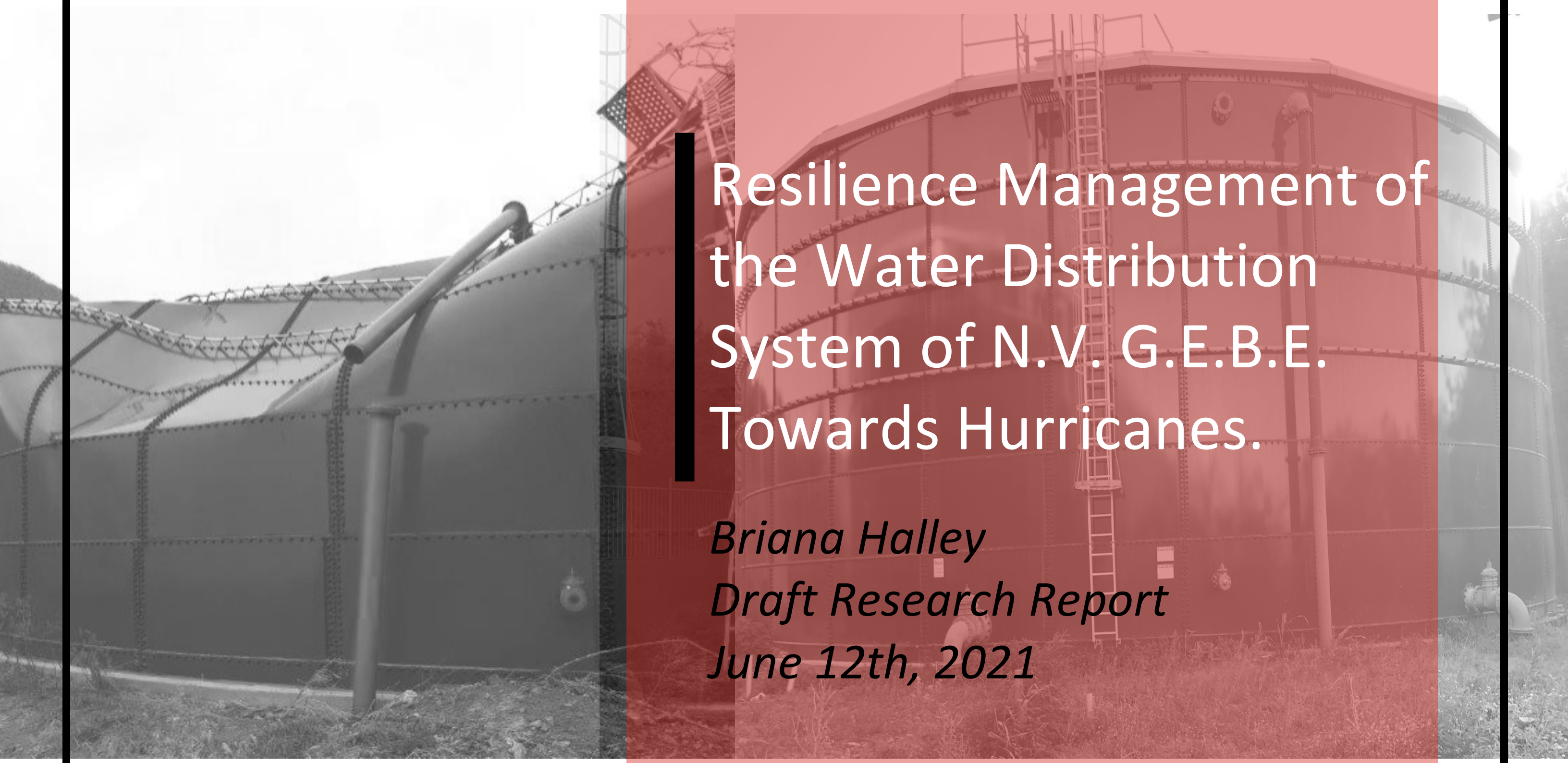

Resilience Management of the Water Distribution System of N.V. G.E.B.E. Towards Hurricanes.

Briana Halley

Draft Research Report

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Abstract

This research paper was done as part of the final asignment of the Water Management/Delta Management bachelor program of the HZ University of Applied Sciences in Middelburg in the Netherlands. The research was conducted at N.V. G.E.B.E. in St. Maarten, the only water and electricity company on the Dutch side of the island. The main topic of the research was to investigate ways in which the company can decrease risk and increase resilience to hurricanes. Since satellite imagery shows that warming has increased the likelihood of tropical cyclones to develop into a Category 3 or higher (Fountain, 2020), it is important to realize possible flaws in the system and suggest measures to further improve the resilience of the system after a hurricane. Different methods and literature such as the RAMCAP Plus Process and 5 Pillars of Climate Resilience have been used to investigate and analyze the water distribution system to answer the research question and sub-questions. The assets like the Water storage tanks of the water distribution system has been rebuilt or repaired in a more robust manner where the new tanks can withstand category 5 strength winds. Making the tanks more robust has decreased risk to the company. The plans to build new water storage tanks will increase resilience as there is more water stoarge capacity and therefore provides more water for consumers after a disaster if tanks are not damaged. Nevertheless, there is always room for improvement. After conducting field visits and desk research, the main recommendation is to improve storage facilities for the materials of the water distribution system. Materials are not properly stored, which causes materials to be damaged before being used and can slow down the recovery process after a passing of a natural disaster moreover, decreasing resilience. Additional recommendations have been outlined in the last chapter of this report. The management of N.V. G.E.B.E. is urged to take these recommendations into account to improve the overall resilience of the company.

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1. Introduction

This graduation internship and thesis will be completed at the water and electricity distribution company on the Dutch side of St. Maarten by the name of N.V. G.E.B.E. (Gemeenschappelijk Elektriciteitbedrijf Bovenwindse Eilanden). This research will examine the drinking water distribution system of N.V. G.E.B.E. before and after hurricanes/ storms to discover ways the system can become more resilient to hurricanes. This will be done by analyzing the water distribution system, current protocols for natural disasters, equipment, materials, etc. Natural disasters cause a big threat to the availability of running drinking water to the households of the island. Depending on the severity of the hurricane, the different assets of the system can be damaged, causing a water shortage until it is restored, or a temporary solution is found to regain the connection of water to the households. Drinking water in St. Maarten is purchased from Seven Seas Water Corporation, and distributed by N.V. G.E.B.E. This water is produced by desalination plants owned by Seven Seas. (Sint Maarten National Recovery and Resilience Plan (English), 2018).

In 2017, hurricane Irma, a category 5 tropical cyclone, hit St. Maarten. with maximum sustained winds of 185 mph/ 295 km/h, moving at 16 mph (Climatological Summary 2017 (Hurrican Season Review), 2018). Hurricane Irma caused catastrophic damage to the island of Sint. Maarten (Netherlands)/Saint. Martin (France), the total damages was estimated at 2.7 billion USD. Water distribution related damages from Hurricane Irma were mainly to the water storage tanks, pump enclosures and management infrastructure which added up to about 6.5 million USD. (Sint Maarten National Recovery and Resilience Plan (English), 2018).

Figure 1: Detailed map of St. Maarten showing the Dutch and French side of the island. (Detailed road and political map of St. Maarten).

1.1 Problem Definition

St. Maarten is situated in the Atlantic hurricane belt, which is likely to receive hurricanes during the Atlantic hurricane season running from June through November, with the most active month being September. (Tropical Cyclone Climatology, n.d.) An average hurricane season produces 12 named storms, where 6 become hurricanes of which 3 become major hurricanes. (Busy Atlantic hurricane season predicted for 2020, n.d.)

Few of the hurricanes directly hit the islands because of the size of the Caribbean, the geographical locations of the island and paths of the hurricanes. Natural disasters come with a multitude of effects which can cripple the islands economy, society, governance, and environment until the ability to fully recover. The phrase “fully recover “has a different definition for all players in the society. The only electricity and water distribution company on the Dutch side of the island, makes N.V. G.E.B.E. a big player in the society. Water is an important resource before and after any disaster for everyday and rebuilding purposes. Restoring the water distribution system after a hurricane is a challenging process, as it depends on how extremely the system was damaged. Other attributes like resources to repair the damages, the availability of resources on the island, the company’s personnel availability to assist the population, the conditions of the sea along with other reasons related to the recovery process after a hurricane. Research of satellite imagery from the past four decades propose that climate change is making storms more intense and destructive. The analysis of satellite images shows that warming has increased the likelihood of tropical cyclones to develop into a Category 3 or higher. (Fountain, 2020) Therefore, analyzing the system is important to possibly point out flaws in the system and suggest measures to further improve the resilience of the system after a hurricane.

1.2 Research Objectives

This research aims to analyze the water distribution system and investigate how resilient the system is to hurricanes as they are predicted to increase in intensity the coming years due to climate change. (The Impacts of Climate Change on the Atlantic Hurricane Season, 2020). The research will display and describe the damage that was done to the water infrastructure of N.V. G.E.B.E., how the company recovered/ adapted in the timeframe that took place after the hurricane. It will outline the production and distribution of water and how the system is compromised before and after the passing of hurricanes. An advice will also be provided to the company if there are more ways in which resilience in the water distribution system can be identified and improved.

1.3 Research Question

This research thesis will answer one central research question which is divided into 3 sub questions.

The central research question is*:*
How can the water distribution system of N.V. G.E.B.E. on St. Maarten become more resilient towards hurricanes?

The central research question will be supplemented by the answers to the sub-questions:

1. *How is water produced and distributed on the Dutch side of St. Maarten?*
2. *How is water production and distribution disrupted before, during and after the passing of hurricanes, using hurricane Irma as an example?*
3. *Which indicators are important for measuring resilience of drinking water distribution system?*

2. Theoretical Framework

This chapter of this proposal will include a summary of relevant sources and topics related to this research. The topics and sources will be explained and will give a greater understanding of the research.

2.1 Hurricanes

Hurricanes are known to be the most aggressive storms on earth, they form near the equator over warm ocean waters during the hurricane season which runs from June 1st to the 30th of November. Hurricanes and typhoons are the same weather phenomenon as a tropical cyclone. A tropical cyclone is a generic term used by meteorologists to describe a rotating, organized systems of clouds and thunderstorms that originates over tropical or subtropical waters with closed, low level circulation. (What is the difference between a hurricane and a typhoon?, 2013) The term hurricane is used for large storms that are created over the North Atlantic, Central North Pacific and eastern North Pacific Ocean. They get different names depending on where in the world they are formed like typhoons in the Northwest Pacific or tropical cyclones in the South Pacific and Indian Ocean. (Li, Kareem, Kiao, Song, & Zhou, 2015)

Tropical cyclones form by a re-existing weather disturbance, warm tropical oceans, moisture, and relatively light winds. When the right conditions continue long enough, they can combine to make violent winds, large waves, severe rains, and floods associated with this event. When a weather system does not meet all the conditions it takes to form but is forecast to bring tropical storm or hurricane force winds to land in the next day or two it is called a potential tropical cyclone in the Atlantic basin and eastern North Pacific basins. (Li, Kareem, Kiao, Song, & Zhou, 2015). Meteorologists have divided the development of a tropical cyclone into four stages, namely Tropical disturbance, Tropical depression, Tropical storm, and Hurricane and is described below in figure 2.

Stage	Description
Tropical wave	A trough of low pressure in the trade-wind easterlies
Tropical disturbance	A moving area of thunderstorms in the tropics that maintains its identity for 24 hours or more
Tropical depression	A tropical cyclone in which the maximum sustained surface wind is ≤38 miles/hour (≤61 km/hour; ≤33 knots†)
Tropical storm	A tropical cyclone in which the maximum sustained surface wind ranges from 39 miles/hour (62 km/hour; >33 knots) to 73 miles/hour (117 km/hour; <64 knots)
Hurricane/ typhoon/ cyclone	A tropical cyclone in which maximum sustained surface wind is ≥74 miles/hour (≥118 km/hour; ≥64 knots)

* Source: National Weather Service, National Oceanic and Atmospheric Administration (8).

† A knot is 1 nautical mile/hour; a nautical mile is approximately equal to 1.15 statute miles (1.84 km).

Figure 2: Stage of a tropical cyclone and a description. (TABLE 1. Stages of development of a tropical cyclone, 2005).*

Hurricane categories are measured by the Saffir-Simpson Hurricane Wind Scale as the categories depend on the wind speed and is divided by five categories as seen in figure 3 below.

Category	Wind Speed (mph)	Damage at Landfall
1	74-95	Minimal
2	96-110	Moderate
3	111-129	Extensive
4	130-156	Extreme
5	157 or higher	Catastrophic

Figure 3: Hurricane Categories. (How does a hurricane form?, n.d.)

2.1.1 Increase in Hurricane Activity in the Atlantic Region Due to Climate Change

As mentioned in the previous chapter, hurricane development requires heat energy from the ocean and low wind velocity. The wind velocity is the most important factor that controls the tropical cyclone formation and destruction. Wind velocity is often low during the summer and fall from the coast of Africa through the Caribbean where the Atlantic hurricanes form. (The Impacts of Climate Change on the Atlantic Hurricane Season, 2020)

Recent hurricane seasons suggests that storms attained category 5 strength in four straight years from 2016-2019 for the first time on record in the satellite era of storm monitoring. In 2019, Hurricane Dorian was the second strongest storm in the Atlantic Ocean with winds of 185 mph, Hurricane Michael in 2018 made landfall in Florida at Category 5 strength which made it one of the strongest hurricanes in US history. In 2017, Hurricanes Harvey, Irma and Maria ranked among the costliest hurricanes in history which affected millions of people in the Atlantic region who were in their paths. (The Impacts of Climate Change on the Atlantic Hurricane Season, 2020).

An analysis of satellite imagery from the past four decades suggests that global warming has increased the chances of storms to be more intense and destructive. This analysis shows that warming has increased the probability of a tropical cyclone developing into a major category 3 or higher, with sustained winds higher than 110 miles per hour by about 8% a decade. (Fountain, 2020) The Atlantic has seen increased hurricane activity in recent decades, by a measure that combines intensity with other characteristics like duration and frequency of storms. Research has suggested, the Atlantic is one region where climate change may be dominated by other factors but regardless of the additional factors, climate change will play a long-term role in increasing the strength of storms in the Atlantic and elsewhere around the world. (Fountain, 2020) Climate change is fuelling extreme rainfall thus increases the threat of flooding driven by hurricanes and sea level rise which enables hurricane storm surges to reach further inland and cause higher coastal inundation levels. (The Impacts of Climate Change on the Atlantic Hurricane Season, 2020).

The global proportion of tropical cyclones that reach very intense category 4 and 5 levels will likely increase due to anthropogenic warming over the 21st century. (Global Warming and Hurricanes, 2021).

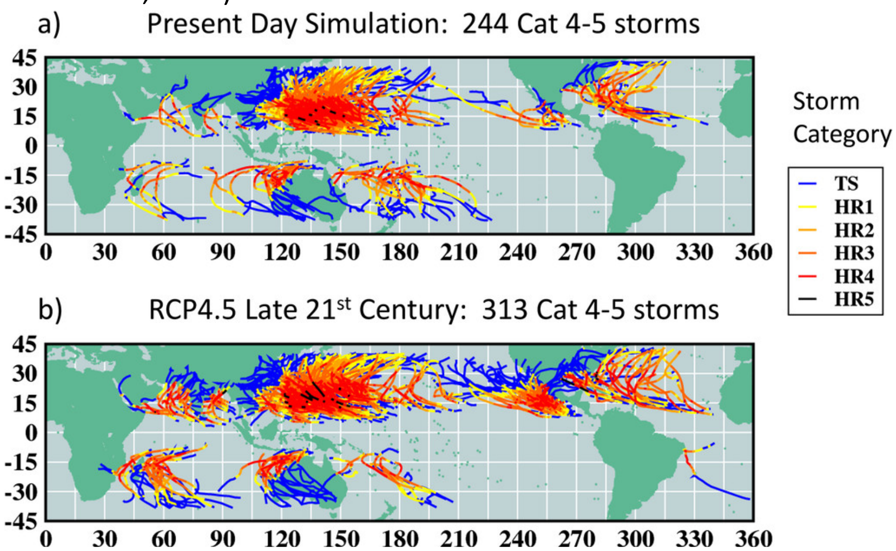


Figure 4: Tracks of simulated cat 4-5 tropical cyclones for present day or late 21st century conditions. (Knutson, 2015)

Figure 4 displays the simulations of tracks of all storms that reach at least category 4 intensity in the present day and late 21st century which were obtained using the Geophysical Fluid Dynamics Laboratory (GFDL) hurricane model. It shows the global increase in the number of the category 4-5 hurricanes from 244 in present day simulations to 313 in the late 21st century. It also shows a decrease in the Southwest Pacific basin and the largest increase in the North East Pacific. There is substantial increase as well projected in the Atlantic, North Indian, and South Indian basins. (Knutson, 2015).

2.2 Disaster Risk

Risk is defined as the potential for loss or harm due to the likelihood of an unwanted event and its adverse consequences. (Brashear & Jones , 2010). Disaster risk signifies the possibility of adverse effects in the future; it derives from the interaction of social and environmental processes, from the combination of physical hazards and the vulnerabilities of exposed elements. (IPCC, 2012). Figure 5 displays the three different factors that influence disaster risk namely, vulnerability, exposure, and hazards (Weather and climate events).

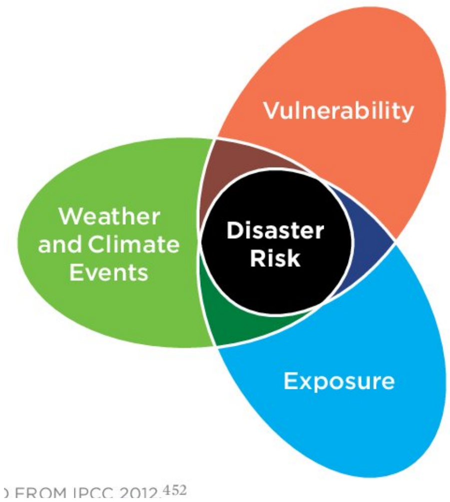


Figure 5: Factors that influence risk include Exposure, Vulnerability, and Hazards (Weather and Climate Events) (Markham, 2015).

Reducing disaster risk and losses and avoiding the creation of new risk are essential for building a stable, sustainable, and more resilient world. (UNDRR, 2020). Risk management is the process of identifying, assessing, and controlling threats to an organization's capital and earnings. (Cole, 2020). Risk management is of importance in any business or organization because it allows the company to prepare, adapt and mitigate the effects of unexpected events that can cost the company which therefore increases resilience.

According to the Disaster Resilience: A National Imperative, resilience is defined as the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events. (Disaster Resilience: A National Imperative, 2012). No one or nothing is immune to disasters or losses related to an unpleasant incidence but, there are ways to reduce the impacts of disasters. (Disaster Resilience: A National Imperative, 2012). It is also important to mention the different types of resilience and different definitions when it comes to resilience. As mentioned in chapter 1 of the Climate Resilient Urban Areas book by Rutger de Graaf van Dinther and Henk Ovink, the concept of resilience initially emerged in ecology where resilience was understood as the ability of ecological systems to persist in the face of disturbance and maintain functional system integrity. It was also mentioned that in recent decades the concept of resilience is being applied in a wide range of disciplines like economics, psychology, social sciences, natural hazards, and engineering. (de Graaf-van Dinther & Ovink, 2021).

One way to reduce the impacts of disasters on the nation and its communities according to the Disaster Resilience report, is to invest in enhancing resilience. Enhanced resilience allows better anticipation of disasters and better planning to reduce disaster losses rather than waiting for an event to occur and paying it forward. (Disaster Resilience: A National Imperative, 2012) .

2.2.1 Resilience of the Water Distribution System

As mentioned in the resilience of urban water supply systems report, a water supply system is an integrated complex design with the idea of sustainable long-term usage, which requires the anticipation and the ability to recover from possible threats such as urbanisation, long term asset degradation, climate change and disasters. (Ciprian Sanchez, Boateng, Soliman, & Thilakarathna, 2019).

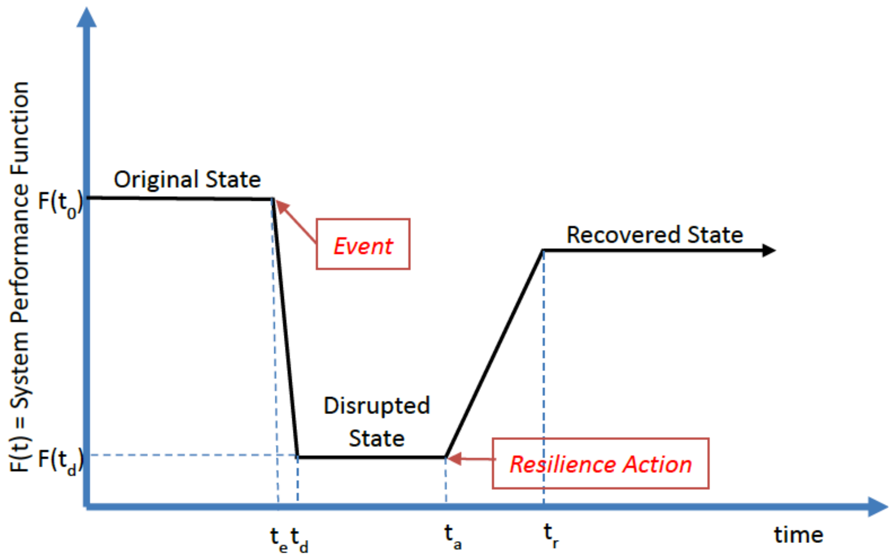


Figure 6: System performance function before, during, and after an event. (Systems Measures of Water Distribution System Resilience, 2015)

Figure 6 illustrates that the goal of a resilient system is to minimize the time a system is disrupted and the magnitude of the disruption and to maximize the performance of the after recovery.

Variable	Explanation
F(t)	System performance measure.
$F(t_0)$	System performance at its original state.
t_e	Time of disruptive event.
t_d	When the system declines until it reaches a minimum state, the disrupted state.
t_a	The time response or recovery actions have been implemented.
t_r	When the system begins to recover and reaches a new stable recovered state.

(Systems Measures of Water Distribution System Resilience, 2015).

The Systems Measures of Water Distribution System Resilience report quotes the National institutes of Standards and Technology report saying that resilience as “the ability to minimize the cost of a disaster, return to status quo, and to do so in the shortest feasible time.” (Systems Measures of Water Distribution System Resilience, 2015). This definition explains exactly what figure 6 is about as it is explaining the goal of a resilient system.

2.3 RAMCAP Plus Process

The Risk Analysis and Management for Critical Asset Protection (RAMCAP) is an all-hazard risk and resilience management process. It is used to identify and prioritize investments in preparedness of critical infrastructure, including protection and resilience to function during or rapidly returning to full function after events that can disrupt the systems function. Risk is defined as the potential for loss or harm due to likelihood of an unwanted event and its adverse consequences in this report. Resilience is defined as the ability of an asset, system, or facility to withstand an adverse event while continuing to function at an acceptable level of function after an event. (Brashear & Jones , 2010).

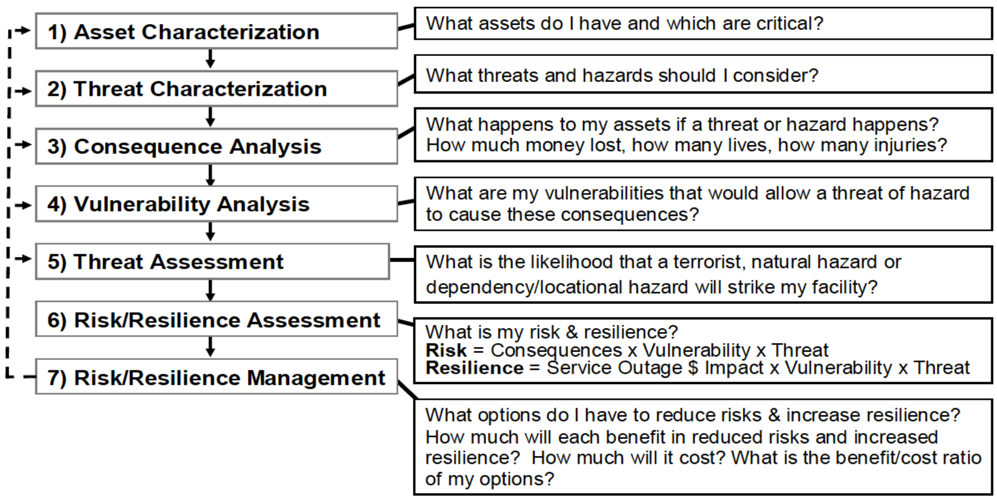


Figure 7: The seven step RAMCAP Plus Process. (Brashear & Jones, 2010).

This process includes 7 steps which provides a rigorous, objective, replicable, and transparent foundation for data collection, interpretation, analysis, and decision-making. (Brashear & Jones , 2010). Step number 6 is used in the process to calculate the expected value of risk and resilience in an adverse event.

The equations go as followed:

Risk = (Threat) X (Vulnerability) X (Consequences)

Resilience = Loss Net Revenue X Vulnerability X Threat

- Threat is the likelihood that an adverse event will occur within a specified period.
- Vulnerability is the probability that given an adverse event, the estimated consequences will ensue
- Consequences is the outcome of an events occurrence, including immediate, short and long term, direct and indirect losses and effects.

2.4 The Five Pillars of Climate Change

The Five Pillars of Climate Change is a framework used as concept to evaluate whether the urban area is resilient or can use improvement to the effects of climate change. This framework is based on an extensive literature review of definitions on resilience and vulnerability. (de Graaf-van Dinther & Ovink, 2021)

1.2 THE FIVE PILLARS OF CLIMATE RESILIENCE

Climate resilience is defined in this book as consisting of five capacities or pillars: threshold capacity, coping capacity, recovery capacity, adaptive capacity, and transformative capacity.

1. Threshold capacity: the capability to prevent damage by constructing a threshold against environmental variation.
2. Coping capacity: the capability of a neighbourhood, city, or country to deal with extreme weather conditions and reduce damage during such conditions.
3. Recovery capacity: society's capability to bounce back to a state equal to, or even better than, before the extreme event.
4. Adaptive capacity: society's capability to anticipate uncertain future developments.
5. Transformative capacity: the capability to create an enabling environment, strengthen stakeholder capacities, and identify and implement catalysing interventions to transition proactively to a climate-resilient society.

Figure 8: The Five Pillars of Climate Change explained by each capacity taken from chapter 1 of Climate Resilient Urban Areas. (de Graaf-van Dinther & Ovink, 2021).

Appendix 9 has the examples of water management measures to strengthen the five pillars or capacities of urban climate resilience which was taken from table 1.1 of the Climate Resilient Urban Areas book by Rutger de Graaf- van Dinther.

2.5 Conceptual Model

Figure 10 below displays the conceptual model which shows the main topics of the theoretical framework and how it relates to the overall research. The black rectangles represent the main topics discussed in the theoretical framework while the black arrows show the relations between the main topics. The blue arrows show the analysis that will be carried out to answer the research questions and the orange rectangles displays the types of analysis that will result in outcomes/indicators. The stripped blue line delineates the main topics from the types of analyses which will be done to answer the main research question and sub-questions of this report.

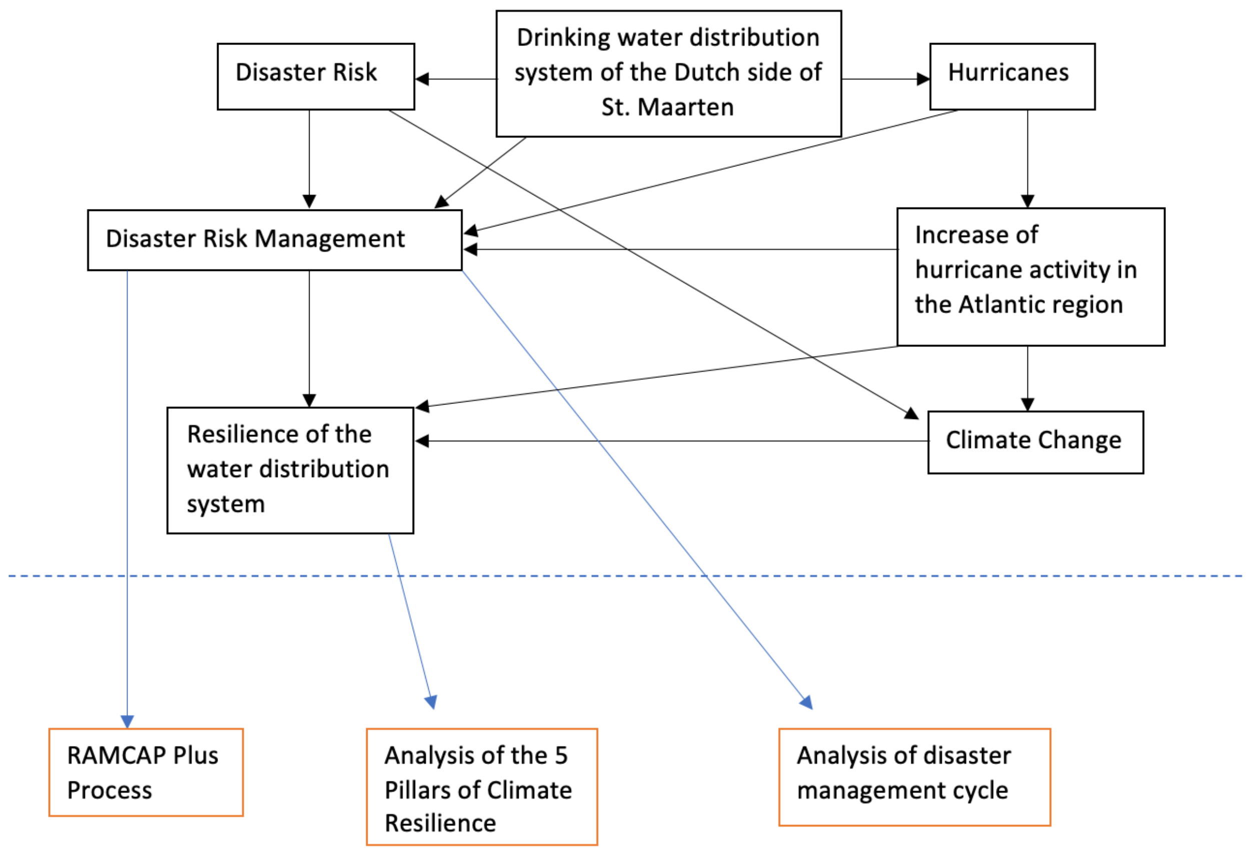


Figure 9: Conceptual Model made by Briana Halley

3. Methodology

This chapter describes the methods that will be used during the duration of this research to gather and outline data which answers the research question and sub questions. The explanation of each method will show what will be done, how it will be done, and therefore contribute to answering the research questions. This qualitative research requires an analysis, collection of desk/data research, literature review and an interview.

Desk research

Locating and analysing different documents that were made after the Hurricane to explain the rebuilding process, mainly that of *The Sint Maarten National Recovery and Resilience Plan (A Roadmap to Building Back Better)* and the N.V. G.E.B.E Hurricane Continuity Plan and Contingency plan to reference to research question 2. These documents were obtained from the disaster preparedness coordinator of N.V. G.E.B.E. Various Documents like the "*Enhanced resilience to respond to disasters*" and "*The St. Maarten National Recovery and Resilience Plan*" will also be of great use for this research as it can help in answering research sub-question 1.

Field visits

Field visits to the water tanks, pump stations, water plants, and storage facilities will be done to have a better comprehension of the system. Moreover, field visits will be used to collect pictures of the water storage tanks at present to provide a visual analysis of pictures. Pictures collected by workers of N.V. G.E.B.E after the hurricane and current pictures of what the system looks like 4 years. The field visits will allow the observation of new developments within the system. The pictures of the storage facilities will be used to aid in answering sub-question 2 and provide support for the recommendations.

Literature review

Evaluating and have good comprehension of literature like "The RAMCAP Plus Process" and "The Disaster Management Cycle" which were obtained using google scholar or research gate. "The 5 Pillar of Climate Resilience" was suggested to be used in this research and will be used as indicators of resilience of the system. Each of these theories will be used to answer the main research question and sub research questions. Searches using key words/phrases: Resilience, Risk, Disaster Risk Management cycle, Risk Management, Major hurricane response, Resilience Management, Resilience of Water Distribution Systems, Hurricane Irma.

Analysis of Water Distribution System

Conduct a complete water distribution system analysis using the water line diagram of the system with a combination of field visits. Improve this line diagram to current situation of the system. This analysis will answer research question number 1.

Climatological summaries

Research actual hurricane facts and climatological summaries to get a better understanding in comparison to the strength and what the water tanks and other materials/ equipment used by the water system can withstand. The summaries will help answer question number 2 as the preparation and response towards hurricanes are based on the category of the hurricane in the contingency and continuity plan.

Interview with Disaster Preparedness Coordinator

A structured interview with the disaster preparedness coordinator will further explain the need for necessary steps in the Continuity and Contingency Plans created for the company. The interview question will also be geared towards getting more information about the experience the company had from Hurricane Irma which will aid in answering research sub-question number 2.

RAMCAP Plus Process

The RAMCAP Plus process will be used in this report as guided process to aid in answering sub question number 2. The RAMCAP Plus Process is a combination of different methods that formulates a risk/resilience strategy. The RAMCAP Plus Process methodology from the official report highlights as few different ways in which each step can be carried out, the different steps can be seen in figure 8. The asset and threat characterization consists of identifying the assets and threats/hazards which the company should consider, these will be simply listed in the results section. The consequence and vulnerability analysis consists of analyzing what would happen to the assets if a natural disaster where to happen and what vulnerabilities would allow a threat or hazard to cause these those consequences. The consequence analysis will be explained while the vulnerability analysis will be carried using an event tree/failure tree, the event tree displays the causes of water distribution system which caused the system to fail. The threat assessment will explain the likelihood of a major hurricane causing devastation to the system in a hurricane season. The risk/ resilience assessment normally uses 2 different equations to calculate the risk and resilience figure, but these figures hold no value to this report as the research questions do not ask for a value and it was not requested by the company. Instead, the equations will be described as they would be in the assessment but will not be calculated. Finally, the last step of the process will discuss what the company did to increase resilience and reduce risk as this process will be used to analyze what happened during Irma and what the company did to make the system more robust and perhaps what they did not do which does not contribute to increasing resilience.

The Five Pillars of Climate Resilience

The five pillars of climate resilience framework will be used to answer research question number 3 and the main research question. The 5 pillars will be used as indicators to investigate the resilience of the water distribution system of N.V. G.E.B.E. The examples of the water management measures to strengthen the five pillars will be used to describe if the system has or does not have the different pillars or capacities. If it is not present in the system, it can be used as an indicator to show where they are deficiencies in the water distribution system.

4. Results

4.1 Drinking Water Production and Distribution

This section of the results will answer research sub-question number 1, which is pertaining to how drinking water is produced and distributed on the Dutch side of St. Maarten. The results were obtained by going on field visits the water plants, water tanks and pumphouses to understand how the network of assets work to provide drinking water consumers. A line diagram was also used to understand the system in a simplified manner and the diagram was updated in the process to fit the currents water distribution system.

Water Plants in St. Maarten

On the Dutch side of St. Maarten, drinking water is produced by a company named Seven Seas Water. Seven Seas Water owns and operates three desalination plants. Seven Seas Water has an agreement with N.V. G.E.B.E. where the company buys the desalinated water for distribution. The three water plants are situated in Cay Bay, Cupecoy, and Point Blanche. Figure 8 displays a location of the water plants on the Dutch side of St. Maarten.

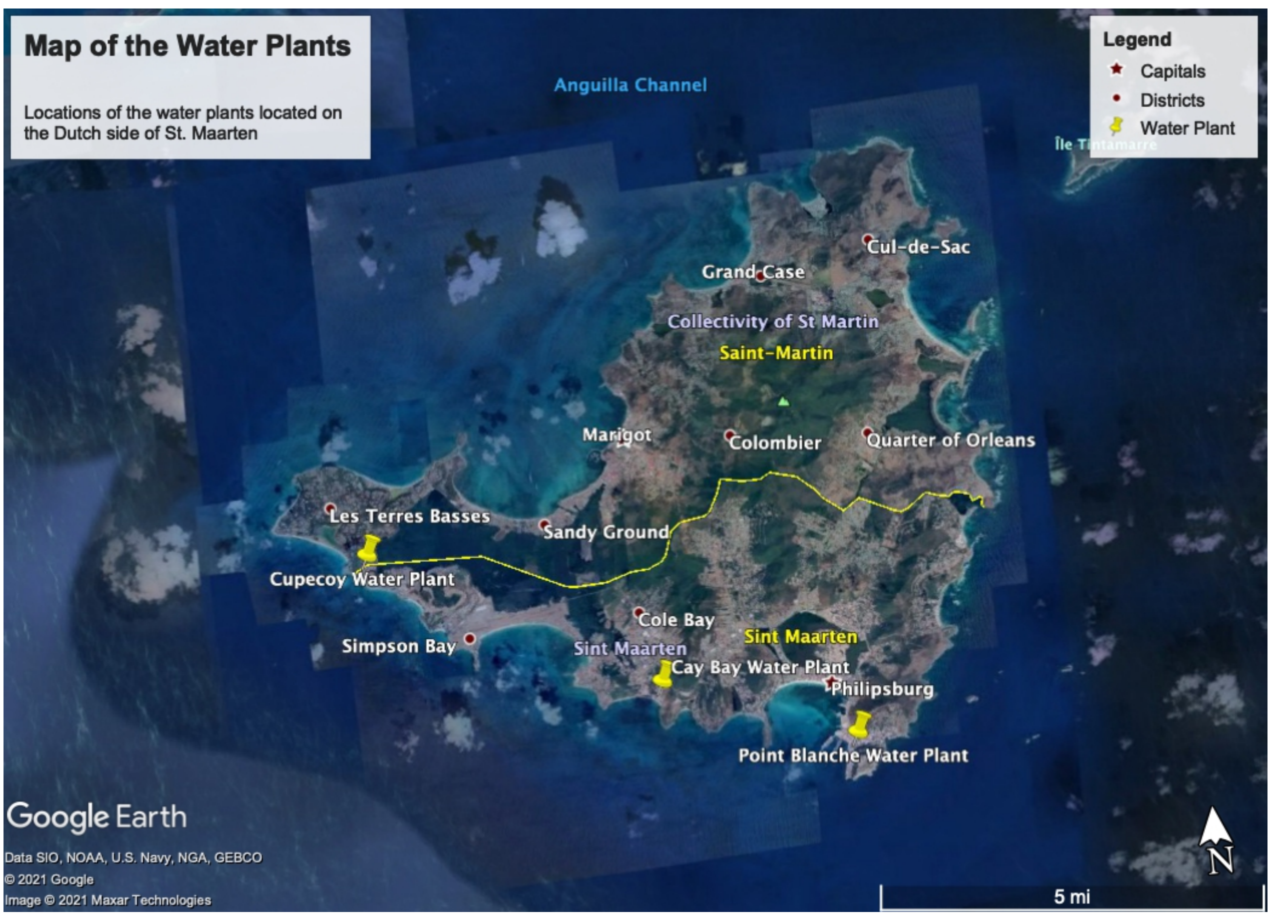


Figure 10: Map of the Water plants on The Dutch Side of St. Maarten. Created using Google Earth by Briana Halley, 2021.

The water is processed by seawater reverse osmosis (SWRO). The process starts by extracting water from the ocean using wells located near the shoreline or via intake structures located in the open ocean.

The sea water then flows through a multimedia filter before going through the reverse osmosis membrane, as it protects the reverse osmosis membrane from becoming clogged by solid particles that can be suspended in the seawater. The multi-media filter is a tank containing layered granular materials.

The filtered sea water then travels to the cartridge filters, this is the second phase of filtration. These cartridge filters are made of yarn like synthetic materials that is wounded into the form of a cartridge, as seen in figure 8. The filter cartridge removes even smaller particles which the multi-media filters could not capture. This filtered sea water is then pushed to the reverse osmosis membranes using high pressure pumps. The pressurized seawater passes through the reverse osmosis membrane, the water molecules are forced through the different envelopes in the membrane which then leaves the salt molecules behind. The desalted water passes through the membrane and emerges at a low pressure where it is collected in a tube and directed to one end of the pressure vessel. The concentrated salt stream that is rejected from flowing through the membrane, continues to pass across the membranes surface. The salt concentrated water is collected separately and sent back to the ocean through a disposal well known as the brine outfall. (Thomas, 2013).

Figure 11: A part of the Point Blanche SWRO plant. Taken by Briana Halley

Figure 12: Filter Cartridge after routine maintenance and change. Taken by Briana Halley

The potable water then goes through three post treatment steps. First, the water goes over a bed of limestone that adds calcium and bicarbonate, then sodium silicate is added as a corrosion inhibitor to protect the pipes in the distribution system. Lastly, Chlorine is injected to provide disinfection properties as the water travels from the reverse osmosis plant to the distribution pipes to households. (High quality Water, n.d.) In appendix 2, a link can be found to the video that explains the process full process and some additional details that were not mentioned in the text above.

Water Distribution of N.V. G.E.B.E on St. Maarten

The water distribution system of N.V. G.E.B.E. consists of transporting water produced from the water plants of Seven Seas Water to the Water storage tanks, and pump houses. In appendix 2, a line diagram displays the water distribution system of N.V. G.E.B.E., the water storage tanks, pump house locations and to which district they provide to.

The system consists of different sizes of main lines varying from DN100 (4 inch pipe), DN150(6 inch pipe), DN200 (8 inch pipe), DN250 (10 inch pipe), DN 300 (12 inch pipe) and lastly the DN400 (16-inch pipe). These pipes connect the whole system together. In the Line diagram, in appendix 3, the pipe sizes are displayed and mentioned here to clarify the meaning.

The function of the pump houses is to transport water from the water production locations to water storage tanks and households. The pumphouses are displayed in the line diagram as a district name and pump house following. The pumps in the pump houses are depicted as a circle with a triangle in the center.

The system is also equipped with valves, district water meters and fire hydrants. The role of the valves is to direct the flow, prevent backflow, shut off water access and adjust water pressure within the system. The district water meters measure and registers the amount of water that passes through the pipes. The network of fire hydrants is directly connected to the main water lines in the distribution system.

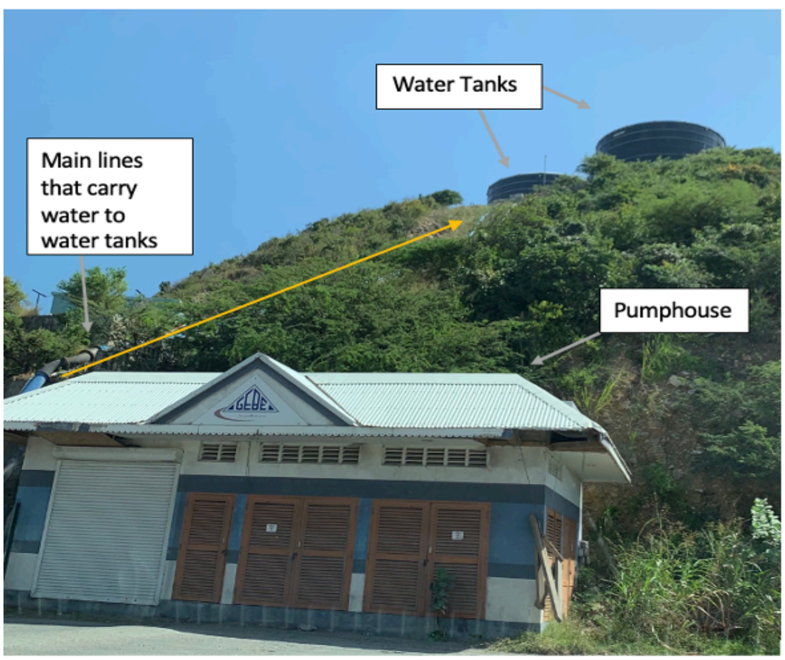


Figure 13: Point blanche location across Seven Seas water plant showing an example of the water distribution system of N.V. G.E.B.E. Taken by Briana Halley

The secondary system comprises of connections from the main lines to households of consumers via manifolds and goosenecks as seen in figures 15 and 16. N.V. G.E.B.E. uses Spire ultrasonic water meters to register the flow velocity and flow total amongst other parameters. The readings of the ultrasonic water meters are used to bill consumers based on the amount of water used monthly by the household.

Figure 14: The Spire ultrasonic residential water meter. Taken by Briana Halley

Figure 15: A Manifold with residential water meters. Taken by Briana Halley

Water Storage Tanks

There are three types of water storage tanks that are used by N.V. G.E.B.E. The newer tanks are glass fused to steel technology, the original tanks that the company started with are the welded steel sheet tanks, and the bolted aluminium sheet tanks.

Before hurricane Irma there were fifteen water storage tanks in the water distribution system which had a storage capacity of 3 days. (NV GEBE Press Release , 2021) Now there are twelve tanks being used to supply water. After the passing of Hurricane Irma and Maria, six of the tanks had some sort of damage and required repairs. There were 3 bolted aluminium sheet tanks that were damaged beyond repair which were the Concordia Tank, Pelican Keys Tank, and Monte Vista Tank. All the water tanks combined had a storage of 31,312 m^3, the breakdown of the different capacities of each water tank can be found in appendix 2. (NV GEBE Press Release , 2021) Appendix 3 shows the water line diagram with color codes depicting tanks that were damaged beyond repair meaning out of service, repaired/in service, and tanks that did not receive any damage and have been in service since. Figure 17 shows a repaired water tank located in Cay Hill, St. Maarten. The difference of the colors (dark blue upper half and dark green lower half) on the tank shows how half of the tank was repaired and the other half was salvaged.

Figure 16: One of the glass fused to steel water storage tanks located in Cay Hill. Photo taken by Briana Halley, 2021

The new water storage tanks being used by the company are from Aquastore, a company in the USA. The tanks are said to have a longer lifetime with the lowest maintenance. The Aquastore tanks are assembled from the top down and a jacking-systems is used to elevate the structure without the need of cranes etc. which leaves the crew who is assembling the tanks on the ground. The construction method enables fast and logical progress for a rapid completion.
In appendix 5, a brochure of the Aquastore water storage tanks can be found with a complete description of how they are made, constructed, and benefits of the tanks.

4.2 Disruption of Drinking Water Before, During and After a Hurricane by using Hurricane Irma As an Example

This section will present the answer to sub-question number 2. The results were obtained by interviewing the disaster preparedness coordinator to get an understanding of what happened, reviewing climatological summaries to understand the progression of the hurricane, analyzing the continuity plan, the RAMCAP Plus Process to display how the water distribution system was disrupted after hurricane Irma and examining pictures that were taken directly after the hurricane compared to how it used to look prior to hurricane Irma.

Water Production Before, During, and After a Hurricane

Seven Seas Water has a hurricane plan which focusses on preparing the 3 water plants. Seven Seas Water also has a post-storm operations plan, it explains operations at the ending of the hurricane to the 24 hours mark after the passing of a hurricane. Lastly, there is a post-hurricane plan that focusses on restarting the plants. In Appendix 5 the plans can be found, and each step is explained.

In terms of water production, Seven Seas Water starts their preparations by securing their assets at the different production locations. At the water plant in Point Blanche, the intake lines are secured by about 24 hours before a hurricane, this will reduce their production pumping capacity. This action reduces the ability to keep the tanks full while supplying water to the consumers of N.V. G.E.B.E. If seas are severely rough, there will be no water production and no way of filling the water storage tanks of N.V. G.E.B.E.

The post hurricane plan is done in collaboration with N.V. G.E.BE. as they must put back on the power and transformers need to be inspected by N.V. G.E.B.E. before any start up or power at the plant is turned back on. Water production after a hurricane is dependent on how the system was damaged, alongside the conditions of the sea because of course the water intake line is in the sea.

Water Distribution Before, During, and After a Hurricane

The different departments within the company have different tasks and responsibilities to make sure that each department is ready depending on the severity of the forecasted hurricane. Regarding the preparation of the water distribution department, the Hurricane Contingency Plan outlines a checklist of actions that should be taken to prepare the company and all its departments in the event of a hurricane. A general task the distribution department has concerning water operations, is assuring all tanks are filled before a certain number of hours prior to a storm depending on the speed of the hurricane. This prepares the tank to make sure the tank is not destroyed. Each pumphouse and water tank is prepared in a similar fashion but, some locations have special requirements, as some of parts of the system are different than others and requires a different shut down process. In Appendix 6, the hurricane contingency plan can be found.

The employees from the water distribution department makes sure all water tanks are filled as seas can become rough which makes water production shut down earlier than Seven Seas Water may expect. Additionally, there is no guarantee that a storm approaching will remain a category 1 or 2, therefore, the only way to help safeguard the investments and infrastructure of N.V. G.E.B.E. is to ensure that the tanks are filled and isolated from the grid. Before the passing of a hurricane, staff promptly address the public about the company's plan which they will follow.

Depending on the weather conditions, the system will be shut off a certain number of hours within impact based on the organizational and governmental recommendations for safety. (N.V. G.E.B.E. Hurricane Continuity Plan, 2018). During the passing of a storm, water distribution is shut off meaning consumers are temporarily out of water until the response and recovery phase.

The response and recovery after the passing of a hurricane is mentioned and explained in the Hurricane Continuity Plan in phases 4 and 5 depending on the severity of the weather conditions, this can be found in appendix 6.

The Risk Analysis and Management for Critical Asset Protection (RAMCAP Plus Process)

Step 1 Asset Characterization

Critical assets that would diminish the company's ability to meet its mission if it were damaged or destroyed will be listed below.

Critical Assets of the Water Distribution System
Water sources (Seven Seas Water Plants)
12 drinking water storage tanks
22 pumphouses that house the pumps in the system
Water meters
Valves
Pipes of different sizes which connect the system to provide water consumers
Manifolds
Goosenecks

Step 2 Threat Characterization

The main threat to the water distribution system is in the category of Natural hazards. Hurricanes of categories 3,4 and 5 hurricanes, which is considered level orange and red from N.V. G.E.B.E contingency. Categories 3,4 and 5 have the potential to disrupt the distribution of water and electricity.

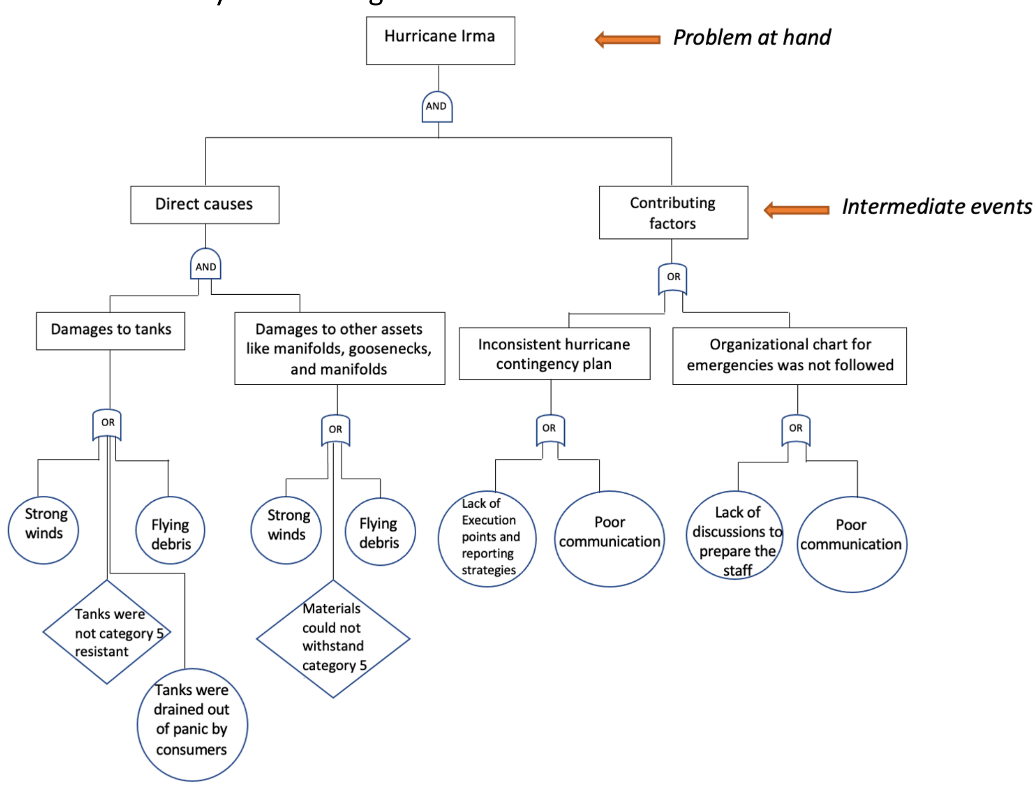
During category 3, 4 and 5 hurricanes, the wind speed can go from 111mph to 157mph and higher. Wind pressure and flying debris can cause major damage to different assets with the water distribution system mainly the water storage tanks. Flood water carrying debris can also cause damage to manifolds and goosenecks which can break pipes and water meters.

Step 3 Consequence Analysis

Depending on the category of the hurricane, determines the damage to the system. Using hurricane Irma as an example as it has been the most recent and most destructive hurricane for the island. The company lost 3 drinking water storage tanks as they were destroyed, 6 tanks had some sort of damage which required repairs, damages to manifolds, gooseneck, water meters and doors of pumphouses. The company also lost one of its main buildings.

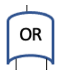
Step 4 Vulnerability Analysis

For this analysis, an event tree also called a failure tree will be used to display the causes of the water distribution system during hurricane Irma.

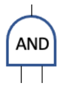


To explain the event tree above, Hurricane Irma was the main problem at hand which cause a major disruption to the water distribution system. The intermediate events describe what caused the system to fail and what attributing factors caused additional disturbance to the response and recovery period.

The rectangle shape/symbol describes the state of the system. The circle shape/symbol describes the primary or basic failure event It shows the root cause of the problem. The rhombus shows the undeveloped event and needs further exploration to see if this event contributed to the failure event. (Fault Tree Analysis , 2020).



= The OR gate is used to show that the event happened when one of the events shown below the symbol occurs. (Fault Tree Analysis , 2020).



= The AND gate is used to describe that the event happened when all the events below the symbol occurs. (Fault Tree Analysis , 2020).

Step 5 Threat Assessment

An average hurricane season produces 12 named storms, where 6 become hurricanes and 3 become major hurricanes. (Busy Atlantic hurricane season predicted for 2020, n.d.) Therefore, the likelihood that a natural hazard (major hurricane) would encounter per hurricane season is 3.

Step 6 Risk and Resilience Assessment

Step 6 of this analysis requires calculations or risk and resilience, but these calculations will bring no value to the analysis because hurricane Irma already happened. The equation below to calculate risk is different than the equation in figure 8 because the research is using hurricane Irma as an example. Therefore, hurricane Irma only had consequences and no vulnerabilities.

The equation would be Risk= Threat X Consequences

The consequences would be calculated by adding up the loss of tanks and residential water meters as those were the two main losses that the system suffered. The consequences would them be multiplied by the threat which is 3 as the likelihood that a natural hazard (major hurricane) would occur per hurricane season is 3.

The equation for resilience would be Resilience= Service outage $ impact X Vulnerability X Threat

The service outage $ impact is considered as the lost net revenue which would be multiplied by the vulnerability also known as the consequences then multiplied by the threat. The consequences and threat amounts would stay the same from the risk calculation.

<u>Step 7 Risk and Resilience Management</u>

N.V. G.E.B.E. has already done some adaptation/mitigation strategies to reduce the risk to the system, as the company has learned and adjusted to the strength of the strongest hurricane that the island experienced within the last 20 years. The main adjustment that took place was structurally upgrading the tanks to withstand 200 mph winds (category 5 strength winds). The glass fused to steel sheets were manufactured to withstand more powerful winds than the initial sheets the tanks were made with prior to hurricane Irma. This is a measure to reduce risk.

The company also decided to switch to a more robust residential water meter seen in figure 12 because the one used before consisted of a frail structure. This was also one of the biggest problems the company had to face after the hurricane, because if a consumer lost their water meter, the consumer could not receive water until it was replaced, which prolonged the recovery process for some. With the passing of hurricane Irma, the company and consumers lost about 3,280 residential water meters.
This also costed the company as they had to purchase the more robust meters during a period where the company was in recovery stage. The decision to repair the system with more robust water meters instead of using the vulnerable water meters was a well thought out decision, as this could've costed the company more in the long run. This decision reduces risk and increases resilience in the face of a hurricane.

Another learning experience for N.V. G.E.B.E. was to make sure that each pump and tank within the system was equipped with a bypass. The water distribution system was repaired and recovered with a bypass system to be able to directly provide water consumers if the water storage tanks were to be damaged. The bypass system is a network of valves. The bypass system provides a reduction of risk and is there to increase resilience in the response and recovery process.

The company also made sure that all manifolds and goosenecks are installed/fixed on the meter walls to make sure that flying debris or floating debris from flood cannot knock over or damage the structures easily. The decision can reduce risk and increase resilience as it can decrease the time it takes to recover and provide water to consumers at a faster rate.

The contingency and continuity plan of N.V. G.E.B.E. was totally revamped in 2018, a year after the passing of Hurricane Irma. The plan was revised because it lacked execution points and reporting strategies according to the current disaster preparedness coordinator. The revised contingency and continuity plan was not yet put to the test yet considering no hurricanes that past the category 3 threshold has hit the island in the last 4 years.
These revised plans, the HURREX trainings organized by the Fire Department of St. Maarten, and the company being part of the ESF groups, there is high confidence that the plan will work if exercised in real life scenarios according to the current disaster preparedness coordinator.

Another learning lesson for the company was to improve communication internally before and after the passing of a hurricane, communication can help to make sure that the response can run smoothly. Having meetings to discuss with those in the organizational chart for emergencies, the revised continuity and contingency plan will increase resilience as it aims to provide a smooth response and recovery strategy to make sure that the company provides to its consumers in quick manner.

Hurricane Irma Experience

Hurricane Irma developed on the 30th of August 2017 near the Cape Verde Islands, from a tropical wave that moved off the West African coast three days prior. Under hurricane forming conditions, hurricane Irma rapidly intensified shortly after formation, becoming a Category 2 hurricane on the Saffir-Simpson scale within 24 hours. Hurricane Irma became a major hurricane (Category 3 hurricane) shortly after. However, the intensity fluctuated between Categories 2 and 3 for several days due to series of eye wall replacement cycles. On September 4th, hurricane Irma continued to intensify to a Category 5 hurricane. (Gibbs, 2017)
On September 6th, hurricane a hit St. Maarten directly with maximum sustained winds recorded at 185 mph/ 295 km/h, moving at 16 mph with a minimum pressure of 914 hPa. (Climatological Summary 2017 (Hurrican Season Review), 2018) (Gibbs, 2017).

N.V. G.E.B.E. is regarded as an ESF 1 (Emergency Support Functions) group. The ESF groups consists of 10 supporting bodies that operate during emergency situations in St. Maarten. (Emergency Support Group, 2017). ESF 1 are representatives from N.V. G.E.B.E. that is part of the disaster management group and are responsible for water and energy. Below is the organizational structure for disaster management in St. Maarten.

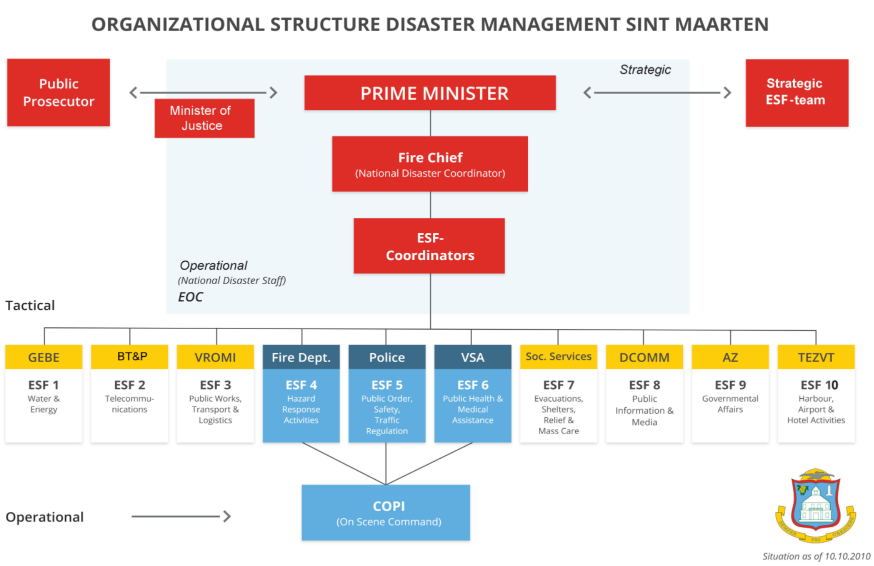


Figure 17: Organizational Structure Disaster Management. (ESF1 Subplan Water & Energy, 2020).

The purpose of the disaster response management is to ensure a well-equipped and effective response on the island to achieve coordinated action by all government and non-governmental organizations and institutions in the event of a large-scale incident, disaster or major accident affecting the population. The aim of the national disaster plan is to aid as soon as possible and as effectively as possible to limit the adverse consequences for people animals, and goods as much as possible and to get disrupted social life back normal as quickly as possible. (LANDSBESLUIT, HOUDENDE ALGEMENE MAATREGELEN, tot vaststelling van het rampenplan Sint Maarten, 2002).

The system suffered a great amount of damage in certain districts of the island depending on how hard the area was hit from the wind. There are certain assets of the system which are in open areas like water tanks which got direct damage from the wind. Some consumers experienced damages to their pipes and residential water meters which connect water to their homes. The company also lost one of the main buildings as seen in figure 19.

Figure 18: The damage to main building of N.V. G.E.B.E. (GEBE and Kadaster in Serious Financial Difficulties, 2018).

As mention in section 4.3, there were three tanks that were damaged beyond repair while 6 of the tanks had some sort of damage that was either salvageable or able to repair quickly. In figure 20, visuals show the damage of the Point Blanche tanks 8 and 9 had and were repaired after the passing of hurricane Irma and serves as an example of the 6 tanks which were damaged and repaired. Figure 21 shows the Pelican Tank before and after Hurricane Irma. The Pelican tank is an example of the three tanks which were damaged beyond repair.

Figure 19: Point Blanche glass fused to steel water storage tanks after Hurricane Irma (top) and current picture(bottom). Made by Briana Halley using a picture from N.V. G.E.B.E staff and current picture taken by Briana Halley.

Figure 20: Bolted aluminium sheet water storage tank in the district of Pelican Key before hurricane Irma (Left) and after the passing of the hurricane (Right). The dome of the tank as seen on the top right collapsed into the tank. Made by Briana Halley using photos provided by N.V. G.E.B.E. staff.

As mentioned before, due to the 9 tanks being either destroyed or needed repairs, the company had to find an alternative way to provide water to consumers. Prior to hurricane Irma, the company had a storage combined capacity of 31,312 m^3, after the passing of hurricane Irma the storage capacity declined to 10,509 m^3 as 9 tanks were damaged or destroyed. (NV GEBE Press Release , 2021). The focus after the hurricane was to restore electricity and water but, there were areas where this was not possible because of issues that could not be solved promptly. Therefore, the next solution was to provide water by using water trucks to supply water to those consumers and taps were installed at some points at specific locations within the district.

Lessons learned from Hurricane Irma

N.V. G.E.B.E. had learned from hurricane Irma and made a log within the in the Hurricane Contingency Plan from 2018. Below in figure 18, the excerpt of lessons learned can be found.

N. V. GEMEENSCHAPPELIJK ELECTRICITEITSBEDRIJF BOVENWINDSE EILANDEN — The Power to Serve

19. Lessons Learned Log - Hurricane season 2017

	Department	Situation	Lessons Learned and Recommendations
Hurricane season 2017	**Distribution Department**	1.The organizational chart for emergencies was not followed	Discussions on the roles of departments in the organizational chart
		2. Assessments of structures (electrical and water grid)was not done correctly	Assessments were not done correctly should be documented with pictures and reports afterwards
		3. Assessments of inventory was insufficient	Inventory was insufficient and should be ordered in advance with care being showed to ensure quantities coincide with needed items
		4. Storage of items were vulnerable	Items were damaged due to unsecure storage, new storage facilities must be established
		5. Lack of vehicles	Fix damaged vehicles beforehand and keep undamaged vehicles secured as best as possible.
	Production Department	1. Assessment of inventory was insufficient	Assessments were not done correctly should be documented with pictures and reports afterwards
		2. Lack of equipment to restart generators	Equipment needed to restart the electrical distribution process
	HSE Department	1.Assesment of locations was insufficient	Assessments of locations safety and security should be done in a timely manner to affect change before hurricane hits
	Human Resource Management	1. Inventory of resources	Resources such as food, water was not
		2. Communication with workers	Communication efforts must be addressed through set protocols beforehand
		3. HR role must be established in org structure.	HR is the logistical support in the organization during an emergency and should be utilized as such
		4. Aftercare is needed.	Worker emotional support should be addressed
	Information technology	1. Secure Servers	Servers security should be addressed in a timely manner to avoid items being destroyed
		2. Secure Pcs	Pcs security should be addressed in a timely manner to avoid items being destroyed
	PR Office	1. Command Center	Establishing of a sustainable command center
		2. Communication between public and private	Established pre-determined communication messages

Figure 22: Lesson learned log from Hurricane Irma 2017. (N.V. G.E.B.E. Hurricane Continuity Plan, 2018).

The lessons learned log was discussed with the disaster preparedness coordinator, and it was mentioned that communication was a major setback internally but externally as well. Lack of communication led to the organizational chart not being followed in point 1 of the log. Assessments of the structures were not done in the right way either and they lacked proper documentation of the structures within the water grid which again was due to lack of communication so that staff can follow instructions.

Point number 4 in the log that was written in 2018 mentioned that storage of items was vulnerable. While doing field visits, it was evident that the situation did not change much. N.V. G.E.B.E. has 2 locations for storage of materials, namely the 'cable yard' and the 'Sucker Garden storage facility'. The Cable yard consists of larger materials from both the distribution and production departments as seen in figure 23. While the Sucker Garden storage facility is a building and a few containers which consists smaller materials from the production and distribution department as seen in figure 24.

Figure 23: Images from Cable Yard field visit in March 2021. Photos taken by Briana Halley

Figure 24: Images of the Sucker Garden storage facility during field visit in March 2021.Top left and bottom left are inside the storage facility while the top left is the inside of a container next to the facility. Photos taken by Briana Halley

At the cable yard, the materials are considered vulnerable because the materials are exposed to the elements, as there is no building or structure to store items as seen in figure 23. At the Sucker Garden storage facility, the structure experienced damage which caused the materials to be exposed but the structure was repaired after the hurricane.

4.3 Important Indicators for Measuring Resilience of the Water Distribution System

In this section of the results chapter, research sub-question number 3 and the main research question will be answered using the theory of the 5 Pillars of Climate Resilience as indicators to investigate in which capacity the company can possibly improve its resilience if not evident within the system.

Indicator	Present or not present within the system	Explanation
Threshold Capacity	Present	Threshold capacity is the capability to prevent damage by constructing a threshold against environmental variation. (de Graaf-van Dinther & Ovink, 2021). Examples of the threshold capacity within the system is the bypass system in place to provide water to consumers in case tanks were damaged or destroyed by a hurricane. Another example is that many consumers still have cisterns (Water storage for the home), therefore consumers have back up water supply if water storage tanks were damaged.
Coping Capacity	Present	The coping capacity is the capability of a system in this case, to deal with extreme weather conditions and reduce damage during such condition. (de Graaf-van Dinther & Ovink, 2021). Examples of the coping capacity in which the company has, or practices the capacity is for example the annual Hurrex trainings for the ESF groups which is used to prepare with the intention to reduce damage because the groups learn to mitigate the effects with emergency plans.

		Government hurricane warning systems which notify the different ESF groups to prepare. N.V. G.E.B.E. provide water trucks to provide water to consumers who don’t have access to water as back up water supply. N.V. G.E.B.E. has also set up temporary taps where the population can collect water as a temporary solution in times of disaster. There are wells located in different districts where the population may collect water if water not restored promptly as back up water supply. There is a lack of a plan when it comes to emergency water supply but there is a plan in place to start the recovery process.
Recovery Capacity	Present	The recovery capacity is the capability to bounce back to a state equal to, or even better than, before the extreme event. (de Graaf-van Dinther & Ovink, 2021). Examples which help the company return to an equivalent state are the recovery plans from the continuity plan. The ESF 1 plan contributes to the contingency plan of St. Maarten which aims to control crisis situations. There are funds from the budget of the company for disasters. Spare materials and equipment are there but as mentioned in the latter part of section 4.2, spare materials are currently being stored in poor facilities.
Adaptive Capacity	Present	Adaptive capacity is the capability to anticipate uncertain future developments. (de Graaf-van Dinther & Ovink, 2021).

		The way in which the company has adapted is by improving the robustness of assets within the water distribution system. Assets like the tanks have been and is continuing to be restored with the intention to withstand the strength of a category 5 hurricane or stronger to anticipate uncertainty. There has also been improvement of the bypass system.
Transformative Capacity	Present	Transformative capacity is the capability to create an enabling environment, strengthen stakeholder capacities, and identify and implement catalysing interventions to transition proactively to a climate resilient system. (de Graaf-van Dinther & Ovink, 2021). The water distribution system is still going through many adaptive changes like constructing additional robust water storage tanks and rebuilding tanks which were destroyed that will increase storage capacity in the future. The increased the daily storage capacity which meets the demand of the community and the world standards. The company has learned from experience and continuously aims to improve water supply to its consumers. The way in which this can be improved is by improving the awareness of preparedness before a hurricane for the society to better prepare in terms of availability of water. This adaptive measure can increase resilience for the company but also for the consumers.

5. Discussion

During this research, it became quite evident by field visits and desk research that the company had already completed many measures to increase resilience and reduce risk. The company had already learnt from hurricane Irma and adapted their assets. Therefore, trying to find methods that would produce ways in which the company could improve resilience of the system was challenging. This section of the report will highlight any additional reasoning to certain results, connections, distinctions, and explanations where needed.

Discussion based on the of results of the section 4.2: Disruption of drinking water before, during and after a hurricane

N.V. G.E.B.E. and Seven Seas Water both prepare, respond, and recover in a similar fashion, both companies start by creating awareness before the hurricane season has started and making sure that the staff has their disaster passes and plans are reviewed. Both companies prepare by securing their assets and main buildings. The main difference in plans from both companies is that N.V. G.E.B.E prepares based on the strength of the hurricane that is forecasted to affect the island, while Seven Seas Water just has a general plan no matter the strength of the hurricane. N.V. G.E.B.E. is also a different type of company that has different departments which have different responsibilities and ways that they must prepare depending on the category of the hurricane.

The RAMCAP Plus process showed exactly how the system was disrupted after hurricane Irma. In this research the RAMCAP Plus process was used to analyze risk and resilience the company had before and after hurricane Irma, but the process did not high anything new. The process partially answered research sub-question number 2, mainly in step 4 by using hurricane Irma as an example. The process was also supplemented by the hurricane Irma experience section where pictures showed damage to assets in the latter part of the section 4.2 and gave more significance to the event tree in step 4 of the RAMCAP Plus Process

N.V. G.E.B.E. follows the ESF 1 subplan which indicates the way the company should conduct its response after a disaster crisis. The contingency plan describes the way the company prepares its assets. The continuity plan describes how the company prepares, responds and recovers depending on the severity of the disaster. The revised contingency and continuity of the company, along with the ESF1 subplan, and yearly HUREX trainings combines for effective preparedness for disasters in the future. It is important to note that the company had a change in the disaster preparedness coordinator who completely revamped the continuity and contingency plan. Therefore, the plan which was followed for the passing of hurricane Irma were the old plans and completely different from what can be seen in appendices 6 and 7. According to the current disaster preparedness coordinator, the plan lacked many execution points which created uncertainties in the response and recovery after hurricane Irma.

The documents received to conduct this report did not include the old plans to make a comparison to the new but during the interview with the current coordinator it was discussed. Therefore, not being able to conduct this comparison between the plans which was followed during hurricane Irma and the current plans can create an insufficiency in the discussion.

After doing research to understand what exactly happened to the tanks during hurricane Irma, an interview with the disaster preparedness coordinator clarified what went wrong. It was concluded that there was a recording on WhatsApp which went viral stating that everyone who has a cistern (a personal reservoir for storing water), should fill them rapidly because water was scheduled to be shut off 24 hours before the hurricane arrives. This resulted in the tanks being drained while the company was trying to fill them simultaneously. By then Seven Seas Water had secured their assets meaning the tanks were unable to be refilled again and then isolated from the grid.

The two storage facilities which the company has both were not improved after the recovery process after hurricane Irma. The Cable Yard remains open to the elements which causes all materials to degrade before they are used in the field. The Sucker Garden Storage Facility was repaired after hurricane Irma, but the problem was that it was not properly repaired, and the materials used to repair cannot withstand winds of a major hurricane.

Discussion based on the results of the 5 Pillars for Climate Resilience

The water distribution system of N.V. G.E.B.E. has all 5 pillars of climate resilience, but is lacking important indicators in the coping, recovery, and transformative capacities. These deficiencies in those capacities are essential for indicating resilience in the system and is used as recommendations in the latter part of this research. The water distribution system has infrastructure to prevent damage which indicates that the threshold capacity is sufficient.

Examples of the coping capacity are evident in the system because there are plans and strategies put in place to deal with extreme weather while reducing damage. Moreover, there are many strategies known to management for back up water supply but there is no plan. A plan will provide a structure to emergency water supply which will strengthen resilience in face of a disaster.

The recovery capacities would be considered sufficient as the system has the capability to bounce back to equal state, or even better than before the extreme event. The only example that is lacking in this capacity is the spare materials, not that there are no spare materials, but there is no proper storage of these materials. The lack of proper storage for spare materials causes these materials to be vulnerable to effects of a hurricanes but also directly after a hurricane, where there is a risk of looting. The cable yard is a lot which no overing and open to the element, the lot is also prone to flooding.

The Sucker Garden storage facility was poorly rebuilt after hurricane Irma and therefore is considered vulnerable to any major hurricane. Lost or damaged materials will increase the time taken to recover after a hurricane as new materials will have to be shipped in which takes a lot of time. This leads to a decrease in resilience.

Examples of adaptive capacity are noticeable in the system as the company adapted by improving their assets within the water distribution system to make it more robust which can withstand the strength of the highest category hurricane. If the contingency plan is followed completely, the expected damage of the system should be to a minimum.

The transformative capacity has examples within the management of the water distribution system to transition being climate resilient but there is a deficiency in the way the company provides advice or awareness for the consumers to prepare for the hurricane season. Providing awareness and advice to consumers to prepare in advance can be a crucial measure to increase resilience as it allows consumers to improve their preparations for personal water storage. Many consumers have cisterns or water reservoirs to collect water before a hurricane approaches the island. Advising consumers to make sure their cisterns or reservoirs are filled in the beginning of hurricane season will reduce the panic after a hurricane as they will have water available after a hurricane. As mentioned by the disaster preparedness coordinator, many consumers filled their cisterns and personal water reservoirs directly before hurricane Irma approached the island which caused the tanks to be drained. With tanks being drained, and Seven Seas Water production closed in preparation for the hurricane, the water storage tanks could not be refilled. Following the contingency plan, the tanks are supposed to be filled to prevent damage and this was not the case for hurricane Irma. Combined with the fact that these tanks could not withstand the powerful pressure and winds of a category 5 hurricane, 9 of the 15 tanks were destroyed or damaged. With that being said, providing information to consumers about preparing their personal cisterns or water reservoirs can prevent future risk to tanks and increasing resilience to the assets of the water distribution system but increasing resilience for consumers themselves.

6. Conclusion

In conclusion, this report analysed the response and recovery to hurricane Irma which caused major disruption to the water distribution system on N.V. G.E.B.E. The report consisted of conducting field visits, desk research, literature reviews, analysis and revamping of the water distribution line diagram, interviewing the disaster preparedness coordinator, analysing the disaster management cycle, risk and resilience analysis, and finding indicators for resilience. The findings highlight how N.V. G.E.B.E. already mitigated/adapted to the effects of a major hurricane by strategies that have already been carried out and continue to be worked on to make a more robust water distribution system. The company is recommended to continue improving the system to reducing risk. The actions to increase resilience of the company is in the recommendations section of this report and decision makers of the company are urged to take advice into account.

7. Recommendations

There are many ways in which N.V. G.E.B.E. can increase resilience after the passing of a hurricane based on the analysis. By further learning from the past and implementing change resilience can be increased. This research was done for the water distribution system, but certain recommendations can benefit the whole company when it comes to disaster preparedness and response.

Recommendations based on results of the analysis of how the system is disrupted by hurricanes and RAMCAP Plus Process

Firstly, based on the lessons learned log which can been seen in section 4.2 which was taken from the continuity plan, it explains that new storage facilities need to be found. Currently in 2021, the storage facilities are still in the same condition as after the passing of hurricane Irma. Materials are still exposed to the elements and can be damaged as the bigger materials are in the "cable yard" where there is no covering to protect materials and is prone to flooding. The Sucker Garden storage facility is a building with a roof and walls made of zinc sheets, the front of the building is a concrete wall, but the rest of the structure was constructed using zinc sheets as seen in figure 20. The building cannot withstand the effects of a major hurricane and could leave all materials vulnerable to the elements and possibly a risk of looting if a hurricane were to pass. This could result in a delay the recovery process as materials that would be used to repair the system would be lost or damaged.

In step 7 of the RAMPCAP Plus process, management techniques that have already been done to reduce risk and increase resilience were explained. There were also pointers to explain how resilience could be improved.

- By introducing more effective modes of communication during and after the passing of a hurricane
- By providing access of the continuity and contingency plan and meetings in the beginning of the hurricane season with all employees involved in the response and recovery phases

  By introducing more effective modes of communication in wake of a hurricane, it can keep all those involved informed. During a hurricane connection of electricity can be lost which would lead to a decline in communication. Introducing more effective modes of communication like long range walkie talkies/ mobile radios will increase resilience because it allows the staff involved to communicate even if phones have died and cell sites are down. Providing employees with the continuity and contingency plans and meetings will be an effective way of preparing staff before the passing of a hurricane and therefore has a great chance of increasing resilience because the staff will know what to do in the response and recovery phase after a natural disaster.

Recommendations based on the results of the indicators of the 5 pillars of climate resilience

All indicators were evident in the system and management of the system but lacked in the coping capacity, recovery capacity and the transformative capacity.

- Creation of an emergency water supply plan
- Spare materials being vulnerable in the storage facilities
- Better communication with consumer in the beginning of hurricane season

For the coping capacity, it was evident that there were strategies known to management when it comes to water outages but there is a lack of plan, an emergency water supply plan can benefit the company. The emergency water supply plan would bring clarity to the process of providing drinking water in a devastating time and should include ways in which delivery of water would be implemented, ways to inform the consumers of this service, amongst other information to manage and keep order to the distribution of the water. The way in which the recovery capacity is lacking is in storage of spare materials. Spare materials are available, but it was mentioned that the storage of these materials is the main problem. This is already addressed above. The idea of the transformative capacity is evident as explained in section 4.3, but it lacks the aspect of providing awareness and preparation techniques for consumers during hurricane season. Providing information for consumers about ways they can prepare for hurricane season in terms of personal water storage. Many consumers still have cisterns on their properties. The problem where awareness is lacking is in the preparation process of these cisterns or personal water reservoirs. Usually, cisterns are filled with rainwater, but if the period before the hurricane season was dry, cisterns would not get filled which forces those with cisterns to fill them with water from N.V. G.E.B.E. This problem contributed to the damage of tanks for hurricane Irma as tanks were drained by filling of cisterns amongst regular water storage techniques used by consumers in wake of a storm. By informing consumers to prepare in advance will increase resilience for consumers but also for the company.

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Appendices

Appendix 1: Link to video of the seven Seas Water Seawater Reverse Osmosis Animation

by Lauren Thomas
https://www.youtube.com/watch?v=vQNj4U05mq4

Appendix 2: Breakdown of the capacities of the water storage tanks before hurricane Irma, After hurricane Irma and current water capacity.

Before IRMA: (31,312 m^3)

Nr.	Tank Location	Ton / Meter	Operational Capacity	Operational Level /m
1	Cay Bay I	400	4,600	11.5
2	Cay Bay II	400	4,600	11.5
3	Cay Hill I	500	3,750	7.5
4	Cay Hill II	500	3,750	7.5
5	Mnt Williams	85	400	4.7
7	Sth Reward	70	399	5.7
8	Pt. Blanche	269	2,475	9.2
9	Pt. Blanche	269	2,475	9.2
11	Mullet Bay	1,050	-	-
14	Jail	448	2,464	5.5
15	Concordia	448	1,613	3.6
16	Pelican Key	448	2,509	5.6
17	Monte Vista	53	244	4.6
18	Guana Bay	275	1,348	4.9
19	Almond Grove	48	221	4.6
20	Weymouth Hill	95	428	4.5

After Irma: (10,509 m^3)

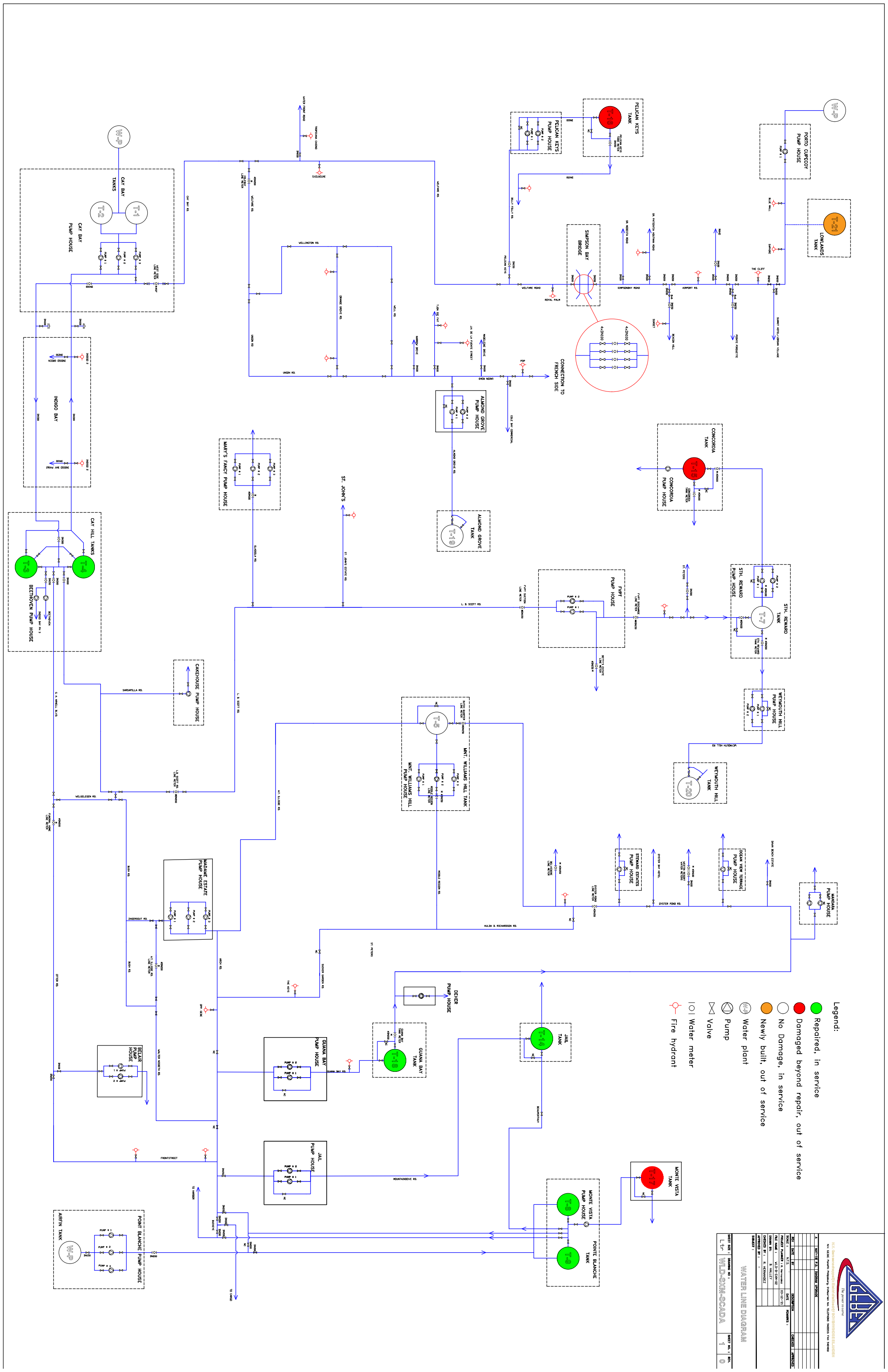
Nr.	Tank Location	Ton / Meter	Operational Capacity	Operational Level /m
1	Cay Bay I	400	4,600	11.5
2	Cay Bay II	400	4,600	11.5
3	Cay Hill I	500		
4	Cay Hill II	500		
5	Mnt Williams	85	400	4.7
7	Sth Reward	70	399	5.7
8	Pt. Blanche	269		
9	Pt. Blanche	269		
11	Mullet Bay	1,050		
14	Jail	448		
15	Concordia	448		
16	Pelican Key	448		
17	Monte Vista	53		
18	Guana Bay	275		
19	Almond Grove	48	221	4.6
20	Weymouth Hill	95	428	4.5

To date: (26,946 m^3)

Nr.	Tank Location	Ton / Meter	Operational Capacity	Operational Level /m
1	Cay Bay I	388	4,462	11.5
2	Cay Bay II	400	4,600	11.5
3	Cay Hill I	500	3,750	7.5
4	Cay Hill II	500	3,750	7.5
5	Mnt Williams	85	400	4.7
7	Sth Reward	70	399	5.7
8	Pt. Blanche	269	2,475	9.2
9	Pt. Blanche	269	2,475	9.2
11	Mullet Bay	-	-	-
14	Jail	448	2,464	5.5
15	Concordia	-	-	-
16	Pelican Key	-	-	-
17	Monte Vista	-	-	-
18	Guana Bay	277	1,524	5.5
19	Almond Grove	48	221	4.6
20	Weymouth Hill	95	428	4.5

(NV GEBE Press Release , 2021).

Appendix 3: Line diagram of the water distribution system of N.V. G.E.B.E.



Appendix 4: Information about the Aquastore water Storage Tanks

Vitrium™ TiO$_2$

ENHANCED GLASS-FUSED-TO-STEEL TECHNOLOGY

Aquastore's glass-fused-to-steel is the premium technology in the tank market. Glass coating's physical properties are specially suited to municipal and industrial storage applications. The factory-applied silica glass coating on Aquastore tanks forms a hard, inert barrier for both the interior and exterior tank surfaces to guard against weather and corrosion. Glass-fused-to-steel is impermeable to liquids and vapors, controls undercutting caused by corrosion and offers excellent impact and abrasion resistance. The color won't fade or chalk and graffiti can easily be removed. ***It never needs painting!***

A multi-step process is the heart of the glass-fused-to-steel technology system:

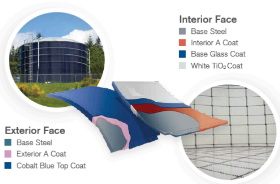
- Fabricated sheets are grit blasted to a uniform, near white surface
- Formulations of borosilicate, minerals, water and clays are blended into a sprayable slurry called "slip"
- After inspection, the slurry is fused to the steel sheets at temperatures above 1500° F (815° C) resulting in an ionic exchange of materials and forming a covalent bond producing the distinctive glossy Aquastore glass finish
- The molten glass reacts with the profiled steel surface to form an inert, inorganic chemical and mechanical bond

State-of-the-art porcelain enameling furnace improves quality, saves energy, increases production and speeds delivery of glass-fused-to-steel products to customers.

The interior of ALL Aquastore tanks feature Vitrium™ coating technology enhanced with titanium dioxide (TiO_2) for the toughest glass available. This coating combines the outstanding chemical and physical resistant properties of titanium-enhanced glass with a highly engineered, ultra-fine glass bubble structure essential to flexibility, quality and longevity. This process results in high performance glass-fused-to-steel technology. Vitrium features and benefits include:

- Tough TiO_2 glass formulations provides longer life
- White interior is easier to inspect than darker coatings
- Factory certified holiday-free sheets
- Designed for use in both cold and hot climates
- Designed, fabricated, shipped and supported within the USA

Guaranteeing the best quality available from our manufacturing facility to your jobsite.



Glass frit is specially formulated to produce the distinctive cobalt blue Aquastore glass coating.

Edgecoat II™

ENGINEERED EDGECOAT TECHNOLOGY

Edgecoat II™ is a result of CST's commitment to an ongoing product development and improvement program. This continuous innovative *Edgecoat II technology is the ONLY process in the world that provides optimum glass encapsulation on all (4) four sides of the sheet edges.* CST took the best Edgecoat technology in the world and made it better with Edgecoat II.

Following Porcelain Enameling Institute guidelines (PEI-101), Edgecoat II sheets are mechanically rounded to specific radii that provides maximum glass adhesion to steel. The combination delivers the maximum corrosion resistance of Vitrium glass coating with the greatest protection on every sheet.

The Edgecoat II engineered approach involves stringent plant quality control procedures to ensure the Edgecoat II remains in place throughout the life of the tank.

Sheet edge corrosion on steel is aesthetically unpleasant and will significantly limit the life of your storage tank. Due to the manufacturing expense and professional engineering necessary to coat the steel edges, other glass tank providers will leave them uncoated and exposed; relying solely on the sealant fillet to prevent corrosion in this area. CST's improved process of mechanically rounding the sheet edges to exact radii ensures adherence of the glass for complete encapsulation on every sheet edge.

Aquastore glass-fused-to-steel tanks with Vitrium TiO_2 and enhanced Edgecoat II technology, offer complete encapsulation and corrosion protection. CST continues to lead innovative improvements in areas that are most susceptible to environmental attack.

The physical properties of all Aquastore tanks' glass coating are especially suited to municipal and industrial liquid storage applications. The tank designs incorporate recognized standards assuring high-quality long-lasting municipal and industrial liquid storage tanks.

Engineered Edge

Benefits of Edgecoat II include:

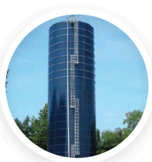
- 5 mils of glass encapsulation on every sheet edge
- Glass is applied on all (4) four sides of the rectangular sheet edges providing the greatest protection
- Edges are engineered to ensure optimum radii for each individual gauge of steel providing the maximum and consistent glass edge
- No sharp edges on tank sheets, eliminating safety hazards
- Highest quality finish

Aquastore Product Portfolio

TANK APPLICATIONS

Aquastore storage tanks with Vitrium glass-fused-to-steel are ideal for the following designs and applications:

Composite Elevated



Standpipe

Leachate

Ground Storage Tank

Fire Protection

Anaerobic Digestion

Municipal Wastewater
Clarifier / Sludge / Storage / Mixing

Construction

FROM THE TOP DOWN - FASTER, SAFER CONSTRUCTION

Every Aquastore tank is factory engineered to customer specifications. Since all components are manufactured in the factory and easily assembled, Aquastore tanks can be installed in many types of weather conditions that field-welded steel or concrete tanks cannot. Tanks are assembled from the top down by factory-trained professional building crews using CST's Proof Load Tested and PE stamped jacking systems that safely and progressively elevate the structure without the need for expensive cranes, large staging areas or extensive scaffolding. Erection crews can stay safely on the ground. This construction method enables rapid, logical progress for timely completion.

- Small footprint
- Site work savings
- Year round construction
- Fast turnaround
- Quick erection
- Trained and certified crews

Floors

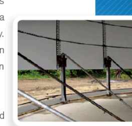
Aquastore floors can be glass-fused-to-steel or reinforced concrete. Steel floors have the same superior glass coating as the Aquastore glass-fused-to-steel sheets. When using concrete, Aquastore walls are embedded in the foundation. Authorized Aquastore Dealers can provide site preparation and foundation installation.

Sidewalls

Sidewall erection is completed using a series of specially engineered motorized jacks. Each glass-fused-to-steel panel is bolted and sealed into place. Upon completion, the motorized jacks raise the sidewall ring so subsequent rings can be erected. Erecting an Aquastore tank does not require heavy-load cranes or lifting equipment on-site. This unique installation process allows for construction in remote regions, as well as metropolitan areas.

Roofs or Domes

The flush batten OptiDome® is a next generation aluminum geodesic dome. OptiDome aluminum domes incorporate a flush batten design that effectively sheds water and reduces ponding on the panels. With a Double Web I-Beam customers get the most efficient, functional, long lasting dome solution in the industry. OptiDome is easy to install and requires less sealant than typical geodesic domes. CST's OptiDome design efficiently complies with the latest requirements that have been adopted by 2010 Aluminum Design Manual, Eurocode, and International Building Code 2012.



Every OptiDome is custom designed to meet the specific requirements of each project and can be engineered for any snow, wind or suspended load capacity, as well as span-to-rise-ratio. The all-aluminum free span OptiDome's are available for the complete range of Aquastore tanks.

Glass-fused-to-steel roofs are available up to 31' in diameter and aluminum geodesic domes are available in all sizes.

Glass-fused-to-steel roofs are manufactured with hard tooling and include radially sectioned steel panels. The roofs are assembled using the same sealant and bolting techniques as the sidewall panels.

Sealants

Aquastore tanks feature sealants specifically formulated for chemical resistance appropriate to the application. Each sealant is inspected on a batch-by-batch basis to ensure quality. The sealant is suitable for contact with potable water and is certified to meet ANSI/NSF Additives Standard 61 for indirect additives and is chlorine resistant. Sealants cure to a rubber-like consistency, have excellent adhesion to the glass coating, low shrinkage and are utilized for both interior and exterior use.

Appendix 5: Seven Seas Water Hurricane Plan, Post Storm Operations, and Post Hurricane plant restarting plan

		Seven Seas Water Hurricane Alert Plan Site : SXM Plants (CB-PB-CYCV)	
ID #	Site Specific	Task name	Preparation time
	Overall	Beginning of Hurricane Season, Before June 1st	
1		Secure post hurricane curfew passes for all employees.	
2		Review this plan for site specific details, all row on deck.	
3		Verify materials on hand to secure each site.	
4		Prepare the hurricane supplies pallet and store safely (Dry food, cans, hygienic items etc.. List detailed in email.)	
5		Prepare the hurricane "communication" pallet and store safely (Gasoline, Diesel, Satellite phone, Walky Talky)	
6		Secure all AC-compressor/Storage containers and anchor them properly.	
7		Coordinate and prepare with appartement owner. Not waiting to the last minute to secure site.	
8		Secure all roofs and MMF protection.	
	Overall	Hurricane Alert - (T- 72 Hrs), Overall plants	
9		Begin coordinated team communication with operations personnel. Review Emergency Action Plant and distribute it. Begin storm tracking. Check sat phone	1 hour
10		- A safe location should be designated as the storm center.	
11		- All site operators will be notified to begin securing their areas, supplies at home and family.	
12		- Each manager will inspect their areas of responsibility for compliance.	
13		- Any contractors onsite will be notified to secure their areas and materials.	
14		Finishing the hurricane supplies pallet and store safely (Dry food, cans, hygienic items etc.. List detailled onto email.)	4 hours
15		- A small amount of canned goods, drinking water, and canned drinks should be purchased and stored in case people get stranded at the site during or after the hurricane. These will be stored in the control room. Supplement food supply.	
16		Verify curfew passes. Begin coordination with customers and power providers.	30 mins
17		Any loose gear outside should be moved inside or secured.	8 hours
18		Critical files on computers should be backed up onto offsite servers and the cloud.	1 hour
19		Check AC, shipping containers strapped and/ or anchored.	2 hours
	Pointe Blanche	Hurricane Alert - (T- 72 Hrs), Overall plants	
20		Contact supplier for removing 2 intakes pipes: T-24hrs.	1 hour
21		Leave space in the building of SWRO for storing future pipes.	
22		Protect office windows with plywood: SSW Storm Center.	2 hours
	Caybay	Hurricane Alert - (T- 72 Hrs), Overall plants	
23		Ensure the fork lift is operationnal for removing Aquadesing motors. T-24hrs	1 hour
24		Bring Oil drums at the intake, at the last moment fill up pumps staying in rooms during storms.	1 hour
	Overall	Hurricane Alert - Continued - (T - 48 Hrs), Overall plants	
25		Continue coordinated team communication. Verify people are ready at home for post storm conditions. Check sat phone	1 hour
26		- Send friendly reminder that GEBE tanks need to be full during the storm.	
27		Move any remaining non-essential equipment to a safe location.	4 hours
28		- Any daily use materials that carry a warning label (solvents, cleaning agents, paint, etc) should be put into their appropriate cabinets and secured.	
29		- Lash down non-essential gear and equipment that must remain outside, recheck lashing of outside equipment.	
30		Make ready all portable generators, air compressors, and portable radios.	2 hours
31		Fill fueling cans and keep them topped off.	2 hours
32		Each department will inspect their areas of responsibility for compliance.	End of the day
	Overall	Hurricane Warning - (T - 24Hrs)	
33		Continue coordinated team communication. MANAGER TO STRESS POST STORM CHECK-IN PLAN. Check sat phone.	1 hour
34		- Ensure all tanks are full.	
35		- List of personnal phone numbers and emengency call check up.	
36		- Customer and power company coordination of shut down plan.	
37		Continue to secure site equipment.	4 hours
38		Coordinate site, preserving vehicles fuel, etc.	1 hour
39		Move desks, files, office equipment, and furniture away from uncovered windows. Put all papers in file cabinets or drawers along with telephones.	1 hour
40		- Computers, copiers, and fax machines should be moved to a safe location. Make sure they are marked with names and locations to hasten redistribution after the storm.	
41		If possible, fill extra fuel cans with fuel, containers with water, etc. and stow in a safe location for use after the storm.	
42		Board up all windows.	4 hours
43		Verify spare generator battery in safe location. Especially at PB and CB.	1 hour
44		Each department will inspect their areas of responsibility for compliance.	End of the day
	Pointe Blanche	Hurricane Warning - (T - 24Hrs)	
45		Removing 2 intake pipes and clog the hole with appropriate flange.	4 hours
46		Store intake pipes into the main building. Nothing should remain outside if is not properly strapped.	1 hour
47		Clog up last hole and doors of the sea side. No Electrical/Important equipement stored into CaCO3 office and restroom.	1 hour

Seven Seas Water Hurricane Alert Plan Site : SXM Plants (CB-PB-CYCV)			
ID #	Site Specific	Task name	Preparation time
	Caybay	Hurricane Warning - (T - 24Hrs)	
48		Removing AD VFD motor and leave the Soft Start running.	2 hours
49		Removing ES Soft Starter motor and leave VFD running.	2 hours
	Overall	Hurricane Warning - Continued - (T - 12 Hrs)	
50		Continue coordinated team communication. Test sat phone	
51		Site operators will be told to check to make sure all container doors are closed and secured.	
52		Customer communications – shut down plan – post storm meet and re-start plan	
53		Secure all electrical power sources not required for minimum operation. Electrical equipment should be turned off and unplugged; lights should be turned off except for areas that might be manned.	
54		Wrap all electrical panels with plastic.	1 hour
55			
56		All equipment should now be secured in a safe location	End of the day
57		All other hurricane preparations should be completed. Excuse all non-essential personnel.	End of the day
58		Final check on hurricane pallet supplies.	End of the day
59		Each department will inspect their areas of responsibility for compliance.	End of the day
	Overall	Hurricane Imminent - (T - 6 Hrs.)	
60		Continue coordinated team communication. Managers to stress post storm check-in and staffing plan	1 hour
61		Confirmation of customer and power company shut down plan.	30 mins
62		Site Managers should make their last check of the site to ensure that nothing has been missed. Any last minute preparations should be completed.	1 hour
63		Prepare to ride out the storm. If you are required to be on premises you should remain indoors. Be sure you have emergency supplies (radio, flashlight, batteries, etc.).	30 mins
64		Monitor the weather information.	30 mins
65		Perform a controlled plant shutdown, if possible. (Power outage may shut the plant down before it can be performed)	1 hour
66		- Turn off all electrical panels. Verify each UPS is properly OFF.	
67		- AC need to be stop at the last moment to avoid moisture onto panels and electrical rooms.	
68		- All extension cords and electrical equipment need to be un-plug.	
69		- Close all intake marine doors, protect cameras.	
70		- Turn the Distribution Pumps OFF, leave our tank facility full.	
71		All vehicles inside plant and secured.	30 mins
72		All employees will leave the site to take cover and ride out the storm.	30 mins

Seven Seas Water Hurricane Alert Plan Site : SXM Plants (CB-PB-CYCV)		
ID #	Site Specific	Task name
	Overall	Post Storm Operations - 0 - 24 Hours
73		Re-staff sites to keep out vandals and sightseers.
74		Check in – all staff to check-in with site manager or direct to SSW TPA. Make contact with SVPOPS as soon as possible with plant status.
75		Survey for damage or injured personnel. Assist any injured as necessary.
76		Assess damage of property; provide to SSW Tampa Management a written report accompanied by photographs when possible.
77		Prioritize cleanup and repairs:
78		- Engine, motor, heavy electrical equipment need to be used only if managers approved.
79		- Remedy dangerous or hazardous conditions.
80		- Remove debris and give access to plant. Mention any unsafe equipment or behavior to supervisors.
81		- Documents, take picture and begin temporary repairs.
82		- Remove debris and give access to plant.
83		- Advise SSW Management of island status and plans after the storm.
84		Coordinate power restoration and plant startup with power provider and customer.
85		- GEBE needs to inspect first our transformers on each location.
86		- Prioritize accordingly the re-start plant procedure.

ID #	Site Specific	Task name	Preparation time	Ressource Names
		Seven Seas Water Post Hurricane Restarting Plants **Site : SXM Plants (CB-PB-CYCV)**		
	Overall	Post Hurricane Operations		
		Survey for damaged or injured personnel. Assist any injured personnel as necessary.		
		Contact power plant and coordinate with local Director.		
		GEBE needs to inspect each transformor before ANY START UP or TURNING ON OF POWER.		
		Schedule workers site according personnal event, ability of traffic etc…		
	Pointe Blanche	Post Hurricane Operations		
	Intake	Confirm that GEBE inspected intake transformor.		
		Visual inspection of pipes, inside and outside building.		
		Slowly re-open suction and discharge valves, pending managerial approval.		
		Check for any leaks, vents and broke parts.		
	Main plant	Confirm that GEBE inspected main plant transformor.		
		Ensure no water went into the electrical rooms. If so inform supervisors.		
		Follow piping and check for any broken pipes, equipment. Visual check.		
		Slowly re-open valves, pending managerial approval.		
		All valves should be set up in manual. Check vents.		
	Power back on	Always check for any burn, smoke, weird smell, any particular events		
		With GEBE (if possible), put on the main power on.		
		Set up all electrical panel ON, turn UPS ON.		
		Air compressor need to be re-filled. Set them ON and check air pressure.		
		Energize intake and main plant VFDs, PLC.		
		Check alarms and display.		
		The first restart from intake needs to be in manual and ensuring communication with the main plant (Walky Talky)		
		Motors set up at 30hz, line needs to be slowly filled up with water. Let it go: Outfall.		
		If flush went smooth, switch back into auto and start sequence. Always keep eye on operations.		
	Caybay	Post Hurricane Operations		
	Intake	Confirm that GEBE inspected intake transformor.		
		Visual inspection of pipes, inside and outside building.		
		Slowly re-open suction and discharge valves, pending managerial approval.		
		Check for any leaks, vents and broke parts.		
	Main plant	Confirm that GEBE inspected main plant transformor.		
		Ensure no water went into the electrical rooms. If so inform supervisors.		
		Follow line and check for any broken pipes, equipement. Visual check.		
		Slowly re-open valves, pending managerial approval.		
		All valves should be set up in manual. Check vents.		
	Power back on	Always check for any burn, smoke, weird smell, any particular events		
		With GEBE (if possible), put on the main power on.		
		Set up all electrical panel ON, turn UPS ON.		
		Air compressor need to be re-filled. Set them ON and check air pressure.		
		Energize intake and main plant VFDs, PLC.		
		Check alarms and display.		
		The first restart from intake needs to be in manual and ensuring communication with the main plant (Walky Talky)		
		Motors set up at 30hz, line needs to be slowly filled up with water. Let it go: Outfall.		
		If flush went smooth, switch back in auto and start sequence. Always keep eye on operations.		

Appendix 6: The Hurricane Contingency Plan of the Water operations of N.V. G.E.B.E.

Hurricane Contingency Plan. Water Operations

Total grid shut down no later than 8pm

Hurricane Speed	15-25km/hr	0-15km/hr
	Hrs Prior to storm	
Lowlands Tank & Pumphouse		
Ensure that the tanks are almost full, atleast 90%	36	24
Open by-pass to feed directly to the customers	36	24
Close valves for downcommer lines from the tanks	36	24
Ensure that the tank is full	8	6
Stop pumps. Turn off main switch	8	6
Pelican Tank		
Open by-pass to feed directly to the customers	36	24
Close valves in the downcommer lines from the tank	36	24
Close valves on the filling lines from the tank	8	6
Pelican Pumphouse		
Ensure that the tank is full	8	6
Stop pumps. Turn off main switch	8	6
Close valve in the suction line to the pumps	8	6
Close valve in the discharge line of the pumps	8	6
Almond Grove Tank		
Close valves in the downcommer lines from the tank	36	24
Almond Grove Pumphouse		
Ensure that the tank is full	8	6
Stop pumps. Turn off main switch	8	6
Close valve in the suction line to the pumps	8	6
Close valve in the discharge line of the pumps	8	6
Almond Grove Small Pumphouse		
Stop pumps. Turn off main switch	8	6
Close valve in the suction line to the pumps	8	6
Close valve in the discharge line of the pumps	8	6
Cay Bay Tanks and Pumphouse		
Ensure that the tanks are full	36	24
Stop pumps. Turn off main switches	36	24
Close valves from the tanks to the pumps	8	6
Close valves in the equalizer line between the tanks	8	6
Close valves in the discharge lines of the pumps	8	6
Cay Hill Tanks and Pumphouse		
Cay Hill Tanks and Pumphouse		
Ensure that the tanks are almost full, atleast 90%	36	
Open by-pass to feed directly to the customers	36	
Close valves for downcommer lines from the tanks	36	
Close valves in the equalizer line between the tanks	8	6
Close valves in the filling line for the tanks	8	6
Stop pumps. Turn off main switch	8	6
Close valve from the tank to the pumps	8	6
Arnell Pumphouse (Old Cake House)		
Stop pumps. Turn off main switch	8	6
Close valve in the suction line to the pumps	8	6
Close valve in the discharge line of the pumps	8	6
Point Blanche Pumphouse		
Ensure that the tank are almost full, atleast 90%	8	6
Stop pumps. Turn off main switch	8	6
Close valve in the suction line to the pumps	8	6
Close valve in the discharge line of the pumps	8	6
Belair Pumphouse		
Stop pumps. Turn off main switch	8	6
Close valves in the suction lines to the pumps	8	6
Close valves in the discharge lines to the pumps	8	6
Monte Vista Tank		
Ensure that the tank are almost full, atleast 90%	36	24
Open by-pass to feed directly to the customers	36	24
Close valves for downcommer lines from the tanks	36	24
Close by-pass to feed directly to the customers	8	6
Close valves in the filling line for the tanks	8	6
Point Blanche Tanks and Pumphouse		
Ensure that the tanks are almost full, atleast 90%	36	
Open by-pass to feed directly to the customers	36	
Close valves for downcommer lines from the tanks	36	
Close by-pass to feed directly to the customers	8	6
Close valves in the filling line for the tanks	8	6
Stop pumps. Turn off main switch	8	6
Close valve from the tank to the pumps	8	6
Close valves in the discharge line from the pumps direction Monte Vista	8	6

	15-25km/hr	0-15km/hr
	Hrs Prior to storm	
FVPT Pumphouse		
Ensure that the Sth. Reward tank is full	8	6
Stop pumps. Turn off main switch	8	6
Close valves in the suction lines to the pumps	8	6
Close valves in the discharge lines from the pumps	8	6
Sth. Reward Tank and Pumphouse		
Ensure that the tanks are almost full, atleast 90%	36	24
Open by-pass to feed directly to the customers	36	24
Close valves for downcommer lines from the tanks	36	24
Close by-pass to feed directly to the customers	8	6
Close valves in the filling line for the tanks	8	6
Stop pumps. Turn off main switch	8	6
Close valve from the tank to the pumps	8	6
Concordia Tank and Pumphouse		
Ensure that the tanks are almost full, atleast 90%	36	24
Open by-pass to feed directly to the customers	36	24
Close valves for downcommer lines from the tanks	36	24
Close by-pass to feed directly to the customers	8	6
Close valves in the filling line for the tanks	8	6
DISMANTLE SMALL TANK	48	
Stop pumps. Turn off main switch	8	6
Close valve from the tank to the pumps	8	6
Prima Vista Pumphouse		
Stop pumps. Turn off main switch	8	6
Close valves in the suction lines to the pumps	8	6
Close valves in the discharge lines to the pumps	8	6
Mary's Fancy Pumphouse		
Stop pumps. Turn off main switch	8	6
Close valves in the suction lines to the pumps	8	6
Close valves in the discharge lines to the pumps	8	6
Madame Estate Pumphouse		
Ensure that the tanks are almost full, atleast 90%	8	6
Stop pumps. Turn off main switch	8	6
Close valves in the suction lines to the pumps	8	6
Close valves in the discharge lines to the pumps	8	6
Close valves in the suction lines to the pumps	8	6
Close valves in the discharge lines to the pumps	8	6
Mnt. Williams Hill Tank and Pumphouse		
Ensure that the tanks are almost full, atleast 90%	36	24
Open by-pass to feed directly to the customers	36	24
Close valves for downcommer lines from the tanks	36	24
Close by-pass to feed directly to the customers direction Dutch Quarter	8	6
Close valves in the filling line for the tanks	8	6
Stop pumps. Turn off main switch	8	6
Close valve from the tank to the pumps	8	6
Close valves in the discharge line from the pumps direction Middle Region	8	6
Claude Estate Tank and Pumphouse		
Ensure that the tanks are almost full, atleast 90%	36	24
Open by-pass to feed directly to the customers	36	24
Close valves for downcommer lines from the tanks	36	24
Close by-pass to feed directly to the customers	8	6
Close valves in the filling line for the tanks	8	6
Stop pumps. Turn off main switch	8	6
Close valve from the tank to the pumps	8	6
Close valves in the discharge line from the pumps direction Monte Vista	8	6
Guana Bay Tank		
Ensure that the tank are almost full, atleast 90%	36	24
Open by-pass to feed directly to the customers	36	24
Close valves for downcommer lines from the tanks	36	24
Close by-pass to feed directly to the customers	8	6
Close valves in the filling line for the tanks	8	6
Guana Bay Pumphouse		
Ensure that the tank are almost full, atleast 90%	8	6
Stop pumps. Turn off main switch	8	6
Close valve in the suction line to the pumps	8	6
Close valve in the discharge line of the pumps	8	6
Deher Pumphouse		
Stop pumps. Turn off main switch	8	6
Close valve in the suction line to the pumps	8	6
Close valve in the discharge line of the pumps	8	6
Ocean View Terraces Pumphouse		

Point Blanche Tanks and Pumphouse

☐ Ensure that the tanks are almost full, atleast 90%	**36**	
☐ Open by-pass to feed directly to the customers	**36**	
☐ Close valves for downcommer lines from the tanks	**36**	
☐ Close by-pass to feed directly to the customers	8	6
☐ Close valves in the filling line for the tanks	8	6
☐ Stop pumps. Turn off main switch	8	6
☐ Close valve from the tank to the pumps	8	6
☐ Close valves in the discharge line from the pumps direction Monte Vista	8	6

Jail Pumphouse

☐ Ensure that the tank are almost full, atleast 90%	8	6
☐ Stop pumps. Turn off main switch	8	6
☐ Close valve in the suction line to the pumps	8	6
☐ Close valve in the discharge line of the pumps	8	6

Jail Tank

☐ Ensure that the tank are almost full, atleast 90%	36	24
☐ Open by-pass to feed directly to the customers	36	24
☐ Close valves for downcommer lines from the tanks	36	24
☐ Close by-pass to feed directly to the customers	8	6
☐ Close valves in the filling line for the tanks	8	6

☐ Close valve in the suction line to the pumps	8	6
☐ Close valve in the discharge line of the pumps	8	6

Deher Pumphouse

☐ Stop pumps. Turn off main switch	8	6
☐ Close valve in the suction line to the pumps	8	6
☐ Close valve in the discharge line of the pumps	8	6

Ocean View Terraces Pumphouse

☐ Stop pumps. Turn off main switch	8	6
☐ Close valves in the suction lines to the pumps	8	6
☐ Close valves in the discharge lines to the pumps	8	6

Steward Estate Pumphouse

☐ Stop pumps. Turn off main switch	8	6
☐ Close valves in the suction lines to the pumps	8	6
☐ Close valves in the discharge lines to the pumps	8	6

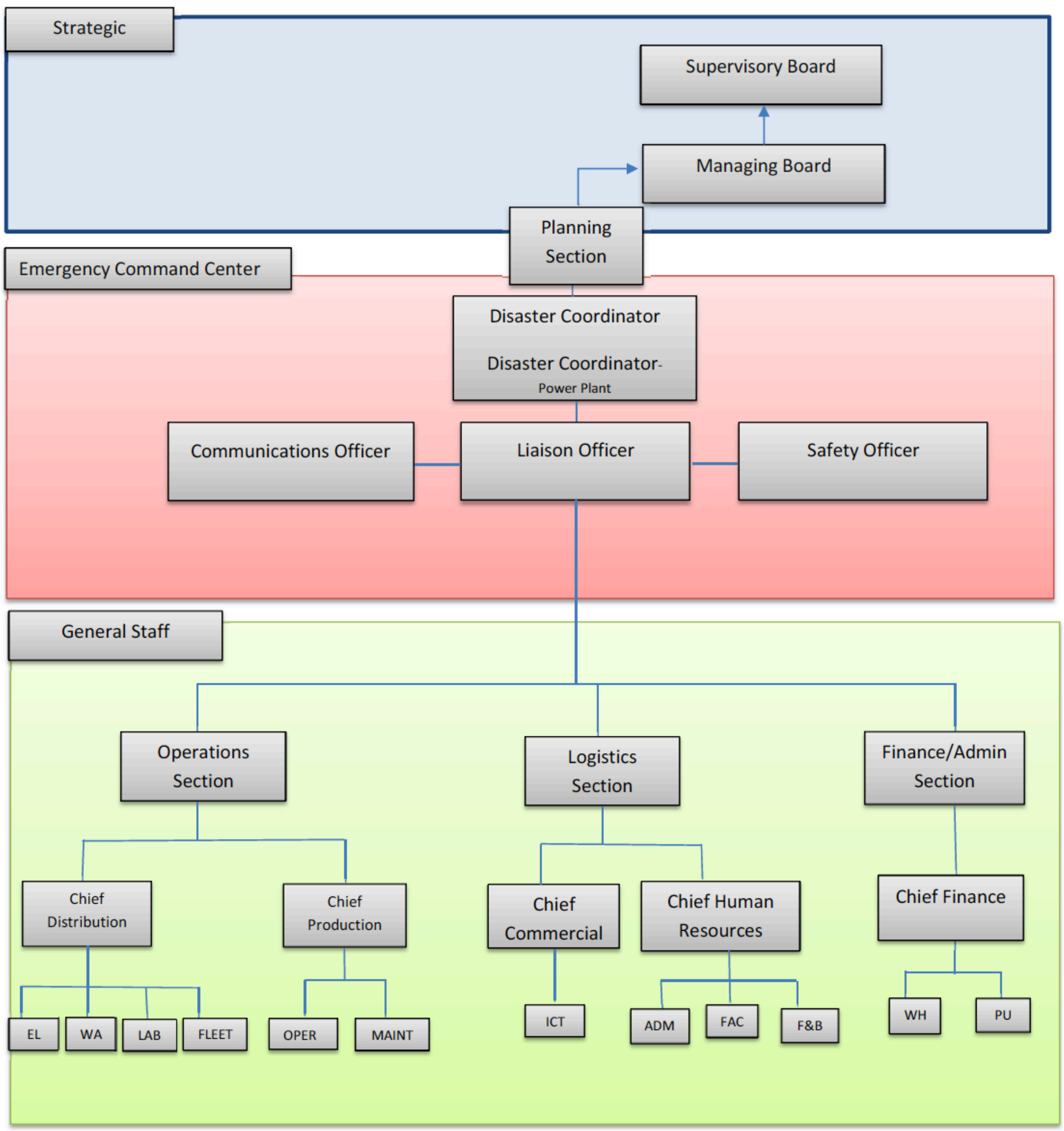
Rice Hill Pumphouse

☐ Stop pumps. Turn off main switch	8	6
☐ Close valves in the suction lines to the pumps	8	6
☐ Close valves in the discharge lines to the pumps	8	6

Appendix 7: Extracts from the N.V. G.E.B.E. Hurricane Continuity Plan

N. V. GEMEENSCHAPPELIJK ELECTRICITEITSBEDRIJF BOVENWINDSE EILANDEN *The Power to Serve*

1. Organizational Chart



N. V. GEMEENSCHAPPELIJK ELECTRICITEITSBEDRIJF BOVENWINDSE EILANDEN *The Power to Serve*

2. Organizational Chart Operating Procedures

The following outlines the modus operandi that will occur in the event of a hurricane.

- The first section is the Planning Section; this section involves the preparatory efforts such as deciding the roles of members of the organization in the hurricane contingency plan and agreeing upon the contingency plans in an emergency situation.
- The heads of Operations, Logistics and Finance and Admin section must be decided with consideration on which employee can contemplate and consider the needs for the general staff that falls with their purview.
- In the event of a hurricane the command of the organization falls under the Emergency Command Center. The Disaster Coordinators makes the decisions for the whole organization with the knowledge received from the Operations, Logistics and Finance and Admin Sections.
- The Chiefs of each department must relay the information to the head of the above-mentioned sections so therefore an employee must be chosen as the head of the above-mentioned sections.
- The first stage of deployment in the event of a hurricane is the Operations Section, the employees of this section will be expected to have an action plan in place which outlines what is the team and what will the team roles and functions. This section is expected to report to the command center as soon as feasibly possible.
- The second stage of deployment is the Logistics Section this section is a facilitator for the Operations section and the Planning section. This section is expected to report to the command center within 2 days of a natural disaster.
- The last stage of deployment is the Finance/Admin section this section is the facilitator for funds for all the above- mentioned sections. This stage will work together with all the stages to facilitate the resources needed to restore the services N.V GEBE requires
- In the event of a worker being unable to respond to labor within the passing of a hurricane it must be communicated thusly.
- Each section is expected to follow the **Communications Pathways** probability matrix to ensure information is sent and received in a cohesive manner.
- Lastly business continuity is important after a disaster the **management board** has to declare when the company is operating in **emergency phase** and they also declare when the company is returning to **normality**.

N. V. GEMEENSCHAPPELIJK ELECTRICITEITSBEDRIJF BOVENWINDSE EILANDEN *The Power to Serve*

4. Risk Matrixes based on Hurricane Categories

Storm Information	Sustained winds	Damage Expected	Color Level
Category 1 hurricane	74-95 mph	Dangerous winds that will produce damage to roofs with shingles, vinyl and gutter. Trees with large branches may snap and shallow trees be uprooted. Damage to power lines are expected that will result in power outages with expected date or restoration around a few days. Storm surge: 4 to 5 feet above normal, flooding expected at low lying roads.	Yellow level
Category 2 hurricane	96-110 mph	Very dangerous winds that will cause widespread damage. Damage to roofs and sidings on houses. Many large trees will be broken and many shallow rooted trees will be uprooted. Larger total power loss is expected which may take several days to restore. Storm surge: 6 to 8 feet above normal, flooding expected at low lying roads and coastal areas.	Yellow level

N. V. GEMEENSCHAPPELIJK ELECTRICITEITSBEDRIJF BOVENWINDSE EILANDEN *The Power to Serve*

Storm Information	Sustained Winds	Damage Expected	Color Level
Category 3 hurricane	111-129 mph	Devastating damage will occur. Homes will experience major damage to roofing and sidings. Many trees will experience snapping and uprooting blocking many roadways. Electricity and water will be affected and may be unavailable for several days to weeks. Storm surge: 9 to 12 feet above normal. Serious flooding near coast lines and low-lying areas.	Orange level
Category 4 hurricane	130-156 mph	Catastrophic damage to well-constructed homes with the loss of the roof structure, windows and doors. Most trees will be uprooted and spanned. Fallen trees will affect roadways. Water loss and Power outages due to downed poles will take weeks to repair. Storm surges: higher than 18 feet, massive flooding to coastal areas and low-lying areas.	Red level
Category 5 hurricane	Winds greater 157	Catastrophic damage will occur, a high number of homes will be damaged due to roof, window, door and walls collapse. Trees and poles will block roadways. Outages will last for weeks to possibly months. Loss of life expected. Storm surges will greater than 18 feet above normal with major flooding to coastal areas and low-lying homes.	Red level

Alert categories based on colors

Red level - Extreme (full emergency conditions) – The weather conditions are considered as extreme and precautions must be taken as there is a large threat and complete shutdown to daily functions of the company.

Orange level - severe (significant emergency conditions) - The weather conditions are considered as severe and precautions must be taken as there is a significant threat and partial shutdown to daily functions of the company.

Yellow level – moderate (active emergency conditions) – The weather conditions are considered as moderate with a slight threat to daily functions of the company.

Green level – Normal (daily operations) – The weather conditions are considered as normal with no threats to daily functions of the company.

5. Phase I – V

Explanation

Phase I (Awareness)	**Phase II (Preparedness)**	**Phase III (Response)**	**Phase IV (Recovery)**	**Phase V (Mitigation)**
Effective when before the hurricane season officially begins. This phase will involve evacuation plans, roles of workers environmental standards, and design standards.	Effective when there is a notification of a tropical storm/hurricane being formed and with an expect impact being near or on St. Maarten. This phase involves the execution of plans which then provides the ability to respond to any incidents that will occur during the disaster.	Effective when a hurricane is within 24 hours of expected impact on St. Maarten. This phase involves early preparedness such as inventory of food, water, equipment and first aid. This stage is where the organizational chart on page 3 comes into effect.	Effective immediately after the passing of a hurricane. When the threat to human life has subsided, this phase begins and it involves the activities to restore the critical components of and organization so that it can resume functions	Effective after phase IV has ended, this phase is used to put effort into procedures, policies and infrastructures that were missing in phase I that may have lessened the impact of the disaster.

Continuity – This is the stage where the discussion on whether normal daily operations can continue. This discussion involves all the Chiefs of Departments, the members of Emergency Command Center and Managing and Supervisory Board and is a democratic decision

-Chief Distribution

Alert Categories Yellow to Orange

Phase I (Awareness)	**Phase II** (Preparedness)	**Phase III** (Response)	**Phase IV** (Recovery)	**Phase V** (Mitigation)
-Secure inventory needed in advance. – Create a distribution action plan with roles defined and teams. -Communication with supporting contractors. -(see appendix for **pre-assessment** and **post assessment** forms) -Completion of Material List **mandatory** per department and to be handed into Planning Section. - **Initial section meetings expected in this stage.**	Evaluate the electrical grid and determine the high-risk locations and allocate response workers from the action plan to these regions. For this alert category expected shut down time at 12-24 hours within impact based off of organizational and governmental recommendations for safety.	Response teams are deployed, must then perform assessments and expected to return to command center so plan is relayed as such to the Liaison officer and PR officer to the public.	-Salvage re-usable items. -Perform basic housekeeping on locations such as transformers/pump houses. -Restoration begins taking into account safety and security during execution. -This is adjusted to severity of the hurricane.	-Ensure vehicles and equipment are stored safely for use. I.e. See storage security before a hurricane hit. -This account is based off of lessons learned. **-Conclusive section meetings expected in this stage.**

Refer to Page 8

Alert category Red

Phase I (Awareness)	**Phase II** (Preparedness)	**Phase III** (Response)	**Phase IV** (Recovery)	**Phase V** (Mitigation)
Inventory checks must be done, be prepared with the stock inventory of fast moving supplies. – Create a distribution action plan with roles defined and teams. -Communication with supporting contractors. -(see appendix for **pre-assessment** and **post assessment** forms) -Completion of Material List **mandatory** per department and to be handed into Planning Section. - **Initial section meetings expected in this stage.**	Evaluate the electrical grid and determine the high- risk locations and allocate workers to these regions. For this alert category expected shut down time at 24-36 hours within impact based off of organizational and governmental recommendations for safety.	Response teams are deployed, must then perform assessments and expected to return to command center so plan is relayed as such to the Liaison officer and PR officer to the public.	-Expect significant damage -Salvage re-usable items. -Perform basic housekeeping on locations such as transformers/pump houses. -Restoration begins taking into account safety and security during execution. -This is adjusted to severity of the hurricane.	Ensure vehicles and equipment are stored safely for use. I.e. See storage security before a hurricane impact. This account is based off of lessons learned. **-Conclusive section meetings expected in this stage.**

Refer to Page 8

Appendix 8: Interview question and summarized answers from the Disaster Preparedness Coordination of NV GEBE

Disaster Preparedness Coordinator: Mr. Patrick Drijvers
Date: Tuesday, April 13th, 2021

1. Was there a continuity and contingency plan before this one from 2018 was made? or was it revised?
   Yes, there was a continuity and contingency plan before, and it was totally revamped in 2018.

2. If it was revised, what prompted the revision?
   It was revamped because there was lack of execution points and reporting strategies.

3. Was there a disaster preparedness coordinator for the passing of Hurricane Irma?
   Yes, back then it was the distribution manager of that time.

4. Based on experience, is the continuity plan followed in its entirety?
   It will once it is put to the test. Luckily, we have not gotten that opportunity to exercise the plan in real life.

5. What could be a reason if the plan is not followed, or parts of the plan is not followed?
   It could be that the disaster is not as devastating to where we don't have to deploy much the plan etc. or it could be that the national decree supersedes.
6.
7. Are there any organized drills that practice the continuity or contingency plan?
   Yes, annually the Fire department of St. Maarten organizes a HUREX simulation to practice the relations between the Emergency Support Function (ESF) groups.

8. Were there any risk analyses done on the assets of the water distribution system to investigate possible threats to the system when it comes to hurricanes?
   Yes, that is why by every tank location there is a by-pass system in place to be able to pump directly to the consumers. The risk analysis was based on technical meetings with the management team. It was concluded that the system should have a built-in bypass system in place therefore if something were to go happen to the tanks, the system can still work and provide directly to consumers. There was no actual written risk analysis report.

9. A safety measure to ensure that the tanks are not destroyed during a hurricane is to keep them full. What happened to the tanks for the passing of Hurricane Irma that caused them to get damaged?
   For Hurricane Irma, there was a WhatsApp recording that went viral stating that everyone who has a cistern should fill them rapidly because N.V. G.E.B.E. was going to be shutting off the water 24 hours before the storm arrives. This was not the case. This resulted in the tanks being drained while they N.V. G.E.B.E. was busy filling them.

10. What additional damages did the water distribution system take on besides the tanks?
    Yes, we experienced damages to manifolds, goosenecks, water meters (the composite ones), and doors of pump stations.

11. Were there extra measures that should have taken place before Irma now looking in hindsight?
    Yes, the manifolds and goosenecks are now installed/fixed on the meter walls. Tanks have been structurally upgraded to withstand 200mph winds, and pumpstations are closed off to the outside.

12. Can you briefly explain what the situation of NV GEBE was directly after Hurricane Irma?
    In one word I would say that it was just “Devastated”. The system went from having 15 working tanks to a total of 9 tanks being destroyed. We had to distribute water with water tanks to areas in need.

13. What adaptation/mitigation measures took place during the recovery phase and to this day to make the system more robust?
    See answer to number 11.

14. What was done directly after Hurricane Irma in terms of providing water to consumers?
    We used water trucks to supply water to the consumers. We also installed some tap points at specific locations within a district which were later removed.

15. How did the distribution department start its repairs to the water distribution system?
    Based on the pre-assessment phase, a plan was made and forwarded on to the execution teams who went out to repair the damages caused by hurricane Irma.

16. From the lessons learned log from 2017 in the continuity plan, what setbacks came along when each situation arose in the moment?
    Communication was the biggest setback. Internally as well as externally. This was due to the tele communication companies also experiencing their own difficulties with the recovery process of their system.

Appendix 9: Table 1.1 from the book, Climate Resilient Urban Areas.

(de Graaf-van Dinther & Ovink, 2021)

Table 1.1 Examples of water management measures to strengthen the five capacities of urban climate resilience

Threshold capacity	
Dikes	Water reservoirs
Flood barriers	Water supply networks
Coping capacity	
Emergency plans	Temporary flood barriers
Forecasting and timely warning of extreme weather events	Flood-proof building materials Increasing risk awareness
Evacuation plans	Providing emergency shelter
First aid capacity	Neighbourhood assistance networks
Backup water supply and other utilities	Connections with other river basins
Flood-proof critical infrastructure	
Recovery capacity	
Recovery plans	Disaster funds
Rehabilitation schemes	Flood-relief organisations
Equipment and spare parts available	Coordinated plans for interregional and international support
Insurance schemes	
Adaptive capacity	
Developing innovation niches and transition experiments	Developing a portfolio of water resources including local sources
Experimenting with flood-proof modes of urbanisation, e.g. floating urban development	Building with nature Room for the river Integrating flood management and spatial planning
Flexible and reversible flood-control infrastructure	
Transformative capacity	
Proactive inclusive planning and design with all stakeholders	Build potential for replication, improvement, upscaling, and mainstreaming of innovation projects
Strengthen local capacity for planning, execution, and maintenance	From single projects to consistent continuous innovation processes
Invest in enabling environment for comprehensive climate resilience strategy and implementation	Strategically link water issues to urban dynamics
Transdisciplinary process, dissolving sectoral, and disciplinary boundaries	Look for synergies between urban development and ecological restoration
Create coalitions of local and global stakeholders in inclusive learning environment	Leapfrogging phases in the development of water cities Regenerative urban developments
Build trust and safe environments, soft spaces	Develop the narrative to aspire and inspire and drive decisions/decision makers