الجمهورية الجزائرية الديمقراطية الشعبية
République Algérienne Démocratique et Populaire

Ministère de l'Enseignement Supérieur
et de la Recherche Scientifique
Université Akli Mohand Oulhadj - Bouira -
Institut de Technologie

وزارة التعليم العالي والبحث العلمي
جامعة أكلي محند أولحاج
- البويرة -
معهد التكنولوجيا

Department of Water Engineering

Defense Report

For the attainment of the degree of

Professional Master's in:

Hydraulics

Theme:

Design of seawater intake for seawater desalination plant of Corso W.Boumerdes

Realized by :

FEKIR Ikram

Supervised by :

- Mr. DAHMANI Saad — Professor/ Institute of Technology
- Mr. MOKRANI Sofiane — Engineer / Algerian Energy Company

Jury Member :

- Examiner: Mrs.REZIG Amina — Professor/ Institute of Technology
- Jury president: Mr. YAHIAOUI Abd El halim — Professor/ Institute of Technology

University Year: ***2023/2024***

ملخص :

نظراً لنقص المياه الصالحة للشرب في ولاية بومرداس، قمنا بدراسة مشروع لتصميم مأخذ مائي لمحطة تحلية مياه البحر في قورصو، وتحديداً نظام الالتقاط. يتكون هذا النظام من برج الالتقاط الموصول بقناة توصيل، حيث يتم جلب مياه البحر بفعل الجاذبية إلى المحطة وصولاً إلى حوض الالتقاط.

تتمثل هذه الدراسة في تحديد أبعاد برج الالتقاط، قناة التوصيل، وحوض الالتقاط. في نهاية هذه الدراسة، اقترحنا إنشاء برج الالتقاط بارتفاع 8500 مم وقطر 3300 مم، وقناة التوصيل بقطر 1400 مم، وحوض الالتقاط بشكل مستطيل بأبعاد10×6×6 متر.

كلمات مفتاحية: التمّوج، تحلية الماء، ماء البحر، برج إلتقاط، حوض إلتقاط.

Abstract:

Due to the shortage of drinking water in the Boumerdes province, we conducted a study for designing a water intake for a seawater desalination plant in Corso, specifically focusing on the intake system. This system consists of an intake tower connected to an intake pipeline, where seawater is conveyed by gravity to the plant, reaching the intake basin.

This study aims to determine the dimensions of the intake tower, the intake pipeline, and the intake basin. At the end of this study, we proposed the construction of an intake tower with a height of 8500 mm and a diameter of 3300 mm, an intake pipeline with a diameter of 1400 mm, and a rectangular intake basin with dimensions of 10×6×6 meters.

Keywords: The wave, desalination, seawater, intake tower, intake basin.

Résumé:

En raison de la rareté d'eau potable dans la wilaya de Boumerdes, nous avons étudié un projet de conception d'une prise d'eau pour une station de dessalement de l'eau de mer à Corso, en particulier le système de captage. Ce système est composé d'une tour de captage reliée à un consuite d'amené, où l'eau de mer est acheminée par gravité vers la station, arrivant jusqu'au bassin de captage.

Cette étude consiste à déterminer les dimensions de la tour de captage, de la conduite d'amenée et du bassin de captage. À la fin de cette étude, nous avons proposé de construire une tour de captage d'une hauteur de 8500 mm et d'un diamètre de 3300 mm, un canal de distribution d'un diamètre de 1400 mm, et un bassin de captage de forme rectangulaire avec des dimensions de 10×6×26 mètres.

Mots clés: La houle, dessalement, eau de mer, tour de captage, bassin de captage.

Thanks

Our heartfelt thanks to God Almighty for everything.

I would also like to express my deep gratitude to all the people who have helped me throughout my work, especially my dear parents for their encouragement throughout my journey.

Our greatest gratitude and sincere thanks go to my supervisor, Mr. DAHMANI Saad, for his availability, attention, patience, and especially his valuable advice, as well as for the honor he bestowed upon me by mentoring me.

I extend my sincere thanks to the entire AEC team, especially Ms. TALEM Meriem, Mr. MOKRANI Sofiane, Mr. HAMZA, and Mr. YAINS for all the support they have provided.

I also thank all the professors of the HYDRAULICS department for their enriching training, their listening, and their encouragement.

My respect goes to the presidents of the jury and the jury members who will honor me by evaluating my work.

Dedication

Whenever we complete an important milestone in our lives, we take a moment to remember those who have shared all the good moments with us, but especially the bad ones. These are the people who helped us without being asked, supported us unreservedly, loved us unconditionally, and believed in us. Thanks to them, our happiness and joy rightfully return, and any sorrow within us transforms into tears. May the Almighty keep these dear ones close to our hearts.

I dedicate this modest thesis, which is the culmination of many years of study, firstly to:

My mother, to whom I owe so much for her sacrifices, her love, her help, and her support.

My father, who supported me and knew how to give me courage when needed.

My brother, Madjid.

My sisters, Abir and Asma.

My dear friends, Silya, Maroua, Hind, Sabrina, Anissa, and Asma.

All my colleagues from the class of 2023-2024.

Table of contents

Chapter IV: Swell study

Chapter V: Design of seawater intake

List of figures

List of tables

General introduction

General Introduction

Access to a source of drinking water is a major concern in many regions of the world, especially in arid or semi-arid areas where freshwater resources are limited. In this context, desalination of seawater has emerged as an indispensable solution to meet the increasing demand for drinking water.

Desalination plants play a crucial role in converting seawater into usable freshwater. However, their effectiveness largely depends on the proper design of various elements, including the seawater intake. The intake structure serves as the starting point of the desalination process, where seawater is extracted for treatment.

This end-of-studies project focuses on "the sizing of the seawater intake in Corso the province of Boumerdes desalination plant". Through a methodical approach, we will examine the various aspects involved in this crucial process, with emphasis on the optimal design of the intake tower, inlet pipeline, and intake basin.

In this general introduction, we will lay the groundwork by briefly presenting the project and describing the overall context of seawater desalination. We will also highlight the importance of proper intake sizing to ensure operational efficiency and environmental sustainability of the desalination plant.

The first part of this document briefly introduces the hosting company that provided the framework for this project. Then, we will present the project in detail, shedding light on the description of the desalination plant and the key elements of the desalination process. Subsequently, we will delve into the core of our study, namely the sizing of the seawater intake, analyzing the various variables and constraints involved in this process.

Finally, we will conclude this introduction by emphasizing the significance of this work in the context of sustainable water resource management and anticipating the potential benefits that a well-designed seawater intake can bring in terms of operational efficiency, costs, and reduced environmental impact.

Chapter I

Internship Company *Presentation*

1 Introduction

"Algerian Energy Company," a company that holds a central position in Algeria's energy landscape. In this chapter, we will introduce this company and explore its mission.

2 Presentation of Algerian Energy Company (AEC)

- **Official Name**: Algerian Energy Company spa,
- **Abbreviation**: AEC,
- **Type of company**: Public enterprise, Joint-stock Company (Spa),
- **Date of establishment**: 2001,
- **Major shareholder**: Sonatrach,
- **Ownership percentage**: 100% Sonatrach, since 2018,
- **Logo of AEC**: The AEC logo, with its distinctive design, symbolizes the company's identity.

Figure I.1: Logo of AEC

The following picture represents the headquarters of AEC.

Figure I.2: The headquarters of Algerian Energy Company (AEC)

3 The geographical location of Algerian Energy Company

Algerian Energy Company is strategically located at 168, Rue Hassiba Ben Bouali street, Hamma, Algiers. The following picture represents the geographical location of AEC.

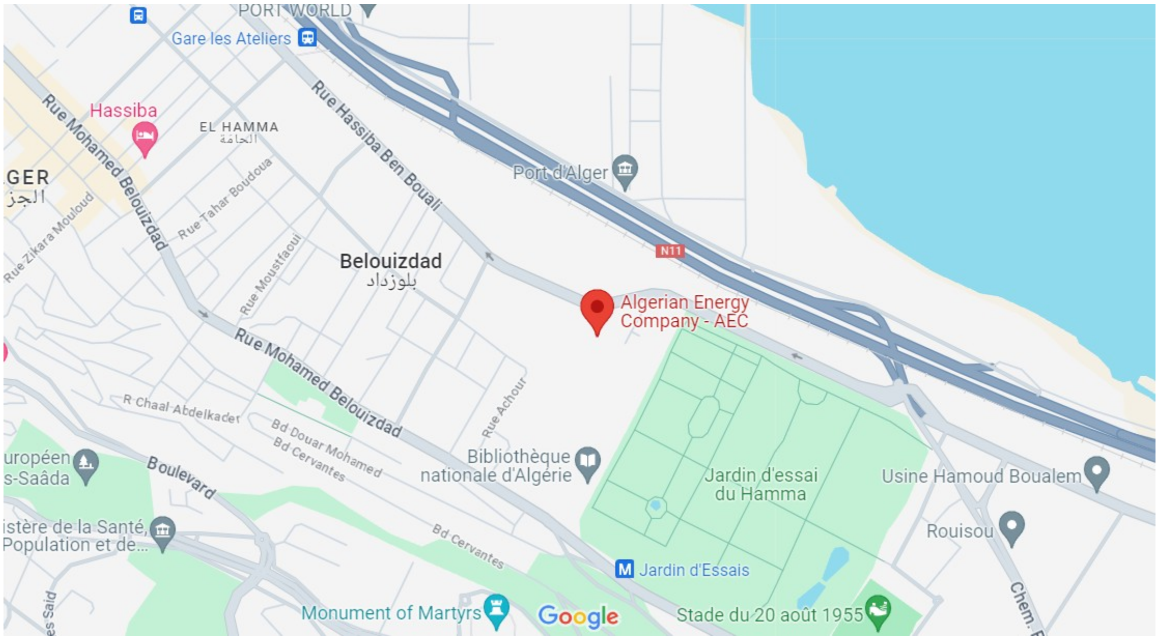


Figure I.3: Geographic location of AEC.

4 History

Algerian Energy Company (AEC) was founded in 2001 as part of the strategic expansion of the energy sector in Algeria. Initially, the company aimed to consolidate national energy resources and contribute to the country's economic development.

In 2018, Sonatrach, Algeria's largest state-owned energy company, acquired all shares of AEC, thereby making it a wholly-owned subsidiary of Sonatrach. This acquisition strengthened AEC's position in the Algerian energy landscape and facilitated closer integration into the national energy policy.

5 The missions of Algerian Energy Company

Its missions consist of promoting large-scale projects, either independently or in partnership with national or foreign firms operating, notably, in:

- Electricity generation;

- Seawater desalination;

-Renewable energy sources.

It is undeniable that the activity for which AEC is most well-known is seawater desalination. The following table shows the desalination plants built by AEC:

Table I.1: The desalination plants built by AEC

Desalination plant	Capacity (m^3/day)
Tenes (W. Chlef)	500 000
Souk Tlata (W. Tlemcen)	200 000
Skikda	100 000
Mostaganem	200 000
Magtaa (W. Oran)	500 000
Kahrama (W. Oran)	86 880
Honain (W. Ain Temouchent)	200 000
Fouka I (W. Tipaza)	120 000
El Marsa (W. Alger)	60 000
El Hamma (W. Alger)	200 000
Corso (W. Boumerdes)	80 000
Cap Djinat I (W. Boumerdes)	100 000
Beni Saf (W. Ain Temouchent)	200 000
Bateau Cassé (W. Alger)	10 000

Concerning the stations that are currently under construction, here is a representative table.

Table I.2: Projects of AEC

Desalination plant	Capacity (m^3/day)
El Taref	300 000
Fouka II (W. Tipaza)	300 000
Capblanc (W. Oran)	300 000
Cap Djinet II (W. Boumerdes)	300 000
Bejaia	300 000

Conclusion

In this chapter, we have presented the company "AEC", explored its missions, projects, and the various desalination plants that have been constructed.

Chapter II

Process of seawater desalination

1 Introduction

Seawater and brackish water desalination becomes a crucial answer in a world where resources are scarce and fresh water demand is rising steadily. This chapter focuses on the various desalination processes used to convert these sources of saline water into potable water. We will examine in detail the main methods, including reverse osmosis, to better understand their operation and their application in addressing the global water crisis.

2 Definition of seawater desalination

Desalinating seawater involves extracting salt and impurities to create freshwater that can be used for drinking, industry or farming. It plays a role, in regions facing water shortages or pollution offering a remedy to water scarcity, along coastlines. **[01]**

3 Seawater quality

Seawater is a complex solution that contains a variety of dissolved inorganic and organic substances. The composition of seawater can vary slightly depending on factors such as location, depth, and proximity to sources of pollution. However, the following table represents the major components found in seawater.: **[02]**

Table II.1:The major components found in seawater.

Cations	Quantity (mg/L)	Anions	Quantity (mg/L)
Sodium	11035	Chlorides	19841
Magnesium	1330	Sulfates	2769
Calcium	418	Bicarbonates	146
Potassium	397	Bromides	68
Strontium	14	Fluorides	1,4
Total salinity:36 019,4 mg/L			

4 Seawater desalination technologies

Desalination can be accomplished through methods. Industrial desalination technologies utilize either phase change or semi permeable membranes to separate the solvent or solutes. As a result desalination methods can be categorized into two groups; phase change or thermal processes and membrane or single phase processes. Each method necessitates the pre-treatment of seawater.**[03]**

The following figure represents various technologies for desalination of seawater.

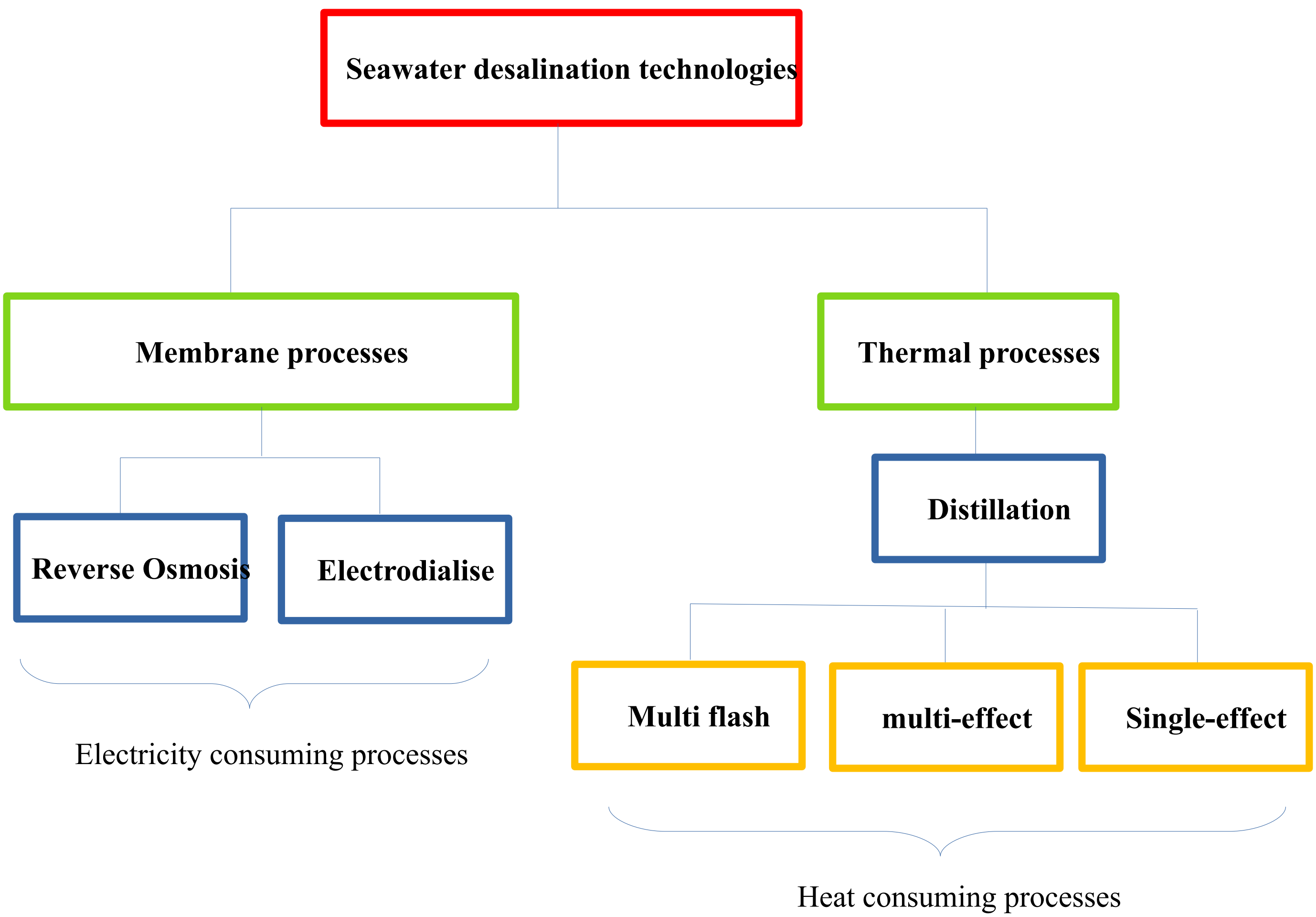


Figure II.1: Seawater desalination technologies **[03]**

The process we will follow is reverse osmosis desalination. Therefore, we will explain in detail the desalination of seawater by reverse osmosis.

4.1 Reverse osmosis

Osmosis is a process present in all living beings at the cellular level. It involves the movement of molecules from an area of low solute concentration to an area of high solute concentration, across membranes such as semi-permeable membranes. When solute molecules cannot pass through the membrane, water moves to balance the concentrations. This equalization results in what is known as osmotic pressure **[02]**.

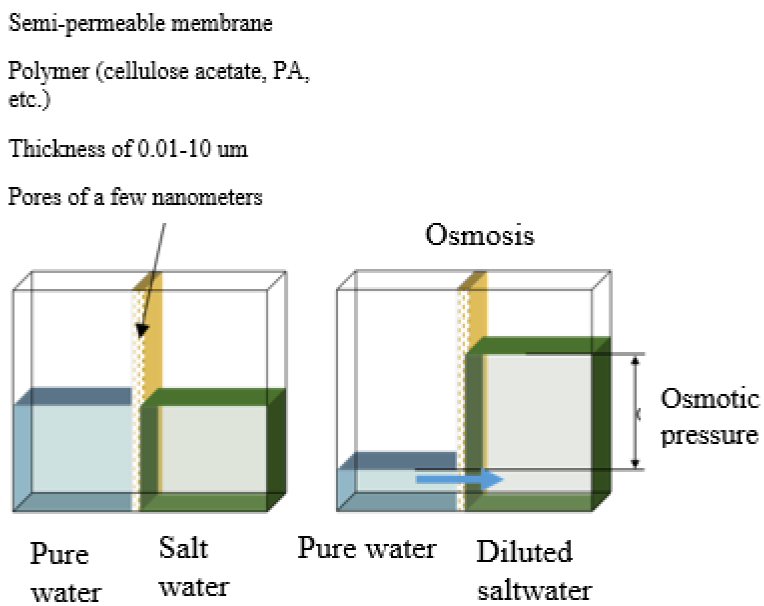


Figure II.2: Osmosis processes **[2]**

Reverse osmosis, contrary to natural osmosis, is a water purification process that involves separating solutes, including salts and other impurities, from water. Reverse osmosis uses an external pressure higher than osmotic pressure to force water through a semi-permeable membrane. This allows for the production of fresh water from saltwater or brackish water, thus providing a source of drinking water or high-quality water for various industrial and commercial applications.**[02]**

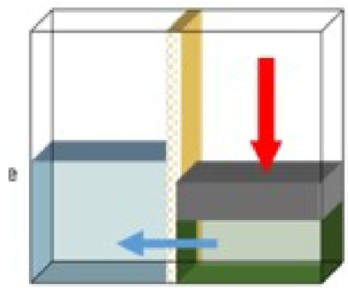


Figure II.3: Reverse osmosis **[2]**

Feedwater supply: Seawater or brackish water is pumped into the reverse osmosis unit at a pressure of about 60 bars. This pressure is necessary to force the water through the semi-permeable membrane **[02]** .

Reverse osmosis membrane: Inside the reverse osmosis unit, there are several membranes installed in high-pressure tubes. These membranes are designed to allow water to pass through while retaining salts and other impurities **[02]** .

Filtration process: The high-pressure water is forced through the reverse osmosis membranes. The pores of the membrane are so small that they do not allow salt molecules to pass through, but they allow pure water to pass. This results in the separation of freshwater from salts and other contaminants **[02]** .

Freshwater production: The water that passes through the membranes is collected as freshwater **[02]** .

Brine rejection: As freshwater passes through the membranes, some of the seawater is rejected as brine, containing a higher concentration of salts and other impurities **[02]** .

Here's the explanatory diagram of this process.

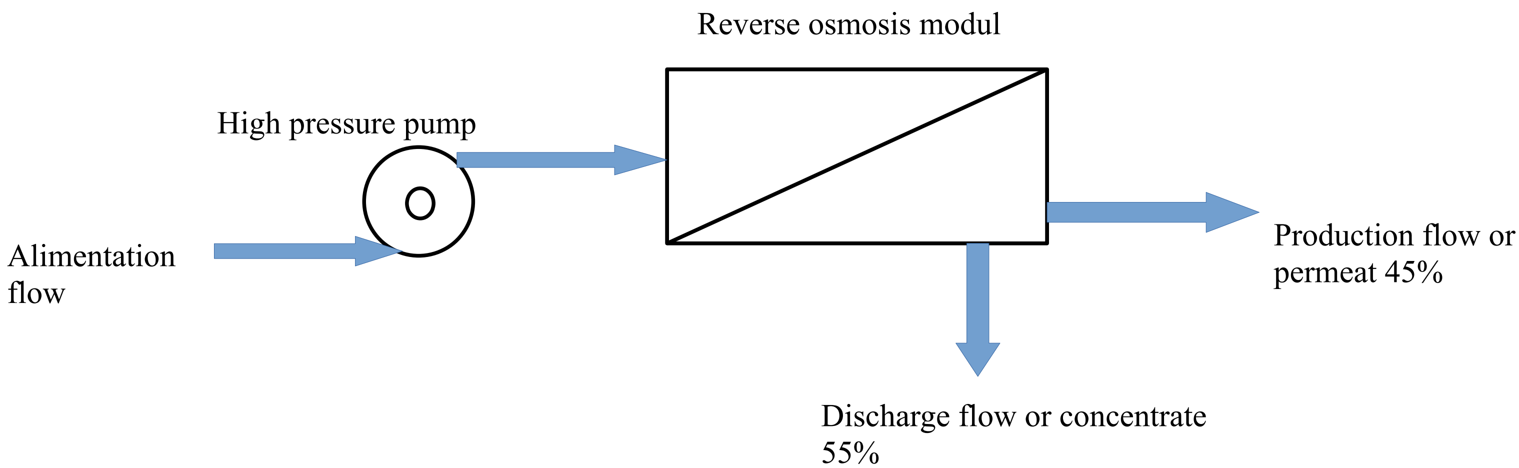


Figure II.4: Process of reverse osmosis

5 Seawater desalination processes

Seawater desalination involves the filtration of water to remove impurities, progressing from larger to smaller particles across multiple stages.

The desalination process of seawater is represented by four essential steps, which are:

- Seawater intake;
- Pretreatment;
- Reverse osmosis;
- Post-treatment.

5.1 Seawater intake

Sea water intake is the initial process that allows for the collection and conveyance of water from its natural environment, primarily the oceans and seas. Here are the typical steps of the sea water intake process:

5.1.1 Identification of intake sites

Suitable sites for sea water intake are selected based on criteria such as water quality, geographical conditions, proximity to usage areas, and environmental considerations (wind speed, wave amplitude, …).

5.1.2 Design of intake structures

Specific structures are designed to efficiently collect sea water while minimizing environmental impacts.

5.1.3 Installation of intake equipment

The necessary equipments for sea water intake, such as seawater intakes, pipelines and retention basins is installed according to project specifications.

5.1.4 Sea water intakes towers

There are three main families of methods for extracting raw seawater. These families have subfamilies that are further diversified according to secondary criteria (site characteristics, technological processes, etc.) **[04]**. We will focus on:

a) Coastal Well Intake

Coastal well intakes are similar to land-based well intakes in groundwater aquifers but are drilled along the coastal fringe at depths sufficient to allow seawater or brackish water to seep through the soil.

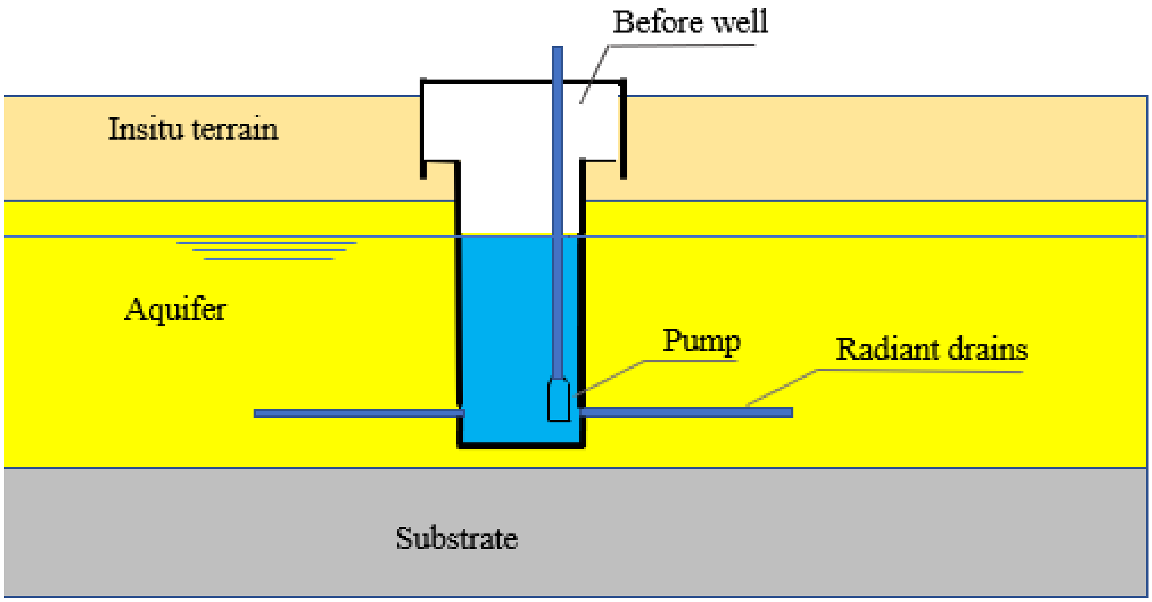


Figure II.5: Beach wells with radial drains (Ranney) **[04]**

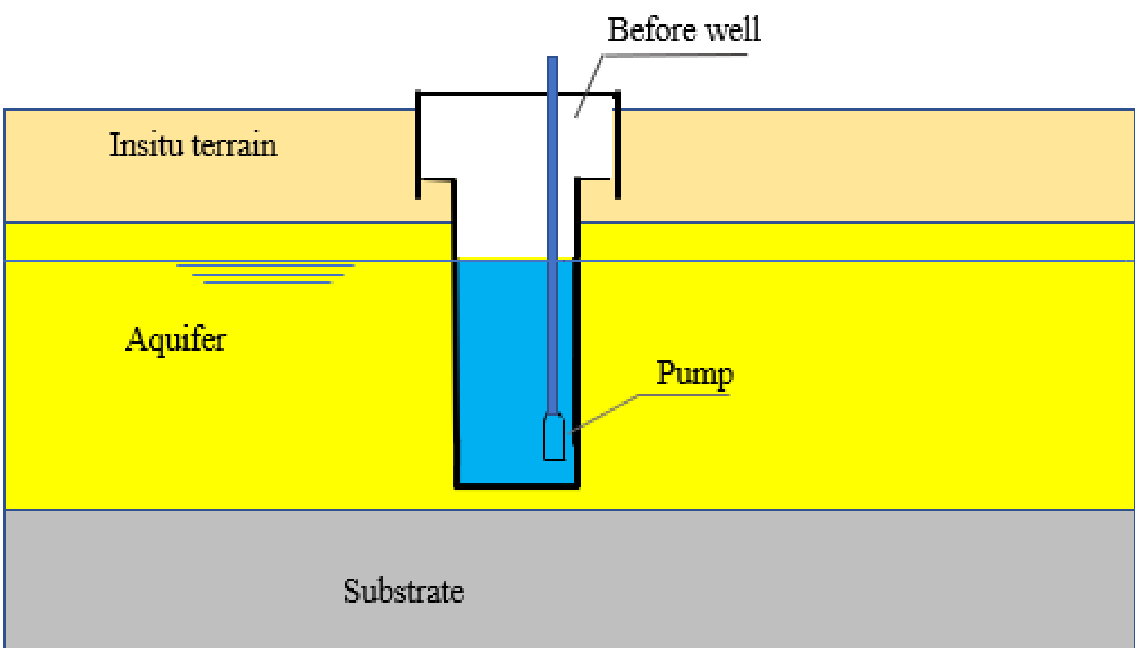


Figure II.6: Coastal wells **[04]**

This type of intake has the following advantages:

- It provides water highly suitable for desalination by reverse osmosis: no suspended matter or algae, low fouling index (FI ~2), low concentration of organic matter (TOC <1 mg/l) **[04]**.
- It helps to limit and simplify pretreatment processes.
- It is unaffected by sediment transit.

However, it has some disadvantages **[04]**:

- It provides only low flow rates (risks of soil clogging and well dewatering if the filtration rate is too high), typically ranging from 10 to 50 l/s per well, which must be spaced several hundred meters apart to avoid interference between their drawdowns of the saline aquifer.
- Possibility of interactions between the saline aquifer and the freshwater aquifer flowing towards the sea.
- Requirement for thorough geological and hydrogeological investigations.
- Need for monitoring of the physical, chemical, and biological characteristics of the water.

b) ***Infiltration Capture Beneath Beaches or Seafloor***

Seawater can be captured beneath a beach or nearshore area through marine wells, drainage trenches, driven or drilled drains, or drain fields **[04]**.

- **Marine wells**

Marine wells are similar to coastal wells but are drilled directly into a seawater aquifer or salt wedge, atop a beach, on a beach, in a lower intertidal zone, or on a shoal. Their drainage can be enhanced by horizontal radial drains, typically several diameters (5 to 20) of the well in length. This type of intake offers the following advantages **[04]**:

- It provides water of very good quality, which can be comparable to that of coastal wells depending on the thickness of the traversed terrains and the filtration rate.
- It delivers higher flow rates than coastal wells (due to greater soil permeability), typically ranging from 50 to 300 l/s per well, which must be spaced 100 to 150 m apart to avoid interference between their drawdowns of the saline aquifer.
- No interaction between the saline aquifer and the freshwater aquifer.
- Marine wells require shallower depths than coastal wells.

However, it has some disadvantages:

- It requires beach access for construction and operation (marine works), making it difficult to use on cliffed coasts (i.e., coasts with high slopes).
- It can become sensitive to sediment transport if filtration rates are sufficient to cause significant beach buildup.
- It requires thorough geological and hydrogeological investigations.

- **Drainage Trenches**

The intake is achieved through a perforated pipe buried below the level of the lowest tides, in a trench within a bed of gravel or ballast surrounded by a geotextile filter. The perforated pipe is connected by a sealed pipe to a well that fills with seawater due to gravity. The drain can be protected against scouring (surf zone) by burying it deeper. The gravel is then covered with a layer of filtering sand and a permeable protection like "rip-rap" **[04].**

Parallel to the coastline beneath the beach (figure II.7): Seawater infiltrates into the drain from the side and partially from above and below. The gravel bed section may be taller than it is wide.

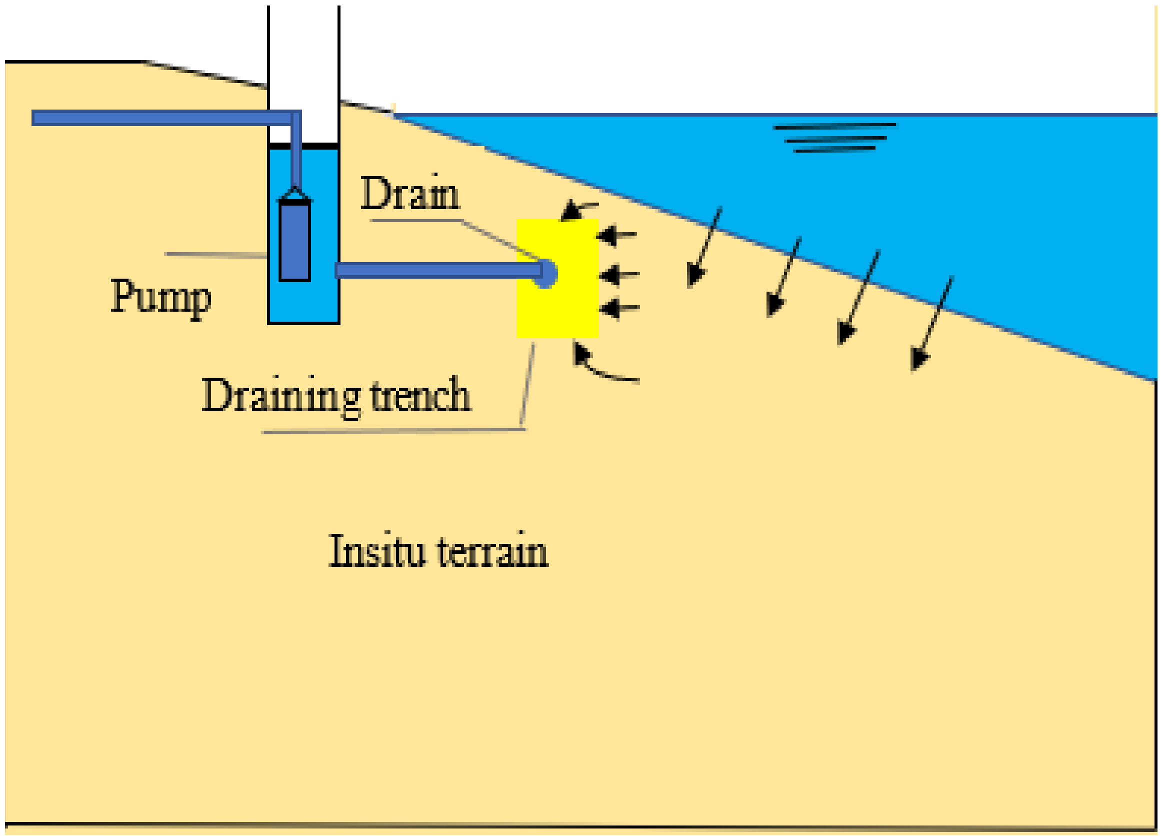


Figure II.7: Drainage Trench Parallel to the Coastline **[04]**

Normal to the coastline beneath the foreshore (figure II.8): Seawater infiltrates into the drain primarily from above. The trench is therefore covered either with original materials if their filtering qualities are satisfactory, or with additional materials of greater permeability.

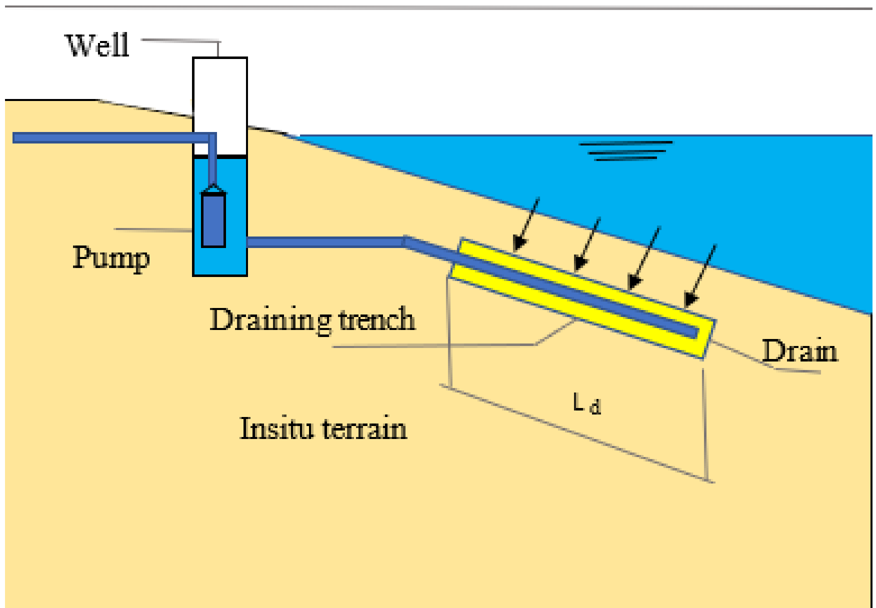


Figure II.8: Normal to the Coastline Drainage Trench **[04]**

- **Subhorizontal Drains or Bored Wells**

A variant of the trench normal to the coastline involves sinking (for loose soils) or drilling (for fractured hard soils) a drain under the sea. The length of the drain can be adjusted to regulate the flow according to soil characteristics. This technique, resembling directional drilling, allows for reaching far under the sea without compromising the integrity of the seabed **[04]**.

- **Drain Fields**

Installing multiple drains, either parallel or converging, in drainage trenches or through directional drilling, helps to limit the distance towards the sea. In semi-slow filtration (0.2 to 0.6 m/h), a drain field can provide a surface flow rate of 0.06 to 0.18 $l/s/m^2$ **[04]**.

c) Direct Seawater Intakes

- **Seawater Intake through Conduit Canal**

The larger the flow rate of the seawater intake, the less acceptable pressure losses become. Therefore, a seawater intake through a canal at the coastline is necessary for very high flow rates.

- **Seawater Intake through Submerged Wells**

Filtration in a basin involves capturing water through a coarse grille (10 to 20 cm) to trap solid bodies that could obstruct or damage the pipeline. It is not possible to install a pump on the pipeline, so the water must be brought by a siphon (gravity or vacuum) into a pumping basin where it is filtered. This method is generally adopted for large flow rates (several m3/s to several tens of m3/s), for example, for the cooling of medium-sized power plants **[04]**.

a) ***Surface water intake through pipelines:*** The pipeline is supported by a structure (dedicated walkway (wharf).). Equipped with a vacuum priming device, it dives below the free surface and draws water through a pipe designed to prevent vortices (figure II.9). The pipe is protected by grilles.

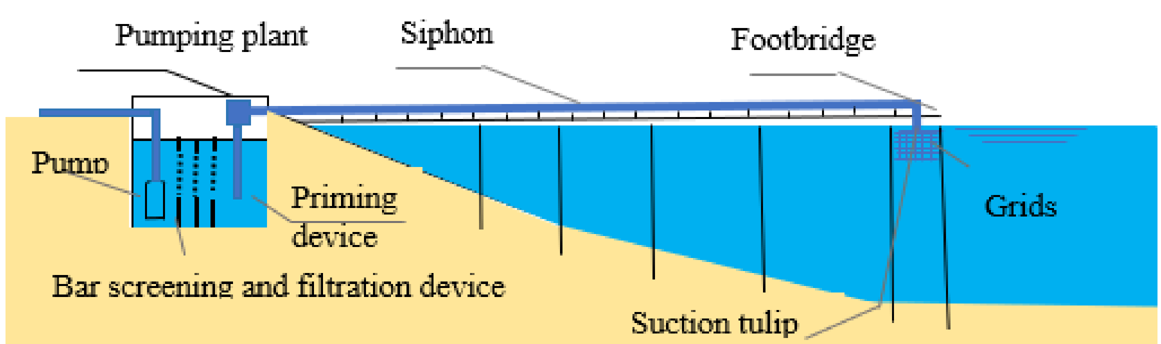


Figure II.9: Surface Water Intake **[04]**

b) ***Deepwater intake through galleries or pipelines:*** Water is brought through a drilled gallery or a buried pipeline in the surf zone, then laid on the bottom and weighted or anchored beyond. Water is drawn through a tulip or a well equipped with grilles **[04]** (figure II.10).

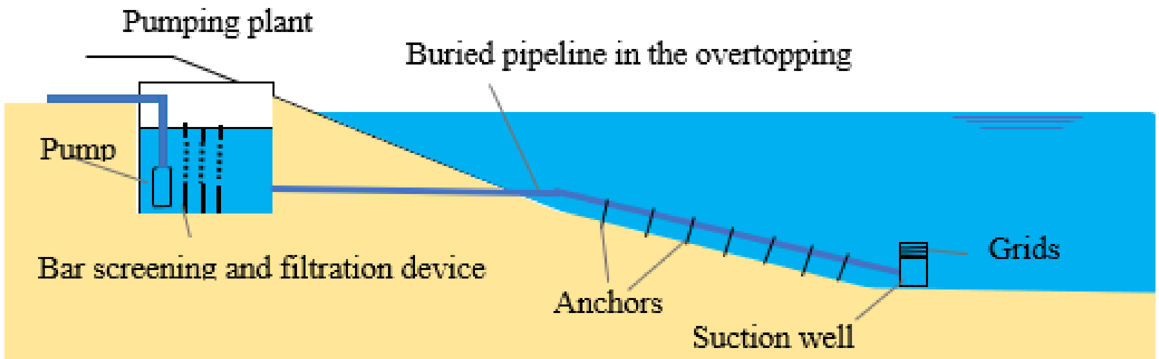


Figure II.10: Deepwater Intake **[04]**

- **Intake with Strainer Screens**

Filtration at the intake involves drawing water through a strainer screen with mesh sizes ranging from a few tens of micrometers to a few millimeters. This filtration allows for the installation of a pump directly on the suction pipeline without exposing it (damage from solid bodies and fish, abrasion from fine particles, etc.). This method is generally reserved for low to medium flow rates (from a few m3/h to a few hundred m3/h). Periodic cleaning of the strainer screen is necessary (water or compressed air flushing, intervention at sea) **[04]**.

a) ***Surface Strainer Intake**:* The principle is the same as before, but the tulip is replaced by a strainer, either vertical or horizontal, installed near the free surface. The pump is located on the pipeline, either on land or at the end of the walkway to pump water over almost the entire length of the pipeline; electricity must then be supplied to the walkway. The use of submerged pumps complicates maintenance and upkeep for installations that are difficult to access **[04]**.

b) ***Bottom Strainer Intake**:* The principle is the same as before, but the water is drawn through a strainer installed above the bottom and protected by a tarpaulin or grille. The pumping station is located on land at an elevation close to the level of the lowest tides. Water is drawn into the pipeline and then pumped to installations at higher levels. For not too significant pressure losses, the water supply can be gravity-fed to the pumping station **[04]**.

5.1.5 Collection of sea water

Sea water is captured from its natural environment using the designated structures, such as sea water intakes. It is then directed to treatment or distribution facilities.

5.1.6 Transport of sea water

Once collected, sea water is conveyed to intended destinations through underwater or land pipelines.

a) The intake pipelines

The intake pipeline, in the context of seawater supply for desalination or other similar applications, is typically a pipeline that connects the seawater intake tower to the seawater intake basin. This pipeline is designed to efficiently transport seawater from the source to the destination.

In many cases, these intake pipelines are made from materials resistant to corrosion and suitable for aggressive marine conditions. Two commonly used materials for intake pipelines are GRP (Fiberglass reinforced plastics) and HDPE (High-Density Polyethylene).

b) ***Seawater intake basin***

A seawater intake basin is a structure designed to collect and store seawater before it is treated or used. It is typically located near the coast for easy access to seawater, and its size and design can vary depending on the specific project needs and local environmental conditions.

Here is a summary of the common characteristics of seawater intake basins:

- **Open or closed structure:** Basins can be open or closed, with often trapezoidal shapes to avoid dead angles, depending on the specific project needs.
- **Construction materials:** They are typically constructed of concrete, steel, or corrosion-resistant composite materials to ensure durability and resistance to marine conditions.
- **Pumping equipment:** Pumps may be installed to facilitate the transfer of seawater to other treatment or storage facilities.
- **Filtration systems:** Filtration systems may be integrated to remove debris and coarse contaminants from seawater before its use.
- **Water quality control:** Monitoring and maintenance measures for water quality may be implemented to ensure it meets required standards for its intended use.

5.2 Pre-treatement

Proper operation of desalination units can be guaranteed by pretreatment. It depends on the type of desalination process adopted.

5.2.1 Screening

The method used to remove large particles and debris is the passage of seawater through inclined screens, which prevent impurities larger than 5 cm from passing through. This method is often employed as the initial pre-treatment step.

There are scrapers specifically designed to clean the bar screens. These scrapers can be automatic or manual and are used to remove debris accumulated on the screens or inclined screens in order to maintain their effectiveness and prevent blockages.

5.2.2 Sieving

The process is sieving, and the method is a rotary screen. The rotary screen is equipped with a perforated cylindrical screen or filter mesh that retains solid particles of specific size while allowing water to pass.

The cleaning of the rotary screen is done in the opposite direction, with a water jet performing the washing during each rotation.

5.2.3 Coagulation-Floculation-Decantation

Coagulation, flocculation, and decantation are three essential processes in water desalination. These processes aim to remove suspended matter in water by grouping them together to facilitate their removal. Here is a detailed explanation of each process:

- ***Coagulation***

Coagulation is the process of destabilizing suspended particles in water by adding coagulants, such as aluminum sulfate (alum) or ferric chloride.

These coagulants neutralize the charges on the particles, allowing them to come together and form larger aggregates called flocs **[2]**.

- ***Flocculation***

Flocculation follows coagulation, it involves gently stirring the water after the addition of the coagulant to promote the formation of flocs. During flocculation, the coagulated suspended particles begin to come together to form larger and heavier aggregates, known as flocs. This occurs through physical forces such as collision and adhesion between the particles. The resulting flocs are much larger than individual suspended particles, making them easier to remove subsequently in the following stages of water treatment, such as sedimentation and filtration **[2]**.

- ***Decantation***

After the formation of flocs in the coagulation-flocculation process, a sedimentation step is often necessary to separate suspended particles and the formed flocs from the treated water. Here's how this sedimentation step works **[2]**:

Introduction into the settler: The water containing the formed flocs is introduced into a settler such as a clarifier or settling basin.

Floc sedimentation: Inside the settler, the water is left undisturbed for a sufficient period to allow the formed flocs to settle to the bottom of the settler under the influence of gravity. The flocs, being heavier than water, tend to settle slowly at the bottom of the settler.

Sediment formation: The flocs that settle at the bottom of the settler form a deposit of mud or sediment. This deposit consists of the suspended particles that have been aggregated together by the coagulation and flocculation processes.

Removal of sediment: After an appropriate settling period, the accumulated sediment at the bottom of the settler is removed, typically through a sludge removal mechanism.

5.2.4 Filtration

Anthracite sand filtration is indeed a widely used process to remove impurities and organic matter from water in order to improve its quality by eliminating odors, color, and other contaminants.

Anthracite sand filtration can be carried out according to two main types: gravity filtration and pressure filtration. Here is some information about each of these types:

- ***Gravity Filtration:***

A sand filtration basin is a structure designed to contain the sand bed used in the water filtration process. It is typically comprised of a large rectangular concrete tank. The size of the basin depends on the amount of water to be treated as well as the required flow rate for the filtration process.

In this type of filtration, water is brought through the sand bed solely by the effect of gravity. The system is typically designed so that water enters through the top of the filtering bed and passes through the sand as it descends. This type requires a large surface.

- ***Pressure Filtration:***

A sand filtration tank, or sand filter, is a structure designed to hold the sand bed utilized in water filtration. Typically constructed from durable and corrosion-resistant materials like concrete, GRP (Fiberglass reinforced plastics), or stainless steel, these tanks vary in size based on the volume of water to be treated and the necessary flow rate for filtration.

Unlike gravity filtration, this type of filtration uses a pump to force water through the sand bed under pressure. Water is usually introduced into the pressure filter through an inlet located on the side or bottom of the filter.

5.2.5 Micro filtration

Micro filtration is another important step in the process of seawater desalination. It involves the use of filter cartridges to remove suspended solids, bacteria, and other larger particles from the seawater. Here's how micro filtration works in the context of seawater desalination:

Filter cartridges are cylindrical devices filled with a porous filtering material, such as activated carbon, membranes, or special media designed to capture suspended particles and impurities in the water. Seawater is pumped through the filter cartridges at high pressure. As it passes through the pores of the filtering material, suspended particles, sediments, marine organisms, and other impurities are trapped, leaving behind cleaner and clarified water.

5.3 Post-Treatement

After treatment by reverse osmosis, water is devoid of minerals, making it unsuitable for consumption. Therefore, it is necessary to remineralize it to make it suitable for human consumption.

5.3.1 Carbon dioxide (CO_2) injection

The automatic injection of carbon dioxide (CO_2) at a concentration of 23 parts per million (ppm) is carried out to lower the pH of the water to around 5. This operation, performed in the CO_2 chamber, helps to adjust the acidity of the water to the desired level **[6]**.

5.3.2 Remineralization of desalinated water

Remineralization of desalinated water is an important post-treatment step aimed at restoring essential minerals that have been removed during the desalination process. Remineralization can be achieved by adding minerals such as calcium, magnesium, potassium, and bicarbonate to the water **[6]**.

Calcite and lime are two commonly used agents for the remineralization of desalinated water:

a) ***Calcite:*** Calcite is a crystalline form of calcium carbonate. It is often used in the remineralization process because it is rich in calcium and readily dissolves in water, thereby increasing its mineral content.

b) ***Lime:*** Lime, in the form of quicklime (calcium oxide) or hydrated lime (calcium hydroxide), is also used for remineralizing desalinated water. It reacts with the carbon dioxide present in the water to form calcium carbonate, which increases water hardness and contributes to its remineralization.

6 Energy Recovery

6.1 Introduction to the System

The conversion factor (τ =45%), which represents the ratio of permeate flow rate to feed flow rate, indicates that 55% of the rejected seawater constitutes the concentrate, possessing significant hydraulic energy. This energy needs to be recovered to reduce electrical energy consumption.

A new energy recovery system, the Pressure Exchanger (PX) system by the American company ERI, has proven its effectiveness in reverse osmosis desalination plants. It allows for the recovery of up to 95% of the energy contained in the brine reject. **[05]**

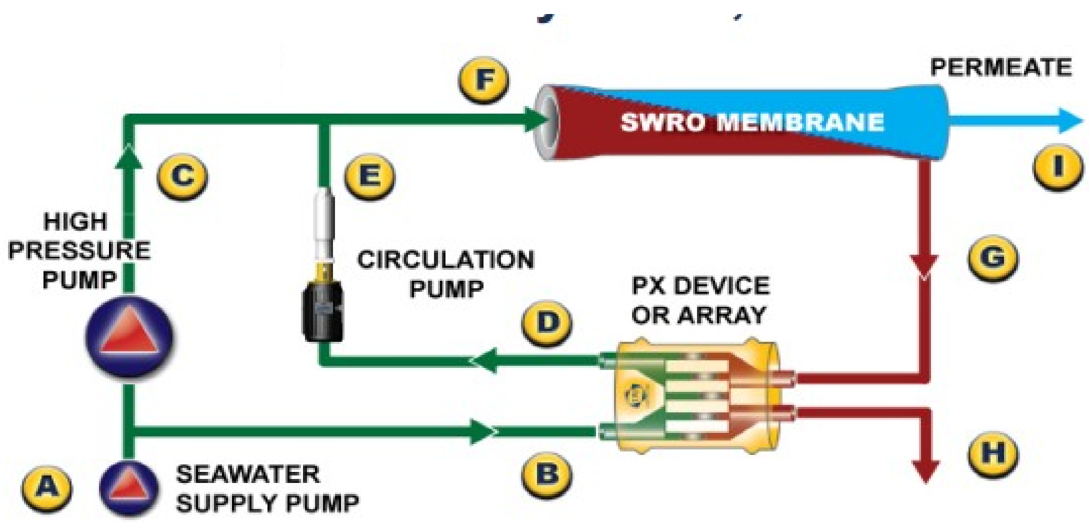


Figure II.11: Installation with PX pressure exchanger **[05]**

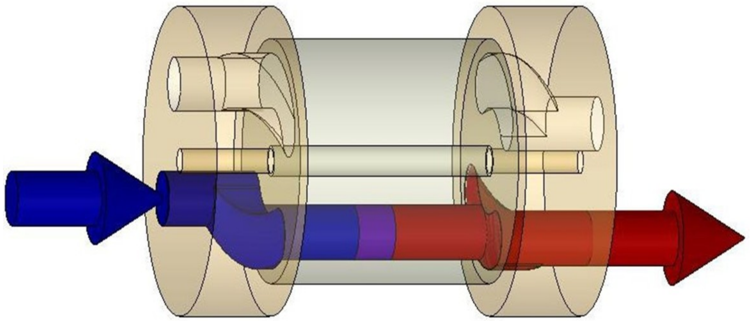
The membrane reject is directed to the PX, which utilizes this reject pressure to compress the fresh seawater, and then sends it back to the membranes. Therefore, the PX provides pretreated water using the energy contained in the concentrate it receives.

Here is the photo of pressure exchangers.

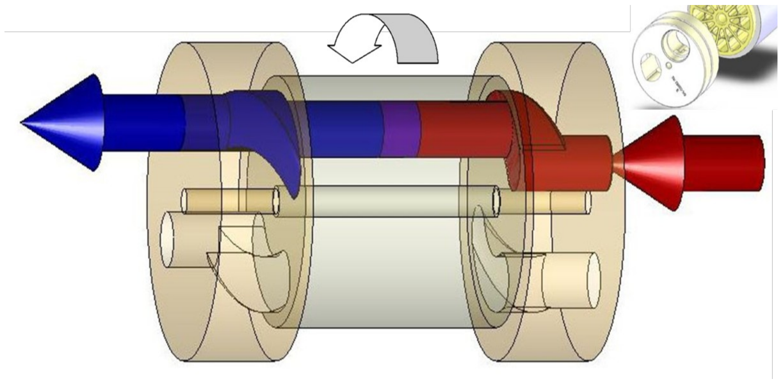
Figure II.12: pressure exchangers **[05]**

6.2 Operating principle of the system

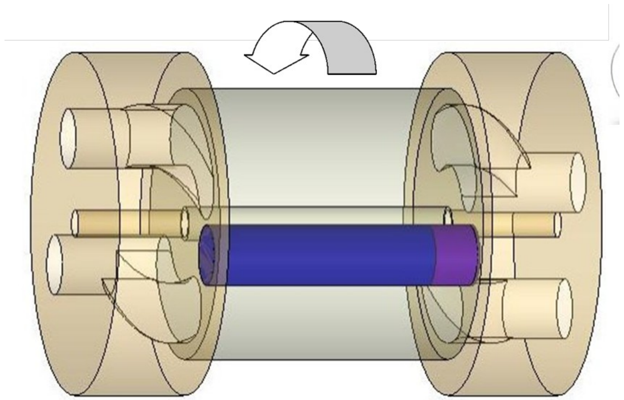
The figure II.13 illustrates the operating principle of the PX system **[05]**:



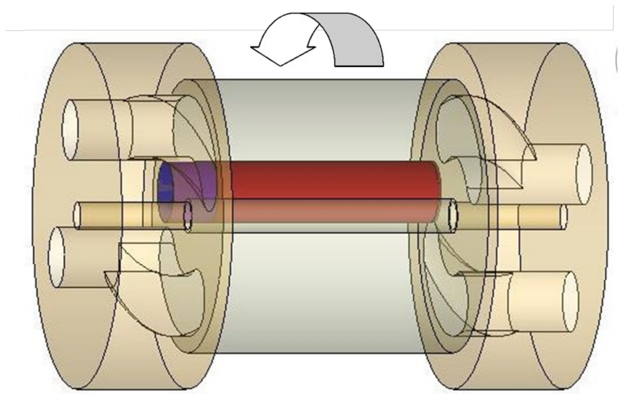
1. The seawater at Low Pressure fills the rotor chambers and displaces the brine towards the reject.



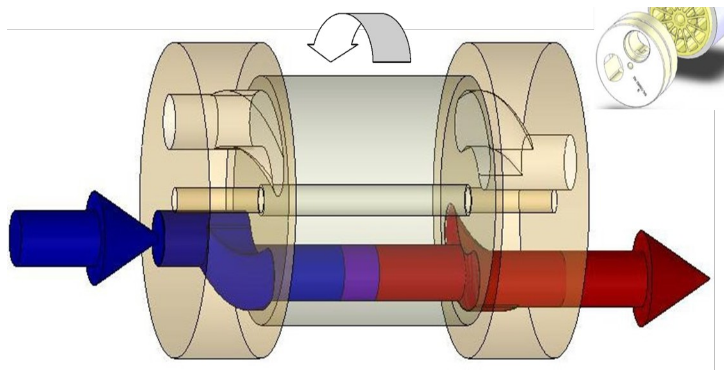
3. The High Pressure concentrate, coming from the membranes, pressurizes and displaces the seawater towards the membrane inlet.



2. The rotor chamber containing the seawater at Low Pressure is isolated



4. The rotor chamber, containing the High Pressure concentrate, is isolated.



5. Low-pressure water fills the chambers and displaces the depressurized concentrate towards the reject

Figure II.13 : The operating principle of the PX system **[05]**

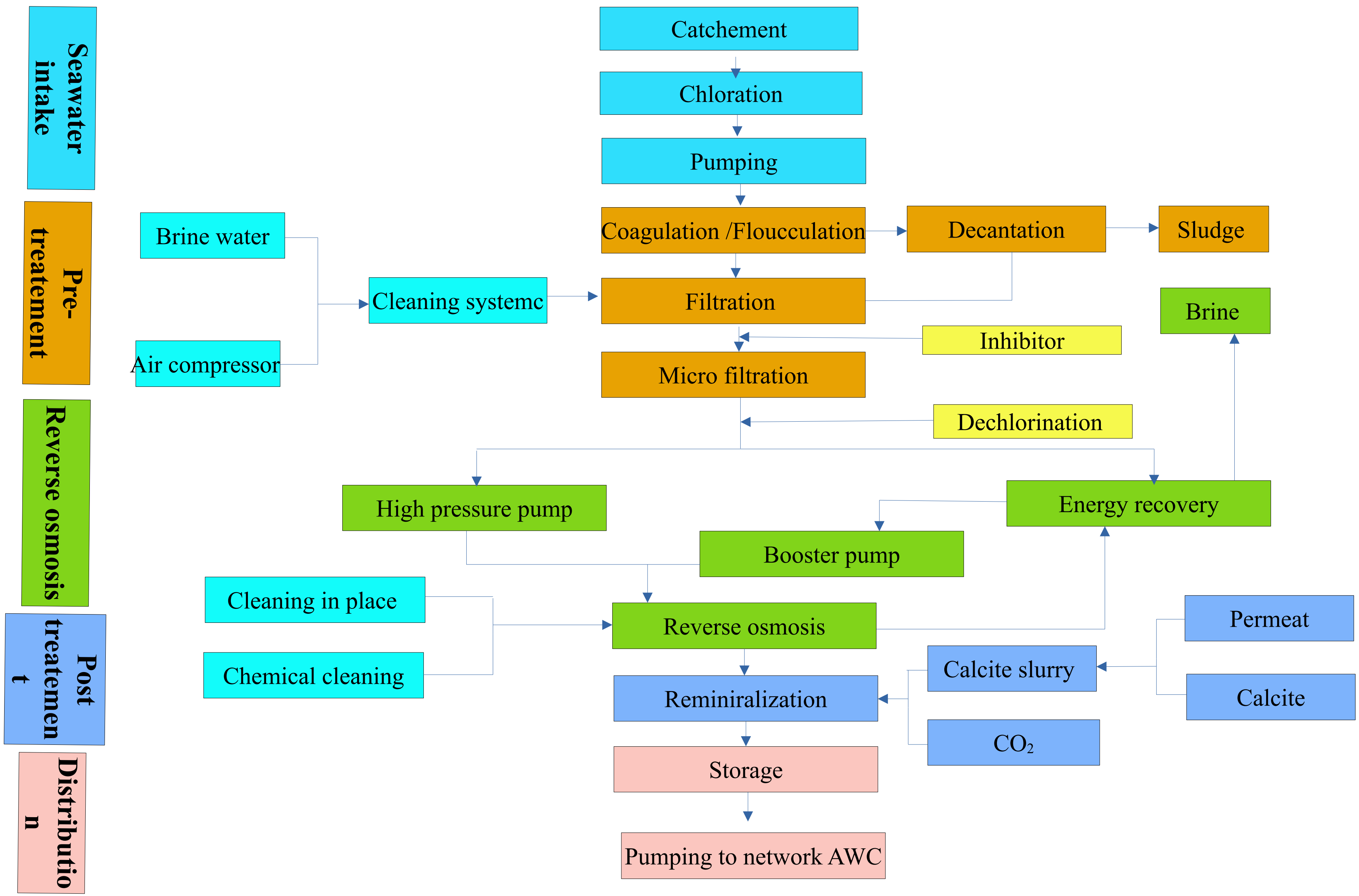


Figure II.14: Processe of seawater desalination **[01]**

Conclusion

In conclusion, desalination of seawater and brackish water proves to be a crucial solution in response to the increasing demand for fresh water, particularly in a context where available resources are becoming increasingly limited. This chapter has examined in detail the main desalination processes, highlighting their importance in the efficient conversion of saline water sources into potable water. We have specifically explored techniques such as reverse osmosis, which play a central role in this transformation.

Chapter III

Pr*esentation of project and description of seawater desalination plant of corso*

Introduction

Desalination of seawater is a vital process in many regions of the world where access to fresh water is limited, as it provides an alternative source of drinking water for coastal populations facing freshwater shortages.

This chapter aims to present the project issue and its description, as well as that of the desalination plant. We will introduce the facilities and processes of the plant.

1 Presentation of project

1.1 Problematic

Algeria is facing a real and pressing issue which is drought. Recently, surface water resources have reached insufficient levels to ensure the supply of drinking water. The Algerian government launched three emergency projects in 2021 to establish seawater desalination plants in the Eastern region of Algiers, with a total capacity of 150,000 m3/day. Among these plants, the construction of the plant of Corso in the province of Boumerdes, with a capacity of 80,000 m3/day, was initiated by AEC (Algerian Energy Company) to address this issue.

1.2 Location and geographical situation of the municipality of Corso

Corso is a small town located 3 km southwest of the capital of the Boumerdes province. Here is the geographical location of Corso.

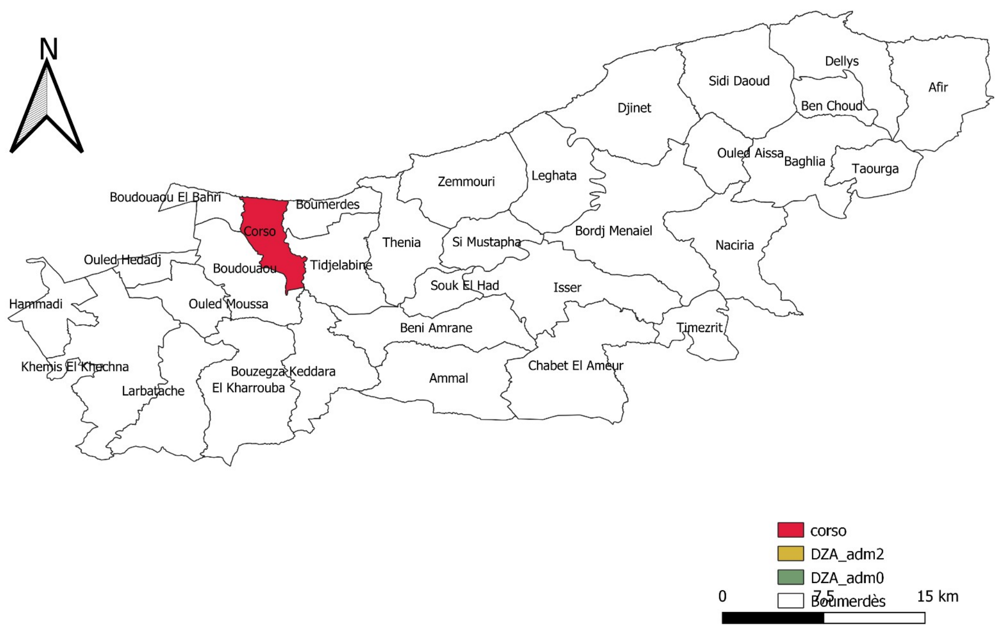


Figure III.1: Geographic map of the province of Boumerdes and the location of the municipality of Corso

1.3 Project Description

The part that interests us is the seawater intake. The seawater intake consists of three parts: the intake tower, located in the seabed and connected to an inlet pipeline to transport seawater gravitationally to the intake basin, from where it is pumped to the pre-treatment process.

The following figure represent the explanatory diagram of the project:

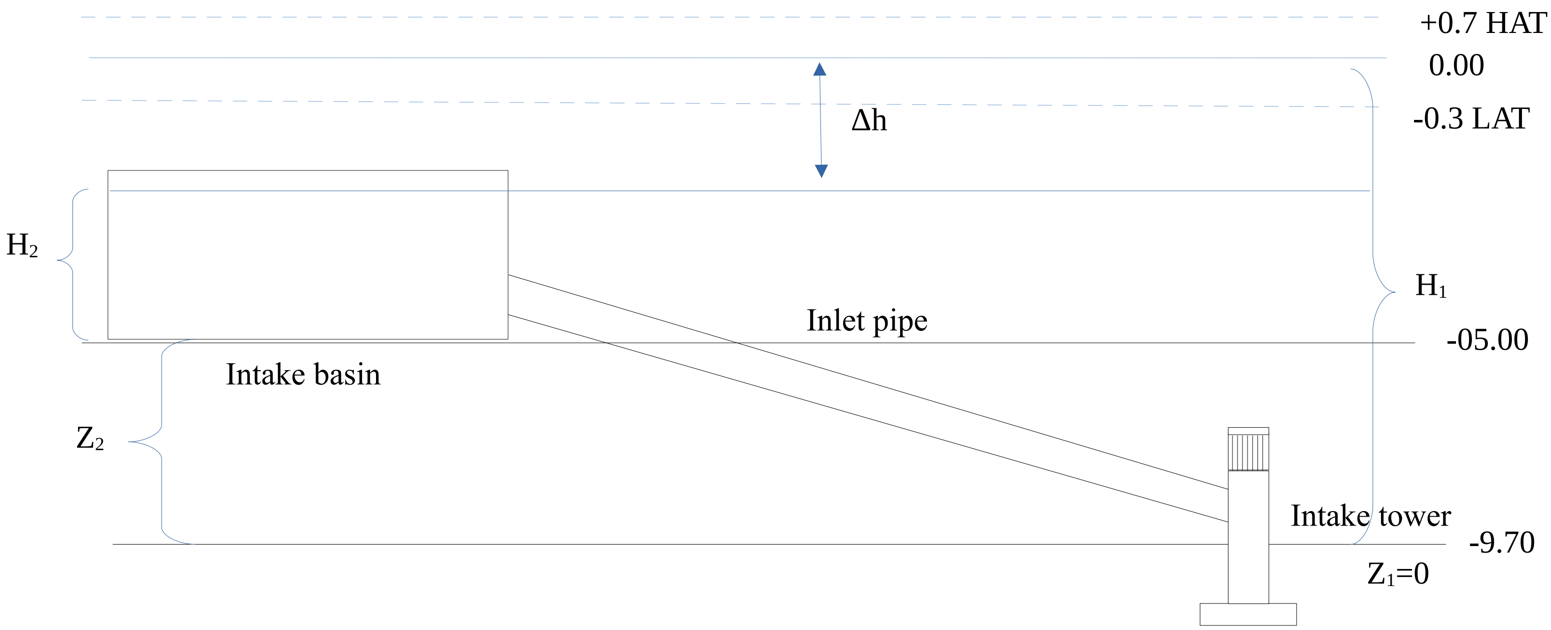


Figure III.2: Project explanatory diagram

HAT: The highest astronomical tide;

LAT: The lowest astronomical tide.

The objectives of this work are as follows:

- Sizing of the intake tower and material selection;
- Sizing of the inlet pipeline;
- Sizing of the intake basin.

2 Presentation of the seawater desalination plant of Corso

Due to the water crisis, the seawater desalination plant of Corso becomes the third facility completed and operated through Algeria's national effort.

Figure III.3: Interface of the seawater desalination plant of Corso

- **Localization**: The Corso seawater desalination plant is located in the province of Boumerdès in Algeria. The following figure shows the its geographic location.

Figure III.4: The geographic location of seawater desalination plant of Corso.

- **Project Start Date**: The project began in January 2022.
- **Partial Operation Start Date**: The plant commenced partial operation on July 4, 2023.
- **Production Capacity**: The plant has a production capacity of 80,000 m3/day.
- **Design and Management**: The plant was designed by a subsidiary of Sonatrach, the Algerian Energy Company (AEC), with the aim of enhancing the supply of drinking water to the municipalities of Tidjelabine, Boumerdès, Corso, Boudouaou-el-Bahri, Larbaâtache, Ouled Moussa, Hammadi, and Khemis-el-Khechna.

3 Description of the facilities and processes of the plant

The seawater desalination plant of Corso is equipped with sophisticated facilities designed to effectively treat seawater and convert it into high-quality drinking water. Here is a description of the main facilities and processes that make up this plant:

3.1 Seawater intake

This section will be properly dimensioned and explained in Chapter 04.

3.2 Pre-treatement

In this section, we will describe in detail the various stages of pretreating seawater at the Corso desalination plant. This will include the pre-filtration process to remove debris and large particles.

3.2.1 Screeniner

There are three screens, each with a maximum capacity of 8176 m^3/h. They allow debris with a size smaller than 25 mm to pass through. Here is the photos 5 and 6 representing the screener.

Figure III.6: Screener

Figure III.5: Top view image of the screener

3.2.2 The rotary screen

There are three rotary screens, each with a maximum capacity of 8176 m^3/h. They don't allow debris with a size greater than 3 mm to pass through. Here is the photo representing the rotary screen.

Figure III.7: The rotary screen

Figure III.8: Size of rotary screen

3.3 Coagulation-flocculation and settling tank

For the coagulation-flocculation and settling process, here it is the following characteristics :

Table III.1: Description of coagulation flocculation decantation process **[11]**

Tank	Coagulation	Flocculation	Settling
Number	04	08	08
Total volume	32.35 m^3	323.45 m^3	/
Flow	7762.90 m^3/h	7762.90 m^3/h	970.36 m^3/h
Tank length	2.50 m	10.00 m	22.00 m
Tank width	3.54 m	10.11 m	10.00 m
Retention time	60 seconds	20 minutes	/

Tank	Coagulation	Flocculation	Settling
Materials	Concrete	Concrete	Concrete
Chemical product	Ferric chloride	polymer	/
Slat slope	/	/	60 degree
Slat depth	/	/	0.80 m
Removal efficiency	/	/	90 %
Maximum dosage	10 mg/l	0.5 mg/l	/
Minimum dosage	2 mg/l	0.1 mg/l	/

3.4 Filtration

In the seawater desalination plant of Corso, 16 pressurized sand filters have been installed to ensure efficient treatment of desalinated water. These sand filters consist of three distinct layers:

- 600 mm of filtralite;
- 400 mm of sand;
- 200 mm of gravel.

Here is the photo of the sand filter installed in the SWDP (Seawater desalination plant) of Corso.

Figure III.9: Installation of sand filter

3.5 Sand Filter Pumps

In a pressurized sand filtration system, pumps are required to provide the necessary pressure to the water, allowing it to pass through the sand filtration. This pressure is necessary to ensure an adequate flow of water through the filter media.

The flow entering the sand filter is 3,815 m3/h (There are 16 sand filters with the same flow rate, 3815 m3/h for each group of 8 filters). This flow is distributed among four centrifugal pumps, each pump will have a flow rate of 953.75 m3/h. These pumps are capable of pumping water to a height of 36 to 58 meters of water column (mwc).

3.6 Cartridge filter

In the seawater desalination plant of Corso, 05 cartridge filters, with a capacity of 7630 m3/h, have been installed for each unit of reverse osmosis to ensure efficient treatment of desalinated water. These filters don’t allow impurities with a size greater than 200 micrometers to pass through.

Here is the photo of the cartridge filters installed in the SWDP (Seawater desalination plant) of Corso.

Figure III.10: Installation of cartridge filters

3.7 High-pressure pumps

High-pressure pumps are essential components in reverse osmosis (RO) desalination plants. These pumps are responsible for pressurizing the seawater to a high level, typically around 60 to 70 bar, before it enters the RO membranes. This pressure is necessary to overcome the osmotic pressure and force the seawater through the semi-permeable membranes, separating the pure water from the salts and other impurities.

In the seawater desalination plant of Corso, 08 High-pressure pumps, with a capacity of 3468 m3/h, have been installed before reverse osmosis unit.

Here is the photo of the high-pressure pumps installed in the SWDP of Corso.

Figure III.11: The high-pressure pump

3.8 Reverse osmosis unit

There are two reverse osmosis units in the building, and each unit is composed of four skids. The 127 pressure tubes are distributed between the four skids. Each pressure vessel contains seven reverse osmosis membranes.

The following figure shows the reverse osmosis unit.

Figure III.12: Reverse osmosis units

The installed membranes have the following characteristics:

Table III.2: Membrane characteristics **[11]**

Characteristics	Values
Number of skids	04 skids
Type of membrane	LG SW 400 GR G2
Membrane lifespan	5 years
Number of pressure tubes	127 tube + 10% reserve

Characteristics	Values
Number of membranes per tube	07 membrane
Conversion rate	45 %
Raw water flow rate per skid	954 m^3/h
Permeate flow rate per skid	429.2 m^3/h
Reject flow rate per skid	524.5 m^3/h
Feed water salinity of the skid	38.5 g/l

3.9 Pressure Exchanger (PX)

Pressure exchangers enable the recovery of energy from the brine produced during the reverse osmosis process,

In the seawater desalination plant Corso, 80 pressure exchangers, model PX-Q300 with a capacity of 52.5 m^3/h , have been installed to recover energy from the brine. These 80 pressure exchangers are distributed across 08 skids, each containing 10 pressure exchangers. They are represented in the following figure.

Figure III.13: Installation of pressure exchanger

3.10 Booster pumps

Booster pumps are used to increase the pressure of water before it enters the reverse osmosis membranes in a desalination plant. They ensure that the water is pressurized sufficiently to pass through the membranes and facilitate the osmosis process.

In the seawater desalination plant of Corso, 08 booster pumps, each with a capacity of 4162 m3/h, capable of pumping water to a height of 20-40 meters Total Dynamic Head (mTDH), have been installed before the reverse osmosis unit. The following figure shows the booster pump.

Figure III.14: Booster pump

3.11 Post-treatement

The remineralization system is carried out with:

3.11.1 Calcite slurry

For the calcite slurry, here it is the following characteristics:

Table III.3: calcite slurry characteristics **[11]**

Characteristics	Values
Total flow rate	3433 m3/h
Percentage to be treated	50%
Flow rate to be treated	1717 m3/h
Number of calcite cells	08
Flow rate per calcite cell	215 m3/h

3.11.2 Carbon dioxide injection

For the CO_2 consumption, Here it is the following characteristics:

Table III.4: CO2 consumption characteristics **[11]**

Characteristics	Values	
Temperature	14 °C	30°C
Per cell	12.66 Kg/hr	13.3 Kg/hr
Total	101.28 Kg/hr	106.4 Kg/hr
Storage time	30 Days	30 Days
Storage capacity	72.9 Ton	76.6 Ton
Selected tank capacity	100 Ton	100 Ton

3.12 Potable water tank

For the potable water tank, here it is the following characteristics :

Table III.5: Description of potable water tank **[11]**

Characteristics	Values
Hourly production	3433 m^3/hr
Quantity	01
Retention time	04
Required capacity	13 732 m^3
Selected capacity	15 000 m^3

3.13 Drinking water pumping plant

In a pumping station, there are four centrifugal pumps, each with a flow rate of 860 cubic meters per hour. These pumps are used to pump water to a height ranging from 85 to 140 meters of water column.

3.14 The control room

The control room of a desalination plant is a control center where operators monitor and control all operations related to the desalination process of seawater or brackish water.

Here is the photo of the control room of the SWDP of Corso.

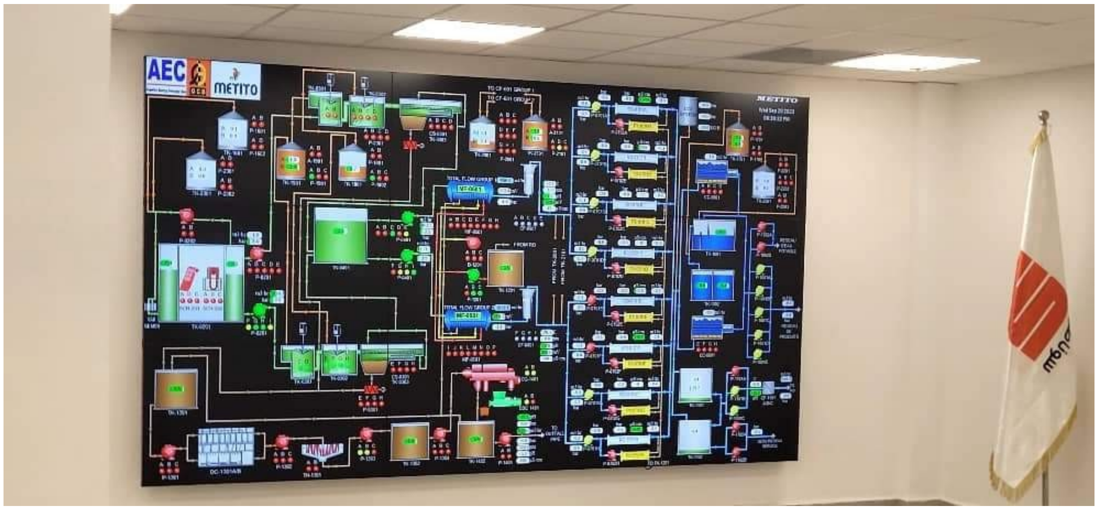


Figure III.15: The control room

Conclusion

In this chapter, we have attempted to provide a general description of the seawater desalination plant in Corso, Boumerdes. This description covers the various processes and procedures of desalination. Additionally, we have provided an overview of the project that we will be studying.

Chapter IV

Swell study

1 Introduction

Swell, a natural phenomenon of wave displacement across the oceans, represents a powerful ever-present force essential in various fields of marine sciences and coastal engineering. This chapter explores the methods for calculating the significant wave height in order to determine the total intake tower height in seawater.

To determine the intake tower height, it is first necessary to calculate the significant wave height.

2 Definition of swell

swell is considered to be the result of a set of identical parallel ripples or waves that intensify with increasing wind speed and result in energy transfer. It also represents a grouping of waves resulting from the propagation of surface waves, which move at the interface between water and the atmosphere.**[06]**

3 Significant wave height calculation

The significant wave height is calculated based on the wave frequencies, with these frequencies derived from ship observations obtained from the KNMI (Royal Netherlands Meteorological Institute *https://www.knmi.nl/home*), responsible for collecting meteorological data in the Mediterranean. The observations cover the period 1970-2005. (Annex 01)

Remark:

Due to the lack of wave data for the area of Boumerdes, we will calculate using the data from the area of Tepaza.

The following drawing represent the various height of wave

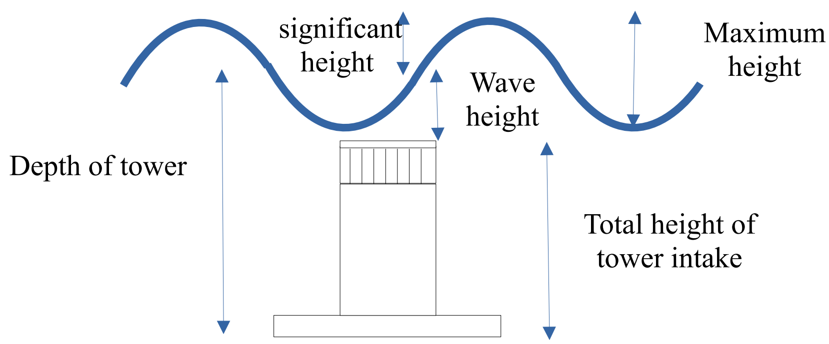


Figure IV.1: A representation of various height of wave

We determine the significant height in order to assess the total height of the intake tower. Here are the calculation steps **[07]**:

1. Exclude certain directions relative to the studied site (such as north, east, or west).

2. Create a table that should include:

- Significant wave heights,
- Cumulative number of observations,
- Number of observations for each direction,
- Frequency calculation:

$$F = \frac{\text{Number of observations for } H_{si}}{totale \quad number \quad of \quad observations}$$

3.Plot the regression curve for each wind direction Hs=f(F) represented on a semi-logarithmic scale where Hs is significant wave height.

We consider two types of data: data concerning wave alone and data related to the combination of wave and wind sea. in order to select the data to be processed to determine the significant wave height. The choice is based on the maximum values of the significant wave height.

The following table represents the occurrence frequencies of the wave.

Table IV.1: The occurrence frequencies of the wave for the period 1970-2005

Significant wave height H_s(m)	**The cumulative number of observations for all directions**	**The relative number of observations for all directions**	**Frequencies**
10	30	30	0,00003
9,5	30	30	0,00003
9	60	30	0,00003
8,5	60	30	0,00003
8	160	100	0,00011
7,5	390	230	0,00026
7	610	220	0,00025
6,5	770	160	0,00018
6	1930	1160	0,00133
5,5	2180	250	0,00029
5	4950	2770	0,00317
4,5	7230	2280	0,00261
4	16700	9470	0,01084
3,5	27270	10570	0,01210

Significant wave height H_s(m)	The cumulative number of observations for all directions	The relative number of observations for all directions	Frequencies
3	56910	29640	0,03393
2,5	98950	42040	0,04813
2	195130	96180	0,0994
1,5	344530	149400	0,1101
1	578780	234250	0,2682
0,5	873400	294620	0,3373

Here is the plot of regression line of waves from all directions combined:

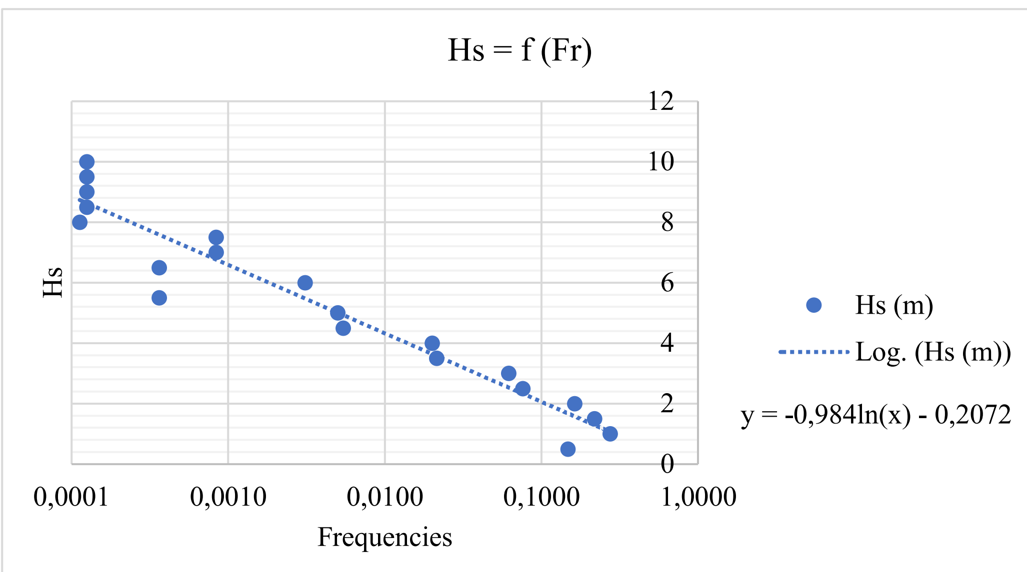


Figure IV.2: Regression line of swells from combined directions

The following table represents the occurrence frequencies of wave combined with wind-induced waves.

Table IV.2: The occurrence frequencies of wave combined with wind-induced waves for the period 1970-2005

Significant wave height H_s(m)	The cumulative number of observations for all directions	The relative number of observations for all directions	Frequencies
10	100	100	0,0001
9,5	100	100	0,0001
9	100	100	0,0001
8,5	100	100	0,0001
8	190	90	0,0001
7,5	860	670	0,0008
7	1530	670	0,0008
6,5	1820	290	0,0004
6	4300	2480	0,0031
5,5	4590	290	0,0004
5	8590	4000	0,0050
4,5	12920	4330	0,0054
4	28980	16060	0,0201
3,5	46090	17110	0,0214
3	95530	49440	0,0620
2,5	156260	60730	0,0761
2	286120	129860	0,1627
1,5	460170	174050	0,2181
1	679830	219660	0,2753
0,5	797650	117820	0,1477

Here is the plot of regression line of combined waves and wind-induced waves from all directions (north, east, and west):

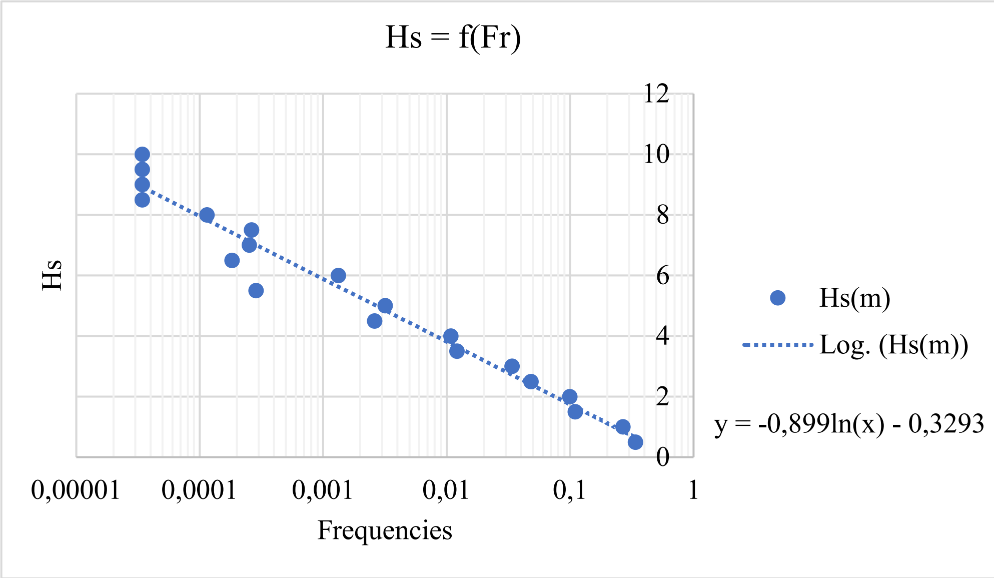


Figure IV.3: Regression line of combined waves and wind-induced waves from all directions

The significant wave height will be calculated for various return periods for each dataset.

According to the regression curves, the following equations are found:

- The plot of regression line of waves from all directions combined:

$$y = -0{,}984 \ln(x) - 0{,}2072$$

- The plot of regression line of combined waves and wind-induced waves from all directions:

$$y = -0{,}899 \ln(x) - 0{,}3293$$

Where:

y: Significant wave height;

x: The occurrence frequencies for a return period T.

Since the observation data consists of interannual monthly frequencies, then:

$$x = f = \frac{1}{T \cdot 12}$$

The following table represents the calculation of significant wave height for various return periods.

Table IV.3: The calculation of significant wave height for various return periods

Return periods (ans)	10	20	50	100
The occurrence frequencies for a return period T	0,00833	0,00417	0,00167	0,00083
significant wave height H_s for wave (m)	4,63	5,26	6,08	6,70
H_s of wave combined with wind-induced waves (m)	4,92	5,60	6,50	7.18

Based on the results found, we notice that the maximum significant wave heights correspond to the wave + wind sea data. Therefore, data processing will be done using this series.

3.1.1 The choice of dominant winds for the side of Corso:

Like the bay of Corso is straight and open, it will be subject to various directions from the North.

However, we must consider the following directions for the statistical calculation of significant wave height Hs:

- North direction: 360°;
- North Northeast direction: 30°;
- East Northeast direction: 60°;

- North Northwest direction: 330°;
- West Northwest direction: 300°;

The specific directions are chosen based on their relevance to the analysis of significant wave heights in the Bay of Corso. They represent the main angles from which waves approach, selected due to their frequency, exposure to prevailing winds, impact on underwater topography, and their necessity for a comprehensive and accurate statistical analysis of local maritime conditions. These factors help in better understanding and predicting the potential impacts of waves on the bay and its coastal infrastructure.

The method used to obtain the maximum values of significant height Hs is processing each direction separately.

We will process the swell + wind sea data for each direction.

As we worked previously, we will calculate H_s.

- North direction: 360°

Table IV.4: The occurrence frequencies of wave + wind sea (360°)

Significant wave height H_s(m)	The cumulative number of observations for all directions	The relative number of observations for all directions	Frequencies
10	0	0	0,0000
9,5	0	0	0,0000
9	0	0	0,0000
8,5	0	0	0,0000
8	0	0	0,0000
7,5	30	30	0,0009
7	100	70	0,0020

Significant wave height H_s(m)	The cumulative number of observations for all directions	The relative number of observations for all directions	Frequencies
6,5	100	70	0,0020
6	100	70	0,0020
5,5	130	30	0,0009
5	480	350	0,0102
4,5	640	160	0,0046
4	1250	610	0,0177
3,5	1700	450	0,0131
3	3020	1320	0,0383
2,5	4690	1670	0,0485
2	8570	3880	0,1127
1,5	13970	5400	0,1568
1	22100	8130	0,2361
0,5	34300	12200	0,3542

The following figure shows the regression of significant wave height in function of occurrence frequencies.

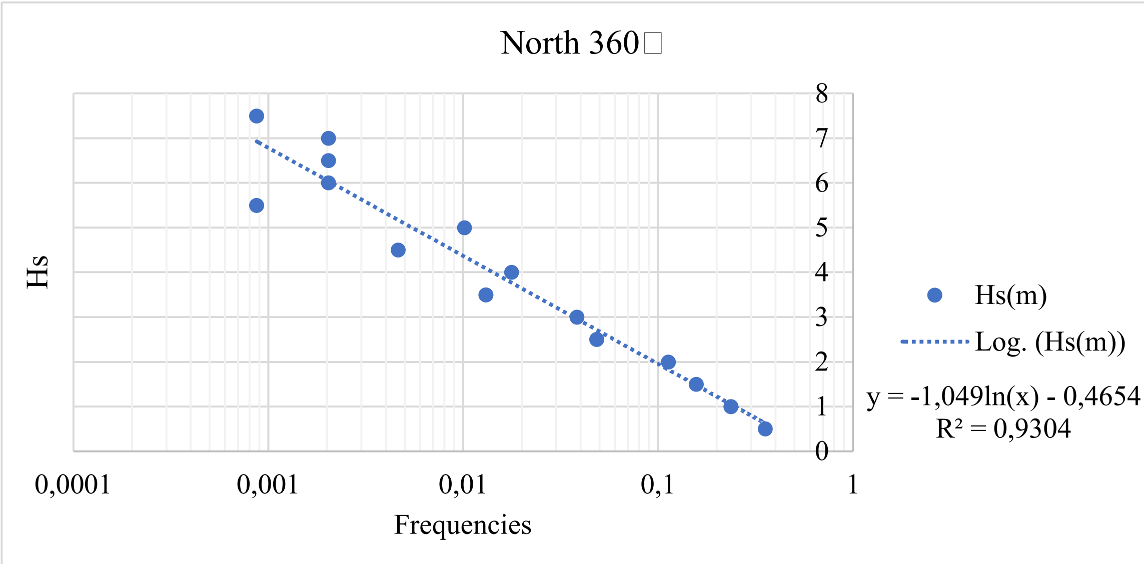


Figure IV.4: Regression line of combined swells and wind-induced waves for N 360°

The calculation of significant wave height for different return periods will be computed from the equation of the regression curve.

$$y = -1{,}049 \ln(x) - 0{,}4654$$

Where:

y: Significant wave height (m);

x: The occurrence frequencies for a return period T.

Since the observation data consists of interannual monthly frequencies, then:

$$x = f = \frac{1}{T \cdot 12}$$

The following table represents the result of the significant wave heights of swell + wind sea for the north direction (360°).

Table IV.5: The occurrence frequencies of wave + wind sea (360°)

Return period (ans)	10	20	50	100
H significant (m)	4,56	5,28	6,24	6,97

- North Northeast direction: 30°

Table IV.6: The occurrence frequencies of wave + wind sea (30°)

Significant wave height H_s(m)	**The cumulative number of observations for all directions**	**The relative number of observations for all directions**	**Frequencies**
10	0	0	0,0000
9,5	0	0	0,0000
9	0	0	0,0000
8,5	0	0	0,0000
8	0	0	0,0000
7,5	0	0	0,0000
7	0	0	0,0000
6,5	30	30	0,0005
6	190	160	0,0028
5,5	220	30	0,0005
5	290	70	0,0012
4,5	450	160	0,0028
4	870	420	0,0074
3,5	1410	540	0,0096
3	3530	2120	0,0376
2,5	6200	2670	0,0473
2	11430	5230	0,0927

Significant wave height H_s(m)	The cumulative number of observations for all directions	The relative number of observations for all directions	Frequencies
1,5	20840	9410	0,1668
1	35780	14940	0,2648
0,5	56430	20650	0,3659

The following figure shows the regression of significant wave height in function of occurrence frequencies.

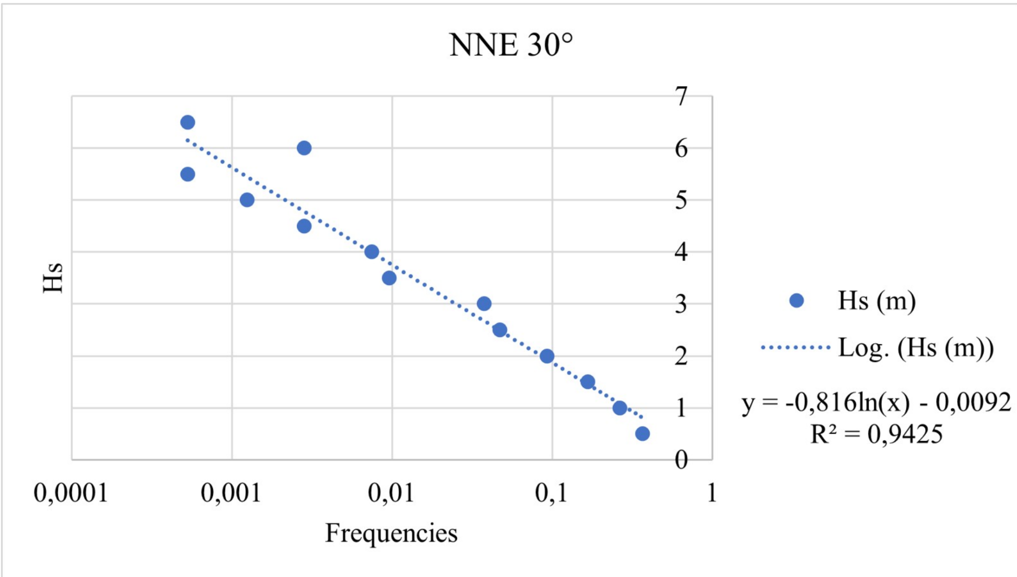


Figure IV.5: Regression line of combined swells and wind-induced waves for NNE 30°

The calculation of significant wave height for differents return periods will be computed from the equation of the regression curve.

$$y = -0,816\ln(x) - 0,0092$$

With:

y: Significant wave height (m);

x: The occurrence frequencies for a return period T.

Since the observation data consists of interannual monthly frequencies, then:

$$x = f = \frac{1}{T \cdot 12}$$

The following table represents the result of the significant wave heights of swell + wind sea for the north northeast direction (30°).

Table IV.7: The significant wave heights of wave + wind sea for the north northeast direction (30°).

Return period (ans)	10	20	50	100
H significant (m)	3,90	4,46	5,21	5,78

- East Northeast direction: 60°

Table IV.8: The occurrence frequencies of wave+ wind sea (60°)

Significant wave height H_s(m)	**The cumulative number of observations for all directions**	**The relative number of observations for all directions**	**Frequencies**
10	0	0	0,0000
9,5	0	0	0,0000
9	0	0	0,0000
8,5	0	0	0,0000
8	0	0	0,0000
7,5	0	0	0,0000
7	0	0	0,0000
6,5	0	0	0,0000
6	60	60	0,0004

Significant wave height H_s(m)	The cumulative number of observations for all directions	The relative number of observations for all directions	Frequencies
5,5	60	60	0,0004
5	390	330	0,0021
4,5	710	320	0,0020
4	2180	1470	0,0092
3,5	4010	1830	0,0114
3	8740	4730	0,0295
2,5	15250	6510	0,0406
2	32820	17570	0,1096
1,5	62370	29550	0,1844
1	109290	46920	0,2927
0,5	160220	50930	0,3178

The following figure shows the regression of significant wave height in function of occurrence frequencies.

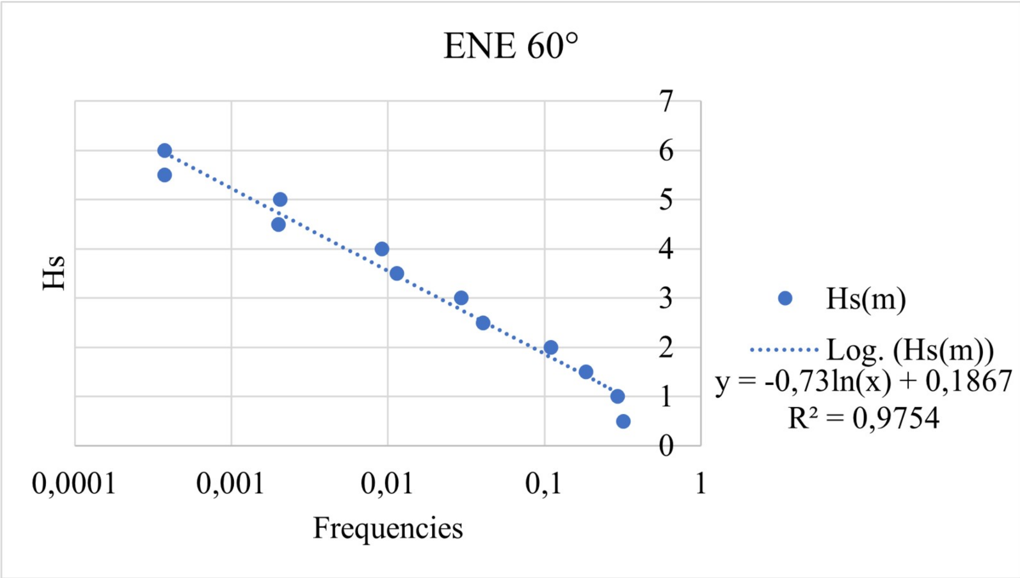


Figure IV.6: Regression line of combined swells and wind-induced waves for ENE 60°

The calculation of significant wave height for different return periods will be computed from the equation of the regression curve.

$$y = -0,73\ln(x) + 0,1867$$

The following table represents the result of the significant wave heights of swell + wind sea for the east northeast direction (60°).

Table IV.9: The significant wave heights of swell + wind sea for the east northeast direction (60°)

Return period (ans)	10	20	50	100
H significant (m)	3,68	4,19	4,86	5,36

- North Northwest direction: 330°

Table IV.10: The occurrence frequencies of wave + wind sea (330°)

Significant wave height H_s(m)	The cumulative number of observations for all directions	The relative number of observations for all directions	Frequencies
10	0	0	0,0000
9,5	0	0	0,0000
9	0	0	0,0000
8,5	0	0	0,0000
8	0	0	0,0000
7,5	0	0	0,0000
7	0	0	0,0000
6,5	0	0	0,0000
6	0	0	0,0000
5,5	0	0	0,0000
5	100	100	0,0032
4,5	160	60	0,0019
4	710	550	0,0176
3,5	1280	570	0,0182
3	2670	1390	0,0445
2,5	4270	1600	0,0512
2	7320	3050	0,0976
1,5	13100	5780	0,1850
1	20390	7290	0,2333
0,5	31250	10860	0,3475

The following figure shows the regression of significant wave height in function of occurrence frequencies.

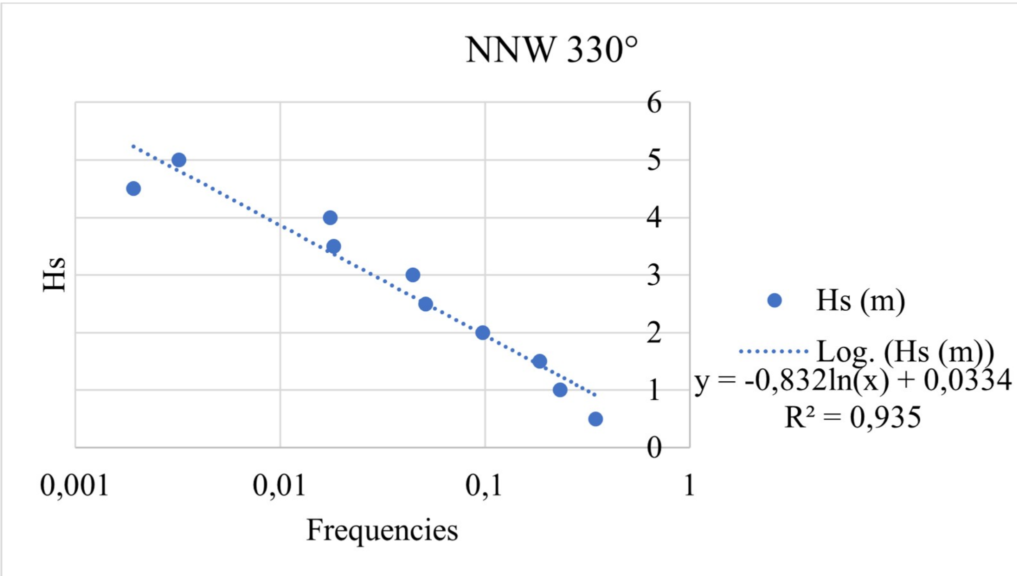


Figure IV.7: Regression line of combined swells and wind-induced waves for NNW 330°

The calculation of significant wave height for different return periods will be computed from the equation of the regression curve.

$$y = -0,832 \ln(x) + 0,0334$$

The following table represents the result of the significant wave heights of swell + wind sea for the north northwest direction (330°).

Table IV.11: The significant wave heights of swell + wind sea for the north northwest direction (330°)

Return period (ans)	10	20	50	100
H significant (m)	4,02	4,59	5,36	5,93

- West Northwest direction: 300°

Table IV.12: The occurrence frequencies of wave + wind sea (300°).

Significant wave height H_s(m)	The cumulative number of observations for all directions	The relative number of observations for all directions	Frequencies
10	0	0	0,0000
9,5	0	0	0,0000
9	0	0	0,0000
8,5	0	0	0,0000
8	0	0	0,0000
7,5	30	30	0,0006
7	30	30	0,0006
6,5	30	30	0,0006
6	220	190	0,0036
5,5	260	40	0,0008
5	580	320	0,0060
4,5	740	160	0,0030
4	1540	800	0,0150
3,5	2250	710	0,0133
3	4240	1990	0,0374
2,5	7190	2950	0,0554
2	13940	6750	0,1268
1,5	23280	9340	0,1754
1	36740	13460	0,2528
0,5	53180	16440	0,3088

The following figure shows the regression of significant wave height in function of occurrence frequencies.

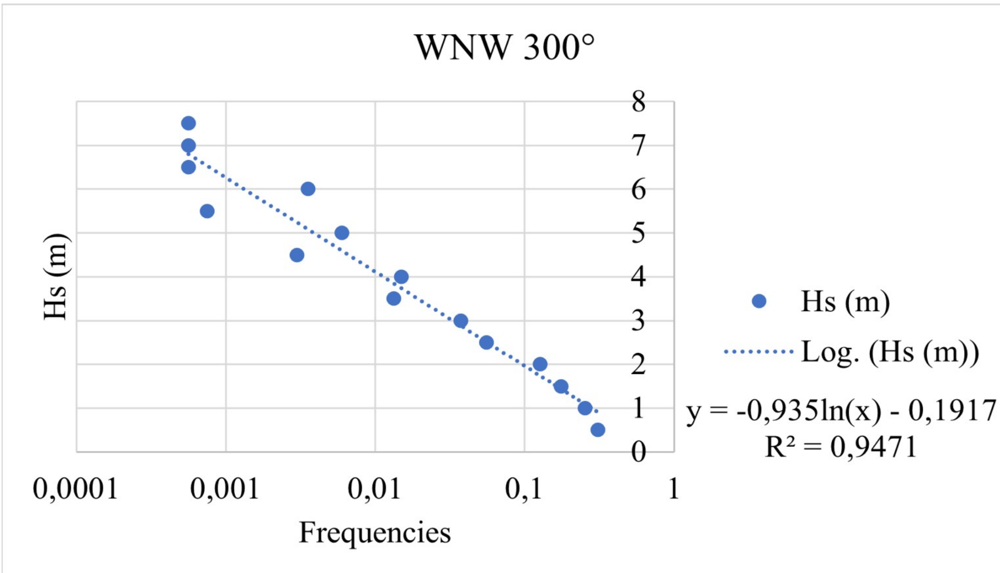


Figure IV.8: Regression line of combined swells and wind-induced waves for WNW 300°

The calculation of significant wave height for different return periods will be computed from the equation of the regression curve.

$$y = -0,935\ln(x) - 0,1917$$

The following table represents the result of the significant wave heights of waves + wind sea for the west northwest direction (300°).

Table IV.13: The significant wave heights of swell + wind sea for the west northwest direction (300°)

Return period (ans)	10	20	50	100
H significant (m)	4,28	4,93	5,79	6,44

After processing all data from each direction separately, we compile a summary table for all directions to determine the maximum values of significant wave height H_s.

Table IV.14: The significant wave heights for all directions and various return periods

Direction / T (years)	N(360°)	NNE (30°)	ENE (60°)	NNW(330°)	WNW(300°)
10	4,56	3,90	3,68	4,02	4,28
20	5,28	4,46	4,19	4,59	4,93
50	6,24	5,21	4,86	5,36	5,79
100	6,97	5,78	5,36	5,93	6,44

The selection of significant wave height Hs corresponds to the most unfavorable case. According to the table, we notice that the values for the North direction are the highest. So H_s = 6,97 m

4 The maximum height:

According to the Longuet-Higgins theory (1959), for a record of 1000 waves or more, the estimation of the maximum height in relation to the significant height will be as follows:**[07]**

$$H_{max} = 1,86 \times H_s$$

5 The overflow limit

The overflow criterion is a concept used in hydrology and hydraulic engineering. It refers to the moment when the flow of a watercourse exceeds the level of its bed. The Mc Cowan criterion establishes the overflow limit.**[07]**

To study the breaking limit, Mc Cowan suggested considering each wave as a solitary wave, such as:

$$\frac{h_{overflow}}{h_{max}} = 0,78$$

So:

$$h_{overflow} = h_{max} \times 0,78$$

6 Presentation of results

We will present the results for various heights as previously mentioned.

Table IV.15: Results for various heights

Height significant (m)	Maximum height (m)	Overflow height (m)	Total height (m)
6,97	12,96	10,11	8,5

It is crucial that the height of the structure does not exceed 10 meters to respect the wave breaking limit. Wave breaking occurs when the wave height becomes sufficient for its crest to break, which can pose safety and stability issues for the structure. By choosing a maximum height of 8.5 meters in our case, we aim to capture clear water and avoid air ingestion during heavy swells.

Conclusion

In conclusion, swell calculations are a vital field of applied oceanography and maritime engineering.

Based on the calculations performed, we obtained the following results: the significant wave height is 6.92 meters, and the total intake tower height is 8.5 meters.

Chapter V

Design of seawater intake

1 Introduction

The sizing of hydraulic structures such as intake towers, intake pipelines, and capture basins is crucial to ensure the efficiency and longevity of water management systems. The intake tower is essential for water extraction, the intake pipeline for its safe transport, and the capture basin for the storage and regulation of the collected water.

This chapter addresses the fundamental principles and calculation methods necessary to size these components, considering hydrological, geotechnical, and environmental aspects to optimize their performance and durability.

2 Seawater intake tower

The water intakes are intended for capturing high-quality water from offshore areas and transporting it via pipelines to the coastal pumping station. We will design two direct water intake structures in open sea, placed on the seabed, considering the design condition that both towers operate simultaneously at 50% capacity and one intake operates at full capacity during maintenance.

The location of the intake tower is determined based on two parameters: depth and offshore distance, which is over 800 meters. These are the reasons for determining these parameters **[07].**

- The depth of the tower ensures water quality by avoiding the influence of waves and floating solids.
- The target depth of 10 to 15 meters aligns with the bathymetry of Corso (Boumerdes province).

- The distance from the coast protects against suspended matter from the wadis.
- The depth allows for the installation of water intake entry grilles at a height of over 5 meters above the seabed, which is a commonly practiced criterion in similar installations.
- The design prevents entrainment of particles from the seabed by currents and exposure to extreme swells.
- The remote location from the coast and chosen depth facilitate installation and maintenance of the intake.

Here is a drawing representing the shape and dimensions of the intake tower.

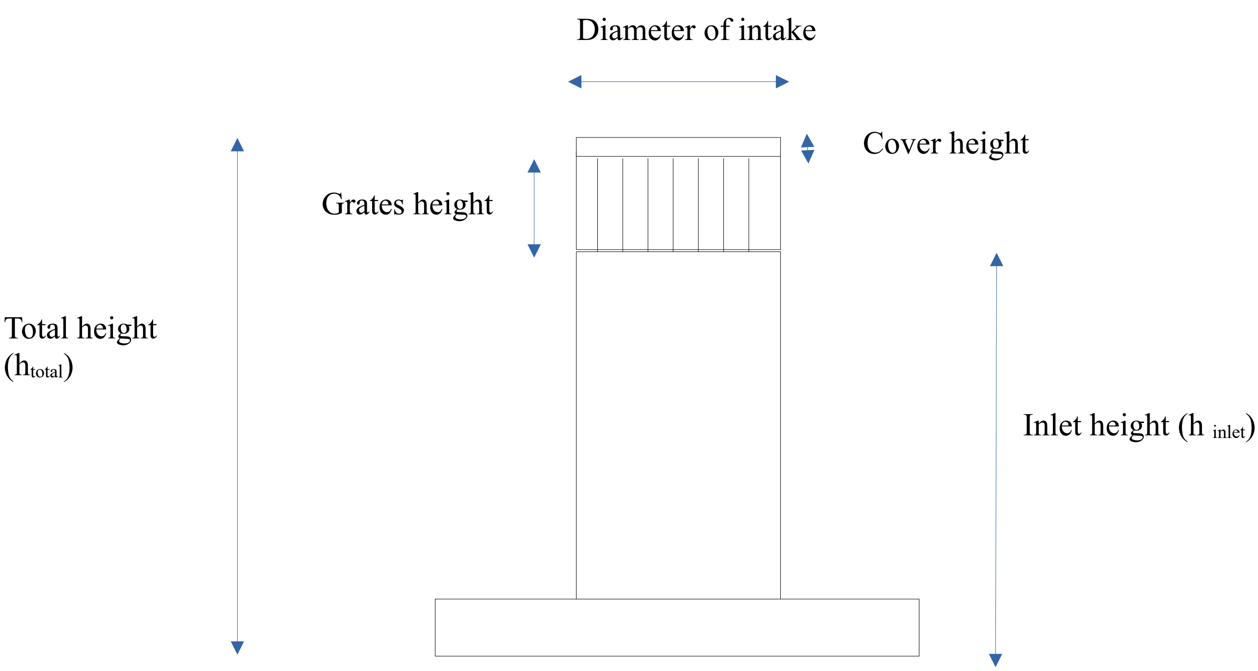


Figure V.1: The shape and dimensions of the intake tower

2.1 The choice of material for the intake tower

The choice of material for the intake tower is a crucial decision that depends on several key factors **[07]**.

1. T**he budget** plays an essential role in material selection, as it determines the available options and directly influences the financial feasibility of the project. While more expensive materials may offer specific benefits, they need to be evaluated in relation to the overall project budget.

2. **Design requirements** are another crucial aspect to consider. The chosen material must be able to meet these design requirements by providing the necessary flexibility to realize the architectural vision while maintaining the structural integrity of the tower.

3. **Durability** is also a determining factor in the choice of material. An intake tower is a structure intended to be used for many years, even decades, so it is essential that the material be durable and resistant.

The choice of **concrete** for the intake tower is justified by its strength, durability, cost-effectiveness, and ability to meet design requirements while considering environmental concerns. These characteristics make concrete a solid choice for intake tower construction projects.

2.2 Calculation of the gross flow rate

The gross flow rate drawn into the intake tower is linked to the conversion rate of the membranes during the treatment phase. This process involves passing seawater through semi-permeable membranes that allow water to pass through but retain salts and dissolved materials such as chlorides, sulfates, sodium, and calcium. Approximately 45% of the treated water, known as permeate, has a very low concentration of dissolved solids, while around 55% consists of brine, which is discharged.

The water flow that must be produced by the station: $Q_{production} = 80\ 000\ m^3/day$.

An additional flow rate is added for service and firewater, equal to 3% of the treated water volume.

To organize the results, the following table represents the calculations of the gross flow rate.

Table V.1: The calculations of the gross flow rate

The flow	Equation	Result
Service flow rate	$Q_{service}$= 0,03×80000	$Q_{service}$= 2400 m^3/day
Production flow rate	$Q_{production}$= 80000+2400	$Q_{production}$=82 400 m^3/day
The calculation of the gross flow rate is related to the membrane conversion rate, which is 45%. This means that: 45 % → Production flow rate 100 % → Gross flow rate		
Gross flow rate	Q_{gross}= 82400 × (100/45)	Q_{gross}=183 111 m^3/day

2.3 Calculation of the inlet sections

We will calculate three types of sections: the inlet area, the grate area and the effective area.

Gross flow rate is Q_{gross}=183 111 m^3/day =2.12 m^3/s.

The following figure shows a reresentation of the various areas.

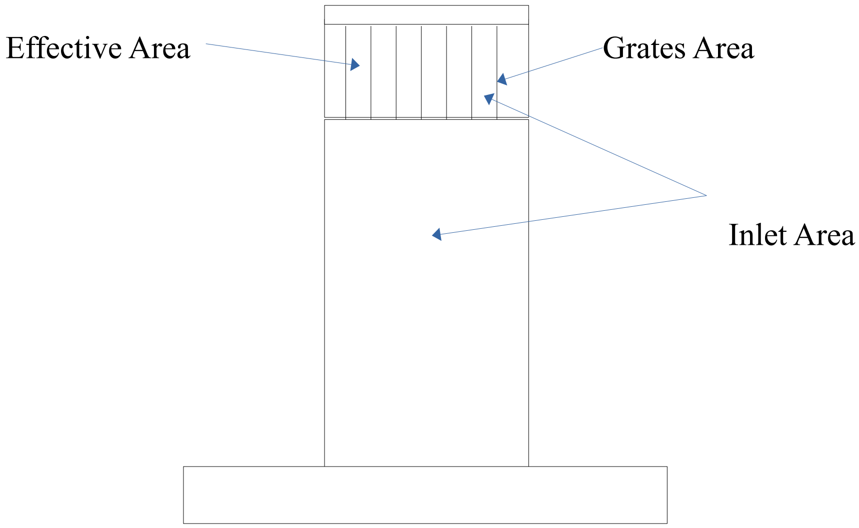


Figure V.2: Representation of the various areas

2.3.1 The inlet area

The inlet area refers to the exposed surface excluding the grate bars. To calculate the area, we consider that the flow regime is uniform.

$$Q_{gross} = v \,.\, A_{inlet}$$

So

$$A_{inlet} = \frac{Q_{gross}}{v}$$

With:

- A_{inlet}: The inlet area;
- v: The inlet velocity of the water intake is limited to 0.15 m/s to prevent the suction of suspended solids as well as aquatic flora and fauna.

2.3.2 Calculation of the grate area

To calculate the grate area, first, calculate the height of the bars and the perimeter of the tower to determine the number of bars.

2.3.3 Calculation of the height of the grates

The minimum entry level is 5 meters from the bottom, which is a design criterion for seawater intake structures in shallow regions where the depth ranges between 10 and 15 meters.**[07]**

It has been demonstrated that the tower has a height of less than 10 meters to meet the wave overtopping criterion. A safety height of 8,5 meters is chosen to prevent air entrainment and avoid the siphon effect.**[07]**

There is a cover above the grids that serves as an inspection point for tower maintenance, with a height of 0.25 meters (h_{cover} = 0,25 m)

The total height is:

$$h_{total} = h_{inlet} + h_{grate} + h_{cover}$$

So the height of the grates is:

$$h_{grate} = h_{total} - h_{inlet} - h_{cover}$$

With:

- h_{total}: The total height of the tower (m);
- h inlet: The inlet height of the tower (m);
- h_{grate}: The grate height of the tower (m);
- h cover: the height of the cover of the tower (m).

2.3.4 Calculation of the diameter of the inlet area

The diameter of the inlet area equals the diameter of the tower. As the intake tower has a cylindrical shape, this implies:

$$A_{inlet} = \pi \times d \times h_{grates}$$

So

$$d = \frac{A_{inlet}}{\pi \times h_{grates}}$$

With:

- A_{inlet}: The inlet area (m2);
- d: The diameter of the tower (m).

2.3.5 Calculation of the perimeter of the intake tower

It is calculated according to this equation.

$$A_{inlet} = P \times h_{grates}$$

So

$$P = \frac{A_{inlet}}{h_{grates}}$$

With

- P: The perimeter of the intake tower (m).

2.3.6 Calculation of the number of bars

It is calculated according to this equation:

$$N = \frac{P}{e+E}$$

With:

- N: The number of bars;
- e: Thickness of the bars (we took 10 cm);
- E: Spacing between the bars (we took 100 cm).

After determining all these parameters, we now calculate the grate area. It is calculated as follows:

$$A_{grates} = N \times e \times h_{grates}$$

With:

- A_{grates}: The grate area.

2.4 The effective area

The effective area corresponds to the passage area of water through the bars. It is calculated as follows:

$$A_{effective} = A_{inlet} - A_{grates}$$

With

- $A_{effective}$: The effective area.

3 Presentation of results

The following table represents the results of various sections calculation.

Table V.2: The results of various sections calculation.

Q (m^3/s)	V (m/s)	A_{inlet} (m^2)	A_{grates} (m^2)				$A_{effective}$ (m^2)
			H_{grates} (m)	D (m)	P (m)	N	
2.12	0.2	10,59	2,25	1,5	4,71	43	9,63
			0,96				

3.1 The verification of the gross flow rate

In this section, we will recalculate the gross flow rate using the effective area we have calculated. If we find that the calculated gross flow rate is lower than the required gross flow rate, it means that the effective area found cannot ensure the passage of the gross flow rate. Therefore, we must increase the diameter and perform a dimensional verification again.

This table represents the result for gross flow rate verification

Table V.3: The result of gross flow rate verification.

$A_{effective}$ (m^2)	V (m/s)	Q (m3/s)
9,63	0.2	1,92

We find:

$$1,92\, m^3/s < 2.12\, m^3/s$$

Then, in this case, we need to increase the diameter of the structure until we reach a minimum speed of 0.1 m/s through it, in order to find a section that allows the flow to pass through. After several iterations of calculation, we find that D = 3.3 m.

The found results are organized in the following table.

Table V.4: The result of dimensional verification.

D (m)	Q (m3/s)	A_{inlet} (m^2)	P (m)	N	N	A_{grates} (m^2)	$A_{effective}$ (m^2)	V (m/s)
3,3	2,13	23,31	10,36	94,2	95	2,13	21,17	0,1

The velocity of 0.1 m/s is acceptable, and the inlet area equal to 23.31 m^2 ensures the passage of gross flow. Therefore, these found results allow us to choose the following dimensions.

The following figure represents the results of the seawater intake tower dimensions.

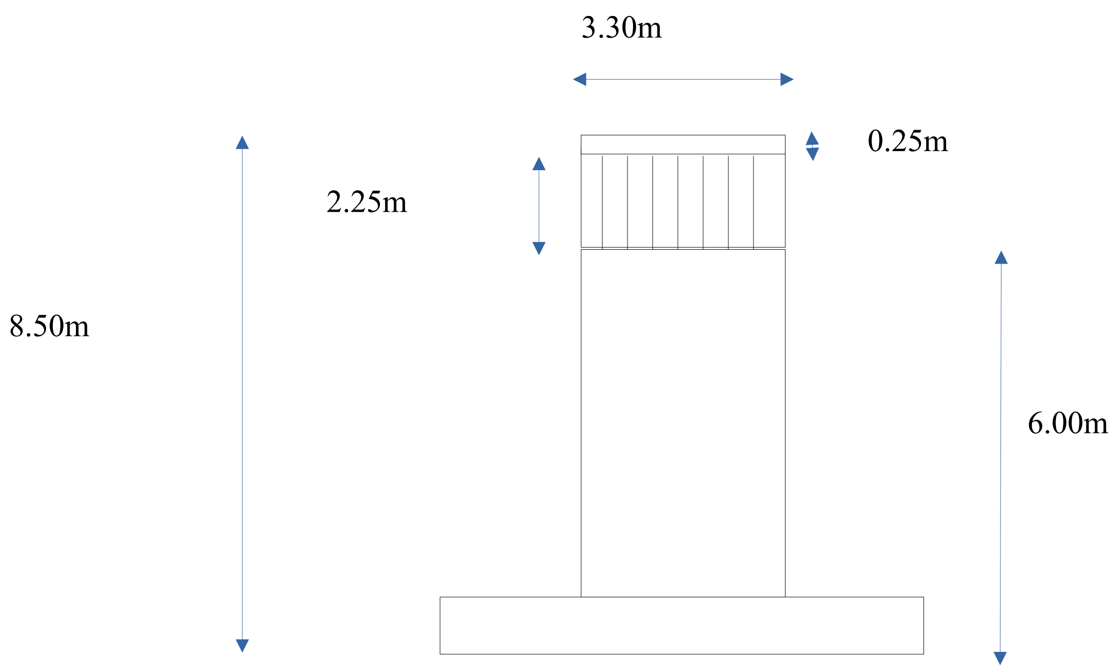


Figure V.3: The results of the intake tower dimensions

3.2. The implantation of the intake tower

The placement of the seawater intake tower in a desalination plant is based on a bathymetric study of the seabed.

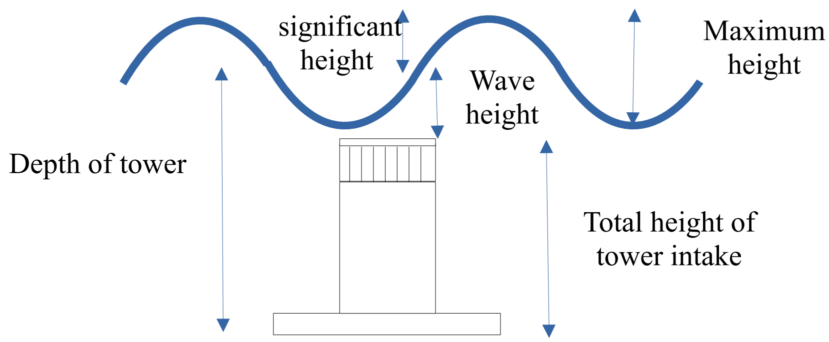


Figure V.4: Representation of significant height

The depth of the tower will be determined relative to the height of the tower.

$$h_{depth} = h_{wave} - h_{tower}$$

With:

- h_{depth}: The depth of the tower (m);
- h_{wave}: The wave height below the hydrographic zero level (m);
- h_{tower}: The height of the tower (m).

$$h_{wave} = h_{max} - h_s$$

With:

- h_{max}: The maximum wave height (m);
- h_s: The significant wave height above the hydrographic zero level (m).

4 Presentation of results

The following table represents the results of various heights of intke tower placement:

Table V.5: The results of various heights calculation.

h_s (m)	h_{max} (m)	h_{wave} (m)	h_{tower} (m)	h_{depth} (m)
6.97	12.96	5.99	8.5	14.49

As we mentioned, the bathymetry of Corso (Boumerdes province) ranges between 10 and 15 meters. Therefore, the tower can be fixed at a depth of 14.5 meters.

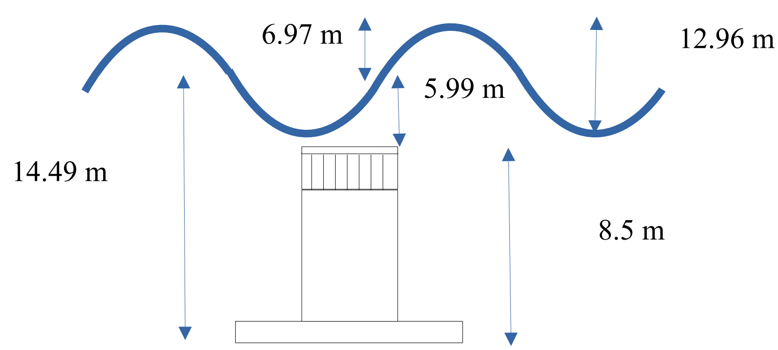


Figure V.5: Representation of of various heights results

5 Design of intake pipelines

5.1 Selection of pipeline material

The choice of pipe's material for a desalination plant depends on several factors, including compatibility with seawater, durability, cost, efficiency, and environmental impact. In this study, we will examine three types of materials: glass fiber reinforced plastics (GRP), high-density polyethylene (HDPE), and stainless steel.

5.1.1 Fiberglass reinforced plastics (FRP)

Fiberglass reinforced plastics (FRP), also known as fiberglass composites or fiber-reinforced plastics (FRP), are composite materials made by combining fiberglass fibers with a polymer resin matrix, often epoxy or polyester resin **[08]**.

Advantages

✔ **Long lifespan**: Pipes are manufactured according to international standards to have a minimum lifespan of 50 years, resulting in negligible operating and maintenance costs.

✔ **Smooth and regular internal surface**: The smooth internal surface of FRP pipes reduces hydraulic head losses (with a roughness equal approximately 0.05 mm).

✔ **High lightweight**: The weight of FRP pipes is approximately 1/4 of steel pipes, 1/5 of cast iron pipes, and about 1/10 of concrete pipes.

✔ **Resistance to corrosion and chemicals**:

- FRP pipes do not rust as they contain no metallic materials.

- They possess insulating properties and are not influenced by electric current.

- They resist pH levels from 1 to 10 for effluent temperatures up to 45°C.

✔ **Diameters**: The range of diameters for GRP pipes is very wide, ranging from DN80 mm to DN2600 mm.

✔ **Availability in the national market**: The Maghreb Pipe factory located in the industrial zone of the M'Sila province ensures the manufacturing and supply of the national market with this type of pipes. Indeed, the supply for the studied water conveyance project will be more affordable due to the local availability of these pipes and low transportation costs.

Disadvantages

- ✔ **High initial cost**: GRP may come with a higher purchase price compared to other construction materials due to the associated costs of materials and manufacturing.
- ✔ **Complexity of repairs:** Repairing GRP can be complex and costly, particularly in the case of significant damage or structural defects.
- ✔ **Sensitivity to extreme temperatures**: GRP can degrade at extreme temperatures, especially high temperatures, which can reduce their lifespan and mechanical strength.
- ✔ **Discoloration and UV degradation**: GRP may discolor and deteriorate when exposed to prolonged sunlight UV exposure, which can affect their appearance and long-term performance.
- ✔ **Design limitations**: GRP may have design limitations due to manufacturing and performance constraints, which can restrict their use in specific applications.

5.1.2 High-density polyethylene (HDPE)

High-density polyethylene (HDPE) is a type of thermoplastic polymer made from ethylene. It is known for its high strength-to-density ratio.

Here's a various advantages and disadvantages of high-density polyethylene (HDPE) **[09]**:

Advantages

✔ **Chemica**l re**sistance**: HDPE offers excellent resistance to a variety of chemicals, making it versatile for numerous industrial applications.

✔ **Waterproofing**: Due to its resistance to moisture, HDPE is ideal for applications exposed to liquids or humid environments.

✔ **Durability**: Its toughness and resistance to impacts make it a durable material for use in demanding conditions.

✔ **Ease** of fa**brication**: HDPE is straightforward to manufacture and handle, streamlining the production process and reducing costs.

Disadvantages

✗ **Sensitivity to high temperatures**: At elevated temperatures, HDPE can deform, limiting its use in certain high-temperature applications.

✗ **UV Degradation**: Exposed to ultraviolet radiation, HDPE can degrade over time, requiring additional protection in outdoor applications.

✗ **Rigidity**: Compared to other plastics, HDPE can be relatively rigid, which may limit its flexibility in certain applications.

✗ **Diameters**: A diameter greater than 800 mm will be custom-made, which will be more expensive and less readily available.

5.1.3 Stainless steel

Stainless steel is an incredibly versatile material that is used in a variety of applications.

***Advantages* [10]**

✔ Highly resistant to corrosion and staining.
✔ Easily cleaned and maintained.
✔ Durable with a long lifespan.
✔ Versatile, catering to a variety of applications.

Disadvantages

✗ Not as durable as some other materials;

✗ Can be very expensive;

✗ Can be difficult to clean;

✗ Susceptible to scratches and dents.

After studying the three types of materials, we have decided to select fiber-reinforced plastics (GRP) due to its advantages.

6 Design of intake pipeline

For the calculations, the intake pipelines will be designed after the condition of 2 pipelines operating simultaneously (operation condition) considering the 50% of the design flow through each pipe. In addition, during maintenance phases (cleaning condition), each pipe will have the capacity to take 100% of the design flow.

6.1 Calculation of diameter

Using the continuity equation:

$$Q = A \times v$$

- A: Area of pipe (m^2);
- v: Water velocity inside the pipe (m/s).

$$Q = \frac{\pi \times D^2}{4} \times v$$

So:

$$D = \sqrt{\frac{4 \times Q}{\pi \times v}}$$

With:

D: internal diameter of pipe (m).

6.2 Calculation of head loss:

Using the DARCY-WEISBACH equation:

$$\Delta h_L = \lambda \times \frac{L}{D} \times \frac{v^2}{2 \times g}$$

With:

- Δh_L: Frictional head losses (m);
- λ: Friction factor.

To calculate the friction factor, we need to calculate the Reynolds number to determine the type of flow.

$$\Re = \frac{v \times D}{\upsilon}$$

With:

- Re: Reynolds number;
- v: Fluid velocity in the pipe (m/s);
- υ: Kinematic viscosity (m^2/s).

In turbulent flow, we use the Colebrook-White equation.

$$\frac{1}{\sqrt{\lambda}} = -2\log\left(\frac{\varepsilon}{3.71D} + \frac{2.51}{\Re e\sqrt{\lambda}}\right)$$

With:

ε: The long-term absolute roughness 0.05 mm.

e: The thickness of the pipeline

Total head loss

$$\Delta h_T = \Delta h_L + 0,15 \times \Delta h_L$$

So:

$$\Delta h_T = 1,15 . \Delta h_L$$

With:

Δh_T: Total head loss.

7 Presentation of results

As we mentioned previously, there are 2 supply pipes. The 10 meters length difference between the intake conduits in a seawater intake system is explained by technical considerations aimed at optimizing the quality, reliability, and efficiency of the capture while minimizing environmental impacts and optimizing costs. By having separate water intake points, the system can capture the best available water quality, considering local variations in currents, temperature, and salinity, while reducing the risk of contamination. The length difference also facilitates access for maintenance and repairs, thus ensuring a continuous supply of seawater through redundancy.

The following table represents the results of intake pipelines diameter calculation, where SD is the standard diameter (in mm).

Table V.6: The following table represents the results of various sections calculation.

Pipeline	Q (m3/s)	V (m/s)	L (m)	Re	λ	ΔH (m)	D (m)	SD (mm)
01	2,13	1,5	863,38	2100000	0,014	1,13	1,34	1400
02	2,13	1,5	874,71	2100000	0,014	1,13	1,34	1400

We have set a velocity of 1.5 m/s for each pipeline within the range of (1-2 m/s) and have selected a diameter of 1400 mm in GRP (Fiberglass reinforced plastics).

8 Seawater intake basin

A seawater intake basin in a desalination plant constitutes an essential infrastructure for supplying the raw water needed for desalination processes. This structure plays a crucial role in collecting seawater, thereby ensuring a reliable and continuous source of water for subsequent treatment stages. It is typically situated near the coastline in an area below sea level where seawater is accessible. Here is a description of its main components:

- **Protective screens:** Located at the entrance of the basin to prevent large debris and marine organisms from entering.
- **Suction basin:** Located after the protective screens, this basin is where the pumps draw water from. It has a rectangular shape.

8.1.Hydraulic Phenomena in the Suction Basin

According to the study by Tsou et al. (1994), certain geometric configurations in basins can lead to undesirable phenomena. These phenomena can decrease pump efficiency and potentially cause vibrations, cavitation, as well as increase operational and maintenance costs. In general, Tullis (1979) highlighted the potential occurrence of the following phenomena **[11]**:

- Vortices originating from the free surface develop up to the pump inlet, sometimes entraining additional air. This causes an unbalanced load on the pump blades, leading to regular vibration. Additionally, when local pressure drops significantly, cavitation may occur. The vortices, originating from the free surface, enter the pipe without being entrained by air.

- Vortices originating from the rear and/or side walls. The distances between the walls and/or the bottom of the pool and the suction pipe greatly influence the position and intensity of these vortices. It is evident that local kinematic conditions are significant.
- An flow with pre-rotation that can affect the inlet angle of the pump and even trigger cavitation phenomena, leading to instabilities.
- The flow separates right at the entrance of the suction pipe.

8.1.1 Vortex phenomenon

A vortex, also known as a whirlpool, is a hydraulic phenomenon that can occur in a seawater intake basin. It typically forms at the basin's entrance when seawater is drawn in through the intake structures. Specific conditions that favor the formation of a vortex include high flow velocities and structural configurations that promote water rotation **[11].**

According to Sweeney (1982), the causes that provoke vortices are:

- An irregular distribution of the flow in the basin that causes circulation around and at the entrance of the suction pipe.
- Vorticity generated by the flow passing through the structural elements in the basin.
- Vorticity generated by the boundary layer near the side walls and the bottom.
- Vorticity generated by the presence of the suction piping placed transversely to the flow.

- Pre-existing heterogeneous turbulence in the upstream flow.

8.2 Design of the intake basin

The following figure represent the intake basin shape.

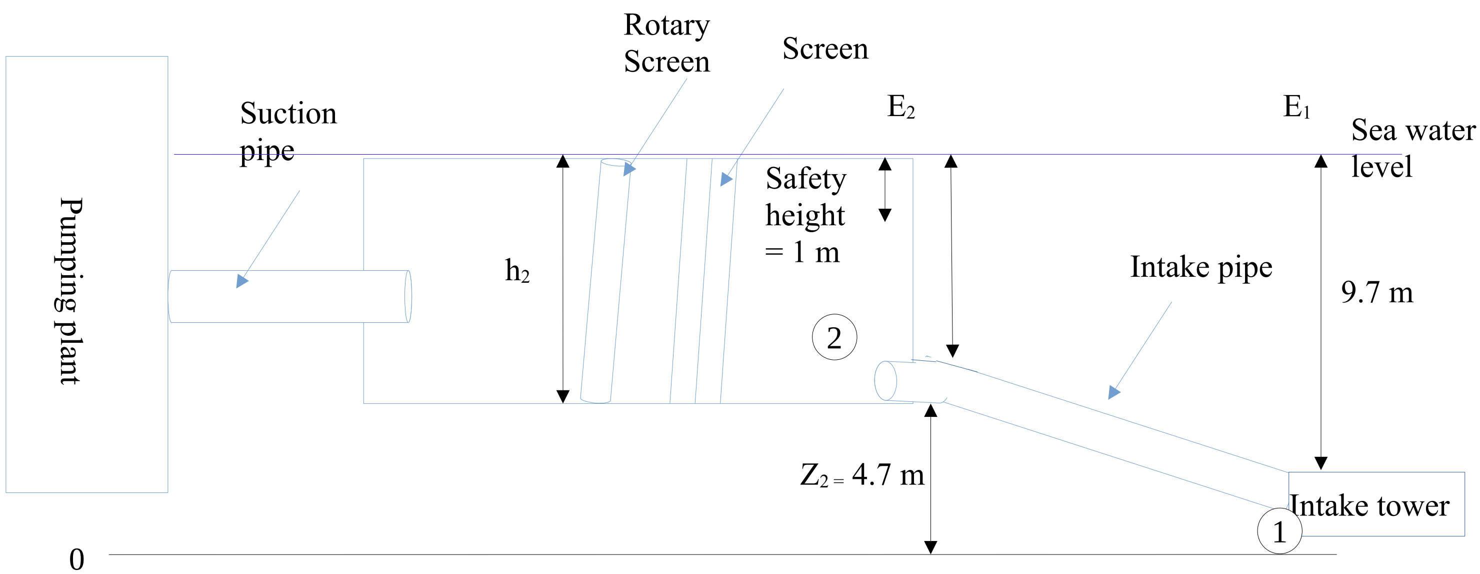


Figure V.6: Representation of the intake basin shape

8.2.1 Total energy

Total energy, often denoted by the symbol (E), is a key concept in hydraulics and fluid mechanics, particularly relevant in the study of open channel flows. It represents the energy per unit weight of the fluid at a given point in the cross-section of a flow. This energy is measured relative to a horizontal reference passing through the lowest point of the section.

Total energy combines two main components:

1. Potential energy due to the height of the fluid above the reference.

2. Kinetic energy due to the flow velocity.

Total energy is expressed in terms of “m” units according to Bernoulli's equation.

$$E=z+\frac{P}{\rho g}+\frac{v^2}{2g}$$

- **Calculation of total energy at point 01**

$$E_1=z_1+\frac{P_1}{\rho g}+\frac{(v_1)^2}{2g}$$

$z_1 = 0$;

$\frac{(v_1)^2}{2g}$: Negligible

So:

$$E_1 = 9.7\text{ m}$$

- **Calculation of total energy at point 02**

  We have

$$E_1=E_2=9.7\text{m}$$

  And

$$E_2=z_2+\frac{P_2}{\rho g}+\frac{(v_2)^2}{2g}$$

$z_2 = 4.7$m;

$$\frac{(v_2)^2}{2g}=\frac{1.5^2}{2\times 9.81} \longrightarrow \frac{(v_2)^2}{2g}=0.12\text{m}$$

So:

$$\frac{P_2}{\rho g}=9.7-4.7+0.12 \longrightarrow \frac{P_2}{\rho g}=4.88 \quad m$$

The water height in the basin is 4.88 m, so the total height of the basin is 6 m (with a margin of safety).

- **Calculation of Froude number**

$$Fr=\frac{Q}{\sqrt{gh}\,b.h}$$

$$Fr=\frac{2.12}{\sqrt{9.81\times4.88}\times6\times4.88}$$

$$Fr=0.01$$

Fr > 1 So the flow regime is fluvial, an energy dissipator is not necessary.

8.3 Sizing of a suction basin

We assumed that our suction basin functions as a buffer reservoir. However, in this case, the goal is to maintain a certain water level in the suction basin, given that the inflow rate equals the outflow rate. This helps to avoid the phenomena of cavitation and vortex formation.

The volume of the buffer reservoir is given by the following formula:

$$V=\frac{Q.T}{4}$$

With:

V: volume of the buffer reservoir (suction basin);

Q: gross inflow rate into the suction basin (2.12 m^3/s);

T: filling time of the reservoir, which is equal to 10 minutes.

$$V = \frac{2.12 \times 10 \times 60}{4}$$

$$V = 318 \quad m^3$$

The volume has been adjusted to 350 m^3.

Furthermore, the volume will be calculated based on the surface area and height, using the following formula:

$$V = A \times H_b$$

A: the area of the suction basin;

$$A = b.L$$

Where:

- *b:* The width of the basin;
- *L:* The length of the basin;
- *Hb:* The height of the basin.

The water level (H) in the basin is calculated by determining the (+-) immersion depth of the pumps. To calculate the immersion depth (just at the entrance of the suction pipe), the necessary parameters for determining the Froude number are as follows:

$$Fr = \frac{v}{(g.D)^{0.5}}$$

With:

- *D*: suction pipe diameter (m);
- *v*: water velocity in the inlet pipe (m/s).

$$v = \frac{Q}{A}$$

Where;

- Q: Flow rate per pump (m^3/s);
- A: Suction bell area (m^2).

8.3.1 Presentation of results

The following table represents the results of the calculation of the Froude number.

Table V.7: The results of the calculation of the Froude number.

Parameters	Q (m^3/h)	D (mm)	A (m^2)	v (m/s)	Fr
Results	1090.29	1000	0.79	0.39	0.12

8.3.2 Suction pipe installation

The suction pipe installation requires to setup geometric variables of the suction basin, which play a crucial role in the design and optimization of flow systems. They include the shape and dimensions of the basin, such as its length, width, and depth. The basin's geometry directly impacts the flow dynamics, particularly velocity and turbulence. Therefore, a thorough understanding of these variables is essential to ensure the efficiency and optimal performance of suction systems.

The figure below represents the geometric parameters of the flow structure within the basin.

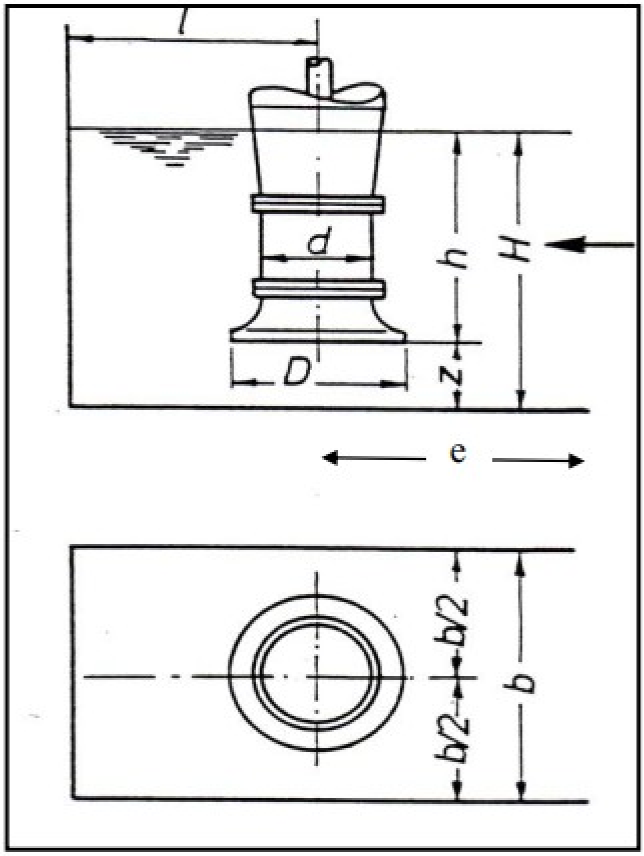


Figure V.7: The representation of a vertically positioned pipe within the basin, including its geometric parameters **[11]**

The geometric parameters depicted in the preceding figure are defined as follows.

- b: the width of the basin.
- l: the distance between the axis of the suction pipe and the rear wall.
- e: the distance between the axis of the suction pipe and the upstream end of the basin.

- h: the submerged height of the pipe.
- z: the distance between the bottom of the basin and the suction bell.

To calculate these parameters, one must follow these formulas, which are also issued by standardization organizations in the USA, the United Kingdom, Japan, and Europe **[11]**.

The Hydraulic Institute in the U.S. incorporates additional criteria.

Table V.8: The formulas used to calculate the geometric parameters **[11].**

Parameters (m)	formulas
z	(0.3-0.5)D
b	2D
l	0.75D
e	5D
h	D(1+2.3Fr)

8.3.3 Presentation of results

The following table represents the results of the calculation of the geometric parameters.

Table V.9: The results of the calculation of the geometric parameters.

Parameters	z (m)	b (m)	l (m)	e (m)	h (m)	H_b (m)	L (m)
Results	0.5	2	0.75	5	1.78	6	10

The water table level, which ensures the complete absence of whirlpools (H), will be the sum of the two previously described levels (h and z, the distance between the bottom of the basin and the suction bell). In other words, the water table level is 1.78 meters.

Then, the dimensions of the basin are as follows: 10 m in length, 6 m in width and 6 in height.

Conclusion

In conclusion, the sizing study of the intake tower, inlet pipeline, and intake basin represents a crucial step in designing an effective seawater intake system for desalination. By carefully examining the various dimensions and characteristics of these elements, we have ensured not only their optimal functionality but also their long-term durability. Based on the calculations performed, we obtained the following results:

Based on the calculations performed, we obtained the following results:

- The height of the grates is 2.25m ;
- The wave height below the hydrographic zero level is 5.99 m ;
- Tuo intake piplines both of them has a diameter of 1400 mm ;
- The choic of material for intake piplines is GRP (Fiberglass reinforced plastics). It is chosen because of its advantages;
- The intake basin has a rectangular shape with dimensions of 10 meters by 6 meters by 6 meters.
- Diameter of the suction pipe is taken D1000mm;
- The water table level is 1.78 meters.

General conclusion

General conclusion

During this work, we established the various steps necessary to conduct a sizing study of seawater intake aimed at meeting the reinforcement of water needs in the Boumerdes province. To achieve this goal, we explored the different facets that allow the development of a study meeting the technical requirements of such projects.

Initially, we introduced the internship location, which is the AEC (Algerian Energy Company). Subsequently, we presented the project and the Corso desalination station (Boumerdes province). We then explained the reverse osmosis desalination process. Following that, we addressed the seawater intake sizing study.

This study has led us to extract the following results:

- Gross flow rate is Q_{gross}=183 111 m^3/day = 2.12 m3/s;
- The significant wave height above the hydrographic zero level is 6.97 meters;
- The total intake tower height is 8.5 meters;
- The diameter of the tower intake is 3.30 m ;
- The height of the grates is 2.25 m ;
- The wave height below the hydrographic zero level is 5.99 m ;
- Tuo intake piplines both of them has a diameter of 1400 mm ;
- The choic of material for intake piplines is GRP (Fiberglass reinforced plastics), It is chosen because of its advantages;
- The intake basin has a rectangular shape with dimensions of 10 meters by 6 meters by 6 meters.

Bibliographic References

01: Ettouney, H.D El-Dessouky and H.M, Fundamental of Salt Water Desalination, 2022

02: Jean-Marie ROVEL, Dessalement de l’eau de mer, 2010

03: BOBAT Alaeddin, Pioneer andcontemporary studiesin agriculture, forestand water issues, JUNE-2023

04: BOUGIS J. (2009). Contribution pour les aspects hydrodynamiques à l’étude stratégique sur le dessalement de l'eau de mer au Maroc. Rapport RET.08.478.02.01.

05: Ibrahim El Agawany, Aadel Ben Brahim , PX™ Pressure Exchanger™ Technology, 2010

06: M.K.Mihoubi, Processus Côtiers TOME HYDRODYNAMIQUE, 2012

07: MOKHTARI. O, MERADJI. H, Dimensionnement de la prise d’eau de mer de la station de dessalement de Fouka, 2015

08: Magreb Pipe, Industrie, Système de canalisations en polyester renforcé de fibres de verre., 2016

09: RACHEDI Hala, Etude des mécanismes derupture du polyéthylène, 2019

10: , The Pros and Cons of Stainless Steel, 2023

11: Abir. I, Etudes hydrauliques de l’influence des géométries desbassins sur l’alimentation des pompes, 2009

Wave + swell sea data

Table 1: Cumulative number of observations per thousand for the period 1970-2005

Direction	360°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°	Calm	Total
10				0.1										0.1
9.5				0.1										0.1
9				0.1										0.1
8.5				0.1										0.1
8				0.1					0.1					0.19
7.5	0.1			0.1					0.38	0.19	0.1			0.86
7	0.29			0.1				0.1	0.48	0.48	0.1			1.53
6.5	0.29	0.1		0.1				0.1	0.48	0.67	0.1			1.82
6	0.29	0.57	0.1	0.1				0.19	1.15	1.53	0.38			4.3
5.5	0.29	0.57	0.1	0.19				0.19	1.15	1.63	0.48			4.59
5	1.24	0.77	0.48	0.57				0.19	1.34	3.16	1.05	0.1		8.59
4.5	1.63	1.15	1.15	0.67				0.38	1.82	4.4	1.24	0.19		12.92
4	2.87	2.01	4.11	2.01	0.1		0.1	0.67	4.49	8.38	2.77	1.53		28.98
3.5	4.02	3.06	6.69	3.35	0.38	0.19	0.29	1.15	6.98	13.01	4.21	2.77		46.09
3	7.08	7.46	15.3	8.89	0.48	0.78	1.24	2.01	13.1	26.3	7.65	5.55		95.53
2.5	10.14	12.91	23.91	17.4	1.24	0.96	1.72	4.02	20.66	42.27	12.53	8.51		156.26
2	16.64	20.27	48.29	39.4	2.96	2.58	4.11	8.42	34.62	71.34	23.43	4.06		286.12
1.5	27.77	33.28	80.14	67.61	7.84	4.97	7.36	15.11	55.66	105.96	35.19	22.28		460.17
1	34.24	47.68	118.96	111.03	16.35	8.7	14.82	24.77	76.89	146.89	48.87	30.7		679.83
0.5	40.07	56.33	137.32	135.03	21.42	12.72	18.74	30.79	86.83	167.73	55.75	34.9		797.65
0													202.35	202.35
Totaux	40.07	56.33	137.32	135.03	21.42	12.72	18.74	30.79	86.83	167.73	55.75	34.9	202.35	1000

Wave data

Table 2: Cumulative number of observations per thousand for the period 1970-2005

Direction	360°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°	Calm	Total
10				0.03										0.03
9.5				0.03										0.03
9				0.03					0.03					0.06
8.5				0.03					0.03					0.06
8				0.03					0.06	0.06				0.16
7.5	0.3			0.03					0.16	0.13	0.03			0.39
7	0.10			0.03				0.03	0.19	0.22	0.03			0.61
6.5	0.10	0.03		0.03				0.03	0.19	0.35	0.03			0.77
6	0.10	0.19	0.06	0.03				0.06	0.58	0.67	0.22			1.93
5.5	0.13	0.22	0.06	0.10				0.06	0.61	0.74	0.26			2.18
5	0.48	0.29	0.39	0.32				0.06	0.87	1.86	0.58	0.10		4.95
4.5	0.64	0.45	0.71	0.48				0.13	1.25	2.67	0.74	0.16		7.23
4	1.25	0.87	2.18	1.28	0.10		0.03	0.26	2.86	5.62	1.54	0.71		16.70
3.5	1.70	1.41	4.01	2.22	0.22	0.06	0.19	0.51	4.46	8.93	2.25	1.28		27.27
3	3.02	3.53	8.74	5.97	0.26	0.16	0.61	1.00	8.93	17.79	4.24	2.67		56.91
2.5	4.69	6.20	15.25	12.40	0.67	0.39	0.90	1.99	14.52	30.48	7.19	4.27		98.95
2	8.57	11.43	32.82	29.26	1.96	1.19	1.86	4.69	25.50	56.59	13.94	7.32		195.13
1.5	13.97	20.84	62.37	57.13	4.82	2.63	4.11	9.15	42.94	90.18	23.28	13.10		344.53
1	22.10	35.78	109.29	107.30	11.59	5.81	8.96	16.96	66.22	137.65	36.74	20.39		578.78
0.5	34.30	56.43	160.22	169.57	21.97	13.78	18.02	29.19	93.65	191.86	53.18	31.25		873.40
0													126.6	126.59
Totaux	34.29	56.42	160.22	169.56	21.96	13.77	18.01	29.19	93.64	191.85	53.18	31.24	126.6	1000

Table 3: Range of pipe diameters in GRP

ND(mm)	NP 16			
	SN2500		SN5000	
	t(mm)*	w(kg/m)	t(mm)*	W(kg/m)
300	5.2	9.18	6.2	10.8
350	5.9	12.26	7.1	14.87
400	6.4	14.7	7.8	17.9
450	6.9	18.34	8.5	22.76
500	7.6	22.0	9.3	27.76
600	8.8	31.49	11.0	37.9
700	10.1	42.36	12.6	53.09
800	11.3	54.34	14.2	68.56
900	12.5	67.82	15.7	85.46
1000	13.8	83.38	17.3	104.82
1200	16.2	117.86	20.6	150.18
1400	18.8	160.0	23.8	202.83
1600	21.3	207.59	27.0	263.38
1800	23.4	261.53	30.3	332.91
2000	26.2	320.07	33.5	409.34
2200	28.7	36.08	36.6	492.34
2400	31.2	458.28	39.9	585.92
2600	34.4	548.14	44.4	706.93