Analysis of ‘Regeneration of Diversion Based Irrigation System and Integrated Livelihood Development’

Report of Phase 1 Study

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Executive Summary

Nashik district is one of the agriculturally advanced districts of Maharashtra and is known for high agriculture (especially horticulture) production round the year. Sinnar block is situated in South of Nashik district. Although Sinnar has a large share of vegetable production, 68% of its area is under cereals and falls in rain-shadow region of Western Ghats. Average rainfall in Sinnar is 616 mm. Devnadi basin is located in the central part of the block.

Devnadi basin is known for British-era Diversion-based Irrigation (DBI) Systems which were planned for increasing area under irrigation in villages along Devnadi by creating weirs and distribution system on the river. These systems were not functioning in most of the villages since last 20-30 years. Local NGO Yuva Mitra (YM) has been influential in reviving and rejuvenating these systems in last 5-6 years.

Tata Trusts is the key funding agency in YM's DBI regeneration work for last two years. The sites like Wadgaon Sinnar have been covered during the 2009-11 period, whereas other sites are being covered in since last two years. This project is a collaboration of Tata Trusts, YM, and TDSC for technical review, assessment of utilization and impact of DBI regeneration work. This includes mapping of existing works, marking of DBI command areas, hydrological study of the region, socio-economic analysis of beneficiaries, study of cropping patterns and possible interventions for expanding the DBI system further to cover rain-fed areas.

This report shows the work done in Phase 1 of the project from October to December 2016. It includes mapping of all DBI structures, canals, minor gates, minor distributaries and marking them on village revenue maps for all ten DBI villages along Devnadi and detailed study of two villages, Wadgaon Sinnar and Deopur. The detailed study includes mapping and analysis of all the data collected by Yuva Mitra (e.g. well-readings, canal discharge data, beneficiary details etc.), well monitoring carried by TDSC, marking of direct and indirect command area on the basis of sample socio-economic surveys and field observations.

The key findings of the work done are:

- Due to DBI, additional area is irrigated either by direct chari, or by well-recharge by canal seepage, thus benefitting a village.
- As per measurements in Wadgaon Sinnar in end of October, around 1300 m^3 water percolated per day per km of the length of DBI canal. This water recharges nearby wells. With the same infiltration, additional 17 hectares of can be irrigated. And can assure 2-3 rabi irrigations as estimated by farmers.
- In Deopur, 115 hectares of land is under direct and indirect command area of the canal. Here also, it was found that DBI distribution network recharges nearby wells which benefit farmers not connected by minors.
- Identified locations with drinking water problems in Deopur and Wadgaon Sinnar
- In both villages, it was observed that farmers lift water from wells recharged by canal and minors to irrigate further away fields. This increases the indirect command area of DBI.

- In Deopur, farmers are aware of canal functioning and WUA. As per field observations and farmer perception, canals are in good condition and sub-minors are working well.
- Flow measurements in Devnadi show that DBI system is supported by many local feeder streams rather than Konambe dam outlet. Watershed treatment works like construction of structures on streams and area treatment (contour bunding, contour trenching, terracing) will increase the quantity and time-span of inflow to DBI.

TDSC is interested in following activities in the future in collaboration with Yuva Mitra for carrying this work forward:

- Intervention planning on feeder streams of Devnadi
- Drinking water status monitoring at habitation level
- Detailed audit and hydrological study of all the DBI civil structures
- Water balance studies at the village level
- Socio-hydrological and cost-benefit study of Devnadi project
- Expansion of DBI to cover more area (through diversion or extension of canal network)

Some of these activities will be carried out in the next phase of this project

TDSC Output

Planned Output	Current Status
Mapping of canal network in ten villages in different layers as per agreement	Completed
Detail study in two villages which includes:	
Well analysis	Completed in Deopur; ongoing in Wadgaon Sinnar
Socio-Economic Study	Completed in Deopur and Wadgaon Sinnar

1 Introduction

Agricultural productivity depends on availability of water. Efforts are made since centuries to support irrigation systems. The British Government built and used Diversion Based Irrigation (DBI) systems and, about twenty such structures were constructed in Sinnar Taluka on Devnadi. Yuva Mitra is regenerating canals and DBI systems as part of its efforts to improve livelihoods via improvement in irrigation potential. These structures have special importance as Sinnar is a drought prone area with an annual average rainfall of 616 mm. This report focuses on the villages located on the bank of Devnadi, starting from Konambe to Deopur (ten villages). 20 DBI and more than fifty Cement bunds are located on the Devnadi river in the study area.

1.1 Background

Yuva Mitra NGO in Sinnar Taluka, Nashik district has worked on regeneration of existing British era DBI systems on Devnadi river. This work has been executed over past 4-5 years through a project funded by Tata Trusts. A program, technical and institutional review of the same was carried out by Deloitte for Tata Trusts. The report was submitted in August 2016.

Previously, Technology and Development Solutions Cell (TDSC) at Centre for Technology Alternatives for Rural Areas (CTARA) at IIT Bombay had expressed interest in conducting a process review, utilization and impact assessment of the same, involving mapping, water flow estimations, beneficiary socio-economic analysis, etc. The main high-level priority recommendations by Deloitte are also on the same lines and thus, TDSC and Yuva Mitra jointly carried out this study after discussing phase-wise project deliverables with Tata Trusts. This is the phase 1 study report.

1.2 Study Area

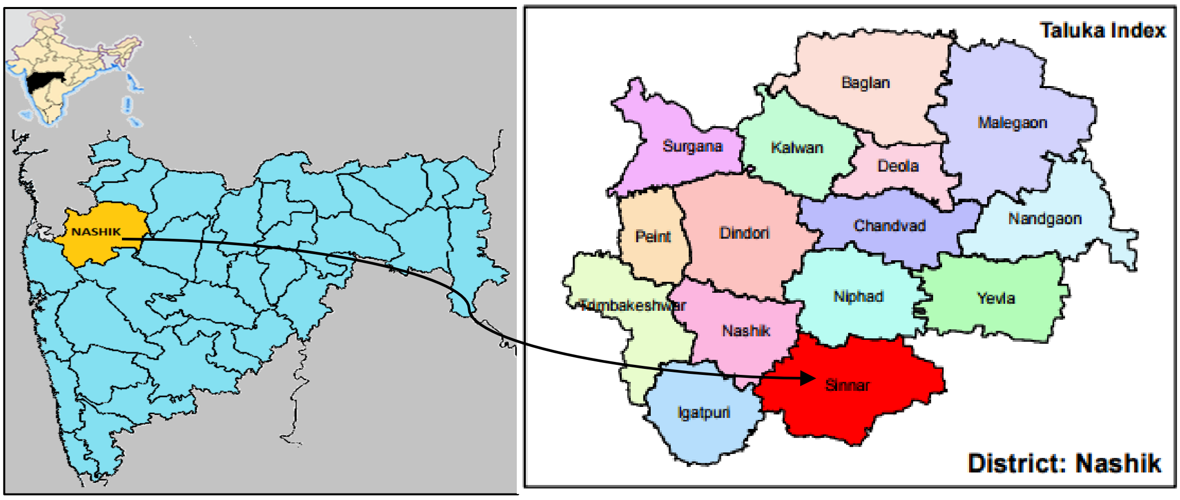

Figure 1: Location map (Sinnar block)

This project studies ten villages of Sinnar Taluka. The villages are:

1. Konambe
2. Sonambe
3. Wadgaon Sinnar
4. Sinnar
5. Kundewadi
6. Musalgaon
7. Datali
8. Khopadi Bk
9. Khopadi Kh
10. Deopur

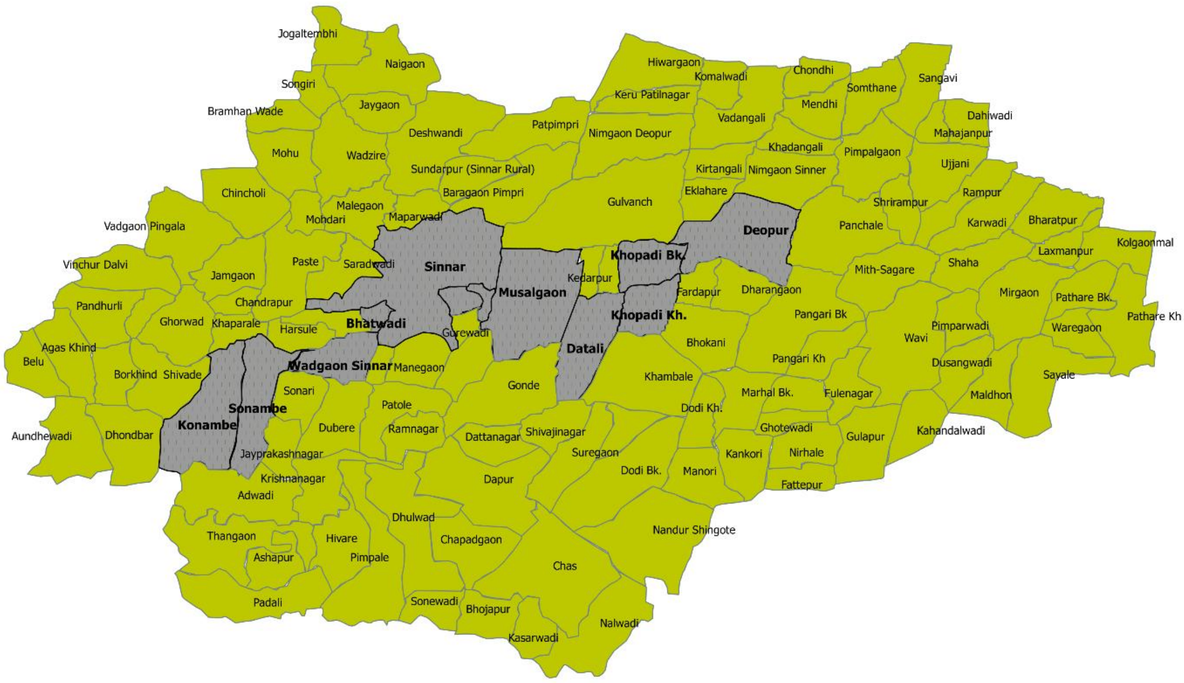

Figure 2: Villages studied

These villages are situated on the bank of Devnadi and have DBI systems. As per GSDA 2013 data, all these villages are overexploited except Sinnar, Khopadi Bk, and Khopadi Kh. Following is the population data of the villages:

Table 1: Population of study villages

Sr. No.	Name of Village	Population	Number of habitations	Habitations covered with PWS
1	Konambe	3113	5	1
2	Sonambe	4396	12	0
3	Wadgaon Sinnar	2722	1	1
4	Sinnar	65299		
5	Kundewadi	1959	2	1
6	Musalgaon	8124	14	14
7	Datali	2356	10	3
8	Khopadi Budruk	1616	6	3
9	Khopadi Khurd	733		
10	Deopur	3035	1	1

(Source: Census of India 2011 data, NRDWP)

In the following table DBI present in the study area are listed out.

Table 2: DBIs in study villages

Sr. No.	Name of Village	Name of Bandhara	DBI/ Dam No.
1	Konambe	Konambe	73
2	Sonambe	Upper side	74
		Middle side	75
		Lower side	76
3	Wadgaon Sinnar	Bibika	77
		Lonarwadi	78*
		Wadgaon	79*
		Bhatwadi	80*
4	Sinnar	Belambe	81*
		Vajiyaran	82
		Sinnar	83*
		Kotam Kholhe	84
5	Kundewadi	Mapara	85
6	Musalgaon	Shahaja	86
		Khetri	87
7	Datali	Datali	89
8	Khopadi budruk	Khopadi budruk	90
9	Khopadi khurd	Khopadi khurd	91
10	Deopur	Deopur	92

* These DBIs are not part of the study as they are currently dysfunctional or do not benefit the 10 villages under study.

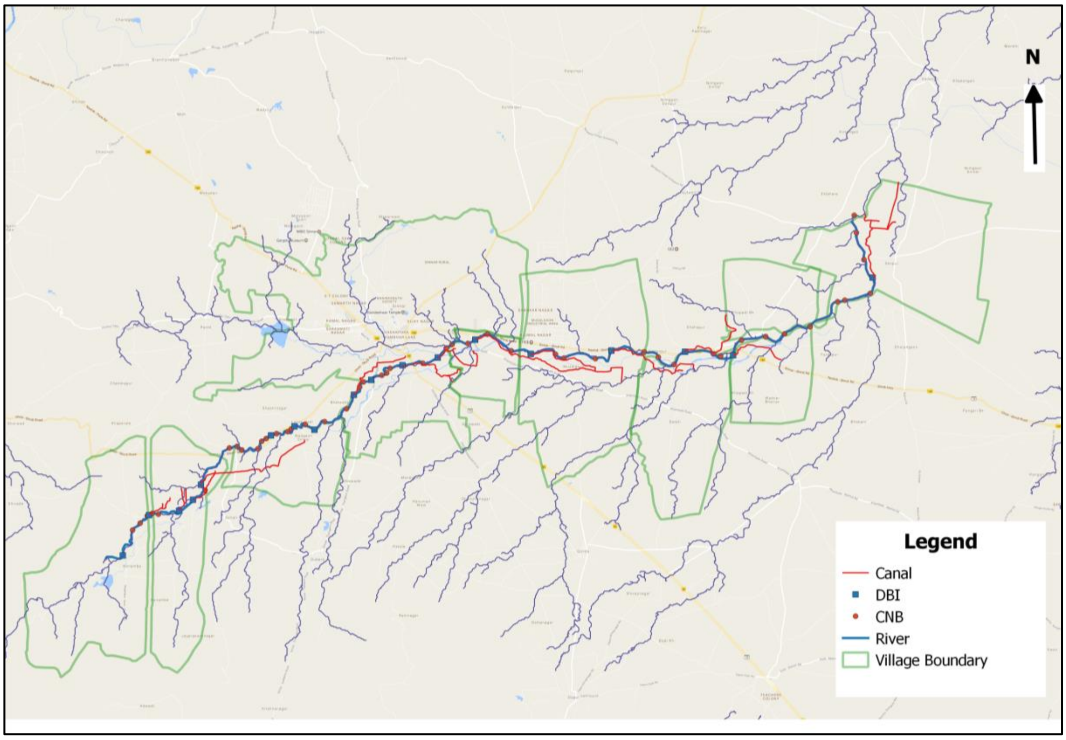

Figure 3: Study area map

1.3 Scope of Work for Phase 1:

The first phase of the project had a duration of three months with the following scope of work:

1. Mapping of Devnadi and the DBI structures
    a. Alignment of Devnadi from Konambe village to Deopur village
    b. Locations of all structures like cement bunds, diversion weirs, K.T. weirs and other hydraulic structures on the river.
    c. Alignment of canals in the ten villages where DBI revival work has been taken up by Yuva Mitra. (Including main canal, branch canal, and minors).
    d. Location of important crossings on canals such as roads, village boundary, cross drainage works at the village level.
2. Mapping of command area of the DBI structures in two villages (Wadgaon Sinnar and Deopur) out of ten.
3. Pilot study for socio-economic impact assessment of revived DBI structures in Wadgaon Sinnar and Deopur villages.
4. Well monitoring and soil strata study for hydrology study in two villages. Monitoring all the wells is not possible, so select 10 - 12 wells from each village to be monitored.

1.3.1 Deliverables

A. At village level, following map layers will be provided for data representation and analysis
    1. Satellite image / Google earth layers
    2. Cadastral/revenue maps of villages
    3. River alignment
    4. Canal alignment
    5. Road network
    6. All diversion weirs, cement bunds, crossing, and other hydraulic structures
    7. Command area / non-command area in two villages

A soft and hard copy of the file including mentioned layer will be provided.

B. Report of a pilot study of socio-economic impact analysis
C. Report of procedure for well monitoring and analysis

2 Description of Study Area

2.1 Sinnar Block

Nashik is an agriculturally developed district in North Maharashtra. 56% of the land is used for agriculture in the region. There are 15 tehsils in Nashik, Sinnar is to the South-East of Nashik city. Sinnar city is at 19.58°N, 74.00°E and elevation of 685m. Sinnar block has a population of 3.5 lakh, an area of 1352.61 km^2 and has 129 villages of which 68 were tanker fed in 2015. Sinnar is known for horticulture and major crops in this region are bajra, vegetables, onion, tomato, and wheat. It has high crop diversity. This is due to assured irrigation sources in the region. Diversion Based Irrigation systems (DBI) were built in the region during the British rule. These were operated by Water User Associations/ community participation but for past few decades, these systems are defunct. Yuva Mitra (YM) revived DBI systems on Devnadi last year through support from Tata Trusts and made them operational in 10 villages.

Table 3: Sinnar basic information

Parameter	Value
Population (lakhs)	3.46
Area (km^2)	1346
No. of Inhabited villages	129
No. of household (lakhs)	0.67
Total workers (lakhs)	1.78
Cultivators (lakhs)	0.93
Agricultural Laborers (lakhs)	0.38

Source: Data from Census of India 2011

2.2 Devnadi Watershed

Watershed delineation was done for Devnadi and Shivnadi to determine the catchment area of rivers. Following this, discharge measurement was done in various locations using a current/ flow meter as explained in section 3.1. Delineation was done using QGIS with GRASS plugin. SRTM DEM (Digital elevation Model) was used for delineation and was obtained from Earth Explorer maintained by USGS. All cells drained by 1000 cells are delineated as a stream. Obtained watershed was compared with river polyline to obtain feeders for the main river. Feeders are streams feeding into the river over its course. These feeders play an important role in keeping the river active post monsoon period in form of base flows.

Table 4: Catchment area details

Watershed	Catchment area (ha)
Devnadi total	38500
Shivnadi	6152
Devnadi before joining Shivnadi	10289.6
Sonambe stream	953
Dubere stream	2063
Jayprakash stream	1124

Estimated using GIS GRASS map. (DEM is downloaded from USGS)

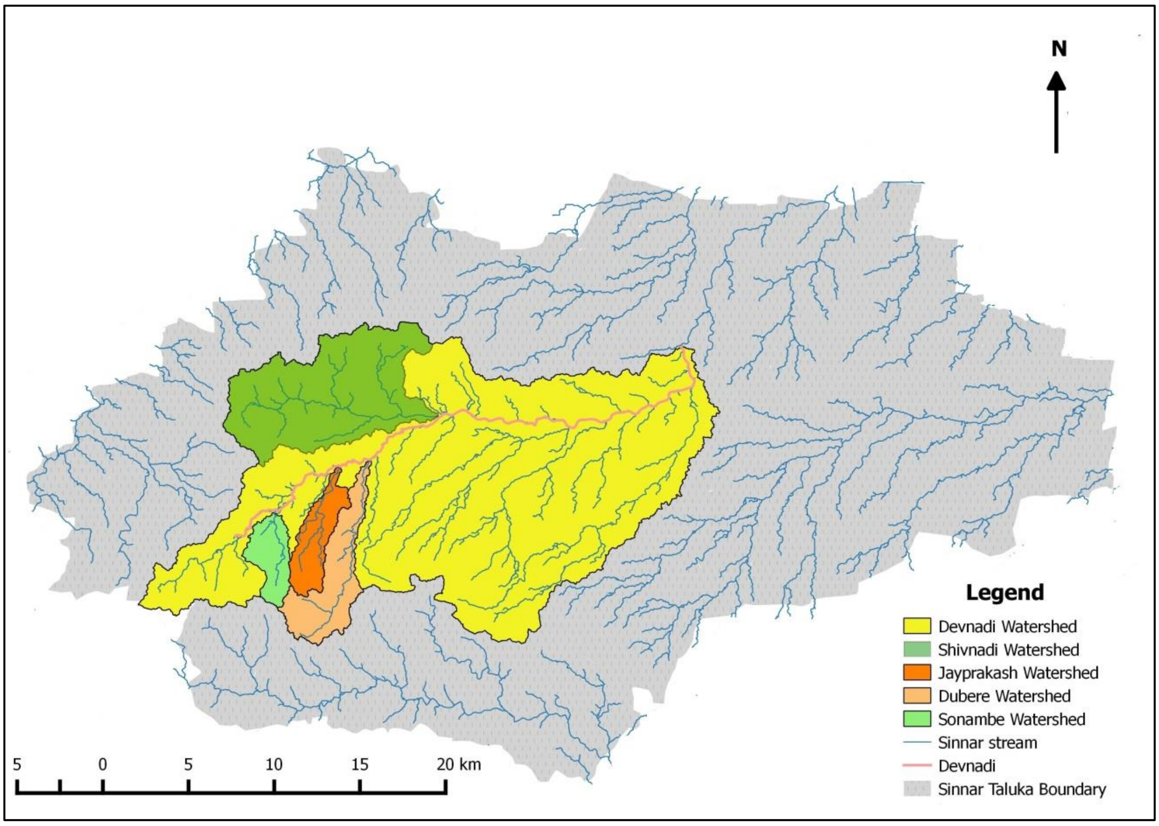

Figure 4: Streams with catchment area

(Generated from DEM in QGIS)

2.2.1 Devnadi elevation profile

Alignment and elevation profile of Devnadi is drawn in Google Earth from Konambe to Deopur. Devnadi is 35 Km long in this patch. Ground level elevation of Devnadi at Konambe is 763 m and 565 m at Deopur (above mean sea level). Alignment is series of the point, line, and curves. Its main purpose is to show exact location on earth. In this study, alignment shows center line or plan view of canal and river on the map.

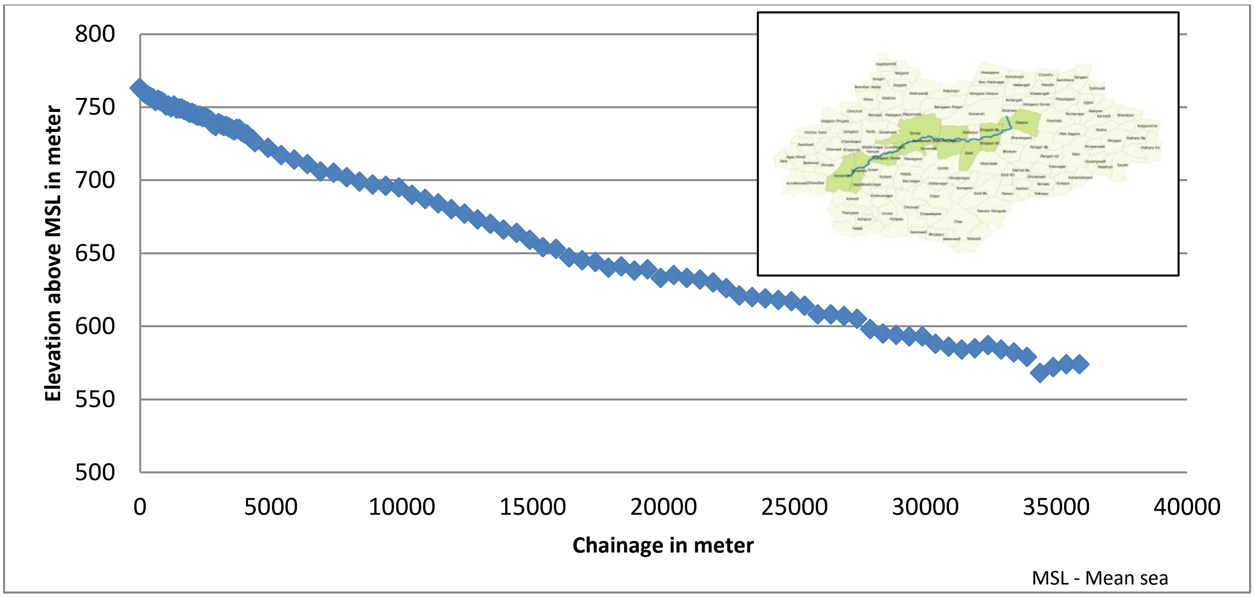

Figure 5: Elevation profile of Devnadi from Konambe to Deopur

2.3 Diversion Based Irrigation (DBI) Systems

A DBI system diverts a portion of overflowing water from a river/ stream and uses it for irrigation or other domestic needs. This system is in use for few centuries in regions with appropriate features. It has different names in different parts of the country; Phad in Maharashtra, Kul in Himachal Pradesh, Zebo in Nagaland, etc. This system does not store water but uses flowing water.[1] The cost of this system is much lower than that of a conventional irrigation system. These systems run successfully only with community participation. In Nashik, Phad system was active in early 16th century in Tapi basin on rivers Panjhra, Mosam, and Aram. A Gazetteer of Bombay Presidency describes DBI as specific to topographies where rivers have a steep gradient which helps in the construction of diversion weir and there is a contribution of base flow post monsoon which keeps the DBI functional till summer months. One important fact is that irrigation through DBI happens only by gravity and hence designing it requires consideration of slopes of the region. Over a period of time, due to neglect and lack of community participation, these systems became defunct in most parts of the country.

The main benefits of DBI systems are given below:

- Irrigation potential is extended beyond the river/ stream
- Irrigation – flood irrigation from minor gates to fields
- Well recharge – Infiltration into ground water recharges wells
- Canal network being spread over a large area (with main canal, sub canal and distributaries), irrigation and ground water recharge benefits are spread out.
- Flood control – Overflowing water in river is diverted through farms reducing flooding in downstream villages
- Gravity flow –Removes need of expensive pumps, has low maintenance and running cost

[1] This information has been collated from various literature by Sir Dorabji Tata Trust

2.3.1 Components of DBI

1. Diverging Weir –A barrier in the river for storing and diverting upstream water.
2. Inlet to canal – Opening on diverging weir for transferring water to canal from river.
3. Main Canal – diverted water flows through the main canal. Escape gates, minor gates, and distributaries are constructed on the main canal.
4. Escape Gate – Controls water level in the main canal. In a high rainfall event, water is diverted back into the river through escape gates.
5. Minor Gate – by controlling these gates farmers irrigate their fields.
6. Sub canal - After main canal comes the area which is to be irrigated by canal system. Water should flow in entire command area. So the main canal is branched to cover the whole area. These bifurcations are called sub canals, branch canals or branches.
7. Distributaries –They take water from branches and distribute it to various farms by direct flood irrigation.

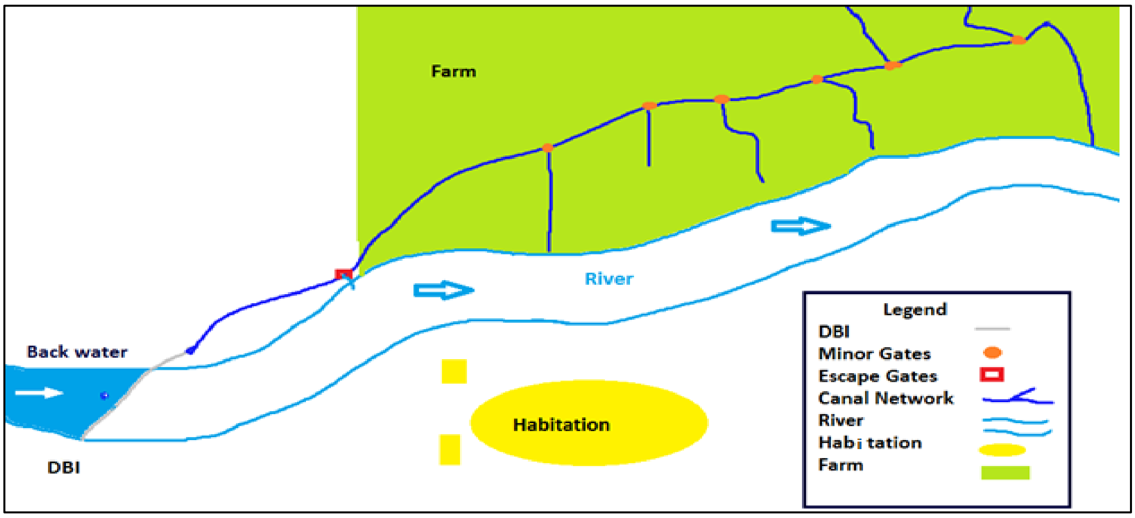

Figure 6: DBI components

2.4 Past Studies and Available Data

2.4.1 Yuva Mitra

Since 2009, Yuva Mitra is regenerating DBI systems with community participation. Yuva Mitra has repaired 12 DBI systems in 2015-2016 on Devnadi river for using canal water to improve agricultural income. Various activities such as changing agricultural practices, use of raised bed cultivation, mulching, drip irrigation, setting up kitchen gardens and cultivation of vegetables were carried out. The NGO works with state government to run Integrated Watershed Management Program (IWMP) in Sinnar watershed (IWMP – 22).

Yuva Mitra team maintains data of well-water levels, cropping pattern, canal water discharge and canal functioning. Wells are being monitored since October 2015. The data of water use by farmers by minor gates in Deopur is used for marking direct command area.

2.4.2 Existing GIS representation of DBIs

Lowe Hjorth, a student from Malarden University, worked in Sinnar taluka 2 years ago, in 2014. He geo-referenced all minor gates, escape gates, river, and weirs. His mapping was verified on-field. Since his work was done at beginning of the repairs, many locations of minor gates were different and in Sonambe, Sinnar, Khopadi Kh and Khopadi Bk alignment of the canals needed correction. His data was used in case of Datali canal (DBI) marking.

Figure 7: GIS representation of existing data

2.4.3 Research work

Pooja, a Ph.D. scholar at CTARA, IITB, studies vegetable cultivation as means of livelihood for smallholding farmers. The objective of this work examines whether horticulture has potential to provide the livelihood for farmers. For this study, farmer surveys were done to collect baseline data. Study and survey were carried out in different villages Wadgaon Sinnar, Khopadi Kh, Dapur, and Pandhurli. This work initiated the idea of the current project.

2.4.4 Discharge data

To measure canal discharge, Cut Throat Flume (CTF) device is used by Yuva Mitra; daily data is collected. To see effect of rainfall on discharge, daily rainfall data of Sinnar, Dubere, and Deopur rain gauge was collected from official sources[2].

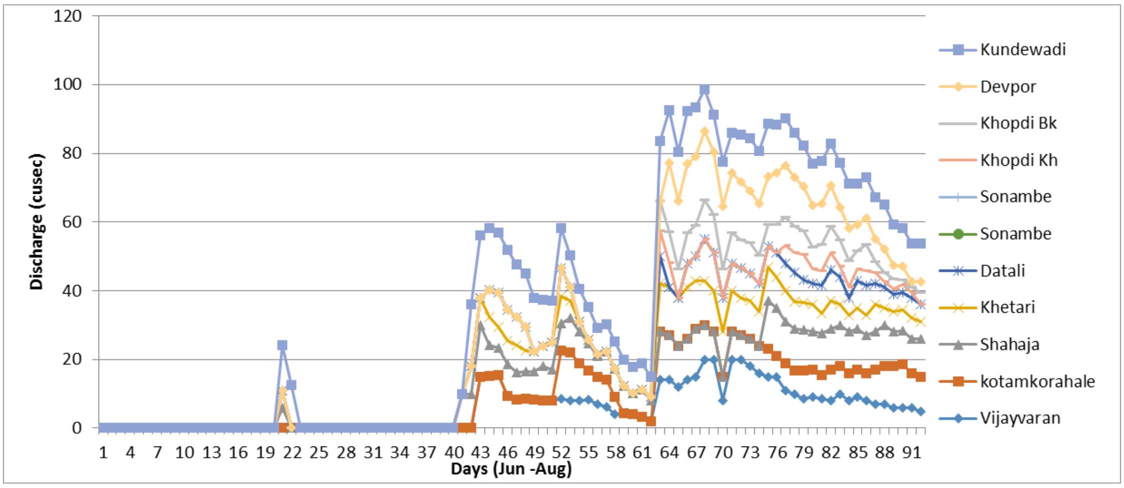

Figure 8: Discharge data (June 16- Aug 2016)

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[2] http://maharain.gov.in/

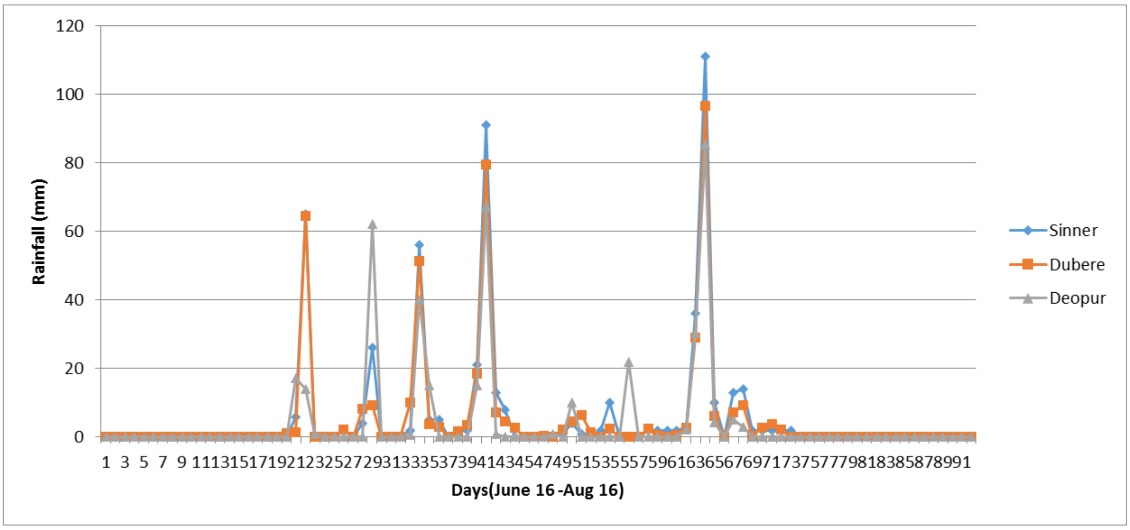


Figure 9: Rainfall data (June 16 – Aug 16)

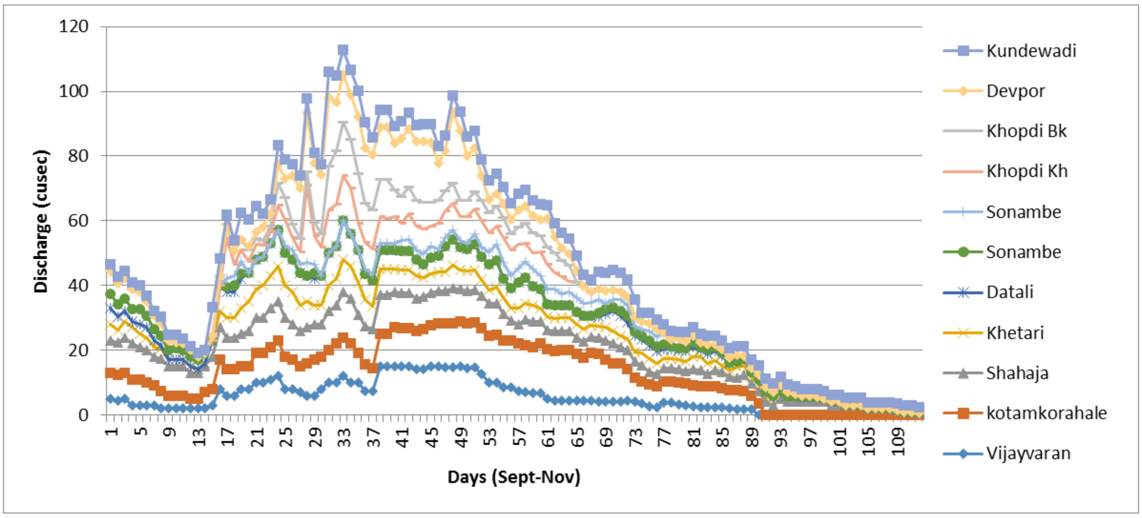


Figure 10: Discharge data (June 16- Aug 2016)

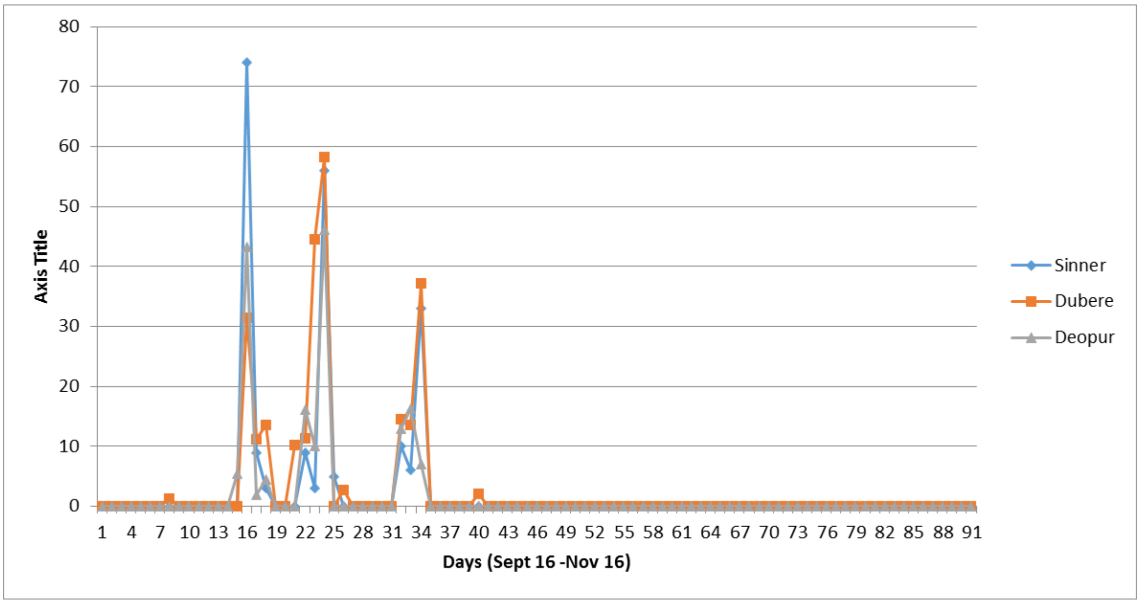


Figure 11: Rainfall data (September 16 – November 16)

Table 5: CTF data

Canal Name	Village Name	Discharge (Cusec)	Functional Days	Start Date	Last Date
Vijayvaran	Sinner	1123	139	13-Jul	28-Nov
Kotam korahale	Sinner	1221.91	130	22-Jul	29-Nov
Shahaja	Musalgaon Bk	1228	152	21-Jun	21-Dec
Khetari	Musalgaon Kh	856	148	21-Jun	10-Dec
Datali	Datali	744	113	08-Jul	01-Dec
Gagan	Sonambe	165.6	57	16-Aug	02-Dec
Madhala thal	Sonambe	341.2	99	17-Aug	07-Dec
Khopadi Kh	Khopadi Kh	476.24	77	02-Aug	15-Nov
Khopadi Bk	Khopadi Bk	550.516	80	02-Aug	03-Oct
Deopur	Deopur	899.09	75	03-Aug	04-Nov
Devnal	Kundewadi	1128.19	173	12-Jul	31-Dec

Comments

Maximum flow observed in Musalgaon (Shahaja), followed by Sinnar (Kotam), Kundewadi and Vijayvaran. Minimum flow observed in Sonambe (Gagan), followed by Sonambe (Madhala Thal), Khopadi Kh and Khopadi Bk.

1. June
    - First rainfall event occurred during 20 - 22, followed by 28 - 29, in all three rain-gauge stations. Maximum rainfall observed on 22nd in Sinnar and Dubere of 65 mm and 64 mm respectively. Discharge was observed in Musalgaon Bk and Deopur for a single day (21st) however Kundewadi canal flowed for two days (21 and 22).
2. July
    - Four to five rainfall events occurred. First was between 3 to 5 July, in which no discharge was found though average rainfall is 65 mm in all the three stations.
    - Second rainfall event was between 9 to 14 July; discharge was observed in most of the canals except Sonambe, Khopadi, and Deopur Canals.
    - Maximum discharge observed in Kundewadi followed by Musalgaon Bk and Vijayvaran. Flow in these canals lasted for a month from start of the canals.
3. August
    - One major rainfall event occurred in the first week of August and flow was observed in all canals expect Sonambe. Flow in Sonambe canal started from 16th at last.
    - Khopadi Bk, Khopadi Kh, and Deopur canal dried on 31st of August.
4. September
    - Maximum discharge was observed in Musalgaon canal. Sonambe (Gagan) was dried in 20th and no flow was observed after.
5. October
    - The last rainfall event of the season was observed in the first week of October and all the canals were functional except Sonambe.
6. November
    - Most of the canals start falling dry in this month except Musalgaon Bk, Musalgaon Kh, Kundewadi, and Datali.

3 Hydrology Study

Water flows through the DBI canals even after the monsoon. The main purpose of letting water flow is to increase infiltration and thus increase ground water table. Our basic aim is to:

- Find the amount of infiltrated water due to canal network
  By finding the amount of infiltrated water, additional area which can be irrigated by this water can be found. This is an important parameter for water balance for a village. While additional area was estimated, water balance calculations were not done.
- Find the discharge of feeder streams of Devnadi

3.1 Methodology

To achieve these aims, following exercises were carried out:

1. Deriving streams using QGIS
2. Measuring infiltration through the Vijayvaran canal
   a. Measuring flow rates at each escape gate, minor gate and intermediate points.
   b. Calculating infiltration from differences in flow rates
3. Measuring current flows at feeder streams of Devnadi
   Deriving streams has been covered in Section 2.2.

3.1.1 Measuring infiltration rate

To understand water balance, we took discharge measurements at various points in Devnadi basin. We used current/flow meter to measure flows in canals, feeders, and river. The location chosen was Sinnar Vijayvaran and we took a stretch of 1.5 km long canal and measured the discharge at two points from initial to the final point. It was seen that there was no other activity being carried out in the chosen stretch like water pumping or obstruction of flow. The following table gives the reading value at different points.

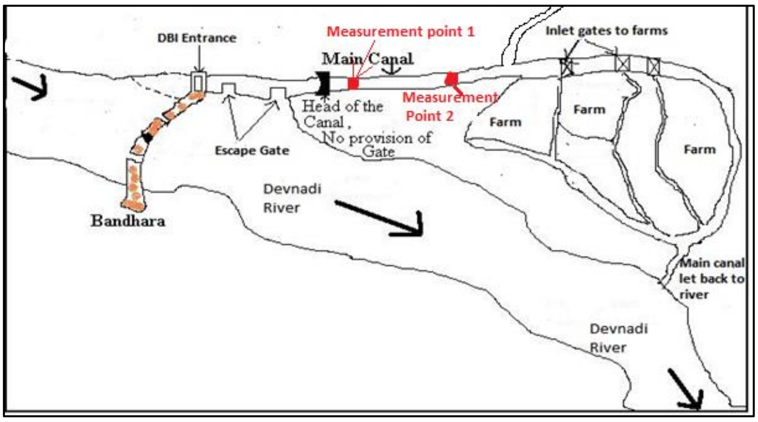


Figure 12: Measurement points to find infiltration in Sinnar Vijayavaran Canal

Table 6: Flow measurement of Sinnar Vijayvaran Canal

Description	Flow
Water discharge at inlet	126.6 lps
Water discharge at outlet	102.4 lps
Water discharge	24.23 lps
Loss of water/km	16.13 lps

Source: Measured data (25 October 2016)

From this, we conclude that we could assume a percolation of 16 lps for one km of length.

The next table depicts canal flow from DBI inlet to the canal end when a farmer had blocked the canal to divert water into a farm.

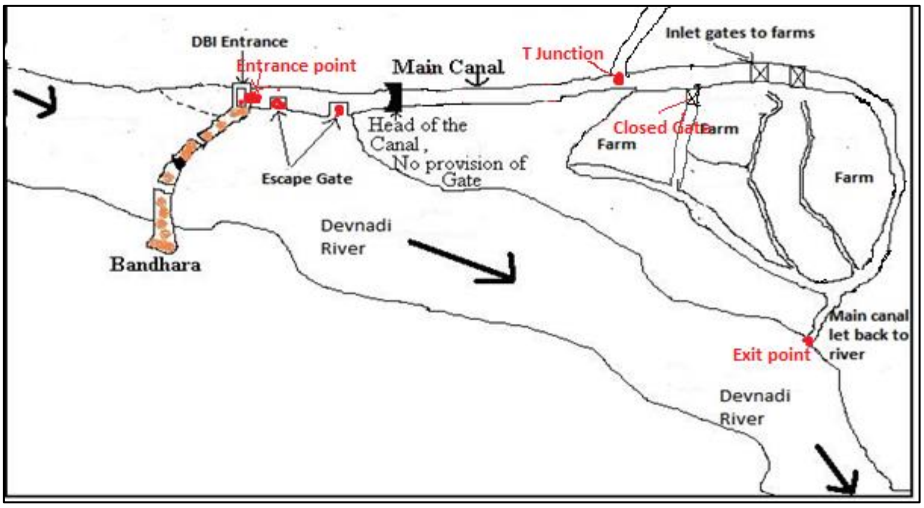


Figure 13: Measurement setup at Sinnar Vijayvaran Canal

Table 5: Flow measurements along Sinnar Vijayvaran Canal

DBI inlet into canal	360 lps
Escape gate 1discharge	170.5 lps
Escape gate 2 discharge	62.53 lps
T point junction	65.53 lps
Exit of DBI	13.508 lps
Difference between T point and exit	52.03 lps
Percolation loss @ 16.13 lps/km for 0.8 km	12.904 lps
Water flow into Minor inflow	39.126 lps

Source: Measured data (26 October 2016)

We took one DBI system i.e., Sinnar Vijayvaran which had water flowing through it. The (figure 8) is a canal network from the DBI inlet till the exit. So, we started taking readings from the inlet then there were escape gates where water was left back to the river, discharge of both the gates were calculated. Then reading was taken at T-point and at the exit. Next day we came to know that a farmer was diverting the canal water through a minor gate. The minor gate was closed on that day hence we found out the percolation rate loss on the same canal between T-Junction and exit point and we calculated the percolation table 5 as mentioned above. Using table data, we calculated the possible inflow into the canal that was present the previous day. The diversion through inlet gates to farm land was taking 39.126 lps of water. [3]

3.1.2 Discharge measurement of feeder streams

Next, we measured the role of feeder streams in maintaining the flow post monsoon. We took measurements at three feeder streams, namely Sonambe stream, Halsure stream and Dubere

[3] This value is site specific

stream. Sonari and Jayprakash stream did not have any flow. We also measured flow at Konambe Dam outlet.

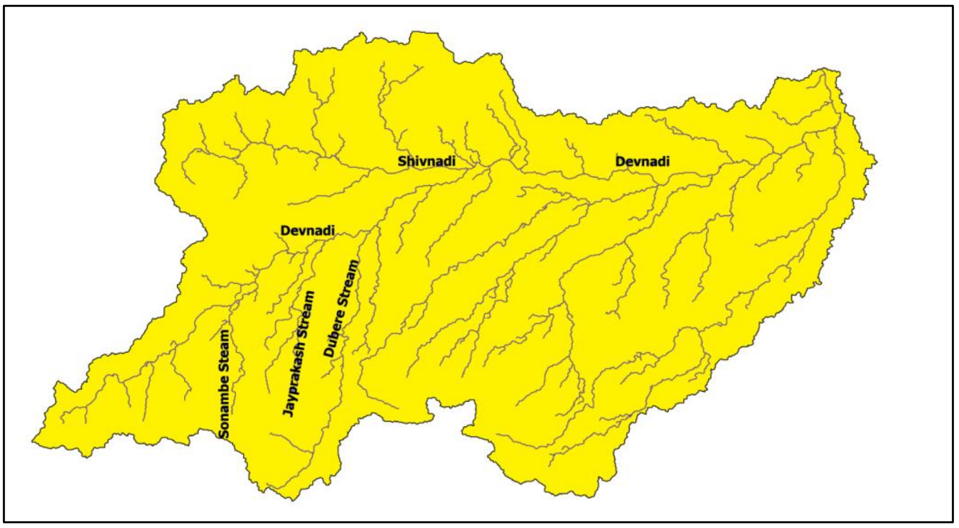


Figure 14: Major Streams feeding Devnadi in study area

Table 7: Flow contributed by streams

Location	Flow in lps
Konambe	16.9
Sonambe stream	22.75
Bibika Stream	19.44
Dubere stream	49.78
Shivnadi	223.5

Source: Measured data (26 October 2016)

A Cut-Throat Flume (CTF) is installed at Musalgaon and the following table gives its monthly data. Data recording was started in September last year.

Table 8: CTF data at Musalgaon Bk

Year	Month	Discharge (cusecs)*
2015	September	148
	October	143.5
	November	47
2016	June	6
	July	183
	August	216
	September	305
	October	315
	November	144
	December	59

Source: Measured data, YM, *Monthly discharge is sum of daily discharge recorded by YM through CTF

3.2 Findings

- Percolation of 16 lps for one km of canal length observed at Sinnar Vijayvaran4. This means 13,82,000 litres of water percolates every day and wells are benefitted by this. Thus, one of the important roles of DBI is increasing the water table in the nearby area.
- Though CTF data it is found that Vijayvaran canal was functional for ~130 days but by rainfall events and CTF data, effective percolation is assumed for 60 days. Volume of water percolated in this will irrigate 17 hectares of wheat or any crop which require 450 mm depth of water depth.[i]
- Assuming the similar water infiltration for all canals, additional 100 hectares of land of crop requiring 450 mm of water can be irrigated through these 13 DBIs.
- Although the main source of all DBIs is Konambe dam, only a small share of water in Devnadi is contributed by Konambe dam outflow in the month of October which was 16.9 lps. The main supply post monsoon to DBI system is through different streams joining Devnadi. Example, Sonambe stream contributed ~20 lps, Dubere stream contributed ~50 lps and Shivnadi contributed ~220 lps and the important point to note is, all these flows in the streams are base flows. (post-monsoon flows)
- So, if watershed treatment work like construction of cement bunds along the streams contour bund, contour trench, terracing is carried out in the catchment areas of these streams, this will have a positive impact on the water availability and longevity of DBI system.
- Additionally, desilting of Konambe dam will improve water availability post November while simultaneously avoiding a flood like situation during high rainfall events.

[4] this percolation data was found on the Environmental conditions (rainfall, climatic conditions) prevailing in last week of Oct 2016.

4 Village level GIS Mapping of DBI Structures

This chapter presents a GIS-based mapping of the DBI structures, which includes the canal network and different types of gates, the Devnadi river, different types of crossings and the road network. Different layers of mentioned structures are prepared and superimposed on the revenue map. As road networks are present in the revenue map, the road layers were not digitized separately. In each village, location of hydraulic structure and canal network on revenue map is provided in appendix B and C. We first present the methodology used for geo-referencing the different points of interest and then present the actual maps.

4.1 Methodology

For mapping of a canal, field visits were carried out to each village and important locations such as minor gates, escape gates and Cut Throat Flumes (CTF) were collected using a GPS device. These locations were marked on Google Earth and canals were drawn on the same. With the help of KML files and waypoints, the final mapping was done using QGIS software.

Steps followed for mapping:

1. Marking waypoints of accessible and known water bodies using GPS on mobile phones through GPS essentials app (at accuracy <5m).
2. Verifying mapping activity previously done by Lowe Hjorth and updating data.
3. Marking canals, sub canals, river, and hydraulic structures (cement bunds, farm ponds, earthen bunds) using Google Earth software and collected waypoints.
4. Geo-referencing village revenue map images.
5. Preparing different GIS layers for DBI, minor gates, escape gates, canals, and distributaries from data mapped above.
6. The final image of the village is prepared using Google Earth satellite image and the GIS layers. All the data and image will be transfer to YM

4.2 Benefits of Mapping

1. Easy to identify different assets.
2. Mapping is the strategic analysis of identifying and creating a visual depiction.
3. Mapping is an input for analysis and study
4. Mapping will be helpful for marking command and non-command area.
5. Finding zone of influence.

4.3 Konambe

Devnadi originates from Konambe village (Dhodbar hills) and flows through many villages. It merges into the Godavari near Sangavi, taluka Sinnar. Konambe is a large village with 575 families. The village has a population of 3113 of which 1632 are males while 1481 are females as per Population Census 2011. Most of the families depend on agriculture and related business, thus irrigation water is a basic need. To fulfill irrigation water demand, many hydraulic structures are constructed on Devnadi. An earthen dam, three cement bunds, and one DBI is present in the village. Details are as follow

Figure 15: Konambe dam

Figure 16: Konambe Google Earth map

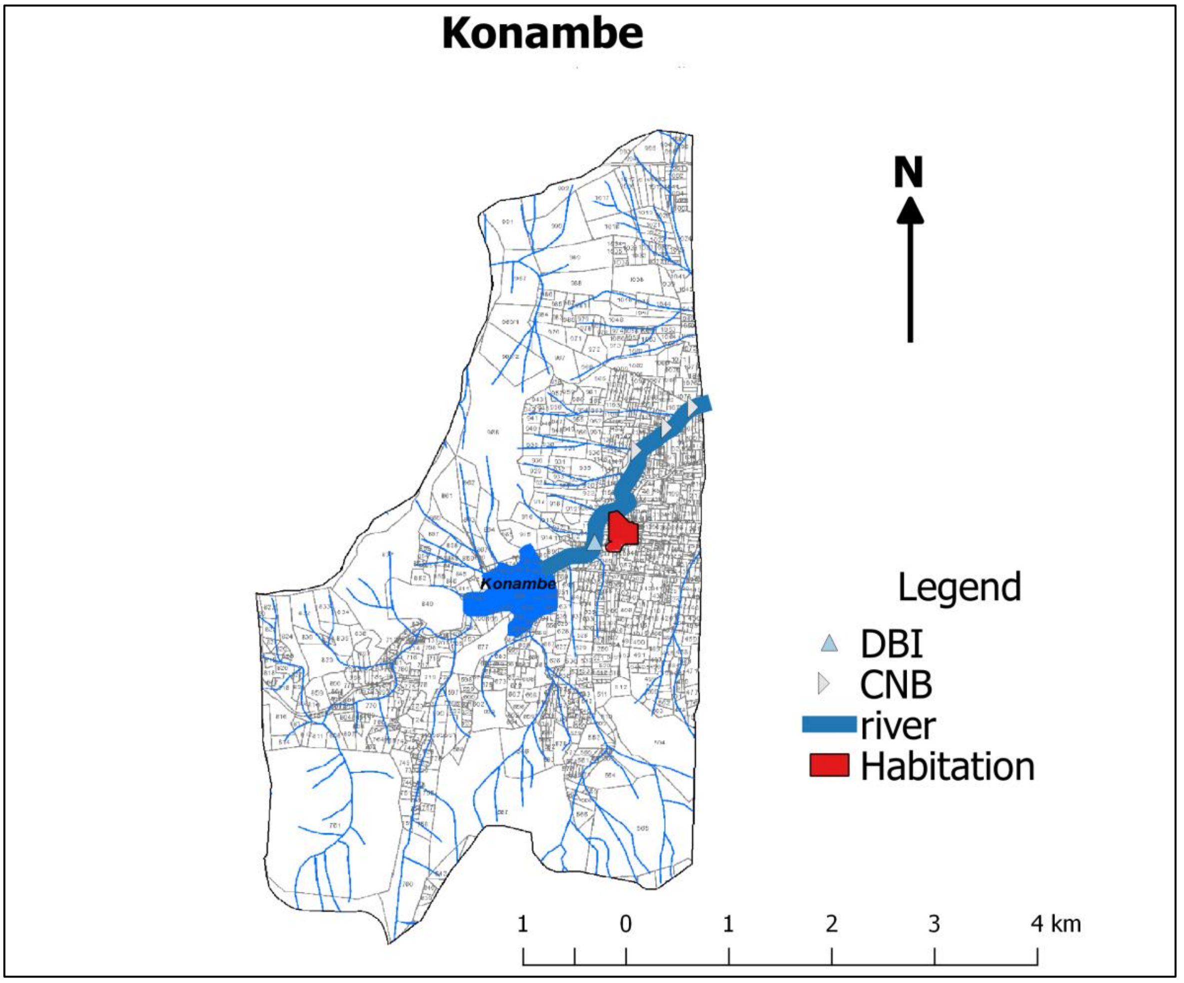


Figure 17: Village map of Konambe

Key Comments -

1. DBI 73 is not functioning for 20 years.
2. Desilting of Konambe Dam is required
   a. Konambe dam is major dam on Devnadi having length ~400 m. Current submersion area of the dam ~18 hectares. Dam is highly silted, silt deposits are about 8 feet. Irrigation potential increase after removing silt is shown below
   b. Due to desilting, irrigation potential can be increased by another 40 to 80 ha.

Table 9 :Konambe dam desilting calculation

Area (ha)	Area (m^2)	Excavation Depth (m)	Increase in storage (m^3)	Irrigation potential (ha)
5	50000	3	150000	30
5	50000	4	200000	40
7	70000	3	210000	42
7	70000	4	280000	56
10	100000	3	300000	60
10	100000	4	400000	80

   c. Desilting will increase capacity of dam and reduce flooding condition as canals will start later in the monsoon and last well into the rabi season.

4.4 Sonambe

Three DBIs are present in Sonambe. Earlier these canals were not functional due to lack of maintenance. When DBI regeneration on Devnadi was done, all canals became functional and people benefitted by this work. Through DBI, water is diverted into the main canal, minor gates are located on canals and farmers use these gates to irrigate their fields. In Sonambe, five cement bunds and 11 farm ponds are present. (Table 11)

Figure 18: Sonambe DBI-74

Figure 19: Image of minor gate with chainage and gate number

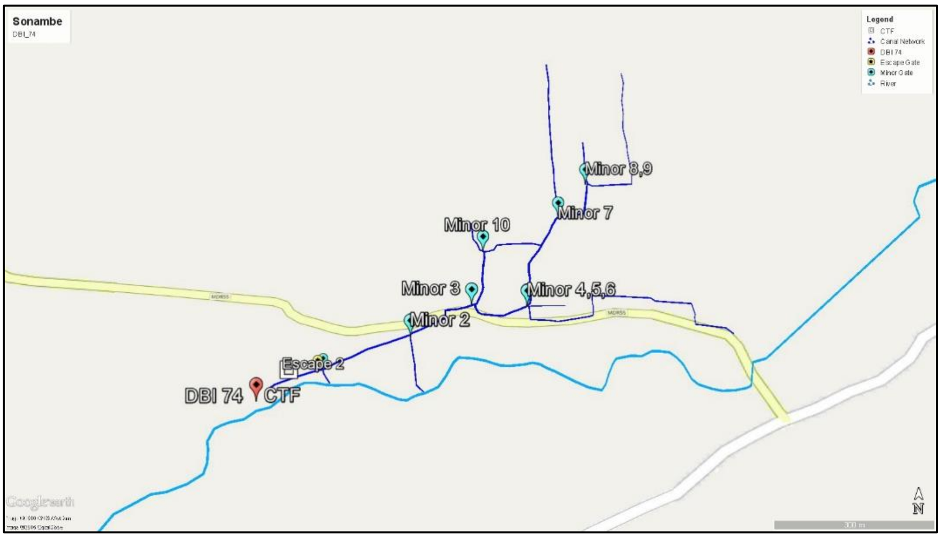


Figure 20: Sonambe DBI 74 Google Earth map

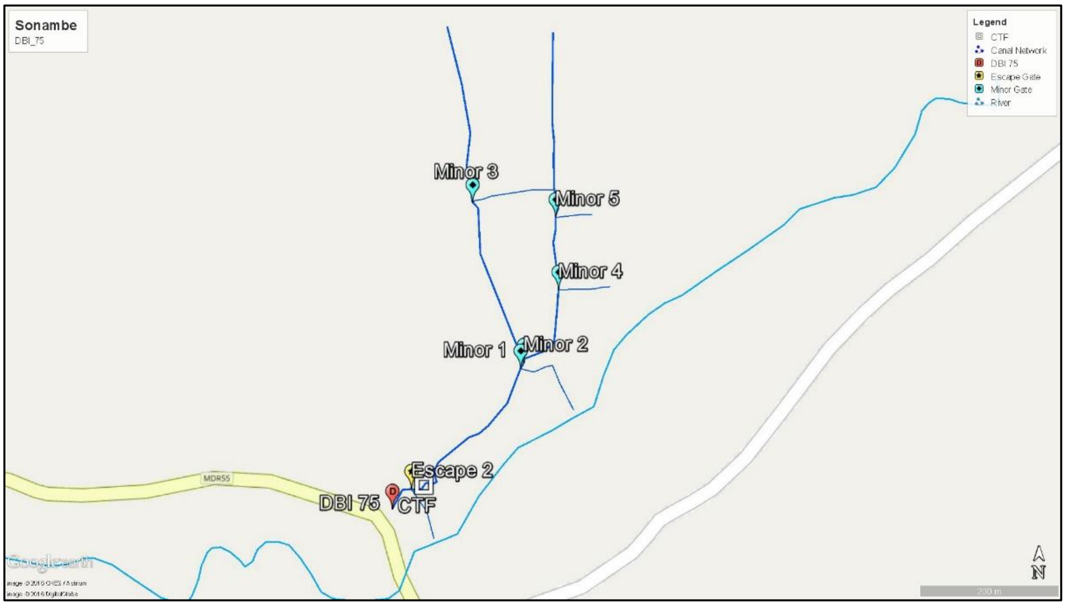


Figure 21: Sonambe DBI 75 Google Earth map

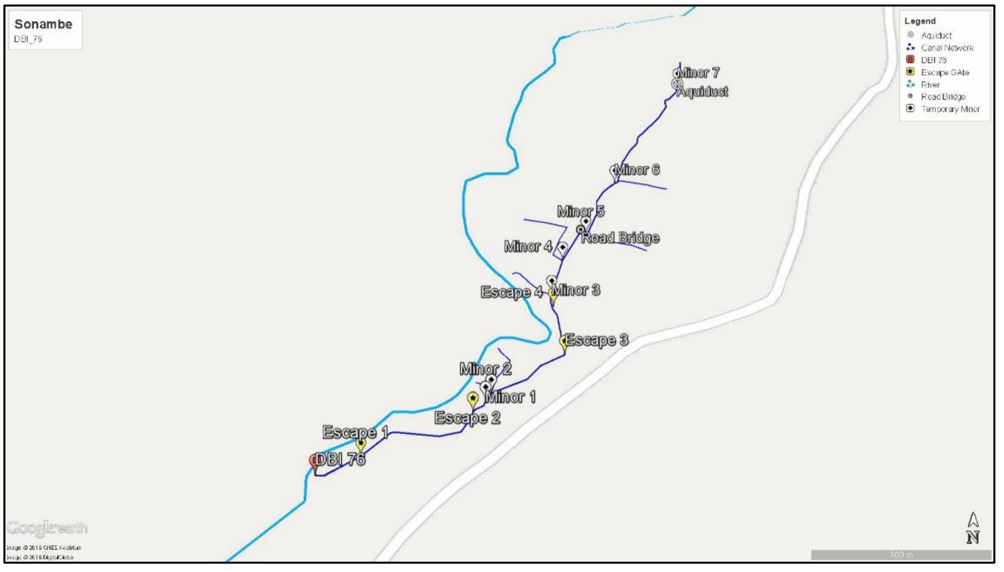


Figure 22: Sonambe DBI 76 Google Earth map

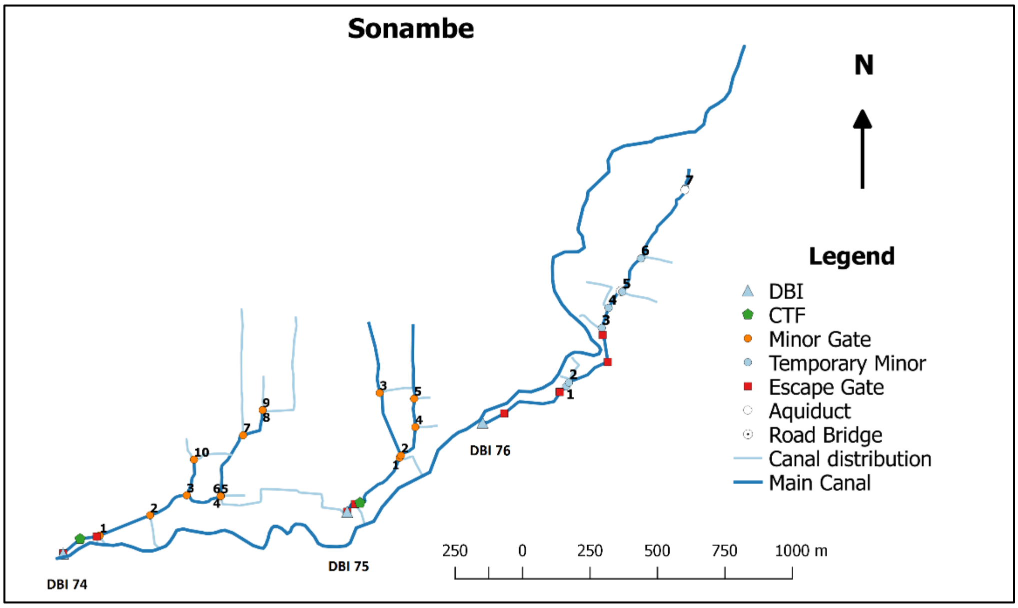


Figure 23: Sonambe canal network

Key Comments

1. Chainage and Minor gate numbers are written on each minor gate.
2. Every minor is permanent, no temporary minor found in DBI 74 and 75.
3. All the minors are temporary in DBI 76.

4.5 Wadgaon Sinnar

DBI 77 is in Sonambe but all the minors are in Wadgaon Sinnar so it is known as Wadgaon canal. Only three permanent minors were observed in Wadgaon Sinnar; with the help of temporary minors on the canal, farmers are diverting water into their fields. Detail study of this village is done in chapter 0. Eleven cement bunds and eight farm ponds are present in Wadgaon Sinnar on Devnadi. (Table 12)

Figure 24: Wadgaon Sinnar DBI 77 Google Earth map

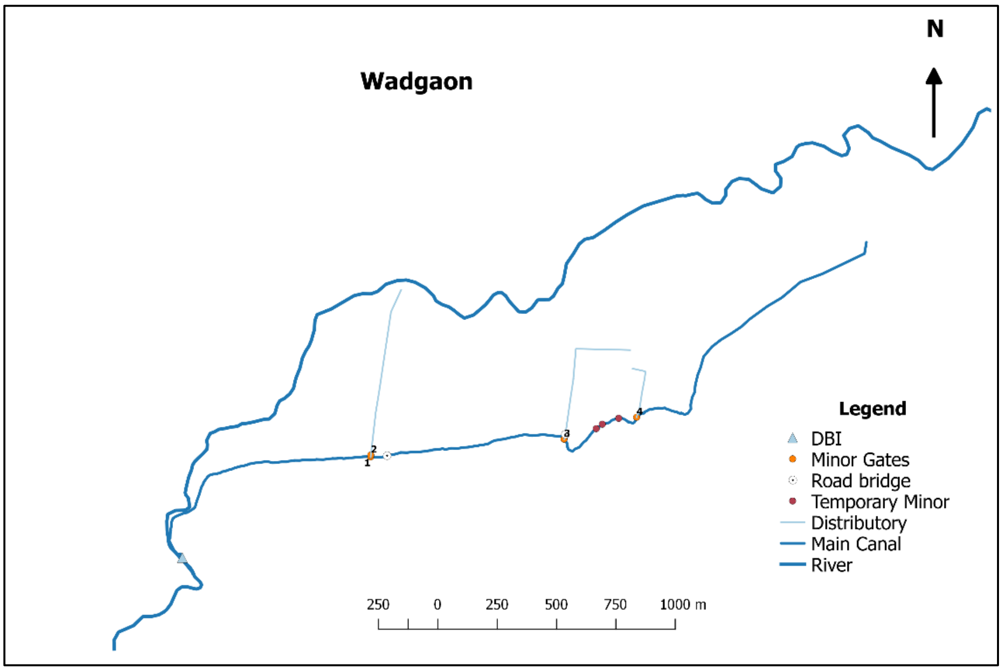


Figure 25: Wadgaon Sinnar canal network

4.6 Sinnar

Sinnar Vijayvaran (DBI number 82) and Kotam (84) DBI are in Sinnar. Except for escape gates and 2 minors, all observed minors are temporary in Kotam. Yuva Mitra has started works to make permanent minors on the nine 9 minor gates in Kotam.

In Sinnar, Devnadi and Shivnadi meet each other and are known as Devnadi. Structures are built on both the rivers, fifteen cement bunds and six farm ponds exist in Sinnar.(Table 12)

Figure 26: Sinnar Vijayvaran DBI 82 Google Earth map

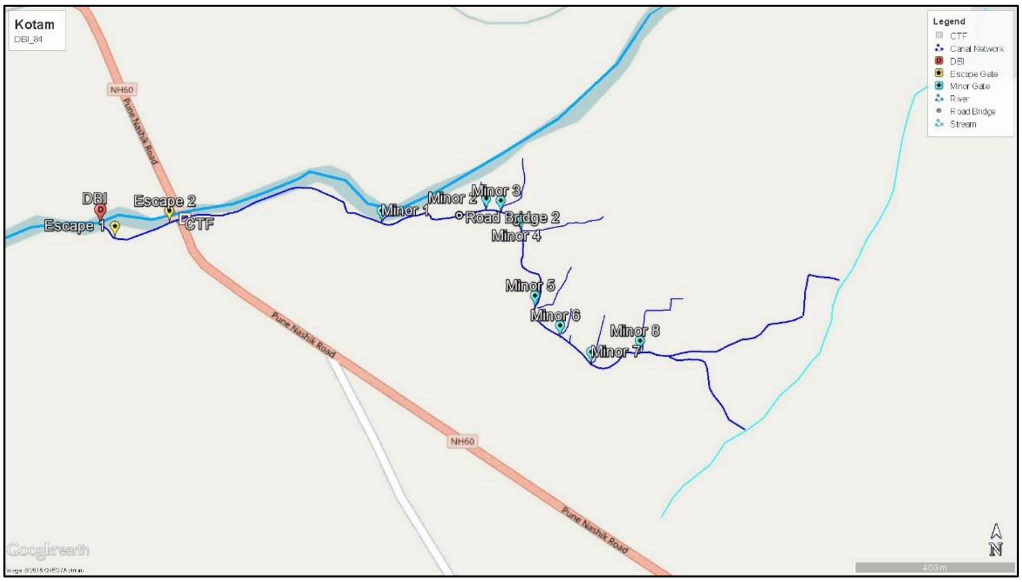


Figure 27: Kotam DBI 84 Google Earth map

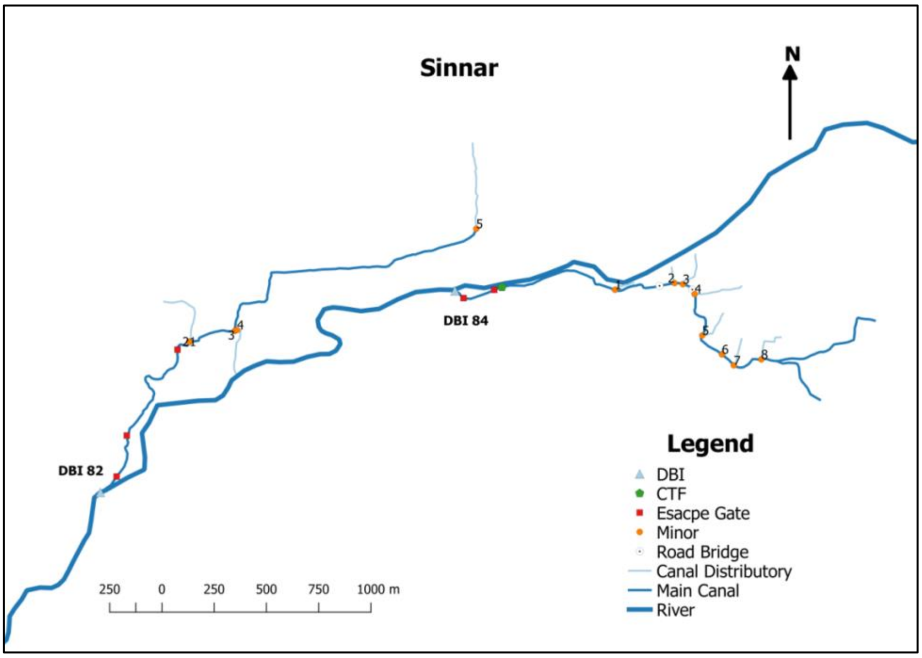


Figure 28: Vijayvaran and Kotam canal network, Sinnar

Key comments

1. DBI 83 is not functional.
2. Only three minors are present on DBI 82 and CTF was broken.
3. Regeneration of DBI 84 was ongoing(December 2016)

4.7 Kundewadi

Actual visit was not done to this village but all locations were collected by Yuva Mitra employee and same were used for mapping. Four cement bunds and two farm ponds are located in Kundewadi (Table 14).

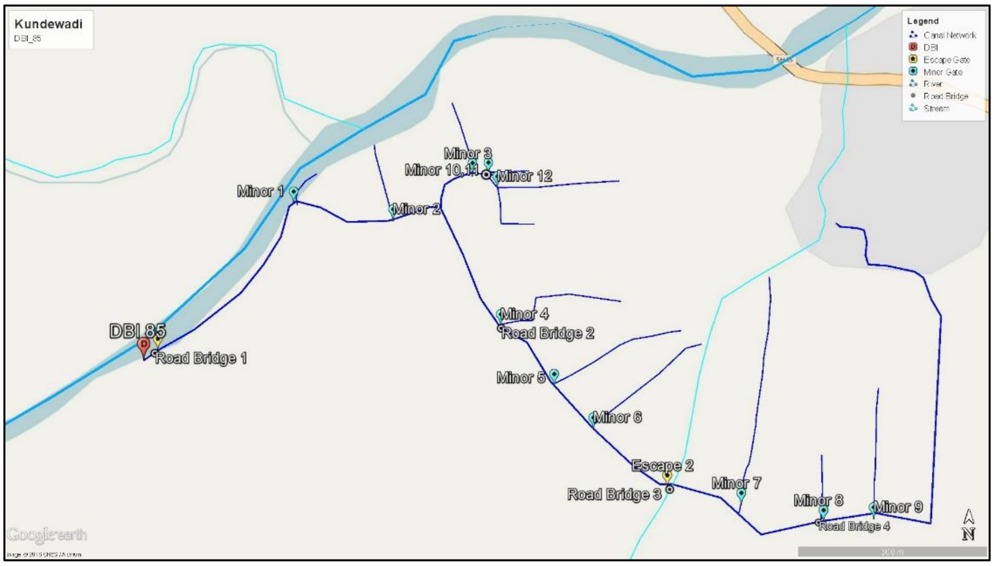


Figure 29: Kundewadi DBI 85 Google Earth map

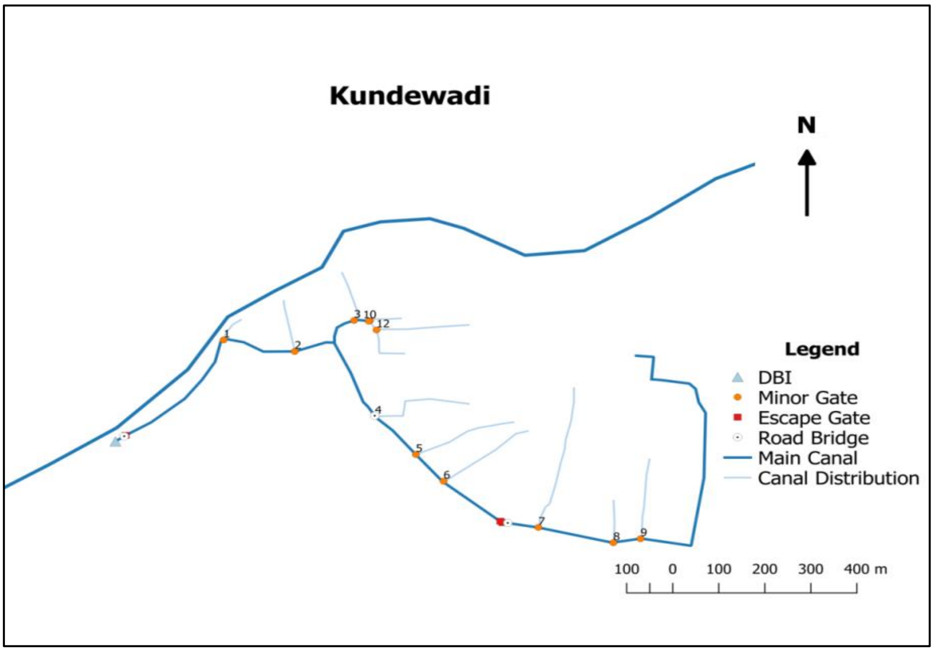


Figure 30: Kundewadi canal Network

Key comments-

1. All the minors are permanent.

4.8 Musalgaon

Longest canal length is in Musalgaon. The network of DBI 86 and 87 is spread in the village with a length of 3.7 km and 4.2 km respectively. A Large area of the village is benefitted as two canals and the river flows through this village.(Table 15)

Figure 31: Musalgaon DBI 86 Google Earth map

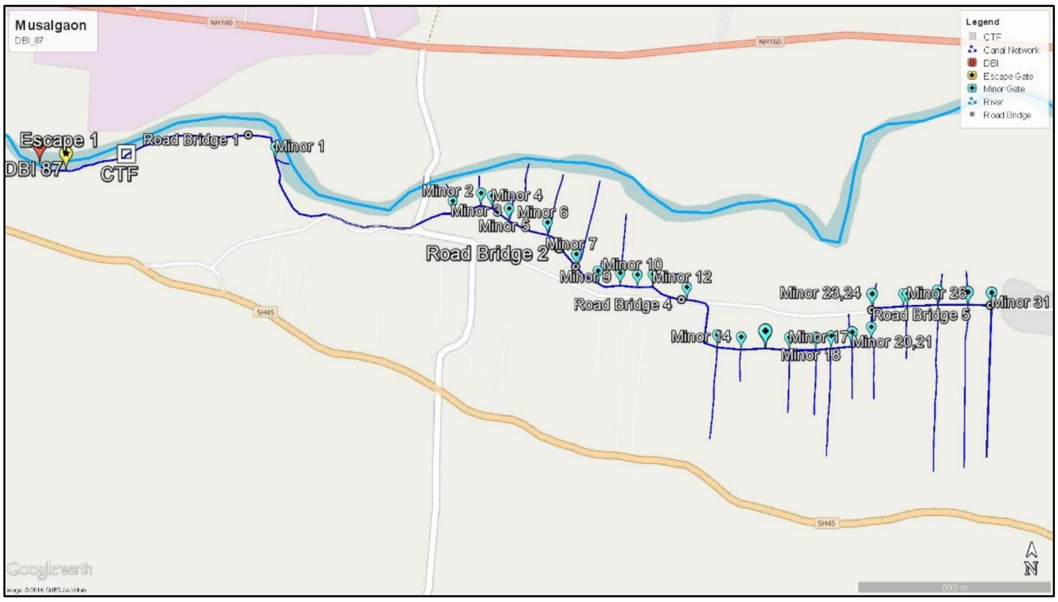


Figure 32: Musalgaon DBI 87.Google Earth Map

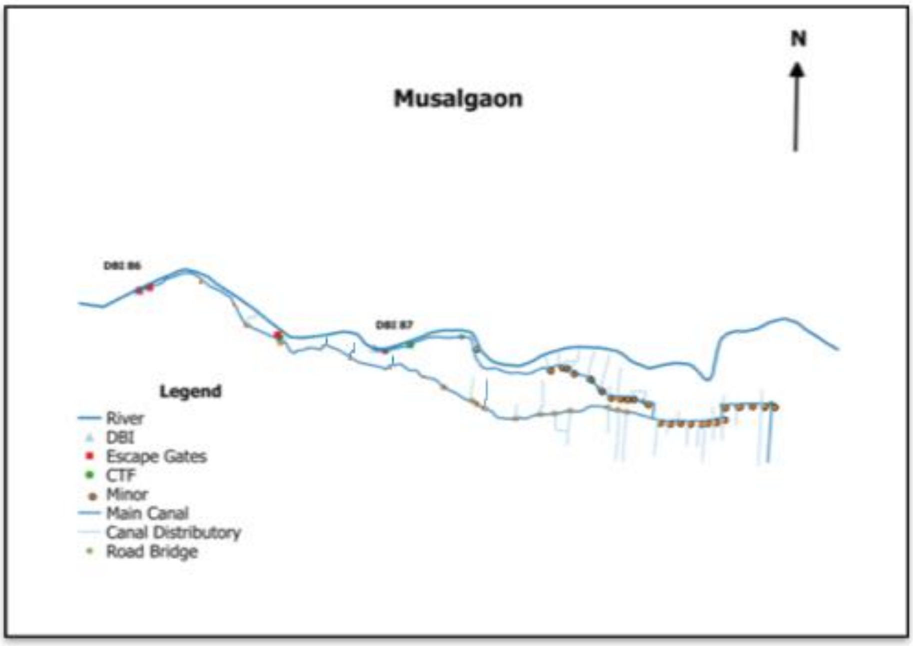


Figure 33: Musalgaon canal network.

Key comments-

1. Maximum length of canal is observed in this village.
2. Before the Junction of 86 and 87 many bushes observed in canal.

4.9 Datali

Two cement bunds are present on the river and are beneficial to the village but are not in revenue boundary of the village.(Table 16)

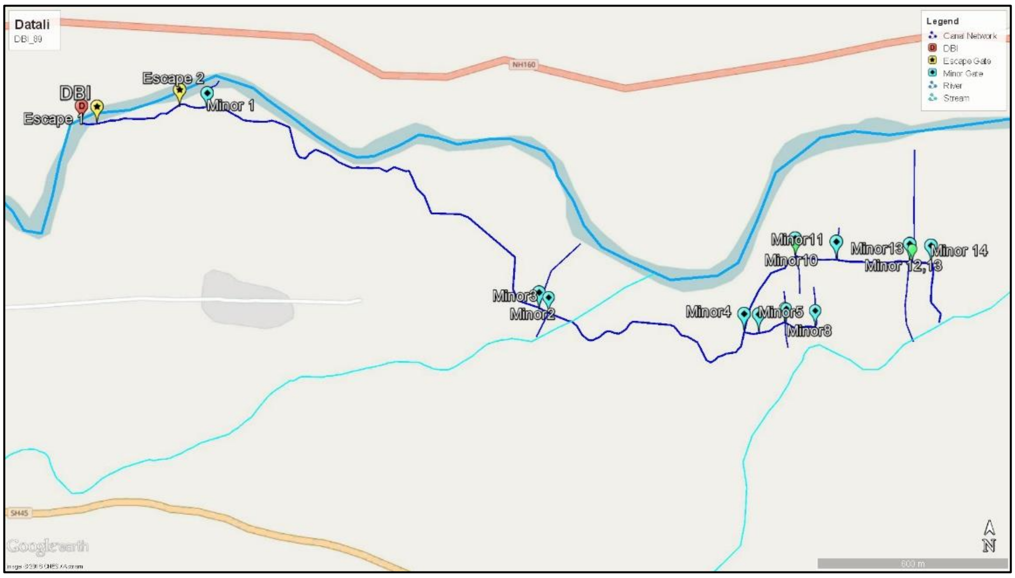


Figure 34: Datali DBI 89.Google Earth Map.

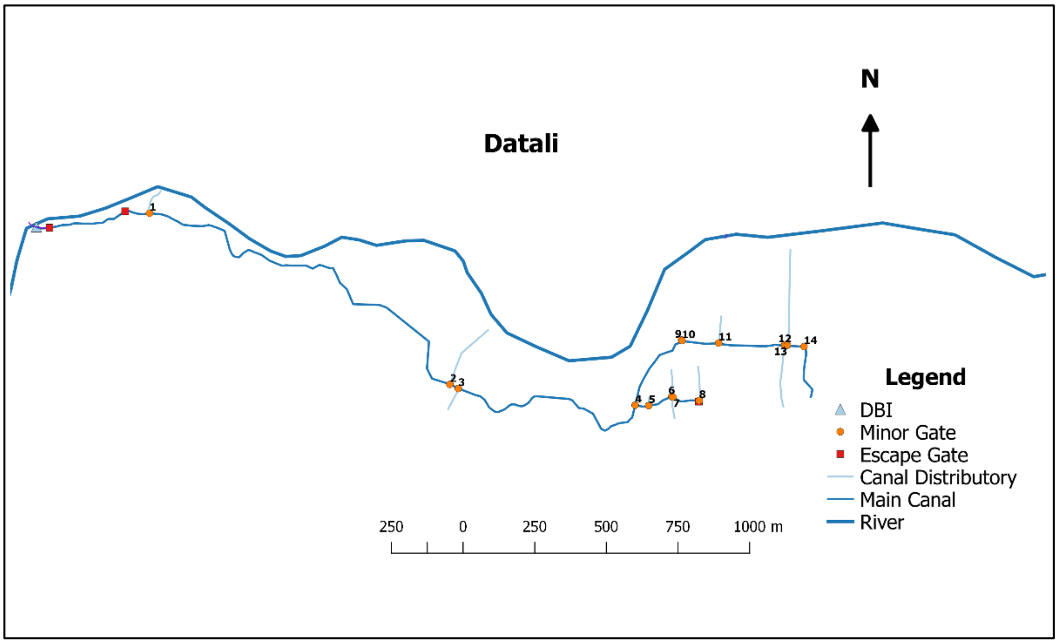


Figure 35: Datali canal network.

4.10 Khopadi Budruk

All minors in Khopadi Bk. are temporary and DBI originates from Datali. It flows through 3 villages named Datali, Kedarpur and Khopadi Bk. Two cement bunds were constructed last year under Jalyukt Shivar Abhiyan.(Table 17)

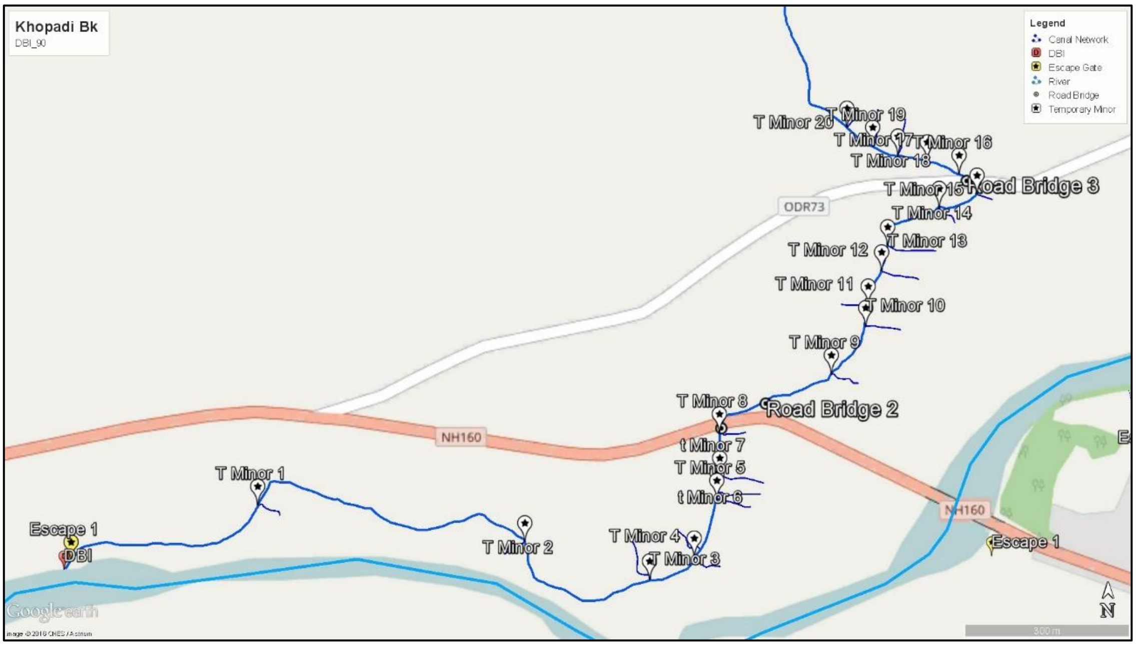


Figure 36: Khopadi Bk 90.Google Earth Map.

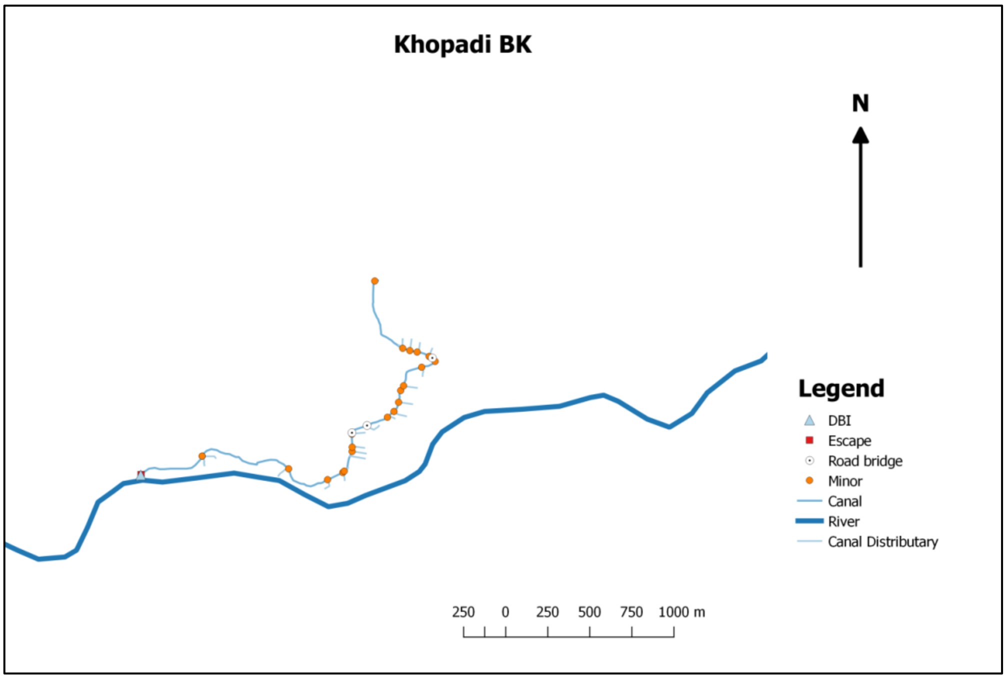


Figure 37: Khopadi Bk canal network.

Key comments –

1. All the observed minor gates are temporary and escape gate are permanent
2. At the end canal meets percolation tank.

4.11 Khopadi Khurd

Thirteen farm ponds are observed in Khopadi Kh. Village. All the minor gates are permanent. Four cement bunds and thirteen farm ponds are present in this village.

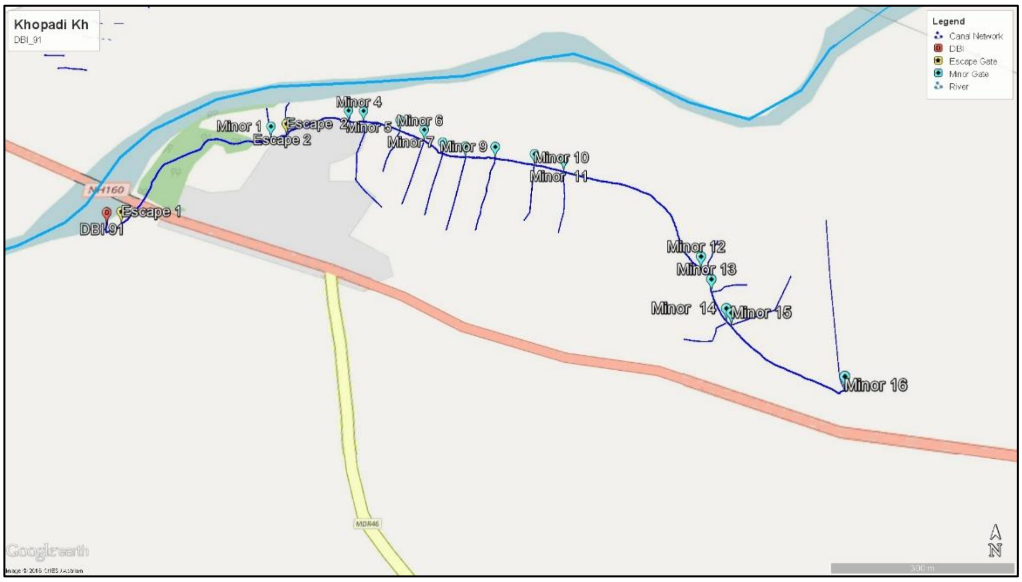


Figure 38: Khopadi kh 91.Google Earth Map

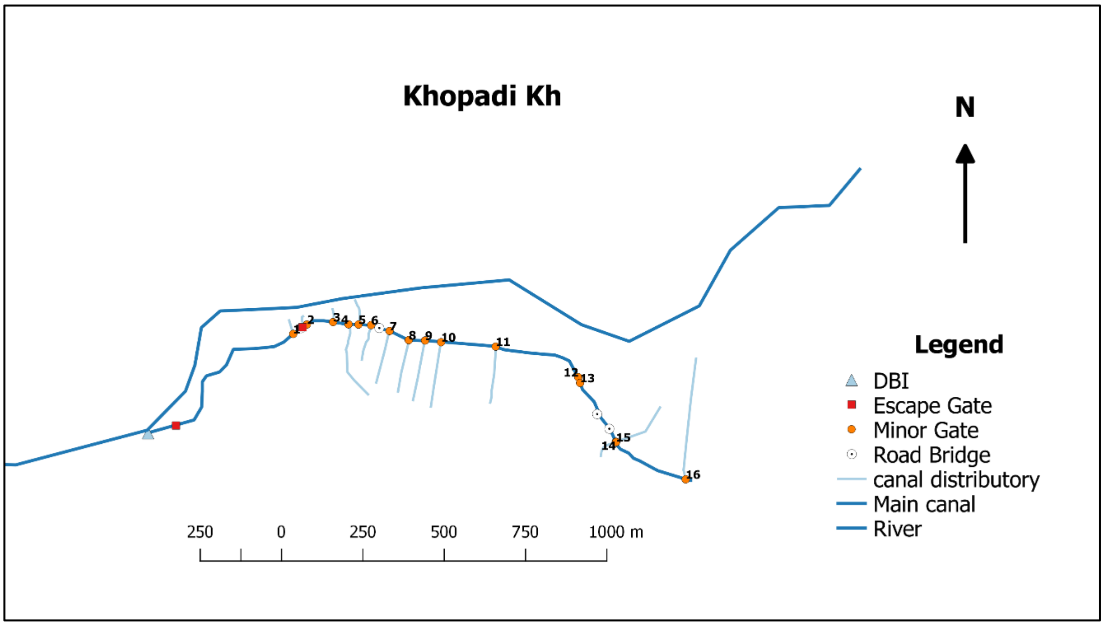


Figure 39: Khopadi Kh canal network

Key Comments –

1. Peoples do minor repairs of this canal
2. As per people perception this canal is better functioning than Khopadi Bk

4.12 Deopur

Deopur detail study is described in Section 5.2. Two cement bunds, two percolation tanks, and fourteen farm ponds and one DBI are present in Deopur.

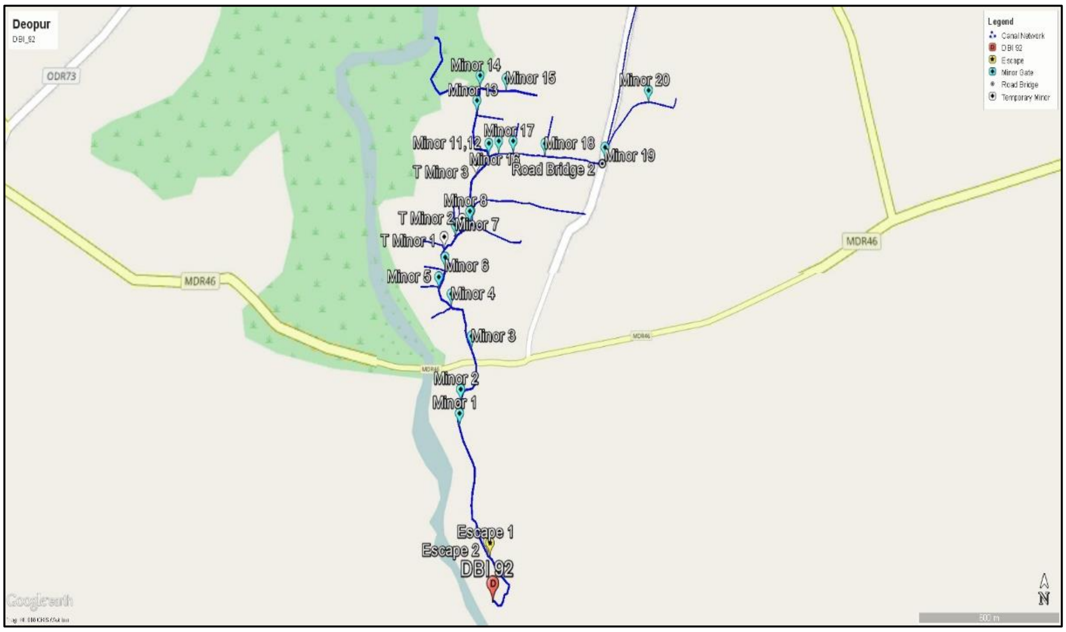


Figure 40: Deopur DBI 92 Google Earth Map

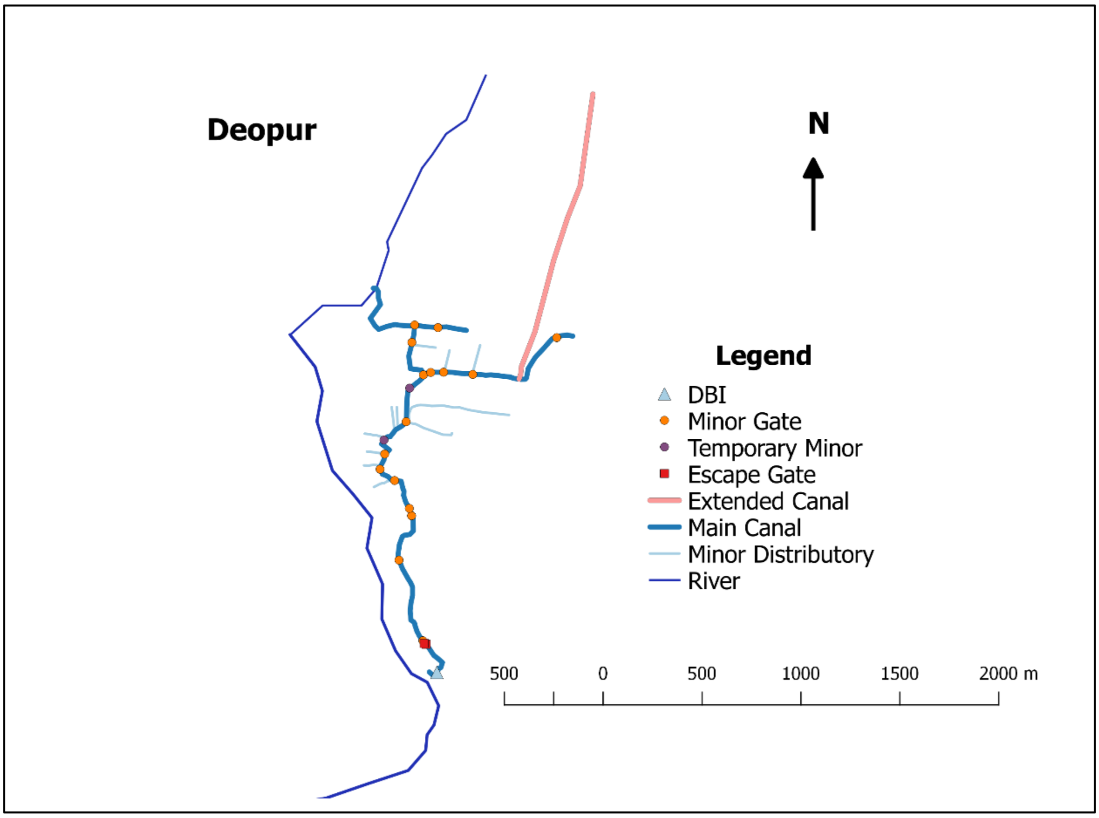


Figure 41: Deopur canal network

5 Detailed analysis of Wadgaon Sinnar and Deopur villages

Detail study of two villages includes socio-economic impact study, well analysis and command area marking in these villages. For this study, we selected Wadgaon Sinnar and Deopur village. Wadgaon Sinnar was selected because regeneration of canal was done five years ago, and few of CTARA students did a base study in this area. Deopur is selected because it is tanker fed and as rejuvenation work was carried out last year (2015). Wadgaon Sinnar is near to Konambe dam and Deopur is at the farthest end.

5.1 Wadgaon Sinnar

Wadgaon Sinnar is situated on the banks of Devnadi and 3 km away from Sinnar. Two streams flow from South to North and meet Devnadi. The eastern stream is known as Dubere and the western stream is called Atkawde stream. To carry out a detailed study, we followed the following methodology:

5.1.1 Methodology

1. Preliminary visit and meeting with Yuva Mitra officials and volunteers
2. Collection of secondary data
    a. Revenue map
    b. Base line survey data of Wadgaon Sinnar from YM
3. Marking of canal on revenue map
    a. Location of all minor gates and canal distributaries collected and mapped in Google Earth and QGIS.
4. Zoning of village based on geographical position
5. Well study and analysis
    a. Deciding cross section
    b. Sampling of wells
6. Socio-economic study – questionnaire survey
7. Reporting of analysis

In the preliminary visit, basic topography and overall condition of the village was studied and in next visit location of all minor gates and canal distributaries were collected. Mapping was done on Google Earth and QGIS (chapter 4.5).

5.1.2 Area division for analysis

Wadgaon Sinnar was divided into three zones. The zoning was done based on location between river, canal, and stream. These three zones were named R-C zone, C-S zone, and S-S zone.

R-C zone is the area between river and canal as shown in the figure (green zone, zone 1), this zone would naturally have more water availability because of its elevation and presence of river and canal. Next is the C-S zone (sky blue zone, zone 2), the area between the canal and Dubere stream. Here the influence of canal and stream could be understood. The third is the S-S zone (red zone, zone 3) where the area is influenced only by Dubere stream. By this division of the village into three zones influence of each factor namely river, canal and stream on the groundwater were to be understood.

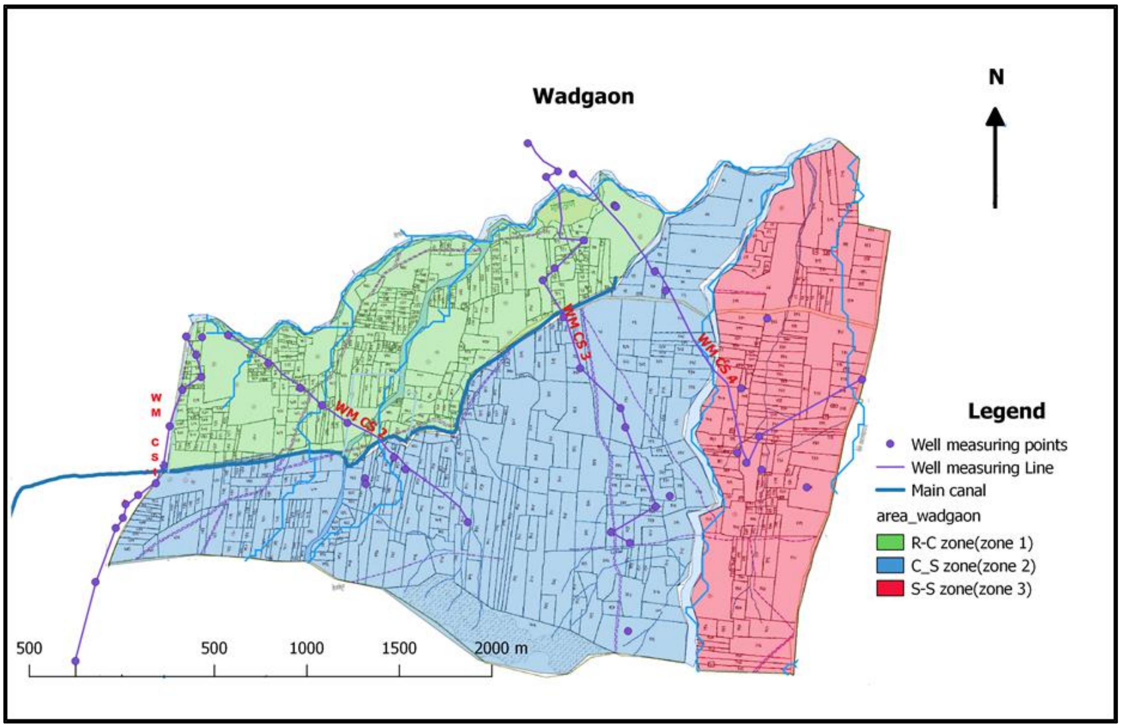


Figure 42: Wadgaon Sinnar zoning

5.1.3 Sampling of wells

Once these zones were defined wells were chosen along 4 cross-sectional lines drawn across three zones as shown in the figure. These lines started at the river and culminated at the village boundary. On these lines, wells were chosen at regular interval if available.

Once the wells were chosen, fieldwork was started wherein the location, depth, and the present water level was recorded at regular intervals. In case water was being pumped, the level where the soil/ murum was wet was considered as water level. Also, elevation data of each well was recorded. Well readings will be recorded till summer (May 2017) or till the wells go dry. Data thus obtained will give a spatial and temporal understanding of water table in the region. In brief, as part of understanding the hydrological condition in the region well readings in these cross sections are recorded and analyzed.

5.1.4 Socio-economic survey

To observe the impact of DBI on livelihood, cropping pattern, well water availability, change in yield of crop and drinking water scarcity, a survey questionnaire is developed. Surveys were carried out in such a way that the whole village must be covered and extrapolated at the village level. Surveys were taken near canal and river and away from the canal. Before progressing to field basic study of a village was carried out and zones which are made earlier (chapter 5.1.2) are used to see the effect of the canal. The main purpose of this study is to find direct and indirect command area and perception of farmers about DBI. The survey form was designed in such a way that past year data should be captured. Information like source of irrigation, the number of wells, pump information, cropping data, the impact of DBI, etc. was collected for each survey. Interviews of farmers were carried out by team members. Though many parameters were collected through the socio-economic survey, analysis of command area and WUA is done. Survey form is attached in Appendix A.

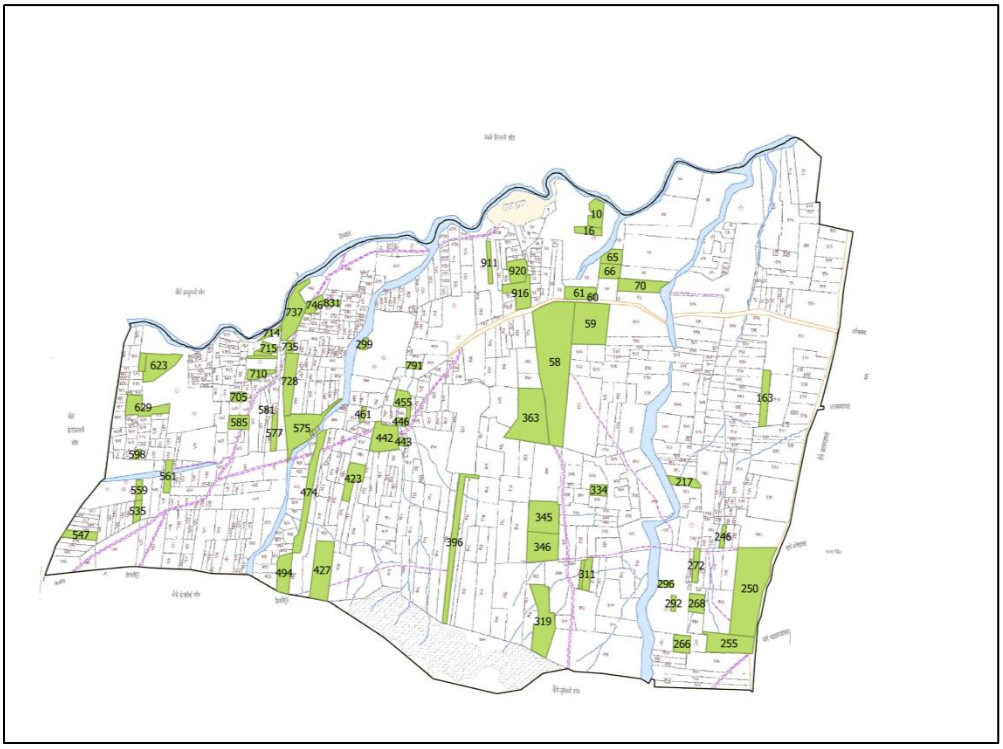


Figure 43: Surveyed farmers, Wadgaon Sinnar

Total 43 farmers were surveyed. During the survey, Gat (plot) information of 86 plots was collected. The survey showed that out of 43 farmers, 19% said that they use DBI minor for irrigating their fields. 44% farmers were found to be in indirect command area (i.e. either they reported their wells getting recharged due to canal or canal + river). Apart from farmers benefiting from the canal, 37% farmers were outside command area of the canal. Out of these, almost half were rain fed farmers and other are benefited by structures.

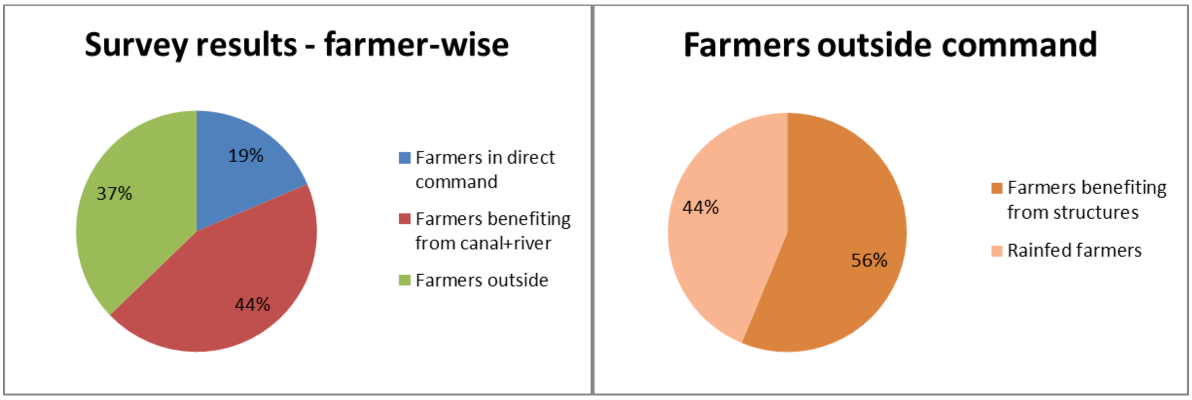


Figure 44: Survey results - farmer wise, Wadgaon Sinnar

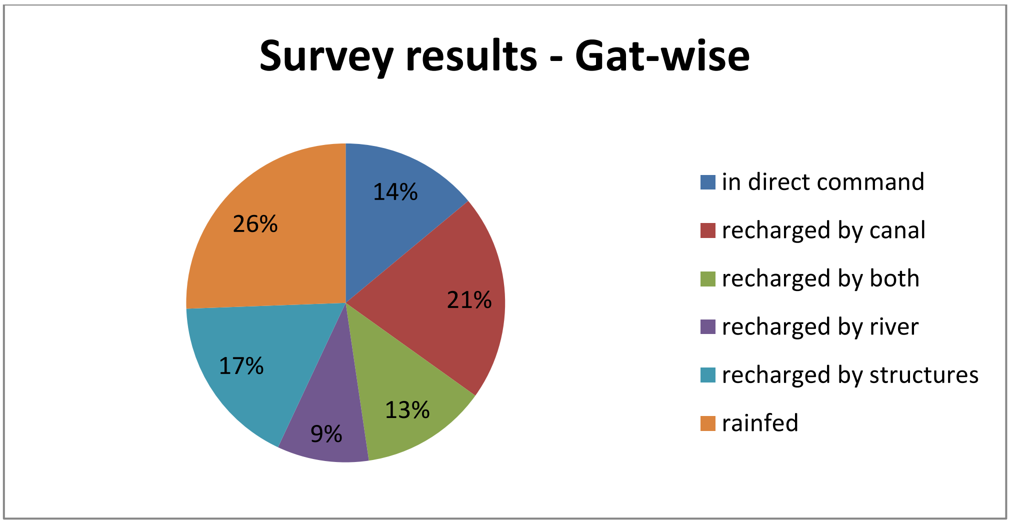


Figure 45: Survey results - Gat wise (irrigation method), Wadgaon Sinnar

Water user association (WUA) plays important role in operation and maintenance of canal still 37% farmers are aware of WUA. 44% and 12% farmers from command area and non-command area respectively are aware of WUA[ii] as shown below.

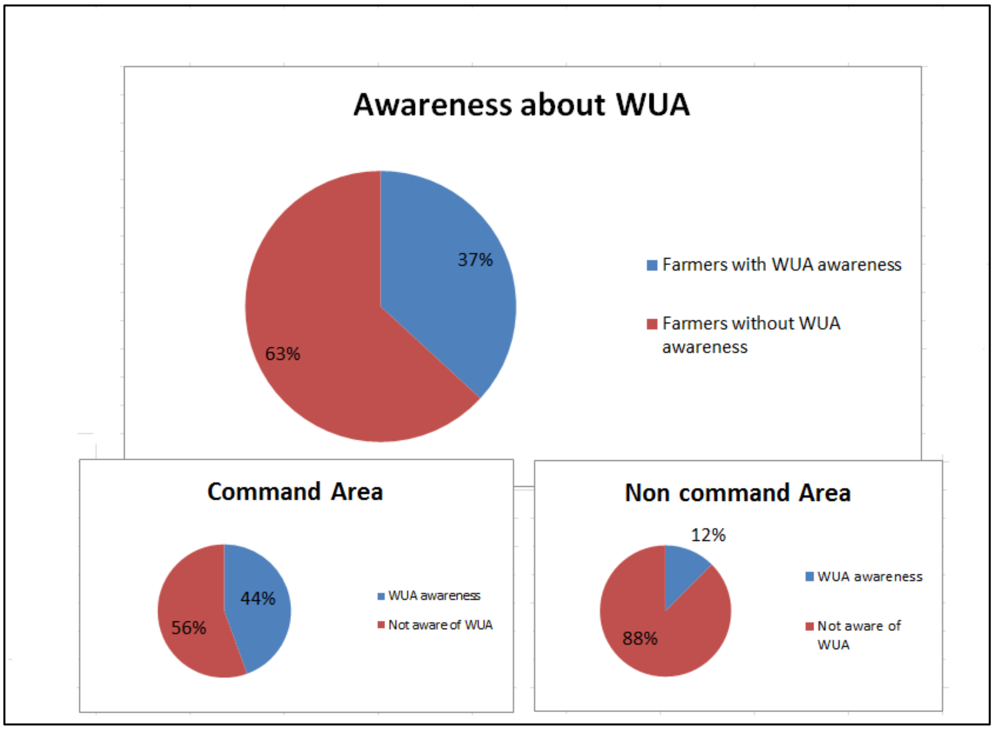


Figure 46: Survey results - Awareness about WUA, Wadgaon Sinnar

Through survey it is found that major crop in Kharif is Soyabean followed by Onion, tomato and Bajra. Previously in baseline survey by YM before the regeneration, the major crop was Bajra followed by Maize and Onion. Now, in rabi season major crop observed is Wheat followed by onion, while before the regeneration major crop was wheat and Gram.

1. Thus it can be seen that due to the intervention, cropping pattern has changed towards high water usage crops with better returns as there is now assured irrigation.

WUA member are responsible for canal related activities. In Wadgaon Sinnar, few people who are unaware about WUA, are maintaining canal in patches. If such people are connected to WUA, canal functioning will improve.

5.1.5 Well analysis

Well readings were recorded thrice between November and January. The data obtained was normalized against the elevation in terms of water table level, elevation, and depth of the well. Then the water column for each of the well was marked as seen in the attached graph. This process was followed for all the four cross-sections marked as in Figure 42: Wadgaon Sinnar zoning.

For nomenclature here, numbers are for cross section number and alphabets denote readings taken in different months.

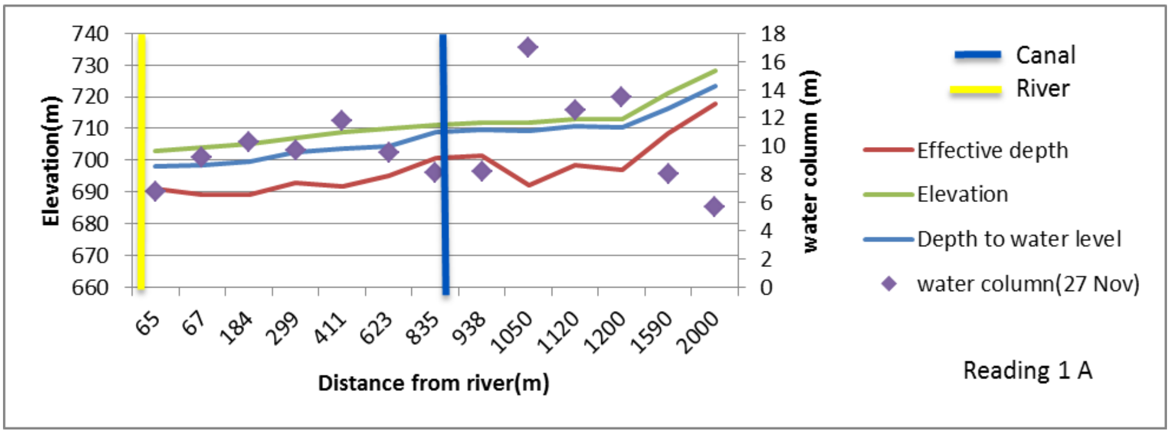


Figure 47: Well data in November (27 November 2016), Wadgaon Sinnar

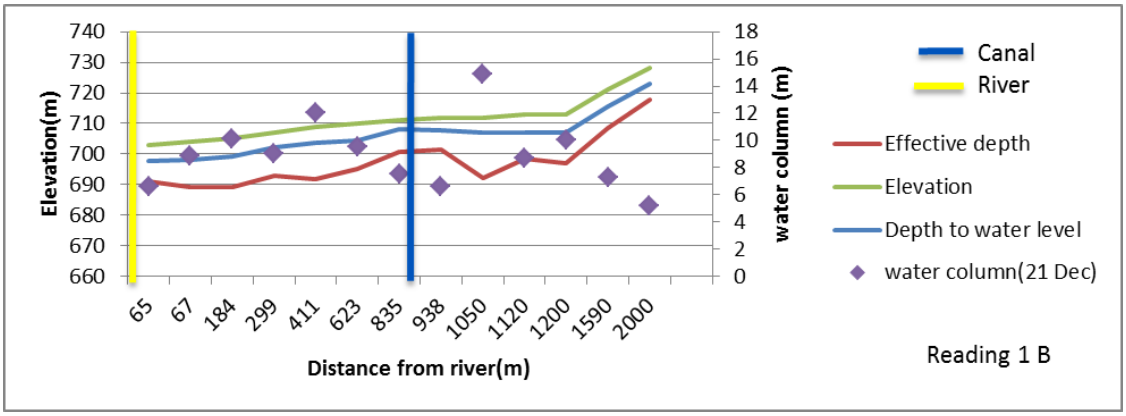


Figure 48: Well Data in December (21 December 2016), Wadgaon Sinnar

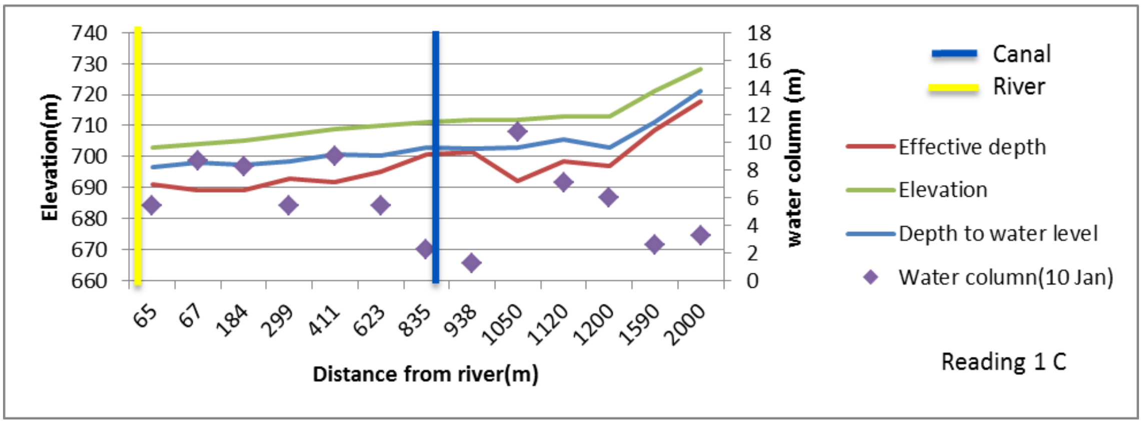


Figure 49: Well Data in January (10 January 2017), Wadgaon Sinnar

From Figure 47 and Figure 48, the difference between elevation line and depth to water level line is slightly increasing which means water level starts falling. From Figure 48 and Figure 49, the difference increases further.

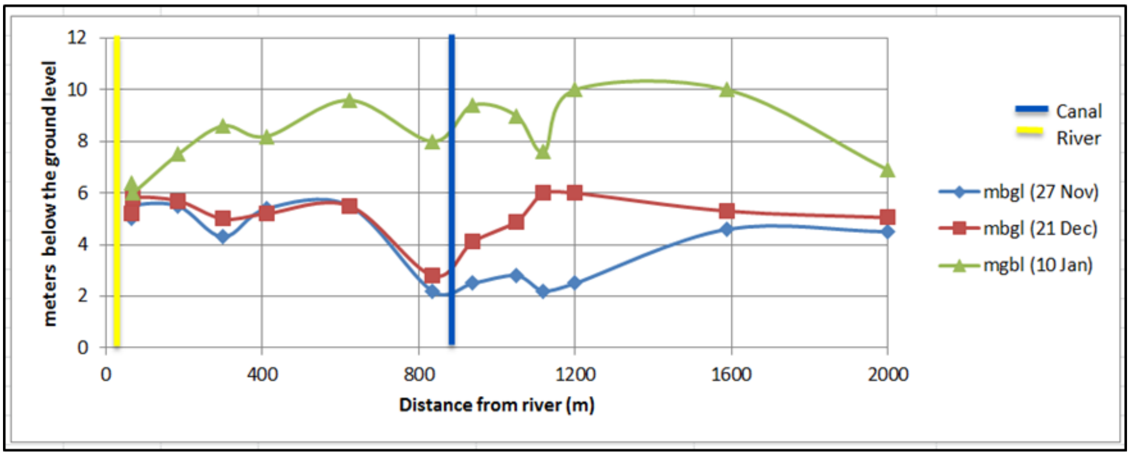


Figure 50: Water table below ground level cross section 1, Wadgaon Sinnar

With the above figure, it is seen that water level falls suddenly in a month of January. However, drastic change was not seen in the region between river and canal in month of December. Canal functioning stopped in the first week of December 2016. The Same analysis was done for other three sections (Appendix D).

5.1.6 Command and Non-command area

Only three minors are present in Wadgaon but the farmers who are near to canal irrigate their field with help of temporary minor. Command area is marked based on visit details, field observation, and topography.

For non-command area marking, well cross-section analysis, socio-economic survey and well-recharge by canal flow data are used.

As per survey analysis and field observation, direct and indirect command area (wells benefited by the canal) was delineated on revenue map. During the survey, out of 86 Gat numbers, the source of irrigation for 20 Gat numbers is through lifting water from other Gat numbers. Out of these, around 80% were lifting water from wells recharged by the canal. This increases the area benefited by the canal. The exact area could not be estimated because all farmers were not surveyed. This requires more concrete study of water use of all farmers. It is found that very few farmers irrigate their field through chari, the main purpose of the canal is to recharge nearby wells.

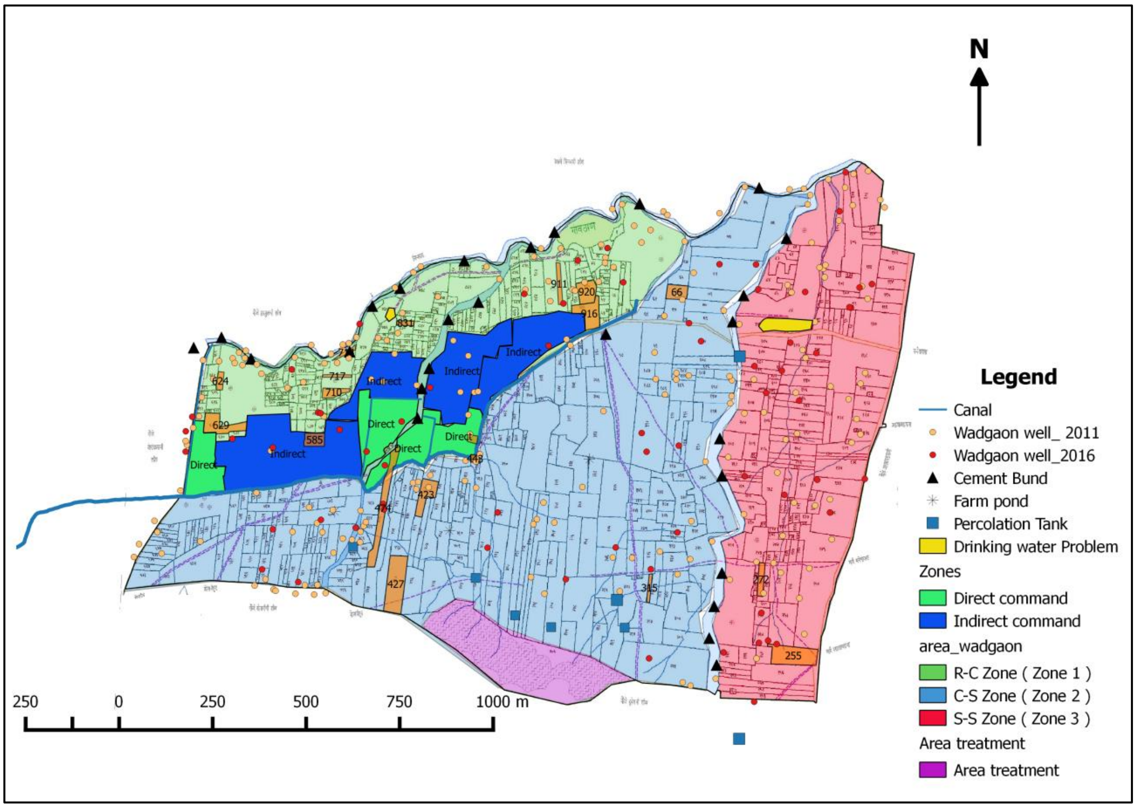


Figure 51: Details of Wadgaon Sinnar

5.1.7 Findings

1) Drinking water scarcity

   Two habitations were identified where drinking water problem was found. (See map: Figure 51: Details of Wadgaon).

   a) Dokimala – an Adivasi hamlet of the village- had severe drinking water scarcity. Their common hand pump had run dry after a grape farmer had dug a bore well right next to the hand pump.
   b) 5 families live near MSCB station; they don't have any drinking water source. They are landless and depend on neighbors for drinking water.

2) Command area

   a) In Wadgaon Sinnar, very few farmers irrigate their field through direct minor distributaries (chari) but canal water is recharging wells in the nearby area which is beneficial for a lot of farmers.
   a. Direct command area of the canal is 25 hectares and indirect command area is 60 hectares. These numbers are derived based on survey data and visit details.

3) Well data

a. There is a trend of decreasing water column in the area above the canal. The difference between elevation line and depth to water level line is slightly increasing which means water level starts falling.
b. In 2011 around 210 wells are found and in 2016 number increases to 270, in that more than 33 % wells are constructed in the Zone 3. Wells are evenly distributed in red zone. This spike may be due to the hydraulic structure on Dubere stream.
c. In the zone between river and canal (Green area), fall in water level is very low as there is ground water pressure from canal and river. In the light green zone, well water level has started declining faster than green zone.
d. Effect of canal is not observed after cross-section 2 in the month of December.
e. Compare to cross section 1, cross section 2 and 3 has high ground water potential.
f. Influence area of canal decreases from head to tail, i.e., wells near cross section 1 are most benefitted than those of cross section 4. (influence width)

4) Watershed
   a. Two streams flow through Wadgaon Sinnar along with Devnadi. Eleven cement nala bunds are constructed on the river and about twelve interventions on Dubere stream. On the second stream, five watershed structures were present. So, there is limited scope for new drainage treatments like construction of new hydraulic structure. Repair, deepening and maintenance of existing structures must be carried out.
   b. Hill is present at south side, contour trench, contour bunding can be constructed
5) Through survey, it was found that in Zone 3 most farmers are able to cultivate only one crop (Kharif).
6) Cropping pattern change is observed where farmers have shifted from low water requirement crops to higher water requirement and higher return crops in both Kharif and rabi.
7) WUA
   a. Gate is required at canal inlet. During high flood, river water enters into canal network as there is no control on the inlet. It creates flooding condition in nearby areas of canal
   b. In Wadgaon Sinnar few people who are unaware about WUA, are maintaining canal in patches. If such people are connected to WUA, canal functioning will improve.
   c. Only 37% farmers are aware of WUA. Most of the villagers must be aware of WUA.

5.2 Deopur

Deopur is a located on the bank of Devnadi and is 20 km away from Sinnar. In Deopur regeneration of canal system was carried out by Yuva Mitra in 2015. This village was tanker fed in 2015. A stream named Dambarnala flows through this village on which two percolation tanks are present.

5.2.1 Methodology

1. A preliminary visit to understand the scenario of the village.

2. Collecting data of direct beneficiaries of DBI from Yuva Mitra.
3. A collection of well-monitoring data from Yuva Mitra.
4. Mapping the monitored wells on Google Earth and QGIS
5. Marking all the wells of 2011 and 2016
6. Mapping canal network on Google earth and QGIS
7. Socio-Economic survey
8. Analysis of well data, Socio-economic survey data, and zoning (Command area, indirect command area)
9. Reporting analysis

5.2.2 Well measurements by Yuva Mitra Data (YM)

Yuva Mitra is monitoring wells from October 2015.They are taking readings of 90 wells. Yuva Mitra has a database of water given to farms by survey number. TDSC member visited Deopur with YM employee (13 December and 20 December). In these visits, 55 well locations were taken.

5.2.3 Marking and analysis of wells

All the wells which are being monitored are marked on Google Earth and QGIS. Wells in 2011 and 2016 are marked using Google Earth historical imagery. There were 308 wells in 2011and this figure has increased to 419 in 2016. Around 35-40% of newly dug wells fall in DBI command area. Following is the map showing old and new wells.

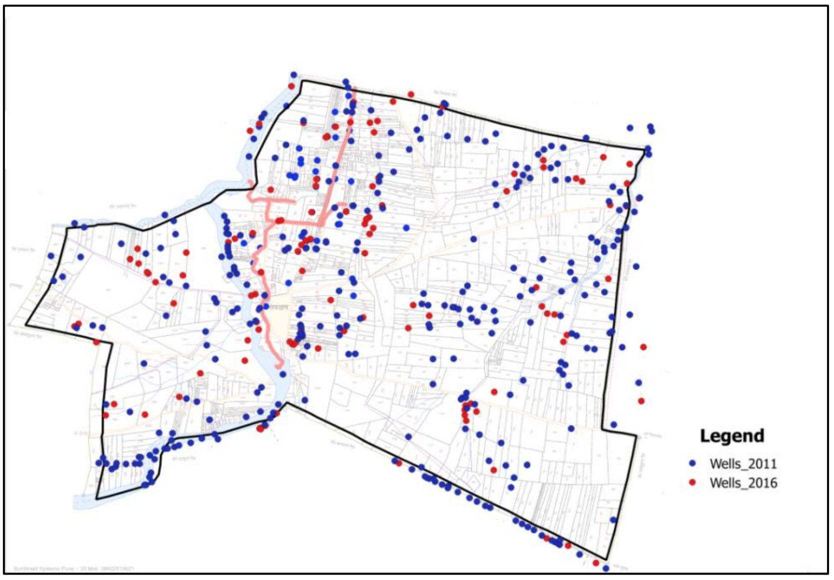


Figure 52: Wells of 2011 and 2016, Deopur

Data which was provided by Yuva Mitra is used for analysis. Firstly, we plotted a graph of all the wells, the sudden rise is observed in a month of November 2015 which indicates rainfall occurred in the month of November (verified from rainfall data). More than 70% of wells dried in the month of February (2015). With the following figure, it is observed that line is straight from the month of January (2016), which means wells were dry.

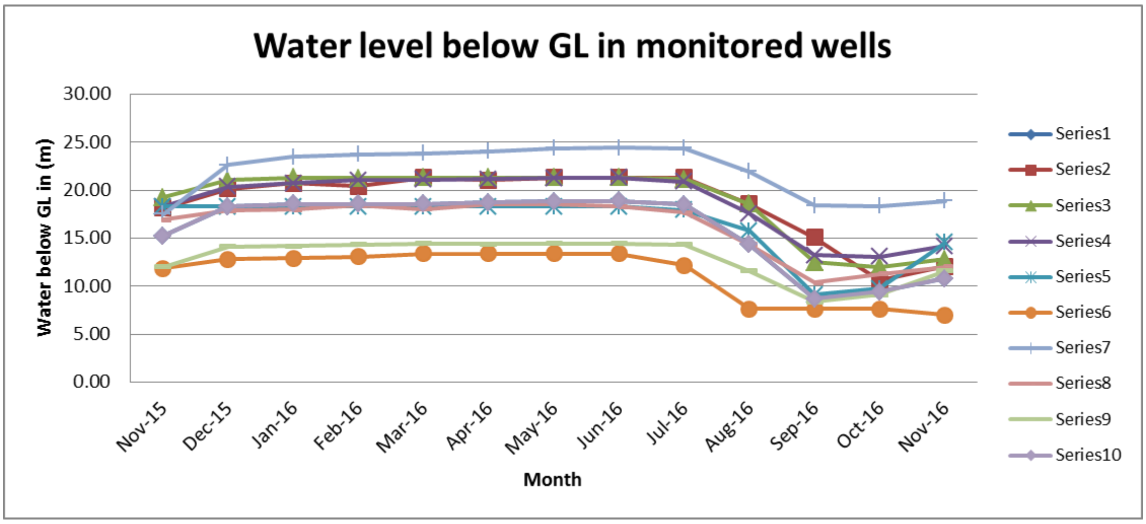


Figure 53: Water levels in monitored wells, Deopur

Note- In above graph 10 wells were plotted, if we plot all the wells curve will not be visible.

5.2.4 Socio-economic survey

Following image shows surveyed farmers on revenue map. Farmers were selected such that the whole village is covered and data can be extrapolated to the entire village.

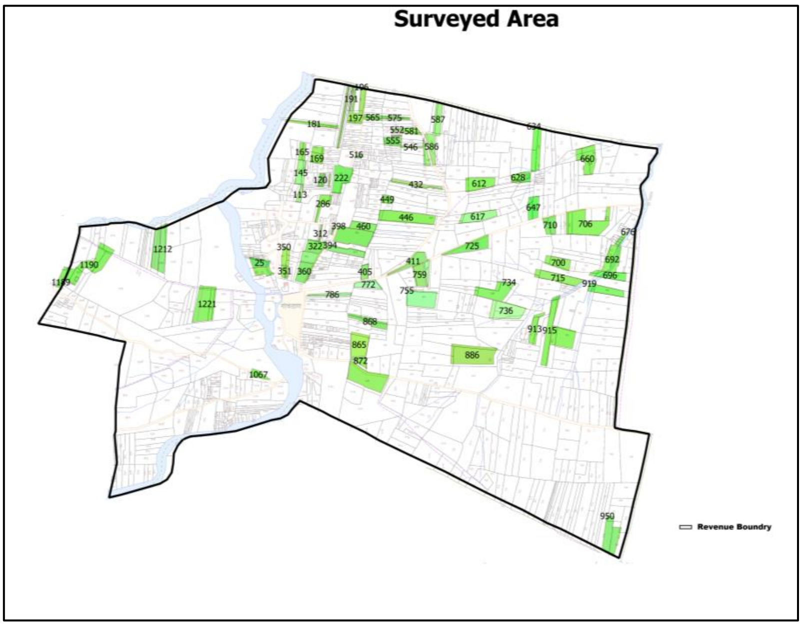


Figure 54: Surveyed farmers, Deopur

Total 49 farmers were surveyed. During the survey, Gat (plot) information of 107 plots was collected. Information like the source of irrigation, the number of wells, pump information, cropping data, the impact of DBI etc. was collected for each survey plot of the above 49 farmers through a questionnaire. Following is Gat wise information captured during survey. 19% surveyed farmers were in direct command and 29 % were in indirect command area.

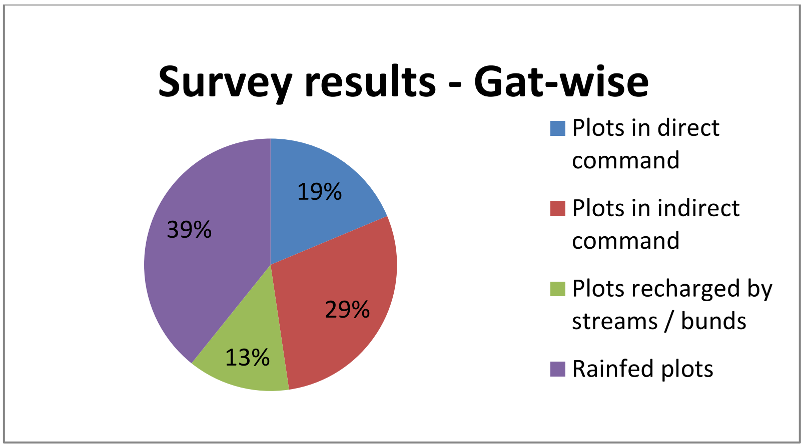


Figure 55: Survey results - Gat-wise, Deopur

The main finding of the survey showed that out of 49 farmers, 23% said that they use DBI minor for irrigating their fields. 35% farmers were found to be in indirect command area (i.e. either they reported their wells getting recharged due to the canal or they lift water from wells near the canal to further farms. Apart from farmers benefiting from the canal, 20% farmers benefited from the stream or water harvesting structures like percolation tank and cement bunds. 22% farmers reported no source of irrigation.

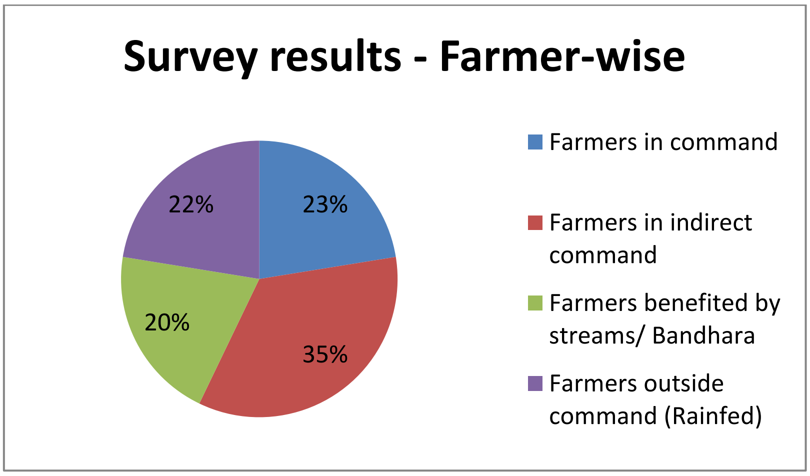


Figure 56: Survey results - irrigation source Farmer wise, Deopur

In Deopur almost half the surveyed farmers are aware of Water user association. In command area, this percentage is 57%.

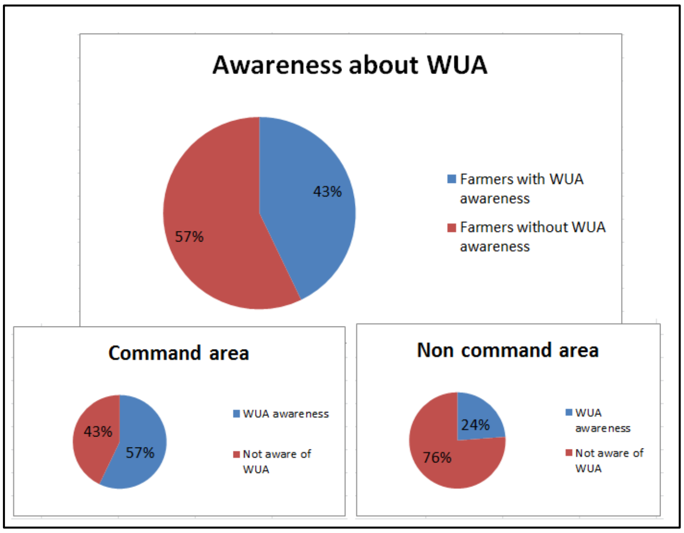


Figure 57: Survey results - Awareness about WUA, Deopur

5.2.5 Impact of canal on good recharge

The plot of 55 marked wells is drawn. The distance of wells which are on the left side of a canal (between canal and river) is taken as negative and positive is taken for the right side. Two months' data (October and November 2016) is plotted for finding the water table below ground level. Wells which are near the canal have water level close to the ground. The following figure clearly shows that as the distance from canal increases, depth to water level from ground level increases. Or, water level starts falling as the distance from canal increases.

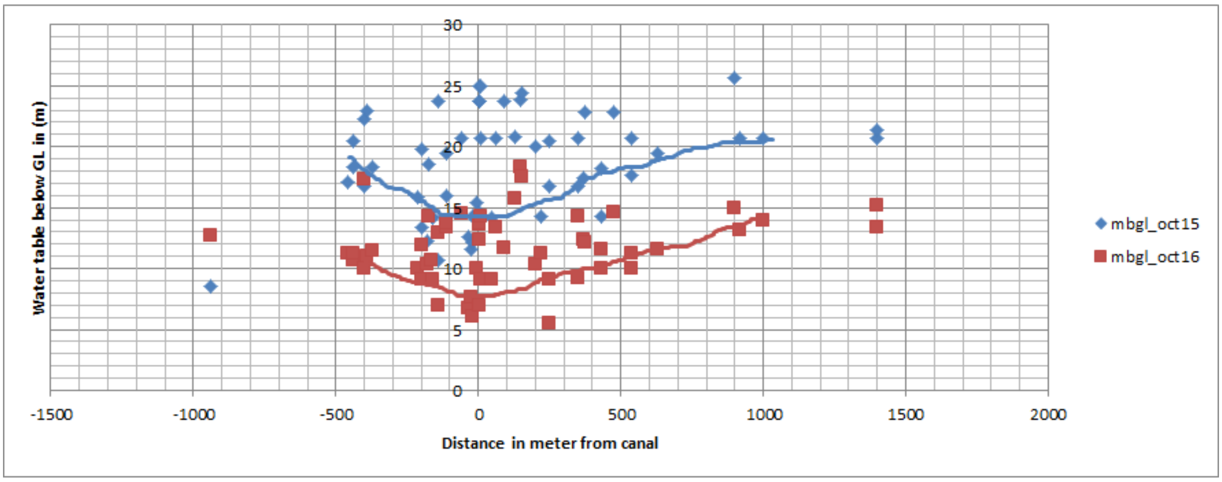


Figure 58: Water table below ground level for monitored wells, Deopur

5.2.6 Cross-section Analysis

Cross section was drawn across a canal to see the influence of canal on ground water. Cross section is taken as per the following figure-

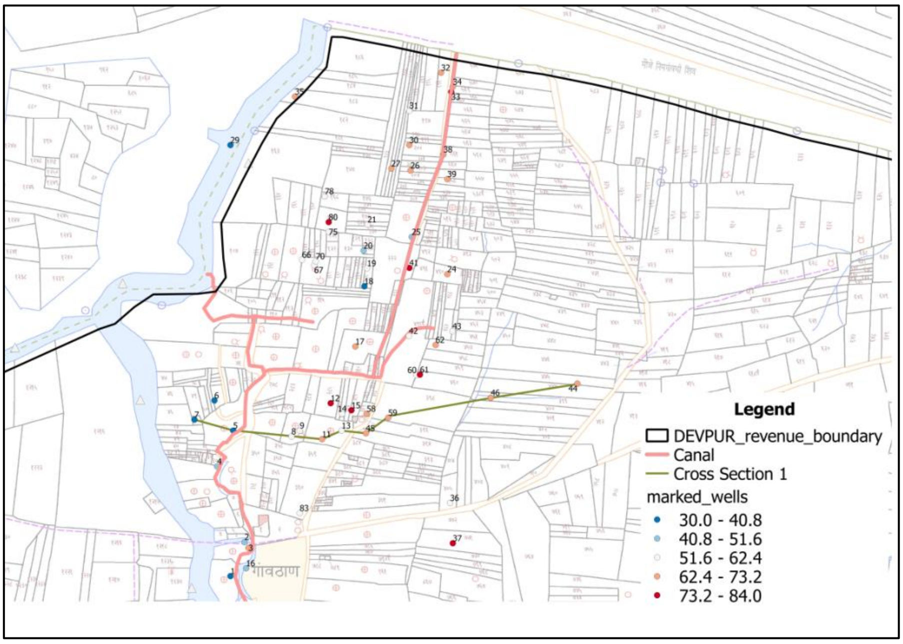


Figure 59: Well cross section, Deopur

Following is graph clearly shows a falling trend of water table against the canal.

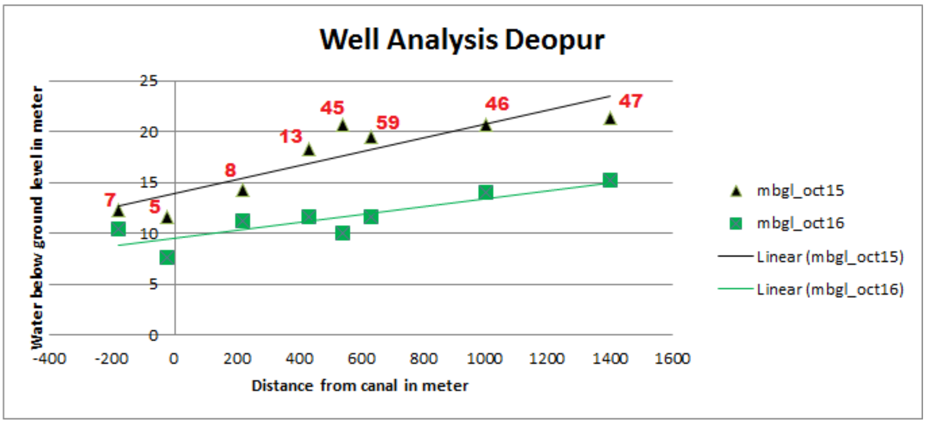


Figure 60: Cross section 1 analysis, Deopur

Following is image of water level below ground level in November 2016 and October 2015

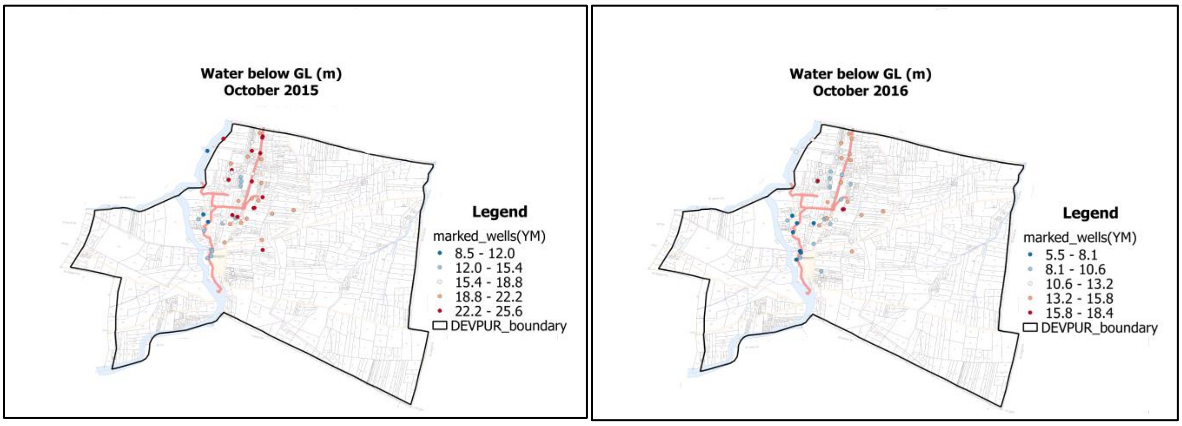


Figure 61: October 2015 and November 2016 well water level below the ground, Deopur

Blue circles indicate that water is available at less than 50 feet from the ground level. Though 50 feet looks very high number but the soil is black cotton so it is an impermeable and water retaining capacity is also high. The average depth of the well is ~ 70 feet in this area.

5.2.7 Command Area and Zones

In this case, Command Area is an area that can be irrigated if average monsoon occurs (rainfall of 525 mm).

In the case of Deopur, Yuva Mitra has a database of water given to the farmer along with survey number. Through socio-economic survey direct and indirect command area is captured. With the help of Yuva Mitra data and socio-economic survey direct and indirect command area are marked.

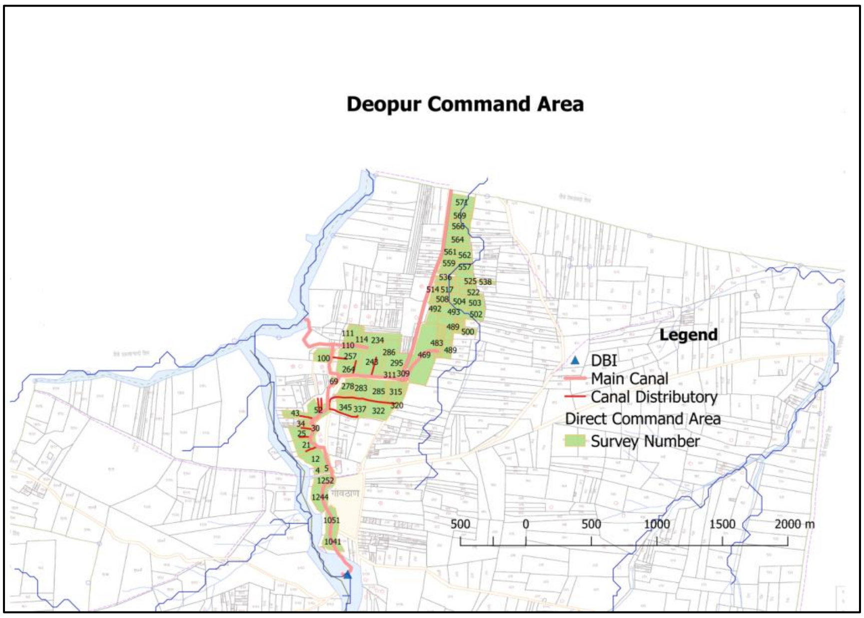


Figure 62: Deopur Direct command area

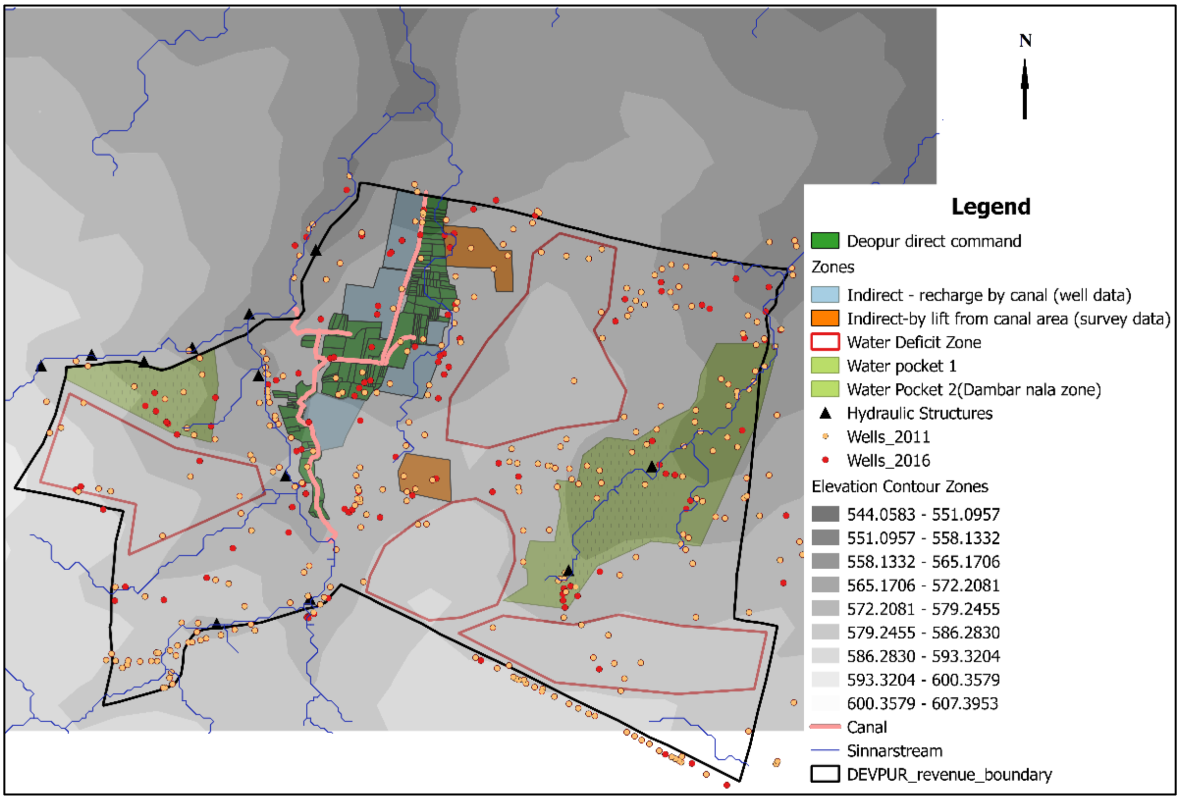


Figure 63: Deopur zones

In above figure, different zones are shown.

1. Indirect command area is marked considering two parameters.

    a. Recharge by the canal- wells and bore wells which are benefitted by canal are categorized as an indirect command. (Blue color region)

    b. Irrigation by lift – many farmers are pumping water from command area to further area. This area is marked on the basis of survey data (coffee color region)

2. Water pockets – All the farmers in this is area can generally take two crops (Kharif and rabi

3. . Water availability is good in this region due to water harvesting structures such as Percolation tanks, Cement Nala Bunds etc.

    a. Water Pocket 1 (Left side light green area)–This region is in between river and stream with four cement bunds and one percolation tank, though these structures are outside the revenue boundary still beneficial to this region.

    b. Water pocket 2 (Dambar Nala Zone) – This area is near the Dambar stream so it is known as Dambar Nala Zone. Two percolation tanks are built in this region.

4. Water Deficit Zone – This is a region where only Kharif crop is taken except few farmers. More attention should be given to this area.

It is estimated that of the total inflow into canal, maximum 6% of water is required for irrigation in command areas and maximum 5% is infiltrated. It shows that a large amount of water is going back to the river through the canal, thus canal network can be extended.

If 5% of total inflow is utilized or diverted to other areas, additional 25 hectares can be irrigated. This can be done by extending the canal or constructing community based structures like farm pond in scarcity area.

Calculation -

- Command area is115 ha and total area of Deopur is ~2000 ha(~6% of total area)
- Through CTF data it is found that total 22,00,000 m^3 of water is inflow into village.
- Command area crop water requirement is (YM database)
    - Assuming two rotations for crop. Each rotation of 5 cm. ~110,000 m^3 of water is requiring for the current cropping pattern. It is ~6% of total inflow.
- Assuming 16 lps of infiltration, ~5% of water will infiltrate that of total inflow.
- It shows that at least 85% of water is going back to river.

If 5% of total inflow is stored or diverted. 25 hectares of area can be irrigate.

5.2.8 Findings

1) Drinking water
    a. Most of the area on the left side of the river needs tankers in summer even in average monsoon year; more attention should be given to this region
2) Command Area
    a. Through direct and indirect command area (including indirect area by lift) it was found that 115 hectares of land is under command area and is beneficial for 90 wells.
    b. Out of 2000 hectare additional 115 hectare. area is irrigated through canal network (~6 %)
    Through CTF data is found that out of total inflow into canal maximum 6 % of water is required for irrigation. It shows that a large amount of water is going back to the river and there is scope to expand the network.
3) Well Data
    a. In a comparison of 2011 and 2016 wells, 111 wells are newly constructed and 35-40% of newly dug wells fall in DBI command area and indirect command.
    b. As the distance from canal increases, depth to water level from ground level increases, means water level start falling as the distance from canal increases.
4) Gate is required at canal inlet. During high flood, river water enters into canal network as there is no control on the inlet. This leads to flooding in areas nearby canal.
5) Area treatment must be carried out in water deficit zone.

6 Inferences and Action items

Based on the study carried out in the ten villages by the TDSC team and inputs from research students at CTARA, following are the inferences and action items.

6.1 Inferences

1. Specific to the DBI system
    - The DBI system of canal has tangible and large scale benefits for the Wadgaon Sinnar and Deopur villages, irrigating an area of 85 ha and 115 ha, respectively.
    - All the canals are unlined, leading to infiltration which helps in increasing the ground water table. It was observed that, for locations away from canal, water table decreased.
    - In the Wadgaon Sinnar and Sinnar (Vijayvaran) villages, the main benefit of DBI is groundwater recharge. Very few farmers irrigate their fields directly through the sub-minor canals (charis).
    - In the Wadgaon Sinnar and Deopur villages, it was observed that farmers lift water from wells recharged by canals and minor canals to irrigate farther away fields. This increased the indirect command area of the DBI system.
    - Farmers in the Wadgaon Sinnar village shifted to high water requirement, high return crops

	2011	**2016**
Kharif	Bajra, Maize, Onion	Soyabean, Onion, Tomato
Rabbi	Wheat, Gram	Wheat, Onion

2. Irrigation potential due to infiltration
    - In Sinnar Vijayvaran, in November, around 1380 cu.m. water percolated every day per kilometer along the length of DBI canal. This means 82000 cu.m. water infiltrates in 60 days.
    - Considering different extraction fractions, net ground water recharge per day is 1300 cu.m. and for 60 days 65000 cu.m. This water can irrigate 17 hectares of crops like wheat, chilly, Jawar, and Bajra. Refer to Endnote i.
    - Through all the DBIs, the volume of water that is available for irrigation is 422177 cu.m., that can irrigate additional ~100 ha of above mentioned crops.
3. Drinking water scarcity
    - Habitations are identified in Wadgaon Sinnar and Deopur where drinking water scarcity was observed. Refer to table
        - Wadgaon Sinnar- Dhokinala and habitation near the MSEDCL sub-station. Refer to 5.1.7
        - Deopur – Habitation on left side of Devnadi (West of Deopur). Refer to 5.2.8

4. Rabi Assurance
    - In Wadgaon Sinnar, there are some pockets in which farmers have to cultivate cereals and grains and are not able to cultivate vegetables like tomato, cabbage, etc. as they lack assured irrigation in the Rabi season.
    - In Deopur, there are large pockets where farmers cannot cultivate more than one crop apart from few farmers who lift water from canal, river, bunds etc.
    - There is a problem of equitable distribution of irrigation water through DBI.
5. Impact of feeder streams
    - As per the flow measurements in Devnadi river, the DBI system is supported by many local feeder streams like Dubere, Bibi-ka-stream, Shivnadi, etc. in addition to the Konambe dam outlet.
    - Watershed treatment work on these streams can increase the quantity and time-span of inflow to the river and the DBI systems.
6. Capacity increase of Konambe Dam
    - Silt deposition found in Konambe dam, removal of silt will increase the capacity of Konambe dam. (200000 cu.m. to 400000 cu.m.) refer to Table 9
7. Awareness of Water User Associations
    - In Deopur, farmers are more aware of the functioning of canal and WUA. As per field observations and farmer perception, canals are in good condition and minors are working very well.
    - In Wadgaon Sinnar few people who are unaware about WUA, are maintaining the canal. If such people are connected to WUA, canal functioning will improve.

6.2 Action Items

1. Desilting of Konambe Dam
    - Desilting will increase capacity of dam, area under irrigation, reduce flood conditions and canals will start later in the monsoon and last well into the Rabi season.
    - Desilting the dam will increase irrigation potential by 40 ha to 80 ha.
2. Gate at canal inlets
    - Flooding condition occurs due to continuous canal flow in the monsoon. This can be avoided by constructing gates at canal inlets or providing sufficient escape gates at the beginning of the canals.
3. Extension of canal in Deopur
    - As large amount of water (at least 85% of total inflow) is fed back to the river through the canal without being utilized for irrigation or groundwater recharge, canal network can be extended.
    - If extra 5% of total inflow is utilized or diverted to other areas, additional 25 ha can be irrigated in the rabi season. This can be done by extending the canal or transferring water to ponds in scarcity areas.

4. Village level interventions
    - As DBI systems cannot serve entire villages, plan for irrigation in non-command zones through either extension of flood chari of Konambe Dam or interventions on feeder streams must be prepared.
    - If Konambe dam flood chari is extended, it will benefit more than ten villages (Dubere, Wadgaon Sinnar, Patole, Bhatwadi, Manegaon, Dhondwirnagar, etc.). Farmers in the initial patch (Konambe and Sonambe village) will suffer if water flows through this chari, thus lining or pipes should be considered.
    - Intervention on feeder streams of Devnadi (Bibi-ka-stream, Jayprakash, Sonambe, and Shivnadi) for water retention. (CNB, ENB, area treatment, etc.)
5. Drinking water availability habitation level
    - In spite of irrigation facilities improvement in the villages, few habitations still have a drinking water problem. Developing drinking water sources through source strengthening or Piped Water Supply should be a priority.

6.3 Future research

- Estimating water balance to determine if the water available through DBIs and other interventions is sufficient for current cropping pattern
    - This will help to find out deficit or surplus water in each village and can be a key factor for design of future interventions.
- Temporal and spatial groundwater analysis to understand recharge, extraction, and availability in different seasons at the village level. This requires long-term data collection.
- Kharif stress and rabi stress area identification
- Estimation of increase in irrigation area due to lift from command area of canal
    - Through study, it is found that many farmers lift water from the command area. Estimate the area that can be irrigated through lift; suggest a community-based solution so that new area will be under irrigation.
    - Estimating the infiltration volume for each canal to understand the groundwater recharge and extraction potentials.
- Jam watershed development plan for the sustainable and long term availability of water in Sinnar block
    - Locating existing water body structures.
    - Finding potential sites for construction of hydraulic structure.
- Strategy for effective use of Kadwa canal

7 Appendix A

Farmer Survey questionnaire Date of survey______________ Interview#_____________ lat/long________/_______

Wadi name: _______________Village name: _______________ Name of interviewer__________________________

1. General information

1	Name of person being surveyed	
2	Contact number	
3	Number of family members	Age 0-15_______ Age15-60_______ Age >60_________
4	Number of earning members	Farm / Other
5	Highest education in family	Under SSC HSC Graduate Postgraduate Technical education
6	Main occupation	☐ Agriculture & Allied ☐ Artisans ☐ Business ☐ Service (Salaried) ☐ Ag. Labor ☐ Non-ag. Labor ☐ Any Others (Specify)
7	Secondary occupation	☐ Agriculture & Allied ☐ Artisans ☐ Business ☐ Service (Salaried) ☐ Ag. Labor ☐ Non-ag. Labor ☐ Any Others (Specify)
8	Caste, sub-caste	
9	Ration card	Antyodaya Yellow (BPL) Kesari White
10	House type	(Kaccha/Pakka) / House in gavthan / farm
11	Assets	☐ 2-wheeler ☐ 4-wheeler ☐ Refrigerator ☐ Tractor ☐ Tempo ☐ Kanda Chal
12	Total land holding area (lease –in? out?)	

2. Survey plot information

Survey Number	Ownership	Area	No. of wells	Well recharge by	Soil type	Cropping intensity (0- 1-2-3 or Multi-year)	Source of irrigation
	☐ Own ☐ Lease-in ☐ Lease-out			☐ DBI Canal ☐ Devnadi ☐ Stream/Bandhara/PTank ☐ None ☐ Other________	Good, Medium Poor	☐ Fallow all year ☐ Kharif only ☐ Kharif + Rabi ☐ K+R+S ☐ Fal-baag	☐ Well on farm ☐ Well outside (survey num_____) ☐ Flood from DBI chari ☐ rainfed ☐ tanker/Farm Pond/ Other ________
	☐ Own ☐ Lease-in ☐ Lease-out			☐ DBI Canal ☐ Devnadi ☐ Stream/Bandhara/PTank ☐ None ☐ Other________	Good, Medium Poor	☐ Fallow all year ☐ Kharif only ☐ Kharif + Rabi ☐ K+R+S ☐ Fal-baag	☐ Well on farm ☐ Well outside (survey num_____) ☐ Flood from DBI chari ☐ rainfed ☐ tanker/Farm Pond/ Other ________

1

3. DBI information

Year	Month till water in main canal	No. of irrigations by chari Kharif	Rabbi	Canal functioning good or bad	Remarks
2016					
2015					
Pre					

4. Resources: water

Source of Drinking Water: ____ availability in months________________________

Well information

No.	Source type: well/bore	survey number	Year in which well dug	Depth	Year of deepening	Year of Horizontal bores done	Dried in month 2015-16	Full in month 2016	Pump capacity (HP)	Pumping Distance (ft/m)

2

5. Livestock: Bulls/ cattle/ goats

Animals	Nos	Shed	Use	Water source	Income	After DBI or Before	Remarks
Bulls		Yes / No					
Cattle(cow, buffalo)		Yes / No					
Goats		Yes / No					
Poultry		Yes / No					

6. Impact of DBI

	2015-16 Bad year		2016-17 Good year		Pre-DBI		Remarks
Total landholding size							
Area under drip/ sprinkler							
Well dried in month			(expected)				
Months of Drinking water scarcity							
Crops	Kharif Rabi Summer Baag		Kharif Rabi sowing Summer plan Baag		Kharif Rabi Summer Baag		
Productivity Quintal per acre	Soyabean		Soyabean		Soyabean		
	Maize		Maize		Maize		
	Wheat		Wheat		Wheat		
	Harbhara		Harbhara		Harbhara		
	Kharif Onion		Kharif Onion		Kharif Onion		
	Rabbi Onion		Rabbi Onion		Rabbi Onion		
	Tomato	Crate/acre	Tomato	Crate/acre	Tomato	Crate/acre	
Reason for change in productivity	☐ More water from DBI ☐ Changes in rainfall		☐ Changes in inputs (seed/chemicals) ☐ Agriculture machinery		☐ Training programs ☐ Labour		Other:

3

7. What is the effect of DBI on water availability? (GW levels, direct use)

	Drinking water	Kharif assurance	Rabbi Assurance	Well recharge	others
Effect in a bad monsoon					
Average monsoon					
Very good monsoon					

8. <u>Other questions:</u>

1. What is the role of Water User Associations in decision making?
2. Who is the WUA functionary in the village?______________________________ Did you attend the last meeting: Yes/No____________
3. Is there any control on cropping pattern by WUA in command area?
4. What are livelihood opportunities created by DBI intervention?
5. In your perception, what are the most important problems in DBI project?
6. How was your income status or living as compared to 5 years ago? Better The same worse
7. Which part of the village in your opinion has benefitted the most from the DBIs?____
8. Is it possible to extend the DBI network and which parts can be covered in your opinion?____________________________________
9. What do you think would the benefits of the project? for Your Village _______________________For your Taluka__________________
10. Are you part of any formal shetkari gat or farmer-group/associations? Yes/No Details:______________________________________
11. Have you taken a bank loan for farming in last 5 years? Yes/No Details:____

4

8 Appendix B

Hydraulic Structures Village wise

Table 10: Geographic coordinates of Konambe hydraulic structures

Description	Longitude	Latitude
Konambe Dam	73°54.74'E	19°46.5211'N
DBI 73	73°54.9805'E	19°46.6238'N
CNB 1	73°55.174'E	19°47.104'N
CNB 2	73°55.323'E	19°47.2355'N
CNB 3	73°55.4546'E	19°47.3635'N

Table 11: Geographic coordinates of Sonambe hydraulic structures

SR.NO	Description	Latitude	Longitude
1	DBI 1	19° 47.38554'N	74°55.48314'E
2	CNB 1	19° 47.10642'N	74°55.17048'E
3	CNB 2	19° 47.2371'N	74°55.32138'E
4	CNB 3	19° 47.3655'N	74°55.45494'E
6	CNB 4	19° 47.40888'N	74°55.5465'E
7	CNB 5	19° 47.39646'N	74°55.66626'E
8	Farm Pond 1	19° 45.33618'N	74°55.95154'E
9	Farm Pond 2	19° 45.52002'N	74°55.08222'E
10	Farm Pond 3	19° 45.9318'N	74°55.152'E
11	Farm Pond 4	19° 45.98136'N	74°55.71348'E
12	Farm Pond 5	19° 47.19354'N	74°55.82622'E
13	Farm Pond 6	19° 47.96952'N	74°55.49322'E
14	Farm Pond 7	19° 48.33318'N	74°55.7106'E
15	Farm Pond 8	19° 48.37734'N	74°56.32806'E
16	Farm Pond 9	19° 48.49488'N	74°56.4804'E
17	Farm Pond 10	19° 48.49968'N	74°56.66304'E
18	Farm Pond 11	19° 48.44742'N	74°56.84952'E

Table 12: Geographic coordinates of Wadgaon Sinnar hydraulic structures

SR.NO	Description	Latitude	Longitude
1	DBI 1	19° 48.8043'N	74° 57.77742'E
2	DBI 2	19° 48.94728'N	74° 58.2246'E
3	DBI 3	19° 48.88392'N	74° 58.60044'E
4	CNB 1	19° 48.81586'N	74° 56.54118'E
5	CNB 2	19° 48.55626'N	74° 57.00426'E
6	CNB 3	19° 48.58992'N	74° 57.1443'E
7	CNB 4	19° 48.52866'N	74° 57.23508'E
8	CNB 5	19° 48.55002'N	74° 57.53382'E
9	CNB 6	19° 48.67998'N	74° 57.60636'E
10	CNB 7	19° 48.73356'N	74° 57.69036'E
11	CNB 8	19° 48.81432'N	74° 57.88662'E

12	CNB 9	19° 48.85368'N	74° 58.0923'E
13	CNB 10	19° 48.897602'N	74° 58.16364'E
14	CNB 11	19° 47.76756'N	74° 58.42494'E
15	Farm Pond 1	19° 48.97602'N	74° 56.5887'E
16	Farm Pond 2	19° 47.79078'N	74° 56.5878'E
17	Farm Pond 3	19° 47.8014'N	74° 56.91792'E
18	Farm Pond 4	19° 48.49614'N	74° 57.5424'E
19	Farm Pond 5	19° 48.38958'N	74° 57.72906'E
20	Farm Pond 6	19° 48.10806'N	74° 57.47568'E
21	Farm Pond 7	19° 47.83962'N	74° 58.35312'E
22	Farm Pond 8	19° 49.03428'N	74° 59.02968'E

Table 13: Geographic coordinates of Sinnar hydraulic structures

SR.NO	Description	Latitude	Longitude
1	DBI 1	19° 49.50528'N	73° 59.34066'N
2	CNB 1	19° 49.25454'N	73° 20.20068'N
3	CNB 2	19° 49.63302'N	73° 59.44098'N
4	CNB 3	19° 49.73214'N	73° 59.51958'N
6	CNB 4	19° 49.8483'N	73° 59.86542'N
7	CNB 5	19° 49.96776'N	74° 0.01986'N
8	CNB 6	19° 50.06028'N	74° 0.63816'N
9	CNB 7	19° 50.15844'N	74° 0.90888'N
10	CNB 8	19° 50.32686'N	74° 1.07502'N
11	CNB 9	19° 50.39352'N	74° 1.18206'N
12	CNB 10	19° 50.3232'N	74° 0.87222'N
13	CNB 11	19° 50.41014'N	74° 0.50352'N
14	CNB 12	19° 50.34276'N	73° 59.7678'N
15	CNB 13	19° 50.28654'N	73° 59.30208'N
16	CNB 14	19° 50.40258'N	73° 59.08398'N
17	CNB 15	19° 50.47938'N	73° 58.37556'N
18	Farm Pond 1	19° 51.41826'N	73° 57.34066'N
19	Farm Pond 2	19° 52.32162'N	74° 1.93182'N
20	Farm Pond 3	19° 52.14306'N	74° 1.06992'N
21	Farm Pond 4	19° 51.99936'N	74°0.99132'N
22	Farm Pond 5	19° 51.87588'N	73° 0.86508'N
23	Farm Pond 6	19° 52.37496'N	73° 59.9955'N

Table 14: Geographic coordinates of Kundewadi hydraulic structures

SR.NO	Description	Latitude	Longitude
1	CNB 1	19° 50.41014'N	74° 1.48278'E
2	CNB 2	19° 50.4771'N	74° 1.61088'E
3	CNB 3	19° 50.57772'N	74° 1.84698'E
4	CNB 4	19° 50.28186'N	74° 2.29782'E
5	Farm Pond 1	19° 49.6536'N	74° 1.33104'E
6	Farm Pond 2	19° 50.28384'N	74° 1.90332'E

Table 15: Geographic coordinates of Musalgaon hydraulic structures

Description	Latitude	Longitude
DBI 86	19°50'28.85"N	74° 1'38.46"E
DBI 87	19°50'13.37"N	74° 2'39.82"E
CNB 1	19°50'14.78"N	74° 4'47.74"E
CNB 2	19°50'10.25"N	74° 5'4.19"E
CNB 3	19°50'13.01"N	74° 3'7.54"E
CNB 4	19°50'9.01"N	74° 3'17.21"E
CNB 5	19°50'8.51"N	74° 3'52.69"E
CNB 6	19°49'45.62"N	74° 3'56.42"E

Table 16: Geographic coordinates of Datali hydraulic structures

SR.NO	Description	Latitude	Longitude
1	DBI	19° 50.277'N	74° 5.57298'E
2	Farm Pond 1	19° 50.61102'N	74° 5.703'E
3	Farm Pond 2	19° 50.769'N	74° 5.78598'E
4	Farm Pond 3	19° 50.343'N	74° 5.622'E

Table 17: Geographic coordinates of Khopadi Bk hydraulic structures

SR.NO	Description	Latitude	Longitude
1	DBI	19° 50.277'N	74° 5.573'E
2	CNB 1	19° 50.226'N	74° 6.098'E
3	CNB 2	19° 50.187'N	74° 6.232'E
4	Farm Pond 1	19.850700°	74.119350°
5	Farm Pond 2	19.849033°	74.126183°

Table 18: Geographic coordinates of Khopadi Kh hydraulic structures

SR.NO	Description	Latitude	Longitude
1	CNB1	19° 50.463'N	74° 6.627'E
2	CNB2	19° 50.539'N	74° 7.078'E
3	CNB3	19° 50.585'N	74° 7.434'E
4	CNB4	19° 50.700'N	74° 7.913'E
5	Farm Pond 1	19° 50.641'N	74° 7.855'E
6	Farm Pond 2	19° 50.535'N	74° 7.800'E
7	Farm Pond 3	19° 50.532'N	74° 7.967'E
8	Farm Pond 4	19° 50.432'N	74° 7.676'E
9	Farm Pond 5	19° 50.388'N	74° 7.523'E
10	Farm Pond 6	19° 50.296'N	74° 7.587'E
11	Farm Pond 7	19° 50.261'N	74° 7.549'E
12	Farm Pond 8	19° 50.368'N	74° 7.292'E
13	Farm Pond 9	19° 49.770'N	74° 7.322'E
14	Farm Pond 10	19° 49.629'N	74° 7.119'E
15	Farm Pond 11	19° 49.406'N	74° 7.015'E
16	Farm Pond 12	19° 49.535'N	74° 6.945'E

17	Farm Pond 13	19° 50.341'N	74° 7.701'E

Table 19: Geographic coordinates of Datali hydraulic structures

SR.NO	DESCRIPTION	Latitude	Longitude
1	DBI	19° 51.594'N	74° 9.133'E
2	CNB1	19° 51.888'N	74° 8.928'E
3	CNB2	19° 52.369'N	74° 8.782'E
4	Farm Pond 1	19° 51.649'N	74° 8.948'E
5	Farm Pond 2	19° 53.016'N	74° 9.932'E
6	Farm Pond 3	19° 51.763'N	74° 10.232'E
7	Farm Pond 4	19° 52.083'N	74° 10.254'E
8	Farm Pond 5	19° 52.505'N	74° 10.326'E
9	Farm Pond 6	19° 51.063'N	74° 8.387'E
10	Farm Pond 7	19° 50.863'N	74° 8.044'E
11	Farm Pond 8	19° 50.875'N	74° 8.067'E
12	Farm Pond 9	19° 51.170'N	74° 9.902'E
13	Farm Pond 10	19° 51.318'N	74° 10.021'E
14	Farm Pond 11	19° 51.480'N	74° 10.853'E
15	Farm Pond 12	19° 52.871'N	74° 10.883'E
16	Farm Pond 13	19° 51.847'N	74° 9.440'E
17	Farm Pond 14	19° 52.004'N	74° 10.327'E
18	Percolation Tank	19° 51.441'N	74° 10.268'E
19	Percolation Tank	19° 51.930'N	74° 10.662'E

9 Appendix C

Canal networks on village revenue maps

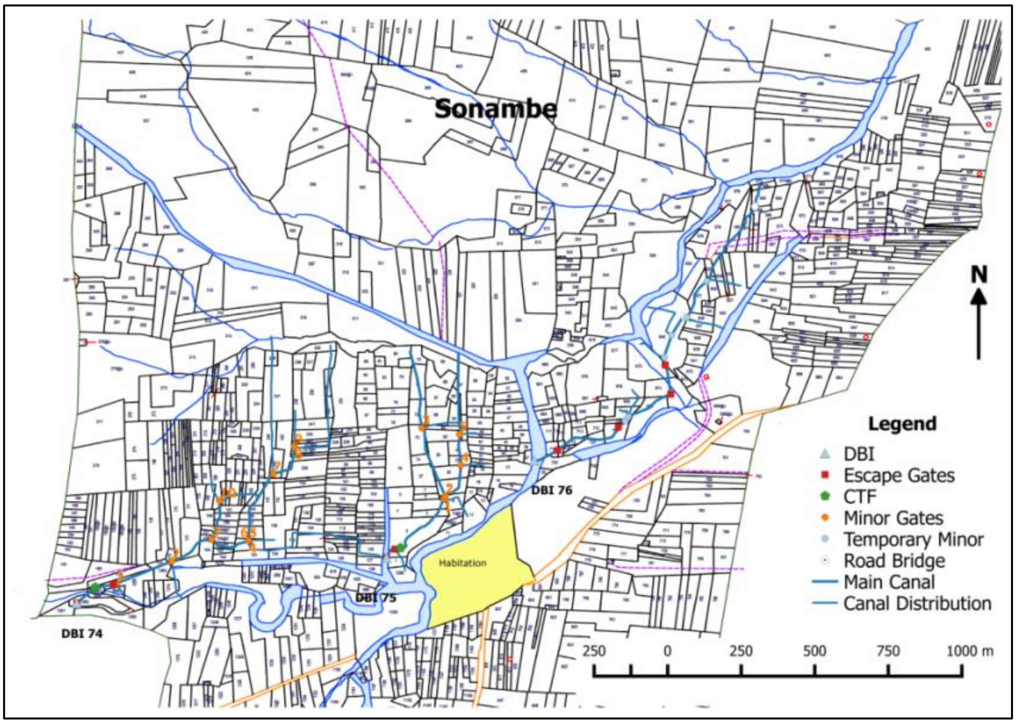


Figure 64: Sonambe map

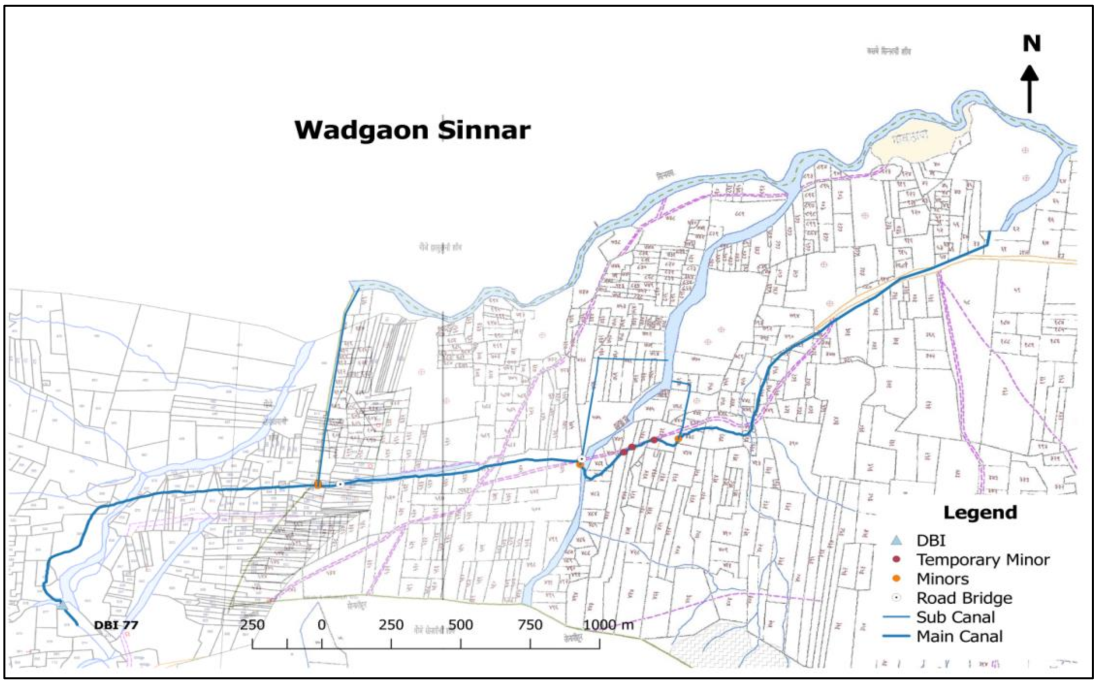


Figure 65: Wadgaon Sinnar map

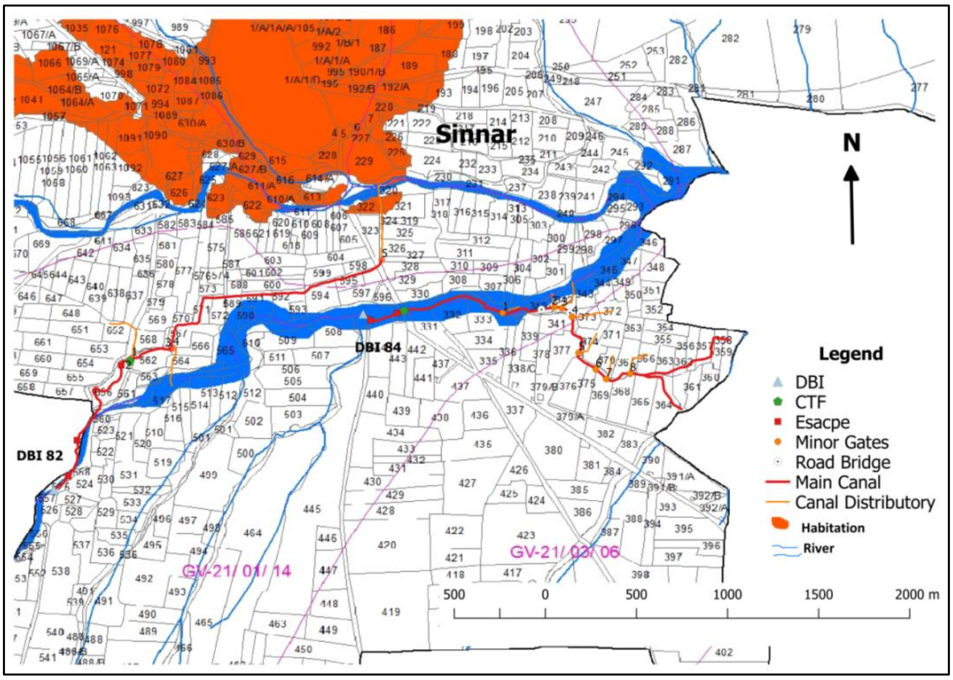


Figure 66: Sinnar map

Though canal looks in river it is not in river. During digitization of revenue map by RS-GIS (Nashik).river layer has been marked incorrectly.

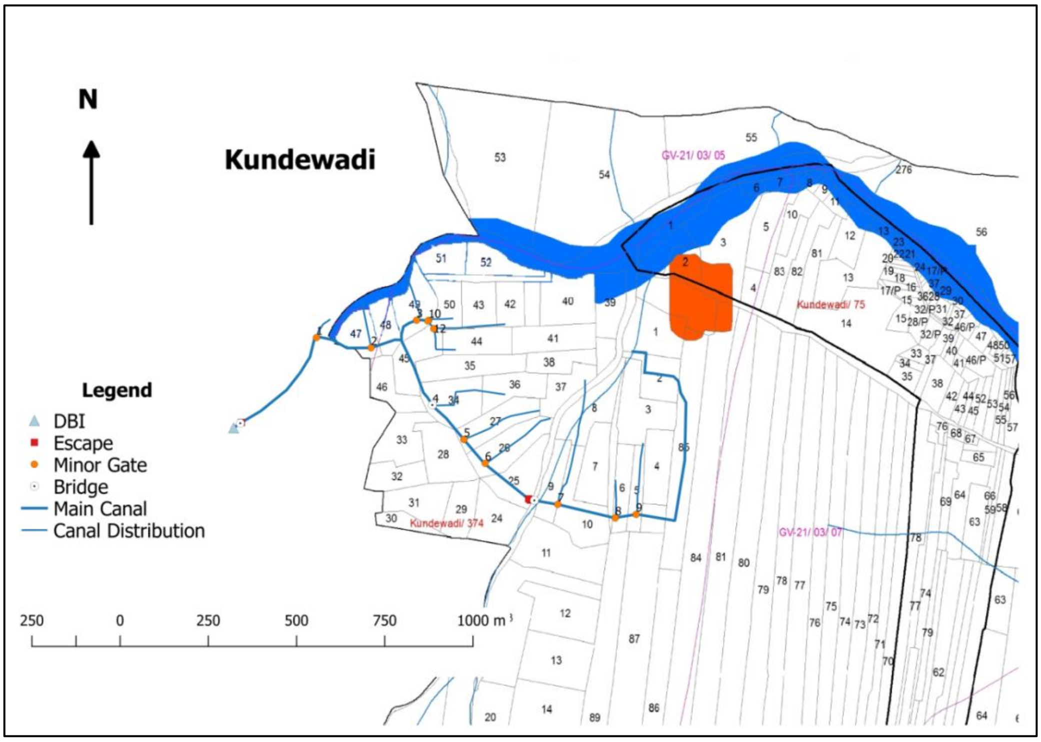


Figure 67: Kundewadi map

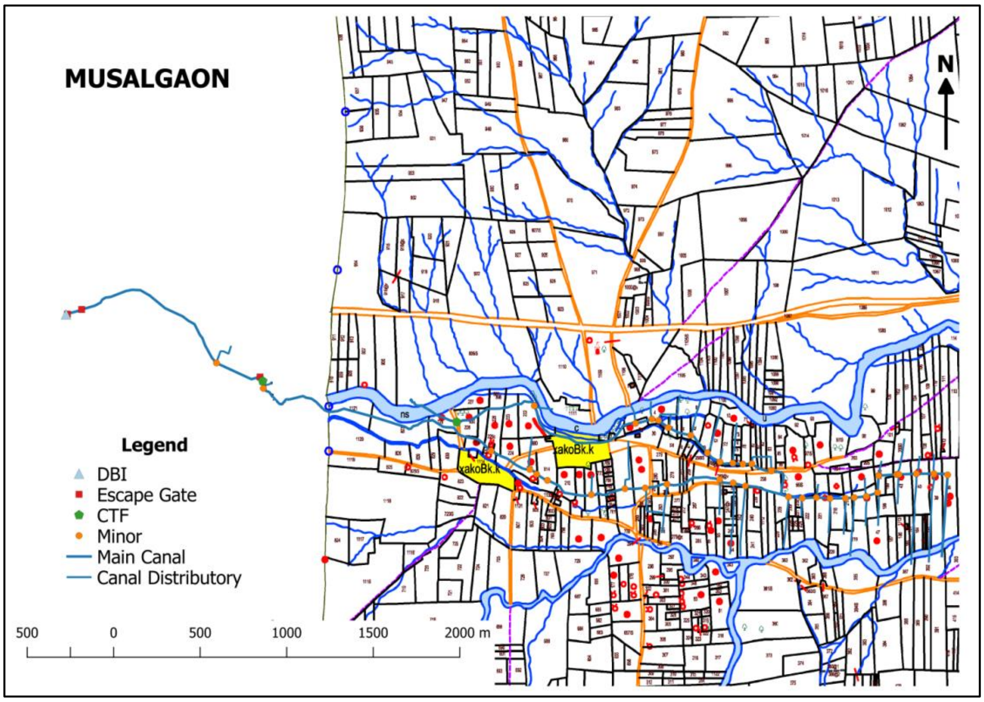


Figure 68: Musalgaon map

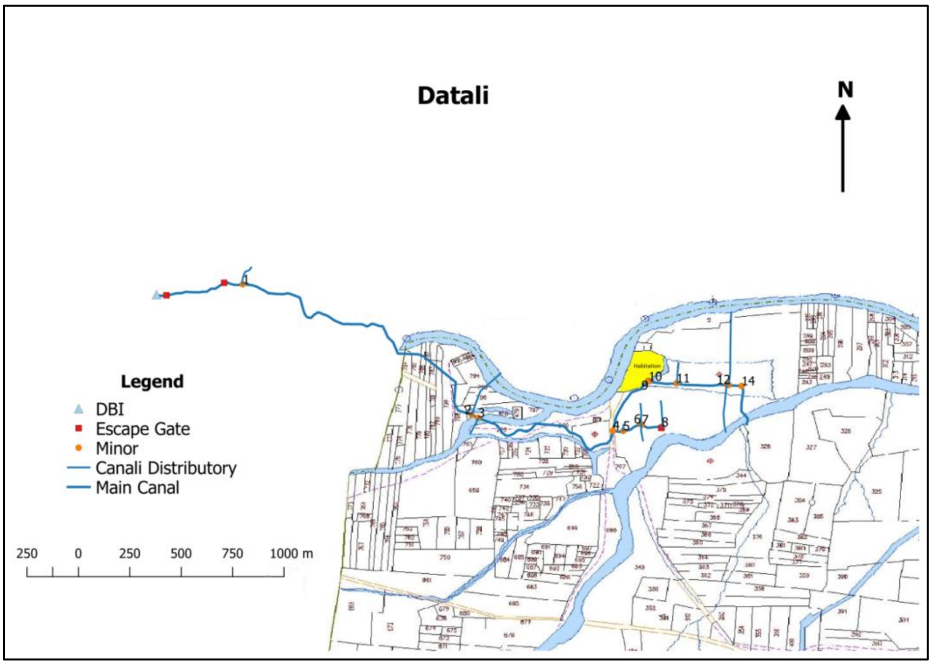


Figure 69: Datali map

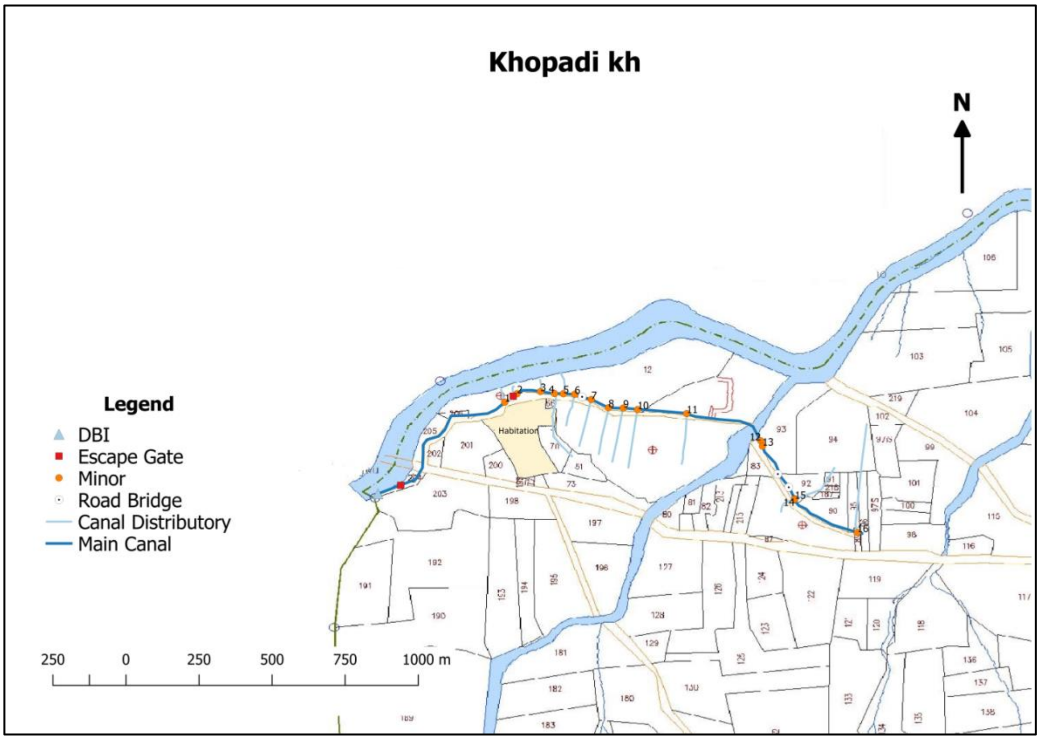


Figure 70: Khopadi Kh map

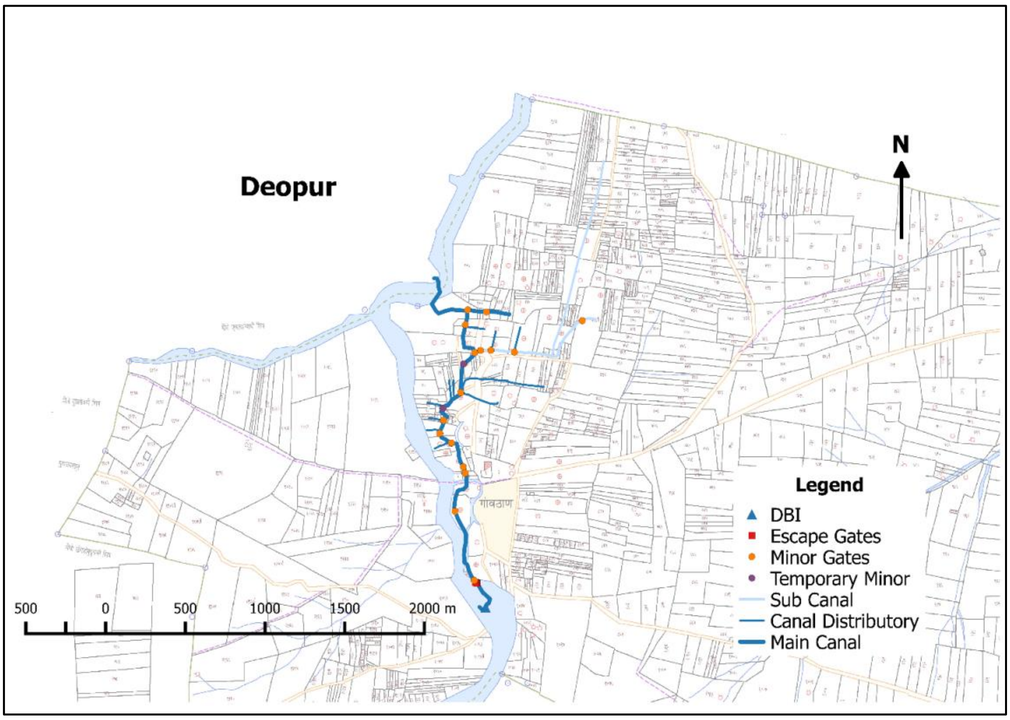
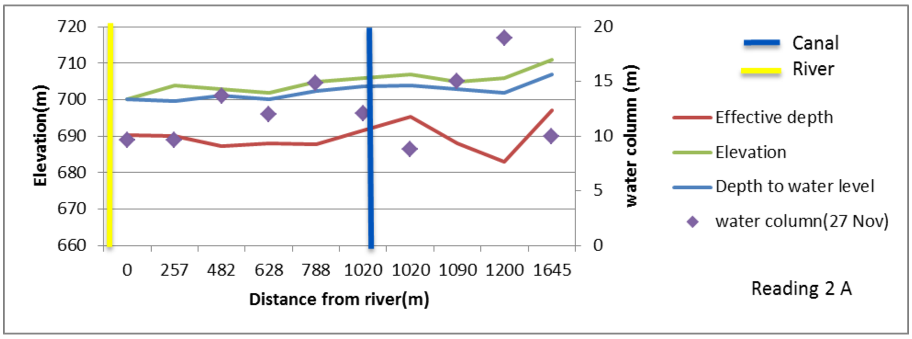


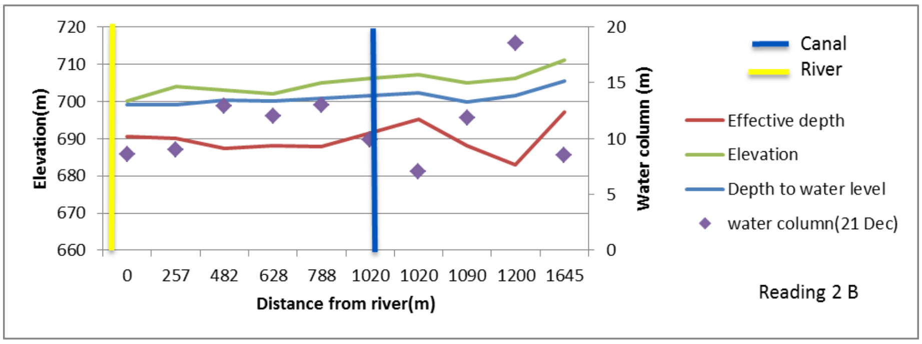
Figure 71: Deopur map

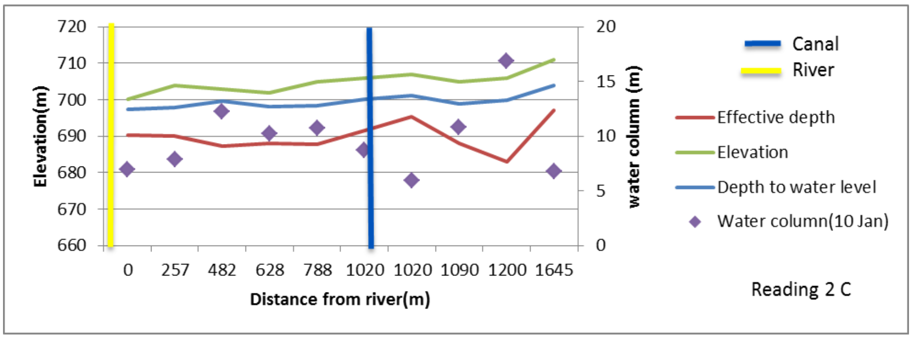
10 Appendix D

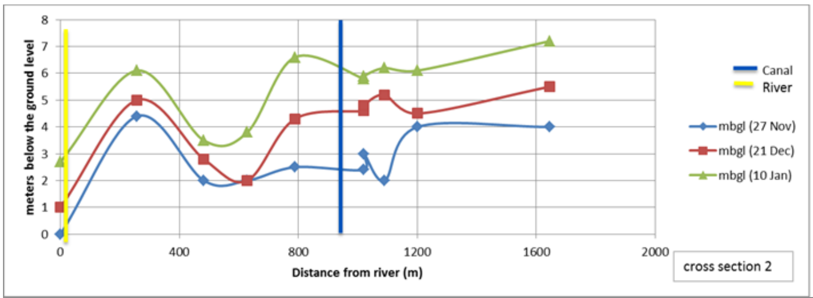
Well analysis of Wadgaon Sinnar

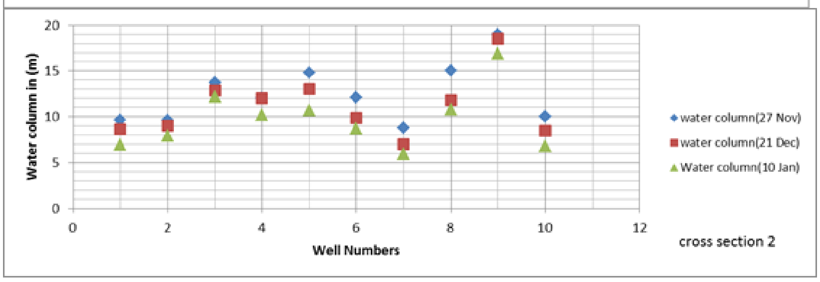
Cross Section 2



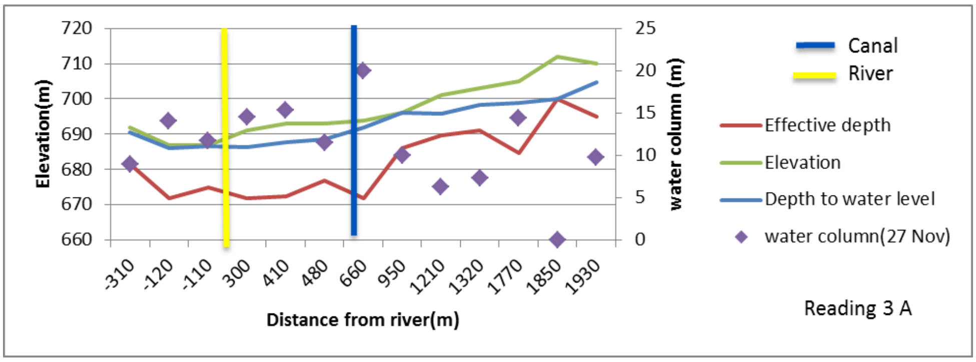


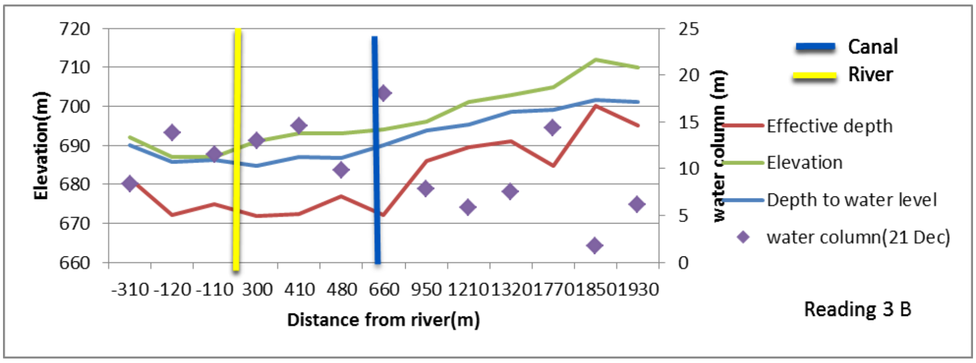


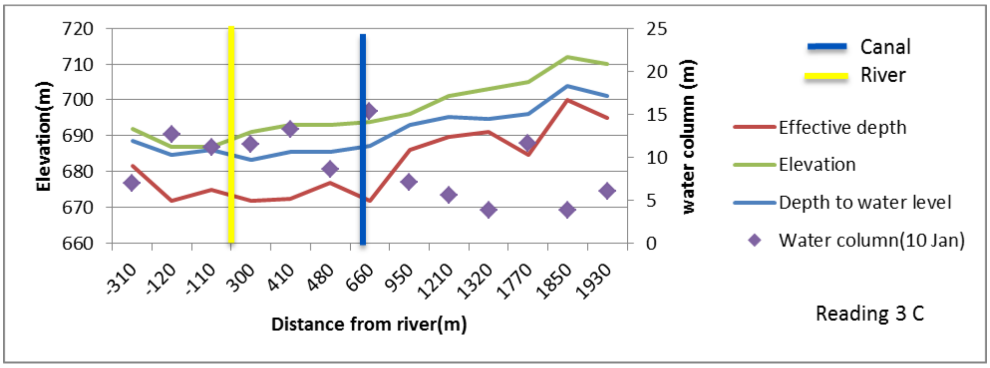


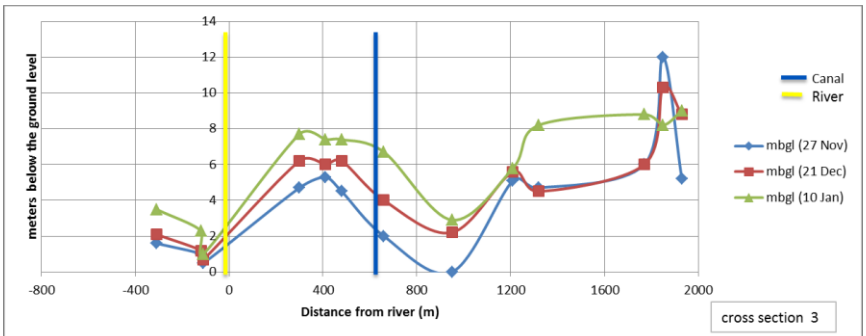


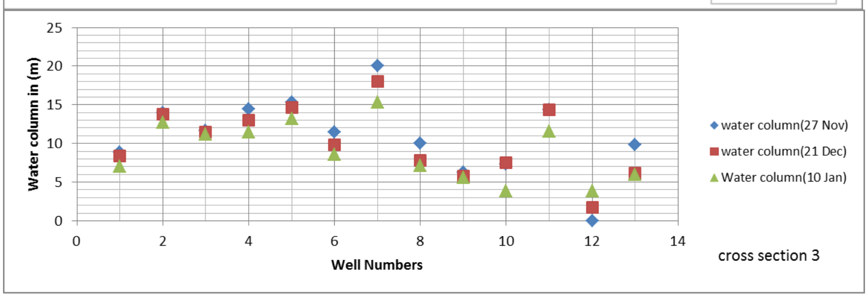
Cross Section 3



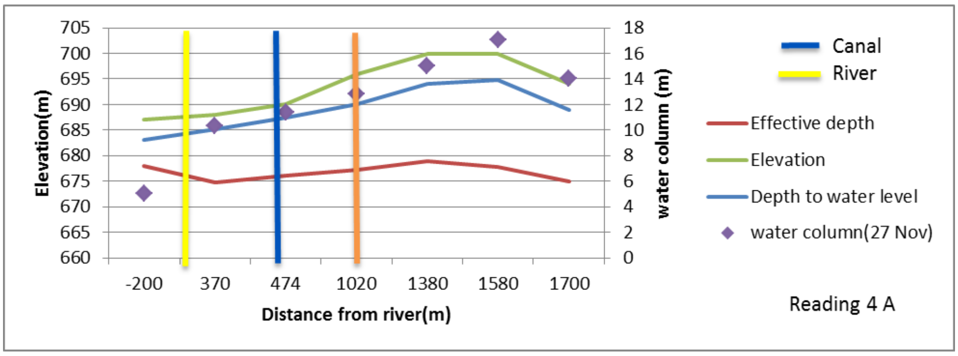


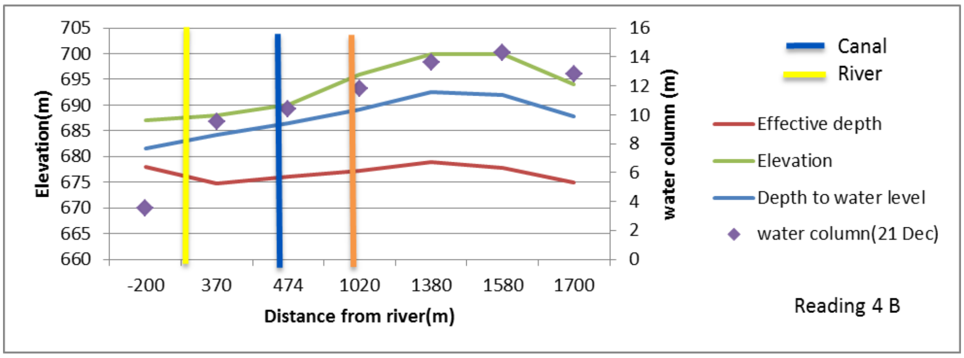


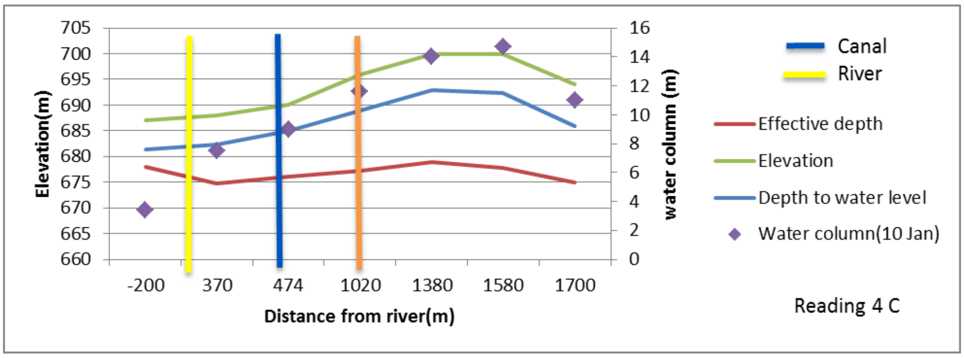


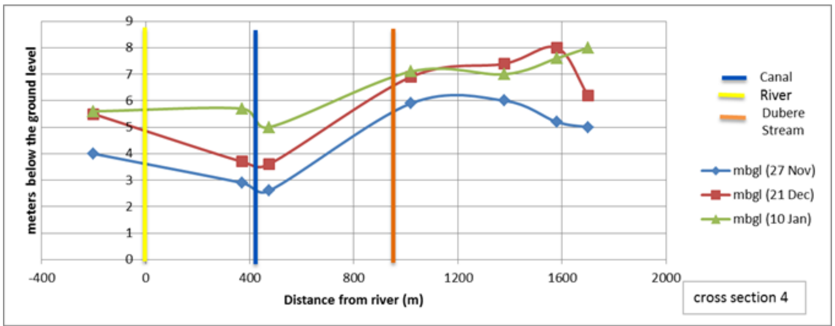


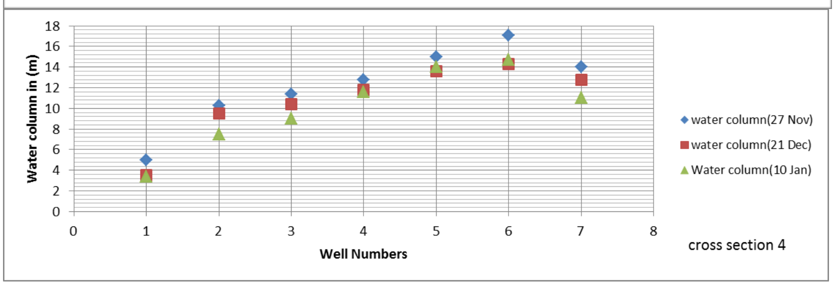
Cross section 4











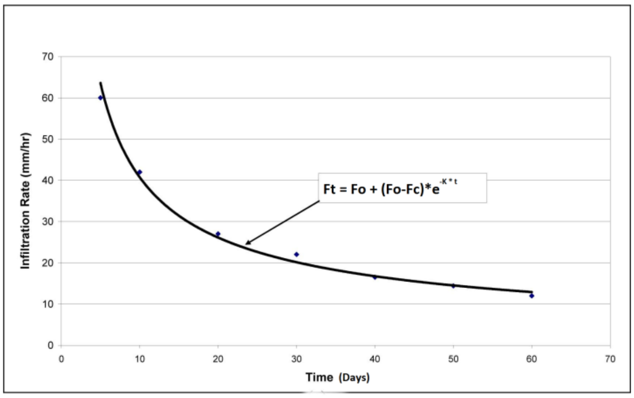
11 Appendix E

Horton's Equation

To calculate infiltration of canal Horton's equation can be used.

$$Ft = Fo + (Fo - Fc)e^{-k*t}$$

Ft= infiltration capacity (depth/ time) at some time t
K=constant representing depth of decrease in f capacity
Fc= final or equilibrium capacity
Fo= initial infiltration capacity



Procedure

1. Select location after CTF at any distance (500 m < d < 1500 m) such that no other activities like pumping are being carried out.
2. Measure the discharge of CTF; at the same CTF calibrate current/ flow meter. Note down current meter reading (a).
3. Measure the discharge using current/ flow meter at selected location (b). Note down the depth of water.
4. Repeat step 2 and 3 for second sample space. At least 8 reading must be collected during canal operation in a season at regular interval.

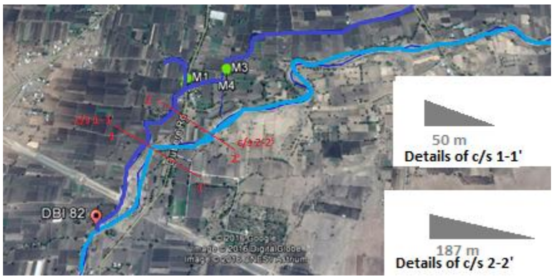
12 Appendix F

Table 20: Sinnar visit details

Date of Visit	Purpose	Tasks done
3 – 4 October	Preliminary Visit	Understanding the DBI system
23 – 29 October	Flow measurement	Infiltration rate is measured at Vijayvaran canal
11 – 15 November	Collecting waypoints and well monitoring	Sonambe and Musalgaon waypoints and well monitoring at Wadgaon Sinnar
26-28 November	Wadgaon Sinnar selection of wells and monitoring	Cross section analysis for marking zones
6 - 13 December	Waypoints collection and socio-economic survey	Waypoints collected at Konambe, Wadgaon Sinnar, Kotam, Khopadi Kh, Khopadi Bk. Socio-Economic survey of Wadgaon Sinnar
20 – 23 December	Socio-Economic Survey and Well Monitoring	Socio-Economic Survey of Deopur and well monitoring at Wadgaon Sinnar

[i] **Calculations**

As per 16 lps amount of water that infiltrates into the soil is 1380 m^3 per day. This means 82000 cu.m. water infiltrates in 60 days. Out of this total amount, some amount of water will go into the river. The amount of water which is discharge into river by canal can be found out by Darcy's law



As per Darcy's Laws

$$Q = K * i * A$$

Where

K is conductivity of soil

i= dh/dL

A = cross section through which infiltration occurs.

K= 0.0103-0.0056 ft/hr (Saxton & Rawl 2005)

dh=3m(difference between water level at canal and river)

dL=120m (average length between canal and river)

A=L*B =area through which water is being infiltrate.

B= 5 m (as average depth of soil collected through field observation and cross verified with Wadgaon Sinnar well data)

L= 1000 m

Consider maximum value of k (0.0103).

- Using above data Q found to be 0.109 lps. That is out of 16 lps 0.109 lps water is going back to river.

Maximum 1 % of water is discharge into river.

Hence daily infiltrate water is 1300 m^3

Capacity of soil

Assuming effect of canal is observed upto 300 m (cross section analysis of Wadgaon Sinnar).

Depth of water available through 1300 m^3 is (1300/300*1000) = 4 mm per day per kilometer.

Additional area that can be irrigated

- Last rainfall occurs in 4 October and canal was functioning till last week of November. Infiltration will not occur for 3 to three days after the rain. Though rainfall event and CTF discharge. Consider 60 days of canal functioning with the same infiltration.
- Volume of water that is infiltrated = 1300*60 = 65000 m^3
- Depth of water = $\frac{65000}{300*1000} =$ 0.26 m= 26 cm
- This volume will give 26 cm of depth for 30 hectares of land. That is additional 17 hectares can be irrigated having delta of 450 mm (like wheat, chilly, Jawar, Bajra, etc.)

ii

Water User Association (WUA)

Co-operative association of individual water users who wish to undertake water related activities for their mutual benefit

WUA supposed to do

1.Acting as an interface between the farmers and the main system management
2.Water distribution management
3.Operation and maintain ace of irrigation and drainage system
4. Collection of water charges and other user charges

Specific nature of service that WUA provide will differ from case to case because member needs will differ from one area to another.

Spoke with 2 members of WUA, 5 people who are aware of WUA and group of people who are independently maintaining the canal.
Different questions were asked few are listed below,

What is function of WUA
Do you conduct any meeting to discuss the canal problem
Points discussed in meeting of WUA.
Problems of canal
Funding agency for WUA
How do you repair canal