CLIMATE CHANGE ASSESSMENT

I. Basic Project Information

Project Title: TA-9327 MLD: Greater Malé Environmental Improvement and Waste Management Project

Project Budget: $

Source	Amount ($ million)	Share of Total (%)
Asian Development Bank		
Special Funds resources (Asian Development Fund grant)[a]	33.07	62.10
Japan Fund for Poverty Reduction (grant)	2.00	5.00
Government	4.93	32.90
Total	**40.00**	**100.00**

Location: Greater Malé, Maldives

Sector: Waste management and other urban infrastructure and services

Theme: Urban infrastructure / Disaster risk management and climate change

Brief Description

The overall project will improve waste management and collection systems by undertaking essential improvements to Malé's overburdened dumpsite on Thilafushi Island, which create environmental and public health hazards for residents and surrounding resorts. The project will also make waste management on Thilafushi Island and the related waste collected systems more reliable and sustainable as well as disaster-proofed and climate-resilient through an integrated approach that will introduce good practices in waste collection, infrastructure design, procurement and construction. The investments will consolidate and enhance the gains made under previous Asian Development Bank (ADB) and other international partner projects, improve service delivery and improve waste management capacity.

The project includes: (i) improved waste collection and transfer in Greater Malé, (ii) improved dumpsite management and logistics on Thilafushi Island, (iii) improved island waste management systems, (iv) strengthened institutional capacity of Waste Management Corporation Limited (WAMCO), and (v) awareness campaign and behavior change including strengthened disaster risk and solid waste management practices on Thilafushi Island, Malé and in Zone 3.

II. Summary of Climate Risk Screening and Assessment[1]

A. Sensitivity of project component(s) to climate/weather conditions and sea level

The project has a low risk level to climate conditions and sea level impacts, though climate change impacts are likely to compound existing issues, particularly during the rainy seasons.

Project components and key climate sensitivities are likely to include:

Project components	*Sensitivity to climate/weather conditions and sea level*
1. **Improved waste collection and transfer in Greater Malé,** includes: (A) On Thilafushi: (i) Improved dumpsite management and logistics on Thilafushi Island; (ii) Waste processing: Construction and demolition waste (CDW) processing and a logistic area; (iii) Unloading/ jetty/ docks. (B) On Malé and Villimalé two transfer stations, and on Hulhumalé a waste center, with related equipment.	Sensitivity of waste collection and transfer systems to climate/ weather conditions: **Low to Moderate** Sensitivity of waste treatment systems to climate/weather conditions: **Moderate** Sensitivity to sea level rise (SLR) is **High** due to geographical location (Maldives) and the fast rate of SLR measured locally

[1] Geo-physical hazards and disaster risk were integrated in the Disaster and Climate Risk Vulnerability Assessment Report. A summary of the findings and recommendations will be presented below.

2. **Improved island waste management centers (IWMCs) on ten islands.** Each of the IWMCs are expected to operate with containerized waste and a small incinerator 3. **Strengthened institutional capacity at WAMCO** combined with disaster risk management and awareness raising and behavior change campaigns.	Sensitivity of institutional and capacity development measures to climate/weather condition: **Low to Moderate** Overall Risk Assessment: **Low to Medium**

B. **Climate Risk Screening**

The climate risk screening is based on the Second National Communication of Maldives to the United Nations Framework Convention on Climate Change[2] and the Intergovernmental Panel on Climate Change (IPCC) Assessment Reports for global modeling.

Risk topic	*Description of the risk*
1. Higher temperatures	1. Temperature is projected to increase for both land and sea surface temperatures. Land temperatures will have minor impact on operations, while structural elements will experience greater heat stress and exhibit a shorter design life. **Risk level – Low.** Operational costs for ocean-based transport may increase due to higher sea surface temperature (SST). Higher SST will cause increased wave action, leading to reduced wave momentum and increased fuel usage. **Risk level – Moderate.**
2. Increased intensity of precipitation and extreme rainfall (storm) events	2. Increased precipitation variability, and more frequent extreme rainfall (storm) events will increase localized flooding. Longer and more frequent drought periods (i.e., drought conditions every five years) are also expected. The combination of increased flooding and increased drought will impact structure foundations and site drainage. **Risk level – Moderate.**
3. Increased tide and wave action	3. Increases in hourly maximum tide levels are expected. These will also amplify coastal storm surge and wave heights, exerting greater water pressure on coastal areas and structures and increasing the extent of flood land. Higher tides will also compound the underlying trends of coastal erosion. **Risk level – High.**
4. Higher intensity of cyclonic activity	4. An increase in the range of tropical cyclones is expected, bringing Region 3 into the expanded zone. In addition, the intensity of the tropical cyclones, along with their associated wind speeds and precipitation, is likely to increase. During these storms, structural damage to roofs and building envelopes is expected. **Risk level – Low.**
5. Sea level rise (SLR)	5. SLR will generate higher storm surge and tidal elevations. It will increase coastal flooding and inundation with saline water, and place increased pressure on coastal structures, such as seawalls and breakwater. Increased upwards seepage through the coral may also occur. Increased flooding and exposure to saline water may affect structures and mechanical systems, with further impacts on operations. **Risk level – High.**
6. Wind pattern	6. No changes to the prevailing wind pattern are projected.

Climate Risk Classification

Although Maldives is highly vulnerable to the impacts of climate change, once the land reclamation project for Thilafushi, which is outside the scope of this ADB Project, is completed, the risk to this Project will be

[2] Ministry of Environment and Energy. Ministry of Environment and Energy. 2016. *Second National Communication of Maldives to the United Nations Framework Convention on Climate Change.* Malé.

reduced. Adaptation and mitigation measures proposed in this Project will further help reduce climate risks. The overall project risk classification is **Moderate.**

Disaster and climate risk assessment[3]

Key findings are as follows:

- Maldives is exposed to a combination of geo-physical and hydro-meteorological hazards including earthquakes, tsunamis, tropical storms, storm surges, floods, droughts and heat waves. The Indian Ocean Tsunami in December 2004 had devastating humanitarian and developmental consequences for the small island state. Climate change is expected to increase the frequency, intensity and unpredictability of hydro-meteorological hazards and extreme climate events and exacerbate the humanitarian, socio-economic and environmental impacts.
- Since 1979, Maldives has experienced 1,210 small earthquakes, usually felt as tremors without notable damages, and three major earthquake events, with a magnitude of 7 or above on the Richter Scale. Though located in a low risk seismic hazard zone, Region 3 is considered highest on the country's overall (multi-hazard) risk lists due to population size and quality of construction. Maldives also faces tsunami threat, largely from the east and to a lesser degree from the north and south. 95% of tsunamis that affect Maldives are generated in the Sumatra Subduction Zone. Coastal flooding may occur from an earthquake-triggered tsunami. There is a 2% chance of such a tsunami in the next 50 years.
- Maldives weather is dominated by two monsoon periods: the northeast monsoon (December – March) and the southwest monsoon (May – November) with well-defined wet and dry periods, particularly in the northern and central regions. The southwest monsoon is the wetter of the two monsoons and is typically the period when most severe weather events occur. Average annual rainfall is 2,124 millimeters (mm), with an annual gradient of increasing rainfall from north to south that varies between 1,786 mm and 2,277 mm. By 2050, changes to the monsoon pattern and increasing precipitation variability will cause decreased precipitation in the northern areas; particularly during the dry (north-east) monsoon period while rainfall intensity increases.
- Extreme rainfall events, defined in Maldives as a rainfall of more than 50 mm in 24 hours, are projected to increase and become more frequent, which may damage infrastructure and affect operations. The increased volume of water and related localized flood velocity may also impact the structural integrity of assets and their foundations. Longer and more frequent drought periods (i.e., drought conditions every 5 years) are also expected. The combination of increased flooding and increased drought will impact structure foundations and site drainage.
- Coastal inundation associated with high waves, swell waves, *udha*,[4] and heavy rainfall is often experienced during the interim period between the two monsoons (April – December). The swells and wind waves are typically strongest between April and July, and occur more frequently in the southern regions. Increases in hourly maximum tide levels by 0.65 meters (m) are expected. The increases in the hourly maximum tide levels will amplify coastal storm surge and wave heights and strengthen the water pressure exerted on coastal areas. As a result, an increase in the extent of land inundated during high tide is expected. Based on the tidal characteristics, up to 30 non-consecutive days, per year, with more than 6 hours of inundation are likely to eventuate by 2050. Higher tides will also compound the underlying trends of coastal erosion.
- The climate of Maldives is greatly influenced by its tropical monsoon weather, and the islands experience a warm and humid climate throughout the year. The annual mean temperature is around 28°C with little inter-seasonal variability. By 2050, mean annual land temperatures are projected to increase by 1.8°C. In this same period, SST is expected to increase by 1.01°C – 1.93°C. The climate models project an increase in the number of warm nights from 40% to 85% by the end of 2050. The warmer temperatures will make conditions more favorable for certain disease vectors, with impact

[3] Given the specific hazard and climate profile of Maldives, there is significant overlap between disaster risk reduction and climate change adaptation. This is particularly true due to the high probability and relative low intensity of hydro-meteorological hazards compared to the low probability and high intensity of geo-physical hazards. Both DRR and CCA share the goal of avoidance, or limitation, of the impacts of natural hazards and/or climate change. Moreover, DRR is often seen as the first line of defense against climate change, and is, therefore, an essential part of CCA. Conversely, for DRR to be successful, it needs to account for the fluctuating risks associated with climate change, and ensure that short-term measures do not increase medium- and long-term vulnerabilities.

[4] *Udha,* which are unique to Maldives, refers to the annual rise in the height of tidal swells during the southwest monsoon (by up to 0.6 m), causing coastal flooding, along the eastern line of islands and atolls (Kench P., et al. 2005. New model of reef-island evolution: Maldives, Indian Ocean. Geology 33: 145–148).

on population health. Land temperatures will have minor impact on operations, while structural elements will experience greater heat stress and exhibit a shorter design life. Operational costs for ocean-based transport may increase due to higher SST. Higher SST will cause increased wave action, leading to reduced wave momentum and increased fuel usage.

- No changes to the prevailing wind pattern are projected, although, an increase in the tropical cyclone range is expected. This expansion brings Region 3 into the tropical cyclone zone. The intensity of the tropical cyclones, along with their associated wind speeds, precipitation, and range is likely to increase. The maximum probable wind speed in Maldives Hazard Zone 5, of which Region 3 is a part, is 96.8 knots (180 kilometers per hour), equivalent to a lower Category 3 on the Saffir-Simpson Hurricane Scale.[5] An increase in the probable maximum storm surge is also expected.
- Maldives is one of the lowest-lying countries in the world. The average elevation of the islands is 1.5 m above mean sea level (AMSL) and the country is greatly threatened by SLR. In the past century, global mean SLR has been about 1.7 millimeters per year (mm/year). In recent decades, this trend has accelerated to around 3 mm/year. For Maldives, gauge records are only available in three locations (Gan, Malé and Hanimaadhoo). The records from these locations indicate significant, and faster than projected SLR rate of 7 mm/year, more than double the global average.[6] The record, however, is too short to be considered definitive.
- The IPCC projects SLR of up to 0.59 m by 2100. However, based on the tide gauge data this MSL elevation is likely to occur within the Project timeframe. The IPCC projection models are considered accurate for MSL, even with the relatively limited number of tidal gauges to verify and triangulate satellite data in the Indian Ocean, and a high uncertainty range (± 0.36–0.5 m) for region-specific projections, especially in delta regions and island states. SLR will generate higher storm surge and tidal elevations. It is likely to increase coastal flooding and inundation by saline water. Increased pressure on coastal structures, such as seawalls and breakwater is also expected. Increased exposure to saline water may also affect structures and mechanical systems, with further impacts on operations. IPCC projections are not considered as accurate for tidal elevations and for probable maximum storm surge, especially in areas that lack detailed ocean data such as Maldives. This uncertainty will further increase vulnerability to tidal action and storm surges during extreme events.[7]
- In addition to natural hazards and climate change, socio-economic factors also increase the level of disaster risk. Risks arise from the combination of hazard events and human vulnerability, especially in marginalized and vulnerable groups and in highly exposed physical locations. The near doubling of Malé's population by 2030 will significantly increase the population at risk within Region 3 unless countered by concerted disaster risk and solid waste management efforts in line with the 2015 National Policy for Solid Waste.
- One of the direct environmental impacts of the December 2004 tsunami was the high volume of waste generated by the destroyed buildings and infrastructure, particularly on islands where waste management systems did not exist. The sheer magnitude of the event meant that the volume and nature of the debris was far beyond the coping capacities of the affected communities and islands. The rapid clean-up also resulted in inappropriate disposal methods, including air burning and open dumping, leading to severe secondary impacts. Following the tsunami, appropriate waste disposal and recycling systems were identified as critical priorities. Improved environmental management, including sustainable waste management, will effectively reduce risk levels, while increasing both local adaptive capacity and post-disaster response and recovery readiness.

III. Disaster and Climate Risk Management Response within the Project

Acting on lessons learned from the Indian Ocean Tsunami in December 2004, the entirety of the Greater Malé Environmental Improvement and Waste Management Project serves as a disaster risk reduction, climate adaptation and mitigation measure. It aims to ensure that the solid waste management infrastructure within the project area is made resilient to the potential impacts of natural hazards and climate change.
The Project used the following principles to allow for systemic realization of an integrated DRR and CCA approach:

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[5] RMSI for UNDP (2006) Developing a Disaster Risk Profile for Maldives, Volume 1 – Main Report.

[6] Based on data provided by the Meteorological Service in Maldives to the Global Sea Level Observing System.

[7] The IPCC notes that there is high confidence that extremes in sea level will increase with mean sea level rise will occur but low confidence in region-specific projections for storm surges, and projects in low-lying coastal areas, such as deltas or island states, should be designed to be robust to the projected extreme increases in global sea level.

- DRR and CCA are mainstreamed throughout all stages of Project development; this includes consideration in project development, prioritization, design, and costing, as well as during monitoring and evaluation;
- Consideration is given both to existing and short-term future risks, and, where relevant to the lifespan of infrastructure, future changes in the frequency and/or intensity of extreme events and long-term changes in average disaster and climate and geo-physical risks;
- Actions relating to DRR and CCA are based on a 'no-regrets' and 'low-regrets' approach to project identification – where possible - in order to optimize the cost effectiveness of future investments;
- Integration of DRR and CCA issues is viewed as a flexible and ongoing process that is subject to adaptive management principles throughout planning, design, costing and budgeting, construction, operation, and maintenance; and
- Actions that enhance the enabling environment for DRR and CCA are considered in line with infrastructure investments to maximize the effectiveness of those investments (see other Project reports for details).

The following are the main disaster-proofing and climate risk mitigation measures that can address the expected natural hazard and climate variables over the economic lifetime of the project (25 years):

Pre-Project

Reclaimed land

- Based on projected SLR, the tide gauge data and the probable maximum storm surge, it is recommended that the Project adopt a SLR benchmark between 1.7 – 2.1 m for the (reclaimed) land elevation, consistent with the EIA report for the land reclamation project and a ground floor base elevation (for critical structures and facilities) of 2.2 m; and
- Revetment or embankment along the coast to protect the fill area. Per the EIA, the current proposed top elevation of the rock/geo bag revetment is 1.9 m AMSL.

Docking facilities

- Seawall foundation strengthened and its anchoring improved to allow for elevating the wall crest height (beyond 1.9 m), when needed; and
- To reduce inundation on nearby slab surfaces and walkways, include 'splash pads' to direct water flows.

Ancillary facilities (uncovered flat surfaces, sheds)

- These facilities typically have a lifespan of 10–15 years, and will need to be rebuilt periodically. As part of their rebuilding, updated design parameters to mitigate climate risks will occur; and
- Establish redundancy of storage and intakes to provide flexibility to shift production from one source or intake to another in the event that one becomes compromised, in case an ancillary facility is essential to availability and operations of major components or entire facilities in the RWMF.

Transfer station in Malé

- To reduce inundation on slab surfaces, which serve the various facilities, include 'splash pads' to direct water flows;
- The 6-storey WAMCO administration building to be flood proofed, with specific focus on its ground floor. At a minimum, this includes elevation of its mechanical and electrical systems above 2.2 m, reinforcing its foundation to address flood loads, and use of flood proof materials; and
- Update roof and building design standards of the 6-storey WAMCO administration building to withstand seismic events of moderate intensity (MMI scale V) and Category 2 storms and related wind speeds, with specific focus on the load-path connectors to strengthen the structural frames and roof structure.

Transfer station in Villimaée, and Hulhumalé waste centre

- Design assumes regular area flooding;
- To reduce inundation, slab surfaces include 'splash pads' to direct water flows.

Outer island waste management centers

- Cyclical (10–15 year cycle) replacement of concrete foundation slab, and its elevation by 10–20 cm above ground level; and
- Replacement of sorting shed roofs, as needed.

Non-structural measures

- Strengthen existing solid waste operations through improved collection, disposal and transfer routes, improved siting of new waste transfer and management stations and increased collection frequency;
- Increased efficiency in the transfer and treatment of waste with improved scheduling and connectivity;
- Regular and proactive collection of solid waste from streets and open spaces to minimize accumulation of waste and informal disposal;
- Increased use of corrosive-resistant, lined and lidded storage systems in collection and disposal services;
- Training and education of waste collectors and system managers to improve understanding of waste collection and its implications;
- Public awareness campaign on solid waste management, climate and disaster risk to improve understanding of waste collection and its implications;
- Community-based disaster risk reduction planning and mitigation efforts on Thilafushi Island, in Malé and Region 3 targeting solid waste management; and
- Support for improved institutional and managerial abilities.

COST OF DISASTER PROOFING AND CLIMATE ADAPTATION MEASURES

1. This note summarizes the preliminary costs of the disaster risk reduction (DRR) and climate change adaptation (CCA) measures to be funded in part by a $1.58 million equivalent grant from the Disaster Risk Reduction Fund of the Asian Development Fund of ADB. The table below identifies the preliminary cost estimates for the recommended disaster-proofing, and adaptation measures in the project, estimated to be $1.718 million.

2. The key parameters for determining DRR and CCA costs are as follows:
   - (i) If a facility base floor elevation (BFE) is below 2.2 meters, then there is a need to elevate the ground floor to ensure that flooding will not impact operations;
   - (ii) Mechanical and electrical systems are to be located above ground level in a protected and water-proof environment to protect them from inundation;
   - (iii) The structures of critical facilities are to be designed to withstand intensity V on the MMI earthquake scale and withstand Category 2 storms and related wind speeds;
   - (iv) Ancillary facilities (i.e., uncovered flat surfaces, sheds) and roads are to be replaced and elevated on an as needed basis on a 10-year cycle; and
   - (v) Awareness and capacity building related to DRR and CCA.

Incremental costs for the recommended Disaster Risk Reduction and Climate Change Adaptation Measures

<table>
<tr><th>Package Number</th><th>General Description</th><th>DRR and CCA Measures</th><th>Estimate cost of adaptation measure (US$)</th></tr>
<tr><td colspan="4">Thilafushi RWMF</td></tr>
<tr><td>1</td><td>Harbor rehabilitation, waste processing, administration building, and civil works (platform) for C&D plant, recycling yard</td><td rowspan="3">• Wharfs/jetties/dock access: the seawall foundation strengthened and its anchoring improved to allow for elevated crest height, when needed
• Where ground elevation is below 2.2 meters (m) and critical components might be damaged by saline water, the BFE of floor and/or components raised above 2.2 m
• To reduce inundation on slab surfaces, which serve the various facilities, include ‘splash pads’ to direct water flows and/or water harvesting ‘pits’ to increase water percolation
• Mechanical and electrical systems elevated to protect from inundation in a protected and water-proof environment
• The power back up system set up in a protected and water proof environment to keep systems operational during storms
• Where critical facilities are housed, mitigate seismic vulnerabilities of the buildings and update roof and building design standards to withstand Category 2 storms and related wind speeds</td><td>Seawall: @ $400/m = $100,000
Elevated slab: 5,000m^2 @ $5/m^3 = $80,000
Housed facilities in Cat 2 building envelope: $150,000</td></tr>
<tr><td>3</td><td>End of Life Vehicle (ELV) dismantling workshop (including Equipment) (Plant Contract)</td><td>Elevated slab: 5,000m^2 @ $5/m^3 = $80,000</td></tr>
<tr><td>4</td><td>C&D waste processing plant (including equipment) (Plant Contract)</td><td>Elevated slab: 5,000m^2 @ $5/m^3 = $80,000
Protective elements for C&D processing plant: $100,000</td></tr>
<tr><td colspan="4">Transfer Stations</td></tr>
<tr><td rowspan="2">5</td><td>Villimalé transfer station and Hulhumalé waste centre (Plant contract)</td><td>• Design assumes regular area flooding
• To reduce inundation, slab surfaces include ‘splash pads’ to direct water flows in the Hulhumalé</td><td>$50,000</td></tr>
<tr><td>Transfer station in Malé</td><td>• To reduce inundation on slab surfaces, which serve the various facilities, include ‘splash pads’ to direct water flows and/or</td><td>$550,000</td></tr>
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Package Number	General Description	DRR and CCA Measures	Estimate cost of adaptation measure (US$)
		water harvesting 'pits' to increase water percolation • The 6-storey WAMCO administration building to be flood proofed, with specific focus on its ground floor. At a minimum, this includes elevation of its mechanical and electrical systems above 2.2 m, reinforcing its foundation to address flood loads, and use of flood proof materials • Update roof and building design standards of the 6-storey WAMCO administration building to withstand seismic events of moderate intensity (MMI scale intensity V) and withstand Category 2 storms and related wind speeds, with specific focus on the load-path connectors to strengthen the structural frames and roof structure to improve disaster resilience	
Outer island waste management centers			
6	Outer island waste management centers (up to 32)	• Cyclical (10-15 year cycle) replacement of concrete foundation slab, and its elevation by 50 cm above ground level, • Strengthen sorting shed roofs with strengthened frame joints • Increase shading and ventilation in and around sheds and other buildings • Lined, vegetative bund on sea side of IWMCs to protect from wave action	32 locations, elevated slab @ \$5/m^3 @ 900m^2 = **\$72,000** 32 locations @ \$3,000 = **\$192,000** 32 locations, vegetative bund @ \$2,000 per location = **\$64,000**
Consultant Services			
7	DRR Specialist (international, 3 person-months)	• Review current disaster risk management practices, systems and capabilities on Thilafushi Island, in Malé and in zone 3 in order to propose priority operational and capacity building interventions. • Develop an emergency and business continuity plan for WAMCO, first responders on Thilafushi (police, fire fighters) and surge providers in Malé (NCDM and health professionals). • Strengthen response readiness by initiating training events for WAMCO officials, first responders and surge providers to establish an early notification hotline, an incident command system, triage and emergency SOPs.	<u>Individual recruitment</u> Total: **\$0.150 million** = \$0.08 million remuneration, \$0.07 million workshops
8	Public Awareness and Capacity Building Consultants	• Based on guidance from DRR Specialist, implement community-based DRR and CCA interventions to safeguard workers and residents from the impact of future disasters.	Costs are built into the consultant package = estimated **\$0.05 million**
Estimated Total for DRR and CC Adaptation Measures			**\$1,718,000**