Piped Water Supply Scheme based on Upper Vaitarna for tanker fed villages in Mokhada Taluka: A Techno Economic Feasibility Study

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Acronyms and Abbreviations

ESR   Elevated Storage Reservoir

GIS   Geographical Information System

GP   Gram Panchayat

LPCD   Litres Per Capita per Day

MBR   Mass Balance Reservoir

MJP   Maharashtra Jeevan Pradhikaran

MSEB   Maharashtra State Electricity Board

MVS   Multi Village Scheme

NGO   Non Government Organization

PWS   Piped Water Scheme

SVS   Single Village Scheme

WTP   Water Treatment Plant

Contents

Abstract

Many parts of coastal area of Maharashtra face severe drinking water shortage in spite of high rainfall lying typically in the range of 2000mm-3000mm. Thane district alone has more than 160 tanker fed villages, majority of which are concentrated in Jawhar, Mokhada and Shahapur talukas which are dominated by tribal population. Ironically, this area has the distinction of being the major supplier of drinking water to city of Mumbai through reservoirs like Upper, Lower and Middle Vaitarna and Bhatsa. The Middle Vaitarna project, the latest among them undertaken by Municipal Corporation of Greater Mumbai (MCGM) is expected to augment drinking water supply of Mumbai city by 455MLD at a cost of about Rs. 2700 crores.

The source of Karegaon scheme, a piped water scheme based on water supply from Vaitarna River will be submerged due to the above project. It is learnt from local Water Supply department officials that MCGM has assured to finance the new Karegaon scheme. However, the scope of the new scheme under design in terms of coverage has been left unchanged. There is a cluster of tanker fed villages north of Karegaon (Palsunde to Kiniste) and another one south of Karegaon extending from Vihigaon to Kothare. Earlier studies have indicated that it would be possible to solve the water scarcity problem of the cluster of tanker fed villages at a tiny fraction of cost (~ 1%) of Middle Vaitarna project by appropriately designing a multi village scheme based on Upper Vaitarna as source.

The present study was undertaken to evaluate techno economic feasibility of a multi-village scheme for supplying water to the north cluster of tanker fed villages based on Upper Vaitarna as source of water. The average elevation of the 13 tanker fed villages in this area is 363m. Preliminary simulation studies had indicated that a multi-village scheme based on Middle Vaitarna as source is not feasible due to the large elevation difference between the source located at elevation of 285m and the villages in the cluster. The much higher elevation of Upper Vaitarna (603m) on the other hand, could offer a critical advantage to the proposed scheme by leveraging gravity flow of water thereby reducing both capital cost of piping as well as energy cost for pumping. A step by step design methodology based on protocols followed by MJP was followed for the design and cost estimation of the proposed scheme. The study revealed that the per capita cost of supplying water to the cluster of 13 tanker fed villages having current population of 13000 and ultimate design population of 58000 works out to be Rs. 1331, much below the current rural norm of Rs. 2330. Also, the annual O&M cost including energy cost works out to be Rs. 5.5 per 1000L of water. Thus, by shifting the source from Middle Vaitarna to Upper Vaitarna, it is possible to drastically bring down the cost thereby providing a permanent solution to the water scarcity problem of the 13 tanker fed villages in North Mokhada. The inclusion of four villages covered by Karegaon scheme in the proposed multi village scheme further brings down the per capita cost to Rs. 1293. Hence, revamping the scope of current Karegaon scheme by including the cluster of 13 tanker fed villages in North Mokhada and shifting the source to Upper Vaitarna deserves a serious high level consideration. Furthermore, adopting 'inclusion' model, it should be possible to solve the water scarcity problem in similar areas well within the current norms of capital cost. It will not only help do away with recurring cost of supplying water by tankers but also remove the perpetual dependency of large number of rural population on tanker supplied water at subsistence level.

Keywords

Piped water supply, rural water supply, multi village scheme, piped network design, drinking water, domestic water, Karegaon, Mokhada, Upper Vaitarna, Maharashtra

1. Introduction

1.1 Background:

The Middle Vaitarna project undertaken by MCGM to augment water supply to Mumbai by 455 MLD by building a dam on Vaitarna River in Mokhada taluka of Thane district was recently commissioned. Karegaon Rural Water Supply Scheme in the vicinity of the project is being revamped because of submergence of its assets due to Middle Vaitarna project. The neighbouring villages facing severe water scarcity problem are upset over the fact that they were not included in the scope of redesigned scheme. There is a cluster of about 13 villages to north of Karegaon that have been dependent on tanker supplied water. In most instances single village water supply scheme fail rural per capita norms of Rs. 2330 due to high elevation(350 m and higher) of most of these villages. According to the villagers, they do not object to their water being taken away as long as their need of drinking water is addressed as part of the project. In this background, the present study was undertaken.

Given this background, it was thought worthwhile to assess the feasibility of a multi village scheme based on Upper Vaitarna as source for solving the water scarcity problem of the cluster of tanker fed villages to the north of Karegaon in Mokhada Taluka. Further, it was worth looking into the feasibility of the scheme by including the four villages covered by the Karegaon.

1.2 Objectives and Scope:

- The objective of the study was evaluation of techno economic feasibility of a multi village water supply scheme (MVS) to supply drinking water to the cluster of tanker fed villages in the neighbourhood of Karegaon scheme in Mokhada Taluka. A step by process following guidelines and protocols used by MJP in their design process will be used for this purpose.

- The study also covered the feasibility of the scheme by including all the four villages covered by the current Karegaon Scheme in the above scope.

- This will be a stepping stone for the long term objective of standardization of the design process that can be universally applied to any multi village scheme by incorporating best practices from time to time.

1.3 Approach and methodology:

Based on the objective and the scope outlined above, the following approach and methodology was adopted.

- Identify all major cost components involved in capital cost estimation of a multi village scheme based on the current MJP protocol.

- Locate all the tanker fed villages in the cluster on the map of Mokhada Taluka along with road network connecting them in the target area and mark them on Google Earth.

- Determine alternate configurations for MBR, ESRs and the entire primary and secondary piping network. Follow the below step for all configurations and choose the most optimal one. "Optimal" may depend on different criteria like cost, level of service provided etc.

- Follow a step by step high level design process and a standard cost estimation method wherever applicable for individual design components/assets of the scheme based on schedule of rates published by MJP after applying appropriate inflation factors as appropriate. Then compute per capita capital cost of the scheme by dividing the total cost by the ultimate design population to compare it with the prevalent rural norms.

2. Design Methodology and Design Parameters

2.1 The Cost Components of the Scheme

The layout of a typical multi village scheme is depicted in Fig below.
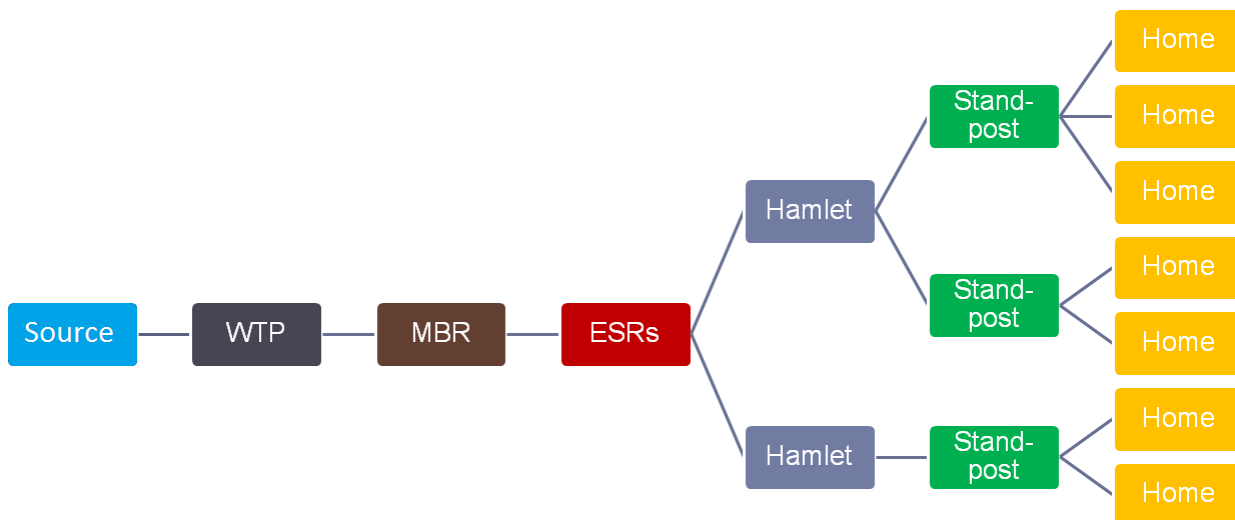
Figure : Layout of a typical Rural Piped Water Scheme

Water is pumped from the source to the water treatment plant (WTP). From the WTP it is then pumped to the mass balancing reservoir (MBR). Then we have the primary network where the water is distributed from the MBR to several ESRs. Then comes the secondary network where the water goes from the ESRs to the individual hamlets. Finally we have the tertiary network where water goes from the hamlets to individual stand posts/homes. In our study we restrict ourselves to the primary/secondary networks.

The major cost components of the scheme are displayed in the table below

Sr. No.	Description of Component
1	Working Survey
2	Jack Well
3	Approach Bridge
4	Raw Water Pumping Machinery
5	Raw Water Rising Main
6	Water Treatment Plant(WTP)
7	Pure Water Pumping Machinery
8	Pure Water Rising Main
9	Mass Balance Reservoir(MBR)
10	ESRs
11	Primary Distribution Network
12	Secondary Distribution Network
13	Miscellaneous (including Land Acquisition, Approach Roads, Compound Wall and Trial Run)

2.2 Scheme Design Parameters and Cost Estimation:

The design protocol along with standards and specifications followed by MJP was used as a guideline for the sizing of the scheme components. Then Schedule of rates published by MJP was applied for estimating cost of individual scheme components.
The MJP design protocol involves the following steps.

1	Principal Features : existing source and proposed source, specs of various machines, wells, mains, reservoirs, etc.
2	Population Forecast : Rate of growth, migration (floating population), current and expected, calculations
3	Daily Demand (zone wise): LPCD norm=> Gross demand = population*rate of demand + losses + other effects.
4	Design of pump machine for raw water: rate of pumping, heads, hours of pumping, description of pumps.
5	Size of proposed R/Main from source
6	Capacity of WTP
7	Design of pump machine for pure water: rate of pumping, heads, hours of pumping, description of pumps.
8	Size of pure water rising Main (tables)
9	Details of MBR (calculations)
10	Statement showing Gravity Main : A software analysis - Branched Water Distribution Design Programme (BWDDP Version 3.0)
11	Capacity of ESR located in each zone : calculation according to respective daily demands
12	Hydraulic Statement (zone wise) : BWDDP calculation
13	Annual Estimate and Other Charges: Establishment, Electricity, Materials, Raw water, etc.
14	Annual M & R Charges : Pumping + Supply + Survey + …

2.3 Identification of Source:

- The proposed source along with specifications of wells (Jackwell), intake channel, inlet pipe, reservoir FSL (Full Service Level) and LDL (Lowest Draw Level)

2.4 Daily Demand Calculation

- Population Forecast: Assuming 30 years life of the scheme population forecasting is done by incremental method as well as geometrical method and then average of the two is used in the calculations.

- The current rural norm is 40lpcd as against 200lpcd used for urban piped water supply schemes. The per capita cost of Mumbai city is Rs. 7000 per capita (unadjusted for any inflation since the date of publication). The corresponding rural norm is Rs. 2330/- per capita.

2.5 Water Pumping Machinery, WTP and MBR

- Design of Pump for Raw Water: The raw water pump is designed based on a daily operation of 16 hours. This is usually limited by the realistic no. of hours of assured supply of electricity in rural area. The flow capacity is based on a velocity of 1.25m/s. The total head is computed based on the following formula:
  Total Head = Static Head + Friction Head + Hammer Head

Based on Flow and Head requirement, pump selection is made and then the cost is estimated based on extrapolation in our case.

- Water Treatment Plan: Water Treatment Plant is generally designed for a capacity of total daily demand. This includes the demand calculation along with any losses. The general loss is assumed at 20%for the purpose of coast estimation. The per unit capacity cost is used for estimation of WTP cost.

- Pure Water Rising Main: Here again all the calculations are made on the assumption of 16 hours operation. As in case of raw water main calculation, a velocity of 1.25 m/s is assumed to arrive at pipe diameter. Based on the head requirement a class of pipe is selected. In our case a pressure of 4kg/sq. cm is sufficient due to lower head requirements.

- Mass Balance Reservoir (MBR): The MBR capacity is designed for 2 hours of storage. The cost is estimated based on cost figures available is schedule of rates published by MJP.

2.6 ESRs and Primary Distribution Network

- Gravity Main: Water is distributed to all the ESRs in the network by gravity main. Water will be continuously distributed to ESR by gravity feed. BRANCH calculation is used to ensure that at least 7m head exists in all the distribution points and also at all the points in the network.

- ESR Capacity: ESR is generally designed for 50% of the daily demand serviced by the ESR. A minimum staging height of 10m and max of 18m is used in the calculations. The staging height is increased until an optimum point is reached. The cost of ESR goes up along with increase in staging height but it is compensated by reduction is pipe size due to availability of higher head and corresponding reduction in cost. The total cost passes through a minimum. To be on conservative side, in our calculation, all the cost estimations are done based on the staging height of 10m.

- The cost of ESRs rises sub linearly with increasing capacity. For example a 1 lakh litre capacity ESR costs Rs 13.12 lakhs (at 2011-12 prices) and a 2 lakh litre capacity ESR costs Rs 18.87 lakhs. Therefore to minimize ESR cost the optimum option is to have one big ESR for the entire network. But with additional number of ESRs the piping cost goes down. So let us look at two alternatives for the ESR layout. Note that for both options ESRs are located at a height of 10m and are 5m tall. That is the minimum to maximum level goes from 10 to 15m above the elevation of the ground where the ESR is located. The diameters for the ESRs are sized according to the capacity required.
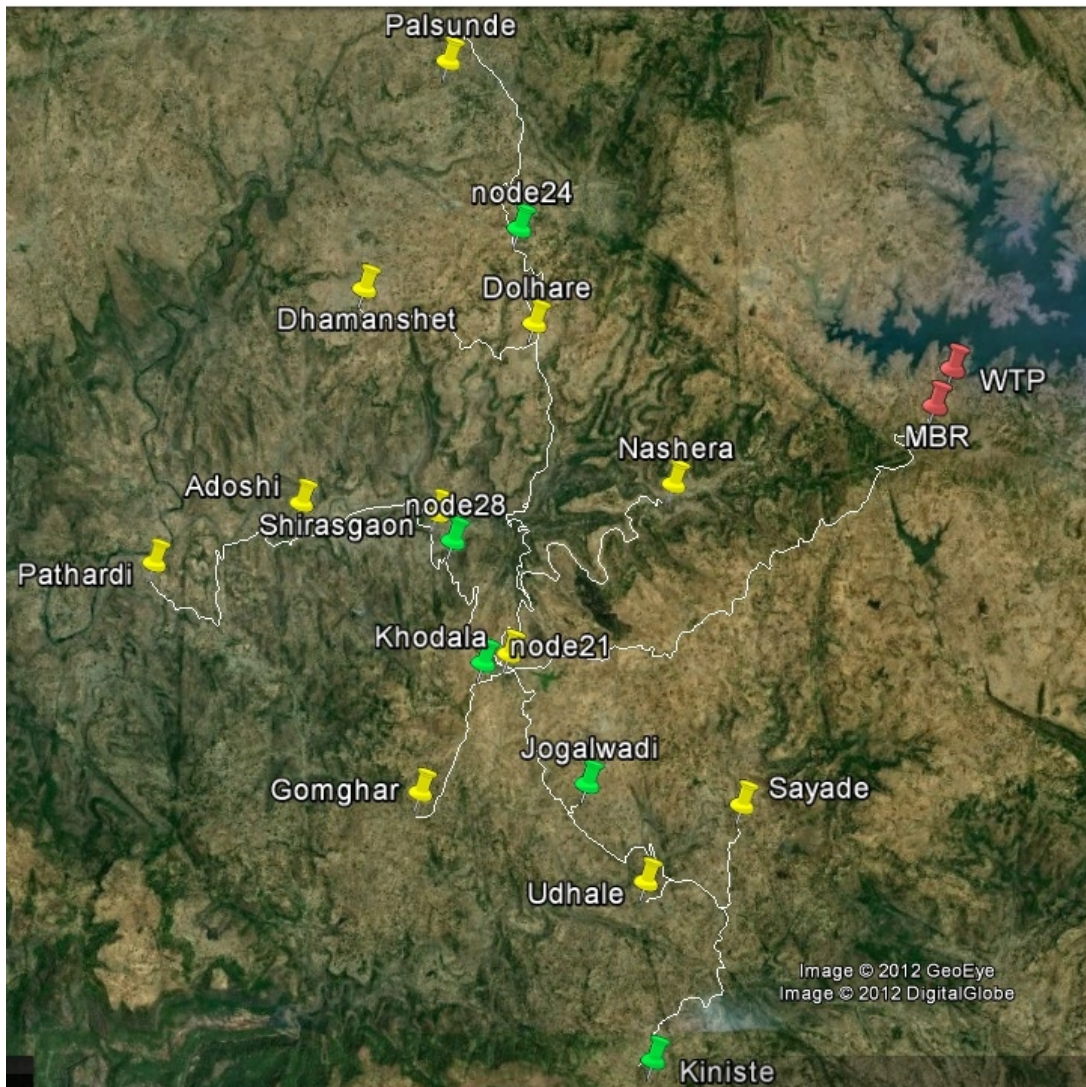
Figure : Option A (ESRs in green)

Option A:

We place the ESRs at central locations such that each ESR serves 2-3 villages each. A total of 5 ESRs are chosen. On simulating in BRANCH and calculating ESR costs from MJP schedule of rates we get the following cost breakup:

Piping (Primary network)	Piping (secondary network)	ESR	Total
1,78,31,176	1,82,65,553	1,11,11,980	4,72,08,708

This corresponds to a per capita cost of Rs 808.

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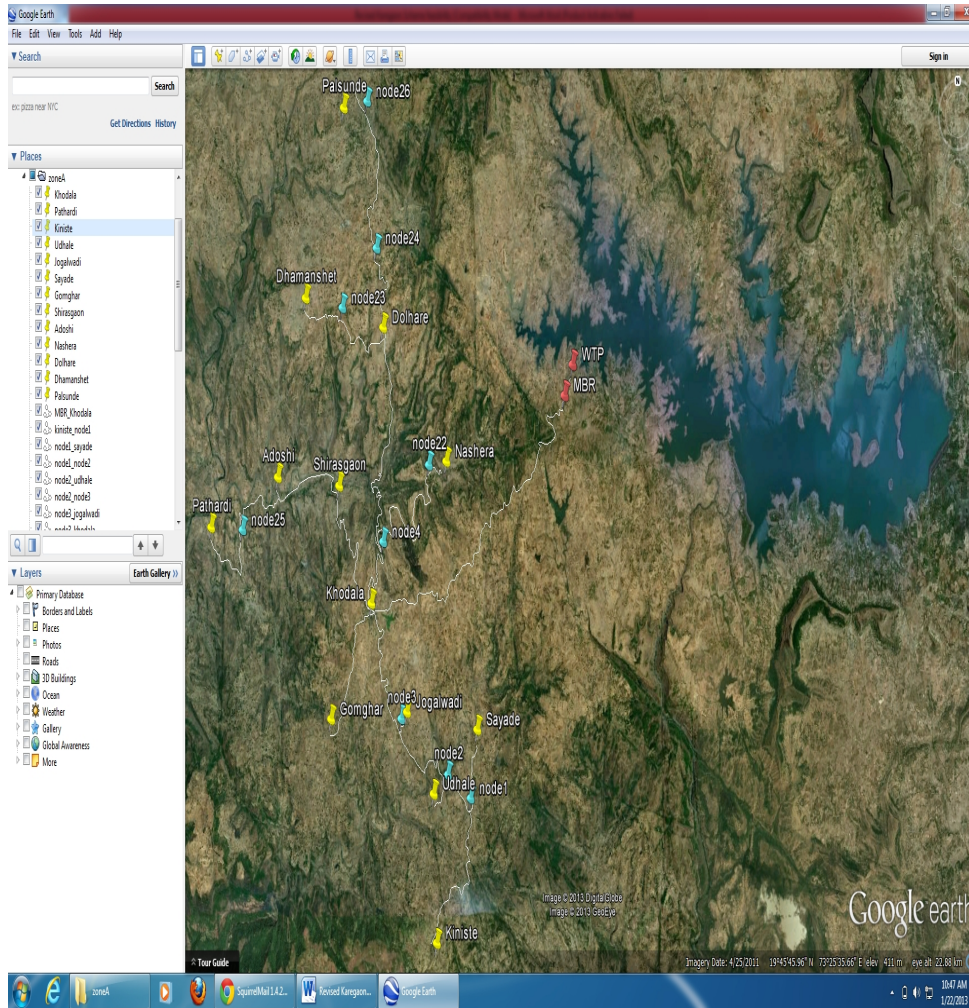
Figure : Option B

Option B:

Here we place an ESR at each village location. For the 13 villages we get 13 ESRs. As there is an ESR at each village there is no secondary network. The cost breakup is as follows:

Piping (Primary network)	Piping (secondary network)	ESR	Total
2,30,36,897	0	1,66,35,614	3,96,72,510

This corresponds to a per capita cost of Rs 679.

Note that in this example the better case turns out to be the one with more number of ESRs. This need not be true in general and for each situation one must look at the alternatives.

Also, here there is scope for further optimization. ESR staging height is chosen as 10m which can be optimized (lower height, lesser the ESR cost and higher the height lower the piping cost for the secondary network). Since there is no secondary network for the option B case, we can get better cost by lowering the ESR heights. As we can see option B gives us significantly better per capita cost. Its cost is 16% less than that of option A's.

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- The choice of ESR location crucially decides the cost of the network. This is because fixing the ESR, fixes the primary and secondary networks. Several ESR configurations must be considered. It is advisable to not have ESRs that serve villages across Gram Panchayats to ease the functioning.

- Important point to note while designing the pipe network is to include dummy nodes at points of highest elevation along paths. This is because water not only has to reach the end point but first it has to cross the highest point along the path.

3. Scheme Description

3.1 Karegaon Scheme:

Since the source of Karegaon scheme is submerged due to Middle Vaitarna Project, Karegaon scheme is being revamped. The coverage area of the old scheme includes villages Karegaon, Kaduchivadi, Kochale and an Ashramshala (a residential school for children belonging to tribals) as shown in Fig 2 below.
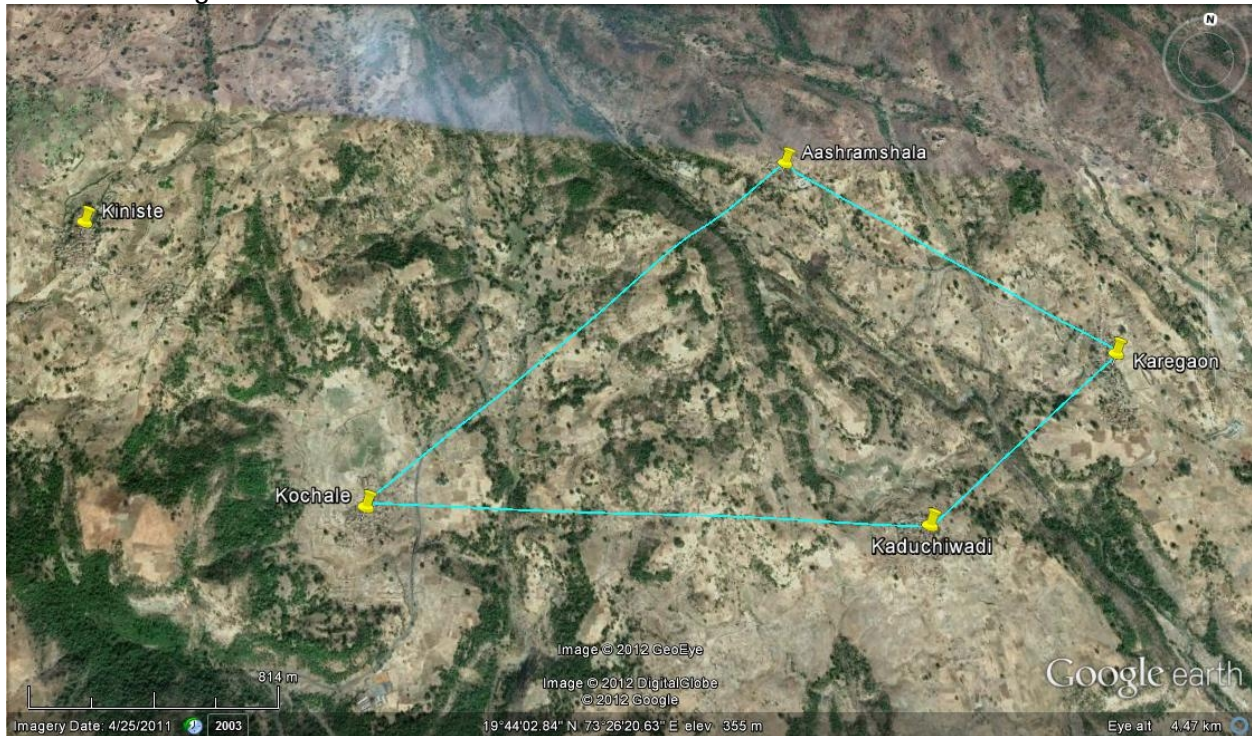
Figure : Karegaon Scheme Scope

There is a cluster of tanker fed villages in Mokhada taluka to the north of Karegaon extending from Palsunde to Kiniste as shown in Fig 3 below.
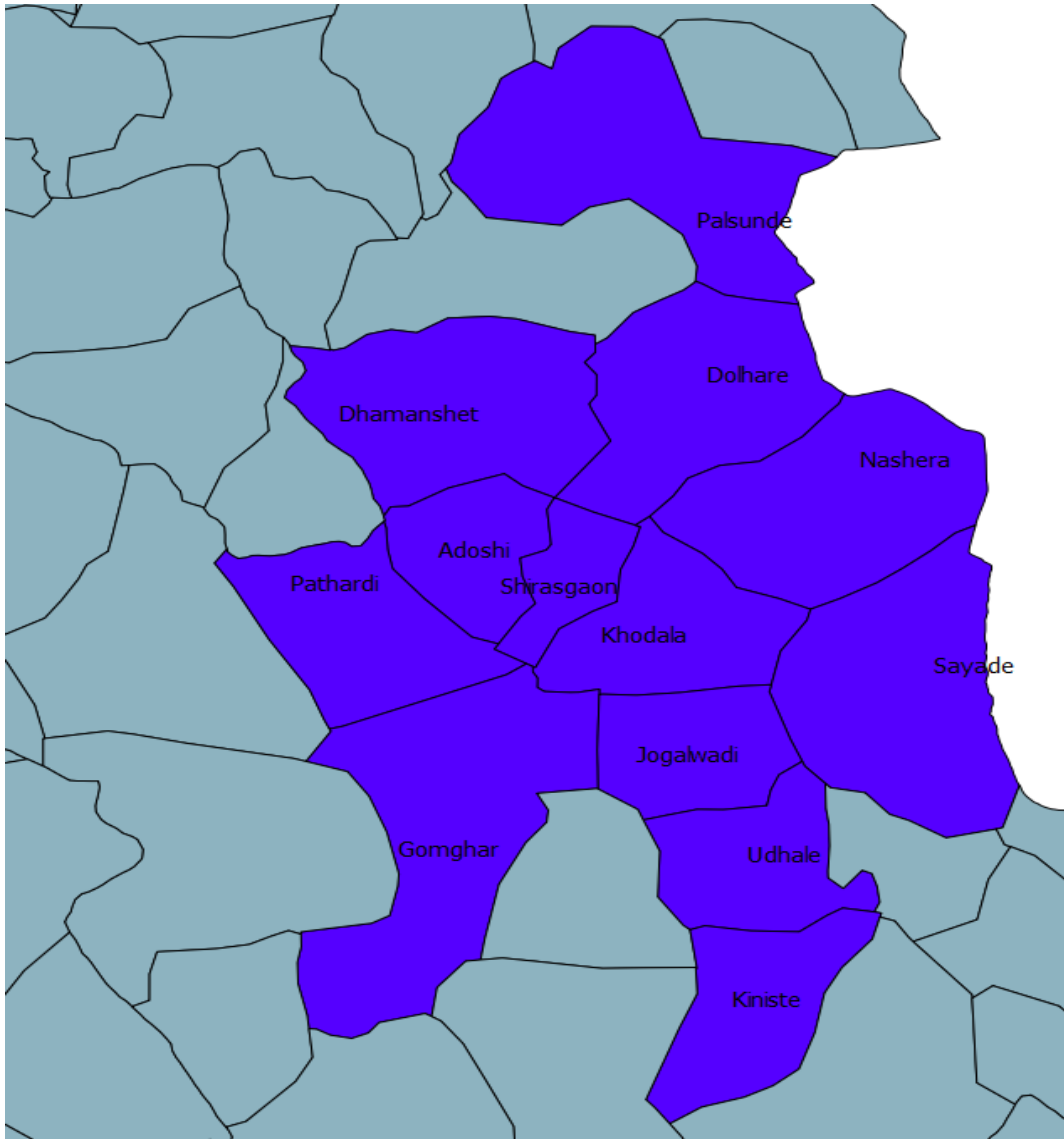
Figure : Cluster of tanker fed villages

However, the scope of revamped Karegaon scheme has not been expanded to include any of the villages including Kiniste which has long been demanding extending the scheme to them due to its proximity to Kochale. At this juncture many other villages also have been demanding that they should be included in the new scheme.

3.2 Problem Revisited
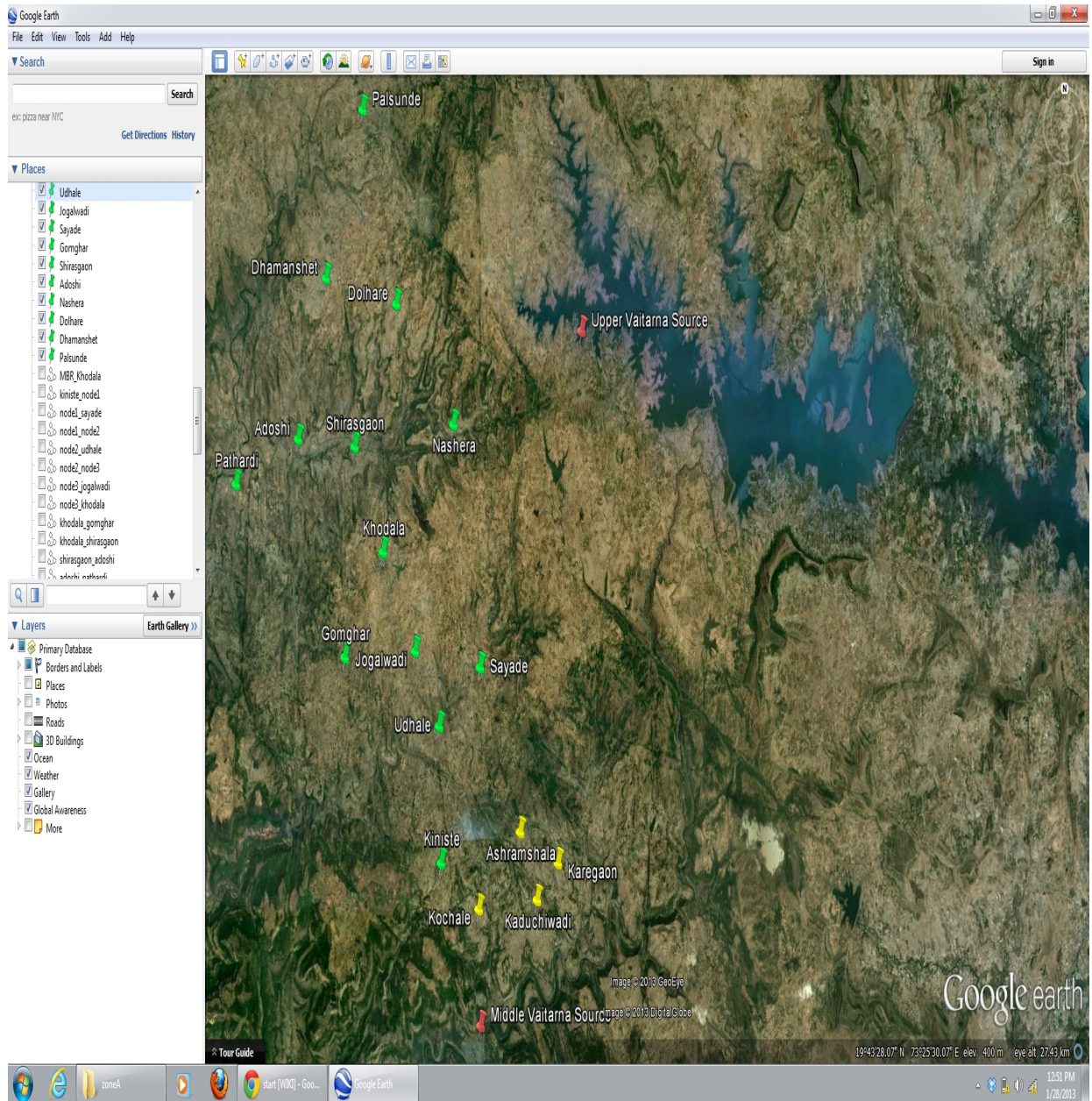
Figure : Alternative Sources (in red), Tanker Fed Villages (in green)
and Karegaon Scheme Villages (in yellow)

There were two alternative sources under consideration to solve the drinking water problem of the tanker fed villages in the vicinity of Karegaon scheme. One was to consider Middle Vaitarna reservoir as source as per current assumption of Karegaon scheme. The other alternative was to consider Upper Vaitarna reservoir as source. The FSL level of middle Vaitarna is 285 m while the same for Upper Vaitarna is 603 meters. Hence the latter offers considerable advantage over the former due to its high elevation in terms of savings not only in capital cost but also in energy costs. Earlier studies indicated that the scheme based on Middle Vaitarna as source is not feasible. Hence, the focus of current studies was maintained on Upper Vaitarna as source.

Another important question is that of choosing the scope of the scheme. Should we design a separate scheme for only the tanker fed villages? Or do we design a consolidated scheme that

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includes the tanker fed villages as well as the villages that are part of the existing Karegaon scheme. While we focus on the latter, the cost estimates for the former scheme were also worked out (the details for which are included in the appendix). The focus on latter would show impact of including the villages under Karegaon on the feasibility of the scheme. It will also provide a new direction for solving the water scarcity problem for a large number of villages by entirely revamping the Karegaon scheme based on Upper Vaitarna as source.

3.3 The Proposed Scheme

A Jack well will be constructed on the basin of Upper Vaitarna reservoir as the source of the proposed scheme. Water will be pumped from this well to Water Treatment Plant (WTP) located at about half a km from the source. After the treatment, water will be pumped to Mass Balance Reservoir (MBR) located at a distance of about 600m and at an elevation of 640m from where it will be distributed by gravity to ESRs located at different places in the network supplying water to 17 villages described below. Choosing Upper Vaitarna has a source now allows us to have a consolidated scheme in the area. Prior reason for not including Kiniste and northern villages was that due to their elevations they could not be served by the Karegaon scheme which drew its water from Middle Vaitarna.

4. Design Details:

4.1 Identification of Source:

Two possible source locations were considered. One lying in middle Vaitarna and another in upper Vaitarna. Preliminary analysis suggested the latter to be a better source. This is because several villages are at higher elevations than the former source (which is at 285m elevation). Since the scheme is designed as a gravity-fed one, significant pumping is required at source. Therefore we choose the source from upper Vaitarna which has a lowest draw level of 595m.

4.2 Population Forecast and Daily Demand Calculation:

Population for year 2001 was got from census data. Population for the year 2011 was consolidated from three different sources. Using this data, projections for the year 2041 were made using the incremental and geometric methods. Where population decreased in the decade 2001-2011, geometric estimates give very low values. To be on the more conservative side we have instead assumed a decadal growth rate of 42% instead (which is the average growth rate for the villages that showed population increase in the 2001-2011 decade).

Incremental method:

Projected population = Current population + decadal growth * (no. of years/10)

Geometrical method:

Projected population = Current population * (1 + decadal growth rate) $^{(no.\ of\ years/10)}$

To get our projection we then take the average of the two methods. This gives us a projected population of 71302 for the year 2041.

Drinking water demand was estimated from population at 40 lpcd (litres per capita per day). This gives a total demand of 28,52,080 litres per day for the 13 villages. A further 20% loss factor was added to the demand for simulations and optimizations. This gives us a total demand of about 3.4 MLD.

Node No	Village Name	Population (2001)	Population (2041 est.)	Demand(litres per day)	Elevation (m)
6	Kiniste	939	4342	1,73,680	460
7	Udhale	1064	2939	1,17,560	422
8	Jogalwadi	812	3301	1,32,040	426
9	Khodala	2805	10813	4,32,520	434
10	Sayade	1770	3594	1,43,760	420
11	Gomghar	1228	1663	66,520	419
12	Shirasgaon	526	2139	85,560	243
13	Dolhare	1141	2160	86,400	380
14	Nashera	733	7733	3,09,320	354
15	Adoshi	923	1114	44,560	202
16	Dhamanshet	1241	5046	2,01,840	384
17	Palsunde	1365	5550	2,22,000	393
19	Pathardi	661	8007	3,20,280	192
33	Kochale	609	2476	99040	345
34	Ashramshala	750	3049	121960	350
35	Karegaon	1196	4863	194520	350
36	Kaduchiwadi	618	2513	100520	350
	Total	15,208	58,401	28,52,080	

Table : Village Details

4.3 ESRs and Primary Distribution Network

We now have our network of villages and the daily water demand for each village. We now need to decide where we want our ESRs. As discussed in section 2.6 we look at different configurations for ESRs and do the ESR+Piping costing for each. In our situation the better alternative is to have an ESR placed at each location. Once we have our ESRs, we run the network in the software BRANCH which gives us the optimal pipe diameters that need to be laid out to satisfy the demand at each location. Using the schedule of rates from MJP (Maharashtra Jeevan Pradhikaran) we can then estimate the cost of building the ESRs as well as the cost of

piping. In branch we assume that the primary network is pumped for 16 hours a day and the secondary network is pumped for 6 hours a day.

The details for the cost of the piped network and the ESRs are as below:

Sr. No.	From Node	To Node	Peak Flow (lps)	Diam (mm)	Headloss (m)	HL/km (m)	Length (m)	Cost (1000 Rs)
1	MBR	Khodala	59.37	225	86.87	8.77	9911	12041.87
2	Khodala	3	22.54	160	24.06	7.69	3130	1993.81
3	3	2	19.79	140	20.78	11.58	1795	879.53
				160	4.82	6.05	797	507.72
4	2	Udhale	2.45	63	6.84	11.85	577	56.55
5	2	1	17.34	140	8.61	9.06	950	465.5
6	3	Jogalwadi	2.75	63	4.17	14.68	284	27.83
7	Khodala	21	1.38	63	2.57	4.11	626	61.35
8	21	Gomghar	1.38	63	9.96	4.1	2430	238.14
9	Khodala	Shirasgaon	9.38	110	35.27	9.41	3747	1082.88
10	Shirasgaon	Adoshi	7.6	90	45.34	16.95	2675	524.3
11	Adoshi	25	6.67	90	33.28	13.31	2500	490
12	25	Pathardi	6.67	90	26.62	13.31	2000	392
13	Khodala	4	17.06	125	12.19	15.28	798	312.78
				140	12.17	8.8	1383	677.72
14	4	22	6.44	90	58.64	12.48	4700	921.2
15	22	Nashera	6.44	90	9.83	12.47	788	154.45
16	4	Dolhare	10.62	110	65.95	11.84	5568	1609.15
17	Dolhare	23	4.2	75	27.63	13.75	2010	293.46
18	23	Dhamanshet	4.2	75	19.98	13.75	1453	212.14
19	Dolhare	24	4.62	90	13.5	6.75	2000	392
20	24	26	4.62	90	21.33	6.75	3160	619.36
21	26	Palsunde	4.62	75	13.84	16.39	844.2	123.25
				90	4.16	6.76	615.8	120.7
22	1	Sayade	2.99	63	23.84	17.14	1391	136.32
23	1	29	14.35	140	7.09	6.39	1110	543.9
24	29	30	5.67	110	2.23	3.72	600	173.4
25	30	Kiniste	3.61	90	8.55	4.28	2000	392
26	30	32	2.06	63	18.07	8.6	2100	205.8
27	32	Kochale	2.06	63	2.15	8.6	250	24.5
28	29	31	8.68	90	43.34	21.67	2000	392
29	31	Ashramshala	2.54	63	5.07	12.68	400	39.2

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30	31	Karegaon	4.05	75	25.71	12.85	2000	292
31	31	Kaduchiwadi	2.09	63	15.91	8.84	1800	176.4
						Total	68393	26573.19

Table : Pipe Network Details

Node No	Village Name	Population (2041 est.)	Demand(litres per day)	Elevation (m)	ESR Staging Height (m)	ESR Capacity (l)	Cost of ESR (Rs)
6	Kiniste	4342	1,73,680	460	470	79000	1346730
7	Udhale	2939	1,17,560	422	432	53000	1080882
8	Jogalwadi	3301	1,32,040	426	436	60000	1154340
9	Khodala	10813	4,32,520	434	444	195000	2183335
10	Sayade	3594	1,43,760	420	430	65000	1206810
11	Gomghar	1663	66,520	419	429	30000	722920
12	Shirasgaon	2139	85,560	243	253	39000	869836
13	Dolhare	2160	86,400	380	390	39000	869836
14	Nashera	7733	3,09,320	354	364	140000	1821875
15	Adoshi	1114	44,560	202	212	21000	538692
16	Dhamanshet	5046	2,01,840	384	394	91000	1451670
17	Palsunde	5550	2,22,000	393	403	100000	1530375
19	Pathardi	8007	3,20,280	192	202	145000	1858313
33	Kochale	2476	99,040	345	355	45000	967780
34	Ashramshala	3049	1,21,960	350	360	55000	1101870
35	Karegaon	4863	1,94,520	350	360	88000	1425435
36	Kaduchiwadi	2513	1,00,520	350	360	46000	984104
	Total	71,302	28,52,080				21114803

Table 3: ESR Details

4.4 Verification of Network using EPANET
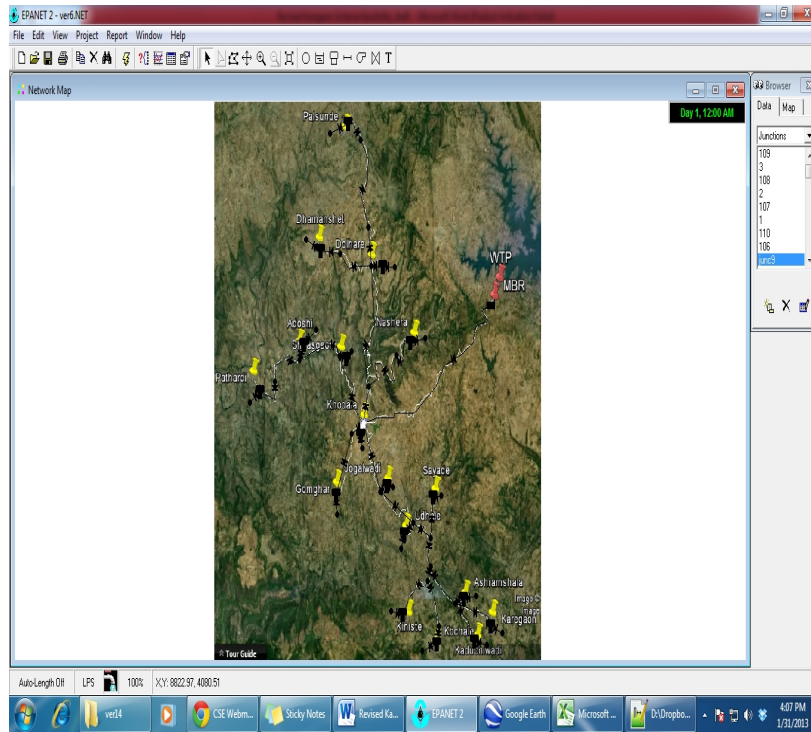
Figure : EPANET model

The network design was verified by using EPANET (www.epa.gov/nrmrl/wswrd/dw/epanet.html). EPANET is a software tool that models the flow of water in pressurized piped networks. After completing the sizing and locations of the pipes and ESRs we construct 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.

The model runs successfully and all the ESRs fill up in time to meet demand at the villages. Fill up time for the ESRs range from an hour for Adoshi up to nine hours for Kiniste. In fact Kiniste owing to its elevation does not start filling up till the third hour due to its high elevation. Only once the other villages in the area start to get filled up does the ESR at Kiniste starts filling up.

Figure : ESR heads

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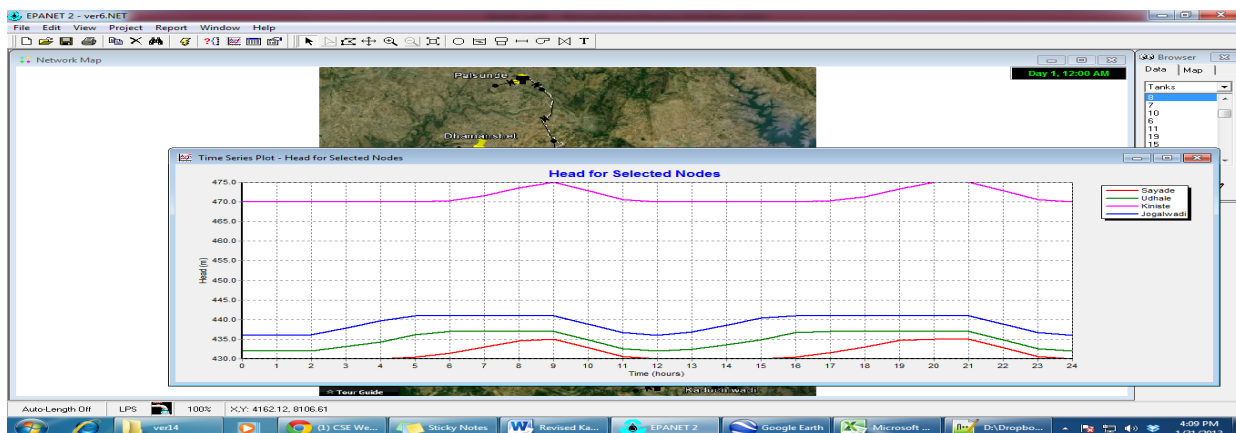
Note that demand occurs at hours 9-12 and 21-24. Since the demand starts only at hour 9 and all ESRs are filled by hour 9, demand is met at all points.

4.5 MBR and WTP

The costing for the WTP has been done by comparing it with the costing done in Khardi Scheme. A WTP for 1 MLD cost Rs 26 lakhs in the Khardi Scheme. For us the daily demand is 3.4 MLD. Accordingly we priced our WTP at 26 * 3.4 *1.1 = Rs 98 lakhs. The 1.1 factor is to account for an inflation of 10% in prices. The MBR was designed with a capacity of half the daily demand i.e. 1.7 MLD. This gave us a cost of almost Rs 51 lakhs.

4.6 Pumping Machinery and Rising Main

Water has to be pumped at two places: from Source to WTP and from WTP to MBR. The lowest draw level of source is 595m. The elevation of WTP and MBR is 631m and 640m respectively. While pumping to the WTP or MBR a further height of 8m has to be accounted for since that is the assumed height of the infrastructure. The diameter of the rising mains is calculated using the flow of water required and assuming a velocity of 1.5 m/s.
Flow = daily demand/time, therefore flow = 3.4 MLD / 16 hours = ~ 59 lps
Dia = 2*root(flow/pi*vel), therefore dia = 2*root(59 lps/3.14*1.5 m/s) = ~224mm
We round up this value and use a diameter of 250mm.

Raw water rising main: The distance is of 500m and diameter required is 250mm. Due to the high flow we choose D.I. pipe for the rising main. This gives us a cost of ~ Rs 13.3 lakhs for the rising main.
Pure water rising main: The distance is of 650m and the diameter is 250mm as before. We again use D.I. pipe which gives us a cost of ~ Rs 17.3 lakhs.
Pumping machinery: Pump capacity required is calculated using the flow rate of water that needs to be pumped and the head difference. For raw water rising main it is 59 lps and head difference of 50m. Assuming an efficiency of 70% we get a power requirement of ~ 55.5hp which we round up to 60hp. Similarly for the pure water rising main, we have a flow of 59 lps and head difference of 25m which gives us a pump power requirement of 27.7hp which we round up to 30hp. Cost for the two pumps is calculated by comparing it with the cost of a 100hp pump in Khardi scheme which was 22 lakhs. So our 60hp and 30hp pumps cost 13.2 lakhs and 6.6 lakhs respectively.

4.7 Capital Cost Summary:

Sr. No.	Cost Component	Cost (Rs)	Remarks
1	Jack Well	25,00,000	standard dimensions for Jack well

2	WTP	97,81,200	Khardi scheme of 1MLD has WTP cost of 26lakh. Our MLD is 3.4. so we choose 26*3.4
3	Raw water rising main (Length 500m, Dia. 250mm)	13,28,405	Based on schedule of rates 2010-11 and plus 7% increase for 2011-12 cost
4	Pure water rising main (Length 650m, Dia. 250mm)	17,26,927	
5	MBR	51,28,059	
6	Cost of raw water pump (60HP)	13,20,000	Based on cost of 100HP pump used for Khardi Scheme
7	Cost of pure water pump (30HP)	6,60,000	
8	Excavation	2,05,17,900	From schedule of rates avg cost is around 300 Rs/m^3. Assuming a volume of 1 x 1 x length of piping. Total pipe network is ~ 68.4 kms
9	Piping	2,84,33,313	
10	ESRs	2,11,14,803	
11	Total Cost	9,25,10,607	
12	Cost per capita	1297	Design population of ~ 71,000

Table : Capital Cost Details

4.8 Operating and Maintenance Cost:

a.   Energy Costs :
Cost per kWh = 6.5 Rs
Per day consumption of 60hp pump = 60 x 16 = 960 hph = 715.9 kWh
Cost per day of operating 60hp pump = 715.9 x 6.5 = Rs 4653
Per day consumption of 30hp pump = 30 x 16 = 480 hph = 358 kWh
Cost per day of operating 25hp pump = 358 x 6.5 = Rs 2327
Total Energy Cost = Rs 6980 per day

b.   Cost of Operators :
Cost per Operator per day = Rs 400
Operators for ESRs = 17 x 1 = 17
Operators for WTP and MBR = 4
Cost for Operators per day = 400 x 21 = Rs 8400

c.   Cost of Chemicals :

Cost of alum = Rs 5500 per ton
Alum required per ML = 7 kg
Total Alum required per day = 3.4 * 7 = 23.8 kg
Total Cost of alum per day = 23.8/1000 * 5500 = Rs 131

Cost of TCL = Rs 15000 per ton
TCL required per ML = 4 kg
Total TCL required per day = 3.4 * 4 = 13.6 kg
Total Cost of TCL per day = 13.6/1000 * 15000 = Rs 204
Sundry Costs per month = Rs 3000
Sundry Costs per day = 3000/30 = Rs 100
Total chemical costs per day = Rs 435

d.   Cost of Water:
Cost of water per ML = Rs 1000
Cost of water per day = 3.4 x 1000 = Rs 3400

Therefore the total O&M cost per day = 6980 + 8400 + 435 + 3400 = 19215
O&M cost per 1000 L = 19215/3400 = <u>Rs 5.65</u>

Therefore the cost for every 1000 litres of water comes to only Rs 5.64. Another measure of interest could be the per capita cost per annum. This comes to around Rs 100. So for self-sustenance of the operation an annual charge of Rs 100 will have to be charged per person.

5. Conclusion:

Our design for the proposed multi village scheme for supplying piped water to 17 tanker fed villages in North Mokhada from Upper Vaitarna has an estimated capital cost of Rs. 1297 per capita at a demand of 40 lpcd for a design population of 71000. Given the fact that the capital cost of Mumbai city water supply scheme is in the neighborhood of Rs. 7000 while the same for Thane city is Rs. 10,000, it is a foregone conclusion that it is possible to solve the water scarcity problem of the taker fed villages in this area at a fraction of cost of a city water supply scheme. The cost figures indicate that it is well below the current norm for a rural water supply scheme. The advantages offered by high elevation of the source go further 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. 5.65 (Assuming cost of water from reservoir at Rs. 1000 per ML). This again is significantly lower than the O&M cost figures published by World Bank

Report for multi village schemes. (There is a wide variation between 26 to 38 while the economical figure is quoted as Rs. 16 per 1000L)

This should make it clear that it makes sense to shift the source from Middle Vaitarna to Upper Vaitarna and revamp the scheme cover all the 13 tanker fed villages besides the four in the current scope. This has significance given the background that earlier attempts to extend the Karegaon scheme to other villages like Kiniste had failed to satisfy the rural norms of capital cost because of higher elevation villages as compared to the source elevation of 285m.

The extended period simulation studies done using EPANET indicate that the demand for all the villages is fulfilled for designed supply of six hours per day including that of Kiniste, the village having the highest elevation.

Another important aspect is the selection of ESR locations and elevation. Although the feasibility studies pass the current norms, further optimization is possible by using software like BRANCH and EPANET.

6. Appendix:

6.1 EPANET Simulation Graphs:
These are the graphs from EPANET simulations for the all the ESRs. ESRs that show an almost flat line do so because of their low demand and elevations. Therefore the demand is able to get fulfilled as the supply comes in. This suggests that sizing of these ESRs can be substantially reduced. Note that demand occurs in hours 9-12 and 21-24.
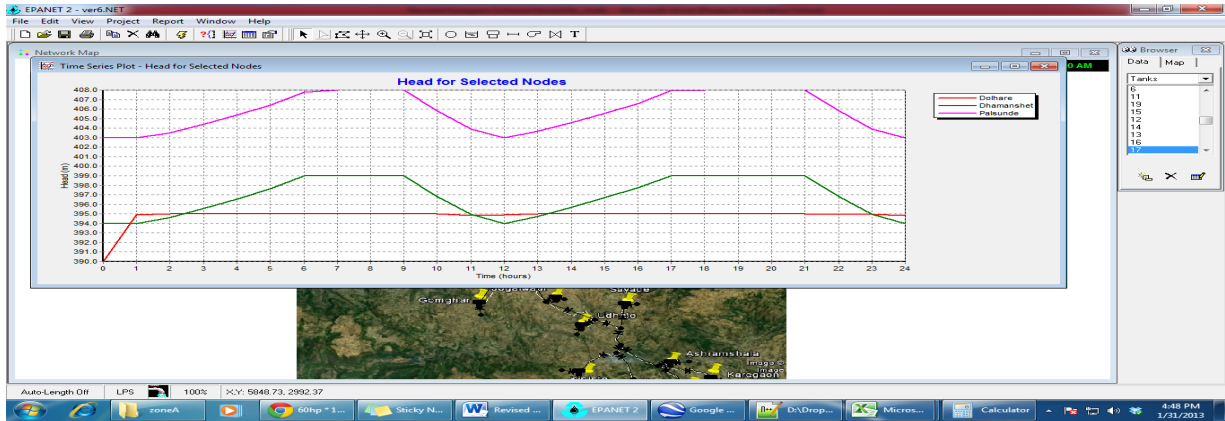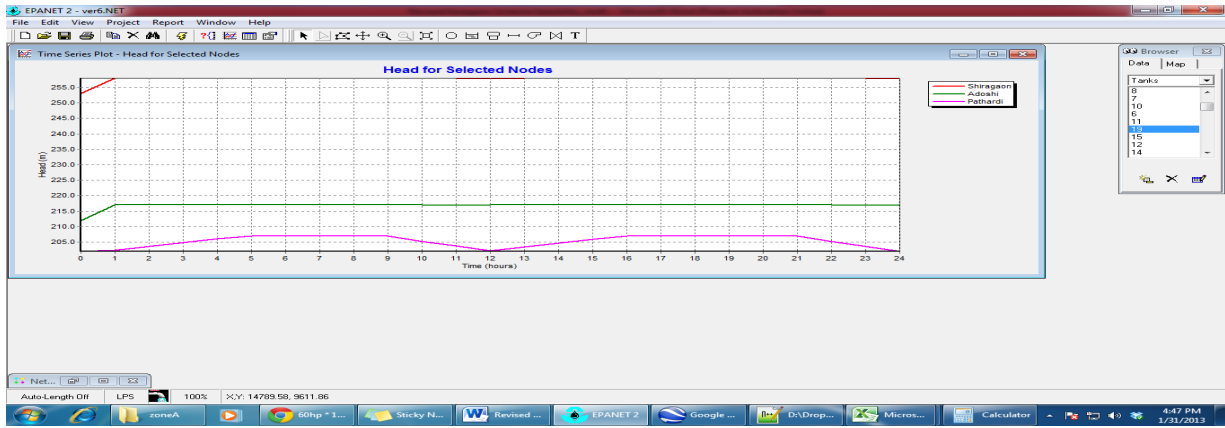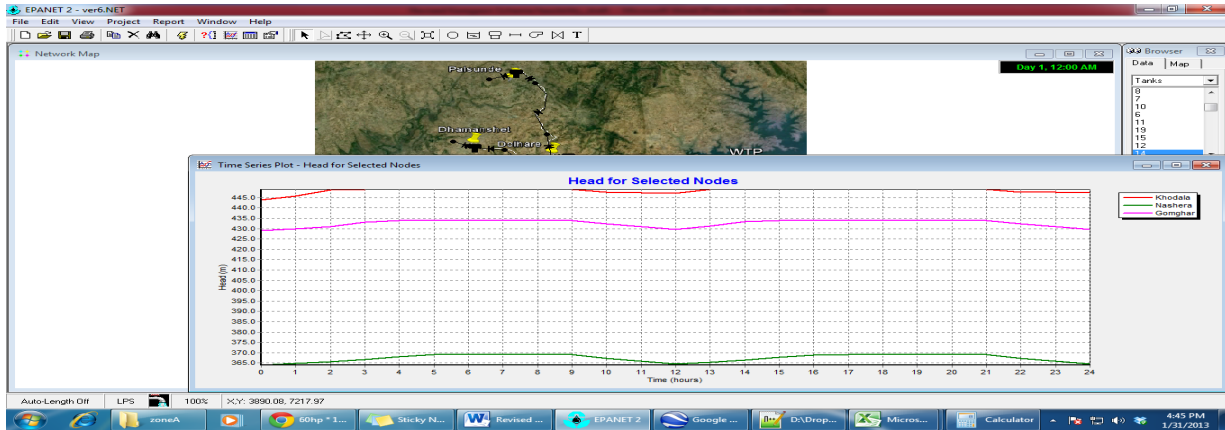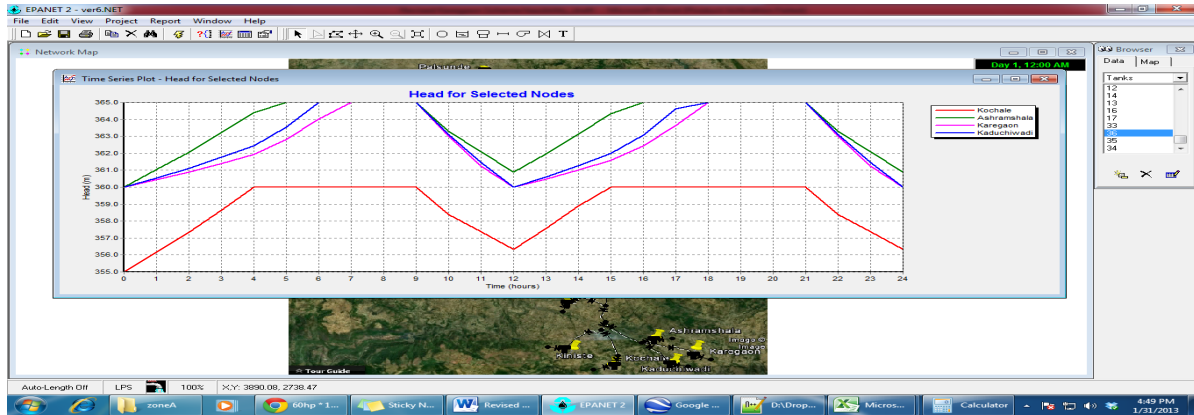
6.2 Details of scheme for only tanker fed villages:

We also looked at the scenario where the two components i.e. the thirteen tanker fed villages and the four villages under Karegaon scheme would be kept separated. We looked at the design for the scheme for just the thirteen villages. This scheme would have a design population of around 58000 people.

a) **Piped Network and ESR cost details**

Sr. No.	From Node	To Node	Peak Flow (lps)	Diam (mm)	Headloss (m)	HL/km (m)	Length (m)	Cost (1000 Rs)
1	MBR	Khodala	48.63	200	106.58	10.75	9911	10032.12
2	Khodala	3	11.8	125	20.91	7.72	2707.89	1135.79
				140	1.88	4.45	422.11	221.31
3	3	2	9.05	125	12.25	4.73	2592	1087.18
4	2	Udhale	2.45	63	6.84	11.85	577	60.51
5	2	Sayade	2.99	63	40.12	17.14	2341	245.48
6	3	Jogalwadi	2.75	63	4.17	14.68	284	29.78
7	Khodala	21	1.38	63	2.57	4.11	626	65.64
8	21	Gomghar	1.38	63	9.96	4.1	2430	254.81
9	Khodala	Shirasgaon	9.38	110	35.27	9.41	3747	1158.68
10	Shirasgaon	Adoshi	7.6	90	45.34	16.95	2675	561.00
11	Adoshi	25	6.67	90	33.28	13.31	2500	524.30
12	25	Pathardi	6.67	90	26.62	13.31	2000	419.44
13	Khodala	4	17.06	140	19.18	8.79	2181	1143.50
14	4	22	6.44	90	58.64	12.48	4700	985.68
15	22	Nashera	6.44	90	9.83	12.47	788	165.26
16	4	Dolhare	10.62	110	34.59	11.85	2919.96	902.94
				125	16.83	6.36	2648.0	1110.69

25

							4	
17	Dolhare	23	4.2	75	27.63	13.75	2010	314.00
18	23	Dhamanshet	4.2	75	19.98	13.75	1453	226.99
19	Dolhare	24	4.62	90	13.5	6.75	2000	419.44
20	24	26	4.62	90	21.33	6.75	3160	662.72
21	26	Palsunde	4.62	75	13.84	16.39	844.2	131.88
				90	4.16	6.76	615.8	129.15
22	2	Kiniste	3.61	90	21.38	4.28	5000	1048.60
						Total	61133	23036.90

Table : Pipe Network Details

Node No	Village Name	Population (2041 est.)	Demand(litres per day)	Elevation (m)	ESR Staging Height (m)	ESR Capacity (l)	Cost of ESR (Rs)
6	Kiniste	4342	1,73,680	460	470	79000	1346730
7	Udhale	2939	1,17,560	422	432	53000	1080882
8	Jogalwadi	3301	1,32,040	426	436	60000	1154340
9	Khodala	10813	4,32,520	434	444	195000	2183335
10	Sayade	3594	1,43,760	420	430	65000	1206810
11	Gomghar	1663	66,520	419	429	30000	722920
12	Shirasgaon	2139	85,560	243	253	39000	869836
13	Dolhare	2160	86,400	380	390	39000	869836
14	Nashera	7733	3,09,320	354	364	140000	1821875
15	Adoshi	1114	44,560	202	212	21000	538692
16	Dhamanshet	5046	2,01,840	384	394	91000	1451670
17	Palsunde	5550	2,22,000	393	403	100000	1530375
19	Pathardi	8007	3,20,280	192	202	145000	1858313
	Total	58,401	23,36,040				16635614

Table 3: ESR Details

b) **EPANET simulation graphs:**
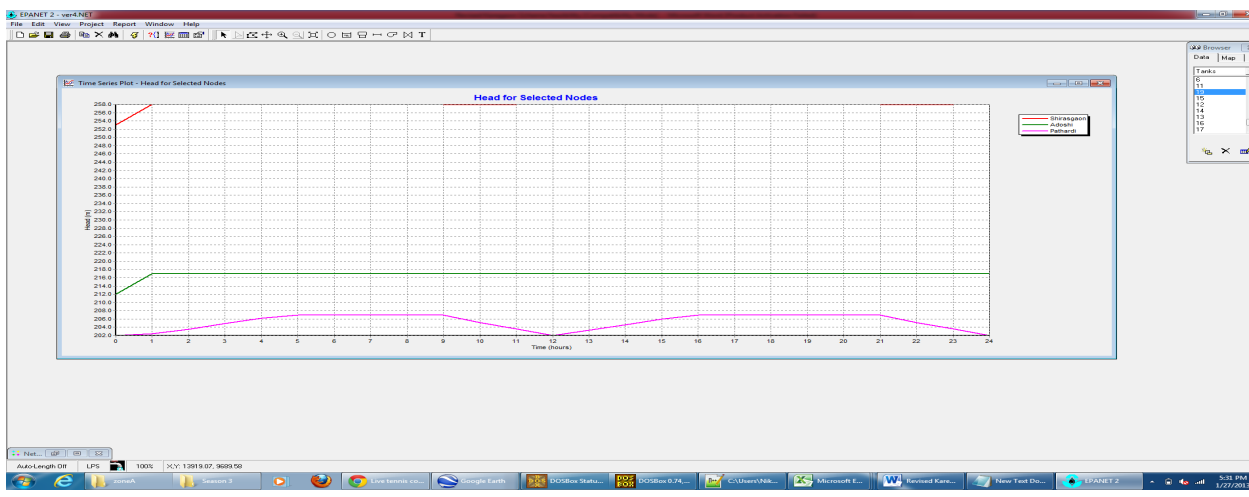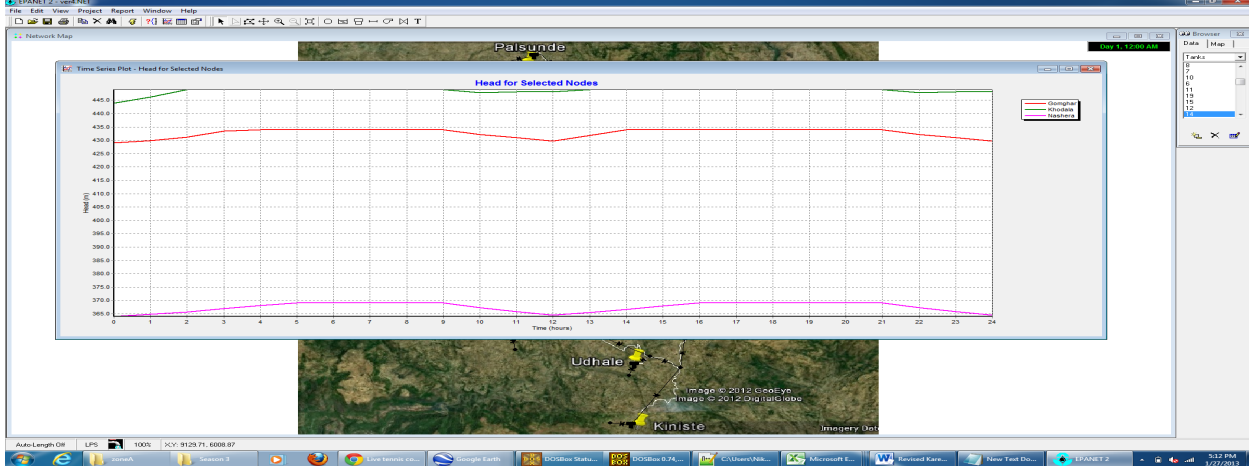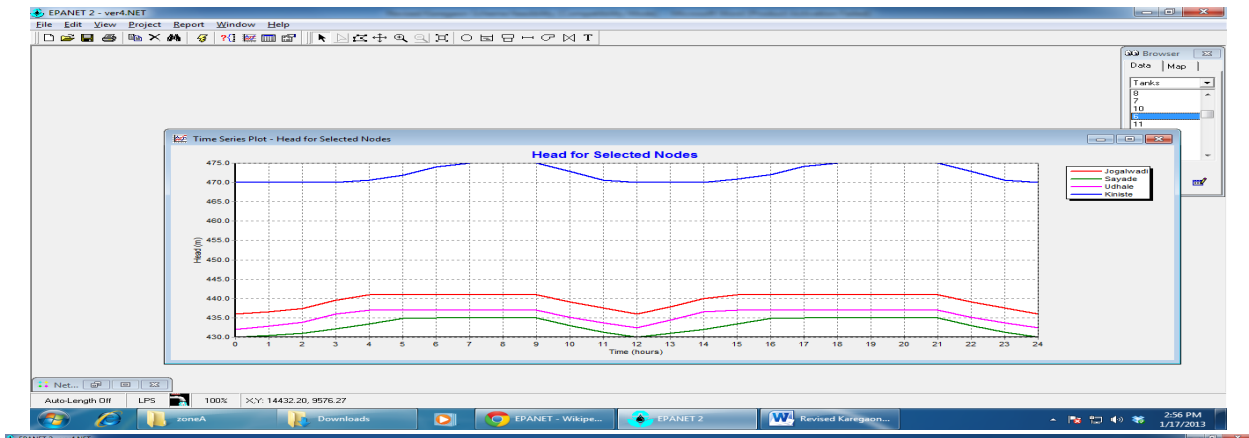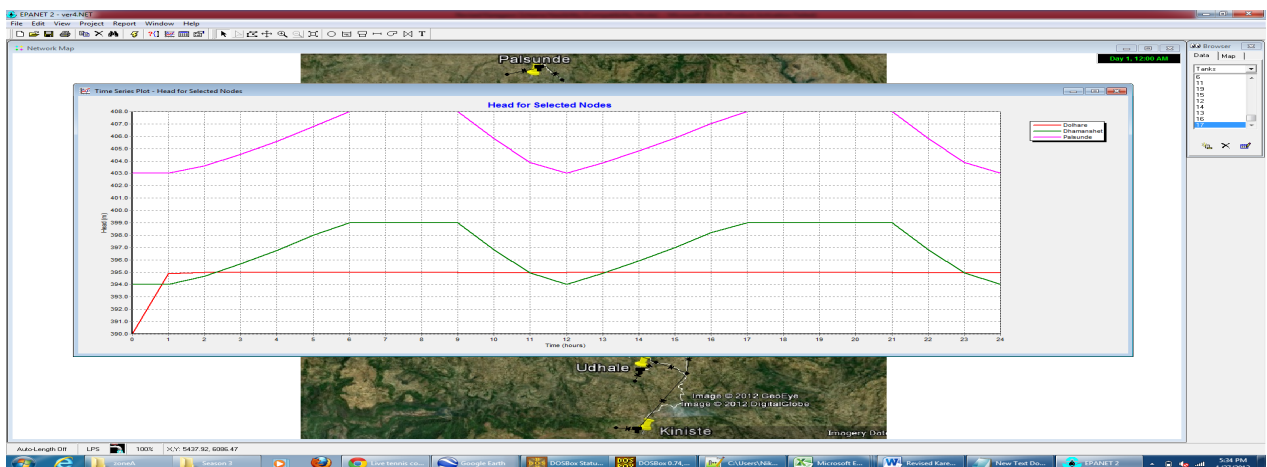
c) **Total Capital Cost**

Sr. No.	Cost Component	Cost (Rs)	Remarks
1	Jack Well	25,00,000	standard dimensions for Jack well
2	WTP	80,08,000	Khardi scheme of 1MLD has WTP cost of 26lakh. Our MLD is 2.8. so we choose 26*2.8
3	Raw water rising main (Length 500m, Dia. 250mm)	13,28,405	Based on schedule of rates 2010-11 and plus 7% increase for 2011-12 cost
4	Pure water rising main (Length 650m,Dia. 250mm)	17,26,927	
5	MBR	47,79,500	
6	Cost of raw water pump (50HP)	11,00,000	Based on cost of 100HP pump used for Khardi Scheme
7	Cost of pure water pump (25HP)	5,50,000	
8	Excavation	1,80,74,700	From schedule of rates avg cost is around 300 Rs/m^3. Assuming a volume of 1 x 1 x length of piping. Total pipe network is ~ 60 kms
9	Piping	2,30,36,897	
10	ESRs	1,66,35,614	
11	Total Cost	7,77,40,042	
12	Cost per capita	1331	Design population of ~ 58,000

d) **Operating and Maintenance Cost**

    a.   Energy Costs :
Cost per kWh = 6.5 Rs
Per day consumption of 50hp pump = 50 x 16 = 800 hph = 596.6 kWh
Cost per day of operating 50hp pump = 596.6 x 6.5 = Rs 3878
Per day consumption of 25hp pump = 25 x 16 = 400 hph = 298.3 kWh
Cost per day of operating 25hp pump = 298.3 x 6.5 = Rs 1939
Total Energy Cost = Rs 5817 per day

    b.   Cost of Operators :
Cost per Operator per day = Rs 400
Operators for ESRs = 13 x 1 = 13
Operators for WTP and MBR = 4
Cost for Operators per day = 400 x 17 = Rs 6800

    c.   Cost of Chemicals :
Cost of alum = Rs 5500 per ton
Alum required per ML = 7 kg
Total Alum required per day = 2.8 * 7 = 19.6 kg
Total Cost of alum per day = 19.6/1000 * 5500 = Rs 108

Cost of TCL = Rs 15000 per ton
TCL required per ML = 4 kg
Total TCL required per day = 2.8 * 4 = 11.2 kg
Total Cost of TCL per day = 11.2/1000 * 15000 = Rs 168
Sundry Costs per month = Rs 3000
Sundry Costs per day = 3000/30 = Rs 100
Total chemical costs per day = Rs 376

    d.   Cost of Water:
Cost of water per ML = Rs 1000
Cost of water per day = 2.8 x 1000 = Rs 2800

Therefore the total O&M cost per day = 5817 + 6800 + 376 + 2800 = 15793
O&M cost per 1000 L = 15793/2800 = <u>Rs 5.64</u>

Therefore the cost for every 1000 litres of water comes to only Rs 5.64. The per capita cost per annum comes to around Rs 100. So for self-sustenance of the operation an annual charge of Rs 100 will have to be charged per person.

6.3 Schedule of Rates (ESR):

This is the schedule of rates provided by the MJP. Note that these rates are for the year 2011-12. For our calculation we have included a 7% rise in prices of pipes and a 10% rise in the prices of ESRs.

XX. RCC ESR

	Designing (aesthetically), and constructing RCC elevated service reservoirs of following capacity with RCC staging consisting of columns, internal and external bracings spaced vertically not more than 4.5 meters center to center for ESR having Capacity upto 500 Cum. and not more than 6 m c/c for ESRs having capacity above 500 cum including excavation in all types of strata, foundation concrete, cement plaster with water proofing compound to the inside face of the container including refilling disposing of the surplus stuff within a lead of 50 meters, all labour and material charges including lowering, laying, erecting, hoisting and jointing of pipe assembly of inlet, outlet, washout, overflow and bypass arrangements as per departmental design, providing and fixing accessories such as M.S. ladder, C. I. manhole frame and covers water level indicatiors, lightening conductor, G. I. pipe railing around walk way and top slab, providing spiral staire case from ground level to roof level, M.S. grill gate of 2 mtr. height with locking arrangement of approved design. B.B. masonry chambers for all valves, ventilating shafts, providing and applying three coats of cement paint to the structure including roof slab epoxy painting to internal surface & anti termite treatment for underground parts of the structure. and giving satisfactory water tightness test as per I.S. code, The job to include painting the name of the scheme and other details on the reservoir as per the directions of Engineer-in-charge.		
	Note :		
1	The design of the structure be in accordance with relevant (I.S. 3370 - 1965 or revised.)		
2	The design shall satisfy the stipulations as per		
	IS 1893 -1984 and I.S. 13920 / 1993 for seismic force and I. S.-11682/1985 for R.C.C. staging of overhead tanks.		
3	For design having more than 6 columns, provision of internal bracing is obligatory. External bracing is also obligatary.		
4	The Entire structure shall be constructed in M300 only.		
5	Plain round mild steel bars grade - I confirming to I.S. 432 part-I or high yield strength deformed bars confirming to I.S. 1786 or I. S. 1139 shall be used, grade-II mild steel bars will not be allowed.		
6	Irrespective of the type of foundation proposed in the		

	design, one set of bracing be provided at the ground level.		
7)	These rates include providing M.S. ladder for E.S.R's up to 2 lakh litres capacity and providing spiral staircase for E.S.R. above 2 lakh litres capacity.		
8)	Stagging shall have to be designed with stresses of M-250 for ESR. However all RCC construction should be done in M-300		
9)	These rates are including the cost of uplift pressure if any and entire dewatering during execution. In case of water logging area where water is struck at shallow depth extra provision of dewatering shall be made as per site condition.		
10)	All conditions given in the Member Secretary's Circular No. MJP / TS-I / 350 / 1668 dt. 2-8-97 and MJP / S-1/350/2127 dt. 13-7-99 shall be strictly followed and additional cost, if any, due to these conditions is included in the rates mentioned below.		
11)	75% part rate shall be payable for reinforcement concrete and plastering items of containers of E.S.R. till satisfactory hydraulic testing for water tightness in given; and till that work shall be treated as incomplete.		
12)	The rates indicated in the table are excluding the cost of pipes, specials and valves required for inlet, outlet, washout, overflow and by-pass arrangement. The scope of work, however and includes cost of erecting, laying and jointing of pipes and valves including cost of jointing materials up to 5 M beyond outer face of outermost column.		
13)	For ESR up to 500 cum capacity C.I. Double flanged pipe up to 300 mm dia shall be provided and C.I. specials shall be used. For ESR above 500 cum capacity C.I. /M.S. pipe assembly with minimum 8 m.m. thick ness up to 500 mm dia. and minimum 10 mm. thickness above 500 mm. dia can be used with proper anti-corrosive epoxy treatment from inside and outside.		
14)	Below mentioned rates are for foundations, with individual footing with bearing capacity of 20 tonnes per square metre. For raft foundations, these rates shall be increased by.7.5% Where safe bearing capacity (SBC) is 5 M.T. per sqm and by 5% where SBC is more than 5 MT/ sqm and upto 10 MT /Sqm. This % of 5% or 7.5 % is applicable for estimation of amount of L.S. item of ESR. For Extra Item due to change from individual foundation to raft, actual increase in concrete and steel be paid as per relevent DSR Item.		

Sr. No.		Unit	
15	The rate shall be increased by 30% for bearing piles upto depth of 10 m & for further increased in depth by 5 M each, it shall be increased by another 10%. These rates are applicable where raft is not feasible for pile foundations sulphate resistant cement shall only be used. Single pile for the column is not permitted Group of piles shall be designed with pile cap for each column of ESR.		
16	The rates are applicable for staging height of 12 M. These rates shall be increased or decreased for per metre variation in this staging height as below.		
	12 to 16 M staging - 2% per metre		
	16 to 20 M staging - 3% per metre		
	20 M and above - 4% per metre		
	For 17 M Staging height percentage calculation will be like below.		
	12 to 16 M --- 4 X 2 = 8 %		
	16 X 17 M --- 1 X 3 = 3 %		
	Total = 11 %		
	For 21 M Staging height percentage calculation will be like below.		
	12 to 16 M --- 4 X 2 = 8 %		
	16 X 20 M --- 4 X 3 = 12 %		
	20 X 21 M --- 1 X 4 = 4 %		
	Total = 24 %		
17	Following rates are for seismic zone-III For zone-IV, these rates shall be increased by 5% and for zone - II, these rates shall be decreased by 5%. Concerned Executive Engineer shall confirm the seismic zone for the scheme from seismic zones plan before estimation and adopt appropriate rates as per actual seismic zones. (Seismic maps attached in this C.S.R.)		
	Note :		
1)	Conditions from Sr. No. 1 to 11 of form a part and parcel of the tender shall be included in the draft tender papers for works of R.C.C.E.S.R.		
2)	Conditions from Sr. No.12to17 are for estimation purpose only and shall not be appear in the tender.		

Sr. No.	Capacity in litres	Unit	
1	Upto 25,000 litres	Per Lit.	22
2	Cost of 25,000 litres capacity E.S.R.	----	5,50,000.00
3	Add for capacity		

		above 25,000 upto 50,000 litres	Per Lit.	14
4		Cost of 50,000 litres capacity E.S.R.	-----	9,00,000.00
5		Add for capacity		
		above 50,000 upto 75,000 litres	Per Lit.	9
6		Cost of 75,000 litres capacity E.S.R.	-----	11,25,000.00
7		Add for capacity		
		above 75,000 upto 1,00,000 litres	Per Lit.	7.5
8		Cost of 1,00,000 litres capacity E.S.R.	-----	13,12,500.00
9		Add for capacity		
		above 1,00,000 upto 1,50,000 litres	Per Lit.	6.25
10		Cost of 1,50,000 litres capacity E.S.R.	-------	16,25,000.00
11		Add for capacity		
		above 1,50,000 upto 2,00,000 litres	Per Lit.	5.25
12		Cost of 2,00,000 litres capacity E.S.R.	----	18,87,500.00
13		Add for capacity		
		above 2,00,000 upto 2,50,000 litres	Per Lit.	5
14		Cost of 2,50,000 litres capacity E.S.R.	-----	21,37,500.00
15		Add for capacity		
		above 2,50,000 upto 3,00,000 litres	Per Lit.	4.75
16		Cost of 3,00,000 litres capacity E.S.R.	-----	23,75,000.00
17		Add for capacity		
		above 3,00,000 upto 4,00,000 litres	Per Lit.	4.5
18		Cost of 4,00,000 litres capacity E.S.R.	----	28,25,000.00
19		Add for capacity		
		above 4,00,000 upto 5,00,000 litres	Per Lit.	4.25
20		Cost of 5,00,000 litres capacity E.S.R.	-----	32,50,000.00

21	Add for capacity		
	above 5,00,000 upto 7,50,000 litres	Per Lit.	4
22	Cost of 7,50,000 litres capacity E.S.R.	-----	42,50,000.00
23	Add for capacity		
	above 7,50,000 upto 10,00,000 litres	Per Lit.	3.75
24	Cost of 10,00,000 litres capacity E.S.R.	-----	51,87,500.00
25	Add for capacity		
	above 10,00,000 upto 15,00,000 litres	Per Lit.	3.5
26	Cost of 15,00,000 litres capacity E.S.R.	-------	69,37,500.00
27	Add for capacity		
	above 15,00,000 upto 20,00,000 litres	Per Lit.	3.25
28	Cost of 20,00,000 litres capacity E.S.R.	----	85,62,500.00

6.4 Schedule of Rates (Pipes):

X : H.D.P.E. Pipes				
1	Providing and supplying in standard lengths Polyethelene Pipes, confirming to IS 4984 / 14151 / 12786 / 13488 with nesessary jointing material like mechanical connector i. e. thread / insert joint / quick release coupler joint / compression fitting joint or flanged joint, including all local & central taxes, transportation and fright charges inspection charges, loading / unloading charges, conveyance to the departmental stores / site & stacking the same in closed shade duly protecting from sunrays & rains, etc. complete.			
			Proposed rate 10-11	
A)	PE-100		With E.D.	Without ED
c)	6kg/sq,cm			
i)	63mm	Rmt	78	71
ii)	75mm	Rmt	112	101
iii)	90mm	Rmt	156	142

iv)	110mm	Rmt	227	206
v)	125mm	Rmt	309	280
vi)	140mm	Rmt	388	352
vii)	160mm	Rmt	503	457
viii)	180mm	Rmt	634	576
ix)	200mm	Rmt	744	675
x)	225mm	Rmt	959	870
xi)	250mm	Rmt	1177	1068
xii)	280mm	Rmt	1476	1339
xiii)	315mm	Rmt	1870	1696
xiv)	355mm	Rmt	2370	2150
xv)	400mm	Rmt	3105	2817
xvi)	450 mm	Rmt	4090	3711
xvii)	500 mm	Rmt	5058	4588
xviii)	560 mm	Rmt	6331	5743
xix)	630 mm	Rmt	10334	9375
xx)	710 mm	Rmt	10956	9939
d)	8kg/sq,cm			
i)	63mm	Rmt	98	89
ii)	75mm	Rmt	146	133
iii)	90mm	Rmt	196	178
iv)	110mm	Rmt	289	262
v)	125mm	Rmt	392	355
vi)	140mm	Rmt	490	445
vii)	160mm	Rmt	637	578
viii)	180mm	Rmt	803	728
ix)	200mm	Rmt	946	858
x)	225mm	Rmt	1215	1102
xi)	250mm	Rmt	1497	1358
xii)	280mm	Rmt	1878	1703
xiii)	315mm	Rmt	2374	2154

xiv)	355mm	Rmt	3005	2726
xv)	400mm	Rmt	3947	3581
xvi)	450 mm	Rmt	5278	4788
xvii)	500 mm	Rmt	6510	5906
xviii)	560 mm	Rmt	8172	7413
xix)	630 mm	Rmt	12381	11232
xx)	710 mm	Rmt	14137	12825
e)	10kg/sq,cm			
i)	63mm	Rmt	123	111
ii)	75mm	Rmt	173	157
iii)	90mm	Rmt	247	224
iv)	110mm	Rmt	364	331
v)	125mm	Rmt	469	425
vi)	140mm	Rmt	586	531
vii)	160mm	Rmt	761	691
viii)	180mm	Rmt	965	876
ix)	200mm	Rmt	1131	1026
x)	225mm	Rmt	1448	1314
xi)	250mm	Rmt	1808	1640
xii)	280mm	Rmt	2233	2026
xiii)	315mm	Rmt	2868	2602
xiv)	355mm	Rmt	3599	3265
xv)	400mm	Rmt	4794	4349
xvi)	450 mm	Rmt	6379	5787
xvii)	500 mm	Rmt	7884	7152
xviii)	560 mm	Rmt	9482	8602
xix)	630 mm	Rmt	14986	13596
xx)	710 mm	Rmt	17151	15560
f)	12.5kg/sq,cm			
i)	63mm	Rmt	144	131

ii)	75mm	Rmt	203	184
iii)	90mm	Rmt	293	266
iv)	110mm	Rmt	432	392
v)	125mm	Rmt	557	506
vi)	140mm	Rmt	698	634
vii)	160mm	Rmt	909	825
viii)	180mm	Rmt	1150	1043
ix)	200mm	Rmt	1351	1226
x)	225mm	Rmt	1744	1582
xi)	250mm	Rmt	2145	1946
xii)	280mm	Rmt	2690	2440
xiii)	315mm	Rmt	3405	3089
xiv)	355mm	Rmt	4323	3922
xv)	400mm	Rmt	5682	5155
xvi)	450 mm	Rmt	7593	6889
xvii)	500 mm	Rmt	9359	8491
xviii)	560 mm	Rmt	11732	10644
xix)	630 mm	Rmt	16232	14725
g)	16kg/sq,cm			
i)	63mm	Rmt	174	157
ii)	75mm	Rmt	245	222
iii)	90mm	Rmt	351	319
iv)	110mm	Rmt	520	471
v)	125mm	Rmt	671	609
vi)	140mm	Rmt	837	760
vii)	160mm	Rmt	1098	996
viii)	180mm	Rmt	1382	1254
ix)	200mm	Rmt	2386	2165
x)	225mm	Rmt	3016	2736

xi)	250mm	Rmt	3721	3376
xii)	280mm	Rmt	4667	4234
xiii)	315mm	Rmt	5899	5352
xiv)	355mm	Rmt	7484	6789
xvii)	400mm	Rmt	9694	8795
xvi)	450 mm	Rmt	12288	11147
xvii)	500 mm	Rmt	15153	13747
-				
2	Lowering, Laying and Jointing H. D. P. E. pipes by heating to the ends of pipes with the help of tefflon coated electric mirror / heater to the required temparature and then pressing the ends together against each other, to form a monolithic & leak proof joint by thermosetting process. The pressing may be required to be done with Jacks/ Hydraulic Jacks/Butt fusion machine etc. complete with all materials labours as directed by Engineer - in - charge, including, given satisfactory hydraulic test.			
			DSR 10-11	
i)	63mm	Rmt	34	
ii)	75mm	Rmt	36	
iii)	90mm	Rmt	50	
iv)	110mm	Rmt	53	
v)	125mm	Rmt	60	
vi)	140mm	Rmt	81	
vii)	160mm	Rmt	86	
viii)	180mm	Rmt	86	
ix)	200mm	Rmt	96	
x)	225mm	Rmt	124	
xi)	250mm	Rmt	128	
xii)	280mm	Rmt	158	
xiii)	315mm	Rmt	174	
xiv)	355mm	Rmt	190	
xv)	400mm	Rmt	192	

xvi)	450mm		Rmt	216	
xvii)	500mm		Rmt	280	
xviii)	560mm		Rmt	314	
xix)	630mm		Rmt	353	

6.5 Sample BRANCH input/output:
Primary network for Option A

```
BRANCH: Branched Water Distribution Design Program - (C) The World Bank
Output Data File : ZA13_1.OUT      05 December 2012      Page #  1

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

 Title of the Project                       : thane
 Name of the User                           : abc
 Number of Pipes                            :  7
 Number of Nodes                            :  8
 Number of Commercial Diameters             :  20
 Peak Design Factor                         :  1
 Minimum Headloss in          m/km          :  .1
 Maximum Headloss in          m/km          :  25
 Minimum Residual Pressure    m             :  7
 Type of Formula                            : Hazen's

 Pipe Data
 ---------
 ============================================================
 Pipe   From   To     Length    Diameter  Hazen's   Status
  No.   Node   Node     m          mm      Const     (E/P)
 ------------------------------------------------------------
    1     18      9    9911.00
    2      9     28    2800.00
    3      9     24    9850.00
    4      9      3    3130.00
    5      3      8     284.00
    6      3      6    7219.00
    7      9     21     626.00
 ============================================================

 Node Data
 ---------
 ============================================================
 Node    Peak      Flow      Elevation  Res. Press  Meet Res.
  No.    Factor    lps          m         mPres (Y/N)?
 ------------------------------------------------------------
   18    1.00      0.000      617.00        7.00
    9    1.00      0.000      434.00        7.00
   28    1.00     -9.380      320.00        7.00
```

```
   24   1.00      -10.630      440.00       7.00
    3   1.00        0.000      402.00       7.00
    8   1.00       -8.190      441.00       7.00
    6   1.00       -3.620      475.00       7.00
   21   1.00      -16.840      464.00       7.00
===========================================================
```

BRANCH: Branched Water Distribution Design Program - (C) The World Bank
Output Data File : ZA13_1.OUT   05 December 2012   Page # 2

 Reference Node Data

```
===================
 Node    Grade Line
  No.        m
 ------------------
   18      640.00
===================
```


 Commercial Diameter Data

```
 ===================================
 Pipe Dia.    Hazen's    Unit Cost
 Int. (mm)    Const    Rs /m   length
 ------------------------------------
    63.0   140.00000        98.00
    75.0   140.00000       146.00
    90.0   140.00000       196.00
   110.0   140.00000       289.00
   125.0   140.00000       392.00
   140.0   140.00000       490.00
   160.0   140.00000       637.00
   180.0   140.00000       803.00
   200.0   140.00000       946.00
   225.0   140.00000      1215.00
   250.0   140.00000      1497.00
   280.0   140.00000      1878.00
   315.0   140.00000      2374.00
   355.0   140.00000      3005.00
   400.0   140.00000      3947.00
   450.0   140.00000      5278.00
   500.0   140.00000      6510.00
   560.0   140.00000      8172.00
   630.0   140.00000     12381.00
   710.0   140.00000     14137.00
 ===================================
```

 Branched Water Distribution Network Design OutPut

 Pipe Details

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```
     --------------
     ===========================================================================
     Pipe From  To   Peak Flow  Diam   Hazen's    HL     HL/1000  Length Status
      No. Node Node   (lps)     (mm)    Const    (m )     (m )    (m )   (E/P)
     ---------------------------------------------------------------------------
       1   18    9     48.660   200.0 140.00000  106.70    10.77   9911.00
```

BRANCH: Branched Water Distribution Design Program - (C) The World Bank

Pipe Details cont`d

```
==============================================================================
 Pipe From  To   Peak Flow   Diam   Hazen's    HL    HL/1000  Length Status
  No. Node Node    (lps)     (mm)    Const     (m )    (m )     (m )  (E/P)
------------------------------------------------------------------------------
   2    9   28      9.380   110.0 140.00000   26.36     9.41   2800.00
   3    9   24     10.630   110.0 140.00000   50.90    11.86   4290.00
                           125.0 140.00000   35.40     6.37   5560.00
   4    9    3     11.810   125.0 140.00000   14.94     7.74   1930.73
                           140.0 140.00000    5.34     4.45   1199.27
   5    3    8      8.190    90.0 140.00000    5.53    19.47    284.00
   6    3    6      3.620    90.0 140.00000   31.02     4.30   7219.00
   7    9   21     16.840   125.0 140.00000    9.34    14.92    626.00
==============================================================================
```

Node Details

```
==============================================================================
 Node    Peak Flow    Elevation   H G L    Cal PresSpcPres   Meet Res
  No.      (lps)        (m )       (m )       (m )      (m )   Pres. (Y)
------------------------------------------------------------------------------
  18 S      48.660     617.00     640.00     23.00       7.00
   9         0.000     434.00     533.30     99.30       7.00
  28        -9.380     320.00     506.94    186.94       7.00
  24       -10.630     440.00     447.00      7.00       7.00
   3 T       0.000     402.00     513.02    111.02       7.00
   8 T      -8.190     441.00     507.50     66.50       7.00
   6 T      -3.620     475.00     482.00      7.00       7.00
  21       -16.840     464.00     523.97     59.97       7.00
==============================================================================
```

Cost Summary

```
=================================================
 Diameter   Length      Cost        Cum. Cost
  (mm)       (m )     (1000 Rs )    (1000 Rs )
-------------------------------------------------
   90.0    7503.00     1470.59       1470.59
  110.0    7090.00     2049.01       3519.60
  125.0    8116.73     3181.76       6701.35
  140.0    1199.27      587.64       7289.00
  200.0    9911.00     9375.81      16664.80
=================================================
```

BRANCH: Branched Water Distribution Design Program - (C) The World Bank

 Pipe-wise Cost Summary

```
============================================================
 Pipe    Diameter      Length        Cost       Cum. Cost
  No       (mm)         (m )      (1000 Rs )    (1000 Rs )
------------------------------------------------------------
   1       200.0       9911.00      9375.81       9375.81
   2       110.0       2800.00       809.20      10185.01
   3       110.0       4290.00      1239.81      11424.82
           125.0       5560.00      2179.52      13604.34
   4       125.0       1930.73       756.85      14361.18
           140.0       1199.27       587.64      14948.82
   5        90.0        284.00        55.66      15004.49
   6        90.0       7219.00      1414.92      16419.41
   7       125.0        626.00       245.39      16664.80
```

BRANCH: Branched Water Distribution Design Program - (C) The World Bank

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6.6 Sample EPANET input/output:

The sample EPANET input/output provided below is for the case of steady-state analysis. For extended-period analysis refer to the graphs in Appendix 6.1

```
  Page 1                              11/25/2012 7:53:55
PM
  ***************************************************************
**
  *                     E P A N E T                     *
  *              Hydraulic and Water Quality                *
  *              Analysis for Pipe Networks                 *
  *                     Version 2.0                     *
  ***************************************************************
**


  Input File: Upper Vaitarna.net

   MVS based on Upper Vaitarna for tanker fed villages in Mokhada
Taluka


  Link - Node Table:
```

```
  ---------------------------------------------------------------------
  Link        Start       End           Length  Diameter
  ID          Node        Node            m       mm
  ---------------------------------------------------------------------
  PI1         RE1         TA1            600      250
  PI3         TA1         JU15           500      250
  PI4         JU15        JU2            500      250
  PI5         JU2         JU3            500      250
  PI6         JU6         JU7            500      250
  PI7         JU7         JU8            500      250
  PI8         JU8         JU9            600      250
  PI9         JU9         JU10           500      250
  PI10        JU10        JU11           600      250
  PI11        JU11        JU12           1000     300
  PI12        JU12        JU16           700      250
  PI13        JU16        JU13           800      250
  PI14        JU13        JU14           1500     250
  PI15        JU14        JU17           500      50
  PI16        JU17        JU18           2430     50
  PI17        JU14        JU28           500      110
  PI18        JU28        JU29           3747     110
  PI19        JU29        JU30           2675     90
  PI20        JU30        JU31           2440     90
```

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PI21	JU30	JU32	500	50
PI22	JU14	JU33	2181	125
PI23	JU33	JU34	500	90
PI24	JU34	JU35	500	90
PI25	JU35	JU36	500	90
PI26	JU36	JU37	500	90
PI27	JU37	JU38	1700	90
PI35	JU20	JU21	500	300
PI36	JU21	JU22	500	300
PI37	JU22	JU23	500	300
PI38	JU23	JU24	577	50
PI39	JU23	JU25	500	300
PI40	JU25	JU26	1391	63
PI41	JU25	JU45	2000	63
PI42	JU45	JU27	1677	63
PI44	JU3	JU4	500	250
PI46	JU4	JU5	500	250
PI47	JU5	JU6	600	250

Page 2   MVS based on Upper Vaitarna for tanker fed villages in Mokhada Taluka

Link - Node Table: (continued)

Link ID	Start Node	End Node	Length m	Diameter mm
PI48	JU14	JU46	500	110
PI49	JU29	JU47	500	50
PI50	JU33	JU40	5568	110
PI51	JU40	JU48	500	50
PI52	JU40	JU49	5160	90
PI53	JU40	JU41	2000	90
PI54	JU20	JU50	500	50
PI55	JU14	JU20	3130	110
PU1	JU1	TA1	#N/A	#N/A Pump

Node Results:

Node ID	Demand LPS	Head m	Pressure m	Quality
JU1	0.00	523.67	-79.33	0.00

Node ID	Demand LPS	Head m	Pressure m	Quality
JU2	0.00	653.43	30.43	0.00
JU3	0.00	651.64	56.64	0.00
JU4	0.00	649.85	40.85	0.00
JU5	0.00	646.52	32.52	0.00
JU6	0.00	642.52	36.52	0.00
JU7	0.00	639.19	29.19	0.00
JU8	0.00	635.85	37.85	0.00
JU9	0.00	631.86	82.86	0.00
JU10	0.00	628.52	73.52	0.00
JU11	0.00	624.52	60.52	0.00
JU12	0.00	621.78	79.78	0.00
JU13	0.00	611.78	181.78	0.00
JU14	0.00	601.79	154.79	0.00
JU15	0.00	655.21	45.21	0.00
JU16	0.00	617.12	140.12	0.00
JU17	0.00	590.68	141.68	0.00
JU18	1.35	536.68	104.68	0.00
JU20	0.00	518.98	116.98	0.00
JU21	0.00	518.92	518.92	0.00
JU22	0.00	518.85	518.85	0.00
JU23	0.00	518.79	518.79	0.00

Page 3   MVS based on Upper Vaitarna for tanker fed villages in Mokhada Taluka

Node Results: (continued)

Node ID	Demand LPS	Head m	Pressure m	Quality

Node ID	Demand LPS	Head m	Pressure m	Quality
JU24	2.45	480.13	45.13	0.00
JU25	0.00	518.76	112.76	0.00
JU26	3.00	495.17	62.17	0.00
JU27	3.60	431.35	-41.65	0.00
JU28	0.00	593.19	248.19	0.00
JU29	0.00	528.77	288.77	0.00
JU30	0.00	445.49	241.49	0.00

JU31	6.67	385.85	180.85	0.00
JU32	0.93	439.92	224.92	0.00
JU33	0.00	540.45	195.45	0.00
JU34	0.00	528.99	178.99	0.00
JU35	0.00	517.54	167.54	0.00
JU36	0.00	506.09	133.09	0.00
JU37	0.00	494.63	152.63	0.00
JU38	6.44	455.69	88.69	0.00
JU40	0.00	475.34	95.34	0.00
JU41	4.20	464.21	67.21	0.00
JU45	0.00	471.21	11.21	0.00
JU46	9.00	593.78	159.78	0.00
JU47	1.75	510.80	254.80	0.00
JU48	1.80	456.41	63.41	0.00
JU49	4.63	440.94	34.94	0.00
JU50	2.75	477.48	38.48	0.00
RE1	198.04	603.00	0.00	0.00 Reservoir
TA1	-246.61	657.00	4.00	0.00 Tank

Link Results:

Link ID	Flow LPS	Velocity m/s	Unit Headloss m/km	Status

PI1	-198.04	4.03	90.00	Open
PI3	48.57	0.99	3.57	Open
PI4	48.57	0.99	3.57	Open
PI5	48.57	0.99	3.57	Open
PI6	48.57	0.99	6.67	Open
PI7	48.57	0.99	6.67	Open
PI8	48.57	0.99	6.67	Open
PI9	48.57	0.99	6.67	Open
PI10	48.57	0.99	6.67	Open
PI11	48.57	0.69	2.74	Open
PI12	48.57	0.99	6.67	Open
PI13	48.57	0.99	6.67	Open
PI14	48.57	0.99	6.67	Open
PI15	1.35	0.69	22.22	Open

Link	Flow	Velocity	Unit Headloss	Status
ID	LPS	m/s	m/km	
PI16	1.35	0.69	22.22	Open
PI17	9.35	0.98	17.19	Open

Page 4   MVS based on Upper Vaitarna for tanker fed villages in Mokhada Taluka

Link Results: (continued)

Link	Flow	Velocity	Unit Headloss	Status
ID	LPS	m/s	m/km	

Link	Flow	Velocity	Unit Headloss	Status
PI18	9.35	0.98	17.19	Open
PI19	7.60	1.19	31.13	Open
PI20	6.67	1.05	24.45	Open
PI21	0.93	0.47	11.14	Open
PI22	17.07	1.39	28.12	Open
PI23	6.44	1.01	22.91	Open
PI24	6.44	1.01	22.91	Open
PI25	6.44	1.01	22.91	Open
PI26	6.44	1.01	22.91	Open
PI27	6.44	1.01	22.91	Open
PI35	9.05	0.13	0.12	Open
PI36	9.05	0.13	0.12	Open
PI37	9.05	0.13	0.12	Open
PI38	2.45	1.25	67.00	Open
PI39	6.60	0.09	0.07	Open
PI40	3.00	0.96	16.96	Open
PI41	3.60	1.15	23.77	Open
PI42	3.60	1.15	23.77	Open
PI44	48.57	0.99	3.57	Open
PI46	48.57	0.99	6.67	Open
PI47	48.57	0.99	6.67	Open
PI48	9.00	0.95	16.02	Open
PI49	1.75	0.89	35.93	Open
PI50	10.63	1.12	11.69	Open
PI51	1.80	0.92	37.85	Open
PI52	4.63	0.73	6.67	Open
PI53	4.20	0.66	5.57	Open
PI54	2.75	1.40	82.98	Open

```
PI55            11.80     1.24    26.46     Open
PU1              0.00     0.00  -133.33      Open Pump
```