CENTRE FOR TECHNOLOGY ALTERNATIVES FOR RURAL AREAS
INDIAN INSTITUTE OF TECHNOLOGY, BOMBAY

Piped Water Supply System for North Karjat

Techno-Economic Feasibility Study

(SHORT VERSION)

By

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August 2010

Abstract

Over a hundred villages in north Karjat, Raigarh district, Maharashtra, suffer from severe water shortage in the months preceding the monsoons. A few check dams have been built to alleviate the problem in some of the villages but most habitations face empty wells and defunct hand-pumps in the summer. This project aims to evaluate the techno-economic feasibility of piped water supply to this region as well to establish a universally applicable design methodology for rural piped water supply systems. The target area within the Karjat block spans 120 sq. km and has a forecasted 2041 population of over 81,000. The source is taken to be the Pej River, south of the target region. We have designed primary and secondary grids for two supply norms: a livelihood norm of 200 lpcd and a sustenance norm of 40 lpcd. Given existing design norms, engineering practices, and schedules of costs our finding is that it economically viable to supply water in pipes from Pej River to the target area at the desirable livelihood norm of 200 lpcd. We estimate the investment cost of this supply system to be around Rs. 7000 per capita at 200 lpcd and Rs. 2100 per capita at 40 lpcd.

Keywords

Piped water supply, rural water supply, piped network design, drinking water, domestic water, Karjat, Maharastra

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1. Introduction

1.1 Motivation

Water for domestic use is scarce in many regions across rural India, especially in the months preceding the annual monsoon rains. The Center for Technology Alternatives for Rural Areas (CTARA) at the Indian Institute of Technology Bombay (IITB) has been exploring solutions to this problem since 2005. A number of projects have been implemented in the Karjat block of Raigarh district where many of the villages north of the river Pej face severe water shortage after February.

There are two main options available for securing year-round water access for water-stressed rural communities: increasing ground water recharge and tapping into surface water. At the community level, check dams can potentially achieve both and numerous CTARA's water related projects have centered around them. An alternative is transporting water in pipes to habitations. This project looks to assess the viability of a piped water supply system as a solution to a community's domestic water woes.

1.2 Objective and Scope

Our project has two key objectives. Primarily, our aim is to assess the feasibility of a piped water distribution system for a target region spanning 120 sq. km and covering 70 villages in rural north Karjat. In addition, we aim to communicate a design methodology for a rural piped water supply system that can be applied universally. To achieve these aims have tried to design a highly optimized distribution network for north Karjat. Ours is a pre-design consisting of one primary and several secondary grids for transporting water from the water source to one point in each village in multiple stages. From estimates of the many costs of constructing and operating this network - and the size of the population served - we can gain a sense of the techno-economic feasibility of supplying piped water to rural regions at this scale.

Ultimately, the key output of the project is not a design that can be implemented exactly as is but rather a sound pre-design from which we can confidently assess the supply system's techno-economic feasibility. Certain salient aspects of rural water supply systems such as the distribution network within each village (tertiary grid) and potential cost-recovery plans have not been addressed in this project.

Much of what follows the pre-design along the path to implementation requires a thorough study of socio-economic implications of the decisions that will need to be made. Such a study is not within the scope of this project but certainly a central theme in the projects that would follow this one.

2. Norms and Investments

2.1 **Norms**

The water supplied per day per capita in piped water schemes varies across the country. The government of Mahatrashtra's norm is 135 lpcd for urban areas and 40 lpcd for rural areas, though Mumbai receives 200 lpcd. 40 liters of water per day is just enough to cover a person's drinking, cooking, bathing, laundry and household cleaning needs.

The current rural norm of 40 lpcd (sustenance norm) cannot provide for other uses such as home building and repairing and sustaining livelihoods. It is argued in Professor Sohoni's lecture notes and elsewhere that there is considerable unmet demand for water in rural areas and that the rural population is willing and able to pay for additional water supply. Additional water can be used to sustain ancillary livelihoods such as livestock rearing and brick making. The additional income from these activities will enable rural consumers to pay for the water and also improve their standard of living. Thus, there is a strong argument for extending the urban norm to rural areas. In this project we have designed a pipe water distribution system for a per capita supply of both 200 lpd (livelihood norm) and 40 lpd (sustenance norm).

2.2 Investments

The capital cost involved in the building of a piped water distribution system include the following:

- piping
- construction of jack well and pump house
- pumping machinery
- construction of a water treatment plant
- construction of a mass balanced reservoir (MBR)
- construction of elevated storage reservoirs (ESR)

- incremental water extraction from source

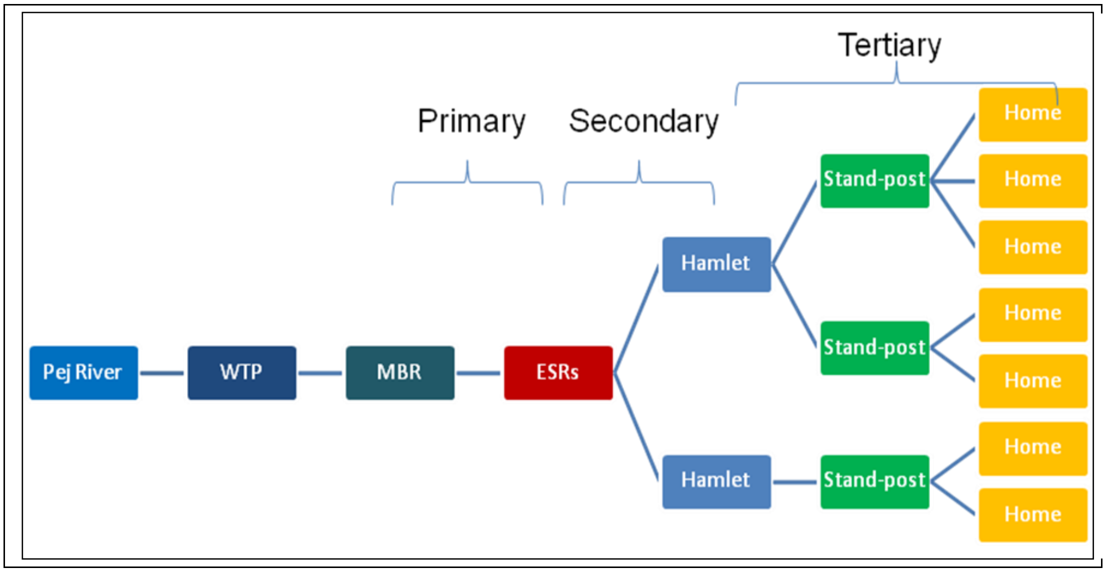
The per capita investment for Mumbai's piped water network, supplying 200 lpcd, is approximately Rs.7000. The investment for Thane (also at 200 lpcd) approaches Rs. 10,000. Maharashtra Jeevan Pradhikaran's Sugve and 6 Villages scheme cost approximately Rs. 2500 per capita for a supply of 40 lpcd . For our proposed supply system to be economically feasible the per capita investment would need to be well under Rs. 10,000. We must note here that there in addition to the capital investment there are the major costs of establishing the system, operation and maintenance, and of the electricity used for pumping.

3. Design Methodology

3.1 Components of Design

The following are the major components of a rural water supply system. We have designed the primary and secondary grids such that the end point of our design are villages. A tertiary network would transport water from a single delivery point at a village to stand posts and/or individual homes. The design of the tertiary network requires consensus at the hamlet level, and includes finalizing a pay-back mechanism and metering details. In addition, the tertiary design requires cadastral data which is GIS intensive. These requirements extend beyond the scope of this project and hence we not designed tertiary networks for the system.

- Source – *perennial surface water source (reservoir, river)*
- Rising Main – *large diameter pipeline that transports water from the source to the MBR via a water treatment plant*
- Water Treatment Plant (WTP) – *water treatment facility that treats raw water from the source*.
- Mass Balancing Reservoir (MBR) - *water tank that receives clean water coming out of the water treatment plant*
- Primary Network (Gravity Main) – *grid that transports water from the mass balanced reservoir to the various ESRs in the system*
- Elevated Storage Reservoir (ESR) – *elevated water tank that delivers water to a cluster of hamlets*
- Secondary Network - *grid that transports water from an ESR to one or more points (stand-posts) in the hamlets it serves*
- Tertiary Network – *grid that transports water from stand posts to homes in the hamlet*



Layout of a typical rural piped water supply system

3.2 Assumptions

Three key assumptions have been made during the process of designing the network.

1. Google Earth elevation data is reasonably accurate, and if there is an error it is constant across the region. Since the difference in elevation between points matters more than absolute elevation values, any constant error should not, in theory, affect the design.

2. A population of 600 has been assigned to the villages whose population data we do not have. We obtained data from difference sources; our area map came from MJP, our population data from the census database. The overlap in the two sources was not perfect, we have many villages whose position we know but whose population we are not sure of. There is a good chance that the name used for a particular village differs in the two sources. It is beyond the scope of this project, however, to research and ascertain the various identities of each village.

   The number 600 was chosen at the end of an involved process of population forecasting. The 2001 census population data for each village in Karjat was projected for 2011, 2026 and 2041 using Karjat taluka's previous years' population data. The projected populations were rounded to the nearest hundred. We found the mode of this modified data for 2026 to be 600. We have chosen the population forecast for 2026 to calculate the water demand at each village, thus we chose to assign a 2026 population of 600 to the villages whose population we do not know.

We believe we are overestimating rather than underestimating the target area population for two reasons. If a village has a population of over 300, it is highly probably that it will be included in the census. Villages whose names are not in present the census but are marked on our map are probably small villages (population under 300) or are villages whose population has been included in a larger village. Thus, we are certain that we have overestimated the population and that given more accurate population data our network would cost less rather than more.

3. The source in our design, the Pej river, has sufficient water flow at and permission has been sought to extract this water. As we do not know the low water level of Pej River, we have taken the depth of the jack well to be 10m. We are certain that this depth is greater than the actual required depth.

3.3 Design Parameters

1. We have chosen one lift-up point along the Pej River which is at an elevation of 63 m. The MBR location has been chosen to be on a nearby hill at an elevation of 255 m. Water will be pumped from the life-up point to this MBR for 16 hours a day.

2. From the MBR the distribution system is entirely gravity fed (no pumping required). Water will be released 24 hours a day to 19 ESRs along a primary looped MBR-ESR network.

3. We have chosen to design our network such that each village receives their quota of water from an ESR within 6 hours every day: from 5-8am and 5-8pm.

4. We have designed for both 40 LPCD and 200 LPCD. The cost comparisons are outlined in report.

5. We have designed the primary and secondary networks such that each node served by the secondary network has a minimum pressure head of 8m. We believe this head will be sufficient to supply water at a reasonable pressure through a tertiary network that may be built in the future.

6. The pipe material we have chosen for the gravity main (primary) and distribution network (secondary) in this design is High Density Poly-Ethylene (HDPE). We chose this material because of its relatively low-cost and resistance to corrosion.

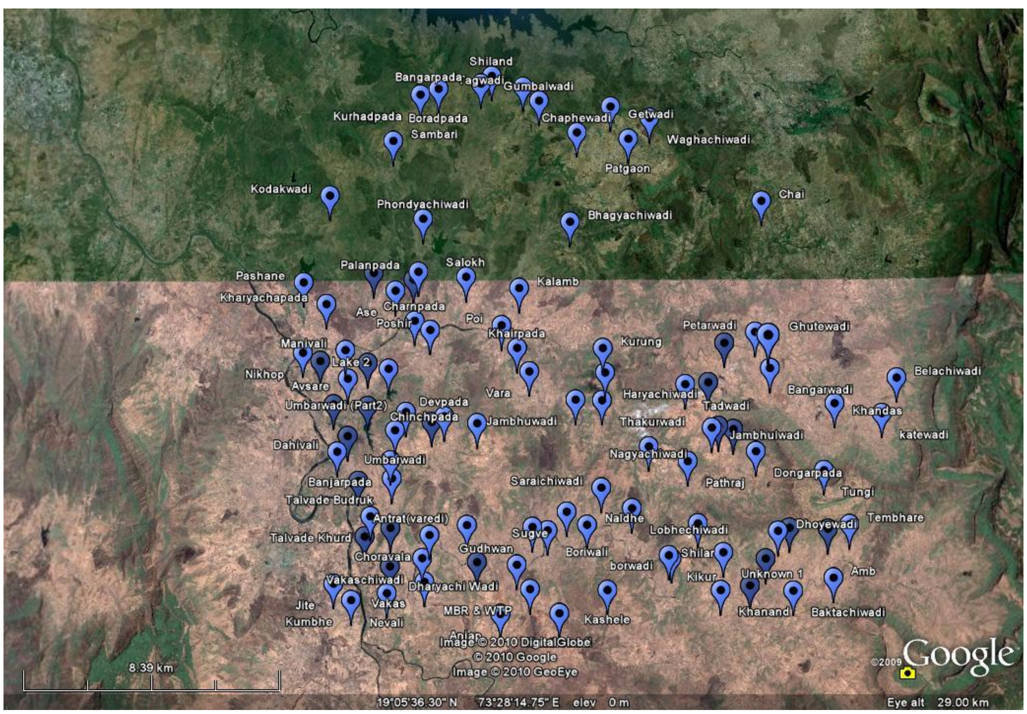
7. For the rising main we have chosen ductile iron as the pipe material because it can reliably meet the main's extreme pressure requirements.

8. We have chosen a Conventional water treatment plant (WTP) as opposed to an Unconventional WTP for the network since we do not anticipate a shortage of space. Unconventional WTPs have the advantage of being more compact.

3.4 Overall Design Methodology

In the following section we hope to illustrate in detail our methodology of design for our piped water supply system.

1. We began by using a detailed map of Karjat (obtained from Disha Kendra) to locate all villages and roads in the target region, and marked these on Google Earth.



Villages marked on Google Earth

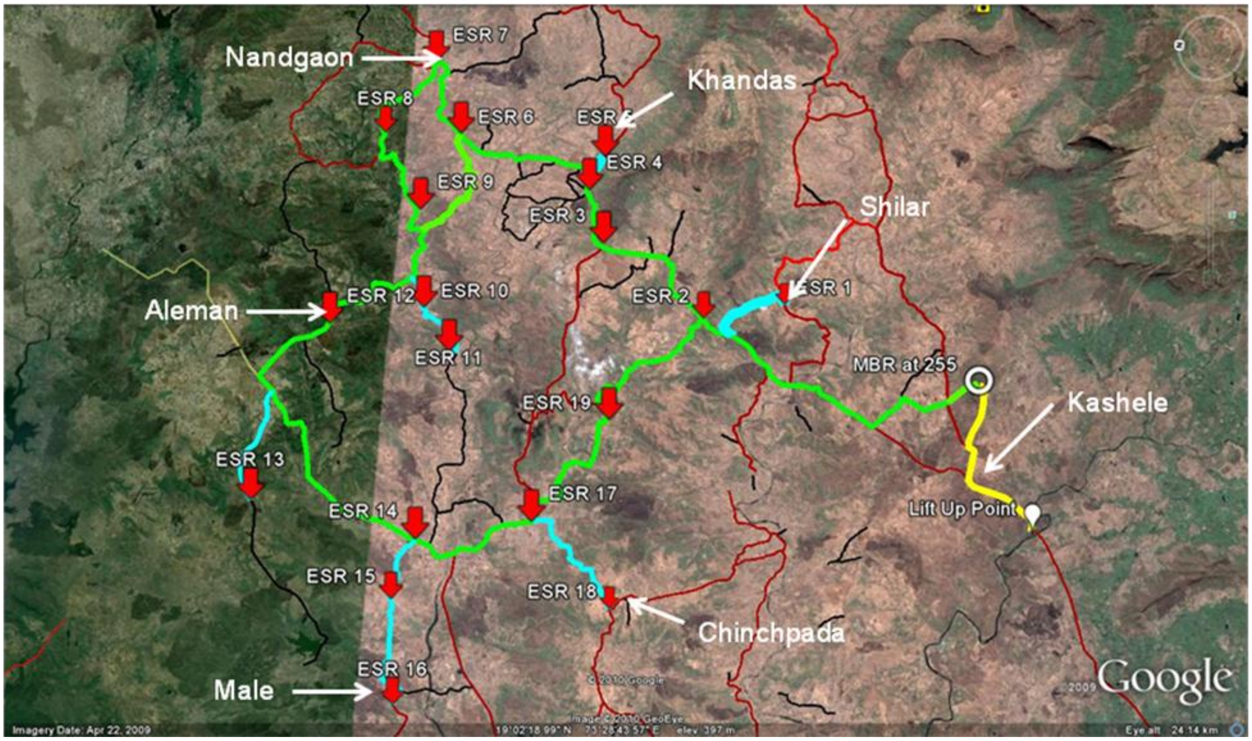
2. Next we collected and tabulated all available population data for Karjat Taluka and averaged the results of the incremental and geometric methods of population forecast to estimate the population of each village in the target area for 2026 (15 years) and 2041 (30 years). [Sample Population Forecast]

3. We then calculated water demand in LPS at each village for 200 LPCD and 40 LPCD given 6 hours of supply and added a 20% water loss margin.

   e.g. The 2041 population of Shilar is 1126. At 200 lpcd, the demand per day in Shilar is 200 multiplied by the population, equal to 225,200lpd. This quantity is to be delivered in 6 hours supply (within 3600*6 = 21600) seconds, thus the unadjusted demand is about 10.4 LPS. We then add a 20% water loss margin to get a design demand of 12.5 LPS.

4. We next decided on number of ESRs, their positions and the villages they will serve based on all of the following factors:

   - Elevation of villages - *Villages with similar elevations can be served by the same ESR easily.*
   - Position of villages – *Piping is expensive*; *it is economical to place an ESR in a central location with respect to the villages it will serve.*
   - Population of villages - *Very large villages will perhaps need an ESR of their own, or will share an ESR with fewer than usual villages*
   - Elevation of terrain - *The higher the ground level elevation of the ESR, the lower the ESR height will have to be to achieve a given pressure (i.e. lower construction costs). Alternatively, the higher the ground level elevation of the ESR, the higher the water pressure for a given ESR height be will be (i.e. lower piping costs).*
   - Proximity to major road – *The ESRs will be connected to the MBR along a main looped network that will consist of very large (and expensive) pipes. It is economical to minimize the length of this piping by keeping ESRs as close to the main looped network as possible. ESRs need to be position by a road also for ease of access.*
   - Appearance of the land – *We avoid positioning the ESR on farmland (visible on Google Earth)*



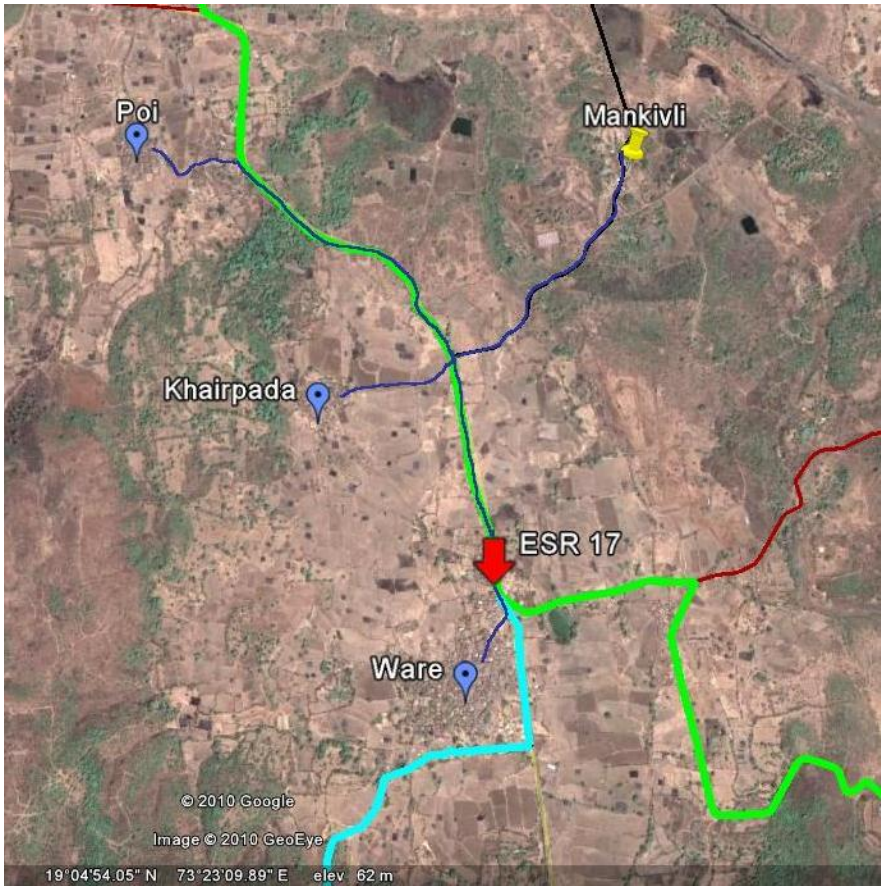
Google Earth image showing proposed positions of the 19 ESRs

5. Once the clusters were established we finalized the ESR-village pipe layout for each ESR-based cluster of villages as follows:

   a. We drew up pipes along the roadways that connect the ESR to each village such that all marked nodes are connected to network.

   b. We then assigned unique pipe and node identification numbers to each pipe and node in the system and recorded the details of village nodes (name, elevation, demand) and node-pipe connections (nodes from and to, length of the pipe)

   c. We entered the above information into BRANCH 3.0, a C++ optimization programme created by the EMC and World Bank. BRANCH 3.0 calculates the lowest pipe diameters (from a user-fed list of available diameters) which will meet user-specified minimum and maximum pressure requirements.



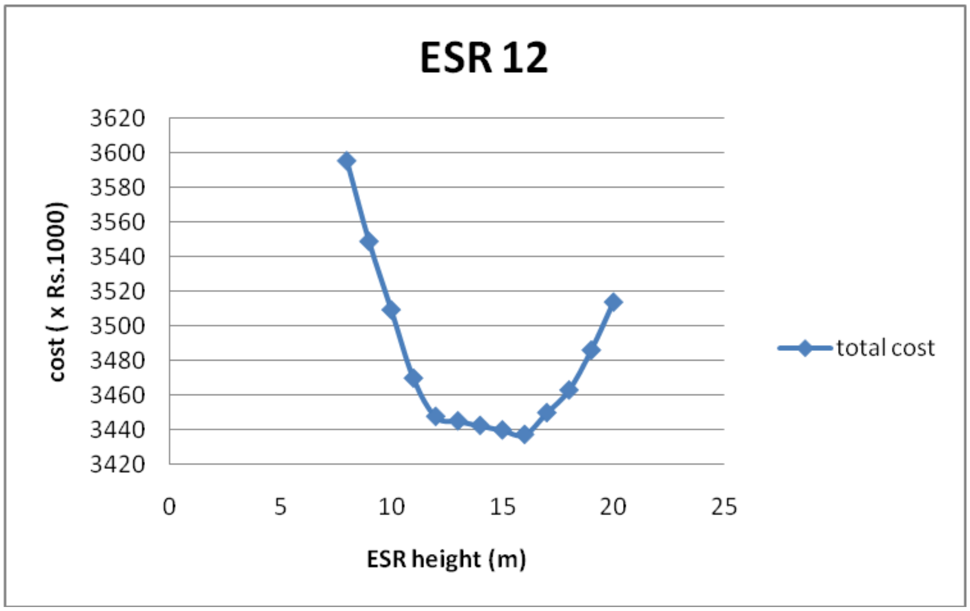
Example of a secondary (ESR to villages) network – ESR 17

6. In the next step we calculated an optimum height for the base of the water tank of the ESR. We believe this step has the potential to substantially save costs. Currently, in designs by the government the ESR height used is the minimum height at which the pressure requirement is met. However, we find that raising the height to an optimum value (which considers the drop in pipe costs due to a added pressure head) has the potential to reduce the overall cost of the project considerably.

    a. We first ran BRANCH/LOOP for HGLs ranging from the minimum allowable HGL to 20 meters above the ESR ground level elevation at intervals of one meter and recorded the total pipe cost in each case. The correlation between pipe cost and ESR height (ESR Height = HGL – GL elevation of ESR) is always negative.

b. We then used an MJP document on ESR construction cost estimates to estimate the cost of constructing an ESR of a given capacity at various heights. The correlation between the cost and ESR height is positive.

c. We summed the cost of piping and ESR construction for each height increment and graphed the total cost verses ESR height. The lowest point on the graph was taken as the optimum ESR height. As you can see, an ESR height of 8m would have satisfied pressure requirements but a height of 16 can save Rs. 1.6 lakh due to the lower piping costs at this staging height.

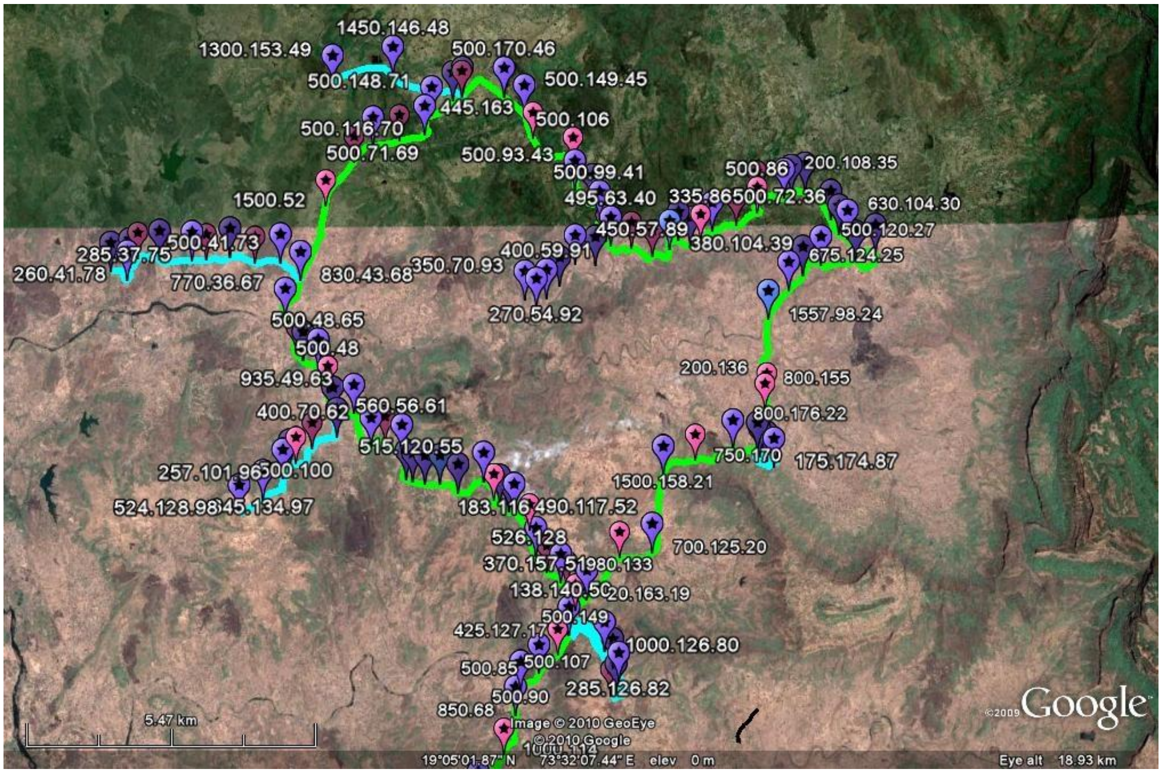


Example of a ESR staging height optimization graph – Optimum height chosen to be 16

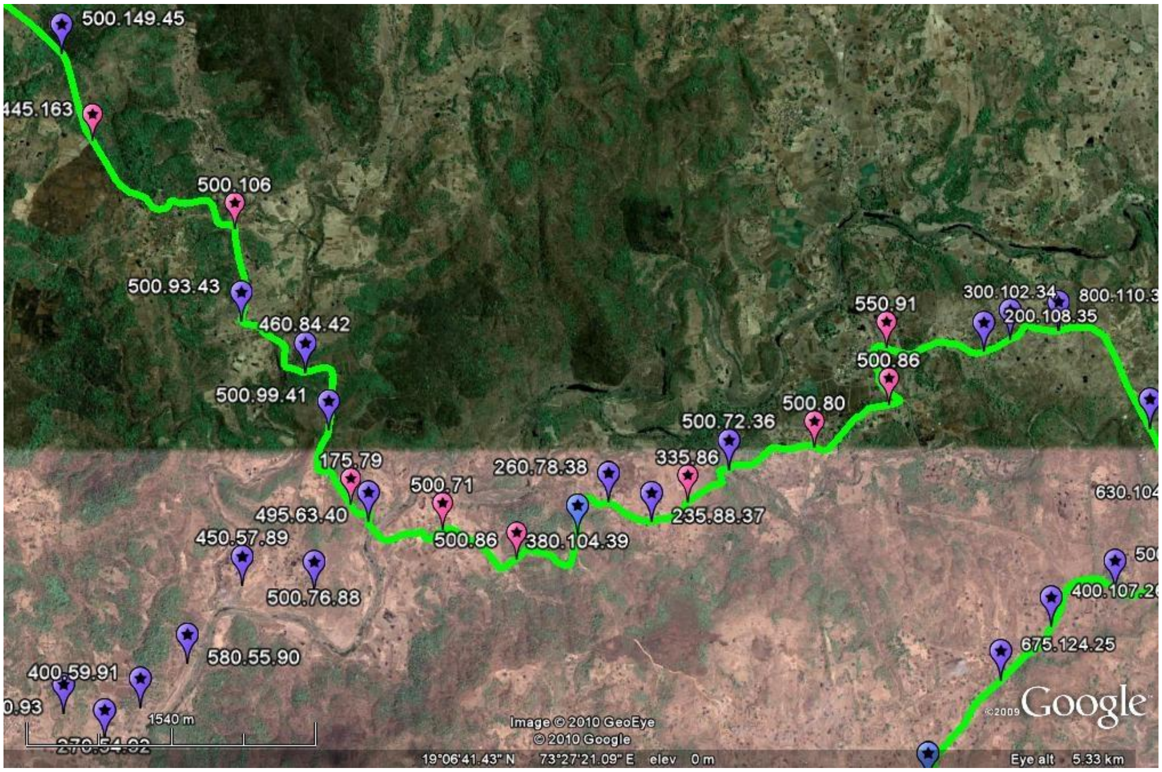
7. We designed the MBR-ESR network, a major component of the overall design, as follows:

a. We first tested several alternative pipe layouts for connecting the MRB to each ESR and chose the layout with the lowest pipeline length and costs. This is a very time intensive and tedious process requiring the creation and running of multiple complex LOOP files.

b. We then created dummy nodes at intervals of 500-1000m and at every sharp elevation drop or rise along the finalized pipelines, and entered them into LOOP 4.0 to ensure the design incorporates dips and rises in the elevation of the terrain. This network cannot be branched due to the head loss from the dead ends being too high.



Google Earth image showing dummy nodes along primary grid



A closer look at dummy nodes (naming convention depicts distance from previous node, elevation at current node and assigned node number in that order)

8. We designed the rising main as follows:

    a. Different diameter inputs were selected assuming an economic velocity of 1.25 m/s.

    b. Overall cost of rising main calculated for different diameters using an Excel spreadsheet provided by MJP with pre-entered formulae. The most economical diameter was selected and corresponding required pump capacity and piping were selected for the design. Rising Main Design Calculation

9. Finally, we tabulated all investment costs. Used documents prepared by MJP to estimate the cost of piping, construction of ESRs, sump, and water treatment plant (WTP) and divide by total population served to obtain a value for capital cost per capita of the project.

4. Design Details

4.1. Water Source

We considered a number of options for the water source. There are three rivers that flow in or around the target region: Ullhas, Shilar and Pej. Ullhas and Shilar are prone to drying up during the pre-monsoon months. Pej lies south of the target region and at an approximate straight-line distance of 20km to village in the target area furthest from it. It is in fact the only perennial river of the three, and our chosen water source. The water in the Pej River is supplied by a TATA power plant that lets out water in pre-determined quantities throughout the year.

Barvi Dam, built and operated by the Maharashtra Industrial Development Corporation (MIDC), seemed at one point a promising source. The enormous reservoir lies far north of the target region. We found, however, that the distance from the reservoir to the nearest point with a sufficiently high elevation was over 13km. This would require a very long rising main whose cost could substantially compromise the economic viability of the system. Furthermore, the reservoir is currently supplying water at its full capacity.

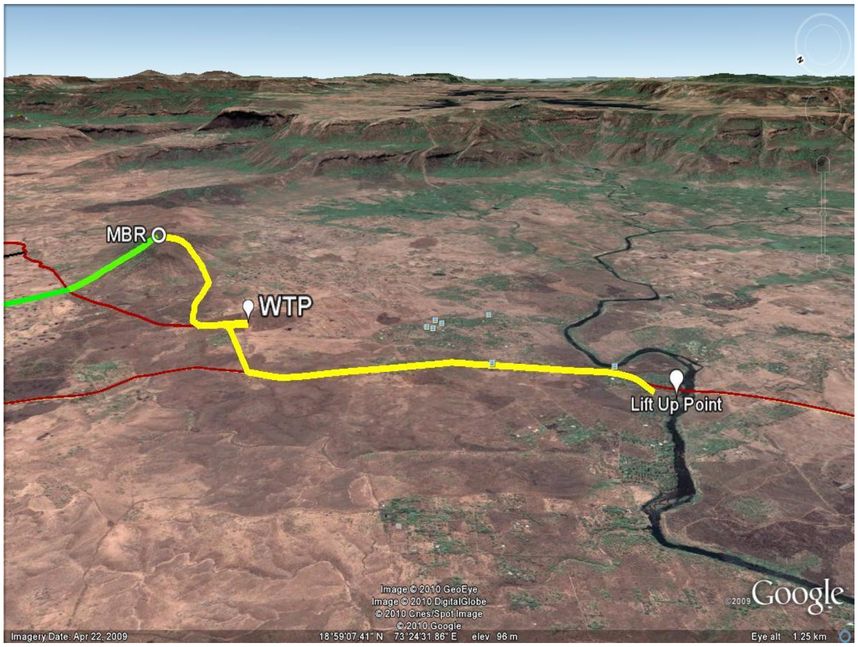
Pej River, May 1010

4.2. Rising Main

Two options were considered for the placement of the WTP. In the first, the WTP is placed 2.845 km from the lift-up point, and in the second the WTP is placed right next to the lift-up point. The piping cost of second option is lower by 4 crore rupees but it requires a pumping capacity that too high. Furthermore, the second option is not feasible for 40 lpcd due to high working pressure.

The following table contains the details of the rising main:

Specification	Raw water rising main(1st stage)	Clean water rising main(2nd stage)
Path	Lift-Up point to WTP	WTP to MBR
Length	1977 m	2845 m
Class of pipe	Ductile Iron	Ductile Iron
Diameter	600 mm (for 200LPCD) 350 mm (for 40LPCD)	700 mm (for 200LPCD) 350 mm (for 40LPCD)



Google Earth image showing the relative positions of the life-up point, MBR and WTP

5. Cost Breakdown

The following table contains the elements of design included in our cost estimate along with the cost breakdown.

S.No.	Particulars		200 lpcd	40 lpcd
			Cost(Rs.)	
1	Jack Well without Over Head Pump House		1122289	377287
2	Raw Water Pumping Machinery	1st Stage(Till 2026)	13335000	2478000
		2nd Stage(Till 2041)	19488000	3507000
3	Raw Water Rising Main		34874000	17762000
4	WTP	1st Stage(Till 2026)	24426480	6977800
		2nd Stage(Till 2041)	8870840	1973700
5	Pure Water Pumping Machinery	1st Stage(Till 2026)	43512000	8736000
		2nd Stage(Till 2041)	55965000	11424000
6	Pure Water Rising Main		34874000	12343000
7	MBR		12446990	3456190

8	Gravity Main	137466950	42368560
9	Distribution system(ESR + Pipe)	61814926	21943110
10	Excavation cost	119569126	38587002
	Total	**57,21,47601**	**17,19,33649**

The following two tables contains details on the cost per capita and the cost ratio between the 200 lpcd and 40 lpcd designs:

Design Population	81,140	51,618
Daily Demand	19.47 MLD	3.90 MLD
Net Investment	Rs. 57,21,47,601	17,19,33,649
Cost per Person	**7051**	**2119**
Ratio of Design Demand	5	1
Ratio of Costs	3.3	1

6. GIS Application

We used Google Earth extensively at every stage of the design process. The nature of this software allowed us enormous flexibility in marking, editing, saving and sharing accumulated data, along with aiding decision making processes by providing a visual representation of the target area.

Early in the project Google Earth was used to detect and mark villages, road networks and water sources manually. All our elevation data was obtain from Google Earth. At a later stage we used it to decide ESR locations and visually assess alternative pipe layouts. In the final stage of the design, once the pipe layout was established, we used Google Earth to ‘survey’ the terrain along our proposed pipelines. Dummy nodes were created at intervals of 500-1000m and at every major elevation rise and dip along the pipeline. These nodes acted as a record of elevation changes along the pipeline and were entered into LOOP 4.0 to ensure our chosen pipe diameters incorporated any head-loss due to a bumpy terrain. This latter use of GIS, we argue, holds tremendous potential to save the man-hours and high costs associated with typically pre-design land surveying.

While Google Earth has proved to be useful GIS tool for pipe network design, we believe a more optimized and streamlined design process is possible with a stronger GIS interface catered specifically towards design of piped water systems. Such an interface could include more reliable elevation data and could automate the detection of road networks, villages, uncultivated land and water sources as well as provide contour lines at small elevation intervals.

7. Conclusion

Our piped water supply network design has an estimated capital cost of Rs. 2100 per capita for a demand of 40 lpcd and Rs. 7000 per capita for a demand of 200 lpcd. These numbers incorporate all major costs of building the network. Given that the per capita capital cost for Thane's water supply scheme is Rs. 10,000 and Mumbai's is about Rs. 7000, our findings suggest that it is indeed economically feasible to supply water in a piped network to the villages of north Karjat.

The water level at our proposed lift-up point along the Pej depends on how much the TATA Bhivpuri hydro-electric plant lets out in a given period of time. The Pej River is already being used for a piped water supply scheme, and certainly the water that flows downstream is being used by someone, in part at least. We have made the assumption in this project that there is sufficient water in the Pej river since we were not certain one way or the other (due to lack of access to data), and also because in large part our aim was to establish a universally application design methodology. Making this assumption allowed us to progress to the pre-design and fulfill part of our aim. Nevertheless, investigating the suitability of Pej river as a water source is the essential next step in CTARA's venture to explore ways to secure water access in north Karjat.

Appendix 8.1

Village Data Summary

S.No.	ESR #	Village	Elevation	Population		
				2011	2026	2041
1	1	Shilar	138	737	912	1126
2		Unknown	119	480	600	800
3		Khadyrachiwadi	133	480	600	800
4		Kikur	91	480	600	800
5		Borwadi	90	480	600	800
6	2	Pathraj	150	2058	2402	2773
7		Nagyachiwadi	158	480	600	800
8	3	Morachiwadi	151	480	600	800
9		Tadwadi	144	827	985	1166
10		Margachiwadi	138	425	577	773
11		Jambhulwadi	137	480	600	800
12		Jalkatwadi	150	480	600	800
13		Dongarpada	165	480	600	800
14	4	Bhangarwadi	159	480	600	800
15		Dhabewadi	161	480	600	800
16		Govanwadi	123	480	600	800
17		Petarwadi	136	480	600	800
18		Ghutewadi	121	480	600	800
19	5	Belachiwadi	174	480	600	800
20		Amberpada	166	480	600	800
21		Katewadi	163	480	600	800
22		Khandas	166	2637	2947	3285
23	6	Mangal	122	480	600	800
24		Chafewadi	129	1418	2117	3207
25		Unknown	113	480	600	800
26		Jamhaiwadi	133	480	600	800
27	7	Nandgaon	120	865	995	1137
28		Daunsewadi1	116	480	600	800
29		Ballvare	117	1168	1477	1867
30		Daunsewadi2	110	480	600	800
31		Gorechiwadi	108	480	600	800

S.No.	ESR #	Village	Elevation	Population		
				2011	2026	2041
32	8	Chevne	87	542	660	795
33		Chai	105	902	1394	2173
34		Kotwalwadi	102	480	600	800
35		Zugarachiwadi	112	785	911	1047
36	9	Bhopalwadi	96	480	600	800
37		Pendarawadi	71	480	600	800
38	10	Bondshet	62	480	600	800
39	11	Borgaon	65	1095	1305	1545
40	12	Aleman	162	1012	1274	1587
41		Telangwadi	132	480	600	800
42		Borichiwadi	161	480	600	800
43		Bhagyachiwadi	128	480	600	800
44	13	Murchulwadi	153	480	600	800
45		Bhikarwadi	136	480	600	800
46		Narthewadi	119	480	600	800
47	14	Kalamb	50	4691	5814	7140
48	15	Salokh	47	1788	2165	2601
49	16	Poshir	45	2624	2962	3332
50		Charnpada	40	480	600	800
51		Ase	43	215	303	427
52		Ardhe	59	854	1062	1308
53		Male	53	1573	1934	2370
54		Palanpada	48	480	600	800
55	17	Ware	65	1755	2009	2286
56		Khairpada	54	480	600	800
57		Mankivili	56	480	600	800
58		Poi	46	436	551	695
59	18	Chinchpada	128	480	600	800
60		Devpada	87	480	600	800
61		Giripada	118	480	600	800
62		Umberwadi2	105	480	600	800
63		Umberwadi1	103	480	600	800
64		Banjarpada	61	480	600	800
65		Talwade Budruk	57	480	600	800
66	19	Thakurwadi	111	480	600	800
67		Jambhulwadi	106	480	600	800

68		Haryachiwadi	121	480	600	800
69		Kurung	96	650	765	899

Appendix - 8.2

Sample ESR Profile

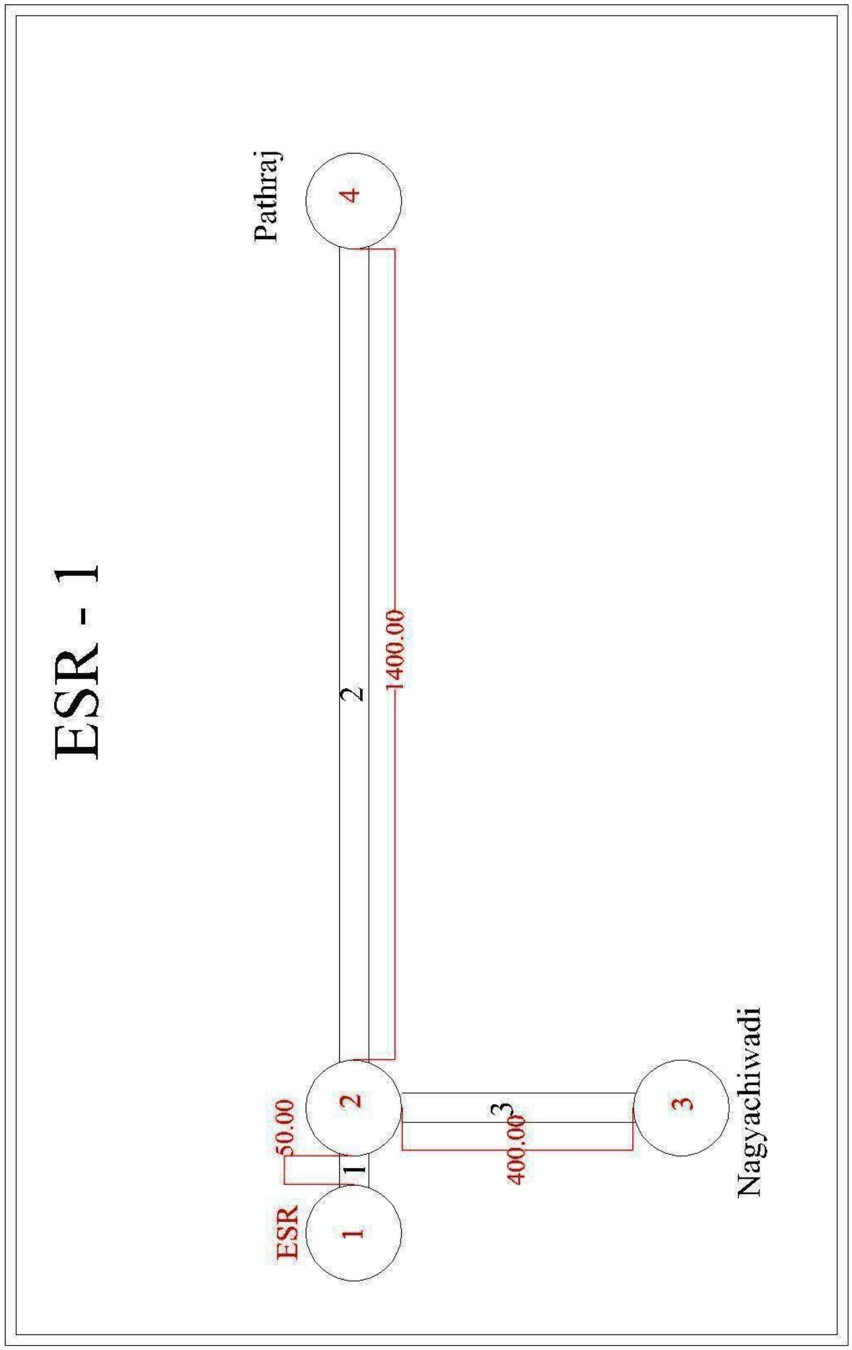
for 200 LPCD Design

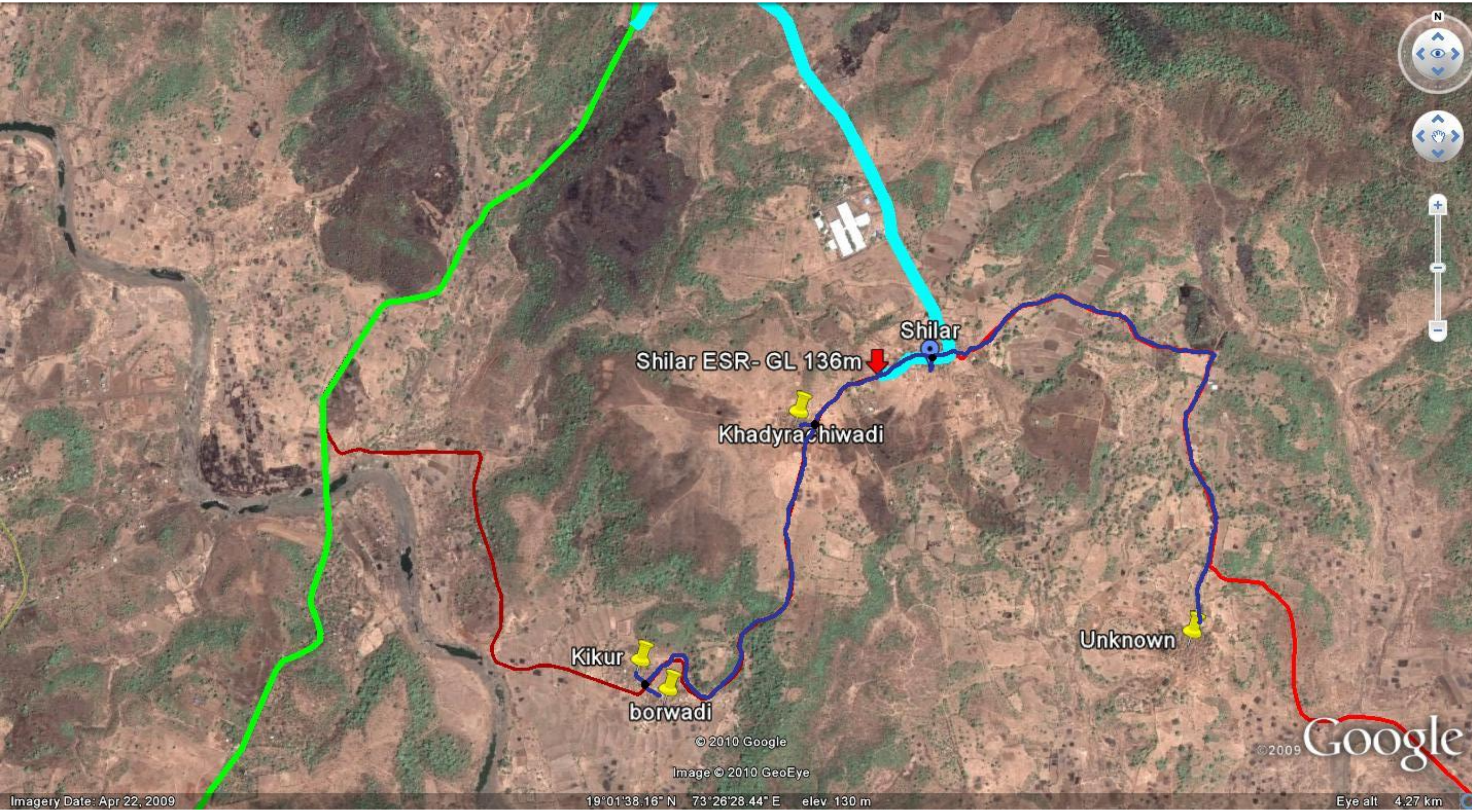
Sample ESR 1 – Shilar

S.No.	Village	Elevation	Population		
			2011	2026	2041
1	Shilar	138	737	912	1126
2	Unknown	119	480	600	800
3	Khadyrachiwadi	133	480	600	800
4	Kikur	91	480	600	800
5	Borwadi	90	480	600	800
	Total		**2657**	**3312**	**4326**

Daily Water Demand at 200LPCD					
S.No.	Village	Demand(MLD)		Demand(LPS)	
		2011	2041	2011	2041
1	Shilar	0.177	0.270	8.189	12.511
2	Unknown	0.115	0.192	5.333	8.889
3	Khadyrachiwadi	0.115	0.192	5.333	8.889
4	Kikur	0.115	0.192	5.333	8.889
5	Borwadi	0.115	0.192	5.333	8.889
	Total	**0.638**	**1.038**	**29.522**	**48.067**

ESR Profiles for 200 LPCD Design




Shilar
Shilar ESR- GL 136m
Khadyrachiwadi
Unknown
Kikur
borwadi
© 2010 Google
Image © 2010 GeoEye
©2009 Google
Imagery Date: Apr 22, 2009
19°01'38.16" N 73°26'28.44" E elev 130 m
Eye alt 4.27 km
N

ESR 1 - Shilar

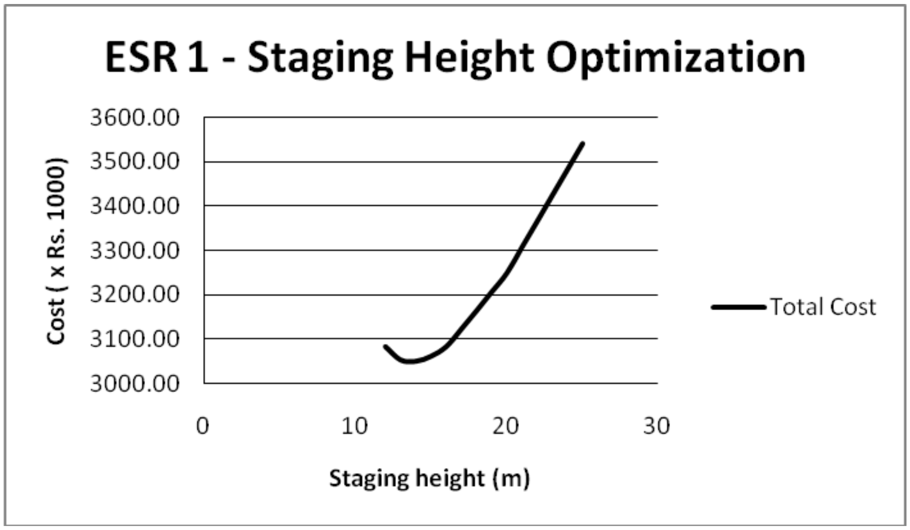
ESR 1 – Staging Height Optimization

Total Daily Demand(l)	1038240
ESR Capacity Required(l)	389340
ESR Capacity Proposed(l)	**390000**
ESR Elevation(m)	**135**
Minimum Working HGL(m)	147

Staging height(m)	HGL(m)	Pipe Cost	ESR Cost	Total Cost
12	147	1477.73	1606.21	3083.94
13	148	1415.47	1638.33	3053.80
14	**149**	**1380.47**	**1670.46**	**3050.93**
15	150	1359.47	1702.58	3062.05
16	151	1349.16	1734.71	3083.87
17	152	1340.54	1782.89	3123.43
18	153	1333.85	1831.08	3164.93
19	154	1328.12	1879.27	3207.39
20	155	1322.39	1927.45	3249.84
21	156	1316.66	1991.70	3308.36

Optimum ESR Height(m)	14
Tank Height(m)	5
Total Height of ESR(m)	**19**

ERS Cost('000 Rs.)	1670.46
Pipe Cost('000 Rs.)	1380.47
Total Cost('000 Rs.)	**3050.93**
Cost per Person(Rs.)	**705**



ESR 1 – Branch Output

```
Echoing Input Variables
------------------------

 Title of the Project                         : ESR 1
 Name of the User                             :
 Number of Pipes                              :  9
 Number of Nodes                              :  10
 Number of Commercial Diameters               :  16
 Peak Design Factor                           :  1
 Minimum Headloss in          m/km            :  .1
 Maximum Headloss in          m/km            :  25
 Minimum Residual Pressure    m               :  8
 Type of Formula                              : Hazen's


 Pipe Data
------------
```

Pipe No.	From Node	To Node	Length m	Diameter mm	Hazen's Const	Status (E/P)
1	1	2	50.00			
2	2	3	200.00			
3	3	4	50.00			
4	3	5	2050.00			
5	2	6	340.00			
6	6	7	50.00			
7	6	8	1400.00			
8	8	9	100.00			
9	8	10	100.00			

Node Data

Node No.	Peak Factor	Flow lps	Elevation m	Res. Press m	Meet Res. Pres (Y/N)?
1	1.00	0.000	135.00	8.00	
2	1.00	0.000	134.90	8.00	
3	1.00	0.000	133.00	8.00	
4	1.00	-12.511	138.00	8.00	
5	1.00	-8.889	119.00	8.00	
6	1.00	0.000	133.00	8.00	
7	1.00	-8.889	133.00	8.00	
8	1.00	0.000	85.00	8.00	

Node Data cont`d

Node No.	Peak Factor	Flow lps	Elevation m	Res. Press m	Meet Res. Pres (Y/N)?
9	1.00	-8.889	91.00	8.00	
10	1.00	-8.889	90.00	8.00	

Reference Node Data

Node No.	Grade Line m
1	149.00

Commercial Diameter Data

Pipe Dia. Int. (mm)	Hazen's Const	Unit Cost Rs /m length
63.0	140.00000	98.00
75.0	140.00000	138.00
90.0	140.00000	189.00
110.0	140.00000	270.00
125.0	140.00000	347.00
140.0	140.00000	432.00
160.0	140.00000	556.00
180.0	140.00000	695.00

200.0	140.00000	789.00
225.0	140.00000	1004.00
250.0	140.00000	1228.00
280.0	140.00000	1532.00
315.0	140.00000	1932.00
355.0	140.00000	2210.00
400.0	140.00000	3147.00
500.0	140.00000	4000.00

Branched Water Distribution Network Design Output

Pipe Details

Pipe No.	From Node	To Node	Peak Flow (lps)	Diam (mm)	Hazen's Const	HL (m)	HL/1000 (m)	Length (m)	Status (E/P)
1	1	2	48.067	200.0	140.00000	0.53	10.60	50.00	
2	2	3	21.400	140.0	140.00000	1.35	13.35	101.16	
				160.0	140.00000	0.69	6.98	98.84	
3	3	4	12.511	125.0	140.00000	0.43	8.60	50.00	
4	3	5	8.889	90.0	140.00000	3.14	22.64	138.68	
				110.0	140.00000	16.29	8.52	1911.32	
5	2	6	26.667	140.0	140.00000	6.83	20.09	340.00	
6	6	7	8.889	90.0	140.00000	0.34	22.47	15.13	
				110.0	140.00000	0.30	8.60	34.87	
7	6	8	17.778	125.0	140.00000	23.08	16.49	1400.00	
8	8	9	8.889	90.0	140.00000	2.26	22.60	100.00	
9	8	10	8.889	90.0	140.00000	2.26	22.60	100.00	

Node Details

Node No.	Peak Flow (lps)	Elevation (m)	H G L (m)	Cal Pres (m)	Spc Pres (m)	Meet Pres.	Res (Y)
1 S	48.067	135.00	149.00	14.00	8.00		

2		0.000	134.90	148.47	13.57	8.00
3		0.000	133.00	146.43	13.43	8.00
4 T		-12.511	138.00	146.00	8.00	8.00
5 T		-8.889	119.00	127.00	8.00	8.00
6		0.000	133.00	141.64	8.64	8.00
7 T		-8.889	133.00	141.00	8.00	8.00
8		0.000	85.00	118.56	33.56	8.00
9 T		-8.889	91.00	116.29	25.29	8.00
10 T		-8.889	90.00	116.29	26.29	8.00

Cost Summary

Diameter (mm)	Length (m)	Cost (1000 Rs)	Cum. Cost (1000 Rs)
90.0	353.81	66.87	66.87
110.0	1946.19	525.47	592.34
125.0	1450.00	503.15	1095.49
140.0	441.16	190.58	1286.07
160.0	98.84	54.96	1341.03
200.0	50.00	39.45	1380.48

Pipe-wise Cost Summary

Pipe No	Diameter (mm)	Length (m)	Cost (1000 Rs)	Cum. Cost (1000 Rs)
1	200.0	50.00	39.45	39.45
2	140.0	101.16	43.70	83.15
	160.0	98.84	54.96	138.11
3	125.0	50.00	17.35	155.46
4	90.0	138.68	26.21	181.67
	110.0	1911.32	516.06	697.72
5	140.0	340.00	146.88	844.60
6	90.0	15.13	2.86	847.46
	110.0	34.87	9.41	856.88
7	125.0	1400.00	485.80	1342.68
8	90.0	100.00	18.90	1361.58
9	90.0	100.00	18.90	1380.48

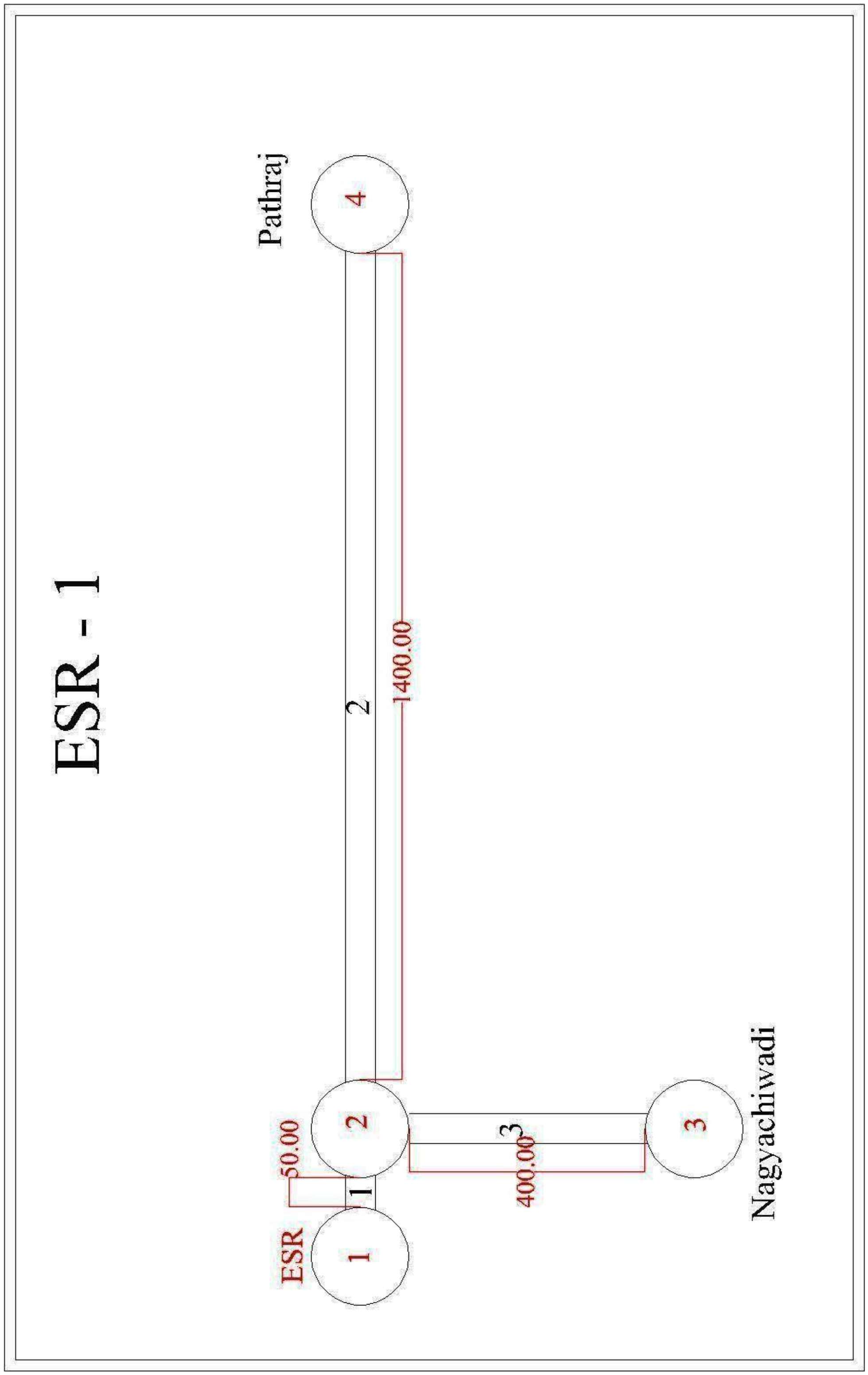
Sample ESR Profile

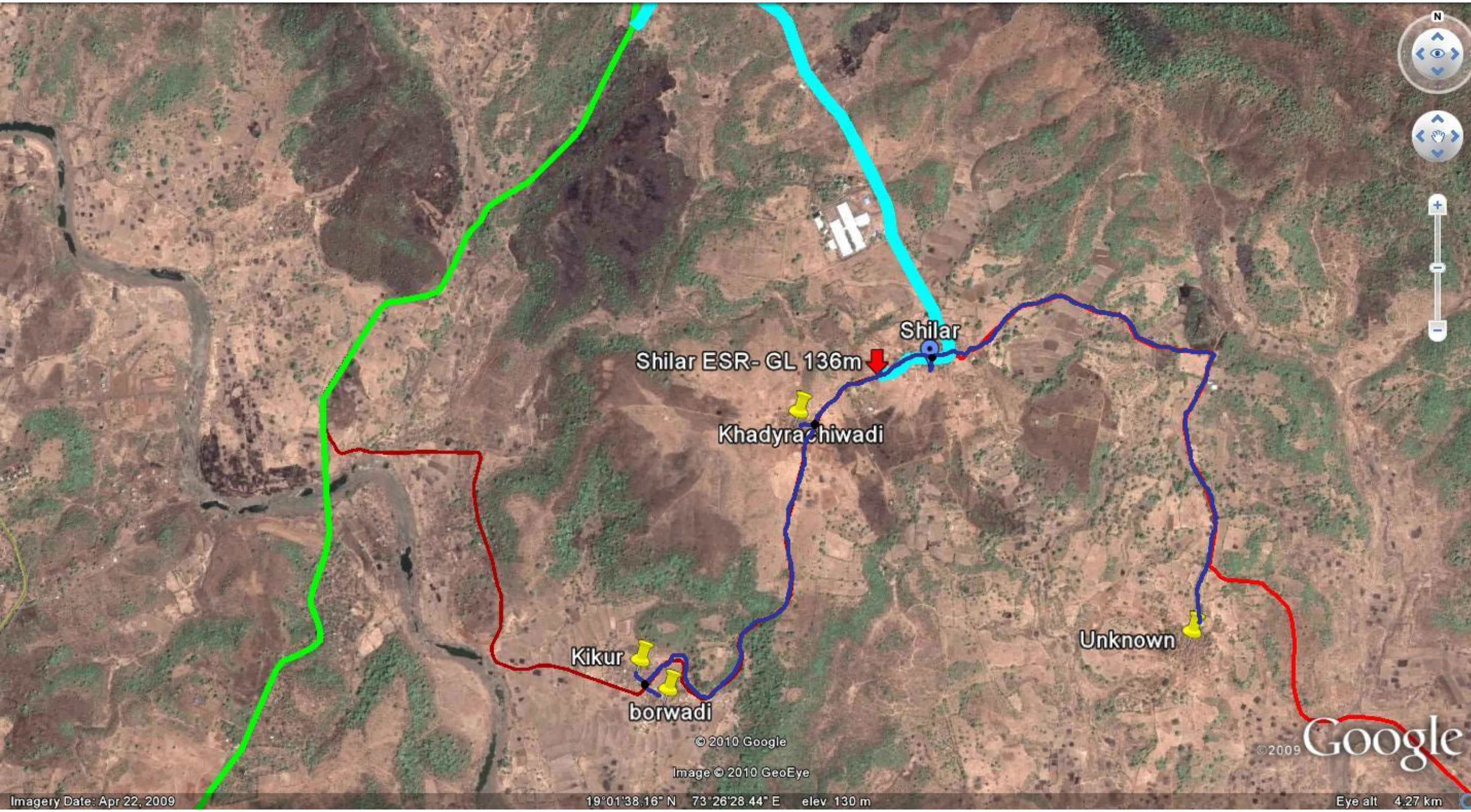
for 40 LPCD Design

Sample ESR 1 – Shilar

S.No.	Village	Elevation	Population		
			2011	2026	2041
1	Shilar	138	737	912	1126
2	Unknown	119	480	600	800
3	Khadyrachiwadi	133	480	600	800
4	Kikur	91	480	600	800
5	Borwadi	90	480	600	800
	Total		**2657**	**3312**	**4326**

Daily Water Demand at 40 lpcd 40LPCD					
S.No.	**Village**	**Demand(MLD)**		**Demand(LPS)**	
		2011	**2041**	**2011**	**2041**
1	Shilar	0.128	0.208	5.904	9.613
2	Unknown	0.128	0.208	5.904	9.613
3	Khadyrachiwadi	0.128	0.208	5.904	9.613
4	Kikur	0.128	0.208	5.904	9.613
5	Borwadi	0.128	0.208	5.904	9.613
	Total	**0.128**	**0.208**	**5.904**	**9.613**


ESR - 1
Pathraj
Nagyachiwadi
ESR
1400.00
400.00
50.00
1
2
3
4


Shilar
Shilar ESR- GL 136m
Khadyrachiwadi
Kikur
borwadi
Unknown
© 2010 Google
Image © 2010 GeoEye
©2009 Google
Imagery Date: Apr 22, 2009
19°01'38.16" N 73°26'28.44" E elev 130 m
Eye alt 4.27 km

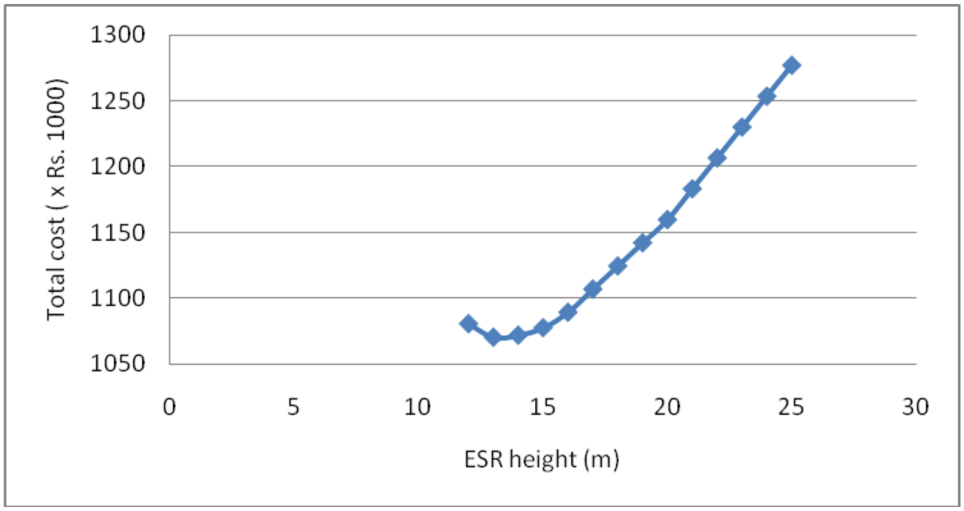
ESR 1 - Shilar

ESR 1 – Staging Height Optimization

Total Demand	207648
ESR capacity Required	77868
ESR capacity Proposed	78000
Low level Height	147
ESR elevation	135

HGL	PIPE cost	ESR cost	Total	height
147	493.74	586.925	1080.665	12
148	471.7	598.6635	1070.3635	13
149	461.56	610.402	1071.962	14
150	455.51	622.1405	1077.6505	15
151	455.51	633.879	1089.389	16
152	455.51	651.48675	1106.99675	17
153	455.51	669.0945	1124.6045	18
154	455.51	686.70225	1142.21225	19
155	455.51	704.31	1159.82	20
156	455.51	727.787	1183.297	21
157	455.51	751.264	1206.774	22
158	455.51	774.741	1230.251	23
159	455.51	798.218	1253.728	24
160	455.51	821.695	1277.205	25

ESR capacity	78000
Optimum ESR height	13
ERS cost	598.66
Pipe cost	471.70
Total	1070.36
/person	247



ESR 1 – Branch Output

Echoing Input Variables

Title of the Project	: ESR 1(40 LPCD)
Name of the User	:
Number of Pipes	: 9
Number of Nodes	: 10
Number of Commercial Diameters	: 16
Peak Design Factor	: 1
Minimum Headloss in m/km	: .1
Maximum Headloss in m/km	: 25
Minimum Residual Pressure m	: 8
Type of Formula	: Hazen's

Pipe Data

Pipe No.	From Node	To Node	Length m	Diameter mm	Hazen's Const	Status (E/P)
1	1	2	50.00			
2	2	3	200.00			
3	3	4	50.00			
4	3	5	2050.00			
5	2	6	340.00			
6	6	7	50.00			
7	6	8	1400.00			
8	8	9	100.00			
9	8	10	100.00			

Node Data

Node No.	Peak Factor	Flow lps	Elevation m	Res. Press m	Meet Res. Pres (Y/N)?
1	1.00	0.000	135.00	8.00	
2	1.00	0.000	134.90	8.00	
3	1.00	0.000	133.00	8.00	
4	1.00	-2.502	138.00	8.00	
5	1.00	-1.778	119.00	8.00	
6	1.00	0.000	133.00	8.00	
7	1.00	-1.778	133.00	8.00	
8	1.00	0.000	85.00	8.00	

Node Data cont`d

Node No.	Peak Factor	Flow lps	Elevation m	Res. Press m	Meet Res. Pres (Y/N)?
9	1.00	-1.778	91.00	8.00	
10	1.00	-1.778	90.00	8.00	

Reference Node Data

Node No.	Grade Line m
1	148.00

Commercial Diameter Data

Pipe Dia. Int. (mm)	Hazen's Const	Unit Cost Rs /m length
63.0	140.00000	98.00
75.0	140.00000	138.00
90.0	140.00000	189.00
110.0	140.00000	270.00
125.0	140.00000	347.00
140.0	140.00000	432.00
160.0	140.00000	556.00
180.0	140.00000	695.00
200.0	140.00000	789.00
225.0	140.00000	1004.00
250.0	140.00000	1228.00
280.0	140.00000	1532.00
315.0	140.00000	1932.00
355.0	140.00000	2210.00
400.0	140.00000	3147.00
500.0	140.00000	4000.00

Branched Water Distribution Network Design OutPut

Pipe Details

Pipe No.	From Node	To Node	Peak Flow (lps)	Diam (mm)	Hazen's Const	HL (m)	HL/1000 (m)	Length (m)	Status (E/P)
1	1	2	9.614	110.0	140.00000	0.49	9.80	50.00	
2	2	3	4.280	75.0	140.00000	0.12	13.97	8.59	
				90.0	140.00000	1.12	5.85	191.41	
3	3	4	2.502	75.0	140.00000	0.26	5.20	50.00	
4	3	5	1.778	63.0	140.00000	13.43	6.55	2050.00	
5	2	6	5.334	75.0	140.00000	5.41	21.37	253.10	
				90.0	140.00000	0.77	8.86	86.90	
6	6	7	1.778	63.0	140.00000	0.33	6.60	50.00	
7	6	8	3.556	63.0	140.00000	33.07	23.62	1400.00	
8	8	9	1.778	63.0	140.00000	0.66	6.60	100.00	
9	8	10	1.778	63.0	140.00000	0.66	6.60	100.00	

Node Details

Node No.	Peak Flow (lps)	Elevation (m)	H G L (m)	Cal Pres (m)	Spc Pres (m)	Meet Pres.	Res (Y)
1 S	9.614	135.00	148.00	13.00	8.00		
2	0.000	134.90	147.51	12.61	8.00		
3	0.000	133.00	146.26	13.26	8.00		
4 T	-2.502	138.00	146.00	8.00	8.00		
5 T	-1.778	119.00	132.83	13.83	8.00		
6	0.000	133.00	141.33	8.33	8.00		
7 T	-1.778	133.00	141.00	8.00	8.00		
8	0.000	85.00	108.26	23.26	8.00		
9 T	-1.778	91.00	107.60	16.60	8.00		
10 T	-1.778	90.00	107.60	17.60	8.00		

Cost Summary

Diameter (mm)	Length (m)	Cost (1000 Rs)	Cum. Cost (1000 Rs)
63.0	3700.00	362.60	362.60
75.0	311.69	43.01	405.61
90.0	278.31	52.60	458.21
110.0	50.00	13.50	471.71

Pipe-wise Cost Summary

Pipe No	Diameter (mm)	Length (m)	Cost (1000 Rs)	Cum. Cost (1000 Rs)
1	110.0	50.00	13.50	13.50
2	75.0	8.59	1.19	14.69
	90.0	191.41	36.18	50.86
3	75.0	50.00	6.90	57.76
4	63.0	2050.00	200.90	258.66
5	75.0	253.10	34.93	293.59
	90.0	86.90	16.42	310.01
6	63.0	50.00	4.90	314.91
7	63.0	1400.00	137.20	452.11
8	63.0	100.00	9.80	461.91
9	63.0	100.00	9.80	471.71