UNIVERSIDAD PARA LA COOPERACION INTERNACIONAL
(UCI)

PROJECT MANAGEMENT PLAN FOR IMPLEMENTING A SEAWATER FILTRATION SYSTEM IN BELIZE COAST GUARD FORWARD OPERATING BASES

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DEDICATION

To my mom, a single parent, who tirelessly invested in my siblings' and my education from the very beginning, instilling in us the values of perseverance and faith.

To my brothers and sisters, Madelinn, Dr. Alvin, Josue, and Jessica; thank you for your constant encouragement and your belief in me.

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"Trust in the LORD with all thine heart; and lean not unto thine own understanding. In all thy ways acknowledge him, and he shall direct thy paths."

— Proverbs 3:5-6

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ABSTRACT

The project management plan for implementing a seawater filtration system at the Belize Coast Guard Forward Operating Bases (FOBs) is a crucial response to the pressing need for a reliable and sustainable potable water supply. The Belize Coast Guard is currently grappling with significant challenges in ensuring water availability at its remote bases, a situation that directly impacts the personnel's health, morale, and operational readiness. Traditional water supply methods, such as external procurement and rainwater harvesting, have proven unsustainable, especially during adverse conditions.

This project aims to introduce a state-of-the-art desalination system that utilizes reverse osmosis technology to convert seawater into potable water. The study is made up of the final deliverables which comprise the following management plans: scope, schedule, cost, quality, stakeholder, communications, risk, project monitoring and control. The methodology used in this project involves a combination of analytical, descriptive, and experimental approaches. Analytical methods evaluate different filtration technologies, while descriptive methods involve gathering data through surveys and interviews with Coast Guard personnel. Experimental methods are used to pilot test the selected technology to ensure its suitability for the specific conditions at the FOBs.

The implementation of the seawater filtration system is expected to significantly enhance the operational efficiency of the Belize Coast Guard by providing a reliable and sustainable water supply. This will not only lead to long-term cost savings but also improve personnel welfare and align with environmental sustainability goals. The project also serves

as a model for other similar initiatives in the region, demonstrating the feasibility and benefits of advanced desalination technologies in remote and resource-constrained environments.

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ABBREVIATIONS AND ACRONYMS

BCG - Belize Coast Guard

BWSL - Belize Water Services Limited

CSOG - Coast Guard Special Operations Group

FGP - Final Graduation Project

FO - Forward Osmosis

FOBs - Forward Operating Bases

KPIs - Key Performance Indicators

MOU - Memorandum of Understanding

MPM - Master's in Project Management

PMBOK - Project Management Body of Knowledge

PMI - Project Management Institute

PMP- Project Management Plan

RBS- Risk Breakdown Structure

RO - Reverse Osmosis

SAR - Search and Rescue

SDGs - Sustainable Development Goals

SOP - Standard Operating Procedure

UCI - Universidad para la Cooperación Internacional

UF – Ultrafiltration

WBS – Work Breakdown Structure

EXECUTIVE SUMMARY

The Belize Coast Guard has been facing ongoing challenges in providing a reliable drinking water supply at its forward operating bases (FOBs), which is crucial for their operations in remote areas. Traditional methods of sourcing water, such as purchasing from external sources or relying on rainwater collection, have proven insufficient, particularly in

unfavorable weather conditions and logistical constraints. These difficulties have significantly affected the well-being, motivation, and readiness of the personnel stationed at these bases, compromising the Coast Guard's mission to safeguard Belize's maritime territories.

The Project Management Plan for implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases was developed to address critical issues. The project aimed to introduce a sustainable solution by utilizing advanced desalination technologies, such as reverse osmosis, to convert seawater into potable water. This initiative aligns with the Coast Guard's broader strategic objectives, including enhancing operational efficiency, reducing logistical dependencies, and promoting environmental sustainability.

The general objective of the project was to develop a comprehensive project management plan for the implementation of a sustainable seawater filtration system at the Belize Coast Guard Forward Operating Bases. The specific objectives were: to conduct a comprehensive assessment of existing seawater filtration technologies and systems; to implement initiation processes, including the development of the project charter and identification of key stakeholders; to elaborate and develop the project management plan, including the creation of subsidiary management plans; to select tools and techniques and define procedures for project execution; to evaluate the cost-effectiveness, energy efficiency, and ease of maintenance of the proposed system; to establish a project monitoring and control system; and to define a project closure procedure that includes the final evaluation of objectives, lessons learned, and product transfer to operations management.

The methodology used in this project involved a combination of analytical, descriptive, and experimental methods. The analytical method was employed to evaluate the efficiency and effectiveness of various seawater filtration technologies. The descriptive method involved conducting surveys and interviews with Coast Guard personnel to gather detailed information about the existing water supply challenges and the specific needs of the forward operating bases. The experimental method, crucial for our reassurance, included pilot testing of the selected filtration technology to validate its effectiveness and suitability for the conditions at the FOBs.

1 INTRODUCTION

Implementing a seawater filtration system at the Belize Coast Guard forward operating bases (FOBs) is an essential initiative that aligns with the strategic mission of safeguarding Belize's maritime domains. The Belize Coast Guard plays a critical role in ensuring the safety, security, and sovereignty of Belize's waters, which requires not only vigilant personnel but also the necessary infrastructure to support their operations ("Belize Constitution Chapter 4," 2021). One of the fundamental challenges faced by the Coast Guard is the need for a sustainable and reliable potable water supply at these remote operating bases. This challenge is particularly acute given the strategic locations of these bases, often far removed from conventional water supply networks.

The need for a consistent potable water supply is not merely a logistical concern; it is a critical factor that directly impacts the health, morale, and operational readiness of the personnel stationed at these FOBs. Without reliable access to clean drinking water, the effectiveness of the Coast Guard's operations is compromised, particularly in scenarios that require prolonged deployment in remote locations. The traditional methods of water supply, which include external procurement and rainwater harvesting, are not only unsustainable but also prone to disruption, especially during adverse weather conditions or in the face of logistical constraints (Amiad et al.; Berniak-Woźny & Rataj, 2023).

This project management plan proposes developing and implementing a seawater filtration system as a sustainable solution to address these challenges. The proposed system will utilize state-of-the-art desalination technologies, such as reverse osmosis, to convert seawater into potable water, ensuring a steady and reliable water supply at the FOBs. By adopting this approach, the Belize Coast Guard will enhance its operational capabilities and align with broader environmental sustainability goals, as the system reduces dependency on freshwater resources and minimizes the logistical burden associated with water transportation (Chibani, 2023).

The seawater filtration project will deliver long-term cost savings and operational efficiencies. The initial capital investment in desalination technology will be offset by decreased water acquisition, transportation, and storage expenses. The enhanced reliability of the water supply will contribute to the overall welfare of the personnel, improving their ability to perform their duties effectively and maintaining high morale (Li & Wu, 2024).

1.1. Background

The Belize Coast Guard, established in 2005, operates under the Ministry of National Defence and Border Security. Its primary responsibilities include maritime security, law enforcement, and search and rescue operations within Belize's territorial waters. The Coast Guard is crucial in safeguarding the nation's maritime interests, requiring personnel stationed at forward operating bases in remote locations (Government of Belize, 2020). However, these bases need help maintaining a reliable potable water supply.

Historically, the Coast Guard has relied on external water procurement, rainwater harvesting, and non-potable seawater for operational needs (Huang et al., 2022). While functional, these methods are not sustainable, particularly during dry seasons or emergencies when resupply may experience a delay. The lack of a dependable water source not only affects the health and morale of the personnel but also limits the Coast Guard's operational effectiveness (Li & Wu, 2024).

In response to these challenges, this project proposes installing a seawater filtration system at the forward operating bases. This system will utilize advanced desalination technologies to convert seawater into potable water, providing a consistent and sustainable supply that supports the Coast Guard's mission (Chibani, 2023). The project aligns with the Coast Guard's broader goals of enhancing operational efficiency, reducing logistical dependencies, and promoting environmental sustainability (Ministry of Water and Irrigation, 2022).

1.2. Statement of the problem

The Belize Coast Guard forward operating bases are currently underserved in terms of reliable potable water supply, a situation that significantly hampers the effectiveness of their operations. The existing methods of water supply, including external procurement and rainwater harvesting, are not sustainable and fail to meet the demands of the personnel stationed at these bases (Amiad Water Systems, n.d.). The lack of a dependable water source has led to severe operational inefficiencies, health risks, and increased logistical burdens (Cowo, 2024).

A reliable water supply system is necessary for the Coast Guard's ability to maintain a constant state of readiness, particularly in remote areas where resupply is challenging. This situation worsens during the dry season when natural water sources are scarce, and the reliance on external suppliers becomes more pronounced (Huang et al., 2022). The current methods of water procurement are costly and logistically complex, diverting resources that could be better utilized in operational activities (Li & Wu, 2024).

This project seeks to address these issues by implementing a seawater filtration system to provide a consistent and reliable source of potable water to the forward operating bases. The proposed system will not only enhance the health and well-being of the personnel, but it will also improve the Coast Guard's operational capabilities by reducing its dependency on external water sources and streamlining logistical operations (Berniak-Woźny & Rataj, 2023).

1.3. Purpose

Implementing a seawater filtration system at the Belize Coast Guard Forward Operating Bases (FOBs) ensures a reliable and sustainable potable water supply. Currently, the bases depend on limited freshwater resources, which are at risk of contamination and scarcity, especially during the dry season. This situation compromises the operational readiness and health of the stationed personnel, thereby undermining the Belize Coast Guard's overall mission.

This project aims to explore and implement state-of-the-art seawater desalination technologies to provide a consistent and sustainable potable water supply. The study will assess the most efficient and cost-effective desalination methods, such as reverse osmosis, which have been proven to achieve energy efficiencies as low as 2.27 kWh per cubic meter of treated water (Chibani, 2023). By integrating these technologies, the project seeks to mitigate the risks associated with freshwater scarcity and contamination, enhancing the operational capabilities and welfare of Coast Guard personnel.

Implementing this seawater filtration system is expected to yield several significant benefits. It will significantly reduce operational costs related to water procurement and transportation. Currently, transporting fresh water to remote bases is both costly and resource intensive. In contrast, desalination offers a more sustainable and cost-effective solution, with the potential for long-term savings as the energy efficiency of modern reverse osmosis plants continues to improve (Li & Wu, 2024).

The project aligns with broader environmental and sustainability goals. As climate change exacerbates the scarcity of freshwater resources, the need for alternative water sources becomes increasingly critical. By utilizing the vast and inexhaustible supply of seawater, desalination provides a viable solution to this challenge. By reducing the Belize Coast Guard's dependency on limited freshwater resources, the project ensures water security for the FOBs and contributes to the preservation of critical ecosystems. This is particularly important in the context of Belize's commitment to environmental conservation and sustainable resource management (Berniak-Woźny & Rataj, 2023).

This initiative sets a precedent for sustainable water management practices in the region. The successful implementation of a seawater filtration system at the Belize Coast Guard's FOBs can serve as a model for other institutions and communities facing similar challenges. It demonstrates the feasibility and benefits of adopting advanced desalination technologies, encouraging wider adoption and contributing to regional water security.

1.4. General objective

To develop a comprehensive project management plan for implementing a sustainable seawater filtration system at the Belize Coast Guard Forward Operating Bases. This plan aims to ensure a reliable supply of potable water, enhance operational efficiency, and improve personnel welfare

1.5. Specific objectives

1. Conduct a comprehensive assessment of existing seawater filtration technologies and systems for the Belize Coast Guard Forward Operating Bases.
2. Implement initiation processes, including developing the project charter and identifying key stakeholders to establish a high-level project structure for the seawater filtration system.
3. Elaborate and develop the project management plan, including the creation of subsidiary management plans for scope, schedule, costs, resources, quality, communications, risks, acquisitions, and stakeholders, to define the project baselines for the seawater filtration system.
4. Select tools and techniques and define procedures for the execution of the seawater filtration system project.
5. Evaluate the cost-effectiveness, energy efficiency, and ease of maintenance of the proposed seawater filtration system from a conceptual and theoretical point of view, applying research to develop a well-defined case study.
6. Establish a project monitoring and control system through tools and techniques to ensure the effective integration of project objectives and goals.

7. Define a project closure procedure that includes the final evaluation of objectives and goals achievement, lessons learned reporting, and product transfer to operations management.

2 THEORETICAL FRAMEWORK

2.1 Company/Enterprise framework

2.1.1 Company/Enterprise background

The Belize Coast Guard (BCG) was established on November 28, 2005, and operates under the Ministry of National Defence and Border Security. Initially formed with assistance from the United States Coast Guard, the BCG was created to provide a dedicated maritime security force with law enforcement powers at sea. Its primary responsibilities include maritime security, search and rescue operations, and law enforcement within Belize's territorial waters. The BCG plays a crucial role in ensuring maritime safety, security, conservation, and sovereignty over Belize's waters.

Rear Admiral Elton Bennett currently leads the Belize Coast Guard. Under his leadership, the BCG has expanded its personnel and fleet, enhancing its capabilities to ensure effective maritime security and law enforcement. Rear Admiral Bennett's tenure has seen a focus on collaboration with other agencies to bolster maritime security efforts.

As of November 2019, the Belize Coast Guard had approximately 600 personnel, referred to as "guardsmen." The BCG continues to grow, with recent recruitments and promotions aimed at enhancing its operational capabilities. The BCG's personnel receive training and education through strong international partnerships with countries such as the United States, Mexico, the United Kingdom, Canada, Guyana, Jamaica and Taiwan.

2.1.2 Mission and Vision Statements

Belize Coast Guard Mission and vision statements:

Mission: To protect Belize Maritime spaces from threats, both foreign and domestic, by providing maritime safety, security and protection of our people, industries and natural resources through military law enforcement and humanitarian operations.

Vision: To create an apex institution highly professional, motivated, trained and resourced, capable of enforcing maritime laws and projecting sea power to the limits of our sea spaces and supporting maritime operations locally and regionally.

The Final Graduation Project (FGP), "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" directly aligns with the mission and vision of the Belize Coast Guard.

Mission Alignment:

1. **Maritime Safety and Security**: The implementation of a seawater filtration system ensures a reliable and sustainable supply of potable water at the forward operating bases. This is crucial for maintaining the health and operational readiness of the personnel, thereby directly contributing to maritime safety and security.

2. **Law Enforcement and Protection**: By ensuring that the Coast Guard personnel have access to clean and safe drinking water, the project supports their ability to perform law enforcement and protection duties more effectively. Healthy personnel are essential for robust law enforcement operations.
3. **Support to National Security Objectives**: A reliable water supply system enhances the overall operational efficiency of the Coast Guard, enabling them to better support national security objectives. This project ensures that the bases remain operationally effective, even in remote locations.

Vision Alignment:

1. **Professional and Capable Maritime Force**: The project contributes to the vision of transforming the BCG into a professional and capable maritime force. By implementing advanced and sustainable technologies, BCG demonstrates its commitment to modernizing its infrastructure and capabilities.
2. **Ensuring Safety, Security, and Sovereignty**: The seawater filtration system project ensures that the BCG can operate effectively in safeguarding Belize's maritime domain. Reliable access to potable water is a fundamental requirement for maintaining the operational integrity of the bases, which in turn supports the broader goals of safety, security, and sovereignty.

Impact on the Belize Coast Guard

The successful implementation of the seawater filtration system will have several positive impacts on the Belize Coast Guard:

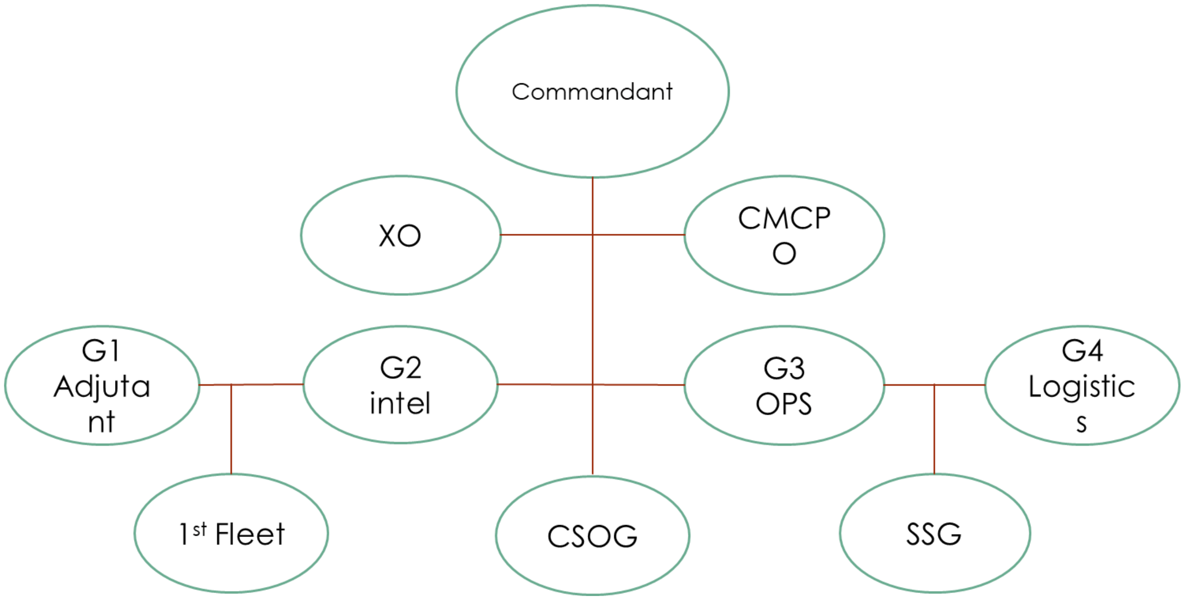
1. **Operational Efficiency:** With a sustainable and reliable water supply, the forward operating bases will be more self-sufficient, reducing the need for water transportation and associated logistical challenges.
2. **Personnel Welfare:** Access to clean drinking water is critical for the health and well-being of the Coast Guard personnel. Improved living conditions will boost morale and productivity.
3. **Cost-Effectiveness:** By reducing dependency on external water sources, the project can lead to significant cost savings over time. The energy-efficient desalination technology can provide a cost-effective solution compared to transporting fresh water.
4. **Sustainability:** The project aligns with broader environmental and sustainability goals. Utilizing seawater for potable water reduces pressure on freshwater resources, contributing to environmental conservation efforts.
5. **Strategic Capability:** Enhanced infrastructure at the forward operating bases strengthens BCG's strategic capability to respond to maritime incidents and enforce laws effectively.

2.1.3 Organizational structure

The Belize Coast Guard is structured to support its wide range of operations. The headquarters is located on the outskirts of Belize City, which also houses storage, maintenance facilities for its fleet and allows for efficient coordination and administration of operations.

Figure 1

Belize Coast Guard Headquarters Structure



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Roles and responsibilities of Staff Officers:

1. **Commandant:**

   The Job Description for the Commandant is laid out in the Coast Guard ACT Part III Section 5, Subsection 2.

2. **Vice Commandant (XO):**

a. Deputize for the Commandant

b. Supervise and coordinate the efforts of the Staff Officers

c. Ensuring that the Commandant is aware of matters affecting Command

d. Ensuring that information flows between the Staff recommendations and the Commandants Decisions

e. Establishing timelines

f. Enforcing SOP's (Standing Order Procedures)

g. Ensuring that the Commandants Directive is executed

h. Overseas Course

3. Command Master Chief Petty Officer (MCPO)

Day to day Administration of the Coast Guard enlisted, particularly the following:

i. Availability ii. Discipline iii. Leave iv. Dress

v. Manpower Allocation

vi. Documentation vii.

Medical Arrangements

B. Supervise the Headquarters Orderly Room

4. **G1- Adjutant**

Assist the Commandant in personnel administration of the Coast Guard, namely manning and arrangements for the efficient employment, discipline and wellbeing of the sailor as an individual.

5. **G2 – Intelligence Officer**

The role of the Intelligence Staff Officer is to Provide the Commandant with the intelligence required to plan and conduct Operations.

6. **G3- Operations Officer**

The Operations Staff Officer assist the Commandant to plan, direct, supervise, coordinate Operations and Training.

7. **G4- Logistics Officer**

The role of the Logistic Staff Officer is to assist the Commandant by arranging the Logistical aspects of combat service support i.e. supply, maintenance, transportation and administrative movement.

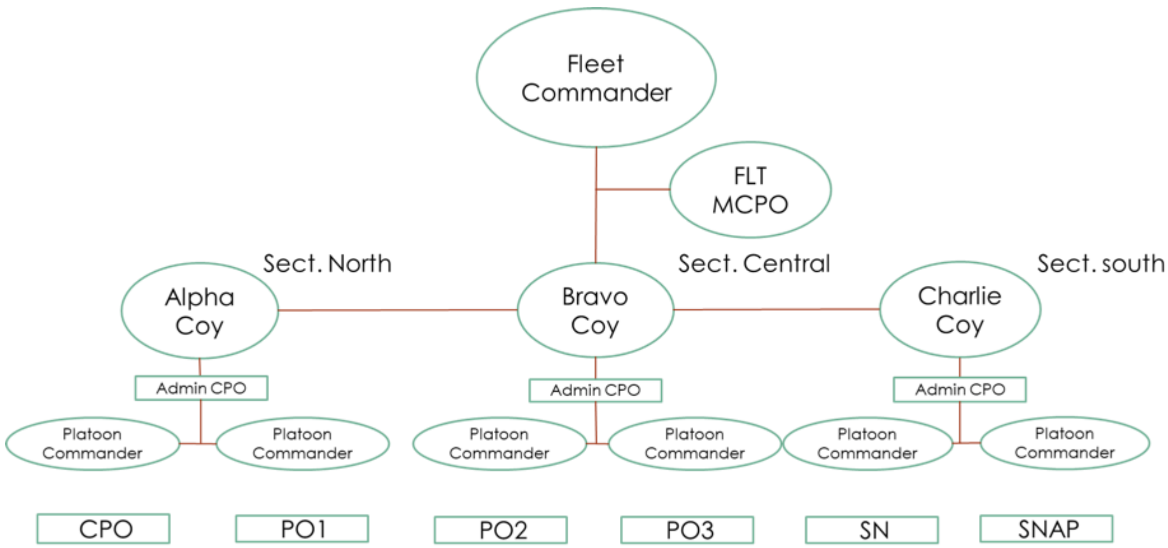
The organizational structure includes several key components:

1. **First Fleet Command:** Divided into northern, central, and southern sectors, each sector comprises three 30-man platoons responsible for various operations. These sectors operate multiple forward operating bases, including six coastguard stations and seven joint facilities with other agencies such as the Belize Defence Force, the Belize Fisheries Department, and other governmental and non-governmental organizations.
2. **Service and Support Group:** This group includes a training company, which manages recruitment training, stores, and equipment supplies, as well as the maintenance component of the BCG.
3. **Strike Team and CSOG:** The Strike Team, a special operations unit specializing in maritime interdiction and counter-narcotics missions, is slated for amalgamation

into the Coast Guard Special Operations Group (CSOG). The CSOG was established to address security issues in northern Ambergris Caye and has since expanded its operations.

Figure 2

Belize Coast Guard 1st Fleet structure



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First Fleet Command:

The First Fleet Command is a vital operational component within BCG.

Its primary role is to coordinate and oversee fleet operations across Belize's maritime territory. The command ensures that vessels are strategically deployed, missions are executed effectively, and resources are optimized.

1. **Geographical Divisions:**

The fleet command is divided into three sectors:

Northern Sector: Covers the northern coastal areas of Belize.

Central Sector: Oversees operations in the central part of the country.

Southern Sector: Manages the southern coastal regions.

Each sector comprises three 30-man platoons, which work together to achieve the BCG's. objectives.

2. **Operational Responsibilities:**

The fleet is actively involved in several critical tasks:

Coastal Patrol: Regularly patrolling Belize's coastline to monitor for any suspicious or illegal activities.

3. **Marine Border Protection:** Ensuring the integrity of Belize's maritime borders by intercepting unauthorized vessels.

Search and Rescue: Responding swiftly to distress calls and conducting rescue operations at sea.

2.1.4 Products offered

The Belize Coast Guard offers a range of services that align with its mission and vision:

- **Maritime Security**: Ensuring the security of Belize's territorial waters through patrols, surveillance, and interdiction operations.
- **Search and Rescue (SAR)**: Conducting search and rescue operations to save lives and assist vessels in distress.

- **Law Enforcement**: Enforcing maritime laws, including anti-smuggling, anti-trafficking, and fisheries regulations.
- **Environmental Protection**: Protecting marine environments and resources through conservation efforts and enforcement of environmental laws.
- **Disaster Response**: Providing support and assistance during natural disasters and emergencies, including hurricane relief operations.

2.2 Project Management concepts

2.2.1 Project management principles

The principles of project management are not prescriptive in nature (PMBOK SEVENTH Edition, 2021, p. 21). These principles will differ based on the methodology or framework; however, they will provide guidance for the behavior of the people involved in the project since they influence the performance domains to achieve the desired outcomes. The principles of project management are:

- Be a diligent, respectful, and caring steward.
- Create a collaborative team environment.
- Effectively engage with stakeholders.
- Focus on value.
- Recognize, evaluate, and respond to system interactions.
- Demonstrate leadership behaviors.
- Tailor based on context.
- Build quality into processes and deliverables.

- Navigate complexity.
- Optimize risk responses.
- Embrace adaptability and resiliency.
- Enable change to achieve the envisioned future state.

Note: Taken from the book, A Guide to the Project Management Body of Knowledge (PMBOK® Guide) (7th edition, PMI, 2021, p.23), by PMI, 2021.

Operationalizing PMI Principles in the Seawater Filtration System Project

The "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" integrates the principles outlined by the Project Management Institute (PMI) to ensure effective and efficient project execution. Below is an explanation of how each PMI principle is operationalized within this project:

1. Be Diligent, Respectful, and Caring Steward- The project manager ensures that all activities are conducted with integrity, care, and accountability. Regular monitoring and transparent reporting mechanisms are established to maintain high ethical standards and compliance with the project plan.

2. Create a Collaborative Team Environment- The project involves various stakeholders, including the Belize Coast Guard personnel, technical experts, and suppliers. Regular team meetings, workshops, and open communication

channels are established to foster collaboration and mutual respect among all team members.

3. Effectively Engage with Stakeholders- Stakeholder engagement is critical for the project's success. The project manager identifies all key stakeholders, including the Belize Coast Guard, government agencies, and the local community. A Stakeholder Management Plan is developed to ensure continuous engagement, feedback, and support throughout the project lifecycle.

4. Focus on Value- The project aims to deliver significant value by ensuring a reliable and sustainable potable water supply for the Belize Coast Guard Forward Operating Bases. The project manager focuses on aligning project outcomes with the strategic objectives of the Coast Guard, such as enhancing operational efficiency and personnel welfare.

5. Recognize, Evaluate, and Respond to System Interactions- The project manager takes a holistic view of the project, considering how different components, such as technology, coordination, and human resources, interact and affect each other. This approach helps in identifying potential issues early and developing integrated solutions.

6. Demonstrate Leadership Behaviors- Effective leadership is demonstrated through clear communication, respect, and trust-building among team members.

The project manager leads by example, ensuring that the team remains motivated and aligned with the project goals.

7. Tailor Based on Context- The project management practices are tailored to fit the specific context of the seawater filtration system project. This includes adopting a hybrid approach that combines predictive and adaptive methodologies to address the unique challenges and complexities of the project.

8. Build Quality into Processes and Deliverables- Quality is integrated into every aspect of the project from the planning stage. Detailed quality management plans, regular audits, and reviews ensure that all deliverables meet the required standards and contribute to the overall success of the project.
9. Navigate Complexity- The project manager identifies and manages the complexities inherent in the project, such as technical challenges, regulatory compliance, and environmental considerations. A comprehensive Risk Management Plan is developed to address these complexities proactively.

10. Optimize Risk Responses- The project team continuously evaluates potential risks and develops mitigation plans to address them. This includes technical risks related to the seawater filtration system and external risks such as supply chain disruptions and regulatory changes.

11. Embrace Adaptability and Resiliency- The project manager and team are prepared to adapt to changing situations and challenges. Flexibility in planning

and execution ensures that the project can continue to progress towards its goals despite unforeseen obstacles.

12. Enable Change to Achieve the Envisioned Future State- The project management plan includes mechanisms for managing and facilitating change to achieve the envisioned future state. This involves regular reviews and updates to the project plan based on current needs and circumstances.

2.2.2 Project management domains

The PMBOK® Guide asserts that eight performance domains are essential for achieving project outcomes and ensuring success. The eight domains are: stakeholders, team, development approach and life cycle, planning, project work, delivery, measurement, and uncertainty (PMI, 2021).

A project performance domain is a group of related activities that are critical for the effective delivery of project outcomes (PMI, 2021). The "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" incorporates the eight project performance domains outlined by the Project Management Institute (PMI) in the PMBOK® Guide, 7th Edition. These domains are critical for the effective delivery of project outcomes and the overall success of the project. Here’s how each domain is operationalized within this specific project:

1. Stakeholders- The project identifies key stakeholders, including the Belize Coast Guard personnel, government agencies, and suppliers. A Stakeholder

Management Plan is developed to ensure continuous engagement, feedback, and support throughout the project lifecycle. Regular updates, meetings, and transparent communication practices are established to keep stakeholders informed and involved.

2. Team- The project team includes a diverse set of individuals with various skills, knowledge, and experience. Roles and responsibilities are clearly defined, and team-building activities are conducted to foster collaboration and mutual respect. Regular team meetings and workshops are held to ensure effective communication and coordination among team members.

3. Development Approach and Life Cycle- The project adopts a hybrid development approach, combining predictive and adaptive methodologies. This approach allows for flexibility in planning and execution, accommodating changes and unforeseen challenges while ensuring the project remains on track. The project life cycle includes phases such as initiation, planning, execution, monitoring and controlling, and closure.
4. Planning- Comprehensive planning activities are conducted, including defining the project scope, objectives, scheduling, budgeting, and risk management. Detailed management plans for scope, schedule, cost, quality, resources, communications, risk, procurement, and stakeholders are developed to guide the project team throughout the project lifecycle.

5. Project Work- The project work domain focuses on the actual implementation of project activities. The project manager ensures that tasks are aligned with the project

work plan, resources are managed effectively, and deliverables are completed on time. Regular monitoring and reporting are conducted to track progress and address any issues promptly.

6. Delivery- This domain ensures that the project objectives and outputs are achieved. The project manager monitors the alignment of activities with the project objectives and ensures that deliverables meet the required standards. Quality control measures are implemented to maintain high standards throughout the project.

7. Measurement- The project team establishes clear performance indicators to track, review, and report the project's progress. Earned Value Management (EVM) is used to assess project performance, comparing planned, earned, and actual values to ensure the project remains within budget and on schedule. Regular performance reviews and audits are conducted to evaluate progress and make necessary adjustments.

8. Uncertainty- The project team identifies potential risks and develops mitigation plans to address them proactively. A comprehensive Risk Management Plan is created to categorize risks based on their likelihood and impact. The project manager and team are prepared to adapt to changing situations and challenges, ensuring the project can continue to progress towards its goals despite unforeseen obstacles.

2.2.3 Predictive, adaptative and hybrid projects

In the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases," it is crucial to understand the characteristics of different development approaches and justify the most suitable one for this project. There are three primary development approaches: predictive, adaptive, and hybrid.

1. Predictive projects, also known as the waterfall approach, are characterized by well-defined requirements that are collected and analyzed at the start of the project. This method is suitable for environments with low uncertainty, where the results are clear and predictable. The project team can plan with a high level of certainty from the beginning to the end of the project life cycle (PMBOK Seventh Edition, 2017, p.35).
2. Adaptive projects are useful when requirements are subject to high levels of uncertainty and volatility. In this approach, a clear vision of the product is established at the start, but the requirements are refined, detailed, changed, or replaced based on customer feedback, environmental changes, or unexpected events. Adaptive projects use iterative and incremental development methods, meaning the project is divided into iterations or sprints. During each iteration, products are developed, tested, and refined for improvement, encouraging constant customer feedback and identifying necessary improvements before the final product is approved (PMBOK Seventh Edition, 2017, p.38).

3. Hybrid projects combine elements of both predictive and adaptive approaches. In this approach, well-known elements of the project use predictive methods, while elements that require evolution and adaptation use adaptive methods. This approach is beneficial when there is uncertainty or risk around the requirements or when deliverables can be developed by several project teams. The hybrid approach also incorporates iterative and incremental development strategies, applying the iterative approach when clarifying requirements and finding solutions, and the incremental approach to produce deliverables through a series of iterations (PMBOK Seventh Edition, 2017, p.36).

For the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases," the hybrid development approach is the most suitable. This project involves both well-defined elements, such as technical specifications and procurement processes, and evolving elements, such as installation and integration at various forward operating bases. The hybrid approach allows for detailed planning of predictable aspects while remaining flexible to adapt to site-specific challenges and stakeholder feedback. This ensures thorough planning and the ability to adjust to unforeseen challenges, ultimately leading to successful project outcomes.

2.2.4 Project management

The Project Management Body of Knowledge (PMBOK) Guide, in its seventh edition, provides standard terminology and guidelines for project management. It covers various development approaches, including predictive, adaptive, hybrid, and more. The guide emphasizes not only delivering project outputs but also enabling desired outcomes.

Project management is a multifaceted discipline that involves the administration, direction, and management of projects to achieve specific goals within defined constraints. This section synthesizes the perspectives of three prominent authors in the field of project management: Lauri Koskela and Greg Howell, Project Management Institute (PMI), and Meredith and Mantel.

1. Lauri Koskela and Greg Howell

Lauri Koskela and Greg Howell have made significant contributions to project management theory, particularly in challenging traditional approaches and advocating for more adaptive methodologies (Koskela & Howell, 2002b). Their work emphasizes:

- **Theoretical Foundation**: They argue that traditional project management lacks a solid theoretical foundation and propose alternative theories for planning, execution, and control.
- **Lean Construction**: They advocate for lean principles in project management, focusing on value creation and waste reduction.
- **Adaptive Approaches**: Their research supports more flexible and responsive project management methods, particularly in complex and uncertain environments.

2. Koskela and Howell's approach highlights the importance of continuous improvement and adaptation in project management practices, challenging the conventional wisdom of rigid planning and control.
3. Project Management Institute (PMI)

The Project Management Institute (PMI) provides a comprehensive framework for project management through its publication, the PMBOK® Guide (Project Management Body of Knowledge). PMI outlines several key principles and performance domains essential for effective project management:

- **Principles**: PMI's principles include being a diligent steward, creating a collaborative team environment, engaging stakeholders effectively, focusing on value, and embracing adaptability and resiliency.
- **Performance Domains**: PMI identifies eight performance domains: stakeholders, team, development approach and life cycle, planning, project work, delivery, measurement, and uncertainty. These domains encompass the critical activities and considerations necessary for successful project management.

PMI's framework emphasizes a structured and methodical approach to project management, ensuring that all aspects of a project are carefully planned, executed, and monitored.

Meredith and Mantel

Meredith and Mantel, in their book Project Management: A Managerial Approach, focus on the managerial aspects of project management (Meredith & Mantel, 2019). They emphasize the importance of:

- **Planning and Control**: Detailed planning and control mechanisms are essential to manage the complexities and uncertainties inherent in projects.
- **Resource Management**: Effective allocation and management of resources, including human, financial, and material resources, are critical for project success.
- **Risk Management**: Identifying, assessing, and mitigating risks is a crucial part of project management to ensure that potential issues are addressed proactively.

  Meredith and Mantel's approach underscores the importance of managerial skills and techniques in overseeing projects, ensuring that they are completed on time, within budget, and to the desired quality standards.

Analysis and Synthesis

The perspectives of Koskela and Howell, PMI, and Meredith and Mantel provide a comprehensive understanding of project management. Here is a synthesis of their key points:

- **Theoretical Foundation and Adaptation**: Koskela and Howell emphasize the need for a solid theoretical foundation and adaptive approaches in project management.
- **Structured Framework and Principles**: PMI provides a structured framework with clear principles and performance domains for methodical project management.

- **Managerial Skills and Techniques**: Meredith and Mantel focus on the importance of strong managerial skills in planning, control, resource management, and risk management.

In the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases," these principles are operationalized as follows:

1. **Adaptive Approach**: The project incorporates flexible planning and execution strategies to handle the complexities of implementing a seawater filtration system in diverse coastal environments.
2. **Structured Framework**: The project follows PMI's principles and performance domains, ensuring comprehensive planning, stakeholder engagement, and risk management.
3. **Managerial Skills**: The project management team employs detailed planning, resource management, and control mechanisms to address the complexities and uncertainties of the project.

2.2.5 Project management knowledge areas and processes

In alignment with the 'Process Groups: A Practice Guide' by the Project Management Institute (PMI), the 'Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases' adheres to a structured approach that integrates five key process groups: Initiating, Planning, Executing, Monitoring and Controlling, and Closing. These process groups are applied with thoroughness to ensure a comprehensive and cohesive project management framework. Below is a detailed explanation of how these process groups are used within the context of this specific project.

- Initiating Process Group: The initiation phase establishes the project's foundation. It involves developing the project charter, which formally authorizes the project and defines its objectives, scope, and key deliverables. The project manager works with stakeholders to identify initial risks, establish high-level requirements, and outline the project's purpose. This process also includes stakeholder identification and the creation of a stakeholder register, ensuring that all relevant parties are considered from the outset.
- Planning Process Group: The Planning Process Group is crucial for establishing a roadmap that directs the project team through execution. This group creates detailed scope, schedule, cost, quality, resources, communication, risk, procurement, and stakeholder management plans. For instance, scope planning involves clearly defining the project scope to ensure all necessary work is included while excluding unnecessary work. Schedule planning focuses on developing a detailed project schedule outlining timelines for each activity, milestones, and deadlines. Cost planning involves preparing budget estimates and establishing cost baselines to ensure the project is completed within approved financial constraints. Risk planning identifies, analyzes, and prioritizes potential risks, developing mitigation strategies to minimize their impact. Communication planning establishes a communication plan to ensure stakeholders receive timely and relevant information throughout the project lifecycle.

- Executing Process Group: During the execution process group, the project management plan is put into action by coordinating people and resources to carry out the project's activities as planned. This includes overseeing the execution of project tasks to ensure that deliverables are produced according to plan. Resources are allocated and used efficiently, with any issues being promptly addressed. Stakeholder engagement is managed through active involvement and regular updates, and contracts are overseen while necessary goods and services are procured to support project activities.
- Monitoring and Controlling Process Group: The Monitoring and Controlling Process Group is responsible for keeping the project on track by monitoring progress and making necessary adjustments. The project manager has several key responsibilities in this process group, including tracking performance by regularly measuring project performance using key performance indicators (KPIs) to ensure it aligns with the project plan. Integrated Change Control involves managing project scope, schedule, and cost changes and ensuring adjustments are appropriately documented, reviewed and approved. The project manager is also responsible for continuously monitoring identified risks and implementing risk response strategies as necessary. Quality control is also crucial, ensuring that all project deliverables meet the required standards through regular quality checks and audits.
- Closing Process Group: The closing process group focuses on finalizing all project activities and formally closing the project. Key activities include ensuring that the task is completed and that the stakeholders have accepted all deliverables;

completing all project documentation, including final reports, and archiving project records for future reference; finalizing and closing all contracts; ensuring that all procurement activities have been completed and all vendor obligations have been met; confirming that stakeholder expectations have been met and conducting a final review to capture lessons learned for future projects.

2.2.6 Project life cycle

The project life cycle is a fundamental concept in project management, providing a structured approach to managing projects from inception to completion. Different authors have proposed various models and phases for the project life cycle, each offering unique perspectives and methodologies. Here, we will explore the project life cycles according to three prominent authors: the Project Management Institute (PMI), Dennis A. Rondinelli, and Gray and Larson.

Project Life Cycles by Three Authors:

1. Project Management Institute (PMI)

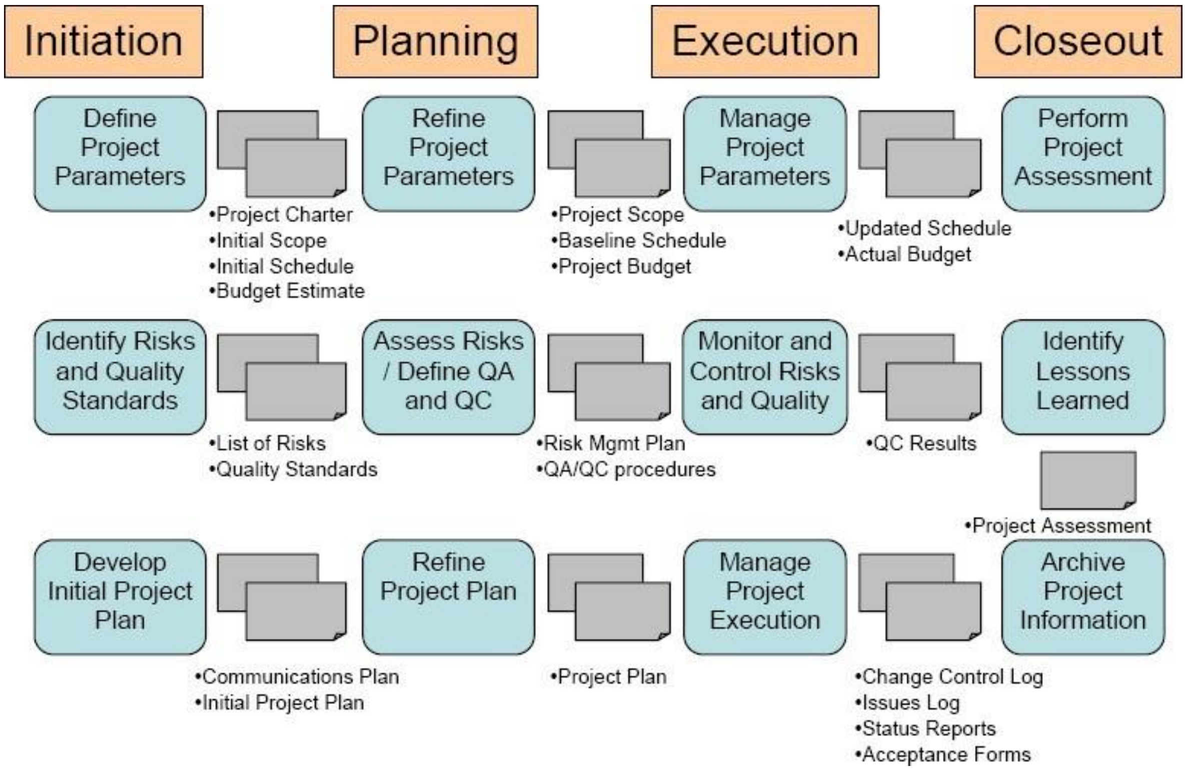
The PMI's project life cycle, as outlined in the PMBOK® Guide, is one of the most widely recognized frameworks in project management. PMI defines the project life cycle in five phases:

1. Initiation: This phase involves defining the project at a high level, including the project’s purpose, objectives, and feasibility.

2. Planning: Detailed planning is conducted to outline the project scope, schedule, budget, resources, and risk management strategies.
3. Execution: The project plan is put into action, and the project deliverables are developed and completed.
4. Monitoring and Controlling: Throughout the project, performance is measured and monitored to ensure that project objectives are being met and adjustments are made as necessary.
5. Closure: The project is formally closed, and a final review is conducted to capture lessons learned and ensure all project work is completed.

Figure 3

Generic Project Management Life Cycle



Note: A generic Project Management Life Cycle.. *Project Management Institute (Source: Project Managing the SDLC) Complete Guide by* Blake J. retrieved 1st August 2024 from https://www.pmi.org/learning/library/project-managing-sdlc-8232

2. Dennis A. Rondinelli

Dennis A. Rondinelli provides a more detailed and extended view of the project life cycle, breaking it down into twelve stages:

1. Project Identification and Definition
2. Project Description, Preparation, and Feasibility Analysis
3. Project Design
4. Project Evaluation
5. Project Selection, Contract, and Approval

6. Project Activation and Organization
7. Project Implementation and Commissioning
8. Project Supervision, Monitoring, and Control
9. Project Completion and Termination
10. Production, Distribution, and Transfer to Regular Administration
11. Project Evaluation
12. Follow-up, Analysis, and Acting

Figure 4

*Project Life Cycle: Definition, and Discussion of 4 Pha*ses

Note: There are four primary stages in the Life Cycle of any project. *Project Management Institute (Source: Project Life Cycle: Definition and Discussion of 4 phases)* retrieved 1st August 2024 from https://www.linkedin.com/pulse/project-life-cycle-definition-discussion-4-phasesshahinurahmed/

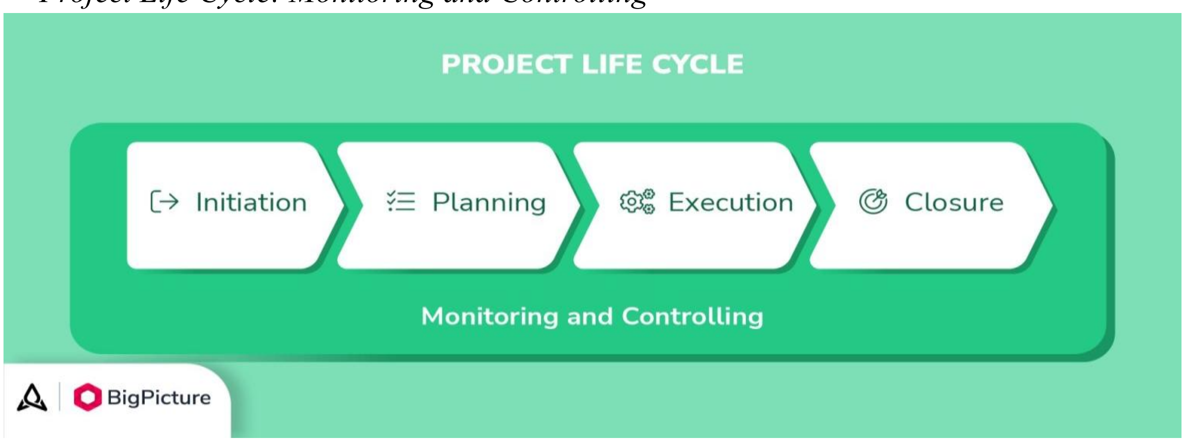
3. Gray and Larson

Gray and Larson simplify the project life cycle into four main stages:

1. Project Definition: This stage involves defining the project's objectives, scope, and feasibility.
2. Planning: Detailed planning is undertaken to develop the project schedule, budget, resource allocation, and risk management plans.
3. Implementation: The project plan is executed, and the project deliverables are developed.
4. Transfer: The project deliverables are handed over to the client or end-users, and the project is formally closed.

Figure 5

Project Life Cycle: Monitoring and Controlling



Note: The Project Life Cycle generally consists of four phases. (Source: The Project Life Cycel explained) retrieved 1st August 2024 from https://bigpicture.one/blog/project-life-cycle-explained/

The project life cycle for the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" corresponds most closely to the hybrid project life cycle. This approach is justified based on the nature and requirements of the project as detailed in the documents provided.

Hybrid Project Life Cycle

Characteristics of the Hybrid Approach

The hybrid project life cycle combines elements of both predictive (waterfall) and adaptive (agile) methodologies. This approach is particularly suitable for projects that have welldefined elements as well as components that require flexibility and adaptation. The hybrid model allows for detailed upfront planning for predictable aspects while maintaining flexibility to adapt to changes and unforeseen challenges during the project execution.

Application to the Seawater Filtration System Project

The seawater filtration system project involves both well-defined elements, such as technical specifications and procurement processes, and evolving elements, such as installation and integration at various forward operating bases. The hybrid approach is suitable for this project due to the following reasons:

1. Predictive Elements:
    - Technical Specifications: The technical aspects of the seawater filtration system, including the selection of appropriate technologies (e.g., reverse osmosis), are well-defined and can be planned in detail.

- Procurement Processes: The procurement of equipment and materials follows a structured process that can be planned and executed predictively.

2. Adaptive Elements:
   - Installation and Integration: The installation of the filtration system at different forward operating bases may encounter site-specific challenges that require adaptive planning and execution.
   - Stakeholder Engagement: Continuous engagement with stakeholders, including the Belize Coast Guard personnel and local communities, requires an adaptive approach to address their feedback and concerns effectively.

Operationalization of the Hybrid Approach

The project management plan integrates both predictive and adaptive methodologies to ensure comprehensive planning and flexibility:

1. Initiation Phase:
   - Develop the project charter and identify key stakeholders.
   - Establish a high-level project structure and objectives.
2. Planning Phase:
   - Detailed planning for scope, schedule, costs, quality, and risk management.
   - Develop subsidiary management plans for various project aspects.
3. Execution Phase:
   - Implement the project plan while maintaining flexibility to adapt to sitespecific challenges.

- Foster collaboration and continuous communication among team members and stakeholders.

4. Monitoring and Controlling Phase:
    - Regularly monitor project progress and performance.
    - Make necessary adjustments based on feedback and changing conditions.
5. Closure Phase:
    - Conduct final evaluations and document lessons learned.
    - Ensure smooth transition of the system to operations management.

2.2.7 Company strategy, portfolios, programs and projects

Business strategy refers to an organization's decisions and actions to achieve its long-term goals and objectives. It is critical for gaining a competitive advantage and ensuring the company's sustainable success. According to Porter (1985), business strategy involves creating a unique position in the market, supported by activities that deliver customer value in a way that competitors cannot easily replicate. Mintzberg (1987) adds that business strategy is not just a plan but also a pattern of actions that aligns the organization's goals with its capabilities and the external environment. The critical elements of our strategy include value creation, competitive advantage, and sustainability. By focusing on creating value for customers, employees, and stakeholders through strategic initiatives, we aim to position the company favorably in the marketplace and ensure longterm success through careful planning and adaptation. This framework is essential because it can guide decision-making, align objectives, and enhance competitiveness. It provides a structured approach for making informed business decisions, ensures that all parts of the organization work towards common goals, and helps the company stay ahead of competitors by leveraging its strengths and opportunities.

A portfolio, a collection of projects, programs, and operations, is a strategic tool managed to accomplish organizational objectives. As defined by the Project Management Institute (PMI), a portfolio is aligned with an organization's strategic goals by selecting and prioritizing projects and programs that provide the most value (PMI, 2021). The strategic alignment of portfolios ensures that all projects and programs contribute to the organization's overarching goals and resource optimization, which aids in the efficient allocation of resources across various initiatives.

A program is a collection of related projects managed together to achieve benefits and control. According to PMI (2021), programs are intended to achieve strategic objectives and deliver value aligning with the organization's goals. The importance of programs includes achieving greater benefits, streamlining management processes, and ensuring that combined project outcomes meet broader organizational objectives.

A project is a temporary endeavor with defined start and end points, constrained by scope, time, and budget. It drives innovation, addresses specific problems or opportunities, and delivers tangible outcomes contributing to the organization's strategic goals.

The Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases, is classified as a project due to its defined start and end date, aim to deliver a tailored seawater filtration system, and clear objectives such as ensuring a reliable supply of potable water, enhancing operational efficiency, and improving personnel welfare.

The project aligns with the strategic objectives of the Belize Coast Guard in several keyways. It enhances operational efficiency by providing a sustainable and reliable water supply to forward operating bases. The project supports national security by ensuring the health and readiness of personnel to effectively perform their duties. The project also promotes sustainability through the utilization of seawater desalination, reducing dependency on limited freshwater resources and aligning with broader environmental goals.

2.3 Other applicable theory/concepts related to the project topic and context

2.3.1 Current situation of the problem or opportunity in study

The Belize Coast Guard (BCG) faces significant challenges in ensuring a reliable water supply for its forward operating bases (FOBs). The current situation involves a mix of water procurement methods, including purchasing water transported by vessels, using seawater for non-potable purposes, and relying on rainwater catchment systems. These methods are not only logistically complex but also unsustainable, especially during dry seasons.

Background: The BCG's FOBs, such as those in San Pedro and Bacalar Chico, depend on external sources for potable water. In San Pedro, water is purchased from a supplier who delivers it in rotoplas water tanks, while drinking water is obtained from a purified water company under a memorandum of understanding (MOU) with Agua Dulce.

Bacalar Chico relies on a nearby resort's well system for showers and makes trips to San Pedro for drinking water. Other bases like Calabash and Hunting Caye depend on rainwater and wells, which are insufficient during dry periods.

Research and Proposed Improvements: Previous submissions have been made to connect San Pedro's FOB to Belize Water Services Limited (BWSL) for a more reliable water supply. However, the high costs associated with running pipes underwater have hindered this proposal. Current research suggests the implementation of a seawater filtration system as a sustainable solution. This system would provide a consistent potable water supply, reduce dependency on external sources, and improve operational efficiency.

Implementation Results: While no concrete steps have been taken yet, the proposed seawater filtration system promises to address the water supply challenges effectively. Further research and feasibility studies are required to evaluate the technical and financial aspects of this solution.

2.3.2 Previous research done for the topic in study

The preliminary research on seawater filtration systems for the Belize Coast Guard's Forward Operating Bases (FOBs) is highly relevant, focusing on feasibility, technological options, cost implications, and sustainability aspects of implementing such systems. The research draws on various case studies, technical assessments, and academic papers that provide a comprehensive overview of how seawater filtration systems have been successfully implemented in other regions and the specific technical requirements for such systems in similar environments.

Several studies have identified technologies such as reverse osmosis (RO), ultrafiltration (UF), and multi-stage flash distillation as effective for converting seawater into potable water. According to Li and Wu (2024), reverse osmosis is particularly effective in regions with high salinity levels, making it a suitable choice for the Belize Coast Guard's FOBs. Their research indicates that RO systems can achieve high efficiency in salt rejection, thus providing clean and safe drinking water. Additional research by Huang et al. (2022) emphasizes the importance of selecting the appropriate filtration technology based on local environmental conditions, resource availability, and the specific needs of the installation site. Their study highlights the adaptability of ultrafiltration systems in areas with varying water quality, which could benefit Belize's coastal and island-based FOBs.

Modern desalination plants have significantly reduced energy consumption, making seawater filtration systems more viable for remote locations with limited power supply. Research by Chibani (2023) in the Gulf region indicates that energy recovery devices and improved membrane technologies in RO plants have decreased the energy required per cubic meter of water produced by up to 30%. The upfront investment in seawater filtration can be offset by long-term savings in reduced water transportation costs and improved operational efficiency for remote bases, as shown by a cost-benefit analysis conducted by Amiad Water Systems (n.d.).

The environmental impact of seawater desalination is a crucial consideration. Studies suggest that utilizing seawater for potable water significantly reduces the pressure on freshwater resources, which is essential for the sustainability of water supplies in Belize.

According to Berniak-Woźny and Rataj (2023), integrating sustainable water management practices, such as using renewable energy sources to power desalination plants, aligns with global environmental conservation goals. Research by the Ministry of Water and Irrigation (2022) in Jordan presents guidelines for planning and managing seawater reverse osmosis plants that minimize environmental harm, such as brine disposal, which can be applied to the Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases.

The reviewed research offers valuable insights and practical examples for developing and implementing a seawater filtration system for the Belize Coast Guard. It provides clear direction for choosing suitable filtration technology, highlights the importance of energy and cost efficiency, and emphasizes incorporating environmentally sustainable practices to contribute positively to Belize's environmental goals.

The findings from these studies are directly relevant. They are essential inputs for the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases." The detailed assessments of filtration technologies, cost and energy considerations, and sustainability practices provide a strong foundation for making informed decisions throughout the project lifecycle. These insights will guide the selection of appropriate technologies, the design of energy-efficient systems, and the integration of sustainable practices, ultimately contributing to the successful implementation of the seawater filtration system.

2.3.3 Other theory related to the topic in study

In addition to the core concepts of project management and seawater filtration systems, there are several other theories and methodologies that can enhance the effectiveness of the project management plan for implementing a seawater filtration system in the Belize Coast Guard Forward Operating Bases (FOBs). These theories, while not directly related to the Final Graduation Project (FGP), offer valuable insights and techniques that can be leveraged to improve project outcomes.

Application to the Seawater Filtration System Project

By integrating these theories and methodologies, the project management plan for implementing a seawater filtration system in the Belize Coast Guard Forward Operating Bases can be enhanced in several ways:

- Lean and Six Sigma: These methodologies can be used to streamline the installation process, reduce waste, and ensure high-quality outcomes.
- Agile: Agile principles can be applied to manage the iterative development and testing of the filtration system, allowing for continuous feedback and adjustments.
- Theory of Constraints: Identifying and managing bottlenecks in the procurement and installation process can help ensure timely project completion.
- Hybrid Approach: Combining predictive planning for well-defined tasks (e.g., procurement) with adaptive methods for evolving tasks (e.g., site-specific installation) can provide the flexibility needed to handle project complexities.

3 METHODOLOGICAL FRAMEWORKS

3.1 Information sources

Information sources, the origins or channels from which individuals obtain data, facts, knowledge, or insights, play a crucial and dynamic role in shaping our understanding of the world (Cabanel,2019). This role is significant, as these sources contribute to the foundation of knowledge and decision-making processes (Opsal et al., 2022). According to Libraries University of Wisconsin-Stevens Point, an information source is defined as "any source of information, knowledge or evidence" ("Types of Information Sources," 2024).

3.1.1Primary sources

The main categories of information sources consist of primary, secondary, and tertiary sources. Emory University describes primary sources as original materials that offer direct evidence or firsthand testimony regarding a specific topic or event ("Primary Sources Research Guide, 2024). These sources are typically created by witnesses or individuals who recorded the events. Examples of primary sources include original research articles, theses and dissertations, technical reports, conference proceedings, patents, diaries, letters, autobiographies, and government documents (University of Wisconsin-Stevens Point, n.d.).

For the Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases, we are using the following types of primary information sources: original research articles on seawater filtration technologies, technical specifications and manuals for filtration equipment, government reports on water management practices, and interviews with experts in water treatment and desalination.

3.1.2 Secondary sources

Secondary sources provide analysis, interpretation, or summary of primary sources. They are authored by individuals who did not witness the event firsthand. Examples of secondary sources include review articles, biographies, textbooks, encyclopedias, commentaries, and critiques (University of Wisconsin-Stevens Point, n.d.)

The Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases relies on various information sources, including secondary sources such as review articles summarizing the latest advancements in desalination technology and textbook project management methodologies. These sources offer insights into effective project management techniques and analyze the costeffectiveness of different water treatment solutions. They serve as valuable resources for understanding the field's current state and guide project planning, execution, and monitoring (Karimi & Momeni, 2023). They also aid in evaluating the feasibility and efficiency of different approaches. By utilizing these information sources, the Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases, aims to gather comprehensive and reliable data to support the research objectives (Aziz et al., 2024) and enhance the project's quality.

Chart 1 Information sources (Source: Author of the study)

Objectives	**Information sources**	
	Primary	**Secondary**
1.Conduct a comprehensive assessment of existing seawater filtration technologies and systems for the Belize Coast Guard Forward Operating Bases.	- Interviews with technical experts in water filtration systems. - Site visits to existing facilities using similar technologies.	- Academic journals and articles on seawater filtration technologies. - Technical reports from water filtration system manufacturers. - Government and industry reports on water management in coastal areas.
2. Implement initiation processes, including developing the project charter and identifying key stakeholders to establish a highlevel project structure for the seawater filtration system.	- Meetings with Belize Coast Guard leadership and critical stakeholders. - Workshop sessions for meticulous project charter development, ensuring every aspect is considered.	- Project management textbooks and guides. -Case studies of similar projects. - Articles on stakeholder analysis and engagement.
3. Elaborate and develop the project management plan, including the creation of subsidiary management plans for scope, schedule, costs, resources, quality, risks, communications, acquisitions, and stakeholders, to define the baselines for the	- Project planning sessions with the project team to ensure alignment and understanding of the project plan. - Interviews with experts in project management and water filtration systems.	- Project management standards and frameworks (e.g., PMBOK Guide). - Previous project management plans from similar projects. - Academic articles on project planning.

seawater filtration system.		
Objectives	**Information sources**	
	Primary	**Secondary**
4. Select tools and techniques and define procedures for the execution of the seawater filtration system project.	-Consultations with project management and engineering experts. - Pilot testing of selected tools and techniques.	- Manuals and guides on project management tools and techniques. - Research papers on best practices in project execution.
5. Evaluate the cost-effectiveness, energy efficiency, and ease of maintenance of the proposed seawater filtration system from a conceptual and theoretical point of view, applying research to develop a welldefined case study.	- Data collection from existing installations. - Interviews with facility managers and maintenance personnel.	- Economic analyses and feasibility studies. - Technical papers on energy efficiency in water filtration. - Case studies of similar projects.
6. Establish a project monitoring and control system through tools and techniques to ensure the effective integration of project objectives and goals.	-Development sessions with the project team. - Feedback from stakeholders on monitoring requirements.	- Articles and guides on project monitoring and control systems. - Case studies on the implementation of monitoring systems in similar projects.

7. Define a project closure procedure that includes the final evaluation of objectives and goals achievement, lessons learned reporting, and product transfer to operations management.	- Workshops will be held with the project team and stakeholders to define closure criteria, underscoring the importance of this phase. - Interviews with project closure experts.	- Textbooks on project closure and post-project evaluation. - Articles on lessons learned and knowledge transfer in project management.

Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" (Valdez, 2024).

3.2 Research methods

Research methods are the strategies, techniques, and procedures used to collect, analyze, and interpret data during a research project. They provide a systematic plan for conducting research and ensure that the findings are reliable and valid (Creswell & Creswell, 2017). According to the APA citation style, research methods are crucial for providing a framework for obtaining accurate and unbiased results (American Psychological Association, 2020).

3.2.1 Analytical method

The analytical method is an in-depth process that entails deconstructing a complex issue or system into smaller, more manageable components to understand its structure and function better. This approach encompasses the collection of data, its analysis, and the interpretation of results to derive meaningful conclusions (Yin, 2018). In the context of Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases, this method will be utilized to evaluate the efficiency and effectiveness of different seawater filtration technologies and to conduct a cost-benefit analysis to implement filtration systems across various bases.

3.2.2 Descriptive Method

The descriptive method involves observing and describing a subject's behavior without influencing it. This can be achieved through case studies, surveys, and observational studies to gather detailed information about a specific phenomenon (Neuman, 2014). In the Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases, surveys and interviews will be conducted with Coast Guard personnel to understand their needs and challenges regarding water supply. Existing water procurement and management practices at the forward operating bases will be documented.

3.2.3 Experimental Method

The experimental method involves altering a single variable to establish whether changes in that variable cause changes in another. This approach establishes cause-andeffect relationships under controlled conditions (Campbell & Stanley, 1963). In the Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases, the experimental method will be applied by conducting a series of tests to identify the system that delivers the highest water quality at the most economical operational cost. Pilot projects can be initiated to assess the practicality and effectiveness of specific filtration technologies.

Chart 2

Research methods (Source: Author of the Study)

Objectives	**Research methods**		
	Analytical Method	Descriptive Method	Experimental Method
1. Conduct a comprehensive assessment of existing seawater filtration technologies and systems for the Belize Coast Guard Forward Operating Bases.	They are used to assess the efficiency and effectiveness of various seawater filtration technologies by breaking them down into their core components and evaluating their performance.	conducted surveys and interviews with Coast Guard personnel to gather detailed information about different filtration systems and their applications in similar settings.	Not directly applied.
2. Implement initiation processes, including developing the project charter and identifying key stakeholders to establish a high-level project structure for the seawater filtration system.	Used to systematically analyze the needs and requirements of the project, leading to the development of a comprehensive project charter and identification of key stakeholders.	Conducted meetings and workshops to gather detailed input from stakeholders and document their needs and expectations.	Not directly applied.

3. Elaborate and develop the project management plan, including the creation of subsidiary management plans for scope, schedule, costs, resources, quality, communications, risks, acquisitions, and stakeholders, to define the project baselines for the seawater filtration system.	Applied to break down the project into manageable parts, creating detailed subsidiary management plans for each aspect of the project.	Documented and described each plan and its components thoroughly.	Not directly applied.
Objectives	**Research methods**		
	Analytical Method	Descriptive Method	Experimental Method
4. Select tools and techniques and define procedures for the execution of the seawater filtration system project.	Evaluated and selected the most appropriate tools and techniques for the project execution through systematic analysis.	Documented the selection process and defined the procedures in detail.	Not directly applied.
5. Evaluate the costeffectiveness, energy efficiency, and ease of maintenance of the proposed seawater filtration system from a conceptual and theoretical point of view, applying research to develop a well-defined case study.	Conducted a thorough costbenefit analysis and evaluated the energy efficiency and maintenance requirements of the proposed system.	Gathered and presented data on cost, efficiency, and maintenance from existing installations and studies.	Conducted pilot testing to validate the theoretical evaluations under controlled conditions.

6. Establish a project monitoring and control system through tools and techniques to ensure the effective integration of project objectives and goals.	I identified the key metrics and KPIs for monitoring and control and developed the necessary tools and techniques for these processes.	Documented the monitoring and control procedures to ensure all stakeholders understand them.	Not directly applied.
7. Define a project closure procedure that includes the final evaluation of objectives and goals achievement, lessons learned reporting, and product transfer to operations management.	Developed a structured closure procedure, ensuring all aspects of the project are evaluated and documented.	Documented lessons learned and ensured a smooth transition of the product to operations management.	Not directly applied.

Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" (Valdez, 2024).

3.3 Tools

According to the Project Management Institute (PMI), a tool is any tangible item used in performing an activity to produce a deliverable or result. Tools can include templates, software programs, charts, and checklists designed to aid project managers in achieving project objectives efficiently (PMI, 2021). Tools help organize and streamline the project process, making controlling project outcomes easier and ensuring successful completion.

Models, Methods, and Artifacts

In the 7th Edition of the PMBOK Guide, PMI introduces the concepts of models, methods, and artifacts as essential tools for project management. Models are frameworks or representations of processes or systems that guide project planning and execution. Methods are systematic procedures or techniques applied to project tasks. Artifacts, as tangible outputs produced during the project, such as documents, plans, and reports, are the concrete results of the team's efforts, providing a sense of accomplishment (PMI, 2021).

Chart 3 Tools (Source: Author of the study)

Objectives	Tools
1. Conduct a comprehensive assessment of existing seawater filtration technologies and systems for the Belize Coast Guard Forward Operating Bases.	Brainstorming, Interviews, Document Analysis, Technical Reports
2. Implement initiation processes, including developing the project charter and identifying key stakeholders to establish a high-level project structure for the seawater filtration system.	Brainstorming, Meetings, Expert Judgment, Charter Template
Objectives	**Tools**
3. Elaborate and develop the project management plan, including the creation of subsidiary management plans for scope, schedule, costs, resources, quality, communications, risks, acquisitions, and stakeholders, to define the project baselines for the seawater filtration system.	Expert Judgment, Scope Management Plan Template, Gantt Chart, Microsoft Project
4. Select tools and techniques and define procedures for the execution of the seawater filtration system project.	Data Analysis, Microsoft Project, Expert Judgment, Interviews
5. Evaluate the cost-effectiveness, energy efficiency, and ease of maintenance of the proposed seawater filtration system from a conceptual and theoretical point of view, applying research to develop a welldefined case study.	Cost Aggregation, Historical Information Review, Pilot Testing

6. Establish a project monitoring and control system through tools and techniques to ensure the effective integration of project objectives and goals.	Monitoring Tools, Status Reports, Risk Log, Earned Value Management
7. Define a project closure procedure that includes the final evaluation of objectives and goals achievement, lessons learned reporting, and product transfer to operations management.	Closure Checklist, Lessons Learned Register, Final Report Template

Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" (Valdez, 2024).

3.4 Assumptions and constraints

Assumptions in project management are factors that, for planning purposes, are considered valid, accurate, or specific without proof or demonstration (Project Management Institute, 2021, p. 235). They form the basis for project planning and influence all aspects of project management, from developing the project charter to the execution and monitoring phases. Assumptions must be validated and documented as they affect the project's risk management plan and may require contingency planning if they are incorrect.

Constraints are limiting factors that affect the execution of a project or process. These include project scope, time, cost, quality, resources, and risks (Project Management Institute, 2021, p.237). Constraints are critical in defining the boundaries within which the project must operate. They are essential for setting realistic project expectations and for effectively managing stakeholder expectations. Identifying and managing constraints is crucial for successful project delivery.

For the Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases, assumptions and constraints significantly shape the project's scope, planning, and execution. Assumptions include the availability of specific technologies, stakeholder support, and environmental conditions, while constraints include budget limitations, regulatory requirements, and resource availability. Correctly identifying and managing these factors ensures that the project is feasible and that potential risks are mitigated.

Chart 4

Assumptions and constraints for the Seawater Filtration System Project (Source: Author of the study)

Objectives	Assumptions	Constraints
1. Conduct a comprehensive assessment of existing seawater filtration technologies and systems for the Belize Coast Guard Forward Operating Bases.	All necessary technical data and specifications regarding existing seawater filtration technologies and systems are assumed to be readily available and accessible for research and analysis.	- It's crucial that we use this time efficiently, recognizing the urgency and importance of our roles. This includes all phases, from initial research to final implementation and evaluation. - The project has a fixed budget that cannot be exceeded. This budget must cover all aspects of the project, including research, equipment procurement, installation, and maintenance.

2. Implement initiation processes, including developing the project charter and identifying key stakeholders to establish a high-level project structure for the seawater filtration system.	All stakeholders, including the Belize Coast Guard personnel and external consultants, will cooperate fully and provide timely input and feedback to ensure the smooth progression of the project.	Complete the project within the allowable time.
3. Elaborate and develop the project management plan, including the creation of subsidiary management plans for scope, schedule, costs, resources, quality, communications, risks, acquisitions, and stakeholders, to define the project baselines for the seawater filtration system.	The project is expected to receive ongoing funding throughout its lifecycle to cover all planned activities, such as research, procurement, and installation of the seawater filtration system.	The project has a fixed budget that cannot be exceeded. The project must adhere to all relevant local, national, and global guidelines and rules about environmental protection, water treatment, and military infrastructure.
Objectives	**Assumptions**	**Constraints**
4. Select tools and techniques and define procedures for the execution of the seawater filtration system project.	All the technical data and specifications necessary for researching and analyzing existing seawater filtration technologies and systems are expected to be readily available and accessible.	The availability of specialized equipment and materials required for the seawater filtration system may be limited, potentially impacting procurement timelines and project schedules.

5. Evaluate the costeffectiveness, energy efficiency, and ease of maintenance of the proposed seawater filtration system from a conceptual and theoretical point of view, applying research to develop a well-defined case study.	The project team will be granted access to the Belize Coast Guard Forward Operating Bases to conduct site assessments, collect data, and carry out implementation activities.	We need to plan carefully and efficiently to ensure that we meet any deadlines. This will help us to manage expectations and deliver results within the given time constraints.
6. Establish a project monitoring and control system through tools and techniques to ensure the effective integration of project objectives and goals.	It is expected that the project will be funded consistently throughout its lifespan to cover all planned activities.	The project must not exceed the fixed budget. All relevant local, national, and international environmental regulations and standards must be followed.
7. Define a project closure procedure that includes the final evaluation of objectives and goals achievement, lessons learned reporting, and product transfer to operations management.	To ensure the smooth progression of the project, all stakeholders, including the personnel from the Belize Coast Guard and external consultants, will fully cooperate and provide timely input and feedback.	Adhering to high-quality standards is essential for all project documentation, such as lessons learned reports and product transfer documents, to guarantee clarity and usability for future operations.

Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" (Valdez, 2024).

3.5 Deliverables

Deliverables are any unique and verifiable products, results, or capabilities to perform a service produced to complete a project or its phases. They are the tangible or intangible outcomes produced from project activities. Deliverables can include reports, documents, software, infrastructure, or any other result that fulfills the project requirements (PMI, 2021).

Chart 5 Deliverables (Source: Author of the study)

Objectives	Deliverables
1. Conduct a comprehensive assessment of existing seawater filtration technologies and systems for the Belize Coast Guard Forward Operating Bases.	- Assessment Report: A detailed analysis of existing seawater filtration technologies and systems.
2. Implement initiation processes, including developing the project charter and identifying key stakeholders to establish a high-level project structure for the seawater filtration system.	- Project Charter: Formal document authorizing the project. - Stakeholder Register: List of all identified stakeholders.
3. Elaborate and develop the project management plan, including the creation of subsidiary management plans for scope, schedule, costs, resources, quality, communications, risks, acquisitions, and stakeholders, to define the project baselines for the seawater filtration system.	- Project Management Plan: Comprehensive plan including scope, schedule, cost, quality, risk, communication, and stakeholder management. - Subsidiary Plans: Specific plans for each management area.

4. Select tools and techniques and define procedures for the execution of the seawater filtration system project.	- Execution Plan: Document detailing the selected tools and procedures for project execution. - Technical Specifications: Document outlining technical requirements for execution.
5. Evaluate the cost-effectiveness, energy efficiency, and ease of maintenance of the proposed seawater filtration system from a conceptual and theoretical point of view, applying research to develop a welldefined case study.	- Feasibility Study: A report evaluating the cost, energy efficiency, and maintenance needs of the proposed system.
Objectives	**Deliverables**
6. Establish a project monitoring and control system through tools and techniques to ensure the effective integration of project objectives and goals.	- Monitoring and Control Plan: A detailed plan for monitoring and controlling the project. - Status Reports: Periodic reports tracking progress.
7. Define a project closure procedure that includes the final evaluation of objectives and goals achievement, lessons learned reporting, and product transfer to operations management.	- Closure Report: Final report summarizing the project outcomes. - Lessons Learned Document: Compilation of lessons learned throughout the project.

Note: Adapted from the “Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases” (Valdez, 2024)

4 Results

4.1. Assessment of Seawater Filtration Technologies for Belize Coast Guard Forward Operating Bases

In addressing Specific Objective One of this project "Conduct a comprehensive assessment of existing seawater filtration technologies and systems for the Belize Coast Guard Forward Operating Bases", a thorough and detailed evaluation was conducted using data collection, expert consultations, and real-world experience. As a member of the Belize Coast Guard for the past ten years, I have firsthand knowledge of the challenges faced by personnel regarding water access, particularly during extended deployments. I have experienced the scarcity of fresh water at the FOBs, where stretching half a bucket of fresh water for a shower is expected. This personal insight adds credibility to the pressing need for a sustainable solution, such as seawater desalination.

The following activities and results outline the critical steps taken to assess the current situation and propose a feasible solution that can reliably address the water supply challenges at the Belize Coast Guard's Forward Operating Bases (FOBs). The proposed solution, seawater desalination, offers several key benefits. It provides a reliable source of fresh water, reduces the need for costly and logistically challenging water transport, and can be implemented sustainably and environmentally friendly.

4.1.1 Data Collection

Interviews with personnel at various Forward Operating Bases (FOBs) highlighted critical water supply challenges that demand immediate attention, particularly during dry seasons when rainwater harvesting proves inconsistent and insufficient. In these cases, the

Coast Guard relies on costly and logistically tricky external procurement, with rough seas and severe weather frequently delaying deliveries, further exacerbating the shortages. These findings confirmed that the seasonal variability of rainwater harvesting, and the unreliability of external procurement make the current water supply methods unsustainable, severely limiting access to clean water and straining operational capacity.

Belize has been advancing its efforts in desalination projects to address freshwater scarcity, particularly in coastal and island communities where traditional water sources are limited or unreliable. One significant desalination initiative is powered by solar energy, which helps reduce the traditionally high energy costs associated with desalination. For example, Elemental Water Makers has successfully implemented sustainable desalination solutions across Belize, particularly on the Cayes and private islands (Cowo, 2019). These projects provide a reliable source of clean water through reverse osmosis (RO) technology, which converts seawater into potable water. The desalination units are designed to be energy-efficient and are often combined with solar power, ensuring minimal operational costs and long-term sustainability. This long-term sustainability of the projects instills confidence in the future of water supply in Belize (Howell & LLC, n.d.).

4.1.2 Technology Evaluation

Desalination technologies have evolved significantly since their inception, primarily driven by the global need for freshwater due to increasing population and industrial growth. The concept of desalination dates to the 18th century when the Royal Navy implemented early thermal distillation processes to improve water supply on ships. Over time, advancements in thermal processes such as Multi-Stage Flash Distillation (MSF) and Multi-Effect Distillation (MED) were developed, particularly during the mid-20th century, as the demand for large-scale desalination increased in arid regions like the Middle East (Youssef et al., 2014). By the 1960s, Reverse Osmosis (RO), a membrane-based technology, was introduced, marking a breakthrough in desalination. Its efficiency in separating salt from water under pressure gives us hope for the future of freshwater supply (Curto et al., 2021).

Desalination is important because of its ability to provide fresh water in areas where natural freshwater sources are scarce. Initially, technologies like MSF were energyintensive and used in energy-rich regions. However, the introduction of RO and the development of energy recovery systems have made desalination more accessible and costeffective for a broader range of locations (Curto et al., 2021).

Today, desalination technologies are not stagnant but continue to evolve, incorporating renewable energy sources such as solar and wind to reduce their environmental impact and operational costs. This evolution informs us about the latest advancements in the field, making desalination a vital solution for addressing water scarcity in coastal and island nations like Belize (Youssef et al., 2014).

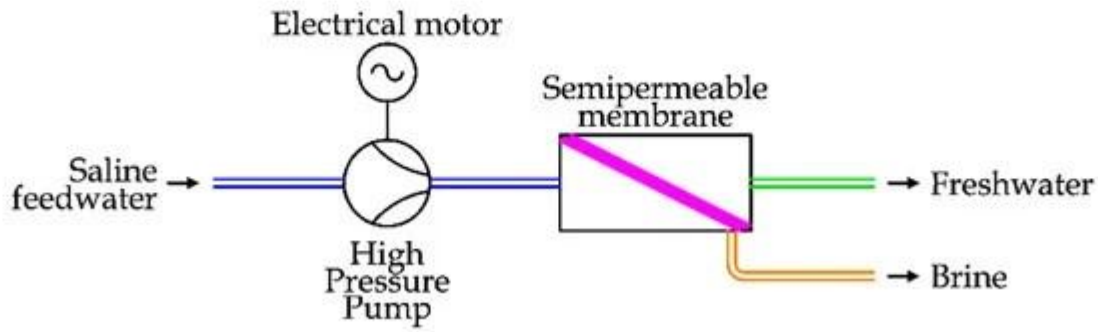
Three main factors should be considered when evaluating seawater filtration technologies: efficiency, cost-effectiveness, and energy consumption. Below is an overview of the most used technologies in desalination and filtration, focusing on how they perform across these criteria.

1. Reverse Osmosis (RO)

- **Efficiency**: RO is highly effective, achieving salt rejection rates of approximately 99.5% or higher. It can remove 99.5% or more of the salt from the water, making it suitable for producing potable water. It utilizes semipermeable membranes to filter water under high pressure, effectively removing dissolved salts and impurities.
- **Cost-effectiveness**: Despite the high initial capital costs of RO systems, the long-term savings they offer through lower operational costs provide a reassuring return on investment. Maintenance involves periodic cleaning and membrane replacement, ensuring the system's longevity.
- **Energy Consumption**: RO is one of the most energy-efficient desalination methods, using about 2.5 to 4 kWh per cubic meter of water produced. RO is especially true when equipped with energy recovery devices (ERDs) that can enhance efficiency by up to 30%. ERDs capture and reuse the energy from the concentrated brine stream, reducing the system's overall energy consumption.
- **Suitability for Belize**: Given Belize's tropical environment and logistical challenges, RO's efficiency and relatively low energy consumption make it a highly suitable option for remote FOBs.

Figure 6

A diagram of a simple Reverse Osmosis (RO) Desalination Unit



Note: Seawater, after a pre-treatment to remove solid particles, is pressurized by a HighPressure Pump (HPP) to supply the RO desalination unit. *A review of the Water Desalination Technologies* retrieved 5th October 2024 from https://www.mdpi.com/2076-3417/11/2/670

2. Ultrafiltration (UF)

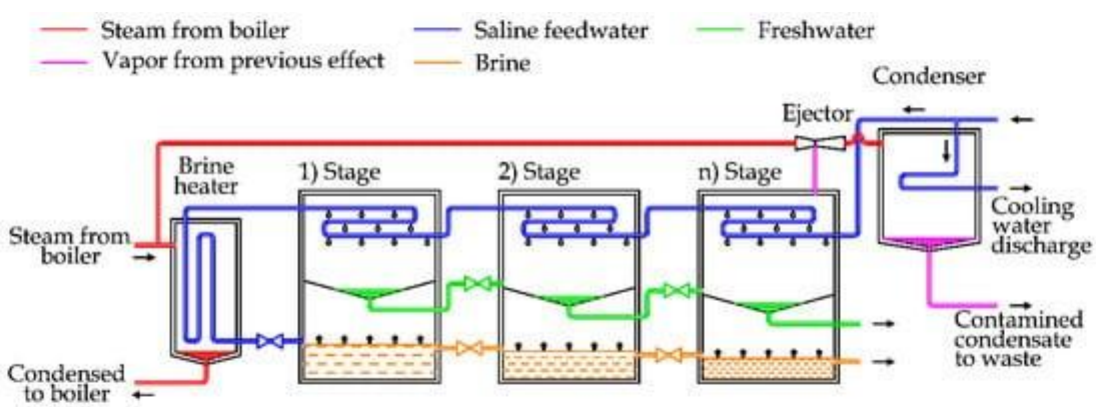
- **Efficiency**: UF serves primarily as a pre-treatment technology before desalination methods like RO. It filters out particles, bacteria, and some viruses, achieving up to 90% removal of suspended solids.
- **Cost-effectiveness**: UF systems are relatively low-cost compared to other technologies and can extend the lifespan of downstream RO systems by reducing membrane fouling.
- **Energy Consumption**: UF's significantly lower energy consumption compared to RO, typically around 0.1 to 0.5 kWh per cubic meter treated, presents an optimistic potential for energy-efficient desalination.
- **Suitability for Belize**: UF can be integrated with RO systems to improve efficiency and reduce operational issues related to high-sediment seawater in Belize's coastal environments.

3. Multi-Stage Flash Distillation (MSF)

- **Efficiency**: MSF can produce large volumes of potable water but has lower salt rejection rates than RO.
- **Cost-effectiveness**: MSF systems have high capital and operational costs due to their energy-intensive nature, making them more suitable for large-scale operations.
- **Energy Consumption**: MSF is highly energy-intensive, consuming between 8 to 15 kWh per cubic meter produced, making it less ideal for regions with limited energy resources like Belize.
- **Suitability for Belize**: Due to its high energy consumption and complexity, MSF is not recommended for small-scale operations at the FOBs. This information provides a clear understanding of the system's limitations.

Figure 7

A schema of a Multi-Stages Flash (MSF) Desalination Unit



Note: The saline feedwater is firstly used as cooling water for the condenser and then as a raw source to produce freshwater. *A review of the Water Desalination Technologies* retrieved 5th October 2024 from https://www.mdpi.com/2076-3417/11/2/670

Chart 6

Comparative Chart of Desalination Technologies (Source: Author of the study)

Technology	**Efficiency (Salt Rejection)**	**Energy Consumption (kWh/m³)**	**Cost Analysis**	**Water Output (m³/day)**	**Suitability for Belize**
Reverse Osmosis (RO)	~99.5%	2.5 - 4.0	High upfront costs but low operational costs; long-term savings expected.	Up to 1000+	Highly suitable for FOBs
Ultrafiltration (UF)	Pre-treatment only (~90% solids)	0.1 - 0.5	Low upfront and operational costs; extends RO membrane life.	Varies based on system	Suitable as a pretreatment step
Multi-Stage Flash Distillation (MSF)	Lower than RO	15-Aug	High capital and operational costs; less cost-effective for small-scale operations.	500 - 2000+	Not suitable for FOBs

Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" (Valdez, 2024).

The insights highlight that RO (reverse osmosis) is the most energy-efficient and cost-effective desalination method, especially when equipped with energy recovery devices. Despite higher initial costs, RO systems offer substantial long-term savings due to lower operational expenses than MSF (multi-stage flash) and other methods. The RO systems can produce significant quantities of potable water daily, aligning well with the needs of the Belize Coast Guard. Considering the logistical constraints and the imperative for reliable potable water at forward operating bases, RO emerges as the most suitable technology, with UF (ultrafiltration) as a viable pre-treatment option. This detailed analysis provides a comprehensive overview of the strengths and limitations of each desalination technology and the specific requirements of the Belize Coast Guard Forward Operating Bases.

4.1.3 Pilot Testing and Available Data for Seawater Reverse Osmosis Systems

Pilot testing is not necessary in this context because proven Reverse Osmosis (RO) systems have already been extensively deployed and evaluated in similar environments, such as coastal areas in Belize and other global regions. Companies like Pure Aqua, Inc. have a strong record of successfully implementing these systems, providing reliable data, technical specifications, and performance metrics that are specifically tailored to the needs of the Belize Coast Guard's Forward Operating Bases (FOBs).

Pure Aqua, Inc. Critical Data and Specifications from Past Installations ("Seawater reverse osmosis systems SWRO," n.d.):

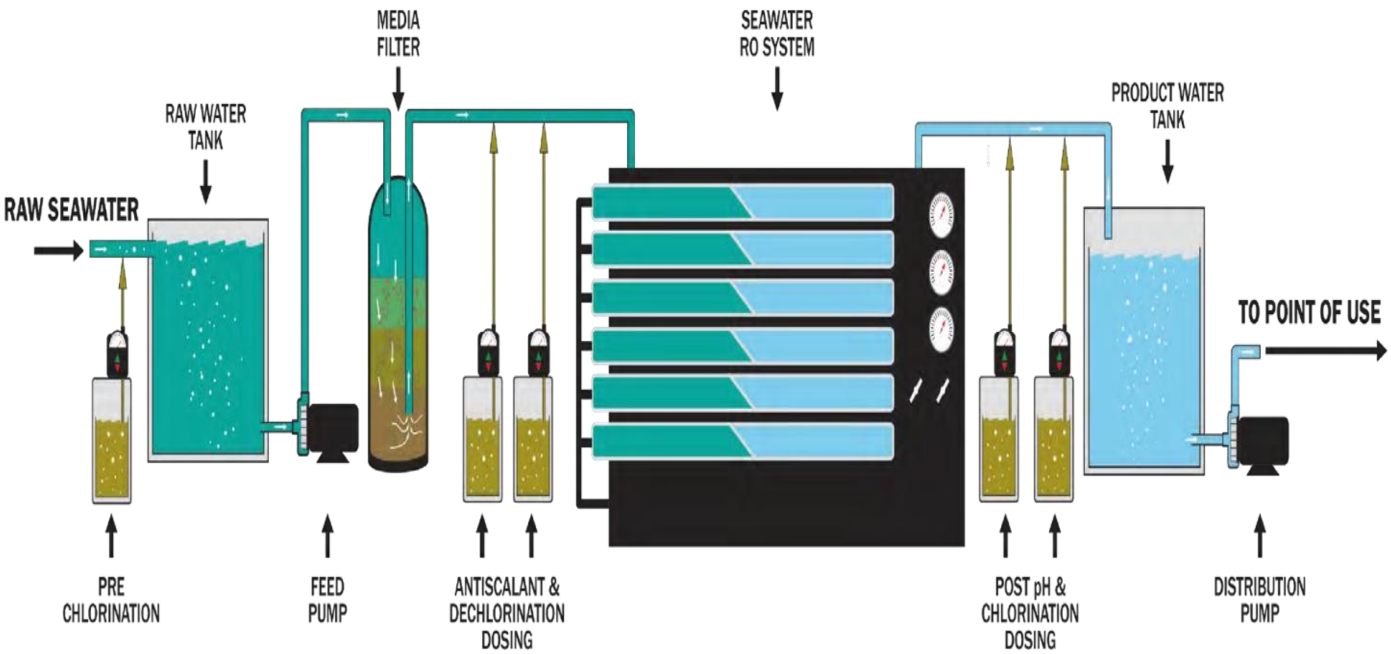
1. Water Quality: RO systems from Pure Aqua and other providers have consistently shown their capability to remove over 99.5% of salt and impurities from seawater. This high removal rate is significant as it converts seawater into potable water that meets international drinking water standards, ensuring a safe and reliable water source.
2. Energy Efficiency: Systems equipped with energy recovery devices (ERDs) have been proven to reduce the energy consumption of seawater desalination to around

2.5 to 4 kWh per cubic meter of water produced. This makes RO technology particularly viable for remote locations, where energy resources may be limited.

3. Production Capacity: Previous installations, such as the 48,000 GPD (gallons per day) seawater reverse osmosis system installed in Belize for a resort, demonstrate the adaptability of these systems to meet the daily water demands of small communities or FOBs. This ensures that the system can be tailored to specific needs.
4. Durability and Materials: RO systems for harsh marine environments use corrosionresistant materials such as Duplex Stainless Steel 2205 and Monel, ensuring longer operational life and reduced maintenance requirements. These materials make the system highly dependable for extended use in coastal and marine settings.
5. Environmental Impact: These systems minimize their environmental footprint by utilizing solar power and advanced filtration technologies. Implementing solarpowered desalination significantly reduces reliance on fossil fuels, making it a responsible and eco-friendly option for Belize’s FOBs.

The case studies and metrics from Pure Aqua, Inc. robust data and the successful deployment of similar systems in coastal Belize, which include high-tech features such as a 48,000 gallons per day production capacity, advanced PLC control systems, and Energy Recovery Turbines (ERTs), provide valuable insights ("Seawater reverse osmosis systems SWRO," n.d.). These installations, located at coastal resorts with environmental and logistical conditions comparable to those at the Forward Operating Bases (FOBs), confirm that the technology is well-suited to meet operational demands. Even though we will be using electrical energy at the FOBs and are not interested in incorporating solar energy or turbines**,** the successful performance of these systems in similar environments strongly supports the decision to adopt this technology for our operations.

Figure 8 *Typical Sea Water RO System Flow Diagram*



Note: Typical flow diagram of the Reverse Osmosis (RO) system used for seawater desalination, which showcases the stages from pre-treatment to post-treatment. *Pure Acqua Inc. Reverse Osmosis and water treatment systems* retrieved 6th October 2024 from https://pureaqua.com/seawater-reverse-osmosis-systems-swro/

4.2. Initiating Project Charter and Stakeholder Identification for Seawater Filtration System Implementation

The project charter provides a comprehensive overview of the Project Management

Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases (FOBs). The charter includes essential information such as the project's estimated start and end dates, general and specific objectives, and a description of the deliverables specifically, the installation of a sustainable seawater filtration system using reverse osmosis technology to meet the potable water needs at the FOBs.

The project charter details the anticipated benefits, such as increased operational efficiency, cost savings, and improved staff welfare, achieved through a consistent and reliable potable water supply. The charter outlines the project's assumptions, risks, and constraints, essential for guiding the project team in minimizing potential disruptions and ensuring smooth execution.

The project charter identifies the key stakeholders involved in the project, including the Belize Coast Guard personnel, project management team, contractors, and government agencies, and highlights major milestones such as project initiation, system installation, pilot testing, and final handover.

Chart 7

Project Charter for Seawater Filtration System for Belize Coast Guard Forward Operating Bases (Source: Author of the study)

PROJECT CHARTER	
Date	**Project Title**
Feb-25	Implementation of a Pilot Seawater Filtration System at a Belize Coast Guard Forward Operating Base
Knowledge areas/processes	**Application area (industry or sector)**
Knowledge areas: project management plan, project scope management, project schedule management, project cost management, project resource management, project quality management, project communications management, project risk management, project procurement management, project stakeholder management.	Military Infrastructure/Environmental Management/ Water Treatment, Sustainability, Public Health
Processes:	
Project Management, System Design, Procurement, System Installation, Training & Hand over, Monitor & Testing	

Start date	End date
Feb-25	Oct-25
Project Objectives (General and Specific)	
General Objective:	
To develop a comprehensive project management plan for implementing a sustainable seawater filtration system at the Belize Coast Guard Forward Operating Bases. This plan aims to ensure a reliable supply of potable water, enhance operational efficiency, and improve personnel welfare.	
Specific Objective:	

1. Conduct a comprehensive assessment of existing seawater filtration technologies and systems for the Belize Coast Guard Forward Operating Bases.

2. Implement initiation processes, including developing the project charter and identifying key stakeholders to establish a high-level project structure for the seawater filtration system.

3. Elaborate and develop the project management plan, including the creation of subsidiary management plans for scope, schedule, costs, resources, quality, communications, risks, acquisitions, and stakeholders, to define the project baselines for the seawater filtration system.

4. Select tools and techniques and define procedures for the execution of the seawater filtration system project.
5. Evaluate the cost-effectiveness, energy efficiency, and ease of maintenance of the proposed seawater filtration system from a conceptual and theoretical point of view, applying research to develop a well-defined case study.

6. Establish a project monitoring and control system through tools and techniques to ensure the effective integration of project objectives and goals.

7. Define a project closure procedure that includes the final evaluation of objectives and goals achievement, lessons learned reporting, and product transfer to operations management.

Justification or Purpose of the project:

The Belize Coast Guard's remote Forward Operating Bases face challenges in maintaining a reliable potable water supply. Existing solutions, such as external water procurement and rainwater harvesting, are unsustainable and expensive. Implementing a seawater filtration system using reverse osmosis technology will ensure a consistent supply of potable water, leading to enhanced operational efficiency, cost savings, and improved welfare for personnel. This project aims to address these issues by introducing a sustainable and scalable water solution. The initial pilot system will serve as a model for future installations at other Forward Operating Bases.
Key Deliverables
Project Management Plan: Comprehensive plan covering scope, schedule, cost, risk, and quality management. Seawater Filtration System Installation: Reverse osmosis system installed and operational at the selected Forward Operating Base. Operation and Maintenance Manual: Documentation provided to personnel for system management. Monitoring and Reporting System: Tools to monitor system performance and generate regular reports. Pilot System Evaluation: Final report evaluating system performance and recommending improvements for scaling.
Risk Identification
Weather-related delays: Adverse weather conditions may disrupt installation. Technical challenges: The reverse osmosis system may not perform optimally due to unforeseen technical issues. Stakeholder resistance: Potential resistance from stakeholders may cause delays in project approvals. Budget constraints: Unforeseen costs could exceed the allocated budget, requiring adjustments to project scope or timeline.
Assumptions
Reverse osmosis technology will be the most viable solution for the specific conditions at the base. Adequate funding will be available to cover procurement, installation, and operational costs. Key stakeholders will support the implementation and provide necessary approvals. The selected base has the infrastructure necessary for installation.

Constraints	
The project is limited to pilot installation at one base. Environmental factors, such as weather or water salinity, may impact on the system's performance. Availability of equipment and specialized expertise could delay the procurement and installation phases.	
Budget	
The total budget expected to implement this project is $100,675.64 USD	
Project Milestones	
Activity	Date
Project Charter Approval	Feb-25
Technology Assessment & Selection	Mar-25
Procurement Process Completion	Apr-25
System Installation	Jun-25
Personnel Training	Jul-25
Pilot Testing System Begins	Aug-25
System Evaluation & Adjustments	Sep-25
Handover and Report Submission	Oct-25
Stakeholders	
Key stakeholders include the Belize Coast Guard, the Ministry of Defense, environmental agencies, and external consultants.	
Project Manager: Susely Valdez	Signature:
Project Sponsor: Belize Coast Guard	Signature:

Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" (Valdez, 2024).

4.2.1 Identifying Key Stakeholders

Identifying stakeholders is essential for successfully implementing the Project Management Plan for the seawater filtration system at the Belize Coast Guard Forward Operating Bases (FOBs). This process involves recognizing and documenting all individuals, groups, or organizations directly or indirectly affected by the project. Effective identification ensures a clear understanding of each stakeholder's role, interests, and potential influence.

The primary advantage of this approach is that it allows the project team to tailor engagement strategies according to each stakeholder's specific needs and levels of involvement. A detailed stakeholder analysis will identify stakeholders and assess their authority, interest, and impact on the project's success. This comprehensive analysis will significantly foster positive relationships and ensure active participation from all relevant stakeholders throughout the project's lifecycle.

This process lays the groundwork for deeper engagement, which will be elaborated upon in subsequent management strategies and methods.

4.2.1.1 Development to Stakeholder Register in the Seawater Filtration Project

Identifying, engaging, and managing stakeholders is essential for success in any project, particularly one as technically complex and operationally critical as implementing a seawater filtration system at the Belize Coast Guard Forward Operating Bases (FOBs). This project, which is significant, requires the active involvement and support of all stakeholders throughout its lifecycle.

This section focuses on crucial stakeholder management activities, specifically developing a Stakeholder Register and a Stakeholder Engagement Plan. These tools are vital for managing communications, roles, responsibilities, and expectations for all parties involved. The Stakeholder Register plays a crucial role in organizing information and ensuring that appropriate communication methods and engagement strategies are employed throughout the project, underscoring its importance.

4.2.1.2 Function Role - identifies whether the stakeholder acts as a sponsor, service provider, beneficiary, or regulatory body. This helps in understanding the type of influence they hold in the project.

4.2.1.3 Roles and responsibilities - section details the specific duties or obligations of each stakeholder, clarifying their involvement and expectations in the project's execution.

4.2.1.4 Requirements - column lists what each stakeholder needs from the project to effectively fulfill their role. This might include compliance with timelines, adherence to technical standards, or receiving adequate updates and communication.

4.2.2.5 Main Expectation- represents the primary outcome that each stakeholder is anticipating from the project, ensuring that their interests and goals are met.

4.2.2.6 Power and Interest - columns indicate the stakeholder's level of influence over the project (High, Medium, or Low) and their interest in its success. Stakeholders with high power can significantly impact project outcomes, while those with high interest are deeply concerned with the project's success, even if their direct influence is minimal. This structured approach allows the project team to prioritize engagement efforts and communication strategies based on the influence and interest of each stakeholder.

Chart 8

Stakeholder Register for Seawater Filtration System (Source: Author of the study)

Stakeholder	Function Area	Roles – Responsibilities	Major Requirements	Main Expectation	Power	Interest
RADM Elton Bennett	Project Sponsor	Strategic guidance, ensures alignment with Coast Guard goals	Ensure project is completed successfully within scope and budget	Effective implementation to improve operational readiness	High	High
Belize Coast Guard HQ	National Implementing Agency	Coordinates logistics and operational support	Project to meet operational requirements, within schedule	Improved sustainability and potable water supply	High	High
Contractors (Installation Team)	Service Provider	Responsible for the technical installation and maintenance of filtration system	Adhere to technical specifications, meet timelines	Successful and timely installation of the filtration system	High	Medium
Ministry of Defense and Environmental Agencies	Regulatory Body	Ensure regulatory compliance with environmental impact	Ensure compliance with legal and environmental regulations	Compliance with environmental laws and minimal impact	High	Low

Project Manager	Project Management	Oversee overall project execution, manages timelines, budget, and resources	Ensure project execution within timeline and budget	Smooth implementation of the project within defined constraints	High	High
Stakeholder	**Function Area**	**Roles – Responsibilities**	**Major Requirements**	**Main Expectation**	**Power**	**Interest**
Coast Guard Personnel (End-users)	Project Beneficiaries	Use and maintain the filtration system	Receive operational training and system updates	Reliable potable water supply, ease of use	Medium	High
Suppliers (Technology Providers)	Service Provider	Supply equipment and technology for the filtration system	Compliance with delivery terms as per contract	Timely and quality delivery of equipment and technology	Medium	Medium
Local Community	Beneficiaries/Advocates	Engage with project's environmental impact and potential benefits to community	Transparent updates on environmental impact	Minimal environmental disruption	Low	Low

Other Military Units	Stakeholders	Provide logistical support when required	Coordination with shared resources and communication	Adequate coordination to support logistical needs	Low	Low

Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" the table categorizes each stakeholder by their role, responsibilities, and communication preferences. (Valdez, 2024)

4.3. Project Management Plan

4.3.1 Scope Management Plan

4.3.1.1 Introduction

The Project Management Institute (2021) defines a Scope Management Plan as a "component of the project management plan that describes how the scope will be defined, developed, monitored, controlled, and validated" (PMI, 2021). This Scope Management Plan provides a framework for managing the scope of the seawater filtration system project for the Belize Coast Guard Forward Operating Bases (FOBs). It outlines the processes required to ensure the project scope is clearly defined, documented, and controlled to meet its objectives while staying within the approved budget and schedule.

The plan also describes the approach for managing scope changes and addressing potential deviations from the original project scope. It includes collecting requirements, defining the scope, developing the Work Breakdown Structure (WBS), creating a WBS dictionary, creating a scope baseline, and implementing processes for scope verification and control. The purpose is to ensure that only the required work is executed, minimizing scope creep and ensuring all project objectives are achieved within the given constraints.

The objective of the seawater filtration project is to install a reliable reverse osmosis desalination system at the FOBs to provide a sustainable potable water supply. This will improve the operational readiness of Coast Guard personnel and combine broader environmental sustainability goals.

4.3.1.2 Define Scope

The scope of the Seawater Filtration System Project was defined through a detailed requirements collection process involving key stakeholders from the Belize Coast Guard, the Ministry of National Defence, and environmental experts. This collaborative approach addressed the critical need for a sustainable potable water supply at the Forward Operating Bases (FOBs) by implementing a reverse osmosis desalination system.

Chart 9

Scope Definition for Seawater Filtration System (Source: Author of the study)

Project Name	Seawater Filtration System for Belize Coast Guard Forward Operating Bases
Project Description	The project aims to install a reverse osmosis seawater filtration system at the Belize Coast Guard Forward Operating Bases (FOBs) to provide a reliable and sustainable source of potable water. This will enhance the operational efficiency of the bases, improve personnel welfare, and align with environmental sustainability goals. Current water sources (external procurement and rainwater harvesting) are unreliable, and the filtration system will mitigate these challenges.
Implementing Entity	Belize Coast Guard, Ministry of National Defence
Project Components	1. Design and Engineering of Filtration System: Tailored design plans for system installation considering each FOB's specific conditions.
	2. Procurement of Filtration Equipment: Sourcing and purchasing reverse osmosis membranes, pumps, and necessary accessories.
	3. Installation of the Filtration System: On-site installation, testing, and commissioning of the system at designated FOBs.
	4. Training and Capacity Building: Training Coast Guard personnel on operation and maintenance of the system.
	5. Monitoring and Evaluation: Continuous water quality testing and system performance monitoring post-installation.

Acceptance Criteria	- The system provides potable water meeting quality standards.
	- Coast Guard personnel are trained in system operation and maintenance.
	- The system is successfully installed and tested at all identified FOBs.
	- Post-installation water quality tests confirm the system's efficiency.
Constraints	- Schedule: Project must be completed within 12 months.
	- Cost: Project is restricted by the approved budget covering procurement, installation, and training.
	- Logistics: Remote FOB locations may pose challenges for transporting equipment and personnel.
Assumptions	1. Timely delivery of equipment.
	2. Regulatory approvals and permits are obtained without delays.
	3. Sufficient personnel are available for training and system operation.
	4. Environmental conditions do not hinder the installation process.

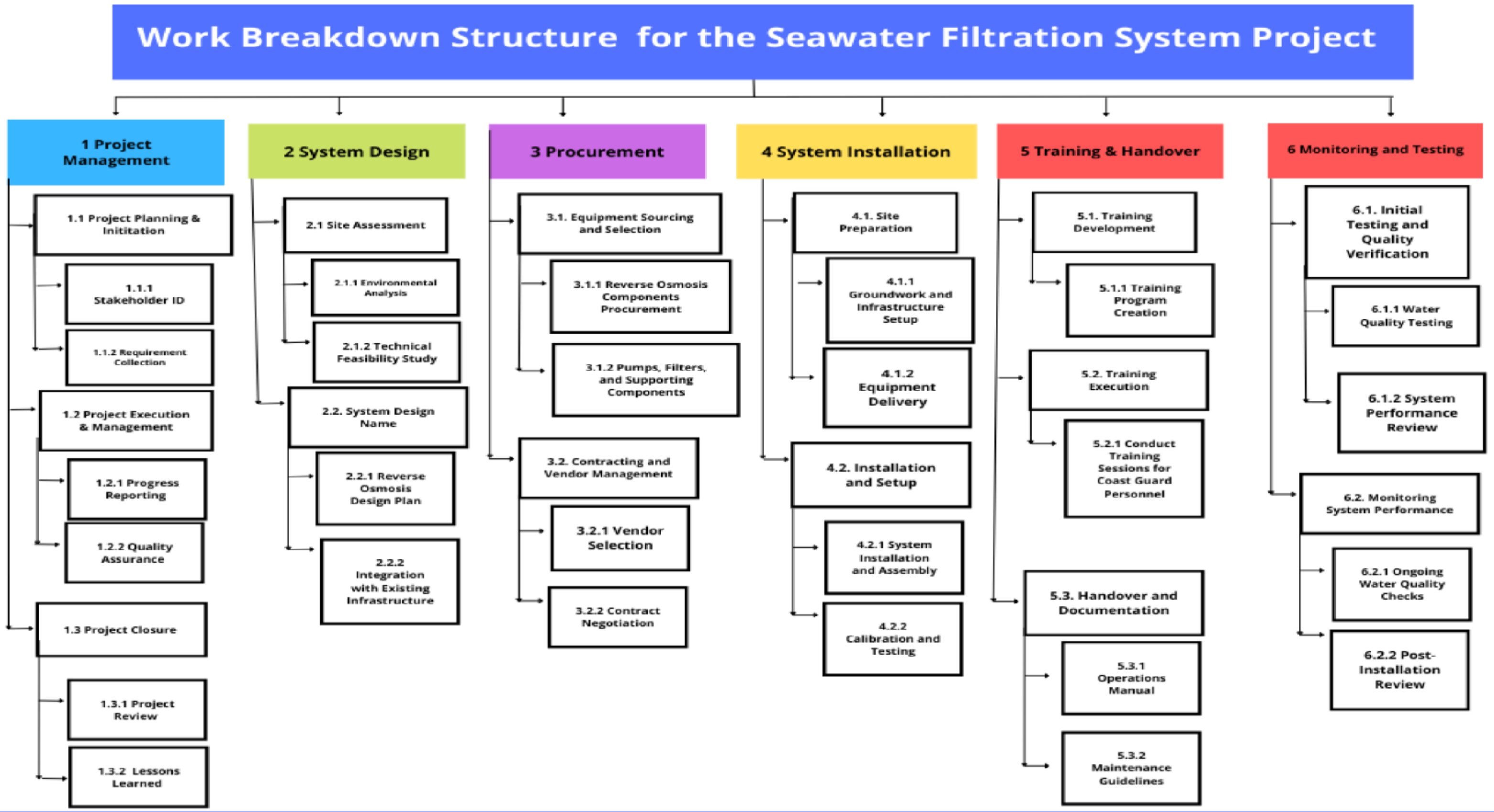
Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" the table provides a clear and concise breakdown of the project scope and its components. (Valdez, 2024).

4.3.1.3 Work Breakdown Structure (WBS)

The Work Breakdown Structure (WBS) for the Seawater Filtration System Project breaks down the project into smaller, manageable components, providing a clear view of the tasks required to complete the project successfully. This hierarchical structure helps allocate resources, assign responsibilities, and monitor the project's progress. Below is a simplified WBS for the project:

Figure 9

Work Breakdown Structure (WBS) for the Seawater Filtration System Project



Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" the WBS provides a clear framework for understanding all components and deliverables of the project. (Valdez, 2024).

4.3.1.3 Work Breakdown Structure (WBS) Dictionary

The Work Breakdown Structure (WBS) Dictionary complements the WBS by providing detailed descriptions of each work package and task within the project. It serves as a reference guide to ensure that all team members and stakeholders clearly understand the scope of each activity, the resources required, and the responsibilities assigned. This dictionary is critical for effectively managing the project, as it helps the project manager allocate resources, track progress, and ensure that the project stays on schedule and within budget.

Chart 10

Work Breakdown Structure (WBS) Dictionary for the Seawater Filtration System Project (Source: Author of Study)

WBS ID	Task Name	Description of Work	Resources
1	**Project Management**	**Oversee and coordinate the entire project from planning to completion.**	**Project Manager, Project Team, Stakeholders**
1.1	Project Planning and Initiation	Establish project objectives, stakeholders, and overall timeline.	Project Manager, Stakeholders
1.1.1	Stakeholder Identification	Identify all key stakeholders for the project, including Coast Guard leadership and environmental experts.	Project Manager, Stakeholders
1.1.2	Requirements Collection	Gather detailed requirements from stakeholders regarding water needs and system capabilities.	Project Manager, Coast Guard Personnel, Engineers
1.2	**Project Execution and Monitoring**	**Implement the project plan and continuously monitor progress, adjusting as necessary.**	**Project Manager, Project Team**
1.2.1	Progress Reporting	Provide regular updates to stakeholders on the progress of the project.	Project Manager, Project Team
1.2.2	Quality Assurance	Ensure that all deliverables meet the required quality standards, particularly the water filtration system's performance.	Project Manager, Quality Control Team
1.3	**Project Closure**	**Complete the project, including all documentation and lessons learned.**	**Project Manager, Project Team**
1.3.1	Final Review	Conduct a final review to ensure that all objectives are met, and all systems are operational.	Project Manager, Coast Guard Representatives

1.3.2	Lessons Learned	Compile lessons learned from the project for future use.	Project Manager, Project Team

2	**System Design**	**Design the seawater filtration system based on environmental and operational conditions of each FOB.**	**Engineers, Environmental Specialists**
2.1	Site Assessment	Assess each FOB to determine design requirements.	Engineers, Environmental Specialists
2.2	System Design Plan	Create a detailed plan for the reverse osmosis filtration system.	Engineers, Project Manager
WBS ID	**Task Name**	**Description of Work**	**Resources**
3	**Procurement**	**Procure all necessary equipment and materials for the filtration system.**	**Procurement Manager, Suppliers**
3.1	Equipment Sourcing	Identify and purchase reverse osmosis filtration units, pumps, and additional components.	Procurement Manager, Suppliers
3.2	Vendor Management	Manage relationships with vendors to ensure timely delivery and quality of equipment.	Procurement Manager
4	**System Installation**	**Install the seawater filtration system at each designated FOB.**	**Project Team, Installation Technicians**
4.1	Site Preparation	Prepare each FOB for system installation, including infrastructure setup.	Installation Technicians, FOB Personnel
4.2	Equipment Installation	Install and assemble the filtration system.	Installation Technicians
4.3	System Calibration and Testing	Test the system to ensure proper functionality and adjust as needed.	Engineers, Quality Control Team
5	**Training and Handover**	**Train Coast Guard personnel on the operation and maintenance of the filtration system.**	**Training Team, Coast Guard Personnel**

5.1	Training Program Creation	Develop training materials and manuals.	Training Team
5.2	Training Execution	Conduct hands-on training sessions with Coast Guard personnel.	Training Team
5.3	Handover Documentation	Provide operational manuals, maintenance guides, and system documentation to Coast Guard personnel.	Training Team, Documentation Specialists
6	**Monitoring and Testing**	**Ensure ongoing performance and water quality through regular monitoring.**	**Quality Control Team, Coast Guard Personnel**
6.1	Water Quality Testing	Test water quality post-installation to ensure it meets potable standards.	Quality Control Team, Engineers
6.2	System Performance Review	Regularly review system performance to detect and address any issues.	Engineers, Coast Guard Personnel

Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" the table provides a complete and structured description of each part of the project (Valdez, 2024).

4.3.1.4 Scope Verification

The scope verification for the seawater filtration system project will ensure that all deliverables meet the defined project requirements and align with the expectations of the Belize Coast Guard and other stakeholders. The process will be conducted in two stages to ensure thorough verification and approval.

1. **On-Site Verification by the Project Manager**:
    - The project manager will conduct regular on-site inspections at the Forward Operating Bases (FOBs) where the seawater filtration systems are installed. These checks will focus on verifying that the filtration systems have been installed according to the approved design and that all components are functioning as required.
    - Photographs, installation reports, and system test results will be collected to document the process and ensure that the installed system meets the technical specifications outlined in the project plan.
2. **Reports and Deliverables Verification**:
    - After the on-site checks, the project manager will prepare detailed reports on the installation process and system functionality. These reports will include visual evidence (photographs) and performance data to support the verification.
    - The reports will then be submitted to the Project Steering Committee for review and final approval.

3. **Stakeholder Review and Sign-Off**:
   - Review meetings will be arranged with stakeholders, including representatives from the Belize Coast Guard, to present the project deliverables. During these meetings, the stakeholders will assess whether the project objectives and deliverables align with their initial expectations.
   - Acceptance criteria for the seawater filtration systems will be defined in advance, ensuring that all parties agree on the standards for functionality and quality.
   - The stakeholders will require formal sign-off once the systems are validated to meet all criteria.
4. **Handling Scope Changes**:
   - A formal change control procedure will be implemented if any deviations or necessary adjustments are identified during the verification process. Any changes to the scope will require stakeholder approval before being executed.

4.3.1.5 Scope Control

The scope control process for the seawater filtration system project ensures alignment with the approved scope while managing changes effectively. The following procedures will be implemented:

- The project manager and team will continually monitor progress using the Work Breakdown Structure (WBS) Dictionary. This ensures that only WBS-defined tasks and deliveries are executed, with any deviations promptly addressed.
- The Project Manager will report to the Project Steering Committee to ensure activities align with the established scope. The committee will review progress reports and oversee adherence to scope control procedures.
- A formal change request process will manage proposed modifications. Ongoing communication will be maintained with stakeholders, including the Belize Coast Guard, to ensure transparency and alignment with project goals.
- Necessary approvals will be obtained before implementing changes. Regular reviews will monitor progress and address scope management issues immediately to prevent scope creeping.

4.3.1.7 Scope Change

Any member of the project team can request a change to the project scope for the seawater filtration system at any time. To initiate a change, the requester must submit a request to the project manager, detailing the rational and potential impacts on objectives, timelines, budget, and resources.

The project manager will conduct an impact analysis to assess how the change may affect the project. Significant changes impacting key factors will be escalated to the Project Board or the project sponsor for final approval. Once approved, the change will be documented and communicated to the project team and stakeholders. Adjustments will be reflected in the project's scope baseline and plan, ensuring careful management of scope changes in alignment with project objectives.

4.3.1.8 Scope Requirement Traceability Matrix

Chart 11

Requirements Traceability Matrix (Source: Author of the study)

ID	Importance	Responsible	Category	Requirement	WBS Code
1	High	RADM Elton Bennett	Stakeholder Requirement	Identify and engage key stakeholders	1.1.1
2	High	Project Manager	Project Requirement	Collect and document all system requirements	1.1.2
3	High	Project Manager, Engineers	Nonfunctional Requirement	Ensure system compliance with operational and environmental standards	1.2.2
4	High	Contractors	Functional Requirement	Install and test seawater filtration components	4.2
5	High	Ministry of Defense and Environmental Agencies	Business Requirement	Ensure adherence to environmental regulations and safety standards	2.1
6	High	Suppliers	Project Requirement	Deliver fully functional and calibrated filtration systems	4.3

7	High	Local Community	Transition and Readiness	Raise awareness and support for system implementation	1.3.2
ID	**Importance**	**Responsible**	**Category**	**Requirement**	**WBS Code**
8	High	Coast Guard Personnel	Quality Requirement	Perform water quality testing postinstallation	6.1
9	Medium	Other Military Units	Stakeholder Requirement	Collaborate on system deployment across shared sites	3.2
10	Medium	Contractors	Functional Requirement	Prepare sites for system installation	4.1
11	Medium	Project Manager	Project Requirement	Provide regular progress updates to stakeholders	1.2.1
12	Medium	Suppliers	Functional Requirement	Procure and deliver all necessary equipment	3.1
13	Medium	Training Team	Training Requirement	Train Coast Guard personnel on system operation and maintenance	5.2
14	Low	Quality Team	Quality Assurance	Conduct final system performance checks and validation	6.2

15	Low	Project Manager	Lessons Learned	Document lessons learned for future reference	1.3.1

Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" the table outlines the key project requirements, their importance, responsible parties, categories, and corresponding work breakdown structure (WBS) codes to ensure traceability and alignment with project objectives. (Valdez, 2024).

This Requirements Traceability Matrix connects the project's requirements with specific work packages from the Work Breakdown Structure (WBS). It outlines the importance of each requirement, assigns responsibilities, and categorizes requirements to ensure traceability throughout the project lifecycle.

4.3.2 Schedule Management Plan

The Project Schedule Management Plan is designed to identify and document the specific actions required to produce and submit project deliverables. Its purpose is to ensure that all activities are not only planned, sequenced, and executed by the schedule, but also proactively managed, with a clear focus on analyzing activity sequences, work requirements, schedule estimations, and resource allocation. This plan also addresses scheduling constraints and incorporates backup plans to manage delays effectively. As a component of the overall project management plan, the schedule management plan establishes criteria for developing, monitoring, and controlling the schedule. Activities are defined and documented in the Work Breakdown Structure (WBS) and refined Activity List Chart, with details on task descriptions, dependencies, milestones, and required resources.

Tasks are sequenced using Predecessors/Successors analysis to ensure proper order and identify the critical path for schedule-sensitive activities. Durations are estimated using historical data, expert judgment, and resource availability, with schedule buffers included for high-risk tasks. Resource planning assigns personnel, equipment, and materials for each task, while resource leveling optimizes utilization. The project schedule integrates all activities, durations, and dependencies, visually represented through tools such as Gantt charts. Regular progress updates monitor alignment with the baseline schedule, and variances are managed with corrective actions. The plan also outlines contingency measures, including risk mitigation strategies, backup plans, and critical path adjustments to address delays. Key deliverables include a detailed and approved schedule aligned with milestones, regular progress reports, and completing all tasks by the project's end date in October 2025. This comprehensive and proactive approach ensures adherence to the schedule and minimizes risks of delays.

4.3.2.1 Activity List Chart

The following task is used to identify the activities that are to take place, sequence of events are the necessary resources needed per task. This ensures that a sequence of work allows the project utmost efficiency to be achieved throughout the project and despite project constraints. The processes here are performed throughout the entire project. The use of lag time may be used to complete one task and continue another however, most activities are aligned with each other.

Chart 12

Activity List Chart

Coding	Activity Name	Predecessors/Successors	Activity Duration
1	Project Management	None/1.1	272 days
1.1	Project Planning and Initiation	1/1.1.1	15 days
1.1.1	Stakeholder Identification	1.1/1.1.2	5 days
1.1.2	Requirements Collection	1.1.1/1.2	10 days
1.2	Project Execution and Monitoring	1.1.2/1.2.1	30 days
1.2.1	Progress Reporting	1.2/1.2.2	5 days
1.2.2	Quality Assurance	1.2.1/1.3	10 days
1.3	Project Closure	1.2.2/1.3.1	20 days
1.3.1	Final Review	1.3/1.3.2	10 days
1.3.2	Lessons Learned	1.3.1/2	5 days
2	System Design	1.3.2/2.1	40 days
2.1	Site Assessment	2/2.2	15 days
2.2	System Design Plan	2.1/3	25 days
3	Procurement	2.2/3.1	60 days
3.1	Equipment Sourcing	3/3.2	30 days
3.2	Vendor Management	3.1/4	30 days
4	System Installation	3.2/4.1	50 days
4.1	Site Preparation	4/4.2	20 days
4.2	Equipment Installation	4.1/4.3	15 days
4.3	System Calibration and Testing	4.2/5	20 days
5	Training and Handover	4.3/5.1	35 days
5.1	Training Program Creation	5/5.2	10 days
5.2	Training Execution	5.1/5.3	10 days
5.3	Handover Documentation	5.2/6	20 days
6	Monitoring and Testing	5.3/6.1	40 days
6.1	Water Quality Testing	6/6.2	20 days
6.2	System Performance Review	6.1/None	15 days

Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration

System in Belize Coast Guard Forward Operating Bases" the activity list chart has been created, including columns for coding, activity name, predecessors/successors, and activity duration (Valdez, 2024).

4.3.2.2 Duration Estimates

Duration estimates are crucial in project management, as they help ensure that projects are completed within the allocated schedule and budget. In the context of the seawater filtration system project for the Belize Coast Guard, these estimates are vital for delivering all components, including installation, calibration, training, and handover, within the 9-month timeline. The project schedule management plan highlights the importance of duration estimates. This plan integrates scheduling and cost management to efficiently deliver the seawater filtration system. The project is set to commence in February 2025 and is expected to conclude by October 2025, with built-in buffers to accommodate any unforeseen delays or quality issues.

Chart 13

Activity list chart with milestones, brief activity description, predecessors/successors list, and resources (Source: Author of the Study)

Coding	Activity Name	Milestone	Brief Activity Description	Predecessor	Successor	Required Resources Per Activity
1	Project Management	Project Management	Oversee and coordinate the entire project from planning to completion.	None	1.1	Project Manager, Project Team, Stakeholders
1.1	Project Planning and Initiation	Project Management	Establish project objectives, stakeholders, and overall timeline.	1	1.1.1	Project Manager, Stakeholders
1.1.1	Stakeholder Identification	Project Management	Identify all key stakeholders for the project, including Coast Guard leadership and environmental experts.	1.1	1.1.2	Project Manager, Stakeholders
1.1.2	Requirements Collection	Project Management	Gather detailed requirements from stakeholders regarding water needs and system capabilities.	1.1.1	1.2	Project Manager, Coast Guard Personnel, Engineers
1.2	Project Execution and Monitoring	Project Management	Implement the project plan and continuously monitor progress, adjusting as necessary.	1.1.2	1.2.1	Project Manager, Project Team

Coding	Activity Name	Milestone	Brief Activity Description	Predecessor	Successor	Required Resources Per Activity
1.2.1	Progress Reporting	Project Management	Provide regular updates to stakeholders on the progress of the project.	1.2	1.2.2	Project Manager, Project Team
1.2.2	Quality Assurance	Project Management	Ensure that all deliverables meet the required quality standards, particularly the water filtration system's performance.	1.2.1	1.3	Project Manager, Quality Control Team
1.3	Project Closure	Project Management	Complete the project, including all documentation and lessons learned.	1.2.2	1.3.1	Project Manager, Project Team
1.3.1	Final Review	Project Management	Conduct a final review to ensure that all objectives are met, and all systems are operational.	1.3	1.3.2	Project Manager, Coast Guard Representatives
1.3.2	Lessons Learned	Project Management	Compile lessons learned from the project for future use.	1.3.1	2	Project Manager, Project Team

Coding	Activity Name	Milestone	Brief Activity Description	Predecessor	Successor	Required Resources Per Activity
2	System Design	System Design	Design the seawater filtration system based on environmental and operational conditions of each FOB.	1.3.2	2.1	Engineers, Environmental Specialists
2.1	Site Assessment	System Design	Assess each FOB to determine design requirements.	2	2.2	Engineers, Environmental Specialists
2.2	System Design Plan	System Design	Create a detailed plan for the reverse osmosis filtration system.	2.1	3	Engineers, Project Manager
3	Procurement	Procurement	Procure all necessary equipment and materials for the filtration system.	2.2	3.1	Procurement Manager, Suppliers
3.1	Equipment Sourcing	Procurement	Identify and purchase reverse osmosis filtration units, pumps, and additional components.	3	3.2	Procurement Manager, Suppliers
3.2	Vendor Management	Procurement	Manage relationships with vendors to ensure timely delivery and quality of equipment.	3.1	4	Procurement Manager

Coding	Activity Name	Milestone	Brief Activity Description	Predecessor	Successor	Required Resources Per Activity
4	System Installation	System Installation	Install the seawater filtration system at each designated FOB.	3.2	4.1	Project Team, Installation Technicians
4.1	Site Preparation	System Installation	Prepare each FOB for system installation, including infrastructure setup.	4	4.2	Installation Technicians, FOB Personnel
4.2	Equipment Installation	System Installation	Install and assemble the filtration system.	4.1	4.3	Installation Technicians
4.3	System Calibration and Testing	System Installation	Test the system to ensure proper functionality and adjust as needed.	4.2	5	Engineers, Quality Control Team
5	Training and Handover	Training and Handover	Train Coast Guard personnel on the operation and maintenance of the filtration system.	4.3	5.1	Training Team, Coast Guard Personnel
5.1	Training Program Creation	Training and Handover	Develop training materials and manuals.	5	5.2	Training Team
5.2	Training Execution	Training and Handover	Conduct hands-on training sessions with Coast Guard personnel.	5.1	5.3	Training Team

5.3	Handover Documentation	Training and Handover	Provide operational manuals, maintenance guides, and system documentation to Coast Guard personnel.	5.2	6	Training Team, Documentation Specialists
6	Monitoring and Testing	Monitoring and Testing	Ensure ongoing performance and water quality through regular monitoring.	5.3	6.1	Quality Control Team, Coast Guard Personnel
6.1	Water Quality Testing	Monitoring and Testing	Test water quality postinstallation to ensure it meets potable standards.	6	6.2	Quality Control Team, Engineers
6.2	System Performance Review	Monitoring and Testing	Regularly review system performance to detect and address any issues.	6.1	None	Engineers, Coast Guard Personnel

Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" the activity list chart has been created, including milestones, description, predecessors/successors, and resources (Valdez, 2024).

4.3.2.3 Process description and Importance

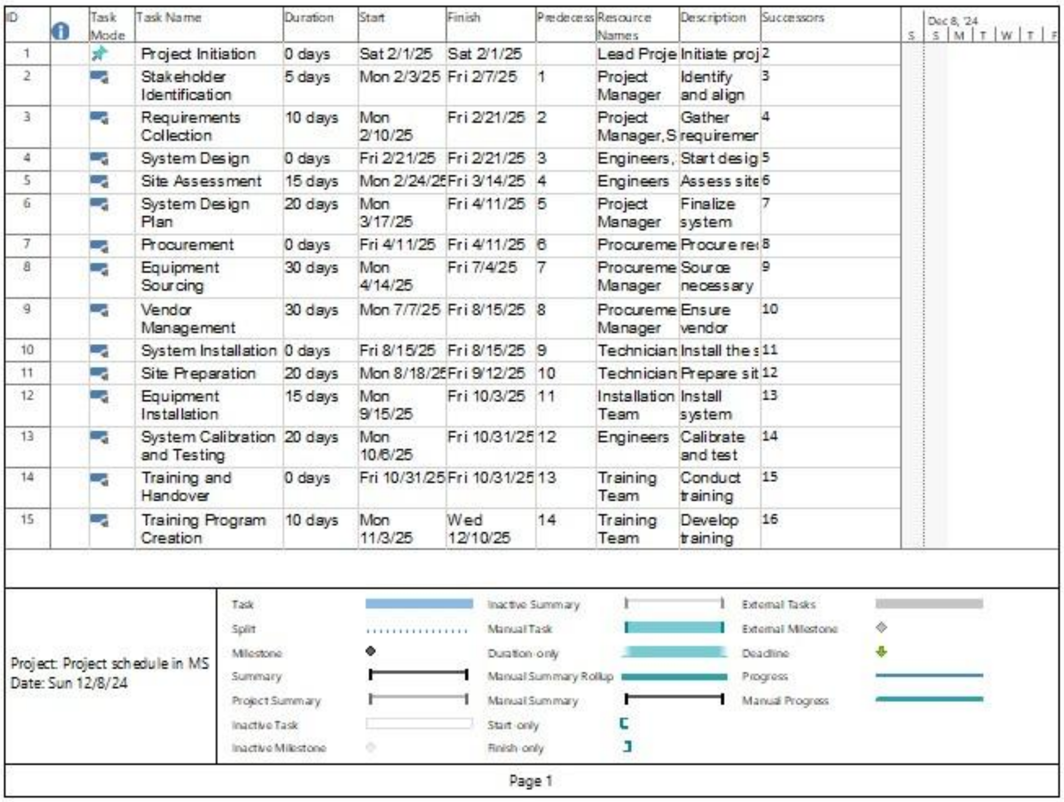
A project schedule is the backbone of successful project management, providing a detailed roadmap outlining tasks, durations, and deadlines. By presenting a structured timeline, the schedule facilitates efficient resource utilization and better management. It allows teams to set achievable milestones, identify potential risks, and track progress effectively, ensuring goals are met within specified timeframes. A well-crafted schedule is crucial for keeping all stakeholders aligned, ensuring everyone is on the same page and the project on track.

The critical path, a key component of project scheduling, represents the sequential chain of tasks that determines the shortest possible duration for project completion. Tasks on the critical path have zero slack, indicating their pivotal role in the project timeline. Understanding the critical path is crucial as it guides focus on essential activities. This guidance enables managers to allocate resources efficiently, prioritize efforts on timesensitive tasks, and minimize the likelihood of delays.

The synergy between a comprehensive project schedule and a clear understanding of the critical path is not just important, it's fundamental to successful project management. While the detailed schedule aids in planning and tracking, the critical path helps prioritize crucial activities. Together, they empower project managers to make informed decisions, optimize resource allocation, and ensure project delivery within the defined timelines and budgets. Mastering both components is key to achieving successful project outcomes.

Chart 10

Project schedule in MS Project

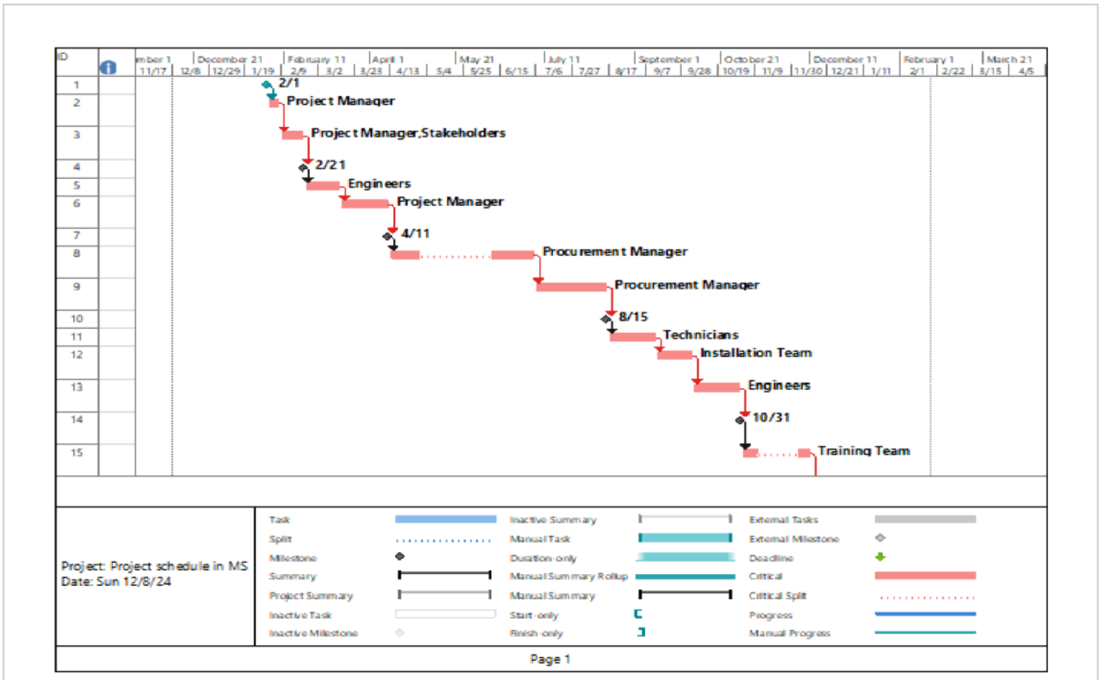


ID	Task Mode	Task Name	Duration	Start	Finish	Predecess	Resource Names	Description	Successors
1		Project Initiation	0 days	Sat 2/1/25	Sat 2/1/25		Lead Proje	Initiate proj	2
2		Stakeholder Identification	5 days	Mon 2/3/25	Fri 2/7/25	1	Project Manager	Identify and align	3
3		Requirements Collection	10 days	Mon 2/10/25	Fri 2/21/25	2	Project Manager, S	Gather requiremer	4
4		System Design	0 days	Fri 2/21/25	Fri 2/21/25	3	Engineers,	Start desig	5
5		Site Assessment	15 days	Mon 2/24/25	Fri 3/14/25	4	Engineers	Assess site	6
6		System Design Plan	20 days	Mon 3/17/25	Fri 4/11/25	5	Project Manager	Finalize system	7
7		Procurement	0 days	Fri 4/11/25	Fri 4/11/25	6	Procureme	Procure re	8
8		Equipment Sourcing	30 days	Mon 4/14/25	Fri 7/4/25	7	Procureme Manager	Source necessary	9
9		Vendor Management	30 days	Mon 7/7/25	Fri 8/15/25	8	Procureme Manager	Ensure vendor	10
10		System Installation	0 days	Fri 8/15/25	Fri 8/15/25	9	Technician	Install the s	11
11		Site Preparation	20 days	Mon 8/18/25	Fri 9/12/25	10	Technician	Prepare sit	12
12		Equipment Installation	15 days	Mon 9/15/25	Fri 10/3/25	11	Installation Team	Install system	13
13		System Calibration and Testing	20 days	Mon 10/6/25	Fri 10/31/25	12	Engineers	Calibrate and test	14
14		Training and Handover	0 days	Fri 10/31/25	Fri 10/31/25	13	Training Team	Conduct training	15
15		Training Program Creation	10 days	Mon 11/3/25	Wed 12/10/25	14	Training Team	Develop training	16

Notes: Source: Author of the study.

Chart 11

Critical Path



Notes: Source: Author of the study.

4.3.3 Cost Management Plan

The Cost Management Plan for the Seawater Filtration System Project outlines the processes for planning, estimating, budgeting, managing, and controlling costs to ensure the project is completed within the approved budget. This plan provides a structured approach to allocate and supervise expenses throughout the project lifecycle. Cost estimates for physical and human resources are derived from the Work Breakdown Structure (WBS) and historical data from similar projects, a practice that instills confidence in the accuracy of our projections. The budget includes all associated costs, contingency reserves, and management reserves, ensuring the efficient allocation of resources to meet project deliverables. The Project Manager, with support from the accounting and procurement teams, will monitor and control the budget to achieve the project objectives successfully.

4.3.3.1 Estimate Budget

The cost estimation for the seawater filtration system project outlines a financial breakdown for each activity within the Work Breakdown Structure (WBS). To determine costs for key activities such as procurement, installation, and commissioning, we utilized analogous estimation based on historical data from similar projects, along with expert judgment. Parametric estimation was used, considering factors like system capacity and energy efficiency to calculate costs for components and services. These methods ensure accurate predictions of project expenses. The estimated costs, presented in USD, provide insight into the financial requirements, facilitating effective planning and resource allocation. For a detailed breakdown of these costs, please refer to the accompanying figure 12, which supports transparency and informed decision-making throughout the project lifecycle.

Figure 12 *Estimated Budget for the Seawater Filtration Project*

COST ESTIMATING AND BUDGETING					
Activity	**Code**	**Description**	**Cost (USD)**	**Contingency Reserve**	**Total Cost**
Project Management	1	Planning, stakeholder identification, and requirements collection	$2,000		
	1.1	Project Planning and Initiation	Included above		
	1.1.1	Stakeholder Identification	Included above		
	1.1.2	Requirement Collection	Included above		
		Subtotal	**$2,000**	**$200**	**$2,200**
System Design	2	Site assessment and designing the seawater filtration system	$1,000		
		Subtotal	**$1,000.00**	**$100.00**	**$1,100.00**

Procurement	3.1	Equipment for remineralization and UV disinfection	$27,594		
	3.1.1	Spare Parts	$2,797		
	3.1.2	Post-Treatment Equipment	$2,010		
		Fresh Water Storage -Rotoplas Water Tank (260 gal, 5 unit @ $520)	$2,600		
		Switch Box and Power Supply	$700		
		Feed Line (Pressure Pipe) 200 ft @$5 /ft	$1,000		
		Production Line (Pressure Pipe) 100 ft @$5	$500		
		Subtotal	**$37,201**	**$3,720.10**	**$40,921**
System Installation	4.1	Preparing bases for system installation	$1,500		
	4.2	Installing the filtration system	$3,000		
	4.2.2	Testing the system and ensuring functionality	$1,308		
	4.3	System Calibration and Testing	$1,500		
		Subtotal	**$ 7,308.00**	**$ 730.80**	**$ 8,038.80**
Training and Handing Over	5	On-site setup and personnel training	$6,802		
		Subtotal	**$6,802**	**$680.20**	**$7,482**
Monitoring and	6.1.2	Electricity cost for desalination (annual)	$2,578		
	6.1.2	Membranes, filters, and spare parts (Annual)	$892		
	6.2.1	Optional annual Remote support service	$436		
		Subtotal	**$3,906.00**	**$390.60**	**$4,296.60**
		Total	**$58,217.00**	**$5,821.70**	**$64,038.70**
		Management Reserve			**$3,201.94**
		Total Project Budget			**$67,240.64**

Notes: Source: Author of the study.

The human resources budget is included as a reference to ensuring comprehensive planning, although most roles are already covered by existing Coast Guard personnel or supplier agreements, reflecting the project's resource-efficient approach.

Chart 14

Human Resources Cost (Source: Author of the study)

Category	Resource	Monthly Salary (USD)	Project Duration	Total Cost per Resource (USD)	Quantity	Total Cost per Category (USD)
Human Resources	Project Manager	2,625	9 months	23,625	1	23,625
	Administrative Staff	1,090	9 months	9,810	1	9,810
	Technical Engineer	Provided by supplier	N/A	0	N/A	0
	Logistics Personnel	Existing Coast Guard role	N/A	0	N/A	0
	Training Specialist	Included in supplier cost	N/A	0	N/A	0
					Total	$33,435.00

Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" the human resources budget ensures comprehensive planning while leveraging existing Coast Guard personnel and supplier agreements for resource efficiency (Valdez, 2024).

4.3.3.2 Determine Cost

The budget for the Seawater Filtration System project is established by summing up the estimated costs of all work packages detailed in the Work Breakdown Structure (WBS). This total includes components such as project management, system design, procurement, installation, training, monitoring, and testing, as presented in the accompanying table. To account for identified risks and uncertainties that may arise during project execution, a contingency reserve of ten percent (10%) of the subtotal is added. This total, which incorporates the contingency reserve, constitutes the cost baseline and represents the approved expenditure on the project.

A management reserve of five percent (5%) of the cost baseline is included to address unforeseen risks or issues that may occur during implementation. The project manager determines this reserve, which serves as a safeguard for unexpected expenses. The final budget, which includes both the cost baseline and the management reserve, is submitted to project sponsors for approval, ensuring transparency and financial accountability.

The total cost baseline for the seawater filtration system project is $64,038.70, with an additional management reserve of $3,201.94, resulting in the overall project budget. This structured budgeting process ensures thorough financial planning and effective resource allocation, facilitating the project's successful delivery.

Chart 15

Determined Cost (Source: Author of the Study)

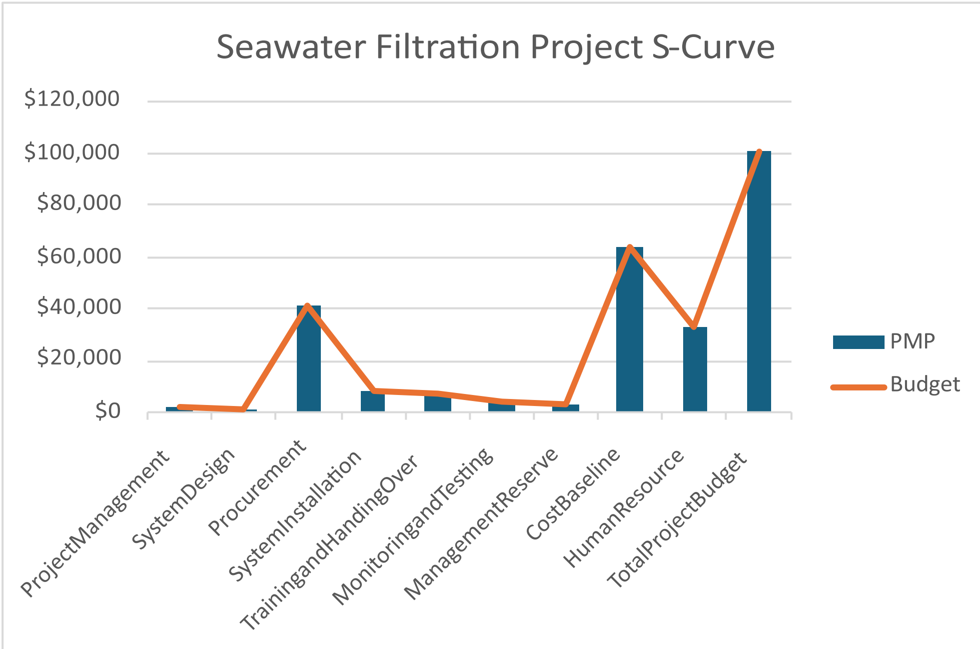
Seawater Filtration System	
Project Management	$2,200
System Design	$1,100.00

Procurement	$40,921
System Installation	$ 8,038.80
Training and Handing Over	$7,482
Monitoring and Testing	$4,296.60
Management Reserve	$3,201.94
Cost Baseline	$64,038.70
Human Resource	$33,435.00
Total Project Budget	$100,675.64

Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" The total project budget, including a 10% contingency reserve and a 5% management reserve, ensures comprehensive financial planning and risk mitigation for the seawater filtration system (Valdez, 2024)

Figure 13

S-Curve



Notes: Source: Author of the study.

4.3.3.3 Control Cost

Once the budget for the seawater filtration system project is approved, a comprehensive cost control process will be implemented to ensure that all expenditures align with the approved budget and project goals. The project manager will monitor and manage costs throughout the project lifecycle using tools such as Cost Variance Analysis, inspections, and monthly expenditure reports. Monthly expenditure reports will track spending against a predetermined cost baseline to identify any deviations. If significant deviations occur, corrective actions will be initiated. These actions may include reallocating funds, implementing cost-saving measures, or submitting a Change Request Form for the approval of budget adjustments. Inspections will be conducted to verify that actual work corresponds to the budgeted expenditures, ensuring the efficient and planned use of funds. These inspections will occur during key project phases, including system installation and training sessions.

The project manager will review monthly reports and variances, presenting findings to the Project Steering Committee for decisions on corrective measures. This iterative process ensures transparency, accountability, and alignment with project objectives, enabling the team to effectively respond to financial risks and maintain control over the project's costs.

4.3.4 Resources Management Plan

This Resource Management Plan ensures the effective identification, allocation, acquisition, and utilization of human, physical, and technical resources to achieve the project's objectives of implementing a seawater filtration system for the Belize Coast Guard Forward Operating Bases (FOBs).

4.3.4.1 Resource Categories

Chart 16 Resource Categories for Seawater Filtration System (Source: Author of the Study)

Category	Resource	Description
Human Resources	Project Manager	Oversee the project lifecycle and ensure alignment with objectives.
	Technical Engineers	Responsible for installation, maintenance, and troubleshooting of the filtration system.
	Logistics Personnel	Manages transportation of equipment and materials to project sites.
	Training Specialist	Conducts on-site training for operational and maintenance teams.
	Administrative Staff	Handles documentation, procurement coordination, and general administrative tasks.

Physical Resources	Equipment	Includes the seawater filtration system (RObased), pre-filtration units, energy recovery devices, and UV systems.
	Spare Parts	Comprises filters, membranes, cartridges, and pumps (feedwater and distribution).
	Tools	Includes piping materials, monitoring/control units, and transport vessels and vehicles for logistics.
	Freshwater Storage Tanks	Used for holding filtered water for usage and distribution.
Financial Resources	Initial Investment	$40,921 for procurement of the filtration system, transport, and commissioning.
	Operational Costs	$3,906 annually for electricity, parts, and maintenance.
Technical Resources	Manuals and Guidelines	Provide instructions for operation and maintenance.
	IT Systems	Enable remote monitoring and control of the filtration system.

Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" the table provides a structured breakdown of the essential resources required for implementing the seawater filtration system at the Belize Coast Guard Forward Operating Bases. (Valdez, 2024).

4.3.4.2 Roles and Responsibilities

Chart 17 Roles and Responsibilities of Human Resources (Source: Author of the study)

Role	Responsibility
Project Manager	Oversee the project lifecycle, including budget, schedule, and stakeholder communication.
Technical Engineers	Install the desalination units, troubleshoot technical issues, and provide operational expertise.
Logistics Coordinator	Ensure timely delivery of all physical resources and manage storage.
Training Specialist	Educate personnel on system operation and maintenance.

Procurement Specialist	Manage contracts, acquire resources, and ensure compliance with procurement policies.

Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" the table outlines the key personnel involved in the implementation and operation of the seawater filtration system and their respective responsibilities. (Valdez, 2024).

4.3.4.3 Tools and Equipment

This table divides the resources provided (from the manufacturer) and Coast Guard responsibilities. It also clearly identifies who is responsible for acquiring, managing, or implementing each resource. The physical resources for the project are outlined in Table 30 below.

Chart 18

Tools and Equipment for Seawater Filtration Project (Source: Author of the study)

Physical/Technical Resource	Quantity/Details	Responsible
Submersible Pump	1 unit	Provided with Efficient Water Maker
Multimedia Filter (Natural Filtration)	1 unit	Provided with Efficient Water Maker
10-micron Meter Absolute Cartridge Filter	1 unit	Provided with Efficient Water Maker
5-micron Nominal Cartridge Filter	1 unit	Provided with Efficient Water Maker
Efficient Water Maker	1 unit	Project Procurement Team
Saltwater Return	Coast Guard to provide	Belize Coast Guard Logistics Officer
Remineralization (post-treatment)	1 unit	Provided with Efficient Water Maker
Fresh Water Storage	Coast Guard to provide	Belize Coast Guard Logistics Officer

UV and Active Carbon Filter (PostTreatment)	1 unit	Provided with Efficient Water Maker
Flush Tank	1 unit	Provided with Efficient Water Maker
Flush Pump	1 unit	Provided with Efficient Water Maker
Cartridge Filter	1 unit	Provided with Efficient Water Maker
Control Box	1 unit	Provided with Efficient Water Maker
Switch Box	1 unit	Provided with Efficient Water Maker
Power Supply	1 unit	Provided with Efficient Water Maker
A 904L (Super Duplex) Feed Water Pump	1 unit	Technical Specialist
Remote Monitoring and Control	Included	Provided with Efficient Water Maker
Skid-Built Equipment	Included	Provided with Efficient Water Maker
Spare Parts Package	1 set for 2 years	Provided with Efficient Water Maker
Remote Support for Operations (Year 1)	Included	Provided with Efficient Water Maker
Fresh Water Storage Product Tank	Coast Guard to provide	Belize Coast Guard Logistics Officer
Feed Water Intake	Coast Guard to construct	Belize Coast Guard Damage and Control Department
Feed Line (Pressure Pipe)	Length depends on distance	Belize Coast Guard Damage and Control Department
Production Line (Pressure Pipe)	Length depends on distance	Belize Coast Guard Damage and Control Department
Physical/Technical Resource	**Quantity/Details**	**Responsible**
Technical Resource (Commission & Training)	Included (Onsite Engineers)	Provided with Efficient Water Maker
Permit (Seawater Extraction/Brine Discharge)	As required	Compliance Officer
Local Transportation	Coast Guard vessels	Belize Coast Guard Logistics Officer

Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" the table divides the resources into provided (from the manufacturer) and Coast Guard responsibilities. (Valdez, 2024).

4.3.5 Quality Management Plan

The Quality Management Plan for the seawater filtration system project outlines the processes and criteria to ensure that all deliverables meet the quality standards and expectations of the Belize Coast Guard and other key stakeholders.

4.3.5.1 Quality Assurance

The Quality Assurance Plan for the seawater filtration system project aims to ensure that all processes, deliverables, and operations align with the rigorous standards required for delivering reliable, high-quality water at the Belize Coast Guard forward operating bases. Key quality factors include the quality of implementation, where team members must thoroughly understand system requirements and quality standards, and system reliability, which will be ensured through robust quality control, testing, and maintenance to withstand environmental and operational challenges. The system's performance is also a priority, aiming to maintain at least 95% uptime under high salinity and challenging conditions. Comprehensive training ensures Coast Guard personnel are proficient in system operation and maintenance and in promoting sustainable system use. Adherence to health, environmental, and safety regulations is also critical to consistently meeting water purity standards to achieve 99% purity in filtered water. Effective cost management further supports project objectives, ensuring expenses remain within budget through strategic planning and procurement practices.

Quality assurance metrics will be applied regularly to monitor and maintain these standards. Weekly water purity checks will verify the system's ability to maintain 99% purity, while monthly uptime reviews will confirm system reliability, aiming for at least

95% operational time. Training will be evaluated to ensure that 100% of personnel are certified, with final training assessments scheduled upon completion of training. Compliance reports will be reviewed quarterly to verify adherence to all regulatory standards, and monthly budget variance checks will help maintain cost control. Maintenance records will also be reviewed monthly to ensure all scheduled maintenance tasks are completed, further supporting system reliability. This structured Quality Assurance Plan emphasizes continuous improvement through regular audits, inspections, and training, ensuring that the project consistently meets its quality objectives and aligns with operational and regulatory standards throughout its lifecycle.

4.3.5.2 Quality Control

The Quality Control Plan for the seawater filtration system project will apply rigorous monitoring to ensure that project outcomes meet established quality standards, as described in PMBOK Guide 8.3.1. Input to Quality control will involve an ongoing review of deliverables and management metrics—such as cost, schedule, and operational performance—to ensure they align with project expectations. Quality control activities will be performed throughout the project lifecycle to identify and address any discrepancies or non-conformities promptly.

To evaluate project quality effectively, the project management team will employ statistical quality control techniques, understanding key concepts such as prevention (keeping errors out of the process) versus inspection (keeping errors out of the final product), attribute sampling (determining if results conform to standards) versus variables sampling (measuring degrees of conformity), special causes versus random causes of variation, and tolerances versus control limits for acceptable results. Critical inputs for quality control include work results (both planned and actual), the quality management plan, operational definitions, and checklists. These inputs provide a baseline for assessing quality and ensuring adherence to project standards.

The tools and techniques applied in this quality control plan include inspections, control charts, Pareto diagrams, statistical sampling, flowcharting, and trend analysis. Inspections will measure and test project outputs at various stages to confirm that they meet established requirements. Control charts will monitor project progress and highlight whether variances are due to random factors or special causes requiring attention. Pareto diagrams will help the project team prioritize corrective actions by identifying the most common sources of defects. Statistical sampling will reduce quality control costs by examining a representative sample of deliverables instead of every item. Flowcharting will assist in diagnosing the root causes of issues, while trend analysis will help project managers anticipate potential problems in technical performance and schedule adherence.

Quality control output includes acceptance decisions, rework requirements, completed checklists, and necessary process adjustments. Acceptance decisions involve determining whether inspected items meet quality standards. If items do not meet requirements, they will be flagged for rework, bringing them into compliance, though the team will strive to minimize rework to avoid cost overruns. Completed checklists will document quality verification for each stage and form part of the project's records. Process adjustments may involve corrective or preventive measures to realign project performance with quality goals, following overall change control procedures when necessary. Through this structured Quality Control Plan, the project team will ensure that the seawater filtration system meets the desired quality standards, resulting in a reliable and efficient final product.

4.3.5.3 Continuous Improvement Plan

The continuous improvement process will be implemented by the project team, with corrective actions documented in a Lessons Learned Register. Monthly quality reviews will focus on identifying areas for improvement, with corrective actions to address any identified deficiencies. For example, if water purity levels fall below the 99% target, immediate adjustments will be made to filter maintenance schedules, and any additional filters needed will be installed. Continuous feedback will be encouraged from all team members to refine processes and enhance quality outcomes.

4.3.5.4 Key factors related to quality

For the seawater filtration system project, chart 19 outlines the key factors related to quality Each of these factors ensures that the project meets high-quality standards across all operational, regulatory, and cost-related aspects, directly contributing to a successful and sustainable seawater filtration system for the Belize Coast Guard.

Chart 19

Key factors related to quality (Source: Author of the study)

Factor	Factor Definition
Quality of Implementation	Project team members must have a thorough understanding of system requirements and quality standards for the seawater filtration system.

System Reliability	The filtration system's reliability is ensured through quality control measures, rigorous testing, and scheduled maintenance to withstand environmental and operational challenges.
Performance	The system should demonstrate efficient operation under high salinity and challenging conditions, with a target of at least 95% operational uptime.
Training	Comprehensive training for Coast Guard personnel is essential to ensure the correct and sustainable operation and maintenance of the system.
Regulatory Compliance	Adherence to health, environmental, and safety regulations is critical, ensuring that the filtered water consistently meets established purity standards.
Cost Management	Effective control over project expenses ensures that budget limitations are maintained, achieved through strategic planning and procurement practices.

Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" the table outlines the key quality factors ensure system reliability, water purity, regulatory compliance, and efficient, costeffective operation. (Valdez, 2024).

4.3.5.5 Metrics and Quality Baseline

With the vital quality factors established, the team has defined specific metrics to assess whether deliverables meet the quality objectives. Chart 20 provides a detailed breakdown of metrics, including their definitions, expected outcomes, measurement frequency, and designated reviewers.

Chart 20

Metrics and Quality Baseline (Source: Author of the study)

Quality Objective	Metric	Metric Definition	Expected Outcome/Result	Measurement Frequency	Responsible
Achieving consistent high-water purity	% Purity	Measures the purity of water produced	Maintain at least 99% purity	Weekly	Project Manager
Ensure system reliability	Uptime %	Measures system operational uptime	Target uptime of 95% or higher	Monthly	Technical Lead
Certify personnel in system operations	% Certified	Percentage of personnel trained and certified	100% of personnel fully certified	End of training	Training Coordinator
Comply with regulatory standards	Compliance Reports	Regulatory inspection and audit results	Full adherence to regulatory standards	Quarterly	Environmental Officer
Maintain budget adherence	Budget Variance	Comparison of actual expenses to budget	Costs remain within budget limits	Monthly	Finance Team
Verify system performance and upkeep	Maintenance Records	Documentation of completed maintenance tasks	All scheduled maintenance actions completed	Monthly	Project Manager

Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" (Valdez, 2024)

4.3.6 Communications Management Plan

The Communication Management Plan for the seawater filtration system project aims to promote clear and efficient communication among all stakeholders from beginning to end. It details how project information will be shared, how often it will be shared, and who is responsible for sharing it. By ensuring that all involved individuals are wellinformed and able to participate effectively, this plan encompasses formal and informal communication methods, including verbal exchanges and comprehensive written reports.

4.3.6.1 Communication Matrix

The chart provided below outlines the project's communication specifics, including methods, frequency, purpose, sender, and recipients of information. The communication matrix is a crucial tool for ensuring that each stakeholder receives pertinent updates based on their role and impact on the project.

Chart 21

Project Communication Matrix (Source: Author of Study)

Communication	Method	Frequency	Purpose	Sender	Receiver
Project Initiation Meeting	In-person/Virtual	Once (Feb 2025)	Introduce project objectives, schedule, roles, and goals.	Project Manager	RADM Elton Bennett, Belize Coast Guard HQ, Contractors, Ministry of Defense, Environmental Agencies
Monthly Status Reports	Email	Monthly	Track project progress, milestones, and risks.	Project Manager	RADM Elton Bennett, Belize Coast Guard HQ, Contractors, Ministry of Defense
Technical Review Meetings	In-person/Virtual	Bimonthly	Review technical specs, installation progress, and issues.	Project Manager	Contractors (Installation Team), Suppliers
Financial Progress Reports	Email/Meeting	Quarterly	Monitor budget, track expenditures, and forecast costs.	Finance Officer	Project Manager, RADM Elton Bennett, Coast Guard HQ
Regulatory Compliance Updates	Email/Meeting	Quarterly	Ensure compliance with environmental and legal regulations.	Project Manager	Ministry of Defense, Environmental Agencies
End-user Training Sessions	In-person	After installation	Train Coast Guard personnel on system operation and maintenance.	Project Manager	Coast Guard Personnel (Endusers)

Pilot System Testing Debrief	In-person/Virtual	Post-pilot testing (Sep 2025)	Evaluate system performance and collect feedback.	Project Manager	RADM Elton Bennett, Belize Coast Guard HQ, Contractors
Change Management Meetings	In-person/Virtual	As needed	Discuss changes in scope, schedule, or budget.	Project Manager	RADM Elton Bennett, Contractors, Ministry of Defense
Communication	**Method**	**Frequency**	**Purpose**	**Sender**	**Receiver**
Final Project Report and Handover	In-person/Email	End of project (Dec 2025)	Document project outcomes, lessons learned, and handover.	Project Manager	RADM Elton Bennett, Belize Coast Guard HQ, Contractors, Environmental Agencies, Coast Guard Personnel

Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" the matrix provides a structured approach to manage the flow of information, promoting clarity, accountability, and consistency throughout the project lifecycle. (Valdez, 2024).

4.3.7 Risk Management Plan

This risk Management Plan outlines the approach for identifying, analyzing, and mitigating risks associated with implementing a seawater filtration system in Belize Coast Guard forward operating bases (FOBs). This project addresses critical needs for a sustainable potable water supply and operational stability in remote areas. Effective risk management ensures the project's alignment with objectives and helps avoid potential disruptions.

4.3.7.1 Risk Management Process

4.3.7.1.1 Risk Identification

Risk identification is conducted through team brainstorming sessions, stakeholder interviews, and a review of environmental and project-specific factors. The primary risk sources include schedule delays, budget overruns, technical failures, ecological conditions, and stakeholder engagement issues.

4.3.7.1.2 Risk Breakdown Structure (RBS)

This Risk Breakdown Structure (RBS) provides a comprehensive categorization of risks to facilitate targeted mitigation strategies that align with your project's scope, schedule, and quality objectives. This Risk Breakdown Structure (RBS) offers a precise categorization of risks to support targeted mitigation strategies that align with your project's scope, schedule, and quality objectives.

1. Technical Risks: This section addresses system reliability and potential technical challenges, particularly those related to the unique conditions of saline environments.

2. Management Risks: This category includes risks associated with project coordination, resource allocation, and support from key stakeholders, which can impact project efficiency and adherence to the schedule and budget.
3. Commercial Risks: This section focuses on vendor reliability, supply chain issues, and market factors that may affect costs, potentially leading to delays or increased expenses.
4. External Risks: This category considers factors beyond the project's control, such as regulatory compliance, environmental impacts, and unpredictable weather conditions, which could disrupt project progress.

The following Chart 22. illustrates the risk breakdown structure (RBS) for the seawater filtration system in Belize Coast Guard forward operating bases (FOBs) that includes the risk categories that are likely to impact the project. The RBS is divided into four (4) main categories: technical, management, organizational, and external risks that will likely impact the project.

Chart 22

Risk Breakdown Structure (RBS) for Seawater Filtration System Project (Source: Author of the study)

RBS Level 0	RBS Level 1	RBS Level 2
All Sources of Project Risk	1. Technical Risks	1.1 Filtration system reliability and potential equipment failure in saline environments
		1.2 Limited availability or high cost of replacement parts
		1.3 Insufficient technical training for Coast Guard personnel
		1.4 Inaccurate project scope or requirements definition
	2. Management Risks	2.1 Delays due to insufficient resource allocation
		2.2 Poor coordination among project team and stakeholders
		2.3 Budget management challenges and potential cost overruns
		2.4 Inadequate support from Coast Guard leadership
	3. Commercial Risks	3.1 Supply chain delays impacting equipment delivery
		3.2 Cost increases due to market fluctuations and exchange rates
		3.3 Vendor contract disputes or unmet contractual obligations
		3.4 Limited availability of alternative suppliers for key components
	4. External Risks	4.1 Adverse weather conditions delaying installation or operation
		4.2 Environmental compliance and permitting delays
		4.3 Potential impact on local ecosystems, leading to community concerns
		4.4 Regulatory changes affecting operational requirements

Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" the RBS provides a clear overview of the risk landscape, helping to ensure comprehensive and proactive risk management. (Valdez, 2024).

4.3.7.2 Probability and Impact Matrix

The Probability and Impact Matrix is an essential tool in the qualitative risk analysis process, designed to assess the likelihood and consequences of identified risks and opportunities. It systematically evaluates risks, allowing the project team to assign numerical scores to each risk's probability (likelihood) and impact (consequence). These scores are typically on a scale from 1 to 5, where 1 represents the lowest and 5 represents the highest level of probability or impact.

Risks are plotted on the matrix grid according to their probability and impact scores, resulting in a probability-impact score (PxI) that reflects each risk’s overall significance to the project. For instance, a risk with a probability of 0.90 (or 90%) and an impact of 0.80 (or 80%) would yield a PxI score of 0.72, categorizing it as a high-priority risk due to its potential for considerable disruption or benefit.

Figure 14

Probability and Impact Matrix with Scoring Scheme

Probability	Threats					Opportunities					Probability
Very High 0.90	0.05	0.09	0.18	0.36	0.72	0.72	0.36	0.18	0.09	0.05	Very High 0.90
High 0.70	0.04	0.07	0.14	0.28	0.56	0.56	0.28	0.14	0.07	0.04	High 0.70
Medium 0.50	0.03	0.05	0.10	0.20	0.40	0.40	0.20	0.10	0.05	0.03	Medium 0.50
Low 0.30	0.02	0.03	0.06	0.12	0.24	0.24	0.12	0.06	0.03	0.02	Low 0.30
Very Low 0.10	0.01	0.01	0.02	0.04	0.08	0.08	0.04	0.02	0.01	0.01	Very Low 0.10
	Very Low 0.05	Low 0.10	Moderate 0.20	High 0.40	Very High 0.80	Very High 0.80	High 0.40	Moderate 0.20	Low 0.10	Very Low 0.05	
	Negative Impact					Positive Impact					

Note: Probability and Impact Matrix Adopted from A Guide to the Project Management Body of Knowledge PMBOK GUIDE (SIXTH EDITION, p.408) by Project Management Institute, Inc., 2017.

The matrix uses a color-coded scheme to easily visualize risk levels, with categories like very high (red), high (orange), medium (yellow), and low (green). This color coding provides a quick reference for the risk's priority level. High PxI scores generally require immediate mitigation or management responses, while lower scores may be monitored with less urgency. The matrix can be adjusted to reflect the unique characteristics of each project, with both positive impacts for opportunities and negative implications for threats defined clearly within the matrix. The results from the matrix analysis are then recorded in the risk register, forming the basis for subsequent risk response planning and monitoring.

Figure 15

PxI Numerical Scoring

PxI Numerical Score		
Low Risk	Green	(PxI <0-2)
Moderate	Moderate	(PxI 0.2-0.4)
High Risk	High Risk	(PxI 0.4 - 0.6)
Critical Risk	Critical Risk	(PxI >0.6)

Notes: Source: Author of the study

4.3.7.3 Risk Register

The Risk Register for the Seawater Filtration System Project is a detailed document that records individual project risks and is regularly updated as part of the risk management process. Following the Identify Risks phase, the register includes a comprehensive list of all identified risks, each assigned a unique identifier for easy reference. Each risk is described in detail to ensure a clear understanding, typically using structured risk statements that differentiate risks from their causes and effects. Each identified risk is assigned to a potential owner who will oversee its management, a confirmation made later during the qualitative risk analysis phase.

Chart 23

Risk Register (Source: Author of the Study)

RBS Level	Cause	Risk	Consequence	Probability	Impact	PxI	Trigger	Strategy	Owner
1. Management Risks									
1.1	Insufficient training of Coast Guard personnel	Personnel may struggle with operating and maintaining the filtration system	Delayed response times and potential system breakdowns	0.5	0.8	**0.4**	Frequent errors in system operation	Mitigate: Provide comprehensive training before deployment and periodic refreshers	Project Manager
1.2	Lack of communication between project team and external stakeholders	Misalignment of project requirements and expectations	Delays and misunderstandings, potentially impacting project scope	0.4	0.7	**0.28**	Conflicting updates from stakeholders	Avoid: Establish a communication management plan with regular updates	Project Sponsor
2. Technical Risks									
2.1	Environmental conditions affecting technology	Seawater salinity and debris may reduce system efficiency	Frequent maintenance required and potential breakdowns	0.6	0.9	**0.54**	Salinity buildup detected in system	Mitigate: Regular maintenance schedule and quality monitoring	Technical Lead

2.2	Limited access to repair parts and technical support	Downtime if equipment requires repairs	Extended system downtime, reducing water availability	0.5	0.8	**0.4**	System diagnostic showing error without available support	Mitigate: Keep essential spare parts on-site and train personnel in basic repairs	Project Manager
3. Commercial Risks									
3.1	Contractual disputes with suppliers	Delayed delivery of critical components	Delayed project schedule and potential budget increase	0.3	0.8	**0.24**	Missed component delivery deadline	Avoid: Establish clear contractual terms and penalties for delays	Procurement Officer
3.2	Increase in material costs	Potential for budget overruns	Project may exceed allocated funds, requiring rebudgeting	0.4	0.7	**0.28**	Market analysis showing price increase	Mitigate: Plan a buffer in the budget for cost fluctuations	Finance Team
4. External Risks									
4.1	Severe weather events (e.g., storms)	May damage the system or delay project activities	Interruptions in water supply, risking operational effectiveness	0.7	0.9	**0.63**	Weather warnings issued	Accept: Install weather-resistant measures where possible	Safety Officer

4.2	Regulatory compliance issues	Environmental standards may require adjustments in setup	Project delays due to compliance checks and modifications	0.3	0.5	**0.15**	Regulatory body request for additional compliance measures	Mitigate: Engage with environmental authorities early to understand requirements	Environmental Officer

Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" the risk register document, track, and manage risks associated with a project. (Valdez, 2024).

4.3.7.3.1 Qualitative Risk Analysis

The Qualitative Risk Analysis for the Seawater Filtration System Project prioritizes risks by assessing their probability and impact. Severe Weather Events pose the most critical threat among the identified risks, with a high PxI score of 0.63. This risk demands immediate attention, as severe weather could severely impact the filtration system's structure and functionality. Proactive responses such as reinforcing structures, installing weather-resistant measures, and developing contingency plans are recommended to mitigate this threat. Another high-priority risk is Environmental Conditions Affecting Technology, with a PxI score of 0.54. Given the saline environment, regular maintenance and quality monitoring should be implemented to reduce the likelihood of equipment damage. Insufficient Training of Coast Guard Personnel and Limited Access to Repair Parts and Technical Support are also significant risks, scoring 0.40 on the PxI scale. These risks highlight the need for comprehensive training programs to ensure operational readiness and maintain a stock of essential spare parts to minimize downtime. Moderate risks include a Lack of Communication Between the Project Team and External Stakeholders and Increased Material Costs, with PxI scores of 0.28 each. Establishing regular communication updates can help maintain alignment with stakeholders while planning for budget contingencies will address potential cost fluctuations.

Lower-priority risks include Contractual Disputes with Suppliers and Regulatory Compliance Issues, with PxI scores of 0.24 and 0.15, respectively. For these, the project team should focus on verifying contracts with clear dispute resolution clauses and maintaining proactive engagement with regulatory bodies to ensure compliance with environmental standards. This prioritization enables the project team to allocate resources effectively, focusing on mitigating high and critical risks while monitoring and managing lower-priority issues to support successful project implementation.

4.3.7.4 Risk Response Planning

The risk response plan for the seawater filtration project is designed to address each identified risk according to Roland Wanner's (2013) structured approach to risk management. For management risks, insufficient training of Coast Guard personnel could lead to delays and system breakdowns. This risk will be mitigated by providing comprehensive training before deployment, along with regular refreshers, to minimize operational errors and ensure prompt responses. To avoid miscommunication between the project team and external stakeholders, which could result in the misalignment of project requirements, a robust communication management plan with scheduled updates will be implemented to keep all parties aligned.

Technical risks include environmental impacts such as seawater salinity and debris. These will be managed by implementing a regular maintenance schedule and quality monitoring to detect and address salinity buildup early, thereby reducing the chance of breakdowns. Limited access to repair parts and technical support, which could result in extended downtime, will be mitigated by keeping essential spare parts on-site and training personnel in basic repairs, thus reducing dependence on external support.

Commercial risks, including potential contractual disputes with suppliers that may delay component delivery, will be addressed by establishing clear contractual terms with penalties for delays, ensuring accountability among suppliers. To counteract the risk of increased material costs potentially leading to budget overruns, a budget buffer will be set aside to accommodate fluctuations, thus providing financial stability.

For external risks, severe weather events that might disrupt the project will be accepted, with the implementation of weather-resistant measures and protocols for securing equipment in adverse conditions. To address regulatory compliance issues that may require adjustments to meet environmental standards, early engagement with environmental authorities will ensure clarity on requirements, allowing for timely adjustments in the project setup.

These strategies follow Project Management Institute guidance on the four-stage risk management process: avoiding, reducing, delegating, and bearing risks. Contingency and fallback plans for critical risks will be established, along with clear triggers to prompt timely response actions. By assigning specific owners to each risk, the project ensures accountability and an organized response plan that aligns with the defined mitigation and avoidance strategies (Project Management Institute, 2017, p.442-443).

4.3.4.6 Risk Monitoring and Control

The seawater filtration project's risk monitoring and control plan will be conducted according to Wanner's (2013) guidelines to ensure that identified risks are continuously evaluated and managed throughout the project. The goal is to systematically implement the risk response plan, periodically assess risks, and adjust strategies to respond to emerging or residual risks. During the monitoring phase, the project team will regularly review whether the initial risk response actions are practical and if risks are still relevant or have escalated in probability and impact. This process involves closely looking at key risk indicators and triggers, such as environmental changes that may affect system efficiency or unexpected delays in supply chains. Residual risks will be evaluated, and actions will be defined to prevent them from becoming significant issues while monitoring the project's critical path to ensure it remains aligned with time and resource allocations. By focusing on the top five critical risks identified in the risk register, the team will dedicate 70% of the risk monitoring efforts to these high-impact risks, using regular team meetings to make risks a priority topic, ensuring all members are aware and engaged in risk-related updates (Wanner, 2013). Monthly risk review meetings will allow the team to analyze new data, confirm the validity of risk assumptions, and implement any necessary corrective actions. If deviations from the original risk management plan are detected, corrective actions will be applied to bring the project back in line with objectives. The PMO will perform risk management audits periodically to confirm the effectiveness of the risk response actions and ensure that continuous improvement practices are integrated, reinforcing a proactive approach to risk management throughout the project (Wanner, 2013).

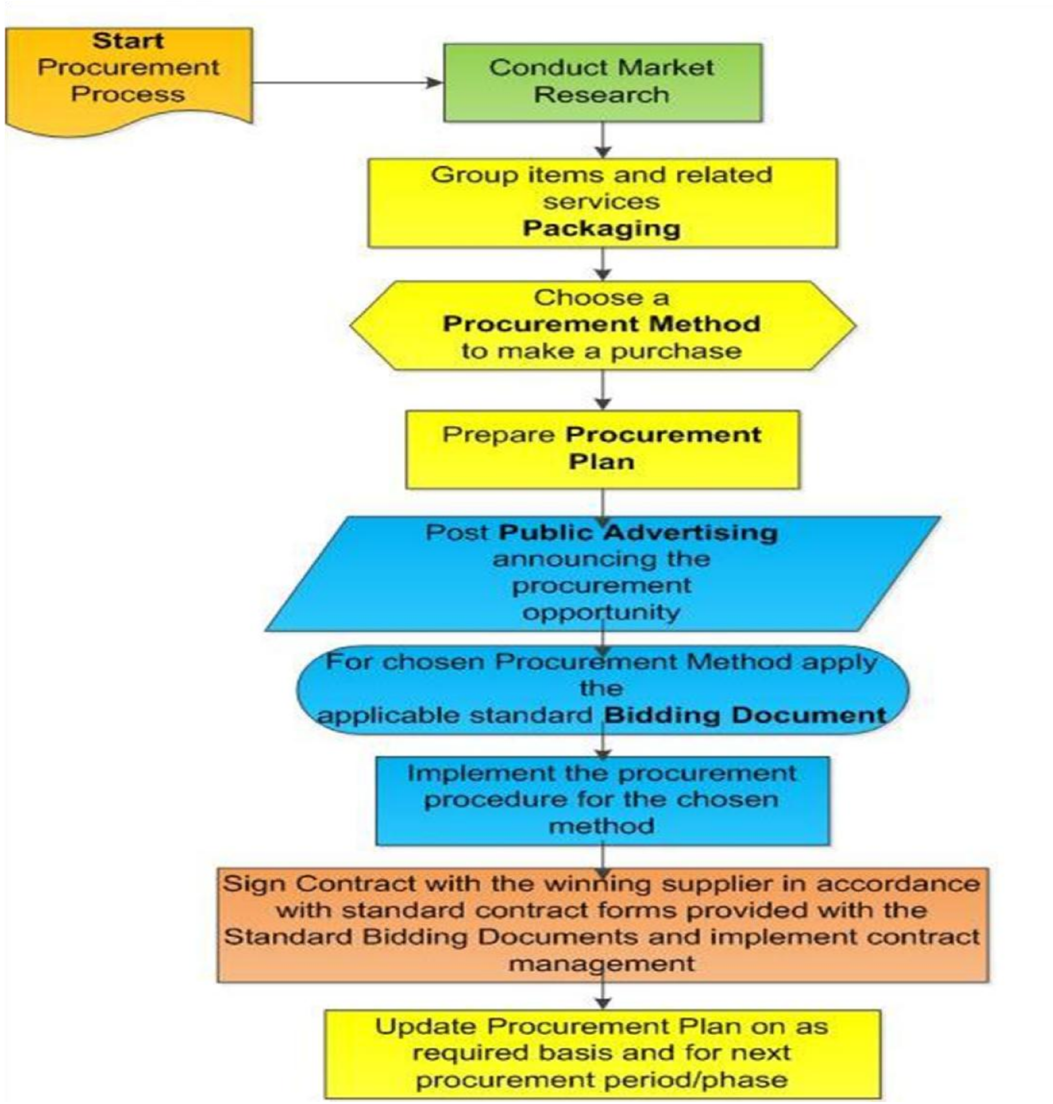
4.3.8 Procurement Management Plan

Procurement management plan is a common component of the project or program management plan that describes how a project team will acquire goods and services from outside of the performing organization (PMBOK SEVENTH Edition, 2021, p. 186). The procurement approach for the seawater filtration system follows the guidelines established in the **Public Procurement Procedures Handbook** as it applies to government bodies like the Belize Coast Guard, under the Ministry of Defense and Border Security. This approach ensures compliance with government procurement principles, emphasizing transparency, fairness, and value for money.

4.3.8.1 Procurement Phases

Figure 16

Overall Procurement Process for Goods and Works



Note: Overall Procurement Process for Goods and Works. *Public Procurement Handbook (Source: Volume I Standardized Procurement Procedures First Edition- January 2013)* retrieved 5th December 2024 from https://procurement.gov.bz/wpcontent/uploads/2023/09/HanbookPartIPublicSector.pdf

The Goods and Works Overall Procurement Process begins by identifying the need for goods or services that align with project objectives and scope. The next step is conducting market research to gather information about potential suppliers, market conditions, and available products, enabling informed decisions by comparing prices, quality, and delivery options while assessing vendor capabilities. Related items and services are then grouped into procurement packages to improve efficiency and reduce costs, with decisions made about bundling similar items or selecting multiple or single suppliers. The procurement method is chosen based on the size, complexity, and urgency of the project, with options such as open bidding for large procurements, shopping for routine needs, or direct contracting for urgent requirements. A detailed procurement plan is then prepared, outlining timelines, budget estimates, resources, and milestones to guide the process effectively. Public advertising is used to announce procurement opportunities, ensuring transparency and attracting broad vendor participation through platforms like government websites or newspapers. Standard bidding documents are applied to provide clear and consistent templates with specifications, evaluation criteria, and terms for suppliers to follow. The procurement procedure is implemented by receiving and evaluating bids or proposals against pre-defined criteria, with bidder conferences held if needed to clarify requirements. The winning supplier is then formalized through contract signing, which includes negotiating terms, deliverables, and timelines while beginning oversight to ensure compliance. The procurement plan is updated regularly to reflect status, incorporate lessons learned, and prepare for future procurement needs, ensuring alignment with project objectives and continuous improvement.

4.3.8.2 Procurement Approach

Procurement planning is an essential process for any public entity, including government ministries, as it aligns annual planning requirements with expected procurement costs, encompassing both recurring and non-recurring expenditures. Planning activities should begin well in advance of budget approvals to mitigate delays in delivery. The procurement plan format, as provided in Appendix 3 of the Public Procurement Handbook, serves as the standard across all government ministries, ensuring consistency. While this standard format is recommended, additional elements may be incorporated as necessary by Procuring Entities. The process requires adherence to financial rules and approved procurement methods, with input gathered from Warehouse/Stores units to avoid stock issues and emergency procurements. Proper planning considers the time required for activities such as research, design, tender documentation development, advertising, prequalification, procurement methods, tendering, evaluation, approvals, acceptance, implementation, and completion. Effective planning reduces the need for emergency orders or waivers, lowers purchase costs, aggregates requirements for economies of scale, and ensures improved service delivery. Procurement plans are integrated with annual budget processes and submitted to the Ministry of Finance and the Contractor General for review.

A sample format for procurement planning is provided below, serving as the standard for all government ministry procurement processes.

Chart 24 Procurement Sample Format (Source: PUBLIC PROCUREMENT PROCEDURES HANDBOOK, 2013, Appendix 3, p.2) Name of Procuring Name of Procuring Entity Name of Department Name of Department Procurement Plan Year Procurement Plan Year

Serial No.	Contract No.	Description of Goods/Works/Services	Status	Total Estimated Cost (BZD)	Method of Procurement	Procurement Responsibility	Estimated Date of Invitation for Bids	Contract		
								Contract Signed	Contract Completed	Remark
1			Plan							
			Revised Plan							
			Actual							
2			Plan							
			Revised Plan							
			Actual							
3			Plan							
			Revised Plan							
			Actual							
4			Plan							

			Revised Plan							
			Actual							
5			Plan							
			Revised Plan							
			Actual							
Total (BZD)				**0**						
	Approved by:		Prepared by:							

Note: Procurement Sample format. *Public Procurement Handbook (Source: Volume I Standardized Procurement Procedures First Edition- January 2013)* retrieved 5th December 2024 from https://procurement.gov.bz/wpcontent/uploads/2023/09/HanbookPartIPublicSector.pdf

4.3.8.3 Type of Contract for the Seawater Filtration System

The selection and negotiation of contract types are critical to ensure effective procurement for the seawater filtration system. This approach aligns with the "Public Procurement Procedures Handbook" for the public sector, as it provides structured guidance on contracting to achieve project objectives effectively. Lump Sum (Fixed Price) Contracts involve an agreement on a fixed total price for all deliverables, making them ideal for welldefined procurement needs such as the seawater filtration system, where the scope, specifications, and deliverables are clearly outlined. These contracts provide significant advantages by offering cost-cutter and simplifying budgeting, as payments are not tied to actual expenses incurred by the contractor, ensuring financial predictability and control.

4.3.8.4 Procurement Documents

The following procurement documents will be developed and maintained by the procurement unit for the seawater filtration system project:

1. Procurement Plan
2. Request for Proposal (RFP)
3. Request for Quotation (RFQ)
4. Terms of Reference (ToR)
5. Standard Bidding Documents (SBDs)
6. Bid Evaluation Report
7. Contract Document

8. Contract Register
9. Summary of Evaluation Report
10. Tender Advertisement/Notice
11. Vendor Correspondence Records 12. Purchase Orders (POs)
13. Performance Monitoring Reports
14. Procurement Approval Records
15. Delivery and Inspection Reports

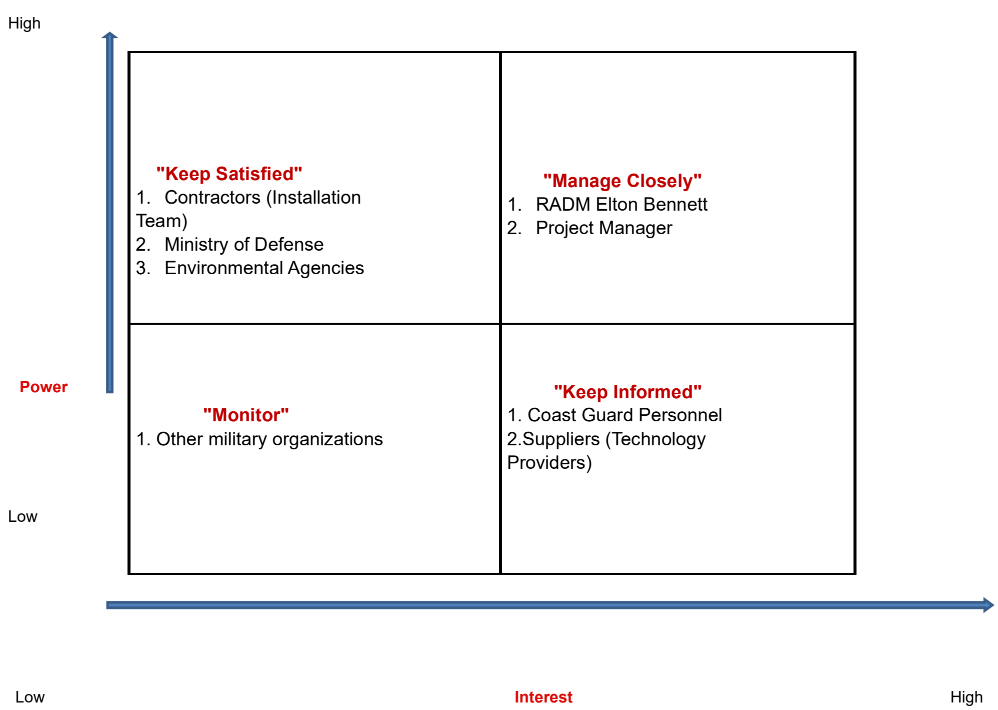
4.3.9 Stakeholder Management Plan

The Stakeholder Management Plan is essential for successfully executing the seawater filtration project for the Belize Coast Guard Forward Operating Bases. This plan focuses on building and maintaining positive relationships with all relevant stakeholders, both internal and externally, who could influence or be impacted by the project. The key objective is to ensure effective engagement, communication, and collaboration throughout the project's lifecycle, thereby minimizing risks, addressing stakeholder concerns, and maximizing support.

For this seawater filtration project, the plan aims to foster positive stakeholder relationships, mitigate risks, and secure stakeholder support, which is crucial for the project's overall success. The project team can assess each group's level of interest, power, and potential impact by identifying key stakeholders, such as Belize Coast Guard personnel, government agencies, contractors, and local communities. The plan incorporates ongoing engagement and communication strategies to ensure all stakeholders remain informed and aligned with project goals. Figures 16, 17 and 18 present the power/interest grid, power/influence grid, and influence/impact grid, respectively, illustrating the stakeholders' positions. The stakeholder register, displayed in Chart 13 below, lists all potential stakeholders involved in the project. This register is continuously reviewed and updated as new stakeholders are identified or existing ones' change, highlighting the team's integral role in the project's success.

Figure 17

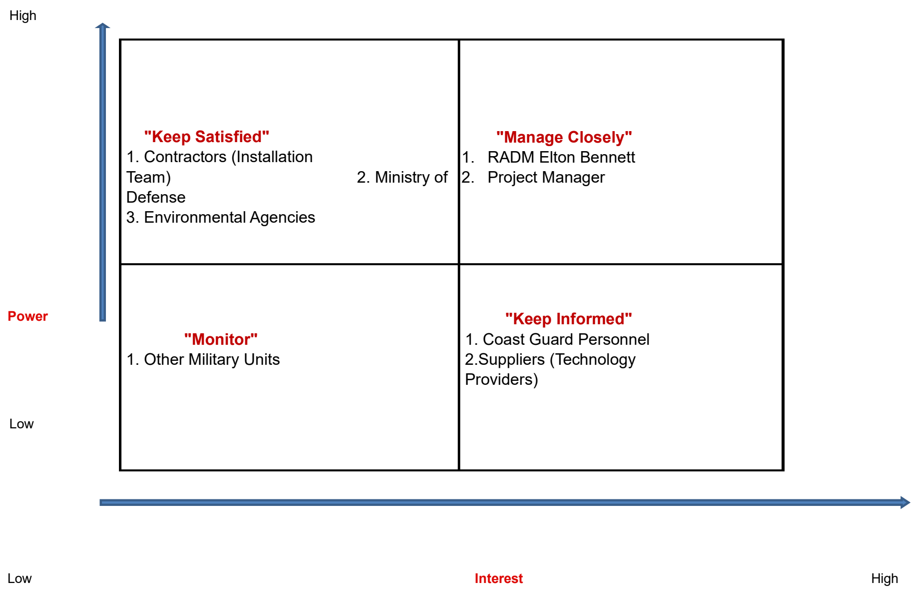
Power/Interest Grid with Stakeholders



Notes: Source: Author of the study

Figure 18

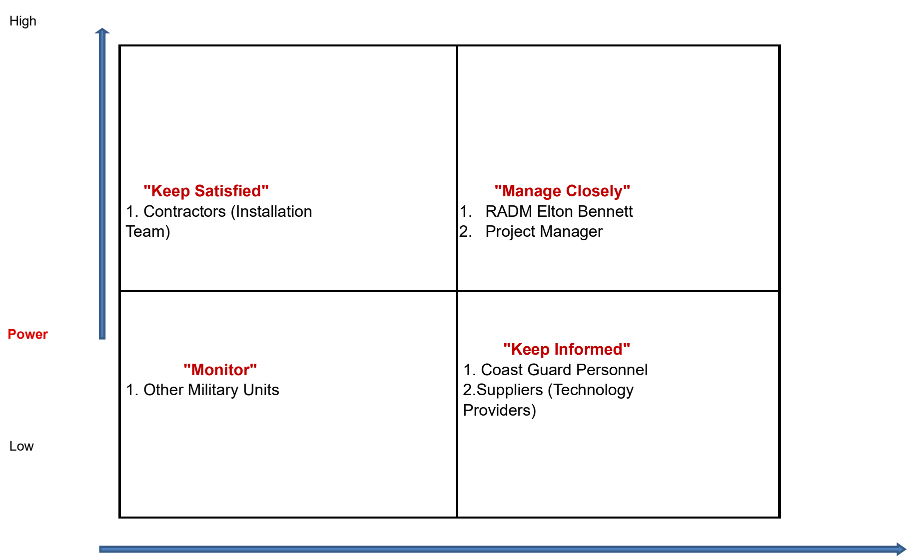
Power/Influence Grid with Stakeholders



Notes: Source: Author of the study

Figure 19

Influence/Impact Grid with Stakeholders



Low Interest High

Notes: Source: Author of the study

4.3.9.1 Stakeholder Engagement

Managing stakeholder engagement for the seawater filtration project entails involving all stakeholders in the decision-making and execution phases. This approach ensures stakeholders are effectively engaged throughout the project lifecycle, tailored to their roles, interests, and influence. Successful management involves continuous communication, collecting feedback, addressing concerns, and fostering positive relationships to maintain stakeholder support.

- Engage Key Stakeholders Regularly: Schedule meetings with Belize Coast Guard personnel, contractors, and government agencies to communicate the project's progress, challenges, and decisions transparently. Regular status updates will keep everyone informed and aligned with project goals.
- Stakeholder Concerns Promptly: Actively listen to concerns raised by stakeholders, particularly those impacted by the installation and operation of the filtration system. Ensure that technical or environmental issues identified by government agencies, or the local community are addressed to mitigate risks.
- Provide Training and Involvement Opportunities: Involve Coast Guard personnel as the primary users of the system through training programs and opportunities for input on usability and operational requirements. This engagement is crucial for successful system adoption.
- Maintain Open Channels of Communication: Establish multiple communication channels (emails, reports, meetings, etc.) for contractors, government bodies, and

personnel to access updates and voice concerns throughout the project. This will help prevent misunderstandings and facilitate smooth project execution.

The Stakeholder Engagement Assessment Matrix for the seawater filtration system project provides a strategic approach to understanding and managing stakeholder communication and engagement. This matrix identifies the current (C) and desired (D) levels of engagement for each stakeholder. For stakeholders such as RADM Elton Bennett and Belize Coast Guard HQ, their current engagement level is already aligned with the desired level (C-D), as they lead the project and act as key driving forces. Contractors and suppliers are currently neutral (C), requiring efforts to increase their engagement to a supportive level (D). Similarly, the Ministry of Defense, Environmental Agencies, and the Local Community are unaware (C) and need targeted communication to raise awareness and garner support (D). Coast Guard Personnel (end-users) and Other Military Units are also unaware (C). They must move to a supportive level (D) as they are critical to the project's operational success. This matrix will evolve throughout the project as stakeholder engagement levels change, and adjustments will be made based on communication efforts and feedback to ensure successful project outcomes.

Chart 25

Stakeholder Engagement Assessment Matrix (Source: Author of the Study)

Stakeholder	**Unaware**	**Resistant**	**Neutral**	**Supportive**	**Leading**
RADM Elton Bennett					C-D
Belize Coast Guard HQ					C-D
Contractors (Installation Team)			C		D

Ministry of Defense and Environmental Agencies	C				D
Project Manager					C-D
Coast Guard Personnel (End-users)	C			D	
Suppliers (Technology Providers)			C		D
Local Community	C			D	
Other Military Units	C				D

Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" customer relationship management; C: current level of engagement; D: desired level of engagement; C-D: level of engagement is as desired (Valdez, 2024)

4.3.9.2 Stakeholder Monitoring

Monitoring stakeholder engagement is essential to keep stakeholders informed, involved, and supportive throughout the seawater filtration project. Continuous monitoring helps identify stakeholder expectations and influence or support changes, allowing the project manager to adjust strategies to maintain engagement and minimize resistance. For the seawater filtration system project, the project manager will:

- Track Engagement Activities: Record all engagement activities, including meetings, communications, and training sessions, to ensure active stakeholder participation. This will help with pinpoint gaps where specific stakeholders may require additional attention or involvement.
- Assess Stakeholder Satisfaction: Implement feedback mechanisms, such as surveys or one-on-one meetings, to evaluate stakeholder satisfaction with the project's

progress. This approach will help identify issues that may not be immediately evident and facilitate timely corrective actions.

- Monitor Changes in Stakeholder Influence or Expectations: Regularly reassess stakeholders' levels of power and interest to anticipate any changes in their involvement or concerns. For instance, shifts in government regulations or personnel within the Coast Guard could have an impact on the project and should be monitored closely.
- Adapt Engagement Strategies as Needed: If stakeholders become less involved or express new concerns, modify engagement strategies to re-engage them or address their issues. This might involve increasing communication frequency, altering engagement methods, or providing more detailed project updates.

4.4 Select tools and techniques and define procedures for the execution of the seawater filtration system project.

The Efficient Water Maker (EWM) is a cutting-edge desalination solution that provides reliable, cost-effective, and sustainable freshwater from seawater. Its innovative features include energy recovery technology, advanced pre-treatment, and chemical-free operation, making it ideal for applications in remote locations such as the Belize Coast Guard Forward Operating Bases. The system offers a production capacity of 4.8 m^3/day (1,268 gallons/day) with energy consumption as low as 3 kWh/m^3. Equipped with remote monitoring and skidbuilt modular design, the EWM ensures ease of installation, maintenance, and operation, making it a long-term asset for water needs in challenging environments.

This section outlines the tools, techniques, and procedures for successfully implementing the seawater filtration system, ensuring compliance with project objectives, sustainability standards, and operational efficiency.

4.4.1 Tools and Technologies of the seawater filtration system

Chart 26

Tools and Technologies (Source: Author of the Study)

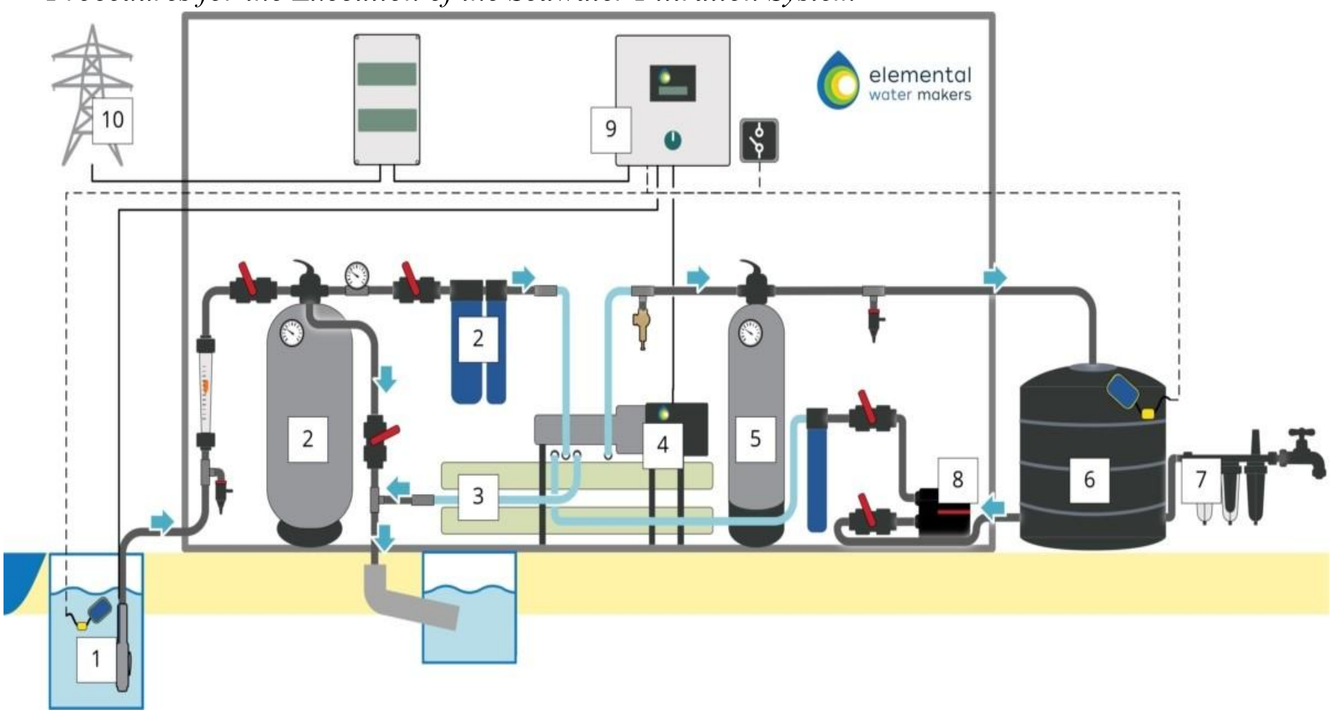
Category	Tool/Technology	Description
Energy Recovery Technology	Energy Recovery Devices	Constructed from high-quality duplex steel, these devices recycle brine pressure, reducing energy consumption by up to 70%. This leads to significant cost savings and environmental benefits.
PreTreatment Filtration	Multimedia Filters	Retain larger particles and debris to protect downstream components, ensuring smooth operation.
	5-Micron and 10-Micron Filters	Remove fine particles and impurities, extending the lifespan of reverse osmosis membranes.
Reverse Osmosis System	RO Membrane System	Operates under high pressure (up to 50 bar/725 psi) to separate salts, bacteria, and contaminants, producing high-quality potable water.
Post-Treatment Systems	Remineralization	Enhances water taste and reduces corrosivity, making the water suitable for consumption.
	UV and Activated Carbon Filters	Remove residual bacteria and organic compounds from stored water to maintain safety and quality.
Remote Monitoring and Control	GSM-Based Monitoring	Real-time tracking of system performance, alarm notifications, and remote management capabilities.
	Online Monitoring Portal	Provides additional operational insights for enhanced system management.

Skid-Built Modular Design	Pre-Assembled Configuration	Compact, modular design allows for easy transportation, installation, and integration into existing facilities.
High-Quality Pumps	904L Super Duplex or Titanium Pumps	Engineered to withstand corrosive marine environments, ensuring durability and reliability over time.

Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" this table provides a clear overview of the tools and technologies incorporated into the seawater filtration system, highlighting their purpose and benefits. (Valdez, 2024)

Figure 19

Procedures for the Execution of the Seawater Filtration System



Note: The entire water treatment process. *Elemental Water Makers (Source: Desalination done right. Chemical free water treatment)* retrieved 3rd December 2024 from https://www.elementalwatermakers.com/solutions/efficient-desalination/

1) Intake pump

Most pumps must be replaced yearly when used in salt water. We believe that investing in quality, efficiency and reliability will bring added value over time. We solely work with super duplex, bronze or 904L pumps that provide a maximum lifetime in warm corrosive environments. And if possible, we add sacrificial anodes to make them last even longer.

2) Pre-treatment

Pre-treatment is crucial to protect the membranes and high-pressure pumps. We retain the rough particles using a multi-media filter that can be backwashed periodically. By a combination of two cartridge filters, the smaller particles are retained.

3) Reverse osmosis

The permeable membrane separates the salts, ions and molecules from the water. The reverse osmosis process requires high pressures in the order of 50 bar (725 psi) for seawater. Bacteria and viruses are also retained in the process.

4) Energy recovery

High-efficiency desalination (< 3 kWh/m^3) is enabled by re-using the brine pressure. The maintenance-free energy recovery devices are constructed from (super) duplex steel. This is the heart of the system.

5) Remineralization

The freshwater can be re-mineralized to reduce the potential aggressivity of the water. Remineralization also can enhance the taste of the water.

6) Water storage

To buffer between water supply and demand, a water storage tank is arranged. This can be anything ranging from an underground cistern, a plastic tank or a corrugated coated tank. The desalination unit automatically starts when the water tank is not full and stops when the water tank is full. 7) Post-treatment

An Ultraviolet (UV), cartridge & active-carbon filter treatment step can be placed after the freshwater storage to remove bacteria that might have entered the water during standstill in the water storage and distribution.

8) Fresh flush

To prevent biofouling, an automated fresh flush cycle rinses the membranes with some fresh water during start/stop, standby and production. This ensures a maximum lifetime of the membranes, without the use of chemicals.

9) Remote monitoring & control

The units are equipped with GSM-based monitoring for remote control and alarm messaging. Check-in on your water supply, anywhere, anytime. An online remote monitoring portal is also an option.

10) Electricity supply

The solution smoothly integrates with the local electricity supply of either 50 or 60 Hz, single or three-phase and for several Voltages supplied globally. This again ensures optimum efficiency to prevent high energy bills.

4.5 Evaluate the cost-effectiveness, energy efficiency, and ease of maintenance of the proposed seawater filtration system from a conceptual and theoretical point of view, applying research to develop a well-defined case study.

Evaluating the proposed seawater filtration system's cost-effectiveness, energy efficiency, and ease of maintenance is critical for determining its feasibility for the Belize Coast Guard's forward operating bases. This analysis aims to assess the system from conceptual and theoretical perspectives, applying research to develop a well-defined case study. By examining operational costs, energy consumption, and maintenance requirements, this study demonstrates how the system can provide a sustainable and efficient solution for the Coast Guard's water supply needs in remote locations.

Chart 27

System overview (Source: Author of the Study)

Reverse Osmosis Efficient Water Maker	4,8 m³/day	1.268 gpd
System overview		
Water production per day	4,8 m³	1.268 gallons
Water production per hour	200 liters	53 gallons
Energy consumption Desalination	4,5 kWh/m³	17,0 kWh/kgal

Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" (Valdez, 2024)

4.5.1 Cost-effectiveness

The proposed seawater filtration system, a financially prudent choice, generates approximately 53 gallons of fresh water per hour, representing a cost-effective solution for the Belize Coast Guard's forward operating bases. With a total investment of $100,675.64

USD including installation and commissioning, the system's operational cost is approximately $3,906 annually. Over a 15-year operational lifespan, the total water rate amounts to $13.52 per 1,000 gallons, making it highly competitive compared to traditional methods such as trucking water or conventional desalination systems. This rate includes both electricity costs and maintenance, reflecting significant long-term savings. For context, traditional trucking solutions and alternative desalination systems often incur substantially higher rates due to transportation logistics and less efficient energy use.

Chart 28

Annual Cost During Operation (Source: Author of the study)

Cost Item	Value (USD)	Value (BZD)
Electricity cost for desalination	$2,578	$5,208.56
Membranes, filters, spare parts	$892	$1,801.84
Remote support service (optional)	$436	$880.72
Annual cost	**$3,906**	**$7,891.12**

Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" (Valdez, 2024)

4.5.2 Energy efficiency

The system incorporates advanced reverse osmosis (RO) technology with an energy recovery mechanism that reduces energy consumption to less than 3 kWh/m^3 of water produced, compared to traditional systems that require approximately 10 kWh/m^3. This represents a 70% reduction in energy use, resulting in significant operational savings, particularly in locations where electricity costs are $0.33 per kWh. With an estimated annual electricity cost of $2,578 for desalination, the energy-efficient design ensures a lower environmental impact and aligns with the Coast Guard's sustainability objectives.

Energy efficiency is especially critical for remote forward operating bases where power resources may be limited or reliant on renewable energy sources.

Chart 29

Local Values Used (Source: Author of the Study)

Parameter	Value (USD)	Value (BZD)
Electricity rate per kWh	$0.33	$0.67
Today's exchange rate	$1.09	$2.02

Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" (Valdez, 2024)

4.5.3 Ease of Maintenance

The system is crafted for simplicity and durability, requiring minimal maintenance. Key components that require upkeep include membranes, filters, and consumables, which cost approximately $892 per year. Its modular design features pre-filtration with multimedia and cartridge filters, protecting the reverse osmosis unit from damage and extending its lifespan. The system offers optional remote support services for $436 annually. It also includes on-site commissioning and training, providing Coast Guard personnel with essential routine maintenance and troubleshooting skills. This approach minimizes reliance on external technical support, ensuring uninterrupted operations in remote locations.

4.6 Establish a project monitoring and control system through tools and techniques to ensure the effective integration of project objectives and goals.

The project monitoring and control system for the seawater filtration project is designed to ensure that all objectives and goals are met efficiently by integrating advanced tools, techniques, and best practices. This section outlines the establishment of the monitoring and control system, utilizing state-of-the-art technologies and structured procedures.

4.6.1 Monitoring Tool and Techniques

Chart 30

Monitoring Tools and Techniques (Source: Author of the study)

Tool/Technique	Purpose	Functionality	Benefits
GSM-Based Remote Monitoring	Enables realtime tracking of the system's performance and operations.	Send alarm notifications for critical events (e.g., pressure drops, equipment faults) for prompt corrective actions.	Accessible from any location, ensuring continuous oversight without requiring on-site presence.
Online Monitoring Portal	Provides detailed insights into the system's performance, water production, and energy efficiency.	Visual dashboards display metrics such as flow rate, pressure, and water quality.	Enhance data-driven decision-making by offering a centralized view of operational parameters.
Automated System Controls	Automates the start/stop of the desalination unit based on water storage levels.	Ensures efficient resource utilization by stopping operations when the water tank is full and restarting when levels drop.	Minimizes energy consumption and extends equipment life.
Energy Efficiency Monitoring	Tracks energy consumption per cubic meter of water produced (<3 kWh/m^3).	Utilizes data from energy recovery devices to measure and optimize electricity usage.	Ensures compliance with sustainability goals and reduces operational costs.

Maintenance Scheduling via Remote Monitoring	Tracks wear and tear on critical components like membranes, pumps, and filters.	Issues automated maintenance alerts based on operational data (e.g., membrane fouling, filter clogging).	Ensures timely maintenance, preventing equipment failure and unplanned downtime.

Note: Adapted from the "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" (Valdez, 2024)

4.6.2 Control System

1. **Intake Pump Monitoring**:
    - High-quality 904L super duplex or titanium pumps are equipped with sacrificial anodes to enhance durability in corrosive environments.
    - Monitoring ensures timely replacement or maintenance to prevent interruptions.
2. **Pre-Treatment and Post-Treatment Systems**:
    - Multi-media and cartridge filters are periodically inspected and backwashed to maintain optimal filtration performance.
    - UV and activated carbon filters are monitored to ensure water safety and quality post-storage.
3. **Reverse Osmosis and Energy Recovery Monitoring**:
    - The RO process operates at pressures of up to 50 bar (725 psi), separating salts, bacteria, and other impurities.

- Energy recovery devices, constructed from maintenance-free duplex steel, are tracked for optimal efficiency and reliability.

4. **Fresh Flush Cycle Automation**:
   - Automated cycles rinse membranes during production, standby, and start/stop phases to prevent biofouling.
   - Remote monitoring ensures flush cycles are functioning properly to extend membrane life without chemical use.

5. **Water Quality Testing**:
   - Continuous testing of water quality ensures compliance with design parameters for potable water.
   - Measured twice every second to guarantee safety and reliability.

4.6.3 Integration with Project goals

The project monitoring and control system for the seawater filtration system ensures that all objectives are achieved by integrating advanced tools, techniques, and best practices. This system leverages technologies such as GSM-based remote monitoring, enabling real-time tracking of system performance. Alarm notifications for critical events, such as pressure drops or equipment faults, allow for prompt corrective actions, ensuring continuous oversight from any location. The online monitoring portal provides insights into water production, energy efficiency, and operational parameters through visual dashboards. Automated controls optimize resource utilization by managing the desalination unit's start/stop function based on water storage levels, minimizing energy consumption, and extending equipment lifespan.

Energy efficiency monitoring tracks electricity usage per cubic meter of water produced (<3 kWh/m^3), ensuring compliance with sustainability goals while reducing operational costs. Maintenance scheduling is supported by remote monitoring, tracking wear and tear of components like membranes, pumps, and filters, and issuing alerts to prevent failures and unplanned downtime. Control techniques include monitoring the intake pump, which is equipped with durable materials and sacrificial anodes to enhance performance in corrosive environments. To maintain filtration efficiency, pre-treatment and post-treatment systems, such as multi-media and cartridge filters, are periodically inspected and backwashed. UV and activated carbon filters ensure water safety post-storage. The reverse osmosis process operates under high pressure to separate impurities, while energy recovery devices optimize efficiency. Automated fresh flush cycles prevent biofouling by rinsing membranes during production and standby phases.

Water quality testing is conducted continuously, with parameters measured twice per second to ensure compliance with potable water standards. The monitoring and control system aligns with project goals by ensuring efficiency through automation, sustainability via chemical-free and energy-efficient technologies, reliability through real-time performance tracking, and scalability with modular design and remote management capabilities, enabling future expansion or adaptation to other bases. This approach guarantees operational excellence and long-term reliability for the seawater filtration system.

4.7 Define a project closure procedure that includes the final evaluation of objectives and goals achievement, lessons learned reporting, and product transfer to operations management.

The project closure procedure ensures a smooth transition from project implementation to operations management while finalizing all objectives and deliverables. The key steps include:

1. Final Evaluation:

- Assess the achievement of project objectives and goals, including water production capacity, energy efficiency, and system reliability.
- Validate system performance through final testing and quality assurance reports.

2. Lessons Learned Reporting:

- Document key challenges, successes, and improvements identified during the project lifecycle.
- Conduct a closure meeting with stakeholders to review insights and create a lessonslearned repository for future reference.

3. Product Transfer to Operations Management:

- Provide comprehensive training for operations personnel.
- Handover operational manuals, maintenance schedules, and spare parts inventory to the designated operations team.

- Conduct a formal system handover, ensuring the operations team is equipped with independent management.

5 CONCLUSIONS

This project has not only comprehensively addressed the objectives but also systematically developed a structured framework to implement an effective and sustainable seawater filtration system for the Belize Coast Forward Operating Bases. Each objective has contributed to a well-rounded plan, ensuring the project aligns with our operational, environmental, and strategic goals, providing a comprehensive solution.

1. A detailed evaluation of seawater filtration technologies identified reverse osmosis with energy recovery as the most suitable solution for the Belize Coast Guard. Key findings highlighted that this technology offers a 70% reduction in energy consumption compared to traditional methods, with a consumption rate of less than 3 kWh/m^3. The assessment also underscored the system's capability to produce 1,268 gallons of potable water daily, meeting the Coast Guard's operational needs for drinking, equipment rinsing, and hygiene.
2. The initiation phase established the foundational structure, including a well-defined project charter outlining objectives, scope, and deliverables. Key stakeholders, such as Coast Guard leadership, who provided strategic direction, environmental agencies, who ensured environmental compliance, and contractors, who executed the project, were identified and engaged early in the process. This ensured alignment with technical, operational, and regulatory requirements, fostering

collaboration. Including end-users (Coast Guard personnel) emphasized the system's practical applicability and long-term usability.

3. A comprehensive project management plan was developed, incorporating subsidiary plans for scope, schedule, costs, resources, quality, communications, risks, acquisitions, and stakeholders. Notable findings include the creation of a schedule that integrates procurement, installation, training, and testing phases, ensuring milestones are achievable within the 9-month timeline. The initial investment of $100,675.64 USD which includes the cost of the system and its installation, was justified by the system's operational water rate of $13.52 per 1,000 gallons over 15 years, emphasizing cost efficiency.
4. Tools and techniques for executing the project were meticulously chosen to enhance efficiency and reliability. This included using modular components for ease of installation, pre-filtration systems to protect reverse osmosis membranes, and advanced energy recovery devices to reduce power requirements. These choices were guided by research and tailored to remote bases' specific environmental and logistical challenges, ensuring practical application and instilling confidence in the project's success.
5. The evaluation of the proposed system confirmed its long-term viability. Key findings revealed a highly competitive water rate of $13.52 per 1,000 gallons, supported by low operational costs of $3,906 annually. The system's energy efficiency, consuming less than 3 kWh/m^3, reduces electricity expenses and aligns

with sustainability goals. This analysis demonstrated that the system is not only economically and operationally feasible for remote deployment but also a costeffective and energy-efficient solution for the long term.

6. Monitoring and control systems were designed to track real-time project progress, costs, and quality. Tools like Gantt charts and progress reports were implemented to ensure alignment with objectives. Key measures include scheduled quality assurance checks during installation and operational phases, which minimize risks and ensure timely delivery.
7. The closure phase was defined to ensure a seamless transition to operational management. This includes a final evaluation of objectives and deliverables, and a comprehensive 'lessons learned reporting' that documents the project's successes, challenges, and best practices. The formal transfer of the system to the Coast Guard's operations team was also part of this phase. Key findings emphasize the importance of documenting operational protocols and creating a repository of lessons learned to inform future projects. This approach ensures the system's sustainability and paves the way for continuous improvement in future initiatives.

6 RECOMMENDATIONS

These recommendations aim to optimize the seawater filtration system's implementation, operation, and long-term sustainability, ensuring it aligns with the Coast Guard’s strategic objectives.

1. To ensure the success and sustainability of the Belize Coast Guard's seawater filtration system, it is recommended that leadership conduct regular updates on

technology assessments. These assessments should include evaluations of advancements in reverse osmosis and energy-efficient systems to remain informed about innovations that could enhance system performance. Collaborating with international organizations to test and validate cutting-edge filtration technologies tailored to remote operational bases would further strengthen the system's efficiency and applicability.

2. The project manager and key stakeholders should enhance engagement by creating a structured communication platform. Continuous interaction throughout the project lifecycle will promote alignment and commitment to the project's objectives. Offering training sessions on the operational and strategic benefits of the filtration system will help ensure that all stakeholders have a shared understanding of its importance and functionality.
3. For project planning teams, developing detailed subsidiary management plans is essential to address contingencies related to potential procurement delays and unforeseen maintenance challenges. Incorporating a resource optimization framework into the management plan will enhance implementation efficiency and reduce waste. The implementation team should also define clear execution and operational procedures to ensure the seamless integration of the filtration system with existing water supply infrastructures. Proper documentation of all processes will provide a valuable reference for future initiatives.
4. Cost-effectiveness and energy efficiency are vital components of the project. The procurement and operations teams should focus on acquiring energy-efficient

filtration systems that provide long-term savings. Exploring the integration of renewable energy sources, such as solar power, can further reduce operational costs. These strategies will not only optimize expenses but also support sustainability goals.

5. The quality assurance team is encouraged to implement advanced monitoring and control systems that provide real-time updates on water quality and system performance. Regular reviews of key performance indicators (KPIs) should be conducted to ensure alignment with the Coast Guard's operational goals. The project manager should emphasize comprehensive closure procedures, including a strong knowledge transfer program that equips Coast Guard personnel with the necessary system maintenance and troubleshooting skills. Documenting lessons learned during the project will be invaluable for improving future initiatives.
6. To address research gaps, the research and development division should explore integrating desalination systems with rainwater harvesting to enhance water supply resilience. Establishing partnerships with academic institutions for further research into sustainable water management solutions tailored to the Coast Guard's needs would be advantageous.

7 VALIDATIONS OF THE FGP IN THE FIELD OF REGENERATIVE AND SUSTAINABLE DEVELOPMENT

The project aims to develop a comprehensive project management plan that will guide the project manager and the project team in successfully executing and completing the seawater filtration system for the Belize Coast Guard Forward Operating Bases. This plan ensures the project's primary objective: providing a reliable and sustainable potable water supply through seawater filtration. This is crucial for the operational efficiency and health of the Coast Guard personnel stationed in remote areas. The Project Management Plan for implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases has a broader impact on Belize's commitment to the Sustainable Development Goals (SDGs), particularly in clean water and sanitation, climate action, and the sustainable use of ocean resources. The following sections provide a detailed validation of the project within a regenerative and sustainable development context.

7.1 Relationship with Regenerative Development

Implementing a seawater filtration system significantly impacts environmental sustainability by reducing reliance on scarce freshwater resources, particularly in droughtprone areas. This seawater conversion into potable water alleviates pressure on local freshwater ecosystems. It supports their natural regeneration processes, aligning with ecological restoration goals and promoting the conservation of vital freshwater resources (Huang et al., 2022). The initiative contributes to mitigating the adverse effects of climate change by ensuring a stable and sustainable water supply, which enhances the resilience of the local environment (Chibani, 2023). From a social and economic perspective, the project directly improves the health and well-being of individuals in the Belize Coast Guard and surrounding communities by providing a consistent and sustainable supply of clean water, thus reducing the incidence of waterborne diseases and supporting operational efficiency and morale among Coast Guard personnel (Li & Wu, 2024). This initiative translates into cost savings and improves regional economic stability by reducing the need to transport water to remote locations, freeing up resources for other critical operations (Amiad et al.). This project addresses the Coast Guard's immediate needs and contributes to Belize's long-term social and economic resilience.

7.2 Relationship with Sustainable Development Goals (SDG)

1. **SDG 6- Clean water and Sanitation -** This seawater filtration project has the potential to significantly contribute to achieving Sustainable Development Goal 6. The system we propose addresses the critical issue of water scarcity in remote islands and coastal areas by providing a reliable and renewable source of potable water. This, in turn, promotes water security and sustainable resource management (Berniak-Woźny & Rataj, 2023).
2. **SDG 13 - Climate Action -** If integrated with energy-efficient technologies or renewable energy sources, such as solar power, the seawater filtration system will contribute to SDG 13 by reducing the carbon footprint associated with water supply. This decreases greenhouse gas emissions and enhances the climate resilience of the Belize Coast Guard's operations. It ensures they can continue functioning effectively, even in climate-related challenges (Ministry of Water and Irrigation, 2022).
3. **SDG 14 - Life Below Water-** The project aligns with SDG 14 by considering its impact on marine life. Proper management of brine, a byproduct of the desalination process, is essential. The project includes strategies such as diluting brine before

disposal or reusing it in other industrial processes. These measures minimize the potential adverse effects on marine ecosystems. By carefully managing brine, the project supports the conservation and sustainable use of oceans, seas, and aquatic resources (Chibani, 2023).

7.3 Impact Analysis (P5 Standard)

The P5 Standard for Sustainability in Project Management assesses projects based on five dimensions: People, Planet, Prosperity, Product and Process ensuring that they not only meet their objectives but also have a positive impact on society, the environment, and the economy. The P5 Impact Analysis, applied to the seawater filtration project, provides a comprehensive evaluation of sustainability across dimensions such as Planet, People, and Prosperity using five lenses: Lifespan, Servicing, Effectiveness, Efficiency, and Fairness. This analysis, conducted using P5 Impact Analysis Version 5.0.1 aligned with Version 3.0, emphasizes the importance of sustainable practices throughout the project's lifecycle. Below is classification of the key findings under the categories of People, Planet, and Prosperity:

1. People

- Ethical Behavior:
    - Sustainable Procurement and Contracts: The emphasis on sustainable procurement practices ensures that the project engages ethical suppliers, promoting social responsibility.

- Anti-Corruption: Strong anti-corruption measures are in place to maintain integrity, which is essential for the project's social sustainability.
- Fairness in Resource Allocation: Ensuring fairness in resource distribution and access, promoting equity among all stakeholders.

- Market and Economic Stimulation:
    - Local Economic Impact: The project contributes to job creation and increased economic activity, positively impacting the local community's social well-being.

Figure 21

P5 Analysis – People Impact

People Impacts										
Category	Labor Practices and Decent Work	Lens	Scored?	Description (Cause)	Potential Sustainability Impact	Initial Impact Score	Proposed Response	New Impact Score	Change	Outcome
Element	Definition									
	Employment and staffing is the process of obtaining the personnel needed to carry out the project. It includes identifying the skills required for successful completion of the project, recruiting potential individuals (internally or externally), managing their time and performance, training them when needed, and compensating them accordingly.	Lifespan	Yes	The employment of skilled professionals for the installation and maintenance of the seawater filtration system is expected to be long-term, given the need for ongoing	Sustainable employment practices ensure long-term job security for workers, reducing turnover and fostering a stable, skilled workforce.	4	Implement training programs for local workers.	5	1	Trained local workforce capable of sustaining operations and contributing to regional employment.
		Servicing	Yes	Requires continuous hiring and training to ensure the system operates efficiently, particularly in remote locations.	Efficient staffing leads to sustainable operations, minimizing the environmental impact of frequent recruitment and training cycles.	3	Implement a robust training program to improve the skills of staff for continuous and effective service.	4	1	Improved operational sustainability through efficient staffing and training.
		Effectiveness	Yes	Staffing directly impacts the system's reliability and functionality. Trained personnel ensure the system meets operational demands.	A well-staffed project contributes to the long-term success and sustainability of the seawater filtration system, ensuring continuous supply and reducing dependency on unsustainable water	4	Ensure targeted recruitment for positions directly impacting system reliability and performance.	5	1	Enhanced system reliability and reduced dependency on unsustainable water sources.
		Efficiency	Yes	Efficient management of human resources will minimize downtime and ensure the system operates at full capacity.	Optimizing staffing reduces resource waste, including time and financial resources, contributing to a more sustainable project	4	Optimize workforce scheduling to reduce resource waste and improve efficiency.	5	1	Optimized resource use, leading to cost savings and sustainability.
		Fairness	Yes	Employment practices will emphasize non-discrimination and equal opportunities for all workers involved in the	Fair hiring practices promote social sustainability by ensuring equal opportunities and fostering a diverse	4	Enforce fair hiring and compensation practices to promote social equity.	4	0	Promoted social equity through fair employment practices.
		Lifespan	Yes	Healthy labor-management relations are crucial for the project's duration.	Strong labor-management relations contribute to long-term project stability, reducing the risk of strikes or work stoppages that could delay the project and increase its environmental	4	Establish a long-term communication and conflict resolution protocol.	5	1	Long-term stability and reduced risk of disruptions.
			Yes	Effective communication and trust-building among project teams and stakeholders.	Positive labor relations enhance the sustainability of service delivery, ensuring that workers are motivated and engaged in	3	Hold regular meetings to address any service-related issues collaboratively.	4	1	Enhanced worker motivation and engagement for sustainable service delivery

Notes: Source: Author of the study

2. **Planet**

- Energy Consumption and GHG Emissions:
    - The project's commitment to reducing energy consumption and greenhouse gas emissions contributes directly to minimizing its environmental footprint.

- Water Consumption and Biodiversity: The project takes significant steps to ensure efficient water use and protect local biodiversity, supporting the health of local ecosystems.

- Environmental Impact Management:
  - Focus on continuous monitoring and improvement of energy use, water management, and biodiversity protection to enhance environmental sustainability

Figure 22

P5 Analysis – Planet Impact

Planet Impacts

Category	Transport	Lens	Scored?	Description (Cause)	Potential Sustainability Impact	Impact Score Before	Proposed Response	Impact Score Afte
Element	Description							
Local Procurement	Local procurement is the practice of purchasing products and services from local suppliers.	Lifespan	No					
		Servicing	No					
		Effectiveness	No					
		Efficiency	Yes	Efficiency in local procurement ensures that goods and services are obtained quickly and cost-effectively from local suppliers.	Efficient local procurement can reduce transportation costs and support the local economy, which is beneficial for project sustainability.	4	Continue to prioritize local suppliers and streamline procurement processes to reduce lead times and costs.	4
		Fairness	Yes	Fairness in local procurement involves ensuring that local suppliers are given equal opportunities to compete for contracts, promoting economic inclusivity.	Fair procurement practices support local businesses and contribute to the socio-economic development of the community.	4	Maintain transparent and fair procurement policies that allow equal opportunities for all local suppliers.	4
Digital Communication	Digital communication is the use of digital tools and platforms to communicate about the project. These tools can include websites, email newsletters, social media accounts, messaging applications, and other digital communication channels.	Lifespan	No					
		Servicing	No					
		Effectiveness	No					
		Efficiency	No					
		Fairness	No					
Traveling and Commuting	Traveling and commuting is the movement of project-related personnel between different locations. Traveling and commuting may include getting to the project site, attending off-site meetings, conducting off-site presentations, collecting data, and providing off-site support.	Lifespan	Yes	Efficiency in traveling and commuting is affected by the distance to remote FOBs and the availability of transportation modes. Efficient planning of travel schedules and the use of the most effective transportation methods are essential.	An efficient travel and commuting plan can minimize delays and reduce fuel consumption, leading to lower operational costs and less environmental impact.	4	Optimize travel routes and schedules, and use energy-efficient vehicles to further reduce costs and environmental impact.	4
		Servicing	No					
		Effectiveness	No					
		Efficiency	No					
		Fairness	Yes	Fairness in traveling and commuting involves ensuring equitable access to necessary transportation for all personnel, regardless of rank or role.	Fair access to transportation resources ensures that all team members can perform their duties effectively, leading to improved morale and	4	Implement a transparent and equitable transportation policy that ensures all personnel have the necessary means to commute efficiently.	4

Notes: Source: Author of the study.

3. **3.** Prosperity
   - Business Agility:
     - Flexibility/Optionality: The ability to adapt to changing conditions ensures that the project remains sustainable and continues to deliver value over time.

- Resiliency: The project’s resilience to external shocks, such as natural disasters or economic instability, is critical for maintaining long-term prosperity.

- Market and Economic Stimulation:
  - Indirect Benefits: The project provides long-term economic benefits, including improved infrastructure and environmental quality, which contribute to the overall prosperity of the region.
  - Financial Analysis: A thorough financial analysis ensures the project's viability, supporting its long-term economic sustainability.

Figure 23

P5 Analysis – Prosperity Impact

perity Impacts

gory / ent	Project Feasibility / Description	Lens	Scored?	Description (Cause)	Potential Sustainability Impact	Impact Score Before	Proposed Response	Impact Score After	Change	Outcome
Business Case Analysis	Business case analysis is the process of developing a business case that provides justification for the initiation or continuation of the project. It involves analyzing the underpinning logic of funding the project. This requires identifying the expected benefits and dis-benefits, likely costs and revenues, staffing requirements, major risks, schedule alternatives, and stakeholder impacts associated with a proposed project.	Lifespan	Yes	Developing a business case for the seawater filtration project requires a detailed analysis of the project's long-term viability and sustainability. This includes assessing the potential benefits, costs, and risks over the project's lifespan.	A robust business case supports long-term project success by ensuring that resources are allocated efficiently and that the project is viable and sustainable over time.	4	Conduct a comprehensive business case analysis that includes sustainability metrics, ensuring that the project remains viable and sustainable in the long term.	5	1	A well-supported business case that ensures the project's long-term sustainability.
		Servicing	Yes	The business case must consider the ongoing maintenance and servicing requirements of the seawater filtration system, which are critical to the project's success.	Proper consideration of servicing in the business case ensures that the system remains operational and effective over its intended lifespan, contributing to overall sustainability.	4	Include detailed servicing and maintenance plans in the business case to ensure the system's long-term functionality.	5	1	Increased confidence in the project's sustainability due to thorough servicing and maintenance planning.
		Effectiveness	Yes	The effectiveness of the business case depends on accurately projecting the project's benefits, costs, and risks, as well as its alignment with sustainability goals.	An effective business case supports decision-making and ensures that the project delivers its intended benefits in a sustainable manner.	4	Enhance the business case by incorporating sustainability impact assessments to ensure effective decision-making.	5	1	A highly effective business case that aligns with sustainability objectives and ensures project success.
		Efficiency	Yes	Efficient resource allocation and risk management are key components of a strong business case, ensuring that the project proceeds smoothly and within budget.	Efficient planning and resource use in the business case contribute to the project's sustainability by minimizing waste and maximizing value.	4	Optimize resource allocation in the business case by using best practices and sustainability benchmarks.	5	1	Increased project efficiency and sustainability due to optimized resource planning.
		Fairness	Yes	The business case should consider the fair distribution of project benefits and resources, ensuring that all stakeholders are treated equitably.	Fairness in the business case ensures that the project contributes to social sustainability and equity.	4	Integrate equity considerations into the business case to ensure fair distribution of benefits and resources.	5	1	A fair and equitable project that supports social sustainability.
Financial Analysis	Financial analysis is the process of evaluating the project from a monetary perspective. Typically, it is used to analyze whether the project warrants initial or additional funding.	Lifespan	Yes	Financial analysis must consider the project's costs and revenues over its entire lifespan, ensuring that it remains financially viable.	A thorough financial analysis ensures the project's financial sustainability, reducing the risk of underfunding or cost	4	Conduct a detailed financial analysis that includes long-term sustainability metrics to ensure project viability.	5	1	Long-term financial viability and sustainability of the project are ensured through comprehensive financial planning.
		Servicing	Yes	The financial analysis should include the ongoing costs of servicing and maintaining the seawater filtration system.	Accounting for servicing costs in the financial analysis ensures that the project remains sustainable and operational over time	4	Include detailed servicing cost projections in the financial analysis to ensure long-term sustainability.	5	1	Improved financial planning that supports the project's sustainability through accurate servicing cost estimates.
			Yes	The effectiveness of the financial analysis depends on accurately predicting the	An effective financial analysis supports informed decision-making and ensures that the	4	Enhance the financial analysis by integrating sustainability considerations	5	1	A highly effective financial analysis that supports sustainable project outcomes.

Note: Source: Author of the study.

Figure 24

Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating bases- P5 Score

People Impacts	Initial Score	New Score	Change
Labor Practices and Decent Work	4.1	4.8	-0.7
Society and Customers	4.3	5.0	-0.7
Human Rights	3.9	4.7	-0.8
Ethical Behavior	3.6	4.6	-0.9
Overall People Score	4.8		
Planet Impacts	**Initial Score**	**New Score**	**Change**
Transport	4.0	4.0	0.0
Energy	3.5	4.5	-1.0
Land Air, and Water	3.3	4.5	-1.2
Consumption	3.8	4.8	-1.0
Overall Planet Score	4.5		
Prosperity Impacts	**Initial Score**	**New Score**	**Change**
Project Feasibility	4	5	-1
Business Agility	4	5	-1
Local Economic Impact	4.533333333	5	-0.4666667
Overall Prosperity Score	5.0		
Overall Project P5 Score	4.7		

Note: Source: Author of the study.

7.4 Mitigation of Unfavorable Effects

The P5 Impact Analysis emphasizes the positive aspects of the seawater filtration project while also addressing potential negative impacts. To mitigate these effects, it is recommended to focus on flexibility and resiliency through robust contingency planning and updated risk management strategies. It is crucial to implement policies that prioritize local hiring and procurement. This will ensure fair distribution of economic benefits and support social equity. The project should continue enforcing anti-corruption policies and promoting fair competition while investing in energy-efficient technologies and monitoring energy consumption to reduce environmental impact. Optimizing water use and implementing best practices in water extraction and waste management are crucial for protecting biodiversity and ensuring sustainability.

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✔ APPENDICES

Appendix 1: FGP Charter

CHARTER OF THE PROPOSED FINAL GRADUATION PROJECT (FGP)

1. Student name

Susely Elizabeth Valdez

2. FGP name

Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases

3. Application Area (Sector or activity)

Military Infrastructure/EnvironmentalManagement/ Water Treatment, Sustainability, Public Health

4. Student signature

5. Name of the Graduation Seminar facilitator

Professor Róger Valverde

9. Research question

What are the most effective water filtration systems and key elements for implementing a sustainable seawater filtration system at the Belize Coast Guard Forward Operating Bases to ensure a reliable water supply?

10. Research hypothesis

By implementing a state-of-the-art water filtration system at the Belize Coast Guard Forward Operating Bases, we can establish a sustainable and reliable source of potable water. This improvement not only enhances operational efficiency but also positively impacts personnel welfare. Simultaneously, we aim to develop a robust project management plan that outlines the necessary processes, resources, and strategies for successful implementation of the seawater filtration system. Factors such as cost-effectiveness, sustainability, and ease of maintenance will be carefully considered to ensure the provision of safe drinking water.

11. General objective

General objective: To develop a comprehensive project management plan for implementing a sustainable seawater filtration system at the Belize Coast Guard Forward Operating Bases. This plan aims to ensure a reliable supply of potable water, enhance operational efficiency, and improve personnel welfare.

12. Specific objectives

Specific objectives

1. Conduct a comprehensive assessment of existing seawater filtration technologies and systems for the Belize Coast Guard Forward Operating Bases.

2. Implement initiation processes, including developing the project charter and identifying key stakeholders to establish a high-level project structure for the seawater filtration system.

3. Elaborate and develop the project management plan, including the creation of subsidiary management plans for scope, schedule, costs, resources, quality, communications, risks, acquisitions, and stakeholders, to define the project baselines for the seawater filtration system.

4. Select tools and techniques and define procedures for the execution of the seawater filtration system project.

5. Evaluate the cost-effectiveness, energy efficiency, and ease of maintenance of the proposed seawater filtration system from a conceptual and theoretical point of view, applying research to develop a well-defined case study.

6. Establish a project monitoring and control system through tools and techniques to ensure the effective integration of project objectives and goals.

7. Define a project closure procedure that includes the final evaluation of objectives and goals achievement, lessons learned reporting, and product transfer to operations management.

13. FGP purpose or justification

Implementing a seawater filtration system at the Belize Coast Guard Forward Operating Bases is crucial to ensure a reliable and sustainable supply of potable water. Now, the bases rely on few freshwater resources, which are vulnerable to contamination and scarcity, especially during dry seasons. By adopting state-of-the-art seawater desalination technologies, the project aims to mitigate these risks and provide a persistent water supply. This idea will enhance operational efficiency and personnel welfare.

Quantitatively introducing a seawater filtration system, we expect to significantly reduce the operational costs related to water procurement and transportation. For instance, the cost of desalinated water can compete with modern reverse osmosis plants achieving energy efficiencies as low as 2.27 kWh per cubic meter of treated water. This efficiency translates into substantive cost savings over time, when contrasted to the high costs of transporting fresh water to remote locations.

The project aligns with broader environmental and sustainability goals. Desalination provides a nearly inexhaustible source of water, which is beneficial in climate change and maximizing freshwater scarcity. By leveraging seawater, the Belize Coast Guard can reduce its dependability on few freshwater resources. This contributes to preserving critical ecosystems. This initiative ensures water security for the bases and sets a precedent for sustainable water management practices in the region.

14. Work Breakdown Structure (WBS). In table form, describing the main deliverable as well as secondary, products or services to be created by the FGP.

2.3.2 Project Planning

2.3.2.1 Project Management Plan

2.3.2.2 Scope Management Plan

2.3.2.3 Schedule Management Plan

2.3.2.4 Cost Management Plan

2.3.2.5 Quality Management Plan

2.3.2.6 Stakeholder Management Plan

2.3.2.7 Communications Management Plan

2.3.2.8 Risk Management Plan

2.3.3 Project Execution

2.3.4 Project Monitoring and Control

2.3.5 Project Closure

2.4 Conclusion

2.5 Recommendations

3. Reading by Reviewers

3.1 Reviewers Assignment Request
3.1.1 Assignment of two reviewers
3.1.2 Communication
3.1.3 FGP Submission to Reviewers
3.2 Reviewers Work
3.2.1 Reviewer 1
3.2.1.1 FGP Reading
3.2.1.2 Reader 1 Report
3.2.2 Reviewer 2
3.2.2.1 FGP Reading
3.2.2.2 Reader 2 Report

4. Adjustments

4.1 Report for Reviewers
4.2 FGP Update
4.3 Second Review by Reviewers

5. Presentation to Board of Examiners
5.1 Final Review by the board
5.2 FGP Grade Report

15. FGP budget

This budget outlines the resource requirements specifically for the development of the FGP document. By leveraging existing Coast Guard assets for transportation, lodging, and meals, the budget focuses primarily on essential expenditures such as software licenses, a field-ready computer, and data management tools.

Item	Description	EstimatedCost (USD)
Software Licenses	Project managementsoftware (e.g. Microsoft Project)	$300
	Data analysis software(e.g. SPSS)	$100
Hardware	Portable laptop for field work	$800
Transportation	Utilizing Belize Coast Guard vessels	$0
Lodging	Accommodatedat Forward OperatingBases	$0
Food	Using patrol complimentration allocation	$0
Information Processing	Cloud storage for documentsharing and backup	$50
Miscellaneous	Printing and binding of final document	$100
	Office supplies	$50
Total EstimatedBudget		$1,400

16. FGP planning and development assumptions

1. Availability of Technical Data: It is assumed that all necessary technical data and specifications regarding existing seawater filtration technologies and systems will be readily available and accessible for research and analysis.
2. Unrestricted Access to Facilities: The project team will have unrestricted access to the Belize Coast Guard Forward Operating Bases for site assessments, data collection, and implementation activities.
3. Consistent Funding: It is assumed that the project will receive consistent funding throughout its lifecycle to cover all planned activities, including research, procurement, and installation of the seawater filtration system.
4. Stakeholder Cooperation: All stakeholders, including the Belize Coast Guard personnel and external consultants, will cooperate fully and provide timely input and feedback to ensure the smooth progression of the project.

17. FGP constraints

1. Time Frame: The maximum allowable time to complete the FGP is 12 months from the start date. This includes all phases from initial research to final implementation and evaluation.
2. Budget Limitations: The project has a fixed budget that cannot be exceeded. This budget must cover all aspects of the project, including research, equipment procurement, installation, and maintenance.
3. Regulatory Compliance: The project must adhere to all relevant local, national, and international regulations and standards related to environmental protection, water treatment, and military infrastructure.
4. Resource Availability: The availability of specialized equipment and materials required for the seawater filtration system may be limited, potentially affecting procurement timelines and project schedules.

18. FGP development risks

1. Weather-Related Delays: Adverse weather conditions, such as hurricanes or heavy rains, could delay site assessments, data collection, and installation activities, impacting the overall project timeline. 2. Technical Failures: There is a risk of technical failures or malfunctions in the seawater filtration system components, which could lead to delays and additional costs for repairs or replacements. 3. Supply Chain Disruptions: Disruptions in the supply chain, such as delays in the delivery of critical components or materials, could hinder the timely completion of the project. 4. Regulatory Changes: Changes in environmental or water treatment regulations during the project lifecycle could necessitate modifications to the project plan, potentially increasing costs and extending the timeline.

19. FGP main milestones

Deliverable	Finish Estimated Date
1. FGP Profile	
1.1 Introduction Module	
1.1.1 FGP Charter	
1.1.1.1 FGP Charter (Items 1-10)	8-Jul-24
1.1.1.2 Appendix 5 - Preliminary Bibliographical Research	9-Jul-24
1.1.2 FGP Charter	15-Jul-24
1.1.2.1 Appendix 1-FGP Charter (Items 11-12)	15-Jul-24
1.1.2.2 Appendix 2- FGP WBS	16-Jul-24
1.1.3 FGP Charter	22-Jul-24
1.1.3.1 Corrections	22-Jul-24
1.1.3.2 Appendix 1-FGP Charter (Item 13-19)	22-Jul-24
1.1.4 Theoretical Framework	29-Jul-24
1.1.4.1 Corrections	29-Jul-24
1.1.4.2 Chapter 2- Theoretical Framework	29-Jul-24

1.1.4.3 Appendix 1 FGP (Item 20)	29-Jul-24
1.1.5 Methodological Framework	5-Aug-24
1.1.5.1 Corrections	5-Aug-24
1.1.5.2 Chapter 3- Methodological Framework	5-Aug-24
1.1.5.3 Appendix 1- FGP Charter-(Item 21)	5-Aug-24
1.1.6 Introduction	12-Aug-24
1.1.6.1 Corrections	12-Aug-24
1.1.6.2 Chapter 1- Introduction	12-Aug-24
1.1.6.3 Chapter 7-Project Validation in the Regenerative and Sustainable Development	12-Aug-24
1.1.6.4 Appendix 1- FGP Charter (Item 22)	12-Aug-24
1.1.6.5 Appendix 3- FGP Schedule	19-Aug-24
1.1.7 Executive Summary	26-Aug-24
1.1.7.1 Corrections to the complete Document	26-Aug-24
1.1.7.2 Executive Summary	26-Aug-24
1.1.7.3 Abstract	26-Aug-24
1.1.7.4 Bibliographical References	26-Aug-24
1.1.7.5 Indexes (contents, figures and charts)	26-Aug-24
1.1.7.6 Signed FGP Charter	26-Aug-24
2.1 Graduation Seminar	26-Aug-24
2.0 Tutoring	3-Sep-24
2.1 Tutor	3-Sep-24
2.1.1 Tutor assignment	3-Sep-24
2.1.2 Communication	3-Sep-24

2.2 Adjustments of previous charters (if needed)	9-Sep-24
2.3 Chapter 4 Development (results)	16-Sep-24
2.3.1 Project Initiation (Project Charter)	16-Sep-24
2.3.2 Project Planning	23-Sep-24
2.3.2.1 Project Management Plan	23-Sep-24
2.3.2.2 Scope Management Plan	23-Sep-24
2.3.2.3 Schedule Management Plan	30-Sep-24
2.3.2.4 Cost Management Plan	7-Oct-24
2.3.2.5 Quality Management Plan	14-Oct-24
2.3.2.6 Stakeholder Management Plan	14-Oct-24
2.3.2.7 Communications Management Plan	28-Oct-24
2.3.2.8 Risk Management Plan	18-Nov-24
2.3.3 Project Execution	25-Nov-24
2.3.4 Project Monitoring and Control	25-Nov-24
2.3.5 Project Closure	25-Nov-24
2.4 Conclusion	25-Nov-24
2.5 Recommendations	2-Dec-24
3.0 Readers Review	
3.1 Reviewers Assignment Request	
3.1.1 Assignment of two reviewers	3-Dec-24
3.1.2 Communication	
3.1.3 FGP Submission to Reviewers	3-Dec-24
3.2 Reviewers Work	
3.2.1 Reviewer 1	
3.2.1.1 FGP Reading	16-Dec-24

3.2.1.2 Reader 1 Report	23-Dec-24
3.2.2 Reviewer 2	
3.2.2.1 FGP Reading	16-Dec-24
3.2.2.2 Reader 2 Report	23-Dec-24
4.0 Adjustments	
4.1 Report for Reviewers	23-Dec-24
4.2 FGP Update	6-Jan-25
4.3 Second Review by Reviewers	10-Jan-25
5.0 Presentation to Board of Examiners	
5.1 Final Review by Board	17-Jan-25
5.2 FGP Grade Report	17-Jan-25

20. Theoretical framework

20.1 Estate of the "matter"

Background Description and Current Status of the Problem

The Belize Coast Guard (BCG) faces significant challenges in ensuring a reliable water supply for its forward operating bases (FOBs). Currently, the water procurement methods include purchasing water transported by vessels, using seawater for non-potable purposes, and relying on rainwater catchment systems. These methods are logistically complex and unsustainable, especially during dry seasons, leading to operational inefficiencies and high costs.

Research and Proposed Improvements

Previous proposals to connect San Pedro's FOB to Belize Water Services Limited (BWSL) for a more reliable water supply were hindered by high costs associated with running pipes underwater. As an alternative, the current research suggests implementing a seawater filtration system as a sustainable solution. This system would provide a consistent potable water supply, reduce dependency on external sources, and improve operational efficiency.

Results of Implementation and Further Research

While no concrete steps have been taken yet, the proposed seawater filtration system promises to address the water supply challenges effectively. Further research and feasibility studies are required to evaluate the technical and financial aspects of this solution. The potential benefits include:

- **Operational Efficiency:** A sustainable and reliable water supply would make the FOBs more self-sufficient, reducing the need for water transportation and associated logistical challenges.
- **Personnel Welfare:** Access to clean drinking water is critical for the health and well-being of the Coast Guard personnel, boosting morale and productivity.
- **Cost-Effectiveness:** Reducing dependency on external water sources can lead to significant cost savings over time. Energy-efficient desalination technology can provide a cost-effective solution compared to transporting fresh water.
- **Sustainability:** Utilizing seawater for potable water reduces pressure on freshwater resources, contributing to environmental conservation efforts.
- **Strategic Capability:** Enhanced infrastructure at the FOBs strengthens the BCG’s strategic capability to respond to maritime incidents and enforce laws effectively.

Other Research Works and Their Results

Research has focused on the feasibility of seawater filtration systems for the BCG's FOBs, highlighting the benefits of such systems, including sustainability, costeffectiveness, and reduced logistical challenges. Studies have identified various technologies, such as reverse osmosis and ultrafiltration, as suitable for converting seawater into potable water. Modern desalination plants have achieved significant reductions in energy consumption, making them viable options for remote locations. Utilizing seawater reduces the pressure on freshwater resources and aligns with environmental conservation goals.

Factors for Better Understanding the Problem

Several factors help to better understand the problem and its current status:

1. **Technical Specifications:** Understanding the technical specifications and capabilities of seawater filtration systems is crucial for selecting the appropriate equipment for the project.
2. **Cost and Energy Efficiency:** Evaluating the cost and energy efficiency of modern desalination plants is essential for determining the feasibility of the proposed solution.
3. **Sustainability Goals:** Aligning the project with broader environmental and sustainability goals ensures that the solution contributes to long-term conservation efforts.

4. **Stakeholder Engagement:** Continuous engagement with stakeholders, including the Belize Coast Guard personnel, government agencies, and the local community, is critical for the project's success.

20.2 Basic conceptual framework

Basic Concepts to be Included in the Document

- **Project Management**: The application of knowledge, skills, tools, and techniques to project activities to meet project requirements.
- **Seawater Filtration Technologies**: Methods and systems used to convert seawater into potable water, such as reverse osmosis and ultrafiltration.
- **Sustainability**: Practices that ensure resources are used efficiently and responsibly to minimize environmental impact.
- **Operational Efficiency**: The ability to deliver services in the most cost-effective manner without compromising quality.
- **Stakeholder Engagement**: The process of involving individuals, groups, or organizations that may affect or be affected by the project.
- **Cost-Benefit Analysis**: A systematic approach to estimating the strengths and weaknesses of alternatives to determine the best approach.
- **Risk Management**: The identification, assessment, and prioritization of risks followed by coordinated efforts to minimize, monitor, and control the probability or impact of unfortunate events.
- **Project Monitoring and Control**: Processes to track, review, and regulate the progress and performance of a project and identify any areas where changes to the plan are required.
- **Project Closure**: The process of finalizing all project activities, completing all deliverables, and formally closing the project.

21. Methodological framework

Objective	Name of deliverable	Information sources	Research method	Tools	Restrictions
1. Conduct a comprehensive assessment of existing seawater filtration technologies and systems for the Belize Coast Guard Forward Operating Bases.	Comprehensive Seawater Filtration Assessment Report	Primary: Interviews with technical experts, Site visits Secondary: Academic journals, technical reports, Government and industry reports	Analytical, Descriptive	Brainstorming, Interviews, Document Analysis, Technical Reports	- It's crucial that we use this time efficiently, recognizing the urgency and importance of our roles. This includes all phases, from initial research to final implementation and evaluation. - The project has a fixed budget that cannot be exceeded. This budget must cover all aspects of the project, including research, equipment procurement, installation, and maintenance.
2. Implement initiation processes, including developing the project charter and identifying key stakeholders to establish a	Project Charter and Stakeholder Register	Primary: Meetings with stakeholders, Workshops Secondary: Project management guides, Case studies,	Analytical, Descriptive	Brainstorming, Meetings, Expert Judgment, Charter Template	Complete the project within the allowable time.

high-level project structure for the seawater filtration system.		Articles on stakeholder engagement			
Objective	**Name of deliverable**	**Information sources**	**Research method**	**Tools**	**Restrictions**
3. Elaborate and develop the project management plan, including the creation of subsidiary management plans for scope, schedule, costs, resources, quality, communications, risks, acquisitions, and stakeholders, to define the project baselines for the seawater filtration system.	Comprehensive Project Management Plan	Primary: Project planning sessions, Interviews with experts Secondary: Project management standards, Previous plans, Academic articles	Analytical, Descriptive	Expert Judgment, Scope Management Plan Template, Gantt Chart, Microsoft Project	-The project has a fixed budget that cannot be exceeded. -The project must adhere to all relevant local, national, and global guidelines and rules about environmental protection, water treatment, and military infrastructure.

4. Select tools and techniques and define procedures for the execution of the seawater filtration system project.	Execution Procedures and Tools Selection Report	Primary: Consultations, Pilot testing Secondary: Manuals, Research papers	Analytical	Data Analysis, Microsoft Project, Expert Judgment, Interviews	The availability of specialized equipment and materials required for the seawater filtration system may be limited, potentially impacting procurement timelines and project schedules.

Objective	**Name of deliverable**	**Information sources**	**Research method**	**Tools**	**Restrictions**
5. Evaluate the costeffectiveness, energy efficiency, and ease of maintenance of the proposed seawater filtration system from a conceptual and theoretical point of view, applying research to develop a welldefined case study.	Feasibility and Cost-Effectiveness Report	Primary: Data collection, Interviews Secondary: Economic analyses, technical papers, Case studies	Analytical, Experimental	Cost Aggregation, Historical Information Review, Pilot Testing	We need to plan carefully and efficiently to ensure that we meet any deadlines. This will help us to manage expectations and deliver results within the given time constraints.

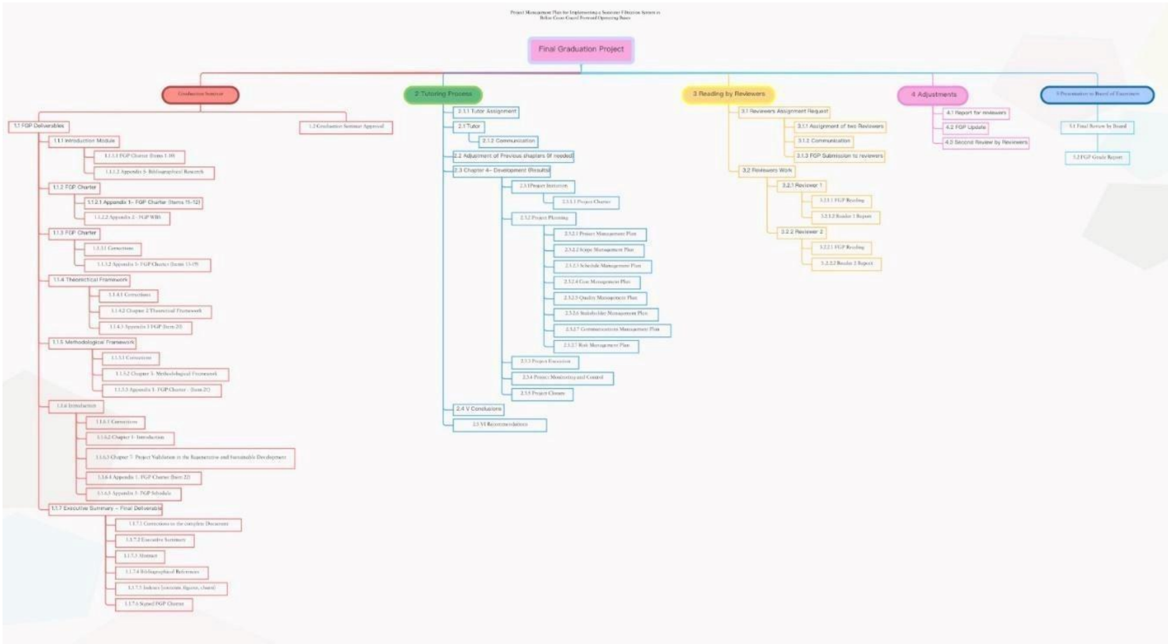
6. Establish a project monitoring and control system through tools and techniques to ensure the effective integration of project objectives and goals.	Monitoring and Control Plan	Primary: Development sessions, Stakeholder feedback Secondary: Articles, Case studies on monitoring systems	Analytical	Monitoring Tools, Status Reports, Risk Log, Earned Value Management	The project must not exceed the fixed budget. All relevant local, national, and international environmental regulations and standards must be followed.
7. Define a project closure procedure that includes the final evaluation of objectives and goals achievement, lessons learned reporting, and product transfer to operations management.	Project Closure and Lessons Learned Report	Primary: Workshops, Interviews with experts Secondary: Textbooks, Articles on project closure and knowledge transfer	Analytical	Closure Checklist, Lessons Learned Register, Final Report Template	Adhering to high-quality standards is essential for all project documentation, such as lessons learned reports and product transfer documents, to guarantee clarity and usability for future operations.

22. Validation of the work in the field of the regenerative and sustainable development.

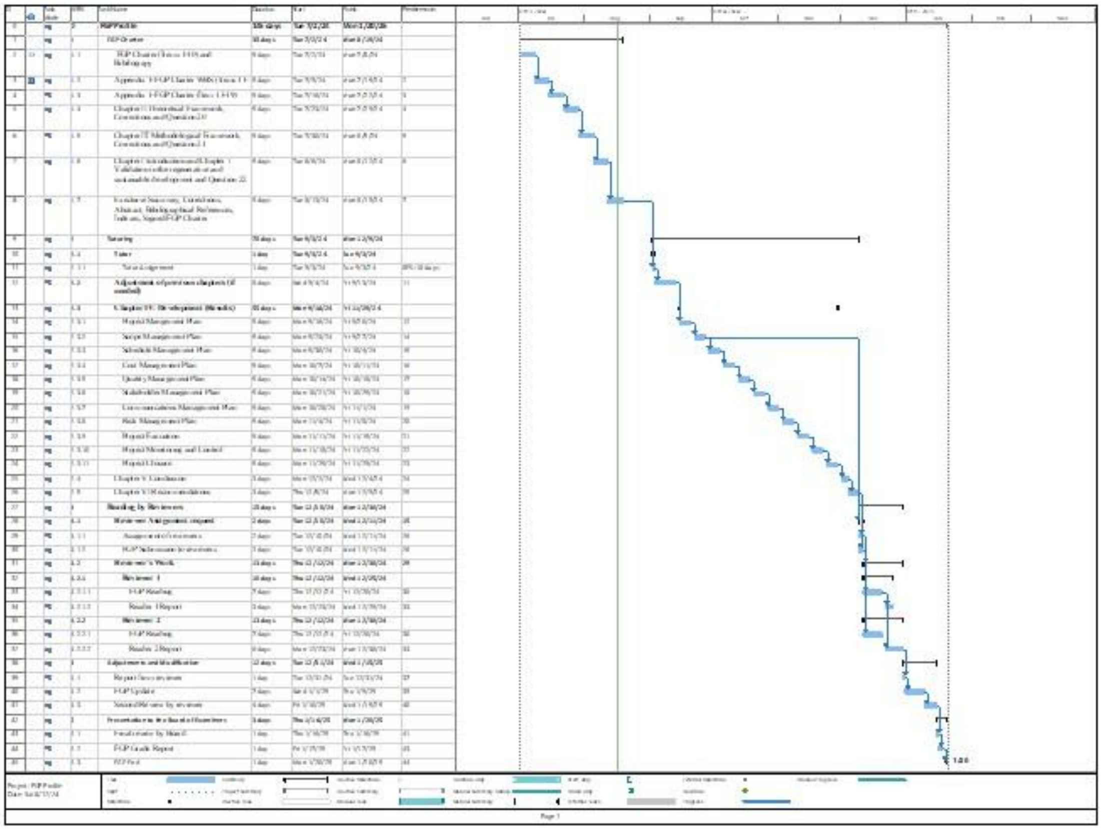
The project's validation in regenerative and sustainable development is evident in its significant contributions to environmental sustainability, the reduction of reliance on scarce freshwater resources, and support for natural regeneration processes. Converting seawater into potable water reduces pressure on local freshwater ecosystems and conserves vital resources. Notably, the project also addresses climate change by ensuring a stable and sustainable water supply, which contributes to the resilience of the local environment. It also promotes social and economic benefits such as improved health and well-being, operational efficiency, and cost savings, consequently fostering regional economic stability. The project aligns with Sustainable Development Goals (SDGs) related to clean water and sanitation, climate action, and life below water. The P5 Impact Analysis underscores the project's positive social and economic impacts while recommending strategies for mitigating unfavorable effects and ensuring a fair distribution of economic benefits. The project outlines potential indicators for tracking water quality, energy consumption, community health, and economic impact. Overall, the project is vital in achieving regenerative and sustainable development by providing a reliable and sustainable potable water supply, preserving the environment, and promoting regional social and economic resilience.

Appendix 2: FGP WBS

WBS FGP life cycle



Appendix 3: FGP Schedule



Appendix 4: Preliminary bibliographical research

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- This article highlights a successful seawater desalination project in Belize, which can provide lessons learned and a reference point for the current project.

Cowo, J. (2019, August 9). *Belize's solution to reliable access to clean water using the sea*. The San Pedro Sun. https://www.sanpedrosun.com/business-and-economy/2019/08/10/belizes-solution-to-reliable-access-to-clean-water-using-the-sea/

- This article provides relevant background information on the water challenges in Belize and how seawater desalination can be a solution, which is directly applicable to the project context.

Filters for sea water treatment & reverse osmosis systems. (2024). Filternox Automatic Self-Cleaning Filters &

Strainers. https://www.filternox.com/filtration/sea-water-treatment-reverse-osmosis-systems/

- This source details the technical specifications and capabilities of seawater filtration systems, which is crucial information for selecting the appropriate equipment for the project.

Filtration, F. (2019, January 17). *Seawater filter: Ultimate guide*. Filson Filter. https://www.filsonfilters.com/seawater-filter

- This comprehensive guide on seawater filters covers important details like types, applications, working principles, and selection criteria that would be valuable for the project planning.

Fox, A. (2020, March 23). *ROWPU military water purification*. Main Website. https://www.ampac1.com/products/industrial-reverse-osmosis-systems/rowpu-military-water-purification

- It provides examples of specific ROWPU models used by the U.S. Marine Corps, such as the Lightweight Water Purification System (LWPS) and Tactical Water Purification System (TWPS). These examples can serve as benchmarks for selecting appropriate systems for the Belize Coast Guard's needs and operating conditions.

Guidelines for the Planning of Seawater Reverse Osmosis Desalination Plants in Jordan. (2022, March). mwi.gov. https://www.mwi.gov.jo/ebv4.0/root_storage/ar/eb_list_page/guidelines_for_planning_and_management_of_seawater_reverse_osmosis_desalination_plants_in_jordan.pdf

- These resources provide essential information about the technical specifications and capabilities of seawater filtration systems, which is vital for choosing the right equipment for the project.

Project Management Institute. (2021). A Guide to the Project Management Body of Knowledge, (*PMBOK® Guide*) - Seventh Edition, Project Management Institute, Inc., 2021.

- As a globally recognized standard, the PMBOK® Guide will help ensure the project management practices align with the industry's best practices, increasing the likelihood of successful outcomes and facilitating any future collaboration or knowledge sharing with other organizations.

Razali, M., Wahab, N., Sunar, N., & Shamsudin, N. (2023, February 27). *Existing filtration treatment on drinking water process and concerns issues*. MDPI. https://www.mdpi.com/2077-0375/13/3/285

- It specifically discusses membrane filtration technologies, such as ultrafiltration (UF), forward osmosis (FO), and reverse osmosis (RO), which are highly relevant to the project's focus on seawater desalination and purification.

Shirle, A. (2022). *Project Management of Water Treatment Plant*. Mathematical Statistician and Engineering Applications. https://www.philstat.org

- The article provides a structured approach to managing water treatment plants, which is directly applicable to the project management of the seawater filtration system. It offers insights into planning, organizing, controlling, and monitoring the project, ensuring it is completed within the specified scope, time, and budget.

Trusted Seawater Filtration System Manufacturer-NEWater. (2024). NEWater Bring New Life for Water. https://www.newater.com/sea-water-filtration-system/

- As a leading manufacturer, these sources provide expert insights into seawater filtration technologies, design considerations, and best practices that can inform the project implementation.

Appendix 5: Other relevant information- Revision Dictum

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20th December 2024

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To Whom it May Concern:

RE: Philological Review of Susely Elizabeth Valdez's Thesis Submission

I have read and reviewed the Final Graduation Project entitled "Project Management Plan for Implementing a Seawater Filtration System in Belize Coast Guard Forward Operating Bases" prepared by Ms Susely Valdez and submitted in partial fulfilment of the requirements for the Master's in Project Management (MPM) Degree at UCI.

I have considered the standard of academic writing and the use of English in the document. I find the language and expression therein to be lucid and precise. Syntax is sophisticated and correct throughout. Spelling is accurate and the register appropriate for work at this level. Overall, the fluency of writing is proficient, precise, and mature. The scholarly apparatus is accurate, consistent, and well-judged. The document appears complete and logically organised.

I have included comments on the draft document in the form of suggestions and tracked minor corrections for the consideration of the writer and tutors. The most significant of these concern completeness and accuracy of cited references and a query on the use of symbols for non-enumerated lists.

Should any further information regarding these comments be required or should the thesis committee wish to discuss any aspect of my evaluation, I would be pleased to assist.

Sincerely,

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