Chapter I
INTRODUCTION

1.1. Background

Water is an essential element in human life. It is used for drinking, washing, bathing, flushing, preparing food, and watering the garden, etcetera. For these necessities, especially for drinking, the clean water supply is required, but in fact, nowadays, more than a billion people in the world still have lack access to clean drinking water especially in developing country such as Indonesia.

At least 80 percent of Indonesia's 215 million populations have no access to drinking water supply. The lack of clean drinking water caused poor health conditions in Indonesia whereas in the Netherlands, almost all of households have an access to it. This condition puts the Netherlands as one of the forefront countries in the world which can supply the potable drinking water.

Therefore the general condition of drinking water, the process of drinking water treatment, and the phase procedures of designing drinking water pump station in the Netherlands, especially in De Punt, Groningen, are interested to be discussed and compared with Indonesian's in order to get a better knowledge of how to improve the drinking water pump station in Indonesia.

1.2. Objectives

The objective of this final thesis is to give recommendations for improving the drinking water pump station in Indonesia through:

- Obtaining knowledge about the drinking water pump station in the Netherlands and Indonesia and the differences between them, including:
  - the general condition
  - the drinking water treatment
  - the phase procedures of designing drinking water pump station
- Obtaining knowledge about the drinking water pump station in De Punt, the Netherlands, including:
  - the general condition
  - the drinking water treatment

– the final design for each of the water pump station buildings

1.3. Benefits

1. To DHV B.V.
   - Draw and calculate some parts of the project (appendix 3, 7, 8, 10-17, 19-22, and 24-36)
   - Know the differences between drinking water pump station in the Netherlands and Indonesia
   - Have a good relationship with Hogeschool Utrecht and Petra Christian University
   - Share the company's knowledge and experience to Indonesia
2. To Hogeschool Utrecht
   - Get knowledge about drinking water pump station in the Netherlands and Indonesia as well as the differences between them.
   - Have a good relationship with DHV B.V. and Petra Christian University
3. To Petra Christian University
   - Get knowledge about drinking water pump station in the Netherlands and Indonesia as well as the differences between them.
   - Have a good relationship with DHV B.V. and Hogeschool Utrecht
4. To authors
   - Finish the last requirement of graduation at Hogeschool Utrecht
   - Get work experience in the international consultant company
   - Get knowledge about drinking water pump station in the Netherlands and Indonesia as well as the differences between them.
5. To all readers
   - Get knowledge about drinking water pump station in the Netherlands and Indonesia as well as the differences between them.

1.4. Scheme of Analysis

There are 5 chapters that will be discussed in this final thesis, they are:

- Chapter I : INTRODUCTION

This chapter consists of the background, objectives, benefits, and scheme of analysis of this final thesis.

- Chapter II : DRINKING WATER PUMP STATION IN THE NETHERLANDS

This chapter will describe the general condition and drinking water treatment in the Netherlands, as well as the phase procedures of designing drinking water pump station.

- Chapter III : DRINKING WATER PUMP STATION DE PUNT, GRONINGEN

This chapter will describe the general condition and drinking water treatment in De Punt, the final design of the buildings, and also the changes of buildings' design from preliminary design to final design.

- Chapter IV : DRINKING WATER PUMP STATION IN INDONESIA

This chapter consists of general condition and drinking water treatment in Indonesia besides the phase procedures of designing drinking water pump station.

- Chapter V : COMPARISONS BETWEEN DRINKING WATER PUMP STATION IN THE NETHERLANDS AND INDONESIA

This chapter will discuss the differences of general condition and drinking water treatment between the Netherlands and Indonesia as well as the difference of the phase procedures of designing drinking water pump station between the Netherlands and Indonesia

- Chapter VI : CONCLUSIONS AND RECOMMENDATIONS

This chapter consists of both conclusions of this final thesis and the recommendations related to it.

- Appendixes

The appendixes consist of some of the authors' production result at DHV (final design of the renovation drinking water pump station De Punt, Groningen, including the new buildings' drawing, the cost estimation of the buildings, structural calculation of the clean water reservoir and the phase's construction of renovating the pump station).

Chapter II

DRINKING WATER PUMP STATION IN THE NETHERLANDS

2.1. General Condition

The Netherlands' drinking water which comes out of the taps is chlorine-free, biologically stable and safe to drink. The drinking water supply is the responsibility of water supply companies. There are municipal companies to supply water in the larger towns besides provincial and regional water companies to supply water in the rural area. In total there are 14 Dutch water companies and 233 pumping stations with their supply area which are organized in the Association of Dutch Water Companies and provide for a 24 hours per day supply of water from the taps[1].

The sources of the raw water that is used for producing drinking water are both groundwater and surface water (Figure 2.1.).

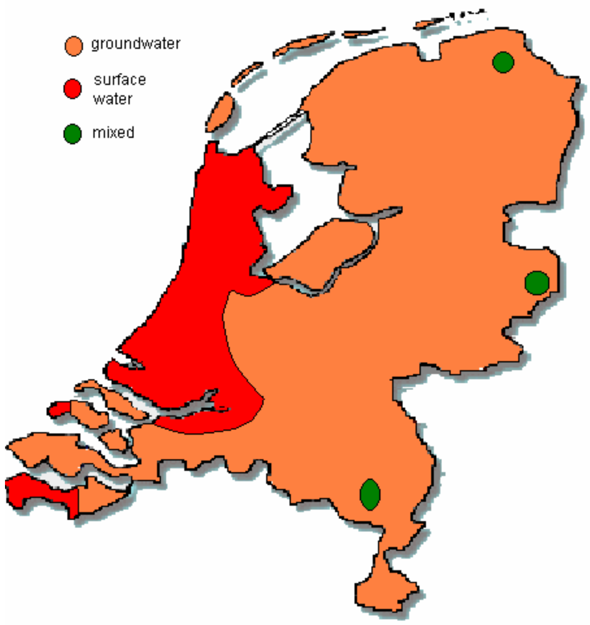

Figure 2.1. Origin of drinking water in the Netherlands

<u>Groundwater</u>

The groundwater provides two thirds of the drinking water production. Around 784 million m^3 of groundwater is extracted every year from the depth of 200 m. Producing drinking water from groundwater is rather simple than surface water. While taking the groundwater as the source, it is important that the aquifer is isolated from the upper soil to prevent contamination. In area where the aquifer has an open connection to upper soil, the water abstraction area is chosen more carefully. The groundwater table in the Netherlands is very high; therefore the effect of the groundwater abstraction on lowering the groundwater table must be taken into account. The lowered groundwater table can lead to drying out in the surrounding area, resulting in agricultural and environmental damage. Therefore, the amount of permitted groundwater abstraction is now decreased by the Dutch policy and a careful planning is needed while abstracting groundwater.

Surface water

The surface water in the Netherland is available in large amount and can be abstracted either from rivers, lakes, or seas. Even so, drinking water production from surface water requires an extensive treatment process to remove suspended solids, turbidity, bacteria, pathogens, harmful compounds, and micropollutants.

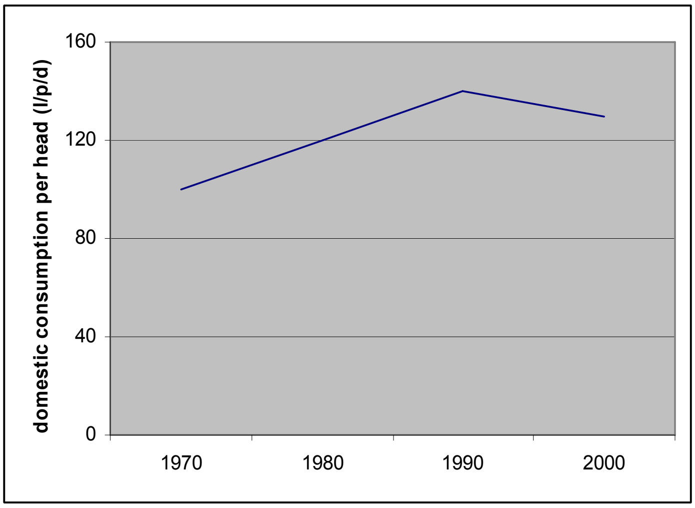

Figure 2.2. Trend of Water Consumption per person per households (l/p/d)

The water production by water supply companies amounted to 1303 million m^3 in 2001 which are used in households, small business, industry, and for other purposes[2]. Households are the largest consumers who consume approximately 740 million m^3/year with an average consumption per person is around 128 l/p/d. The average consumption per person between 1970 and 1990 increased as a result of increased standard of living whereas from 1990 consumption per person decreased as a result of large scale campaigns for water saving (Figure 2.2.). Moreover, the quality of drinking water in the Netherlands is regulated by the legal standard; Water Supply Act (WSA) which has stricter regulation than the general European one (Table 2.1.).

Table 2.1. Typical Quality Standards for Drinking Water

Parameter	Unit	Netherlands[3]	EU[4]
E-coli		0/100ml	0/250ml
Colony count	/ml	100	100
Pesticides (per compound)	µg/l	0.1	0,1
Bromate	µg/l	1 (5)	10
Iron	mg/l	0.2	0,2
Manganese	mg/l	0.05	0,05
Ammonia	mg/l	0.2	0,5
Suspended solids	FTE	1 (4)	1 (4)
Hardness (calcium + magnesium)	mmol	1-2.5	1-2.5
Sodium	mg/l	150	250
Chlorine	mg/l	150	250
pH	-	7.0 – 9.5	6,5-9,5
Temperature	ºC	< 25	< 25

2.2. Drinking Water Treatment

As every type of water source has its own characteristic, each of them has its way to be treated. The most important thing to treat groundwater is to increase the level of oxygen whereas to surface water is to remove the suspended solids, turbidity, bacteria, pathogens, harmful compounds, and micropollutants.

2.2.1. Groundwater Treatment

The oxygen level distinguishes the way groundwater is treated. Three different types of treatment are[3]:

- Aerobic groundwater treatment

In this case, the groundwater has an open groundwater table; therefore the water contains enough oxygen. Thus the water can be abstracted and directly distributed as drinking water. Only if there is organic matter present in the water, additional treatment of aeration, conditioning, will be used, (Figure 2.3.)

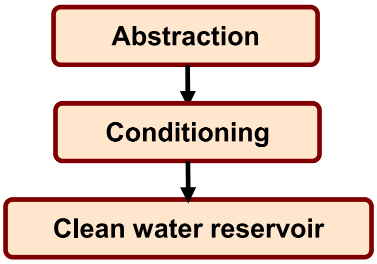

Figure 2.3. Aerobic Groundwater Treatment

- Slightly aerobic water treatment

This treatment fits with the groundwater that is located under a confining layer, lacked of oxygen content and the presence of ammonium, iron, and manganese. Thus, for addition of oxygen and the removal of carbon dioxide, aeration is required. Aeration is followed by submerged sand filtration (Figure 2.4.). In here, the biological transformation of ammonium and manganese and the physical removal of the iron hydroxide ($Fe(OH)_3$) flocs happen.

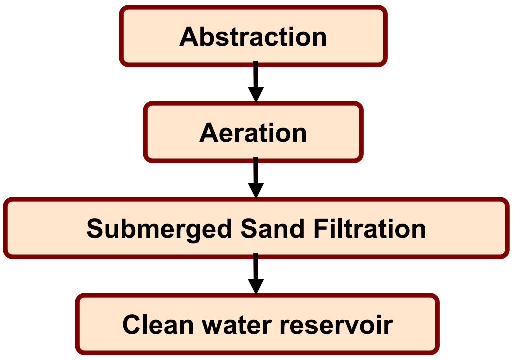

Figure 2.4. Slightly Aerobic Water Treatment

- Deep aerobic groundwater treatment

Here, the groundwater is abstracted under a confining layer and no oxygen is present in the water. Iron, manganese, hydrogen sulfide, methane, and especially ammonium are present in high concentrations. As the amount of ammonium is very high, the amount of oxygen needed for the removal is larger than the total amount of oxygen which can be dissolved in water. Thus, double filtration is required to prevent anaerobic conditions, dry filtration and rapid sand filtration. An aeration phase will be present before every filtration step so the oxygen concentration will be high before the water enters the filter.

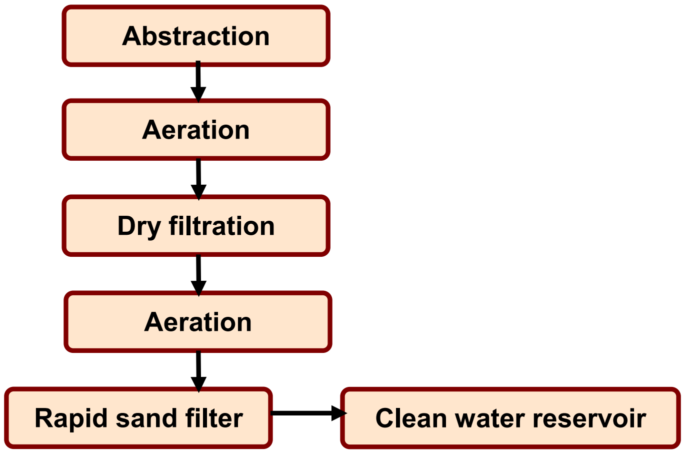

Figure 2.5. Deep Aerobic Groundwater Treatment

There is another treatment called riverbank groundwater (Figure 2.6.).

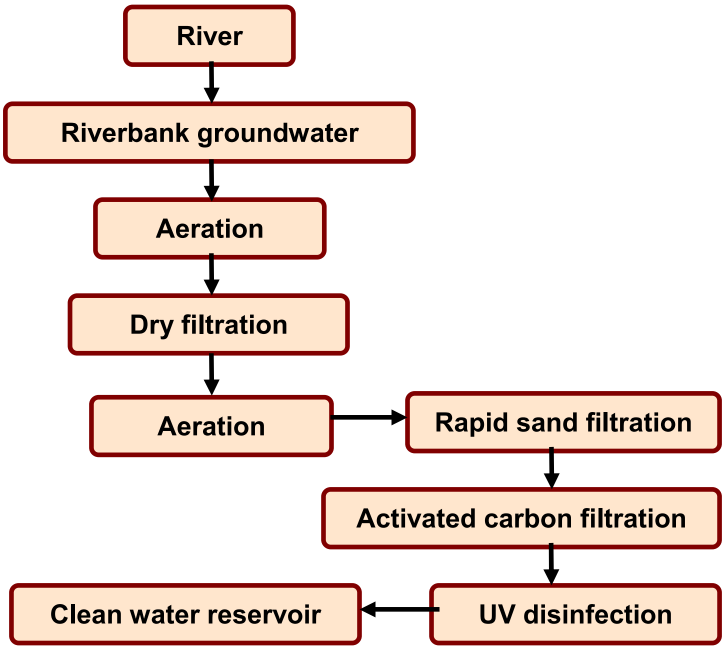

Figure 2.6. Riverbank Groundwater Treatment

Riverbank groundwater is groundwater that is abstracted directly adjacent to surface water, usually from river. The abstracted water is the mixture of surface and natural groundwater. Overall, this treatment is quite the same as deep anaerobic groundwater treatment. The differences are the presence of activated carbon filtration and UV disinfection. These two additional treatments are intended to kill the microorganisms and remove the taste and pesticides.

2.2.2. Surface Water Treatment

Two types of surface water treatment are[3]:

- Direct treatment

Figure 2.7. shows the general treatment of the surface water. The presence of basin is intended to yield a consideration amount of self purification, make an intake stop in case of river contamination, and control algae growth. As the surface water contains suspended solids, the important step is to remove it from the water by flocculation and floc removal by filtration. Traditionally, direct treatment was done by clarification in large basin and followed by slow sand filtration. But as this procedure enquires large amount of space and labor, the usage of the slow sand filtration is decreased and replaced by rapid sand filtration.

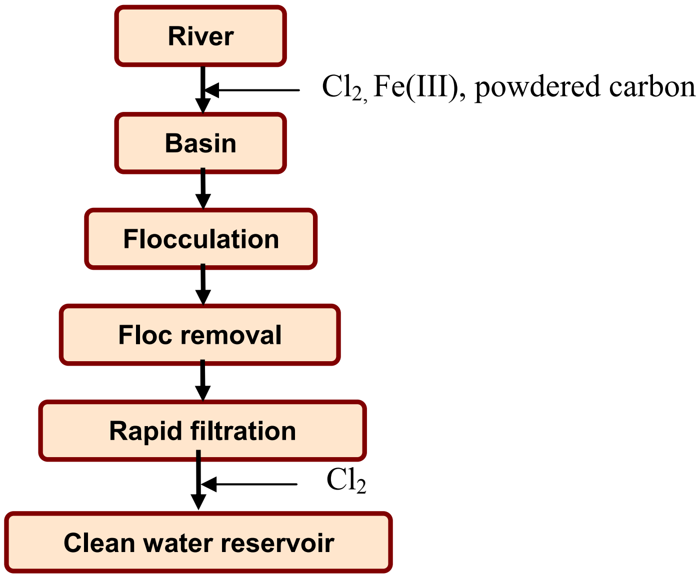

Figure 2.7. Direct Treatment of Surface Water

The usage of chlorine is also decreased as it is harmful to human health. To remove the micropollutans, biological and physical processes (activated carbon filtration, UV disinfection, and membrane filtration) are considered to take over the role of the chemical processes of disinfection and oxidation.

- Indirect treatment

Indirect treatment means that some amount of the surface water will be infiltrated into the ground so that its quality is improved. This means that the pathogenic microorganisms are degraded and that the water is in a better biological and chemical state, causing no settling and no regrowth to occur[3]. Besides, the temperature changes are leveled so that the temperature and the salinity will be more or less constant. Infiltration projects require large protected area, because they mainly deal with large amounts of water.

2.3. Phase Procedures of Designing Drinking Water Pump Station

Designing drinking water pump station is a creative process, influenced by several factors with its difference importance. These differences cause people to conceive of different results. Thus the design should pass trough some phases (Figure 2.8.) and be negotiated.

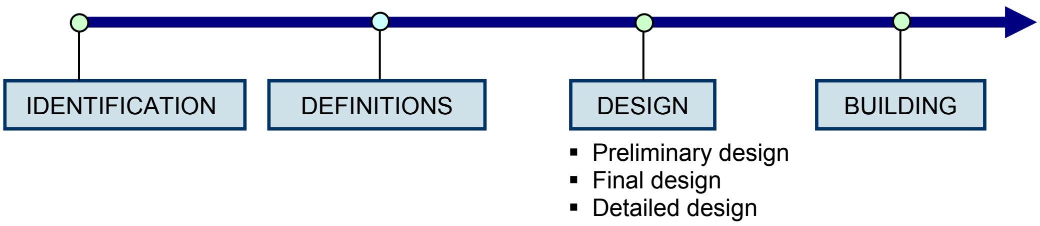

Figure 2.8. Phase Procedure of Designing Drinking Water Pump Station

Table 2.2. Characteristic of Each Phase Procedure

Phase	**Accuracy of costs**	**Changeability of design**	**Change in costs**
Identification	± 50%	-	-
Definitions	± 30%	100%	1%
Preliminary design	± 25%	40%	5%
Final design	± 15%	10%	10%
Detailed design	± 5%	2%	25%
Building	± 1%	-	100%

During the design process, the motivation for selecting the chosen solution should be made clear to the third parties as well. An open planning process is required since the large parties involved. Therefore, the characteristic of the phase procedure is a coarse to fine approach (Table 2.2.) which will make clear not only the progress in each specific design phase, but also the way in which the design have been changed, and it will make the changeability in the design be possible.

Identification

There are so many reasons and problems motivate water supply company to construct a pump station, therefore these problem should be examined first at the earliest stage of the design process. It will be the base for the future phase. Several possible solutions are drawn up and provisional decisions are made. Technological research will lead to a general direction for the desired treatment. Furthermore, this phase consists of [3]:

- Feasibility studies (technological, technical, financial, economical, and environmental impact)
- Location studies (possibility of land acquisition) and Literature studies
- Project comparisons by site visits
- Specialist research (hydraulics, soil mechanics, ergonomics, material science, physics, chemistry, environmental science, social aspects, etc.)
- System design studies (comparison of different treatment methods)

Data that will be used for further phase will also be collected during this phase

- Data on existing plan (raw water source, process flow diagram, hydraulic scheme, drawings, operating experiences)
- Data on surrounding area concerning foundation, soil conditions, groundwater level, wires, pipes, roads, etc.)
- Data concerning necessary permits

Definitions

In this phase, some documents need to be drawn up, such as[3]:

- Requirements program

  This program considers the following aspects:
  - Motivation for the project and summary of preliminary design
  - Purpose of the project, wishes and side purpose
  - Future developments after constructions
- Sketch design

General options are considered and the chosen option will be sketched in its technical, as well as in its spatial outline[3]. The sketch design consists of a more in depth elaboration of the design, such as:

  - Treatment scheme and rough hydraulic line scheme
  - Rough terrain arrangement
  - Phasing of construction and Cost estimation
- Building scheme

It is the general project plan, covering all aspects of the construction phase. It consists of:

  - Requirement program and sketch design
  - Time schedule for design, contract and construction
  - Design of the project organization and estimation of investment cost

They will be the basic documents for collecting employees' viewpoints, supporting management's decisions and for external communication as well.

Preliminary Design

This phase is intended to give a rough overview of the plant including their mutual coherence and a description of any large mechanical and electronic devices. Moreover, the activities for this phase are[3]:

- Processing of responses to sketch design
- Discussing the design with other partners, government agencies, suppliers, and third parties
- Formulating process descriptions and considering alternatives/formulating the necessary technical design drawings for the different operating conditions (minimal, maximal, and normal capacity) among which are:
  - Process flow diagram (PFD) and Hydraulic line scheme
  - Rough design of building
- Calculating rough dimensions of building and determining their sizes
- Specifying main components of civil structure (foundation, materials, architecture, spatial coding), mechanical installations, electrical installations, instruments and control system
- Formulating construction drawings
- Formulating rough estimates of construction cost, operation cost, and construction time
- Handing out documents for results' approval of the preliminary design

Final Design

This phase is more detailed and contains construction drawings and the calculations of the unknown parts during earlier phases. Examples of these unknown parts are all the components not immediately involved in the treatment process, such as heating, air conditioning, pressurized air facilities, etc. This phase is mainly intended to make sure that everything will fit in, not only after but also during construction as well. The activities for this phase are[3]:

- Processing responses to the preliminary design
- Discussing the design with other partners, government agencies, suppliers, third partners and calculating final capacity and dimensions
- Elaborating preliminary design into final construction drawings
- Formulating:
  - Process flow diagrams (PFD) for main stream and secondary flows (chemicals, energy, sludge treatment, backwash water treatment)
  - Hydraulic line scheme; Piping and instrument diagrams (P&ID)
  - Control schemes based on an automatization master plan
- Deciding on necessary space for auxiliary facilities
- Preparing requisitions for technical details and prices of necessary documents; Discussing financial topics and the method of contracting
- Estimating investment cost and completion time
- Handing out documents of approval of the final design

Detailed Design

This phase is intended to make everything clear for the construction part of the project. For civil parts, for concrete structure, it refers to reinforcement calculation and the several finishing elements.

Building

After the detailed design has been assigned and the contract document has been made, the contractor and suppliers will begin the construction of the building. Because of the requirement of hygienic nature of drinking water supply, it is necessary to work clean during the construction.

Chapter III

DRINKING WATER PUMP STATION DE PUNT, GRONINGEN

3.1. General Condition

De Punt, an old pump station in the Province of Groningen (Figure 3.1.), is owned by Water Bedrijf Groningen. The pump station was opened in 1937 and is still functioning until now. The sources of the drinking water here are both groundwater and surface water and now the province wants to decrease the amounts of abstracted groundwater not only because each abstraction of groundwater results in drying out of the soil (lowering the groundwater level), which can harm agriculture and nature but also because the demand of water in Groningen is decreasing and the mechanical installation at the pump station is very old. Therefore, Water Bedrijf Groningen needs renovating this pump station.

Figure 3.1. Location of De Punt, Groningen, Netherlands

The total amount of water resources will be reduced from 13 to 12.5 million m^3 every year (Table 3.1.); 4 million m^3 of groundwater, 7 million m^3 of surface water, and an additional water of 1.5 million m^3 from WMD.

Table 3.1. Composition of Water Resources in De Punt

Water Resources	Discharge (million m³/year)	
	Existing Situation	Future Situation
Groundwater	7	4
Surface Water	6	7
Another water company (WMD)	-	1,5
Total	**13**	**12,5**

In an attempt to renovate the drinking pump station, some boundary conditions are encountered and should be taken into account during designing.

1. Existing situation
   - Existing building (Appendix 1) and underground utilities, such as: pipe and wire networks, provide physical constraints in placing and designing new buildings and utilities for future situation.
   - As the pump station is still producing water at this moment, the production of drinking water may not be obstructed, either during construction or during the transition from the old to the new plant.
2. Environmental aspect
   - The amount of abstracted groundwater is limited to prevent the negative impact of groundwater extraction to the nature development.
   - The groundwater level is so high that it requires consideration to place the new building. The deeper the level of the building, the more ground water pressure, and the thicker under water concrete is
3. Other parties and client's wishes
   - As there are so many parties involved such as the process technology, mechanical and electrical part, their requirements should also be considered while designing the station.
   - Client's wishes and their financial condition should be considered

3.2. Drinking Water Treatment

3.2.1. Groundwater Treatment

The groundwater in the pump station De Punt is located under a confining layer and taken from the depth of -60 until -100 NAP, thus the water contains less oxygen and ammonium, iron, and manganese presence in the water.

The general treatment of groundwater here is quite simple (Figure 3.2). First of all the oxygen is added to the water by aeration (downward spraying) to remove carbon dioxide (Figure 3.3.). The oxygen is used for the oxidation of Fe^{2+} to Fe^{3+}, $NH_4^+$to NO_3^- , and Mn^{2+} to MnO_2. Then the aeration will be followed by rapid sand filtration to remove the oxidized substances. Fe^{3+} will be transformed into $Fe(OH)_3$ flocs, manganese will be chemically and biologically transformed, and ammonium is accomplished by the *Nitrosomonas* and *Nitrobacter*. As a result, the pores between the sand grains in the filter will be filled by bacteria, flocs, and deposits. Thus the rapid sand filter should be backwashed.

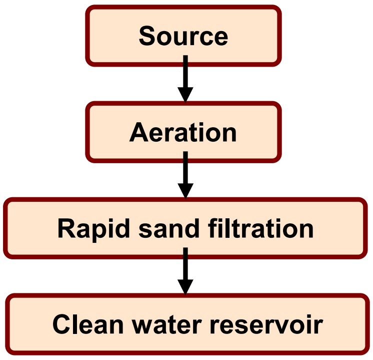

Figure 3.2. Drinking Water Treatment of Groundwater in De Punt

After passing the rapid sand filtration, clean water will be collected in the clean water reservoir and distributed to the customer. In the existing situation, both of clean water from groundwater and surface water are collected in the same reservoir, but in the future, it will be separated to prevent contamination.

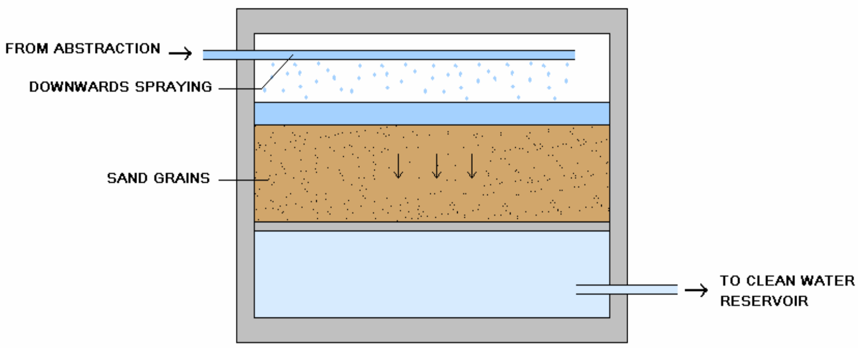

Figure 3.3. Aeration and Rapid Sand Filter

3.2.2. Surface Water Treatment

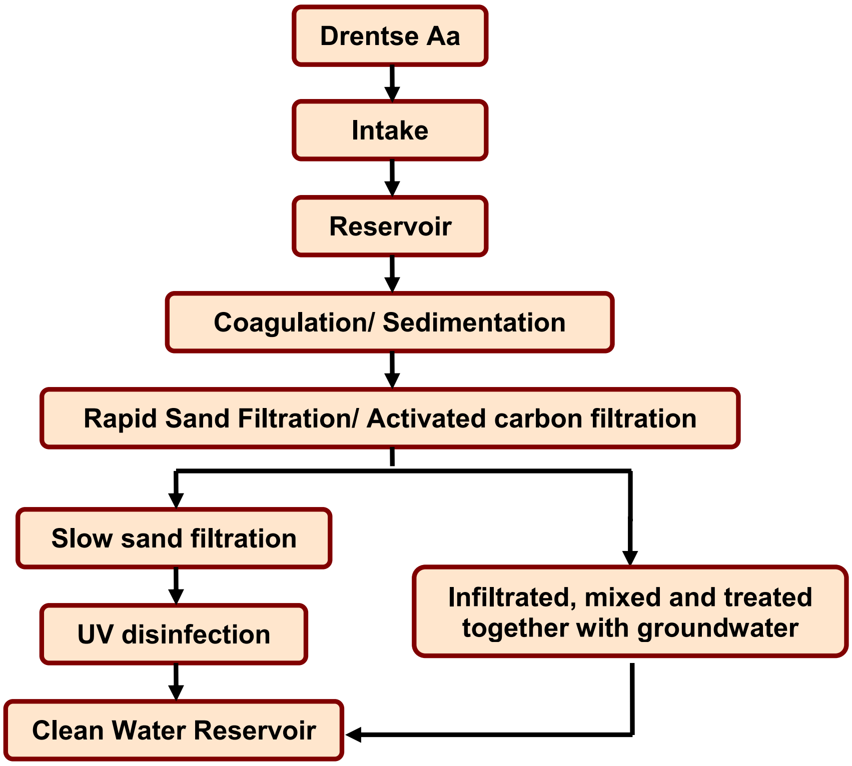

Figure 3.4. Existing Drinking Water Treatment of Surface Water in De Punt

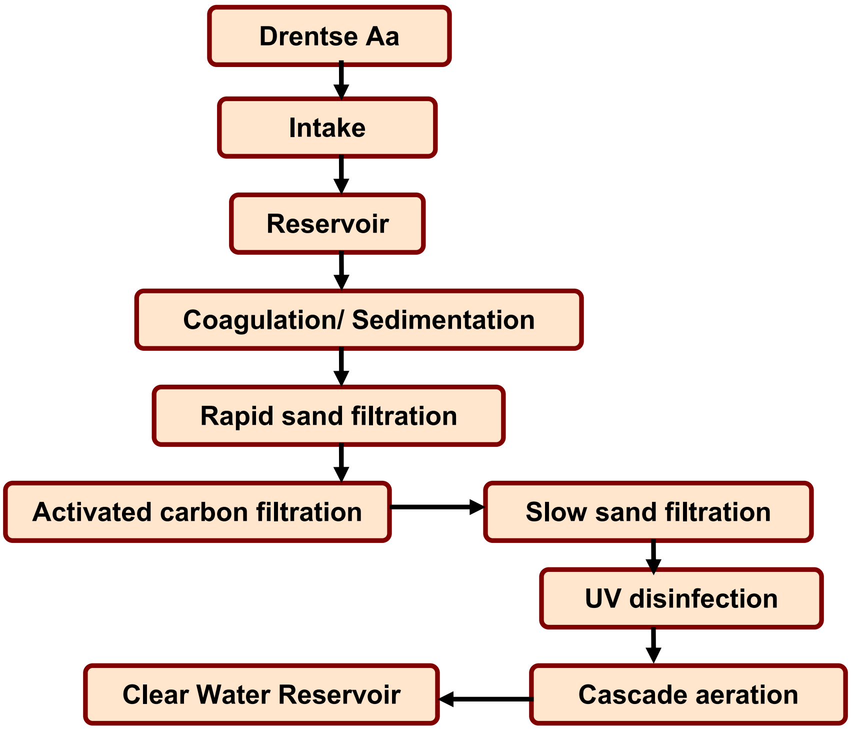

Figure 3.5. Future Treatment of Surface Water in De Punt

In the existing situation, at the early stage, the raw surface water is pre-treated first by coagulation (adding flocculants), rapid sand filtration, and activated carbon filtration to remove suspended particles from the water. Then, some parts are treated with direct treatment through slow filtration, UV disinfection, and then collected in the clean water reservoir whereas the other part is treated by indirect treatment, transported and infiltrated into the ground (Figure 3.4.). After two months of retention time, the water would be mixed as well as abstracted together with the groundwater and collected in the clean water reservoir after getting treatments.

In the future, the existing treatment for groundwater will still be used whereas a new direct surface water treatment will be totally applied (Figure 3.5.).

The components of the future direct treatment are described below:

Drentse Aa

In the drinking water pump station De Punt, the surface water is abstracted from the brook called Drentse Aa (Figure 3.6.). The basin of the brook-area is about 26.000 ha which consists of 8.500 ha of scenic area, 8.800 ha of pasture land, and 7.700 ha of farmland[5]. The largest part of the area is situated in the Province of Drenthe and the smaller part in the Province of Groningen. Until now, the Drentse Aa is still considered as the purest and most undamaged system of brooks in Drenthe. The catchments basin is not a water-collection area in the sense of the law. Only areas where groundwater is used for drinking water supply belong to the protected water supply areas. In the rest of the area allowable pesticides, herbicides, weed killers etc. may be used.

Figure 3.6. Drentse Aa

Problems in case of intake and purification of water from the Drentse Aa are:

- The temperature, because of the shallowness of the brooks, temperature differences are high and change strongly. In Summertime: 25^{o} and in Wintertime: 0^{o}
- Different effluents in case of rainy weather causes turbidity and colour

Intake

Intake is intended to abstract the raw water from the Drentse Aa. Wood barrier is applied to decrease the influence of water streamline. Leaves and duckweed will be retained by fine strainer, placed inside the intake building, with opening between 0.5-2 cm which require frequent cleaning. The intake of floating material can also be prevented by abstracting the water below the surface.

In order to check the quality of the intake water, a fish guarding system is linked. In case of an intake of contaminated water, the fish will warn and then the intake will be stopped. Intake of water is also connected to a monitoring system in which turbidity, pH, oxygen, conductivity, and temperature are measured.

Reservoir

After passing the strainer, the raw water will be pumped and collected in the reservoir, located outside the pump station with the capacity of 5000 m^3. In common, there are three different types of reservoirs (Table 3.2.). In De Punt, the reservoir is functioned as storage reservoir with 5-7 days of retention time.

Table 3.2. Types of Reservoir[3]

Type	Function
Analysis reservoir	Analysis of the intake water. Based on this analysis it is decided if the water can be used for intake or the intake has to be stopped
Mixing reservoir	Quality improvement due to mixing or dosing of chemicals Self purification of the water due to decay and sedimentation
Storage reservoir	Storage during times of bad water quality (a disaster/ low river discharge) Water quality dampening due to mixing Self purification of the water due to decay and sedimentation

Coagulation/ Sedimentation

Even though the self purification of water has taken place in the reservoir, the surface water still contains different compounds that must be removed. The compounds can be subdivided into suspended solids, colloidal solids, and dissolved solids. Suspended solids have a diameter larger than 10^{-6}m, colloidal solids between 10^{-9} and 10^{-6} m and dissolved solids smaller than 10^{-9}m (Figure 3.7.). Particles with a specific density of 2650 kg/m^3 (e.g. sand) and a diameter larger than 10^{-5} m will settle in water. Smaller particles will also settle, but slower. To remove, particles that are smaller than 10^{-5} m must be made larger or heavier.

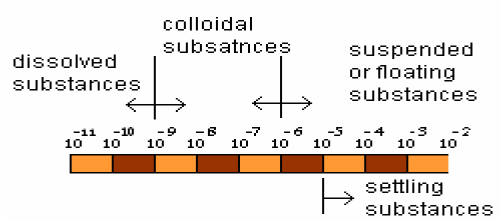

Figure 3.7. Dimensions of Compound in the Water

The particles will be incorporated into flocs after the coagulants are added in to the water. The coagulants should be harmless to public health. In the pump station De Punt, Powdered Activated Carbon Treatment (PAC) and $FeCl_3$ will be used as coagulant. As the flocs are heavier than water, they can be removed by sedimentation. With this treatment, the effectiveness of sedimentation is increased so it will not cause the rapid filtration system to be heavily loaded.

Rapid Sand Filtration

As indicated by its name, the water to be treated flows at high rates, 4.6 m/h down through the granular filter bed. In these speed, the suspended material will be trapped and will remain on the bed. By passing these filters, the remaining flocs are significantly reduced and ammonium will be decomposed.

Because of the resistance to water by a granular bed, the rates mentioned above can only be achieved when using coarser and more regular filter material, which will store the contaminants from the untreated water at greater depths and make high sludge storage possible. Two layers of material are applied for the rapid sand filtration; 0.9 m of normal sand and 0.6 m of anthracite (Figure 3.8.).

The material must be sieved first before application to avoid stratification of the filter bed during back washing. The value of the uniformity coefficient is 1.3 for normal sand and 1.4 for anthracite.

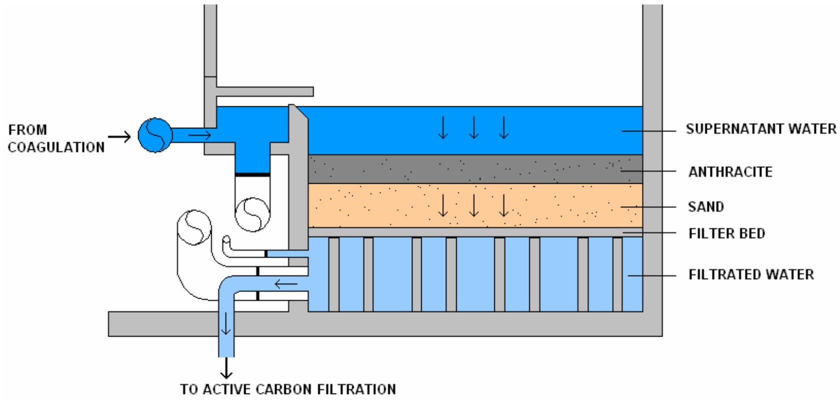

Figure 3.8. Rapid Sand Filtration

After passing the filter bed, the water is drained through a nozzle, synthetic tube that is incorporated in the bottom construction of the filter. To avoid loss of filter sand, perforated heads are placed onto the tubes[3]. The nozzles have also a function in the supply of backwash water and air. The tributary area of the nozzles should be the same so that it can distribute the same amount of water.

After a certain operation period the pores in a filter bed are filled with accumulated suspended solids. While the porosity has decreased, which results in a higher resistance and/or a poor effluent quality, the filter bed must be cleaned by back washing. Back washing is flushing the filter with air from the bottom at high rates (700-1100 m^3/h) and reversing the water flow (Figure 3.9.).

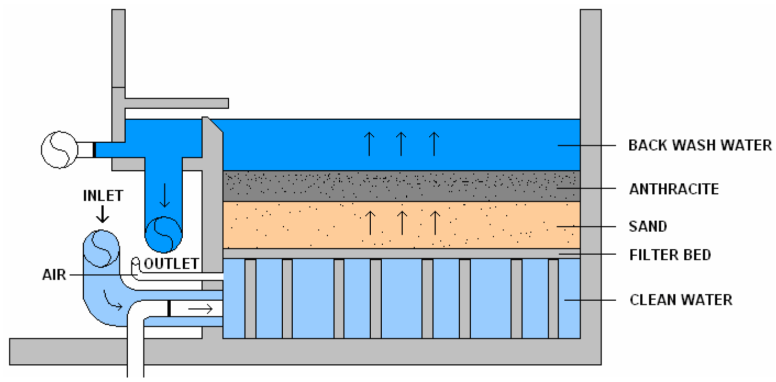

Figure 3.9. Backwashing of Rapid Sand Filtration

These rates are so high that an expansion of the filter bed occurs, causing the accumulated suspended solids between the grains to loosen and be removed. The air wash cycle lasts for about three minutes. After that, the backwash cycle starts with water flowing up through the filter bed[6]. Clean water from the clean water reservoirs is passed through the filter bed in order to wash it and remove most of the accumulated particles deposited on it. After passing the filter bed, the back wash water is transported to treatment of backwash water and sludge. This cycle continues until the backwash water looks clean. The combination between clean water and air is used for back washing because by using air, a more turbulent situation is created which facilitates the removal of the solids from the pores. The pipes that are used to transport the water from the clean water reservoir to the rapid sand filtration are the largest pipes in the treatment plant. The process of cleaning this filter is carried out once in five days.

Activated Carbon Filtration

It is used since rapid sand filtration has very little effect on removing the remaining turbidity, taste, odor, and micro pollutants. Principally, the way the water is treated in here is quite the same as the rapid sand filtration but the material that is used in here is activated carbon. Activated carbon is carbon which has a slight electro-positive charge added to it, making it even more attractive to chemicals and impurities. As the water passes over the positively charged carbon surface, the negative ions of the contaminants are drawn to the surface of the carbon granules[3]. In this treatment, the water goes down trough the activated carbon material by the gravitation with the rate of 6 m/h (Figure 3.10.).

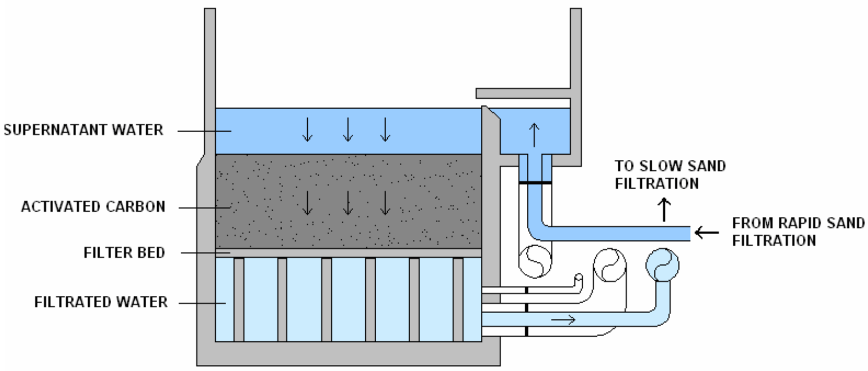

Figure 3.10. Activated Carbon Filtration

The same as rapid sand filtration, after a certain period the pores in a filter bed are filled with accumulated contaminants. Hence, this treatment is needed to be cleaned every 2 weeks with the rate of 550-875 m^3/h and as the carbon activity decreases over time; it must be reactivated every 1-1.5 years (Figure 3.11.).

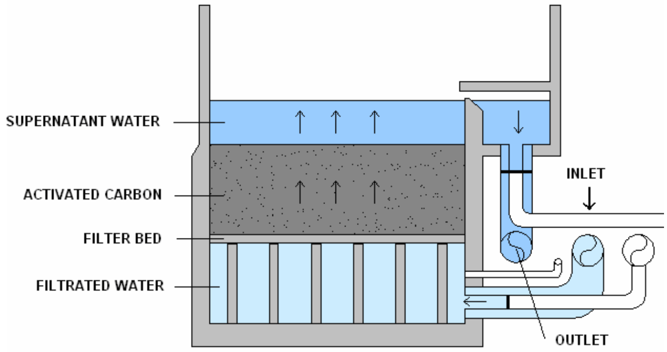

Figure 3.11. Back Washing of Activated Carbon Filtration

Slow Sand Filtration

In here, the filter material has a small grain size, around 0.2 to 0.6 mm and the treatment rate is only 14-17 cm/h. This treatment is suitable to remove suspended solids, bacteria, and viruses and an alternative for chemical disinfection. Actually, if the rapid sand filtration and activated carbon have been applied in the treatment, the presence of the slow sand filtration is not necessary anymore. But, as the slow sand filtration has already existed in the pump station, it will still be used as part of the treatment process.

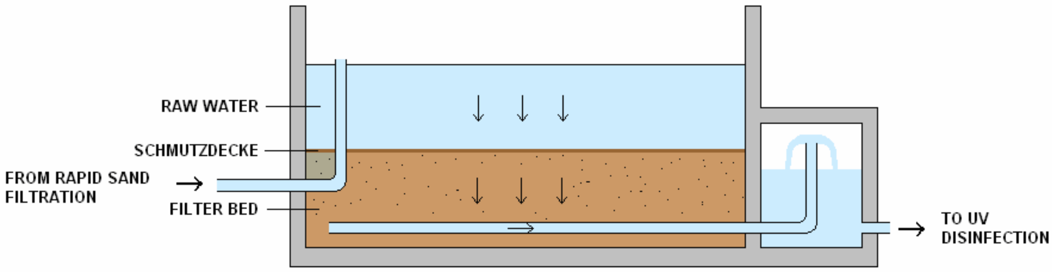

Figure. 3.12. Slow Sand Filtration

Slow sand filtration work through the formation of a gelatinous layer, consists of bacteria, fungi, protozoa, rotifera and a range of aquatic insect larvae, called *Schmutzdecke* in the top few millimetres of the fine sand layer (Figure 3.12.). The *Schmutzdecke* is the layer that provides the effective purification in potable water treatment, the underlying sand providing the support medium for this biological treatment layer. As untreated water percolates slowly through the *Schmutzdecke*, particles of foreign matter are trapped and dissolved, organic material is adsorbed and metabolised by bacteria, fungi and protozoa. And then the water will be drained from the bottom. Slow sand filters slowly lose their performance as the *Schmutzdecke* grows and thereby reduces the rate of flow through the filter. It means the cleaning of slow sand filtration is now necessary. To clean it, the upper sand layer (usually 1 cm) is scraped since filtration occurs mainly in the top layer of a slow sand filtration. As it treats the same water flow as activated carbon filtration and the treatment rate is only below 1 m/h, thus an enormous amount of area is required (Figure 3.13.).

Figure. 3.13. Existing Slow Sand Filtration in De Punt

UV Disinfection

According to Netherlands' regulations, drinking water should contain none to minimum amounts of Escherichia coli bacteria only. UV disinfection will be applied in order to destroy the bacteria, by irradiating them with UV-light. Besides, UV disinfection is a relatively safe and easy way to disinfect.

Cascade Aeration

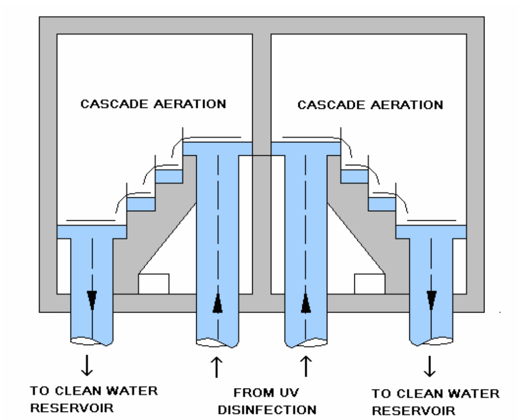

Figure 3.14. Cascade Aeration

It is the process where the oxygen is brought into the water before the water is stored in the clean water reservoir and is required because the content of the oxygen in the water is very low after passing previous treatment. The amount of oxygen in the water after passing the slow sand filtration is 3 mg/liter whereas the required amount of the oxygen is 6-8 mg/liter. Here, the water falls over different weirs to the lower part and air bubbles are forced into it and, because of the turbulence, these separate into many small air bubbles (Figure 3.14.)

Clean Water Reservoir

After the surface water treatment is completed, the clean water will be stored in the clean water reservoir. From here, then the clean water will be supplied to consumers via distribution pumps.

Treatment of Backwash Water and Sludge

The backwash water production is usually 2 - 4% of the total drinking water production. It is produced by strainers, sedimentation, rapid filtration, activated carbon filtration, and slow sand filtration. Some chemicals will be added to the backwash water so the effluent will flow back to the Drentse Aa whereas the sludge will be taken and reused by a company named Reststoffenunie.

3.3. Final Design

In order to accommodate all the future surface water treatment above, mechanical and electrical parts will be renewed, some buildings will be demolished, and five new buildings will be built (Appendix 2 and 3). They are intake intake and raw water pump station *(inlaatwerk)*, filtration and disinfection pump building *(filtratie desinfectie pompgebouw)*, clean water reservoir *(reinwater reservoir)*, treatment of backwash water and sludge *(slibverwerking)*, groundwater pump station *(pompgebouw groundwater).* Filtration and disinfection pump building consists of rapid filtration, activated carbon filtration, UV disinfection, and cascade aeration.

As described in Chapter II that designing the drinking water pump station should pass through a phase procedure, this project also passes that phase procedure. The identification, definitions, and preliminary design were carried out by Witteveen+Bos whereas the final design is now being designed by DHV. There are two big differences between the preliminary and final design (Table 3.3.); the treatment process and the hydraulic line (Appendix 4 and 5)

Table 3.3. The Differences between Preliminary Design and Final Design

Description	Differences		Reason
	Preliminary Design	**Final Design**	
Cascade aeration	No	Yes	The level of oxygen in the water is very low
Hydraulic line (Appendix 5 and 6)	The level in rapid sand filtration is lower than activated carbon filtration, so a pump is needed	The level in rapid sand filtration is higher than activated carbon filtration, so fall by gravity	Cheaper

During the final design, the hydraulic line is the basis of placing the buildings. Besides, the characteristics and requirements of each building, components that are not immediately involved in the treatment process such as air conditioning, pressurized air facilities, workshop, etc will also be considered while the buildings are being designed. Thus in this stage, there will be some changes so that the design fits with the existing pump station and constructable during the construction phase. The life time design of the building will be 50 years. The investment cost and phases of renovating the pump station will also be determined in this stage.

In the next paragraph are the description of the final design of each building and the changes between preliminary and final design.

3.3.1. Intake and Raw Water Pump Station *(Inlaatwerk)*

There will be some changes from the preliminary design to the final design (Table 3.4.) The new intake and raw water pump station building will be built and located near by the Drentse Aa and the existing intake (Appendix 6 and 7). As functioned to take and pump the raw water, this building is not only equipped with strainer but also designed with two levels to accommodate the strainer and two pumps. Between the pumps, a valve is placed so that if one of them is out of order, another one can directly take over. Moreover, the building will be built on the level of -1.45 NAP because the pumps in this building should be located below the water level considering to air cavitations which cause loss in the pump's capacity (Figure 3.15.).

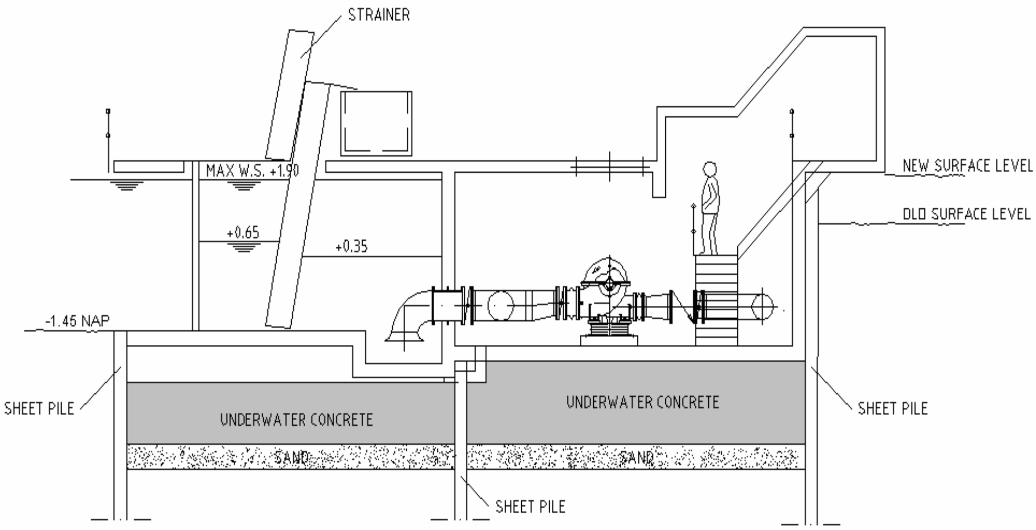

Figure 3.15. Cross Section of Intake and Raw Water Pump Station

In order to obtain a water tight building, the parts of this building that are under surface level will be made of concrete whereas the construction parts that are above the surface level will be made of steel. Thus, leakage can be prevented.

Besides, the water level in the Drentse Aa is very high during the winter, around +1.90 NAP. Therefore to construct the building, sheet pile should be driven in to the ground to accommodate a continuous barrier in the ground. The sheet pilings reach two meters above NAP. Then the soil will be excavated from the construction pit so that a layer of underwater concrete can be poured in to the construction pit. This layer will secure the construction pit against the groundwater pressure. After the construction pit has a watertight floor, the water can be pumped out and the actual construction work can be started. At the end of construction of the building, the sheet pile will remain on the ground because the location of building is adjacent to the Drentse Aa thus it will requires special auxiliary to remove it and to prevent the possibility that the building's structure will be damaged. The total cost to build this building is estimated to be € 312.245,87 including the cost for excavation and the sheet piles (Appendix 8).

Table 3.4. Preliminary to Final Design of Intake and Raw Water Pump Station

Description	**Differences**		**Reason**
	Preliminary Design	**Final Design**	
Stair	One side on the left corner	Two sides on the middle	Convenient to climb from both sides of the pump
Wood barrier	No	Yes	To decrease the influence of water streamline
Strainer	Two types, coarse and fine	One	There is already a wood barrier in front
Height of the pump reservoir	2,750 m	3,500 m	The pump can absorb much more water
Bottom level of the pump's pipe	Flat	Deeper	To increase the pump's suction capacity

3.3.2. Filtration and Disinfection Pump Building *(Filtratie Desinfectie Pompgebouw or FDP)*

There will be some changes from the preliminary design to the final design (Table 3.5.) The final FDP consists of three levels and accommodates some treatments such as rapid sand filtration, activated carbon filtration, cascade aeration, and UV disinfection (Appendix 9-17). Distribution pumps, blowers, transformator, control room, low voltage room, and chemical room will also be placed here.

Table 3.5. Preliminary to Final Design of FDP

Changes	**Description**
Level of building	In preliminary design, the level of rapid sand filtration is lower than the level of activated carbon filtration so pumps are required
	In final design, the level of rapid sand filtration is higher than the level of activated carbon filtration so the water can flow directly to activated carbon filtration
Function of building	In the final design, the distribution pumps are located in this building whereas in preliminary design the distribution pumps are located separately. Besides, the building is redesigned to accommodate components that are not immediately involved in the treatment such as control room, trafo room, etc which have not been determined before
Cascade aeration	As it is the additional treatment designed by DHV, the treatment will also be located in this building
Dimension of building	The dimension of the building is also readjusted because it accommodates more components

As the water from rapid sand filtration is expected to fall gravidity to activated carbon filtration, the rapid sand filtration will be located on higher level than active carbon filtration, cascade aeration, UV disinfection, distribution pumps, and control room (Figure 3.16.). Thus, due to the difference elevation of bottom level, the building will be a unity of four separated buildings with three dilatations (Figure 3.17.).

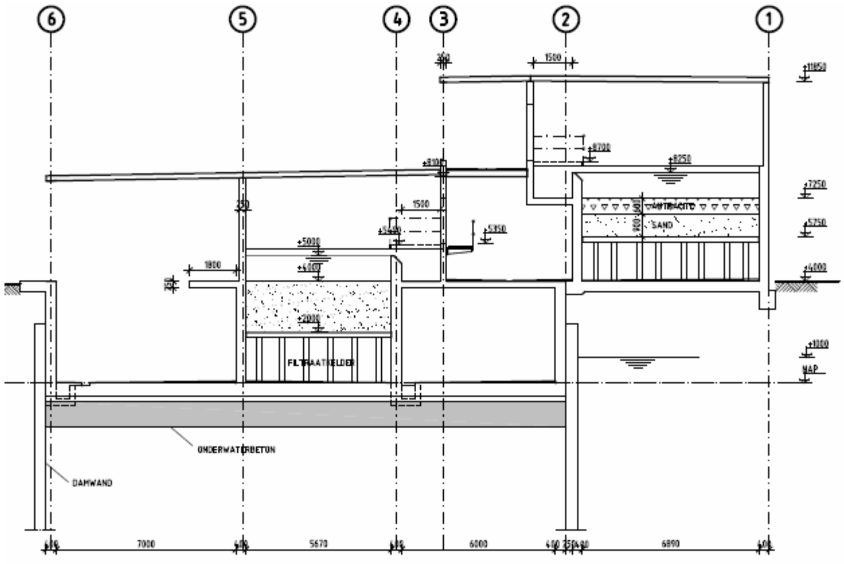

Figure 3.16. Cross Section of the FDP

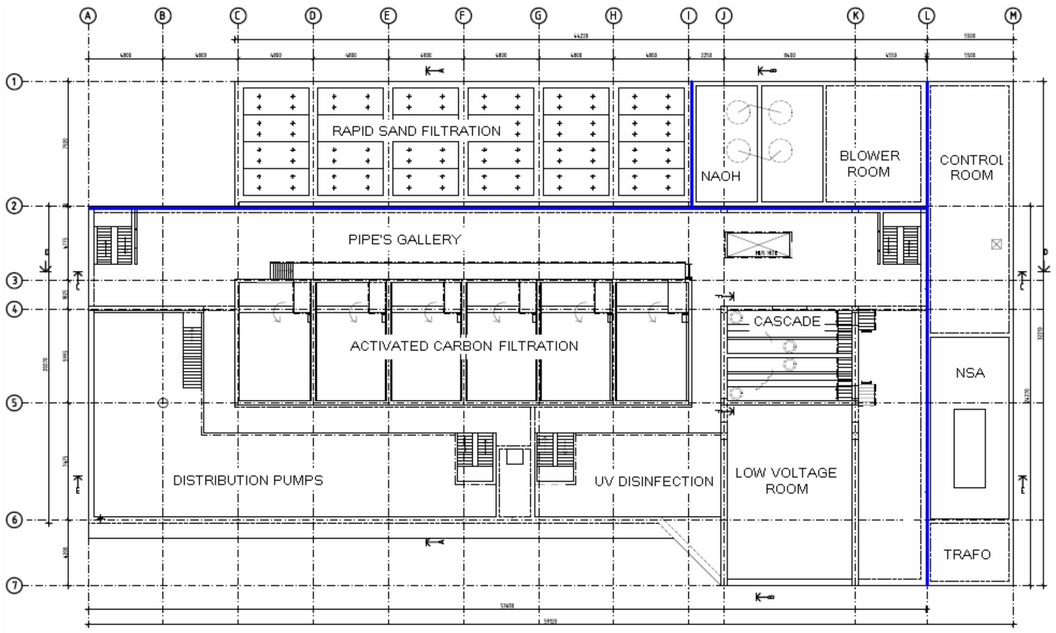

Figure 3.17. Four Buildings in the FDP

The main building will be constructed below the ground water level so that sheet pile will be drilled in to the ground to accommodate a construction pit. And then, the same as intake and raw water pump station, the soil will be excavated and the underwater concrete will be poured to form such a layer that can secure the construction pit against the groundwater pressure. To get a water tight structure, the building will be made of reinforced concrete.

As rapid sand filtration and activated carbon filtration have special requirements, some considerations should be taken into account while designing.

Rapid sand filtration

The rapid sand filtration building consists of six filters so that the maintenance and filter backwashing can be done without interrupting the production of drinking water. The number of filter is determined based on the production capacity of the plant.

The yearly capacity is 7 million m^3/y, the average production is 765 m^3/h and the maximum production is 840 m^3/h. While the filtration rate in this filtrate is 4.6 m/h, thus the required area for filter bottom is182.6 m^2, around 30.3 m^2 per filter with six filters. The shape of the filter bottom is rectangular with the measurement of 4.4 m x 6.89 m.

The height of the tank is 4.25 m, including 1 m of the supernatant water, 1.5 m of the filter bed, and 1.75 m of filtrate reservoir. The filter bottom consists of four concrete slabs and consists of 1424 nozzles. To drain the water, the nozzle is placed in the distance of 142.4 mm x 142.4mm, so that each of them can distribute the same amount of water.

The filter will be located in its own enclosed space. In this way, the maintenance will be possible for every filter without causing microbiological contamination. The level of the supernatant water in the rapid sand filtration is +8.25 NAP and the bottom level of filtrate reservoir is +4.00 NAP. This building is positioned in the higher level so that the water can flow directly to the activated carbon filtration without existence of pump.

Activated Carbon Filtration

The principal design of the activated carbon filtration is the same as rapid sand filtration. It also consists of six filters and numbers of nozzles on the filter bottom. The filter bed consists of activated carbon grains. Due to the different rate is applied; the required area and the distance between nozzles will be different.

The filtration rate in the activated carbon filtration is 6 m/h. Thus to filtrate 840 m^3/h of water, the area that is needed is around 140 m^2 or 23.3 m^2 per filter with the measurement of 4.4 m x 5.67m.

The height of this tank is 5 m, including 1 m of the supernatant water, 2 m of the filter bed, and 2 m of filtrate reservoir. The bottom of the filter consists of three concrete slabs and consists of 1332 nozzles per filter. The nozzle is placed in the distance of 133.2 mm x 133.2 mm to drain the same amount of water. The bottom level of the activated carbon filtration is +0.00 NAP.

UV Disinfection

There is no special requirement for placing the UV disinfection installations. The UV disinfection installations will be placed on the same level as active carbon filtration's reservoir so that the water from activated carbon filtration can be flown directly to UV disinfection.

Cascade Aeration

Cascade aeration will be conducted in two separate rooms. It is intended for back up while one of the pumps is out of order, so that the production of the water will not be interrupted. Each of cascades consists of four steps with a total height of about 1.2 meters to bring oxygen into water. The level of the highest step is +6.20 NAP and the level of the lowest step is +5.00 NAP. The cascade aeration will be made of concrete.

3.3.3. Clean Water Reservoir *(Reinwater Reservoir)*

There will be some changes from the preliminary design to the final design (Table 3.6.) Treated water reservoir for drinking water has to comply with a large number of requirements because of the quality aspects of drinking water. First of all, the treated water reservoir will be located next to the filter building in order to make the shortest length of the distribution pipe (Appendix 18 and 19). The distribution pump is located inside the filter building so that the treated water from the reservoir should be flown back to the filter building, then distributed to the consumers. The shorter the pipe length, the less energy and costs will be spent.

Table 3.6. Preliminary to Final Design of Clean Water Reservoir

Changes	Descriptions
Level of the reservoir	In preliminary design, the level of reservoir is -1.25 NAP whereas in final design, the level of reservoir is +1.50 NAP
Capacity of the reservoir	The capacity is decraesed from 2 x 3830m³ to 2 x 2500m³ due to the demand of clean water
Number of luik	There are two more manholes in the final design for safety, preventing people from trapped in the reservoir

The reservoir has to be well sealed, not only to protect against weather influences, but also against human, animals, and insects. However, complete hermetical sealing is not possible because a reservoir has to "breath." While a reservoir is filling, air has to leave, and during emptying, air has to enter. Besides, drinking water should not remain in a reservoir for too long because the quality could decline due to bacteriological growth. Therefore, a treated water reservoir should have an air filter in order to have a good circulation.

Air filter is placed in a manhole, which will be situated in the roof (Figure 3.18.). At here, a manhole is a 2.54 m x 1.83 m aluminum suitcase which consists of entrance box and air filter. The entrance box functions as an access either for people coming in or out in order to place equipments inside or clean the reservoir. The only reason that there should be two entrance boxes is for safety, preventing people from trapped in the reservoir and escaping in emergency. Overall, this manhole will have two sensor locks for providing the water from poison given.

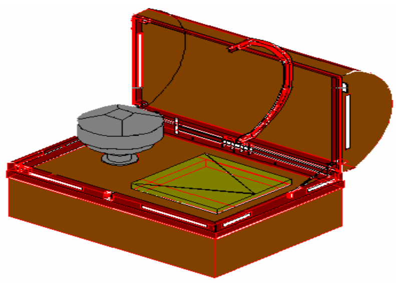

Figure 3.18. A Manhole (*Luik*) with Air Filter and Entrance Box inside

In practice large reservoirs will never be completely water tight. Due to the settling and aging of the construction material, small cracks are unavoidable. Anticipating such a "leakage", the treated water reservoir is situated in such a way that the lowest water level in the reservoir is above the highest groundwater level. In this case, the reservoir will be built one meter above the groundwater to prevent "contaminated groundwater" from entering the reservoir.

A reservoir has to be inspected and cleaned regularly. After cleaning the reservoir, the rinse water has to be drained well. The reservoir bottom and roof are constructed at a slope. After maintenance and inspection, the reservoirs have to be thoroughly disinfected. Over several days, water with high chloride content is stored in the reservoir. It is subsequently rinsed out, and the water is checked to determine if it is bacteriologically reliable again. Thus, there should be two clean water reservoirs so that when one reservoir either needs to be cleaned or the water is infected, the water from another reservoir will be able to be distributed.

Every reservoir is equipped with three types of pipe: supply, discharge, and overflow pipe. The supply pipe is subjected to supply the water from cascade aeration every day whereas a discharge pipe is used to flow the treated water into the distribution pump. The height of the reservoir will be +5300 NAP since the deeper the reservoir, the thicker the under water concrete, and the more investment should be spent. Moreover, in The Netherlands, there is a regulation of maximum height for excavation below the groundwater level otherwise penalty will be got.

An emergency overflow prevents the water from touching the roofs of the reservoir. Its purposes are to prevent the decline of the water quality and avoid damage to the roof construction due to unexpected upward forces. Treated water reservoir may not completely empty during the operation period, because sediment will resuspend from the bottom. Here, a minimum water level of 1.6 m is used. Reinforcement concrete will be the structural material of the reservoir in order to be waterproof (Appendix 20). The capacity of the treated water reservoir is 2 x 2500 m^3 equals to 25 % from 840 m^3/hour (max. day). The investment cost of this building is estimated to be € 1.013.879,92 (Appendix 21)

3.3.4. Treatment of Backwash Water and Sludge *(Slibverwerking)*

This building is built for backwash water treatment (Appendix 22). It consists of buffer reservoir and a treatment installation (cascade, sludge trickling filter, lamella separator, thickener, and sludge storage) (Figure 3.19.). The buffer reservoir consists of two reservoirs which can both store two backwashes, from surface water and ground water, each with the capacity of 300 m³.

First, the backwash water comes into buffer reservoir, then pumped out to the cascade, fall by gravity to the sludge trickling filter, transported to the lamella separator, pumps to the sludge thickener, and pump again to the sludge storage. After that, there will be a truck which takes the sludge in the height of +3.6 NAP and reuses it as an additive for the production of bricks or as phosphate binder (after acidification) in wastewater treatment. The sludge thickener and storage are used to thicken further the settled sludge or concentrated backwash water.

In the sludge storage, there will be a discharge pump in level +6.93 NAP, so if the effluent passes that level, the effluent will be transported back to the Drentse Aa. In the preliminary design, Witteveen+Bos did not designed the treatment of backwash water.

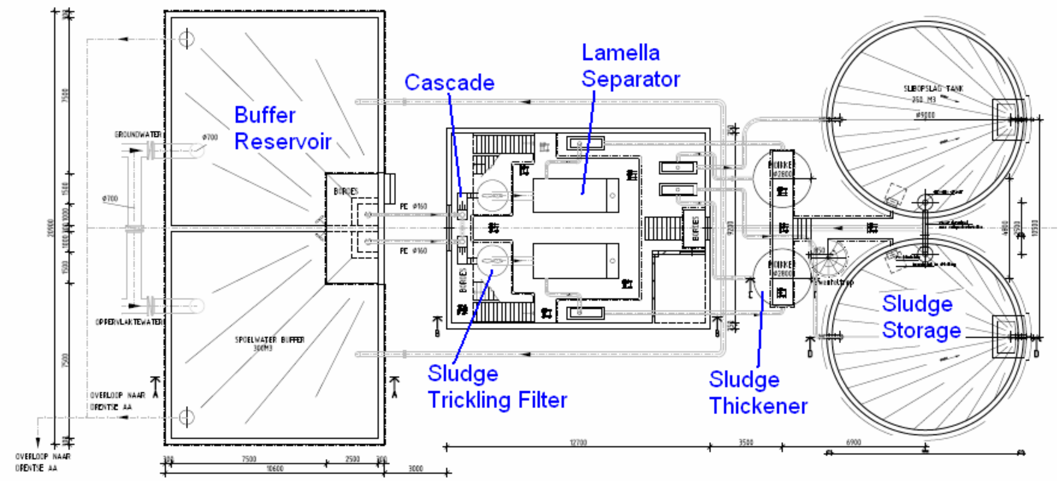

Figure 3.19. Treatment of Backwash Water and Sludge

3.3.5.Groundwater Pump Station *(Pompgebouw Groundwater)*

There will be some changes from the preliminary design to the final design (Table 3.7.) This pump station is located near by the existing groundwater reservoir and used to transport the clean groundwater from the reservoir to the distribution area (Appendix 23 and 24). It consists of two levels; the underground structure will be used as pump cellar where all the distribution pumps are located whereas the upper structure will be used as operation, control, transformator and machinery rooms.

Table 3.7. Preliminary to Final Design of Groundwater Pump Station

Changes	Descriptions
Bottom level of the pump station	In preliminary design, the bottom level of the pump station is + 0.23 NAP whereas in final design, the level of reservoir is - 1.9NAP
Dimension of the pump station	The dimension in final design is a bit bigger since bigger rooms are designed
Number of manhole	There are two manholes in the preliminary design but not in the final design

Besides designing the buildings it selves, in the final design, the construction phase should also be considered as the water supply may not be obstructed during the construction and transition from the old to the new plant.

Bellow is the general construction phases of renovating this pump station (Appendix 25-36):

- First of all is to build the intake and raw water pump station
- Install the new pipe connection from the intake to the reservoir without obstruct the existing pipe thus the intake of water from Drentse Aa will not be destroyed. As the new pipe connection pass the existing building, the building will be demolished first before the pipe connection is installed
- Build the groundwater pump station which is located in front of the groundwater reservoir. Since the new distribution pumps takes place in the area where there is already the existing pipe which supply the water from the reservoir (GW2) to the existing distribution pumps, the existing pipe should be demolished first before the building is built. And then a temporary pipe that connects the reservoir with existing distribution pump will be installed. In this case only one reservoir (GW1) will be used to supply water to the existing distribution pumps the supply of clean water from the clean water reservoir may not be stopped.
- Built the filtration and disinfection pump building, clean water reservoir, and treatment of backwash water and sludge.

- After all new buildings are built, the pipes connections are installed to connect one building to each other, including the new distribution pipes. In this phase, three slow sand filtrations will be out of order since the pipes will be renewed and the process will be change. The new pipes of these filtrates will be connected to the new filtration and disinfection pump building whereas in the previous the pipes are connected to the reservoir.

  In this phase, two slow sand filtrations will still produce the drinking water besides the groundwater. Thus the production of the water will not be obstructed.
- When all new buildings and the pipe connections are ready, the start-up of the production process will be conducted. Only after it has been proved that the plant produces reliable drinking water, can the water be supplied to the distribution network. Then the pipes of the two slow sand filtrations will be renewed and in this phase, the production of drinking water from groundwater and surface water will be truly separated.
- Demolished the existing building

Chapter IV
DRINKING WATER PUMP STATION IN INDONESIA

4.1. General Condition

Situated along the equator, Indonesia is an archipelago, consisting of 17,508 islands which 6000 islands are inhabited and 60% of the total area is sea territory (Figure 4.1.). The amount of water in Indonesia fluctuates by season and is distributed differently among the regions. In general, 60% of Indonesian regions have an annual rainfall of about 2 000 - 3 500 mm whereas 3% have annual rainfall over 5000 mm and others having rainfall of less than 1000 mm annually. This data indicates that Indonesia with its humid tropical climate gets uncountable natural abundance in the form of high rainfall, though in certain areas occasional water shortages or drought takes place.

Figure 4.1. Map of Indonesia

However, only 10% of the average annual rainfall (2700 mm) infiltrates and percolates as groundwater, which is an average of 278 mm. The remaining (larger) portion flows as runoff or surface water (1832 mm). If this water- groundwater and surface water- can be managed properly, it would be readily available with a total amount of about 2100 mm annually. Total water storage capacity in terms of area in Indonesia is about 13.75 million ha - consisting of lake storage (1.78 million ha or 13 percent), dam and reservoir storage (50000 ha or 0.4 percent), rivers (2.9 million ha or 21 percent) and inland swamp/polder (9 million ha or 65 percent).

Nonetheless, up until this moment the government is still confronted with the difficulties to provide its habitants with clean and reliable drinking water. In Indonesia, the water that comes out of the taps is not potable and should be boiled before drinking or using in cooking. Urban water supply in Indonesia is generally under control of PDAM (*Perusahaan Daerah Air Minum*) or Regional Water Supply Company besides sometimes cooperating with private company. PDAM is owned by the local government, be it on city or district. At present, there are around 300 PDAM throughout Indonesia that abstract the raw water - from 201 river, 248 springs, and 91 arthesis wells- treat and purify the raw water, then connect the households with pipes and distribute the drinking water. Recently, at least 40% urban citizen and more than 70% rural citizen has no access to piped water. Thus, large number of people is still using raw water from river for drinking water.

The sources of drinking water in Indonesia are groundwater, surface water, and spring where surface water contributes the most.

<u>Groundwater</u>

Groundwater is crucial for human drinking and food security, especially in the developing countries like Indonesia. The impact of groundwater use is positive and included such benefits as increased productivity, food security, job creation, and livelihood diversification and general economic and social improvement.

However, only 15% of drinking water is derived from groundwater since the resources of groundwater is limited and the impact of groundwater extraction might be negative especially in over-exploitation situation, such as permanent lowing of the water table, deterioration of water quality or contaminated, saline intrusion in coastal area, etc[7]. In Indonesia, every household has the right to exploit groundwater as long as it located in unconfined layer. Thus these wells are referred to deep wells where in fact there are a lot of households withdrawing groundwater from confined aquifer without possessing a license.

Surface water

As covered with large amount of water, the sources of surface water in Indonesia are available in large amount and abstracted from river, lake, and seas. Around 60% of Indonesia's piped water supplies are derived from surface water[7]. However the availability of clean water in term of quality tends to decrease due to environmental degradation and pollution.

Spring

Beside those two sources, the drinking water can be abstracted from the spring. A spring is a place on the earth's surface where groundwater emerges naturally. The water source of most springs is rainfall that seeps into the ground uphill from the spring outlet. In Indonesia it usually can be found in the hill or mountain. As the water that comes out from spring contains minerals and has water flavour, spring water is often consumed directly without boiling first. Springs do not provide enough water for the entire city, thus it only contributes around 25% of drinking water supply[7].

Regional Water Supply Company applies a water quality standard subject to the Decree of the Ministry of Health number 416/MENKES/X/PER/1990 (PERMENKES 416/1990). There are two standards, one for potable water and the other for clean water which should be boiled first before drinking (Table 4.1.).

In Indonesia, 74.1% of water is used for irrigation since agriculture is the most important sector, 11.34% is used for domestic, municipal, and industries, and 11.53% is used for fishpond and livestock.

In 2002 domestic water consumption in Indonesia is amounted to be 185 l/p/day which 45% is used for bathing. Moreover, only 47% water production from Regional Water Supply Company is distributed to the customer. It means around 53% is lost. The losses of water distribution are usually caused by the leakage of the distribution pipes, illegal use, and billing error[8]. The consumption of clean water is still predicted to be high, but the water quality is deteriorating by domestic and industrial waste.

Table 4.1. Typical Quality Standards for Drinking Water in Indonesia

PARAMETER	UNIT	MAXIMUM CONCENTRATION/LEVEL ALLOWED	
		Drinking Water Standard*	Clean Water Standard**
A. Physic:			
1. Odour	-	No Odour	No Odour
2. Total Dissolved Solid	mg/l	1 000	1 500
3. Turbidity	NTU scale	5	25
4. Taste	-	No Taste	No Taste
5. Temperature	°C	Air temperature + 3 °C	Air temperature + 3 °C
6. Colour	TCU scale	15	50
B. Chemical:			
a. Inorganic			
1. Mercury	mg/l	0.001	0,001
2. Aluminium	mg/l	0.2	-
3. Arsenic	mg/l	0.05	0,05
4. Barium	mg/l	1.0	-
5. Iron	mg/l	0.3	1.0
6. Fluoride	mg/l	1.5	1.5
7. Cadmium	mg/l	0.005	0.005
8. Hardness (CaCO3)	mg/l	500	500
9. Chloride	mg/l	250	600
10. Cr +6	mg/l	0.05	0.05
11. Manganese	mg/l	0.1	0.5
12 Sodium	mg/l	200	-
13. Nitrate, as N	mg/l	10	10
14. Nitrite, as N	mg/l	1.0	1.0
15. Argentums	mg/l	0,05	-
16. pH		6.5 - 8.5	6.5 - 9.0
17. Selenium	mg/l	0.01	0.01
18. Zinc	mg/l	5.0	15
19. Cyanide	mg/l	0.1	0.1
20. Sulphate	mg/l	400	400
21. Sulphide	mg/l	0.05	-
22. Cooper	mg/l	1.0	-
23. Lead	mg/l	0.05	0.05
b. Organic			
1. Aldrin and Dieldrin	mg/l	0.0007	0.0007
2. Benzene	mg/l	0.01	0.01
3. Benzo (a) pyrene	mg/l	0.00001	0.0007
4. Chlordane (total isomer)	mg/l	0.0003	0.007
5. Chloroform	mg/l	0.03	0.03
6. 2,4 D	mg/l	0.10	0.1
7. DDT	mg/l	0.03	0.03
8. Detergent	mg/l	0.05	0.05
9. 1,2-Dikloretan	mg/l	0.01	0.01
10. 1,1 Di-chloro-ethane	mg/l	0.0003	0.0003
11. Heptachlor and Hepachlorepoxide	mg/l	0,003	0.003
12. Heksachlorobenzene	mg/l	0.00001	0,00001
13. Gamma-HCH	mg/l	0.004	0.004
14. Metoxiklor	mg/l	0.03	0.10
15. Pentachlorophenol	mg/l	0.01	0.01
16. Pesticide total	mg/l	0.10	0.10
17. 2,4,6-trichlorophenol	mg/l	0.01	-
18. Organic Compound (KMnO4)	mg/l	10	-

4.2. Drinking Water Treatment

4.2.1. Ground Water Treatment

In Indonesia, the ground water is usually abstracted by drilling the ground until unconfined layer. A typical domestic setup consists of a well pump that lifts the water from the well and pumps it into a bucket (Figure 4.2.).

Figure 4.2. Groundwater Hand Pump

Then, the water will be directly consumed without certain treatment. Most renewable groundwater has high quality for domestic use and does not require treatment. But sometimes the groundwater can be contaminated. Unsafe drinking water is the major cause of diarrhea and water-borne diseases in Indonesia.

4.2.2. Surface Water Treatment

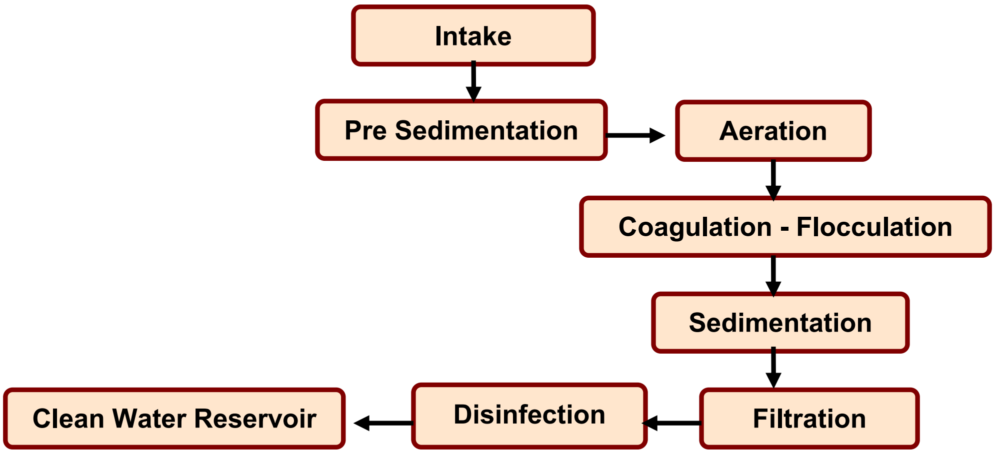

Figure 4.3. The Scheme of Surface Water Treatment in Indonesia

There are three types of processing of surface water as follow (Figure 4.3.)[9]:

- Physical process, to remove the suspended solid such as floating material, sand, and organic compounds and carried out by bar screen, sedimentation, and filtration.
- Chemical process (aeration, coagulation, flocculation, and neutralization.), to remove undesired compound in the water by adding chemical organic.
- Bacteriological process, to kill all the bacteria that presents in the water by disinfection.

Intake

Usually the raw water is abstracted from the source that is far from the plant. Figure 4.4. shows the intake of drinking water pump station in one of treatment plant in Surabaya, Indonesia.

Figure 4.4. Intake

Canal

Then the raw water from the source will be transported through a canal (Figure 4.5.)

Figure 4.5. Canal

Pre sedimentation

Pre sedimentation is a self purification process to dissociate the raw water with suspended material such as silt, coarse or fine sand (Figure 4.6.). Gravitationally, the suspended material will settle in the bottom of the reservoir. This is the preliminary treatment intended to decrease the load so that the next treatment will not be heavily loaded. This is very effective to process the raw water which has high turbidity level.

Figure 4.6. Pre Sedimentation

Aeration

Aeration (Figure 4.7.) is also one of the preliminary treatments to increase the level of dissolved oxygen in the water and, decrease the amount of H_2S, Fe, Mn, CO_2, and detergent. Thus anaerobic process in the next treatment can be prevented.

Figure 4.7. Aeration

Coagulation – Floculation

After passing the pre sedimentation and aeration, the water still contains smaller compounds that must be removed. As the compounds are very small, it should be made larger and heavier by adding coagulant (Figure 4.8.). The common coagulant that is used is $Al_2(SO_4)_3$.

Figure 4.8. Coagulation

Sedimentation (Clearator)

After the coagulant has been added, the compounds will be larger and heavier. Then it will be removed by gravitation in the sedimentation (Figure 4.9.). Besides, the polymer is also added in this treatment.

Figure 4.9. Sedimentation

Filtration

Rapid sand filtration is the only type of filtration applied in the surface water treatment. It is intended to remove the remaining suspended material from previous stage by trapping the suspended material in the filter bed (Figure 4.10.). There are two types of material for the filtration bed; single and dual send media (combination between sand and anthracite).

Figure 4.10. Filtration

Disinfection

The main purpose of disinfection is to fulfil the bacteriological requirement for drinking water, to remove the pathogen bacteria. The common disinfection is chlorine with contact time of 20-30 minutes. The amount of remaining chlorine is 0.05-0.2mg/l. The contact time and the amount of remaining chlorine are determined by the amount of ammonia presents in the water. Another way for disinfect the water is using the ozone, requires less time than chlorine.

<u>Clean Water Reservoir</u>

Figure 4.11. Clean Water Reservoir

This is the latest stage of treating the drinking water. After the water has been disinfected, it will be stored in the clean water reservoir and the will be distributed to the customer (Figure 4.11.).

4.3. Phase Procedure of Designing Drinking Water Pump Station

The phase procedure of designing the drinking water pump station in Indonesia is regulated according to Government Regulation Number 16 in 2005 (*Peraturan Pemerintah Republik Indonesia no 16 tahun 2005*) [10]. Designing pump station should through four stages; project planning, feasibility study, engineering design, and building (Figure 4.12.).

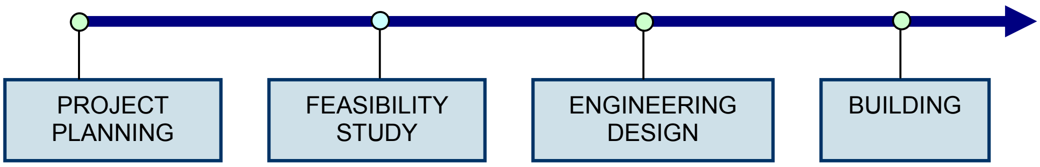

Figure 4.12. Phase Procedure of Designing Drinking Water Pump Station in Indonesia

<u>Project planning</u>

Initiating construction project of drinking water pump station is part of Regional Water Supply Company's (*PDAM*) regular business. In this phase, the plan of making drinking water pump station is arranged and some considerations are taken into account; such as:

- Treatment of drinking water
- Regulation and strategy of drinking water pump station
- Environmental, social, economic, and culture condition

- Future master city's plan

During this phase, before the project planning is implemented, the project planning will be socialized through public consultancy to refine and to get response from the society in intended area. After that, in the final part of this phase, the project planning should at least consist of:

- General plan
- Network plan
- Future development of drinking water pump station
- Criteria and standard of service
- Plan of raw water allocation
- Integrity of drinking water pump station with sewerage water system
- Financing and type investment
- Design of project organization

Feasibility study

After the project planning has been arranged, the drinking water company will start to do the feasibility study. Feasibility study will be done based on:

- Project planning that has been determined in the previous stage
- Analysis of technological, environmental, social, economic, and culture impact
- Analysis of source of investment

Engineering design

Engineering design is arranged by considering:

- Project planning that has been determined in the previous stage
- Feasibility study
- Time schedule for construction
- Source of investment

At least, engineering design should consist of:

- Technical design which encompass detail design, phase and time schedule of construction
- Calculation and technical drawings
- Technical specification

- Document for construction

This phase will be done by consultant company which is selected from bidding process and qualified for government project.

Building

The final part of designing drinking water pump station is to construct the building and it should be based on:

- Project planning that has been determined in the previous stage
- Feasibility study
- Engineering Design

The building can be either constructed by the water company (in case the water company has the qualification of constructing a building) or another construction company through a bidding. While the building is constructed by the contractor, the supervision and inspection of construction should be carried out by the drinking water company to adjust the construction progress and principal.

After the building is ready, the drinking water company will take over and they should maintain the water pump station routinely and periodically. Moreover, after a certain period of time the drinking pump station should be renovated or demolished based on the Ministry's Regulation *(Peraturan Menteri)*.

Chapter V
COMPARISONS BETWEEN DRINKING WATER PUMP STATION IN THE NETHERLANDS AND INDONESIA

5.1. General Condition

Obviously, the main difference between the drinking water in The Netherlands and Indonesia is that drinking water in Indonesia is not reliable to drink even in places where water is piped into homes. The water that comes out of the tap is not potable and should be boiled first.

The Indonesian's water companies usually get water mainly from the ground, surface, and spring which is usually contaminated. Many households dispose of their waste directly into rivers and canals and many factories also dump their waste into rivers without treatment such as small scale industries, agriculture, textile, pulp and paper, petrochemical, mining, and oil and gas. The result of water quality monitoring in 30 rivers in Indonesia indicates that most of river water quality do not meet water criteria class 1 (drinking water raw based on Government Regulation Number 82 in 2001). It is also reported that the amount of iron (Fe) and heavy metal on ground water sources in Indonesia is beyond water criteria class. The quality of the water is getting worse since there are so many sources are located near the sewerage water system which causes contamination of water with Escherichia coli or other pathogens.

Instead of the bad condition of the source of drinking water, the drinking water quality in Indonesia is getting worse since the drinking water standard in Indonesia itself, as shown in Table 5.1., is not as straight as the Netherlands'.

Moreover the water companies function poorly and sometimes not at all due to no money to renovate and extend the water mains system and lack of advanced technical treatment. The plants are badly designed and maintained. Filters are not replaced on time and also many installation parts are not functioned properly which are resulting in poor quality water. Besides, number of connected area is amounted only about 20%. Many water supply networks are suffering from low pressure and experience problems with continuity of piped water. The average running time of water is only 9 hour a day. Around 60-70% of water leaks away as there are unsuitable pipe network connections, compared to the Netherlands, only 2.5% is estimated to be lost. Also, the availability of drinking water is not equal for every area. For instance Java, with only 4.5% of national clean water potential, needs to support 65% of Indonesia's population of around 210 million lives. This results in water crises during drought seasons.

Table 5.1. The Drinking Water Standard in the Netherlands and Indonesia

Parameter	Unit	Netherlands	Indonesia
E-coli		0/100ml	
Colony count	/ml	100	
Pesticides (per compound)		0.1 µg/l	0.1 mg/l
Bromate		1 (5) µg/l	1 mg/l
Iron	mg/l	0.2	0,3
Manganese	mg/l	0.05	0,1
Ammonia	mg/l	0.2	1.5
Suspended solids	FTE	1 (4)	
Hardness (calcium + magnesium)	Mmol	1-2.5	5
Sodium	mg/l	150	200
Chlorine	mg/l	150	250
pH	-	7.0 – 9.5	6,5-8,5
Temperature	ºC	< 25	30

The business operations in drinking water company itself are also inefficient. There is one employee per 80 connections whereas in the Netherlands there is one employee per 1000 connections. While the drinking water company can not supply sufficient drinking water, there is another fact that makes this problem be more complicated. The water consumption in Indonesia is very high - 185 l/p/d - whereas in the Netherlands, it is only 128 l/p/d. The reason of the high consumption of water in Indonesia is because most of people work in agriculture area (paddy) which required huge amount of water for irrigation.

5.2. Drinking Water Treatment

5.2.1. Groundwater Treatment

In Indonesia, the groundwater will be directly consumed after abstracted. There is no maintenance for groundwater whereas in the Netherlands; the treatment is distinguished by the level of oxygen present in the water.

People in Indonesia drill the ground and abstract the water from the well and will directly drink it. Since there are so many wells located less than 10 meters next to the septic tanks or sewerage system, the groundwater is usually contaminated especially with Escherichia coli. This causes the lack access of safe drinking water source and diarrhea becomes the second most killed disease for children under five years old in Indonesia, more than 100.000 children per year.

5.2.2. Surface Water Treatment

The Netherlands and Indonesia both have the same principal of surface water treatment. Starting by removing suspended soil, adding coagulants to form flocs to remove small particles, then using filtration to trap remaining material from sedimentation, and finally destroy the bacteria by disinfection.

Nevertheless, the surface water treatment in Indonesia is a simple treatment system whereas over the years the surface water treatment in The Netherland has been transformed from simple treatment system into more complex scheme in order to meet standard quality of water and to cope with the increased pollution in the river. The multiple barrier treatment in the Netherlands results in high quality of drinking water production.

Presently, drinking water pump stations in the Netherlands have early warning system such as a fish guarding system. Thus during contamination, the intake in the reservoir is interrupted. The drinking water pump station is also equipped with a monitoring system to measure turbidity, pH, oxygen, conductivity, and temperature.

Moreover, the treatment in Indonesia still uses only one type of filtration, rapid sand filtration and to bring oxygen into water, open aeration is still being used. The Netherlands always includes double filtration system; dual media filtration and granular activated carbon.

In order to remove the micropollutans, chemical process is being used in Indonesia whereas in The Netherlands biological and physical processes are considered to take over the role of the chemical processes of disinfection and oxidation such as activated carbon filtration, UV disinfection, and membrane filtration. It results that the water is biologically stable.

Indonesia is still using chlorine as disinfectant to remove organic and non organic compound. In 1974, it was discovered that chlorination leads to the formation of trihalomethanes which are harmful for the human health. In the Netherlands, chlorine is prohibited due to the health condition, dries and damages skin and hair and causes permanent respiratory problems if it is combined with VOCs. In case of chlorine, ozone and UV/H_2O_2 are widely used.

5.3. Phase Procedure of Designing Drinking Water Pump Station

Even the phase procedure of designing drinking water pump station in Indonesia has been regulated by Government Regulation, drinking water company in Indonesia still experiences difficulties in designing the drinking water pumps station. The limitations of designing this kind of project are insufficient possibilities for financing either new plant or renovating new plant, insufficient knowledge to operate system, and insufficient management. To develop a new drinking water pump station or renovate it, a loan agreement should be achieved first otherwise the project can not be proceeded since that kind of project requires enormous budget. Insufficient knowledge to operate system and management affect and increase complexity of making drinking water pump station.

Moreover, in Indonesia there are only some certain consultant companies that can carry out this kind of project. Hence, problems in supplying drinking water, designing and operating drinking water pump station often happen in Indonesia whereas in The Netherlands is less affected by this issue. In the Netherlands the design of drinking water pump station usually takes years from the time the first idea comes up until the completion and start up of the plant. A highly diverse development process is carried out, involving many different specialties. As a result, during the design process, there are compromises and discussions between the parties involved so that they will have timely insight into the progress and development of the design and the effects on their own role.

Chapter VI
CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

The Netherlands is one of the countries in the world which concerns about the drinking water, not only the quantity but also the quality. It can be seen from its' strict drinking water quality standard regulation. Every source of water either groundwater or surface is treated based on its characteristic to get reliable drinking water. The groundwater is treated based on the amount of oxygen presents in the water and the surface water is treated in two ways; direct and indirect treatment. As many surface water sources are contaminated, multiple barrier treatments are applied to get high quality of drinking water production.

The sufficient knowledge to operate system, possibilities for financing the pump station and management sustain the possibility to design a drinking water pump station. Moreover, the characteristic of the phase procedure, which uses a coarse to fine approach and unites many parties, make the more precise detailed design and estimation cost besides the less changes in the construction stage. Renovating the drinking water pump station De Punt, Groningen is an example of the design process in the Netherland.

Not only are the background of the project and the treatment considered, but also attention is paid to the process of designing and the growth of the design. It becomes more interesting since the company which carried out the identification, definitions, and preliminary design is not the same as the company which carried out the final design. This (practice of) designing methodology gives overview and inputs how to improve the design and realization process of a drinking water pump station in Indonesia since Indonesian government is still confronted with the difficulties to provide its habitants with clean and reliable drinking water.

In Indonesia, the water that comes out of the taps should be boiled before drinking or using in cooking. There are three sources of drinking water. The groundwater and spring will be directly consumed without any certain treatment whereas the surface water is processed through physical, chemical, and bacteriological process

At least 40% urban citizen and more than 70% rural citizen has no access to piped water even Indonesia has 6 percent of the world's fresh water resources. Only 47% water production from drinking water company is distributed to the customer. It means around 53% is lost. The losses of water distribution are usually caused by the leakage of the distribution pipes, illegal use, and billing error.

Designing process of drinking water pump station in Indonesia is regulated by Government Regulation Number 16 in 2005. It should develop through four stages; project planning, feasibility study, engineering design, and building. Nevertheless, drinking water company in Indonesia still experiences difficulties in designing the pump stations. The limitations of designing this kind of project are:

- Insufficient possibilities for financing pump station
- Insufficient knowledge to operate system
- Insufficient management inside the drinking water company

Hence, problems in supplying drinking water, designing and operating drinking water pump station often happen in Indonesia whereas in The Netherlands is less affected by this issue. Below is the recommendation of improving the design or realization process of drinking water pump station in Indonesia.

6.2. Recommendations

In attempt to guarantee sustainable water availability in Indonesia, a good, integrated and professional management efforts from the design phase until the operation and management are needed. Interdisciplinary engineering management process that evolves and verifies an integrated, life-cycle balanced set of system solutions should be implemented to design a drinking water pump station.

Therefore, according to all information in the previous chapters, following are recommendations to improve the design of drinking water pump station in Indonesia by implementing system engineering process.

The Systems Engineering Process (SEP) consists of a set of working fields which enables a comprehensive, iterative and recursive problem solving process, applied sequentially top-down by integrated teams[11]. It transforms needs and requirements into a set of system product and process description, generates information for decision makers, and provides input for the next level of development. The process is applied sequentially, one level at a time, adding additional detail and definition with each level of development.

The general concepts of SEP are used all around the world for various kinds of projects under the umbrella of The International Council on Systems Engineering (INCOSE)[12]. The adoption and implementation of this concept depends on the type of project and the country's local circumstances.

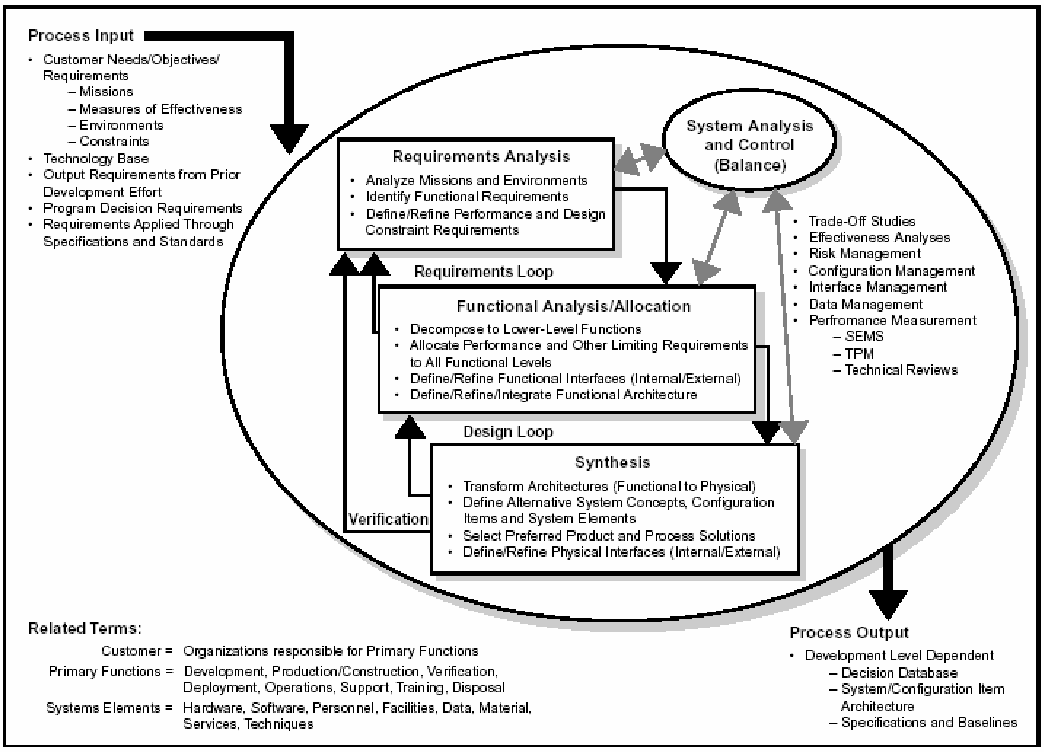

Figure 6.1. The System Engineering Process[11]

As shown by Figure 6.1, the SEP includes: inputs and outputs; requirements analysis; functional analysis and allocation; requirements loop; synthesis; design loop; verification; and system analysis and control.

Systems Engineering Process Inputs

Inputs consist primarily of the customer's needs/ requirements and project constraints. All of the design's constrains should be considered as they bound the development teams' design opportunities. Requirement is the primary focus in the systems engineering process because the process's primary purpose is to transform the requirements into designs. The process develops these designs within the constraints. They eventually must be verified to meet both the requirements and constraints.

Requirements Analysis

The first step of the SEP is to analyze the process inputs. It is used to develop functional and performance requirements; that is, customer requirements are translated into a set of requirements that define what the system must do and how well it must perform, the result is stored in a requirement tree. The systems engineer must ensure that the requirements are understandable, unambiguous, complete, and concise. It must clarify and define functional requirements and design constraints. Functional requirements define quantity, quality, coverage, time lines, and availability.

Functional Analysis/Allocation

Functions analysis is the process of decomposing higher level functions into lower-level functions. This process is intended to translating system level requirements into detailed functional and performance design criteria.

The result, often called as the functional architecture/tree (Figure 6.2.), is a description of item in terms of what it does logically and performance required. Functional analysis and allocation allows for a better understanding of what the system has to do, in what ways it can do it, and to some extent, the priorities and conflicts associated with lower-level functions (Figure 6.2.).

Requirements Loop

Performance of the functional analysis and allocation results in a better understanding of the requirements and should prompt reconsideration of the requirements analysis. Each function identified should be traceable back to a requirement. This iterative process of revisiting requirements analysis is referred to as the requirements loop.

Design Synthesis

Then the process of designing can be continued with the process of developing the functional analysis and allocation into the design. The result is often referred to as the physical architecture/object tree (Figure 6.2.). Every developed design must meet at least one functional requirement, and any part may support many functions. During the design, subsystem and component description are elaborated, and detailed interfaces between all system components are defined.

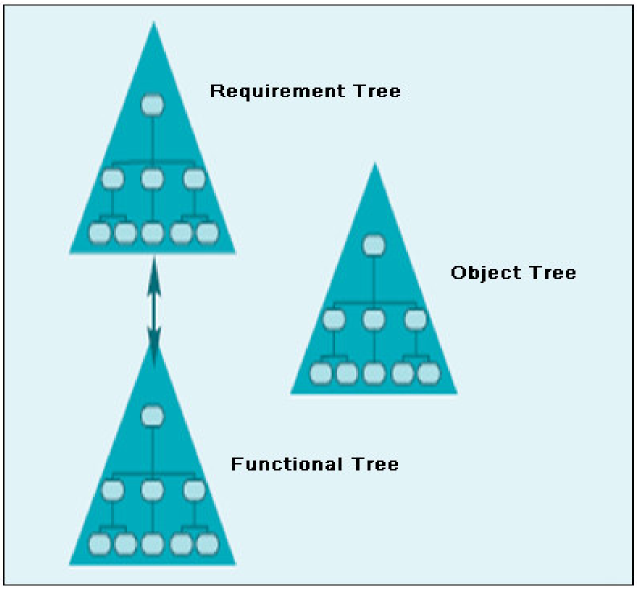

Figure 6.2. Connection between Requirement, Functional, and Object Tree

Design Loop

Similar to the requirements loop described above, the design loop is the process of revisiting the functional architecture to verify that the physical design synthesized can perform the required functions at required levels of performance. The design loop permits reconsideration of how the system will perform its mission, and this helps optimize the synthesized design. It also makes the changeability of the design will be possible and the project will proceed within smaller and smaller boundaries.

Verification

For each application of the system engineering process, the solution will be compared to the requirements. This part of the process is called verification.

Each requirement at each level of development must be verifiable. Baseline documentation developed during the systems engineering process must establish the method of verification for each requirement. Appropriate methods of verification include examination, demonstration, analysis (including modeling and simulation), and testing. Formal test and evaluation (both developmental and operational) are important contributors to the verification of systems.

Systems Analysis and Control

They include technical management activities required to measure progress, evaluate and select alternatives, and document data and decisions. These activities apply to all steps of the systems engineering process. They should evaluate that alternative approaches satisfy technical requirements and program objectives, and provide a rigorous quantitative basis for selecting performance, functional, and design requirements.

The purpose of Systems Analysis and Control is to ensure that:

- Solution alternative decisions are made only after evaluating the impact on system effectiveness, life cycle resources, risk, and customer requirements
- Technical decisions and specification requirements are based on outputs
- Traceability from systems engineering process inputs to outputs is maintained
- Schedules for development and delivery are mutually supportive
- Impacts of customer requirements on resulting functional and performance requirements are examined for validity, consistency, desirability, and attainability
- Product and process design requirements are directly traceable to the functional and performance requirements. They were designed to fulfill, and vice versa.

Systems Engineering Process Output

Process output is result of the systems engineering process which should consist of the documents that define the system requirements and design solution such as the system/configuration item architecture, specifications and baselines, and the decision database. Process output is dependent on the level of development. It will be more detailed as the system definition proceeds from concept to detailed design.

In designing drinking water pump station, the customer's requirement is to obtain the supply of clean drinking water. Environmental, existing conditions, finance, regulatory standards and laws are the project constraints. Thus this requirement should be analyzed and translated into a set of requirements that define what the system must do and how well it must perform, such as quantity and quality of the water, coverage area, water continuity, and technical parts. This requirement should be decomposed into detailed requirement and stored into requirement tree (Figure 6.3.).

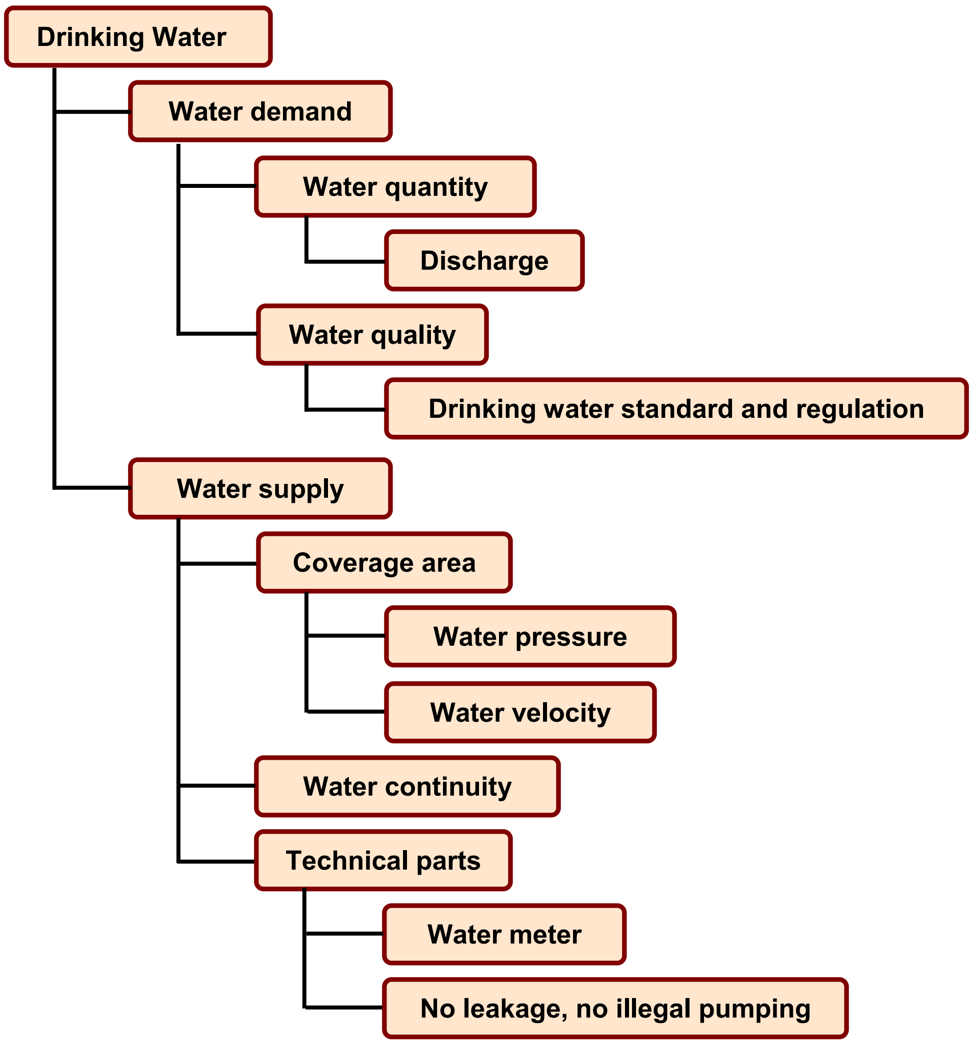

Figure 6.3. Drinking Water Pump Station's Requirement Tree

After the requirement has been set, the next step is to make the functional analysis. In this step, every level of requirements is translated into functional and performance design criteria (Figure 6.4.).

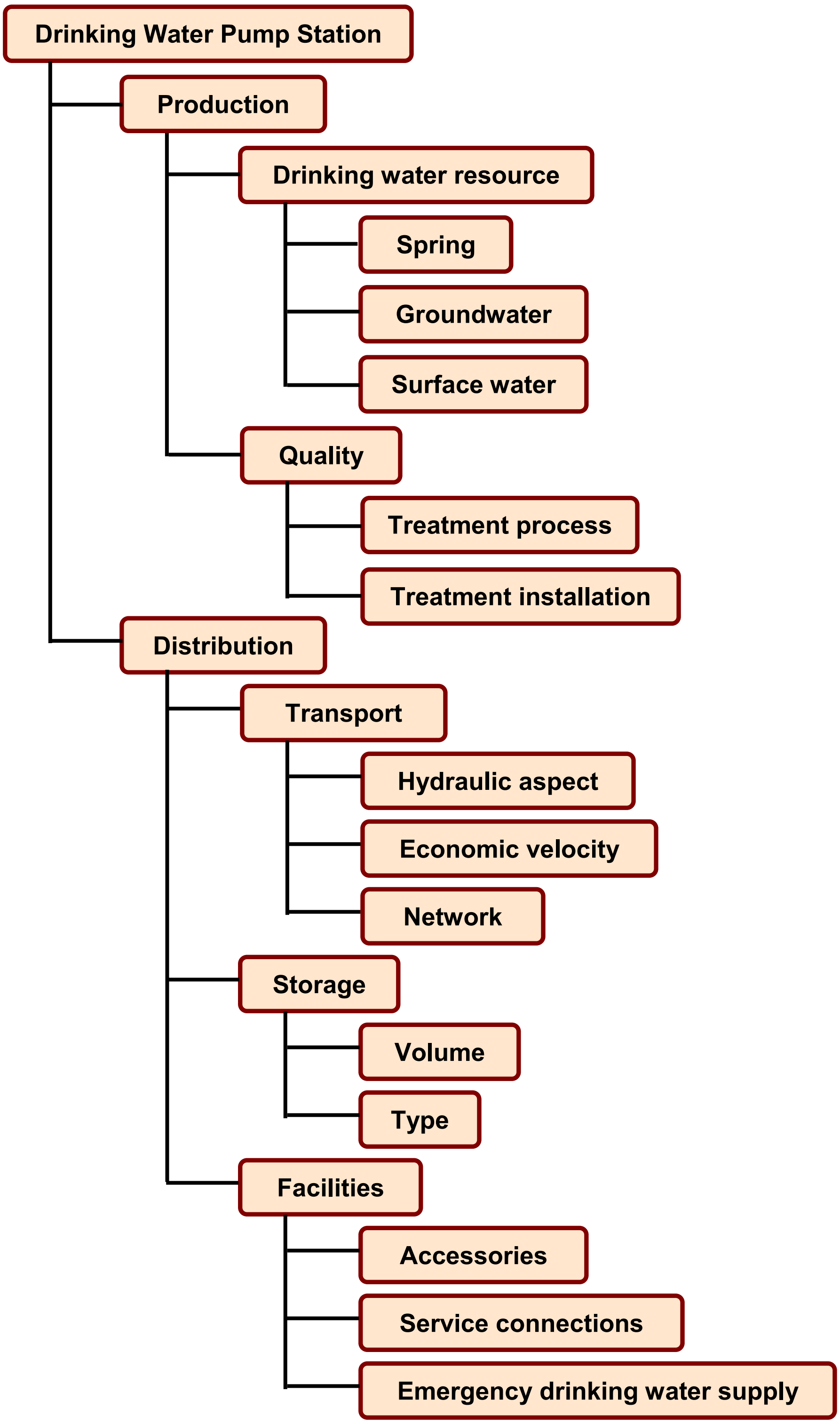

Figure 6.4. Drinking Water Pump Station's Functional Tree

After the function analysis and allocation has been defined, the process of developing the functional analysis and allocation into the design can be continued. In the design phase, every option is generated, the chosen option should meet the requirement and should be verified whether it can perform the required functions or not.

It should be realized that designing drinking water pump station is a complex project in which various parts or designers are involved in the whole process. It gives a wide possibility of occurring conflict among them. Therefore, every part should be involved continuously from the earliest stage of design process so that every problem can be solved together and get the best solution.

Therefore, if this System Engineering Process can be implemented and every part involved work based on their function and can be integrated in the global design, at the end, by spending the same amount of money as the current local design process, the buildings can be built more efficient and effective to accommodate all the drinking water treatment. The distributed water will be able to rise in a high quality level and the capacity of drinking water is fulfilled.

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