project was assessed. A brief assessment of the existing conditions of the proposed site was provided. Baseline data was obtained on relevant environmental aspects including the physical, coastal oceanographic and biological parameters.

3) Description of potential impacts – Major environmental issues was identified with short and long term impacts. The significance, the magnitude and the reversibility was assessed.

4) Mitigation of negative impacts – Cost-effective and feasible measures to reduce the negative impacts was provided.

5) Discussion of project alternatives – Project alternatives including alternative sites and the “no project” option was analyzed.

6) Monitoring and reporting – Project’s environmental monitoring methods was discussed.

2.3 The legal setting of the project

The construction of harbors in the Maldives should follow the guidance provided by several environmental laws, regulations, by-laws, plans, and strategies. Some of these included.

- Environment Protection and Preservation Act of Maldives (Law No. 4/93)
- EIA Regulation 2007
- Second National Environmental Action Plan (1999)
- National Biodiversity Strategy and Action Plan

- Regulation on Sand and Coral Mining
- By-Law, Cutting down, uprooting, digging out and export of trees and palms from one island to another

In addition to these national laws and regulation there are several international conventions and treaties that are Maldives is a party. These should also be taken into consideration. Some of the most important ones include the Convention on Biological Diversity (CBD), UN Framework Convention on Climate Change (UNFCCC), and the UN Law of the Seas (UNCLOS).

3 Survey methods

The data collection, analysis and compilation of this impact study included;

- Assessment of existing environment to identify significant environmental components that would be impacted,
- Public consultations to exchange information on the project,
- Literature review.

Data on existing environment was collected during the field visit to Narudhoo during 22 November 2007. General information on the existing environment was based on available secondary data, such as climatic data for other regions.

Both quantitative and qualitative methods were used to assess the coastal vegetation, marine benthic substrate and fish at the survey sites. Where possible and appropriate a 0.5 by 0.5 m quadrat were used to quantify benthic types. Belt transects were used to assess (count) the fish community structure. Fish count and the invertebrates count were conducted on the same area where the quadrat survey was done. Visual assessment was used in sites where physical or weather conditions hinder the use of quadrat methods. This was mainly carried out using the 'timed swims' techniques.

This study was complemented with extensive photographs of the areas in question. Methodologies adopted for these surveys are internationally accepted (English et al. 1997) and are widely used to assess the status of coral reefs and other coastal areas in the Maldives as well.

3.1 Vegetation transects

Qualitative surveys of vegetation around the project site were carried out. These include estimates of percentage cover and identifying the dominant species. These surveys in most cases documented bushes and trees that are just at the forefront facing the beach. The Line intercept transect (LIT) method was used here. The length of the each transect was 50m. Only those that intercept with the tape are recorded. The commonly encountered vegetation was documented in their local Dhivehi names. The vegetation transects are marked and depicted in Figure 5.

3.2 Quadrat method

Quadrat method was used to assess the benthic substrate at the survey sites. Data from 15 random quadrats (0.25m^2 each) were taken from the selected representative sites on and around the proposed harbor development area. Quadrats were thrown randomly over head in a demarcated area (See Figure 5). Percentage cover of each benthic substrate is recorded.

Quantitative percent cover data of morphological characteristics of the reef community is obtained using this method and it can be repeated over time to obtain temporal changes. Disadvantages of this method include difficulty in standardizing the life form categories and the limitation of the data collected, on percent cover and relative abundance (English et al. 1997). Quadrat method surveys produce valuable data even though they require considerable effort and skills to record notes underwater.

3.3 Timed-swim surveys

These surveys were carried out using snorkelling gear for both fish and benthic communities including live coral, dead coral, algae and other sessile organisms. Swims on a straight path were done on the selected sites. The duration of each swim was 15 minutes for benthic cover and an additional 15 minutes for assessing mobile organism such as fish that are conspicuous. There is a tendency to underestimate fish when using this method of fish senses. This results due to rare species not being effectively sampled and failure to observe all the fish present. However this method represents a quick and easy way of obtaining data in a limited time frame. The data obtained is valid and dependable and can be replicated.

3.4 Public consultation

Consultations were carried out with the Harbor Committee (HC). Their concerns were heard and incorporated in the impact statement. Apart from the HC, leading people of the community provided valuable inputs in terms of coastal processes and beach movements. The HC rejected the MCPI’s proposed location of harbor on the northern side. Instead the Island Office with the consultations of the HC proposed to locate the harbor on the eastern side near the existing soccer field Figure 1).

This side according to the islanders is suitable for safe entrance and anchorage in most part of the year. The committee further noted the importance of keeping the harbor as far inland as possible to reduce wave action and damage to protection walls. This according to the islanders will also help to maintain the breakwaters for a longer period. The HC asked whether it would be possible to compromise about 60 to 90ft of land from the island to build the harbor.

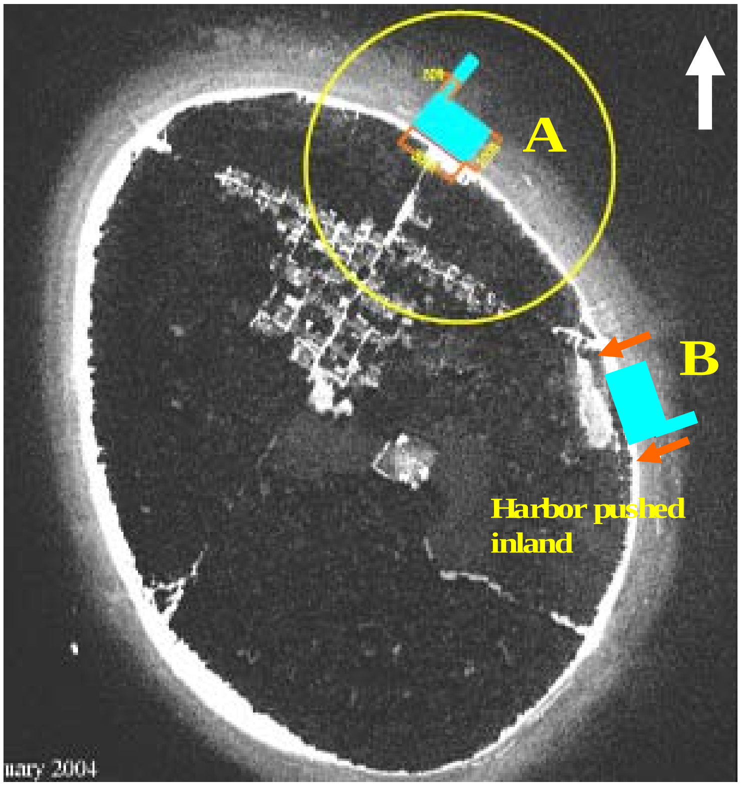

Figure 1: Proposed harbor position of MCPI (A); agreed harbor location (B). Note that the harbor may have to be pushed inland due to narrow width of the reef-flat. Photo MPND.

The HC believes that if the harbor could be placed inland it would greatly increase the protection to the harbor basin, promote the easy entrance into the harbor and will help to prolong the life of breakwaters. The Figure 2 below represents a schematic representation of reef zones of a typical island.

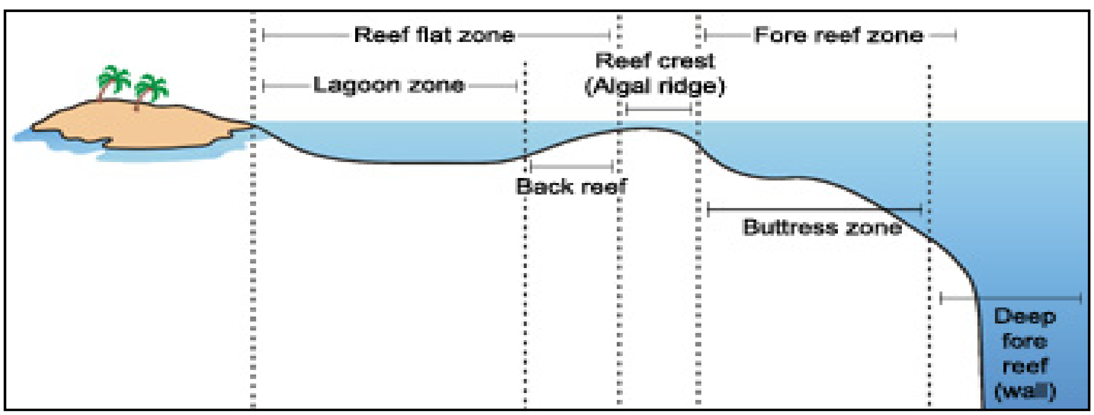

Figure 2: Schematic representation of reef zones

The Figure 3 represents dimensions of the reef-flat areas around the propsed harbor area. It is obvious that the available reef-top areas between the reef crest and the beach is rather narrow.

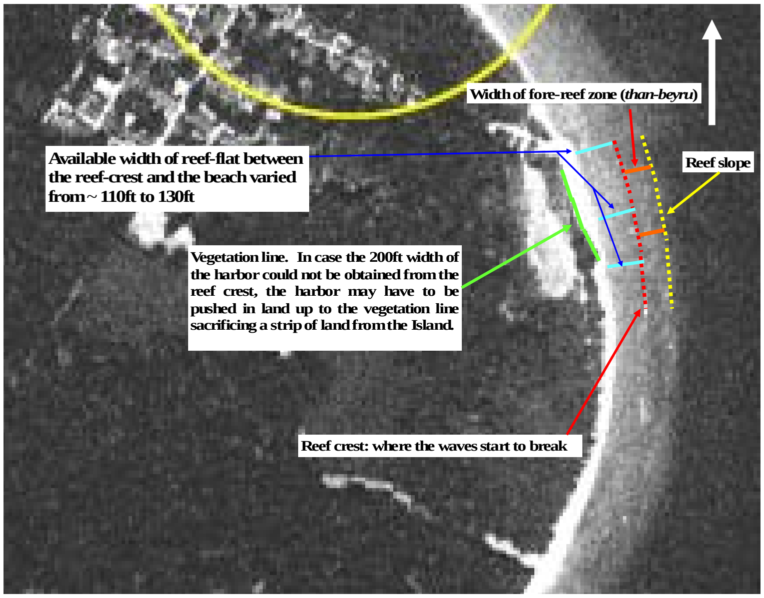

Figure 3: Dimensions of the reef-flat areas around the proposed harbor area. In case the 200ft width of the harbor could not be obtained before the reef crest, the harbor may have to be pushed in land up to the vegetation line sacrificing a strip of land from the Island - bottom.

4 Description of the project

4.1 The proponent

The project proponent of this project is MPCI. The project is funded by the Government of Maldives.

4.2 The project

This harbor construction project is executed under the Access Improvement Program of the Government of the Maldives. The project was awarded to the Aima Construction Private Limited. The scope of the project included:

- Dredging the harbor basin of 300ft length and 200ft width to a depth of 8ft in mean low tide
- Building a quay-wall of 300ft along land-ward side of the island
- Building of breakwaters along other sides of the harbor
- Dredging of a 70ft long and 50ft wide, entrance channel to the harbor

4.3 Project location

Narudhoo is situated on the eastern side of Miladhun-madulu Uthuru-buri (Shaviyani Atoll). The island was on the central portion of the atoll. Narudhoo was formed on a patch reef occupying over 80% of that reef. The harbor will be dredged on the eastern side of the island as marked in Figure 4. Inhabited islands that are close proximity to Narudhoo included Milandhoo and Funadhoo. Uninhabited islands that are near to Narudhoo are Narurinbudhoo and Migoodhoo.

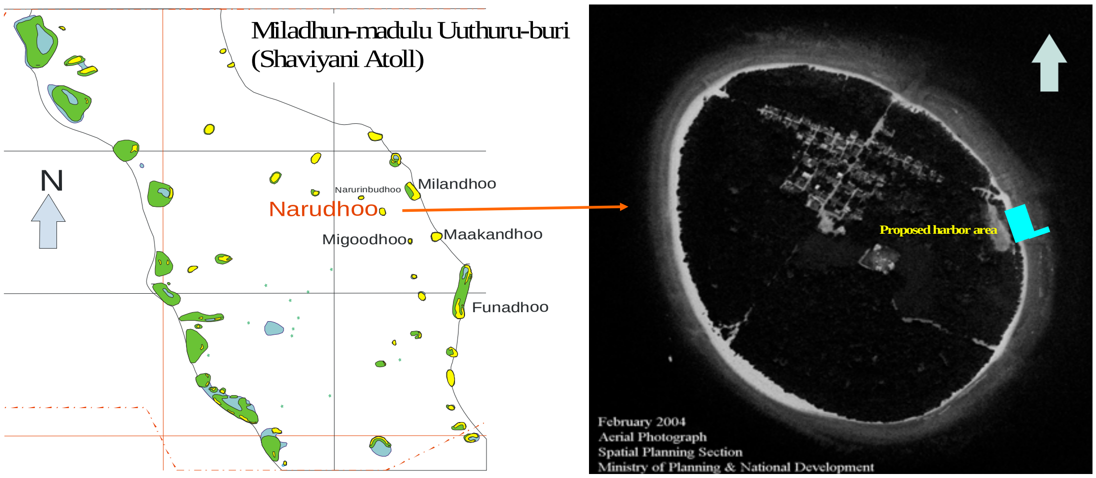

Figure 4: Location map of Sh. Narudhoo and the project site

4.4 Project justification

The Narudhoo is an island with no safe access or anchorage. The lack of a proper access to the island hindered both the agricultural productivity and fishing activities of the island which are directly linked to the economic development of the Island. The housing (construction of modern houses) was also greatly affected by this. The communication (transport to other islands) was very difficult due to the lack of a harbor or a proper access. In general the health and well being of the islanders are linked to having a proper access the Island. The current project is aimed to build a harbor that would improve the access to the Island.

4.5 Project boundaries

The construction work will be carried mainly on the reef-flat of the island. If unavoidable a small strip of land from the island may be compromised. The project site is rather un-altered except for a small 20 to 30ft manually cleared area where boating was done traditionally. The dredging of the harbor will have a significant direct impact on the seabed and its associated flora and fauna. This direct impact area will be limited to the 300ft by 200ft harbor basin and 50ft by 70ft entrance channel. The indirect impact area in relation to sedimentation will be felt on the northern and southern sides of the harbor (see Figure 6).

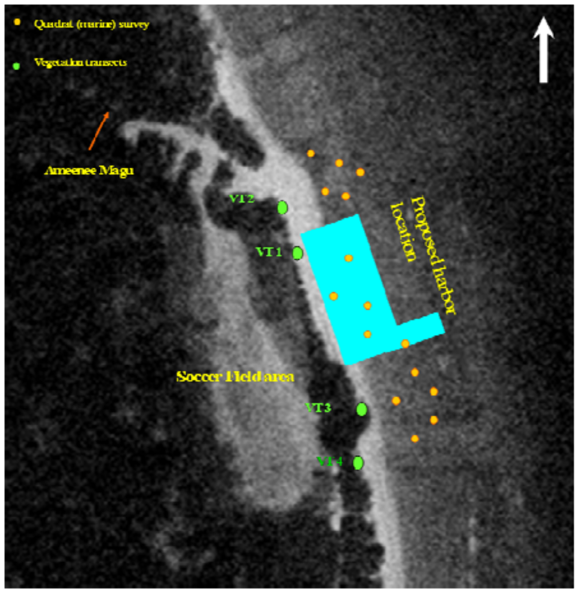

Figure 5: Proposed harbor area and survey sites. Green dots represent the vegetation survey area. The orange dots represent the quadrats (marine survey area)

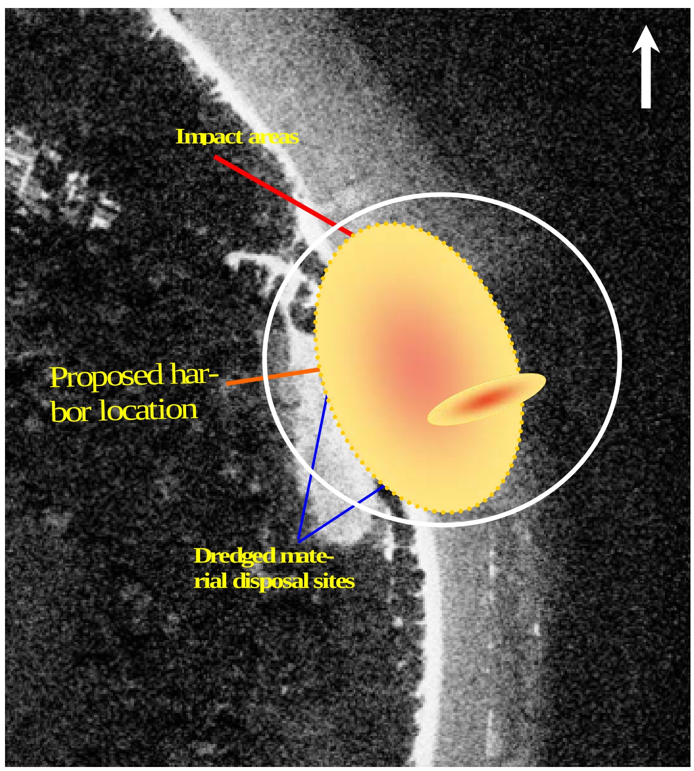

Figure 6: Project boundaries with possible direct and indirect impact areas. Dark red color represents direct impacts while the lighter color represents indirect impacts

There will be a loss of coastal vegetation near the harbor area to pave the way for harbor utilization. The loss of coastal vegetation will increase if a portion of the harbor basin is to be pushed inside the Island. This area is estimated to be 2000 to 4000 ft^2. It is worth noting that a large portion of this land is already cleared and bare (the soccer field) as can be seen in the areal photograph (Figure 6). The back filling of the dredged spoil will be on the sides of the harbor and the eroding areas around the island.

4.6 Project inputs and outputs

Major inputs of the project included:

- construction materials – cement, rock boulders, rock aggregates, river sand, iron bars, timber, wood-flakes etc
- machinery and equipments – excavators, dump trucks, lorries, barges, concrete mixers
- workforce – locals and expatriates

Major outputs of the project will be:

- The harbor and the entrance channel
- quay walls
- breakwaters
- dredge spoil and
- solid waste

4.7 Project risks and impacts

Potential risks associated with the project are damage to the marine environment due to sedimentation by excavation and clearance works. Chronic impacts such as this could be cumulative and long term.

Coastal modification involved with this project may have considerable impacts on the littoral movement of the island. At present no net beach erosion is observed.

Death and damage to live coral is inevitable in this harbor construction project. Impacts involved are sedimentation and smothering of live coral that are near the dredging areas.

Disposal of dredge materials would have a positive impact by creating more land around the harbor area and stabilizing the beach if dumped into an eroding area. The impact of spoil disposal will be minimal since the dredged spoil disposal sites are almost dead reef-flat areas.

Positive socioeconomic impacts are envisaged by the proposed project. The construction of the harbor will enable the islanders to interact with other islands in terms of economic and social aspects.

5 Existing environment

5.1 Physical environment

Shaviyani Atoll is a large and complex atoll with relatively few reefs and islands. The island of Narudhoo is about 16 km north of the atoll capital Funadhoo and located at the coordinates 73° 12' 53" E and 06° 15' 48" N. This is an inhabited island with a population of 506 people (Island Office 2007). The island has a length of approximately 850m and an average width of 650m. The total land area of the island, i.e. area within the vegetation line 41.77 hectares (MOAD online). The lagoon surrounding the island is less than 1m depth at mean sea level (MSL).

5.2 Climatology

The Indian Ocean Monsoons govern the climatology of the Maldives hence monsoonal reversal plays a significant role in weather patterns. Two very distinct monsoon are observed: the Northeast (*Iruvai*) and the Southwest (*Hulhangu*) monsoon. Monsoons can be best characterized by direction of wind and the amount of rainfall. The southwest (SW) monsoon is the rainy season which lasts from May to September and the northeast (NE) monsoon is the dry season that occurs from December to February. The transition period of SW monsoon occurs from March and April while that of NE monsoon occurs from October to November.

Generally the SW monsoon generates westerly winds and the seas are rougher than the NE monsoon. Due to the strong winds the seas get so rough (in many of the days) that islands like Narudhoo becomes inaccessible on the west and northwest sides during this season. The NE monsoon in the Maldives is marked by east to northeast winds (Woodroffe 1992) which are generally lighter except during the *Iruvai halha* during which the winds is rather strong with high waves.

Localized climate data for the Island of Narudhoo does not exist. Therefore, available data on HDh. Hanimaadhoo, and K. Male' is used here since the proximity of these regions will enable it to make good estimate for Narudhoo (see Figure 7).

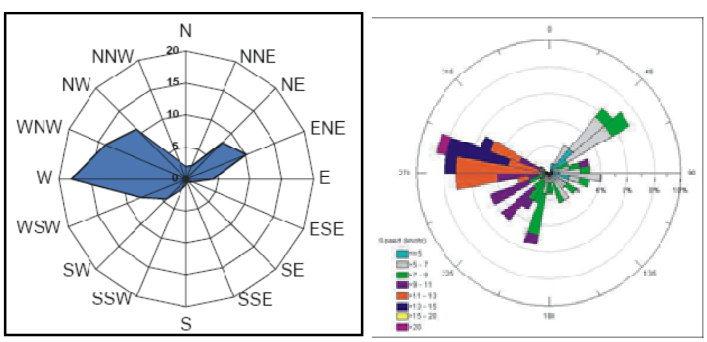

Figure 7: Right: general wind rose for the Maldives (Environment 2005) and left monthly average wind for HDh. Hanimaadhoo (DoM).

General wind rose for the Maldives and HDh. Hanimaadhoo shows that frequency of wind coming directly from the east is less and the speed is low. This suggests that the location of the Narudhoo harbor is appropriate since the mouth of the entrance channel and the inner harbour will be calm most part of the year.

5.3 Tides and currents

Maldives experiences mixed semi-diurnal and diurnal tides with a strong diurnal inequality. Tide records at K. Hulhule, and HDh. Hanimaadhoo which can be applied for estimating tide levels at Narudhoo with reasonable accuracy, shows that, the maximum tidal range to be about 1.20m (see Figure 8). The highest astronomical tide level is +0.64m (Mean Sea Level) and the lowest astronomical tide level is -0.56m (MSL).

In the Maldives tides have significant influence on the formation, development, and sediment movement process (coastal processes) around the islands. Tides also play an important role in lagoon and reef-flat water circulation.

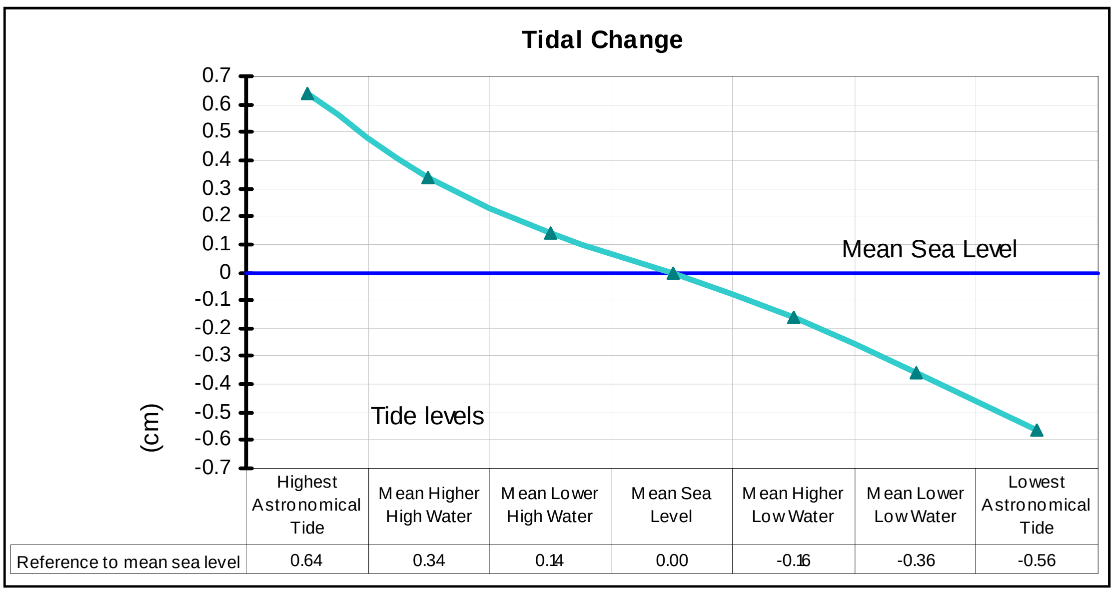

Figure 8: Astronomical tidal variation in Maldives, (Environment Maldives SoE Maldives 2002)

The currents on the reef-flat and near the reef edge changes direction daily with the ebb and flood tides. During the ebb tide the direction of current near at the harbor area is from west to east. When at flood tide the vise versa is seen. At flood tides the atoll basin is flushed with fresh oceanic waters.

During the low tide a large portion of the reef-flat is exposed to air in Narudhoo making it virtually impossible to reach the island even in very small vessels such as dinghies. The water level during the low tide at the proposed harbor area is between 0 to 0.8m at (MSL). In some instances dead coral heads are exposed to air (see Figure 9).

Figure 9: Parts of reef-flat exposed at mean tide.

5.4 Waves

The coastal dynamics such as accretion and erosion of islands depends on wave energy. The type of beach and the beach materials also depends largely on the strength of wave energy. Narudhoo is exposed to high waves generated by swells on the whole eastern side of the Island. On the western side, short wind generated waves from the atoll lagoon are felt (see Figure 10). These waves become quite high during rough weather in SW monsoon making it very difficult to access the Island. The situation is worsened due to the narrow extent of the reef-flat.

5.5 Sediment transportation

The beach and nearshore environments of Maldivian islands are composed of coralline and skeletal remnants derived from the reef. The sediments in this environment are mostly coral fragments, calcareous algae and foraminiferans. It has been determined that the major forces which produce sediment on the reefs, are storm waves and waves driven by monsoon winds Figure 10.

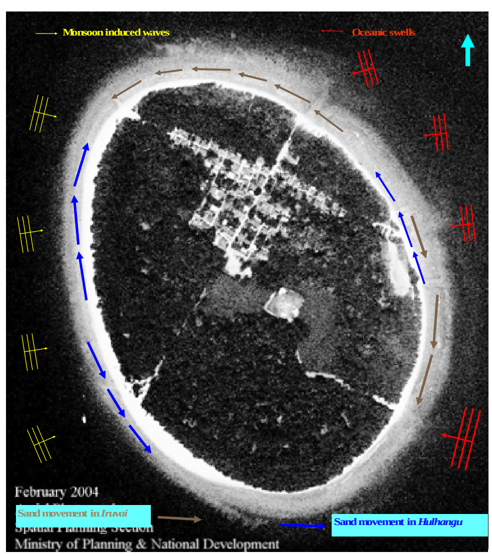

Figure 10: Wave and sand movement around Narudhoo during the two monsoons

Tides and wave driven currents play a very important role in the transport of sediment around the islands. The sediment movement around Narudhoo was crudely presented in the Figure 10.

5.6 The beach environment

Beach is normally defined as the white sandy area between the vegetation line and the lowest astronomical tide. Width of the beach varies with the tidal fluctuations. The beach has a narrow width (except at *thundi*) along much of the length of the east coast at Narudhoo (see Figure 11). The west coast beach is relatively wider.

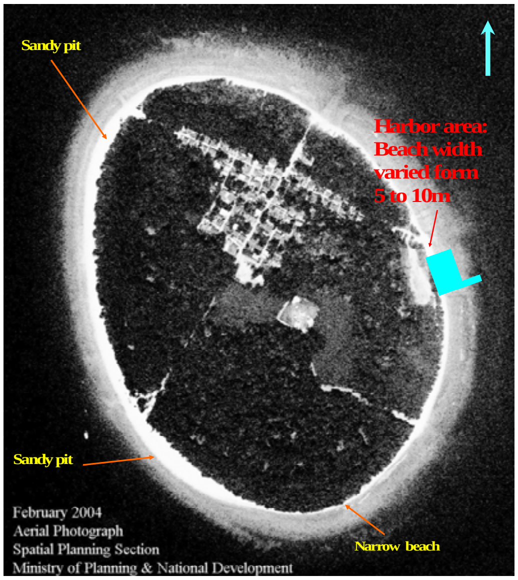

Figure 11: Beach width of Narudhoo showing areas of accretion and erosion

The island's shoreline is mainly made up of a sandy beach. Existing beach at the proposed harbor also consisted of medium grained sand derived from biogenic substances. Observations of the beach during the survey showed that the north-western side beach was much wider than the beach facing the other sides of the island. A rather narrow strip of beach was seen at the southern side. Two large sand spit (*thundi*) was observed on the north-western and south-western end of the Island. These sand spits would be experiencing higher waves generated during the stormy SW monsoon, hence is likely to under go seasonal variations. No sign of net erosion at the proposed harbour area's beach was seen during the field visit.

In Narudhoo's beach sediment movement is mostly from western to northern side and southern side in SW monsoon and from north-western to western side during NE monsoon. Most of the sediment movement is seen on the northern and western part of the Island. In general beach around the island is quite stable.

5.7 Coastal vegetation

The coastal vegetation of the harbour area is characterised by typical island coastal vegetation consisting of m*agoo, dhigga, hirundhu, boashi, varukandhu, uni, kaani, mrihi, midhili* and *dhivehi ruh*. Dominant species at the harbor area was *magoo*.

The results to the 2 transects (VT 1 and VT 2) carried out on the northern side of the harbour reveals that 26% of the beach vegetation cover was *dhiggaa*. Other species encountered included *magoo* and *kanburu*. About 42% was observed to be bare with no vegetation cover (see Figure 12).

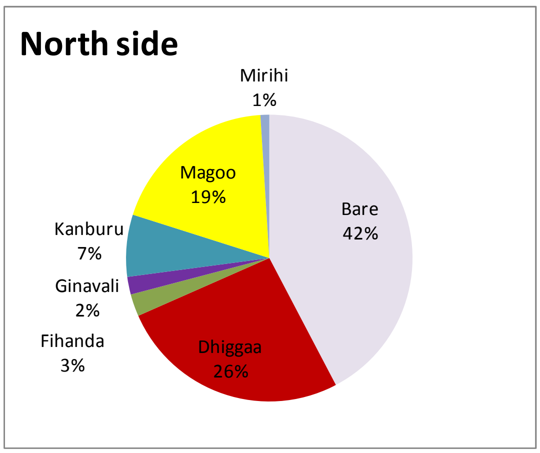

Figure 12: Coastal vegetation cover at northern side of the proposed harbor area (left), dominant vegetation *dhiggaa* at the site (right).

The vegetation cover at the southern side of the harbour (VT 3 and VT 4) shows that that 26% of the beach vegetation cover was *magoo* - the dominant. Other species encountered included *mirihi, uni, midhili, boakashikeyo* and *ginaveli* (see Figure 13). About 15% was observed to be bare with no vegetation.

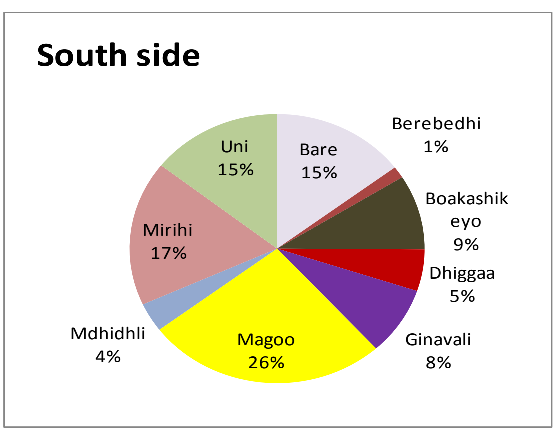

Figure 13: Coastal vegetation cover at southern side of the proposed harbor area (left), dominant vegetation here is *magoo*. This photograph shows a mixture of *magoo, uni* and many more (right).

No inland vegetation surveys were conducted since the area adjacent to the proposed harbour was the soccer field without any trees.

5.8 Marine environment

Marine environment was surveyed to assess and obtain baseline data of the existing environmental conditions. Major components of the marine ecosystems surveyed are the reef-flat, the coral thickets, other benthic communities, and the fish communities. The findings of the surveys were used for impact evaluation and mitigation during the proposed development. The surveys used here are easily replicable and involves in-expansive techniques. Theses surveys could be repeated through out the life of the project and there after to monitor the changes occurring in the biotic and abiotic components of the environment.

The marine environment around Narudhoo is being somewhat modified since the blasting and clearance of entrance channels around the Island. The modifications may have changed the hydrodynamic flow patterns. The environmental impacts of these coastal modifications are not known since there was no systematic monitoring of the effects of these coastal modifications in the Maldives (Kench et al. 2006).

5.8.1 Coral reef system

The reef-flat around the proposed harbor area is not well developed with less than 2% live coral cover (see Figure 14). The bottom of the reef-flat was dominated by rock, and dead coral remnants. The reef slope at this side forms a steep slope to the channel north of the Island. The reef condition here was better than the reef-flat in terms of coral cove, fish and other marine life.

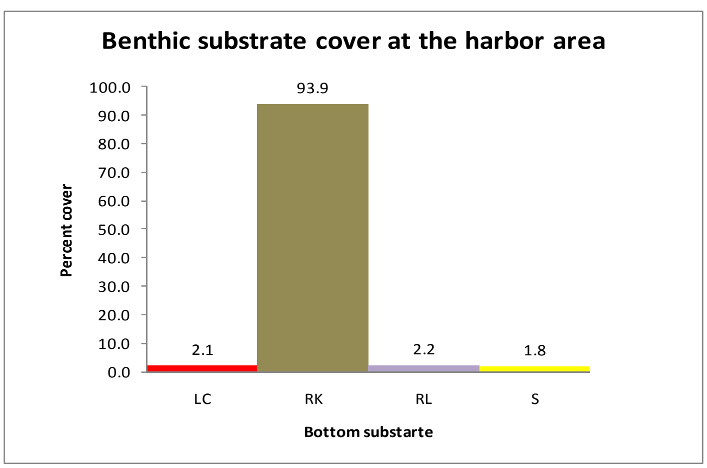

Figure 14: Percentage cover of benthic substrate present at the proposed harbor site's reef-flat. The dominant forms of benthic cover is coral rock. Massive forms of *Porites* spp. predominates the live benthic cover. Branching type corals namely *Acropora* spp. (staghorn), other massive types *Favites* spp., and encrusting types were also present. The benthic covers are given in percentages of the bottom area surveyed. LC = Live coral, RK = rock, RL = rubble, and S = sand.

The coral reef system of Narudhoo is apparently not recovering (after 1998 bleaching event) in terms of diversity and percentage live coral cover. Only a few small colonies of live corals were seen at the reef slope as well as on the reef-flat around the harbor area. Species richness and diversity of corals and fish were low at the surveyed sites.

Based on the survey data of the harbor area, dead coral remnants coral rock was found to be over 94%. The photographs below (Figure 15) provide an idea of benthic cover present at the survey sites.

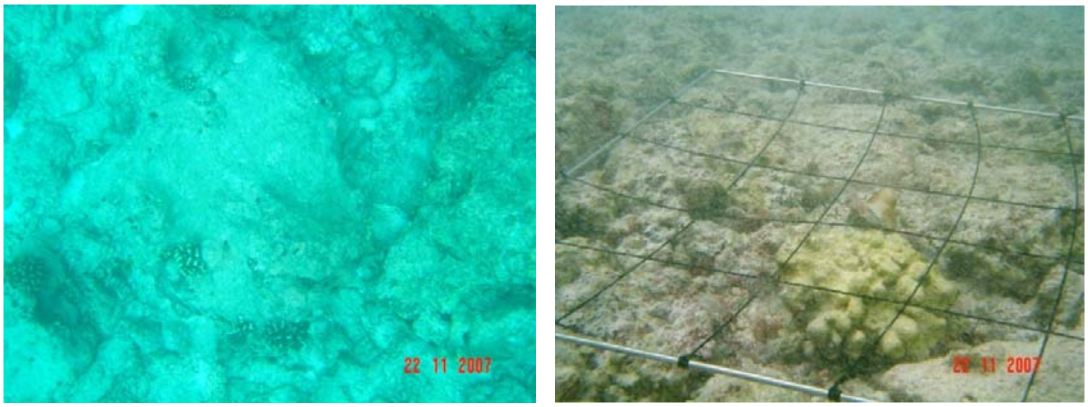

Figure 15: Benthic substrates observed at the surveyed area. Small live *Pocillopora* colonies scattered (left); consolidated rock and rubble (right)

5.8.2 Assessment of fish communities in the surveyed area

The result of 15 minutes swim for fish count along the harbor area revealed that the abundance and diversity of fish as very low. This may be due to the lower level of live coral cover. Since most of the area was covered with coral rock, sand and rubble, fishes associated with this type of environment were encountered. The dominant fish taxa observed in the surveyed area included grazers like surgeon fishes, wrasses and parrotfishes (see Table 1).

Table 1: Results of the fish encounter survey at the harbor area

Family	Species	Count
Acanthuridae	*Acanthurus lineatus*	4
Acanthuridae	*Acanthurus leucosternon*	1
Acanthuridae	*Acanthurus triostegus*	10
Acanthuridae	*Ctenochaetus* sp.	3
Chaetodontidae	*Chaetodon* sp.	1
Labridae	*Labroides dimidiatus*	4
Labridae	*Thalassoma hardwicke*	1
Pomacentridae	*Pomacentrus indicus*	4
Pomacentridae	*Chrysiptera brownriggii*	2
Scaridae	*Scarus sordidus*	4

5.8.3 Reef invertebrates

Two species of echinoderms were encountered. Due to the nocturnal nature of mollusks, they were not encountered during the survey. What is observed during the timed swims are:

- Common star fish
- Diadema urchin and

6 Predicting the environmental impacts and mitigation measures

Impacts on the marine environment from the proposed project have been predicted through analysis of the project, discussions with the project proponent, field surveys, observations and assessment as well as based on field experience of similar works in the country. Quantitative and qualitative data collected from filed work were analyzed to predict the extent and significance of the impacts that may arise from the proposed harbor rehabilitation project's activities.

The four components of the environment that will be impacted are identified as the beach, coastal vegetation, coral reef benthos and reef-flat waters and associated nektons. Quantitative assessment of potential direct and indirect impacts due to the proposed project was based on area calculation of the affected area.

6.1 Impacts on the environment from the proposed harbor project

Harbor dredging projects have both construction and operational impacts on the coastal environment. These impacts may be either short term reversible or long term irreversible damage or alterations. The impacts identified here will be according its location and magnitude. The intensity or severity of the impacts is further grouped into negligible, minor, moderate and major. This will help in identifying and carrying out remedial and mitigation measures. A description of the impact categories are presented below (LaMer 2006).

- Negligible: no significant impact on environment
- Minor: the impact is short term and cause little damage to the environment which may be reversible on the long run.
- Moderate: Impacts are significant, may cause long term environmental concerns but are likely to be short termed, acceptable and justifiable
- Major: long term impact, large scale environmental alterations

Potential environmental impacts predicted for this project will be the damage during construction and irreversible modification of environment as a result of excavation and vegetation clearance. These impacts are presented together with mitigation measures in the Table 3.

Dredging and excavation work generally lead to major impacts on reef habitats, lagoon and coastal hydrodynamics. The Impacts of excavation and dredging may range from smothering of live corals and other flora and fauna. Coastal modification involved in the construction of the harbor can have short to long term impacts on the on the coastal processes and beach profiles of the island.

Specific impacts on the marine environment arising from the proposed project will be mainly an alteration of the bottom of reef-flat where dredging is done and a moderate impact on the sediment movement along the shore-line and near the entrance channel. There is also a moderate impact on the benthic and nektonic communities that inhabit in the possible impact zone.

Indirect impacts will be felt to the adjacent coastal vegetation, pelagic organisms inhabiting the reef-flat, lagoon and coral reef areas close to the development locality.

6.2 Impacts on disposal sites due to dredged materials

The dredged material disposal sites of Narudhoo will be on both sides of the harbor (see Figure 6). Additional materials, if present will be dumped in to the eroding areas of the island. The observations conducted revealed that the disposal sites are almost devoid from life; hence there will be no major impact on the biotic environment. The long term changes in the coastal hydrodynamics are unclear. However it is evident that the filling of these areas will have some impacts on the coastal processes of the Island.

6.3 Mobilization impacts

The transport and supply of construction material, the excavators and other heavy equipments may have an impact as a result of increased traffic with barges and other large vessels. The impacts may arise from:

- Accidental spillage of construction materials (cement bags, timber, iron bars).
- Accidental oils and other chemical spills.
- Accidental grounding of large vessels.
- Propellers’ wake can break fragile corals.
- Anchor damage from the vessels.

6.4 Impacts from construction materials and other waste

Construction materials such as cement, timber, metal, and fuel for excavators and trucks have the potential to damage environment. Pollution of the lagoon and reef system can be caused by waterborne and windblown debris escaping from the construction site.

During the construction of the quay-walls, leaching of cement will have short term minor impact on the immediate area. Once the cement is hardened, re-colonization of marine fauna and flora will take place.

6.5 Impacts due to construction work

Deepening work of the entrance channel and harbor basin will be carried out using excavators. Therefore the negative impact of sedimentation is unavoidable even with the construction of sandy bund walls. The impacts of sedimentation are short termed since the currents will aid in the dispersal and removal of fine suspended materials. Growth and recruitment of live corals may have moderate short term negative impact due to sedimentation.

The impacts of excessive sedimentation on corals include:

- Direct physical impacts like smothering of corals and other benthic organisms,
- Reduced light penetration reducing the productivity of corals.
- Formation of false bottoms due to unstable shifting of sediments.
- Eutrophication due to increased fine sediments leading to algal blooms.
- Formation of anoxic (black) bottoms under the fine sediments.

Construction of wharfs and protection walls may have impacts on the reef-flat habitat by seepage of cement material. This work includes a lot of manual transport of materials, trampling and breakage of live coral is possible at the seaward side of the harbor basin and the sides of the entrance channel.

Vegetation clearance and site-hardening is un-avoidable in harbor construction projects due to the use of large and heavy vehicles.

6.6 Impacts of built coastal structures

The impact of anthropogenic physical structures such as breakwaters, access channels and harbors on the coastal processes and marine life, can be quite significant and often permanent. Some of these include:

- Change in near-shore hydrodynamics (see Figure 16).
- Erosion and loss of vegetation at the low energy areas during either monsoons.
- Sedimentation and turbidity resulting poor water quality which negatively impacts vitality of marine organisms.
- Alteration of bottom substrate.
- Degradation of sea water quality due to turbidity.

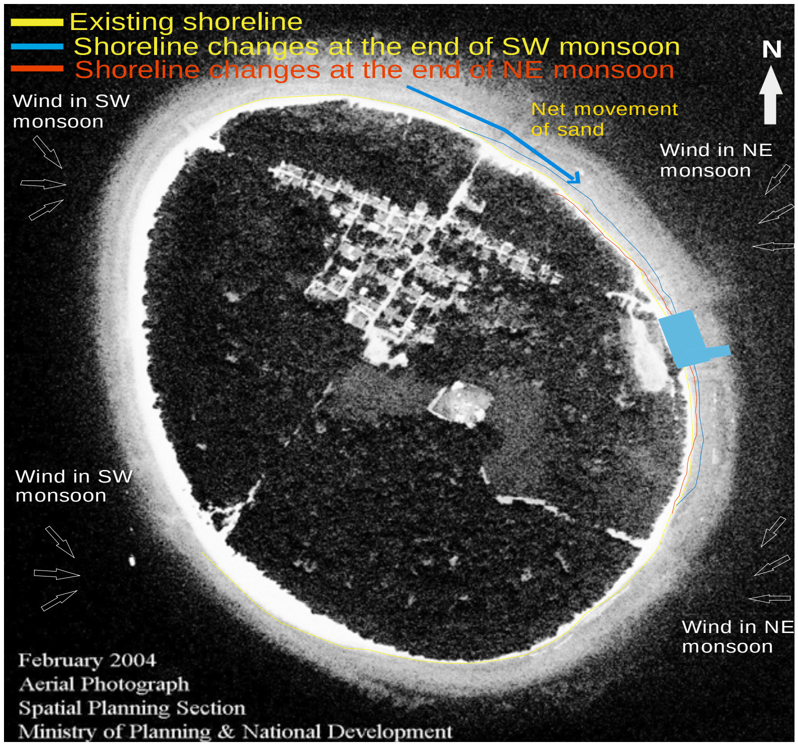

Figure 16: Possible alteration of shoreline as a result of harbor construction

6.7 Impacts due to harbor operation

Impacts associated with the harbor operation can be considered as minor to moderate and short to long term. These impacts include (but are not limited to):

- Poor water quality due to siltation and stagnation of water.
- Impacts due to accidental spillage of oils, other chemicals and waste.
- Hydrodynamic changes forming dead zones in the inner harbor where litter may accumulate
- Erosion and its associated impacts like the loss of coastal vegetation.

6.8 Significance of the impacts

Impacts that may arise from activities of the proposed harbor project were categorized into the characteristics mentioned in the Table 2.

The significance of impacts was determined based on these characteristics and analysis of the impacts from this project and other analogous projects. These impacts correspond in the worst case scenario and after mitigation measures were taken. The Table 2 shows the main impacts that would arise from the proposed project activities and their significance based on impact characteristics.

Magnitude of impact is calculated in relation to the total area. Direct geographic range of impact felt will be the immediate proposed development area and indirect impacts on the environment will be felt on a larger area due spreading of fine sediment and vegetation clearance of adjacent areas. Duration of the impact is predicted in terms of severity of impacts. The impacts are likely to be felt on an estimated 10% of the reef-flat and 2% of the coastal vegetation.

Reversibility of impacts was predicted based on natural recovery of the habitats affected. Coral reefs naturally take longer to recover than the lagoon habitats. Significance of the impacts is predicted based on the nature, geographic range where impacts are felt, magnitude, duration and reversibility of the impacts.

Table 2: Significant impacts of the proposed harbor project

Impact characteristics	**Dredging**	**Dredged spoil discharge**	**Vegetation clearance**
Nature of impacts	Cumulative	Cumulative	Cumulative
Magnitude of impacts	Moderate - negative	Moderate - negative on coastal ecosystems. Major +ve on socioeconomic aspects – sand for various purposes	Moderate - negative
Geographical range and environmental attributes	Direct impact on $6000m^2$ of reef-flat and lagoon Direct impact on coral reef on $1000m^2$ Indirect impact on $8000m^2$ of reef-flat	Negligible $1000m^2$ $1000m^2$	Direct impact on $5,000m^2$ of coastal vegetation In direct impact on $5,000m^2$ of coastal vegetation
Duration of impacts	Short term on coral reef and long term on reef-flat and beach	Long term	Long term
Reversibility of impacts	Permanent alteration of physical and biological system of the harbor basin, Short term reversible impacts on coral reefs, and reef-flat adjacent to the harbor basin	irreversible	Permanent alteration of coastal vegetation around the harbor area, Impacts can be reversible.
Significance of the impacts	Major impacts on the harbor basin, shore-line and beach. Minor impacts on the adjacent areas of reef-flat and other environmental attributes	Moderate impact on the reef-flat benthos,	Moderate impact on the coastal vegetation

6.9 Mitigating the impacts

Several actions can be taken to minimize the above mentioned impacts. Expert consultations, past experience and local knowledge are essential in reducing the impacts. Mitigation measures are employed to eliminate or reduce the severity of any predicted impacts. This will ultimately improve the environmental outcomes of the project. The predicted impacts on the coastal environment of Narudhoo can be mitigated by joint cooperation and careful environmental planning. All parties, the Island authorities, the implementing agency and the contractors must work carefully to eliminate or reduce the identified risks. Given the magnitude of impacts for this project, the adverse effects can be mitigated at virtually no cost if best environmental practice and precautionary principles are used.

Supervision and inspection of the project activities are imperative to minimize adverse impacts. Therefore, competent environmental consultants with experience in same or similar work in the local environment will be consulted and allowed to inspect and monitor the work activities of the project life-cycle. Supervising party will carry out compliance monitoring and reporting to ensure that the predicted impacts are not exceeded. If predicted impacts were exceeded, the work will be halted and impacts re-assessed and reported.

Proposed project's dredging work will be carried out to coincide with low tide and easterly current so as to minimize effects of sediment on the reef. The work will be carried out in calm weather condition.

Machinery, equipment and vessels used in the project activities will be maintained in good condition and operated in a manner that they do not pose a risk of environmental degradation.

All activities will be kept to the minimum period of time to reduce impacts on the environment.

The Table 3 below provides more information on potential impacts during construction and operation of the harbor project and mitigation measures (LaMer 2006).

Table 3: Potential impacts during construction and operation of the harbor project and mitigation measures to minimize the impacts

Potential impacts	Mitigation measures	Impact locality	Development phase	Intensity and reversibility	Responsible authority	Projected cost (MRf)
Littering on environment	Avoided by proper planning in transportation and waste disposal. Use 3R (reduce, re-use, recycle). Proper garbage disposal	Reef-flat, and land	During construction	Minor to moderate, short term -ve impact. Reversible	Contractor, Island authorities	N/A
Alteration to localized hydrodynamic regime	Maintaining water exchange through the protection walls	Reef slope, reef-flat, beach	During construction	Moderate, long term, likely irreversible	Contractor, MCPI	N/A
Damage to reef by Loading/unloading works	Raising awareness and utilizing environmental best practice, careful planning	Reef-flat and reef slope	During construction	Minor, short term –ve impact. Reversible over long run	Contractor, MCPI	N/A
Sedimentation and siltation on the reef and lagoon due to excavation works	Creation of a sandy bed to reduce the sedimentation impact, this bed would reduce sediment from spreading; work to be carried out in low tides.	Reef-flat and reef slope	During construction	Moderate, short term –ve impact. Reversible over long run	Contractor, Island authorities	N/A
Loss of habitat, damage or death of Coral at harbor basin and protection wall area	Clearly marking the areas to be excavated.	Reef-flat,	During construction	Minor, long term –ve impact. Most likely irreversible	Contractor	N/A
Habitat modification at the spoil disposal site and loss of coastal vegetation around the harbor area	The material will be disposed at the sites where there was virtually no life. Trees will be cut only in unavoidable circumstances. Once the harbor is complete, new trees will be planted.	Land, coastal area	During construction and Operational phase	Minor –ve impact Positive impacts due to availability of sand for multiple purposes. +ve impacts once the new trees grow. Reversible	Contractor, Island authorities	N/A

Potential impacts	Mitigation measures	Impact locality	Development phase	Intensity and reversibility	Responsible authority	Projected cost (MRf)
Impacts of storm-water drainage and coastal flooding.	The dredge spoil will be disposed at both sides of the harbor. The reclaimed area will not be higher in elevation than the existing level of the Island.	Coastal area	During construction and Operational phase	Minor, impacts not fully clear. Most likely no change.	Contractor, Island authorities	N/A
Impact of dredging works on the existing operations of the lagoon	Dredging will be carried in a low tide; hence the activity will be less.	Reef-flat, lagoon	During construction	Minor, –ve impacts on the use of the lagoon, Reversible	Contractor, Island authorities	N/A
Air pollution	Completing the excavation works as soon as possible.	Air	During construction	Negligible, short term –ve impact. Reversible	Contractor	N/A
Noise pollution	Completing the excavation works as soon as possible, avoid working at night	Land	During construction	Minor, short –ve term impact. Reversible	Contractor	N/A
Possible erosion due to obstruction of littoral sediment movement	Keep part of the dredge material on the Island to supplement areas showing erosion	Beach	Operational phase	Minor, long term and unpredictable –ve impact. Most likely irreversible	Contractor, Island authorities	Cost is difficult to estimate since the timing of impact unpredictable
Solid waste	Employee a staff for monitoring and cleaning the harbor	Harbor area	Operational phase	Minor, long term –ve impact Reversible	Contractor	monthly salary equivalent to 2000.00
Accidental spillage	Put up sign boards	Harbor area	Operational phase	Minor, short term –ve impact Reversible	Island authorities	1000.00 - 1500.00

6.10 Uncertainties in impacts identification

Although measures will be taken to mitigate known impacts, there is always the probability that an unforeseen impact may occur. It is also important to note that some of the impacts may turn out to be far greater than predicted. This could make mitigation measures less effective. To avoid or reduce the chances of such events it is vital to monitor key important parameters at the vicinity of the project.

7 Project alternatives

7.1 Locations

The current project location was agreed by the Island Harbor Committee with the consultation of the island community and the Island Office. One other location was also on the table initially, the north side (MCPI option). The north side is rather rough through out the year since this side is not protected from the waves generated by SW monsoon. Therefore, building the harbor on this side is not wise since mouth of the entrance channel will be impassable during rough weather conditions of the SW monsoon. The drawback of the currently agreed position on the east could be that the reef-flat area is rather narrow at that area. This may require the harbor to be pushed inland.

Considering these two sites, the proposed location can be justified since that area will be calmer and easier to access in most part of the year. Therefore considering possible alternatives, the proposed location (on the east near the soccer field) seemed most appropriate and economically feasible.

7.2 Construction method

The method used for deepening the proposed harbor using excavator, will have significant impacts on the environment. One alternative to employ a cutter-suction dredger which reduces the amount of silt suspended in the water column. It will also eliminate the need for blasting hard substrate if encountered. However, the use of cutter-suction dredger for the small scale dredging project is not economical due to the high costs of mobilization and operation. Given the financial constraints this technology could not be used for this project.

A single sandy bed will be used to reduce environmental impacts of suspended sediments. An alternative to this is the use of geo-textile curtains. Given the strong tidal flushing of Maldivian waters the use of such barriers becomes un-necessary with respect to the expenses it incurs. Therefore, the construction methods for this project seemed to be cost effective with minimal environmental impacts.

7.3 Constructing jetties

Instead of dredging a harbor jetties could also be built to facilitate access to islands. This could have less environmental impacts if properly built. Jetties if built on pillars will do very little to alter hydrodynamic flow, thus reducing erosion/accretion problems. For the case of Narudhoo, building a single jetty will not suffice considering the level of exposure of the island to the monsoonal rough weather. Building a jetty will not solve grave difficulty that the boat owners face due to the lack of a safe anchorage. Maintaining jetties has also proven to be rather costly. Therefore building a harbor – however small - will be more beneficial since it can serve both as a safe access and a safe anchorage.

7.4 The no project scenario

If “no project scenario” was considered, environmental impacts associated with the project could be avoided completely. Consider this option is not worthwhile since the reef system and the coastal areas (beach and vegetation) have no significant features that could be labeled as significant environmental assets.

The “no project scenario” can be ruled out since the current policy of the government is to provide a safe and sound access to all communities. A safe access is vital for the well being and socioeconomic development of an island.

8 Environmental monitoring

Proper environmental monitoring is essential to ensure that potential impacts are minimized and unanticipated impacts are mitigated. The parameters that are most relevant for monitoring the impacts that may arise from the proposed harbor project include turbidity and nutrient, sedimentation, beach profile, coastal vegetation cover and live coral cover and nektonic fauna. However, given the scope of this project and budgetary deficiencies, monitoring work will be limited. Nevertheless it is important to note that all necessary measures and precautionary action will be taken to mitigate and minimize negative environmental impacts. The Table 4 below summarizes the aspects of monitoring program. The monitoring team consists experienced staff from the MCPI and MEEW.

A monitoring report will be compiled after the completion of the civil works based on the data collected for monitoring the parameters included in the monitoring program. This report will be submitted to the relevant government agencies for compliance.

The report will include details of the site, data collection and analysis, quality control measures, sampling frequency and monitoring analysis and details of methodologies and protocols followed.

Table 4: Aspects of the monitoring program

Monitoring Attribute	Indicator	Methodology	Monitoring Frequency	Estimated Cost (if out sourced
Coral and other benthic cover	Percent cover	Quadrat	Once during the project and one year after the completion of the project	US$ 350 per survey
Diversity and abundance of fish communities	Number of fish present. Population structure	Visual fish census	Once during the project and one year after the completion of the project	US$ 350 per survey
Coastal vegetation	Percent cover	Line Intercept Transect	A year after the completion of the project	US$ 100 per survey
Seawater quality	DO and turbidity	Lab analysis	Once during the project and one year after the completion of the project	US$ 80 per test performed
Freshwater quality	Salinity and other important parameters	Lab analysis	Once during the project and one year after the completion of the project	US$ 80 per test performed
Beach profile	Beach dynamics	GPS tracks along the beach	Once during the project and one year after the completion of the project	US$ 100 per survey
Hydrodynamic s	Changes in the current movements	Drouge tracks	Once during the project and one year after the completion of the project	US$ 350 per survey

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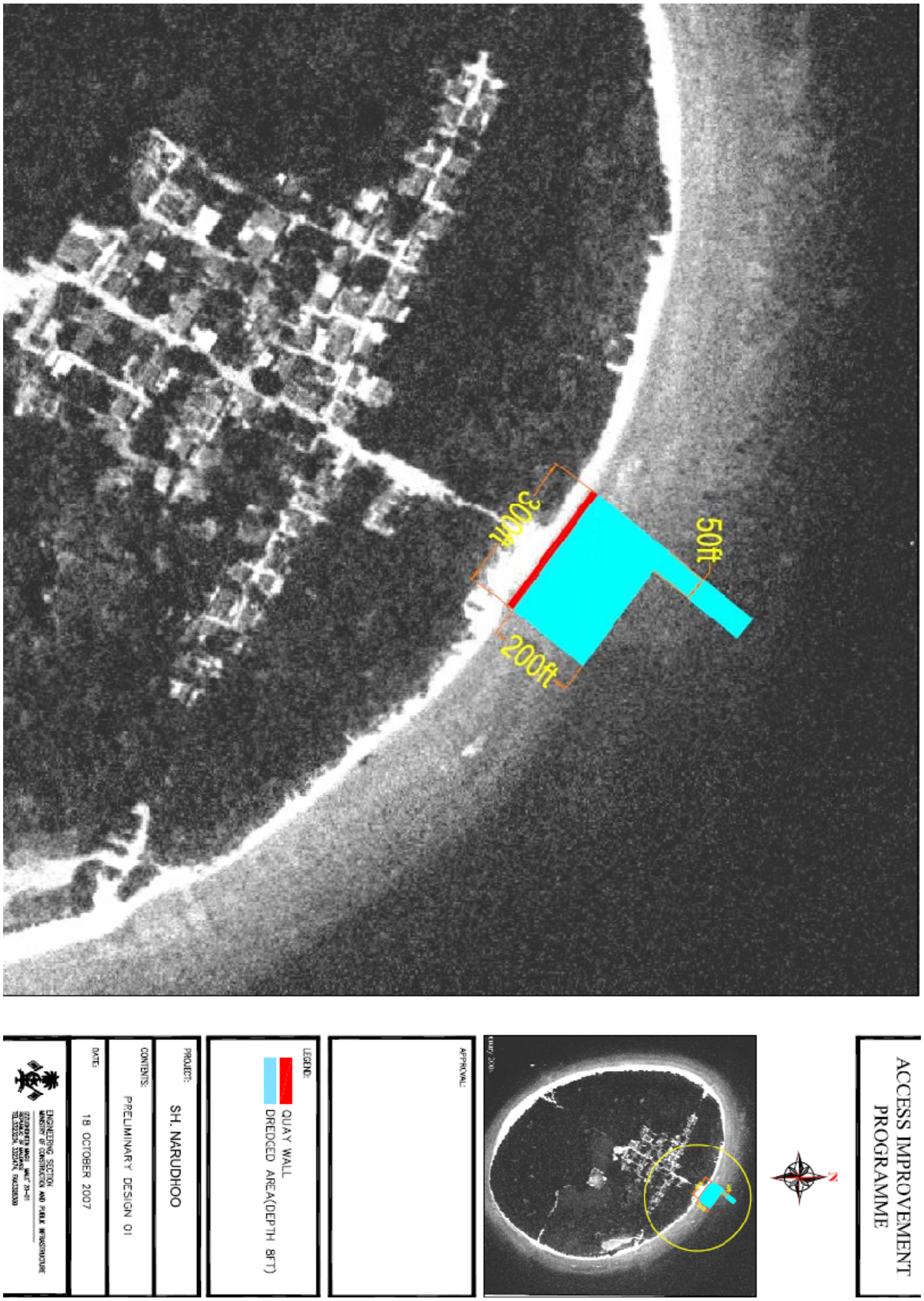
10 Annex 1: Proposed harbor concept drawing



Note: This is the original concept and location proposed by the MCPI. The island authorities disagreed with this location so the harbor's proposed location has been moved to the eastern side near the soccer filed.