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OPTIMIZATION OF THE PUMP HOUSE LAYOUT FOR LIFT IRRIGATION SCHEME: A REVIEW

MR. HRISHIKESH R. KANE[1*], MR. DHIRAJ BHOPLE [2], PROF. DEEPA TELANG [3],

[1 & 2] PG Student, CIVIL ENGINEERING DEPARTMENT, G H RAISONI INSTITUTE OF ENGINEERING AND TECHNOLOGY, NAGPUR, MAHARASHTRA, INDIA

[3]Assistant Professor, CIVIL ENGINEERING DEPARTMENT, G H RAISONI INSTITUTE OF ENGINEERING AND TECHNOLOGY, NAGPUR, MAHARASHTRA, INDIA

Abstract: Efforts have been made to impound the water by constructing storage in the high rainfall area and supply it by gravity to the drought-prone area. However, it is not always possible to impound water at a higher level in the water available area and supply it by gravity to the water-deficient drought-prone area due to geographical constraints. Thus, water is to be stored in the high rainfall area and it is to be lifted and supplied to the drought-prone area. It is necessary to store and utilize the water awarded by the water tribunal to the drought-prone area by lift irrigation when it is not possible to utilize it by flow irrigation. However, the civil component of pump house is an enormous and expensive structure. size of which depends on the Highest flood level, availability of high bank level, minimum drawdown level, approach length etc.
The previous researches and the norms depict optimization in the least cost pumping system, analysis and design of the underground retaining wall, analysis and design of the gravitational sub-pumping station, optimization of underground water pumping, geological stability etc. This study aims to reduce the redundancies and excessive provisions by varying the parameters such as type of pump, HFL, MDDL, approach length, site location of the pump house. results may provide a reference for the prevailing design guidelines for underground pumping stations.

***Keywords* - Highest flood Level (HFL), Lateral Earth pressure, Lift Irrigation Scheme (LIS), Minimum Drawdown Level (MDDL).**

I. INTRODUCTION

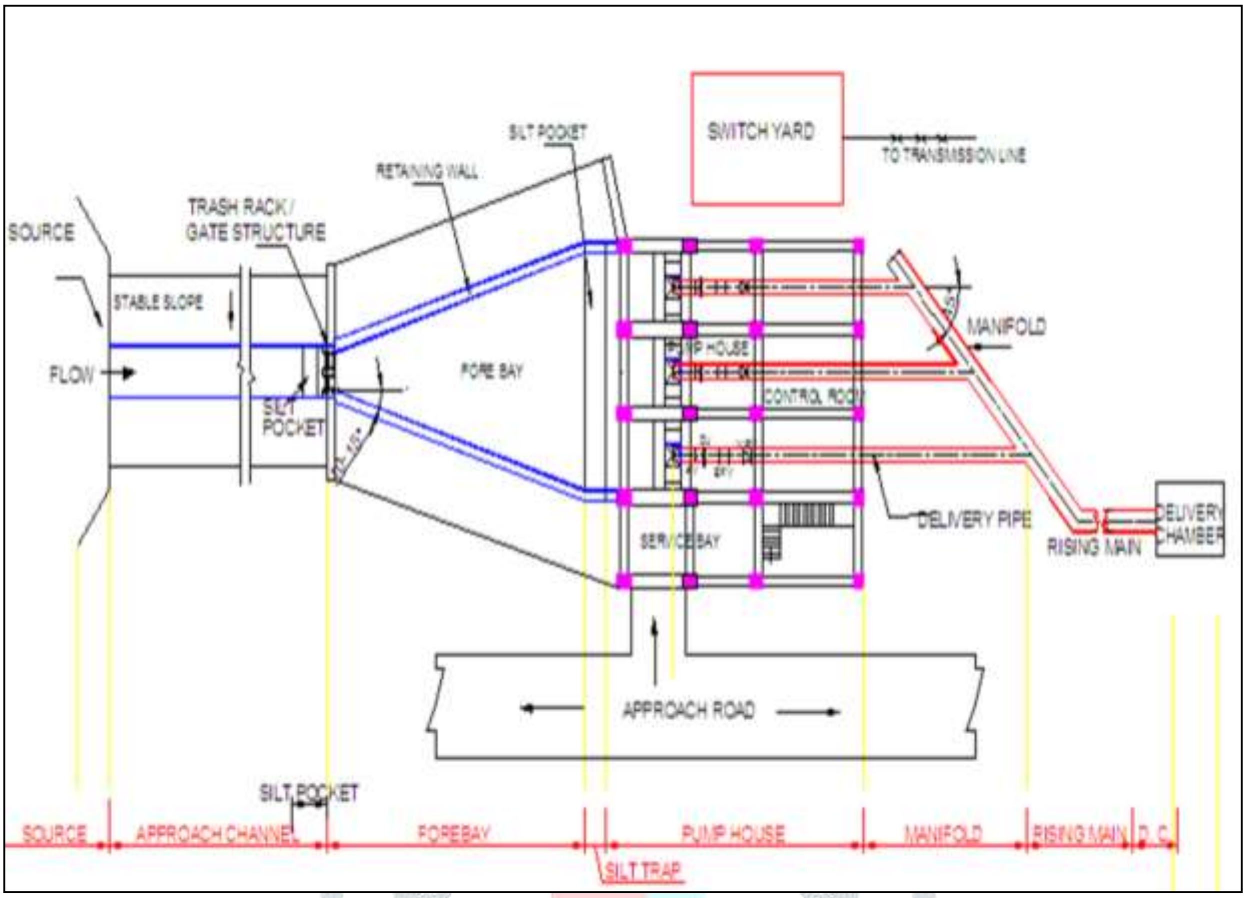
1.1 General Introduction:

Majorly, the following components contribute to a Lift Irrigation scheme. 1.Approach channel is situated before the Forebay channel and is of a uniform cross-section. 2.Forebay channel serves as a transition zone between Approach channel & sump. 3.Pump House is a civil structure provided to install the pumps for lifting purposes. It also has a control room & service bay for the maintenance of electromechanical installations and pumps respectively. 4. Electromechanical components within the pump house consist of Pump, Motor or Diesel engine, Control protection unit etc. 5. Manifold is used for combining the flow from delivery of individual pump to rising main. 6. Rising main-As far as possible, the pipeline should be laid underground. 7. Anti Surge Arrangements is provided to counteract the impact of upsurge or down surge. 8. Delivery chamber at the end of the rising main is required, to dissipate the energy of the high-velocity flow emerging out of the rising main. 9. Switchyard includes transformers, switchyard equipment, cable spreaders, etc. 10. Electric-Transmission from the nearest substation is conveyed by transmission line to Switchyard.

The LIS is designed and executed by combined efforts of Civil, Mechanical and Electrical wings of various Government agencies i.e. Water resource department (WRD), Central designs organizations (CDO).

The civil part of the Pumphouse structure is designed to withstand the High flood level of the source, facilitating intake and offtake of water, housing the pumps and safeguarding the vulnerable electromechanical components i.e., pump motor, CPU, HT/LT Panels, battery bank DCDB etc. However, due to the limitations of the Highest flood Level (HFL), Minimum Drawdown Level (MDDL), Pump Operating Level (POL), and the topographic constraints such as ground levels of bank and river bed level at source, the pumphouse turns out to be a gigantic structure extending from the Sump bottom level to top of the pumphouse.

This study reduces the redundancies and excessive provisions by varying the parameters such as type of pump, HFL, MDDL, approach length, site location of the pump house.



(Figure 1 : Plan of General layout of typical LIS)

II. LITERATURE REREVIEW

Optimization of Pumping parameters

To obtain the minimum total cost investment + operation costs by optimizing the characteristic and efficiency curves, together with the pumping pipe diameter, a methodology using MATLAB environment is developed by considering hydrologic, topographic, hydraulic and economic variables. The results show that the steepness of the characteristic curve is mainly associated with the water table level variation throughout the year, and the pumping pipe diameter is mainly associated with the water demand volume (Moreno et al., 2010)

The pumping can also be optimized by evaluating the system energy cost and for selecting the least cost and optimum pump combinations and by determining the reservoir storage capacity that permits water to be pumped when energy tariffs are lowest and establish an annual pumping schedule per time-of-use energy tariffs (Inmaculada et al., 2011).

For the design and operation of underground pumping stations, analysis of vortex flow is performed, the phase diagrams of various vortices, in terms of different dimensionless numbers are presented, which can reveal their appearance and evolution process. (Miao et al., 2020)

The feasibility of provision of sub-pumping station design to assist the existing pumping station in that locality. Such a design of pumping station involved investigating the existing sub-pumping station in terms of its structure, financial resources, and the effect in the health of end-users, its maintenance including the traffic, operations and reduction of flood water. (Ganiron, T., 2016).

Geological, Geotechnical, Structural and efficiency parameters

An underground pumping station of a water diversion project having complicated geological conditions and high-level ground stress are often encountered with challenges in the construction of underground caverns. The key problem to ensure the stability of surrounding rock during construction and operation. The numerical method can be used to simulate and predict the actual situation, to evaluate the feasibility and safety of the excavation and reinforcement scheme, and to provide optimization suggestions and reduce the engineering risk. using numerical inversion of in-situ stress, and analysis plastic volume and key points of displacement are conducted and compared under the supporting and no supporting cases, predicting the rock stability during the excavation process (Xiang et al., 2017).

The pumping system is modelled in Software i.e Quick control, to mine water pumping systems to enable energy management and control of these systems. and the possibility to accurately simulate the operation of the pumping systems. (Bijl, J. 2016)

The design of underground retaining wall for pumping station has been carried out by seismic coefficient method for dynamic analysis and design of the underground retaining wall. parameters like shear force, bending moment and deflection of a structure are determined by STAAD PRO v8i, so the retaining wall contains the beam and column which reduces the thickness of the retaining wall and make it economical. (Khan et al., 2017).

The research observed in the optimization of pumphouse structure is mostly limited to the pumping parameters optimization, as it is directly proportional to the recurring charges i.e., operation cost.

However, the geological, geotechnical, structural parameters affect the stability and capital investment on the pumphouse structure. A robust foundation with stable banks is highly preferable and saves a lot of capital cost, which otherwise requires foundation treatment, longer approach length, settlement of structure due to secondary consolidation, misalignment of the rising mains and anchor blocks, silting of forebay and approach section.

Research gap

The Lift Irrigation Schemes for irrigation projects are often state-sponsored projects. For longevity of such a scheme, the important factor is minimum operational cost, which is borne by the end-user i.e., Water users Associations, Farmers, Industries etc. which can be achieved by optimizing the pumping parameters. Many a time, less importance is given towards optimizing the capital requirement for pump house and often results in excessive spending on the structure.

The prevailing research focuses on optimizing the operation or a certain part of pump house structure. (Moreno et al., 2010; Inmaculada et al., 2011; Miao et al., 2020). Literature reviews show, the research gap in the optimization of the Layout of the Pumphouse structure. It also lacks the combined hydraulic and Structural considerations needed for optimization i.e., Approach Length, Submersible Pumps etc. Whereas the proposed study aims to optimize the Pumphouse structure by studying the hydrologic, hydraulic, structural and also operational aspects of the scheme and may provide a reference for the prevailing design guidelines for underground pumping stations.

III. OBJECTIVES AND PARAMETERS

3.1 OBJECTIVES

1. The main objective of this study is to examine the redundancies in the underground pump-house layout
2. Optimizing the structure by suggesting modification in type of pumps, reduction in approach channel and forebay section etc.

Parameters

Sr. No.	Parameters	Optimization
1	Controlling Levels	Use of 100 years HFL instead of PMF or SPF
2	Height of PH struture	Reduction based on HFL
3	Length of approach channel	Length reduction based on lower Valve floor level and stable high banks nearest to command
4	Length of Forebay section	Installing trash rack at the sump bottom level to first bracing level for screening the coarser debris,
5	Pump Type	Use of Higher capacity Submersible pumps rather than Vertical Turbines pumps. which reduces the size of pumphouse (preferred where variation of the head is more i.e., >40m))

3.2 METHODOLOGY

The methodology followed for the current study is as follows:

a. **Study of the features of the existing LIS** - (Palasgaon Amdi, Tah- Ballarpur, Dist.- Chandrapur, Left bank of Wardha river) i.e. Hydrology and flood of Wardha river, Design flood calculations, Geotechnical investigation, Discharging capacity, Pump design (HP calculations), Rising main design.

Features of Existing scheme

Sr. No	Features/ Parameters	Details
1	District/ Tahsil	Chandrapur/ Ballarpur
2	Source	Wardha River
4	Irrigable command area (ICA)	2462 Ha
5	Discharging Capacity	2.02 Cumecs
6	Total Utilization	10.71 Mm^3
7	Controlling levels 1. RBL 2. MDDL 3. PMF HFL	 153.755 m. 156.755 m. 175.365 m.
8	Pump House details 1. Dimensions of PH 2. Approach Length	 8m x 13m 330m
9	Pump Details 1. Capacity 2. Total HP 3. Static head of RM 1 4. Static head of RM 2	 4 Nos x 280 HP 1120 HP 29.74 m. 22.24 m.
10	Rising Mains, No-1 1. Length 2. Diameter	 3.37 Km 1100 mm
11	Rising Mains, No- 2 1. Length 2. Diameter	 2.90 Km 600 mm
12	DC1 1. Size 2. FSL @ DC1	 10 x 5 x 2.10 m 186.500 m
13	DC2 1. Size 2. FSL @ DC2	 6 x 6 x 2.30 m 186.500 m
14	Distribution Network	Piped Distribution Network
15	Total Cost of project	99.115 Cr. INR

Fig. 2. Satellite Imagery of existing Palasgaon Amdi LIS

b. **Revision of layout of PH structure-**

i. Using design HFL as 100years flood, instead of SPF or PMF. 100years flood offers a reasonable level of safety and is comparatively economical as the raising of structure is reduced.

ii. Stepping up the of foundation at hard rock level on service bayside

iii. Relocating the PH site to a higher bank location (not far from DC point) yielding smaller approach channel

iv. Instead of forebay section, installing trash rack at the sump bottom level to first bracing level for screening the coarser debris,

v. Submersible Pumps at bottom of the sump are used instead of Vertical Turbine Pumps mounted on Valve floor Level. Submersible pumps also eliminate the necessity of the booster pumps which are mandatory for priming and starting of the VT Pumps

vi. Replacing the vertical turbine (VT) pumps with submersible pumps. Even though the efficiency of both the types is comparable, the submersible pumps have the added advantage of catering to the higher range of variation in the head of water, whereas the VT pumps have suspended shaft delivery pipes, which limits the vertical suspension length and thus limiting the capacity to cater for larger variation in head. Submersible pumps have zero suction head and their motor assembly is at bottom of the sumps whereas the motor of the VT pumps needs to be kept above HFL.

c. **Finalization of controlling levels** for the revised layout i.e., HFL, Valve floor level (VFL), Minimum drawdown level (MDDL), Sump bottom level (SBL), bracing levels, control room levels, EOT crane level and top of the pump house.

d. **Provisions and appurtenances-**

i. Submerged Vertical Turbine Pumps are proposed to rest on R.C.C. Raft at Sump Bottom. These pumps are capable for handling large variation in heads.

ii. Trash Racks are proposed at the inlet of pump house up to 2nd bracing level. For lifting of these trash racks, hoisting arrangement with ISMB200 is kept at VFL

iii. R.C.C. Baffle walls are provided up to Second Bracing level from Raft, to avoid vortex interference from adjacent pumps during simultaneous operations. However, these walls provided additional stiffness at bottom levels of pump house.

iv. Rung Ladder – MS Ladder is provided up to VFL to access for the maintenance at sump bottom.

v. Service Bay as functional area for the installation, lifting & maintenance of pumps are proposed on valve floor level. The number of service bay depends on length of pump house. It is designed for the pump loads and its impacts.

vi. EOT is electrically operated overhead type crane is proposed to be installed at height of approximately 1.7 times the height of pump from Valve Floor Level. EOT comprises of gantry girder with a crab, this arrangement rests on RCC Beam which finally transfer the loads to columns. RCC Beam is designed for pump loads and total load of EOT assembly.

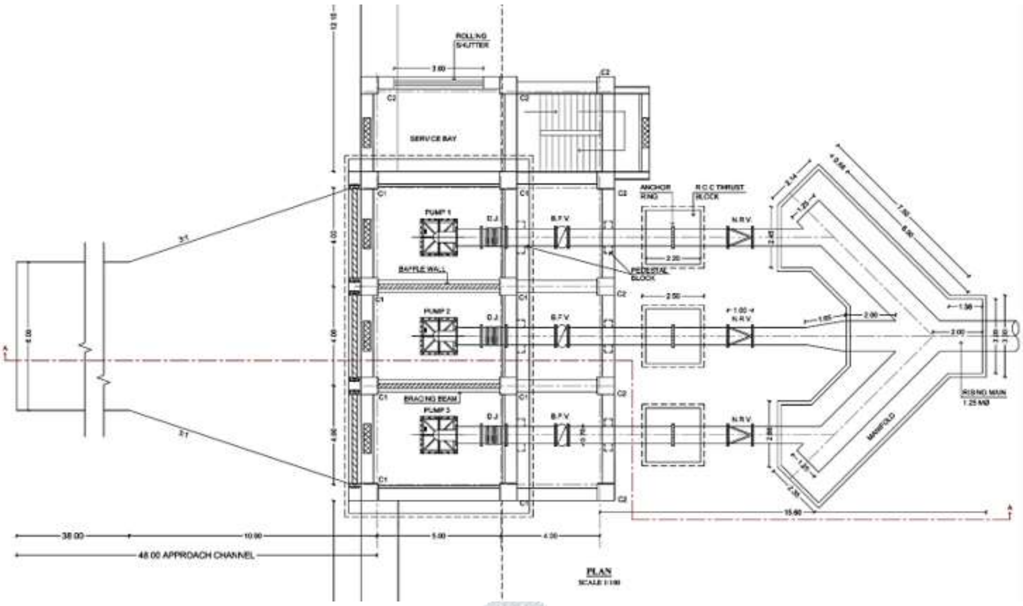


Fig. 3. Plan of proposed layout of pumphouse.

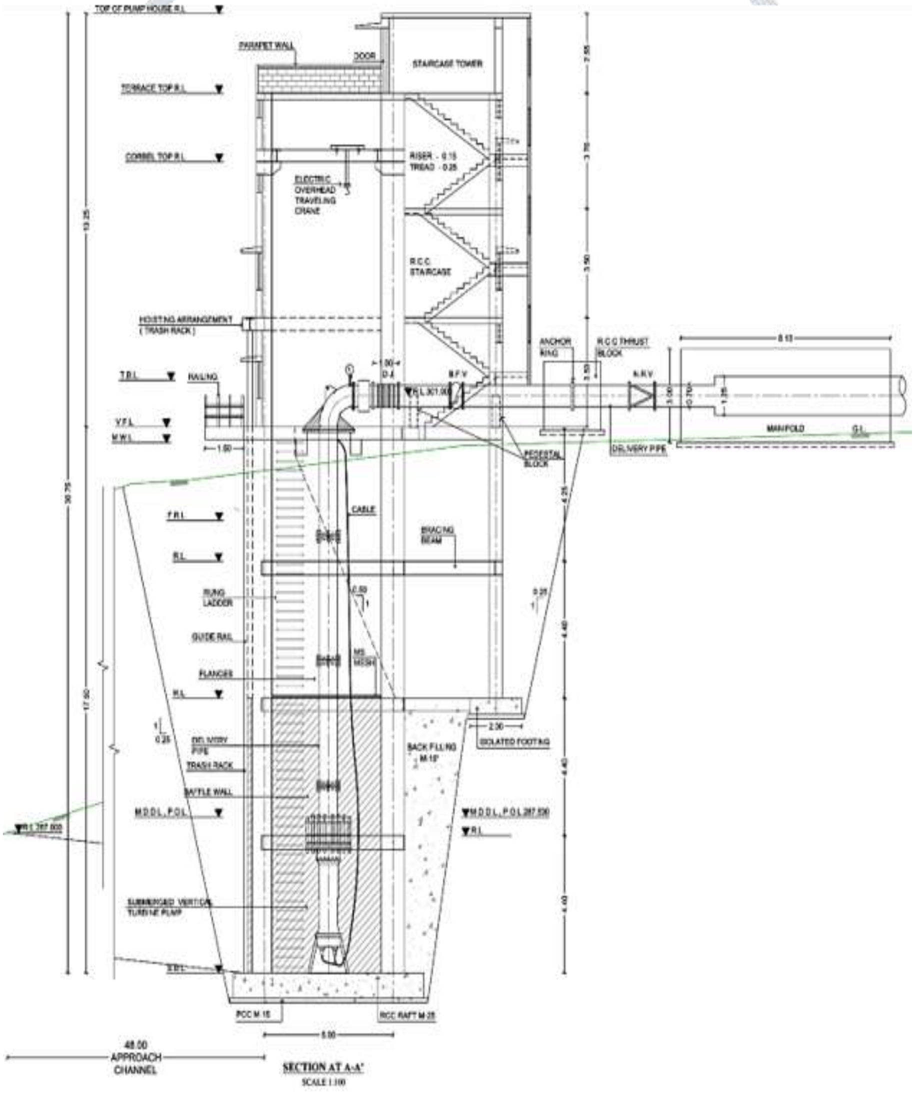


Fig. 4. Cross section of proposed layout of pumphouse.

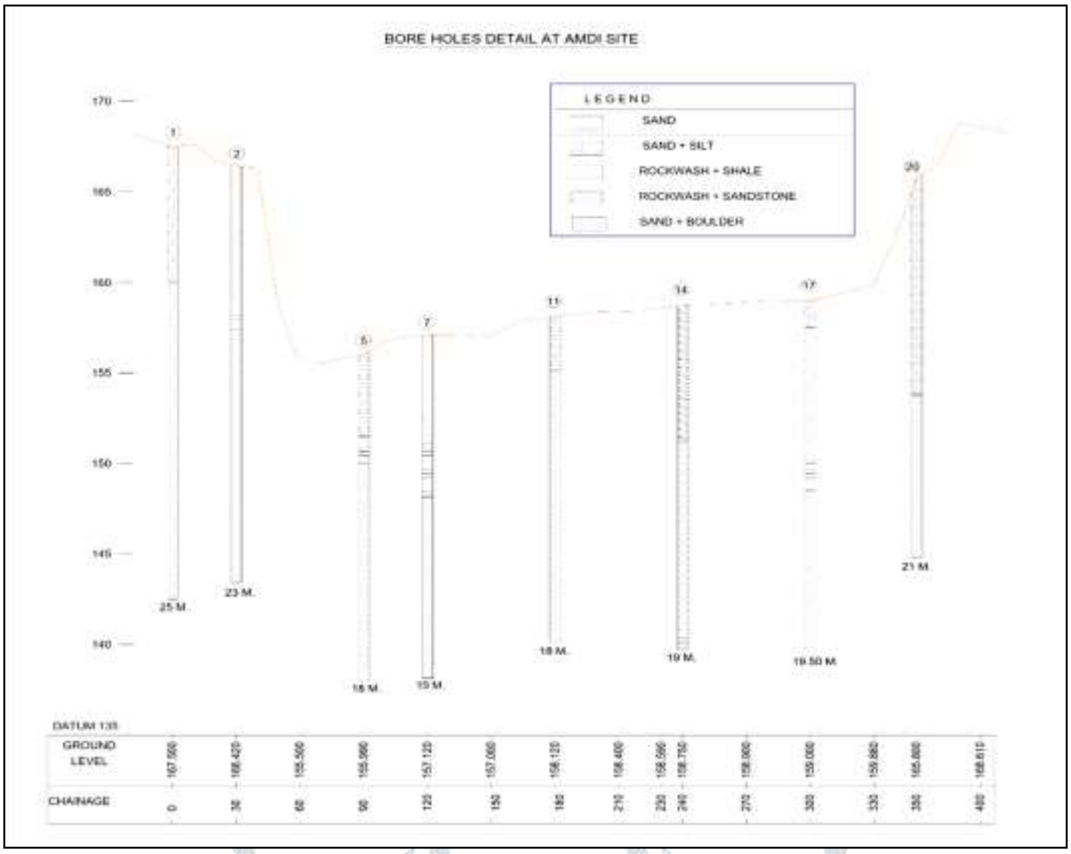


Fig. 5. Details of Geotechnical investigation at proposed Pump house site

3.3 RESULTS

Sr. No.	Parameters	Results
1	Controlling Levels	100-year flood calculated by series up to 2017 yields flood of 24321 Cumecs (Calculated by Bamni River gauging data upto year 2017) and HFL of 172.00m.
2	Height of PH struture	The height of PH structure is reduced by 3.36 m
3	Length of approach channel	Approach length reduced to 230 m based on lower Valve floor level and stable high banks nearest to command
4	Length of Forebay section	Forebay section is removed, Trash rack is installed at the sump bottom level to first bracing level for screening the coarser debris.
5	Pump Type	Use of 3 Submersible pumps (3*374 HP) of rather than 4 Vertical Turbine pumps. which reduces the size of pumphouse by 1 bay. Even though efficiency of submersible pump is comparatively less than that of the VT Pumps, but it handles large variation of heads with ease, also the motor parts are submersible and water proof too, which ensures safety incase of Flood exceeds HFL.
6	Foundation	Stepping up of foundation at Hard rock level at the service bay portion.

Discussion:

The said alternative maybe modified accordingly based on the geotechnical investigation and strata availability at the PH site. The availability of higher banks (HFL level) at the site is of preferred so as to reduce the approach length. The approach section can be kept unlined depending on the availability of hard rock at foundation.

CONCLUSION

i. The modifications suggested in the existing layout of the pump house structure can be considered as a viable option. Even though the economic comparison is not a part of this study, however the changes suggested i.e. Type of pumps, HFL, Approach channel length, Forebay reduction can substantially reduce the capital cost of Lift irrigation scheme.
ii. The height of super structure (above VFL) can be optimized as the EOT level height is fixed based on height of the sections of the delivery pipe (or) height of submersible pump. also, a floor for control room can be reduced if height of EOT is reduced.
iii. Structural analysis and design of this modified structure can be performed.

FUTURE SCOPE

This study might prove to be of greater importance in the future as the irrigation projects in the drought-prone areas are planned based on the topography and availability of water considering the geography of the area. The feasible Dam/ Weir sites for gravitational serving are diminishing day by day due to new projects being taken up by the government, issues of land acquisition for storage creation etc. Thus, lift Irrigation might be the only option depending on the topography of certain areas. Thus reduction in capital cost can certainly be of significance.

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