(PP)266-SECE/266/2025/13

VOLUME 2

HAZARD, VULNERABILITY, AND CAPACITY ASSESSMENT REPORT

KULHUDHUFFUSHI CITY, MALDIVES

July 2024

Project:

Disaster Management, Hazard Mitigation And
Climate Change Adaptation Plan

Client:

Kulhudhuffushi City Council

Prepared by:

Charrette Studio

Hussain Ziyath
Hassaan Abdul Muhsin
Hassan Akram
Nadhuwa Mohamed
Aishath Ashiya Shathir
Aishath Abdulla
Mohamed Inayath
Zulaikha Shabeen
Mohamed Sameeh
Jinah Shareef
Ahmed Mahudhee
Suhaa Mohamed

Peer reviewed by:
Sonath Abdul Sattar

I. CONTENTS

II. LIST OF ABBREVIATIONS 7

III. DEFINITIONS 8

CHAPTER 1 - PROJECT INTRODUCTION & TIMELINE 16

1.1 CONTEXT AND RATIONALE 19

1.2 METHODOLOGY 22

CHAPTER 2 - ISLAND PROFILE 28

2.1 PHYSICAL ENVIRONMENT 30

2.2 SOCIAL ENVIRONMENT 76

2.3 ECONOMIC ENVIRONMENT 82

2.4 HOUSE CONDITIONS / BUILT ENVIRONMENT 89

2.5 OTHER IMPORTANT ISLAND INFORMATION 92

CHAPTER 3 - RISK ASSESSMENT 100

3.1 HAZARDS 102

3.2 VULNERABILITIES 123

3.3 LOCAL CAPACITY TO RESPOND TO HAZARDS 158

3.4 RISK ASSESSMENT 178

3.5 GAPS IDENTIFIED WITHIN THE STUDY 196

CHAPTER 4 - WAY FORWARD 198

4.1 ENHANCED SURVEILLANCE AND EARLY WARNING SYSTEMS 200

4.2 INVESTMENT IN INFRASTRUCTURE AND RESILIENCE 200

4.4 WASTE MANAGEMENT AND POLLUTION CONTROL 200

4.5 COMMUNITY ENGAGEMENT AND CAPACITY BUILDING 201

4.6 SOCIAL SUPPORT SYSTEMS 201

4.7 ECONOMIC RESILIENCE 201

4.8 INTER-AGENCY COLLABORATION AND COORDINATION 201

4.9 LIMITATIONS 201

4.10 CONCLUSION 202

CHAPTER 5 - REFERENCES 204

CHAPTER 6 - ANNEXURES 208

ANNEX 1 - INSTITUTIONAL AND SOCIAL NETWORK IDENTIFICATION EXERCISE 210

ANNEX 2 - CHILD CONSULTATION PLAN 211

ANNEX 3 - COMMUNITY CAPACITY ASSESSMENT 212

ANNEX 4 - DETAILS OF MATERIAL RESOURCES 213

ANNEX 5 - QRE TOOL RISK MATRIX SCORING DETAILS 219

ANNEX 6 - QRE TOOL OUTPUT 220

II. LIST OF ABBREVIATIONS

HVCA	Hazard, Vulnerability and Capacity Assessment
MCR2030	Making Cities Resilient - 2030
UNDRR	UN Office for Disaster Risk Reduction
QRE Tool	Quick Risk Estimation Tool

III. DEFINITIONS

Acceptable Risk

Or tolerable risk, is the extent to which a disaster risk is deemed acceptable or tolerable.

Adaptation

The passive or active process of acclimatization or acceptance or tolerance of / to a change.

Affected

People who are affected either directly or indirectly by a hazardous event.

Anthropogenic Hazard

Hazards created through the action of human activity.

Berm

A nearly horizontal shore parallel ridge formed on the beach due to the landward transport of the coarsest fraction of the beach material by the wave uprush.

Biological Hazard

Of organic origin or conveyed by biological vectors, including pathogenic microorganisms, toxins, and bioactive substances.

Build Back Better

The use of recovery, rehabilitation and reconstruction phases after a disaster to increase the resilience of nations and communities through integrating disaster risk reduction measures into the restoration of physical infrastructure and societal systems, and into revitalization of livelihoods, economies and the environment.

Building Code

A set of ordinances or regulations and associated standards intended to regulate aspects of the design, construction, materials, alteration and occupancy of structures which are necessary to ensure human safety and welfare, including resistance to collapse and damage.

Capacity

Physical, social, economic and institutional means as well as skilled personal or collective attributes such as leadership and management.

Capacity Building

Efforts aimed to develop human skills or societal infrastructures within a community or organization needed to reduce the level of risk. Capacity building also includes a development of institutional, financial, political, and other resources such as technology at different levels and sectors of the society.

Climate Change

The Intergovernmental Panel on Climate Change (IPCC) defines climate change as: "a change in the state of the climate that can be identified (eg: by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere on in land use."

The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as: "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.

Comprehensive Disaster Management (CDM)

Comprehensive Disaster Management which includes attention to all phases of the Disaster Management Cycle - prevention, mitigation, preparedness and response, recovery and rehabilitation.

Comprehensive Disaster Risk Management (CDRM)

Comprehensive Disaster Risk Management includes attention to all phases of the disaster management cycle with increased emphasis on reducing risk. This nomenclature has been used to replace the term CDM in the Caribbean Strategy and Framework in keeping with the stakeholder view that the term should reflect the global trend in the discipline for increased focus on risk management and the intense desire among disaster management.

Community Resilience

The ability of a community to cope with the effects of hazardous events through appropriate prevention, mitigation, preparedness, response and recovery mechanisms.

Contingency Planning

A management process that analyzes disaster risks and establishes arrangements in advance to enable timely, effective and appropriate responses.

Coping Capacity

The means by which people or organizations use available resources and abilities to face adverse consequences that could lead to a disaster. In general this involves managing resources, both in normal times as well as during crises or adverse conditions.

Corrective Disaster Risk Management

The immediate risk minimization, removal, mitigation, or management of an active hazard or disaster.

Critical Facilities

Elements of the infrastructure that support essential services in a society.

Critical Infrastructure

The physical structures, facilities, networks and other assets which provide services that are essential to the social and economic functioning of a community or society.

Disaster

A serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic, and environmental losses and impacts.

Disaster Loss Database

A set of systematically collected records about disaster occurrence, damages, losses and impacts, compliant with the Sendai Framework for Disaster Risk Reduction 2015-2030 monitoring minimum requirements.

Disaster Risk

The potential loss of life, injury or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity.

Disaster Risk Assessment

A qualitative or quantitative approach to determine the nature and extent of a disaster risk by analyzing potential hazards and evaluating existing conditions of exposure and vulnerability that together could harm people, property, services, livelihoods and the environment on which they depend.

Disaster Risk Management (DRM)

The systematic process of using administrative decisions, organization, operational skills and capacities to implement policies, strategies and coping capacities of the society and communities to lessen the impacts of natural hazards and related environmental and technological disasters.

Disaster Risk Reduction (DRR)

The conceptual framework of elements considered with the possibilities to minimize vulnerabilities and disaster risks throughout a society, to avoid (prevention) or to limit (mitigation and preparedness) the adverse impacts of hazards, within the broader context of sustainable development.

Disaster Risk Reduction Plan

A document prepared by an authority, sector, organization or enterprise that sets out goals and specific objectives for reducing disaster risks together with related actions to accomplish these objectives.

Early Warning

The provision of the means by which people or organizations use available resources and abilities to face adverse consequences that could lead to a disaster. In general, this involves managing resources, both in normal times as well as during crises or adverse conditions.

Emergency Management

The organization and management of resources and responsibilities for addressing all aspects of emergencies, in particular preparedness, response and initial recovery steps.

Emergency Services

The set of specialized agencies that have specific responsibilities and objectives in serving and protecting people and property in emergency situations.

Environmental Degradation

The reduction of the capacity of the environment to meet social and ecological objectives and needs.

Environmental Hazards

Include chemical, natural or biological hazards. Can be created by environmental degradation or physical or chemical pollution in the air, water and soil.

Environmental Impact Assessment

Process by which the environmental consequences of a proposed project or programme are evaluated, undertaken as an integral part of planning and decision-making processes with a view to limiting or reducing the adverse impacts of the project or programme.

Exposure

People, property, system, or other elements present in hazard zones that are thereby subject to potential losses.

Extensive Risk

The widespread risk associated with the exposure of dispersed populations to repeated or persistent hazard conditions of low or moderate intensity, often of a highly localized nature, which can lead to debilitating cumulative disaster impacts.

Forecast

Definite statement or statistical estimate of the likely occurrence of a future event or condition for a specific area.

Geological Hazard

Originate from internal earth processes.

Hazard

A process or phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation.

Hydrometeorological Hazard

Of atmospheric, hydrological, or oceanographic origin.

Intensive Risk

The risk associated with the exposure of large concentrations of people and economic activities to intense hazard events, which can lead to potentially catastrophic disaster impacts involving high mortality and asset loss

Intensive Disaster Risk

The risk of high-severity, mid- to low-frequency disasters, mainly associated with major hazards.

Mitigation

Structural and nonstructural measures undertaken to limit the adverse impact of natural hazards, environmental degradation and technological hazards.

Multi-hazard

1. The selection of multiple major hazards that the country faces

2. Specific contexts where hazardous events may occur simultaneously, cascading, or cumulatively over time, and taking into account the potential interrelated effects.

Natural Hazard

Natural processes or phenomena that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods, and services, social and economic disruption, or environmental damage.

Preparedness

Activities and measures taken in advance to ensure effective response to the impact of hazards, including the issuance of timely and effective early warnings and the temporary evacuation of people and property from threatened locations

Prevention

Activities to provide outright avoidance of the adverse impact of hazards and means to minimize related environmental, technological, and biological disasters.

Prospective Disaster Risk Management

Management activities that address and seek to avoid the development of new or increased disaster risks.

Public Awareness

The extent of common knowledge about disaster risk, the factors that lead to disasters and the actions that can be taken individually and collectively to reduce exposure and vulnerability to hazards.

Recovery

Decisions and actions taken after a disaster with a view to restoring or improving the pre-disaster living conditions of the stricken community, while encouraging and facilitating necessary adjustments to reduce disaster risk.

Relief

Assistance and/or intervention during or after disaster to meet the life preservation and basic subsistence needs. It can be an emergency or protracted duration. (UN DHA)

Response

Actions taken directly before, during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected.

Residual Risk

The disaster risk that remains even when effective disaster risk reduction measures are in place, and for which emergency response and recovery capacities must be maintained.

Resilience

The capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure.

Retrofitting

Reinforcement or upgrading of existing structures to become more resistant and resilient to the damaging effects of hazards.

Risk

The probability of harmful consequences or expected losses (death, injury, property livelihood, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions.

Risk Assessment

A methodology to determine the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend.

Risk Management

The systematic approach and practice of managing uncertainty to minimize potential harm and loss.

Risk Transfer

The process of formally or informally shifting the financial consequences of particular risks from one party to another whereby a household, community, enterprise or state authority will obtain resources from the other party after a disaster occurs, in exchange for ongoing or compensatory social or financial benefits provided to the other party.

Socio-natural Hazard

Associated with a combination of natural and anthropogenic factors including environmental degradation and climate change.

Structural and Non-structural Measures

Structural measures: any physical construction to reduce or avoid possible impacts of hazards, or application of engineering techniques to achieve hazard resistance and resilience in structures or systems;

Non structural measures: any measure not involving physical construction that uses knowledge, practice, or agreement to reduce risk impacts, in particular through policies and laws, public awareness raising, training and education.

Sustainable Development

Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Technological Hazard

From technological or industrial conditions, dangerous procedures, infrastructure failures, or specific human activities.

Toe

The seaward extent of the frontal dune and it begins where the contour of the dune rises up from the landward extent of the ocean beach creating a distinct change in slope or elevation

Vulnerability

The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.

CHAPTER 1 -
PROJECT INTRODUCTION & TIMELINE

Kulhudhuffushi City's aerial imagery
Image credit: MRC team

This document presents the Hazard, Vulnerability, and Capacity Assessment (HVCA) report for the Disaster Management, Hazard Mitigation, and Climate Change Adaptation Plan for Kulhudhuffushi. The project, advertised under the reference number, (IUL)266-PR/266/2023/225, was awarded to the Charrette Studio, by Kulhudhuffushi City Council (KCC), on the 17th January 2023 under the agreement number referenced and registered, (AGR)266-PR/PRIV/2024/4. The document is the main HVCA component for the Disaster Management and Hazard Mitigation plan.

The HVCA conducted for the community of Kulhudhuffushi City offers a comprehensive insight into the risks posed by various hazards, the vulnerabilities inherent within the community, and the existing capacity resources available for disaster management planning. This assessment encompasses a wide range of hazards, including disasters such as storm surges, heatwaves, and tsunamis, as well as social hazards like drug-related crimes, assault, and domestic violence, among others. Through the systematic identification and documentation of assets and capabilities within the community, the HVCA aims to inform future steps in disaster management planning to enhance community resilience and response capabilities.

The data collected through community capacity resource mapping provides a detailed inventory of tangible and intangible resources across multiple domains, including physical infrastructure, human resources, social assets, cultural resources, financial resources, and institutional capacity. These resources, ranging from essential equipment and skilled personnel to social support systems and financial networks, collectively form a robust support network to address diverse needs within the community. By leveraging these assets effectively, stakeholders can strengthen the community's resilience and response capabilities in the face of various hazards.

Furthermore, the HVCA highlights key infrastructural resources related to water supply, electricity, cooking, telecommunication, media, and transportation, providing insights into the existing infrastructure and services available to support disaster management efforts. Through detailed assessments of water production, electricity capacity, cooking fuel usage, and communication networks, stakeholders can identify areas for improvement and investment to enhance the community's preparedness and response to disasters.

In summary, the HVCA for Kulhudhuffushi serves as a valuable tool for identifying risks, vulnerabilities, and capacity resources within the community, laying the foundation for evidence-based disaster management planning. The evidence based disaster management planning is the next step of the project and must be noted that in this deliverable, the only output is the HVCA and not the disaster management (see Figure 3 for the details of the timeline). By prioritizing the findings of this assessment and implementing targeted interventions, stakeholders can work towards building a safer, more resilient community capable of effectively responding to a wide range of hazards and challenges.

1.1 CONTEXT AND RATIONALE

There are various occasions in which the residents living in these Maldivian islands had been subjected to conditions that pushed them to the very limits of survival. Often taken by surprise, the relief action that followed had evolved over time. In recent history 2004, the Tsunami that devastated the archipelago of Maldives is one that sparked a major push for readiness and resilience in the geographically isolated island communities that is Maldives.

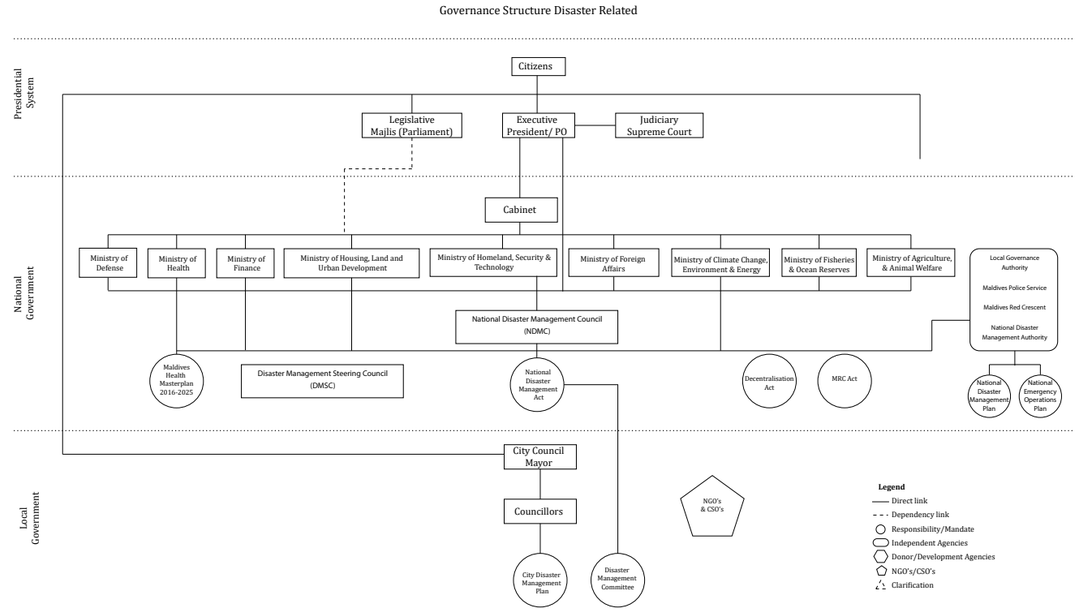


Figure 1. Governance Structure of Maldives for Disaster Management or Disaster Risk Reduction

With the implementation of the Decentralization Act (7/2010) and the Disaster Management Act (28/2015), all local councils are to ensure that the locals are aware of the potential hazards in the island that can cause a disaster, the potential hazard prevention mitigation measures that can be implemented at the local level, the potential climate change adaptation options that are available to each individual island. Thus, creating a resilient island that is ready for action when it comes to managing a disaster. Figure 1 shows the governance structure of Maldives for disaster management or disaster risk reduction. originating from the citizen level. The 3 main tiers of classification are the presidential system, national government, and local government.

The council's responsibilities, as specified in section 35 of the National Disaster Management Act (Law no. 28/2015), encompass mitigating the impact of disasters, providing prompt response to disasters, and developing and executing disaster preparedness strategies. The council is required to include disaster risk management concepts into its initiatives and strengthen the ability of city, atoll,

and island councils to be prepared for disasters and reduce risks. It is crucial to allocate funds for disaster preparedness and risk reduction efforts, as well as to ensure efficient communication and distribution of information on citizen actions during catastrophes, in compliance with the Disaster Management Act and multi-hazard early warning protocols. The council's primary responsibilities include equitably and impartially giving relief and support to citizens impacted by disasters, establishing disaster management committees at different levels, and ensuring that local disaster management plans are in accordance with the national disaster management act and risk reduction plan. It is essential to engage in cooperation with pertinent organizations and institutions in order to effectively manage and reduce the impact of disasters. The council is required to fulfill the obligations assigned by the NDMA in relation to disaster risk assessment and ensure that temporary shelter is provided to affected individuals in a transparent and fair manner, while following the standards set by the NDMA and respecting the rights of citizens.

Currently, in the event of a disaster, Kulhudhuffushi City Council has established an Emergency Operations Center (EOC). This center is operational during various emergencies, including the COVID-19 pandemic and incidents of rainwater flooding. Upon activation, the EOC promptly informs all relevant institutions and stakeholders about the disaster situation, ensuring a coordinated response. The EOC is responsible for identifying all available resources and formulating plans for disaster risk reduction to mitigate the impact of the disaster.

A key player in this collaborative effort is the Maldivian Red Crescent's Kulhudhuffushi branch, recognized as one of the main active stakeholders during disasters. The branch boasts specifically trained staff and volunteers, including a dedicated Emergency Response Team (ERT). This team's expertise and readiness are crucial in supporting the EOC's efforts to manage and reduce disaster risks, ensuring the safety and well-being of the community during times of crisis.

Figure 2. Eastern Beach, shows recession patterns on the eastern side where the smaller and much lighter sand particles are relatively less in comparison to the larger heavier pieces. This is a sign of movement of the smaller particles due to an external force of movement that shifts the sand to a particular direction. The external force can be anything from the tide change and the swell wave energy to the morphological changes brought about on the beach

Kulhudhuffushi City has achieved a considerable milestone by becoming the inaugural municipality in the Maldives to align with the 'Making Cities Resilient 2030 (MCR2030)' initiative, spearheaded by the United Nations Office for Disaster Risk Reduction (UNDRR).

In a proactive move, Kulhudhuffushi City Council is actively exploring ways to enhance disaster risk reduction and climate resilience. The collaborative approach involves forging partnerships with key stakeholders from the public and private sectors, as well as engaging with civil society organizations. This concerted effort signifies a commitment to building a more resilient and sustainable future for Kulhudhuffushi City, reinforcing its dedication to mitigating the impact of disasters and addressing the challenges posed by a changing climate.

The project's rationale is to identify hazards within the island, investigate potential Climate Change Adaptation opportunities, and Disaster Management mitigation potentials and to empower the residents through the Kulhudhuffushi City Council to manage, thrive and adapt to the challenges that the city faces in the years to come.

This HVCA process; where in the hazards, vulnerabilities and capacities of the Kulhudhuffushi City is identified, is the stepping stone to the next process of the project, that is the disaster management process, wherein the community will. Be provided the steps and solutions that the city level managers will have to implement to prepare for the possible, probable or inevitable hazards (Figure 3).

Figure 3. Shows a flooded sandy road of Kulhudhuffushi City

1.2 METHODOLOGY

The following is the methodology on how HVCA was carried out. This methodology serves as a comprehensive approach to assess the risks and strengths within the community, essential for effective disaster management and climate change adaptation.

Central to this methodology is the organization and facilitation of consultation meetings with local experts, authorities, and community representatives. Through collaboration and engagement with key stakeholders, including the KCC focal point, we aim to gather diverse perspectives and insights into the hazards, vulnerabilities, and capacities of the community.

Focused group discussions are instrumental in exploring specific dimensions of hazard, vulnerability, and capacity assessment. Using maps, consultation extract sheets, and stakeholder interviewee reflection sheets, we extract invaluable insights into potential hazards, risks, challenges, solutions, and management strategies. These discussions are tailored to various key groups, including women, disabled persons, migrant workers, the elderly, and youth. Although children were identified as a significant group, logistical constraints prevented us from engaging with them during the consultation period due to school activities. Throughout these sessions, we provided the groups with comprehensive information about the plan and identified hazards, fostering rich discussions that provided crucial perspectives during the inception stage. Furthermore, during the HVCA stage, we ensured the validation of collected and analyzed data with the same groups and relevant institutions, reinforcing the reliability and comprehensiveness of our assessment.

In addition to stakeholder consultations, data collection is carried out through household surveys, online surveys, and assessments, providing a comprehensive understanding of the local context. This includes detailed surveys such as hazard surveys, geomorphological surveys, capacity surveys, and elevation surveys.

A door-to-door household survey was conducted to gather additional insights from the community. Eleven survey enumerators were recruited from Kulhudhuffushi City and underwent a one-day training session to acquaint themselves with the survey protocols and methodologies. To ensure comprehensive coverage, the city was divided into five zones, with two enumerators assigned to each zone, thus facilitating spatial representation during data collection.

The surveys were executed using an online questionnaire developed on Survey123, administered verbally through semi-structured interviews. Enumerators meticulously completed the online forms based on respondents' answers, ensuring precision and consistency in data entry.

The sample size was determined using Raosoft, with parameters configured for a 5% margin of error and a 95% confidence level, derived from a population of 1783 households. Anticipating a response distribution of 50%, the recommended sample size was 317 households. Ultimately, the survey garnered responses from 319 households, meeting the statistical requisites for robust analysis. Among the respondents, 27% identified as male, while 73% identified as female.

Ground check surveys and location check surveys using real time kinematic tools, drone surveys that provide digital elevation models using point cloud data ensure the accuracy and reliability of the collected data (Charrette, 2024a). The detailed report was submitted to the council.

The collected data is rigorously analyzed to derive meaningful insights and findings, identifying the main issues at hand. The layers of data collected are stacked onto a GIS platform and used for analysis. A team of experts utilized the UNDRR Quick Risk Estimation (QRE) Tool to evaluate exposure, vulnerability, and response measures. The tool derives likelihood, severity, and risk levels from input data, which are then depicted on a risk matrix (Table 1). The team of experts involved in this assessment comprised environmental analysts, urban planners, social and legal experts, and disaster consultants.

Table 1. Quick Risk Estimation (QRE) Tool, the definitions, the components being explored and the scale rating for the project

	Exposure	Vulnerability	Current Actions/ Measures Taken
Definition (UNISDR, 2009)	The extent to which people, property, assets, systems or other elements are present in the hazard zones that are thereby susceptible to losses	Characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard	Activities and measures to avoid and/or address existing and new disaster risks.
Components		Infrastructure (roads, harbor, airport, houses) Productive Sectors: Livelihood/job market Essential or Basic Services: health, telecom, water, energy Human and Social Aspects: displacement, safety, etc.	
Rating Scale	0: Negligible 1: Extremely unlikely 2: Very unlikely 3: Unlikely 4: Improbable 5: Possible 6: Probable 7: Likely 8: Very likely 9: Extremely likely 10: Inevitable	0: Negligible 1: Extremely unlikely 2: Very unlikely 3: Unlikely 4: Improbable 5: Possible 6: Probable 7: Likely 8: Very likely 9: Extremely likely 10: Inevitable	0: No measures in place 1: Extremely few measures in place 2: Very few measures in place 3: Few measures in place 4: Some measures in place 5: Reasonable measures in place 6: Good measures in place 7: High measures in place 8: Extremely high measures in place 9: Immense measures in place 10: Complete control of disaster

A validation workshop was organized separately for the institutions and community members in Kulhudhuffushi and the Disaster related key stakeholders in Male' (Figure 4). During this session, the findings were presented and deliberated upon. The QRE tool was also employed in the session for institutions, and a comparative analysis of results obtained by experts and locals was conducted. Subsequently, values were re-evaluated based on the outcomes of these discussions.

Through reference to the local context and possibilities, the HVCA report is developed, presenting a clear picture of the community's resilience and vulnerabilities. This report serves as a vital tool in guiding the development of strategies and interventions to enhance disaster resilience and climate change adaptation within the KCC region.

By following this methodology, we aim to empower the community and stakeholders with the knowledge and tools necessary to mitigate risks, build resilience, and adapt to the changing climate landscape effectively. The following table summarizes the process (Figure 5).

Figure 4. Validation Workshops in Kulhudhuffushi City and Male' City

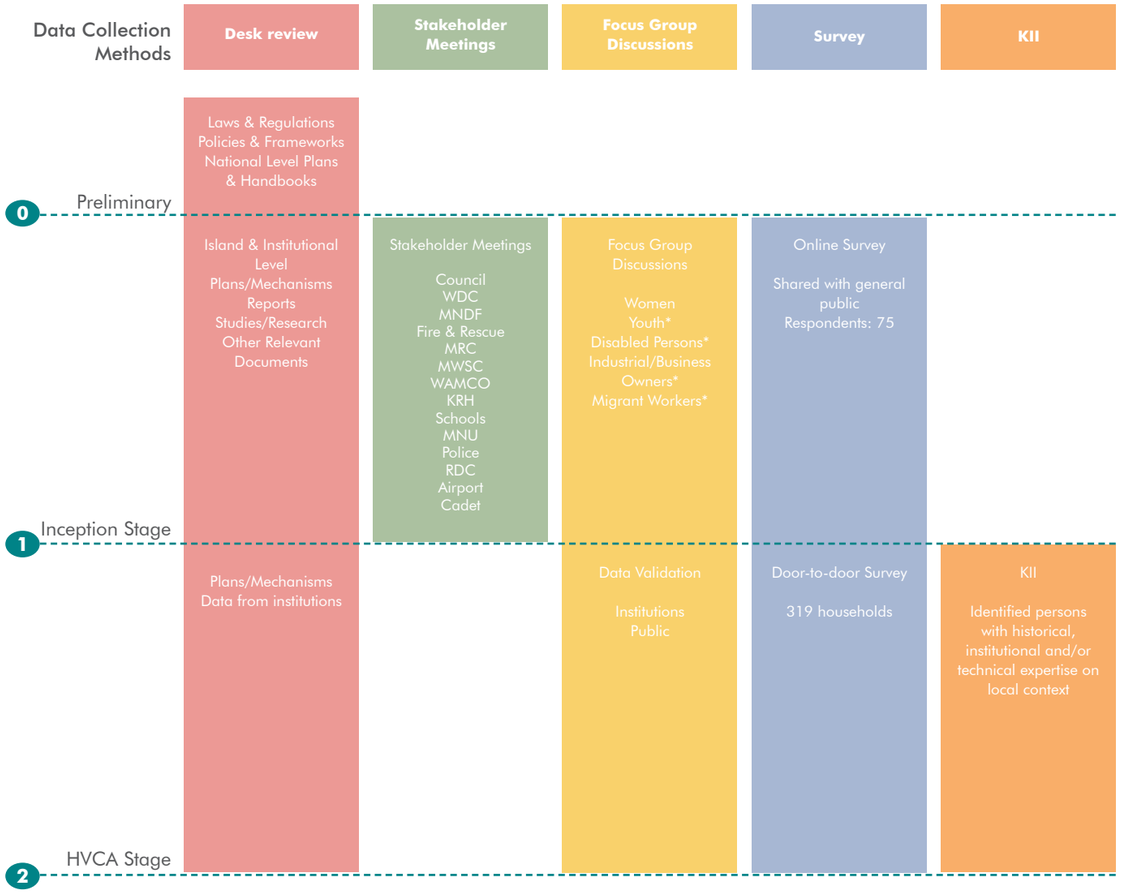


Figure 5. Summary of Data Collection Process

1.2.1 JUSTIFICATION OF THE METHODOLOGY AND TOOLS USED

For the recreation of the project, to re-evaluate the baseline and for the monitors to find and establish parallels in case the tools are not available during the timeline, the following (Table 2) are the details of the tools, the references for the tools and the justification of the tools used.

Table 2. Methodology & Tools Used and justification of the selection for recreation of the methodology

Components	Tools	Justification for use	Reference
Photography	Handheld devices	Good quality pictures at a reasonable price.	
Drone imagery, point cloud format and GeoTiff	Digital elevation Model	Detailed geo referenced image,	DJI models
Image stitching software	Pix4D	To stitch images and generate models	https://www.pix4d.com/
Geo survey	CHCNAV RTK GPS	Used for its pin-point accuracy and easy turnover to the GIS platform.	
Location Survey	CHCNAV Handheld GPS.	Used for its pin-point accuracy and easy turnover to the GIS platform.	
Stakeholder consultation	Participatory mapping. Modified SWOT exercises, Participatory organization mapping.	The community and the local council are aware of the connections and will ensure the rapid description of the organizational connections better than an external party.	
Social survey tool	Survey123	This tool provides a complete platform for the surveyors to modify the stakeholder forms and generate user friendly usable forms for quick surveys that require a minimal internet connection.	https://survey123.arcgis.com/
Mapping exercise	Esri ArcGIS	Complementary to the Survey123 platform. This can be used to show both geological, social, and environmental maps on one platform.	https://experience.arcgis.com/
Modeling	QGIS & ArcGIS	Open-source and commercial tools that are extensively used for mapping and analysis of hazards. Data such as high resolution digital elevation models can be used with qualitative and quantitative data.	www.qgis.com www.arcgis.com
Risk assessment	UNDRR QRE tool	A recommended, proven, and established tool that the team can use to calculate the risk.	https://mcr2030.undrr.org/quick-risk-estimation-tool

CHAPTER 2 -
ISLAND PROFILE

The following chapter provides the island's profile. The profile describes the geology, climate, demography, the economic livelihood, housing conditions of the built environment, and the institutional and social networks within the island.

Kulhudhuffushi City's aerial imagery
Image credit: MRC team

2.1 PHYSICAL ENVIRONMENT

2.1.1 LOCATION

Kulhudhuffushi, (Figure 6) is a significant island in the northern part of the Maldives. The island is recognized for its substantial size and population. Serving as the administrative capital of the South Thiladhunmathi or Haa Dhaalu (H.Dh) Atoll. Kulhudhuffushi has its own airport, port and harbour facilitating transportation through domestic flights and sea transport.

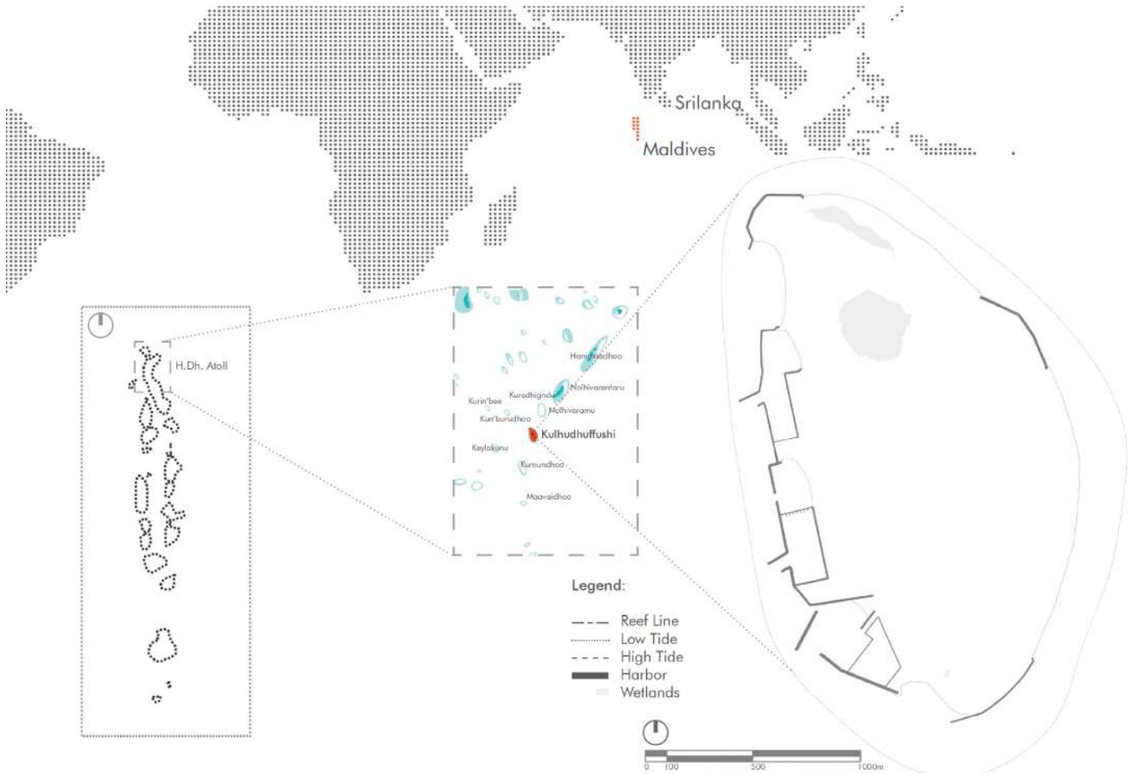


Figure 6. The northern hub of the Maldives, Kulhudhuffushi. General information: Location: 6° 37′ 21.04′ N, 73° 4′ 12.9″ E, Land Area: 199.6 Ha, Urbanised Area: 97.6 Ha, Distance from Male': 278 km, and Distance from the closest resort: 25 km.

Figure 7. Kulhudhuffushi City over the years. From the 1970s to the 2010s

Kulhudhuffushi exhibited distinct changes in its landscape from the 1970s to the 2010s, as evidenced by historical imagery (Figure 7). In the 1970s, the island portrayed a verdant environment with abundant vegetation, highlighting its pristine natural state. The expansive wetlands surrounding Kulhudhuffushi were integral to its ecological balance during this period, fostering biodiversity and enhancing the island's aesthetic appeal. However, in the 2010s, significant alterations occurred with extensive reclamation projects diminishing the original size of wetlands. The transformation of Kulhudhuffushi's landscape was further characterized by urban sprawl, reflecting the consequences of human settlement and infrastructure development over time. Of particular significance was the impact of airport development, which not only changed the island's accessibility but also influenced land use patterns. The imagery capturing these changes serves as a documentation of the complex interplay between human activities and the natural environment, illustrating the evolving dynamics of Kulhudhuffushi's landscape throughout its history.

2.1.2 CLIMATE

The Republic of Maldives is an archipelago of small islands that lie no higher than 1.5m above sea level and experience a tropical climate, with a relatively constant annual mean temperature of 28°C (varying from 31°C in daytime to 23°C in nighttime) (Stojanov et al. 2017; MMS 2020). The weather is dominated by two monsoon periods, the southwest monsoon from May to November and the north-east monsoon from January to March. The south-west monsoon system is controlled by continental scale circulations during which moisture is transported from the Arabian Sea to the Bay of Bengal (UNDP 2013). For the rest of the year, the process is reversed, with low activity between February and May (UNDP 2013). This produces a slightly longer rainfall season over the southern Maldives.

The average annual rainfall for the Maldives is 2,124mm; however, this rainfall varies regionally. While temperatures remain relatively stable, the occurrence of rainfall varies depending on the monsoon seasons. The distribution of rainfall fluctuates throughout the year and across different latitudes within the Maldives (Moosa 2014). Weather and climate data point closest to Kulhudhuffushi is from the weather station located in Hanimaadhoo.

The Maldives is expected to receive a higher amount of rainfall compared to its southern region, with variations dependent on the season. The wettest months, namely June, July, and August, will continue to experience elevated rainfall, predominantly concentrated in the northern areas. There may be slight fluctuations in the region receiving 4–8 mm/day of rainfall, according to projections.

The annual projections (Figure 8) shows an expansion of the precipitation zone from 2011 to 2050.

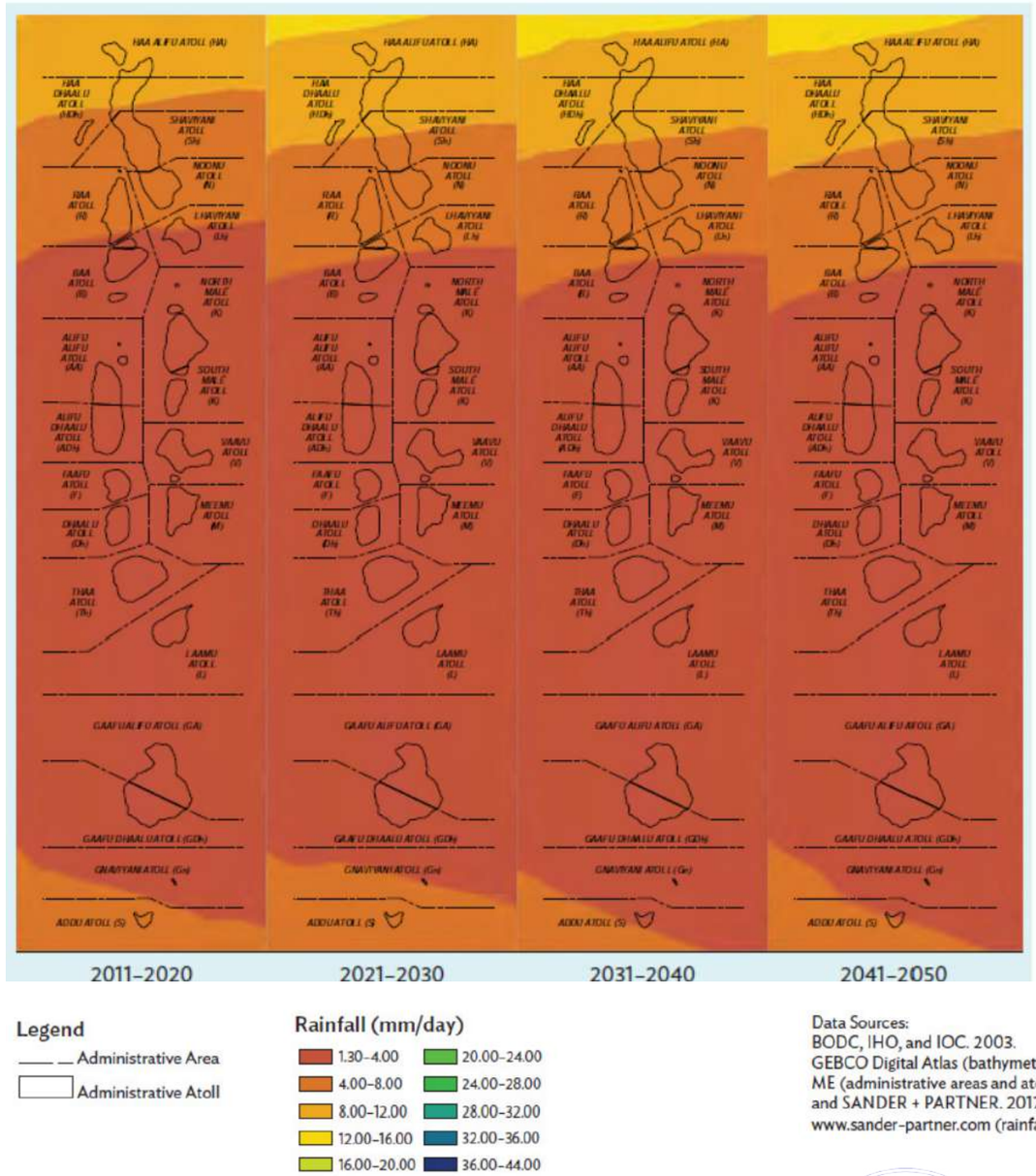


Figure 8. Average Annual Rainfall Projection Multi-Hazard Atlas (ADB,2020)

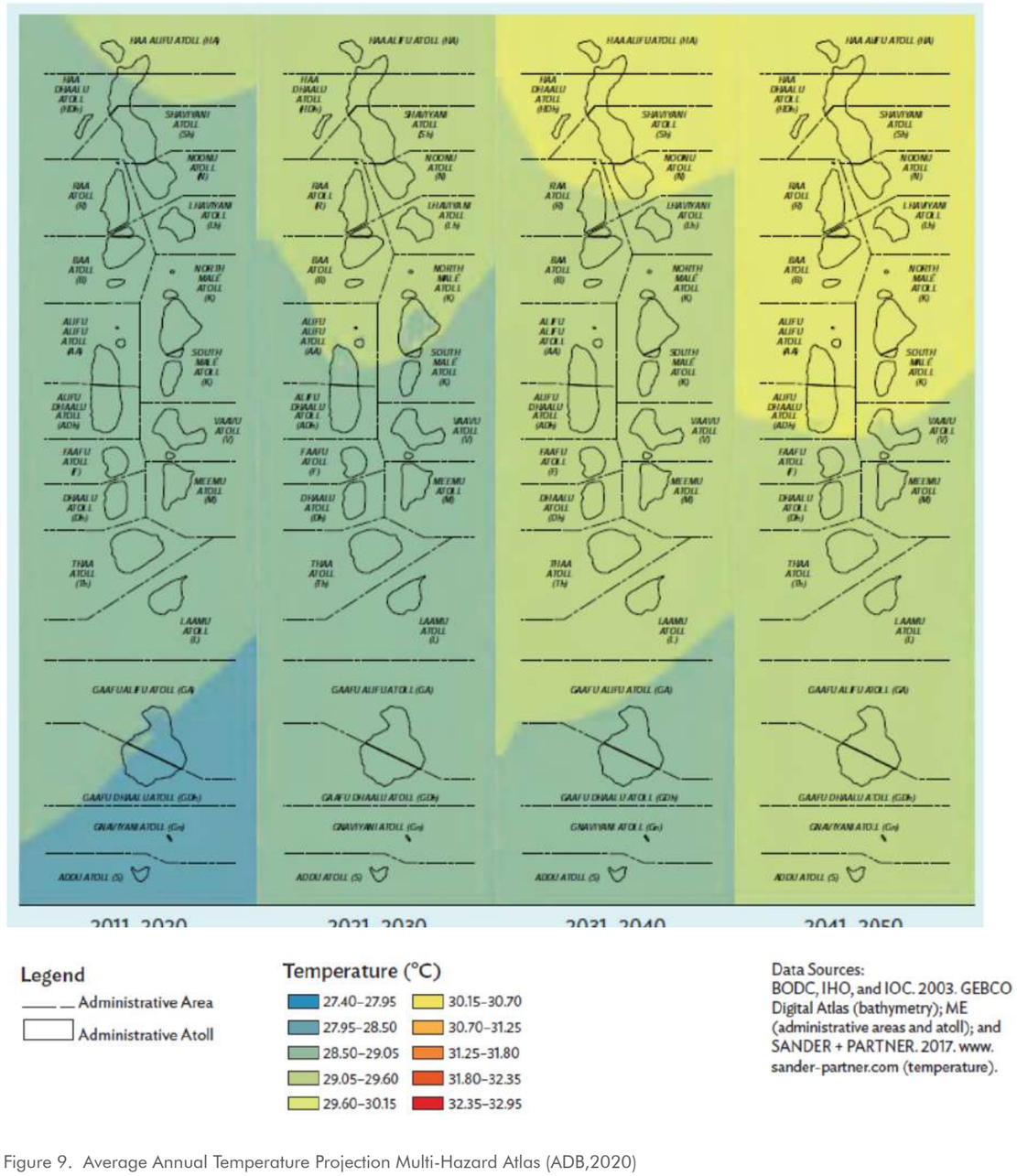


Figure 9. Average Annual Temperature Projection Multi-Hazard Atlas (ADB,2020)

The Maldives is anticipated to undergo a temperature increase in the 2030s and 2040s, with more pronounced warming expected in the northern atolls, particularly during March, April, and May. This consistent pattern is projected to persist across various seasons and decades (Figure 8 and Figure 9).

The Maldives has faced various disasters in its history. According to a 2006 United Nations Development Program (UNDP) report analyzing cyclone tracks over the century, the country encountered 11 cyclones in 12 decades, with the most powerful ones affecting the northern atolls (UNDP 2006). While cyclones are not frequent, when they occur, they bring wind, rain, and storm surges to the low-lying islands, leading to recurrent flooding, often caused by surges. In 1987, for example, "bodu raalhu" or big waves flooded some islands, particularly impacting the northeastern islands (UNDP 2006).

Apart from cyclones, Maldives is susceptible to earthquakes and tsunamis. Over a 25-year span, three earthquakes with a magnitude of at least 7.0 struck the Maldives (UNDP 2006). The report also assessed the decay of peak ground acceleration for a 475-year return period, identifying the southern Gnaviyani Atoll and Addu Atoll as having the highest peak ground acceleration. Earthquakes, often generated at subduction zones along tectonic plate edges, can lead to tsunamis.

The most devastating disaster in recent history was the tsunami on December 26, 2004, which generated waves up to 4.2 meters. This event damaged numerous inhabited islands, thousands of homes, affected countless lives, and caused a significant economic setback, with approximately two-thirds of the country's gross domestic product lost (UNDP 2006). According to the UNDP model, the eastern borders of atolls have a higher probability of experiencing tsunamis ranging from 320 to 450 centimeters in height. Kulhudhuffushi is exposed to the same climate hazards as the rest of the Maldives and the impacts are evident on the ground.

2.1.3 MONSOON

The Maldives experiences a typical tropical monsoon climate throughout the year, characterized by two distinct monsoon seasons: the south-west monsoon and the north-east monsoon. Kulhudhuffushi being in the northern tip of Maldives is under the same cycle.

The south-west monsoon occurs between mid-May to November, bringing with it higher levels of rainfall. Conversely, the north-east monsoon occurs between January to March and is generally drier compared to the south-west monsoon. Transition periods between these monsoon seasons occur between March and April for the south-west monsoon and between October and November for the north-east monsoon (Table 3).

During these monsoon seasons and transition periods, the temperature in the Maldives ranges from 27°C to 31°C daily. The maximum mean dry temperature is around 30.4°C, while the minimum mean dry temperature is approximately 25.7°C.

Rainfall patterns in the Maldives are influenced by the Indian Ocean monsoons. On average, the Maldives receives around 2,124 mm of rainfall annually, with the southern regions generally experiencing more rainfall than the northern regions.

Table 3. Monsoon Calendar of Maldives with the Dhivehi name for the monsoon classification

Season	Dhivehi name	Month
NE-Monsoon	Iruvai	December
NE-Monsoon	Iruvai	January
NE-Monsoon	Iruvai	February
Transition period 1	Hulhangu Halha	March
Transition period 1	Hulhangu Halha	April
SW-Monsoon	Hulhangu	May
SW-Monsoon	Hulhangu	June
SW-Monsoon	Hulhangu	July
SW-Monsoon	Hulhangu	August
SW-Monsoon	Hulhangu	September
Transition period 2	Iruvai Halha	October
Transition period 2	Iruvai Halha	November

These seasonal variations in temperature and rainfall contribute to the unique climate and ecosystem of the Maldives, playing a crucial role in shaping life on the islands.

A plant in bloom at Kulhudhuffushi City
Image credit: Charrette team

2.1.4 HUMIDITY

Figure shows the monthly mean for Hanimaadhoo, extracted from MET 2024 data. The mean shows the annual trend of lower humidity in the NE monsoon and transition period, and a higher humidity in the SE monsoon and transition period.

In the northeast monsoon, December's values fluctuate between 68 and 84, showing some variability but generally lower than earlier months. In January the mean humidity percentages range from 69 to 82, showing some variability across the years. In February, the values fluctuate between 72 and 81, indicating moderate variability.

In the transition session 1, March shows the mean humidity levels vary from 72 to 82, with some fluctuations but generally higher than February. In April the mean humidity percentages range from 74 to 82, with relatively consistent values over the years.

In the southwest monsoon, the humidity in May ranges from 73 to 83, with some variability but generally stable. In June the humidity levels vary from 73 to 85, showing some fluctuations but generally higher than earlier months. In July the mean humidity percentages range from 73 to 84, with some variability but generally high values. In August the mean humidity fluctuated between 74 and 85, showing moderate variability but generally high humidity. In September the humidity levels range from 73 to 85, with some variability but generally high values.

In the transition session 2, in October the mean humidity values range from 75 to 84, showing moderate variability but generally high humidity. In November, the mean humidity levels ranged between 68 and 84, showing some variability but generally lower than earlier months.

July consistently exhibits the highest mean humidity levels, with values often reaching 80% or above. This suggests that July tends to be the most humid month throughout the dataset. On the other hand, December consistently shows the lowest mean humidity levels, frequently falling below 75%. This indicates that December tends to be the driest month in terms of humidity. Furthermore, there are fluctuations within each month across different years, highlighting the variability in humidity levels from year to year. For instance, while July generally has high humidity, there are instances of lower humidity levels in certain years compared to others. Similarly, December, despite being consistently dry, still shows variations in humidity levels across different years.

The humidity is a factor that elevates the felt heat within in a landmass. With an island like Kulhudhuffushi, the built up being the most reflective surfaces, the high humidity will further increase the heat felt within, the city.

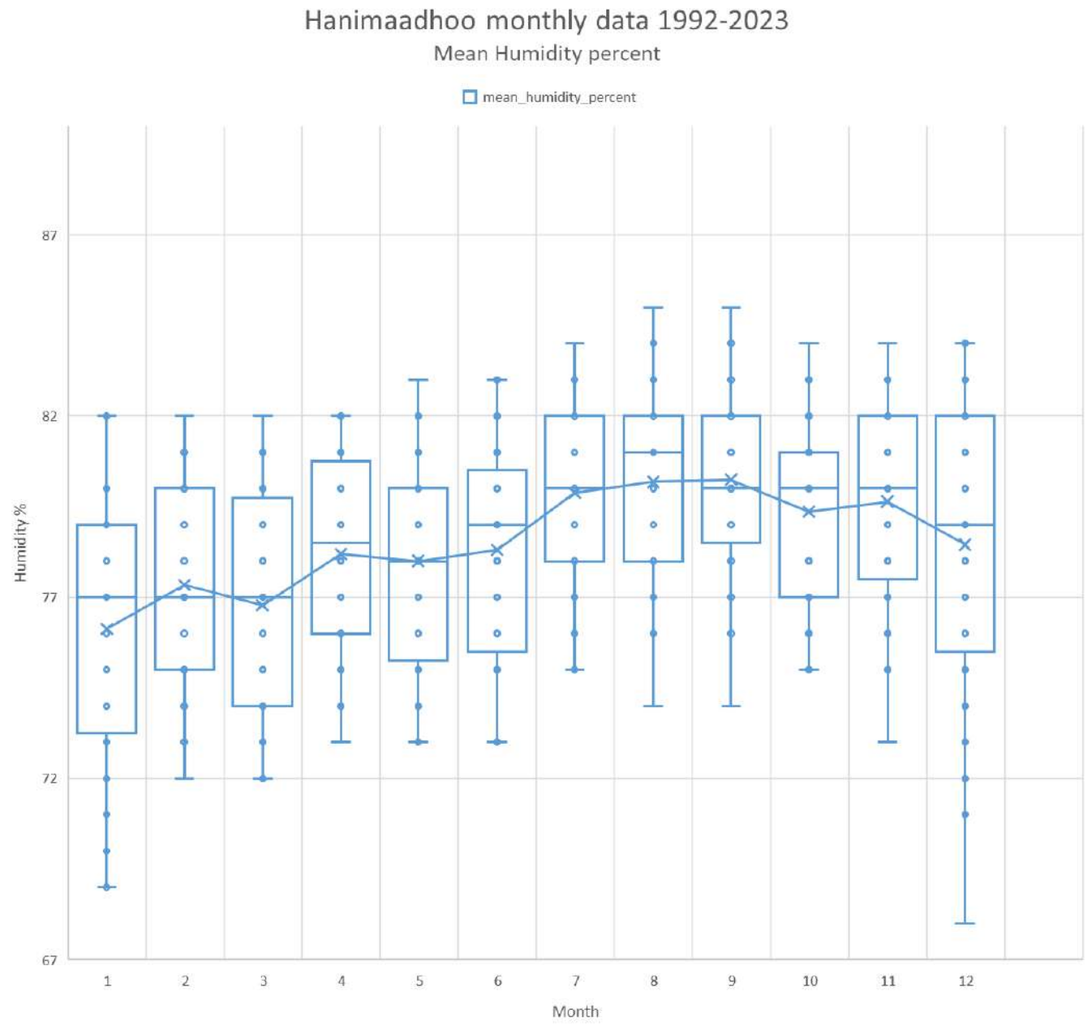


Figure 10. Monthly Mean Humidity Percentage

2.1.5 RAINFALL

Figure 11 above shows the rainfall data, extracted from MET 2024, the outliers show extreme events that are out of the average. The pattern follows the monsoon rain pattern.

Figure 12 shows the annual mean rainfall from 1992 to 2023. In the North east monsoon, December shows varying levels of rainfall, with some years experiencing substantial precipitation, such as 1992 (340.9 mm) and 2021 (441.5 mm), while others have minimal rainfall amounts, like 2013 (9.3 mm) and 2014 (26.5 mm). January shows a wide range of rainfall values, with some years experiencing significant rainfall amounts, such as 1992 (423.7 mm) and 2005 (497 mm), while others have minimal or no rainfall, like 1999 (0 mm) and 2012 (0 mm). February also displays variations, with notable rainfall events in certain years, such as 1995 (314.6 mm) and 2001 (372.7 mm), contrasting with drier periods like 2017 (0 mm) and 2018 (27 mm).

In the Transition period 1, March exhibits similar variability, with some years recording substantial rainfall, such as 2011 (541 mm) and 2018 (368.3 mm), while others have minimal precipitation, like 2022 (5.6 mm) and 2023 (321 mm). April generally shows a mix of moderate to high rainfall amounts, with notable years like 1994 (474.2 mm) and 2019 (333.2 mm) alongside drier periods like 2012 (26.5 mm) and 2022 (110.6 mm).

In the south west monsoon, May typically experiences diverse rainfall levels, with significant events in certain years like 2008 (438.1 mm) and 2021 (408.7 mm), but minimal precipitation in others like 2014 (1.8 mm) and 2015 (4.3 mm). June often sees varying amounts of rainfall, with notable years like 1991 (483.5 mm) and 2014 (303.3 mm) alongside drier periods like 2019 (0 mm) and 2023 (353.2 mm). July exhibits a mix of rainfall patterns, with some years recording substantial amounts, such as 1993 (253.6 mm) and 2003 (389.1 mm), while others have minimal precipitation, like 2019 (234.4 mm) and 2022 (6.9 mm). August typically shows diverse rainfall levels, with significant events in certain years like 1993 (511.7 mm) and 2021 (500.3 mm), but minimal precipitation in others like 2002 (1.3 mm) and 2018 (111.4 mm). September generally displays varied rainfall amounts, with notable years like 1998 (321.1 mm) and 2010 (353.3 mm) alongside drier periods like 2019 (337.5 mm) and 2020 (81.5 mm).

In the transition period 2, October shows fluctuating precipitation levels, with some years experiencing significant rainfall, such as 1998 (410.3 mm) and 2010 (519.4 mm), while others have minimal or no rainfall, like 1994 (0 mm) and 2019 (0 mm). November typically exhibits diverse rainfall patterns, with significant events in certain years like 2013 (419 mm) and 2015 (426.1 mm), but minimal precipitation in others like 2010 (4.9 mm) and 2022 (14.9 mm).

In Kulhudhuffushi, the rainfall data shows the volume that will have to be delt with in case of a surface flow out or accumulation. The collected water is an indicator of the water that will have to be delt with during the flow off.

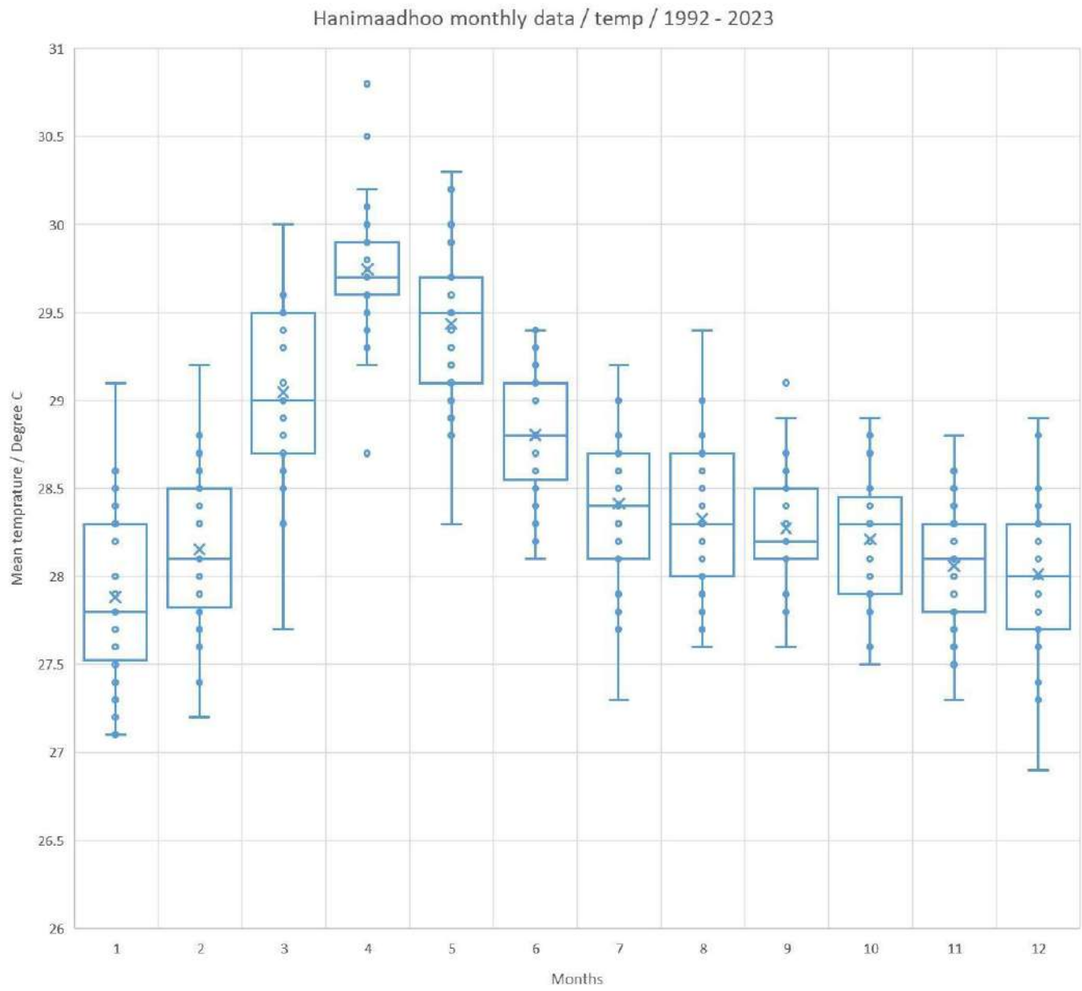


Figure 11. Monthly Mean Rainfall (mm)

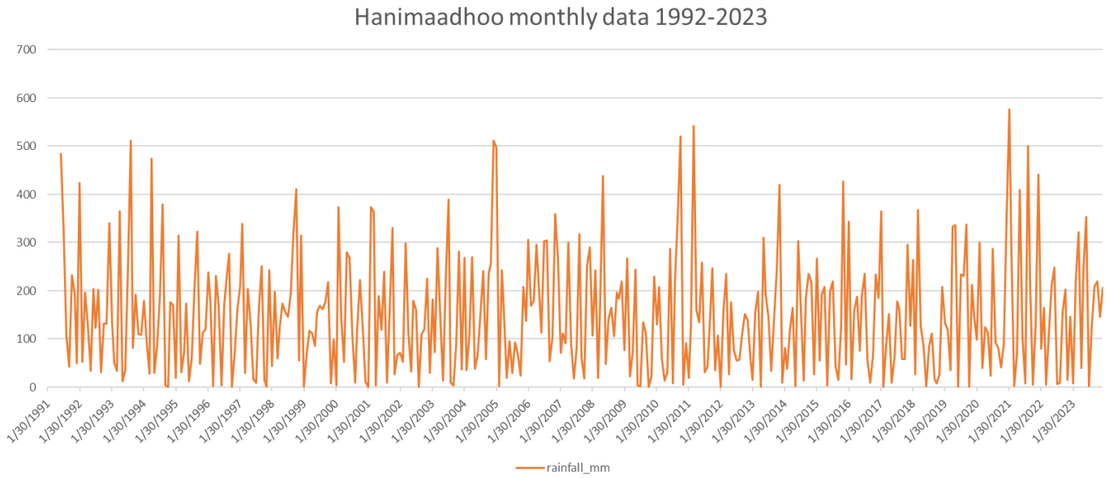


Figure 12. Annual Mean Rainfall, the y axis shows the rainfall collected in mm. The x axis shows the year of the record.

The High-Resolution Digital Elevation Models in the ArcGIS Platform were used to generate flood maps due to rain. Increments of flood depth were added to the model to show patterns of flooding due to rain. The flood pattern simulated (Figure 13) shows the flood pattern for the island flood pattern of the island laid over on a DEM. The lowest elevation areas are shown filled with the maximum rainfall recorded to show the pattern of accumulation assuming there is no drainage. Further details are presented in the relevant sections

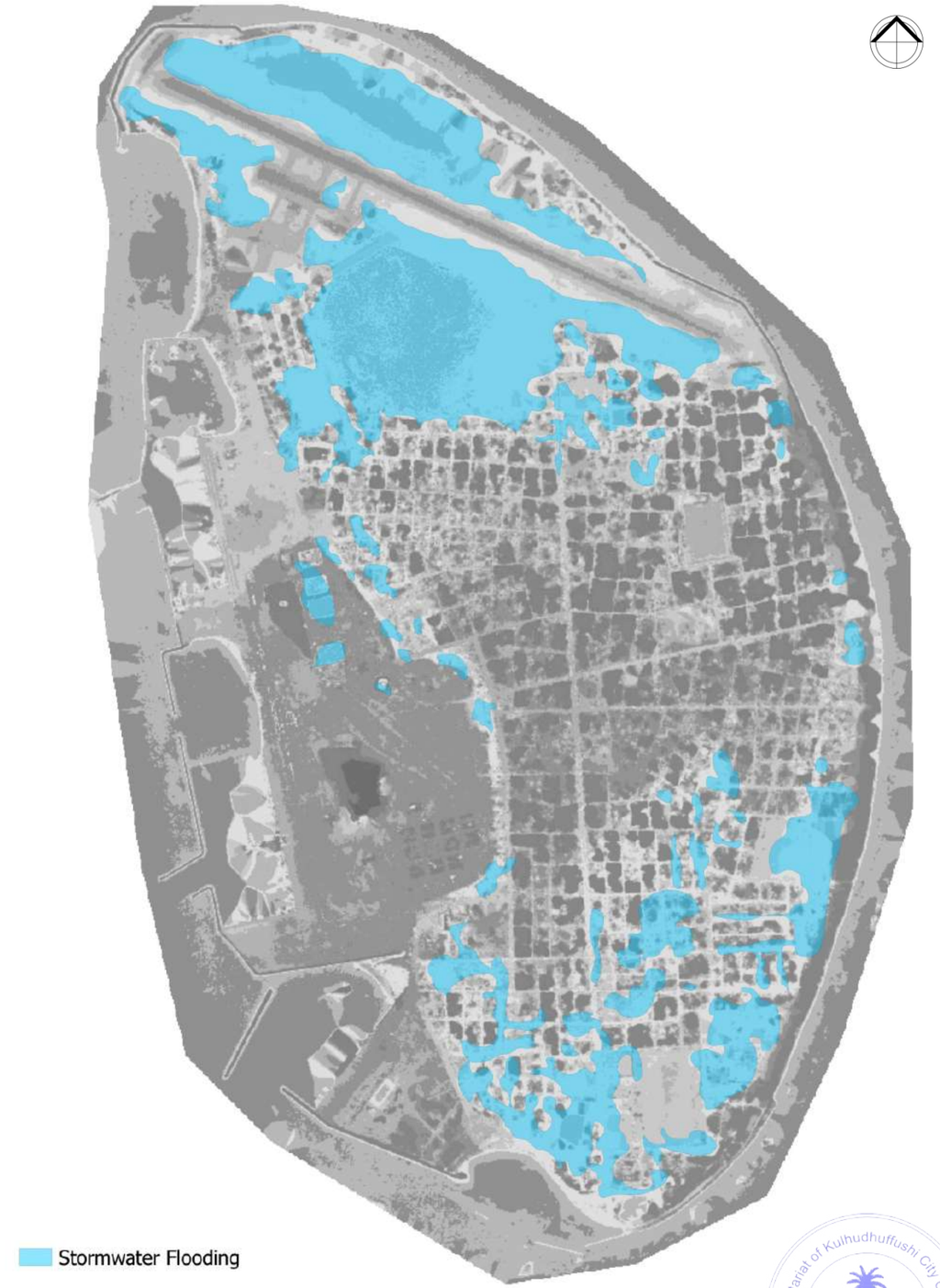


Figure 13. General pattern of flood propagation due to topography

2.1.6 WIND SPEED

In the Northeast monsoon, December shows varying levels of wind speed, with some years experiencing substantial speeds, such as 1992 (40 kts) and 2021 (36 kts), while others have minimal wind speeds, like 2013 (24 kts) and 2014 (28 kts). January shows a wide range of wind speed values, with some years experiencing significant speeds, such as 1992 (76 kts) and 2005 (40 kts), while others have minimal or moderate speeds, like 2012 (18 kts) and 2022 (26 kts). February also displays variations, with notable wind speeds in certain years, such as 1996 (43 kts) and 2021 (40 kts), contrasting with calmer periods like 1999 (29 kts) and 2019 (34 kts).

In the Transition period 1, March exhibits similar variability, with some years recording substantial wind speeds, such as 2012 (48 kts) and 2013 (47 kts), while others have minimal speeds, like 2019 (21 kts) and 2020 (27 kts). April generally shows a mix of moderate to high wind speeds, with notable years like 1992 (39 kts) and 2019 (38 kts) alongside calmer periods like 2012 (22 kts) and 2023 (22 kts).

In the south west monsoon, May typically experiences diverse wind speed levels, with significant events in certain years like 2019 (48 kts) and 2021 (40 kts), but minimal speeds in others like 1994 (25 kts) and 2015 (18 kts). June often sees varying amounts of wind speed, with notable years like 1991 (36 kts) and 2014 (31 kts) alongside calmer periods like 2019 (21 kts) and 2022 (40 kts). July exhibits a mix of wind speed patterns, with some years recording substantial amounts, such as 1992 (43 kts) and 2003 (49 kts), while others have minimal speeds, like 2019 (32 kts) and 2022 (23 kts). August typically shows diverse wind speed levels, with significant events in certain years like 1993 (49 kts) and 2021 (26 kts), but minimal speeds in others like 2002 (22 kts) and 2018 (42 kts). September generally displays varied wind speed amounts, with notable years like 1998 (42 kts) and 2012 (24 kts) alongside calmer periods like 2019 (37 kts) and 2020 (34 kts).

In transition period 2, October shows fluctuating wind speed levels, with some years experiencing significant speeds, such as 2010 (37 kts) and 2012 (27 kts), while others have minimal or moderate speeds, like 1994 (19 kts) and 2019 (19 kts). November typically exhibits diverse wind speed patterns, with significant events in certain years like 2011 (49 kts) and 2017 (43 kts), but minimal speeds in others like 2019 (26 kts) and 2022 (20 kts).

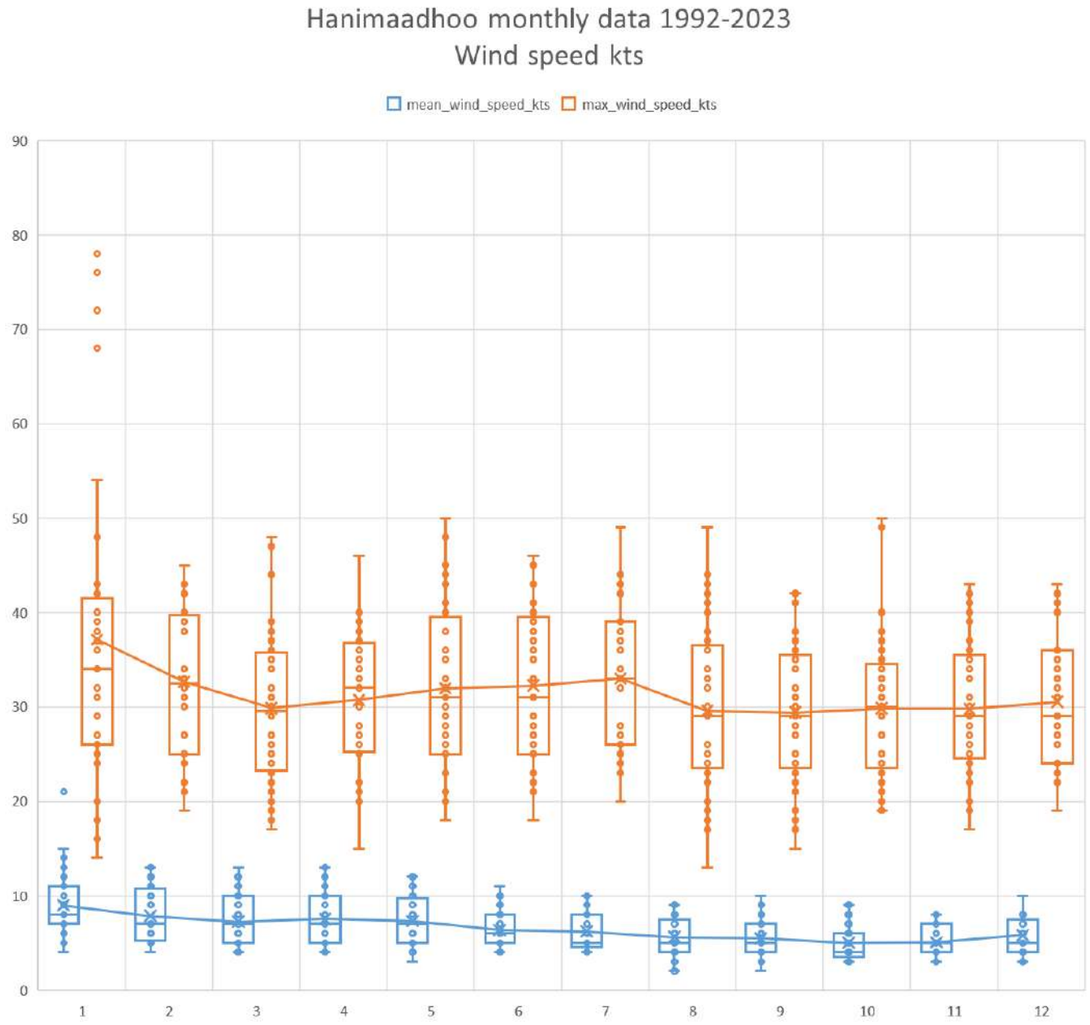


Figure 14. Monthly Mean Wind Speed

2.1.7 WIND DIRECTION

During December, which falls under the Northeast Monsoon period, wind patterns vary . The predominant wind direction is primarily westward (W), with some instances of north-northwest (NNW) and variable (VRB) directions. Wind speeds average around 10.8 knots during this period, with maximum speeds reaching up to 78 knots in certain years.

In March, a transition period, we continue to observe variability in wind patterns. The predominant wind direction is variable (VRB), with some instances of westward (W) and east-northeast (ENE) directions. Mean wind speeds remain relatively consistent at approximately 9.2 knots during March.

May, characterized by the Southwest Monsoon, displays diverse wind patterns. The prevailing wind direction shifts to west-northwest (WNW), with some occurrences of east-northeast (ENE) and north (N) directions. Wind speeds maintain an average of around 10.2 knots during this period.

October, marking the second transition period, exhibits fluctuating wind patterns. The predominant wind direction during this time is westward (W) and variable (VRB), with some instances of west-northwest (WNW) and north (N) directions. Mean wind speeds remain consistent at approximately 7.9 knots in October.

A forest area of Kulhudhuffushi City
Image credit: Charrette team

2.1.8 AIR QUALITY

The air quality standards for pm 2.5 are 25 ug/m3, 37.5 ug/m3 50ug/m3, and 75ug/m3 for 24 hours as per the WHO standard Figure 16. As evident by the pm 2.5 historical data laid out over time, it is evident that Kulhudhuffush experiences months with the locals exposed to higher 2.5 PM concentration . this peak is further evident on NE monsoon (Figure 15)

The air quality standards above show the air is affected by the haze season form the NE monsoon, blown in form the main continent. Further, this also suggests that the locals are exposed to unhealthy levels of particulate matter.

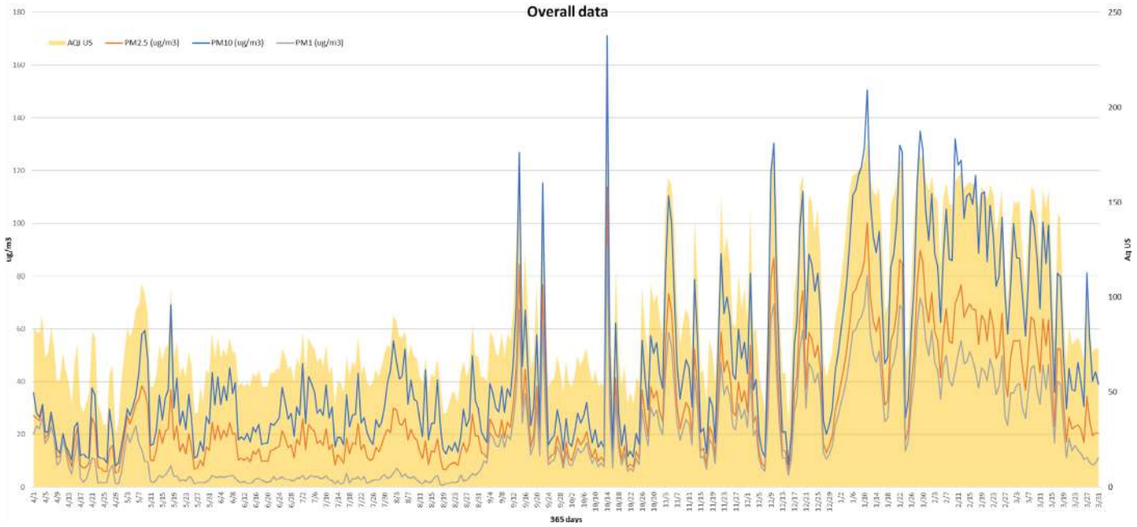


Figure 15. Air quality data for PM 2.5, PM10, and PM1 at Kuludhufushi. The peak can be observed on the NE monsoon. (data from Kuludhufushi station)

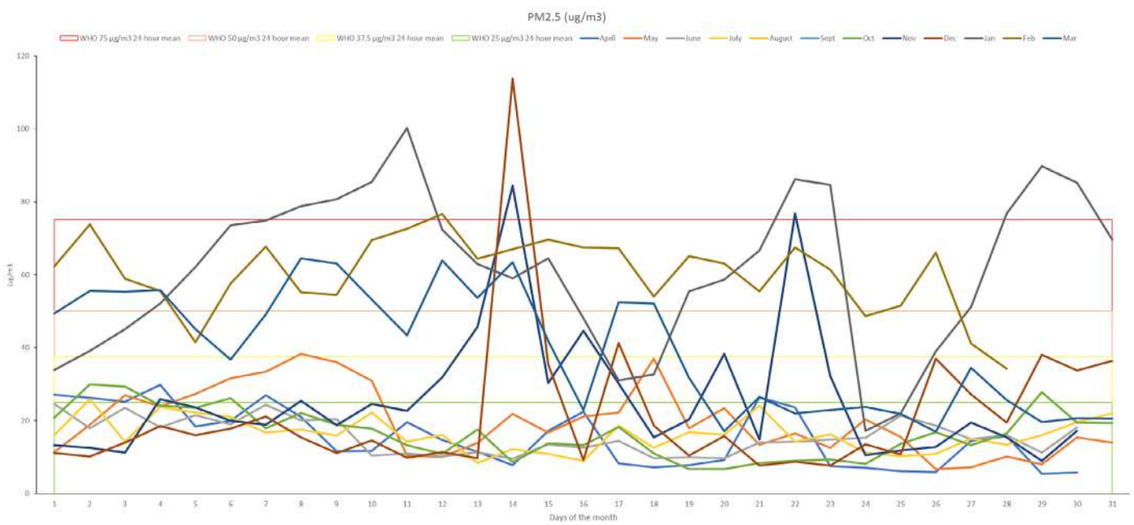


Figure 16. Air quality standards for pm 2.5 shown as 25 ug/m3, 37.5 ug/m3 50ug/m3, and 75ug/m3 for 24 hours as per the WHO standard (data from Kuludhufushi station)

2.1.9 TEMPERATURE

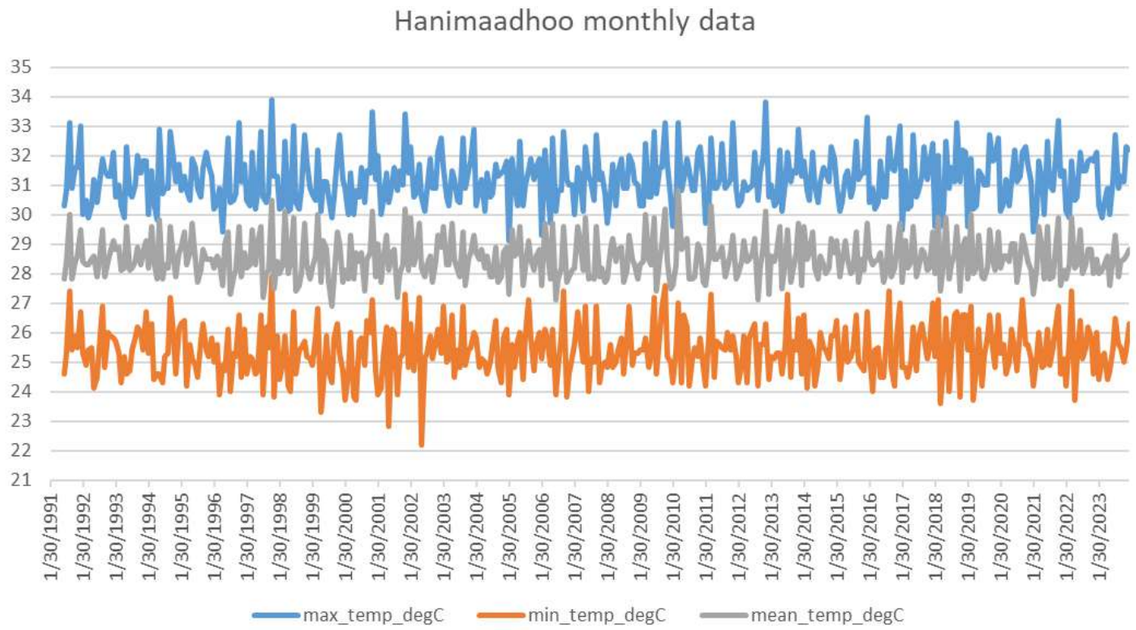


Figure 17. Monthly Maximum, Mean, and Minimum Temperature

Figure 17 shows the monthly maximum, mean and minimum temperatures for Hanimaadhoo. In the Northeast monsoon, December shows varying levels of temperature, with some years experiencing high temperatures, such as 2013 (33.6°C) and 2019 (33.9°C), while others have lower temperatures, like 2010 (27.2°C) and 2014 (27.1°C). January shows a wide range of temperature values, with some years experiencing significant warmth, such as 2005 (31.2°C) and 2016 (32.1°C), while others have milder temperatures, like 2002 (24.9°C) and 2003 (25.2°C). February also displays variations, with notable temperature highs in certain years, such as 2017 (32.8°C) and 2019 (32.5°C), contrasting with cooler periods like 2010 (25.5°C) and 2013 (26.0°C).

In the Transition period 1, March exhibits similar variability, with some years recording high temperatures, such as 2015 (33.2°C) and 2018 (33.5°C), while others have lower temperatures, like 2009 (26.3°C) and 2006 (26.5°C). April generally shows a mix of moderate to high temperature levels, with notable years like 2012 (26.7°C) and 2010 (26.8°C) alongside cooler periods like 2008 (25.8°C) and 2011 (26.0°C).

The Southwest monsoon typically experiences diverse temperature levels, with significant warmth in certain years like 2005 (33.0°C) and 2019 (33.8°C), but milder temperatures in others like 2013 (26.0°C) and 2015 (26.3°C). June often sees varying amounts of warmth, with notable years like 2015 (33.2°C) and 2018 (33.7°C) alongside cooler periods like 2009 (26.5°C) and 2011 (26.8°C). July exhibits a mix of temperature patterns, with some years recording high temperatures, such as 2012 (33.7°C) and 2017 (33.6°C), while others have milder temperatures, like 2006 (26.5°C) and 2008 (26.3°C).

August typically shows diverse temperature levels, with significant warmth in certain years like 2011 (33.8°C) and 2014 (33.7°C), but milder temperatures in others like 2002 (26.7°C) and 2007 (26.5°C). September generally displays varied temperature amounts, with notable years

like 2016 (33.9°C) and 2019 (33.6°C) alongside cooler periods like 2003 (27.0°C) and 2005 (27.1°C).

In transition period 2, October shows fluctuating temperature levels, with some years experiencing significant warmth, such as 2017 (33.7°C) and 2019 (33.6°C), while others have milder temperatures, like 2010 (27.2°C) and 2012 (27.1°C). November typically exhibits diverse temperature patterns, with significant warmth in certain years like 2013 (33.5°C) and 2016 (33.8°C), but milder temperatures in others like 2009 (26.3°C) and 2011 (26.5°C).

Flooding of Kulhudhuffushi City's Ameenee Magu
Image credit: Charrette team

2.1.10 MEAN WIND AND RAINFALL

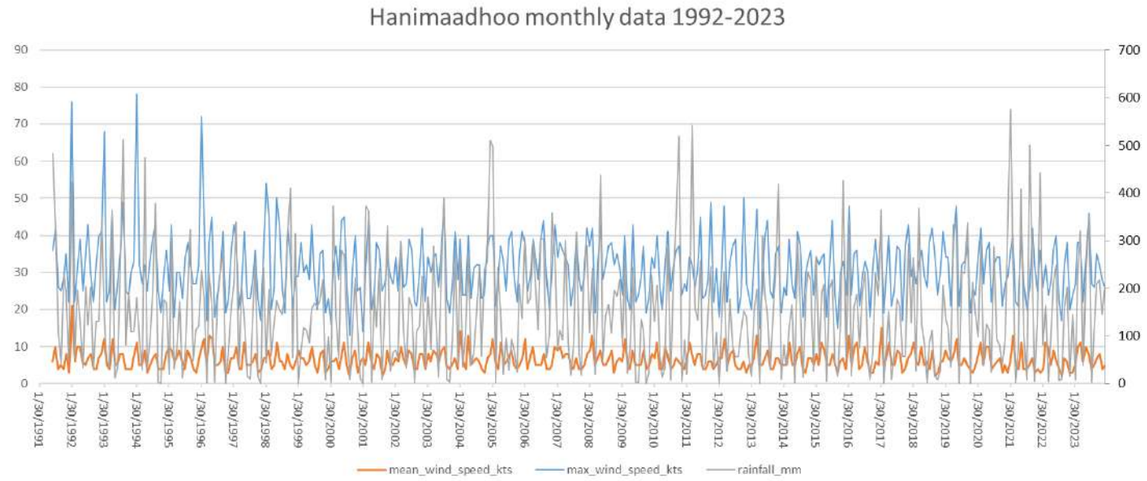


Figure 18. Monthly Mean Rainfall & Wind

Table 4. The statistical correlation between the rainfall, maximum wind speed, and mean wind speed. (Data: MET Office Maldives, 2024)

Rainfall mm	1
Max wind speed /kts	0.595688766
Mean wind speed / kts	0.470311343

The correlation coefficient between rainfall and maximum wind speed is approximately 0.5957, suggesting a moderately positive correlation. This indicates that as rainfall levels increase, there tends to be a corresponding increase in maximum wind speed, and vice versa, though not to an extreme degree. This association implies that weather conditions characterized by heavy rainfall may coincide with higher maximum wind speeds, potentially indicative of stormy or cyclonic weather patterns.

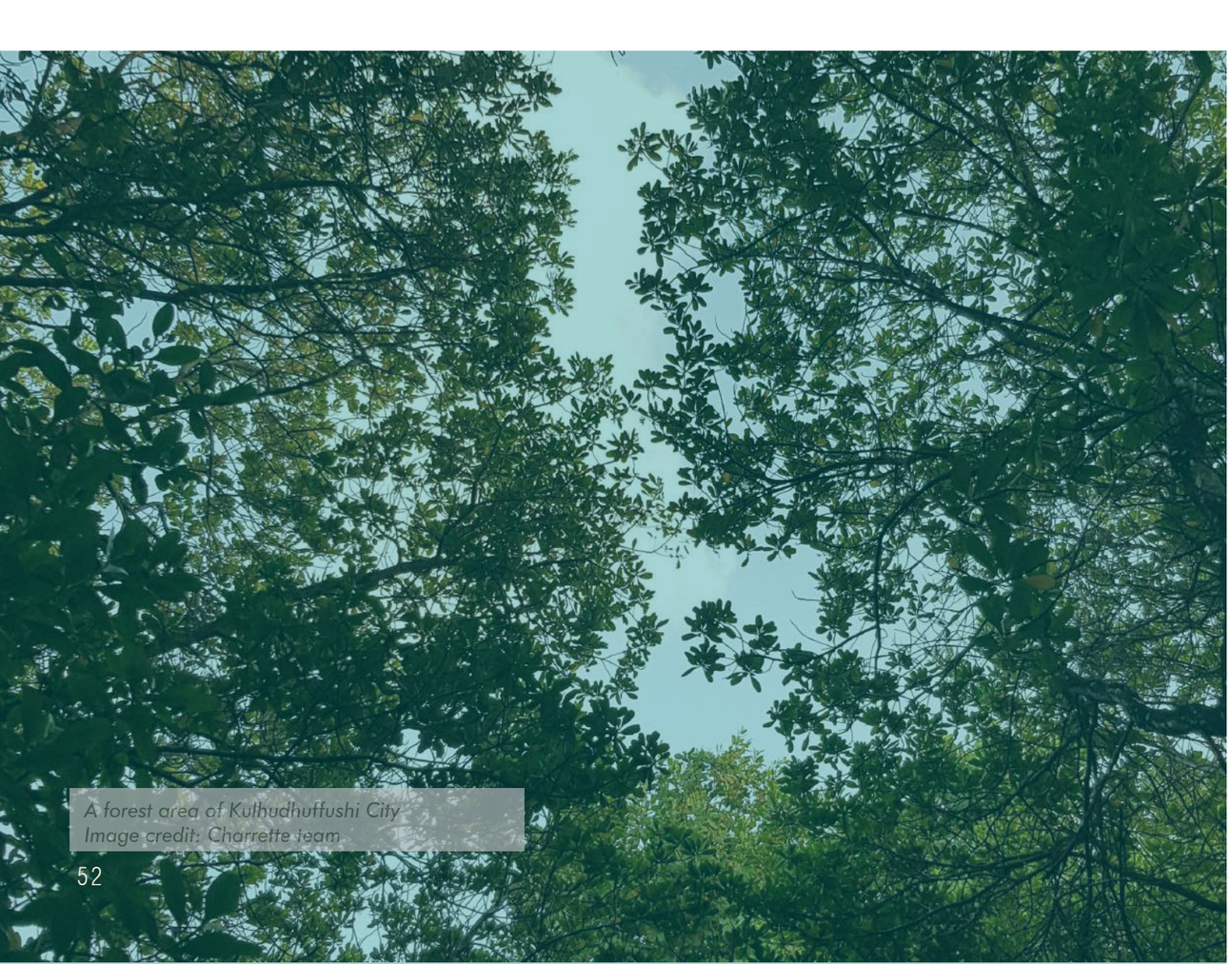
Conversely, the correlation coefficient between rainfall and mean wind speed is approximately 0.4703, also indicating a moderately positive correlation. This suggests that variations in rainfall levels are moderately associated with changes in mean wind speed. While not as strong as the correlation between rainfall and maximum wind speed, this relationship still implies that certain weather patterns associated with increased rainfall may also influence mean wind speeds to a moderate extent.

Looking at the rainfall versus maximum wind speed (Figure 18) , we observe fluctuations in rainfall levels over the years. For instance, there are notable peaks in rainfall in January 1992, January 2005, January 2017, and January 2021, with values exceeding 400 millimeters. Correspondingly, maximum wind speeds also show variability, although they do not strictly follow the pattern of rainfall. While there are instances of elevated maximum wind speeds during periods of high

rainfall, such as in January 1992 and January 2005, this relationship is not consistently observed throughout the dataset. This suggests that while there may be some association between rainfall and maximum wind speed, other factors likely influence the variability in maximum wind speed independently of rainfall.

Similarly, when examining the relationship between rainfall and mean wind speed (Table 4), we find that the patterns are not perfectly aligned. While there are instances where higher rainfall corresponds with increased mean wind speed, such as in January 1992 and January 2005, this association is not consistent across all data points. For example, there are instances of high rainfall with relatively low mean wind speed, such as in January 1994 and January 2011. This indicates that while there may be some correlation between rainfall and mean wind speed, other factors contribute to the variability in mean wind speed independent of rainfall.

While there appears to be some association between rainfall and both maximum and mean wind speed over the timeline, the relationship is not strictly linear or consistent. Other factors likely play a role in influencing the variability of wind speeds independently of rainfall.



A forest area of Kulhudhuffushi City
Image credit: Charrette team

2.1.11 RAINFALL AND HUMIDITY

The mean temperature (Figure 19) ranged from approximately 28.1°C to 28.7°C. Maximum temperatures ranged from around 30.9°C to 31.8°C, while minimum temperatures varied from approximately 24.5°C to 25.3°C.

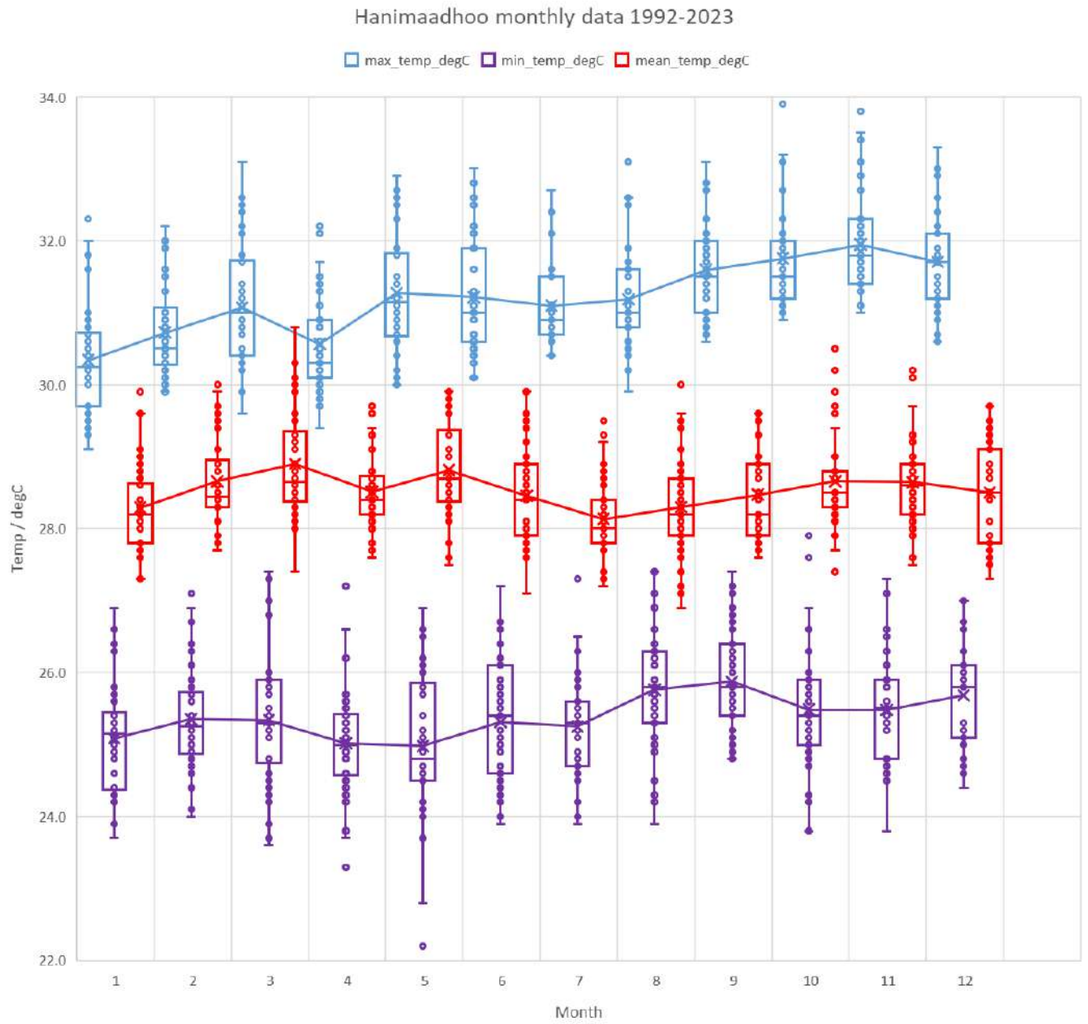


Figure 19. Monthly Maximum, Mean, and minimum Temperature

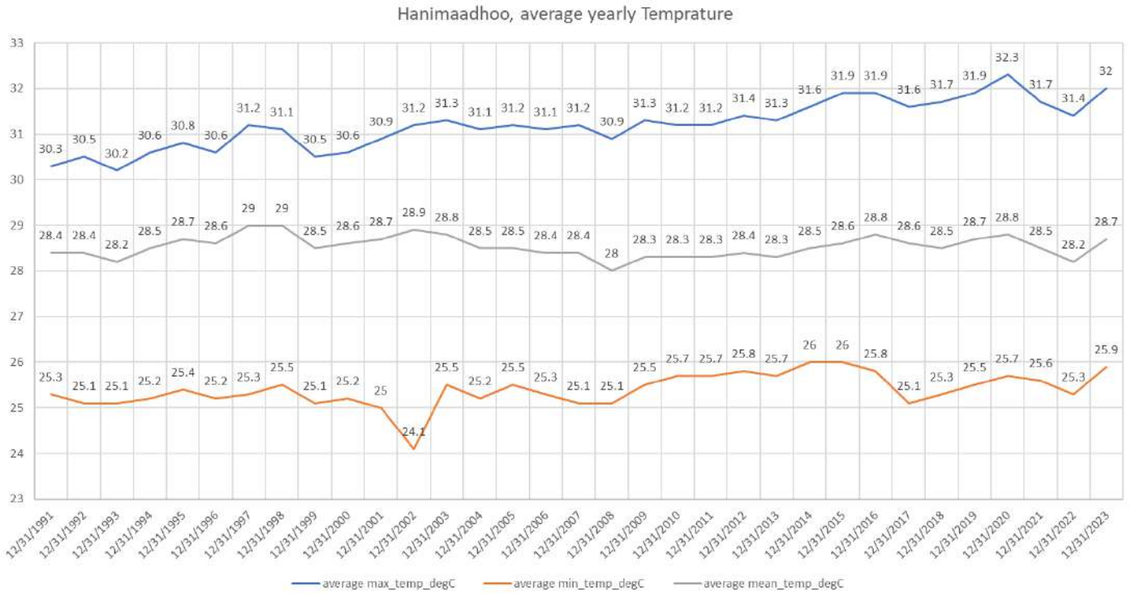


Figure 20. The mean temperature (Figure 19) ranged from approximately 28.1°C to 28.7°C. Maximum temperatures ranged from around 30.9°C to 31.8°C, while minimum temperatures varied from approximately 24.5°C to 25.3°C.

Analyzing the trends Figure 20 of the temperature rise over the years, there doesn't appear to be a significant overall trend in mean, maximum, or minimum temperatures over the years. While there are fluctuations from year to year, there is no consistent pattern of temperature increase or decrease observed throughout the dataset.

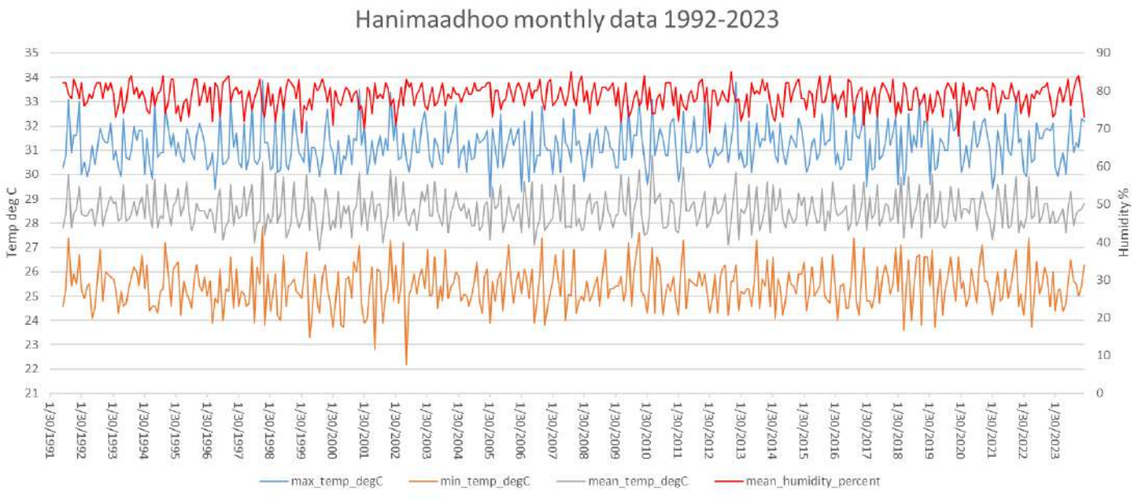


Figure 21. Monthly Maximum, Mean, minimum Temperature and humidity.

Table 5. Correlation between humidity and temperature

mean_humidity_percent	1
mean_temp_degC	-0.357961406
max_temp_degC	-0.292864207
min_temp_degC	-0.046493166

The table above (Table 5) shows the statistical correlation between mean humidity percentage, mean temperature, maximum temperature and minimum temperature (Data: MET Office Maldives, 2024) (Figure).

The correlation coefficient between mean humidity and mean temperature is approximately -0.358, suggesting a weak negative correlation between these variables. Similarly, the correlation coefficient between mean humidity and maximum temperature is around -0.293, indicating another weak negative correlation. Lastly, the correlation coefficient between mean humidity and minimum temperature is approximately -0.046, also suggesting a weak negative correlation. Overall, the correlations imply that as mean humidity increases, there is a tendency for mean, maximum, and minimum temperatures to decrease slightly, although the correlations are weak.

2.1.12 GEOGRAPHY

2.1.12.1 Elevation & Topography

The profiles (Figure 24 and Figure 25Figure) are taken from the digital elevation model below (Figure 22 and Figure 23). The model is corrected to the mean sea level. From north to south orientation, the average island elevation is approximately 1.41m above mean sea level (MSL). The island is lower towards the north and south while the mid island holds the highest general elevation. In the east to west orientation the average island elevation is 1.72m above MSL. From east to west, till the reclaimed component of the island, the island slopes towards the west and maintains the level a bit higher than that of the native island on the reclaimed island till the harbour quay wall. There are numerous depressions on the island that are lower in elevation from the surrounding mainland, which can accumulate water as shown in Figure 24 and Figure 25.

DEM 1

Figure 22. The DEM1 , shows the color scale where the highest surfaces are red in color and the lower surfaces are green in color. The reclaimed land, eastern ridge and the airport are higher in elevation than the rest of the island and the burrow areas for the reclamation, the mangroves and the roads are lower in elevation than the rest of the island.

DEM 2

Figure 23. The DEM2 , shows the color scale where the highest surfaces are red in color and the lower surfaces are green in color. The reclaimed land, eastern ridge and the airport are higher in elevation than the rest of the island and the burrow areas for the reclamation, the mangroves and the roads are lower in elevation than the rest of the island.

Figure 24. Profile taken for DEM 1, For context, the elevation on the y axis is exaggerated to show the prominence. Towards the Y axis (origin) is the northern side and away from the y axis is the southern side. From the profile, the depression of the island on the northern and the southern side is evident. And the central elevation is also evident.

Figure 25. Profile taken for DEM 2, For context, the elevation on the y axis is exaggerated to show the prominence. Towards the Y axis (origin) is the northern side and away from the y axis is the eastern side. From east to west, the elevation of the reclaimed land can be observed, followed by the depression of the connection between the reclaimed land and the main island, followed by the gradual elevation of the island towards the east and the high point of an approximate 3m ridge on the south side of the island.

The beach profiles were captured from the same locations as the report Detailed Island Risk Assessment Report (2013) (Figure 26). For general comparison, in this study, the same areas are used.

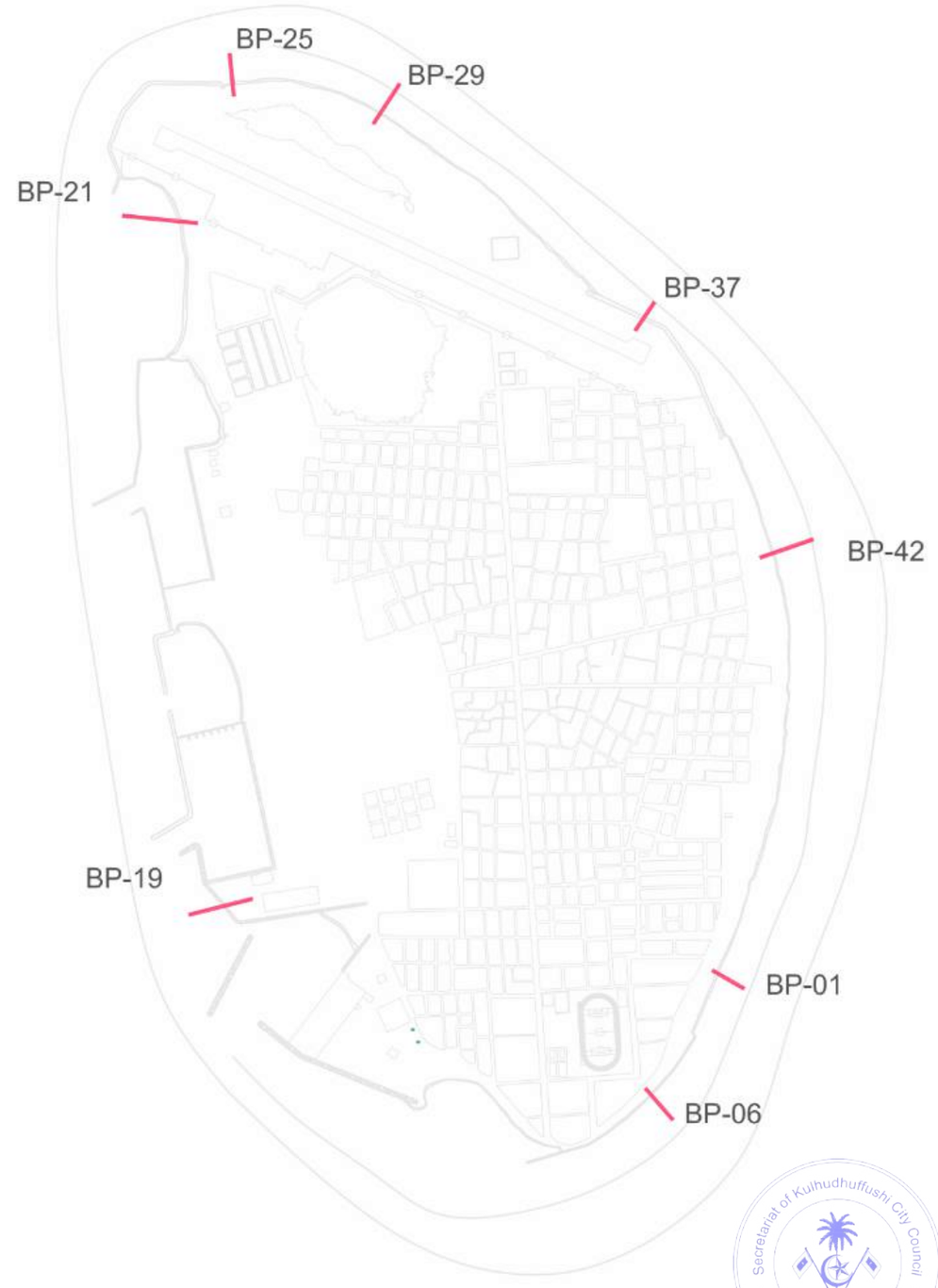


Figure 26. Beach Profile Locations of Detailed Island Risk Assessment Report (2016)

2.1.12.1.1 Beach Profile (BP) - 01

The location of the profile (Figure 27) is on the south eastern side of the island. The profile taken in 2013, reports a high coastal ridge followed by a steep beach slope. The beach consists of shingle and rubble rock.

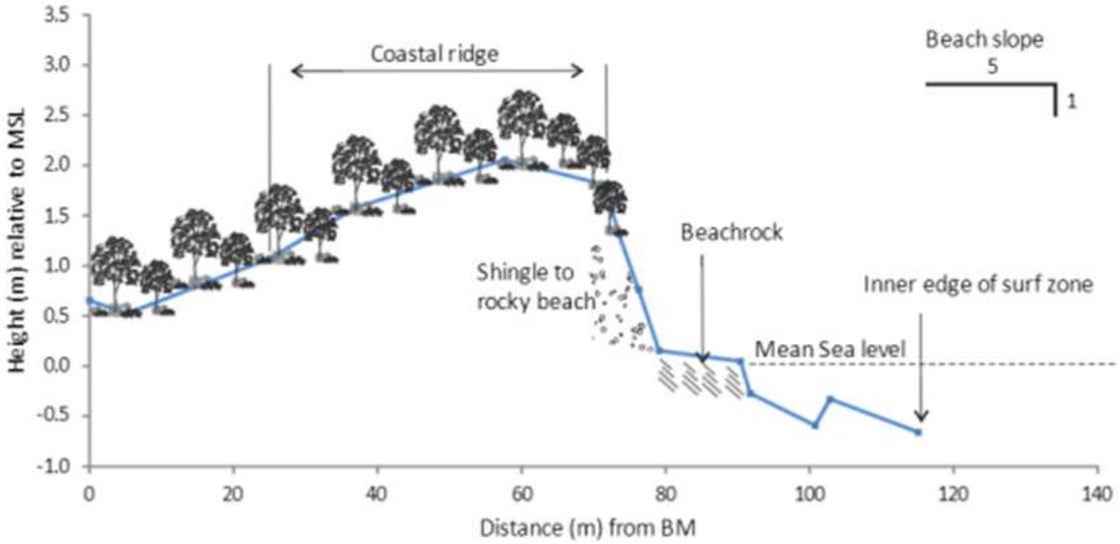


Figure 27. Profile 01 (Riyan, 2013)

Figure 28. Profile 01 (2024) location render from the point cloud model.

Figure 29. Profile 01 (2024) location render from the point cloud model.

Location render (Figure 28, Figure 29) of the latter survey shows that the site has been modified over time. The vegetation line persists and the eastern vegetation is intact with the beach line. During the time of the survey the sediment concentration of the finer particles are higher on the beach.

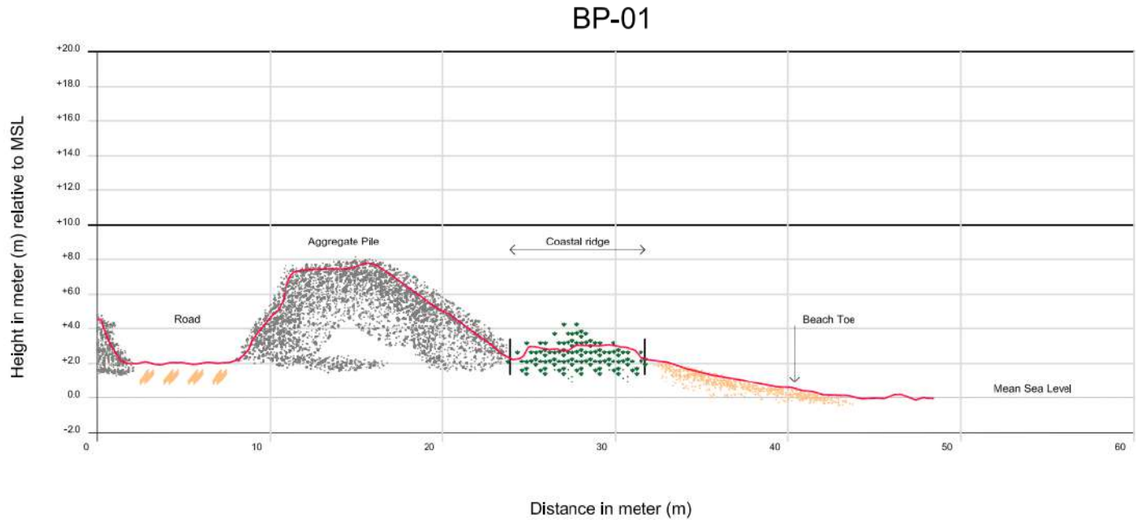


Figure 30. Profile 01 (2024), substrate analysis.

The profile (Figure) from this study shows a high beach toe, a gradual slope and a beach vegetation covering the berm. The coastal ridge starts around 24m and the berm can be observed around 32m. The beach toe can be observed around 45m, where the beach crosses the MSL line.

2.1.12.1.2 Beach Profile (BP) - 06

The profile is on the southern side of the island. The profile taken in 2013 shows an exposed beach rock with a gradual slope and a toe behind the beach rock. A deeper region shore side from the beach rock and a rubble beach with a high berm at the edge of the vegetation.

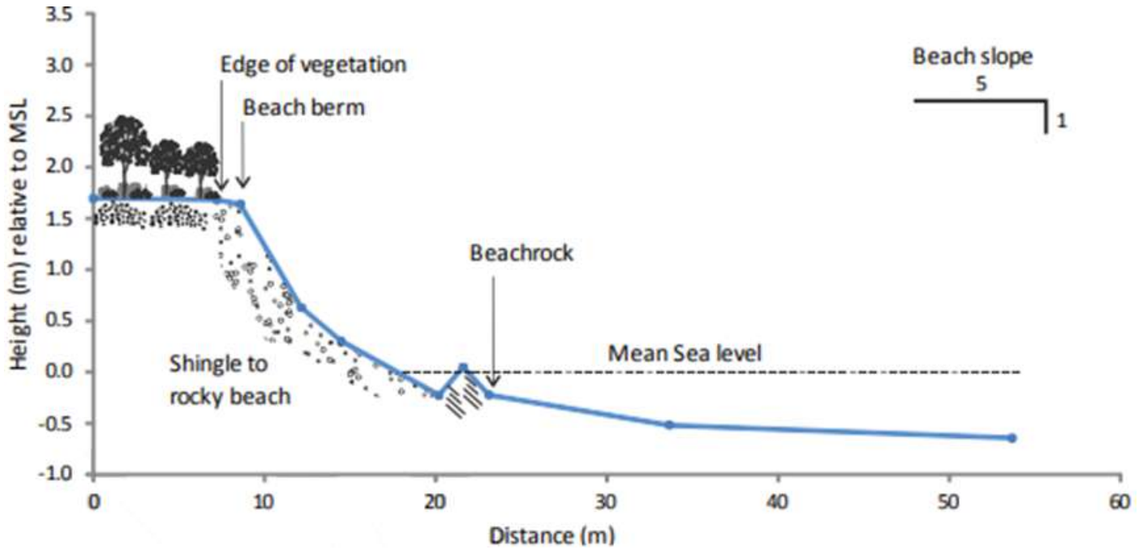


Figure 31. Profile 06 (Riyan, 2013)

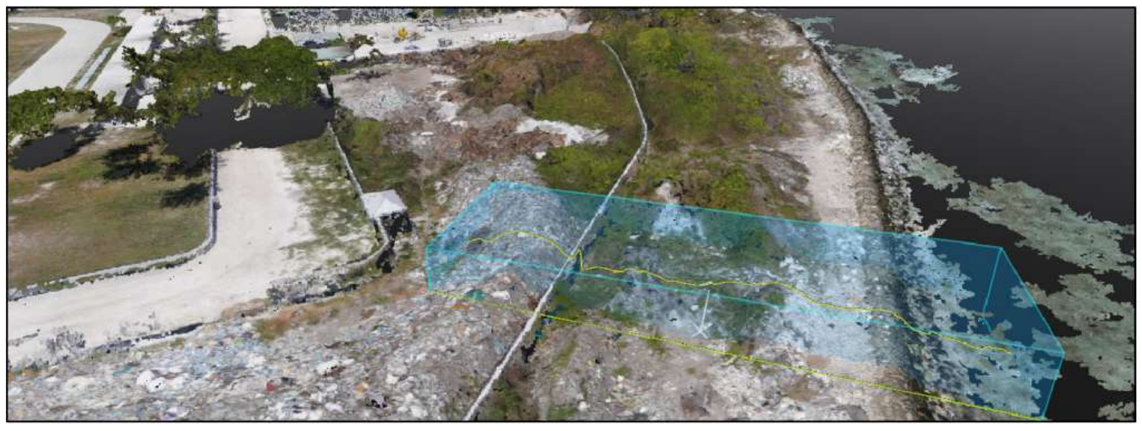


Figure 32. Profile 06 (2024) location render from the point cloud model.

Figure 33. Profile 06 (2024) location render from the point cloud model.

Location render shows significant changes brought about to the area. Specifically, to the island ridge and the berm area when compared between the 2016 and 2024 data. Reclamation and shore protection has stabilized the ridge area considerably.

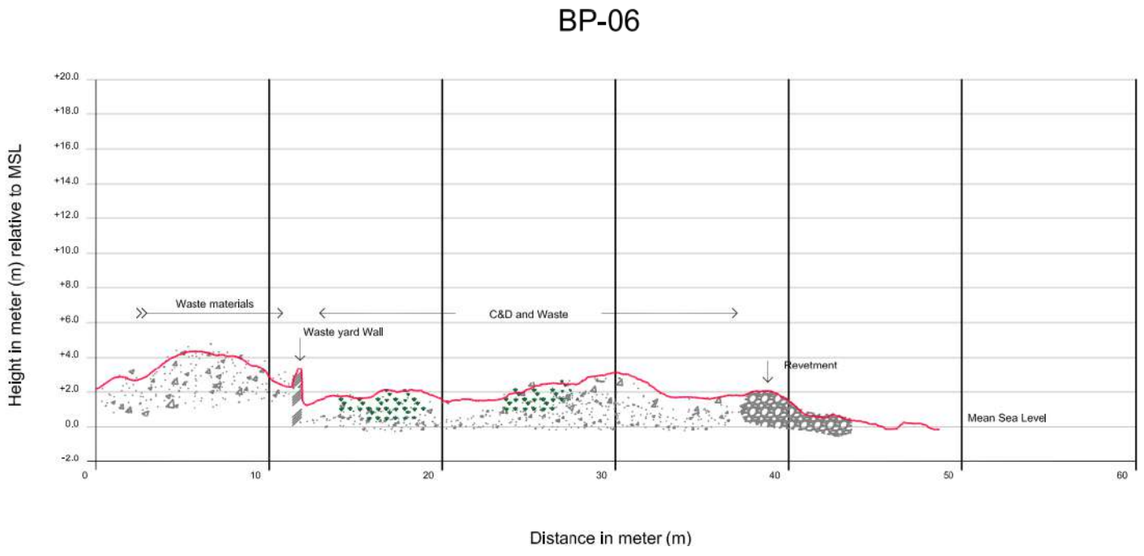


Figure 34. Profile 06 (2024), substrate analysis.

The profile for this study shows a beach slope gradual that blends with the revetment rock put in place as a shore protection. The berm and the coastal ridge being the revetment is at 37m of the profile, the height is at 2m from MSL, the toe is at 44m form the profile, at MSL.

2.1.12.1.3 Beach Profile (BP) - 19

The profile is on the south western side of the island. The profile taken in 2013 reports the reclaimed land and a high beach berm, rubble, steep slope and a close to shore toe.

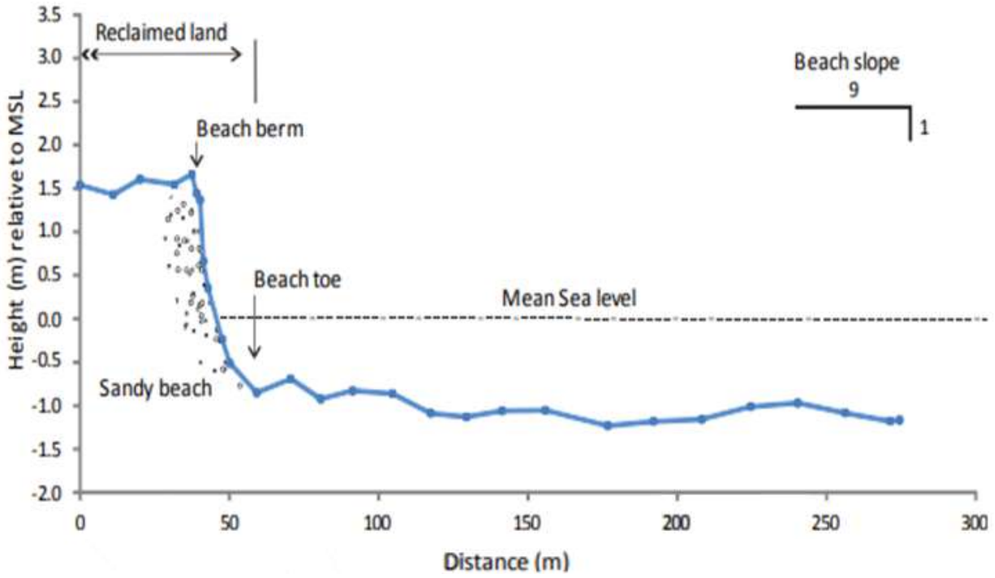


Figure 35. Profile 19 (Riyan, 2013)

Comparing the profile and the site survey, considerable shore modification can be seen on this profile as well. The shore protection is now complete and the reclamation zone is stabilized.

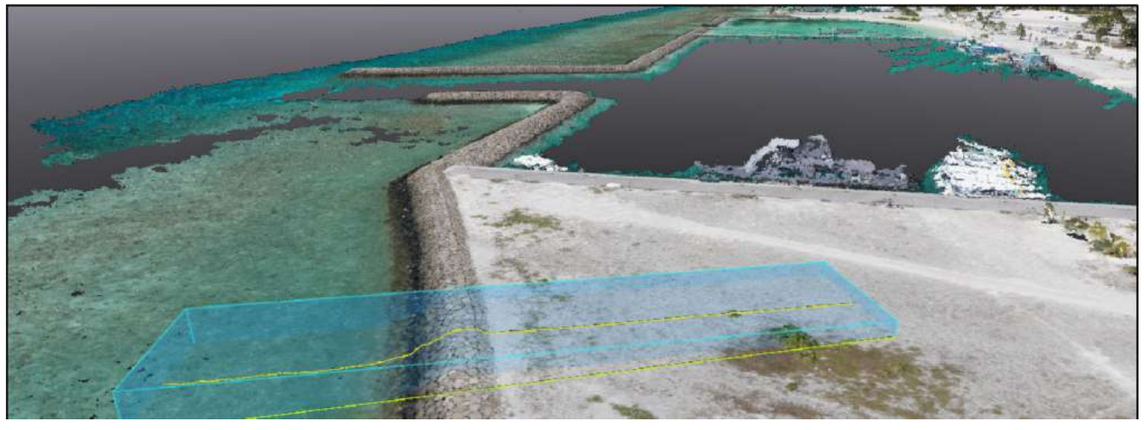


Figure 36. Profile 19 (2024) location render from the point cloud model.

Figure 37. Profile 19 (2024) location render form the point cloud model.

The profile taken for this study shows the reclaimed land and the revetment used as shore protection. The crest of the revetment and the berm is 36m from the origin, at a height of 2m from MSL. The toe is at 48m from the point of origin and at MSL.

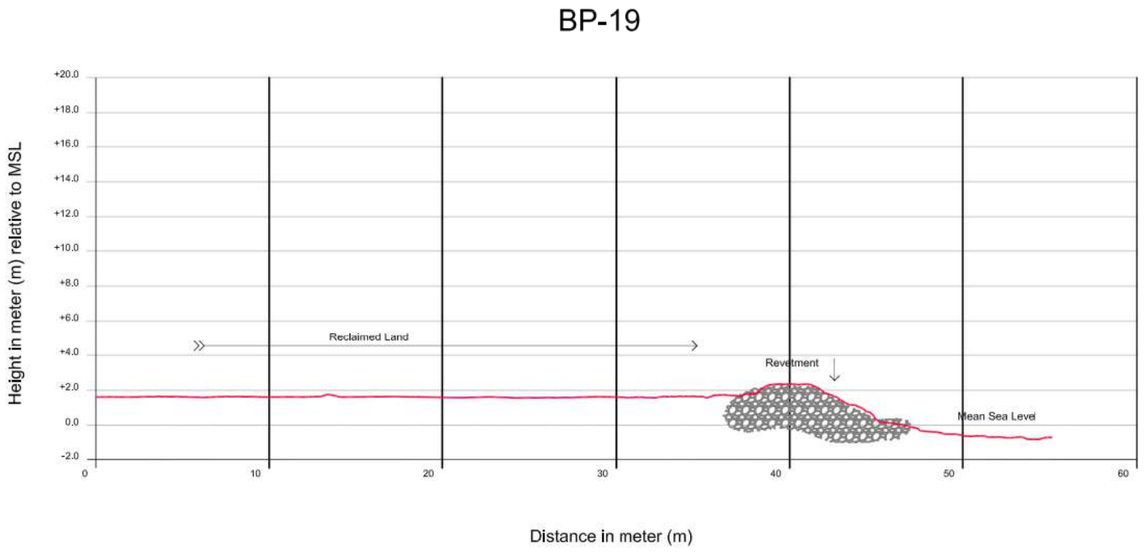


Figure 38. Profile 19 (2024), substrate analysis

2.1.12.1.4 Beach Profile (BP) - 21

The profile is on the north western side of the island. The 2013 records report a high beach berm, a steep beach slope, a rubble beach and a close to edge toe.

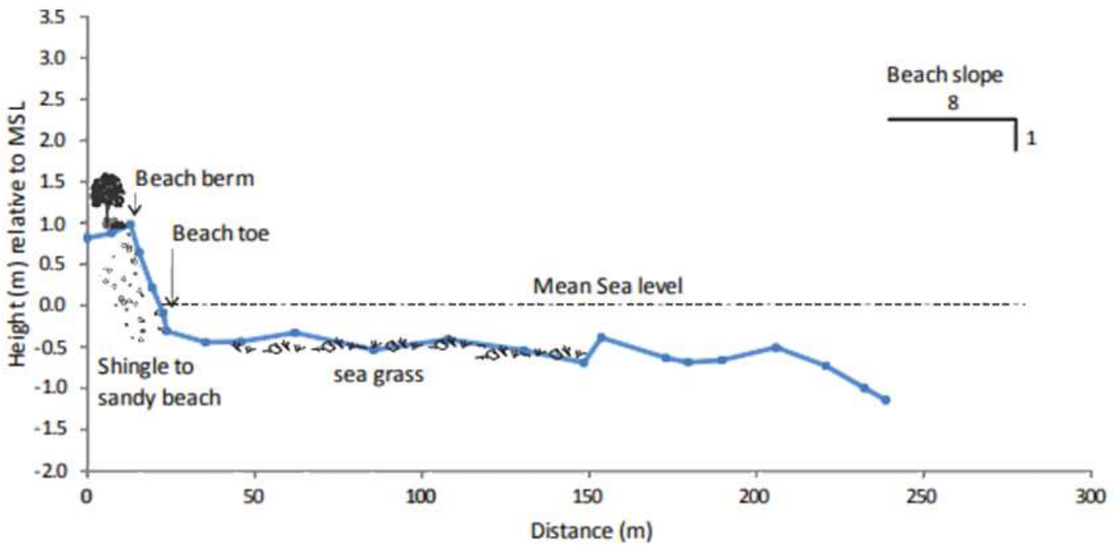


Figure 39. Profile 21 (Riyan, 2013)

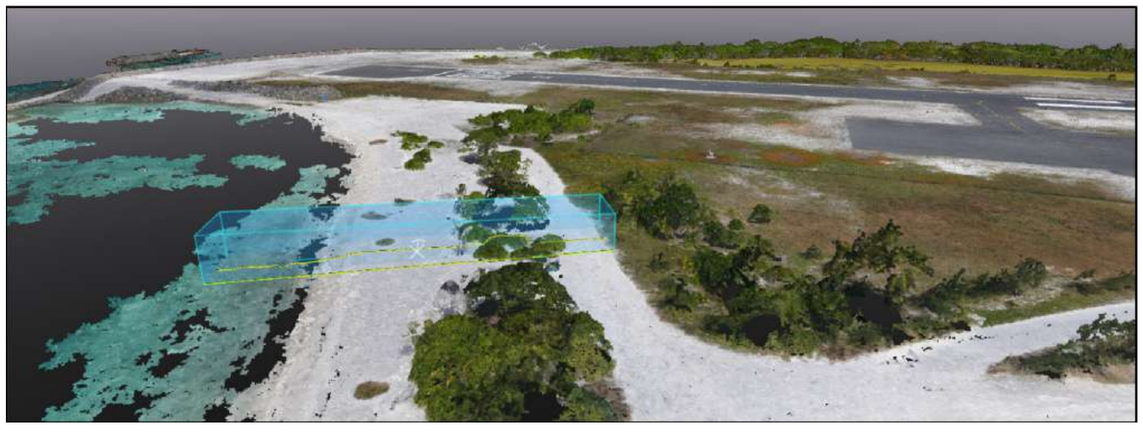


Figure 40. Profile 21 (2024) location render from the point cloud model.

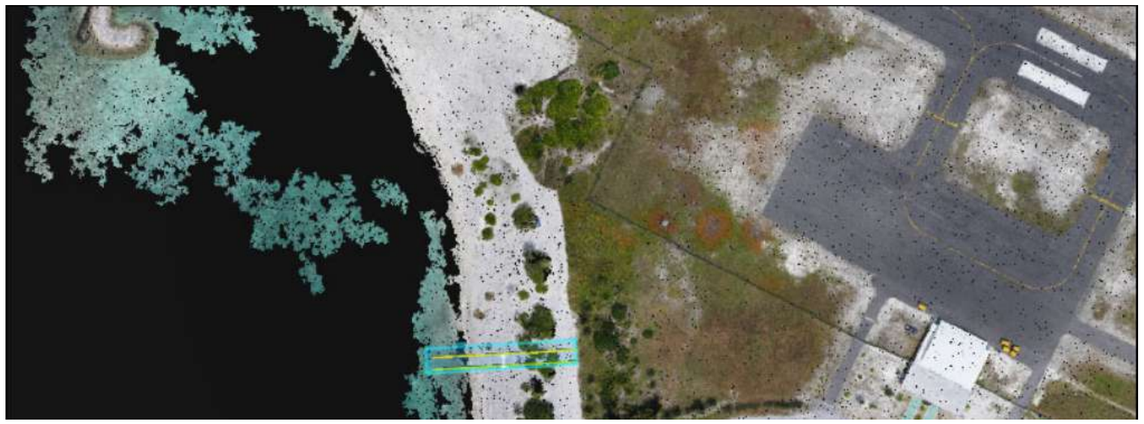


Figure 41. Profile 21 (2024) location render form the point cloud model.

Comparing the profile and the site survey, considerable shore modification can be seen on this profile as well. There is no shore protection laid, however the natural ridge seems sufficient for the stability of the area.

BP-21

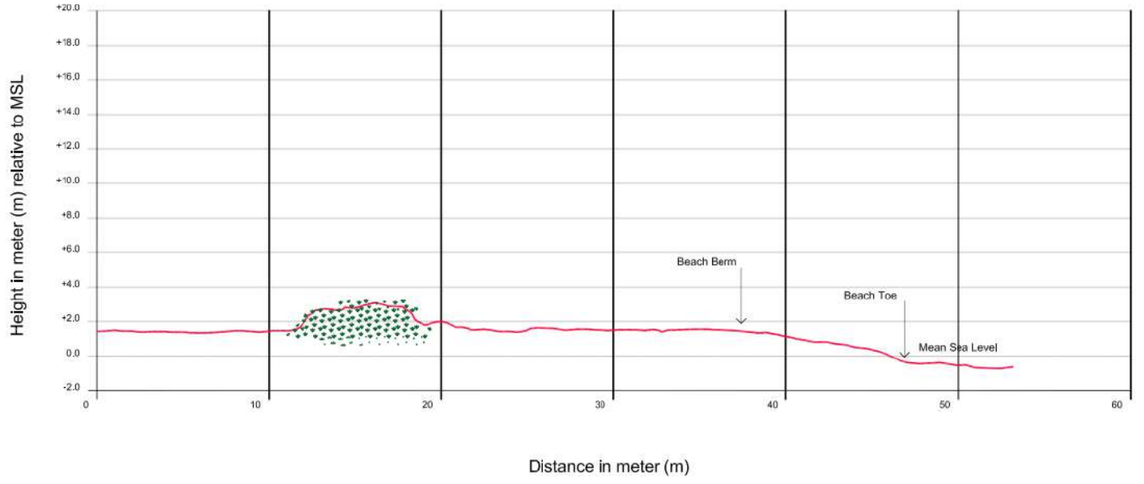


Figure 42. Profile 21 (2024), substrate analysis.

The profile taken on this study shows a high beach berm, a gradual beach slope and a beach toe at MSL. The coastal ridge of the profile is at 13m for the origin at an elevation of 1.7m the berm is at 19m from origin at 2m from MSL. The Toe is at 48m from the origin at MSL.

2.1.12.1.5 Beach Profile (BP) - 25

The profile is on the northern side of the island. The 2013 profiles report a high beach berm, a sandy beach, a high beach toe and a rock rubble deposit on the reef flat.

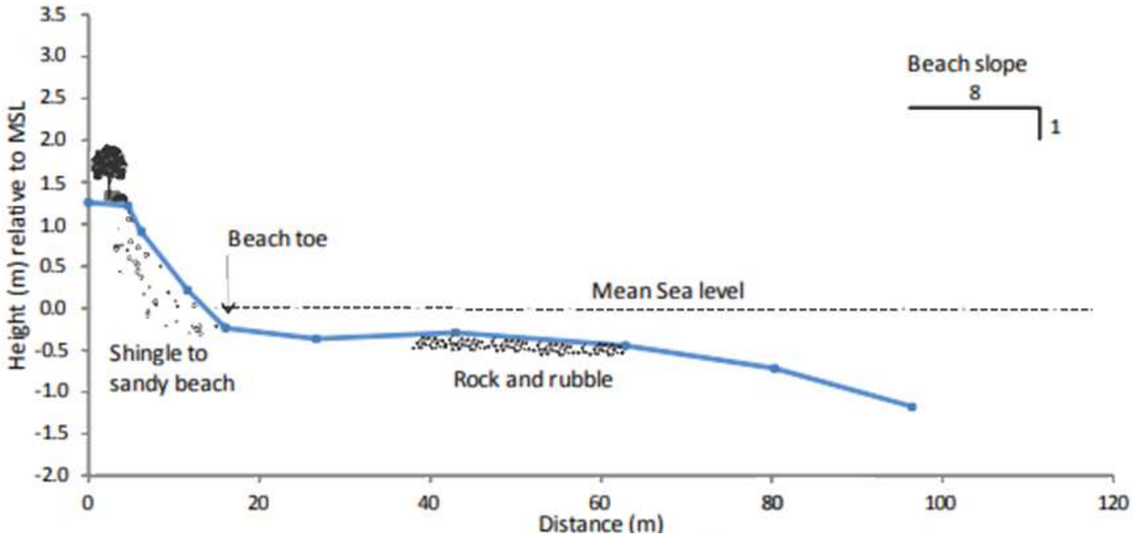


Figure 43. - Profile 25 (Riyan, 2013)

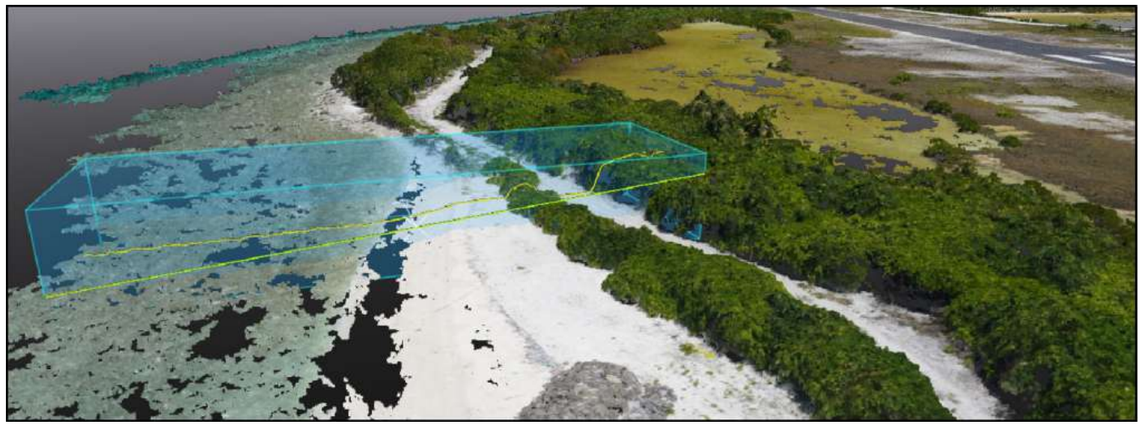


Figure 44. Profile 25 (2024) location render from the point cloud model.

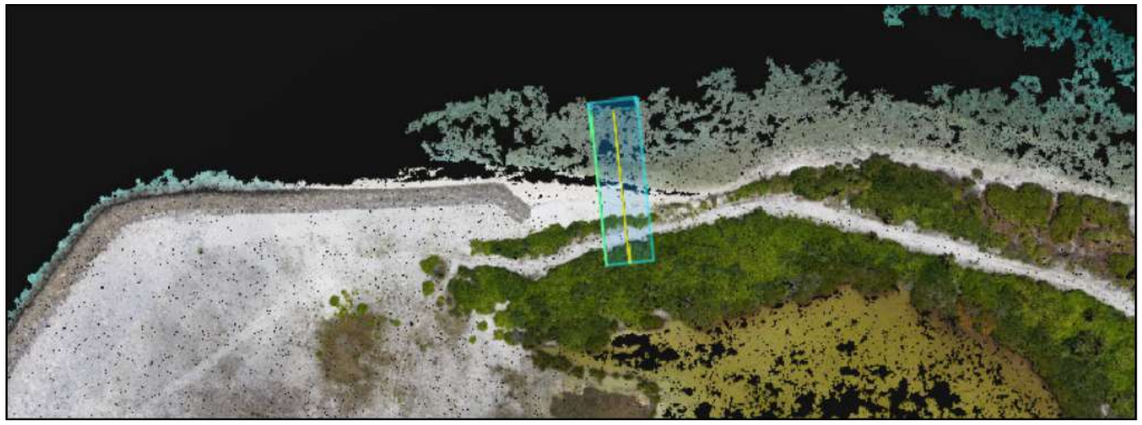


Figure 45. Profile 25 (2024) location render form the point cloud model.

Comparing the profile and the site survey, shore changes can be seen on this profile as well. However, the morphology remains the same.

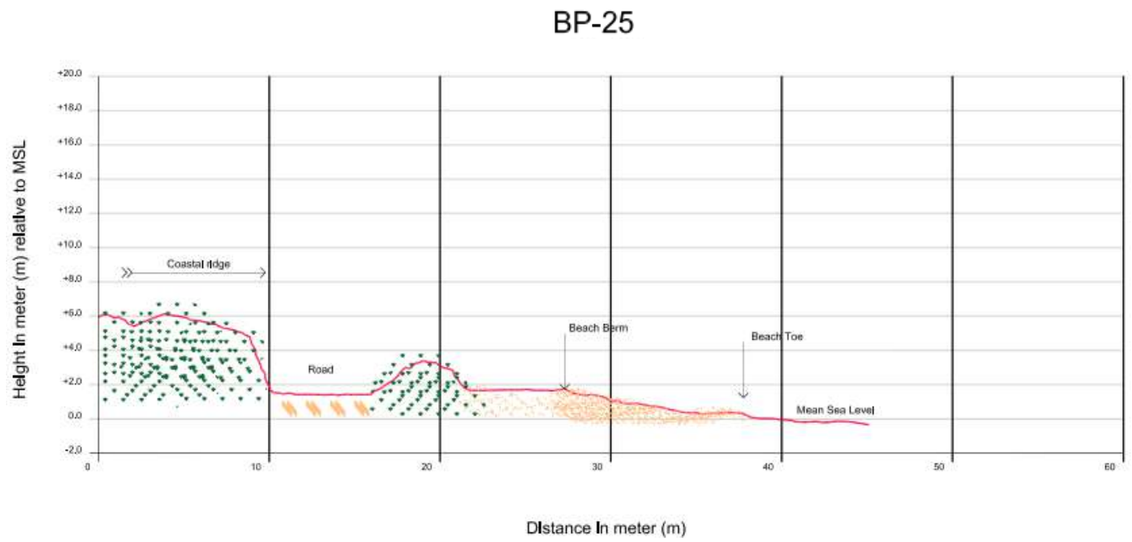


Figure 46. Profile 25 (2024), substrate analysis.

The profile taken for this report also shows a similar pattern. A high beach berm and a sandy beach. The coastal ridge is at 17m form origin and elevated at 1.7m form MSL. The berm is at 27m form origin at 1.8m from MSL. The TOE is at 37m from origin at MSL.

2.1.12.1.6 Beach Profile (BP) - 29

This profile is north east facing. Records of 2013 reports a high ridge high berm and a sandy steep beach with the toe below MSL.

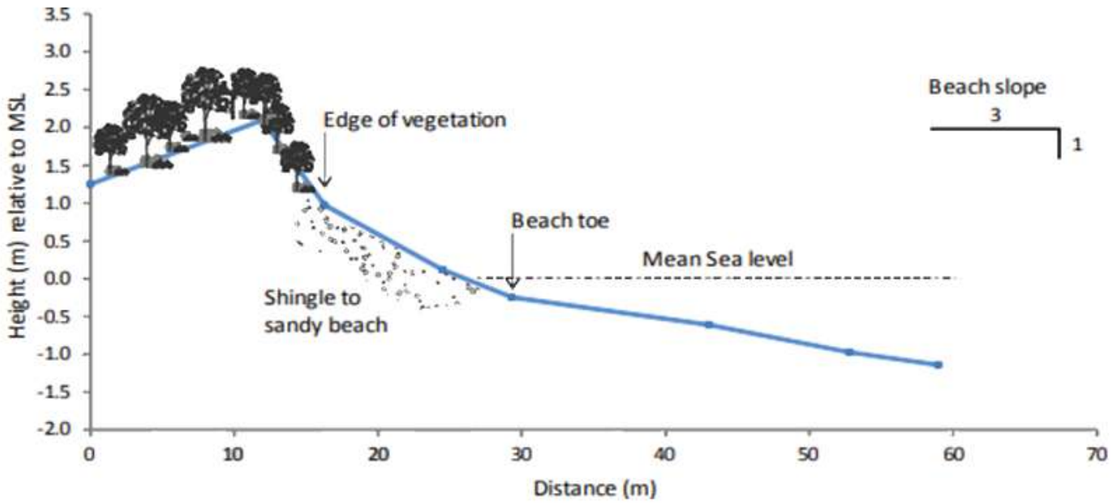


Figure 47. Profile 29 (Riyan, 2013)

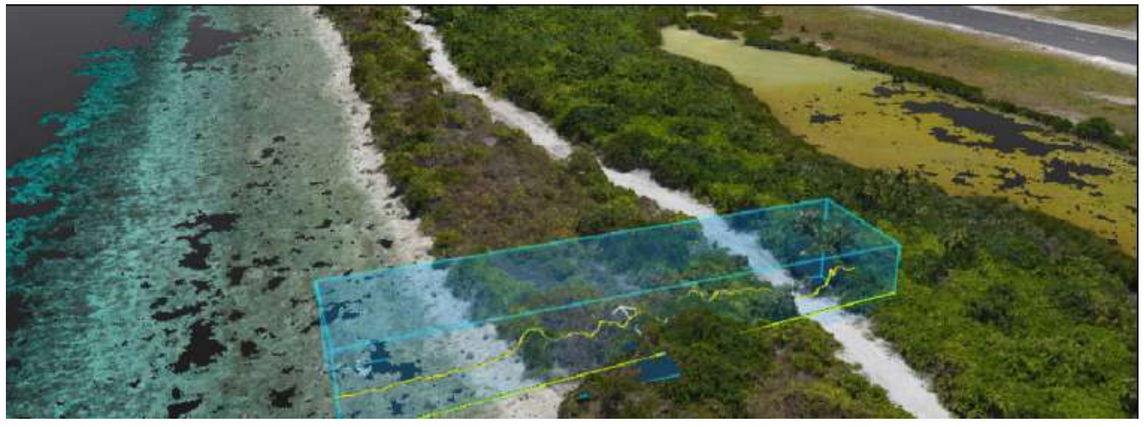


Figure 48. Profile 29 (2024) location render from the point cloud model.

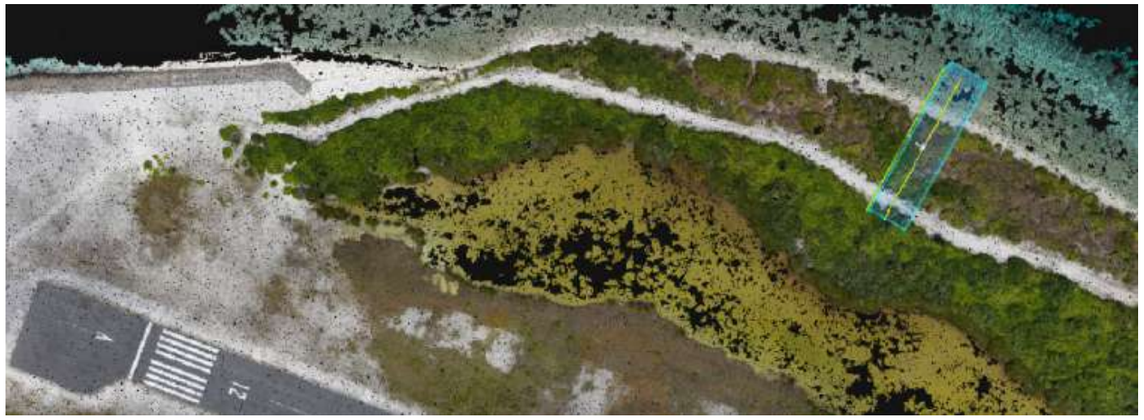


Figure 49. Profile 29 (2024) location render form the point cloud model.

Comparing the profile and the site survey, shore changes can be seen on this profile as well. However, the morphology remains the same.

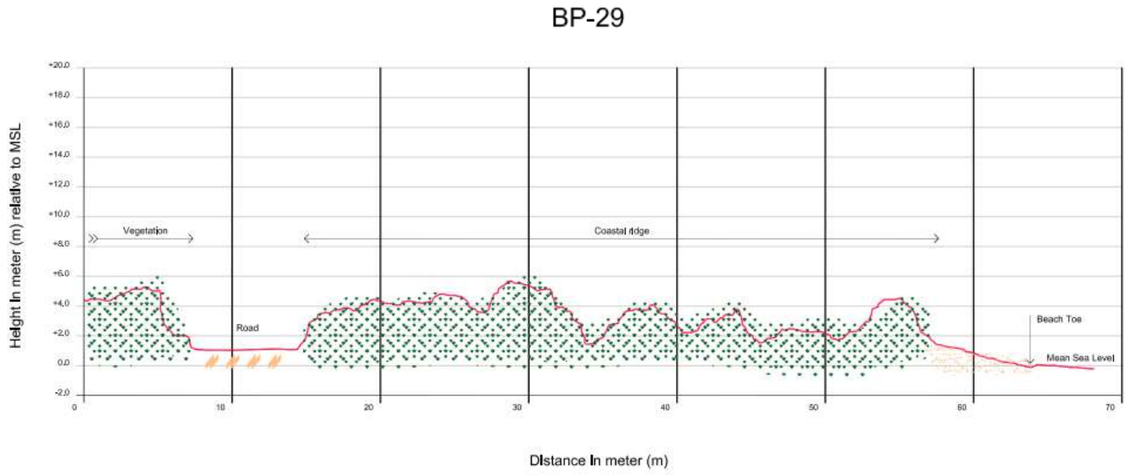


Figure 50. Profile 29 (2024), substrate analysis.

Similarly, our profiles show a high ridge high berm and a sandy steep beach with the toe below or at MSL. The ridge starts at 15m from the origin at an elevation of 1m from MSL. The berm is at 58m from origin at an elevation of 1m from MSL. The toe is at 68m at an elevation of -0.5m from MSL.

2.1.12.1.7 Beach Profile (BP) - 37

This is a west facing profile. The records of 2013 report a high berm, steep rubble beach, a toe close to the shore, rubble reef flat and beach rock peaking the MSL.

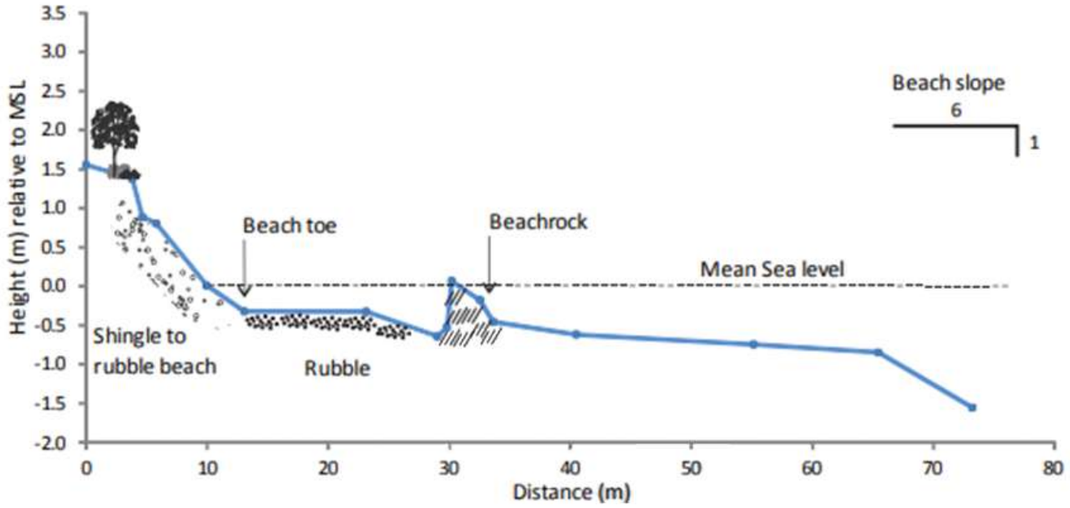


Figure 51. Profile 37 (Riyan, 2013)

Figure 52. Profile 37 (2024) location render from the point cloud model.

Figure 53. Profile 37 (2024) location render form the point cloud model.

Comparing the profile and the site survey, considerable shore changes can be seen on this profile However, the morphology has changed and the revetment provides considerable protection to the shoreline.

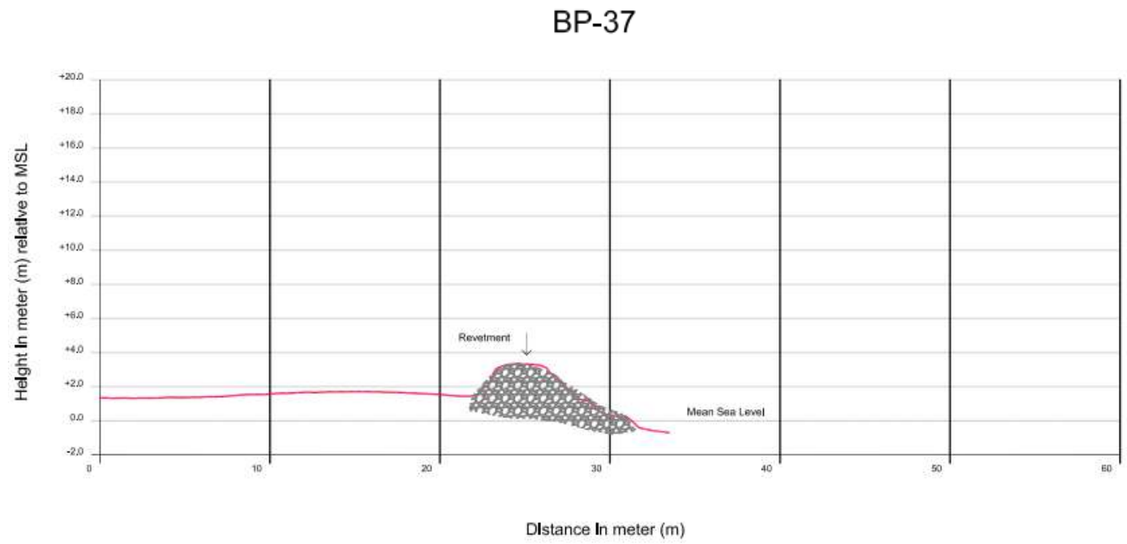


Figure 54. Profile 21 (2024), substrate analysis.

The crest of the revetment and ridge is at approximately 25m from origin and 1.9m from MSL. The toe is at 31m at -0.5m from MSL.

2.1.12.1.8 Beach Profile (BP) - 42

This beach profile shows the coastal ridge of the area sloping down to a beach rock face. The slope is relatively shallow in comparison.

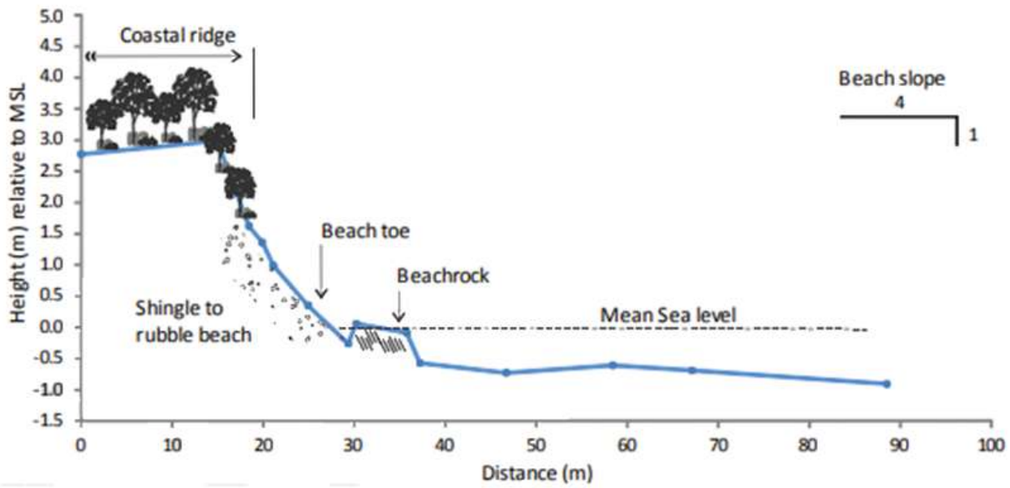


Figure 55. Profile 42 (Riyan, 2013)

Figure 56. Profile 42 (2024) location render from the point cloud model.

Figure 57. Profile 42 (2024) location render form the point cloud model.

Comparison with the 2016 profile and the current state, The location had gone through considerable changes including changes due to erosion. However, the main coastal ridge, still remains functional.

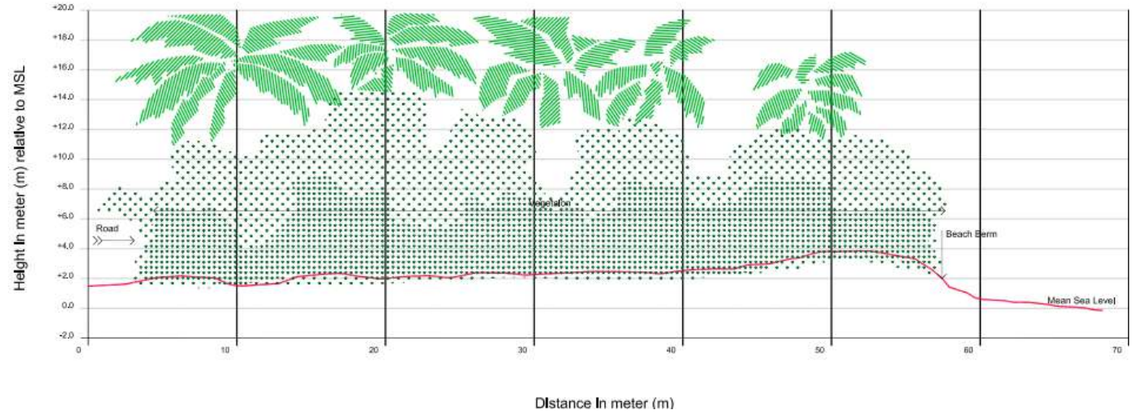


Figure 58. Profile 42 (2024), substrate analysis

Analysis shows that the natural ridge starts approximately at 5m and ends at 57m and is at a height of 4m at the berm end.

2.2 SOCIAL ENVIRONMENT

2.2.1 POPULATION

According to the 2022 National Bureau of Statistics, the island's resident population had increased to 10,131, indicating a gradual yet consistent growth since the 2014 survey. The growth rate for the Maldivian population residing on the island between 2014 and 2022 is recorded at 1.6%. The demographic composition of Kulhudhuffushi reveals a total population of 10,131 people, of which 5,206 are male and 4,952 are female. The elderly population comprising 266 men and 252 women signifies a gender distribution that is comparatively equitable within this age bracket. The young adult cohort, consisting of 1,559 women and 971 men, is dominated by females, suggesting that young women comprise a greater proportion of the population in this age bracket. Likewise, within the age group of 15 to 24, 757 individuals are female and 532 are male, indicating a comparable pattern wherein this demographic group is dominated by females. There are 953 girls and 931 boys in the adolescent age group of 10 to 19 years, suggesting that the proportion of females is marginally greater in this age bracket. Indicative of a comparatively equitable gender composition within the younger demographic, the age group of 0 to 14 years comprises 1,593 boys and 1,488 girls.

Figure 59. Image credit: Zuvaanmasveriya ,HDh. Kulhudhuffushi, https://zuvaanmasveriya.com/hdh-kulhudhuffushi/

Further complicating the demographic picture is the inclusion of foreigners, of which 714 are men and 83 are women in the workforce of Kulhudhuffushi. The gender discrepancy observed among migrant workers highlights the male preponderance within this demographic group, which may be indicative of particular labour market patterns or recruitment strategies prevalent in the area.

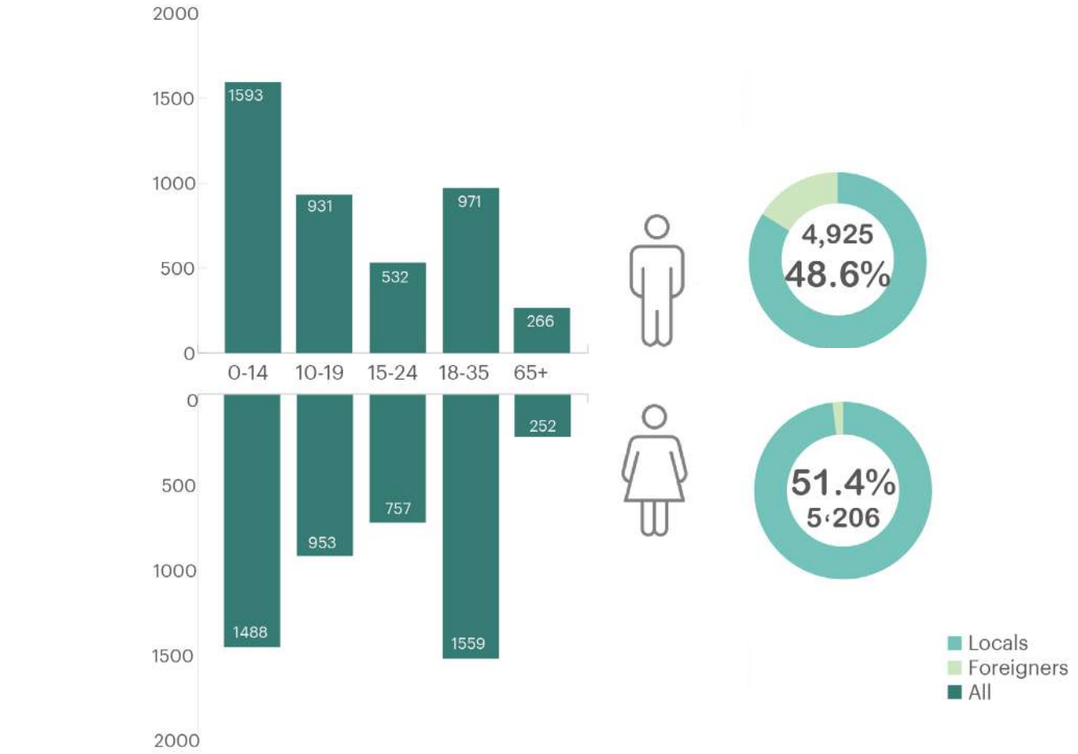


Figure 60. Population and demography of the city

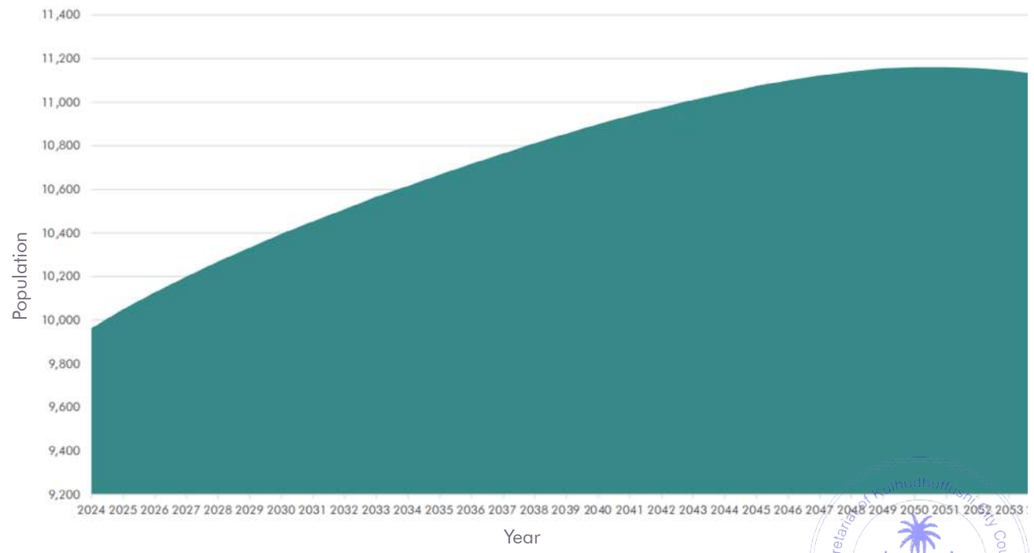


Figure 61. Population Data and Projection (NBS, 2024)

2.2.2 HOUSEHOLDS

As per the 2022 census, Kulhudhuffushi has a total of 1736 housing units. The chart in Figure 62 delineates the housing composition into two primary categories: Housing Units (HU) and Collective Living Quarters (CLQ), typically utilized by expatriate workers. Under HU, the chart further specifies Residential Houses, Apartments, and other housing types, each with its respective count. Additionally, CLQ accounts for units usually designated for expatriate workers. Furthermore, the most popular bedroom composition is 2 and 3 bedrooms. The trend shows that people may prefer multi-generational living. Notably, the Maldives also has one of the highest proportions of female-headed households in the world, mainly due to divorce and absent husbands who are often away for work. In 2014, 38 percent of households in Male' were headed by a female, while in the atolls, this figure was 42 percent .

Kulhudhuffushi City number of households by type of living quarter occupied

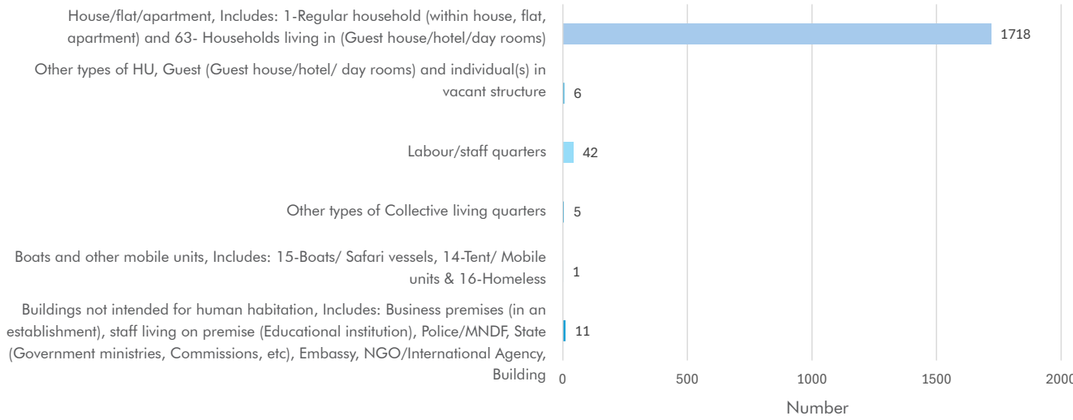


Figure 62. Kulhudhuffushi city number of households by type of living quarters.

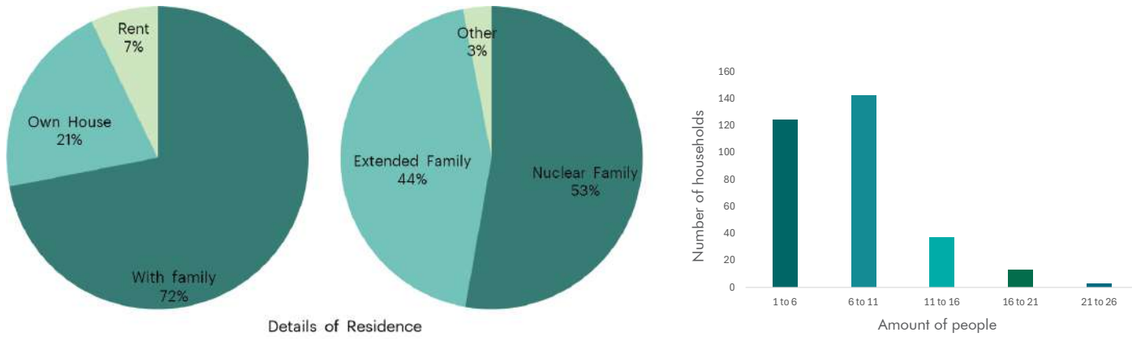


Figure 63. Details of Household Composition (Source: Household Survey (Charrette Studio 2024b)

Kulhudhuffushi City's aerial imagery
Image credit: Charrette team

2.2.3 VULNERABLE GROUPS

The demographic landscape of Kulhudhuffushi City highlights several vulnerable groups, including women, children, the elderly, persons with disabilities, and migrant workers. These groups often encounter barriers to participation in decision-making processes and may face difficulties related to accessibility, employment, and social inclusion (Figure 64). According to data collected from the household survey (Charrette Studio, 2024b) various vulnerabilities are observed across different demographic segments. Individuals with disabilities constitute 16% of the population, with 235 persons registered as such in the disability register, while drug users represent 3%. Migrant workers account for 10% of the population, the elderly comprise 19%, and displaced individuals make up 5% of the population. Moreover, poverty affects a significant portion of the population, with 33% living below the poverty line. Additionally, other vulnerable groups, constituting 3%, face specific challenges that require targeted interventions to address their multifaceted vulnerabilities. Efforts to support these groups necessitate comprehensive strategies that prioritize inclusivity, equity, and social justice to foster a more resilient and supportive community.

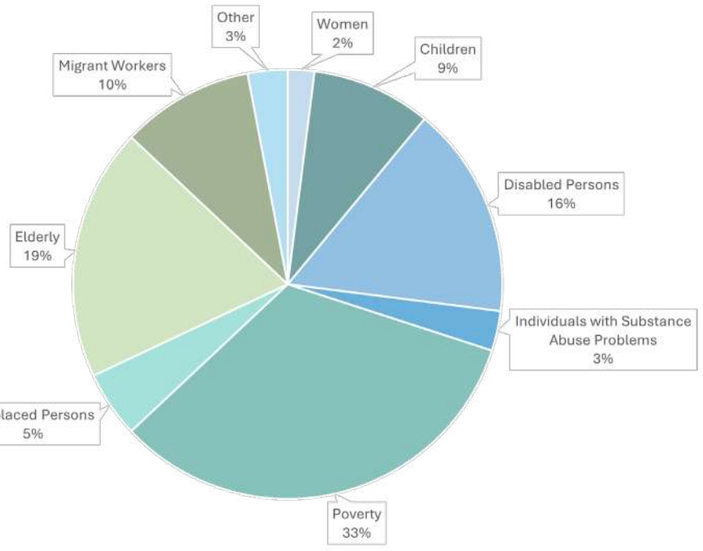


Figure 64. Vulnerable Groups (Source: Household Survey (Charrette Studio, 2024b) and data by KCC (Kulhudhuffushi City Council, 2024))

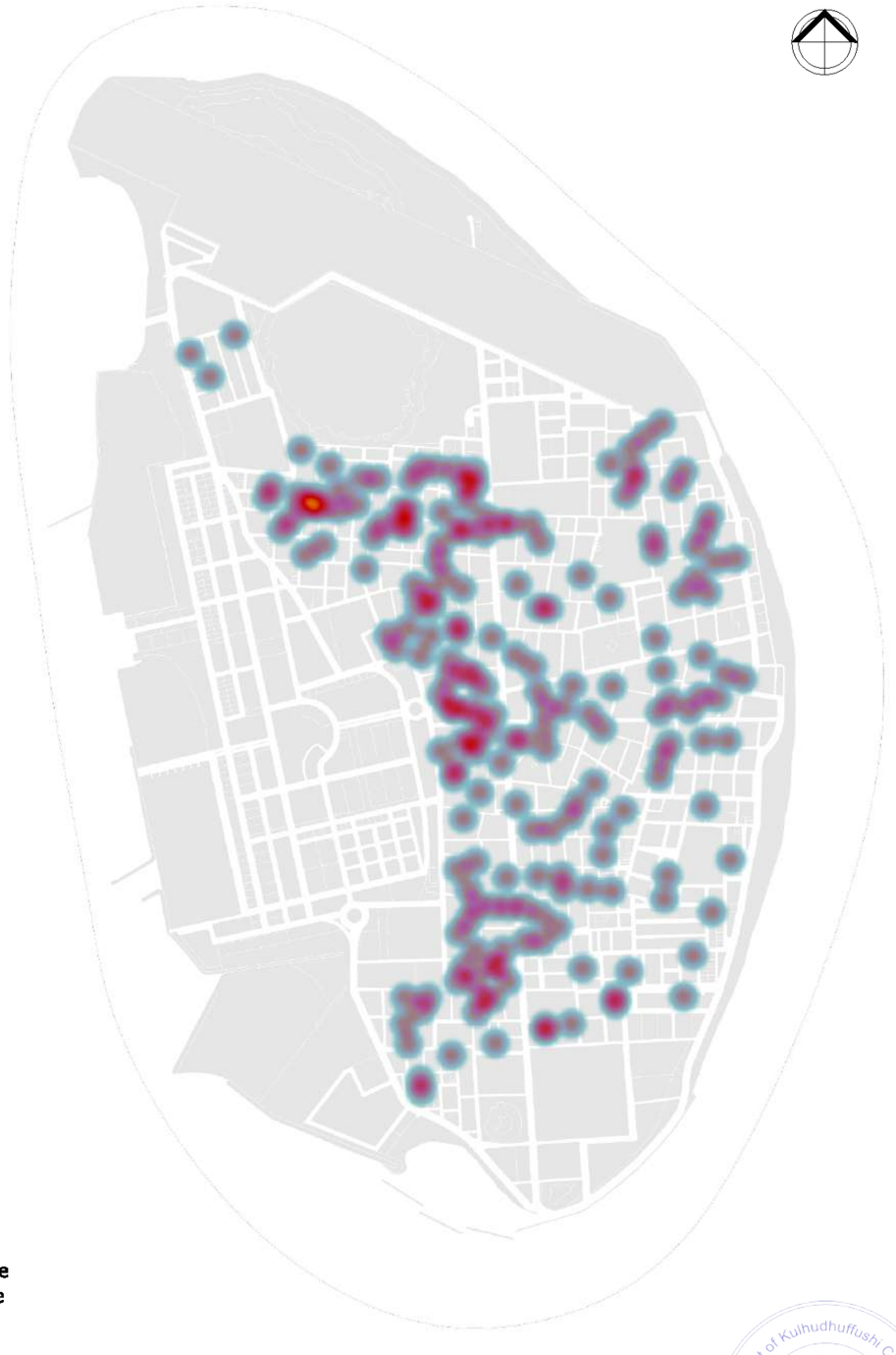


Figure 65. Heat Map of Vulnerable Groups within the island. The map resolution is deliberately diminished to retain this sensitive information. (Data Source: Kulhudhuffushi City Council and Household Survey)

2.3 ECONOMIC ENVIRONMENT

2.3.1 DEMOGRAPHY AND EMPLOYMENT

The residents of the island participate in diverse economic pursuits, with a significant segment of the populace employed in government roles, state-owned enterprises (SOEs), and the private sector, encompassing resorts and companies. Furthermore, a number of locals choose to practice traditional crafts and skills as part of their means of living. Majority of the labor force is employed.

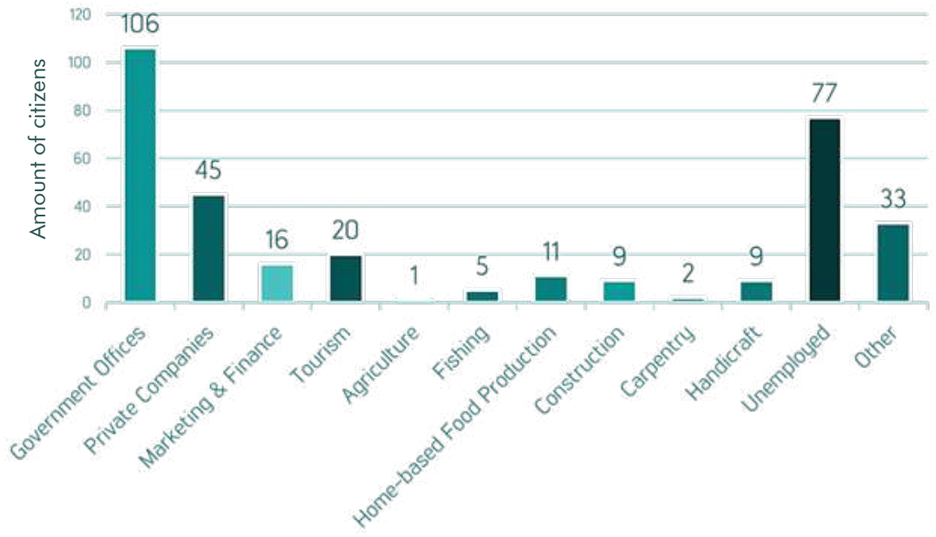


Figure 66. Employment Sectors (Source: Household Survey)

The Socio-Economic Assessment baseline study conducted in 2022 (SIGS, 2022) reveals that the public sector continues to be the primary employer across many islands in the country, including Kulhudhuffushi City. The unemployment rate for Kulhudhuffushi is 4.2%. (NBS, 2022). Out of those employed, 3212 people, as per census 2022, 735 are civil servants working in different government institutions. ((NBS, 2022) with the remaining participants categorized under various 'other' sectors specified in the questionnaire. The construction sector appeared to be a predominant area of employment for men, while women were largely involved in activities such as baking and traditional livelihood practices.

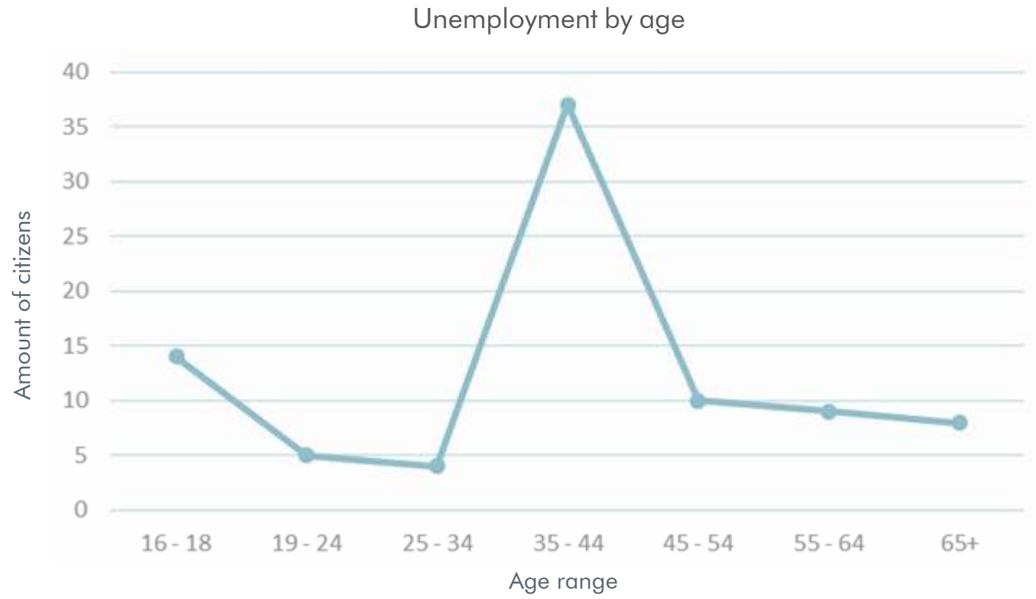


Figure 67. Unemployment Sectors by age (NBS, 2022)

The unemployment rates by age group (Figure 67) reveal that middle-aged adults (35-44) have the highest rate of unemployment with 37 individuals, indicating significant employment challenges for this demographic. Teenagers (16-18) also show notable unemployment with 14 individuals, reflecting difficulties in entering the job market. Older adults (65+) have 8 individuals unemployed, which may be influenced by retirement or health issues. Age groups 45-54 and 55-64 show moderate unemployment rates with 10 and 9 individuals respectively, suggesting potential issues with job displacement. Young adults (19-24 and 25-34) have lower unemployment counts, but these rates still highlight challenges in securing stable employment early in their careers. (NBS, 2022)

2.3.2 ECONOMIC SECTORS

Given the limited access to comprehensive data, it is difficult to precisely determine the economic value of the city-level economy on Kulhudhuffushi. However, using our field survey data and various secondary data, we constructed a model to estimate the economy's value.

The Kulhudhuffushi economy is projected to be worth MVR 2.3 billion. The most significant economic sector is the transportation, utilities, infrastructure, and institutional sectors, which also provide the greatest amount of job opportunities. The next-largest contributor is the combination of wholesale and retail trade, highlighting the city's high general trading activity. The manufacturing sector is also large, expanding the presence of economic activities.

The Table 6 below shows the economic value of Kulhudhuffushi.

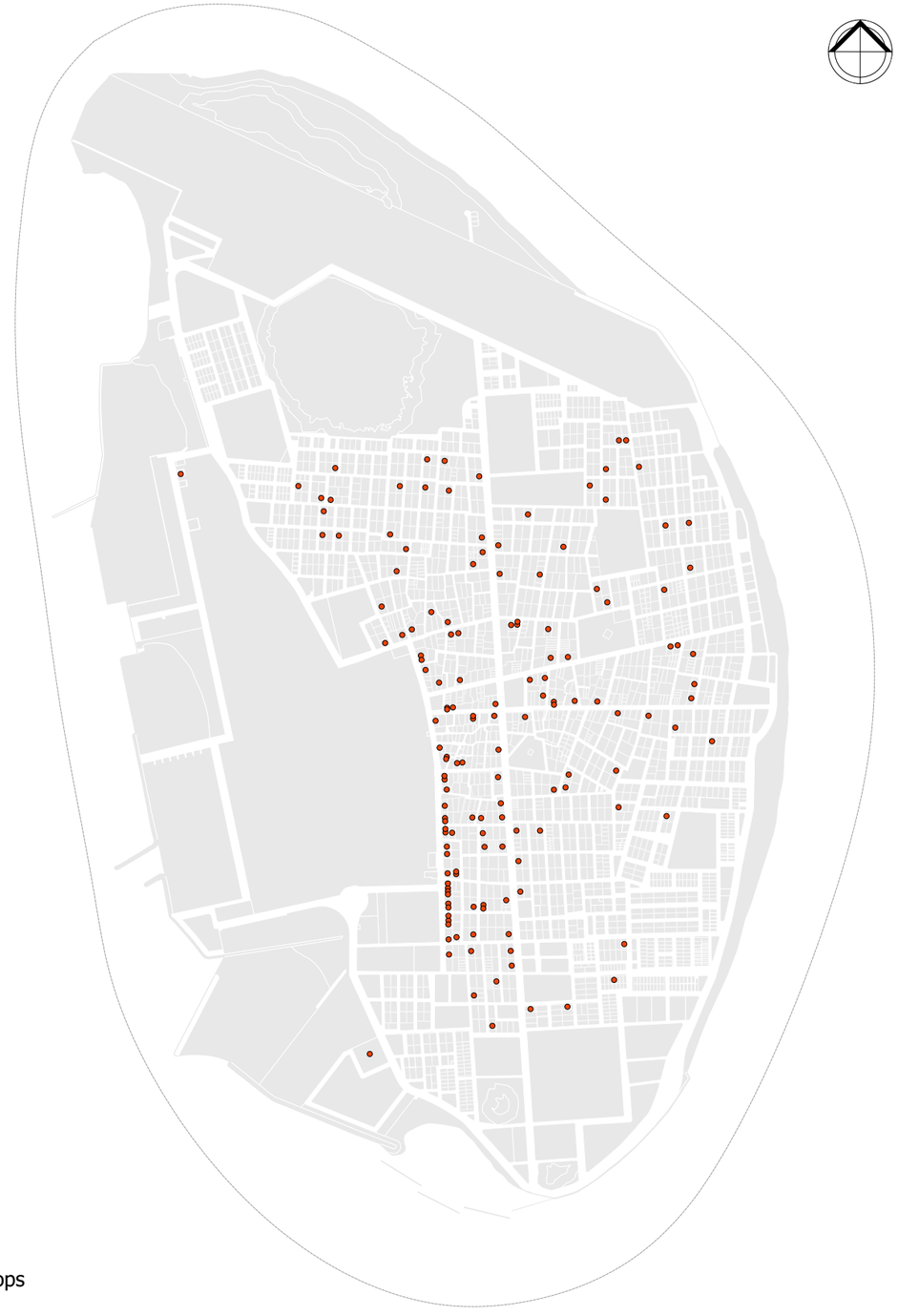
Table 6. Valuation of Economic Sectors in Kulhudhuffushi City.

Sector	Est. Value (MVR)
Wholesale & Retail Trade (Incl. Warehouse, Workshops Café's, Restaurants etc)	342,851,500.00
Fishing	81,814,240.00
Tourism	28,622,400.00
Manufacturing & Construction (Incl. WIP)	307,230,888.00
Institutional (Schools, Hospital, Public/civil buildings etc)	392,645,589.00
Utilities & Infrastructure	421,447,892.00
Transportation	491,976,305.00
Real Estate leasing & business activities	201,150,000.00
Home Based occupational works	2,400,000.00
Other activities (communal & social activities)	5,000,000.00
Total	2,275,138,814.00

This estimated economy value has been increased by several significant investments in recent years, such as regional airport developments, heavy road infrastructure developments, and the expansions of the Kulhudhuffushi harbor. Additionally, the wholesale & retail trade sector has grown significantly with many established businesses opening regional branches in the city.

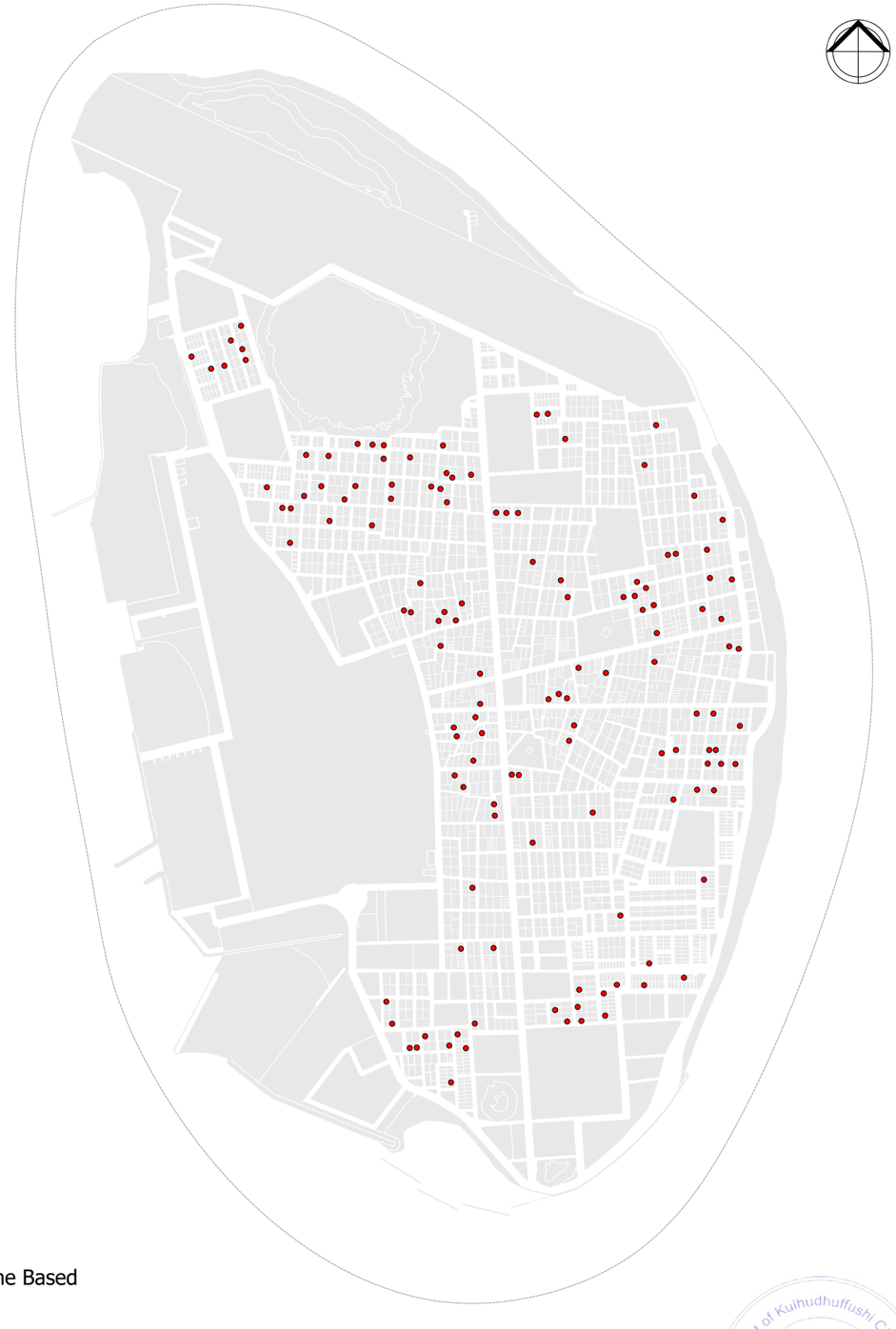
It is important to note that the economic values presented in our study are based on assumptions and should not be viewed as official economic valuations.

Figure 68. Image credit: Zuvaanmasveriya ,HDh. Kulhudhuffushi, https://zuvaanmasveriya.com/hdh-kulhudhuffushi/



Shops

Figure 69. Economic activities in Kulhudhuffushi City; shops locations



Home Based

Figure 70. Economic activities in Kulhudhuffushi City; home based workers locations

Figure 71. Economic activities in Kulhudhuffushi City; café's and restaurant locations

2.4 HOUSE CONDITIONS / BUILT ENVIRONMENT

The Figure 72 delineates Kulhudhuffushi's built environment, serving as a land use plan. Notably, approximately 42% of the current built-up area is allocated for residential purposes, primarily comprising modest 1 to 2-story dwellings situated on individual land plots. The remaining 60% of land is auxiliary functions, with Kulhudhuffushi airport occupying a significant portion alongside expansive tracts of undeveloped vacant land.

This area also houses essential amenities such as schools, mosques, and a hospital. Although a draft land use plan has been proposed for the undeveloped zones, it awaits official approval.

Some households of Kulhudhuffushi City
Image credit: Charrette team

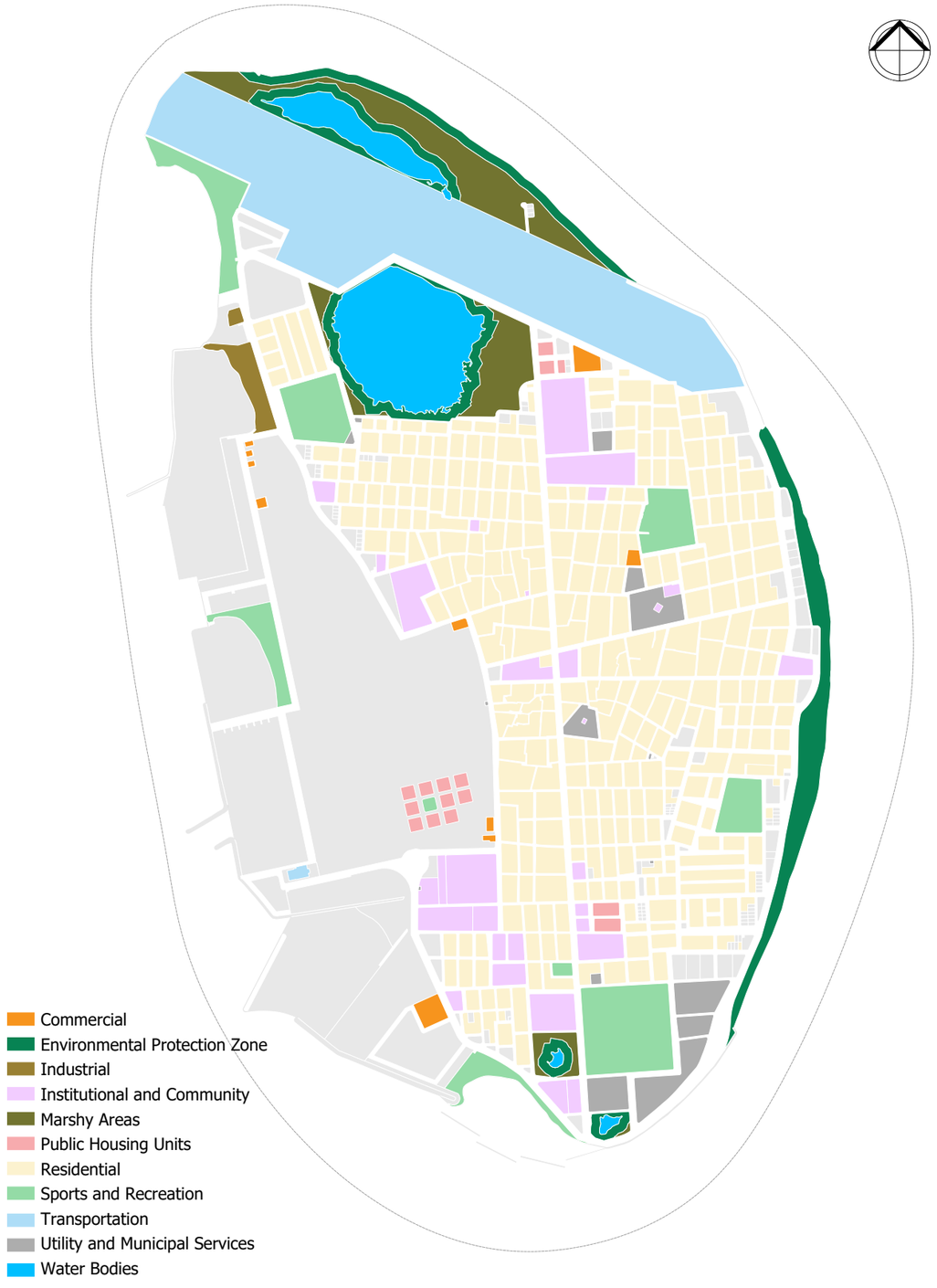


Figure 72. Land Use Plan (LUP) of Kulhudhuffushi (Source: Kulhudhuffushi City Council)

Table 7. Details of residential land plots from the LUP (Source: Kulhudhuffushi City Council)

Number of land plots	2,830
Developed land plots	1,732
Vacant land plots	271
Size	1400sqft 3200 sqft 5000 sqft

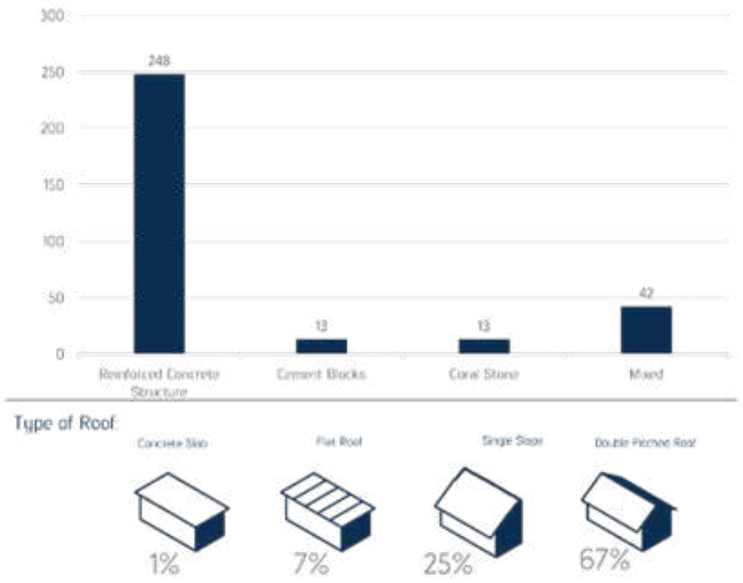


Figure 73. Types of built structures (Source: Household Survey)

The total built environment in Kulhudhuffushi, a substantial 40% consists of privately owned residences, highlighting the significance of understanding their structural characteristics and built form. A household survey was conducted to ascertain the prevalent building materials, revealing a predominant use of masonry and concrete in the construction of new and existing homes (Figure 73). This choice of materials not only ensures durability but also enhances resilience against disasters.

While the survey provided useful information on materials and roof types, an attempt to collect building elevation data was unsuccessful due to challenges in accessing residential buildings within the limited time available for the study.

Given Kulhudhuffushi's susceptibility to heavy rainfall during the monsoon season, assessing the condition of roof structures becomes imperative. The survey findings shed light on this aspect, indicating a commendable level of awareness among homeowners and local builders. Notably, 67% of respondents reported having double-pitched roofs, while 25% opted for single-pitched designs. This architectural preference not only demonstrates an understanding of climatic considerations but also underscores the practical benefits, such as improved rainwater collection and better performance during inclement weather.

2.5 OTHER IMPORTANT ISLAND INFORMATION

2.5.1 INSTITUTIONAL AND SOCIAL NETWORK ANALYSIS

The analysis undertaken in Kulhudhuffushi City explored the complex network of formal and informal institutions, relationships, and interactions among key players involved in disaster preparedness, response, and recovery. By doing thorough mapping (Figure 74) it revealed the diverse and complex functions, duties, and capabilities of government agencies, non-governmental organizations, community-based organizations, religious institutions, and informal networks. Furthermore, the analysis clarified the intricacies of how information is transmitted, how decisions are made, how coordination is achieved, and how resources are distributed within these networks. By understanding these patterns, individuals involved can promote more effective cooperation, enhance channels of communication, and strengthen overall ability to withstand and recover from calamities.

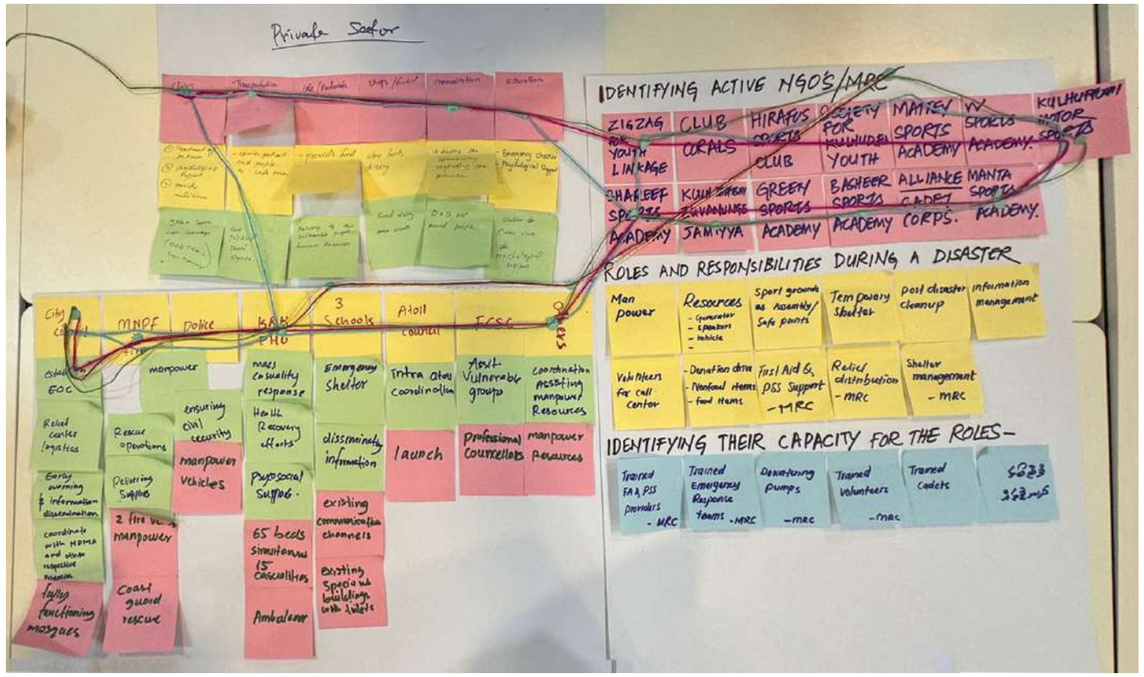


Figure 74. Community Mapping Exercise

The mapping exercise conducted during the consultation with various institutions revealed a comprehensive overview. Participants were organized into three primary categories: government institutions, private sector entities, and NGO/community-based organizations. Delving into their respective roles, responsibilities, and capacities, this session served to validate the data garnered from institutions and surveys. The intricate network of organizations within Kulhudhuffushi City became evident, each possessing unique capacities to respond to disasters. Moreover, it underscored the clear communication protocols established within these institutions, proven effective during crises. However, challenges emerged, notably in intra-agency communication, exacerbated by differing alert levels across agencies, a complexity yet to be fully addressed.

The community mapping exercise in Kulhudhuffushi City identified a range of assets critical for disaster and risk mitigation. Key findings highlight the roles and capacities of private sector, CSOs and government sectors in enhancing community resilience.

In the private sector, clinics can provide medical treatment, psychosocial support, and essential medicines. Transportation services ensure mobility and access during emergencies, while cafes, restaurants, and shops supply food and fuel. Communication services play a vital role in disseminating information, and schools can serve as emergency shelters and offer psychosocial support.

The government sector is well-equipped to manage disaster response and risk mitigation. The City Council is responsible for establishing the Emergency Operations Center (EOC), managing relief logistics, and disseminating early warnings and information in coordination with the National Disaster Management Authority (NDMA). The Maldives National Defence Force (MNDF) provides rescue operations and supply deliveries, supported by fire trucks and coast guard units. The police ensure civil security with their manpower and vehicles.

Kulhudhuffushi Regional Hospital is equipped for mass casualty response and health recovery efforts, with a capacity of 65 beds and the ability to attend to 15 casualties simultaneously. The hospital also has ambulances for emergency transport. The three schools in the city can act as emergency shelters and information dissemination points, utilizing their existing communication channels and spacious buildings.

The Atoll Council facilitates intra-atoll coordination, aided by their launch vessel, while the Family and Children Service Centre (FCSC) supports vulnerable groups with professional counselors.

The community mapping exercise has identified a robust network of NGOs, including MRC, various sports academies, and youth organizations, each equipped with significant disaster response capacities such as manpower, essential resources (generators, vehicles), and infrastructure (sports grounds as safe points, temporary shelters). These NGOs play crucial roles in post-disaster cleanup, information management, volunteer mobilization, donation drives, and providing first aid and psychosocial support. Their coordinated efforts, utilizing trained emergency response teams and existing community infrastructure, underscore a well-prepared and resilient community capable of efficient and effective disaster response and recovery.

These findings emphasize the community's robust network of resources and coordinated efforts across sectors, crucial for effective disaster and risk mitigation in Kulhudhuffushi City.

Figure 75. Image credit: MRC, Healthy Ageing Programme - Kulhudhuffushi City, https://redcrescent.org.mv/healthy-ageing-programme-kulhudhuffushi-city

2.5.2 LIVELIHOOD AND COPING STRATEGIES

The citizens of Kulhudhuffushi City demonstrate their resilience in the face of dangers and disasters through their adoption of livelihood and coping mechanisms. This involves examining the range of livelihoods, such as fishing, agriculture, tourism, trade, and employment in both the public and private sectors. It also entails evaluating the availability of fundamental services such as water, sanitation, healthcare, and education, along with social safety nets and support systems. Furthermore, it is necessary to comprehend conventional methods of dealing with stress, cultural customs, and networks of community support in order to develop resilience. Through the identification of the strengths and weaknesses of livelihood systems and coping methods, interventions can be formulated to improve adaptive capacity and mitigate vulnerability. The data for this evaluation was gathered using a variety of methodologies, including household surveys, interviews with knowledgeable individuals, and participatory techniques such as community mapping and transect walks.

2.5.2.1 Livelihood Dynamics:

Kulhudhuffushi has a diverse economy that includes a combination of government jobs, private sector activity, and involvement in areas such as tourism, fishing, and agriculture. Although the island's economy is not primarily dependent on tourism, a significant section of the population is involved in the sector, highlighting the diverse employment opportunities available. Nevertheless, a significant number of inhabitants continue to rely on government employment as their major source of income, which offers stability and crucial perks. Based on the data from household surveys, it is evident that low-income households make up a mere 9.49% of the population surveyed. This suggests that most of the surveyed population falls into the mid- to high-income brackets, which is likely impacted by the steady employment provided by the government. Simultaneously, the private sector, namely retail establishments, provides additional job prospects, but these may be characterized by differences in wage and job stability when compared to government posts. Further, there are a number of home based workers/self-employed individuals. Some of these work are notable in Kulhudhuffushi livelihood dynamics, these include artisans working in different craftsmanship and trade such as "haalufolh hedhun"; a form of protein and carbohydrate based staple that can be made with everyday products available locally, and uses wood as a source of fuel,"roanu veshun"; the local coir rope made from harvested coconut fiber from the island, and metal work; local varieties of knifes, utensils, metal work tools made within the island that is sourced from metal from the mainstream market and rarely recycled.

Furthermore, although fishing and agriculture do not constitute major businesses, they do offer specialized opportunities for some individuals, highlighting the diverse economic options available on the island. Although there has been a modest annual population change of 2.3% from 2014 to 2022, indicating moderate population growth, and the urban population is rather dense with a population density of 4,018/km^2, the employment situation seems to be steady. Disparities in the work sector contribute to different poverty rates, as indicated by statistics from the Multi-Dimensional Poverty Inde (NBS, 2020). Specifically, self-employed individuals in the primary and secondary sectors experience greater poverty rates.

Figure 76. Image credit: Zuvaanmasveriya ,HDh. Kulhudhuffushi, https://zuvaanmasveriya.com/hdh-kulhudhuffushi/

2.5.2.2 Coping Techniques and Social Support Systems:

When facing economic uncertainties and hardships, the residents of Kulhudhuffushi depend on a variety of coping techniques and social support mechanisms. Household survey data indicates that under difficult circumstances, such as disasters or economic recessions, the community's ability to recover and adapt is strengthened by strong social connections and family relationships. Choosing to remain at home and dedicating time to one's family is shown to be the most prevalent methods of dealing with difficulties, emphasizing the crucial importance of social unity in alleviating challenges. Furthermore, the community's togetherness is seen in their inclination to distribute resources and knowledge in times of disasters, demonstrating a shared mindset of resilience.

Nevertheless, although these casual support organizations offer a vital safety net, the island also struggles with inadequacies in official social support services. Although the Police and Family and Children Service Centre exist, there are still deficiencies in psychosocial support services and mental health provisions. This suggests that there is a requirement for improved systemic infrastructure to cater to the overall well-being of inhabitants. In addition, although there are different types of government assistance programs, such as benefits for vulnerable populations like the elderly, disabled individuals, and single parents, the relatively small number of people receiving these benefits indicates that the current social safety nets may not be sufficient in addressing widespread economic inequalities.

During the COVID-19 pandemic, many individuals in Kulhudhuffushi adopted various coping strategies to mitigate the impact of the crisis. Those who ventured into farming or animal rearing often relied on loans and assistance from family and friends. Similarly, individuals who began own-account activities or small home businesses received support from their personal networks, frequently withdrawing savings to fund their new ventures. Notably, men tended to take more risks by starting new income-generating activities, whereas women were more cautious, relying on savings and familial support to compensate for income losses (SIGS, 2022).

The livelihood patterns and coping mechanisms of Kulhudhuffushi demonstrate the complex relationship between economic resilience, social cohesiveness, and institutional assistance. The economic structure of the island, which combines government employment, private sector involvement, and peripheral sectors, highlights its ability to withstand and adjust to economic changes. Furthermore, the community's dependence on family ties and collective togetherness in the face of hardship underscores the intrinsic resilience of its social structure.

Although informal coping techniques are important sources of support, it is crucial to strengthen formal social support networks in order to overcome current deficiencies in psychosocial treatment and economic aid. It is crucial to prioritize the enhancement of these institutional structures, while also promoting inclusive economic possibilities and tackling income inequalities, in order to guarantee the long-term welfare and ability to withstand changing socio-economic challenges of the population of Kulhudhuffushi.

Kulhudhuffushi City's aerial imagery
Image credit: Charrette team

2.5.3 HISTORICAL PROFILE

The following (Figure 77) is the history of disasters, sex crimes and violence on the island of Kulhudhuffushi City. Understanding this data set is important to understand if there is a historical pattern of violence in the island.

Over the years, the island of Kulhudhuffushi City has weathered a series of tragic incidents, each leaving its mark on the community. The year 1853 saw the devastating destruction of Keylakunu, setting a precedent for the challenges to come. In 1943, a boat lost at sea resulted in the loss of three lives, foreshadowing the recurring theme of maritime peril. The island faced famine in 1947 and again in 1964 after the great famine, highlighting ongoing struggles with food security.

Past hazards at Kulhudhuffushi

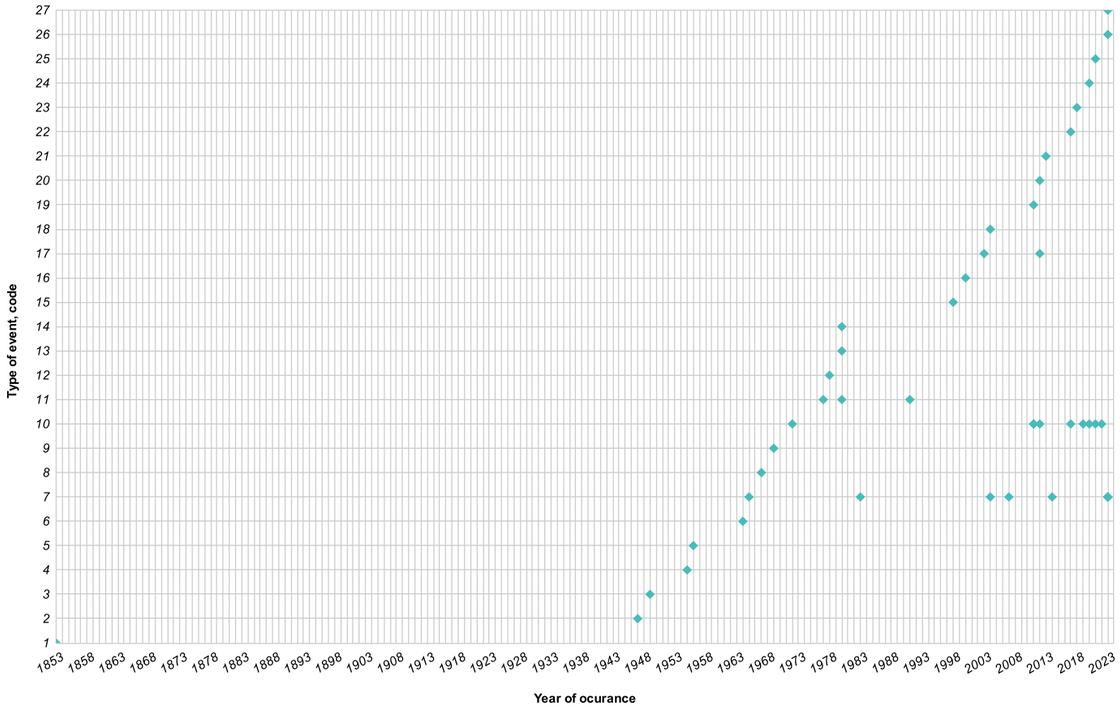


Figure 77. Past hazards overcome by the city.

Social unrest erupted in 1949 and again in 1960, with the arrest of the island chief by the local government during a period of civil discord. Disasters, including storms in 1956, floods in 1969 and 1972, and a tornado in 1980, compounded the island's woes. Tragic incidents of violence and crime, such as a child abduction in 1967, and cases of rape and murder in 1970 and 2007, marred the island's peace. The outbreak of diseases like cholera in 1978 and shigellosis in 1967 brought further hardship. Accidents, including boat sinkings and fires, punctuated the years, with notable incidents like the loss of the Hiyaalu boat in 1998 and the sinking of a boat in 2011, followed by another sinking of the same boat. Instances of abduction, hysteria, and suicide further underscored the island's struggles.

Table 8. List of past hazards overcome by the city (event code)

#	Event
1	Destruction of Keylakunu
2	Famine
3	Social unrest
4	Starting of 'avashu maaluudhu' due to citizen deaths
5	Storm
6	Famine after The Great Famine
7	Fire incident
8	Shigellosis incidents
9	Rain flood
10	Flooding due to heavy rain
11	Body washed ashore
12	Cholera outbreak
13	Tornado at the island
14	High swell waves
15	A falling tree destroyed a residential house
16	Hysteria
17	Swell waves
18	Tsunami
19	Damage due to heavy rain and flooding
20	Incident related to a gas cylinder
21	Acid rain, water supply contaminated
22	Reclamation of the island's mangrove
23	Thunder striking Friday mosque / 'Hukuru Miskiy'
24	Covid-19 nationwide outbreak
25	Catching of a snake
26	Exploding of a gas cylinder at Kulhudhuffushi airport
27	Filariasis outbreak

These records underreport some of the incidents and accidents that are recorded within the law enforcement authorities which diminishes the accuracy of the referenced record. However, we report the historical data as is, to stay true to the methodology. Further, when specific hazards were analyzed, we used the specific data available and provided for the team (Table 8).

CHAPTER 3 -
RISK ASSESSMENT

The HVCA provides the assessments of the identified risks for Kulhudhuffushi City. The specific risks identified, analyzed using the available data and quantified using a standardized index. The risk assessment tool and the justification of the use is provided in the methodology section. The flow of the chapter is that the hazards, vulnerabilities and capacities are described and analyzed.

Kulhudhuffushi City's aerial imagery
Image credit: MRC team

3.1 HAZARDS

3.1.1 IDENTIFYING HAZARDS AND THEIR POTENTIAL IMPACTS ON THE COMMUNITY

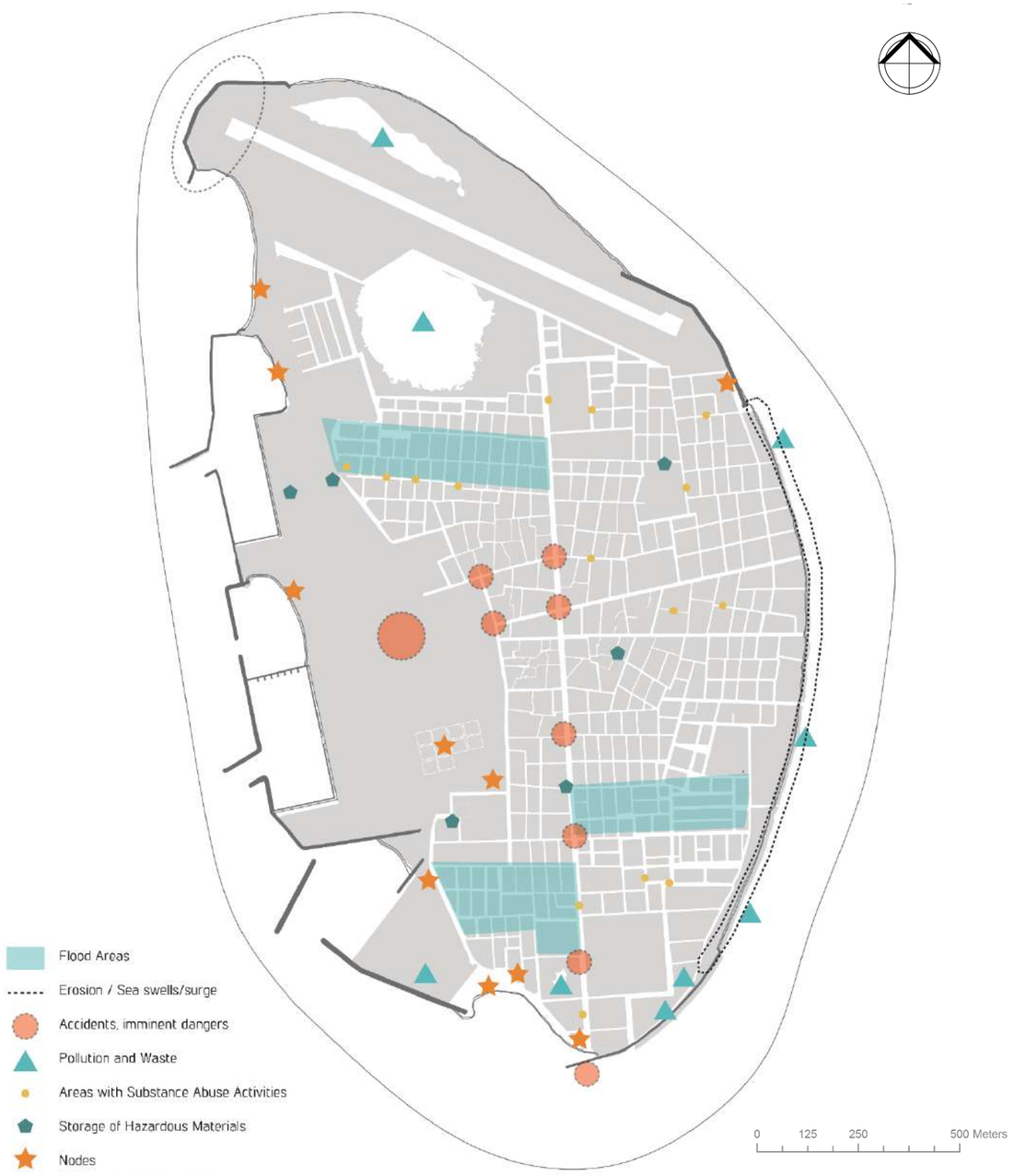


Figure 78. Hazards mapped for the city. The hazards mapped are the flood areas, erosion areas, accident prone zones, pollution and waste collected areas, areas with substance abuse, areas with hazardous material stored, and nodes.

The combination of historical and empirical data available for the island can identify hazards. The social observations of the community, and the observations of the built environment and the biological environment can define the vulnerabilities and the potential impacts the island and the community can be exposed to.

Henceforth, the identification of hazards and their potential impacts are explored.

Figure 79. Mapping Exercise outputs during the stakeholder consultations

3.1.2 SHORTLISTED HAZARDS

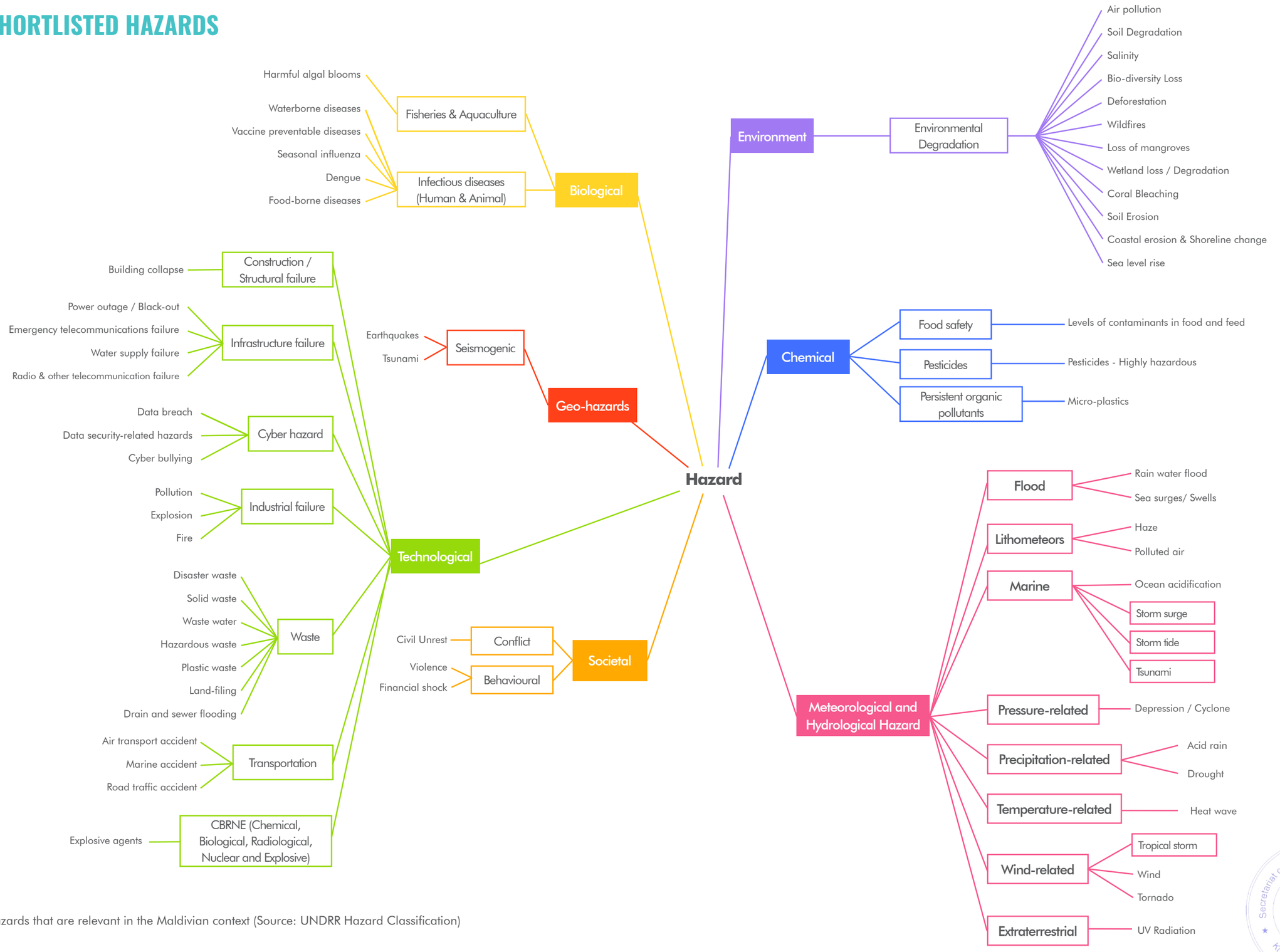


Figure 80. Hazards that are relevant in the Maldivian context (Source: UNDRR Hazard Classification)

The diagram above (Figure 80) shows the hazards that are relevant to Kulhudhuffushi City derived from Hazard Definition and Classification Review (UNDRR & ISC, 2020). The main families of hazards are; environmental, biological, geo-hazards, chemical, technological, metrological, and social. The subcategories that branch further are the groups of hazards, and the main hazards.

The Figure 81 below shows the identified specific hazards that is further explored in this HVCA for the Kulhudhuffushi City, within the identified families of hazards.

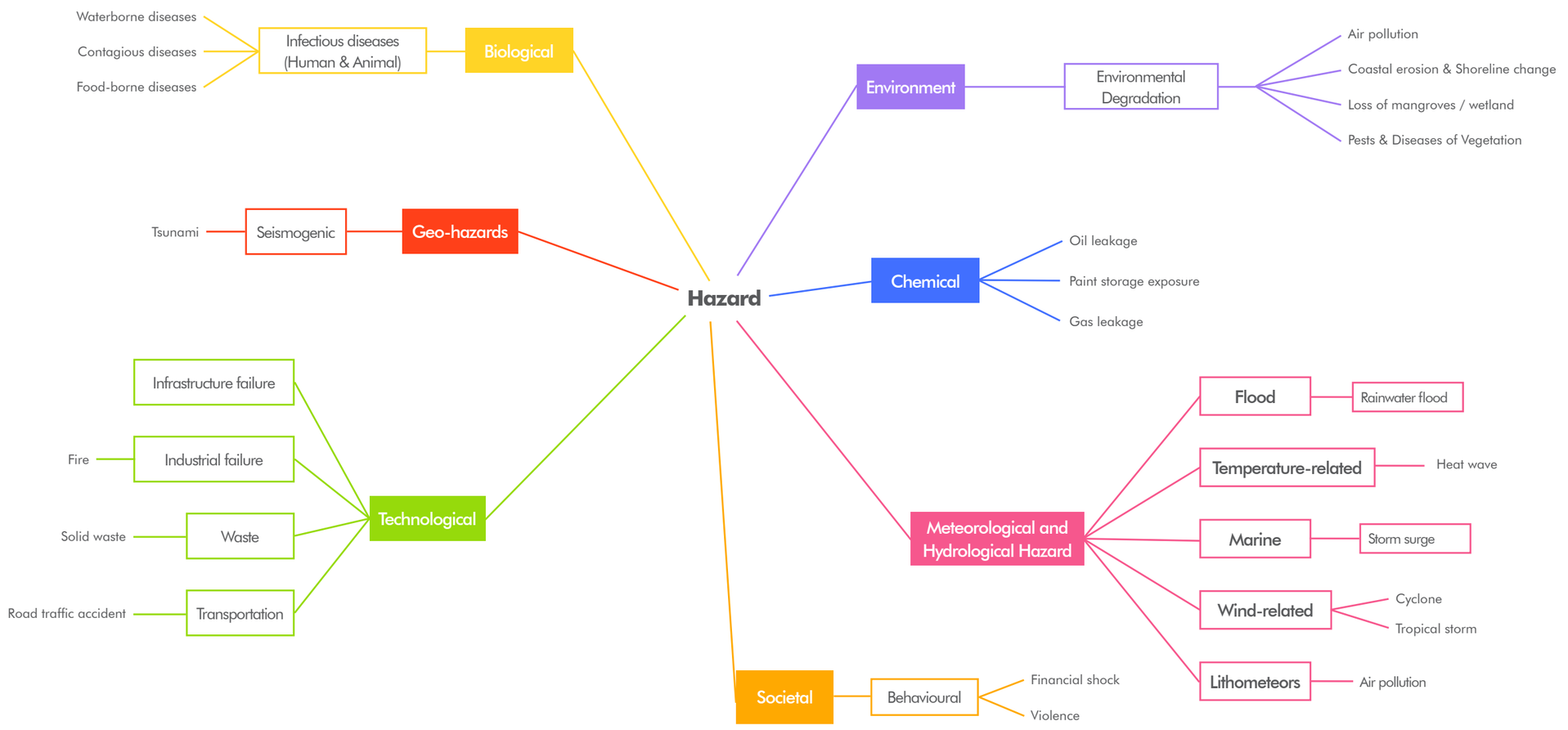


Figure 81. Hazards relevant to Kulhudhuffushi City

The table below describes the essence of the issues identified as hazards and discusses some of the considerations.

Table 9. Details of Hazards Applicable to Kulhudhuffushi City

Hazard Classification	Hazard Family	Hazard	Identification description and context of the hazard
Biological Hazards			
	Infectious Diseases	Waterborne Diseases	The historical profile shows incidents of waterborne disease in the island. Historically water borne diseases have the potential to spread throughout and harm the residents of the island. Locals report of the spread of cholera in the 70s and the heavy loss of human life due to this spread. The level of exposure back then was much higher in comparison to now and as a result the impact was devastating. The locals are not as highly exposed as before due to the available alternative water sources such as RO and integrated harvesting. However, the same hazard exists as a major threat that is relevant to the island in case of a loss of the alternative methodologies of water harvesting. Further, although the locals were to change over to the reverse osmosis water supply available by MWSC, not all had carried out the process. As a result, the locals use the water from the water table, which is exposed to salt intrusion from inundation, leachate from the legacy waste and the numerous open wells present throughout the island.
		Contagious Diseases	The island being a central hub, the residents are exposed to the incoming and the outgoing residents of the area. The airport, the port, and the 'Honihiru baazaar', cafes and restaurants, shops and schools are points of interaction. As a result, any contagious disease that can spread from contact may spread through interactions. The close proximity of the resident locals and the high density of locals per square meter increases the possibility of a spread of contagious diseases in the island. Further, existing hospitals in the island are another cause for a spread and a point of hazard introduction to the island due to medical tourism.
		Food Borne Diseases	The island is open to numerous neighboring islands due to the commerce, medical services, and other activities in the island. This brings in numerous possibilities for interactions within the cafes, restaurants and markets in the city. The locals will be exposed to the hazards through daily interactions.
		Vector Borne Diseases	Apart from the advantages of the open water bodies within the peripheries of the island, one of the disadvantages of these open spaces is the presence of insects that can potentially spread vector borne diseases. Mosquitoes being dominant breeders in these areas, can easily spread diseases through its life cycle. The exposure as of now is high due to the human population living so closely with the water bodies.

Hazard Classification	Hazard Family	Hazard	Identification description and context of the hazard
Hydrometeorological Hazards			
	Marine	Storm Surge	The island being on the eastern rim of the Maldives is exposed to the effects of storm surges from the east.
	Temperature-related	Heatwave	Rapid urbanization and the loss of provision for green space in the development that followed had led to loss of green spaces and an increase in the surface area of the island. As a result the island has a built environment percentage, increasing the urban temperature. Heat waves, although inevitable in the equatorial zones, when paired with the seasonal changes of monsoon (Table 3– Monsoon Calendar of Maldives with the Dhivehi name for the monsoon classification.) and global climate change can have a devastating effect on the resident population. Further, the anthropological changes brought about by the local residents to make the island habitable can further alleviate the effects of heat. The added reflective surfaces and the constant green removal can be major contributors to the island heat effect. This can increase the effect the impact has on the resident population.
	Flood	Coastal Flooding (Storm Surges)	Kulhudhuffushi is getting increasingly urbanized hence development of housing and infrastructure along with modifications on the coastal zone are increasing. These developments reduce the natural resilience of the island and increase potential exposure to hazards on the coast. Storm surges have been identified in preceding studies as one of the hazards. Kulhudhuffushi is situated in the eastern rim of the atoll which would offer less protection from storm surges and tsunamis originating from the East Indian Ocean. According to Detailed Island Risk Assessment in Maldives DIRAM (MEE, 2013), the severity of the storm surges in the Maldives is like that of swell waves. However it has a less frequency of occurrence. Flooding due to sea level rise, tides and surges is estimated from studies and illustrated depicting one scenario for the year 2030 (Kulp & Strauss, 2019). The flooded area correlates to low-lying topography generated by the High-Resolution Digital Elevation Model for the project. Further analysis reveals that Kulhudhuffushi is situated in the highest-level Hazard Zone where storm surges of 1.32 meters have been estimated (Developing a Disaster Risk Profile for Maldives, 2006)

Hazard Classification	Hazard Family	Hazard	Identification description and context of the hazard
Hydrometeorological Hazards			
	Wind Related	Cyclone and Surface-water Flooding	The built infrastructure effectively lowered the drain water infiltration capacity of the island. This can increase the flowing water on the rough surfaces and further alleviate the impact magnitude by the eventual flow infiltration to the households.
		Tropical Storm	Historically the island had the potential to drain the flood waters to the available surface catchment area of the island. • The urban infrastructure was similar to the traditional houses. Small surface area off the built up houses ensured that the amount of rain that is blown off by the housing structure was a minimum. • The open courtyards ensured containment and infiltration of the water in the household boundary. • The coral limestone walls retain the water in the higher surface area and moss grown on the wall and slows the trickle that reaches the dirt road. • The native dirt roads which were not compacted ensured the drainage and containment of the rainwater Heavy rainfall is more than 0.30 inches (7.62mm) of rain per hour. When we consider the rainfall of the past 3 years in Kulhudhuffushi City, the number of hours it rained above 7.5mm is 50 hours of 613 hours, that is 8.9% of the hours it rained in 2021, 22 hours of 931 hours that is 2.4 hours, that is 2.36% of the hours it rained in 2022, and 32 hours of 297 hours, that is 10.8% of the hours it rained in 2023. The latest recorded rainfall year shows a decrease in the total rainfall hours, but a high volume. This results in periodic floods. The current island infrastructure can be considered a result of a boom in the construction industry. • The urban infrastructure is built high and results in a higher vertical surface area that contacts the rain water and collects water increasing the trickle from the built structures to the roads. • Typically, the entire household is built completely utilizing the said footprint. The developments often come with hard concrete structures that are inside the courtyard minimizing the water infiltration. Further, the foundation laid: that is laid to a depth of 1m or below, takes up the space of the entire footprint that can potentially drain the rainwater. In most of these households the water directed to the streets. Further, even if the water is to be drained into the ground as per the regulation R22/2021, the practice is not monitored and implemented in all civil developments. • The walls of the new development are mostly plastered, if not plastered, built using hollow bricks, which are built to not retain water. • The roads are built to direct water to the drainage areas. The drainage areas are mostly infiltration drainages. The roads are compacted after the road developments as a result the water infiltration is not as per the design requirements. • The roads are built factoring in the native ground elevation, some areas are lower than others. Further, some houses are built lower than the others. This results in pockets of retention of the runoff. • The mangroves are now contained by built infrastructure, as a result the mangroves are going through a process of succession that can change the morphology of the structure to a wetland. This can minimize the runoff containment capacity of the wetland. Making the houses in the near vicinity potential hazard zones. Cyclones and tropical storms are recorded in the historical profile. The 'loss of Keylakunu' is assumed to be due to a cyclone that impacted the area. The island's built environment is not at any significant advantage when it comes to the impact of Cyclones and tropical storms.

Hazard Classification	Hazard Family	Hazard	Identification description and context of the hazard
Technological Hazards			
	Waste	Solid Waste	Most of the 860 metric tons of waste generated daily in the Maldives is burned out in the open, as landfills are not possible in a nation that is 99% water. Although the island contains bins that can promote enabling behavior for cleaner cities, the number of intervention points are less. The island has a legacy waste heap. This heap is situated on the sand backfilled wetland footprint that was on the south. The method of reclamation and whether a geo layer was placed to manage or mitigate the leachate is unclear. WAMCO, (national waste management branch) is now managing the waste. As of the time of the survey, the island has signed with WAMCO for waste management. Currently there is no waste management system in place. All types of waste including hazardous waste is sent to the same location. . However, the waste is proposed to be moved to a waste transfer station. The current practice is not waste management as the area does not sort the waste we can define it as a transfer station. Locals are accustomed to the waste collection process where the waste is transported daily by the locals to the collection point.
	Industrial Failure/ Non-compliance	Fire	Fire is a specifically prominent hazard as some houses with wooden frames and decks exist. However, most households are not completely wooden. Many households are adjacent to the waste collection area, which is known for spontaneous methane fires. Many warehouses that store paint and other hazardous materials are papered inside the island village. Further, garages are embedded into the residential areas of the city, specifically in the northern tip of the island. In case of a fire, the fire can spread in the maize like areas of the city. The waste heap is a constant source of smoke. The ignition source is assumed to be spontaneous gaseous methane fires due to the heat. Some locals report that some fires are started by residents. However, neither us or any local authorities have any evidence to back up the allegations. The locals live in close proximity to the smoke and are exposed to the impacts.
		Infrastructure Failure	The critical infrastructures in the city are most non engineered structures and semi engineered structures. This makes the buildings susceptible to extreme weather events and natural hazards. Structures in poor condition, especially those in hazard-prone areas, are at a heightened risk of severed damage during disasters. Although the power house is situated in a high-risk zone, damage to its systems is unlikely because the engines and distribution boards have been elevated, making them resilient to flooding, particularly after the 2004 tsunami. There is no specific management or maintenance procedure for most of the structures. Funding for management or further development is often inaccessible to locals, as the required equity for construction loan applications is typically unattainable.
		Traffic Accidents	In the maize like city, the number of vehicles that can be on the road is not managed. Except for the main road, mainly the smaller inner roads lack the pedestrian pathway. The lack of pathways can be a potential hazard to the locals. The main road lacks a divider and is a major hazard to the safe and unsafe driver. Traffic accidents are quite common on the island. The narrow roads lead to blind spots that increase the risk of hazard of collisions throughout the island. Further, the island contains a major road that runs across the island that has the main buffer removed to enable cross lane change; proposed by the locals during the project phase. This removal has led to incidents and accidents of varying impacts and is a major contributor to the number of accidents in the island.

Hazard Classification	Hazard Family	Hazard	Identification description and context of the hazard
Geohazards			
	Seismogenic (Earthquake)	Tsunami	The island can be affected by an event that can affect all of Maldives. Maldives is in the Tsunami impact zone from 2 major systemic faults. Historically, the 2004 Tsunami which was the most documented, did not have a major impact on Kulhudhuffushi City due to the elevation of the island. However, this is not to say that an event will not have an impact on the island. The locals did not experience the 2004 Tsunami like most of the local island of Maldives and lacked the relief experience of then.
Environmental Hazards			
	Environmental Degradation	Air Pollution	Effects of air pollution are evident on the island. The island is composed of coralline loose sand. The main composition of the sand is accreted and is naturally vegetated. Clearing for habitation, road infrastructure and cultural habits such as trying to maintain a road clear of bush vegetation, and any plant that can add leaf litter has led to a road system devoid of organic matter that can retain the smaller finer sand particles. Thus, feeding the dust pollution problem of the island. Further, the leftover sediment bank of the reclaimed land of the island and the lack of infrastructure on the said area further adds to the particulate matter pollution in the air of the island. The island is exposed to the Haze from the Asian continent. The residents are exposed to the dust from the numerous construction projects actively happening and proposed in the island. The lack of trees and lack of implementation of a dust management system from the construction sites in the island further alleviates the issue. The fires from the waste management area is another factor that adds to the particulate matter composition of the island. The waste management area contains a legacy waste heap that is not managed, hence due to the lack of turnover of the waste to expel the methane gas, burning is often observed. These fires are hypothesized as spontaneous methane fires. The fires are often managed by the local fire departments if need be. These fires add to the particulate matter pollution of the island as well. The embedded garages and workshops in the houses are a major source of air pollution.
	Environmental Degradation	Coastal Erosion and Shoreline change	The island footprint has seen an expansion over the years. The western side of the island has seen a major reclamation expansion which is retained by a quay wall on the harbor side. The northern mangrove shoreline has been reclaimed for the airport project. A component of the north eastern side and the south eastern side have shore protection installed. Coastal erosion is managed in the island through hard engineered structures. There is evidence of extreme recession in the artificial beach on the south western side and the eastern side. The eastern side has a very high berm. Potential erosion overtime of the eastern ridge of the island resulting in loss of the only available natural woodland of the island and the built infrastructure of the island. With the current shore protection on a portion of the island shoreline to protect the airport development, the eastern shoreline is subjected to an erosion that can only be described as a placement loss erosion, whereby the northern half of the eastern shoreline is rich in sediment with a smaller grain size and the eastern side is rich with sediment with bigger grain size and thus is shows steeper berms with the toe of the beach closer to the berm. The larger grain size and steeper slopes can also be associated with varying levels of exposure to wave action.

Hazard Classification	Hazard Family	Hazard	Identification description and context of the hazard
Environmental Hazards			
	Environmental Degradation	Loss of Mangroves	In Maldives and elsewhere, the mangroves are the first to go when it comes to infrastructure projects. Kulhudhuffushi City is no exception and as a result the mangrove vegetation of the island is the first to be reclaimed, this area is currently the waste deposit area. This is followed by the development of the airport on the mangrove and wetland. The remaining mangroves of the island are on the northern side of the island. The previously single section is now split into three sections due to the airport being developed and can function as three separate wetlands. Current ring road project tied with the cable project is being carried out in the eastern woodland, further increasing the edge effect of the woodland. This can have devastating effects on the existing biodiversity. Due to sediment being eroded from the island with the rain water flooding down to the northern side of the island, the sediment collects to the previously open mangroves. Eventually this will fill the mangrove and result in a wetland. The change in the sediment will eventually result in the mangrove changing into a wetland
		Pests and Disease of Vegetation	Pests are a major concern within the locals of the island, numerous organisms of the order diptera are present in the island. This is mostly due the increased urban built footprint and the overall loss of natural predators coupled with the addition of breeding ground as built infrastructure and unmanaged waste in the island. Mosquitos, house flies and fruit flies are a common pest on the island. In addition, insects of the order blattodea and infra order isoptera are common in the urban landscape notably cockroaches and termites respectively. Further, on the eastern side, locals note the concentration of organisms of the order coleoptera and lepidoptera, for example variations of beetles and butterfly worms (Huvani). Both pose a threat to the remaining woodland and human resident population. Further, the additional built infrastructure is a refuge to numerous mammals such as rodents, bats and domestic stray cats. This further alleviates the issues that arise due to pests and associated host organisms occupying the same space as humans.

Hazard Classification	Hazard Family	Hazard	Identification description and context of the hazard
Social Hazards			
	Crime	Drugs	Drugs pose a significant hazard in Kulhudhuffushi City, with reports of drug-related crimes including trafficking, possession, and consumption. The city may face challenges related to drug abuse, addiction, and associated social and health consequences. Efforts to address the drug hazard may involve law enforcement interventions, community outreach programs, rehabilitation services, and public awareness campaigns.
		Assault	Assault is a hazard characterized by physical violence, threats, or intimidation within Kulhudhuffushi City. Incidents of assault may have occurred in various settings, including public spaces, households, and establishments.The details of these data has not been received yet. Addressing the assault hazard requires effective law enforcement responses, victim support services, community-based conflict resolution mechanisms, and initiatives to promote non-violent behaviors.

Hazard Classification	Hazard Family	Hazard	Identification description and context of the hazard
Social Hazards			
	Crime	Theft	Theft is a prevalent hazard in Kulhudhuffushi City, with the highest number of occurrences as a crime in Kulhudhuffushi City. The city may experience challenges related to property crime, loss of valuables, and feelings of insecurity among residents. Strategies to address the theft hazard may include enhancing security measures, neighborhood watch programs, community policing initiatives, and public education on crime prevention.
		Sexual Offenses	Sexual offences represent a serious hazard in Kulhudhuffushi City, encompassing acts of sexual assault, harassment, and exploitation. Victims of sexual offenses may experience physical and psychological trauma, with long-term consequences for their well-being. Efforts to address the sexual offenses hazard may involve strengthening legal protections, providing survivor support services, promoting consent education, and fostering a culture of respect and gender equality.
		Domestic Violence	Domestic violence is a significant hazard within households in Kulhudhuffushi City, involving physical, emotional, or sexual abuse among intimate partners or family members. Victims of domestic violence may face barriers to seeking help, including fear of reprisal, economic dependence, and social stigma. Addressing the domestic violence hazard requires a multi-sectoral approach, including law enforcement interventions, shelter services, counseling support, legal protections, and community awareness campaigns promoting healthy relationships and gender equality.
	Economic	Financial Shock	The financial shock in times of disaster is significantly compounded by the systematic issues within the broader Maldivian financial landscape. The difficulty in accessing finance and high interest rates in the Maldives, poses a risk to the private businesses to recover independently. These financial constraints can severely limit the capacity of both individuals and businesses to rebuild and restore the economy. The lack of readily accessible financial resources and affordable credit options means that the recovery efforts are often delayed or inadequate, leading to prolonged economic disruptions.
Hazard Classification	Hazard Family	Hazard	Identification description and context of the hazard
Chemical hazards			
	Chemical hazards	Chemical Exposure	The locals are exposed to numerous chemical hazards due to the forced close proximity of the locals to the workshop that fix vehicles and other fiber work done openly on the island. Further, storage and selling of numerous chemicals is an everyday activity that increases the exposure. The petrol station established and upcoming on the island and the petrol being sold in small shops on the island is a major concern identified by some key informants for the project.

3.1.3 HAZARDS PERCEIVED BY COMMUNITY

Consolidated data from the household survey (Figure 82) showing likelihood versus impact of perceived hazards in Kulhudhuffushi City and within the vicinity of the respondent's home. As per the community, the hazards identified in order of decreasing severity and likelihood are heatwave, sea surge/swells, air pollution, flooding, epidemic, storm surges, fire, erosion, water scarcity, and food scarcity. These local hazards were incorporated into the study and further analyzed.

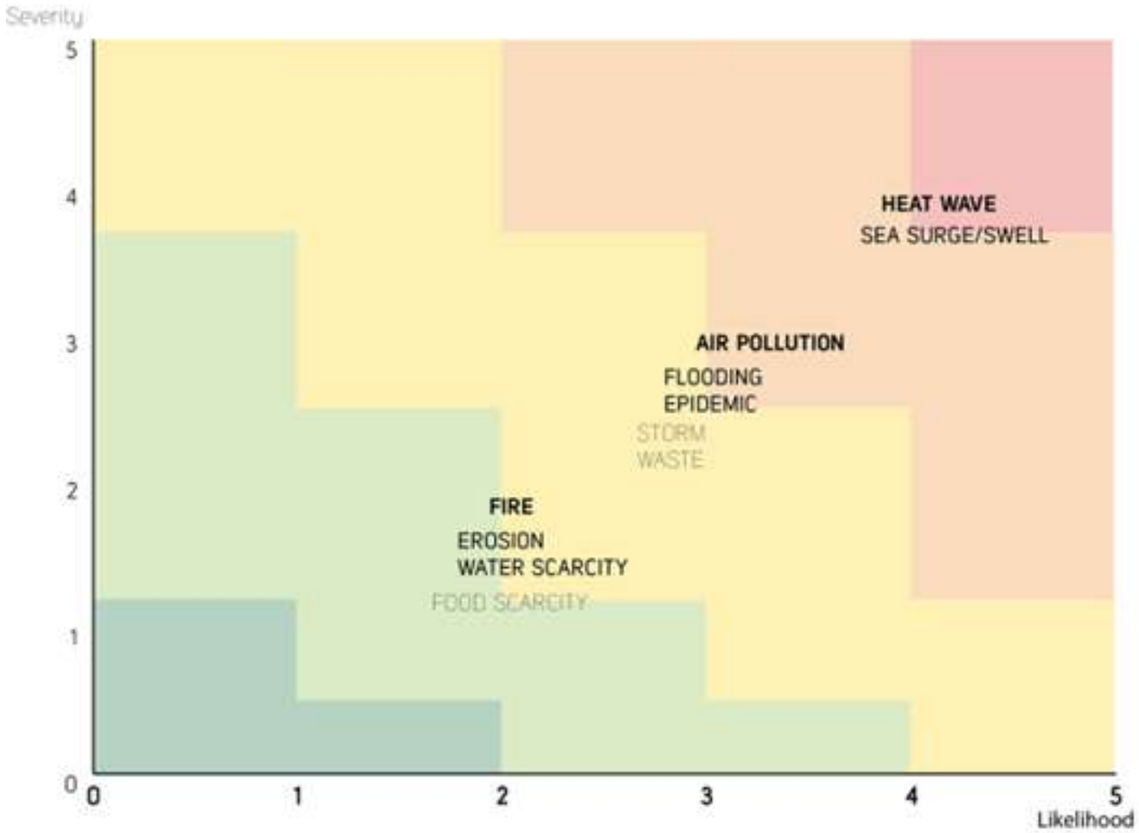


Figure 82. Risk Matrix of Hazards Perceived by the Community

3.2 VULNERABILITIES

After the analysis of the hazards, the transition is made to the vulnerabilities within the island. This chapter explores the factors of vulnerability that are prominent in the context of Kulhudhuffushi City.

3.2.1 SOCIAL VULNERABILITIES

3.2.1.1 Understanding Social Vulnerabilities in Kulhudhuffushi City

Social vulnerabilities in Kulhudhuffushi City encompass a range of factors that contribute to varying degrees of susceptibility to hazards and disasters among different segments of the population. These factors include socioeconomic status, education levels, access to healthcare, housing conditions, age, gender, ethnicity, and disability status. For example, marginalized groups such as the elderly, women, children, persons with disabilities, migrant workers and low-income households often face heightened vulnerability due to limited access to resources, social exclusion, and dependency on informal networks. Understanding these social vulnerabilities is essential for identifying at-risk populations and tailoring interventions to address their specific needs. Data for this assessment was collected through a comprehensive household survey conducted by trained local enumerators.

3.2.1.2 Key Factors Contributing to Social Vulnerability:

Socioeconomic Status:

Disparities in income, employment opportunities, and access to basic services and the lack of support systems contribute significantly to social vulnerability. Low-income households often lack the resources to prepare for and recover from disasters, exacerbating their susceptibility to adverse impacts. According to the data collected from the household survey (Charrette Studio, 2024b) in Kulhudhuffushi City almost 10% of the population is low-income households.

Education Levels:

Limited access to quality education hinders individuals' ability to understand and respond effectively to hazards and disasters. Illiteracy and low educational attainment among certain segments of the population further compound their vulnerability, hindering their access to critical information and resources.

In Kulhudhuffushi City, educational opportunities are readily available, spanning from preschool to higher education levels. The city boasts three schools offering education from preschool to 10th grade, with one school extending its offerings to A Levels or 12th grade, as per the council's data (Kulhudhuffushi City Council, 2024). Additionally, two universities are present in the city. The educational attainment of the population reflects a notable level of achievement, with a significant portion having completed O-level qualifications, as indicated by 51 out of 319 respondents in the household survey. Additionally, 15 individuals have attained bachelor's degrees, underscoring the community's commitment to and engagement with higher education pursuits, as per the data collected from the household survey (Charrette Studio, 2024b).

Figure 83. MNU campus at Kulhudhuffushi City, Image credit: MNU,Kulhudhuffushi, https://mnu.edu.mv/kulhudhuffushi/

Furthermore, the lack of awareness on issues such as mental health, abuse prevention, disaster management, and life skills can increase the social vulnerability of society.

Access to Healthcare:

Inadequate access to healthcare services, including preventative care and emergency medical assistance, increases vulnerability to health-related disasters such as disease outbreaks or disasters. Limited healthcare infrastructure and resources disproportionately affect vulnerable populations, including the elderly and individuals with chronic illnesses.

It is notable that Kulhudhuffushi City has a strong healthcare system, however, given that Kulhudhuffushi Hospital is the regional hospital and caters for a large number of the population. Social vulnerability could increase given the lack of mental health care, psychosocial support, and the lack of quality service provision to specific vulnerable groups.

Housing Conditions:

Substandard housing, including informal settlements and overcrowded dwellings, exposes residents to heightened risks during disasters such as floods, storms, and earthquakes. Poorly constructed housing lacks resilience to natural hazards, placing marginalized communities at greater risk of displacement, injury, and loss of livelihoods.

Figure 84. Row houses area at Kulhudhuffushi City, Image credits: Charrette

Age, Gender, and Ethnicity:

Vulnerability to hazards and disasters often intersects with demographic factors such as age, gender, and ethnicity. Children, the elderly, and women face distinct challenges and risks during disasters, including increased vulnerability to exploitation, violence, and displacement. Cultures may encounter barriers to accessing assistance and resources, exacerbating their vulnerability.

The Baseline Assessment Report of Kulhudhuffushi by SIGs indicates that while Kulhudhuffushi houses a significant number of migrants, these individuals appear to be relatively well integrated into the community. A notable proportion of these migrants are actually returning migrants, individuals who had previously resided in Kulhudhuffushi, left for purposes such as education, and have now returned. This pattern suggests a strong connection and sense of belonging to the island. Additionally, with 1 in 3 residents being migrants and having lived in Kulhudhuffushi for over 14 years on average, it is evident that these individuals are not transient but rather long-term residents who have established their lives in the community. The fact that many choose to return to Kulhudhuffushi implies that the island presents viable economic opportunities and a supportive environment, reducing the likelihood of social vulnerability among migrants. (SIGS, 2022) Therefore, based on the data provided, migrants in Kulhudhuffushi are more or less well integrated and not socially vulnerable.

In Kulhudhuffushi, with a resident population of 10,131* (NBS, 2022) social vulnerabilities vary across different age and gender demographics. The elderly population, comprising 252 women and 266 men aged 65 and above, may face challenges related to health, mobility, and access to care. Young adults aged 18 to 35, consisting of 1,559 women and 971 men, may encounter vulnerabilities associated with employment, education, and financial independence. Similarly, the age group of 15 to 24, with 757 women and 532 men, may experience unique challenges related to transitioning into adulthood, including access to education and employment opportunities. Among adolescents aged 10 to 19, comprising 953 girls and 931 boys, vulnerabilities may include issues related to education, health, and protection. The youngest segment of the population, aged 0 to 14, with 1,488 girls and 1,593 boys, may face vulnerabilities related to child protection, health, and education. Additionally, the presence of 797 migrant workers, predominantly 714 men with 83 women, introduces another dimension of vulnerability, including potential challenges related to employment rights, access to healthcare, and social integration within the community. Understanding these demographic profiles is crucial for designing targeted interventions and support systems to address the diverse social vulnerabilities present within the community.

Disability Groups and Other Vulnerable Groups:

Persons with disabilities face unique challenges in preparing for and responding to disasters, including barriers to accessing evacuation routes, communication, and essential services. Inadequate consideration of disability-inclusive approaches in disaster planning and response further marginalizes this population, increasing their vulnerability to harm.

According to the data provided by KCC (Kulhudhuffushi City Council, 2024), Kulhudhuffushi City exhibits various vulnerabilities across different demographic groups. Among them, individuals with disabilities constitute 16% of the population, facing challenges related to accessibility, employment, and social inclusion. The presence of drug users, comprising 3%, highlights concern regarding substance abuse and its associated health and social implications. Children, accounting for 9%, represent a vulnerable group requiring specific attention to ensure their well-being, safety, and access to education and healthcare. Women, constituting 2%, may face gender-specific vulnerabilities such as discrimination, unequal access to resources, and gender-based violence. Migrant workers, representing 10% of the population, are susceptible to exploitation, discrimination, and inadequate access to social services and legal protections. The elderly, comprising 19%, confront issues related to aging, health, and social isolation, necessitating support for their well-being and inclusion. Displaced individuals, accounting for 5%, may experience challenges associated with displacement, including housing instability, loss of community ties, and limited access to resources. Poverty affects a significant portion of the population, with 33% living below the poverty line, highlighting the pervasive vulnerability to economic insecurity, inadequate housing, and lack of access to essential services. Other vulnerable groups, constituting 3%, may include those facing specific challenges not captured by the categories, underscoring the multifaceted nature of social vulnerabilities within the community. Addressing the needs of these diverse vulnerable groups requires comprehensive strategies that prioritize inclusivity, equity, and social justice to foster a more resilient and supportive community.

Implications for Disaster Risk Reduction and Response:

Understanding the social vulnerabilities outlined above is crucial for informing targeted interventions aimed at reducing disaster risk and enhancing community resilience in Kulhudhuffushi City. By identifying at-risk populations and addressing their specific needs, stakeholders can ensure more equitable and effective disaster preparedness, response, and recovery efforts. Collaboration between government agencies, civil society organizations, and local communities is essential for implementing inclusive and context-specific strategies that mitigate social vulnerabilities and build adaptive capacity at the grassroots level.

3.2.1.3 Analysis

The examination of social vulnerabilities in Kulhudhuffushi City unveils a number of significant elements that contribute to the susceptibility of the local community to perils and catastrophes. The influence of socioeconomic status becomes a substantial factor, as inequalities in income, access to fundamental services, and employment prospects exacerbate susceptibility. The prevalence of approximately 10% low-income households highlights the formidable obstacles that economically marginalized people encounter when it comes to both disaster preparedness and recovery. Vulnerability is exacerbated by the lack of access to high-quality education; illiteracy and low educational achievement hinder individuals' capacity to comprehend and respond appropriately to potential dangers. In contrast, the educational infrastructure in Kulhudhuffushi City is praiseworthy, as it provides readily available opportunities spanning from preschool to higher education. This demonstrates a dedication to cultivating knowledge and developing skills among the local populace.

Furthermore, the absence of knowledge regarding crucial matters including mental health, prevention of abuse, management of disasters, and life skills presents further obstacles, thereby intensifying societal susceptibility. With regard to healthcare accessibility, Kulhudhuffushi City possesses a comparatively strong healthcare system; however, certain weaknesses endure, specifically with regard to the provision of mental health services, psychosocial support, and provisions for vulnerable populations. Vulnerability is further exacerbated by substandard housing conditions, which are especially prevalent in marginalized communities. The lack of resilience in inadequately constructed housing towards natural hazards presents potential dangers such as injury and displacement.

Vulnerability is intertwined with demographic variables including age, gender, and ethnicity; particular difficulties are encountered by children, the elderly, women, and migrant laborers. The existence of individuals with disabilities and other marginalized communities serves to emphasize the complex and diverse characteristics of social vulnerability. For example, individuals with disabilities face obstacles when attempting to reach critical services and evacuation routes, underscoring the importance of incorporating disability-inclusive strategies into disaster preparedness and management.

In order to mitigate these vulnerabilities, it is imperative that local communities, civil society organizations, and government agencies work in concert. Advocates for inclusive and context-specific approaches can effectively address social vulnerabilities and foster the development of grassroots adaptive capacity. The implementation of focused interventions that specifically address the needs of vulnerable populations, in conjunction with improved measures for disaster preparedness, response, and recovery, is crucial in cultivating a community in Kulhudhuffushi City that is more resilient and supportive.

Figure 85. Image credit: Avas, Kulhudhuffushi to be considered an island for upcoming council elections, https://avas.mv/en/75533

3.2.1.4 Social Hazards in terms of Vulnerability

The social vulnerabilities in Kulhudhuffushi City are characterized by a complex web of interconnected issues, including crime rates, economic inequality, and limited access to basic services. A thorough examination uncovers intricate dynamics that influence the city's ability to recover from challenges and emphasizes specific areas where focused actions can be taken. This section will look into the above social hazards identified in terms of vulnerability.

Crime rates are a crucial measure of social vulnerability in a society. Kulhudhuffushi City experiences a range of criminal activities, such as drug-related occurrences, assaults, thefts, sexual offenses, and domestic violence, which highlight the existing social weaknesses (Maldives Police Service, 2024).

Drug-related occurrences have a significantly high exposure rating, since historical evidence consistently shows a persistent risk. The city's high prevalence of drug-related activities is seen from the average monthly incidence of 2.2 instances. Drug cases have exhibited variability over time, although the data indicates a persistent prevalence of this problem. In 2024, there were a total of 12 documented instances of drug-related occurrences. Although law enforcement initiatives and community engagement programs are now implemented, the challenge is in effectively addressing the root causes of issues such as poverty and substance abuse.

The frequency of assault cases has significantly risen, above the historical average. This trend highlights the weaknesses in social cohesiveness and security within the society. During the initial quarter of 2024, a total of 7 assault incidents were reported, surpassing the usual monthly frequency. Unemployment, poverty, and social instability are factors that can increase the likelihood of attack events. In order to effectively combat violence and safeguard the welfare of citizens, it is imperative to implement comprehensive strategies that not only focus on law enforcement and victim support services, but also target the underlying causes of violence.

The prevalence of theft occurrences continues to be a notable worry, with an average annual frequency of 8.62 cases over the previous five years. The presence of economic inequalities in this region exacerbates weaknesses, leading to negative impacts on productivity and growth in industries like agriculture and tourism. During the initial quarter of 2024, there were a total of 7 documented instances of theft, which suggests an ongoing prevalence of this problem. Although law enforcement initiatives and community awareness programs are currently implemented, it may be essential to allocate extra resources to effectively reduce the negative effects of theft on businesses and individuals.

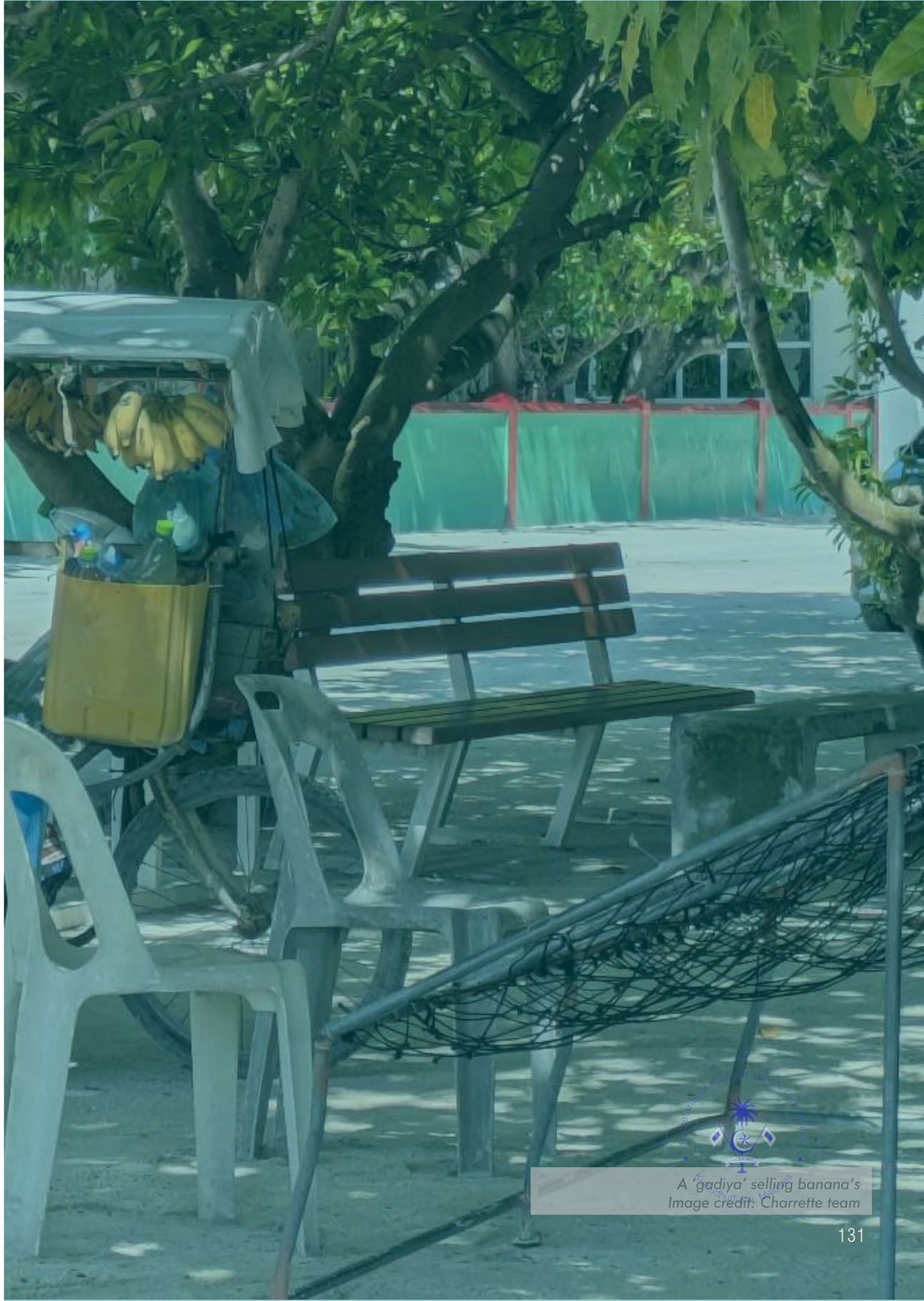
Sexual offenses and domestic violence expose weaknesses in crucial services and societal unity. The level of exposure to these crimes ranges from moderate to high, suggesting significant effects on both individuals and society. Between January and March 2024, there were a total of 3 documented instances of sexual offenses, exceeding the normal monthly frequency. Likewise, occurrences of domestic violence have varied across time, as weaknesses in both physical structures and human factors combine to intensify the likelihood of harm. Although response measures such as law enforcement initiatives and victim support services are in place, it is imperative to persistently address the root causes and provide comprehensive care to survivors.

Based on extrapolated statistics, traffic accidents have been assigned a moderate exposure grade, highlighting the importance of implementing improved road safety measures. The convergence of vulnerabilities in both infrastructure and human factors magnifies hazards, hence requiring comprehensive initiatives to enhance road safety and mitigate the occurrence of accidents. During the initial quarter of 2024, there were a total of three documented instances of traffic accidents, suggesting an ongoing requirement for actions to tackle this problem.

Figure 86. Image credit: Avas, COVID-19: Eight new cases in Kulhudhuffushi, tally at 42, https://avas.mv/en/104358

To effectively tackle social vulnerabilities in Kulhudhuffushi City, it is crucial for stakeholders to adopt a comprehensive approach. This encompasses bolstering law enforcement initiatives, augmenting community engagement initiatives, and executing focused interventions to tackle fundamental socio-economic problems. Furthermore, it is imperative to foster cooperation among government agencies, civil society organizations, and local communities in order to effectively implement inclusive measures that reduce vulnerabilities and enhance resilience at the grassroots level.

To conclude, a data-driven examination of social vulnerabilities in Kulhudhuffushi City highlights the intricate nature of the difficulties confronting the community. Through comprehending the interrelated elements that contribute to crime rates and economic inequalities, individuals with a vested interest can formulate comprehensive approaches that foster safety, prosperity, and adaptability for all inhabitants. By implementing coordinated endeavors and fostering cooperation, Kulhudhuffushi City may effectively tackle social susceptibilities and ultimately strengthen its resilience in the face of challenges.



A 'gadiya' selling banana's
Image credit: Charrette team

3.2.2 ECONOMIC VULNERABILITIES

Kulhudhuffushi, as a regional hub in the Northern Maldives, faces significant economic vulnerabilities primarily due to its geographical and infrastructural setup. The island's economy heavily relies on sectors such as wholesale and retail trading, particularly within Ha. and Hdh Atolls, which are susceptible to external shocks like natural disasters, including tsunamis and storm surges. Key infrastructure crucial for economic activities, such as the airport, local harbor, and regional port, are vulnerable to damage during such calamities due to their coastal locations.

3.2.2.1 Key Factors Contributing To Economic Vulnerabilities

The economic vulnerabilities of Kulhudhuffushi stem from its infrastructure and susceptibility to natural disasters. Zoning for commercial and industrial activities are lacking, leading to over 90% of businesses integrating with residential areas. Many residential houses have been modified for commercial use. While larger wholesale and retail operations cluster around Bandaara Magu near the hospital and along Ameenee Magu, smaller enterprises are scattered, including flood-prone areas.

3.2.2.2 Analysis

The island faces significant risks from natural disasters, such as tsunamis, storm surges, and flooding, which threaten critical infrastructure. Specific areas like the airport, RO plant on the northeastern side, sewage treatment plant on the southern coast, and boat building area in the northwest are particularly susceptible to damage. Protective measures at the local harbor and regional port mitigate risks but do not eliminate vulnerability, especially for businesses in flood-prone zones.

Kulhudhuffushi's economy has shifted considerably from a predominantly primary economic sector to several sections falling under the wholesale retail and transport sectors. These changes were made possible largely by the regional airport and the establishment of the transportation network, which significantly caused the rise in retail and wholesale to several billions, especially over recent years. Additionally, the economy heavily relies on a steady supply of goods to the other atolls and islands.

Our assessment identifies those economic infrastructures at risk in the event of a disaster, including the airport, RO plant, sewage treatment plant, and the powerhouse. We have attempted to estimate the potential losses to these infrastructures under various disaster scenarios.

The table below outlines the estimated value of losses amounting to an estimate of MVR 202,747,880 in different disaster scenarios, focusing only on existing developments and not considering any proposed infrastructure improvements

Table 10. Estimated Value of Losses in Disaster Scenarios

Sector	Est. Tsunami Losses (MVR)	Est. Storm Surge losses (MVR)	Est. Flooding Losses (MVR)
Wholesale & Retail Trade (Incl. Warehouse, Workshops Café's, Restaurants etc)	30,856,635.00	10,971,248.00	8,228,436.00
Fishing	7,363,282.00	2,618,056.00	-
Tourism	1,717,344.00	228,979.00	457,958.00
Manufacturing & Construction (Incl. WIP)	7,373,541.00	1,253,502.00	737,354.00
Institutional (Schools, Hospital, Public/civil buildings etc)	28,270,482.00	3,141,165.00	1,570,582.00
Utilities & Infrastructure	50,573,747.00	8,428,958.00	1,348,633.00
Transportation	23,614,863.00	1,967,905.00	3,935,810.00
Real Estate leasing & business activities	6,034,500.00	402,300.00	804,600.00
Home Based occupational works	115,200.00	19,200.00	153,600.00
Other activities (communal & social activities)	300,000.00	60,000.00	200,000.00
Total	156,219,594.00	29,091,313.00	17,436,973.00

To estimate the economic loss, it was assumed that the current economy remains stable without significant disruptions, maintaining stable demand for products and services within a competitive market environment. Key macroeconomic indicators such as GDP growth (5.5%), lending rates (assumed at 10%), and employment levels were expected to stay within anticipated ranges. No major regulatory changes affecting the business or asset valuation were anticipated. Average business income was projected to grow annually by 4%, aligned with inflation forecasts as costs were expected to increase by 3.15% per year. Operational efficiency improvements were also anticipated, with capacity utilization projected to increase from 85% to 90% over the next five years.

The estimated economic valuation figure was derived for two main components: the investment costs assessed using the replacement cost method for each sector, and the value generated by these sectors, which was assumed to reflect the economic loss.

3.2.3 INFRASTRUCTURAL VULNERABILITIES

Infrastructure forms the backbone of the city, encompassing transportation networks, utilities, buildings, and communication systems, among others. These critical components are often exposed to various hazards, including disasters, technological failures, and human-induced events. Identifying and assessing infrastructure vulnerabilities is essential for mitigating risks, enhancing resilience, and ensuring effective response and recovery efforts. This analysis provides insights into the potential consequences of hazards on infrastructure based on available data. Also highlights areas of weakness or deficiency and informs strategies for strengthening resilience and reducing vulnerability within Kulhudhuffushi.

3.2.3.1 Key Factors Contributing to Infrastructural Vulnerability:

3.2.3.1.1 Limited Fire Safety Measures:

The infrastructural vulnerabilities concerning fire safety measures are evident in the city's old quarters, characterized by numerous non-engineered and semi-engineered structures. These buildings lack the robust construction and safety features required to withstand fire incidents effectively. Historical data indicate that traditional housing in the city was particularly susceptible to fire outbreaks. Additionally, the lack of clear management practices in waste management areas, as highlighted, contributes to spontaneous methane fires, especially in densely built-up areas. These fires pose a significant threat to the structural integrity of nearby buildings, exacerbating the risk of widespread damage and endangering residents' lives. Addressing these vulnerabilities necessitates comprehensive measures to enhance fire safety infrastructure and implement effective waste management strategies to mitigate the risk of fire incidents.

Figure 87. Image credit: Sun, Fire breaks out at Kulhudhuffushi migrant quarters, https://en.sun.mv/84725

3.2.3.1.2 Lack of Adequate Traffic Management Infrastructure:

The city's traffic management infrastructure exhibits vulnerabilities that pose risks to public safety and emergency response efforts. The data highlights that roads are inadequately designed to separate traffic zones, contributing to congestion and increasing the likelihood of accidents. Additionally, the absence of enforced local speed limits further exacerbates these risks, particularly during emergency situations. Furthermore, limited road infrastructure and narrow roads hinder emergency services' prompt access during disasters, impeding timely response efforts. Addressing these vulnerabilities requires comprehensive traffic management strategies, including road redesigns, speed limit regulations, and improved emergency response protocols to enhance public safety and mitigate risks associated with traffic accidents.

3.2.3.1.3 Inadequate Accessibility and Emergency Response:

The city's infrastructural vulnerabilities significantly impact accessibility and emergency response capabilities. Limited fire stations and narrow spaces for firefighting, are challenges posed for emergency responders in accessing affected areas during disasters. Moreover, the lack of established road crossings and minimal provision for pedestrians, as highlighted above, further hinder emergency response efforts, delaying critical interventions. These accessibility challenges underscore the importance of investing in emergency infrastructure, including the establishment of additional fire stations, road improvements, and pedestrian-friendly measures, to enhance accessibility and expedite emergency response during crises.

3.2.3.1.4 Insufficient Upkeep of Infrastructure:

Infrastructure maintenance deficiencies contribute to vulnerabilities in the city's built environment, exacerbating risks during disasters. Poorly managed vegetation obstructing roads and drainage systems hampers infrastructure resilience, increasing the likelihood of flooding and structural damage. Additionally, the lack of specific waste management practices, results in improper waste disposal, further contributing to environmental degradation and infrastructure decay. Addressing these vulnerabilities necessitates proactive maintenance efforts, including regular vegetation clearance, drainage system upgrades, and the implementation of effective waste management strategies, to enhance infrastructure resilience and mitigate disaster risks.

3.2.3.1.5 Infrastructure Failure Due To Natural Hazards:

The analysis of tsunami risks and infrastructure failure in Kulhudhuffushi City highlights vulnerabilities stemming from historical development patterns and informal settlements. While the island is not in a seismic vulnerable zone, the potential for tsunamis and infrastructure failure remains a concern, particularly given the prevalence of non-engineered and semi-engineered structures. The data underscores the importance of disaster preparedness measures and investments in resilient infrastructure to mitigate risks associated with natural hazards and ensure the safety and well-being of residents.

3.2.3.1.6 Limited Structural Integrity:

The structural integrity of buildings in the city is compromised by various factors, contributing to infrastructural vulnerabilities. Moreover, historical data indicate that traditional housing in the city was highly susceptible to fire, further highlighting vulnerabilities in structural integrity. These vulnerabilities underscore the need for building codes and regulations that ensure robust construction standards, especially in areas prone to fire hazards. Strengthening structural integrity through building retrofits and implementing fire-resistant materials can mitigate risks and enhance the resilience of infrastructure in the face of potential disasters.

3.2.3.2 Analysis

This analysis offers a comprehensive examination of infrastructural vulnerabilities in Kulhudhuffushi City, elucidating various risks and challenges confronted by the island community. It encompasses a broad spectrum of infrastructural vulnerability concerns, including Limited Fire Safety Measures, Lack of adequate traffic management infrastructure, Inadequate Accessibility and Emergency Response, Insufficient upkeep of infrastructure, Infrastructure Failure due to natural hazards, and Limited Structural Integrity, Each vulnerability is thoroughly explored, shedding light on the intricate interplay of natural processes and human activities contributing to infrastructural vulnerability hazards in Kulhudhuffushi City.

One major finding is the Limited Fire Safety Measures due to the traditional structure of plot arrangement, natural splitting of the plots due to the local inheritance structure, historical, local management and governance of approval and upgrade process of non engineered and engineered construction, and the inclusion of feasible fire safety procedures and implementation of preventive mitigation procedures that can prevent a spread of fire in the maize like structure of the island. This highlights the importance of implementing comprehensive fire safety measures, including upgrading infrastructure and waste management practices, is crucial to mitigating the risk of fire incidents and protecting lives and property.

Moreover, the analysis highlights the importance of enhancing traffic management infrastructure that can reduce accident risks and facilitate emergency response, enhancing public safety and expediting relief efforts during disasters.

Further, the analysis highlights the lack of accessible emergency infrastructure throughout the island that is imperative when it comes to managing the speed and quality of response in an emergency. Investing in accessible emergency infrastructure, such as additional fire stations and improved road crossings for pedestrians, is essential for reducing response times and enhancing accessibility to affected areas during disasters.

The analysis also highlights the insufficient upkeep of infrastructure in the city. The fact that the majority of government lead projects are funded by the government and is accessed by the residents tax-free, active management revenue generation is not a major aspect of many projects, at least the evidence suggests to this. As a result the infrastructure that exists is provided minimum management, and upkeep which leads to a diversion of the status from optimum, which impacts the quality of intertwined infrastructure within the city. Therefore, proactive maintenance efforts, including vegetation clearance and waste management upgrades, and infrastructure upkeep are necessary to enhance infrastructure resilience and minimize disaster risks.

In addition, the analysis also highlights the close proximity and exposure of the locals to the industrial and everyday hazards due to infrastructure placement close to hazardous zones. Therefore, strengthening industrial safety protocols and waste management practices is critical for protecting public health and mitigating risks associated with industrial accidents.

Further, the analysis highlights the lack of infrastructure designs implemented for disaster preparedness, within the local investments and government upgrades. This can potentially lead to considerable disaster in the long run as the impacts can be cumulative if developments follow the same trajectory. For instance, the management of the elevation difference of the wetland and the main island village and the reclaimed land and the main island village needs to be actively managed in the developed infrastructure projects to minimize the financial loss due to flood water damage at a household level. Hence, investing in disaster preparedness measures and resilient infrastructure is essential for minimizing risks associated with natural hazards and ensuring the city's resilience to disasters.

Addressing these vulnerabilities requires a multi-faceted approach, including investment in fire safety measures, traffic management improvements, accessible emergency infrastructure, proactive maintenance efforts, industrial safety protocols, and disaster preparedness initiatives. By implementing these measures, authorities can enhance disaster resilience, mitigate risks, and safeguard lives and property in the face of various hazards and emergencies.

Kulhudhuffushi Friday Mosque
Image credit: Kulhudhuffushi Online

3.2.4 ENVIRONMENTAL VULNERABILITIES

3.2.4.1 Understanding Environmental Vulnerabilities in Kulhudhuffushi City

Kulhudhuffushi City within recorded history has been an island of progress, infrastructure development, and trade. As is of any economic hub, the first resource that is harvested is the environmental resource. The current biological environment is a result of built environment expansion. This being only beneficial to the limits of harvest of the biological environment and the viability of trade, has more negative impacts on the residents and impacts the adaptability of the residents. The contextual summarized description of the island's environment shows a more dominant built environment percentage than the biological environment. The vulnerabilities described below are the results of changes to this island habitat.

Figure 88. Image credit: Aavas, Local NGO urges to protect rest of Kulhudhuffushi mangrove, https://avas.mv/en/52251

3.2.4.2 Key Factors Contributing to Environmental Vulnerability:

3.2.4.2.1 Waterborne Diseases:

Inadequate sanitation infrastructure and contamination of groundwater sources contribute to the prevalence of waterborne diseases. Communities reliant on groundwater for domestic use face heightened risks of exposure to pathogens and pollutants from surface-level contaminants, such as cottage agricultural runoff and industrial discharges. Poor sanitation practices further exacerbate microbial contamination, perpetuating the transmission of infectious diseases and undermining public health outcomes.

3.2.4.2.2 Loss of Biodiversity:

Anthropogenic activities, including deforestation of the eastern ridge, habitat fragmentation, and land-use changes, precipitate biodiversity loss and ecological degradation. Deforestation for urban expansion, urbanization, and infrastructure development diminishes habitat suitability for diverse flora and fauna, disrupting ecological balances and diminishing ecosystem resilience. Fragmentation of natural habitats fragments ecosystems, impeding species mobility and genetic exchange, thereby exacerbating vulnerability to invasive species, disease outbreaks, and ecological disintegration.

3.2.4.2.3 Environmental Degradation:

Unregulated industrial activities, improper waste management, and urbanization-induced habitat loss contribute to environmental degradation. Industrial effluents, improper waste disposal, and urban runoff degrade water quality, contaminate soil, and compromise ecosystem integrity; loss of mangroves and loss of woodland. The cumulative impacts of environmental degradation include habitat destruction, loss of biodiversity, and ecosystem collapse, posing multifaceted risks to human health, ecological sustainability, and socio-economic stability.

3.2.4.2.4 Urban Heat Islands:

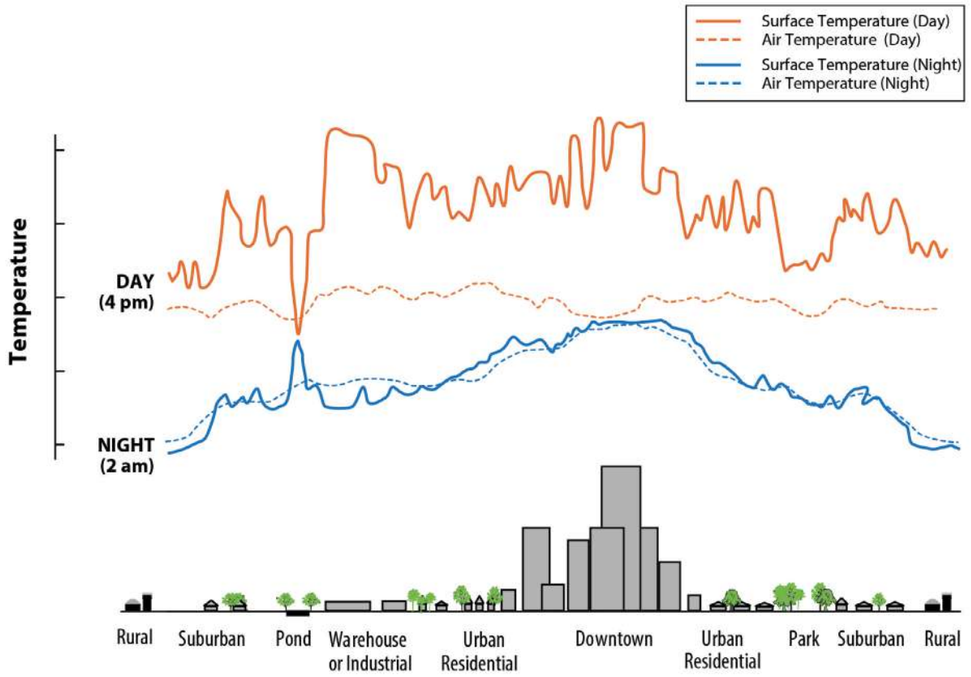


Figure 89. Urban Heat Island Effect (U. H. I. Basics 2011 Reducing Urban Heat Islands: Compendium of Strategies, US EPA, http//www. epa. gov/heatisland/resources/compendium. htm. Viewed, vol. 14.)

In Kulhudhuffushi City, heat islands are present due to varying temperatures within the urban area in comparison to shaded areas. This is caused by factors like the concentration of heat-absorbing structures and the presence of cooling elements such as greenery. Urban parks, wetlands, and residential areas tend to be cooler than main town areas. Surface temperatures fluctuate more than atmospheric temperatures during the day but stabilize at night. Bodies of water maintain constant temperatures due to latent heat capacity. Heat islands form because urban surfaces absorb and emit heat more than natural surfaces. On warm days, conventional roofing materials in Kulhudhuffushi may reach temperatures up to 15 degrees Celsius warmer than the air temperature. These surface heat islands are most intense during daylight hours.

Kulhudhuffushi City's Ameenee Magu
Image credit: kulhudhuffushi Online

3.2.4.2.5 Urban Flooding:

The analysis of urban flooding in Kulhudhuffushi City reveals a concerning trend of increased heavy rainfall hours over the past years, coupled with inadequacies in urban development and maintenance practices. According to the meteorological data (2024) heavy rainfall events exceeding 0.30 inches (7.62mm) per hour have been on the rise. Specifically, in 2021, 8.9% of the total rainfall hours surpassed this threshold, totaling 50 out of 613 hours. In 2022, 2.36% of the hours experienced heavy rainfall, equating to 22 out of 931 hours. Similarly, in 2023, heavy rainfall occurred for 10.8% of the time, amounting to 32 out of 297 hours. These figures underscore the increasing frequency of heavy rainfall events, contributing to urban flooding risks.

Figure 90. Image credit: Sun, Kulhudhuffushi City experiences heavy flooding, https://en.sun.mv/61890

Figure 91 shows the PWD classifications and the most vulnerable components of the community overlaid over the drone imagery under the urban flood path. In case of flood, the marked community is the most vulnerable and exposed.

Figure 92 - Storm water shown, underlaid over institution map and overlaid over DEM to show the local institutions that will be the most vulnerable.. It is an analysis of the impact of the stormwater on the island's institutions. The most vulnerable components of the community will be the locally owned. On the northern and the southern side of the island, some home base workers are on the fringes of the storm water flood zones and are the most vulnerable within the community.

Figure 93 - Storm water shown, underlaid over Key government institution map and overlaid over DEM to show vulnerable key institutions.shows that key infrastructure are in the zone of storm storm water flooding zones. Educational institutions, hospitals Mosques, public administrative offices, utility and municipal offices and the airport is on the impact zone.

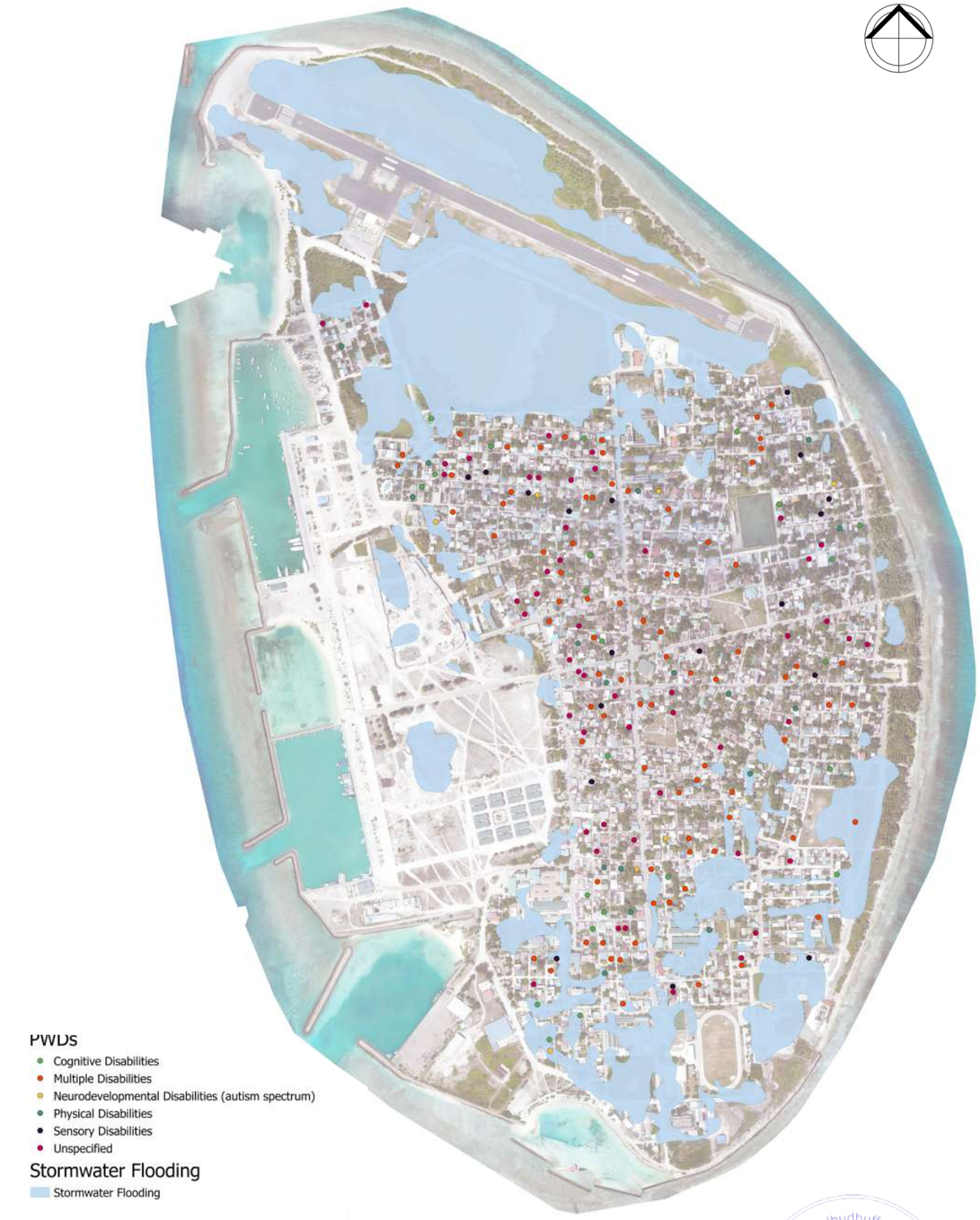


Figure 91. Shows the PWD classifications and the most vulnerable components of the community overlaid over the drone imagery under the urban flood path

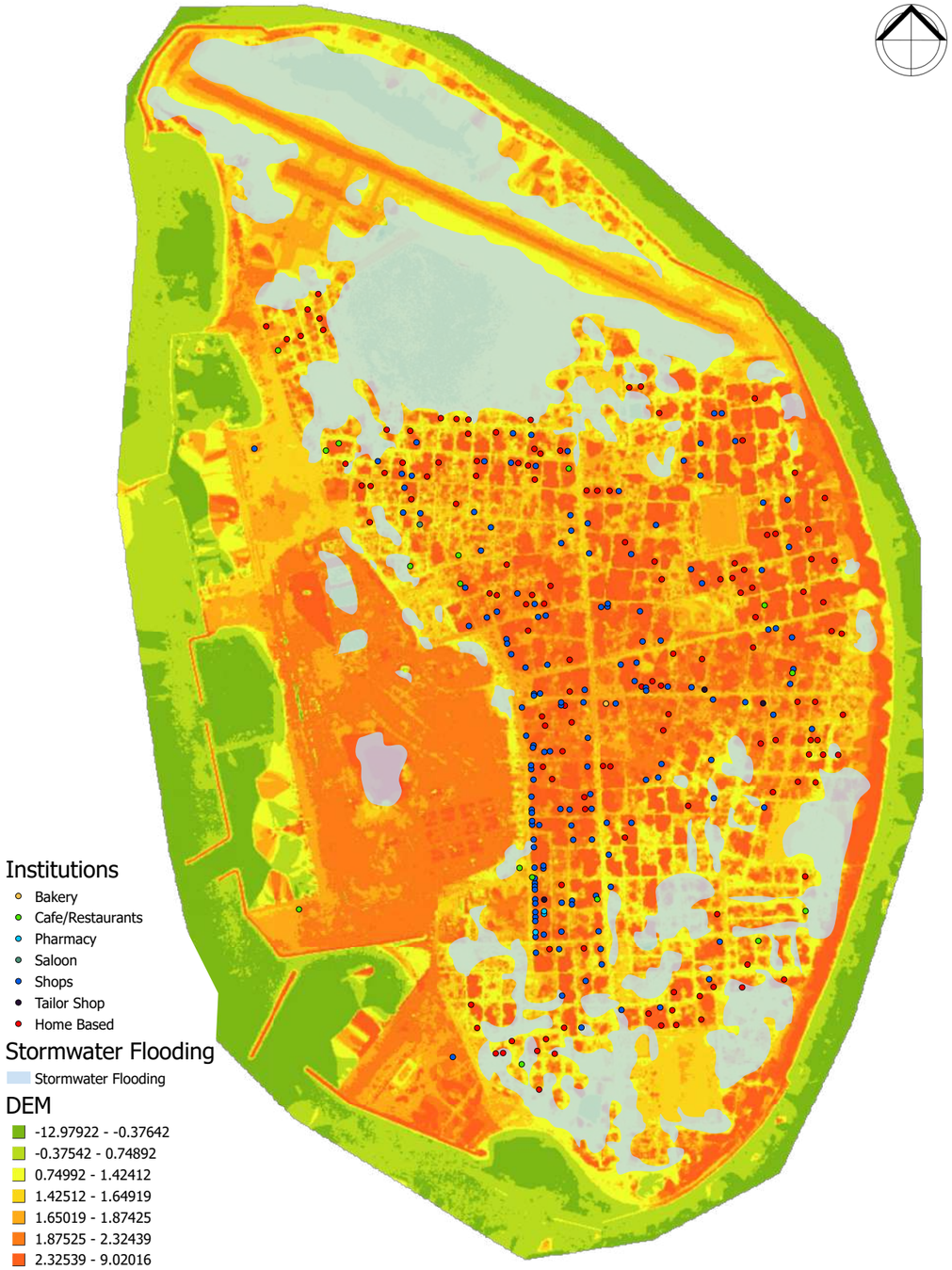


Figure 92. Storm water shown, underlaid over institution map and overlaid over DEM to show the local institutions that will be the most vulnerable.

Figure 93. Storm water shown, underlaid over Key government institution map and overlaid over DEM to show vulnerable key institutions.

3.2.4.2.6 Coastal Erosion:

The analysis of coastal erosion highlights the impact of reclamation projects and hard-engineered structures on the natural coastline of Kulhudhuffushi City (Figure 94). Despite efforts to mitigate erosion through engineered structures, such as quay walls and shore protection measures, the data suggests ongoing challenges in effectively managing coastal erosion. Specifically, the data indicates that 23% of locals believe the likelihood of coastal erosion is low, while 22% perceive the impact of coastal erosion to be high. These figures underscore the complex nature of coastal erosion dynamics and the need for comprehensive strategies to address this vulnerability.

A beach area of Kulhudhuffushi City
Image credit: Charrette team

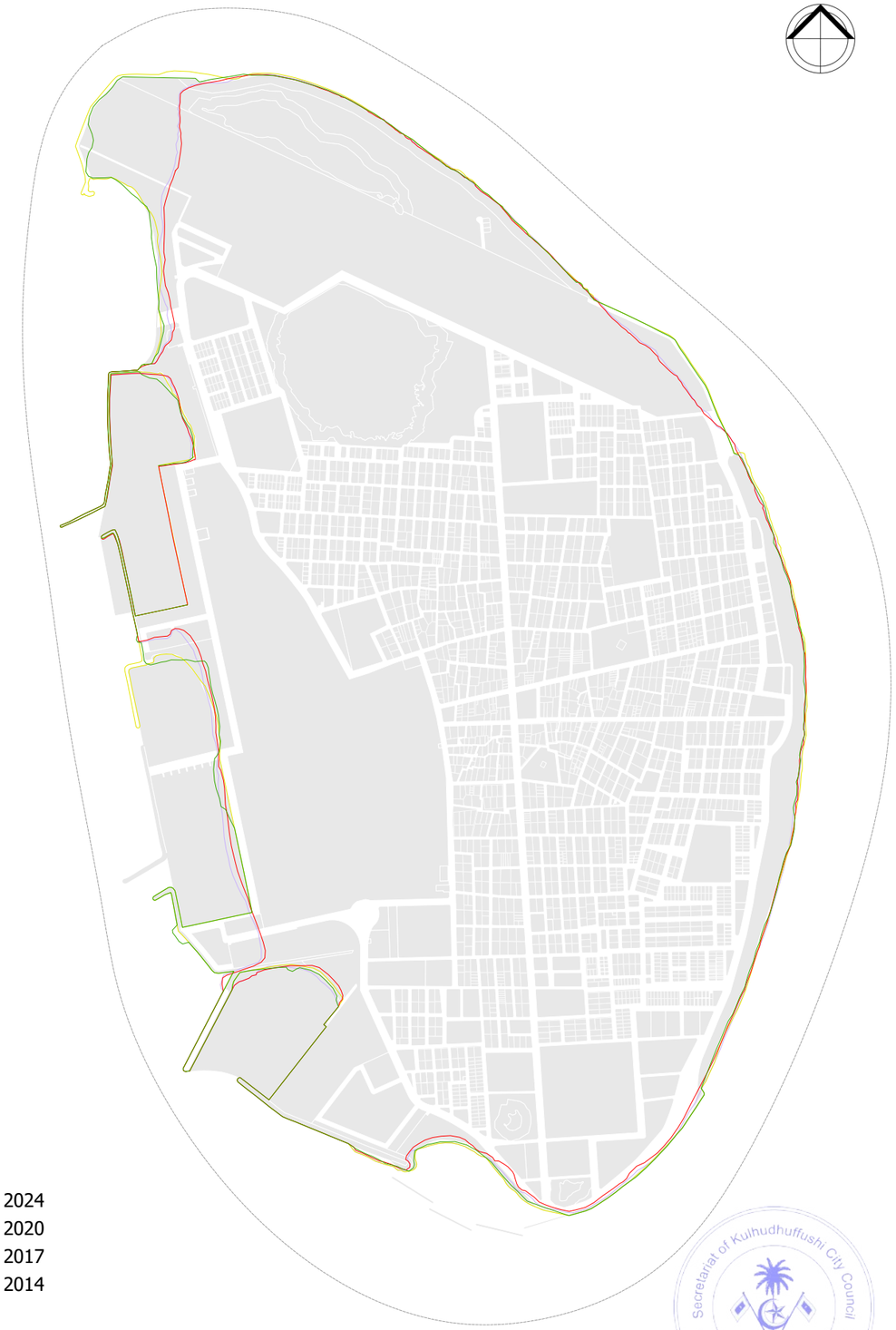


Figure 94. Erosion and accretion pattern seen around the island through out the years.

3.2.4.2.7 Coastal Floods:

The assessment of coastal floods underscores the interplay between natural and anthropogenic factors in shaping vulnerability to sea swells and surges in Kulhudhuffushi City. Despite efforts to mitigate risks through infrastructure development, such as the construction of swimming areas and the installation of shore protection measures, the data indicates ongoing vulnerability to coastal floods. Specifically, 25% of locals consider the island to be safe from sea surges, while 23% perceive the impact of sea swells to be very low. These figures highlight the importance of continued resilience-building efforts to address coastal flood risks effectively.

Figure 95 shows the PWD classifications and the most vulnerable components of the community overlaid over the drone imagery under the coastal flood path. On the north, the south and the east, numerous households are in the flood path and are the most exposed and vulnerable in the community.

Figure 96 shows the community establishments overlaid over the DEM under the coastal flood path; these establishments are institutional establishments and are the most vulnerable when it comes to property damage and recovery. The previous wetland grounds with the considerable low elevation will flood first spreading due to the high ridge to the east, throughout the eastern lowlands right after. Further the houses near the wetland on the northern side and the southern side will be the most vulnerable with the eastern community.

Figure 97 shows the critical infrastructure that falls under the coastal flooding zone, it is alarming to see that most of the utility and municipal institutions in this case are within the coastal flood zones on the south and one institutional and one mosque are under the flood zone.

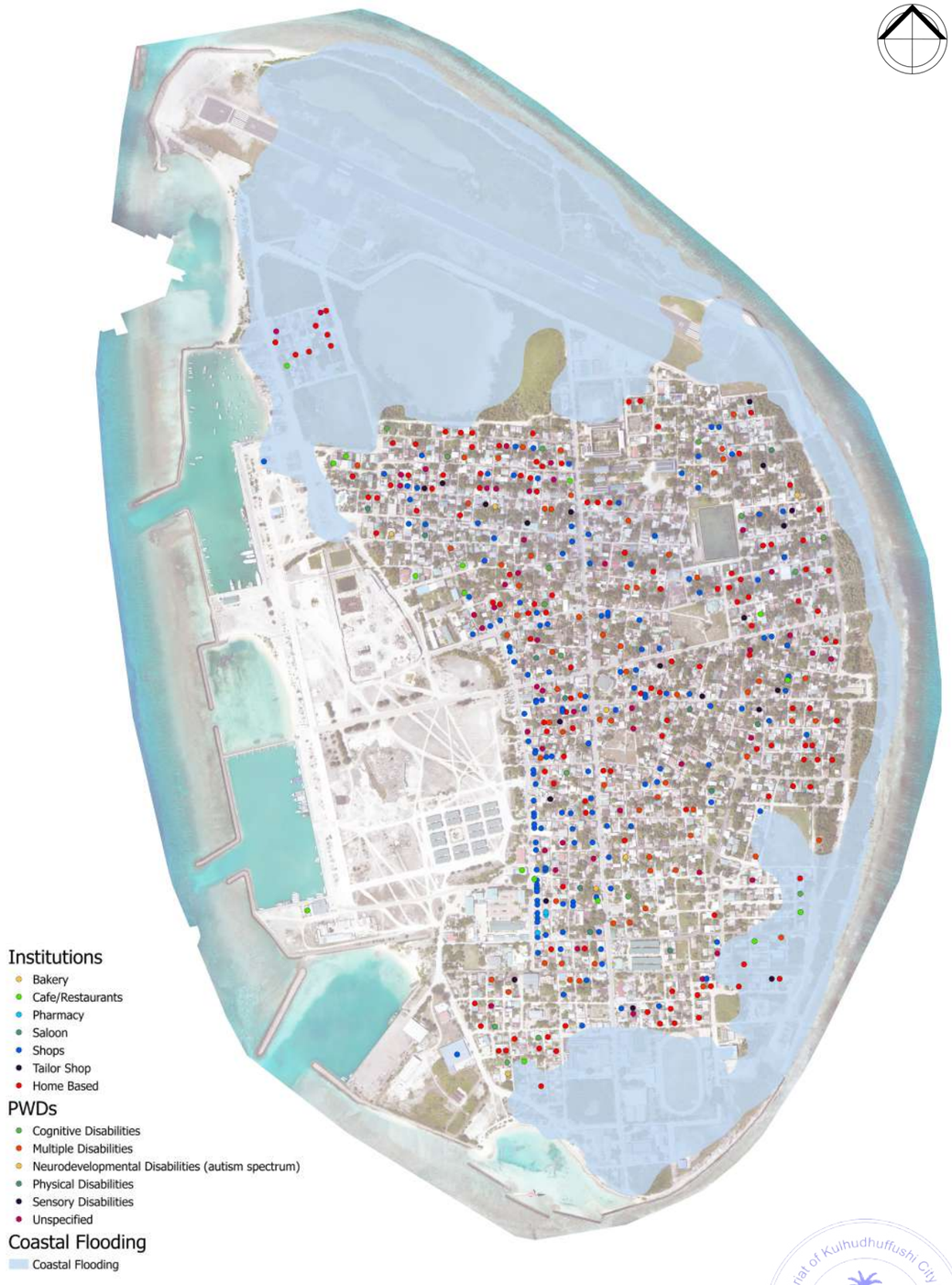


Figure 95. Shows the PWD classifications and the most vulnerable components of the community overlaid over the drone imagery under the coastal flood path

Figure 96. Shows the community establishments overlaid over the DEM under the coastal flood path; these establishments are institutional establishments and are the most vulnerable when it comes to property damage and recovery.

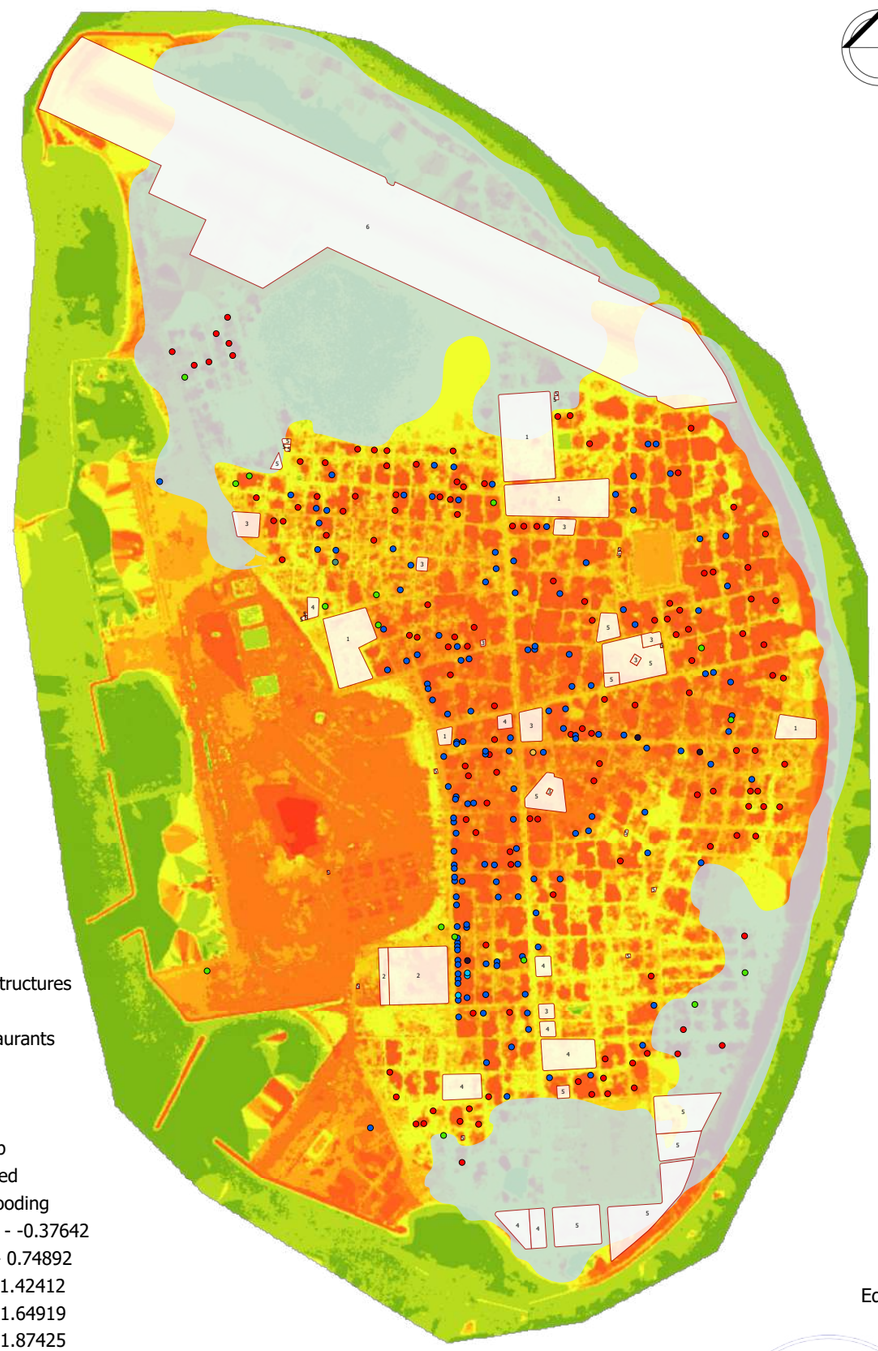


Figure 97. Coastal flooding shown, underlaid over Key government institution map and overlaid over DEM to show vulnerable key institutions.

3.2.4.2.8 Water Scarcity:

The analysis of water scarcity in Kulhudhuffushi City reveals a complex interplay of historical practices, regulatory frameworks, and infrastructural challenges. Despite initiatives to improve water management, such as the provision of rainwater tanks in households, the data suggests ongoing vulnerabilities to water scarcity. Specifically, 51% of households come with rainwater harvesting capability, with 44% having the capacity to store 3000 liters of water. These figures underscore the need for holistic approaches to water resource management to enhance resilience against water scarcity.

3.2.4.2.9 Under Developed Waste Management System:

The assessment of waste management practices in Kulhudhuffushi City reveals a transition from informal burning to formal waste management under WAMCO, the national waste management branch. However, challenges remain, including the lack of a comprehensive waste management system and the need for proper waste sorting and disposal practices. Specifically, all types of waste, including hazardous waste, are sent to the same location, highlighting the need for improved waste management infrastructure and practices.

3.2.4.2.10 Food Scarcity:

The analysis of food scarcity in Kulhudhuffushi City highlights the island's reliance on trade for food supply and the emergence of cottage industries for agricultural products. Despite initiatives to enhance infrastructure, such as the development of the port for trade, challenges persist in ensuring food security. The data underscores the importance of diversifying food sources and enhancing local agricultural production to build resilience against food shortages.

3.2.4.2.11 Heat Waves and Air Pollution:

The assessment of heatwaves and air pollution in Kulhudhuffushi City reveals significant vulnerabilities stemming from the lack of vegetation and poor air quality. Urbanization and industrial activities have exacerbated the urban heat island effect, leading to increased susceptibility to heatwaves. Additionally, poor air quality resulting from dust from construction sites and proximity to waste management areas poses health risks to residents. The data highlights the need for comprehensive strategies to mitigate heatwaves and air pollution, including urban greening initiatives and dust management measures.

3.2.4.2.12 Epidemics:

The analysis of epidemic risks in Kulhudhuffushi City underscores the island's role as a medical tourism hub and the presence of an active airport, which pose significant challenges for disease transmission. Despite the island's central location facilitating medical services, challenges remain in managing epidemic risks, particularly in densely populated areas. The data underscores the importance of robust public health infrastructure and preparedness measures to mitigate epidemic risks and ensure the health and well-being of residents.

Figure 98. - Image credit: Ras, Covid-19: Kulhudhuffushi island placed under monitoring, https://ras.mv/en/post/1286

3.2.4.2.13 Public Health Risks:

The city's industrial infrastructure exhibits vulnerabilities that pose significant risks to public health and safety. Hazards related to waste management and toxic exposures, underscore the importance of addressing industrial infrastructure vulnerabilities. Furthermore, the lack of waste management systems and exposure to hazardous substances further exacerbate risks, endangering residents' well-being and environmental health. These vulnerabilities necessitate comprehensive industrial safety measures, including the implementation of stringent waste management protocols, the adoption of environmentally friendly practices, and the enforcement of regulatory standards to mitigate risks and protect public health and safety.

3.2.4.2.14 Implications for Disaster Risk Reduction and Response:

Understanding the environmental vulnerabilities can prepare the local response in a predicted, possible and active environmental hazard. The local preparedness in case of a disaster will determine the speed of response, the quality of response and the number of casualties and the cumulative impact of the hazard.

The Figure 91, Figure 92, Figure 93, Figure 95, Figure 96, and Figure 97 show vulnerable residents and key businesses layered over potential flood and sea surge scenario risk map for the preparation of potential disaster management and mitigation action.

3.2.4.3 Analysis

This analysis offers a comprehensive examination of environmental vulnerabilities in Kulhudhuffushi City, elucidating various risks and challenges confronted by the island community. It encompasses a broad spectrum of environmental concerns, including waterborne diseases, loss of biodiversity, environmental degradation, urban heat islands, urban flooding, coastal erosion, coastal floods, water scarcity, waste management issues, food scarcity, heatwaves, air pollution, and epidemic risks. Each vulnerability is thoroughly explored, shedding light on the intricate interplay of natural processes and human activities contributing to environmental hazards in Kulhudhuffushi City.

One major finding is the prevalence of waterborne diseases due to inadequate sanitation infrastructure and contamination of groundwater sources. This underscores the urgent need for improved sanitation practices and water management strategies to safeguard public health and reduce the risk of waterborne illnesses.

Moreover, the analysis underscores the significant loss of biodiversity in Kulhudhuffushi City, driven by anthropogenic activities such as deforestation, habitat fragmentation, and land-use changes. These activities disrupt ecological balances, diminish habitat suitability, and exacerbate vulnerability to invasive species and disease outbreaks, posing threats to ecosystem resilience and stability.

Environmental degradation emerges as another critical issue in Kulhudhuffushi City, resulting from unregulated industrial activities, improper waste management, and urbanization-induced habitat loss; loss of mangrove and loss of the remaining eastern vegetation. These factors degrade water quality, contaminate soil, and compromise ecosystem integrity, leading to habitat destruction, loss of biodiversity, and ecosystem collapse.

The analysis also highlights the adverse impacts of urbanization on heatwaves and air pollution, exacerbating heat-related health risks and compromising air quality in densely populated urban areas. Additionally, urban flooding and coastal erosion pose significant challenges, necessitating improved urban development practices and coastal management strategies to mitigate these risks effectively.

Furthermore, water scarcity, waste management issues, food scarcity, and epidemic risks underscore the need for holistic approaches to address environmental vulnerabilities in Kulhudhuffushi City. These include sustainable resource management, infrastructure development, community resilience-building, and public health interventions to enhance environmental sustainability and mitigate risks associated with natural hazards and human activities.

In conclusion, the analysis provides valuable insights into the environmental vulnerabilities facing Kulhudhuffushi City, highlighting the interconnected nature of environmental challenges and the importance of integrated approaches to address these issues effectively. By understanding and addressing these vulnerabilities, policymakers, stakeholders, and community members can work together to build a more resilient and sustainable dewaterfuture for Kulhudhuffushi City.

The Table 11 below shows the hazards, exposure, and vulnerabilities relevant to Kulhudhuffushi City in a contextualized table.

Table 11. Hazard, Exposure & Vulnerability

Hazard Classification	Hazard Family	Hazard	Exposure	Vulnerability
Biological Hazards	Infectious Diseases	Waterborne Diseases	Very Unlikely	Some houses still use groundwater, which is exposed to the top surface trash.
		Contagious Diseases	Extremely Likely	Locals are exposed as medical tourism is a major industry in the island.
			Extremely Likely	The island has an airport that enables easy transmission of diseases into the city.
Hydrometeorological Hazards	Marine	Storm Surge	Probable	At some locations, locals are meters away from the marine coastline.
	Temperature-related	Heatwave	Inevitable	Lack of trees, Lack of shade, Few areas with provision for greening on the built streets.
	Flood	Surface-water flooding	Very likely	Roads are built higher than some old houses, Houses are not elevated.
	Wind-related	Cyclone	Probable	Lack of trees, Lack of shade, Local subjected to the cyclones because of geographical location
		Tropical storm	Probable	Lack of trees, Limited engineered infrastructure, Local subjected to the cyclones because of geographical location
Technological Hazards	Waste	Solid Waste	Improbable	Waste management is at the very infant stages, a large legacy waste collection, locals are exposed to the fumes and smoke.

Hazard Classification	Hazard Family	Hazard	Exposure	Vulnerability
	Industrial Failure/ Non-compliance	Fire	Possible	A lot of narrow spaces to enter to extinguish a fire, infrastructure close to each other, Limited fire stations.
		Infrastructure Failure	Possible	Most critical infrastructures in the city are non-engineered or semi-engineered structures, making them highly susceptible to extreme weather events and natural hazards. Poorly maintained buildings in hazard-prone areas face a heightened risk of severe damage during disasters.
		Traffic Accidents	Likely	Roads not designed to separate the traffic zones, local speed limit is not established, residents cross the road in an organized manner, road crosses are not established, minor roads have a minimum space for pedestrians, no room for further management of the road system.
Geohazards	Seismogenic (Earthquake)	Tsunami	Very Likely	Maldives is in the impact zone of tsunamis from the carlsberg ridge and the java trench, Kulhudhuffushi City is exposed to the java trench, there is the possibility of high impact from a tsunami.
Environmental Hazards	Environmental Degradation	Air Pollution	Very Likely	Houses have garages and workshops embedded in them, Many residents live in close proximity to the waste management area, many industrial activities takes place in the area,

Hazard Classification	Hazard Family	Hazard	Exposure	Vulnerability
	Environmental Degradation	Coastal Erosion	Likely	The EPZ of the island is thin, the eastern side shows signs of active erosion.
		Loss of mangroves	Likely	Rainwater shifts the sediment to the remaining mangroves. Eastern mangrove isolated. Accretion of sand can change the mangrove to a wetland, then woodland. Natural succession.
		Pests and disease of vegetation	Likely	Reports of unidentified pests in the eastern ridge. They can spread to the households of the area.
Social Hazards	Crime	Drugs	Likely	Lack of rehabilitative support, mental health issues, peer pressure, individual susceptible to addiction
		Assault	Likely	Gang activity, criminal involvement, Lack of security measures,
		Theft	Likely	Lack of security measures, Gang activity, criminal involvement
		Sexual Offenses	Likely	Power imbalances, lack of consent education, cultural norms, and societal attitudes
		Domestic Violence	Likely	Power dynamics within relationships, cultural norms that condone or excuse abusive behavior, financial dependency, and lack of support networks
	Economic	Economic Inequalities - income, employment & poverty, financial shock	Likely	Financial shock that can destabilize the economy.

3.3 LOCAL CAPACITY TO RESPOND TO HAZARDS

An advantage within disaster management is to have the environmental, social, economic and infrastructure capacity to manage and buffer the hazard. This capacity will mitigate the major impact of a hazard, further allowing the community to adopt change and build back better.

This chapter discusses and analyzes the capacities within the island to mitigate the impacts of the hazards within the island and will be a gateway to explore the risks and understand the management strategies within the island.

3.3.1 COMMUNITY CAPACITY RESOURCE MAPPING

Community capacity resource mapping involves the systematic identification and documentation of assets, resources, and capabilities across various levels within the community. This process encompasses both tangible and intangible components, including physical infrastructure, human resources, social networks, cultural assets, financial resources, and institutional capacities. By compiling a comprehensive inventory of these resources, stakeholders can leverage existing strengths, address gaps, and mobilize support for initiatives aimed at enhancing community resilience. The data collection methods for this exercise included participatory mapping exercises, stakeholder discussions, and analysis of secondary data sources.

To understand the community's capacity resources, data was collected through a household survey and further validated during a community consultation session. During this session, various categories of assets were identified to support the community in times of need.

The community's emergency response and resilience are bolstered by a diverse array of resources across different categories. Physical resources such as pumps, ambulances, and fire trucks, alongside transportation assets like vehicles and speedboats, ensure swift and effective emergency response. Human resources, ranging from firefighters and medical staff to carpenters and psychosocial workers, form the backbone of community resilience efforts. Social assets, including journalists, NGOs, and sports clubs, provide essential support networks and services. Cultural resources such as mosques and initiatives promoting social cohesion foster community unity during crises. Financial resources from local artisans to international aid enable funding for emergency response activities. Finally, institutional capacity through hospitals, disaster response centers, and local councils provides crucial infrastructure and expertise for coordinated response efforts. Together, these resources create a robust framework for community resilience in the face of emergencies.

These resources, spanning various domains, collectively form a robust support network to address the diverse needs within the community. By leveraging these assets effectively, stakeholders can enhance the community's resilience and response capabilities in the face of challenges.

Table 12. Existing Resources in Kulhudhuffushi City

Physical	Human	Social	Cultural	Financial	Institutional
Pumps	Manpower	Journalists	Mosque	Kamburuverikan/ Artisans	Hospital
Ambulance	Fire-fighters	Tree planting events	Rahvehi Aasaru	Hardware shops	School
Fire truck	Pump operators	Cleanup events	Social Cohesion	Grocery Shops	Stadium
Sandbags	Engineers	Speech therapist	Hinavaa meehun (70+)	Boat owners	Police
Higher grounds	Chefs	Psychosocial support systems		Pickup owners	MNDF
Vacant Grounds	Carpenters	Clinics		Saturday Market	MRC
Vehicles	Fishermen	Self-help group/ peer support groups		International Aid	Airport
Speed boat/ boats	Psychosocial workers	Volunteers		Insurance	Custom
Loudspeakers	Medical staff (docs/nurses/ nutri/tech)	Bulbul therapy center		Government Aid	Immigration
RTL	Public workers	Kudakudhinge Hiya		Charity	Educational Institutions
	Mechanics	NGO's		Shops in general	Council
	Volunteers	Sports clubs			International seaport.

3.3.2 INFRASTRUCTURAL RESOURCES

3.3.2.1 Water

The average daily water production in the surveyed area stands at 522 cubic meters per day, indicating a substantial supply to meet daily demands. However, the current water stock is limited to a 24-hour supply, with a tank capacity of 800 metric tons, of which only 600 metric tons are currently available. Despite this constraint, the existing reverse osmosis (RO) plant is reported to be in working condition, ensuring continued water supply to the community. It is worth noting that construction is underway for a second RO plant, driven by the need to augment water production and address access limitations associated with the existing plant's proximity to the airport, which necessitates controlled access. Once completed, the new plant is expected to significantly enhance water availability, with an anticipated output of approximately 3000 metric tons, thereby bolstering the resilience of the water supply infrastructure and meeting future demand more effectively.

3.3.2.2 Electricity

Fenaka, the primary electricity provider in Kulhudhuffushi, operates with a total capacity of 8.6 Megawatts from diesel generators and an additional 600 kilowatts from solar energy sources. The company prioritizes safety measures, ensuring the availability of necessary equipment such as fire extinguishers, which undergo regular maintenance and daily checks to address emergency situations effectively. Currently, Fenaka is in the process of constructing a new powerhouse designed to withstand external stresses more robustly, with an anticipated completion date in 2025. However, the chosen location for this new facility, situated on the beachfront of the island's most southern tip, poses vulnerability to potential tsunamis, although it also helps mitigate air pollution by placing it at a distance from residential areas.

The forthcoming powerhouse, engineered with extensive safety measures by professionals, aims to enhance the reliability and resilience of Kulhudhuffushi's electricity supply. Despite the advancements in safety, the proximity of the powerhouse to the waste collection area raises concerns about fire outbreaks, which are frequent occurrences throughout the year. While other nearby locations pose minimal threats to the powerhouse, ensuring fire prevention and containment measures remains critical. Additionally, the strategic placement of the powerhouse allows for easy accessibility via wide roads, facilitating maintenance and emergency response efforts.

Electricity failures have become increasingly common since February 2024, attributed to overloading and overheating of existing generators. The construction of a larger powerhouse, slated for completion in 2025, is deemed necessary to address these issues effectively. Despite challenges, other Fenaka offices and substations are situated in favorable locations with strong structures, contributing to the overall reliability of the electricity distribution network in Kulhudhuffushi.

3.3.2.3 Cooking

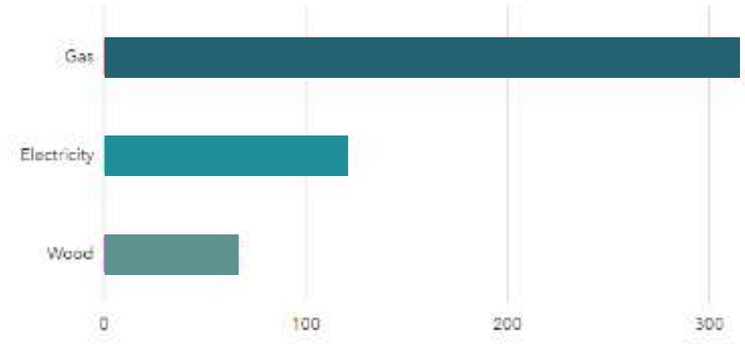


Figure 99. Method of cooking (Source: Household Survey)

Based on the household survey, the majority of the people cook with gas. However, there are also a considerable number of people who use wood for cooking.

3.3.2.4 Fuel

No. of fuel shed: 02

3.3.2.5 Telecommunication

Table 13. Telecom capacity

	Dhiraagu	Ooredoo
Mobile Phone Towers	04	06
Call Center	01	01

3.3.2.6 Media

Table 14. Media Capacity

Kulhudhuffushi Online	News Website
PSM	News Website + TV Channel
Dhiraagu TV	Media Service Provider
Media Net	Media Service Provider

3.3.2.7 Loudspeaker

Table 15. Loudspeaker locations

Loudspeaker locations	Number of loudspeakers
Masjidul Halorath	04
Masjidul Hasanaath	04
Masjidul Noor	04
Masjidul Jama'athu	04
Masjidul Firdaus	04
Masjid Mohamed	04
Kulhudhuffushi Council	02

3.3.3 HUMAN RESOURCES

3.3.3.1 Health Sector

Table 16. Health sector capacity

Profession	Specialisation	Total	Gender		Nationality	
			Female	Male	Local	Expats
Doctors	General Medicine	32	15	17	5	27
	Pediatrics	5	2	3	3	2
	OBGYN	6	2	4	0	6
	Dermatologist	2	0	2	0	2
	Ophthalmologist	2	1	1	0	2
	ENT	2	2	0	0	2
	Endocrinologist	0	0	0	0	0
	Psychiatrist	1	0	1	0	1
	Psychologist	1	1	0	1	0
Nurses	Registered Nurse	125	119	6	119	6
	Nurse Practitioner	0				
Emergency medical personnel	EMT	0	0	0	0	0
	Paramedics	0	0	0	0	0
	EMD	0	0	0	0	0
Social Workers		6				
Radiographers & Lab Technicians	MRI technician	6	3	3	1	5
	CT technician	6	3	3	1	5
	Mammography technician	6	3	3	1	5
	X Ray technician	6	3	3	1	5
	Medical Laboratory Technologist	18	10	8	7	11
	Lab Assistants	0				

3.3.3.2 Emergency Workers

Table 17. Emergency human resource capacity

	Male	Female	Total
Standard First-aiders	23	34	57
Psychological First-aiders	09	15	24
Emergency Response Team (ERT)	21	15	36

3.3.4 MATERIAL RESOURCES

Below are details of some of the key resources available in the city of Kulhudhuffushi thatcan be useful in disaster management.

3.3.4.1 Health

Table 18. Material Resources available at Kulhudhuffushi Regional Hospital

Facilities Available	Details
Number of beds:	65
Number of ambulances:	2
Emergency Department	
Inpatient Specialized Wards	OBG Medical Surgical Pediatrics NICU ICU LR
Outpatient Clinics	NCD RHC Methadone Maintenance Smoke Cessation
Diagnostic Services	Laboratory Physiotherapy Radiology (Xray, CT, MRI, Mammogram, USG) Neurodiagnostics Mobile laboratory Service
Rehabilitation Services	CDC for children below 18 years Physical Rehabilitation
Mental Health Services	Consultation & Therapy
Specialized Centers	Dialysis Wound Care

3.3.4.2 Transport

Table 19. Transport vessels available in Kulhudhuffushi

Fishing Boats	33
Cargo Boats	10
Private Speedboat	10
Pick-ups	15
Lorry	9
Taxi Center	02
Taxi	45

3.3.4.3 Fire Fighting

Table 20. Fire fighting equipment available in Kulhudhuffushi

Category	Details
Fire Fighting & Rescue	2 fire trucks (1 tender vehicle, 1 foam tender)
	MNDF Fire Station
	1 water bowser (10 tons capacity)
	Firestation at Kulhudhuffushi airport: dedicated fire fighting vehicles and fire squad
Existing Fire Vehicles	Ladders reach up to 3 storey buildings (lacking capacity for high-rise buildings)
Fire Hydrants	No operational fire hydrants at KFC currently, plans for installation in ongoing road development project

3.3.4.4 Dewatering

Table 21. Available dewatering equipment in Kulhudhuffushi

Flood Dewatering	4 pump systems with adequate hoses (usable in multiple locations)
	City Council and MRC: additional dewatering pumps (usable individually or for emergency response)

3.3.5 ECONOMIC CAPACITY

Table 22. Economic Capacity

Shops	170
Café/Restaurant	14
Guest House	19
Financial Institutions	3
State-owned Enterprises	6

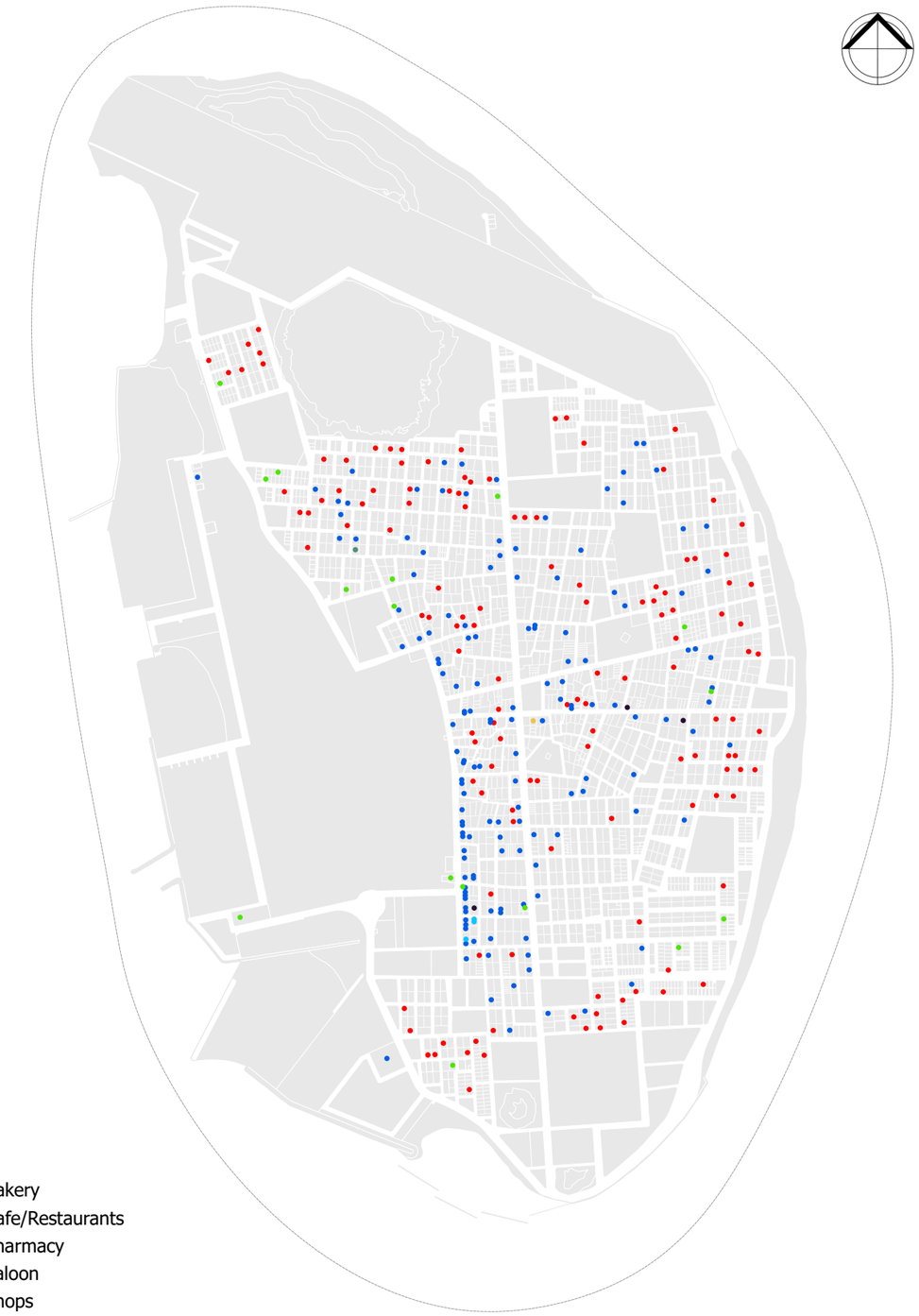


Figure 100. Economic Activities in Kulhudhuffushi City

Kulhudhuffushi City's aerial imagery
Image credit: Charrette team

3.3.6 CAPACITY TO ADDRESS HAZARDS

The Table 23 below shows the breakdown of the capacity of Kulhudhuffushi City to respond to the hazards.

Table 23. Breakdown of Capacity to Address Hazards

Hazard	Exposure	Vulnerability	Capacity	Gaps
Waterborne Diseases	Very Unlikely	Some houses still use groundwater, which is exposed to the top surface trash.	MWSC provides water to all households and follows safety measures, has necessary emergency equipment, but vulnerability remains due to limited control over individual households' use of groundwater. The regional hospital is equipped with staff though limited to attend to such diseases.	• Lack of an in depth study on the prevalence of waterborne diseases in Kulhudhuffushi City as it is important to: 1. Understand the household use of the groundwater. 2. Understand the household ground water source, proximity to the sewage seepage area. 3. Understand the local breeding area range. 4. Understand the measures in place for the prevention of waterborne diseases
Contagious Diseases	Extremely Likely	Residents are exposed due to medical tourism; the island has an airport facilitating easy transmission of diseases.	The regional hospital is equipped with staff though limited to attend such diseases. New medical facilities and a proficient workforce available.	• Lack of an in-depth study on the prevalence of contagious diseases in Kulhudhuffushi City as it is important to understand the measures taken in Kulhudhuffushi City to maintain a contagion free zone, and the status of those measures.
Loss of Mangroves	Likely	Rainwater shifts the sediment to the remaining mangrove. Eastern mangrove isolated. Accretion of sand can change the mangrove to a wetland, then woodland. Natural succession.	The flood mitigation function of the area is native knowledge.	• Absence of sufficient data on how the locals use the wetland currently. • Low public awareness on the importance of having mangroves for the island's ecosystem. It is considered more of a burden than a valuable resource.
Pests and Disease of Vegetation	Likely	Reports of unidentified pests in the eastern ridge. They can spread to the households of the area.	The potential harm of introducing pests to the area is local knowledge.	• Lack of data on the history of invasive species affecting the plants and the number of outbreaks. • Absence of any research conducted on the issue given the current reports of unidentified pests in the eastern ridge.
Storm Surge	Probable	At some locations, locals are meters away from the marine coastline, increasing the chance of water intrusion into houses.	Enhanced transportation networks for evacuation and emergency relocation methods established. Presence of MRC/MNDF/POlice/Cadet as response teams in times of such an incident.	• Low community preparedness and resilience to handle storm surges and related emergencies

Hazard	Exposure	Vulnerability	Capacity	Gaps
Heatwave	Inevitable	Lack of trees, shade, and limited provision for greening on built streets contribute to increased urban heat.	New powerhouse under construction with potential to mitigate heat effects. Some of the new infrastructure for urban greening and shade provision in place and in the Land Use Plan.	• Lack of urban heat prevention strategies.
Surface-water Flooding	Very likely	Roads built higher than some old houses, lack of elevation in houses, potential for household damage.	Flood Dewatering Facilities are available: - 4 pump systems with adequate hoses which could be used in multiple locations during flooding incidents. - Pumps available at City Council and MRC Enhanced transportation networks for evacuation and emergency relocation methods established. Use of sandbags for flood management to minimize water influx. Presence of MRC/MNDF/POlice/Cadet as response teams in times of such an incident.	• Absence of a functioning drainage system to effectively mitigate urban flooding. • Lack of recent studies to assess the extent of damage caused by floods to households in flood-prone areas. • Limited implementation of measures or plans to mitigate floods and their impact on households.
Cyclone	Probable	Lack of trees. Lack of shade. Locals are subjected to the cyclones because of the geographical location.	Limited capacity to address the impact of a possible cyclone, and the debris damage that can be the result of a cyclone. However, evacuation and emergency relocation methods are established. For instance, the evacuation procedure used during the fire can be superimposed to cyclone and other related hazards for impacted residents. Presence of MRC/MNDF/Police/Cadet as response teams in times of such an incident	• Absence of a proper island level or institutional level disaster management plan. • Lack of trained staff at island level to handle an emergency operation. • Low public awareness on the possible impacts of a cyclone, prevention, response, recovery.
Tropical Storm	Probable	Lack of trees. Lack of shade. Locals are subjected to the cyclones because of the geographical location.	Limited capacity to address the impact of a possible cyclone, and the debris damage that can be the result of a tropical storm. However, evacuation and emergency relocation methods are established. For instance, the evacuation procedure used during the fire can be superimposed to cyclone and other related hazards for impacted residents. Presence of MRC/MNDF/Police/Cadet as response teams in times of such an incident	• Lack of a proper island level or institutional level disaster management plans. • Lack of trained staff at island level to effectively handle an emergency operation. • Low public awareness on the possible impacts of storm, prevention, response, recovery.
Coastal Erosion	Likely	Inadequate Environmental Protection Zone at most parts around the island, which is further compromised by the ring road project due to loss of significant vegetation contributing to erosion. Signs of active erosion on eastern side	Considerable coastal protection measures and vegetation in place. Enhanced coastal resilience strategies and ecosystem restoration initiatives.	Lack of regular monitoring carried out for the coastal protection measures which is essential to: • Understand Longshore current sediment shift impact for the island. • See if the northern tip is acting as a point for potential placement loss • Evaluate the effectiveness of the measures undertaken

Hazard	Exposure	Vulnerability	Capacity	Gaps
Solid Waste	Improbable	Waste management at early stages, exposure to fumes and smoke.	The process of establishing a proper waste management system is ongoing by WAMCO. This would include constructing a well equipped waste management facility.	• Waste is still not properly managed. • Lack of awareness amongst the community on managing waste, especially hazardous waste . • Lack of studies on the dangers of open burning/ impact on air quality due to the legacy waste that exists in the waste dumping site. • Regional waste management center not established yet.
Fire	Possible	Narrow spaces for firefighting, infrastructure proximity, limited fire stations, potential for fire spread and building collapse.	MNDF_Firefighting service available: - 2 fire trucks (1 tender vehicle and 1 form tender) - 1 water Bowser with 10 tons capacity - Plans to install fire hydrants during ongoing road development project Back-up option available at Kulhudhuffushi airport, with fire fighting vehicles and fire squad. Presence of MRC/Police/Cadet as response teams in terms of man-power	• Insufficient availability of equipment, such as ladders of required heights, to address potential fires in high-rise buildings. • No clear procedures in place for effectively managing fires with the potential to spread extensively.
Infrastructure Failure	Possible	Not all buildings are engineered, most are built with mixed construction materials. Vegetation not managed; green verges are not planned or maintained over time, potential for structural failure.	Improved community building standards and structural engineering capabilities. A new land use plan is being developed. Structural Engineers available on the island	• Absence of proper infrastructure planning. • Absence of climate-proof building regulations.
Traffic Accidents	Likely	Roads lack traffic zone separation and speed limits, pedestrian safety measures, contributing to increased accidents.	Enhanced traffic management systems and public awareness campaigns being carried out. MPS aware of accident prone zones	• Lack of adequate road safety measures in place to address the increased number of accidents.
Tsunami	Very Likely	Vulnerable location to tsunamis from Carlsberg Ridge and Java Trench, lacking survival experience from past events.	Limited capacity to mitigate tsunami impact; need for community education and preparedness.	• Lack of a proper island level or institutional level disaster management plans • Lack of trained staff at island level to effectively handle an emergency operation • Low public awareness on the possible impacts of a Tsunami, prevention, response, recovery
Air Pollution	Very Likely	Proximity of waste management areas and industrial activities to residential areas, poor air quality affecting residents of all ages.	New powerhouse construction could include measures to reduce emissions. Intervention of waste management can mitigate the waste emissions. Collection of air pollution data	• Air pollution data collected not readily accessible

Hazard	Exposure	Vulnerability	Capacity	Gaps
Drugs	Likely	Lack of rehabilitative support, mental health issues, peer pressure, susceptibility to addiction.	Improved social support systems and education programs required. Enhanced rehabilitation facilities and community-based addiction treatment services.	• Limited availability and access to effective rehabilitation programs • Lack of sufficient preventive measures and early intervention programs • Insufficient targeted interventions to address the drug supply and demand
Assault	Likely	Gang activity, lack of security measures, contributing to physical and psychological harm.	Enhanced community policing and security measures needed. Improved access to legal aid and victim support services.	• Inadequate gang prevention and intervention programs as well as support services.
Theft	Likely	Lack of security measures, gang activity, increasing the risk of property loss and emotional distress.	Improved security infrastructure and community vigilance required. Enhanced neighborhood watch programs and crime prevention initiatives.	• Inadequate security measures and the prevalence of petty crimes.
Sexual Offences	Likely	Power imbalances, lack of consent education, cultural norms, and societal attitudes contributing to physical and emotional trauma.	Need for comprehensive education and support systems for victims. Enhanced access to confidential support services and legal assistance.	• Pervasive power imbalances, entrenched cultural norms and societal attitudes. • Lack of adequate support services and awareness/education regarding the issue.
Domestic Violence	Likely	Power dynamics, cultural norms, financial dependency, lack of support networks contributing to physical and emotional harm within relationships.	Enhanced support services, legal frameworks, and community awareness needed. Improved access to shelters and counseling services for survivors.	• Lack of support networks. • Inadequate support services and awareness. • Power imbalances and the pervasive social norms.
Economic Inequalities	Likely	Income disparities, employment issues, financial shock affecting the community's economic stability.	Need for targeted economic development programs and social safety nets. Enhanced job training and employment opportunities for marginalized groups.	• Lack of support services in times of a shock. • Lack of financial literacy and empowerment of the society to build resilience to shocks.

The capacity to address various hazards in Kulhudhuffushi City is multifaceted, incorporating both existing strengths and areas for improvement. While some hazards, such as waterborne diseases, benefit from established safety measures and emergency equipment, others, like contagious diseases, require ongoing investment in medical facilities and workforce development.

Infrastructure projects, such as the construction of a new powerhouse, offer opportunities to enhance resilience to heatwaves and mitigate air pollution, although vulnerabilities persist, particularly concerning solid waste management and the risk of fire.

Traffic accidents, coastal erosion, and the potential for tsunamis necessitate comprehensive planning, including improved road safety measures and coastal protection initiatives.

Addressing social hazards such as drug abuse and violence requires comprehensive strategies that encompass community education, bolstering support services, and improving law enforcement efforts. By raising awareness within the community, providing accessible support services, and implementing effective law enforcement measures, communities can work together to mitigate these risks and promote safety and well-being for all residents. Economic inequalities further underscore the importance of targeted development programs and social safety nets to ensure the resilience of the community against financial shocks.

3.4 RISK ASSESSMENT

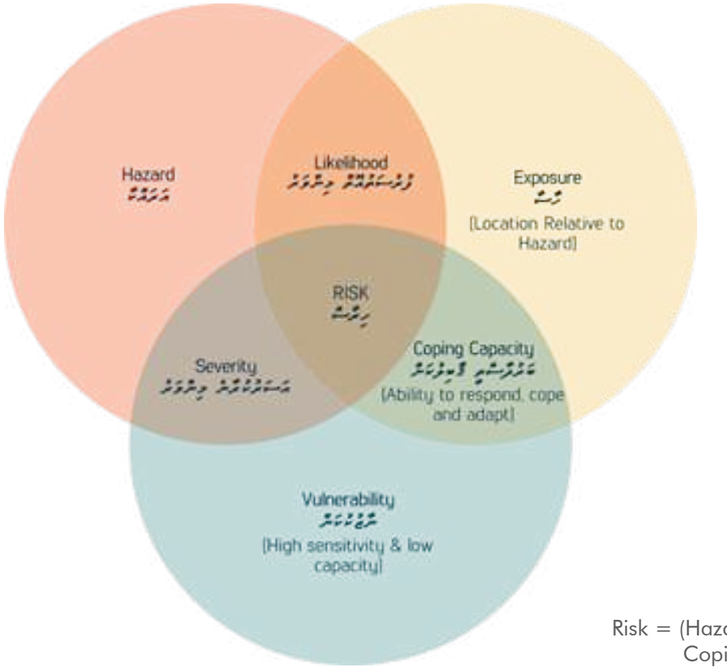
Risk assessment allows us to score and make informed decisions to mitigate and manage the hazards. In this part of the document, we will explore the risk assessment of Kulhudhuffushi City for risk assessment, we have also considered components that are suggested by the locals as potential hazards.

3.4.1 RISK ANALYSIS

There are several methods of calculating the risk (Figure 101). But risk is generally perceived as the result of three factors: hazard, vulnerability and exposure. The table below defines each factor.

Table 24. Definitions of factors Source: UNDRR QRE Tool (taken from UNISDR, 2009)

Exposure	People, property, assets, systems or other elements present in hazard zones that are thereby subject to potential losses.
Vulnerability	The characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard.
Likelihood	Refers to the likelihood of the event occurring in comparison to the other assessed events in the specified location, based on the location's exposure and vulnerability to the event, and the current actions and measures undertaken. The lower the ranking score, the lower the potential requirement for action. The higher the ranking score, the higher the potential requirement for action. Note: This score is not a statistical measure of a probability but a ranking score to enable prioritization of hazards/hazard events across all assessed hazards/hazard events.
Response Measures	Activities and measures to avoid and/or address existing and new disaster risks. Indicates the level of disaster-resilience of the specified location.
Severity	Refers to the impact and consequences level that a hazard would have on the location under study and its community, ranging from 1 to 100 with 1 being the lowest severity and 100 being the highest.
Risk	Refers to the allocation of a risk rating ranging from Very Low to Catastrophic aligned to the 'Risk Matrix' which is dependent upon the likelihood ranking and severity rating calculated. Note: A negative severity rating indicates you are outside the threshold of a material risk to invest in a response to. Obtaining a severity rating of zero or negative may indicate unrealistic scoring of the level of current actions and measures in place to respond to the specific hazard.



Risk = (Hazard x Vulnerability) / Coping Capacity

Figure 101. Risk Dynamics & Formulae

Each hazard event is meticulously evaluated based on multiple parameters including exposure rating, vulnerability rating, total vulnerability rating, current level of response measures in place, likelihood ranking score, severity rating, and risk matrix output.

For instance, within the domain of Biological Hazards, the assessment encompasses pivotal events such as Waterborne diseases and Contagious diseases. Waterborne diseases are appraised as "Very unlikely" in terms of exposure and "Negligible" concerning vulnerability, yielding a total vulnerability rating of 45. Conversely, Contagious diseases are classified as "Extremely likely" in exposure and "Negligible" in vulnerability, resulting in a total vulnerability rating of 53.

In the domain of Hydrometeorological Hazards, critical events like Storm surge and Tropical storm are meticulously analyzed. Storm surge is denoted as "Probable" in exposure and "Likely" in vulnerability, culminating in a total vulnerability rating of 55. Similarly, Tropical storm is adjudged as "Likely" in exposure and "Inevitable" in vulnerability, leading to a total vulnerability rating of 100.

Furthermore, within the sphere of Technological Hazards, occurrences such as Solid waste and Fire are scrutinized. Solid waste is evaluated as "Improbable" in exposure and "Possible" in vulnerability, resulting in a total vulnerability rating of 50. Conversely, Fire is categorized as "Possible" in exposure and "Likely" in vulnerability, yielding a total vulnerability rating of 55.

These discerning assessments offer profound insights into the inherent risks posed by various hazards, thereby furnishing a comprehensive basis for informed decision-making processes concerning risk mitigation and disaster management strategies.

A breakdown of the risk findings is provided in the below table with the explanations.

Rain puddles on a sandy road of Kulhudhuffushi
Image credit: Charrette team

3.4.1.1 An analysis of severity versus exposure

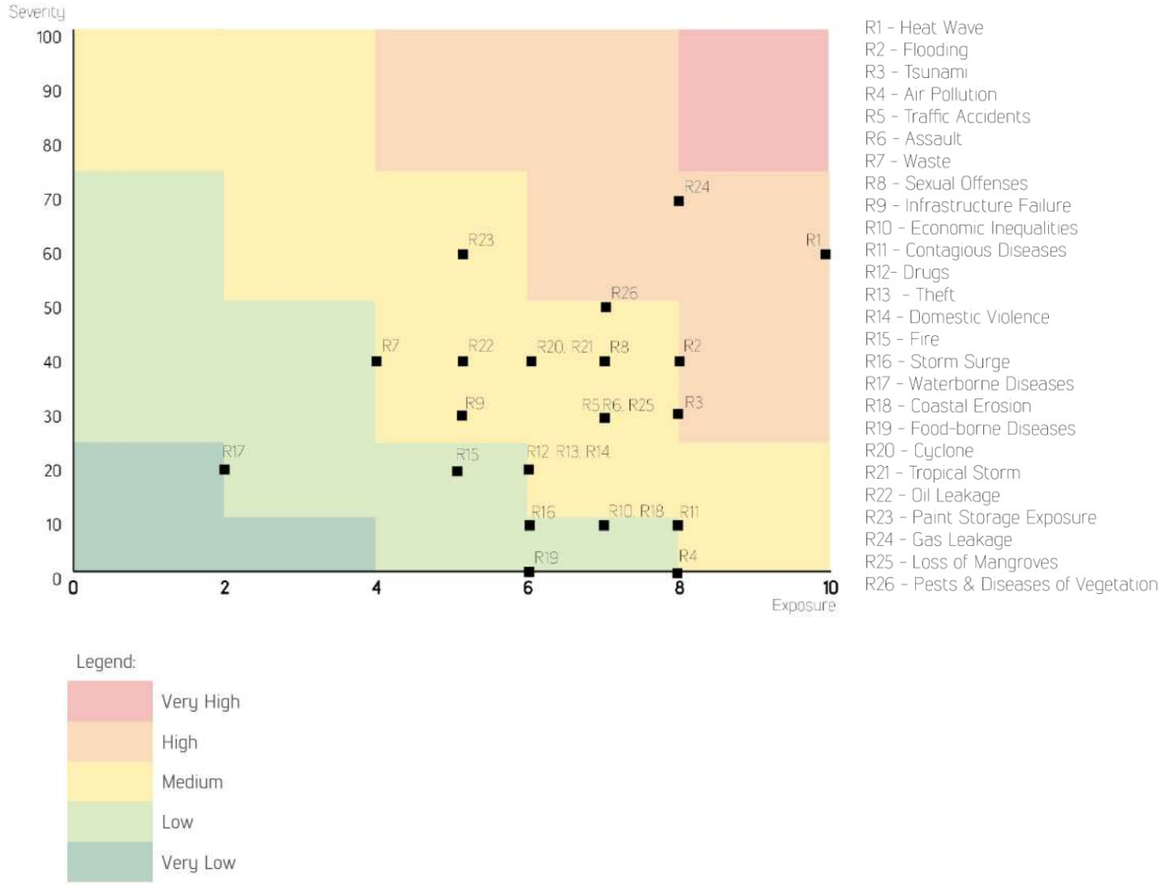


Figure 102. Severity vs Exposure Risk Graph

The analysis of risk for each hazard underscores the importance of considering severity and exposure ratings. Severity rating indicates the potential impact or damage caused by a hazard event, while exposure rating reflects the likelihood or frequency of encountering the hazard. By evaluating both factors, a comprehensive understanding of the risk landscape is attained. Hazards with high severity ratings pose significant potential impacts, while those with high exposure ratings suggest a higher likelihood of occurrence. It's the combination of these factors that determines the overall risk level. Hazards with both high severity and exposure ratings represent scenarios of heightened risk, requiring immediate attention and proactive risk management strategies. Conversely, hazards with low severity and exposure ratings may still warrant consideration, as their cumulative effects over time or in combination with other hazards could escalate the risk profile of the city.

A description of the hazards risk, ranked on severity and exposure rating follows (Figure 102).

i. (R23) Paint Storage Exposure and (R24)Gas Leakage: These chemical hazards pose the highest risk due to their extremely high exposure and severity ratings. Immediate and stringent measures are essential to prevent potential incidents and mitigate their severe consequences effectively.

ii. (R2) Flood - Surface Water Flooding: Despite having a lower severity rating compared to chemical hazards, flooding hazards rank high in risk due to their very high exposure ratings. Comprehensive flood management strategies are crucial to minimize the significant impact of flooding on the city.

iii. (R3) Tsunami (earthquake trigger): These geohazards present significant risk with high exposure and severity ratings, indicating substantial potential impact and widespread damage. Strengthening infrastructure resilience and implementing early warning systems are critical to mitigate seismic risks effectively.

iv. (R22) Oil Leakage: This chemical hazard ranks moderately high in risk with a high exposure rating and severity rating. Immediate measures should be implemented to prevent and manage potential oil leakage incidents, considering their adverse environmental and public health impacts.

v. (R1) Heatwave: Despite its lower exposure rating, the heatwave hazard poses a considerable risk due to its high severity rating. Measures to mitigate heat-related health risks and protect vulnerable populations are essential, especially during extreme temperature events.

vi. (R20) Cyclone - Tropical Storm: These wind-related hazards present moderate risks with high severity ratings but slightly lower exposure ratings compared to other hazards. Preparedness measures should focus on mitigating wind-related damage during cyclones and tropical storms.

vii. (R11) Contagious Diseases and (R6, R13, R14) Crime, Assault, Theft, Domestic Violence: These hazards rank moderately in risk, with moderate exposure and severity ratings. Continuous monitoring, public health interventions, and community-based crime prevention strategies are necessary to address these risks effectively.

viii. (R12) Drugs: These hazards present a lower risk with low severity ratings and relatively lower exposure ratings. Nonetheless, long-term measures to address social issues should be prioritized to ensure sustainable development and community well-being.

ix. (R7) Solid Waste: While having a moderate severity rating, these technological hazards have relatively lower exposure ratings, indicating a lower risk compared to other hazards. Nonetheless, proper waste management and infrastructure maintenance are essential to prevent potential adverse impacts on public health and urban infrastructure.

x. (R4) Air Pollution and (R10) Economic Inequalities: These hazards pose the lowest risk with relatively lower exposure and severity ratings. However, addressing economic disparities and improving air quality remain important for fostering equitable development and ensuring the well-being of all residents.

3.4.1.2 An analysis of severity versus likelihood

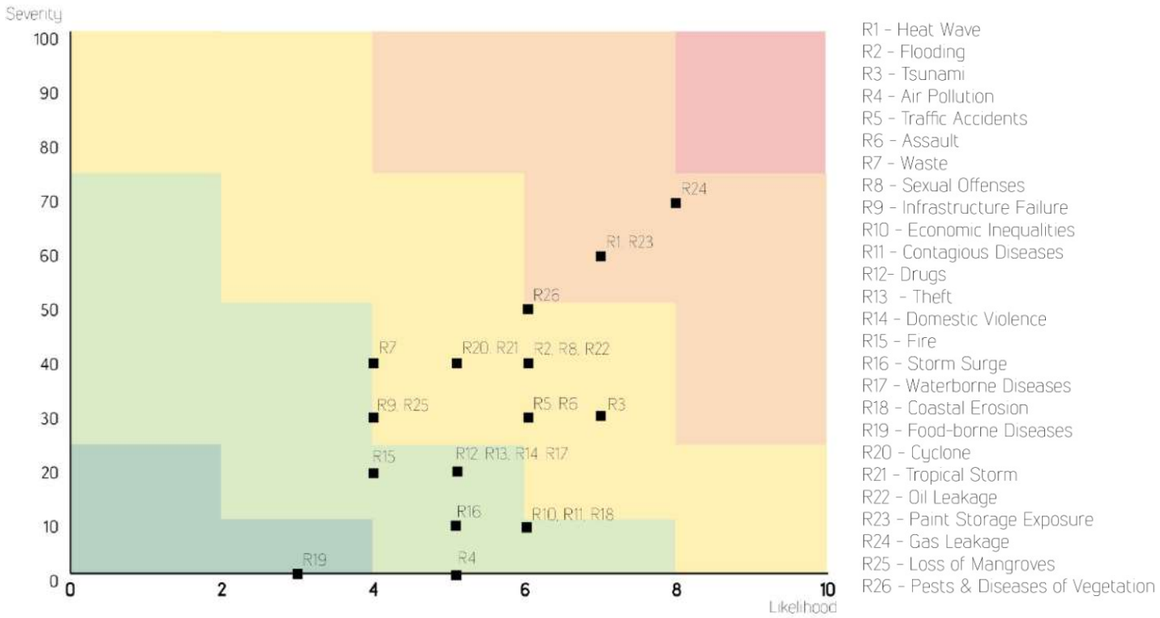


Figure 103. Severity vs Likelihood Risk Graph

Severity rating indicates the potential impact or damage caused by a hazard event, while the likelihood ranking score assesses the probability of occurrence. These two factors together provide a comprehensive understanding of the risk posed by each hazard. Hazards with high severity ratings and high likelihood ranking scores represent scenarios of elevated risk, indicating both a significant potential impact and a high probability of occurrence. Such hazards require urgent attention and robust risk management strategies to mitigate their effects effectively. Conversely, hazards with low severity ratings and low likelihood ranking scores may still warrant consideration, as their cumulative impact over time or in combination with other hazards could escalate the overall risk profile of the city.

A description of the hazards risk, ranked on severity and likelihood ranking follows (Figure 103).

i. (R24) Gas Leakage: This hazard presents the highest risk due to its very high severity rating and likelihood ranking score, indicating both a severe potential impact and a high probability of occurrence. Immediate measures are imperative to mitigate this risk effectively.

ii. (R23) Paint Storage Exposure: Similarly, this hazard ranks high in risk with extremely high severity rating and likelihood ranking score, demanding urgent attention and proactive risk management strategies to prevent potential incidents.

iii. (R3) Tsunami (earthquake trigger): These geohazards pose a significant risk with very high severity ratings and likelihood ranking scores, signifying a considerable potential impact and a high probability of occurrence. Strategies to enhance preparedness and resilience against seismic events are crucial.

iv. (R2) Surface Water Flooding: With very high severity ratings and likelihood ranking scores, these hazards represent a significant risk requiring immediate action to mitigate their impact on the city.

v. (R22) Oil Leakage This chemical hazard ranks moderately high in risk, with a high severity rating and likelihood ranking score. Effective measures should be implemented promptly to prevent and manage potential oil leakage incidents.

vi. (R1) Heatwave: Despite its lower likelihood ranking score, the heatwave hazard poses a considerable risk due to its high severity rating, indicating potential significant adverse impacts, particularly on vulnerable populations.

vii. (R20) Cyclone and (R21) Tropical Storm: These wind-related hazards present moderate risks with high severity ratings but slightly lower likelihood ranking scores compared to other hazards. Preparedness measures should focus on mitigating wind-related damage during cyclones and tropical storms.

viii. (R11) Contagious Diseases: While having a moderate likelihood ranking score, contagious diseases exhibit varying severity ratings, indicating a moderate risk overall. Continuous monitoring and response measures are necessary to address infectious disease outbreaks effectively.

ix. (R18) Coastal Erosion and (R26) Pests and Disease of Vegetation: These environmental hazards pose moderate risks with moderate severity ratings and likelihood ranking scores. Strategies should be implemented to mitigate the long-term impacts of coastal erosion and biodiversity loss.

x. (R5) Traffic Accidents and (R12, R6, R13, R8, R14) Crime (Drugs, Assault, Theft, Sexual Offences, Domestic Violence): Social hazards such as crime and traffic accidents present moderate risks with moderate severity ratings and likelihood ranking scores. Community-based interventions and law enforcement efforts can help mitigate these risks effectively.

xi. (R4) Environmental Degradation - Air Pollution: Despite its moderate severity rating, air pollution presents a lower risk due to its lower likelihood ranking score. However, long-term mitigation efforts are necessary to address environmental degradation and its impact on public health.

xii. (R10) Economic Inequalities - Income, Employment & Poverty, Financial Shock: While posing a moderate risk with high severity ratings, economic hazards have a lower likelihood ranking score, indicating a lower probability of occurrence. Nonetheless, measures to address economic inequalities and financial shocks should be prioritized to enhance community resilience.

Figure 104. Image credit:Vashifoshi, Kulhudhuhffushi, https://www.vashifoshi.com/maldives/local-islands/kulhudhuffushi.html

3.4.1.3 The Overall Risk Assessment

Table 25. The summary of the Quick Risk Estimation (QRE) Tool Output to evaluate exposure, vulnerability, and response measures

Hazard family	Hazard event	Risk Matrix output
Temperature-related	Heatwave	H7
Environmental degradation	Paint Storage exposure	H7
Environmental degradation	Gas Leakage	H7
Seismogenic (earthquake)	Tsunami (earthquake trigger)	M6
Wind-related	Cyclone	M5
Wind-related	Tropical storm	M5
Flood	Surface water flooding	M5
Crime	Traffic Accidents	M5
Environmental degradation	Pests and disease of vegetation	M5
Environmental degradation	Oil leakage	M5
Crime	Assault	M5
Crime	Sexual Offenses	M5
Infectious diseases	Waterborne diseases	L4
Waste	Solid waste	L4
Infrastructure failure	Infrastructure failure	L4
Environmental degradation	Loss of mangroves	L4
Crime	Drugs	L4
Crime	Theft	L4
Crime	Domestic Violence	L4
Infectious diseases	Contagious diseases	L3
Marine	Storm surge	L3
Industrial failure/Non-compliance	Fire	L3
Environmental degradation	Coastal erosion	L3
Economic	Economic inequalities - income, employment & poverty, financial shock	L3
Infectious diseases	Food-borne disease	VL1
Environmental degradation	Air pollution	VL1

High (H), Moderate (M), Low (L), Very Low (VL)

The details of the QRE tool's risk matrix scoring system details is included in the annex.

Kulhudhuffushi City's aerial imagery
Image credit: Charrette team

Table 26. Risk Assessment

High (H), Moderate (M), Low (L), Very Low (VL)

Hazard	Exposure	Vulnerability	Capacity	Risk	Explanation
Waterborne Diseases	Very Unlikely	45	Few measures in place	L4	Waterborne diseases have a reasonable likelihood of occurrence (45), with moderate severity (20.0). Although there are few measures in place, the vulnerability stems from potential exposure to contaminated groundwater due to inadequate waste management infrastructure. Capacity to respond is high due to the availability of a high quality water supply available on the island through Fenaka.
Contagious Diseases	Extremely Likely	53	Reasonable measures in place	L3	Contagious diseases pose a significant risk due to their high likelihood (53) and potential for widespread transmission. While there are reasonable measures in place,like new medical facilities and a skilled workforce to enhance capacity. The vulnerability remains high due to the island's exposure through medical tourism and the airport.
Loss of Mangroves	Likely	30	Extremely few measures in place	L4	Loss of mangroves pose a significant risk due to their high likelihood (30) and potential for widespread impact due to the relative sub impacts of the hazard.
Pests and Diseases of Vegetation	Likely	60	Extremely few measures in place	M5	Pests and diseases of vegetation present a very likely risk (60), especially for areas with adequate vegetation, with potential for household damage.
Storm Surge	Probable	55	Some measures in place	L3	Storm surges have a moderate likelihood (55) and severity (10.0), posing a significant risk, especially for locations close to the coastline. Although some measures are in place, the vulnerability remains due to potential water intrusion into houses, emphasizing the need for further mitigation efforts.
Heatwave	Inevitable	58	Extremely few measures in place	H7	Heatwaves pose an extreme risk due to their inevitability (58) and high severity (60.0). Although there are extremely few measures in place, the vulnerability arises from the lack of trees, shade, and urban greening, exacerbating the urban heat island effect. The construction of a new powerhouse may mitigate heat effects, but further efforts are needed to address this significant risk.
Surface-water Flooding	Very Likely	68	Very few measures in place	M5	Surface-water flooding presents a very likely risk (68) with significant severity (40.0), especially for areas with inadequate elevation and potential for household damage. While some measures are in place, the vulnerability remains high due to the lack of comprehensive flood management strategies, highlighting the need for further mitigation efforts.
Cyclone	Probable	60	Few measures in place	M5	Cyclone presents a very likely risk (60), especially for areas with adequate vegetation, with potential for fall debris damage.
Tropical Storm	Probable	60	Few measures in place	M5	Tropical Storm presents a very likely risk (60), especially for areas with inadequate vegetation, with potential for household exposure and consequential damage.
Solid Waste	Improbable	50	No measures in place	L4	Solid waste management poses a potential risk (50), with moderate severity (40.0), especially due to the limited exposure to fumes and smoke. However, the vulnerability remains high due to the lack of measures in place for improved waste management infrastructure, emphasizing the need for further action to mitigate potential exposure.

Hazard	Exposure	Vulnerability	Capacity	Risk	Explanation
Fire	Possible	55	Very few measures in place	L3	Fire presents a possible risk (55) with moderate severity (20.0), especially due to infrastructure proximity and limited firefighting resources. While there are some measures in place, the vulnerability remains high, emphasizing the need for further efforts to mitigate potential fire hazards.
Infrastructure Failure	Possible	55	Extremely few measures in place	L4	Infrastructure failure poses a possible risk (55) with moderate severity (30.0), especially due to inadequate engineering and construction practices. While there are extremely few measures in place, the vulnerability remains high, emphasizing the need for enhanced infrastructure planning and building regulations to mitigate potential structural failures.
Traffic Accidents	Likely	60	Few measures in place	M5	Likely risk due to mixed construction materials. Lack of the security measures and road signage can further increase this risk. Traffic accidents pose a likely risk (60) with moderate severity (30.0), especially due to inadequate road safety measures. While some measures are in place, the vulnerability remains high, emphasizing the need for further infrastructure improvements and public awareness campaigns to mitigate potential accidents.
Tsunami	Very Likely	78	Some measures in place	M6	Tsunamis pose a very likely risk (78) with moderate severity (30.0), especially due to the island's vulnerability to seismic events. While some measures are in place, the vulnerability remains high, emphasizing the need for further community education, preparedness, and enhanced early warning systems to mitigate potential tsunami impact.
Air Pollution	Very Likely	48	Extremely few measures in place	M5	Air pollution presents a very likely risk (48) with moderate severity (30.0), especially due to proximity to waste management areas and industrial activities. While there are extremely few measures in place, the vulnerability remains high, emphasizing the need for further measures such as emission reduction strategies and improved waste management to mitigate potential air pollution.
Coastal Erosion	Likely	68	Reasonable measures in place	L3	Coastal erosion poses a likely risk (68) with moderate severity (10.0), especially due to signs of active erosion and loss of significant vegetation. While there are reasonable measures in place, the vulnerability remains high, emphasizing the need for further coastal protection measures and ecosystem restoration initiatives to mitigate potential erosion.
Drugs	Likely	58	Few measures in place	L4	Drug-related crimes pose a likely risk (58) with moderate severity (20.0), especially due to inadequate measures in place. Due to the number of cases reported and given the historical data, exposure to drugs is likely in KC, individual susceptibility and lack of support systems such rehabilitative services cause this to be a high risk.

Hazard	Exposure	Vulnerability	Capacity	Risk	Explanation
Assault	Likely	60	Few measures in place	M5	Assault-related crimes pose a likely risk (60) with moderate severity (30.0), especially due to inadequate measures in place. Likely risk due to lack of security measures and preventive systems. High vulnerability requires enhanced policing and access to legal aid and a strengthened social service provision.
Theft	Likely	58	Few measures in place	L4	Theft-related crimes pose a likely risk (58) with moderate severity (20.0) Likely risk due to criminal involvement and lack of security measures such as CCTV or community watch. High vulnerability necessitates improved security measures and community vigilance.
Sexual Offences	Likely	60	Very few measures in place	M5	Sexual offences pose a likely risk (60) with moderate severity (40.0).While some measures are implemented, the vulnerability remains high. High risk arises from the lack of mechanisms to address the issue, given the number of reported cases, it is likely that there are many unreported cases. High density population can create anonymity of the offenders and given the nature of the offense it is often difficult for the survivors/victims to report the cases. High vulnerability requires comprehensive support systems, legal assistance and strengthened law enforcement to be in place.
Domestic Violence	Likely	58	Few measures in place	L5	Domestic violence poses a likely risk (58) with moderate severity (20.0). Likely risk due to cultural norms, domestic violence often has to do with power dynamics and makes it harder for the victims to come forward. High vulnerability necessitates enhanced support services and community awareness, strengthened law enforcement and legal assistance.
Economic Inequalities	Likely	70	Reasonable measures in place	L3	Economic inequalities and financial shocks pose a likely risk (70) with moderate severity (10.0). Likely risk due to power dynamics. High vulnerability requires targeted economic development programs and social safety nets.

Analyzing the risk assessment reveals several key insights into the diverse hazards and their associated risks.

Topping the list of hazards are Chemical Hazards, encompassing Gas Leakage, Paint Storage Exposure, and Oil Leakage. These hazards command the highest degree of concern due to their elevated exposure and severity ratings. Gas leakage, in particular, presents an imminent threat to public safety and environmental integrity, necessitating immediate regulatory interventions and heightened surveillance protocols to avert potential catastrophic consequences.

Following closely are Extreme Weather Events, notably Heatwaves and Floods, with Surface Water Flooding carrying slightly higher severity implications. Heatwaves, though marginally lower in exposure rating compared to floods, pose significant risks to human health, especially among vulnerable demographics. Concurrently, floods, particularly surface water inundation, pose substantial threats to infrastructure resilience, agricultural productivity, and public health. Consequently, proactive measures such as enhanced drainage systems and early warning mechanisms are imperative to mitigate their adverse effects.

In the realm of Geohazards, Seismogenic Hazards, including earthquakes and tsunamis, exhibit considerable risk due to their elevated exposure and severity profiles. Concurrently, Cyclones and Tropical Storms also present formidable challenges, notably concerning infrastructural damage and population displacement. Implementing robust disaster preparedness plans, encompassing evacuation protocols and the establishment of resilient shelters, is indispensable to bolster the island's resilience to these hazards.

Biological Hazards, typified by Contagious Diseases and Environmental Degradation, emerge as moderately concerning. Contagious diseases, stemming from waterborne and foodborne sources, necessitate proactive measures in disease surveillance and hygiene promotion to mitigate their adverse impacts on public health. Similarly, addressing environmental degradation, such as coastal erosion and loss of vegetation, requires concerted conservation efforts to safeguard ecological integrity and enhance resilience to natural hazards.

Technological and Infrastructure-Related Hazards, inclusive of Waste Management, Industrial Failures, and Infrastructure Breakdowns, present moderate risks necessitating diligent attention to prevent disruptions to essential services and environmental contamination. Adherence to stringent waste management practices, regulatory compliance in industrial sectors, and proactive infrastructure maintenance are indispensable in mitigating potential adverse outcomes.

Finally, Social Hazards, including Crime and Economic Inequalities, though ranking lower in exposure and severity, are nonetheless significant concerns warranting attention. Alleviating social disparities, bolstering law enforcement mechanisms, and fostering economic opportunities are essential strategies to fortify community safety and resilience.

This risk assessment underscores the importance of proactive risk management strategies that address a wide range of hazards, vulnerabilities, and societal factors to build resilient communities and enhance overall disaster preparedness and response capabilities

Strong winds and rough seas at the harbour
Image credit: kulhudhuffushi Online

3.5 GAPS IDENTIFIED WITHIN THE STUDY

The following are the gaps identified within the phase of the study for further emphasis within the process. These are important to be highlighted in the next step of the disaster management planning process. A detailed interpretation of the approach of this conclusion is presented in Table 23 - breakdown of Capacity to Address Hazards:

• Lack of an in-depth study on the prevalence of waterborne diseases in Kulhudhuffushi City as it is important to:

1. Understand the household use of the groundwater.

2. Understand the household ground water source, proximity to the sewage seepage area.

3. Understand the local breeding area range.

4. Understand the measures in place for the prevention of waterborne diseases

• Lack of an in-depth study on the prevalence of contagious diseases in Kulhudhuffushi City as it is important to understand the measures taken in Kulhudhuffushi City to maintain a contagion free zone, and the status of those measures.

• Absence of sufficient data on how the locals use the wetland currently.

• Low public awareness on the importance of having mangroves for the island's ecosystem. It is considered more of a burden than a valuable resource.

• Lack of data on the history of invasive species affecting the plants and the number of outbreaks.

• Absence of any research conducted on the issue given the current reports of unidentified pests in the eastern ridge.

• Low community preparedness and resilience to handle storm surges and related emergencies

• Lack of urban heat prevention strategies.

• Absence of a functioning drainage system to effectively mitigate urban flooding.

• Lack of recent studies to assess the extent of damage caused by floods to households in flood-prone areas.

• Limited implementation of measures or plans to mitigate floods and their impact on households

• Absence of a proper island level or institutional level disaster management plan

• Lack of trained staff at island level to handle an emergency operation

• Low public awareness on the possible impacts of a cyclone, prevention, response, recovery

• Lack of a proper island level or institutional level disaster management plans

• Lack of trained staff at island level to effectively handle an emergency operation

• Low public awareness on the possible impacts of storm, prevention, response, recovery

Lack of regular monitoring carried out for the coastal protection measures which is essential to:

• Understand Longshore current sediment shift impact for the island.

• see if the northern tip is acting as a point for potential placement loss

• Evaluate the effectiveness of the measures undertaken

• Waste is still not properly managed

• Lack of awareness amongst the community on managing waste, especially hazardous waste

• Lack of studies on the dangers of open burning/ impact on air quality due to the legacy waste that exists in the waste dumping site

• Regional waste management center not established yet

• Insufficient availability of equipment, such as ladders of required heights, to address potential fires in high-rise buildings.

• No clear procedures in place for effectively managing fires with the potential to spread extensively

• Absence of proper infrastructure planning

• Absence of climate-proof building regulations

• Lack of adequate road safety measures in place to address the increased number of accidents

• Lack of a proper island level or institutional level disaster management plans

• Lack of trained staff at island level to effectively handle an emergency operation

• Low public awareness on the possible impacts of a Tsunami, prevention, response, recovery

• Air pollution data collected not readily accessible

• Limited availability and access to effective rehabilitation programs

• Lack of sufficient preventive measures and early intervention programs

• Insufficient targeted interventions to address the drug supply and demand

• Inadequate gang prevention and intervention programs as well as support services.

• Inadequate security measures and the prevalence of petty crimes.

• Pervasive power imbalances, entrenched cultural norms and societal attitudes.

• Lack of adequate support services and awareness/ education regarding the issue.

• Lack of support networks.

• Inadequate support services and awareness.

• Power imbalances and the pervasive social norms.

• Lack of support services in times of a shock.

• Lack of financial literacy and empowerment of the society to build resilience to shocks.

CHAPTER 4 -
WAY FORWARD

The main next step for the project is the disaster management planning process(see Figure 3 for the details of the entire project and the upcoming steps). Based on this HVCA the following steps can be outlined in disaster management planning for Kulhudhuffushi City:

Kulhudhuffushi City's aerial imagery
Image credit: MRC team

4.1 ENHANCED SURVEILLANCE AND EARLY WARNING SYSTEMS

Implement robust surveillance systems for monitoring infectious diseases, surface-water flooding, and air pollution. Strengthen early warning systems for hazards such as storm surges, heatwaves, and tsunamis to improve response time and community preparedness.

4.2 INVESTMENT IN INFRASTRUCTURE AND RESILIENCE

Allocate resources towards infrastructure upgrades and resilience measures to mitigate the impact of hazards such as storm surges, heatwaves, and surface-water flooding. This may include improving drainage systems, constructing seawalls, enhancing urban greening, and strengthening building codes to withstand disasters.

4.3 PUBLIC HEALTH INTERVENTION

Implement targeted public health interventions to prevent and control the spread of infectious diseases and waterborne illnesses. This may involve vaccination campaigns, sanitation improvements, and community education programs to promote hygiene practices and disease prevention.

4.4 WASTE MANAGEMENT AND POLLUTION CONTROL

Develop comprehensive waste management strategies and pollution control measures to address risks associated with solid waste and air pollution. This could include implementing recycling programs, enforcing pollution regulations, and promoting cleaner production practices in industries.

Figure 105. Harbour area of Kulhudhuffushi City, Image credit: Charrette team

4.5 COMMUNITY ENGAGEMENT AND CAPACITY BUILDING

Foster community engagement and capacity building initiatives to enhance disaster preparedness and response at the grassroots level. Conduct training sessions, workshops, and simulations to educate residents on disaster risks, evacuation procedures, and first aid techniques.

4.6 SOCIAL SUPPORT SYSTEMS

Strengthen social support systems and services to address vulnerabilities related to social hazards such as drugs, assault, theft, sexual offenses, and domestic violence. This may involve establishing victim support centers, counseling services, and legal aid programs to assist affected individuals and families.

4.7 ECONOMIC RESILIENCE

Develop economic resilience strategies to address underlying risks associated with economic inequalities and financial shocks. This could include implementing targeted economic development programs, social safety nets, and financial assistance schemes to support vulnerable populations during times of crisis.

4.8 INTER-AGENCY COLLABORATION AND COORDINATION

Foster inter-agency collaboration and coordination among government agencies, non-governmental organizations, and community stakeholders to ensure a cohesive and effective disaster management response. Establish clear communication channels, protocols, and partnerships to facilitate information sharing and resource mobilization during emergencies.

4.9 LIMITATIONS

Limited or negligible response has been received from key stakeholders, including government institutions and service providers, despite multiple attempts made through various channels to acquire the necessary information.

Additionally, institutional memory loss is evident due to frequent turnover in local government officials and limitations in disaster record-keeping practices, compounded by the fact that data is not consistently made public, further impeding access to historical event information.

Limited to no participation was observed during validation meetings, despite prior notification provided to stakeholder groups such as government institutions involved in emergency operations, expatriate workers, and children's groups. Despite allocating time for these meetings, minimal engagement was observed from the aforementioned stakeholders.

4.10 CONCLUSION

In conclusion, this risk assessment (HVCA) offers insights into the potential hazards and vulnerabilities facing Kulhudhuffushi City. It highlights various risks, including waterborne and contagious diseases, storm surges, heatwaves, surface-water flooding, solid waste, air pollution, and social hazards like drugs, assault, theft, sexual offenses, and domestic violence. The assessment underscores the importance of proactive disaster management planning to mitigate these risks effectively.

Building upon the findings, the future steps outlined offer a comprehensive roadmap for disaster management planning in Kulhudhuffushi City. These steps encompass enhanced surveillance and early warning systems, investment in infrastructure and resilience, public health interventions, waste management and pollution control measures, community engagement and capacity building, social support systems, economic resilience strategies, and interagency collaboration.

By integrating the recommendations, Kulhudhuffushi City can develop a robust disaster management framework tailored to its specific needs and vulnerabilities. This framework will not only enhance the island's resilience to various hazards but also strengthen community preparedness and response capabilities. Ultimately, it will contribute to safeguarding the safety, well-being, and prosperity of Kulhudhuffushi City's population and infrastructure in the face of future disasters. The development of this disaster management framework will be the natural next step for this process using this HVCA.

Kulhudhuffushi City's aerial imagery
Image credit: Charrette team

CHAPTER 5 -
REFERENCES

A park of Kulhudhuffushi City'
Image credit: MRC team

Asian Development Bank (ADB) 2020, Multi-Hazard Risk Atlas of Maldives, ADB, Manila, Philippines.

Charrette Studio 2024a, Elevation and Topographic Survey and Hazard Mapping Report of KCDMHCCAPH [Unpublished].

Charrette Studio 2024b, Household Survey carried out for this Hazard Vulnerability Capacity Assessment of KCDMHCCAPH [Unpublished].

Climate Change Adaptation Project (CCAP) 2016, Disaster Risk Assessment Report, CCAP, Maldives.

Maldives Police Services 2024, Crimes Statistics of Kulhudhuffushi.

Disaster Management Act (Act No. 28/2015), Maldives.

International Federation of Red Cross and Red Crescent Societies (IFRC) 2020, World Disasters Report 2020, IFRC, Geneva.

Kulp, S.A. & Strauss, B.H. 2019, 'New elevation data triple estimates of global vulnerability to sea-level rise and coastal flooding', Nature Communications, vol. 10, no. 1, article 4844, https://doi.org/10.1038/s41467-019-12808-z

Kulhudhuffushi City Council 2024, Island data provided by Kulhudhuffushi City Council [Unpublished].

Maldives Meteorological Service (MMS) 2020, Climate Data and Trends in the Maldives, MMS, Male'.

Maldives Meteorological Service 2024, Historical rainfall data: Kulhudhuffushi City, MMS, Male'.

Ministry of Environment and Energy (MEE) 2013, Detailed Island Risk Assessment in Maldives DIRAM Volume III: Detailed Island Reports, UNDP, Maldives

Ministry of Environment, Energy and Water (MEE) 2007, National Adaptation Programme of Action (NAPA), MEEW, Male'.

Ministry of National Planning and Infrastructure 2020, Strategic Action Plan 2019–2023, MNPI, Male'.

Ministry of National Planning, Housing and Infrastructure (MNPHI) 2019, Planning Regulation 2020, MNPHI, Male'.

Moosa, Z. 2014, Spatial and Temporal Analysis of Rainfall Patterns in Maldives, MSc thesis, University of the South Pacific.

National Bureau of Statistics (NBS) 2020, Multi-Dimensional Poverty Index, NBS, Male'.

National Bureau of Statistics (NBS) 2022, Census: Island Level Indicator Sheets, Kulhudhuffushi, NBS, Male'.

National Disaster Management Authority (NDMA) 2019, Disaster Management Policy, NDMA, Male'.

Riyan 2013, Detailed Island Risk and Vulnerability Assessment: HDh. Kulhudhuffushi, Integrating Climate Change Risk into Resilient Island Planning in the Maldives (ICCRRIP), Ministry of Environment and Energy, Maldives.

Small Island Geographic Society (SIGS) 2022, Socio-Economic Assessment Baseline Study for Kulhudhuffushi, Australian Aid and Kulhudhuffushi City Council, Maldives.

Stojanov, R., Duží, B., Kelman, I., N□mec, D., Procházka, D. & Vaishar, A. 2017, Local perceptions of climate change impacts and migration patterns in Maldives and Sri Lanka, Island Studies Journal, vol. 12, no. 1, pp. 25–44.

UNDP (United Nations Development Programme) 2006, Developing a Disaster Risk Profile for Maldives, UNDP, Maldives.

United Nations Development Programme (UNDP) 2013, Climate Risk Profile of the Maldives, UNDP, Maldives.

United Nations International Strategy for Disaster Reduction (UNISDR) 2009, UNISDR Terminology on Disaster Risk Reduction, United Nations.

United Nations Office for Disaster Risk Reduction (UNDRR) & International Science Council (ISC) 2020, Hazard Definition and Classification Review: Technical Report, UNDRR, Geneva. Available at: https://www.undrr.org/publication/hazard-definition-and-classification-review-technical-report [Accessed 21 Jun. 2024]

World Bank 2017, Climate and Disaster Risk Screening Tool, World Bank.

Ameenee Magu of Kulhudhuffushi City at night
Image credit: Charrette team

CHAPTER 6 -
ANNEXURES

A forest area of Kulhudhuffushi City
Image credit: Charrette team

ANNEX 1 - INSTITUTIONAL AND SOCIAL NETWORK IDENTIFICATION EXERCISE

This annex presents a workshop activity held to identify and map the key institutional and social actors involved in disaster risk management. The exercise was conducted through group brainstorming and visual mapping to explore stakeholder roles, responsibilities, and interconnection.

Activity	Methodology	Materials	Time
Introduction	- Briefly explain the purpose and importance of understanding institutional and social networks in disaster management, emphasizing the goal of enhancing resilience.		5 minutes
Group Brainstorming	- Divide participants into small groups and assign each group a specific stakeholder category (e.g., government agencies, NGOs, community-based organizations). - Task them with identifying the roles, responsibilities, and capacities of their assigned stakeholders in disaster preparedness, response, and recovery. Encourage participants to draw upon their knowledge and experiences.	- A4/A5 color paper - Blue tac - Markers - Sticky notes	30 minutes
Interactive Mapping	- Ask each group to paste the identified roles, responsibilities, and capacities on the wall. - Provide each group with thread/wool to create a visual representation of their stakeholder category's network. - Have all groups map out relationships, interactions, information flows, decision-making processes, and resource allocation patterns. - Facilitate discussions within groups to ensure comprehensive exploration.	- Thread/wool - 4 colors to each group	20 minutes
Cross-Group Sharing	- Invite representatives from each group to present their findings to the larger group. Encourage discussions on commonalities, differences, and potential areas for collaboration or improvement.		10 minutes
Reflection and Action Planning	- Facilitate a reflection session where participants discuss insights gained from the exercise. - Prompt them to identify actionable steps to strengthen collaboration, communication, and resilience within the institutional and social networks. (Add on to a digital action plan as they talk) - Encourage the formulation of concrete plans or initiatives to address identified gaps or challenges.		10 minutes
Conclusion	- Summarize key takeaways from the consultation session and express gratitude to participants for their contributions.		5 minutes

ANNEX 2 - CHILD CONSULTATION PLAN

This annex outlines a consultation session conducted to meaningfully involve children in the HVCA process. Through structured, age-appropriate activities, children were engaged to share their views and experiences of hazards, vulnerabilities, and capacities.

Activity	Methodology	Materials	Time
Introduction	- Brief explanation of Hazard, Vulnerability, and Capacity Assessment (HVCA) - Importance of involving children in the assessment process - Ice breaker – Children introduce themselves and share one thing they like. Facilitators build rapport and establish a positive atmosphere.	- PPT	10 minutes
Objectives	- Clarify the purpose of consulting children. - Identify specific goals for involving children in the HVCA as well as in the DRMHMCCAP		05 minutes
Understanding Hazards	- Facilitator explains different types of hazards using simple language and visuals. - Children share their experiences with past hazards or disasters, and how they affected them.	- PPT	15 minutes
Vulnerability Exploration – Risk Spiderweb	- Facilitator draws a large spider web on a poster board. - Children identify and discuss factors that make them vulnerable to hazards, such as age, location, or access to resources, and place them on the spiderweb. - Facilitator guides a discussion on strategies to reduce vulnerabilities.	- PPT - Spider Web on A2 paper - Sticky notes - Markers	20 minutes
Capacity Assessment – Strength cards	- Facilitator presents a set of cards with images representing different strengths and resources. - Children choose and discuss which strengths they possess individually or as a community. - Facilitator to encourage children to suggest how these strengths can be utilized in emergencies.	- Card set - PPT	20 minutes
Reflection & Sharing findings	- Facilitator to summarize key points discussed during the consultation - Share with them and show our findings (QRE toolkit finding) - Children are asked to share their thoughts.		
Wrap up	- Inform children about the next steps of the process and how their input will be used. - Thank children for their input.		

ANNEX 3 - COMMUNITY CAPACITY ASSESSMENT

This annex summarizes a participatory session held to assess local assets and capacities that contribute to community resilience. Participants identified and mapped the resources in their community.

Activity	Methodology	Materials	Time
Explanation of Asset Mapping	- Provide an overview of what asset mapping is and why it's important. - Explain the types of assets to be identified: physical, human, social, cultural, financial, and institutional.	- PPT	10 minutes
Asset Identification Exercise	- Divide participants into small groups (3-5 people per group). - Distribute large sheets of paper and markers to each group. - Instruct groups to brainstorm and write down all the assets they can think of within Kulhudhuffushi City, considering the different categories mentioned. - Encourage participants to think broadly and creatively, considering both tangible and intangible assets. - Example prompts: "What physical infrastructure exists in our city?" "Who are the skilled individuals or professionals in our community?" "What cultural events or traditions are unique to our city?"	- Flip Chart or A3 paper - Markers - Sticky notes	20 minutes
Group Presentation	- After the brainstorming session, ask each group to present their findings to the larger group. - Facilitate discussion and clarification on any assets mentioned.		10 minutes
Reflections	- Facilitate a brief discussion on the importance of the identified assets for community resilience. (Jam board or physical) - Thank participants for their contributions		5 minutes

ANNEX 4 - DETAILS OF MATERIAL RESOURCES

This annex contains a compiled inventory of key material and logistical resources available within the city. Data was collected on transport and operational assets such as fishing boats, cargo boats, pickups, taxis, and private speedboats.

Fishing Boats Details:

Name	Tonnage	No. of Crew	Details
Heeraa	10.78	9	Pole and line
Miaren	10.22	10	Pole and line Handline Trolling Reef fishery Grouper fishery
Moosun 7	46.23	15	Pole and line Handline Trolling Reef fishery Grouper fishery
Moosun 3	16.33	6	Pole and line Handline Trolling
Saveyraa	5.69	7	Pole and line Handline Trolling Reef fishery
Randhi 2	4.51	7	Pole and line Handline Trolling Reef fishery Grouper fishery
Zoom 4	11.59	13	Pole and line Handline Trolling Reef fishery Grouper fishery

Name	Tonnage	No. of Crew	Details
Janbo	10.82	12	Pole and line Handline Trolling Reef fishery Grouper fishery
Ufuli	2.7	3	Pole and line Handline Trolling Reef fishery Grouper fishery
Barakaai	10.03	3	Pole and line Handline Trolling Reef fishery Grouper fishery
Dhiyavaru	2.65		Pole and line Handline Trolling
Hiyani Dhoani	40.82		Pole and line Handline Trolling Reef fishery Grouper fishery
Kaainath	6.45	8	Pole and line Handline Trolling Reef fishery Grouper fishery
Kandumas	36.09		Pole and line Handline Trolling

Name	Tonnage	No. of Crew	Details
Nasru	15.52	12	Pole and line Handline Trolling Reef fishery
Roma			
Ujaalaa	16.33		Pole and line Handline Trolling
Monamo			
Marina			
Kuda Kaman			
Maavaru Kalo			
Giulhu			
Hora			
Raath			
Molly			
Carrot			
Boadhi			
Falidhoo			
Kiruna 2			
Arumaa			
Paneeno			
Azum	26.14	8	Pole and line Handline Trolling Reef fishery Grouper fishery

Cargo Boats:

Name	No. of Trips	Capacity	Owner
Royal			Mohamed Zuhair
Bilaadharu			Mohamed Zuhair
Sikandharu			Mohamed Zuhair
Iskandharu			Mohamed Zuhair
Bahaadharu			Mohamed Zuhair
Aa Ummeedhu			Aa Point Company Pvt Ltd
Sea Queen			
Baadhshaah			
Liyaa Boat			
Aisham Boat			

Pickup:

Vendor Name	Type	Contact Number	Owner
T4013	Lorry	7777340	Bahee Salaam
Banna Vadaan	Lorry	9990722	Ahmed Hassan (Banna)
T2573	Lorry	7943484	Abdul Rasheed
T4342	Lorry	9829273	Mohamed Ali
T2811	Lorry	7943484	Abdul Rasheed
T2544	Lorry	9429000	Baani
T2886	Pickup	7211916	
T5132	Pickup	9145549	Muneer
T5314	Pickup	9991150	Mohamed Hassan
T5403	Pickup	9922286	
T5609	Pickup	7291020	
T3061	Pickup	7373848	
T4635	Pickup	7646118	
	Lorry	9108266	
T2902	Lorry	9915857	
		7560000	
T3074		9784498	
T1450	Lorry	9905651	
T4606	Pickup	7641313	
T2778	Pickup	9152012	
T3321	Pickup	9904070	
	Pickup	9680081	
T4380	Pickup	7688080	

Taxi:

Taxi Centers			
#	**Name**	**Number of Cars**	**Contact**
1	Fahi Dhuveli Taxi Center		6521515
2	V-cab		6521717

Private Speedboats:

Speed Boats		
#	**Launch Name**	**Contacts**
1	Empire	7697379/7866334
2	Kiruna	7939585/ 9889585
3	Mariaaz	7697379
4	Ransaath	7991940
5	Lonsi 6	7666950
6	Funama 1	9797929/ 7799905
7	Waveline 2	9665535
8	Wave line 1	7733730
9	Blue fish	7444222
10	Fulhangi	9797929/ 7799905

ANNEX 5 - QRE TOOL RISK MATRIX SCORING DETAILS

This annex presents a brief overview of the scoring framework of the QRE tool.

Likelihood ranking			**Very Low**	**Low**	**Moder-ate**	**High**	**Very High**
Likelihood ranking score			*0 - 2*	*2 - 4*	*4 - 6*	*6 - 8*	*8 - 10*
Severity Weighted average severity score (based on responses provided for vulnerability, exposure and response measures)	Insignificant	0 - 10	VL1	VL2	L3	L4	M5
	Minor	11 - 25	VL2	L3	L4	M5	M6
	Moderate	26 - 50	L3	L4	M5	M6	H7
	Major	51 - 75	L4	M5	M6	H7	H8
	Catastrophic	76 - 100	M5	M6	H7	H8	VH9

Guide to Likelihood		
Level	*Definition based on likelihood*	*Definition based on historical data*
Very High (VH)	It is almost certain to occur at least once	Has occurred 3 or more times in the last 5 years
High (H)	Reasonable chance of occurring at least once	Has occurred twice in the last 5 years
Moderate (M)	Might occur at least once	Has occurred once within the last 5 years
Low (L)	Not expected to occur	May occur and has occurred once in the last 10 years
Very Low (VL)	Will only occur in exceptional circumstances	May only occur in exceptional circumstances and has occurred in the last 20 years

ANNEX 6 - QRE TOOL OUTPUT

This annex provides the outputs generated from the QRE tool, detailing identified hazard events, exposure and vulnerability ratings, existing response measures, and final risk scores.

Hazard family	Hazard event	Exposure rating	Vulnerability rating				Total vulner-ability rating	Current level of response measures undertaken or in place	Likeli-hood ranking score	Severity rating	Risk matrix output
			Infrastructure	Productive sectors	Essential or basic services	Human and social aspects	1 (low) - 100 (high)		1 (low) - 10 (high)	1 (low) - 100 (high)	
Infectious diseases	Waterborne diseases	Very unlikely	Negligible	Improbable	Likely	Likely	45	Few measures in place	5.0	20.0	L4
	Contagious diseases	Extremely likely	Negligible	Possible	Very likely	Very likely	53	Reasonable measures in place	6.0	10.0	L3
	Food-borne disease	Probable	Negligible	Possible	Extremely Unlikely	Unlikely	23	High measures in place	3.0	-40.0	VL1
Marine	Storm surge	Probable	Likely	Extremely unlikely	Likely	Likely	55	Some measures in place	5.0	10.0	L3
Wind-related	Cyclone	Probable	Likely	Unlikely	Likely	Likely	60	Few measures in place	5.0	40.0	M5
	Tropical storm	Probable	Likely	Unlikely	Likely	Likely	60	Some measures in place	5.0	40.0	M5
Temperature-related	Heatwave	Inevitable	Possible	Possible	Likely	Inevitable	58	Extremely few measures in place	7.0	60.0	H7
Flood	Surface water flooding	Very likely	Extremely likely	Extremely unlikely	Very likely	Extremely likely	68	Very few measures in place	6.0	40.0	M5
Waste	Solid waste	Improbable	Possible	Extremely unlikely	Probable	Extremely likely	50	No measures in place	4.0	40.0	L4
Industrial failure/ Non-compliance	Fire	Possible	Likely	Possible	Possible	Possible	55	Very few measures in place	4.0	20.0	L3

Hazard family	Hazard event	Exposure rating	Vulnerability rating				Total vulner-ability rating	Current level of response measures undertaken or in place	Likeli-hood ranking score	Severity rating	Risk matrix output
			Infrastructure	Productive sectors	Essential or basic services	Human and social aspects	1 (low) - 100 (high)		1 (low) - 10 (high)	1 (low) - 100 (high)	
Infrastructure failure	Infrastructure failure	Possible	Likely	Possible	Possible	Possible	55	Extremely few measures in place	4.0	30.0	L4
Crime	Traffic Accidents	Likely	Likely	Unlikely	Likely	Likely	60	Few measures in place	6.0	30.0	M5
Seismogenic (earthquake)	Tsunami (earthquake trigger)	Very likely	Very likely	Very likely	Very likely	Likely	78	Some measures in place	7.0	30.0	M6
Environmental degradation	Coastal erosion	Likely	Likely	Extremely unlikely	Possible	Probable	68	Reasonable measures in place	6.0	10.0	L3
	Loss of mangroves	Likely	Unlikely	Unlikely	Unlikely	Unlikely	30	Extremely few measures in place	4.0	30.0	L4
	Pests and disease of vegetation	Likely	Unlikely	Unlikely	Likely	Unlikely	60	Extremely few measures in place	6.0	50.0	M5
Chemical	Oil leakage	Possible	Extremely Likely	Extremely Likely	Extremely Likely	Extremely Likely	90	Very few measures in place	6.0	40.0	M5
	Paint Storage exposure	Possible	Inevitable	Inevitable	Inevitable	Inevitable	100	Extremely few measures in place	7.0	60.0	H7
	Gas Leakage	Very Likely	Inevitable	Inevitable	Inevitable	Inevitable	100	Extremely few measures in place	8.0	70.0	H7
Lithometeors	Air pollution	Very likely	Unlikely	Unlikely	Possible	Very likely	48	Extremely few measures in place	5.0	-30.0	VL1
Crime	Drugs	Likely	Possible	Unlikely	Likely	Very likely	58	Few measures in place	5.0	20.0	L4
	Assault	Likely	Possible	Possible	Likely	Likely	60	Few measures in place	6.0	30.0	M5

Hazard family	Hazard event	Exposure rating	Vulnerability rating				Total vulner-ability rating	Current level of response measures undertaken or in place	Likeli-hood ranking score	Severity rating	Risk matrix output
			Infrastructure	Productive sectors	Essential or basic services	Human and social aspects	1 (low) - 100 (high)		1 (low) - 10 (high)	1 (low) - 100 (high)	
Crime	Theft	Likely	Possible	Possible	Probable	Likely	58	Few measures in place	5.0	20.0	L4
Crime	Sexual Offences	Likely	Negligible	Improbable	Probable	Very likely	60	Very few measures in place	6.0	40	M5
Crime	Domestic Violence	Likely	Possible	Possible	Possible	Very likely	58	Few measures in place	5.0	20	L4
Economic	Economic inequalities - income,employment & poverty, financial shock	Likely	Improbable	Likely	Very likely	Extremely likely	70	Reasonable measures in place	6.0	10.0	L3

Kulhudhuffushi City Council

July 2024