HYDRAULIC DESIGN
OF
WATER TREATMENT PLANT

CAPACITY - 40 MLD

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ANNEXURE - I

- STANDARD TABLES

STANDARD DIMENSIONS FOR PARSHALL FLUME									
*(*Reference Manual on Sewerage and Sewerage Treatment- Table 5.5)*									
Flow Range Q_{max}(MLD)	**W**	**A**	**B**	**C**	**D**	**F**	**G**	**K**	**Z**
Upto 5	75	460	450	175	255	150	300	25	56
5 to 30	150	610	600	315	391	300	600	75	113
30 to 45	225	865	850	375	566	300	750	75	113
45 to 170	300	1350	1322	600	831	600	900	75	225
170 to 250	450	1425	1357	750	1010	600	900	75	225
250 to 350	600	1500	1472	900	1188	600	900	75	225
350 to 500	900	1650	1619	1200	1547	600	900	75	225
500 to 700	1200	1800	1766	1500	1906	600	900	75	225
700 to 850	1500	2100	2060	2100	2625	600	900	75	225
850 to 1400	2400	2400	2353	2700	3344	600	900	75	225

STANDARD POWER REQUIREMENT			
*(*Reference IS 7090 - 4985)*			
Detention Time	**Velocity Gradient**	**Net Power Input per Unit Volume**	**Net power Input**
Sec	**S^{-1}**	**Watts/m^3 Volume**	**Watts/m^3 of flow per hr**
60	300	72	1.2
50	360	104	1.4
40	450	162	1.8
30	600	288	2.4
25	720	415	2.9
20	900	648	3.6
***Calculations based on water temperatureof 30 ^{o} C*			

ANNEXURE - II

- ## HYDRAULIC DESIGN CALCULATIONS

TABLE NO.1 - DESIGNED FLOWS AND CAPACITIES FOR VARIOUS ELEMENTS

SR NO.	ELEMENT	FLOW	NO. OF UNITS	OVERLOADING	LOSS
		MLD	NOS.	%	%
1	Cascade Aerator	40	1	20	5
2	Parshall Flume	40	1	20	5
3	Flash Mixer (Square DC)	40	2	20	5
4	Pipe	40	1	20	5
5	Clarriflocculator (Radial flow)	40	1	20	5
6	Channel	40	1	20	5
7	Rapid Sand Gravity Filter	40	1	20	5
8	Pure Water Channel	40	1	20	5
9	Pipe	40	1	20	5
10	Circular Sump	40	1	20	5

SR NO.	ELEMENT	DESIGNED FLOW / UNIT	CAPACITY / UNITS		
		MLD	m^3/day	m^3/hr	m^3/sec
1	Cascade Aerator	50.000	50,000.000	2,083.333	0.579
2	Parshall Flume	50.000	50,000.000	2,083.333	0.579
3	Flash Mixer (Square DC)	25.000	25,000.000	1,041.667	0.289
4	Pipe	50.000	50,000.000	2,083.333	0.579
5	Clarriflocculator (Radial flow)	50.000	50,000.000	2,083.333	0.579
6	Channel	50.000	50,000.000	2,083.333	0.579
7	Rapid Sand Gravity Filter	50.000	50,000.000	2,083.333	0.579
8	Pure Water Channel	50.000	50,000.000	2,083.333	0.579
9	Pipe	50.000	50,000.000	2,083.333	0.579
10	Circular Sump	50.000	50,000.000	2,083.333	0.579

Formula Used:

1 **Designed Flow in MLD**

$$Designed\ Flow\ Per\ Unit = \frac{\left[Flow \times \left[\frac{Overloading}{100} + \frac{Loss}{100}\right]\right] + Flow}{No.\ of\ Units}$$

2 **Capacity in m^3/day**

$$Capacity\ (Q) = Designed\ Flow\ Per\ Unit \times 10^3$$

3 **Capacity in m^3/hr**

$$Capacity\ \left(Q\right) = \frac{Designed\ Flow\ Per\ Unit \times 10^3}{24}$$

4 **Capacity in m^3/sec**

$$Capacity\ \left(Q\right) = \frac{Designed\ Flow\ Per\ Unit \times 10^3}{24 \times 60 \times 60}$$

HYDRAULIC DESIGN

- INLET SHAFT
- STEPS AND PLANNER
- COLLECTION LAUNDER

HYDRAULIC DESIGN OF CASCADE AERATOR

The role of Aeration is to remove undesirable dissolved gases in water and to add oxygen to water to convert undesirable substances to a more manageable form.

1. INLET SHAFT

(Reference Table No. 1)

- ✓ *Number of Units = 1 Nos*
- ✓ *Designed Flow Per Unit = 50 MLD*
- ✓ *Designed Capacity in m^3/sec = 0.579 m^3 /sec*

1.1 ASSUMPTIONS & CALCULATIONS:

- ⋗ *Assumed velocity of flow through Inlet Shaft = 0.65 m/sec*

$$\text{Diameter of Inlet Shaft Required} = \left[\frac{4 \times Designed\ Flow\ (m^3/sec)}{\pi \times \text{Velocity}\ \ (\text{m/s})}\right]^{0.5}$$

$$= \left[\frac{4 \times 0.579}{3.14 \times 0.65}\right]^{0.5}$$

$$D_{Required} = 1.065\ m$$

Provided Internal Diameter of Inlet Shaft = 1.1 m

- ⋗ *Assumed thickness of Inlet Shaft = 0.1 m*

Hence, Outer Diameter = 1.300 m

1.2 VALIDATION CHECKS:

1. *Provided Diameter 1.1 m > Required Diameter = 1.065 m*

Diameter Provided > Diameter Required.

2. *Velocity Achieved = 0.610 m/sec*

Hence, Velocity achieved is within the permissible Range (0.6 -1.25m/sec)

DESIGN SUMMARY - INLET SHAFT

Velocity	=	0.610 m/sec
Internal Diameter of Inlet Shaft	=	1.1 m
Thickness of Inlet Shaft	=	0.1 m
Outer Diameter of Inlet Shaft	=	1.300 m

2. STEPS AND PLANNER

(Reference Table No. 1)

- ✓ *Number of Units = 1 Nos*
- ✓ *Designed Flow Per Unit = 50 MLD*
- ✓ *Designed Capacity in m^3/hr = 2,083.333 m^3/hr*

2.1 ASSUMPTIONS & CALCULATIONS:

- ⋗ *Assumed criteria for area of Aerator = 0.015 $m^2/m^3/h$*

$$\text{Area of Aerator Required} = Designed\ Flow\ (m^3/hr) \times Criteria\ (m^2/m^3/h)$$

$= 2{,}083.333 \times 0.015$

$Area_{Required} = 31.250\ m^2$

Provide Area of Aerator = 32 m^2

$$\text{Diameter of Aerator} = \sqrt{\frac{4}{\pi}\ \text{x}\ A\ +\ O.D^2}$$

$$= \sqrt{\frac{4}{\pi}\ \text{x}\ 32\ +\ 1.300^2}$$

$\text{Diameter of Aerator} = 6.516\ m$

- *Assumed Number of steps = 5 NOS*
- *Assumed Rise of each step = 0.3 m*

$$\text{Size of Tread} = \frac{Diameter\ of\ Aerator - O.D_{Shaft}}{2 \times No.\ of\ Steps}$$

$$= \frac{6.516 - 1.300}{2 \times 5}$$

$\text{Size of Tread} = 0.522\ m$

Provided Tread= 0.6 m

$\text{Actual Diameter of Aerator} = Tread_{Provided} \times (2 \times No.\ of\ Steps) + O.D_{Shaft}$

$= 0.6 \times (2 \times 5) + 1.300$

$\text{Actual Diameter of Aerator} = 7.300\ m$

$\text{Total Height of Rise} = Rise \times No.\ of\ Steps$

$= 0.3 \times 5$

$\text{Total Height of Rise} = 1.5\ m$

VALIDATION CHECKS:

Actual Area Criteria = 0.020 $m^2/m^3/h$

Actual Area Criteria achieved is within the permissible Limit (0.015 to 0.045 $m^2/m^3/h$)

DESIGN SUMMARY - STEPS & PLANNER

Actual Area Criteria	=	0.020 $m^2/m^3/h$
Diameter of Aerator	=	7.300 m
Number of Steps	=	5 NOS
Tread Size	=	0.6 m
Rise Size	=	0.3 m
Total Rise height	=	1.5 m

3. COLLECTION LAUNDER

- ✓ *Number of Units = 1 Nos*
- ✓ *Designed Flow Per Unit = 50 MLD*

✓ *Designed Capacity in m^3/sec = 0.579 m^3/sec*

3.1 ASSUMPTIONS & CALCULATIONS:

- *Assumed velocity of flow = 0.65 m/sec*
- *Assumed width of collecting Launder = 0.6 m*
- *Assumed Free Board = 0.3 m*

$$\text{Side Water Depth of Collection Launder} = \frac{Design\ Flow\,(m^3/sec)}{2 \times Velocity \times Width\ of\ Launder}$$

$$= \frac{0.579}{2 \times 0.65 \times 0.6}$$

$$SWD_{Launder} = 0.742\ m$$

$$\text{Total Depth of Collection Launder} = SWD_{Launder} + Free\ Board$$

$$= 0.742 + 0.3$$

$$\text{Total Depth of Collection Launder} = 1.042\ m$$

DESIGN SUMMARY - COLLECTION LAUNDER		
Velocity	=	*0.65 m/sec*
Width	=	*0.6 m*
Side water Depth (SWD)	=	*0.742 m*
Free Board	=	*0.3 m*
Total Depth of Launder	=	*1.042 m*

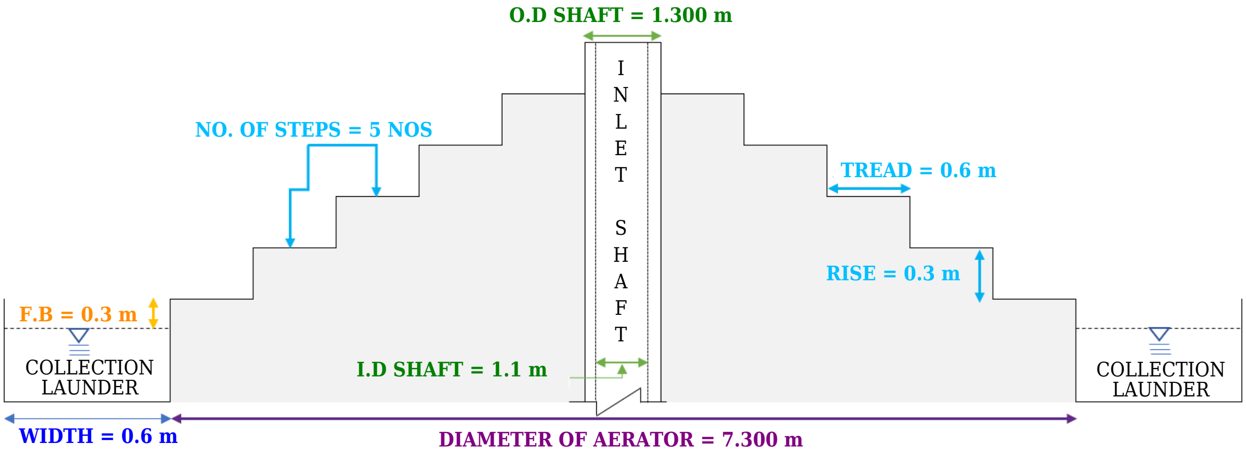


Figure - Cascade Aerator Details

*For Schematic purpose only

HYDRAULIC DESIGN

- PARSHALL FLUME
- UPSTREAM CHANNEL
- DOWNSTREAM CHANNEL

HYDRAULIC DESIGN OF PARSHALL FLUME

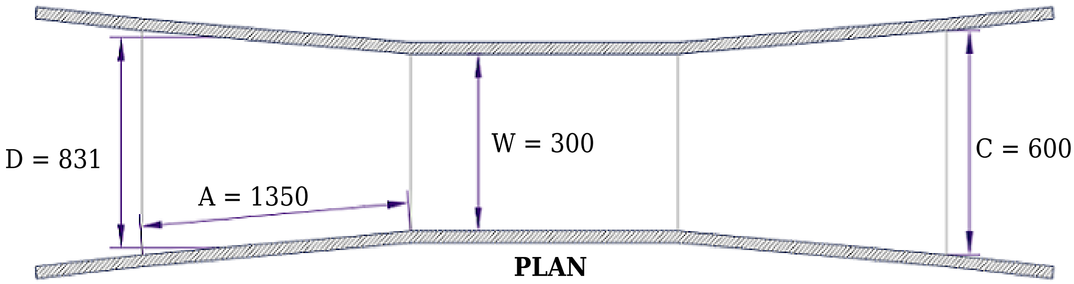
The role of Parshall Flume (U/S & D/S Channel) is to measure the flow and convey water from Aerator to Flash mixer. Parshall Flume is a type of standing wave flume which is widely used. It can measure discharges varying from 0.001 m^3/sec to 100 m^3/sec.

1. PARSHALL FLUME

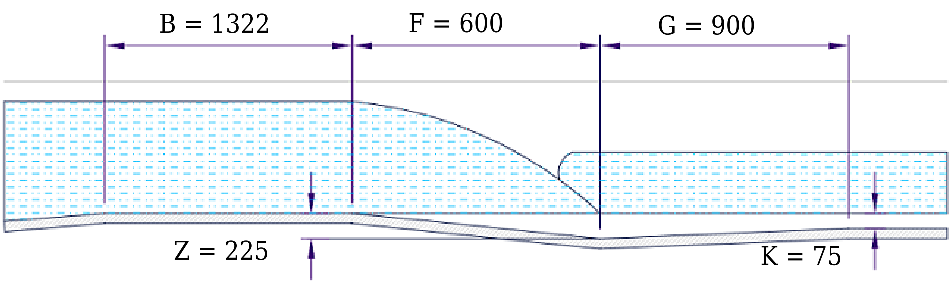
(Reference Table No. 1)

✓ *Number of Units = 1 Nos*
✓ *Designed Flow Per Unit = 50 MLD*

1.1 STANDARD DIMENSIONS:



PLAN



LONGITUDNAL SECTION

All above mentioned dimentions are in mm.

1.2 DIMENSIONS OF PARSHALL FLUME:

*(*Reference Manual on Sewerage and Sewerage Treatment- Table 5.5)*

W	A	B	C	D	F	G	K	Z
300	1350	1322	600	831	600	900	75	225

*All above mentioned dimentions are in mm.

2. UPSTREAM CHANNEL

(Reference Table No. 1)

✓ *Designed Capacity in m^3/sec = 0.579 m^3/sec*

2.1 ASSUMPTIONS & CALCULATIONS:

- *Assumed Velocity of Flow = 0.65 m/sec*
- *Assumed Free Board = 0.3 m*
- *Assumed Length of Channel = 2.5 m*

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HYDRAULIC DESIGN

- CENTRAL SHAFT
- FLOCCULATOR
- POWER REQUIREMENT
- CLARIFIER
- WEIR
- NOTCHES
- PERIPHERAL LAUNDER

TYPICAL CLARIFLOCCULATOR SKETCH

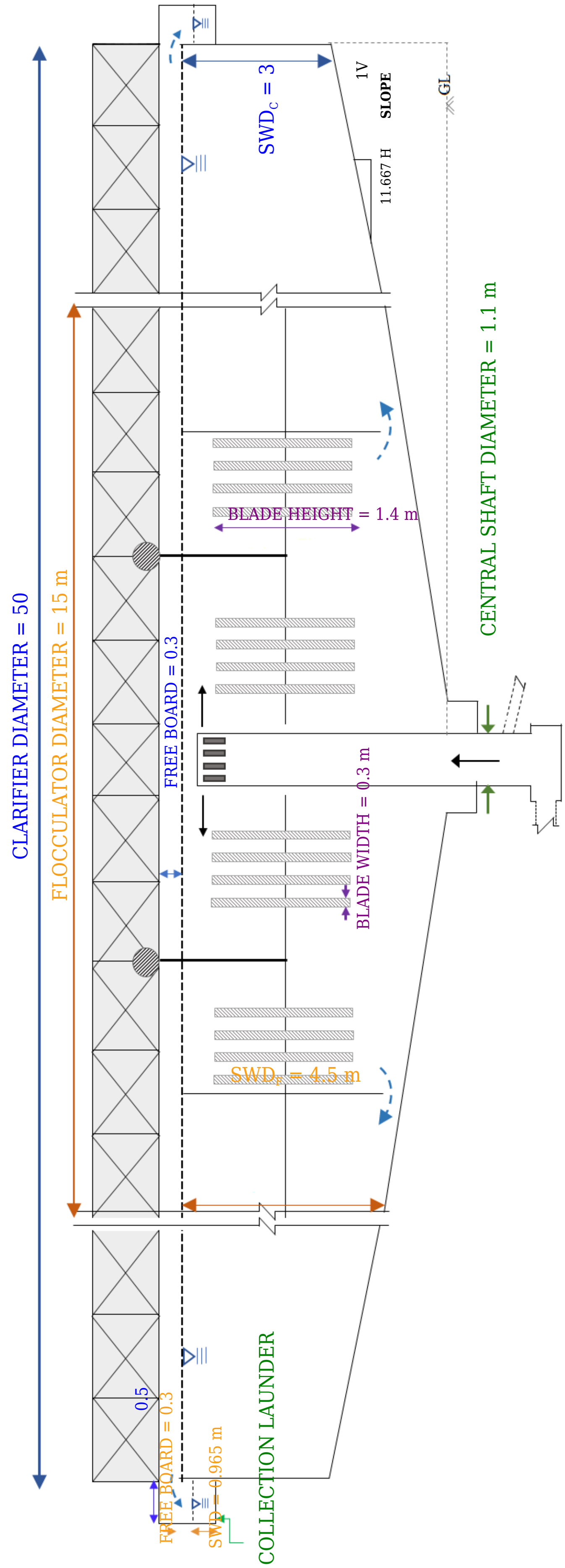

Figure - Clarifloccculator Details

*For Schematic purpose only.

HYDRAULIC DESIGN OF CLARIFLOCCULATOR

1 CENTRAL SHAFT

The role of Central Shaft is to convey water to the clariflocculator.
(Reference Table No. 1)

- ✓ *Number of Units = 1 Nos*
- ✓ *Designed Flow Per Unit = 50.000 MLD*
- ✓ *Designed Capacity in m^3/sec = 0.579 m^3/sec*

1.1.1 ASSUMPTIONS & CALCULATIONS:

- ⩥ *Assumed velocity of flow through Central Shaft = 0.65 m/sec*

$$\text{Diameter Of Central Shaft Required} = \left[\frac{4 \times Designed\ Flow\ (m^3/sec)}{\pi \times \text{Velocity (m/s)}}\right]^{0.5}$$

$$= \left[\frac{4 \times 0.579}{3.14 \times 0.65}\right]^{0.5}$$

Diameter Of Central Shaft Required = 1.065 m

Provide Internal Diameter of Central Shaft = 1.1 m

- ⩥ *Assumed thickness of Central Shaft = 0.15 m*

Hence, Outer Diameter = 1.400 m

1.1.2 VALIDATION CHECKS:

1. *Provided Diameter = 1.1 m > Required Diameter = 1.065 m*

Hence, Diameter provided of Central Shaft is Sufficient.

2. *Velocity Achieved = 0.610 m/s*

Hence, Velocity achieved is within the permissible Range(0.6-1.2m/sec).

DESIGN SUMMARY - CENTRAL SHAFT

Velocity	=	0.610 m/sec
Internal Diameter of Central Shaft	=	1.1 m
Thickness of Central Shaft	=	0.15 m
Outer Diameter of Central Shaft	=	1.400 m

1.2 PORTS

Ports are being provided at the top portion of the Central shaft with the purpose for outlet of water.
(Reference Table No. 1)

- ✓ *Number of Units = 1 Nos*
- ✓ *Designed Flow Per Unit = 50.000 MLD*
- ✓ *Designed Capacity in m^3/sec = 0.579 m^3/sec*

1.2.1 ASSUMPTIONS & CALCULATIONS:

- ⩥ *Assumed velocity of flow through Ports = 0.65 m/sec*

$$\text{Area of Openings of Ports} = \frac{Design\ Flow\ (m^3/sec)}{Velocity\ (m/sec)}$$

$$= \frac{0.579}{0.65}$$

Area of Openings of Ports = *0.891 m*^{2}

- ⩥ *Assumed Number of Rows = 1 Nos.*
- ⩥ *Assumed Number of Ports per Rows = 5 Nos.*
- ⩥ *Assumed width of port = 0.541 m*
- ⩥ *Assumed Clear Spacing of Ports = 0.150 m*

Area of each port required $= \frac{Area\ of\ Openings\ of\ Ports}{Nos.\ of\ Rows \times Nos.\ of\ Ports\ per\ Row}$

$$= \frac{0.891}{1 \times 5}$$

Area of each port required = *0.178 m*^{2}

Height of port $= \frac{Area\ of\ port\ required}{width\ of\ port}$

$$= \frac{0.178}{0.541}$$

Height of port = *0.329 m*

Provide height of port = 0.35 m

Actual Clear Spacing of Ports $= \frac{(\pi \times \mathrm{I.D}) - (Width\ of\ Port \times No.\ of\ Ports\ per\ Row)}{No.\ of\ Ports\ per\ Row}$

$$= \frac{(3.14 \times 1.1) - (0.541 \times 5)}{5}$$

Actual Clear Spacing of Ports = *0.150 mm c/c*

NOTE: *For ease in construction of ports, clear spacing is maintained as a standard value and thereby width of port is calculated accordingly*

1.2.2 VALIDATION CHECKS:

1. *Provided Area of Ports = 0.189 m*^{2} > *Required Area = 0.178 m*^{2}

Hence, Dimensions of Ports are Sufficient.

DESIGN SUMMARY - PORTS		
Velocity through Ports	=	*0.65 m/sec*
No. of Rows	=	*1 Nos.*
Number of Ports per Row	=	*5 Nos.*
Height of Port	=	*0.35 m*
Width of Port	=	*0.541 m*
Actual Clear Spacing Between Ports	=	*0.150 m*

2. FLOCCULATOR

The role of flocculator is to agglomerate the macroflocs generated in the Flash Mixer. The agglomeration helps to build large size and dense flocs which are effectively removed in the Clarifier/Sedimentation Tank. (Reference Table No. 1)

✓ *Number of Units = 1 Nos*
✓ *Designed Flow Per Unit = 50.000 MLD*
✓ *Designed Capacity in m^3/sec = 0.579 m^3/sec*

2.1 ASSUMPTIONS & CALCULATIONS:

- *Assumed Detention Time in Flocculator = 20 minutes*
- *Assumed SWD in Flocculator = 4.5 m*

$$Volume\ of\ Flocculator = Design\ Flow \times Detention\ Time \times 60$$

$$= 0.579 \times 20 \times 60$$

$$Volume\ of\ Flocculator = 694.800\ m^3$$

$$Diameter\ of\ Flocculator\ Required = \left[\frac{4}{\pi} \times \left[\frac{Volume(m^3)}{SWD(m)} + O.D^2_{Shaft}\right]\right]^{0.5}$$

$$= \left[\frac{4}{3.14} \times \left[\frac{694.800}{4.5} + 1.400^2\right]\right]^{0.5}$$

$$D_{F\ Required} = 14.091\ m$$

Provide Diameter of Flocculator(D_F) = 15 m

2.2 VALIDATION CHECKS:

1. *Actual Detention Time Maintained = 22.891 > Assumed Detention time = 20 min*

Actual Detention Time Maintained > Assumed Detention Time.

DESIGN SUMMARY - FLOCCULATOR

Detention Time	=	20 min
Side Water Depth (SWD_F)	=	4.5 m
Diameter of Flocculator (D_F)	=	15 m

3. POWER REQUIREMENT

- *Assumed Velocity Gradient = 30 sec^{-1}*
- *Assumed absolute Viscocity of Water = 0.00089 kg/m.s*

$$Power\ Required = G^2 \times \mu \times \frac{\pi}{4} \times \left(D_F{}^2 - OD_{shaft}{}^2\right) \times SWD_F$$

$$= 30^2 \times 0.00089 \times \frac{3.14}{4} \times \left(15^2 - 1.400^2\right) \times 4.5$$

$$Power\ Required = 0.631\ kw$$

3.1 PADDLE & BLADE REQUIREMENT:

- *Assumed Drag Coefficient = 1.1*
- *Assumed Density of Water = 997 kg/m^3*
- *Assumed Paddle Tip Velocity = 0.5 m/sec*
- *Assumed Water Velocity at Paddle Tip = 0.125 m/sec*
  (*As per CPEEHO Manual Water Velocity at Paddle tip should be 25% of Paddle tip Velocity.)
- *Assumed Number of Drive Units = 2 Nos.*
- *Assumed Number of Arms per Drive Unit = 4 Nos.*
- *Assumed Number of Blades = 4 Nos.*

Area of Paddles Required = $\frac{2P}{C_D \times \rho \times (V - v)^3}$

= $\frac{2 \times 0.631 \times 10^3}{1.1 \times 997 \times (0.5 - 0.125)^3}$

\

A_P = $21.821\ m^2$

Area of Blades/Drive Unit = $\frac{A_P}{Number\ of\ Drives}$

= $\frac{21.821}{2}$

Area of Blades/Drive Unit = $10.911\ m^2$

**Note : For Detail Calculation & Diagram Refer Annexure III*

- *Assumed Height of Blades = 1.4 m*
- *Assumed Width of Blades = 0.3 m*
- *Assumed rpm of Blade = 3 rpm*

Area of Each Blade = $Height\ of\ Blade \times Width\ of\ Blade$

= 1.4×0.3

Area of Each Blade = $0.420\ m^2$

3.2 VALIDATION CHECKS:

1. *Ratio of $A_{blades\ to}$ C/S Area of Flocculator = 10.980 %*

The Ratio is in between 10 to 25% which is permissible Limit.

DESIGN SUMMARY - POWER, PADDLE & BLADES

Velocity Gradient	=	30 sec^{-1}
Power Required	=	0.631 kw
Drag Coefficient	=	1.1
Paddle Tip Velocity	=	0.5 m/sec
Water Velocity at Paddle Tip	=	0.125 m/sec
No. of Drive Units	=	2 Nos.
No. of Arms per Drive Units	=	4 Nos.
No of Blade per Arm	=	4 Nos.
Height of Blade	=	1.4 m
Width of Blade	=	0.3 m
rpm of Blade	=	3 rpm

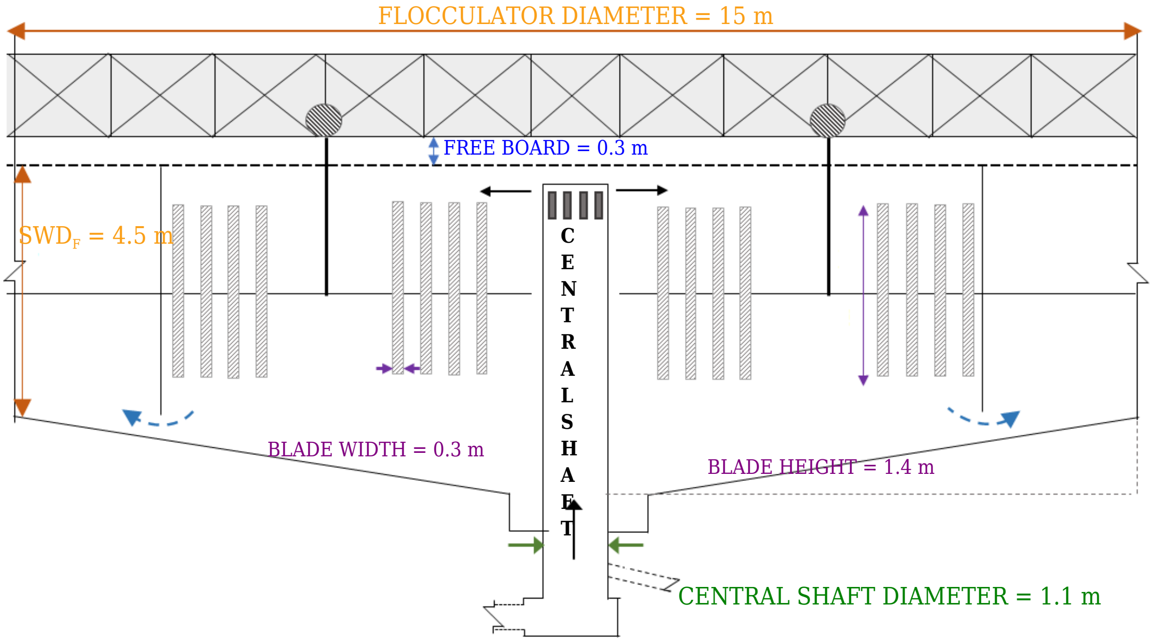

Figure - Typical Flocculator Diagram

*For schemantic purpose only

4. CLARIFIER

The role of Clarifier is very similar of that of sedimentation tank. Clarifier is the unit in between Flocculator and Filteration Unit.

(Reference Table No. 1)

- ✓ *Number of Units = 1 Nos*
- ✓ *Designed Flow Per Unit = 50.000 MLD*
- ✓ *Designed Capacity in m^3/hr = 2,083.333 m^3/hr*

4.1 ASSUMPTIONS & CALCULATIONS:

- *Assumed Slope to Horizontal = 1 in 11*
- *Assumed Detention Time in Flocculator = 2.5 hours*
- *Assumed SWD in Clarifier = 3 m*
- *Assumed Thickness of partition = 0.2 m*
- *Assumed Surface Overflow Rate (SOR) = 30 $m^3/m^2.d$*

$$\text{Volume of Clarifier} = \text{Designed Capacity} \times \text{Detention Time}$$

$$= 2{,}083.333 \times 2.5$$

$$\text{Volume of Clarifier} = 5{,}208.333\ m^3$$

$$\text{Area Of Clarifier} = \frac{Q}{SWD}$$

$$= \frac{5208.3333}{3}$$

$$\text{Area Of Clarifier} = 1{,}736.111\ m^2$$

$$\text{Diameter of Clarifier Required} = \left[\frac{4}{\pi} \times A + Df^2\right]^{0.5}$$

$$= \left[\frac{4}{3.14} \times 1{,}736.111 + 15^2\right]^{0.5}$$

$$D_{C\ Required} = 49.21\ m$$

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HYDRAULIC DESIGN

- FILTER BED
- SAND AND GRAVEL
- DEPTH OF WATER
- UNDER DRAIN SYSTEM
- BACKWASHING OF FILTER
- WASH WATER THROUGH
- GULLET/GUTTER
- WASH WATER TANK

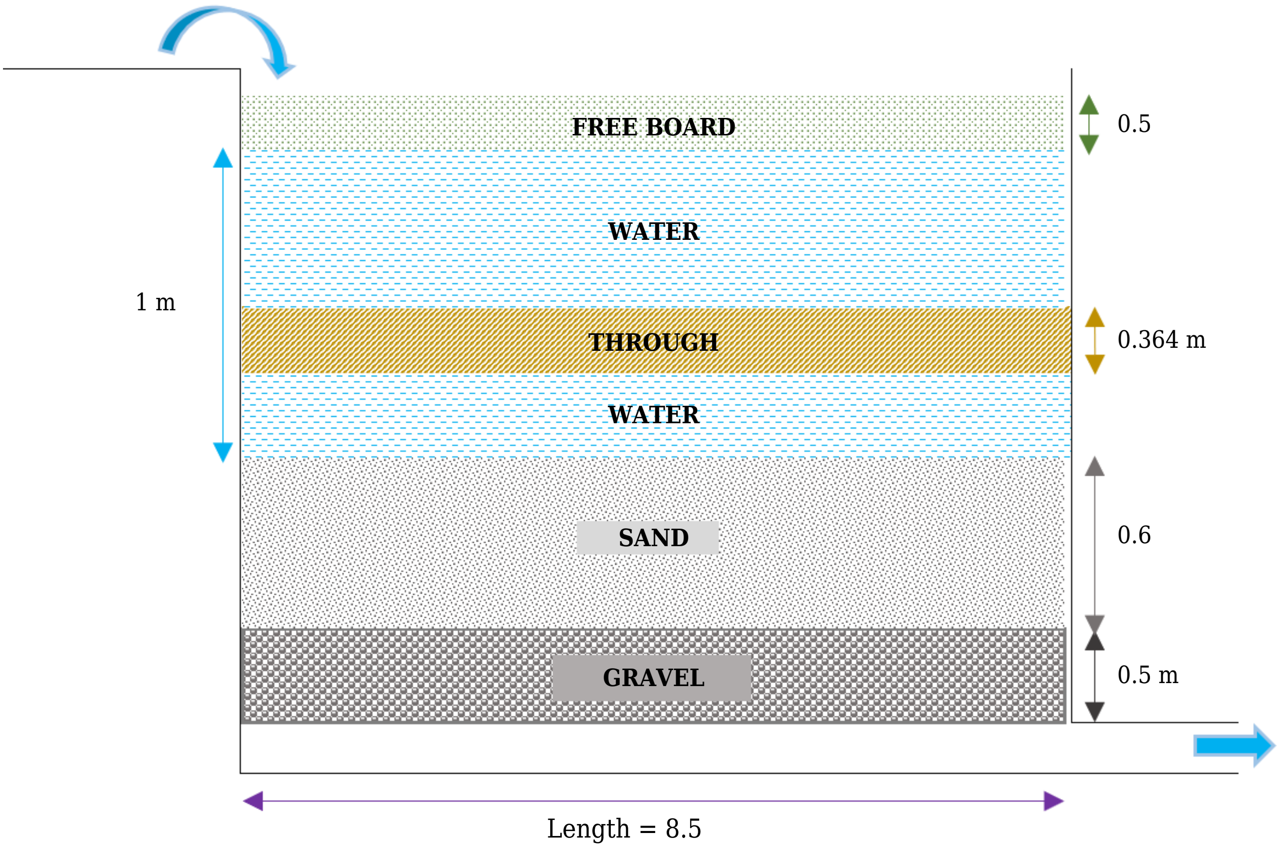

Figure - Rapid Sand Gravity

HYDRAULIC DESIGN OF RAPID SAND GRAVITY FILTER

1. FILTER BEDS

(Reference Table No. 1)

- ✓ *Number of Units = 1 Nos.*
- ✓ *Designed Flow Per Unit = 50.000 MLD*

1.1 ASSUMPTIONS & CALCULATIONS:

- *Assumed Water for Backwashing = 5 %*
- *Cumulative Time for Backwashing = 10 min*
- *Assumed Number of Filter Beds = 2 Nos.*
- *Assumed Rate of Filtration in 20 $m^3/m^2.h$*
- *Assumed Ratio of Length to Width = 1.3*

Total Water to be Filtered = $Designed\ Capacity + Water\ for\ Backwashing$

$$= 50.000 + \left[\frac{5 \times 50.000}{100}\right] \times 10^3$$

Total Water to be Filtered = *52,500.000 m^3/day*

Actual Time for Filteration = $24 - \frac{Time\ for\ Backwashing}{60}$

$$= 24 - \frac{10}{60}$$

Actual Time for Filteration = *23.833 Hours*

Flow per Bed = $\frac{Total\ Water\ to\ be\ Filtered}{Actual\ Time\ for\ Filteration}$

$$= \frac{52{,}500.000}{23.833}$$

Flow per Bed = *2,202.797 m^3/hr*

Area Required for each Bed = $\frac{Flow\ per\ Bed\ (m^3/hr)}{Rate\ of\ Filteration\ (m^3/m^2.h)\ \times\ No\ of\ Beds}$

$$= \frac{2202.797}{20\ \times\ 2}$$

Area Required for each Bed = *55.070 m^2*

Length of Bed Required = $\left[\frac{Area\ Required\ (m^2)}{1/(L/W\ Ratio)}\right]^{0.5}$

$$= \left[\frac{55.070}{1/1.3}\right]^{0.5}$$

Length of Bed Required = *8.461 m*

Provide Length of Bed = 8.5 m

$$\text{Width of Bed Required} = \frac{\text{Length Required}}{\text{Ratio}}$$

$$= \frac{8.461\ m}{1.3}$$

Width of Bed Required = *6.509 m*

Provide Width of Bed = 6.6 m

1.2 VALIDATION CHECKS:

1. *Area Provided = 56.100 m^2 > Area Required = 55.070 m^2*

Area Provided > Area Required

2. *Actual L/W ratio maintained is 1.288*

Actual L/W ratio maintained is within the permissible range.(1.11 to 1.66)

DESIGN SUMMARY - FILTER BED

Water for Backwashing	=	*5 %*
Time for Backwahing	=	*10 min*
Number of Filter Beds	=	*2 Nos.*
Rate of filteration	=	*20 m^3/m^2.h*
L/W ratio	=	*1.288*
Length of filter bed	=	*8.5 m*
Width of filter Bed	=	*6.6 m*

2. DEPTH OF SAND AND GRAVEL

DESIGN SUMMARY - SAND

Depth of Sand	=	*0.6 m*
d_{10} Size	=	*0.6 mm*
d_{60} Size	=	*0.75 mm*

SR.NO	RANGE IN SIZE (mm)	RANGE IN DEPTH (mm)	PROVIDED DEPTH (mm)
1	2 to 5	50 to 80	70
2	5 to 12	50 to 80	50
3	12 to 20	80 to 130	100
4	20 to 38	80 to 130	120
5	38 to 65	130 to 200	160

DESIGN SUMMARY - GRAVEL

Depth of Gravel	=	*500 mm*

3. DEPTH OF WATER

3.1 ASSUMPTIONS & CALCULATIONS:

- *Assumed Depth of water above sand = 1 m*
- *Assumed Free Board = 0.5 m*

$$\text{Total Depth of Filter Box} = D_{Sand} + D_{Gravel} + D_{Water} + Free\ Board$$

$$= 0.6 + 0.5 + 1 + 0.5$$

Total Depth of Filter Box = *2.600 m*

DESIGN SUMMARY - DEPTH OF WATER

Depth of Water	=	*1 m*
Free Board	=	*0.5 m*
Total Depth of Filter Box	=	*2.600 m*

4. UNDER DRAIN SYSTEM

(Reference from Filter Bed Design)

- ✓ *Provided Length of Filter Bed = 8.5 m*
- ✓ *Provided Width of Filter Bed = 6.6 m*

4.1 ASSUMPTIONS & CALCULATIONS:

- ⊳ *Assumed Sections per filter bed = 2 Nos.*
- ⊳ *Assumed Ratio of Filter to Perforations = 0.3 %*
- ⊳ *Assumed Ratio of Laterals to Area of Orifice = 4*
- ⊳ *Assumed Ratio of Area of Manifolds to Area of Laterals = 1.5*

$$\text{Area of filter per underdrain section} = Length\ of\ Filter \times \frac{Width\ of\ Filter}{No.\ of\ Underdrain\ sections/Filter\ Bed}$$

$$= 8.5 \times \frac{6.6}{2}$$

$$\text{Area of filter per underdrain section} = 28.050\ m^2$$

$$\text{Area of Orifice Required} = Ratio\ of\ Filter\ to\ Perforations \times Area\ of\ Filter/Underdrain\ Section$$

$$= \frac{0.3}{100} \times 28.050$$

$$\text{Area of Orifice Required} = 0.084\ m^2$$

$$\text{Area of Lateral Required} = Ratio\ of\ Lateral\ to\ Area\ of\ Orifice \times Area\ of\ Orifice$$

$$= 4 \times 0.084$$

$$\text{Area of Lateral Required} = 0.336\ m^2$$

$$\text{Area of Manifold Required} = Ratio\ of\ Area\ of\ Manifold\ to\ Area\ of\ Lateral \times Area\ of\ Lateral$$

$$= 1.5 \times 0.336$$

$$\text{Area of Manifold Required} = 0.504\ m^2$$

$$\text{Diameter of Manifold Required} = \left[\frac{4 \times A_{Manifold}}{\pi}\right]^{0.5}$$

$$= \left[\frac{4 \times 0.504}{3.14}\right]^{0.5}$$

$$\text{Diameter of Manifold Required} = 0.801\ m$$

Provide Diameter of Manifold = 0.85 m

- ⊳ *Assumed width of Pit for Manifold = 0.9 m*
- ⊳ *Assumed height of Pit for Manifold = 0.9 m*

- *Assumed Diameter of Laterals = 50 mm*

Area of each Lateral = $\frac{\pi}{4} \times D^2_{Lateral}$

= $\frac{3.14}{4} \times 50^2$

Area of each Lateral = *0.00196 m*^{2}

Number of Laterals Required = $\frac{Area\ of\ Laterals}{Area\ of\ Each\ Lateral}$

= $\frac{0.336}{0.00196}$

Number of Laterals Required = *171 Nos*

Provide Number of Laterals = 172 Nos

Number of Laterals on each side of Manifold = $\frac{Number\ of\ Lateral}{2}$

= $\frac{171}{2}$

Number of Laterals on each side of Manifold = *85.500 Nos*

Length of Each Lateral = $\frac{\frac{Width\ of\ Filter\ Bed}{2} - D_{Manifold}}{2}$

= $\frac{\frac{6.6}{2} - 0.85}{2}$

Length of Each Lateral = *1.225 m*

Ratio = $\frac{Length\ of\ Each\ Lateral}{Diameter\ of\ Lateral}$

= $\frac{1225}{50}$

Ratio = *24.500 < 60*

Required Spacing of Lateral = $\frac{Length\ of\ Filter\ Bed}{(Number\ of\ Lateral/2)}$

= $\frac{8.5}{(172/2)}$

Required Spacing of Lateral = *100 mm*

Provide Spacing of Lateral = 100 m c/c

- *Assumed diameter of Orifice = 7 mm*

Area of each Orifice = $\frac{\pi}{4} \times D^2_{Orifice}$

= $\frac{3.14}{4} \times 7^2$

Area of each Orifice = *0.0000385 m^2*

Number of Orifices per Lateral Required = $\frac{Area\ of\ Orifice}{No\ of\ Laterals \times Area\ of\ Each\ Orifice}$

= $\frac{0.084}{171 \times 0.0000385}$

Number of Orifices per Lateral Required = *14 Nos*

Provide Number of Orifices = 15 NOS

Required Spacing of Orifice = $\frac{Length\ of\ Each\ Lateral}{(No\ of\ Orifice/2)}$

= $\frac{1.225}{(15/2)}$

Required Spacing of Orifice = *165 mm c/c*

Provide Spacing of Orifice = 140 mm c/c

4.2 VALIDATION CHECKS:

1. *Diameter of Manifold Provided = 0.85 m > Diameter of Manifold required = 0.801 m*

Spacing of Manifold Provided > Spacing of Manifold Required

2. *Ratio of Length of Laterals to Spacing of Lateral = 24.500*

Ratio of Length of Laterals to Spacing of Lateral < 60, Hence Okay.

DESIGN SUMMARY - UNDER DRAIN SYSTEM		
Sections per filter bed	=	*2 Nos*
Ratio of Filter to Perforation	=	*0.3 %*
Ratio of Area of Manifolds to Area of Laterals	=	*1.5*
Diameter of Manifold	=	*0.85 m*
Width of Manifold Pit	=	*0.9 m*
Depth of Manifold Pit	=	*0.9 m*
Diameter of Lateral	=	*50 m*
Number of Laterals	=	*172 Nos*
Diameter of Orifice	=	*7 mm*
Spacing of Lateral	=	*100 mm c/c*
Spacing of Orifice	=	*140 mm c/c*

5. BACKWASHING OF FILTER

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HYDRAULIC DESIGN

- PURE WATER CHANNEL

HYDRAULIC DESIGN OF PURE WATER CHANNEL

The role of Pure Water Channel is to convey water from one element to the another.

(Reference Table No. 1)

- ✓ *Number of Units = 1 Nos*
- ✓ *Designed Flow Per Unit = 50 MLD*
- ✓ *Designed Capacity in m^3/sec = 0.579 m^3/sec*

1.1 ASSUMPTIONS & CALCULATIONS:

- *Assumed velocity of flow through Pure Water Channel = 0.6 m/sec*
- *Assumed Width of Pure Water Channel = 2 m*
- *Assumed Free Board = 2 m*
- *Assumed Length of Pure Water Channel = 3 m*

$$\text{Side Water Depth of Pure Water Channel} = \frac{\text{Designed Capacity}(m^3/sec)}{Velocity \times Width\ of\ Channel}$$

$$= \frac{0.579}{0.6 \times 2}$$

Side Water Depth of Pure Water Channel = 0.482 m

$$\text{Total Depth of Pure Water Channel} = SWD_{Channel} + Free\ Board$$

$$= 0.482 + 2$$

Total Depth of Pure Water Channel = 2.482 m

1.2 VALIDATION CHECKS:

1. *Velocity Achieved = 0.6 m/s*

Hence, Velocity achieved is within the permissible Range (0.6 -1.2 m/sec)

DESIGN SUMMARY - CHANNEL

Velocity	=	0.6 m/sec
Width	=	2 m
Side water Depth (SWD)	=	0.482 m
Length	=	3 m
Free Board	=	2 m
Total Depth of Pure Water Channel	=	2.482 m

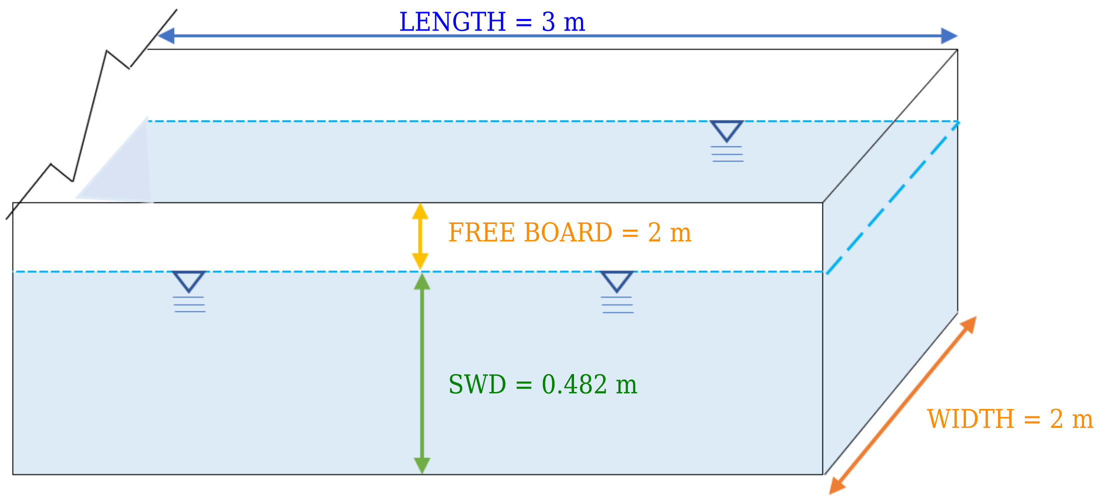

Figure - Pure Water Channel Details

HYDRAULIC DESIGN

- PIPE

HYDRAULIC DESIGN OF PIPE

The role of Pipe is to convey water from one element to the another.

(Reference Table No. 1)

- ✓ *Number of Units = 1 Nos*
- ✓ *Designed Flow Per Unit = 50 MLD*
- ✓ *Designed Capacity in m^3/sec = 0.579 m^3/sec*

1.1 ASSUMPTIONS & CALCULATIONS:

- *Assumed velocity of flow through Pipe = 0.6 m/sec*

$$\text{Diameter of Pipe Required} = \left[\frac{4 \times Designed\ Flow(m^3/sec)}{\pi \times \text{Velocity(m/s)}}\right]^{0.5}$$

$$= \left[\frac{4 \times 0.579}{3.14 \times 0.6}\right]^{0.5}$$

Diameter of Pipe Required = 1.108 m

Provide Standard D.I Pipe of Internal Diameter = 1.200 m

- *Corresponding thickness of Pipe (K7) = 0.01530 m*

Hence, Outer Diameter = 1.231 m

1.2 VALIDATION CHECKS:

1. *Provided Diameter 1.200 m > Required Diameter = 1.108 m*

Hence Diameter provided of Pipe is Sufficient.

2. *Velocity Achieved = 0.512 m/s*

DESIGN SUMMARY - PIPE

Velocity	=	*0.512 m/s*
Internal Diameter of Pipe	=	*0.512 m*
Thickness of Pipe	=	*0.01530 m*
Outer Diameter of Pipe	=	*1.231 m*

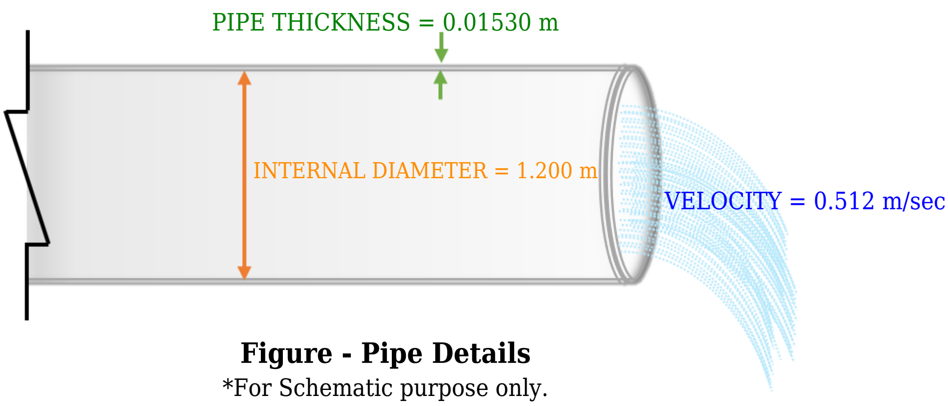

Figure - Pipe Details

*For Schematic purpose only.

HYDRAULIC DESIGN

- ## PURE WATER SUMP (CIRCULAR)

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ANNEXURE - II

- HYDRAULIC HEAD LOSSES AND REDUCED LEVELS

HYDRAULIC HEAD LOSSES AND REDUCED LEVELS	
NOTATION	**ABBREVIATION**
HL	Head Loss
TWL	Total Water Level
FSL	Full Supply Level
RL	Reduced Level
h_{fr} , h_f	Frictional Loss
g	Gravitational Acceleration
C	Manning's Coefficient
f	Hazen William Coefficient
R	Hydraulic Radius
S	Hydraulic Gradient
h_{en}	Head Loss at Entry
h_{ex}	Head Loss at Exit
h_b	Head Loss due to Bend
h_{se}	Head Loss due to Suddden Expansion
h_{sc}	Head Loss due to Sudden Contraction
K_{en}	Entry Head Loss Coefficient
K_{ex}	Exit Head Loss Coefficient
K_b	Bend Head Loss Coefficient
K_{se}	Expansion Head Loss Coefficient
K_{sc}	Contraction Head Loss Coefficient
Q	Discharge in m^3/sec
v	Velocity in m/sec
SWD or d	Side Water Depth in m
b	Width in m
d	Diameter in m
L	Length in m

Formulae Used for Calculating Head Losses:

I. Frictional Losses in Open Channels:

Using Manning's Formula Hydraulic Gradient (S) $= \left[\dfrac{Velocity \times n}{R^{2/3}}\right]^{1/(1/2)}$

n	=	Manning's Coefficient
Hydraulic Radius (R)	=	$\frac{Cross\ Sectional\ Area}{Wetted\ Perimeter}$
	=	$\frac{b \times d}{b + 2d}$
Frictional Loss	=	$Hydraulic\ Gradient\ (S) \times Length$

II. Frictional Losses in Pipes:

a. Frictional Losses by Hazen William Equation:

✓ *Assuming value of C = 100*

h_{fr}	=	$\left[\frac{Velocity}{0.85 \times C \times R^{0.63}}\right]^{1/0.54} \times Length\ of\ Pipe$
Where, C	=	Hazen William Coefficient (Refer Table No.)
R	=	Hydraulic Radius
	=	$\frac{Diameter}{4}$

b. Frictional Losses by Darcy Weisbach Equation:

h_f	=	$\left[\frac{f \times L \times Q^2}{12.1 \times d^5}\right]$
Where, f	=	Darcy Weisbach Coefficient (Refer Table No.)
L	=	Length of Pipe in m
Q	=	Discharge in m^3/sec
d	=	Diameter of Pipe in m

III. Minor Head Losses in Pipes:

a. Loss at Entry:

$$h_{en} = \frac{K_{en} \times V^2}{2 \times g}$$

b. Loss at Exit:

$$h_{ex} = \frac{K_{ex} \times V^2}{2 \times g}$$

c. Loss due to Bend:

$$h_b = \frac{K_b \times V^2}{2 \times g}$$

d. Loss due to Sudden Enlargement:

$$h_{se} = \frac{K_{se} \times {V_1}^2}{2 \times g}$$

e. Loss due to Sudden Contraction:

$$h_{sc} = \frac{K_{sc} \times {V_2}^2}{2 \times g}$$

Where K_{en} , K_{ex} , K_b, K_{se} , K_{sc} are Head Loss Coefficients
For Coefficient Details refer Table No.
v = velocity in m/sec
g = Gravitational Acceleration

Formulae Used for Calculating Water and Reduced Levels:

TWL at Start of an Element = $Preceeding\, TWL_{Element} - Assumed\ Drop_{Element}$

TWL at End of an Element = $TWL_{Element}\ at\ start - Total\ Head\ Loss_{Element}$

RL at Start of an Element = $TWL_{Element}\ at\ start - SWD_{Element}$

RL at End of an Element = $TWL_{Element}\ at\ End - SWD_{Element}$

HEAD LOSSES

- ## REDUCED LEVELS

HEAD LOSSES AND REDUCED LEVELS
(CASCADE AERATOR)

1. STEPS AND PLANNER

✓ *No. of Steps = 5 Nos.*
✓ *Rise of Steps = 0.3 m*
✓ *Diameter of Aerator = 7.3 m*

2. COLLECTION LAUNDER

✓ *Velocity in Launder = 0.65 m/sec*
✓ *Width of Launder = 0.6 m*
✓ *SWD = 0.742*
✓ *Free Board = 0.3 m*

HEAD LOSS CALCULATIONS AND LEVELS:

➢ *R.L at Lip of Aeration Fountain = 150 m*
➢ *Free Fall from last step to collection launder = 0.01 m*

Total Loss from lip of fountain = $(No\ of\ Steps \times Rise_{Step}) + Free\ Fall$

= $(5 \times 0.3) + 0.01$

Total Loss from Lip of Fountain = *1.510 m*

➢ *Assumed Total Loss from Lip of Fountain = 1.510 m*

TWL of Collection Launder at start = $RL\ of\ Lip - (Total\ Loss + Additional\ Losses)$

= $150 - (1.510 + 0.01)$

TWL of Collection Launder at start = *148.480 m*

R.L of Collection Launder Bottom at start = $TWL\ of\ Collection\ Launder\ at\ start - SWD\ of\ Launder$

= $148.480 - 0.742$

R.L of Collection Launder Bottom at start = *147.738 m*

R.L of Collection Launder Top at start = $TWL\ of\ Collection\ Launder\ at\ start + Free\ Board$

= $148.468 + 0.3$

R.L of Collection Launder Top at start = *148.038 m*

Length of Launder = $\frac{\pi}{2} \times \ (Diameter_{Aerator} + Width_{Launder})$

= $\frac{3.14}{2} \times \ (7.3 + 0.6)$

Length of Launder = *12.40 m*

➢ *Frictional Loss in Launder, Using Manning's Formula and taking Manning's Coefficient for R.C.C as n = 0.13*

Hydraulic Gradient (S) = $\left[\frac{Velocity \times n}{R^{\left(2/3\right)}}\right]^{1/\left(1/2\right)}$

$$= \left[\frac{0.6 \times 0.013}{0.21363^{\left(2/3\right)}}\right]^{1/\left(1/2\right)}$$

Hydraulic Gradient (S) = *0.00056*

Frictional Loss in Launder = $Hydraulic\ Gradient \times Length\ of\ Launder$

= 0.00056×12.40

Frictional Loss in Launder = *0.007 m*

TWL of Collection Launder at End = $TWL\ of\ Launder\ at\ Start - (Frictional\ Loss + Additional\ Loss)$

= $148.480 - (0.007 + 0.005)$

TWL of Collection Launder at End = *148.468 m*

R.L of Collection Launder Bottom at End = $TWL\ of\ Collection\ Launder\ at\ End\ - SWD_{Launder}$

= $148.468\ - 0.742$

R.L of Collection Launder Bottom at End = *147.726 m*

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HEAD LOSSES AND REDUCED LEVELS
(PURE WATER CHANNEL)

✓ *Velocity of Flow in Channel = 0.6 m/sec*
✓ *Depth of Water (SWD) = 0.482 m*
✓ *Length of Channel = 3 m*
✓ *Width of Channel = 2 m*

HEAD LOSS CALCULATIONS AND LEVELS:

⊳ *TWL of Rapid Sand Gravity Filter at end = 146.435 m*
⊳ *Assumed Drop in Channel = 0 m*

TWL of Channel at start = $TWL\ of\ Launder\ at\ End - Drop$
= $146.435 - 0$
TWL of Channel at start = *146.435 m*

RL of Channel at Start = $TWL\ of\ Channel\ at\ Start - SWD_{Channel}$
= $146.435 - 0.482$
RL of Channel at Start = *145.953 m*

⊳ *Frictional Loss in Channel, Using Manning's Formula and taking Manning's Coefficient for R.C.C as n = 0.13*

Hydraulic Gradient (S) = $\left[\frac{Velocity \times n}{R^{\left(2/3\right)}}\right]^{1/\left(1/2\right)}$

= $\left[\frac{0.6 \times 0.013}{0.32524^{2/3}}\right]^{1/\left(1/2\right)}$

Hydraulic Gradient (S) = *0.00027*

Frictional Loss in Channel = $Hydraulic\ Gradient \times Length\ of\ Channel$
= 0.00027×3.00
Frictional Loss in Channel = *0.00081 m*

⊳ *Assumed Frictional Loss in Channel = 0.00081 m*
⊳ *Assumed Additional Head Losses Remark = 0 m*

TWL of Channel at End = $TWL\ of\ Channel\ at\ Start - (Frictional\ Loss + Additional\ Loss)$
= $146.435 - (0.00081 + 0)$
TWL of Channel at End = *146.434 m*

R.L of Channel Bottom at End = $R.L\ of\ Channel\ Bottom\ at\ Start$
R.L of Channel Bottom at End = *145.953 m*

HEAD LOSSES AND REDUCED LEVELS
(PIPE)

- ✓ *Designed Flow = 0.579 m^3/sec*
- ✓ *Velocity of water in Pipe = 0.6 m/sec*
- ✓ *Diameter of Pipe = 1.200 m*
- ✓ *Length of Pipe = 3 m*

HEAD LOSS CALCULATIONS AND LEVELS:

- *TWL of Channel at end = 146.434 m*

Total Head Losses in Pipe = A_{HL}

= 0

Total Head Losses in Pipe = *0.000 m*

TWL at the start of Pure Water Sump = $TWL\ of\ Pure\ Water\ Channel\ at\ end\ -\ Total\ Head\ Losses\ in\ Pipe$

= $146.434 - 0.000$

TWL at the start of Pure Water Sump = *146.434 m*

HEAD LOSSES AND REDUCED LEVELS
(PURE WATER SUMP)

✓ *Water Depth (SWD) = 3 m*

HEAD LOSS CALCULATIONS AND LEVELS:

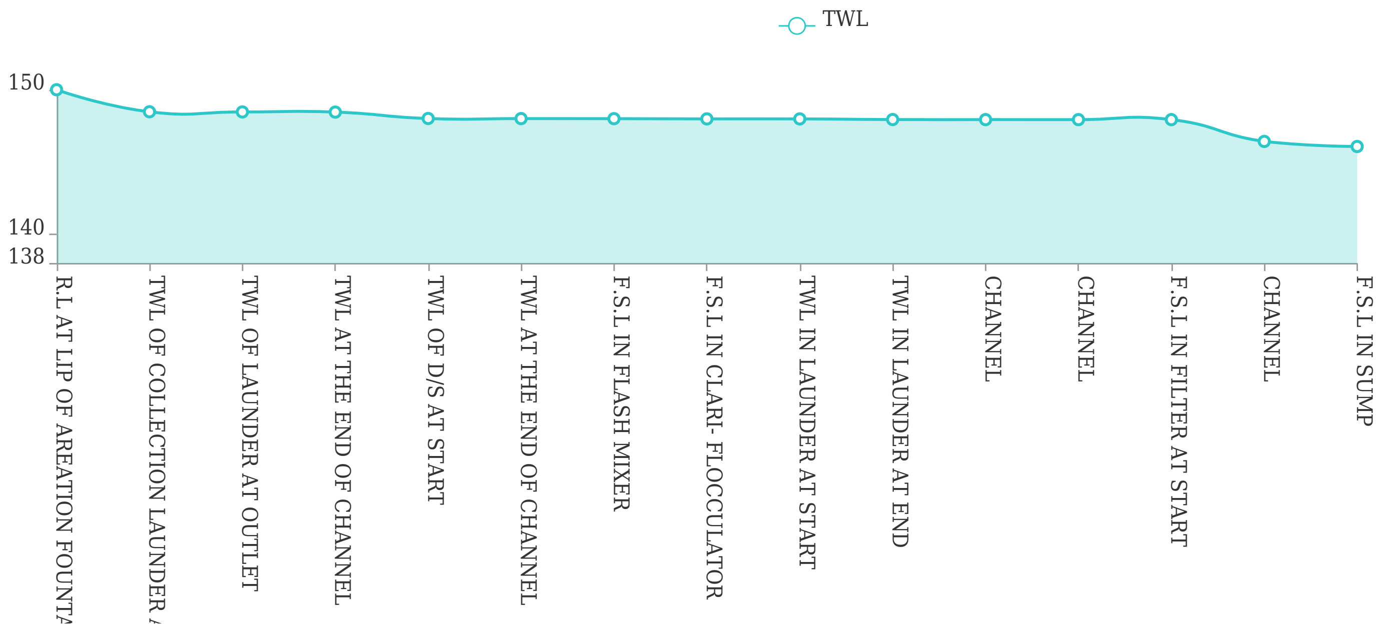
- *TWL of Pure Water Sump at the start = 146.434 m*

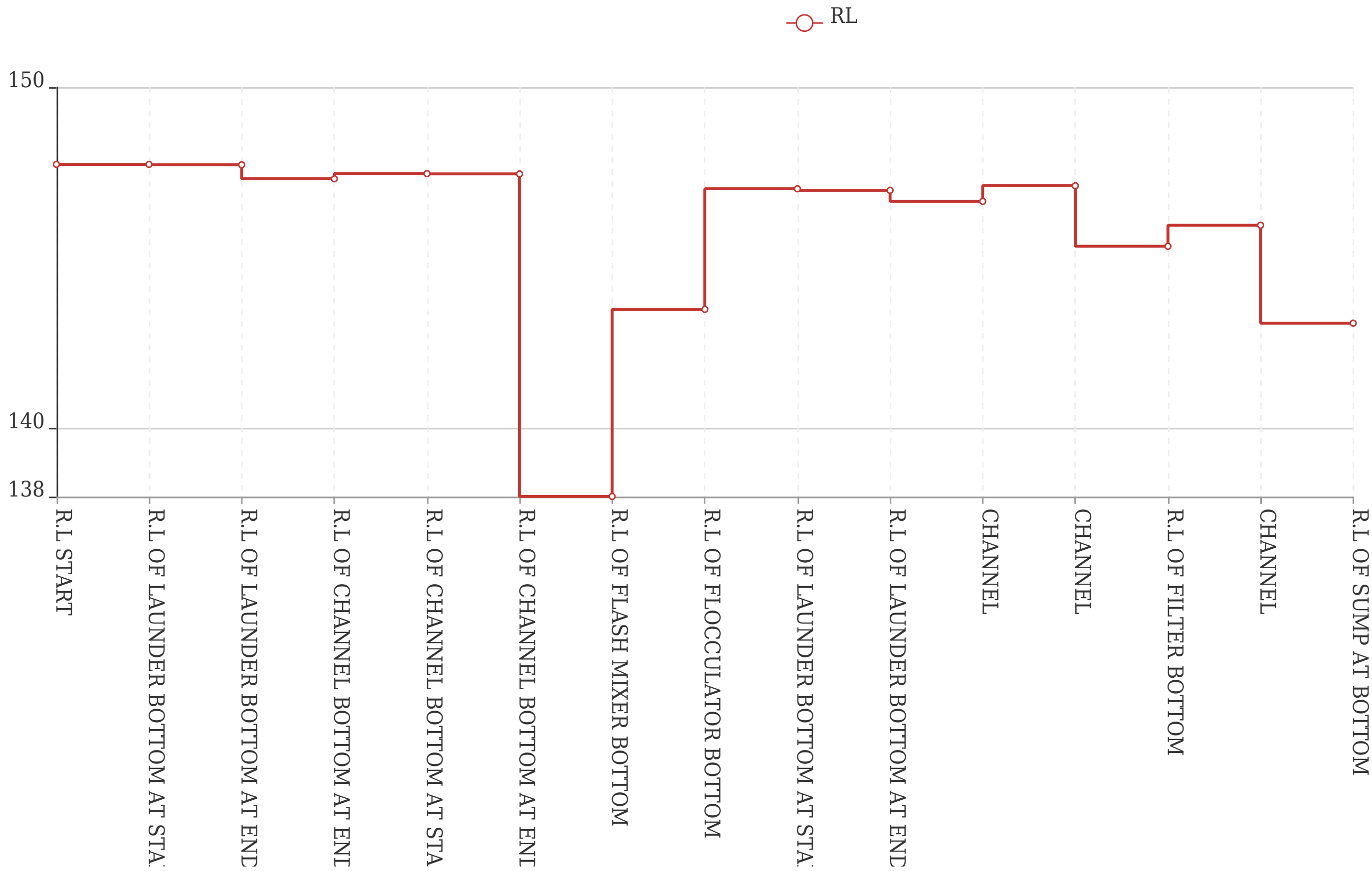
$$FSL\ in\ Sump = TWL\ at\ Start - (Drop + Free\ Fall)$$
$$= 146.434 - (0.050\ \mathrm{m} + 0.300\ \mathrm{m})$$
$$FSL\ in\ Sump = 146.084\ m$$

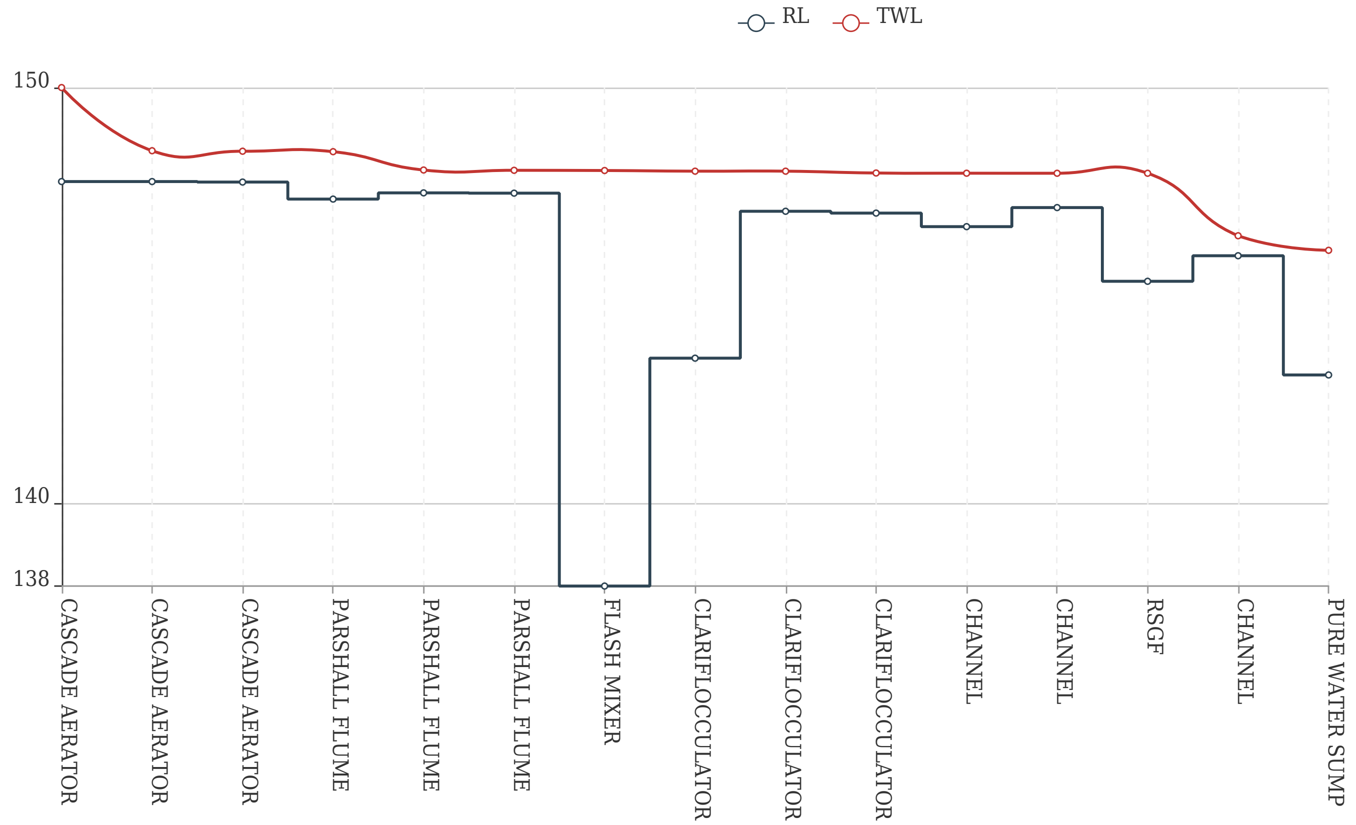
$$RL\ of\ Sump\ Bottom = FSL\ in\ Sump - SWD_{Sump}$$
$$= 146.084 - 3$$
$$RL\ of\ Sump\ Bottom = 143.084\ m$$

TOTAL WATER LEVEL AND REDUCED LEVELS

AVERAGE GL OR RL AT START = 150 m							
SR NO.	ELEMENT	CUMULATIVE HEAD LOSS	TOTAL WATER LEVEL		REDUCED LEVEL		
			START	END	START	END	
1	CASCADE AERATOR	1.532 m	150	148.468	150	147.726	
2	PARSHALL FLUME	1.991 m	148.468	148.009	147.322	147.459	
3	FLASH MIXER	1.996 m	148.009	148.004	138.004	138.004	
4	PIPE	2.011 m	148.004	147.989			
5	PIPE	2.011 m	147.989	147.989			
6	CLARIFLOCCULATOR	2.056 m	147.989	147.944	147.023	146.979	
7	CHANNEL	2.061 m	147.944	147.939	146.657	146.653	
8	FILTER INLET CHANNEL	2.062 m	147.939	147.938	147.112	147.112	
9	RAPID SAND GRAVITY FILTER	3.565 m	147.938	146.435		145.338	
10	PURE WATER CHANNEL	3.566	146.435	146.434	145.953	145.953	
11	PIPE	3.566 m	146.434	146.434			
12	PURE WATER SUMP	3.916 m		146.434		143.084	




RL
150
140
138
R.L START
R.L OF LAUNDER BOTTOM AT STA
R.L OF LAUNDER BOTTOM AT END
R.L OF CHANNEL BOTTOM AT END
R.L OF CHANNEL BOTTOM AT STA
R.L OF CHANNEL BOTTOM AT END
R.L OF FLASH MIXER BOTTOM
R.L OF FLOCCULATOR BOTTOM
R.L OF LAUNDER BOTTOM AT STA
R.L OF LAUNDER BOTTOM AT END
CHANNEL
CHANNEL
R.L OF FILTER BOTTOM
CHANNEL
R.L OF SUMP AT BOTTOM



TWL	150	148.480	148.468	148.457	148.016	148.009	148.004	147.988	147.988	147.944	147.939	147.938	147.938	146.434	146.084
RL	147.738	147.738	147.726	147.316	147.466	147.459	138.004	143.488	147.023	146.979	146.653	147.112	145.338	145.953	143.084