1.4 COMPONENT FACILITIES

1.4.1 PRIMARY CLARIFIERS

Primary clarifiers specifications are calculated by the following equation.

Average daily flow, Qad = 200,000 m^3/day
Maximum daily flow, Qmd = 235,000 m^3/day
Maximum hourly flow, Qmh = 285,000 m^3/day
Wet weather glow Qww = 570,000 m^3/day
Hydraulic surface load rate = 35 $m^3/m^2 \cdot$day
Totally 4 clusters, each consisting of 2 tanks, total number of basins is 8 units
Hydraulic load on each basin is 235,000 ÷ 8 = 29,375 m^3/day/basin
Required surface area of each basin = 29,375 ÷ 35 = 839 m^2

(1) Tank Geometry (In accordance with the Romanian Standards),

Internal diameter 35 m
Effective depth 2.0 m
Number of basins 8 basins
Surface area of a basin 843 × 8 = 6,744 m^2
Hydraulic capacity of a basin 6,744 × 2 = 13,488 m^3
Check for hydraulic conditions of basins under the different flow rates.
Retention time
Qmd 13,488 × 24 / 235,000 = 1.38 hours
2Qmh 13,488 × 24 / 570,000 = 0.57 hours > 0.5
Surface load rate
Qmd 235,000 / 6,744 = 34.8 m^3/m^2.day < 35
2Qmh 570,000 / 6,744 = 84.5 m^3/m^2.day < 96

(2) Raw Sludge Pumping Equipment

The pumps will handle the mixture of primary and excess sludge having solids concentration of 2%.

Sludge solids 46.44 t/day, Solids concentration 2 %
Sludge volume 2,322 m^3/day = 1.61 m^3/min.
Pump type: Centrifugal screw pump
Pump bore size: 100 mm
Delivering capacity: 1 m^3/min.
Total dynamic head: 10 m
Number of pumps: 3 Units (including 1 standby)

1.4.2 REACTOR TANKS

Reactor tanks specifications are calculated by the following equation.

Design flow, Qmd = 235,000 m^3/day
BOD – SS load 0.30 kgBOD/kg SS day
MLSS 1,667 mg/L
Return sludge solids concentration 5,000 mg/L
Sludge return ratio = 1,667 ÷ (5,000 – 1,667) = 0.50
Inflow BOD to reactors 235,000 × 170 × 10^{-3} kg BOD/day × (1 – 0.3)
= 27,965 kg BOD/day
Reactor tanks SS = V × 1,667 × 10^{-3} kgMLSS
Required tank capacity = 27,965 ÷ 1.667 ÷ 0.30 = 55,919 m^3

Aeration time = 55,919 × 24 ÷ 235,000 = 5.7 hours

At Qmd, aeration time of 6 hours or more is secured.

Required tank capacity = 6 × 235,000 ÷ 24.00 = 58,750 m^3

Tank geometry

Width = 5.5 m

Effective depth = 5.5 m

Cross sectional area = 5.5 × 5.5 − 1/2 × 1.0^2 × 2 − 1/2 × 0.6^2 × 2

= 29 m^2

Number of tanks = 8 tanks 4 clusters 32 tanks

Capacity of one tank = 55,919 ÷ 32 = 1,747 m^3

Tank length = 1,747 ÷ 29 = 60.26 use 67 m

Tank geometry			
W	5.5 m	×	32 Tanks
L	67 m		
H	5.5 m		

Check of aeration time

Tank capacity = 29 × 67 × 32 = 62,176 m^3

Aeration time = 62,176 × 24 / 235,000 = 6.3 hours

Check for additional tank requirement to upgrade the process

Additional tank capacity required for the advanced treatment process will be provided by adding tanks to the conventional activated sludge aeration tanks. The wastewater inflow will be distributed both to the existing and additional tanks. The wastewater will be distributed in proportion to the treatment capacity of both trains.

The total detention time will be 13.2 hours.

As the detention time in the conventional treatment process is 6.3 hours, the required retention time for additional tanks is

13.2 − 6.3 = 6.90 hours

Check capacity and wastewater distribution ratio

Existing tanks 6.3 / 13.2 = 0.48

Additional tanks 6.9 / 13.2 = 0.52

Wastewater flow distribution rates

Existing tanks 235,000 × 0.48 = 113,047 m^3/day

Additional tanks 235,000 × 0.52 = 122,841 m^3/day

Additional Reactor Tanks

Required tank capacity = 235,000 × 6.9 ÷ 24 = 67,563 m^3

Number of tanks = 8 tanks 4 clusters 32 tanks

Tank capacity = 67,563 ÷ 32 = 2,111 m^3

Tank length = 2,111 ÷ 29.00 = 72.8 use 73 m

Tank geometry			
W	5.5 m	×	32 Tanks
L	73 m		
H	5.5 m		

Check retention time

Tank capacity = 29 × 73 × 32 = 67,744 m^3

Retention time = 67,744 × 24 / 235,000 = 6.9 hours

1.4.3 FINAL CLARIFIERS

Final clarifiers specifications are calculated by the following equation.

Design flow QD = 235,000 m^3/day
Surface load rate = 25 $m^3/m^2\cdot$day
4 clusters each consisting of 2 tanks, total tank number is : 8 tanks
Influent to each tank = 235,000 ÷ 8 = 29,375 m^3/day/tank
Required surface area of each tank = 29,375 ÷ 25 = 1,175 m^2

(1) Check by the Romanian Standards

Internal diameter 45 m
Effective depth 3.5 m
Tank numbers 8 units
Surface area 1,424 × 8 = 11,392 m^2
Capacity 11,392 × 3.5 = 39,872 m^3
Surface load rate 21 $m^3/m^2\cdot$day
Retention time
At Qmd 39,872 × 24 / 235,000 = 4.07 hours
Qv=Qmh + Qrmax = 285,000 + 117,500 = 402,500 m^3/day
39,872 × 24 / 402,500 = 2.38 > 2.0
Surface load rate
At Qmd 235,000 / 11,392 = 21 $m^3/m^2\cdot$day < 25
At Qv 402,500 / 11,392 = 35.3 $m^3/m^2\cdot$day < 52.8
Weir loading
Weir length L = π × 42.7 × 8 = 1,073 m
At Qmd 235,000 / 1,073 = 219 $m^3/m\cdot$day
At Qv 402,500 / 1,073 = 375 $m^3/m\cdot$day

As compared with the Japanese Standards, the weir loading appears to be high side. The weir length may be increased in detailed design.

(2) Check for Advanced Treatment

The advanced treatment will be performed through two trains, existing and advanced treatment process trains.
The wastewater will be distributed to each train in proportion to the reactor tanks hydraulic retention time.

Wastewater distribution
Existing train 113,047 m^3/day
Additional train 122,841 m^3/day

Check for additional tanks
Surface load rate 15 $m^3/m^2\cdot$day or lower
Cluster 4 with 2 tanks, then total tank number is 8 units
Flow rate to each tank 122,841 ÷ 8 = 15,355 m^3/day.tank
Required surface area of each tank = 15,355 ÷ 15 = 1,024 m^2
D = 40 → 2.3 = 37.7 m
According to Romanian Standards A = 0.785 × $(D^2 - 3^2)$ = 1,109 m^2
Diameter 40 m
Effective depth 3.5 m
Number of tanks 8 units
Water surface area 1,109 × 8 = 8,869 m^2
Capacity 8,869 × 3.5 = 31,042 m^3
Overflow rate 13.9 m^3/m^2/day
Check the existing tank surface load rate
122,841 / 11,392 = 10.8 m^3/m^2/day < 15

(3) Return Sludge Pumps

Return sludge pumps are specified as follows.

Average 50 % sludge return rate is considered, but pump capacity 100 % return rate is provided to prevent and restore sludge bulking.

Return sludge volume = 117,500 m^3/day = 82 m^3/min.

60 % and 40 % of sludge will be transported by 4 and 2 pumps respectively, through double pipelines.

Pump capacity	41	×	0.2	=	8.16	use	8.2 m^3/minute/unit
"	41	×	0.15	=	6.12	use	6.2 m^3/minute/unit

By operating above pumps, the return sludge rates can be adjusted at the order of 5% to 15 %.

Pump type	No.1 Screw centrifugal	No.2 Screw centrifugal
Diameter	250 mm	250 mm
Capacity	6.2 m^3/min.	8.2 m^3/min.
TDH	10 m	10 m
Number of pumps	8 units	4 units
Motor output	22 kW	30 kW

(4) Excess Sludge Pumps

Excess sludge pumps are specified as follows.

Excess sludge volume = 5,904 m^3/day = 4.1 m^3/min

Two lines will be provided, then the capacity of a pump = 1.02 m^3/min

Type of pump	No.1 Screw centrifugal pump
Diameter	250 mm
Capacity	1.1 m^3/min
TDH	10 m
Number of pumps	6 units (2-standby)
Motor output	22 kW

(5) Chlorine Contact Tanks

Chlorine contact tanks specifications are calculated by the following equation.

Design flow rate = 235,000 m^3/day

Chlorine contact time = 15 minutes

Required tank capacity: 235,000 ÷ 1,440 × 15 = 2,448 m^3

Channel width: 4.0 m

Effective depth: 3.0 m

Tank length: 2447.9 ÷ 4.0 ÷ 3.0 = 204.0 m → 204 m

Number of tanks 1 unit

Chlorine contact tank geometry					
W	4 m	×	H 4.0 m	×	1 Tanks
L	204 m				

1.5 ANAEROBIC SLUDGE DIGESTER

1.5.1 SLUDGE THICKENERS

(1) Hydraulic Capacity of Tanks

Hydraulic capacity of tanks are specified as follows.

Solids input	= 46.44 t/day
Input sludge volume	= 6,750 m^3/day
Output sludge volume	= 1,061 m^3/day
Floor loading	= 60 kg/m^2/day
Required surface area	= 774 m^2
Tank geometry	Circular radial flow type
Internal diameter	= 16 m
Effective depth	= 4 m
Number of tanks	= 4 units
Water surface area	$3.14 / 4 \times 16^2 \times 4 = 804$ m^2

(2) Sludge Withdrawal Pumps

Sludge withdrawal pumps are specified as follows.

The pumps will have capacities that can send thickened sludge in around 8 hours.

Pump capacity	$Q = 1061 \times 1/8 \times 1/60 = 2.21$ m^3/min.
Pump	Sludge pump
Diameter	100 mm
Discharge capacity	1.20 m^3/min.
TDH	20 m
Motor output	15 kW
Number of pumps	3 units(including one standby)

(3) Sludge Screens

Sludge screens are specified as follows.

Type	Rotary drum screen
Screen opening	4 mm
Capacity	2 m^3/min.
Motor output	0.4 kW
Number of screens	1 unit

Screen capacity is so determined that the sludge quantity being sent concomitantly from 2 raw sludge pumps (each q =1.0 m^3/min.) can be screened.

1.5.2 ANAEROBIC SLUDGE DIGESTION TANKS

(1) Hydraulic Capacity of Tanks

Hydraulic capacity of tanks are specified as follows.

Sludge solids input	= 37.15 t/day
Input sludge	= 1,061 m^3/day
Retention time	20 days
Tank temperature	35 °c
Required tank capacity	$1,061 \times 20 = 21,230$ m^3

(2) Tank Geometry

Type	Single stage digestion
Internal diameter	17.5 m
Effective tank depth	31 m
Number of tanks	2 clusters × 2 tanks
Capacity	5,580 m^3/tank, 22,321 m^3 total tank capacity

1.5.3 GAS STORAGE TANKS

(1) Capacity of Tanks

Capacity of tanks are calculated by the following equation.

Total solids input to digesters = 37.15 t/day
Assuming that 70 % of the input sludge solids are volatile, and 1 kg of which produce 0.425 m^3 gas, the total gas production can be estimated as follows:
Total gas production = 37.15 × 0.7 × 10^3 × 0.425 = 11,053 m^3/day
Storage time 8 hours
Tank storage capacity = 11,053 × 8 / 24 = 3,684 m^3/day

(2) Tank Geometry

Type	Dry-seal type steel tanks
Number of tanks	2 units
Diameter	16 m
Effective height	17 m
Storage capacity	2,000 m^3

1.5.4 MECHANICAL SLUDGE DEWATERING

(1) Filter Capacity

Filter capacity is calculated by the following equation.

Solids input = 24.15 t/day, Input sludge volume 805 m^3/day
Belt press filter
Yields per unit length 130 kg/m/hr
Filter width 3 m
Daily operation time 6 hr
Working days/week 5 day
Solids loads per hour = 24.15 × 7 / 5 × 10^3 / 6 = 5,635 kg/hr
Required number of belt press
= 5,635 / 130 / 3 = 14 use → 14 units

Type	:	Belt filter press
Filter loading rate	:	130 kg/m/hr
Filter width	:	3 m
Number of filters	:	14 unit

1.6 CHLORINE REQUIREMENTS

Required quantity of hypochlorite solution can be calculated by multiplying the dosing rate by the wastewater flow rate as shown in the following equation:

$$VR = Q \times R \times (100 / C) \times (1 / d) \times 10^{-3}$$

where

VR	Required hypochlorite solution (L / hr.)
Q	Wastewater flow rate (m^3 / hr)
R	Chlorine dosing rate(mg / L)
C	Effective chlorine concentration in chemical (%)
d	Specific gravity of hypochlorite solution (at the effective concentration of C%)

At the maximum daily flow rate, the required hypochlorite solution is:

Q	=	235,000 m^3/day	=	9,792 m^3/hr
R	=	3 mg/L		
C	=	10 %		
d	=	1.2		
VR	=	Q × 3 × (100 / 10) × (1 / 1.2) × 10^{-3}		
	=	0.036 × Q = 353 L/hr = 6 L/minute		

At the wet weather flow (maximum hydraulic rate)

Qww	=	570,000 m^3/day	=	23,750 m^3/hr.
R	=	8 mg/L		
VR	=	0.012 × 8 × Qww = 2,280 L/hr = 38 L/minute		

(1) Hypochlorite Solution Storage Tanks

8 days storage capacity for the maximum daily flow rate. Then, the capacity is:

V = 0.353 m^3/h × 24 × 8 = 67.78 m^3

Tank specifications

Type	FRP made cylinder type
Internal diameter	2.8 m
Height	3.9 m
Capacity	20 m^3
Number of tanks	4 units

(2) Dosing Pumps Specification

	(No.1)	(No.2)
Type	Diaphragm	Diaphragm
Diameter	20 mm	20 mm
Discharge	6 L/min.	13 L/min.
Motor output	0.2 kW	0.4 kW
No. of unit	2 units	3 units(including 1 standby)

1.7 DIGESTER HEATING SYSTEM

1.7.1 TEMPERATURE

Lowest daily average temperature	0 °c
Soil temperature	15 °c
Input sludge temperature	10 °c
Digester tank temperature	35 °c

1.7.2 REQUIRED CALORIES FOR SLUDGE HEATING SPECIFIC HEAT 1.0 KCAL/KG · ℃

Required calories for sludge heating system is calculated by the following equation.

Q = 1,061 × (35 – 10) × 103 × 1.0 = 26,537,073 Kcal/d

1.7.3 HEAT LOSSES TANK INTERNAL DIAMETER 17.5 M

(1) Surface Area of the Digestion Tank

	Internal diameter 17.5 m		
	r	R	h
Top slab (gas portion)	1.00	3.00	2.0
A1		38.7 m^2	
Top slab(liquid portion)	3.00	8.75	5.75
A2		300.0 m^2	
Side wall(above ground)	8.75	8.75	13.05
(down to 1m below ground) A3		717.1 m^2	
Side wall(underground)	8.75	8.75	4.45
(up to 1m from surface) A4		244.5 m^2	
Bottom slab	1.00	8.75	7.75
A5		338.7 m^2	

A1 = 35.5(side) + 3.14(top, r) = 38.67
A2 = 300.0 , A3 = 717.7 , A4 = 244.5 , A5 = 335.5 + 3.14 = 338.7

(2) Overall Thermal Conductivity Coefficient (kcal/m², °C/hr)

	RC thickness (m)	Water proof motor	Insulation (polyurethane foam)	Concrete block	Spray concrete	Gas portion	Internal α 1(thermal conductivity)	External α 2(thermal conductivity)	K
	(λ=1.4)	(λ=1.2)	(λ=0.22)	(λ=1.0)	(λ=1.4)	(λ=0.48)			
Roof slab(gas portion)	0.3	0.03	0.04				20	20	0.464k1
Roof slab(liquid portion)	0.3	0.03	0.04				300	20	0.474k2
Upper side walls (1m underground or higher)	0.3		0.04	0.15		0.26	300	20	0.360k3
Lower sidewalls (1m underground or lower)	0.3						300	5	2.395k4
Bottom slab	0.8				0.1		300	5	1.182k5

The overall thermal conductivity coefficient can be calculated by the following equation:

$$1 / K = 1 / \alpha_1 \times \delta_1 / \lambda_1 + \delta_2 / \lambda_2 + 1 / \alpha_2$$

where

K Overall thermal conductivity coefficient (kcal/m²·°c·hr.)

α_1 Thermal conductivity coefficient of gas or sludge (kcal/ m²·°c·hr.)
1 / k1 = 2.16 k1 = 0.464

α_2 Thermal conductivity coefficient of air or ground (kcal/ m²·°c·hr.)
1 / k2 = 2.11 k2 = 0.474

λ_1,λ_2 Thermal conductivity coefficient of insulation material (kcal/ m²·°c·hr.)
1 / k3 = 2.78 k3 = 0.360

δ_1, δ_2 Thickness of insulators (m) 1 / k4 = 0.42 k4 = 2.395
1 / k5 = 0.85 k5 = 1.182

(3) Overall Heat Losses

Portion of tank	Heat transfer area	Thermal conductivity coefficient	Number of tanks	Difference of temperature	Total heat losses
	(m^2)	(Kcal/m^2/°c/hr)	(unit)	(°c)	
Roof slab(gas portion)	38.67	0.464	4	35	2,509
Roof slab(liquid portion)	300.0	0.474	4	35	19,899
Upper sidewalls(1m under ground above)	717.1	0.360	4	35	36,146
Lower sidewalls (up to 1m below ground surface)	244.5	2,395	4	35	81,974
Bottom slab	338.7	1.182	4	35	56,035
				Total	196,562

Overall heat losses = 196,562 Kcal / hr

1.7.4 HEATING SYSTEM

24 hours continuous heating. A total of 20 % heat losses from pipes are considered.

26,537,073 / 24 + 196,562 × 1.2 = 1,341,586 Kcal / hour

Efficiency of water heater 0.9

1,341,586 / 0.9 = 1,490,651 Kcal / hour

Water heater

800,000 Kcal / hr × 3 units (including 1 standby)

1.8 ANAEROBIC SLUDGE DIGESTION SYSTEM

1.8.1 DIGESTION TANK

Hydraulic capacity of tanks are specified as follows.

Solids input = 1,061 m^3/day
Retention time 20 days
Temperature 35 °c
Required tank capacity 1,061 × 20 = 21,230 m^3

1.8.2 TANK GEOMETRY

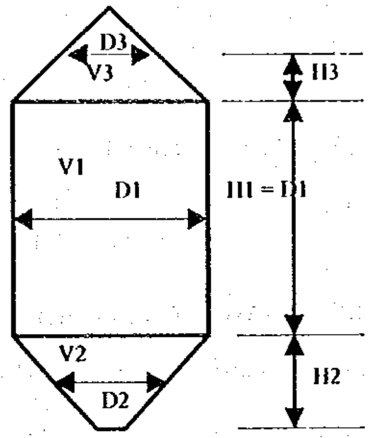
Tank geometry is specified as follows.

Type single stage tank
Internal diameter 17.5 m
Effective tank depth 31 m
Number of tanks 2 clusters 4 tanks
5,580 m^3/tank D1 = 17.5 m
(5,307 m^3 / tank or larger) D2 = 2 m
D3 = 6 m

1.8.3 TANK CAPACITY

Tank capacity is calculated by the following equation.

Effective depth		17.5 m	Portion V1
"		7.75 m	Portion V2
"		5.75 m	Portion V3
Total		31m	
V1	=	$\pi / 4 \times D1^2 \times D1$	
	=	$\pi / 4 \times D1^3$ = 4,207 m^3	
V2	=	$\pi / 4 \times D1^2 \times (D/2) / 3$	
		$- \pi / 4 \times D2^2 \times (D2/2) / 3$	
	=	$\pi / 4 / 6 \ (D^3 - D2^3)$	
	=	700 m^3	
V3	=	$\pi / 4 / 6 \ (D1^3 - D3^3)$	
	=	673 m^3	
		V total 5,580 m^3	



1.9 REQUIRED OXYGEN

Required oxygen is calculated by the following equation.

Required O_2 : OD = OD_1 + OD_2 + OD_3

where

OD_1 : Oxygen required for BOD oxygenation (cell synthesis)

OD_2 : Oxygen required for endogenous respiration

OD_3 : Oxygen to be utilized for maintaining required dissolved oxygen level

1.9.1 REQUIRED OXYGEN FOR BOD OXIDATION(CELL SYNTHESIS) : OD_1(KGO_2/DAY)

OD_1 = A(kgO_2/kgBOD) × BOD removed (kg BOD/day)

where

A : kg oxygen required to remove kg BOD (kgO_2/kgBOD), 0.5~0.7 -> 0.6

Q = 235,000 m^3/day

OD_1 = 0.6 × Q × 101.2 × 10^{-3} = 0.0607 Q kgO_2/day

Influent BOD = 119 − 18 = 101.2 mg/l

1.9.2 OXYGEN REQUIRED FOR ENDOGENOUS RESPIRATIONOD_2(KGO_2/DAY)

OD_2 = B(kgO_2/kgMLVSS·day) × VA(m^3) × MLVSS(kgMLVSS/m^3)

where

B : Oxygen consumption due to endogenous respiration per unit MLVSS 0.05~0.15 (kgO_2/kgMLVSS·day) 0.05

VA: Capacity of aerobic portion of reactor(m^3) Q × 6 ÷ 24 = 0.25 Q

MLVSS/MLSS = 0.8

OD_2 = 0.05 × 0.25 × Q × 1,500 × 10^{-3} × 0.8

= 0.0150 Q kgO_2 / day

1.9.3 Required Oxygen to Maintain Dissolved Oxygen Level: OD_3 (kgO_2/day)

OD_3 = COA × Q × 10^{-3}

where COA : Aeration tank dissolved oxygen 1.5 mg/l concentration

OD_3 = 1.5 × Q × 10^{-3}

= 0.0015 Q kg O_2/day

1.9.4 Total Oxygen Requirements

OD = OD_1 + OD_2 + OD_3

= 0.0607 Q + 0.015 Q + 0.0015 Q = 0.0772 Q (kgO_2/day)

1.9.5 Aeration Equipment (diffusers, fine bubles, spiral flow)

Aeration equipment is calculated by the following equation.

EA = 7.5, ρ = 1.293, Qw = 0.233

Air volume (Nm^3/day)

= (Required oxygen(kgO_2)) / (EA(%) × 10^{-2} × ρ (air/Nm^3) × Qw(kgO_2/kg air))

= (0.0772 Q) / (7.5 × 0.01 × 1.293 × 0.233)

= 3.42 Q = 802,811 (Nm^3/day) = 558 (Nm^3/min.)

Install one blower for each train

Required blower capacity	558 ÷ 4 = 139 m^3/tank·unit
Blower spec.	Cast-iron made multi-stage turbo blower
Inlet/outlet diameters	ϕ350 / ϕ300
Capacity	140 m^3/min.
Motor output	190 kW
Number of units	5 units (including 1 standby)

1.10 SCREENS AND PUMPING STATION

1.10.1 Flow Rate

Flow rate is determined as follows.

Qad	200,000 m^3/day	2,315 L/s
Qmd	235,000 m^3/day	2,720 L/s
Qmh	285,000 m^3/day	3,299 L/s
Qww	570,000 m^3/day	6,597 L/s

1.10.2 Incoming Sewer

Incoming sewer is specified as follows.

Friction formula	Manning (n= 0.013)
Size of incoming sewer	ϕ 2,200 mm
Sewer slope	1.2 ‰
Incoming sewer invert elevation	−3.699 m above M.W.L.
Full flow rate of incoming sewer	6.597 m^3/sec
Full flow velocity in incoming sewer	1.789 m/sec

Item	Wastewater flow rates (m³/s)	Flow velocity (m/sec)	Water depth (m)	Water surface elevation at entrance (m)	Head loss ahead of chamber	Gate chamber water elevation (m)
Average	2.315	1.617	0.884	-2.815	0.133	-2.948
daily	0.340	0.904	0.402			
Maximum	2.720	1.689	0.981	-2.718	0.146	-2.863
daily	0.440	0.944	0.446			
Maximum	3.299	1.775	1.080	-2.619	0.161	-2.779
hourly	0.485	0.992	0.491			
Wet	6.597	2.038	1.747	-1.952	0.212	-2.164
weather flow	0.970	1.139	0.794			
Note:	Ratio of flow to full flow	Ratio to full velocity	Ratio to full sewer depth		From tables	

1.10.3 INFLUENT GATE

Influent gate is specified as follows.

Elevation of gate bottom -3.85 M.W.L.
Gate type and size square 1.2 m

Items		Average daily flow	Max. daily flow	Max. hourly flow	Wet weather flow	Remarks
Wastewater Inflow rates (Q)	m³/s	2.315	2.720	3.299	6.597	
No. of gates operated (n)	Unit	2	2	3	4	
Wastewater inflow to each gate	m³/s/gate	1.157	1.360	1.100	1.649	Q/n
Wastewater elevation ahead of gate	M.W.L.	-2.948	-2.863	-2.779	-2.164	
Wastewater depth at gate (H)	m	0.902	0.987	1.071	1.686	
Wastewater flow area at gate (A)	m²	1.082	1.184	1.285	1.44	1.2×H
Flow velocity through gate(V)	m/s	1.069	1.149	0.856	1.145	Q/nA
Head losses at gate(Δh)	m	0.087	0.101	0.056	0.100	
Water elevation after gate	M	-3.036	-2.964	-2.836	-2.264	

Total head losses at gate (Δh) $1.5 \times v^2/2g = 0.0765 \times v^2$

1.10.4 COARSE SCREEN

Coarse screen is specified as follows.

Channel invert elevation –3.85 m M.W.L.
Channel width 1.6 m
Screen clear opening 100 mm
No. of screens 4
Slope of screens 60 degrees from horizontal

Items		Average daily flow	Maximum daily flow	Maximum hourly flow	Wet weather flow	Remarks
Wastewater inflow rates (Q)	m^3/s	2.315	2.720	3.299	6.597	
No. of channels used (n)		2	2	3	4	
Wastewater inflow to each channel	m^3/s	1.157	1.360	1.100	1.649	Q/n
Wastewater elevation ahead of screen	m M.W.L.	-3.036	-2.964	-2.836	-2.264	
Wastewater depth ahead of screen	m	0.814	0.886	1.014	1.586	
Flow area in channel(A)	m	1.303	1.417	1.278	2.537	1.6×H
Approaching flow velocity to screen	m/s	0.888	0.960	0.860	0.650	Q/nA
Flow velocity in screen(V2)	m/s	0.941	1.017	0.912	0.689	
Head loss in screen(Δh1)	m	0.002	0.003	0.002	0.001	
Actual head loss in screen(Δh2)	m	0.007	0.008	0.006	0.004	3×Δh1
Allowable head loss at screens (Δh3)	m	0.100	0.100	0.100	0.100	Δh3>h2
Wastewater elevation after screen	m M.W.L	-3.136	-3.064	-2.936	-2.364	Δh3

$\delta h = \beta \times (s/d)^{4/3} \times \sin\alpha = 0.0492268$

$\beta = 2.42$, $d = 150$ mm, $s = 9$ mm, $\alpha = 60°$, $\sin 60 = 0.866$

Loss by screen $= \delta h \times v^2/2g = 0.04923 \times v^2/2g$ (hw)

Flow velocity through screen V1 × (s+d) / d = 1.06 V1

1.10.5 FINE SCREEN

Fine screen is specified as follows.

Channel invert elevation	–4.0 M.W.L.
Channel width	1.6 m
Bar screen clear opening	20 mm
Thickness of screen bars	8 mm
No. of units	4 units
Slope of screen	75 degrees to horizontal

Items		Average daily flow	Maximum daily flow	Maximum hourly flow	Wet weather flow	Remarks
Wastewater Inflow rate (Q)	m^3/s	2.315	2.720	3.299	6.597	
No. of channels in use (n)		2	2	3	4	
Flow rate in each channel	m^3/s	1.157	1.360	1.100	1.649	Q/n
Water elevation ahead of screen	M.W.L.	-3.136	-3.064	-2.936	-2.364	
Water depth ahead of screen (H)	m	0.864	0.936	1.064	1.636	
Sectional area of flow in channel	m^2	1.383	1.497	1.341	2.617	1.6×H
Approaching velocity to screen(V1)	m/s	0.837	0.908	0.820	0.630	Q/nA
Flow velocity through screen(V2)	m/s	1.171	1.272	1.148	0.882	
Head loss through screen(Δh1)	m	0.048	0.057	0.046	0.027	
Actual head loss in screen(Δh2)	m	0.145	0.171	0.139	0.082	3×Δh1
Allowable maximum loss(Δh3)	m	0.100	0.100	0.100	0.100	Δh3<h2
Water surface elevation after screen	M.W.L.	-3.236	-3.164	-3.036	-2.464	Δh2

$\delta h = \beta \times (s/d)^{4/3} \times \sin\alpha = 0.688907$

$\beta = 2.42$, $d = 20$ mm, $s = 8$ mm, $\alpha = 75°$, $\sin 75 = 0.9659$

Loss by screen $= \delta h \times v^2/2g = 0.68891 \times v^2/2g$ (hw)

Flow velocity through screen $V1 \times (s+d)/d = 1.400\ V1$

1.10.6 PUMPING EQUIPMENT

(1) Design Flow Rate

Flow rate is determined as follows.

Qad	200,000 m^3/day	139 m^3/minute
Qmd	235,000 m^3/day	163 m^3/minute
Qmh	285,000 m^3/day	198 m^3/minute
Qww	570,000 m^3/day	396 m^3/minute

(2) Wastewater Pumps

4 units (including 1 standby), mixed flow centrifugal type driven by electric motor. Storm water pumps: 4 units(including 1 standby), mixed flow centrifugal type, smaller pumps driven by motor, and large pumps driven by diesel engine. Pump operation schedule is as follows:

Wastewater inflows	Wastewater inflow rates (m^3/minute)	Pump discharges					Total pump discharge (m^3/minute)
		Wastewater pumps		Storm water pumps			
		50	100	50	100	m^3/min/unit	
		2	2(1)	2	2(1)	No. of units	
Qad	139	50	100				150
Qmd	163	100	100				200
Qmh	198	100	100				200
Qww	396	100	100	100	100		400

(3) Pump Size:

No.1 Pumps
$Q = 50\ m^3/minute$
$D = 146(Q/V)^{0.5}$ $V = 5$ m/sec
$= 653$ mm use → 600 mm

No.2 Pumps
$Q = 100\ m^3/minute$
$D = 146(Q/V)^{0.5}$
$= 923$ mm use → 900 mm

(4) Wastewater Surface Elevations:

Suction water levels at inflow of

Qad	–3.236	M.W.L.
Qmd	–3.164	M.W.L.
Qmh	–3.036	M.W.L.
Qww	–2.464	M.W.L.

Suction water levels at outflow of

Qad	11.100	M.W.L.
Qmd	11.100	M.W.L.
Qmh	11.100	M.W.L.
Qww	11.100	M.W.L.

(5) Actual Head

Qad	11.100	–	(–3.236)	=	14.336 m
Qmd	11.100	–	(–3.164)	=	14.264 m
Qmh	11.100	–	(–3.036)	=	14.136 m
Qww	11.100	–	(–2.464)	=	13.564 m

(6) Total Head Losses at Pump Equipment:

Pump size	ϕ600	ϕ900
Pump bore(m)	0.6	0.9
Pump discharge(m^3/min)	50	100
Pump discharge(m^3/sec)	0.833	1.667
Delivery bore sectional area (m^2)	0.283	0.636
Pump velocity(m/s)	2.949	2.621

(7) Loss Coefficients

Inlet		0.15	0.15	
Sluice valve		0	0	
Check valve		1.0	1.0	
Outlet		1.0	1.0	
Bend		0.25	0.25	
Friction loss	f' × L / D	0.781	0.514	
	Total	3.181	2.914	F

(8) Head Losses

ϕ600 = 1.411 m $F \times V^2/2g$

ϕ900 = 1.021 m

Pipe length L = 15 m

Friction loss by Darcy-Wiseback Formula

$hf = f \times L / D \times V^2 / 2g$

$f = 0.02 + 1 / (2000 \times D)$ (New cast iron pipe)

For old cast–iron pipes multiply the f' by 1.5

	ϕ600	ϕ900
D(m)	0.6	0.9
F	0.021	0.021
f' = 1.5 × f	0.031	0.031

(9) Total Head Required

Qad	14.336	+	1.411 (ϕ600)	=	15.747 m
			1.021 (ϕ900)	=	15.357 m
Qmd	14.264	+	0.000	=	14.264 m
Qmh	14.136	+	0.000	=	14.136 m
Qww	13.564	+	1.021 (ϕ900)	=	14.586 m

The required total pump head is then 16.0 m

(10) Shaft Power of Mixed Flow Centrifugal Pumps

$L = k \times \gamma \times Q \times H / \mu$

where

L	Shaft power of pump
k	0.163 kW or 0.222 PS
Q	Pump discharge (m^3/min)
H	Pump total dynamic head (m)
γ	Specific gravity of water ($\gamma = 1$)
μ	Pump efficiency

Calculations for shaft power requirements

Items		φ600	φ900	φ900 Engine
Pump discharge(Q)	m^3/min	50	100	100
TDH (H)	m	16.0	16.0	16.0
Pump efficiency (μ)		0.78	0.81	0.81
Shaft power	kW	167	322	439

(11) Outputs of Pump Drives

$$P = L(1+\alpha) / \mu G$$

where

P	Pump power (kW)	
L	Pump shaft power (kW)	
α	Allowance for motor	0.15
	Allowance for engine	0.2
μG	Transmission efficiency (1.0 for direct connection)	

Items	φ600	φ900	φ900 Engine
Shaft power (L)	167	322	439
Allowance (α)	1.15	1.15	1.20
Efficiency of transmission (μ G)	1.00	1.00	0.95
Pump drive output (P) kW	192	370	554

(12) Pump Specifications

Items		Vertical mixed flow centrifugal pumps		
Pump bore	mm	600	900	900
Pump discharge	m^3/min.	50	100	100
Total dynamic head	m	16	16	16
Motor/engine outputs	kW	192	370	554
Pump drive		Motor	Motor	Engine

1.11 GRIT, OIL/GREASE REMOVAL EQUIPMENT

1.11.1 DESIGN WASTEWATER FLOW RATES

Design wastewater flow rates are determined as follows.

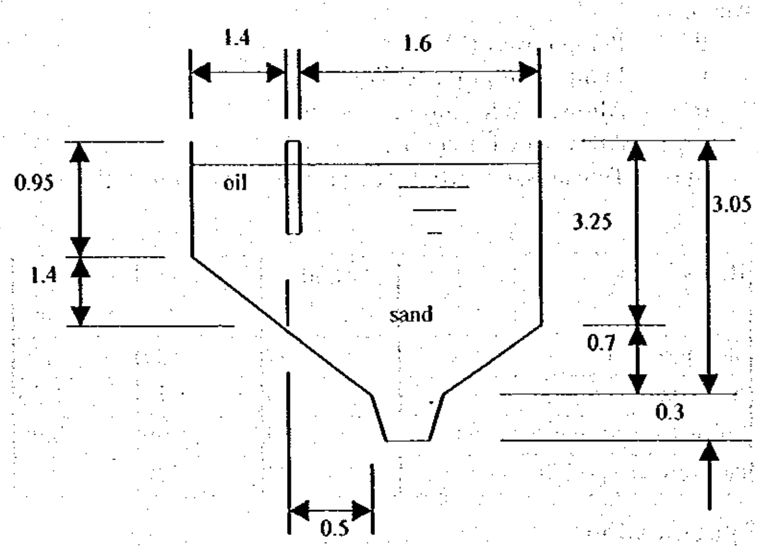
Qad 200,000 m^3/day 2,315 L/s

Qmd	235,000 m^3/day	2,720 L/s
Qmh	285,000 m^3/day	3,299 L/s
Qww	570,000 m^3/day	6,597 L/s

1.11.2 Grit, Oil/Grease Separation

Grit, oil/grease separation is specified as follows.

4 trains 2 channels each, then totally 8 channels
Qww 570,000 m^3/day = 6,597 L/sec
Flow to each channel 71,250 m^3/day = 825 L/sec
Retention time 3 minutes
Capacity 570,000 × 3 ÷ 1,440 = 1,187.5 m^3
Section area 6.8 m^2
Length 22 m
Capacity 6.8 × 22 × 8 = 1,196.8 m^3
(check for flows)
At maximum daily flow Qmd 235,000 m^3/day
Retention (1187.5 × 1440) / 235,000
Time = 7.3 min.



Chamber cross sectional area

1.4	×	0.95	=	1.33
1/2	×	1.4^2	=	0.98
1.6	×	3.05	=	4.88
−1/2	×	0.5^2	=	−0.13
−1/2	×	0.7^2	=	−0.25
Total				6.82 m^2 use → 6.8 m^2

Air supply volume
Romanian Standards Q = 0.3 m^3 air / m^3 water
= 0.3 × 23,750 = 7,125 m^3/hour
= 119 m^3/min
Japanese Standards Q = 0.01 m^3/sec·m × channel length/m (0.005~0.013)
= 0.01 × 22 × 8
= 1.746 m^3/sec = 105 m^3/min

Then, the total air is 119 m^3/min
Blower equipment
1 unit each for 1 train
then, 1 blower capacity = 119 ÷ 4 = 29.7 use → 30 m^3/min
Air blower specifications
Roots blower 5 units (including 1 standby)
ϕ 200mm 30 m^3/min
Grit volume from combined sewage: 0.001~0.02m^3 grit/1000m^3 sewage
Then, grit volume = 0.02 / 1000 × 570,000 = 11.4 m^3/day

1.11.3 Grit Pumps

Grit pumps are calculated as follows.

Pump capacity is to remove the grit in 20 minutes. As allowances the capacity is Two times of the grit quantity. Then , the pump capacity is
11.4 m^3/day × 2 / 8 units × 20 minutes = 0.14 m^3/min.
Assuming the grit content in the withdrawn wastewater at 10 %, the required pump capacity is ;
0.14 × (100 / 10) = 1.4 m^3/min
Assume the pump velocity to be 2.5 m/sec, the pump diameter will be
146 × $(1.4 / 2.5)^{0.5}$ = 109 use 100 mm

1.11.4 Flow Measurement

Use two units of Parshall flume

				Flow per each unit(Q / 2)
Qad	200,000 m^3/day	=	8,333 m^3/hour	4,167 m^3/hour
Qmh	285,000 m^3/day	=	11,875 m^3/hour	5,938 m^3/hour
Qww	570,00 m^3/day	=	23,750 m^3/hour	11,875 m^3/hour

Select 7 ft flume, range of flow 306 ~ 12,380 m^3/hour use 2 units

1.12 SLUDGE DIGESTER EQUIPMENT

1.12.1 Mixers

(1) Specifications

Type Up/down flow screw mixers (with a draft tube, from manufacturer's catalog)
Capacity 2,300 m^3/hour
Draft tube diameter 500 mm
Motor output 22 kW
Quantity 4 units

(2) Sludge Mixing Capacity

Sludge turn over rate (mixing the whole sludge volume 8 ~ 12 times/day)
Q = (8~12) × 5,580 (Tank volume = 5,580m^3) / 24
= 1,860 ~ 2,790 m^3/hour use → 2,300 m^3/hour

1.12.2 Tank Apparatus(on roof top)

Tank apparatus are specified as follows.

Gas collectors(steel made) ϕ600 mm × 1 unit
Gas relief valve (wet type) ϕ200 mm × 1 unit

Gas relief valve (dry type) ϕ200 mm × 1 unit (including valve and flame arrester)
Quantity Total 4 units

1.12.3 WATER HEATERS

(1) Specifications

Type	Vacuum type water heater	
Heater capacity	800,000 Kcal/hr.	
Heater transfer area	17.5 m^2	
Fuel	Sludge gas and oil	
Electric motors	Burner motor	3.7 kW
	Oil pump	0.4 kW
	Oil heater	2.0 kW
	Fan	2.2 kW
Quantity	3 units (1standby)	

(2) Nominal Heat Output

Total required heat = 1,341,586 Kcal/hr
Nominal heater capacity Q = (1,341,586) / (2 × 0.9)
= 335,397 Kcal / hr → 800,000 Kcal / hr
(Heater efficiency 0.9) (No. of units:2)

1.12.4 OIL SERVICE TANKS

(1) Specifications

Type	Steel made rectangular tank
Tank capacity	300 L
Quantity	1 unit

(2) Tank Capacity

Store oil of more than one hour consumption

q = (800,000 × 2) / (10,200 × 0.85) = 185 L / hr. use → 300 L
β :Heating value of A-diesel oil 10,200 kcal / kg
γ :Specific gravity of A-diesel oil 0.85 kg/L

1.12.5 OIL PUMPS

(1) Specifications

Type	Gear pump
Size	ϕ 15 mm
Discharge	10 L/min.
Discharge pressure	3 kg/cm^2
Electric motor	0.4 kW
Quantity	2 units (including 1 standby)

(2) Pump Discharge

Capable of supplying a 300-liter capacity tank within 30 minutes
Q = 300 / 30 = 10 L/minute

1.12.6 OIL STORAGE TANK

(1) Specifications

Type	Underground cylinder type
Storage capacity	15,000 L
Quantity	1 unit

(2) Tank Capacity

Store more than 3-day oil consumption.

V = 185 × 24 × 3 = 13,287 L use → 15,000 L

1.12.7 GAS BOOSTER FANS

(1) Specifications

Type	Turbo fan
Capacity	145.5 m^3/hr.
Pressure (static pressure in water column)	500 mm Aq
Electric motor	1.5 kW
Quantity	2 units (including 1 standby)

(2) Capacity

Sludge gas consumption

q = 800,000 / 5,500 = 145.5 m^3/hr.

(Sludge gas heat value 5,500 Kcal/m^3)

Check for gas consumption

Required energy	Kcal/day	32,198,064
Heater operation time	Hour	20.1
Gas production	m^3/day	11,053
Gas consumption	m^3/day	2,927

Required heat energy	1,341,586 Kcal/hr.
Heater output	800,000 Kcal/hr.
No. of units	2 units

1.12.8 HEAT EXCHANGE

(1) Specifications

Type	Spiral type heat exchanger
Heat transfer area	25 m^2
Water temperature	Inlet 70 °c, 60 °c Outlet 40 °c, 35 °c
Quantity	Total Nos. 4 units

(2) Energy Transfer

Provide an exchanger to each digester

Required energy per unit, M = 32,198,064 × 1 / 4 = 8,049,516 Kcal/day

= 335,397 Kcal/hr.

(3) Required Heat Transfer Area

$$A = (M \times 1.2) / (K \times \Delta tm) = (335{,}397 \times 1.2) / (600 \times 27.4)$$

= 24.5 m^2 use 25 m^2

M = Heat transfer 335,397 Kcal/hr.

K = Overall heat transfer coefficient 600 Kcal/m^2 hr.°c

Δtm Logarithmic average of temperature difference

= (Δt1−Δt2) / (ln Δt1 / Δt 2)

= (30 – 25) / (ln (30/ 25) = 27.4 °c

Δ1 = 70 – 40 = 30 °c

Δ2 = 60 – 35 = 25 °c

(4) Sludge Recirculation

Q 1 = M / (C × Δt× γ × 60) = 335397 / (1 × 5 × 1,000 × 60) = 1.12 m^3/min.

C Sludge specific heat 1 Kcal/kg·°c

Δt Temperature difference between inlet and outlet sludge

40 – 35 = 5 °c

γ Unit weight of sludge 1,000 kg/m^3

(5) Water Recirculation

Q 2 = 335,397 / (1 × 10 × 1,000 × 60) = 0.56 m^3/min.

Δt Difference of temperature between inlet and outlet

70 – 60 = 10 °c

1.12.9 Sludge Circulation Pumps

(1) Specifications

Type	Sludge pump with suction screw
Size	100 mm
Discharge	1.4 m^3/min.
TDH	15 m
Motor output	5.5 kW
No. of units	4 units

(2) Capacity

Sludge circulation rate Q = 1.12 m^3/min. use → 1.4 m^3/min.

(3) Head

Total head = Actual head + pipe losses + losses in heat exchanger (10m)

= 15 m

(4) Motor Output

P_m = 0.163 × 0.7 × 15 × (1 + 0.2) / 0.4 = 5.13 kW use → 5.5 kW

1.12.10 Hot Water Circulation Pumps

(1) Specifications

Type	Line pump
Size	65 mm
Capacity	0.6 m^3/min.
TDH	25 m
Motor output	3.7 kW
Quantity	4 units

(2) Capacity

Return from exchanger, $Q = 0.56\ m^3/min.$

(3) Head

Total heads = Actual head + pipe losses + losses in heat exchanger (20m)
= use 25 m

(4) Motor Output

$$Pm = 0.163 \times 0.4 \times 25 \times (1 + 0.2) / 0.6$$
$$= 3.26\ kW \quad use \rightarrow 3.7\ kW$$

1.12.11 GAS HOLDER

(1) Specifications

Type	Steel made dry seal type
Capacity	2000 m^3
Size	15.5m $\phi \times$ 16.8mH
No. of tanks	2 units

(2) Capacity

Gas generation	11,053 m^3/day
Retention time	8 hr.
Storage capacity	$11,053 \times 8 / 24 / 2 = 1,842\ m^3$ use $\rightarrow$ 2000 m^3

1.12.12 GAS SCRUBBERS

(1) Specifications

Type	Dry type (intermittent) scrubbers	
Capacity	150 m^3/hr.	
Size	1,800 mm × 4,200 m H × 2 units	
No. of units	2 × 1,800 mm × 4,200 m H × 2 units	4 units

(2) Capacity

Treat all the gas produced

$$Q = 11,053 \times 1 / 24 / 4 = 115\ m^3/hr. \quad use \rightarrow 150\ m^3/hr.$$

(3) Diameter of Towers

Velocity of gas flow 1 m/min.

$$D = (4 \times 150 / 60 / 3.14 / 1)^{0.5} = 1.785\ m\phi, \quad use \rightarrow 1800\ mm\phi$$

(4) Chemical Consumption

Inflow and outflow gas H_2S concentrations are 100 ppm and 10 ppm, respectively.

$$VI = 0.235 \times 10^{-3} \times Q \times \mu$$
$$= 0.235 \times 10^{-3} \times 150 \times 24 \times 0.9 = 0.761\ L/day$$

(μ Removal efficiency = 90%)

$$VO = VI / (C0 \times 0.8) = 0.761 / (100 / 1,000) \times 0.8$$
$$= 9.5\ L/day$$

C0 : Chemical requirements to absorb 100 kg hydrogen sulifide= 1000 kg γ : Nominal specific gravity of chemical 0.8

(5) Life of Chemical

T = $(V \times 10^3) / V0$ = $(5 \times 10^3) / 9.5$ = 525 days
V = Volume 5 m^3

1.12.13 Waste Gas Burners

(1) Specifications

Type	In furnace
Capacity	500 m^3/hr.
Size	2,000 mm D × 10,200 mm H
Motor	Cooling fan
"	Gas blower
No. of units	2 units

(2) Treatment Capacity

Capacity: all produced gas

Q = 11,053 × 1/24 × 2.0 × 1/2
= 461 m^3/hr. use → 500 m^3/hr.

1.12.14 Seed Sludge Pumps(sludge withdraw)

(1) Specifications

Type	Sludge pumps with suction screw
Size	100 mm
Capacity	1 m^3/min.
T.H.L	15 m
Motor output	7.5 kW
No. of units	2 units

(2) Capacity

Q = 1 m^3/min.

(3) Total Dynamic head

H = 15 m

(4) Motor Output

Pm = 0.163 × 1 × 15 × (1 + 0.2) / 0.4
= 7.34 kW use → 7.5 kW

1.13 APPARATUS FOR SLUDGE DEWATERING EQUIPMENT

1.13.1 Sludge Storage Tank Mixer

(1) Specifications

Type	Vertical paddle type
Shape	Approximately 7,000mm ×11,500mm × 2,500mmH
Capacity	200 m^3

Blade size	2000 mmϕ
Motor output	7.5 kW
No. of units	4 units

(2) Tank Capacity

Store average one-day sludge production

$V = 805 \times 1/4 = 201\ m^3$ use $200\ m^3$

1.13.2 Sludge Supply Pomp

(1) Specifications

Type	Single-axis screw pump
Size	ϕ 100 mm
Capacity	20 m^3/hour
TDH	20 m
Motor output	5.5 kW
No. of units	2 units

(2) Discharge Capacity

One pump to each dewater equipment (one-standby pump for all dewatering Equipment)

$Ql = 130 \times 3 \times 10^{-3} \times 100 / (3 \times 1.5)$

$= 19.5\ m^3/hour$ use → $20\ m^3/hour$ $0.33\ m^3/minute$

Filter velocity	130 kg/m·hr.
Filter width	3 m
Sludge solid concentration	3 %
Allowance	1.5

(3) Electric Motor Output

$Pm = 0.163 \times 20 \times 0.33 \times (1+0.3) / 0.3$

$= 4.71\ kW$ use → $5.5\ kW$

1.13.3 Chemical Feed Pump

(1) Specifications

Type	Single-axis screw pump
Size	ϕ 50 mm
Capacity	3 m^3/hour
TDH	20 m
Motor output	1.5 kW
No. of units	15 units (including one standby)

(2) Discharge Capacity

A pump to each dewater equipment (one standby pump for all dewatering Equipment)

$Ql = 130 \times 3 \times 10^{-3} \times 0.01 \times 100 / 0.2 \times 1.5$

$= 2.925\ m^3/hour$ → $3\ m^3/hour$ $0.05\ m^3/min.$

Filter velocity	130 kg/m·hr.
Filter width	3 m
Solid concentration of sludge	0.2 %

Allowance 1.5

(3) Electric Motor Output

$$Pm = 0.163 \times 20 \times 0.05 \times (1+0.3) / 0.25$$
$$= 0.85 \text{ kW} \quad \text{use} \rightarrow 1.5 \text{ kW}$$

1.13.4 CHEMICAL SOLUTION TANKS

(1) Specifications

Tank type	Steel made cylinder type
Tank capacity	15 m^3
Approx. size	2,900 mmϕ × 3,000mmH
Electric motor output	7.5 kW (for mixer)
No. of tanks	3 units

(2) Sludge Storage Tank Capacity

Dosing rate 24.15 × 10^3 × 0.008 × 7/5 = 270.47 kg/day

Dewatered solids 24.15 t/day

Chemical dosing rate (Polymer) 0.8 %/kg·ds

(5 days/week operation)

Storage capacity. 2 hours of design sludge volume

3 tanks (alternately used)

$$V = (270 \times 100) / (0.2 \times 2 / 6 / 3)$$
$$= 15{,}026 \text{ L} \quad \text{use} \rightarrow 15{,}000 \text{ L}$$

Chemical solution concentration 0.2 %

Operation time a day 6 hours

Retention time 2 hours

1.13.5 CHEMICAL FEEDERS

(1) Specifications

Type	Chemical pump
Supply rate	4 L/min.
Electric motor output	0.4 kW
Quantity	3 units

(2) Supply Rate

One feeder is attached to each solution tank, supplying chemical in 15 to 20 minutes.

$$Q = 15{,}000 \times 10^3 \times 0.2 / 100 \times 1 / (15 \sim 20) \times 1 / 0.5$$
$$= 4.0 \sim 3.0 \rightarrow 4 \text{ L/min.}$$

Apparent specific gravity of polymer 0.5

1.13.6 CHEMICAL CONTAINERS

(1) Specifications

Type	Stainless steel made, cylinder container
Effective capacity	700 L
Quantity	2 units

(2) Capacity

Provide 2 tanks (alternately used), with capacity of 7-day chemical consumption.

$V = 270.47 \times 7/5 \times 0.5 \times 7 \times 1/2$

$= 663$ L use → 700 L

1.13.7 FILTER CLOTH WASHING PUMPS

(1) Specifications

Type	Multi-stage centrifugal pump
Size	ϕ 50 mm
Discharge	0.3 m^3/min.
Total head	60 m
Electric motor output	7.5 kW
Quantity	15 units (including 1 standby)

(2) Discharge

One pump to each dewatering machine, and one standby pump for all equipment.

Q = 100 × 3 = 300 L/min. use → 0.3 m^3/min.

Then, the pump discharge per 1 m cloth is 100 L/min.

Total dynamic head 60 m

Electric motor output

$Pm = 0.163 \times 60 \times 0.30 \times (1+0.2) / 0.5$

$= 7.04$ kW → 7.5 kW

1.14 EFFLUENT PUMPING STATION

1.14.1 FLOW RATE

Flow rate is determined as follows.

Qad	200,000 m^3/day	2,315 L/s
Qmd	235,000 m^3/day	2,720 L/s
Qmh	285,000 m^3/day	3,299 L/s
Qww	570,000 m^3/day	6,597 L/s

1.14.2 PUMPING EQUIPMENT

(1) Design Flow Rates:

Qad	200,000 m^3/day	139 m^3/minute
Qmd	235,000 m^3/day	163 m^3/minute
Qmh	285,000 m^3/day	198 m^3/minute
Qww	570,000 m^3/day	396 m^3/minute

(2) Wastewater Pumps

4 units (including 1 standby), mixed flow centrifugal type driven by electric motor.

(3) Storm Water Pumps

4 units(including 1 standby), mixed flow centrifugal type, smaller pumps driven by motor, and large pumps driven by diesel engine. Pump operation schedule is as follows.

Wastewater inflows	Wastewater inflow rates (m³/minute)	Pump discharges					Total pump discharge (m³/minute)
		Wastewater pumps		Storm water pumps			
		50	100	50	100	(m³/min/unit)	
		2	2(1)	2	2(1)	No. of units	
Qad	139	50	100				150
Qmd	163	100	100				200
Qmh	198	100	100				200
Qww	396	100	100	100	100		400

(4) Pump Size

No.1 Pumps $Q = 50\ m^3/minute$

$D = 146(Q/V)^{0.5}$ $V = 2.5\ m/sec$

$= 653$ mm use → 600 mm

No.2 Pumps $Q = 100\ m^3/minute$

$D = 146(Q/V)^{0.5}$

$= 923$ mm use → 900 mm

(5) Wastewater Surface Elevations:

Suction water levels at inflow of

Qad	7.100	M.W.L.
Qmd	7.100	M.W.L.
Qmh	7.100	M.W.L.
Qww	7.100	M.W.L.

Suction water levels at outflow of

Qad	9.100	M.W.L.
Qmd	9.100	M.W.L.
Qmh	9.100	M.W.L.
Qww	9.100	M.W.L.

(6) Actual Head:

Qad	9.100	– (7.100)	=	2.000 m
Qmd	9.100	– (7.100)	=	2.000 m
Qmh	9.100	– (7.100)	=	2.000 m
Qww	9.100	– (7.100)	=	2.000 m

Total head losses at pump equipment:

Pump size	ϕ600	ϕ900
Pump bore(m)	0.6	0.9
Pump discharge(m³/min)	50	100
Pump discharge(m³/sec)	0.833	1.667
Delivery bore sectional area (m²)	0.283	0.636
Pump velocity(m/s)	2.949	2.621
Loss coefficients		
Inlet	0.15	0.15
Sluice valve	0	0
Check valve	1.0	1.0
Outlet	1.0	1.0

Bend		0.25	0.25	
Friction loss	$f' \times L/D$	0.781	0.514	
	Total	3.181	2.914	F

(7) Head Losses

ϕ600 = 1.411 m $F \times V^2/2g$
ϕ900 = 1.021 m
Pipe length L = 15 m
Friction loss by Darcy-Wiseback Formula
$hf = f \times L/D \times V^2/2g$
$f = 0.02 + 1/(2000 \times D)$ (New cast iron pipe)
For old cast-iron pipes multiply the 'f' by 1.5

	ϕ600	ϕ900
D(m)	0.6	0.9
f	0.021	0.021
f' = 1.5×f	0.031	0.031

(8) Total Head Required

Qad	2.000	+	1.411 (ϕ600)	=	3.411 m
			1.021 (ϕ900)	=	3.021 m
Qmd	2.000	+	0.000	=	2.000 m
Qmh	2.000	+	0.000	=	2.000 m
Qww	2.000	+	1.021 (ϕ900)	=	3.021 m

The required total pump head is then 5.0 m

(9) Shaft Power of Mixed Flow Centrifugal Pumps

$L = k \times \gamma \times Q \times H / \mu$

where

- L Shaft power of pump
- k 0.163 kW or 0.222 PS
- Q Pump discharge (m^3 / min)
- H Pump total dynamic head (m)
- γ Specific gravity of water($\gamma = 1$)
- μ Pump efficiency

Calculations for shaft power requirements

Items		ϕ600	ϕ900	ϕ900 Engine
Pump discharge(Q)	m^3/min	50	100	100
TDH (H)	m	5.0	5.0	5.0
Pump efficiency(μ)		0.78	0.81	0.81
Shaft power	kW	52	101	137

(10) Outputs of Pump Drives

$P = L(1+\alpha) / \mu \times G$

where

- P Pump power (kW)
- L Pump shaft power (kW)

α	Allowance for motor	0.15
	Allowance for engine	0.2
μG	Transmission efficiency (1.0 for direct connection)	

	ϕ600	ϕ900	ϕ900 Engine
Shaft power (L)	52	101	137
Allowance (α)	1.15	1.15	1.20
Efficiency of transmission (μG)	1.00	1.00	0.95
Pump drive output (P) kW	60	116	173

(11) Pump Specifications

		Vertical mixed flow centrifugal pumps		
Pump bore	mm	600	900	900
Pump discharge	m^3/min.	50	100	100
Total dynamic head	m	5	5	5
Motor/engine output	kW	60	116	173
Pump drive		Motor	Motor	Engine

2. RECIRCURATION PROCESS

2.1 DESIGN BASIS

2.1.1 Design Wastewater Inflow Rates

Design wastewater inflow rates are determined as follows.

Average daily flow	Qad	200,000 m3/day	2,315 L/s
Maximum daily flow	Qmd	235,000 m3/day	2,720 L/s
Maximum hourly flow	Qmh	285,000 m3/day	3,299 L/s
Wet weather flow	Qww	570,000 m3/day	6,597 L/s

2.1.2 Design Wastewater Quality

Design wastewater quality is determined as follows.

BOD = 130 mg/L
SS = 150 mg/L
T-N = 20 mg/L
T-P = 3 mg/L

2.1.3 Design Wastewater Quality (Including Sidestream Waste Loads)

Design wastewater quality (including sidestream waste loads) calculated as follows.

BOD = 170 mg/L
SS = 180 mg/L
T-N = 25 mg/L
T-P = 4.5 mg/L

Parameter	Removal Efficiency(%)			Wastewater Quality (mg/L)		
	Primary treatment	Secondary treatment	Overall removal rate	Raw waste-water	Primary effluent	Secondary effluent
BOD	30	91	93.7	150	105	9
SS	40	93	95.8	180	108	8
T-N	10	60	64.0	25	22.5	9
T-P	10	78	80.2	4.5	4.05	0.9

2.1.4 POLLUTANT DISCHARGE LIMITS BY NTPA 001

Pollutant discharge limits by NTPA 001 is regulated as follows.

BOD5	<	20 mg/L
SS	<	60 mg/L
T-N	<	10 mg/L
T-P	<	1.0 mg/L

2.2 CALCULATIONS OF SIDESTREAM POLLUTANT LOADS

2.2.1 RAW SLUDGE VOLUME

Raw sludge production volume is calculated by the following equation.

Solid production (t/day) = 235,000 × 150 × 10^{-6} × 0.4
= 14.1 t/day

Sludge concentration 2.0 %

Sludge volume 14.1 × 100 ÷ 2.0 = 705 m^3/day

2.2.2 WASTE SLUDGE VOLUME

Parameter	Influent quality (mg/L)	Reaction tank influent quality (mg/L)	Primary clarifiers removal Efficiency(%)
BOD	130	91	30
SS	150	90	40

Assuming that the reactor influent S-BOD is 66.7% of the total BOD; then Scc is 60.7 mg/L
Waste sludge production volume can be calculated by the following equation:

$$Qw \times Xw = (a \times Scs + b \times Sss - c \times \theta \times XA)Q$$

where,

Qw	Volume of waste sludge (m^3/day)		
Xw	Average SS concentration of waste sludge (mg/L)		
Q	Influent volume to reactors (m^3/day)		235,000
XA	MLSS concentration in reactors (mg/L)		3,000
Scs	Influent soluble-BOD concentration to reactors (mg/L)		60.7
Sss	Influent SS concentration to reactors (mg/L)		90
a	Sludge yield coefficient of S-BOD (mg MLSS/mgSS)	0.4~0.6	0.5
b	Sludge yield coefficient of SS (mg MLSS/mgSS)	0.9~1.00.	0.95
c	Coefficient of SS reduction due to indigeneous respiration of activated sludge micro-organisms (1/day)	0.03~0.05	0.04

0 HRT in reactor basins (day) 13.2 / 24 = 0.55

therefore,

$Qw \times Xw = (0.5 \times 60.7 + 0.95 \times 90 - 0.04 \times 0.5510621 \times 3{,}000) \times Q \times 10^{-6}$

$= 49.72 \times Q \times 10^{-6} = 11.68$ t/day

Solid production = 11.68 t/day

Sludge concentration = 0.9 %

Sludge production = 11.68 × 100 ÷ 0.9 = 1,298 m^3/day

2.2.3 THICKENED SLUDGE

Thickened sludge production volume is calculated by the following equation.

Sludge solids = 14.1 + 11.68 = 25.78 t/day
(Primary sludge + Excess sludge)

Sludge volume = 705 (2.0%) + 1,298 (0.9%) = 2,003 m^3/day

Solids = 25.78 × 0.85 = 21.92 t/day

Assuming sludge concentration is 3.5 %

Sludge volume = 21.92 × 100 ÷ 3.5 = 626 m^3/day

2.2.4 SLUDGE SUPERNATANT OF THICKENERS

Sludge supernatant of thickeners weight is calculated by the following equation.

Liquor volume = 2,003 – 626 = 1.377 m^3/day

Solids weight = 25.78 × 0.15 = 3.87 t/day

BOD = 1.377 × 2000 × 10^{-6} = 2.75 t/day

BOD is assumed to be of 2,000 mg/L

T-N = 1.377 × 700 × 10^{-6} = 0.96 t/day

T-N is assumed to be of 700 mg/L

T-P = 1.377 × 180 × 10^{-6} = 0.25 t/day

T-P is assumed to be of 180 mg/L

2.2.5 DIGESTED SLUDGE

Digested sludge production volume is calculated by the following equation.

Digested sludge solids = 21.92 × (1 – 0.7 × 0.5) = 14.25 t/day

Digested sludge volume 3.0 %

Sludge volume = 14.25 × 100 / 3.0 = 475 m^3/day

2.2.6 DEWATERED SLUDGE(SLUDGE CAKE)

Dewatered sludge production volume is calculated by the following equation.

Solids = 14.25 × 100 / 0.9 = 12.82 t/day

(Assuming 20.0 % solids concentration)

Cake volume = 12.82 × 100 / 20.0 = 64 m^3/day

2.2.7 DIGESTED SLUDGE FILTRATE

Digested sludge filtrated weight is calculated by the following equation.

Filtrate volume = 475 – 64 = 411 m^3/day

Dry solids weight = 14.25 × 0.10 = 1.42 t/day
BOD = 411 × 1,500 × 10^{-6} = 0.62 t/day
(Assumed BOD concentration = 1,500 mg/L)
T-N = 411 × 150 × 10^{-6} = 0.06 t/day
(Assumed BOD concentration = 150 mg/L)
T-P = 411 × 80 × 10^{-6} = 0.03 t/day
(Assumed BOD concentration = 80 mg/L)

2.2.8 SIDESTREAM VOLUME AND WASTE LOAD

Sidestream volume and waste load is calculated by the following equation.

		Thickener supernatants		Sludge filtrate		
Liquor volume	=	1,377	+	411	=	1,788 m^3/day
Dry solids	=	3.87	+	1.42	=	5.29 t/day
BOD	=	2.75	+	0.62	=	3.37 t/day
T-N	=	0.96	+	0.06	=	1.03 t/day
T-P	=	0.25	+	0.03	=	0.28 t/day

2.2.9 WASTEWATER QUALITY (INCLUDING ALL SIDESTREAMS)

Wastewater quality (including all sidestreams) is calculated by the following equation.

Overall wastewater flow = Influent + Sidestreams
Maximum daily flow = 235,000 + 1,788 = 236,788 m^3/day
Then, the design wastewater flow characteristics are;

BOD = (235,000 × 130 × 10^{-6} + 3.37) / 236,788
= 0.000143252 × 10^6 = 143 → 150 mg/L

SS = (235,000 × 150 × 10^{-6} + 7.64) / 236,788
= 0.000171218 × 10^6 = 171 → 180 mg/L

T-N = (235,000 × 20 × 10^{-6} + 1.03) / 236,788
= 0.000024180 × 10^6 = 24.2 → 25 mg/L

SS = (235,000 × 3 × 10^{-6} + 0.28) / 236,788
= 0.000004163 × 10^6 = 4.2 → 4.5 mg/L

2.3 SLUDGE PRODUCTIONS

2.3.1 RAW SLUDGE

Raw sludge production volume is calculated by the following equation.

Solid production (t/day) = 235,000 × 180 × 10^{-6} × 0.4
= 16.92 t/day
Sludge concentration 2.0 %
Sludge volume 16.92 × 100 ÷ 2.0 = 846 m^3/day

2.3.2 WASTE SLUDGE VOLUME

Parameter	Influent quality (mg/L)	Reaction tank influent quality (mg/L)	Primary clarifiers removal Efficiency(%)
BOD	170	119	30
SS	180	108	40

Assuming that influent S-BOD to reactor basins is 66.7 % of the raw wastewater BOD,S-BOD concentration is estimated to be; 70.04 mg/L
Waste sludge production volume is calculated by the following equation.

$$Qw \times Xw = (a \times Scs + b \times Sss - c \times \theta \times XA)\ Q$$

where,

Qw	Volume of excess sludge (m^3/day)		
Xw	Average SS concentration of waste sludge (mg/L)		
Q	Influent volume to reactors (m^3/day)		235,000
XA	MLSS concentration in reactors (mg/L)		3,000
Scs	Influent soluble-BOD concentration to reactors (mg/L)		70.04
Sss	Influent SS concentration to reactors (mg/l)		108
a	Sludge yield coefficient of S-BOD (mg MLSS/mgSS)	0.4~0.6	0.5
b	Sludge yield coefficient of SS (mg MLSS/mgSS)	0.9~1.00.	0.95
c	Coefficient of SS reduction due to indigeneous respiration of activated sludge micro-organisms (1/day)	0.03~0.05	0.04
θ	HRT in reactor basins (day)	13.2 / 24 =	0.551062

therefore,

$$Qw \times Xw = (0.5 \times 70.04 + 0.95 \times 108 - 0.04 \times 0.551 \times 3{,}000) \times Q \times 10^{-6}$$

$$= 71.49 \times Q \times 10^{-6} = 16.80 \text{ t/day}$$

Solid production = 16.80 t/day
Sludge concentration = 0.9 %
Sludge production = 16.80 × 100 ÷ 0.9 = 1,867 m^3/day
= 1.30 m^3/min.

2.3.3 Return Sludge

Return sludge volume is calculated by the following equation.

Sludge return ratio 50 %
Return sludge volume = 235,000 × 0.5 = 117,500 m^3/day
= 81.6 m^3/min.

2.3.4 Gravity Sludge Thickeners

Gravity thickened sludge production volume is calculated by the following equation.

Solids inflow = 16.92 + 16.80 = 33.72 t/day
(Primary sludge, Excess sludge)
Sludge inflow = 846 + 1,867 = 2,713 m^3/day
Thickened sludge solids = 33.72 × 0.8 = 26.98 t/day
Assume solids content to be 3.5 %
Thickened sludge volume = 26.98 × 100 / 3.5 = 771 m^3/day

2.3.5 Anaerobic Sludge Digesters

Anaerobic digested sludge production volume is calculated by the following equation.

Input solids = 26.98 t/day
Input sludge volume = 771 m^3/day
Volatile solids content of sludge 70 %
Solids destruction rate 50 %
Digested sludge solids = 26.98 × (1 − 0.7 × 0.5) = 17.53 t/day

Assume solids concentration is 3.0 %
Digested sludge volume = 17.53 × 100 / 3.0 = 584 m^3/day

2.3.6 Sludge Dewatering

Dewatered sludge production volume is calculated by the following equation.

Input solids = 17.53 t/day
Recovered solids (90%) = 17.53 × 0.9 = 15.78 t/day
Assuming solids concentration as 20.0 %
Sludge cake volume = 15.78 × 100 / 20.0 = 79 m^3/day

2.4 COMPONENT FACILITIES

2.4.1 Design Basis

Design wastewater inflow rate is determined as follows.

Average daily flow Qin = 200,000 m^3/d
(Maximum daily flow in winter season)
Maximum daily flow Qin-max = 235,000 m^3/d

Design wastewater quality :
Influent wastewater quality to reactor tank is calculated as follows.

BOD	105	mg/L
SS	108	mg/L
T-N	22.5	mg/L

(S-BOD is 71.4 mg/l) 68 % (SBOD/BOD)

Design discharge wastewater quality :
Design effluent wastewater quality from final sedimentation tank (average quality) is determined as follows.

			Removal efficiency		
BOD	9	mg/L	91.4	%	96
SS	8	mg/L	92.6	%	100
T-N	10	mg/L	55.6	%	12.5

T-N condition of Treated water is NOT-N 8.3 mg/L Removal efficiency
K-N 1.7 (T-N)60~70%
Design water temperature 10 °c

2.4.2 Design Calculation

(1) Recircuration Ratio(R)

Recircuration ratio (R) is calculated by the following equation.

Influent concentration of T-N to reactor tank CTN. in = 22.5 mg/L
(effluent water quality from final sedimentation tank)
NOT-N concentration, Cnox·eff = 8.3 mg/L, Assuming that nitrogen ratio which concerned about nitrification in CTN·in is $\alpha = 0.7$, recircuration ratio R is

$$R = \alpha \times CTN{\cdot}in / CNOX{\cdot}eff - 1$$

$R = 0.7 \times 22.5 / 8.3 - 1 = 1.90 - 1 = 0.90 \rightarrow 1$

(2) MLSS Concentration

MLSS concentration is calculated by the following equation.

Assuming that MLSS concentration at reactor tank 3,000 mg/L (2,000~3,000MLSS) and return sludge concentration 9,000 mg/l, so that return sludge ratio R r is

$9000\,Rr = 3000 \times (1 + Rr)$

$Rr = (3,000) / (9,000 - 3,000) = 0.5$

Recircuration flow Qc and return sludge flow Qr are respectively

$R - Rr = 1 - 0.5 = 0.5$

$Qr = Qin \times 0.5 = 100,000\ m^3/day$

$Qc = Qin \times 0.5 = 100,000\ m^3/day$

(3) A -SRT

Retention time at aerobic tank is calculated by the following equation.

Assuming that complete nitrification, and to consider daily and seasonally change of water quantity and quality, A-SRT(d) is

$\delta = 1.5$ (Assuming)

$T = 10\ ^{\circ}c$ (Assuming)

$\theta XA = \delta \times 20.6 \times \exp(-0.0627 \times T) - 0.627$

$= 1.5 \times 20.6 \times 0.534192 = 16.5$ day

(4) Aerobic Tank Capacity VA(m^3)

$VA = (Q\,in \times \theta XA \times (a \times C_S\text{-}BOD{\cdot}in + b \times SS{\cdot}in)) / (1 + c \times \theta XA) \times X$

θXA	=	Aerobic solids retention time	16.5 day
a	=	Gross yield coefficient of dissolved BOD (0.5~0.6)	0.55 gMLSS/ gS-BOD
Cs-BOD	=	Dissolved BOD concentration of influent flow	71.4 mg/L
B	=	Gross yield coefficient of SS (0.9~1.0)	0.95 gMLSS/gSS
C	=	Autolysis coefficient of sludge (0.025~0.035)	0.03 L / d
X	=	MLSS concentration	3,000 mg/L

$VA = 200,000 \times 16.51 \times 142 / 4486 = 104,414\ m^3$

$A \times C_S\text{-}BOD{\cdot}in + b \times SS{\cdot}in = 0.55 \times 71.4 + 0.95 \times 108$

$= 142$

$(1 + c \times \theta XA) \times X = (1 + 0.03 \times 16.5) \times 3,000 = 4,486$

(5) Biological Reaction Tank Capacity V(m^3)

Biological reaction tank capacity is calculated by the following equation.

Assuming BOD-SS load(LBOD/x) is 0.06 kgBOD/kgMLSS/day (0.05~0.1)

$V = (BOD{\cdot}in \times Qin) / (LBOD/x \times X)$

$= (105 \times 200,000) / (0.06 \times 3,000) = 116,667\ m^3$

(6) Anoxic Tank Capacity VDN (m^3)

Anoxic tank capacity VDN m^3 is calculated by the following equation.

$VDN = V - VA = 116,667 - 104,414 = 12,253\ m^3$

(7) Capacity Ratio of Anoxic Tank and Aerobic Tank

VDN : VA = 12,253 : 116,667 = 1 : 9.5

(8) Speed Constant of Denitrification KDN (mgN/ g MLSS/h)

Speed constant of denitrification KDN is calculated by the following equation.

$KDN = (LNOX.DN \times 10^3) / (24\ VDN \times X)$

Here

$CNOX.A = \alpha \cdot CTN\text{-}in \times 1 / (1+R)$

$= (0.7 \times 22.5 \times 1) / (1 + 1) = 7.9\ mg/L$

$LNOX.DN = CNOX.A \times (Qr + Qc) \times 10^{-3}$

$= 7.9 \times (100{,}000 + 100{,}000) \times 10^{-3} = 1{,}575\ kg/d$

$KDN = (1{,}575 \times 10^3) / (24 \times 12{,}253 \times 3)$

$= 1.785\ (mgN/gMLSS/h) > 0.872$ OK

Check of denitrification speed

Less than(y') is NO $y' = 6.2 \times 0.06 + 0.5 = 0.872$

More than (y') is OK

Calculate	Vdn =	1,575	×	10^3		
back		24 ×	0.872	×	3	
					=	25,086 m^3

VD : VA = 1 : 4.16

V = 25,086 + 104,414 = 129,500 m^3

(9) Biological Reaction Tank Capacity and Retention Time

Biological reaction tank capacity and retention time is calculated by the following equation.

Retention time at biological reaction tank in winter season, t(h) is

$t = (24 \times 129{,}500) / 200{,}000 = 15.5\ h$

Retention time at aerobic tank in winter season, tA(h) is

$t = (24 \times 104{,}414) / 200{,}000 = 12.5\ h$

Retention time for daily maximum flow at biological reaction tank in winter season, t(h) is

$t = (24 \times 129{,}500) / 235{,}000 = 13.2\ h$

(10) Necessary Oxygen Demand ΣD (kg/d)

Necessary oxygen demands is calculated by considering of oxidation of carbonic organic matter, necessary oxygen for endogenous respiration and nitrification reaction of microorganisms in activated sludge, and necessary oxygen for maintain a dissolved oxygen.

OD = OD1 + OD2 + OD3 + OD4

Here

OD	Necessary oxygen demands (kgO_2/day) (AOR)	
OD1	Necessary oxygen for oxidation of carbonic organic matter	(kgO_2/day)
OD2	Necessary oxygen for endogenous respiration	(kgO_2/day)
OD3	Necessary oxygen for nitrification reaction	(kgO_2/day)
OD4	Necessary oxygen for maintain a dissolved oxygen	(kgO_2/day)

OD1 = A (kgO_2/kgBOD) × [Removal BOD (kgBOD/day) – Denitrification volume (kgN/day) × K (kgBOD/kgN)}

Here A : Necessary oxygen for removal of BOD (0.5~0.7)

K : BOD consumption for denitrification (2.86)

OD2 = B (kgO_2/kgMLVSS·day) × VA (m^3) × MLVSS (kgMLVSS/m^3)

Here B : Oxygen consumption by endogenous respiration at MLSS unit (0.05~0.15)

VA : Reaction tank capacity at aerobic part

OD3 = C (kgO_2/kgN) × Nitrificated Kj-N volume (kgN/day)

Here C : Nitrificated oxygen at nitrification reaction (4.57)

Nitrificated KJ-N (Inflow Kj-N) – (Outflow Kj – N volume)
– (Removal volume of Kj -N by excess sludge)

OD4 = Q × DO concentration of reaction tank

Here DO : Dissolved oxygen concentration at end point of aerobic tank 1.5mg/L

(Design flow = 200,000 m^3/day)

BODin = 105 mg/L, T-N = 22.5 mg/L

BODout = 9 mg/L, VA = 104,414 m^3

The results of calculation is shown in table below.

		unit		note	
Necessary oxygen demands for oxidation of BOD (OD1)	(1) Q	m^3/day	200,000		
	(2) BODin	mg/L	105		
	(3) BODout	mg/L	9		
	(4) $\{(2)-(3)\}\times(1)\times10^{-3}$	kg/day	19,200		
	(5) ΔDN (denitrification volume)	kg/day	1,575		
	(6) k × (5)	kg/day	4,505	k =	2.86
	OD1= A × {(4) − (6)}	kg/day	882	A =	0.06
Necessary oxygen demands for endogenous respiration (OD2)	(1) MLSS	mg/L	3,000		
	(2) VA	m^3	104,414		
	(3) (1) × (2) × 10^{-3}	kg/day	313,241		
	OD2 = B × (3)	kg/day	31,324	B =	0.1
Necessary oxygen demands for nitrification reaction (OD3)	(1) α (nitrification ratio)		0.7		
	(2) T-Nin	mg/L	22.5		
	(3) Q	m^3/day	200,000		
	OD3= 4.57×(1)×(2)×(3) × 10^{-3}	kg/day	14,396	C=	4.57
Necessary oxygen demands for maintain dissolved oxygen (OD4)	(1) DO concentration at reaction tank	mg/L	1.5		
	(2) Q	m^3/day	200,000		
	(3) Qr+Qc	m^3/day	300,000		1.5
	(4) {(2)+(3)}	m^3/day	500,000		
	OD4 = (1)×(4)×10^{-3}	kg/day	750		
Necessary oxygen (OD) demands	OD= OD1+OD2+OD3+OD4	kg/day	47,351		
			0.237 Q		

Design of air diffuser (Assuming that diffused air aeration, fine bubble, spiral flow)

EA = 7.5 , ρ = 1.293

Qw = 0.233 (Assuming)

Supplied air (N m^3/day) =

(Necessary oxygen demands (kgO_2)) / EA(%) × 10^{-2} × ρ (Air/Nm3) × Ow (kgO_2/kgAir)

= (0.237 × Q) / (7.5 × 0.01 × 1.293 × 0.233)

= 10.48 Q = 2,095,638 (N m^3/day) = 1,455 (Nm^3/min)

2.4.3 Measure for Advanced Treatment

Way of thinking

Changing from conventional activated sludge process to advanced treatment process (T-N,T-P removal)

Calculate a necessary treatment capacity of advanced treatment process and evaluate a capacity of conventional activated sludge process.
Extend a necessary ponds and equipment in the future.

Necessary treatment capacity of advanced treatment process	−	Treatment capacity of conventional activated sludge process	=	Extend or remodeling of treatment about shortage of capacity

Explanation of measures for advanced treatment

Here showing a treatment capacity of two processes in table below.

* Conventional activated sludge process
* Advanced treatment process(Recircuration process)

Explanation of Measures for Advanced Treatment

	unit	Necessary advanced capacity	Facility and equipment for advanced treatment	
			Conventional activated sludge process	Measures for shortage of capacity
•Primary sedimentation tank surface load	$m^3/m^2/day$	35	35	—
Facility shape			φ35m × 4 tanks	
•Reaction tank				
Retention time	hour	13.2	13.2	13.2
Distribution ratio of water	%		6.1/13.2×100= 46 Making a wall in reaction tank, and divided an anoxic zone and aerobic zone	100 − 46 = 54 Build an extend tank for reaction tank
Facility shape			W5.5m × H5.5m × L64m × 32 tanks	W5.5m × H5.5m × L73m × 32 tanks
•Final sedimentation tank surface load	$m^3/m^2/day$	15	9.5	13.9
Facility shape			φ45m × 8 tanks	New ponds φ40m × 8 tanks
•Return sludge flow	%	Usually 50% (Sludge pump Capacity 100%)	Same to the left	Same to the left (New pumps are Necessary)
•Recircuration flow of nitrificated water	%	50%	Provide a recircuration pumps at the outflow point of reaction tank(aerobic tank)	Same to the left
•Supplied air flow	m^3/min	1,455	558	897 Extend capacity
•Waste sludge volume (Inflow sludge solids of thickener) (exclude T-P removal)	t/day	33.72	46.44 (Sludge products from Conventional activated sludge process)	Not necessary a extend of capacity
(include T−P removal)		37.86		Not necessary a extend of capacity
• T-P removal by addition of coagulant		New equipment is necessary	Same to the left	Same to the left

Waste sludge volume produced from T-P removal

Waste sludge production volume by addition of coagulant

Influent T-P concentration of reaction tank 4.05 mg/L

Additional concentration of aluminum sulifacc CA(mg/L) is calculated by following equation

CAL = Csp·in × m × AL / P

Here

Csp·in	Influent dissolved T-N concentration(mg/l)	4.05
P	Valence of phosphorus	31
AL	Valence of aluminum	27
m	Additional molality ratio	1 (assuming)

CAL = (4.05 × 27 × 1) / (31) = 3.5 mg/L

Assuming that waste sludge production volume by addition of coagulant is 5 times as Additional phosphorus volume

Waste sludge volume by addition of coagulant = QD ×5 × CAL × 10^{-6}

= 235,000 × 5 × 3.5 × 10^{-6} = 4.14 t/day

Waste sludge volume in case of removal of T-N and T-P simultaneously

= 33.72 + 4.14 = 37.86 t/day

APPENDIX-6 CONSTRUCTION PLAN AND COST ESTIMATE

1. CONSTRUCTION PLAN

1.1 GENERAL

Construction works for the project includes earth work, concrete work, pipe work, mechanical/electrical work, architectural work and miscellaneous work. These works, in general, will be executed by ordinary construction methods using construction equipment readily available in Galati. Major works are planned to be carried out with mechanical equipment for smooth and economical performance.

Construction site for the proposed facilities are located in the north-eastern part of Galati City. There would be no difficulty to transport materials and equipment because the area has adequately provided road networks. There is neither difficulty in obtaining water nor electricity for construction.

1.2 CONSTRUCTION METHOD

Major construction works are construction of WWTP, installation of wastewater pumps, installation of sewer pipes and construction of CSO regulators.

1.2.1 CONSTRUCTION OF WWTP

The major construction works of WWTP are construction of primary and final sedimentation tank, aeration tank, influent pumping station, sludge treatment facilities and administration building.

No special construction method will be applied for the construction of WWTP except placing of Pre-stressed concrete for sludge digester tank. Since there are many experiences to construct pre-stressed concrete structure by Romanian contractors, there would not be any difficulty to construct this kind of structures.

1.2.2 INSTALLATION OF SEWER PIPES

Open trench method would be adopted for installation of sewer pipes in principal. However, application of shield tunneling method and pipe jacking method would be considered in the part where pipe crosses the railway and will be installed in deeper depth.

1.2.3 CONSTRUCTION OF CSO REGULATOR

The CSO regulator is a underground reinforced concrete structure with a excavation depth of 3 to 5 m. Therefore, only ordinary construction methods are used for the construction.

1.3 CONSTRUCTION SCHEDULE

1.3.1 WORKING DAYS

Annual working days are estimated to be 225 days based on the following assumptions:

- Winter season idle period: 3 month (from Dec.15 to Mar. 15)
  Workable period: 275 days
- Sundays in workable period: 9 month x 4 days = 36 days

National holidays in workable period: 1 day
Rainy days in workable period: 10 days
(more than 10 mm/day, ave. last 5 years)
Total work suspension days in workable period: 47 days

- Working days: 275 days - 47 days = 228 days : 225 days

1.3.2 WORK TIME

All the construction works will be done during day time in principle. The working time is eight (8) hours per day

1.3.3 REQUIRED CONSTRUCTION PERIOD AND SEQUENCE OF WORKS

Required construction periods are estimated based on the construction volume and the above mentioned working days and work time assumptions by each construction works/structures by ordinary scale of inputs. Construction plan for the Galati project is presented below.

	Period (Year)	1st year 2000	2nd year 2001	3rd year 2002	4th year 2003	5th year 2004
Wastewater Treatment Plant						
Influent Pumping Station	1.5		■	■		
Wastewater Treatment Process	2.5		■	■	■	
Sludge Treatment Process	2			■	■	
Discharge Pumping Station	1.5				■	■
Power Receiving Facility	1					■
Administration Building	1					■
Interceptor	2				■	■

Construction Plan and Sequence of Works for the Galati Project

2. COST ESTIMATE

2.1 BASIS OF COST ESTIMATE

The project cost consists of I) construction cost, II) equipment cost, III) engineering service cost, IV) government administration cost and V) physical contingency, as shown below.

Structure of Project Cost

	Item	Remarks
I	Construction Cost	
II	Engineering Service Cost	10% of (I)
III	Government Administration Cost	2% of (I)
IV	Contingency	10% of (I+II+III)
V	Project Cost	I+II+III+IV

The project cost is estimated under the following conditions.

- All base costs are expressed under the economic conditions that prevailed in June 1999.
- The exchange rates of currencies are US$1 = ROL15,756 = ¥122.
- Only equipment cost is classified into foreign and local currency portions and their rate is FC : LC = 70% : 30%, because all construction works are done by local products and equipment.

- Engineering service cost is including all services for detailed design, tendering assistance and construction supervision. The cost is assumed at 10% of the construction cost.
- Government administration cost is costs that should be prepared by government and/or executing agency (*e.g.* cost for personnel and organization for the project management, cost for commission for external loan, etc.). The cost is assumed at 2 % of the construction cost.
- All percentages mentioned above are assumed from former example of the same kind of projects.
- Price escalation is not counted.

2.2 CONSTRUCTION COST

The construction cost consists of 1) mobilization and demobilization cost, 2) cost for preparatory works, 3) cost for main works, and 4) cost for miscellaneous works.

2.2.1 MOBILIZATION AND DEMOBILIZATION COST

Mobilization and demobilization cost is assumed at five (5) percent of the cost for main works.

2.2.2 PREPARATORY WORKS

Cost for preparatory works is assumed at five (5) percent of the cost for main works.

2.2.3 COST FOR MAIN WORKS

The direct cost for main works (cost for civil work, mechanical/electrical equipment cost, mechanical/electrical equipment installation cost, and construction cost for administration building) will be estimated based on the results of preliminary engineering design. Indirect costs such as site expenses and overhead and profit are estimated by percentage.

- The site expense is estimated to be ten (10) percent of the direct cost of main works.
- The overhead and profit are estimated to be ten (10) percent of the direct cost of main works.
- The cost for the miscellaneous works is estimated to be ten (10) percent of the cost for main works.

Structure of Construction Cost

	Item	Remarks
I	Construction Cost	Total of I-1 to I-6
I-1	Mobilization and demobilization	5 % of I-3
I-2	Preparatory works	5 % of I-3
I-3	Main works	Total of I-3-1 to I-3-4
I-3-1	Civil work	
I-3-2	Mechanical/electrical equipment	
I-3-3	Mechanical/electrical equipment installation	
I-3-4	Administration building	
I-4	Miscellaneous works	10 % of I-3
I-5	Site expenses	10 % of I-3
I-6	Overhead and profit	10 % of I-3

(1) Cost for Civil and Architectural Work

The cost for civil and architectural work is estimated by multiplying the quantity of works by unit construction costs. The unit construction costs are estimated by unit prices of labor, construction materials and equipment.

The unit prices of personnel, material and equipment operation are estimated based on prevailing market prices referring the data collected from MPWTP and other organizations concerned. The unit prices that are used in the study are shown in the following tables.

Unit Costs of Personnel

	lei/month	lei/day
Engineer	3,500,000	140,000
Foreman	2,600,000	104,000
Skilled Labor	2,200,000	88,000
Common Labor	1,600,000	64,000
Technician	2,200,000	88,000
Equipment Operater	2,000,000	80,000
Driver	1,800,000	72,000
Administrator/Clark	3,000,000	120,000

Unit Price of Material

Item		Unit	Price (Lei)
Sand		m3	100,000
Soil		m3	100,000
Crushed stone		m3	200,000
Asphalt		ton	800,000
Tack coat		l	15,000
Reinforcing bar		ton	5,000,000
Wooden material		m3	700,000
Ready mix concrete	B50	m3	500,000
	B200		700,000
	B250		900,000
RC pipe	Dia200 mm	m	100,000
	Dia300 mm		150,000
	Dia400 mm		175,000
	Dia500 mm		215,000
	Dia600 mm		250,000
	Dia700 mm		350,000
	Dia800 mm		450,000
	Dia1000 mm		750,000
	Dia1500 mm		2,000,000
	Dia1650 mm		2,350,000
	Dia2000 mm		3,500,000
	Dia2200 mm		4,500,000
	Dia2800 mm		7,000,000
	Dia3400 mm		12,000,000
Steel Pipe	Dia400 mm		500,000

Unit Price of Equipment Operation

Item		Price (Lei/day)
Dunp Truck	10t	800,000
Truck		800,000
Concrete Transporter		1,200,000
Concrete Pumping Car		1,200,000
Bulldozer	11t	1,200,000
Backhoe	0.6m3	1,000,000
Crawler Crane	20t	1,800,000
Truck Crane	20t	1,800,000
Pile Dirving Machine		2,500,000
Tire Roller		800,000
Vibration Roller		400,000
Compactor		200,000

(2) Cost for Mechanical/Electrical Equipment and Installation

Since there are no published standard market price list for mechanical/electrical equipment for wastewater treatment, the cost for mechanical/electrical equipment will be obtained from manufacturer that have experience in Romania and/or neighboring countries based on the specifications resulting from preliminary engineering design.

The appropriate cost decided based on the obtained quotation would be used for the mechanical/electrical equipment cost for the project.

(3) Direct Cost for Main Works

The direct cost for main works are estimated for WWTP and interceptor separately as shown in *Tables AII.6.1 and AII.6.2.*

2.3 PROJECT COST

Estimated total project cost is about ROL 1,684,237 million, and its breakdown is shown below. Of the total project cost, ROL 504,061 million or 30% is foreign currency portion, and remaining ROL 1,180,176 million or 70% is local currency portion.

Project Cost (Galati Project)

	Item	Cost (million Lei)	FC (million Lei)	LC (million Lei)
I	Construction Cost	1,367,075	435,707	931,368
	Mobilization and Demobilization	48,824	0	48,824
	Preparatory Works	48,824	0	48,824
	Main Works	976,482	435,707	540,775
	Wastewater Treatment Plant	906,417	435,707	470,710
	Influent Pumping Station	89,076	47,677	41,399
	Wastewater Treatment Process	387,738	193,589	194,149
	Sludge Treatment Process	257,540	146,238	111,302
	Discharge Pumping Station	113,202	47,678	65,524
	Site Finalization	42,789	0	42,789
	Power Receiving Facility	8,592	0	8,592
	Administration Building	7,479	525	6,954
	Interceptor	70,066	0	70,066
	Miscellaneous Works	97,648	0	97,648
	Site Expenses	97,648	0	97,648
	Overhead and Profit	97,648	0	97,648
II	Engineering Service Cost	136,708	68,354	68,354
III	Government Administration Cost	27,342	0	27,342
IV	Contingency	153,112	0	153,112
V	Project Cost	1,684,237	504,061	1,180,176

(unit: million lei)

2.4 OPERATION AND MAINTENANCE (O/M) COST

Major portions of O/M cost of the WWTP are electric power charge for the equipment and cost for personnel. The O/M cost for the Galati project is estimated at ROL 16,518 million as shown in the following table.

Operation and Maintenance Cost for Galati Project

Item	unit	unit price	Q'ty	Total
Personnel	lei/month/person (average)	2,000,000	55	1,320
Electricity	lei/kwh	500	2,134	9,217
Chemical	lei/kg	5,000	1,822,000	911
Excess Sludge Disposal	m^3	20,000	553,578	2,768
Repairing	0.5% of Mechanical cost		40,000	800
ohters	10% of above			1,502
Total				16,518

(unit: million lei)

3. IMPLEMENTATION PROGRAM

3.1 IMPLEMENTATION SCHEDULE

The project will be completed within five (5) years from 2000. Pre-construction stage of one (1) year is assumed for the detailed design period and tender process followed by four (4) years' construction works.

Proposed implementation schedule is presented below.

	Period (Year)	1st year 2000	2nd year 2001	3rd year 2002	4th year 2003	5th year 2004
Detailed Design	1					
Construction	4					
Wastewater Treatment Plant						
Influent Pumping Station	1.5					
Wastewater Treatment Process	2.5					
Sludge Treatment Process	2					
Discharge Pumping Station	1.5					
Power Receiving Facility	1					
Administration Building	1					
Interceptor	2					

Implementation Schedule (Galati Project)

3.2 DISBURSEMENT SCHEDULE

Proposed annual cost disbursement schedule of the Galati project for entire project life is shown in *Table AII.6.3.*

Table AII.6.1 Direct Construction Cost of WWTP (Galati)

Item		Unit	Quantity	Unit Price (Lei)	Amount (million Lei)	FC (million Lei)	LC (million Lei)
1 Influent Pumping Station							
1-1 Civil Work							
1) Earth Work							
Excavation		m3	17,842	5,000	89	0	89
Backfill		m3	11,942	22,000	263	0	263
2) RC Concrete							
RC Concrete I	Floorborad	m3	330	1,543,000	509	0	509
RC Concrete II	Wall	m3	1,168	1,771,000	2,069	0	2,069
3) Pile Work (ave.L=10m, incl. driving work)		pcs	119	4,810,000	572	0	572
1-2 Architectural Work		m2	745	4,000,000	2,980	0	2,980
1-3 Mechanical							
1) Equipment		ls	1	68,110,400,000	68,110	47,677	20,433
2) Installaiton		%	15		10,217	0	10,217
1-4 Electorical		ls	1	4,267,089,000	4,267	0	4,267
2 Wastewater Treatment Process							
2-1 Preliminary Treatment Process							
(1) Civil Work							
1) RC Concrete					0	0	0
RC Concrete I	Floorborad	m3	4,192	1,543,000	6,468	0	6,468
RC Concrete II	Wall	m3	1,808	1,771,000	3,202	0	3,202
2) Pile Work (ave.L=10m, incl. driving work)		pcs	388	4,810,000	1,866	0	1,866
(2) Mechanical							
1) Equipment		ls	1	52,822,400,000	52,822	36,976	15,847
2) Installaiton		%	15		7,923	0	7,923
(3) Electorical		ls	1	167,805,000	168	0	168
2-2 Secondary Treatment Process							
(1) Civil Work							
1) Earth Work							
Excavation		m3	30,860	5,000	154	0	154
Backfill		m3	3,385	22,000	74	0	74
2) RC Concrete							
RC Concrete I	Floorborad	m3	17,147	1,543,000	26,458	0	26,458
RC Concrete II	Wall	m3	14,834	1,771,000	26,271	0	26,271
3) Pile Work (ave.L=10m, incl. driving work)		pcs	24	4,810,000	115	0	115
(2) Architectural Work		m2	338	4,000,000	1,352	0	1,352
(3) Mechanical							
1) Equipment		ls	1	213,567,200,000	213,567	149,497	64,070
2) Installaiton		%	15		32,035	0	32,035
(4) Electorical		ls	1	996,812,400	997	0	997
2-3 Final Treatment Process							
(1) Civil Work							
1) Earth Work							
Excavation		m3	2,745	5,000	14	0	14
Backfill		m3	795	22,000	17	0	17
2) RC Concrete							
RC Concrete I	Floorborad	m3	517	1,543,000	798	0	798
RC Concrete II	Wall	m3	778	1,771,000	1,378	0	1,378
(2) Architectural Work		m2	90	4,000,000	360	0	360
(3) Mechanical							
1) Equipment		ls	1	10,166,400,000	10,166	7,116	3,050
2) Installaiton		%	15		1,525	0	1,525
(4) Electorical		ls	1	6,102,000	6	0	6
3 Sludge Treatment Process							
3-1 Civil Work							
1) Earth Work							
Excavation		m3	17,378	5,000	87	0	87
Backfill		m3	8,929	22,000	196	0	196
2) RC Concrete							
RC Concrete I	Floorborad	m3	2,642	1,543,000	4,077	0	4,077
RC Concrete II	Wall	m3	431	1,771,000	763	0	763
3) PC Concrete	Sludge digestion tan	m3	1,707	3,010,700	5,139	0	5,139
4) Pile Work (ave.L=10m, incl. driving work)		pcs	219	4,810,000	1,051	0	1,051
3-2 Architectural Work		m2	1,120	4,000,000	4,480	0	4,480
3-3 Mechanical							
1) Equipment		ls	1	208,911,200,000	208,911	146,238	62,673
2) Installaiton		%	15		31,337	0	31,337
3-4 Electorical		ls	1	1,498,345,800	1,498	0	1,498
4 Discharge Pumping Station							
4-1 Civil Work							

Table AII.6.1 Direct Construction Cost of WWTP (Galati)

Item		Unit	Quantity	Unit Price (Lei)	Amount (million Lei)	FC (million Lei)	LC (million Lei)
1) Earth Work							
Excavation		m3	1,514	5,000	8	0	8
Backfill		m3	682	22,000	15	0	15
2) RC Concrete							
RC Concrete I	Floorborad	m3	156	1,543,000	241	0	241
RC Concrete II	Wall	m3	654	1,771,000	1,158	0	1,158
4-2 Architectural Work		m2	416	4,000,000	1,664	0	1,664
4-3 Mechanical							
1) Equipment		ls	1	68,111,200,000	68,111	47,678	20,433
2) Installaiton		%	15		10,217	0	10,217
4-4 Electorical		ls	1	274,996,800	275	0	275
4-5 Discharge Sewer	dia 2800 mm, EC=2m	m	3,200	9,848,000	31,514	0	31,514
5 Site Finalization							
5-1 Civil Work							
1) Embankment by Excavated soil		m3	44,606	22,000	981	0	981
2) Embankment by Purchased soil		m3	326,620	128,000	41,807	0	41,807
6 Power Receiving Facility		ls	1	8,592,315,600	8,592	0	8,592
7 Administration Building							
7-1 Architectural Work							
1) Architectural Work		m2	1,500	4,000,000	6,000	0	6,000
2) Pile Work (ave.L=10m, incl. driving work)		pcs	104	4,810,000	498	0	498
7-2 Labo. and Office Equipment							
1) Labo. and Office Equipment		ls	1	750,000,000	750	525	225
2) Installaiton		%	0		0	0	0
7-3 Electorical		ls	1	231,600,000	232	0	232
TOTAL					906,417	435,707	470,710

701,846

Table AII.6.2 Direct Construction Cost of Interceptor (Galati)

Item		Unit	Quantity	Unit Price (Lei)	Amount (million Lei)	FC (million Lei)	LC (million Lei)
1 Pipe, Manhole and CSO							
1-1 Installation of interceptor pipe (RC pipe)							
1) RC pipe 300 mm	earth coverage 1 to 3 m	m	20	914,000	18.3	0	18
2) RC pipe 400 mm	earth coverage 1 to 3 m	m	40	989,000	39.6	0	40
3) RC pipe 500 mm	earth coverage 1 to 3 m	m	40	1,109,000	44.4	0	44
4) RC pipe 700 mm	earth coverage 1 to 3 m	m	300	1,459,000	437.7	0	438
5) RC pipe 800 mm	earth coverage 1 to 3 m	m	20	1,750,000	35.0	0	35
7) RC pipe 1500 mm	earth coverage 1 to 3 m	m	282	3,871,000	1,091.6	0	1,092
8) RC pipe 1500 mm	earth coverage 3 to 5 m	m	14	4,155,000	58.2	0	58
9) RC pipe 2000 mm	earth coverage 1 to 3 m	m	2,258	5,881,000	13,279.3	0	13,279
10) RC pipe 2200 mm	earth coverage 1 to 3 m	m	517	7,113,000	3,677.4	0	3,677
11) RC pipe 2200 mm	earth coverage 3 to 5 m	m	1,957	7,543,000	14,761.7	0	14,762
12) RC pipe 2200 mm (with sup	earth coverage 3 to 5 m	m	20	9,805,900	196.1	0	196
1-2 Sewer construction by sheild tunneling method							
1) Dia 2200 mm sewer	sheild tunneling method	m	2,734	12,950,000	35,405.3	0	35,405
1-3 Installation of CSO							
1) CSO type I	small type	place	1	22,906,000	22.9	0	23
2) CSO type II	large type	place	4	92,960,000	371.8	0	372
1-4 Installation of Manhole							
1) Manhole	d=1500mm, EC=2m	place	3	14,370,000	43.1	0	43
2) Manhole	d=2000mm, EC=2m	place	10	19,811,000	198.1	0	198
3) Manhole	d=2200mm, EC=2m	place	4	22,253,000	89.0	0	89
4) Manhole	d=2200mm, EC=4m	place	9	25,945,000	233.5	0	234
5) Manhole	d=2200mm, EC=6m	place	1	29,572,000	29.6	0	30
6) Manhole	d=2200mm, EC=8m	place	1	33,199,000	33.2	0	33
Total					70,065.7	0	70,066

54,252

Table AII.6.3 Disbursement Schedule of Galati Project

		Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Detailed Design	Total	68,354	68,354																													
	FC	34,177	34,177																													
	LC	34,177	34,177																													
Construction		1,387,075		240,235	340,454	423,751	382,635																									
Mobilization and Demobilization		48,824		24,412			24,412																									
Wastewater Treatment Plant Construction																																
Influent Pumping Station	Total	89,076		43,492	45,584	0	0																									
	FC	47,677		15,892	31,785	0	0																									
	LC	41,399		27,599	13,800	0	0																									
Wastewater Treatment Process	Total	387,738		116,378	155,095	116,266	0																									
	FC	193,589		38,718	77,436	77,436	0																									
	LC	194,149		77,660	77,660	38,830	0																									
Sludge Treatment Process	Total	257,540		0	51,508	103,016	103,016																									
	FC	146,238		0	29,248	58,495	58,495																									
	LC	111,302		0	22,260	44,521	44,521																									
Discharge Pumping Station	Total	113,202		0	0	59,575	53,627																									
	FC	47,678		0	0	15,893	31,785																									
	LC	65,524		0	0	43,683	21,841																									
Site Finalization	Total	42,789		0	0	0	42,789																									
	FC	0		0	0	0	0																									
	LC	42,789		0	0	0	42,789																									
Power Receiving Facility	Total	8,592		0	0	0	8,592																									
	FC	0		0	0	0	0																									
	LC	8,592		0	0	0	8,592																									
Administration Building	Total	7,479		0	0	0	7,479																									
	FC	525		0	0	0	525																									
	LC	6,954		0	0	0	6,954																									
Interceptor Construction	Total	70,066		0	0	35,033	35,033																									
	FC	0		0	0	0	0																									
	LC	70,066		0	0	35,033	35,033																									
Other Costs	Total	341,769		55,954	88,266	109,861	87,688																									
	FC	0		0	0	0	0																									
	LC	341,769		55,954	88,266	109,861	87,688																									
Construction Supervision	Total	68,354		17,088	17,088	17,088	17,088																									
	FC	34,177		8,544	8,544	8,544	8,544																									
	LC	34,177		8,544	8,544	8,544	8,544																									
Government Administration		27,342		4,805	6,809	8,475	7,253																									
Contingency		153,112	6,835	26,213	36,435	44,931	38,698																									
O/M Cost	Total	1,551,950						15,638	15,638	15,638	15,638	15,638	15,638	15,638	402,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	402,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	402,638	15,638
	FC	1,161,000													387,000								387,000								387,000	
	LC	390,950						15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638
Total Disbursement		3,236,187	75,189	288,341	400,786	494,246	425,674	15,638	15,638	15,638	15,638	15,638	15,638	15,638	402,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	402,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	402,638	15,638
FC		1,665,061	34,177	63,154	147,012	160,368	99,350	0	0	0	0	0	0	0	387,000	0	0	0	0	0	0	0	387,000	0	0	0	0	0	0	0	387,000	0
LC		1,571,126	41,012	225,187	253,774	333,878	326,325	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638	15,638

APPENDIX-7 FINANCIAL AND ECONOMIC ANALYSIS

1 FINANCIAL ANALYSIS

1.1 MAJOR PRECONDITIONS AND ASSUMPTIONS

Following preconditions and assumptions were applied in the financial plan.

- The financial plan deals with only the cost and the revenue accrued by the project.
- Currency unit is ROL and the value of ROL is expressed as the June 1999 prices.
- Projection period is 30 years since the start of project implementation.
- Target year is 2010. From 2010 on the values of variables related to revenues and O & M cost are assumed to keep the 2010 level.
- Implementation period is 5 years from 2000 to 2004.
- 38 % of profit before tax is levied as a corporate tax.

Depreciation period is assumed as follows.

Depreciation Period

Item	Mechanical equipment	Civil works and sewer pipes
Depreciation period	8 years	40 years

1.2 TERMS AND CONDITIONS OF EXTERNAL FINANCIAL SOURCES

Conditions of possible external financial sources are assumed as shown in the table below.

Assumed Financing Terms for Possible External Financial Sources

Financial Organs	Financing Ratio (%)	Loan/Grant	Interest Rate (%)	Repayment Period (Years)	Grace Period (Years)
JBIC	70	Loan	2.7	30	10
EBRD	70	Loan	6.5	15	3
ISPA	75	Grant	-	-	-

It should be noted that they are nothing other than an example or assumption. In the case of EBRD, financing ratio depends on the circumstances and interest rate fluctuates in parallel with LIBOR (London Inter-bank Offered Rate).

1.3 BACKGROUND DATA FOR FINANCIAL PLAN

1.3.1 SERVED POPULATION

The sewerage served population in 2010 was estimated 377,000. It was assumed that the present population increases linearly until 2010 and ever since remains 377,000. In addition, the household size was assumed to be constant at present value of 3.1 persons/household.

The numbers of served population and served household were estimated as follows.

Number of Served Population and Household

Year	2005	2006	2007	2008	2009	2010	from 2011
Served population	356,625	360,700	364,775	368,850	372,925	377,000	377,000
Served household	115,040	116,355	117,669	118,984	120,298	121,613	121,613

1.3.2 Quantity of Wastewater

Similar to the served population, the quantity of wastewater was assumed to increase linearly from the present value to the estimated value in 2010, and since ever to remain at the level in 2010. Non-domestic wastewater is composed of commercial, institutional and industrial ones.

The estimated quantities of domestic and non-domestic wastewater are as follows.

Quantity of Domestic and Non-domestic Wastewater

(Unit : 1,000 m^3/year)

Year	2005	2006	2007	2008	2009	2010	from 2011
Domestic	34,919	35,354	35,790	36,226	36,664	37,102	37,102
Non-domestic	31,824	32,641	33,455	34,269	35,083	35,898	35,898

The coefficient *b*, the ratio of non-domestic sewerage charge to domestic one, was estimated 3.38 based on the values in 1998 and 1999.

1.3.3 Household Income

The average monthly household income was estimated at ROL 3,063,748 in 1999 based on the result of the people's awareness survey conducted in this study. It was assumed to grow 3 % per year until 2010, and to remain the level of 2010 whereafter. The annual household income was calculated by multiplying the monthly value with 12.

The estimated average annual household income is as follows.

Average Annual Household Income

(Unit : 1,000 ROL/year)

Year	2005	2006	2007	2008	2009	2010	from 2011
Annual Household Income	43,899	45,216	46,573	47,970	49,409	50,891	50,891

1.3.4 Collection Rate

The charge collection rate was assumed to linearly increase from 72 % in 1999 to 95% in 2010, then remain 95% ever since.

The collection rate of sewerage charge was estimated as follows.

Sewerage Charge Collection Rate

Year	2005	2006	2007	2008	2009	2010	from 2011
Collection Rate	84.5 %	86.6 %	88.7 %	90.8 %	92.9 %	95.0 %	95.0 %

1.4 Financial Statements for Proposed Financial Plans

The financial statements for the proposed financial plans are shown in *Tables AII.7.1 to AII.7.4.*

The structure of applied financial statements is as follows.

Structure of Applied Financial Statements

S.C. APATERM S.A. account	
Revenue	A
Operation and maintenance cost	B
Lease fee	C
Profit before tax	D = A – B – C
Corporate tax	E = D × 0.38
Profit after tax	F = D – E
Working capital	G = F
Cumulative working capital	H = Σ G
City's sewerage service account	
Revenue from lease fee	I = C
Depreciation	J
Payment of interest	K
Profit	L = I – J – K
Loan	M
Subsidy from general budget	N
Depreciation	O = I
Sources	P = L+M+N+O
Investment cost	Q
Payment of principal	R
Applications	S = Q + R
Working capital	T = P – S
Cumulative working capital	U = Σ T
City's general account	
City general revenue	V
Corporate tax from S.C. APATERM S.A.	W = E
Revenue from lease fee	X = I
Total current revenue	Y = V + W + X
Subsidy	Z = N
Subsidy ratio	AA = Z/Y
Repayment ratio	AB = (K + R)/Y

It is noted that leveled allocation of lease fee was applied for EBRD cases, taking into consideration of quite intense repayment schedule for relative short period under EBRD conditions.

2 ECONOMIC ANALYSIS

Based on the economic benefit of the project estimated by the people's awareness survey conducted in this study and the project cost, an economic analysis was conducted.

Applied preconditions and assumptions are as follows:

- Currency unit is ROL and the value of ROL is a constant one expressed at the June 1999 prices.
- Project Life: 30 years since the start of project implementation.

- Target Year: 2010. From 2010 on the values of O & M cost variables are assumed to keep the 2010 level.
- Implementation Period: 5 years 2000 to 2004.
- OCC (Opportunity Cost of Capital): 10%.
- Conversion factor: 98.4% to capital cost (initial and replacement cost) taking account of customs duty for foreign components.

The cost benefit stream of the project, which calculates the EIRR (Economic Internal Rate of Return), NPV (Net Present Value), and B/C (Ratio of Benefit to Cost), is shown in *Table AII.7.5*.

Obtained EIRR, NPV, and B/C are as below:

NPV (ROL 1,000,000)	B/C	EIRR (%)
111,708	1.07	13.1

Results of the sensitivity analysis are as shown below:

Conditions	EIRR (%)	NPV (million Lei)	B/C
Cost: +20%	NA	- 210,418	0.89
Cost: +10%, Benefits: -10%	NA	- 221,589	0.87
Benefits: -20%	NA	- 232,760	0.86