Design and Implementation of River Water Intake System

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Abstract: The river water intake system is designed to cater the water demand of dust suppression system for the project constructed on the bank of Ganga river. The project was executed by considering that the water demand of dust suppression system will meet through water supply connection from the local municipal authority. Therefore, all civil, mechanical and electrical woks were already completed considering the above indicated water source. However, allocation from the local municipal corporation has not been accorded for the project. The water is available throughout the year in the river Ganga and ground water is also available at lesser depth in the project site. Therefore, the river water and bore wells were proposed as the source of water for the dust suppression system. However, the water demand of dust suppression system is higher than yield of common bore well. Therefore, river water is considered as the source of water and the river water intake system is designed to cater the demand of the dust suppression system. The berth was already constructed. Hence, the system needs to be designed without causing much excavation and disturbance to the constructed system which was the major challenge in designing and selection. Also, the river Ganga has high water currents. Therefore, the system needs to be designed to sustain the water current loads as well as to protect the system from damaging due to solid materials flowing along the river. The various options were studied and analysed during the design of the river water intake system. The borewell pumps with the casing pipe have been selected for the project based on the techno-commercial aspects. The system is designed to pump the river water into the underground service water tank using borewell pumps and further it is utilized for the dust suppression system.

***Keywords* - Hazen Williams Coefficient; Negative lift; Pressure Ratings; Representative Resistance Coefficients; Pumps.**

1. Introduction:

The project consists of berth, approach bridge, coal and chip yard with material handling systems. The block diagram for the project is shown in the figure 1. The coals and chip pieces produce dust during the handling which gets mixed in the air. This phenomenon is predominantly observed during high winds and summer conditions. Thus, the dust suppression system is designed to mitigate the mixing of the dust in the atmospheric air by sprinkling the water. The river water intake system is designed to pump the water from the river into the underground storage tank. Then, it will be utilized for the dust suppression system by dedicated pumping and sprinkler system. The operating floor level of the berth is 12.5 m from the low water level (LWL) and 2.5 m from the high water level (HWL). (The low water level is the lowest level of water reached during $1/100^{th}$ time of the year and high water level is the highest level of water reached during $1/100^{th}$ time of the year). These water levels have significant impact on the selection of the pumping for the river water intake systems.

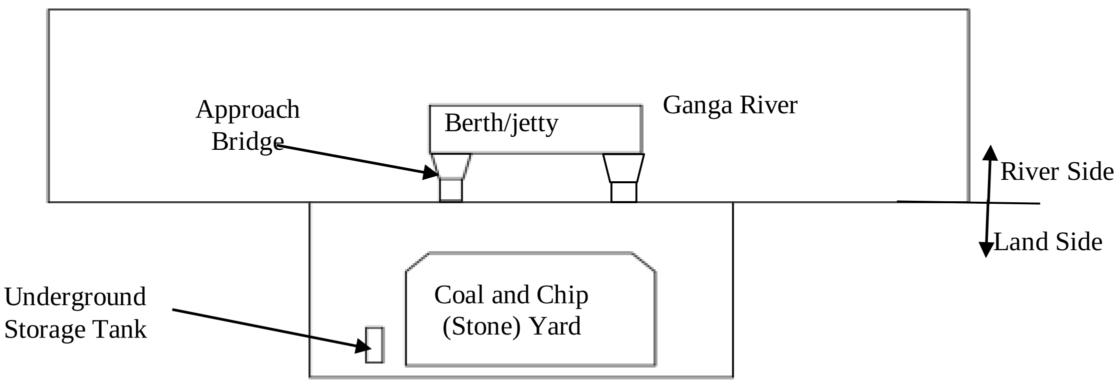

Figure 1 Block Diagram for IWT.

2. Proposed options for the river water intake systems

The dust suppression system requires 78 m^3/hr of the water for the operation. Various options were considered for the river water intake system. The main important constrain was to design the optimized scheme with less execution time as berth was already constructed. Therefore, the pumping scheme, supply pipe material and the pipe route has been decided such that the designed system will have less excavation work, optimized cost and less installation time. The following are the different options that were considered for the river water intake system to meet the project requirements:

Option 1:- Pumping system with the end suction pump

The arrangement with the end suction pump is shown in figure 2. The end suction pump supposed to be mounted on the top of berth or jetty. The foot valve and suction strainer will be kept well below the low water level to ensure the water availability throughout the year. The pressurized water from pump discharge will be transferred to underground storage tank and water will be utilized for the dust suppression purpose.

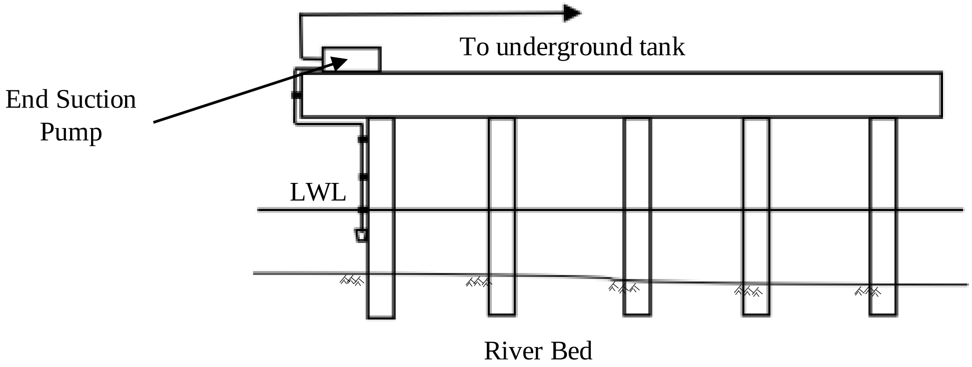

Figure 2 Arrangement of End suction pumps.

However, the manufacturer's catalogue for end suction pump recommends that maximum value of the negative lift (elevation difference between the water level and eye of the impeller) shall be 4 m. Practically, the end suction pumps shall not be used for the suction head greater than 4 m as the vacuum created by impeller of pump will not be sufficient to suck the water into the eye of impeller. For our case, the elevation difference between low water level and eye of impeller is 12.5 m. Therefore, this option is not feasible and hence same was not considered for the further evaluation.

Option 2:- Pumping system with open well submersible pump

In this option, the submersible pump will be placed on the river bed and clamped to the existing piles using clamps and supports. The pumped water using this system will be utilized for the dust suppression system. The eye of impeller will always be inside the water and hence problem of providing the enough suction head stated in option 1 will be solved and the cost of installation for the system is minimum. But, the Ganga is India's one of the widest rivers and it has high water currents throughout the year. Also, during rainy and high runoff conditions it carries solid particles, stones, gravels, etc. with the flow. Therefore, exposing the pump directly to river water may damage the pumps and require frequent maintenance. Therefore, this option has not been considered for further evaluation.

Option 3:- Construction of pump house inside the river (intake well)

This option was to construct the separate pump house inside the river. The submersible type end suction pump could be placed inside the pump house. Therefore, water current loads are supposed to be taken by the walls of the pump house. Also, even during high run off conditions the maintenance of the pumping system supposed to be easy as entire pump set would have been placed inside the pump house. However, the construction cost and excavation requirement for this system is high. Also, to meet the limiting entry velocity requirement, large sized pump house was required and fish entrapment is also commonly observed in such schemes. This type of scheme is mostly suited for the projects with high water demands. Therefore, this option was not considered for further evaluation based on techno-commercial aspects and project schedule.

Option 4:- Construction of shallow well near the river bank

The shallow well was supposed to be constructed at the river bank. The river water would have entered in the well from the pipe provided with strainer. Then that water was supposed to be pumped using submersible pumps to the underground water tanks. The option of the construction of the well was feasible and also, economical than construction of the pump house. But, the constrain for this option was that the river bank protection and flooring work was already completed. For construction of the well, excavation work is needed and adequate space is also not available. Therefore, this option is not considered for further evaluation.

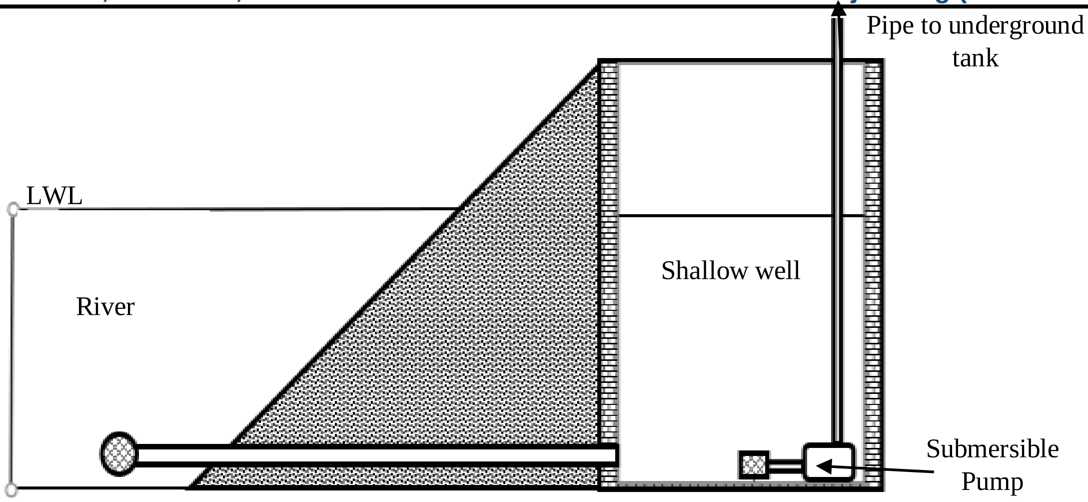

Figure 3: Shallow well type of river water intake system.

Option 5:- Intake system with borewell pumps and casing pipe

The system will have slotted casing pipes and bore well pump. The slotted casing pipe will be clamped to piles using the clamps. The chain and pulley arrangement will be provided to lift the pump during the maintenance activities. The casing pipe is planned to keep behind the piles to protect system from the heavy currents and solid materials. The water will be pumped from the river into the underground tank after passing through the gravity filters. The system will have easy installation, less maintenance, low cost, less execution time and system can be installed without doing much excavation works.

3. Selection of the best feasible option

The total five options were studied during the design of the river water system. It is necessary to select the best feasible option amongst the available options. Therefore, selection of the option carried as per the selection matrix. The cost, excavation work, ease of maintenance, feasibility of installation, installation time and life has been considered as the selection criteria. Amongst above 5 criteria cost, excavation work & feasibility of installation are important and has given higher weightage than other criteria. Based on the weightage, the rank will be obtained for each option. The option 5 i.e. Intake system with borewell pumps and casing pipe has highest rank. Therefore, it is selected for implementation.

Table 1 Selection Matrix.

Criterion	River Water Intake Scheme Options					Weightage
	Option 1	Option 2	Option 3	Option 4	Option 5	
Cost	0	0	-3	-2	0	0.20
Excavation work	0	0	-3	-2	0	0.15
Ease of maintenance	0	-2	0	0	0	0.1
Feasibility of installation	0	3	3	3	3	0.20
Life	0	-2	1	1	0	0.15
Installation time	0	0	-3	-3	0	0.20
Total	**0**	**0.1**	**-0.9**	**-0.55**	**0.6**	**-**
Rank	**3**	**2**	**5**	**4**	**1**	

4. Design of river water intake system

The design of the river water intake system involves selection of the pump, obtaining the diameter of the pipes, finalization of pipe route, design of slotted casing pipes, etc. The pipe route is finalized such that installation can be done within available space and minimal excavations. The maximum demand of the water for the dust suppression system is 78 m^3/hr. The pump capacity is considered as 90 m^3/hr considering the 10 % wear and tear margin over the designed period of life.

4.1 Selection of the bore well pumps

The head and discharge are the two important parameters for the pump selection. The discharge required for the pump is considered as 90 m^3/hr. The net head developed by the pump is the sum of maximum frictional loss and net static head which pump can produce to deliver the desired quantity of the water. Therefore, head or frictional loss to flow through the pipe is calculated and the head requirement of pump is kept higher than the sum of head loss in the pipe and net static head. The head loss is calculated using the Hazen-William's formula [3] (equation 1). The sum total of head losses due to bend, valves and head losses calculated for overall length of pipe along with 10 % margin is considered as the total head loss.

$$H_L = \frac{1.3541 \times v^{1.852}}{R_h^{1.167} \times C^{1.852}} \qquad \ldots(1)$$

Where,

H_L = Loss of head per unit length of pipe,

$R_h = \frac{A_c}{p}$ = Hydraulic Radius of the pipe (m),

C = Hazen-William's Coefficient (140 for HDPE pipes),

A_c = Cross section area of pipe (m^2),

p = Circumference of Pipe (m).

The head loss due to bends, valves and fittings is calculated as using the equation 2 [3].

$$H_F = K\frac{v^2}{2g} \quad \ldots(2)$$

Where,

H_F = Loss of head per fittings (m),

K = Representative Resistance Coefficients.

g =Acceleration due to gravity (m/s^2),

v =Flow velocity (m/s).

The total head loss (including loss due to valves and fittings) is obtained as 14 m, total static head (From LWL to top of the underground reservoir) is 21.4 m of water and 10 m is the head required for the gravity filter. Therefore, in order to cater the demand 3 NOS of submersible pumps (2 working + 1 Standby) of capacity 45 m^3/hr and head of 45 m is selected.

4.2 Design of the piping system

It involves selection of the material, diameter and pressure ratings of the pipe. The diameter of the pipe is obtained using the one-dimensional continuity equation [2] (equation 3). As per the general engineering practice, limiting velocity for water flowing through pipe is 2 m/s.

$$Q = A \times v \quad \ldots(3)$$

Where,

Q = Maximum flow rate through the pipe (m^3/s),

A = Cross Sectional Area of Pipe (m^2),

v =Flow velocity (m/s).

The main header with flow rate 90 m^3/hr, the minimum calculated diameter is 130 mm and the pipes connecting pump to main header with flow rate 45 m^3/hr, minimum required diameter is 90 mm. The diameters selected for the main header and connecting pipes are 160 mm and 100 mm respectively by considering market availability. The project site is located on the river bank and nearby soil is moist. If carbon steel pipes are used in such place, they are subjected to the corrosion. The external and internal coating is required for the carbon steel pipes for corrosion resistance. However, the HPDE pipes has higher corrosion resistance, less frictional drop and low cost than carbon steel pipes. Therefore, HDPE pipe is selected for the water distribution system. The HDPE pipes are available in the different ratings like PE 63, PE 80, PE 100, etc. Indian Standard 4984 specifies that the minimum required strength of the PE 100 pipe material for 50 years at 20^0 C is 10 MPa i.e. 100 bars. The HDPE PE 100 pipes are selected for the project by considering the minimum life of 30 years. As stated earlier, it is necessary to decide the pressure ratings for the pipes. The pumps are selected with net head of the 45 m of water column. The shutoff pressure for the pipe is taken as 1.5 times the head developed by the pumps. Shutoff pressure is the pressure exerted by fluid on the walls of pipe when all valves are closed. Therefore, shutoff pressure for the pumping system will be 67.5 m (6.62 bars). The Indian Standard 4984 specifies that next available pressure rating after 6 bars (PN 6) is 10 bars (PN 10). Therefore, the PN 10 pressure rating is selected for the pipe HPDE pipe.

4.3 Design of casing pipe for the pumps

The borewell pumps need casing pipe for the support and inlet water filtration. The various company's catalogue for bore well pumps viz. Kirloskar Pumps, KSB pumps, Texmo pumps, etc. have been referred for the dimensions of the casing pipe. The catalogues recommended 6" borewell pumps will be required to meet system requirements. Therefore, 200 mm is selected as the diameter for the casing pipe by considering smooth raising and lowering of the 150 mm diameter pump. The slots or the holes need to be provided on the casing pipe to ensure the sufficient quantity of water will be always available even at low levels throughout the year. The arrangement of slots is considered as specified in the Indian Standard and same is shown in the figure 5. The length of slotted pipe is calculated by considering the slotting arrangement shown in figure and specified as per the IS 8110. The maximum allowable velocity for the water entry is taken as 0.03 m/s and 50 % clogging of the slots is assumed. The area slotted are required for the pipe is calculated using the equation 4 [4].

$$2Q = A \times v \quad \ldots(4)$$

Where,

Q = Maximum flow rate through the pipe (m^3/s),

A = Area required for the slots(m^2),

v = Allowable Flow velocity (m/s),

And,

The 2 is multiplied to assume that the 50 % of slots are clogged.

The slot of length 75 mm and width 1.6 mm is considered. Therefore, number of slots required are calculated as the ratio of total area required by slots to the area of the slots. Total 6942 number of slots are required to be provided on the pipes. Now, the arrangement of the slots is selected according to IS 8110. The length of pipe is calculated using following method:

1. Calculated number of slots per row.
2. Calculated number of rows required.
3. Calculate length of pipe as the product of number of rows and length occupied by each row.

The required length is calculated using the above considerations for the arrangement of slots shown in the figure 5. The length of the slotted pipe is obtained as 6 m.

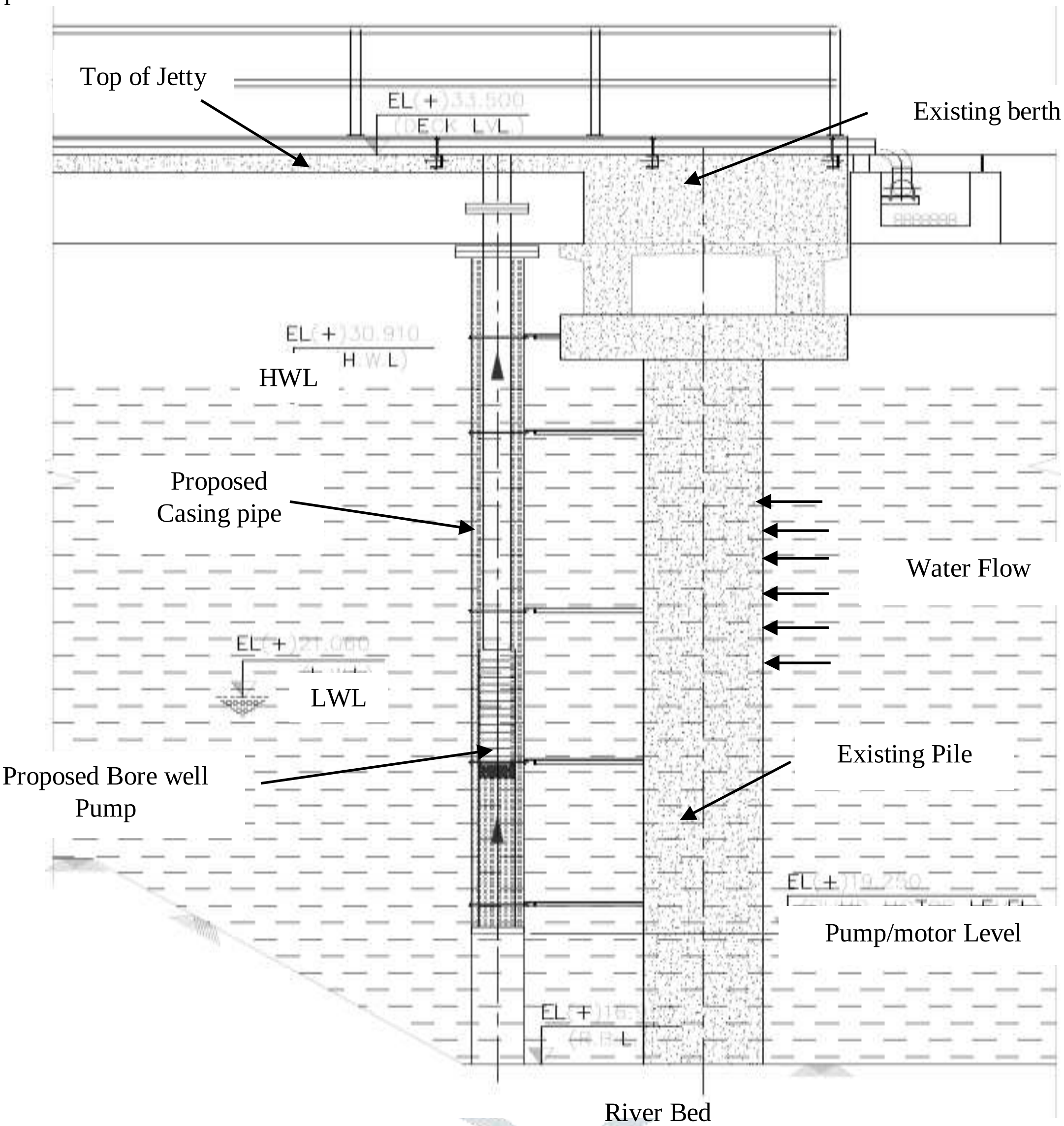

Figure 4 River Water Intake System with bore well pumps.

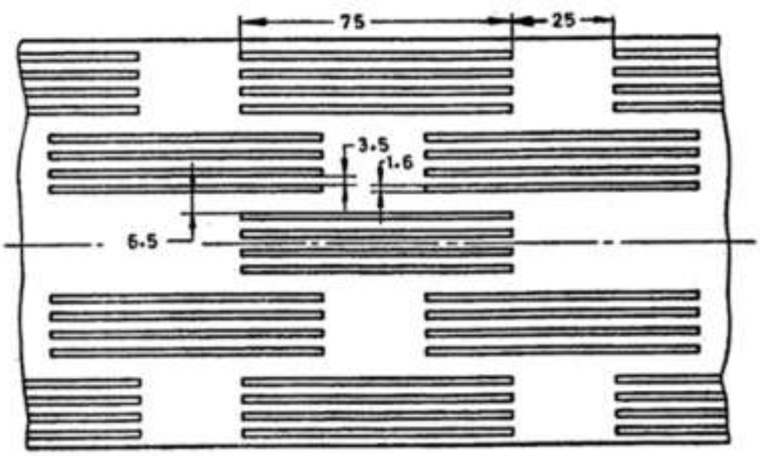

Figure 5: Arrangement of Slots (IS 8110)

5. Conclusion

The various available options were studied during the design of the river water intake system. Low excavation work, less installation time, ease of maintenance, feasibility of installation and longer life were considered as criteria of selection which leads to optimized cost. Among all selected criteria, the feasibility, optimum cost and less installation time had been given higher weightage over the other criteria. Based on the weightage, rank is obtained. The option 5 i.e. option with borewell pump and casing pipe has highest rank amongst other options. Therefore, it is considered for the implementation.

The pump is selected based on the water quantity and the net head requirement. The net head developed by the pump is the sum total of a net static head and a head loss due to friction (head loss in the pipes and fittings). The head loss in the piping calculated using Hazen William's formula and in fittings is calculated using Darcy-Weisbach Equation. The diameter of the pipe is calculated assuming the maximum limiting velocity of the water as 2 m/s. The diameter of casing pipe is obtained by considering smooth installation and maintenance of pump. The length of slotted casing pipe is obtained as per the IS 8110. The technical feasibility, optimum cost and minimum execution time are the main design criteria. Therefore, the entire system is designed and installed based on the both technical and commercial aspects.

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