Appendix A-4

Design Calculations for Water Supply Works

I . Capacity Caluculation for W.T.P
Capacity = 100,000cu m/day

Item	Total System				
Planned Flow	Q =	100,000 cu m/day			
				After Filter	
Plant Capacity	Q =	105,300 cu m/day		100,000 cu m/day	
(Daily Max)	=	4,388 cu m/hour		4,167 cu m/hour	
	=	73.1 cu m/min		69.4 cu m/min	
	=	1.22 cu m/sec		1.16 cu m/sec	
1.W.T.Ficilites					
(1) Distribution Chamber	Q=	210,000 cu m/day		146 cu m/min	
Type	Rectangular				
Desige Criteria					
Retention Time	T >			2.0 min	
Number of units	No.			1 units	
Dimensions	L m	x W m	x D m	x N units	
	10.0	10.2	6.0	1	
Volume	V =			612.0 cu m	
Retention Time	T_1=			4.2 min	
(2) Receiving Well	Q=	105,300 cu m/day			
Type	Rectangular				
Desige Criteria					
Retention Time	T >			1.5 min	
Number of units	No.			2 units	
Dimensions	L m	x W m	x D m	x N units	
	7.0	4.2	6.0	2	
Volume	V =			176.4 cu m	
Retention Time	T_1=			2.4 min	
(2)' Mixing Chamber	Q=	105,300 cu m/day			
Type	Square, Gravity Flow Mixing				
Desige Criteria					
Retention Time	T=			1 - 5 min	
Number of units	No.			2 units	
Dimensions	L m	x W m	x D m	x N units	
	4.2	4.2	4.3	2	
Unit Effective Volume	UV =			75.9 cu m/unit	
Total Volume	TV =			151.7 cu m	
Retention Time	T_1 =			2.1 min	
G - Value	G =			113 sec-1 > 100sec-1	
(3) Flocculator	Q=	105,300 cu m/day			
Type	Rectanglar, Horizontal Zigzag Flow				
Desige Criteria					
Retention Time	T=			20 - 40 min	
Required Volume	V=	1,463 cu m	to	2,925 cu m	
Unit Flow	q =			333.0 cu m/min/basin	
Number of basin	N=			6 basins	
Dimensions Step 1	W m	x L m	x D m	f Channel	
	9.0	1.2	3.7	2	
Step 2	W m	x L m	x D m	f Channel	
	9.0	1.5	3.7	2	

Item	Total System		
Step 3	W m x L m x D m of Channel		
	9.0 2.3 3.7 2		
Unit of Volume	Step 1	79.9	cu m/unit
	Step 2	99.9	cu m/unit
	Step 3	153.2	cu m/unit
	Volume/unit	333.0	cu m/unit
Effective Volume	V =	1,998	cu m
Retention Time	T_1 =	27.3	minutes
G - Value	G =	60	sec-1 > 10～75sec-1
GT- Value	GT=	98,030	< 23,000～210,000
	Q = Unit flow 0.203cum/sec		
	H = Head loss 0.6m		
	p = Dencity of water 1000kg/m3		
	V = Volume of units 333cum/unit		
	u = Viscosity of liquid $1x10^{-3}kg/m \cdot Sec$		
(4) Sedimentation Basin	Q=	103,700	cu m/day
Type	Rectangular, Horizontal Flow		
Desige Criteria			
Unit Flow	q =	720	cu m/hr/basin
Retention Time	T =	2.5	hours
Surface Load	a =	15 - 30	mm/min
Hor. Flow Velocity	v <	0.40	m/min
L/W Ratio	L/W =	3 - 8	times
Depth	D =	3 - 4	m
	Depth of 30 cm or more is provided for sludge settlement.		
Number of Basin	N=	6	basins
Dimensions	W m x L m x D m		
	9 50 4.0		
Effective Volume	V =	1,800	cu m/basin
Retention Time	T_1 =	2.5	hours
L/W Ratio	L/W =	5.6	
Surface Load	a =	26.7	mm/min
Hor. Flow Velocity	v =	0.33	m/min
Overflow Weir	Load =	350	cu m/m/day
Trough Length	L =	49	m or longer
Number of troughs	No.	6	troughs
Dimensions	L m x N		
	4.2 6		
Total Length	L =	50.4	m > 49m
Sludge Removal	Cable-operated underwater bogie sludge collector		
(5) Rapid Sand Filter	Q=	103,700	cu m/day
Type	Down Flow, Single Media		
Number of nuits	No. 12 units	2	unit stand-by
Unit Flow	q =	8,642	cu m/day/unit
DesigeCriteria			
Filtration Rate	Fr =	120 - 144	m/day
Effective Filter Area per U	A =	73.1	sq m
Dimensions	W m x L m x units		
	5.8 12.6 12		
	A =	73.1	sq m/unit
Filtration Rate	Fr =	118	m/day (12units)

Item	Total System			
Filtration Rate	Fr'=		142	m/day (10units)
During washing	2 units out of 10 are washing			
Filter Washing				
Frequency	Once a day for each filter			
Rate	Surface Washing	rate =	0.15	cu m/sq m/min
		duration =	5	min
	Backwashing	rate =	0.60	cu m/sq m/min
		duration =	7	min
Water Amount	Surface Washing	Vs =	54.8	cu m/unit
for washing	Backwashing	Vb =	306.9	cu m/unit
		Vs + Vb =	361.7	cu m/unit
for Total Units	Total Amount for Washing		4,341	cu m/day (Back Wash 3,700cu m/day)
	Percentage for Planned Flow		4.1	% (Back Wash Only=3.5%)
(6) Chlorination Mixing Cha	Q= 100,000 cu m/day			
Location	at the Inlet of the Distribution Reservoir			
Criteria				
Contact Time	T=		5	minutes
Required Volume	V =		347	cu m
Number of Unit	No.		1	unit
Dimensions	L m x W m x D m x N units			
	48.0 x 3.0 x 2.8 x 1			
Effective Volume	V =		403	cu m
Retention Time	T_1=		5.5	min
(7) Distribution Reservoir	(Existing) Q 100,000 cu m/day			
Criteria				
Retention Time	T >		8.0	hours
Required Volume	V =		57,667	cu m
Number of Unit			3	units
Dimension	L m x W m x D m x N units			
	64.0 x 64.0 x 5.0 x 3			
Effective Volume	V =		61,440	cu m
Retention Time	T_1=		8.5	hours
(8) Total Water Loss	Sedimentation1,600+Filter3,700=5,300cu m		5.0	%

2. WTP Drainage Facilites

(1) Design Criteria

	Annual Ave	Hight Turbidity	Low Turbidity
Treated water Volume	87,750 cu m/day	105,300 cu m/day	87,750
Turbidity (deg)	5	30	3
Alum Feeding rate (mg/l)	7.5	30	1
Solid Volume s(t-Ds/day)	0.58	4.40	0.23
Generated Sludg (S.B)	0.3 %	0.3 %	0.3
(S.T.T)	2 %	4 %	2
Sludge Volume (S.B)	193 cu m/day	1,468 cu m/day	77
(S.T.T)	29 cu m/day	110 cu m/day	11.6

B.S : Sedimentation Basin, S.T.T : Sludge Tickener Tank

A : $So = Q \times [k \times (T_1 - T_2) + B \times 156/666] \times 10^{-6}$

Q= Treated Water Volume

k= Conversion rate of Turbidity and SS=1.2 (0.8~1.5)

T_1= Turbidity of Raw Water

T_2= Turbidity after Sedimentation = 1

B= Alum Feeding Rate

Item	Total System
	B : Withdrawal Sludge Volume Total number of sludge withdrawal hopper is 24 units and sludge will be withdarwal 24times in a day. Sludge withdrawal duration is 60sec/times Accoding to the withdrawal pipe capacity, sludge withdrawal volume is 0.046cu m/sec (Dia 250 mm, I = 2.3/440 ,Q=4,000 cum/day) Dairy sludge withdrawal volume=0.046cum/secx60secx24unitsx24times/day So= 1,600 cum/day **C : Withdrawal Sludge Concentration** Based on the aforementioned calculation results, concentration of sludge in Sedimentation Basin was calculation as follows; W = 0.3 %

(1) Back-wash Drainage Basin

Type	Rectangular, Horizontal Flow							
Volume per Filter (Exis)	Q1 =						594	cum
Volume per Filter (New)	Q2 =						362	cum
Required Volume	V=						1,242	cum (30%Plus)
Number of Unit	N =						2	units (1 unit stand-by)
Dimension	L m	x	W m	x	D m	x	N	units
	34.5		12.4		3.0		1	
Effective Volume	V1 =						1,283	cum > 1,242cum
Return Pump	to receiving well							
Pump Type	Sluge pump with suction screw							
Pump Capacity	Pump Capacity shall be sufficient to return the back-washing water per 1 unit of fil up to raw water receiving well in 1hour.							
	m3		minuts		m3/min		units	
Q=	1,283		60		10.7		3	(1 unit stand-by)
			m3/min		m		kw	
P=	0.163		10.7		17.0		47	=' 55kw
Sludge Pump	to Sludge Thickener Tank							
Pump Type	Horizontal shaft non-clog type sludge pump							
Pump Capacity	Pump Capacity shall be sufficient to send the back-washing water sludge with volum valent to the capacity of 1 unit of Sludge Thickener Tank in 1hour.							
	m3		minuts		m3/min		units	
Q=	201		60		3.3		2	(1unit stand-by)
			m3/min		m		kw	
P=	0.163		3.3		7.0		11.4	=' 15kw

(2) Sludge Thickener Tank

Type	Circular				
Required Area	Adopting the soild loading			20.0	kgDS/day
	A=			220	sq m/unit
Number of Unit	No.			2	units
Required Volume ①	High turbidity 7 day storag		V=	771	cu m/tank
②	Low turbidity 2.5months st		V=	867	cu m/tank
Dimensions (circular)	Diameter	Depth			
	18.0	3.5			SNIP
Unit Effective Volume	UV=			890	cum > 867cum
Total Volume	TV=			1,780	cum

Item	Total System					
Check (Concentration2%)	Low turbidity sludge				154	day > 150day
Check (Concentration4%)	Hight turbidity sludge				16	day > 7day
Surface Area	A_1 =				254	sq m >221sq m/unit
Check (Soild loading)	Low turbidity sludge				0.9	<20kgDS/sq m/day
	Hight turbidity sludge				17.3	<20kgDS/sq m/day
Sludge Pump	to Sludge drying bed					
Pump Type	Horizontal shaft non-clog type sludge pump					
Pump Capacity	Pump Capacity shall be sufficient to send the Sludge Thickener Tank with volume equivalent to the capacity of Sludge drying bed in 2 days(one day 6 hours)					
		m2	m	m3/min	units	
Q=		900	0.5	1.3	2	(1 unit stand-by)
			m3/min	m	kw	
P=		0.163	1.3	8.0	4.9	= 5.5kw
(3) Sludge Drying Bed						
Type	Rectangular, Horizontal Flow					
Cycle Time	All beds are oprated 2 times a year.					
Required Area	Adopting the soild loading				20.0	kgDS/sq m/time
		A=			5,293	sq m
Number of Unit		No.			6	units
Dimensions		L m x	W m x	D m	cu m	
		45.0	20.0	1.0	900	
Effective Area		sq m	units			
Total Area=		900.0	6.0		5,400	sq m > 5,293m2
Check					19.6	< 20kgDS/sq m/time
(4) Drying Cake Yard						
Type	Rectangular, Horizontal Flow					
Number of Unit		No.			1	units
Dimensions				L m x	W m	
				30.0	20.0	
Effective Area		A =			600	sq m
Effective Volume		V =			212	cum/year
(5) Discharge Pool						
Type	Rectangular, Horizontal Flow					
Required Volume	S.T.T 2,550m3/day + S.D.B 450m3/day				3,000	m3/day
Retention Time		T=			8	hour
Required Volume		V =			1,000	cu m
Number of Unit		No.			2	units
Dimensions		L m x	W m x	H m x	units	
		34.5	11.8	3.0	2	(1unit stand-by)
Effective Volume		V_1=			1,221	cum > 1,000cum
Sludge Pump	to WWTP manhole					
Pump Type	Horizontal shaft non-clog type sludge pump					
Pump Capacity	Pump Capacity shall be sufficient to pump stored supernatant of 3,000m3 in one day					
		m3	minuts	m3/min	units	
Q=		3,000	1,440	2.1	2	(1unit stand-by)
			m3/min	m	kw	
P=		0.163	2.1	8.0	4.3	5.5kw

II. Treatment Facilities for Sludge and Back-washing Water

1. Design Criteria upon Capacity Calculation

1.1 Design Turbidity

As design turbidity upon capacity calculation, four times of annual average turbidity will be applied. Since annual average turbidity in 2002 was5 degree, 3degree in recent four years, 30 degree will be adopted as design turbidity.

1.2 Design Solid Volume and Sludge Volume

Design solid volume and sludge volume is tabulated in Table 1.1.

Table 1.1 Design Solid Volume and Sludge Volume

	Treated Water Volume (m^3/day)	Turbidity (deg)	Alum Injection Rate (mg/L)	Solid Volume s (t -Ds/day)	Generated Sludge	Sludge Concentration (%)	Sludge Volume (m^3/day)
Annual Average Turbidity	87,750	5.0 (3.0)	7.5 (4.74)	0.58	S.B. Sludge	0.3	193
					S.T.T. Sludge	2.0	29
In case of High Turbidity	105,300	30 (29)	30.0 (19.5)	4.40	S.B. Sludge	0.3	1,468
					S.T.T. Sludge	4.0	110
In case of Low Turbidity	87,750	3.0 (2.7)	1.0 (1.0)	0.23	S.B. Sludge	0.3	77
					S.T.T. Sludge	2.0	11.6

Note) S.B. : Sedimentation Basin, S.T.T. : Sludge Thickener Tank

( ) Actual operational rate.

1) $So = Q \times [k \times (T_1 - T_2) + B \times 156/666] \times 10^{-6}$

Q : Treated Water Volume

k : Conversion rate of Turbidity and SS = 1.2 (0.8～1.5)

T_1 : Turbidity of Raw Water

T_2 : Turbidity after sedimentation = 1

B : Alum Injection Rate

2) Withdrawal Sludge Volume

Total number of sludge withdrawal hopper is 24 units and sludge will be withdrawn 24 times in a day. Sludge withdrawal duration is 60 sec/time.

According to the withdrawal pipe capacity, sludge withdrawal volume is q = 0.046 m^3/sec.

(ϕ 2 5 0mm, I=2.3m/440m=0.0052, Q=4,036 m^3/day=0.046 m^3/sec.)

Daily sludge withdrawal volume = 0.046m^3/sec x 60 min x 24 times/day x 24 units

= 1,600 m^3/day

3) Withdrawal Sludge Concentration

Based on the aforementioned calculation results, concentration of sludge in Sedimentation Basin was calculated as follows;

W = 4.4t-DS/d x 1/1,600 m^3/day x 100 = 0.3%

2. Capacity Calculation

2.1 Back-washing Drainage Basin

This tank will receive the back-washing water from Rapid Sand Filter and return the treated water to Raw Water Receiving Well. Necessary tank capacity shall be back-washing water volume per filter, adding 30% of that volume as allowance.

Back-washing drainage volume per filter (Existing WTP)

Back-washing 0.8 m^3/m^2/min x 106 m^2/filter x 7min x 1 unit = 594 m^3

Back-washing drainage volume per filter (New WTP)

Surface washing	0.15 m^3/m^2/min x 73.1 m^2/filter x 5 min x 1 unit	= 54.8 m^3
Back-washing	0.6 m^3/m^2/min x 73.1m^2/filter x 7min x 1 unit	= 307 m^3
Sub Total		= 361.8m^3
Total	594+361.8=955.8 m^3	

Accounting 30% of allowance, 1,242 m^3 shall be adopted.

Dimension : W 12.4 m x L 34.5 m x H 3.0 m

No. of Units : 2 units (1 unit stand-by)

Capacity : 1,283 m^3/unit x 2units

2.2.1 Return Pump (to Receiving Well)

Capacity : Pump capacity shall be sufficient to return the back-washing water per 1 unit of filter up to receiving well in 1 hours.

$Q = 1{,}283\ m^3/\ 60min = 10.7m^3/min \times 3$ units (1 unit stand by)

$P = 0.163 \times 10.7m^3/min \times 17m/0.75 \times 1.2 = 55kw$

2.2.2 Sludge Pump (to Sludge Thickener Tank)

Capacity : Pump capacity shall be sufficient to send the back-washing water sludge with volume valent to the capacity of 1unit of Sludge Thickener tank in 1 hours.

$Q = 201\ m^3/\ 60min = 3.3m^3/min \times 2$ units (1 unit stand by)

$P = 0.163 \times 3.3m^3/min \times 8m/0.75 \times 1.2 = 15kw$

2.3 Sludge Thickener Tank

This tank will store the sludge from Sedimentation Basin. Thickened sludge will be sent to Sludge Drying Bed.

Necessary Area : Adopting the solid loading of 20kgDS/m^2/day;

$A = 4.4kgDS/day \times 1/20\ kgDS/d = 220\ m^2/tank$

Necessary Capacity : 2 units of thickener tank will be needed. According to the following capacity calculation methods, larger capacity will be adopted.

a) Capacity equivalent to 7 days' storage volume against high turbidity sludge, concentration is 4 % ;

$4.4\ t\text{-}DS/day \times 1/0.04 \times 7\ day = 771\ m^3/tank$

b) Capacity equivalent to 2.5 months' (150 days) storage volume against low turbidity sludge, concentration is 2 %

$0.23\ t\text{-}DS/day \times 1/0.02 \times 75day = 867m^3/tank$

Therefore, tank capacity shall be 890m^3/tank.

Dimension : Inner diameter 18.0m x effective depth 3.5 m

(Surface Area 254m^2/tank)

Capacity : 890m^3 x 2 tanks = 1,780 m^3

Check : In case of low turbidity sludge (concentration is 2 %)

$t = 1{,}780m^3/11.6m^3/day = 154day > 150day$ OK

In case of high turbidity sludge (concentration is 4 %)

$t = 1{,}780m^3/110\ m^3/day = 16day > 7day$ OK

Surface Area : $A = 254m^2/tank$

Check (Solid Loading) :

In case of low turbidity sludge

$t = 230kgDS/day/254m^2/tank = 0.9kgDS/m^2/day < 20\ kgDS/m^2/day$

In case of high turbidity sludge

$t = 4{,}400kgDS/day/254m^2/tank = 17.3kgDS/m^2/day < 20\ kgDS/m^2/day$

2.3.1 Return Pump (to Sludge Drying Bed)

Type : Horizontal Shaft Non-clog Type Sludge Pump

Design Sludge Volume : Pump capacity shall be sufficient to send the thickened sludge with volume equivalent to the capacity of 1 unit of sludge drying bed in 2 days (1 day 6 hours)

$Q = 900m^2 \times 0.5\ m/12\ hrs \times 60\ min = 1.3m^3/min \times 2$ units (1 unit stand by)

$P = 0.163 \times 1.3\ m^3/min \times 8\ m/0.4 \times 1.2 = 5.5kW$

2.4 Sludge Drying Bed

Solid loading of 20 $kgDS/m^2/time$ is applied on Sludge Drying Bed. All beds are operated 2 times a year.

Necessary Area :	$211{,}700kgDS/year \times 1/20\ kgDS/m^2/time \times 1/2\ times = 5{,}293m^2$
Dimension :	20.0 m x 45.0 m x 1.0 m (Effective Area $900m^2$)
Number of Beds :	6 beds
Capacity :	$900\ m^2/bed \times 6\ beds = 5{,}400\ m^2 < 5{,}293m^2$

2.5 Sludge Cake Yard

This yard will store the dried sludge cake removed from sludge drying bed temporally before transportation by truck.

Dimension :	$20\ m \times 30\ m = 600\ m^2$
Number of Yard :	1 unit

Capacity : $600m^2$ x0.5 m =300m3 > 212 m^3/year

(0.58t-DS/day x 365days = 212m^3/year)

2.6 Discharging Pool

Discharging pool will store the supernatant of sludge thickener tank and sludge drying bed.

Necessary Capacity : Sludge Thickener Tank 2,550m^3 + Sludge Drying Bed 450m^3 = 3,000m^3

Retention time 8hr (3,000 m^3 x 8/24=1,000 m^3/tank)

Dimension 11.8 m x 34.5m x 3.0m

No. of Tank 2 tanks (1 unit stand by)

Capacity 1,221 m^3/tank > 1,000 m^3/tank

2.6.1 Sludge Pump : (to WWTP manhole)

Pump Type : Horizontal Shaft Non-clog Type Sludge Pump

Design Capacity : Pump capacity shall be sufficient to pump stored supernatant of 3,000 m^3 in one day.

Q =3,000m^3/24 hr x 60 min = 2.1m^3/min x 2units (1unit stand-by)

P = 0.163 x 2.1m^3/min x 8.0m/0.75 x 1.2 = 5.5kW

2.7 Water loss

Total Water loss : Sedimentation sludge 1,600m^3+Back-wash water3,700 m^3=5,300 m^3

Percentage = 5,300m^3/105,300 m^3/day =5%

Appendix A-5

Hydraulic Calculations for Water Treatment Plant

Hydraulic Calculation for Water Treatment Plant

0. Design condition

0.1 Water supply volume

Item	Water supply volume				Remark
	Qsd (m^3/day)	Qsh (m^3/hr)	Qsm (m^3/min)	Qss (m^3/sec)	
This project	100,000	4,167	69.44	1.157	
Existing	100,000	4,167	69.44	1.157	
Total	200,000	8,334	138.88	2.314	

0.2 Water treatment volume

Item	Qtd			Remark
	Exist (m^3/day)	This Project (m^3/day)	Total (m^3/day)	
Water supply volume	100,000	100,000	200,000	
Water volume consumed in WTP	5,000	5,000	10,000	5 %
Total	105,000	105,000	210,000	
	≒ 105,000	≒ 105,000	≒ 210,000	

Water treatment volume	Qtd (m^3/day)	Qth (m^3/hr)	Qtm (m^3/min)	Qts (m^3/sec)	Remarks
This Project	105,000	4,375	72.92	1.215	
Total	210,000	8,750	145.83	2.431	Distribution chamber

1. Distribution chamber

1.1 Design Condition

1.1.1 Design flow

Total flow	Qtd=	210,000 m^3/day
Unit number	N=	1 chamber
Unit design flow	Qud=	210,000 m^3/day/chamber
	Qus=	2.4306 m^3/sec/chamber

1.1.2 Design water level

Water level at inlet. 363.40 m

1.2 Head loss calculation

1.2.1 Baffle wall

Applied formula : $h=1/C^2 \times v^2/(2g)$

Item	Symbol	Design value
Parameters		
Opening ratio	Ro	9.9 %
Width	W	10.2 m
Height	H	7.4 m
Velocity coefficient	C	0.6
Gravity acceleration	g	9.81 m/sec^2
Calculation		
Average velocity at opening	Vo	0.3253 m/sec
Head loss	h	$1/C^2 \times V^2/(2g)=$ 0.015 m
		Say 0.02 m

Water level after baffle wall 363.38 m

1.2.2 Suppressed-rectangular weir

Applied formula : $Q=C\times H\times h^{3/2}$

$C=1.785+(0.00295/h+0.237\times h/H)\times(1+\epsilon)$

$\epsilon=0$ (H =< 1.0m)

$\epsilon=0.55\times(H-1.0)$ (H>1.0m)

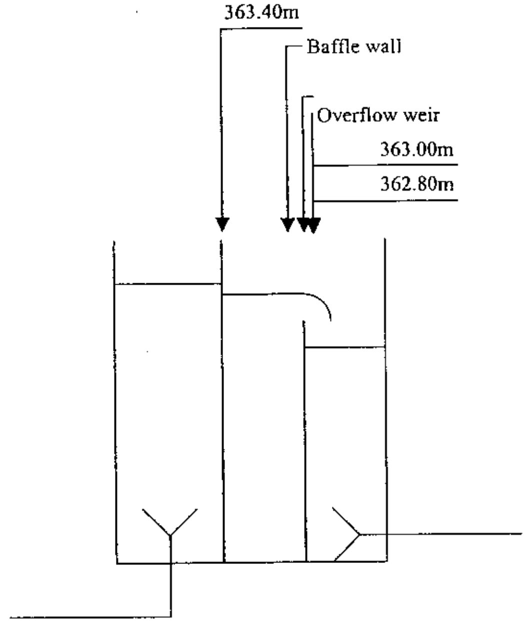
Item	Symbol	Designed	Value
Parameters			
Weir width	Ww		3.00 m
Weir height	Hw		7.00 m
Weir number	N		2 weirs
Calculation			
Unit flow	Qud	Qudw/N=	105,000 m^3/day/weir
Correction coefficient	ϵ		3.3000
Flow index	C		1.87267
Calculated flow	Qc		1.2155 m^3/sec
Absolute error		Qus-Qc	0.0002 m^3/sec
Overflow depth	h_o	Refer to "Overflow weir"	0.3604
		Say	0.36 m
Clearance	h_{fb}		0.22 m
Head loss	h	h_o+h_{fb}=	0.58 m

A.5-2

Water level after Weir 362.80 m

Weir level 363.00 m ...OK

1.2.3 Water level drawing



A.5-3

2. Distribution Chamber - Receiving Well

2.1 Design Condition

2.1.1 Design flow

Total flow	Qtd=	105,000 m^3/day
Unit number		1 line
Unit Design flow	Qud=	105,000 m^3/day
	Qus=	1.2153 m^3/sec

(2) Design water level

Distribution Chamber	362.80 m

2.2 Head loss calculation

2.2.1 Connection pipeline

Applied formula : $h_f = I \times L$

$I = 10.666 \times C^{1.85} \times D^{-4.87} \times Q^{1.8}$ Hazen-Williams formula

$h_s = f_i \times v^2/(2g)$

Item	Symbol	Design value	
Parameters			
Diameter	D		1,200 mm
Length	L		80.0 m
Velocity coefficient	C		130
Gravity acceleration	g		9.81 m/sec^2
Calculation			
Average velocity	V		1.0746 m/sec
Friction loss	h_f	Refer to "Pipeline"	0.062 m
Shape loss	h_s	Refer to "Pipeline"	0.130 m
Sum	h_p	h_f+h_s=	0.192 m
		Say	0.19 m
Clearance	h_{fb}		0.31 m
Head loss	h	h_p+h_{fb}=	0.50 m

Water level after connection pipeline	362.30 m

3. Receiving Well

3.1 Design condition

3.1.1 Design flow

Total flow	Qtd=	105,000 m^3/day
Unit number	N=	2 wells
Unit design flow	Qud=	52,500 m^3/day/well
	Qus=	0.6076 m^3/sec/well

3.1.2 Design water level

Distribution Pipeline	362.30 m

3.2 Head loss calculation

3.2.1 Baffle wall

Applied formula : $h = 1/C^2 \times v^2/(2g)$

Item	Symbol	Design value	
Parameters			
Opening ratio	Ro		19.6 %
Width	W		4.2 m
Height	H		6.0 m
Velocity coefficient	C		0.6
Gravity acceleration	g		9.81 m/sec^2
Average velocity at opening	v	Qus/(W×H×Ro)=	0.1230 m/sec
Calculation			
Head loss	h	$1/C^2 \times V^2/(2g)$ =	0.002 m
		App	0.00 m

Water level after baffle wall	362.30 m

4. Coagulation Basin

4.1 Design condition

4.1.1 Design flow

Design flow	Qtd=	105,000 m^3/day
Unit number	N=	2 basins
Unit design flow	Qud=	52,500 m^3/day/basin
	Qus=	0.6076 m^3/sec/basin

4.1.2 Design water level

Receiving Well 362.30 m

4.2 Head loss calculation

4.2.1 Suppressed-rectangular weir

Applied formula : $Q=C\times H\times h^{3/2}$

$C=1.785+(0.00295/h+0.237\times h/H)\times(1+\epsilon)$

$\epsilon=0$ $(H =< 1.0m)$

$\epsilon= 0.55\times(H-1.0)$ $(H>1.0m)$

A.5-4

Item	Symbol	Designed Value
Parameters		
Width	Ww	4.20 m
Height	Hw	5.30 m

Item	Symbol		Designed Value
Calculation			
Correction coefficient	ϵ		2.3650
Velocity coefficient	C		1.86696
Calculated flow	Qc		0.6078 m^3/sec
Absolute error		Qus-Qc=	0.0002 m^3/sec
Overflow depth	h_o	refer to "Overflow weir"	0.1818 m
		Say	0.18 m
Clearance	h_f		0.72 m
Head loss	h	h_o+h_f=	0.90 m

Water level after Weir	361.40 m	
Weir level	362.10 m	...OK

4.2.2 Outlet orifice

Applied formula $h=1/C^2\times v^2/(2g)$

Item	Symbol		Design value
Parameter			
Width	Wo		1.00 m
Height	Ho		1.00 m
Velocity coefficient	C		0.6
Gravity acceleration	g		9.81 m/sec^2
Calculation			
Average velocity at opening	v	Qus/(Wo×Ho)=	0.6076 m/sec
Head loss	h	$1/C^2\times v^2/(2g)$=	0.052 m
		Say	0.05 m

Water level after outlet orifice 361.35 m

5. Flocculation Basin

5.1 Design condition

5.1.1 Design flow

Total flow		Qtd=	105,000 m^3/day
Unit number		N=	6 basins
Unit flow		Qud=	17,500 m^3/day/basin
		Qus=	0.2025 m^3/sec/basin

5.1.2 Design water level

Coagulation Basin 361.35 m

5.2 Head loss calculation

5.2.1 Inlet channel

Required flow	Route a-b	Rab=	3 basins
	b-c	Rbc=	2 basins
	c-d	Rcd=	1 basin
Route design flow	Route a-b	Qrsab=	0.6075 m^3/sec
	b-c	Qrsbc=	0.4050 m^3/sec
	c-d	Qrscd=	0.2025 m^3/sec

A.5-5

Applied formula : $h=L/v^2/(C^2/R)$ Munning's formula

$C^2=R^{1/3}/n^2$

Item	Symbol	Design value
Parameters		
Distance each section	La-b	5.90 m
	Lb-c	9.60 m
	Lc-d	9.60 m
Channel width	Wa-b	2.00 m
	Wb-c	2.00 m
	Wc-d	2.00 m
Channel height	Ha-b	4.35 m
	Hb-c	4.35 m
	Hc-d	4.35 m
	Hd-e	4.35 m
roughness coefficient	n	0.015
gravity acceleration	g	9.81 m/sec^2
Calculation		
Average velocity	Va-b	0.0698 m/sec
	Vb-c	0.0466 m/sec
	Vc-d	0.0233 m/sec
Head loss	ha-b	$L / v^2 / (C^2/R)$ = 0.000 m
	hb-c	$L / v^2 / (C^2/R)$ = 0.000 m
	hc-d	$L / v^2 / (C^2/R)$ = 0.000 m
	Sum	0.000 m
		Say 0.00 m

Water level at downstream side 361.35 m

5.2.2 Inlet orifice

Applied formula $h=1/C^2 \times v^2/(2g)$

Item	Symbol	Design value
Parameters		
Width	Wo	0.60 m
Height	Ho	0.60 m
Flow index	C	0.6
Gravity acceleration	g	9.81 m/sec^2
Calculation		
Average velocity at opening	v	Qus/(Wo×Ho)= 0.5625 m/sec
Head loss	h	$1/C^2 \times v^2/(2g)$= 0.045 m
		Say 0.05 m

Water level after outlet orifice 361.30 m

A.5-6

5.2.3 Flocculation baffle wall

Refer to Section 5.3

Head loss 0.503 m

Say 0.50 m

Water level after 6th baffle wall 360.80 m

5.2.4 Outlet baffle wall

Applied formula $h=1/C^2 \times v^2/(2g)$

Item	Symbol	Design value
Parameters		
Opening ratio	Ro	6.0 %
Width	W	9.0 m
Height	H	4.0 m
Flow index	C	0.6
Gravity acceleration	g	9.81 m/sec^2
Calculation		
Average velocity at opening	v	Qrs/(W×H×Ro)= 0.0938 m/sec
Head loss	h	$1/C^2 \times V^2/(2g)$= 0.001 m
		Say 0.00 m

Water level after Outlet baffle wall 360.80 m

5.3 Flocculation baffle wall (zigzag flow)

5.3.1 Design Condition

5.3.1.1	Total flow	Qtd=	105,000	m^3/day
		Qts=	1.215	m^3/sec
	Unit number		6	basins
	Unit flow	Qud=	17,500	m^3/day/basin
		Qus=	0.2025	m^3/sec/basin

5.3.1.2 Design water level

Water level at inlet point 361.30 m

5.3.2 Head loss calculation

A.5-7

Applied formula $G = [\rho \times g \times h_T/(\mu \times Tr$; GT = 23,000 - 210,000

$h_T = \mu \times V \times G^2/(\rho \times g \times Q)$

$h_T = ho + hc$

$ho = fo \times vo^2/(2g)$

$hc = L \times n^2 \times vc^2/R^{4/3}$

5.3.2.1 Parameters

Item	Symbol	Unit	Formula	1st stage	2nd stage	3rd stage	Total
Flow	Qus	m^3/sec		0.2025	0.2025	0.2025	
Channel width	Wc	m		1.20	1.50	2.30	
Channel depth	Dc	m		9.00	9.00	9.00	
Bottom level	Hb	m			0.00	0.00	
Baffle wall depth	Db	m		0.15	0.15	0.15	
Divided number	N	-		7	7	7	
Primary channel width	Wpr	m		2.55	1.30	1.30	
Intermediate channel width	Wi	m		1.10	1.10	1.10	
Post channel width	Wpo	m		1.30	1.30	1.30	
Upstream end water depth	Dwu	m		361.300	360.901	360.822	
Downstream end water depth	Dwb	m		360.901	360.822	360.797	
Average water depth	Dwa	m		361.101	360.862	360.810	
Designed average water depth	Dw	m		4.00	3.76	3.71	
Downstream end water level	Lw	m	Hb+Dwb=	360.901	360.822	360.797	
Flow index	C	-		0.6	0.6	0.6	
Roughness coefficient	n	-		0.015	0.015	0.015	
Gravity acceleration	g	m/sec^2		9.81	9.81	9.81	
Volume	V	m^3		71.88	84.60	128.89	285.37
Retention times	Trm	min		5.92	6.96	10.61	23.49

	Trs	sec		355	418	637	1,410

5.3.2.2 Head loss calculation

Item	Symbol	Unit	Formula	1st stage	2nd stage	3rd stage	Total
Head loss at Baffle							
Baffle number	N	-		11	12	12	
Open width	Wo	m		0.10	0.25	0.45	
Velocity	vo	m/sec	Qus/(Wor×Dw)=	0.506	0.215	0.121	
Friction coefficient	fo	-	$1/C^2=$	2.78	2.78	2.78	
Head loss	ho	m	$fo \times vo^2/(2g)=$	0.399	0.079	0.025	
Head loss at channel							
Length	Lc	m		14.75	17.25	21.45	
Hydraulic radius	Rc	m		0.4835	0.4798	0.4790	
Velocity	vc	m/sec		0.046	0.0490	0.0496	
Head loss	hc	m	$L \times n^2 \times vc^2/R^{4/3}=$	0.000	0.000	0.000	
Total head loss	h_T	m		0.399	0.079	0.025	0.503
G value, GT value							
Water temperature : 0 °C							
Density of water	ρ	kg/m^3		999.9	999.9	999.9	
viscosity	μ	10^{-3} kg/m/sec		1.792	1.792	1.792	
G value	G_0	sec^{-1}	$[\rho \times g \times h_T/(\mu \times Trs)]^{1/2}$	78	32	15	44
GT value	GT_0	-	$G_0 \times Trs$	27,690	13,376	9,555	62,040
Water temperature : 20 °C							
Density of water	ρ	kg/m^3		998.2	998.2	998.2	
viscosity	μ	10^{-3} kg/m/sec		1.002	1.002	1.002	
G value	G_{20}	sec^{-1}	$[\rho \times g \times h_T/(\mu \times Trs)]^{1/2}$	105	43	20	59
GT value	GT_{20}	-	$G_{20} \times Trs$	37,275	17,974	12,740	83,190

A.5-8

6. Sedimentation Basin

6.1 Design condition

6.1.1 Design flow

Total flow	Qtd=	105,000 m^3/day
	Qds=	1.2153 m^3/sec
Unit number	Ro=	6 basins
Unit flow	Qud=	17,500 m^3/day/basin
	Qus=	0.2025 m^3/sec/basin

6.1.2 Design water level

Flocculation Basin 360.80 m

6.2 Head loss calculation

6.2.1 Inlet baffle wall

Applied formula : $h=1/C^2 \times v^2/(2g)$

Item	Symbol	Design value	
Parameters			
Opening ratio	Ro		17.7 %
Width	W		9.0 m
Height	H		4.0 m
Velocity coefficient	C		0.6
Gravity acceleration	g		9.81 m/sec^2
Calculation			
Average velocity at opening	v	Qus/(W×H×Ro)=	0.0318 m/sec
Head loss	h	$1/C^2 \times v^2/(2g)=$	0.000 m
		Say	0.00 m

Water level after inlet baffle wall 360.80 m

6.2.2 1st Intermediate baffle wall

Applied formula : $h=1/C^2\times v^2/(2g)$

Item	Symbol	Design value	
Parameters			
Opening ratio	Ps		17.7 %
Width	W		9.0 m
Height	H		4.0 m
Velocity coefficient	C		0.6
Gravity acceleration	g		9.81 m/sec^2
Calculation			
Average velocity at opening	v	Qus/(W×H×Ro)=	0.0318 m/sec
Head loss	h	$1/C^2\times v^2/(2g)$=	0.000 m
		Say	0.00 m

Water level after 1st intermediate baffle wall 360.80 m

A.5-9

6.2.3 2nd Intermediate baffle wall

Applied formula : $h=1/C^2\times v^2/(2g)$

Item	Symbol	Design value	
Parameters			
Opening ratio	Ps		17.7 %
Width	W		9.0 m
Height	H		4.0 m
Velocity coefficient	C		0.6
Gravity acceleration	g		9.81 m/sec^2
Calculation			
Average velocity at opening	v	Qus/(W×H×Ro)=	0.0318 m/sec
Head loss	h	$1/C^2\times v^2/(2g)$=	0.000 m
		Say	0.00 m

Water level after 2nd intermediate baffle wall 360.80 m

6.2.4 Outlet baffle wall

Applied formula : $h = 1/C^2 \times v^2/(2g)$

Item	Symbol	Design value	
Parameters			
Opening ratio	Ps		17.7 %
Width	W		9.0 m
Height	H		4.0 m
Velocity coefficient	C		0.6
Gravity acceleration	g		9.81 m/sec^2
Calculation			
Average velocity at opening	v	Qus/(W×H×Ro)=	0.0318 m/sec
Head loss	h	$1/C^2 \times v^2/(2g)$=	0.000 m
		Say	0.00 m

Water level after Outlet baffle wall 360.80 m

A.5-10

6.2.5 Outlet trough

Applied formula : Thomas-Camp formula

$h=(2hc^2+(hc-iL/3)^2)^{1/2}-2/3\times iL$

Item	Symbol	Design value	
Parameters			
Trough length	Lt		4.20 m
Trough width	Wt		0.35 m
Trough height	Ht		0.35 m
Trough number	N		6 troughs
Collecting orifice diameter	Do		40 mm
Collecting orifice interval	Io		150 mm
Orifice number	No	Lt/(Io/1000)=	56 orifices/trough
Velocity coefficient	C		0.6
Coefficient	α		1.1
Gravity acceleration	g		9.81 m/sec^2
Inclination of Trough	i		0 ‰

Item	Symbol	Design value
Calculation		
(a) Head loss at orifice		
Overflow per a trough	Qot	Qus/Nt= 0.0338 m^3/sec/trough
Overflow per a orifice	Qoh	Qot/No= 6.0357 $\times 10^{-4} m^3$/sec/orifice
Outlet velocity per a orifice	vo	$Qoh/(3.14/4\times(Do\times 10^{-3})^2)$= 0.4805 m/sec/orifice
Head loss at orifice	ho	$1/C^2\times vo^2/(2g)$= 0.033 m
		Say 0.03 m
(b) Head loss at collecting trough		
Critical depth at downstream end	hc	$(\alpha\times Qot^2/(g\times Wt^2))^{1/3}$= 0.102 m
		Say 0.10 m
Water depth at upstream end	hu	$(2hc^2+(hc-i\times Lt/3)^2)^{1/2}-2/3\times i\times Lt$
		= 0.177 m
		Say 0.18 m

Orifice level (Ho)= Water level at Post baffle wall - ho=	360.77 m
Bottom level of trough (Htb)= Ho-(hu+htfb)	360.50 m
Clearance of collecting trough (htfb)=	0.09 m
Water level at upstream end of trough = Htb+hu=	360.68 m
Water level at downstream end of trough = Htb+hc=	360.60 m
Upper level of Trough (Htu) = Htb+Ht=	360.85 m
Outlet channel clearance depth (Hoccd)=	0.30 m
Water level at upstream end of outlet channel =Htb-Hoccd=	360.20 m

6.2.6 Outlet channel

Applied formula : It shall be calculated as a open channel flow with side inflow (inlet angle is 90 degree). Water depth (h), at x meter from downstream side with continuously a side inflow, expresses "$dx^2/dh=x^2/h-(g/b^2/(\alpha/q^2)\times h^2$". Therefore, $f(h)=g\times Wc^2/(2\alpha\times q^2)\times h^3-C\times h+x^2=0$

Item	Symbol	Design value
Parameters		
Outlet channel length	Lc	57.00 m
Outlet channel width	Wc	2.00 m
Outlet channel bottom level		355.80 m
Coefficient	α	1.1
Gravity acceleration	g	9.81 m/sec^2
Calculation		
Inlet flow from side	q	Qrs/L= 0.0213 m^3/sec/m
Outlet channel water depth (downstream end)	Hc	4.40 m
Water depth at x meter from downstream end	f(h)	$g\times Wc^2/(2\alpha\times q^2)\times h^3-C\times h+x^2$ = 39,313.99 $h^3-C\times h+x^2$...(a)
Water depth at downstream end (x=0)	h(0)	4.400 m
Coefficient	C	(a) 761,857.26 ...(b)
Water depth at upstream end (x = Lc)	h(Lc)	(a),(b) 4.402 m
Head loss	h	h(0)-h(Bc)= 0.002
		Say 0.00 m

Water level at downstream side of outlet canal	360.20 m

7. Sedimentation Basin - Rapid Sand Filter

7.1 Condition

7.1.1 Design flow

Total flow		Qtd=	105,000 m^3/day
Route number			1 route
Route flow		Qrd=	105,000 m^3/day/route
		Qrs=	1.2153 m^3/sec/route

7.1.2 Design water level

Water level at downstream end of outlet channel 360.20 m

7.2 Head loss calculation

7.2.1 Distribution channel

Required flow for filter	Section a-b	Na-b=	12 filters
	b-c	Nb-c=	6 filters
	c-d	Nc-d	5 filters
	d-e	Nd-e	4 filters
	e-f	Ne-f	3 filters
	f-g	Nf-g=	2 filters
	g-h	Ng-h=	1 filter
Each section flow	Section a-b	Qsa-b=	1.2153 m^3/sec
	b-c	Qsb-c=	0.6077 m^3/sec
	c-d	Qsc-d=	0.5064 m^3/sec
	d-e	Qsd-e=	0.4051 m^3/sec
		Qse-f=	0.3038 m^3/sec
	f-g	Qsf-g=	0.2026 m^3/sec
	g-h	Qsg-h=	0.1013 m^3/sec

Applied formula : $h=L/v^2/(C^2/R)$ Munning formula

$C^2=R^{1/3}/n^2$

Item	Symbol	Design value
Parameter		
Length each section	La-b	18.40 m
	Lb-c	9.75 m
	Lc-d	9.60 m
	Ld-e	8.15 m
	Le-f	8.15 m
	Lf-g	8.15 m
	Lg-h	8.15 m
Channel width	Wa-b	2.00 m
	Wb-c	2.00 m
	Wc-d	2.00 m
	Wd-e	2.00 m
	We-f	2.00 m
	Wf-g	2.00 m
	Wg-h	2.00 m
Channel height	Ha-b	1.70 m
	Hb-c	1.70 m
	Hc-d	1.70 m
	Hd-e	1.70 m
	He-f	1.70 m
	Hf-g	1.70 m
	Hg-h	1.70 m
Roughness coefficient	n	0.015
Gravity acceleration	g	9.81 m/sec^2

Item	Symbol	Design value	
Calculation			
Average velocity	Va-b		0.3574 m/sec
	Vb-c		0.1787 m/sec
	Vc-d		0.1489 m/sec
	Vd-e		0.1191 m/sec
	Ve-f		0.0894 m/sec
	Vf-g		#DIV/0! m/sec
	Vg-h		0.0298 m/sec
Head loss	ha-b	$L/v^2/(C^2/R)=$	0.000 m
	hb-c	$L/v^2/(C^2/R)=$	0.000 m
	hc-d	$L/v^2/(C^2/R)=$	0.000 m
	hd-e	$L/v^2/(C^2/R)=$	0.000 m
	he-f	$L/v^2/(C^2/R)=$	0.000 m
	hf-g	$L/v^2/(C^2/R)=$	#DIV/0! m
	hg-h	$L/v^2/(C^2/R)=$	0.000 m
	Sum		0.000 m
		Say	0.00 m

Water level at downstream side 360.20 m

7.2.2 Inlet part head loss

Filter number		12 filters
Simaltanious backwash filter number		1 filter
Suspended filter number at backwashing period		1 filter
Operated filter number under backwashing process		10 filters
Unit flow	Qud=	10,500 m^3/day
	Qus=	0.1215 m^3/sec

a) Inlet siphon

Design flow   Section a-b   Qusa-b= 0.1215 m^3/sec

Applied formula : $h=L/v^2/(C^2/R)$ Munning formula

$C^2=R^{1/3}/n^2$

Item	Symbol	Design value	
Parameters			
Length	La-b		4.22 m
Width	Wa-b		0.65 m
Height	Ha-b		0.30 m
Inlet friction coefficient	fi		1.0
Outlet friction coefficient	fo		1.0
Roughness coefficient	n		0.015
Gravity acceleration	g		9.81 m/sec^2
Calculation			
Average velocity	va-b		0.6075 m/sec
Head loss by siphon channel	hc	$L/v^2/(C^2/R)=$	0.000
Inlet head loss	hi	$fi\times v^2/(2g)=$	0.019 m
Outlet head loss	ho	$fo\times v^2/(2g)=$	0.019 m
Sum	hs	hc+hi+ho=	0.038 m
		Say	0.04 m
Clearance	h_{fb}		0.04 m
Head loss	h	$hs+h_{fb}=$	0.08 m

Water level at downstream side 360.12 m

b) Inlet weir

Applied formula :

$Q=C\times H\times h^{3/2}$

$C=1.785+(0.00295/h+0.237\times h/H)\times(1+\epsilon)$

$\epsilon=0$ (H =< 1.0m)

$\epsilon=0.55\times(H-1.0)$ (H>1.0m)

Item	Symbol	Designed Value	
Parameters			
Width	Ww		1.50 m
Height	Hw		1.50 m
Calculation			
Correction coefficient	ϵ		0.2750
Flow index	C		1.84028
Calculated flow	Qc		0.1216 m^3/sec
Absolute error		Qus-Qc=	0.0000 m^3/sec
Overflow depth	h_o	Refer to "Overflow weir"	0.1247
		Say	0.12 m
Clearance	h_{fb}		0.25 m
Head loss	h	h_o+h_{fb}=	0.37 m

Water level after Weir 359.75 m

Weir level 360.00 m ...OK

A.5-14

c) Inlet pipeline

Applied formula :

$h_f=I\times L$

$I=10.666\times C^{1.85}\times D^{-4.87}\times Q^{1.85}$ Hazen-Williams formula

$h_s=f_i\times v^2/(2g)$

Item	Symbol	Design value	
Parameters			
Diameter	D		500 mm
Length	L		4.0 m
Velocity coefficient	C		130
Gravity acceleration	g		9.81 m/sec^2
Calculation			
Average velocity in pipe	v		0.9305 m/sec
Head loss at straight	h_f	Refer to "Pipeline"	0.003 m
Head loss by shape	h_s	Refer to "Pipeline"	0.034 m
Sum of head loss	h_p	h_f+h_s=	0.037 m
		Say	0.04 m
Clearance	h_{fb}		0.01 m
Head loss	h	h_p+h_{fb}=	0.05 m

Water level after connection pipeline 359.70 m ...OK

Filter HWL 359.70 m

8. Rapid sand filter

8.1 Condition

8.1.1 Design flow

Total flow	Qtd=	105,000	m^3/day
Filter number		12	filters
Simultaneous backwash filter number		1	filter
Suspended filter number at backwashing period		1	filter

Inlet flow to each filter shall be calculated at the backwashing period.

Operated filter number under backwash process		10	filters
Unit flow	Qud=	10,500	m^3/day
	Qus=	0.1215	m^3/sec

8.1.2 Design water level

High water level	359.70	m
Effective water depth	3.80	m
Filter surface level	355.90	m

A.5-15

8.2 Head loss calculation

a) Initial head loss by filter media

Applied formul $h=\Sigma(0.178\times C_D/g\times Lv^2/\epsilon^4\times\alpha/\beta\times L/D)$ Fair-Hatch Formula

$Re=\rho_F\times D\times Lv/\mu$

C_D: $24/Re$ (Re<1)

$24/Re+3/Re^{1/2}+0.34$ (Re>=1)

Calculated at temperature = 15°

Item	Symbol	Designed Value		
Parameters				
Width	W_f		5.8	m
Length	L_f		12.6	m
Filter area	A_f	$W_f\times L_f$=	73.08	m^2
Density	ρ_F		1,000	kg/m^3
Viscosity	μ		1.002	10^{-3}kg/m/sec
Gravity acceleration	g		9.81	m/sec^2
Filtration velocity	Lv	Qus/A_f=	0.0017	m/sec

a-1) Head loss by filter media

Filter media

Filter	HMD $D(10^{-3}m)$	Depth L(m)	Re number Re	Coefficient C_D	Porosity ϵ	Shape coefficient α/β	Head loss h(m)
Sand	0.60	0.700	1.018	26.8890	0.35	5.5	0.603
						Sum(h1)	0.603

HMD : Harmonic mean diameter

a-2) Head loss by gravel

Calculated head loss as same as filter media

Filter	HMD $D(10^{-3}m)$	Depth L(m)	Re number Re	Coefficient C_D	Porosity ϵ	Shape coefficient α/β	Head loss h(m)
1st Gravel	2.0	0.100	3.3932	9.0416	0.35	5.5	0.009
2nd Gravel	5.0	0.100	8.4830	4.1992	0.35	5.5	0.002
3rd Gravel	9.0	0.100	15.2695	2.6795	0.35	5.5	0.001
4th Gravel	16.0	0.100	27.1457	1.7999	0.35	5.5	0.000
						Sum(h2)	0.012

HMD : Harmonic mean diameter

b) Under drain

b-1) Collecting orifice

Applied formula $h=1/C^2\times v^2/(2g)$

Item	Symbol	Design value		
Parameters				
Channel length	Lc		12.60	m
Channel number	Nc		16	channels
Collecting orifice diameter	Do		12	mm
Collecting orifice interval	Io		75	mm
Orifice number	No		1,008	pieces/channel
Orifice area	Ao		0.11	m^2/channel
Velocity coefficient	C		0.6	
gravity acceleration	g		9.81	m/sec^2
Calculation				
Average velocity at orifice	v	Qus/(Ao×Nc)=	0.0690	m/sec/orifice
Head loss	h3	$1/C^2\times v^2/(2g)$=	0.001	m

b-2) Underdrain channel

Applied formula : $h=L/v^2/(C^2/R)$ Munning's formula

$C^2=R^{1/3}/n^2$

Item	Symbol	Design value	
Parameters			
Number	Nc		16 channels
Length	Lc		13.2 m
Width	Wc		0.20 m
Height	Hc		0.24 m
Roughness coefficient	n		0.015
Calculation			
Unit section area	A	Nc×Wc=	0.048 m^2
Wetted perimeter	S	(Wc+Hc)×2=	0.88 m
Hydraulic radius	R	A/S=	0.0545 m
Average velocity	v	Qus/A=	0.1582 m/sec
	C^2	$R^{1/3}/n^2$=	1685.0637
Head loss	h4	$L/v^2/(C^2/R)$=	0.017 m

A.5-16

b-3) Underdrain outlet opening

Applied formula: $h=f\times v^2/(2g)$

Item	Symbol	Design value	
Parameters			
Gate width	Wg		2.40 m
Gate height	Hg		0.24 m
Number	N		2 openings
Inlet friction coefficient	fi		0.5
Outlet friction coefficient	fo		1.0
Gravity acceleration	g		9.81 m/sec^2
Calculation			
Average velocity at Gate	v	Qus/(Wg×Hg×N)=	0.1055 m/sec
Inlet head loss	hi	$fi\times vi^2/(2g)$ =	0.000 m
Outlet head loss	ho	$fo\times v^2/(2g)$=	0.001 m
Head loss	h5	hi+ho=	0.001 m

b-4) Outlet gate

Applied formula: $h=1/C^2\times v^2/(2g)$

Item	Symbol	Design value	
Parameters			
Width	Wg		0.60 m
Height	Hg		0.60 m
Number	N		2 gates
Velocity coefficient	C		0.6
Gravity acceleration	g		9.81 m/sec^2
Calculation			
Average velocity at opening	v	Qus/(Wg×Hg×N)=	0.1688 m/sec
Head loss	h6	$1/C^2\times v^2/(2g)$=	0.004 m

Total	h=h1+h2+h3+h4+h5+h6=	0.638 m	
	Say	0.64 m	
Initial effective head loss		1.16 m	
Water level at outlet of rapid sand filter		357.90 m	...OK

9. Rapid sand filtration (Backwash process)

9.1 Design condition

9.1.1 Design Flow

Maximum backwash flow	Qbm=	0.60 $m^3/m^2/min$
Coefficient	α=	1.0
Filter area	Af=	73.08 m^2
Design flow (Qbm×α×Af/60)	Qus=	0.7308 m^3/sec
	Qud=	63,141 m^3/day
Backwash velocity	Lvb=	0.0100 m/sec

9.1.2 Design water level

Inlet Channel 357.90 m

A.5-17

9.2 Head loss calculation

9.2.1 Backwash inlet gate

Applied formula $h=f \times v^2/(2g)$

Item	Symbol	Design value	
Parameters			
Gate width	Wg		0.60 m
Gate height	Hg		0.60 m
Number	N		2 gates
Inlet friction coefficient	fi		0.5
Outlet friction coefficient	fo		1.0
Gravity acceleration	g		9.81 m/sec^2
Calculation			
Average velocity at Gate	v	Qus/(Wg×Hg×N)=	1.0150 m/sec
Inlet head loss	hi	$fi \times vi^2/(2g)$ =	0.026 m
Outlet head loss	ho	$fo \times v^2/(2g)$=	0.053 m
Sum	h1	hi+ho=	0.079 m

9.2.2 Under drain and Filter media

1) Underdrain inlet opening

Applied formula $h=f\times v^2/(2g)$

Item	Symbol	Design value	
Parameters			
Opening width	Wg		2.40 m
Opening height	Hg		0.24 m
Number	N		2 openings
Inlet friction coefficient	fi		0.5
Outlet friction coefficient	fo		1.0
Gravity acceleration	g		9.81 m/sec^2
Calculation			
Average velocity at Gate	v	Qus/(Wg×Hg×N)=	0.6344 m/sec
Inlet head loss	hi	fi×vi^2/(2g) =	0.010 m
Outlet head loss	ho	fo×v^2/(2g)=	0.021 m
Sum	h2	hi+ho=	0.031 m

2) Underdrain channel

Applied formula : $h=fi\times v^2/(2g)$
$h=L\times v^2/(C^2/R)$
$C^2=R^{1/3}/n^2$

Item	Symbol	Design value	
Parameters			
Channel length	Lc		12.60 m
Channel Width	Wc		0.20 m
Channel Height	Hc		0.24 m
Number	N		16 channels
Equivalent length	Le	Lc/2=	6.30 m
Inlet friction coefficient	fi		0.5
Roughness coefficient	n		0.015
Gravity acceleration	g		9.81 m/sec^2
Calculation			
Section area	A	Wc×Hc=	0.048 m^2
Wetted perimeter	S	(Wc×Hc)×2=	0.88 m
Hydraulic radius	R	A/R=	0.0545 m
Average velocity	v	Qus/(A×N)=	0.9516 m/sec
Inlet head loss	hi	fi×v^2/(2g)=	0.023 m
Inside channel head loss	hc	C^2=R$^{1/3}$/n^2=	1685.06
		Le×v^2/(C^2/R)=	0.000 m
Sum	h3	hi+hc=	0.023 m

3) Collecting orifice

Applied formula $h=1/C^2 \times v^2/(2g)$

Item	Symbol	Design value	
Parameters			
Channel length	Lc		12.60 m
Channel number	Nc		16 channels
Collecting orifice diameter	Do		12 mm
Collecting orifice interval	Io		75 mm
Orifice number	No		1,008 pieces/channel
Orifice area per a channel	Ao	$3.14/4 \times Do^2 \times No=$	0.114 m^2/channel
Velocity coefficient	C		0.6
Gravity acceleration	g		9.81 m/sec^2
Calculation			
Average velocity at opening	v	$Qus/(Ao \times Nc)=$	0.4007 m/sec
Head loss	h4	$1/C^2 \times v^2/(2g)=$	0.023 m

A.5-19

4) Gravel

Applied formula : $h=\Sigma(0.178 \times C_D/g \times Lv^2/\epsilon^4 \times \alpha/\beta \times L/D)$ Fair-Hatch formula

$Re = \rho F \times D \times Lv/\mu$

C_D: $24/Re$ $(Re<1)$

$24/Re+3/Re^{1/2}+0.34$ $(Re>=1)$

Item	Symbol	Designed Value
Parameters		
Density of water	ρF	1,000.0 kg/m^3
Viscosity	μ	0.001 kg/m/sec
Gravity acceleration	g	9.81 m/sec^2
Back wash velocity	Lv	0.0100 m/sec

Filter	HMD $D(10^{-3}m)$	Depth L(m)	Re number Re	Coefficient C_D	Porosity ϵ	Shape coefficient α/β	Head loss h(m)
1st Gravel	2.0	0.100	20.00	2.2108	0.35	5.5	0.074
2nd Gravel	5.0	0.100	50.00	1.2443	0.35	5.5	0.017
3rd Gravel	9.0	0.100	90.00	0.9229	0.35	5.5	0.007
4th Gravel	16.0	0.100	160.00	0.7272	0.35	5.5	0.003
						Sum(h5)	0.101

HMD : Harmonic mean diameter

5) Filter media

Applied formula : $h=L(1-\epsilon)(\rho s-\rho_F)/1,000$

Item	Symbol	Designed Value
Parameters		
Filter layer depth	L	0.70 m
Porosity	ϵ	0.35
Dencity of sand	ρ_s	2,600 kg/m^3
Dencity of water	ρ_F	1,000 kg/m^3
Calculation		
Head loss	h6	$L(1-\epsilon)(\rho_s-\rho_F)/1,000=$ 0.728 m

Sum $h=h1+h2+h3+h4+h5+h6=$ 0.984 m

Say 0.98 m

Water level 356.92 m ...OK

Trough upper level + Critical depth for drain = 356.72 m

A.5-20

9.2.3 Backwash water drain trough

Filter layer surface level 355.90 m

Distance between filter surface and trough upper level 0.80 m

Trough upper level 356.70 m

1) Collecting trough inlet

Calculate as overflow weir.

Applied formula : $Q=C\times H\times h^{3/2}$

$C=1.785+(0.00295/h+0.237\times h/H)\times(1+\epsilon)$

$\epsilon=0$ (H =< 1.0m)

$\epsilon= 0.55\times(H-1.0)$ (H>1.0m)

Item	Symbol	Designed Value	
Parameters			
Trough length	Lt		6.05 m
Trough width	Lw		0.50 m
Trough height	Lh		0.35 m
Trough number	N		10 troughs
Distance between Filter surface level and Trough upper side level	W		0.80 m
Inlet flow	Qts	Qus/(N×2)=	0.0365 m^3/sec/side
Calculation			
Correction coefficient	ϵ		0.0000
Flow index	C		1.92919
Calculated flow	Qc		0.0365
Absolute error		Qc-Qts=	0.0000 m^3/sec
Overflow depth	h1	refer to "Over flow weir"	0.0214
		Say	0.02 m

Weir inlet water level 356.72 m

Drain Channel upper level 356.85 m ...OK

2) Collecting trough

Applied formula : $hc=(\alpha \times Q^2/(g \times Wt^2))^{1/3}$

Thomas-Camp formula

Freefall at bottom stream end

Item	Symbol	Designed Value
Parameters		
Trough length	Lt	6.05 m
Trough width	Wt	0.50 m
Trough height	Ht	0.35 m
Trough number	Ln	10 troughs
coefficient	α	1.1
Gravity acceleration	g	9.81 m/sec^2
Inclination of trough	i	0.0 ‰
Calculation		
Unit Trough flow	Q	Qus/N= 0.0731 $m^3/sec/trough$
Critical depth	hc	$(\alpha \times Q^2 / (g \times Wt^2))^{1/3}$ = 0.134 m
		App 0.13 m
Water depth at upstream end	hu	$(2hc^2 + (hc - iL/3)^2)^{1/2} - 2/3 \times iL$
		= 0.232 m
		Say 0.23 m
Clearance		0.34 m

A.5-21

Trough bottom level = Trough top level - trough depth = 356.35 m

Trough upstream end water level = Trough bottom level + upstream end water depth = 356.58 m

Trough downstream end water level = Trough bottom level + hc = 356.48 m

Drainage channel upstream end water level = Trough bottom level - Clearance = 356.01 m

3) Drainage channel

Applied formula : It shall be calculated as a open channel flow with side inflow (inlet angle is 90 degree). Water depth (h), at x meter from downstream side with continuously a side inflow, expresses "$dx^2/dh=x^2/h-(g/b^2/(\alpha/q^2)\times h^2$". Therefore, $f(h)=g\times Wc^2/(2\alpha\times q^2)\times h^3-C\times h+x^2=0$

Item	Symbol	Design value
Parameters		
Drainage channel length	Lc	13.55 m
Drainage channel width	Bc	1.5 m
Drainage channel water depth	Hc	1.41 m
Drainage channel Bottom level		354.60 m
Coefficient	α	1.1
Gravity acceleration	g	9.81 m/sec^2
Calculation		
Inlet flow from side	q	Qrs/L 0.0539 $m^3/sec/m$
Water depth at distance(x)	f(h)	$g\times Wc^2/(2\alpha\times q^2)\times h^3-C\times h+x^2$
		= 3,453.44 $h^3-C\times h+x^2$...(a)
Water depth at downst		
(x=0)	h(0)	1.410 m
Coefficient	C	(a) 6,996.00 ...(b)
Water depth at upstream end		
(x = Lc)	h(Lc)	(a),(b) 1.423 m
Head loss	h	h(0)-h(Bc)= 0.013
		Say 0.01 m

Downstream end water level = Upstream end water level - h = 356.00 m

4) Outlet siphon

Applied formula : $h = L/v^2/(C^2/R)$ Munning's formula

$C^2 = R^{1/3}/n^2$

Item	Symbol		Design value
Parameters			
Length	La-b		13.55 m
Width	Wa-b		0.75 m
Depth	Ha-b		0.90 m
Inlet friction coefficient	fi		0.9
Outlet friction coefficient	fo		0.7
Roughness coefficient	n		0.015
Gravity acceleration	g		9.81 m/sec^2
Calculation			
Average velocity	va-b		1.0747 m/sec
Head loss by syhon channel	hc	$L / v^2 / (C^2/R) =$	0.001 m
Inlet head loss	hi	$fi \times vi^2/(2g) =$	0.053 m
Outlet head loss	ho	$fo \times v^2/(2g) =$	0.041 m
Sum	hs		0.095 m
		Say	0.10 m
Clearance	h_{fb}		0.00 m
Head loss	h	$hs + h_{fb} =$	0.10 m

Water level after siphon 355.90 m

A.5-22

9.2.4 Drainage channel

1) Channel

Applied formula : $h = L/v^2/(C^2/R)$ Munning's formula

$C^2 = R^{1/3}/n^2$

Item	Symbol		Design value
Parameters			
Length	La-b		18.40 m
	Lb-c		10.00 m
Channel width	Wa-b		2.80 m
	Wb-c		2.00 m
Channel Bottom Level	Hba-b		354.40 m
	Hbb-c		354.40 m
Channel height	Ha-b		1.50 m
	Hb-c		1.50 m
Roughness coefficient	n		0.015
Gravity acceleration	g		9.81 m/sec^2
Calculation			
Average velocity	va-b		0.1744 m/sec
	vb-c		0.2444 m/sec
Head loss	ha-b	$L/v^2/(C^2/R)=$	0.000 m
	hb-c	$L/v^2/(C^2/R)=$	0.000 m
Sum	h1		0.000 m
		Say	0.00 m

2) Suppressed-rectangular weir

Applied formula : $Q=C\times H\times h^{3/2}$

$C=1.785+(0.00295/h+0.237\times h/H)\times(1+\epsilon)$

$\epsilon=0$ (H =< 1.0m)

$\epsilon=0.55\times(H-1.0)$ (H>1.0m)

Item	Symbol	Designed Value	
Parameters			
Width	W		2.00 m
Height	H		1.20 m
Calculation			
Correction coefficient	ϵ		0.1100
Velocity coefficient	C		1.86858
Calculated flow	Qc		0.7308 m^3/sec
Absolute error		Qc-Qus=	0.0000 m^3/sec
Overflow depth	h_w	Refer to "Overflow weir"	0.3369
		Say	0.34 m
Clearance	h_{fb}		0.10 m
Sum	h2	h_w+h_{fb}=	0.44 m

A.5-23

Sum h=h1+h2= 0.44 m

Water level after Weir 355.46 m

Weir level 355.60 m

10. Rapid Sand Filter - Chlorination Basin

10.1 Design condition

10.1.1 Design flow

Total flow	Qtd=	100,000 m^3/day
	Qts=	1.1574 m^3/sec
Filter number		12 filters
Backwashing filter number		1 filter
Suspended filter number at backwashing period		1 filter
Operated filter number under backwashing process		10 filter
Unit flow	Qud=	10,000.0 m^3/day/filter
	Qus=	0.1157 m^3/sec/filter

10.1.2 Design water level

Outlet end of Rapid sand Filter 357.90 m

10.2 Head loss calculation

10.2.1 Outlet channel

Section flow	Section a-b	Qsa-b=	0.2315 m^3/sec
	b-c	Qsb-c=	0.4630 m^3/sec
	c-d	Qsc-d=	0.6944 m^3/sec
	d-e	Qsd-e=	0.8102 m^3/sec
	e-f	Qse-f=	1.0417 m^3/sec
	f-g	Qsf-g=	1.2731 m^3/sec

Applied formula : $h = L / v^2 / (C^2/R)$ Munning's formula

$C^2 = R^{1/3}/n^2$

Item	Symbol	Design value
Parameters		
Length	La-b	10.00 m
	Lb-c	10.00 m
	Lc-d	10.00 m
	Ld-e	10.00 m
	Le-f	10.00 m
	Lf-g	10.00 m
Section area	Aa-b	10.29 m
	Ab-c	10.29 m
	Ac-d	10.29 m
	Ad-e	10.29 m
	Ae-f	10.29 m
	Af-g	10.29 m
Wetted perimeter	Sa-b	12.00 m
	Sb-c	12.00 m
	Sc-d	12.00 m
	Sd-e	12.00 m
	Se-f	12.00 m
	Sf-g	12.00 m
Roughness coefficient	n	0.015
Gravity acceleration	g	9.81 m/sec^2

Item	Symbol	Design value	
Calculation			
Average velocity	va-b		0.0225 m/sec
	vb-c		0.0450 m/sec
	vc-d		0.0675 m/sec
	vd-e		0.0787 m/sec
	ve-f		0.1012 m/sec
	vf-g		0.1237 m/sec
Head loss	ha-b	$L / v^2 / (C^2 / R) =$	0.000 m
	hb-c	$L / v^2 / (C^2 / R) =$	0.000 m
	hc-d	$L / v^2 / (C^2 / R) =$	0.000 m
	hd-e	$L / v^2 / (C^2 / R) =$	0.000 m
	he-f	$L / v^2 / (C^2 / R) =$	0.000 m
	hf-g	$L / v^2 / (C^2 / R) =$	0.000 m
	Sum		0.000 m
		Say	0.00 m

Water level at downstream end of channel 357.90 m

10.2.2 Outlet weir at end of Rapid sand filter

Weir type: Suppressed-rectangular weir

Applied formula: $Q=C\times H\times h^{3/2}$

$C=1.785+(0.00295/h+0.237\times h/H)\times(1+\epsilon)$

$\epsilon=0$ (H =< 1.0m)

$\epsilon=0.55\times(H-1.0)$ (H>1.0m)

Item	Symbol	Designed	Value
Parameters			
Width	Ww		1.50 m
Height	Hw		3.10 m
Number	N		10 weirs
Calculation			
Unit flow	Qus	Qds/N=	0.1157 m^3/sec/weir
Correction coefficient	ϵ		1.1550
Flow index	C		1.85287
Calculated flow	Qc		0.1519 m^3/sec
Absolute error		Qus-Qc=	0.0362 m^3/sec
Overflow depth	h_o	refer to "Overflow weir"	0.1440
		Say	0.14 m
Clearance	h_{fb}		0.26 m
Head loss	h	h_o+h_{fb}=	0.40 m

Water level after Weir 357.50 m

Weir level 357.76 m ...OK

10.2.3 Outlet channel

Applied formula: $h=L/v^2/(C^2/R)$ Munning's formula

$C^2=R^{1/3}/n^2$

Item	Symbol	Design value	
Parameters			
Length	La-b		31.80 m
Width	Wa-b		2.45 m
Height	Ha-b		2.90 m
Roughness coefficient	n		0.015
Gravity acceleration	g		9.81 m/sec^2
Calculation			
Average velocity	va-b		0.1630 m/sec
Head loss	ha-b	$L/v^2/(C^2/R)$=	0.000 m
		Say	0.00 m

Water level at downstream end 357.50 m

10.2.4 Outlet orifice

Applied formula $h=1/C^2\times v^2/(2g)$

Item	Symbol	Design value	
Parameters			
Width	Wo		3.00 m
Height	Ho		2.70 m
Velocity coefficient	C		0.6
Gravity acceleration	g		9.81 m/sec^2
Calculation			
Average velocity at opening	v	Qds/(Wo×Ho)=	0.1429 m/sec
Head loss	h	$1/C^2\times v^2/(2g)$=	0.003 m
		say	0.00 m

Water level after outlet orifice 357.50 m

11. Chrolination Basin

11.1 Design condition

11.1.1 Design flow

Total flow	Qdd=	105,000 m^3/day
Unit number		1 channel
Design unit flow	Qud=	105,000 m^3/day/channel
	Qus=	1.2153 m^3/sec/channel

(2) Design water level

Inlet end of Chrolination Basin	357.50 m

11.2 Head loss calculatiuon

11.2.1 Channel

Applied formula : $hc=L\times v^2/(Cc^2/R)$ Munning's formula

$Cc^2=R^{1/3}/n^2$

$ht=ft\times v^2/(2g)$

A.5-26

Item	Symbol		Design value
Parameters			
Width	W		3.00 m
Channel width	Wc		3.80 m
Length	L		48.00 m
Wall depth of baffle wall	Db		0.20 m
Turn number	Nt		12
Channel bottom level	Hcb		354.40 m
Opening width	Wo		1.00 m
Velocity coefficient	C		0.6
Loss coefficient by turn	ft	$1/C^2$=	2.8
Roughness coefficient	n		0.015
Gravity accelaration	g		9.81 m/sec^2

Item	Symbol			Design value
Calculation				
Upstream water depth	Dwu			3.100 m
Downstream water depth	Dwd			2.815 m
Average water depth	Dwa			2.958 m
Design average water depth	Ddw			2.98 m
Average velocity at opening	vt			0.4078 m/sec
Average velocity at channel	vc			0.1073 m/sec
Section area	A			11.32 m^2
Wetted perimeter	S			9.76 m
Hydraulic radius	R			1.1598 m
Channel length	L			50.00 m
	Cc^2	$R^{1/3}/n^2$=		4,669.59
Head loss by turn	ht	$N\times ft\times vt^2/(2g)$=		0.285 m
Head loss by channel	hc	$L/v^2/(Cc^2/R)$=		0.000 m
	Sum			0.285 m
	h		Say	0.29 m
Clearance	h_{fb}			0.01 m
Head loss	h			0.30 m

Water level at downstream end of channel	357.20 m

11.2.2 Outlet orifice

Applied formula $h=1/C^2\times v^2/(2g)$

Item	Symbol			Design value
Parameters				
Width	Wo			3.00 m
Height	Ho			2.70 m
Velocity coefficient	C			0.6
Gravity acceleration	g			9.81 m/sec^2
Calculation				
Average velocity at opening	v	Qus/(Wo×Ho)=		0.1500 m/sec
Head loss	h	$1/C^2\times v^2/(2g)$=		0.003 m
			Say	0.00 m

Water level after outlet orifice	357.20 m

12. Chrolination Basin - Distribution Reservoir

12.1 Design condition

12.1.1 Design flow

Total flow	Qtd=	105,000 m^3/day
Route number		1 route
Design flow per a route	Qrd=	105,000 m^3/day/route
	Qrs=	1.2153 m^3/sec/route

12.1.2 Design water level

Outle end of Chlorination Basin 357.20 m

12.2 Head loss calculation

12.2.1 Connection pipeline

A.5-27

Applied formulary : $h_f = I \times L$

$I = 10.666 \times C^{1.85} \times D^{-4.87} \times Q^{1.85}$ Hazen-Williams formulary

$h_s = f t \times v^2/(2g)$

Item	Symbol	Design value	
Coefficient			
Diameter	D		1,200 mm
Length	L		14.0 m
Velocity coefficient	C		110
Gravity acceleration	g		9.81 m/sec^2
Calculation			
Average velocity	V		0.9305 m/sec
Friction loss	h_f	Refer to "Pipeline"	0.019 m
Shape loss	h_s	Refer to "Pipeline"	0.092 m
Sum	h_p	$h_s+h_f=$	0.111 m
		Say	0.11 m
Clearance	h_c		0.09 m
Total	h	$h_p+h_c=$	0.20 m

Water level after connection pipeline 357.00 m ...OK

Distribution Reservoir HWL 357.00 m

13. Sedimentation Basin - Thickener

13.1 Design condition

13.1.1 Design flow

Drainage flow		2,200 m^3/day
Drainage period		48 times/day
Drainage time		10 min
Route number		1 route
Design flow per time	Qus=	0.0764 m^3/sec/time
	Qud=	6,601 m^3/day/time

13.1.2 Design water level

Sedimentation Basin LWL-500	356.80 m
Thickener HWL+500	354.50 m

13.2 Head loss calculation

13.2.1 Drainage pipeline

Applied formular : Hazen-Williams

$h = 10.666 \times C^{-1.85} \times D^{-4.87} \times Q^{1.85} \times L$

Item	Symbol	Design value	
Coefficient			
Diameter	D	Da-b	250 mm
Length	L	La-b	440.0 m
Flow index	C		110
Gravity accerelation	g		9.81 m/sec^2
Calculation			
Average velocity	v		0.932 m/sec
Friction loss	h_f		2.244 m
Shape loss	h_s		0.000 m
Sum	h	$h_f+h_s=$	2.244 m

Outlet water level 354.500 ...OK

14. Rapid Sand Filter - Wash Drain Basin

14.1 Design condition

14.1.1 Design flow

Unit Drainage flow	63,141	m3/day/time
	0.7308	m3/sec/time

14.1.2 Design Water Level

Backwash drainage channel	355.46	m
Washing Drain Basin HWL	353.80	m

14.2 Head loss calculation

14.2.1 Drainage pipeline

Applied formular : Hazen-Williams

$h=10.666\times C^{1.85}\times D^{-4.87}\times Q^{1.85}\times L$

Item	Symbol	Design value		
Coefficient				
Diameter	D	Da-b	1,000	mm
Length	L	La-b	30.0	m
Flow index	C		110	
Gravity accerelation	g		9.81	m/sec^2
Calculation				
Average velocity	v		1.520	m/sec
Friction loss	h_f		0.770	m
Shape loss	h_s		0.000	m
Sum	h	h_f+h_s=	0.770	m
		App	0.77	m

Outlet water level 354.69 m ...OK

15. Washing Drain Basin - Distribution Basin

15.1 Design Condition

15.1.1 Design Flow

Distribution flow		1,284	m^3/time
Distribution time		60	min
Unit number		1	line
Unit flow	Qus=	0.3567	m^3/sec
	Qud=	30,819	m^3/day

15.1.2 Design Water Level

Washing Drain Basin LWL	349.50	m
Distribution Basin HWL	363.40	m

15.2 Head Loss Calculation

15.2.1 Pipeline

Applied formular : Hazen-Williams

$h=10.666\times C^{1.85}\times D^{-4.87}\times Q^{1.85}\times L$

Item	Symbol	Design value		
Coefficient				
Diameter	D	Da-b	600	mm
Length	L	La-b	615.0	m
Flow index	C		110	
Gravity accerelation	g		9.81	m/sec^2
Calculation				
Average velocity	v		0.641	m/sec
Friction loss	h_f		0.554	m
Shape loss	h_s		0.000	m
Pump loss	h_p		3.000	m
Sum	h	$h_f+h_s+h_p$=	0.554	m
		App	3.55	m

Required pump head	19.000 m	
Outlet water level	364.947 m	. . . OK

16. Thickener - Dischrage Pool

16.1 Design Condition

16.1.1 Design Flow

Inlet flow into Thickener		2,200	m^3/day
Outlet flow to Sludge Drying Bed		900	m^3/day
Outlet flow to Discharge Pool		1,300	m^3/day
Unit number		1	line
Unit flow	Qud=	1,300.0	m^3/day
	Qus=	0.0150	m^3/sec

16.1.2 Design Water Level

Thickener HWL	353.30	m
Discharge Pool HWL	350.50	m

16.2 Head loss Calculation

16.2.1 Pipeline

A.5-29

Applied formular : Hazen-Williams

$h=10.666\times C^{-1.85}\times D^{-4.87}\times Q^{1.85}\times L$

Item	Symbol	Design value		
Coefficient				
Diameter	D	Da-b	200	mm
Length	L	La-b	60.0	m
Flow index	C		130	
Gravity accerelation	g		9.81	m/sec^2
Calculation				
Average velocity	v	Refer to "Pipeline"	0.478	m/sec
Friction loss	h_f	Refer to "Pipeline"	0.084	m
Shape loss	h_s	Refer to "Pipeline"	0.022	m
Pump loss	h_p		3.000	m
Sum	h	$h_f+h_s+h_p=$	3.106	m

Required pump head	8.500	m	
Inlet water level at Discharge Pool	358.694	m	...OK

17. Thickener - Sludge Drying Bed

17.1 Design Condition

17.1.1 Design Flow

Required Sludge Flow		900	m^3/day
Pump operation time		12	hr/day
Design Sludge Flow per time	Qrd	1,800	m^3/day
	Qrs	0.0208	m^3/sec

17.1.2 Design Water Level

Thickener LWL	350.50	m
Sludge Drying Bed WL	363.40	m

17.2 Head loss Calculation

17.2.1 Pipeline

Applied formular : Hazen-Williams

$h=10.666\times C^{-1.85}\times D^{-4.87}\times Q^{1.85}\times L$

Item	Symbol	Design value		
Coefficient				
Diameter	D	Da-b	200	mm
Length	L	La-b	60.0	m
Flow index	C		130	
Gravity accerelation	g		9.81	m/sec^2
Calculation				
Average velocity	v		1.783	m/sec
Friction loss	h_f	Refer to "Pipeline"	1.373	m
Shape loss	h_s	Refer to "Pipeline"	0.251	m
Pump loss	h_p		3.000	m
Sum	h	$h_f+h_s+h_p=$	4.624	m
		App	4.62	m

Required pump head	20.00	m	
Inlet water level at Sludge Drying Bed	365.88	m	...OK

18. Sludge Drying Bed - Discharge Pool

18.1 Design Condition

18.1.1 Design Flow

Total flow		450	m^3/day
Unit number		1	line
Unit flow	Qud=	450	m^3/day
	Qus=	0.0052	m^3/sec

18.1.2 Design Water Level

Sludge Drying Bed WL	351.00	m
Discharge Pool HWL	350.50	m

18.2 Head loss Calculation

18.2.1 Pipeline

A.5-30

Applied formular : Hazen-Williams

$h=10.666\times C^{-1.85}\times D^{-4.87}\times Q^{1.85}\times L$

Item	Symbol	Design value	
Coefficient			
Diameter	D	Da-b	200 mm
Length	L	La-b	60.0 m
Flow index	C		130
Gravity accereleration	g		9.81 m/sec^2
Calculation			
Average velocity	v	Refer to "Pipeline"	0.166 m/sec
Friction loss	h_f	Refer to "Pipeline"	0.012 m
Shape loss	h_s	Refer to "Pipeline"	0.001 m
Sum	h	h_f+h_s=	0.013 m
		App	0.01 m

Inlet water level at Discharge Pool 350.99 m ...OK

19. Discharge Pool - Manhole

19.1 Design Condition

19.1.1 Design Flow

Total flow		3,000	m3/day
Unit number		1	line
Unit flow	Qud=	3,000	m^3/day
	Qus=	0.0347	m^3/sec

19.1.2 Design Water Level

Discharge Pool LWL	347.50	m
Manhole WL	350.00	m

19.2 Head loss Calculation

19.2.1 Pipeline

Applied formular : Hazen-Williams

$h = 10.666\times C^{-1.85}\times D^{-4.87}\times Q^{1.85}\times L$

Item	Symbol	Design value	
Coefficient			
Diameter	D	Da-b	200 mm
Length	L	La-b	25.0 m
Flow index	C		110
Gravity accereleration	g		9.81 m/sec^2
Calculation			
Average velocity	v		1.100 m/sec
Friction loss	h_f		0.028 m
Shape loss	h_s		0.000 m
Pump loss	h_p		3.000 m
Sum	h	$h_f+h_s+h_p$=	3.028 m
		App	3.03 m

Required pump head 8.000 m

Inlet water level at Discharge Pool 352.47 m ...OK

Head loss at pipeline

Applied formula $h = I \times L$ Hazen-Williams formula
$I = 10.666 \times C^{1.85} \times D^{-4.87} \times Q^{1.85}$

1. Distribution Chamber - Receiving Well

1.1 Designed flow

Section	Flow
A-B	105,000 m^3/day

1.2 Head loss calculation

(1) **Friction loss**

C= 130
g= 9.81 m/sec^2

Interface / Section	Flow Q (m^3/sec)	Flow Q (m^3/day)	Pipe Diameter D (mm)	Length L (m)	Velocity of flow v (m/sec)	Hydraulic gradient I (‰)	Head loss h (m)	Remarks
A								
A - B	1.2153	105,000.0	φ 1,200	80.0	1.0746	0.7731	0.062	
B								
Sub-total Route A-B				80.0			0.062	

(2) **Shape Loss**

Items	Diameter D (mm)	Number N (-)	Friction f	Quantity Q (m^3/sec)	Quantity Q (m^3/day)	Velocity v (m/sec)	Head loss h (m)	Remarks
A-B	φ 1,200			1.2153	105,000.0	1.0746		
Inlet	φ 1,200	1	0.250	1.2153	105,000.0	1.0746	0.015	
Bend 90°	φ 1,200	2	0.260	1.2153	105,000.0	1.0746	0.031	
11°1/4	φ 1,200	2	0.026	1.2153	105,000.0	1.0746	0.003	
Distributic ×φ1200	φ 1,200	1	0.060	1.2153	105,000.0	1.0746	0.004	
Valve Gate	φ 1,200	1	0.300	1.2153	105,000.0	1.0746	0.018	Full open
Outlet	φ 1,200	1	1.000	1.2153	105,000.0	1.0746	0.059	
Sum							0.130	
Sub-total Route A-B							0.130	
Total Friction loss + shape loss							0.192	

Applied formula $h = I \times L$ Hazen-Williams formula
$I = 10.666 \times C^{1.85} \times D^{-4.87} \times Q^{1.85}$

2. Inlet pipeline (Rapid sand filter)

2.1 Design Flow

Section	Flow
A-B	10,500 m^3/day

2.2 Head loss calculation

(1) **Friction loss**

C= 130
g= 9.81 m/sec^2

Interface / Section	Flow Q (m^3/sec)	Flow Q (m^3/day)	Pipe Diameter D (mm)	Length L (m)	Velocity v (m/sec)	Hydraulic gradient I (‰)	Head loss h (m)	Remarks
A								
A - B	0.1215	10,500.0	φ 500	4.0	0.6188	0.7757	0.003	
B								
Sub-total Route A-B				4.0			0.003	

(2) **Shape Loss**

Items	Diameter D (mm)	Number N (-)	Friction f	Quantity Q (m^3/sec)	Quantity Q (m^3/day)	Velocity v (m/sec)	Head loss h (m)	Remarks
A-B	φ 500			0.1215	10,500.0	0.6188		
Inlet	φ 500	1	0.500	0.1215	10,500.0	0.6189	0.010	
Bend 90°	φ 500	1	0.220	0.1215	10,500.0	0.6189	0.004	
Outlet	φ 500	1	1.000	0.1215	10,500.0	0.6189	0.020	
Sum							0.034	
Sub-total Route A-B							0.034	
Total Friction loss + shape loss							0.037	

Applied formula $h = I \times L$ Hazen-Williams formula
$I = 10.666 \times C^{1.85} \times D^{-4.87} \times Q^{1.85}$

3. Chlorination Basin - Distribution Reservoir

3.1 Design flow

Section	Flow
A-B	105,000.0 m^3/day

3.2 Head loss calculation

(1) Friction loss

C= 130
g= 9.81 m/sec^2

Interface / Section	Flow Q (m^3/sec)	Flow Q (m^3/day)	Pipe Diameter D (mm)	Length L (m)	Velocity v (m/sec)	Hydraulic gradient I (‰)	Head loss h (m)	Remarks
A								
A - B	1.2153	105,000.0	φ 1,200	25.0	1.0746	0.7731	0.019	
B								
Sub-total Route A-B				25.0			0.019	

(2) Shape Loss

Items	Diameter D (mm)	Number N (-)	Friction f	Quantity Q (m^3/sec)	Quantity Q (m^3/day)	Velocity v (m/sec)	Head loss h (m)	Remarks
A-B	φ 1,200			1.2153	105,000.0	1.0746		
Inlet	φ 1,200	1	0.250	1.2153	105,000.0	1.0746	0.015	
Valve Gate	φ 1,200	1	0.300	1.2153	105,000.0	1.0746	0.018	Full Open
Outlet	φ 1,200	1	1.000	1.2153	105,000.0	1.0746	0.059	
Sum							0.092	

Head loss at pipeline

Applied formula h=I×L Hazen-Williams formula
$I=10.666\times C^{-1.85}\times D^{-4.87}\times Q^{1.85}$

4. Sedimentation Basin - Thickener

4.1 Design Flow

Section	Flow
A-B	6,601.0 m^3/day

4.2 Head loss calculation

(1) Friction loss

C= 130 g= 9.81 m/sec^2

Interface / Section	Flow Q (m^3/sec)	Flow Q (m^3/day)	Pipe Diameter D (mm)	Length L (m)	Velocity v (m/sec)	Hydraulic gradient I (‰)	Head loss h (m)	Remarks
A								
A - B	0.0764	6,601.0	φ 150	140.0	4.3234	115.7083	16.199	
B								
Sub-total Route A-B				140.0			16.199	

(2) Shape Loss

Items	Diameter D (mm)	Number N (-)	Friction f	Quantity Q (m^3/sec)	Quantity Q (m^3/day)	Velocity v (m/sec)	Head loss h (m)	Remarks
A-B	φ 150			0.0764	6,601.0	4.3234		
Inlet	φ 150	1	0.250	0.0764	6,601.0	4.3234	0.238	
Suddenly expansion	φ 150	0	0.000	0.0764	6,601.0	4.3234	0.000	
Suddenly reduction	φ 150	0	0.000	0.0764	6,601.0	4.3234	0.000	
Gradually expansion	φ 150	0	0.000	0.0764	6,601.0	4.3234	0.000	
Gradually reduction	φ 150	0	0.000	0.0764	6,601.0	4.3234	0.000	
Bend 90°	φ 150	4	0.000	0.0764	6,601.0	4.3234	0.000	
45°	φ 150	0	0.000	0.0764	6,601.0	4.3234	0.000	
22°1/2	φ 150	0	0.000	0.0764	6,601.0	4.3234	0.000	
11°1/4	φ 150	0	0.000	0.0764	6,601.0	4.3234	0.000	
Elbow 90°	φ 150	0	0.986	0.0764	6,601.0	4.3234	0.000	
45°	φ 150	0	0.183	0.0764	6,601.0	4.3234	0.000	
22°1/2	φ 150	0	0.039	0.0764	6,601.0	4.3234	0.000	
11°1/4	φ 150	0	0.009	0.0764	6,601.0	4.3234	0.000	
Distribution	φ 150	0		0.0764	6,601.0	4.3234	0.000	
Combination	φ 150	0		0.0764	6,601.0	4.3234	0.000	
Valve Gate	φ 150	3	1.000	0.0764	6,601.0	4.3234	2.858	Full Open
Check	φ 150	0	0.500	0.0764	6,601.0	4.3234	0.000	
Outlet	φ 150	1	1.000	0.0764	6,601.0	4.3234	0.953	
Sum							4.049	
Sub-total Route A-B							4.049	
Total Friction loss + shape loss							20.248	

Applied formula h=I×L Hazen-Williams formula
$I=10.666\times C^{-1.85}\times D^{-4.87}\times Q^{1.85}$

5. Sedimentation Basin - Washing Drain Basin

5.1 Design flow

Section	Flow
A-B	63,141 m^3/day

5.2 Head loss calculation

(1) Friction loss

C= 130
g= 9.81 m/sec^2

Interface / Section	Flow Q (m^3/sec)	Flow Q (m^3/day)	Pipe Diameter D (mm)	Length L (m)	Velocity v (m/sec)	Hydraulic gradient I (‰)	Head loss h (m)	Remarks
A								
A - B	0.7308	63,141.0	φ 1,000	30.0	0.9305	0.7332	0.022	
B								
Sub-total Route A-B				30.0			0.022	

(2) Shape Loss

Items	Diameter D (mm)	Number N (-)	Friction f	Quantity Q (m^3/sec)	Quantity Q (m^3/day)	Velocity v (m/sec)	Head loss h (m)	Remarks
A-B	φ 1,000			0.7308	63,141.0	0.9305		
Inlet	φ 1,000	1	0.250	0.7308	63,141.0	0.9305	0.011	
Bend 90°	φ 1,000	2	0.240	0.7308	63,141.0	0.9305	0.021	
Valve Gate	φ 1,000	1	0.300	0.7308	63,141.0	0.9305	0.013	Full open
Outlet	φ 1,000	1	1.000	0.7308	63,141.0	0.9305	0.044	
Sum							0.089	
Sub-total Route A-B							0.089	
Total Friction loss + shape loss							0.111	

Head loss at pipeline

Applied formula $h = I \times L$ Hazen-Williams formula
$I = 10.666 \times C^{-1.85} \times D^{-4.87} \times Q^{1.85}$

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6. Rapid Sand Filter - Wash Drain Basin

6.1 Design Flow

Section	Flow
A-B	63,141 m^3/day

6.2 Head loss calculation

(1) Friction loss

C= 130
g= 9.81 m/sec^2

Interface / Section	Flow Q (m^3/sec)	Flow Q (m^3/day)	Pipe Diameter D (mm)	Length L (m)	Velocity v (m/sec)	Hydraulic gradient I (‰)	Head loss h (m)	Remarks
A								
A - B	0.7308	63,141.0	φ 1,000	30.0	0.9305	0.7332	0.022	
B								
Sub-total Route A-B				30.0			0.022	

(2) Shape Loss

Items	Diameter D (mm)	Number N (-)	Friction f	Quantity Q (m^3/sec)	Quantity Q (m^3/day)	Velocity v (m/sec)	Head loss h (m)	Remarks
A-B	φ 1,000			0.7308	63,141.0	0.9305		
Inlet	φ 1,000	1	0.250	0.7308	63,141.0	0.9305	0.011	
Bend 90°	φ 1,000	1	0.240	0.7308	63,141.0	0.9305	0.011	
Outlet	φ 1,000	1	1.000	0.7308	63,141.0	0.9305	0.044	
Sum							0.066	
Sub-total Route A-B							0.066	
Total Friction loss + shape loss							0.088	

Head loss at pipeline

Applied formula $h = I \times L$ Hazen-Williams formula
$I = 10.666 \times C^{-1.85} \times D^{-4.87} \times Q^{1.85}$

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7. Wash Drain Basin - Distribution Chamber

7.1 Design Flow

Section	Flow
A-B	30,240.0 m^3/day

7.2 Head loss calculation

(1) **Friction loss**

C= 130 g= 9.81 m/sec^2

Interface / Section	Flow Q (m^3/sec)	Flow Q (m^3/day)	Pipe Diameter D (mm)	Length L (m)	Velocity v (m/sec)	Hydraulic gradient I (‰)	Head loss h (m)	Remarks
A								
A - B	0.3500	30,240.0	φ 500	250.0	1.7825	5.4922	1.373	
B								
Sub-total Route A-B				250.0			1.373	

(2) **Shape Loss**

Items	Diameter D (mm)	Number N (-)	Friction f	Quantity Q (m^3/sec)	Quantity Q (m^3/day)	Velocity v (m/sec)	Head loss h (m)	Remarks
A-B	φ 500			0.3500	30,240.0	1.7825		
Inlet	φ 500	1	0.250	0.3500	30,240.0	1.7825	0.040	
Suddenly expansion	φ 500	0	0.000	0.3500	30,240.0	1.7825	0.000	
Suddenly reduction	φ 500	0	0.000	0.3500	30,240.0	1.7825	0.000	
Gradually expansion	φ 500	0	0.000	0.3500	30,240.0	1.7825	0.000	
Gradually reduction	φ 500	0	0.000	0.3500	30,240.0	1.7825	0.000	
Bend 90°	φ 500	0	0.220	0.3500	30,240.0	1.7825	0.000	
45°	φ 500	0	0.112	0.3500	30,240.0	1.7825	0.000	
22°1/2	φ 500	0	0.064	0.3500	30,240.0	1.7825	0.000	
11°1/4	φ 500	0	0.018	0.3500	30,240.0	1.7825	0.000	
Elbow 90°	φ 500	0	0.986	0.3500	30,240.0	1.7825	0.000	
45°	φ 500	0	0.183	0.3500	30,240.0	1.7825	0.000	
22°1/2	φ 500	0	0.039	0.3500	30,240.0	1.7825	0.000	
11°1/4	φ 500	0	0.009	0.3500	30,240.0	1.7825	0.000	
Distribution	φ 500	0		0.3500	30,240.0	1.7825	0.000	
Combination	φ 500	0		0.3500	30,240.0	1.7825	0.000	
Valve Gate	φ 500	1	0.300	0.3500	30,240.0	1.7825	0.049	Full open
Check	φ 500	0	0.500	0.3500	30,240.0	1.7825	0.000	
Outlet	φ 500	1	1.000	0.3500	30,240.0	1.7825	0.162	
Sum							0.251	
Sub-total Route A-B							0.251	
Total Friction loss + shape loss							1.624	

Applied formula h=I×L Hazen-Williams formula

$I=10.666\times C^{-1.85}\times D^{-4.87}\times Q^{1.85}$

8. Thickener - Sludge Drying Bed

8.1 Design Flow

Section	Flow
A-B	1,800.0 m^3/day

8.2 Head loss calculation

(1) **Friction loss**

C= 130 g= 9.81 m/sec^2

Interface / Section	Flow Q (m^3/sec)	Flow Q (m^3/day)	Pipe Diameter D (mm)	Length L (m)	Velocity v (m/sec)	Hydraulic gradient I (‰)	Head loss h (m)	Remarks
A								
A - B	0.0208	1,800.0	φ 200	60.0	0.6621	2.5681	0.154	
B								
Sub-total Route A-B				60.0			0.154	

(2) **Shape Loss**

Items	Diameter D (mm)	Number N (-)	Friction f	Quantity Q (m^3/sec)	Quantity Q (m^3/day)	Velocity v (m/sec)	Head loss h (m)	Remarks
A-B	φ 200			0.0208	1,800.0	0.6621		
Inlet	φ 200	1	0.250	0.0208	1,800.0	0.6621	0.006	
Suddenly expansion	φ 200	0	0.000	0.0208	1,800.0	0.6621	0.000	
Suddenly reduction	φ 200	0	0.000	0.0208	1,800.0	0.6621	0.000	
Gradually expansion	φ 200	0	0.000	0.0208	1,800.0	0.6621	0.000	
Gradually reduction	φ 200	0	0.000	0.0208	1,800.0	0.6621	0.000	
Bend 90°	φ 200	4	0.170	0.0208	1,800.0	0.6621	0.015	
45°	φ 200	0	0.084	0.0208	1,800.0	0.6621	0.000	
22°1/2	φ 200	0	0.048	0.0208	1,800.0	0.6621	0.000	
11°1/4	φ 200	0	0.016	0.0208	1,800.0	0.6621	0.000	
Elbow 90°	φ 200	0	0.986	0.0208	1,800.0	0.6621	0.000	
45°	φ 200	0	0.183	0.0208	1,800.0	0.6621	0.000	
22°1/2	φ 200	0	0.039	0.0208	1,800.0	0.6621	0.000	
11°1/4	φ 200	0	0.009	0.0208	1,800.0	0.6621	0.000	
Distribution	φ 200	0		0.0208	1,800.0	0.6621	0.000	
Combination	φ 200	0		0.0208	1,800.0	0.6621	0.000	
Valve Gate	φ 200	3	1.000	0.0208	1,800.0	0.6621	0.067	Full open
Check	φ 200	0	0.500	0.0208	1,800.0	0.6621	0.000	
Outlet	φ 200	1	1.000	0.0208	1,800.0	0.6621	0.022	
Sum							0.110	
Sub-total Route A-B							0.110	
Total Friction loss + shape loss							0.264	

Applied formula h=I×L Hazen-Williams formula

$I=10.666\times C^{-1.85}\times D^{-4.87}\times Q^{1.85}$

9. Thickener - Discharge Pool

9.1 Design Flow

Section	Flow
A-B	1,300 m^3/day

9.2 Head loss calculation

(1) **Friction loss**

C= 130 g= 9.81 m/sec^2

Interface / Section	Flow Q (m^3/sec)	Flow Q (m^3/day)	Pipe Diameter D (mm)		Length L (m)	Velocity v (m/sec)	Hydraulic gradient I (‰)	Head loss h (m)	Remarks
A									
A - B	0.0150	1,300.0	φ	200	60.0	0.4775	1.4027	0.084	
B									
Sub-total									
Route A-B					60.0			0.084	

(2) **Shape Loss**

Items	Diameter D (mm)		Number N (-)	Friction f	Quantity Q (m^3/sec)	Quantity Q (m^3/day)	Velocity v (m/sec)	Head loss h (m)	Remarks
A-B	φ	200			0.0150	1,300.0	0.4775		
Inlet	φ	200	1	0.250	0.0150	1,300.0	0.4775	0.003	
Suddenly expansion	φ	200	0	0.000	0.0150	1,300.0	0.4775	0.000	
Suddenly reduction	φ	200	0	0.000	0.0150	1,300.0	0.4775	0.000	
Gradually expansion	φ	200	0	0.000	0.0150	1,300.0	0.4775	0.000	
Gradually reduction	φ	200	0	0.000	0.0150	1,300.0	0.4775	0.000	
Bend 90°	φ	200	2	0.170	0.0150	1,300.0	0.4775	0.004	
45°	φ	200	0	0.084	0.0150	1,300.0	0.4775	0.000	
22°1/2	φ	200	0	0.048	0.0150	1,300.0	0.4775	0.000	
11°1/4	φ	200	0	0.016	0.0150	1,300.0	0.4775	0.000	
Elbow 90°	φ	200	0	0.986	0.0150	1,300.0	0.4775	0.000	
45°	φ	200	0	0.183	0.0150	1,300.0	0.4775	0.000	
22°1/2	φ	200	0	0.039	0.0150	1,300.0	0.4775	0.000	
11°1/4	φ	200	0	0.009	0.0150	1,300.0	0.4775	0.000	
Distribution	φ	200	0		0.0150	1,300.0	0.4775	0.000	
Combination	φ	200	0		0.0150	1,300.0	0.4775	0.000	
Valve Gate	φ	200	1	0.300	0.0150	1,300.0	0.4775	0.003	Full open
Check	φ	200	0	0.500	0.0150	1,300.0	0.4775	0.000	
Outlet	φ	200	1	1.000	0.0150	1,300.0	0.4775	0.012	
Sum								0.022	
Sub-total									
Route A-B								0.022	
Total Friction loss + shape loss								0.106	

Applied formula $h = I \times L$ Hazen-Williams formula

$I = 10.666 \times C^{-1.85} \times D^{-4.87} \times Q^{1.85}$

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10. Sludge Drying Bed - Discharge Pool

10.1 Design Flow

Section	Flow
A-B	450 m^3/day

10.2 Head loss calculation

(1) **Friction loss**

C= 130 g= 9.81 m/sec^2

Interface / Section	Flow Q (m^3/sec)	Flow Q (m^3/day)	Pipe Diameter D (mm)		Length L (m)	Velocity v (m/sec)	Hydraulic gradient I (‰)	Head loss h (m)	Remarks
A									
A - B	0.0052	450.0	φ	200	60.0	0.1655	0.1976	0.012	
B									
Sub-total									
Route A-B					60.0			0.012	

(2) **Shape Loss**

Items	Diameter D (mm)		Number N (-)	Friction f	Quantity Q (m^3/sec)	Quantity Q (m^3/d)	Velocity v (m/sec)	Head loss h (m)	Remarks
A-B	φ	200			0.0052	450.0	0.1655		
Inlet	φ	200	1	0.250	0.0052	450.0	0.1655	0.000	
Suddenly expansion	φ	200	0	0.000	0.0052	450.0	0.1655	0.000	
Suddenly reduction	φ	200	0	0.000	0.0052	450.0	0.1655	0.000	
Gradually expansion	φ	200	0	0.000	0.0052	450.0	0.1655	0.000	
Gradually reduction	φ	200	0	0.000	0.0052	450.0	0.1655	0.000	
Bend 90°	φ	200	1	0.170	0.0052	450.0	0.1655	0.000	
45°	φ	200	0	0.084	0.0052	450.0	0.1655	0.000	
22°1/2	φ	200	0	0.048	0.0052	450.0	0.1655	0.000	
11°1/4	φ	200	0	0.016	0.0052	450.0	0.1655	0.000	
Elbow 90°	φ	200	0	0.986	0.0052	450.0	0.1655	0.000	
45°	φ	200	0	0.183	0.0052	450.0	0.1655	0.000	
22°1/2	φ	200	0	0.039	0.0052	450.0	0.1655	0.000	
11°1/4	φ	200	0	0.009	0.0052	450.0	0.1655	0.000	
Distribution	φ	200	0		0.0052	450.0	0.1655	0.000	
Combination	φ	200	0		0.0052	450.0	0.1655	0.000	
Valve Gate	φ	200	1	0.300	0.0052	450.0	0.1655	0.000	Full open
Check	φ	200	0	0.500	0.0052	450.0	0.1655	0.000	
Outlet	φ	200	1	1.000	0.0052	450.0	0.1655	0.001	
Sum								0.001	
Sub-total									
Route A-B								0.001	
Total Friction loss + shape loss								0.013	

Applied formula $h = I \times L$ Hazen-Williams formula

$I = 10.666 \times C^{-1.85} \times D^{-4.87} \times Q^{1.85}$

11. Discharge Pool - Manhole

11.1 Design Flow

Section	Flow
A-B	1,290 m^3/day

11.2 Head loss calculation

(1) **Friction loss** C= 130 g= 9.81 m/sec^2

Interface / Section	Flow Q (m^3/sec)	Flow Q (m^3/day)	Pipe Diameter D (mm)	Length L (m)	Velocity v (m/sec)	Hydraulic gradient I (‰)	Head loss h (m)	Remarks
A								
A - B	0.0149	1,290.0	φ 200	60.0	0.4743	1.3854	0.083	
B								
Sub-total Route A-B				60.0			0.083	

(2) **Shape Loss**

Items	Diameter D (mm)	Number N (-)	Friction f	Quantity Q (m^3/sec)	Quantity Q (m^3/d)	Velocity v (m/sec)	Head loss h (m)	Remarks
A-B	φ 200			0.0149	1,290.0	0.4743		
Inlet	φ 200	1	0.250	0.0149	1,290.0	0.4743	0.003	
Suddenly expansion	φ 200	0	0.000	0.0149	1,290.0	0.4743	0.000	
Suddenly reduction	φ 200	0	0.000	0.0149	1,290.0	0.4743	0.000	
Gradually expansion	φ 200	0	0.000	0.0149	1,290.0	0.4743	0.000	
Gradually reduction	φ 200	0	0.000	0.0149	1,290.0	0.4743	0.000	
Bend 90°	φ 200	1	0.170	0.0149	1,290.0	0.4743	0.002	
45°	φ 200	0	0.084	0.0149	1,290.0	0.4743	0.000	
22°1/2	φ 200	0	0.048	0.0149	1,290.0	0.4743	0.000	
11°1/4	φ 200	0	0.016	0.0149	1,290.0	0.4743	0.000	
Elbow 90°	φ 200	0	0.986	0.0149	1,290.0	0.4743	0.000	
45°	φ 200	0	0.183	0.0149	1,290.0	0.4743	0.000	
22°1/2	φ 200	0	0.039	0.0149	1,290.0	0.4743	0.000	
11°1/4	φ 200	0	0.009	0.0149	1,290.0	0.4743	0.000	
Distribution	φ 200	0		0.0149	1,290.0	0.4743	0.000	
Combination	φ 200	0		0.0149	1,290.0	0.4743	0.000	
Valve Gate	φ 200	0	0.300	0.0149	1,290.0	0.4743	0.000	Full open
Check	φ 200	0	0.500	0.0149	1,290.0	0.4743	0.000	
Outlet	φ 200	1	1.000	0.0149	1,290.0	0.4743	0.011	
Sum							0.016	
Sub-total Route A-B							0.016	
Total Friction loss + shape loss							0.099	

B. **Head loss at open channel**

Applied formula : $h = L \times v^2/(C^2 R)$: Munning formula

$C^2 = R^{1/3}/n^2$

h : head loss

L : Channel length

v : velocity

W : Channel width

n : rough coefficient

(1) Coagulation Basin - Flocculation Basin

Section	Q (m^3/sec)	L (m)	W (m)	H (m)	A (m^2)	S (m)	R (m)	v (m/sec)	n	C^2	h (m)
A-B	0.6075	5.90	2.00	4.35	8.70	10.70	0.8131	0.0698	0.015	4,148.26	0.000
B-C	0.4050	9.60	2.00	4.35	8.70	10.70	0.8131	0.0466	0.015	4,148.26	0.000
C-D	0.2025	9.60	2.00	4.35	8.70	10.70	0.8131	0.0233	0.015	4,148.26	0.000
Sum											0.000

(2) Rapid Sand Filter Distribution channel

Section	Q (m^3/sec)	L (m)	W (m)	H (m)	A (m^2)	S (m)	R (m)	v (m/sec)	n	C^2	h (m)
A-B	1.2153	18.40	2.00	1.70	3.40	5.40	0.6296	0.3574	0.015	3,809.25	0.000
B-C	0.6077	9.75	2.00	1.70	3.40	5.40	0.6296	0.1787	0.015	3,809.25	0.000
C-D	0.5064	9.60	2.00	1.70	3.40	5.40	0.6296	0.1489	0.015	3,809.25	0.000
D-E	0.4051	8.15	2.00	1.70	3.40	5.40	0.6296	0.1191	0.015	3,809.25	0.000
E-F	0.3038	8.15	2.00	1.70	3.40	5.40	0.6296	0.0894	0.015	3,809.25	0.000
F-G	0.2026	8.15	2.00		0.00	2.00	0.0000	#DIV/0!	0.015	0.00	#DIV/0!
G-H	0.1013	8.15	2.00	1.70	3.40	5.40	0.6296	0.0298	0.015	3,809.25	0.000
Sum											0.000

(3) Rapid sand filter inlet siphon

Section	Q (m^3/sec)	L (m)	W (m)	H (m)	A (m^2)	S (m)	R (m)	v (m/sec)	n	C^2	h (m)
A-B	0.1215	4.22	0.65	0.30	0.20	1.90	0.1053	0.6075	0.015	2,098.75	0.000
Sum											0.000

B. **Head loss at open channel**

Applied formula : $h = L \times v^2/(C^2/R)$: Munning formula

$C^2 = R^{1/3}/n^2$

h : head loss

L : Channel length

v : velocity

W : Channel width

n : rough coefficient

(4) Filtered water outlet channel

Section	Q (m^3/sec)	L (m)	W (m)	H (m)	A (m^2)	S (m)	R (m)	v (m/sec)	n	C^2	h (m)
A-B	0.2315	10.00	-	-	10.29	12.00	0.8575	0.0225	0.015	4,222.43	0.000
B-C	0.463	10.00	-	-	10.29	12.00	0.8575	0.0450	0.015	4,222.43	0.000
C-D	0.6944	10.00	-	-	10.29	12.00	0.8575	0.0675	0.015	4,222.43	0.000
D-E	0.8102	10.00	-	-	10.29	12.00	0.8575	0.0787	0.015	4,222.43	0.000
E-F	1.0417	10.00	-	-	10.29	12.00	0.8575	0.1012	0.015	4,222.43	0.000
F-G	1.2731	10.00	-	-	10.29	12.00	0.8575	0.1237	0.015	4,222.43	0.000
Sum											0.000

(5) Chlorination Basin contact channel

Section	Q (m^3/sec)	L (m)	W (m)	H (m)	A (m^2)	S (m)	R (m)	v (m/sec)	n	C^2	h (m)
A-B	1.1574	31.80	2.45	2.90	7.10	10.70	0.6636	0.1630	0.015	3,876.62	0.000
Sum											0.000

A.5-37

(6) Backwash outlet siphon

Section	Q (m^3/sec)	L (m)	W (m)	H (m)	A (m^2)	S (m)	R (m)	v (m/sec)	n	C^2	h (m)
A-B	0.7308	13.55	0.75	0.90	0.68	3.30	0.2061	1.0747	0.015	2,625.29	0.001
Sum											0.001

(7) Backwash drainage channel

Section	Q (m^3/sec)	L (m)	W (m)	H (m)	A (m^2)	S (m)	R (m)	v (m/sec)	n	C^2	h (m)
A-B	0.731	18.40	2.80	1.50	4.19	5.79	0.7237	0.1744	0.015	3,990.28	0.000
B-C	0.731	10.00	2.00	1.50	2.99	4.99	0.5992	0.2444	0.015	3,746.92	0.000
Sum											0.000

Suppressed-rectangular weir Ishihara-Ida Formula

$Q = C \times B \times h^{3/2}$

$C = 1.785 + (0.00295/h + 0.237 \times h/W) \times (1+\epsilon)$

ϵ : $\epsilon = 0$ ($W =< 1.0m$)

$\epsilon = 0.55 \times (W-1.0)$ ($W > 1.0m$)

W : Weir width

H : Height from bottom to top of weir

h : Overflow depth

Distribution Chamber Q= 105,000 m^3/day

Input

Design Flow Qd m^3/sec	Weir Width W m	Weir Height H m	Overflow Water depth h m	Adjustment Coefficient ϵ	Flow Index C	Calculated Flow Qc m^3/sec	Equation Qc-Qd m^3/sec
1.2153	3.00	7.00	0.3600	3.3000	1.87265	1.2135	-0.0018
1.2153	3.00	7.00	0.3601	3.3000	1.87265	1.2140	-0.0013
1.2153	3.00	7.00	0.3602	3.3000	1.87266	1.2145	-0.0008
1.2153	3.00	7.00	0.3603	3.3000	1.87266	1.2150	-0.0003
1.2153	3.00	7.00	0.3604	3.3000	1.87267	1.2155	0.0002
1.2153	3.00	7.00	0.3605	3.3000	1.87267	1.2160	0.0007
1.2153	3.00	7.00	0.3606	3.3000	1.87268	1.2165	0.0013
1.2153	3.00	7.00	0.3607	3.3000	1.87268	1.2170	0.0018
1.2153	3.00	7.00	0.3608	3.3000	1.87269	1.2175	0.0023
1.2153	3.00	7.00	0.3609	3.3000	1.87269	1.2181	0.0028

Coagulant basin Q= 52,500 m^3/day

Input

Design Flow Qd m^3/sec	Weir Width W m	Weir Height H m	Overflow Water depth h m	ϵ	Flow Index C	Calculated Flow Qc m^3/sec	Equation Qc-Qd m^3/sec
0.6076	4.20	5.30	0.1810	2.3650	1.86708	0.6039	-0.0038
0.6076	4.20	5.30	0.1811	2.3650	1.86706	0.6043	-0.0033
0.6076	4.20	5.30	0.1812	2.3650	1.86705	0.6048	-0.0028
0.6076	4.20	5.30	0.1813	2.3650	1.86703	0.6053	-0.0023
0.6076	4.20	5.30	0.1814	2.3650	1.86702	0.6058	-0.0018
0.6076	4.20	5.30	0.1815	2.3650	1.86700	0.6063	-0.0013
0.6076	4.20	5.30	0.1816	2.3650	1.86699	0.6068	-0.0008
0.6076	4.20	5.30	0.1817	2.3650	1.86697	0.6073	-0.0003
0.6076	4.20	5.30	0.1818	2.3650	1.86696	0.6078	0.0002
0.6076	4.20	5.30	0.1819	2.3650	1.86694	0.6083	0.0007

Suppressed-rectangular weir Ishihara-Ida Formula

$Q = C \times B \times h^{3/2}$

$C = 1.785 + (0.00295/h + 0.237 \times h/W) \times (1+\epsilon)$

ϵ : $\epsilon = 0$ (W=<1.0m)

$\epsilon = 0.55 \times (W-1.0)$ (W>1.0m)

W : Weir width

H : Height from bottom to top of weir

h : Overflow depth

Rapid sand filter inlet weir Q= 10,500 m^3/day

Input

Design Flow Qd m^3/sec	Weir Width W m	Weir Height H m	Overflow Water depth h m	Adjustment Coefficient ϵ	Flow Index C	Calculated Flow Qc m^3/sec	Equation Qc-Qd m^3/sec
0.1215	1.50	1.50	0.1240	0.2750	1.84031	0.1205	-0.0010
0.1215	1.50	1.50	0.1241	0.2750	1.84031	0.1207	-0.0008
0.1215	1.50	1.50	0.1242	0.2750	1.84030	0.1208	-0.0007
0.1215	1.50	1.50	0.1243	0.2750	1.84030	0.1210	-0.0006
0.1215	1.50	1.50	0.1244	0.2750	1.84030	0.1211	-0.0004
0.1215	1.50	1.50	0.1245	0.2750	1.84029	0.1213	-0.0003
0.1215	1.50	1.50	0.1246	0.2750	1.84029	0.1214	-0.0001
0.1215	1.50	1.50	0.1247	0.2750	1.84028	0.1216	0.0000
0.1215	1.50	1.50	0.1248	0.2750	1.84028	0.1217	0.0002
0.1215	1.50	1.50	0.1249	0.2750	1.84028	0.1218	0.0003

Rapid sand filter outlet weir Q= 0.1157 m^3/sec/wair

Input

Design Flow Qd m^3/sec	Weir Width W m	Weir Height H m	Overflow Water depth h m	Adjustment Coefficient ϵ	Flow Index C	Calculated Flow Qc m^3/sec	Equation Qc-Qd m^3/sec
0.1157	1.50	3.10	0.1435	1.1550	1.85294	0.1511	0.0354
0.1157	1.50	3.10	0.1436	1.1550	1.85293	0.1512	0.0355
0.1157	1.50	3.10	0.1437	1.1550	1.85291	0.1514	0.0357
0.1157	1.50	3.10	0.1438	1.1550	1.85290	0.1516	0.0359
0.1157	1.50	3.10	0.1439	1.1550	1.85289	0.1517	0.0360
0.1157	1.50	3.10	0.1440	1.1550	1.85287	0.1519	0.0362
0.1157	1.50	3.10	0.1441	1.1550	1.85286	0.1520	0.0363
0.1157	1.50	3.10	0.1442	1.1550	1.85284	0.1522	0.0365
0.1157	1.50	3.10	0.1443	1.1550	1.85283	0.1523	0.0366
0.1157	1.50	3.10	0.1444	1.1550	1.85282	0.1525	0.0368

Suppressed-rectangular weir Ishihara-Ida Formula

$Q = C \times B \times h^{3/2}$

$C = 1.785 + (0.00295/h + 0.237 \times h/W) \times (1+\epsilon)$

ϵ : $\epsilon = 0$ (W=<1.0m)

$\epsilon = 0.55 \times (W-1.0)$ (W>1.0m)

W : Weir width

H : Height from bottom to top of weir

h : Overflow depth

Backwash outlet trough Q= 0.0365 m^3/sec/side

Input

Design Flow Qd m^3/sec	Weir Width W m	Weir Height H m	Overflow Water depth h m	Adjustment Coefficient ϵ	Flow Index C	Calculated Flow Qc m^3/sec	Equation Qc-Qd m^3/sec
0.0365	6.05	0.80	0.0210	0.0000	1.93170	0.0356	-0.0009
0.0365	6.05	0.80	0.0211	0.0000	1.93106	0.0358	-0.0007
0.0365	6.05	0.80	0.0212	0.0000	1.93043	0.0361	-0.0004
0.0365	6.05	0.80	0.0213	0.0000	1.92981	0.0363	-0.0002
0.0365	6.05	0.80	0.0214	0.0000	1.92919	0.0365	0.0000
0.0365	6.05	0.80	0.0215	0.0000	1.92858	0.0368	0.0003
0.0365	6.05	0.80	0.0216	0.0000	1.92797	0.0370	0.0005
0.0365	6.05	0.80	0.0217	0.0000	1.92737	0.0373	0.0008
0.0365	6.05	0.80	0.0218	0.0000	1.92678	0.0375	0.0010
0.0365	6.05	0.80	0.0219	0.0000	1.92619	0.0378	0.0013

Backwash drainage channel Q= 0.7308 m^3/sec

Input

Design Flow Qd m^3/sec	Weir Width W m	Weir Height H m	Overflow Water depth h m	Adjustment Coefficient ϵ	Flow Index C	Calculated Flow Qc m^3/sec	Equation Qc-Qd m^3/sec
0.7308	2.00	1.20	0.3365	0.1100	1.86850	0.7295	-0.0013
0.7308	2.00	1.20	0.3366	0.1100	1.86852	0.7298	-0.0010
0.7308	2.00	1.20	0.3367	0.1100	1.86854	0.7301	-0.0007
0.7308	2.00	1.20	0.3368	0.1100	1.86856	0.7305	-0.0003
0.7308	2.00	1.20	0.3369	0.1100	1.86858	0.7308	0.0000
0.7308	2.00	1.20	0.3370	0.1100	1.86860	0.7311	0.0003
0.7308	2.00	1.20	0.3371	0.1100	1.86861	0.7315	0.0007
0.7308	2.00	1.20	0.3372	0.1100	1.86863	0.7318	0.0010
0.7308	2.00	1.20	0.3373	0.1100	1.86865	0.7321	0.0013
0.7308	2.00	1.20	0.3374	0.1100	1.86867	0.7325	0.0017