4.4 MECHANICAL WORKS

4.4.1 Main Inlet Chamber (Facility No.0)

The main inlet chamber is built of ferro-concrete and it is connected to the main collector by a pipe of diameter 2,000 mm at invert level of + 481.12 m. The Rajlovac collector with diameter 800 mm is connected at invert level of + 482.02 m. From the inlet chamber, wastewater flows to the Raw Water Pumping Station through a concrete pipe with diameter of 2,000 mm and length of 57 m. The flow of wastewater to the WWTP is controlled by sluice gate driven by a motor through a reducer. The main sluice gate has the following characteristics:

Mark	10 - TB - 01
No. of pcs	1
Manufacturer	MIN NIS
Type	Plane with thread spindle Driven by electrical motor through reducer
Emergency drive	Manual
Motor power	2.5 kW
No. of turns	1,450 rpm

The drive motor was removed and part of reducer is broken. The stop gate spindles as well as retainers are damaged severely. Therefore, the main sluice gate assembly needs to be replaced with new one including necessary auxiliaries.

4.4.2 Raw Water Pumping Station (Facility No.1)

Raw wastewater flows into the wet well where it is then lifted by the screw pumps into the channel of the Screening Station. The screw pumps has following characteristics:

Mark	0 - P - 01
No. of pcs	4
Manufacturer	Flygt
Type	Screw Pump (Archimedean spiral)
Capacity (Max.)	1.3 m^3/ s per unit
Inclination angle	38 degree
Rise height	8.91 m
No. of turns / pump screw	30 turns / min
Motor power	160 kW
No. of motor turns	1,480 rpm

The pump screw and shaft are constructed of carbon steel, with rust protection coat made of plastic base. The lower bearing is of sliding type and it is oiled by grease under pressure by gear pump driven by the pulley from main drive motor. The upper bearing is radio-axial, cylindrically installed in box mounted on the concrete floor. The screw is driven by a speed reducer of the following characteristics:

Mark	10- R-01
No. of pcs	4
Manufacturer	Hansen-Patent France

Type	NK 31-BRY
Reduction ratio	1,480/29.4 rpm

Reducers are placed in cast boxes, where oiling and power transmission are done by pulley with trapezoidal V-belts. Reducers are damaged severely by the action of the incoming foreign materials during operation. All 4 pumps can be rehabilitated by replacing the parts except for the screws and shafts. The screws and shaft require readjustment and application of anti-rust protective painting.

4.4.3 Screening Station (Facility No.2)

The Screening Station is composed of 4 sets of coarse and fine screens. The automatic coarse screens has the following characteristics:

Label	10-AR-01
No. of pcs	4
Manufacturer	Degremont France
Type	Plane with bars
Bar width	1,500 mm
Bar Spacing	50 mm
Drive/ moving of rakes	Electrical motor/wrench with wire cables
Drive motor	2.5 kW
No. of turns	2,950 rpm

The coarse screens are made of carbon steel, welded construction with anti-rust coating made of plastics base. It is electrically driven by a motor with reducer and rakes are operated by wrenches with wire cables. Screenings are transferred to the belt conveyor for disposal. Part of the drive motors of all 4 automatic coarse screen are missing and the wrenches cables are damaged severely. All 4 coarse screens are to be newly replaced.

The characteristics of the automatic fine screens are as follows:

Label	10-AR-02
No. of pcs	4
Manufacturer	Degremont France
Type	Plane with bars
Bar width	1,500 mm
Bar spacing	25 mm
Drive/moving of rakes	Drive motor/wrench with wire cables
Drive motor	2.5 kw
No. of turns	2,950 rpm

The fine screens are made of carbon steel, welded construction with anti-rust coating made of plastic base. It is electrically driven by motors with reducer and the rakes are are operated moving by wrenches with wire cables. Screenings are transferred to the belt conveyor for disposal. Part of the drive motors of all 4 screens are missing and their wrenches' cables are damaged severely. New replacement of the 4 fine screens is necessary.

4.4.4 Aerated Grit Chamber (Facility No.3)

Grit is removed by an aerated grit chamber consisting of 3 channels with the following characteristics:

Label	10-AP-01
Form	Rectangular
No. of channels	3
Length of channels	29 m
Total width	12.4 m
Depth	4.4 m
Surface area per channel	116 m^2
Total surface area	348 m^2
Volume per channel	400 m^3
Total net volume	1,200 m^3

The chamber is made of ferro-concrete with side channels for transport of grit and scum. The channels are inclined at the bottom to allow slow sedimentation and sludge evacuation. Sand trap is equipped with aeration system, made of galvanized pipe with nozzles for production of air bubbles, and by mammoth pumps for sludge evacuation. The pumps are fixed at the mobile sand trap bridge. The sand trap bridge has following characteristics:

Label	10-MP-01
No. of pcs	1
Manufacturer	Degremont France
Type	DES 3AL 06-80
Bridge drive	Electrical motor through reducer
Drive motor	1.5 kW

The bridge is welded carbon steel, with anti-rust protection painting. It is moving on concrete rails with rubber wheels driven by drive motor through reducer. There is a roofing at the bridge, where compressor for air lift is installed.

Metal bridge construction is attacked severely by corrosion. Bridge drive motor is rusted and flexible cab tire cable for the motor is missing. Aeration system, including galvanized pipe is damaged heavily. The mammoth pumps and pipelines appear to have lapsed their useful lives. As a conclusion, whole aeration and sand trap mechanism and auxiliaries need to be replaced with new one.

4.4.5 Primary Sedimentation Tank (Facility 4)

Wastewater treated at the pre-treatment flows by gravity to the radial primary sedimentation tanks. The Primary Sedimentation Tanks are provided with the mechanisms with drive heads of the following characteristics:

Label	11-MZ-01
No. of pcs	2
Manufacturer	Degremont France
Type	EP. 4.07-80
Bridge drive	By electro-motor through reducer
Drive motor	0.75 kW

The mechanism is welded carbon steel with anti-rust protection painting. It moves radially on central ball bearing, driven by electro-motor through reducer peripherally on circular concrete rail with rubber roller. At the mechanism, there are scrappers for sludge collection and facilities for removing scum called scum skimmer.

Drive motors of mechanisms are dismounted. Drive heads for mechanisms are both damaged. Therefore, drive motors and drive heads should be replaced with new ones. The heavily corroded diagonal beams need to be replaced with new ones. All bolts and nuts for need to be replaced with stainless steel. The rake's blade need new replacement.

4.4.6 Aeration Tank (Facility No.5)

There are 36 aeration turbines with the following characteristics:

Label	11-AT-01
No. of pcs	36
Manufacturer	Degremont France
Type	2 speeds with horizontal rotor
Drive motor	37 kW
No. of motor turns	1,465/51.9/28.4 rpm

The revolution in the aeration turbines is reduced from 1,465 rpm to 51.9, and finally to 28.4 rpm by reducers of the following characteristics:

Label	11-R-01
No. of pcs	36
Manufacturer	Hansen-Patent France
Type	NE 36-AN
Drive motor	37 kW
No. of turns	1,465/51.9/28.4 rpm

The reducer is placed in cast iron casing with oil bath. The transmission is done through shaft with helical gear reducers.

Among the 36 aeration turbines, 3 sets are out of drive motors, 2 sets are inclined, 2 sets have oil piping broken and 10 sets have coupling between drive motors and reducers broken. Therefore, the remaining 19 sets of turbines were tested for two hours continuous load test.

The result of the turbine load test shows that 19 out of 33 aeration turbines are usable. Detailed information of the test are compliled in **Appendix C, Vo.Ⅲ**

4.4.7 Final Sedimentation Tank (Facility No.6)

The Final Sedimentation Tanks are radial form with the following characteristics:

Label	11-ST-02
Form	Radial
No. of pcs	4
Diameter	52 m
Water depth	3.0 m

Manufacturer	Degremont France
Surface area	2,224 m^2
Volume	7,390 m^3

The Final Sedimentation Tanks are center drive with rigid accesses. The bridges are welded carbon steel, with anti-rust protection painting coated with plastic base. These are provided with scrapers for sludge collection and scum skimmer for floating objects. Drive motors of all 4 final sedimentation tanks are dismounted and all drive heads are incomplete. The structures' mechanisms are partly attacked by rust and almost all bolts and nuts are corroded heavily. The structures' mechanisms need cleaning and application of anti-rust protection painting.

The drive units and central sliding sleeves need to be replaced with new ones. All bolts and ruts are to be replaced with stainless steel.

4.4.8 Recycled Sludge Pumping Station (Facility No.8)

Sludge from Final Sedimentation Tanks flows to this pumping station, where it is mixed and recirculated to Aeration Tank for keeping up the biological process. The pumping station for sludge recirculation is made of ferro-concrete with two screw pumps of the following characteristics:

Label	11-P-02
No. of pcs	2
Manufacturer	Flygt
Type	Screw pump (Archimedean spiral)
Capacity (Max.)	120 m^3/hrs.
Diameter of spiral	2,500 mm
Height of lifting	8 m
No. of turns pump spindle	26 turns/min
Drive motor	100 kW
No. of motor turns	1,480 rpm

The revolution in the screw pumps are reduced from 1,480 rpm to 26 rpm by reducers of the following characteristics:

Label	11-R-02
No. of pcs	2
Manufacturer	Hansen-Patent France
Type	NH 31-BRY
Reduction ratio	1,480/26 rpm

Reducer is placed in cast iron casing with oil bath, and reduction is done by pulley with trapezoidal belt.

Pump screws are of carbon steel, with anti-rust protection painting coated with plastic base. Lower bearings are sliding system and these are oiled by gear pumps driven by pulley from main drive motors. Upper bearings are radio-axial, cylindrically installed in box mounted on the concrete floor. Screws and shaft are in good condition but require anti-rust protection painting, and readjustment. Parts for oiling of the foot bearing are partially dismounted. Drive units and foot bearings including all necessary auxiliaries for grease lubrication need to be replaced with new ones.

4.4.9 Primary Sludge Pumping Station (Facility No.9)

Sludge from Primary Sedimentation Tanks are induced by pumps with the following characteristics:

Manufacturer	Unitec
Drive motor	15 kW
No. of turns	1,450 rpm
Type	Vortex Torque Flow Type
No. of pcs	2

These pumps are damaged severely and no drive motors exist. Therefore all pumps including auxiliaries and drive motors need to be newly replaced.

4.4.10 Sludge Thickener (Facility No.10)

Sludge thickeners are radial, made of ferro-concrete, having coned bottom with 20% inclination towards the center for thickened sludge. They are provided with bridge mechanisms and center drive for sludge collector gathering with the following characteristics:

Label	12-MU-01
No. of pcs	2
Manufacture	Degremont France
Type	EP
Bridge drive	by electro-motor through reducer
Drive motor	1.5 kW

The bridge mechanisms are welded carbon steel with anti-rust protection painting. These equipment is driven by electro-motor through reducer.

The drive motors of sludge thickeners were found missing, and drive heads incomplete. The structure's mechanisms are partly attacked by rust and certain numbers of bolts and nuts are corroded heavily. The structure's mechanisms need cleaning, application of anti-rust protection painting and readjustment. All bolts and nuts need to be replaced with stainless steel. Drive heads need to be replaced with new ones.

4.4.11 Thickened Sludge Pumping Station (Facility No.11)

Thickened sludge in the sludge thickeners are sucked by pumps with the following characteristics:

Label	12-P-01
No. of pcs	2
Manufacturer	Unitec
Type	Vortex Torque Flow Type
Capacity	60 m^3/hrs.
Discharge head	49 m

Drive motor	15 kW
No. of turns	1,450 rpm

These pumps are damaged severely and no drive motors exist. Therefore all pumps including auxiliaries with drive motors are to be replaced.

4.4.12 Sludge Digester (Facility No.12)

The thickened sludge are pumped into the anaerobic digesters with the following characterictics:

Label	12-DG-01
Form	Radial
No. of pcs	2
Diameter	27.80 m
Height	14.0 m
Surface area	607 m^2
Volume in use	9,000 m^3

Digesters are ferro-concrete with device for mixing, i.e. agitating of sludge with digestor's gas, device for sludge recirculation and reheating. Sludge is heated by heat exchangers with the following characteristics:

Label	12-IT-01
No. of pcs	2
Manufacturer	Degremont France
Type	Tube- like, anti electrical
Heating power of unit	3,350 kJ

The heat exchangers are damaged and corroded heavily therefore, all heat exchangers and auxiliaries need to be replaced with new ones.

4.4.13 Boiler House (Facility No.13)

Sludge recirculation is done by 3 pumps installed in the Boiler House with the following characteristics:

Label	12-P-02
No. of pcs	3
Manufacturer	Unitec
Type	F6, Vortex Torque Flow Type
Capacity	225 m^3/hr
Discharge head	9 m
Motor power	18.5 kw
No. of turns	1,450 rpm

These pumps are damaged very severely. Therefore, all pumps and auxiliaries with drive motors are to be replaced with new ones.

4.4.14 Gas Compressor Station (Facility No.14)

There are 6 gas compressors in the Gas Compressor Station. Three of them are utilized for recirclation of sludge mixing with the following characteristics:

Label	12-K-02
No. of pcs	3
Manufacturer	MPR France
Type	RF 70
Capacity	582 Nm^3/hrs.
Pressure	2 bars
Drive motor	37 kW
No. of turns	975 rpm

The other three are utilized for transporting digested gas from gas storage tank to power generation. These compressors have the following characteristics:

Label	12-K-04
No. of pcs	3
Manufacturer	MPR France
Type	RF 40
Pressure	2.2 bars
Drive motor	30 kW
No. of turns	1,450 rpm

All six gas compressors are damaged very severely. Because of the complexity of these compressors transporting the very explosive gas, these are to be replaced with new ones, including its auxiliaries.

4.4.15 Gas Storage Tank (Facility No.15)

Digested gas is stored in a reservoir with the following characteristics:

Label	12-TK-01
No. of pcs	1
Type	Floating roof
Capacity	5,000 m^3/hrs.

Floating roof of the reservoir is made of steel plate, welded and with anti corrosion protection. Sealing is done by water. The gas tank is provided with necessary service pipes and reinforcement for pressure keeping and device for separation the water from gas. The roof and floating guide need to be repaired and applied with anti-rust protection painting. Service pipes including auxiliaries need to be replaced.

4.4.16 Homogenized Sludge Holding Tank (Facility 16)

From digesters, where it is stabilized completely, the digested sludge is pumped into the Homogenized Sludge Holding Tank. The tanks are provided with bridge mechanism with center drive for sludge mixing and thickening with the following characteristics:

Label	12-MH-01

No of pcs	1
Manufacturer	Degremont France
Type	EP, sludge thickener with picket (center drive)
Drive motor	1.5 kW
Diameter	30 m
Water depth	3.5 m
Volume	3,410 m^3

Bridge mechanism are welded carbon steel, anti rust-protection painting. It moves radially on the center bearing driven by electro-motor through reducer. Raking mechanism facility for removing floating materials are moving together for collecting thickened sludge and collecting floating objects at scum trough.Drive motor of the thickener is dismounted and drive head is incomplete.

The structure's mechanism is partly attacked by rust, and most bolts and nuts are corroded severely. The structure's mechanism needs cleaning, and application of anti-rust protective painting. The drive head needs to be replaced with new one and all bolts and nuts to be replaced with stainless steel.

4.4.17 Sludge Pumping Station (Facility No.17)

From the sludge tank, the thickened sludge is pumped for dewatering by 5 pumps with the following characteristics:

Label	12-P-03
No. of pcs	5
Manufacturer	PCM-Moineau
Type	VR 121
Capacity (Max.)	28 m^3/hrs.
Discharge head	15 m
Drive motor	1.5 kW
No. of turns	1,450 rpm

Pumps have eccentric rotors, driven by electrical motor through reducer, so the numbers of turns can be regulated. All drive motors, part of transmission mechanisms and reducers were dismounted. Almost all parts except pump casings are not existing. Therefore all 5 sets of pumps need to be replaced with new ones.

4.4.18 Sludge Dehydration (Facility No.18)

Homogenized and stabilized sludge is pumped to the 5 filter presses, where dehydration is done, i.e. separation of water to make sludge cake with decreased volume and dry enough for disposal. The filter presses have following characteristics:

Label	12-PF-01
No. of pcs	5
Manufacturer	Degremont-Press Deg France
Type	736
Width of filter press	3 m
Length of filter press	11 m
Working capacity	33 m^2

Capacity	800 kg SM/hr

All 5 presses are devastated, the electrical motors, transmission mechanisms, part of automatics, filter clothes are dismounted. Pipe lines of air automatics are cut. Therefore all the 5 filter presses need to be replaced with new ones.

The filter presses facility is served by overhead bridge crane with the following characteristics:

Label	12-KR-01
No. of pcs	1
Manufacturer	Vulkan Rijeka
Type	TRM 63 KN
Lifting capacity	6.3 ton
Feed range/ length	40 m
Drive-main/2aux. Drives	6 kW/2kW

The crane is bridge type, made of carbon steel, with anti-rust protection painting and provided with steel wire and lifting hook. The crane can be controlled from the ground through the switch cabinet or hand mobile commander. The crane is in good condition but needs cleaning, application of anti-rust painting and readjustment. Cables from the ground command and from switch cabinet are devastated and not complete, therefore need to be replaced with new one including auxiliaries.

4.4.19 Air Blower Room (Facility No.19)

Aeration sand trap contains galvanized pipelines and air nozzles. Aeration is done by blowers with the following characteristics:

Label	10-D-01
No. of pcs	3
Manufacture	Aerzenert-Aerzen
Type	GLA-1317
Capacity	13 Nm^3/hrs
Working pressure	1 bar
Drive motor	10 kW
No. of turns	1,450 rpm

There are no motors existing and part of flexible coupling is missing. The blowers are damaged severely therefore, all these blowers need to be replaced with new ones including auxiliaries.

4.4.20 Power Station (Facility No.20)

The digested gas is transformed into electric power by 2 diesel engine generators with the following characteristics:

Label	12-GM-01
No. of pcs	2
Manufacturer	Diesel Sacm France
Type	G8 LS

No. of cylinders	8 lines
Power	900 kW
No. of turns	1,000 rpm

Diesel gas engines have systems for air admission, drain exhaust gasses and heat exchangers for cooling.

These diesel engines were manufactured 19 years ago in 1980. During that period, its operation was short due to the following:

(1) test period for commissioning,
(2) suffered many operational interruption due to lack of gas production, and
(3) the whole plant stopped operation in April 1992 due to war and never started again since then.

Due to the long stand-still condition and disastrous conservation since April 1992, these machines were found to have suffered extensive damages which make their replacement with new units safer and more cost effective than refurbishment.

4.4.21 Service Water Pumping Station (Facility No.24)

The plant uses treated water for washing the filter clothes of the Presdeg and supply of the fire hydrant. It is provided with 2 pairs of bigger pumps with the following characteristic:

Label	13-P-01
No.of pcs	2
Manufacturer	Listroj Slovennija
Type	3CN 7
Capacity (Max.)	35l/s
Discharge head	7.06~6.47 m
Drive motor	37 kW
No. of turns	2,900 rpm

The smaller sets of pumps have the following characteristics

Label	13-P-02
No. of pcs	2
Manufacturer	Listroj Slovenija
Type	2CN 7
Capacity (Max.)	14l/s
Discharge head	6.85~5.98 m
Drive motor	22 kW
No. of turns	2,900 rpm

The pumps are horizontally driven by electrical motors through periflex coupling directly. The pumps and the motors are installed on the same concrete base. Pump bodies are of cast iron with mechanical seals. The bigger pumps are with motors and smaller pumps are without motors. These 4 pumps are damaged severely including accessories therefore all four pumps including auxiliaries need to be replaced. The small pumps need new motors and the bigger pump's motors can be used with small repairs such as replacement of bearings and rewinding.

4.5 ELECTRICAL WORKS

4.5.1 Electric Power Supply System

The electric power supply system in the WWTP is consisting of Power Station and Substation. **Figure 5.2** shows single line diagram of electric power supply system.

(1) Power Station (Facility 20)

The 2 units of synchronous generators (640 kW, 800 kVA, 400 V, 50 Hz) being coupled with diesel engine were found existing in the Power Station. These generators are presently damaged on the exciter. Therefore, these generators should be replaced with new one.

Generator control panels are seriously damaged. The metal enclosed panels are broken. Almost all electric instruments/parts were removed and taken away. All inside wirings of panel inside are cut.

The high tension (HT) switch gears and low tension (LT) power distribution/motor control panels are heavily damage as much as the generator control panels.

The 2 units transformers of 10/0.4 kV, 1,000 kVA and 2 units transformers of 10/0.4 kV, 1,600 kVA were removed and taken away.

All HT and LT cables were cut and were taken away.

It is considered that all electric equipment and cables should be newly replaced or reconstructed.

(2) Substation(Facility 21)

In this substation, the HT switch gear and LT power distribution/motor control panels are heavily damaged. The metal enclosed panels are broken, and stain & corrosion are progressing on the panels. Almost all electric instruments/parts were almost removed and taken away. All inside wirings of panel inside are cut.

Transformer 10 / 0.4kV 1,600kVA (1pcs) were removed and taken away.

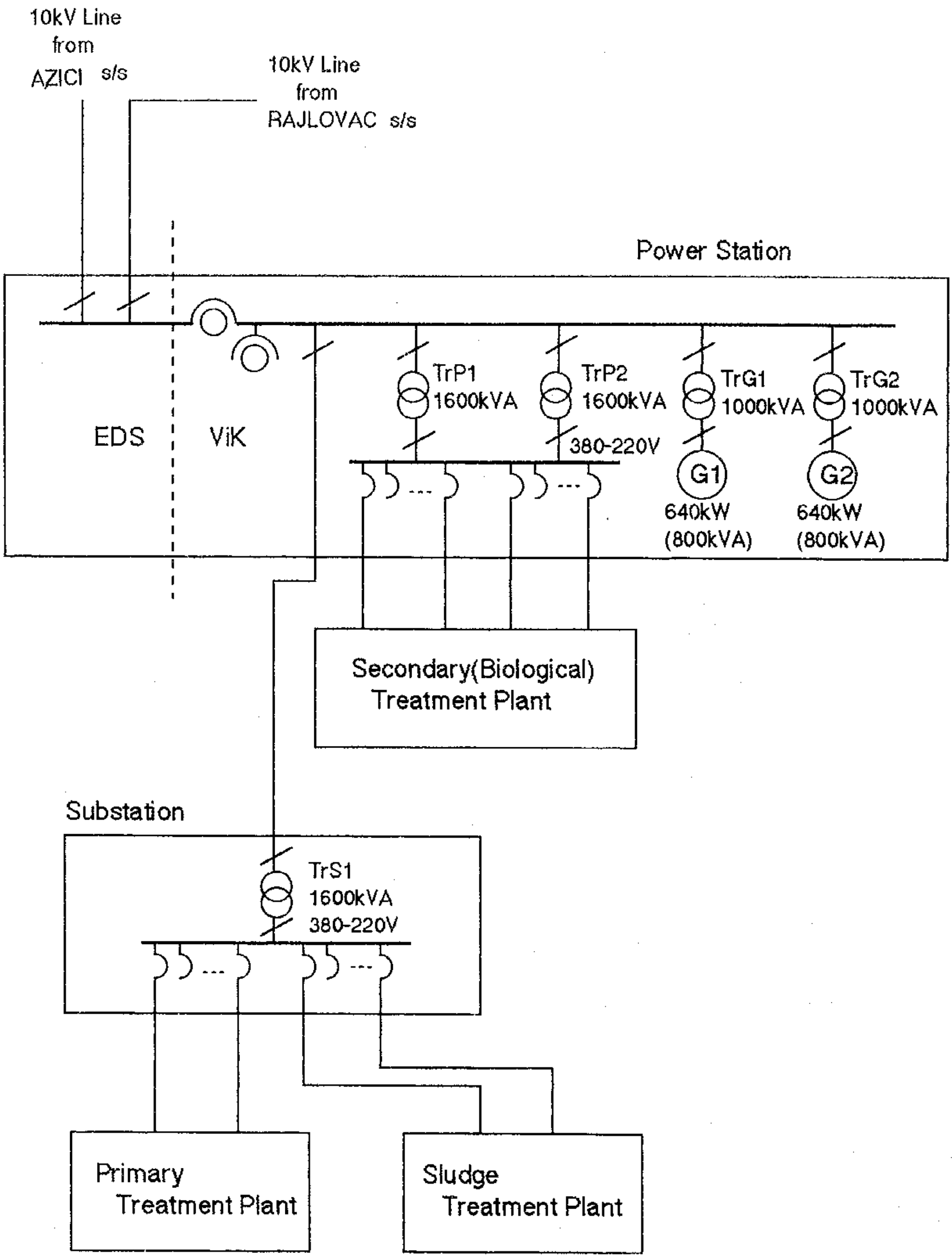
All cables of H T and L T were cut and were taken away.

It is considered that all electric equipment and cables should be newly replaced or reconstructed.

4.5.2 Electric Motor

The following electric motors are existing under non-operating condition.

(1) Motor for Aeration Turbine (37 kW, 4 P, 380 V × 33 units)
(2) Motor for Raw Water Pump (160 kW, 4 P, 380 V × 4 units)
(3) Motor for Recycling Sludge Pump (100 kW, 4 P, 380 V × 2 units)
(4) Motor for Service Water Pump (37 kW, 2 P, 380 V × 2 units)
(5) Motor for Gas Compressor (37 kW, 6 P, 380V × 3 units)



(Note) EDS ; Electric Distribution Sarajovo
ViK ; Vodovod i Kanalizacija

Figure 4.2 SINGLE LINE DIAGRAM FOR THE WWTP

(30 kW, 4 P, 380 V × 3 units)

All the rest of the motors not mentioned above are missing.

(1) Inspection and Test Performed

1) Motor for Aeration Turbine

Out of the 36 aerators, the motors for 33 aerators exist and 3 are missing. Physical inspection such as body assessment degree of stain/corrosion, coil conductivity check and insulation resistance measurement were performed on the 33 existing motors.

Out of the 33 aerators with motors, 19 of them passed the criteria (mechanical and electrical soundness and structural stability) for testing. On load test was performed under normal water condition in the Aeration Tank.

2) Other Motors

Physical inspection was performed on these motors to include body assessment, degree of stain/corrosion, coil conductivity check and insulation resistance measurement.

For these motors, mechanical load facilities exist but not arranged. Therefore on load test can not be performed.

(2) Assessment

Accordingly, the inspection and test result of these motors showed that they could still be used. However, since they had not been operated for 7 years, overhauling including change of bearing is necessary to attain a long operational life.

In regards to the motors for Gas Compressor, rust and corrosion are severely progressing inside the terminal box and on the terminal itself. The insulation resistance of these motors is reduced. Therefore, a long operation life of these motors can not be expected.

It is recommended that these motors should be newly replaced.

4.5.3 Control Facilities

(1) Central Control Equipment

The central control equipment is installed in the Administration Building (Facility 23). It is consist of main control panel and operator console. These panels are heavily damaged. Although the metal enclosed panels exist, the electric instruments/parts are missing. Therefore no function can be performed in the central control equipment.

It is considered that these panels should be newly replaced.

(2) Local Control Panels

The Local Control Panels are installed in following locations.

1) Raw Water Pumping Station (Facility 1)
2) Power Station (Facility 20)
3) Recycling Sludge Pumping Station (Facility 8)
4) Primary Sludge Pumping Station (Facility 9)
5) Thickened Sludge Pumping Station (Facility 11)
6) Boiler House (Facility 13)
7) Sludge Dehydration (Facility18)
8) Compressor Station II (Facility19)
9) Service Water Pumping Station (Facility 24)

All of these panels severely damaged in the same manner as the central control panels.

It is recommended that these panels should be newly replaced.

(3) Measuring Equipment

Figure 4.3 is the measuring flow diagram of the WWTP. Measuring equipment were installed previously in the Flow Metering (Facility 7), Aeration Tank (Facility 5), and others.

1) Flow Metering
   There is no instrument.
   The instrument were removed and taken away.

2) Aeration tank
   There are Dissolved Oxygen meters (4pcs).
   But these meters are all broken.

3) Others
   Measuring instruments were removed and taken away, or broken.

It is considered that all measuring instruments should be newly replaced or reconstructed.

4.5.4 Cabling

All HT and LT cables and measuring/control devices were cut and taken away. Therefore it is recommended that these cables and measuring/control devices shall be newly replaced or reconstructed.

4.5.5 Electric Power Supply from Electric Distribution Sarajevo (EDS)

(1) Electric Power Supply Organization in BiH

The electric power supply in BiH is managed by public enterprise, Electroprivreda of Bosnia and Herzegovina (EPBiH). **Figure 4.4** shows the organization of the company.
The company generates electric power and transmits electric power to district division in Bosnia and Herzegovina including Sarajevo, Zenica, etc. These power districts distribute the electric power to their consumers. The Sarajevo WWTP is supplied with electric power from Electric Distribution of Sarajevo(EDS).

(2) Electric Power Distribution to WWTP from EDS

The Sarajevo WWTP is supplied with electric power from EDS by 10kV underground distribution line (4 MW, 250 A capacity), as shown in **Figure 4.5**. While the WWTP was still in operation, EDS supplies electric power to the WWTP from 2 sources as follows:

1) Azici Substation: 3.2 MW maximum capacity due to the limitation of the 10kV transmission line.
2) Rajlovac Substation: 1.5MW and is reduced during winter season. Power supply from this source is only switched on by EDS in case of power outages from Azici Substation.

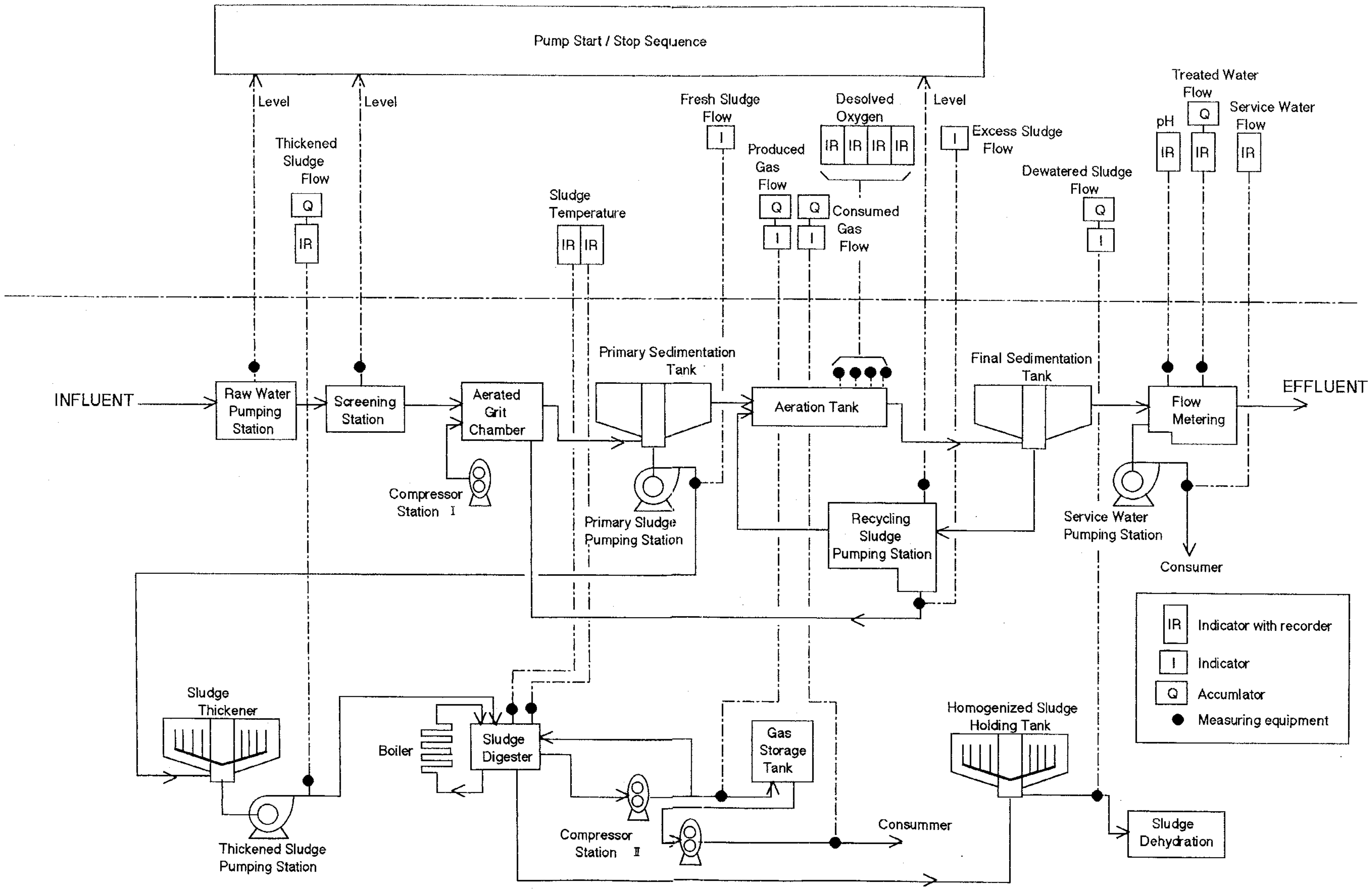


Figure 4. 3 MEASURING FLOW DIAGRAM

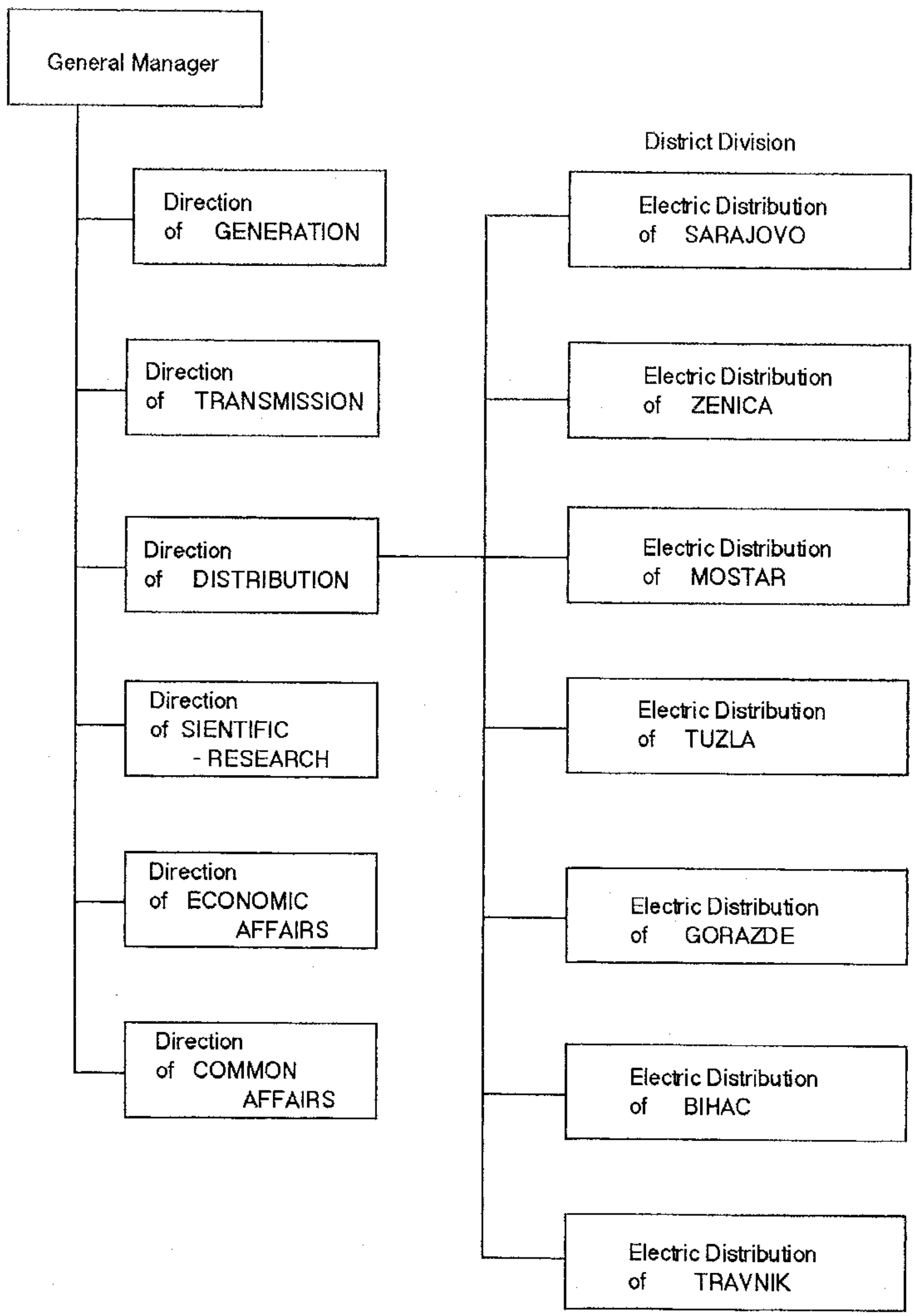


Figure 4.4 ORGANIZATION OF EPBiH

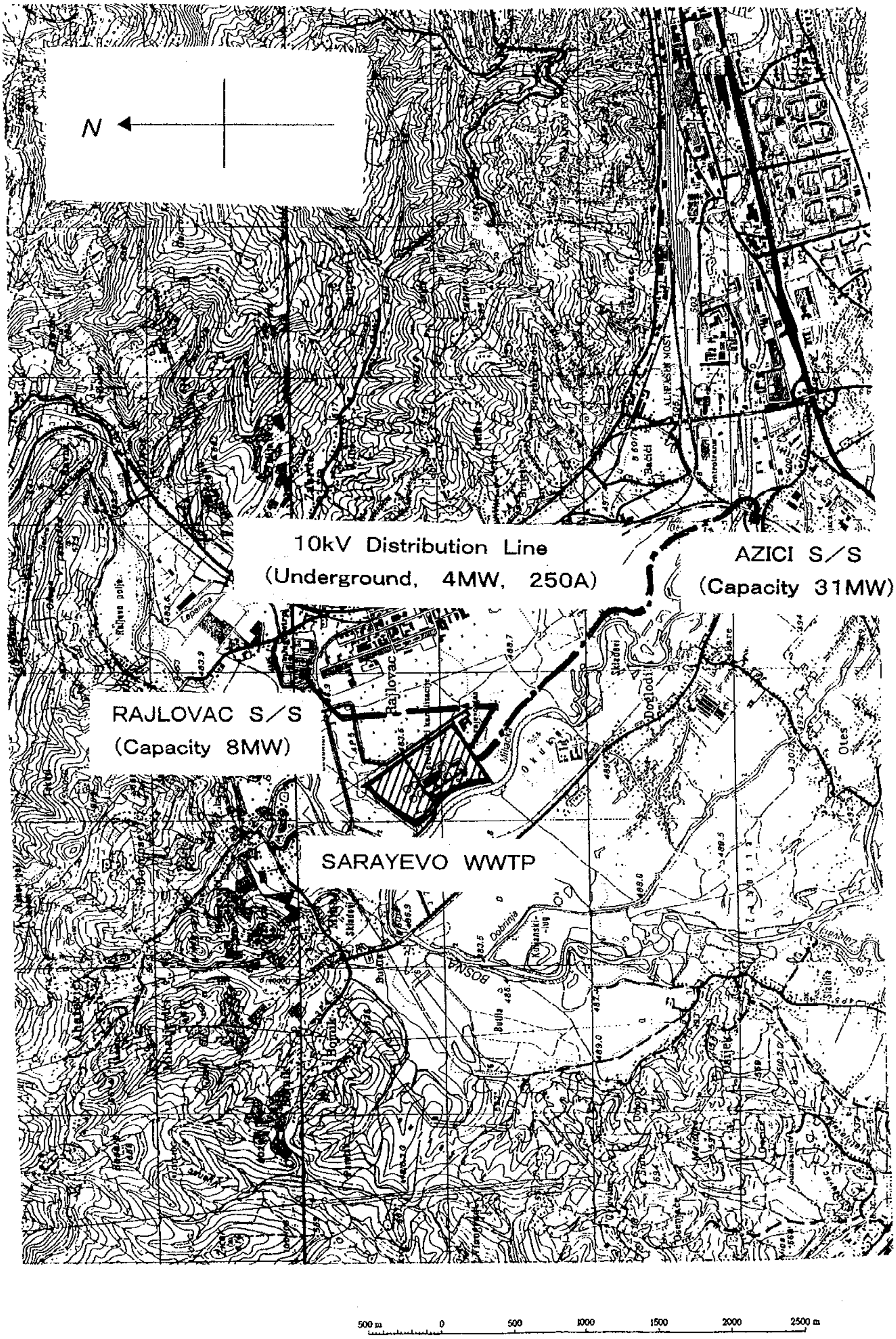
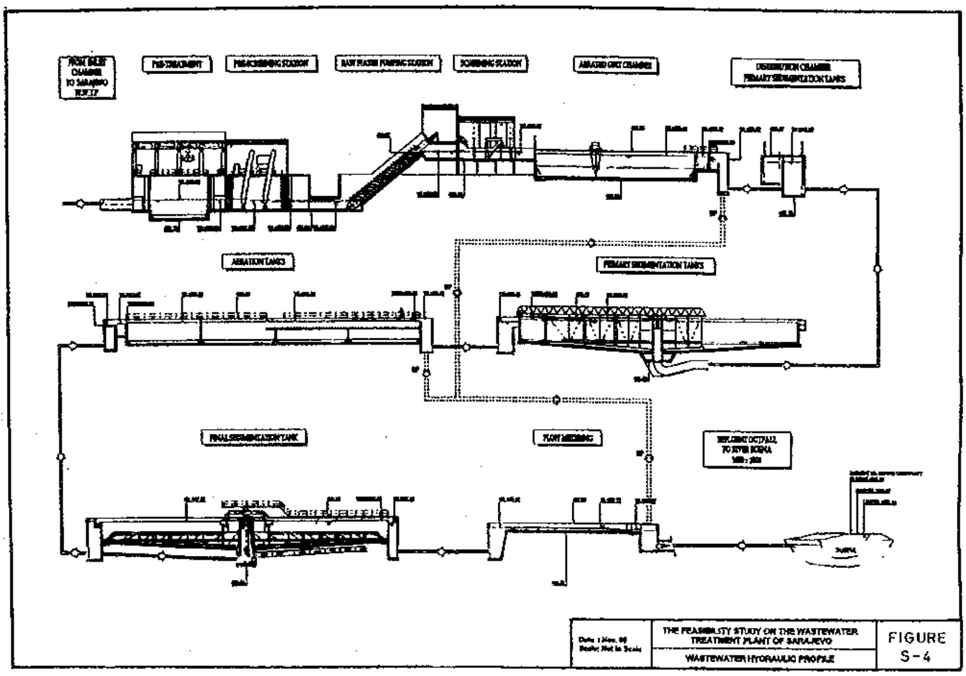


Figure 4.5 ELECTRIC DISTRIBUTION LINE TO THE WWTP

CHAPTER 5. TREATMENT PROCESS ALTERNATIVES



CHAPTER 5 TREATMENT PROCESS ALTERNATIVES

5.1 REHABILITATION COMPARED TO RECONSTRUCTION

The question for the investor is whether rehabilitation cost less than reconstructing a new plant. The answer is not immediately obvious since damage to M&E equipment is extensive and some of the facilities such as the boiler house, and gas compression station must be reconstructed.

The cost for a new treatment plant of this size (not including demolition costs) is roughly in the order of 350 to 500 DEM per capita. For a new plant to serve a design population of 600,000 (year 2015) the cost would be approximately 210 to 300 million DEM.

The total cost to rehabilitate the civil structures, replace most of the M&E equipment and construct new pre-treatment and boiler house facilities is estimated at approximately 60 million DEM, which is about 22% of the cost of a new treatment plant. Therefore rehabilitation is the least cost solution.

Replacement and reconstruction of M&E equipment and facilities provides an opportunity to evaluate the benefits of new technology and process options which may improve operations and reduce future O&M costs. Such alternatives are discussed in the following sections.

5.2 NEW PRELIMINARY TREATMENT FACILITIES

As discussed in **Section 5.1** very large amounts of coarse grit were observed in the raw wastewater during peak wet weather flows. Also, screw pumps were damaged or blocked by large objects and rags.

The largest part of the grit settled at the inlet to the pump station, in the screening channels and in the aerated grit chamber. The grit was in such large amounts that operators had to stop pumping operations for several days to clean and make repairs to damaged equipment. During these periods untreated wastewater is directed via a high level overflow to the Miljacka river.

This part of the process must be improved or else the treatment process will forever be failing during wet weather. Based on past experience the plant was often shut down for periods of days or even weeks resulting in the overflow of untreated sewage.

Improving aerated grit removal will not solve the grit problem since the coarse grit settles in the screens before the aerated grit chamber. Therefore the only logical solution is to install a rectangular horizontal flow grit chamber to remove heavier grit particles before they are lifted by the screw pumps. Likewise, coarse and medium screens should be relocated ahead of the pumps to protect them.

5.3 COMPARISON BETWEEN SURFACE AERATORS AND DIFFUSED AIR SYSTEM

There are two options for providing air to the activated sludge biological treatment process

(1) rehabilitate the existing surface aerators or

(2) use positive displacement air blowers for air production with fine bubble membrane air diffusers in the aeration tank or

The relative merits of each option are compared in the following **Table 5.1**:

Table 5.1 QUALITATIVE COMPARISON OF SURFACE AERATORS AND DIFFUSED AIR SYSTEM

PROCESS	ADVANTAGES	DISADVANTAGES
Air blowers with fine bubble membrane diffusers	- Reduced energy consumption, therefore substantial savings in annual electrical costs. - Improved operating flexibility and ability to change oxygen production to match changing flow and pollution loading	- Requires skilled operators - Higher investment cost - Specialized mechanical maintenance of blowers - Regular maintenance required to keep diffuser heads clean
Surface Aerators	- Lower initial equipment cost for rehabilitation - Easy to operate and maintain	- Higher energy costs - Reduced operational control over D.O. levels and mixing. - Poor reliability of machines in the long-term

The trend in most modern installations is to use diffused air systems because it offers a substantial reduction in energy consumption. The comparison of energy requirements for each option is presented in **Table 5.2**.

Table 5.2 COMPARISON OF ENERGY REQUIREMENTS FOR SURFACE AERATORS AND DIFFUSED AIR SYSTEM

	MECHANICAL SURFACE AERATORS	AIR BLOWERS + FINE BUBBLE MEMBRANE DIFFUSERS
Installed power for oxygen requirements	36 x 37 = 1, 332 kW (for year 2000 & 2015)	4 x 160 = 640 kW (year 2000) 6 x 160 = 960 kW (year 2015)
Installed power for mixing requirements	0 kW	80 kW
Total installed power	1, 332 kW	720 kW (year 2000) (year 2015)

In the case of Sarajevo WWTP diffused air would result in a 46% reduction in energy consumed in the year 2000 and a 22% reduction in the year 2015 when 2 additional blowers would be required.

The cost of electricity in Sarajevo is rather high at 0.11 DEM/kW-hrs. and a diffused air system could save approximately 120,000 DEM per year. This cost saving must be compared to the investment and operating cost stream over the life of the project in order to determine if the investment is worthwhile.

The cost of retrofitting the aeration tanks with air piping, diffusers and air blowers is estimated at approximately 10 million DEM including:

(1) Removal of aerators, supporting slabs and columns,
(2) New air piping, fine bubble membrane diffuser heads and 4 air blowers,
(3) A new building to house the blowers and auxiliary systems

The cost of rehabilitating and putting the surface aerators back in service is estimated at approximately 3.5 million DEM including:

(1) Rehabilitation of 36 machines
(2) Reconstruction of supporting slabs and columns

The cost streams for the two options are compared and internal rate of return calculation is presented **Table 5.3.**(End of Ch.5) The comparison indicates that changing to diffused air system does not provide any financial advantage. Rehabilitating the surface aerators is recommended as the least cost solution.

The result is surprising as it contradicts the present trend towards air diffusion for plants with larger flows, surface aeration normally being limited to smaller facilities. The case for Sarajevo is very specific because the civil structures already exist and the tanks are sized to optimise conditions for surface aerators. Diffused air systems would require a more narrow and deep structure to obtain optimum diffuser efficiencies. Therefore the full cost benefits of air diffusion cannot be realised with the present structures.

5.4 SLUDGE TREATMENT ALTERNATIVES

The existing sludge treatment process uses anaerobic digestion to stabilise and reduce sludge volumes. The digested sludge is then dewatered before being transported for disposal at the landfill site. The auxiliary mechanical systems required for sludge mixing, heating and gas collection were completely destroyed during the war and replacement will represent a significant investment cost. Therefore a review of treatment options is required to determine if there are better technological or lower cost alternatives to the expensive rehabilitation of the existing anaerobic sludge treatment process.

There are generally four broad options for sludge treatment and disposal:
(1) Disposal of untreated, liquid sludge
(2) Disposal of untreated de-watered sludge
(3) Disposal of treated liquid sludge
(4) Disposal of treated de-watered sludge.

The relative merits and feasibility of each option are presented in **Table 5.4.**(End of Ch.5) The need for sludge treatment (stabilisation) and the need to remove water from sludge depend on a number of factors such as:
(1) the regulations governing the reuse and disposal of sludge
(2) the type of sludge
(3) the ultimate end use of the sludge
(4) the disposal method of the sludge
(5) the proximity of the disposal site and transportation costs

In Bosnia there are currently no regulations governing the disposal or reuse of sludge. In the absence of FBiH regulations regarding sludge disposal and re-use it is recommended that EU regulations and directives be adopted for the project. These regulations are discussed in **Chapter 8** Environmental Assessment. EU regulations presently prohibit the disposal of untreated sewage sludge therefore some form of sludge treatment (stabilization) process will be required.

The relative technical merits of various treatment methods are compared in **Table 5.5** (End of Ch.5) and the degree of attenuation for the different sludge treatment processes is presented in **Table 5.6**.

Table 5.6 DEGREE OF ATTENUATION FOR VARIOUS SLUDGE TREATMENT PROCESSES

TREATMENT PROCESS	DEGREE OF ATTENUATION		
	PATHOGENS	PUTREFACTION	ODOR POTENTIAL
Anaerobic digestion	Fair	Good	Good
Aerobic digestion	Fair	Good	Good
Aerobic (autothermal thermophilic)	Excellent	Good	Good
Lime stabilisation	Good	Fair	Good
Composting	Fair	Good	Good
Composting (thermophilic)	Excellent	Good	Good
Pasteurisation	Excellent	Poor	Poor
Heat conditioning	Excellent	Poor	Poor
Heat drying	Excellent	Good	Good

On the basis of qualitative comparison of options two sludge treatment alternatives are considered for further evaluation:

(1) Anaerobic digestion
(2) Lime stabilisation

Although the use of lime to stabilise organic matter is not a new concept, post-treatment of dewatered sludge sewage sludge using lime is a relatively recent development. In this process, hydrated lime or quicklime is mixed with dewatered sludge in a pugmill, paddle mixer or screw conveyor to raise the pH of the mixture. Quicklime is preferred because the exothermic reaction of quicklime and water can raise the temperature of the mixture above 50℃, sufficient to inactivate worm eggs.

Adequate mixing is critical for post-lime stabilisation system to avoid pockets of putrescible material. A post-lime stabilisation system typically consists of a dry lime feed system, dewatered sludge cake conveyor, and a lime-sludge mixer. When the lime and sludge are well mixed, the resulting mixture has a crumbly texture, which allows it to be stored for long periods or easily distributed on land by a conventional manure spreader.

Estimated quantities of lime are calculated in **Table 5.7** (End of Ch.5) and summarised as follows:

(1) dry solids in sludge cake (before CaCO addition) = 24%
(2) Lime dose required to raise temperature 40℃= 0.52 kg CaCO/kg sludge solids
(3) Daily required lime = 15,841 kg/day or 26 m^3/day in the year 2000

Although there are lime quarries available nearby, the supply of this large amount of lime is presently not commercially available in Sarajevo. Even if lime was available, the option of post-lime stabilization has a number of disadvantages that must be considered:
(1) Storage and handling of large quantities is impractical,
(2) Without gas production from digestion, electrical consumption will increase resulting in higher operating costs,
(3) Without digestion, the volume of sludge is not reduced and

(4) Lime further adds to the weight and volumes that have to be disposed.

A draft EU proposal for Directives on the Landfill of Waste indicates that by the year 2005 disposal of sewage sludge to landfill sites could no longer be allowed in order to promote beneficial reuse and reduce quantities of landfill wastes. Discussions with Sarajevo's waste management authorities (RAD) also confirm their intention to make reduction of solid waste to the landfill is a high priority. Therefore it is essential that the treatment process reduce the amount sludge produced. Only anaerobic digestion can meet the requirements for reducing waste amounts and future legislation.

In conclusion, lime stabilization is not a feasible option. Therefore the existing anaerobic digestion process must be rehabilitated.

5.5 SLUDGE DEWATERING ALTERNATIVES

Land application of treated liquid sludge is possible by injecting directly into the soil. The sludge at Sarajevo WWTP is low in heavy metals and would be quite suitable for agricultural use. There is no previous practice of land application of liquid sludge an accepted practice in the near future. Even if land application of sludge gains acceptance the quantities re-used in this way will likely be small. Therefore the bulk of the sludge must be de-watered to reduce the weight and volumes of waste that must be transported for re-use as bio-solids or disposal to the landfill site.

The existing belt filter presses were damaged during the war and must be replaced. Many technological options are available for removing water from sludge. The relative technical merits of various dewatering methods are compared in **Table 5.8**.(End of Ch.5) Based on the qualitative comparison two options are considered for evaluation:

(1) Belt filter presses and
(2) centrifuge

The amount of sludge to be de-watered will be approximately:

(1) year 2000: 20, 214 kg/day 609 m^3/day
(2) year 2015: 33, 958 kg/day 991 m^3/day

Based on these quantities of sludge the following comparisons in **Table 5.9** are made between the two options:

Table 5.9 COMPARISON OF FILTER PRESS AND CENTRIFUGE OPTIONS

	BELT FILTER PRESS (YEAR 2000)	**CENTRIFUGE** (YEAR 2000)
Number of units	5	3
Sludge cake concentration	24%	28%
Investment cost	4,000,000 DEM	10,000,000 DEM
Energy requirement	7.5 kW	270 kW
Polymer consumption	4 kg/kg DS	8 kg/kg DS

Although centrifuges provide a cleaner operating environment and can produce a drier sludge cake they are substantially more expensive to own and operate. The investment cost for centrifuges is approximately 2.5 times higher than belt filter presses. Centrifuges consume significantly more energy and polymer than filter presses thereby increasing operating costs.

The added expenses of centrifuges can only be justified if drier sludge cake is required by legislation. It is therefore recommended that new belt filter presses be purchased to replace those that were damaged during the war.

Table 5.3 INTERNAL RATE OF RETURN FOR AERATION OPTIONS

Year	Blower project			Rehab Surface Aerators			Net benefits (DEM)
	Capital cost	O & M	[1] Total costs	Capital cost	O & M	[2] Total costs	Option1-Option2
	10,000,000			3,500,000			
2001	1,000,000	745,344	1,745,344	350,000	866,758	1,216,758	(528,586)
2002	1,000,000	745,344	1,745,344	350,000	866,758	1,216,758	(528,586)
2003	1,000,000	745,344	1,745,344	350,000	866,758	1,216,758	(528,586)
2004	1,000,000	745,344	1,745,344	350,000	866,758	1,216,758	(528,586)
2005	1,000,000	745,344	1,745,344	350,000	866,758	1,216,758	(528,586)
2006	1,000,000	745,344	1,745,344	350,000	866,758	1,216,758	(528,586)
2007	1,000,000	745,344	1,745,344	350,000	866,758	1,216,758	(528,586)
2008	1,000,000	745,344	1,745,344	350,000	866,758	1,216,758	(528,586)
2009	1,000,000	745,344	1,745,344	350,000	866,758	1,216,758	(528,586)
2010	1,000,000	745,344	1,745,344	350,000	866,758	1,216,758	(528,586)
2011		745,344	745,344		866,758	866,758	121,414
2012		745,344	745,344		866,758	866,758	121,414
2013		745,344	745,344		866,758	866,758	121,414
2014		745,344	745,344		866,758	866,758	121,414
2015	3,000,000	1,076,608	4,076,608		1,187,636	1,187,636	(2,888,972)
2016		1,076,608	1,076,608		1,187,636	1,187,636	111,028
2017		1,076,608	1,076,608		1,187,636	1,187,636	111,028
2018		1,076,608	1,076,608		1,187,636	1,187,636	111,028
2019		1,076,608	1,076,608		1,187,636	1,187,636	111,028
2020		1,076,608	1,076,608		1,187,636	1,187,636	111,028
Total	13,000,000		19,689,472	3,500,000		14,767,849	(7,134,039)

IRR = -37.7%

Annual operating and maintenance cost (DEM)	Year 2000		Year 2015	
	Surface Aerators	Air Diffusers	Surface Aerators	Air Diffusers
M&E	225,000		225,000	
diffusers		100,000		150,000
mech. Equip.		75,000		100,000
piping		25,000		25,000
elect. Equip.		25,000		50,000
Total maintenance & renewal cost	**225,000**	**225,000**	**225,000**	**325,000**
Electrical consumption (kW/year)	5,834,160	4,730,400	8,751,240	6,832,800
Cost of electricity (DEM per kW/hr)	0.11	0.11	0.11	0.11
Total Energy cost	**641,758**	**520,344**	**962,636**	**751,608**
Total operating cost	**866,758**	**745,344**	**1,187,636**	**1,076,608**

Table 5.4 COMPARISON OF DISPOSAL OPTIONS & NEED FOR SLUDGE TREATMENT

Disposal Option	Advantages	Disadvantages	Application	Selected for evaluation
Non-stabilized, thickened liquid sludge	- Does not require expensive treatment process.	- Health and environmental implications of pathogenic organism - Vector attraction at disposal site - Increased mass & volume add to hauling cost	- Disposal of non-stabilized liquid sludge in landfills is prohibited in most countries - The European Union (EU) countries will prohibit discharge to landfill of all sewage sludge by 2005.	- no
Non-stabilized de-watered sludge	- easier to handle than liquid sludge	- Health & environmental implications of pathogenic organisms - Vector attraction at disposal site	- Sludge cannot be land applied - Landfilling requires careful control of leachate, runoff and daily cover. - Feasible but not recommended because future EU regulations will prohibit discharge of bio-solids to landfill site.	- no
Stabilized liquid sludge	- reduced pathogenic content - reduced odor potential - no expensive de-watering process - stabilized liquid sludge can be land applied by injecting below the surface	- disposal of liquid sludge to landfill can increase vector attraction - potential increase in risk of ground/surface water contamination, and odor potential. - mass and volume of liquid sludge adds to disposal costs	- Feasible but there is no experience with land application of liquid sludge in Bosnia. - Liquid sludge for land application must meet stringent requirements for attenuation of pathogenic content, and site specific application conditions. - This option is also rejected because it is difficult to implement, control and monitor.	- no
Stabilized de-watered sludge	- reduced pathogenic content - reduced odor potential - high beneficial re-use potential - greatest reduction in volume & mass - easier to handle than liquid sludge	- de-watering is potentially expensive and difficult to operate	- Re-use potential for de-watered bio-solids - This option meets existing regulatory requirements and provides flexibility for enhancing level of treatment if more stringent regulations are implemented.	- yes

Table 5.5 COMPARISON OF SLUDGE STABILIZATION PROCESSES

Treatment Process	Advantages	Disadvantages	Application	Selected for evaluation
Anaerobic digestion	- Good reduction of volatile suspended solids and total sludge mass - Operating costs can be reduced if gas is used to generate electricity - Bio-solids suitable for agricultural use - Low net energy requirements	- requires skilled operators - high initial cost - process is sensitive to loading and temperature variations - recovers slowly from upset - cleaning is difficult (scum & grit)	- Almost always preferred for plants with flows > 19,000 m3/d - This method is considered for further evaluation.	- Yes
Aerobic digestion	- Low initial cost - simple operational control - reduces total sludge mass	- high energy costs - lower volatile suspended solids destruction - bio-solids are typically difficult to de-water by mechanical means - cold temperatures adversely affect performance	- Typical for small plants Q< 19,000 m3/d - This method is rejected because of the high energy costs required for large flows.	- no
Composting (in-vessel)	- high quality product suitable for land application - can be combined with other processes - high initial cost	- requires 18 to 30% de-watered solids - requires bulking agent - requires forced air system and temperature control - high operational costs for power, labor and chemicals - requires carbon source - co-generation of electricity is not possible	- used to convert sludge into high quality fertilizer - capacity ranges from 5 to 45 dry tons per day - This method is rejected because the large quantities of daily sludge exceed practical limits of application.	- no
Lime stabilization	- low capital cost - easy operation - good as interim or emergency stabilization method	- bio-solids not always suitable for land application - chemical intensive - volume of bio-solids to be disposed of is increased - co-generation of electricity is not possible	- Typical for small plants but less practical for large applications. - This option is a good interim solution it can allow quick start up of liquid process while work continues on solids facilities. It can also be used in cases when digesters are temporarily not available.	- Yes
Sludge dryers	- substantially reduces volume - produces high quality product - excellent pathogen reduction - can be started quickly - retains nutrients - can use gas from anaerobic digestion as source of energy.	- some dryers could be labor intensive - produces an off-gas that must be treated - energy intensive	- This option eliminates the need for expensive and troublesome de-watering and can produce a very high quality bio-solids for re-use.	- no

Table 5.7 CALCULATION OF QUANTITY REQUIRED FOR POST-LIME TREATMENT OF SLUDGE

% Dry solids in sludge (before CaO addition) 24%

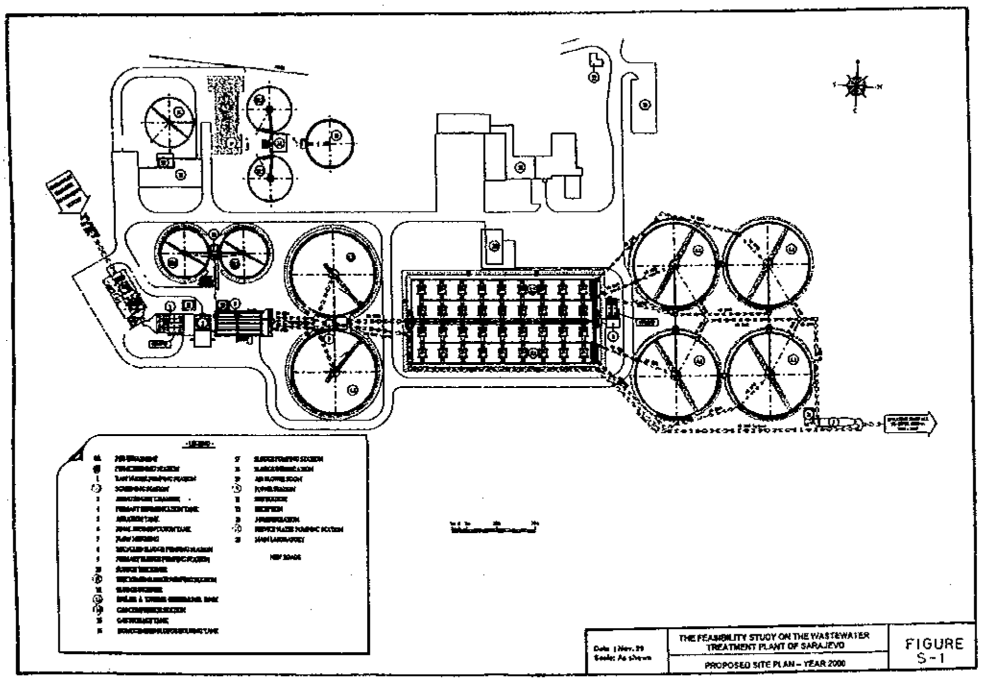
Lime dose required to increase sludge temperature by 40^{0}C Kg CaO/Kg sludge solids 0.52

	Year 2000	Year 2015
Amount of Sludge (Kg dry solids/day)	30,463	48,587
Wet Weight of Sludge Cake (Kg/day)	127,000	202,000
Amount of lime for stabilisation (Kg/day)	**15,841**	**25,265**
Total Dry Solids Weight (Kg/day)	46,304	73,852
Total Wet Weight for Disposal (Kg/day)	**142,841**	**227,265**
Volume (m^3) of Sludge at 1100 Kg/m^3	115	184
Volume (m^3) of Lime at 600 Kg/m^3	26	42
Total Volume for Disposal (m^3)	**142**	**226**
No. of operating days per week	5	5
No. of operating days per month	20	20
Volume of bulk storage	**528**	**842**

Table 5.8 COMPARISON OF SLUDGE-DEWATERING METHODS

Process	Advantages	Disadvantages	Application	Selected for Evaluation
Vacuum filter	- Skilled personnel is not required - Maintenance requirements are low for continuously operating equipment	- Highest energy consumer per unit of sludge - Continuous operator attention required	- Rejected because of high energy & operational requirement - 18 to 25% sludge cake	- no
Solid bowl centrifuge	- clean and minimal odor problems - easy to install - fast start-up and shutdown capabilities - produces relatively dry sludge cake 15-20% - low capital cost-to-capacity ratio	- scroll wear is a high maintenance problem - requires good grit removal and possibly a sludge grinder in the feed stream skilled maintenance personnel required - moderately high suspended solids in the centrate	- considered for further evaluation	- Yes
Imperforate basket centrifuge	- chemical conditioning may not be required - easy to install - fast start-up and shutdown capabilities - very flexible in meeting process requirements - not affected by grit - excellent results for difficult sludge	- limited size capability - except for vacuum filters, consumes more energy per unit of sludge de-watered - for easily de-watered sludge, has highest capital cost-to-capacity ratio - significantly high recycle loads	- rejected because of low cake solids. For most sludges, produces lowest cake solids concentration 8 to14%	- no
Belt filter press	- low energy requirements - relatively low capital and operating costs - less complex mechanically and easier to maintain	- hydraulically limited throughput - requires sludge grinder in feed stream - very sensitive to incoming sludge feed characteristics - short media life - automatic operation generally not advised	- considered for further evaluation - high-pressure machines are capable of producing very dry cake	- Yes
Recessed plate filter press	- highest cake solids concentration 20 to 25%	- high equipment cost - high labor cost - large floor area required for equipment - special support structure required - skilled maintenance personnel required - additional solids due to large chemical addition	- rejected because of high capital. O&M costs.	- No
Heat Drying	- substantially reduces volume - produces high quality product - excellent pathogen reduction - can be started quickly - retains nutrients - can use gas from anaerobic digestion as source of energy.	- some dryers could be labor intensive - produces an off-gas that must be treated - energy intensive if digester gas is not available	- rejected because of high capital, O&M costs.	- No
Sludge drying beds	- lowest capital cost method where land is readily available - small amount of operator attention and skill required - low energy consumption - higher solids content than mechanical methods	- requires large area of land - requires stabilized sludge - design requires consideration of climactic effects - sludge removal is labor intensive	- rejected because of unfavorable climatic conditions.	- No
Sludge lagoons	- low energy consumption - no chemical consumption - low capital cost where land is available - least amount of operator skill required for operation	- potential for odor and vector problems - potential for groundwater pollution - design requires consideration of climactic effects	- rejected because of unfavorable climatic conditions. -	- No

CHAPTER 6. REHABILITATION PLAN OF THE WWTP



CHAPTER 6 REHABILITATION PLAN OF WWTP

6.1 URGENT REHABILITATION WORK

Primarily, the Feasibility Study was done on the concept of rehabilitating the WWTP by bringing it back to the pre-war condition. Hence, the assessment works have done in order to bring the each facility, including mechanical and electrical equipment, back to the pre-war capacity. Based on the result of assessment works, the preliminary design has done.

Generally, the design of the WWTP shall be performed in accordance with all applicable codes, standards and regulation in effect in the relevant countries. The nature of this WWTP is a secondary treatment plant in one of European countries. The facilities, therefore, shall be designed following the design fundamentals with European standards.

Based on the alternative comparison study for the rehabilitation work of the WWTP, the most appropriate plan will be selected for the year 2000, which is the target year of urgent rehabilitation work. The fundamentals of the urgent rehabilitation plan shall be determined and justified according to the capacity of the WWTP. Taking into consideration these fundamentals, the preliminary design will be carried out for each component work of the urgent rehabilitation plan towards implementation.

The concept of the rehabilitation works is mainly for the following:

(1) To bring back the treatment plant and facilities to the pre-war condition.
(2) To rectify serious operational and maintenance problems encountered during the operational period of the WWTP.
(3) To treat and discharge wastewater up to the required environmental and health standards.
(4) To maintain a less troublesome and environmentally friendly WWTP.
(5) To safeguards the lives of the plant operators.

6.1.1 Design Sewage Flow

To proceed with the process design of the WWTP, the planning fundamentals were calculated as per page 2-12 and 4-1 in the previous chapter. **Table 6.1** is the result of calculation for these fundamentals. It can be noted that all existing process designed for 1979, shall be utilized to deal with the design flow for the planning horizon in year 2015.

Table 6.1 DESIGN SEWAGE FLOW

Upper : 2000, Lower : 2015, Unit : m3/day

Sewerage zone	Daily Average	Daily Maximum	Peak Flow	Infiltration Flow	Design Flow (WWTP)	Design Flow (Sewers)
①	②	③=②*1.20	④=②*1.75	⑤	⑥=③+⑤	⑦=④+⑤
1. Stari	12,492	14,990	21,861	920	15,910	22,781
Grad	18,000	21,600	31,500	1,085	22,685	32,585
2. Centat	18,079	21,695	31,638	960	22,655	32,598
	28,875	34,650	50,531	1,245	35,895	51,776
3. Novo	17,175	20,610	30,056	1,500	22,110	31,556
Sarajevo	29,625	35,550	51,844	1,365	36,915	53,209
4. Novi	30,067	36,080	52,617	1,330	59,520	53,947
Grad	50,250	60,300	87,938	2,985	63,285	90,923
5. Ilidzici	9,375	11,250	16,406	1,670	12,920	18,076
	17,625	21,150	30,844	2,680	23,830	33,524
6. Hadzici	5,705	6,847	9,985	1,520	8,367	11,505
	7,500	9,000	13,124	4,590	13,590	17,714
Total	92,893	111,472	162,563	7,900	119,372	170,463
	151,875	182,250	265,781	13,950	196,200	279,731

Sources : "Sarajevo WWTP Design Project Report", 1979.

6.1.2 Design Wastewater and Effluent Quality

The designed wastewater and effluent quality will be adopted to confirm with the preliminary design wastewater and effluent characteristics as per Minutes of Meeting held on 17th June 1999 at Terezija between the Study Team and ViK (refer to Minutes of Meeting dated 25th June 1999).

The following **Table 6.2** shows the basic design wastewater quality adopted in the initial stage, year 1979 vis-a-vis the design criteria by JICA Study Team in 1999.

Table 6.2 COMPARISON OF DESIGN PARAMETER

DESIGN PARAMETER	INITIAL DESIGN		JICA FEASIBILITY STUDY (YEAR 2015)	
	INFLUENT	EFFLUENT	INFLUENT	EFFLUENT
BOD Concentration	194	20	200	20
BOD Load (kg/day)	36,000	-	37,969	-
TSS Concentration	-	30	270	30
TSS Load (kg/day)	-	-	48,094	-
Fecal Coliforms (MPA/100ml)	-	-	-	200

6.1.3 Pre-Treatment Facilities

In general, the fundamentals for construction of the civil & hydraulic structure/sub-structure are required in order to expect water tightness and sufficient strength of structure, such as:

1) Expansion Joint and/or Construction Joint,
2) Deep Crack,
3) Water Leakage Point,
4) Exposed Reinforcing Steel and
5) Coating of Inside Wall.

(1) Preliminary Grit Removal Chambers and Screens

Ever since the existing WWTP has been commissioned to treat the wastewater, very large amount of grit have been observed in the raw sewage (see photographs of **the Assessment Work Report, Volume III** taken at the inlet channel of the Screening Station and Primary Sedimentation Tank). The past operational records of the WWTP shows large amount of sand, stones and pavement materials that enter the existing grit chamber passing through the coarse and medium screen channels. This condition is due to the combined sewerage system, topographical characteristics, ground conditions and pavement ratio of road and/or street. This condition resulted to a severe O&M problems. Therefore, the existing grit removal facility is not enough to get rid of enormous grit.

In order to avoid grit settlement at these stages of the WWTP, new additional grit removal chamber is proposed. This facility to be constructed upstream of the raw water pumping station will be designed to avoid grit removal problems downstream. It shall also be designed to capture grit particles of more than 2.0 mm diameter.

The following technical specifications are proposed for the preliminary design of the new facilities, namely; "Pre-Treatment" & "Pre-Screening"

0A) Pre-Treatment

Type of Grit Chamber	: Horizontal Flow Rectangular Chamber
Number of Facility	: Three Chambers (two for duty and one for stand-by)
Dimensions	: Width = 1.50 m, Length = 10.0 m, Effective Depth = 1.50 m
Effective Volume	: 1.50 m* 10.00 m* 1.50 m= 22.50 m^3
Type of Grit Removal	: Grab Bucket

0B) Pre-Screening

Type of Screen	: Mechanical Coarse and Medium Screen
Number of Screens	: Three Coarse Screens and Three Medium Screens (each two for duty and one for stand-by)
Dimensions	: Width = 1.50 m, Effective Height = 6.00 m
Bar Spacing	: 50 mm, 25 mm

The deposited grit from the chamber will be extracted from the channels by using an electrical grab bucket and transferred into appropriate skips or vessels located along the channels. Simultaneously, the removed grit will be transferred to the hopper and washed with treated water before final disposal by vehicle to the Deponija Gradska.

(2) The Existing Inlet Works

The existing inlet works consists of the following facilities:

1) Raw Water Pumping Station (Facility 1),
2) Screening Station (Facility 2), and
3) Aerated Grit Chamber (Facility 3).

The sub-structure and super structure of the existing inlet works can be rehabilitated by

1) a repair of the expansion/construction joints,
2) sealing of the deep crack and water leakage point,
3) appropriate protective layer of exposed reinforcing steel bars, and
4) coating of the inside wall.

Heating & ventilation and odor control method will be considered for process design of the screening stations.

Regarding the M&E works, screw pumps and motors will be rehabilitated by overhauling. Mechanical fine screen units will be newly installed in an alternate arrangement. New aeration and grit removal equipment will be newly installed in conformity with the former systems. Electric heat tracing method will also be introduced along the top of walls of the facility.

6.1.4 Secondary Treatment Facilities

The same method of rehabilitation works can precisely be applied for the Civil and Architectural works as mentioned in previous section for these facilities. New supplemental concrete slab and wall for primary sedimentation tanks will be constructed after chipping off the deteriorated surface. The aeration tanks shall also be rehabilitated with supplemental concrete wall and reinforcement of the columns for slabs.

Regarding the Mechanical & Electrical works for sedimentation tanks, new motors will be installed with other necessary works. New motors with accessories will be installed for the surface aerator based on the findings of the site assessment works. Seventeen (17) of the surface aerators including motors and gear boxes shall be replaced and the rest of the 19 shall be rehabilitated based on the outcome of assessment work done by Study Team and contractor (Refer to **Volume III**).

After secondary treatment, effluent chlorination before discharge into River Bosna will be required to meet future environmental regulation in the year 2015 onwards. A new bacteriological requirement for the treated water, such as fecal coliform = 200 FC/100ml will be introduced. To achieve this target a dosage ratio of 5 to 8 % is proposed for chlorination with 20 minutes retention time.

6.1.5 Sludge Treatment Facilities

Regarding the civil facilities, it is assumed that the sub-structure will be rehabilitated in the same method as the secondary treatment facilities. Further heat-retaining method for the sludge digestion tanks shall be installed using heat insulation materials and appropriate protective concrete cover. The internal coating of both the sludge digestion and gas holding tanks shall be carried out in consideration with the ventilation and sufficient support of the dome.

New mechanical & electrical equipment for sludge treatment will be installed for all the facilities. Appropriate anti-frozen measure during the cold weather shall be considered.

6.1.6 Building Facilities

Part of the building works such as roofing and metal-framing have been rehabilitated based on the reconstruction programme funded by ViK, World Bank and USAID right after the war. However, other supplementary and related works are necessary to complete the rehabilitation / repair of the building structure and equipment.

The same rehabilitation works can be done for the main laboratory, which is proposed and requested by VBH (Kindly refer the VBH's proposal and their official request letter dated 1st July 1999 in **Volume IV**).

Other necessary architectural work except for the above-mentioned facilities shall be done for the Boiler and Engine Generator Room (Facility 13). A new boiler and engine generator building will be constructed in the same location as the existing Boiler House. The proximity of the generator room to the sludge digestion tanks will reduce heat loss.

6.1.7 Design Criteria

The following table compares previous stage 1 design parameters to the flows and loading forecast by the JICA Study team for the year 2000 and 2015:

Table 6.3 FORECASTED FLOW AND LOADING COMPARED TO ORIGINAL DESIGN

	AS BUILT 1979 – PHASE 1		JICA STUDY FORECAST FOR YEAR 2000		JICA STUDY FORECAST FOR YEAR 2015	
	Raw Wastewater	Treated Wastewater	Raw Wastewater	Treated Wastewater	Raw Wastewater	Treated Wastewater
Population	600,000		371,600		506,300	
Average dry weather flow (ADWF)	186,000 m^3/d		120,000 m^3/d 1.39 m^3/s		196,200 m^3/d 2.27m^3/s	
Peak wet weather flow (PWWF)	306,700m^3/hrs. 3.55m^3/s		171,100 m^3/hrs. 1.98m^3/s		276,500m^3/hrs. 3.20 m^3/s	
BOD load (kg/day)	36, 000		22,294		37,969	
BOD concentration (mg/l)	194	20	186	20	194	20
TSS load (kg/day)			29,726		48,094	
TSS load (mg/l)		30	248	30	245	30
Fecal coliforms (MPN/100 ml)				200		200

Table 6.3 indicates that flows and loads forecast for the year 2000 loads are less than those used for the design of the plant. For year 2015 the BOD load exceeds original design criteria by 5%. Process calculations prepared for the purpose of preliminary design indicate that the biological aeration process has sufficient capacity for the year 2015 BOD loading conditions. However, secondary sedimentation tanks will be slightly overloaded at peak wet weather flow. It will therefore be necessary to add 2 more sedimentation tanks 52m in diameter.

The existing treatment process does not include disinfection and it is currently not required. However, a proposed National Effluent Standard is being discussed. If the standard is adopted it would require disinfecting effluent to reduce faecal coliform counts below 200 MPN.

6.1.8 Urgent Rehabilitation Works

As discussed in the assessment report rehabilitation and repair is required in order for the treatment process to function properly. The following rehabilitation items are considered urgent:

(1) Leak sealing and protection of reinforced concrete structures
(2) Repair to architectural elements of all buildings
(3) New power station transformers and switchgear
(4) new pre-treatment facilities
(5) rehabilitation of screw pumps at lift station and recycled sludge pumping station
(6) rehabilitation of aerated grit chamber
(7) new motor drives on all sedimentation tank scrapper mechanisms

(8) reconstruction of sludge heating, recirculation and gas collection systems
(9) rehabilitation of sludge digesters and gas collector
(10) replacement of belt filter presses and all sludge pumping equipment

A detailed description of the required scope of work and preliminary design considerations for each facility is discussed in **Sections 8.2** of the Report.

6.2 PRELIMINARY DESIGN FOR CIVIL WORK

6.2.1 Site Plan

(1) Year 2000

The proposed plant layout for the year 2000 is shown on **Drawing G2, Appendix M, Vol. Ⅳ**. The layout closely resembles the existing plant layout with the following additions:

1) New pre-treatment facilities (0A and 0B) are shown ahead of the raw wastewater pumping station.
2) A new boiler house (No.13) will replace the existing building to house boilers, heat exchangers, sludge recirculation pumps and new engine generators.
3) Roads have been extended around the new pre-treatment facility and around the secondary sedimentation tanks to improve access.

(2) Year 2015

Although not included in the immediate rehabilitation, a concept for the future layout of the treatment plant is shown on **Drawing G3** for planning purposes. The plan for the year 2015 includes additional secondary sedimentation tanks and optional disinfection (No.26 & No.27) and odour control facilities (No.28).

6.2.2 Concrete Repair Methods

The scope of rehabilitation work for each civil structure is summarised in **Table 6.4** (End of **Section 6.2**). The most significant rehabilitation in terms of cost consists of repairs to concrete, which consist of the following activities:

(1) sealing cracks,
(2) repairing leaking expansion joints,
(3) treating corroded reinforcement and providing adequate cover,
(4) repairing weathered surfaces and sealing exposed concrete surfaces

Several structures have open surface areas over wet wells, weirs, inlet and outlet structures. These should be covered to with lightweight aluminium grates to facilitate operation and maintenance. Cost estimates include covering the following areas:

(1) inlet to grit chamber
(2) outlet of grit chamber
(3) access well over primary inlet structure
(4) primary sludge pumping station wet well
(5) inlet to aeration tank
(6) outlet of aeration tank
(7) thickened sludge pumping station wet well

Other miscellaneous works included in cost estimates are:

(1) improving access to mechanical equipment by adding stairs
(2) replacing corroded ladders and railings
(3) replacing concrete narrow concrete walkways with wider platforms to facilitate operations
(4) replacing all wooden stop planks

The method of repair for defective concrete is discussed in the following sub-sections.

(1) Expansion Joint Repairs

Identifying the location or cause of leakage is never quite straightforward, as the place where liquid enters is seldom where leakage is apparent on the surface. It is impossible to assess with precision if a joint should be repaired or will continue to perform well without repair. Since it is quite likely that most joints leak to some degree it is better to treat every joint as a potential source of leakage.

Since a new internal wall is proposed to provide enhanced protection of reinforcement the most effective solution for expansion joints is to provide a new water bar across the new expansion joint. The new wall will be 150 mm thick therefore too thin for a centrally placed water bar. A channel gasket that can be applied on the exterior surface is the preferred solution since it can easily be installed on the wet side of the tank as illustrated in **Figure 6.1**(End of **Section 6.2**) to make the joint watertight. As an added precaution the sealant in the existing joint should be replaced prior to building the new wall.

It is highly probable that expansion joints in the floor slabs also leak. The easiest (least cost) way to deal with these expansion joints is to provide a new floor slab with a water bar located on the bottom across the existing joint as shown in **Figure 6.2** and **Figure 6.3**.

(2) Sealing Cracks & Construction Joints

Structures that retain liquids at the treatment plant are subjected to severe exposure and require special consideration to ensure durability and control cracking. The presence of deep vertical cracks is predominant on all exposed wall surfaces and most numerous on the outside walls of effluent launders in the sedimentation tanks and sludge thickeners.

The temptation to fill every crack in a reinforced concrete structure must be resisted because filling does not always improve the situation. It is generally safe to fill cracks where the cause for cracking is no longer active. Non movement cracks can therefore be filled using the epoxy injection method.

Construction joints appear in many locations on all structures. Many of these joints contribute to significant leakage. Since construction joints are non-movement those that leak can also be filled by injecting epoxy resin grout.

Epoxy resin grouts when applied by specialists are extremely successful when used to inject narrow cracks. Very high tensile and flexural strength is gained within 48 hours and permanent flexibility, depending on the formulation can be greater than with other crack repair methods. Placing is usually by pressure injection.

Cracks subjected to seasonal or diurnal movements are a special case. These cracks should be filled with a material that is flexible enough to accommodate the expected movement. Manufacturers of epoxy resin and polyurethane have modified some of their products for use in moving cracks and low viscosity versions of these may be suitable for cracks less than 0.5 mm. Whatever material is selected, it is important that movement will not rupture the filler. The epoxy resin must be carefully selected to ensure that new cracks will not be induced because the resin is stronger than the surrounding concrete.

All cracks should be filled from the liquid side of the structure to provide an effective seal.

(3) Treating Corrosion and Protecting Reinforcement

Corrosion of reinforcement is widespread and occurs predominantly at the liquid face of walls. In many large areas rust stains appear at the surface of the concrete and follow the line of reinforcement. Material tests show that corrosion has not yet resulted in the loss of steel from the reinforcing bars.

Adequate cover is extremely important in protecting reinforcement. Treatment of interior wall surfaces will therefore require removing all concrete to expose reinforcement. All corrosion products must be removed from the steel by grit blasting using a small quantity of water to prevent dusting. Wire brushing is not effective, as all it does is polish the rust. Within a few hours of cleaning he reinforcement should be protected with a rust inhibitor that is compatible with the concrete repair that will follow. Additional steel should not be required since corrosion has not resulted in loss of section.

After the steel has been treated a new concrete wall should be constructed with cover of sufficient thickness and quality to protect reinforcement steel from further corrosion. The new wall should be constructed using modified formwork techniques. For most exterior walls cover appears adequate and there is no visible evidence to suggest corrosion of steel. A protective coating such as silicone can be applied to seal the pores and slow down the process of carbonation.

(4) Rehabilitating Weathered Surfaces

Sanitary engineering structures normally require special attention for durability. Specifications for concrete mix design and for construction should be drawn up to provide for dense, impermeable concrete which will resist to naturally occurring chemicals and have a smooth well formed surface finish. Dense, well-compacted concrete is rarely affected by frost.

In general concrete in damaged areas should be removed to a solid layer and replaced with polymer modified concrete. Polymer acts as both a plasticiser (thus reducing the water-cement ratio) and a bonding agent. Generally the polymer used in Europe is acrylic resin latex. Specially prepared air-entrained concrete can increase resistance to freezing and thawing cycles. Air voids relieve the pressure caused by frozen water in concrete therefore air-entrainment producing 5 to 8% air is strongly recommended.

Internal walls and columns have suffered frost damage at the water line. New concrete surfaces at the water line should be coated with a protective finish such as polyester resin to make them impermeable.

As a result of poor drainage and poor concrete, stairs and walkways have all been damaged by water and frost. To prevent the same problem from recurring, concrete stairs and walkways should be replaced by open grate aluminium or galvanised steel.

6.2.3 Process Calculations

Process calculations based on the design criteria for year 2000 and 2015 are prepared for the preliminary design of facilities and are presented in **Appendix O, Vol. Ⅳ**.

Wastewater samples indicate that BOD is actually much lower than design criteria therefore calculations showing the impact of weak sewage on the treatment process are also provided. The impact of weak sewage is discussed under **Section 6.7 Operation and Maintenance**.

A process schematic for liquid and solids streams is shown in **Drawing G4**. Balance sheets for estimated flow, suspended solids and BOD are derived from the process calculations and presented in **Drawings G6, G7 and G8** respectively. The hydraulic profile for the treatment plant under design flow conditions is presented in **Drawing C1&2**.

6.2.4 Proposed Pre-Treatment (facility No.0)

(1) Process

In order to avoid excessive grit accumulation it is recommended that a new pre-treatment facility be located ahead of the pumping station. The proposed facility is shown on **Drawings C3**. The facility is intended to capture heavy grit particles of 1.5 mm in diameter or greater. Finer grit will be removed later in the process at the existing aerated grit chamber no.3.

Grit removal will consist of 3 channels each 1.5m wide x 10 m long x 1.5 m deep. One channel is kept free for standby use during severe events or when other channels are out of service for cleaning. The net storage volume of each channel is 20m^3. Grit will be removed from the channel by grab bucket and transferred to a skip area located along the channels. Approximately 5 m^3/day of grit are expected during average day flows. The total amount during wet weather cannot be predicted however the total net storage volume of 60 m^3 provided by 3 channels should be more than sufficient to handle even the worse event.

The building will be enclosed to improve winter operating conditions and ventilated to prevent odour. The facility also incorporates coarse and medium screens after the grit removal step.

Screens are installed in this facility to protect the pumps and eliminate operating problems previously encountered at the base of the pumps. A total of 10 m^3/day of screenings are expected at this step.

(2) Civil

The structure will be located between the existing inflow gate chamber and the pumping station wet well. The structure is deep and will need to resist floatation caused by uplift forces created by the high groundwater table. Floatation can be overcome by increasing the dead weight of the structure by using thicker walls and slabs. Buttress retaining walls are proposed to provide strength and reduce the reinforcement required to resist bending moments in the sidewalls.

Plant operators confirm that the inflow gate never operated properly since the day it was first installed. The guides appear to be damaged near the bottom and the gate cannot be fully closed. The gate will not be required when the new coarse grit chamber is constructed. Therefore the gate should be removed. The chamber must be retained since it acts as a junction for two interceptor sewers.

6.2.5 Pumping Station (Facility No.1)

(1) Process

The primary clarifiers cannot effectively treat more than 4m3/s treated therefore it is proposed to modify the motor reducing gears on the screw pumps to reduce the maximum pumping capacity of each pump to 1.1 m^3/s:

1) Two pumps are sufficient to meet peak wet weather flows of 1.98 m^3/s for year 2000.
2) Three pumps are required to meet peak wet weather flows of 3.2 m^3/s for year 2015.

(2) Civil

The concrete stairs leading up to the pump station control room are badly damaged. Reconstructing them with new concrete is one option however to reduce future maintenance it is proposed that the stairs should be replaced with open grate galvanized steel.

In the wet well it is proposed to eliminate the mesh and the concrete posts ahead of the screw pumps since they will no longer be required when the new pre-treatment facility is constructed. The handrails around the open perimeter of the wet well are damaged and should be replaced for personnel security.

6.2.6 Screening Station (Facility No. 2)

(1) Process

Existing coarse and medium screens will be removed since this function will be provided by the new pre-treatment facility. In place of coarse screens it is proposed to install fine screening to eliminate fine plastics, razor blades and fibrous materials. These materials find their way into the sludge treatment process and are undesirable if treated sludge is used for agriculture.

Step screens with 6 mm openings are proposed. The screens are every robust and require a minimum of maintenance. Four screens will be installed one in each channel. The screens will be in two rows, staggered to increase the space available for operation and maintenance around each screen. Step screens have a high head loss of 220 mm and water height upstream of the screens is expected to be 1.71 m deep at 4.4 m^3/s. The existing screening channels can accommodate a maximum of 1.8m therefore the screens can function under maximum flow conditions. The new screening room layout is shown in **Figure 6.7 (1), (2).**

During dry weather flow only two screens will be required. During peak wet weather flows three screens will receive the entire flow. The fourth screen will be used as a stand-by. Automatic operation of the screens will be ensured by a programmable logic controller that allows operators to adjust the operating time and sequence. The screens will be interlocked to match the number of pumps in operation and high water level sensors located upstream of the screens will start the cleaning sequence automatically.

Screenings will collected by screw conveyors and sent to hoppers. Conveyors will be operated automatically when the screens operate. Hoppers will be drained and water returned to the drainage network for treatment. Hoppers will be discharged at the landfill site daily. A quantity of Hoppers will be drained and water returned to the drainage network for treatment. Hoppers will be discharged at the landfill site daily. A quantity of 5 m^3/day of fine screenings is expected.

(2) Civil

The chamber ahead of the screens will be modified to increase velocities and reduce the amount of grit that settles in the chamber between the pumps and the screens. Plan and sectional views of the proposed modifications are shown on **Drawing M3**. The new sluice gate is normally closed to channel flows directly into the screens.

6.2.7 Aerated Grit Chamber (Facility No. 3)

(1) Process

The aerated grit chambers are adequate for removing fine grit and will function properly when coarse grit is removed at the pre-treatment facility. Aeration will be carried out using blown air produced by two blowers (plus a third as a standby) and fed at the bottom of each grit chamber by means of a manifolds equipped with air diffusers. Blowers will be installed in the existing air blower building No.19.

Chamber dimensions are fixed therefore the following operating characteristics in **Table 9.5** can be expected under design flow conditions:

Table 6.5 OPERATING CHARACTERISTICS OF AERATED GRIT CHAMBER

	YEAR 2000	YEAR 2015
Hydraulic loads:		
At average flow	14 m/hrs.	23 m/hrs.
At PWWF of 4.4 m^3/s	46 m/hrs.	46 m/hrs.
Retention time:		
At average flow	14.4 min.	8.8 min.
At PWWF of 4.4 m^3/s	4.5 min.	4.5 min.

The amount of fine grit collected at this step in the process will vary but is expected to reach a maximum of about $10m^3$/day.

(2) Civil

Access to the travelling bridge needs to be improved for proper operation and maintenance. New stairs and walkways are required on each side of the grit chamber.

Hydraulic tests confirmed that there is heavy leakage at cracks and construction joints. All cracks and construction joints need to be sealed from the wet side of the structure using techniques described in **Section 6.2.2.**

6.2.8 Primary Sedimentation Tanks (Facility No. 4)

(1) Process

The two tanks have sufficient capacity for year 2015 conditions and will have the following operating characteristics in **Table 6.6** under assumed design conditions:

Table 6.6 OPERATING CHARACTERISTICS OF PRIMARY SEDIMENTATION TANKS

	YEAR 2000	YEAR 2015
Overflow rate at ADWF	1.18 m^3/m^2/hrs.	1.93 m^3/m^2/hrs.
Overflow rate at ADWF	1.68 m^3/m^2/hrs.	2.75 m^3/m^2/hrs.
BOD_5 removed	1,781 kg/day	
Overflow rate at ADWF	1.68 m^3/m^2/hrs.	2.75 m^3/m^2/hrs.

(3) Civil

The footings on the primary sedimentation tanks are only 0.5 meters below grade whereas frost penetration depth is at least 0.8 meters. Frost action result in movement of the structure and additional stresses that the structure was not designed to withstand. One visible result of excessive movement is failure (leakage) of the water bar in several expansion joints. It is therefore recommended to backfill around the primary sedimentation tanks in order to protect the footings from frost heaving. Proposed backfilling is shown on **Figure 6.4**.

Backfill of 1 meter will provide protection to exposed concrete surfaces and reduce the access height to the top of the effluent launder and travelling bridge. Higher ground elevations also have the added advantage of protecting the primary sludge pumping station from flooding.

Access to the peripheral drive and scraper bridge will be improved by adding an open grate stair and a peripheral walkway complete with railings around each tank. The stairs and walkways should be lightweight aluminum. The walkway should span between the two tanks by crossing over the primary sludge pumping station roof.

As recommended in the assessment report a new inside wall 150 mm thick is required to protect reinforcement and repair expansion joints. A new floor slab 100 mm thick is also needed to permit installing new water bars to seal leaks across expansion joints. The new wall thickness is required to permit proper placement and compaction of concrete inside the formwork. These repairs will require removal and re-adjustment of the scrappers to fit new internal dimensions. The volume of the tank will be reduced only slightly and will not have an impact on treatment performance.

6.2.9 Aeration Tanks (Facility No.5)

(1) Process

The total volume of the two tanks is 23,900 m^3. Aeration using surface aerators will have the following operating characteristics in **Table 6.7** at forecast flows and sewage strengths:

Table 6.7 OPERATING CHARACTERISTICS OF AERATION TANKS

	YEAR 2000	YEAR 2015
Hydraulic retention time ADWF	4.78	2.92
Hydraulic retention time PDWF	3.35	2.05
Mixed liquor Suspended solids (MLSS)	2.5 kg/m^3	4.0 kg/m^3
BOD5 loading	0.66 kg BOD_5/m^3.day	2.0 kg BOD_5/m^3.day
F/M ratio (calculated on TSS concentration)	0.27 kg BOD_5/ kg TSS.day	0.29 kg BOD_5/ kg TSS.day
% VSS in mixed liquor	74.7%	84.6%
F/M ratio (calculated on TSS concentration)	0.35 kg BOD_5/ kg VSS.day	0.34 kg BOD_5/ kg VSS.day

(2) Civil Works

As discussed in the assessment report, the cracks in the walls of the aeration tank are the result of bending moments induced by the rigid connection between walkway slabs and the top of the wall. Simply sealing the cracks would not be effective since the forces that caused them in the first place will still be present and new cracks will form. It is important to change the walkway connection detail to remove the restraint provided by the walkway and allow the wall to function as it was intended (i.e. as a cantilever wall). The existing walkway slab should be replaced by an open-grate walkway freely supported at the outside wall and aerator slab.

As recommended in the assessment report inside walls should be resurfaced with 150 mm thick reinforced concrete to protect reinforcement and repair expansion joints. A new floor slab 100 mm thick is also needed to permit installing new water bars to seal leaks across expansion joints. The new wall thickness is required to allow proper placement and compaction of concrete inside formwork. The volume of the tank will be reduced only slightly and will not have an impact on treatment performance.

The two exterior walls (East and west) will need additional reinforcement to control cracking induced by temperature changes. These outside (dry side) surface should be covered with a new reinforced concrete wall 150 mm thick with sufficient steel to control cracking. The concrete surface should be sealed with silicone to prevent moisture penetration and carbonation.

Aerator slabs and columns will need extensive reconstruction to correct the many problems observed:

1) installation of aerator anchor bolts through the slab creates stress point s that cause cracking
2) there is no pad for leveling screws
3) There is no vibration isolation pad between the machine and the concrete.
4) The concrete slabs and walkways are severely damaged by water and frost as a result of poor drainage. Reinforcement is exposed and corroded
5) The concrete fence walls are severely damaged by water and freezing action. The reinforcement at the base of the wall is exposed.
6) Columns are damaged at the water line by the action of turbulent water and freezing
7) Reinforcement in columns on the south and west faces is corroded.

The existing 150 mm aerator slabs are not worth rehabilitating since the damage is deep and the slabs are too thin to dampen vibration. Adding a new topping of sufficient thickness to protect the steel is not feasible because it would lift the surface aerator above the surface of the water and the shaft length cannot be adjusted.

Therefore it is proposed that a completely new slab be constructed. The existing aerators weigh 3,500 kg. To dampen vibrations the new slab should be at least 300mm thick to provide 5 times the weight of the machine. The concrete fence walls should be removed completely and replaced with guardrails. This is almost the same cost as repairing the concrete and will provide better long-term and maintenance free performance.

The cover over reinforcing steel in columns is insufficient on the South and West face. Corrosion of the reinforcing steel has produced rust stains on the surface in line with the reinforcement. The same defect is observed at every column, always on the same two faces. Lifting hooks on the North side of every column indicates that the columns were pre-cast then lifted into place. The lack of cover is probably caused by poor formwork during the fabrication of the columns.

Corrosion in the columns is not yet severe and has not resulted in the loss of section. Therefore the steel should be exposed, cleaned and treated in the same way that is specified for the walls. Proposed modifications are shown on **Figures 6.5** and **Figure 6.6**.

Concrete walkways connecting the aerators should be removed and replaced with open grate steel walkways between aerator slabs and simply supported at each end. This will prevent concrete deterioration from recurring and will facilitate maintenance in the future.

By detaching the walkway slabs the aerator slab and column become independent frames with no lateral bracing to prevent side sway. Therefore slender columns should be reinforced with additional steel to make them sufficiently rigid. To facilitate concrete operations the columns should be enlarged by a minimum of 100mm. The columns should be stripped back completely for the top 1 m leaving only the reinforcing steel. This will make it easier to connect with the new aerator slab.

To simplify access between aerators it is recommended that a walkway be extended to allow operators to cross from one row of aerators to another without having to climb down and back up. Winter conditions make access difficult therefore it would also be better if ladders were replaced with stairs. Ladders should be removed and access provided by stairs located on each side and at each end of the aeration tank (total 4 stairs).

6.2.10 Secondary Sedimentation Tanks (Facility No. 6)

(1) Process

The dimensions of the tanks provide the following operating characteristics in **Table 6.8** for assumed designed flows and loading:

Table 6.8 OPERATING CHARACTERISTICS OF SECOND SEDIMENTATION TANKS

	YEAR 2000 (4 UNITS)	YEAR 2015 (4 UNITS)
Surface overflow rate at ADWF	0.59 m^3/m^2/hrs.	0.96 m^3/m^2/hrs.
Surface overflow rate at PWWF	0.84 m^3/m^2/hrs.	1.37 m^3/m^2/hrs.
HRT at ADWF	5.91 hrs.	3.61 hrs.
HRT at PWWF	4.14 hrs.	2.53 hrs.

The design of the tanks is based on criteria for surface overflow rates that were commonly used in the early eighties. Since then a more sophisticated standard for secondary sedimentation tanks has been developed by ATV (German Institute for Hydraulics) and is now widely used by designers for analysis of sedimentation tank performance. The ATV standard states that the product of the rising velocity, sludge volume index and concentration of MLSS must be less than or equal to 450 to prevent overflow of sludge floc into the effluent during peak wet weather flows.

ATV Standard for PWWF 450 $\geq$ v x SVI x MLSS where,
v = rising velocity m/hrs.
SVI = sludge volume index
MLSS = concentration in g/l

Assuming a SVI of 120 mg/l and a MLSS of 2 g/l the maximum surface overflow rate for good performance is 1.88 m/hrs. > 0.84 m/h @ PWWF therefore the sedimentation tanks will perform properly under year 2000 conditions.

For the year 2015 a stronger MLSS of 3g/l is assumed. The maximum overflow rate for good performance will be 1.25m/hrs. < 1.37 m/hrs. @ PWWF. Therefore 4 units will not perform well under year 2015 PWWF and it may be necessary to add two more secondary sedimentation tanks depending on actual sludge characteristics and mixed liquor concentrations.

(2) Civil

As recommended in the assessment report a new inside wall 150 mm thick is required to protect reinforcement and repair expansion joints. A new floor slab 100 mm thick is also needed to permit installing new water bars to seal leaks across expansion joints. The new wall thickness is required to permit proper placement and compaction of concrete inside the formwork. These repairs will require removal and re-adjustment of the scrappers to fit new internal dimensions. The volume of the tank will be reduced only slightly and will not have an impact on treatment performance.

6.2.11 Flow Metering (Facility No. 7)

(1) Process

Treated water will be discharged from the secondary sedimentation tanks and flow by gravity to the Parshall flume chamber. The rate of flow will be measured by reading the water level in the flume using non-contacting ultrasonic transponder to record water levels. Water levels will be automatically converted into flows and recorded graphically.

(2) Civil

There are no civil structural repairs or modifications to this structure.

6.2.12 Recycled Sludge Pumping Station (Facility No. 8)

(1) Process

There are no process changes for this facility. The pump station is equipped with 2 Archimedean screw pumps, which will be rehabilitated. Each screw pump has a unit capacity of 2 m^3/s. One screw pump will be used as a standby unit therefore the maximum recycle flow with one pump operating is 2 m^3/s.

Two submersible pumps located in the wet well remove waste (excess) sludge. The pumps will deliver the waste sludge to the inlet of the primary sedimentation tanks at a flow rate of approximately 120 m^3/hrs. This is the same flow rate for year 2000 and 2015 conditions.

(2) Civil

The concrete stairs leading up to the pump station control room are badly damaged. Reconstructing them with new concrete is one option however to reduce future maintenance it is proposed that the stairs should be replaced with open grate galvanized steel.

Leakage in the construction joints along the bottom of the recirculation channel should be sealed.

6.2.13 Primary Sludge Pumping Station (Facility No. 9)

(1) Process

There are no process changes for this facility. Primary and biological sludge will be settled together in the primary sedimentation tanks and drawn off by gravity to the wet well of the pump station. The pumping station will need two new centrifugal pumps with a unit capacity of 150 m^3/hrs. One pump will be used as a standby unit. The same pumping capacity is required for year 2000 and 2015 conditions. Withdrawal of mixed sludge is expected at a minimum concentration of 10 g/l. The concentration can be increased according to operating requirements. A low concentration makes it possible to:

1) reduce the sludge retention period in the primary tanks to avoid undesirable fermentation
2) to feed the thickeners as regularly as possible

(2) Civil

The wet well structure is in good condition but is showing signs of aging (many small cracks) that could start leaking. Prior to backfilling, the exterior of the wet well and pumping station structure will need to be waterproofed with a bituminous coating. The inside of the wet well should be lined with a waterproof epoxy resin coating to prevent leakage.

6.2.14 Sludge Thickeners (Facility No.10)

(1) Process

The layout of the cyclone is shown on **Drawing M4**. Installation will require only minor modification of the existing thickened sludge pumping station. The maximum mixed sludge flow rate to be cycloned will be 150 m^3/hrs. There are no changes proposed to the thickeners however a new step in the process is proposed to remove grit from the sludge before sludge is sent to the thickeners. Although most of the grit should be removed from primary sludge during preliminary treatment the cyclones are proposed as an added measure of safety to prevent grit from accumulating in the digesters and clogging gas mixing tubes.

Estimated sludge quantities are described in the following **Table 6.9**:

Table 6.9 ESTIMATED SLUDGE QUANTITIES

	YEAR 2000	YEAR 2015
Primary sludge	19,440 kg/d	30,725 kg/d
Biological sludge	11,023 kg/d	18,843 kg/d
Total mixed sludge	30,463 kg/d	49,567 kg/d

Only one thickener is required in the year 2000 and two thickeners have sufficient capacity for year 2015 conditions. Dimensions will lead to the following operating characteristics in **Table 6.10**:

Table 6.10 OPERATING CHARACTERISTICS OF SLUDGE THICKENERS

	YEAR 2000	YEAR 2015
SS concentration in thickened sludge	50 g/l	50 g/l
Volume of thickened sludge	609 m^3/d	991 m^3/d
Withdrawal flow rate	60 m^3/d	60 m^3/d
Time for sludge extraction	10.15 hours/day	16.52 hours/day
Mass loading	50 kg/m^2.day	50 kg/m^2.day
Minimum required surface area	609 m^2	991 m^2
Number of thickeners in operation	1	2

(2) Civil

As recommended in the assessment report a new inside wall 150 mm thick is required to protect reinforcement. This structure has no expansion joints therefore a new floor slab is no required. Wall repairs will require removal and re-adjustment of the scrappers to fit new internal dimensions. The volume of the tank will be reduced only slightly and will not have an impact on treatment performance.

6.2.15 Thickened Sludge Pumping Station (Facility No.11)

(1) Process

Sludge will be processed at the rate of 60 m^3/hrs. and a concentration of 50 g/l using two pumps with a capacity of 60 m^3/hrs. each (one pump is standby). This low pumping rate will make it possible to spread the loading of the digesters over a relatively long period of time (10.15 hours for year 2000 and 16.52 hours for year 2015) which is one of several essential factors for proper operation of the digestion unit.

(2) Civil

The wet well structure is in good condition but is showing signs of aging (many small cracks) that could start leaking. Prior to backfilling, the exterior of the wet well and pumping station structure will need to be waterproofed with a bituminous coating. The inside of the wet well should be lined with a waterproof epoxy resin coating to prevent leakage.

6.2.16 Digesters (Facility No. 12)

(1) Process

After accounting for solids lost in the thickener supernatant the total quantity of dry solids to be treated by digestion will be:

1) 29,194 kg/d in the year 2000
2) 47,502 kg/d in the year 2015

The dimensions of the digesters will provide the following sludge retention times:

1) 29.6 days in the year 2000
2) 18.2 days in the year 2015

Therefore the digesters have sufficient capacity to treat the expected sludge production rates.

The sludge resulting from the treatment of urban wastewater has a proportion of volatile solids that ranges from 55 to 70%. Assuming a value of 70% gives the following operating characteristics in **Table 6.11**:

Table 6.11 OPERATING CHARACTERISTICS OF DIGESTER

	YEAR 2000	YEAR 2015
Sludge loading	1.69 kg SS/m^3.day	2.75 kg SS/m^3.day
Organic sludge loading	1.19 kg SS/m^3.day	1.93 kg SS/m^3.day
Reduction in volatile solids	48%	45%
VSS destroyed in Digestion	10,248 kg/day	15,610 kg/day
Digested sludge concentration	33.2 g/l	34.3 g/l
SS weight after digestion	20,214 kg SS/day	33,958 kg SS/day

Process calculations assume the bio-gas contains 65% methane and have a calorific heating value of 8,570 kcal/m^3 at 0℃ and 760 mm HG corresponding to a specific heating value of 5,571 kcal/ Nm^3.

Biogas will be produced at the approximate rate of 1 Nm^3 per kg of VSS destroyed. Therefore the quantity of biogas produced for the design criteria will be approximately 10,248 m^3 per day for year 2000 and 15,619 m^3 per day for year 2015. These values are about 40% less than previously estimated in the original plant process design.

Biogas consumption and net production after deductions for sludge heating and heat losses in the digesters is tabulated in the following **Table 6.12**.

Table 6.12 BIOGAS CONSUMPTION AND NET PRODUCTION IN DIGESTERS

	YEAR 2000		YEAR 2015	
	winter	summer	Winter	summer
Gas produced by digestion	10,248 m^3/day		15,610 m^3/day	
Total consumed	3,480 m^3/day	1,964 m^3/day	5,332 m^3/day	3,130 m^3/day
Excess bio-gas production	6,769 m^3/day	8,284 m^3/day	10,278 m^3/day	12,480 m^3/day

(2) Civil

Anaerobic digesters are hermetically sealed containers in which liquid sludge is heated to undergo biological fermentation. As a result of this process the sludge is stabilized and transformed into biogas.

It was impossible to inspect the interior of the digesters because they are still 2/3 full of sludge. The insulation on the outside of the digesters conceals the concrete making it impossible to inspect for cracks and other defects. Thermal insulation and roofing will need to be replaced entirely. Rehabilitation related to civil works for the digesters is discussed in the following sections:

a) Cleaning

Prior to doing any rehabilitation work the digesters should be emptied and cleaned. The sludge can be pumped out to the holding tank and loaded into vacuum trucks for disposal at the landfill site. It is expected that there will be a significant amount of grit in the bottom of the tank. Grit will need to be shoveled out. Special precautions for confined space entry will be required for all work inside the digester. The inside should be washed with water prior to inspection of wall and roof surfaces.

b) Thermal insulation

Insulation of the digesters is required to minimize heat losses and energy consumption required for sludge heating. It is also vital to the treatment process in maintaining constant temperatures. Heat loss occurs mainly at walls, roof and floor of the digester

Insulation on walls and roof are in poor condition and will need to be replaced. New insulation should be expanded polystyrene sheets laid with staggered joints and spot-glued to the concrete. The insulation should be at least 100mm thick on walls and 50mm thick on the roof. Insulation on walls should be protected with a suitable pre-finished metal cladding mounted on metal ring hoops that are anchored to the concrete. A waterproof synthetic membrane bonded to the insulation is required to protect insulation on the roof.

c) Required testing

After cleaning the digesters and before installing the new insulation the digesters should be hydraulically tested. Leaks through cracks in the concrete and embedded sleeves should be identified and sealed from the inside face.

d) Anti-corrosion protection

Contact to bio-gas can lead to considerable and rapid deterioration of the concrete of the internal wall surfaces and the dome of the side-wall sections, including the zone between the high and low sludge levels. The risk can be avoided by coating the walls with an anti-corrosion lining that is impervious to gas. Discussions with Degremont who built the treatment plant, confirms that the protective coating was applied to the internal surfaces of the roof extending along the sidewalls down to 1 m below the minimum sludge level in service. This lining should be inspected for signs of distress before any insulation or cladding is applied. The lining can be verified by spraying water containing a surfactant liquid soap on the exterior until the concrete is thoroughly soaked. The tank can then be pressure tested for imperviousness to gas. Soap bubbles will appear if there is any air leaks.

6.2.17 Sludge Heating (Boiler House Facility No. 13)

(1) Process

To obtain proper digestion the temperature inside the digester must be maintained at a constant 35℃. Therefore the incoming sludge must be heated from a temperature that varies from 8℃ in the winter to 18℃ in the summer. The existing boiler plant was completely destroyed during the war and all new equipment is required.

Heat loss calculations are included as part of the process calculations presented in **Appendix O, Vol. Ⅳ.** Assuming extreme winter conditions (air temperature −15℃ and incoming sludge 8℃) the heating requirement for raising the incoming sludge temperature to 35℃, and balancing heat losses is estimated in **Table 6.13** :

Table 6.13 BALANCING HEAT LOSSES

	Year 2000	Year 2015
Summer	10, 942, 263 kcal/day	17, 437, 948 kcal/day
Winter	19, 383, 771 kcal/day 939 kW	29, 700, 443 kcal/day 1,439 kW

The heat loss calculations assume that the digesters will be entirely reinsulated with 100 mm polystyrene on the walls and 50 mm on the roof. Two new boilers are required for sludge heating. In addition a third boiler unit of the same capacity is required for building heating loads, estimated at 550 kW. Equipment requirements and preliminary design considerations are discussed in mechanical sections of the report.