Calibration of Design, Optimization and Simulation for Pipe Distribution Network with Geospatial Data

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Abstract : Considering the losses of open canal Upper Kundlika Medium Project has been proposed and technically sanctioned for Pipe Distribution Network to increase its Culturable Command Area by Godavari Marathwada Irrigation Development Corporation Limited. A total of 2900 Ha area is to be brought under irrigation by designing a maximum of 20 Ha area of each chak. The whole designing process is calibrated from design perspective between Bentley WaterGEMS V8i and MS-Excel Design spreadsheet of Maharashtra Engineering Research Institute, Nasik. The need of engineering survey has been eliminated and the results (elevation, pipe diameter, length and residual pressure) are comparable to some extent..

***IndexTerms* - Geospatial surveying, pipe distribution network, WaterGEMS, MERI.**

1. INTRODUCTION

The calibration process is alienated under various stages. In general, the procedure involves data assortment (geospatial data, market available pipe diameters, material properties, Government circulars, including supplementary measurements if desirable), data verification and data arrangement for calibration model. In course of time, at the age of computer models and algorithms that are capable of iteratively concluding a key solution, more attention is paid onto different geospatial altitudes and their rationality, proficiency and not much devotion is followed to irrigation practices being arrayed. In tallying however new modelling skills make its arrival into water network field, little attention is paid onto input data and only artificially created network is used. Even still the space of study is better understood that designing should be tested in organized situation, it is true that the concluded results that are obtained are too liberal and probable not appropriate when real network data will be used.

1.2 SIGNIFICANCE OF STUDY

A pressure piped irrigation system is a network connection consisting of pipes, fittings and other devices properly designed and connected to supply water under pressure from the source of the water to the irrigable area. The engineering design is the second phase in irrigation planning. The first stage is the consideration of the crop water requirements, the type of soil, the climate, the water quality and the irrigation scheduling. The water supply circumstances, the availability of electricity and the field topography also need to be considered. The economic considerations, the labor and the expertise also need to be taken into consideration. The irrigation system is selected after a detailed evaluation of the above data and the computation of the system’s flow, the irrigation measure, the duration of application and the irrigation interval.

1.3 LITERATURE REVIEW

Traditional approach for automatically solving the problems of network is done by using specialized software such as EPANET. The reason behind this scarcity is the pressure variation. Variation in pressure head and the pressure delivered is not satisfactory to fulfill the requisite of water demand. Leakages in pipe may cause pressure variation. EPANET is used to analyse and solve problems such problems (Darshan M., 2007).An area is selected with the problems of not only of water scarcity but also by poor water management practices. The grouping of GIS and modeling as an operating tool allows managers to diagnosis a network, to study solutions of problems and to predict future situations. Network modeling was employed to analyze and to simulate the Chetouane network using GIS (MapInfo 8.0). Precisely, problems were diagnosed, such as supply discontinuity, leakages and worn out pipes. Area was chosen for the simulation of the distribution of velocities and pressures. Knowing where fractures have occurred, and where renewals have been made, for instance, is very useful for predicting future interventions in the network, and thus for planning purposes. (Cherifa Abdelbaki, 2017). The cost optimization of rural piped water networks is essential. These networks are typically gravity fed, since reliable electricity supply is not a given. BRANCH is an optimization tool by the World Bank that tries to minimalize pipe cost for branched pipe networks with a single water source. Though it has limited capabilities in terms of number of pipes, and does not guarantee optimal solution, it is used in the developing world as the only alternatives are expensive commercial tools like WATERGEMS. Using the general formulation we have implemented a water network design system called JalTantra. The method also has GIS integration for ease of adding network details. The overall goal for JalTantra is wide reaching and will attempt to solve several network design constraints like source selection, storage location, capacity, choice of pipe diameters, water supply scheduling, cost allocation etc (N. Hooda, 2016). The use of Pipe Distribution Network (PDN) instead of Canal Distribution Network (CDN) to increase the overall project efficiency of irrigation project and thereby reducing the stresses due to water insufficiency. . High initial deal in pipeline- but in the long run pipelines are inexpensive, due to saving in water, labour, maintenance, land & immovability of installation (Sandesh B., 2017). It is preferable to provide some excess capacity in pipe sizing to account for uncertainty in demands and the fact that upsizing piping is quite economical. Engineers should not use optimization to cut corners and install a bottleneck in the system simply to obtain the lowest cost solution in the short term. (Thomas M. Walski, 2013). Water GEMS model results to be published to a utility's existing SCADA control room screens, helping to forecast operating conditions and potential issues. Darwin Designer automatically finds maximum benefit or minimum-cost designs and rehabilitation strategies, based on presented budget, construction cost, and pressure and velocity constraints (Sunil D., 2017).

1.4 GUIDELINES FOR DESIGN

Pipeline distribution system needs to be designed very carefully to transport a required quantity of water proficiently. If the pipe lines are too small in diameter, pumping costs are increased and the capacity of the system may be rigorously limited. On the other hand, pipelines larger than necessary add to the cost of system and may cause unequal flow. All joints and connection are to be constructed to withstand the maximum designed working pressure without causing leakage and should have the inside of the line free of any obstacle. Essential control structures such as stands, valves and outlets, measuring devices etc. are to be installed appropriately for effective and efficient functioning of the system.

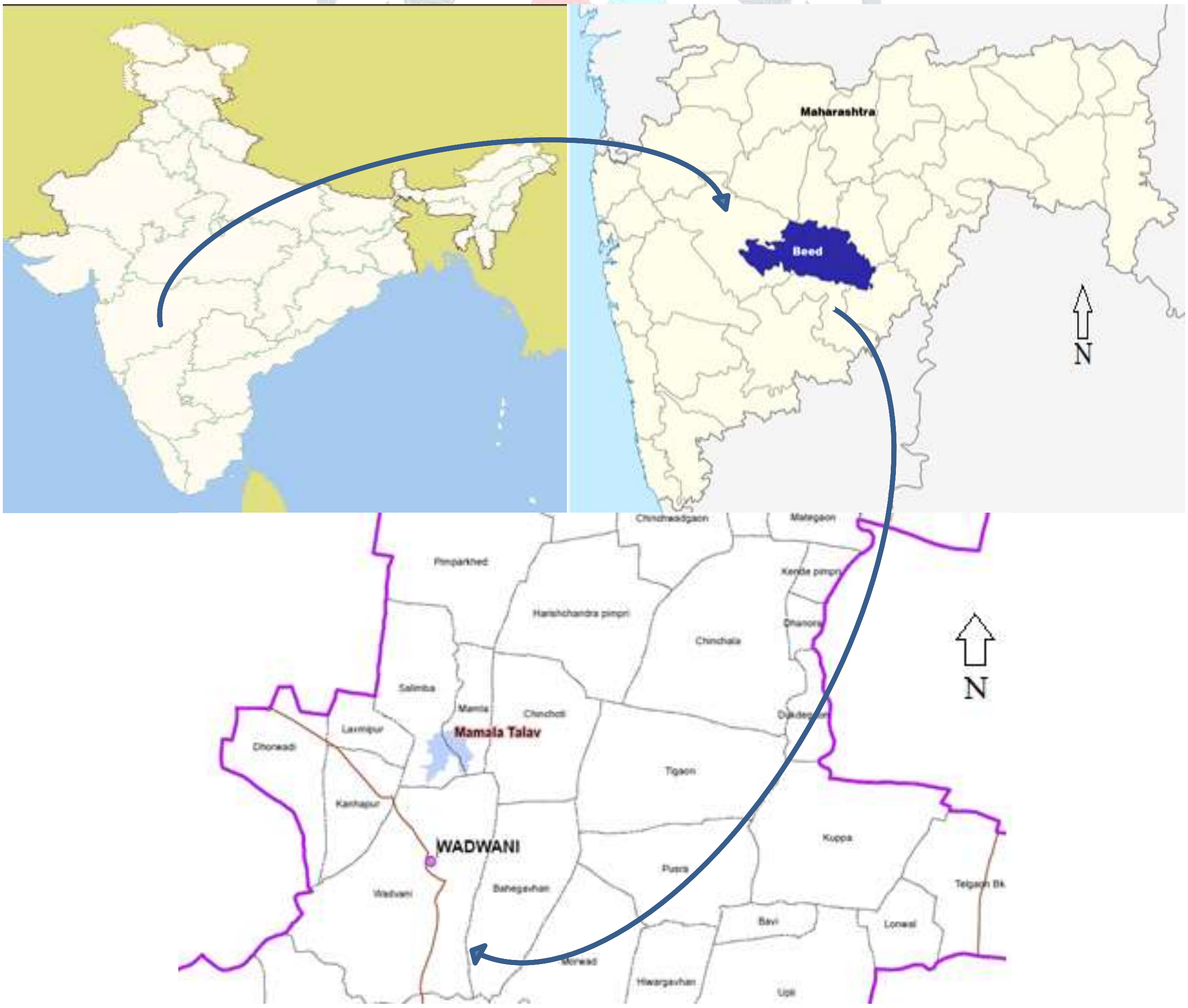
Points to be considered in designs of WaterGEMS and MERI:

- The residual head is maintained to be > 0.6m at each emitter junction.
- Air valve is provided at an interval of 300 m.
- A trash rack is installed to avoid the entry of any foreign material directly into the pipeline.
- A desilting tank is provided if high silting is recorded to keep the pipeline functioning smoothly.
- A 5% loss is considered in conveyance of the distribution system.
- Orifice valves are provided at an interval of 65-75 m to regulate the residual head.
- Ample attention is taken to evade negative pressure head.

1.5 OBJECTIVE:

- To reduce losses from Canal Distribution Network and replace it by Pipe Distribution Network.
- Design comparison by WaterGEMS and MERI, Nasik Design.
- Reduce cost of actual engineering survey to geospatial data interpolation.

1.6 STUDY AREA



2. METHODOLOGY

2.1 DESIGNING A PIPE NETWORK MODEL FOR IRRIGATION.

Water requirement is worked out by modified Penman Method for the given cropping pattern.

$$ET_r = \frac{C}{\rho_w}\left[W\frac{(R_n - G)}{\lambda} + (1-W)f(u)(e_a - e_d)\right] \quad \text{Eq.1}$$

ET_r is the orientation evapotranspiration, mm/day; W is a temperature and the elevation of the area related weighting factor; R_n is the net solar emission, $MJm^{-2}d^{-1}$; G is the soil heat flux in $MJm^{-2}d^{-1}$; λ is the latent heat of evaporation, MJ kg^{-1}; $\rho_w = 1000\ kgm^{-3}$, is the density of water; f(u) is the wind related function, kg $hPa^{-1}m^{-2}d^{-1}$;e_a is the saturation vapour pressure at mean air temperature, hPa; e_d is the mean actual vapour pressure of the air, hPa; and C is an adjustment factor to account for day and night weather circumstances.

There are a number of formulae available for use in calculating the velocity of flow. However, MERI, Nasik suggests using Modified Hazen-Williams formula as per latest GR dated 2.2.2017.

$$V=143.534C_R r^{0.6575} S^{0.5525} \quad \text{Eq.2}$$

$$h=[L(Q/C_R)^{1.81}]/994.62D^{4.81} \quad \text{Eq.3}$$

V= velocity of flow in m/s,C_R=pipe roughness coefficient;(1 for smooth pipes;<1 *for rough pipes*);r=hydraulic radius in m;s=friction slope;D=internal diameter of pipe in m;h=friction head loss in m;L=length of pipe in m ;Q=flow in pipe in m^3/s

$$D = A \times PWR \times 10 \quad \text{Eq.4}$$

D = Demand on each node (m^3/day);A=Area (ha);PWR=Peak Water Requirement depth (mm)

2.2 INPUT DATA PROCESSING FOR WATEGEMS

Steps to be followed in preparing contour and new WaterGEMS file.

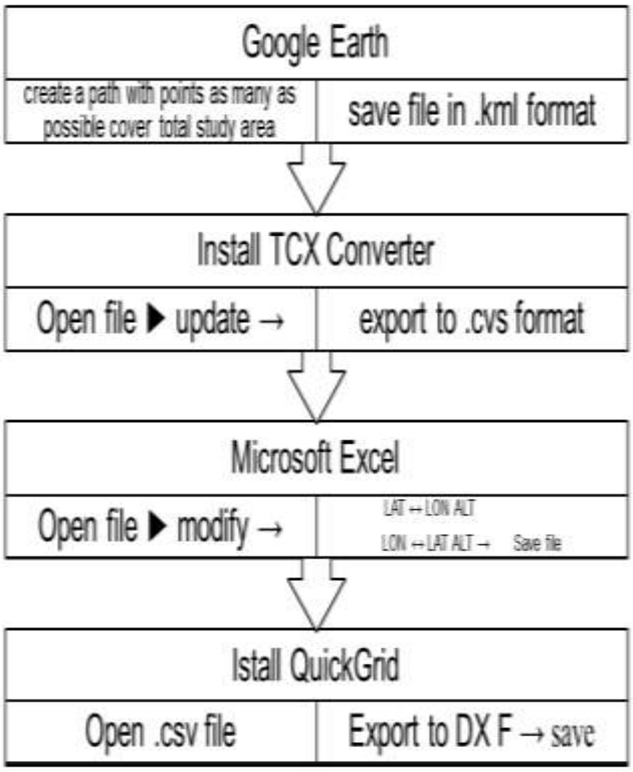


Figure 1.Flow Chart showing preparation of Contour Map

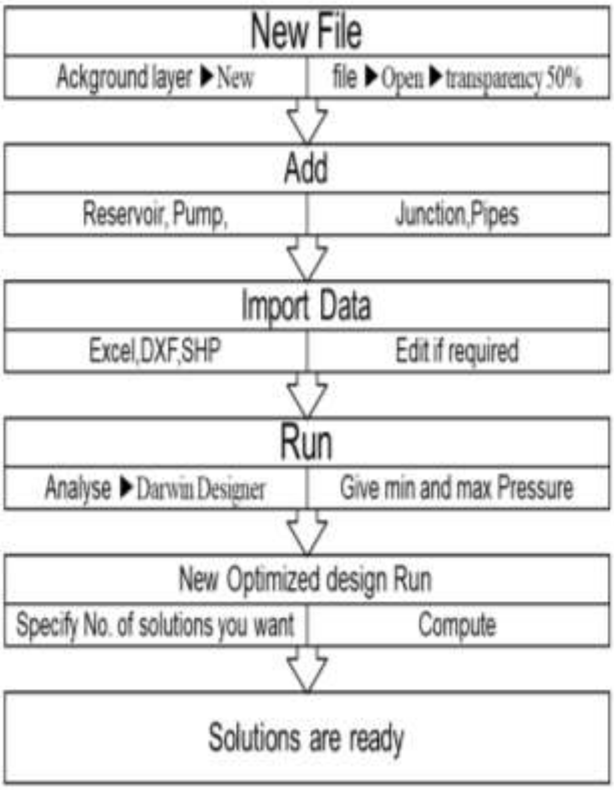


Figure 2.WaterGEMS Flow Chart

The contour .dxf file created by the above process shows a meagre difference of 0.5 m with the actual Total Station survey done. The difference in elevation of 0.5 m is effortlessly fulfilled by the minimum head of 2.29 m at the Chak ID:L-7 and can be considered negligible. The remaining hydrants have enough head to cover up the error if any made by the Google Earth contour .dxf .

3. LAYOUT OF PIPE NETWORK DESIGN

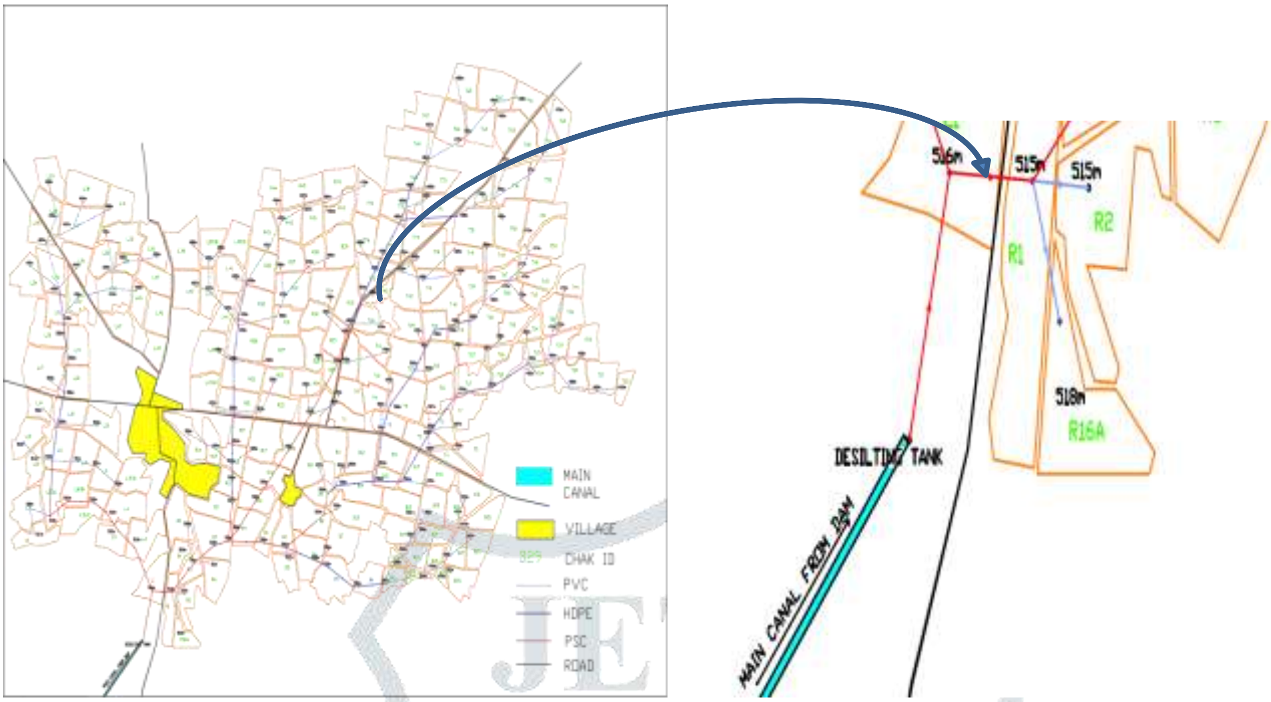


Figure 3. Pipe Distribution Network.

The gravity fed irrigation network is under analysis and its desilting chamber is positioned at the end of canal. The circulation for the irrigation water is achieved by a 24 x 7 irrigation system with 170 chaks, with 16.20 L/s discharge per hydrant, each hydrant aiding 18-80 ha of irrigable area, supplying a minimum pressure head as 0.6 m to maximum 28.91m above GL, since the elevation of desilting chamber 1m above GL at 524m above MSL.

The maximum discharge was 0.9 L/s/ha for the period of peak water requirement in the month of January. The design provision is made to achieve all valves open for supplying continuous water at each hydrant.

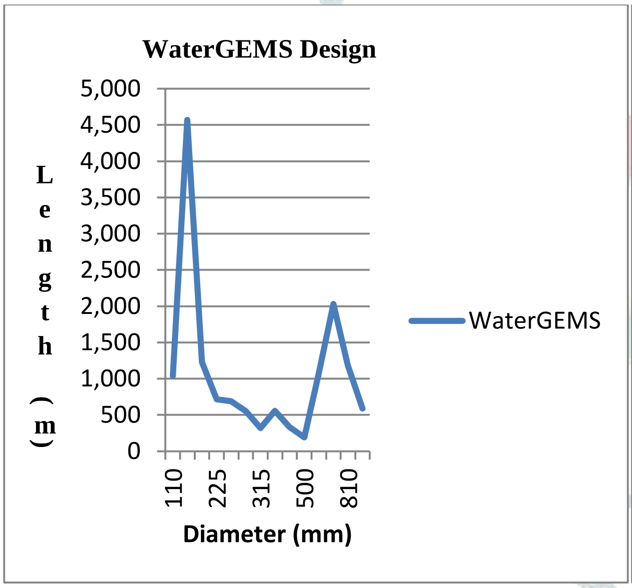
4. RESULTS AND DISCUSSION

Cost of ISI standard PSC, HDPE & PVC pipes in standard lengths of Class 4 diameter suitable for either collar joints or rubber ring joints, including all taxes (Central and local), inspection charges, transport to departmental stores / site, unloading and stacking, etc. . complete.(IS-458/1988)

Table 1. Estimated cost of the left branch pipe distribution system.

Water GEMS	**Int.dia (mm)**	**Length**	**Rounded length**	**Rate/m**	**Amount (Rs.)**
PVC					
110	104	1038.18	1040	124	128960
140	132	4568.97	4570	208	950560
160	151	1229.45	1230	274	337020
225	213	715.78	720	589	424080
250	237	688.11	690	719	496110
280	265	553.38	560	953	533680
315	299	317.59	320	1213	388160
HDPE					
355	323	556.99	558	2790	1556820
400	364	330.82	336	3654	1227744
500	456	192.48	198	5953	1178694
630	573	1069.46	1074	9385	10079490
710	645	2030.65	2034	11891	24186294
810	727	1184.94	1188	14336	17031168
PSC					
1600	1440	589.47	592	21575	12772400
			Total	**Rs.**	**71291180**

MERI, Nasik	Int. dia (mm)	Length	Rounded length	Rate/m	Amount (Rs.)
PVC					
110	104	1188.55	1192	124	147808
140	132	2140.11	2144	208	445952
160	151	1276.38	1280	274	350720
180	170	925.1	928	372	345216
200	189	486.01	488	460	224480
225	213	639.99	640	589	376960
280	265	1427.96	1428	953	1360884
HDPE					
355	323	317.59	318	2790	887220
400	364	917.89	918	3654	3354372
450	409	820.44	822	4814	3957108
710	645	388.57	390	11891	4637490
800	727	1017.73	1020	14336	14622720
900	818	1059.84	1062	18161	19286982
1000	909	2155.75	2160	22394	48371040
PSC					
1600	1440	589.47	592	7782	4606944
			Total	**Rs.**	**102975896**



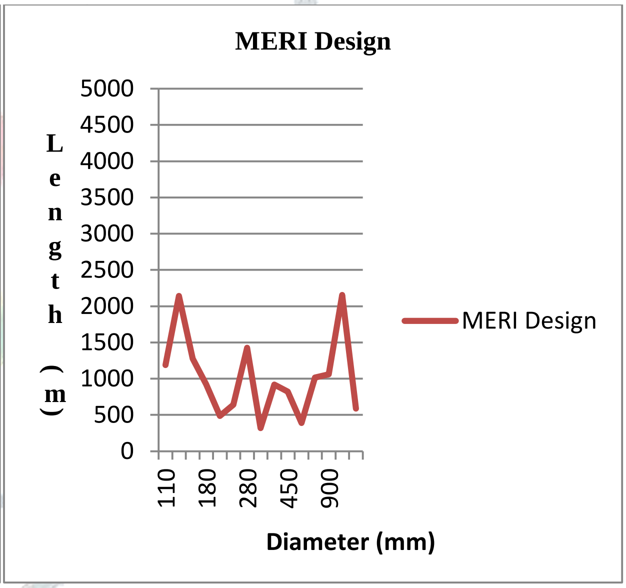


Figure 4.Diameters of pipes used in WaterGEMS

Figure 5.Diameters of pipes used in MERI Design

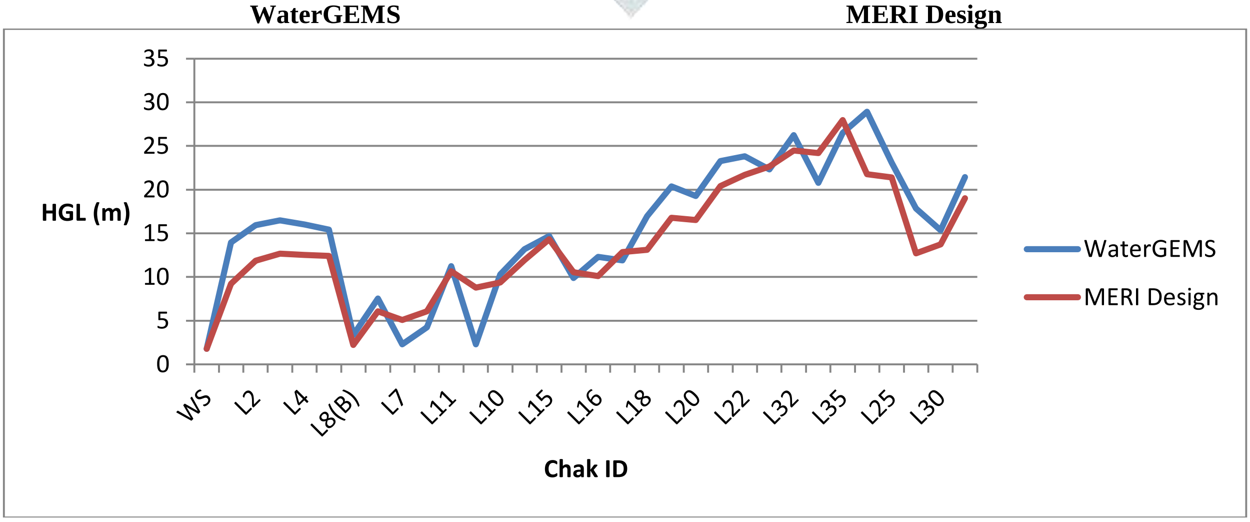


Figure 6.Comparative residual head available between designs.

5. CONCLUSION

The use of lower diameter pipe decreases the cost of pipe material required. The estimated amount considering only costs of material is Rs.7,12,91,180/ha from WaterGEMS Design**.** Whereas, the cost is Rs.10,29,75,896/ha from MERI Design. Therefore, it results in a difference of approximately Rs.50,000/ha .

The WaterGEMS model yields a greater residual head as compared to MERI, Design.

The difference in amount is Rs.14,50,00,000/- for the total CCA of 2900 ha in the Upper Kundlika Medium Project, Beed. This shows considerably an enormous decrease in cost of material, which is the major component in the project . It is expected to have 30% shrinkage in cost of overall total project.

Another approach of digital surveying by extracting geospatial data from the Google Earth and other supporting software, the need of Total Station survey is eliminated. The data from the Google Earth and Total Station survey varies around 0.5m in elevation which can be easily covered up by maintaining lager residual head. Hence, the topography of the area can be surveyed effortlessly. This tends to reduce the expenses of surveying for a large project, subsequently maintaining economy of the project.

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