الجمهورية اللبنانية

وزارة الطاقة والمياه

دراسة محطة معالجة مياه بحيرة المسيلحة ومحطات الضخ وخطوط النقل والدفع والخزانات وتصميم محيط الأشغال أسفل سد المسيلحة بما فيها القلعة – قضاء البترون

الجزء الأول: دراسة محطة معالجة المياه وضخها إلى الخزانات الرئيسية

1-3 وضع الدراسات المبدئية للمحطة

1-3-1 دراسة فنية ومعمارية مبدئية للمحطة ودراسة مفصلة لمحطة الضخ

Water Treatment Plant Report

حزيران ٢٠١٧

DAR AL HANDASAH NAZIH TALEB & PARTNERS
دار الهندسة نزيه طالب وشركاه
Founded 1956

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1 GENERAL

1.1 Introduction

1.1.1 Background

The Ministry of Energy and Water granted the Contract Detailed Design of El Msailha Lake water Treatment Plant, pumping Stations, Conveying Lines, Reservoirs; And Landscaping of the Downstream of the Dam including El Qalaa to Dar Al Handasah Nazih Taleb and Partners (DAR TALEB). The project consists of a potable water treatment plant, a pumping station, 4 potable water storage tanks, two Booster Stations and 37 km of Pumping and Transmission Lines.

Dar Al Handasah Nazih Taleb has been requested to design the project in accordance with the latest standards and guidelines. The system will allow for the delivery of potable water by pumping from the treatment plant site to the reservoirs of Ras Nhach, Hamat and Batroun providing Batroun, Kfar Aabida, Selaata, Koubba, Chekka, Anfe, El Heri, Ouajh el Hajar, Ras Nhach and Hamat areas with a source of safe drinking water. In addition, the project aims to develop the area located between the dam and the international road.

This report describes the preliminary design of the proposed water treatment plant and the detailed design of the pumping station. The projected facilities are designed to meet quality regulations.

1.1.2 General Description of the Works

As described in the scope of work, the work for this contract comprises the development of water supply system to feed Batroun, Kfar Aabida, Selaata, Koubba, Chekka, Anfe, El Heri, Ouajh el Hajar, Ras Nhach and Hamat Areas. The project consists of the following components:

- Water treatment plant with a nominal design capacity of 30,000 m^3/day and the required reservations for an extension of the capacity to 60,000 m^3/day consisting of:
  - Cascade aeration
  - Disinfection (chlorine is being used for primary and secondary disinfection)
  - Influent metering and rapid mix
  - Coagulation using alum and polymer (coagulant aid)
  - Flocculation
  - Sedimentation (circular sedimentation tank)
  - Gravity filtration – rapid sand
  - Treated water storage
  - Main Pumping Station
  - Guard house
  - Store and Workshop
  - Administration building
  - Electrical unit building (Generator and power station)
- Proposed pumping station within the treatment plant
- Four proposed reservoirs; Hamat regional (2000 m^3), Batroun (2000 m^3), chekKa (1500 m^3), Kfar Aabida (1000 m^3)

- Two booster stations, Hamat and Kfar Aabida
- 37 Km of Pumping and Transmission pipelines

1.1.3 Report Objectives

The aim of this Report is to define the WTP project components and the pumping station based on the site and topographic survey and the proposed design, together with the design criteria adopted in the various design components.

The following report will include a detailed design for the water treatment plant elements and for the pumping station. The design criteria will be based on the information available in the TOR and on previous similar projects already designed and executed by DAR Taleb.

The specific defining characteristics are to ensure:

- The maximum improvement in water quality for the concerned villages is achieved.
- The facilities have the lowest life cycle cost.
- The facilities are easy to operate and maintain.
- The water treatment plant uses the best available proven technology.
- The project causes the least possible disturbance to the community.

1.1.4 Report Organization

The report is sub-divided into several parts, as follows:

- Part A – General
- Part B – Treatment Plant
- Part C – Pumping Station

1.2 Project Background

1.2.1 Water Quality

Connections to existing raw water pipe shall be from the intake tunnel of Mseilha Dam.

Dam water level varies between 45 m and 75.5 m.

1.2.1.1 Background

The Mseilha dam is the source of water for the proposed scheme. The raw water from this dam will be treated in the proposed treatment plant to make it hygienically safe and aesthetically attractive before supplying the water to the project area.

1.2.1.2 Water Quality Objectives

The quality of the effluent will be as perof LIBNOR NL 161 and/or 98/83/EC standards given in Table 1-1.

Table 1-1 LIBNOR NL 161 and/or 98/83/EC Standards for drinking water

Parameter	Parametric value	Unit	Notes[1]
PART A – Microbiological Parameters			
Escherichia coli	0	nb/100ml	

[1] Refer CUNCIL DIRECTIVE 98/83/EC of 3 November 1998 on the quality of water intended for human consumption (Official Journal of the European Communities)

Parameter	Parametric value	Unit	Notes1
Enterococci	0	nb/100ml	
PART B – Chemical Parameters			
Acrylamide	0.10	µg/l	
Antimony	5.0	µg/l	
Arsenic	50	µg/l	
Benzene	1.0	µg/l	
Benzon(a)pyrene	0.010	µg/l	
Boron	1.0	mg/l	
Bormate	10	µg/l	
Cadmium	5.0	µg/l	
Chromium	50	µg/l	
Copper	1.0	mg/l	
Cyanide	50	µg/l	
1,2-dichloroethane	3.0	µg/l	
Epichlorohydrin	0.10	µg/l	
Fluoride	1.5	mg/l	
Lead	10	µg/l	
Mercury	1.0	µg/l	
Nickel	20	µg/l	
Nitrate	45	mg/l	
Nitrite	0.050	mg/l	
Pesticides	0.10	µg/l	
Pesticides- Total	0.50	µg/l	
Polycyclic aromatic hydrocarbons	0.10	µg/l	
Phenolic Compounds	0.001	mg/l	
Mineral Oil	Nil		
Selenium	10	µg/l	
Tetrachloroethene and Trichlorethene	10	µg/l	
Trihalomethane - Total	100	µg/l	
Vinyl chloride	0.50	µg/l	
PART C – Indicator Parameters			
Aluminium	200	µg/l	
Ammonium	Nil	mg/l	
Chloride	250	mg/l	
Clostridiumperfringens(includin g spores)	0	number/100 ml	
Colour	Acceptable to consumers and no abnormal change		

Parameter	Parametric value	Unit	Notes1
Conductivity	1500	µS cm-1 at2O °C	
Hydrogen ion concentration	6,5 and 8,5	pH units	
Iron	300	µg/l	
Manganese	50	µg/l	
Zinc	5	mg/l	
Odour	Acceptable to consumers and no abnormal change		
Oxidisability	5.0	mg/l O2	
Sulphate	250	mg/l	
Phosphate (P2O5)	1	mg/l	
Sodium	150	mg/l	
Calcium as CaCO3	200	mg/l	
Chloride (Cl-)	200	mg/l	
Total Hardness as CaCO3	250	mg/l	
Taste	Acceptable to consumers and no abnormal change		
Colony count 22°	No abnormal change		
Coliform bacteria	0	number/100 ml	
Dissolved Solids	500	mg/l	
Organic matter	0.5	mg/l	
Hydrogen Sulfide (H2S)	0.05	mg/l	
Total organic carbon (TOC)	No abnormal change		
Turbidity	5 NTU*		

1.3 Design Basis

1.3.1 Structural Design Basis

1.3.1.1 Introduction

The purpose of this note is to define the basis of the design that is used for the structural design review of the pumping station.

1.3.1.2 Design Philosophy

1.3.1.2.1 General

The design philosophy aims to achieve the optimum solutions addressing performance and aesthetic, by providing to the client structural solutions that are forward-looking and cost-efficient.

1.3.1.2.2 Design Process

The project is designed to withstand the worst combinations induced by dead loads, fluid pressure live loads, wind and seismic loads.

The design process consists of the following steps:

1. Configure the structural system in the original design.
2. Determine the design data: design load distribution, design criteria, and specifications.
3. Make necessary changes in the concept structural design to meet the requirement of the international codes.
4. Calculate member cross-sectional properties; perform structural analysis to obtain internal force demands: moment, axial force, shear force, and torsion. Review magnitudes of deflections.
5. Calculate the required reinforcement based on the internal calculates the required transverse reinforcement from the shear and torsional moment demands.
6. If members do not satisfy the safety, functionality and economy criteria, modify the design and make changes to steps 4, 5 and 6.
7. Complete the elaborated evaluation of member design to include additional load cases and combinations, and strength and serviceability requirements required by code and specifications.

1.3.1.2.3 Design Philosophy Application

The design philosophy aims are achieved by:

a. Configuring a workable, functional and economical structural system. This involves the selection of the appropriate structural types, in close coordination with other trades (Mechanical, Electrical,..). In addition, the structure design must be practical and economical to build.
b. Proposing structural solutions that meet:
   - Structural engineering norms and standards for achieving a safe, stable, enduring, structurally-sound;
   - Serviceability requirements to reach a livable, workable and functional product;
   - Other constraints, requirements and modifications taken into consideration while attempting to balance the certainties of structural logical solutions against the requirement of other trades;
   - Client's requests;
   - Deadlines.
c. Proposed solutions shall cover but not be limited to the following:
   - Selecting structural dimensions, with sufficient margins of safety against failure. These selections are made on the basis of replicating member sizes and minimizing number of corbels, to result in easier and faster construction, since the largest part of the reinforced concrete construction cost lies in costs of labor and formwork.
   - Determining the required reinforcement ratios of each structural member while satisfying serviceability requirements such as deflections and crack widths.
d. Bringing out cost-efficient solutions in terms of:
   - Practicality in construction;
   - Rapidity of execution;
   - Economic structural sections and reinforcement ratios;
   - Avoiding extra cost

1.3.1.3 Structural Software

The design verification of the pumping station was performed by adopted structural softwares. The main international finite element software used for the design in Robot.

The software is a package from Autodesk for structural analysis and design. Each package is a fully integrated system for modeling, analyzing, designing, and optimizing structures of a particular type.

The software is a package from Autodesk, Inc. (CSI) for structural analysis and design. The package is a fully integrated system for modeling, analyzing, designing, and optimizing structures of all types.

ROBOT is used for general and building structures, dams, bridges, water structures, stadiums, towers, plants, offshore structures, piping systems, and many others.

In this software the following analysis can be performed:

- Static and dynamic analysis
- Linear and nonlinear analysis
- Dynamic seismic analysis and static pushover analysis
- Vehicle live-load analysis for bridges
- Geometric nonlinearity, including P-delta and large-displacement effects
- Buckling analysis
- Steady-state and power-spectral-density analysis
- Frame and shell structural elements, including beam-column, truss, membrane, and plate behavior
- Two-dimensional plane and axisymmetric solid elements
- Three-dimensional solid elements
- Nonlinear link and support elements
- Frequency-dependent link and support properties
- Multiple coordinate systems
- Many types of constraints
- A wide variety of loading options
- Large capacity
- Highly efficient and stable solution algorithms
- Design of all types of Reinforced concrete structural elements according to ACI code, BS code, French code, and most of international concrete design codes.
- Design of all types of steel structural elements according to American codes, British code, and most of international steel design codes.

1.3.1.4 Design Criteria

1.3.1.4.1 Design standards and codes

The Design of the pumping station is based in the followings American and British standards codes:

ACI 318-05 Structural Use of Concrete and all other relevant ACI codes

ACI 350.3-05 Seismic Design of liquid-containing concrete structure and commentary.

ASCE 7-05 American Society of Civil Engineers

ASCI Structural Steel Design

UBC 1997 Uniform Building Code

1.3.1.4.2 Loads

- **Material Self-Weight**

Item	Material Self-Weight
Concrete (normal weight)	25 KN/m^3
Concrete Screed	24 KN/m^3
Water (unit weight)	10 KN/m^3
Soil (unit weight)	20 KN/m^3

- **Superimposed Dead Loads (for building structure)**

Item	Load
Ground Floor Level	4 KN/m^2
Stairs	4 KN/m^2
Terrace / Balcony	4 KN/m^2
Roofing (including all: waterproofing, insulation, screed,…etc)	3.5 KN/m^2

- **Live Loads**

Live loads proposed for building structure are:

Item	Load (KN/m^2)	Concentrated Load (KN)
Accessible roof	1,5	-
Walk wasp and stairs	5.0	-
Mechanical area	5.0	-

Live loads proposed for water structure are:

Item	Load (KN/m2)	Concentrated Load (KN)
Cover slab of tanks	3.0	-
Traffic load adjacent to tank	10	-
Temperature load	± 33C°	-

- **Seismic loads**

For buildings the seismic design is based on UBC: 1997 and for water structure the design is based on ACI 350 the following factors are used:

Seismic Zone 1

Seismic Importance factor Ip = 1.25

Soil Profile Type = SE,

Seismic Zone Coefficient:0.25

- **Wind loads**

  The wind load design is based on ASCE-7-02, 3sec-Gust wind speed 160Km/h.

- **Loads combination**

  The loads combinations to determine the required strength U are as given in section 9.2 in ACI 318.

  The required strength U shall be at least equal to the effect of factored loads in the following equation.

  U = 1.4 (D + F)

  U = 1.2 (D + F + T) + 1.6 (L + H) + 0.5 (Lr or S or R)

  U = 1.2D + 1.6 (Lr or S or R) + (1.0L or 0.8W)

  U = 1.2D + 1.6W + 1.0L + 0.5 (Lr or S or R)

  U = 1.4D + 1.2F + 1.0E + 1.6H + 1.0L + 0.2S

  U = 0.9D + 1.2F + 1.6W + 1.6H

  U = 0.9D + 1.2F + 1.0E + 1.6H

  Where:

  D = Dead load

  L = Live load

  Lr = Roof Live load

  E = Load effect of earthquake

  H = Load due to weight and pressure of soil, water in soil

  T = Cumulative effect of temperature, creep, shrinkage, differential settlement, and shrinkage compensating concrete.

  W = Wind load

  F = Loads due to weight and pressure of Fluids with well defined densities and controllable maximum heights.

  S = Snow load

1.3.1.4.3 Performance Criteria

The limitations of deflections to acceptable limits are designed according to ACI 318-05:

- L/180: Immediate deflection due to Live Load L - For Flat Roofs not supporting or attached to non Structural elements likely to be damaged by large deflections.
- L/360: Immediate deflection due to Live Load L -For Floors not supporting or attached to non structural elements likely to be damaged by large deflections.
- L/480: Total Deflection occurring after attachment of non structural elements - For Roof or Floor Construction supporting or attached to non structural elements likely to be damaged by large deflections.
- L/240: Total Deflection occurring after attachment of non structural elements - For Roof or Floor Construction supporting or attached to non structural elements not likely to be damaged by large deflections.

1.3.1.5 Material Characteristics

1.3.1.5.1 Concrete

Structural concrete cylinder crushing strength at 28 days (fc) shall be as follows:

1. Foundations and all structures under ground level: fc' = 30 Mpa
2. Slabs / Beams fc' = 30 Mpa
3. All other elements not covered above fc' = 30 Mpa
4. Equivalent concrete strength for cubes 37.5 Mpa
5. Concrete strength for cubes / concrete strength for cylinders 1.25

1.3.1.5.2 Steel Reinforcement

Reinforcement Properties

Refer to ASTM A615, A616, A617, A706, A767 and A775

The designation "T" denotes deformed high yield steel bars with specified yielding strength exceeding 60,000 psi (420 N/mm^2).

1.3.1.5.3 Concrete Cover

Concrete cover shall be in accordance with BS8500 as follow:

Element / Location	Min. Clear Cover (Including Links)
Buildings, Footings	75mm (concrete cast against and permanently exposed to earth, where waterproofing system is not applied).
Solid Slabs	30mm
Columns	40mm
Beams	40mm
Water tank - footing	75 mm
Water tank - wall	50mm
Water tank – cover slab	40mm

2 TREATMENT PLANT

2.1 Plant Description

The Mseilha Water Treatment Plant is used for removal of specific contaminants and improving the quality of the distributed drinking water. The proposed Water treatment plant will improve water quality by reducing certain health hazards, including chemical pollutants and bacteria and by removing hardness or odors.

The proposed plant has a capacity of 30,000 m^3/day. However, it is designed to be extended in the future to handle 60,000 m^3/day.

In addition, the proposed plant is designed to produce a high quality treated effluent safe to drink. To do this, the water treatment plant and system operators control high-tech equipment, such as control pumps, valves, and computers, which moves the water through the numerous treatment processes. Operators are responsible for testing the water at various stages of treatment; interpreting and adjusting meters and gauges; and performing chemical and biological laboratory analyses. Advanced computer technology will provide operators with a valuable tool in monitoring equipment, testing the water for harmful materials, and troubleshooting problems in the treatment process.

The general layout and the hydraulic profile of the treatment plant are illustrated respectively in Figures 2-1 and 2-2.

2.2 Design Basis

2.2.1 Site Conditions

2.2.1.1 Climatic Conditions

Information regarding climatic conditions has been obtained from "Atlas Climatique du Liban”.

2.2.1.2 General

The climate in the project area of Mseilha is of Mediterranean type with warm and dry summer and fall, and moderately cold, windy and wet winter months. It is classified as:

- "Wet" during December, January and February.
- "Humid" in November and March.
- "Semi-humid’ in October (partly) and April.
- "Arid" from May to September.

2.2.1.3 Temperature

The annual mean temperature is 20°C with monthly variations ranging from 12.5°C in January to 27.5°C in August. Temperatures above 30°C and below 0°C are very seldom. The difference between day and night temperatures is generally moderate and amounts to 7°C on average.

2.2.1.4 Relative Humidity

Due to the Mediterranean cyclonic disturbances in winter and the monsoonal air masses in summer, the relative humidity is fairly constant throughout the year at a rather high level of about 67%, with mean monthly values ranging from 63% to 72%.

2.2.1.5 Wind

The prevailing wind direction in Mseilha is south-west nearly throughout the year. The appertaining frequency amounts to more than 30% followed by winds from all other directions at more or less the same frequency level ranging from 1% to 9%. In general, the wind velocity is small with less than 5 m/s during more than 70% of the year. Wind velocities above 15 m/s are rare with < 1% on average. However, during storms, velocities of more than 20 m/s have been observed.

The mean monthly wind velocity varies from very low in October, when in about 90% of all cases the wind velocity is lower than 5 m/s, to higher ones in March, when approximately 50% of the wind has a velocity of more than 5 m/s, and 10% of more than 10 m/s.

2.2.2 Design Life

The design asset life of the WTP shall be as follows:

- Civil Works 30 years
- Buildings 30 years
- Mechanical Plant 15 years
- Electrical Plant 15 years
- Instrumentation 5 years
- Pipelines 60 years

The Contractor shall ensure that all materials and workmanship are provided to suit these design asset lives.

Figure 2-1 WTP Layout

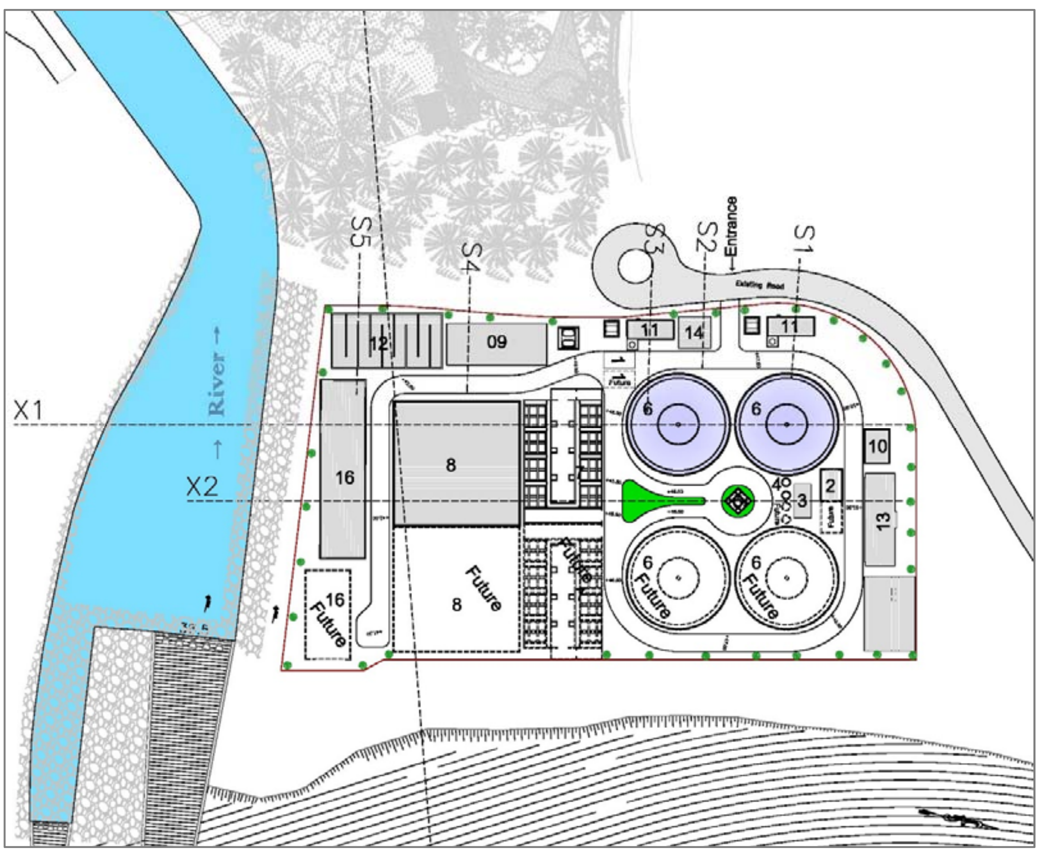
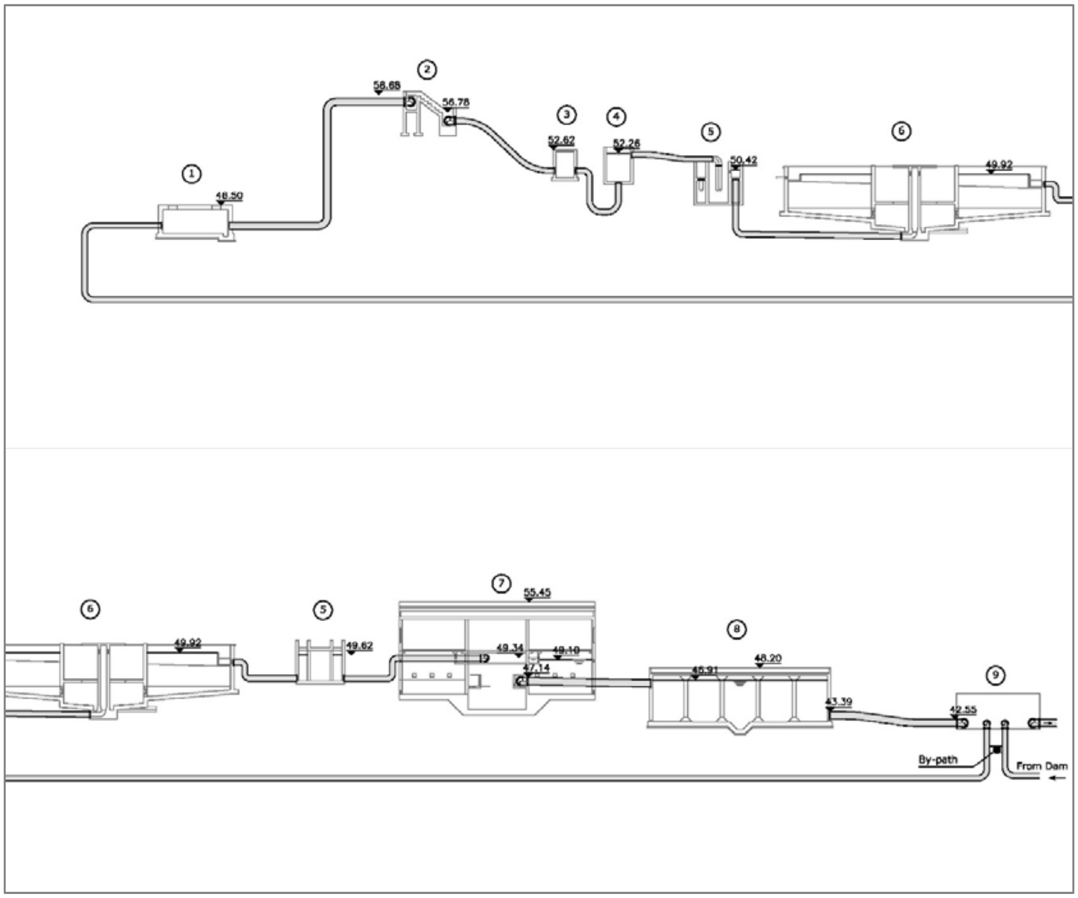


Figure 2-2 WTP Hydraulic Profile



2.3 Influent Load and Treated Water Requirements

Table 2-1 Influent Load Data

Influent	Phase I	Phase II
Average Flow (m^3/day)	33,000	66,000
Peak Flow (m^3/hr)	1,375	2,750
Turbidity (NTU)	300	300
Total Dissolved solids (mg/L)	< 1,500	< 1,500

The site will operate 365 days per year. The WTP must achieve the maximum permissible level of treatment level on a continuous basis. Also, it must achieve the “Desirable Level” of treatment on 99.5% basis. The parameters which values are not specified in the “Desirable Level’ column, are supposed meeting the requirements and are not treated in this plant. Planned periodical laboratory analysis should confirm that those parameters are with recommended limits as per WHO regulations.

2.4 Treated Water Requirement

The treated water must meet LIBNOR NL 161 and/or 98/83/EC standards (Refer to§1.2.1.2)

2.5 Design Codes and Standards

The Water treatment Plant Process in compliance with the AWWA Standards

2.6 Proposed Process and Equipment Description

2.6.1 General Process Description

A large portion of particles suspended in water can be sufficiently small that their removal by sedimentation or filtration is not practical .Most of these small particles are negatively charged, which is the major cause of the stability of suspended soil particles. Particles which might otherwise settle are mutually repelled by these charges and remain in suspension. Coagulation is a chemical technique directed toward destabilization of particle suspension. Coagulation is followed by flocculation, which is a slow mixing technique promoting the aggregation of the destabilized (coagulated) particles. Coagulation followed by flocculation as an aid to sedimentation and filtration has been practiced for centuries. It is by far the most widely used process for the removal of substances producing turbidity in water. If water has high turbidity, flocculation followed by sedimentation is used to reduce the quantity of material prior to entering the filter.

Filters for suspended particle removal utilize graded sand. The most widely used are rapid-sand filters in tanks. In these units, gravity holds the material in place and the flow is downwards. The filter is periodically cleaned by a reversal of flow and the discharge of back flushed water into drain. Pre-and post-chlorination are typically applied in order to keep the plant and effluent water disinfected.

2.6.2 Proposed Equipment Description

The raw water is pumped from the dam to the flash mixing chamber. Before it reaches the flash mixing chamber Coagulants when required and Chlorine are dosed into the line.

2.6.2.1 Influent metering

An electromagnetic flowmeter shall be installed outside the pump room in a flowmeter chamber. The flow meter shall have all fittings to allow easy maintenance and isolation. It shall provide local and remote instantaneous and cumulative flows. Both parameters shall be displayed on HMI screen provided with the MCC panel.

2.6.2.2 Cascade Aerator

Cascade aerator consist of stepped structure with no mechanical or electrical control.

Design Parameter for cascade aerator	Phase I	Phase II
Number of Units	1	2
Inlet channel width (m)	1.2	1.2
Inlet channel depth (m)	1.5	1.5
Outlet channel width (m)	1.2	1.2
Outlet channel depth (m)	1.5	1.5
Number of steps	6	6
Step dimensions (m) Horizontal / Vertical	0.4 / 0.3	0.4 / 0.3
Width per unit (m)	8.8	8.8
Surface area per unit (m2)	24.64	24.64

2.6.2.3 Rapid Mixer

The role of the Rapid mixer, or flash mixer or quick mixer is to rapidly and uniformly disperse a coagulant through the mass of the water. The process usually occurs in a small basin immediately preceding or at the head end of the 'coagulation basin'. This process is used to generate a homogeneous mixture of raw water and coagulants which result in the destabilization of the colloidal particles in the raw water to enable coagulation. Mixing can be provided by pumps, venture flumes, air jets or rotating impellers (paddles, turbines, or propellers). Where possible, the rapid mix should be a two-compartment unit. Design parameters for rapid mix are as follows:

- Velocity Gradient 300 – 1500 s-1
- Detention time. 10 – 60 sec
- Basin Depth 2 – 4 m
- Rotational Speed 20 – 100 rpm

The proposed design criteria of the flash mixer are shown in Table 2-3.

Table 2-2 Flash Mixer Proposed Design Data

Design Parameter	Phase I	Phase II
A: Flash Mixer		
Number of Units	2	4
Duty	2 in normal operation	4 in normal operation
Standby	NA	NA
Type of Mixer	Mechanical, vertical shaft, paddle type	Mechanical, vertical shaft, paddle type
Flow Per Mixer (m3/h)	687.5	687.5
Velocity Gradient (s-1)	332	332
Peripheral Velocity of paddles (m/s)	1.13	1.13
Type of Motor Control	VFD	VFD
Rotational Speed (rpm)	30	30
Mixer Power (kW)	1 kw	1 kw
Flash Mixing Tank detention time (s)	48	48
Flash Mixing tank volume (m3)	9.07	9.07
Flash Mixing Tank Depth (m)	3.8	3.8
Free Board (m)	0.6	0.6
Flash Mixing Tank Diameter (m)	1.9	1.9
Mixer shaft and paddles material of construction	SS 316	SS 316

The design should allow the coagulant aids to be added first. The raw water should have the proper pH and alkalinity, and have other aids like polymers present before the flow enters the mixer chamber.

It is important to add the coagulant aid far enough upstream that the pH adjustment occurs before the coagulant is added. The raw water should be tested for pH, alkalinity, turbidity, temperature, tastes and odors, and color. pH should also be checked after coagulation.

Jar tests should run on the raw water to determine the optimum coagulant dosage. The amount of coagulant needed for good floc formation can be affected by changes in the raw water quality. Raw water should be checked for turbidity, pH, alkalinity, temperature, color, and tastes and odors. Floc does not form as well or as fast in colder temperatures requiring higher coagulant doses. Changes in pH will change the amount of coagulant aid needed. Changes in turbidity will have an effect on the amount of coagulant required.

2.6.2.4 Distribution Box/ Collection Box

A Distribution box shall be provided to collect the flow from the Flash mixers and divide it into 2 streams going to the Clariflocculators. This unit will later on collect the flow coming from the clariflocculators before going to the gravity filters.

2.6.2.5 Clariflocculator

Clariflocculator is a combination of flocculator and clarifier designed to attain economic and speedy construction. It shall have two concentric tanks where inner tank serves as a flocculation basin and the outer tank serves as a clarifier. Clariflocculators generally are used to perform the chemical primary treatment of effluents. Contractor must use superior quality material for manufacturing the clariflocculator and keep a stringent check during the entire process to make that superior final output is delivered.

The design must enable the clariflocculator to handle heavy slugs while delivering shortest floc settling time.

2.6.2.5.1 Skimming Device

A skimming mechanism is required by the client to remove floating debris, solids, which floats on effluent surface. It shall compromise of:

- Rotating Skimmer
- Scum Scraper
- Scum Box.

Neoprene Rubber wipers are generally provided. The scum scraper collects the scum and drops it in scum box, which is connected to withdrawal piping. A scum skimming arm, supported on one of the scrapper arm, is provided for removal of floating debris, solids. The collected scum is pushed by a level-loaded or spring loaded scraper into a scum box. Through this scum box the scum drains off the paddle and pipe. Thus floating scum is taken out from the clarifier.

The Clariflocculator shall consist of a rotation unit with central drive including a gear motor and slewing ring, a high efficiency turbine, a bottom scraper system having two blade holder arms, a central deflector cylinder which defines the mixing and flocculation compartment and a peripheral weir. The control and drive unit is located in the middle.

It shall comprise an electric motor, a multistage reduction unit of coaxial and/or planetary type and a slewing ring with hardened and tempered teeth of adequate size. The protection against overloads is carried out by an electronic torque limit switch for diameters up to 20 meters while as regards the diameter equal to or greater than 20 meter, an adjustable dynamometric torque limit switch complete with alarm signaling device is required. The gear motor to drive the turbine is located in the middle of the slewing ring and since it has a variable speed, the coagulants mixture is optimized and the floc precipitation made easier. The sludge scraper blades remove the sludge precipitated to the sloping bottom of the tank and gathers it in a central ditch wherefrom it is then sucked. The clarified water is removed by means of the weir. The scraper and any moving parts of the bridge are supported and moved only through the central slewing ring bearing.

This way, the sedimentation tank volume, free from any parts in motion allows, for example (if needed in the future), the installation of lamella packs in its inside and it avoids the maintenance on the clarifier edge required if the bridges is peripheral driven type, in correspondence of the traction trolleys. A walkway for the inspection on the central unit shall be provided. Bridge construction shall consist of hot dip galvanized steel. All immersed parts shall be SS316.

The flocculator shall be designed based on the following criteria:

- Detention Time 10 – 40 minutes
- Velocity Gradient 10 – 75 s-1
- Tank Depth 3 – 4.5 m
- Peripheral Velocity of Paddles 0.2 – 0.6 m/s

The proposed design criteria of the clariflocculator are shown in Table 2-4.

Table 2-3 Clariflocculator Units Design Data

Design Parameter	Phase I	Phase II
B: Clariflocculator Unit		
General		
Number of Units	2	4
Duty	2 in normal operation	4 in normal operation
Standby	NA	NA
Design Flow per unit (m3/hr)	687.5	687.5
Type	Circular, Central Driven	Circular, Central Driven
Flocculator		
Number of Flocculator per unit	2	2
Type of Flocculator	Vertical Shaft, Paddle type	Vertical Shaft, Paddle type
Power of each Flocculator (W)	~ 500	~ 500
Velocity Gradient (s-1)	36	36
Peripheral Velocity of paddles (m/s)	0.2 – 0.6	0.2 – 0.6
Rotational Speed (rpm)	2 – 4	2 – 4
Detention time (min)	33	33
Volume (m3)	380	380
Total Area of Paddles (m2)	~ 14	~ 14
Diameter of Flocculator tank (m)	11	11
Clarification Unit		
Detention Time	3	3

Design Parameter	Phase I	Phase II
B: Clariflocculator Unit		
Overflow rate (m3/m2/day)	35	35
Required Clarification Area (m2)	472	472
Overall Diameter (m)	28	28
Water Depth (m)	4	4
Free board (m)	0.8	0.8
Depth below partition wall	1	1
Depth provided for sludge storage (m)	0.75	0.75
Length of Weir (m)	82	82
Weir Loading (m3/h/m)	8.4	8.4
Tip Velocity of Scraper (m/s)	1 – 2 m/s	1 – 2 m/s
Rotational Speed (rpm)	~ 0.1	~ 0.1
Floor Slope	8%	8%
Scraper motor Power (kW)	~ 5.5	~ 5.5

2.6.2.6 Collection Box

The flow from the 2 clariflocculators shall be collected into a collection box before going to a gravity filter.

2.6.2.7 Rapid Gravity Filters

Filtration is the final step in the removal of chemical impurities in water. Any organic or inorganic particles that have not been removed during the sedimentation process must be filtered out in order to meet the effluent turbidity requirement mentioned in Table 2-2 Treated Water Requirement. The turbidity of the water in the filter influent should not exceed 15 NTU's, and should actually be less than 5 NTU’s, or filter runs will be reduced dramatically. When the filter becomes dirty it must be backwashed. Since the backwash water is treated potable water, the length of the filter run directly impacts the cost of the filter operation. The backwash water must either be returned to the head of the plant or mixed with the raw water flow or impounded so that sludge can be separated.

The filter shall be of the Rapid Gravity Type with a filtration rate not exceeding 12 m/h (or 5 GPM/Sq.ft). The supplier justify that the proposed filter can work under those design conditions to meet the required effluent.

The rapid sand filter can be cleaned of accumulated turbidity by reversing the direction of the flow of water. This process is called backwashing. In backwashing, the flow of water expands the sand, scours the bed and carries the accumulated solids to the treatment facility.

The filter shall be of the dual media type: Sand and Anthracite.

The gravity filter shall be of reinforced concrete construction. Its length, width and depth are determined to suit the desired rate of flow. The depth of the filter box is determined by the amount of head or pressure required and also by the type of underdrain. The principal parts, which make up a gravity filter are shown in and include:

- The underdrain system;

- The gravel subfill;
- The filter media; and
- The surface washer, wash troughs and air scour system.

The prime function of a filter is to remove suspended matter and thereby removing pathogenic organisms from the water.

Most of these organisms are bound up in the coagulated floc particles entering the filter. The turbidity remaining in the filter effluent is the best indicator of filter performance.

2.6.2.7.1 Underdrain System

The underdrain system collects the filtered water that passes through the media. The recommended type of underdrain is the vitrified clay "LEOPOLD" drain tile. Holes on the upper side of the drain tile are properly sized to handle the water flows required for adequate water distribution during filtration and backwash operation. The backwash flow rate of the average filter is 490 - 610 lpm per sq. m (12 to 15 gpm per sq. ft.) and the operating rate only about 163 lpm per sq. m (4 gpm per sq. ft.) The only head available during the filtration process is the depth of water in the filter. Consequently the holes are sized to handle the filter flow. Adequate distribution of water is ensured at the higher flows encountered in backwashing due to the diffusing effect achieved by the flow and resultant loss of head through the underdrain systems.

2.6.2.7.2 Gravel Subfill

The subfill performs two primary functions:

- It supports the upper layers of sand and anthracite and separates them from the underdrain system, and
- It distributes evenly the flow of water through the filter in both directions. (The depth of gravel required in design of filters is directly related to the distance between the holes and their size in the underdrain system).

Different layers, or size, of gravel make up the required depth. Progressively finer grades of gravel are spread on top of the coarse gravel. The minimum depth of a layer is 2". The final layer of gravel will support the actual filter media.

2.6.2.7.3 Filter Media

The actual filter media is on top of the gravel bed and varies in depth depending on plant design. Typical filter bed depths shall consist of Sand and Anthracite.

Anthracite, hard coal that has been crushed (screened) for size and graded to have a uniform density is the most widely used filter media. Crushed anthracite coal has a lower specific gravity (1.75) than sand (2.65); consequently, a lower velocity is required when backwashing the filter compared to that required to wash a sand filter of equal depth.

Crushed anthracite coal is lighter in weight – 880 kg per cu. m. (55 lbs. per cu. ft.) than sand – 1600 kg per cu. m (100 lbs. per cu. ft.); therefore, in order to benefit from both of these media, they are generally used together. They can be readily backwashed together and should always remain separated due to the difference in their specific gravities. The coarse anthracite on top gives the filter a larger capacity for turbidity removal, while the finer sand layer is below the anthracite supporter by a gravel support layer. The combination of the two provides a media that will give longer filter runs with a resulting better quality of water.

2.6.2.7.4 Wash Water Troughs

The wash water troughs are located above the surface wash equipment. They are installed, half the bed depth above the bed to provide a free space between the underside of the trough and the top of the bed. This space is normally provided for when the filter is backwashed to allow for the filter media to expand when cleaning without losing filter media.

2.6.2.7.5 *Other Necessary Accessories*

Other necessary components include:

- The influent wash water valve;
- The effluent wash water valve;
- A valve to control the flow of water to the surface wash equipment; and
- Pumps.

All of these valves are controlled from a console, usually located in front of and facing the filter.

Built into the control console are gauges showing loss of head, rate of flow through the filter, backwash rate of flow, and effluent turbidity.

2.6.2.7.6 *Filter Operation*

- **Pre-Treatment**

The most important thing to remember about the water arriving at the filter(s) is to condition and pre-treat it thoroughly before it gets there. Without this pre-treatment, or if the pre-treatment is inefficient the operating efficiency of the filter(s) is going to be drastically reduced. Filter runs will be cut short, resulting in a considerable increase in backwashing and the amount of wash water used. Consequently, plant output will be reduced because filters have to be washed with filtered water that could have been delivered to the customer. The filter beds will become overloaded with algae and particulate matter, and mud balls will very likely develop.

As already discussed, the type of conditioning applied to the raw water depends on the quality of the raw water entering the plant. The demand on water treatment plants, however, is continually increasing. If a given chemical treatment produces a good floc, coagulates well, and results in a water passing over the filter with, for example, turbidity of one (1) unit, at a flow rate of 25 MGD, an increase in flow rate to 40 MGD may not produce the same quality water over the filters even if the chemical dosage is increased in proportion to the increase in flow. This is because increasing the flow rate by 60% will allow less time for the floc to settle out. This results in a greater carry-over to the filters, causing shorter filter runs.

- **Filtration Rates**

Until a few years ago, the normal design filter rate for a rapid sand filter producing potable water, was 80 – 160 lpm per sq. m (2 - 4 gpm per sq. ft.) of filter bed-area. Since then investigations of filter aids have been carried out, using dual and multi-media filters. As a result, operating filter rates are notably increased. It is common today to find filters operating at rates of 245 – 325 lpm (6 - 8 gpm per sq. ft.) of filter bed area.

It is sometimes possible to increase the flow rate through the filter. Filters are normally designed for specific rates of flow, and such things as the inlet flumes, the underdrain system, rate of flow controllers, and the discharge piping are all sized for this flow plus a factor of safety. Therefore, to double the rate of flow, the total head available in the filter may be sufficient to maintain this flow rate for short periods of time. New filters use a media in which the particle size is greatest at the top. By using various types of filter media, the particle size gets progressively finer, down through the bed to the bottom. Since the voids (or spaces) between the particles will be larger where the particle size is greatest, the voids in the upper portion of the bed are largest. These provide a greater storage area for turbidity particles. As the water proceeds through the bed, the size of these voids becomes progressively smaller due to the accumulation of turbidity particles.

At the same time, the storage for the turbidity is becoming less, but the degree of filtration is becoming better.

It is common today to have up to five different layers of material in a filter bed. In other types of media, two layers are used, generally sand and crushed anthracite: two-layer filters are commonly known as dual media filters. The type of filter to be used is determined after a thorough study of the treatment process and raw water conditions.

The conventional rapid sand filter uses one grade of sand (0.45 - 0.55 mm and a S.G. of 2.65) approximately 75 cm (30 inches) thick underlaid by graded layers of gravel as supporting media. Normally under these conditions, the actual entrapment of suspended matter is restricted to the top several centimetres of the sand bed. The remaining sand acts as insurance against a serious turbidity breakthrough, which means the turbidity on the filter has increased to the point where it is being carried through by the water being filtered.

The storing capacity for suspended matter in the conventional rapid sand filter is considerably less than in a dual-media filter where the top 45 cm (18 inches) of the sand bed have been replaced with a coarser and lighter media, such as a graded crushed anthracite (0.8 - l.2 mm and a S.G. 1.75). Under ideal conditions, the entire 45 cm depth of anthracite plus 3 - 5 centimetres of sand is available for the storage of suspended matter. This means that the head loss, instead of being concentrated in the top 5 cm in the conventional sand bed, is distributed through a depth of 45 cm to 50 cm (18 - 20 inches) in the dual-media bed. This makes it possible to use higher filter rates for longer filter runs.

- **Backwashing**

Backwashing a filter is the exact opposite to filtration. When backwashing, the water rises up through the filter rather than passing down through it. The backwashing process removes the accumulated turbidity from the filter. Municipal filtration plants always utilize treated water for backwashing. The water is delivered to the filter either from an elevated tower or via a backwash pump (from the clearwell). Either method provides the necessary pressure and volume for carrying out the backwash process.

A normal rate of flow during the backwash cycle for conventional filters is 610 lpm per sq. m

(15 gpm per sq. ft.) of filter bed area. These figures will vary depending on the temperature of the water used to backwash. As the temperature increases, the backwash rate is increased to give the same amount of expansion to the filter bed. The backwash water enters through the underdrain. Rising up through the gravel bed, it enters the filter media. The gravel bed further distributes the water uniformly throughout the entire filter.

It is extremely important to note that in the operation of any filter, all valves have to be opened or closed slowly. As the backwash valve is opened, the amount of water rising up through the filter media gradually increases and as more and more water is forced up through the sand bed, the pressure on the underside of the individual grains of filter media becomes greater. This pressure eventually overcomes the weight of the particle of filter media and the point at which this occurs is known as the point of fluidity. Once the flow reaches this point, the article will rise and the filter bed will start expanding.

The normal expansion of the filter bed is 30 to 50 per cent during the backwash period.

Backwash space must be provided in the filter to permit this expansion during the washing period. This is why the wash trough must be at a fixed height above the filter bed. The particles of media roll around in the bed, continuously rising and falling. In the process, they rub against each other. The combined action of the water moving past the particle of media and the scrubbing action of the particles rubbing against each other removes the accumulated turbidity from the filter media grains.

It was found from experience that this does not always remove all of the turbidity from the filter media, and that over the years turbidity will accumulate on the media grains, limiting their effectiveness as a filter media. Superior backwashing may be achieved in the winter due to the denser water, however, a savings may be realized by reducing the backwash time because the bed is cleared faster.

Adequate backwashing in every filter operation is extremely important. The backwash flow rate should be as high as possible without losing filter media. The backwash should be carried on until the filter media is substantially cleaned. No media will ever be absolutely clean, regardless of the extent of the backwash.

- **Surface Wash System**

Auxiliary scour better describes the function of this device as it aids in cleaning much more than the filter surface. The purpose of the surface wash is to aid in cleaning the filter surface and prevent mudball formation by applying a jet of water to the encrusted surface before and during wash cycles.

The most common surface washers are rotary surface washers; the washer is mounted just above the filter bed and begins to rotate when water jets out of the nozzles. As the filter bed starts to expand during backwashing the washer not only cleans the top of the filter bed but becomes immersed in the filter media. Fixed jets are sometimes used as well instead of rotating washers.

Initially the filter media is backwashed at about 245 lpm per sq. m (6 gpm/sq. ft.). This is the point at which the particles of media are in effect "weightless" in the filter bed. The agitator is then turned on and allowed to run for a period of 5 to 7 minutes. The force of the jets of water from the agitator cleans the grains of the filter media and moves them so that the entire bed is gradually turned over and exposed to the jet action.

Following this, the backwash rate is gradually increased and the agitator turned off. The filter is backwashed at its normal backwash rate for as long as economically necessary to remove all accumulated turbidity. The water is then slowly turned off and the media allowed to settle before returning the filter back to operation.

- **Air Scour Wash**

Another method used to assist in cleaning the filter is accomplished by introducing compressed air into the backwash stream before it reaches the filter. Underdrain systems used for air scour usually have smaller holes, thereby creating a much diffused air-water mixture. This mixture causes extensive agitation of the media as it passes through the bed. Many feel that the method is more efficient at cleaning the filter bed than is possible by standard backwashing.

Air scour systems blast the filter media with jets of air from the bottom of the filter. The air scour systems are activated prior to backwashing and remains on until the wash water troughs begins to fill with wash water. A common problem with air scour systems is that they inadvertently remove filter media into the wash trough damaging the filter. This can usually be remedied by reducing the backwash velocity, by properly guarding the filter media and by ensuring the air scour is turned off before the backwash reaches the wash water troughs.

The proposed design criteria of the gravity filter is shown in Table 2-5.

To be noted that for future extension of the treatment plant a second gravity filter building with the same dimensions and characteristics shall be constructed.

Table 2-4 Gravity Filter Design Data

Design Parameter	Phase I	Phase II
C: Gravity Filtration Unit		
General		
Total Input Flow (m3/hr)	1,375	2,750
Number of Cells	4	8
Duty	3	6
Standby	1	2
Design Flow per unit (m3/hr)	458.3	458.3
Type of filter cell	Twin bed	Twin bed
Dimensions of each filter cell (No x m x m)	2 x 7x 5.9	2 x 7x 5.9
Area of selected cell (m2)	82.6	82.6
Inlet sluice gate width (mm)	400	400
Inlet sluice gate depth (mm)	400	400
Inlet velocity (m/s)	0.59	0.59
Outlet Sluice Valve diameter (mm)	400	400
Outlet velocity (m/s)	0.76	0.76
Wash water flow rate (Lpm/m2)	500	500
Wash water rate required (m3/min)	20.65	20.65
Air Scour rate (Lpm/m2)	750	750
Air Flow rate (m3/min)	37.75	37.75
Air Scouring Pipe diameter (mm)	250	250
Backwash water flow (m3/hr)	1239	1239
Number of Duty Backwash Pumps	1	1
Number Of Standby Backwash Pumps	1	1
Backwash Pump Capacity (m3/hr)	1239	1239
Backwash Pump Head (m)	15	15
Number of Duty Air Blower	1	1
Number of Standby Air Blower	1	1

2.6.2.8 Clear Water Tank

The Clear Water Tank volume shall be 5,000 m^3, for phase I, to be pumped to overhead distribution reservoirs via the Main Pumping Station. The reservoir shall be covered complete with access manholes and cover.

Pump start level switch and pump stop level switch shall be installed in this tank to start/stop the pump. The volume between those levels is then 1,000 m^3 to make sure that the pumps, in any case, shall have less than 10 starts per hours (this case may never happen). A Low Low Level Switch shall also be installed in the tank to provide dry run protection of pumps.

For future extension, Phase II, a second storage/strategic tank with a volume of 5,000 m^3 shall be added.

2.6.2.9 Main Pumping Station

Refer to Part 3.

2.6.2.10 Chemical Dosing Room

It shall include the following:

- Polymer Dosing set to add the polymer to the Flash mixer. It shall include, duty/standby dosing pump, mixer (when needed), level switches, flowmeter, PE or PVC tank, and all necessary control to make it complete in all aspect. Fully automatic three-chamber preparation system for dry and liquid polyelectrolytes, complete with dry powder feeder, agitators, water control station with water meter, level controls and control panel incorporating a PLC unit. The operation of this set shall be linked to the operation of the HLPS pumps. It shall have a capacity to dose 5 mg/L of polymer. Capacity: 1000 L/hr Tank volume: 2 m^3.
- Alum Feed System shall consist of Chemical Tank, It shall include, duty/standby dosing pump, mixer (when needed), level switches, flowmeter, PE or PVC tank, and all necessary control to make it complete in all aspect. The operation of this set shall be linked to the operation of the HLPS pumps. It shall have a capacity to dose 30 mg/L of Alum. Tank volume: 10 m^3. Dosing Pump Capacity: 1000 L/ hr at 3 bars.
- Prechlorination System: Gas chlorine shall be used for pre-chlorination. It shall be able to dose 1-2 mg/l and up to 3 mg/l. It shall be as per specifications of section “Chlorination System”.
- Chlorinator capacity: 8 Kg Cl2 /hr. Number of 1 Ton Chlorine Drums: 2 duty / 2 standby.

A drench shower shall be provided outside the room.

2.6.2.11 Post Chloriation

Gas chlorine shall be used for pre-chlorination. It shall be able to dose 0.6 mg/l and up to 2 mg/l. It shall be as per specifications of section “Chlorination System”.

- Chlorinator capacity: 6 Kg Cl2 /hr. Number of 1 Ton Chlorine Drums: 2 duty / 2 standby

2.6.2.12 Gantry Cranes

All lifting equipment shall be provided by the Contractor, at his own Cost, and shall be fully responsible for the operation and maintenance of such equipment. All slings and lifting equipment shall be proof load tested and stamped prior to use on the Site and shall be subject to approval of the Employer, who has the right to prohibit the use of equipment or methods considered unsafe at his sole discretion.

The Contractor shall provide the Employer with copies of the load test certificates for all lifting equipment brought onto the Site.

1. Lifting equipment – hoist unit and end carriages, drives
2. Lifting accessories (slings, grippers, hooks, beam connection plates
3. Equipment rails
4. Equipment rail attachments – rail fixtures, under-rail inserts, under-rail plates and corresponding embedment, grouting, mortar or setting resin.

5. Rail adjustments
6. End of travel stops with track mounted shock absorbers
7. Pendant and mains panel
8. Festoon Cable System
9. Power supply lines and cable reeling drum
10. Spare parts
11. First-fill oils and lubricants, and all other consumables needed for service
12. Special purpose items for equipment load testing, lifting accessories to enable test load attachment, special purpose tooling
13. Special breakdown repair or maintenance tooling.

2.6.2.12.1 General Technical Requirements for the Cranes

The crane shall be complete including all specialist equipment necessary for maintaining the crane, inspection facilities, platforms, supporting steelwork, control equipment, power supplies, lighting, lifting equipment, and walkways etc.

The crane shall be designed and constructed in accordance with BS 466. The permissible stresses design of the crane structures and mechanisms shall comply with BS 2573: Parts 1 and 2.

Any cradles used for test weight purposes or similar equipment shall be designed to appropriate international standard and to comply with the appropriate legislation.

The safe working load (SWL) shall be marked on all lifting equipment.

The crane hook envelope coverage and height of lift requirements shall service adequately all plant that needs to be lifted.

The crane shall be designed to operate on a 380V, 50Hz, 3 phase power supply. The electrical installation of the crane shall start at the long travel section. A means shall be provided on the crane for isolating the crane from the power supply close to the power pick-up point. Control circuits shall be supplied at a nominal voltage not exceeding 110V.

The crane shall have push button control from a mobile pendant suspended from its own cable track.

Crane operating speeds shall be selected to allow safe operation while using the pendant. The maximum operating speed for pendant travel operation shall be no greater than 40m/min. There shall be two operating speeds with a fast/slow ratio of 4:1. A variable speed control system may be offered as an option with advantage identified by the Contractor.

The selection of motion speeds for hoisting, cross travel and long travel shall reflect the requirements of both erection and maintenance with due consideration to the cross traverse and long travel distances.

The crane shall be provided with an overload alarm and protection device.

The design shall include a fail-safe braking system incorporating a manual-release mechanism for emergency lowering in the event of a power supply failure.

The hoist, long travel and cross traverse motion brakes and motion limiting devices shall comply with the requirements of BS 466.

Where the crane cannot gain access to particular items of plant, either due to location or where items of plant prevent floor access, lifting tackle and equipment shall be provided.

The crane and any lifting equipment shall be capable of performing their duties in the hands of normally skilled operators.

Access platforms, walkways, ladders, handholds and footholds shall be provided as necessary to give safe access to parts of the crane requiring routine inspection and maintenance. The outer sides of the platforms, walkways (including openings in platforms and walkways) shall be securely fenced with guard rails. The guard rails shall have a minimum height of 1m above the walking surface and toe boards shall have a minimum height of 50mm about the walking surface. Walking surfaces shall be non-slip. Ladders shall comply with BS 4211.

The crane shall be provided with suitable means of anchoring when left unattended.

The equipment (if installed outside) shall include suitable weather protection consistent with the atmospheric conditions specified. Enclosures shall be provided for all electrical equipment. The motor enclosure rating shall be IP55, and the instrumentation enclosure rating shall be IP65.

The design life of the cranes and associated equipment shall be 25 years.

The crane paint finish shall be Hazard Yellow to BS 4800.

2.6.2.13 Chlorination System

The chlorination system shall be for ease of operation and for maximum simplicity, reliability and for minimum maintenance.

2.6.2.13.1 Chlorine Drums

Chlorine shall be delivered and stored in drums with 1000 kg nominal capacity as specified in the earlier sections and/or shown on the relevant drawings. The chlorine drums shall be of the double dished end type and protected with a protection dome for transport. The drums shall be fitted with two outlet valves with dip pipes.

Chlorine drums not in use shall be provided with a purpose made rack to store the drums at a single level close to the floor, the rack position for each drum taking the form of an arc of a circle of greater radius than that of the drum.

Chlorine drums which are connected to a take-off manifold, in use or standby, shall be provided with one set of rollers for online drum rotation for alignment of the take-off valves.

Each set shall comprise 4 rollers of heavy duty construction. Any drum stored outside the main building should be housed in a shaded covered area so as to avoid direct sunlight.

2.6.2.13.2 Lifting Equipment

If asked for in the Particular Specifications and/or respective drawings, an electrically operated monorail shall be supplied to allow for lifting of the chlorine drums. The monorail shall comply with the specifications for lifting equipment.

The drums shall be lifted by a purpose made lifting beam suitable for hooking onto the hoist hook, comprising a horizontal bar with center lifting shackle to take the hoist hook and hooks at either end for hooking onto the drum.

Chlorine drums shall be weighed by a crane weigher comprising a dial type indicator, minimum diameter 400mm, range 0-3000 kg, with top lifting eye and bottom hook suitable for operation between the hoist hook and the lifting beam. A wall mounted rack for support shall be provided to retain the crane weigher safely out of the way when not in use. The indicator dial shall be marked with chlorine drum full and empty weights.

2.6.2.13.3 Chlorine Gas Manifold

The manifold shall be constructed of suitably sized grade 316 seamless stainless steel pipe and shall be suitable for use with dry chlorine gas with screwed or flanged connections.

Screwed joints shall be made with an approved jointing compound only. Gaskets for flanged joints shall be suitable for use with chlorine gas (i.e. PTFE).

All piping used to supply dry chlorine, liquid or gas shall be of grade 316 stainless steel. All fittings shall be forged stainless steel 316.

The pipework shall conform to API 5L or approved equal.

Isolation valves shall be designed for use on chlorine liquid/gas service and shall conform to the recommendations of the Chlorine Institute.

The valves shall be of globe type and have forged stainless steel 316 body with monel spindles and stem and PTFE packing. The valve shall be provided with screwed end connections and shall be full bore sized.

The flexible container connector shall be constructed of 10 mm O.D. cadmium plated, copper tubing. The connector shall be provided with an isolating valve and a header valve, constructed of brass. The flexible connector shall terminate with a valve and union connector set at the drum end. The arrangement will be such as to release the very minimum of chlorine gas into the atmosphere when changing drums or cylinders.

Gaskets for the flanged joints shall be of inert material compatible with the chlorine liquid or gas. A pressure gauge shall be provided on each manifold. The manifolds shall be located at a higher level than the drums to allow liquid chlorine to drain back to the drums.

2.6.2.13.4 Catchpot

Catchpots shall be connected in the manifold lines immediately before the vacuum regulators.

These shall serve to intercept any liquid chlorine which passes with the gas and allow it to vaporize back into the gas stream.

2.6.2.13.5 Vacuum Regulators

A wall mounted vacuum regulator with heater assembly shall be provided on each manifold to reduce the gas pressure to partial vacuum before going into the chlorinators. The vacuum regulator shall include pressure check/pressure relief vale assemblies. Each vacuum regulator shall be complete with a union to allow easy disconnection from the gas manifold for servicing.

The vacuum regulator shall seal off the gas supply in the event of either loss of vacuum or excess vacuum. A pressure relief valve shall be provided to prevent pressures in excess of atmospheric pressure occurring. This shall be independently piped to the neutralizing equipment (if provided), otherwise it shall be directed outside the building.

2.6.2.13.6 Automatic Changeover Device

The automatic changeover device shall be installed between the two chlorine gas line feeds from the drums to automatically switch from an exhausted chlorine gas source to a standby source without interruption of the chlorination process.

The device shall consist of a motorized ball valve at each inlet (2 in total), diaphragm protected pressure switch, 150mm diameter pressure indicator and one automatic changeover operator. The operator shall be equipped with two red and two green indicating lights, one for each source. The green light shall indicate that the source is in service. The red light shall indicate that the source is exhausted.

The device shall operate such that when both chlorine sources are available, only one will feed chlorine gas. The green indicating light on the changeover operator shall indicate which source is in service.

When the source in service becomes exhausted, the system pressure falls causing the pressure switch to actuate. This action shall automatically change the supply from one source to the other.

The automatic changeover device shall be wall mounted type. It shall be housed in a suitable sealed enclosure (IP 65) designed and manufactured specifically for the purpose stated.

Facility shall be provided to enable both motor driven valves to close on a signal from the fume detector to isolate the chlorine at source in the event of a leak. The change over device should incorporate a manual override feature.

2.6.2.13.7 Electrically Operated Gas Pressure Reducing & Shut-Off Valve

The gas pressure reducing and shutoff valve shall be of the electrically operated, diaphragm type, and shall be suitable for use with chlorine gas. The valve shall automatically regulate a varying supply pressure to a reduced and constant value. The gas pressure reducing and shut-off valve shall have a maximum capacity to suit the design requirements.

When downstream pressure exceeds the control setting, gas flow shall be shut off. The valve shall close on electrical failure, and also upon alarm or shut-down condition.

The valve shall be of the cartridge type with seat and stem assembly mounted directly into a rigid pipeline without additional support.

2.6.2.13.8 Electrically Heated Evaporator

The evaporator shall be of the electrically heated type with a thermostatically controlled water chamber. The evaporator shall automatically vaporize and superheat the liquid chlorine at a rate controlled by the usage of the system.

The vaporizing chamber shall be constructed of a steel cylinder immersed in a hot water bath which is heated by electric immersion heaters. The electric heater shall be mounted in the lower portion of the water chamber to ensure proper heat distribution with no additional circulating apparatus required.

The evaporator shall be equipped with a front panel mounted control thermostat, water level gauge, gas pressure and temperature gauges. A front panel mounted low temperature switch shall also be provided to cause the closing of the gas pressure reducing and shut off valve in the event of low water temperature. The thermostat and the temperature switch shall have calibrated gauges for ease of adjustment. Low water level switch shall also be installed in the water chamber which shall cut the power to the heaters if activated. A gas pressure relief valve complete with a safety head/rupture disc and pressure switch with diaphragm protector shall also be provided for venting.

The evaporator shall be housed in a color impregnated, corrosion resistant, fiberglass reinforced polyester cabinet which shall be removable from the front. This shall permit multiple evaporators to be mounted in order to minimize floor space requirements. The unit shall be supplied with 2 inch thick fiberglass insulation for the water chamber in order to conserve energy.

2.6.2.13.9 Automatic Chlorinator

The chlorinator shall be of the vacuum operated, solution feed type and shall automatically control chlorine gas feed rate in relation to flow and residual signals. The control signal applied to an automatic reversible motor driven V. notch gas flow control valve shall control the chlorine gas dosage, to maintain the preset residual, when selected to operate in the automatic mode. Manual and hand modes of operation shall also be provided.

The chlorinator equipment shall be designed to ensure maximum safety of operating personnel and equipment. The chlorine gas control system shall operate under vacuum to prevent gas leakage. The chlorinator shall consist of floor/wall mounted cabinet containing a flowrate indicator, an ejector vacuum gauge, an electric motor actuated control valve, a vacuum regulator and a flowmeter. The vacuum regulator shall incorporate a positive chlorine gas shut-off valve, a pressure relief valve, and an excess vacuum shut-off valve.

The flowrate indicator and the vacuum gauge shall be mounted on the cabinet face to indicate chlorine flowrate and ejector vacuum, respectively. Switches for manual electric control and auto/manual selection for the automatic control valve shall be mounted on the front of the cabinet. The vacuum regulator shall be provided with an integral liquid trap and removable inlet filter having an effective area of 5 square inches and bore size of 90 microns. An inlet heater shall also be provided to prevent liquid chlorine from reaching the regulator. The heater shall operate on 240 Vac, 50 Hz power. The ejector shall be provided with ball check and diaphragm actuated valves to prevent back flow of water into the chlorinator and vacuum lines. Loss of vacuum and out-of-gas alarm switches shall be provided.

The turn down ratio of the chlorinator shall be at least 20:1 and the flowmeter shall have an accuracy of + 4%. The chlorinator shall be fitted with a secondary check valve to prevent any water entering the chlorinator should the ejector check valve fail. A manual override facility shall be provided that has a 20 to 1 down capability.

The V. notch control valve shall be designed to automatically control gas feed rate in a compound loop control mode. The valve shall incorporate a precisely machined, corrosion resistant plug and orifice which shall provide a linear control characteristic. The valve actuator shall accept an Increment/Decrement control signal from the process controller. In the event of power failure, gas flow shall be regulated by manual knob adjustment of the automatic valve. No separate manual valve shall be required for this purpose. The chlorinators shall incorporate position feedback potentiometer in order to adjust the dosage accurately on auto mode. It shall operate on 240 Vac, 50 Hz power supply. The valve actuator signal conditioner and positioner shall incorporate state-of-the-art integrated circuitry. All valve actuator components, electronics and terminations shall be housed within a gas tight and corrosion resistant enclosure.

The chlorinator shall contain a process controller mounted in IP67 protective enclosure. The controller shall receive external 4-20 mA analogue signals from the Plant flowmeter transmitter and the chlorine residual analyzer, and an internal signal from the chlorinator that is proportional to gas flow. Suitable spans shall be available and selectable.

The controller shall be microprocessor-based type. It shall compare the measured residual with an operator-established set point, multiply this value by the plant water flow rate signal, and transmit an Increment/Decrement signal to the automatic control valve. All necessary instrumentation shall be installed to achieve stability in positioning the control valve.

The controller shall have a selectable automatic or manual output. It shall display all the selected parameters and process values.

The following alarm signals shall be provided as a minimum:

- high/low residual signals.
- low plant water flow rate.

In addition to the above, a fixed orifice valve shall be provided to manually feed chlorine gas to achieve higher ppm values (10 ppm maximum at reduced water flow rate).

The chlorinator shall be constructed entirely of materials resistant to the corrosive attack of chlorine gas. All operating components of the chlorinator shall be housed within a polyester impregnated fiberglass cabinet.

2.6.2.13.10 *Automatic Duty/Standby Changeover Panel for Chlorinators*

Each set of chlorinators (duty/standby) shall include an automatic duty/standby change over panel. It shall include a selector switch to select the duty chlorinator. The 4-20 mA flow and residual signals shall be diverted to the respective duty chlorinators through this unit. In the event of low/high vacuum failure, the standby chlorinator shall start automatically with an alarm (visual) indication on the panel. It shall automatically inhibit the chlorinators in the event of no flow in the mainline.

2.6.2.13.11 Residual Chlorine Analyzer

The residual chlorine analyzer system shall consist of a sensor assembly and an indicating transmitter. The system shall measure and indicate the residual chlorine concentration of the process liquid and transmit a linear 4-20 mA d.c signal proportional to the residual. High and Low residual switches shall be provided.

The sensor assembly shall be of three (3) electrode type using potentiostatic measurement principle. It shall be constructed of corrosion resistant materials and contain a field replaceable electrode held in place with a threaded retainer ring. The reference electrode shall be immersed in an electrolyte solution. A thermistor mounted in the sensor shall provide a wide range of automatic temperature compensation from 0 to 50°C. The sensor shall be insensitive to varying hydraulic heads and pH variations encountered during normal process operation. A corrosion and weather resistant cable supplied with the sensor shall be used for connection to the transmitter. The sensor shall permit operation within specifications at process fluid velocities down to 0 m/sec. The analyzer cell shall be of transparent Plexiglas. The sample flow rate to the analyzer shall be automatically regulated at a maximum of 4 liters/min, using a flow control valve.

The pressure of the sampling water shall be reduced through a pressure reducing valve to an acceptable level. The analyzer shall also include a fine screen filter.

The chemical analyzer equipment shall be installed in special designated chemical analyzer cubicles. The chemical analyzer cubicles shall be located such as to ensure a transportation delay of samples as short as possible. Each chemical analyzer cubicle shall house 1 duty / 1 standby residual analyzer system. The analyzer cubicles shall be double enclosure insulated type with proper sun shades. The air conditioning systems in all cases shall be redundant.

The cubicles shall be fitted with the relevant small power and lighting fittings.

The residual chlorine transmitter electronics shall all be of the solid state utilizing integrated circuitry. All components shall be mounted on printed circuit boards. The measured value of the residual concentration shall be displayed on a digital meter mounted in the transmitter case. The meter shall be of the direct reading type and the range shall be selectable from 0 to 5 mg/l. Input/output isolation shall be provided. Power supply shall be 240V ac, 50 Hz.

Degree of protection for the transmitter casing shall be IP65 (min). All analyzer transmitters shall have integral indicators and facilities for checking their calibration. Automatic compensation/correction shall be integrated in the equipment. Zero and span adjustments shall be available for calibration purposes.

The residual chlorine analyzer system shall be of the latest type, reliable and maintenance free. The analyzer shall have the capability to be fully calibrated at site.

A buffer solution feed (if required) shall be provided by a peristaltic pump using a positive head feed. This will be used to eliminate the effects of varying PH on the sample. An electrode cleaning system shall be provided by means of hydro-mechanical action or approved equal. A buffer solution tank with low level alarm shall also be provided.

2.6.2.13.12 Injection Point

Where chlorine solution is to be injected into a pipeline, an injection pipe of material not affected by chlorine solution shall be provided. The injection fittings shall comprise flanged or screwed pipe branch and isolation valve of suitable diameter to allow the injection pipe to pass through. The outer end of the isolation valve shall be fitted with a compression fitting thus enabling the injection pipe to be partially withdrawn and the isolating valve closed before complete withdrawal of the injection pipe.

2.6.2.13.13 Chlorine Dozing Pumps (Booster Pumps)

Two (2) chlorine dozing pumps (1 duty/1 standby) shall be supplied for each point of injection.

The dozing pumps shall supply water to the ejector.

Dozing water pumps shall be of single or multistage centrifugal type. The dozing pumps shall have duplex stainless steel casing, shaft and impellers.

The dozing pumps shall generally comply with the standard specifications for water transmission and distribution pumps.

Each pump shall have suction and delivery isolating valves and delivery non-return valve and safety pressure relief valve.

2.6.2.13.14 Chlorine Sampling Pumps

Two (2) chlorine sampling water pumps (1 duty/1 standby) shall be supplied for each point of sampling to pump sample water to the analyzer (if necessary). The sample water pumps shall be located in the position shown on the drawings.

Chlorine sampling pumps shall be centrifugal single stage pumps. The sampling pumps shall have D.I. casing with duplex stainless steel shaft and impellers.

2.6.2.13.15 Chlorine Gas Leak Detector

The chlorine gas leak detector shall be of the electro-chemical type, of the low maintenance type and designed to detect and provide a warning of the presence of chlorine gas in air.

The chlorine gas leak detector shall respond in less than one (1) second and be sensitive to chlorine gas at range of concentration from as low as 0.1 ppm to as high as 10 ppm by volume. An alarm condition shall be displayed on the instrument by continuous/flashing light depending on the level of chlorine gas concentration in the air. The alarm circuit shall be provided with two sets of normally open and normally closed auxiliary contacts for actuation of remote alarms and safety devices. The detector shall not be affected by other gases which may be present in the protected area. An alarm shall also be provided to indicate failure of the sensor or control unit. Illuminating and/or alarm indicators shall be provided on the control unit.

The chlorine detector shall not require reagent or buffer solution, specific to chlorine gas and shall be capable of not less than one year of unattended operation. The gas sensors shall be capable of starting extraction fans at low level of chlorine and stopping these fans at high level. The detector heads sensors shall be suitable for close coupled installation next to the control unit or remote mounting away from the control unit.

The control unit/transmitter shall be housed in a molded plastic, fume proof casing which shall have IP65 Protection degree as a minimum. The control unit shall be suitable for wall mounting with all control devices mounted on the front panel. The control unit shall be suitable for operation in the presence of high concentration of chlorine. The control unit shall be suitable for operation from 240V a.c., 50Hz supply system. The control unit shall incorporate battery backup for not less than 5 hours of operation in case of power failure. The control unit shall give history of past alarms with date and hour.

The control unit shall also include push buttons for alarm reset, alarm test and alarm accept.

The control unit shall incorporate digital display of the measured value of chlorine concentration of each sensor head. Resolution of the display shall not be greater than 0.1 ppm.

Two multi-channel control units (1 duty/1standby) shall be installed in the chlorinator room and the sensors shall be wired to both units.

The digital outputs from the control unit shall be used in conjunction with the warning lights and sirens (specified elsewhere) and shall also provide alarms in the control room and other locations as indicated in the Particular specifications. The control unit should have the facility to transmit all alarms through telemetry system if such system is available.

2.6.2.13.16 Warning Lights and Alarms

At each entrance to the chlorine store and the chlorination room two warning lights shall be installed.

A green light shall indicate that no alarms are active and thus it is safe to enter.

A red continuous light shall indicate the presence of chlorine gas in low concentrations. The same light shall be used in a flashing mode to indicate the presence of chlorine gas in high concentrations. In the event of a leak detection equipment failure, the visual warning system shall default to high concentration warning.

An external siren shall also be installed adjacent to each entrance which shall operate only on detection of high chlorine level within the room.

A large notice in both English and Arabic shall be fixed adjacent to each entrance station:

- Green Light Safe to enter
- Red Continuous Light NOT safe to enter
- Start extract fans
- Wait until green light shows.
- Red Flashing Light NOT safe to enter unless wearing breathing apparatus.
- All authorised personnel to be evacuated.

Note: It shall not be possible to start the extract fans while the red light is flashing.

2.6.2.13.17 Air Supply / Extraction System

Extract fans capable of 12 air changes/hour shall be installed in the chlorination room and drum store room. These fans shall be thermostatically controlled in auto mode. They will only start if the room temperature exceed a preset limit. Manual override facility shall always be available. These fans should automatically stop on high levels of chlorine being detected or upon failure of the leak detection equipment. These fans should be installed at low level. The above fans shall also be door interlocked so that they will start upon opening of the access door.

The extraction system shall be with ducting arrangement to discharge points at high level outside the building.

Extract fans capable of 30 air changes/hour shall be installed in the drum store and chlorination rooms. The fans shall be started automatically on detection of low level of chlorine. The fans should also be manually controlled from a switch outside the building. The fans shall be inhibited by the chlorine leak detector when it registers high level of chlorine or failure of the leak detection equipment. The fans shall be installed at low level. The extraction system shall also be with ducting arrangement to discharge points at high level outside the building.

Motor operated air supply louvers shall be provided in chlorination and drum store rooms. The louvers shall be installed at high level. The supply louvers shall open when the extract fans start and shall close when the fans stop. The motor actuators should be spring assisted so that they will close in the event of power failure.

2.6.2.13.18 Respirators

10 minutes escape sets for use in low concentration of chlorine shall be provided. This shall comprise of a face mask, an alloy steel cylinder with integral reducing/constant flow valve assembly, carried in either a jerkin or carrying bag. A pressure gauge shall be fitted to the

reducing valve and shall give a constant indication of cylinder contents. The cylinder shall comply with the requirements of BS 5045.

Each breathing apparatus set shall be supplied with spare cylinder assembly complete with control valve, pressure gauge and supply hose. The breathing apparatus shall be mounted on the inside wall immediately adjacent to each entrance to the building or on the inside of each entrance door unless otherwise directed by the Engineer. The installation shall be complete with all necessary mounting fixings and a prominent label.

2.6.2.13.19 Breathing Apparatus

A self-contained breathing apparatus for use in high concentrations of chlorine suitable for duration of 20 minutes shall comprise a full face mask with adjustable straps, a demand valve and air supply hose with contents gauge and quick release coupling for a second air hose and face mask, a compressed air cylinder with back harness and pillar valve, all of a standard pattern suitable for emergency use and rescue work in a chlorine gas contaminated area.

The equipment shall be complete with a GRP or stainless steel wall mounting storage case with transparent cover and prominent label. These should be wall mounted but stored in a suitable internal location away from the chlorination but easily accessible. This storage case shall be supplied by the system manufacturer.

Each set of breathing apparatus shall be complete with a spare compressed air storage cylinder and pillar valve for storage separately.

Chlorine proof suit with contained breathing apparatus to avoid damage due to contact with chlorine gas shall also be provided. This suit shall be approved/listed/certified for use in chlorine gas contaminated area.

2.7 Calculation Note

This design note includes process and hydraulic calculation for the water treatment plant providing a total net capacity of 1,375 m^3/hr.

As per the recommendation of ASCE (refer to Table 2-5), the WTP component shall consist of:

- Cascade aerator
- Flocculation / Coagulation / Sedimentation
- Rapid Gravity Filtration
- Disinfection.

Table 2-5 Recommended Treatment (based on Table from American Society of Civil Engineers)

TABLE 7.V. Recommended Treatment* (based on Table from American Society of Civil Engineers, *et al*[4])

	Coarse screens	Fine screens	Microstrainers	Pre-chlorination	Raw water storage	Preliminary settlement	Aeration	Flocculation	Coagulants and settling	Rapid filtration	Mixed media filtration	Slow sand filters	Post-chlorination	Superchlorination and dechlorination	Lime (—soda) softening	Activated carbon	Special aids	Desalting
Floating debris	E	E	O	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Algae	—	—	O	O	—	—	—	—	E	E	O	—	—	—	—	—	—	—
Turbidity:																		
0—5 JTUs	—	—	—	—	—	—	—	—	O	O	—	—	E	—	—	—	—	—
5—30 JTUs	O	O	—	—	—	—	—	O	E	E	O	O	E	—	—	—	—	—
30—100 JTUs	O	O	—	—	—	—	—	O	E	E	O	—	E	—	—	—	O	—
100—750 JTUs	O	O	—	—	—	—	—	O	E	E	—	—	E	—	—	—	O	—
750—1000 JTUs	O	O	—	—	O	O	—	O	E	E	—	—	E	—	—	—	O	—
> 1000 JTUs	O	O	—	—	O	E	—	O	E	E	—	—	E	—	—	—	O	—
Colour:																		
< 30 Hazen	—	—	—	—	—	—	—	O	O	O	—	—	—	—	—	—	—	—
> 30 Hazen	—	—	—	—	—	—	—	E	E	E	—	—	—	—	—	—	—	—
Tastes and odours	—	—	—	O	—	—	O	—	—	—	—	—	—	—	—	E	—	—
Calcium carbonate > 200 mg/l	—	—	—	—	—	—	—	—	—	—	—	—	—	—	E	—	—	—
Iron and manganese:																		
< 0.3 mg/l	—	—	—	O	—	—	O	—	—	O	—	—	—	—	—	—	—	—
0.3—1 mg/l	—	—	—	—	—	—	O	—	E	E	—	—	—	—	—	—	—	—
> 1 mg/l	—	—	—	E	—	—	E	—	E	E	—	—	—	—	—	—	O	—
Chlorides:																		
0—250 mg/l	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
250—600 mg/l	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
> 600 mg/l	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	E
Coliform bacteria, MPN per 100 ml:																		
0—20	—	—	—	—	—	—	—	—	—	—	—	—	E	—	—	—	—	—
20—100	—	—	—	—	—	—	—	—	E	E	—	—	E	—	—	—	—	—
100—5000	—	—	—	O	—	—	—	—	E	E	—	—	E	—	—	—	—	—
> 5000	—	—	—	E	O	O	—	—	E	E	—	—	E	—	—	—	—	—

* E essential, O optional.

2.7.1 Cascade Aerator

Aeration will help remove VOCs from water (mainly taste and odor) and increase DO level. We shall use a cascade aerator which consists of stepped concrete structure. The Hydraulic loading per m of width for a cascade aerator should be in the range of 1240 – 6200 $m^3/m.d$, and the surface loading between 50 and 200 $m^2/m^3.s$.

- For a length of cascade aerator equal to 8.8m, the hydraulic loading will be:

  1,375 * 24 /8.8 = 3,750 $m^3/m.d$ ➔ OK

- If we consider cascade aerator having 6 steps horizontal 40 cm x vertical 30 cm:

  Height of aerator H = 6 x 0.3 = 1.8 m.

  Width of aerator = (6+1) x 0.40 = 2.8 m

  Surface area = 2.8 x 8.8 = 24.64 m^2

  Surface loading = 24.64 / (1,375 / 3,600) = 64.51 $m^2/m^3.s$ ➔ OK

- Considering a pipe of DN800:

  Velocity = 0.76 m/s ➔ OK.

2.7.2 Flash Mixers (Coagulation)

Two flash mixers shall be provided each having a nominal capacity of 687.5 m^3/hr and maximum capacity 1,375 m^3/hr (in case one of the Flash Mixers is under maintenance).

Typical design values for mechanical rapid mix system provide a detention time 10s to 60 s, and a velocity gradient300 to 1500 s^{-1}.

- Selected Flash mixer tank diameter : 1.9 m

  Selected Flash mixer tank effective height : 3.2 m

  Volume V = 9.06 m^3

  Detention time t_{mixer}= 48 s ➔ OK

- Let $G = (P/\mu.V)^{\wedge 0.5} = 300\ s^{-1}$

  $P = 300^2$ x 9.06x 0.001 = 816 watts

  Select P= 1 kW

  Then G = 332 s^{-1} ➔ OK

If one flash mixer was put out of operation and the full flow was passed to the other flash mixer, the mixing time will be 24 s.

2.7.3 Clariflocculators

We will use 2 clari-flocculators each with a capacity of 687.5 m^3/hr.

2.7.3.1 FLocculator

For detention time T = 30 min;

Volume V = 687.5 x 30 / 60 = 343.75 m^3

Assume water depth = 3.7 m ➔ plan area = 92.9 m^2.

Calculate diameter of inlet pipe:

V = 0.6 m/s ➔ A = 687.5 / 3,600 /0.6 = 0.318 m^2.

- D_{pipe} = 0.63m → select D_{pipe} = 0.7m
- Concrete column thickness = 0.3m → $D_{external}$ = 1.3 m
- Area of inlet pipe = 1.33 m^2.
- Total required area of flocculator = 92.9 + 1.33 = 94.23 m^2.
- Diameter required > 10.95 m → Use diameter = 11 m.

Velocity of water below partitioning wall between clarifier and flocculator: 0.3m/min

- Area of opening required below partitioning wall = 687.5 / (0.3 x 60) = 38.2 m^2.
- Depth below partition wall = 38.2 / (3.14 x 11) = 1.10 m

Depth provided for sludge storage = 0.75 m

Total depth assuming a free board of 0.6m: 0.6 + 3.7 + 1.15+ 0.75 = 6.2 m

2.7.3.2 Clarifier

Surface loading rate: 35 m3/m2/d

- SA of clarifier = (687.5 x 24) / 35 = 471.43 m^2.
- Area of flocculator = 3.14 x $(11 + 2 \times 0.3)^2$ /4 = 105.63 m^2.
- Total area = 471.43 + 105.63 = 577.06 m^2.
- Required Diameter of clariflocculator = 27.11 m
- Use diameter = 28 m.

Length of weir = 3.14 x 26.04 = 81.76 m

- Weir loading = 687.5 x 24 / 82 = 201.22 m3/m.d: OK

2.7.4 Rapid Gravity Filter

We will have 4 filters, each composed of 2 parts, Twin bed type. 1 filter will be stand by and the 3 others in normal operation.

- Use Twin bed filters 2 x 7 x 5.9 m = 82.6 m^2. Each part of the Twin bed filter will be backwashed one at a time to save on the size of blowers and backwash pumps.
- Filtration rate = 1,375 / (82.6 x 3) = 5.54 <12 m/h → OK
- For Backwash flow rate = 500 Lpm/m2 = 30 m/hr

  Backwash pump capacity = 30 x 5.9 x 7 = 1239 m3/hr

  For Backwash pipe DN500, V= 1.75 m/s → OK
- Backwash air flow rate: 750 Lpm/m2 = 2.45 CFM/SQ.FT

  Blower capacity = 5.9 x 7 x 2.5 x 3.28 x 3.28 = 1,111 CFM = 31.48 m3/min

  If we apply 3 CFM/SQ.FT , then Blower capacity =1,333 CFM = 37.75 m3/min
- For Inlet Sluice valve/penstock: 400 x 400 mm

  V= 1,375/3600/ (3 x 2) / (0.4x0.4) = 0.398 m/s →OK
- Filtered water outlet: from each cell: 1,375 / (3 x 2) = 229 m^3/hr

  For Outlet pipe diameter = 400 mm, V= 0.506 m/s →OK

2.8 Hydraulic Profile

2.8.1 Head loss between Cascade aerator and Flash Mixer

Head Loss between Cascade aerator and Valves chamber

Pipe DN 700

Pipe length = 10 m

Flow through pipe = 0.382 m^3/s

Flow velocity = 0.99 m/s

Friction loss method: Hazen-Williams

'C' value = 100

Total pipe loss = Friction loss + Fitting loss

Total fitting K value = 1

Friction loss ={Solids factor*[0.002126*Length*(100 / C) ^ 1.85] * [(Q ^ 1.85) / (D ^ 4.8655)]}

={1*[0.002126*10*(100 / 100) ^ 1.85] * [(0.382 ^ 1.85) / (0.7 ^ 4.8655)]}

= 0.02 m

Fitting loss = K value * (v^2 / 2g) = 1 * (0.99^2 / 19.62) = 0.05 m

For pipe DN 700 :Total pipe loss = 0.02 + 0.05 = 0.07 m

Head Loss between Valves chamber and Flash mixer

Pipe DN 600

Pipe length = 10 m

Flow through pipe = 0.191 m^3/s

Flow velocity = 0.675 m/s

Friction loss method: Hazen-Williams

'C' value = 100

Total pipe loss = Friction loss + Fitting loss

Total fitting K value ≈ 1

Friction loss ={Solids factor*[0.002126*Length*(100 / C) ^ 1.85] * [(Q ^ 1.85) / (D ^ 4.8655)]}

={1*[0.002126*10*(100 / 100) ^ 1.85] * [(0.191 ^ 1.85) / (0.6 ^ 4.8655)]}

= 0.012 m

Fitting loss = K value * (v^2 / 2g) = 1 * (0.675^2 / 19.62) = 0.023 m

For each pipe DN 600 :Total pipe loss = 0.012 + 0.023 = 0.035 m

If one flash mixer is under maintenance, the head loss in the pipe becomes 0.119 m

Total Head Loss between cascade aerator and Flash mixer is 0.07 +0.136 = 0.206 m

The elevation of water level in cascade aerator is higherthan21 cm compared to flash mixer → OK.

2.8.2 Head loss between Flash Mixer and Clariflocculator

Head Loss between flash mixer and distribution box

1. Pipe DN 600

   Pipe length = 6 m

   Flow through pipe = 0.191 m^3/s

   Flow velocity = 0.675 m/s

   Friction loss method: Hazen-Williams

   'C' value = 100

   Total pipe loss = Friction loss + Fitting loss

   Total fitting K value ≈1

   Friction loss ={Solids factor*[0.002126*Length*(100 / C) ^ 1.85] * [(Q ^ 1.85) / (D ^ 4.8655)]}

   ={1*[0.002126*6*(100 / 100) ^ 1.85] * [(0.191 ^ 1.85) / (0.6 ^ 4.8655)]}

   = 0.007m

   Fitting loss = K value * (v^2 / 2g) = 1 * (0.675^2 / 19.62) = 0.025 m

   For pipe DN 600: Total pipe loss = 0.007 + 0.025 = 0.032 m

2. Pipe DN 700

   Pipe length = 14 m

   Flow through pipe = 0.382 m^3/s

   Flow velocity = 0.99 m/s

   Friction loss method: Hazen-Williams

   'C' value = 100

   Total pipe loss = Friction loss + Fitting loss

   Total fitting K value = 1.5

   Friction loss ={Solids factor*[0.002126*Length*(100 / C) ^ 1.85] * [(Q ^ 1.85) / (D ^ 4.8655)]}

   ={1*[0.002126*14*(100 / 100) ^ 1.85] * [(0.382 ^ 1.85) / (0.7 ^ 4.8655)]}

   = 0.028 m

   Fitting loss = K value * (v^2 / 2g) = 1.5 * (0.99^2 / 19.62) = 0.074 m

   For pipe DN 700: Total pipe loss = 0.028 + 0.07 = 0.102 m

Total Head Loss between Flash mixer and Distribution box is 0.032 +0.102 = 0.134 m

If one flash mixer is under maintenance, the head loss becomes 0.221 m

Head Loss between distribution box and clariflocculator

Pipe diameter = 500 mm

Pipe length = 25 m

Flow through pipe = 0.191 m^3/s

Flow velocity = 0.973 m/s

Friction loss method: Hazen-Williams

'C' value = 100

Total pipe loss = Friction loss + Fitting loss

Total fitting K value = 1

Friction loss = {Solids factor*[0.002126*Length*(100 / C) ^ 1.85] * [(Q ^ 1.85) / (D ^ 4.8655)]}

={1*[0.002126*25*(100 / 100) ^ 1.85] * [(0.191 ^ 1.85) / (0.5 ^ 4.8655)]}

=0.072 m

Fitting loss = K value * (v^2 / 2g) = 1 * (0.973^2 / 19.62) = 0.048 m

Total pipe loss = 0.072 + 0.048 = 0.12 m

If one clariflocculator was under maintenance, the head loss becomes 0.454 m

Total Head Loss between Flash mixer and Clariflocculator is 0.221 +0.454 = 0.675 m

2.8.3 Head Loss between clariflocculator and Filter

Each clariflocculator receives a normal flow of 687.5 m^3/hr =0.191 m^3/s.

Head Loss between clariflocculator and collection box

Pipe diameter = 500 mm

Pipe length = 10 m

Flow through pipe = 0.191 m^3/s

Flow velocity = 0.973 m/s

Friction loss method = Hazen-Williams

'C' value = 100

Total pipe loss = Friction loss + Fitting loss

Total fitting K value = 1

Friction loss = {Solids factor*[0.002126*Length*(100 / C) ^ 1.85] * [(Q ^ 1.85) / (D ^ 4.8655)]}

= {1*[0.002126*10*(100 / 100) ^ 1.85] * [(0.191 ^ 1.85) / (0.5 ^ 4.8655)]}

= 0.029m

Fitting loss = K value * (v^2 / 2g) = 1 * (0.973^2 / 19.62) = 0.048 m

Total pipe loss = 0.029 + 0.048 = 0.077 m

If 1,375 m^3/hr will pass through one pipe (due to maintenance works), the head loss will be 0.29m.

Head loss from collection box to filters

Pipe diameter = 700 mm

Pipe length = 80 m

Flow through pipe = 0.382 m^3/s

Flow velocity = 0.99 m/s

Friction loss method: Hazen-Williams

'C' value = 100

Total pipe loss = Friction loss + Fitting loss

Total fitting K value = 7

Friction loss = {Solids factor*[0.002126*Length*(100 / C) ^ 1.85] * [(Q ^ 1.85) / (D ^ 4.8655)]}

= {1*[0.002126*80*(100 / 100) ^ 1.85] * [(0.382 ^ 1.85) / (0.7 ^ 4.8655)]}

=0.162 m

Fitting loss = K value * (v^2 / 2g) = 7 * (0.99^2 / 19.62) = 0.352 m

Total pipe loss = 0.162+ 0.352 = 0.514m

The total head loss between the clariflocculator and the filters is 0.812m

2.8.4 Head loss from filters to clear water tank

Pipe diameter = 700 mm

Pipe length = 45 m

Flow through pipe = 0.382 m^3/s

Flow velocity = 0.99 m/s

Friction loss method = Hazen-Williams

'C' value = 100

Total pipe loss = Friction loss + Fitting loss

Total fitting K value = 3

Friction loss = {Solids factor*[0.002126*Length*(100 / C) ^ 1.85] * [(Q ^ 1.85) / (D ^ 4.8655)]}

= {1*[0.002126*45*(100 / 100) ^ 1.85] * [(0.382 ^ 1.85) / (0.7 ^ 4.8655)]}

= 0.09m

Fitting loss = K value * (v^2 / 2g) = 3 * (0.99^2 / 19.62) = 0.149 m

Total pipe loss = 0.09 + 0.149 = 0.239 m

The head loss through the clean filter media bed is 0.6 m.

Current level of water: +49.1 m

Highest water level in storage tank: +46.91 m

Residual pressure remaining 49.1 – 46.91 – 0.6 – 0.239 = 1.35 m. OK.

The Hydraulic Profile of the Water Treatment Plant is illustrated in Part 1-4.Volume V:Tender Drawings

3 MAIN PUMPING STATION

3.1 Introduction

The proposed pumping station will be located within the treatment plant facility and shall include 6 sets of pumps. One to transfer water from the dam to the treatment plant, one to transfer water from the dam to the irrigation canal, 3 sets to transfer treated potable water from the treatment plant storage tank to Ras Nihach, Hamat and Batroun reservoirs and one set of backwash pumps.

Therefore the proposed pumping station is a large structure that should offer a high level of both efficiency and durability.

Pumping time is assumed to be 16 h/day; thus it is the sum of the daily demands multiplied by 1.5.

To be noted that site visits were performed by Dar Taleb Engineers and a topographic survey was performed for the selected location.

3.2 Pumping Station Components

The pumping station will includes the following:

- 1 set of pumps (2 duty pumps, 1 stand-by pump and 1 pump for future extension) to transfer water from the dam to the treatment plant.
- 1 set of pumps (1 duty pumps and 1 stand-by) to transfer water from the dam to the irrigation canal.
- 1 set of horizontal centrifugal pumps, (1 duty and 1 stand-by) to transfer the treated water to overhead distribution reservoir of Ras Nihach.
- 1 set of horizontal centrifugal pumps, (2 duty and 1 stand-by each) to transfer the treated water to overhead distribution reservoir of Hamat.
- 1 set of horizontal centrifugal pumps, (2 duty and 1 stand-by each) to transfer the treated water to overhead distribution reservoirs of Batroun.
- 1 set of backwash pumps (1 duty and 1 stand-by) to clean the gravity filter from accumulated turbidity.

Table 3-1 Gravity Filter Design Data

Reservoir	Parameters	Number/Description
W.T.P.	Set of pumps	1
	Duty	2
	Stand-by	1
	For future extension	1
	Type of Pump	Horizontal centrifugal
	Flow Per Pump (m^3/h)	690
	Total Dynamic Head (m)	20
For Irrigation	Set of pumps	1
	Duty	1
	Stand-by	1
	Type of Pump	Horizontal centrifugal

Reservoir	Parameters	Number/Description
	Flow Per Pump (m^3/h)	612
	Total Dynamic Head (m)	70
Ras Nhach Reservoir	Set of pumps	1
	Duty	1
	Stand-by	1
	Type of Pump	Horizontal centrifugal
	Flow Per Pump (m^3/h)	57
	Total Dynamic Head (m)	338
Hamat Regional Reservoir	Set of pumps	1
	Duty	2
	Stand-by	1
	Type of Pump	Horizontal centrifugal
	Flow Per Pump (m^3/h)	418
	Total Dynamic Head (m)	250
Batroun Reservoir	Set of pumps	1
	Duty	2
	Stand-by	1
	Type of Pump	Horizontal centrifugal
	Flow Per Pump (m^3/h)	338
	Total Dynamic Head (m)	223
Backwash	Set of pumps	1
	Duty	1
	Stand-by	1
	Type of Pump	Horizontal centrifugal
	Pump Capacity (m^3/h)	1240

All pumps connection shall be rated to withstand the surge pressure (but not less than PN 25).

In addition to the level controls mentioned above (which are mentioned below also), the Main Pumping Station shall have the following protection:

- Ultrasonic Level sensor: It shall provide 4 – 20 mA for level reading and control of Low and High Level of the water. At Low level, all the pumps shall stop. At High Level, an Alarm (Visible and audible) shall be energized.
- Low Low Level (LLVL) switch as backup in case the Ultrasonic Level switch fails. The LLVL shall stop the pumps and energize the Low Level Alarm.
- High Level Switch (HLVL) as backup in case the Ultrasonic Level switch fails. The HLVL switch shall energize the High Level Alarm.
- The pumps shall be protection by the following devices:
- No Flow: consisting of limit switch installed the check valve of each pump.
- Closed valves: Valves are automatic and equipped with limit switches. If any valve (at suction or discharge) is closed, the pump will not start.

- Vibration sensor and monitor installed for each pump. This will stop the pump of vibration limit is exceeded
- Hi Pressure switch/Transmitter installed at the discharge of each pump. This protects the pumps against mistakenly closed valves. Also if an altitude valve is installed at the discharge into the remote distribution reservoir, this pressure switch will help in stopping the pump. The altitude valve will mechanically / hydraulically open and /or closed depending on present water level in the reservoir.
- Vacuum switch or Low Pressure switch: to stop the pump if suction valve is closed or there is not enough water in the reservoir.
- Bearing temperature sensor
- PTC thermistor for the motor
- Overload relay
- Oil leak detection for pump.

A chlorine sensor/analyzer shall be installed at the suction of the Pump to give reading of the chlorine value and to automatically increase or decrease the chlorine dosage rate. The chlorine dosage rate at pumps suction shall be 0.5 mg/l to 0.8 mg/l to make sure that residual chlorine will remain in the distribution reservoir. This value can be adjusted during operation if the chlorine residual in the storage reservoir is less than 0.2 mg/l. The chlorine dosage rate is then controlled by Two devices: flowmeter and chlorine analyzer.

Each Pumping set shall be equipped with the proper surge vessel to prevent high water hammer.

The Motor Control Center (MCC3) for those pumps shall be installed in the HLPS.

The figures 3-1 and 3-2 illustrate respectively the plan view and section of the Pumping station design.

Figure 3-1 Plan View of the Pumping Station

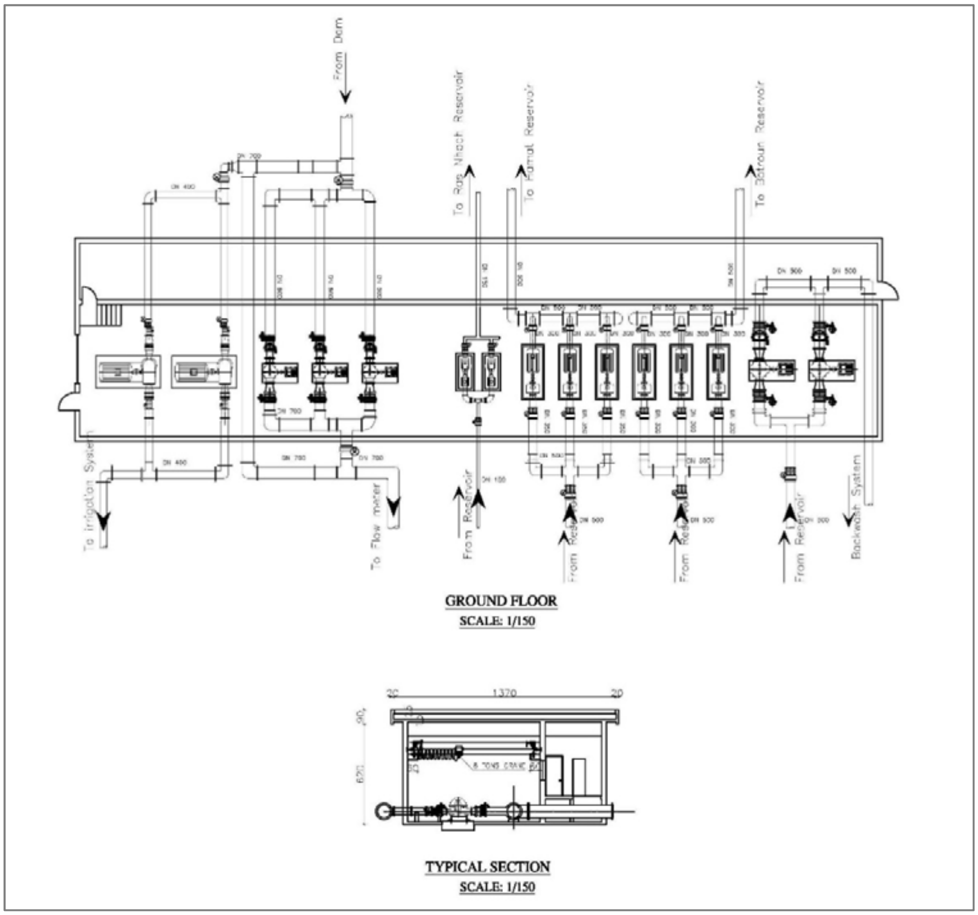


Figure 3-2 Section of the Pumping Station