

Environmental Impact Assessment Report

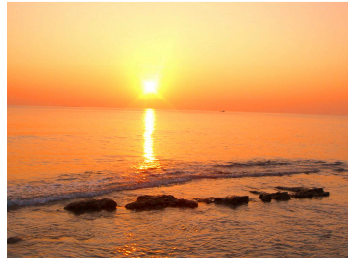
Ha.Madulu Island for Agricultural Development

Ihavandhippolhu Atoll

Republic of Maldives



February 2008



Consultants:

Mr. Ibrahim Naeem
Mr. Hussain Naeem
Mr. Hazim Rasheed
Mr. Hussain Shameem
Mr. Mohamed Musthafa

Proposed by:

Mr. Ali Ibrahim
Finivaage
A.DH fenfushi

Prepared and Issued by:



E-CAD ASSOCIATES PVT LTD
TOTAL + BUILDING + SOLUTIONS

Consultant's Declaration

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

Name: Ibrahim Naeem (Master of Env. Magt.) - EIA 13/2007

Signature



Date: 27th February 2008

Contents

CONTENTS	a
NON-TECHNICAL SUMMARY	i
1. INTRODUCTION	1
1.1 Background information of the project	1
1.2 Project costs.....	2
1.3 The proponent and its experience with similar projects	2
1.4 Terms of Reference	2
2. PROJECT SETTING	3
2.1 Existing plans, policies, guidelines, regulations, laws related to the project	3
3. PROJECT DESCRIPTION	6
3.1 Intended duration of the project	6
3.2 Work schedule	7
3.3 Need and justification of the project	8
3.4 Components of the project design, size and scale.....	9
3.4.1 Structures on land	9
3.4.2 Harbour	9
3.4.3 Harbour jetty	9
3.4.4 Entrance channel.....	10
3.4.5 Southwest jetty	10
3.4.6 Land clearance	10
3.4.7 Coastal protection	11
3.5 Location of the project.....	12
4. DESCRIPTION OF THE NATURAL ENVIRONMENT	14
4.1 Marine environment	15
4.1.1 Coral reef.....	15

4.1.2	<i>Lagoon</i>	16
4.2	Terrestrial environment.....	17
4.2.1	<i>Beach</i>	17
4.2.2	<i>Vegetation</i>	17
4.3	Description of Existing Terrestrial Environment.....	18
4.3.1	<i>Beach environment</i>	18
4.4	Beach erosion.....	23
4.5	Beach accretion.....	26
4.6	Beach sediment dynamics.....	27
4.6.1	<i>Section A</i>	27
4.6.2	<i>Section BC</i>	28
4.6.3	<i>Section C</i>	29
4.6.4	<i>Section D</i>	29
4.6.5	<i>Section E</i>	30
4.7	Beach profiles.....	30
4.8	Vegetation.....	32
4.8.1	<i>Coastal vegetation</i>	32
4.8.2	<i>Inside vegetation</i>	37
4.8.3	<i>Mangrove</i>	39
4.9	Soil.....	41
4.10	Groundwater.....	42
4.11	Description of existing marine environment.....	44
4.11.1	<i>Coral Reef System</i>	45
4.11.2	<i>Reef fish communities</i>	49
4.11.3	<i>Reef invertebrates</i>	52

4.12	Bathymetry	53
4.13	Currents.....	55
4.14	Waves.....	55
4.15	Tides.....	55
5.	SOCIO-ECONOMIC AND POPULATION	57
5.1	Atoll population	57
5.2	Population distribution	58
5.3	Environmental issues	59
6.	METHODOLOGY	60
6.1	Marine environment assessment methods.....	60
6.1.1	<i>Reef Aesthetic Survey – using Mata Tow Technique.....</i>	60
6.1.2	<i>Manta Tow Survey</i>	62
6.1.3	<i>Coral Reef Fish Visual Census</i>	66
6.2	Bathymetry surveys	70
6.3	Surface current surveys	70
6.4	Beach and beach dynamic surveys	70
6.5	Vegetation surveys.....	70
6.6	Soil surveys.....	70
6.7	Groundwater surveys.....	70
7.	PUBLIC CONSULTATION.....	71
8.	ASSESSMENT OF DIRECT AND INDIRECT ENVIRONMENTAL IMPACTS.....	72
8.1	Introduction	72
8.2	Methodology used for Impact Identification.....	72
8.3	Existing Natural and Anthropogenic Impacts	74
8.4	Physical Impacts in Construction Stage	74
8.4.1	<i>Structures on land</i>	74
8.4.2	<i>Harbour</i>	74

8.4.3	<i>Harbour jetty</i>	75
8.4.4	<i>Entrance channel</i>	75
8.4.5	<i>Southwest jetty</i>	75
8.4.6	<i>Vegetation clearance</i>	76
8.4.7	<i>Coastal protection</i>	76
8.5	Ecological Impacts in Construction Stage	77
8.6	Physical Impacts of Operation Stage	79
8.7	Ecological Impacts of Operation Stage	80
8.8	Socio-economic impact.....	80
9.	MITIGATION MEASURES	81
9.1	Mitigation Measures in Construction Stage	81
9.2	Mitigation Measures in Operation Stage.....	84
10.	EVALUATION OF ALTERNATIVES	85
10.1	Alternative location for the jetty.	85
10.2	Alternative location for harbour	85
10.3	Scale of the Project and allocation of land area	85
10.4	Alternative location (island) for the project	85
10.5	No development option.....	86
11.	IMPACT MONITORING	87
11.1	Monitoring of coastal and beach environment	87
11.1.1	<i>Monitoring programme for the beach and coastal zone</i>	88
11.1.2	<i>Monitoring programme for the terrestrial environment</i>	88
11.2	Monitoring programme for the marine environment.....	89
11.3	Aim of Monitoring.....	89
11.4	Objectives of Monitoring	89
11.5	Breakdown of Monitoring Yearly Monitoring Cost.....	91

12.	CONCLUSIONS	92
13.	APPENDICES	93
13.1	Appendix 1. Terms of reference.....	93
13.2	Appendix 2. Additional technical information and baseline data.....	94
14.	REFERENCE	5

List of Tables

Table 1	Work schedule.....	7
Table 2	Groundwater test results	42
Table 3	List of fishes found in Madulu reef.....	49
Table 4	Result of invertebrate survey at Sites 1 & 2.....	52
Table 5	Log 4 abundance category for fish count.....	69
Table 6	Extent of predicted physical impacts	77
Table 7	Impact significance.....	78
Table 8	Mitigation measures in construction stage.....	83
Table 9	Beach & coastal monitoring programme	88
Table 10	Terrestrial environment monitoring programme	88
Table 11	Marine environment monitoring programme	90
Table 12	Estimated cost of environmental monitoring	91

List of Figures

Figure 1	location of the project	12
Figure 2	Site plan.....	13
Figure 3	Beach sediment dynamics and characteristics	19
Figure 4	Beach erosion.....	25
Figure 5	Beach accretion.....	26
Figure 6	Beach profile map	31
Figure 7	Vegetation map.....	33

Figure 8 Western side coastal vegetation cover	34
Figure 9 Southern side coastal vegetation cover	35
Figure 10 Eastern side coastal vegetation cover	36
Figure 11 Locations of large trees.....	38
Figure 12 Inside vegetation cover.....	39
Figure 13 Map of marine environment and surveys sites	45
Figure 14 Percentage of benthic cover at Sites 1 & 2.....	46
Figure 15 Percentage cover of benthic substrate at visual observation sites	47
Figure 16 Result of fish survey at sites VOS 3, 4, 5 & 6.....	50
Figure 17 Bathymetry of Madulu lagoon	54
Figure 18 Tidal change	55
Figure 19 Population of Ha. Atoll 2000 - 2006.....	57
Figure 20 Populations of island in Ha. Atoll	58
Figure 21 Unemployment in Ha. Atoll	59

List of Plates

Plate 1 aerial phot (left) western side mid section (right)	14
Plate 2 Coral reef.....	15
Plate 3 Lagoon.....	16
Plate 4 Beach.....	17
Plate 5 Vegetation.....	18
Plate 6 Beach Section A.....	20
Plate 7 Beach Section B.....	20
Plate 8 Beach Section C.....	21
Plate 9 Beach Section D	21
Plate 10 Beach Section E	22

Plate 11 Beach erosion in NW.....	23
Plate 12 Seasonal beach erosion in SW	23
Plate 13 Aerial photos of Madulu	24
Plate 14 Accretion on western side	26
Plate 15 Beach section A.....	28
Plate 16 Sand-spit of the island.....	28
Plate 17 BEach section C.....	29
Plate 18 Beach Section D	29
Plate 19 Beach section ED.....	30
Plate 20 Western side coastal vegetation.....	32
Plate 21 Western side coastal vegetation.....	34
Plate 22 Southern side coastal vegetation.....	35
Plate 23 Eastern side coastal vegetation	36
Plate 24 Large trees inside the island	37
Plate 25 Inside vegetation.....	39
Plate 26 Mangrove area.....	40
Plate 27 Locations of soil profiles	41
Plate 28 Groundwater sampled locations.....	42
Plate 29 Marine environment of Madule	44
Plate 30 Benthic cover at Sites 1 & 2	48
Plate 31 Some of reef fishes in Madulu reef.....	51

Non-technical Summary

Outline of project

This EIA report is prepared in accordance with Environmental Impact Assessment Regulations, 2007 under the Environmental Protection and Preservation Act (Law No. 4/93). The purpose of this EIA is to fulfill the requirement of the Law and to conduct an assessment of possible impacts on biophysical and human environment arising from proposed development project of Project Madulu at Madulu island (in Ha. Atoll, Maldives) as a farming island. The project is proposed by Ali Ibrahim, Finivaage, A.Dh. Fenfushi, Maldives.

Madulu is one of the several islands leased by Government to develop agriculture throughout the country. The island is leased for 21 years through a tendering process by Ministry of Fisheries, Agriculture and Marine Resources.

The main construction activities of the proposed project involves development of a harbour and a navigation channel in northeastern side of the island, clearance of vegetation in north and central area of the island to construct service buildings and allocate land for farming and eastern side shore protection by filling in with materials taken from proposed harbour area. The construction activities will be completed within one year from the start of the construction phase.

The main operation activities will be cultivation of vegetables, fruits and poultry farming and storage and transportation of these products to nearby islands, Male' and to the resorts that will be developed in the atoll in future. Implementation of the proposed project will last for 20 years.

Location

The proposed development project is located in the island of Madulu in North Thiladumathee Atoll at 7°03'17.09"N and 72°57'13.00"E. The nearest airport is Hinimaadhoo Airport approximately 41km southeast of Madulu.

The closest islands to the project location are; inhabited islands of Berinmadhoo (population 167) approximately 2km southeast, Uligamu (population 419) approximately 4km northeast of Madulu. Other inhabited islands in the project area are; Mulhadhoo (population 337) approximately 6km southeast and Thuraakunu (population 596) approximately 8km northwest of Madulu.

The closest uninhabited islands to the project location are Gaamathikulhudhoo approximately 3km southeast and Vagaaru approximately 9km northeast, Medhafushi approximately 5km



southwest and Govvafushi approximately 5.5km southwest of Madulu. Manafuru island where a tourist resort being constructed is approximately 6km southwest of Madulu.

The project location, Madulu island is located on eastern rim of Ihavandippolhu Atoll which is a geographically separate atoll within Noth Thilandunmathi Atoll. Ihavandippolhu is the northernmost atoll of the country. Ihavandippolhu atoll measures a linear length and width of approximately 26km and 13km respectively. Madulu is formed within a separate coral reef system (within a separate Falhu). Any part of Madulu island or reef is not included in the list of sites requiring special protection.

Alternative developments

Various alternative to the proposed development have been suggested in this study including alternative location for the jetty, a harbour, smaller scale project, alternative. The selected location (island) for the project was based on overall development policy of the Government. The proposed location was found to be the most appropriate in terms of minimizing negative environmental and maximizing socio-economic positive impacts. No development option can have negative socio-economic impacts as the economic opportunities for the locals will not be created if no development option was selected.

Key impacts

Key impacts of the preferred development option of the proposed project are related to a few development activities. These include impacts to the lagoon area from construction of jetties, development of harbour and operation of machinery such as excavators on land and in the lagoon. This activity was found to impact the lagoon from turbidity increase and alteration of the lagoon bottom. Approximately 10.5 % of the lagoon was found to be impacted due to the proposed developments in the lagoon. The proposed channel clearance will impact less than 1% of the reef. Approximate 21% of the beach and shoreline will be impacted due to coastal protection in northwestern side of the island. Partial and complete vegetation clearance will impact approximately 54% of the vegetation. However, this impact is mainly related to the bushes as larger trees will be kept intact when clearing land for farming areas. Main vegetation clearance will impact approximately 3% of the island vegetation. This will have a significant impact as many coconut palms and large trees will be removed. However, the impact will be minimized through relocation of the large trees.

Long-term ecological impacts of the proposed project can be assessed through long-term monitoring of the entire island environment in relation to the proposed development and

operation. Thus an on-going monitoring programme will be conducted in order to assess the long-term ecological impacts of the proposed project.

Mitigation measures

Mitigation measures were taken by conducting appropriate through field surveys and environmental assessment of the proposed locations for development of structures such as harbour, jetty building structures with respect to the island environment. The proposed project is based on extensive field surveys to identify the best locations and scale of the proposed development work and scale of operation. Consultation among the proponent, developers and the environmental consultants were conducted to find the most appropriate development options, methods, scale and timing in order to mitigate and minimize potential impacts due to the proposed development project. Optimum size of the harbour, navigation channel and jetty were proposed based on consultations. Optimum area for land clearance of vegetation was proposed for farming.

Specific measures will be taken during construction and development of proposed infrastructures. These include mitigation measures in construction of harbour, jetty and all building structures on land. During harbour excavation possible spreading of fine sediment will be controlled by creating bund-walls around the area. Partial clearance of land will be carried out. Large trees will not be cut down. Any large tree that needs to be removed will be re-located to an area where no development is planned.

Construction activities will be monitored to minimize potential negative impacts to the marine and terrestrial environment of the island. These include minimization of waste and proper disposal and management of wastes. Continuous monitoring will be conducted to find possible long-term and ecological impacts that may arise from the proposed project development and operation

1. Introduction

1.1 Background information of the project

Project Madulu aims to develop and promote agriculture industry in the country specifically in Thiladhumathi Atoll, by developing Madulu island as an environment friendly and sustainable organic agricultural and farming center. The project has two main components: utilisation of traditional farming methods and appropriate farming technology in cultivation of vegetables and fruits in the island and development of infrastructure in the island needed for the operation of the project.

Environment friendly and sustainable agriculture development in Madulu integrates three main goals: environmental stewardship, agriculture profitability, and contribution to local and national economy. Sustainable agriculture in the island will facilitate to grow vegetables and fruits without causing irreversible damage to ecosystem health. Two key issues are biophysical and socio-economic.

The project aims to contribute to national economy directly and indirectly through large scale production of vegetables and fruits, poultry products, reduction of dependency on imports of such products and creation of employments and employment opportunities especially in the atoll.

The project especially aims to generate commercial benefits by production and promotion of locally produced vegetables and fruits and poultry by organic farming. Organically grown vegetables and fruits will be packed to high standards and marketed to upper-market tourist resorts in the country and supermarkets in Male'. Organically grown vegetables and fruit products have a high demand in tourist resorts in the country and worldwide.

Organic farming is a form of agriculture which avoids or largely excludes the use of synthetic fertilisers and pesticides, plant growth regulators and livestock feed additives. Organic farming relies on crop rotation, integrated pest management, animal manures and mechanical cultivation to maintain soil productivity to supply plant nutrients, and to control weed, insects and other pests. The role of organic agriculture is to sustain and enhance the health of ecosystems and organisms from the smallest in the soil to human beings.

Infrastructure development needed for the project mainly involves creation of an access (navigation) channel, a harbour, construction of a jetty, powerhouse, storage and staff accommodation buildings. In addition to this infrastructure development, plots of land will be cleared of existing vegetation in order to create land for farming in the central area of the

island. The project also involves island shore protection on eastern side of the island by filling in the shore area with material that will be taken from the proposed harbour area.

1.2 Project costs

The value of investment during the first five years for the proposed project is Rf 20,000,000/- (twenty million Ruffiya) in addition to an average annual lease rent of Rf 1,200,000/- The total investment of for the first ten years is Rf 32,000,000/- The proposed infrastructure development cost or capital investment that will incur in the first year is Rf 10,000,000/-. This cost will be related to development of structures and facilities namely harbour, jetty, accommodation, powerhouse, power generators, desalination plant and waste management facility.

The human resource development plan will cost a significant amount as it involves cost of adequate welfare including medical insurance, mental and physical well-being of the staff. Staff accommodation and facilities will be to the highest standards that is equivalent to tourist resorts in the country.

1.3 The proponent and its experience with similar projects

The Madulu Agriculture Development project is proposed by Ali Ibrahim, Finivaage, A.Dh. Fenfushi. The proponent has over 15 years of experience in dealing with international suppliers and producers of agriculture products, resort management and airline operation. In addition to the expertise of the proponent, technical expertise needed for the project development and operation will be recruited.

1.4 Terms of Reference

The agreed Terms of Reference for this EIA is attached in Appendix 1 of this report. This EIA has been conducted in accordance with the agreed Terms of Reference

2. Project Setting

2.1 Existing plans, policies, guidelines, regulations, laws related to the project

All the activities during both development and implantation stage of the proposed agriculture development project will be carried out in accordance with existing plans, policies, guidelines, laws and regulations of Maldives in addition to international conventions to which Maldives is a party to.

Policies and Plans relating to the proposed development project include, Strategic Economic Plan, Seventh national Development Plan 2006 – 2010 and Agriculture Development Master Plan.

According to the Strategic Economic Plan, agriculture continues to play a minor and diminishing role in the economy, constrained by limited availability of cultivable land and the abundance of cheap imports of vegetables and fruits. And apart from domestic consumption need, the continuous influx of tourists will generate an increasing demand for fresh agricultural products. The Strategic Economic Plan also highlights that the agriculture sector has the potential for further development to enable Maldives to become self-sufficient in some vegetables and fruits, save foreign exchange and to provide alternative occupation in the sector. Agriculture development strategies include;

- strengthening development of uninhabited islands into agricultural islands
- recognition of a domestic market of 300,000 and a half a million of tourists
- recognition of influx of cheaper vegetable imports resulting in substantial foreign exchange loss
- distribution of fresh vegetable products to resort
- recognition of lack of capital to finance agriculture development

The Strategic Economic Plan highlights the following areas as possible areas for enhancement

- develop agricultural activities to meet the needs of locals as well as tourists
- establish catalytic roles of the Government to support agriculture development
- set up trade/distribution centers on main the islands within the Northern and Southern Growth Regions regional to facilitate distribution of agriculture products

Under Seventh National Development Plan a number of policies area formulated for development of agriculture.

These include;

- ensuring sustainable agriculture development,
- strengthen human resources for agriculture sector development,
- enhance capacity for technology generation and dissemination
- developing system, networks and physical infrastructure for strengthening marketing and trade and to encourage commercial agriculture, and
- ensure food security and improve nutritional status of the rural and urban populace

The government of Maldives recognizes that the agriculture industry is an important sector for the economy of the country. In this respect a 15 year Agriculture Development Master Plan has been formulated. Under the 15 year Agriculture Development Master Plan the Government is facilitating the private sector to develop of agriculture industry in the country. In this regard the Government has started leasing uninhabited islands on long-term basis for the development of agriculture in the country. In response to this initiative by the Government, the proponent has bided for four islands out of the eleven islands recently announced for leasing for the purpose of agriculture development in the country.

Ministry of Fisheries, Agriculture and Marine Resources is the leading Government Agency having mandates for management of uninhabited islands hence formulates Laws and regulations with respect to leasing of uninhabited islands on long-term basis for such developments. An important Law in this regard is Law No. 20/98 on uninhabited islands of Maldives. Under this Law uninhabited islands shall be leased for a maximum period of 21 years to eligible individuals or parties for the best proposals of development. However, if the initial investment for such development is more than US\$10 million, the lease period shall be 35 years. A number of regulations have been formulated and enforced under this Law, including felling of trees for timber, and sand and aggregate collection. Permission shall be obtained from the relevant Government authorities prior to such actions in leased (on Varuvaa) islands.

According to the Lease Agreement between the Government and the lessee of Islands leased on long-term basis for major economic development such as agriculture development, trees shall not be damaged and a written permission shall be obtained from Government prior to felling of trees and collection of sand and aggregate in such islands. Also lessee is responsible for looking after the island in terms of beach and coastal erosion and measures shall be taken

by the lessee in protection the island from such events. Therefore, the Lease Agreement between Government and lessee is an important regulatory document for management of islands leased on long-term basis for economic development including Madulu.

Ministry of Environment, Energy and Water has the mandates for protection and preservation of environment. In this respect Ministry of Environment, Energy and Water formulates policies, Laws and regulations on environmental protection and conservation.

The most important regulation is Environment Impact Regulations, 2007 enforced under Environment Protection and Preservation Act (Law No. 4/93). The Clauses of Environment Protection and Preservation Act address the following that relate to the proposed project development and implementation.

- An impact assessment study shall be submitted to the relevant Government authority before implementing any development project that may have a potential impact on the environment
- The relevant Authority of Government shall formulate the guidelines for environmental impact assessment and shall determine the projects that need such assessment as mentioned in above
- The Termination of projects. The relevant Government Agency has authority to terminate any project that has any undesirable impact on the environment. A project so terminated shall not receive any compensation
- Waste Disposal, Oil and Poisonous Substances. Any type of waste, oil, poisonous gases or any substance that may have a harmful effect on the environment shall not be disposed within the territory of the Maldives
- Government of Maldives reserves right to claim compensation for all the damages that area caused by the activities that are detrimental to the environment.

In addition to EIA regulations, other relevant regulation will be followed in development and implementation of the proposed project. These regulations include ban on coral mining. Coral mining from house reef and atoll rim reef has been banned since 1990. Sand mining from any island has also been banned since March 2000. Coral or sand will not be used for any purpose for the proposed project.

An important regulation relevant to the proposed project is also the regulation on uninhabited island with respect to felling trees for the purpose of timber resources. According to this

regulation no tree shall be fell without prior permission of relevant Government authorities and trees that need to be fell shall be replaced or replanted elsewhere.

The proponent is committed for huge investments in the development of the agriculture industry in accordance with these existing policies and plans while strictly following all relevant laws and regulation related to the proposed project activities.

3. Project Description

The Madulu Agriculture Development project is primarily a medium size agriculture development project. The project is focused on cultivation and production of mainly vegetables and fruits and poultry in Ha. Madulu island. In order to facilitate production and distribution of vegetables and fruits, the project involves development of necessary infrastructure in the island. The main infrastructure development in the island involves development of a harbour, entrance (navigation) channel to the harbour, building of staff quarters, storage buildings and powerhouse. In addition to these land area allocated to cultivation and farming of vegetables and fruits will be cleared of the existing natural vegetation of the island.

The project is targeted to develop the island as a medium size sustainable agriculture center in the atoll. Production of vegetables and fruits and poultry products by using organic farming methods and distribution of these products to the tourist resorts, locals and Male' will be the main operational activity of the project.

The project aims to develop the agriculture industry, specifically in the atoll and in the country in general. It also aims to contribute to national economy by creating direct and indirect job opportunities related to the project and by reducing dependency on imports of agriculture products therefore saving foreign currency.

The project also aims to; ensure sustainable development of agriculture, strengthen human resource capacity for agriculture sector, and develop networks and physical infrastructure, strengthen marketing and trade and set an example for commercial agriculture in the country.

3.1 Intended duration of the project

The intended duration of the proposed agriculture development project in Madulu island is a total of 21 years. Out of these 21 years 2 years is proposed for the project development period. Proposed periods of different work activities of the development stage is given in the work schedule below

3.3 Need and justification of the project

The contribution to the agriculture sector to GDP has continued to decline in the recent years. According to Seventh National Development Plan the agriculture industry contributed only 2.6 percent of GDP in 2005. However, the agriculture sector plays an important role to the island communities in terms of employment opportunities, source of food and nutrition.

At present lack of development of the agriculture sector resulted in heavy dependency of imports of agriculture products to the country. About 90 percent of the country's demand for food is met from imports making the national food security situation vulnerable.

Import of agriculture products has continued to increase. There has been a 17.5 percent increase in imports of agriculture products from 2003 to 2004. In 2006 vegetable imports was valued at Rf 395 million (Maldives Customs Statistics 2004-2006). In addition to cut flowers and ornamental foliage valued at Rf 12 million. This has been resulting in a significant loss of country's foreign exchange. In this regard it is of strategic importance that agriculture the industry to be developed in the country to save foreign exchange, ensure food security and to create job opportunities.

For development of country's agriculture sector, the Government has started leasing uninhabited islands on long-term basis to carry out agriculture activities on commercial scale. Madulu island in North Thiladhuma Atoll is one of the 32 islands leased for development of agriculture. Madulu island is leased for a period of 21 years to cultivation, development and promotion of agriculture in the island.

The island had been used for small scale cultivation of vegetables and fruits in the recent past however, abandoned now due to unsustainability of small scale farming. The proposed developments in the island are targeted to medium scale industrial agriculture so that the project can be sustained. The proposed infrastructure developments in the island are minimal, necessary for medium scale industrial agriculture activities. The project is designed to make the project economically feasible as well as to minimize negative environmental impacts due to the project by minimizing infrastructure development.

3.4 Components of the project design, size and scale

The proposed project involves two stages. The first stage will be infrastructure development stage and the second stage will be operation of the proposed activities. During the first stage development of infrastructure needed for operation of the proposed project will be carried out. The infrastructure development stage will have seven main components. These will include; a) construction of structures on land including accommodation houses and service facilities including powerhouse, stores, garage and mosque, b) development of a detached harbour, c) construction of a long jetty to the harbour, d) creation of an entrance channel, e) construction of a jetty in southwest of the island, f) vegetation clearance to make farming area and g) coastal protection.

3.4.1 Structures on land

The proposed project will involve building accommodation houses on land for staff. A total of nine accommodation buildings for staff and senior staff will be built mostly on northern side of the island. Each of these buildings will measure 12m x 12m area and accommodate 4 people. In addition to these a total of 13 service facility buildings will be constructed on land. These are staff kitchen/store, mess, office, clinic, lab, toilet, laundry, carpentry, vehicle garage, stores, water tank, powerhouse/workshop, oil tank, mosque, shop, classroom and café'. These building will be all single storey building lower than the canopy of the island vegetation. Conventional materials and methods will be used in construction of these structures.

3.4.2 Harbour

As shown in figure 2. (Site plan of the project) a detached harbour for safe anchoring of vessels, loading and unloading of goods will be developed in northwestern side of the island. The detached harbour will be connected to the island by a jetty constructed on concrete columns. The dimensions of the harbour are 100m x 50m. The harbour basin will be excavated to a depth of 2m at low tide. Excavation will be carried out by adopting conventional method using standard excavator. The materials generated by excavation will be used for coastal protection in eastern side of the island. Harbour walls and protection walls will be constructed around the deepened area. Harbour walls will be constructed by deploying pre-fabricated re-enforced concrete blocks in the front and breakwater in the rear by deploying imported rock boulders. Entrance to the harbour will be towards southwestern corner of the harbour so that it will be safest for the vessels against the waves to enter the harbour.

3.4.3 Harbour jetty

Relatively long jetty will be constructed to connect the harbour to the land as the proposed harbour is detached from the island. This jetty will be 115m long and 3m wide and constructed on pre-fabricated re-enforced concrete columns with a base resting on the lagoon floor. The top platform of the jetty will be constructed using re-enforced concrete and timber.

3.4.4 Entrance channel

An entrance channel will be cleared through the reef in western side of the island. The dimensions of this channel will be 30m long and 25m wide. Depth of the channel will be 2m at low tide. The channel will be cleared by using excavator. The field surveys revealed that the reef in this area consisted of sparsely distributed boulders, rubble and sandy areas. Therefore blasting of the reef will not be needed. The channel will be protected by deploying imported rock boulders on both sides of the channel.

3.4.5 Southwest jetty

In order to facilitate operation of the proposed project, access to the island is needed. At present the islands has no jetty or a harbour area for anchoring vessels. Access to the island will be provided by a jetty in southwestern side of the island where the lagoon is deep enough for medium size vessels to berth the jetty. The jetty will be constructed on concrete columns from the land to the deep lagoon in southwestern side of the island as shown in figure 2 (Site plan of the project). The proposed jetty will be 38m long and 3m wide. The platform of the jetty surface will be constructed by laying wooden planks. The jetty is designed and located so that the beach sediment dynamics will not be obstructed hence potential risk of beach erosion due to the jetty is minimized. Conventional methods will be used in construction of the proposed jetty.

3.4.6 Land clearance

Partial and total land clearance will carried out for building structures and to make land for cultivation of vegetables and fruits, poultry farming and goat rearing. Partial clearance will be carried out as much as possible rather than total clearance of vegetation. Total clearance will be needed for building structures on land mostly in northern side of the island. Partial clearance will be carried out for cultivation of vegetables and fruits in the central area of the island as shown in the site plan. Partial clearance is only clearing the bushes and leave large trees. Total clearance will involve cutting down of some large trees. However, as many large tree as possible, those are in the proposed site for buildings will be relocated.

The main components of the operation stage of proposed project involve production and distribution of agriculture and poultry products in the country. Agriculture activities will include; horticulture – cultivation of vegetables and fruits, and floriculture. Poultry farming will include rearing of chicken for production of egg and meat. In addition goat rearing will be carried out for production of meat.

For cultivation of vegetables and fruits, plot sizes of 10,000sq ft. will be taken from central areas of the island. The fields will be divided by tree zones of 50ft. Crop rotation will be practiced to avoid mono cropping and to minimize incidences of pest and diseases. Apart from

traditional earth farming, poly bag system of cultivation for ridge pepper, tomato and sweet pepper will be adopted using coco peat and perlite medium. Crops that are suitable for the agro climate condition of the country will be selected for cultivation. The crop types will be selected based on easy marketability and high return types. The targeted markets will be tourist resorts, locals, consumer market in Male' and other islands.

3.4.7 Coastal protection

Coastal protection measures will be taken in northwestern side of the island where there is permanent erosion of the island. Materials taken from the proposed harbour deepening will be used to fill in the coastal and beach area in the eroding area. Approximately 200m long and 15m wide area is needed to be filled in to protect the eroding area. The filled in area of the beach will be sheltered by the proposed harbour. The filled in materials will therefore be retained and the erosion in the area will be controlled.

3.5 Location of the project

The proposed development project is located in the island of Madulu in North Thiladumathee Atoll at 7°03'17.09"N and 72°57'13.00"E. The nearest airport is Hinimaadhoo Airport approximately 41km southeast of Madulu.

The closest islands to the project location are; inhabited islands of Berinmadhoo (population 167) approximately 2km southeast, Uligamu (population 419) approximately 4km northeast of Madulu. Other inhabited islands in the project area are; Mulhadhoo (population 337) approximately 6km southeast and Thuraakunu (population 596) approximately 8km northwest of Madulu.

The closest uninhabited islands to the project location are Gaamathikulhudhoo approximately 3km southeast and Vagaaru approximately 9km northeast, Medhafushi approximately 5km southwest and Govvafushi approximately 5.5km southwest of Madulu. Manafuru island where a tourist resort being constructed is approximately 6km southwest of Madulu.

The project location, Madulu island is located on eastern rim of Ihavandippolhu Atoll which is a geographically separate atoll within North Thilandunmathi Atoll. Ihavandippolhu is the northernmost atoll of the country. Ihavandippolhu atoll measures a linear length and width of approximately 26km and 13km respectively. Madulu is formed within a separate coral reef system (within a separate Falhu). Any part of Madulu island or reef is not included in the list of sites requiring special protection.

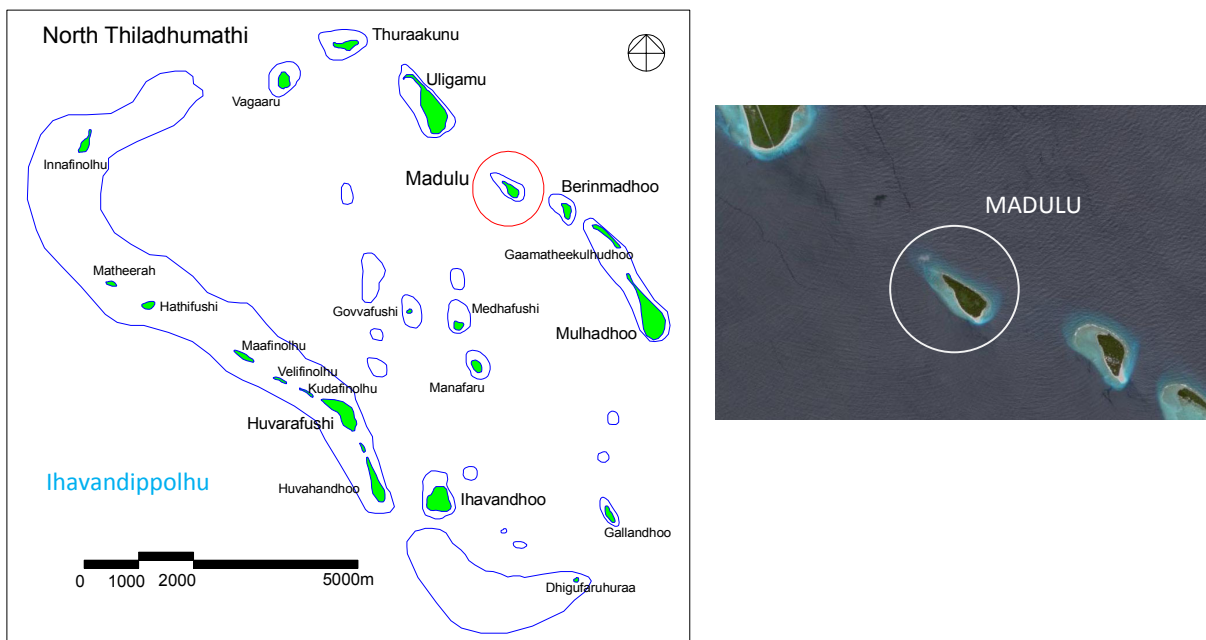
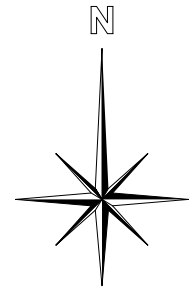


Figure 1 location of the project



LEGEND :

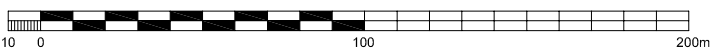
- 1 - JETTY
- 2 - HARBOUR
- 3 - STAFF KITCHEN / STORE AND MESS
- 4 - OFFICE / PUBLIC TOILETS / CLINIC / LABORATORY
- 5 - SHOP / DRIVE IN GODOWN
- 6 - CARPENTRY
- 7 - LAUNDRY
- 8 - POWER HOUSE / RO PLANT & MECHANICAL WORKSHOP
- 9 - VEHICLE GARAGE
- 10 - WATER TANKS FOR RO PLANT
- 11 - OIL TANKS FOR GEN SETS
- 12 - MAIN STORE
- 13 - GODOWN
- 14 - MOSQUE
- 15 - MULTI-FUNCTION HALL
- 16 - GUARD HOUSE
- 17 - STAFF CAFE'
- 18 - JUNIOR STAFF ACCOMMODATION
- 19 - SENIOR STAFF ACCOMMODATION
- 20 - STAFF FAMILY ACCOMMODATION
- 21 - OWNERS HOUSE

NOTE :

TOTAL LAND AREA (BUSH LINE) : 142,507 SQM
 TOTAL LAND AREA (HIGH TIDE) : 152,850 SQM
 TOTAL AREA FOR AGRICULTURE: 68,845 SQM
 AREA FOR AGRICULTURE (%) : 48.31%

Figure 2

SCALE 1 : 2500



PROJECT: HA. MADULU ISLAND FOR AGRICULTURAL DEVELOPMENT	CLIENT: Mr. ALI IBRAHIM FINIVAAGE, A.D FENFUSHI	AMENDMENTS	DESIGN BY: H.R	PROJECT. NO: EA - 122
TITLE: Figure 2	SCALE: AS GIVEN	CHECKED BY:	STRUC. DESIGN BY: -	DATE : FEBRUARY 2008
			SURVEYED BY: H.R/H.S/M.M	SHEET NO:
			DRAWN BY: H.R/H.S	

Do not scale drawing. Figured dimensions are to be followed. All measurements must be verified on site. Any discrepancies to be reported to the architect, engineer and/or interior designer. Contractor to provide shop drawings for approval.

4. Description of the Natural Environment

Madulu is a relatively small island formed within a small separate coral reef system in eastern rim of Ihavandippolhu. Ihavandippolhu is a geographically separate atoll in North Thiladhunmathee (Haa Alifu) Atoll.

As the island is located on eastern rim of the atoll, eastern side of the island is windward side and faces open deep ocean. Western side of the island faces the atoll lagoon hence this side is leeward side. As usual the windward reef is structurally well developed and gets exposed during low tides thus provide shelter to the island. Western side reef is deeper and provide less protection to the island.

The natural environment of the island consists of terrestrial and marine environment. These environments can be categorized into four distinctive components. They are the coral reef system, the lagoon, the beach and the vegetation. Different sub-categories within each of these components are also found. The coral reef system consisted of the windward reef, the leeward reef and patch reef within the lagoon area. The lagoon environment consists of the more exposed shallower windward lagoon and deeper leeward lagoon. The beach consisted of more sandy areas in western side and more beach-rock and boulders in eastern and northern side of the island. Very dynamic beach area is found in southern end of the island. The vegetation consisted of peripheral coastal vegetation having more salt tolerant plants with low canopy and the inner vegetation where larger trees are found. All these components of the island functions and interacts each other both physically and ecologically making the island as a system.



Aerial photo of Madulu



Western side elevation of Madulu

Plate 1 aerial phot (left) western side mid section (right)

4.1 Marine environment

The marine environment of the island consisted of two main components; they are the coral reef system and the lagoon system. The coral reef and the lagoon covers more than 78% of the entire island system. The coral reef area covers approximately 58% and the lagoon area covers approximately 20% of the island system.

Distinctive reef areas exist within the reef system. They are the reef slope, reef-flat and patch reefs within the shallow lagoon. Geomorphology and biodiversity of each of these reef areas are significantly different. The lagoon surrounding the island also consists of two distinctive areas in terms of bottom substrate. They are sandy bottom lagoon area close to the island and patch reef areas of the lagoon further from the shore.



Hard corals in Madulu reef



Soft corals in Madulu reef

Plate 2 Coral reef

4.1.1 Coral reef

The coral reef and the island is elongated and oriented in southeast-northwest direction. The island is formed more on windward side within the reef system. This formation makes the lagoon on eastern side narrower than on western side. Eastern side of the island is more exposed to more wave energy than the western side. A strong surf zone is found at the edge of the reef on entire eastern side of the island.

The coral reef of the island has a linear length and width of 1525m and 572m respectively. The total reef area was calculated as approximately 39.2 hectares (392,000m²).

Reef system of Madulu is elongated oval shape and it is oriented northwest southeast direction. The windward reef is very narrow and has a very shallow reef edge and a gradually descending extensive reef slope to approximately 40m depth. This formation of the reef makes the area a strong surf zone and the windward reef is exposed to high wave energy. The windward reef is well formed in terms of substrate geology to withstand high wave energy. The reef area on

northern side of the island is very deep and has extensive gradual reef slope extending to more than 500m and to a depth of approximately 50m

The leeward reef is deeper and poorly formed in terms of substrate cover. The substrate cover on leeward reef is patchy. The extent of reef slope is less and much steeper compared to windward reef. The leeward reef is more sheltered as it on the atoll lagoon side.

4.1.2 Lagoon

The shallow lagoon area around the island was calculated as approximately 14 hectares (140,000m²). Lagoon area on western side of the island is approximately three times wider having an average width of 150m and deeper compared to eastern side. The average depth of the western side lagoon close to the shore is approximately 1m at mean tide and gets gradually deeper further from the island. Lagoon bottom consisted of mostly sand, rubble and patch reefs and individual coral heads. Wave in the western side lagoon is more and larger as the reef on western side is deep and poorly formed. During southwest monsoon the western side lagoon is extremely rough especially in windy conditions.



NW side lagoon



Lagoon environment

Plate 3 Lagoon

The eastern side lagoon is very narrow and shallow having less than 1m at mean tide and the depth is more uniform compared to western side lagoon. The substrate cover on eastern side lagoon consisted of mostly rubble and boulders. Eastern side lagoon is more sheltered from the waves as the reef on western side of the island is shallower and geologically well-formed. During southwest monsoon the eastern side lagoon is also protected by the island itself.

4.2 Terrestrial environment

The terrestrial environment of the island consisted of two main components; they are the beach environment and the vegetation. The vegetation consisted of coastal vegetation and the inner vegetation. Grass areas due to vegetation clearance are found in the central areas of the island. The beach environment consisted of sandy beach areas, boulders and rubble area and beach-rock areas.

4.2.1 Beach

The sandy beach area is only found on western and southern side of the island whereas the entire northern and eastern side consisted of rubble and boulder beach. The total beach area was calculated as 1.5 hectares, which is approximately 2% of the entire island system. The western side beach is approximately 8m wide in average and 500m long. The southern side beach is the sand spit of the island and moves east and west with the changing monsoon wind and currents. Beach-rock is found on eastern and northwestern side of the island.



Sandy beach on western side



Rocky beach on northern and eastern side

Plate 4 Beach

4.2.2 Vegetation

The vegetated area of the island was calculated as approximately 15 hectares (150,000m²). The coastal vegetation is mostly intact all around western side of the island however, sparse areas are found on eastern side of the island. Part of eastern side coastal vegetation consisted of mangroves where sparse areas are found. The main vegetation type found inside the island are coconut palms. Major coastal vegetation consisted of screwpines.



Vegetation of Madule



Mangrove area on E. side of Madule

Plate 5 Vegetation

4.3 Description of Existing Terrestrial Environment

Terrestrial environment of Madulu can be categorized into four main components; they are the i) beach, ii) soil, iii) flora (vegetation) and iv) fauna. Among these terrestrial components of the island's environment, the vegetation and the beach of the island will be most affected by the proposed development. The vegetation will be affected due to the proposed clearance of the bushes. The beach on eastern side is the windward side beach and receives enormous wave energy and has been having seasonal erosion causing loss of some of the bushes. No development is planned on eastern side beach. The western side beach is also very dynamic especially the south sand-spit.

4.3.1 Beach environment

Madulu has a very dynamic beach area in terms of seasonal erosion and accretion and sand movement especially on southern side of the island where the sand-spit of the island is found.

The beach area around the island can be categorized into 5 different sections A, B, C, D, and E in terms of beach characteristics and beach dynamics as shown in figure 2. Each of these sections is significantly different in terms of sediment dynamics and sediment compositions. Eastern side of the island corresponding Sections A consisted of less fine sand but more rubble, cobble and boulders. Southern side of the island, corresponding Sections B is the sand-spit of the island where sand movement is most pronounced. Southwestern side corresponding Section C is intersection of most sand movement. Western side of the island corresponding Section D is the leeward side where beach is relatively sheltered and stable. Northwestern side of the island corresponding Section E very exposed transitional monsoon wind and waves. Given this nature of the island's beach, the beach area around the island can be categorized into three sections in general with respect to sediment dynamics. Sediment dynamics on eastern side beach area is less frequent compared to western side however; more in terms of energetic as it is the windward side and the beach materials consists of larger sizes.

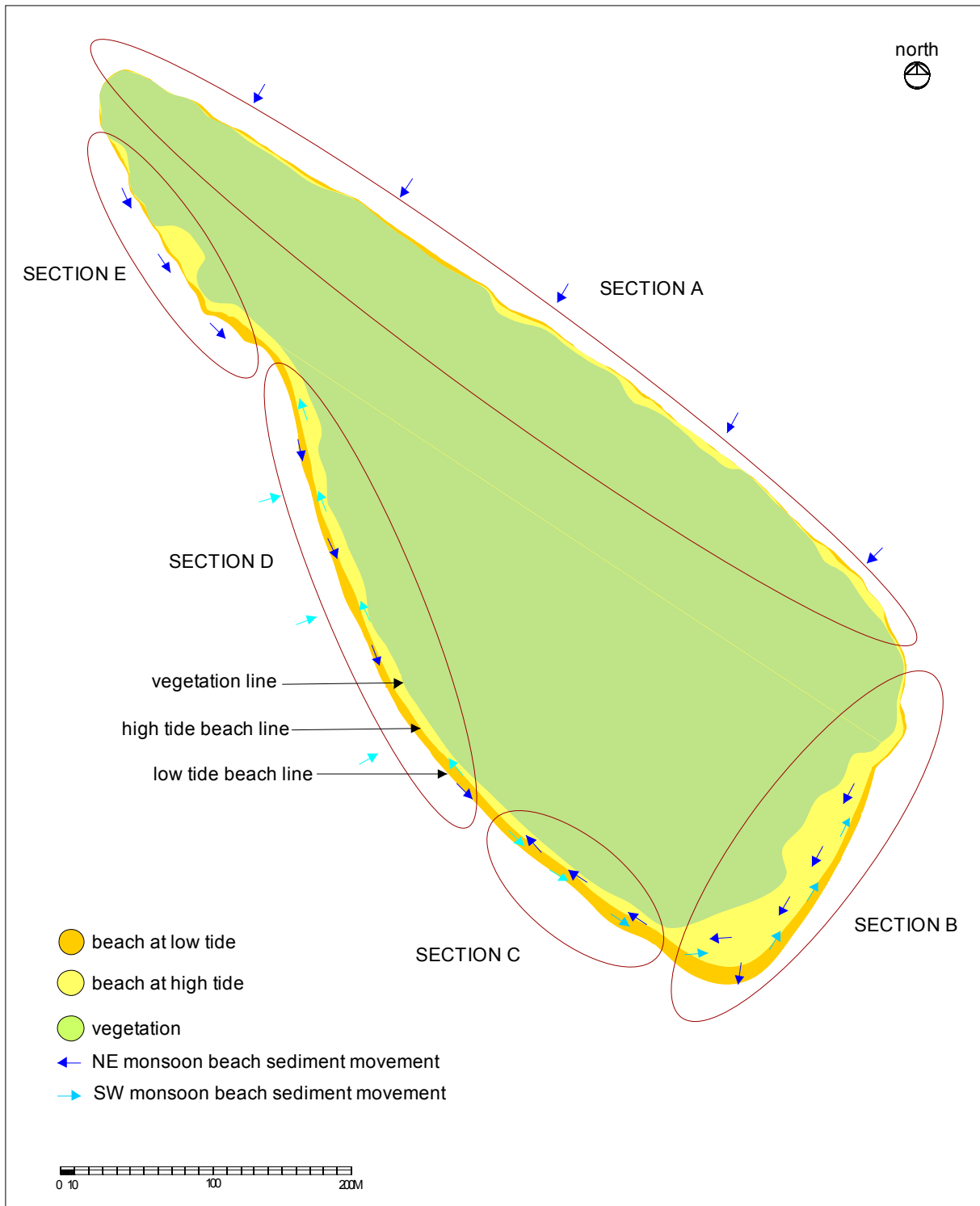


Figure 3 Beach sediment dynamics and characteristics

Plate 6 Beach Section A



Eastern side beach consisted of mostly boulders and sand in between on few areas

Section A is the eastern side of the island. This section of the beach materials are dominated by boulders followed by cobble, rubble and pebble and few sand within them. The larger size beach material on this section of the beach is originated from the windward reef-flat on eastern side of the island. Section A measures approximately 670m (35%) of the beach perimeter. The average width of the beach area in this section is 3m. Approximate average height of the beach above mean sea level is 1m. As this section of the beach faces the open sea on eastern side of the atoll the beach is exposed to constant wave energy and wind generated and tidal currents.

Plate 7 Beach Section B



The sand-spit on southern side of the island covering a very large area

Section B is the southern side of the island where the sand-spit of the beach is found. The beach material in this section is fine sand. This section of the beach has a length of approximately 250m (13%) of the island's beach perimeter. The average width of this section of the beach is 16m. The average height of the beach in this section is approximately 1.5m

Plate 8 Beach Section C



Extensive seasonal erosion found on SW. side of the island beach.

Section C is the southwestern side of the island where sediment dynamics is most pronounced as this area is the intersection of sand most dynamic beach area and the stable beach area. Therefore most frequent seasonal beach erosion and accretion is found in this area. This section of the beach measures approximately 130m (7%) of beach perimeter and the beach width in this area varies significantly with the monsoons currents. This section's beach materials consisted of fine sand.

Plate 9 Beach Section D



Stable beach on central area of western side of the island

Section D is the western side of the island where the most stable beach is found. Beach materials in this section of the beach consisted fine sand. Length of beach in this section is 370m which is 20% of the total perimeter of the beach. The average width of beach in this section is 7m. This is the longest beach area of the island.

Plate 10 Beach Section E



Beach rock and rubble found on NW side of the island beach

Section E is the northwestern side of the island where the beach receives high wave energy especially during the transitional period of monsoon from southwest to northeast monsoon. The beach length of this section is 140m (7%) of the perimeter of the island beach. The beach materials in this section are dominated by cobbles followed by rubble and sand. Beach rock further from the beach found is in southern area of this section of the beach.

Sandy beach is found only in western and southern side of the island whereas the beach in eastern, northern and northwestern side of the island has a beach consisting of boulders, cobble and rubble. Approximately 40% of the beach perimeter of the island consisted of sandy beach area which is found in eastern and southern sides of the island. Small sandy beach areas (accounting approximately 5% of beach perimeter) are also found in eastern side of the island within the boulders and rubble beach found in eastern side of the island. Approximately 55% of the beach perimeter accounted beach consisting of boulders, cobble and rubble.

4.4 Beach erosion

Beach all around Madulu receives very high wave energy, especially in eastern and north eastern sides of the island corresponding beach Section A and E in figure 2. Permanent beach erosion is found in these areas. Some of the coastal vegetation in these areas, especially in northwestern areas corresponding Section E in figure 2 are being lost due to the erosion in these areas. However, due to the high wave energy larger size materials had accumulated in these regions. As a result of accumulation of larger size beach materials beach erosion is minimized to some extent so the erosion is relatively slow.



Continuous beach erosion on NW side of the island.

Plate 11 Beach erosion in NW

Seasonal beach erosion during SW monsoon was observed to be severe but not serious in southwestern side of the island corresponding Section C in figure 2. Roots of the coastal vegetation (sea lettuce and screw pines) in this section of the beach are being exposed due to erosion in this section of the beach.



Seasonal beach erosion on SW side of the island

Plate 12 Seasonal beach erosion in SW

Historic beach erosion assessed by comparing scale aerial photos taken in 1969 (top left), 1998 (top right) and 2005 (bottom) show that there has been significant beach erosion in northwestern side corresponding Section E of figure 2 within the last 35 years. Approximately 4,030m² of the island (3%), with the beach had been eroded in this area of the island and beach rock has been exposed. This assessment also showed that erosion in this area had taken place faster within the last 10 years. The more recent aerial photos and the field surveys showed that this area continues to erode relatively slowly compared to some of the islands undergoing erosion. Other area of the beach was found to be relatively stable in terms of permanent beach erosion as shown by the historic aerial photos and the recent field surveys.

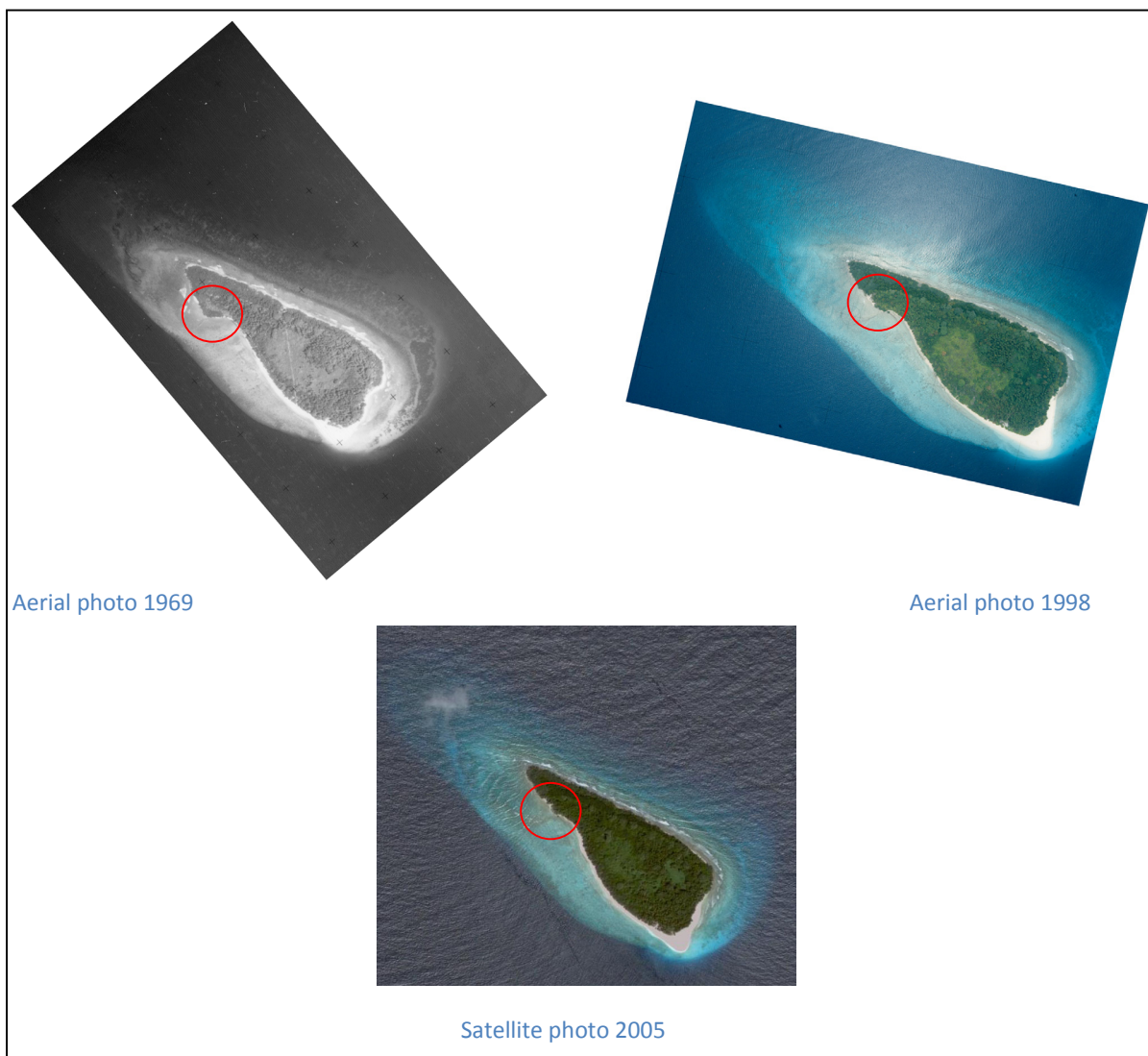


Plate 13 Aerial photos of Madulu

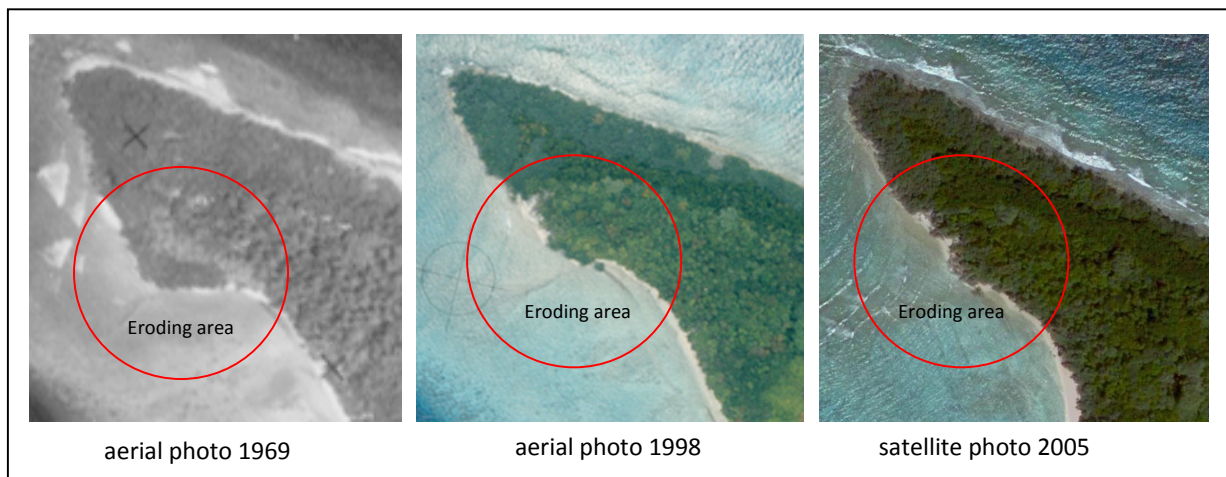


Figure 4 Beach erosion

The above figure shows permanent beach erosion in northwestern side of the island (corresponding Section E in figure 2) that has continued until today. The field surveys and observations showed that beach rock has been exposed in this area. Beach shows the historic beach location. The distance between the exposed beach rock and the present shoreline is over 12m at present. This shows that a 12 wide beach area had been eroded in the last 30 to 40 years. Eroding beach linear length in this area was estimates as 190m. The actual eroding area in this section of the beach is significant in terms of the total beach area of the island.

In general serious beach erosion of the island is confined to Section E as shown in figure 2. Beach erosion in other areas around the island is seasonal and accretion takes place in the following monsoon.

4.5 Beach accretion

Comparison and analysis of aerial photos taken in 1969, 1998 and 2005 field data and observations showed that there is slow beach accretion in western side of the island corresponding Section D in figure 2. This accretion is partly due to erosion in northwestern areas of the beach and partly due to natural accumulation of beach sediment from the lagoon on western side.



Figure 5 Beach accretion

Beach has been growing due to sediment accretion on western side of the island as shown in figure 4. The surveys and observations also showed that the vegetation has also extended westward during the last 30 to 40 years meaning that the island is growing on western side but eroding in northwestern side.



Plate 14 Accretion on western side

Accretion of large size beach materials i.e. boulders and cobble during occasional extreme weather condition especially in NE monsoon are also found in eastern side of the island. However, this is different from the gradual natural accretion of fine sand, forming beach found in western side of the island.

4.6 Beach sediment dynamics

Beach dynamics is the movement of beach materials within the coastal environment with the alternating current regimes and waves caused by monsoon winds. Other factors involved in beach dynamics are shape and orientation of the island, location of the island within the atoll with respect to alternating monsoon current regimes location of other islands and reefs.

Madulu is an elongated island system on eastern rim of the atoll, therefore eastern side of the island is very exposed to the NE monsoon wind generated waves and currents. Western side of the island is more sheltered as the atolls relatively small and extensive western side atoll rim reef. The island system of Madulu is northwest-southeast oriented making the beach on either sides to face directly to NE and SW monsoon currents. Wave generated currents are also felt strongly on the entire eastern, southeastern and northwestern sides due to surf generated by the extensive reef slope especially on southeastern and northeastern sides. Beach sediment dynamic pattern around the island are set most evidently by these factors.

Significant beach sediment dynamics around the island can be divided into four sections A, BC, D and E in relation to the factors mention above and as shown in figure 2. Sediment dynamics within each of these sections are generally confined within the approximate areas as shown in figure 2 and are significantly different in terms of sediment sizes, movement, frequency and extent. However, exchange of sediment to some extent occurs between northwestern, western, southwestern and southern sides of the island.

4.6.1 Section A

Section A is relatively large beach area consisting of mostly coral boulders, cobble, pebble, rubble and sand in small and few isolated areas. The beach material in this section is dominated by coral boulders. Sediment in this section is related to mostly boulders, cobble and pebble rather than sand. Therefore, involves extensive wave energy, which is only felt during occasional extreme weather conditions like tidal wave events so that the frequency of sediment dynamics in this section is less compared to other sections. However, most extensive in terms of energetic. Beach materials in found in this section are brought from the shallow lagoon and the reef on western side of the island by waves as shown in figure 2. Sediment dynamics in this section of the beach is most significant in terms of accretion of large areas altering the eastern side elevation of the island.



Eastern side beach area consisted of mostly coral boulders and rubble

Plate 15 Beach section A

4.6.2 Section BC

Section BC is the most dynamic beach area of the island as it is the sand-spit of the island. This section of the beach is most dynamic in terms of frequency however, least in terms of energetic. Beach sediment movement twice a year in relation to the alternating monsoon is found in this section of the beach. Sediment in this section of the beach moves from west to east during SW monsoon (May – November) and from east to west during NE monsoon (February – May). Observations showed that beach sediment in this section is spilling into the deep atoll lagoon and lost from the sediment budget of the island to some extent. The spilling sand may be partly coming from the eroding area in Section E as shown in figure 2 and partly from the natural accretion in Section D. The spilling of sand from Section B in to the deep atoll lagoon is occurring as the shallow lagoon of the island in southern area is very narrow and saturated. The access sand will naturally spill out of the sediment budget then the shallow lagoon area is full.

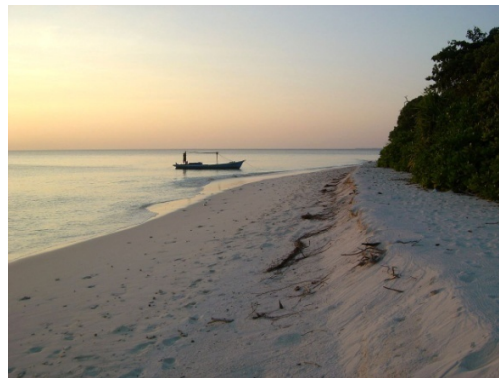


Sand spilling out of the sand-spit slowly in southern side of the island.

Plate 16 Sand-spit of the island

4.6.3 Section C

The beach Section C as shown figure 2 is has similar beach sediment dynamics in terms of frequency, however less in terms of quantity but more in terms of extent of sediment movement causing seasonal erosion in this section of the beach. Significant beach steps in this section of the beach are formed by erosion in this area during SW monsoon. The eroded beach sediment is accumulated in the sand-spit in Section B of the beach. The beach steps formed by SW monsoon erosion are again filled up during NE monsoon accretion in this section of the beach. The interaction of beach sediment in C also occurs similarly with the Section D however, to much lesser extent.



SW side of the island beach

Plate 17 BEach section C

4.6.4 Section D

This is the western side of the island beach. This section of the beach is the least dynamic in terms of frequency, extent and quantity. This section is the most stable beach of the island where least beach erosion is found. This section was observed to be having net accretion over the long-term. The accreted sediment may be partly coming from the eroding area in Section E and from the lagoon in the natural accretion process of the beach sediment.



Plate 18 Beach Section D

4.6.5 Section E

Section E is the northwestern side of the island where there is serious beach erosion. Sediment in this section of the beach is partly fine sand and partly pebbles and cobbles to some extent. Sediment dynamics in this section is most significant in terms of net erosion. Field surveys and observations showed that sediment in this section is moving from northern areas of this section to Section D as shown in figure 2 in NW monsoon resulting permanent beach erosion in this section of the beach.



Eroding area on NW side

Plate 19 Beach section ED

4.7 Beach profiles

Beach profiles gives useful data on beach dynamics over long-term by providing beach height, beach width and estimated amount of beach materials in a given location at any given time. Beach profiles were taken in eight locations around the beach as a baseline for monitoring the beach sediment dynamics over long-term. Beach profiles showed that beach height, beach width and beach materials are more in Section BC compared to other section.

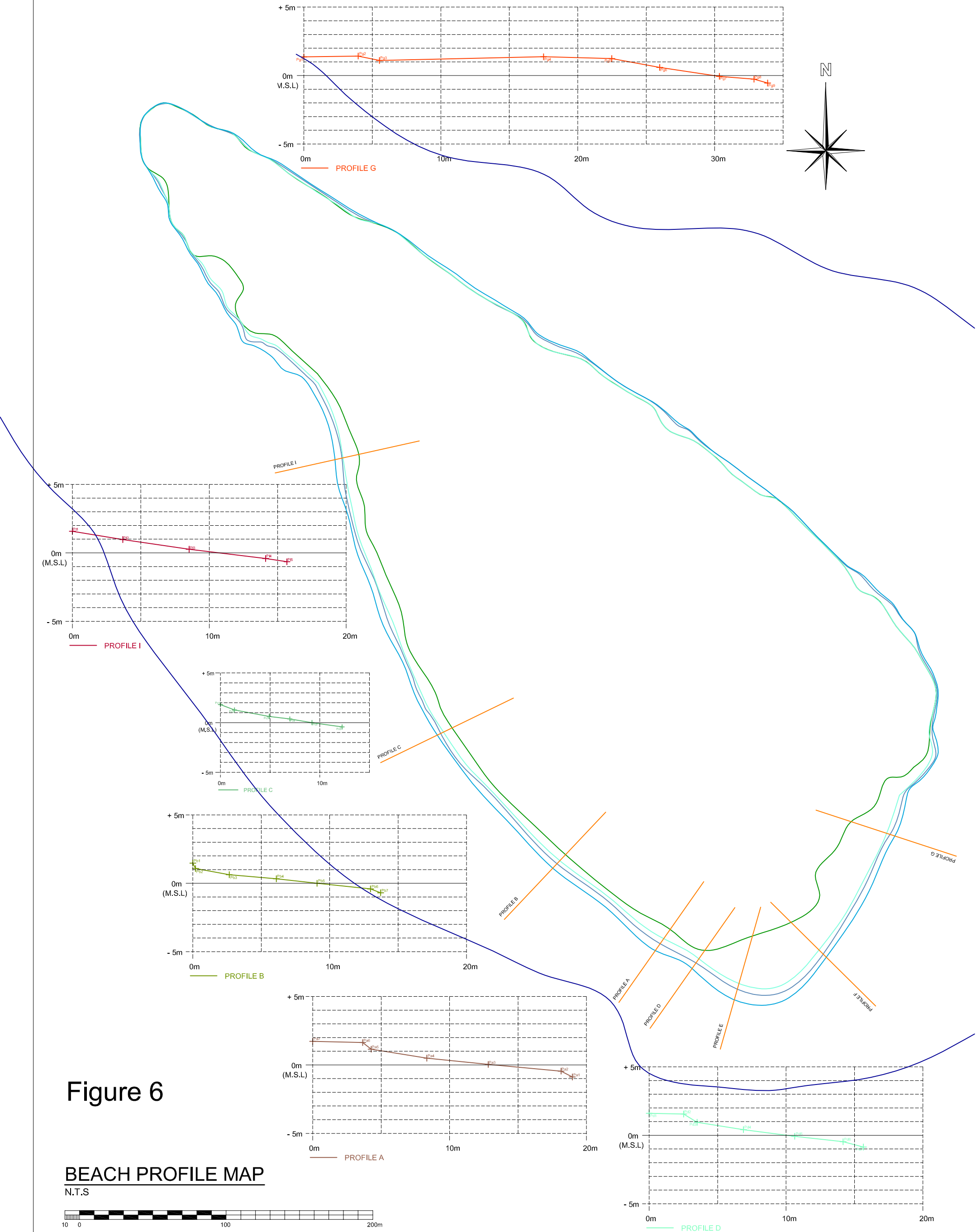
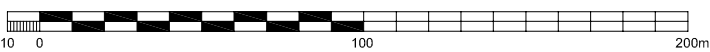


Figure 6

BEACH PROFILE MAP

N.T.S



4.8 Vegetation

Vegetation of the can be categorized into different three main types; they are the coastal or the peripheral vegetation, the inner vegetation or the vegetation inside the island, vegetation cleared area and the mangrove vegetation. The coastal vegetation is a belt of vegetation about 15m wide around the island that consists of more salt tolerant and bushy plants that are more adopted to coastal environment and plays an important role in protecting the island from beach and soil erosion. Coastal vegetation covers approximately 3 hectares (20%) of the vegetated area. The inside vegetation consisted of larger and older trees that area more adapted to less salty water and covers approximately 11 hectares (75%). The mangrove area covering approximately 0.7 hectares, 4% of the vegetation is found in eastern side of the island and covers a part of the coastal vegetation area as well. The cleared area covers approximately 1.5 hectares (10%) of the island total vegetated area.

4.8.1 Coastal vegetation

Coastal vegetation around the island is intact consisting of the usual species of plants that are found around the islands in the country. The dominant coastal plant species included Screw pine (*Pendanus tectoris*), Sea lettuce (*Scaveola taccada*), Ironwood (*Penphis sp.*), Seahibicus (*Hibiscus tilaceous*), Nit pitcha (*Guettarda speciosa*) and mangrove species. Composition of these species of plants varied from eastern and western sides and northern and southern sides. Western side coastal vegetation is dominated by Screwpine comprising approximately 46%. Southern side coastal vegetation is dominated by ironwood comprising approximately 44%. Eastern side is dominated by ironwood and mangrove (Kandoo) comprising of 25% and 20% respectively.



Plate 20 Western side coastal vegetation

The coastal vegetation around the island were assessed using line intersect transects. Transect surveys were conducted at western, southern and eastern side coastal vegetation of the island. A total of 21 transects were taken around the island covering the coastal vegetation. Each transect was 30m long and covered a coastal perimeter of 630m. A total of 3 transects were taken inside the island covering 90m of inner vegetation. Distribution of vegetation types of the island and transects locations are shown in figure 5.

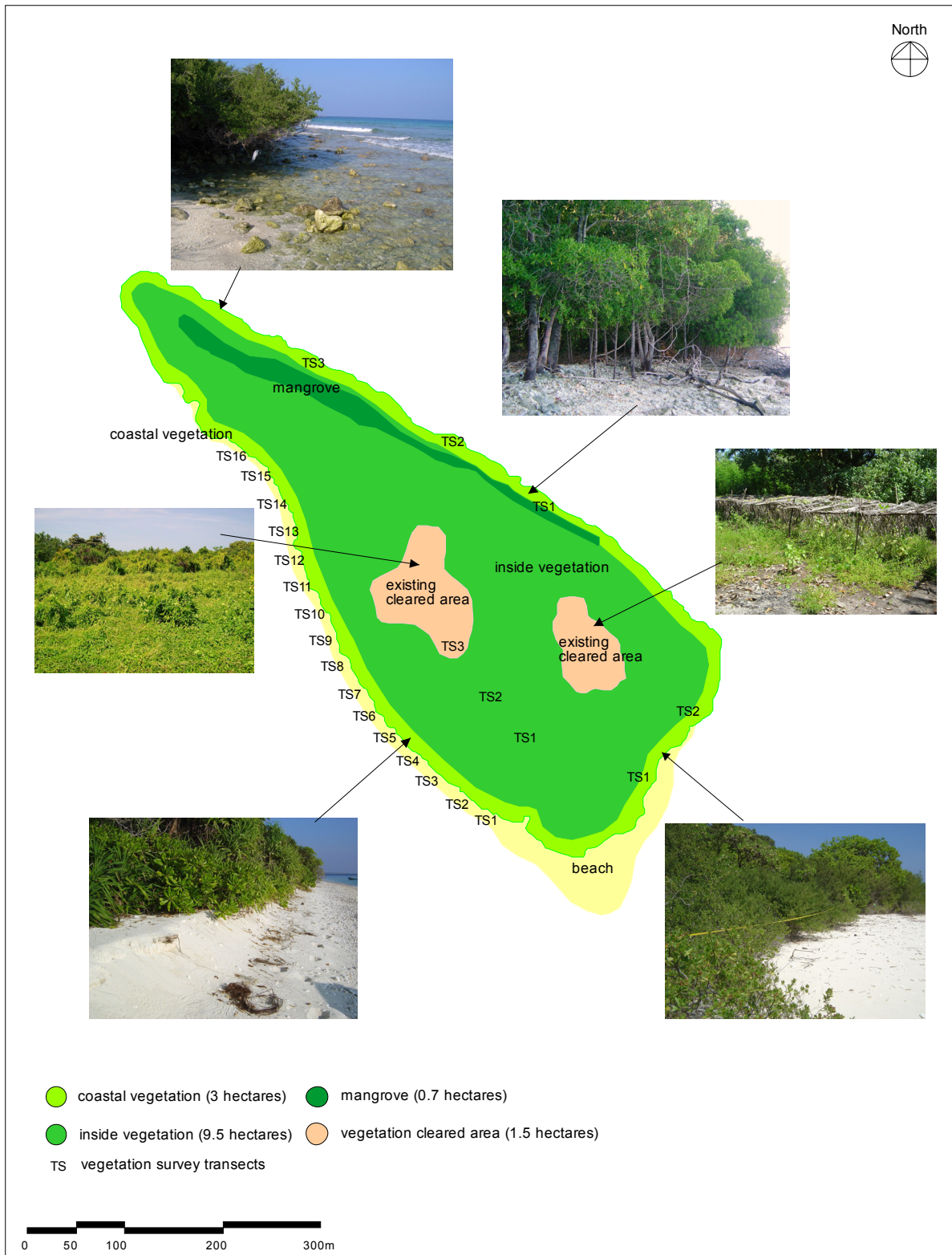


Figure 7 Vegetation map

The following figure shows the coastal vegetation covered by different species of plant as relative percentages, assessed by transects conducted on western side coastal vegetation.

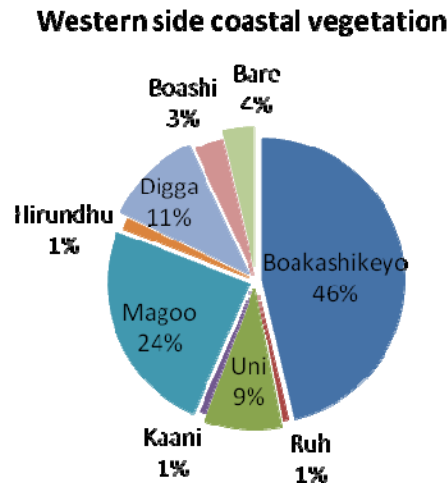


Figure 8 Western side coastal vegetation cover

The pooled data of 21 transects (TS1 – TS21 as shown in figure 5) taken at western side of the island showed that the coastal vegetation is dominated by Boakashikeyo (*Pendanus tectoris*) covering approximately 46% followed by Magoo (*Scaveola taccada*) covering approximately 24% of the coastal vegetation in western side. Approximately 11% of the western side vegetation is covered by Diggga (*Hibiscus tilaceous*). Uni (*Guettarda speciosa*) covered approximately 9% and Boashi (*Tournefortia argentea*) covered approximately 3%. Other species in western side coastal vegetation included Ruh (*Cocos nucifera*), Kaani (*Cordia subcordata*) and Hirindhu (*Thespesia populnea*) each species covering 1% of the western side coastal vegetation. Approximately 4% of the coastal vegetation on western side is bare area, cleared for making access paths to enter inside the island.



Screw pines (Boakashikeyo) is the dominant species of plant on W. side of the island

Plate 21 Western side coastal vegetation

The following figure shows the coastal vegetation covered by different species of plant as relative percentages, assessed by transects conducted on southern side coastal vegetation.

Southern side coastal vegetation

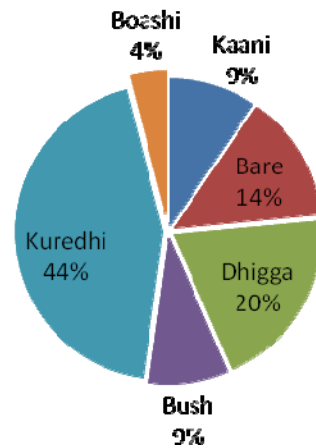


Figure 9 Southern side coastal vegetation cover

The pooled data of 2 transects (TS1 – TS2 as shown in figure 5) taken at southern side of the island showed that the coastal vegetation is dominated by Kuredhi (*Penphis acidula*) covering approximately 44% followed by Dhigga (*Hibiscus tilaceous*) covering approximately 20% of the coastal vegetation in western side. Approximately 9% of the western side vegetation is covered by bushes if unknown species and Kaani (*Cordia subcordata*). Approximately 4 is covered by Boashi (*Tournefortia argentea*). Approximately 14% of the coastal vegetation on southern side is bare area, cleared for making access paths to enter inside the island.



Southern side vegetation transects



Ironwood (Kuredhi) on southern side

Plate 22 Southern side coastal vegetation

The following figure shows the coastal vegetation covered by different species of plant as relative percentages, assessed by transects conducted on southern side coastal vegetation.

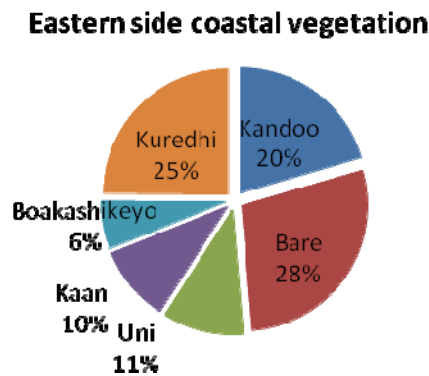


Figure 10 Eastern side coastal vegetation cover

The pooled data of 3 transects (TS1 – TS3 as shown in figure 5) taken at eastern side of the island showed that the coastal vegetation is dominated by Kuredhi (*Penphis acidula*) covering approximately 25% followed by Kandoo (*Bruguiera gymnorhiza*) covering approximately 20% of the coastal vegetation in eastern side. Approximately 11% of the eastern side vegetation is covered by Uni (*Guettarda speciosa*) and 10% Kaani (*Cordia subcordata*). Approximately 6% of the eastern side vegetation is covered by Boakashikeyo (*Pendanus tectoris*), Approximately 28% of the coastal vegetation area on southern side is bare as a result of occasional tidal waves felt on eastern side of the island.



Mangrove (Kandoo) on E. side



Ironwood (Kuredhi) on NE side

Plate 23 Eastern side coastal vegetation

4.8.2 Inside vegetation

Inner vegetation survey included larger trees that are significant in terms of species, canopy size and age. Significant large trees were located using total station surveying equipment and shown in figure 6. Significant large tree inside the island included Nika (*Ficus bengalensis*), Uni (*Guettarda speciosa*), Kaani (*Cordia subcordata*), Funa (*Calophyllum inophyllum*), Kandhu, Midhili (*Terminalia catappa*) and Madhoshi (*Adenantha pavonina*).



Banyan tree (Nika) inside the island



Nit pitcha inside the island



Sea hibiscus (Dhigga) inside the island



Coconu palms (Ruh) inside the island

Plate 24 Large trees inside the island

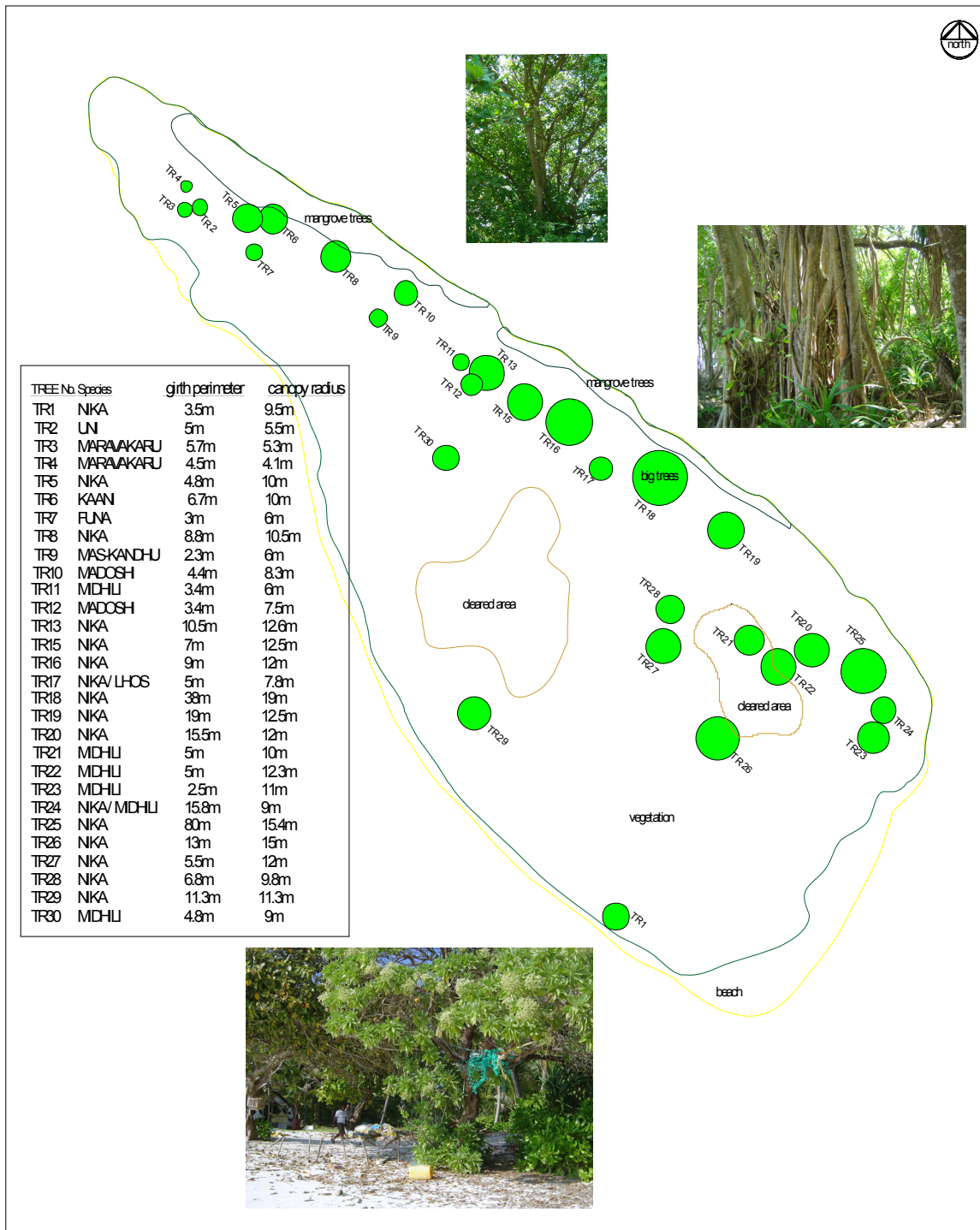


Figure 11 Locations of large trees

Transects surveys were also conducted inside the island to assess the vegetation cover of the island. The following figure shows the inside vegetation covered by different species of plant as relative percentages, assessed by transects conducted in central area of the island.

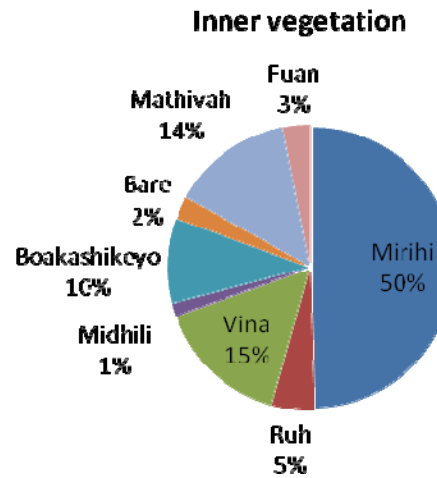


Figure 12 Inside vegetation cover

The pooled data of 3 transects (TS1 – TS3 as shown in figure 5) taken inside of the island showed that the inside vegetation in the area is dominated by Mirihi covering approximately 50% followed by Boakashikoyo accounting for 10%. Other plants included various species of weed covering 15%, Mathivah covering 14%, Ruh covering 5%, Funa covering 3% and Midhili covering 1% of the inside vegetation in the surveyed area. The surveyed area covered part of the vegetation cleared area when the transects were laid randomly. Mirihi is grown extensively in the cleared area so the dominating plant in the area is Mirihi.



Bushes grown in cleared area inside the island



Path cleared inside the island

Plate 25 Inside vegetation

4.8.3 Mangrove

A long stretch of mangrove area is found close to the eastern periphery more to the NE area of the island as shown in figure 5. Southern part of the mangrove area covers part of the coastal vegetation and is less muddy whereas the northern part of the mangrove is more muddy and waterlogged. Rainwater is retained in the northern part during the rainy season and gets dry during dry seasons. The

mangrove area is approximately 430m long and 10m wide in southern part and 20m wide in northern part, covers approximately 6519m² and consisted of a single species of plant *Bruguiera gymnorhiza* (Kandoo) which is the edible species of mangrove. The cover of the mangrove plants in this area consisted of different age categories including seedling and fully grown plants, however plant cover density is relatively sparse in most part. The mangrove area in Madulu is significant in relation to the size of the island and age of most of the individual plants as they are fully grown and fruit bearing. Ecological significance of this mangrove area can be said as relatively low as there is no diverse habitat types and diversity of flora and fauna is low.



Kandoo (*Bruguiera gymnorhiza*)



Fauna found in the area, mangrove crab



Fully grown mangrove plants



Waterlogged area in north of mangrove area

Plate 26 Mangrove area

4.9 Soil

Madul is a relatively small island in terms of size geology and vegetation. The island can be divided into four parts in terms of amounts of fertile soil contents. The soil profiles taken from various locations (periphery, inside and central area) of the island showed that the contents of the soil varied from periphery to the central areas.

Soil profile 1: the periphery of the island is less fertile having thin layer of dark soil measuring 10cm and more white sand. Soil profile 2: Soil inside the island consisted of thicker layer of dark soil measuring 20cm. Profile 3: The soil profile taken in central area of the island showed that the fertile layer of soil has a thickness of 25cm and a humus layer on top of the soil.

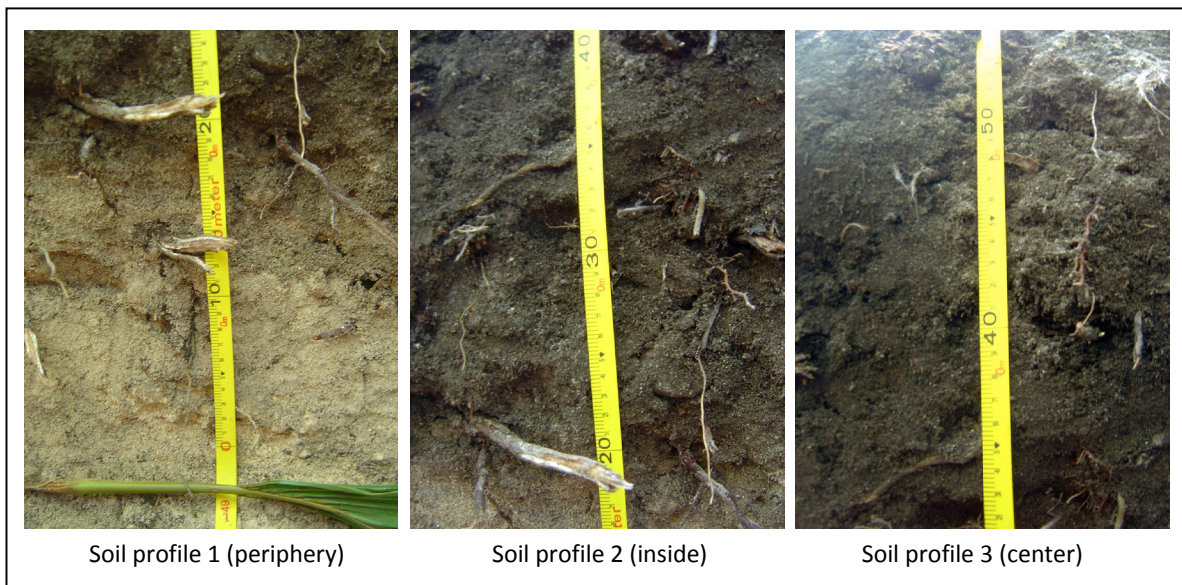


Plate 27 Locations of soil profiles

The soil profiles taken from three locations of the island showed that the soil is relatively fertile in terms of fertile soil and humus contents in the central areas whereas less fertile in periphery of the island as in other similar islands in the country. The waterlogged area of the island has considerable amount of muddy soil, more humus and water contents. In general the soil of the island can be said as very fertile and suitable for agriculture. Agriculture was carried out in the island in the recent past.

4.10 Groundwater

Groundwater samples were taken from existing wells at three locations of the island as shown in figure 5. Water samples were taken from southeast (WS 1), central area of the island (WS 2) and southeast side of the island (WS 3). Water samples were tested at National Health Laboratory for parameters that can be used for analysis of impacts due to the proposed infrastructure development for agriculture and farming activities. The tested parameters were physical appearance, pH, salinity, phosphate, Nitrate and sulphate. The following table shows the results of the water tests.

Table 2 Groundwater test results

Parameters tested Sample	WS 1	WS 2	WS 3
Physical appearance	clear	clear	clear
pH	7.1	7.0	7.0
Salinity	1900mg/L	800mg/L	400mg/L
Phosphate	0.40mg/L	0.49mg/L	0.09mg/L
Nitrate	0.0mg/L	0.0mg/L	1.33mg/L
Sulphate	175mg/L	57mg/L	20mg/L



Plate 28 Groundwater sampled locations

Groundwater tests showed that the groundwater of Madulu is very similar to other such islands when compared to the same parameters tested from other islands groundwater samples. As the island is uninhabited the groundwater of the island has not been used very much for any purpose therefore at natural status. The depth of the groundwater lens is 1.5m during high tide as shown by the soil profiles taken.

The status of the groundwater varied from periphery to the central areas of the island as found in other similar islands in the country. The groundwater in periphery of the island has more salt content (higher salinity) than in central area as shown in table 2. Sulphate concentration in the groundwater is higher in periphery of the island. No particular such pattern of concentration of other contents tested was found in the groundwater as shown in table 2.

The high salinity of the samples is due to the samples taken from periphery of the island rather than in central area of the island. Central area of the island was not accessible to take water samples due to the thick vegetation in the central area of the island.

4.11 Description of existing marine environment

Marine environment of Madulu can be categorized into two main components; the coral reef environment and the lagoon environment. Different habitats are found within each of these categories of marine environment. The coral reef environment has the leeward or the atoll side reef on western side of the island and the windward or the ocean side reef on eastern side of the island, reef-flat and reef slope having distinctive habitat characteristics. The total reef area covers approximately 40 hectares.

The lagoon environment also has the leeward or the atoll side lagoon on western side of the island and the windward or the ocean side lagoon on eastern side of the island, shallow and deep lagoon having distinctive habitat characteristics. The total lagoon area covers approximately 28 hectares.

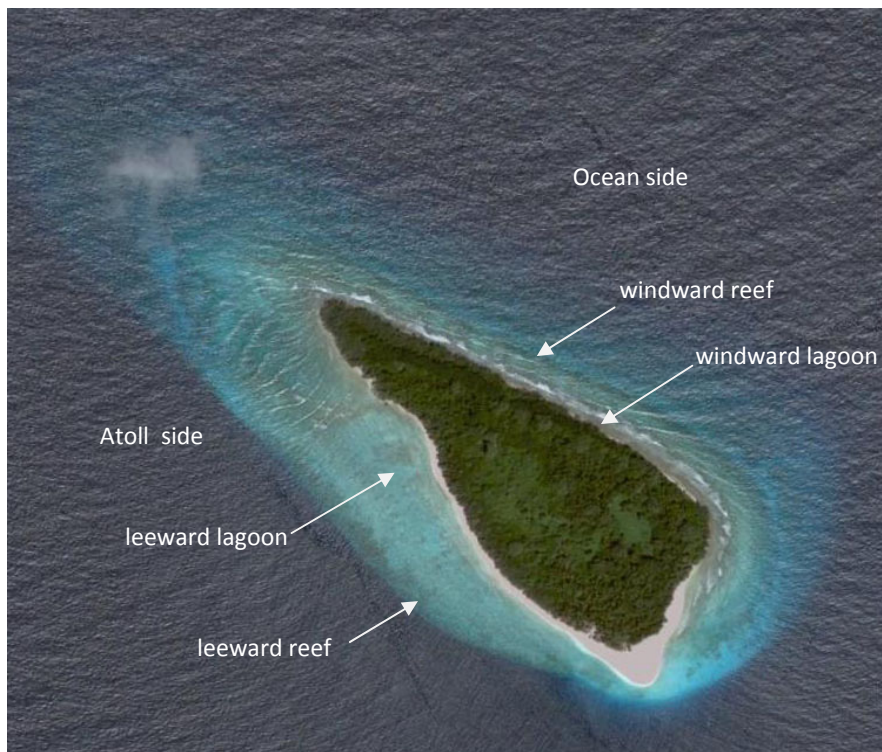


Plate 29 Marine environment of Madulu

The marine environment, including the coral reef and the lagoon of Madulu covers approximately 53 hectares. The most significant component of the marine environment of Madulu can be said as the coral reef system in terms of biodiversity and area.

The marine environment around Madulu is in almost near pristine condition as the island is uninhabited. However there was evidence of a human interactions with island environment

Vegetation has been cleared for agriculture. The impact of anthropogenic factor on the marine environment can be considered negligible. It is also important to note that environmental impacts of human interaction are not well documented since there was no systematic monitoring of the effects of these interactions in the Maldives (Kench et al. 2006).

4.11.1 Coral Reef System

The coral reef system of Madulu was quantitatively, semi-quantitatively and qualitatively surveyed using standard marine environmental survey methodologies. The surveyed sites are shown in figure 13.

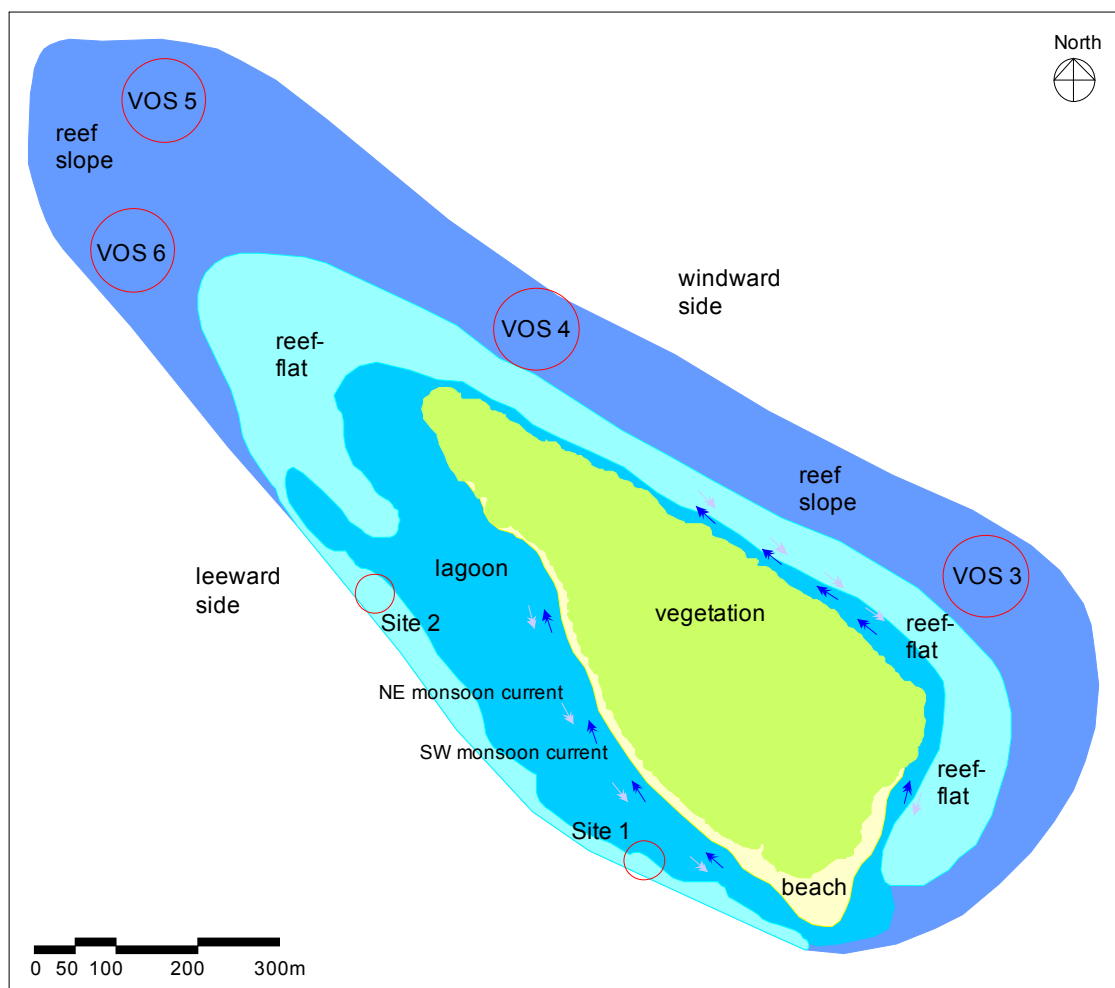


Figure 13 Map of marine environment and surveys sites

The reef around Madulu is not very well developed and has less than 10 percent live coral cover on the western and southwestern side reef-edge. The bottom of reef edge was dominated by

coral rock followed by sand and rubble. The reef slope on the western side was somewhat steep with a higher live coral cover. Most commonly encountered genera of hard corals are:

- *Acropora*
- *Echinopora*
- *Favia*
- *Goniopora*
- *Laptoria*
- *Porites*
- *Pocillopora*

On the eastern and south eastern sides the reef-slope is rather steep and adjoins the Indian Ocean. No quantitative surveys were conducted on this side due to the strong surge and breaking waves on the reef-crest.

The coral reef system of Madulu is poor in terms of diversity and percentage live coral cover. Live coral cover was also observed to be even lower at the atoll rim reef's slope as well as on the reef-flat. The visual survey results for sites (VOS) 3 to 6 showed that the live coral cover to be about 2 to 3 percent on the northwest and southeast sides of the island. A few soft coral species were encountered during the visual observations. Species richness and diversity of corals and fish were very low at these sites. A large number of grazers (Scarids, acanthurids and labrids) were seen at these sites. This according to Reef Check was an indicator of the poor health of the reef since most of these fishes feed on algae that grow on dead or dying portions of the reef.

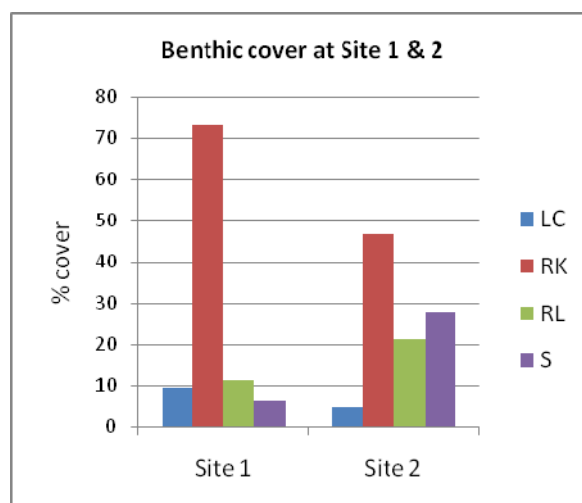


Figure 14 Percentage of benthic cover at Sites 1 & 2

The dominant forms of benthic cover are rock, rubble and sand. Branching forms of *Acropora* spp. (staghorn) corals predominates the live benthic cover. Massive types corals namely *Porites* spp., *Favites* spp. and encrusting type *Pavona* and *Echinopora* were also present. The benthic covers are given in percentages of the bottom area surveyed. LC = live corals, RK = rock, RL = rubble, and S = sand

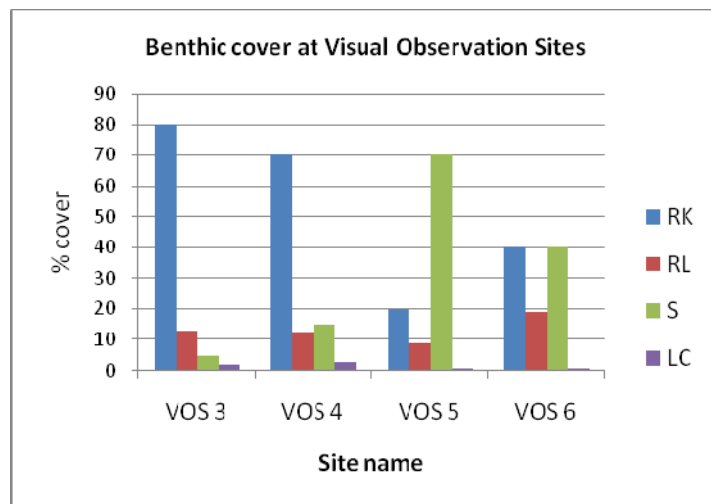


Figure 15 percentage cover of benthic substrate at visual observation sites

The dominant forms of benthic cover are rock and rubble in all the sites except 5 where sand dominated. Massive type coral colonies predominated at these areas. Branching forms of *Acropora* spp. (staghorn) corals were also present in very low numbers. The benthic covers are given in percentages of the bottom area surveyed. LC = live coral, RK = rock, RL = rubble, and S = sand.

The photographs below shows the benthic cover at the survey sites.

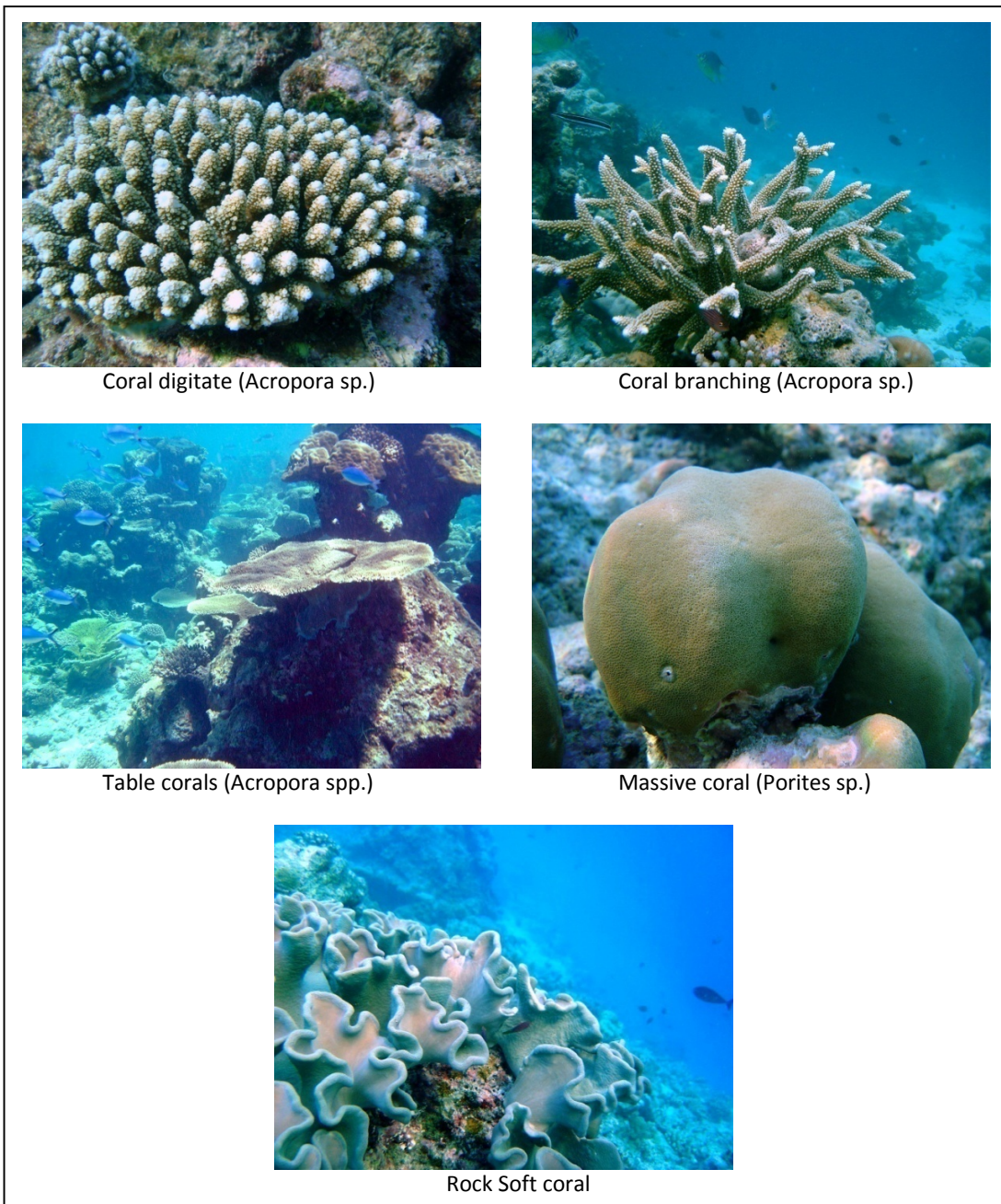


Plate 30 Benthic cover at Sites 1 & 2

4.11.2 Reef fish communities

The result of 15 minutes swim for fish count along surveyed sites 1 and 2 revealed that the abundance and diversity of fish is good on the reef-edge and reef-slope. This may be due to the presence of a number of live coral colonies and other complex structures such as crevices formed due to the rugosity of the area. Since most of the area was covered with rock, fishes associated with this type of environment were encountered. The dominant fish taxa observed in the surveyed area included surgeon fishes and wrasses. The presence of Acropora coral colonies was associated with the occurrence of number butterfly fishes at site 2. These fishes are an indicator of reef health. Variety of commercially important fish and food fish such as snappers, groupers and goatfishes were observed at these two sites.

Table 3 List of fishes found in Madulu reef

Family	Species	Count S1	Count S2	Family	Species	Count S1	Count S2
Acanthuridae	<i>Acanthurus leucosternon</i>	6	3	Labridae	<i>Epibulus insidiator</i>	1	-
Acanthuridae	<i>Acanthurus tennentii</i>	1	-	Labridae	<i>Gomphosus caeruleus</i>	2	1
Acanthuridae	<i>Acanthurus lineatus</i>	-	15	Labridae	<i>Hemigymnus fasciatus</i>	1	-
Acanthuridae	<i>Acanthurus triostegus</i>	18	-	Labridae	<i>Thalassoma amblycephalum</i>	10	4
Acanthuridae	<i>Ctenochaetus</i> sp.	24	10	Labridae	<i>Thalassoma hardwicke</i>	14	3
Acanthuridae	<i>Zebrassoma scopas</i>	2	-	Labridae	<i>Thalassoma janseni</i>	2	-
Balistidae	<i>Balistapus undulatus</i>	-	2	Lethrinidae	<i>Gnathodentex aurolineatus</i>	2	3
Balistidae	<i>Melichthys indicus</i>	-	1	Lutjanidae	<i>Lutjanus kasmira</i>	2	15
Balistidae	<i>Sufflamen</i> sp.	-	2	Lutjanidae	<i>Lutjanus monostigma</i>	-	1
Chaetodontidae	<i>Chaetodon auriga</i>	-	1	Lutjanidae	<i>Macolor</i> sp.	-	1
Chaetodontidae	<i>Chaetodon citrinellus</i>	2	2	Mullidae	<i>Parupeneus barberinus</i>	2	-
Chaetodontidae	<i>Chaetodon collare</i>	-	2	Mullidae	<i>Parupeneus bifasciatus</i>	4	2
Chaetodontidae	<i>Chaetodon lunula</i>	-	2	Pinguipedidae	<i>Parapercis</i> sp.	2	-
Chaetodontidae	<i>Chaetodon meyeri</i>	-	1	Pomacanthidae	<i>Centropyge multispinis</i>	5	-
Chaetodontidae	<i>Chaetodon trifascialis</i>	-	1	Pomacanthidae	<i>Pomacanthus imperator</i>	-	1
Chaetodontidae	<i>Chaetodon trifasciatus</i>	2	4	Pomacentridae	<i>Chromis dimidiatus</i>	2	9
Chaetodontidae	<i>Chaetodon xanthocephalus</i>	-	2	Pomacentridae	<i>Chromis ternatensis</i>	2	5
Chaetodontidae	<i>Forcipiger flavissimus</i>	2	-	Pomacentridae	<i>Dascyllus aruanus</i>	4	-
Cirrhitidae	<i>Paracirrhites forsteri</i>	4	-	Pomacentridae	<i>Pomacentrus chrysurus</i>	3	1
Holocentridae	<i>Myripristis</i> sp.	2	3	Pomacentridae	<i>Stegastes</i> sp.	3	3
Holocentridae	<i>Neonophon</i> sp.	-	1	Scaridae	<i>scarus</i> sp1	1	1
Holocentridae	<i>Sargocentron</i> sp.	-	2	Scaridae	<i>scarus</i> sp2	1	-
Kyphosidae	<i>Kyphosus</i> sp.	-	2	Serranidae	<i>Cephalopholis argus</i>	1	-
Labridae	<i>Coris</i> sp.	-	1	Serranidae	<i>Cephalopholis leopardus</i>	3	-
Labridae	<i>Helichoeres hortulanus</i>	3	3	Serranidae	<i>Plectropomus</i> sp.	-	1
Labridae	<i>Labroides dimidiatus</i>	3	5				

Fish diversity was also assessed for the visual observation sites. The result of 15 minutes swim for fish count along surveyed sites revealed that the abundance and diversity of fish was not very good on the reef-edge and reef-slope of these sites. This may be due to the presence of a only a smaller number of live coral colonies. Since most of the area was covered with rock, fishes associated with this type of environment were encountered. The dominant fish taxa observed in the surveyed area included acanthurids (surgeon fishes) scarids (parrot fishes) and balistids (trigger fishes) (see figure 13). The presence of Acropora coral colonies was associated with the occurrence of some butterfly fishes. Variety of commercially important fish and food fish such as lutjanid (snappers), serranid (groupers) and mullids (goatfishes) were observed at these two sites. Large schools of scarids (parrot fishes), balistids (trigger fishes), kyhosids (rudderfishes) and caesionids (fusiliers) were seen at these sites. Some of the conspicuous fish encountered are shown in Plate 30.

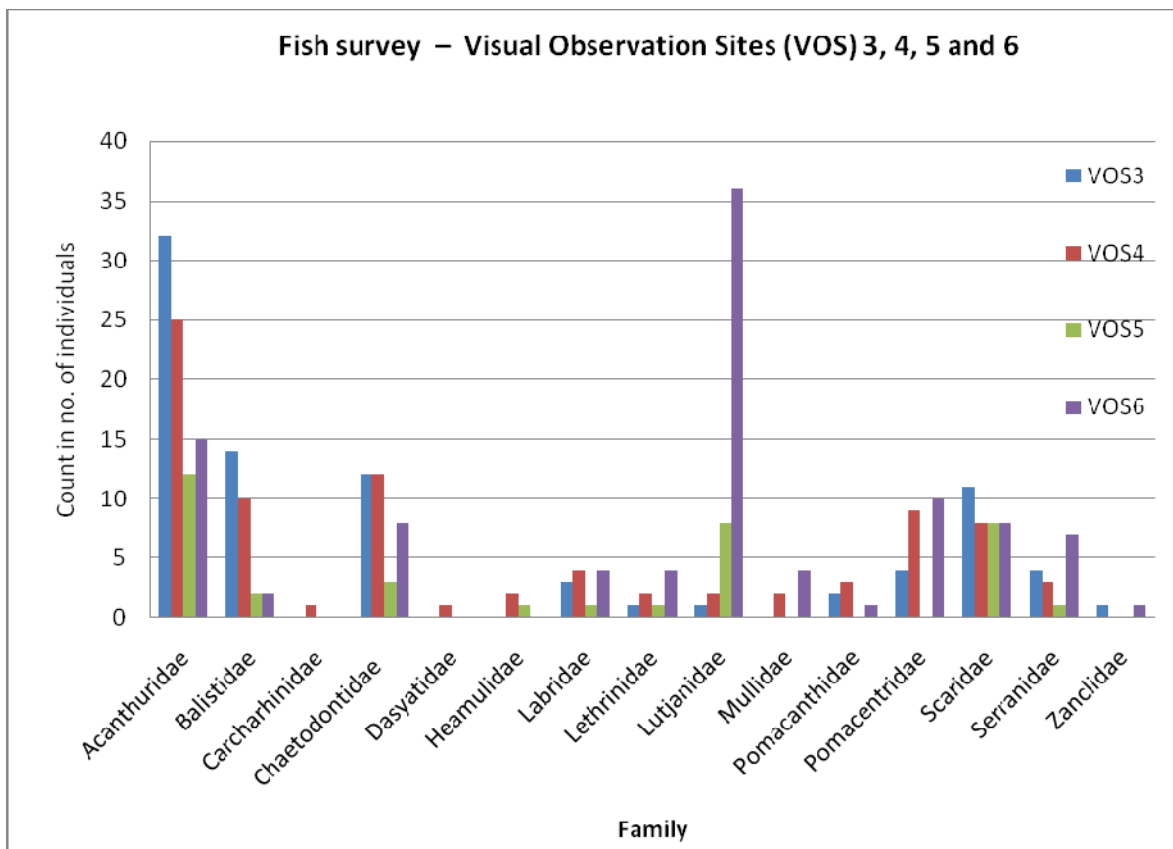


Figure 16 Result of fish survey at sites VOS 3, 4, 5 & 6



Acanthurus leucosternon



Chaetodon trifasciatus



Lutjanus kasmira



Forcipiger flavissimus



Serranidae sp.



Acanthurus triostegos

Plate 31 Some of reef fishes in Madulu reef

4.11.3 Reef invertebrates

Only a few species of mollusks and echinoderms were encountered in these 2 sites whci area shown in Plate 31. This may be due to the nocturnal nature of mollusks and echinoderms. What was observed during the timed swims is presented in the table below.

Table 4 Result of invertebrate survey at Sites 1 & 2

Common name	Count S1	Count S2
Giant clam	5	6
Sea cucumber	4	2
Starfish	6	4
Tiger cowrie	1	-
Urchin	3	7



Giant clam



Feather star



Sea cucumber



Sea anemone

Plate 31 Some of invertebrates in Madulu reef

4.12 Bathymetry

Bathymetric surveys were conducted in around the island and concentrated in northern areas in accordance with the proposed development plan. The bathymetric surveys results are shown in figure 14. The bathymetry surveys showed that the lagoon on eastern side of the island is shallower than on western side. The average depth in eastern side lagoon is 0.6m during mean tide whereas the average depth of lagoon on western side is 0.8m – 1.5m during medium tide. Depth of western side lagoon increases more abruptly as moving further from the shore than on eastern side. The eastern side lagoon has a more uniform depth covering a smaller area.

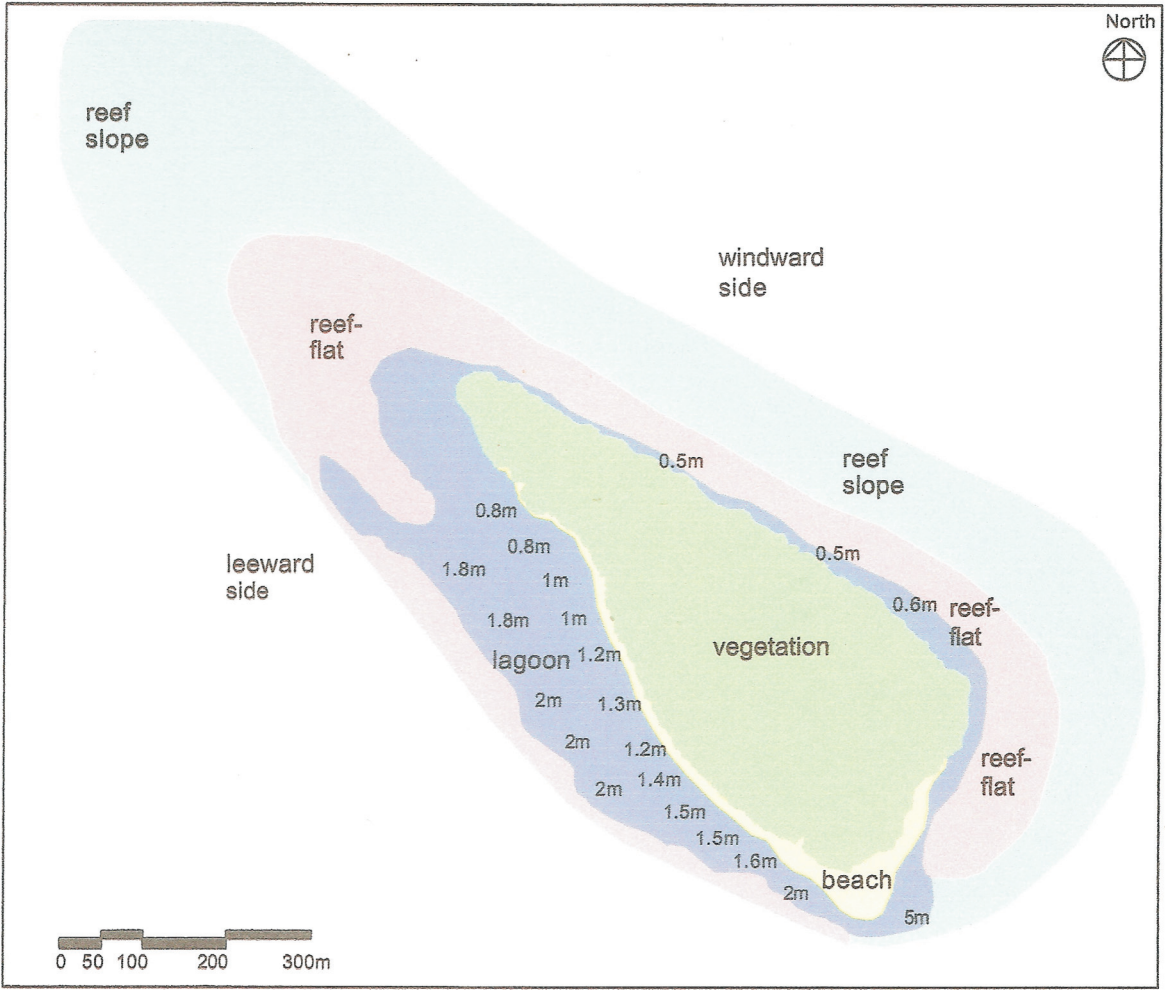


Figure 17 Bathymetry of Madulu lagoon

4.13 Currents

Both monsoonal and tidal currents were found around the island. Monsoonal water current around the island is northerly during SW monsoon with an average speed of 8m/m and southerly during NE monsoon an average speed of 5m/m. Monsoonal currents varies with the monsoon twice a year. Tidal currents changes daily with the fluctuating low and high tides. Tidal currents around the island was found to be predominantly northerly due to the narrower channel on northern side of the island and the longer reef system on south of Madulu reef system. Surface current directions around Madulu in NE and SW monsoon is given in figure 11.

4.14 Waves

An extensive surf zone is found in eastern side especially in southeastern corner of the island where the reef system forms an extensive reef slope. The eastern side of the island is the windward side hence wave action is more on eastern side compared to western side. However, western side is also exposed to tremendous wave action during SW monsoon bad weather conditions. Eastern side of the island is very sheltered by the island itself during SW monsoon. However, eastern side of the island faces sever wave conditions during NE monsoon bad weather conditions.

4.15 Tides

Like most of the places semidiurnal tides are experienced in the atoll, that is two high tides and two low tides a day. The tide varies from place to place, depending on the location and on the shape and depth of the basin, channels and reefs and also time of the year.

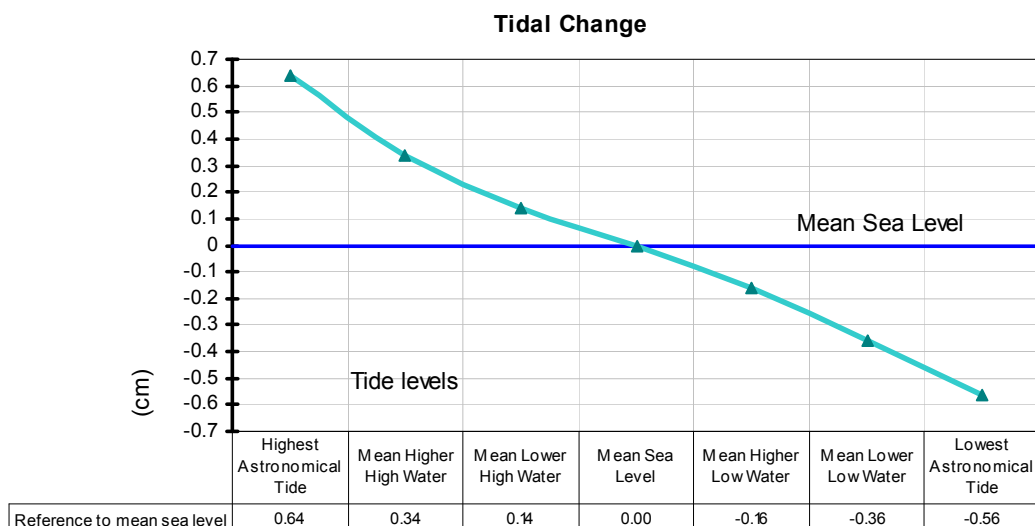


Figure 18 Tidal change

The above chart shows the astronomical tidal variation recorded in the country with respect to the mean sea level. Astronomical tides are related to the motion of the earth-moon-sun system, and have a range of periodicities. The highest astronomical tide was recorded as 0.64 cm above the mean sea level and the lowest astronomical tide was recorded as 0.56 below the mean sea level. Tidal variation of 1.2m from lowest to the highest tide levels were recorded in the country.

Tidal variation of approximately 1.5m was recorded in Ha Atoll (North Thiladhunmathee). The variation in tidal changes has a profound effect size of the beach area in the islands. In some of the islands surveyed in Ha. Atoll, more than half of the beach is flooded during the highest tides. In Madulu for instant, approximately over 3% of the area of the beach is flooded during high tides as given by the surveyed high and low tide lines

5. Socio-economic and population

North Thiladunmathee atoll is the northernmost atoll of the country furthest from economic centers of the country. Madulu is in Ihavandippolhu which is a geographically isolated atoll. The atoll capital is Dhidhdhoo about 25km away in geographically separate atoll. Dhidhdhoo has a population of about 2,500 and very limited economic activities. Other main populations within the area are Ihavandhoo and Hoarafushi with populations of 2,447 and 2,204 respectively. The nearest airport is Hanimaadhoo Airport in HDh. Atoll approximately 40km away. The nearest economic center is Kulhuduffushi the atoll capitol of HDh. Atoll.

The main economic activity in the atoll has been tuna fishery. Agriculture is poorly developed in the atoll and agriculture production is declining in the recent years. Tourism is being introduced to the atoll recently however, direct benefits of tourism to the locals are not significant in the atoll as indicated by the socio-economic assessment.

Given the limited economic activities in the atoll the job opportunities and means of income generation in the atoll is very limited. The socio-economic assessment showed that there is an urgent need for income generation opportunities in the atoll especially in the area. In this respect the proposed project will have significant positive impact to the atoll community especially within the locality of the project, through development of agriculture and opportunities for direct jobs and income generation opportunities.

5.1 Atoll population

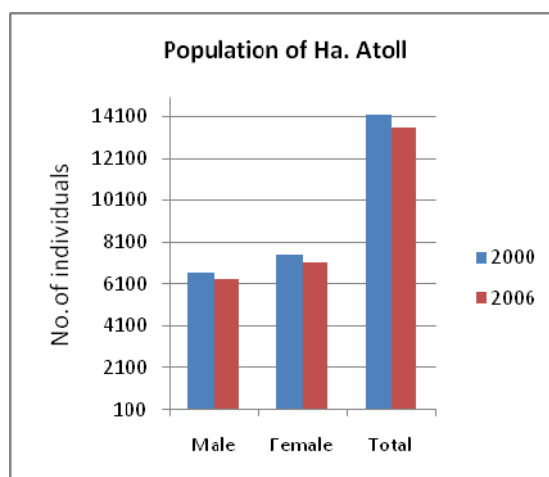


Figure 19 Population of Ha. Atoll 2000 - 2006

Thiladhuma (Ha. Atoll) has a population of 13,495 in 2006 which is about 5% of the country's population and it is one of the least populated atolls. Male and female of the population is almost equal with a slightly higher number of females than males. The atoll also has relatively fewer inhabited islands of 16 in 2006 and only 15 islands at present as Hathifushi population has been

moved to Hanimaadhoo in adjacent HDh. Atoll. The population census shows that the population of the atoll has decreased 5% from 2000 to 2006 as shown in figure 15. The socio-economic surveys suggest that this declining trend is due to people moving to seek employment and other opportunities that are not available in the atoll.

5.2 Population distribution

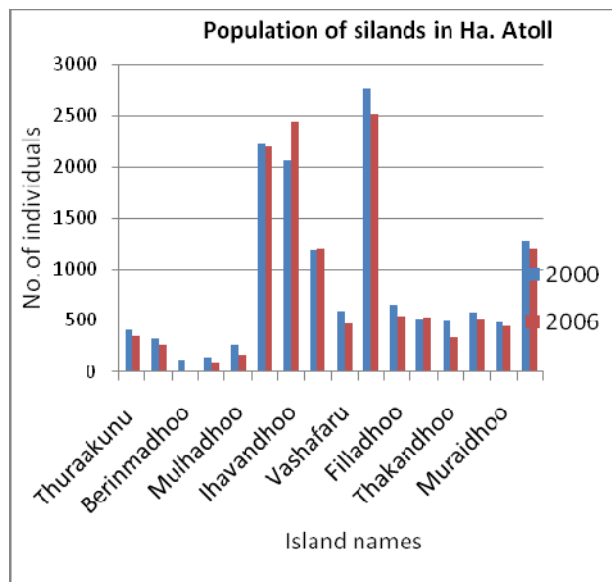


Figure 20 Populations of island in Ha. Atoll

The population of the atoll is concentrated in western and southern areas of the atoll which is about 12 to 23km away from the proposed project location, the northeastern side of the administrative atoll. The proposed project area covers the eastern side of Ihavandippolhu and has ha population of 1,519 in four island combined. However, the atoll is relatively small thus transportation between other population within the atoll is relatively easier, therefore the project is expected to have a significantly positive impact to all the inhabited islands in the atoll.

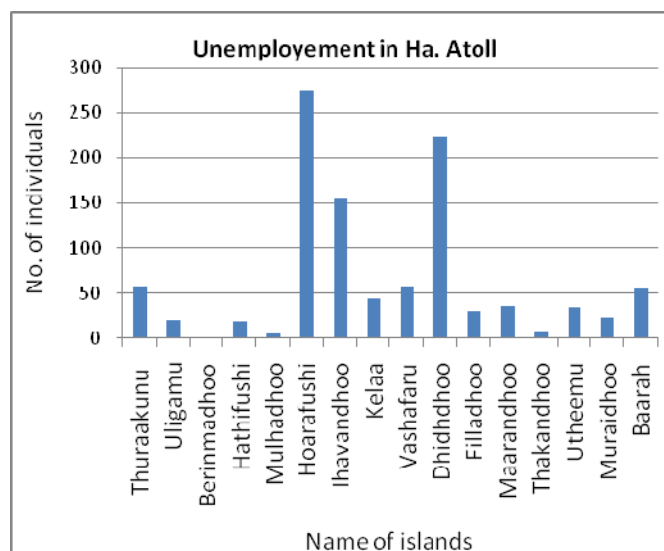


Figure 21 Unemployment in Ha. Atoll

The atoll has an unemployment population of over one thousand people which is 8% of the population. Unemployment is more in islands with larger populations such as Hoarafushi, Dhidhdhoo and Ihavandhoo. Interviews with locals of the proposed project area suggested that the unemployment in the atoll will be minimized with the start of the project.

5.3 Environmental issues

The significance of small population is the impacts on the environment as a result of increased resource exploitation such as fisheries, development activities in the atoll such as land reclamation, harbour development and various other impacts from population pressures such as solid waste and sewage disposal.

The environmental issues are related to population pressures and environmental mismanagement in terms of economic development in the atoll that are found to be increasing, especially in the populated islands such as Dhidhdhoo and Hoarafushi where there is intense pressure on land due housing and infrastructure development. Some of the issues area coastal erosion waste management and transportation. Harbours have been developed without proper designs which have led to pollution in the harbours and coastal erosion.

6. Methodology

Data for assessment of environmental impact that may arise due to the proposed project were collected using methods most appropriate for specific environmental, social and economic conditions of the island and atoll environment. Quantitative, semi-quantitative and qualitative data were collected for this EIA study.

Assessment of the existing environment was conducted using standard methods that are internationally accepted and locally practiced.

6.1 Marine environment assessment methods

6.1.1 Reef Aesthetic Survey – using Mata Tow Technique

This is a subjective attribute based on the observer's judgment and experience of the relative merits of a reef. This value judgment should incorporate coral cover, diversity of life forms, fish life, reef structure and general appeal. Observers should take care not to allow the present weather conditions to bias their judgment when assigning this category as poor visibility will impair this judgment. The following categories can be used to determine reef aesthetic.

1. Very poor
2. Poor
3. Average
4. Good
5. Very good
6. Excellent

Dominant benthic form

When determining percentage cover of hard coral during a manta tow survey the observer should note if a particular benthic form dominates an area. The dominant benthic form categories used to describe a reef are:

1. Hard coral - *Scleractinia* coral species
2. Soft coral - *Alcyonaria* species
3. Macro algae - Large, non-filamentous algae with a well-developed stems
4. Coralline/turf algae - All forms of encrusting algae and filamentous turf algae
5. Sand/Rubble - All unconsolidated substrate such as sand and broken fragments of coral and rock
6. Sponge - *Porifera* species

Dominant hard coral genus

If hard coral is the dominant benthic form in a zone, then it is broadly categorised as Acropora or non-Acropora. If hard coral is not dominant, or there appears to be equal dominance of Acropora and non-Acropora, then it is classified as 'no one coral genus dominant'.

A. *Acropora* genus

C. non-*Acropora* genus

N. No one coral genus dominant

Dominant hard coral form

There are eight coral life forms, which commonly dominate a reef slope. If there is no one dominant coral form, or if hard coral is not dominant, then it is recorded as 'no dominant form'.

Live hard coral cover

Coral cover is determined from the median cover category estimate recorded by manta tow over the given reef zone.

Structural complexity

This is a subjective category designed to indicate the topography of the reef slope.

1. Uniform - a consistent, featureless area of reef, such as reef pavement, vertical drop-offs, flat, sandy, back reef areas or an area of staghorn coral.
2. Mixed - a variable reef slope that may be a solid edge interspersed with occasional grooves.
3. Complex - a very diverse slope that may consist of "spur and grooves," caves, holes, overhangs or bommies.

Fish abundance

This attribute is an estimate of the total fish abundance over the zone. The categories are subjective and rely on the observer's perception and experience.

1. Low
2. Moderate
3. High
4. Very high

Coral bleaching

Coral bleaching looks similar to scars caused by COTS, as the corals appear brilliant white. A close inspection of bleached coral will reveal that the polyps are still visible, although colourless. Bleaching should be recorded only if it is unambiguous. It is recorded as a percent cover category.

6.1.2 Manta Tow Survey

The manta tow technique is used to assess broad changes in the benthic communities of coral reefs where the unit of interest is often an entire reef, or large portion thereof. It enables visual assessment of large areas of reef within a short time and is highly recommended for determining the effects of large-scale disturbances such as those caused by coral bleaching, outbreaks of *Acanthaster* (crown-of-thorn starfish) and storm damage. The technique is useful for selecting sites that are representative of the large areas of the reef.

The technique involves towing of an observer, using a rope and a manta board, behind a small boat powered by an outboard motor. Tows are carried out at a constant speed around the perimeter of a reef and are broken into units of 2 minute duration. During each 2 minute tow, observations are made on several variables (e.g. percent cover of live coral, dead coral and soft coral). These are recorded onto data sheets as categories of integer values. Additional information can be collected, depending on the survey objectives, e.g. percent cover of sand and rubble, and the number of *Tridacnid clams*, *Diadema* or *Acanthaster*. However, Fernandes (1989), caution against recording data on too many variables, and the technique is not recommended for fish counts.

The method described in this manual is not useful in assessing the distribution and abundance of corals, but is also widely used for the study of *Acanthaster*. Details of *Acanthaster* assessment have been included because of the extensive destruction to many reefs in Indo-Pacific which have been caused by these starfish. The technique may also be used to assess other organisms of particular interest to a survey region. However, it should be noted that estimates of accuracy and precision of the technique have only been in relation to coral cover and *Acanthaster*

Background

In general, the manta tow technique has been used to investigate issues at broad level to assess the effects of *Acanthaster* on coral reefs in Micronesia, similar surveys have been conducted on the reefs within the Red Sea and the Great Barrier Reef. The technique has also been used for more general, broad scale surveys of coral reef systems. While manta tow techniques have been used extensively since the early 1970's, the details of the method have varied between the different studies. Work by Moran et al. (1988, 1989) to assess the broad scale distribution and abundance of *Acanthaster* and their effect on the Great Barrier Reef has greatly refined the technique.

More recently, studies have focused on the precision of manta tow techniques for estimating coral cover and *Acanthaster* abundance. These studies have shown the technique to be particularly useful for assessing broad changes in the distribution and abundance coral cover (especially live coral) and

Acanthaster. For example, a typical manta tow survey (of approximately 50-60 tows) is capable of detecting a 20% change in the abundance of an outbreaking population of *Acanthaster*. The studies also show that, despite underestimating the number of *Acanthaster*, manta tow counts can be calibrated to predict estimates obtained from SCUBA swim. Hence, the combined information from a relatively large number of tows can give more accurate estimates of abundance when the spatial distribution of the target organism is highly variable (e.g. *Acanthaster*), and the unit of interest is whole reef.

Advantages

- Large area of a reef can be surveyed in a relatively short time. This reduces the possibility of overlooking population changes or disturbances which can be variable in space and time (bleaching, storm damage, *Acanthaster*).
- It is relatively simple to perform after some training.
- It does not use expensive or specialized equipment which would require the observer to have special qualifications. (e.g. SCUBA apparatus).
- It can be performed in remote locations with minimal support.
- The observer can cover great distances without fatigue.

Disadvantages

- The survey may be conducted over inappropriate sections of the reef (e.g. large areas of sand or deep water) because the tow path is controlled by the driver who views the reef from above the water.
- If animals are not obvious they may be overlooked.
- The observer may have too much information to remember, particularly if many variables are being recorded.
- The method is not suitable for areas with poor visibility (less than 6m).

Logistics - Personnel

- Manta tow surveys are conducted by teams of one or more pairs of trained personnel. The duties of the teams are divided between the boat driver and the observer.
- Each series of manta tows is coordinated by a leader who is responsible for the safety of personnel and for ensuring that the technique is conducted in a standardized way, and for determining when conditions are appropriate for surveying.

Equipment

- A small boat with an outboard motor is used for towing observers. The boat should be fitted with towing bridle.
- A 17m tow rope connects the manta board to the boat. The rope should be braided and approximately 10mm in diameter (polyethene ski-rope is recommended). Two buoys

are placed on the rope, one at 6m from the manta board, and the other at 12m. These buoys allow the observer to estimate visibility in a standard manner.

- The dimensions of the manta board are 600 x 400 x 20 mm (length x breadth x thickness). It is recommended that the board be made from marine ply and painted white. Two indented handle grips are positioned towards each corner of the front of the board. A single hand hold is located centrally at the back of the board.
- A data sheet (A4 underwater paper is recommended) is held in position within a recess on the centre of the board. The data sheets should be preprinted to assist the observer record a set of biological variables and other significant observations.
- Diagrammatic representations of coral cover categories are attached to the board for observer reference. Any other list which may assist the observer may also be attached e.g. if survey will include *Acanthaster*, then categories used to record feeding scars and *Acanthaster* size should be provided.
- A pencil is attached with light twine to the board.
- The observer wear snorkeling equipment (mask, snorkel and fins) and preferably a full length dive suite or nylon ('stinger') suite.
- The driver should be protected from the sun and should have the following equipment in the boat:
 - Waterproof watch for timing the duration of tows.
 - An image of the reef sealed in plastic and attached with rubber bands to a plastic board. An aerial photograph of the reef is recommended however, a map or copy can be substituted if this is not available.
 - A waterproof pen for marking the position of the tows.

Site Selection

- Whole (unbroken) reef perimeter are surveyed where possible. Shoals and ill-defined areas of reef, separated by deeper water, are not usually surveyed.
- Tows are begun from an easily identifiable point on the reef. This is particularly important when resurveys are intended. A GPS if available, can be very useful for relocating sites.
- For long sections of coastline with fringing reefs, allocate a section of the length as a reef.
- If there are two teams conducting the survey, the teams should start from the same point and then proceed in the opposite directions. Tows are continued until the boats meet again. In situation where the reef is not circular, teams should start in the opposite ends of the reef and proceed towards one another, repeating the tows until the boats meet. Hence, each reef will consist of consecutive tows which will vary in number according to the size of the reef to be surveyed.
- If it is possible to complete a survey in a single set of consecutive tows, marker buoys are left to denote where the next set of tows will begin.

General procedure

- The survey of the reef is broken into manta tows of 2 minute duration. At the end of each 2 minute tow, the boat is stopped to allow the observer to record the data on the printed sheet attached to the manta board. At this time, the driver marks the tow number and position of the boat on the aerial photograph. When the observer is ready to continue, he signals the driver to start another 2 minute tow. This procedure is repeated until the entire perimeter or length, of the reef has been surveyed.
- The observer is towed parallel to the reef crest so that the maximum amount of the reef can be seen, i.e. tow path should be close to the reef crest. The tow speed should be constant. During calm weather the speed should be between 3 to 5 km per hour (1 to 1.5 knots, the equivalent to a slow walk). Factors such as currents and sea conditions may vary the tow speed.
- Since the boat driver may not be able to position the boat on an ideal tow path, the observer may have to vary the search relative to their position on the reef slope. The width of search is variable, but a scan of a 10 to 12 m strip of the reef is recommended. The search path and width will also vary according to the visibility, reef gradient, distance from the substratum, and the distribution and density of the organisms being counted.
- The direction of the reef is determined by factors such as wind, currents and angle of sun. When weather conditions allow, it is advised to standardize the direction in which tows are conducted (e.g. clockwise on circular reef; north to south, or east to west, along a length of fringing reef) so that comparison of resurveyed reefs require less correction.
- Observations should be discontinued where visibility is less than 6m. This distance is determined using the buoys located along the tow rope. If the back of the boat can be seen, the visibility is judged to greater than 18m.
- Standard hand signals should be used between the observer and the boat driver to allow effective communication. For instance, observer should signal the driver to move closer to the reef when being towed over deep water.
- The maximum number of consecutive tows conducted by an observer is 15. Once a series of 15 tows have been completed, the observer and the driver (or a fresh observer) exchange roles. During this change over a briefing should occur. This includes discussions about general conditions, state of the reef and anything else of note seen by the observer during the tows.
- Observations are generally made from the surface. Manta towing below the surface may be necessary when the substratum is not clearly visible or closer inspection is required. Prolong diving should be avoided.

6.1.3 Coral Reef Fish Visual Census

Coral reef fish populations are assessed by visual census of the fishes along 50m transects. The transects are censused during day light hours using SCUBA and should be done in conjunction with Line Intercept Transect (LIT) method. The method used for the assessment and monitoring of fish is a combination of 2 techniques. The first detects differences in assemblages of reef fishes at different sites using abundance categories. It provides baseline data for zoning, management and monitoring of coral reefs. The second technique counts individual fish and estimates their total lengths in order to determine the standing stock and population size and structure of specific species (those that are favoured by fishermen). The method is one of the most common quantitative and qualitative sampling methods used in coral reef surveys.

Background

Fish communities are a major resource of coral reefs. They play an important role in coral reef ecosystem (e.g. the role of grazers controlling algal growth), and are commercially important for both fisheries, and more recently, tourism.

Visual census techniques have been used in coral reefs around the world to assess and monitor reef fish abundance and diversity. Combination of fish visual census and Line Intercept Transect are also used to examine the influence of substrate structure on reef fish community structure.

Advantages

- Visual census of fishes is one of the most quantitative and qualitative sampling methods used in coral reef surveys.
- It is rapid, non destructive and inexpensive.
- It utilizes a minimum of manpower and specialized equipment.
- It can be used to survey the same area through time.
- It has the potential to produce large databases rapidly for management and stock assessment purposes.

Disadvantages

- The observers must be very well-trained and experienced.
- There may be repulsion and / or attraction of fishes to the divers.
- Observer's error and bias occur in estimating numbers and sizes.
- There is low statistical power to detect change in rare species.
- The use of abundance categories reduces the power to detect small changes.
- The techniques are restricted to shallow depth due to decompression constraints.

Logistics -Personnel

- The fish survey team consists of 2 or 3 divers. The observer (fish counter) must be able to identify the fish species of the area.
- One diver is designated as the observer to reduce the bias.
- In areas of high fish abundance, the technique could be divided between the 2 divers: undertaking the census using abundance categories; while the other counts and estimates the lengths of specific 'target' species.

Equipment

- Small boat with outboard engine and safety equipment.
- SCUBA equipment.
- Pencil and slates, with prepared data sheets (preprinted A4 underwater paper is recommended). Prepare data sheets after a list of fish species from the area has been compiled.
- Fiberglass measuring tape – 50m long.
- Fish models or 'fiddle sticks' to practice estimating total lengths of fishes while diving.

Site selection

- Select the sites after a general survey of the reef slope so that the sites are representative of the reef. All sites should be similar with respect to physical characteristics, slope and coral cover.
- Where possible, the site for visual censuses of fishes should include those selected for collection of benthic lifeform data using LIT. This will provide the fish team with detailed description of the reef being censused.
- Select at least two sites (replicates) on the windward slope to estimate between the site variability within the one habitat. Each site within the habited (windward slope) must be similar to the other windward sites.
- If distinct windward and leeward habitat exist, select at least 1, preferably 2, sites in each zone. In regions where reversing monsoon winds prevail, selects sites from areas of the reef exposed to the different monsoons.
- The sites within habitats should be separated from each other by a reasonable distance (100 to 200m).
- Avoid variable habitats such as spur formation, which are likely to include sand and fissures.
- Record the exact positions of all replicates. If available, a GPS can be very useful for relocating the sites.

General procedure - Selection of species

- Reconnaissance dives at each must be done to list dominant species for inclusion on prepared data sheets before the actual census begins. This minimizes the time needed to write species names on the sheets, thereby improving observer's ability to record fishes continually.
- Select species to be censused using the following criteria:
 - The species should be visually and numerically dominant, without cryptic behaviour.
 - They should be easily identified underwater.
 - They must be associated with reef-slope habitats.
- A core group of species appropriate for coral reef assessment should be made to:
 - Quantitatively estimate density and size structure of species that are favoured (targeted) by fishermen (e.g. *Serranids*, *Ludjanids*, *Lethrinids*, *Haemulids*, *iganids*).
 - Quantitatively estimate the abundance of 'indicator' species (e.g. Chaetodontids).
 - Semi-quantitatively estimate the relative abundance of other species belonging to major trophic categories (planktivores, algal grazers, fish and coral feeders) such as *Pomacanthids*, *Acanthurids*, *Caesionids*, *Scarids*, *Siganids*, *Labrids*, *Mullids* and other species that are 'visually obvious'.
- With experience, observers may be able to count each fish encountered along the transect. Where this is possible, actual counts should be done since they give greater power to data analysis.
- Sample data sheets of species should be prepared for both abundance estimates, and for density and size estimates. These data sheets should be attached to the slate.

Laying of the transect

- At each site on the reef, lay at least 3 transect lines of 50m lengths at each of the two lengths (3-5m and 8-10m)
- The transect line should include the benthic lifeform transects (LIT) whenever both fish and benthic lifeforms are surveyed at the same reef.
- The fish transect and LIT are different lengths but may use the same transect line (tape) – 50m is the lengths for individual fish census, while for the LIT, a shorter transect length (20m) is used. Count the fish first using the same transect.
- The fish transect lines are straight and follow a depth contour.
- The replicate transect lines (at least 3) at each depth are located haphazardly and should not overlap. Each transect must be separated by 10 to 20m .
- The basic unit of data collection for fish visual census is 50m x 5m. Thus, 3 replicate provide a total census area of 750m² at each depth.
- For greater safety work from the deeper transects to the shallow.

Census technique

- Wait for 5 to 15 minutes after laying the transect before counting, to allow the fishes to resume normal behaviour.
- Each transect is censused as a complete 50x5m belt. Transects should not be broken into smaller units as this will underestimate the abundance of more mobile species.
- The observer swims slowly along the transect (using the SCUBA), recording the fishes encountered within 2.5m either side of the transect, and 5m above, the transect. Always verify the diver's ability to estimate 5m before beginning the census.
- If visibility is poor, it may be reduce the width of the transect belt to 2.5m wide, 2.5m above, the transect. This should be clearly noted on the data sheet.
- Count the actual number of 'target' species seen within the transect strip and estimate the size (in cm) of each of these fish.
- Count actual number of 'indicator' species.
- Estimate the abundances of 'visually obvious' species on a cumulative log 4, abundance scale from 1 to 8 (Russ 1985).

Logarithmic abundance categories used in estimates of abundance of numerically dominant fish species (Russ 1985).

Table 5 Log 4 abundance category for fish count

Log 4 Abundance Category	Number of Fishes
1	1
2	2-4
3	5-16
4	17-64
5	65-256
6	257-1024
7	1025-4096
8	4097-16384

- Experienced observers can count actual numbers of 'visually obvious' species to provide superior data to the abundance categories. For species where fish are particularly numerous, however, abundance categories are the best estimate.
- Do not compromise getting a good overview of the community by trying to count all individual of some taxa, while not getting reliable estimates of abundance for others.
- One diver makes the census dive within the transect area while the other serves as a dive buddy swimming behind the observer and making general observations of the reef environment and the fish assemblages.
- In areas of high fish diversity and abundance, it is recommended that the tasks be separated. This can be done either by counting in 2 passes (different species each pass); or by having one diver concentrate on the 'target' species, while the second counts other species.

6.2 Bathymetry surveys

Bathymetry surveys were conducted by using GPS interfaced eco-sounder and position corrections made using total station surveying equipment. Data were presented using a computer software known as Surfer. Computer aided design software is also used in presentation of the bathymetry data collected. A bathymetry map is given in figure x.

6.3 Surface current surveys

Current direction and speed were estimated using floating drough system. Buoy was released for a specified times and the distance moved within a given time was used to calculate the speed of surface current around the island. Direction of the surface current was estimated using a magnetic compass.

6.4 Beach and beach dynamic surveys

Beach surveys were conducted by adapting qualitative visual methods and quantitative methods using total station to take beach profiles. A total of 8 beach profiles were taken around the island for assessing the beach slope profiles and amount of beach materials in different areas of the beach.

6.5 Vegetation surveys

Coastal vegetation were surveyed using line intercept transect method. A total of 16 transects of each 30m long were conducted on western coastal vegetation and a total of 3 transects of 30m each were also conducted in eastern side of the island. Qualitative visual observations of the coastal vegetation were also conducted. A total 3 transects were taken inside the island. Inside vegetation surveys were mainly conducted using qualitative methods to assess the overall status of the vegetation in terms of species and maturity of trees. Significant large tree were counted, girth perimeter measures and located using total station surveying equipment.

6.6 Soil surveys

Semi-quantitative assessment of soil of the island was conducted by taking soil profiles at various locations of the islands. Humus contents and depth of dark soil was assessed using visual assessment and taking measurement from the soil profiles.

6.7 Groundwater surveys

Groundwater surveys were conducted by taking samples from various locations of the island. The samples were taken to the National Health Laboratory and quantitatively analysed using laboratory equipments.

7. Public Consultation

Non-formal public consultations were conducted in the form of interviews with key personnel with respect to the proposed development. The people who were consulted included Abdul Rahman from nearby Uligamu island who is familiar with Madulu island environment. The general public of Uligamu is also consulted for their views on the proposed development in Madulu in terms of positive and potential negative impacts. In general the key issue raised by the public on the proposed project was assurance of the start of the project and benefits from the project to the general public.

The public consultation revealed that the expectation of the public from the project is jobs and job opportunities from the project both in the construction and operation stage of the project. In the consultation the general public including fishermen and farmers, did not raise any conflicting issues in terms of economic, social or environmental.

The tourism in the area so far only involved a relatively few tourist who come for the one operational resort in HDh. Atoll which is about 36km away. However, in near future tourism will be developed in the area as some of the resorts in the locality are under construction. The consultation with the tourism operators revealed that the proposed project in Madulu will be a bonus for future tourism operators in the area as the project would provide locally grown fresh vegetables, fruits and egg which area produced using environment friendly organic method.

The public consultation concluded that the public is looking forward for the start of the project construction and operation in order to maximize the benefits of the project to the atoll community.

8. Assessment of Direct and Indirect Environmental Impacts

8.1 Introduction

The Maldives has a very fragile environment: small volcanic islands, rising just a couple of meters above sea level, surrounded by clear, lucid waters over white coral sandy bottom and protected by corals reefs: the back born of the country.

The importance of healthy coral reefs for the country cannot be over emphasized. The islands on which we live are constructed of coral. Reefs protect islands and habitation from destruction by storm waves. Houses were built using coral. Tuna, the mainstay of the Maldivian diet depends on reef ecosystems. Reef-oriented tourism is the largest source of income for the Maldives. Therefore, protection of the natural resources should be a component of any development project.

The growth in the agriculture, tourism and fisheries sectors and related industries and services has posed threats to the quality of the environment and the natural resource stock of the country. This situation has presented serious challenges in ensuring minimal damage to the very environment on which the sustainable development of the Maldives depends.

8.2 Methodology used for Impact Identification

The environmental impacts of the proposed project have been looked into separately as follows:

- a. Existing natural and anthropogenic impacts. Extensive field surveys and assessment of the existing environment of Madulu have been conducted to establish the historic and current status.
- b. Negative and positive environmental impacts in construction and operation phase of the proposed project work. Extensive field surveys and assessment identified potential negative impacts that may result from the work activities of the proposed project.
- c. Potential environmental impacts during the operation or post-construction phase of the proposed project. A rigorous long-term monitoring programme will be implemented to identify positive and negative operation and post-construction work of the proposed project.

Impacts on environment of the island system from various activities of the proposed project work and operation of the island as an agriculture island, have been identified through analysis of the proposed project, discussions with the project proponent, extensive field surveys, observations and assessment as well as based on field experience of similar other work in the country. Quantitative, semi-quantitative and qualitative methods were used to collect data and information on the island environment and the proposed project by field work and consultations. These data and information were analysed to predict significance and extent of impacts that may arise from the proposed project activities. Analogous project data have been used wherever possible since the use of such data is applicable and less time consuming and makes the impact prediction and analysis more accurate.

The problem in data collection imposed by the time constraint, unavailability of data, and gaps in knowledge did not allow for the quantification of impacts on the environment from the proposed work fully and very thoroughly. In addition lack of guidelines on, for instance set standards and acceptable values of turbidity, siltation or sedimentation on the reef and the lagoon during construction and operation, complicated identification of potential impacts due to the project. So this assessment did not compare how much the proposed work could cause siltation/sedimentation on the reef and siltation on lagoon bottom to depart from the standard set values. Consequently it was not possible to use predictive analysis to fully determine the nature, magnitude, extent, significance of the impacts critically. Therefore, it was opted for describing these impacts as determined by expert judgment, in addition to the acquired data and information from the field surveys.

This assessment identified and quantified the significance of possible negative impacts of the proposed work on the environment. Impacts were identified and described according to their type, extent, short-term or long term, reversible or irreversible and assessed in terms of their significance according to the following categories:

- d. Negligible – the impact is too small to be of any significance (category I);
- e. Minor negative – the impact is undesirable but acceptable (category II);
- f. Moderate negative – the impact give rise to some concern but is likely to be tolerable in short-term or will require judgment as to its acceptability category III);
- g. Major negative – the impact is large scale, give rise to great concern, it should be considered unacceptable and requires a significant change to the proposal (category IV).

8.3 Existing Natural and Anthropogenic Impacts

The field surveys and assessment revealed that environment of the island system have been impacted both by natural and anthropogenic causes to varying degrees. Impact due to the tsunami in 26 December 2004 was identified not significant in general. Field surveys of the reef, beach, coastal and inland vegetation and groundwater showed that there was no significant impact due to the tsunami. Natural impact identified were significant beach erosion especially in northwestern side of the island beach. Major anthropogenic negative impacts included clearance of significant area of vegetation in the central area of the island and path through the vegetation. Approximately 1.5 hectares (10%) of vegetation were cleared in the central area of the island for agriculture use in the past. Analysis of aerial photos taken in 1969 and interviews with the locals in the locality revealed that Madulu had been used for agriculture for over forty years. At present bushes and weeds are grown in the previously cleared area of the vegetation.

8.4 Physical Impacts in Construction Stage

Major negative impacts on environment of the island would be associated mainly with the work activities of the proposed project. Significant negative impacts due to the proposed work activities would be on the vegetation from partial and total vegetation clearance for farming and on marine environment from construction of jetty to a lesser extent. Negative impacts of proposed work activities on other attributes i.e. beach and coastal vegetation would be not significant in terms of nature, extent and magnitude as shown by the assessment of the proposed project work activities and existing environment.

Significant direct and indirect negative impacts arising from the proposed work activities would be attributed to the following activities of the project

8.4.1 Structures on land

Development of proposed structures on land will impact the vegetation of the island in northern area of the island. Approximately 4000m² (3%) area of vegetation will be permanently removed for the proposed development of accommodation and service building structures and access roads. This impact is not considered to be a significant impact to the vegetation as the total area of the vegetation.

8.4.2 Harbour

The size of the proposed harbour is 100m x 50m. An area of 5000m² in the lagoon northwest of the island will be excavated so that the harbour area will have a depth of 2m at low tide. Actual depth of the excavation of the lagoon floor will be approximately 1m as the average depth of the lagoon in the area is 1m during low tide. Approximately 5000m² area of the lagoon bottom will be removed. With this fauna in the lagoon bottom in this area will be removed. Direct impacts of harbour development will be felt in an area of approximately 6600m² as during excavation materials will be piled in the lagoon to create a bed of sand on which the excavator to carry out excavation. Excavated materials will also be used to put a bund-wall around the

excavation area to retain fine sediment within the area so that spreading of sediment plumes will be minimized. All the excavated materials will be taken out when the excavator rolls back after excavation work is completed. The materials will be used to fill in the eroded area in northwest of the island. As Bathymetry of the lagoon will be altered after excavation in the harbour area, hydrodynamic in the lagoon maybe changed however, as it is approximately 100m away from the shoreline possible impacts to the island beach will be minimum. After installation of the harbour walls and the breakwater hydrodynamics will be further altered due to these solid structures. However, as it is a detached harbour impacts to the shoreline and the beach will be minimum.

8.4.3 Harbour jetty

Construction of harbour jetty will impact the lagoon area of approximately 345m² directly due to installation of the concrete columns. Approximately 2500m² of lagoon bottom will be indirectly impacted due to the jetty construction activities and operation of excavator in the area. Part of the jetty will also be in the beach however, impact on the beach from jetty construction will not be significant as the jetty will be on columns. Alteration of hydrodynamics in the lagoon due to the jetty will be minimum as the jetty will be on columns.

Indirect impacts due to jetty construction will be felt on the lagoon water column mostly from release of fine sediment in the lagoon bottom as a result of disturbance to the lagoon during the jetty construction. Impacts of sediment spreading in the lagoon will impact an estimated maximum area of approximately 5,000m² if the work carried out in relatively calm conditions. Extent of impact resulting from sediment spreading in the lagoon environment will depend very much on the status of the current regime tidal status.

8.4.4 Entrance channel

A 30m long and 25m wide entrance channel will be cleared to create an access channel through the reef in western side of the island. Since the reef in the area is deep the actual reef clearance will be removal of boulders and coral bomies in the area. Approximately 750m² of the reef in western side of the island maybe impacted due to the proposed channel clearance. Impact to the reef due to channel clearance will not be significant in terms of living reef benthos as the proposed area has coral rock consisting of 48%, sand consisting of 28%, rubble consisting of 20%. Only 5% of the reef consisted of live corals in the area.

8.4.5 Southwest jetty

A 38m long 4m wide jetty will be constructed in southwestern side of the island as a means of access to the island by larger sea vessels. The jetty will be constructed by erecting concrete columns in the lagoon and in the beach. Approximately 6m length of the jetty columns will rest in the beach and 36m will rest in the lagoon bottom. Conventional materials and methods will

be used in construction of the jetty. The top platform of the jetty will be constructed using re-enforced concrete and timber. The concrete columns will be pre-casted on land and placed in the lagoon manually using excavator.

The jetty will cover maximum of approximately 30m² of beach area and 114m² of lagoon area. The actual area of the lagoon bottom covered by the footings of the concrete piles will be less than this area. The direct impact of jetty construction will be felt on a lagoon bottom area of approximately 114m². However, during the construction of the jetty, direct impact to the lagoon bottom will be felt to a greater area as the concrete columns are being install. It is estimated that approximately twice the size of the jetty, approximately 288m² area of the lagoon bottom area will be impacted during the jetty construction.

Impact to the coral reef of the island will be insignificant as reef is not found in the proposed location of the jetty.

The proposed location of the jetty has only a sandy lagoon slope. The above estimation is based on observation of the jetty construction and field surveys and assessments

8.4.6 Vegetation clearance

Vegetation clearance to prepare land for cultivation of vegetables and fruit and poultry farming will have a significant impact on the islands vegetation in terms of area of vegetation loss. However, plots used for cultivation will be only partially cleared. Partial clearance will only remove bushes and weeds leaving large and significant trees. Approximately 75,000m² of vegetation (51%) will be partially cleared.

8.4.7 Coastal protection

The proposed coastal protection is in northwestern side of the island where there is severe permanent erosion. It is proposed that materials taken from the proposed harbour excavation will be used to fill in the eroding area. Part of the filling will fall into the lagoon adjacent to the filling area therefore the lagoon in this area maybe impacted due to spreading of sediment plumes from the filling material. Approximately 2000m² of the lagoon may in indirectly impacted during filling period.

The following table summarizes the extent of direct physical impacts on various attribute of the island environment from various project activities.

Table 6 Extent of predicted physical impacts

Attribute impacted	Reef	Lagoon	Shore / beach	Vegetation
Work activity				
Structures on land	0	0	0	4000m ²
Harbour	0	6600m ²	0	0
Harbour jetty	0	2500m ²	180m ²	0
Entrance channel	750m ²	500m ²	0	0
Southwest jetty	0	880m ²	48m ²	0
Land clearance	0	0	0	75000m ²
Coastal protection	0	2000m ²	3000m ²	0
Total impacts from all activities	750m ² (0.6%)	12,480m ² (10.5%)	3,228m ² (21%)	79,000m ² (54%)

8.5 Ecological Impacts in Construction Stage

Potential negative ecological impacts on the terrestrial and the marine environment from the proposed work are more variable and difficult to predict as the long-term data are not available. It is predicted that the following impacts maybe felt due to the proposed work activities.

- Turbidity increase in the water column from spreading of silt plumes.

When lagoon floor is disturbed by excavation, fine sediment and silt may be released into the water column. Lagoon sediments consisting of varying sizes of particles may be suspended for hours in the water column cutting down light to photosynthetic reef benthos. The magnitude of this impact will depend on various factors such as size of particles; hydrodynamic conditions; and reef and lagoon topography. In addition to this may infauna and their habitats will be lost. However, it found that lagoon infauna re-establishes sometime after excavation of the lagoon bottom.

- Possible siltation and excessive sedimentation on coral reef

Excessive sedimentation and siltation on coral reefs is detrimental to corals and other reef benthic organisms as it cuts down necessary light and physically smothers corals. This may reduce coral growth and more importantly coral recruitment. Sediment free reef substrate is needed for coral larvae to settle

and grow and continue the reef building process. In addition to this some of the coral colonies will be physically removed that may result in loss of other important reef benthic organisms.

- Direct disturbance of the lagoon bottom by excavation and filling lagoon bottom with sand may result loss of habited for some lagoon infauna such as polychaete worms and amphipods which inhabit in the lagoon bottom.

Lagoon bottom is an important habitat for certain organisms such as worms, mollusks, amphipod etc. which are important food sources for bottom feeders such as certain species of fishes. By removing sand from the lagoon bottom would disturb habitats of these organisms.

Long-term ecological impact arising from the proposed work activities is not predicted to be significant as the proposed work is limited and localized in a small part of the island system. However, long-term monitoring is required to identify ecological impacts more completely and thoroughly.

The following table shows magnitude, duration and significance of predicted impacts to the island environment due to the proposed project work activities.

Table 7 Impact significance

	Harbour jetty construction	Harbour development	Southwest jetty construction	Channel clearance	Coastal protection	Vegetation clearance	Equipment operation
Magnitude of impact / Impact category	Category II Minor negative	Category III Negative	Category II Minor negative	Category II Minor negative	Category II Minor negative	Category III Negative	Category II Minor negative
Duration of impact	Short-term	Long-term	Short-term	Long-term	Short-term	Long-term	Short-term
Reversibility	Reversible	Reversible	Reversible	Reversible	Reversible	Reversible	Reversible
Impact significance	Significant	Significant	Significant	Significant	Significant	Significant	Significant

8.6 Physical Impacts of Operation Stage

The operation or using of the proposed channel and mooring area will not have significant negative physical impacts on the environment of the island system. Based on other similar projects potential operation impacts maybe related to periodic maintenance of the deepened channel through the lagoon and the mooring area. This maintenance impacts is related to periodic deepening that maybe require maintaining the depth of the channel and the mooring area. Magnitude of this impact will depend on the rate of filling up of the area by natural sedimentation. This impact however, small and limited to few activities will be long-term and therefore will be assessed through long-term monitoring. Positive impacts as a result of this project will be safeguarding the island environment from negative impacts such as illegal sand extraction from the beach by the locals Potential operation negative impacts will be as follows;

- Turbidity increase in the lagoon water from the boat activities in the channel and the mooring area.

Propellers of the boats can disturb lagoon bottom and increase turbidity of the lagoon water as the boats come into the mooring area and leave from the mooring area. Aesthetic value of the lagoon maybe reduced in addition to negative impacts of disturbance to the lagoon bottom organisms. Certain pelagic species especially fishes inhabiting in the lagoon maybe negatively impacted due to increase of turbidity above the natural level.

- Turbidity increase in the lagoon water of the surrounding as a result of periodic maintenance deepening of the channel and mooring area.

Deepening by excavation of the lagoon bottom will increase turbidity of the lagoon water resulting in similar consequences as mentioned above.

- Alteration of lagoon bottom community as a result of periodic maintenance deepening of the channel and the mooring area

Periodic excavation to maintain the needed depth of the mooring area may not allow for the lagoon bottom organisms to establish after and thus benthic community may change. This change maybe decrease abundance and diversity

- Impact of the wake produced by the vessels on the beach

Vessels that come to the mooring area may produce wake that can lead to coastal modification over long-term. This may result in beach erosion depending on rate and extent of the use of the mooring area.

8.7 Ecological Impacts of Operation Stage

Biological and ecological impacts related to the proposed development can be long-term and difficult to identify and assess in short-term. These impacts maybe related to chronic turbidity increase in the lagoon water and its consequences to the ecology of the lagoon and the reef. Biodiversity in the area maybe reduced over long-term and community structure of the lagoon bottom may also be changed from the natural status to a different one. Lagoon bottom and pelagic species composition maybe changes to species that is more resilient to changing environmental conditions due to high water turbidity.

Ecological impacts of the operation of proposed project will be assessed in detail through implementation of the monitoring programme given in the report.

8.8 Socio-economic impact

The proposed project will be investing Rf20 million for infrastructure development including the proposed work activities. A significant amount of this will be distributed within the atoll community. In addition to this a significant amount of money per year will be spent as salary for the permanent employees. Also revenue for the Government from this project will be the lease rent of Rf 13 million over a period of 5 years.

One of the most important positive impacts of the proposed project will be both short-term and long-term positive socio-impacts to the atoll community. Direct positive short-term socio-economic impacts will be creation of jobs and job opportunities within the atoll during the project work activities. It is estimated that the proposed project work activities will create over 200 jobs directly related to the proposed work activities. In addition to this local people from the atoll and other regions will be trained for cultivation of vegetables and fruits in sustainable manner and permanent jobs will also be created in the island in long term. Agriculture sector in the atoll will be developed and expanded to meet the demand for agriculture products for the local people as well as for the upcoming tourist resort islands in the atoll as well as nearby atoll.

9. Mitigation measures

9.1 Mitigation Measures in Construction Stage

Early planning is the key to minimise the impacts on the marine and coastal environment from the proposed development in Madulu island. If environmental concerns are considered concurrently with technical and logistical planning of the proposed work and precautions are applied from the outset of the planning process it will not be difficult to mitigate and minimise the negative impact from the proposed development on the environment of the island.

In all development projects, it is essential to identify possible impacts to the natural environment and suggest best possible ways of minimising or overcoming those impacts. In this regard, there is a number of mitigation measures that are taken can be taken to minimise the impacts identified in the previous section of this report. Therefore, it is important to take the following mitigation measures to minimise the impacts form the proposed development in Madulu island.

1. Locations of the proposed structures are selected based on extensive field surveys and assessment of the terrestrial and the marine environment of the island.
2. Two locations most suitable for the proposed jetty construction and harbour development in terms of feasibility and least impact has been assessed in detail to select most appropriate location.
3. The proposed development was assessed to decide the minimum required infrastructure development.
4. The jetty and harbour are located in the most sheltered location with no reef area so that no reef clearance or blasting will be needed
5. The proposed development in Madulu will be completed in as short period as possible and the work in marine environment will be carried out during outward drift of current so that potential sediment settling on the reef would be minimised. Therefore, the proposed work of channel clearance and lagoon deepening will be conducted when the current direction is away from the reef.

6. Possible spreading of sediment plumes due to the excavation of lagoon will be controlled and minimised by use appropriate retention methods. Conventional method used for retention of sediment plume due to the lagoon excavation is by enclosing the area with bund wall prior to excavation.
7. Vessels and equipment used for the work will be properly maintained at all times during the operation to avoid possible damage to the environment from them.
8. The project manager, and the work force involved during the operation of the work will be briefed of environment friendly practices.
9. The work will be properly supervised and monitored to minimise negative effect on the environment.
10. The terrestrial and the marine environment will be monitored for potential impacts on the biological and ecological aspects of the environment.
11. Littering and accidental disposal of any construction wastes will be avoided by pre-planning modalities for waste disposal or re-use wherever possible. Careful planning of the work activities will be carried out to reduce the amount of waste generated.
12. Whenever heavy equipment and vessels are mobilized closer to the reef care will be taken to avoid accidents and damage to the reef

The following table summarizes the general measures that will be taken to minimize impacts during the main work activities of construction stage of the project.

Table 8 Mitigation measures in construction stage

	Construction of jetties	Channel clearance	Equipment operation	Harbour development	Vegetation clearance
Mitigation measures	Use silt screen or other appropriate methods to prevent spreading of sediment plumes Conduct work during low tides and calm conditions Use environmentally friendly materials and methods	Avoid damage to reef and relocate any coral colony in the channel area to other location where there will be no development	Maintain equipment in best condition Conduct work during low tides and calm conditions	Avoid damage to reef and relocate any coral colony in the harbour area to other location where there will be no development Use bund walls to prevent sediment plumes Conduct work during low tides and calm conditions	Relocate all the trees that are significant in age and species to other locations where there will be no development
	Complete the work in shortest time period	Conduct work during low tides and calm conditions	Complete the work in shortest time period	Complete the work in shortest time period	Complete the work in shortest time period
	Use manual methods as much as possible	Complete the work in shortest time period	Use manual methods as much as possible	Use manual methods as much as possible	Use manual methods as much as possible
	Organize and inspect the work to minimize impacts	Use manual methods as much as possible	Organize and inspect the work to minimize impacts	Organize and inspect the work to minimize impacts	Organize and inspect the work to minimize impacts
	Create awareness and brief the workforce how to minimize impacts	Organize and inspect the work to minimize impacts	Create awareness and brief the workforce how to minimize impacts	Create awareness and brief the workforce how to minimize impacts	Create awareness and brief the workforce how to minimize impacts
	Minimize waste generation	Create awareness and brief the workforce how to minimize impacts	Erect signboards on environmental protection	Minimize waste generation	Minimize waste generation
	Erect signboards on environmental protection	Erect signboards on environmental protection		Erect signboards on environmental protection	Erect signboards on environmental protection

9.2 Mitigation Measures in Operation Stage

Most of the impacts of operation will be identified during operation of the project hence mitigation measures during the operation of the proposed project will be subject to rigorous and continuous environmental monitoring that is presented in this report. Some of the predicted operation impacts are waste, boat activities and general impacts from human habitation.

Waste management will be included in the overall environment management plan of the project. Waste generation will be minimized through use of appropriate operational methods. Packaging of goods brought into the island will be controlled and minimized. Usable materials such as cardboard, timber and other materials will be reused in packing of products that will be taken out of the island. Biodegradable wastes such as kitchen wastes, plant wastes and waste produced by poultry farm will be used for composting to make fertilizers that will be used for cultivation of vegetables and fruits.

Use of groundwater will be minimized through recycling of water and waste water from the toilets and kitchen. Rainwater will be collected and stored as much as possible to be used for bathrooms and watering plants. Mostly desalinated water will be used for all purposes of the operation of the project.

Energy used will be minimized through use of energy efficient tools and equipment. Minimum electric lightings will be used for buildings and utilities. Energy efficient light bulbs will be used throughout all the facilities. Solar energy will be used as much as possible as appropriate.

Potential impacts to the coral reef will be minimized through proper coral reef and fish monitoring and evaluation. Beach and shoreline will be monitored for erosion and measures will be taken to mitigate and minimize impacts. Groundwater samples will be tested periodically to keep check of potential contamination due activities of the project operation. Vegetation including bushes, plants and large trees will be monitored for pest and insect infestation.

Environmental awareness among the staff and laborers will be created through awareness campaign and programmes to mitigate impacts of workforce and the senior staff working in the island. Environmental monitoring reports will be evaluated by competent environmental specialist in addition to submitting them to the Government authorities.

10. Evaluation of Alternatives

Alternatives developments including no development option for the proposed development have been evaluated. Alternative developments are evaluated based on physical and biological environment of the island as well as the costs and feasibility of the proposed project development components. These are;

10.1 Alternative location for the jetty.

Northwestern side of the island was the next most appropriate location for a jetty construction in terms of costs and feasibility of usage. Construction of jetty to reach the deep lagoon in this location will be more expensive and the impacts on the lagoon environment will be more as the length of the jetty should be more if this location is chosen. A shorter jetty in this location be constructed however, lagoon will be needed to deepen and an entrance through the reef should also be made if this location is chosen for a jetty. This alternative therefore, will be more costly and damaging to the marine environment of the island lagoon as well as to the reef.

10.2 Alternative location for harbour

Harbour can be created only in western side of the island as the eastern side lagoon is too narrow. Hence the only alternative location for a harbour is southwestern side. However, the lagoon in south western side of the island is very deep hence breakwater for the harbour cannot be constructed to provide shelter for the harbour. In addition the lagoon in southwester side of the island had a limited area for harbour of required minimum size.

10.3 Scale of the Project and allocation of land area

Land area needed for cultivation and poultry farming was evaluated based on the scale, duration, lease rent and investment of the project in order to make the project profitable. Less land area than proposed area of land for agriculture development was found to be not feasible for the project in terms of sustainability of the project.

10.4 Alternative location (island) for the project

The project location (island) has been identified and allocated by high level consultation within the concerned Government agencies. These consultations involved technical as well as overall development policy currently being implemented. In terms of minimizing environmental impacts and maximizing economic benefits Madulu will be the best location for the proposed project. Madulu had been used for agriculture purposes from long time ago until recently. Large part of the vegetation is already cleared

for farming and the access to the island is easy as the deep lagoon is close to the island in southwestern side of the island. The island is also close to the considerable population of the atoll.

10.5 *No development option*

The no project development option can avoid all the negative impacts to the environment. However, no project development option can also have the risk of the island environment being neglected of environmental protection in long-term. For instance the coastal erosion can lead to loss of a significant amount of coconut palms and loss of land causing adverse natural environmental impacts in long-term. No project option will also result in loss of the socio-economic opportunities to the locals and to the country as a whole.

11. Impact Monitoring

Since most environmental changes occur over long period of time, it is important to implement a specific long-term monitoring programme for the marine and coastal environment. the coastal zone irrespective of the options chosen because no method or option particularly guarantees a stable coastline. It is important to monitor the effects of development prior to, during and after project implementation. It will also be important to ensure that environmental design criteria are met during construction. This can be achieved by inspections at appropriate intervals during the construction phase. Environmental supervision or inspection during project implementation was not practiced in the Maldives until recently. Recent environmental supervision or inspection has proven to be an effective tool in minimising the impacts and in ensuring that appropriate precaution and care is employed.

11.1 Monitoring of coastal and beach environment

Coastal and beach monitoring, must focus on both construction and operation stages of the proposed project. Coastal and beach monitoring should also consider monsoonal changes and the transitional period and therefore long-term coastal monitoring shall be carried out at least in every three month intervals. The following monitoring requirements may be adequate for the purpose of evaluating potential environmental effects from the proposed development in order to implement more effective mitigation measures.

1. Beach profiles will be taken at designated locations at not more than 50m distance from one another to provide enough data to establish changes in coastline at designated locations and around the island.
2. Currents will be monitored using current meters or drogues.
3. Wind and tide data will be obtained from the meteorological records. However, it would be useful to measure wind speed and directions at the site
4. If available, periodic aerial photos may also be used to assess long-term changes to the hydrodynamic and littoral regimes.

11.1.1 Monitoring programme for the beach and coastal zone

Following table shows coastal and beach monitoring programme suggested for the proposed development project in Madulu island.

Table 9 Beach & coastal monitoring programme

Parameters / Method	Frequency of monitoring	Purpose
Beach/erosion & accretion Beach profiles	Before and after project implementation and every three months afterwards	Understand the changes to the beach profile of the island and how sand moves around the island
Sediment dynamics Currents (using drogue or current meter)	Before and after project implementation and every three months afterwards	Understand how currents vary in the coastal system and assess its relation to sand movement around the island
Sediment dynamics Bathymetry	Every six months before and after project implementation	To monitor the effects of shoaling
Sediment dynamics Waves and tides	Once or twice a year	Understand effects on coastal environment including erosion & accretion

11.1.2 Monitoring programme for the terrestrial environment

Table 10 Terrestrial environment monitoring programme

Parameters / Method	Frequency of monitoring	Purpose
Vegetation Transects and visual observations	Twice a year	Understand the changes to the vegetation and vegetation cover as percentage of the island
Fauna Visual observation	Every month	To monitor pests such as rats and insects that may cause impact to the vegetation
Groundwater – physical appearance, pH, salinity, phosphate, nitrate, sulphate Laboratory test of groundwater samples	Every three months	To take mitigation measures in case of increasing salinity due to water extraction, or deviation of phosphate, nitrate and sulphate from the natural (baseline) levels.

11.2 *Monitoring programme for the marine environment*

Suggested marine environmental monitoring programme to assess and mitigate possible major negative impact on the marine environment is given below. The impacts predicted above and the effectiveness of the control and mitigatory measures proposed must be evaluated during the work and changes brought if necessary.

The parameters that are most relevant for monitoring the impacts that may arise from the proposed project activities and operation are included in the monitoring plan. These include turbidity and nutrient contents of lagoon water, sedimentation and live coral cover and coral recruitment. Monitoring will be carried out as part of the environmental impact assessment and mitigation of possible negative impacts from the proposed project of the resort redevelopment.

11.3 *Aim of Monitoring*

The primary aim of the monitoring is to provide information that will aid impact management, and secondarily to achieve a better understanding of cause-effect relationship and to improve impact prediction and mitigation methods.

11.4 *Objectives of Monitoring*

The following monitoring plan is used to measure impacts that occur during the proposed project activities and determine the accuracy of impacts that are predicted and the effectiveness of mitigation measures. The objectives of the monitoring plan are to measure:

- the amount of sedimentation on the reef
- water quality and visibility
- coral cover and recruitment and
- beach erosion

to ensure that these measurements are kept within the baseline limits and predicted impacts are accurate and mitigation measures taken are effective.

The following table shows methods, parameters monitoring, frequency and purpose of the marine environmental monitoring programme.

Table 11 Marine environment monitoring programme

Methods / Parameter	Frequency of Monitoring	Purpose
Ambient Environmental Temperature, Salinity, Turbidity/light penetration, Currents	Twice a month during the work And once every two months thereafter	Important to the 'health' of living marine resources, reefs and fish populations and other benthos
Coral reef Manta Tow Technique or Time Swim	Once after the work is completed And once every year thereafter	Broad scale qualitative and Semi-quantitative assessment of general status of the reef system / coral and other benthic organisms
Marine Environmental Aesthetic Survey using Time Swim and Manta Tow Technique	Once after the work is completed	Broad scale semi quantitative assessment of anthropogenic activities e.g. wastes disposal, amount of rubbish on the reef and general appeal of the reef system
Fish populations Underwater Fish Census	Once after the work is completed And one every year thereafter	Quantitative assessment of fish population of selected species
Coral cover/recruitment Permanent Photo Quadrates	Once after the work is completed And twice every year thereafter	Quantitative assessment of temporal changes in the reef system e.g. coral growth rates
Sedimentation Sediment traps deployment/collection	Twice a month during work and Once every 3 months thereafter	Quantitative assessment of sediment loading on the reef benthos.
Water quality Water quality test	Once every month	Quantitative assessment of Nitrogen and Phosphorous contents and other parameters: Assess total Dissolved Solids

The objectives of this monitoring program are to detect and document the changes occurring to the reef system due to the proposed project. The purpose will be to 1) assess the magnitude of the impacts resulting from the various stages of the proposed work and 2) to take mitigation measures to minimize the negative impacts and protect the reef and the lagoon system of the island.

Table 12 Estimated cost of environmental monitoring

11.5 Breakdown of Monitoring Yearly Monitoring Cost

Activity	Quantity	Cost USD
Establishment of baseline environmental status for monitoring	1	5,000/-
Field work	24	3,000/-
Document preparation	4	3,000/-
Logistics (for 12 trips)	1	1,000/-
Travel and accommodation for a team of four (No. of trips)	12	20,000/-
Total		32,000/-

12. Conclusions

This environmental impact assessment study depicted that the proposed development project will cause a short-term significant impact to the marine and terrestrial environment of the island. The impact to the marine environment arising from the proposed development will be felt on the lagoon environment on southwest of the island that would arise from construction of the proposed jetty. This impact will be the loss of the natural habitat for lagoon infauna of the lagoon environment due placing of the concrete footings of the jetty columns. However, in terms of area this impact can be said insignificant as it will impact approximately 2% of the island lagoon. Short-term impacts of this development activity will be spreading of fine sediment in the lagoon water which will be minimized through appropriate mitigation measures.

Most significant impact on the terrestrial environment will be felt on the island vegetation from the proposed vegetation clearance in the central area for farming activities. However, vegetation clearance is proposed in two levels to minimize the impacts. Partial clearance of the vegetation will remove only the bushes and leave the large trees intact. Total clearance will involve removal of large trees and these trees will be re-located as much as possible.

Socio-economic impact of the proposed project will be creation of job opportunities in the atoll and development of the agriculture industry in the country. The project will create enormous economic opportunities both in the construction and operation stage through creation of both short-term and permanent jobs and business opportunities especially for the locals. The project will also provide better dietary products for the locals and tourist resorts through production of fresh fruits and vegetables.

In terms of long-term benefits, the project will help to sustain the existing environment through consistent monitoring, evaluation and taking appropriate action to protect and preserve the ecology of the island.

This assessment showed that negative impacts to the island environment system arising from the proposed project is relatively low and the benefits of the project is justified in terms of benefits to the socio-economic environment and conservation of natural environment as the developer is taking responsibility for environmental protection and conservation of the island system.

13. Appendices

13.1 *Appendix 1. Terms of reference*

13.2 Appendix 2. Additional technical information and baseline data
western side coastal vegetation cover

Madulu	W.side		
TS1			
Boashi	0	300	300
Bare	300	910	610
Magoo	910	1520	610
Boashi	1520	1920	400
Magoo	1920	2730	810
Boashi	2730	3000	270
TS2			
Magoo	0	570	570
Boakashikeyo	570	920	350
Uni	920	1240	320
Magoo	1240	2220	980
Boakashikeyo	2220	2760	540
Bare	2760	3000	240
TS3			
Uni	0	600	600
Boakashikeyo	600	880	280
Magoo	880	1030	150
Boakashikeyo	1030	1090	60
Magoo	1090	1530	440
Boakashikeyo	1530	1930	400
Magoo	1930	2080	150
Boakashikeyo	2080	2420	340
Magoo	2420	3000	580
TS4			
Boakashikeyo	0	460	460
Magoo	460	590	130
Boakashikeyo	590	930	340
Magoo	930	1110	180
Boakashikeyo	1110	1400	290
Magoo	1400	1640	240
Boakashikeyo	1640	1790	150
Magoo	1790	1900	110
Boakashikeyo	1900	2070	170
Magoo	2070	2540	470
Boakashikeyo	2540	3000	460
TS5			

Magoo	0	140	140
Bare	140	440	300
Hirundhu	440	1010	570
Bare	1010	1500	490
Boakashikeyo	1500	2750	1250
Kaani	2750	2910	160
Boakashikeyo	2910	3000	90
TS6			
Boakashikeyo	0	160	160
Magoo	160	1170	1010
Boashi	1170	1390	220
Magoo	1390	1660	270
Boakashikeyo	1660	2230	570
Magoo	2230	3000	770
TS7			
Boakashikeyo	0	1450	1450
Magoo	1450	1800	350
Boashi	1800	2000	200
Uni	2000	2200	200
Boashi	2200	2280	80
Magoo	2280	2620	340
Boakashikeyo	2620	3000	380
TS8			
Boakashikeyo	0	540	540
Magoo	540	1460	920
Boakashikeyo	1460	2900	1440
Magoo	2900	3000	100
TS9			
Magoo		60	60
Boakashikeyo	60	370	310
Magoo	370	1770	1400
Boakashikeyo	1770	2050	280
Magoo	2050	2260	210
Boakashikeyo	2260	3000	740
TS10			
Boakashikeyo	0	3000	3000
TS11			
Boakashikeyo	0	1710	1710
Magoo	1710	2420	710
Boakashikeyo	2420	3000	580
TS12			

Boakashikeyo	0	550	550
Uni	550	1430	880
Boakashikeyo	1430	2050	620
Dhigga	2050	2210	160
Boakashikeyo	2210	2820	610
Uni	2820	3000	180
TS13			
Uni	0	200	200
Dhigga	200	880	680
Boakashikeyo	880	1340	460
Uni	1340	1770	430
Dhigga	1770	2240	470
Boakashikeyo	2240	3000	760
TS14			
Dhigga	0	1050	1050
Uni	1050	1360	310
Dhigga	1360	3000	1640
TS15			
Dhigga	0	710	710
Boakashikeyo	710	1500	790
Dhigga	1500	1710	210
Boakashikeyo	1710	3000	1290
TS16			
Boakashikeyo	0	220	220
Ruh	220	480	260
Boakashikeyo	480	2010	1530
Uni	2010	2820	810
Kaani	2820	3000	180

Inside side vegetation cover

Inside vege			
TS1			
Mirihi	0	90	90
Ruh	90	130	40
Mirihi	130	610	480
Vina	610	840	230
Boakashikeyo	840	1020	180
Ruh	1020	1090	70
Vina	1090	1210	120
Bare	1210	1300	90
Boakashikeyo	1300	1470	170
Midhili	1470	1520	50
Vina	1520	1720	200
Mirihi	1720	2240	520
Ruh	2240	2300	60
Mirihi	2300	3000	700
TS2			
Boakashikeyo	0	560	560
Mathivah	560	1010	450
Midhili	1010	1190	180
Bare	1190	1590	400
Midhili	1590	1640	50
Ruh	1640	1770	130
Boakashikeyo	1770	2000	230
Midhili	2000	2130	130
Boakashikeyo	2130	2450	320
Mirihi	2450	2530	80
Mathivah	2530	2580	50
Mirihi	2580	2940	360
Boakashikeyo	2940	3000	60
TS3			
Vina	0	650	650
Fuan	650	760	110
Bare	760	1220	460
Vina	1220	1330	110
Boakashikeyo	1330	1450	120
Bare	1450	3000	1550

Eastern side coastal vegetation cover

TS1			
Kandoo	0	80	80
Bare	80	320	240
Kandoo	320	570	250
Bare	570	720	150
Kandoo	720	850	130
Bare	850	950	100
Kandoo	950	1110	160
Bare	1110	1370	260
Kandoo	1370	1790	420
Bare	1790	2200	410
Kandoo	2200	3000	800
TS2			3000
Uni	0	70	70
Bare	70	500	430
Kaani	500	740	240
Uni	740	1120	380
Bare	1120	1480	360
Uni	1480	1750	270
Boakashikeyo	1750	1980	230
Uni	1980	2200	220
Boakashikeyo	2200	2320	120
Kaani	2320	2550	230
Boakashikeyo	2550	2720	170
Bare	2720	2960	240
Boakashikeyo	2960	3000	40
			3000
Kuredhi	0	2120	2120
Bare	2120	2470	350
Kaani	2470	2880	410
Kuredhi	2880	3000	120
			3000

Coral cover data

Madulu	Site 1		
0		1180	POR
50	RK	1195	RK
60	RL	1205	P.VAR
70	POR	1207	RK
120	RK	1210	ACR
125	S	1240	RK
130	FUNGI	1245	P.VAR
150	RK	1280	RK
153	P.VAR	1305	S
180	RK	1340	RK
190	POR	1345	ACT
247	RK	1460	RK
303	RL	1465	ACR
345	RK	1472	RK
445	RL	1480	ACR
480	RK	1500	RK
490	P.VERU	common genera	
618	RK	Acropora	
625	P.VAR	Astreopora	
630	RK	Echinopora	
635	ACB	Favia	
654	RK	Fungia	
660	POR	Galaxea	
702	RK	Goniopora	
706	P.VAR	Laptoria	
712	RK	Porites	
718	POR	Pocillopora	
810	RK	Soft Coral	
815	ACB		
860	RK		
865	P.VERU		
1023	RK		
1027	P.VAR		
1050	RK		
1080	S		
1090	POR		
1130	RK		
1140	POR		

Madulu Site 2

0
 72 rl
 160 rk
 190 s
 230 rk
 260 act
 364 rl
 410 rk
 450 rl
 460 Porites
 475 rk
 480 Porites
 500 rk
 510 s
 528 rk
 535 P.var
 603 rk
 620 rl
 650 rk
 690 rl
 941 rk
 980 rl
 1010 rk
 1018 dc
 1022 Porites
 1085 rk
 1460 s
 1470 rk
 1475 rl
 1478 acr
 1500 rk

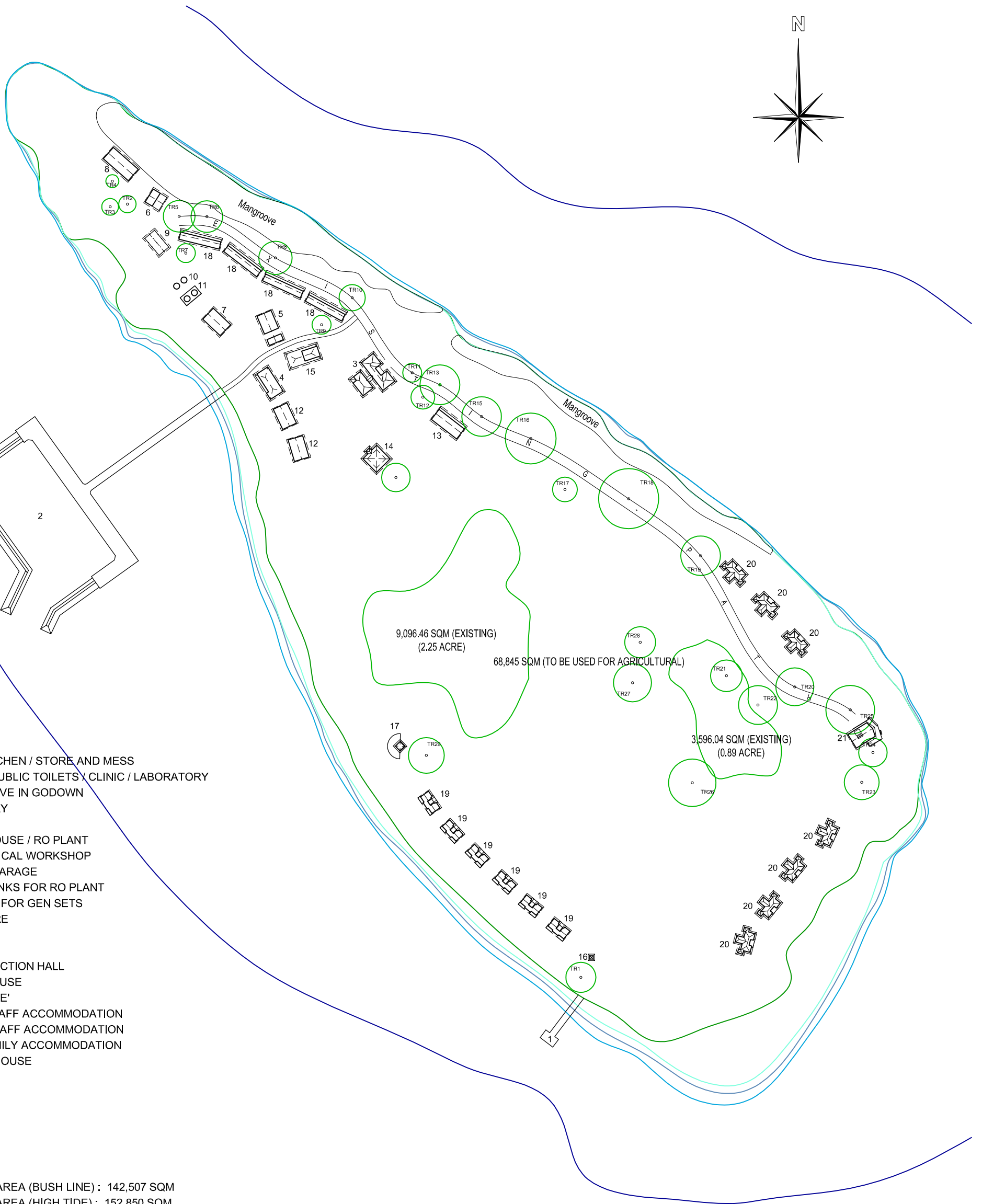
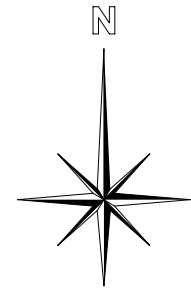
	VOS 3	VOS 4	VOS 5	VOS 6
RK	80	70	20	40
RL	13	12	9	19
S	5	15	70	40
LC	2	3	1	1
	100	100	100	100

Fish survey data

Family	Species	VOS 3	VOS 4	VOS 5	VOS 6
Acanthuridae	<i>Acanthurus leucosternon</i>	2	7	-	2
Acanthuridae	<i>Acanthurus tennentii</i>	-	4	4	-
Acanthuridae	<i>Acanthurus lineatus</i>	13	3	-	-
Acanthuridae	<i>Acanthurus xanthopterus</i>	-	-	4	-
Acanthuridae	<i>Ctenochaetus</i> sp.	12	5	-	-
Acanthuridae	<i>Naso brevirostris</i>	2	-	-	-
Acanthuridae	<i>Naso hexacanthus</i>	3	-	3	10
Acanthuridae	<i>Naso lituratus</i>	-	3	-	3
Acanthuridae	<i>Naso unicornis</i>	-	3	-	-
Acanthuridae	<i>Naso vlamingi</i>	-	-	1	-
Balistidae	<i>Balistoides conspicillum</i>	-	-	-	1
Balistidae	<i>Balistspus undulatus</i>	1	3	1	-
Balistidae	<i>Melichthys indicus</i>	8	4	-	-
Balistidae	<i>Odonus niger</i>	2	-	sch>100	sch>100
Balistidae	<i>Sufflamen</i> sp.	3	3	-	-
Carcharhinidae	<i>Carcharhinus amblyrhynchos</i>	-	1	-	-
Chaetodontidae	<i>Chaetodon auriga</i>	-	-	2	-
Chaetodontidae	<i>Chaetodon collare</i>	4	2	-	4
Chaetodontidae	<i>Chaetodon falcula</i>	-	-	-	1
Chaetodontidae	<i>Chaetodon lunula</i>	-	1	-	-
Chaetodontidae	<i>Chaetodon meyeri</i>	1	-	-	-
Chaetodontidae	<i>Chaetodon trifascialis</i>	1	-	-	-
Chaetodontidae	<i>Chaetodon trifasciatus</i>	2	-	-	1
Chaetodontidae	<i>Chaetodon xanthocephalus</i>	1	-	1	-
Chaetodontidae	<i>Forcipiger flavissimus</i>	-	3	-	2
Chaetodontidae	<i>Hemitaurichthys zoster</i>	3	6	-	-

Dasyatidae	<i>Dasyatis</i> sp.	-	1	-	-
Haemulidae	<i>Plectorhinchus gibbosus</i>	-	-	1	-
Haemulidae	<i>Plectorhinchus vittatus</i>	-	2	-	-
Kyphosidae	<i>Kyphosus</i> sp.	-	-	sch>50	-
Labridae	<i>Helichoeres hortulanus</i>	2	1	-	3
Labridae	<i>Labroides dimidiatus</i>	1	3	-	-
Labridae	<i>Thalassoma hardwicke</i>	-	-	1	-
Labridae	<i>Thalassoma janseni</i>	-	-	-	1
Lethrinidae	<i>Gnathodentex aurolineatus</i>	-	-	-	1
Lethrinidae	<i>Lethrinus</i> sp.	-	-	1	-
Lethrinidae	<i>Monotaxis grandoculis</i>	1	2	-	20
Lutjanidae	<i>Aphareus furca</i>	-	-	-	1
Lutjanidae	<i>Aprion virescens</i>	-	-	2	-
Lutjanidae	<i>Caesio</i> sp.	-	sch>30	-	-
Lutjanidae	<i>Lutjanus bohar</i>	1	-	3	3
Lutjanidae	<i>Lutjanus gibbus</i>	-	2	-	12
Lutjanidae	<i>Lutjanus kasmira</i>	-	-	-	20
Lutjanidae	<i>Lutjanus monostigma</i>	-	-	3	
Mullidae	<i>Parupeneus barberinus</i>	-	-	-	1
Mullidae	<i>Parupeneus bifasciatus</i>	-	2	-	3
Pomacanthidae	<i>Apolectichthys trimaculatus</i>	2	2	-	-
Pomacanthidae	<i>Pomacanthus imperator</i>	-	1	-	1
Pomacentridae	<i>Abudefduf</i> sp.	2	3	-	10
Pomacentridae	<i>Chromis dimidiatus</i>	2	3	-	-
Pomacentridae	<i>Chromis ternatensis</i>	-	3	-	-
Pomacentridae	<i>Chromis viridis</i>	sch>30	-	-	-
Scaridae	<i>Cetoscarus bicolor</i>	2	3	-	-
Scaridae	<i>Scarus</i> sp1	1	3	4	4

Scaridae	<i>Scarus sp2</i>	4	2	4	4
Scaridae	<i>Scarus sp3</i>	4	-	-	-
Serranidae	<i>Aethaloperca rogae</i>	1	-	-	3
Serranidae	<i>Cephalopholis argus</i>	-	1	-	3
Serranidae	<i>Cephalopholis leopardus</i>	1	-	-	-
Serranidae	<i>Epinephelus merra</i>	1	1	-	-
Serranidae	<i>Variola louti</i>	1	1	1	1
Zanclidae	<i>Zanclus cornutus</i>	1	-	-	2



LEGEND :

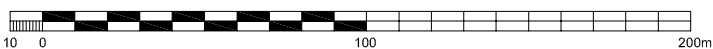
- 1 - JETTY
- 2 - HARBOUR
- 3 - STAFF KITCHEN / STORE AND MESS
- 4 - OFFICE / PUBLIC TOILETS / CLINIC / LABORATORY
- 5 - SHOP / DRIVE IN GODOWN
- 6 - CARPENTRY
- 7 - LAUNDRY
- 8 - POWER HOUSE / RO PLANT & MECHANICAL WORKSHOP
- 9 - VEHICLE GARAGE
- 10 - WATER TANKS FOR RO PLANT
- 11 - OIL TANKS FOR GEN SETS
- 12 - MAIN STORE
- 13 - GODOWN
- 14 - MOSQUE
- 15 - MULTI-FUNCTION HALL
- 16 - GUARD HOUSE
- 17 - STAFF CAFE'
- 18 - JUNIOR STAFF ACCOMMODATION
- 19 - SENIOR STAFF ACCOMMODATION
- 20 - STAFF FAMILY ACCOMMODATION
- 21 - OWNERS HOUSE

NOTE :

TOTAL LAND AREA (BUSH LINE) : 142,507 SQM
 TOTAL LAND AREA (HIGH TIDE) : 152,850 SQM
 TOTAL BUILT-UP AREA: 4151.41 SQM
 BUILT-UP AREA (%) : 2.91 %

PROPOSED SITE PLAN

SCALE 1 : 2500



PROJECT: HA. MADULU ISLAND FOR AGRICULTURAL DEVELOPMENT
TITLE: PROPOSED SITE PLAN

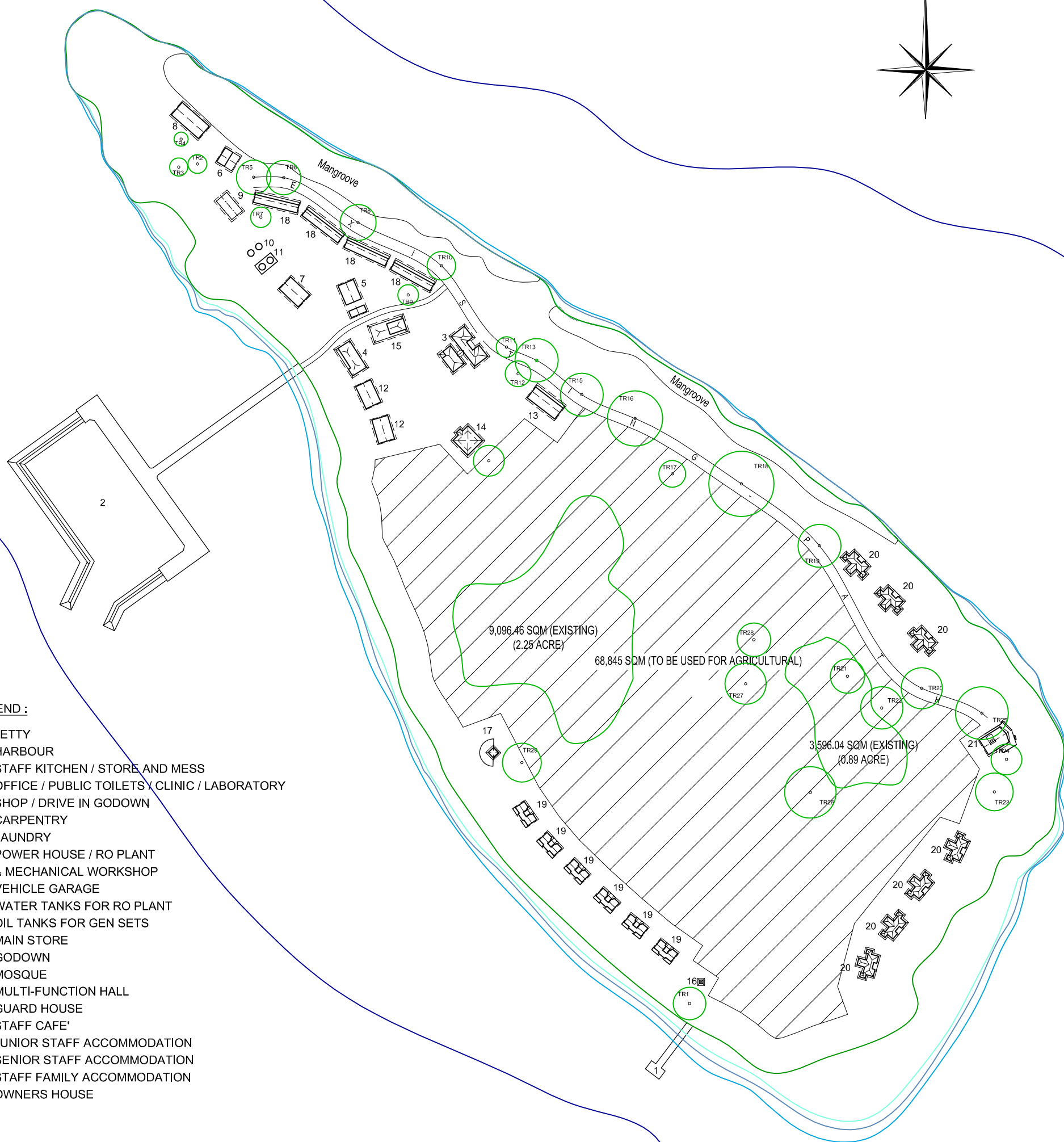
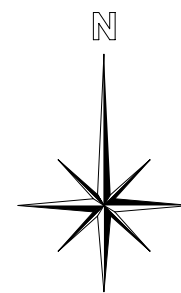
CLIENT: Mr. ALI IBRAHIM FINIVAAGE, A.D FENFUSHI
SCALE: AS GIVEN

AMENDMENTS
CHECKED BY:

DESIGN BY: H.R
STRUC. DESIGN BY: -
SURVEYED BY: H.R/H.S/M.M
DRAWN BY: H.R/H.S

PROJECT. NO: EA - 122
DATE : FEBRUARY 2008
SHEET NO: SV - 01

Do not scale drawing. Figured dimensions are to be followed. All measurements must be verified on site. Any discrepancies to be reported to the architect, engineer and/or interior designer. Contractor to provide shop drawings for approval.



LEGEND :

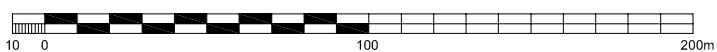
- 1 - JETTY
- 2 - HARBOUR
- 3 - STAFF KITCHEN / STORE AND MESS
- 4 - OFFICE / PUBLIC TOILETS / CLINIC / LABORATORY
- 5 - SHOP / DRIVE IN GODOWN
- 6 - CARPENTRY
- 7 - LAUNDRY
- 8 - POWER HOUSE / RO PLANT & MECHANICAL WORKSHOP
- 9 - VEHICLE GARAGE
- 10 - WATER TANKS FOR RO PLANT
- 11 - OIL TANKS FOR GEN SETS
- 12 - MAIN STORE
- 13 - GODOWN
- 14 - MOSQUE
- 15 - MULTI-FUNCTION HALL
- 16 - GUARD HOUSE
- 17 - STAFF CAFE'
- 18 - JUNIOR STAFF ACCOMMODATION
- 19 - SENIOR STAFF ACCOMMODATION
- 20 - STAFF FAMILY ACCOMMODATION
- 21 - OWNERS HOUSE

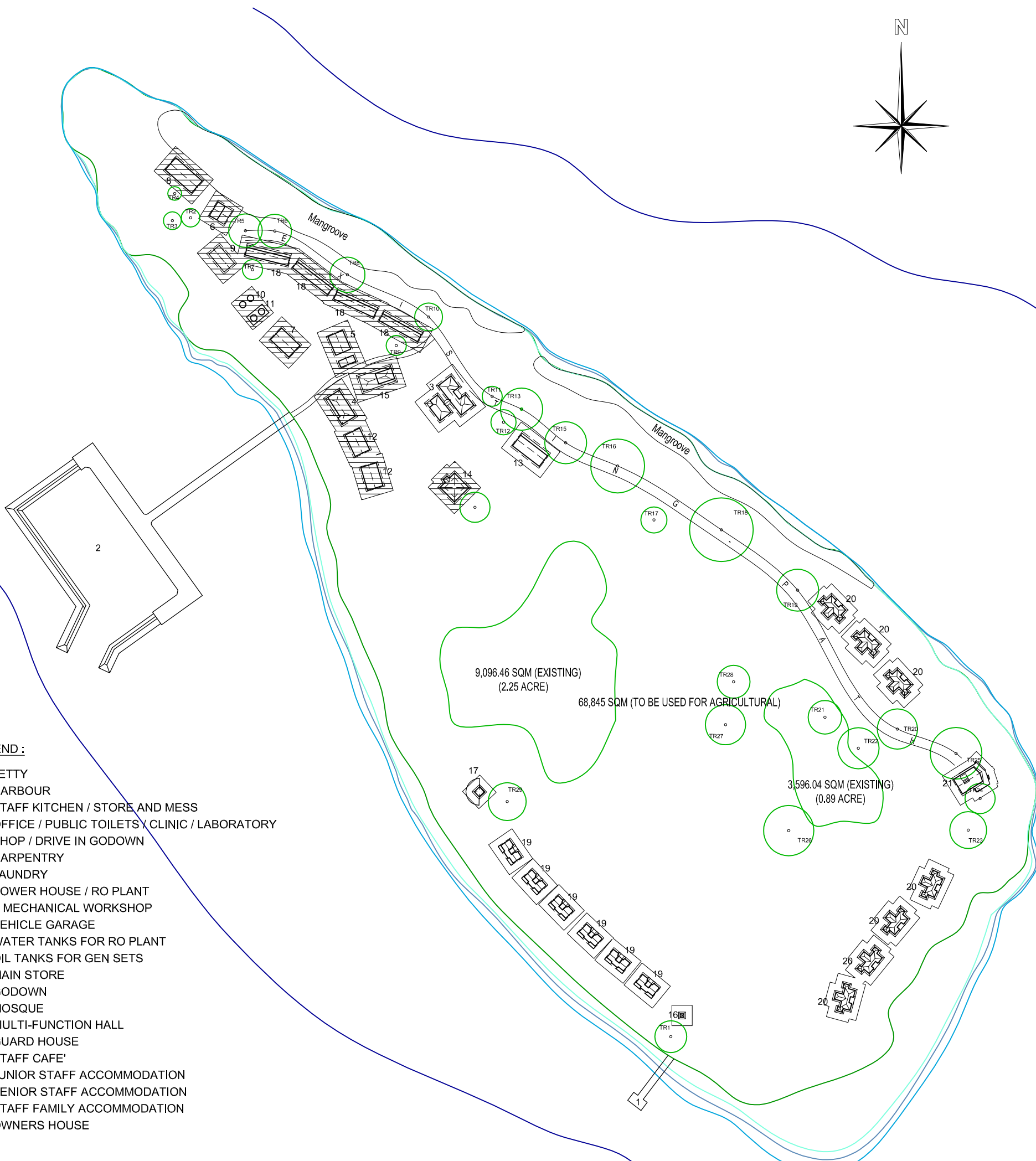
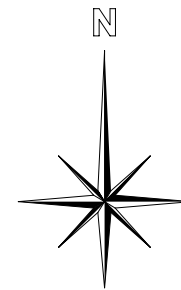
NOTE :

TOTAL LAND AREA (BUSH LINE) : 142,507 SQM
 TOTAL LAND AREA (HIGH TIDE) : 152,850 SQM
 TOTAL AREA FOR AGRICULTURE : 68,845 SQM
 AREA FOR AGRICULTURE (%) : 48.31%

PROPOSED LAND USAGE PLAN

SCALE 1 : 2500





LEGEND :

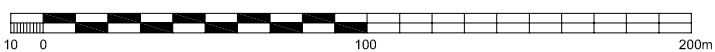
- 1 - JETTY
- 2 - HARBOUR
- 3 - STAFF KITCHEN / STORE AND MESS
- 4 - OFFICE / PUBLIC TOILETS / CLINIC / LABORATORY
- 5 - SHOP / DRIVE IN GODOWN
- 6 - CARPENTRY
- 7 - LAUNDRY
- 8 - POWER HOUSE / RO PLANT & MECHANICAL WORKSHOP
- 9 - VEHICLE GARAGE
- 10 - WATER TANKS FOR RO PLANT
- 11 - OIL TANKS FOR GEN SETS
- 12 - MAIN STORE
- 13 - GODOWN
- 14 - MOSQUE
- 15 - MULTI-FUNCTION HALL
- 16 - GUARD HOUSE
- 17 - STAFF CAFE'
- 18 - JUNIOR STAFF ACCOMMODATION
- 19 - SENIOR STAFF ACCOMMODATION
- 20 - STAFF FAMILY ACCOMMODATION
- 21 - OWNERS HOUSE

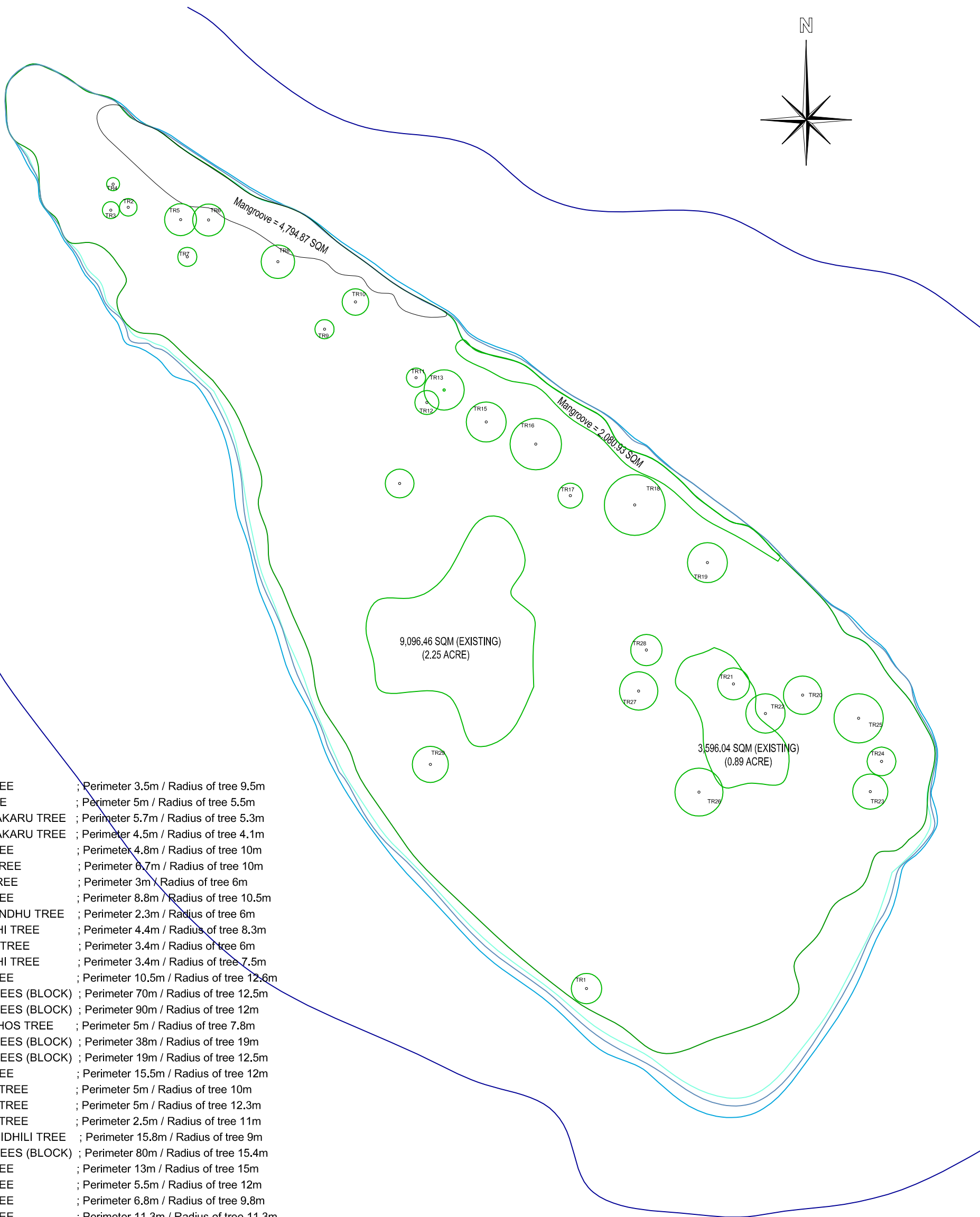
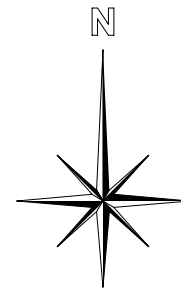
NOTE :

TOTAL LAND AREA (BUSH LINE) : 142,507 SQM
 TOTAL LAND AREA (HIGH TIDE) : 152,850 SQM
 TOTAL AREA FOR AGRICULTURE: 15,461 SQM
 AREA FOR AGRICULTURE (%) : 10.85%

VEGETATION CLEARING PLAN

SCALE 1 : 2500



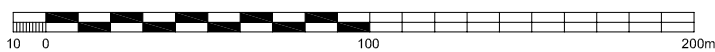


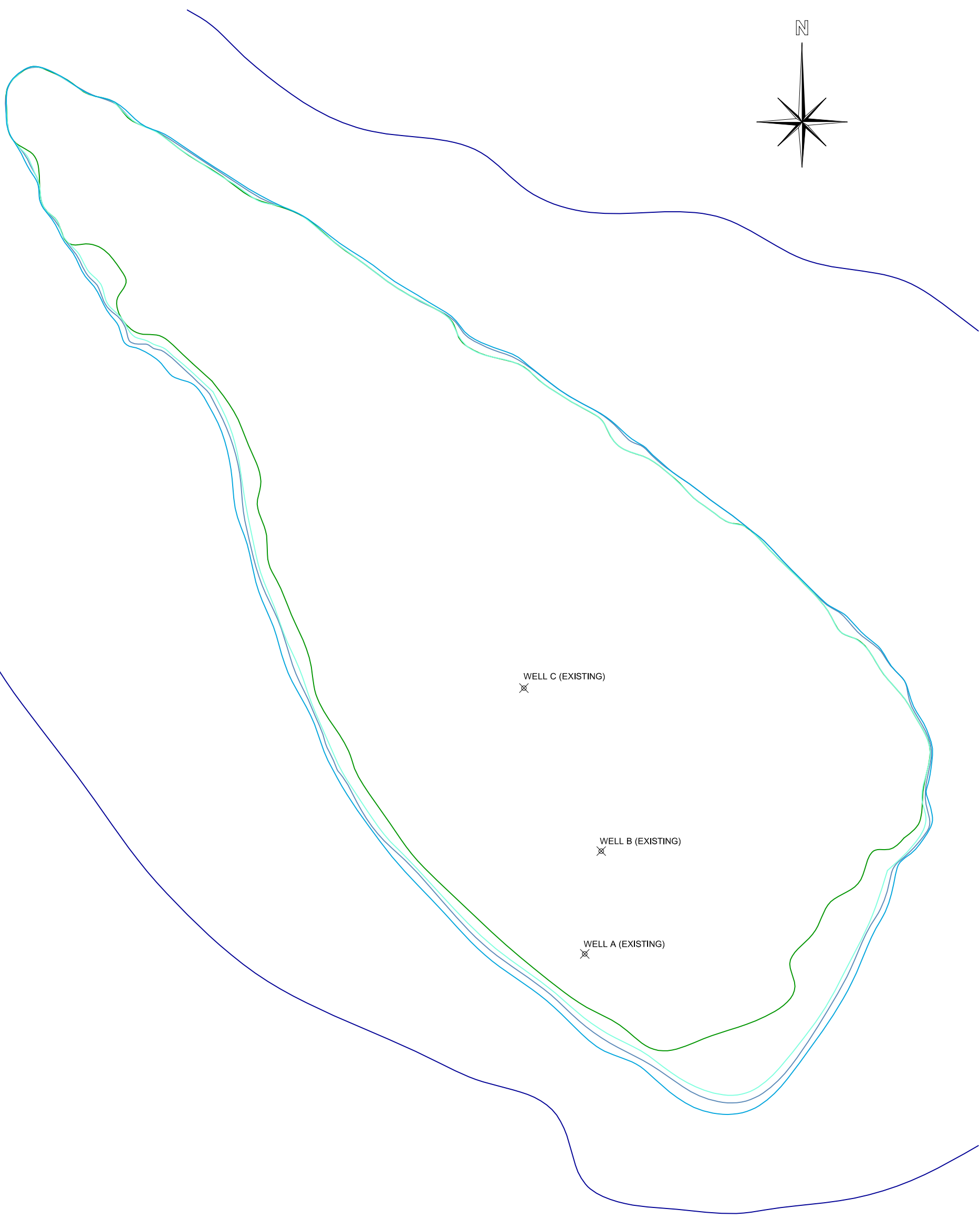
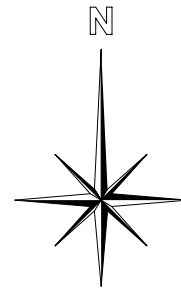
LEGEND :

- TR1 - NIKA TREE ; Perimeter 3.5m / Radius of tree 9.5m
- TR2 - UNI TREE ; Perimeter 5m / Radius of tree 5.5m
- TR3 - MARAVAKARU TREE ; Perimeter 5.7m / Radius of tree 5.3m
- TR4 - MARAVAKARU TREE ; Perimeter 4.5m / Radius of tree 4.1m
- TR5 - NIKA TREE ; Perimeter 4.8m / Radius of tree 10m
- TR6 - KAANI TREE ; Perimeter 6.7m / Radius of tree 10m
- TR7 - FUNA TREE ; Perimeter 3m / Radius of tree 6m
- TR8 - NIKA TREE ; Perimeter 8.8m / Radius of tree 10.5m
- TR9 - MAS-KANDHU TREE ; Perimeter 2.3m / Radius of tree 6m
- TR10 - MADOSHI TREE ; Perimeter 4.4m / Radius of tree 8.3m
- TR11 - MIDHILI TREE ; Perimeter 3.4m / Radius of tree 6m
- TR12 - MADOSHI TREE ; Perimeter 3.4m / Radius of tree 7.5m
- TR13 - NIKA TREE ; Perimeter 10.5m / Radius of tree 12.6m
- TR15 - NIKA TREES (BLOCK) ; Perimeter 70m / Radius of tree 12.5m
- TR16 - NIKA TREES (BLOCK) ; Perimeter 90m / Radius of tree 12m
- TR17 - NIKA / LHOS TREE ; Perimeter 5m / Radius of tree 7.8m
- TR18 - NIKA TREES (BLOCK) ; Perimeter 38m / Radius of tree 19m
- TR19 - NIKA TREES (BLOCK) ; Perimeter 19m / Radius of tree 12.5m
- TR20 - NIKA TREE ; Perimeter 15.5m / Radius of tree 12m
- TR21 - MIDHILI TREE ; Perimeter 5m / Radius of tree 10m
- TR22 - MIDHILI TREE ; Perimeter 5m / Radius of tree 12.3m
- TR23 - MIDHILI TREE ; Perimeter 2.5m / Radius of tree 11m
- TR24 - NIKA / MIDHILI TREE ; Perimeter 15.8m / Radius of tree 9m
- TR25 - NIKA TREES (BLOCK) ; Perimeter 80m / Radius of tree 15.4m
- TR26 - NIKA TREE ; Perimeter 13m / Radius of tree 15m
- TR27 - NIKA TREE ; Perimeter 5.5m / Radius of tree 12m
- TR28 - NIKA TREE ; Perimeter 6.8m / Radius of tree 9.8m
- TR29 - NIKA TREE ; Perimeter 11.3m / Radius of tree 11.3m
- TR30 - MIDHILI TREE ; Perimeter 4.8m / Radius of tree 9m

TREE SURVEY PLAN

SCALE 1 : 2500





WATER SAMPLE LOCATIONS PLAN

SCALE 1 : 2500



eCAD ASSOCIATES PRIVATE LIMITED
 TOTAL + BUILDING + SOLUTIONS
 M.SILVER STAR,HAVEEREE HINGUN 20-02 MALE,REPUBLIC OF MALDIVES
 TEL:+960 3344654,FAX:+960 3344653,EMAIL:ecad.associates@gmail.com
 www.ecadassociates.com

PROJECT:
HA. MADULU ISLAND FOR AGRICULTURAL DEVELOPMENT
 TITLE:
WATER SAMPLE LOCATIONS PLAN

CLIENT:
 Mr. ALI IBRAHIM
 FINIVAAGE, A.D FENFUSHI
 SCALE:
 AS GIVEN

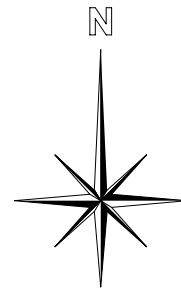
AMENDMENTS

 CHECKED BY:

DESIGN BY: H.R
 STRUC. DESIGN BY: -
 SURVEYED BY: H.R/H.S/M.M
 DRAWN BY: H.R/H.S

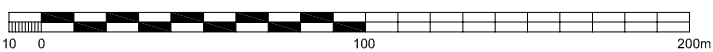
PROJECT. NO:
 EA - 122
 DATE :
 FEBRUARY 2008
 SHEET NO:
 SV - 05

Do not scale drawing. Figured dimensions are to be followed. All measurements must be verified on site. Any discrepancies to be reported to the architect, engineer and/or interior designer. Contractor to provide shop drawings for approval.



BEACH PROFILES

SCALE 1 : 2500



eCAD ASSOCIATES PRIVATE LIMITED

TOTAL + BUILDING + SOLUTIONS
 M.SILVER STAR,HAVEEREE HINGUN 20-02 MALE,REPUBLIC OF MALDIVES
 TEL:+960 3344654,FAX:+960 3344653,EMAIL:ecad.associates@gmail.com
 www.ecadassociates.com

PROJECT:
HA. MADULU ISLAND FOR AGRICULTURAL DEVELOPMENT
 TITLE:
BEACH PROFILES

CLIENT:
 Mr. ALI IBRAHIM
 FINIVAAGE, A.D FENFUSHI
 SCALE:
 AS GIVEN

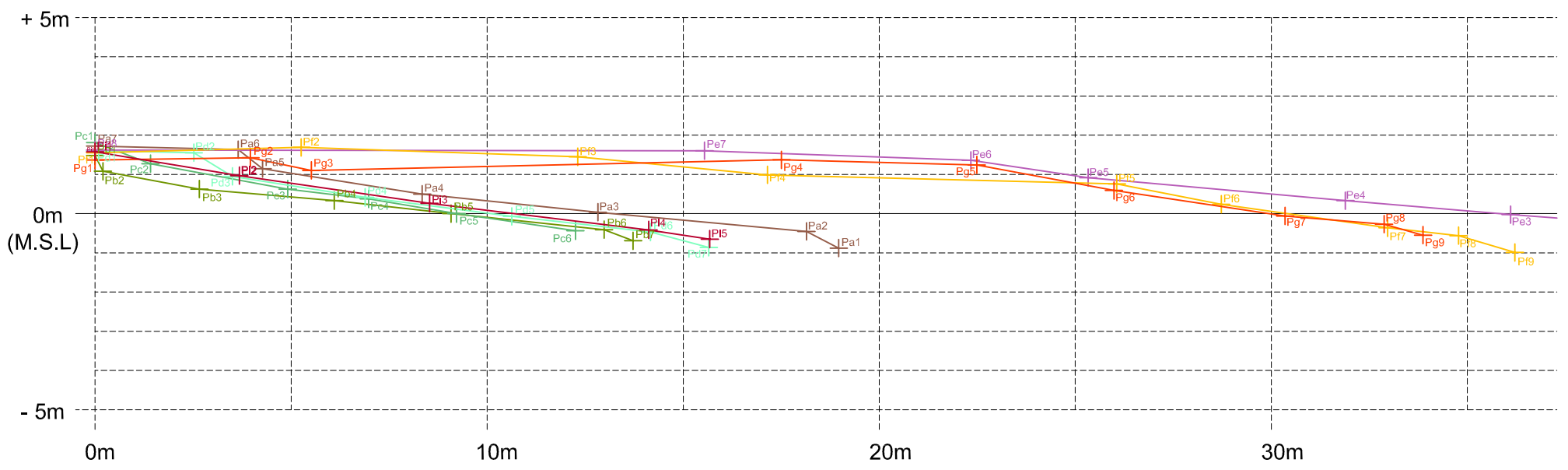
AMENDMENTS

 CHECKED BY:

DESIGN BY: H.R
 STRUC. DESIGN BY: -
 SURVEYED BY: H.R/H.S/M.M
 DRAWN BY: H.R/H.S

PROJECT. NO:
 EA - 122
 DATE :
 FEBRUARY 2008
 SHEET NO:
 SV - 06

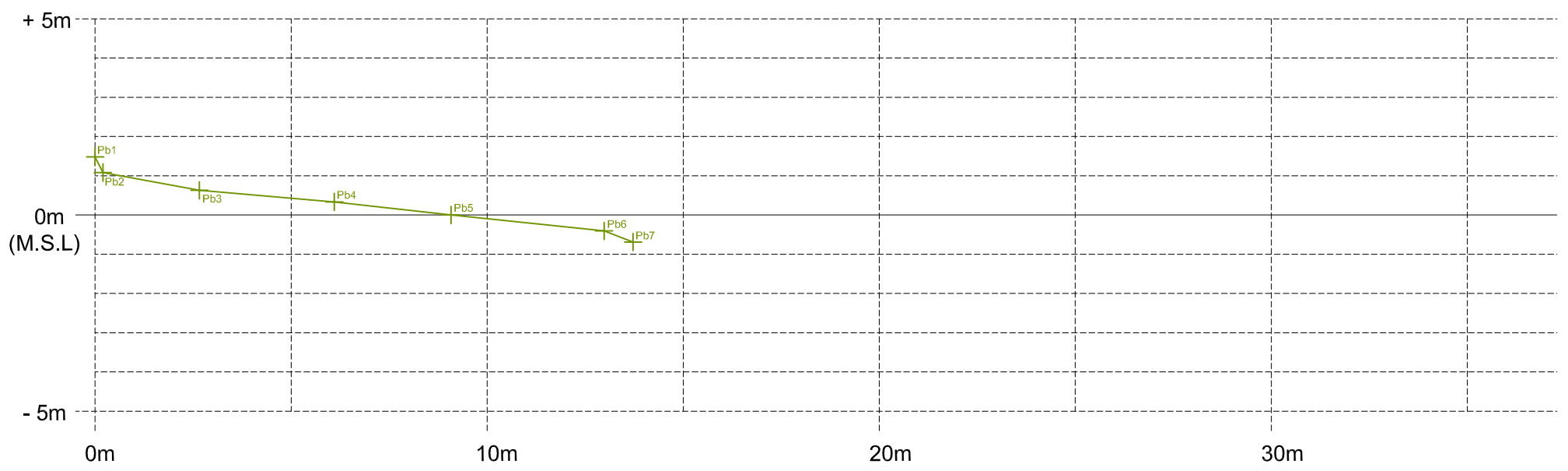
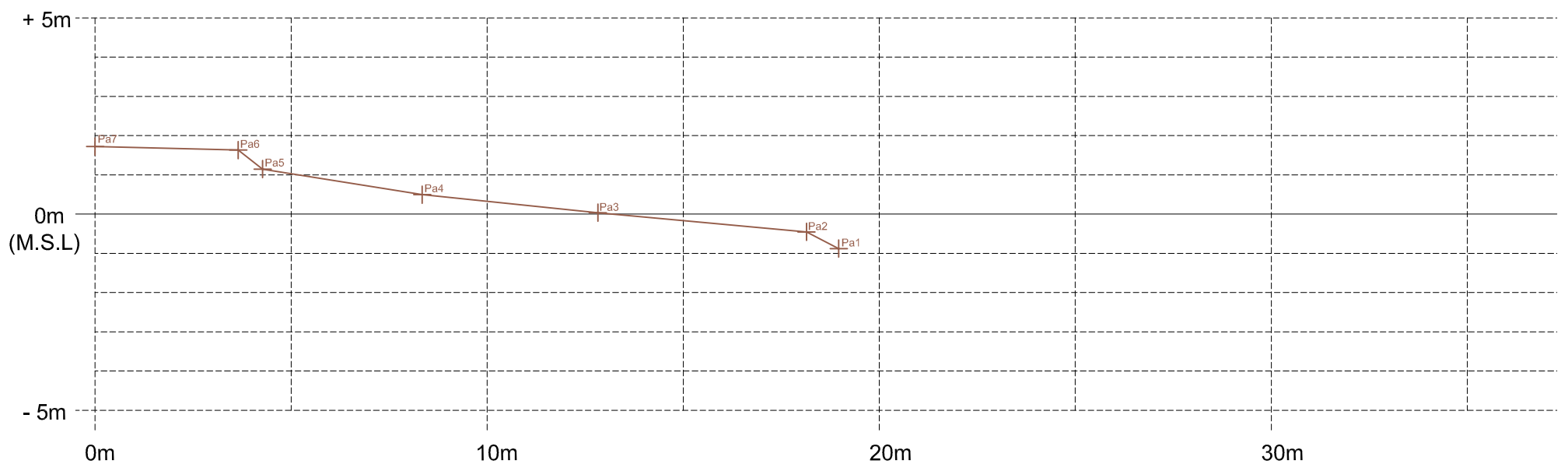
Do not scale drawing. Figured dimensions are to be followed. All measurements must be verified on site. Any discrepancies to be reported to the architect, engineer and/or interior designer. Contractor to provide shop drawings for approval.

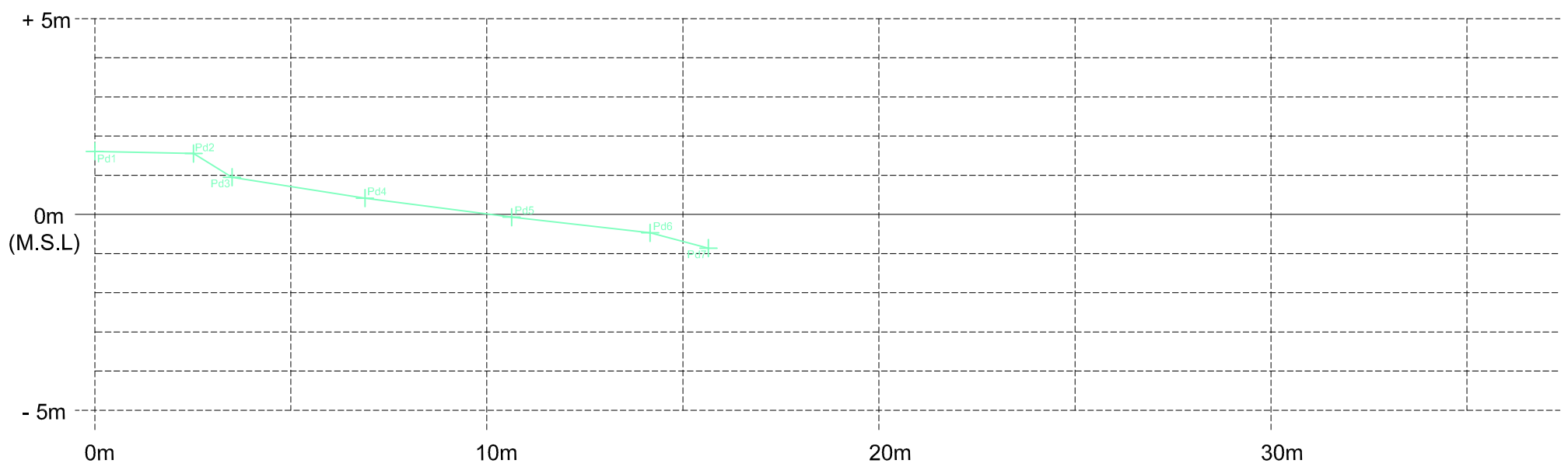
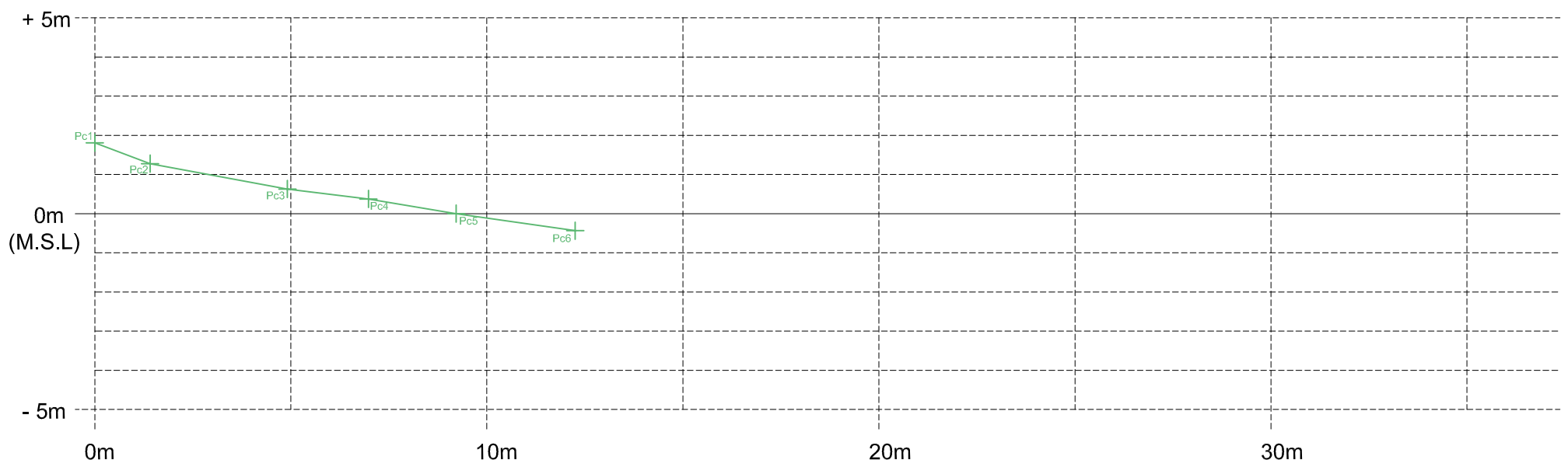


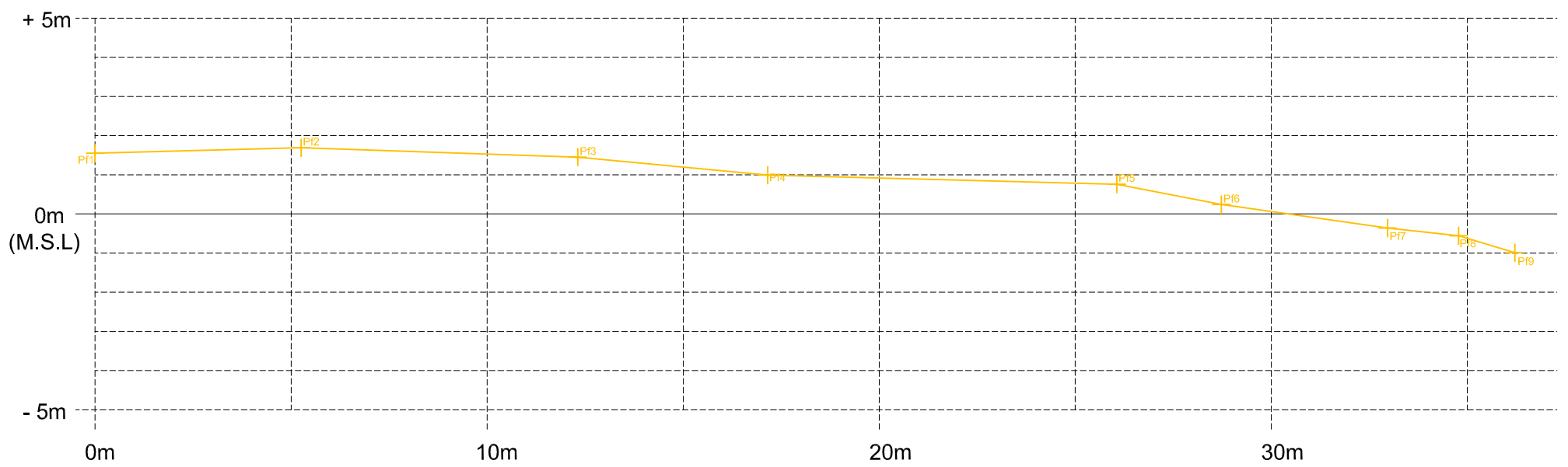
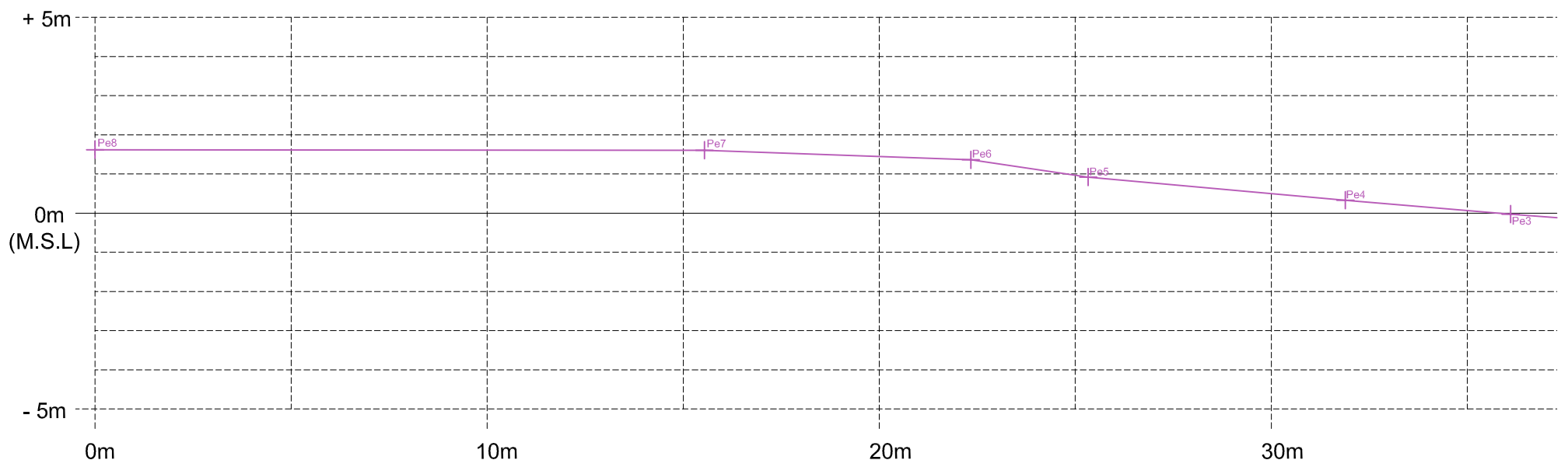
PROJECT:	HA. MADULU ISLAND FOR AGRICULTURAL DEVELOPMENT
TITLE:	ALL BEACH PROFILES

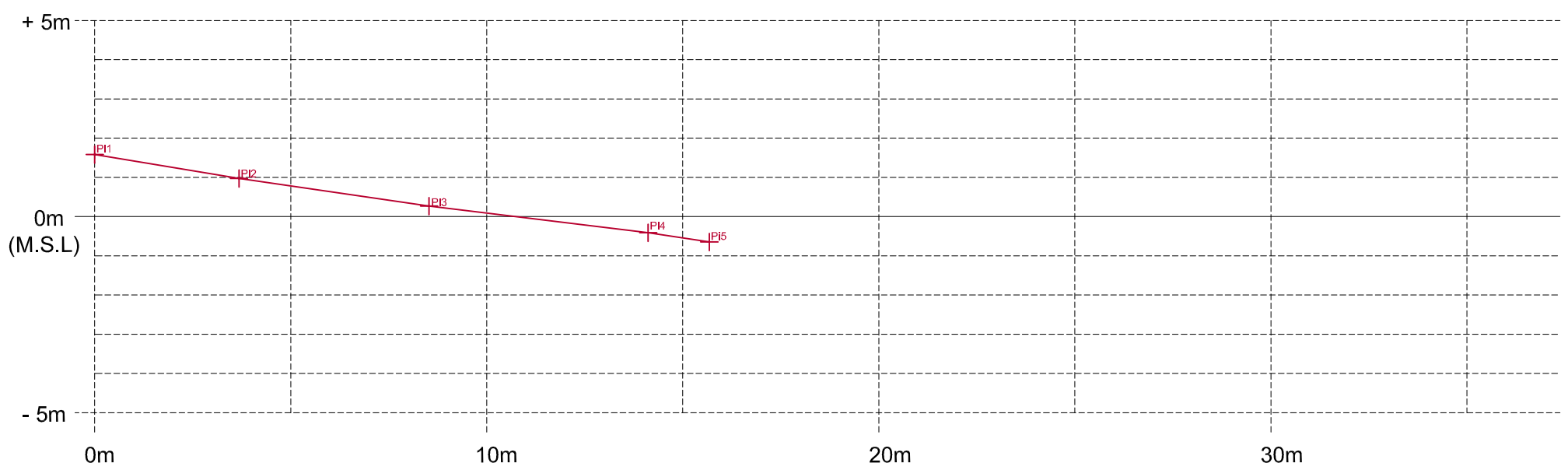
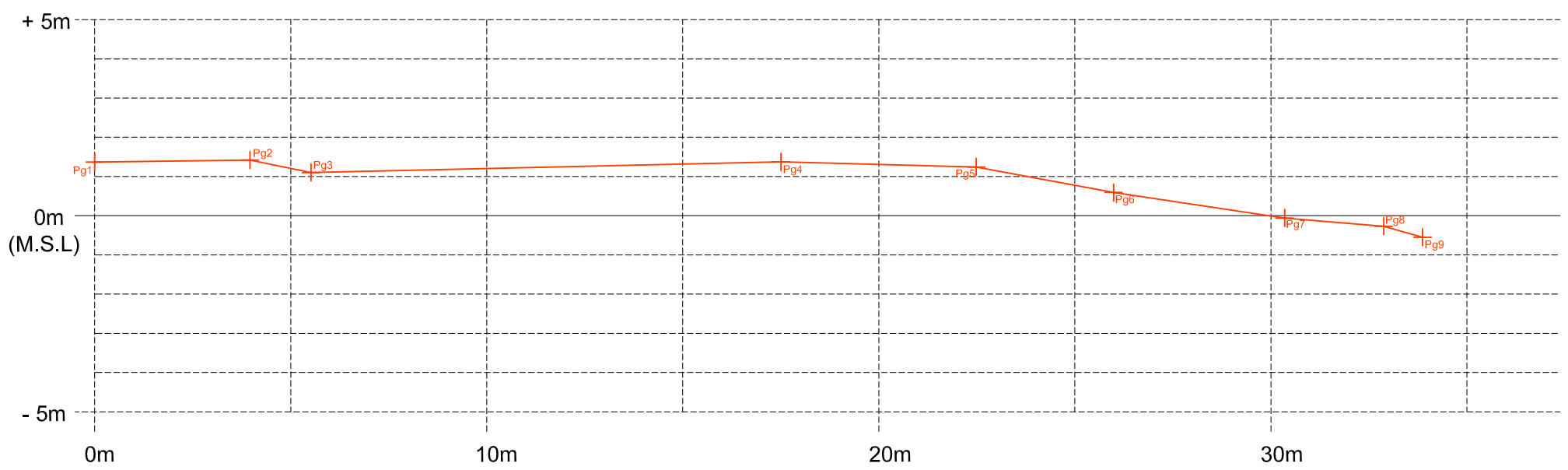
CLIENT:	Mr. ALI IBRAHIM FINIVAAGE, A.D FENFUSHI
SCALE:	NOT TO SCALE

AMENDMENTS	_____
CHECKED BY:	_____









14. Reference

Clark, S., Akester, S. and Naeem, H. (1999). *Conservation and Sustainable Use of Coral Reefs: Status of Coral Reef Communities in North Male' Atoll, Maldives; Recovery Following a Severe Bleaching Event in 1998,*

MacAlister Elliot and Partners Ltd.

English, S., Wilkinson, C, and Baker, V. (1997). *Survey Manual for Tropical Marine*

Resources, 2nd Edition. Published by Australian Institute of Marine Science,

Townsville

Kenchington, R.A. (1984). *Large Area Survey of Coral Reef, UNESCO Report in Marine Science*, 21: 92-103

Kenchington, R.A., *The Republic of Maldives, Managing Marine Environment*, Taylor and Francis New York Inc. (1990).

Loya, Y. (1978). *Plotless and Transect Methods*.

Stoddart, D.R. and R.F. Johnnes (editors). "Coral Reefs: Research Methods". UNESCO, Paris.

Open University (1994)., *Waves, Tides and Shallow Water Processes*,

Elsivier Science Ltd. Oxford.

Pernetta, J.C (1993) ed. *Marine Protected Area Needs in the South Asian Region*,

Volume 3: Maldives, IUCN, Gland, Switzerland.

Roe D, Dalal-Clayton & Hughes, R (1995). *A Directory of Impact Assessment*

Guidelines. International Institute for Environment and Development, Russell

Press, Nottingham, UK.

Salvat, B (1997). *Dredging in Coral Reefs. In Human Impacts on Coral Reefs: Facts and Recommendations*.

B. Salvat, ed. Antene Museum . E.P.H.E., French Polynesia.

State of the Environment Maldives (2002).

Ministry of Home Affairs, Housing and Environment - Maldives.

State of the Environment (SoE), 2002, Ministry of Home Affairs, Housing and

Environment, Maldives.

USACE (2001), *US Army Coastal Engineering Manual*, USACE

Viles, H. and Spencer, T. (1995).

Coastal Problems: Geomorphology, Ecology and Society at the Coast

Edward Arnold, a division of Hodder Headline PLC, 338 Euston Road, London.