DETAILED ISLAND RISK AND VULNERABILITY ASSESSMENT
Gdh. Thinadhoo, Maldives

2013

Prepared by:

riyan Pte.Ltd

for

Ministry of Environment and Energy

UNDP

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GDh. Thinadhoo

Integrating Climate Change Risk into Resilient Island Planning in the Maldives (ICCRRIP)

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Acknowledgments

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Acronyms

DEM	Digital Elevation Model
DIRAM	Detailed Island Risk Assessment of Maldives
DNP	Department of National Planning
EIA	Environmental Impact Assessment
GIS	Geographic Information System
Gdh	Gaaf Dhaalu (Administrative atoll name)
MEE	Ministry of Environment and Energy
MHE	Ministry of Housing and Environment
MMS	Maldives Meteorological Service
MPND	Ministry of Planning and National Development
MWSC	Male' Water and Sewerage Company Pvt Ltd
MSL	Mean Sea Level
NOAA	National Oceanic and Atmospheric Administration
ICCRRIP	Integration of Climate Change Risk Resilience in Island Planning
IPCC	International Panel on Climate Change
RF	Rufiyaa (Maldivian Currency)
RIMES	Regional Integrated Multi-Hazard Early Warning System
SST	Sea Surface Temperature
STELCO	State Electric Company
SWOT	Strengths, Weaknesses, Opportunities and Threats
UNDP	United Nations Development Program

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Executive Summary

This report on the island of Gaaf Dhaalu Thinadhoo of Maldives provides an update of the risk assessments conducted in 2008 to understand the vulnerability of the island towards natural hazards. It aims to provide a better understanding of the topography of the island and the physical changes that have occurred since the last assessment. These elements are mapped against the potential natural hazard risks; Tsunami, swell waves and rainfall flooding predicted for the island.

Since the last study conducted in 2008, the main changes Thinadhoo has experienced in terms of physical development include development of infrastructures such as the extension of the local harbour, implementation of water network system and development of housing in the reclaimed lands.

The vulnerability assessment showed that Thinadhoo is highly vulnerable to rainwater flooding. Due to lack of a proper drainage system the problem still persists and it has been impacting the people in many different ways. Nevertheless, the rainfall patterns have changed over the past years and data shows that there has been a decline in mean annual rainfall between 2007 and 2011 while in 2012 it has increased. The future projection of rainfall by RIMES (2011), show both an enhanced variability and an increasing tendency, with the southern zones having a greater increasing in rainfall in the future. This increase in rainfall would be accompanied by extreme events such as maximum one-day rainfall and increased number of consecutive wet days. It was also found that Thinadhoo is exposed to storm surges generated due to low atmospheric pressure of severe localized storm events. The western coast of Thinadhoo is very vulnerable to flooding due to these storm surge events, swell waves and large wind generated waves. But the western side is protected from these waves by the wide reef flat. The eastern side has a very large lagoon with the outer island reef very far from the island shoreline acting as a barrier to reduce impacts from swell waves. Yet wind generated waves can become hazardous causing widespread flooding. As far as impacts from a Tsunami are concerned, it is relatively safe compared to some other parts of the country.

Furthermore impacts of sea level rise were analysed based on the IPCC reports and the RIMES study. While IPCC (2007) predicted an increase of 0.88m in sea level by 2100, RIMES (2011) found that for the Gaafu Dhaalu atoll, the sea level is projected to rise by 0.95m in the year 2080. It was concluded that such an increase would make the island more vulnerable to hazards such as flooding of low-lying coastal areas, loss of land due to increase in coastal erosion, higher impact from future tsunami events etc.

Vulnerable groups in Thinadhoo who are subjected to these conditions include elderly people, mentally and physically challenged individuals, at-risk children and youth, the families living near coastal areas, women etc. The potential social impacts the island would experience due to any potential natural disaster include loss of life, injury to members of household; destruction/damage of household properties; spread of diseases; damage to roads and infrastructure; disruption to economic activities; disruption to transport of goods; increased quantity of waste and water scarcity. All these impacts would mostly affect the vulnerable groups in the island. According to the current findings, factors that would exacerbate the impacts are; location of housing and infrastructure; improper waste management; increase in population and vulnerable groups; housing condition and condition of critical infrastructures and political imbalance. These factors were taken into consideration when proposing disaster risk reduction measures for the island.

Based on the natural hazard assessments the key economic establishments and infrastructures at high risk include the RO plant, power house, fuel tanks, fish market, dhiraagu site and some of the retail shops. The critical social infrastructures at high risk are the Abubakuru School and the regional hospital. The economic losses are expected to be highest during a high magnitude Tsunami or a swell wave event although the high frequency of flooding events could also be hazardous. The estimated loss from a severe tsunami event in Thinadhoo ranges between Rf 25 Million and Rf 30 million. The estimated tangible loss from a severe swell wave or storm surge event in Thinadhoo is Rf 7.6 million. The estimated tangible loss from a severe rainfall flooding event is Rf 1.6 million.

Measures to reduce the identified environmental vulnerabilities include; protecting the western shoreline of the island; protection of the northern side of the island; coastal protection of the south side of the island; creating and maintaining the EPZ and most importantly establishing a proper drainage system.

In order to reduce the social vulnerability to risks, it is essential to integrate the Hyogo framework 2005-2015, the Millennium Development Goals (MDGs) and the Cairo principles in implementing the measures. The measures are to promote disaster risk reduction and management; make the communities prepared for the disaster events and to strengthen the emergency response and recovery services. A cost-benefit analysis was also conducted to realize the cost and benefits the proposed mitigation measures would cost in the different scenarios; 1) single Tsunami event, 2) a flooding event and 3) multiple disaster events.

Limitations of the current study and recommendations for further studies are also discussed to strengthen the present study and make it a comprehensive assessment. These include identification of the ways to incorporate climate smart planning into disaster risk reduction.

1. Introduction

Detailed Island Risk Assessment in the Maldives (DIRAM) is a set of reports based on studies conducted in 10 different islands of the Maldives in 2008 to understand the past, present and future risks associated with different events including natural hazards, urbanization and other developments in the islands and its surroundings (UNDP, 2008). With the change in population and physical developments in the islands, these studies call for an update in order to understand how the risk profiles have varied over the years due to these changes. Under this line, the first climate adaptation project of Maldives, "Integrating Climate Change Risks into Resilient Island Planning in the Maldives" (ICCRRIP) aims to review, update and strengthen the assessments that have been conducted for Hdh. Kulhudhuffushi and Gdh. Thinadhoo. The objective is to assist in developing policies, regulations and guidelines relevant to the islands to ensure risk resilience in the islands. The project also aims to contribute to the understanding of natural risks associated with climate change and other natural and human induced activities.

In this report, the DIRAM report prepared for GDh. Thinadhoo (hereafter referred to as "*previous DIRAM study*"/ "*previous study*") has been revised and assessed based on the current condition of the island. This update aims to provide a better understanding of the topography of the island and the physical changes that have occurred over the past 5 years. These elements are mapped against the potential natural hazard risks; Tsunami, swell waves and rainfall flooding predicted for the island. With time and data constraints the study has attempted to assess and analyse how the changes have affected the vulnerability of the island through developing a digital elevation model by using a Geographic Information System (GIS). A similar methodology as used in the previous DIRAM study was adopted but with detailed surveying and modelling of the elevations (refer Annex I for the study approach taken to conduct the review). The studies showed that the increase of population and the rapid urbanization have increased the socioeconomic vulnerability and the geomorphology of the island and some of the physical developments also have increased the environmental and structural vulnerability of the island to great extent.

The analyses of the different vulnerabilities are discussed in the report in separate chapters. Chapter 2 of the report gives the background of the island and describes the environmental and socioeconomic setting of Thinadhoo. These data are then used to assess the environmental, social and economic vulnerability of Thinadhoo to natural disasters in Chapters 3, 4 and 5 respectively. The findings are summarized with a SWOT analysis in Chapter 6 and measures to reduce the vulnerabilities are proposed to conduct a cost benefit analysis

(Chapter 7). The report is concluded with recommendations for further studies, which are discussed in Chapter 9.

A road of Gdh. Thinadhoo
Photo by: Shifna Saeed/ Riyan Pvt Ltd (2013)

2. Island context

2.1. Location

Thinadhoo is located at the western periphery of Huvadhu atoll at geographic coordinates $72^{0}59'50"$E, $0^{0}31'49"$N. While there are no islands on the north of Thinadhoo, on the south is Kaadedhoo (regional airport), Madaveli and Hoadedhdhoo. Thinadhoo is approximately 4.5km south of Kaadedhoo and approximately 410km from Male' City. Thinadhoo is the administrative capital of Gaafu Dhaal atoll. As the island is located in the western rim facing the Indian Ocean, the island is exposed to the southwest monsoonal winds and waves (UNDP 2006). Figure 1 shows the location of Thinadhoo.

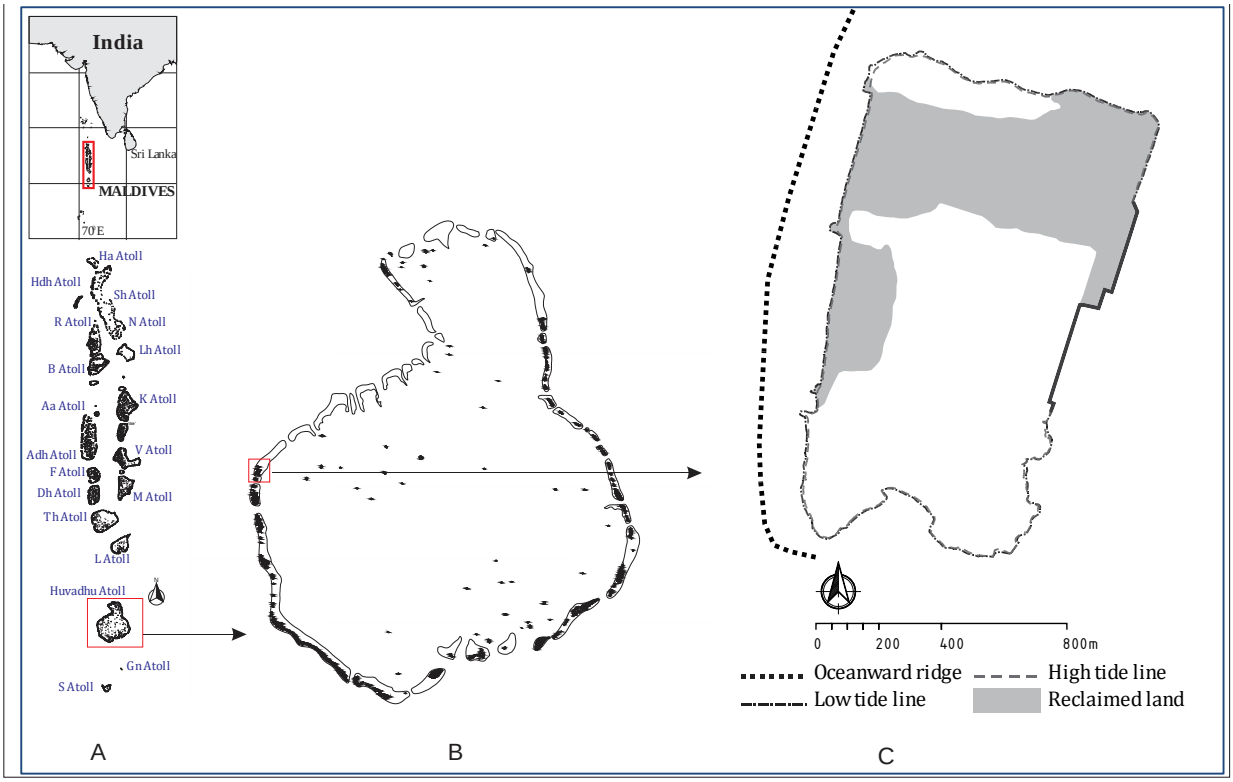


FIGURE 1 LOCATION MAP, GDH. THINADHOO; A. GEOGRAPHIC LOCATION OF GDH. ATOLL IN THE MALDIVES ARCHIPELAGO, LOCATION OF THINADHOO IN GDH. ATOLL, C. THE ISLAND THINADHOO

2.2. Physical Environment

i. Geomorphology

Thinadhoo Island, which used to be in a free form shape, is now almost rectangular with the reclaimed lands. Prior to the reclamation, the island covered a land area of 39 ha (0.39km^2) and a wetland area of 16ha (0.16km^2). During the 1980s, the entire wetland area was reclaimed and Maahutta Island was also joined through reclamation of parts of the reef flat. Approximately 61% of the existing island is reclaimed lands (UNDP 2008). Now the island covers a total area of 118.6 ha (1.186km^2).

The island is located at the southern tip of the reef system and has a fairly large reef with a surface area of approximately 1150 ha (11km^2). It is next to a main reef entrance; the Thinadhoo Sea (*Thinadhoo kan'du*). The reef flat is a bit shallow with an average depth of -1m MSL. The distance between the island shoreline and the ocean ward reef rim ranges from 83m in the southwest end to 200m in the west side. The average distance to reef edge is approximately 170m. A summary of the physical attributes of Thinadhoo is illustrated in table 1

TABLE 1 PHYSICAL ATTRIBUTES OF THINADHOO

Physical attributes	
Length of the reef (visible extent)	8.3 km
Width of the reef (visible extent)	2 km
Length of the island	1.57 km
Width of the island	0.9 km
Reclaimed land area	71 ha
Total land area (average of HWL and LWL)	118.6 ha

ii. Water bodies

As discussed in section 2.2 above Thinadhoo has undergone major modifications. The previous mangrove areas/wetlands at the south end have been reclaimed leaving no wetlands on the southern end. However with the joining of the original island to the Maahutta Island, now the island consists of a small wetland area of approximately 0.25 ha. This area has been zoned as the conservation zone in the proposed land use plan. However, the STP is now planned to be placed in this area. This new development is likely to cause some impacts on the pristine environment surrounding the mangroves.

iii. Vegetation

Vegetation cover in Thinadhoo is very scarce compared to other inhabited islands. Since a large potion has been reclaimed and no re-vegetation has been done following the reclamation, most of the areas are bare (further discussed in section 3.2).

iv. Settlement

Thinadhoo with a total registered population of 7,210 is spread across the island leaving the small wetland area at the north end. The island is highly urbanized with housing and commercial activities. The island has adopted a grid form layout where the blocks are aligned perpendicular to each other (see Annex II). The population density of the island (excluding the wetland area) is approximately 60 person per hectare. Since Thinadhoo is the regional hub and also the atoll capital, the island is growing at a faster pace. This rapid growth demands for changes that may be harmful to the environment resulting in the island becoming more vulnerable to the environmental changes and climate change impacts. Hence, the island becomes less safe for the residents.

2.3. Existing land use

Thinadhoo, previously known as '*havaru Thinadhoo*' was repopulated in the year 1966 after some rebellious movements between the people and the government of the Maldives. As it was a resettlement, a planned, but very rigid distribution of households can be observed as seen from the existing land use plan (see Annex II). Most part of island was reclaimed in potions and according to the island community it took approximately 17 years to complete the whole reclamation. Since it was not done as one major project, the exact dates are not known. The most recent reclamation (north side joining the Maahutta Island) was undertaken during the 1990s. The reclaimed areas are still undergoing development, where most of the areas are being already taken for housing purposes and commercial activities. Even with the increase in landmass the island is still experiencing scarcity of land for housing and other urban services.

Similar to other inhabited islands the main land use is residential covering approximately 61% of land area. The settlement footprint covers more than 90% of the island. With the high density population, all available land is being utilized for residential, commercial and infrastructure uses. The institutions, economic and social infrastructures cover approximately 11% of the total land area. The commercial areas are not zoned separately and are wide spread across the island established within housing plots. Nevertheless some of the industrial activities such as fish processing, market selling fish and light industries are now located at the industrial zone. The land use zonation and distribution are mapped in the land use map (see Annex II).

The land used for institutions and public facilities basically covers schools, university campus, the regional hospital and mosques. The infrastructures include the harbour, powerhouse, fuel supply, the waste disposal site and the communication infrastructures. The reclaimed areas at the northern and western sides are also being used for residential and commercial purposes.

They are now implementing the sewerage system with the sewerage treatment plant (STP) to be located north-west corner at the mangrove area. Previously this area has been proposed as a conservation zone and it is a flood prone area. Measures need to be undertaken to flood proof the STP if cannot be relocated to another location.

2.3.1. Proposed land use plan

The most recent land use plan is proposed in year 2012. Since then lot of changes has occurred to the island. While some are in accordance with the plan others are newly proposed developments to cater the need of the current communities in and around the island.

The plan has attempted to address the land shortage issue by allocating more land for residential housing of different types including, individual housing lots and public housing (row houses & flats, see Figure 2). More areas for commercial and industrial activities are provided at the reclaimed area. The plan is being implemented to some extent with construction of row houses and other residential units (see Annex II map 2 for the proposed land use plan).

FIGURE 2 SINGLE STORY HOUSES, PROVINCE HOUSING DEVELOPMENT PROJECT

2.4. Social Setting

2.4.1. Population and Migration characteristics

i. Population

The population of Thinadhoo has shown an interesting growth over the past years. While a gradual increase is seen, the island experienced a drop in year 2006 showing a negative growth rate of -1.6. However, currently the population is growing at a faster pace with a total registered population of 7,210 this year. Thus the growth rate is now expected to be positive with the frequent in-migration observed over the past years. The exact figures can only be reviewed once the Census is conducted which is now scheduled to be on 2014.

TABLE 2 ENUMERATED AND REGISTERED POPULATION TREND OF GDH. THINADHOO

	Maldives Census (Actual)					Registered	
	1985	1990	1995	2000	2006	2012	2013
Total	3030	3636	4408	4,893	4,442	7,108	7,210
Male	1436	1775	2174	2387	2168	3625	3546
Female	1594	1861	2234	2506	2274	3483	3664

As illustrated in table 2, since 2006 there has been a significant increase in the population. But these figures show the registered population of which a portion is most likely to be living elsewhere for employment, education or health reasons. Since the figures in 2006 shows the enumerated population and are very outdated, it is difficult to analyse the growth rate based on the available data. As reported in DNP (2012) there were 3,625 males and 3,483 female in 2012 and as per island office records these numbers have slightly increased as they reached mid of 2013. Since 2006 the total population has increased by 38% and it can be seen that number of males have increased more than number of females. This difference is due to the difference in data reported, whereby, the 2006 census data shows the enumerated population while data from 2012 shows the registered population. From this difference, it is clear that men are usually out of the island for work whereas women stay in the island, making them more vulnerable to disaster risks.

The current population density based on 2013 figures is 60 person per hectare. This shows how dense the population is in Thinadhoo. As discussed, one of the reasons for the increase in population and density is the migration of people from other neighbouring islands to Thinadhoo for its improved infrastructures, facilities and amenities. This increase in population and the rapid urbanization increases the vulnerability of the island to disasters to a great extent (ESCAP & UNISDR 2012).

The previous island assessment conducted in 2007 identified 41% of the population as dependent population based on the age groups. According to the study, children of age below 15 and elderly people with age of 65 and above are considered as dependent as they would require assistance and support for mobilization in case of a disaster event (UNDP 2008). Unfortunately for this study, updated figures for population per age group are not available. Nevertheless it was noted that, currently 161 people are recorded as above 65 years, which accounts for only 2% of the total population of the island. Previously it was 6%. Thus it can be deduced that at present the island carries a younger population compared to 2006 reducing the vulnerability level of the island to some extent (refer chapter section 4 for details on vulnerability groups). In general a fair distribution is observed in terms of males and females with a ratio of 1:1.03.

ii. Migration and foreign population

Thinadhoo has experienced a high in-migration rate over the past years with the massive reclamation of the island and the new developments offering better services. People prefer to move to the island for better facilities and amenities. Most of the people are from the same atoll and the neighbouring atoll Gaaf Alif. Over the past 10 years a number of people have been migrated to the island while the out migration, mostly to Male' is also evident. Unfortunately, due to lack of recent detailed data on migration, the numbers could not be determined. With the proposed housing projects, and education opportunities more people are expected to move to the island putting more pressure on the natural resources. It has also been noted that the newly built row-houses are reserved to provide housing for migrants. The island aims to

> "The living standard of the people is high in Thinadhoo. If a couple is living alone they don't want to leave there kids to be watched by their parents alone. They want a foreigner to babysit there child so as to make it easy for them and because they can afford it" (Atoll council member, Gdh Thinadhoo, 2013).

promote and support the migrations movements although this may have a negative impact on the vulnerability of the island to disasters. These impacts are further discussed in section 4.

From the observation during field visits it is evident that there are a significant number of foreign workers residing in the island. More than 50 foreigners work in the health sector while a number of foreigners also work in education field, construction works and also at domestic level (house maids). Unfortunately the figures are not available as the island office does not maintain their records. Also there is the possibility of illegal immigrants working in the island offering cheap labour as was noted by the community. This has increased the population residing in the island adding more pressure to the increased population.

2.4.2. Households and Families

According to the island records the total number of households in Thinadhoo accounts for 1,817. This covers 50 hectares of the total land area. Among these, people are living in 977 houses while 603 are yet vacant. According to Census 2006, the average household size was 6.1, however as observed during the field survey for this study, with the increased population, this has now increased to 7 people per household. The plot size of the houses ranges from 2,000 square feet to 5,000 square feet.

In the Maldives, households are mainly based on extended family systems; families living under one roof. However this trend is slowly changing as nuclear families choose to live separately. Nevertheless, in Thinadhoo extended families are still found to be more than nuclear families, which explains the large household size. This may be due to land shortage and the emigration of men to work in Male' and tourist resorts. Another reason could be the respect for the elders of the family and the communal values which is relatively strong amongst Thinadhoo families. This key feature of respect also shows a strong bond between family members and the support they provide at times of any difficulty.

2.4.3. Community Capacity and Resources

i. Natural Resources

Similar to any other island of Maldives, the largest natural resource for the island is its surrounding environment which constitutes the sea, beaches, vegetation and the land. The resources available within the island include the coconut palms, fruit and vegetable trees (breadfruit, yam, cassava, banana, pumpkin etc.), wetlands (kulhi), reef and ground water. However, these resources are under the threat of destruction and depletion with the change in climate and human interventions. The beaches are eroding; the land is becoming scarce; and the trees are being removed with every new development. Impacts caused by these changes are further discussed in section 3 of this report which focuses more on the environmental impacts.

ii. Physical Resources

The physical resources include the public infrastructure also considered as the critical infrastructures of the island. These include the power house, schools, mosques and hospitals. Parks and other open spaces allocated for recreational uses can also be considered as part of their physical resources from which they could gain benefit on a day-to-day basis.

iii. Financial Resources

As far as the island alone is concerned, they do not have many financial resources readily available. However, the Bank of Maldives branch situated in the island facilitates the loan applications of investors and other residents. While they provide these facilities to a certain extent, investors mostly travel to the capital city Male' to seek loans. Also, people depend on interpersonal loans from large businesses and vessel owners to establish small businesses.

iv. Human Resources

Although employment has been noted as one of the main issues in the island, the level of education provided in the island and also the number of people with higher education is relatively high compared to most of the islands of the Maldives. However, there is no recent data available on employment.

In addition to education, the number of skilled workers is also high. These include fishermen, people involved in fish processing, construction workers, engineers, health care providers, carpenters, boat builders, vessel operators, teachers and administrative staff. Skills involved in

agricultural activities, rope weaving, food production and trading is also observed to be high in the island. The employment trends are further discussed in section 2.5.

v. Administrative and Institutional capacities

Health

The regional hospital for the region of Gaaf Alif and Gaaf Dhaalu atolls is located in Thinadhoo. The 50 bed hospital provides general medical services, specialist care, surgery (minor), emergency services, services of the intensive care unit (ICU), laboratory, X-ray, physiotherapy, inpatient and outpatient services. Although this hospital is supposed to cater for the whole region, it was evident from the stakeholder consultations that the people are not satisfied with the services provided. Main reason for the dissatisfaction was reported as the limited services and low capacity in terms of medical staff and equipment.

> "We don't have enough medical officers even. We have to maintain 8 islands' health centers, excluding Thinadhoo hospital. If one of the doctors from the health centers takes a leave, we have to send one from the hospital to there. But the problem is doctors do not want to go to these islands due to unsatisfactory accommodations" (*hospital staff, Gdh. Thinadhoo*).

Education

Thinadhoo caters for students from Thinadhoo and other islands in 8 schools which consist of 5 preschools, two primary schools, one school offering secondary and higher secondary education. They also have a university campus offering few courses in the areas of teaching, nursing, business administration and management. However, the quality of education offered is low compared to Male' due to lack of professional teachers and sufficient budget. There are also private institutions, which offer tuition classes and Quran recitation classes.

Emergency services

Emergency services are provided by the hospital and police station. The regional hospital provides the service of ambulance in case of any medical emergency. Consequently the police offer the services of island security, fire fighting and emergency services in events such as flooding. However, in case of a disaster or large scale emergency the existing facilities and equipment will not be able to cater to the whole island. Also, no institution has a disaster management plan and the community members are not aware of what should be done in case of such an emergency.

Municipal Services

With the decentralisation of the government, the island councils elected by the public are now responsible for providing the municipal services. They are also in charge of providing road maintenance and waste management services. The utility companies manage such services in urban centres such as Thinadhoo. Likewise, the waste site and water services are managed by *Fenaka Corporation Limited*[1]. However, services such as waste disposal and management of the waste site are not well provided. While a certain area is designated for waste disposal, the distance of the site from the residential areas and the absence of dustbins within the island results in waste being disposed in different parts of the island. The island needs a better system with necessary equipment and staff to provide the regular municipal services.

2.4.4. Social trends

i. Youth

With the provision of O' level and higher secondary education in the island, the youth are more educated and aware on the most pressing issues of the island. Although fishing is the main income generating activity in the island, number of youth involved in fishing has decreased over the past years. One of reasons noted was the availability of jobs in other fields. Drug abuse is a severe issue and the youth who actually works also work to earn for drugs. The lack of recreational activities for youth maybe one of the contributing factors of the increase in number of at-risk youth in the society.

> "Thinadhoo is an island with very few youths turning up for fishing. I believe that what happens in Thinadhoo is that youth hang out with the wrong type of people and ends up taking a wrong road" (*Atoll council member*, Gdh Thinadhoo, 2013)

Moreover they are not familiar with the concept of climate change and its impacts on the environment. There is potential to advocate the youth on such issues and empower them to get actively involved in taking initiatives to protect the environment and raise awareness amongst others. More trainings and awareness campaigns are necessary for this to work.

[1] *Fenaka Corporation Limited* is a government owned utility company with a mandate to provide island communities with electricity, water and sewerage. Also, the company aims to establish to establish an environment friendly waste management system in the different parts of Maldives

ii. Drug abuse and antisocial behaviour

Drug abuse has become one of the most concerning social issues amongst the island communities. All stakeholder groups consulted identified this as one of the major social problems as more people are entering the drug circle. This has also led to other issues such as robberies, violence and arson. In addition, any income they earn is spent on purchasing drugs, hence affecting their career and future development of the island.

iii. Changes in governance

With the new Decentralisation Act in 2010, atoll and island councils were publicly elected. The aim of this Act is to make the councils accountable for the decisions made with regards to all matters relating to the island and to empower the people of the island to work together in a better environment, to improve their quality of life. Bringing what they need closer to island level is one of its objectives. This would allow transparency and is expected to speed up the procedural works.

The main responsibilities of the atoll/island councils are to work for the development of the atoll/island, provide all the municipal services by closely involving the community in planning, developing and providing the services to the atolls/ islands (*Decentralisation Act* 2010).

2.4.5. Poverty

The 2nd *vulnerability and poverty assessment* conducted in 2004 estimated that population with per capita income less than Rf10 falls under the poverty line (UNDP 2005). According to the assessment, in Thinadhoo 11% of the population has an income less than Rf15 per day while 3% has an income less than Rf10 per day (UNDP & World Bank, 2005). However, this study was conducted in 2004 and the island has gone through a number of changes in terms of land use and population numbers over the past 9 years.

In comparison to other islands of Gaaf Dhaalu atoll, the people of Thinadhoo are relatively well-off. Although there may be a small fraction of the population under the poverty line, the economic condition of the island has improved significantly with more economic activities being carried out in the island.

2.5. Island economic setting and baseline economic conditions

Thinadhoo economy should be considered as one of the largest island economy in the south of Male'. Thinadhoo has one of the most modern fleet of fishing vessels in the country and the

economy is primarily based on the fishing industry. It is also known as one of the main fishery islands in the southern atolls of Maldives.

Thinadhoo, with the presence of whole sale and retail centre of State Trading Organizations (STO) and other well established wholesalers, operates as the main distribution hub to Gaaf Dhaalu and parts of Gaaf Alifu atoll. The extension of harbour has eased the usage of harbour especially for commercial and fishing vessels. The improved connectivity within islands through the national transport system has reduced cost of transport and travel by people from neighbouring islands. This has increased the number of people visiting the island for health care and other purposes also contributing to the increase of whole sale and retail trade and the export sector through re-exports to nearby islands.

As far as tourism is concerned, one resort in Gaaf Dhaalu atoll and 4 resorts in Gaaf Alif atoll are operational. The people of Thinadhoo noted that they do not get enough opportunities in tourism sector and only few are involved in tourism related activities.

Government (civil service) and Public enterprises are the major employers. Also employment in fisheries, whole sale and retail sector, transport sector shows significant increase. The rest of this section will explore the economic setting in more detail.

2.5.1. Employment and occupational structure

Since the previous DIRAM report, there have been no studies conducted to analyse the employment and occupation of the islands. According to Census 2006, a total of 1,755 people are economically active (MPND, 2007). However with the increase in population and economic activities in the island the figures stated in table 3 below would be very different now. Unfortunately recent figures are not available and the analysis is based on the change of trends observed during field work surveys.

TABLE 3 EMPLOYMENT OF THINADHOO COMMUNITY AS REPORTED IN POPULATION CENSUS 2006 (MPND 2007)

Economically active population	**2,176**
Economically inactive population	965
Labour force participation	57.6%
Rate of unemployment	20%

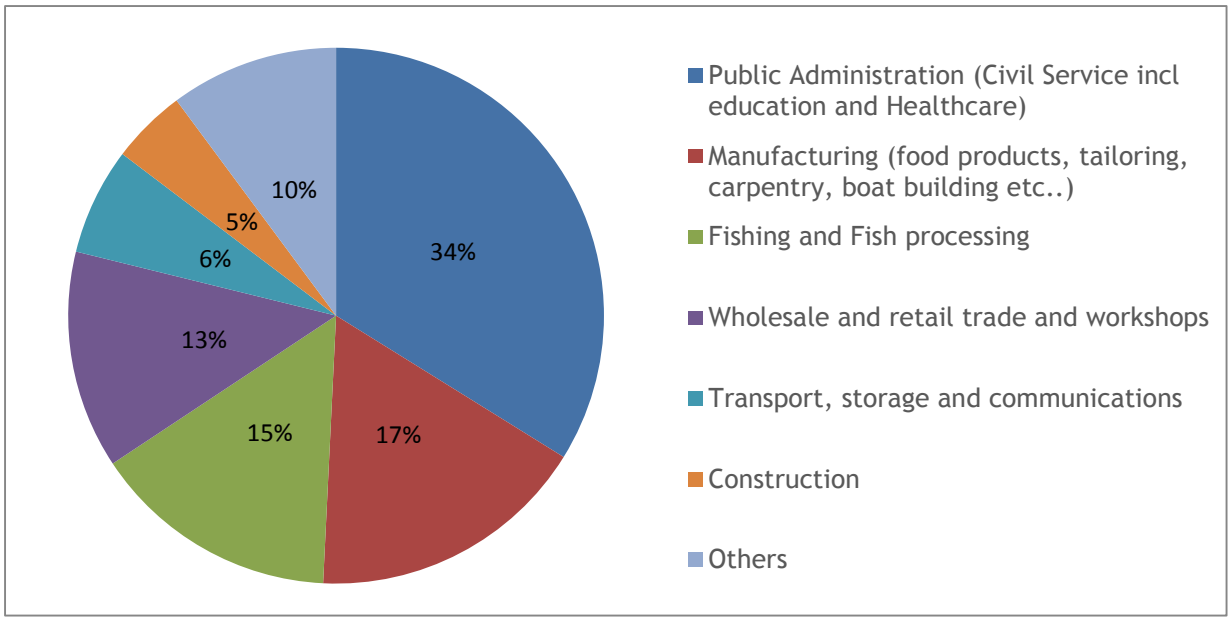


FIGURE 4 PROPORTION OF EMPLOYMENT BY ECONOMIC ACTIVITY FROM CENSUS 2006 (MPND 2007)

As observed during the field work and based on data provided by the island office, the main employers are the government (civil service) and public enterprises.

The current trends in employment observed in Thinadhoo are as follows:

- Employment in whole sale and retail trade is on the increase.
- Employment in the fisheries sector is also increasing with the size of vessels. There is a high demand for more crew members and more youth are taking up employment in the industry due to the extremely good pays and as they are closer to the island.
- Number of females in employment has increased, especially in administrative and salesman positions in the whole sale and retail sector.

2.5.2. Economic structure by investment and income

The main economic activity of Thinadhoo in terms of estimated employee level income is fishing, which contributes 36% of total income earned. It is followed by employment in civil service and public enterprises which is 35% of total income earned. Manufacturing accounts for 7% and Electricity, Gas and Water supply is 5%. The estimated value for the monthly income is presented in table 4 below.

As noted above the main economic activities are in the basic sector; fishing, manufacturing and trade. The rest are non-basic sectors which include construction, real estate, small business activities and transport. These are highly dependent on the basic sectors. Thus any

impact to the fisheries industries and whole sale and retail would have a direct impact on the non-basic sectors.

TABLE 4 ESTIMATED VALUES OF INVESTMENT AND MONTHLY INCOME BY SECTOR

Sector	Estimated Monthly Income [1]
Fishing	4,400,000.00
Public Administration/Public Enterprises (Civil Service incl education and Healthcare)	4,256,000.00
Manufacturing	790,000.00
Wholesale and retail trade and workshops	520,000.00
Transport, storage and communications	430,000.00
Construction	207,000.00
Other community, social and personal service activities	150,000.00
Hotels and restaurants	110,000.00
Electricity, Gas and Water supply	650,000.00
Mining and quarrying	250,000.00
Financial intermediation	55,000.00
Agriculture	20,000.00
Real Estate, renting and business activities	225,000.00

[1] Estimated income is stated for salaried employees only and is based on average income multiplied by the number of employees.

2.5.3. Key sectors

Fishing: Fishing is the dominant sector with estimated monthly income increased to 13-15 million Rufiyaa per month since year 2008. Although the fish catch has decreased, the rates have increased hence increasing the profit. The main types of fishery are yellow fin tuna and skipjack tuna fishery. There is a decline in fish processing and production of other related goods in the islands as most of the catch is sold to exporters who pay better prices. There are

25 fishing vessels involved in fishing activities. The main types of fishery are yellow fin tuna and skipjack tuna fishery. They also do reef fishery to some extent. While the bigger vessels spend 1 to 2 weeks out at sea, the smaller vessels normally return daily with their catch. The main market is the collector vessels operating in the south region and the Koodoo fish canning factory. Although most of the catches are sold outside, a small proportion of tuna is processed on the island. Currently there are 4 parties involved in fish processing. They are mainly involved in cooking, drying and salting. The processed fishes are directly exported overseas. The main investments are made on fishing vessels to buy engines and other equipment.

Agriculture: Agricultural activities in Thinadhoo are practiced on a small scale. According to the people who are involved in such activities, the main issue is the scarcity of land and lack of financial capacity. Thus it is not feasible for them to carry out in a large scale. The main crops grown include vegetables such as cucumbers, beans, tomatoes, egg plants, chillies and green leaves. In addition they grow fruit trees at their backyards including breadfruit, banana, mango and coconuts. Also they grow yam, taro and cassava to some extent. The products are mainly sold to the neighbouring islands and some are sent to Male'. Since it is being practiced on a small scale, investments made in the area are also small and comprise mainly of water pumps, fertilizers and seeds. Large fruit trees are also present within the island but are sparsely distributed.

> "We received a very small location to farm, and when we look to farm we don't receive enough income after paying the expenses. Also the subsidies provided by the government, each time they come and fill up forms but we never get anything." (A *businessman involved in agriculture*, Gdh Thinadhoo, 2013)

Manufacturing: In manufacturing sector, people are mostly involved in boat building/repair, tailoring, carpentry, baking, food processing (different types of local snacks) etc. Most of the products are sold in the island. Some of the processed foods are also exported to Male'. Women are dominant in this sector.

Trade: There are about 157 trade businesses established in Thinadhoo. The volume of trade is estimated to have increased from 4 million Rufiyaa per month in 2008 to 6.5 million Rufiyaa per month in 2013. The main reasons for this increase are the practice of monthly stocking of their items and storing them in warehouses. Local and atoll wide retail shops may purchase stock from the wholesalers. Although the goods are stored in warehouses, they are not insured making them economically vulnerable in case of a disaster/severe flooding event.

The increase in volume of trade is mainly due to decrease in transportation cost with the national transport system. The distribution network is supported by public transport network and private cargo boats. Goods are distributed throughout Gaafu Dhaal and Gaafu Alif atoll.

Civil Service & Public Enterprises: This sector accounts for 35% of total income earned by the islanders. Government is the largest single employer and employment in other public enterprises has increased the employment economy. Employment is primarily in education, general island administration and health care sectors. These sectors provide the main source of income for most of the people of Thinadhoo. Their dependence on government for income/finance reduces their vulnerability towards personal income losses from a disaster.

Construction: Although there is a high demand for construction especially on government housing projects, the construction in the island is yet to be developed. Most construction projects are undertaken by foreigners who work in groups, however, construction of the 10 row houses were awarded to companies from Thinadhoo. Foreign workers are more preferable among the community as their prices are lower compared to awarding to a contractor for a higher lump sum fee. Investments in this sector are estimated to be around 1.4 million Rufiyaa. The foreign labour has become a concerning issue. Community members who are in construction work are jobless since they are being replaced by the foreign workers who offer cheaper rates.

Transport Sector: The transport sector is well-established with cargo boats, speed boats and multipurpose boats (dhoni). The cargo boats play a key role in the trade sector both on the island and surrounding inhabited islands. The speed boats are mostly used for inter-island transport, transfer between airport and island and medical emergency transfers.

Other businesses: There are many small businesses in the service sector and also small-medium industries. However, exact numbers cannot be determined due to lack of available data. Businesses involved in the service sector include the bank, tailors, saloons, carpentry, renting out places etc. Small-medium industries include processing food, cake baking and decorations etc. The available data on these establishments are presented in table 5 below.

TABLE 5 LOCAL BUSINESS ESTABLISHMENT INVENTORY AS OBTAINED FROM FIELD SURVEYS

Economic Establishments	Number
Retail & Wholesale	157
Cafe's, Restaurants, *Hotaa* (tea shops)	14
Rented places	7
Warehouse	5
Fuel Supply	2
Personal Services (salon, tailors etc.)	10
Carpentry	5
Private Health Services	1
Workshops	7

2.5.4. Infrastructure and Services

i. Transport infrastructure

The key transport infrastructure on the island is the local harbour. The harbour has a dredged basin (350m by 85m) and a quay wall (330 m). The quay wall has been largely damaged over the past year due to the strong waves during rough seasons. An extension has been made to the harbour in 2010 with a total cost of 16.7 million Rufiyaa.

ii. Communications infrastructure

The *DHIRAAGU* and *Wataniya* site offices with the communication towers are the main communication infrastructures on the island. The site offices also house the necessary communication equipment to service a large part of the atoll. Major investments include improvement to the network with the introduction of new products.

iii. Health care

Thinadhoo has the regional hospital catering to Gaaf Alifu, Gaaf Dhaalu and Gnaviyani atoll (Fuahmulak). The 50 bed hospital is currently equipped with 4 medical officers, 7 specialist doctors and 59 nurses. The laboratory service provides blood and urine testing services. A number of people from nearby islands and atolls move in and out every week mainly to attain health care services from the hospital. Approximately 3.1 million Rufiyaa has been invested since 2008 in the sector mostly in infrastructure development.

iv. Water supply

The main sources of water are rainwater and ground water. Although they have a water network system established in the island with an RO plant people are still not using this service on a daily basis.

v. Sanitation

Currently the sewerage system is managed using a combination of small bore and septic tanks. However, a sanitation project has been proposed to address the difficulties the community is having with the current system. The project will involve designing and building of sewage collection network, sewage pumping station and wastewater treatment plant and allied works. It was inaugurated on March 2013 and currently the design phase is ongoing and the whole contract is expected to be completed in 15 months.

vi. Waste management

A waste management site has been established on the northern corner of the island. However they need a better system as at present the site and waste disposal is not managed properly.

vii. Power

Power supply for Thinadhoo is provided and managed by upper south utility company. The supply system comprises of 4 diesel generators. These generators are stationed at a higher elevation to protect them from disasters. The power grid is laid underground along the streets. A backup generator is stationed at the hospital which can be used in case of an electric emergency.

viii. Critical infrastructures

The regional hospital, pharmacies, power house and power grid, water supply system, sewerage system, island harbour and the communication infrastructures are all considered as critical infrastructures which are further analysed under risk assessment (section 5.2).

Thinadhoo flooded due to heavy rain fall
Photo by: Shifna Saeed/ Riyan Pvt Ltd (2013)

3. Environmental Vulnerability Assessment

3.1. Natural Hazards

Natural hazards facing the Maldives can be classified into geological hazards (earthquakes, coastal erosion, reef slope failure), meteorological hazards (tropical cyclones, tropical storms, thunder storms, windstorms), hydrological hazards (tsunamis, storm surge, swells and other storm induced flooding (*Udha*), drought, saltwater intrusion) and climate change related hazards (sea level rise, changes in precipitation, sea surface temperature rise) (UNDP, 2008). For detailed background information of different types of natural hazards, the reader is directed to the previous DIRAM study (UNDP, 2008).

Out of these different types of natural hazards, the following major hazards were identified specifically for Thinadhoo (UNDP, 2008).

- Windstorms
- Flooding due to heavy rainfall/storms
- Swell waves, storm surges and udha
- Tsunami
- Earthquake
- Climate change

3.1.1. Windstorms

The southwest monsoon generally brings heavy rain and strong winds. Apart from this annual monsoonal cycle, severe local storms (thunder storms) and tropical cyclone induced strong winds leads to extensive damage to trees and infrastructure. According to Maldives Disaster Risk Profile (UNDP, 2006) 11 cyclones crossed the Maldives during the last 128 years. Most of the cyclones passed over the north of the country and Thinadhoo lies in the least hazardous zone with respect to cyclone related hazards (UNDP 2006).

There is no official record of any cyclone event in the region. However due to local depressions and storms, winds exceeding gale force (34 knots or 17.2 m/s) have been recorded by the weather station in Kaadeddhoo. Compared to the north of the country, the monsoonal winds are generally weaker and more uniform in yearly distribution in the south (Naseer, 2003). Between 2001 and 2007 winds exceeding gale force were recorded annually in Kaadedhoo with a maximum recorded wind of 96 km/h which is equivalent to a category 2 cyclone according to the Beaufort scale (UNDP 2008). However data from Gan between 1978 and 2001 reports a maximum of 34 knots (63 km/h) with only 4 events of similar, but smaller, intensity over this period. This difference in intensity of wind speeds over the 2 periods maybe due to the comparison of data from 2 different weather stations being analysed at different resolutions. In order to understand the wind pattern since the 2008 DIRAM report, hourly wind data from Kaadedhoo was analysed and results are shown in table 6 and figure 5. From the analysis it was clear that between May 2008 and December 2012, the highest recorded wind speed at Kaadedhoo was 27 knots which was well below gale force winds. Over this period, 99% of the time the recorded wind speed did not go above 4 in the Beaufort scale which is classified as moderate breeze. It was also evident that the highest wind speed and frequency was from the southwest and northwest quadrant, which corresponds to the southwest monsoon. According to the discussions and interviews held with the island community, there was no major damage to the island resulting from strong wind since 2008.

TABLE 6 HOURLY WIND DATA FROM KAADEDHOO STATION

Wind Speed (Knots)																
Wind Direction		Freq	>0 - 2	>2 - 4	>4 - 6	>6 - 8	>8 - 10	>10 - 12	>12 - 14	>14 - 16	>16 - 18	>18 - 20	>20 - 22	>22 - 24	>24 - 26	>26 - 28
22.5	NNE	4.52%		2.503%	1.726%	0.277%	0.009%	0.006%	0.003%							
45	NE	2.82%		1.885%	0.843%	0.087%	0.003%									
67.5	ENE	2.10%		1.283%	0.693%	0.117%	0.003%	0.003%								
90	E	2.10%		1.506%	0.512%	0.072%	0.009%	0.003%								
112.5	ESE	1.88%		1.400%	0.419%	0.060%	0.003%									
135	SE	3.46%		1.906%	1.135%	0.322%	0.078%	0.015%								
157.5	SSE	3.95%		0.934%	1.358%	0.906%	0.476%	0.202%	0.051%	0.021%	0.003%	0.003%				
180	S	7.98%		2.168%	2.527%	1.864%	0.994%	0.343%	0.066%	0.012%	0.003%					
202.5	SSW	6.38%		1.831%	1.988%	1.647%	0.711%	0.145%	0.030%	0.021%	0.006%		0.003%			
225	SW	6.53%		1.705%	2.054%	1.563%	0.792%	0.292%	0.057%	0.048%	0.012%	0.006%	0.003%			
247.5	WSW	10.37%		2.457%	2.981%	2.439%	1.301%	0.705%	0.313%	0.136%	0.036%	0.006%				
270	W	20.08%		3.713%	4.749%	4.824%	3.258%	1.939%	0.891%	0.416%	0.205%	0.054%	0.021%	0.006%		
292.5	WNW	11.01%		1.527%	2.430%	2.777%	2.114%	1.174%	0.482%	0.304%	0.126%	0.048%	0.015%	0.012%		
315	NW	6.57%		0.997%	1.497%	1.617%	1.322%	0.699%	0.229%	0.117%	0.042%	0.027%	0.012%	0.003%	0.003%	0.003%
337.5	NNW	4.29%		1.367%	1.430%	0.858%	0.404%	0.145%	0.033%	0.033%	0.012%	0.003%				
360	N	5.95%	0.003%	3.066%	1.985%	0.732%	0.136%	0.024%	0.006%	0.003%						
Cumulative %			0.003%	30.25%	28.33%	20.17%	11.61%	5.69%	2.16%	1.11%	0.45%	0.15%	0.05%	0.02%	0.003%	0.003%

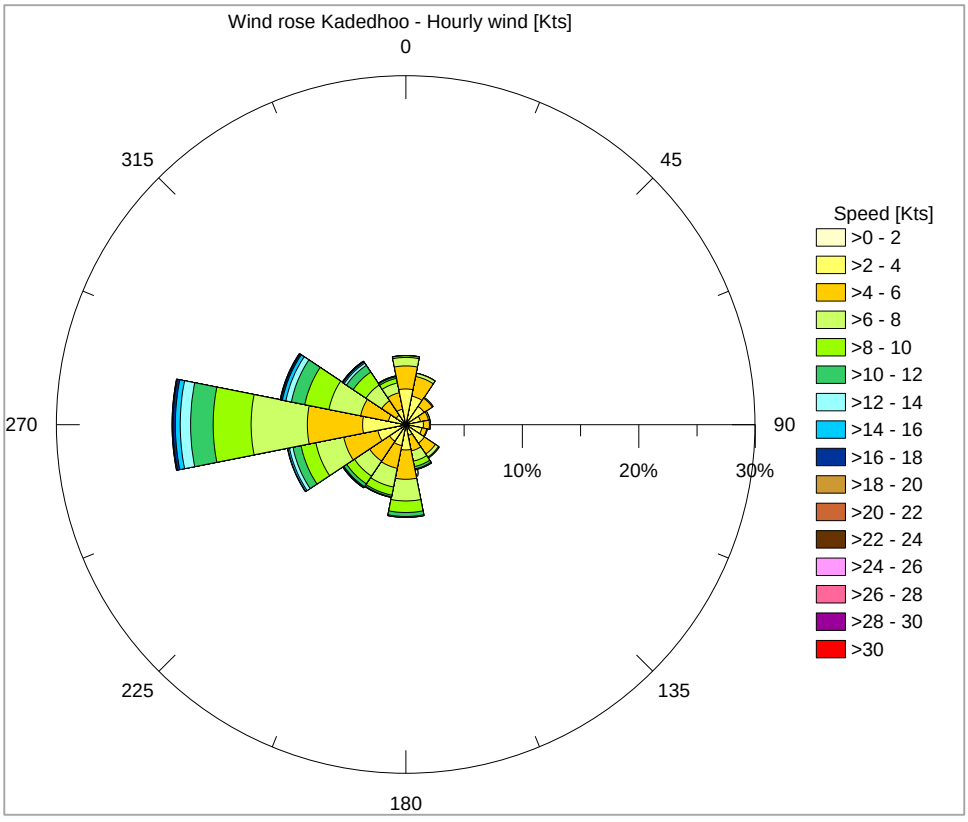


FIGURE 5 WIND ROSE DIAGRAM FOR RECORDED HOURLY WIND SPEED BETWEEN 2008 AND 2012

3.1.2. Flooding due to heavy rainfall

Flooding due to heavy rainfall is a very frequent event in Thinadhoo. One of the main reasons for the frequent rainfall induced flooding is the major variations in topography caused by the unplanned reclamation activities that have been carried out in the island since the 1980s, without addressing drainage issues. Approximately 61% of the present island is reclaimed land. Reclamation has been undertaken almost around the entire perimeter of the original island with the largest area reclaimed in the north. The south end of the island used to have a large wetland area which has since been reclaimed.

Since the Detailed Island Risk Assessment of Thinadhoo was carried out in 2008, no major modification to the island has taken place. The only major coastal infrastructure works that has taken place after 2008 is the construction of 160m long quay wall or harbour front area in the eastern side of the island adjacent to the existing harbour area. This also did not involve any modification to the existing shape of the island shoreline nor did it involve any significant reclamation works. Since the landward side of this new harbour area coincides with the interface between the original island and new reclamation to the north, which was an area prone to flooding, 2 storm water pipes were incorporated in the project in an effort to allow drainage of water into the lagoon through the quay wall. It should be noted that this was not by any means a comprehensive drainage project aimed at solving the bigger flooding issue in the area. Hence it is envisaged that the flooding issue has still remained to be a significant issue since the previous DIRAM study in 2008.

In the previous DIRAM study, due to the failure to access rain fall data from the Kaadedhoo meteorological station, rainfall hazard was studied using data from Gan weather station and event reports from the island. For this study, daily rainfall data between 1998 and 2012 was obtained from the Kaadedhoo weather station. According to the previous study the mean annual rainfall at Gan was 2299.3mm and the mean monthly rainfall was 191.6mm. From the analysis of Kaadedhoo data, it was found that the mean annual rainfall near Thinadhoo is 2101.3mm and the mean monthly rainfall is 175.1mm. Figure 6 shows the annual rainfall for the 15 year period between 1998 and 2012. The highest rainfall was measured at 2981.5mm in the year 2002 with the lowest measured at 1563.2mm in the year 2011. There is a clear decline in the mean annual rainfall starting from the year 2007 to 2011 followed by an increase in the year 2012.

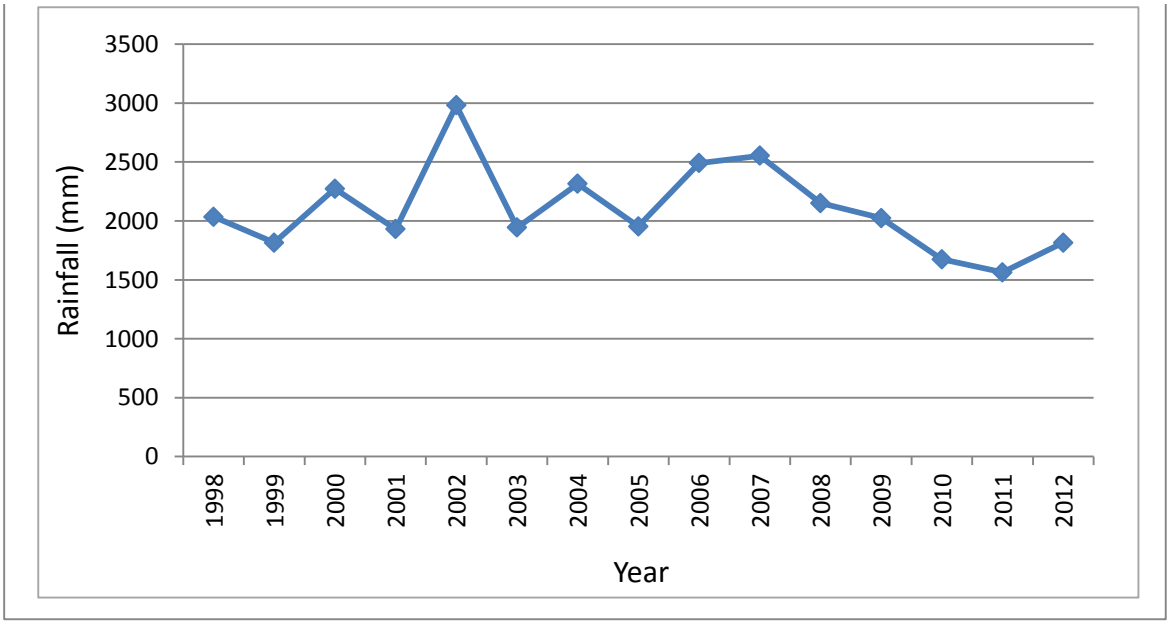


FIGURE 6 ANNUAL RAINFALL FOR THE 15-YEAR PERIOD BETWEEN 1998 AND 2012-GENERATED FROM DATA PROVIDED BY MALDIVES METEOROLOGICAL SERVICES (MMS)

For rainwater flooding, intensity of rain plays a major role, which can be determined by the rainfall per hour. However, the data that was available from Kaadedhoo was daily measurements. Figure 7 shows the frequency of the daily rainfall measurements from the Kaadedhoo data set.

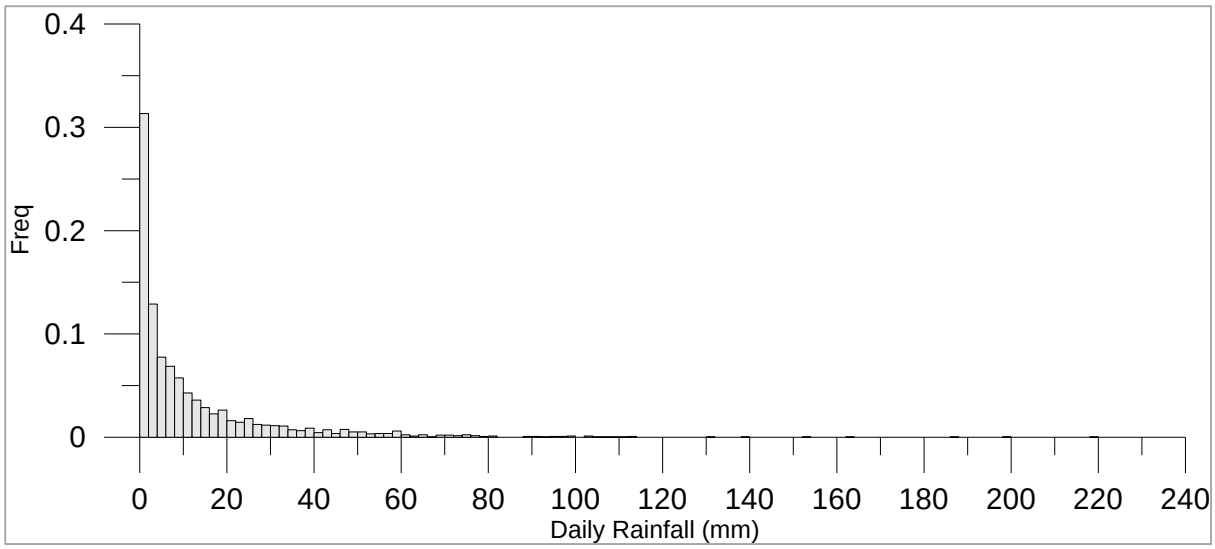


FIGURE 7 FREQUENCY OF THE DAILY RAINFALL (GENERATED FROM DATA PROVIDED BY MMS)

The highest daily rainfall was measured at 219.8mm on 9th July 2002, which can be classified as Torrential Rain. This date was also highlighted by the island community as a day of major flooding in the island. From the results it was clear that for over 95% of the time, the daily

rainfall limit was less than 50mm. If daily rainfall exceeds 50mm it is commonly referred to as Heavy rain. From these results it is evident that within a year, approximately 17 days would experience heavy rainfall, which can potentially cause flooding events in the island.

Future Predictions

UNDP (2006) predicted the probable maximum rainfall for different return periods using rainfall data from the Gan weather station (Table 7).

TABLE 7 PROBABLE MAXIMUM RAINFALL FOR DIFFERENT RETURN PERIODS

Return Period	50 Years	100 Years	200 Years	500 Years
Rainfall (mm)	218.1	238.1	258.1	284.4

More recently in 2011, Regional Integrated Multi-Hazard Early Warning System for Africa & Asia (RIMES) worked on the development of High-Resolution Regional Climate Change Model for the Maldives through statistical and dynamic downscaling of global climate change models to provide future projects for rainfall, sea level rise and sea surface temperature. The future projection of rainfall by RIMES (2011), show both an enhanced variability and an increasing tendency, with the entire country having a greater increase in rainfall in the future.

According to the findings of RIMES (2011), the increase in rainfall would be accompanied by extreme events such as maximum one-day rainfall and increase number of consecutive wet days increasing over the Maldives. For example the baseline maximum daily rainfall of 55mm for the Maldives is projected to reach 100 mm in 2021-2050 and 112mm in 2082-2100. Similarly, consecutive five days rainfall 217mm would increase to 318mm in 2021-2050 and 382mm in 2082-2100.

3.1.3. Flooding due to swells, storm surge and *Udha*

"Udha" is the local term used historically to describe a flooding event caused by elevated water levels coupled with swells and/or wind generated waves. However in recent times "Udha" is commonly used to describe any flooding event caused by waves and high tides. This of course does not include flooding due to Tsunamis. As described in the previous DIRAM study (UNDP, 2008) it is difficult to discern the difference between "Udha" and flooding due to swells and storm surge events. Hence for the purpose of this report, flooding due to swell and storm surge would also cover "Udha".

Swells are long period waves generated from off-shore storm events. It has been established that swells predominantly approach the Maldives from a southerly direction (Young, 1999). Due to the island's location in the western rim of the Huvadhoo atoll, swells generally approach the island from south westerly and westerly direction. Furthermore, swell waves propagating through the atoll channel impacts the south and southeast corner of the island.

According to the disaster risk profile (UNDP, 2006), Thinadhoo is located in the least vulnerable storm surge hazard zone due to cyclonic events with predicted zero storm surge. However, the island is still exposed to storm surges generated due to low atmospheric pressure of severe localized storm events. The western coast of Thinadhoo is very vulnerable to flooding due to these storm surge events swell and large wind generated waves.

Thinadhoo coastline is also exposed to wind generated waves which are governed by the monsoonal winds. During the southwest monsoon and northeast monsoon, west and east coast would be impacted by wind generated waves respectively. The wind generated wave heights is a function of wind speed, duration and fetch length. Since to the west of Thinadhoo is open to the ocean, wind generated waves from this direction are generally speed and duration limited. Whereas waves during the southwest monsoon generated inside the atoll would probably be fetch limited. Nonetheless Huvadhu atoll being one of the largest atolls in the World, the inner atoll is also subject to relatively high wind generated waves. The western side of the island is protected from these waves by the wide reef flat and the eastern side has a very large lagoon with the outer island reef very far from the island shoreline. Therefore wind generated waves become hazard when combined with a severe storm surge that could lead to wave overtopping causing widespread flooding.

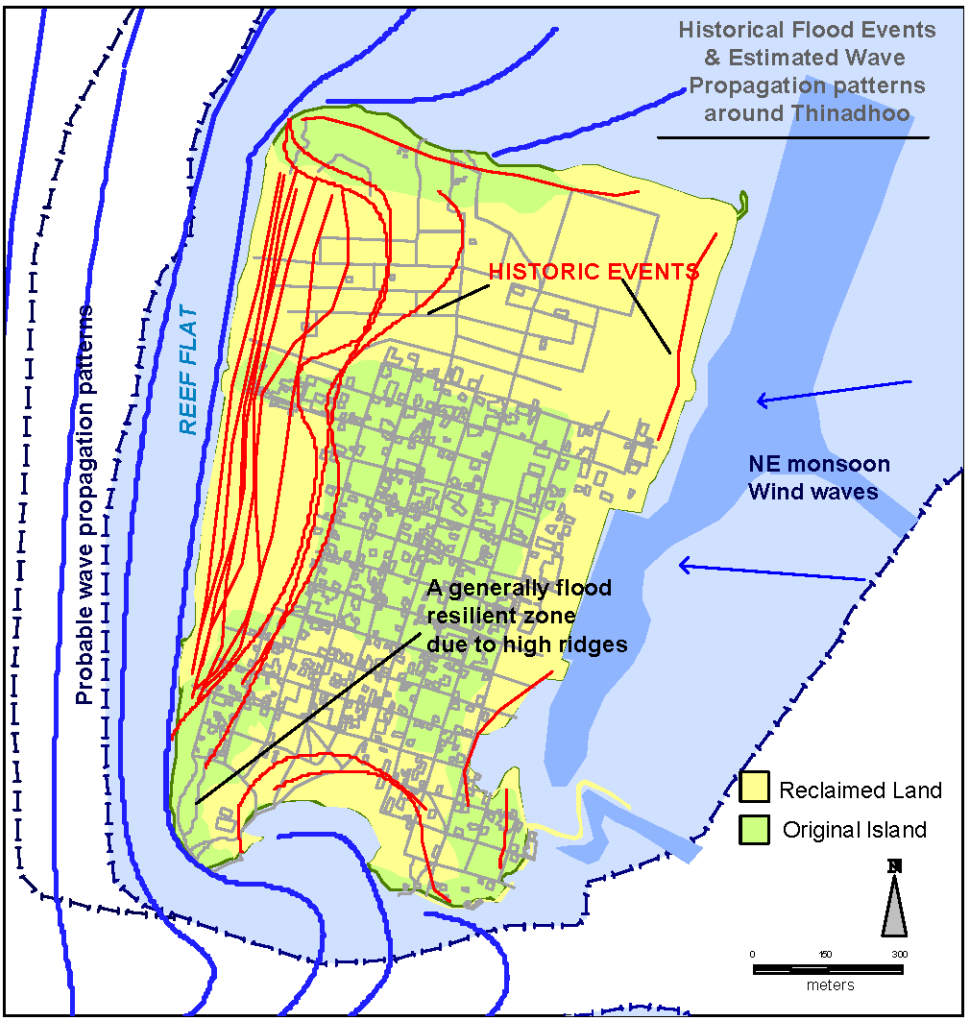


FIGURE 8 HISTORICAL FLOOD EVENTS AND PROBABLE WAVE PROPAGATION PATTERNS AROUND THINADHOO (UNDP, 2008)

3.1.4. Tsunamis

Prior to the 2004 Indian Ocean Tsunami, there is no record of any tsunami events impacting the Maldives. This is in part due to the fact that tsunamis are relatively rare in the Indian Ocean. According to the National Geophysical Data Centre of NOAA, only a total of 86 tsunami events are recorded in the Indian Ocean over the entire recorded history. Most of these events are of relatively low magnitude (NOAA 2005).

Tsunamis can be generated from various sources such as submarine earthquake, volcanic explosion, underwater landslides, underwater explosions and meteorite impact. Earthquake generated tsunamis are the most common and mostly likely to impact compared to other generation sources. There are 3 earthquake zones in the Indian Ocean that could lead to the

generation of a tsunami, which are The Sunda Trench, the Makran region and the Carlsberg Ridge (Figure 9).

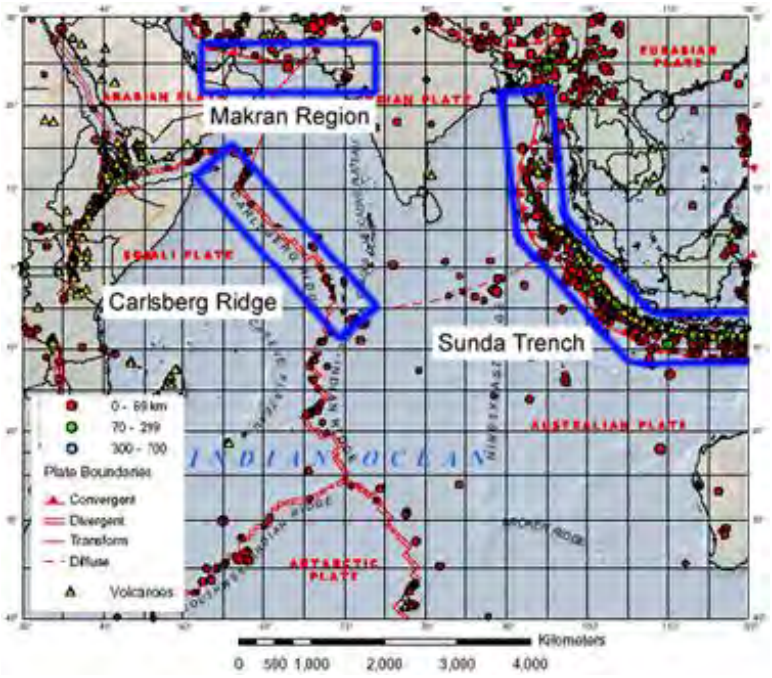


FIGURE 9 TSUNAMI SOURCE AND SIGNIFICANT EARTHQUAKES IN THE INDIAN OCEAN (USGS, 2003)

The NOAA tsunami catalogue indicates that only three tsunamis were generated from the Makran region and a single tsunami was generated from the Carlsberg ridge in the entire recorded history. Most of the tsunamis generated in the Indian Ocean are the result of submarine earthquakes in the subduction zone known as the Sunda Trench.

Therefore tsunami hazard is the highest to east side of the country. Tsunami propagation and inundation in the islands is subject to a lot of parameters. Propagation is mainly governed by the offshore bathymetry. Figure 10 show the offshore bathymetry and tsunami wave propagation model for a tsunami generated in the Sunda Trench.

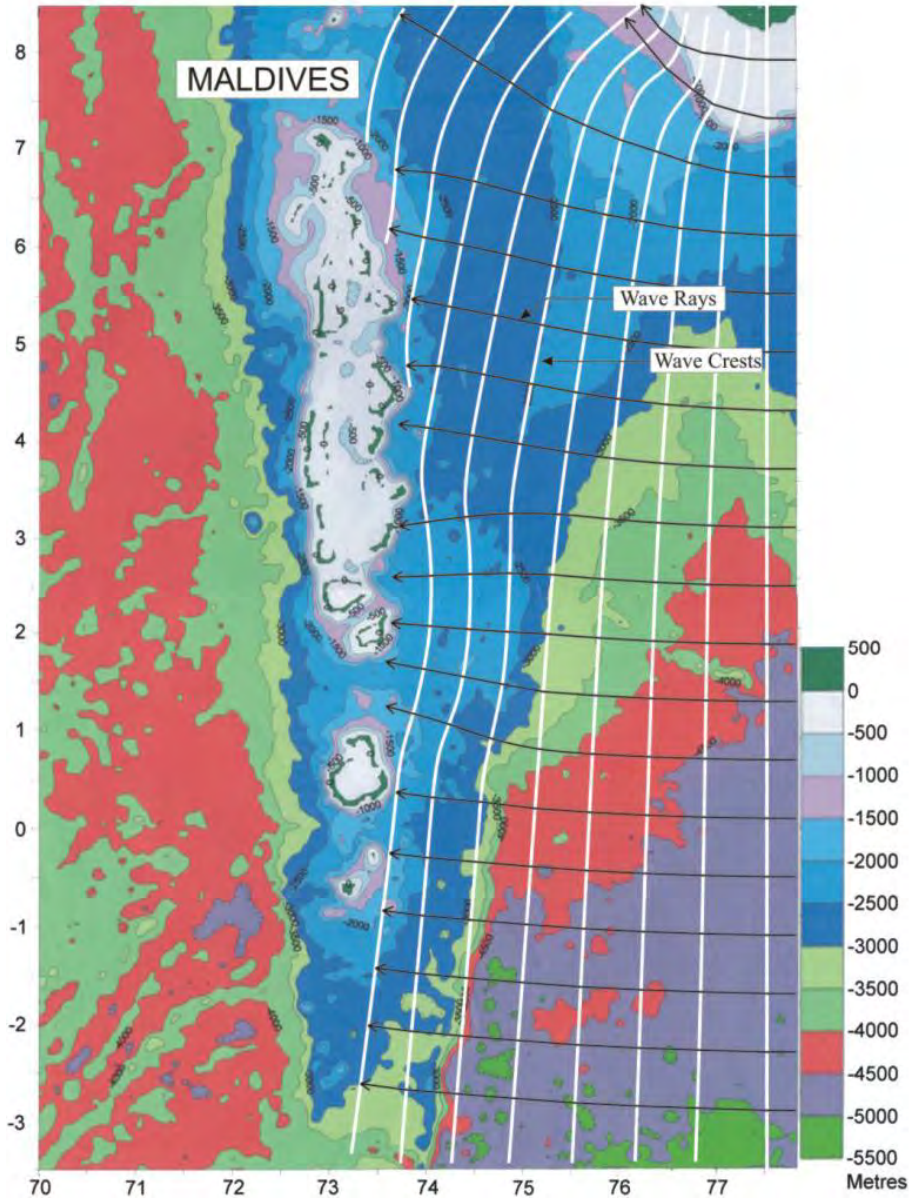


FIGURE 10 INDIAN OCEAN BATHYMETRY AND TSUNAMI PROPAGATION MODEL (ALI, 2005)

According to Ali (2005), due to the offshore bathymetry of the Maldives, tsunami wave convergence is always predicted for the central part of the country. This is true for any tsunami wave generated from the Sunda Trench. Therefore islands in Laamu, Thaa, Dhaalu and Vaavu are generally at the highest risk of tsunami impact compared to the rest of the country. Thinadhoo being in the western rim of the Gaafu Dhaalu atoll, it is relatively safe compared to the some other parts of the country. Figure 11 shows the tsunami hazard zones (Ali, 2005)

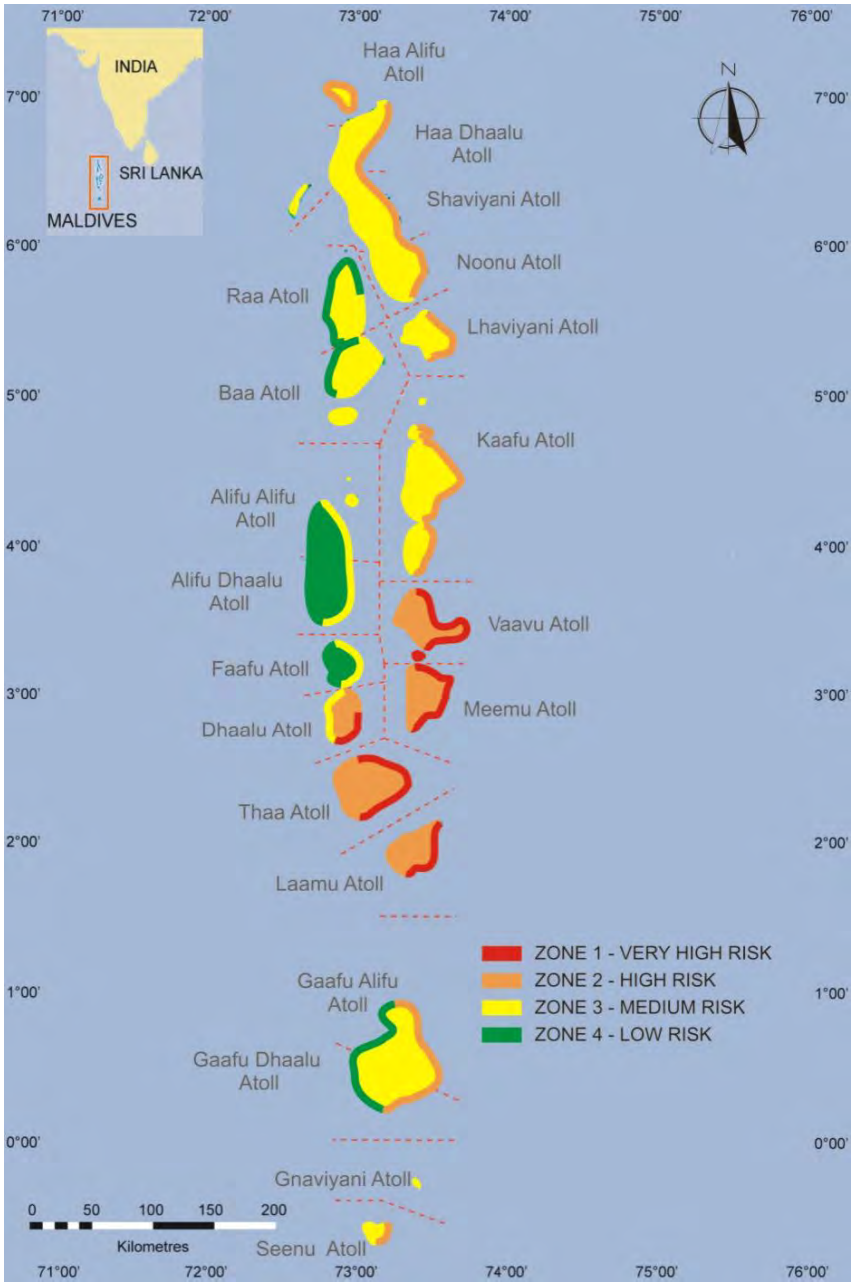


FIGURE 11 TSUAMI RISK ZONE MAP (ALI, 2005)

3.1.5. Earthquakes

Maldives is not located in a seisicmally active zone and there are no records of any major earthquake activity in the Maldives. However tremors from distant earthquakes are felt in the country. The nearest source of earthquake activity is the mid-ocean ridge known as Carlsberg ridge located southest of the country. Earthquakes generated at mid-ocean ridges are generally weak compared to subduction zone earthquakes. According UNDP (2006) Thinadhoo lies in zone 3 of the earth quake hazard zone (figure 12).

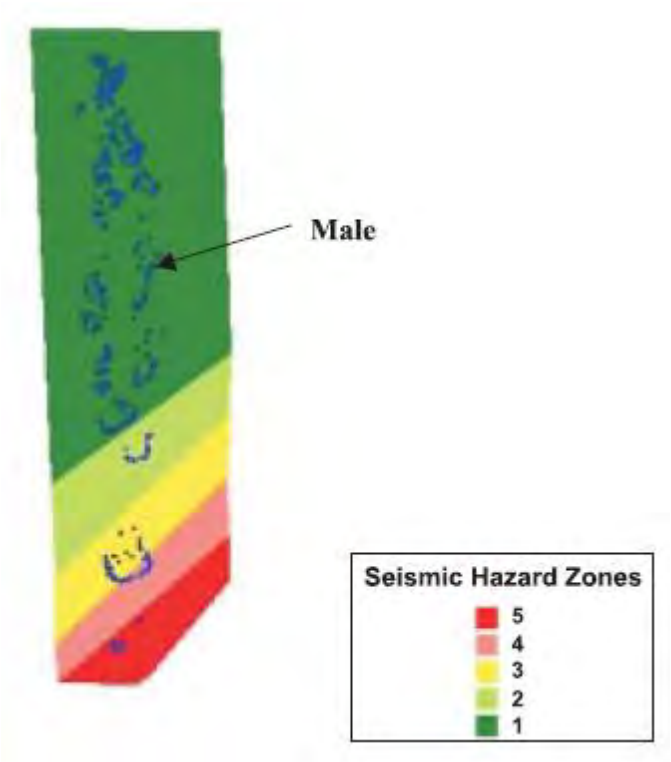


FIGURE 12 MALDIVES SEISMIC HARZARD ZONES (UNDP, 2006)

3.1.6. Climate change

Climate change has become one of the most critical issues facing the Maldives. Climate change induced Sea Level Rise (SLR) and Sea Surface Temperature (SST) rise would potentially have a devastating impact on the island ecology and geomorphology.The statisistical downscaling carried by RIMES (2011) indicated that the sea surface temperature is projected to increase by 1.01°C to 1.93°C in the year 2050 and 1.27°C to 3.40°C in the year 2080. According to Khan et al. (2002) sea surface temperature around the Maldives could rise at a rate of 0.3°C per year.

The most comprehensive sea level rise study in the Maldives was carried out by Singh et. al (2001) who concluded that the sea level has risen between approximately 5.8 and 8.5 mm per year around the Maldivian coast. This estimate is higher than the IPCC (2001) forecasted rate of 5mm per year. IPCC also forecasted that at the end of this centuary the sea level would rise to 0.88m above the current levels (IPCC, 2007). However it should be noted that the RIMES (2011) found that for the Gaafu Dhaalu atoll, the sea level is projected to rise by 0.95m in the year 2080.

The consequence of SLR and rise in SST increase is that the Maldives would be more vulnerable to hazards such as flooding of low-lying coastal areas, loss of land due to increase in coastal erosion, higher impact from future tsunami events, coral bleaching etc.

3.2. Existing environmental condition

3.2.1. Historical changes to Thinadhoo shoreline and erosion

The shoreline of Thinadhoo has been modified over the years both due to natural and man made changes. A satellite image from the 1969 shows the island prior to any major man made modification. The south of the island had a large wetland area and the western side shoreline was formed like a bay. The island of Thinadhoomaahutta or Maahutta is seen to the north (See figure 13).

Due to increased population and associated land requirement the southern side marsh lands were reclaimed first. The reclaimation works started in the early 80s when harbour development works was first started in the island. The 1998 aerial image shows the island following the reclamation of the south side wetland. Later a project on dredging and reclamation works was carried out where the western and eastern side of the island were reclaimed. Under these works the island *Maahutta* was joined with Thinadhoo mainland (See figure 13 for the aerial views of the island in 1969, 1998, 2003 and 2006).

The eastern shoreline is observed to have undergone significant changes over the years due to development activities. The first harbour works at Thinadhoo was carried out in the 80s. The latest harbour development works were carried out in 2011 for extension of the harbour. The dredged soil generated from the basin excavations works were used to reclaim the land behind the harbour quay walls and the south side wetlands. These coastal modifications and reclamation projects had straigtened the previous bay shape of the western shoreline.

Erosion around the island remains similar as discussed in the previous DIRAM study. The most severe erosion is observed at western reclaimed shoreline. Major sectoin of the eastern shoreline is protected with harbour quay wall with only the reclaimed section to the north not protected. This area is not as critical as the western side. This is due to the fact that the eastern side is protected with a large lagoon while the western side reef flat width varies between only 100m to 200m while facing the severe wave condition generated by the south west monsoon and the swell waves. The western reef flat is very shallow with depth varying between about 0.2m and 0.6m MSL. According to the EIA report prepared by Ministry of Housing and Environment (MHE) for the construction of sewerage system at Thinadhoo, in 2010, 27% of the Thinadhoo shoreline was eroding, while 59% was neutral and 13% was

accreting. The western side erosion problem is exacerbated by the fact that people are mining sand and finger coral from the shoreline for construction and other purposes.

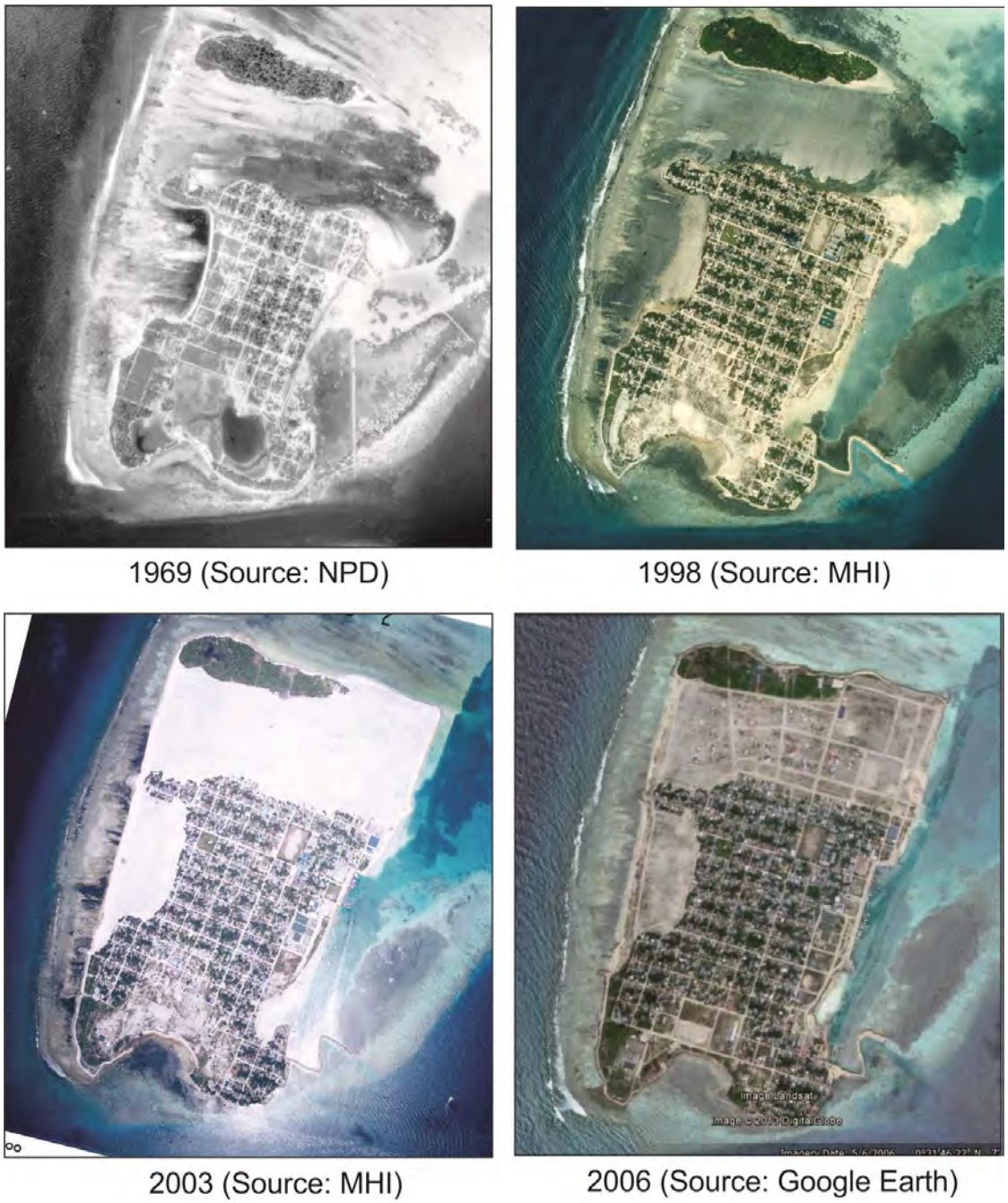


FIGURE 13 SATELLITE AND AERIAL IMAGES OF THINADHOO FROM 1969, 1996 AND 2011

3.2.2. Topography

Topographic assessment of Thinadhoo in previous DIRAM study was assessed by using 3 profiles as shown in figure below.

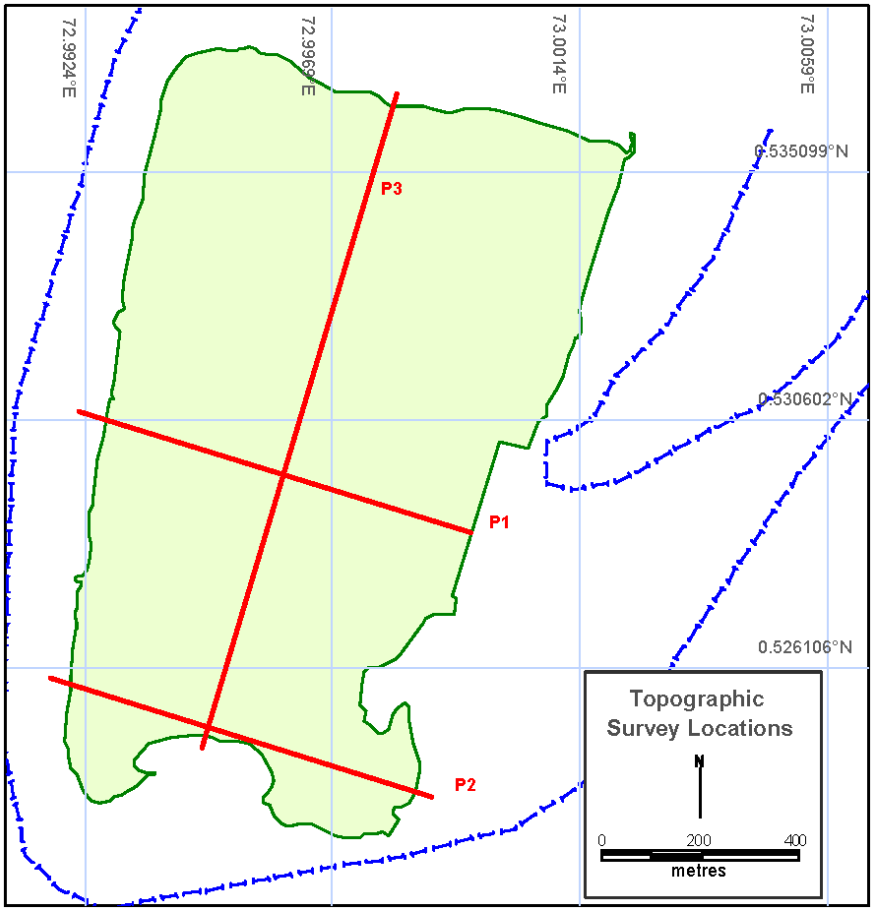


FIGURE 14 PROFILE LOCATION OF THINADHOO FROM PREVIOUS DIRAM (DIRAM 2008)

The report also recommended producing a detail Digital Elevation Model (DEM) of the island. As part of this review process a DEM was produced using elevation data collected from all roads, and reclaimed land (see figure 15). Two profiles were also derived from the DEM to assess changes to topography of the island (main road south to north and road across the island from west to east). As part of DEM data collection process, 46 beach profiles were also taken. The beach profiles were taken from inside vegetation line to surf zone where possible. Selected profiles from this 46 are shown in this report for presentation purposes (Figure 19-26).

The DEM showed that the central area of the island, which used to be the natural island is elevated compared to the rest of the island. According to the DEM, average maximum elevation (natural) of the island is 1.82 m MSL which was measured on western side island ridge area. This is in line with the previous study, which observed a height of +1.94m from the same location (UNDP 2008).

The DEM showed that the finish height of southern side wetland and the area adjacent to the north side reclamation is lower than the natural island, confirming the findings in the previous study (UNDP 2008). Rainwater drainage is therefore diverted to these low elevated areas at the southern side of the island. Similarly the area adjacent to the harbour front is also found to be reclaimed to a lower level than the original island.

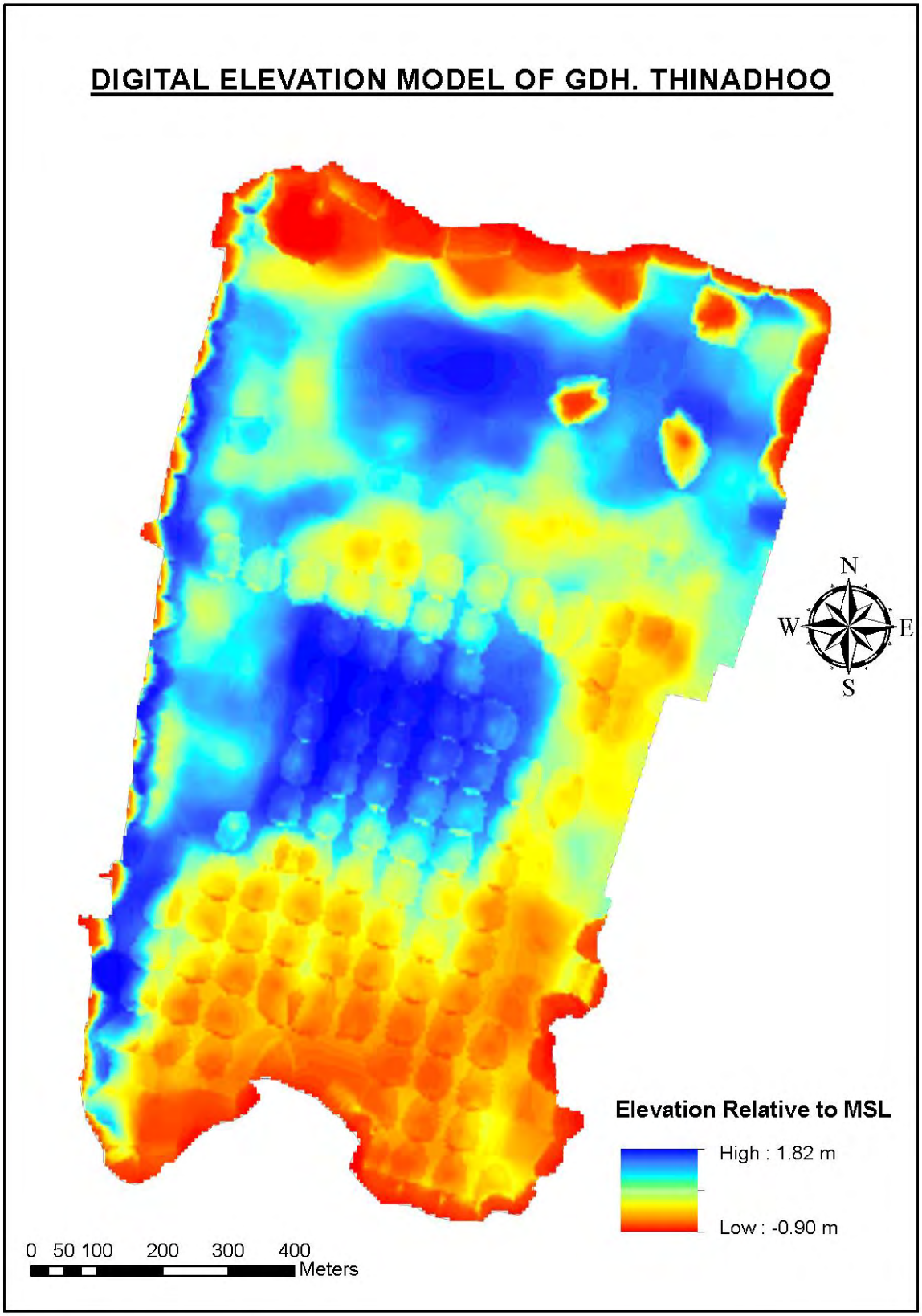


FIGURE 15 DIGITAL ELEVATION MODEL GENERATED USING ARCGIS SOFTWARE

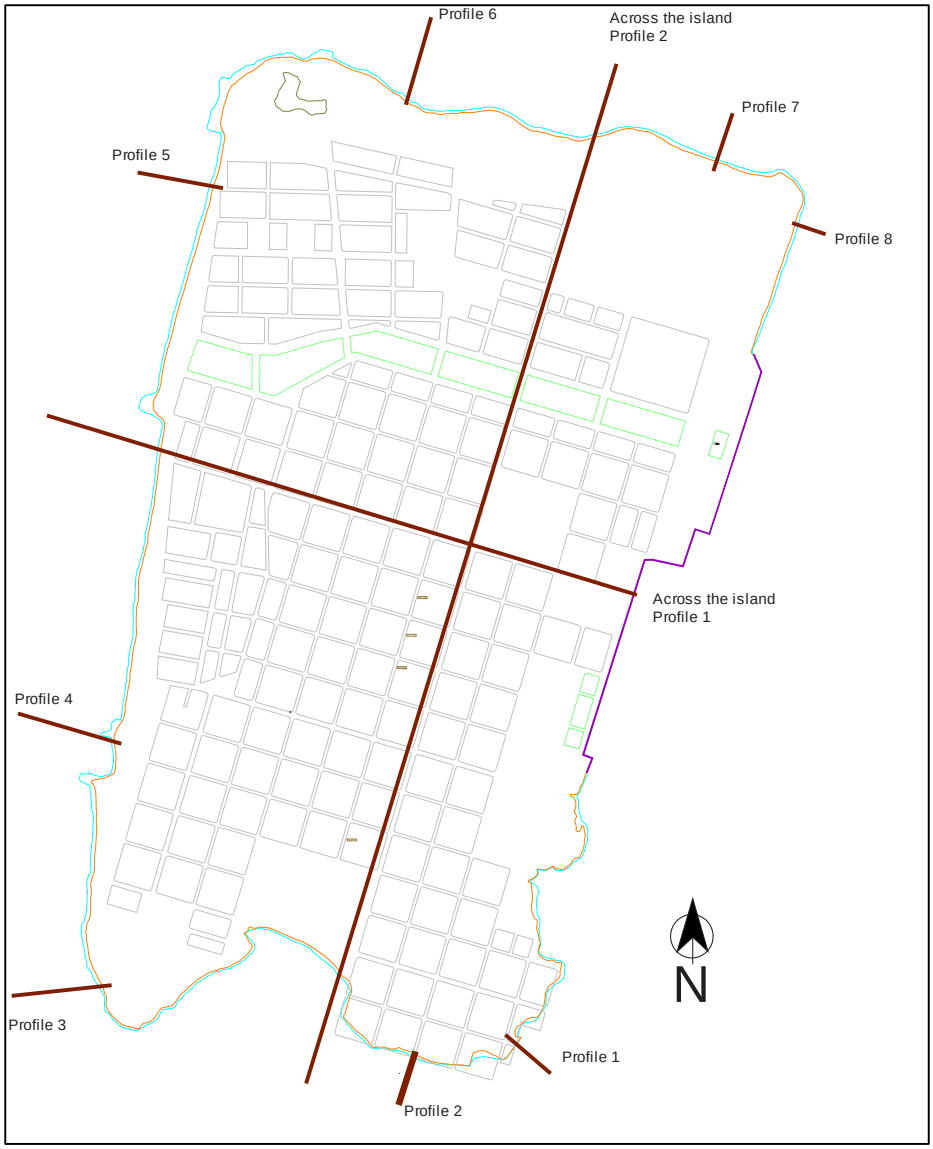


FIGURE 16 LOCATION OF ACROSS THE ISLAND PROFILES AND BEACH PROFILES

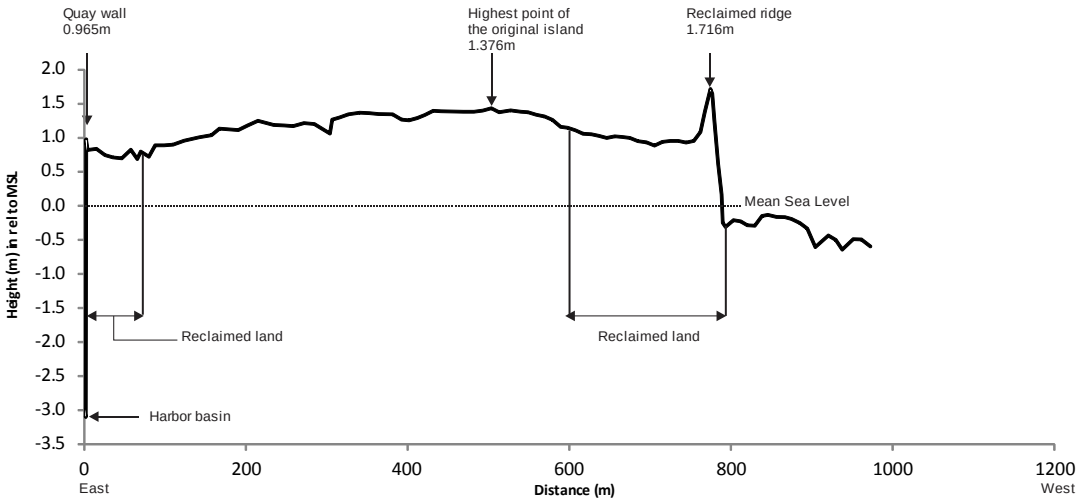


FIGURE 17 ACROSS THE ISLAND PROFILE 1

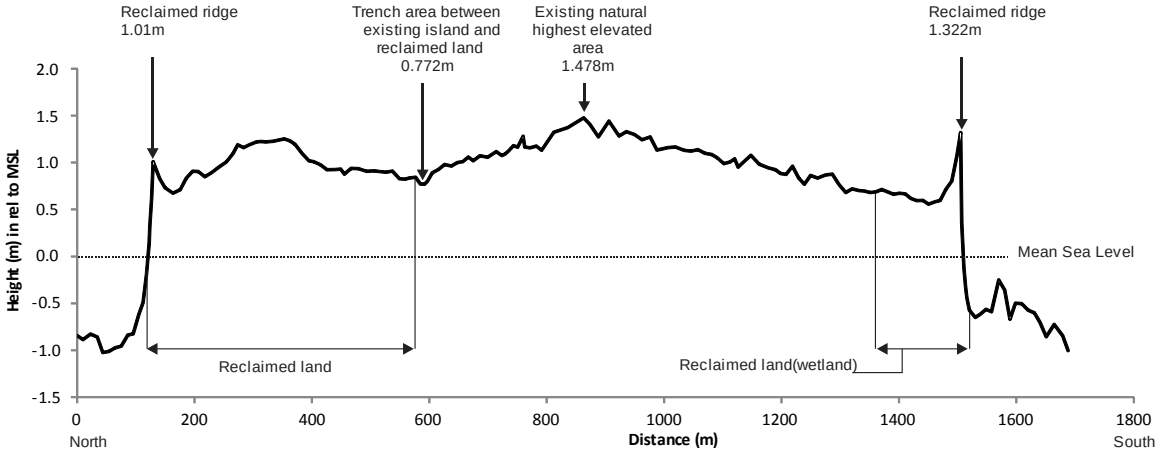


FIGURE 18 ACROSS THE ISLAND PROFILE 2

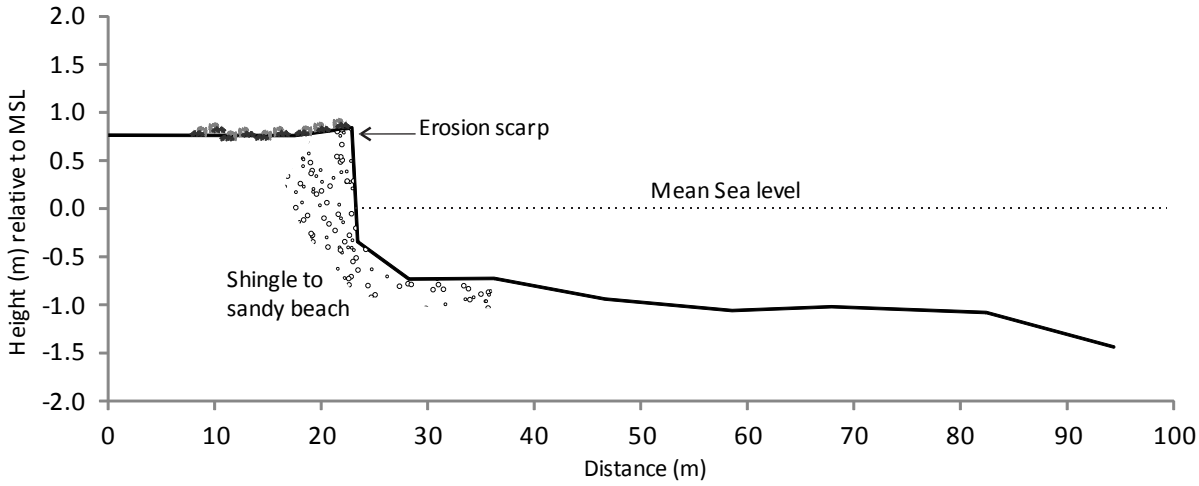


FIGURE 19 BEACH PROFILE 1

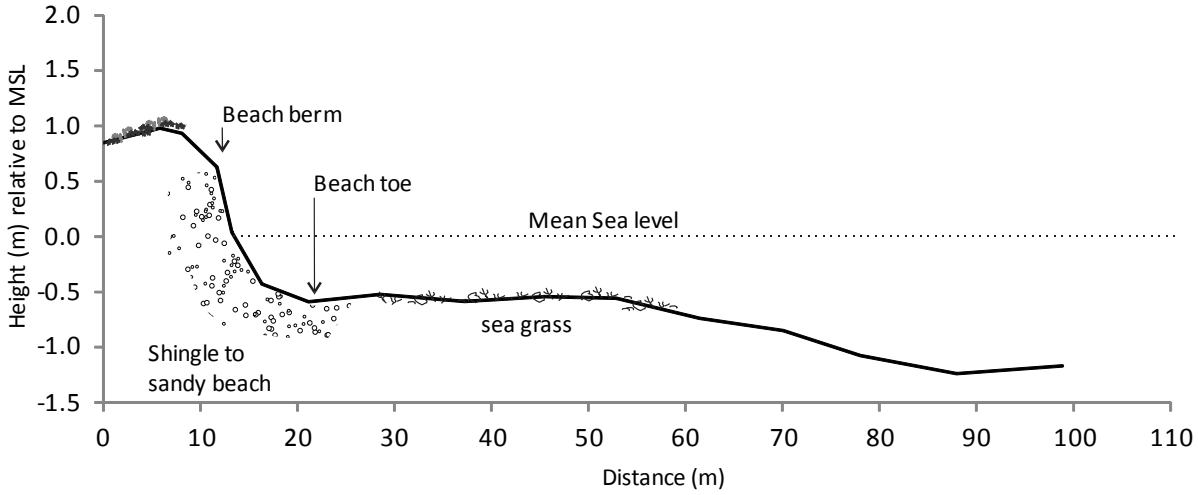


FIGURE 20 BEACH PROFILE 2

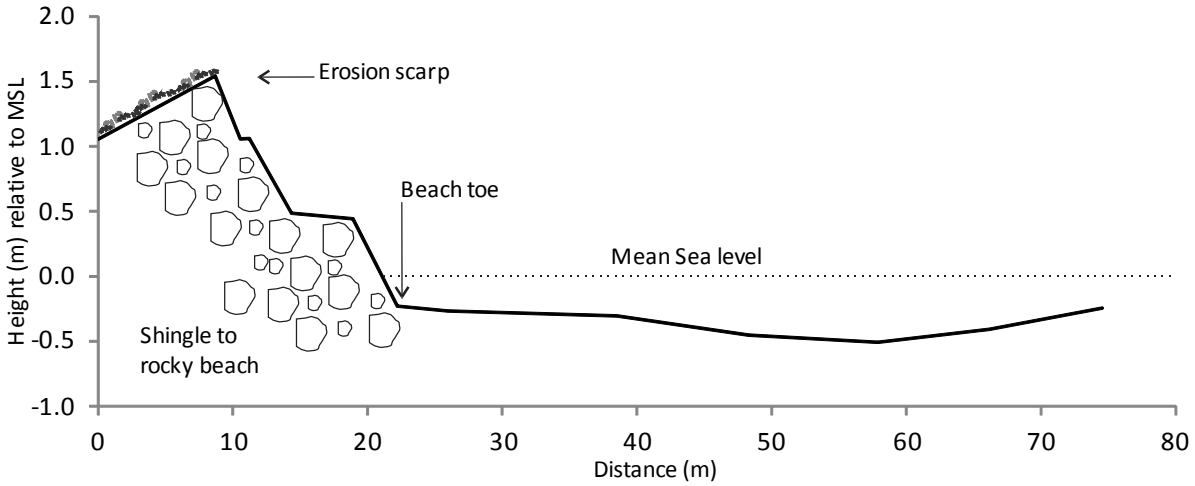


FIGURE 21 BEACH PROFILE 3

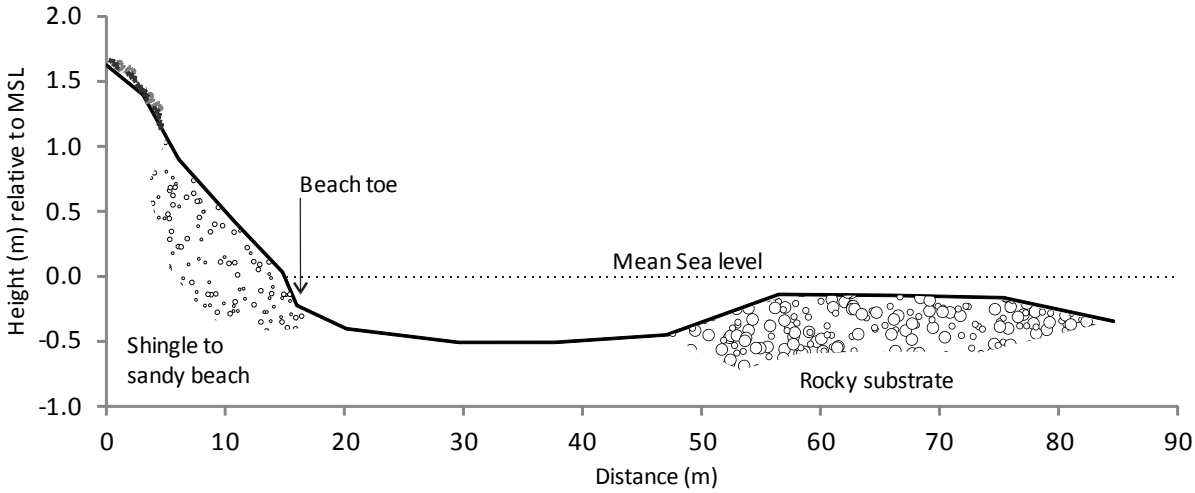


FIGURE 22 BEACH PROFILE 4

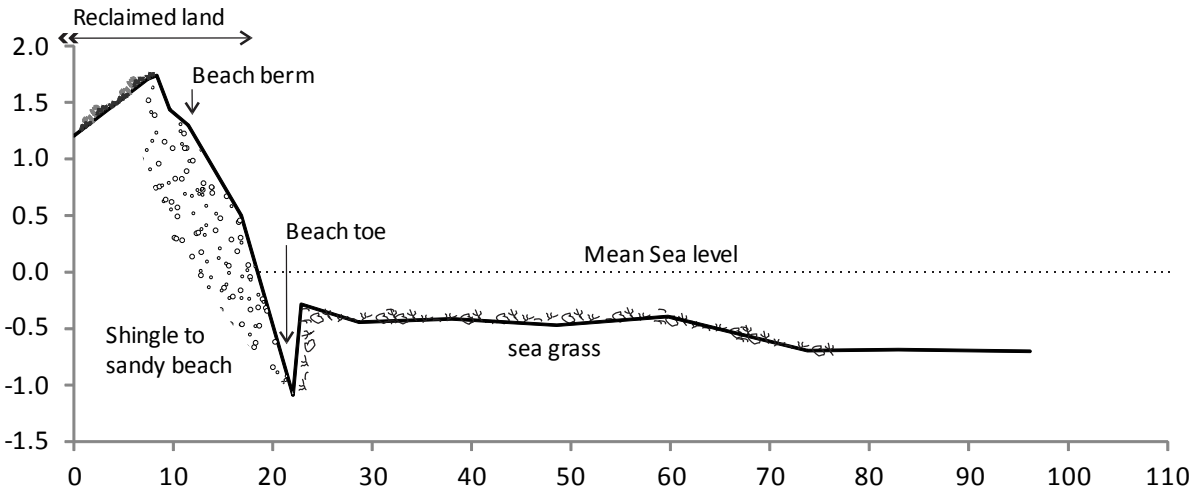


FIGURE 23 BEACH PROFILE 5

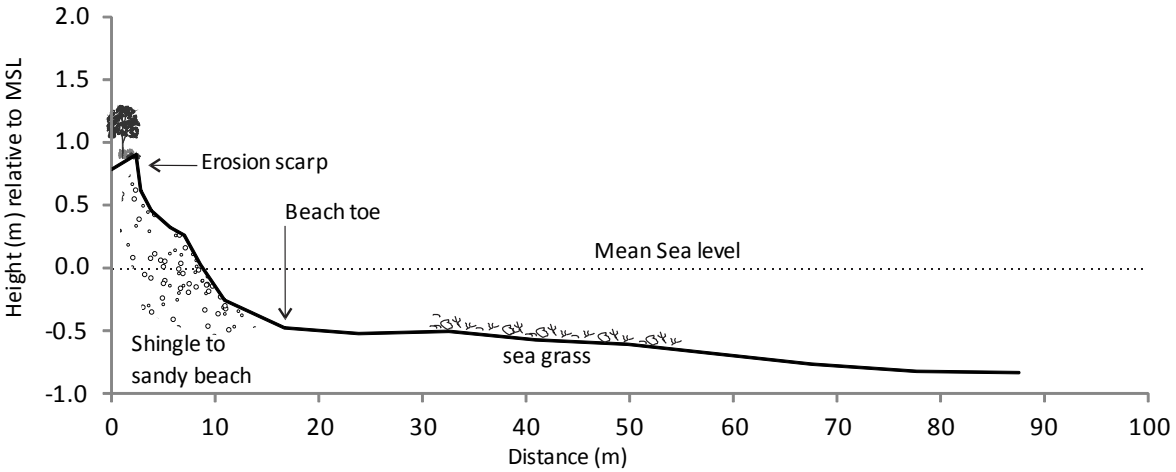


FIGURE 24 BEACH PROFILE 6

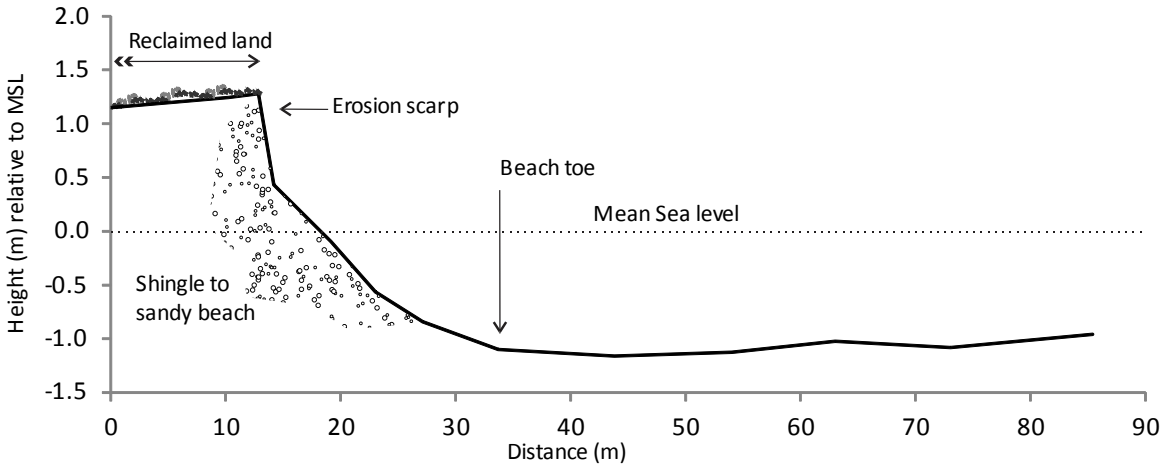


FIGURE 25 BEACH PROFILE 7

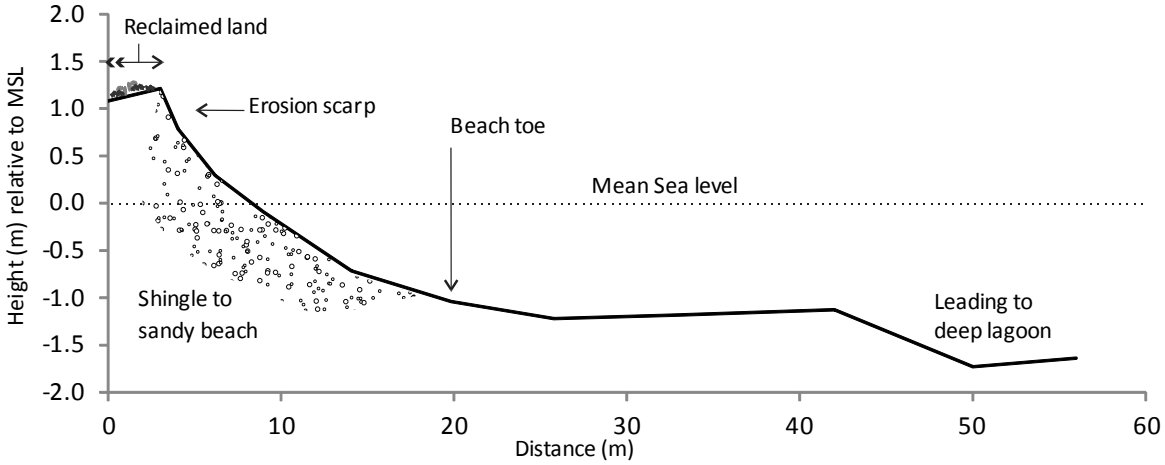


FIGURE 26 BEACH PROFILE 8

3.2.3. Vegetation

In Thinadhoo vegetation is scarce. As described in early sections, the island has undergone major reclamations and yet no vegetation program was conducted along with the reclamation leaving most part of the island with bare lands. From the aerial views and site visits, it was observed that the vegetation patches are only present at the original islands; Thinadhoo and Maahutta. Nevertheless even in the natural Thinadhoo island the amount of vegetation cover is less due to the high population density and demand for land for housing. Although a dense vegetation cover was observed at the maahutta island which also has a small potion of wetland with a mangrove area, a significant potion has been cleared for industrial development.

Unfortunately, there is no coastal vegetation surrounding the island. The only area where some vegetation is observed is in the south west corner of the island. Even at the reclaimed wetland area no revegetation was observed although in similar cases in other islands there has been a rapid growth of trees. One main reason could be the salinity of the area as the wetlands were very openly connected to the lagoon prior to reclamation. The island needs a severe revegetation program to enhncae the environment and also help in protecting the island from storm surges and erosion.

3.2.4. Marine environment

Marine environment of Thinadhoo is significantly impacted due to development activities such as reclamation and harbour projects carried out around the island over the years. According to MHE (2010), there are signs of eutrophication, increased growth of algae and seagrass due to disposal of sewerage to the surrounding lagoon. MHE (2010) estimated that about 13% of the population use toilets that are connected directly to the sea. Officially there are 10 effluent outfalls around the island with a further unofficial 22 outfalls. These outfalls discharge into the near-shore waters with some discharging within a few meters off the shore.

3.3. Vulnerability and risk assessment

In order to understand the vulnerability of the island it is important to have a detailed understanding of past hazard events. However, apart from rainfall and wind data collected by the Kaadedhdhoo weather station, records of past hazard events are not properly maintained. From the field interviews and review of existing data, it was noted that since the previous DIRAM study in 2008, no hazard event of significance impacted the island. The table 8 below shows a list of known historic hazard events and their impacts on the island adopted from the previous DIRAM study (UNDP, 2008). There has been no recorded event since then.

TABLE 8 LIST OF HISTORIC HAZARD EVENTS OF THINADHOO

Hazard	Dates of the recorded events	Impacts
Flooding due to heavy rain	13 July 1983 08 September 200 9-10 July 2002 12 December 2002 14 November 2003 06 December 2003 26-27 November 2006	Flooding due to heavy rainfall is a very common occurrence in the Island. Flooding is most common during the southwest monsoon. Most flooding occurs in the south where the old wetland has been reclaimed and also in the north near the interface between the new reclamation and the old island. Some other low lying areas are also subject to flooding due to poor drainage. Flooding has known to cause blockage of septic tanks, severe damage to backyard crops and damage to property. The biggest impact is the disruption it brings to daily life of the community which impacts the economic activities, school functioning and transport.
Flooding caused by waves	07 May 1978 07 April 1984	Flooding due to storm surge and wave activity is also frequent (once every few years) in Thinadhoo. However the

	03 June 1987 10 September 1987 June – July 1991 June – July 2003 05 May 2004 June – July 2005 15-19 May 2007	impact is mostly limited to the western shoreline. It has been recorded that the flood waters reach almost 300m inland from the western shoreline. This is mainly due to the low reclaimed area in the west of the island. There have not been any records of any major structural damage to buildings due to this hazard. However coastal erosion and damage to backyard crops has been reported.
Windstorms	13 July 1983	While the elders talk about numerous such events, there are no official records of any such event in the island
Droughts	No records of such an event	No records of such an event
Earthquake	No records of such an event	No records of such an event
Tsunami	26th December 2004	The 2004 Indian Ocean Tsunami caused only limited flooding compared to some of the other islands. The eastern side of the island near the harbour front area was inundated with waves reaching nearly 150m inland with maximum height of approximately 0.3m above natural ground level. Western side was not inundated with other areas showing only minor inundation. The eastern side that was inundated also did not suffer any major impacts since the waves inundated with less force.

3.3.1. Environmental vulnerabilities to natural hazards

The previous DIRAM study identified the environmental vulnerabilities to natural hazards in Thinadhoo (UNDP 2008). The following table is adopted from previous DIRAM study highlighting the potential environmental vulnerabilities to natural hazards.

TABLE 9 POTENTIAL ENVIRONMENTAL VULNERABILITIES TO NATURAL HAZARDS

Hazard scenario	Probability of occurrence	Potential Major Environmental Impacts
Tsunami **(Max. +2.5m MSL based on UNDP, 2005)**	Very Low	Short term impacts include major damage to coastal vegetation. Realignment of shoreline including major erosion. Long term impacts include damage to some inland vegetation and including common species such as mango and breadfruit. Saltwater intrusion into wetland areas and the freshwater lens. Contamination of ground water from potential damage to sewerage Moderate damage to coral reefs
Storm surge 0.6m (1.53m storm tide) **(based on UNDP,2005)**	Low	Minor damage to coastal vegetation Minor damage to coastal structures. Minor geomorphologic changes to the island shoreline including increased erosion
Strong wind 28-33 Knots	Very High	Minor damage to vegetation Debris dispersion near waste yard
Strong wind 34-64 Knots	High	Moderate damage to vegetation including failing branches and occasional whole trees. Debris dispersion near waste yard
Strong wind +65	High	Widespread damage to vegetation including failing

Knots		branches and occasional whole trees. Minor damage to infrastructure including damage to roofs of buildings. Debris dispersion near waste yard
Heavy rainfall 187mm	Moderate	Minor flooding in low level areas including roads and houses
Heavy rainfall 240mm	Very Low	Widespread flooding in low level areas. Moderate to major damage to vegetation especially to backyard fruit and vegetable trees. Damage to individual septic tanks leading blockage and possible leakage.
Sea level rise **(+0.88m in year 2100)**	Moderate	Permanent inundation of low lying areas in the island. Increased susceptibility to widespread flooding due to wave induced flooding Salt water instruction and contamination of ground water. Loss of flora and fauna.

Based on these scenarios a hazard mapping analysis was conducted for the three major events, rainwater flooding swell waves and Tsunami.

3.3.2. Impacts of a Tsunami

The 2004 Indian Ocean Tsunami had relatively minimum impact on Thinadhoo. The maximum recorded tsunami height measured at the Gan tide station was 0.8m above mean sea level. This is the nearest tide gauge to Thinadhoo. The tsunami height was generally lower in the southern region of the country compared to the central and northern parts. The tsunami height was just higher than the average land elevation in the eastern side of the island, but much lower than the average elevation in the central part of the island. The following is the summary of inundation and damage extent at Thinadhoo gathered from eyewitness accounts.

- The tsunami mainly inundated from the east and to a much lesser extent from the south and north.
- There was no inundation in the western shoreline.
- In the north coast, since there was no infrastructure in this side of the island, there was no impact to be seen.
- No structural damage to any building or infrastructure was reported in the island.

While these survey data and eyewitness reports give an excellent idea about the extent of tsunami impact on Thinadhoo, the challenge is to determine the impact of future events. According to Dudley and Lee (1998) tsunamis from the same general geographic origin produce relatively similar patterns of wave run-up. Since run-up is generally used as a function of danger for tsunami events, it can be assumed that we would expect similar patterns of impact from possible future tsunami events from the Sunda Trench. Given that this is the only recorded tsunami event in the Maldives and is the largest event in the entire recorded history of the Indian Ocean, it is probably safe to assume that this tsunami event and the resulting impacts are on the high end of possible tsunami hazard to the island. According to the risk assessment carried out by Ali (2005), the 2004 event has a return period of 255 years with a probability of approximately 10 percent that a similar event might occur in the next 25 years. As indicated in the tsunami hazard zone map of the country by Ali (2005), Thinadhoo lies in the lowest risk zone for tsunami hazards. However UNDP (2006) classifies this region in the moderate tsunami hazard zone with a potential maximum wave run-up of 0.8m to 2.5m. Taking all the available information into account, the elevation data with distance from shoreline was used in a weighted overlay to create the tsunami hazard intensity zone for Thinadhoo (figure 27).

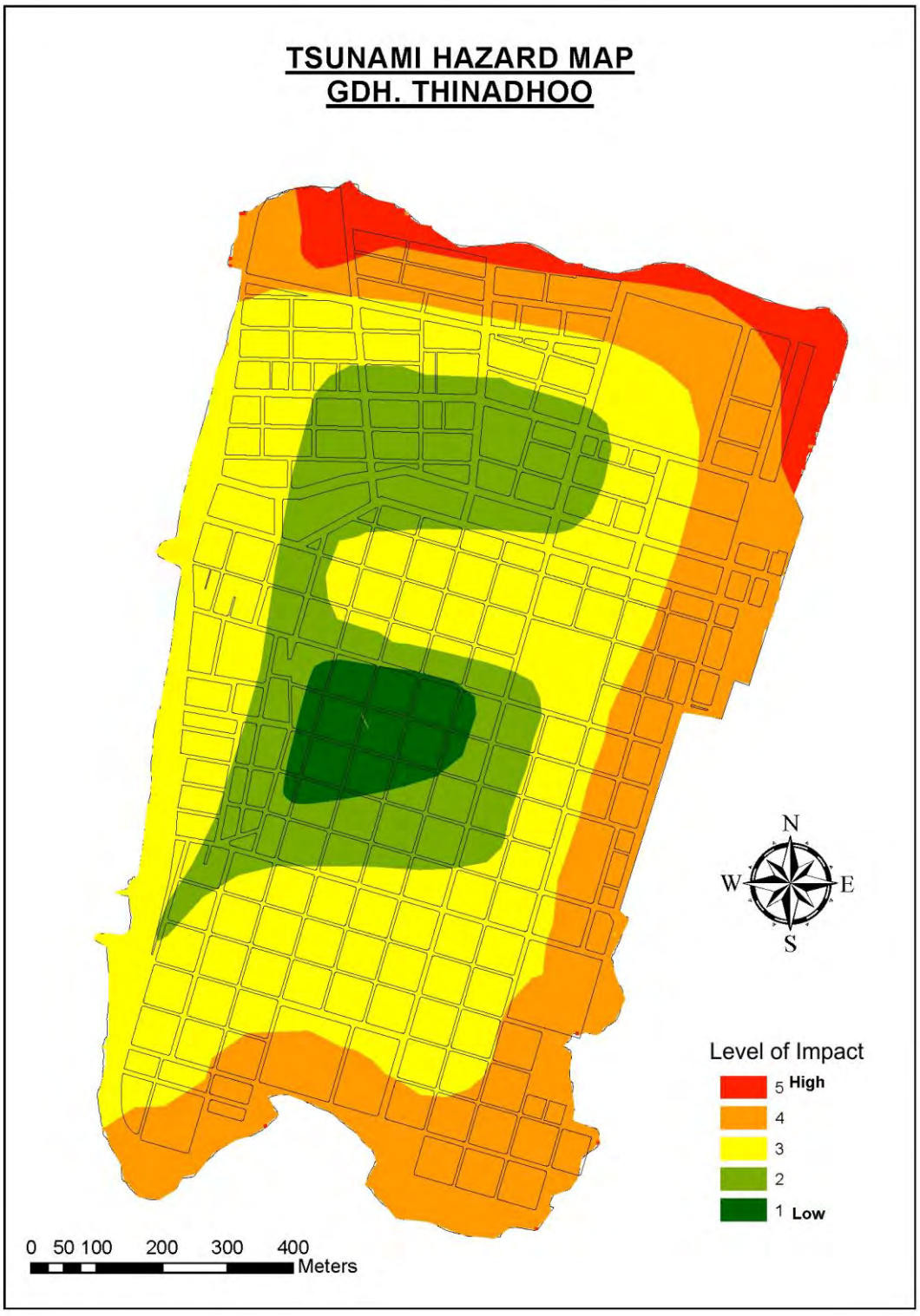


FIGURE 277 HAZARD ZONING MAP FOR TSUNAMI

The western part of the island classified as the lowest risk area based on the experience of the 2004 tsunami and future predictions. It should be noted that the zones indicate possible inundation zones and does not necessarily imply total infrastructure damage.

3.3.3. Flooding due to storm surge, swell waves

Due to the proximity to the equator, Thinadhoo is located in relatively safe zone from cyclone related storm surges compared to the islands in the north (UNDP, 2006). However swell waves combined with storm surge and wind generated waves from localized storms coupled with high tide result in frequent flooding of the island. From field surveys and interviews it can be concluded that while such events do occur occasionally the extent of impact is generally limited to the areas adjacent to the shoreline. The most susceptible area for flooding due to the waves is identified the western side reclaimed area. This is mainly due to the low elevation of the reclamation compared to the natural island and the proximity of the new shoreline to the reef edge. As indicated in Table 8 and 9, storm surge or wave induced flooding event can be identified. However in almost all these events, the impact was limited to the western shoreline with floodwater reaching 300m inland. No major structural damage to infrastructure has been recorded due to these events. No measures have been taken to address the issue of wave induced flooding in the island to date.

In order to estimate the impact zone of potential future wave induced flooding events, the elevation data of the island was used in conjunction with distance from shoreline buffer zones undertake a weighted overlay in the GIS software. In the absence of inundation data of past events, apart from running numerical or physical models (which is not part of the scope of this project), this was determined to be the most practical approach to identify potential hazard zones due to wave induced flooding (see figure 28).

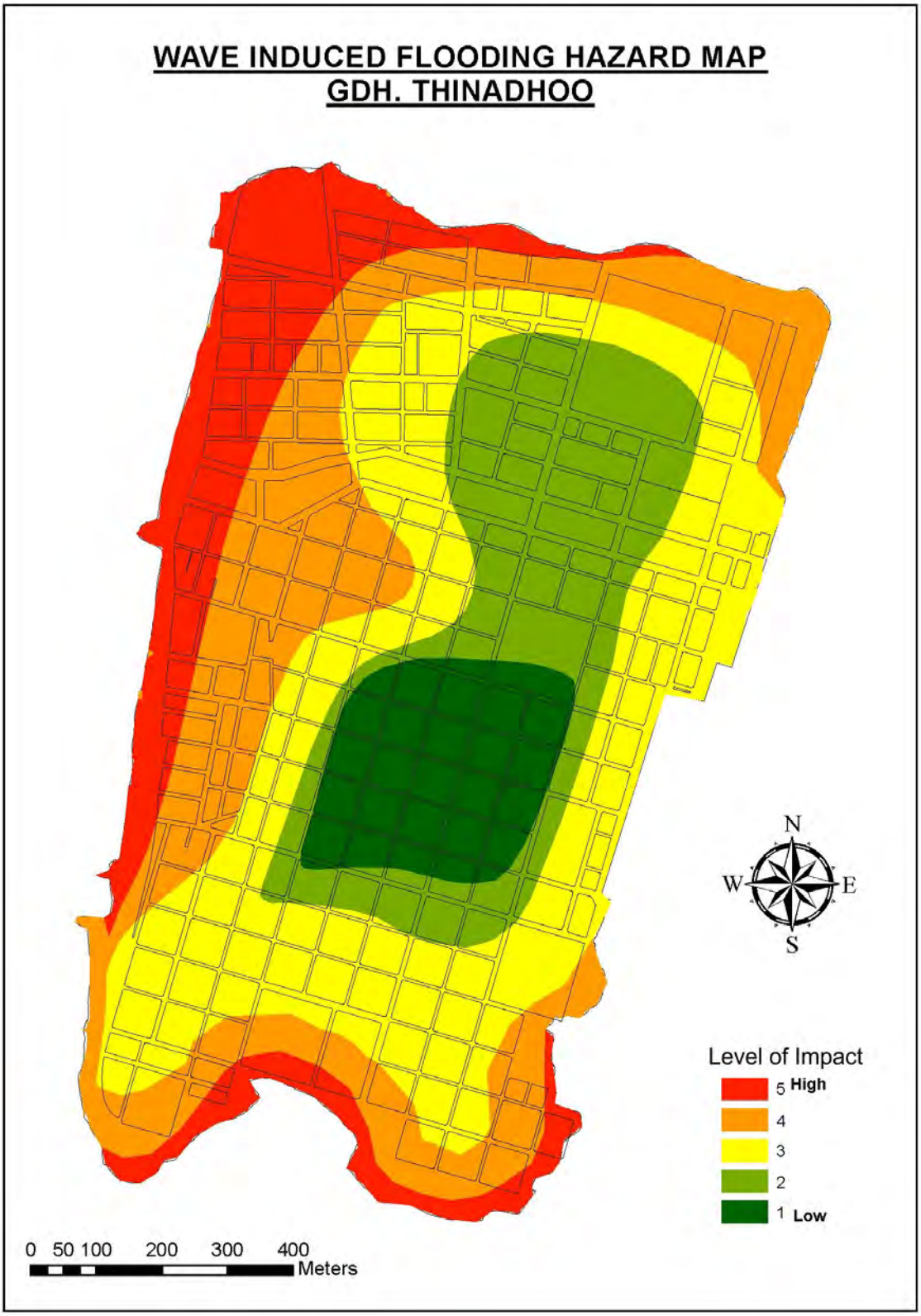


FIGURE 28 HAZARD ZONING MAP FOR SWELL WAVE INDUCED FLOODING

3.3.4. Flooding due to rainfall

The existing topography combined with the poor drainage of the island makes it very susceptible for some areas to be flooded under heavy rainfall. The extent of flooding is generally governed by the topography and the drainage capacity of the island. Low areas with no means of drainage are the most vulnerable for flooding and flood related damage. Flooding due to rainfall is almost an annual occurrence in Thinadhoo (Table 9 lists major events) and to date no measures have been taken to specifically address the issue of flooding in the island. As discussed in section 3.1.2, the Statistical downscaling of global climate change models by RIMES (RIMES 2011) predicts 60% to 100% increase in rainfall in the year 2050. The highest recorded daily rainfall for Thinadhoo area is 219.8mm. By using the results of RIMES (2011), it can be deduced that the maximum daily rainfall could reach 440mm in the year 2050.

To understand the topography of the island a complete topographic survey of the island was conducted. This was carried out using Real Time Kinematic (RTK) surveying equipment with sub-15mm accuracy. This survey data was used to create a Digital Elevation Model (DEM) of the island (Figure 15).

From the DEM results it was clear that the highest elevation in the island was found on the south western natural ridge of the island which had an average maximum height of 1.82m. This natural ridge was present in a relatively small section of the western shoreline whereas the rest of the western shoreline comprises of lower reclaimed land. Apart from this small area, generally the highest elevation (+1.5m on average) was found in the centre of the island, which coincides with the original natural island. The lowest elevation at -0.9m was measured in the wetlands or "*Kulhi*" area in the north. The south side of the island and the harbour front area was generally lower than the island. Historically this area used to be a huge wetland (see figure 15 in section 3.2.1) and subsequent reclamation was done to a lower elevation (between +0.6 and +0.8m). The north side reclamation found to be done to a higher elevation compared to the south side reclamation. The average height of north side reclamation was found to be +1.2m.

The natural drainage capacity of the island has been greatly reduced due to the reclamation projects undertaken over the years. From the early topography of the island, it is clear that storm water would flow into the south wetlands and into the lagoon in other area. However this natural drainage basin in the south and the capacity to drain water in other parts of the island has been lost due to the reclamation works. It should be noted that the north side reclamation works has provided a temporary solution to the potential flooding issue in the area by providing relatively wide drainage ditch between the old island and the new reclamation.

However this was not a properly planned or engineered solution and the effectiveness of this ditch has since diminished to subsequent road and other developments in the area.

The result of the DEM was used to map the most vulnerable areas to flooding (figure 29).

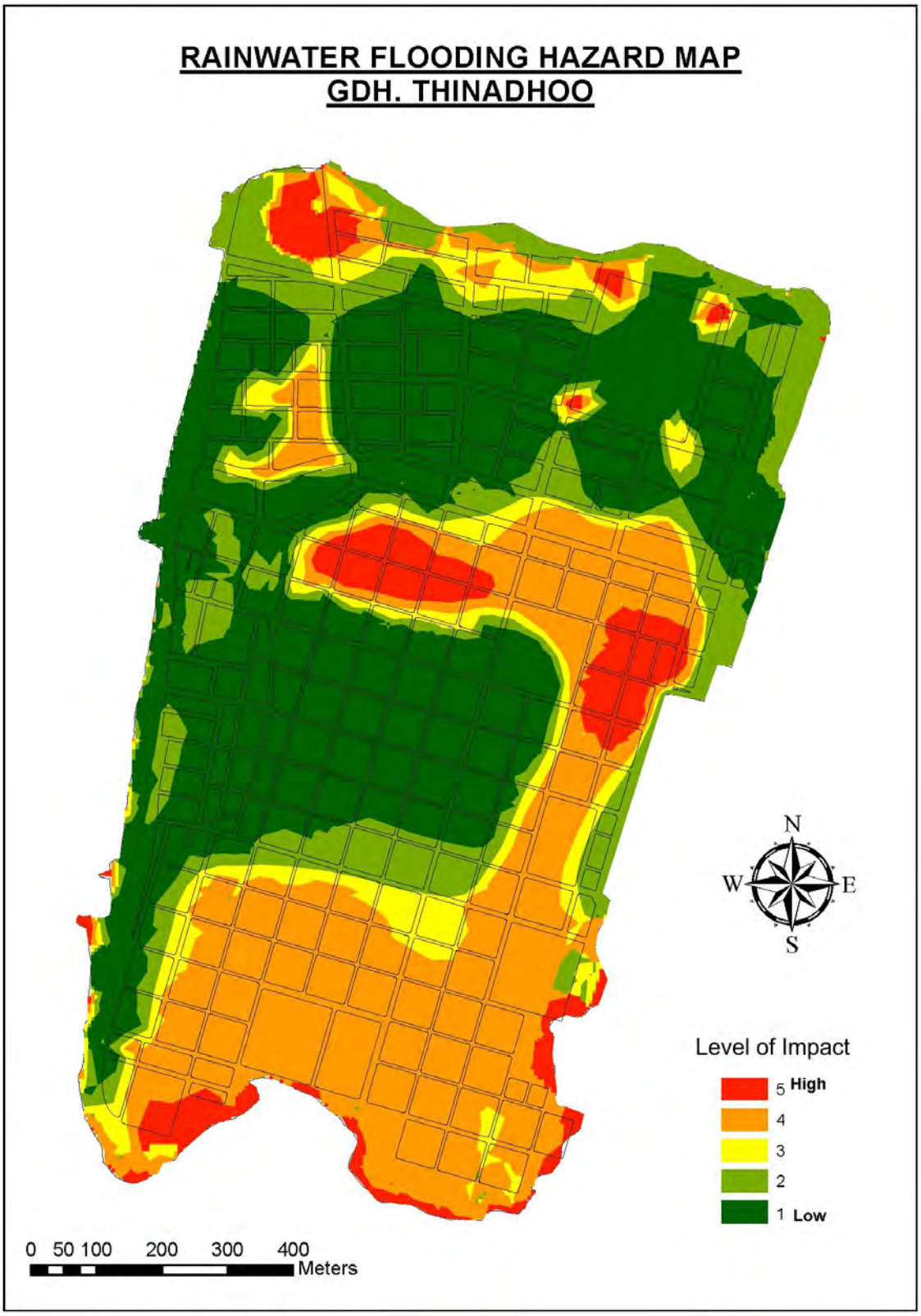


FIGURE 29 HAZARD ZONING MAP FOR RAINWATER FLOODING

3.4. Potential Impacts of climate change variability and sea level rise

As discussed in section 3.1.6, Sea Level Rise (SLR) and rise in Sea Surface Temperature (SST) due to climate change could have severe impact on the islands' ecology and geomorphology. Apart from land-loss due to sea level rise, climate change would exacerbate other hazards such as wave induced flooding, rainwater flooding and tsunami hazard.

In order to identify potential land loss due to sea level rise the elevation data was used to map areas that would be inundated at the end of the century using IPCC (2001) forecasted sea level rise (Figure 30).

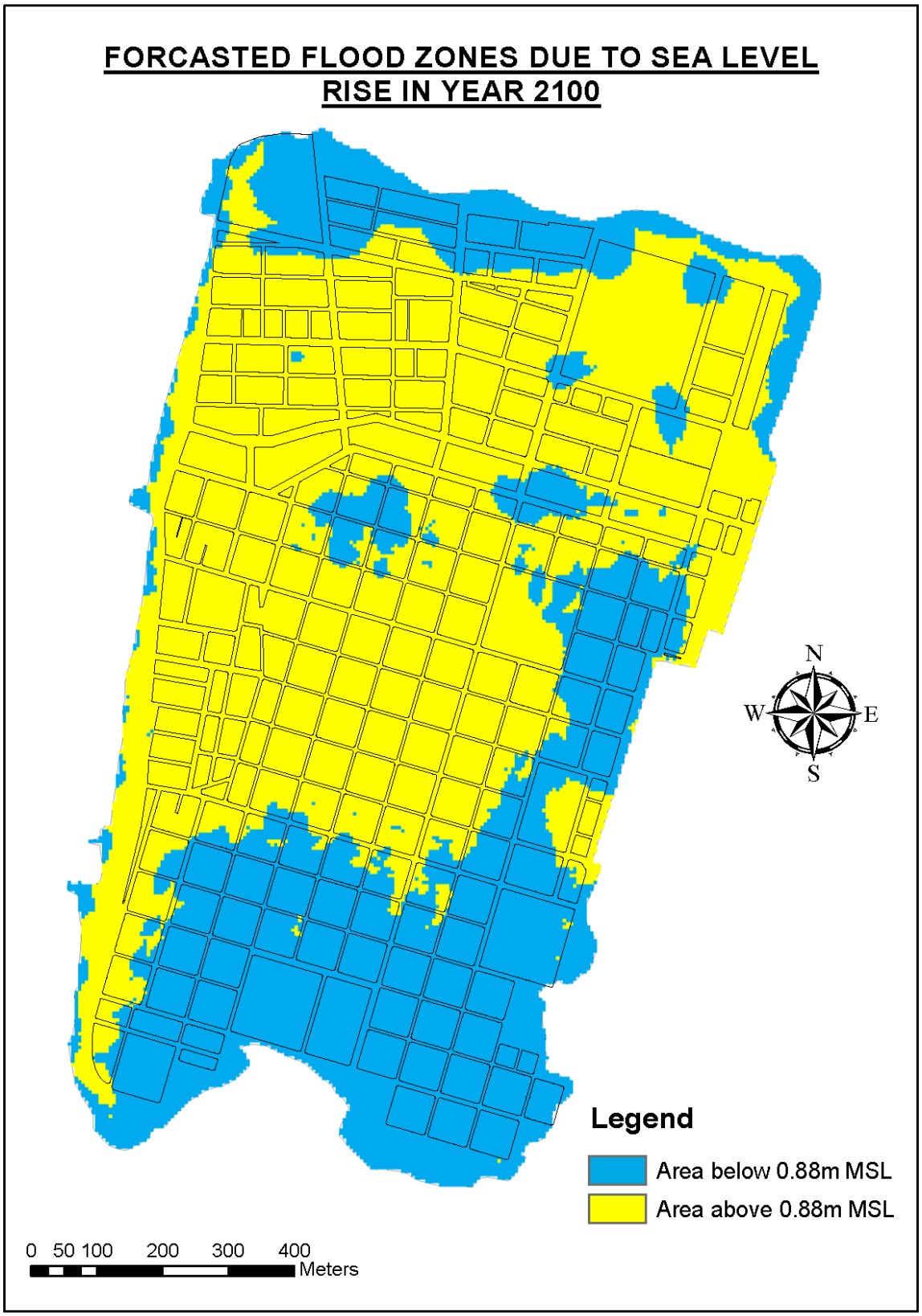
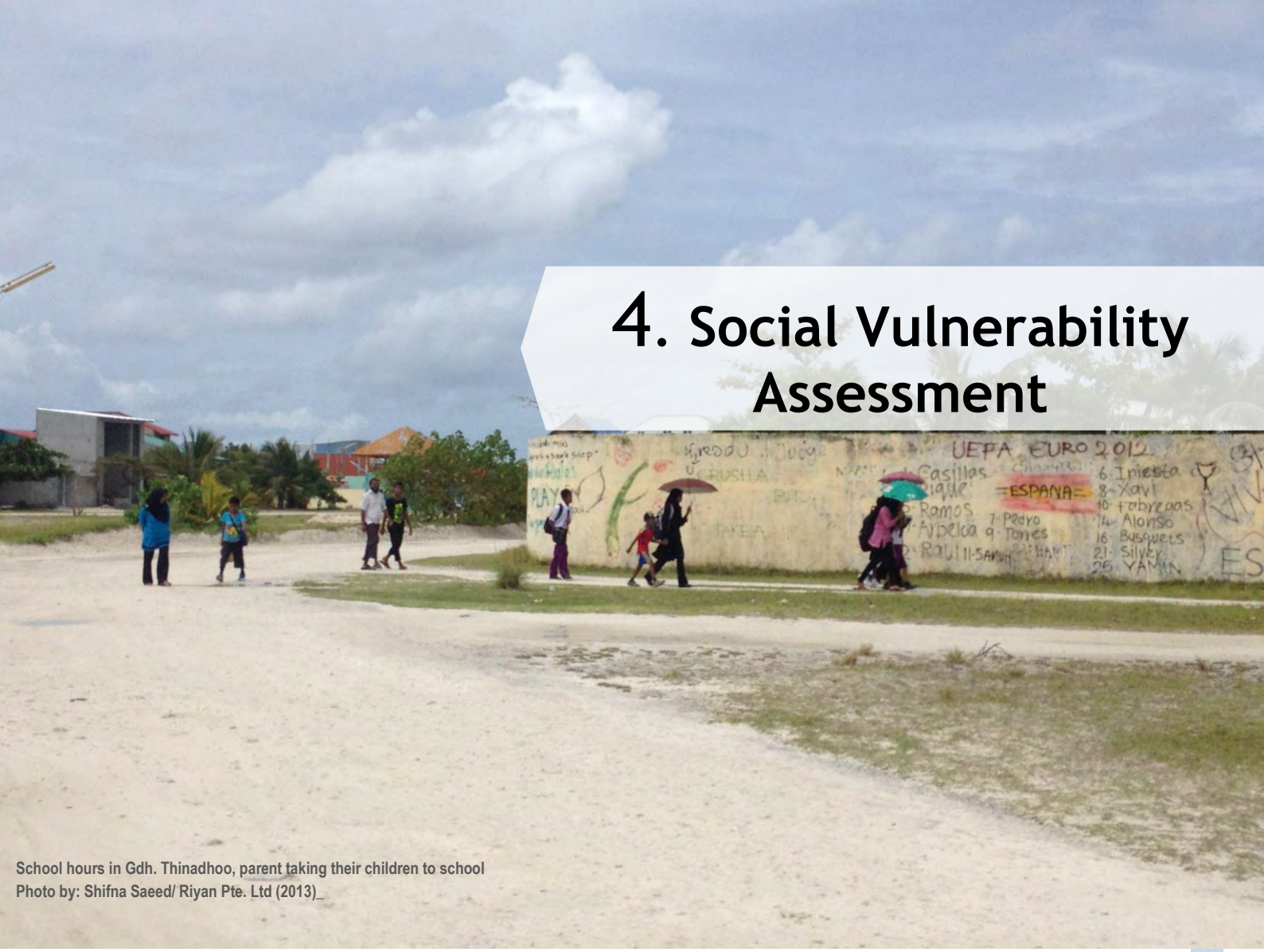


FIGURE 30 FORECASTED FLOOD ZONES DUE TO SEA LEVEL RISE (YEAR 2100)

4. Social Vulnerability Assessment



School hours in Gdh. Thinadhoo, parent taking their children to school
Photo by: Shifna Saeed/ Riyan Pte. Ltd (2013)_

In addition to hazard assessment, to evaluate hazard risks it is equally important to study and understand the social vulnerability (Wisner 2007).

4.1. Existing condition

> "The vulnerability of communities and societies to disasters is closely and inversely related to the level of social and economic development" (Li 2012, p.1)

The social island context has been derived and assessed from a number of studies including field survey data (focus group discussions, one-to-one interviews), previous studies including the previous DIRAM study, disaster risk profile of Maldives, statistical databases (Census 2006; Statistical year books), vulnerability assessments etc. Main methods used in collecting these data are through participatory approaches where stakeholders and community members were involved in collecting data, identifying issues and also the possible solutions. The following profile summarizes the key findings.

4.1.1. Accessibility to the basic services

i. **Island Access**

The major access point to the island is from the local island harbour.

ii. Education

Thinadhoo provides all levels of education. These include preschools, primary, secondary higher secondary and tertiary education. Students from nearby island migrate to Thinadhoo in search of better education facilities. However, the students are not happy with the education services offered in the university campus. According to them, improving the quality of education and types of courses offered in this institution has remained as one of the challenges for the island.

iii. Health

The regional hospital for the southern region is located in Thinadhoo. This is another reason for people to visit/migrate to the island. However, the islanders are not happy with the services provided by the hospital. There is a lack of essential facilities available at the hospital. Limited doctors, nurses and equipment have decreased the quality of services and also have limited the number of services that could be provided to the patients. Improving the quality of services provided by the hospital is one of the highest priorities amongst the people of the island.

iv. Drinking Water

Although a desalinated plant has been installed with a complete water network system, people still use rainwater for drinking and cooking and ground water for washing, bathing and other purposes. However, the practice of rain water harvesting which is one of the recommended ways to address the issue of water scarcity is now decreasing. More awareness needs to be created amongst the people, to encourage them to use rain water as much as possible for the different activities.

v. **Sewerage**

Currently, septic tank sewerage systems were used by most of the households. However, a new sewerage system will be established soon. At present, during heavy storms they experience over flow of septic tanks preventing the people from using the toilets and making life very difficult. These issues are expected to be addressed once the new system will be installed.

vi. **Waste management**

The waste site is not well managed. Currently the utility (Fenaka) manages the waste site. Although a certain area is designated for waste disposal, due to its distance from the

residential areas and the unavailability of dustbins within the island, waste is disposed at any area which is convenient for the residents. The issue of waste has been noted as one of the major issues in the island that needs immediate attention.

vii. Food Security

There is no major issue on food security within the island. Since Thinadhoo is the regional hub that re-exports food supply to the neighbouring islands, they normally have enough stock in the island. However, it was noted that in case of any interruption to the transport network, other islands that depend on Thinadhoo for their food supply will have to face food security issues (shortage of food).

In Thinadhoo, they do not have main food reserves for storage. Although there is no specific food storage or cold storage service, the food stocks are maintained by the major wholesalers and are stored in warehouses located within the island. As for local produce, agricultural activities within the island are minimal although people do home gardening where they grow chillies, cucumbers and different types of greens.

viii. Safety and Security

With the large population residing in the island, stakeholders reported issues of violence, theft, robbery and break-ins. The regional police station is also located in the island and they are in charge of making the island a safe and secure place to live.

4.1.2. Organizations and networks

The main organisation at the highest hierarchy is the Island Council who is responsible to work for the development of the island through provision of all the municipal services (*Decentralisation* Act 2010). Previously there used to be government organisations such as the Island Development Committee and Women's Development Committee. However, with the decentralisation of the government, the roles and responsibilities of these committees were transferred to the island council and the women's development committee has now been reconvened with their previous roles and responsibilities.

As for non-governmental organizations, there are small scale NGOs who work independently and as teams for the development of the island communities. In general, these NGOs promote recreational activities, awareness campaigns, sports events and work for the betterment of the community. Although there are number of NGOs with the aim of working towards the development of the island community, the participation has reduced significantly over the past years.

4.2. Social Vulnerability to disasters

Vulnerability can be defined in many ways while for the purpose of this study vulnerability can be expressed as "the characteristics of a person or group and their situation that influences their capacity to anticipate, cope with, resist, and recover from the impact of a natural hazard" (Wisner et.al 2003, p.11 as cited in Desai & Potter 2013). In various vulnerability assessments disaster is illustrated by the formula: **Disaster = Hazard + Vulnerability**. This implies that disaster risk has a direct impact from the hazard and the vulnerability of hazard (Blaikie et.al 2004).

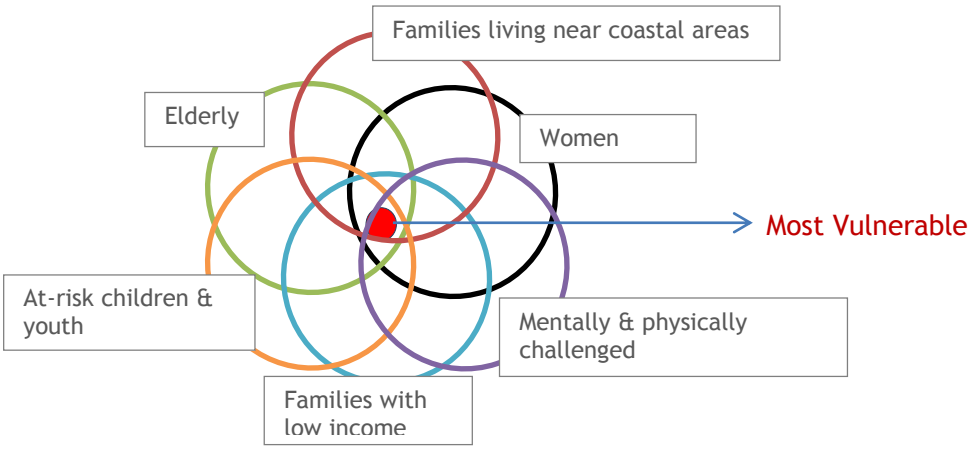


FIGURE 31 A REPRESENTATION OF VULNERABLE GROUPS

Vulnerability can be affected by physically unsafe conditions and socially unsafe conditions. Physically unsafe conditions include risky locations (near coastal area) and unprotected building, while socially unsafe conditions include the risks to local economies, lack of disaster preparedness measures, etc. Vulnerable groups who are subjected to these conditions include elderly people, mentally and physically challenged individuals, at-risk children and youth, the families living near coastal areas, women etc. Among these, the most vulnerable are the people who fall into the shaded area as shown in the diagram (figure 31).

i. Elderly people

In Thinadhoo, approximately 2% of the population is above 65 years. This group of people, although less compared to the whole population, are highly vulnerable in the community as they are mostly helpless in terms of fighting by themselves for survival, in the instance of a disaster. Most of the elderly requires assistance and support to evacuate themselves from their homes in case of a disaster.

ii. At-risk children and youth

At-risk youth/children or high risk youth are referred to the ones who drop out from school or who do have the opportunity to attain education at any level. The US code defines high risk youth as

> "an individual who has not attained the age of 21 years, who is at high risk of becoming, or who has become, a drug abuser or an alcohol abuser, and who is identified as a child of a substance abuser; a victim of physical, sexual, or psychological abuse; has dropped out of school; has become pregnant; is economically disadvantaged; has committed a violent or delinquent act; has experienced mental health problems; has attempted suicide; has experienced long-term physical pain due to injury; or has experienced chronic failure in school" (title 42, chapter 6A, subchapter III-A, part B, subpart 2, § 290bb–23).

This can be due to many reasons which include demographic, socioeconomic, and institutional characteristics of the island/family. Although the number of children and youth at risk cannot be determined because of lack of comprehensive data, it is evident that such individuals are highly vulnerable to disasters.

iii. Mentally & physically challenged individuals

The total number of disabled people in Thinadhoo is not known. According to the regional hospital, disabled people include the physically challenged and mentally ill patients. They are among the most vulnerable people as they will need full support and assistance in moving from one place to another.

iv. Women

Women are considered to be more vulnerable to disasters than men due to many reasons including their nature, the patriarchal structure of the society and the low income level. Thus disasters make them more vulnerable to poverty, health implications, abuse of different kinds including rape and assault (APWLD, 2005). During the 2004 Tsunami, it was found that in India, Aceh and Sri Lanka where the impact of Tsunami was highest, 80% of the dead were women. From the above statistics it is evident that women have a higher risk in case of a disaster than men. It is important to note that in Thinadhoo, like most of the other inhabited islands,

number of women residing in the island is more than men who are mostly out of the island for work related purposes.

v. People living near coastal areas and low lands

As shown in figure 28 in section 3.3, the coastal area especially at the north, east and south ends are at high risk in case of a Tsunami event whereas coastal area at north, west and south are at high risk at times of swell waves. This shows how vulnerable coastal communities would be in such a case. The heavier socio-economic costs that would be caused by climate related hazards and disasters are also greater in coastal zones (Smith, 2009). Also, the families at the low lands are highly exposed to flooding caused by such disasters. In Thinadhoo approximately 20% of the households are located near the coast and 25% are located at low lands making them the most vulnerable among all.

vi. Families with low income

Low income groups are vulnerable to any shock that would force them to spend their earnings. Likewise, the low income families are more vulnerable to disasters than the middle and high income groups. The low income groups do not have the resources and capacity to act on disaster relief. In Thinadhoo, the income levels of the households seem to be relatively good compared to previous years. According to the community discussions, they do not feel poor and they do not have much of a difficulty in terms of money. Nevertheless, even if it is small, there will be a fraction of people who are under the poverty line and a study like this should not neglect the minority in assessing the vulnerability. More data is required to identify the poverty index and to assess their vulnerability. Economic imbalance and disparity in power among social groups are among the several social factors Blaikie et.al (2004) highlighted as factors that can lead to vulnerability.

4.3. Community participation

From the field visits and the community consultations, it was evident that there is a strong community spirit among the people of the island. However, with the different political views, there also seems to have been segregation among groups and even within families. These issues were raised during the random individual interviews conducted within the island.

4.4. Perception of risks/disasters

During the focus group discussions, all the groups noted flooding as the most hazardous event. This is mainly because they have been experiencing flooding over the past few decades. Tsunami, erosion, swell waves and strong wind storms were also noted as natural hazards but

not as much as flooding due to heavy rainfall. Thus their main perception of risks and disaster are mostly based on heavy rain and flooding, and to some extent *Udha* caused due to storms.

4.5. Potential social impacts due to disasters

The Table 10 below summarizes the potential impacts which could be caused during a natural hazard event. Since Tsunami is considered as the most hazardous disaster, and flooding was noted by the community as the most concerning issue, the impacts are predicted for such events. Nevertheless, the impacts caused by swell surges and wind storms are also incorporated in assessing the impacts. Furthermore, the new developments are taken into consideration in predicting these impacts and their consequences.

TABLE 10 POTENTIAL IMPACTS DURING A NATURAL HAZARD EVENT

Major projected Impacts	Consequences	Groups Affected	Coping Strategy
Event: Tsunami, heavy rain storm **Loss of life/injury to members of household**	• Possible loss or injury of the head of household or 'bread-winners' • Disruption of economic and livelihood activities • The affected families and the whole island community would go through psychosocial health issues (injuries, fear, trauma, anxiety) thus impacting decision making	• Vulnerable groups (See section 4.2)	• Support from families, friends & community members
Destruction/damage of household properties	• Homelessness • Loss of valuables and personal belongings • Loss of productive assets (backyard agriculture, rope making, facilities & fishing vessels) causing unemployment, low productivity and loss of	• Vulnerable groups identified in section 4.2 (Low income groups, women, children, families close to coastline), households not using bank services, key economic groups-	• Relocation of property • Move to temporary housing (provided by relatives, neighbours, other community members) • Support from

	income • Scarcity of food • Psychosocial health issues (injuries, fear, trauma, anxiety) thus impacting decision making	fisherman, backyard, manufacturing & agriculture	relatives/neighbours/community members •
Diseases	• Possibility of epidemic of diseases • Overburdened health services due to lack of good health facilities.	• Everyone	• Emergency medical services provided by the government • Services from hospital • Local medicines • Home remedies • Cleaning up the island • Support from family, friends, the whole community
Damage to Roads	• Disruption to movement of pedestrians • Disruption to vehicle movement • Inconvenience caused due to all disruptions of movement	• Pedestrians • Drivers/passengers	• Sand filling of roads
Flooding of community buildings, houses & rooms	• Loss and damage to properties • Psychosocial health issues (injuries, fear, trauma, anxiety)	• People living in flood prone areas (section 3.3)	• Pumping out water from the places
Damage to infrastructure	• Disruption to services provided by the critical infrastructures (power house, schools,	• People living/using the infrastructures • Vulnerable groups	• Services such as health services provided at temporary buildings

	mosques, health institutions)		• Support from all community members, family & friends, NGOS, Aid groups
Disruption of economic activities	• Damage to business establishments	• Businessmen, service providers, customers of the businesses • Vulnerable groups who carry out small businesses	• Support from the rich, well established individuals • Support from aid providers
Disruption to transport of goods	• Damage to vessels • Decline in transferring goods from Male' to the island and from the island to other islands • Scarcity of food	• Vulnerable groups • Fishermen, farmers, wholesalers, retailers • Other island communities •	• Support from the rich, well established individuals • Support from aid providers • Help from neighbours & all community members
Increased quantity of waste	• Waste spread all over the island • Spread of diseases	• Vulnerable groups • (Elderly, children, women etc.)	• Cleaning the island by the community members (difficult to dispose the waste)
Water scarcity	• Pollution of ground water • Damage to the water plant will cause disruption of water supply to the houses	• Everyone, especially households who do not have alternative ways of water supply such as rain water	• Buy bottled water for drinking • Use ground water for other purposes

4.6. Social factors exacerbating the effects of a disaster

The diagram illustrates the key factors that would worsen the effects of a disaster in Thinadhoo.

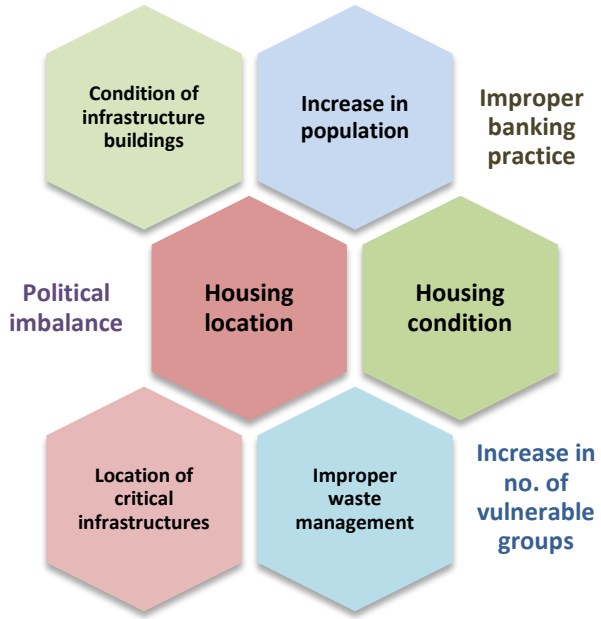


FIGURE 32 SOCIAL FACTORS EXACERBATING THE EFFECTS OF A DISASTER

Location of housing and Infrastructure

As stated in section 4.2, houses located near severe hazard zones such as the coastal areas and low lands are more vulnerable to disasters. Also the houses built on swamp areas (reclaimed wetlands) pose higher risk of flooding making them more vulnerable than the houses located in safe zones.

Some of the critical infrastructures such as the power house, schools & the water plant are located at areas prone to flooding and storm surges.

Improper waste management

The waste site is not well managed. Although a certain area is designated for waste disposal, waste is dumped at any area of convenience by the residents, due to the far proximity of the allocated disposal site.

At a time of disaster, issue of waste would worsen the problem as it will pollute the whole island and will cause spread of different types of diseases.

Increase in population and Vulnerable groups

When there is an increase in population,the population density and urbanization further increases to cater for the growing population. This would in turn increase the vulnerable population and also would increase the vulnerability of the whole population to disasters (Donner & Rodríguez 2011).

Housing condition and Condition of critical infrastructures

The poor structural designs and construction methods practiced in the island make the buildings more vulnerable to extreme weather events and natural hazards. Houses and infrastructures with poor conditions located within hazard prone areas pose a higher risk of severe damage during an event of a disaster.

Political imbalance

Political differences are having a huge impact on peoples' perception towards helping and supporting people. Communities are being segregated because of their different political views. This could be the situation even in a case of a disaster.

It would also impact the decision making process even for environmental protection measures. Political views will influence the decision making and with many different views it becomes difficult to make the most optimum decision.

Income saving practice

The income and savings are normally stored in their houses. Valuable items and huge amount of money are kept at home without properly banking although banking services are provided on the island.

These practices expose the assets / money / valuables to disasters making the owners more vulnerable.

4.7. Factors that contribute to the relief of disaster effects

The positive social elements that have been identified as factors that would help in reducing the effects of disasters are illustrated in figure 33.

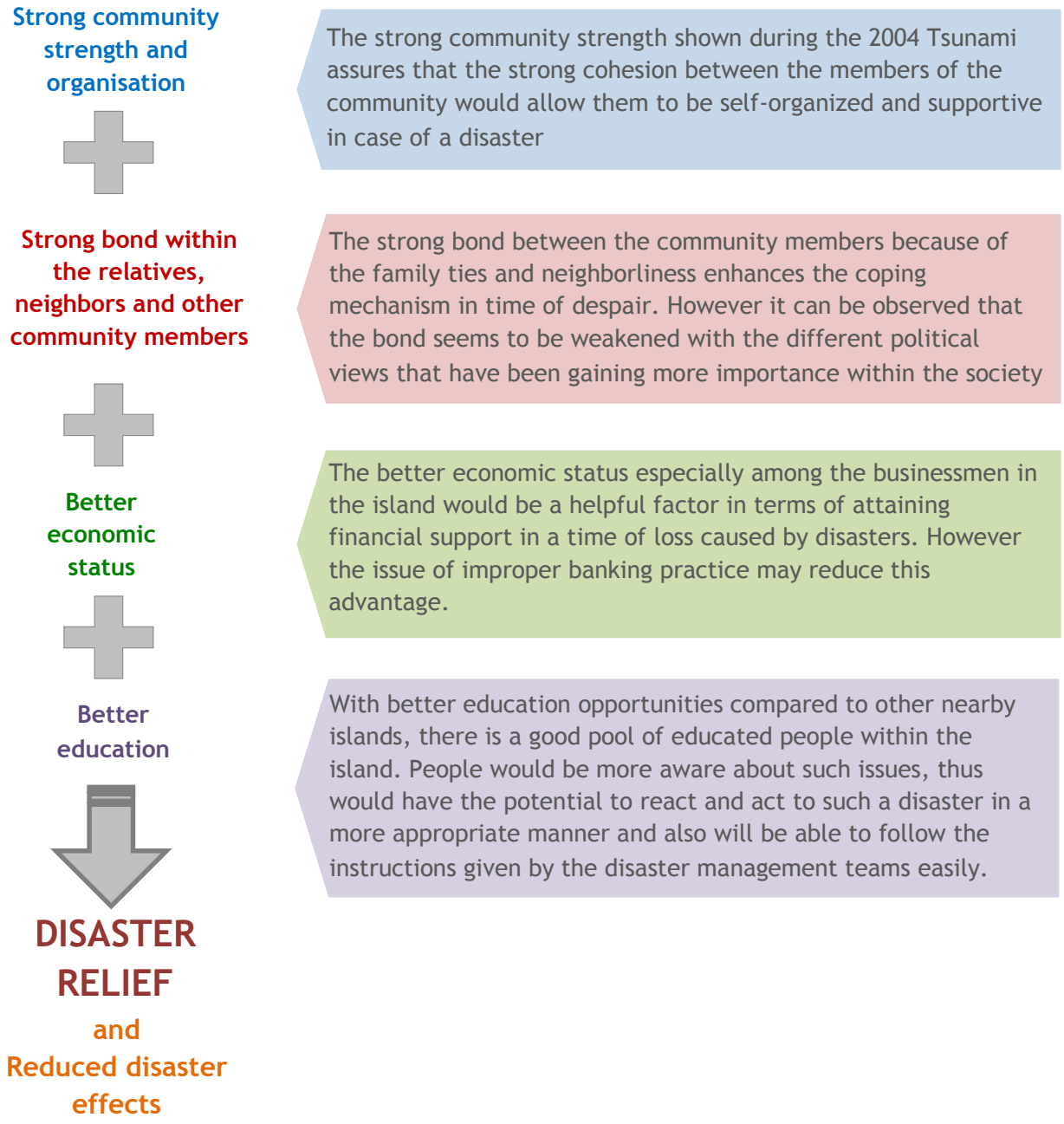
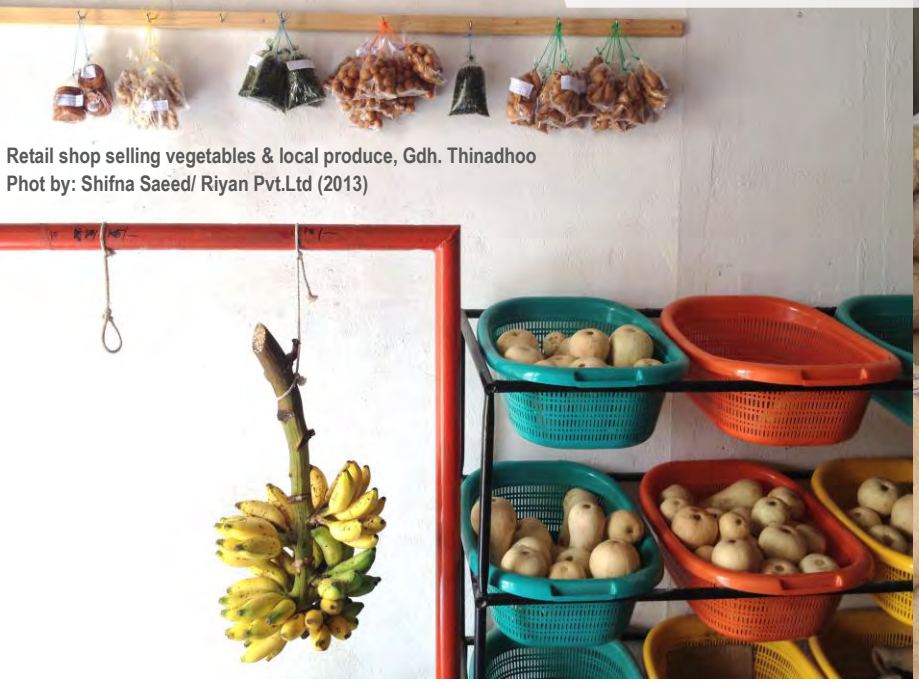


FIGURE 33 FACTORS THAT CONTRIBUTE TO THE RELIEF OF DISASTER EFFECTS

Smoked fish, Gdh. Thinadhoo
Phot by: Shifna Saeed/ Riyan Pvt.Ltd (2013)

Housing construction in Gdh Thinadhoo
Phot by: Shifna Saeed/ Riyan Pvt.Ltd (2013)

5. Economic Vulnerability Assessment



Retail shop selling vegetables & local produce, Gdh. Thinadhoo
Phot by: Shifna Saeed/ Riyan Pvt.Ltd (2013)

Warehouse storing staples,, Gdh. Thinadhoo
Phot by: Shifna Saeed/ Riyan Pvt.Ltd (2013)

5. Economic Vulnerability Assessment

5.1. Value of economy

As discussed in the previous DIRAM study, unavailability of sufficient local economic data limits the study to generate an estimation of the value of an island economy. Normally economic data are aggregated at the national level thus it will be difficult to determine the local economy at individual island level. Nevertheless a rough estimate has been derived using the data from previous study and average values attained through field interviews and consultations. Similar method as that used for previous DIRAM study was used to conduct the analysis. This includes:

- An inventory of the economic establishments and socio-economic infrastructures to determine the number and size of the establishments.

- Field interviews with random business establishments to attain some detailed information regarding employment income and investments/expenditure cost.
- Using the data, a rough estimate of the costs of public and private investments, their production values and expenditure were calculated and presented in table 11 below.

TABLE 11 ESTIMATED VALUE OF THE THINADHOO ECONOMY

Sector	Public Investment	Private Investment	Production[2]	Total
Fishing		73,000,000	13,200,000	86,200,000
Public Administration (Civil Service including education and Healthcare)	139,718,311		4,256,000	143,974,311
Manufacturing		2,247,000	460,000	2,707,000
Wholesale and retail trade and workshops		20,650,000	6,420,000	27,070,000
Transport, storage and communications	82,163,478	50,410,000	6,500,000	139,073,478
Construction		1,400,000	600,000	2,000,000
Hotels and restaurants		1,800,000	500,000	2,300,000
Other community, social and personal service activities	24,014,600	450,000	200,000	24,664,600
Real Estate, renting and business activities		8,400,000	225,000	8,625,000
Electricity, Gas and Water supply	89,913,816	4,500,000	3,500,000	97,913,816
Agriculture		300,000	150,000	450,000
Households		388,800,000		388,800,000
Tourism			520,000	520,000
Total	**335,810,204**	**551,957,000**	**36,531,000**	**924,298,204**

Note: The above values are based on data sourced during field work for current report

The total estimated value of Thinadhoo economy is between 900 Million and 1.1 billion Rufiyaa. The single largest investment is on housing. Using the replacement value of houses

[2] Production is calculated for a month using the number of business establishment and average income figures derived during field surveys

the total value was estimated to be Rf 388 million. The major investment after 2008 is also in housing (19 Million) followed by water network and desalination plant (15 Million) and harbour development (16 Million). Public infrastructure including health and education and others accounts for Rf31 Million. Significant investments were observed in fisheries, wholesale and retail trade. In terms of production, fisheries sector contributes the highest with 13 million, followed by transport, storage and communications (Rf6 million) and by trade (Rf6 million).

The above values are indicative figures based on average numbers and should not be used as exact values of the economy. Nonetheless, these values are useful and sufficient in estimating the economic losses during a disaster in the absence of official statistical figures.

5.2. Key economic establishments and their physical distribution

5.2.1. Distribution of economic establishments

As noted in section 2.4, land was previously allocated for housing needs and agricultural purposes. No specific zoning was undertaken for business or industrial uses. Thus over 90% of the business establishments are located within the housing areas. Mostly the houses are transformed or parts of the houses are used for business activities similar to Male'. Nevertheless, a pattern can be observed in the distribution (figure 34).

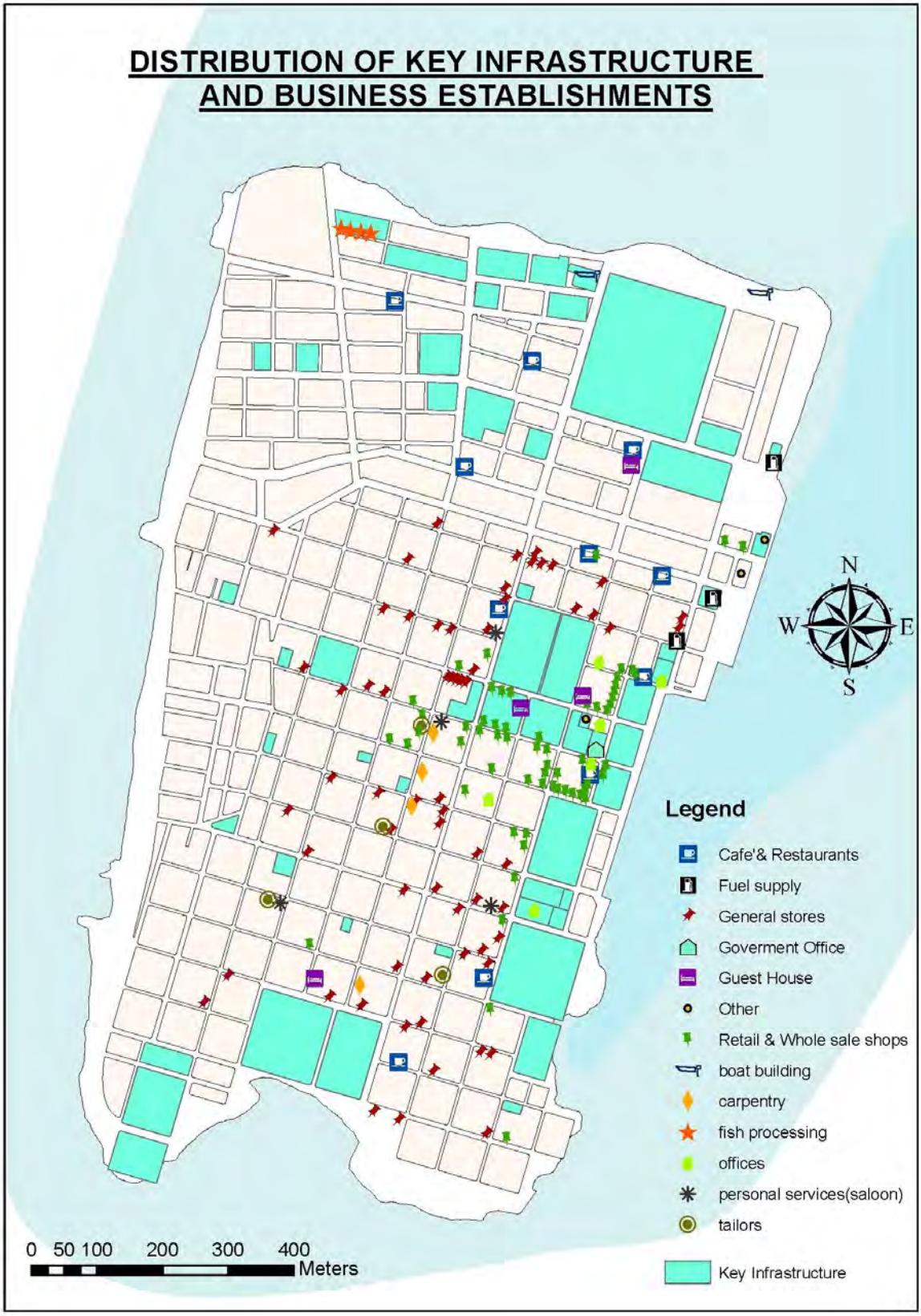


FIGURE 34 DISTRIBUTION OF ECONOMIC ESTABLISHMENTS AND KEY INFRASTRUCTURES

As it can be seen in the figure above, a high concentration of business activities are spread across the older island of Thinadhoo. Also more establishments are now located near the existing harbour to cater to the visitors as proposed in the land use plan. Almost all the business activities are located facing the roads. This is mainly due to good accessibility to the roads making it easy for the customers and also for loading and unloading. The boat building and repair activities are located at the northern end of the island.

5.2.1. Distribution of economic infrastructure

Economic infrastructures can be described as the facilities that drive the business activities which include communication, transportation and distributing networks, financial institutions and market and energy supply systems (Business Dictionary, 2013). In Thinadhoo, the key economic infrastructures include the local harbour, communication infrastructures (DHIRAAGU and Wataniya site), power house, roads and the Bank of Maldives branch. In addition, the public facilities, public amenities and institutions can also be considered as contributors to the economy. Thus these elements are also mapped together with economic infrastructures. The figure 34 above shows the location of the infrastructures along with the business establishments.

5.3. Economic elements at risk and their vulnerability

This section presents the economic elements at risk to the major natural hazards identified in 3.1. The hazards are tsunami, swell wave, swell surge, rainfall flooding, strong wind and coastal erosion. A GIS was used to compute the hazard zones and these zones are compared against the business establishments and economic infrastructures.

The elements at risk of the existing land use at the different scenarios are described below:

i. Tsunami Hazard

The hazard analysis conducted for Thinadhoo showed that a high magnitude Tsunami is most likely to approach from the eastern coastline. This wave would also wrap around the island and approach from the north and sound ends causing floods around the island. How a Tsunami would impact the infrastructures are summarized in the table 12 below and results of the hazard analysis are presented in figure 35.

TABLE 12 SUMMARY OF ECONOMIC ELEMENTS AT RISK TO A HIGH MAGNITUDE TSUNAMI (ADOPTED & UPDATED FROM PREVIOUS DIRAM REPORT)

Infrastructure and economic elements at risk	Locational vulnerability	Physical Vulnerability	Overall Vulnerability	Notes
Critical infrastructure				
- **Harbour**	High	High	**High**	Poor construction; the quay wall is severely damaged
- **Regional Hospital**	High	Moderate	Moderate	Located close to eastern shoreline. During previous Tsunami water entered the building though no damage was caused to any equipment.
- **Power**	High	High	**High**	Buildings, engines, fuel storage and distribution at high risk.

- **RO Plant**	Moderate	Moderate	Moderate	The building and the tanks would affected
- **Communications**	Moderate	Moderate	Moderate	The infrastructures are elevated, reducing the risk
Potential evacuation centres				
Mosques, schools, higher grounds	Moderate	Low	Moderate	Although these places are in fairly good condition most of them are located in moderate risk zones.
Economic sectors				
- **Fishing**	Moderate	Moderate	Moderate	Vessels and processing centres at moderate risk
- **Construction**	Low	Low	Low	Most facilities located away from coastline
- **Agriculture**	High	High	**High**	Salt water damage to crops
- **Manufacturing**	Moderate-low	Moderate	Moderate	Their products, raw materials and means of production maybe damaged/lost
- **Wholesale & retail**	Moderate-High	Moderate-High	**High**	Stocks would be affected Since they are not insured the loss cannot be recovered easily
- **Personal service sectors**	Moderate	Moderate	Moderate	There may be structural damages
- **Transport**	Moderate	Moderate	Moderate	Vehicles/vessels maybe damaged disrupting the service causing secondary impacts

				Fuel supply would also be at moderate risk.
- **Public administration**	Moderate	Moderate	Moderate	Key administrative buildings, equipment and documents may be affected.
Other social & economic infrastructure				
- **Schools**	High	Moderate	Moderate-High	The school at the south end and the university campus will be highly affected
- **Households**	Moderate-low	Moderate-low	Moderate-low	3% of Households at moderate risk, rest at low risk; structures generally weak and only recently built houses are elevated loss of personal belongings
- **Waste management site**	High	High	High	Located too close to coastline. It could cause secondary pollution as the high pressure wave would disperse all the waste into the island polluting the island and thus leading to other types of risks including health hazards.

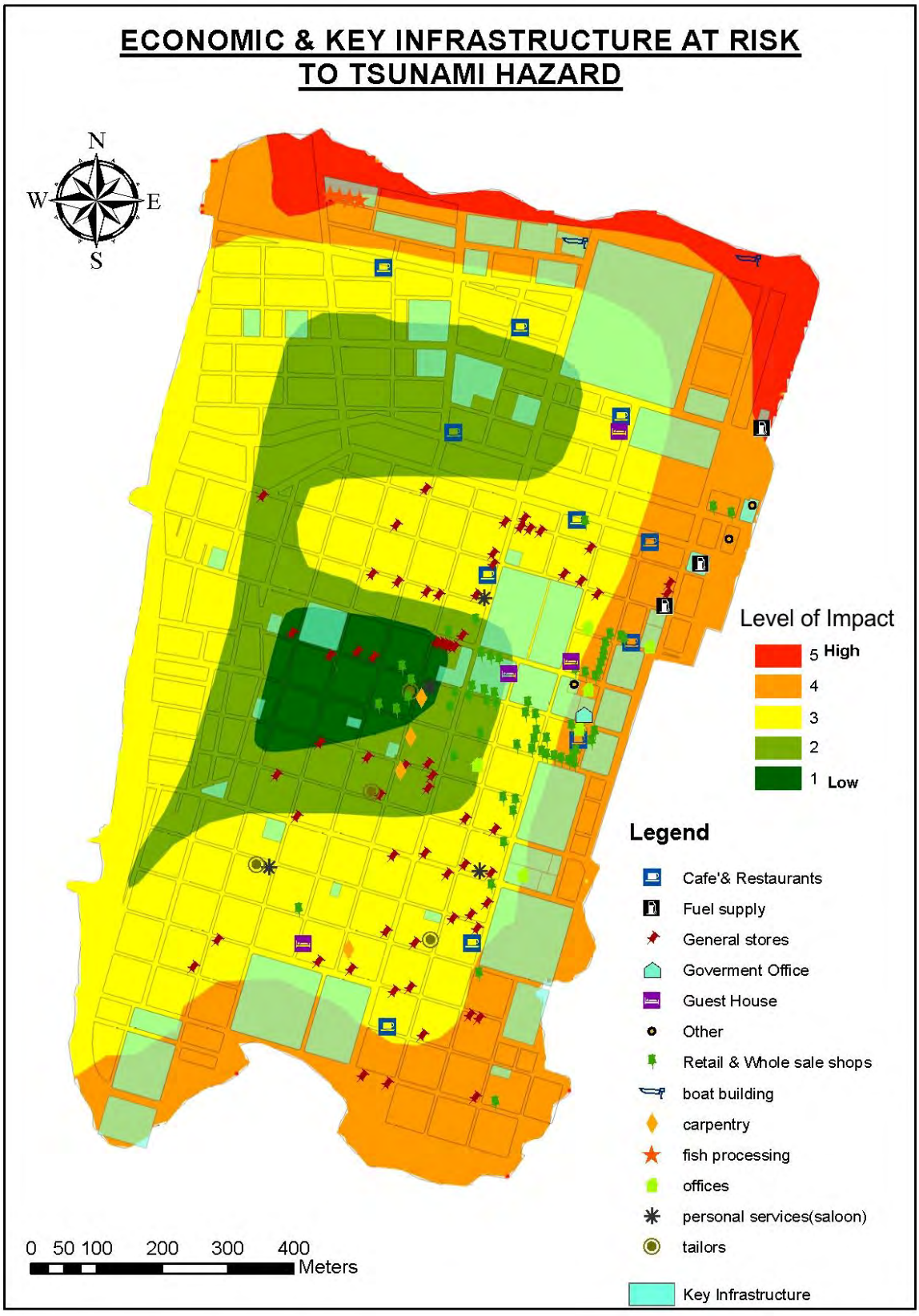


Figure 35 Economic elements and public infrastructures at risk to a Tsunami Hazard

ii. Swell wave hazard

Swell waves and surges are expected to approach the island from west, south and north side of the island. Thus the coastal areas surrounding the island except the eastern coastline are vulnerable to the effects of swells. However, swell waves and storm surges are expected to impact at a low intensity compared to Tsunami. How a severe swell would impact the infrastructures are summarized in the table 13 below and results of the hazard analysis are presented in figure 36.

TABLE 13 SUMMARY OF IMPACTS OF A SWELL WAVE HAZARD TO THE KEY INFRASTRUCTURES

Infrastructure and economic elements at risk	Locational vulnerability	Physical Vulnerability	Overall Vulnerability	Notes
Critical infrastructure				
- **Harbour**	Low	Low	Low	Not within the high risk zone
- **Hospital**	Low	Low	Low	Not within the high risk zone
- **Power**	Moderate-low	Moderate-low	Moderate-low	Located close to high risk area, but maybe blocked by the RO plant reducing the impact
- **RO Plant**	Moderate	Moderate	Moderate	The building and the tanks would affected
- **Communications**	Moderate-low	Moderate-low	Moderate-low	The infrastructures are elevated, reducing the impacts

Potential evacuation centres				
- **Mosques, schools, higher grounds**	Moderate-low	Low	Moderate-Low	Most of the places are located away from the risk areas, however one preschool and few mosques are located at moderate risk zones
Economic sectors				
- **Fishing**	Moderate-low	Moderate-low	Moderate-low	Processing centres at moderate risk
- **Construction**	Low	Low	Low	Most facilities located away from coastline
- **Agriculture**	Moderate-low	Moderate-low	Moderate-low	Salt water would damage crops
- **Manufacturing**	Moderate-low	Moderate-low	Moderate-low	Their products, raw materials and means of production maybe damaged/lost
- **Wholesale & retail**	Moderate-low	Moderate-low	Moderate-low	Few shops are located at high risk zones. The stocks may be affected
- **Personal service sectors**	Moderate	Moderate	Moderate	Some establishments are located at moderate-low risk zones, their buildings may be slightly flooded

- **Transport**	Low	Low	Low	Marine vessels would not be affected, and only a slight impact is expected to cause to the vehicles on land
- **Public administration**	Low	Low	Low	Most of the buildings are located away from risk zones
Other social & economic infrastructure				
- **Schools**	Moderate-Low	Moderate-Low	Moderate-Low	One primary school located at high risk area, the salt water cause damage to the structure and its fittings
- **Households**	Moderate-High	Moderate-High	Moderate-High	Approx.10% of households at moderate risk causing damage to the personal belongings and disrupting their daily life
- **Waste management site**	High	High	High	Would impact largely damaging the site and also causing secondary damages (in-flow of waste to the island)

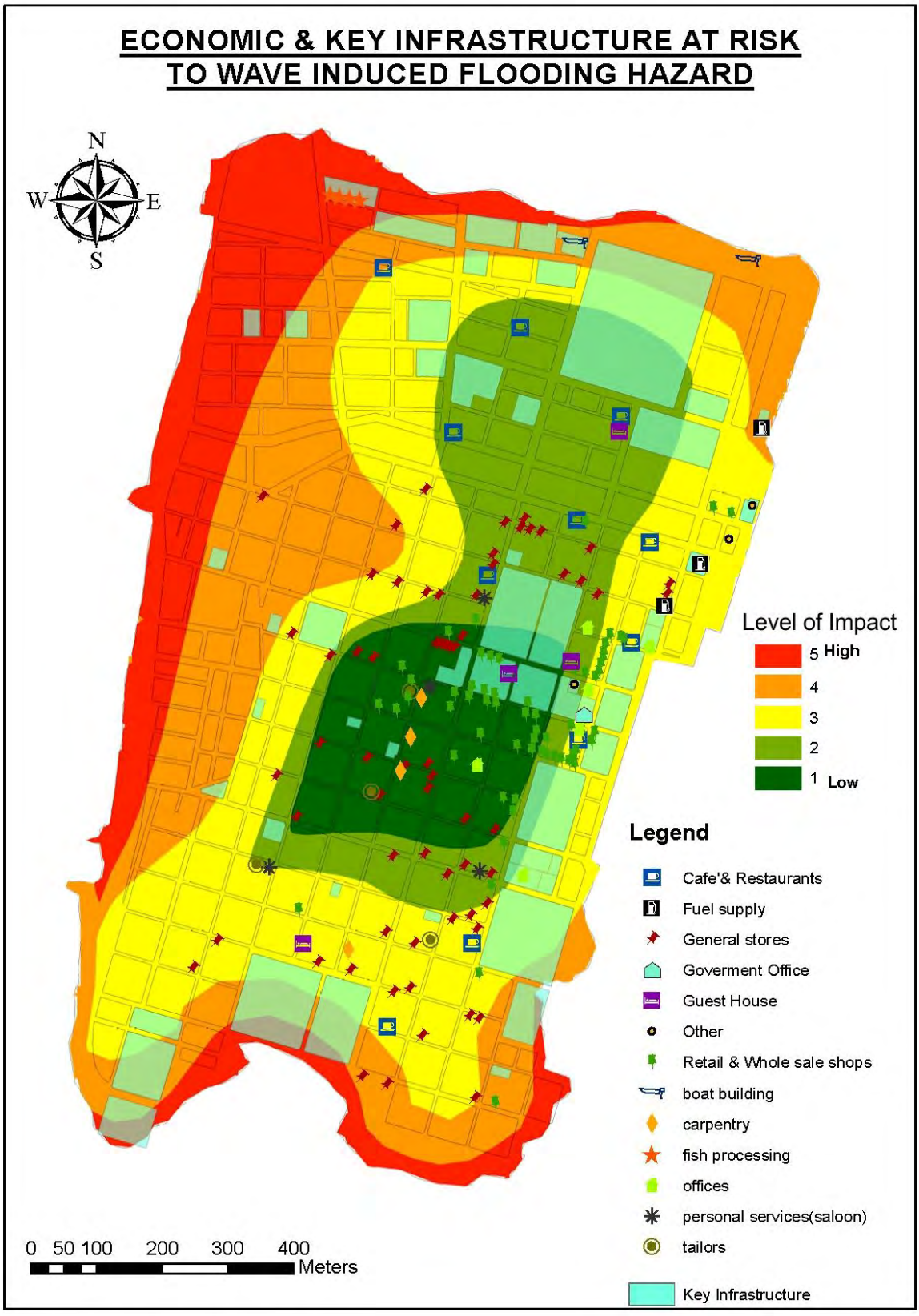


FIGURE 36 ECONOMIC ELEMENTS AT RISK TO A SWELL WAVE HAZARD

iii. Rainfall flooding hazard

The areas, which are likely to be severely affected by a heavy rainfall event, are the swamp area at southern end, wetland area at north-west corner and some low land areas at the central part of the island towards the eastern side of the island. As these areas are the lowest areas of the islands the water flow is expected to run towards these areas causing severe floods. How a severe rainfall event would impact the infrastructures are summarized below and results of the hazard analysis are presented in figure 36.

Impacts of a heavy rainfall flood event to the key infrastructures:

- According to the analysis, flooding due to a heavy rainfall event is expected to have a significant impact on the powerhouse, the RO water plant, DHIRAAGU site, fish market, regional hospital, Abu bakuru school and university campus. In addition the flooding would highly impact the business establishments at flood risk zones.
- Since the powerhouse and the RO plant are located in the flood prone area, floodwaters are likely to enter the buildings. However, the engines are located at an elevated height making them safe from the floods. Nevertheless the RO plant is expected to flood causing damage to its infrastructure and water network system.
- The communication sites (Wataniya and DHIRAAGU) maybe flooded although no damage is expected as the structures are elevated.
- The business establishments at risk of flooding are the retail shops located at the North West end and the shops at South East side of the island. The goods sold at these shops maybe affected but measures currently adapted by the shops, such as putting concrete bags and elevating the entrance would minimize the impacts. The shops located in the inner island are safe from flooding.
- The primary school located at the south end is highly vulnerable to flooding, as it is located at a medium-high risk flood zone. Even now they experience the floods during heavy rainfall.
- The households located within the southern half of the island and low areas at the eastern side of the island have high risk of flooding during a heavy rainfall event. Their personal belongings and back yard trees maybe damaged disrupting their daily life.
- The hospital may also be affected leading to disruption in operations and movements of people.
- The proposed STP is to be located at the northwest end. This area is prone to flooding as it consists of a small wetland area with mangroves. Proper flood proofing is required of it is to be located at this area.

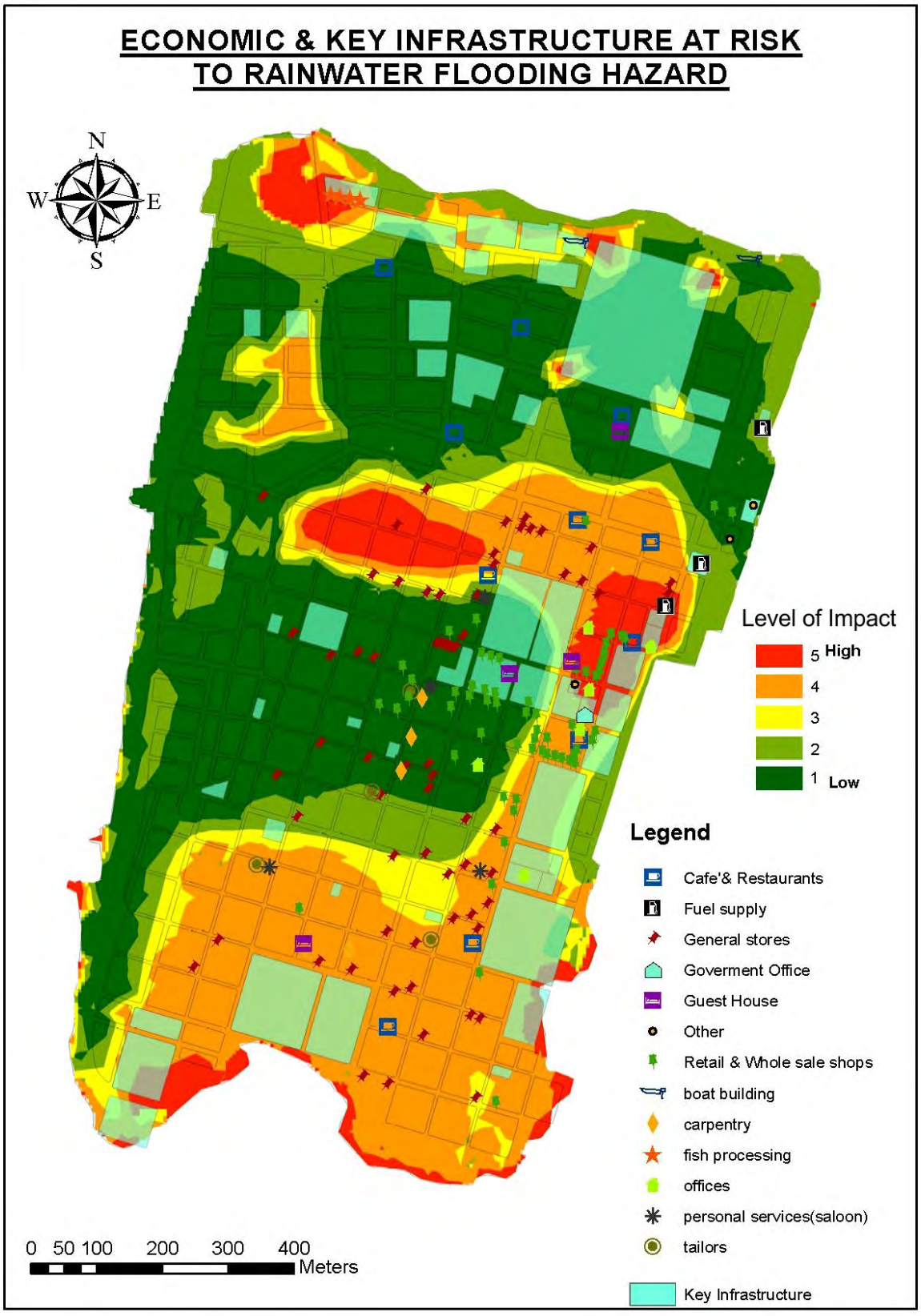


FIGURE 37 ECONOMIC ELEMENTS AT RISK TO A RAINFALL HAZARD

iv. Strong wind hazard

Although Thinadhoo is a zone prone to cyclonic events, the island is expected to highly impact from strong wind from localized storms. The strong wind generated from these storms would put the island at risk if it strikes the vegetation and the buildings. The expected impacts of a strong wind hazard include:

- Damage to the key infrastructures due to falling of trees and damage to roofs; Although the modern buildings constructed recently have stronger roofing system, old buildings are vulnerable to such events. Secondary impacts that arise from storms such as storm surges and rainfall would cause different impacts as described in sections ii and iii above.
- Damage to business establishments; damage maybe caused due to destruction of roofs due to strong wind or damage caused by falling of trees. These damages are not expected to cause any significant loss to the establishments. However secondary impacts such as rain followed by the storm may damage the stock if the roofs are damaged.

v. Coastal Erosion

As noted in section 3.1, coastal erosion is a natural process exacerbated by hazard events and human induced events. Details of extent of coastal erosion and the areas prone to erosion are explained in section 3.1. Although erosion may not directly impact any infrastructure, it increases the vulnerability of the island to other natural hazards that would in turn affect the infrastructures as explained above.

Note: The risk analyses of the infrastructures are based on the existing land use. Since the proposed land use plan is undergoing changes, no judgments can be made on the future developments. However, it is important that the vulnerabilities of the infrastructures and the hazard zones are taken into consideration in updating the new land use plan.

5.4. Economic consequences of a disaster

5.4.1. General Findings

Thinadhoo economy has evolved over the past years. Now fisheries are not the only activity generating income to the island. The whole sale a retail business is also contributing to the growth of the economy at a significant level. In addition to the major investments in fisheries, substantial private investments have been made in wholesale, retail and transport sectors. Also one of the key contributors to the economy is income earned from government and other public enterprises. Thinadhoo economy is also dependent on travel and supply of goods from neighbouring islands especially from Gaaf Alifu, Gaaf Dhaalu and Fuvahmulah. Thus there would be a huge impact to the islands economy if the vessels for transport or harbour are damaged.

According to the natural hazard assessments, most of the key economic infrastructures are at risk in case of any disaster event. According to the assessments, as explained in section 5.3 and calculations based on the figures gathered, economic losses are expected to be highest during a high magnitude tsunami or a swell wave event. Impacts of other disasters such as rainfall flooding and strong wind are expected to be relatively low compared to tsunami and swell waves. However it is important to note that since flooding caused by heavy flooding is very frequent in Thinadhoo the losses over a stretch of number of years would be higher than the single events of Tsunami and swell waves.

The key economic infrastructures which are at high risk of being damaged during the disaster events analysed in this study are the power house and RO water plant. The critical social infrastructures at risk are the hospital, Abu Bakuru School, University campus and some of the households. It is essential to understand the direct and indirect economic loss of the disasters as the functioning of the whole community depends on these infrastructure on a daily basis. It was found that a significant loss will be experienced by these infrastructures in the different disaster scenarios. These are further explained in the next section.

Most of the wholesale and retail shops are located at high risk areas and the boat building industry assets located at high risk zone are expected to cause significant losses in case of a severe disaster event. A temporary decline in the economy is highly expected and recovery may take a considerable amount of time depending on the intensity of the disaster and the damage caused. It is evident that if the expected losses of infrastructures, facilities and other assets are experienced, there will be a significant drop in the economic growth.

Although Thinadhoo is experiencing rapid development in terms of physical development, not much consideration has been given to disaster risk reduction or mitigation. These factors need to be taken into consideration in order to make the island resilient to such unexpected events as the rapid urbanization increases the risk and vulnerability of the island to disasters.

5.4.2. Detailed Findings

The table 14 below shows estimated values of losses. The figures only represent losses for the tangible developments and do not consider developments proposed for the newly reclaimed area.

TABLE 14 ESTIMATED VALUES OF LOSSES

Sector	Tsunami losses	Swell waves and storm surge losses	Rainfall flooding losses
	(Rufiyaa)	(Rufiyaa)	(Rufiyaa)
Infrastructure	9,791,382	2,368,496	420,000
Households	1,944,000	1,166,400	466,560
Fisheries	3,448,000	1,379,200	-
Agriculture	350,000	110,000	70,000
Wholesale and retail trade	3,135,912	500,000	200,000
Manufacturing	280,000	65,000	20,000
Transport, storage and communications	2,583,724	104,305	50,000
Construction	30,000	14,000	-
Hotels and restaurants	460,000	140,000	20,000
Public Administration	2,879,486	1,100,000	300,000
Other community, social and personal service activities	50,000	15,500	-
Real Estate, renting and business activities	862,500	517,500	100,000
Tourism	50,000	200,000	-
Total	**25,865,004**	**7,680,401**	**1,646,560**

The estimated loss from a severe tsunami event in Thinadhoo ranges between Rf 25 million and Rf 30 million. The losses to infrastructures, particularly to the power house, RO plant, hospital and the school at south end form a significant proportion of the total losses. Damage to harbour will adversely impact economic activities related to travel such as fishing, wholesale and retail businesses. The costs of infrastructure and public administration include damage to school and the hospital.

The estimated tangible loss from a severe swell wave or storm surge event in Thinadhoo is Rf 7.6 million. The losses are small compared to a tsunami event as the intensity of the impact is low.

The estimated tangible loss from a severe rainfall flooding event is Rf 1.6 million. Compared to tsunami and swell wave events, a heavy rainfall event is expected to result in a smaller loss as the intensity of rainwater flooding is much lower than flooding caused by Tsunami/swell waves. However it is important to note here that with the increased number of flooding events in a given number of years, the losses may go higher than a single event of swell wave or a Tsunami (as they are rare to happen compared to flooding). Rainwater flooding would mostly impact the low areas of the island and reclaimed wetlands.

6. Key island findings

The environmental, social and economic assessments have shown the extent of vulnerability of Thinadhoo to a natural disaster. This section summarises the findings as a SWOT analysis to provide an overall picture of the outcomes of the study.

Strengths

Socio-economic

- Strong community spirit
- Strong economy
- Educated and skillful people
- Locals enthusiastic to work at different level of jobs
- More land created for better facilities

Environmental

- Wide reef flat at west side and the large lagoon at the eastern rim provides a self-defense system which reduce the intensity of impacts of swell waves and surges

Opportunities

Socio-economic

- Strong bonds between community members would help in creating resilience among the communities.
- Economically stable community will be able to cope better in a case of disaster crisis.
- Potential entrepreneurs willing to work in the island; strengthening the economy of the island.
- Climate-smart planning can be used to plan the newly reclaimed area hence increasing its resilience

Environmental

- The island has the opportunity to expand due to the large lagoon and reef flat. It can be reclaimed with a better drainage system
- The island can be a safe island from natural disasters through proper mitigation measures such as a comprehensive drainage system, rehabilitation of the vegetation belt and protection of coastlines.

Weaknesses

Socio-economic

- Population growth increases the vulnerability of the island
- Poor condition of housing and infrastructure
- Location of housing and infrastructures
- Buildings built at reclaimed areas are prone to damages
- Different political views slow down the decision making process

Environmental

- Lack of vegetation make the island more vulnerable to flooding, swell waves and surges.
- No proper drainage system
- Reclamation of the wetlands disrupts the natural drainage system and creates more areas prone to flooding

Threats

Socio-economic

- High population growth rate would increase the population density; more people are at risk in case of disaster- poverty may increase
- Location of some of the critical infrastructures/institutions/housing are subject to erosion, swell waves and flooding. Homelessness and loss of facilities
- Damage to critical infrastructures such as water plant leading to water scarcity
- The different political views among the public decreases community spirit leading to segregation of the society

Environmental

- The fact that the original wetland areas were reclaimed; these areas are prone to flooding and may damage the existing and upcoming buildings in those areas.
- Improper drainage system would cause flooding

7. Reducing Vulnerability and exposure to disasters

7.1. Measures to reduce environmental vulnerability

- *Protecting the western shoreline of the island*
  From the vulnerability assessment it was clear that the western side of the island is very susceptible to flooding due to storm surge and swell waves. Due to the reclamation in this area, there is no natural ridge system that is normally present in islands in similar geographic that would act as a natural response to high energy environment. Furthermore, without the natural vegetation or any coastal protection structure, this area has been undergoing erosion at an alarming rate. The island council estimates that 25m wide section of the reclaimed shoreline has eroded away since it was reclaimed.
  As part of the ICCRRIP project by the Ministry of Environment and Energy, soft coastal measures are proposed for this area of the island. Hence it is envisaged that a combination of ridge system combined with a vegetation belt would provide a sustainable solution that would mimic the natural protection provided in the adjacent shoreline section just to the south of this proposed area. This green zone should be established as an Environmental Protection Zone.

- *Protection of the northern side of the island*
  The northern shoreline is proposed as an industrial zone. Since a large section of the northern side shoreline is part of the small natural island, it is relatively stable compared to western shoreline. However due to the low lying nature of the area, it is susceptible to wave induced and tsunami flooding. There have been various plans to expand the island towards the north by reclaiming further land from the shallow reef flat. If these works are carried out, then the area would be protected. But the project should be designed such that mistakes made in the past with drainage issues are avoided.

- *Coastal protection of the south side of the island*
  The south side shoreline forms a bay type feature with the south western tip having the natural high ridge and the rest of the shoreline being relatively low. Due to the reclamation of the wetland area to lower level compared to the rest of the island, buildings constructed in this area are very low lying and are facing both rainfall and wave induced flooding. Apart from residential infrastructure, critical infrastructures like the power house, water plant and a school is located very close to the shoreline.

- *Creating and maintaining the EPZ*

  The reclaimed stretch of western shoreline between the natural ridge of the old Thinadhoo and the small island in the north is approximately 1.2km. As described above this stretch of land is most prone to erosion and flooding due to storm surge and swells waves. The proposed shore protection project for this area as described above would hopefully create a green zone that would mimic the green belts of the natural island in the Maldives. This type of no development zones should be provided where possible right around the perimeter of the island. For future planning and potential future reclamation projects, importance should be given to provide this type of green buffer zone between the shoreline and the development.

- *Establishing a proper drainage system*

  A functioning drainage system is critical to prevent major damage to flooding and even from tsunami inundation. A large scale road development project has been announced recently by the government. The government should ensure that the newly constructed roads are implemented with a properly designed functional drainage system. Another critical area is the interface between the old and new reclamation. The existing ditch should be properly designed and ensured that water flow into this area is safely channelled out to the sea.

7.2. Measures to reduce socioeconomic vulnerability to disasters

Socioeconomic vulnerability depends on many factors such as income, education, health, age and location of households as described in section 4. In order to reduce the risks, it is essential to integrate the Hyogo framework 2005-2015[3] , the Millennium Development Goals[4] (MDGs) and the Cairo principles[5] in implementing the measures. Following measures details out how this can be achieved and how the island community can be made resilient to natural disasters.

> "Anticipating, educating and informing are the keys to reducing the deadly effect of natural disasters" UNESCO Director-General Koïchiro Matsuura, 3 January 2005

i. **Promote disaster risk reduction and management:**

- Make disaster risk reduction a local priority through educating and creating awareness among the island community on natural disasters, the impacts they cause and the importance of risk reduction to ensure risk resilience (UNISDR 2007; Laukkonen 2009).
- Empower the island council to act as the key facilitator to build awareness on disaster risks among the community.
- Use knowledge and innovation to educate the people and create a culture that opts for safety and resilience of the island and the people (Latham n.d.)
- Initiate capacity building programs in the public sector to increase their capabilities in addressing disaster risk reduction issues (Laukkonen 2009)
- Adopt participatory approaches such as Participatory Rural Appraisal (Chambers 1997), to empower the vulnerable groups to be actively involved in risk reduction programs.
- Identify ways to diversify the economy to improve the economic well-being of the community and eradicate poverty by adopting a sustainable approach as proposed in the UNDP's Millennium Development Goals (UNDP, 2010).

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[3] "The World Conference on Disaster Reduction …adopted the present Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters…The Conference provided a unique opportunity to promote a strategic and systematic approach to reducing vulnerabilities and risks to hazards. It underscored the need for, and identified ways of, building the resilience of nations and communities to disasters" UNISDR (2007)

[4] "The eight Millennium Development Goals (MDGs) – which range from halving extreme poverty to halting the spread of HIV/AIDS and providing universal primary education, all by the target date of 2015 – form a blueprint agreed to by all the world's countries and all the world's leading development institutions" (http://www.un.org/millenniumgoals/bkgd.shtml)

[5] Guiding Principles for post-tsunami rehabilitation and reconstruction (UNEP-GPA 2005)

- Develop financial plans to strategize the available resources and involve the community in the planning process to identify efficient ways to use the resources in a sustainable way. Equal opportunities can be provided to all, especially for youth and women by creating jobs and livelihoods through the diversification of the economy of the island, (UN 2013).
- Identify the most vulnerable groups and provide them with social safety nets to reduce their vulnerability to disaster (ESCAP & UNISDR 2012).
- Encourage the community to insure the high risk establishments and valuable assets at risk such as fishing vessels.
- Incorporate hazard mapping and hazard zone analysis at policy level. Revise the land use planning regulation and building code to incorporate hazard analysis as part of the planning process as has been proposed in the *Integration of Climate Change Risks into Land Use Planning* (MHE, 2011).

ii. Prepare the communities for the possible disaster events

- Use their local knowledge and incorporate scientific knowledge to anticipate, educate and inform on the disasters and ways to reduce the risks. It was evident from the consultations that the people are not very aware about the intensity of the risks and their impacts. Their perception towards risk shows that most of the people are not very concerned about natural hazards, but are rather concerned about other socio-economic factors. They need to be informed about how impacts on the natural environment would affect the socioeconomic structure of the island and their social and economic well-being are factors that could make them more vulnerable to such events.
- Develop disaster management plans complemented with an early warning system at all levels; national, regional, atoll and island level. The plan for the island should cover ways to assist and support the vulnerable groups, evacuation plans and response procedures for the critical infrastructures.
- Train teams from the island for disaster response.
- Prepare a comprehensive registrar including permanent and temporary residents and expatriate population.
- Sufficient supply of food and water should be always kept in stock to avoid food and water shortage at a time of disaster.

iii. Strengthen the emergency response and recovery services

- Retrofit the hospital building to avoid flood impacts and equip the ambulance and emergency services with appropriate emergency response facilities.

- Revitalize the community spirit through interactive programs and awareness campaigns to strengthen their relationships and support especially during a time of a disaster and during time of recovery.

7.3. Costs and benefits of mitigation measures

This section presents a cost benefit analysis for the proposed measures to reduce socioeconomic and environmental vulnerability to disasters. The costs are calculated based on prices in 2013. Table 15 below provides a summary of the costs of mitigation measures and the responsible sector.

TABLE 15 SUMMARY OF MITIGATION ACTIVITIES FOR THINADHOO AND THEIR COSTS

Mitigation options	Cost (Rufiyaa)	Responsibility
Diversifying and strengthening the economic base		public
Coastal protection measures (Western coastline)	35,000,000	public
Coastal protection measures (Southern coastline)	25,000,000	public
Environment Protection Zone	15,000,000	public
Flood proof hospital	200,000	Public
Protecting fuel storage	200,000	Private
Flood proof powerhouse	500,000	Public
Flood proof communication infrastructure	300,000	Private
Flood proof waste management sites	100,000	public
Constructing artificial drainage systems in low lying areas and main roads – harbour area and near power site	15,000,000	public
Strictly establish the environmental protection zone (Assuming no relocation required)	300,000	
Creating disaster risk awareness among business establishments	50,000	
Creating awareness on importance of insuring high risk investments	50,000	
Creating awareness on storing cash through banking facilities	50,000	

The cost and benefit analysis has been carried out using the standard methods of the analysis. For the purpose of this study, the costs for the proposed measures are the direct expenditure estimated to implement the measures. The benefits comprises of two parts: a) the direct and indirect losses avoided from severe disaster event(s) and b) the value of life and injuries avoided.

The tables below summarises the cost and benefits of the proposed mitigation measures for the different scenarios. In this analysis all the expenses that are required for making the island resilient to natural disasters are considered as costs. This assessment considers a 25-year time span due to the possibility of significant land use changes within such a timeframe.

The two scenarios evaluated in the previous DIRAM study; analysis for a single disaster (Tsunami) event (table 16) and analysis for possible multiple disaster events within a 25 year time span (table 17), are re-evaluated using the current costs and benefits. In addition, given the frequent events of flooding, single rainfall flooding event per year for the 25 time span (table 18) has also been evaluated. For the flooding event, the cost mitigation measures for coastal protection is deducted and measures relevant to flooding is considered.

TABLE 16 COSTS AND BENEFITS OF MITIGATION MEASURES: ASSUMPTION A SINGLE DISASTER EVENT IN 25 YEARS

Measures	Costs (Rufiyaa)	Benefits (Rufiyaa)	Net Benefits (Rufiyaa)
Benefits 1. Damage to infrastructure, public investments avoided; production losses avoided.		25,865,004	
2. Lives saved and injuries prevented[6]		20,583,316	
Costs 1. Cost of Mitigation measures	91,750,000		
Net Benefits			-45,301,680

The calculations show a negative net benefit of approximately -45.3 million Rufiyaa for the first scenario considered. Mitigation measures are often not designed for single disasters; it is designed for multiple hazards.

[6] Assumption: 0.001% lives may be lost; 0.5% may be injured; Statistical Value of Life = 1,927,500.00 using income-over-life method.

TABLE 17 COSTS AND BENEFITS OF MITIGATION MEASURES: ASSUMPTION MULTIPLE DISASTER EVENTS[7] IN 25 YEARS

Measures	Costs	Benefits	Net Benefits
Benefits 1. Damage to infrastructure, public investments avoided; production losses avoided.		35,191,965	
2. Lives saved and injuries prevented		26,625,794	
Costs 1. Cost of Mitigation measures	91,750,000		
Net Benefits			-29,932,241

The second scenario considers multiple hazards during the 25-year timeframe and it shows a negative net benefit of approximately -29.9 million Rufiyaa (See table 17). The buildings and facilities proposed are not included in this analysis as the land use plan is under review and the developments are expected to change after the review. Hence, once the developments are complete or the plan gets approved it is recommended to revise the analysis as per the developments and their vulnerability.

[7] Assumes a disaster event of each type (tsunami, swell wave and rainfall flooding) in 25 years.

TABLE 18 COSTS AND BENEFITS OF MITIGATION MEASURES: ASSUMPTION ONE RAINFALL FLOODING EVENT PER YEAR FOR 25 YEARS

Measures	Costs (Rufiyaa)	Benefits (Rufiyaa)	Net Benefits (Rufiyaa)
Benefits 3. Damage to infrastructure, public investments avoided; production losses avoided.		41,164,000	
4. Lives saved and injuries prevented[8]		9,056,080	
Costs 2. Cost of Mitigation measures	16,750,000		
Net Benefits			33,470,080

The third scenario (Table 18) considers a rainfall flooding event per year for the 25-year timeframe and it shows a net benefit of 33 million Rufiyaa.

[8] Assumption: 0.001% lives may be lost; 0.5% may be injured; Statistical Value of Life = 1,927,500.00 using income-over-life method.

7.4. Climate risk monitoring, assessment and data sharing

The above proposed mitigation measures would help the island to restore its defence mechanism to protect the island from the adverse impacts of climate change and natural hazards. However, in order to ensure that these measures are functioning and to identify how successful the measures are, it is essential to have a monitoring plan. The plan should be able to provide a way to monitor the predicted risks identified in this study in a continuous manner before and after implementation of the measures proposed.

Since the island community understands the nature of the island dynamics better than any outsider, this monitoring should ideally be conducted by the community members and reported to the relevant authorities so that the data is shared among the relevant stakeholders for them to take any action regarding the findings. The following table 19 plans out how the data can be collected for the monitoring. Annex III provides template sheets to collect the data followed by the methodology on how to collect them.

TABLE 19 RISK MONITORING PLAN

Monitoring parameter	Methodology	Sampling frequency	Training / equipment requirement
Shoreline mapping (high tide, low tide and vegetation line)	Mapping of high and low tide using precision GPS (0.5m accuracy) Mapping of Vegetation line using precision GPS (0.5m accuracy)	Once every two months Once every 4 months	**Surveyors at Thinadhoo Island Council or Gdh Atoll Council office can do these surveys without further training.** **GPS system which has an accuracy of 0.5m is required for these surveys.**
Beach profiles	At least 10 beach profiles around the island need to be recorded. Initially permanent bench marks should be setup around 10 locations (spread around the perimeter of the island). MSL of these bench marks should be established by connecting the bench marks via level control survey. Features to be recorded are; inside island ridge, top of ridge, bottom of ridge, edge of vegetation, erosion scarp top, erosion scarp bottom, mid beach, beach toe, beach toe bottom, beach rock start, beach rock top, beach rock bottom and lagoon bottom	Every four months	**Surveyors at atoll or island council does not need additional training** **Auto level with barcoded staff will be required to speed up the survey.**
Storm surge related flooding/ tsunami	In the event of storm surge related flooding, extent of flooding should be recorded using GPS (0.5m accuracy). This can be recorded as points and later on during data processing a line feature should be generated from these points. Height of floodwater should be recorded using a staff. The height can be measured as water level above road level. The	N/A Should be carried out before water recedes.	**Graduated staff and GPS system (0.5m accuracy)**

	location of measurement should be recorded using GPS. Measurement locations should be spread such that measurements are taken at near shore area, central area and at furthest extent of flooding		
Rainwater flooding	Baseline locations shall be established using GPS based on the rainwater flooding zonation map generated in this report. At least 10 locations shall be established (5 within worst flooding zones and 5 at moderate flooding zones). During SW monsoon extreme weather events (high precipitation periods), floodwater heights should be measured at the baseline locations. The height of floodwater should be taken from the centre of the road using graduated staff.	N/A	**Graduated staff and GPS system (0.5m accuracy)**

As illustrated in the plan above, the parameters can be used to measure the changes that could be useful in analysing the impacts caused by climate change and natural hazards. These parameters are also considered in accordance with the recently developed coastal protection guidelines (MEE, 2013).

However some parameters mentioned in this guideline are not covered in the list. These include a) the tide data, which cannot be taken at island level and can be attained from the Kaadedhdhoo station, as they are more equipped in collecting such data; and b) Bathymetric data, where the guideline recommends to use LIDAR which is too costly that it is not feasible to be carried out at island level. The monitoring plan provided here is mainly for data sharing purpose and is designed in a way that the island council can collect most data and share it with the relevant authorities.

8. Conclusion

In this review, the findings of the previous DIRAM study have been updated with the most recent data available. However, some of the data that could only be attained from a comprehensive census could not be updated as no census has been carried out after the previous study.

The studies showed that Thinadhoo is highly vulnerable to flooding caused by heavy rainfall and swell waves caused during heavy storms. The unplanned reclamation and the lack of a proper drainage system are the main reasons for the flooding. Thus, soft and hard measures need to be adopted to minimize the impacts of such natural hazards and protect the island in an environmentally, socially and economically sustainable manner.

Moreover the increase in population and the rapid urbanization has also increased the vulnerability of Thinadhoo to disasters and impacts of climate change. Especially the vulnerable groups including elderly, women, low income households, at risk-children and youth etc. would be more susceptible to such events if proper risk reduction measures are not undertaken. Also the high population density is expected to put more pressure on the land where most part are reclaimed and are not in a good condition to withstand this pressure. The swamp areas have been having the problem of flooding even before 2008 and now the extent has increased as no mitigation measures are undertaken to address this issue.

In case of a disaster event, the economy of the island would also be at risk. The damages caused would be more compared to what was observed during the previous DIRAM study (UNDP, 2008). Main reasons for this are that since 2008, the island still lacks a better drainage system and more trees are cut down making the land more vulnerable to flooding and erosion.

Certain measures that are required to reduce the vulnerability of the island to disasters and impacts of climate change have been proposed in this study. Measures to reduce the identified environmental vulnerabilities include; protecting the western shoreline of the island; protection of the northern side of the island; coastal protection of the south side of the island; creating and maintaining the EPZ; establishing a proper drainage system. Additionally, to reduce the socio economic vulnerability of the island, it is critical to: promote disaster risk reduction and management measures, prepare the communities for possible disaster events and strengthen the emergency response and recovery services. By doing so the community would be more informed and ready for such a disaster event. Also they would be more resilient with a strong economic base and a better environment. A monitoring plan is also proposed to measure the parameters that would be useful in determining the impacts of natural hazards

and climate change events. The plan is designed in such a way that the island council can be actively involved in collecting the data and share it with the relevant authorities of the ministry to mitigate such measures. The cost benefit analysis conducted for the measures proposed and for the scenarios of a single Tsunami event and multiple disaster events in 25 years period showed that there would be a negative net benefit of -45.3 million Rufiyaa and -29.9 million Rufiyaa respectively for the two scenarios. Since the proposed measures are meant for a longer period, for a 25-year span the benefits may be negligible. However, it is expected that these measures would bring benefits in the long run. Also, in case of a flood event the proposed measures are expected to give a net benefit of Rufiyaa 33 million.

Thus it is evident that with proper implementation of the proposed measures, the island could be made highly resilient to natural disasters and impacts of climate change.

9. Limitation of the study & recommendations for futher studies

9.1. Limitations of the study

A number of limitations noted in the previous DIRAM study have been tackled in conducting this assessment, with the aid of a detailed land survey. The digital elevation model generated from these data helped in predicting the hazard event scenarios in a better form. However this study also had some major limitations that constrained the assessments at different levels. These include:

- Lack of recent socioeconomic data limited the socio-economic analysis as all the numbers had to be estimated based on the limited data gained from field surveys.
- Predicting impacts of tsunami/ swell waves requires complex data collected over a longer period of time as well as physical/numerical modelling for a comprehensive analysis. However this is out of scope of the project and is not possible within the short time frame of the project
- The limited time to complete the project and unexpected weather conditions caused significant delay in conducting the study. It also restricted the level of detailed work which was initially planned to be carried out.
- Uncertainties of climate change events especially regarding sea level rise and sea surface temperature restricts the predictions to assumptions which may or may not be realized.

9.2. Recommendations for further studies

Although this study has been successful in assessing the vulnerability of Thinadhoo to the natural disasters to a detailed level there is always room for improvement. There is also room to expand the study in other directions to make it a more comprehensive assessment so as to ensure sustainable outputs which can be generated from the numerous studies. Following are some of the recommended activities that need to be carried out to make this study and the previous studies useful in making the island resilient.

- Identify ways to collect and analyse the available data on coastal process including sediment movement patterns, shoreline changes, currents and waves at different parts of Maldives. Create a database of these data that could be shared for such studies.
- Identify ways to incorporate climate smart planning and Climate Smart Disaster Risk Management Approach (CSDRM) in disaster risk reduction of the island. CSDRM offers ways to “tackle changing disaster risks and uncertainties, enhance adaptive capacity

and address poverty and vulnerability and their structural causes" (*Climate Smart Disaster Risk Management*, 2013)

- Evaluate the best possible ways to improve the livelihoods of the vulnerable groups to make them resilient to climate change and natural disasters.
- Prepare and implement management and monitoring plans for the mitigation and adaptation measures proposed in this study.

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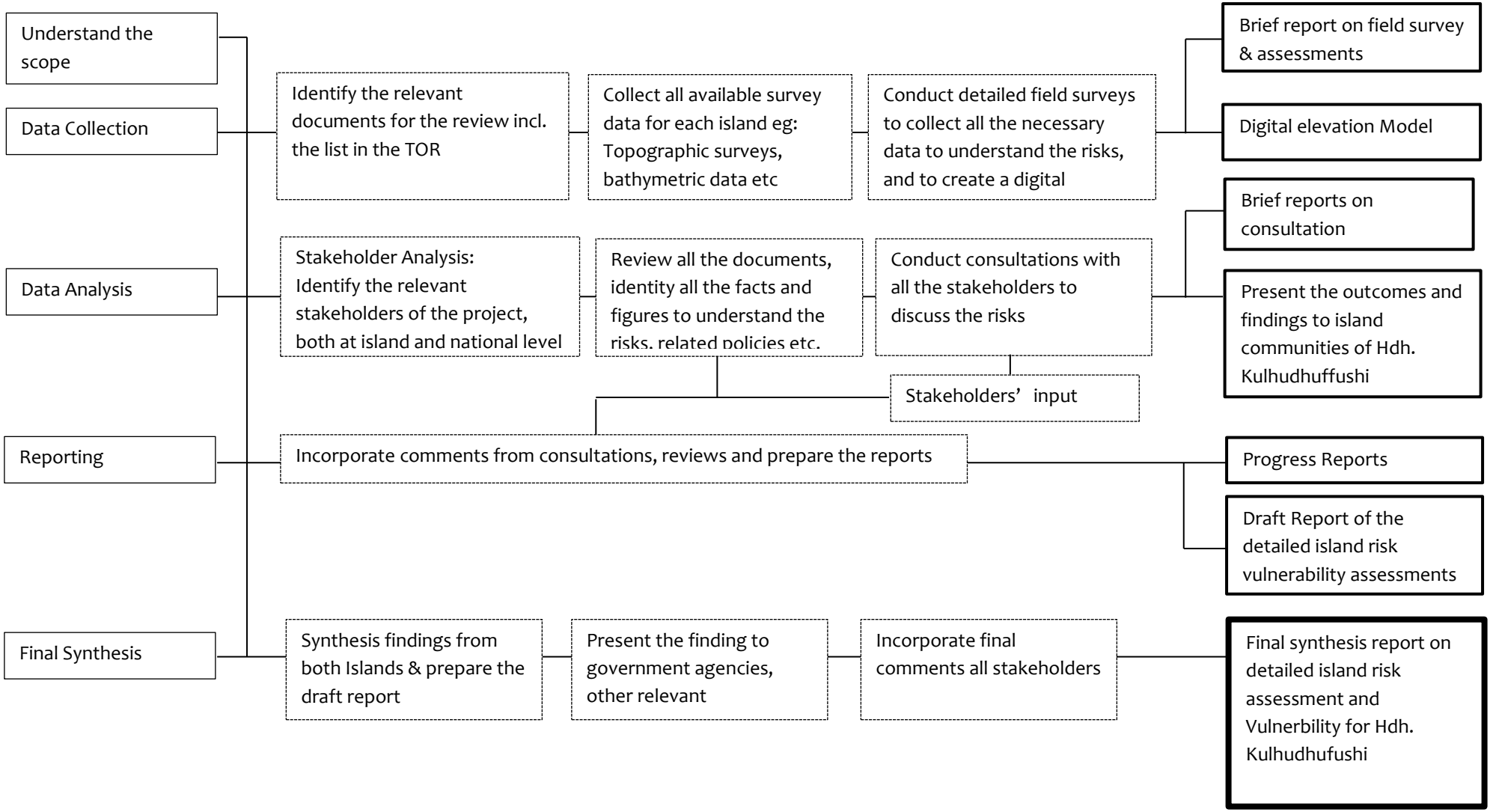
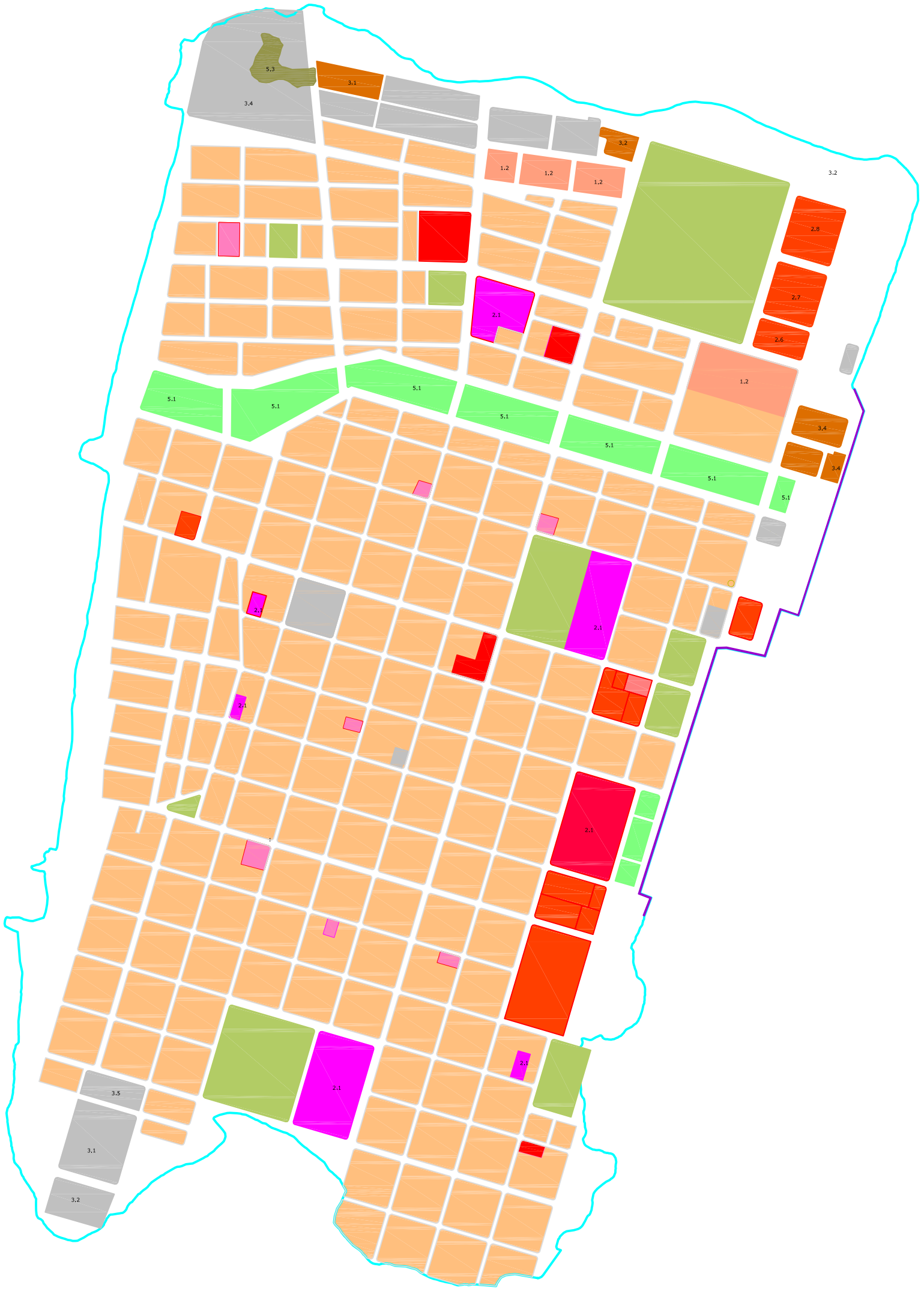
Annexes

Annex I: Methodology Flow Diagram



ANNEX II EXISTING LAND USE OF G.DH THINADHOO



EXISTING LAND USE OF G.DH THINADHOO

Map Legend :

RESIDENTIAL ZONE

- 1.1 HOUSING UNITS/BLOCKS
- 1.2 FLATS/ROW HOUSES

INSTITUTIONAL & COMMUNITY ZONE

- 2.1 SCHOOLS
- 2.2 HOSPITAL
- 2.3 TELECOM INSTITUTIONS
- 2.4 OFFICES
- 2.5 MOSQUES
- 2.6 POLICE STATION
- 2.7 MNDF
- 2.8 OTHER AREAS DESIGNATED FOR INSTITUTIONAL/COMMUNITY ZONES

UTILITY AND MUNICIPLE ZONE

- 3.1 POWER HOUSE
- 3.2 RO PLANT
- 3.4 WASTE SITE
- 3.5 UTILITIES

INDUSTRIAL ZONE

- 3.1 FISH PROCESSING
- 3.2 BOAT BUILDING
- 3.3 ICE PLANT
- 3.4 FISH MARKET

SPORTS AND RECREATION ZONE

- 4.1 FOOTBALL STADIUM
- 4.2 PARKS/ PLAY AREAS
- 4.3 YOUTH CENTER

GREEN AREA

- 5.1 GREEN ZONES/ FLOOD CONTROL ZONES
- 5.3 WETLANDS

HARBOUR AND LOADING AREA

BEACH TOE

NORTH

SCALE 1:1000

0 10 M 20 M 50 M

PROJECT:	REVIEW & UPDATE OF DETAILED ISLAND RISK ASSESSMENT OF GDH. THINADHOO			
TITLE :	EXISTING LAND USES - G.DH.THINADHOO			
CLIENT :	MINISTRY OF ENVIRONMENT AND ENERGY			
SURVEYED BY : MOHAMED SHAKIR		DRAWN BY : MOHAMED SHAKIR	DATE :	DWG No
SCALE : 1:1000		CHECKED : NAME	JUNE 2013	01/01
IF IN DOUBT - ASK - DO NOT SCALE				

riyan Pte.Ltd
3rd FLOOR, [illegible], AMEENEE MAGU
MALE' 20-05, REPUBLIC OF MALDIVES
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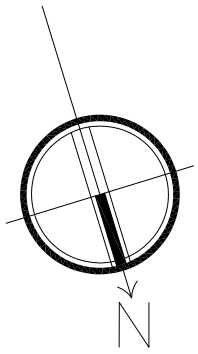
Surveyed on March - May-June 2013



LEGEND

EXISTING LAND USE

- RESIDENTIAL ZONE
- INSTITUTIONAL & COMMUNITY ZONE
  - 1.1–1.3 PRE–SCHOOL
  - 1.4 SCHOOL
  - 2.1 REGIONAL HOSPITAL
  - 2.2 HOSPITAL RESIDENCE
  - 2.3 POLICE STATION
  - 2.4 MNDF
  - 2.5 V.T.C
  - 3.1–3.6 NEIGBOURHOOD MOSQUES
  - 4.1 BLOCK DETAILS
    - –POPULATION CENTER
    - –STELCO OFFICE
    - –ISLAND OFFICE
    - –MEDIA CENTER
  - 4.2 BLOCK DETAILS
    - –CINEMA
    - –YOUTH CENTER
    - –COURT
    - –ATOLL OFFICE
    - –ATHOLHUGE'
    - –ATHOLHUGE' KIT DIN
  - 4.3 BLOCK DETAILS
    - –WOMENS DEVELOPMENT COMMITTE
    - –HOSPITAL EXTENSION
    - –PROPOSED COURT
  - 4.5 BLOCK DETAILS
    - –SWIFT ENGINEERING
    - –STELCO TRANSFORMER
- SPORTS AND RECREATIONAL ZONE
  - 5.1 FOOTBALL PITCH
  - 5.2 OPEN PLAY AREAS
- INDUSTRIAL ZONE
  - 6.1 WORK SHOPS
  - 6.2 BOAT REPAIR & STORAGE
  - 6.3 WAREHOUSES
- UTILITIES AND MUNICIPAL ZONE
  - 7.1 POWER HOUSE
  - 7.2 OLD POWER HOUSE
  - 7.3 DHIRAAGU SITE
  - 7.4 FUEL TANK
  - 7.5 CEMETERY
- COMMERCIAL ZONE
  - 8 SHOPS IN RESIDENTIAL AREA
  - 8.1 FISH MARKET
  - 8.2 ICE PLANT
  - 8.3 SHOPS
  - 8.4 FUEL SERVICE
  - 8.5 S.T.O
  - 8.6 FUEL SUPPLY
- HARBOUR LOADING AREA

PROPOSED LAND USE

- RESIDENTIAL ZONE
- PUBLIC HOUSING UNITS
  - P1–P2 ROW HOUSES
- INSTITUTIONAL & COMMUNITY ZONE
  - 9.1 PRE–SCHOOL
  - 9.2 SCHOOL
  - 9.3 FRIDAY MOSQUE
  - 9.4 NEIGHBOURHOOD MOSQUE
  - 11.1 YOUTH CENTRE
  - 11.2 FERRY STATION
- COMMERCIAL ZONE
  - 13.1 MIXED COMMERCIAL AREA
  - 13.2–13.5 NEIGHBOURHOOD SHOPS/CAFES
  - 13.6 CLINICS
- SPORTS AND RECREATION ZONE
  - 15.1 ZONE STADIUM
  - 15.2 PARKS/ OPEN PLAY AREAS
  - 15.3 PRESENT LAND FILL (FUTURE PLAY AREA)
  - 15.4 FLOOD CONTROLL AREA (GREEN AREA WITH RECREATIONAL ACTIVITIES)
  - 15.5 FUTURE CEMETRY
- INDUSTRIAL ZONE
  - 16.1 WAREHOUSES
- UTILITY & MUNICIPAL ZONE
  - 17.1 WASTE DISPOSAL SITE
  - 17.2 CEMETERY
- ENVIRONMENTAL PROTECTION ZONE (EPZ)
- CONSERVATION ZONE
- RESERVED FOR FUTURE NON RESIDENTIAL USES
  - 23.1 NON RESIDENTIAL AND NON POLUTING ACTIVITIES
  - 23.2 GOV. ADMIN OFFICES
- ALLOCATED PLOTS BUT NOT APPOROVED

PASSENGER TRAFFIC LANDING

MOORING FOR CARGO AND FISHING VESSELS

SITE FOR HOUSING UNITS (Total Area= 82,897.71 sqft)

MINISTRY OF HOUSING AND INFRASTRUCTURE AMEENEE MAGU, MAAFANNU 20392, MALE', REPUBLIC OF MALDIVES TEL: 3004300 FAX: 3004301 email: planning@mhe.gov.mv	**TITLE:** GAAF DHAALU THINADHOO LANDUSE PLAN	**PROJECT:** GDH. THINADHOO PLANNING	**DRAWN BY:** MA **CHECKED BY:** ZS	**SURVEYED BY:** **SCALE:** **DATE:** 13 SEPTEMBER 2012

Parameter A. Shoreline mapping (high tide, low tide and vegetation line)

Table 1: Methodology for shoreline mapping

Methodology	**Sampling frequency**	**Training / equipment requirement**
Mapping of high and low tide using precision GPS (0.5m accuracy) Mapping of Vegetation line using precision GPS (0.5m accuracy)	Once every two months Once every 4 months	• Surveyors at Thinadhoo Island Council or GDh Atoll Council office can do these surveys without further training. • GPS system that has an accuracy of 0.5m is required for these surveys.

Parameter B. Beach profiles

Table 2: Methodology on taking beach profiles

Methodology	Sampling frequency	Training / equipment requirement
i. At least 10 beach profiles around the island need to be recorded. Initially permanent bench marks should be setup around 10 locations (spread around the perimeter of the island). MSL of these benchmarks should be established by connecting the benchmarks via level control survey. ii. Features to be recorded are; inside island ridge, top of ridge, bottom of ridge, edge of vegetation, erosion scarp top, erosion scarp bottom, mid beach, beach toe, beach toe bottom, beach rock start, beach rock top, beach rock bottom and lagoon bottom	Every four months	• Surveyors at atoll or island council does not need additional training • Auto level with barcoded staff will be required to speed up the survey.

Parameter C: In a case of storm surge related flooding/ Tsunami

Table 3: Methodology on taking data on storm surge events

Methodology	**Sampling frequency**	**Training / equipment requirement**
i. In the event of storm surge related flooding, extent of flooding should be recorded using GPS (0.5m accuracy). The can be recorded as points and later on during data processing a line feature should be generated from these points. ii. Height of floodwater should be recorded using a staff. The height can be measured as water level above road level. The location of measurement should be recorded using GPS. Measurement locations should be spread such that measurements are taken at near shore area, central area and at furthest extent of flooding	N/A Should be carried out before water recedes.	• Graduated staff and GPS system (0.5m accuracy)

Table 4: Data collection sheet for storm surge events

Date: dd/mm/yy			
Flooding extent (Distance of water intrusion):			
Road name	**GPS coordinates**		**Remarks**
	Easting	Northing	
Height of floodwater:			
Location	**Height (cm)**	**GPS coordinates**	
		Easting	**Northing**
Near shore area			
Central area			
At furthest extent of flooding			

Parameter C: In an event of Rainwater flooding

Table 5: Methodology on taking data on rainwater flooding

Methodology	Sampling frequency	Training / equipment requirement
i. Baseline locations shall be established using GPS based on the rainwater flooding zonation map generated in this report. At least 10 locations shall be established (5 within worst flooding zones and 5 at moderate flooding zones). ii. During SW monsoon extreme weather events (high precipitation periods), floodwater heights should be measured at the baseline locations. The height of floodwater should be taken from the center of the road using graduated staff.	N/A	• Graduated staff and GPS system (0.5m accuracy)

Table 6: Data collection sheet for flood events

Locations	GPS coordinates		Floodwater heights (cm)
	Northing	Easting	
F1			
F2			
F3			
F4			
F5			
F6			
F7			
F8			
F9			
F10			