UNIVERSIDAD SAN FRANCISCO DE QUITO USFQ

Colegio de Ciencias e Ingenierías

Design of a 50 KLD Mobile Water Treatment Plant for Brackish and Stormwater.

Juan Carlos Martínez Castillo

Ingeniería Química

Trabajo de fin de carrera presentado como requisito

para la obtención del título de

Ingeniero Químico

Quito, 13 de mayo de 2022

UNIVERSIDAD SAN FRANCISCO DE QUITO USFQ

Colegio de Ciencias e Ingenierías

HOJA DE CALIFICACIÓN

DE TRABAJO DE FIN DE CARRERA

Design of a 50 KLD Mobile Water Treatment Plant for Brackish and Stormwater.

Juan Carlos Martínez Castillo

Nombre del profesor, Título académico Debalina Sengupta, Ph.D.

Diego Sebastián Ponce Cahuasqui, Ph.D.

José Francisco Álvarez Barreto, Ph.D.

Quito, 13 de mayo de 2022

© DERECHOS DE AUTOR

Nombres y apellidos:	Juan Carlos Martínez Castillo
Código:	00201532
Cédula de identidad:	1719877019
Lugar y fecha:	Quito, 13 de mayo de 2022

ACLARACIÓN PARA PUBLICACIÓN

Nota: El presente trabajo, en su totalidad o cualquiera de sus partes, no debe ser considerado como una publicación, incluso a pesar de estar disponible sin restricciones a través de un repositorio institucional. Esta declaración se alinea con las prácticas y recomendaciones presentadas por el Committee on Publication Ethics COPE descritas por Barbour et al. (2017) Discussion document on best practice for issues around theses publishing, disponible en http://bit.ly/COPETheses.

UNPUBLISHED DOCUMENT

Note: The following capstone project is available through Universidad San Francisco de Quito USFQ institutional repository. Nonetheless, this project – in whole or in part – should not be considered a publication. This statement follows the recommendations presented by the Committee on Publication Ethics COPE described by Barbour et al. (2017) Discussion document on best practice for issues around theses publishing available on http://bit.ly/COPETheses.

RESUMEN

Este proyecto propone la producción de 50 KLD de agua potable a partir de agua salobre y pluvial en una planta móvil de tratamiento de agua. Este proyecto tiene como objetivo proporcionar agua potable a los municipios que se han visto afectados por desastres naturales y carecen de acceso a agua potable. Se desarrolló un diseño preliminar y estudio de viabilidad mediante la selección de la tecnología apropiada, el diseño de un proceso y el desarrollo de un análisis económico. Para el tratamiento de aguas salobres y pluviales, el proceso se definió para tener un tanque de sedimentación, filtros de carbón activado, membranas de ósmosis inversa y un tanque de desinfección. Además, se estableció el uso de dos bombas y dos tamaños de tubería diferentes con diferentes características. Se observó que el proyecto tiene un ROI del 53% y un PBP de 0,51 días lo que lo hace económicamente viable. Además, se demostró que el sistema podría lograr agua potable si se inyecta agua de mar. La implementación de este proyecto conduciría al acceso a agua potable segura a precios asequibles y fácilmente.

Palabras clave: tratamiento móvil de agua, ósmosis inversa, agua salobre, aguas pluviales, tratamiento de agua, agua potable.

ABSTRACT

This project proposes the production of 50 KLD of drinkable water from brackish and stormwater in a mobile water treatment plant. This project is aim for providing drinkable water to municipalities that have been affected by natural disasters and lack access to drinkable water. It was developed a preliminary design and study of feasibility by selecting the appropriate technology, designing a process, and developing an economic analysis. For treating both brackish and stormwater the process was defined to have a sedimentation tank, activated carbon filters, reverse osmosis membranes, and a disinfection tank. In addition, it was established the use of two pumps and two different pipe sizes with different characteristics. It was observed that the project has an ROI of 53% and PBP of 0.51 days which makes it economically viable. Moreover, it was demonstrated the system could achieve drinkable water if seawater is injected. The implementation of this project would lead to access to safe drinkable water at affordable prices and easily.

Keywords: mobile water treatment, reverse osmosis, brackish water, stormwater, water treatment, drinkable water.

TABLE OF CONTENT

INDEX OF TABLES

INDEX OF TABLES IN ANNEXES

INDEX OF FIGURES

INDEX OF FIGURES IN ANNEXES

1. INTRODUCTION

1.1 Background

1.1.1 Water as a right for people and access during a natural disaster

According to [1] drinking water is a type of water that has been previously treated according to regulations and standards for human consumption. These regulations depend on the location of the water that has been consumed. Moreover, drinking water is a crucial resource for human beings and without it, people could die. Therefore, a lot of international institutions have established water to be a human right. For example, in 2010 the UN Human Rights Council (HRC) adopted a resolution recognizing the existence of a human right to access safe drinking water [2]. In addition to that, SDG 6 states "Ensure availability and sustainable management of water and sanitation of all" [3].

However, sometimes drinkable water cannot be accessed due to some extraordinary situations. For example, in 2017 when Hurricane Harvey appeared, the Texas Commission on Environmental Quality (TCEQ) reported that 61 public-water systems (PWS) were rendered inoperable at the height of the storm, and more than 200 systems had to issue boil-water notices (BWNs) [4]. Therefore, drinkable water was not easily available, and if it was it was very expensive (almost $100 per bottle of water) [4].

1.1.2 Characteristics of drinkable water

As mentioned before, water standards are determined by the location where it is consumed. In this study, the EPA (Environmental Agency Protection) standards will be used since the water quality data of brackish and stormwater is used from Texas, U.S. [5]. Also, the data was compared to the WHO (World Health Organization) in the case that there were no available standards in the EPA [6][7][8][9][10][11][12]. It is worth highlighting that there are several standards of drinking water quality. But it will be prioritized the levels of the pollutants and variables that are commonly found in brackish and stormwater (see Annexes).

1.1.3 Definition of brackish water and stormwater and their qualities

Stormwater is defined as the rainwater that has all the pollutants of a watershed characteristics, surrounding hydrogeology, etc. [13]. This type of water has a different type of pollutants however, for this design it was established to use the data from hurricane Harvey. On the other hand, brackish water is defined as water with TDS content between freshwater (≤500 mg l^{-1} TDS) and seawater (33 000–48 000 mg l^{-1} TDS). It can also be found as brackish groundwater in subsurface saline aquifers. Or a mix of river water and seawater [14].

1.2 Presentation of the Project

1.2.1 Objectives of the Project

1.2.1.1 General Objective

Perform the preliminary design and study of the feasibility of a 50 KLD mobile water treatment plant of stormwater and brackish water to provide drinkable water for a municipality of 2000 people during a natural disaster.

1.2.1.2 Specific Objective

For achieving the general objective stated previously the following specific objectives are planned:

1. Search for the most suitable technology for treating brackish and stormwater.

2. Design the process through the sizing of equipment and pumps.
3. Determine the economic viability of the project with economic indicators (ROI and PBP).

1.2.1.3 Justification of the project

Nowadays, approximately 2 billion people don't have access to safe drinking water [15]. Consequently, people had to drink available water like stormwater, brackish water, etc. But this type of water doesn't meet the standards of drinkable water [16][17] and therefore a lot of diseases are caused like diarrheal disease, respiratory distress, reproductive and fertility problems, neurological disorders, and death [18]. As a result, is important to reduce the infections and diseases of people with treatment of water.

While some communities and families have their private wells it has been demonstrated that the drinkable water produced there sometimes does not meet the standards for drinking it [16]. After Hurricane Harvey, some private wells reported that the total coliform occurrence was 1.5 times higher, and Escherichia Coli was 2.8 times higher [16]. Although some of the owners of the private wells added chlorine to protect the water against bacteria, the lack of knowledge of the owners lead to a bad disinfection process and there were a significant amount of bacteria left in the water [16]. Thus, during natural disasters, it would be better if drinkable water is provided by a system that ensures quality water.

During Hurricane Harvey, the cost of damages was raised to 131Billion dollars in industry, which includes the drinkable water treatment industry [19]. This caused a lot of communities to lack drinkable water and the stores started to rice the price of water. Some reports show that after the hurricane the cost of a bottle of water cost as much as $99 [4]. If it is considered, that the volume of a bottle of water on average is 16.9 oz [20] and the damages of the hurricane lasted for 4 months [4], the cost of water per liter per day would be $1.65. Moreover, if it is considered a community of 2000 people that consumes 50 KLD (kiloliters per day) the cost will rise to as much as $82534.23 per day. As a result, this amount of money could be used for developing the system that has been proposed which makes the project feasible.

1.2.1.4 Expected results from the implementation of the project

The main result of the implementation of the project would be access to safe drinkable water for a municipality of 2000 people after a natural disaster. As it was mentioned previously, due to the lack of drinkable water people would usually get diseases that could let them die [18]. However, with the implementation of the system, the risk of death during and after a natural disaster would be reduced.

Implementing the project will also help to wisely allocate government funds. Previously, it was mentioned that the U.S. government had to invest in boiling systems for providing safe drinkable water to the communities [4]. In addition, people would be spending a lot of money on buying water [4]. However, with the implementation of this project, the U.S. government could use that money to restore the homes and buildings that were destroyed and, people would spend their money on other needs after the disaster like food, shelter, restoring their homes, etc.

Finally, another expected outcome of the project would be easy access to drinkable water. Before, it was mentioned that people usually had to construct their private wells to get water or had to travel to get it [16]. Nevertheless, with the implementation of the project people will have easy access to water given that the system for treating water is mobile.

2. DESIGN BASES

2.1 Description of raw water

2.1.1 Stormwater

After searching for sources, the data that's going to be used for designing the system was obtained from [16][21][22]. The data were obtained during Hurricane Harvey from at least 326 private wells of stormwater. Some chemical parameters of water had a mean that meet the standards of drinkable water, but the percentage of exceeding standards was at least 10%. Therefore, it was analyzed each set of data and it was established that the mean value of a parameter was going to be used when the percentile of exceeding standards was below 4%. If the parameter had a percentage of exceeding standards of at least 10%, the 90th percentile value was going to be used. Therefore, the following data were obtained (see Table 1).

Table 1. Chemical data of stormwater

Chemical	Measurement	
Arsenic	2.8	µg/L
Cadmium	0.5	µg/L
Chromium	8.6	µg/L
Fluoride	0.4	mg/L
Nitrate	0.7	mg/L
Uranium	2.1	µg/L
Total coliform	172.0	cfu
E. Coli	10000.0	gene copies/ mL
Copper	34.2	µg/L
Lead	3.6	µg/L
Chloride	240.4	mg/L
Copper	34.2	µg/L
Fluoride	0.4	mg/L
Iron	768.3	µg/L
Manganese	109.6	µg/L
Sulfate	16.4	mg/L

Zinc	171.8	µg/L
TSS	122.0	mg/L

2.1.2 Brackish water

Brackish water data was obtained from [17]. This set of data was selected because it has the chemical composition of 12 private wells all around Texas. Some chemical variables from the data were very spread and some statistical analysis was done. The mean, the standard deviation, and the first and third quartile were calculated. Using the interquartile rule [23], the outlier values were rejected and the mean was calculated again. As a result, the following table was obtained with the new means of each parameter (see Table 2).

Table 2. Data of brackish water

Parameter	Measurements	
pH	8.01	
TDS	6603.27	mg/L
Calcium	407.67	mg/L
Magnesium	183.25	mg/L
Potassium	13.72	mg/L
Sodium	2109.13	mg/L
Bicarbonate	901.44	mg/L
Chloride	2871.30	mg/L
Fluoride	1.48	mg/L
Nitrate	32.61	mg/L
Sulfate	1761.74	mg/L
Silica	37.34	mg/L

2.2 Exceeding values from chemical data

After the data of both brackish and stormwater was processed it was compared with the standards [5][6][7][8][9][10] and as a result, the following pollutants are addressed in the design (see Table 3 & 4).

Table 3. Stormwater parameters that do not meet drinkable water standards

Chemical	Measurement	
Total coliform	172.0	cfu
E. Coli	10000.0	gene copies/ mL
Chloride	240.4	mg/L
Iron	768.3	µg/L
Manganese	109.6	µg/L
TSS	122.0	mg/L

Table 4. Brackish water parameters that do not meet drinkable water standards

Parameter	Measurements	
TDS	6603.27	mg/L
Calcium	407.67	mg/L
Magnesium	183.25	mg/L
sodium	2109.13	mg/L
Bicarbonate	901.44	mg/L
Chloride	2871.30	mg/L
Nitrate	32.61	mg/L
Sulfate	1761.74	mg/L

2.3 Location of the project

The system is designed in theory and has no specific location because is a mobile system. However, since the quality of water depends on the place that is stored and every water treatment process is specifically tailored to each type of water, the system will only be useful within the location of the data used. In this case, the system will perfectly work in Texas since the data used was from that place. Nevertheless, the values being used are the most conservative ones (worst case scenario). This means that the system designed is capable to adapt itself to various sources of brackish water and stormwater from all around the world.

2.4 Limitations of the system

One of the limitations of the system is the standards of drinking water that were previously mentioned. However, there are some other limitations like the availability of brackish water and stormwater. In the case of brackish water, there are approximately 10 major aquifers and 20 minor aquifers in Texas that could be used for the system [24]. The most important major aquifer is the Gulf Coast Aquifer System, and the most important minor aquifer is the Rustler Aquifer. It is worth mentioning that both aquifers are located around the zones where most of the hurricanes have occurred in the past decades [25]. Therefore, the minimum predicted amount of brackish water available in that region is 3,086,100 acres/feet [24].

In the case of stormwater during Hurricane Harvey, it was reported that almost 52" of rain fell in three days along in the Gulf Coast Region in Texas [26]. Consequently, during natural disasters stormwater is available for treatment.

3. SELECTION OF TECHNOLOGY USED

According to [27], mobile water treatment systems can be incorporated into standard trailers or trucks. Thus, fitting the system into a trailer is one of the challenges of the project. Consequently, it is important to consider the size of the equipment that will be used in the system and considered different scenarios. For example, [27] developed a system for brackish water treatment in India with screening and reverse osmosis (RO) membrane as unit operations. Another example is the system proposed by [28] which is developed for valley water, seawater, underground water, and steam water-flooded water. This system is composed of 4-unit operations, coagulation, pore control fiber, activated carbon, and disinfection with UV light. As a result, from the two systems proposed what is commonly used for treating saline water are RO membranes, thus this type of membrane could be considered as the main treatment of the system being designed.

3.1 Pretreatment

Usually, the first treatment of water is a physical treatment because it prevents the plugging of more advanced treatments, thus they can last longer[29]. The first treatment is sedimentation since its perfect for reducing TSS (Total soluble solids) which are always present in any type of water obtained from natural sources [19]. It is worth mentioning that although other types of pretreatments could be more efficient than sedimentation and with less space usage, rectangular sedimentation tanks are an easy and cheap way to remove big solids. Moreover, there are minimal to no pretreatments for tubular membranes because of their cost-effective implications in small mobile water treatment [27], and using sedimentation tanks is one of the few options left.

In addition, it is planned to use filtration as a unit operation after the sedimentation tank. This is because of two big reasons. The first reason is that filtration is an efficient and cheap option for protecting against flocking any forward operation of the system [30]. The second reason is that water being treated contains significant concentrations of different metals that should be reduced, such as iron, and filtration is the cheapest and most efficient method to do so [31] [29]. There are different types of filtration units however, it will be selected the pressure filter one because it is normally used for small systems, some equipment does not need a backwash flow and the operation is continuous [29].

Finally, it is planned to use an antiscalant before the RO membrane system. This is because the RO membranes tend to plug, but with an antiscalant, this process is delayed and membranes could operate longer [31][30][19]. In addition, for cleaning the residues of the antiscalant, the RO membranes should be cleaned every day at 10 am and 6 pm by flowing 30 min of 0.5M citric acid [32].

3.2 Primary treatment

For the primary treatment, it was selected reverse osmosis (RO) membrane operation because one of the objectives of the system is to treat brackish water and the best economic-efficient option is reverse osmosis [28] [29][30][33]. Even though, some researchers may claim that thermal membrane distillation could be a better option, "reverse osmosis can produce fresh water at one-third of the cost of membrane distillation, RO membranes can eliminate from 95 – 99% TDS with nearly 100% of heavy metals, organic matter, viruses and bacteria, and RO membranes are easily used in compact systems" [27].

3.3 Disinfection

Even though there is no real need for additional disinfection since the RO membrane selected can reject around 2 – log to 3 – log of different bacteria and viruses [34][35][36][37]. Mobile water treatment plants in Texas are subjected to regulations that establish to do a 4 – log (99.99%) disinfection for viruses and bacteria [38].

The three main methods of disinfection are ozone, chlorination, and UV light [39]. Therefore, to consider which is the best option for the treatment it was developed a decision matrix with values from 1 (worst option) and 3 (best option) (see Annexes).

From the data of the matrix [29][33], it is concluded that the best option is chlorine since it is relatively safe, it has strong power for inactivation of viruses, the system implementation is simple and it has a long-lasting effect. However, there are several ways in which chlorine is presented. The most common ones are chlorine gas, calcium hypochlorite, and sodium hypochlorite. For selecting the best option, a decision matrix was developed with values from 1 (worst option) and 3 (best option) (see Annexes).

As it is concluded from the data of the matrix [39], the best option is sodium hypochlorite since it is very safe to handle, the system implementation is simple and it is not necessary to use a high amount of it to perform good disinfection.

4. DESIGN OF PROCESS AND PLANT

4.1 Mass balance and sizing of equipment

4.1.1 Disinfection unit

For developing the mass balance of the system, it was planned to start backward considering that the target was 50 KLD (9 gpm). To develop the mass balance it was first determined the CT value at 4 log, according to regulations for disinfection with chlorine previously mentioned [38]. The CT value of 6 mg*min/L [40] was selected because there are not just bacteria in stormwater but some viruses as well [16][4][41]. Also, the final concentration of chlorine after leaving the reactor was selected to be 2 mg/L, which is two units below EPA standards [5]. Also, this value ensures that there won't be any harm to human health. Finally, with the CT value, it was calculated that the volume of the disinfection reactor is 27.5 gal and 3 min the residence time (see Annexes). From the decision matrix (see Annexes), CWS-1354 is selected as the retention tank because it is chlorine-resistant, it has a 30-gallon capacity, it is cheap, and it can operate at a higher pressure than the other retention tanks. The dimensions of the retention tank are 60" in length and 13" in internal diameter.

In addition, it was calculated the chlorine flowrate to the retention tank. A mass balance of chlorine was developed (see Annexes) based on the previous statement that the outlet concentration of chlorine is 2ppm. In addition, for the calculations, it was considered that the initial solution of chlorine should be 5% according to standards of sodium hypochlorite used in houses [39][42]. As a result, the flow rate should be 0.000367 gpm, which was neglected from the general balance because the flow rate is insignificant to the inlet flowrate of water and outlet flowrate of water.

4.1.2 Permeation Unit

The mass balance started with the Filmtec™ Seamaxx™ – 440 RO membrane with a recovery of 45% [30]. Consequently, with the mass balance, it was determined that it should be used 3 series membranes (see Annexes). Thus, the membrane is 40” in length and 1.125” in internal diameter.

For the antiscalant dosing, it was done a mass balance (see Annexes) with a dosing concentration of the antiscalant between 0.02 – 5 ppm [43][44][45]. After, an antiscalant was selected using a decision matrix (see Annexes). The selected antiscalant used was SpectraGuard 111 because it can be operated in brackish water and stormwater, also it can control up to 7 compounds to prevent fouling and it has no phosphate presence. In addition, the antiscalant solution should be diluted to 10% wt [39][46]. For this project, dosing of 0.2 ppm was selected to prevent overdosing or underdosing. Finally, the flowrate of the dosing rate is 0.0000359 gpm (see Annexes).

4.1.3 Filtration unit

First, a pressure filter was selected since it could be easily used in small water treatment plants, the operation can be continuous, and could use an automatic backwash [29]. In addition, for designing the filter it was selected 6 gal/ft^2*min which is a common filtration rate for pressure filters [47]. As a result, the internal diameter of the filter was obtained to be 25.13" and an inlet flow rate of 20.66 gpm.

Afterward, it was researched for different types of filters and a decision matrix was developed (see Annexes). US water MIF – 250 filter was selected because it can purify iron up to 12 ppm, it has included 1 pretreatment unit, it has an automatic oxidant backwash with hydrogen peroxide, it is cheap and the maximum flow rate to operate the system is10 gpm. Thus, by doing the mass balance it was determined that it should be used 2 filters (see Annexes). It is worth mentioning that each filter has a diameter of 13" and a length of 54".

4.1.4 Sedimentation tank

First, was selected 14 um was the diameter of particles since most of the particles found in stormwater were bigger or had a similar diameter [48]. After, it was assumed that the particles could be modeled by Stokes Law, and the settling velocity was obtained [29]. Assuming a height of the tank of 38" the residence time was obtained (1.9h). Therefore, with that data, the volume of the sedimentation tank was calculated to be 2385.83 gal (see Annexes).

After it was researched for the size of the rectangular sedimentation tank, it was founded that no tank would exist of such dimensions. Therefore, it was decided that at the time of buying equipment, the tank would be sent to a manufacturer to make the actual size tank. Meanwhile, for modeling this system it was decided to use the biggest and thinnest tank found which has a capacity of 1250 gal. Consequently, with a mass balance, it was calculated that 2 tanks should be used in the system with dimensions of 130" in length, 81" in width, and 38" in height.

In addition, to enhance the sedimentation of the particles it was selected to use some plates per tank. Although the size of the plates was already established by the supplier, the slope of the plates was not and it is planned to be 45° for best performance [29]. Finally, it was calculated the number of plates needed for sedimentation and it was divided by the number of tanks (7 plates per tank) (see Annexes).

4.1.5 Controllers and valves

It is established that there will be at least two pumps on the system that will be sized in the next section. The first pump will be for starting the flow in the system. The second pump will be used to obtain the desired operating pressure of the RO membrane. Consequently, the system is presented in the following diagram where the green pipeline is the reject flow of the membranes (see Figure 1).

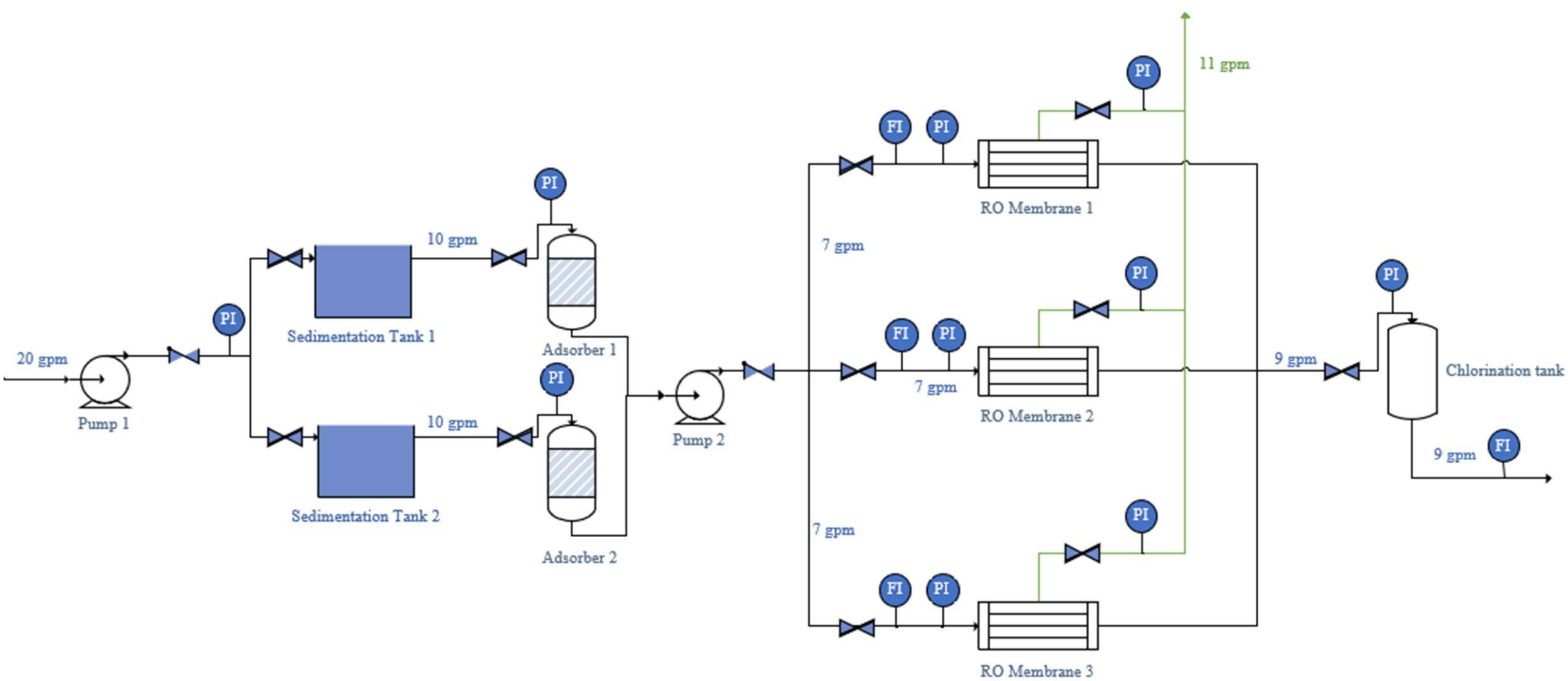

Figure 1. General mass balance of the system with controllers and valves.

Before the system is used it should be added some controllers and valves to have a safer design and operability. After each pump, two check valves will be used to prevent the pump from being damaged in case of a backflow [49][50]. Moreover, for maintenance purposes or changing purposes of equipment, a butterfly valve will be put before each piece of equipment [51]. For the sedimentation tank, a level indicator could be placed, but since the sedimentation tank will be constructed, it can have a transparent wall so that the level of water could be seen from the outside.

About the pressure filter, a pressure gauge will be implemented beside the butterfly valve before each filter for assuring that the filter works at 94.7 psia [52]. Moreover, each of the RO membranes will have a pressure gauge and a flowmeter to assure the operating conditions of the membrane beside the butterfly valve [53][54]. Also, each reject flow of the membrane will have a pressure gauge and a reject valve for controlling an overpressure and assuring the correct operation of the membrane until it is plugged [53][54]. In addition to the butterfly valve, the disinfection process will have a pressure gauge before the contact tank because the tank can operate up to 125 psia[55]. Finally, the system will have a flowmeter at the end of the system to assure the targeted flow rate [49] (see Annexes).

4.2 Energy balance

4.2.1 Dimensions of the system

First, for the transportation of the facility design it was established the use of a truck with dimensions of 327” x 96” x 102” (see Annexes) [56]. Given the dimensions of the truck, it was decided to put the sedimentation tanks outside the truck to save inside space. As a result, a diagram with the unit operations was made in Autocad to determine the hydraulics of the system (see Annexes). Additionally, the system was divided into two sections A and B for performing the pump's head requirements in each case.

4.2.2 Energetic requirements Part A

First, for determining the head requirement of pump 1 a diagram of part A was designed (see Figure 2). Point A starts at the outlet of pump 1 and point B is established at a tee of the pipe after the outlet of the filtration unit. According to the datasheet of the filter, it can operate at 100 psia. Thus, at point B the absolute pressure will be 94.7 psia [57]. Also, it is worth mentioning that for hydraulic losses the height of the adsorber was considered twice because the filter has the inlet and outlet at the top part of it. Moreover, the sedimentation tank was neglected for the hydraulic calculations since it is opened to air [58][59].

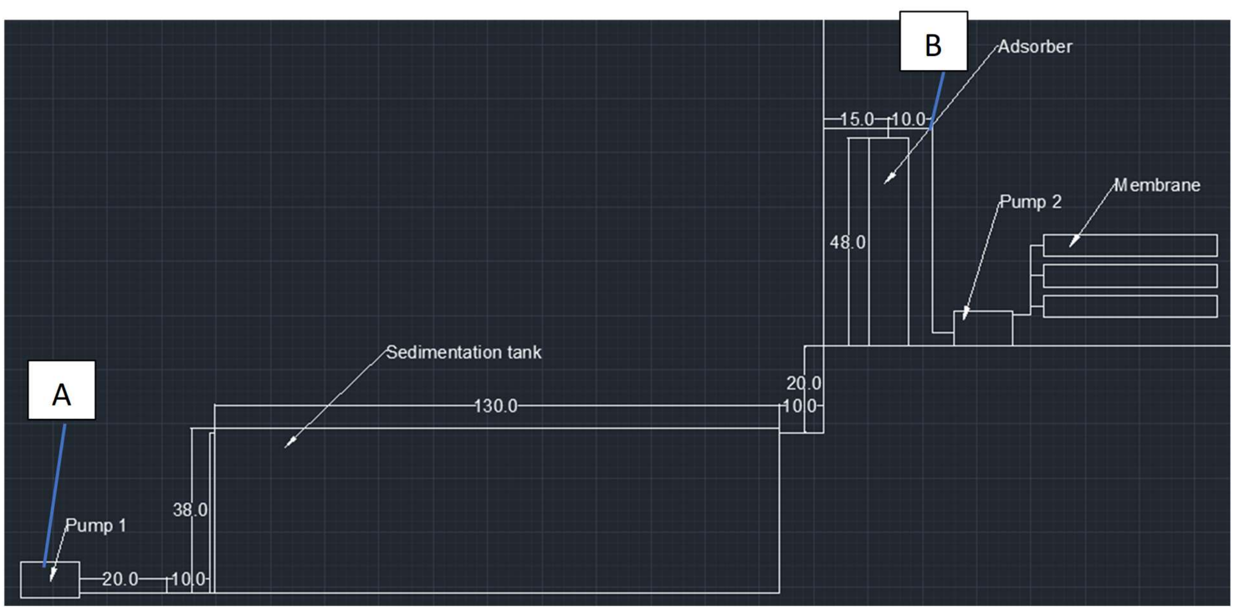

Figure 2. Hydraulic size of Part A of the system

Since there are different flow rates in each section of the pipeline it was established a different pipe diameter for each section. Considering the flowrate of each section and the diameter of the pipes available on the market, it was calculated the velocity of each pipeline (see

Table 5 & Annexes). Moreover, the velocity of each pipe was checked to be between 98.43 - 59.06 in/s since that is the usual range of hydraulic velocity in a water treatment system[59].

Table 5. Velocities of every pipe in the system.

Velocity (in/s)	Inside diameter (in)	Flowrate (gpm)
91.88	1.033	20
87.15	0.75	10

For calculating the head loss of fittings it was applied the minor loss equation and K values were obtained with Le/D values for elbows, tees, inflows, outflows, check valves, butterfly valves, pressure gauges, and flow gauges (see Annexes) [58]. Moreover, PVC pipes were selected to use for the project since they are best suited for water treatment systems, they can tolerate pressures up to 150 psia and they are very cheap compared to the type of pipes [58][59].

By using the dimensions information, it was calculated the height of point B to point A (see Annexes). In addition, with the lengths of the dimensions, the minor losses were calculated by using the Darcy – Weishbach equation and an approximation of the friction factor proposed from [58](see Annexes). It is worth highlighting that the specific weight used was the one of water at 68°F since it is the average temperature of the year in Texas [60]. Finally, it was calculated the head loss of the velocities at point A and point B since there is a change in the inside diameter (see Annexes). With all the information obtained on the head losses of pressure, head losses of velocity, and minor losses of length and fittings; Bernoulli's energetic equation was used, and the head of the pump was calculated to be 2610.0 in or 66.29 m (see Annexes).

It is worth mentioning that the NPSHa of this pump was calculated assuming that this pump will be delivered on a well of brackish water or in a tank full of stormwater that is opened to atmospheric pressure. In addition, it is considered that the pump will be submerged 78” inside water. With this information, it was calculated the static pressure head and the vapor pressure head of water assuming a temperature of 68°F [60]. As a result, it was obtained that the NPSHa of the system is 319.38” (see Annexes).

For selecting the pump, it was searched for a pump that had a big head and a small flowrate. The perfect suit was a submersible pump since it is designed for operating in wells that have a very long depth but a low flow rate is needed [59]. Consequently, a decision matrix was developed for the selection of the pump (see Annexes).

The model ASP8 - 10 is the most suitable option for the system since it correctly meets the requirements of flowrate and head. In addition, it is one of the cheapest options, it is made with stainless steel and less energy is needed for the pump since it operates with solar panels.

4.2.3 Energetic requirements Part B

Part B was divided into two subsections. The first subsection is established to begin from point B of section A to pump 2 and the second subsection is established to begin from pump 2 to point B of section B.

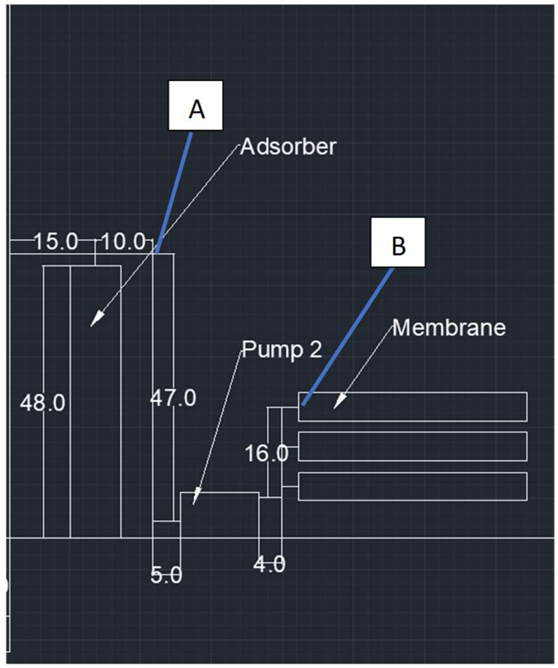

Figure 3. Hydraulic graph of Part B

4.2.3.1 Outlet pressure of subsection 1

First, it was assumed that the velocity in point A and the velocity at the inlet of pump 2 will be the same at a steady state. In addition, the pipe being used will be a PVC pipe of 1" because there are no parallel flows as it was previously mentioned. For calculating the head loss of fittings Le/D values were found for each case (see Annexes) [58].

With the data obtained, the fittings and minor head losses were calculated (see Annexes). In addition, with the dimensions of the pipes, the minor head losses of the system were calculated with the Darcy – Weishbach Equation and an approximation of the friction factor proposed from [58](see Annexes). Finally, with the minor head losses, the difference in heights, and hydraulic velocity; Bernoulli's equation was used and the inlet pressure to the pump 2 was found to be 95.57 psia (see Annexes).

4.2.3.2 Sizing subsection 2

First, it was established that the pipe being used will be a 1” black steel pipe before the flow is divided for the three membranes and a black steel pipe ¾” after the flow is divided (see Figure 3). In addition, the type of pipe was changed from PVC because of the high pressure being delivered by pump 2 (800 psia). Finally, for calculating the head loss of fittings, controllers, and valves the Le/D value was found for each case and each type of pipe (see Annexes) [58].

Using ft values of a steel pipe and K values the fitting's minor head losses were calculated for each type of pipe (see Annexes). Second, the minor losses were calculated according to the dimensions of Figure 3 with the Darcy – Weishbach Equation and an approximation of the friction factor proposed from [58](see Annexes). In addition, the head pressure loss was calculated from the outlet pump pressure to the membrane inlet pressure at the last branch. It is worth mentioning that the principle of equal pressure in parallel branches was established for the calculation of this part [58] (see Annexes). Moreover, the head velocity loss was calculated with the different velocities in the different pipes (see Annexes). Finally, using fittings minor head losses, minor losses, the difference in heights, the pressure head, and the velocity head Bernoulli’s equation was used and the inlet pressure to the pump 2 was found to be 19639.76 in or 498.84m (see Annexes).

For the calculation of the NPSHa of this pump, it was considered point A from Figure 3 as the beginning of the system for calculating NPSHA. With this information, it was calculated the static pressure head, the head minor losses, height, and the vapor pressure head of water assuming a temperature of 68 degrees Fahrenheit [60]. As a result, it was obtained that the NPSHa of the system is 2640.52” (see Annexes).

For the selection of the pump, it was searched for a pump that had a big head and a small flowrate. The perfect suit may be a submersible pump since it is designed for operating in wells that have a very long depth but a low flow rate is needed [59]. However, the pump cannot be submerged since it must be in the middle of the system between two pipes. Therefore, a multistage centrifugal pump with a small flowrate was searched. Also, the possibility of using two small pumps in series was searched as well, but it was discarded because due to a high incidence of seal failures in the second pump. Consequently, a decision matrix was developed for the selection of the pump (see Annexes).

The model 6-50 from ZHONGDA PUMP0 is the most suitable option for the system since it correctly meets the requirements of flowrate and head. In addition, it is one of the cheapest options, and less energy is needed. Although the pump is not made of stainless steel it has a better efficiency since it is only needed one pump and not two pumps in series.

4.3 Purification

4.3.1 Sedimentation tank

For this case, it was researched an efficiency of a similar rectangular sedimentation tank. Although the researched tanks have significantly different sizes, the efficiencies lay around 60 – 70% for TSS [61][62][63]. Therefore, it was determined that the efficiency that was used in the system would be 65%. Consequently, the mass balance was developed and the data after sedimentation for stormwater was obtained (see Annexes).

Although the concentration of TSS did not achieve the requirements established by the regulations it is a good treatment to get rid of big solids like slit, clay, decaying plant and animal matter that can be in eighter stormwater or brackish water and that could floc the filtration unit easily [31]. In addition, the remaining TSS concentration will be reduced with the filtration unit.

4.3.2 Filtration

In the case of the filtration, since it was already selected the US water filter with catalytic carbon, the efficiency of removal was taken from the datasheet of the product [57]. In the case that there was no available information, the efficiencies were obtained with the most conservative value from papers that used catalytic carbon for water treatment (see Annexes) [64][65][66].

4.3.3 RO membrane

For the Filmtec^{TM} Seamaxx^{TM} – 440 membrane the removal efficiencies of contaminants were taken from its datasheet [67], with that data it was simulated the process (see Annexes). It is worth mentioning that although the reduction of E. Coli and total coliforms is significantly important, the results do not meet the EPA requirements mentioned previously, therefore it is needed a disinfection treatment.

4.3.4 Disinfection unit

Finally, for the contact tank, it was searched for the datasheet [55], and it has established a 4-log (0.9999%) volume for 9 gpm. Consequently, the final concentration of each contaminant and each type of water was obtained (see Table 6 & 7).

Table 6. Purification data of stormwater after the disinfection process.

Chemical	Measurement	
Total coliform	0.00	cfu
E. Coli	0.01	gene copies/ mL
Chloride	2.40	mg/L
Iron	7.68	µg/L
Manganese	1.10	µg/L
TSS	0.00	mg/L

Table 7. Purification data of brackish water after the disinfection process.

Parameter	Measurements	
TDS	13.22	mg/L
Calcium	3.61	mg/L
Magnesium	0.16	mg/L
sodium	1.08	mg/L
Bicarbonate	4.51	mg/L
Chloride	2.87	mg/L
Nitrate	0.49	mg/L
Sulfate	0.58	mg/L

5. ECONOMIC EVALUATION

5.1 FCI (Fixed Capital Investment)

For calculating the FCI the cost of each piece of equipment was obtained by contacting each supplier. In addition, it was also considered the costs of the pipes and fittings of each of them. Moreover, it was considered the cost of the plastic gallons used for storing water [68]. Consequently, it was used Lang factors of installation, instrumentation and controls, electrical systems, legal expenses, engineering, and supervision [25]. With those factors, the costs of each piece of equipment added up and it was multiplied by a factor of 6 since the system is a liquid [25]. Finally, the Total Capital Investment of the project was $77448.98 (see Annexes).

For each piece of equipment, it was considered a linear depreciation during the duration of each warranty. In the case that there was no warranty data for the equipment it was established a depreciation of 5 years which is the minimum depreciation of equipment in the industry [25].

Table 8. Cost of equipment and their depreciation.

Equipment	Cost ($)	Depreciation (years)	Lineal depreciation ($/year)
Pump	220	3	73.33
Pump	4489	5	897.80
Membrane SEAMAXX FILMTEC	2685	5	537.00
Filtration unit	1799.9	7	257.13
Sedimentation tank	5582	5	1116.40
Plates for tank	700	5	140.00
Storing tanks	1298	5	259.60

5.2 OPEX (Operating Cost)

For this entry, it was searched for the energy that each equipment needed according to their datasheet (see Table 9). The energetic requirements were added up and the total energy obtained is 12.1 kW. Therefore, since the system will be placed in areas where the access to electricity is exceedingly difficult it was searched for a battery of 13 kW that costs around $15600. It is worth mentioning that there is no charge for engineers since it is a charitable project, it will be considered a volunteer.

Table 9. Amount of energy per equipment

Equipment	Energy consumption [watts]
Chlorinator tank	0.022
Filtration system	0.18
Motor of pump 2	11
Motor of pump 1	0.75

Moreover, for the operation cost, it was considered the flowrates of each of the chemicals needed for the filtration, antiscalant, and disinfection process. Knowing the cost of the chemical per volume it was multiplied by their respective flowrates and the cost per day was obtained (see

Table 10). Finally, multiplying the cost obtained for the time of operation (3 – 4 months) and adding them up an OPEX of $79223 per year was obtained.

Table 10. OPEX total costs per year.

Solutions	Size	Unitary cost ($)	Number of units	Total cost ($/year)
Hydrogen peroxide (gal)	5	29.95	73	2180.36
Sodium hypochlorite (L)	10	684.5	74	50653.00
Antiscalant (L)	10	700	8	5600.00
Catalytic Carbon (ft^3)	0.5	99.95	208	20789.60

5.3 ROI and PBP

Since this project is a community service project there are no incomes at all. However, to cover the operation costs and the cost of the equipment and become a self-sustainable project it was assumed that the cost of water would be $2 per gallon of water which is approximately twice the cost of a gallon nowadays [69]. However, it is very charitable value considering that during hurricanes a bottle of drinkable water could cost as much as $99 [4]. In addition, it was assumed that the supply of water would be for 3 months which is the time that it was found contaminants in drinking water during a hurricane [4]. Considering that the flowrate of the system is 50 KLD and zero tax on the system [70]. With the previous data, it was calculated the annual net after-tax profit. Consequently, with the data of depreciation, OPEX, and FCI 53% of ROI and 0.0014 yr of PBP were obtained which makes the system very feasible (see Annexes).

5.4 Net present value (NPV)

At last, it was assumed based on the historical data of hurricanes that the system would be used every other year two times a year [71]. In addition, it established a discount factor of 4% to the U.S. dollar considering future events in the world [72]. Moreover, the working capital investment of the project was taken to be 25% of TCI [73]. Also, it is considered 5 years of cash flow since the average warranty of the equipment used for the system has that amount of warranty. Finally, by adding all the annual net after-tax profit, the NPV of the project is $2213248.84.

6. SENSITIVITY ANALYSIS

Because one of the main purposes of the project is to provide people with drinkable water during disasters, as well as the fact that it is feasible from an engineering standpoint and economically, seawater could also be a viable source of water. Therefore, this chapter analyzes if the system can purify seawater. Consequently, the following data was selected for this scenario (see Table 11) [74][75][76][77].

Table 11. Data of Quality of Seawater

Parameter	Measurement
pH	7.9
Na+ (ppm)	10,570
Mg2+ (ppm)	1,276
Ca2+ (ppm)	447
K+ (ppm)	393
Cl− (ppm)	19,325
SO42- (ppm)	2,740
NO3−(ppm)	160
Br− (ppm)	67
F− (ppm)	1.3
TSS (ppm)	289.75
TDS (ppm)	33000.00
Iron (ppm)	0.06
Turbidity (NTU)	0.99
E. Coli (CFU/mL)	21.60

With the help of the efficiencies used previously for each piece of equipment during the purification process, it was calculated that the final concentration of the impurities (see Annexes)[57][64][65][66][67][55][78][79][80].

Table 12. Final concentration of seawater contaminants after treatment.

Parameter	Final concentrations
Na^+ (ppm)	5.4118
Mg^{2+} (ppm)	1.1303
Ca^{2+} (ppm)	3.9595
K^+ (ppm)	11.7900
Cl^- (ppm)	19.3250
SO_4^{2-} (ppm)	0.8943
NO_3^-(ppm)	2.4000
Br^- (ppm)	0.2010
F^- (ppm)	0.0078
TSS (ppm)	0.3042
TDS (ppm)	66.0528
Iron (ppm)	0.0006
Turbidity (NTU)	0.0024
E. Coli (CFU/mL)	0.0000

After comparing the final concentration of each of the parameters of the contaminants of seawater with the parameters of drinkable water [6][7][8][9][10][11][12], it was determined that the system is capable of purifying this type of water as well. However, it is worth considering that the data was obtained from the Mediterranean Sea due to the lack of data from other seas. This means that the system can also be used in different locations other than the Mediterranean Sea if these locations have less contamination than the data used in this case.

In addition, according to researchers [65][66][78][79], activated carbon can purify water contaminated with organic compounds which makes the system more robust to different types of water. Moreover, RO membranes have at least 2-log removal of bacteria and viruses, and the disinfection tank was designed for a 4-log removal. Therefore, the system has a total of 6-log removal which makes the system very powerful for removing strong viruses and bacteria [29].

7. CONCLUSION

The feasibility and preliminary design of a 50 KLD drinkable water mobile water treatment plant for stormwater and brackish water was studied. This system solves the problem related to the lack of drinkable water during natural disasters and the unsafety procedures done by citizens for purifying water. Likewise, the system showed to be an innovation in water treatment systems since it is a mobile unit, and it can deal with two types of water.

In the first place, the most suitable technology was selected for treating both brackish and stormwater. It is concluded that the use of sedimentation tanks, activated carbon filters, and antiscalants are an economically viable pretreatment solution for RO membranes. Moreover, it is concluded that the use of both RO membranes and disinfection tanks could achieve a 6-log removal of microbes.

Second, by knowing the final flowrate of 50 KLD of the system, it was possible to build the mass balances and the energy balances for sizing equipment and pumps. These calculations determined that the system should have some parallel flows and a high energetic requirement. However, with the use of solar panels used for providing energy to the pumps, the energy requirements were reduced.

Third, the economic analysis determined that the project is also economically viable. In this part, it was possible to identify the values of the operational cost, the cost of containers, and the cost of equipment. Although this project was implemented considering twice the value of a gallon of drinkable water today in the US, it is charitable for a natural disaster situation. Moreover, with the sensibility analysis, it is concluded that the system has a robust design that can also manage seawater.

Although the system is already economic and technically viable it can still be improved. In the first place, recirculation of the reject flow could be performed with evaporators. This could reduce the use of source water and could be beneficial in cases where there is not enough water for treatment available.

Finally, another improvement of the system could be the recovery of energy by using a turbine. After the water passes through the membranes it still has a lot of pressure and this pressure could be minimized with the use of a turbine which recovers energy and makes the system safer.

8. BIBLIOGRAPHIC REFERENCES

[1] C. Johnson, “2.4 - Advances in Pretreatment and Clarification Technologies,” in *Comprehensive Water Quality and Purification*, S. Ahuja, Ed. Waltham: Elsevier, 2014, pp. 60–74.

[2] I. A. Ibrahim, “Water as a human right, water as a commodity: can SDG6 be a compromise?,” *Int. J. Hum. Rights*, 2021, doi: 10.1080/13642987.2021.1945582.

[3] M. M. Rahaman, A. I. Galib, and F. Azmi, “Achieving drinking water and sanitation related targets of SDG 6 at Shahidbug slum, Dhaka,” *Water Int.*, 2021, doi: 10.1080/02508060.2021.1901189.

[4] M. R. Landsman *et al.*, “Impacts of Hurricane Harvey on drinking water quality in two Texas cities,” *Environ. Res. Lett.*, 2019, doi: 10.1088/1748-9326/ab56fb.

[5] T. Environmental Protection Agency, “Secondary drinking water standards: Guidance for nuisance chemicals,” *United States Environmental Protection Agency*. 2017.

[6] World Health Organisation (WHO), “WHO guidelines for drinking-water quality - Third edition,” *WHO Press. Geneva*, 2008.

[7] World Health Organisation (WHO), “Hardness in Drinking-water,” 2011, [Online]. Available: https://www.who.int/water_sanitation_health/dwq/chemicals/hardness.pdf.

[8] Cedar Park, “2020 Annual Drinking Water Quality Report,” 2020, [Online]. Available: https://www.cedarparktexas.gov/home/showdocument?id=16406&t=637564161743046026.

[9] E. P. A. (EPA), “Drinking Water Advisory: Consumer Acceptability Advice and Health

Effects Analysis on Sodium," 2003, [Online]. Available: https://www.epa.gov/sites/default/files/2014-09/documents/support_cc1_sodium_dwreport.pdf.

[10] World Health Organisation (WHO), "Potassium in drinking-water Background document for development of WHO Guidelines for Drinking-water Quality," 2009, [Online]. Available: https://www.who.int/water_sanitation_health/water-quality/guidelines/chemicals/potassium-background.pdf.

[11] N. Rahmanian *et al.*, "Analysis of physiochemical parameters to evaluate the drinking water quality in the state of perak, Malaysia," *J. Chem.*, 2015, doi: 10.1155/2015/716125.

[12] J. M. VanBriesen, "Potential Drinking Water Effects of Bromide Discharges from Coal-Fired Electric Power Plants," *US EPA*, [Online]. Available: https://www3.epa.gov/region1/npdes/merrimackstation/pdfs/Comments2RevisedDraftPermit/VanBriesenReport.pdf.

[13] D. C. W. Tsang, I. K. M. Yu, and X. Xiong, "Chapter 18 - Novel Application of Biochar in Stormwater Harvesting," in *Biochar from Biomass and Waste*, Y. S. Ok, D. C. W. Tsang, N. Bolan, and J. M. Novak, Eds. Elsevier, 2019, pp. 319–347.

[14] S. Gray, R. Semiat, M. Duke, A. Rahardianto, and Y. Cohen, "4.04 - Seawater Use and Desalination Technology," in *Treatise on Water Science*, P. Wilderer, Ed. Oxford: Elsevier, 2011, pp. 73–109.

[15] R. Bain, R. Johnston, and T. Slaymaker, "Drinking water quality and the SDGs," *npj Clean Water*. 2020, doi: 10.1038/s41545-020-00085-z.

[16] K. J. Pieper *et al.*, "Microbial contamination of drinking water supplied by private wells after hurricane harvey," *Environ. Sci. Technol.*, 2021, doi: 10.1021/acs.est.0c07869.

[17] U.S. Deparment of the Bureau of Reclamation, “Treating Brackish Groundwater in Texas: A Comparison of Reverse Osmosis and Nanofiltration,” *Reclamation*, [Online]. Available: https://www.usbr.gov/gp/otao/treating_brackish_groundwater_texas.pdf.

[18] K. Rhoden, J. Alonso, M. Carmona, M. Pham, and A. N. Barnes, “Twenty years of waterborne and related disease reports in Florida, USA,” *One Heal.*, 2021, doi: 10.1016/j.onehlt.2021.100294.

[19] S. Bhojwani, K. Topolski, R. Mukherjee, D. Sengupta, and M. M. El-Halwagi, “Technology review and data analysis for cost assessment of water treatment systems,” *Sci. Total Environ.*, 2019, doi: 10.1016/j.scitotenv.2018.09.363.

[20] HEB, “Hill Country Fare Drinking Water 16.9 oz Bottles,” 2022, [Online]. Available: https://www.heb.com/product-detail/hill-country-fare-drinking-water-16-9-oz-bottles-24-pk/1042431.

[21] P. Yu *et al.*, “Elevated Levels of Pathogenic Indicator Bacteria and Antibiotic Resistance Genes after Hurricane Harvey’s Flooding in Houston,” *Environ. Sci. Technol. Lett.*, 2018, doi: 10.1021/acs.estlett.8b00329.

[22] J. L. Steichen *et al.*, “Microbial, Physical, and Chemical Changes in Galveston Bay Following an Extreme Flooding Event, Hurricane Harvey,” *Front. Mar. Sci.*, 2020, doi: 10.3389/fmars.2020.00186.

[23] D. C. Montgomery and G. C. Runger, “Applied Statistics and Probability for Engineers,” *Eur. J. Eng. Educ.*, 1994, doi: 10.1080/03043799408928333.

[24] Texas Water Development Board, “Brackish Groundwater Manual for Texas Regional Water Planning Groups,” *LBG - Guyt. Assoc.*, 2003, [Online]. Available: https://www.twdb.texas.gov/publications/reports/contracted_reports/doc/2001483395.pdf.

[25] M. M. El-Halwagi, D. Sengupta, E. N. Pistikopoulos, J. Sammons, F. Eljack, and M.-K. Kazi, "Disaster-Resilient Design of Manufacturing Facilities Through Process Integration: Principal Strategies, Perspectives, and Research Challenges," *Front. Sustain.*, 2020, doi: 10.3389/frsus.2020.595961.

[26] I. Han *et al.*, "Heavy metal pollution of soils and risk assessment in Houston, Texas following Hurricane Harvey," *Environ. Pollut.*, vol. 296, p. 118717, 2022, doi: https://doi.org/10.1016/j.envpol.2021.118717.

[27] Q. Li *et al.*, "Development of a mobile groundwater desalination system for communities in rural India," *Water Res.*, 2018, doi: 10.1016/j.watres.2018.08.001.

[28] Y. K. Park, J.-S. An, J. Park, and H. J. Oh, "Development of Mobile Water Treatment Package System for Emergency Water Supply," *Int. J. Struct. Civ. Eng. Res.*, 2015, doi: 10.18178/ijscer.4.3.296-300.

[29] W. Metcalf and C. Eddy, "Metcalf and Eddy Wastewater Engineering: Treatment and Reuse," *Wastewater Eng. Treat. Reuse McGraw Hill. New York, NY.*, 2003.

[30] B. Salgado, J. M. Ortega, J. Blazheska, J. Sanz, and V. García-Molina, "High-permeability FILMTEC^{TM} SEAMAXX^{TM} reverse osmosis elements: a success story in the Canary Islands," *Desalin. Water Treat.*, 2015, doi: 10.1080/19443994.2014.940211.

[31] A. F. Ismail, K. C. Khulbe, and T. Matsuura, *Reverse osmosis*. 2018.

[32] R. Singh, *Hybrid Membrane Systems for Water Purification*. 2005.

[33] N. F. Gray, *Water Technology : An Introduction for Environmental Scientists and Engineers*. 2021.

[34] J. Ahmed and Y. Jamal, "A pilot application of recycled discarded RO membranes for low strength gray water reclamation," *Environ. Sci. Pollut. Res.*, 2021, doi: 10.1007/s11356-

020-11117-z.

[35] J. Abbadi *et al.*, “Microbial Removal from Secondary Treated Wastewater Using a Hybrid System of Ultrafiltration and Reverse Osmosis,” *Former. part J. Environ. Sci. Eng.*, 2012.

[36] S. Torii, T. Hashimoto, A. T. Do, H. Furumai, and H. Katayama, “Repeated pressurization as a potential cause of deterioration in virus removal by aged reverse osmosis membrane used in households,” *Sci. Total Environ.*, 2019, doi: 10.1016/j.scitotenv.2019.133814.

[37] A. Egea-Corbacho Lopera, S. Gutiérrez Ruiz, and J. M. Quiroga Alonso, “Removal of emerging contaminants from wastewater using reverse osmosis for its subsequent reuse: Pilot plant,” *J. Water Process Eng.*, 2019, doi: 10.1016/j.jwpe.2019.100800.

[38] Texas Commission on Environmental Quality, “Review and Approval Process for Regulation of Mobile Water Treatment Systems (MWTS),” 2018, [Online]. Available: https://www.tceq.texas.gov/assets/public/permitting/watersupply/pdw/MWTS_WSD_Guidance_Document_Revised_Aug_2018.pdf.

[39] A. . Fallis, “Handbook of Industrial Water Treatment,” in *Handbook of Industrial Water Treatment*, 2013.

[40] EPA, “Guidance Manual - Alternative Disinfectants and Oxidants EPA 815-R-09-014,” *Environ. Prot. Agency*, 1999.

[41] J. Rhoads, “Post-Hurricane Katrina challenge: Vibrio vulnificus,” *J. Am. Acad. Nurse Pract.*, 2006, doi: 10.1111/j.1745-7599.2006.00139.x.

[42] W. N. Lee and C. H. Huang, “Formation of disinfection byproducts in wash water and lettuce by washing with sodium hypochlorite and peracetic acid sanitizers,” *Food Chem. X*, 2019, doi: 10.1016/j.fochx.2018.100003.

[43] A. Sweity *et al.*, “Side effects of antiscalants on biofouling of reverse osmosis membranes

in brackish water desalination," *J. Memb. Sci.*, 2015, doi: 10.1016/j.memsci.2015.02.003.

[44] V. S. Frenkel, A. G. Pervov, A. P. Andrianov, and V. A. Golovesov, "Investigation of antiscalant dosing influence on scaling process in reverse osmosis facilities and membrane surface adsorption," *Vestn. MGSU*, 2019, doi: 10.22227/1997-0935.2019.6.722-733.

[45] X. Li, D. Hasson, and H. Shemer, "Flow conditions affecting the induction period of CaSO4 scaling on RO membranes," *Desalination*, 2018, doi: 10.1016/j.desal.2017.08.014.

[46] PWT, "SpectraGuard Product Datasheet," 2022, [Online]. Available: https://www.pwtchemicals.com/wp-content/uploads/2020/04/PWT-SpectraGuard_111-TDS-21.pdf.

[47] M. J. Brandt, K. M. Johnson, A. J. Elphinston, and D. D. Ratnayaka, "Water Filtration," in *Twort's Water Supply*, 2017.

[48] USGS, "Characterizing the Size Distribution of Particles in Urban Stormwater by Use of Fixed-Point Sample-Collection Methods," 2011, [Online]. Available: https://pubs.usgs.gov/of/2011/1052/pdf/OFR20111052.pdf.

[49] R. K. Sinnott and G. Towler, *Chemical Engineering Design*. 2013.

[50] S. Guo, B. Li, B. H. Cai, and J. H. Xie, "Study on adaptive technology for flow regulation of cooling water system," 2019, doi: 10.1088/1742-6596/1168/6/062026.

[51] H. Asgharzadeh, B. Firoozabadi, and H. Afshin, "Experimental investigation of effects of baffle configurations on the performance of a secondary sedimentation tank," *Sci. Iran.*, 2011, doi: 10.1016/j.scient.2011.07.005.

[52] KOCH TM Separations Solutions, "Pulsion Hollow Fiber Modules Data - sheet," p. 1, 2019, [Online]. Available: https://www.kochseparation.com/wp-content/uploads/2020/10/Pulsion-MBR-modules.pdf.

[53] S. S. Madaeni and Y. Mansourpanah, “Screening membranes for COD removal from dilute wastewater,” *Desalination*, 2006, doi: 10.1016/j.desal.2006.01.015.

[54] D. Tabassi, A. Mnif, and B. Hamrouni, “Influence of operating conditions on the retention of phenol in water by reverse osmosis SG membrane characterized using Speigler-Kedem model,” *Desalin. Water Treat.*, 2014, doi: 10.1080/19443994.2013.807049.

[55] Clean Water Store, “Datasheet CWS-1354,” 2022, [Online]. Available: https://www.cleanwaterstore.com/contact-retention-tanks/contact-retention-tank-30-gallon-1354.html.

[56] Seatac Express, “Warehouse 28’ Pup Trailer,” 2022, [Online]. Available: http://seatacexpress.com/equipment.html.

[57] US Water Systems, “Datasheet Matrixx inFusion Iron And Sulfur Removal System,” 2022, [Online]. Available: https://www.uswatersystems.com/media/pdf/USWaterMatrixxInfusionIronandSulfurRemovalSystem.pdf.

[58] R. L. Mott, *Applied fluid mechanics*, Pearson. Boston, 2015.

[59] Frank White and H. Xue, *Fluid mechanics*, 9th ed. New York: McGraw-Hill, 2021.

[60] J. W. Nielsen-Gammon, “The 2011 Texas Drought,” *Texas Water J.*, vol. 3, no. 1, pp. 59–95, 2012, doi: 10.21423/twj.v3i1.6463.

[61] S. Falco, G. Brunetti, G. Grossi, M. Maiolo, M. Turco, and P. Piro, “Solids removal efficiency of a sedimentation tank in a peri-urban catchment,” *Sustain.*, 2020, doi: 10.3390/su12177196.

[62] S. M. Khezri, A. Biati, and Z. Erfani, “Determination of the effect of wind velocity and direction changes on turbidity removal in rectangular sedimentation tanks,” *Water Sci.*

Technol., 2012, doi: 10.2166/wst.2012.533.

[63] D. A. Yaseen, S. Abu-Alhail, and R. N. Mohammed, “An experimental sedimentation tank for enhancing the settling of solid particles,” *J. Water L. Dev.*, 2021, doi: 10.24425/jwld.2021.137097.

[64] National Research Council (US) Safe Drinking Water Committee, *Drinking Water and Health: Volume 2*. Washington (DC): National Academies Press (US), 1980.

[65] J. M. C, P. Shetty, and R. A. | D. V Reddy, “Desalination Approach of Seawater and Brackish Water by Coconut Shell Activated Carbon as a Natural Filter Method,” *Int. J. Trend Sci. Res. Dev.*, 2018, doi: 10.31142/ijtsrd19123.

[66] Z. Zhang *et al.*, “Highly efficient capacitive desalination for brackish water using super activated carbon with ultra-high pore volume,” *Desalination*, vol. 529, p. 115653, 2022, doi: https://doi.org/10.1016/j.desal.2022.115653.

[67] DuPont TM, “FilmTec™ Seamaxx™-440 Element Product Data Sheet,” 2021.

[68] Jiangmen Zone Top Metal Products Co., “Factory Price 5 Gal 18 Litre 18.9 Liter 19 Ltr 20L 5Gallon Water Bottle 5 Gallon Plastic Buckets For Sale,” 2022, [Online]. Available: https://www.alibaba.com/product-detail/Factory-Price-5-Gal-18-Litre_60838944094.html.

[69] Waltmart, “Great Value Purified Drinking Water, 1 Gallon,” 2022, [Online]. Available: https://www.walmart.com/ip/Great-Value-Purified-Drinking-Water-1-Gallon/10315383.

[70] Glenn Hegar, “GROCERY AND CONVENIENCE STORES,” 2022, [Online]. Available: https://comptroller.texas.gov/taxes/publications/96-280.php.

[71] National Oceanic and Atmospheric Administration U.S. Department of Commerce, “NOAA Historical Hurricane Tracks,” *NOAA*, 2022, [Online]. Available: https://coast.noaa.gov/hurricanes/#map=3.71/25.09/-

78.73&search=eyJzZWFyY2hTdHJpbmciOiJUZXhhcywgVVNBIiwic2VhcmNoVHlwZSI6Imdlb2NvZGVkIiwibWF0Y2giOiJwYXJ0aWFsIiwib3NtSUQiOiIxMTQ2OTAiLCJjYXRlZ29yaWVzIjpbIkg1IiwiSDQiLCJIMyIsIkgyIiwiSDEiLCJUUyIsIlREIiwiRVQiXSw.

[72] N. Vani, "AN ANALYTICAL STUDY OF INDIAN AND US INFLATION RATES," *Int. J. Multidiscip. Educ. Res.*, vol. 11, no. 2(2), 2022, doi: : http://ijmer.in.doi./2022/11.02.28.

[73] M. M. El-Halwagi, "Chapter 2 - Overview of Process Economics," in *Sustainable Design Through Process Integration*, M. M. El-Halwagi, Ed. Oxford: Butterworth-Heinemann, 2012, pp. 15–61.

[74] F. Al-Hulail and S. Neelamani, "The variation of total suspended sediments due to the change in sea water depth, tidal phase and elevation of sea water sample collection in khor sabiya inlet of the arabian Gulf, Kuwait," 2011, doi: 10.2112/SI61-001.41.

[75] S. Shaddel, T. Grini, S. Ucar, K. Azrague, J. P. Andreassen, and S. W. Østerhus, "Struvite crystallization by using raw seawater: Improving economics and environmental footprint while maintaining phosphorus recovery and product quality," *Water Res.*, 2020, doi: 10.1016/j.watres.2020.115572.

[76] T. C. Timmes, H. C. Kim, and B. A. Dempsey, "Electrocoagulation pretreatment of seawater prior to ultrafiltration: Pilot-scale applications for military water purification systems," *Desalination*, 2010, doi: 10.1016/j.desal.2009.03.021.

[77] D. V. Lušić *et al.*, "Temporal variations analyses and predictive modeling of microbiological seawater quality," *Water Res.*, 2017, doi: 10.1016/j.watres.2017.04.046.

[78] J. Fito, H. Said, S. Feleke, and A. Worku, "Fluoride removal from aqueous solution onto activated carbon of Catha edulis through the adsorption treatment technology," *Environ.*

Syst. Res., 2019, doi: 10.1186/s40068-019-0153-1.

[79] T. Kabir, M. S. Hasan, and P. Das, “Applicability of Activated Carbon Filtration in Surface Water Treatment,” *Asian J. Innov. Res. Technol.*, vol. 1, no. 10, 2016.

[80] O. Coronell, B. Mi, B. J. Mariñas, and D. G. Cahill, “Modeling the effect of charge density in the active layers of reverse osmosis and nanofiltration membranes on the rejection of arsenic(III) and potassium iodide,” *Environ. Sci. Technol.*, 2013, doi: 10.1021/es302850p.

[81] M. Asadollahi, D. Bastani, and S. A. Musavi, “Enhancement of surface properties and performance of reverse osmosis membranes after surface modification: A review,” *Desalination*, vol. 420, pp. 330–383, 2017, doi: https://doi.org/10.1016/j.desal.2017.05.027.

[82] W. Geller, M. Koschorreck, M. Schultze, and K. Wendt-Potthoff, “Restoration of Acid Drainage,” in *Encyclopedia of Inland Waters*, G. E. Likens, Ed. Oxford: Academic Press, 2009, pp. 342–358.

[83] C. Bellona, J. E. Drewes, P. Xu, and G. Amy, “Factors affecting the rejection of organic solutes during NF/RO treatment—a literature review,” *Water Res.*, vol. 38, no. 12, pp. 2795–2809, 2004, doi: https://doi.org/10.1016/j.watres.2004.03.034.

[84] J. Zhu, J. Cheng, Z. Liao, Z. Lai, and B. Liu, “Investigation of structures and properties of cyclic peptide nanotubes by experiment and molecular dynamics,” *J. Comput. Aided. Mol. Des.*, vol. 22, no. 11, pp. 773–781, 2008, doi: 10.1007/s10822-008-9212-9.

[85] Premiere Sales, “What is well water?,” 2021, [Online]. Available: https://premieresales.com/well-water-basics/#:~:text=Well water is water that,(also called ground water).&text=Basically%2C a hole is dug,water in almost every region.

[86] F. D. Marks, “HURRICANES,” in *Encyclopedia of Atmospheric Sciences*, J. R. Holton, Ed. Oxford: Academic Press, 2003, pp. 942–966.

[87] K. Ito and T. Hirokawa, “Chapter 9 - Iodine and Iodine Species in Seawater: Speciation, Distribution, and Dynamics,” in *Comprehensive Handbook of Iodine*, V. R. Preedy, G. N. Burrow, and R. Watson, Eds. San Diego: Academic Press, 2009, pp. 83–91.

[88] N. Popham, “8 - Resin infusion for the manufacture of large composite structures,” in *Marine Composites*, R. Pemberton, J. Summerscales, and J. Graham-Jones, Eds. Woodhead Publishing, 2019, pp. 227–268.

[89] N. F. Gray, “Chapter Thirty - Pathogen Control in Drinking Water,” in *Microbiology of Waterborne Diseases (Second Edition)*, Second Edi., S. L. Percival, M. V Yates, D. W. Williams, R. M. Chalmers, and N. F. Gray, Eds. London: Academic Press, 2014, pp. 537–569.

[90] American Rivers, “What is green infrastructure?,” 2021, [Online]. Available: https://www.americanrivers.org/threats-solutions/clean-water/green-infrastructure/what-is-green-infrastructure/#:~:text=Green infrastructure is an approach,costly new water treatment plant.

[91] C. L. Patterson, C. A. Impellitteri, K. R. Fox, R. C. Haught, M. C. Meckes, and J. C. Blannon, “Emergency response for public water supplies after Hurricane Katrina,” 2007, doi: 10.1061/40927(243)131.

[92] A. van Asselt and M. te Giffel, “19 - Pathogen resistance and adaptation to disinfectants and sanitisers,” in *Understanding Pathogen Behaviour*, M. Griffiths, Ed. Woodhead Publishing, 2005, pp. 484–506.

9. ANNEXES

9.1 Annex A – Abbreviations and terminology

9.1.1 Specified terminology

- Brackish water: Is defined as water with TDS content between freshwater ($\leq$500 mg l^{-1} TDS) and seawater (33 000–48 000 mg l^{-1} TDS). It can as brackish groundwater in subsurface saline aquifers. Or a mix from river water and seawater. [14]
- Stormwater: Is rainwater that has all the pollutants of the watershed characteristics, surrounding hydrogeology, etc. [13].
- Desalination: Is a process of removing minerals, contaminants or salts from wastewater, brackish water and sweater for industrial or domestic purposes [81].
- Mobile desalination: Is a desalination system that can move or be moved freely [81].
- Reverse osmosis (RO): Is a process that occurs at high pressures in which water passes through a membrane leaving behind concentrated salts [82].
- Osmosis: Is the movement of water across a selective membrane to reduce the concentration difference of a solute between a concentrate and permeate solution [83].
- Total Suspended Solids (TSS): Portion of total solids retained by the filter with a specific pore size measured after being dried at a specific temperature [29]. They can include slit, decaying plant and animal matter, industrial wastes, and sewage.

- Turbidity: It is a measure of the cloudiness of the water sample due to clay, slit, organic matter, plankton, and other microscopic organisms.
- Total Dissolved Solids (TDS): Mixture of colloidal and dissolved solids that pass through the filter that are evaporated and dried at a specific temperature [29].
- Inside diameter (ID): Is the measure of the distance from the center of a pipe to the inner wall of it [84].
- Well water: Is water that comes from the ground and it is usually stored underground [85].
- Drinking water: Is water that has been previously treated according to regulations and standards for human consumption [1].
- Hurricane: Is a strong tropical cyclone, typhoons and similar systems that have a low pressure system that derives its energy from evaporation at the sea [86].
- Seawater: Is a saline solution that contains a lot of salts like sodium, magnesium and some major anions like sulfate ions and chloride ions [87].
- High permeability: An easy flow of a fluid through a porous material [88].
- Water treatment: Is a made up system of unit processes operated in series that can purify water to certain desired extend [89].
- Green water infrastructure: Is a system that mimics, protects or restores the natural cycle of water through water management [90].
- Chlorination: Is a common disinfection process that uses chlorine to treat water [91].
- Disinfection: Is a physical or chemical treatment performed to reduce the amount of microorganisms present to an acceptable level [92].

- Antiscalant (AS): Group of organic and inorganic chemicals, most of them organic compounds man-made that prevent fouling of RO membranes and nano filters by preventing the formation and precipitation of crystallized mineral salts from scale [81].

9.1.2 Abbreviations

$$\tau: Residence\ time\ [min]$$

$$CT: Contact\ time\ \left[\frac{mg * min}{L}\right]$$

$$C: Concentration\ of\ chlorine\ \left[\frac{mg}{L}\right]$$

$$V: Volume\ of\ reactor\ of\ chlorine\ [L]$$

$$F: Outflow\ \left[\frac{gal}{h}\right]$$

$$F_{Cl,in}: Inlet\ flowrate\ of\ chlorine\ \left[\frac{gal}{h}\right]$$

$$X_{cl,in}: Inlet\ concentration\ of\ chlorine\ [wt\%]$$

$$F_{out}\ : Outlet\ flowrate\ of\ chlorine\ mixture \left[\frac{gal}{h}\right]$$

$$X_{cl,out}: Outlet\ concentration\ of\ chlorine\ [wt\%]$$

$$Feed: Flowrate\ of\ feed\ of\ RO\ membrane [gpm]$$

$$F_{permeate}: Flowrate\ of\ permeate\ [gpm]$$

$$F_{antiscalant,in}: Feed\ flowrate\ of\ antiscalant\ [gpm]$$

$$X_{antiscalant,in}: Inlet\ concentration\ of\ antiscalant\ [\%wt]$$

$$F_{water,in}: Feed\ flowrate\ of\ water\ [gpm]$$

$$F_{out}: Outflow\ of\ antiscalant\ solution\ [gpm]$$

$$X_{antiscalant,out}: Outlet\ concentration\ of\ antiscalant\ [\%wt]$$

$$v_p: Velocity\ of\ particle\ sedimentation\ \left[\frac{m}{s}\right]$$

$$Re: Reynold's\ number\ [dimensionless]$$

$$\vartheta: Kinematic\ viscosity\ \left[\frac{in^2}{s}\right]$$

$$u: Horizontal\ velocity\ of\ water\ at\ the\ sedimentation\ tank\ \left[\frac{m}{s}\right]$$

$$N: Number\ of\ baffles$$

$$N\ per\ tank: Number\ of\ baffles\ per\ tank$$

$$v: Internal\ velocity\ of\ water\ in\ a\ pipe\ \left[\frac{in}{s}\right]$$

$$Q: Flowrate\ of\ water\ in\ a\ pipe\ \left[\frac{in^3}{s}\right]$$

$$D: Internal\ diameter\ of\ a\ pipe\ [in]$$

$$P_B: Presure\ at\ point\ B\ of\ the\ pipe\ [psia]$$

$$P_A: Presure\ at\ point\ A\ of\ the\ pipe\ [psia]$$

$$\gamma: Specific\ weight\ \left[\frac{lb}{in^3}\right]$$

$$v_B: Velocity\ of\ water\ inside\ the\ pipe\ at\ point\ B\ \left[\frac{in}{s}\right]$$

$$v_A: Velocity\ of\ water\ inside\ the\ pipe\ at\ point\ A\ \left[\frac{in}{s}\right]$$

$$g: Gravity\ \left[\frac{in}{s^2}\right]$$

$$f: Friction\ factor\ [dimensionless]$$

e: $Roughness\ of\ pipe\ [in]$

$h_{L1.1}$: $Minor\ loss\ of$ 3/4" $pipe\ [in]$

$h_{L1.2}$: $Minor\ loss\ of$ 1" $pipe\ [in]$

L: $Length\ of\ pipe\ [in]$

h_{L2}: $Fitting\ losses\ of\ \ pipe\ [in]$

$K_{elbows\ 90°}$: $Resistance\ coefficient\ of\ elbows\ of\ 90°\ [dimensionless]$

K_{Tee}: $Resistance\ coefficient\ of\ a\ Tee\ [dimensionless]$

$K_{inflows}$: $Resistance\ coefficient\ of\ inflow\ [dimensionless]$

$K_{outflows}$: $Resistance\ coefficient\ of\ outflow\ [dimensionless]$

$K_{check\ valves}$: $Resistance\ coefficient\ of\ check\ valves\ [dimensionless]$

$K_{butterfly\ valves}$: $Resistance\ coefficient\ of\ butterfly\ valves\ [dimensionless]$

$K_{pressure\ gauge\ and\ flow\ gauge}$: $Resistance\ coefficient\ of\ pressure\ gauge\ and$ $flow\ gauge\ [dimensionless]$

$\frac{L_e}{D}$: $Equivalent\ leght\ ratio\ [dimensionless]$

f_T: $Friction\ factor\ in\ the\ pipe\ [dimensionless]$

z_B: $Relative\ height\ at\ point\ B\ [in]$

z_A: $Relative\ height\ at\ point\ A\ [in]$

h_p: $Requiered\ head\ of\ pump\ [in]$

$NPSHa$: $Net\ Positive\ Suction\ Head\ available\ [in]$

h_{vp}: $Vapor\ pressure\ head\ of\ the\ liquid\ at\ the\ pumping\ temperature\ [in]$

h_{sp}: $Static\ pressure\ head\ (absolute) above\ the\ fluid\ in\ the\ reservoir [in]$

$$h_s: Elevation\ difference\ from\ the\ level\ of\ fluid\ in\ the\ reservoir\ to\ the\ centerline\ of\ the\ pump\ suction\ inlet\ [in]$$

$$h_f: Head\ loss\ in\ the\ suction\ piping\ due\ to\ friction\ and\ minor\ losses\ [in]$$

$$TSS_{out}: Outlet\ of\ total\ suspended\ solids\ \left[\frac{mg}{L}\right]$$

$$TSS_{in}: Inlet\ of\ total\ suspended\ solids\ \left[\frac{mg}{L}\right]$$

9.2 Annex B – Water quality standards

Table A 1. Summary of standards of drinkable water

Contaminant	Maximum Contaminant Level MCL (mg/L)
Aluminum	0.05
Antimony	0.006
Arsenic	0.01
Bicarbonate	196
Bromide	2
Cadmium	0.005
Calcium	100 – 200
Chloride	250
Chromium (total)	0.1
Copper	1.0
Fluoride	2.0
Free Chlorine	4.0
Iron	0.3
Lead	0.015
Magnesium	52.1
Manganese	0.05
Mercury (inorganic)	0.002
Nitrate (measured as Nitrogen)	10
Nitrite (measured as Nitrogen)	1
pH	6.5 - 8.5
Potassium	82 - 164
Sodium	20
Sulfate	250
Total Coliforms (including fecal coliform and Escherichia Coli)	0
Total Dissolved Solids (TDS)	500
Total Soluble Solids (TSS)	25
Turbidity (NTU)	0.3
Uranium	0.03
Zinc	5

9.3 Annex C – Mass balance

9.3.1 Retention tank calculations

$$\tau = \frac{CT}{C} = \frac{6\, mg * min/L}{2\, mg/L} = 3\, min$$

$$V = \frac{F}{\tau} = \frac{550\, gal/h}{3\, min} * \frac{1\, h}{60\, min} = 27.5\, gal$$

$$Amount\ of\ tanks = \frac{Volume\ of\ product}{Volume\ obtained} = \frac{30\, gal}{27.5\, gal} \approx 1$$

9.3.2 Flowrate calculation of the sodium hypochlorite dispenser

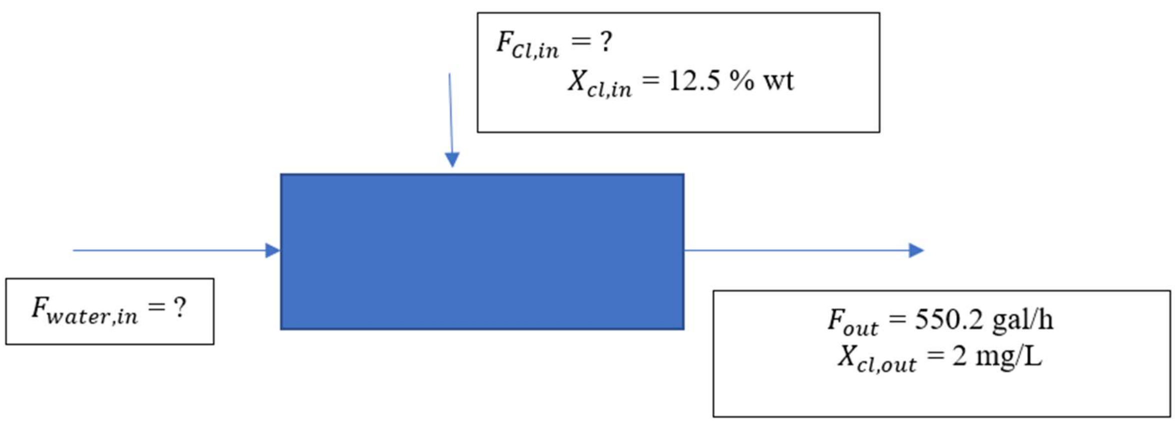

Figure A 1. Mass balance of sodium hypochlorite at the contact tank.

$$F_{Cl,in} * X_{cl,in} = F_{out} * X_{cl,out}$$

$$F_{Cl,in} = \frac{F_{out} * X_{cl,out}}{X_{cl,in}} = \frac{550.2\frac{gal}{h} * 2 * 10^{-3}\frac{g\, CL}{L\, Sol} * 1\frac{mL\, water}{g\, Water} * \frac{1\, L\, water}{10^3\, ml\, water}}{0.05\frac{g\, Cl}{g\, Sol}} = 0.022\frac{gal}{h}$$

$$F_{Cl,in} = 3.67 * 10^{-4}\, gpm$$

9.3.3 Membrane calculations

$$Feed = 1.56\frac{m^3}{h} * \frac{1000\ L}{1\ m^3} * \frac{1\ hour}{60\ min} * \frac{0.2641\ gal}{1\ L} = 6.87\ gpm$$

$$F_{permeate} = Recovery * Feed = 0.45 * 6.87\ \frac{gal}{min} = 3.09\ gpm$$

$$Amount\ of\ membranes = \frac{Actual\ Feed}{Membrane\ feed} = \frac{9.17\ gpm}{3.09\ gpm} \approx 3$$

$$Total\ Feed = 6.87\ gpm * 3 = 20.6\ gpm$$

$$Total\ Permeate = 3.09\ gpm * 3 = 9.27\ gpm$$

$$Total\ Reject = 20.6 - 9.27 = 11.33\ gpm$$

9.3.4 Flowrate calculation of the antiscalant dosing

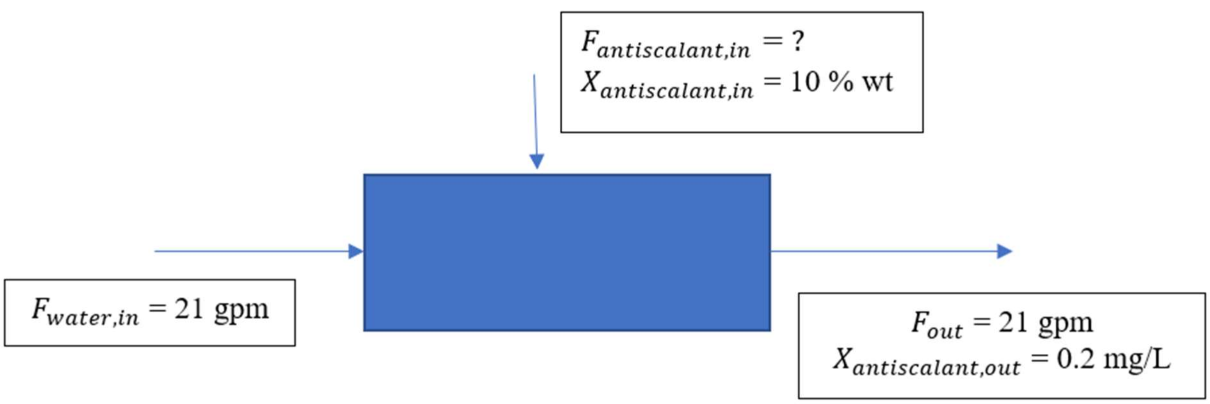

Figure A 2. Mass balance for the antiscalant system.

$$F_{antiscalant,in} * X_{antiscalant,in} = F_{out} * X_{antiscalant,out}$$

$$F_{antiscalant,in} = \frac{F_{out} * X_{antiscalant,out}}{X_{antiscalant,in}} = \frac{21\ \frac{gal}{min} * 0.2 * 10^{-3}\ \frac{g\ antiscalant}{L\ Sol}}{0.1\frac{g\ antiscalant}{g\ Sol} * 1.17\ \frac{g\ Sol}{10^{-3} L\ Sol}}$$

$$F_{antiscalant,in} = 3.59 * 10^{-5}\ gpm$$

9.3.5 Filtration calculations

$$Area\ of\ the\ filter = \frac{20.66\ gpm}{6\ gpm/ft^2} = 3.44\ ft^2$$

$$Diameter\ of\ the\ filter = \sqrt{\frac{4 * 3.44\ ft^2}{\pi}} = 2.09\ ft$$

$$Amount\ of\ filters = \frac{Diameter\ calculated}{Diameter\ available} = \frac{2.09\ ft}{1.08\ ft} \approx 2$$

9.3.6 Sedimentation tank and plates calculations

For the sedimentation tank:

$$v_p = \frac{386.22 \frac{in}{s^2} * (2.5 - 1) * (5.51 * 10^{-4})^2\ \mathrm{in}^2}{18 * 0.00004528 \frac{in^2}{s}} = 0.00549\ \frac{in}{s}$$

$$Re = \frac{0.00549\ \frac{in}{s} * 0.73 * 5.51 * 10^{-4}\ \mathrm{in}}{0.00004528 \frac{in^2}{s}} = 0.001238$$

This confirms the assumption of Re < 1

$$Detention\ time = \frac{0.9652\ m}{0.000139\ \frac{m}{s}} = 6927.42\ s = 115.46\ min$$

$$Real\ volume\ of\ tank = 20.66\ gpm * 115.46\ min = 2385.83\ gal$$

$$Amount\ of\ tanks = \frac{2385.83\ gal}{1250\ gal} \approx 2$$

For calculating the number of plates

$$u = \frac{0.00549\ \frac{in}{s} * 39.37\ in * \cos(45°)}{0.9842\ in} + 0.00549\ \frac{in}{s} * \cos(45°) = 0.1590\ \frac{in}{s}$$

$$N = \frac{0.0513\ \frac{in^3}{min}}{38\ in * 0.984\ in * 0.1590 \frac{in}{s}} = 14$$

$$N\ per\ tank = \frac{14}{2} \approx 7$$

9.4 Annex D – Energy balance

9.4.1 Dimensions of the system

Truck dimensions of Seatac [56]:

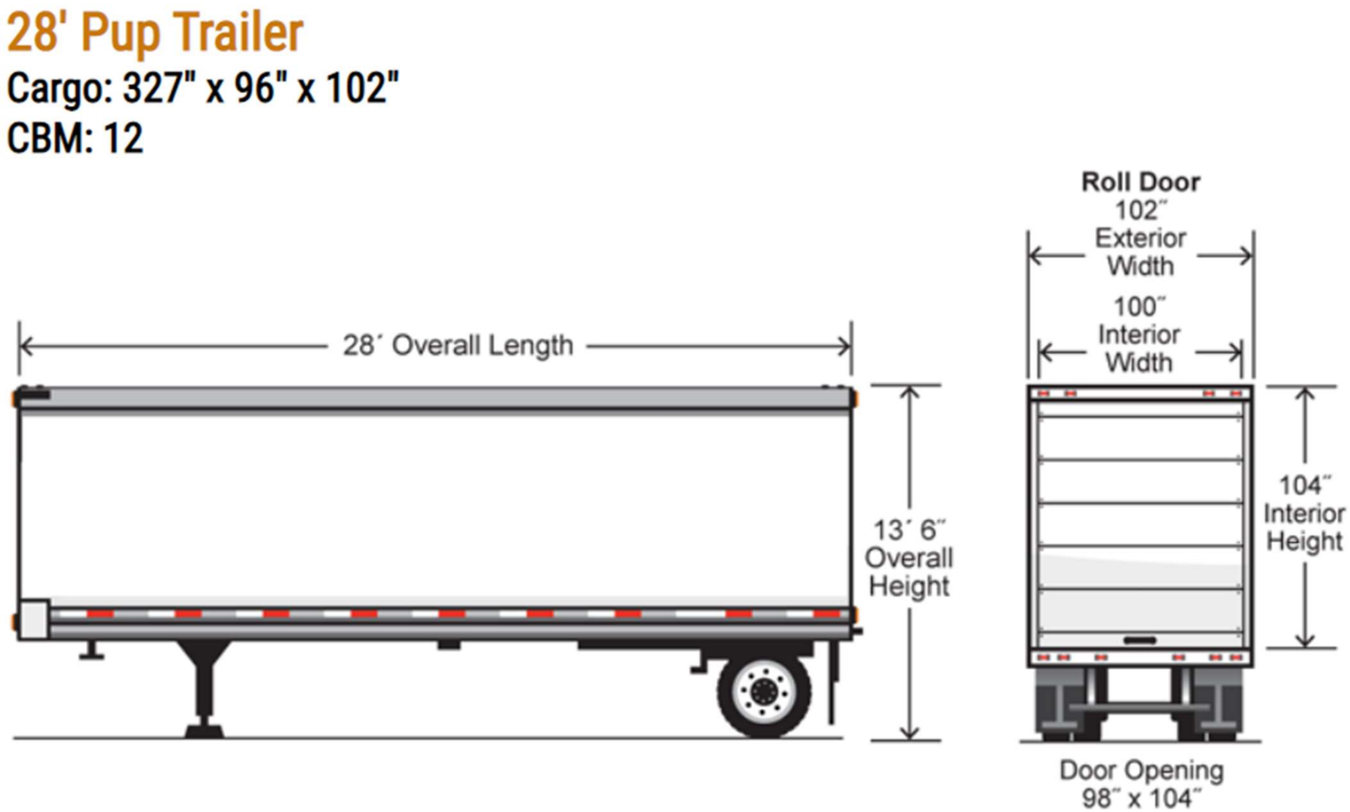

Figure A 3. Truck dimensions.

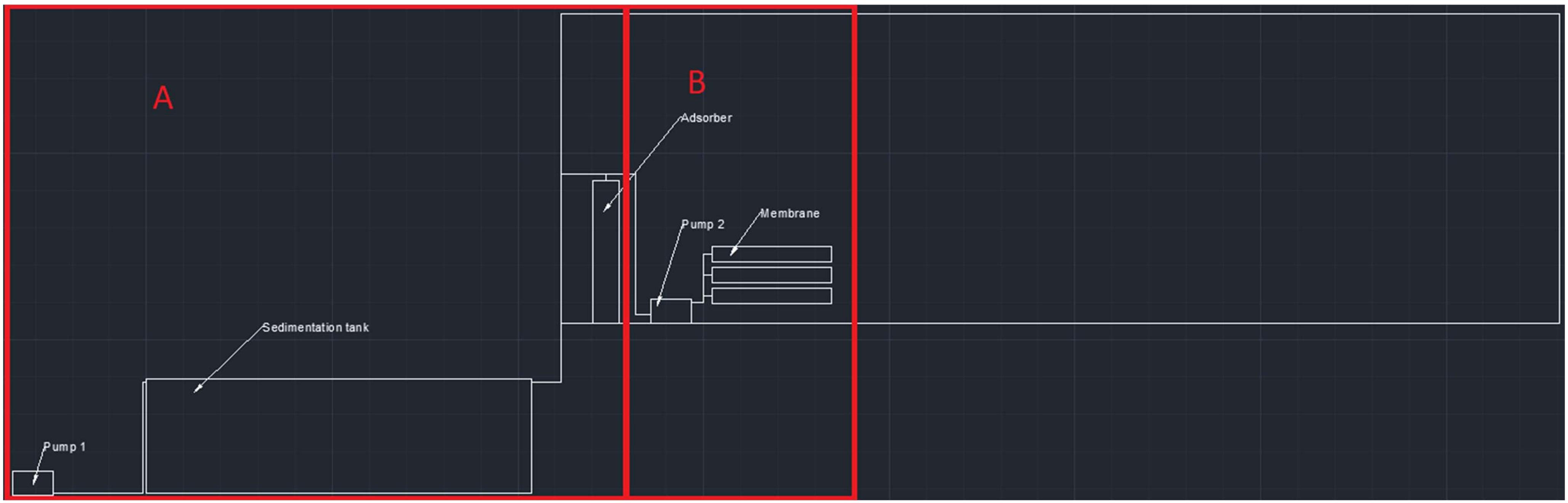

Figure A 4. Different sections of the mobile water treatment system

9.4.2 Determination of the diameter of each section in the system

For 20 gpm = 77 in^3/s

$$v = \frac{Q}{\pi \frac{D^2}{4}} = \frac{77 \frac{in^3}{s}}{\pi \frac{1.033^2\ in^2}{4}} = 91.88 \frac{in}{s}$$

For 10 gpm = 38.5 in^3/s

$$v = \frac{Q}{\pi \frac{D^2}{4}} = \frac{38.5\ \frac{in^3}{s}}{\pi \frac{0.75^2\ in^2}{4}} = 87.15 \frac{in}{s}$$

9.4.3 Part A

9.4.3.1 Pressure losses

$$Head\ loss\ of\ pressure: \frac{P_B - P_A}{\gamma} = \frac{94.7 \frac{lb}{in^2} - 14.7 \frac{lb}{in^2}}{0.0360 \frac{lb}{in^3}} = 2222.22\ in$$

9.4.3.2 Velocity head losses

$$\text{Velocity head loss: } \frac{{v_B}^2 - {v_A}^2}{2g} = \frac{87.15^2 \frac{in^2}{s^2} - 91.88^2\ \frac{in^2}{s^2}}{2 * 386.09 \frac{in}{s^2}} = -1.09\ in$$

9.4.3.3 Minor losses

For 10 gpm

Total length from point A to point B = 95 in

Diameter of the pipe = 0.75 in

The roughness of plastic pipe = 0.000012 in

Velocity of the pipe = 87.15 in/s

Kinematic viscosity of water at 68 °F = 0.0001298 in^2/s

$$Re = \frac{v * D}{\vartheta} = \frac{87.15\frac{in}{s} * 0.75\ in}{0.0001298\frac{in^2}{s}} = 503386$$

$$f = \frac{0.25}{\log\frac{1}{3.7 * D/e} + \frac{5.74}{Re^{0.9}}} = \frac{0.25}{\log\frac{1}{3.7 * \frac{0.75}{0.000012}} + \frac{5.74}{503386^{0.9}}} = 0.013$$

$$h_{L1.1} = \frac{f * L * {v_A}^2}{2g * D} = \frac{0.013 * 85\ in * 87.15^2\frac{in^2}{s^2}}{2 * 386.09\ \frac{in}{s^2} * 0.75\ in} = 14.86\ in$$

For 20 gpm

Total length from point A to point B = 50 in

Diameter of the pipe = 1.033 in

Roughness of plastic pipe = 0.000012 in

Velocity of the pipe = 91.88 in/s

Kinematic viscosity of water at 68 °F = 0.0001298 in^2/s

$$Re = \frac{v * D}{\vartheta} = \frac{91.88\,\frac{in}{s} * 1.033\ in}{0.0001298\,\frac{in^2}{s}} = 730957$$

$$f = \frac{0.25}{\log\frac{1}{3.7 * D/e} + \frac{5.74}{Re^{0.9}}} = \frac{0.25}{\log\frac{1}{3.7 * \frac{1.033}{0.000012}} + \frac{5.74}{730957^{0.9}}} = 0.012$$

$$h_{L1.2} = \frac{f * L * {v_A}^2}{2g * D} = \frac{0.012 * 50\ in * 91.88^2\,\frac{in^2}{s^2}}{2 * 386.09\ \frac{in}{s^2} * 1.033\ in} = 6.60\ in$$

9.4.3.4 Fitting losses

Table A 2. Resistant coefficient for fittings, valves, and controllers

Fittings	Number of units	Le/D	K
90° elbows	5	30	3.6
Tee	1	60	1.44
Inflows	2	0.78	1.56
Outflows	2	0.78	1.56
Check valves	1	150	3.6
Butterfly valves	4	45	4.32
Pressure gauge and Flow gauge	4	1.15	4.6

$$h_{L2} = \sum K * \frac{{v_A}^2}{2g}$$

$$= \left(K_{elbows\,90°} + K_{Tee} + K_{inflows} + K_{outflows} + K_{check\ valves} + K_{butterfly\ valves} + K_{pressure\ gauge\ and\ flow\ gauge}\right) * \frac{{v_A}^2}{2g}$$

$$h_{L2} = \left(\#amount * \frac{L_e}{D} * f_T + \#amount * \frac{L_e}{D} * f_T + \#amount * \frac{L_e}{D} + \#amount * \frac{L_e}{D} + + \#amount * \frac{L_e}{D} * f_T + \#amount * \frac{L_e}{D} * f_T + \#amount * \frac{L_e}{D}\right) * \frac{{v_A}^2}{2g}$$

$$h_{L2} = (5 * 30 * 0.024 + 1 * 60 * 0.024 + 2 * 0.78 + 2 * 0.78 + 1 * 150 * 0.024 + 4 * 45 * 0.024 + 4 * 1.15) * \frac{87.15^2}{2 * 386.09} = 203.39\ in$$

9.4.3.5 Pump head

$$h_p = h_{L2} + h_{1.2} + h_{1.1} + \frac{P_B - P_A}{\gamma} + z_B - z_A + \frac{{v_B}^2 - {v_A}^2}{2g}$$

$$h_p = 203.39\ in + 6.60\ in + 14.86\ in + 2222.22\ in + 156\ in - 1.09\ in = 2610.0\ in = 66.29\ m$$

9.4.3.6 NPSHa of pump

$$NPSHa = -h_{vp} + h_{sp} \pm h_s - h_f$$

$$NPSHa = -9.48 + 407.60 - 78.74 = 319.38\ in$$

9.4.3.7 Pump selection chart

Model 50Hz	Motor Power		Three Phase	Single Phase			Q	Capacity							
							US.gpm	0	5.3	10.6	13.2	15.8	18.5	21.1	26.4
							m³/h	0	1.2	2.4	3	3.6	4.2	4.8	6
			380V	220V			l/min	0	20	40	50	60	70	80	100
	HP	kW	A	A	µF	VC		Total head in meters							
4SP3-06	0.5	0.37	1.8	3.6	20	450	H m	37	33	29	26	23	19	13	4
4SP3-09	0.75	0.55	2	4.8	25	450		56	50	43	40	35	28	19	7
4SP3-12	1	0.75	2.5	6.3	35	450		74	66	58	53	46	37	26	9
4SP3-15	1.5	1.1	3.4	8.6	45	450		93	83	72	66	57	47	32	11
4SP3-18	1.5	1.1	3.4	8.6	45	450		112	99	86	79	69	56	39	13
4SP3-22	2	1.5	4.4	10	55	450		136	121	106	97	84	68	47	16
4SP3-25	2	1.5	4.4	10	55	450		155	138	120	110	96	78	54	18
4SP3-32	3	2.2	6.2	14	70	450		198	176	154	141	123	99	68	23
4SP3-39	4	3	8.3	20	80	450		242	215	187	172	149	121	83	29
4SP3-44	4	3	8.3	20	80	450		272	242	211	194	169	136	94	32
4SP3-58	5.5	4	10.3	27	100	450		359	320	279	255	222	180	124	42
4SP3-80	7.5	5.5	14	-	-	-		495	441	384	352	307	249	171	58
4SP3-110	10	7.5	18.5	-	-	-		681	606	528	484	422	342	236	80

Figure A 5. Operation Pump 1 chart

9.4.4 Part B – Subsection 1

9.4.4.1 Minor losses

For 20 gpm

Total length from point A to pump = 5 in

Diameter of the pipe = 1.033 in

The roughness of plastic pipe = 0.000012 in

Velocity of the pipe = 91.88 in/s

Kinematic viscosity of water at 68 °F = 0.0001298 in^2/s

$$Re = \frac{v * D}{\vartheta} = \frac{91.88\,\frac{in}{s} * 1.033\ in}{0.0001298\,\frac{in^2}{s}} = 730957$$

$$f = \frac{0.25}{\log \frac{1}{3.7 * D/e} + \frac{5.74}{Re^{0.9}}} = \frac{0.25}{\log \frac{1}{3.7 * \frac{1.033}{0.000012}} + \frac{5.74}{730957^{0.9}}} = 0.012$$

$$h_{L1} = \frac{f * L * {v_A}^2}{2g * D} = \frac{0.012 * 5\ in * 87.15^2\,\frac{in^2}{s^2}}{2 * 386.09\,\frac{in}{s^2} * 0.75\ in} = 0.66\ in$$

9.4.4.2 Fittings losses

Table A 3. Resistant coefficient for fittings

Fittings	Number of units	Le/D	K
90° elbows	1	30	0.66
Tee	1	60	1.32
Inflows	1	0.78	0.78

$$h_{L2} = \sum K * \frac{{v_A}^2}{2g} = \left(K_{elbows\,90°} + K_{Tee} + K_{inflows}\right) * \frac{{v_A}^2}{2g}$$

$$h_{L2} = \left(\#amount * \frac{L_e}{D} * f_T + \#amount * \frac{L_e}{D} * f_T + \#amount * \frac{L_e}{D}\right) * \frac{{v_A}^2}{2g}$$

$$h_{L2} = (1 * 30 * 0.022 + 1 * 60 * 0.022 + 1 * 0.78) * \frac{91.88^2\ \frac{in^2}{s^2}}{2 * 386.09\ \frac{in}{s^2}} = 30.17\ in$$

9.4.4.3 Pressure calculation

$$P_p = \left(\frac{P_A}{\gamma} + z_A - z_p - h_{L2} - h_{L1}\right) * \gamma = (2348.54 + 47 - 30.17 - 0.66)\ in * 0.036\ \frac{lb}{in^3}$$

$$= 95.57\ psia$$

9.4.5 Part B - Subsection 2

9.4.5.1 Pressure losses

$$Head\ loss\ of\ pressure: \frac{P_B - P_p}{\gamma} = \frac{800\ \frac{lb}{in^2} - 85.28\frac{lb}{in^2}}{0.0360\frac{lb}{in^3}} = 19817.57\ in$$

9.4.5.2 Minor losses

For 7 gpm

Total length from elbow to point B = 3 in

Diameter of the pipe = 0.75 in

The roughness of plastic pipe = 0.0018 in

Velocity of the pipe = 61.00 in/s

Kinematic viscosity of water at 68 °F = 0.0001298 in^2/s

$$Re = \frac{v * D}{\vartheta} = \frac{61.00\,\frac{in}{s} * 0.75\ in}{0.0001298\,\frac{in^2}{s}} = 352370.16$$

$$f = \frac{0.25}{\log\frac{1}{3.7 * D/e} + \frac{5.74}{Re^{0.9}}} = \frac{0.25}{\log\frac{1}{3.7 * \frac{0.75}{0.0018}} + \frac{5.74}{352370.15^{0.9}}} = 0.025$$

$$h_{L1.1} = \frac{f * L * {v_A}^2}{2g * D} = \frac{0.025 * 3\ in * 61.00^2\,\frac{in^2}{s^2}}{2 * 386.09\,\frac{in}{s^2} * 0.75\ in} = 0.49\ in$$

For 20 gpm

Total length from pump to tee = 4 in

Diameter of the pipe = 1 in

Roughness of plastic pipe = 0.0018 in

Velocity of the pipe = 91.88 in/s

Kinematic viscosity of water at 68 °F = 0.0001298 in^2/s

$$Re = \frac{v * D}{\vartheta} = \frac{91.88\frac{in}{s} * 1.033\ in}{0.0001298\frac{in^2}{s}} = 730957.313$$

$$f = \frac{0.25}{\log\frac{1}{3.7 * D/e} + \frac{5.74}{Re^{0.9}}} = \frac{0.25}{\log\frac{1}{3.7 * \frac{1.033}{0.0018}} + \frac{5.74}{730957.289^{0.9}}} = 0.023$$

$$h_{L1.2} = \frac{f * L * {v_A}^2}{2g * D} = \frac{0.023 * 4\ in * 91.88^2\frac{in^2}{s^2}}{2 * 386.09\ \frac{in}{s^2} * 1.033\ in} = 0.971\ in$$

9.4.5.3 Fittings losses

Table A 4. Resistant coefficient for fittings, valves, and controllers for 3/4" pipe

Fittings	Number of units	Le/D	K
90° elbows	1	30	0.72
Tee	1	60	1.44
Outflows	1	0.78	0.78
Check valves	1	150	3.6
Butterfly valves	3	45	3.24
Pressure gauge and Flow gauge	6	1.15	6.9

Table A 5. Resistant coefficients for fittings for 1" pipe

Fittings	Number of units	Le/D	K
90° elbows	2	30	1.44

For 20 gpm

$$h_{L2.1} = \sum K * \frac{{v_A}^2}{2g} = \left(K_{elbows\,90°} + K_{Tee} + K_{outflows}\right) * \frac{{v_A}^2}{2g}$$

$$h_{L2.1} = \left(\#amount * \frac{L_e}{D} * f_T + \#amount * \frac{L_e}{D} * f_T + \#amount * \frac{L_e}{D}\right) * \frac{{v_A}^2}{2g}$$

$$h_{L2.1} = (1 * 30 * 0.024 + 1 * 60 * 0.024 + 1 * 0.78) * \frac{61.00^2 \ \frac{in^2}{s^2}}{2 * 386.09 \ \frac{in}{s^2}} = 14.17\ in$$

For 7 gpm

$$h_{L2.1} = \sum K * \frac{{v_A}^2}{2g} = (K_{elbows\,90°}) * \frac{{v_A}^2}{2g}$$

$$h_{L2.1} = \left(\#amount * \frac{L_e}{D} * f_T\right) * \frac{{v_A}^2}{2g}$$

$$h_{L2.1} = (2 * 30 * 0.024) * \frac{91.88^2 \ \frac{in^2}{s^2}}{2 * 386.09 \ \frac{in}{s^2}} = 15.74\ in$$

9.4.5.4 Pump head

$$h_p = h_{L2.1} + h_{L2.2} + h_{1.2} + h_{1.1} + \frac{P_B - P_A}{\gamma} + z_B - z_A + \frac{{v_B}^2 - {v_A}^2}{2g}$$

$$h_p = 14.17in + 15.74in + 0.49\ in + 0.971 + 19817.57\ in - 6.11\ in = 19844.39\ in$$

$$= 504.05\ m = 1653.7\ ft$$

9.4.5.5 NPSHa of pump

$$NPSHa = -h_{vp} + h_{sp} \pm h_s - h_f$$

$$NPSHa = -9.48 + 2625.83 + 55 - 30.83 = 2640.52\ in$$

9.5 Annex E – Purification of the system

9.5.1 Sedimentation tank removal system

$$\frac{TSS_{out}}{TSS_{in}} = 1 - 0.65$$

$$TSS_{out} = 0.35 * 122.0 = 42.7\ ppm$$

Table A 6. Purification data after sedimentation tank unit of stormwater

Chemical	Measurement	
Total coliform	172.0	cfu
E. Coli	10000.0	gene copies/ mL
Chloride	240.4	mg/L
Iron	768.3	µg/L
Manganese	109.6	µg/L
TSS	42.7	mg/L

9.5.2 Filtration removal system

Table A 7. Purification data of the filtration unit of stormwater

Chemical	Measurement		Efficiency	After treatment	
Total coliform	172	cfu	0.00	172.00	cfu
E. Coli	10000	gene copies/ mL	0.00	10000.00	gene copies/ mL
Chloride	240.4	mg/L	0.90	240.40	mg/L
Iron	768.3	µg/L	0.99	7.68	µg/L
Manganese	109.6	µg/L	0.99	1.10	µg/L
TSS	42.7	mg/L	0.99	0.43	mg/L

Table A 8. Purification data of the filtration unit of brackish water

Parameter	Measurements		Efficiency	After treatment	
TDS	6603.27	mg/L	0.3328	4405.70	mg/L
Calcium	407.67	mg/L	0.1142	361.11	mg/L
Magnesium	183.25	mg/L	0.1142	162.32	mg/L
sodium	2109.13	mg/L	0.9488	107.99	mg/L
Bicarbonate	901.44	mg/L	0.5000	450.72	mg/L
Chloride	2871.3	mg/L	0.9000	287.13	mg/L
Nitrate	32.61	mg/L	0.5000	16.31	mg/L
Sulfate	1761.74	mg/L	0.6736	575.03	mg/L

9.5.3 RO removal system

Table A 9. Purification data of the RO membrane of stormwater.

Chemical	Measurement		Efficiency	After treatment	
Total coliform	172	cfu	0.99	1.72	cfu
E. Coli	10000	gene copies/ mL	0.99	100.00	gene copies/ mL
Chloride	240.4	mg/L	0.99	2.40	mg/L
Iron	7.683	μg/L	0	7.68	μg/L
Manganese	1.096	μg/L	0	1.10	μg/L
TSS	0.427	mg/L	0.997	0.00	mg/L

Table A 10. Purification data of the RO membrane of brackish water.

Parameter	Measurements		Efficiency	After treatment	
TDS	4405.702	mg/L	0.997	13.22	mg/L
Calcium	361.1141	mg/L	0.99	3.61	mg/L
Magnesium	162.3229	mg/L	0.999	0.16	mg/L
sodium	107.9875	mg/L	0.99	1.08	mg/L
Bicarbonate	450.72	mg/L	0.99	4.51	mg/L
Chloride	287.13	mg/L	0.99	2.87	mg/L
Nitrate	16.305	mg/L	0.97	0.49	mg/L
Sulfate	575.0319	mg/L	0.999	0.58	mg/L

9.5.4 Disinfection removal system

Table A 11. Purification data of stormwater of the disinfection process.

Chemical	Measurement		Efficiency	After treatment	
Total coliform	1.72	cfu	0.9999	0.00	cfu
E. Coli	100.00	gene copies/ mL	0.9999	0.01	gene copies/ mL
Chloride	2.40	mg/L	0	2.40	mg/L
Iron	7.68	µg/L	0	7.68	µg/L
Manganese	1.10	µg/L	0	1.10	µg/L
TSS	0.00	mg/L	0	0.00	mg/L

Table A 12. Purification data of brackish water of the disinfection process.

Parameter	Measurements		Efficiency	After treatment	
TDS	13.22	mg/L	0	13.22	mg/L
Calcium	3.61	mg/L	0	3.61	mg/L
Magnesium	0.16	mg/L	0	0.16	mg/L
sodium	1.08	mg/L	0	1.08	mg/L
Bicarbonate	4.51	mg/L	0	4.51	mg/L
Chloride	2.87	mg/L	0	2.87	mg/L
Nitrate	0.49	mg/L	0	0.49	mg/L
Sulfate	0.58	mg/L	0	0.58	mg/L

9.6 Annex F – Decision matrixes

9.6.1 Disinfection methods

Table A 13. Decision matrix for selecting the disinfection process.

Disinfection process	**Safe system**	**Residual disinfectant**	**Inactivating viruses**	**Cost (cheapest)**	**System simplicity**	**Total**
Ozone	1	1	1	1	1	5
Chlorine	2	3	2	3	3	13
UV light	3	1	1	2	3	10

Table A 14. Decision matrix for selecting the type of chlorine.

Disinfection process	**Safe to handle**	**Shelf life**	**System simplicity**	**Amount needed**	**Cost**	**Total**
Calcium hypochlorite	1	3	3	2	2	11
Sodium hypochlorite	3	2	3	3	2	13
Chlorine gas	1	3	1	2	1	8

9.6.2 Selection of equipment

Table A 15. Decision matrix for the type of retention tank.

Name	**Capacity (gal)**	**Resistant to chlorine**	**Operating pressure (psi)**	**Total cost**	**Total**
UT30	3	3	1	3	10
HP-7	3	3	1	2	9
Mixmaster	2	3	2	1	8
CWS - 1354	3	3	3	3	12
UT30	3	3	1	2	9

Table A 16. Decision matrix for the type of antiscalant.

Name	Feedwater source	Compound controlling	Phosphate presence	Total
SpectraGuard 111	3	3	3	9
Titan ASD	3	2	3	8
Pretreat Plus Y2K	2	2	1	5
Pretreat Plus 100	2	1	1	4
RPI 3000A	3	1	1	5

Table A 17. Decision matrix for selecting the filtration unit.

Name	Material	Amount of pretreatment units	Backwash	Purification of iron	Flow using gpm	Total cost	Total
Iron Max - 10	1	1	3	3	3	3	14
WF4-P	3	3	1	2	3	1	13
081-MXF-GS-250	3	3	1	1	3	1	12
MIF - 250	3	2	2	3	3	3	16
CAFO948	1	1	3	3	1	3	12

Table A 18. Decision matrix for selection of pump 1.

Provider	Max head (ft)	Flowrate (gpm)	Cost	Power supplied (HP)	Discharge head material	Total
DAYTON	2	3	1	3	3	12
DAYTON	3	2	1	3	3	12
DAYTON	2	3	2	3	2	12
WALPA	2	2	2	3	1	10
SINCR	3	3	3	3	3	15
OEM	3	1	3	1	3	11

Table A 19. Decision matrix for selection of pump 2.

Supplier	Max head (ft)	Flowrate (gpm)	Cost	Power	Material	Total
ZHONGDA PUMP0	3	3	3	3	1	13
GRUNDFOS	2	2	2	2	1	9
GRUNDFOS	2	2	3	3	3	13
GRUNDFOS	2	2	1	2	3	10
GRUNDFOS	2	3	1	1	2	9
FLOWSERVE	3	3	1	1	1	9
FLOWSERVE	2	2	1	1	1	7
FLOWSERVE	3	2	1	1	1	8
FLOWSERVE	2	2	1	1	1	7
FLOWSERVE	2	2	1	1	1	7

9.7 Annex G – Economical analysis

9.7.1 Lang factors usage

Table A 20. Detailed Lang Factors for fluid processing.

Direct costs	Factor
Installation	0.47
Instrumentation and Controls	0.36
Electrical Systems	0.11
Indirect costs	
Legal expenses	0.04
Engineering and supervision	0.33
Total	1.31

Table A 21. FCI and TCI Lang factor.

FCI Lang Factor	5
TCI Lang factor	6

9.7.2 Annual net after-tax profit

$$Annual\ income = \frac{\$2}{1\ gal} * \frac{13208.60\ gal}{day} * \frac{90\ days}{year} = \$2377548.47$$

$$Annual\ net\ (after-\ tax)\ profit$$

$$= (Annual\ income - Annual\ operating\ cost - Depreciation)$$

$$* (1 - Tax\ rate) + Depreciation$$

$$= (\$2377548.47 - \$79222.96 - \$3281.26) * (1 - 0) + \$3281.26 = \$2298325.51$$

9.7.3 ROI and PBP

$$ROI = \frac{Annual\ net\ (after -\ tax)\ profit}{TCI} * \frac{\$2298325.51}{\$4357036.23} * 100 = 53\%$$

$$PBP = \frac{Annual\ net\ (after -\ tax)\ profit}{Depreciation} * \frac{\$2298325.51}{\$3281.26} = 0.0014\ years = 12.33\ hours$$

9.7.4 Net present value (NPV)

Table A 22. Cash flow for 5 years of the project.

Year	1	2	3	4	5
Working capital Investment	1089259.06	1089259.06	1089259.06	1089259.06	1089259.06
Savings	0.00	4755096.94	0.00	4755096.94	0.00
Operating cost	0.00	79222.96	0.00	79222.96	0.00
Discount Factor	1.04	1.08	1.12	1.17	1.22
Investment	3630863.53	0.00	0.00	0.00	0.00
Depreciation	3281.26	3281.26	3281.26	3207.93	3207.93
Annual after-tax profit	-1132829.42	3879282.70	-1225268.30	4195832.17	-1325250.19
Cumulative discounted cash flow	-1132829.42	2746453.28	1521184.98	5717017.15	2213248.84

9.8 Annex H – Sensitivity Analysis

Table A 23. Seawater purification analysis.

Parameter	Measurement	Sedimentation	Filtration	Permeation	Disinfection	Standards	Final concentrations
Na^+ (ppm)	10570.00	0.0000	0.9488	0.9900	0.0000	30.0000	5.4118
Mg^{2+} (ppm)	1276.00	0.0000	0.1142	0.9990	0.0000	52.1000	1.1303
Ca^{2+} (ppm)	447.00	0.0000	0.1142	0.9900	0.0000	100.0000	3.9595
K^+ (ppm)	393.00	0.0000	0.0000	0.9700	0.0000	82.0000	11.7900
Cl^- (ppm)	19325.00	0.0000	0.9000	0.9900	0.0000	250.0000	19.3250
SO_4^{2-} (ppm)	2740.00	0.0000	0.6736	0.9990	0.0000	250.0000	0.8943
NO_3^-(ppm)	160.00	0.0000	0.5000	0.9700	0.0000	10.0000	2.4000
Br^- (ppm)	67.00	0.0000	0.0000	0.9970	0.0000	2.0000	0.2010
F^- (ppm)	1.30	0.0000	0.4030	0.9900	0.0000	2.0000	0.0078
TSS (ppm)	289.75	0.6500	0.0000	0.9970	0.0000	25.0000	0.3042
TDS (ppm)	33000.00	0.0000	0.3328	0.9970	0.0000	500.0000	66.0528
Iron (ppm)	0.06	0.0000	0.9900	0.0000	0.0000	0.3000	0.0006
Turbidity (NTU)	0.99	0.0000	0.2000	0.9970	0.0000	0.3000	0.0024
E. Coli (CFU/mL)	21.60	0.0000	0.0000	0.9900	0.9999	0.0000	0.0000

9.9 Annex I – Information of each decision matrix

Table A 24. Informational data of the decision matrix for contact tanks.

Name	Capacity (gal)	Resistant to chlorine	Operating pressure (psi)	Total cost
UT30	30	Yes	75	370.83
HP-7	30	Yes	75	667
Mixmaster	90	Yes	100	1053.66
CWS - 1354	30	Yes	125	489
UT30	30	Yes	75	599

Table A 25. Informational data of the decision matrix of dosifiers.

Name	Pump included	Valves	Water meter included	Capacity of the tank (gal)	Can contain chlorine and antiscalants	Cost
J-PRO-22	Yes	Yes	No	35	Yes	649
Tamco 3059	No	No	No	30	Yes	133.46
RM-35-24	Yes	No	No	30	Yes	389
STS30NC	Yes	Yes	No	30	NO	465.79
EWATER-JYX001	Yes	No	No	21	Yes	388
410-CLBOOST	Yes	Yes	Yes	15	Yes	1195

Table A 26. Informational data of the decision matrix of antiscalants.

Name	Feedwater source	Compound controlling	Phosphate presence
SpectraGuard	Brackish and stormwater	7	No
Titan ASD	Brackish and stormwater	6	No
Pretreat Plus Y2K	All types of water	6	Yes
Pretreat Plus 100	All types of water	4	Yes
RPI 3000A	Brackish and stormwater	5	Yes

Table A 27. Informational data of the decision matrix of filtration systems (Part A).

Name	Material	Cost	Energy used	Amount of pretreatment units	Backwash	Purification of iron
Iron Max - 10	Not available information	1645	120 v - 60 hz	0	Automatic	up to 12 ppm
WF4-P	Greensand	3611.7	24 V - 60 Hz	3	Not automatic	up to 10 ppm
081-MXF-GS-250	Greensand	3865.5	Less than 2$ electricity per year	2	Not automatic	up to 6 ppm
MIF - 250	Catalytic carbon/ Gravel	2606.36	12 V - 60 Hz	1	Oxidation	up to 12 ppm
CAFO948	Not available information	1099.99	120 V AC power	0	Automatic	up to 15 ppm

Table A 28. Informational data of the decision matrix of filtration systems (Part B)

Producer	Flow using gpm	Number of units	Diameter of product in	Total cost
Rain dance water systems	10	3	10	4935
Pentair	10	2	12	7223.4
US Water	10	2	13	7731
US Water	10	2	13	5212.72
Rainfresh	6	4	13.5	4399.96

Table A 29. Informational data of the decision matrix of pump 1

Provider	Type of pump	Max head (ft)	Flowrate (gpm)	Cost	Power supplied (HP)	Discharge head material
DAYTON	Submersible deep well	221	20	850.66	1	Stainless steel
DAYTON	Submersible well	200	35	930.1	2	Stainless steel
DAYTON	Submersible deep well	221	20	741.4	1	Thermoplastic
WALPA	Centrifugal water pump	183.7270341	31.70064628	70	2.950248597	Cast Iron
SINCR	Submersible Solar Water Borehole Pump	190.2887139	20	220	2	Stainless steel
OEM	Multistage pump	190.2887139	220.14	199.74	14.75124299	Stainless steel

Table A 30. Informational data of the decision matrix of pump 2

Supplier	Name	Type of pump	Max head (ft)	Flowrate (gpm)	Cost	Power supplied (HP)	Discharge head material
ZHONGDA PUMP0	´6-50	Centrifugal pump	1968.503937	22	No data	4.023066	Cast Iron
GRUNDFOS	CR, CRN 45/ 7 stages	Multistage centrifugal pump	850	15	11800	50	Cast Iron
GRUNDFOS	CR, CRN 10-17 stages	Multistage centrifugal pump	820	15	5464.8	15	Stainless Steel
GRUNDFOS	CRN 32-10-2 stages	Multistage centrifugal pump	870	15	15791.2	40	Stainless Steel
GRUNDFOS	MPVN 3550 rpm	Centrifugal pump	1600	20	No data	100	Bronze fitted
FLOWSERVE	HED	Between Bearings Pumps	2100	20	No data	No data	Stainless Steel
FLOWSERVE	DMX - RO	Single case pump - multistage	2789	No data	No data	No data	No data
FLOWSERVE	DVSH - RO	Single case pump - axially split	1968	No data	No data	No data	No data
FLOWSERVE	Molten Salt VTP	Vertical Pump	1740	No data	No data	No data	No data
FLOWSERVE	MSP	Vertical Pump	2955	No data	No data	No data	No data