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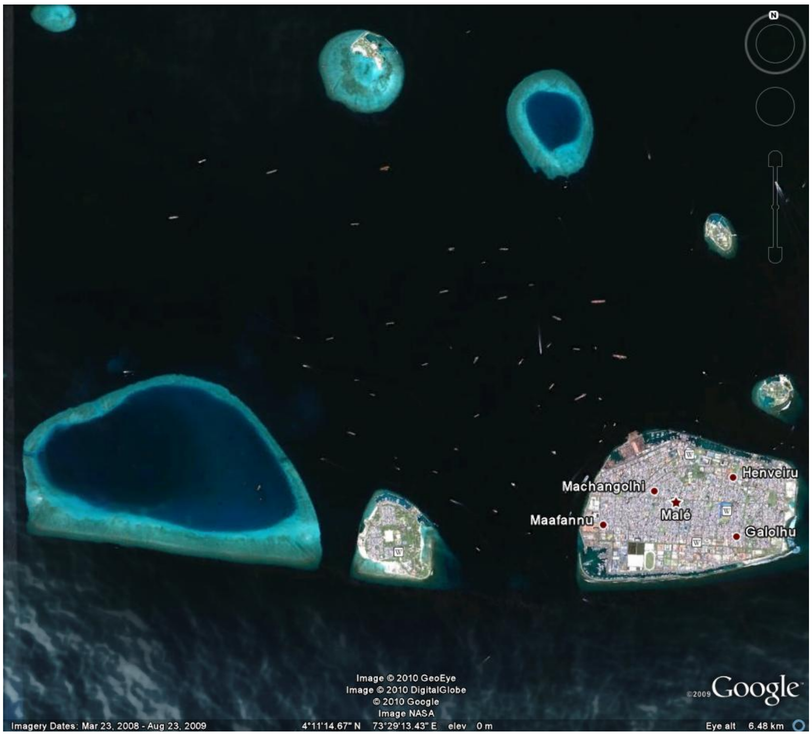
# Environmental Impact Assessment

## Development of Gulhi Falhu, Kaafu Atoll, Maldives

**Doc number: 06008-08-R-02-SROS-c-EIA Gulhi Falhu**
**Date : 1 July 2010**



## Document Control Sheet

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بسم الله الرحمن الرحيم

Ministry of Housing, Transport and Environment
Malé, Republic of Maldives

# TEMPORARY
# CERTIFICATE OF REGISTRATION

This is to certify that

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(Registration no: EIAT03/09)
is hereby registered as a temporary Environmental Impact Assessment Consultant under 14 (1) of Environmental Impact Assessment Regulations.

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Mohamed Aslam
Minister

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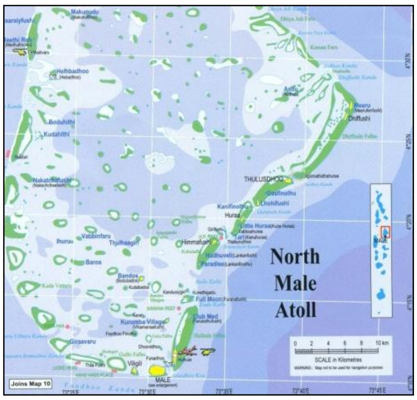
# 1 Introduction

## 1.1 General




The Republic of Maldives consists of some 1,200 coral islands grouped in a double chain of twenty-seven atolls. Most atolls consist of a large, ring-shaped coral reef supporting numerous small islands. Islands average only a few hectares in size, and lie between one and 1.5 meters above mean sea level. The Maldives have no hills or rivers. Some larger atolls are approximately fifty kilometers long from north to south, and thirty kilometers wide from east to west; no individual island is longer than eight kilometers. Each atoll has approximately five to ten inhabited islands; the uninhabited islands of each atoll number approximately twenty to sixty.

Only part of the surface area of the Maldives is inhabited. The population is concentrated on a limited number of rather densely populated islands, thereby providing a reasonable basis for social subsistence. Twenty atolls are populated ranging from 1,600 to 18,000 people (not including Malé). The entire population of the Maldives is scattered over 200 inhabited islands. In 2006 the population was calculated at 290,000, with about one-third of the population concentrated in the capital. The population growth in the Maldives has recently been as high as 2 to 3%. In the outer atolls the majority of the population is below 20 years of age. These outer atolls experience a large outward migration notably to Malé.

There are two main (international) ports in the Maldives. The most important port is Malé, located on the north-west side of Malé Island. This port has been improved during the First Malé Port Development Project completed in late 1992. The other larger port is Gan, located in the South of the Maldives; until the 1970's the Port of Gan was a Military/Air Force Base of the British. Until very recently, the port of Malé was the only port of the country where international cargo was handled. Since industrial activities began expanding to other islands, other ports have begun to be used for exports. With about one third of the country's population living in the greater Malé area, the Port of Malé retains its status as the central and the most important port of the country.

Gulhi Falhu (GF) reef and lagoon are located about 3 km west from Malé.

## 1.2 Background of the Study

The Government of the Maldives (GOM) in its efforts to enhance the economic potential of the Maldives has been considering the reclamation and development of the lagoon at Gulhi Falhu (GF) as a potentially attractive investment opportunity in infrastructure, for the past several years. The rationale for the development of GF lagoon is to provide an alternative location in the proximity to Malé, to carry out various commercial and light manufacturing activities, easing out the current congestion in Malé.
Gulhifalhu Industrial Zone limited, Maldives and Capital Investment and Finance Limited. United Kingdom have entered into a concession agreement with GOM, represented by the Ministry of Economic Development &

Trade to reclaim and develop the GF lagoon on March 18th 2010.

The complete reclamation of Gulhifalhu will consist of 4 phases. The first phase of the GF development project includes the reclamation of approximately 10 hectares of land along with the necessary shore protection. The second phase of the GF project concerns the development of a further 30 hectares. Phase 3 will consist of a 75 hectares and phase 4 of 115 hectares.

Planning of the phases will be in agreement of the concession agreement between the developer and the GOM.

The planned activities for these phases of the project are restricted to dredging, land reclamation, and shore protection. The impacts of the development of houses, roads and warehouses will be assessed in a separate EIA.

The GOM will offer the Joint Developers a long term lease on the land with the right to sub-lease the land for undertaking selected investments approved by the GOM. The GOM will also accord other incentives to the investors operating on the newly reclaimed land.

The present report contains a proposal for the Environmental Impact Assessment (EIA) for the dredging, reclamation and shore protection works of phases 1 to 3 of the GF land development. For the reclamation of phase 4 a separate EIA will be made. This report has been prepared by Hydronamic bv of Papendrecht, the Netherlands.

## 1.3 Aim and scope of EIA

The present scope of the EIA is based on the EIA Regulations from the Ministry of Housing, Transport and Environment (EIA Regulations 2007, ref. 1) and on EIA's for several other, similar, projects in the Maldives (Vilufushi Island Reconstruction and Viligili Island Reconstruction, ref. 2, ref. 3, Three Islands Project, refs. 4, 5). The EIA report covers both the natural and the social environment and includes the following main aspects:

- a description of the project including the usefulness and need of the project
- the policies and plans of which the project is a part and the legal framework of the project;
- information about the general environmental settings of the project area, covering both the marine and terrestrial environment and including physical and climatological characteristics;
- information on the social and economic baseline conditions;
- information on potential impacts of the project and the characteristics of the impacts;
- information on potential mitigating measures to minimise undesired environmental and social impacts;
- assessment of the best alternative for the project or for certain project components;
- basic information for formulating the environmental monitoring program and the environmental and social management plan;
- inventory of possible gaps in presently available information.

The focus of this EIA is on the construction phase of the project. Alternative locations for the development of new land in the Greater Male Area are briefly discussed.

## 1.4 Terms of Reference

The Terms of Reference (TOR) for this EIA were submitted to the Ministry of Housing, Transport and Environmenton 20 May 2010. A scoping meeting was held on 9 June 2010. Based on this meeting the TOR were adjusted and a final version was submitted on 27 June 2010 and approved by the EPA on June 30th 2010. The TOR follow the Environmental Impact Assessment Regulations 2007, as prepared by the Ministry of Environment, Energy and Water.

The approved Terms of Reference can be found in Annex 1.

## 1.5 Experience of proponents with similar projects

The project proponent, Capital Investment and Finance Ltd.(CIFL), has contracted Royal Haskoning, an internationally renowned engineering and consultancy, to make engineering designs for the project. Royal Haskoning is one of the largest port development consultants in the world and has wide experience in the fields of urban development and water & environment.
CIFL has also contracted Royal Boskalis Westminster to do the dredging and reclamation works necessary for the development of Gulhi Falhu. Boskalis has worldwide experience in dredging and reclamation works and has worked for the Government of the Maldives on tsunami reconstruction projects at Vilufushi, Thaa Atoll (2005-2006) and Viligili, Gaafu Alifu Atoll (2007-2008).

## 1.6 Field work

The field work necessary for the environmental and social impact assessment was carried out by expert professionals.

The environmental field work (coral surveys) in June 2010 was done by 2 divers and a snorkeler from Multi Marine Services Pvt. Ltd., in charge of the underwater photography and dive safety, and 1 marine biologist from Seamarc Pvt. Ltd. to organize the survey layout with the Boskalis environmental engineer.

The social consultations were done by Mr. Chris Geerling PhD, of Carnbee Consult. Previously, Mr Geerling was in charge of the social impact studies for the projects in Vilufushi and Viligili and for the Three Islands Project.

# 2 Problem Analysis and Justification of Project

## 2.1 General

In the Maldives in general and also in the Kaafu Atoll and the greater Malé area, there are significant problems directly related to the natural environment. The most important problems are caused by population pressure and lack of space for future development, but also by natural phenomenons such as increasingly extreme weather conditions and sea level rise. The tsunami of 26 December 2004 and the damages caused have created a further threat to the environment in the area; although the direct damages were large but in general manageable, the migration from the outer atolls to Malé increased substantially. In this chapter the relevant problems will be shortly analyzed and the need for the project and its general outline and dimensions will be discussed.

## 2.2 Problem analysis

### *2.2.1 Land scarcity in the Malé area*

Land is extremely scarce in the Maldives, which acts as a constraint on the development of the country. This is especially true for Malé, the capital city of the country, with a population of more than 100,000 people, concentrated in just two square kilometers. Due to a lack of employment opportunities in the outer atolls in recent years, many people migrated from small islands towards Malé. The percentage of the country's total population living in Malé has increased from 25% to 35% during the period 1990 - 2006. This concentration seems to continue, especially after the 2004 tsunami, despite efforts of GoM to discourage people coming to Malé. The continuing overcrowding in Malé has resulted in a lot of economic and social problems: high land rental rates, no room for industrial/commercial development, environmental issues, crime, etc.
To ease out the current congestion and enhance the economic potential of Malé, the GoM is considering and/or has undertaken several land development projects in the Malé area. The Gulhi Falhu land development project is one of them.

### *2.2.2 Population pressure*

The population growth in the Maldives has recently been as high as 2 to 3%; in the outer atolls the majority of the population is below 20 years of age. Due to the significant population growth, many of the islands are completely full. This means that there is no place for additional people, for further communal and/ or commercial activities, and for migration from smaller islands to the bigger regional centres.

Due to the relatively 'small' populations (average 500-1,500 persons) per island, the costs of providing community infrastructure (electricity, water supply, sewerage, waste collection) and communal services (health, education, local administration) is extremely high. Even the limited depth of the islands ports and the low transport volumes, lead to high per-ton transport costs for import of food, construction materials and other goods.
In a country with high GDP growth, and a society that is rapidly modernizing, demand for better infrastructure and services will often grow at a much faster pace than even GDP growth.

Both the population pressure and the high costs of communal infrastructure and provisions in the smaller islands will in time result in mitigation to larger islands, often to Malé.

### *2.2.3 Extreme weather conditions and sea-level rise*

At the Maldives virtually no cyclones occur, but sometimes there are significant storm surges with up to one meter sea level rise. In April 1987 there was a storm surge at Malé, which resulted in unusually high waves. One third of Malé was inundated by about 60 cm of water. Again in 1991 a storm surge occurred near Malé. Although the damage was minimal, the experience was a forceful reminder of how vulnerable the Maldives can be to even a small rise in water level. Then of course there was the December 2004 tsunami and the resulting waves and flooding in Malé.

Climate change and predicted sea level rise are of great importance to the Maldives, due to the low elevation of the islands, making them vulnerable to even small rises in the sea level. During the past century the global temperature increased by about 0.6 degree. Climate models calculate that the global mean surface temperature of the earth could rise by about 1 to 4 degrees by 2100. During the past century the average sea level increased by about 15 to 20 cm. The estimated predicted sea level rise in the period 2000 to 2100 will be, according to the latest UN/IPCC (Intergovernmental Panel on Climate Change) report (Jan 2007), between 18 and 59 cm, average 0.4 meter. This sea-level rise combined with more frequent extreme weather occurrences makes the Maldives one of the most vulnerable countries to climate change and sea level rise.

## 2.3 Justification of the project

There are three main objectives of the project:

- Increase the useable land-space in the Greater Malé area, allowing extra space for industrial activities, housing, and services, including related infrastructure, which should be provided on the new island against reasonable costs.
- Build the new island as a safe-island, providing reasonable safety against the sea for at least the next 50 years.
- Provide efficient transport facilities for the new industries and services, and the people employed on the new land.

The economy of the Maldives is growing and with it the population, transportation of goods, the need for harbours, schools, hospitals, housing and wharehouses and industrial activities increase as well. The necessity of space for all these activities is extensive. In Kaafu atoll there are currently more development projects in execution or planned.

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| **Area** | **Main land use** |
|---|---|
| Hulhumale 1 | Residential (+light industry) |
| Hulhumale 2 | Residential |
| Hulhumale DP World | International shipping |
| Hulhumale airport ext | International air traffic |
| Male NW port area | Shipping |
| Thilafushi | Heavy Industries |

Gulhi Falhu is located close by Malé in the southern rim of Kaafu Atoll. Overall some 200 hectares of land could be developed in/on Gulhi Falhu reef and lagoon; this land will border (enclose) a large protected anchorage area, accessible virtually at all times. After its implementation the project is expected to have a huge effect on employment in the Greater Malé area. When completed GF island will be a part of the urban corridor on the south-east side of Kaafu Atoll consisting of (west to east) Thilafushi, Gulhi Falhu, Villingili, Malé island, Hulhumale airport, and Hulhumale residential landfill.

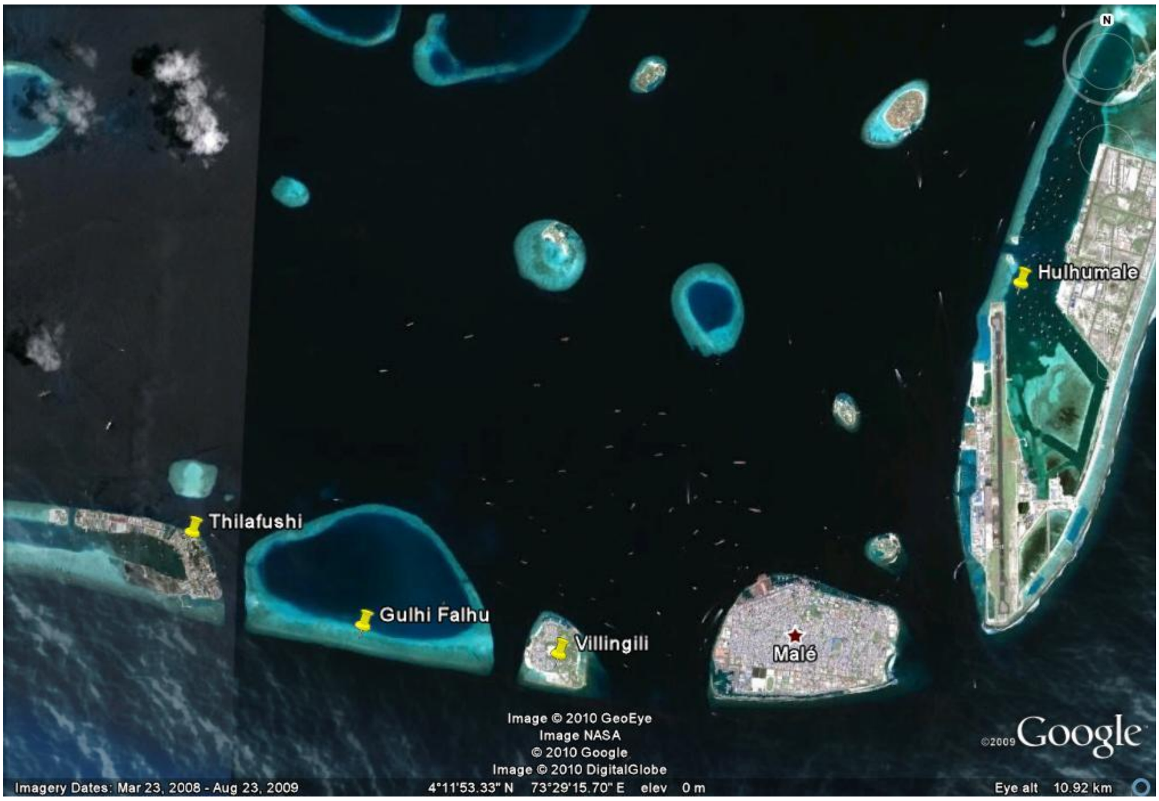


Figure 2-1 - Location of Gulhi Falhu in Kaafu Atoll

## 2.4 Potential users

The key functions for the development of Gulhi Falhu include the relocation of some industrial activities from Malé, the relocation of logistics inter-island redistribution activities, and it caters for related population growth.

The Maldivian Foreign Investment Services Bureau (FISB) confirmed in its Letter of 17 October 2006 which activities could be operated on Gulhi Falhu. The Joint Developers, made an assessment of these operations and concluded that the potential users as identified in Table 2-1 were to be included in the master planning for Gulhi Falhu.

Table 2-1 Potential Users for Gulhi Falhu

| Potential Users |
|---|
| Warehousing Complex |
| Cool and Cold Storage |
| (Business) Hotel |
| Maritime Training College |
| Social Housing |
| Low Cost Labour Housing |
| Hospital |
| Duty Free Shopping / shopping mall |
| Offshore Banking, Finance and Insurance |
| Power Generation |
| Bonded Stores |
| International school |

# 3 Project Setting

## 3.1 General

The Maldives are a democratic republic with a written constitution. The protection of the environment is a national priority in the Maldives and efforts have been made to incorporate environmental protection and preservation across all sectors. As such, environment is granted ministerial status (Ministry of Housing, Transport and Environment); in addition, an Environmental Protection Agency (EPA) and a high level National Commission for the Protection of the Environment (NCEP) have been set up.

## 3.2 Environmental legislation

The enforcement of EIA regulations in the country began with the formulation of the Environmental Protection and Preservation Act (Law 4/93) in April 1993 in order to protect, preserve and safeguard the fragile environment of the country. The Environmental Act or Law 4/93 is the single most important legal instrument with regards to environmental management. The main aim of the legislation is to protect and preserve the environment of the Maldives, and to sustainably manage its resources for the collective benefit and enjoyment of present and future generations.

It is currently being implemented by the Ministry of Housing, Transport and Environment. Under this act, regulations and guidelines have been developed concerning the environmental protection, especially regarding development activities, through implementation of EIA procedures.

Important national environmental legislations relevant to this study are, including the above-mentioned act no. 4/93:

- National Environmental Action Plan III (2008/2009);
- Environmental Protection and Preservation Act of the Maldives (law No 4/93);
- The law of Tourism (law No15/79);
- Environmental Impact Assessment Regulations (2007);
- Regulations for coral mining (1992);
- Fishery Law of the Maldives (law No 5/87);
- National Biodiversity Strategy; project initiated late 1998;
- National Strategy for Sustainable Development (2009).

The Environmental Act also provides the basic framework for the Environmental Impact Assessment (EIA) process in the Maldives. Under article 5a of the act, an impact assessment study shall be submitted to the Ministry of Housing, Transport and Environment before implementing any project related to economic development that has potential environment implications. According to the EIA regulations, for example, all new resort developments require an EIA before approval for development can be issued. In an early stage of project-development a so-called IEE (Initial Environmental Examination) may be prepared. After the evaluation of this IEE, the Ministry of Housing, Transport and Environment, together with the project proponent will decide whether a full EIA study is still required.

## 3.3 National policies

In addition to the relevant environmental legislation, various National Policy Plans address the environment as well. The most important ones are:

- the Third National Environment Action Plan (NEAP III);
- the National Strategy for Sustainable Development, and;
- the Seventh National Development Plan.

The National Strategy for Sustainable Development is a new policy developed by the new government. Its aim is to unite all existing policies regarding environmental, social and economic development, and to provide a framework for future policies addressing these issues.

The aim of NEAP III is to protect and preserve the country's environment and to properly manage natural resources for the sustainable development of the country. It also encompasses a framework for action for the future. The NEAP III identifies the environmental priorities and policy directions for the next five years and also addresses key issues and respective measures towards the betterment of the environment, which will benefit present and future generations. The NEAP III aims to achieve six results:

- Resilient Islands
- Rich Ecosystems
- Healthy Communities
- Safe Water
- Environmental Stewardship
- Carbon Neutral Nation

To achieve these six results, thirty 'Goals' have been formulated, addressing issues such as protection of human settlements, increasing resilience of the coral reef to climate change, improving waste and sewage management, providing safe drinking water, improved environmental education and awareness, environmental legislation and research. The development of Safe Islands is one of the goals listed under "Resilient Islands".

The seventh National Development Plan was developed in 2007 and also identifies important measures and the role the government will play in terms of developing and implementing sound environmental management strategies. The goals formulated for economic, spatial and social development are also incorporated in the NEAP III and the National Strategy for Sustainable Development, both of which were developed after the NDP7 was released.

As part of these development and action plans, the Government of the Maldives has adopted a policy of passive population consolidation that encourages mobility of the population by connecting all the islands with a proper transport network, rather than the active relocation of people.

## 3.4 International Context

The major global issue facing the Maldives is climate change, global warming and subsequent sea-level rise. The small size of the islands and their low elevation above MSL makes the islands susceptible to sea level rise. Consequently, the country plays a prominent role in fore fronting environmental issues faced by many other small-island developing states, mainly located in the Pacific regions of Polynesia and Micronesia. The Maldives is therefore, a party and signatory to various international conventions and declarations. These include:

- UN Framework Convention on Climate Change;
- Kyoto Protocol;
- UN Convention on Biological Diversity;
- Montreal Protocol on Substances that Deplete Ozone Layer;
- Basel Convention on Transboundary Movement of Hazardous Waste;
- UN Convention on Law of the Sea;
- Washington Declaration of Protection of the Marine Environment from Land-based Activities;
- UN Convention to Combat Desertification;
- Regional Agreement to Conserve Marine Turtles under the Convention on Migratory Species.
- Copenhagen Accord, 2009

## 3.5 Responsible Ministries and Institutions in the Maldives

The main governmental institutions, involved in the development of Gulhi Falhu are described below.

The act 4/93 names the (then) Ministry of Planning and Environment as the main responsible ministry for safeguarding the environment. Some years later this responsibility went to the (then) Ministry of Home Affairs, Housing and Environment; whereas in 2004 the responsibility went to the Ministry of Environment and Construction (MEC), and more recently to a new Ministry of Environment, Energy and Water. Under the new government of President Nasheed, who was elected president in 2008, the Ministry of Housing, Transport and Environment (MHTE) is responsible for safeguarding the environment.

At present, the MHTE is the authoritative and responsible body for the effective implementation of the Environmental Protection and Preservation Act in the Country and has the statutory power over various issues related to the environment. The MHTE plays the main role within the government system with regard to environmental matters. It has the central control over environmental protection, conservation, management and related matters. This is mainly manifested at the policy level. The ministry is also responsible for developing, advising and undertaking environmental policies and government positions in national and international context as well as undertaking monitoring and research related to the environment.

In May 2004 the Environment Section of the (at that time) MEC published the so-called "Information Handbook for Proponents for EIA" (draft), which describes and clarifies the EIA process to be followed. In 2007 an updated version, Environmental Impact Assessment Regulations 2007, was published by the Ministry of Environment, Energy and Water.

The MHTE will, in case of project approvals, normally seek the advice of the National Commission for the Protection of the Environment (NCPE). The NCPE was appointed by the President in 1989 and restructured in 1993 at the time of the Environmental Act (Law No 4/93). The Commission was again restructured in 1999 to broaden the consultative process on environmental protection among the government concerned agencies. The mandate of the NCPE is to advice the Minister of Environment on environmental matters such as environmental assessment, planning and management and political decisions with regard to protection of the environment. A number of government agencies and ministries (Ministry of Tourism, Arts and Culture, Ministry of Fisheries and Agriculture) have environment-related mandates, sometimes these overlap with the mandate of the MHTE.

In the case of the development of Gulhi Falhu Industrial Zone Limited is the project proponent and client (employer) for the construction contract execution. The Ministry of Housing, Transport and Environment will act as Licensing Agency.

A Concession Agreement was signed with Gulhi Falhu Industrial Zone Limited (State owned company in Maldives) followed by a Foreign Investment agreement with the Ministry of Economic Development. The project has been approved by the Ministry of Finance and Treasury. In the former government the project was also approved by Presidential Degree in 2007. Both approval letters can be found in annex 2.

## 3.6 IEE or EIA

Due to the size of this project, an EIA study is strongly recommended. For this project, Hydronamic bv of Papendrecht, the Netherlands has prepared a Proposal for Terms of Reference for this EIA. This proposal has been submitted to the competent authorities in the Maldives.
The terms of reference (TOR) are fully in accordance with the demands of the relevant authorities in the Maldives in this respect; they are also very similar to the TOR prepared for similar projects ('Reconstruction of Viligili island' and 'Post-tsunami reconstruction of Vilufushi island', as proposed in 2007 and 2005 respectively) by the Netherlands Commission on Environmental Impact Assessment. The TOR are also based on those approved by the Maldives EPA for the Three Islands Project in December 2009.

# 4 Project description

The global construction design for the development of Gulhi Falhu and the main construction activities for the dredging, reclamation and the shore protection are described in this chapter. First some general information about the project is given. The following items are addressed:

- Master Plan considerations including the characteristics of Gulhi Falhu, marine conditions and phased development
- Technical boundary conditions
- Design considerations such as reclamation design levels and the design and construction quantities for phase 1 and 2
- Dredging and reclamation method and equipment alternatives
- Revetment construction
- Quay walls
- Project planning

## 4.1 Master Plan Considerations

In developing the master plan for Gulhi Falhu, the following issues have been considered: characteristics of the Gulhi Falhu reef and lagoon, marine conditions and phased development.

### *4.1.1 Characteristics Gulhi Falhu*

Gulhi Falhu is a ringed reef located on the southern rim of North Male' atoll. It has a central location with the artificial island of Thilafushi to the west and that of Vilingili to the east (Figure 4-1). As such it is more protected from the direct hit of the southeast swell wave than Male' or Viligili, but is also less affected by the diffraction of the swell progressing northward in the inner sea, which reaches the reefs of Thilafushi and Giraavaru with more energy. The reef is therefore lacking a number of characteristics usually present in exposed reefs and the periphery of the reef is deeper and narrower. The reef crest is virtually absent and there are no breakers except at the reef corners facing the Vaadhoo Kandu to the south. The hydrodynamic forces are not strong enough to pile up large amounts of rocks. At the corners, two small sand banks are naturally created where the reef is shallower.

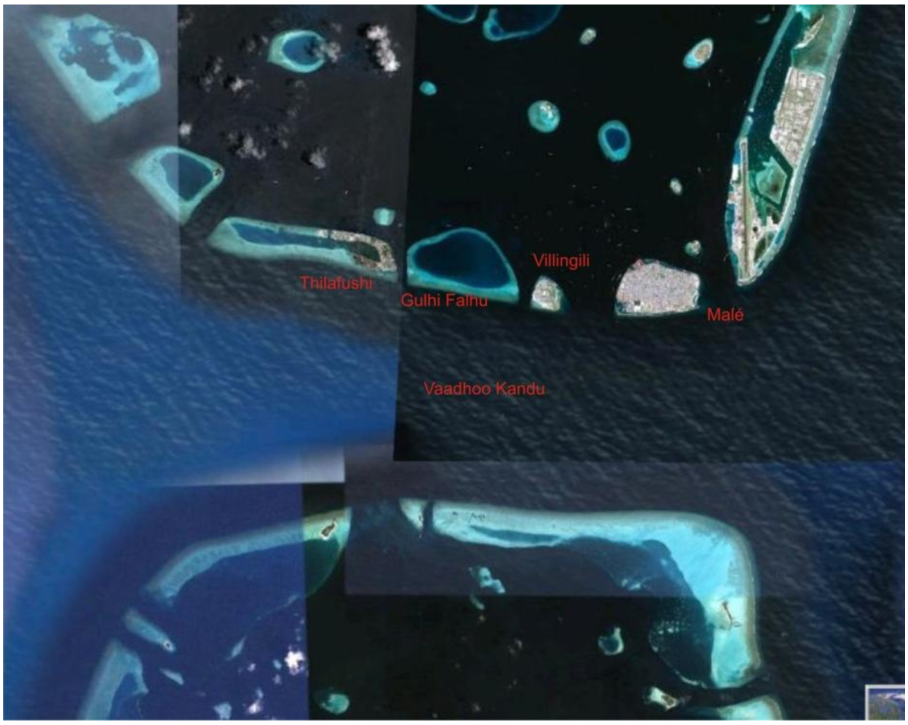


Figure 4-1: Location of Gulhi Falhu

On the southern side, the flat foreslope of the reef edge drops sharply at 4 meters to a wall where many overhangs are present. One of them has broken off on a whole section and is a popular dive site called "Hans Hass Place". On its shallow side, it is replaced with a rocky platform with little loose substrate where the wave influence is the strongest. It later becomes more and more like a lagoon and more sandy.

Gulhi Falhu is a typical atoll shape reef, which is at present almost entirely below water. Only a small area in the southwest corner of the reef flat emerges at low tide. A detailed bathymetric survey has been made. The outer edges of this reef are located just below Mean Sea Level (MSL) and have a (variable) width of 200m to 400 m. In the middle / western part of the lagoon the water depths are up to MSL – 20m.

In developing Gulhi Falhu it is therefore best to reclaim land area around the edges of the lagoon to reduce required land fill volumes. The shallow southern edge is wider than the northern one and therefore more land can be readily reclaimed on this southern side. Based on these characteristics of Gulhi Falhu lagoon, the reclaimed areas in the master planning are located around the edges, phase 1 and 2 mainly along the southern reef.

### *4.1.2 Sea Conditions*

The marine conditions at Gulhi Falhu can be described as being moderate. The tidal levels related to MSL for Malé port have been derived from Admiralty Chart 3323 and are presented in *Table 4-1* below.

| Tide | Level [m] MSL |
|---|---:|
| HAT | +0.6 |
| MHHW | +0.3 |
| MLHW | +0.1 |
| MHLW | -0.2 |
| MLLW | -0.4 |
| LAT | -0.6 |

Table 4-1: Tidal Levels at Malé Port related to MSL.

The Maldives are located in a monsoon area. Moderate to stronger winds are therefore coming from a westerly sector in the period April to November, whilst in the NE monsoon moderate winds are blowing from the NE sector. Wind generated waves are coming from the same sectors, whilst the swells are mainly coming from southerly directions. Currents can be characterized as moderate running around the atoll from north to south or vice versa. The main directions of the winds, waves, swell and currents are shown in **Error! Reference source not found.**.


Figure 4-2: Winds, Waves, Swells and Currents at Gulhi Falhu

### *4.1.3 Phased Development*

In any master planning project, due attention is required for a phased development of the facilities and the same is the case for the development of Gulhi Falhu. Phasing is needed to best anticipate on market requirements (land areas needed) as well as developments (type of users).

At the time of writing of this Environmental Impact Assessment the Master Plan for the development of Gulhi Falhu has dedicated the land created in Phases 1 mainly for warehousing and distribution and land created in Phase 2 mainly for housing (see also the Master Plan in Annex 3). During the development of the phases, the following facilities will also be developed:

- Power supply
- Drinking water supply

The following phasing is proposed for the development of Gulhi Falhu (see also Figure 4-3):

- Phase 1: approximately 10ha
- Phase 2: approximately 30ha
- Phase 3: approximately 70 ha
- Phase 4: to be determined at a later stage

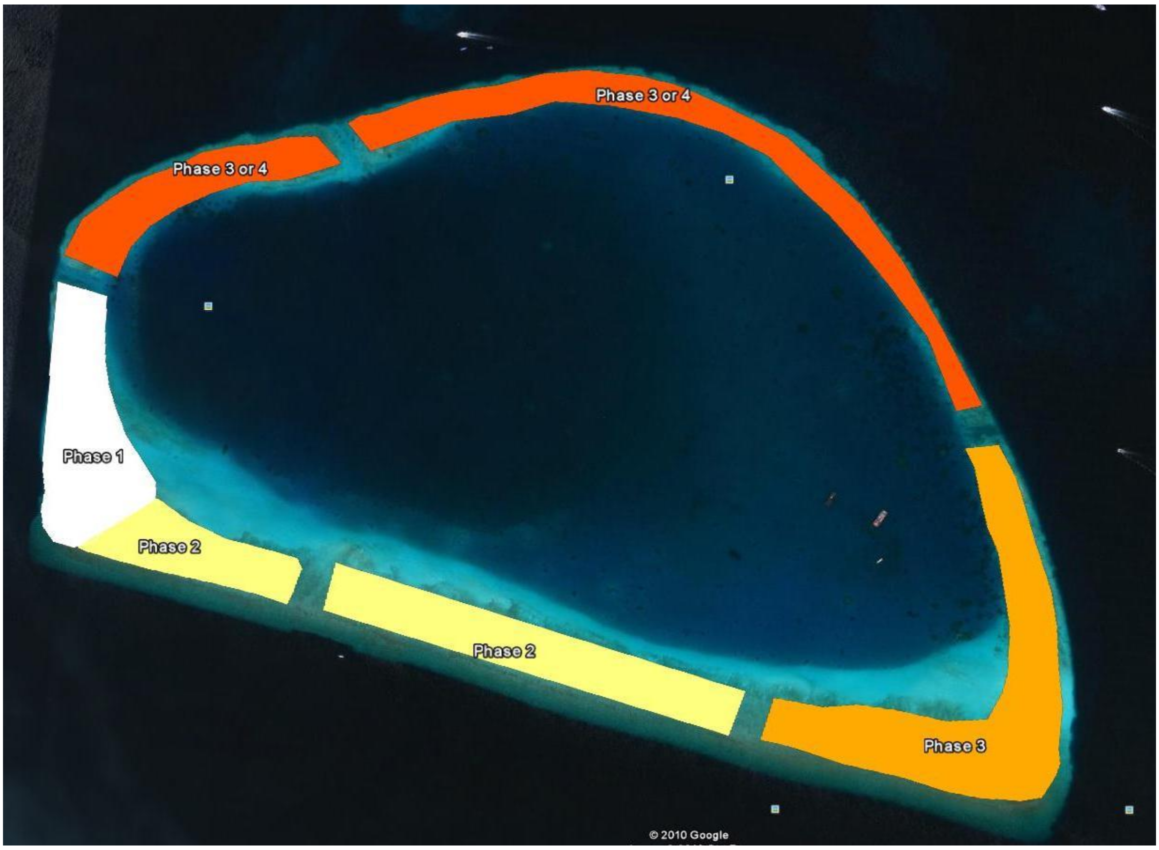


Figure 4-3 Gulhi Falhu project phasing

## 4.2 Technical Boundary Conditions

Gulhi Falhu consists of a shallow reef, enclosing an inner lagoon area. The outer dimensions of the Gulhi Falhu reef are approximately 2500 m (east-west) by 1500 m (north-south). The width of the surrounding shallow reef varies between 300 m (south side) and 100 to 150 m (north side). The waterdept related to MSL over the reef varies between 1.0 and 2.0 m; there is no land in Gulhi Falhu. The enclosed inner lagoon has waterdepths of around -10/-12 m MSL (appr. 100 ha in the east) and around -18/-20 m MSL (appr. 100 ha in the west).

The general boundary conditions for the project design will be described in chapter 6 including: location, geography, climatic conditions, hydraulic conditions, geology, soils, and marine ecology.

## 4.3 Design Considerations and Design

The design of the reclamation and shore protection works has been based on the following main concepts and considerations:

- To make maximum use of the topography / bathymetry as presently exists at Gulhi Falhu on the one hand and using least-cost considerations on the other hand:
  - The phase 1 and 2 reclamation takes as much as possible place in areas with present water depths of 1 to 2 meters.
  - The phase 3 and further reclamation may take place in areas with present water depths of 1 to 10 meters.
- Depending on the work method chosen, the borrow area will be located inside Gulhi Falhu lagoon (when using a Cutter Suction Dredge, see paragraph 4.4), or just north of Gulhi Falhu in the Kaafu lagoon (when using a Trailing Suction Hopper Dredge).

- The newly reclaimed areas of the Gulhi Falhu island must be protected against flooding, wave action and erosion.
- The existing currents (mainly tidal) around the Gulhi Falhu reef should be affected as little as possible by the project.
- The dredging (or borrow) areas should be located, if possible, within a pumping distance of maximum 1500 meters from the reclamation when using a CSD.
- The existing natural values on the outside of Gulhi Falhu reef must be preserved as much as possible.

### *4.3.1 Reclamation design levels*

Taking into account the presently occurring water levels, the future sea-level rises, and also the relatively high-value industries and services that Gulhi Falhu land-development caters for, the finished level of the industrial land will be +1.5 m MSL. It is noted that most of Malé and the other inhabited islands in the Maldives are at +1.0 m MSL to +1.4 m MSL; so called “Safe Islands” are presently constructed at +1.4 m MSL.

### *4.3.2 Design and construction quantities for phase 1 and 2*

Taking into account the above main considerations, the project design has been prepared and is shown in Figure 4-3. Further details and the relevant considerations are described here below.
Phase 1 of the project will include the following main construction activities (all approximate and depending on final design):

- Phase 1: Dredging and reclamation of about 300.000 $m^3$ of coral sand
- Phase 2: Dredging and reclamation of about 700.000 $m^3$ of coral sand
- Construction of revetment

| Location | Impact of waves/ current | Length of revetment (m) |
|---|---|---|
| Seaside (south side of Gulhi Falhu) | Heavy (waves) | 1500 – 1700 |
| Between channels | Heavy (current) | 500 |
| Lagoon side (inner slopes) | Light – medium | 1000-2000 |

- Mitigation measures for the environment.

Dredging and construction quantities for phase 3 have not yet been determined.

Duration of the construction works is estimated to be 6-7 months per phase.

## 4.4 Dredging and reclamation method alternatives

This section describes the different options for dredging methods and the location of borrow areas. Options include the use of a Cutter Suction Dredge (CSD) to dredge material from a borrow area in the reef lagoon or the use of a Trailing Suction Hopper Dredge (TSHD) to dredge material from a borrow area in the atoll lagoon area.

### *4.4.1 Method and equipment, alternatives*

#### *4.4.1.1 Sources of fill material and type of dredger*

The potential available sources of fill material, which can be used in this project, are given below:

1. sand and coral material from the shallow reef flat and the lagoon area within in the reef, to be dredged by a cutter suction dredge (CSD);
2. sand from the bed of the lagoon of the atoll (away from islands), to be dredged by a trailing suction hopper dredge (THSD);
3. sand and coral material from a reef elsewhere in the atoll, to be dredged by a CSD;

4. sand imported from overseas using a large scale TSHD.

Option 1 has simple logistics, the impacts on the environment are localised (limited to an area around the island and inside the lagoon where dredging and reclamation activities take place) and manageable.
Option 2 also has relatively simple logistics, although deep water access to the islands is required. The impacts on the environment are localised (limited to the borrow area and the island where reclamation activities take place) and manageable.
Option 3 involves more complicated logistics for transportation of the dredged material from the borrow area to the reclamation area. The impacts on the environment are also more severe, due to the fact that coral reefs will be exposed to dredging and reclamation activities at two different locations. Environmental impacts are therefore more difficult to manage. This makes this option environmentally prohibitive.
Option 4 involves very long sailing distances for the TSHD and a very long execution time of the project. This makes this option economically prohibitive.

*Option 1: Dredging with a CSD in the reef near the island and in the lagoon of the reef*
A CSD is a stationary dredger, which dislodges the material with a rotating cutterhead mounted on a ladder (see also Figure 4-4). The cutterhead is equipped with cutting teeth. The loosened material is sucked into the suction mouth located in the cutter head by means of a centrifugal pump, which is installed on the dredge pontoon or on the ladder of the dredger. The amount of material not entering the suction mouth may be as much as 30% of the total dislodged material. Much of this material will fall immediately to the seabed and will be dredged on the next cut. Only the finer particles will stay in suspension and will be distributed throughout the water column by the local currents. With a CSD, the creation of turbidity is a more or less a continuous process. Due to the fact that a rather deep basin will be created by the CSD of about 6 – 7 meters depth, the majority of the suspended sediments will stay within this created basin. As the cut material will be disposed by a discharge pipeline to the land reclamation site no additional turbidity will be created at the dredging site. To assess how the suspended sediments are spread over the coral reef areas, it is necessary to consider the local hydrodynamic conditions.

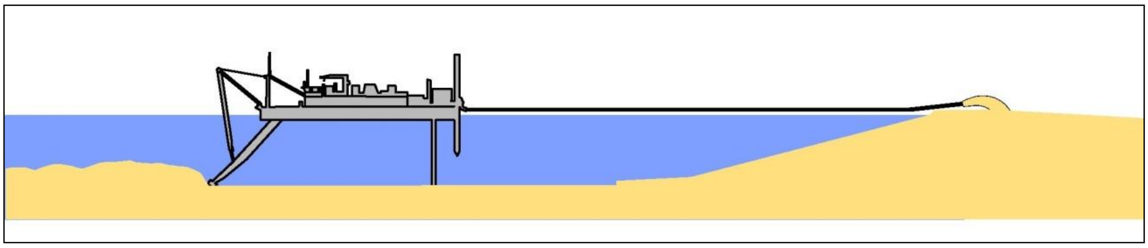
Figure 4-4 - Sketch of cutter suction dredge

*Option 2: Dredging with a TSHD in the lagoon area of the atoll*
A TSHD is a normal sea-going ship equipped with one or two suction pipes. At the end of each suction pipe is a draghead, which can be lowered onto the seabed while the TSHD navigates at a reduced speed. The material loosened by the draghead, together with some transport water, is sucked into the suction pipe by means of a centrifugal pump, and subsequently placed in the hopper of the dredger. The TSHD will transport the sediments to the reclamation where they will be brought to shore.

Most of the turbidity generated by a trailer suction hopper dredge is caused by the overflow of turbid water during the hopper filling operations. Overflow is the flowing overboard of excessive process water, together with a large part of the finest material. Overflow is used to maximise the load of sand inside the hopper. When dredging pure sandy sediments the amount of overflow of particles is mainly determined by the grain size distribution of the dredged sediment. It is to be noted that the overflow process will not be a continuous activity, since its duration will be limited to operational dredging time, which is usually less than half the total cycle time.
The suspension of sediments and the effects on the coral reefs will mainly depend on the grain size distribution, the local currents and the distances to the coral reef areas.

*Preferred option*
With both types of dredgers a sediment-water mixture will be pumped to the reclamation site from where the excess of water will flow back (return flow) to the sea and most of the sediments stay behind. The potential issue of turbidity is basically the same for both dredging methods. The main differences between the methods are that:

- Impact of the re-suspension from the CSD at the borrow area can be better controlled than from the THSD at the atoll lagoon;
- During overflowing with the TSHD a large portion of the fines will be returned to the borrow area. The dredged material arriving at the reclamation area therefore contains less fines compared to the material from the CSD;
- Option 1 will have less negative impact on the ecology of the borrow area and nearby sensitive areas compared to option 2. Option 2 has less negative impact on sensitive receivers around the reclamation area compared to option 1. Since the reclamation area is located close to a marine Protected Area option 2 would be preferred above option 1.

Other issues which may have to be included in the evaluation, can be:

- sailing distance,
- affected surface in the borrow area etc.;
- keeping the reef intact
- etc.

#### *4.4.1.2 Size of CSD*
Three alternatives can be considered, viz. a small, a medium and a large CSD. For the selection a number of aspects have been taken into account:

- dimensions in relation to mob/demob;
- dimensions in relation to the access to the borrow area;
- dimensions in relation to the size of the borrow area (including depth = thickness of layer of relatively loose sediments);
- capacity in relation to pumping distance (max length of pipeline is an important factor);
- capacity in relation to construction time;
- economical and environmental consequences;
- operational consequences.

The small size cutter dredge is advantageous in relation to the dimensions but not in relation to the capacity. The use of a medium size CSD seems to be positive, also in relation to the economical, environmental and operational aspects.

*Size of TSHD*
Three alternatives can be considered, viz. a small, a medium and a large TSHD. For the selection a number of aspects have been taken into account:

- dimensions in relation to mob/demob;
- dimensions in relation to the distance to the borrow area;
- dimensions in relation to the depth of the seabed at the borrow area (including thickness of layer of relatively loose sediments);
- capacity in relation to pumping distance (max length of pipeline is an important factor);
- capacity in relation to construction time;
- economical and environmental consequences;
- operational consequences.

A small sized TSHD will not be able to dredge sand from the seabed at the required depths (20-80m), and even a medium sized TSHD will not be able to do this. There is therefore a technical need to use a large size TSHD.

#### *4.4.1.3 Design of the reclamation area*
As for the design of the reclamation area there are 3 options

1. Enclosed reclamation area with bunds all around in all phases of the reclamation
2. Open reclamation area without bunds in all phases

3. Reclamation area with no bunds in phase 1 and 2 and with bunds for phases 3 and 4

Option 1 involves more complicated logistics since Gulhi Falhu reef is completely submerged and there is no material to create bunds with at the start of the development. Material needs to be imported to create the bunds. Additionally there needs to be land reclaimed before excavators or bulldozers will be able to prepare the bunds for the revetments. Another option is to build the bunds from the water. For this cranes on pontoons, barges or a hopper with sand. The impacts on the environment are localised (limited to an area around the island and inside the lagoon where the construction of the revetment takes place) and manageable. The revetment will reduce the size of the impact area during reclamation activities by keeping the excess water containing fine sediment within the bunded area. Release of this water is manageable.
The import of sand from overseas, the equipment and the long execution time make this option economically prohibitive.

Option 2 has simple logistics since no preparations need to be made prior to the reclamation. The impacts on the environment are temporary increased turbidity levels, a relatively high load of sediment which is potentially difficult to control, due to the fact that excess water will be released on all sides of the reclamation and during each phase. Environmental impacts are therefore more difficult to manage. This makes this option environmentally prohibitive.

Option 3 has moderately easy logistics. Phase 1 and 2 will be executed according to option 2. Before phase 3 and 4 will commence bunds can be set up with material stored on the reclamations from phase 1 and 2. The bunds can be set up with excavators and bulldozers from the now existing land. The impacts for the creation of the bunds on the environment are localised (limited to the area of the revetment) and manageable. The impacts of the reclamation of phase 1 and 2 such as increased turbidity and a high sediment load will however be short term. The turbidity increase and the sediment load during the reclamation of phase 3 and 4 will be reduced, more local and much more manageable.

*Preferred option*
Option 1 will have the least impact on the ecology of the area around the reclamation area and nearby sensitive areas. However this option is economically not feasible and does not fit in the Master Plan of the development of the Gulhi Falhu project. Option 2 is environmentally prohibitive and will therefore not considered as an option. Option 3 is economically feasible with the strongest impact mainly focused on phase 1 and 2. In combination with mitigating measures in order to try and reduce the influence area of the impact this is considered as the preferred option.

### *4.4.2 Revetment construction*

For the south side revetment an optimization has shown that a 50-70 meter wide strip of reef area will be left untouched in order to allow wave energy dissipation and a resulting reduction of cost of the revetment; a wider strip would result in cheaper revetment but also in a loss of easily reclaimed reef area.

All shore protection works have been designed in rock placed on geo-textile; at some locations concrete blocks, X-blocks or acropods may be considered as an alternative. Rock is imported from India or Sri Lanka. Phase 1 and 2 will be attached to each other. No shore protection will therefore be placed between the reclamation sides of these phases.

Figure 4-5 shows a typical cross section of a revetment.

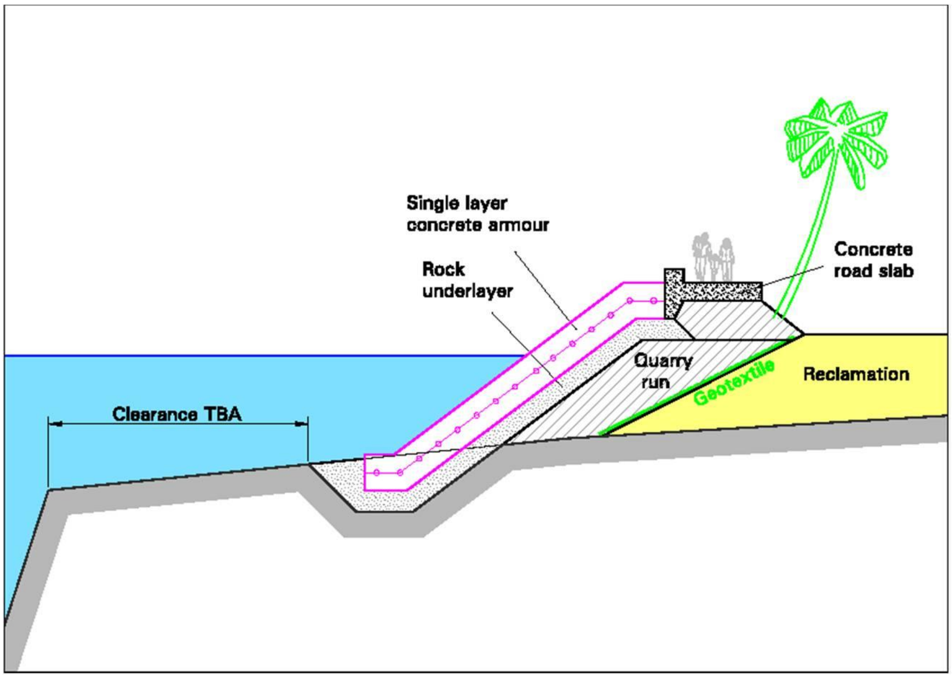


Figure 4-5: Typical cross-section of revetment

### *4.4.3 Quay wall*

Quay wall length in phase 1 will be between 200 and 600 meter and will be located at the western side of Gulhi Falhu. The design vessel for the ocean-going berths has the following main characteristics:

- Length 150 m
- Beam 30 m
- Draft 10 m
- Carrying capacity 7000-10000 BRT.

The most common vessel for transport to and from the outer islands is the second generation 50-foot Dhoni with the following specifications:

- LOA 15.5m
- Beam 4.4m
- Depth 1.75m
- Draught 1.05m
- Engine power 75 hp.

Another vessel, the so called “2000 bag Dhoni” (carrying capacity 100 tons), is at present the largest transport vessel carrying food and other goods from Malé to the outer atolls.

In order to allow these vessels easy access at all times and all tides, the depth along the quay wall has been chosen at -3.6 m MSL. The crest level of the capping beam of the quay wall is +1.4 m MSL. It is proposed to construct 200- 600 m of quay wall for alongside or head-on mooring.

## 4.5 Project Planning

Phase 1 of the project will include the following main construction activities (all approximate and depending on final design):

- Dredging and reclamation of about 300.000m$^3$ of coral sand.
- Construction of revetment:

  - seaside (1000m south + 250m east) 1250 m
  - inner Gulhi Falhu lagoon side 1000 m
- Mitigation measures for the environment.

Sequence and timing of the main construction activities for phase 1 are shown in Table 4-2 below.

Table 4-2: planning phase 1

| nr. | construction activity | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | contractors mobilization | 1 | | | | | | |
| 2 | detailed design | 1 | | | | | | |
| 4 | Installation of mitigating measures | 1 | | | | | | |
| 5 | landfilling by TSHD | 1 | | | | | | |
| 6 | dry-earth works and revetments lagoonside | | 2 | 3 | 4 | | | |
| 7 | shore protection works | | 2 | 3 | 4 | | | |
| 9 | quaywall sea-going vessels | | | 3 | 4 | 5 | 6 | |
| 11 | contractors demobilization | 1 | | | | | 6 | 7 |

Demobilization of the dredger will take place directly after the reclamation. The dredging and reclamation works in phase 1 will approximately take 1 week. Demobilization of the equipment for the dry earth works, revetment and quay wall will take place after 6 or 7 months.

Total construction time of phase 1 will be 6-7 months. Certain parts of the area could be given out for further construction works (by lease-holders) as early as month 5.

# 5 Description of the Natural Environment

## 5.1 General

Gulhi Falhu is a submerged reef, located in the southern part of the Kaafu Atoll between 4° 10' 20" N, 73° 28' 45" E and 4° 10' 59 N, 73° 27' 17" E (see Figure 5-1). The size of the reef structure is about 2800m by 1600m and has no land surface above MSL.

Kaafu atoll is located approximately 400 km north of the equator. Its diameter is approximately 40-50km. The water depth in the semi-enclosed lagoon ranges from 40m to 80m. Gulhi Falhu is located in the south-east of Kaafu Atoll, close to the capital city of Malé.

The tidal cycle is diurnal with an irregular high and a low peak. High tide and ebb tide levels vary between plus or minus 50 cm related to MSL.

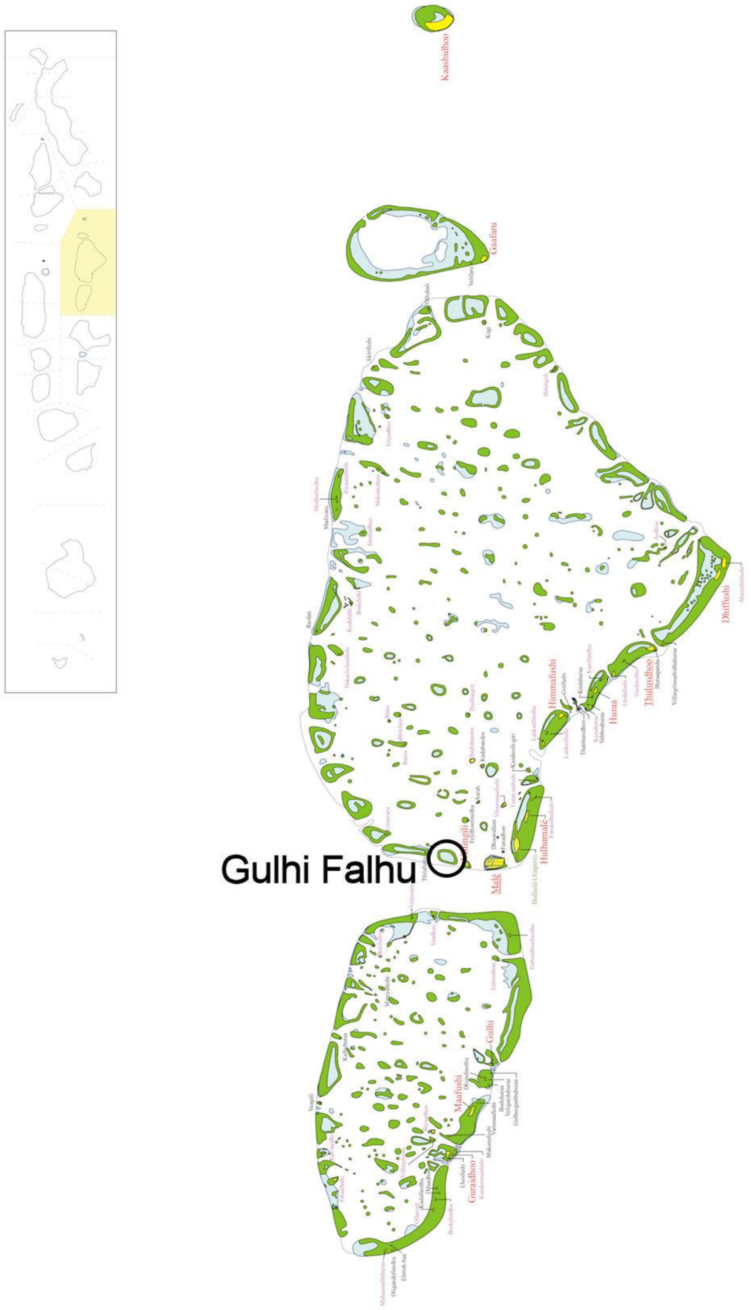


Figure 5-1 - Location of Gulhi Falhu in Kaafu Atoll

## 5.2 Methodology

In June 2010 ecological surveys were conducted on Gulhi Falhu. The objective of the site visit was to collect data and information about the local ecosystems. Dive and snorkel surveys at various depths have been carried out to determine the distribution of habitats in the marine waters around Gulhi Falhu. The collected information is described in this chapter and has been used to determine the sensitivity and vulnerability of the marine flora and fauna with respect to the proposed dredging and reclamation works at Gulhi Falhu.

The consultancy team for the dive surveys was composed of 2 divers and one snorkeler from Marine Multi Services Pvt. Ltd. in charge of the underwater photography and dive safety and for the survey in 2010 with 1 marine biologist from Seamarc Pvt. Ltd. to organize the survey layout together with the Hydronamic environmental engineer.

For the analysis of the results of the dive and snorkel survey the software programme CPCe was used to determine the percentages live coral cover. The used work method will be described in detail in paragraph 5.4.

## 5.3 Physical Environment

### *5.3.1 Geology*

Figure 5-2 shows the typical geological structure of an atoll in the Maldives. The islands owe their origin to the deposition of shingle or coral debris during storms. The islands are made up of coralline sand, partly covered with a thin layer of soil consisting of a mixture of sand and organic matter.

The reef at Gulhi Falhu evolved in a similar manner, but was never raised above sea level through natural processes. Gulhi Falhu has no top soil.

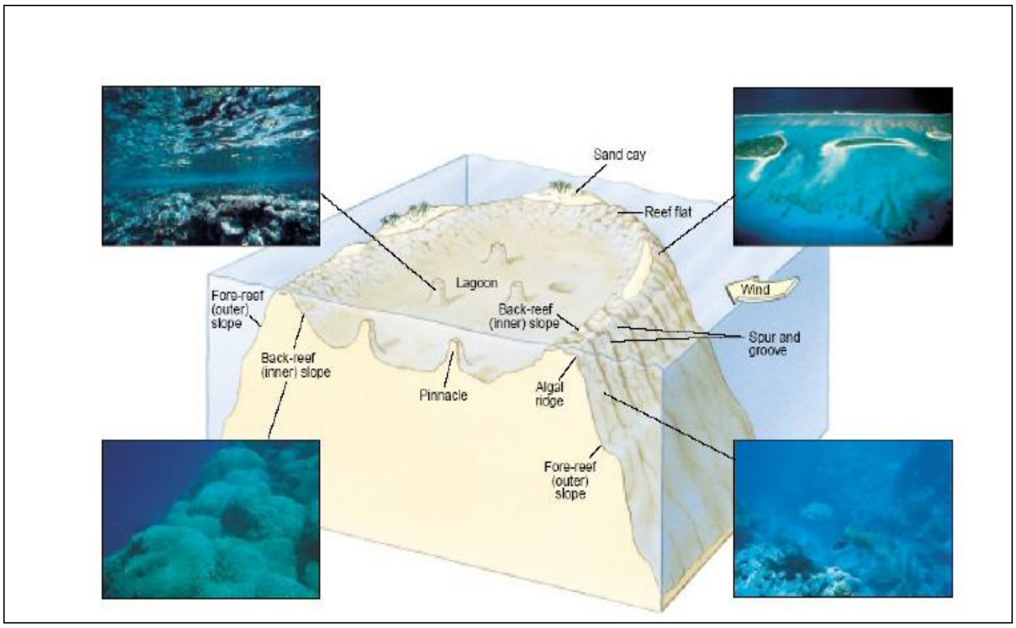


Figure 5-2 - Typical structure of an atoll

Based on earlier geological investigations and awaiting further drilling and laboratory testing, the material of the Gulhi Falhu borrow area can in general terms be described as “loosely packed, silty, coral sand, with pieces of coral and shells”. The grain size envelope is expected to be as in Figure 5-3.

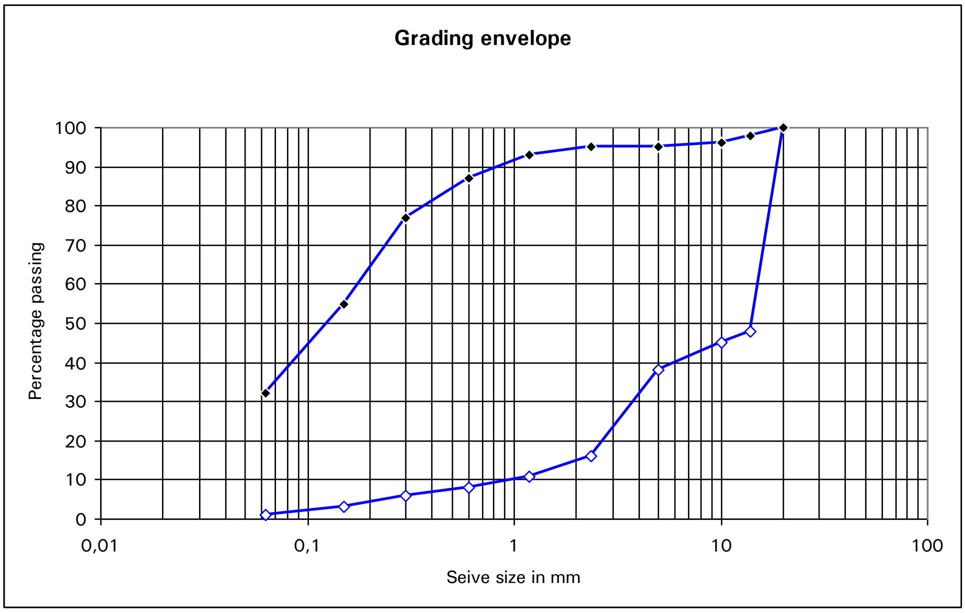


Figure 5-3 – Gulhi Falhu, assumed grading envelope

One vibrocore sample was taken in the area north of Gulhi Falhu in January 2010. The results of the analysis of this sample are shown in Table 5-1 Characteristics of vibrocore sample taken near Gulhi Falhu.

Table 5-1 Characteristics of vibrocore sample taken near Gulhi Falhu

| | |
|---|---|
| Water depth | 25 – 50m |
| Type of environment | Inside atoll lagoon, sandy seabed, coral reef formations such as farus, thilas and giris are located outside the perimeter of this area |
| Typical D50 | 625 |
| Typical D10 | 60 |
| Typical D90 | 1900 |
| Percentage fines | 11 |
| Percentage coarse material | 40 |
| Percentage sand | 49 |

### *5.3.2 Climate*

The Maldives have a tropical climate with warm temperatures (25-30 degrees) and a great deal of sunshine throughout the year. There is a considerable variation of climatic conditions between northern and southern atolls in the Maldives. The weather in the Maldives is determined to a large extent by the monsoon circulation. Each year, there are two monsoon seasons: the northeast monsoon and the southwest monsoon.

*Monsoon*

The Maldives lie in the Monsoonal Belt in the northern Indian Ocean and consequently rthe Maldives have a rather complex climate.The climate in the Maldives is dominated by southwestern (Hulhangu) and northeastern (Iruvai) monsoons. 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 the southwest monsoon occurs between March and April while that of the northeast monsoon occurs from October to November. Gales are uncommon, and cyclones are very rare in the Maldives.

*Winds*

The monsoons are relatively mild due to the country's location near the equator and strong winds and gales are infrequent in the Maldives. However, storms and line squalls can occur, typically in the period May to July. The winds usually get stronger in the southwest monsoon especially during June and July. During storms the impact is greater on the northern atolls than on the southern atolls.

The northeast and southwest monsoons have a dominant influence on the winds experienced in the Kaafu atoll. The southwest monsoon, with winds predominantly between SW and NW, lasts from May to October. In May and June, winds are mainly from WSW to WNW, and in July to October, winds between W and NW predominate. The northeast monsoon, with winds predominantly from NE to E, lasts from December to February. During March and April, winds are variable. During November, winds are W, becoming variable.

Wind measurements taken on Malé airport in the period January 1986 to December 1990 indicate that during the northeast monsoon, winds can occasionally exceed 30 knots (force 7 Bf) from the NE sector. During the southwest monsoon, winds have on one occasion during the period described above exceeded 40 knots (force 8-9 Bf) from the W sector. Generally, however, winds during the northeast and southwest monsoons are around 10-15 knots (force 5 Bf).

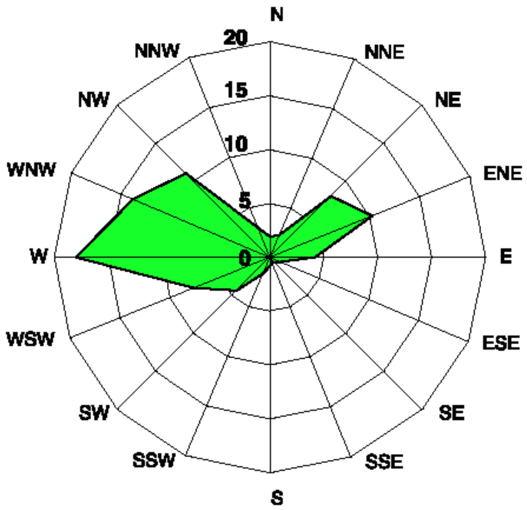


Figure 5-4: Percentage of wind direction for Malé International Airport (1980-1999)

Figure 5-4 shows the wind direction pattern for Malé International Airport. Winds from the north-east and the east-north-east are predominant during December and February. During March to April the direction varies with the general direction being westerly. Strong winds are associated with the southwest monsoon season. Strong winds and gales are infrequent, and cyclones reach only occasionally as far south as the Kaafu Atoll. Storms and line squalls can occur, typically in the period May to July. Gusts up to 50-60 knots (force 10-11 Bf) have been recorded at Malé during these storms.

*Temperatures*
The Maldives enjoy a tropical climate with mean annual temperature of 30.8°C, daytime highest reach 32°C, but night time lows rarely drop below 25°C.

*Rain*
The average annual rainfall amounts to 1900mm, and there is an increase in the rainfall from north to south. The average annual rainfall for north is 1977mm and for south, it is 2470mm. The wettest months are May, August, September and December; and the driest are January to April.
The northeast monsoon is known as the dry monsoon, with an average monthly precipitation of 50-75mm. On average, the NE monsoon months have 5 days a month with rainfall exceeding 1mm. The southwest monsoon is the wet season, with monthly average rainfall ranging from 125mm to 250mm. During the SW monsoon months, each month will on average have 10 to 15 days with rainfall exceeding 1mm.

Open water evaporation rates are in the range of 6mm per day and transpiration from plants is also high. The relative humidity generally ranges between 75 to 80%.

### *5.3.3 Tides and Waves*

*Tides*

During spring tides, the tidal range is between about 90-110 cm and during neap tides the range can be as little as a few centimetres. The height of the tide is also affected by the weather. Winds from different directions influence the raising and lowering of the water level and situations of high sea levels on the outside of the atolls are caused by storm surges and wave set-up. The water also stands higher with a low barometer, to what extent is uncertain. Maximum water levels are estimated to be in order of MSL+1m.

The tides observed in the country are twice daily (semidiurnal), and typical spring and neap tidal ranges are approximately 1.0m and 0.3m respectively. Maximum spring tidal range in the central and southern atolls is approximately 1.1m. There is also a 0.2m seasonal fluctuation in regional mean sea level, with an increase of about 0.1m during February – April and decrease of 0.1m during September – November. Table 5-2 shows tidal variations for Malé Airport.

| Tide level | Reference to Mean Sea Level |
|---|---|
| Highest Astronomical Tide (HAT) | 0.64 m |
| Mean Higher High Water (MHHW) | 0.34 m |
| Mean Lower High Water (MLHW) | 0.14 m |
| Mean Sea Level (MSL) | 0.00 m |
| Mean Higher Low Water (MHLW) | -0.16 m |
| Mean Lower Low Water (MLLW) | -0.36 m |
| Lowest Astronomical Tide (LAT) | -0.56 m |

Table 5-2: Water levels

*Sea level rise*

The present estimate for the sea level rise at the Maldives due to the climatic changes is approximately 0.5cm per year. The sea level is predicted to rise by 12-18cm by 2030.

*Currents*

Currents which affect the sea area around the Maldives and around and within the Thaa atoll are caused by one or more of the following systems: oceanic currents, tidal currents, wind-induced currents, and wave-induced currents.

The oceanic currents flowing ‘across’ the Maldives are notorious for their strength. The exposure of the Maldives to the vast Indian Ocean ensures that an immense body of water is constantly flowing across the plateau on which the atolls are built. In the Arabian Sea, as you get closer to the equator, the prevailing winds become more and more indicative of the oceanic surface current. Thus, wind (especially during monsoons) can be a major factor affecting current velocity and direction, and currents can be of great strength (wind-induced currents). For example: currents in the channels near Malé have been recorded at 4 knots or more. Inside an atoll, current speeds are more settled.
Oceanographic currents are driven by two monsoonal winds, namely the westerly and easterly wind. The westerly flowing currents tend to dominate from January to March while the easterly currents dominate from May to November. The changes in current flow patterns occur in April and December. The current velocities are about 0.5 m/s, only in May values may increase to 0.8 m/s.

The vertical water movements associated with the rise and fall of the tide are accompanied by horizontal water motion termed tidal currents. These tidal currents have the same periodicities as the vertical oscillations, but tend to follow an elliptical path and do not normally involve simple to-and-from motion. Generally the tidal currents are eastward in flood and westward in ebb. Tidal currents, which flow according to the height of the tide, are generally not strong. There is a strong diurnal influence which governs the tides in the Maldives, but in general the tidal range is less than 1m.

On a more local scale, especially on the reef flats, wave-induced currents (cross-shore and/or long-shore) also form an important factor affecting the current regime.

*Waves*
The swell and wind waves experienced on the Maldives are governed mainly by the two monsoon periods. Swell caused by cyclonic storms in the area west of Australia may also reach the southern atolls of the Maldives on occasion.

The swells and wind waves experienced by the Maldives are conditioned by the prevailing biannual monsoon wind directions, and are typically strongest during April – July in the south-west monsoon period. During this season, swells generated north of the equator with heights of 2-3m with periods of 18-20 seconds have been reported in the region.
The Maldives also experiences swells originating from cyclones and storm events occurring well south of the equator. It is reported that the swell waves from southeast to south-south-east occur due to strong storms in the southern hemisphere in the area west of Australia with direction towards the Maldives. The swell waves that reached Malé and Hulhule in 1987 had significant wave heights in the order of 3 meters. Local wave periods are generally in the range 2-4 seconds and are easily distinguished from the swell waves.

Due to the shallow depths on the reef flat, significant wave breaking (energy dissipation) will take place at the reef's edge, reducing the wave height of waves which pass over the reef flat.

*Tsunami waves*
Although records are inexact, it would appear that earthquake-generated tsunamis of greater than 1.0m in height have occurred on three occasions in the Indian Ocean since 1883. A tsunami of the magnitude experienced on 26th December 2004, which was approximately 4.0m in height, is an extremely rare event.

In the morning of 26th December, three hours and 18 minutes after the Sumatran earthquake, the tsunami reached the shores of Maldives islands. Sea-level station records show a southward decrease in the amplitude of the tsunami tidal-record signal from ~1.8m above mean sea level (MSL) at Hanimaadho in the north, ~1.5m for Hulhule, Malé in the central region, and ~0.8m for Gan in the south. The sea-level station data are filtered and do not show absolute heights of the tsunami. Uncorrected tsunami water levels measured by UNEP showed a range from barely measurable to 3.25m, with most measurements in the 2.0 to 2.6m range. Tsunami inundation heights ranged from 0.65m in south Malé to 3.20m in L. Fanadhoo.

The tsunami's height typically decreased from east to west as it travelled across islands. Many islands reported the tsunami approaching from the west, quite probably because it refracted around the ends of the islands. Eyewitness accounts often referred to several (usually three) waves approaching in rapid succession (30 seconds to minutes) with minimal draining of water between waves. Wave effects were most pronounced on eastern shores, but flooding and damage to coastal infrastructure was widespread among the islands. The tsunami arrived in Maldives during daylight hours near low tide.

## 5.4 Marine environment

### *5.4.1 biodiversity*

The Maldives is well known for its rich marine biodiversity found along the reefs. More than 250 species of coral, 1,200 reef fish species, 5,000 species of shells, 100 – 200 species of sponges, over 1,000 species of marine crustaceans and more than 100 species of echinoderms have been recorded at the waters surrounding the islands.

The coral reefs are the most important ecosystems in the Maldives. Up until 1998 the extensive coral reefs throughout the Maldives were found to be in good condition. In 1998 an extensive bleaching event occurred due to the increase in sea surface temperatures and destroyed large areas of shallow-water coral reefs. As a result, in several areas about nearly 90% of the corals died. Although new recruitment has been noticed at numerous sites, the cover of live coral is not nearly as extensive as before the bleaching event.

The dominant species on the reefs are corals and fishes. The top ten families of fishes in the Maldives are: gobies, wrasses, groupers, damsel fishes, snappers, cardinal fishes, moray eels, blennies, butterfly fishes and surgeon fishes. 37 species of sharks can be spotted in the Maldives. The only protected shark specie, by law, is the whale shark. Some species can be found close to the edge of the reef, but most can only be found in deep waters. Stingrays are bottom feeders, they dig out clams and other animals which are covered in the seabed and can be spotted on the shallow reef flats close to shore.

The most popular fishes for divers are sharks (especially the whale shark) and rays. The whale shark is the largest fish in the world; the manta ray is very popular and can have a width of about 3m; both fishes are plankton feeders.

Five species of sea turtles can be spotted in the waters of the Maldives, being: the Hawksbill turtle, the Loggerhead turtle, the Green turtle, the Olive Ridley turtle and the Leatherback turtle. The Green turtle (Chelonia mydas) and the Hawksbill (Eretmochelys imbricata) are the most common two species that breed in the Maldives. During the ecological survey green turtles were observed on the lagoon side of the island at the slope of the reef flat.

Seven species of dolphins can be seen in the Maldives. The most common specie is the spinner dolphin **-** *Stenella longirostris*. Large groups of dolphins can be found at the ocean side as well as at the atoll side of the island. These dolphins roam from area to area.

Several components of the marine environment of the atoll islands can be distinguished. A cross section of a typical atoll reef in the Maldives is given in Figure 5-5

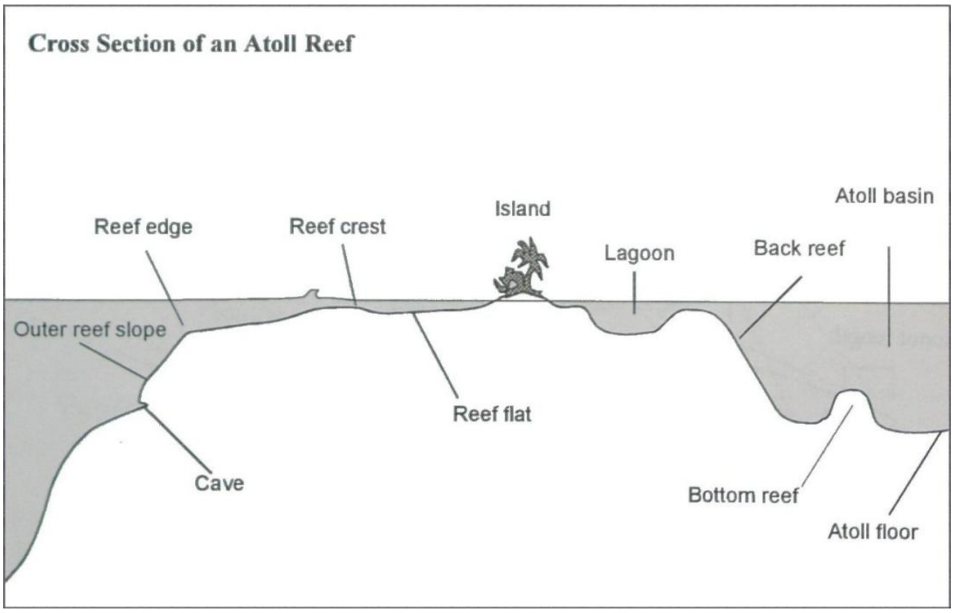


*Figure 5-5: Typical cross section of an atoll reef*

#### *5.4.2 Coral survey*

In June 2010 a coral survey was conducted at 6 locations on the Gulhi Falhu reef. Six sites were surveyed, sites 1, 2 and 3 are on the northern side of the reef, which is also the lee side. Site 4, 5 and 6 are located on the southern or exposed side of the reef.
Figure 5-6 shows these locations. The GPS coordinates of the locations are given in Table 5-3.

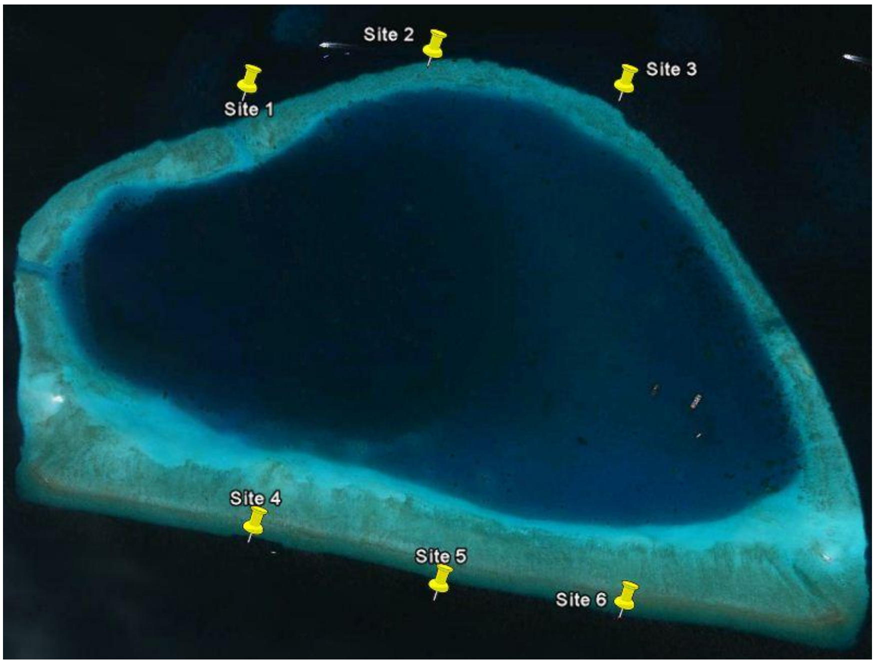


Figure 5-6: Coral survey locations of Gulhi Falhu

Table 5-3: Survey Site Location and geo-coordinates

| Transect | Location | Geographical coordinates in degrees/min | | UTM coordinates in meters | |
|---|---|---|---|---|---|
| | | N | E | N | E |
| Site 1 | North West side | 04° 11.21' | 73° 27.67' | 461.950 | 329.200 |
| Site 2 | Middle North side | 04° 11.27' | 73° 27.99' | 463.050 | 329.800 |
| Site 3 | North East side | 04° 11.21' | 73° 28.32' | 462.950 | 330.400 |
| Site 4 | Centre Hans Hass | 04° 10.45' | 73° 27.68' | 461.550 | 329.215 |
| Site 5 | Middle South side | 04° 10.35' | 73° 28.00' | 461.370 | 329.800 |
| Site 6 | South East side | 04° 10.32' | 73° 28.32' | 461.300 | 330.400 |

At each site, one or two transects were carried out depending on whether or not the slope was not too steep to carry out a meaningful transect. Usually, one transect is taken on the reef top near the edge, and referred as being at 5 meters, even though it is sometimes shallower. The deeper transect is usually taken at a depth of 10 m. At site 4, an additional transect was carried out to characterize the top of the rocky platform, which is the equivalent of the reef crest in this instance. 5 high resolution pictures were selected to assess the benthic cover of each site. Each picture is analyzed using 25 points grids to characterize the substrate composition at each site with a sample of 125 points per transect. Quantitative substrate cover data of the morphological characteristics of the reef community was obtained using this method and could be repeated over time to assess variations.

### *5.4.3 Reef atoll side*

Given that the coral community is little developed, the site discussion will present the main categories with a focus on the structure of the abiotic substrate, which components, pavement, rubble sand and silt are shown separately. This enables a discussion on sediment and hydrodynamic regimes and an assessment of recovery process at each site.

#### *5.4.3.1 Site 1*

The top of the reef is flat and relatively deep for a reef edge, at a depth of 2.5 to 3 m. The substrate is composed of loose stones which may move when wave action is strong (Figure 5-7). This seems to happen rarely on this side sheltered from the oceanic swell and the sand component is quite important (12 %). In this place a small channel had been previously in use to enter the reef lagoon. Figure 5-8 gives the composition of the substrate at the site. The coral cover is virtually nil and most of the living substrate (17 %) is comprised of turf algae (13 %) and ascidians (4 %).

Figure 5-7: Substrate appearance on the reef top at site 1

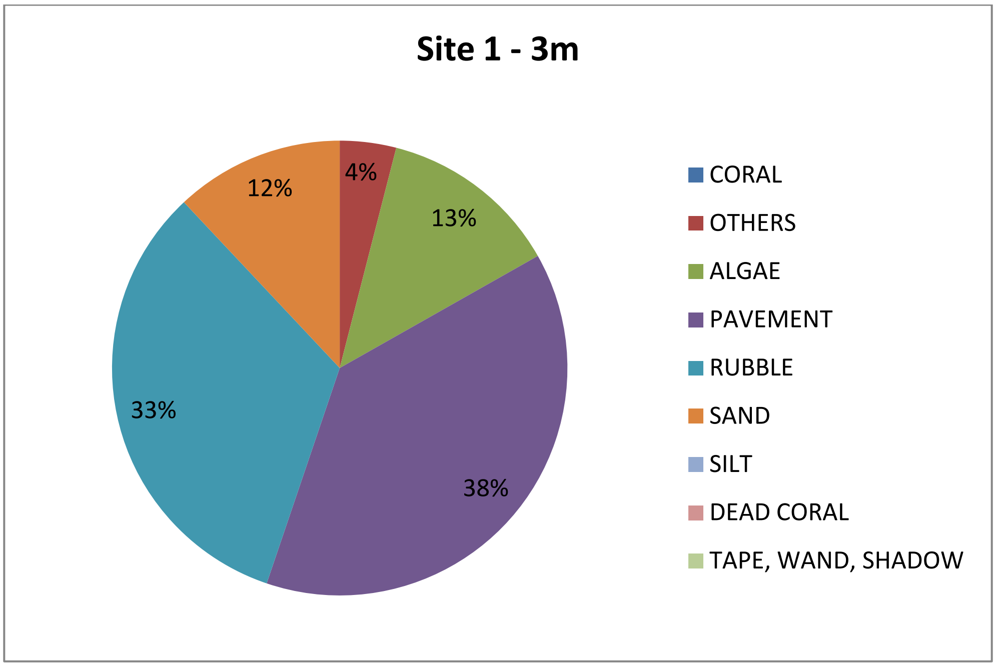


Figure 5-8: Substrate composition with separation of the abiotic components on the reef top at site 1

Some of the rocks seems to be moving to the northern reef slope which appears to be made from the rubbles accumulated over time (Figure 5-9). Therefore the substrate is not very stable and coral growth is limited. The substrate composition is given in Figure 5-10. Live coral mostly comprise of small colonies of acropridae, with the digitate and tabular forms totalling 53 % of the coral cover. It is not clear if this could be due to a late recruitment following the 1998 bleaching event or if the bigger colonies invariably are toppled over under their weight.

Figure 5-9: The outer reef slope at site 1

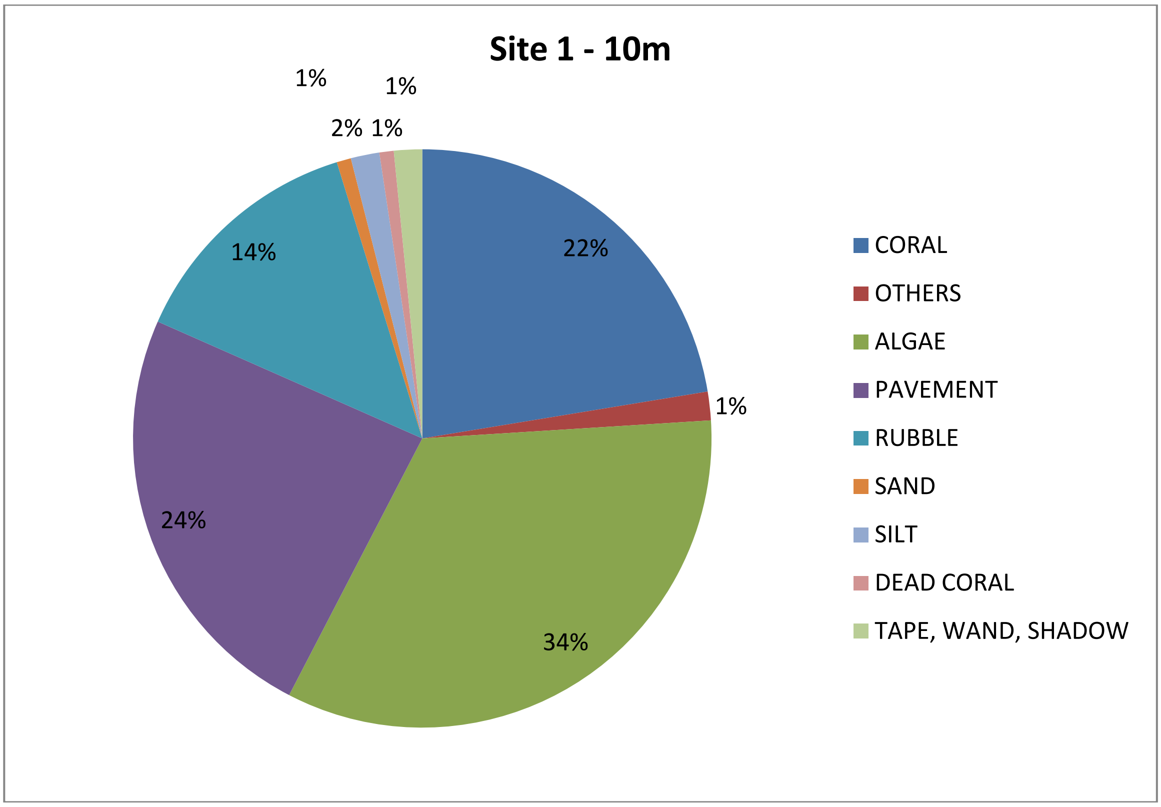


Figure 5-10: substrate composition on the reef slope at site 1

A number of large porites bommies are present down the slope, some of them still living and these gather a school of yellow sweeper and house a number of groupers.

Figure 5-11: yellow sweepers gather around the few coral heads present down the slope.

#### *5.4.3.2 Site 2*

Site 2 is located at the northern most point of the reef, a point which is indicated by a navigation light. The reef top is similar to site 1 but the coral cover is more important, maybe owing to better water quality and less sediment movement over the reef flat. Even though this is not obvious from the substrate composition, it is clear that the current is stronger and that the size of the rocks is smaller, and this could have enabled a better coral growth. The midnight coral, Tubastrea micrantha, fragile, but living in areas exposed to currents is present indicating a good water movement. The substrate on site 2 is given in Figure 5-12. The composition is given in Figure 5-13

Figure 5-12: Substrate on site 2

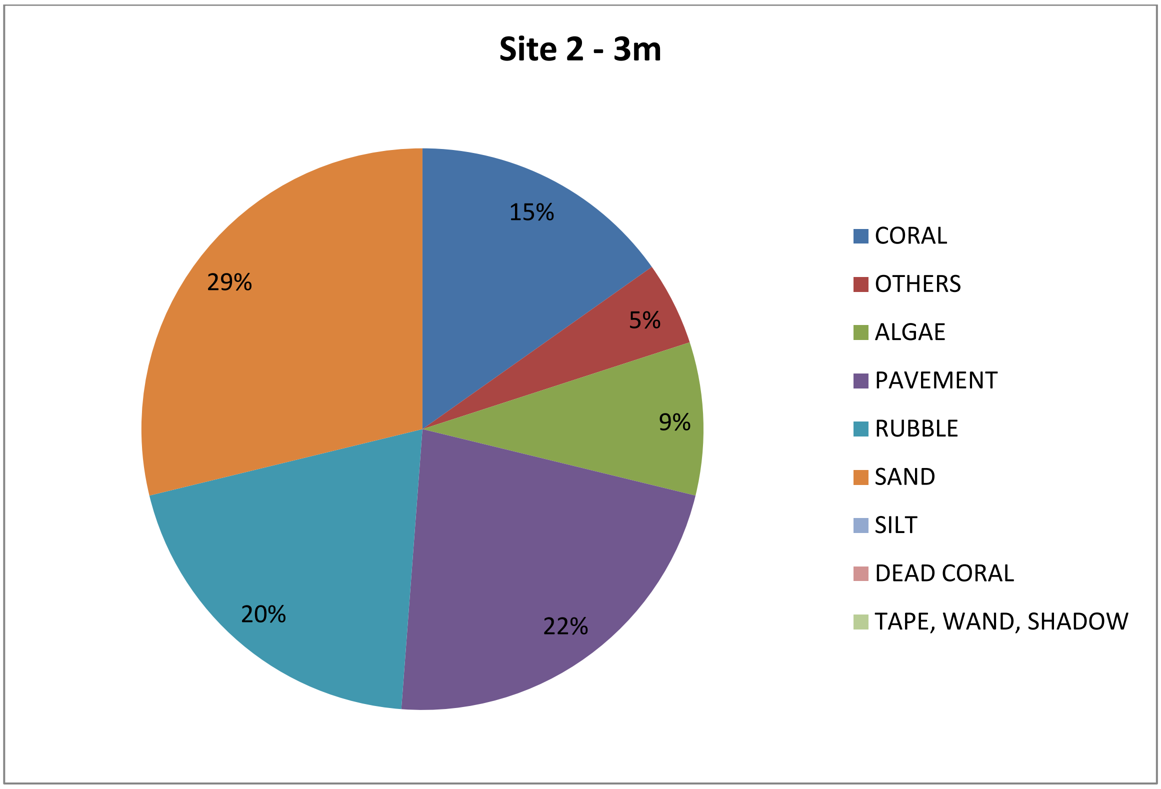


Figure 5-13: substrate composition on the reef top at site 2

The slope is also not comprised of rocks being transported over the edge but exhibits a steep wall heavily colonized by coralline algae (Figure 5-14).

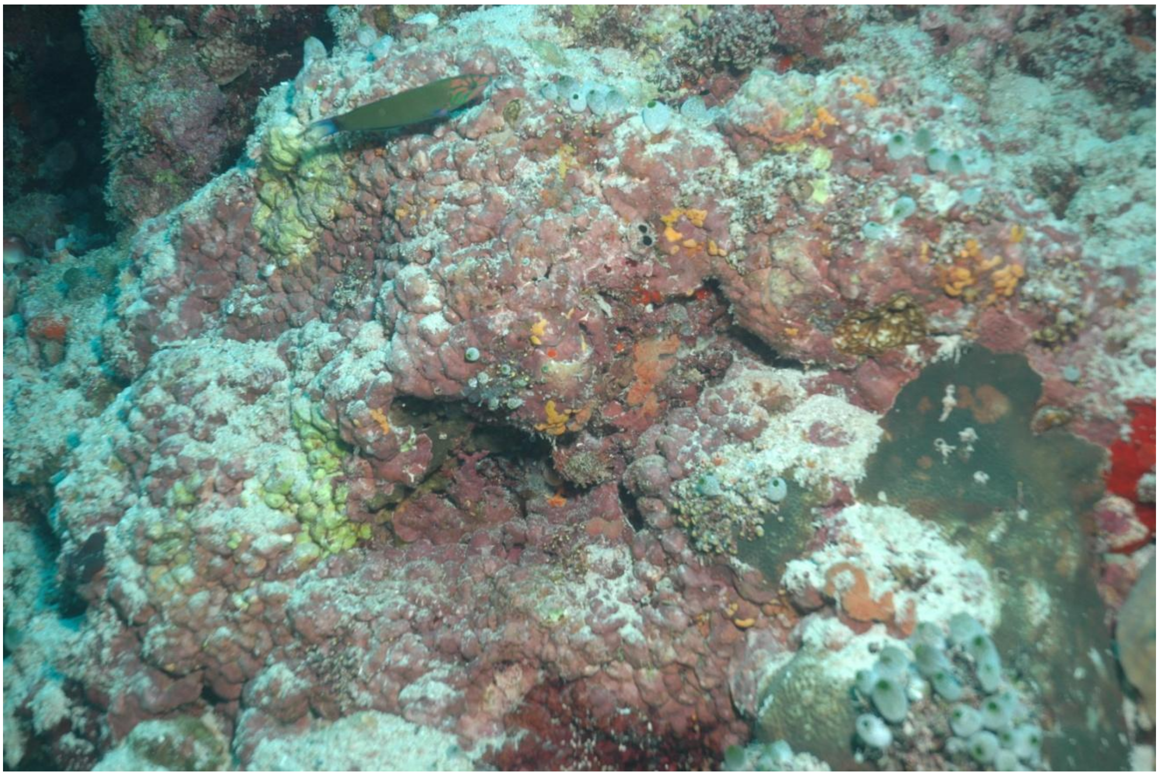

Figure 5-14: coralline algae have heavily colonized the steep wall at site 2.

Despite this apparent consolidation of the reef structure, it seems that the reef wall is subject to collapsed and the reef edge is very jiggered, with on such collapse present just in front of the navigation light (Figure 5-15).

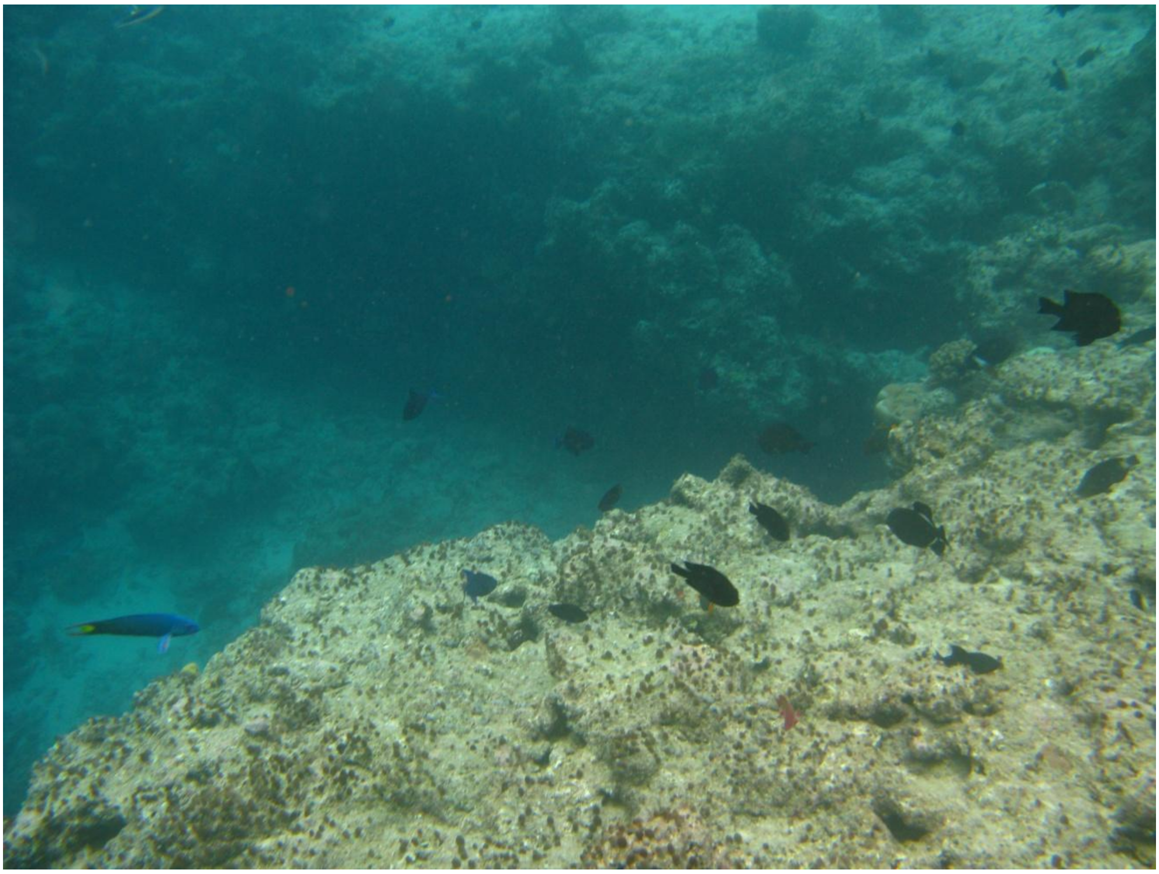

Figure 5-15: some parts of the reef have collapsed creating a jaggered appearance of the reef edge.

The fish life is comprised mostly of planctonivores such as the blue trigger fishes, sea basslets and moon wrasses, but a number of moray eels are present.

#### *5.4.3.3 Site 3*

The reef top at site three is similar to that at site 2, but the coral cover is lower. No transect was done at the site, but the whole width of the reef flat was explored and very little coral was present throughout. A few hard slabs enable some colonies to settle in an otherwise empty substrate (Figure 5-16).

Figure 5-16: hard slabs on the reef flat enable colonies to settle sparsely.

The transect was carried out at a depth of 5 m, on the upper part of the reef slope. In this area, the erosion and breaking off of the reef crest is even more important than at site 2, and the slope is even more uneven, with steep walls alternating with gullies.

The composition of the substrate is given in Figure 5-17.

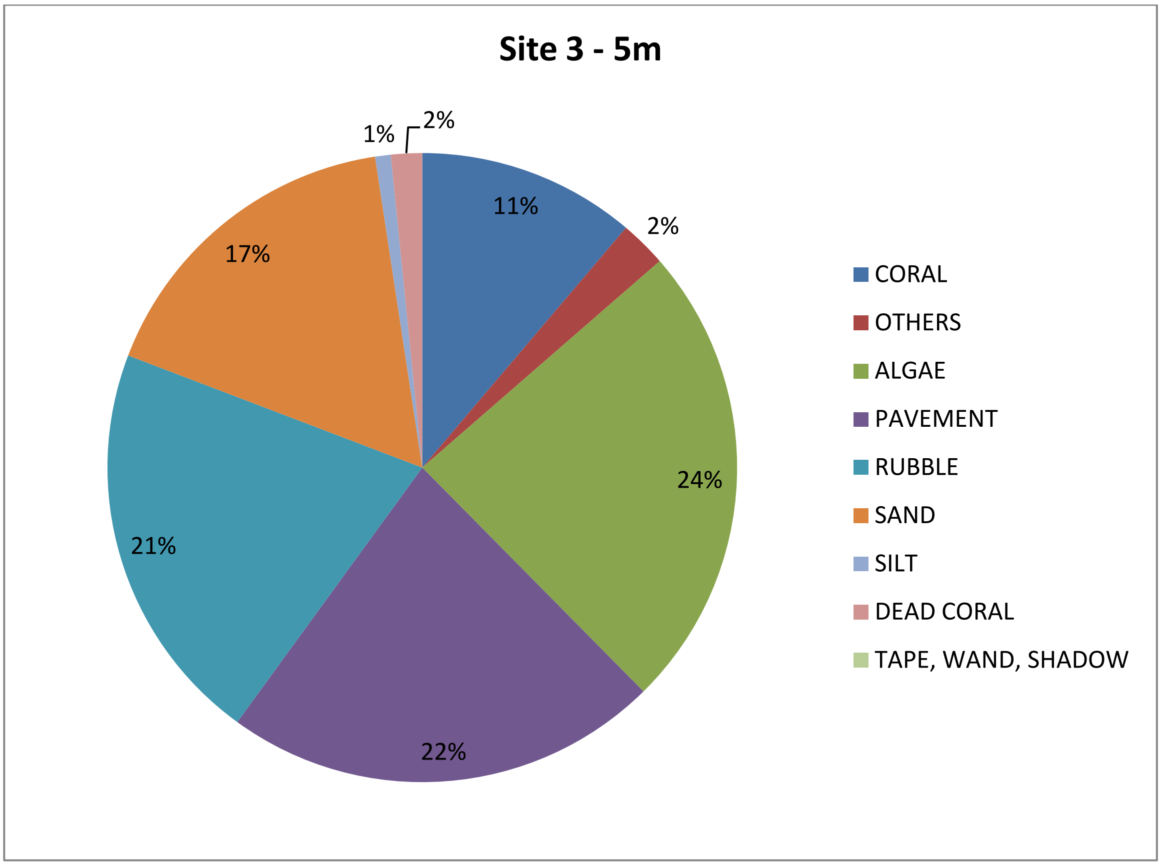


Figure 5-17: Substrate composition at 5 m at site 3

The live coral cover is relatively low for the reef slope and well below the average at depth encountered around the reef (20 % at 10 m). Algae are an important component which is dominated by turf algae over coralline algae. As the substrate is quite loose, the abiotic component is also predominant with equal parts of pavement, rubble and sand.
Whether at the bottom of the outer slope or inside the lagoon, there is a high number of garden eel of different species. These also are planctonivores, as the species mentioned above.

### *5.4.4 Reef Vaadhoo Kandu side*

#### *5.4.4.1 Site 4*

Site 4 is a popular dive site, Hans Hass Place. It consists in a reef slope exposed to the Vaadhoo Kandu. The reef edge has collapsed on a distance of over 150 m and this gives some interesting reef formation, with a number of caves. The reef is steep past the reef edge but evolves into a slope at around 15 m depth. This is continuous until it meets with another terrace at around 40 m.

On the reef top, the coral cover is quite good, especially on the edge. The substrate composition is given in Figure 5-18 .

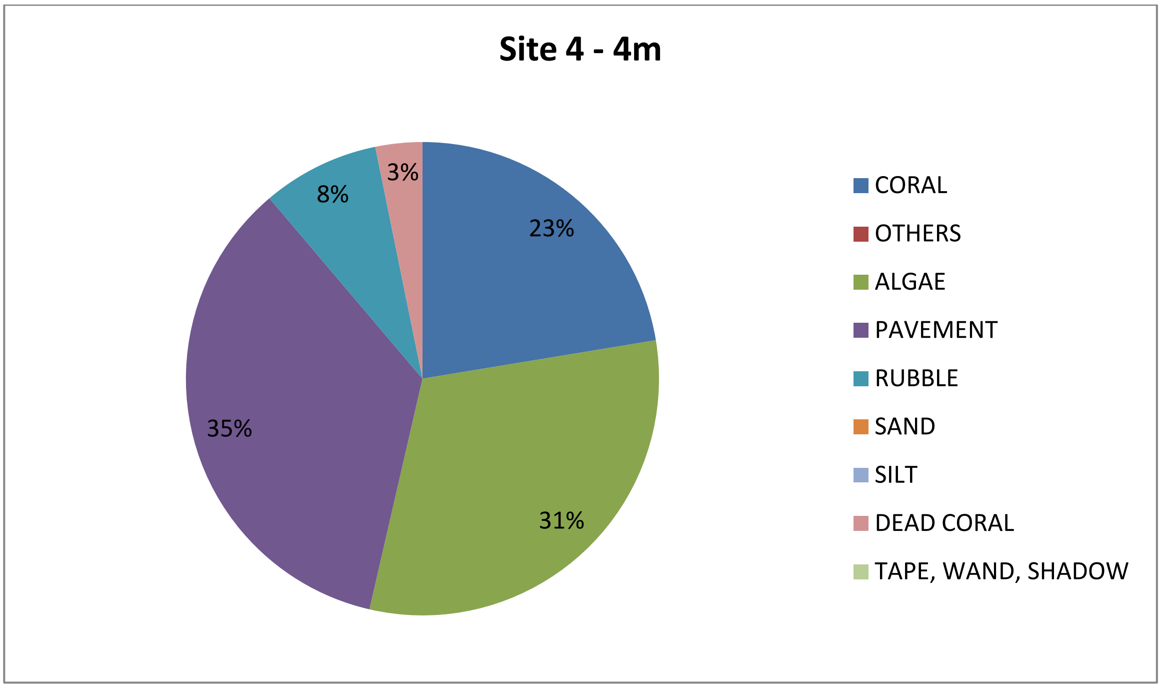


Figure 5-18: Substrate composition on the reef edge at site 4

As the wave action is quite important in the area, the component of loose rubble and sand is not important. The corals represent 23 %, and most of it is comprised of massive species with a few encrusting and sub massive life forms. Algae are also important with a high proportion of turf algae (28 %) and little coralline algae. There is still a fair amount of bare substrate and coral cover can still increase.

On the shallow part of the reef edge, the loose substrate is also little where the reef crest and algal ridge is usually present (Figure 5-19).

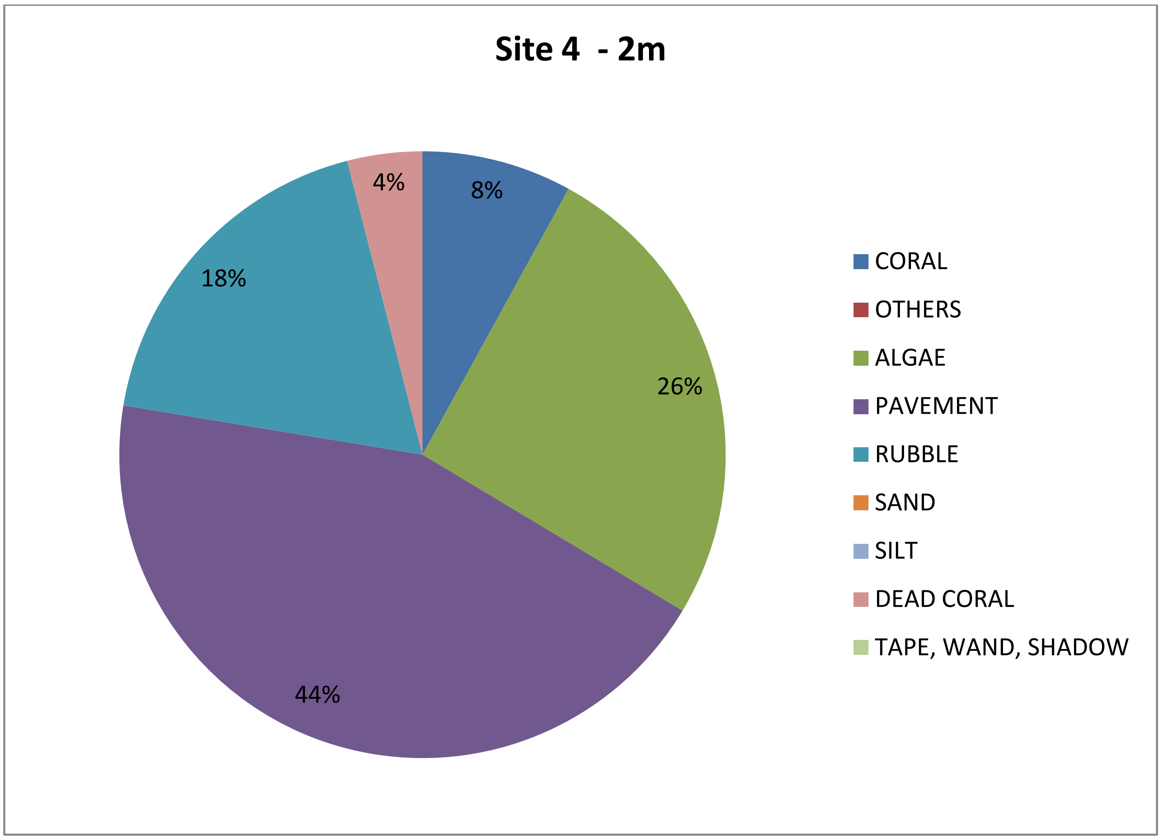


Figure 5-19: Substrate composition with separation of the abiotic components on the reef top at site 4

Here the substrate is rocky with a lot of turf algae. Most of the coral colonies present are from the Pocillopora genus. A large number (50 %) of them were bleached (Figure 5-20).

Figure 5-20: pocillopora colonies on the shallower part of the reef flat near site 4.

At depth, the coral cover remains quite satisfactory for an exposed reef slope, with a live coral cover of 16 % (Figure 5-21). The abiotic substrate remains dominant and coralline algae (16 %) also occupies a large proportion of the substrate.

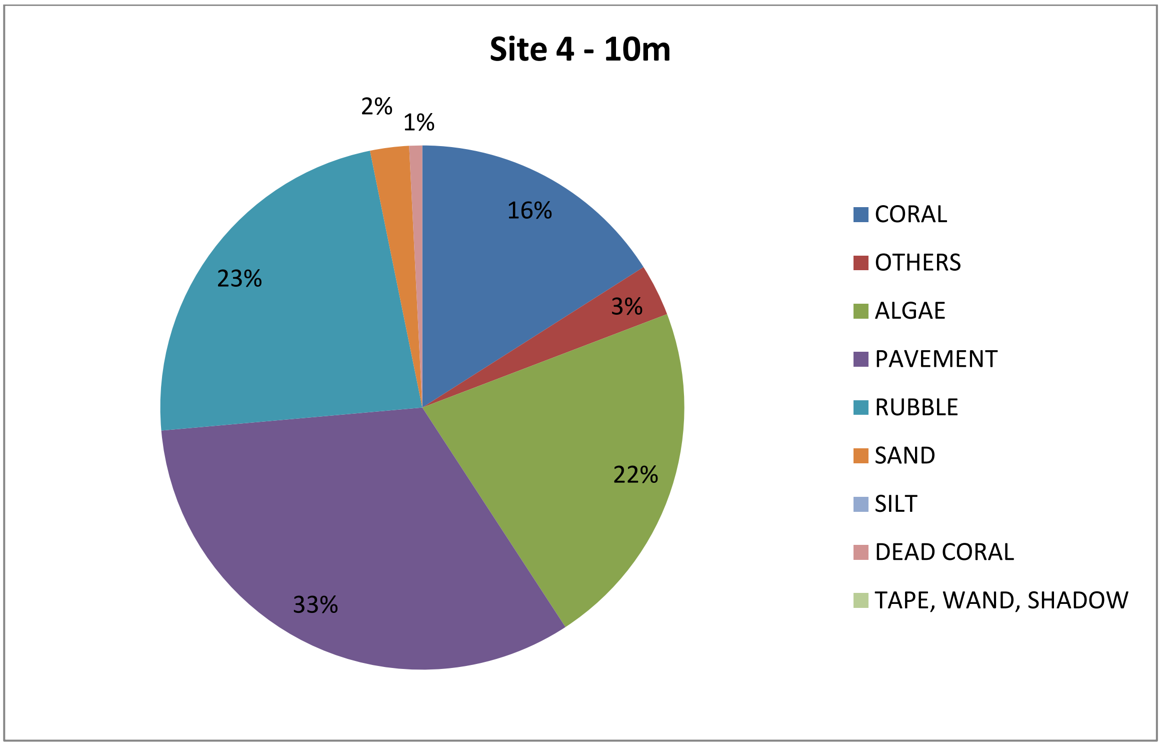


Figure 5-21: Benthic substrate at 10 m at site 4

The current in that area is important, and sand does not settle. To attest of this good current flow, many gorgonians sea fans are present on the slope and under the overhangs (Figure 5-23).

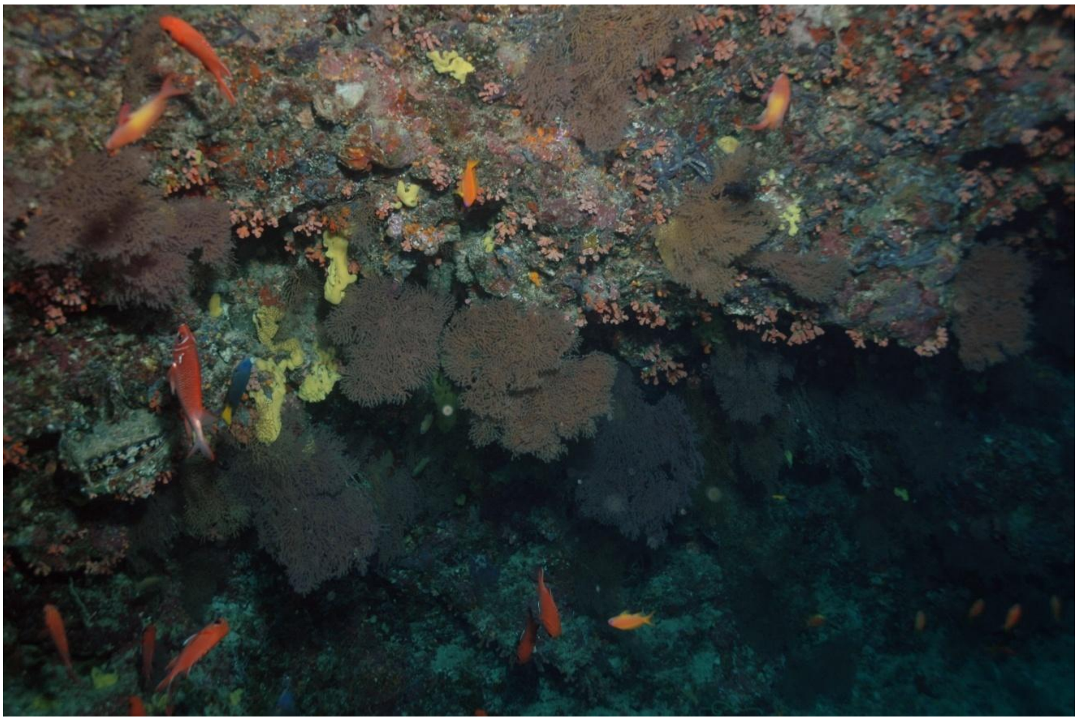

Figure 5-22: Gorgonian sea fans are present under the ledges at Hans Hass place.

### *5.4.4.2 Site 5*

Site 5 is located very close to the middle of the southern side. The reef slope differs in that it is more regular and do not shot the so many ledges and caves as at site 4 (Figure 5-23). The gradation from a reef edge with good coral cover (Figure 5-24), mostly massifs, to the shallower platform with Pocillopora is a common feature with site 4 and site 6.

Figure 5-23: the regular transition between the reef top and the regular slope below

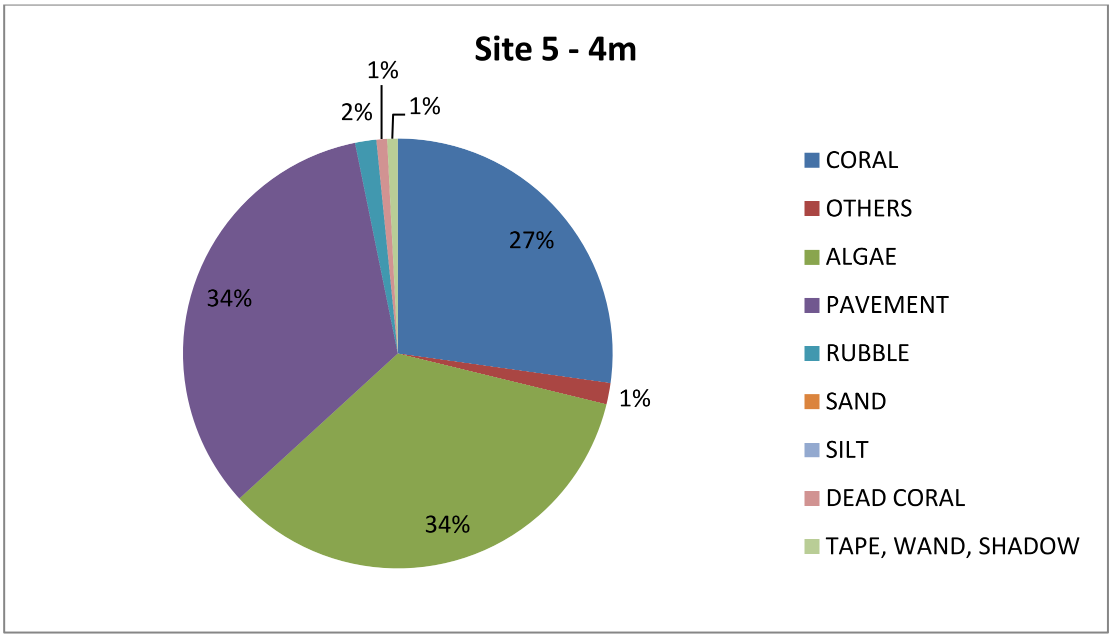


Figure 5-24: Substrate composition on the reef edge at site 5

There is little loose material on the reef top and coralline algae are more important than at site 4 (16 %), probably cementing the structure more efficiently. The coral cover is high, and mostly comprised of massives and encrusting.

At depth the coral cover is still good and mostly comprises of massive species (15 %). Coralline algae dominate over the turf algae and consolidate the structure. Some of the sand and rubble originating from the reef top trickles down the slope.

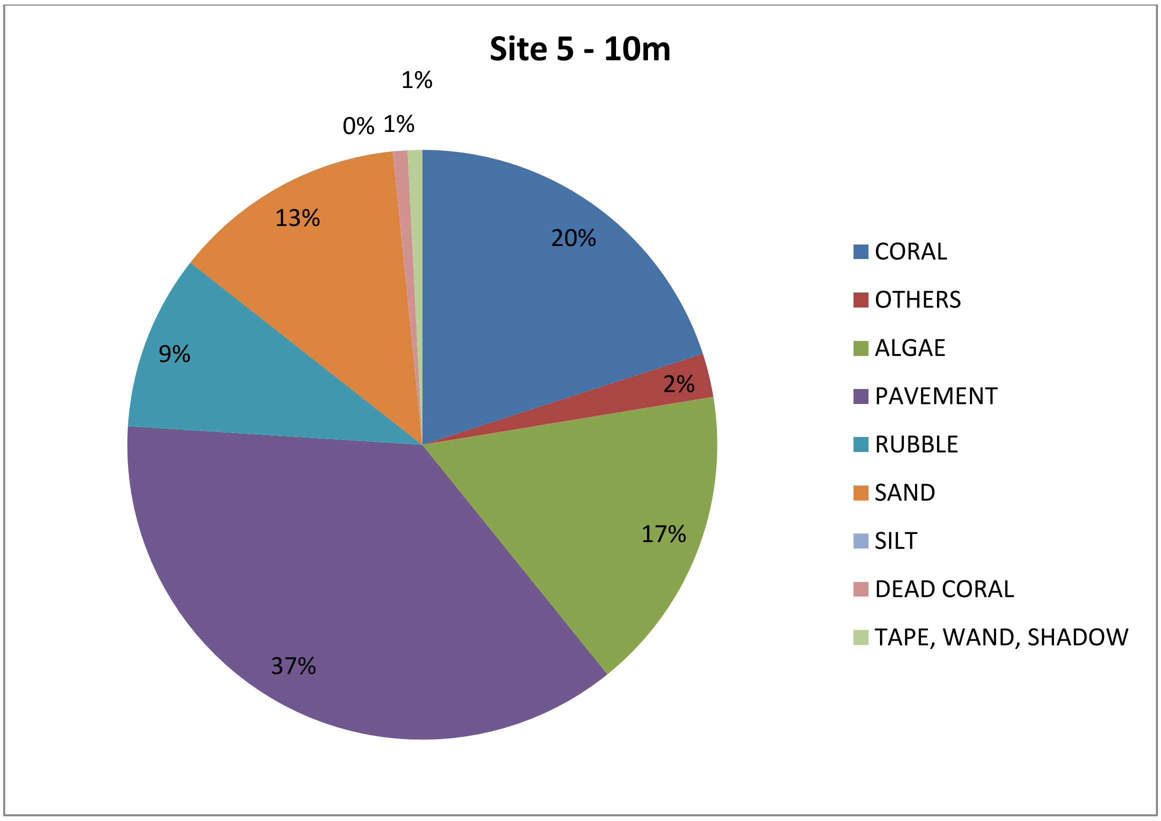


Figure 5-25: Substrate composition at 10 m at site 5

#### *5.4.4.3 Site 6*

Site 6 is very similar in all respects to site 5, with an even healthier reef edge (Figure 5-26)

Figure 5-26: Healthy reef edge at site 6.

With a live coral cover of 34 % (Figure 5-27), the site has the highest coral cover among all the sites surveyed. Again coralline algae dominates over turf and there is little loose sediment. Fish life is abundant with a large number of grazers such as the surgeon fishes and planctonivores such as sergeant fishes.

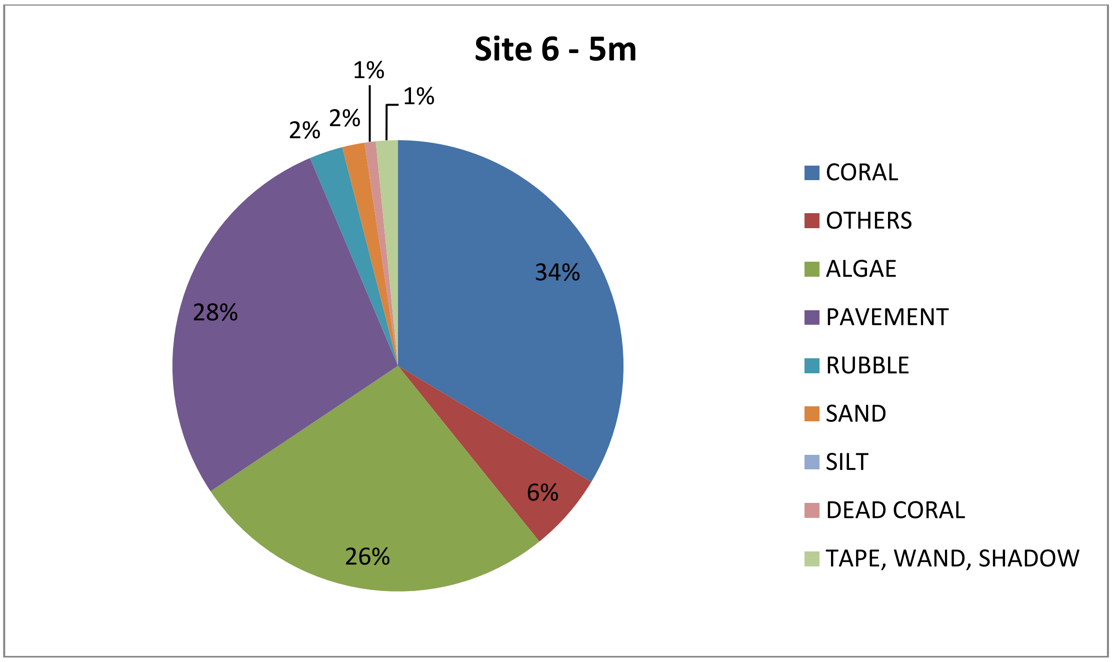


Figure 5-27: Substrate composition on the reef edge at site 6

At depth, the coral cover diminishes (Figure 5-28) and many ascidians are present, accounting for 13 %

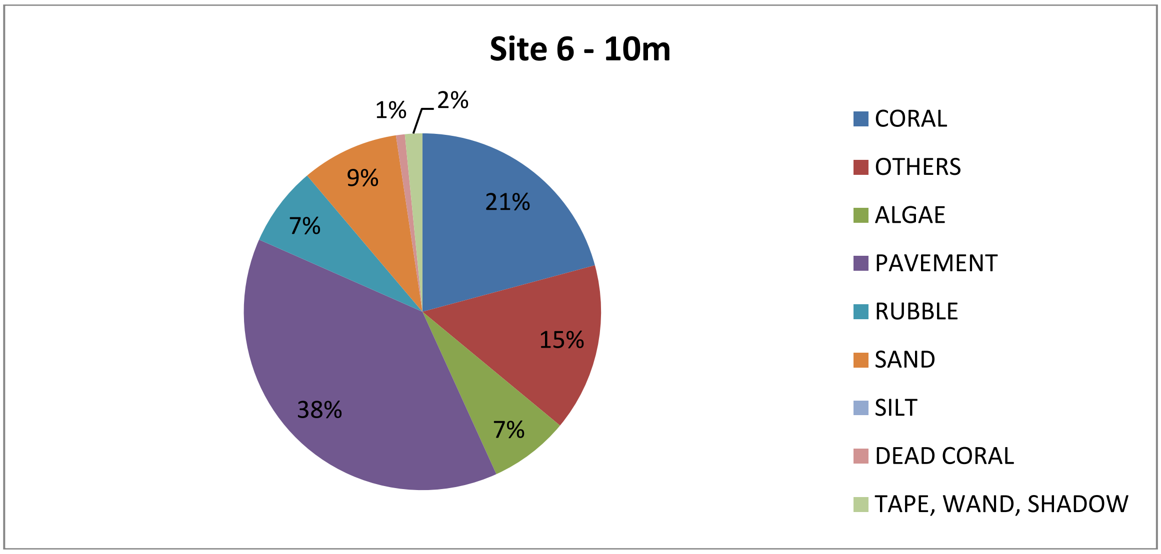


Figure 5-28: Substrate composition on the reef slope at site 6

The surface is quite rugged causing a lot of shadows to increase the unidentifiable points in the survey. Similarly as at site 5, rubbles and sand falls down the slope.

### *5.4.5 Summary results ecological survey 2010*

The results from the photographic transects carried out on the 28th of June 2010, are given in table form (Table 5-4) and bar chart form below (Figure 5-29).

Overall, the live coral cover is not great, averaging 18 % on all transects. The massive and encrusting life forms represent the bulk of the coral cover. The reef top on the northern side (site 1 to 3) is rather bare and consists of a flat rocky substrate in the 2.5 to 3 m depth range. This seems due to a poor recovery from the 1998 bleaching event rather than a mass mortality during the recent bleaching event. As a general rule, the coral cover was quite better on the reef edges and poor on the lagoon side, with the exception of the Pocilloporids present on the platform crest on the southern side (Site 4 2 m). At depth the coral cover seems to be quite even all around the reef with a cover in the range of 20 %.

Table 5-4 Main substrate statistics for the different transects (transect names indicate the site and depth where appropriate, cover in %)

| TRANSECT NAME | Site 1 3m | Site 1 10m | Site 2 3m | Site 3 5m | Site 4 2m | Site 4 4m |
|---|---|---|---|---|---|---|
| CORAL | 0.00 | 22.76 | 15.20 | 11.20 | 8.00 | 22.40 |
| OTHERS | 4.00 | 1.63 | 4.80 | 2.40 | 0.00 | 0.00 |
| ALGAE | 12.80 | 34.15 | 8.80 | 24.00 | 25.60 | 31.20 |
| SAND, PAVEMENT, RUBBLE | 83.20 | 40.65 | 71.20 | 60.80 | 62.40 | 43.20 |
| DEAD CORAL | 0.00 | 0.81 | 0.00 | 1.60 | 4.00 | 3.20 |
| TAPE, WAND, SHADOW | 0.00 | 1.60 | 0.00 | 0.00 | 0.00 | 0.00 |

| TRANSECT NAME | Site 4 10m | Site 5 4m | Site 5 10m | Site 6 5m | Site 6 10m | MEAN |
|---|---|---|---|---|---|---|
| CORAL | 16.00 | 27.42 | 20.16 | 34.15 | 21.14 | 18.04 |
| OTHERS | 3.20 | 1.61 | 2.42 | 5.69 | 15.45 | 3.75 |
| ALGAE | 21.60 | 34.68 | 16.94 | 26.83 | 7.32 | 22.17 |
| SAND, PAVEMENT, RUBBLE | 58.40 | 35.48 | 59.68 | 32.52 | 55.28 | 54.80 |
| DEAD CORAL | 0.80 | 0.81 | 0.81 | 0.81 | 0.81 | 1.24 |
| TAPE, WAND, SHADOW | 0.00 | 0.80 | 0.80 | 1.60 | 1.60 | 0.58 |

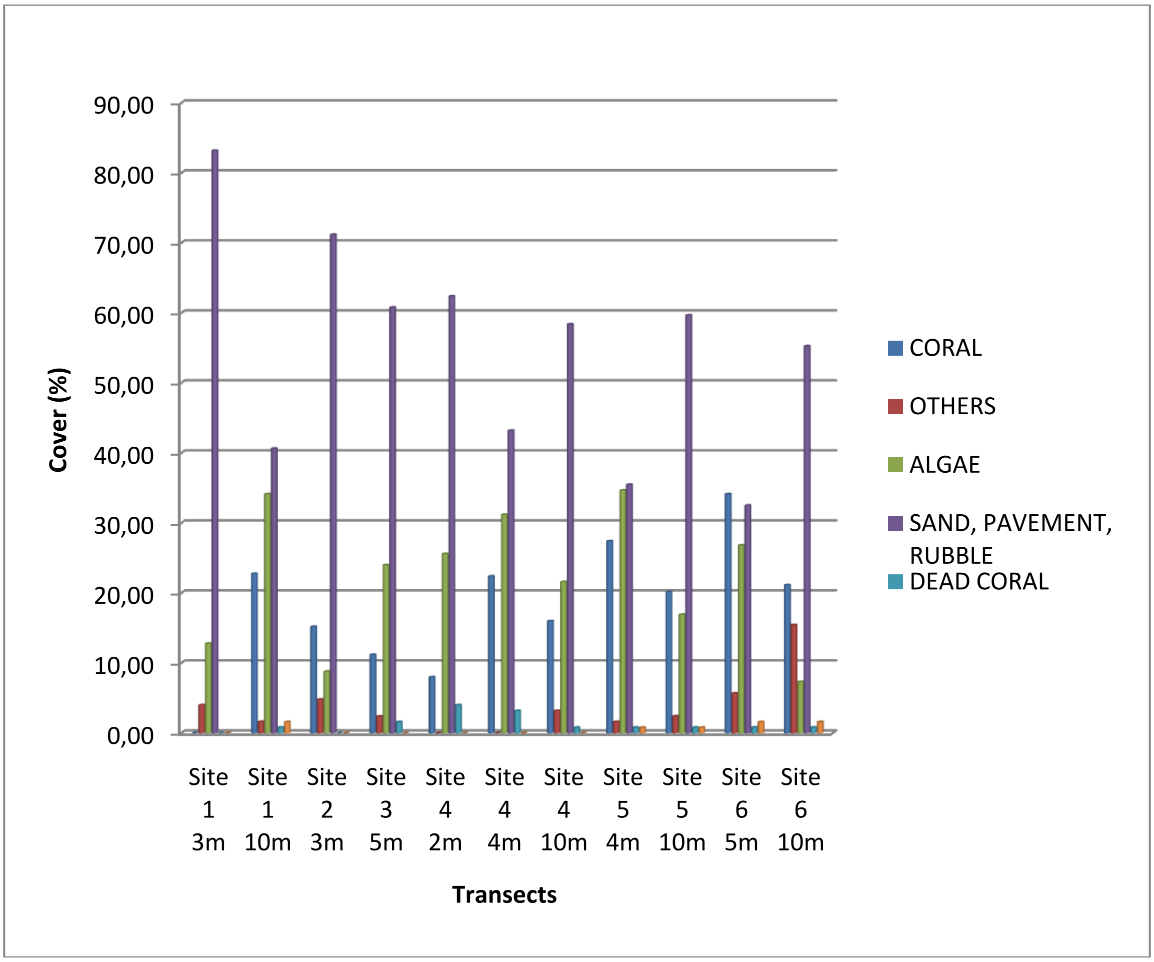


Figure 5-29: Main substrate categories for the different transects

The fish life even though abundant was comprised of the smaller species of reef associated fish and only few larger predators were encountered. The blue trigger fish is particularly abundant with different size cohorts quite obvious. There were a number of quite not so commonly encountered species such as this triggerfish tentatively identified as a juvenile of Suflamen fraenatum (Figure 5-30), an electric ray, and three napoleon fish.

Figure 5-30: A juvenile of *Suflamen fraenatum*

### *5.4.6 Resorts and dive sites*

In the North Male Atoll there are more than 25 resorts operational, in the South Male Atoll there are more than 15 resorts. The closest resorts to Gulhi Falhu are Giravaru Island resort, Velassaru (former Laguna Maldives) and Vadoo Island resort at a distance of less than 6km.

A consultation meeting was organised on June 23rd 2010 to inform nearby resorts, their dive centers, the Maldives Divers Association and the Maldivian Tourism Promotion Board. Other parties that were invited were the: Environmental Protection Agency, Marine Research Center, Ministry of Tourism, Ministry of Economic Development, Thilafushi Development Corporation, Ministry of Fisheries and Agriculture. The invitation letter, the invitation receipt acknowledgement, the attendance list and the minutes of this meeting can be found in annex 4.

No representatives of the resorts and their dive centers were present at this meeting. Individual consultations with the general managers of Giravaru Island resort and Vadoo island Resort were therefore held in Male. The general manager of Velassaru and Kurumba Village was informed by email but gave no reaction.

Resorts located further than 6 km distance from Gulhi Falhu (Embudu,Taj Exotica and Club Med) were considered as too far from the reclamation site to experience direct impacts on the resort or the surrounding waters from the reclamation activities. A representative from their dive centers was contacted by phone to discuss the project.

All parties were informed on the development plans of the Gulhi Falhu project and the possible impacts on the resorts and surrounding dive sites were discussed.

In the consultation meetings the following concerns were raised:

### *5.4.7 Dive sites & coral reefs*

- The dive sites of Vadoo Island, Taj Exotica and Embudu Village are mainly located in the South Male atoll. Only Embudu Village uses dive locations south of Guli Falhu on a regular basis (location 2,3,4 and 5). The other dive centers do not use the MPA “Hans Hass” more than once per year.
- The reason why Hans Hass Place is not used by dive centers in the South Male atoll is the travel distance and the quality of the dive site. The site is still considered “nice” but

has gone done much after the development of Thilafushi. Sand on the corals, waste in the water and the bad smell have made the site less attractive. There also seems to be a lot of coral fishing that has reduced the amount of fish on the dive sites.

### *5.4.8 Navigation*

- A lot of suppliers take shortcuts from Male to Giravaru Island resort through the lagoon of Gulhi Falhu when the sea is rough. The concern is whether or not that is still possible.

### *5.4.9 Waste & pollution*

- Giravaru Island resort is facing a lot of problems from the presence of Thilafushi Island. Waste, bad odour, water pollution and flies are the main problems. This problem will also affect Gulhi Falhu since the effects have been noticed as far as Bandos Island resort. More waste is also expected when Gulhi Falhu is being developed and after completion of the island.

### *5.4.10 Currents*

- A shift in the currents will occur when the reclamation starts. After the reclamation of Thilafushi the current in the channel between Thilafushi and Gulhi Falhu has changed and increased. With the size of the planned reclamation all the currents around the reef and in the lagoon will change. This doesn’t have to be necessarily bad but shore protection and maybe groynes will be key issues.

### *5.4.11 Planning*

- Giravaru Island Resort is going to close in August for one year to do a renovation of the resort. Therefore the GM does not see any problems for the resort since there will be no guests.

- Even though the reclamation might impact the environment both General Managers of Giravaru and Vadoo island resort see the Development of Gulhi Falhu as a positive development for the greater Male area.

A list or a map of the current dive and snorkel sites was requested of each resort and obtained from 1 resort. This map can be found in Annex 5.

## 5.5 Protected areas and species

In the Maldives there are 33 marine protected Areas (MPA) of which 8 are located in the North Male Atoll and 2 in the South male atoll. The closest marine protected area to Gulhi Falhu is Hans Hass place (04°10.5’ N 73°28’ E) located just south of the GF reef (Figure 5-31).


Figure 5-31 location of MPA Hans Hass Place

The MPA's in the North and South Male atoll are:
North

- Gulhifalhu Medhuga / Hans Hass Place
- Dhekunu Thilafalhuge Miyaru vani / Lions Head
- Giravaru Kuda Haa
- Gaathugiri / Banana reef
- Lankan Thila/ Nassimo Thila
- Thamburudhoo Thila / Girufushi Thila / HP Reef
- Rasfari Island
- Makunudhoo kandu
- Huraa Mangrove Area

South

- Embudhoo kandu
- Guraidhoo kandu

The areas have been chosen for a number of reasons such as their underwater beauty, fragility and their unique biodiversity.

A number of species have been protected in relation to the biological diversity convention. The marine protected species are:

- Napoleon wrasse (*Cheilinus undulates*)
- Lobsters (of the family Palinuridae)
- All marine sea turtles: Hawksbill (*Eretmochelys imbricate*) and Green turtles (*Chelonia mydas*) are the most common species in the Maldives.
- Conch (triton) shell (Charonia spp.)

- Black coral (*Antipathes aperta*)
- Giant clams (of the family Triacnidae)
- Whale shark (*Rhincodon typus*)
- Dolphins (of the family Delphinidae)
- Whales (of the order Cetacean)

Some of the protected species were observed in the waters around Gulhi Falhu reef. This was the Napoleon wrasse, giant clams and conchs. Spinner dolphins were observed south of the GF reef.

In addition, 70 bird species (including5 species which are native to the Maldives) are protected under the Environment Protection and Preservation Act (Act 4/93 of the Maldives). These include Noddy's, Terns, Shearwaters, Frigate Birds, and the White-tailed tropic bird. The bird species living in the Maldives are Herons, Maldivian water hen and the Asian Koel.

Gulhi Falhu is currently completely submerged and has therefore no beaches and no function as a turtle nesting area. Annex 6 gives an overview of the turtle nesting areas in the Maldives. The nearest location with recorded nesting sites lies in the Baa atoll.

## 5.6 Gaps in baseline information

Currents
A detailed study of the currents around Gulhi Fahlu has not been executed during this ecological survey. A better understanding of the complex current system is needed in order to:

- predict plume dispersion during the dredging and reclamation works
- create an optimal design for the revetments and the need for groynes

# 6 Description of Economic and Social Environment

## 6.1 General

Gulhi Falhu has no land mass above sea level, and has no inhabitants. Therefore there is no current economic and social environment. However, the socio-economic development in Male' is under great pressure from increased demands by an increasing population, and severe shortages in available land. Paragraph 6.2 will address these issues in detail.
The rest of the chapter will describe the public consultations that were held on nearby Villingili regarding the development of their neighbouring "island" of Gulhi Falhu.

## 6.2 Socio-economic conditions and employment opportunities in the Maldives

The main reason for the GF project is directly derived from the fast growing Maldives economy as a tropical island state, and from the GF's location close to Malé, the country's political and economic capital, a highly congested city and the most densely populated capital in world according to some sources.
The present socio-economic situation of GF is rather limited as it is completely submerged, there is no land. A thoroughfare for shipping to and from Thilafushi – an industrial island – is its most obvious function; reef fisheries has some local interest, and the Hans Hass place or Nikki reef is a spectacular reef diving site and a Protected Marine Area.

GF's future role follows from the above-mentioned economic conditions, in particular as related to Malé's congestion. Following is a per sector overview of activities with their relation and importance to the future GF development.

Table 6-1: GDP development per sector in the Maldives period 1998 - 2004.

**Table A.1: Gross Domestic Product by Industrial Origin in Constant 1995 Prices**
(Rf million)

| Sector | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004[a] |
|---|---|---|---|---|---|---|---|
| **Primary Sector** | **578.8** | **599.1** | **595.2** | **625.5** | **724.8** | **740.0** | **765.3** |
| Agriculture | 165.5 | 168.8 | 174.7 | 181.4 | 188.6 | 196.3 | 204.6 |
| Fisheries | 373.8 | 388.1 | 381.2 | 402.4 | 494.7 | 498.0 | 512.9 |
| Coral and Sand Mining | 39.5 | 42.2 | 39.3 | 41.7 | 41.5 | 45.7 | 47.8 |
| **Secondary Sector** | **801.2** | **900.5** | **914.8** | **989.0** | **1,091.7** | **1,177.7** | **1,251.5** |
| Manufacturing | 435.4 | 483.3 | 505.1 | 532.4 | 615.1 | 629.8 | 660.9 |
| Electricity and Water Supply | 156.4 | 178.5 | 203.9 | 226.3 | 247.6 | 273.0 | 290.6 |
| Construction | 209.4 | 238.7 | 205.8 | 230.3 | 229.0 | 274.9 | 300.0 |
| **Tertiary Sector** | **4,493.4** | **4,798.6** | **5,084.5** | **5,205.4** | **5,448.8** | **5,988.9** | **6,298.4** |
| Wholesale and Retail Trade | 270.4 | 278.9 | 287.8 | 288.9 | 295.6 | 308.3 | 323.1 |
| Tourism | 1,854.2 | 1,982.3 | 2,094.0 | 2,093.5 | 2,162.6 | 2,482.5 | 2,600.1 |
| Transport and Communication | 825.4 | 854.2 | 919.1 | 934.2 | 998.0 | 1,078.8 | 1,156.5 |
| Financial Services | 194.3 | 208.6 | 215.1 | 220.4 | 235.1 | 259.5 | 273.7 |
| Real Estate | 460.6 | 483.9 | 496.7 | 507.4 | 530.7 | 566.9 | 589.3 |
| Business Services | 166.1 | 178.3 | 183.9 | 188.4 | 201.0 | 221.9 | 233.9 |
| Government Administration | 590.5 | 677.8 | 750.7 | 833.0 | 883.9 | 906.8 | 975.4 |
| Education, Health and Social Services | 131.9 | 134.6 | 137.2 | 139.6 | 141.9 | 144.2 | 146.4 |
| FISIM | (225.2) | (241.8) | (249.3) | (255.5) | (272.5) | (300.8) | |
| **GDP in Constant 1995 Prices** | **5,648.2** | **6,056.6** | **6,345.5** | **6,564.4** | **6,992.8** | **7,585.8** | **7,997.9** |
| **GDP at Current Prices** | **6,356.9** | **6,935.4** | **7,348.4** | **7,650.8** | **8,201.0** | **9,156.7** | **9,529.6** |
| **GDP at Current Prices ($ million)** | **540.1** | **589.2** | **624.3** | **625.1** | **640.7** | **715.4** | **744.5** |

FISIM = Financial services indirectly measured, GDP = gross domestic product, Rf = rufiyaa.
[a] Projection.
Source: Ministry of Planning and National Development.

As for the role of the **Primary Sector** on the GF-island to be:

- Agriculture has no role, apart from some fruit trees such as coconut and mango along the roads or in the residential area.
- Fisheries, important as it may be on the national level, has no particular and certainly no direct business on GF-to-be.

As for the **Secondary Sector**:

- Light manufacturing primarily for the internal (Maldives) market, will have an important place on GF island. This will include probably (but is not limited to): assembly of computer hardware, laboratory activities, other research, materials testing, other assembly activities, etc.
- Electricity supply: the State Electricity Company – Stelco - is to install further capacity to meet a growing demand; the Malé Power Plant presently has total capacity of 21.5 MW. With the construction of energy-intensive high-rise buildings and growing ownership of household equipment, the consumption of energy has been growing rapidly, the demand for electricity in Malé has been growing at a rate of 12% per year. Stelco is interested to relocate part of its current activities to Gulhi Falhu and to set up new activities.

The **Tertiary Sector** provides the main reason and drive for the GF land development with transport and communication, in order to relieve the congestion at Malé port. The various projects include:

- As for business services, a location for wharehouses is planned;
- Services such as an international school, a shopping mall and a hospital have to be set up;
- A luxury shop, to attract both tourists and residents, together with a 7-star hotel and a golf course;
- Social housing and labourers quarters. Additionally luxury housing and accommodation for support staff, as far as those are not commuting from Malé is planned.

## 6.3 Objectives

Public consultation provides information for those not directly involved, but with a potential – reciprocal influence upon the project. It will allow making adjustments to address the issues raised and the concerns expressed.
For the Gulhi Falhu project, the exercise focused on Villingili island, as being the most affected populated area. Gulhi Falhu, being a submerged reef does not have any structured type of stakeholders to be addressed directly.

## 6.4 Villingili, the Island

Villingili is situated west of Malé, and east of Gulhi Falhu, separated by narrow channels. It is a typical Maldivian island without any particular features.
Villingili, once a resort, is now a residential area with about 500 houses, catering for the increasing demand for space on Malé itself.
As for the number of inhabitants, the official figure is about 15.000, however the real figure is probably something like 9000 / 10.000; as the island is administratively a ward of Malé municipality, detailed statistics for the Island as such are not available.
As for the economy, the government (in the broad sense including services such as electricity) employs up to 250 people; a further 200 people are employed or have business in Malé, and shop keeping on Villingili with 3 bigger shops and about 40 small general purpose shops and other such activities as sewing, employs another 100 people. Three fishing dhonis provide for the local market.
The island has a complete range of services comparable to Malé with electricity (local generation) and desalination water plant, a school up to 7$^{th}$ grade with some 600 pupils, and medical facilities and the like. Two upscale restaurants are catering for visitors from Malé.

## 6.5 The consultation

The public consultation started with a visit to the Villingili Ward office and an interview with Mr. Mohammed Sameer, Director of the Ward Office and his Deputy. Following this, 28 interviews were carried out after asking for approval to do so (no refusals). This involved a total of 53 persons, 25 female and 28 male, with in terms of age a same number of younger and older people. No names were asked.
After a brief explanation, the first questions were whether they knew about the project, what in general was their opinion and whether there were any issues - positive of negative - to be taken into account.
When word spread about the exercise, more people came for information; these people were not interviewed .

## 6.6 Opinions expressed

About one quarter of those interviewed had heard about the project, mostly via the radio.
The general attitude was positive, all but one ('no idea') saw the project as an opportunity in terms of employment and business (one remark: "at last something NOT in Malé"). A question asked more than a few times by the people was whether there would be a bridge from Gulhi Falhu to Villingili.
As for items for attention:

- Strong increase in traffic between Gulhi Falhu and Malé, with the additional remark that 'busy' in this sense also meant 'business';
- Noise from dredging during construction and whether there would be explosions;
- A small number of people worried about an increase in the currents between Gulhi Falhu and Villingili compensating for the hydraulic "barrier" the built-up island would be, with problems of increased erosion.
- Some of the men interviewed spent occasionally time at fishing near the outside of the Gulhi Falhu reef, and had questions about the situation after–the-project.

## 6.7 Conclusion and recommendations

Given the in general positive opinion no issues need to be addressed urgently, with exception of the current in the channel between Gulhi Falhu and Villingili. Once the project is about to be launched, a information campaign addressing the whole exercise for Villingili residents and others should be launched.

# 7 Assessment of Environmental and Social Impacts

## 7.1 General

This chapter discusses the environmental and socio-economic impacts, both during construction of the island and after construction has finished. It also discusses the different dredging and reclamation options and the option of No Construction and the environmental effects related to these options.

## 7.2 Environmental impacts during construction

The major environmental impacts during construction at Gulhi Falhu are related to:

- The selection of the dredging location and impact of dredging processes on benthic communities;
- Suspension of sediments caused by the dredging and reclamation works with effects on the marine ecology, and
- Waste handling and pollution control by the dredging contractor

Smaller short term aspects of the dredging and reclamation works at Gulhi Falhu are related to:

- Noise, light and air
- Socio-economic impacts (see paragraphs 7. 2 and 7.3)

### *7.2.1 The dredging locations*

There are three alternative locations for the mining of sand for the development of Gulhi Falhu.

1. Mining sand by trailer dredger (TSHD) from the seabed in the atoll lagoon. In this case it is most likely that the dredging dept will be 1 meter or less; in that case the affected area will be some 1,000,000 $m^2$ during phase 1.
2. Dredging sand (by cutter dredger/ CSD) within Gulhi Falhu's lagoon area. The area affected, will be between 350,000 and 750,000 $m^2$.
3. Dredging sand (by cutter dredger/ CSD) within a shallow reef or reef lagoon area nearby.

Since benthic organisms live in the top 30 – 40 cm of the seabed and on the seabed, the damage to the benthic communities at the reef flat area will be much smaller compared to dredging the atoll lagoon area. It is expected that on the sandy reef flat area, limited benthic communities are present, due to the limited water depth and the high water temperatures. On the sandy seabed areas in the atoll lagoon, it is likely that more benthic communities will be present, due to the conditions being less extreme. However, in areas where high current speeds occur, the presence of benthic fauna will also be limited. Additionally, benthic fauna communities have the capacity to recolonize areas with disturbed seabed fairly quickly. Recovery in highly dynamic systems is quick, taking anywhere from as little as a few months up to a few years.

Concluding: from an ecological point of view regarding the benthic communities, dredging at a reef lagoon or reef flat area would be preferred over dredging in the atoll lagoon area. However, given the availability of suitable dredging material in the atoll lagoon, this area is preferred above Gulhi Falhu's reef lagoon. Dredging in the atoll lagoon is also the preferred option with respect to the impact on nearby coral reefs.

### *7.2.2 Suspension of sediments*

The distribution of suspended sediments is related to three aspects:

- Dredging with a Cutter suction dredger (CSD) in the reef lagoon area;
- Dredging with a Trailing suction hopper dredger (TSHD) at the atoll lagoon area;
- Outflow of the pumped water at the reclamation area.

Each of the dredging methods and the outflow of water from the land reclamation areas will re-suspend sediment to a greater or lesser extent in the open sea. This may cause significant effects on the coral reef areas.

*CSD*
A CSD is a stationary dredger, that dislodges the material with a rotating cutter head mounted on a ladder. The cutter head is equipped with cutting teeth. The loosened material is sucked into the suction mouth located in the cutter head by means of a centrifugal pump, which is installed on the dredge pontoon or on the ladder of the dredger. The amount of material not entering the suction mouth may be as much as 30% of the total dislodged material. Much of this material will fall immediately to the seabed and will be dredged on the next cut. Only the finer particles will stay in suspension and will be distributed throughout the water column by the local currents. With a CSD, the creation of turbidity is a more or less a continuous process. Due to the fact that a rather deep basin will be created by the CSD of about 5 – 7 meters below the existing seabed, the majority of the suspended sediments will stay within this created basin. As the cut material will be disposed by a discharge pipeline to the land reclamation site, no additional turbidity will be created at the dredging site. Due to the shape, size and depth of the reef lagoon at Gulhi Falhu, it is expected that suspended sediments generated by a CSD dredging inside the reef lagoon will barely disperse outside the Gulhi Falhu reef.

*TSHD*
A TSHD is a normal sea-going ship equipped with one or two suction pipes. At the end of each suction pipe is a drag head, which can be lowered onto the seabed while the TSHD navigates at a reduced speed. The material loosened by the drag head, together with some transport water, is sucked into the suction pipe by means of a centrifugal pump, and subsequently placed in the hopper of the dredger. The TSHD will transport the sediments to the shore.
Most of the turbidity generated by a trailer suction hopper dredge is caused by the overflow of turbid water during the hopper filling operations. Overflow is the flowing overboard of excessive process water, together with a part of the finer material. Overflow is caused by continued loading after the hopper has been filled to its maximum. When dredging pure sandy sediments, the amount of overflow of particles is mainly determined by the grain size distribution of the dredged sediment. It is to be noted that the overflow process will not be a continuous activity, since its duration will be limited to operational dredging time, which is usually less than half the total cycle time.
The suspension of sediments and the effects on the coral reefs will mainly depend on the grain size distribution, the local currents and the distances to the coral reef areas.
The proposed borrow area is located just north of Gulhi Falhu, on the side of the reef with the lowest percentages live coral cover. The closest reef structures to the north, east and west are located more than 2.5km away. To the southeast, Villingili is 1.5km away, and to the southwest, Thilafushi is 1.25km away. The nearest resorts are more than 5km away, well outside the potential area of influence.
Depending on the monsoon season, the reef structures to the north and northeast may, under severe conditions during the southwest monsoon, be impacted by the suspended sediments generated at the TSHD borrow area. During the northeast monsoon, Villingili and Thilafushi are likely to experience some increase in suspended sediments.
These impacts are temporary, and will disappear within a few days after the dredging works have ended.

*Outflow of the pumped water*
The reclamation works can result in considerable volumes of sediment escaping into the water column and this may affect local marine habitats and may cause increased turbidity levels and sedimentation at the coral reef locations. To prevent this, it is generally recommended to construct permanent or temporary bund walls around the reclamation areas in the shallow water, using suitable materials. Preferably this should be done before the land reclamation will be carried out. Working with a reclamation area that was fully enclosed by bunds and included settling (or siltation) basin(s) proved very effective in minimising the release of suspended sediments to the ocean during the reclamation works at Viligili and Vilufushi.

However, in the case of Gulhi Falhu, it is impossible to deploy dry earth movement equipment necessary to create these bunds without first creating some dry land. In order to create dry land it is unavoidable that dredged sand is placed by the dredge without bunds being into place.
It is recommended that this amount of sand that is placed without containment bunds is kept to an minimum.
It is also recommended that this sand is placed during incoming tide, to ensure that excess water runs off towards the north, thereby minimising the impact on Hans Hass Place on the south side of Gulhi Falhu.

In addition to enclosing the reclamation area with bunds as soon as practicably feasible it is also recommended to study whether it is technically possible to place silt screens between the relocation area and the Hans Hass Place and if this will have an added value to the protection of the coral reef. A study of the local current pattern should therefore be studied..

*Area of influence*
Figure 7-1 shows the area of direct influence (bright green) by suspended sediments generated at the borrow area and from the reclamation area run off. In the bright green area, a temporary increase in suspended sediment concentrations may be measured at any time during the dredging and reclamation works, depending on weather conditions, tide and currents. In the darker green area, a temporary reduction in visibility may be observed during, and for a short time after, storm events.
These areas will be monitored during dredging and reclamation works as part of the water quality monitoring program (see chapter 9). When suspended sediment concentrations exceed warning levels, appropriate actions will be taken.

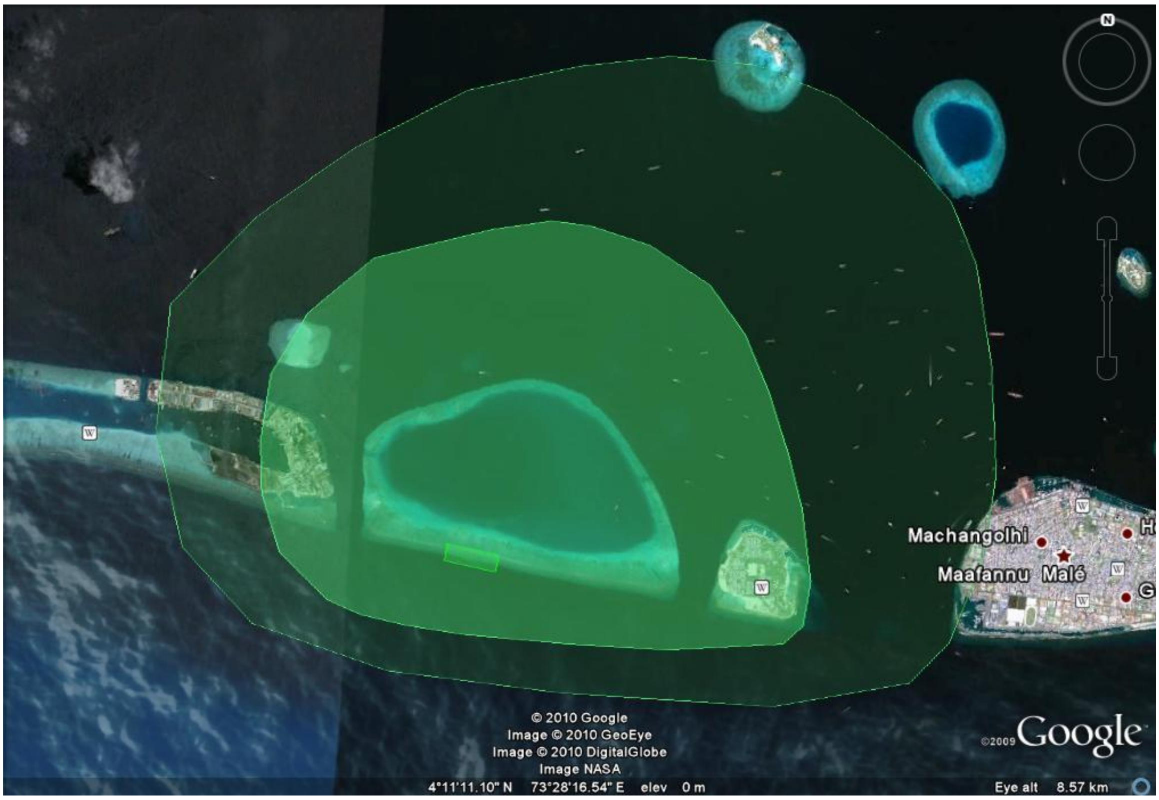


Figure 7-1 - Possible area of direct influence (bright green, temporary increase in suspended sediment concentration during dredging and reclamation works) and less direct influence (darker green, short term reduction of visibility during storm events) of suspended solids released from the proposed borrow area and the reclamation area under worst case conditions

*Impacts on nearby dive locations*
Due to the possibility of reduced visibility the dive site Hans Hass Place (Kiki reef) might be temporarily not available. This dive site is well known for the presence of a large variety of fish species. Some of these species might temporarily move away from the most turbid zone around the reclamation area. When turbidity levels are back to normal they will return to the site. The impact on corals on the steep slopes is considered relatively small due to their orientation. The amount of live and healthy corals on this dive site is also relatively limited compared to other dive sites and has decreased significantly over the last years.

The dive centers who use this dive location will be briefed on the activities by a news letter in order for them to chose an alternative location.

### 7.2.3 Waste handling and pollution control

At the working sites on land, as well as on board the construction vessels, waste water, oily wastewater and solid waste will be produced. To prevent pollution of the coastal waters the following restrictions are set:

- All the construction vessels need to be equipped with wastewater and solid waste handling facilities, to collect and handle the wastewater and the solid waste generated by each vessel. Disposal of wastewater and solid waste directly into the sea is not allowed.
- Oily wastewater and oily contaminated material generated from the construction machinery during the construction activities is also not allowed to be discharged directly into the sea. These wastes need to be collected and transferred back on shore for treatment/disposal, to avoid causing any adverse impact on the marine environment.
- Solid construction wastes generated during offshore construction works are also not allowed to be discharged directly into the sea. They shall be collected and transferred for onshore disposal, to avoid causing of any adverse impact on the marine environment.

### 7.2.4 Noise, light and air quality

Dredging and reclamation works will continue 24 hours per day.

*Noise*
Experience from the projects at Viligili and Vilufushi has shown that the dredge (in those cases a CSD) cannot be heard on the island while it is working. Distance from the island to the dredge varied from 100m to 500m. A TSHD generates a similar amount of noise while pumping material ashore as a CSD, so no noise impacts are expected from the dredges.
At the reclamation area, bulldozers, excavators etc will be working non-stop. This will generate some noise, but it is unlikely that this noise will be heard on Villingili. During north eastern and eastern winds, some noise may be heard on the east side of Thilafushi when reclamation takes place at the west site of Gulhi Falhu.

*Light*
When using a CSD to dredge sand from the reef around the island, the CSD will be visible day and night. Lighting on deck is necessary to maintain safe working conditions during the night. The lights can be directed away from the surrounding water as much as possible, as long as this does not jeopardise safe working conditions.
When using a TSHD, the dredge will move between the borrow area and the reclamation area. Same as on board a CSD, lighting on deck is necessary to maintain safe working conditions. These lights can be directed away from the surrounding water as much as possible, as long as this does not jeopardise safe working conditions.
The reclamation area, once it is raised above sea level, will be lit during night times to maintain safe working conditions. These lights can be directed away from the surrounding areas as much as possible, as long as this does not jeopardise safe working conditions.

*Air quality*

Due to the open nature of the working areas (enough ventilation) the impact is assumed to be light. Nevertheless, the following actions should be undertaken in order to ensure that pollution of the atmosphere is minimised:

- The engines will be maintained in good working conditions, so that exhaust emissions of pollutants will be kept to a minimum.
- With complete combustion, emissions of soot particles, hydro carbons and carbon monoxide are minimised.
- The vessels will be subjected to regular inspection and maintenance programs.

Equipment used on land will also be subject to regular maintenance in order to minimise emission of pollutants to the air.

Since the dredging activities take place entirely in a wet environment dust problems will not be encountered.

## 7.3 Boskalis SHE-Q

Royal Boskalis Westminster nv has ISO 9001, ISO 14001 and OHSAS certifications. The requirements of these certifications are met through company-wide Safety, Health, Environment and Quality system (SHE-Q), which provides clear procedures for safety, health and environmental management both at offices and project sites around the world.
Boskalis applies the same SHE-Q standards at all its projects around the world and to all its employees and subcontractors. These standards meet Dutch and international OHSA and environmental requirements, and are adjusted if a client has even more stringent requirements.
Dredging vessels are IMS certified and have to meet international standards for waste, hazardous materials and sewage management, and fire, oil spill and other emergency response and prevention. Annex 7 contains the framework that is used to make a specific Environmental Management Plan for each individual project that Royal Boskalis Westminster undertakes. Similar frameworks are applied for project specific Safety and Health Management Plans.

## 7.4 Environmental impacts after construction

The major long term aspects for the dredging and reclamation works at Gulhi Falhu are related to:

- Loss of marine habitats due to the land reclamation;
- The safety of the local population and the land ecology;
- A large basin within the reef lagoon area (in case of a CSD);
- Alien species transported to the island
- Increased population.

### *7.4.1 Loss of marine habitats*

The land reclamation to enlarge the island will result in a permanent loss of marine habitats and resources. However, the land reclamation is limited to the shallow reef area and will not destroy the coral reef areas at the reef slopes at the lagoon side and the ocean side. The reef flat itself is of low ecological value.

### *7.4.2 A large basin at the shallow reef flat*

When a CSD is employed, the borrow area for the land reclamation works may be located inside the reef lagoon. A basin will be created with a depth of 15-20 meters in the existing lagoon (which is 8-15m deep). Over time, sand may be transported from the surrounding areas into the basin area. In time this may result in changes in bathymetry and morphology around the borrow area.

### *7.4.3 Alien species*

Ships and vessels selected for the construction works are likely to come from areas outside the Indian Ocean. These vessels may contain foreign ballast water. Ballast water is fresh or saltwater held in the ballast tanks and cargo holds of ships. It is used to provide stability and manoeuvrability during a voyage, or when more stability is required due to rough seas. Organisms living in coastal waters may be pumped into ballast tanks along with the water. If a ship takes on ballast water in a shallow area, sediments and any associated organisms may be pumped into the ballast tanks. When ballast water is released, these organisms may also be released.

The release of ballast water may introduce non-native organisms into the Maldives coastal waters. These introduced species, or bio-invaders, are also referred to as exotic species, alien species and non-indigenous species. Typically, very few organisms are able to survive in new surroundings because temperature, food, and salinity are less than optimal. However, the few that do survive and establish a population have the potential to cause ecological and economic harm. Populations of bio-invaders may grow very quickly in the absence of natural predators. In turn bio-invaders may displace native organisms by preying on them or outcompeting native species for food and habitat space. Economic damage may occur when a bio-invader displaces species that are harvested for food or other goods, or when bio-invaders damage structures. Worldwide, the introduction of foreign species is a leading environmental issue.
The introduction of alien invasive organisms is now considered to be one of the most serious threats to the biological diversity of the Maldives.
To prevent exotic species from being introduced in the Maldives, all dredging and auxiliary vessels that are brought into the Maldives will follow international conventions and regulations regarding ballast water.

### *7.4.4 Increased human activities and population*

The new presence of human activities and population will lead to waste and sewage being generated. This creates an increased need for sustainable waste and sewage management to ensure safe and healthy living conditions on the island.

## 7.5 Social impacts during construction

The effects and impacts of the dredging and filling on the nearby island of Villingili and its population are rather limited. A dredger, including the crew will be out on the sea. Relocation and the like is not an issue, neither people nor the built-up area will be affected.
On Gulhi Falhu, a small number of people will be active and 10 – 20 people, local or from elsewhere, may be employed for about 6 -8 weeks. All this is well within the range of what is going on in the area at any given time and there are no specific categories of people which could be vulnerable.
With Boskalis´ wide experience in working with local people at their projects, there are no special issues to be addressed. Continuous contacts and access to information and addressing issues as they arise will be an integrated part of the operation.

The impact on the fishing community will be minimal. The majority of fishing (for tuna) takes place on the open ocean. The effects of increased suspended sediments will mainly be limited to within 500-1000m from the reclamation run off point and the borrow area. Fishing for bait fish will still be possible at islands and reefs located 5km or more away.

Marine traffic might be affected by the dredging and reclamation areas. Dredging activities in the borrow area can temporarily increase the turbidity in the water making visual navigation around the shallow reefs difficult.

Suspended sediment levels will be monitored at the Hans Hass Place MPA and nearby dive sites as part of the water quality monitoring program described in chapter 9.

## 7.6 Socio-economic impacts after construction

The social-economic impacts of the project are large in relation to the number of people and the size of the economy. These impacts are expected to be positive. No potentially adverse effects have been identified.
The outcome means land for:

- Warehousing
- Logistics and distribution
- Hotel and golf course
- Housing

This will give an impetus to economic development, and relief of the pressure on Male'.

The most important positive impact will be the availability of new urban land both for housing, communal activities and (new) economic activities in the Greater Malé area. In principle no negative socio-economic effects are associated with this extra land; careful planning of land-allocation to various users and activities will maximize the result.
Estimates of new employment opportunities in the industries and services on GF island have already been presented in paragraph 6.2.

All of the above impacts will have positive longer term socio-economic consequences.

Socio-economic consequences of the GF project related to Malé island are potentially beneficial and large: the negative consequences of overcrowding on Malé will be reduced.

(Re)location to the new island of Gulhi Falhu will be voluntary. Interested businesses can rent plots, and people interested in living on Gulhi Falhu can move there of their own free will once housing becomes available. As stated before, the Government of the Maldives has a passive population consolidation policy, rather than seeking to actively relocate people.

## 7.7 Comparison of No Development and different dredging & reclamation options

For this EIA there are two main options, which are (1) no-construction at all and (2) the development of Gulhi Falhu. Regarding the overall design of the island, the shape of the reef presents severe limitations on the shape. Different phases of the development of the island have been discussed in chapter 4. This paragraph discusses the impacts on the natural environment related to no-construction and the alternative construction methods.

### *7.7.1 No construction*

In case the development of Gulhi Falhu would not take place at relatively short notice, the direct impacts on the land and the marine environment would seem to be neutral. In the somewhat longer term some environmental impacts will take place not at Gulhi Falhu, but at Thilafushi, Villingili and Male', mainly due to the fact that the pressure on the marine environment will increase. The port facilities in Male' will be overextended even further, leading to higher risks of spills and other marine accidents. Goods will be temporarily stored in any space available, whether this space is suitable or not, leading again to higher risks of spills and accidents.

### *7.7.2 Dredging alternatives*

The project requires up to 1 million $m^3$ of suitable fill sand for phase 1 and 2. The possible sources of fill material are the following:

- Option 1: Sand from the reef lagoon area to be dredged by a CSD (cutter suction dredger) with a pipeline system;
- Option 2: Sand from the seabed of the atoll lagoon just north of Gulhi Falhu, to be dredged by a TSHD (trailing suction hopper dredger);
- Option 3: Sand and coral material from a coral reef (faro) elsewhere in the Kaafu atoll to be dredged by a CSD;

- Option 4: Sand imported from overseas by a jumbo trailer (very large trailer).

Option 1 is an attractive alternative both from an economic and an environmental point of view, provided there is enough sand of sufficient quality available in the reef lagoon.
Option 2 is a realistic alternative depending on the water depth of the seabed in the atoll lagoon, and the available quantity of sand within the atoll lagoon. Sand mining in the atoll lagoon can be done by a Trailing suction hopper dredger. As the water depth is between 20 – 80m, a large TSHD is required.
Option 3 will cause considerable damage to the environment.
Option 4 will result in very high costs.

### *7.7.3 The dredging location and its impact*

Two alternative locations for sand mining for the reclamation can be used. The first alternative is located in the reef lagoon area; the second alternative is dredging sand from the seabed in the atoll lagoon.

Dredging within the reef lagoon area by a CSD (option 1) will affect an area of about 350,000 - 500,000m$^2$. The created depth within the dredging area will be about 15-20 meter inside the reef lagoon, which is 8-15m deep. In case dredging is carried out within the atoll lagoon by a TSHD (option 2), it is most likely that the dredging depth will be less than 1m. In that case the affected area will be at least 1,000,000m$^2$, which is 2-3 times larger than in case of dredging within the reef lagoon.

Since the benthic organisms live in the top 30–40cm of the seabed and on the seabed, the damage to the benthic communities when dredging at the reef lagoon will be limited to 50%, compared to dredging in the atoll lagoon area. However, it is expected that the benthic communities in the seabed of the reef lagoon are richer than those in the seabed of the atoll lagoon. The reef lagoon is shallower, and sunlight can penetrate all the way to the seabed, allowing for a more species to survive. The atoll seabed is too deep to receive direct sunlight, which means that fewer species can survive here.
Recovery of the benthic communities in both areas is expected to happen relatively quickly after the dredging works have finished.

For this project, the depth of the borrow area is directly related to the dredging method used. When a Cutter Suction Dredger (CSD) is employed, a relatively small but deep borrow area will be created in the reef lagoon. A Trailer Suction Hopper Dredger (TSHD) will create a relatively large and shallow borrow area in the seabed of the atoll lagoon at greater water depths.

Working with a TSHD in the atoll will generate a source of suspended sediments in a location outside the Gulhi Falhu reef. Although the TSHD will dredge away from coral reefs and patches, the benthic fauna living on and in the seabed at the borrow area will be affected. The process of filling the reclamation area by TSHD however will allow for more control over the release of suspended sediments from the reclamation area.

Working with a CSD elsewhere in the atoll will cause damages to the life organisms at a second reef and coral patches and is therefore not seen as a viable alternative.

### *7.7.4 Resuspension of sediments*

The distribution of resuspended sediments is different for the dredging processes:

- Dredging with a cutter suction dredger in the reef lagoon;
- Dredging with a trailing suction hopper dredger at the atoll lagoon area.

Each of these dredging methods will cause resuspension of sediments; this may in turn have significant effects on the coral reef areas.

*CSD (option1)*
A CSD is a stationary dredger which dislodges the material with a rotating cutter-head. During the dredging process part of the finer particles will stay in suspension and may be distributed by the local currents. To assess how the suspended sediments are spread over the coral reef areas, it is

necessary to consider the local current regime. Given the limited water depths over the reef edges (2 to 4m) it is expected that the water inside the reef lagoon is relatively still. Furthermore, the sediments will settle to the deeper parts of the water column, while it is the upper parts of the water column that will move in and out of the reef lagoon with the tides. It is therefore expected that the majority of the suspended sediments will remain within this basin.

*TSHD (option 2)*
A TSHD has one or two suction pipes and dragheads; the material is loosened by the draghead from the sea bottom, sucked into the suction pipe and placed in the hopper of the dredger. The TSHD then moves to the reclamation for discharging. Most of the turbidity generated by a TSHD is caused by the overflow of water and part of the finer materials during the hopper filling operations. The resuspension of these sediments and the effects on the coral reefs will mainly depend on grain size distribution, local currents and distance to the reef. The proposed borrow area is located just north of Gulhi Falhu, and although some of the closest islands and reefs will experience some increase in suspended sediment concentrations, these effects however will be temporary.

*Table 7-1 comparison of dredging options including mitigating measures*

| Dredging alternatives | No dredging | CSD/ reef lagoon | TSHD/ atoll lagoon | CSD/reefs elsewhere | TSHD/ overseas |
|---|---|---|---|---|---|
| *Environmental impacts* | | | | | |
| Disturbed bottom $m^2$ | 0 | 350,000 – 500,000 | 1,000,000 | 750,000 | 1.000.000 |
| Turbidity | 0 | -- | - - | - - - | - - |
| Loss of corals | 0 | -- | - | - - - | 0 |
| Loss of macro benthic | 0 | - | - - | - - - | - - |
| Loss of fishes | 0 | - | - - | - - | - - |
| Alien species | 0 | 0 | 0 | 0 | - - |
| *Economic impacts* | | | | | |
| Costs dredging | 0 | - | - - | - - - | - - - - |
| **Total** | **0** | **--** | **- -*** | **- - -** | **- - -** |

0 = no impact,
- = small impact,
-- = medium impact,
--- or ---- = big impact.
* The increased overall impact is mainly caused by the fact that dredging with a TSHD leads to a second area being exposed to increased suspended sediments concentrations. However, this area would be less sensitive, as it would be chosen well away from coral reefs.

# 8 Selection of Preferred Alternative and Mitigating Measures

## 8.1 Preferred Alternatives

The four alternative work methods that have been discussed all have their own specific advantages and disadvantages:

- Dredging with a CSD at the reef lagoon area means that an access channel into the Gulhi Falhu reef lagoon needs to be dredged. Where this channel is dredged, most likely on the atoll (north, east or west) side of Gulhi Falhu where live coral cover percentage are low (between 0-10%), coral reef communities will be destroyed. On the other hand, the total area of seabed directly impacted by dredging is smaller when using a CSD than when using a TSHD.

- Working with a TSHD in the atoll will generate a source of suspended sediments in a location further away from Gulhi Falhu. This will cause temporary impacts on both the environment as well as on navigation. Although the TSHD will dredge away from coral reefs and patches, the benthic fauna living on and in the seabed at the borrow area will be affected. The benthic fauna will, over time, recolonise the seabed at the borrow area.

- Working with a CSD elsewhere in the atoll will cause damages to the life organisms at a second reef and coral patches.

- The costs of dredging overseas with a jumbo trailer will be very high.

Based on these results, dredging sand from a borrow area in the atoll lagoon by TSHD is the preferred option. Dredging sand in the reef lagoon by CSD is a viable alternative option, provided the location of the access channel is chosen properly (i.e. at a location where live coral cover is lowest)

## 8.2 Mitigating Measures

### *8.2.1 Preventive measures*

The following preventive measures are strongly advised at the dredging and reclamation areas:

- Construction of bunds to fully enclose the reclamation area to minimise the loss of suspended sediments from the reclamation area. Due to the depth below sea level of Gulhi Falhu (2-4m) bunds cannot be constructed for the reclamation of phase 1 and 2 until a large enough area of the reclamation is brought above sea level to deploy dry earth movement equipment. Bunds should be constructed especially on the south and east sides of the reclamation area to protect Hans Hass Place, as soon as practicably possible. For the reclamation of phase 3 and 4, bunds should be in place and should fully enclose the reclamation area before filling of the reclamation starts.
- Construction of one or more settling basins in phase 3 and 4 (depending on the final layout of the reclamation area), to further minimise the loss of suspended sediments from the reclamation area
- Ensuring that there will be settling basin space available at all times until the dredging works have completed by creating of a stockpile of material that will be used to fill the final phase of the reclamation area.
- Choice of the location of the entrance channel for the dredge to be able to reach the reef lagoon. Construction of this entrance channel should cause minimum damage to coral reefs. In case a TSHD is employed (option 2), the entrance channel will not be needed and hence no damage will occur.
- Choice of location of the TSHD borrow area away from coral reefs, coral patches, Marine Protected Areas, resorts and dive sites.

### *8.2.2 Mitigating measures*

The following mitigating measures will have to be given consideration during the preparation and execution phases of the dredging and reclamation works:

- Use of limited overflowing when dredging sand from the atoll seabed by TSHD. Limiting overflow has large consequences relating to the cost of the dredging operations
- Use of navigation aids around shallow reefs when visual navigation is temporary impossible in order to prevent groundings.
- Deployment of silt screens in phase 1 and 2 between the reclamation areas and the sensitive environmental receivers when technically possible.

Experience at Vilufhsi and Viligili has shown that creating temporary bunds using an excavator generates only a minimal amount of suspended sediments that does not disperse beyond 50 m from the excavator.

The decision to take additional mitigating measures such as the construction of temporary bunds will depend on the results of the water quality monitoring program (see chapter 9). Warning levels and maximum allowable levels for suspended sediment concentration are defined as part of this monitoring program. When warning levels are exceeded, an assessment is made of the best mitigating measure(s), based on where levels are exceeded, the activities, weather conditions etc, encountered before and during the incident.

### *8.2.3 Compensation measures*

The following compensation measure can be taken into consideration during the preparation and execution phases of the dredging and reclamation works or can be taken into consideration after completion of the works.

- Since the reclamation of Gulhi Falhu takes place in very close proximity of Hans Hass Place it is possible that the activities will impact this marine protected area even despite the deployment of preventive or mitigating measures. Appointment of a new Marine Protected Area by the Environmental Protection Agency could be a measure to compensate for the decline of this ecosystem. According to the Divers Association, nearby resorts and local dive centers the autonomous trend in species abundance and biodiversity due to the impact of Thilafushi and fishing is declining anyway.
- Coral transplantation on a pilot scale to compensate for coral loss as a result of the Gulhi Falhu project could be considered as a compensation measure after completion of the project. The transplantation has to add value to the location of the reception area and not cause any loss to the donor area. It must be taken into account here that the current status of the coral on Gulhi Falhu reef is not significantly high and the trend in the last years has shown a decline in quantity and diversity. The transplantation pilot will therefore be a small scale project and will have to be financially feasible.

# 9 Environmental Monitoring Plan

The monitoring program and its equipment, monitoring locations and frequencies and reporting requirements, is based on the information needs for the project. The monitoring program includes three sections:

- information needs
- the monitoring program including the equipment, the locations and frequencies
- the monitoring reports

## 9.1 Information needs

In this monitoring plan, which includes both the construction phase and the long term (both of which will be the responsibility of the project proponent), the most relevant information needs are described:

- water quality aspects, including suspended sediments and sedimentation;
- ecological aspects related to coral;
- the re-colonization of the borrow area;
- erosion around the borrow area.

### *9.1.1 Water quality aspects*

Information need: what is the actual effect of the dredging and reclamation activities near Gulhi Falhu on the water quality?

One of the most important potential marine environmental impacts associated with dredging and reclamation works is the deterioration of water quality due to increased levels of suspended sediments and possible reduced oxygen levels.

Due to the re-suspension of the fine fraction of the coral sand, dispersion and resettling of the sediments during the dredging and the reclamation activities, a wide range of effects can be caused, including damage to coral and other organisms that cannot leave the area to escape the increased suspended solids concentrations. If the turbidity level is continuously high for a period of 3 months or more, significant damage can occur to coral.
Significant sedimentation will also cause damage to coral and other sessile organisms. In the EIA a range of mitigating measures has been selected to minimize the re-suspension and dispersion and sedimentation of suspended sediments from the borrow and reclamation areas.

However, because the exact effects of the dredging and reclamation works at Gulhi Falhu cannot be predicted in detail, it is necessary to monitor the actual effects of the works on water quality. In this way the scale of the impacts as well as the duration of the impacts and the influence of the weather conditions will become clearer. The monitoring will have two purposes:

- to evaluate the effectiveness of mitigating measures already in place, such as the silt screen and in later phases the bund closing off the reclamation area from the ocean, and the settling basin
- to signal the need for additional mitigating measures, such as adjustments in the dredging and reclamation processes.

The effects of dredging and reclamation on water quality are directly related to the working activities and the local physical characteristics, like the currents and waves. It is recommended to periodically monitor the currents along the reef to get more information on where the suspended sediments released at the borrow and reclamation areas may be transported to by the local currents.
During the construction of the reclamations at Vilufushi and Viligili, the suspended sediment plume did not disperse further than 2.5km away from the source under storm conditions. Suspended sediments settled within 2-5 days.

#### *9.1.2 Ecological aspects related to coral*

Information need: what can cause damage to coral?

At the shallow reef area around the island there is hardly any coral. After the surveys at the shallow reef areas it is estimated that the life coral is less than 1%. Even at the reef edges there is practically no live coral coverage. This is mainly due to the coral bleaching in 1998 and the tsunami in December 2004. Consequently at the shallow reef no monitoring of coral is required. At the line transects that were surveyed on the slopes around the shallow reef area, the life coral coverage varies from less than 5% to 15% at the ocean side and from 0% to more than 10% at the atoll side.

*Turbidity and sedimentation*
If turbidity levels are significant during several months, the light available to the coral is reduced and consequently coral colonies may die. The Sedimentation on coral is quite different. Soft corals and branching corals are less vulnerable than massive and table corals. Most coral species have a mechanism to clean very fine sediments off of their surface, but they have difficulty cleaning off coarse sediments.

#### *9.1.3 The re-colonization of the borrow area created by a CSD*

Information need: how long will it take for the borrow area to be colonised by marine organisms?

Re-colonisation of meiobenthos (< 1mm) is a much faster process than the recovery of the macrobenthos (>1mm). Complete restoration of the nematodes community can take place within some days. The restoration of the macrobenthos community after the sand extraction depends on the degree in which the new substrate is arranged for re-colonisation and establishment of larvae. The biological period of recovery can take place within some months to 2 or 3 years.

#### *9.1.4 Erosion around the borrow area*

Information need: what can cause damage around the borrow area?

The borrow area created by a TSHD will be located at relatively large depth (20-50m). It will be shallow, but covering a large area. At these depths, waves will not hit the seabed to stir up sediments.
It is expected that currents will barely influence these borrow areas, since the fastest currents run through the channels between islands and reefs where no dredging of sand will take place.

The borrow area created by a CSD will be located in the reef lagoon area, and will have a more basin-like shape. This borrow area will be 15-20m, and waves will not be able to build up inside a lagoon to such a height that they will hit the seabed here. If sediments are stirred up by currents, they will likely remain inside the reef lagoon. As a result the borrow area will silt up slowly.

## 9.2 The monitoring program

In this section, the requirements, methodology, equipment and monitoring locations and frequency for the monitoring components are presented. Included in this section are:

- water quality monitoring;
- sedimentation monitoring;
- erosion around the borrow area;
- recolonisation of the borrow area (when working with a CSD).

#### *9.2.1 Water quality monitoring*

Water quality monitoring at the islands shall be carried out by an environmental monitoring team to ensure that any deteriorating water quality is readily detected and that timely action is taken to rectify the situation. The objective of the water quality monitoring program is to determine the effectiveness of the operational controls and mitigation measures employed, and the need for supplementary mitigation measures to protect the coral.

General parameters to be recorded during sampling and measurements

- Location;
- time and date;
- weather conditions;
- sea conditions;
- tide;
- monitoring / sampling depth.

Parameters to be measured in situ

- dissolved oxygen (DO) (% saturation);
- dissolved oxygen (DO) (in mg/l);
- temperature (°C);
- turbidity (NTU);
- salinity (ppt);
- water depth (m).

Additionally, water samples will be taken periodically in conjunction with turbidity readings to determine Suspended Solids Concentration (SSC) and establish a relationship between Suspended Solids Concentration (mg/l) and turbidity (NTU). This relationship will help translate the turbidity readings that are taken at the monitoring locations into SSC so that comparison with the maximum allowed value is possible.

Parameters to be measured in the laboratory

- suspended solids (mg/l)
- heavy metals

*Methodology*
For water quality monitoring the following equipment is required:
a survey vessel with DGPS positioning equipment;

- dissolved Oxygen and temperature measuring equipment;
- turbidity measurement equipment;
- water depth gauge;
- water sampling equipment.

*Locations and frequency*
A total of 8 sampling and monitoring locations (2 of these are background stations) for the water quality have been selected (see *Figure 9-1*). Prior to the start of dredging activities a baseline survey will be done.

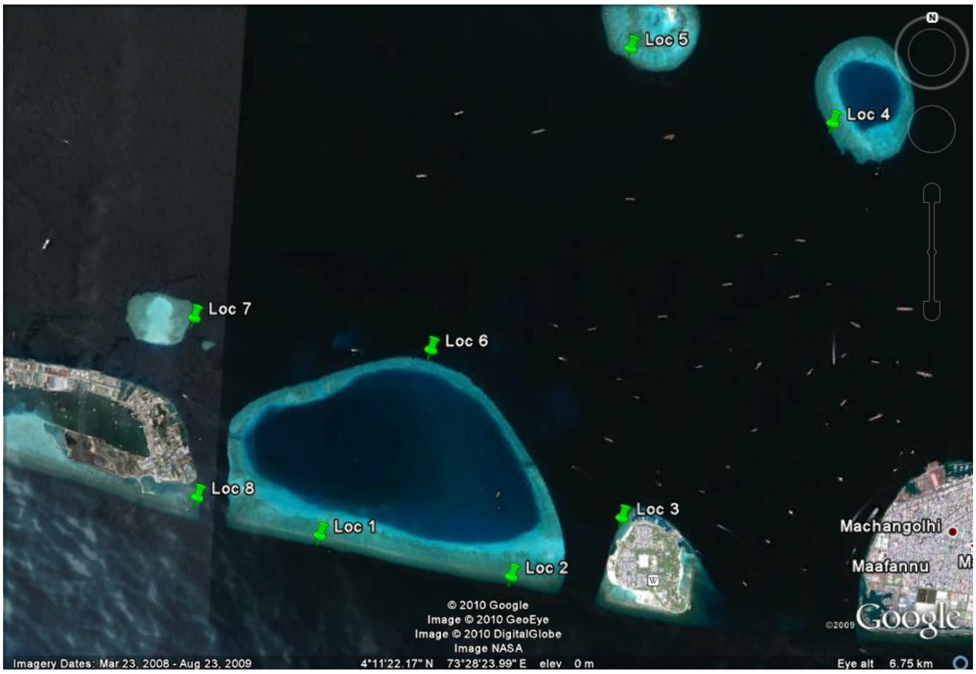


Figure 9-1- Monitoring locations around Gulhi Falhu

It is recommended that the following parameters will be monitored at the indicated frequencies:

Table 9-1 water quality sampling and monitoring

| Type | Parameters | Locations | Frequency |
|---|---|---|---|
| In situ monitoring<br>• 1m below surface<br>• middle of water column<br>• 1m above seabed | • Dissolved oxygen (% saturation)<br>• Dissolved oxygen (in mg/l)<br>• Temperature (°C)<br>• Turbidity (NTU);<br>• Water depth (m). | All locations | 2 times per week during dredging and reclamation works + once per day during one week before the start of dredging and during the first week after the start of dredging and reclamation works and during 1 week after completion of the works |
| Water sampling for laboratory investigations anywhere in the water column | • Suspended solids (mg/L) | In the vicinity of dredging and reclamation works | Covering a sufficient range of suspended solids concentration to establish a satisfactory correlation + monthly to update the established correlation |
| | • heavy metals | two locations near the reclamation area and two reference locations | Once before the start of the works, once a month during the execution of the works and once at completion of the works |

### *9.2.2 Sedimentation monitoring*

Sedimentation monitoring should be carried out by a dive team to ensure that a proper assessment is made of the sedimentation levels on coral. The objective of the sedimentation monitoring program is to determine the effectiveness of the operational controls and mitigation measures employed, and the need for supplementary mitigation measures to protect the coral.

General parameters to be recorded during sampling and measurements:

- Location;
- time and date;
- weather conditions;
- sea conditions;
- tidal mode;
- monitoring depth.

Parameters to be assessed by a scuba diver (visual inspections):

- percentage coral covered with sediment.

*Methodology*
For sedimentation monitoring the following equipment is required:

- survey vessel with DGPS positioning equipment;
- scuba diver with photo/video camera.

*Locations and frequency*
The sampling and monitoring locations are indicated in Table 9-2. The frequency and the monitoring and sampling depths are indicated in Table 9-2.
Exact monitoring location for sedimentation and coral health monitoring will be determined based on the baseline coral survey. Locations will be chosen in areas where coral may be impacted by the dredging and reclamation works, but accepting the fact that there will be some inevitable impact in an area up to 500 m from the borrow and reclamation areas.

Table 9-2 sedimentation rate monitoring

| Type | Parameters | Locations | Frequency |
|---|---|---|---|
| Visual inspection At coral areas investigated during the baseline benthic surveys | Coral coverage with sediment | All locations | 1 time before the start of the dredging and reclamation works + once during the dredging and reclamation works + 1 time after completion of the dredging and reclamation works |

### *9.2.3 Erosion around the borrow area*

It is expected that the erosion around the borrow area will be rather limited due to the water depth at which the borrow area will be located. No additional monitoring actions are recommended at this stage.

## 9.3 The monitoring reports

*Weekly monitoring reports*
The weekly reporting will be based on the monitoring results, site inspections and the evaluation/ interpretation of the monitoring results.

Based on the weekly monitoring results the effectiveness of the operational controls, the mitigation measures employed and the need for supplementary mitigation measures will be discussed between the Engineer and the contractor on a weekly basis. In case of extreme urgent matters a meeting between the engineer and the contractor will be arranged within 24 hours. The weekly reports shall be submitted to the engineer, the employer and the contractor.

## 9.4 Monitoring after construction

In the year after completion of the reclamation and revetments, monitoring will be undertaken by the Project Proponent to ensure no significant long-term environmental effects arise from the project.

At the reclamation area, it is recommended that the following aspects are monitored:

- Signs of erosion and/or sedimentation
- Recolonisation by benthic flora and fauna at areas that were affected by the construction
- Condition of the revetments

At the borrow area, it is recommended that the following aspects are monitored:

- Recolonisation of the borrow area by benthic flora and fauna (when working with a CSD)

Additionally, the land use plan needs to be finalised, after full consultation with prospective users and the relevant Ministry.

## 9.5 Monitoring Responsibility

The Project Proponent is responsible for ensuring that the monitoring program is implemented both during and after the construction works. The Project Proponent is also responsible for ensuring that the recommended preventative and mitigating measures are implemented by the dredging contractor.

It is recommended that all preventative measures as described in chapter 8 of the EIA will be implemented as part of the construction work method. Cost for these adjustments are included in the project budget.

Monitoring efforts after completion of the dredging and reclamation works are limited to surveys of bathymetry and coral health, with survey works taking approximately one day per six months.

# 10 Conclusions

*Environmental*
The following conclusions are drawn, based on the gathered information:

- The reclamation of Gulhi Falhu with revetments on the exposed sides can be done with medium impacts on the environment in phase 1 and 2 and with minimal impacts in phase 3 and 4, provided that preventative measures (silt screens, closed reclamation, use of siltation basins) are implemented during construction and further mitigating measures are implemented when necessary.
- A closed reclamation with siltation basins is not possible in phase 1 and 2 of the Gulhi Falhu development project.
- During the dredging and reclamation activities, good care should be taken to allow only a pre-determined minimum of suspended sediments to escape from the working areas. Preventative measures will be in place to ensure minimal loss of suspended sediments, and additional mitigating measures will be available for implementation should the need arise. Monitoring should concentrate upon these aspects.
- Some coral reef will be impacted at locations near dredging and reclamation works. All feasible measures will be taken to minimise the amount of coral damage by dredging the absolute minimum required volume of sand needed to fill the reclamation area.

*Socio-economic*
The social-economic benefits of the project are large in relation to the duration of the dredging and reclamation works needed. No potentially adverse effects or any risks have been identified. The project results in new land for:

- Warehousing
- Logistics and distribution
- Housing

This will give an impetus to economic development, and relief of the pressures on Male'.

The following conclusions are drawn, based on the gathered information:

- An existing and immediate need for land and space in the Greater Male' area would be fulfilled by this project.
- The activities that are foreseen for the Gulhi Falhu development are so-called "light industry", with relatively low impact on the marine environment.
- The consultations at Villingili were done in an open atmosphere, and people were positive about the development.

# 11 Annexes

1. Terms of Reference approved by GoM
2. Presidential Degree (2007) and approval letter from Ministry of Finance and Treasury (May 2010)
3. Gulhi Falhu Land use Master Plan
4. Consultation meeting 23rd June 2010: invitation letter, attendance list, minutes of meeting
5. Dive sites & resorts in the North and South Male atoll
6. Turtle nesting sites in the Maldives
7. Environmental Management Framework (Boskalis SHE-Q)

# 12 Reference

1. *Environmental Impact Assessment Regulations*, Ministry of Environment, Energy and Water, Government of the Maldives, 2007

2. *EIA for the Post-tsunami Reconstruction of Safe Island Vilufushi, Thaa Atoll*, EDC, 2005

3. *EIA for the Construction of Safe Island Viligili*, EDC, 2006

4. *Environmental Impact Assessment for the Three Islands Project – Thulhaadhoo, Baa Atoll*, Hydronamic, 2009-2010

5. *Environmental Impact Assessment for the Three Islands Project – Hinnavaru, Lhaviyani Atoll*, Hydronamic, 2009-2010