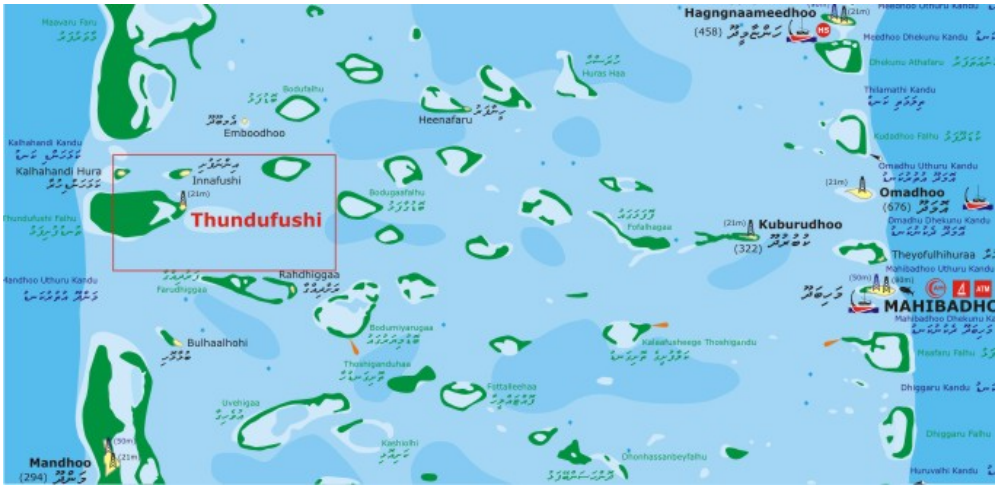
ENVIRONMENTAL IMPACT ASSESSMENT

For the proposed Upgrade and Redevelopment in Thudufushi Resort, South Ari Atoll, Maldives



Proposed by

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For Water Solutions Pvt. Ltd., Maldives

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1 Non Technical summary

- This report discusses the findings of an environmental impact study undertaken by Water Solutions Pvt. Ltd. for the undertaking the proposed upgrade and redevelopment project in Thudufushi island

- This project is proposed by Seagull Group to develop; 21 new water bungalows, 2 water bungalow suites, an over water reception, bar, restaurant, sea plane platform, a sewerage treatment plant, increasing the capacity at power house and desalination plant to cater for additional demands. The redevelopment project would also deepen the existing channel, development of a submerged breakwater on western side, southern side and repair the breakwater on northern side of the island.

- This report has identified, that major impact of the project will be felt on the marine environment as almost all the new structures proposed will be over water. Impacts on the marine environment will be felt through indirect impact on corals due to sedimentation and siltation caused by the construction activities to the lagoon, during the construction period. Baseline data has, therefore, been collected in order to monitor the changes to the marine environment which will be identified in periodical monitoring reports. The most significant impact will be felt on the lagoon bottom.

- Alternatives to the project have also been considered in detail and several alternatives to the proposed project were considered, including alternative methods of water villa construction and alternative locations. One alternative that has been suggested is to construct the water villas on large but minimal number of columns. Other alternatives considered include alternative locations and construction strategy. An alternative location has also been suggested. Due to various reasons, these alternatives have not been considered. The advantages and disadvantages of these alternatives have been discussed.

- Towards, the end of the report, a monitoring programme has been suggested which mainly covers the marine environment. These include coral cover and marine water quality among many other parameters. As the impacts are felt on the marine environment, it is important to undertake this monitoring.

2 Introduction

This Environmental Impact Assessment report (EIA) has been prepared to fulfil the requirements of the Environmental Protection and Preservation Act, law no. 4/93 for the proposed upgrade and redevelopment of Thudufushi island resort, located in south Ari atoll.

2.1 Structure of the EIA

The report has been structured to meet the requirements of the EIA regulations 2007 issued by the Ministry of Environment, Energy and Water.

The major findings of this report are based on qualitative and quantitative assessments undertaken during site visit in December 2009 and March 2010 and the EIA for the Beach Replenishment Project Report of March 2010. The impact assessment methodology has been restricted to field data collected, consultations, experience and professional judgment and available long term data.

2.2 Aims and Objectives of the EIA

The objective of the report is to:

- Assist in mitigating impacts caused due to the construction of additional over water structures and undertaking the coastal protection
- Promote informed and environmentally sound decision making
- To demonstrate the commitment by the proponent on the importance of environmental protection and preservation.
- To fulfill the obligations of the proponent to undertake an EIA under Clause 5 of the Environmental Protection and Preservation Act of the Maldives and requirements of the Tourism Regulations.
- Undertake the project work with minimum damage to the environment.

2.3 EIA Implementation

This EIA has been prepared by a local environmental consulting firm, Water Solutions. Water Solutions have been chosen by the proponent as the environmental consultants for this project. The team members were:

- Ahmed Jameel, Environmental Engineer (EIA Registration No: EIA 07/07)
- Abdul Aleem, Environment Consultant (EIA Registration No: EIA 09/07)
- Verena Wiesbauer, MSc (Zoology /Marine Biology) Marine Biologist
- Amir Mustafa, Environmental Engineering Student
- Mohamed Mazin, Surveyor
- Mohamed Riyaz, Assistant Surveyor

2.4 Terms of Reference

The terms of reference for this EIA have been attached as an annex. This EIA has been prepared based on these terms of reference.

3 Policy, Legal and administrative Framework

3.1 Overview

This section outlines the relevant environmental legislation pertaining to this project.

3.2 Applicable Policies, Laws and Regulations

3.2.1 Environmental Protection and Preservation Act

Article 5. (a) of the Environmental Protection and Preservation Act (Law No. 4/93) addresses the submission of an EIA. It states that an EIA shall be submitted to MEEW before implementing any developing project that may have a potential impact on the environment.

3.2.2 Protected Areas and Sensitive Areas

Under Article 4 of the Environment Protection and Preservation Act, the Ministry of Environment is vested with the responsibility of identifying and registering protected areas and natural reserves and drawing up of rules and regulations for their protection and preservation. At present there are no rules and regulations made available to the public on designation and protection of habitats and heritage areas.

There are no protected sites or resources such as protected birds, reefs and trees in the island environment.

3.2.3 Regulation on sand and aggregate mining

This regulation addresses sand mining from uninhabited islands that have been leased; sand mining from the coastal zone of other uninhabited islands; and aggregate mining from uninhabited islands that have been leased and from the coastal zone of other uninhabited islands.

This regulation will be strictly respected and there would not be any sand and aggregate mining except that which is required and approved under the terms of this Environmental Impact Assessment.

3.2.4 Ban on coral mining

Coral mining from the house reef and the atoll rim has been banned through a directive from the President's Office dated 26th September 1990. According to these policies,

- coral mining is not to be carried out on island house reefs;
- coral mining cannot be carried out on atoll rim reefs and common bait fishing reefs;
- coral or sand mining is only allowed from designated sites, and approval from the concerned Atoll Office is required prior to the commencement of any mining operation.
- requests for coral or sand mining from residents of inhabited islands are required to be submitted to the Atoll Office through their respective island office
- the island office is required to estimate the quantity of corals required for the applied construction work and hence this ensures that permission is granted to mine just the

required amount;

- every island is required to keep a log book of the amount of corals mined.
- sand mining is not allowed on the beaches of inhabited islands, islands leased for industrial developments and tourist resorts and within the lagoons adjoining these islands.

This project does not involve coral mining. Mined coral would also not be used.

3.2.5 Tourism Act (Law no. 2/99)

This Act provides for the determination of zones and islands for the development of tourism in the Maldives. This EIA has been developed in accordance with the Tourism Act

3.2.6 Ministry of Tourism Regulations and Circulars

The Tourism Regulations in the Maldives ensure that carrying capacity of the island and atoll ecosystems are well within limits and the negative effects of the development are minimal. The Ministry also issues circulars on several occasions and when necessary to discourage activities such as sand and coral mining, developing on the coastal environment and waste disposal which may cause harm or damage to the natural environment, which is the main tourism product.

Tourism regulations strictly discourage modifications to the natural movement of sand around the islands. Therefore, Tourism Regulations require that special permission from the Ministry of Tourism, Arts and Culture be sought before commencing any coastal modification works on any tourist resort. It is also stated that hard engineering solutions are not encouraged and construction of solid jetties and groynes be controlled and shall only be undertaken after conducting an Environment Impact Assessment study. Similarly, design of boat piers, jetties and other such structures are required to be in such a way that these shall not obstruct current and sediment circulation patterns of the island.

The Ministry also issues circulars on several occasions and when necessary to discourage activities such as sand and coral mining, developing on the coastal environment and waste disposal which may cause harm or damage to the natural environment, which is the main tourism product.

The proposed redevelopment at Thudufushi has been proposed in conformity to tourism regulations. The conceptual plan has been approved by the Tourism Ministry.

3.2.7 Environmental Impact Assessment Regulation 2007

The Ministry of Environment, Energy and Water issued the EIA regulation on May 2007. The guidance provided in this Regulation was followed in the preparation of this EIA report. The EIA has also been prepared by registered consultants.

4 Project Description

4.1 Project Proponent

This project is proposed by Seagull Group Pvt Ltd. The project is to upgrade and undertake redevelopment at Thudufushi island resort. The redevelopment component of the project includes to develop 21 new water bungalows, 2 water bungalow suites, an over water reception, bar, restaurant, sea plane platform, a sewerage treatment plant, increasing the capacity at power house and desalination plant to cater for additional demands. The redevelopment project would also deepen the existing channel, development of a submerged breakwater on western side, repair the breakwater on northern side of the island and undertake beach nourishment on western side of the island. Seagull Group has been operating Thudufushi for many years and hence is a company known for its service in the hospitality industry in the past two decades. Seagull Group is owned by multiple shareholders. The shareholders of Seagull Group are all experienced industry personnel. The new development will increase the bed capacity 94 beds to 144 beds.This is an increase in bed capacity over 50 percent.

4.2 Project Location and Study Area

The project takes place in the island of Thudufushi, located inside south Ari atoll (see Figure 1). Thudushi Island resort is expected to be closed for the upgrade and redevelopment on 1st May 2010.

4.3 Geography

The island is located at about latitude of 3°45'25.14"N and longitude of 72°40'05.53"E. The island is located on eastern side on a large isolated coral reef system, oval in shape with the widest area on the west to east orientation and narrowest portion on the east.

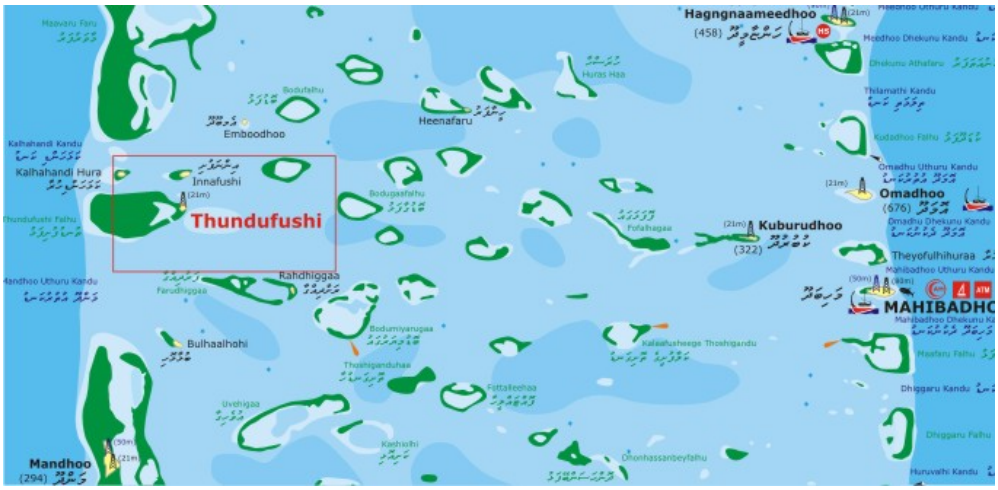


Figure 1: Location of Thudufushi in south-Ari Atoll (Map by: Water Solutions)

In March 2010, the perimeter of the island from the shore line measured 700.13 meters (from high tide line) with a total area of the island accounting to approximately 32,787.20 m2 (from the high

tide line) and 22,739.10 m2 (from the vegetation line). The registered land area of the island is 40,007.38 m2

4.4 Need and Justification

4.4.1 Need to Redevelop and Upgrade the Resort

4.4.1.1 Diversifying the tourism product

Thudufushi island has been in operation without any overwater structures since it was opened in early 1990's. The resort has not undergone any major upgrade since the resort was opened, but it has constantly invested in up keeping the Resort at a very high standard of a product in line with the new tourism product of the Maldives. The tourism product of the Maldives has undergone many revolutionary changes since the resort was opened in early 1990s with the formulation of the second and third Tourism Master Plan.

Tourism in the Maldives is rapidly expanding with tourist arrivals increasing at about 60% between 1990 and 1995 and about 50% from 1995 to 2000. However, the tsunami of December 2004 and global financial crisis has left the industry crippled requiring additional infrastructure and investments. Therefore, there is a need to create added capacity to cater for the growing tourism industry in the Maldives to brand the resort product as to cater the tourism product the Maldives offer as a destination.

One of the key tourism product which Maldives is strong as a destination is the overwater bungalows. Overwater real estate product is on the key strength of the Maldives tourism industry. Hence the proposed upgrade and redevelopment is to develop overwater structures and to include additional infrastructures including those to protect the island's fragile environment. The proposed project would bring some modifications to the existing infrastructure which includes expansion of the existing powerhouse, desalination system and development of a sewerage treatment system.

In order to be competitive in the market, diversifying the services available in the island is urgently required. Therefore, diversifying the product to an internationally marketable resort having different levels of accommodation and facilities to offer is required. Having additional beds, in accordance with the tourism regulations, in the resort will be economically feasible to invest for upgrading the property to be competitive in the market. In addition, Maldives Tourism Industry will be benefited in terms of bed capacity and its income. Therefore, the justification to undertake this project is based on diversifying service.

4.4.1.2 Coastal protection and beach replenishment

Erosion is a critical environmental problem at Thudufshi since the management of beach of the island has been regulated by the Ministry of Tourism's Environmental regulations.

The beach at Thudufushi has been maintained by a set of groynes and a submerged breakwater built on northern side of the island. The groynes at the island has been built by coral rubbles on western and southern side. In the past, the groynes fields have been utilised as a soft engineering solution to the erosion issue by building these when and where it was needed. The groynes which

were built to protect the beach on the western side of the island during the south west monsoon would be removed during the north east monsoon.

However, due to the new Tourism Environment Regulations, the management of the resort cannot built any structures on the coastal area of the island without a written approval from the Ministry of Tourism. The management of the resort has been trying to get the approval to underage urgent coastal protection at Thudufushi since October 2009.

Hence, the coastal protection component has been included as part of the redevelopment project at Thudufushi. This component will include the development of a submerged breakwater on western side and southern of the island as to mitigate the loss of beach on western side and southern of the island, replenished the lost sand by pumping sand to the areas where beach has lost on southern side, undertake repairing of the existing coral and coral rubble breakwater which is located on northern side of the island. [Note: a permit to replenish the sand has been granted by Ministry of Tourism through an EIA titled: EIA for the Beach Replenishment Project at Thudufushi – March 2010. Hence the beach replenishment component is not included with the redevelopment project]. The existing access channel to the island has become very shallow and it cannot be used in low tide and hence deepening the channel has been included as part of the redevelopment project.

4.5 Project duration

The project is expected to take eight months starting from the approval of the EIA. A tentative schedule is annexed to the report. It is estimated that the work will begin in July.

4.6 Project boundary

This project is limited to Thudufushi. The project boundary is illustrated below.

Figure 2: Project boundary

4.7 Existing infrastructure in the island

Thudufushi is a resort which is presently been operated under a resort operation license issued by Ministry of Tourism. Hence the resort has all the infrastructure and facilities that is required to be in a resort. The following is a list of existing infrastructure in the island.

Guest bungalows, Restaurant, bars, spa, discotheque, water sports centre, shop, power house, mosque, desalination plant, incinerator and waste management area, fuel storage tanks, compressor room, diving equipment room, housekeeping, workshop area, store

4.8 Description of the project components

This project involves two components; upgrading and redevelopment component. See the attached site plan appended.

1.1.1 Upgrading of existing facilities

4.8.1.1 Powerhouse

The redevelopment will install a 400 KW generator with a secondary residential silencer with attenuation of better than 85 dB (A) at 1 meter. The soundproofing would ensure a total free field sound level of not more than 85 dB (A) at full load outside the power house. The generators at the power house would be arranged for waste heat recover from water jacket, with skid mounted heat exchanges, three way diverting valves, motorized stop valves & thermostat control equipment.

4.8.1.2 Desalination System

The redevelopment will install additional 150 MT/Day reverse osmosis desalination plant. The plant can produce fresh water from sea water with TDS of 375,000 ppm at 25 °C. The water produced from the plant would have a quality TDS<500 ppm at a pressure of less than 2 Bar. The system efficiency shall be not less than 35%.

1.1.2 Redevelopment Component

4.8.1.3 New Over water structures

The proposed development include the construction of a restaurant, sea plane platform, reception and housekeeping hut. The proposed area for the new overwater structures including the water bungalows and water bungalow suites is 1,843 m².

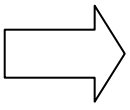
4.8.1.4 Construction of new 23 Water Bungalows

The bungalows will be developed on the western side lagoon with an offset of 10 from the reef line. (Refer to the attached site plan attached as an annex). The water villas will be constructed on concrete columns. Precast columns will be placed on lagoon floor (See the engineering details of the concrete column footings). The footings and columns will be constructed on the island. The columns will be carried out by excavators and placed in locations which are marked on the lagoon by the surveyors. Once this process is complete, horizontal beams will join the piles and the water villa building will be constructed. Electrical wiring / fitting and plumbing will then be fixed. Refer to the site plan attached.

4.8.1.5 Construction of new Sewage System House

Currently, the island's waste water is treated using septic tanks buried underground. With the new redevelopment, a brand new treatment system, with a capacity of treating 250 m³ per day will be installed. Existing septic tanks will be sealed and disconnected from existing sewerage system. After completion of New STP plant and its installation, remaining sludge in existing septic tanks will be emptied to the septic tanks of the STP system and will be treated accordingly.

The sewage network will collect wastewater from the individual rooms and other buildings and transport them to the treatment plant where wastewater will be treated. Water, not used for irrigation will be discharged to the sea via the existing sea outfall located on northern side of the island. The location of the sea outfall is indicated on the site plan, attached as an annex. The following illustrations depict the input and output characteristics of wastewater.

Influent characteristics		**Expected effluent quality**
pH : 7.0 – 8.0 BOD5 : 250 mg/L Suspended solid : 125 mg/L Flow Rate : 250m3/d (estimated)		pH : 7.0 – 8.0 BOD5 : 20 mg/L Suspended solid : 50 mg/L Clear & free from odour

4.9 Coastal protection

4.9.1 Construction of a submerged breakwater

It is been proposed that a submerged breakwater is be built on western side and south western of the island to protect the beach. The existing breakwater on northern side of the island which is made from coral rubble would also be repaired using geotextile bags. Offshore breakwaters are structures built approximately parallel to the beach but some distances offshore. The purpose of offshore breakwaters is to reduce the intensity of wave action in inshore waters and thereby reduce coastal erosion. Submerged breakwaters are similar to natural reefs. Submerged breakwaters or artificial reefs, unlike emerged breakwaters, allow sand to pass over their crest and aids long-shore transport between the reef and the shoreline. Then beach would be replenished with sand. The beach would be monitored in the monitoring programme as outlined in the monitoring section.

Based on existing wave conditions in the area, the following design has been suggested.

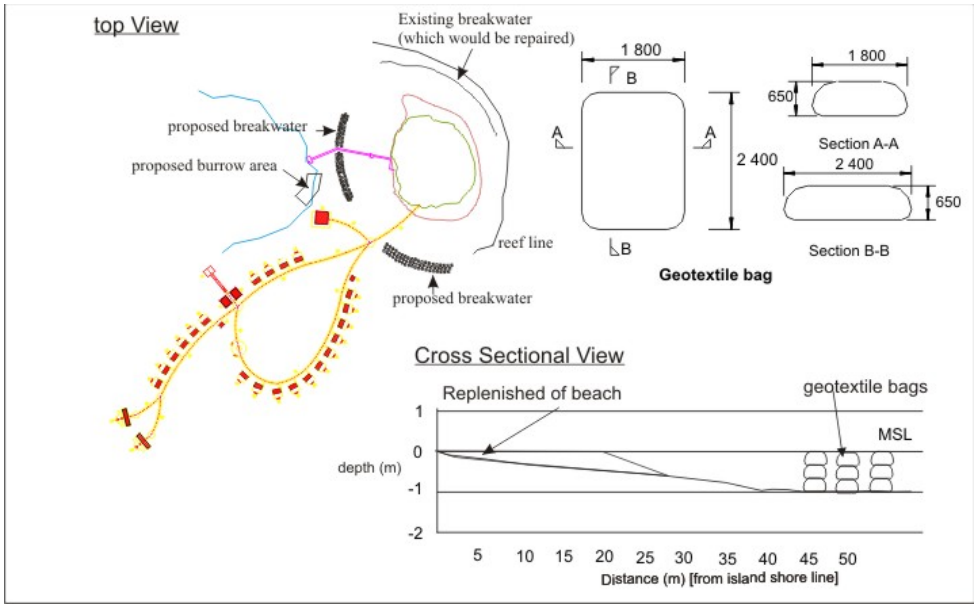


Figure 3: coastal protection plan for Thudufushi Island Resort

Figure 4: cross-section of a breakwater made from geotextile bag

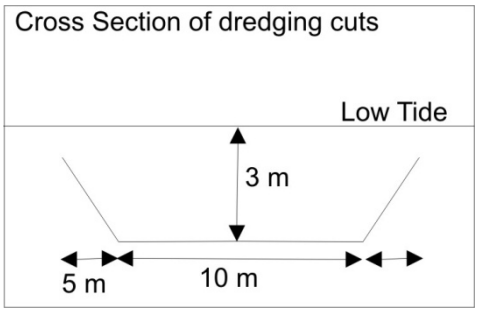
The breakwater has been designed to create an artificial reef using geotextile bags. The geotextile bags will be filled with sand and placed in three rows. The distance between rows would be 5 meters. A row is made of discrete geotextile bags. The distance between bags in a row is about 4 – 5 meters.

The length of the new breakwater on western side of the island is about 150m and southern side is 120m and the breakwater on northern side of the island would be 200m. The gap between the geobags is about 2-5 m. Figure 4 shows the location of the submerged breakwaters and their possible orientation.

4.9.2 Deepening the existing channel

The existing channel which is located on the north western side of the island can be used on high tide by boats. The proposed development would block the existing channel which is located on southwestern side of the island. Even this channel has become very shallow at less than 1.0 m at low tide making the boats difficult to access the island in low tide causing disruption to the supply to the island. Hence, it has been proposed to deepen the channel which is located on north western side of the island as to allow easy and safe access to the island by boats.

The dredging of the channel would be carried out using a excavator with a bucket size of 1.5 m^3. Dredging phase will be carried out in the southwest monsoon period. This is to minimise the impact of the dredging on the reef environment of the island. See diagram below for the cross section of the dredging cut of the channel



The material excavated will be loaded on barge and barge will carry it the beach for the nourishment. The impact of dredging will be monitoring as outlined in the monitoring plan. The dredge material from dredge areas will be used for the beach nourishment.

4.9.3 Reusing coral from demolition waste

Twenty years ago, the most common material for the construction of the resorts was corals. These were mined from reefs with a permit when the island was developed. As such, Thudufushi was also built with legally obtained corals. However, due to the demolition of some of the old buildings and walls, the redevelopment project at Thudufushi would generate corals in the demolition waste stream.

The concept of redevelopment is to capture the architectural signature that was originally created at the island. Hence, with this intention, the new buildings which are constructed with building blocks is being planned to be decorated with a layer of corals that have been recovered in the waste stream. Also, since one of the principles of waste management is to recover what is usable and valuable in the waste stream, it would be a waste to dispose the corals would be recovered and separated from the demolition waste stream. Hence it is proposed to reuse the recovered corals in the waste stream, if such permit is given by EPA.

4.10 Construction schedule, process and methodology

As soon as the EIA is approved and a decision note is issued, the upgrade and redevelopment project will begin at Thudufushi. Mobilisation will start as the first activity of the project. The construction will be undertaken in the planned time period to reduce cost and also reduce the environmental damage.

4.10.1 Work methods for new structures

All water bungalows, water bungalow suites, bar, reception, lagoon spa & overwater restaurant will be constructed on concrete columns and footings. This method involves constructing the concrete columns and footings on land and then transporting them to the lagoon by an high rise excavator. The footings will then be placed on their fixed locations and they will be connected by the supporting horizontal beams. Once these horizontal beams are in place, then construction of the water bungalow and overwater structure will be undertaken. Afterwards, plumbing, electrical and fire networking lines will be laid.

4.10.1.1 Management of waste

The executive arrangement in place for managing construction stage waste is simply by stockpiling the waste for the shortest duration possible, in the island. The combustible waste will be incinerated or burnt on the island. The residual waste then transport immediately to facility or place identified by the Ministry of Housing, Transport and Environment and communicated to the developer through the Decision statement issued for this EIA. This operation is not expected to be disrupted and the management of the waste will not be a significant issue as waste is regularly transferred to Thilafushi.

4.10.2 Montreal Protocol

The upgrade and redevelopment considers the Maldives commitments to the implementation of the Montreal Protocol on Substances that depletes the Ozone Layers. The accelerated HCFC phase-out schedule for Maldives for consumption and production of HCFC as agreed Montreal Protocol is presented in table below. Hence the new infrastructure that would be added for the development in the area of cooling and refrigeration systems would comply with the national requirements that had been outlined and communicated by the Ministry of Tourism.

Control measure	**Schedule**
Baseline	Average of 2009 & 2010
Freeze	2013
90% (10% reduction)	2015
65% (35% reduction)	2020
32.5% (67.5% reduction)	2025
0% (100% reduction in manufacturing)	2030
Annual average consumption of 2.5% (for servicing)	2030 to 2040

4.10.3 Carbon Emission

The upgrade and redevelopment will demand, daily additional 1,000 L of diesel to generate power for the island. It is estimated, using reference approach as outlined by IPCC, that additional 3,072 Gg of carbon dioxide will be emitted from the proposed redevelopment. The actual carbon emission from the energy sector from the increasing in demand would be 837.9 Gg.

4.10.4 Expected environmental conditions

Since the project will take place in south-west monsoon, environmental conditions can at times influence the work. But June and July, being the worst period of south-west monsoon, working conditions is not expected to be of any significance as the construction will most likely take place in August. Despite this, the strategy would be to complete the construction of water villa columns as soon as possible. This would give more window for construction workers to undertake other works rather than causing delays due to bad weather. The most difficult part of the construction would be placing the concrete columns of the water villa footings.

4.10.5 Risks associated with the project

There are few risk factors associated with this project that could possibly have financial and environmental implications. First, there is the risk of project delays caused by bad weather as the construction period falls within the south-west monsoon. This risk can be minimized if the footings of the water villas could be completed within the minimum period. This risk will also be minimized by awarding the contract to only experienced contractors with experience in working in similar situations. Therefore, work delays will be least impacted. Secondly, there is the risk that the marine environment can be damaged severely if the construction process is not carefully managed. This can occur if unskilled labours are used and also if the workforce is not briefed about the sensitive environment.

4.11 Project Inputs and Outputs

4.11.1 Project Inputs

The types of resources that will go into the project and from where and how these will be obtained are given in table 1 & 2.

Table 1: Matrix of major inputs during construction period

INPUT RESOURCE(S)	SOURCE/TYPE/QUANTITY	HOW TO OBTAIN RESOURCES
Construction workers (300)	Maldivians and foreigners	Already available for resort construction
Water supply (construction period)	Existing Desalination plant in the island for construction period	100 m3/day desalination plant
Electricity/Energy (construction period)	Existing Diesel generators in the island for construction period	800kva, generator
Construction machinery	Concrete Mixer, barge, excavators, and general construction tool	Already available for resort construction
Telecommunications	Island's Phone Systems, Fax Machines, E-mail and internet facilities	Already this services is available in the island
Transport (sea)	Sea transport by dhoni and speed boats. Materials to be transported in cargo vessels/dhoni or large barges. All construction debris will be transported to a facility identified and communicated by Ministry of Environment via cargo vessels/dhoni	Setup already established.
Food and Beverage during construction period	Mainly imported sources except a few locally available.	Already setup available
Fuel, Kerosene and LPG	Light Diesel, LPG Gas, Petrol, Lubricants	Already setup available

4.11.2 Project Outputs

The type of outputs (products and waste streams) and what is expected to happen to the outputs are given in the next table.

Table 2: Matrix of major outputs of environmental significance during construction stage

PRODUCTS AND WASTE MATERIALS	ANTICIPATED QUANTITIES	METHOD OF DISPOSAL / CONTROL
Sewage and wastewater Grey water/laundry wastewater	Estimated to be at 100 litres/person/day	Utilize the existing disposal system in the resort.
Construction waste from construction activities,	5 to 10 cubic meters of debris weekly	Debris sent to waste management facility identified by Ministry of Environment and

PRODUCTS AND WASTE MATERIALS	ANTICIPATED QUANTITIES	METHOD OF DISPOSAL / CONTROL
mainly timber and other building materials.	during the construction period and general construction waste. This includes, timber, empty cement bags, aggregate, steel bars etc.	communicated through the Decision Statement
Waste oil and grease	5 to 10 L (monthly) as only small excavators will be used to place the villa footings.	waste management facility identified by Ministry of Environment
Noise	Localised to the island environment	No controls are need as the level of noise would not be significant. Only localised to the island environment only.
Air pollution	Limited quantities of dust .	Mainly arising as a result of dust emission from the construction work such as cement mixing, and other processes. Only localised to the island environment only.

5 Methodology

The section covers methodologies used to collect data on the existing environment. The key environmental components of the project under consideration are coral reef areas, the marine environment and the coastal environment. The following data collection methodologies were used during the field visit undertaken in December 2009 and March 2010.

5.1 General Methodologies of data collection

Conditions of the existing environment were analyzed by using appropriate scientific methods. The environmental components of the study area were focused for marine and coastal environment. The marine environment of the island covered the coral reef and the lagoon. Coastal environmental data collection involved taking beach profiles from selected locations and assessing the coastal environment.

5.2 Mapping and Location identification

The island, including shore line including the low tide line, mid tide line and high tide line and vegetation lines were mapped for the assessment. Mapping was undertaken using hand held differential GPS and available statellite photos. The location of data collection sites were marked using handheld GPS. These data collection points include marine water sampling locations, marine survey locations and beach profile locations.

5.3 Marine Water Quality

One of the main environmental components that would be affected by implementing the project would be marine environment. Water quality was assessed during the field trip in March 2010 by collecting samples and testing them at National Health Laboratory. The locations, frequency and parameters to be monitored are given in the monitoring programme outlined later in the EIA report.

5.4 Marine Environment surveys

Marine environmental surveys were conducted to collect data on key environmental components (i.e. the coral reef system and the lagoon), that will be impacted due to the construction works. Three methods were primarily used to collect data, namely:

- Detail LIT for sessile benthic community estimation, complimented by photo documentation,
- Fish census and
- Qualitative surveys through visual observations.

The purpose of the surveys is to define and establish marine environmental baseline conditions for impact evaluation during and after the proposed project. Surveys are based on standard marine environmental surveys so that they can be repeatedly carried out to monitor and record changes and assess possible impacts on the marine environment from the proposed work activities. They

include quantitative and qualitative methods. In addition, a series of photo images using an underwater digital camera (SONY DCS-T300, 10 MPix) was taken along the transect lines and in close vicinity around them to support a qualitative survey for benthic assessment studies.

5.4.1 Line Intercept Transects (LIT)

Line Intercept Transect (LIT) surveys were carried out to assess the benthic types and species at the surveyed sites. This method uses life form categories to assess the benthic sessile community of reefs and it is possible to incorporate taxonomic data as well. LIT surveys can be used to evaluate the community structure of corals in terms of species composition and diversity patterns in different zones on a reef. LIT method also provides a rapid estimate of percent cover of corals, algal cover, and cases of other prominent organisms as well as bare substratum.

Quantitative percent cover of the reef community can be obtained using this method and it can be repeated to obtain changes over a period of time. Disadvantages of this method include difficulty in standardizing the life form categories and the limitation of the data collected, to information on percent cover and relative abundance (English et al. 1997). LIT surveys produce valuable data even though they are time consuming and require considerable effort and skills to record notes underwater. To demonstrate the existing situation of the benthic community of the island's house reef, particularly the live coral coverage (LCC), LITs of 20m length were placed randomly along the reef crest at the proposed redevelopment area. In addition, photos were taken and the sites were qualitatively assessed.

5.5 Coastal environment

Data collected on coastal environment included beach profiles, existing coastal defence structures, beach composition, beach width, shore line and vegetation line. All beach profile locations were marked on GPS maps and their geographical coordinates were marked on a map. Beach profiles were taken as baseline data to make comparisons during monitoring programme so that any changes resulting from proposed project can be assessed accurately. Beach profiles were measured using Auto levels and a staff.

5.6 Bathymetry

A detailed bathymetric survey was undertaken in the lagoon using Echosounder attached to a boat. The levels were then corrected for mean sea level and represented in a map. Bathymetric map is attached as an annex.

5.7 Aerial photos

A satellite photo was used in the assessment. Aerials photos provide useful information such as assisting the analysis of marine environment, identifying wave patterns and changes to shoreline and also vulnerable areas of the island. Satellite aerial photos were from Google Earth. This has been used extensively in this EIA and has been presented in different sections of the report.

6 Existing Environment

This section discuss the existing environmental conditions. In doing so, the section will begin with an outline of the general environmental conditions in Maldives, including the climatic settings, tides, wind and wave. As there are no specific such data for individual islands, these data will form the basis for describing the conditions for the islands of the Maldives. The data collection on climate and sea level are undertaken from weather stations based strategically throughout the Maldives, including Male', international airport, Hulhule. The nearest weather station to Thudufushi is located in Hulhule island.

Describing and analysing climate and weather information will provide projections and baseline conditions for islands that are close to a specific weather station. Existing coastal and the marine environments are described later. Therefore the climatic data from Hulhule has been applied for Thudufushi as it is the closest weather station.

6.1 Existing Coastal environment

6.1.1 Geological Setting and Island Formation

Thudufushi is a circular shaped island lying on its own reef system on western side of the Ari Atoll. The reef system of the island is oriented in a east-westerly direction and has a oval shape. The reef system is sheltered from other reefs in north east monsoon but the there is no protection from effects of oceanic swells in south west monsoon when the wind direction is from west. Hence the oceanic swells and wind-generated waves play an important role in island formation and sediment transport around the island. Since the reefs on the eastern side of the island do not offer the same degree of protection as those on the west, the effects of the northeast monsoon on the island is expected to be greater than that of the southwest monsoon.

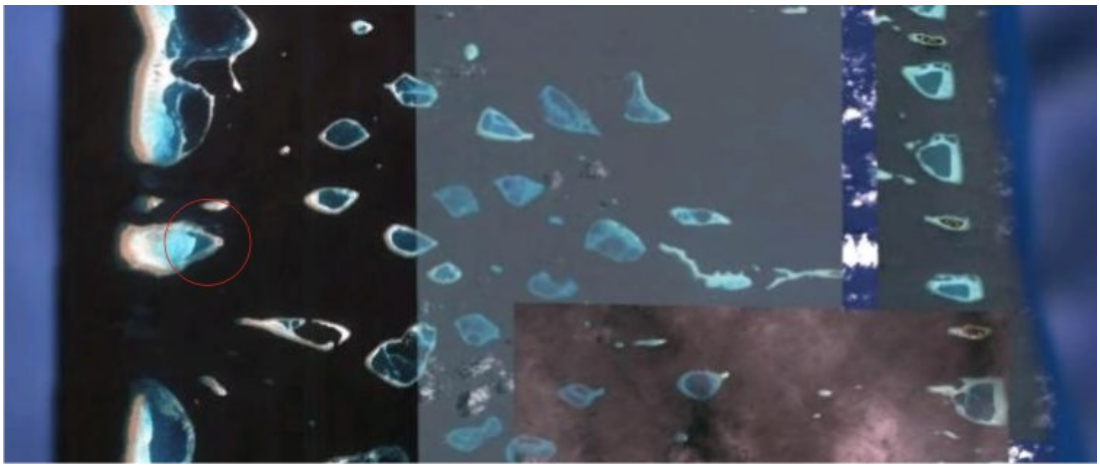


Figure 5: Thudufushi located on western side of Ari Atoll (Photo: Google Earth)

The closest islands are Moofushi Island Resort and Himandhoo island located 10 km north and south of Thudufushi. Himandhoo is an inhabited island found in south Aril Atoll.

In March 2010, the perimeter of the island from the shore line measured 700.13 meters (from high tide line) with a total area of the island accounting to approximately 32,787.20 m2 (from the high tide line) and 22,739.10 m2 (from the vegetation line). The registered land area of the island is 40,007.38 m2.

There have been dynamic changes to the vegetation and shorelines of Thudufushi over the past. These changes are mainly due to natural evolution of the island but have also been affected to a great extent by the different changes that have been made in the name of coastal protection in the past.

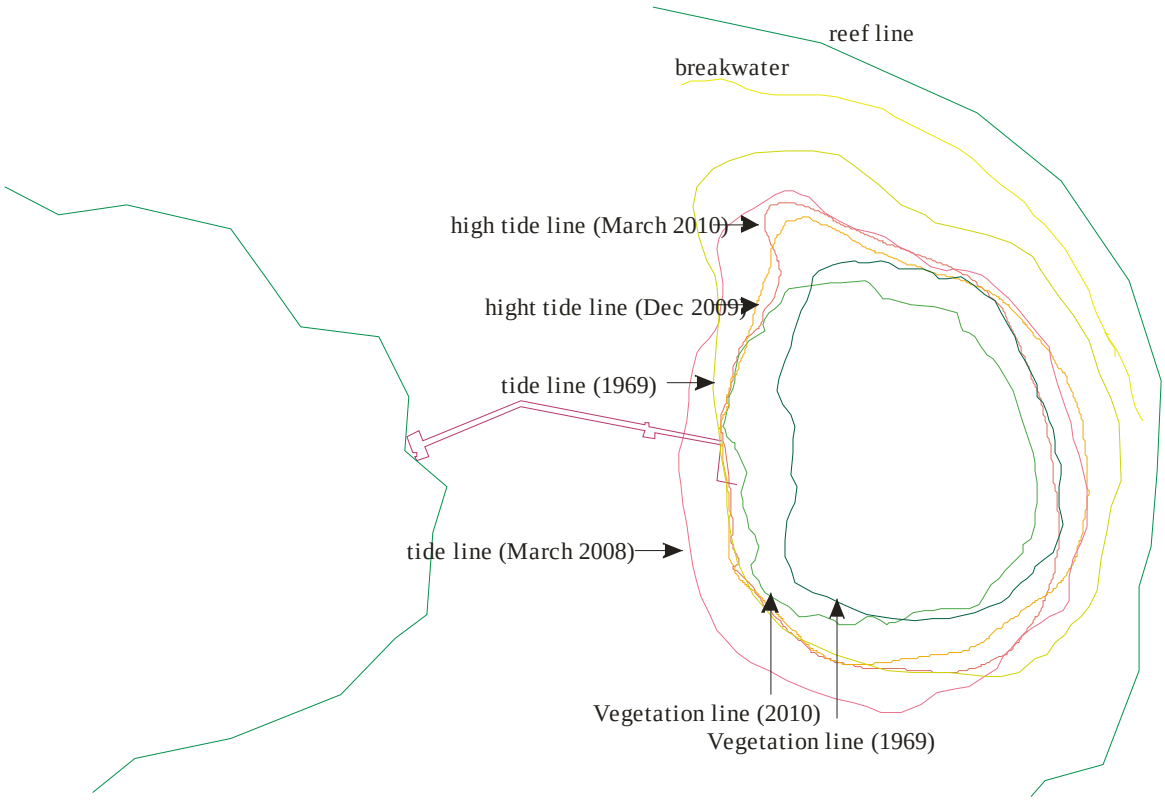


Figure 6: Comparison of Thudufushi vegetation and beach lines in 1969, 2008 , 2009 & 2010

According to the geological formation, vegetation and soil characteristics of the island the island is young and growing from a nodal point in the east corner of the reef system. The dynamic nature of the island can be seen from Figure 5, especially the shift in coastal vegetation.

The eastern reef extent is much smaller than the western reef extent. The western side lagoon gradually slopes into a deeper vilu which is about 150m from the beach. The vilu area is about 53 hectares. This vilu has been used for seaplane platform and vessels are moored to buoys in the area.

Figure 7: Satellite photo (March 2008) from Google Earth

From Figure 5 as well as the aerial photo shown in Figure 7 it can depicted that the island appears to grow in the westerly direction with the island building occurring mainly during the northeast monsoon. However, there is very little sediment deposition during this period compared to the sediment deposition potential during the southwest monsoon. This is because the submerged breakwater on northern side of the island had a created calmer condition as such the movement of the beach had been restricted than it used to be.

6.1.2 Beach erosion

Thudufushi has undergone severe erosion in the past 50 years. Table 3 show that the area covered by the vegetation line and the land area covered by the low tide line has fallen since 1969. According to the survey that was carried out by Water Solutions in December 2009 and March 2010, the total land area of the island has been reduced by 7,220 m^2, that of the registered land area at the Ministry of Tourism. The reduction of the land areas has been mainly due to the erosion that is seen in the western side of the island.

Period	Vegetation (m2)	Vegetation area change compared to 1969	Island Area (m2)	Island area change compared to registered area (m2)	Beach Area (m2)	Beach Line (m)
1969	22,372		22,739	(17,268)	367	815
Mar-08	22,739	367	42,924	2,917	20,185	777
Dec-09	22,739	367	33,559	(6,449)	10,819	700
Mar-10	22,739	367	32,787	(7,220)	10,048	684

Table 3: change of Thudufushi's land area

6.1.3 Climatic Setting

The Maldives, in general, has a warm and humid tropical climate with average temperatures ranging between 25°C to 30°C and relative humidity ranging from 73 per cent to 85 per cent. The country receives an annual average rainfall of about 2000mm. There is considerable variation of climate between northern and southern atolls. Table 4 provides a summary of key meteorological findings for Maldives. General studies on climatic conditions of Maldives were taken into account during study as local level time-series data are limited for longer periods at the nearest meteorological station.

Table 4: Key meteorological information

Parameter	Data
Average Rainfall	9.1mm/day in May, November 1.1mm/day in February
Maximum Rainfall	184.5 mm/day in October 1994
Average air temperature	30.0 C in November 1973 31.7 C in April
Extreme Air Temperature	34.1 C in April 1973 17.2 C in April 1978
Average wind speed	3.7 m/s in March 5.7 m/s in January, June
Maximum wind speed	W 31.9 m/s in November 1978
Average air pressure	1012 mb in December 1010 mb in April

Monsoons

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

Rainfall

Annual average rainfall in Maldives is about 1900mm. There is a marked variation in rainfall across Maldives with an increasing trend towards south. The annual average rainfall in north is 1977mm and for south is 2470mm.

The southwest monsoon is known as the wet season with monthly average rainfall ranging from 125-250mm. The northeast monsoon is known as the dry season with average monthly rainfall of 50-75mm.

The intensity of rainfall is a concern in the Maldives since intensity is high with low frequency. However, excessive rainfall is not a concern for Thudufushi since the island does not cup towards the middle but rather diverts the runoff towards the western shore. Baseline beach profiles taken during the field trip in May 2009 indicate that the island is slightly higher on the eastern side than on the western side for obvious reasons.

Temperature

Daily temperatures of Maldives vary little throughout the year with a mean annual temperature of 28°C. The annual mean maximum temperature recorded for Male' during the period 1967-1995 was 30.4°C and the annual mean minimum temperature for the same period was 25.7°C. The highest recorded temperature for Male' was 34.1°C on 16th and 28th of April 1973. The hottest month recorded was April 1975 with a maximum monthly average temperature of 32.7°C, the next highest being 32.6°C in April 1998. The lowest minimum average temperature of 23.7°C was recorded in July 1992.

Wind

Wind has been shown to be an important indirect process affecting formation development and seasonal dynamics of the islands in the Maldives. Winds often help to regenerate waves that have been weakened by travelling across the reef and they also cause locally generated waves in lagoons. Therefore winds are important here, as being the dominant influence on the sediment transportation process (waves and currents). With the reversal of winds in the Maldives, NE monsoon period from December to March and a SW monsoon from April to November, over the year, the accompanying wave and current processes respond accordingly too. These aspects have ramification on the seasonal sediment movement pattern on the islands and also the delivery/removal of sediments from the reef platform/island.

The two monsoon seasons have a dominant influence on winds experienced across Maldives. These monsoons are relatively mild due to the country's location close to the equator and strong winds and gales are infrequent. However, storms and line squalls can occur, usually in the period May to July; gusts of up to 60 knots have been recorded at Male' during such storms.

Wind was uniform in speed and direction over the past twenty-plus monsoon seasons in the Maldives. Wind speed is usually higher in central region of the Maldives during both monsoons, with a maximum wind speed recorded at 18 m.s-1 for the period 1975 to 2001. Maximum wind speed recorded in the south was 17.5 m.s-1 during the period 1978 to 2001. Mean wind speed was highest during the months January and June in the central region, while wind speed was in general lower and more uniform throughout the year in the southern region. Wind analysis indicated that the monsoon was considerably weaker in the south. During the peak months of the SW monsoon, southern regions have a weak wind blowing from the south and south-eastern sectors.

Table 5 summarises the wind conditions in Thudufushi throughout the year. Medium term meteorological data from Malé International Airport weather station was used in this analysis.

Table 5: Summary of general wind conditions in Thudufushi

Season	Month	Wind
NE - Monsoon	December	Predominantly from NW-NE. High Speeds from E
	January	
	February	
Transition Period 1	March	From all directions. Mainly W. High Speeds from W
	April	
SW - Monsoon	May	Mainly from W. High Speeds from W
	June	
	July	
	August	
	September	
Transition Period 2	October	Mainly from W. High Speeds from W
	November	

Table 6: Scatter diagram for Thudufushi. Wind speed versus wind direction (%). All Year (1999) - (adapted from DHI, 1999)

Wind speed (m/s)	Wind Direction							
	NE	E	SE	S	SW	W	NW	N
1	0.94	0.95	0.96	1.19	1.02	0.97	0.82	0.78
2	2.02	1.95	2.13	1.91	1.81	1.92	1.57	1.46
3	2.30	2.79	2.98	2.74	2.74	2.99	2.31	2.12
4	2.04	2.26	2.75	2.91	2.86	2.90	2.15	1.91
5	1.45	1.97	2.30	2.21	2.98	2.49	1.51	1.27
6	0.54	0.99	1.42	0.94	1.79	2.36	1.02	0.80
7	0.10	0.32	0.74	0.28	0.91	2.04	0.43	1.10
8	0.05	0.06	0.26	0.11	0.52	1.39	0.19	0.04
9	0.01	0.01	0.16	0.01	0.19	0.94	0.10	0
10	0	0	0.05	0	0.04	0.75	0.04	0
11	0	0	0	0	0	0.46	0.01	0
12	0	0	0	0	0	0.07	0.01	0
13	0	0	0	0	0	0.02	0	0

Since most of the project components including water bungalows, arrival platform and jetty face the western side of the island, which is open from wind-generated waves during the southwest monsoon because the island is in the lee of the island's reefs, these structures as well as the beach on the western side would have wind and wave impacts. The western side would be usually in the lee of the island especially during the peak tourist season, which is the northeast monsoon.

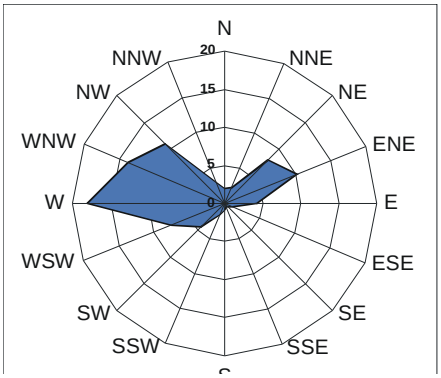


Figure 8: General wind rose diagram for the Maldives

The leeward sides for the island as shown in the following figure have been depicted based on the wind-rose diagram shown above. It is illustrated here that the existing thundi area will see huge accretion during the northeast monsoon. However, due to the breakwater on northern side of the island, erosion from this area during the southwest monsoon would be slower, as a result of which the thundi on the western side would not form on western side of the island. Hence the island has a net deficit of sediment movement from western side to northern side resulting in erosion on western side of the island.

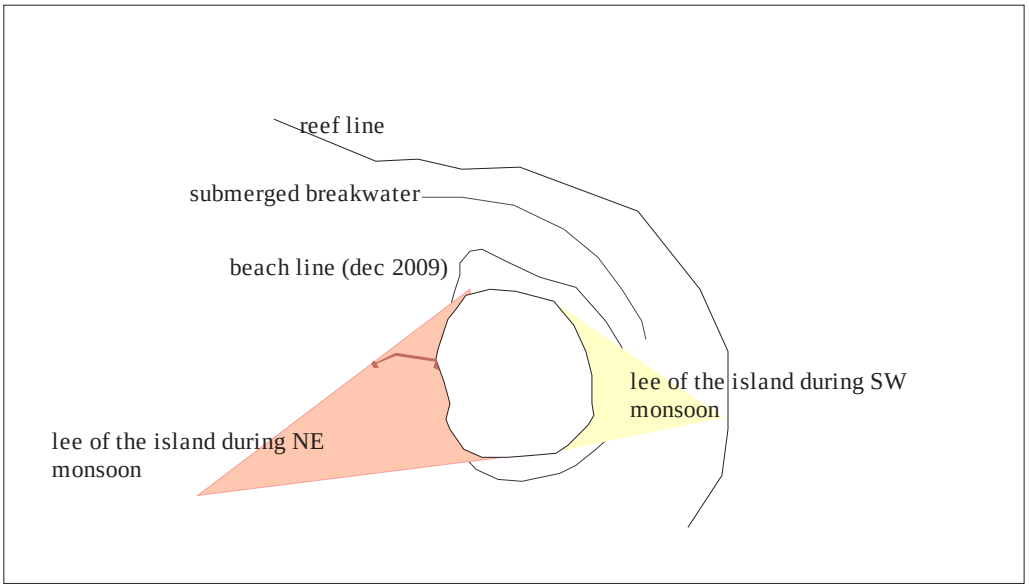


Figure 6-9: Prediction of lees of the island during the two monsoons

Waves

Wave energy is important for sediment movements and settlement, and it is also a crucial factor controlling coral growth and reef development. Waves have been attributed to the diversity and the abundance of coral and algal species. These aspects have implications for the type and perhaps the supply of sediment s into the island.

Studies by Lanka Hydraulics (1988a & 1998b) on Malé reef indicated that two major types of waves on Maldives coasts: wave generated by local monsoon wind and swells generated by distance

storms. The local monsoon predominantly generates wind waves which are typically strongest during April-July in the south-west monsoon period. During this season, swells generated north of the equator with heights of 2-3 m with periods of 18-20 seconds have been reported in the region. Local wave periods are generally in the range 2-4 seconds and are easily distinguished from the swell waves.

Distant cyclones and low pressure systems originating from the intense South Indian Ocean storms are reported to generate long distance swells that occasionally cause flooding in Maldives (Goda, 1988). The swell waves that reached Malé and Hulhule in 1987, thought to have originated from a low pressure system of west coast of Australia, had significant wave heights in the order of 3 metres.

In addition, Maldives has recently been subject to earthquake generated tsunami reaching heights of 4.0m on land (UNEP, 2005). Historical wave data from Indian Ocean countries show that tsunamis have occurred in more than one occasion, most notable been the 1883 tsunami resulting from the volcanic explosion of Karakatoa (Jameel, 2006). Thudufshi was not severely affected by the tsunami of 26 December 2004.

Thudufushi is exposed to swells and high waves generated by swells from Indian Ocean during the southwest monsoon and short wind-generated waves from the atoll lagoon on the eastern side during the northeast monsoon. Impact of waves is strongest on the western side of the island as this side would be prone to waves during southwest monsoon. However, the southeast side will have the minimum impact from waves according to predictions based on the wind rose diagram shown in Figure 8.

Waves breaking on the eastern side are stronger because of the narrow reef extent and wave formation patterns on this side. Due to severe erosion at the northern side of the island a breakwater had been build. This has resulted the built of beach on this side of the island.

General wave conditions in Thudfushi is summarised in Figure 10 (adapted from DHI, 1999).

Figure 10: Summary of wave condition in Thudufushi

Season	Total	Long Period	Short Period
NE - Monsoon	Predominantly from E-S. High Waves from W	From S-SW	Mainly E-NE. High waves from E
Transition Period 1	Mainly from SE-E	From S-SW	Mainly from NE-SE
SW - Monsoon	From SE-SW. Mainly from S. High Waves also from W	From S-SW	Mainly from SE-S. High waves from E
Transition Period 2	As SW monsoon	From S-SW	From SE-W. Higher waves from E

This aspect of climate will therefore have an effect on the design of any coastal infrastructure such as jetties and water sports activities planned for the resort.

Tides

Tides affect wave conditions, wave-generated and other reef-top currents. Tide levels are believed to be significant in controlling amount of wave energy reaching an island, as no wave energy crosses the edge of the reef at low tide under normal conditions. In the Maldives where the tidal range is small (1m), tides may have significantly important influence on the formation, development, and sediment movement process around the island. Tides also may play an important role in lagoon flushing, water circulation within the reef and water residence time within an enclosed reef highly depends on tidal fluctuations.

Currents

Studies on current flow within a reef flat in Male' Atoll suggests that wave over wash and tides generate currents across the reef platforms, which are also capable of transporting sediments (Binnie Black & Veatch, 2000). However, available information suggests that tidal currents are not strong due to small tidal range.

Generally current flow through the Maldives is driven by the dominating two-monsoon season winds. Westwardly flowing currents are dominated from January to March and eastwardly from May to November. The change in currents flow pattern occurs in April and December. In April the westward currents flow are weak and eastward currents flow will slowly take place. Similarly in December eastward currents flows are weak and westward currents will take over slowly.

Studies on current flow process within a coral atoll have shown that waves and tides generate currents across the reef platforms, which are capable of transporting sediments on them. Currents, like waves are also modified by reef morphology. Under low-input wave conditions (0.5m heights) strong lagoonward surge currents (>60cm/sec) are created by waves breaking at the crest. Studies on current flow across reef platforms have shown that long-period oscillations in water level cause transportation of fine-grained sediments out of the reef-lagoon system, while strong, short duration surge currents (<5sec.) transport coarse sediments from the breaker zone to seaward

margin of the backreef lagoon. Always sediment accumulates at the lee of high-speed current zones. Generally zones of high current speed (jets or rips, 50-80cm/sec) are systematically located around islands.

Data on current speed and direction around Thudufushi was measured on the day of the field visit. These are given in Figure 11. However, spot data taken on a single day would not yield sufficient data to understand coastal dynamics. Therefore, long term monitoring of data will be recommended in the monitoring programme proposed for the resort. Figure 11 provides an analysis of longshore currents around Thudufushi, based on past data from other projects and experience.

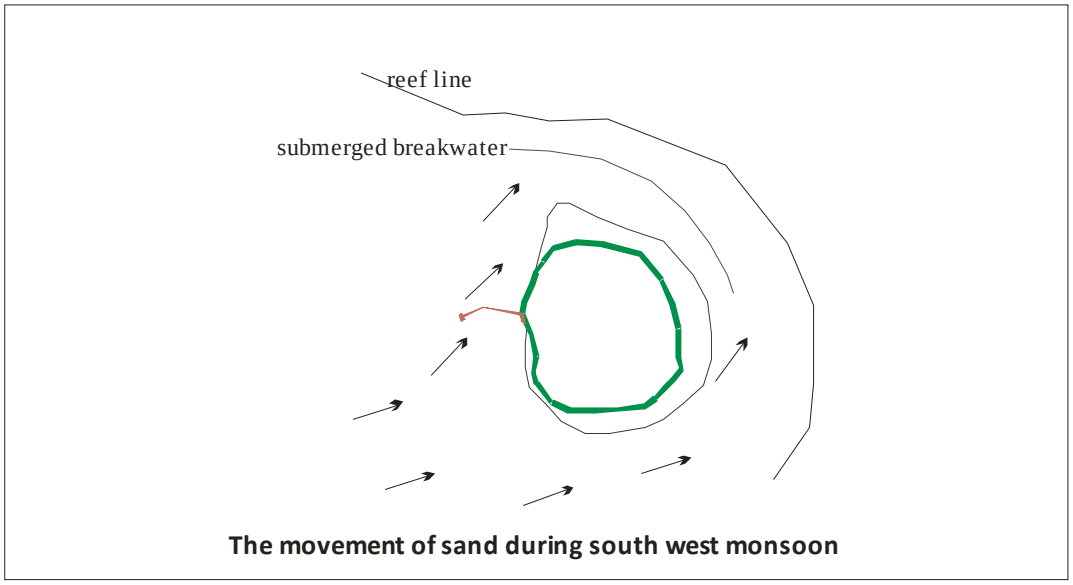


Figure 11: Longshore currents around the island during the southwest monsoons

6.1.4 Features of the Coastal Environment

The coastal environment was considered as a main component that would be affected by the development. The existing coastal dynamics were studied during field visits. Site specific data on the coastal environment including currents and sediment movement patterns were measured and studied. Beach erosion and accretion patterns around the island were studied using aerial photographs taken in 1969 and 2008 and survey of 2009 and 2010. Also, interviews with the manager who has been in Thudufushi for a considerable period of time has been useful.

The coastline was mapped using a differential GPS. This allowed measurement of the total area of existing beach. The implications of these baseline data are very important for future quantitative measurements as this will allow calculation of the beach loss or erosion or sediment accretion. A drogue survey was also undertaken in specific locations. Coastal vegetation was also mapped.

The coastal environment of Thudufushi comprised of mainly white sandy beaches, beach rubble, shallow lagoon or *falhu*, deep lagoon or *vilu* and coral patches. The figure represents the different features of the coastal environment of Thudufushi and a description of these different features is given in the following sections.

6.1.5 Lagoon

Clear lagoon exists all around Thudufushi. The lagoon has average depths of 1.0 to 2m until it starts to gradually dip into the deeper *vilu* that exists on the western side. The depth of the vilu varies from 5 to 7 m at the periphery to about 15 to 18m in the deeper area towards the middle. The narrowest lagoon extent is on the east side where the reef is about 25m from the shoreline.

The western lagoon consists of medium-fine size sandy floor, and scattered patches of coral colonies (patch reefs). The deeper lagoon (vilu) on the west is approximately 100m away from shore. There is a gradual change in depth between the shallow lagoon and the deep lagoon. The reef system has a large reef flat on western side of the island.

6.1.6 Beach

There is no distinctive variation in beach composition around the island. However, the beach extent can be seen to vary monsoonally. The beach material is mainly composed of loose skeletal carbonate sediments, mainly fragments of green calcareous algae *Halimeda* sp., encrusting and branching red algae, molluscs, foraminiferans, echinoderms and bryozoans. Based on observations, survey data and discussions with island management, it is estimated that approximately 20m wide white sandy beach exists on the eastern side of the island throughout the year. The beach on this side of the island gets wider to 35 m on south west monsoon.

Plate 1: wide beach on northern side of the island

The west side shows severe erosion as a result of southwest monsoon weather. This area sees most erosion as a result of which the area has three rubble-mound groynes and seawall on the

western side of the island. These groynes, however, do not seem to serve the purpose, since it is due to wave scour that the sediment moves mainly.

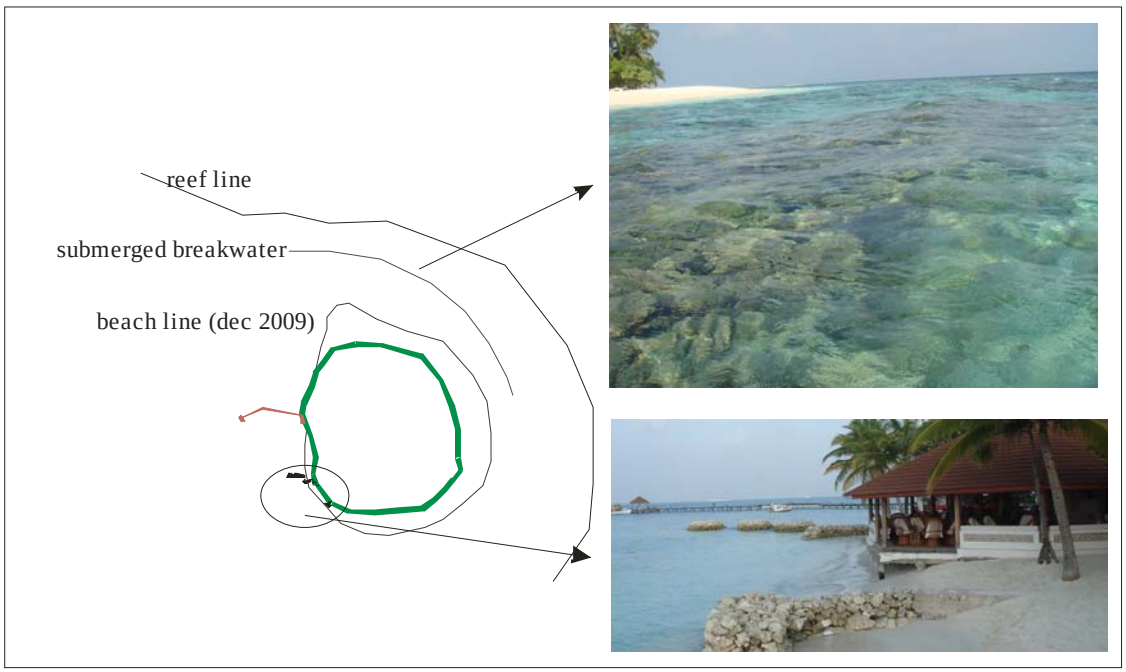
There is a 200 m submerged breakwater on northern side of the island. This breakwater has been constructed when the island faced severe erosion on northern side of the island during the NE monsoon. After the breakwater, the beach on this side of the island has become stabled.

Plate 2: Two groynes which had been constructed using coral on western side of the island

6.1.7 Coastal defence structures build around the island

Erosion is a sever issue facing at Thudufushi. A number of rooms which are located on western side of the island is under treat from erosion. The management of the resort has been trying to undertake an urgent remedial project to replenish the lost beach since October 2010. However due to slowness of the government's permit process the project has not yet received the approval. Hence the coastal protection project has been included as coastal protection component of the redevelopment and upgrade project at Thudufushi.

To combat the erosion on northern side of the island, a submerged breakwater has been built at the island in 2005. The breakwater was built from corals rubbles. The 200 m long breakwater has improved the beach on northern side of the island. Presently, the island has a large beach on north and eastern side of the island. However, the breakwater is failed and needs a repair. The proposed project would repair the breakwater on northern side of the island.



Erosion is visible on western side of the island. 3 groynes has been built on western side and a seawall under the arrival reception deck. These coastal structures are not improving the erosion situation at the island. it is believed, if no remedial action is taken in next few months, the south west monsoon will cause severe damages to the rooms which are located on western side of the island.

6.2 Existing Marine Environment

6.2.1 Introduction

This section of the EIA report describes baseline conditions of the marine environment at Thundufushi reef, with specific emphasis on the coral reef status close to the proposed direct impact site for the development of overwater villas in the shallow lagoon on the south-western side of the island. The island is formed on a the eastern side of a coral reef system with a dominant lagoon to its western side. The coral reef lies on the western rim of South Aril atoll. The western rim of the coral reef system is exposed

6.2.2 Survey methods

In order to obtain pre-impact baseline data for the island's reef, we conducted a marine survey on the sessile benthic community and the fish life. In future, these results can be compared to post-impact data, estimating the severity of the impact water villas and the channel deepening have on the marine environment at Thundufushi Island Resort.

The purpose of this survey is to define and establish marine environmental baseline conditions for impact evaluation during and after the proposed project. Surveys are based on standard marine environmental surveys so that they can be repeatedly carried out to monitor and record changes and assess possible impacts on the marine environment from the proposed work activities.

6.2.3 Marine water quality and bathymetry

The primary objective of the marine water quality sampling was to determine the baseline conditions of the marine water quality of the lagoon. Qualitative and quantitative assessments were made on sea water. As the proposed new water bungalows will be developed on the southwestern lagoon, sampling was undertaken in this area. Water quality was also tested from the north-western lagoon where the channel deepening will be undertaken. For comparison, water quality was tested from another control point where development will not take place. Samples were taken from 1 m below sea level using a clean bottle from the designated sites. The geographical coordinates were also recorded using a handheld GPS. The qualitative assessment indicates that the sea water is clean and clear. To confirm this, water quality tests were done at the National Health laboratory. The results indicate no pollution from any human activities nor any other source.

The bathymetry of the proposed water villa construction area indicates that the average depth is between 0.5 to 2 m. A detailed bathymetric map is attached as an annex. Following table illustrates the marine water quality results.

Table 7: Results of the marine water quality tests undertaken in April 2010

Parameters	S1	S2
GPS coordinates	3°47'16.96"N 72°43'36.76"E	3°46'59.26"N 72°43'39.36"E
Suspended solids (mg/L)	3	3
pH	8.5	8.5
Temp	28.20	29.80
COD (mg/L)	466	540
DO (% of saturation)	106	103
Salinity (ppt)	32.0	33.90
Turbidity (NTU)	2	3
Nitrates (mg/L)	0	0
Phosphates (mg/L)	0.040	0.041
Total dissolved solids (mg/L)	25200	25200

6.3 Description of the marine environment

The marine environment of Thundufushi island system encompasses two main attributes. They are the coral reef and the shallow lagoon. Distinctive reef areas exist within the reef system. They are the reef slope and reef-flat and coral patches in the lagoon. Geomorphology and biodiversity of each of these reef areas are also significantly different. The shallow lagoon on the north-western side of the reef contains comparatively high coral cover than on the south-western side. The most significant marine environmental attribute in terms of area and biotic environment of the island system is its coral reef system. For the purpose of the assessment, marine environmental surveys were undertaken from four locations.

6.3.1 Biotic marine environment

The biotic marine environment of the system was assessed for the lagoon and the coral reef system, as this was the areas that are likely to be impacted. The two major habitats within the reef system include the reef slope and the reef-flats having distinct biotic marine environments. The major habitat within the lagoon is the lagoon bottom. Marine surveys were undertaken from four sites. These sites were selected based on the developments that will be taking place in the island.

6.3.1.1 Coral reef system and amount of live corals

Amount of different categories of live corals and other benthos in the reef slope/reef edge and lagoon was quantitatively estimated using LIT and photo-quadrate survey described in the methodology section. Four representative sites of the reef were assessed using LIT and photo-quadrate method. The geographical coordinates of these locations are given in the following table.

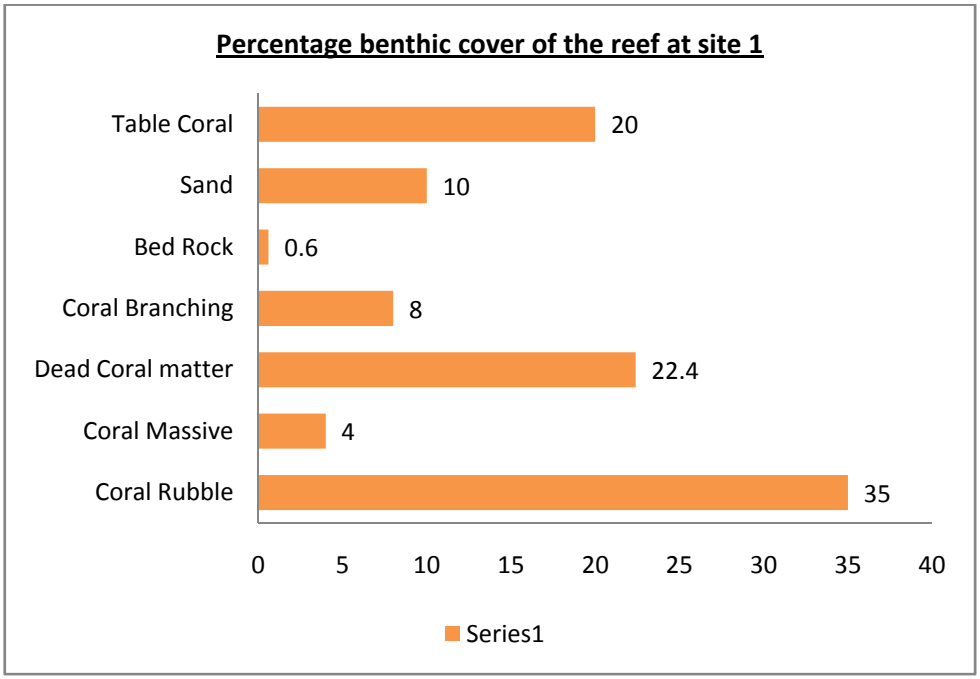
Table 8: GPS locations of the marine survey sites

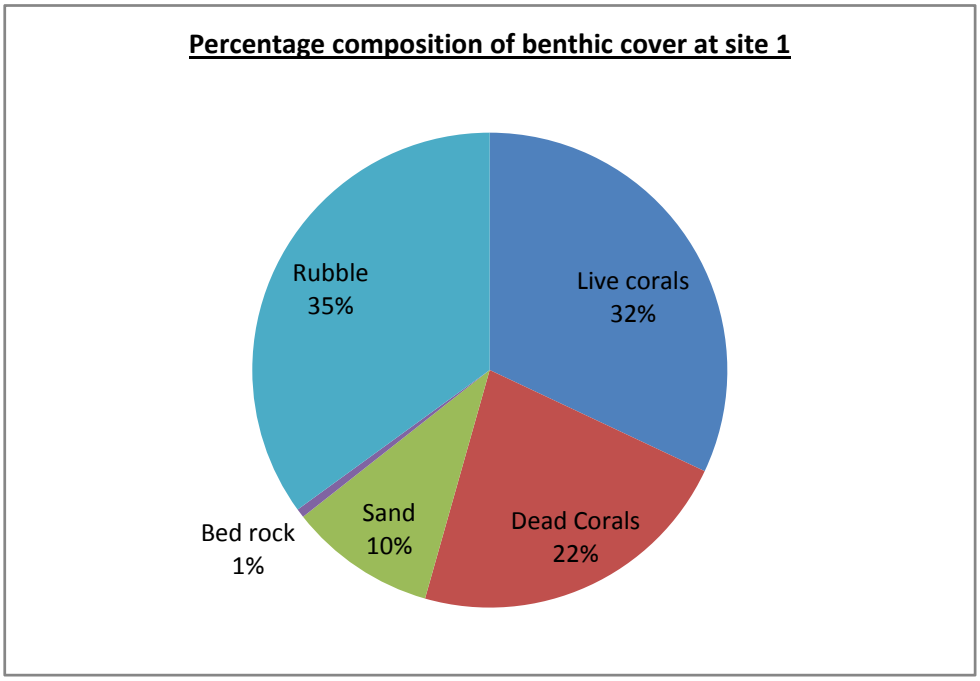
Site 1	Site 2	Site 3 .	Site 4
3°47'18.23"N 72°43'36.15"E	3°47'0.93"N 72°43'42.20"E	3°47'4.43"N 72°43'47.57"E	3°47'10.12"N 72°43'46.73"E

The coral reef system of Thundufushi can be considered healthy as the percentage of live coral coverage is good and also there are lots of new emerging corals at all the sites. The fish population was also very good during the survey with abundant fish populations at all the sites. The following sections outline the quantitative results of the assessment.

Marine survey location 1

Figure 12: Percentage benthic cover of the reef at Site 1

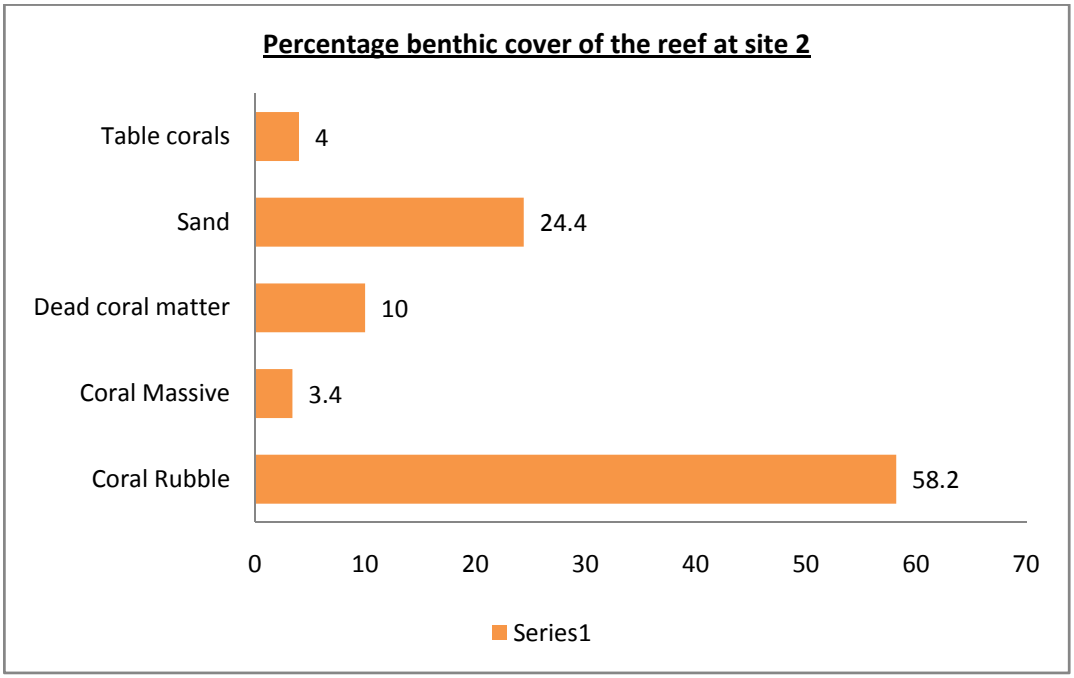


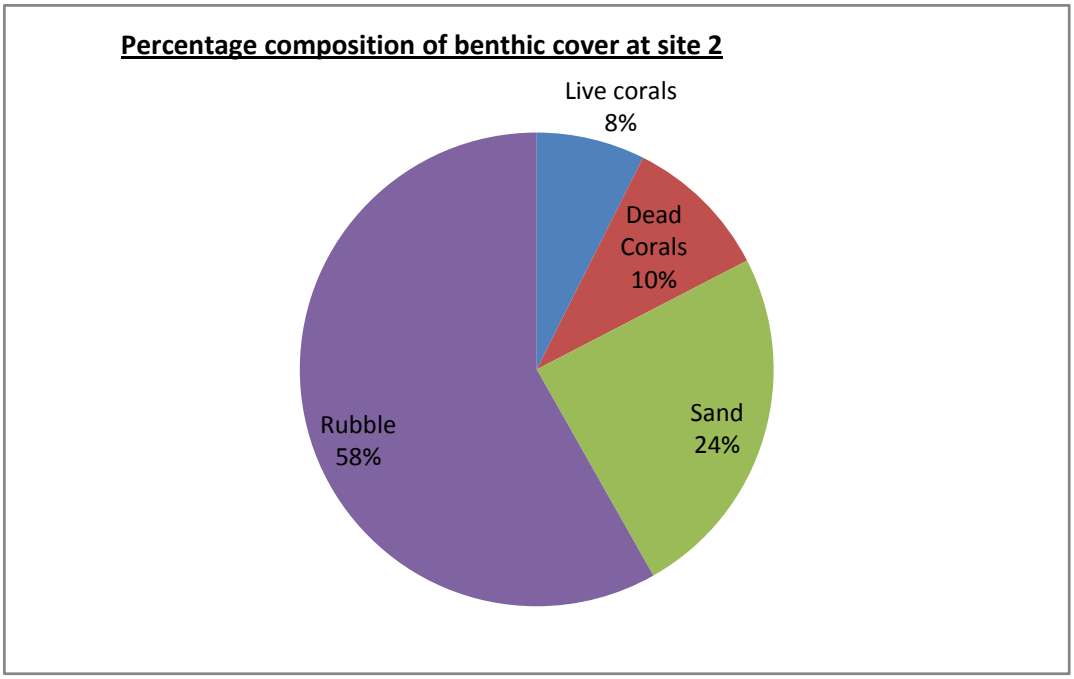


The survey showed that the coral reef at site 1 had 32% live coral cover consisting of corals mainly belonging to the *Acropora* group. Other composition include 20 % Acropora Tabular, 10% sand, 0.6 % bed rock, 8% Acropora Branching, 22 % dead corals, 4 % massive corals, and 35 % coral rubble. This area is dominated by coral rubble and the live coral cover is quite high. Standard error for these estimates is within ±10%.

Marine survey location 2

Figure 13: Percentage benthic cover of the reef at Site 2

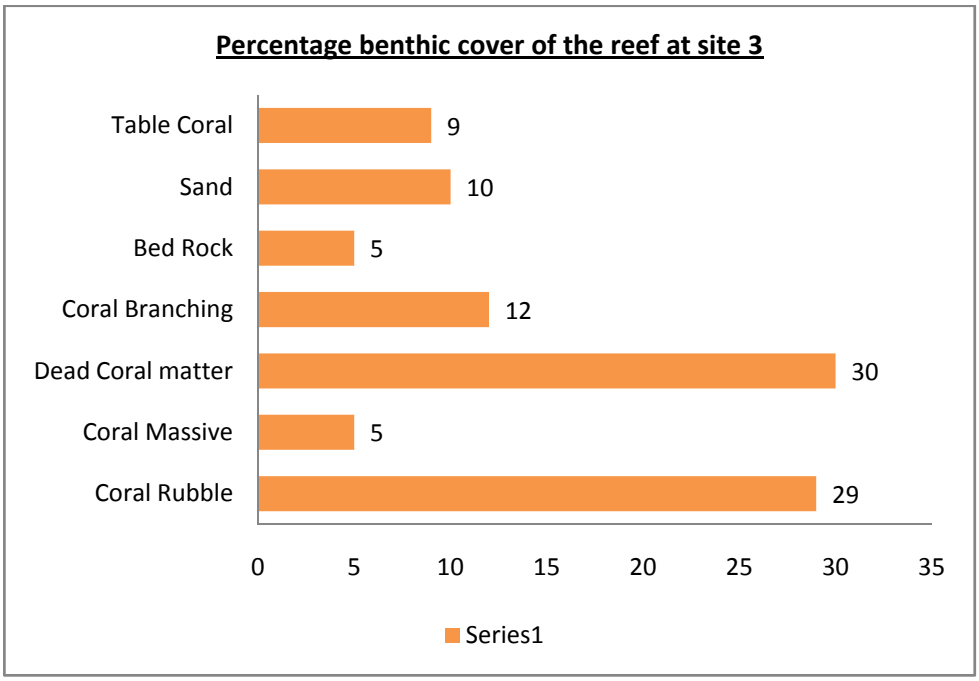


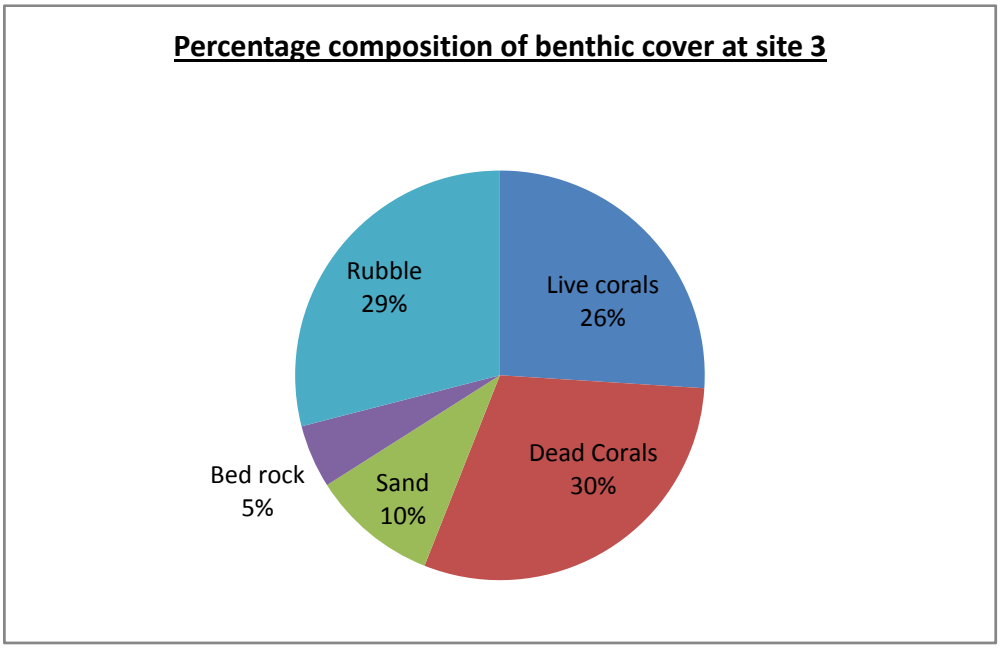


The reef survey conducted showed that the coral reef at site 2 had 8% live coral cover. The most abundant types of coral were table corals. The survey showed that site 2 consisted of 3.4 % massive corals, 4 % table corals, 24.4% sand, 10% dead coral matter and 58% coral rubble. This area is dominated by coral rubble. Standard error for these estimates is within ±10%.

Marine survey location 3

Figure 14: Percentage benthic cover of the reef at Site 3

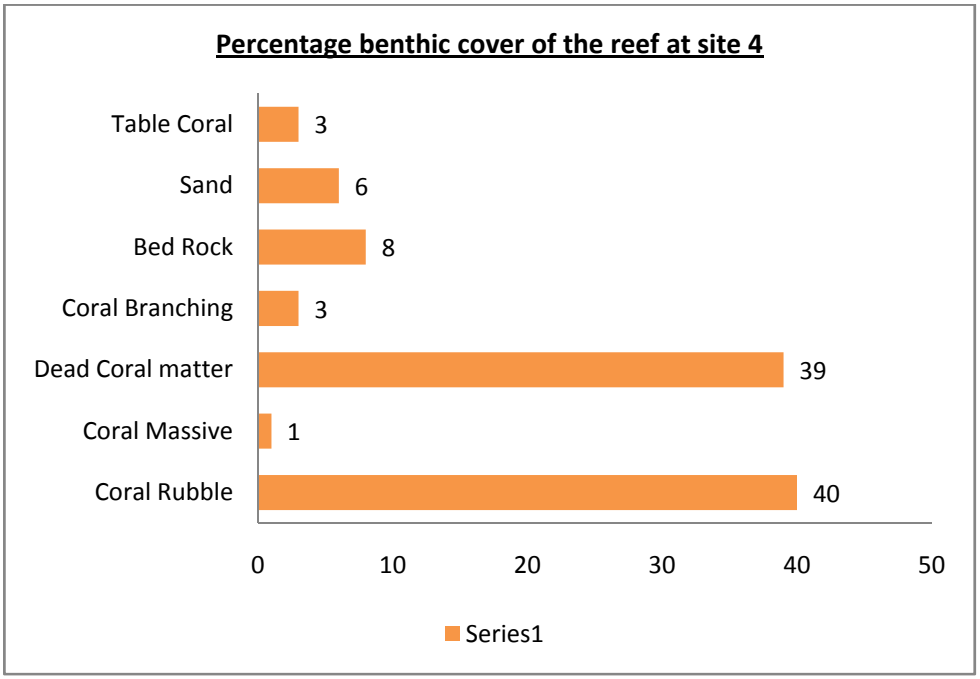


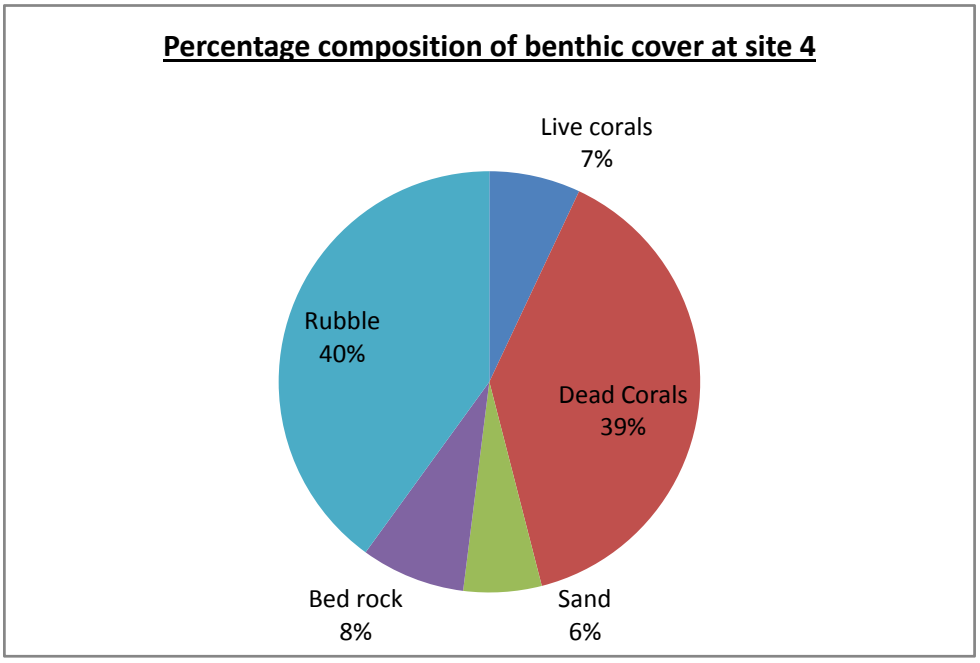


The reef survey conducted showed that the coral reef at site 3 had nearly 26% live coral cover. The most abundant types of coral were coral branching. The survey showed that site 3 consisted of 9% table corals, 5% bed rock, 30% dead coral matter and 5% coral massives. This area is dominated by dead coral. Standard error for these estimates is within ±10%.

Marine survey location 4

Figure 15: Percentage benthic cover of the reef at Site 4





The reef survey conducted showed that the coral reef at site 4 had nearly 7% live coral cover. The most abundant types of coral were coral branching and table corals. The survey showed that site 4 consisted of 3% table corals, 8% bed rock, 39% dead coral matter and 1% coral massives. This area is dominated by coral rubble. Standard error for these estimates is within ±10%.

6.3.1.2 Coral reef system and fish communities.

The amount and type of fish present at a given site can be a good indicator of the marine environment. For example, Increased grazers is generally a sign of increased nutrients in the area thus decreased coral and other increased algae.

The result of 10 minute swim for fish count on the survey reveals that the abundance and diversity of fish is very good in all the sites

Table 9: Results of the fish community assessment survey

Family	Species name	Scientific name	Abundance			
			Site 1	**Site 2**	**Site 3**	**Site 4**
Angelfishes (Pomacanthidae)	Regal angel fish	*Pygoplites diacanthus*	-	C	-	R
Bigeyes (Priancanthidae)	Bigeye Bream	*Monotaxis grandoculiz*	C	R	R	C
Butterflyfishes (Chaetodontidae)	Schooling banner fish	*henochus acuminatus*	C	-	A	-
Butterflyfishes (Chaetodontidae)	Double saddled butterfly fish	*Chaeton falcula*	C	C	C	C
Butterflyfishes (Chaetodontidae)	Teardrop butterfly fish	*Chaeton unimaculatus*	C	C	R	-
Butterflyfishes (Chaetodontidae)	Chevron butterflyfish	*Chaeton trifascialis*	C	-	-	C
Butterflyfishes (Chaetodontidae)	Black pyramid butterflyfish	*Hemitaurichthys zoster*	-	-	R	-
Damselfishes (Pomacentridae)	Humbug Dascyllus	*Dascyllus aruanus*	C	A	C	-
Damselfishes (Pomacentridae)	Sergent Major	*Abdudefdut vaigiensis*	-	C	C	R
Damselfishes (Pomacentridae)	White-belly damselfish	*Amblyglyphidodon Leucogaster*	-	-	-	-
Damselfishes (Pomacentridae)	Blackaxil Chromis	*Chromis atripectoralis*	-	-	A	C
Fusiliers (Caesionidae)	Striped fusilier	*Pterocaesio trilineata*	A	A	C	C
Lethrinidae (Emperors)	Gold-striped emperror	*Gnathodentex aureolineatus*	C	A	R	-
Moorish idol (Zanclidae)	Moorish Idol	*Zanclus cornutus*	R	R	-	-
Parrotfishes (Scaridae)	Bicolor parrotfish	*Cetoscarus bicolor*	R	-	C	-
Parrotfishes (Scaridae)	Palenuse Parrotfish	*Scarus psittacus*		R	R	R
Rudderfishes (Kyphosidae)	Highfin Rudderfish	*Khyphosus Cinerascens*	A	-	-	C
Snappers (Lutjanidae)	Kashmir Snapper	*Lutjanus Kasmira*	A	A	-	R
Snappers (Lutjanidae)	Black and white snaper	*Macolor niger*	-	-	C	-
Squirrelfishes (Holocentridae)	Sabre Squirrel fish	*Sargocentron spiniferum*	-	A		C
Surgeonfishes (Acanthuridae)	Convict surgeon fish	*Acanthurus triostegus*	R	C	C	A
Surgeonfishes (Acanthuridae)	Eye-striped surgeonfish	*Acanthurus Nigricauda*	R	-	C	C

Family	Species name	Scientific name	Abundance			
			Site 1	Site 2	Site 3	Site 4
Surgeonfishes (Acanthuridae)	Lined surgeon fish	*Acanthurus lineatus*	C	C	C	R
Surgeonfishes (Acanthuridae)	Powder-blue surgeonfish	*Acanthurus leucosternon*	C	R	R	R
Surgeonfishes (Acanthuridae)	Vlamings Unicornfish	*Naso Vlamingii*	R	C	R	A
Surgeonfishes (Acanthuridae)	Spotted unicorn fish	*Naso brevirostris*	R	-	C	C
Triggerfishes (Balistidae)	Titan triggerfish	*Balistoides Viridescens*	C	R	C	R
Wrasses (Labridae)	Checkerboard Wrasse	*Halichoeres hortulanus*	R	R	A	C
Wrasses (Labridae)	Barred thicklip wrasse	*Hemigymnus fasciatus*	C	C	R	C
Wrasses (Labridae)	Blunthead wrasse	*Thalassoma amblycephalum*	R	R	C	A

6.4 Terrestrial Environment

6.4.1.1 Methodology

The terrestrial environment of Thudufushi was studied in detail by selecting transects at different regions of the island on the vegetation line of the island. Visual and qualitative surveys were carried out during the field trip to the island on 12 – 13th May 2008. Transects were selected to study the floral composition along the islands vegetation and tree classification and enumeration was undertaken. Tree species were identified and recorded on a piece of paper. The presence of rare and endemic plants was also determined, and an indication of biodiversity of the island was determined. These findings are discussed in detail in the sections below. Groundwater conditions were appraised through water samples. Water samples were taken from 1 point from within the island. Water samples were tested onsite using a conductivity meter and chemical test strips.

6.4.1.2 Floral Landscape

The landscape of Thudufushi is fairly mature and cannot be considered diverse and representative of many other uninhabited islands of similar nature in Maldives. There are limited varieties of plant species than what is observed in other large uninhabited islands with greater diversity. There are also no terrestrial landscapes of significance nor any threatened species of plants. The landscape could be described as having two major types of vegetation: vegetation on the coast line or vegetation line and inner vegetation. Stark differences can be noticed along the vegetation line and the vegetation on the inside of the island. The island has fairly low green belt around the island, specially on western side of the island. The main difference is the composition of different tree species along the inside of the island in contrast to the vegetation line. Differences also exists in their diversity along the vegetation line and from inside the island.

There are more mature trees on the inside than along the vegetation line and mature trees such as coconut palms significant. As a result, the percentage of large mature trees in the island is fairly hight. The main type of mature trees in the island is coconut palms and dhigga.

6.5 Terrestrial Fauna

No attempts were made to do a detailed survey of their habitat. However, various species of crabs, and common garden ants were observed in the island. Turtles were sighted near the island but no nests were found in the island.

6.6 Groundwater Condition

Groundwater assessment was conducted to assess the ambient conditions of groundwater. The water table is expected to stands at 1.0 to 1.5 meter below ground. Groundwater sample tested on site using a water quality logger. Groundwater of the island, on the site, was tested for electrical conductivity, pH, and nitrates. These investigations of groundwater revealed that the groundwater of the island is relatively fresh. Samples were taken from an existing well in the island.

Sample No	EC (uS/cm)	pH	Nitrates (mg/L)
GW	4,284.00	7.9	0.02

Table 10: Results of the groundwater analysis in Thudufushi

Conductivity reading was high at 4,284 us/cm which is way above the freshwater mark. Conductivity readings of 2500 us/cm is the cut off limit for freshwater. Nitrates and phosphate levels were also tested in addition to pH. Nitrate and phosphate levels were relatively low.

6.7 Socio-economic Environment

The resort is expected to be closed for upgrade and redevelopment in May 2010. It is expected that the redevelopment will create additional employment opportunity to community of atoll. It is expected that additional 200 jobs would be created with the new development.

The management of the resort encourages to hire dhonies which are owned by people of the neighbouring islands.

Hazards and Disasters

6.7.1 Vulnerability to Natural Disasters

The islands of the Maldives are less prone to tropical cyclones and are only impacted in the northern part of the country by weak cyclones that formed in the southern part of the Bay of Bengal and the Arabian Sea. Since 1877, only 11 cyclones crossed the archipelago (Maniku, 1990). Most of the cyclones crossed Maldives north of 6.0^{o} N and none of them crossed south of 2.7^{o} N during the period. All the cyclones that affected Maldives were formed during the months of October to January except one, which formed in April (UNDP, 2006).

Map 1: Cyclonic Wind Hazard Map (source: UNDP, 2006)

The northern atolls have a greater risk of cyclonic winds and storm surges. This reduces gradually to very low hazard risk in the southern atolls (see Map 1). The maximum probable wind speed in Zone 5 is 96.8 knots (180 kilometers per hour) and the cyclonic storm category is a lower Category

3 on Suffir-Simpson scale. At this speed, high damage is expected from wind, rain and storm surge hazards (UNDP, 2006).

Figure 16 shows historical earthquakes around Maldives; and three events of magnitude above 7.0 struck the region which had their sources in the Indian Ocean (UNDP, 2006).

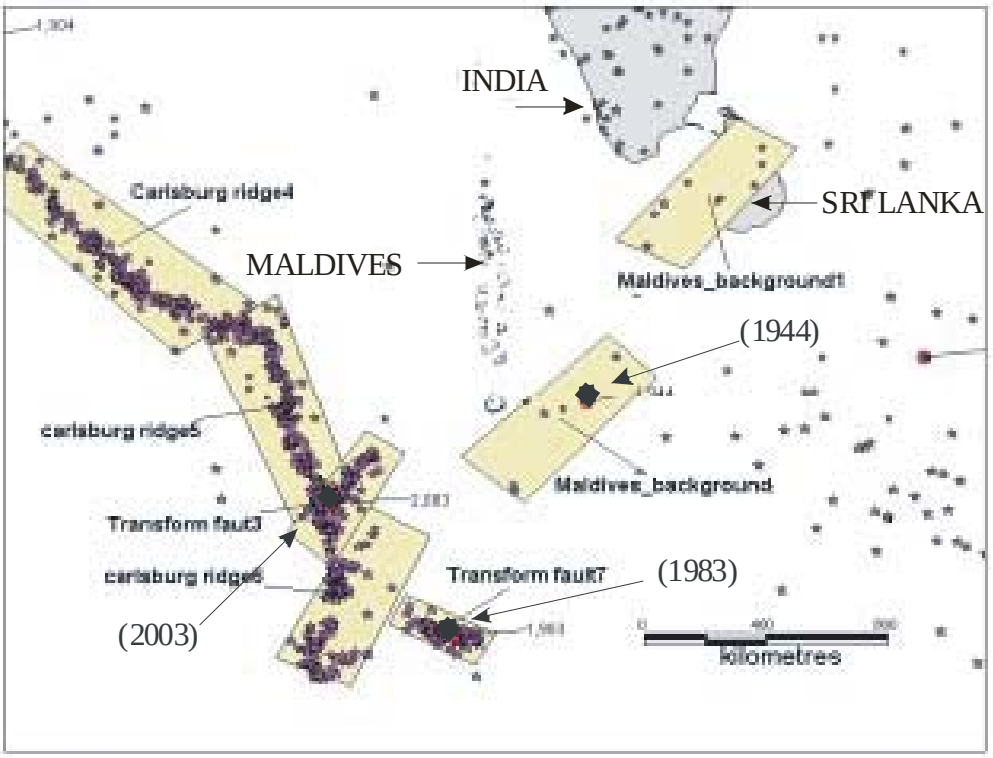


Figure 16: Earthquake Epicentres around Maldives (Source: UNDP, 2006)

UNDP (2006) identified that hazard risk from earthquake is low for the Maldives and considered as a disaster risk for only islands located in the south of the country. See Map 2.

Map 2: Earthquake Hazard Zone (source: UNDP, 2006)

Maldives faces tsunami threat largely from the east, and lower threat from the north and south. Islands along the eastern fringe of the atolls are more prone to tsunami hazard than those along the northern and southern fringes. Islands along the western fringe experience a relatively low tsunami hazard. Historically, Maldives has been affected by three earthquakes which had their sources in the Indian Ocean. Of the 85 tsunamis generated since 1816, 67 originated from the Sumatra Subduction zone in the east and 13 from the Makran Coast Zone in the north and Carlsburg Transform Fault Zone in the south. The probable maximum tsunami wave height is estimated at 4.5 metres.

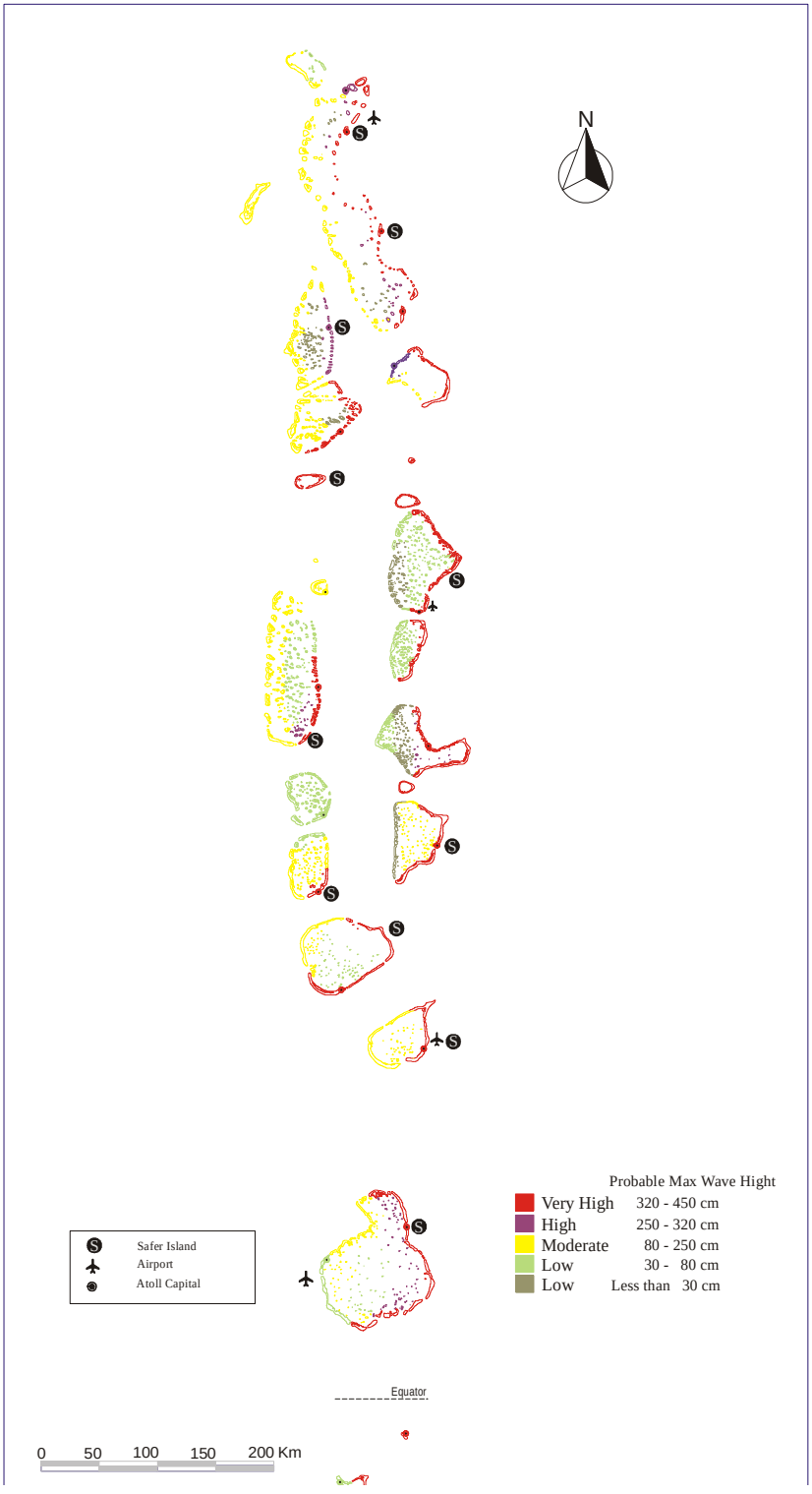


Figure 17: Tsunami Hazard Zones (adopted from UNDP, 2006)

6.7.2 Natural Vulnerability of the Island of Thudufushi

The islands of the Maldives have natural characteristics which make them vulnerable to disasters such as tsunami. An island's Natural Vulnerability depends on geographic and geomorphologic characteristics of the island. These include geographic features of the island like the side of the

country where the island is located, the formation of the island, location of the island respect to the atoll, orientation of the island, region of the country where island is located, level of shadow to the island from the reefs and other islands; area of the inland lake found on the island, width of the island's house reef, coastal defence structures on the island, shape of the island and the area of the island. A Model to Integrate the Management of Hazards and Disasters in the National Sustainable Development Planning of the Maldives which was developed as part of the Masters of Science (Hazard and Disaster Management) thesis at the University of Cantebruy (Jameel, 2007) identified the relationship between natural characteristics of the island and the *natural vulnerability* of the islands using the data that was collected following the Indian Ocean Tsunami.

Based on this research, the natural vulnerability of the Thudufushi was found to be moderate for flooding disasters such as caused by tsunami or high waves approaching the island from the east.

7 Environmental Impacts and Mitigation

7.1 Impact Identification

Impact identification has been undertaken by considering the proposed activities and examining the level of impact the new construction will have on the environment. Each activity was then examined in detail to identify the construction methods, technology and other factors that would determine the potential impact of the various activities.

7.2 Assessing Impacts

Environmental impacts of the proposed redevelopment work have been examined through a number of processes. These include consultations with the stakeholders, field surveys, observations and assessment, and field experience gained from similar development projects implemented throughout the country. Potential positive and negative impacts on the environment have been considered.

The impacts on the marine environment are going to be high as the proposed modifications take place in the reef flat and lagoon. The impacts are categorized into short-term and long-term. Most of the short-term impacts are related to constructional phase, while the long-term impacts are associated with the operational phase.

Possible negative impacts on the environment have been considered in worst-case scenario to recommend mitigation measures in the best possible ways so that these impacts would be minimized and perhaps eliminated in both constructional and operational phases. For example, the anticipated indirect impacts on the coral reef have been slightly exaggerated to account for uncertainties.

This EIA identifies and quantifies the significance of adverse impacts on the environment from the proposed project. Impacts on the environment were identified and described according to their location/attribute, extent (magnitude) and characteristics (such as short-term or long term, direct or indirect, reversible or irreversible) and assessed in terms of their significance according to the following categories: Negligible – the impact is too small to be of any significance; Minor– the impact is minor; Minor adverse – the impact is undesirable but accepted; Moderate adverse – the impact give rise to some concern but is likely to be tolerable in short-term (e.g. construction phase) or will require a value judgement as to its acceptability; Major adverse – the impact is large scale giving rise to great concern; it should be considered unacceptable and requires significant change or halting of the project. Positive – the impact is likely to bring a positive change in the sense that it is aimed at further minimizing the impacts as a result of the proposed actions.

7.3 Uncertainties in impact prediction

Environmental impact prediction involves a certain degree of uncertainty as the natural and anthropogenic impacts can vary from place to place due to even slight differences in ecological, geomorphological or social conditions in a particular place. There is also limited data and information regarding the particular site under consideration, which makes it difficult to predict impacts.

However, the level of uncertainty, in the case of Thudufushi is expected to be low as many similar projects have been undertaken elsewhere in the Maldives. In the marine environment, there is slightly elevated degree of uncertainty as the marine environment is more sensitive in extreme cases such as severe weather conditions. Water villas have already been developed on similar island environment and therefore, the impact of constructing additional water villas can be fairly accurately predicted. The eastern side of the islands shore is protected by breakwater and thus will not induce any erosion or accretion of sand in this area. However, the western side coastline is expected to have positive impacts as the submerged break water proposed to be built on this side would help to reduce the existing erosion faced to the island.

Such developments have been undertaken other parts of the Maldives and their impacts are well known and have been well documented. Therefore, there is very little uncertainty involved in this project with regard to the construction of water villas. Therefore, there is a high degree of accuracy in prediction of the impacts.

7.4 Impacts on the Coastal environment

The development of submerged breakwater on western side of the island would help to reduce the existing erosions which the island is presently faced. The erosion of beach on western side of the island during the south west monsoon will be mitigated with the construction of the breakwater and subsequent nourishing of the lost beach.

7.4.1 Submerged breakwater

Impacts

The construction of the submerged breakwater will have a significant positive impact on the western side beachline in stabilizing the beach. The impact of proposed breakwaters would be mainly related to changes to hydrodynamics and sand transport. Since the breakwater can be dismantled and removed if necessary, the impact of constructing breakwaters is considered reversible. The impact on sand transport around the island would be a significant impact but a desirable one. Wave energy will be considerably reduced by the breakwaters and therefore long shore transport sedimentation will be reduced thereby stabilizing the shoreline.

Mitigation Measures

It is important to undertake work at low tide hours, especially when laying the based of the submerged breakwaters.

7.4.2 Water Villas

Impacts

Impact 1: Changes to sediment transport

The construction of a series of footings and columns for the water villas and water villa jetties would disrupt sediment transport around the island, especially due to the wave attenuation these structures would offer during the southwest monsoon. This impact would help minimize net erosion on the north western side of the island.

Impact 2: Siltation and water quality deterioration

There will be some sedimentation due to the movement of excavators on the seabed during the construction phase when footing and coloumns of the water villas are placed in the lagoon. The engineers has designed the water villas as such that 200mm of the water villa's footing need to buried into the lagoon floor after excavation. This will be minimal and unavoidable given the construction methods employed in water villas construction in the Maldives.

Water quality deterioration would also occur as a result of suspended fines. However, due to the dynamic nature of the water body in the area, silt will be cleared almost immediately after the work is completed.

7.4.3 Seaplane platform with floating deck

Impacts

The seaplane platform is proposed to be built close to the edge of the vilu where depths would vary from 5-7m. Therefore, the construction of the platform would have no impacts on the coral reef or the coral patches in close vicinity.

Mitigation Measures

As a general mitigation measure for all over water structures proposed for the redevelopment, some of the live corals in the impacted area would be transplanted to a safe location in which a coral propagation programme would be undertaken.

Cost of Mitigation

Contractors will be required to undertake the mitigation measures, as most of these include measures that can be taken if carefully planned.

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7.4.4 Spa

Impacts

The spa is proposed to be built in clear shallow lagoon on south western side of the isalnd. The main impact of the spa building will be to the lagoon floor during the construction phase of the development. The spa building is supported by the columns, where the footing of the coloumns will be buried 200mm into the lagoon floor. The columns will be placed using an excavator and sedimentation would be resulted due to the process.

Mitigation Measures

The most important mitigation measures would be to raise the height of the spa jetty, especially from the mean tide line so that the beams would have less impact on the sediment movement. It is also important to keep the spa as far away from the beachline as possible. The current location is appropriate given the smallness of the reef extent in this area.

Cost of Mitigation

No costs included. Mitigation measures have been taken during the engineering design stage.

Contractors will also be required to undertake the mitigation measures, as most of these include measures that can be taken if carefully planned.

7.4.5 Restaurant

Impacts

The construction of over-water deck standing on piles would cause some degree of sedimentation (discussed in Marine Environment section) and potential changes to the longshore transport

Mitigation Measures

For the restaurant, the whole structure needs to be raised so as to minimize the beams affecting the littoral transport severely.

Cost of Mitigation

No costs included. Mitigation measures have been taken during the engineering design stage.

Contractors will also be required to undertake the mitigation measures, as most of these include measures that can be taken if carefully planned.

7.4.6 Submerged breakwater

A submerged breakwater is proposed to be built on western side of the island. The submerged breakwater would reduce the erosion faced on beach on western side of the island by creating calmer conditions for beach to accrete even in south west monsoon. The breakwater is expected to impact on the long shore current around the island.

7.5 Impacts on the marine environment

Impacts on the marine environment arising from the proposed project are limited to only the construction of overwater structures.

7.5.1 Creation and deepening of the existing entrance channel

Impacts

Most of the negative impacts on the marine environment arising from the proposed project will mainly be from excavation of the entrance channel. In this project, excavators will be used to deepen the entrance channel and therefore sedimentation will be an ultimate outcome which will be unavoidable. Despite this, it has to be noted that this is only a short term effect and will only last during the excavation period. The entrance channel will be excavated to a depth of 3 meters at mean sea level (MSL).

The sea bottom of the entrance channel currently consists mainly of coral rubble which was left behind after the creation of the channel and sand. An indirect impact will be felt on the nearby reef due to sand smothering.

Both work phase and operation phase will have direct and indirect negative impacts. Direct impacts during work phase will result from the removal of lagoon bottom areas to deepen the lagoon and make the navigation channel. This impact will include damage to lagoon bottom benthos namely burrowing worms and crustaceans. Indirect impacts will result from release of sediment to the water column and increase in turbidity during the work phase. Lagoon bottom is an important habitat for certain organisms such as worms, mollusks, amphipod etc. which are important food sources for bottom feeders such as certain species of fishes. By removing sand from the lagoon bottom would disturb habitats of these organisms.

Proposed Mitigation Measures

Following are the specific mitigation measures that will be taken to mitigate negative impacts on the marine environment that are likely to arise from the proposed project activities.

- Channel deepening will be restricted to the width of the existing channel.
- Undertaking work during low tide.
- The monitoring programme specified in this report will be followed and reported in order to take necessary mitigation measures.
- Channel will be deepening to the required depth of – 3.0 m at low tide.

- Sedimentation and siltation resulting from the proposed work activity will be minimised and contained within the area by using appropriate techniques such as undertaking the works in low tide to reduce spreading of sediment and silt plumes to the lagoon floor, lagoon water and the coral reef.
- The excavation will be carried out by placing the excavator on a barge, if the excavator is unable to work in the area.
- The excavated material will be transported to the island and will be used as a beach replenishing material.

7.5.2 Water Villas

Impacts

Impact 1: Damage to the coral reef due to physical construction of the over water structure

The surveys and assessment showed that the proposed construction of over-water villas would impact the coral reef indirectly and the lagoon directly and indirectly. Direct impact on coral reef is not expected as the development of the water villas will be undertaken on the lagoon (see the Master Plan). Direct impact on the lagoon will be disturbance to the lagoon bottom in laying the footings of the overwater structures. Indirect impact on the lagoon will be spreading of low level of sediment in the lagoon water column.

Impact 2: siltation and sedimentation created by the construction phase

Indirect impact on coral reef will be spreading of sediment fines on the coral reef during the construction stage when the footings of the jetty and villas will be placed, thus creating sedimentation. The duration of the impact will be very short and expected to be limited to days. The construction period falls in south west monsoon and therefore, the winds and the winds-generated currents will likely distribute the sediment towards the south, south east.

7.5.3 Mitigation Measures on Marine Impacts

The following mitigation measures will help minimize the impacts on the marine environment:

Mitigation Measure	**Cost of Mitigation**
The water villas will be built on columns. Strictly no solid structures are to be used on which they will be constructed	No costs included. Mitigation measures have been taken during the engineering design stage.
Ensure appropriate supervision and monitoring during the works	Cost included in the monitoring programme
Carry out the work in low tide hours during calm weather and sea conditions	No costs included
Complete the work in the shortest period of time possible	No costs included
Use manual methods as much as possible	No costs included
Create awareness and brief the workforce on how to minimize	Cost included in the monitoring programme

Mitigation Measure	Cost of Mitigation
impacts	
Limit the working area within the boundary of the construction zone and avoid disturbing other areas. An ideal method would be to mark the area with tape to indicate the construction zone.	No costs included
Regular monitoring during construction stage	Cost included in the monitoring programme
Machinery, equipment and vessels used in the project activities have to be maintained, kept in good condition and operated in a manner that they do not pose a risk of the environmental degradation	No costs included
Work has to be inspected and supervised during the whole lifecycle of the proposed project. If predicted impacts were exceeded, the work will be halted and impacts re-assessed and reported. The monitoring program specified in this report will be followed and reported in both work phase and operation phase.	Cost included in the monitoring programme
Although silt screens are not used in Maldives, similar retention material such as low cost geo-fabric nets are to be used to contain sediment plume, especially on the seaward side to contain sediments flowing on the reef flat.	Cost included in the monitoring programme

7.6 Demolition Waste and Construction Waste

Demolition and construction waste will impact the environment as they have to be managed and disposed using proper methods. This component is not expected to have significant impact on the island's environment as the residual waste will be regularly transferred to a designated disposal facility, identified by the EPA, for final disposal.

Temporary stockpiling of waste in the island will not have any significant impact as it will only be short term/temporary.

Additional burden on Thilafushi or any other designated disposal facility resulting from the demolition and construction waste is not considerable.

Demolition of structures will have temporary impact through the emission of dust which will settle on the vegetation. However, the dust emitted will not be toxic and harmful and the impact is only temporary in nature.

The construction of new structures will not have any impact on terrestrial environment as no trees will be cut. Impacts of dewatering would be short term saline intrusion.

7.6.1 Mitigation of the Impact

To reduce the amount of residual demolition and construction waste, waste generated from the project will be sorted into different waste streams. The re-usable waste from the waste stream which is recovered will be used for the construction activity.

To mitigate the impact of waste on the coastal environment, temporary stockpiling would be carried out on land. Beach and Marine environment would be avoided.

Debris from the water villa construction to be immediately taken to the island and minimizing their contact with the marine environment.

To mitigate the generation of demolition waste, demolition will only carried out for those building that will be required for demolition.

To mitigate the generation of construction waste, cutting trees will be limited to those that have to be removed. Cutting may be limited to only branches if they intervene with the demolition or construction activity.

To mitigate the impact of demolition waste, regular water spraying of trees would be carried to get rid of dust, if they arise too much at the demolition and construction site and limiting the period of demolition

Table 11: Summary of the impacts and their characterization

Environmental Aspect	**Nature of impact**	**Magnitude of impacts (negligible/minor /minor adverse/moderate adverse/major adverse/ positive)**	**Significance of the impact (low/moderate/high)**	**Duration of Impact**	**Reversibility**
Construction of over water villas	Cumulative	Moderate adverse	High	Short to long term	Reversible
Construction of SPA	Cumulative	Minor	Low	Short to long term	irreversible
Construction of sea plan platform	Cumulative	Minor	Low	Short to long term	irreversible
Construction of the bar & restaurant	Cumulative	Minor	Low	Short to long term	irreversible
Construction of the break water	Cumulative	Minor	Low	Short to long term	irreversible
Deepening the existing channel	Cumulative	moderate	Low	Short to long term	irreversible
Construction of the sewage treatment plant	Cumulative	positive	Low	Lont-term	reversible
Noise and air pollution	Cumulative	Moderate adverse	Moderate	Short term	reversible
Generation of construction debris	Cumulative	Minor	Low	Short term	reversible
Impacts on the western coastline	Cumulative	positive	high	Lont-term	irreversible

8 Stakeholder Consultations

For the purpose of this project, public consultations were limited to relevant government agencies, the proponent and the designer / Architects. As the project is a redevelopment of an existing resort, these key stake holders were identified relevant to undertake public consultations. Methodology for undertaking these discussions was through interviews and discussions.

8.1 Consultation with the proponent

In general, discussions were held with the proponent to obtain information about the need for this redevelopment and to justify the project. The major outcome of these consultations is outlined below.

- Hence, the new developer wishes to increase the number of rooms mainly because there are not enough beach bungalows.
- Increase profitability does not mean that it is only beneficial for the proponent. Naturally, it will increase the government's revenue.
- The new developer is not interested in reclaiming land and hence opted to increase the water villas.
- If the new water villas overlap live corals, then the developer is willing to shift the water villas to the lagoon in order to avoid live coral.
- Some of the live corals in the area which will be affected by the water villa jetty area will be relocated.

8.2 Consultation with long term staff

Long term staff working in the resort was also consulted to obtain their views on the development. The following are the main outcomes

- The island faces erosion on western side of the island. Existing coastal defense structures have not been properly designed. The sand pit on northern side of the island has been extending, naturally when the breakwater on this side was constructed.
- Upgrading will definitely be good for the resort as the market segment is changing rapidly.

8.3 Consultations with the Ministry of Tourism, Arts and Culture

Consultations were held with officials of Ministry of Tourism and Civil Aviation at the Ministry. Following are the main outcome.

- This project has been approved by the ministry including all the concepts.
- The Ministry is generally very positive about such additional developments.
- The redevelopment will help to mitigate the existing beach erosion problem facing to the island.

8.4 Consultations with Ministry of Housing, Transport and Environment

Consultations were held with Mr. Mohamed Zahir, Director General at the Ministry. Following are the main outcome.

- All the development in the tourism industry would have to do EIA before the project is given approval.
- EPA is the main institution which overseas the EIA work under the Ministry
- The redevelopment shall refrain from the removal of any trees and importation of trees from other island shall be undertaken accordance with the regulation under the Ministry.
- Environment Ministry's interest lies in protection of the environment at the same time allowing development to take place. This means, that developers should implement all mitigation measures and also undertake regular monitoring.
- New developments need to take into consideration the goals outlined in the new Third National Environment Action Plan and the National Sustainable Development Strategy. The development shall try to aim to reduce the carbon emission. Reduction of carbon emission from private sector would help to achieve the carbon neutral policy of the government.

8.5 Consultations with the Architect

Consultations were held with Mr. Hannan Yoosuf. Following are the main outcome.

- Water villas will be developed on concrete pads and columns. These will be pre-casted in the island.
- The island has lost a considerable amount of beach on western side of the island. Bringing back the beach shall be the main aim of the redevelopment as the beach is the main theme of Maldivian resorts.
- There is a great need to complete the resort at the earliest in order to make this property a profitable one. The project is planned as to open the resort for business by next winter season.
- Feels that this development is considerably small as most of the infrastructure has already been constructed.

8.6 Consultation with the Marine Biologist

Consultations were held with Ms. Verena Wiesbauer. Following are the main outcome.

- Attention shall be given to the protection of the marine environment during the construction stage of the development. Marine environment could be impacted, during the construction phase, when workers are not properly educated. hence, creating

awareness to the workers, through an orientation, could help to minimise the impact on the marine environment

- Marine environment would be protected, if proper attention is given. Creating a post for resident marine biologist would help to create awareness of the staff and guest, during the operation stage, on protecting the marine environment.

8.7 List of persons consulted

Following are the names and designation of persons consulted.

Name	**Designation**	**Office**
Mr. Mohamed Adhlee	Assistant Director	Ministry of Tourism, Arts and Culture
Mr. Mohamed Zahir	Director-General	Ministry of Housing, Transport and Environment
Hasim	Resident Manager	Thudufushi
Shiju	Front Office Manager	Thudufushi
Ms. Verena Wiesbauer	Marine Biologist	Water Solutions
Mr. Carlo Cipolini	Director	Plan Hotel
Ms Sara Rosso Cipolini	Director	Plan Hotel
Mr. Mohamed Shafeegu	Director	Seagull Group Pvt Ltd

9 Alternatives

EIA Regulation requires two alternatives to be suggested for such developments and therefore two alternatives have been suggested in addition to the no project alternative. These alternatives are discussed below:

9.1 No Project Option

The no project option takes the following into account.

- The resort will be operated with its existing infrastructure.
- No additional infrastructures/services are introduced, therefore, price cannot change and profit margin will decrease year by year

The main advantages and disadvantages of these are given in Table 12.

Table 12: Advantages and disadvantages of the no project option

Strategy	Advantages	Disadvantages
Allow the resort to be operated with the present infrastructure	Environmental problems related to additional development can be avoided No upgrading costs to the Proponent, short term benefit	With the existing infrastructure, the resort can only be marketed to certain markets. Target clientele cannot be diversified.
Existing guest rooms would be left as it is and not constructing new water villas.	Environmental problems related construction of new water villas can be avoided No upgrading costs to the Proponent, short term benefit	Profit cannot be increased. Modifying the existing villas would be more costly, as most of them are not specially designed to suit the current market.

9.2 Design Alternatives

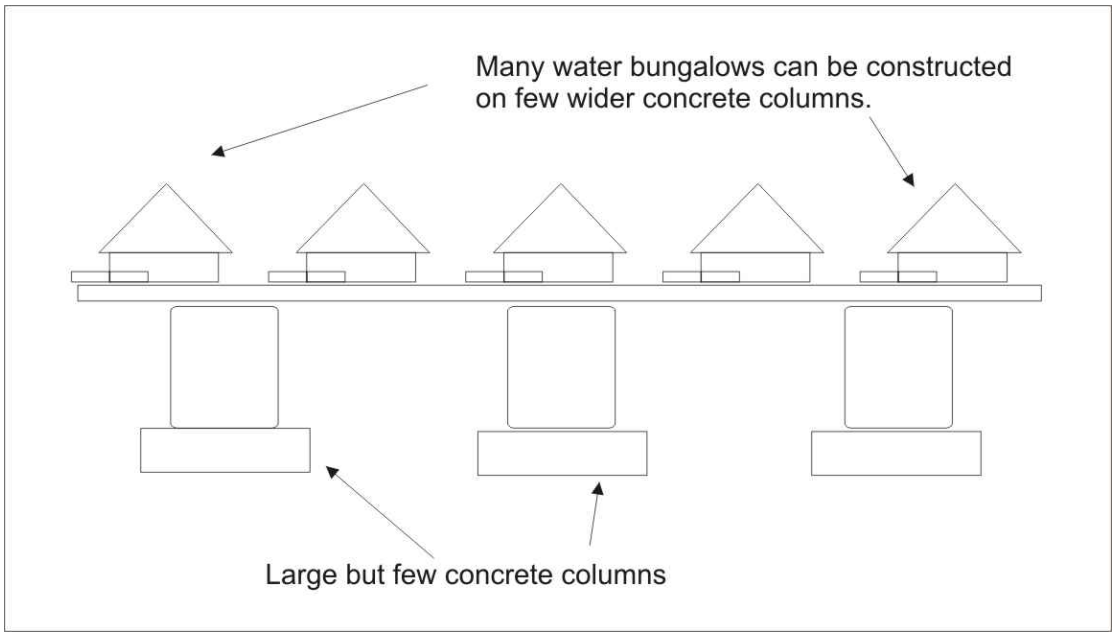
During the EIA process, few alternatives were considered, mainly for the construction of the water villas and their location. They are discussed below.

9.2.1 Construct multiple water villas on few large columns

An alternative method of water villa construction was considered at the planning stage. This method involves constructing large, but few concrete columns on the lagoon and then building multiple water villas on them. This method is illustrated in Figure 18. This method was rejected for several reasons. First, this is a very new concept for Maldives and hence requires a greater degree of uncertainty. Secondly, the large columns would be very unattractive and will not blend with the

existing water villa columns. There would be lot of negative visual perception. Thirdly and very importantly, the large surface area of the columns will disrupt the sediment movement greatly than if it was constructed sing standard column sizes. Hence, there would be a greater degree of sediment disruption and at present; there is very limited information and experience within Maldives as far as this method is considered. Lastly but not least, the new method of construction will not blend with the existing water villas.

Figure 18: Alternative construction method for water villas.



9.3 Alternative locations

9.3.1 Location of the Water villas

There are few alternative locations for the water villas, but the most practical alternative is on the south western side reef flat.. The disadvantage of moving water villas to this side of the island is that, this will block the existing entrance channel. The entrance channel to the reef is located on south western side of the island. However, even at its present location, they will block the view. There are no other alternative locations as the area allowed by the existing regulations of Tourism and Environment is limited.

9.4 Alternatives to construction technologies

The foundations or the footings of the water villas, spa and jetties will be constructed using concrete pads on columns. All structures will then be constructed on them. During the concept development stage, drilling the sea bed to a depth of 6 m to erect the columns were considered in order to ensure that water villas and the jetty will be structurally strong. However, the cost of this operation would be much more.

The proposed methodology involves constructing footings on the island. Drilling will involve the use of heavy machinery and hence, not very suitable for this situation in terms of cost. Therefore, this alternative has not been considered.

9.4.1 Alternative method to deepening the entrance channel

The current project proposes to excavate the channel using an excavator placed on a barge. This method will have significant logistical difficulty during the construction stage. One alternative to minimize this impact is to employ a cutter-suction dredge which will be easy to operate and will reduce the amount of silt suspended in the water column. However, the use of cutter-suction dredger is not very suitable for such a small scale project, and therefore is not economically justifiable due to high cost of mobilization and operation.

The other option would be to use a sand pump. Sand pumps are less costly and causes less sedimentation. Even if sand pumps were to be used, the sand shall be pumped onto barge and transported to land as the distance to cover if the pump were to pump directly to land would reduce the efficiency of the pump. Also, similar to the dredger the pumped sand would be more compact than excavated sand. Therefore, excavator is preferred over the sand pump to minimize compaction and ensure that the sand can be easily sorted or sieved and used for future beach replenishment, etc.

9.5 Alternative to Corals recovered from demolition waste

An alternative to reusing the coral rubble that is recovered from the waste stream is to destroy the corals completely so that it cannot be further reused or transport it to the landfill at Thilafushi.

Destroying the coral rubble in the demolition waste stream can be done in several ways, all of which would not be of any particular benefit to the environment. It is not guaranteed that even if recovered corals are transported to Thilafushi that it would be destroyed. It is most likely that these corals will be picked by scavengers at Thilafushi and sold in the market.

The destruction would also include an additional cost, which could be easily avoided by opting for a simple, yet effective waste management strategy such as reusing or recycling the corals.

9.6 Alternative methods to protect the beach

There are a number of options for shore protection on the western side of the island. Since wave action is the main concern in Thudufushi, a structure that protects the area in its lee from wave attack, i.e. a breakwater is considered the most suitable solution. Some impractical options such as floating breakwater and regular beach replenishment have not been considered.

Based on the above, the suitable options that may be considered during the design of the second phase are:

- Emerged breakwater
- Artificial reef
- Artificial headland
- Seawall or revetment along the coast

9.6.1 Emerged breakwater

The emerged breakwaters were popular coastal protection features in the resorts. However, the emerged breakwater has an aesthetic impact that had become unpopular. The emerged breakwater functions like a submerged breakwater but these are designed to prevent overtopping of waves and keep the lee side of it calm. The biggest disadvantage with emerged breakwaters is that the complete prevention of wave overtopping will make the leeward side too clam that sediment build up reaches to a level that will result in the beach connecting to the breakwater. This is a result that is not desirable. Hence, emerged breakwaters are not considered.

9.6.2 Artificial reef

Artificial reefs on the western side would be similar to submerged breakwater in terms of design but with a greater base and lower crest. Since the western side is the sandy lagoon area, creating an artificial reef using submerged structures similar to “reef balls” or similar substrate may be useful. Once the reef balls are in place, coral growth will take place, if not, it can be induced by artificial coral transplantation that helps to populate the area with live corals.

9.6.3 Artificial headlands

The natural headlands of a pocket beach restrict long-shore sand transport. Such headlands act as groynes. Artificial headlands can be constructed to achieve a similar effect. On the open coast, this form of protection requires large and expensive structures. Consequently, their use has been restricted to more protected shallow areas with less severe wave conditions. Therefore, it is not considered suitable for Thudufushi. Yet, these would be given further consideration during the final design of the second phase of the proposed project.

9.6.4 Seawall or revetment

Instead of submerged breakwaters or groyne field, a seawall, low retaining wall or a revetment along the entire length of the western shoreline may be considered. The seawall is considered inappropriate for the resort because it is seen at all times, whereas a low retention wall would be seen only when exposed after a storm event or following wave attack during the southwest monsoon. A revetment is similar to seawall but is inclined according to the profile of the beach. In Thudufushi, revetments on western side would have to be made quite strong if they were to be kept intact. Hence, revetments, seawalls and low retention walls are considered inappropriate for Thudufushi. However, they will help to protect the properties behind them from the threats of erosion.

9.6.5 Continuous Re-nourishment of the beach

Re-nourishment would be an ongoing process, but the proposed coastal protection measures such as the breakwaters would help to minimize the frequency of re-nourishment. It is estimated that re-nourishment may be required once a year if no coastal protection is undertaken.

9.7 Preferred alternative

Several alternatives have been preferred including alternative locations for the proposed new over water structures and construction technologies. Constructing water villas using pile drilling have not been selected as alternative construction method for the supporting columns.

The preferred alternative for this project is to relocate the water villas on north western side of the island.

9.7.1 Mitigation measures for the proposed alternative

Following mitigation measures are proposed for preferred alternative.

- Relocate live corals in the lagoon that fall within the foot print of villas as much as possible.
- Undertake the construction in the shortest possible time to minimize sedimentation as well as any disturbances to the sea bed and the marine environment.
- Undertake the construction during low tide hours.
- Completely avoiding walking or any construction activity on the reef flat.

10 Environmental management and monitoring plan

10.1 Introduction

Environmental monitoring is essential to ensure that potential impacts are minimized and to mitigate unanticipated impacts. Monitoring will be carried out as part of the environmental impact assessment and monitoring requirements addressed in this EIA report.

10.2 Cost of Monitoring

The proponent has committed fully for the monitoring programme outlined in this report. The cost indicated below is for monitoring the project during the construction stage and for an additional two years during the operational stage. Monitoring will be undertaken by subcontracting the work to an independent consultant or a consulting firm.

10.3 Aspects of monitoring

Monitoring will include marine aspects and coastal aspects only. Monitoring report will be provided at the end of the construction stage and will adhere to Schedule M of the EIA Regulations, 2007.

10.4 Methods of monitoring

Environmental monitoring will be undertaken using standard methods described in the Methodology section. Monitoring is only recommended for marine and coastal environment.

Table 13: Aspects of the environmental monitoring program with cost breakdown

Monitoring Attribute	Indicator	Methodology	Monitoring Frequency	Estimated Cost (construction and operational phase for 2 years) (US$)
Marine water visibility in the lagoon	Visibility	Secchi Disc & Tow line distance	Every other day during work. Every 3 month thereafter	No cost. Contractor to undertake this during construction period.
Coral cover at survey sites 1 to 5	Percentage live cover	Qualitative & Quantitative	Once during the construction stage. Once a year thereafter (US $ 500 per survey).	3,000 per quarter
Coral recruitment at survey sites 2 and 3	Recruit/m²	Qualitative & Quantitative using photo quadrate	Once a year (US $ 500 per survey).	3000 per quarter
Marine water quality	suspended solids, pH, temp , COD, DO, Salinity, turbidity, nitrates, phosphates,	Onsite or Lab analysis	Every two months during work; twice a year thereafter (US $ 50 per test).	250 per quarter
Siltation	Sediment deposited on reef substrate	Qualitative	Every other day during work. Every 3 month thereafter	No cost. Contractor to undertake this.
Beach profiles	Changes to the beach	Using auto level	Every 3 months after construction	750 per quarter
Currents	Changes to the current	Using drogues	Every 4 months after construction	500 per quarter

Table 14: Detail cost of monitoring during construction period and for two years.

DESCRIPTION	UNIT COST (US$)	TOTAL (US$)
Logistics		
Transport to the island	Client to provide	
Food, accommodation and logistics	Client to provide	
Survey costs		
Cost of undertaking the environmental surveys during the project construction stage and operational stage		8,700.00
Report writing and submission to EPA (construction and 2 years thereafter)		8,000.00
Sub Total		16,700.00
30 % contingency		5,010.00
Grand total for monitoring during construction stage		21,710.00

10.5 Monitoring responsibility

Monitoring responsibility will be with the client and financial provisions will be made in the project to undertake the monitoring.

10.6 Monitoring Report

A detailed monitoring report will be compiled after the completion of the civil works. This report will be based on the baseline 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.

11 Conclusion and Recommendations

This EIA report has identified the major impacts of the proposed additional construction work.

It has been assessed that the most significant negative impacts from the proposed development will be on the lagoon bottom as a result of constructing new water bungalows, breakwaters and the deepening of the channel. The most significant impact period will be during construction stage as a result, several mitigation measures to reduce the impact on the marine environment have been proposed during the construction stage. These measures include measures such as undertaking work during low tide hours and also limiting the construction duration as much as possible. In addition, several other mitigation measures such as proper supervision have also been proposed.

Although the social impacts of the project were not assessed in detail, relevant stakeholders were consulted to obtain their views and opinion about the project. The project is also expected to have positive impacts, including the diversification of the services and increased revenue to the resort and to the country as a whole.

The monitoring programme for this project will mainly focus on marine and coastal environment and for this reason; specific parameters have been outlined for monitoring. Additionally, beach profiles will be taken to monitor long term changes to the beach. It therefore, appears justified to undertake this development.

Various alternatives were considered including alternative locations for the water villas and alternative methods of constructing water villas and coastal protection. Based on the assessment, it is recommended to urgently implement the coastal protection component to mitigate the existing erosion problem faced to the island.

12 Declaration of the consultants

This EIA has been prepared according to the EIA Regulations 2007, issued by the Ministry of Environment, Energy and Water. The EIA was carried out by a multidisciplinary consulting team representing Water Solutions Private Ltd.

We certify that the statements in this Environmental Impact Assessment study are true, complete and correct, to our best of our knowledge and ability.

Name: Ahmed Jameel (EIA 07/07)

Signature:

13 Commitment from the proponent

14 References

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15 Annex: Terms of reference

16 Annex: Proposed Master plan of the resort

17 Annex: Details of new water villas (over water)

18 Annex: Cross sectional Drawings

19 Annex: Bathymetry of the lagoon

20 Annex: Beach profiles and their locations