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CLIMATE PROOFING IN G-CREWS’ WATER INFRASTRUCTURE

For the project
FP059 Climate Resilient Water Sector in Grenada (G-CREWS)

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List of abbreviations

ADB	Asian Development Bank
BMU	Germany’s Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
GCF	Green Climate Fund
CFA	Challenge Fund for Agriculture
CP	Climate Proofing
EPA	Environmental Protection Agency
G-CREWS	Climate-Resilient Water Sector in Grenada
GDB	Grenada Development Bank
GIS	Geographic Information System
GoG	Government of Grenada
MOA	Ministry of Agriculture
NAWASA	National Water and Sewage Authority
PURC	Public Utilities Regulatory Commission
WRMU	Water Resource Management Unit

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0. EXECUTIVE SUMMARY

Climate proofing (CP) is an essential tool in climate related project management. Therefore, a climate screening has been executed during the planning phase of the Climate-Resilient Water Sector Project in Grenada (G-CREWS). During the implementation phase the screening was extended to a full climate proofing process to ensure, on the one hand, that the infrastructure to be built under the project contributes to the climate resilience of the water sector and, on the other hand, that the planned activities are resilient with respect to extreme climate events that may affect the island in the future.

In a workshop that involved all main stakeholders, risks, threats, vulnerability, and countermeasures regarding the infrastructure to be implemented under G-CREWS were identified. This report presents the findings of the workshop and complements these outcomes with further knowledge and experiences of technical experts.

The following report therefore gives a helping hand to the planners of the G-CREWS project activities in preparing detailed designs, elaborating terms of references, and in making recommendations to decision makers for further development of policies, plans, and standards. In addition, the discussions during the climate proofing workshop and this report help to raise awareness about climate resilient infrastructure.

The reader may study the chapters 1 to 3 and then concentrate on the specific subsection of interest in chapter 4. Any comment or additional ideas are welcome. The report is considered as a living document which may be enriched by the experiences of all stakeholders.

1. INTRODUCTION

1.1. G-CREWS PROJECT

Water is a scarce resource within the state of Grenada and climate change has already begun to aggravate the problem with an increasing average temperature and more erratic rainfall. Frequent heavy rainfall events make water supply outages more common due to high turbidity in the raw water supply. The main objective of the G-CREWS project is to increase systemic climate change resilience in Grenada’s water sector. To achieve its objective, the project supports the water sector’s comprehensive transformation on multiple levels, which represents a nationwide ‘paradigm shift’ for Grenada’s overall resilience. This paradigm shift will include citizens and businesses as water users, the public sector as provider of potable water and infrastructure. Through appropriate governance, regulation, economic incentives and raising awareness, behaviour changes are expected to be triggered. The G-CREWS project is developed in the following five components:

- Climate-Resilient Water Governance
- Climate-Resilient Water Users
- Climate-Resilient Water Supply Systems
- Additional Contributions of the Water Sector to Grenada’s climate goals
- Regional learning and replication

Jointly financed by the Green Climate Fund (GCF) and the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) under its International Climate Initiative (IKI), the Government of Grenada and the German Development Cooperation (GIZ) are implementing the G-CREWS project. On the Grenadian government side, the Ministry of Finance, Economic Development and Physical Development, the Ministry of Infrastructure Development, Public Utilities, Energy, Transport and Implementation, the Grenada Development Bank (GDB), and the National Water and Sewerage Authority (NAWASA) are involved in the project. The project is scheduled for a period of 6 years and has a total budget of 45.297 Million Euro (Approximately $135 million XCD). All citizens of Grenada, including the agricultural and commercial sectors, are expected to benefit from improved water supplies, especially during times of drought and after extreme weather events.

1.2. CLIMATE PROOFING

Climate proofing (CP) is an essential tool in today's climate related project management. In recent years, CP concepts and tools have been developed by various donor organisations, each adapted to the characteristics of their projects. GIZ has carried out several CP processes in various projects on behalf of its clients, working together with universities and experts. However, a CP process in the context of water infrastructure measure was new for GIZ. For that reason, many of the ideas and concepts of CP in this report is based on publications of the Asian Development Bank, which has developed manuals for various sectors, including the water sector.

Following the definition of ADB[i], climate proofing means identifying risks to a development project as a consequence of climate variability and change ensuring that those risks are reduced through changes in planning, design, construction, operation, and decommissioning.

In preparation for the G-CREWS project in 2015, a detailed screening process was conducted using a climate risk analysis tool developed in the Caribbean (see *https://www.caribbeanclimate.bz/caribbean-climate-chage-tools/tools/*). As a result of the analysis, risks to the Grenadian water sector in connection to climate variability and climate change were identified. Based on the outcomes of additional workshops, measures for the G-CREWS project were developed.

The German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) requires GIZ to conduct a climate proofing for the infrastructure measures under the G-CREWS project after project implementation. The results are presented in this report. The document is intended to be a dynamic document based on exchange with partners and experts in the field.

G-CREWS climate proofing in the implementation phase was conducted in the second year of the project when more detailed information on infrastructure measures became available. The Climate proofing process has several objectives:

1. Reviewing the measures planned regarding their effectiveness in relation to climate events

2. Checking the resilience of the measures planned with regard to climate events
3. Sensitizing partners with respect to the resilience concept of G-CREWS
4. Developing countermeasures to mitigate climate events
5. Developing measures at higher planning levels including standards, policies, plans (to be developed further in component 1.2)

The intention is thus not only to improve the water sector, but to expand it in a climate-responsive way.

1.3. UNDERSTANDING RISKS

There are countless definitions of risk and related terms. In this report we use the following definitions:

A risk is the combination of the probability or frequency of occurrence of a defined threat and the magnitude of the consequences of the occurrence.; or in short form

Risk = f (Threat x Vulnerability x Consequence)

In this context, more keywords need to be defined:

A **threat** is any specific event that could impair the utility from achieving its mission.

In this context an event can also be considered **punctual** (e.g. Hurricanes) or as not concentrated in one point of time, also known as **chronical**, e.g., a development in the context of climate change.

Vulnerability is the likelihood that a specific threat, if it occurs, will damage or impair the operation of a utility asset.

Consequences are the adverse impacts that result when a threat occurs and damages or impairs the operation of the utility's asset.

Countermeasures are systems or practices that reduce the risk from a threat.

Climate resilience is the ability to anticipate, prepare for, and respond to hazardous events, trends, or disturbances related to climate. Improving climate resilience involves assessing how climate change will create new, or alter current, climate-related risks, and taking steps to better cope with these risks.

In determining a risk, the following questions can be asked:

- What causes a risk? (threat)
- How often do specific events occur? (probability)
- How strong is the response of the environment to such events? (vulnerability)
- What damages can be expected? (consequences)

The consequences can be reduced by taking countermeasures. In contrast, it is often much more difficult to influence the event itself or the probability of its occurrence.

G-CREWS aims to make the water sector climate resilient. Extensive studies about climate conditions and its impacts were already available at the beginning of the project conception:

- Climate Vulnerability Assessment of Grenada's Water Sector (GIZ, 2017)[ii]
- Climate Risk and Vulnerability Assessment Report (HR Wallingford, 2017)[iii]
- Climate Change Risk Profile for Grenada (CCCRA, 2012)[iv]
- Grenada Drought Management Plan (2019)[v]
- Caribbean Action Plan on Health and Climate Change (PAHO, 2019) [vi]
- Smart Hospitals Toolkit (PAHO, 2017)[vii]

These quite extensive collection of reports was used to develop measures and to integrate them into the project concept (see also CCORAL Analysis). Unfortunately, these studies are only partially sufficient to quantify direct impacts of climate change to systems and infrastructure. Therefore, additional data and more specific studies were used:

- Meteorological data (partially erratic)
- LEIDAR GIS Map of Grenada
- Demand data (partially erratic)
- Information about material resistance (tanks and pipes)
- Hydraulic and hydrological models
- Caribbean Handbook on Risk Management (CHARIM)[viii]
- Think Hazard! (GFDRR)[ix]

Analysis and collection of these data is time-consuming, especially since many of these data are usually collected by a water resources management unit, which has not been established yet in Grenada. As a result, more detailed studies had to be conducted to gather the parameters needed for detailed planning.

Climate models in the Caribbean show that the increase of extreme weather events in the future (increase in intensity and probability) cannot be denied. However, it remains very difficult to quantify the impacts of future climate events at the temporal and spatial resolution required for detailed planning. Obtaining reliable forecast for the hydrological parameters needed is a challenge. On the other hand, the experiences of the population and the local experts show that the risk, threat, and probability for climate events to occur are high. Especially, hurricanes, floods, and droughts put the Grenadian water sector at risk. Historic events are analysed to elaborate parameters for protective measures. If we are able to increase the climate resilience of the infrastructure to withstand climate events such as Hurricane Ivan or the 2009/2010 drought, the project can be considered very successful.

The situation is somewhat different with regard to sea level rise. Here, no experience is available for Grenada. The predicted data is taken solely from the climate scenarios.

2. CLIMATE RISK SCREENING AND PROOFING

The G-CREWS climate proofing process follows the ADB model for the water sector and was enriched by guidelines for climate proofing of water utilities published by the US Environmental Protection Agency (EPA). However, the ADB approach was shortened and adapted to the current project situation, the available information and the specifics of the current project phase. In particular, the study focuses on the infrastructure to be planned in the project and its vulnerability. To draw conclusions about the evaluation of risks, the identification of countermeasures, and necessary policy elements to be developed, the following steps were developed in a one-day workshop:

- Description of the planned infrastructure measure
- Conducting a detailed climate risk screening
- Survey of existing information and knowledge
- Identification of climatic vulnerability of project components
- Assessment of impacts on investment project
- Prioritization and selection of adaptation options
- Establishing arrangements for implementation
- Identification of needs for technical support and capacity building
- Definition of responsibilities for monitoring
- Definition of feedback into policymaking and knowledge management processes

3. THREATS

Both, climate change and climate variability pose a threat to water services. Important threats include intense rainfall, decreased and more variable water availability, increased temperatures, and droughts (see table 1). These factors do not only affect the physical infrastructure of water supply, but also have institutional and financial consequences: management capability challenges, monetary and regulatory implications. Additionally, the day-to-day challenges of a water utility to provide good services to their clients, on top of facing climate-related impacts, increase the vulnerability in water systems and lead to increased capital and operating costs. Not preparing the water sector and its physical and non-physical infrastructure against the risks of climate events will lead to escalating costs and deteriorating service levels, compromise a country's ability to provide for the social well-being of its citizens, and hinder development.

Table 1: Impact of climate change on water services

Driver	State	Impact	Response
Intense rainfall	• Landslides • Flooding • Debris flows	• Damage to intake structures, pump stations, pipelines, reservoirs, water treatment works, and wastewater treatment works	• Adopt climate resilient design codes • Increase inter-connectivity of water systems

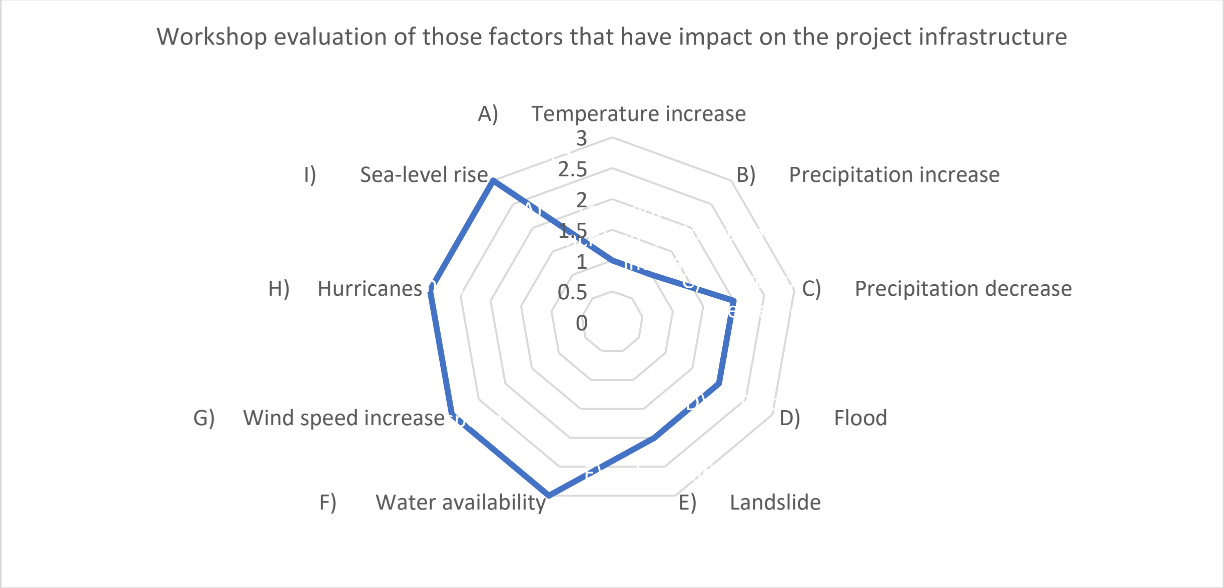
Decreased and more variable water availability	• Decrease in streamflow • Variable surface water flows • Decreased aquifer recharge	• Insufficient storage, poorer water quality and increased treatment costs, increased complaints • Increased competition for water	• Diversify water sources • Pipeline replacement programme • Increase water use efficiency • Reduce leaks and bursts (NRW)
Higher temperatures	• Soil movement • Increased evaporation from impoundments	• Reduction in water quantity and increased pollutant loads • Increased in bursts and leakages • Increases in water demand • Wastewater treatment improvement	• Increase water quality monitoring • Update design standards
Drought conditions	• Reduced water availability • Poorer water quality	• Restricted and constrained supply rationing. • Decrease in productivity • Increase in social and economic stresses	• Reduce consumption through rationing and cut-offs • Introduce water efficient incentive mechanisms • Increase storage • Introduce conjunctive use schemes

A survey of water utilities and responsible ministries[x] identified damage to infrastructure, saline intrusion, drought and extreme flooding as the primary threats to the water sector from climate change. It is worth to mention that the impacts on utilities primary productive input – water resources, were not mentioned in the study. Only salinization of coastal aquifers is related to water resources. The top priority actions identified by the survey included: redesign and protection of critical water infrastructure, improved water management, and improved water storage[2]. In contrast to the Wallingford study, this report also addresses the issues of water resources.

The following threats with certain relevance for the G-CREWS project have been analysed:

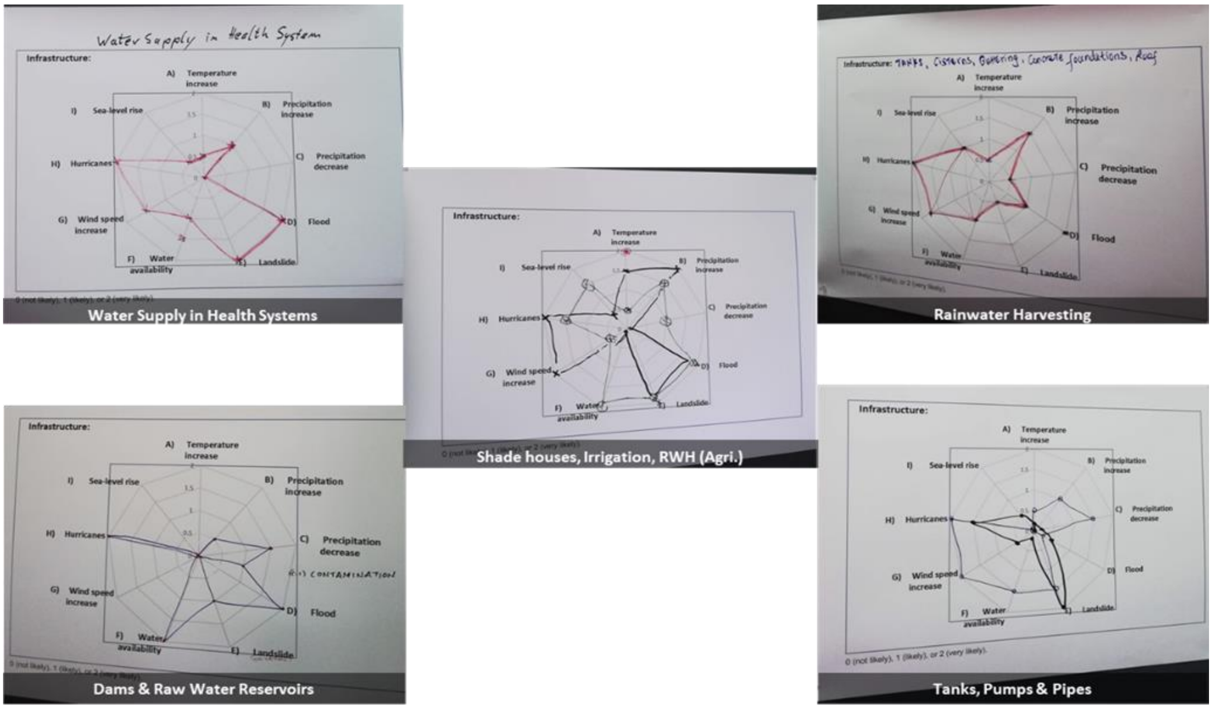
- Temperature increase
- Precipitation increase
- Floods
- Landslides
- Precipitation decrease / droughts
- Water availability
- Wind speed increase
- Hurricanes
- Sea-level rise

For each threat the likelihood of occurrence has been evaluated by the experience of workshop participants.



Legend: 0 (not likely), 1 (likely), or 2 (very likely)
All scores were added together, a total score of 0 indicates a project at no or low risk to climate change. A total score of 1, 2, 3, or 4 indicates a project at medium risk to climate change, provided that no individual question has received a score of 2. A score of 2 to any individual question indicates a project at high risk to climate change. Similarly, a total score of 5 or more (the maximum score being 10) indicates a project at high risk to climate change.

Figure 1: Workshop evaluation of those factors that have impact on the project infrastructure


Water Supply in Health Systems

Shade houses, Irrigation, RWH (Agri.)

Rainwater Harvesting

Dams & Raw Water Reservoirs

Tanks, Pumps & Pipes

Figure 2: Threat diagrams developed during the climate-proofing workshop

As already mentioned, punctual and chronical threats exist. In the following, all analyses focus on the already observed punctual threats (Hurricanes, droughts, floods as occurred in the past), with the exception of sea level rising (caused by climate change). An increase of the recurrence of punctual threats was not considered as there are no reliable and quantifiable data on local level available.

3.1. TEMPERATURE INCREASE

A detailed description is not provided here, as the topic has been classified as not relevant as a direct impact to the project infrastructure.

3.2. PRECIPITATION INCREASE

A detailed description is not provided here, as for the G-CREWS context, the topic is sufficiently described in the chapter “Flood”.

3.3. PRECIPITATION DECREASE

A detailed description is not provided here, as the topic is sufficiently described in the chapter “Water Availability”.

3.4. WATER AVAILABILITY

Rainfall is Grenada's only source of freshwater supply. The climate is tropical, rainfall exhibits a bimodal structure with two rainfall maxima (May-June and September-October) separated by what has been termed a (minor) mid-summer drought, in July and August. The average annual rainfall for mainland Grenada ranges between 1,000 mm and 1,500 mm along the coastal zone, to approximately 4,000 mm in the interior, and which is sufficient to support surface stream flow and recharge of sub-surface aquifers[xi]. The average annual precipitation is 2350 mm. Renewable water resources are estimated at about 200 million m^3/year (FAO 2015) making Grenada a country that is not water scarce as per the Falkenmark indicator[xii].

Despite the high annual rainfall in Grenada, severe dry seasons can be experienced from time to time particularly during the months of February to June when less than 175 mm of rain may fall during the period leading to agricultural and socio-economic droughts. To put it in the words of the UN Secretariat of the International Strategy for Disaster Reduction, a drought is a *"deficiency of precipitation over an extended period of time, usually a season or more, which results in a water shortage for some activity, group, or environmental sectors"*[xiii]. The most recent drought that affected Grenada was the one in the last months of 2009 and the beginning of 2010. Comparing the driest month of each year over the past decades, strong fluctuations can be observed, and the 2009/2010 drought can easily be identified in the graph below. In addition, the graph also reveals a downward trend for the month with low precipitation in the long term. According to Grenada's Drought Management Plan (DMP) developed in 2019, the 2009/2010 drought may be an indicator of a new normal in times of climate change [iv].

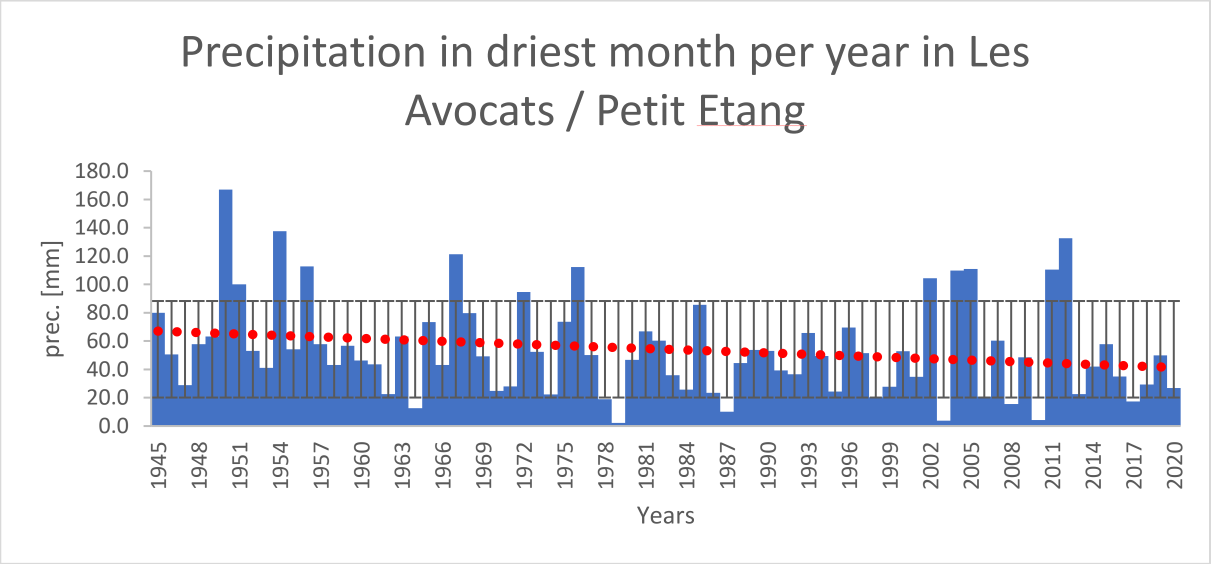


Figure 3: Precipitation in the driest month per year in Les Avocats / Petit Etang, GIZ Grenada, 2021

Grenada's dependence on rainfall creates a high vulnerability to drought events and future changes in both the occurrence and the distribution of rainfall[xiv]. Over the past decades, several drought events have already caused problems. The consequences of drought, according to the DMP, include loss of crops and livestock, erosion of landscapes, damage to terrestrial and aquatic wildlife habitats, enhanced wildfires, and economic damage [iv]. The 2009/2010 drought event, for example, led to a decline in crop and livestock production and an increase in domestic food prices. In addition, the hotel industry suffered from the droughts, as water shortages resulted in guest complaints and declining bookings. The water utility had to regulate the water demand through hard restrictions in the water distribution.

As Grenada experiences high rainfall during the rainy season, the DMP suggests that water shortages during drought are due to the lack of storage and interconnections between Grenada's various water supply sectors. Currently, the reservoirs are located in the upper catchments where the volume of the reservoirs is relatively small. The stored water is enough to cover the water supply for one to two months without rainfall only. Longer lasting drought periods put on risk the water supply system of Grenada.

3.5. SEA-LEVEL RISE

The Climate Change Risk Profile for Grenada (CCCRA, 2012[iv]) explains that observed records of sea level from tidal gauges and satellite altimeter readings indicate a global mean of Sea Level Rising (SLR) of 1.8 (+/- 0.5) mm/year over the period 1961-2003. Acceleration in this rate of increase over the course of the 20th Century has been detected in most regions. The study points out that for the Caribbean region the prediction in SLR of various scientific studies show ranges between 0.20 m and 1.4 m until the year 2100.

No tanks or pipes are situated in the coastal zone and would be affected by SLR. However, the salt intrusion to the groundwater wells already causes problems for NAWASA today. A SLR would increase the risk for the quality of the groundwater wells in the South-East.

3.6. FLOODS

Grenada frequently faces flooding events. Since 2000, at least six extreme flooding events have been registered. Such events are often related to other hazards and can be results of tropical storms and hurricanes. Most floods in Grenada are referred to as "flash floods" because of their short duration and rapid occurrence. Other designations classify events based on geography: coastal flooding, urban flooding, and river flooding are all examples of alternative classifications.

According to a hazard data set available via *CHARIM* [viii], the last six major flood events recorded occurred in the period since 2005. The website *thinkhazard.org* also provides information on risks such as flood risks using data from the *Grenada Meteorological Service*, the *Caribbean Meteorological Organization*, and the *Grenada National Disaster Management Agency (NaDMA)*. According to *thinkhazard.org*, coastal floods are the most relevant hazard in Grenada with the hazard level classified as *"medium"* (see *https://thinkhazard.org/en/report/99-grenada*). Furthermore, the risk level for urban floods is classified *"low"*, while the risk level for river flooding is classified *"very low"*.

Grenada relies on a flood risk assessment and flood hazard map to better define its risks. The national flood hazard map was developed by CHARIM and last published in 2016. It shows the extent of potential flooding, but does not take into account water depth information, as the report explains, *"At this scale and resolution, water depth information is not accurate enough to make a hazard classification combining depth and extent"*[xv]. The flood map is presented in figure 4.

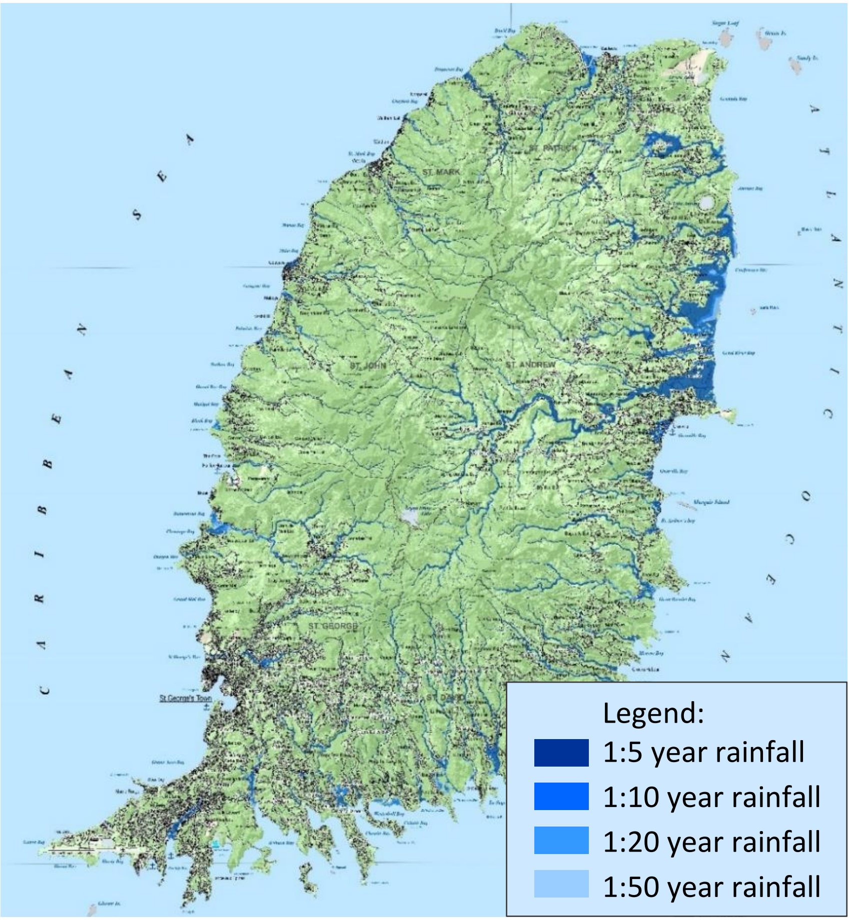


Figure 4: Grenada's Flood hazard map; adapted from: Jetten, 2016[xiv]

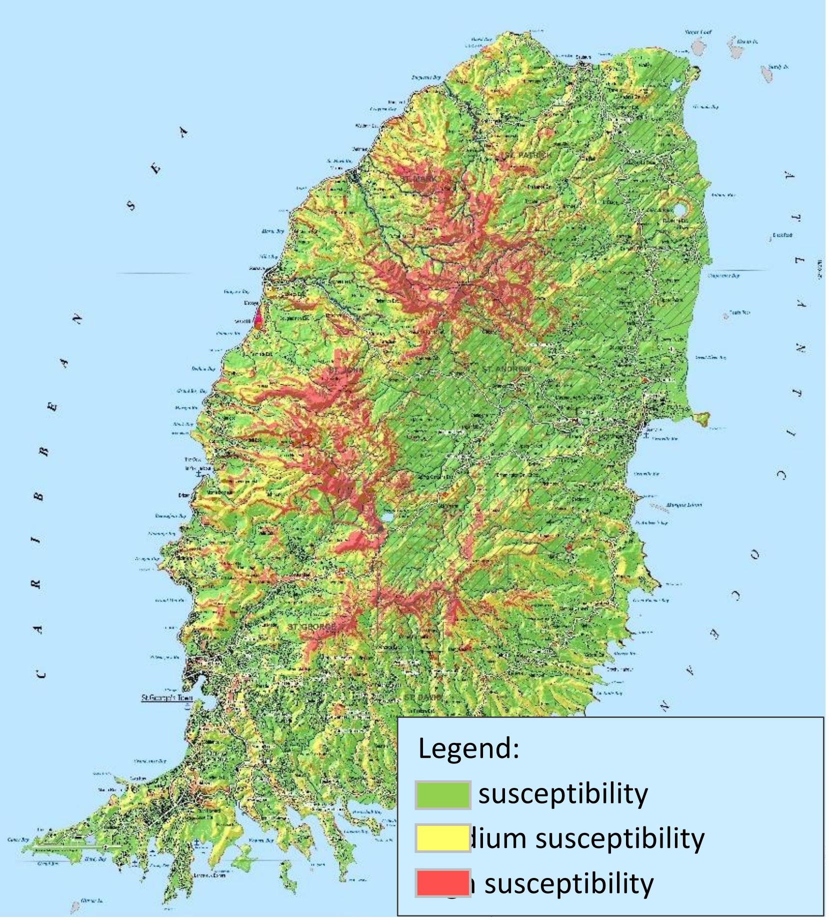


Figure 5: Grenada's landslide susceptibility map; adapted from: van Westen, C. 2016[xvi]

3.7. LANDSLIDES

Landslides occur when the slope of the ground (or a portion of it) undergoes processes that change its condition from stable to unstable. A change in the stability of a slope can be caused by different natural and anthropogenic factors, acting together or alone. The Caribbean Handbook on Risk Information Management Project identified tropical storms and hurricanes as well as heavy rainfall events outside of the hurricane season as the most relevant triggers for landslides in the Grenada (see van Westen, 2016[xvi]).

Natural factors

- Saturation by rainwater infiltration
- Rising of groundwater or increase of pore water pressure
- Increase of hydrostatic pressure in cracks and fractures
- Loss or absence of vertical vegetative structure, soil nutrients, and soil structure
- Erosion of the toe of a slope by rivers or sea waves
- Physical and chemical weathering
- Ground shaking caused by earthquakes
- Volcanic eruptions

Anthropogenic factors

- Deforestation, cultivation and construction
- Vibrations from machinery or traffic
- Blasting and mining
- Earthwork
- In shallow soils, the removal of deep-rooted vegetation that binds colluvium to bedrock
- Agricultural or forestry activities, and urbanization, which change the amount of water infiltrating the soil
- Temporal variation in land use and land cover

Figure 6: Factors that contribute to landslides, source: Wikipedia; https://en.wikipedia.org/wiki/Landslide

In the past 150 years, 58 out of a total of 91 hazard events were related to landslides. Going back in time, the exact number of landslides is not easy to determine, but there is a clear trend of increasing frequency of landslides in recent years.

In 2016, the Caribbean Handbook on Risk Information Management (CHARIM) investigated all data available related to landslides in Grenada and further improved an earlier assessment of Grenada’s landslide susceptibility map, thus generating a more accurate representation of the country’s vulnerability to this hazard (see van Westen, 2016[viii]). The landslide susceptibility map is illustrated in figure 5.

3.8. WIND SPEED INCREASE

Wind speed has interesting implications in evapotranspiration rates when it comes to water balance assessments, but with respect to climate proofing, increases in wind speeds represent the most important risk. In a similar way to hurricanes (see chapter 3.9: Hurricanes), high wind speeds can disrupt or even destroy infrastructures, and lead to interruptions to water distribution and other effects. Based on speed and duration, winds can be classified as storms or different categories of hurricanes (see table 2).

Table 2: Wind-speed scale

Beaufort scale	1-minute sustained winds (NHC/CPHC/JTWC)	**10-minute sustained winds (WMO/JMA/MF/BOM/FMS)**	**NE Pacific & N Atlantic NHC/CPHC**[48]
0–7	<32 knots (37 mph; 59 km/h)	<28 knots (32 mph; 52 km/h)	Tropical Depression
7	33 knots (38 mph; 61 km/h)	28–29 knots (32–33 mph; 52–54 km/h)	
8	34–37 knots (39–43 mph; 63–69 km/h)	30–33 knots (35–38 mph; 56–61 km/h)	Tropical Storm
9–10	38–54 knots (44–62 mph; 70–100 km/h)	34–47 knots (39–54 mph; 63–87 km/h)	
11	55–63 knots (63–72 mph; 102–117 km/h)	48–55 knots (55–63 mph; 89–102 km/h)	
12+	64–71 knots (74–82 mph; 119–131 km/h)	56–63 knots (64–72 mph; 104–117 km/h)	Category 1 Hurricane
	72–82 knots (83–94 mph; 133–152 km/h)	64–72 knots (74–83 mph; 119–133 km/h)	
	83–95 knots (96–109 mph; 154–176 km/h)	73–83 knots (84–96 mph; 135–154 km/h)	Category 2 Hurricane
	96–97 knots (110–112 mph; 178–180 km/h)	84–85 knots (97–98 mph; 156–157 km/h)	Category 3 Major Hurricane
	98–112 knots (113–129 mph; 181–207 km/h)	86–98 knots (99–113 mph; 159–181 km/h)	
	113–122 knots (130–140 mph; 209–226 km/h)	99–107 knots (114–123 mph; 183–198 km/h)	Category 4 Major Hurricane
	123–129 knots (142–148 mph; 228–239 km/h)	108–113 knots (124–130 mph; 200–209 km/h)	
	130–136 knots (150–157 mph; 241–252 km/h)	114–119 knots (131–137 mph; 211–220 km/h)	
	>136 knots (157 mph; 252 km/h)	>120 knots (138 mph; 222 km/h)	Category 5 Major Hurricane

Source: Wikipedia, 2021; *https://en.wikipedia.org/wiki/Beaufort_scale*

3.9. HURRICANES

High wind speeds or even hurricanes are not uncommon in Grenada. The worst hurricane known to date in the country was Hurricane Ivan. Ivan was a large, long-lived, Cape Verde hurricane that caused widespread damage in the Caribbean and United States.

The cyclone was the ninth named storm, the sixth hurricane and the fourth major hurricane of the active 2004 Atlantic hurricane season. Ivan formed in early September and reached Category 5 strength on the Saffir–Simpson Hurricane Scale (SSHS). Ivan caused catastrophic damage in Grenada as a strong Category 3 storm, heavy damage in Jamaica as a strong Category 4 storm, and then severe damage in Grand Cayman, Cayman Islands, and the western tip of Cuba as a Category 5 hurricane.

Table 3: Storm occurrence table

Event	Occurrence
Tropical Storm	50 in 150 years
Category 1 Hurricane	9 in 150 years 1856 NN, 1877 NN, 1878 NN, 1892 NN, 1921 NN 1944 NN, 1954 Hazel, 1955 Janet, 2005 Emily
Category 2 Hurricane	4 in 150 years 1886 NN, 1921 NN 1955 Janet, 1963 Flora
Category 3 Major Hurricane	1 in 150 years 2004 Ivan
Category 4 Major Hurricane	
Category 5 Major Hurricane	0

Source: National Oceanic and Atmospheric Administration of the US (NOAA)*;* *https://coast.noaa.gov/hurricanes/#map=4/32/-80*

Compared to other islands, Grenada is considered to be less affected by hurricanes. However, Hurricane Ivan shows that besides droughts, hurricanes pose the greatest risks to Grenadians water supply.

4. DETAILED RISK ANALYSIS OF G-CREWS INFRASTRUCTURE

To increase the water security and resilience approximately 37 infrastructure measures are being built as part of the G-CREWS project:

- 16 water supply systems with water transmission pipes and water tanks
- 2 water reservoirs
- 4 Rainwater Harvesting Systems for the drinking water supply
- 3 Groundwater wells
- 12 refurbishment and new building of intakes and silt traps

Aside from that, hundreds of irrigation systems, Rainwater Harvesting Systems for hotels, shade houses and hydroponics are proposed to be built.

4.1. WATER TANKS

A key element of the G-CREWS project is to increase available storage capacity by adding glass-welded and bolted water storage tanks at selected sites, along with pipes and valves to connect to the grid. These tanks are known to be a very cost-effective way to make fresh-water storage more climate resilient. They help extend supply times during dry periods, but also provide an additional buffer in the event of a production system failure, such as after heavy rains.

The locations for the additional storage have been selected based on detailed GIS modelling, which included water supply and demand data as well as network data and climate change assumptions, in order to identify the most critical areas where storage needs to be

Figure 7: Water tank in Grenada, 2021, © GIZ Grenada / Marion Geiss

improved to ensure climate-resilient water supply in the medium and long term. The findings of this assessment were checked and verified by NAWASA's Planning and Development Division.

Risks

The assessment made in the climate-proofing workshop identified the most relevant threats for water tanks, including changes in precipitation and water availability, landslides, wind-speed increase and hurricanes. Out of these threats, landslides were identified as a threat to the infrastructure to both underground and above-ground water tanks, while wind speed increase and hurricanes were identified as the major threat to above-ground water tanks. Figure 8 presents the combined evaluation of threats to underground and above ground water tanks.

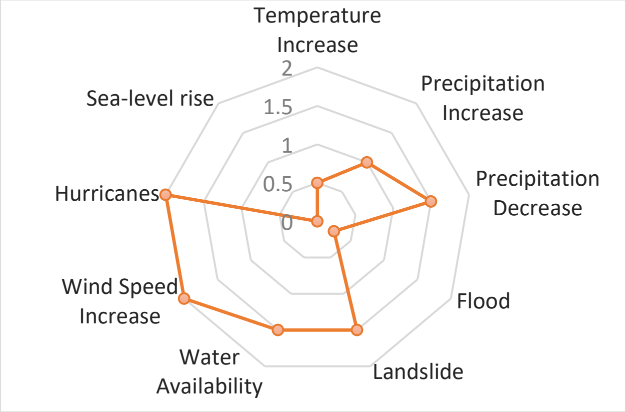


Figure 8: Evaluation of threats for water tanks

Landslides

Due to climate change, and changes in land use and land cover, the stakeholders involved in the climate-proofing workshop assessed a medium to high likelihood of water tanks being affected by landslides.

Likely (1.5)

Landslides can affect the foundation of the water tanks, create cracks that can either leak water or contaminate the storage unit with pathogenic and other contaminants. Ultimately, they can endanger water quality, increase the propagation of water-borne diseases and even interrupt water access for a prolonged time, thus creating a real threat to human and possibly animal safety. This might force communities to look for alternative sources and require them to redirect resources from other important projects. Furthermore, this significantly increases the costs for water.

Figure 9: Water tank damage due to landslide; source: https://www.gns.cri.nz/Home/Our-Science/Natural-Hazards-and-Risks/Landslides/Project-Examples/Lyttleton-Port-Fuel-Storage-Tanks-Landslide-March-5-2014

Summary of possible impacts

Cross contamination

No water supply!

45.000 People. 16 tanks (2.800/tank)

Replacement of 1 tank approx.. 500.000 USD

Critical stress in individual solutions

Wind speed increase and hurricanes

Very likely (2)

The threat of high wind speeds and hurricanes is significant both in terms of impacts and high probability of occurrence. Especially during the hurricane season, the country becomes a site of high risks to infrastructure like above-ground water tanks.

In combination with weakened foundation from increased precipitation or landslides, higher wind speeds can have similar effects as hurricanes and destroy the water tanks, almost immediately leaving communities without access to water.

Figure 10: Destroyed tanks after high wind speeds due to a hurricane, © DeSMOG / Julie Dermansky

Summary of possible impacts

No water supply!

45.000 People. 16 Tanks

(2.800/tank)

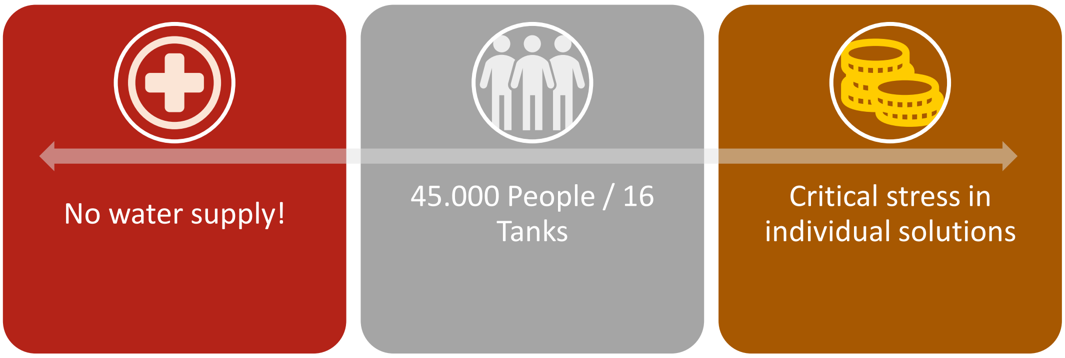
Replacement of 1 tank approx.. 500.000 USD

Precipitation change and water availability

Likely (1.5)

Precipitation change, water availability as well as climate change poses a severe threat to Grenada's water supply because the small island state relies on surface water sources and rainwater catchment. Water is a scarce resource in Grenada and climate change has already begun to aggravate the problem with an increasing average temperature and more erratic rainfall. More frequent heavy rainfall events make water supply outages more common due to high turbidity in the raw-water supply. Saltwater intrusion in coastal groundwater aquifers due to sea-level rise will further reduce the availability of freshwater in the future. High-intensity rainfall can also increase landslide risks at certain locations and put the drainage system in high stress.

Summary of possible impacts



No water supply!

45.000 People / 16 Tanks

Critical stress in individual solutions

Data and information available

Data regarding threats

The likelihood for landslides to occur is not easy to detect as such threats often occur in combination with hurricanes, floods and thunderstorms, which puts into doubt the legitimacy of the data available today, especially when looking at old data. The available data however, suggest that there is an increase in the frequency of landslides.

Grenada counts with measurements from weather radars to identify and manage upcoming storms and hurricanes. Such information enables more reasonable estimates for wind speeds and frequency of hurricanes, as explored in section 3 in this document.

Data regarding vulnerability

The proposed water tanks are made of glass-fused-to-steel, also known as industrial porcelain enamel. This material is a combination of ceramic or glass applied to a subtract of metal. Its main characteristic is its very strong resistance against corrosion. The system has been proven over many decades across thousands of installations, and is supported by international standards which cover the following design and finish requirements[xvii]:

- EN ISO 28765:2011: "Vitreous and porcelain enamels – Design of bolted steel tanks for the storage or treatment of water or municipal or industrial effluents and sludges"

- ANSI / AWWA D103-09: AWWA Standard for “Factory-coated bolted steel tanks for water storage”
- EEA 7.20, EEA 7,24, EEA 7.25: “Vitreous enamel coated bolted steel tanks / silos”
- BS 5502: “Buildings and structures for Agriculture”
- NRCS: Slurry tank design approval for waste storage structures in the USA

Furthermore, industrial porcelain enamel features further advantages including short construction periods, easy installation, expansion possibilities and overall cost efficiency. When it comes to coping with landslides however, foundation, dimension and location play a bigger role and must be assessed prior to installation.

Data regarding consequences

The water tanks are supposed to increase storage capacity and overall resilience of the water-supply system against shortages. The consequences of a failure can only be estimated, but the current system can provide some insights to possible failure scenarios. During the 2009/2010 drought, for example, hotels had to truck water at prices as high as 28.15 USD per cubic meter (Peters, 2015), or approx. 126 USD per 1000 gallons), resulting in additional cost of 119 USD per 1,000 gallons. In addition, the replacement of the water tanks can be assessed. When it comes to health issues due to cross contaminations from damaged underground tanks, the impacts of such issues are not easy to assess. That is especially true considering that the G-CREWS project involves educating the public about the risks. This, in turn, solidifies the communication channels between water utilities and the general population, strengthening measures such as orientation on how to deal with potentially contaminated water.

Countermeasures

An important measure to manage landslide risk, as well as some high rainfall scenarios, is to establish safety criteria for the selection of construction areas. Building in landslide-prone areas should be avoided, and drainage systems are required to reduce the risk of landslides. The preliminary design considers the landslide risk while choosing the right location for the tanks and transmission pipes.

Water tanks must be constructed to withstand potential debris and especially high velocity storms and Category 3 or lower hurricanes. These requirements can be revised but must be included in the terms of references (ToR) for water tank purchases and installation (relative to the site). In addition, the Physical Development Authority (PDA) should establish construction specifications for the type of construction, and a hydraulic model is needed to better assess water management scenarios.

Identify needs for technical support and capacity building

Training and certification are recommended as capacity building measures. Another important technical assistance is to provide adequate guidance on the safety criteria in the terms of reference, both for water tank construction and installation (including a risk assessment of the sites). However, training for risk scenarios is always indicated and should be standard practice, both for staff and the general population.

Monitoring (Entity, System)

The G-CREWS project plays an important role in the development and implementation of a new and modern regulatory framework. This includes the establishment of a Water Resources Management Unit (WRMU) as a regulatory body outside of NAWASA, which should not only prevent conflicts of interest that are detrimental to the proper management of water resources, but also allow for third-party monitoring of the water system. In the initial stages of implementation, the Ministry of Infrastructure Development, Public Utilities, Energy, Transportation, and Implementation should review the ToRs to ensure that the water tanks are wind and storm resistant and that the sites selected for construction have adequate drainage and are not prone to landslides.

Feedback into policymaking

Feedback focused on the importance of risk assessments for water tank siting, more stringent regulations for tank acquisition and installation, and general guidance for various stakeholders to better manage emergency situations (fire, EMS, public, water utilities, water truck professionals, media, community groups, etc.).

4.2. TRANSMISSION PIPES, PUMPS, SCADA AND MICROGENERATORS

The expansion of the water transmission system with newer pipelines is important not only to connect the newer solutions in terms of storage (see previous section), but also to improve the flexibility of the water supply system by connecting the pipelines to each other and to improve the operation of the network. A series of electromechanical equipment such as pumps, a monitoring and data acquisition system (SCADA), and microgenerators are planned. In this way, the system is expected to have a higher coping capacity in different scenarios.

New water pipelines will be built to connect the water tanks to the existing network and the wastewater treatment plant. Wherever it is possible the water will flow gravitationally to the supply zone. Pumps have to be installed at only a few sites to bring the water to a higher the hydraulic level.

The rationale behind the use of the SCADA system is to use modern information and communication technology to enable remote monitoring of water quality parameters and control of water inflows and outflows at 14 water treatment plants and 2 wells. This will reduce interruptions in water systems (e.g., after heavy rains), resulting in a more climate-resilient water supply for approximately 45,000 residents.

SCADA systems consist of both hardware and software. Typical hardware includes a master terminal unit (MTU) in a control centre, communications equipment (e.g., radio, telephone line, cable, or satellite), and one or more geographically dispersed field offices consisting of either a remote terminal unit (RTU) or programmable logic controller (PLC) that controls actuators and/or monitors sensors. The MTU stores and processes information from the RTU inputs and outputs, while the RTU or PLC controls the local process.

Risks

Based on available information and stakeholder participation, landslides and hurricanes were identified as the most significant threats to transmission lines and electromechanical equipment. With respect to pipelines and pumps, flooding was rated as a significant threat, although it received a lower rating in the Climate Proofing Workshop (see Figure 11). Flooding can increase the impact and likelihood of other risks, such as the occurrence of landslides, and can also disrupt pipelines or electromechanical systems through mechanical failure or electrical short circuits.

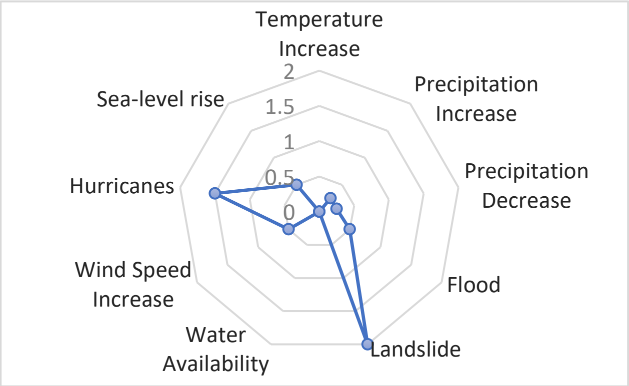


Figure 11: Evaluation of threats for pipes and pumps

Landslides

Very likely (2)

A pipeline's susceptibility to landslides is always only apparent after an event but studying soil and geologic conditions can help us better plan the distribution of our pipelines to reduce disruption to the water supply system. Pipes can be destroyed or simply damaged, resulting in leaks or connections that are even more vulnerable to future hazards.

Because pipes are interconnected, a break in one pipe can disrupt a large portion of the line if proper valves or sections are not installed. It is difficult to assess how many people will be affected, but in general the risks may be spread across all network users. If pipes are disrupted, not only is access to water impeded, but additional costs may be incurred to replace pipes, perform additional maintenance, and repair damaged electromechanical equipment. Damaged pipes can reduce the system's water efficiency through undetected leaks, and pumps, microturbines, and SCADA systems can experience mechanical or electrical failures that partially or completely interrupt the respective station's potable water production.

Summary of possible impacts

No water supply at certain nodes of the system.
Enviromental pollution

45.000 People.
25 Km of pipeline

Maintanance costs.
Replacement costs
(100.000 Euro/ Km)

Hurricanes

Likely (1.5)

Hurricanes are a common threat in Grenada and can contribute to landslides and extreme flooding. They can also have a direct impact on exposed pipelines, especially pipelines along bridge systems.

Pipe material and construction play an important role in resistance to various threats. When a pipe is exposed to high winds, it can crack or break, leaving part of the system temporarily without access to water and ultimately incurring replacement and maintenance costs that were often intended for other local problems.

Figure 12: Water pipe along a bridge system; source: http://www.urecon.com/applications/municipal_bridges.html

Summary of possible impacts

No water supply at certain nodes of the system.

45.000 People.

Increase in maintanance costs.

Replacement costs (100.000 EUR / Km).

Floods

Likely (0.5)

Despite the lower risk rating by stakeholders, flooding is often cited by the same stakeholders as a relevant threat to pumping and pipeline systems due to its significant impact.

Flooding can increase the risk of landslides, but it can also have a direct impact on pipelines and electromechanical systems. Ocean flooding and higher sea levels can cause saltwater to enter groundwater pumping systems, depending on their location and operation. This can both damage the pumps due to the higher corrosivity of salt and put the water system under stress if the salt water is not properly managed. Flooding also has a direct physical impact on piping and can destroy joints and damage pipes, which in turn can disrupt water supplies and increase replacement and maintenance costs.

Figure 13: Bridge crossing St. John's River in St. George's, Grenada; source: Mapio; https://mapio.net/

Figure 14: The same bridge, during a flood event; source: Facebook; https://www.facebook.com/

Summary of possible impacts

No water supply!
Seawater intrusion to the groundwater system.

45.000 People.
25 Km pipes.

Maintanance costs.
Replacement costs (100.000 / Km).
Repairs on pumping station.

Data, information available

Data regarding threats

Due to the prevailing hydrological and climatic conditions, the water supply system in Grenada is frequently interrupted. During flood events, it is often necessary to shut off the supply directly from the water treatment plant, preventing raw water from entering the storage system.

However, in the event of a pipeline break, the supply is at risk even if storage measures are taken. This applies to all threats that directly impact the pipeline, especially those that are most vulnerable.

Data regarding vulnerability

During severe storms, the water supply system is unable to treat the water and must cease operations, which stresses the storage systems. Under the G-CREWS project, an expansion of the storage system will provide a continuous water supply for three days, even if production is interrupted. Aside from that, there is a risk that if the pipeline cannot withstand the effects of landslides, floods, and hurricanes, certain regions will not have access to water for long time.

In terms of data availability, Grenada has topographic information, but neither measurements of past floods nor sufficient information on river discharge (extreme floods). It also lacks information on the design of bridges, which is important for evaluating and planning solutions for the pipelines that cross these bridges.

Countermeasures

After assessing the vulnerability of the system and better understanding the threats and their possible impacts, some of the countermeasures should be considered for implementation. Operational safety of the pipeline, gate chambers, and electromechanical systems, including protection against flooding, landslides, damage to nearby roads, or pipe damage due to traffic congestion or river flooding at bridge crossings has been ensured. Solutions such as culverts are useful in controlling flooding while providing a resilient structure to support bridges and road systems. In special cases of pipelines installed above ground, they must be protected against external impacts. Pipelines installed above ground shall include pipe thrust restraints.

River crossings should preferably be made by laying the pipes in the riverbed, which is considered the safest option. The possibility of attaching the pipes to the bridge on the downstream side should be investigated with additional site investigations. The final solution is to be determined during the detailed design phase. Pipelines should only be attached to bridges where a risk assessment has been carried out to ensure that the infrastructure can withstand Category 3 hurricanes and the effects of a 100-year flood. If this is not the case, pipelines should cross rivers with a new, reinforced structure.

Figure 15: Fortified pipeline river crossing; source: USAID, 2017[xviii]

In any case, a preliminary design and a detailed design of the pipelines must be approved. To calculate the 100-year flood, more information about the hydraulic capacity of the river must be evaluated together with the hydrological data of extreme events and the development of a hydraulic model.

With respect to electromechanical systems, it is necessary to ensure that all electromechanical systems are installed in such a way that they are protected against physical damage from floods, landslides, heavy rains, and wind, and backup systems and spare parts are in place. In addition, manuals must be developed for the protection of the systems and their operation in emergency and disaster situations. Finally, electromechanical systems must be installed in such a way that they do not pose any additional risk (e.g., electric shocks).

For further studies, it is recommended to consult the USAID guidelines for climate-resilient water infrastructure published in 2017[xviii].

Monitoring

The Ministry of Infrastructure Development, Public Utilities, Energy, Transport and Implementation is responsible for overseeing the implementation and maintenance of pipelines and pumping stations, particularly with regard to climate resilient solutions implemented in river sections (bridges, culverts, or others). In addition to being climate resilient themselves, infrastructure should not serve as critical points for other risks, e.g., culverts should not restrict water flow to the point of increasing flood risk.

Identify needs for technical support and capacity building

To further support the implementation of meaningful solutions for the resilience of Grenada's water supply system, assistance is needed in the development of ToR as well as in the formulation of technical standards for climate resilient buildings, bridges, and pipelines. Another important aspect identified during the climate resilience workshop is the need for capacity building activities in the area of hydraulic modelling.

Feedback to policy making

The most effective policy measure recommended is for Grenada to develop its own building code for climate resilient infrastructure or a building code specifically for bridges and connected pipelines. In addition to the legal framework for building codes, an official database of runoff curves for all catchments is needed.

4.3. DAMS AND RAW WATER RESERVOIRS (MT. WILLIAM DAM)

The projected water demands of the urban and semi-urban service areas in south-eastern Grenada indicate the need to increase the capacity of the existing dam system of Les Avocats, Petit Etang, Cocoa Dee, and Blin-eff. This is to be accomplished by constructing a new dam – Mt. William dam – and rehabilitating the existing dam structure of the Les Avocats (LA) Dam.

This project was preceded by a feasibility study for the LA Dam, and a hydrological study of the catchments of the nearby reservoirs, that is, Les Avocats and Petit Etang (PE). The main recommendations of the study are that a new dam should be constructed about 10 to 20 meters downstream of the existing dam and that the new dam could have a volume of 15,000 m^3 and a height of 15 meters. The hydrological studies concluded that the construction of the new Mt. William Dam in the PE supply system would provide a better safe yield than replacing the old LA Dam. Therefore, it was decided to build a new dam named "Mt. William Dam", and to rehabilitate the LA Dam to ensure proper operation in the years to come.

An Environmental and Social Management Plan (ESMP) was developed for the entire G-CREWS project. Potential environmental and social impacts were identified considering the initial technical assessment of a general feasibility study for G-CREWS. However, a specific Environmental and Social Impact Assessment (ESIA) is required for the proposed activity. Requirements for the release of environmental toxins from the reservoir should be evaluated as part of the integrated planning and environmental impact assessment.

The current reservoir system, which is the main source of water supply for the urban areas in the southwest of the island, consists of four small reservoirs: Les Avocats (LA), Petit Etang (PE), Cocoa Dee Reservoir, and Blin-eff.

The water supply area to be covered by the LA and PE Reservoir systems is located northeast of the densely populated area of the island in the parish of St. David and St. George's. Population growth is moderate and estimated at 0.5% per year. Further tourism development in the east of St. George's is also expected for the neighbouring community of St. David, which will require optimized exploitation and use of regional and local water resources.

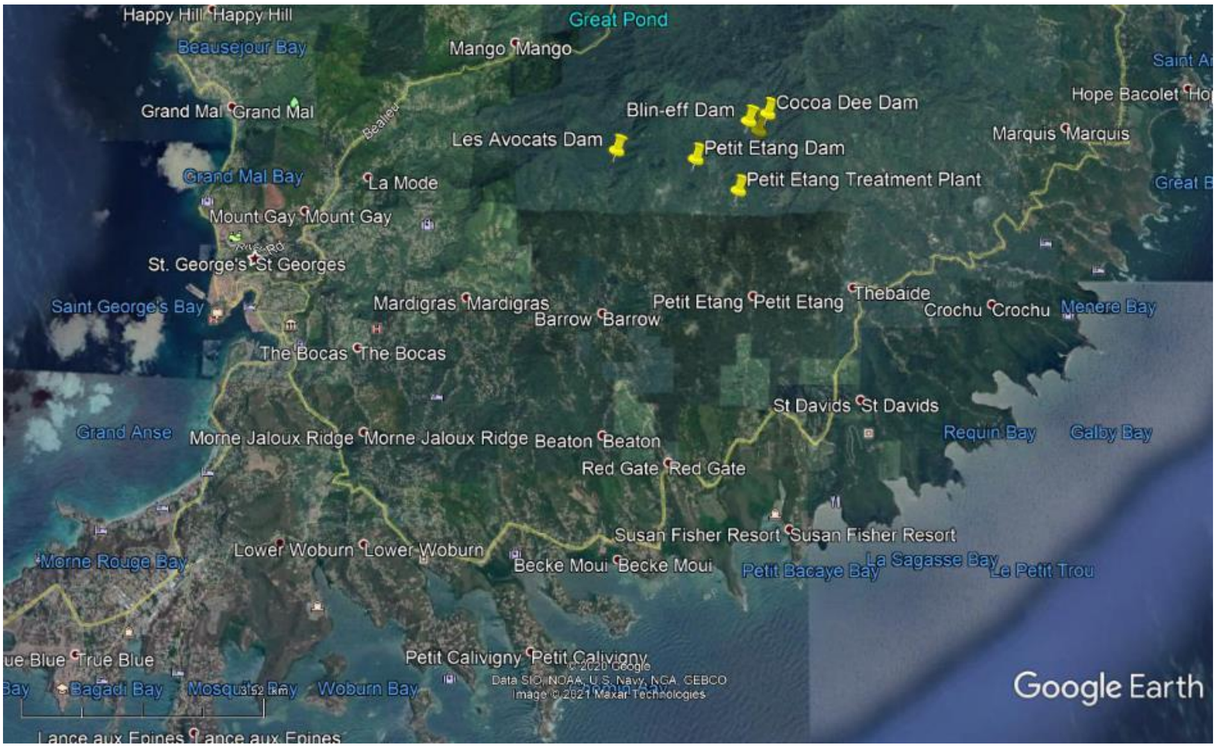


Figure 16: Overview Dam locations in the Les Avocats and Petit Etang reservoir system; source: Google Earth

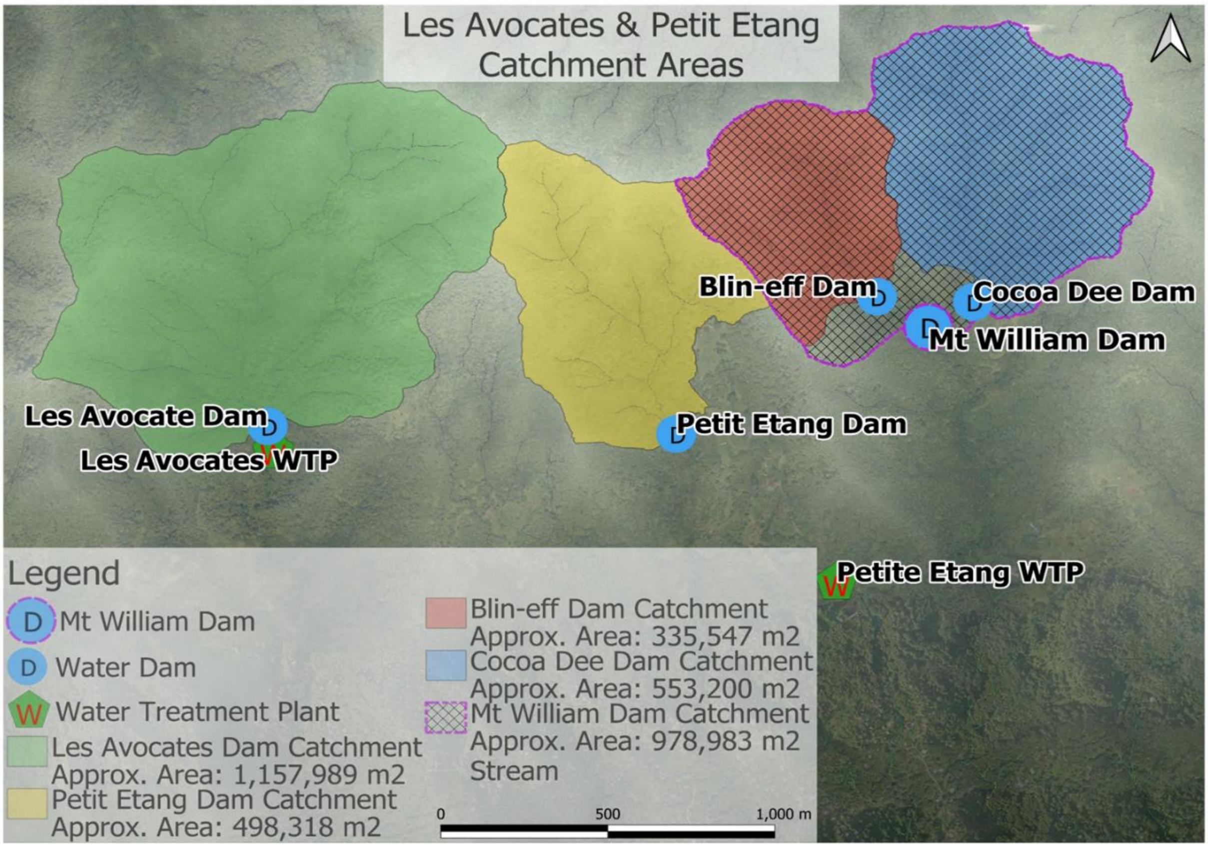


Figure 17: Dam locations in the Les Avocats and Petit Etang reservoir system, source: GIZ Grenada

The LA system serves 5,190 connections in a service area downstream of the LA wastewater treatment plant (WTP-LA), providing drinking water for 9,100 people. The capacity of the WTP-LA is 1,590 m^3/d (350,000 GPD). In addition to the WTP-LA, there are pressure filters at Windsor Forest (capacity: 636 m^3/d; 140,000 GPD). The water storage capacities of the Les Avocats tank system are 326 m^3 (71,630 gallons) in the WTP-LA and 364 m^3 (80,000 gallons) in the Richmond Hill water tank. The LA water distribution system is connected to the PE supply system. The following diagram shows the combined water supply system of the LA and PE watersheds:

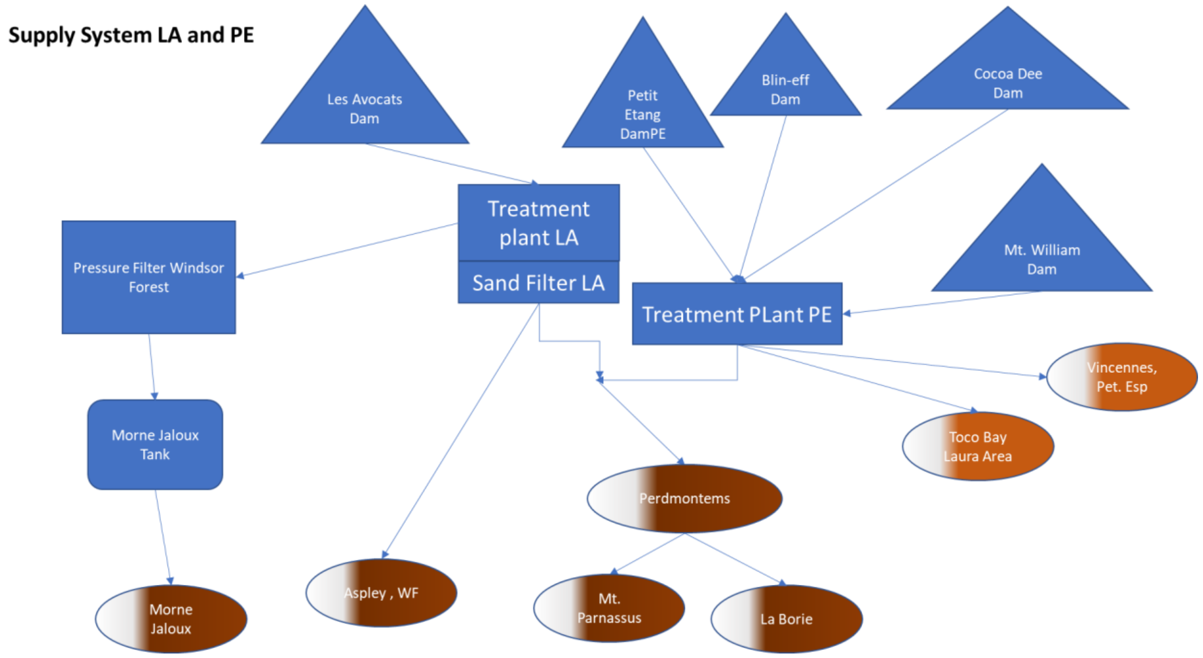


Figure 18: Combined water supply system of the Les Avocats and Petit Etang watersheds, source: GIZ Grenada

Les Avocats (LA) dam is located in the south of the island on the Baillies Bacolet River about 1.8 km north of Barrows in the parish of St. David. It feeds the LA wastewater treatment plant with a capacity of about 2,200 m^3 per day. The pear-shaped catchment area upstream of the existing LA reservoir is about 1.2 km^2 and extends north to the summit of Mt. Sinai at +768 m elevation. In this steep and partly very steep area, the surface water is drained by four streams. The area is covered by dense flora and forests, which are recovering after being destroyed by Hurricane Ivan. Erosion on the steep slopes is believed to have led to an increase in alluvial material that was transported and deposited in the reservoir. According to the ENB study, landslides are likely to continue to occur primarily in the high elevations of the basin, particularly during months of heavier rainfall at higher elevations, including the hurricane season between June and November.

Post-hurricane basin recovery ensures effective infiltration and reliable daily minimum baseflow during the dry season, ranging from 1,200 to 1,400 m^3/d. During the wet season, baseflow and interflow are very high and provide the average source for the reservoir. The average annual rainfall ranges from 2,100 to 2,700 mm/yr. Minimal precipitation between January and April significantly reduces the contribution of surface water runoff, resulting in a seasonal deficit in water availability and in the reservoir-related water supply system.

The existing dam of the old LA reservoir was built in 1957 and has an estimated capacity of 3,300 m^3. The dam is made of masonry. It has a stepped crown at +347.50 to +349.36 m elevation and two spillways at +346.77 to +346.83 m elevation. The minimum ground elevation is +343.00 m. The condition of the old dam has deteriorated due to lack of maintenance. A vertical crack is located on the left downstream side of the straight section and some stones are missing. Leakage occurs on the right abutment and on the left side of the straight part of the dam near the dam foundation.

The **Petit Etang (PE)** system is located in the south-central part of the island, east of Les Avocats. The three catchments of Petit Etang, Coco Dee and Blin-eff supply raw water to the PE Water Treatment Plant (WTP-PE). Water is diverted from the three intake points (weirs) by gravity through raw water pipelines to the treatment plant. The pipelines from the Coco Dee and Blin-eff dams/weirs are connected to a common raw water pipeline to the WTP-PE.

The PE system serves 850 connections in a service area downstream of the PE treatment plant (WTP-PE) and provides drinking water for 2,300 people. According to Bornemann (2015[xix]), the design capacity of the plant is 1,146 m^3/d (252,000 GPD). The water storage capacities of the PE supply tank are 368 m^3 (81,000 gallons) at WTP-PE and 909 m^3 (200,000 gallons) at La Pastora. Water is piped to the supply areas via gravity mains. A planned expansion of the treatment plant will increase capacity to 2460 m^3/d (650,000 gallons/d), and construction of a glass-fused steel tank will provide 1,364 m^3 of storage capacity.

The two systems, LA and PE, are interconnected and should be considered a common supply area.

The three catchments of the Petit Etang, Blin-eff and Cocoa Dee reservoirs have the same hydrological and geological characteristics as the catchment of Les Avocats. The difference is mainly in the catchment area of each reservoir and in the characteristics of the dams.

Precipitation gauges are installed in both areas. Records have existed since 1928 in Les Avocats and since 1947 in Petit Etang. Precipitation characteristics are similar, and data can be interchanged in case of gaps.

To improve water supply, the construction of a new reservoir named Mt. Williams is planned. The location of this reservoir is about 100 m downstream of the confluence of the Cocoa-Dee and Blin-eff rivers. The catchment area of the Mt. Williams reservoir is 1,400,000 m^2. Included in this area are the two catchments of Cocoa Dee (614,000 m^2) and Blin-eff (326,900m^2). This means that the reservoir will collect rainfall from the additional catchment area of about 459,100 m^2 and water from the two smaller reservoirs upstream. The dam height must be limited to 15 m (including foundation). The expected usable storage volume is 23,000 m^3.

Table 4: Dam locations and key figures for Les Avocats and Petit Etang watersheds

Location	***Latitude***	***Longitude***	***Elevation (m)***	***Catchment Area (m^2)***	***Volume [m^3]***	***Safe yield rainfall period of last 5 years [m^3/d]***
Les Avocats Treatment Plant	12.06510	-61.700900	338			
Les Avocats	12.06600	-61.701000	345	1.200.000	3.300	1.550
Petit Etang WTP (Water Treatment Plant)	12.062574	-61.685658	350			
Petit Etang Dam (Catchment 1)	12.065778	-61.688635	415	523.643	325	635
Blin-eff Dam (Catchment 2)	12.069161	-61.682735	450	326.900	30	363
Cocoa Dee Dam (Catchment 3)	12.068927	-61.682137	426	614.000	150	703
River merge point	12.068723	-61.683676	414			
Mt. William	12.068800	-61.682800	361	1.400.000	23.000	1.225
Total yield based on weather condition of last 5 years (no extreme weather conditions) [m^3/d]						4.500
Total yield based on dry weather condition 10-15a recurrence. [m^3/d]						4,090
Total demand [m^3/d]						4,200

The safe yield of the existing reservoir and the new reservoir was calculated based on rainfall data for the last 6 years (no extreme weather conditions) and taking into account the effects of some dry years with a recurrence of one in 10 to 15 years from rainfall data for the last 50 years. Future water demand in the supply area was calculated (4,200 m^3/d) and compared to the safe water supply (4,500 m^3/d in the last 5 years / 4,140 m^3/d in dry years).

Risks

Compared to the infrastructure measures described above, the risk assessment for the construction of a reservoir is somewhat different. Dams and reservoirs are important solutions to our water management needs, but they also expose our communities to significant risks. Although some dams were built primarily to reduce flood hazards, exposure to such hazards or hurricanes can disrupt the operation of these structures or even cause dam failures, with disastrous consequences for the economy and human lives.

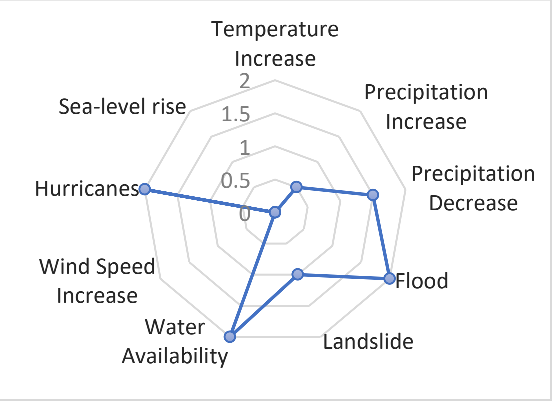


Figure 19: Evaluation of threats for dams & water reservoirs

Therefore, it must be ensured that (a) reservoirs remain functional despite the effects of climatic events, and it must be made sure that (b) they do not pose a risk to downstream users. In addition, (c) failure of the reservoir to remain usable also poses a risk to the entire connected drinking water supply system. Hence, on the one hand, the dam must be designed and constructed with care, and the spillway as well as the removal devices must have the correct size. On the other hand, safe yields must be calculated so it does not pose a risk to downstream users. This includes the proper definition of the management plan with the exact determination of the withdrawal amount.

Hurricanes

Very likely (2)

Hurricanes pose a threat to all buildings and pipelines in their catchment area, including the support structures used to operate the dams and tributary pipelines, which can be damaged or destroyed during such an event. Because the dams are operational, workers at these sites are at serious risk during such events, and surrounding communities are also at risk in the event of a breach of the dam structure. The impacts can be immeasurable, ranging from loss of life to loss of property to disruption of water supply. Dams are critical structures within a water supply system and take extended periods of time to repair, so even minor damage can have long-lasting impacts.

Summary of possible impacts

Loss of life!
Environmental impacts
No water supply!

12.000 People.

Replacement costs
Repair and
maintanence costs
Lower lifespan of the
dam

Floods

Very likely (2)

Floods pose similar risks like hurricanes in terms of endangering human lives, infrastructure stability, and access to water. These events can also lead to siltation, a process related to soil erosion that reduces the storage capacity of the dam by transporting significant amounts of sediment into the dam system. Siltation also degrades the overall quality of the raw water by increasing the concentration of suspended solids in the water, which affects treatment operating costs or even brings the treatment process to a halt.

Impacts to dams are very costly because these infrastructures operate on a larger scale and can have significant impacts on the environment, communities, and the water supply system.

Figure 20: Dam during a flood event; source: ABC News; *https://abcnews.go.com/*

Summary of possible impacts

Loss of life!
Environmental impacts
No water supply!

Not Yet Quantified

Replacement costs
Repair and
maintanence costs
Lower lifespan of the
dam

Data and information available

Dams already built in the system also provide valuable information required for their expansion or future developments in the region. Combined with data from meteorological stations the following datasets are available: geotechnical and survey data, hydrometeorological data, land-use data, and ecological data for all the related sites. However, usually there is insufficient data on extreme climate events. Detailed data on outflow volumes for any length of time are missing as well. Therefore, for the design of the dam, assumptions must be made. The most important decision after calibration of a storage simulation model is to define the security of supply as a function of a probability of failure.

Countermeasures

Addressing the risks associated with dams is a complex task and requires significant efforts to create systems and tools capable of supporting key actions ranging from capacity building to infrastructure development and financial solutions.

Regarding the dam infrastructure, the design of new dams and expansions must take into account different climate scenarios by incorporating rainfall, runoff, and evaporation values into the design. Dams must also be hurricane proof, and structures must be protected against Category 4 hurricanes. Another important consideration is the monitoring systems (e.g., SCADA) that must be in constant operation, along with routine maintenance service, to ensure that the dams are functioning as intended.

Another way to increase the climate resilience of the dams is to strengthen the intake pipes to make them more secure against the impacts of 1000-year floods and Category 4 hurricanes. In dam watersheds, logging activities such as tree trimming must be controlled, as these activities can alter the hydraulic properties of the system and affect erosion and the overall life of the dam.

Due to the high risks involved, adequate insurance policies and contracts are recommended to better protect the public and the water utility during emergencies.

Identify needs for technical support and capacity building

In terms of knowledge and information relevant to proper implementation of measures, it is important to offer hydraulic modelling and operational capacity building in both the implementation and operational phases of a new dam or dam expansion. When it comes to supervision, monitoring, or construction standards, international best practices and standards can be good benchmarking and starting points.

Monitoring

An improved monitoring system is to be developed by the Government of Grenada, but some responsibilities can already be tracked or delegated, for example: the WRMU should determine the safe yield of dams during droughts to ensure ecosystem services within river and lake systems, and NAWASA should monitor the pressure of the water distribution network during extreme events.

Feedback to policymaking

Monitoring and control guidelines are needed to ensure safe operation of dams and reservoirs. In addition, stakeholders recommended that land use policies be developed to promote sustainable use of resources and climate resilient solutions.

4.4. WATER SUPPLY FOR HEALTH CENTRES

One of the objectives of the G-CREWS project is to increase existing potable water storage capacity in community health facilities by more than 50% to improve their resilience to extreme weather events and droughts. The interventions will be implemented in four municipalities in Grenada and on the sister island of Carriacou and will include drinking water storage tanks and improved sanitation and/or rainwater harvesting infrastructure in 16 community health facilities and related services. With the implemented activities, the community health centres will meet the Pan American Health Organization's (PAHO) requirement to store an average of five days of consumption if water supplies are interrupted, for example, by heavy rains, storms, or periods of drought. Together, the facilities accommodate an estimated 2,200 patient visits per week.

Risks

Because of the diversity of solutions to address climate resilience in health centres, most of the most impactful hazards contribute to the overall risks of the solution when analysed in combination. This does not mean, for example, that hurricanes will affect pipelines as much as water tanks, or that flooding will affect rainwater collection infrastructure as much as the plumbing system.

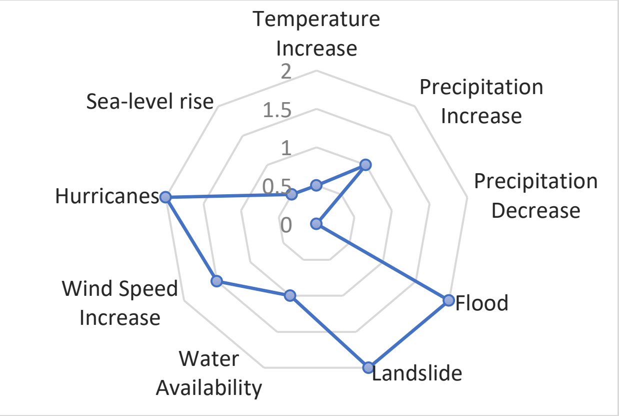


Figure 21: Evaluation of threats for water supply for health centres

Floods

Figure 22: Flooding in northern Grenada in 2016; source: CARICOM Today; https://today.caricom.org/

Very likely (2)

The effects of flooding on exposed infrastructure are similar to the effects of hurricanes. Pipelines, water tanks, and stormwater harvesting facilities can be damaged or destroyed, and landslides can occur more easily. However, floods can also increase seawater intrusion into the system (coastal flooding) and have a different time of entry, so they may be better managed if the right tools are in place.

Summary of possible impacts

No water supply!

No service at health centres!

Seawater intrusion.

up to 2200 Patients.

16 community health facilities.

New water tanks (5.000 - 15.000 EUR /tank).

Landslides

Landslides can be triggered by a variety of stresses and can affect not only exposed infrastructure, but also underground structures such as building foundations and underground collection and distribution lines.

Very likely (2)

Summary of possible impacts

No water supply!

No service at health centres!

up to 2200 Patients.

16 community health facilities.

New water tanks (5.000 - 15.000 EUR /tank).

Replacement of pipelines and RWH

Hurricanes

Hurricanes can wreak havoc on stormwater harvesting (RWH) infrastructure and supplemental storage tanks, driving up repair costs and disrupting local water supplies. Hurricanes also increase the risk of landslides and can destroy exposed pipelines.

Very likely (2)

Summary of possible impacts

No water supply!

No service at health centres!

up to 2200 Patients.

16 community health facilities.

New water tanks (5.000 - 15.000 EUR /tank).

Data and information available

Initiatives related to health centres have improved the available information on water demand and other data related to these sites. Such initiatives include the PAHO Smart Hospitals initiative and the Reducing Risk to Human and Natural Assets Resulting from Climate Change (RRACC) project initiated by the Organization of Eastern Caribbean States (OECS). Now there is documented information on topographic data, installation of cisterns, pipes, wells, and roofs, rainfall intensity values, and other site-specific information.

Countermeasures

Since most of these threats can cause severe damage or even destruction to infrastructure, countermeasures to increase resilience are important. Two recommendations are to increase the protection of the rainwater harvesting (RWH) reservoir and to use reinforced blockwork and protective walls in the water tanks. A recirculating water system for RWH is also recommended to improve water quality as it increases aeration.

To manage the impact of pipe bursts, a spare parts store (gutters, downspouts, pipes) is recommended to facilitate repairs and replacements and reduce the time that part of the network is shut down.

Finally, the emergency plan developed by the National Disaster Management Authority (NADMA) should include all extreme scenarios and be adequately communicated to effectively mitigate the impact of the threats.

Establish arrangements for implementation

To implement the measure and countermeasures, a list of precautions was developed together with the various stakeholders of the G-CREWS project. A checklist should be developed for all health stations to ensure proper follow-up of implementation processes. There should be an interface with the Ministry of Health to ensure more efficient information sharing and compliance with standards. An approved preliminary design and detailed design are required for all infrastructure. You will also need an operation manual and evaluated service contracts. The screening, assessment, and system design should be performed by NAWASA.

Identify needs for technical support and capacity building

As technical support, the consultants will need to prepare checklists, ToRs, and an operation manual. In terms of capacity building, training on RWH/storage infrastructure maintenance is recommended for Financial Complex Ltd.

Monitoring

The Ministry of Health should conduct standardized audits to ensure that the system is providing quality water to health centres. Periodic water quality monitoring should be conducted by NAWASA and the Bureau of Standards, which have laboratories. A certificate of completion should be issued by the Physical Development Authority (PDA), which is responsible for approving the designs.

Feedback to policymaking

Implementation and operation of RWH and other solutions should be a standard for all health centres. RWH should be regulated and these specific regulations should be included as an update in the building code. A disaster preparedness plan should be developed that prioritizes health centres.

4.5. COMMUNITY RAINWATER HARVESTING

In addition to rainwater harvesting (RWH) at the household level, larger systems are also being deployed to improve or maintain supplies to entire communities to cope with reduced or erratic rainfall. Larger systems supply households through a piped network, which allows for the implementation of centralized operations by NAWASA, thus viewing rainwater harvesting as a source that feeds into the national piped network. Based on the experience with a community RWH system in Blaize, G-CREWS will support the installation of four larger community-based RWH systems in Grenada (Brooklyn, Clozier) and Carriacou (Dover, Mt. Royal), which will be operated and maintained by NAWASA. Blaize is an example of a catchment built for municipal service (120 people) because the existing source of supply was no longer reliable and alternative supply options were too costly. In this system, a large catchment area collects rainwater and fills it into a built-in concrete tank, where it is chlorinated and then distributed to consumers. The pilot system demonstrated how centralized systems address and overcome challenges related to maintenance, water quality, financial resources, and lack of technical experience and expertise at the individual and community levels.

Figure 23: Rainwater capture; source: Wikipedia; https://en.wikipedia.org/wiki/Rainwater_harvesting

Risks

RWH systems are vulnerable to most of the threats identified in Grenada. This is primarily because such systems consider a combination of infrastructures, each with its own unique characteristics and vulnerabilities. In addition to the greatest potential impact to RWH, which is damage or destruction of infrastructure, RWH are also vulnerable to water contamination from various threats such as flooding, heavy rainfall, landslides, high winds, and hurricanes. RWH can also become hotspots for vectors and waterborne diseases under critical conditions, leading to public health issues beyond water availability.

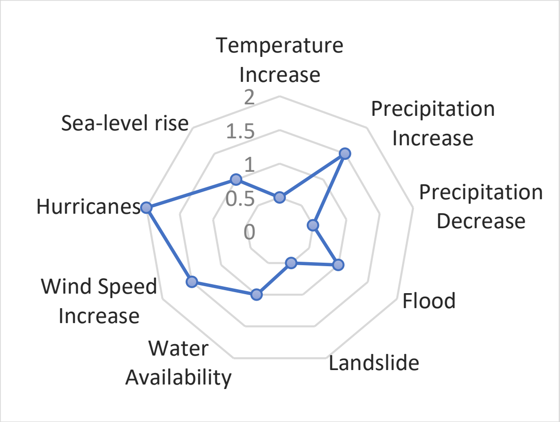


Figure 24: Evaluation of threats for rainwater harvesting

Hurricanes

Hurricanes can directly impact stormwater infrastructure by damaging exposed elements such as tanks and roofs, driving up repair costs or even temporarily disrupting local water supplies. Hurricanes also increase the risk of landslides, which in turn can expose stormwater collection facilities to debris, affecting both operations and water quality.

Very likely (2)

Summary of possible impacts

No water supply! Worsening of water quality

1.000 People / RWH.

Rebuilding and repair costs of RWH.

Precipitation Increase

The increase in precipitation poses risks to RWH systems because surface water can run off near the RWH and contaminate the collection area with dirt, oils, and other pollutants. The volume of water can also cause the system to overflow and, as a result, damage nearby buildings.

Likely (1.5)

Summary of possible impacts

No water supply! Worsening of water quality

1.000 People / RWH.

Rebuilding and repair costs of RWH.

Data and information available

All necessary information will be collected in the design phase. Rainfall data are only available for daily and monthly rainfall data. Only in very few locations rainfall data of a higher resolution is available.

Countermeasures

As a general countermeasure to possible system failures, whether minor damage or mechanical malfunctions, it is advisable to create a collection of spare parts for faster maintenance and repair. A maintenance plan is also useful, as it can pre-emptively identify weaker elements within the system. Another rule of thumb is to purchase adequate insurance to financially protect the system in the event of a natural disaster.

To ensure safe design and construction of RWH systems, first flush systems must also be properly installed. The designs should be based on expert recommendations and in collaboration with the engineers and architects of the Department of Infrastructure Development and the engineers of NAWASA. The Physical Development Authority (PDA) should approve the designs or require the necessary corrections, and the Ministry of Health should issue notices on the required water quality of the system.

Identify needs for technical support and capacity building

A major knowledge gap is the information gap that Grenada has in terms of rainfall data availability. Thirty years of detailed precipitation data (higher resolution) is needed to properly design the RWH, and technical support is needed to do this.

Monitoring

After the construction of RWH structures, the progress, technical quality and costs will be monitored to better evaluate its efficacy and guarantee its proper operation. The involvement of relevant stakeholders in the monitoring process if important for a good continuity of the project. Stakeholder involvement in the monitoring of the water quality and the water balances would be helpful. The Water Resources Management Unit (WRMU) could play a major role in the improvement of the data availability.

Feedback into policymaking

As the RWH will be tailored to the specificities of the Grenada region it is opportune to also provide recommendations to the building code as to guarantee certain aspects of climate resilience in future buildings and to adapt these infrastructures to the official regulations. A strong set of recommendation should constitute technical standards, insurance rebate and regulations for resilience building.

4.6. IRRIGATION SYSTEMS

The vulnerability assessment in Grenada showed that little water is used in irrigation systems. Irrigation can increase farm yields and enable sustainable water use when coupled with smart technologies and systems such as micro-sprinklers, drip irrigation, and rainwater harvesting. One of the goals of the G-CREWS project is to provide EUR 2.63 million from the Challenge Fund for Agriculture (CFA), which is tailored to Grenada's agricultural sector and can subsidize up to 50% of equipment costs. The goal is for 50% of farms that do not yet irrigate but are eligible to do so to switch to micro-sprinklers or drip irrigation; 50% of farms that currently irrigate with inefficient equipment to switch to micro-sprinklers or drip irrigation; 20% of farms that already irrigate or are starting to irrigate with the help of the CFA to also install rainwater harvesting systems, 5% to adopt shade houses and 1% to adopt hydroponic systems.

Figure 25: Drip irrigation; source: Israel21c; *https://www.israel21c.org/*

Risks

Irrigation systems are subject to similar threats as other supply systems. From source to transport, storage, and use, these systems can be affected by various stresses and hazards to varying degrees. In Grenada, flooding and landslides have been identified as the main causes of failure or destruction of such systems. However, increasing rainfall, sea level rise, and hurricanes were also rated highly in the climate security assessment. Regarding water availability, not only does water shortage pose a threat to the operation of the systems and the crops themselves, but it can also lead to competition for the use of scarce water resources, as the water supply system should prioritize other uses over irrigation under stress, which is not always easy to control in practice.

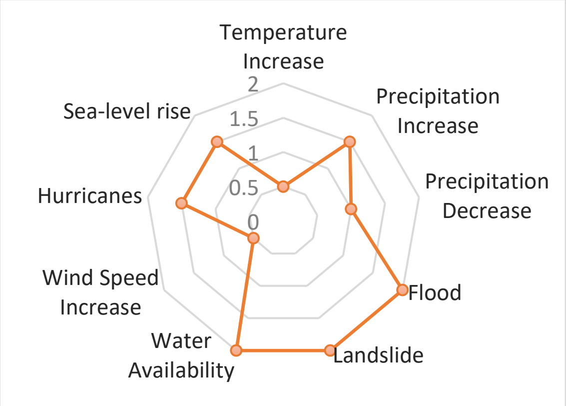


Figure 26: Evaluation of threats for irrigation systems

Floods and landslides

Very likely (2)

Floods can destroy water tanks of rainwater harvesting (RWH) systems, affect local groundwater pumping stations, and even affect water quality, posing a higher risk to food security. Irrigation pipes and filters can become clogged and buried, and the cost of replacing equipment can be very high if it is not readily available in the local market. Repairing some infrastructure can also be challenging due to the lack of specialized services. Repairing pumps is also particularly costly. Landslides can similarly destroy infrastructure and even contaminate water with a higher concentration of suspended solids. Landslides are also a greater threat to the underground system and can destroy transportation lines, foundations, or other underground structures.

Summary of possible impacts

Lack of water.
Food security.

200 Farms.

Loss of production.
Rebuilding costs.
High repair costs.

Water availability

Very likely (2)

Water availability poses a direct threat to water use, and in the case of irrigation systems, it also threatens farmers' investments and returns, posing risks to the economy and food security.

The expansion and intensification of agriculture enabled by irrigation can cause: increased erosion, pollution of surface and groundwater by agricultural biocides, water quality degradation, increased nutrient levels in irrigation and drainage water leading to algal blooms, the spread of aquatic plants, and over-fertilization of irrigation canals and downstream waterways. The new irrigation systems can become a threat to various water sources and potentially lead to conflicts over water use (FAO, 2021[xx]).

Summary of possible impacts

Food security.

Increase in water conflict.

200 Farms.

Loss of production.

Rebuilding costs.

High repair costs.

Data and information available

Very few data are available and must be collected during the design phase

Countermeasures

As with any project, high quality material often falls into a lower cost-benefit ratio if the criteria do not take into account some of the benefits that quality brings. In a mitigation project, it is important to emphasize the importance of resilient equipment so that our built systems can be considered resistant to 100-year floods and landslides. In this context, pumping protection and system resilience assessment plays an important role in the design and construction process. Achieving such resilient systems requires training farmers and consultants, identifying on-farm flood lines, and establishing standards for high-quality equipment.

In terms of addressing economic threats, two countermeasures are strongly recommended. One is to consider the availability of a technology before it is introduced, taking into account the entire life cycle of the equipment, preferably using locally available materials or systems that can be maintained and repaired by local communities. The purchase of additional parts for faster repair times should be considered, as well as the development of financial tools to channel funds to farmers.

Regarding potential water conflict issues, it is recommended that a system be established whereby irrigation pipelines are removed in the event of disasters, and that adequate involvement of all stakeholders in the appropriate decision-making processes be ensured.

Identify needs for technical support and capacity building

Following the climate security assessment conducted with various stakeholders in a joint workshop, it was determined that technical assistance and capacity building are needed at virtually every step of the irrigation system: system design, installation, repair, and maintenance. Specifically, data collection systems need to be established, flow measurements for all streams and rivers are required, and monitoring plans and frameworks are needed.

Once the systems are implemented, support will be needed to repair and maintain the pumps and to measure the water use efficiency of the equipment used.

Monitoring

As for monitoring, not only is regular maintenance important, but the use of resources and the efficiency of water use must be constantly monitored. Responsible for monitoring irrigation systems and water resources should be the Ministry of Agriculture and Lands, the new Department of Water Resources Management, and the Ministry of Health, which should focus on controlling pollution and water quality.

Feedback to policymaking

Legislation must be enacted to monitor pollution of water sources, and legal regulations are needed to control water withdrawals by farmers. Similar measures are also needed regarding water quality in irrigation systems to ensure food security.

4.7. SHADEHOUSES AND HYDROPONICS

A shade house consists of a mesh material designed to protect plants from potential damage such as insects, excessive heat, light or drought, and other climate-related problems. The shade protects the plants and the structure generally provides a safer and more efficient area for plant growth, allowing for even higher yields than normal plantings. The materials are usually lightweight and less costly than greenhouses. They are often made of a metal structure and cloth but can also be built from wood and certain plastics.

Figure 27: Greenhouse as part of the Biodiver City project, Costa Rica, 2021, © GIZ / Sofia Araya-

Hydroponics is easily promoted by the CFA as a technical solution to improve water availability in Grenada, as such systems are much more water efficient than traditional agriculture. The main concept of hydroponics is not to use soil and to supply the plants directly with water and a nutrient substrate. Water consumption can thus be maximized.

Risks

Because of their lighter structure, shade houses and hydroponic systems are susceptible to breakage when pressure is applied to them from the outside. This makes most hazards a very likely threat to the stability of such infrastructure. High wind speeds or even high rainfall can also damage or break the structure, especially if the site does not protect it from the wind.

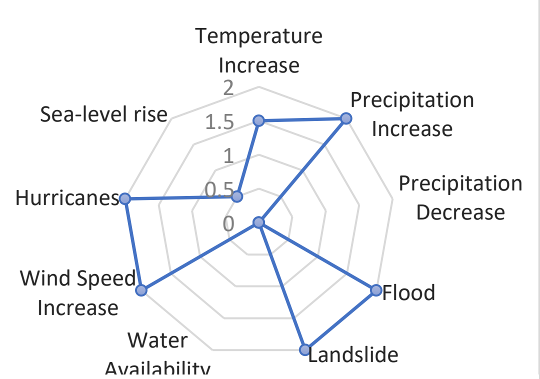


Figure 28: Evaluation of threats for shade

Hurricanes and wind speed increase

Hurricanes and wind speed increases can severely compromise the supporting structure of shade houses and hydroponics, posing further risks to animals, people, and infrastructure. The material that most shade houses and hydroponics structures are made of can crack more easily from wind pressure and the impact of flying objects such as sticks and debris, requiring more repairs and possibly replacement.

Very likely (2)

Floods and precipitation increase

Flooding and increased rainfall are both threats that can directly and indirectly affect shade houses and hydroponics. Even with stronger materials, flooding can carry away infrastructure and potentially cause it to collide with other buildings, cars, light poles, or even animals and people. The water can also weaken fault lines in the soil and cause landslides.

Very likely (2)

Landslides

Like hurricanes, landslides can destroy shade house and hydroponic infrastructure or damage it with falling debris. Although repairing portions of the metal structure or mash material is not costly, the likelihood of impacts is higher, such as full restoration or rebuilding of systems.

Very likely (2)

In general, all threats to shade houses and hydroponics have similar impacts, so a combination of these impacts is presented in the summary of potential impacts. In general, impacts are primarily economic in nature, as production may be affected, but depending on the threat, yield losses may also be severe enough to pose a risk to food security.

Summary of possible impacts

Data and information available

Hydrologic and topographic data are often inadequate for adequate risk assessment, which presents challenges for climate proofing infrastructure. However, these problems generally apply to all other measures proposed under the G-CREWS project.

Countermeasures

Shade houses and hydroponics should be easy to build with local materials and in a variety of designs. The design and choice of materials should consider high wind speeds and ease of repair, ideally by the farmers themselves. When choosing a location for shade houses and hydroponics, at least two criteria must be considered: solar radiation, which must be uniform, and wind direction.

Figure 29: Hurricane-proof greenhouse; source: greenhousegrower.com; *https://www.greenhousegrower.com/*

To cope with certain wind speeds, windbreaks can be used. In this case, it is recommended to place them at a distance of up to 40 meters from the shade houses and hydroponic plants. During the hurricane season, the corn material can also be folded. The benefit of the infrastructure will be lost, but the overall damage can be reduced.

Quality standards for materials, design and localization of the systems can also help reducing the risks to farmers.

Identify needs for technical support and capacity building

Technical assistance is needed to fill the data gap on potential hazards and setting technical standards for infrastructure and building capacity can improve farmer operation and maintenance of shade houses and hydroponics and create a more resilient and self-managed system.

Monitoring

The Ministry of Agriculture and Lands and the new Water Resources Management Unit are responsible for monitoring the use of water resources, and the Ministry of Health must monitor water quality in systems and assess the food security of their yields.

Feedback to policymaking

Legislation to regulate food safety and standardize water use in shade houses and hydroponics must be adopted in national or local jurisdictions.

4.8. GROUNDWATER WELLS AND BOREHOLES

In Grenada, about 10% of the total water supply comes from groundwater. Two wells currently draw water around the clock from alluvial aquifers located in valleys in the south of the island. This groundwater is susceptible to seawater intrusion. Because of the high cost of electricity, pumping is limited to five wells in south-eastern Grenada, pumping raw water from Mardigras Dam to the treatment plant, and drawing raw water from Grand Etang Lake to augment the source of the Annandale treatment plant during the dry season. Three new groundwater wells and rehabilitation of three other existing wells are planned to improve Granada's water supply system. All groundwater wells are located near the coast and are at risk of seawater intrusion.

Data, information available

In 2013, a feasibility study was prepared by Gassen[xxi]. For south-eastern Grenada, the study recommended rehabilitating the existing wells and drilling three new wells, determining the optimal withdrawal rate of the rehabilitated and new wells, and installing an improved monitoring and operating system. Unfortunately, no monitoring system has been installed to date. Data and information on well capacity and operation is limited.

Ocean flooding and higher sea levels can cause saltwater to enter groundwater pumping systems, depending on their location and operation. This can both damage the pumps due to the higher corrosivity of salt and place the water system under stress if the salt water is not properly managed.

Countermeasures

Countermeasures should include the establishment and implementation of a regular monitoring system to ensure sustainable operation of the wells. Such a system would include specific capacity tests after rehabilitation and - in the form of a simple single-stage pumping test - once a year so that changes in specific capacity can be recorded. In addition, the fresh/saltwater boundary should be defined and monitored on a regular basis. This needs to be done through a Vertical Electrical Soundings (VES) geophysical survey and regular electrical conductivity measurements and documentation. This could be done by installing monitoring equipment in observation wells, such as CTD divers that record pressure (equivalent to water level), temperature, and electrical conductivity in a well.

Furthermore, countermeasures should involve the development of an operations plan. Based on the results of the monitoring measurements, a detailed operations plan will be developed to prevent saltwater intrusion.

Finally, countermeasures should include well protection. A concept of groundwater protection zones for the existing wells should be developed and implemented, in order to ensure consistently good water quality. The concept could, for instance, feature three zones that place different restrictions on land use within these zones: Zone 1 would include the immediate area surrounding the well. No activities other than those required to operate the well would be allowed in this fenced area. Protection Zone 2 would be defined by a line from which a particle entering the groundwater takes 50 days to reach the well. Within this 50-day line, it would be necessary to ensure that no bacteriological contamination enters the groundwater. This would include limiting the use of fertilizers and pesticides. Protection Zone 3 would encompass the groundwater basin of the well. Agricultural activities would be allowed in this zone, but persistent chemicals from industrial activities would not be allowed to enter the groundwater.

Identify needs for technical support and capacity building

The Climate Change Risk Profile for Grenada (CCCRA, 2012[iv]) recommends a comprehensive study of groundwater potential and mapping of groundwater resources to address the impacts of sea level rise on groundwater levels. Because surface water is abundant in Grenada, groundwater resources have not been fully utilized to date. Future development of this resource could reduce vulnerability during droughts.

Monitoring of groundwater potential needs to be developed by NAWASA or the new Water Resources Management Unit, but if internal capacity is insufficient, it may need to be undertaken by external consultants either from the private sector or from a research institute.

Monitoring

NAWASA will provide monitoring in cooperation with the newly established Water Resources Management Division.

Feedback to policymaking

The new water law will provide a more comprehensive description of the regulations governing the management of groundwater management areas.

4.9. PHOTOVOLTAIC SYSTEMS

Grenada has a tremendous potential for solar photovoltaics (PV) (yearly average PV power output is almost 1450kWh/kWp). Regardless Grenada generates just over 98% of its electricity from Diesel fuel costing its commercial customers, like NAWASA, \$0.95/kWh (02/2022). The stark underutilization translates to a renewable energy penetration at just under 2% and makes up a meagre 12% of supply at peak demand. One of the goals within the GCREWS project is to analyse the PV potential at pumping sites and otherwise in NAWASA's water storage and distribution network. The aim is to reduce emissions from water sector (NAWASA) and reduce operating costs allowing the utility to invest savings into other areas of the system.

Data, information available

During the last quarter of 2021 a study was conducted by Energy Dynamics Ltd. assessing the potential for solar PV across NAWASA sites. This study recommended various NAWASA sites for the potential installation of varying potential (capacity) PV systems including detail financial analysis of investment cost and payback. The aim is to select, based on available budget, highest potential site(s) for installing solar PV systems to offset electricity consumption from the grid or provide reliable low carbon electricity for self-consumption.

Countermeasures

Solar PV system are available locally however usually installation companies order based on customer demand. Installation materials are dictated by the capacity of the PV system, location of PV and location of mounting structure. Installation should take into consideration technical specifications such as shading, irradiance and structural integrity of the mounting structure. To cope with tropical disturbances panels should be mounted with specific materials for the type of mounting structure to ensure low vulnerability of the system along with identify needs for technical support and capacity building.

Monitoring

Since these systems will be part of NAWASA's assets, NAWASA will provide monitoring. This can be done in cooperation with the newly established Water Resources Management Division, if relevant to their mandate.

Feedback to policymaking

Regulations for the electricity sector is currently being promulgated by the Public Utility Regulatory Commission.

4.10. SILT TRAPS, RIVER INTAKE RETROFITS

As part of the contingency plan, the G-CREWS project will provide final design and implementation of work on various sediment retention weirs and inlet retrofits. Work will begin in 2024. A detailed analysis will be conducted later.

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