Design of a Sustainable Piped Water Solution based on Upper Vaitarna Reservoir for Providing Drinking Water Security to Scarcity Affected Mokhada Taluka

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Abstract- **This report demonstrates the feasibility of a surface water based, gravity assisted, energy efficient, and sustainable piped water solution for scarcity affected Mokhada Taluka (block) of Palghar district, Maharashtra. It also demonstrates the use of GIS technology and JalTantra, an in house developed tool for intuitive, efficient design and optimization of pipe water networks.**

Rural Drinking Water Department is redesigning the Karegaon scheme as the original source has been submerged in the newly constructed Middle Vaitarna Reservoir. Although a block of 13 tanker fed villages lies in the immediate vicinity of the scheme locality, the geographical coverage of the new design was kept unchanged. A preliminary assessment indicated that a scheme design based on Middle Vaitarna as source was not feasible due to the large elevation difference between the source located at elevation of 285m and the villages in the cluster having average elevation of about 391 m.

However, the higher elevation of Upper Vaitarna (603m) reservoir in the same area offered a critical advantage by leveraging gravity flow of water thereby reducing both the capital cost of piping as well as the energy cost for pumping. The techno economic feasibility study undertaken by CTARA of a multi-village scheme based on Upper Vaitarna reservoir as source and augmenting the scope of Karegaon scheme to include the cluster of 13 tanker fed villages revealed that per capita cost came down to Rs. 2890 as compared to per capita cost of Rs. 5083 for Karegaon scheme being designed by the Rural Water Supply Division. Also, the annual Operation and Maintenance (O&M) cost including energy cost came down from Rs. 24/1000L to Rs. 6.34/1000L.

When this solution was presented to all the stake holders in a Water Conference held in Khodala village in Mokhada taluka in May 2014, there was overwhelming demand from the local people to expand the scope of coverage to remaining scarcity affected villages in the taluka to remove dependency of people of Mokhada taluka on tanker supplied water. Accordingly, a set of 17 villages located in North Mokhada and their habitations along with the block of 13 tanker fed villages in the vicinity of Karegaon scheme were included in the scope of present study.

A step by step design methodology based on protocols followed by Maharashtra Jeevan Pradhikaran (MJP) involving extensive use of GIS tools and hydraulic modelling software JalTantra and EPANET were used for design and optimization of the proposed scheme. The study revealed that the total cost of the proposed solution for a design population of 86000 is merely 35 crores which is less than 2% of the cost of Middle Vaitarna project. The per capita capital cost of the proposed solution is Rs. 4078 as compared to per capita cost of Rs. 5083 for Karegaon scheme while the annual O&M cost including energy cost is Rs. 5.74/1000L as compared to Rs. 24/1000L. Thus, there is still an opportunity for implementing a sustainable drinking water solution for entire Mokhada taluka. In future, by adopting 'inclusion model' and giving sustainability of a scheme based on surface water source a prime consideration, there exists a great potential to not only do away with recurring cost of supplying water by tankers, but also to remove the perpetual dependency of large number of rural population on tanker supplied water.

Keywords: rural water supply, piped water network, GIS, multi village scheme, Jaltantra, EPANET, drinking water, Mokhada

I. INTRODUCTION

A. Background:

Located at about 120 km from Mumbai on its North East side, Mokhada Taluka, is a block in Palghar district of Maharashtra state. In spite of high rainfall in the range of 3000 mm to 4000 mm, there are currently around 30 villages (70 habitations) in the taluka that are perpetually dependent on tanker supplied water during pre-summer and summer months. Irony is that this tribal dominated area with a hilly terrain also has the distinction of being biggest supplier of drinking water to Mumbai city. It hosts two big reservoirs namely, Upper Vaitarna and Middle Vaitarna, supplying over 1000 million litres of water per day (MLD). To augment water supply to Mumbai by 455 MLD, the Middle Vaitarna project on Vaitarna River in this taluka was recently commissioned. The construction of the dam on Middle Vaitarna submerged the source Karegaon Rural Water Supply Scheme which supplies drinking water to four villages besides Karegaon village. When Karegaon scheme was revamped because of submergence of its assets in the backwater of the dam, the people in the neighbouring water-scarce villages were upset over the fact that they were not included in the scope of redesigned scheme. They do not object to their water being taken away as long as their need of drinking water is addressed.

B. CTARA Proposal for Redesign of Karegaon Scheme

The coverage area of revamped Karegaon scheme was restricted to five villages, namely, Karegaon, Kaduchiwadi, Kochale, Bhasmyachiwadi, and Karegaon Ashramshala. In 2013, a study was undertaken by CTARA, IIT Bombay [1] to evaluate the feasibility of augmentation of scope of Karegaon scheme to include a cluster of 13 tanker fed villages in its neighbourhood. The study report recommended the shifting of the source of water to Upper Vaitarna in order to leverage its higher elevation and designing a gravity assisted piped water scheme for a sustainable solution. The technical and financial feasibility of the scheme was demonstrated by following the standard government protocol for water scheme design. On presentation of the solution to various stakeholders in May 2014, there was increasing demand by local people to expand the scope of the scheme to cover entire Mokhada taluka in favour of a permanent and sustainable drinking water solution and remove the dependency on tanker supplied water.

C. Current Status

In response to peoples' demand, the present study is undertaken to cover all the tanker fed villages in Mokhada taluka. Besides the ones included in earlier study [1], there are 17 tanker fed villages in the North Mokhada. Both the clusters are covered by the present study. Since the Government authorities have decided to go ahead with implementation of Karegaon scheme in spite of presentation of CTARA proposal for augmentation of the scheme, the four villages covered by the scheme are excluded from the scope of the present study. Figure 1 shows the two clusters, South Zone consisting of 13 villages covered by earlier study and North Zone consisting of 17 villages added to the scope of the present study for entire Mokhada Taluka. A majority of village Gram Panchyayats have already come forward with Gram Sabha resolution for implementation of sustainable solution by endorsing CTARA's design based on Upper Vaitarna Reservoir.

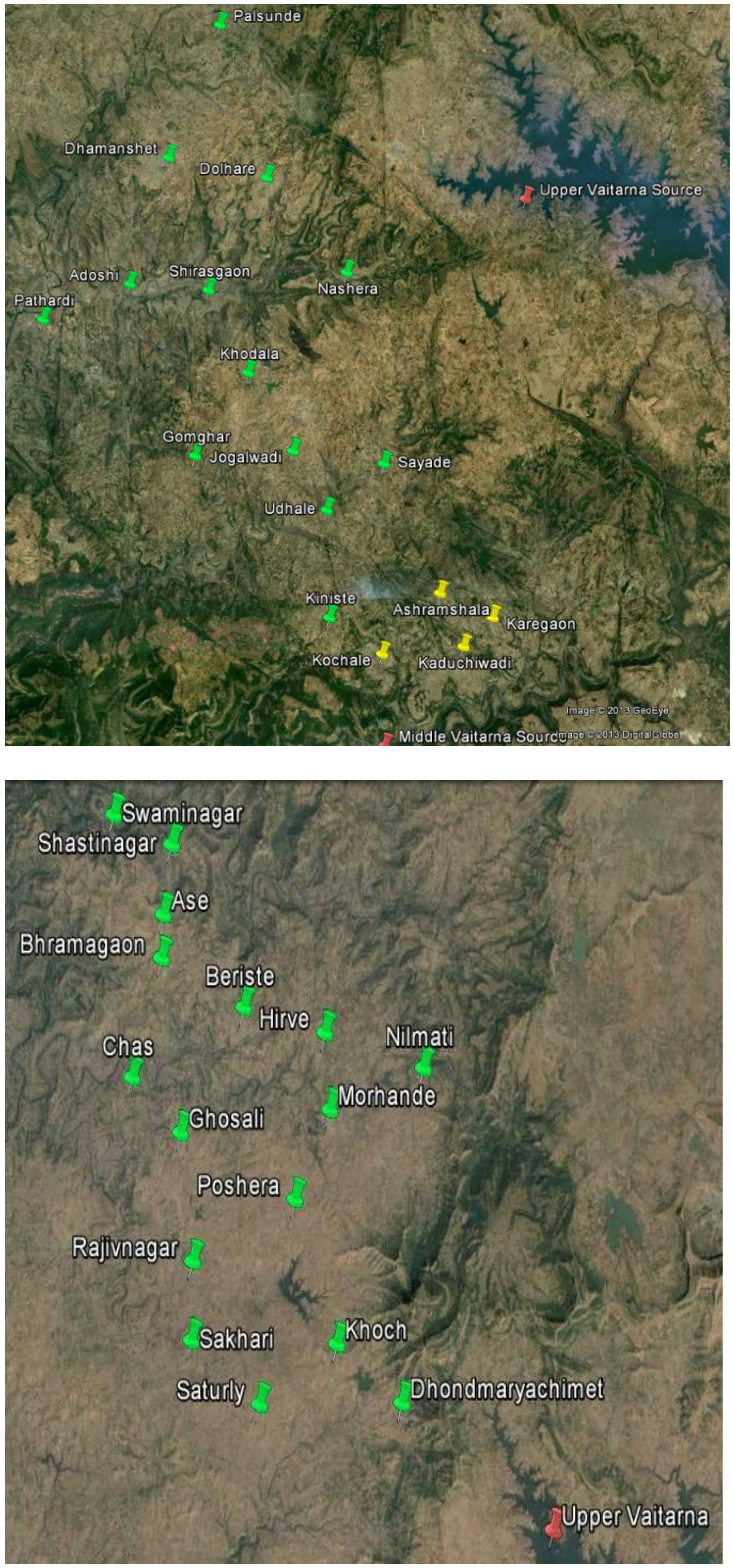

Figure 1: South Zone and North Zone tanker fed villages (in green) and Karegaon Scheme villages (in yellow) and their location relative to the Upper Vaitarna Reservoir

The details of all the villages included in the present study are presented below in Table I.

TABLE I
DETAILS OF VIALLGES COVERED BY PROPOSED SCHEME

Village	Population (2011)	Population (2030 est.)	Demand(litres per day)	Elevation (m)
Kiniste	939	2957	1,18,280	460
Udhale	1064	2281	91,240	422
Jogalwadi	812	2245	89,800	426
Khodala	2807	7721	3,08,840	434
Sayade	1770	3006	1,20,240	420
Gomghar	1228	1536	61,440	419
Shirasgaon	526	1454	58,160	243
Dolhare	1141	1838	73,520	380
Nashera	733	4179	1,67,160	354
Adoshi	923	1060	42,400	202
Dhamanshet	1241	3431	1,37,240	384
Palsunde	1365	3774	1,50,960	393
Pathardi	661	4153	1,66,120	192
Ase	4139	8955	3,58,200	465
Brahmagaon	827	1156	46,240	478
Shastrinagar	590	739	29,560	268
Swaminagar	687	1180	47,200	470
Beriste	1794	2700	1,08,000	409
Chas	2609	3182	1,27,280	317
Hirve	1780	1817	72,680	401
Dhondmaryachimet	534	1264	50,560	464
Khoch	1890	2915	1,16,600	464
Ghosali	1309	2124	84,960	372
Rajivnagar	740	1155	46,200	365
Morhande	2667	4249	1,69,960	401
Nilmati	601	1368	54,720	491
Lakshiminagar	582	1043	41,720	417
Poshera	4417	7497	2,99,880	417
Sakhari	1462	1848	73,920	380
Saturly	2141	3999	1,59,960	425
Total	**43,979**	**86,826**	**34,73,040**	-

II. SEARCH FOR A SUSTAINABLE DRINKING WATER SOLUTION

A. Source of Water and Planned Use of GIS

Earlier studies [1,5] on tanker fed villages in Mokhada Taluka have highlighted the role of GIS system in putting together an integrated view of the various components of drinking water scheme viz. beneficiary villages, piped water scheme assets, and water sources, for making proper assessment. The earlier study [1] has already demonstrated both the technical and financial feasibility of a Upper Vaitarana based multi village scheme as a sustainable solution to provide drinking water security to the scarcity affected area in Mokhada taluka, because of Upper Vaitarana's high elevation suitable for a gravity assisted scheme design. In this work also, we plan to use GIS tools and techniques for design and optimization of a multi village drinking water supply scheme based on comparative analysis of different configurations.

B. Scheme Design Process and Design Options

First, all the tanker fed villages in the cluster along with road network connecting them are located on the map of Mokhada Taluka and marked on Google Earth. Then alternate configurations for MBR, ESRs and the entire primary and secondary piping network are marked. The elevation and distance data captured from Google Earth is fed into the JalTantra [13, 14] software. The piping is placed along the road and dummy nodes are marked to take care of changing elevation along paths. This is because water not only has to reach the end point but also it has to meet the minimum head requirement of 7m at the highest point along the path.

For each configuration, a step by step high level design process and a standard cost estimation method for individual design components/assets of the scheme is followed based on MJP protocol and schedule of rates published by MJP with appropriate inflation factors. Then per capita capital cost of the scheme is computed by dividing the total cost by the ultimate design population and compared with the prevalent rural norms. By side by side comparison of the options under consideration, the 'optimal' configuration is selected based on a set of criteria such as capital cost, energy cost, O&M (Operation and Maintenance) cost, level of service etc. Total scheme cost including pumping machinery, WTP (Water Treatment Plant), MBR (Mass Balancing Reservoir) was considered for comparing options related to scope and coverage of the scheme.

III. THE PROPOSED SCHEME

The scheme will consist of two zones: North Zone consisting of 17 villages, and South Zone consisting of 13 villages. A jack well will be constructed for each of the two zones on the basin of Upper Vaitarna reservoir as the two sources of the proposed scheme. For each zone water will be pumped from this well to the Water Treatment Plant (WTP). After the treatment, water will be pumped to Mass Balance Reservoir (MBR), from where it will be distributed by gravity to Elevated Storage Reservoirs (ESRs) located at different places in the network supplying water to the tanker fed villages. Choosing Upper Vaitarna has a source now allows us to have a consolidated scheme in the area.

Figure 2: Pipe Water Network Layout of North Zone and South Zone (red for D.I. pipes and blue for H.D.P.E. pipes)

A. *Scheme Design*

Drinking water demand was estimated from the forecasted population of 86,826 at 40 lpcd (litres per capita per day). This gives a total demand of 34,73,040 litres per day for the 17 villages. A further 20% loss factor was added to the demand for the simulations. This gives us a demand of 4.2 MLD. The total cost of the scheme is Rs. 35.41 Crores and the per capita cost is Rs. 4078.

As shown in Table II, the cost for every 1000 litres of water comes to only Rs 5.74. By assuming an average size of five people per household and 80% recovery, annual tariff charges per household turn out to be Rs 625 or Rs. 52 per month.

TABLE II
O&M COST DETAILS

Sr. No.	Description	Amount(Rs./day)
1	Operator Cost	13,200
2	Energy Cost	6,525
3	Cost of Chemicals	673
4	Maintenance and Repairs	378
5	Cost of Raw Water	4,168
6	Total	23,944
	Energy cost per 1000L of water	1.56
	O&M cost per 1000L of water	5.74
	O&M cost per person per year	100.65

B. *Verification of Network flow using EPANET*

The network design was verified by using EPANET [12], a software tool that models the flow of the water in pressurized piped networks. After completing the sizing and locations of the pipes and ESRs, we constructed the network in EPANET to verify whether sufficient head is being realized at all nodes. EPANET allows analysing how the various ESRs in the network fill up and empty during the daily life cycle. This helps indicates if there are any “problem” nodes where sufficient head is not being met.

As can be seen in the Figure 3 below, upstream villages get filled up first. Khodala in particular being the first village in the network gets filled up within the first hour. Other villages gradually fill up and empty during the demand period i.e. during the hours 9 to 12 and 21 to 24 while supply is done during the hours 1 to 6 and 13 to 18.

IV. CONCLUSIONS

Our design of a multi village scheme as a sustainable solution supplying piped water from Upper Vaitarna Reservoir to 30 tanker fed villages spread across the Mokhada taluka has an estimated capital cost of Rs. 4078 per capita for a design population of about 86000. Given the fact that the per capita capital cost of Mumbai city water supply scheme is in the neighbourhood of Rs. 10000, while the same for Thane city is Rs. 7000, it is clear that it is possible to solve the water scarcity problem of the entire taluka at a fraction of cost of a city water supply scheme.

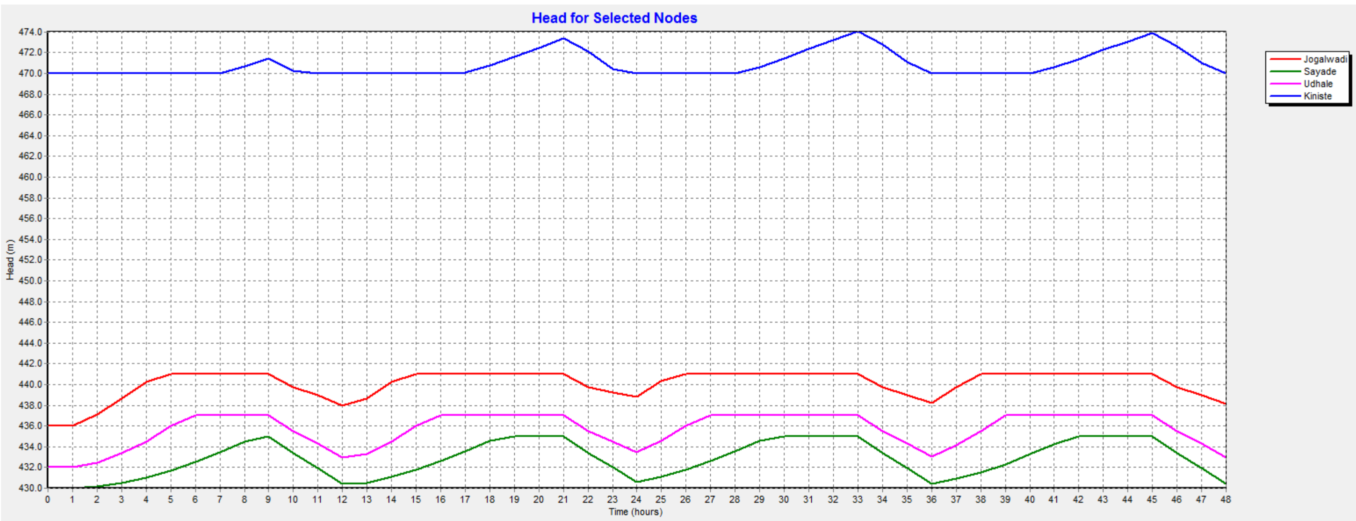

Figure 3: ESR heads

The difference is even more striking when compared with the cost figure of Rs. 5083 of the Karegaon scheme. The advantages offered by the high elevation of the source go beyond the capital cost savings. The cost of water per 1000L based on the annual O&M charges inclusive of energy cost of pumping works out to be Rs. 5.74 compared to Rs. 24 for the Karegaon scheme under implementation. The relative financial viability of this scheme is self evident. It is further reinforced by taking into account that it is significantly lower than the O&M cost figures published by World Bank Report for multi village schemes. (There is a wide variation of Rs. 26 to 38 while the economical figure is quoted as Rs. 16 per 1000L).

The economics of the proposed solution brings in focus the energy efficiency and sustainability as key criteria for designing rural water supply schemes.

The bulk water supply solution can be used in conjunction with the existing single village schemes to extend it to any village in the taluka on demand, making the entire Mokhada taluka tanker free and ensuring drinking water security round the year.

In Mumbai, water charges for residential buildings are Rs. 3 per 1000 lit of water [10] against a reported cost of Rs. 11. Therefore, providing subsidized water a tribal area from where almost all the water is taken for Mumbai's water supply should be given serious consideration.

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