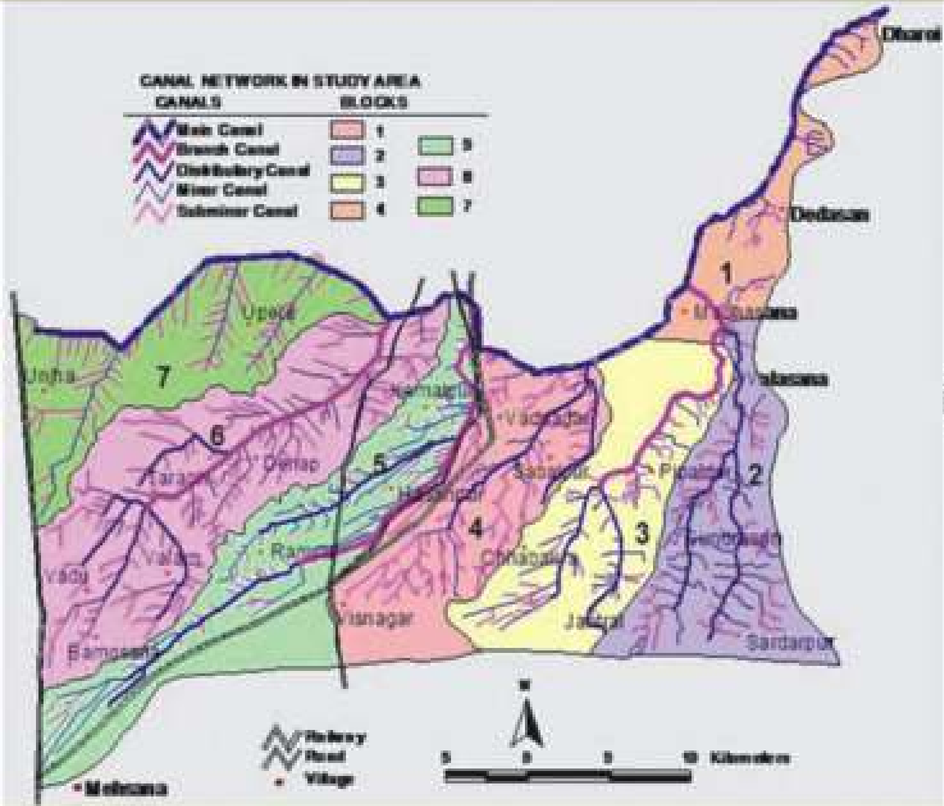
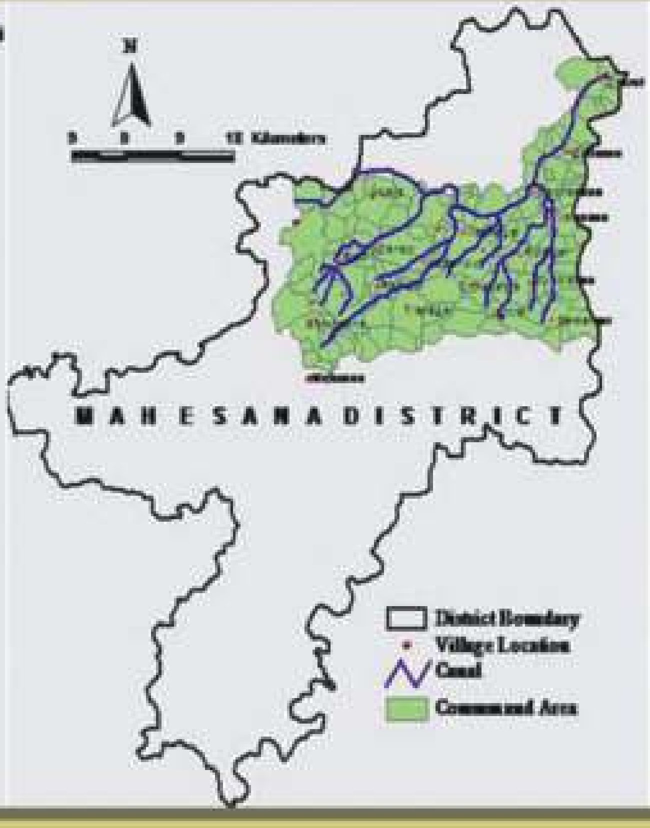
# Study on
# Designed Capacity of the Dharoi Dam
# vs.
# Actual Command Area Irrigated

## (Impact of PIM in Right Bank Main Canal Area of Dharoi Dam)





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ARID COMMUNITIES AND TECHNOLOGIES,
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# Executive Summary

Surface water irrigation of Gujarat state had began during 70s with the planning of major and medium irrigation schemes such as, Ukai, Kakrapar, Kadana, Sardar Sarovar, and Dharoi etc. Dharoi dam was built across Sabarmati River during 1971 to 1978. The estimated cost of the project was Rs 17.58 crores since then the project cost has increased many folds. The latest estimated cost as per revised implementation schedule works out to Rs. 134.51 crores. The main purpose of the scheme was to provide irrigation facilities to 127 villages of Kheralu, Visnagar, Mehsana, Sidhpur and Vijapur talukas of Mehsana district through R.B.M.C. and 49 villages of Idar and Himmatnagar talukas of Sabarkantha district through L.B.M.C. The annual area under irrigation was estimated as 36842 ha (91000 Acres). There after cropping pattern was changed to suit the command area requirement of 43320 hectares. Along with this changes several issues emerged such as (01) lack of irrigation in tail area; (02) difference in actual command area in compare to designed command area; (03) mismanagement and over utilization of water by farmers; (04) poor or late response against failure by farmer as well as department; (05) Inappropriate repair and maintenance of canals and damage made by users etc. In whole all the issues were leading towards mismanagement of command area. To overcome mismanagement issues Government of Gujarat had adopted the concept of Participatory Irrigation Management (PIM) in Gujarat state since 1995. Iit was also introduced in the Dharoi Right Bank Command jointly by Irrigation Department (ID) and Development Support centre Ahmedabad. Village Thalota of Visnagar taluka was selected as pilot project. After completing the rehabilitation works of old canals, the entire command area of 337 ha of village Thalota was taken over by the canal water co-operative society by signing a Memorandum of Understanding with ID.

Experiences of village Thalota have provided opportunity of learning to scale up PIM activities in other parts of command area. The experiences then spread over command area and presently the whole RBMCA has about 128 ICs managing about 25,784 ha of command area and about 20,491 farmer members. The performance of water co-operatives in Dharoi Right Bank command area is promising. But due to uncertainty of irrigation water, the required targets have not been achieved.
It is true that any positive development raises more expectations to make system more and more efficient. Keeping this in mind and to check the impact of PIM on command area as well as to address newly emerging issues like feasibility of inflow water against reducing rainfall in catchment area, water use efficiency in command area, parallel use of groundwater in command area, changing cropping pattern and extension of command area etc., the present study has been conducted with the following objectives to achieve main aim of checking up of the water use efficiency of the Dharoi irrigation project in order to culling out lessons for improving efficiency, equity and sustainability of irrigation in the command area.

(01) Study design capacity of the dam vs Actual command area irrigation – by studying spread of canal network and increase or decrease of irrigated areas before and after PIM introduction;
(02) Use of canal water as intensive source or extensive source within command area – by analyzing use of canal water as intensive or extensive source of irrigation with respect to use of groundwater in study area. The command area falls under the North Gujarat region of Mehsana and other districts that have been declared Dark Zone by the Central Ground Water Board. The intension of this agreement was to carry out identification of such area within command area, when canal water is utilized as intensive source of irrigation and
(03) Assessment of water availability in the catchment area of the dam - This has been carried out with a view to understand over all feasibility of the system with respect to changing rainfall pattern and land use in catchment as well command area.

An integrated approach was adopted to carry out the study by a team of Arid Communities and Technologies (ACT), Development Support Center (DSC)- Visnagar, Officials of Irrigation Department

and members of WUA. WUAs had been formed to discuss methodology and desired outcomes of the study. Methodology and findings of the study had been finalized through review and discussion in consultation with stakeholders in workshops and meetings. Several primary and secondary data were collected through appropriate sources and methods. Seasonal monitoring was carried out during the study. GIS and remote sensing data of appropriate period, pre PIM i.e. year 2003-04 and post PIM year 2007-08 were collected and used to generate various thematic maps of command area. Based on these maps and field data on water use efficiency and zone wise categorization such as land use, watershed etc. had been made to achieve the objectives of study. Even though the study had main focus on right bank canal however, some of the aspects at catchment area level were also been undertaken for considerations for more effectiveness of the study.

In addition to above methodology various literature was also reviewed to device specific methods of assessment of water use efficiency, to define extensive or intensive areas of command as well as to frame further developmental strategies for better utilization of water in command area. The important literature reviewed were research papers published by International Water Management Institution, Development Support Center, Government publications, Central Groundwater Board , universities etc. As far as specific analysis was concern several consultations with farmers, experts were also carried out during study. For water use efficiency approach proposed by Israelsen (1950) amendment proposed by American Society of Civil Engineer's Irrigation and Drainage Division Task Committee, later on concept revised by Jozef Takac, Pavol Nejedlik, Bernard Siska in 2008 and they have derived method for water use efficiency based on crop yield were also reviewed. However, due to lack of some consistency in data and resources efficiency has been evaluated by own methodology devised based on experts' advice.

### *Irrigation Management in Dharoi Irrigation Scheme*

The Sabarmati Reservoir Project is located across river Sabarmati near village Dharoi in Satalasana taluka of Mehsana district, Gujarat state. From geodetic Co-ordinates point of view it is located on latitude N 24$^{0}$ 00'00'' and longitude E 72$^{0}$52'00''. The project comprises a masonry gated spillway structure flanked on either side by non over flow dams and earthen dams and 4 numbers of saddle dams in dykes of 5420 m long. Command area of project is on both sides of Sabarmati River, through two main canals namely, L.B.M.C. (Left Bank Main Canal) 29.50 km long and R.B.M.C. (Right Bank Main Canal) 43.50 km. long. (Table 1)

**Table 1: Estimated Command Area of Dharoi Irrigation Scheme**

| Irrigation Type | Command | Estimated Area (ha) |
|---|---|---|
| Under flow irrigation | LBMC | 12350 |
| | RBMC | 45559 |
| Under Lift irrigation | LBMC | 630 |
| | RBMC | 2546 |
| **Total** | | **61085** |

The project was planned for irrigation facilities to 127 villages of Kheralu, Visnagar, Mehsana, Sidhpur and Vijapur talukas of Mehsana district through R.B.M.C. and 49 villages of Idar and Himmatnagar talukas of Sabarkantha district through L.B.M.C. The annual area under irrigation was estimated as 36842 ha (91000 Acres). There after cropping pattern had changed and had changed command area requirement of about 43320 hectares. (GoG, 2007) The distribution system of canal was originally considered as unlined. There after lining to the canal was considered up to 8 ha block. On account of saving due to lining, command area increased from 43320 to 56680 hectares keeping the total water requirement same as 218.33 $Mm^3$ (1.77 lift). The actual survey of command area was carried out and it was found that the area under irrigation system was 61085 hectares against 56680 hectares assumed while preparing project report. (Table 1) Extension of Right Bank Command area has been proposed by irrigation department in southeast and north western areas around Mehsana city. As per this proposal in the year 2004, total 23887 ha have been added to total command area at the cost of Rs. 5477.61 Lakh. The benefit of this extended command area has gone to 149 villages of Mehsana (100 villages) and Patan (49 villages) districts. Till year 1997 drinking water was supplied to Ahmedabad and Gandhinagar Cities.

However, latter on it has been stopped and the same quantity has being allocated to command area villages. Government of Gujarat had adopted the concept of participatory irrigation management (PIM) in Gujarat state since 1995. Accordingly the concept of PIM had been introduced in the Dharoi Right Bank Command. Village Thalota of Visnagar taluka was selected as pilot project. To achieve the concept implementation the Development Support Center, Ahmedabad has extended its full co-operation as an NGO. Generally, the ID manages the canal irrigation in the command areas of completed irrigation scheme. The farmers receive water according to fixed irrigation shdules. In PIM, the Water Users Associations (WUAs); called ICs in the study as the WUAs were registered under Cooperative Act, play important role in system and irrigation management particularly at tertiary (minor canal) and secondary ( Distrbutary/ Branch canal) levels. The Following is a comparative analysis of ID managed irrigation and PIM.

| Managed by Department | Managed by Irrigation Cooperatives (IC) under PIM |
|---|---|
| Stage I: Department estimates quantity based irrigation potential( generally area) after monsoon<br>Stage II: Executive Engineer (EE) issues notice for asking irrigation demand application from farmers within a mentioned period. In case of insufficient demand, the EE can increase the duration<br>Stage III: At completion of notice period, the EE calls the Irrigation Advisory Committee meeting. If there is no advisory committee, then, EE calls meeting of Deputy Executive Engineers, Section Officers, Work Assistants, Village Sarpanch, President and Secretary of Irrigation Cooperatives. In this meeting they decide expected crops and crop wise area rotation period, number of watering, watering wise volume of water etc.<br>Stage IV: Department takes action for completing cleaning and repair works of canal system before commencement of irrigation.<br>Stage V: Farmer submits demand form and pays water charges to the department in advance in a stipulated time frame.<br>Stage VI: Based on demand, responsible officer prepares demand format and then forwards it to higher authority.<br>Stage VII: If the farmer does not pay in advance or even after receiving water or he/she do mischief then department fines him with one half time more charge or as prescribed in Dept. Rules<br>Stage VIII: After completion of above formalities department releases water for irrigation during Rabi season normally after 16th October. ID also releases supplementary irrigation for kharif crops based on the local situation<br>Stage IX: Water distribution in Main, Minor, sub minor takes place simultaneously<br>Stage X: Farmer is responsible to drawing water for his own crop<br>Stage XI: To prevent over use / misuse , monitor water | • In PIM, the ICs and their upper level Associations i.e. Distributary Federation, Branch federation and Main canal federation participate in the irrigation planning, implementation and monitoring processes actively depending on progress of their formation and stage of operations.<br>• The ICs signs an agreement for 5 years to take over canal irrigation management from the ID.<br>• The ID hand over following authority to the ICs; irrigation and crop planning, water distribution to individual farmers, water charge fixing and collection from farmers, operation and maintenance of canal system, conflict resolution among farmers etc.<br>• In case of distribution management by Cooperatives, Stages I, II, III, and VIII remain same, while following procedures are different than department management system.<br>• The Chairman of ICs and their federations ( if esists any) are also involved in the stage-II and stage-III for the purpose of project level irrigation planning.<br>• In stage-II, the EE collect the irrigation demand directly from the IC and not from the individual farmers.<br>• Irrigation department is responsible to supply demanded quantity of water by particular Cooperative at its canal head.<br>• Officials of Irrigation departments help IC to prepare compiled demand form that is going to be forwarded to higher authority.<br>• Along with irrigation department's technical assistants, and canal watchmen, presidents and secretary of IC are equally responsible for misuse of water.<br>• Th IC prepares budget considering likely income and expenditures on different heads and it can raise the water charges if it got defict |

| | |
|---|---|
| flow and level in canal, irrigation department appoints technical assistants and canal watchmen. | budget. IC appoints its own canal operator and other paid staff<br>• IC collects water charges from farmer at the time of submission of demand form by farmer<br>• IC's canal operator inform and gives gate pass to farmer in advance for his turn of irrigation<br>• Watchmen gives permission to farmer to irrigate his farm only after he shows receipt of paid charges<br>• IC provides irrigation report to the ID on regualr interval and ID officers check IC`s reported irrigation area @ 10% sample for verification at the end of season<br>• ID issue Bill to the IC against the irrigated area from canal<br>• On timely submission of Govt. dues from collected water charges, IC receives incentives of 20 % rebate on irrigation revenues.<br>• IC has authority to fine the farmer against his mischief or offending rules of IC<br>•<br>• Irrigation department's canal officer provides technical support to IC to fulfill their technical procedures.<br>• The ICs and their federations conduct irrigation review meeting for culling our lessons |

Presently, about 196 ICs manage irrigation in Right Bank Main Canal Command area of Dharoi dam. Initially during 1995-2005, the ICs were registered under Cooperative Act but subsequently from 2005 onwards, all the ICs or say Water User Associations (WUAs) formed through recognition by Circle Office of Superintending Engineer. About 129 IC have been formed ad facilitated by DSC whereas remaining cooperatives have been coordinated ID directly or by other NGOs. All these ICs are managing canal water irrigation. In addition, there are several private *Borewell mandalis* who are also managing bore well irrigation but source of water is groundwater in the command area. ICs established by DSC are spread over about 89 villages and manage about 25,784 ha of irrigation area. There are about 20,491 farmers who are members of these ICs and rests of the farmers are entitled for receiving water from respective IC as non-members. There are two Federations which are constituted by these ICs at Branch level, one of them (Branch 2 Federation) has undergone for agreement with Government and has taken charge of water distribution also. The other Branch canal-1 federation is an informal body constituted by about 80 ICs of branch canal-1. This federation is yet to be registered.

## *The Study Area*

There are two distinct divisions of study area i,e. (01) Catchment area of the Dharoi dam and (02) the Dharoi Right Bank Main Canal Command. Most (about 60%) of the Sabarmati river catchment area falls under the jurisdiction of Rajasthan state. The total catchment area is about 5540 sq.km. While the Right Bank Main Canal Command (SRBMC) area spreads over 817.54 sq.km (81,754 ha) including 4298 ha of lift irrigation. The canal network in RBMC area has total length is about 969.5 km where main canal has total length of about 63.5 km. Land use pattern in the RBMC area has been estimated with the help of remote sensing data of LISS 4 of years 2003 and 2008. However, it is important to mention here that the resolution of image of year 2003 was of 23 x 23 m pixels whereas that of year 2008 was of 6 x 6 m pixels. The RBMC area has been classified in to five classes such as (01) Irrigated land; (02) Fallow/Dry Land;

(03) Water Logged Areas; (04) Settlements and (05) Water Body. The dominant land use in the command area is irrigated agriculture (52853 Ha) followed by wet and fallow areas (28664 Ha). Water bodies in the RBMC area are spread over about 1.82 sq.km.

### *Water Resources in RBMCA*

The Right Bank Main Command Area has also other water resources than canal such as storage tanks, ponds, check dams as well as wells and bore wells extracting the groundwater. There are about 237 water bodies distributed in RBMC area. Categorization of the water bodies based on their storage capacity, use and depth of water column was carried out. According to depth of water column about 175 structures are of less than 3 m depth while about 58 structures are of more than 3m depth. The water column depth criteria have been considered mainly to redefine the use of a particular structure in irrigation support, such that, structures less than 3 m depth can be considered as recharge structures and more than 3m depth can be used as storage structures which can be linked with canal system and then it can collectively be used by farmers. The total water storage capacity of all structures is about 53 MCM out of which about 13 MCM water is stored in small structures while about 40 MCM storage is in more than 3 m deep structures.

Geologically Mehsana District area represents two main rock formations viz., The Aravalli hills, in north and in north east, the catchment area of Dharoi dam is built up by the Precambrian basement rocks and the late Quaternary unconsolidated sedimentary deposits, part of Cambay basin (occurs in downstream areas of Dharoi Dam) are derived by fluvial transport from north-eastern catchments of Aravalli hills and are partly mixed with blown sands from southwest (Patel, 1986). Geo-morphologically, the area is divided into three main zones viz., (01) The hilly or mountainous terrain; (02) Piedmont zone; and (03) The central and southern alluvial plains

**Table 2: Aquifer Characteristics in Mehsana District**

| Aquifer | Thickness (m) | Depth (m) | Formation Parameters |
|---|---|---|---|
| Phreatic | 5 – 30 | Up to 30 | Except in pediment zone and flood plains generally dry (3 - 12 % and transmissibility 210-350 sqm/day) |
| Aquitard | 5 – 30 | 10 – 60 | Sandy clays with Kankar |
| Confined I | 20 – 30 | 35 – 90 | Clayey sand with gravel piezometric surface 15– 30 m |
| Aquitard | 10 – 15 | 55 – 110 | Yellow sticky sandy clay |
| Confined II | 15 – 25 | 110 – 160 | Same as above piezometric surface 20 – 35 m Average transmissibility 75 – 160 sqm/day |

District Mehsana is one of the classical examples of groundwater resource development and subsequent deterioration and depletion. As far as the study area is concerned there are total 8834 wells and bore wells out of which about 5930 structures are continuously extracting groundwater. About 3078 of groundwater structures are bore wells and 5746 are open wells. (Table 3) According to various geohydrological studies carried out by geological survey of India, UNDP, and CGWB during different periods, groundwater development history of Mehsana can be categorized in to three phases such as (01) **Pre 1935 phase:** Groundwater at shallow depth (5-10m) and obtained from dug wells by bullock and manual lift of water; (02) **1935 – 1955 phase:** Groundwater level declined to 10-30 m and dug cum bore wells became prevalent and diesel pump set were used for lifting the water and (03) **Post 1955 phase:** Groundwater level began to declined rapidly and from sixties decline has been between 1.3 m every year. Deep tube wells fitted with electric motor have been used to lift groundwater from 100-250 m depth. In short, all studies have concluded that

- The ground water mining has depleted a series of alluvial aquifers
- Groundwater quality deterioration is almost a parallel phenomenon from post 1955 with the development of tube wells and electric motors
- Soil feasibility is gradually affected due to irrigation by high TDS water and has resulted into disappearance of several crops

**Table 3 Use wise categorization of Wells and Bore wells in RBMC Area**

| Type of GW Source | Bore well | Open Well |
|---|---|---|
| Used No. | 2791 | 3129 |
| Disuse no. | 287 | 2617 |
| Total | 3078 | 5746 |
| Irrigation (ha) | 23571 | 7628 |

So far the study area is concerned; wells and bore wells together provide irrigation to about 31,199 ha area. To understand the exploitation as well as extensive or intensive use of canal water in RBMC area well density per village / block was computed. In Dharoi RMBC area the depth of water table, below ground level (bgl), ranges from less than 5 m to more than 20 m within unconfined aquifers whereas in confined aquifers it ranges from 100 m to more than 180 m at places. Based on static water level, the study area has been categorized into four zone viz., (01) Very Shallow zone SWL less than 10 m; (02) Shallow zone SWL 10 to 20 m; (03) Deep groundwater zone SWL ranges from 20 to 100 m and (04) Very deep groundwater zone SWL more than 100 m. Comparison between well density and water level shows well density is more in areas where groundwater occurs at shallow depth and it decreases as the depth of groundwater level is more. GWRDC has categorized Mehsana as Dark zone in their categorization.

During the study groundwater quality in RBMC area was determined based on various physico-chemical parameters such as Total Dissolved Solids (TDS), pH, hardness and ionic content. TDS and pH determination in groundwater of study area was carried out at 10 sq km grid within RBMCA. The assessment was done for post monsoon and post winter seasons of the year 2008 & 2009 respectively, because during winter most of the farmers intensively use groundwater for irrigation purposes. To characterize study area from salinity point of view TDS maps were prepared for whole area for both the seasons and the areas were categorized into five zones such as (01) Excellent water quality (TDS <500 mg/l); (02) Good water quality (TDS 500-1500 mg/l); (03) Moderate/ permissible water quality (TDS 1500-2000 mg/l); (04) Brackish /partial saline water quality (TDS 2000-3000 mg/l); and (05) Saline water quality (TDS>3000 mg/l). Fig 3 shows that TDS concentration increases in western part as well as in areas around Meshva, Sankhalpur, Champa villages during pre monsoon seasons. The eastern part of command area shows good to excellent groundwater quality from TDS point of view during post monsoon as well as post winter season.

## *Impact of PIM*

Cropping pattern in study area has been studied in order to understand change in cropping pattern before and after PIM activities as well as to understand water use efficiency. After PIM Wheat, Mustard and Caster productions have significantly increased in the command areas whereas slight decrease has been seen in Cumin seed, isabgool, grass and vegetable crops. Another major impact on crop in the area is change in crop variety such as earlier in most of the areas indigenous cotton and caster were sawn which are replaced by BT cotton and hybrid caster.

PIM impact has also been assessed based on before and after PIM changes in irrigated area. PIM has been promoted since 1995-96 but the intensive spread of PIM activity started after year 2004. Before year 2004 there was only 28 ICs in entire command area. Therefore considering year 2004 as benchmark year, changes in irrigation area as well as land use in RBMCA have been analyzed. Analysis of remote sensing data shows that total about 22,512 ha of area was under irrigation during Rabi season of year 2003-04 in block no. 1,2,3 and 4 while it was about 36,412 ha during year 2007-08. Total irrigation area in seven blocks was about 63,235 ha. Comparative analysis of first four blocks show about 61.74% of increase in irrigated area after PIM. Two factors can be considered for this significant change in RBMCA (01) Canal rehabilitation works in **about 254 km length of canals were completed by WUAs** whereas about **488 km length of canal was surveyed** and Rs. 658 were estimated to complete the task and (02) Re-Lining of main canal, branch canal-2 and branch canal 3 by the ID. Involvement of ICs in R&M, O&M, irrigation management, evolution of better management practices, regulatory norms for water management and distribution etc. Today in RBMCA, PIM activities are already spread over about 25,784 ha area that was only about 5100 ha before year 2004. Today there are about 129 ICs in 89 villages, managing irrigation water in command area and about 20,491 farmers who are members of these WUAs.

Increase in irrigated area is definitely a measure of improvement of overall system but, sustainability of this increase still remains questionable unless understanding on improvement in water use efficiency, maintenance of inflow in reservoir, extension in command area as well as intensive or extensive use of canal is developed. Therefore the present study has also carried out such estimation with some sort of limitations such as data, time and resources.

Water use efficiency was computed from scheme irrigation efficiency, per ha water use (duty), and yield. If the scheme irrigation efficiency is 57 %, that can be categorized as good category according to some eminent irrigation engineers like Israelsen (1950). Annually computed water use per hectare area shows about 0.4031 mcft/ha was during year 1979-80 whereas it was 0.188 during 2009-2010. However minimum water use per ha was in year 1996-97 and maximum was in year 1980-81. An average duty before PIM period was 0.34 mcft/ha whereas after PIM it is 0.232 mcft/ha. The water use efficiency on the bais on Grain productivity (for 100 kg production) and income (for 1000 Rs) has been carried out based on case studies of 10 minors of command area. Wheat, Mustard, Cumin, Fennel, Cotton, Caster, Lucerne, and maize crops were irrigated in total 506 ha area by farmers during year 2007-08. However main winter crops such as wheat, mustard, cumin and fennel irrigated in 376 ha were considered for this analysis. Quantity of irrigation water was calculated considering number of waterings and discharge measurement 10 cm water column per watering. Grain production of the particular crop was estimated based on average production of respective crop through survey of four farmers in particular Minor command beneficiaries. Water use efficiency based on grain productivity was computed for per 100 kg production. In addition to production base water use efficiency, attempt was made to understand water use efficiency for Rs. 1000 income from a particular crop. According to this analysis for Rs. 1000 income wheat crop requires water in the range of 128 – 231 cum whereas cumin requires maximum water i.e. 471 cum. DSC has also carried out study for water use efficiency from productivity and income point of view for wheat crop in detail through trial with about 10 farmers of the RBMC area in Rabi season of year 2006. As per this study, water requirement per kg of wheat production ranges between 381 - 2038 lits where as gross and net water productivities range between 50 – 258 lits and 20 to 173 lits respectively. Total per ha wheat production varies from 2500 – 5000 kg. Minimum water requirement of 381 liters was consumed for one kg wheat in black/clay loam soil in village Hasanpur in branch canal-2 while 2038 liters consumption was noticed in sandy/ sandy loam soil of Dedasan village in the head reach areas near reservoir

## Canal water use

The RBMC command area has been designed for extensive use of Dharoi canal water, as other local water resources are available in the command area. The system is designed on 50% irrigation intensity. . Various factors like extend of ground and surface water use, number of watering provided through ground v/s. surface source, gradual extension of command area and changes in cropping pattern characterize use of canal water as extensive or intensive. Therefore, to consider any particular part of RBMC area as intensive irrigation command area or extensive irrigation by canal irrigation one one particular factor is very difficult. RBMC area has also very good groundwater potential within shallow and deep aquifer systems of loose alluviums. In both kinds of areas people use canal water extensively as well as intensively depending on numbers of watering allocated by department during a particular irrigation season. However, in some areas immediately adjoining the dam i.e. villages around Dharoi, Madhasana people use canal water mainly for recharge purpose. In case of deep groundwater areas people use groundwater and canal water supplementary to each other based on crop type and number of watering. Block wise percentile analysis of irrigation in areas by different sources has been carried out to define an area as intensive command or extensive command area. About 31199 ha area was irrigated during 2007-08 through groundwater. Maximum groundwater based irrigation practices (7008 ha) exist in block no. 7 where as minimum is in block no. 1 (1742 ha.) Total groundwater based irrigation is provided in about 24,329 ha (77.98 %) whereas that of open well based is provided in about 6870 ha. (22.02 %) Source wise comparison shows that in case of block no. 1 open well based irrigation (68.22 % ha) is higher than the bore well based irrigation (31.78 %). The ratio of well irrigation is very low in case of block no. 2 (9.43 %), 3 (3.10%) and 4 (6.63 %). The analysis clearly shows whole command area is using both the sources of water almost equally. However, bock no. 6 and 7 can be categorized as intensive groundwater irrigated and intensive canal water irrigated areas respectively whereas rest of the blocks are almost using both the resources equally. Number of irrigations in a particular season was also studied with 11 selected cooperatives in order to understand extensive vs intensive use of canal water during year 2007. Out of total 300 waterings only 135 waterings were made available from canal water whereas 168 waterings were facilitated by groundwater. The fact itself indicates that the command area is now using canal water as an extensive source of water.

The ID and ICs would develop a joint action plan for water allocation and irrigation rescheduling in intensive and extensive canal irrigation pockets for maintaining equity and efficiency.

RBMC area has continuously extended after the irrigation started. The bases of expansion were gradual development and up-gradation of canal network system. Total about 23410 ha has been added to RBMC area since year 2005 mainly in block no 2, 3, 4, 5, 6 and 7. Besides expansion in different blocks, maximum extension of about 12,738 ha has been added through expansion of right bank main canal along with expansion in branch no. 4 and 5. Irrigation department had planned to expand command area to about 56,695 ha and yet they have achieved expansion to about 41.3 % only. According to irrigation department they have stopped water supply of 115340 cusec/year to Gandhinagar, and Ahmedabad since 1997 and has diverted it for the expansion.

The sustainability of command area extension has been understood from catchment yield point of view. The total catchment area of Dharoi Dam is about 5540 sq.km out of which about 2361 sq.km area is interrupted by construction of small and big reservoirs such as tank, dam etc. Therefore, only about 58 % of total catchment is directly generating runoff for Dharoi reservoir. The rainfall records of 4 stations for last 33 years have been analyzed for runoff estimation and inflow water computation in reservoir. Average annual rainfall of the catchment area is 703 mm distributed among 32 days during rainy seasons. Fig. 3 shows decreasing trend in average annual rainfall from year 1977 as about 800 mm to 2009 as about 700 mm. However, there is no significant change seen in daily intensity of rainfall. The Hydrograph study of catchment yield in compare to irrigation water supply indicates there was narrow gap between rainfall and inflow % in to dam during 1977-78 that has widen over the period of time.

Hydrograph of received rainfall, vs. received inflow in reservoir for a period from year 1977 to 2009 shows even though gradual decrease in inflow and impact on area irrigated is not as significant as was in the years e.g. 1986-87 or during year 1999-2000. It also reveals that before 1995-96 there was a clear dependency of irrigated areas on water inflow in the dam. Whereas period of year 1995 - 2004 seems transitional period while from 2004 onwards variation in inflow has not much significant impact over irrigated area that clearly shows an impact of spread of PIM activities in RBMCA.

### *Recommendations*

Findings of the study have clearly revealed that spread of PIM in RBMCA has resulted into better management practices at almost all the levels i.e. from sub minors to main canals. It has also led to extension of command area as well as helped in increasing efficiency of the overall system. Besides canal water, groundwater has also played very important role in maintaining and increasing irrigated areas in RBMC. Along with all these positive impacts several threats are also taking place as far as the management and sustainability is concerned. These threats are at both the levels i.e. catchment and command area level. It seems that PIM in Dharoi is on the verge of paradigm shift from surface vs. groundwater irrigation management to well planned conjunctive use of ground and surface water management for sustaining agriculture based livelihoods in this water deficit region.

Catchment level main threat is, decreasing run off due to decrease in rainfall and changes in landuse pattern whereas threat in command area is its extensive use because of groundwater use. The depletion in water level and deterioration of water quality are major threats for groundwater. Application of bad quality groundwater has impacted soil quality. Another command area threat is linked with equitable distribution management in extended command area. With these considerations, geo-hydrological characteristics and popularity of PIM activities in RBMC area, four main sets of recommendations have been made for future sustainability and better irrigation management in RBMC area.

1. Recharging ground water and local surface water bodies through canal water
2. Watershed management Activities in the command areas
3. Evolving Better Irrigation management practices at main/ distributor canals and below Minor canal level

On farm Irrigation management and agriculture extension

### 1. Recharging Local Surface and Groundwater Bodies through canal water

There are about 233 small, medium and major water structures already existing in RBMC area. These bodies have been created under various Govt. schemes and local initiatives. Recharging of at least medium and major of these structures by canal water is proposed to make use of such structures for decentralized pond based irrigation management. Block wise distribution of these structures shows that about **58 structures are of medium and major size that can be consider for this.** Major physical activity required for this is to construct feeder canal from nearest outlet or canal network. To establish proper irrigation management with this strategy initially one should go for two to three pilot projects in each block in first phase then plan for up-scaling in next phase based on experience. The respective near by IC and federation can be encourages and empowered for canal fed management of pond irrigation. This is also help in reducing pressure on direct irrigation from canals.

Considerations of Groundwater Potential for Block wise Distribution:_following strategies can be proposed for use of groundwater potential

| Groundwater Class | Water Level Range (M) | TDS (mg/l) | Strategy |
|---|---|---|---|
| Shallow Good Groundwater Areas | 10 – 20 | <1500 | Re-estimate allocation of water volume according to requirement for groundwater recharge and allocate surplus water to bad quality deep groundwater areas. |
| Deep Good Groundwater Areas | >20 | < 1500 | Promote micro irrigation practices and efforts for change in cropping pattern less water intensive crops. Needs micro level mapping for intensive and/or extensive groundwater and canal water use. |
| Shallow Bad Groundwater Areas | 10 – 20 | >1500 | Use Canal water for recharge and improve groundwater quality |
| Deep Bad Groundwater Areas | >20 | >1500 | Use only canal water intensively |

## 2. Watershed Development and Management Activities

There are two major rivers viz., (01) Rupen and (02) Pushpavati are passing through block no 5, 6 and 7 in western part of RBMC area. Watershed development activities in this area can have qualitative and quantitative impact on groundwater resources of the area. It is already discussed earlier that block no. 4, 5 and 6 of RBMC area have more than 5000 open wells which can be directly benefited by these activities through improvement of water quality. Activities like construction of new recharge structure, de-silting of existing small sized water harvesting structures, recharge of groundwater through dug wells etc. can be planned to encourage recharge within watershed areas. However, for micro planning of watershed, PRA needs to be held in command area in respective watershed areas. Various agencies like NABARD, ID, CGWB, and Integrated Watershed Management Support Unit and others can be approached for the funding.

## 3 Better Irrigation Management Practices

Main / Distributary canal level: There needs to be improvement in management at Main and Distributory canal levels through following practices,

- Improvement in System Infrastructures through canal lining
- Water Measuring structures throughout the length of the main and distributary canals for better planning and monitoring
- Improvement in communication facilities like use of Information Coomunication technologies ( cell phones SMS services, establishing irrigation / farmer call centre, mobile irrigation van, audio/ video confeencing) to control over illegal water pooling
- Revisiting watering schedule method and the scheduling planning process with WUA's consultations keeping in view cropping pattern, soil types, ground water use etc.
- Encourage *Wara bandhi* / rotational water supply
- Decentralized decision making and review of irrigation processes with ICs and their federation
- Redefine and/ or review roles and responsibilities of different stake holders such as Irrigation department, WUAs, federations, and NGOs based on experiences.
- Award, reward and incentives for judicious water user, water meter usage, adaptation of low water intensive crop, adaptation of micro irrigation systems.
- Disincentives in case of misuse or over use of water, high water intensive crops, water stealing.
- Computerized record keeping and data management at all levels. This needs a proper capacity building of various stake holders.
- Motivation and awareness programmes for the farmers and other water users for soil and water conservation and management

**Minor / Sub Minor Level:**

- Setting up of performance monitoring of WUAs at minor / sub minor level is one of the important requirements.
- All minors should be facilitated with volumetric measurement, supply and pricing system for controlled water use and incentivizing farmers
- Farmer should be encouraged / incentivized for adoption of volumetric water allocation.
- Need to develop mechanism and management of resource for asset management like canals, volumetric infrastructure etc.
- Improvement requires in communication facilities up to the minor level, also to enable continuous and easy management by the department or the WUA
- Capacity building of the WUAs and farmers for creation of awareness about right to get water as per designed discharge
- Department along with NGO should organize a mass awareness program on economics in crop selection and emphasis on return per drop of water.
- Design a capacity building program for development of at least one Para worker per village with specific capacity skills of irrigation management techniques.
- Additional facilities like office building/ command area hut/ command area service center and night irrigation facilities with control monitoring system.

**4 On Farm Irrigation Management and agriculture extension**

For better irrigation management at farm level there is a need to give more emphasis on farmer's education and updating him with latest information of management of irrigation water demand through agriculture extension system. Department should launch specific schemes for modern water saving techniques in specifically targeted areas such as good quality deep groundwater areas, (Fig. 5.3) etc. mapping of such areas and blocks needs to be prepared by department so that techniques like drip / sprinkler / PINS can be promoted to large mass.

Promotion of soil testing and vermi compost and other techniques for improvising humus content and water holding capacity of soil especially sandy soils of branch -1 command area.

# 1. INTRODUCTION

Development Support Centre (DSC) is a Non Governmental Organization (NGO) working for Participatory Natural Resource Management. Since 1995, DSC is associated with the promotion of Participatory Irrigation Management (PIM) program in tail end villages of Sabarmati Reservoir Project (a major irrigation project) at Dharoi in Gujarat. Village Thalota was the first villages where DSC has started its PIM activities. Experiences of this village have expanded the PIM activities in whole Dharoi command area. Along with irrigation department, DSC has played major role in promoting Participatory Irrigation Management (PIM) in the state as well as in the country. In case of Dharoi command through north Gujarat field unit DSC has promoted about 175 Water User Associations (WUAs). So far as Right Bank Main Command area is concerned DSC has formulated about 130 Irrigation cooperatives in about 89 villages. Not only that DSC also facilitates systematic capacity building of ICs, canal renovation works, water distribution management etc.

Present report is of the study conducted by Arid Communities and Technologies (ACT), based on invitation of DSC, to understand various aspects of Dharoi dam command area in order to its water use efficiency, changes taking place with respect to PIM promotion, use of command area as extensive or intensive as well as extension of command area in compare to its designed capacity.

## 1.1 AIM AND OBJECTIVES

The main aim of the study proposed by DSC is to check the water use efficiency of Dharoi irrigation project. To achieve the designed aim the study has been divided into three phases such as

- Study design capacity of the dam vs Actual command area irrigation.
    - In this case the spread of canal network has been studied after PIM introduction however to carry out assessment of expansion of area previous data, i.e. since 1980 have been reviewed.
- Use of canal water as intensive or extensive source of irrigation within command area
    - Use of canal water as intensive or extensive source of irrigation has been understood, with respect to use of groundwater in study area. The intension of this agreement was to carry out identification of such area within command area, where canal water is utilized as intensive source of irrigation.
- Assessment of water availability in catchment area of the dam.
    - This agreement has been carried out with a view to understand over all feasibility of the system with respect to changing rainfall pattern and land use in catchment as well command area.

## 1.2 APPROACH AND METHODOLOGY

An integrated approach has been adopted to carry out the study where a team of ACT, DSC Visnagar, officials of irrigation department and members of WUA had been formed to discuss the methodology and desired outcomes of the study. Workshops and consultations were main tools for the interactions. Several primary and secondary data were collected through appropriate sources and methods. Seasonal monitoring was carried out during the study. GIS and remote sensing data of appropriate period, pre PIM i.e. year 2003-04 and post PIM i.e. year 2007-08 were collected and used to generate various thematic maps of command area. . Based on these maps and field data, water use efficiency and zone wise categorization such as land use, watershed etc. have been made to achieve the objectives of study. Even though the study has main focus on right bank canal, some of the aspects at catchment area level were also considered for bettereffectiveness of the study. Detail methodology of the study is discussed below.

***Data collection:*** Various primary and secondary data were collected through available published /non published data in various forms such as reports, research papers, matrix, maps etc. Required primary data such as groundwater level, water quality, soil quality, cropping pattern etc. were collected through field works in study area. These data were acquired through various methods viz., well inventory, farmer surveys, soil sampling and inflow – outflow measurement of canal water. Selected water use associations (Annexure 1.1) were consulted for water use efficiency analysis in the area. Crop cycle was understood through focus group discussions with farmers of different villages of RBMCA.

Meteorological data, especially annual rainfall data recorded at different locations in command and catchment areas were acquired by using web site of Indian Meteorological Department. In addition, rainfall recorded at Dharoi dam site was also reviewed for rainfall analysis.

Further, block wise irrigation data was collected from irrigation department as well as branch office of DSC. Various canal maps and command area maps were also acquired from irrigation department which were digitized on GIS software to generate various thematic maps. Information related to water allocated in different command area and respective irrigation were collected for longer period and used to see the changing trend in command area.

***Field Surveys:*** RBMCA villages were surveyed to assess the potential of surface and ground water resources and their contribution to irrigation. Specific formats were developed to carry out this survey.

***Soil Water Sampling:*** To evaluate the physical-chemical properties of the soil and water sampling method was adopted. The whole area was divided in to ten sq. km. sized grid. Samples were analyzed in laboratory. About 86 samples of soil and water were collected from command area and then analyzed for Total Dissolved Solids and pH. About 16 water samples were analyzed for detail water chemistry.

***Thematic Mapping:*** IRS P6 remote sensing data of irrigation for the years December 2004, 2007 and January 2008 were used to carry out land use analysis. It is important to clarify here that the

PIM activities in RBMC had started during 1995-96 however the sizable spread of PIM in the area has taken place during 2004. Therefore irrigation season of year 2004 was considered here as before PIM period. The LISS – 4 images were used for this assessment. Besides this, image toposheet and command area maps (prepared by irrigation department) were used to generate various thematic maps such as canal network, water resource distribution, water quality maps, crop pattern maps, land use map etc. Various soft-wares such as Carta Linx, Irdas, Arc view, and Idrisi were used for analysis and mapping.

***Water Use Efficiency Assessment:*** Based on several parameters water use efficiency, intensive and extensive canal water use areas were assessed. However, detail methods of these assessments are discussed in respective chapter.

***Consultation and Workshops:*** Interaction through workshop, consultation and meeting was done at various stages of study for different objectives like finalization of methodology, to discuss and fine tune the outcomes, to propose future strategies and directions etc. In this, consultations with various resource persons from different fields were held including technical experts, government officials, academicians and rural experts. They were consulted individually and / or collectively through workshops.

**Plate 1.1 Consultation with Stake Holders**

# 2. DHAROI IRRIGATION SCHEME

## 2.1 LOCATION

The Sabarmati Reservoir Project is located across river Sabarmati near village Dharoi in Satalasana taluka of Mahesana district, Gujarat state. From geodetic co-ordinates point of view it is located on latitude N $24^0$ 00’00’’ and longitude E $72^0$ 52’00’’. The nearest meter gauge railway station is about 14 km at Taranga hill station where as it is directly approachable by road. With respect to state capital, Gandhinagar it is about 125 km in north and linked to Ahmedabad – Gandhinagar – Visnagar – Ambaji State Highway.

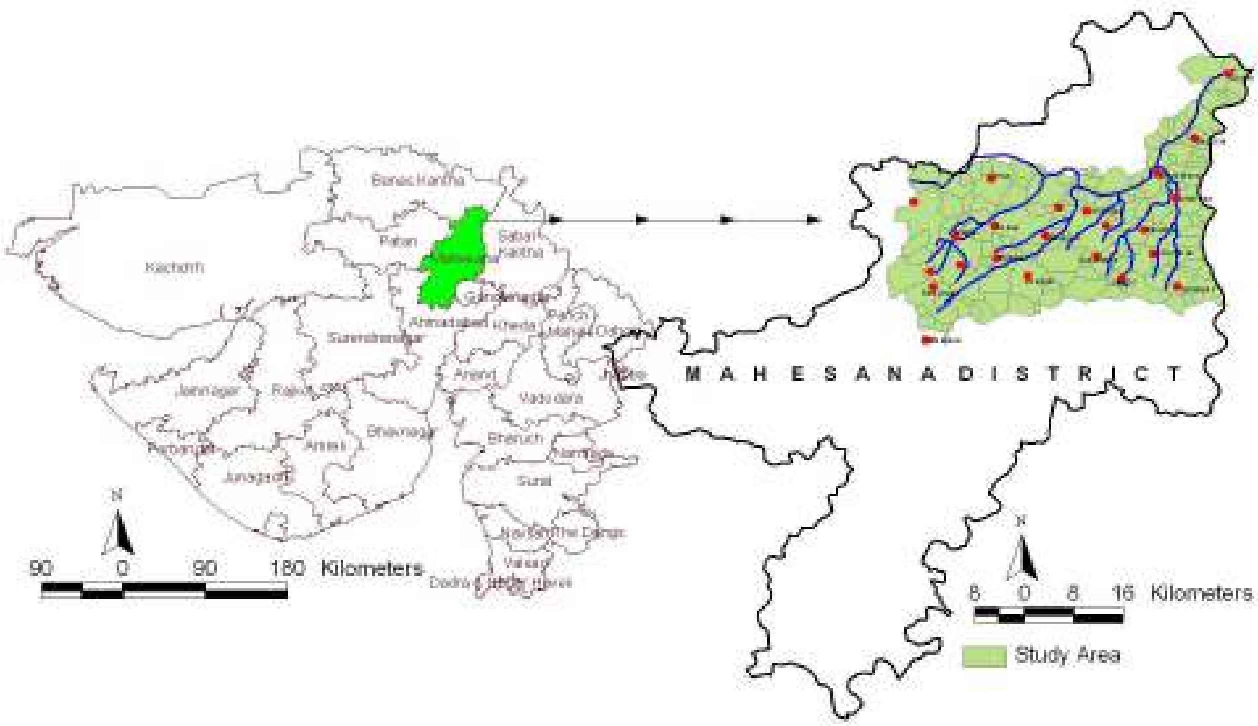



**Fig 2.1 Location of Dharoi Command Study Area**

Source: Census Handbook, GoG (2001), GoG, Irrigation Department (2005), SOI (1965)

## 2.2 PROJECT COMPONENTS

***Dam:*** The project comprises of a masonry gated spillway structure flanked on either sides by non over flow dams, earthen dams and 4 saddle dams in dykes of 5420 m long. Earthen portion of the dam is about 828.91 m long while the gated spill way consists of 12 gates of 49 x 37 feet size and has a total length of about 219.46 m. The length of non over flow portion of spill way is about 149.96 m.

***Canal / Distribution system:*** Command area of project is on both sides of Sabarmati River. There are two main canals namely, LBMC (Left Bank Main Canal) of 29.50 km length and RBMC (Right Bank Main Canal) of 43.50 km. length. The full supply discharge at the canal head of LBMC and RBMC is 4.96 Cumecs (175 Cusecs) and 29.25 Cumecs (715 Cusecs) respectively. Distribution system is lined up to 8 ha block to serve a total CCA of 61085 ha including 2546 ha under lift irrigation.

**Table 2.1: Estimated Command Area of Dharoi Irrigation Scheme**

| Irrigation Type | Command | Estimated Area (ha) |
|---|---|---|
| Under flow irrigation | LBMC | 12350 |
| | RBMC | 45559 |
| Under Lift irrigation | LBMC | 630 |
| | RBMC | 2546 |
| **Total** | | **61085** |

Total ultimate potential in Right Bank Command of Mahesana District is 45559 + 2546 ha = 48105 ha and 12980 ha in Left Bank Command (Sabarkantha District). Thus out of total area of 61085 ha, total ultimate irrigation potential created up to June 2000 is 59963 ha. (Table no. 2.1)

**Plate 2.1 View of Canal Water Control System**

***Benefits:*** The project provides irrigation benefits to villages of Mahesana and Sabarkantha Districts and water supply to cities of Ahmedabad and Gandhinagar. Depending upon availability of water, the project also provides water to thermal power station at Ahmedabad and Gandhinagar.

***Irrigation:*** The project was planned for irrigation facilities to 127 villages of Kheralu, Visnagar, Mahesana, Sidhpur and Vijapur talukas of Mahesana district through RBMC and 49 villages of Idar and Himatnagar talukas of Sabarkantha district through LBMC. The annual estimated area under irrigation was 36842 ha (91000 acres). There after cropping pattern has changed. This has changed the command requirement of about 43320 hectares (GoG, 2007). The distribution system of canal was originally considered as unlined. Later on lining to the canal was considered up to 8 ha block. On account of water saving due to lining, command area increased from 43320 to 56680 hectares keeping the total water requirement same as 218.33 $Mm^3$ (1.77 lift). The actual survey of command area was carried out and it was found that the area under irrigation system was 61085 hectares against 56680 hectares assumed while preparing project report (Table 2.1).

Irrigation performance has been assessed for both side command area by irrigation department (Table 2.1). As per this, with full supply discharge of 4.96 cumecs and 29.25 cumecs respectively at the canal head of LBMC and RBMC , a lined distribution system up to 8 ha block has been planned to serve a total ICA of 61085 hectares including 3176 hectares under lift irrigation..

The year-wise and season wise irrigation potential created and utilized under both canals since 1979-80 are compiled. It is seen from the data that full potential has been created by June 2000. Further it is seen that maximum area irrigated so far has been 40182 hectares during 1993-94 through RBMC, LBMC and Tank Bed cultivation.

Extension of right bank command area was proposed by irrigation department in southeast and north western areas around Mehasana city. As per this proposal in the year 2004, total 23887 ha area was added to total command area at the cost of Rs. 5477.61 Lakh (Annexure 2.1 and 2.2). The benefit of this extended command area has gone to 149 villages of Mehasana (100 villages) and Patan (49 villages) districts.

***Water supply:*** Till year 1997 drinking water was supplied to Ahmadabad and Gandhinagar cities. However, later on it was stopped and the same quantity was allocated to command area villages.(Table no. 2.2)

**Table 2.2 Water Supply Distribution from Dharoi Scheme**

| **Supply To** | **Quantity** | |
|---|---|---|
| | **Mgd** | **Cusecs** |
| Ahmedabad | 150 | 278 |
| Gandhinagar | 11 | 20 |
| D/S riparian right | 16 | 50 |
| Ahmedabad and Gandhinagar Thermal Power stations | 10 | 18 |
| **Total** | **187** | **346** |

Source: Irrigation Department, 2005

***Finance:*** The Sabarmati project was cleared by Central Water Commissioner (CWC) and planning commission in 1971 at the estimated cost of Rs 17.58 crores. Since then the project cost has increased many folds. The latest estimated cost as per revised implementation schedule works out to be Rs. 134.51 crores. Total expenditure up to August 2000 is Rs. 120.60 crores. The increase in cost of the project was mainly on account of change of scope of the work and escalation in prices of labor and material. The project has been funded by the Gujarat State from its own resources and there has been no external assistance for the project. The benefit to cost ratio of the project is 1.61.

***Participatory Irrigation Management:*** Government of Gujarat had adopted the concept of participatory irrigation management (PIM) in Gujarat state since 1995. Accordingly the concept of PIM had been introduced in the Dharoi Right Bank Command. Thalota village of Visnagar taluka was selected as pilot project. After completing the rehabilitation works of old canals, the entire command area of 337 ha of village Thalota was taken over by the irrigation co-operative society. To achieve the concept Development Support Center, Ahmadabad has extended its full co-operation as an NGO till 2009. The efforts made by DSC to establish PIM cooperatives have been discussed in proceeding chapters. Methods of irrigation management through participatory approach have been discussed in subsequent discussion.

## 2.3 IRRIGATION MANAGEMENT

<table>
<tr><th colspan="2">Managed by Department</th><th>Managed by Irrigation Cooperatives (IC) under PIM</th></tr>
<tr><td>Stage I:<br>Stage II:<br><br><br><br><br>Stage III:<br><br><br><br><br><br><br><br><br><br>Stage IV:<br><br><br>Stage V:<br><br><br>Stage VI:<br><br><br>Stage VII:<br><br><br><br>Stage VIII:</td><td>Department estimates quantity based irrigation potential( generally area) after monsoon<br>Executive Engineer (EE) issues notice for asking irrigation demand application from farmers within a mentioned period. In case of insufficient demand, the EE can increase the duration<br>At completion of notice period, the EE calls the Irrigation Advisory Committee meeting. If there is no advisory committee, then, EE calls meeting of Deputy Executive Engineers, Section Officers, Work Assistants, Village Sarpanch, President and Secretary of Irrigation Cooperatives. In this meeting they decide expected crops and crop wise area rotation period, number of watering, watering wise volume of water etc.<br>Department takes action for completing cleaning and repair works of canal system before commencement of irrigation.<br>Farmer submits demand form and pays water charges to the department in advance in a stipulated time frame.<br>Based on demand, responsible officer prepares demand format and then forwards it to higher authority.<br>If the farmer does not pay in advance or even after receiving water or he/she do mischief then department fines him with one half time more charge or as prescribed in Dept. Rules<br>After completion of above formalities department releases water for irrigation during Rabi season normally after 16th October. ID also releases supplementary irrigation for kharif crops based on the local situation</td><td>• In PIM, the ICs and their upper level Associations i.e. Distributary Federation, Branch federation and Main canal federation participate in the irrigation planning, implementation and monitoring processes actively depending on progress of their formation and stage of operations.<br>• The ICs signs an agreement for 5 years to take over canal irrigation management from the ID.<br>• The ID hand over following authority to the ICs; irrigation and crop planning, water distribution to individual farmers, water charge fixing and collection from farmers, operation and maintenance of canal system, conflict resolution among farmers etc.<br>• In case of distribution management by Cooperatives, Stages I, II, III, and VIII remain same, while following procedures are different than department management system.<br>• The Chairman of ICs and their federations ( if esists any) are also involved in the stage-II and stage-III for the purpose of project level irrigation planning.<br>• In stage-II, the EE collect the irrigation demand directly from the IC and not from the individual farmers.<br>• Irrigation department is responsible to supply demanded quantity of water by particular Cooperative at its canal head.<br>• Officials of Irrigation departments help IC to prepare compiled demand form that is going to be forwarded to higher authority.<br>• Along with irrigation department’s technical assistants, and canal watchmen, presidents and</td></tr>
</table>

| | |
|---|---|
| Stage IX: Water distribution in Main, Minor, sub minor takes place simultaneously<br>Stage X: Farmer is responsible to drawing water for his own crop<br>Stage XI: To prevent over use / misuse, monitor water flow and level in canal, irrigation department appoints technical assistants and canal watchmen. | secretary of IC are equally responsible for misuse of water.<br>• Th IC prepares budget considering likely income and expenditures on different heads and it can raise the water charges if it got defict budget. IC appoints its own canal operator and other paid staff<br>• IC collects water charges from farmer at the time of submission of demand form by farmer<br>• IC's canal operator inform and gives gate pass to farmer in advance for his turn of irrigation<br>• Watchmen gives permission to farmer to irrigate his farm only after he shows receipt of paid charges<br>• IC provides irrigation report to the ID on regualr interval and ID officers check IC`s reported irrigation area @ 10% sample for verification at the end of season<br>• ID issue Bill to the IC against the irrigated area from canal<br>• On timely submission of Govt. dues from collected water charges, IC receives incentives of 20 % rebate on irrigation revenues.<br>• IC has authority to fine the farmer against his mischief or offending rules of IC<br>•<br>• Irrigation department's canal officer provides technical support to IC to fulfill their technical procedures.<br>• The ICs and their federations conduct irrigation review meeting for culling our lessons |

# 3. THE STUDY AREA - Right Bank Main Command Area

## 3.1 SPREAD AND LOCATION

There are two distinct divisions of study area i,e. (01) Catchment area of the dam and (02) the Sabarmati Right Bank Main Canal Command. Most of the catchment area falls under the jurisdiction of Rajasthan state. The total catchment area is about 5540 sq.km, while the Sabarmati Right Bank Main Canal Command (SRBMC) area spreads over 817.54 sq.km (81,754 ha) including 4298 ha of lift irrigation command. The canal network provides irrigation facility to about 149 villages of Kharalu, Mehasana, Satlasana, Unjha, Vadnagar, Vijapur, and Visnagar Talukas (Fig. 3.1). Vinegar (35 villages) and Vadnagar (36 villages) talukas have maximum number of villages facilitated by canal irrigation. The entire command area has been divided into 7 blocks (Annexure 3.1). Taluka wise distribution of villages of RBMC is given in Table 3.1.

**Table no. 3.1: Number of Villages Covered and Type wise Length of Canal in RBMC Area.**

| Village wise Distribution | | Details of Canal Network | | |
|---|---|---|---|---|
| **Taluka** | **Village (No.)** | **Type of Canal** | **No.** | **Length (km)** |
| Kheralu | 25 | | | |
| Mehasana | 8 | Main Canal | 1 | 63.5 |
| Satlasana | 15 | Branches | 3 | 51 |
| Unjha | 13 | Distributaries | 14 | 117 |
| Vadnagar | 36 | Minors | 151 | 285 |
| Vijapur | 17 | Sub Minors | 451 | 453 |
| Visnagar | 35 | **Total** | | **969.5** |
| Total | **149** | | | |

The canal network in RBMC area has total length of about 969.5 km where in main canal has total length of about 63.5 km. As far as number of canals is concerned, sub minors in the RBMCA are about 451 where as minors and distributaries are about 151 and 14 respectively. Main canal has total three branches.

## 3.2 CLIMATE

The climate of study area is characterized by a hot summer and general dryness for the major part of the year. The year may be divided into four seasons. The cold season is from December to February. The hot season is from March to the middle of June followed by the southwest monsoon season which continues up to the end of September. October and November constitute the post monsoon or transition period.

***Rainfall:*** Records of rainfall in the district are available for 12 stations for sufficiently long period (Annexure 3.2). The details of the rainfall at these stations and for the district as a whole are given in Table 3.2. The average annual rainfall in the district is 618.7 mm. About 97 % of the annual rainfall in the district is received during the southwest monsoon, i.e. during months of June to September, the rainiest month being July. The rainfall in the district in general increases from the west towards the east. The variation in the rainfall from year to year is large. In the eight year period the highest annual rainfall amounting to 181 % of the normal occurred in 1956 and 1951 was the year with the lowest annual rainfall amounting to 46 % of the normal. In this eighty years period, the annual rainfall in the district was less than 80 % of the normal in 18 years. Out of these 18 years there were two occasions of two consecutive years and three occasions of three consecutive years. It will be seen from Table 3.2 that the annual rainfall in the district was between 301 and 900 mm in 43 years out of 50. On an average there are 29 rainy days (i.e. days with rainfall of 2.5 mm or more) in a year in the district. This number varies from 21 at Sami to 34 at Dharoi. The heaviest rainfall in 24 hours recorded at any stations in the district was 369.6 mm at Kalol on September 17, 1950.

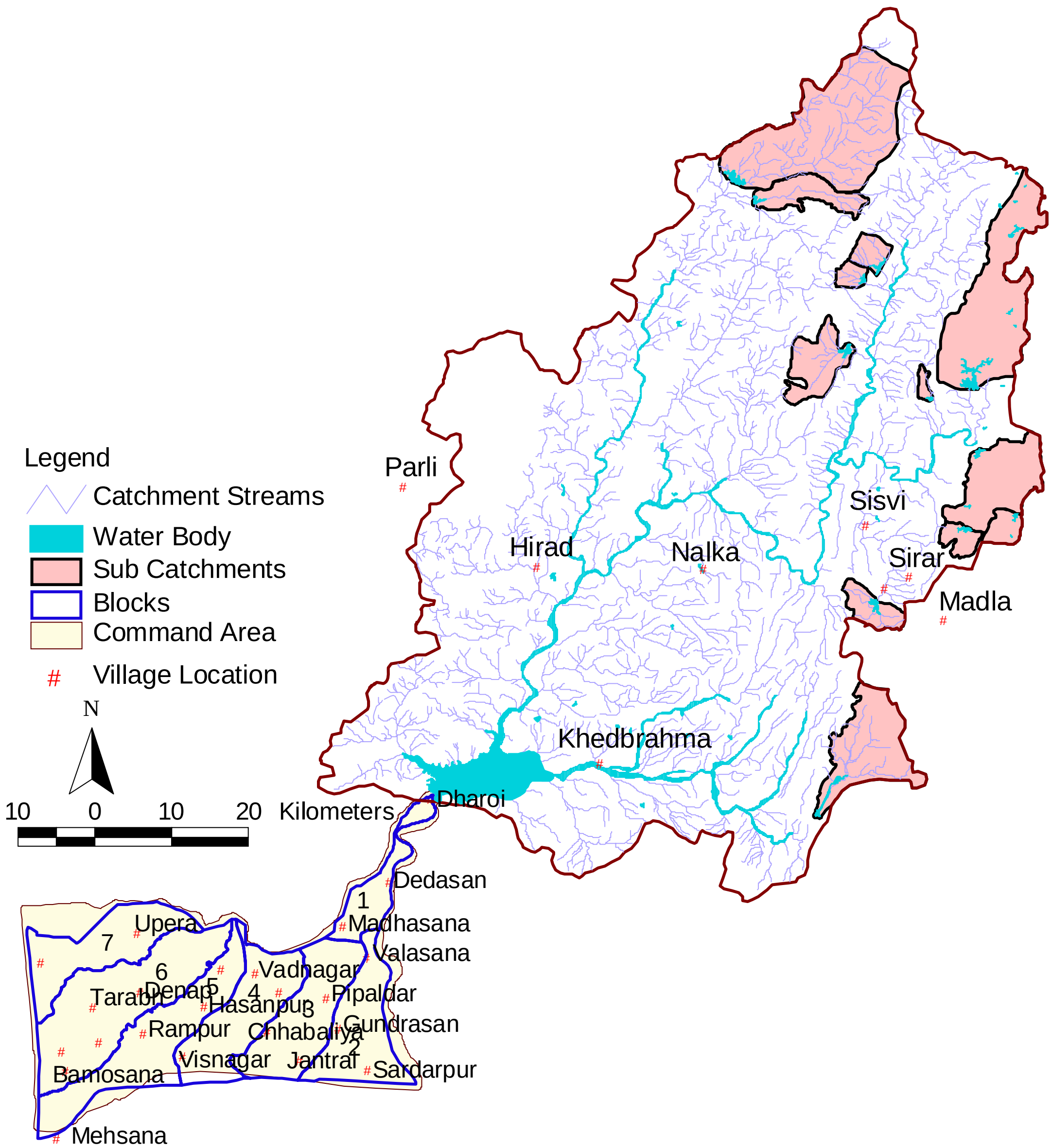



**Fig. 3.1 Catchment and Command Area of Dharoi Irrigation Dam**
Source: GoG Irrigation Department (2005), SOI (1965)

**Table 3.2 Frequency of Annual Rainfall in Mahesana District**

| Range in mm | No. of years | Range in mm | No. of years |
|---|---|---|---|
| 201-300 | 2 | 701-800 | 9 |
| 301-400 | 9 | 801-900 | 6 |
| 401-500 | 8 | 900-1000 | 2 |
| 501-600 | 3 | 1001-1100 | 1 |
| 601-700 | 8 | 1101-1200 | 2 |

Source: GoG, 2008

***Temperature:*** There is no meteorological observatory in the district. The description which follows is based on the records of the observatories in the neighboring districts, where the climatic conditions are similar to that of this district. After February there is rapid increase in the temperature. May and the early part of June before the onset of the monsoon constitute the hottest part of the year. Mean daily maximum temperature in May is about 41º C and the mean daily minimum temperature is about 26º C. Nights during June are comparatively hotter than May. The heat in summer is intense and on individual days the maximum temperature may reach over 47º C. With the advance of the monsoon in the district by about middle of June, there is appreciable drop in the day temperature but the nights continue to be as warm as during the summer season. After the withdrawal of monsoon, about the end of September, there is an increase in day temperature and a secondary maximum in dry temperature is reached in October. However, the nights become progressively cooler after September. It is only after November that there is rapid decrease in both, the day and night temperatures. January is the coldest month with the mean daily maximum temperature at 28ºC and the mean daily minimum temperature at about 11ºC. During the cold season, in association with passing western disturbances, cold waves affect the district and the minimum temperature occasionally drops down to about the freezing point of water.

***Humidity:*** During the monsoon season, the relative humidity is high being generally above 70 %. The air is generally dry during the rest of the year, the driest part being the summer season when the relative humidity is less than 30 %.

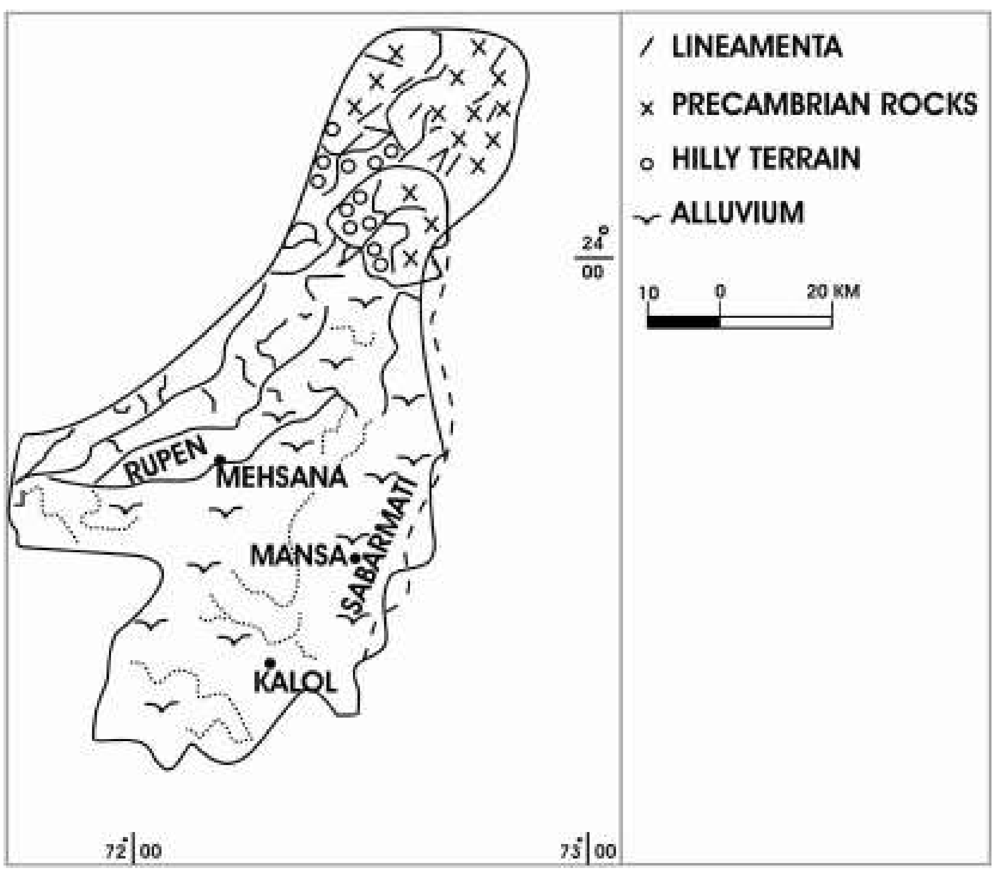
***Winds:*** Winds are generally light with some increase in speed during the later part of summer and early part of monsoon season. During the period April to September the winds blow mostly from directions between south and west, the south-western being predominant. The winds are light and variable in directions during October, the easterly and northwesterly being more common in the morning and the westerly and northwesterly occasionally in the afternoons during the period November to March, while the morning winds are mostly between north and east, the afternoon winds are generally from direction between west and north.

## 3.3 GEOLOGY AND HYDRO-GEOMORPHOLOGY

Geologically, Mehasana district area represents two main rock formations viz., The Aravalli hills, in north and north east, the catchment area of Dharoi dam is built up by the Precambrian basement rocks and the sedimentary deposits occur in downstream areas of Dharoi Dam. These sediments are part of Cambay basin. The sedimentary formations are un-consolidated alluvial derived by fluvial transport from north-eastern catchments of Aravalli hills and are partly mixed with blown sands from southwest. The deposition took place during late Quaternary sedimentary formation. The site of deposition was the Cambay basin which was formed during Tertiary sedimentary formation due to block faulting and has been a tectonically active region ever since. Neo-tectonic movements also accompanied the sedimentation process (Patel, 1986). Thus the deeper layers have fluvio-marine characters, while the upper layers have fluvio-aeolian characters. The thickness of sediments is more than 1,000 m and comprises alternate layers of clay, silt, sand and gravel that show pinching and swelling structure of layers (Fig. 3.3).

Geo-morphologically, the area is divided into three main zones (Fig. 3.2) (01) The hilly or mountainous terrain; (02) Piedmont zone; and (03) The central and southern alluvial plains

The ***hilly or mountainous*** terrain having high relief and rugged topography covers northern part and most of the catchment area of the Dharoi dam. This zone is composed of hard and fractured rocks. Dissected hills and major valleys are important landforms of this zone. Many lineaments representing either fractures or faults are providing pace to water movement to carve such landforms in this zone. Vegetation density is sparse on the lower slopes (debris slope) of hill whereas more in the valleys.




(After Mulay and Nayak, 1983)

**Fig. 3.2 Hydro-geomorphic Map of Mahesana District from Landsat Imagery.**

***Piedmont zone*** occurs along the foothills of hilly terrain and is sloppy towards south west. It comprises of loose to semi-consolidated materials which seems to be derived from hilly terrain and deposited on lower slopes. In this zone, the natural vegetation is sparsely seen and an almost complete absence of cultivated areas.

The central and southern ***alluvial plains*** of clay and sand are of alluvial origin. This zone is gradually sloppy towards SW. This inference is mainly drawn from the stream and river courses. Most of this area provides good agriculture land as it is gentle in slope and comprises of clayey alluvial. The main river passing through the study area is Sabarmati which originates in Aravali hilly tract of Rajasthan in north and flows through alluvial plains of Mehasana and Ahmadabad districts of Gujarat in south and southwest. Rivulets of Banas River are also passing through western part of RBMC area. River Sabarmati shows its ephemeral nature in downstream of the dam area.

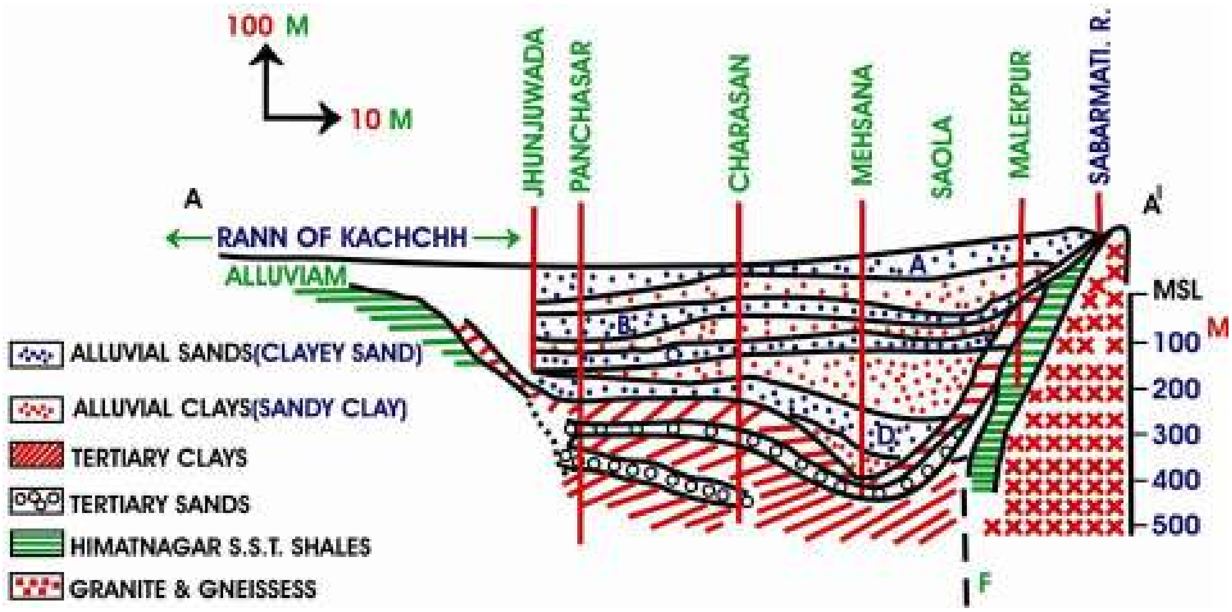
**Table 3.3 Aquifer Characteristics in Mehasana District**

| Aquifer | Thickness (m) | Depth (m) | Formation Parameters |
|---|---|---|---|
| Phreatic | 5 – 30 | Up to 30 | Except in pediment zone and flood plains generally dry ( 3 - 12 % and transmissibility 210-350 sqm/day |
| Aquitard | 5 – 30 | 10 – 60 | Sandy clays with Kankar |
| Confined I | 20 – 30 | 35 – 90 | Clayey sand with gravel piezometric surface 15–30 m |
| Aquitard | 10 – 15 | 55 – 110 | Yellow sticky sandy clay |
| Confined II | 15 – 25 | 110 – 160 | Same as above piezometric surface 20–35 m Average transmissibility 75–160 sqm/day |

As discussed, post Miocene alluvium and older Quaternary sedimentary formations form multi-layered confined aquifer systems designated as A, B and C in the post Miocene, and D and lower Tertiary sands, within the Miocene sediments. The depth to piezometric surface in the tube wells in the region varies from less than 20 meters bgl in extreme west and northeast to more than 120 meters bgl in the central and southern parts, The piezometric surface elevation varies from +10 meters (amsl) in the extreme west to -20 meters in the central, to -50 meters in the southern to +70 meters in northeast (Fig. 3.3).

Due to their high permeability, the coarse layers comprising of sandy and gravelly horizons formed the aquifers which are separated by semi-permeable silty and clayey horizons. Two major aquifer units have been identified. The upper unit is mostly phreatic but becomes semi-confined to some parts. The lower unit comprises of a few hundred meters of alternating sandy and argillaceous beds from the confined aquifer system.

Fig. 3.3 is the subsurface cross section from Sabaramati River to Rann of Kachchh. Brackish to saline conditions are observed in deeper aquifers which are generally found below 250 m depth but occasionally even at much shallower depths. The continuity of aquifers occasionally gets disrupted due to pinching of layers or fault displacement. According to Patel (1986), the lower aquifers are hydro-statically under artesian conditions. The general gradient of aquifers is towards west and these merge in eastern direction where, along the foothill zone of Palanpur-Kheralu, these are exposed and receive natural recharge. Towards their western extension, the deeper aquifers abut against a thrust plane near Radhanpur-Viramgam belt. Along this belt, tube wells tapping the deeper artesian aquifers show free flow at ground, have high temperature and saline water.




Baweja 1954, 69, Rane 1963, Oza 1967, and UNDP/CGWB 1971-74

**Fig 3.3 Hydro-geological Cross Section of North Central Cambay Basin**

The upper aquifers are under semi-confined condition. They receive recharge (i) directly by seepage from the shallow unconfined aquifer, (ii) by lateral flow from the recharge zone of Palanpur-Kheralu foothill region in the east. The shallow unconfined aquifer receives direct recharge from (a) rainfall infiltration, (b) nearby stream flow and, (c) by return flow from the irrigation. As one moves westwards the groundwater progressively becomes saline.

The areas on the banks of the rivers draining the region, namely Saraswati, Rupen, Banas and other smaller streams, get recharged during the rainy season (June to September). At such locations, groundwater levels are relatively higher and shallow aquifers supply good quality water.

## 3.4 OTHER WATER RESOURCES

The Right Bank Main Command Area has also other water resources than canal water. These are storage tanks, ponds, check dams as well as wells and bore wells extracting the groundwater. These water sources were evaluated to understand their probable potential for efficient decentralized irrigation in command area. Well inventory and surface water source inventory were carried out in all villages. A specific format has been developed for well inventory (Annexure 3.4).

### 3.4.1 Surface Water

There are about 237 water bodies distributed in RBMC area (Fig 3.4). Categorization of the water bodies was carried out based on their storage capacity and use. Considering depth of water column all structures have been categorized into two classes such as less than 3 m deep structure (total 175) and more than 3 m deep structures (total 58). The water column depth criteria have been considered mainly to redefine the use of a particular structure in irrigation support. Such as structures less than 3 m depth can be considered as recharge structure and more than 3 m can be used as storage structures which can be linked with canal system then it can collectively be used by farmers.

**Table 3.4 Water Bodies in RBMC Area**

| Details | Number | Unit |
|---|---|---|
| Total No. of Villages Surveyed | 93 | No. |
| Total Structures | 237 | No. |
| Storage Capacity | | |
| Water Stored in < 3 m average deep structure | 13 | MCM |
| Water Stored in > 3 m average deep structure | 40 | MCM |
| Total Storage Capacity | 53 | MCM |
| Use wise Analysis | | |
| Cattle Drinking Water | 167 | No. |
| Domestic | 12 | No. |
| Recharge Structure | 48 | No. |
| Irrigation | 3 | No. |
| Fishing | 1 | No. |

The total water storage capacity of all structures is about 53 MCM out of which about 13 MCM water is stored in small structures while about 40 MCM storage is in more than 3 m deep structures (Table 3.4). So far as the use of these structures is concerned about 167 structures are used for cattle drinking water while about 48 structures are functioning as recharge structures. About 12 structures are used for domestic and remaining 3 and 1 structures are used for irrigation and fishing respectively.

Block wise distribution of water structures has also been carried out to understand its probable potential in irrigation management or to increase irrigation efficiency in a respective block and than for overall irrigation management. As per this distribution, maximum water structures (63) are in block no. 5 followed by block 6 (44 structures). Size wise all major structures (3) are located in block 7. Blocks 1 and 2 have lowest number of water structures, even less than 20 in numbers.

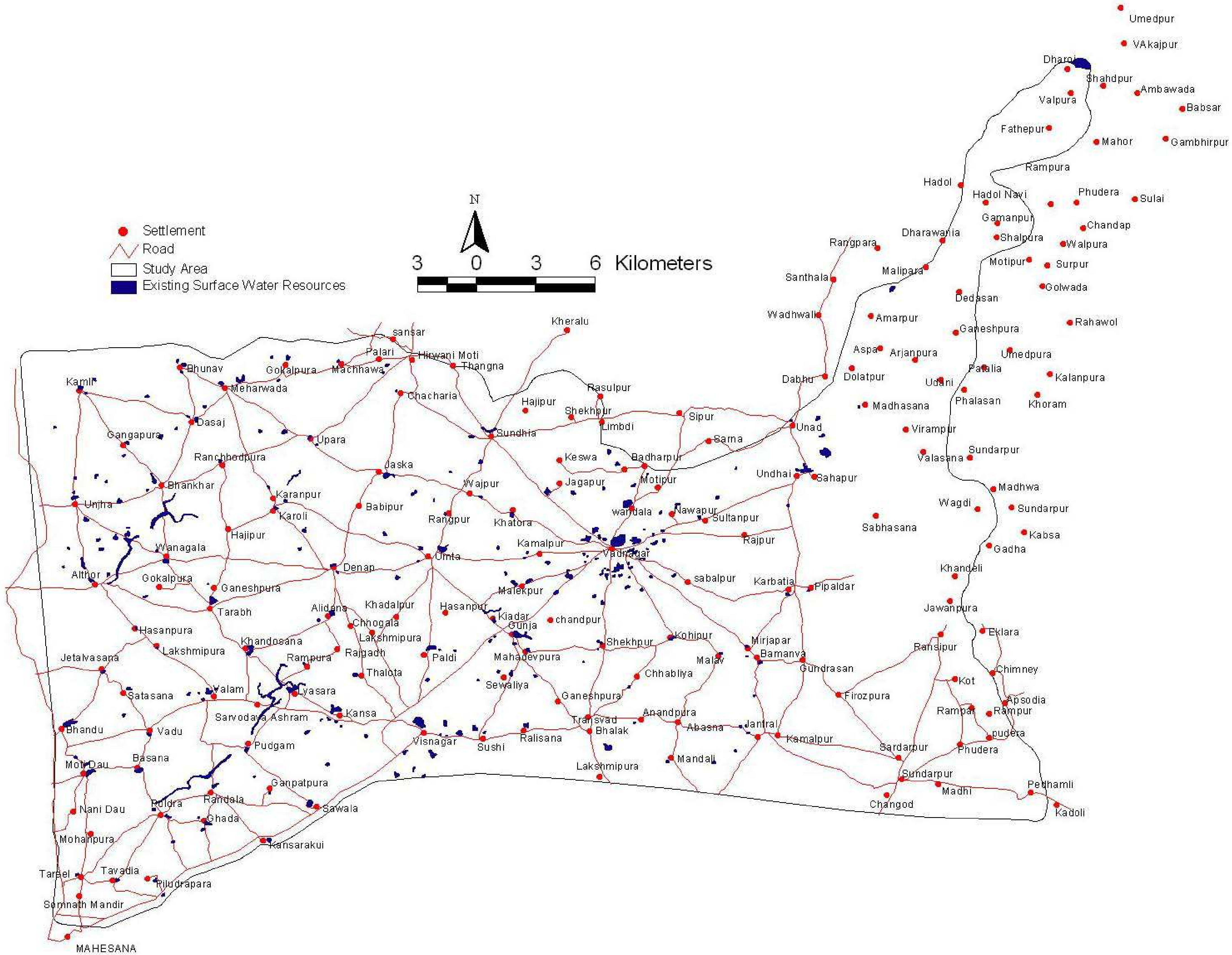



**Fig 3.4 Map Showing Surface Storage in Different villages**

Source: NRSA, RS Data, (2008), SOI, (1965), GoG Irrigation Department, (2007)

### 3.4.2 Groundwater Resource

District Mahesana is one of the classical examples of groundwater resource development, subsequent deterioration and depletion. As far as the study area is concerned there are total 8834 wells and bore wells out of which about 5930 structures are continuously extracting groundwater. About 3078 groundwater structures are bore wells and 5746 are open wells. The geological survey of India had carried out groundwater investigation in Mahesana area as early as 1953-54. This was the period when groundwater based development in Mahesana was in initial phase. But within 15 years history of development has strongly raised a demand of artificial recharge of groundwater by rainfall through open wells by constructing appropriate recharge structures. Even then since past few decades this area is known for large scale groundwater mining for irrigation. The study had concluded that

- The ground water mining has depleted a series of alluvial aquifers.
- Groundwater quality deterioration is almost a parallel phenomenon from post 1955 with the development of tube wells and electric motors.
- Soil feasibility is gradually affected due to irrigation by high TDS water and has resulted in disappearance of several crops.

Another study had been conducted by UNDP and CGWB for groundwater management during 1976, where in over exploited areas more than level of declination has taken place even more than 25 m. Another exploratory work had been carried out during pilot projects for artificial recharge during 1980s. The conclusion from the study was that local vertical downward leakage accounts for 90% or more of natural recharge to the alluvial aquifer zone in the overexploitation area and that the only minimal contribution could migrate laterally from the common recharge zone. In short groundwater development history in Mahesana region can be sub divided in to three phases

- **Pre 1935 phase:** Groundwater at shallow depth (5-10m) and obtained from dug wells by bullock and manual lift of water
- **1935 – 1955 phase:** Groundwater level declined to 10-30 m and dug cum bore wells became prevalent and diesel pump sets were used for lifting the water.
- **Post 1955 phase:** Groundwater level began to decline rapidly and from sixties decline has been between 1.3 m every year. Deep tube wells fitted with electric motor have been used to lift groundwater from 100-250 m depth.

So far as the study area is concerned, wells and bore wells together provide about 31,199 ha of irrigation. To understand the exploitation as well as extensive or intensive use of canal water in RBMC area well density per village / block has been computed. Detail of extensive and intensive command area is explained in proceeding chapters. Fig. 3.5 shows village wise and block wise distribution of wells and bore wells in RBMCA.

**Table 3.5 Use wise categorization of Wells and Bore wells in RBMC Area**

| Type of GW Source | Bore well | Open Well |
|---|---|---|
| Used No. | 2791 | 3129 |
| Disuse no. | 287 | 2617 |
| Total | 3078 | 5746 |
| Irrigation Ha | 23571 | 7628 |

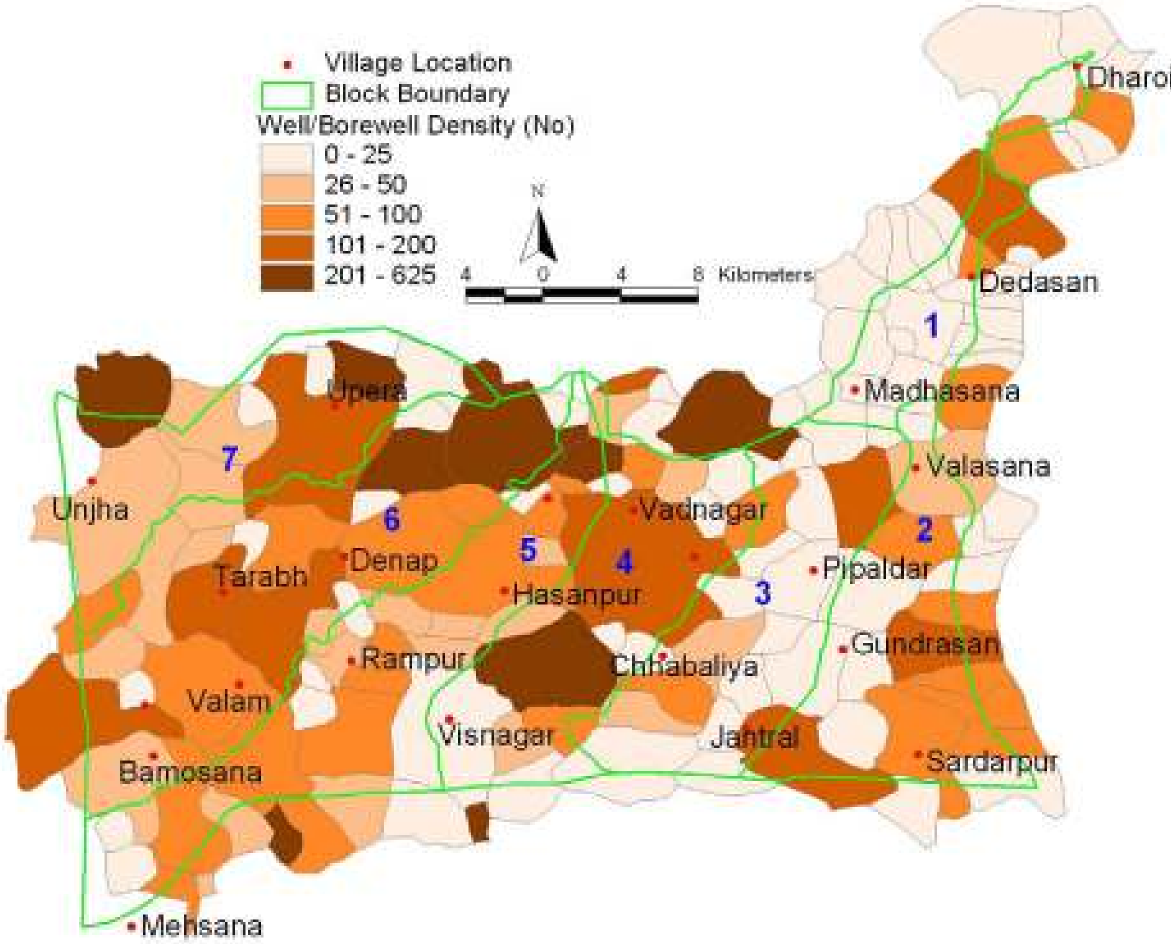



**Fig. 3.5 Village wise and Block wise Distribution of Wells and Bore wells**
Source: GoG, Census Handbook, 2001, GoG, Irrigation Department (2005) ACT Field Data (2009)

**Water Level:** Depth of water level is one of the indicators of groundwater potential in an area. In Dharoi RMBC area, the depth of water table, below ground level (bgl), ranges from less than 5 m to more than 20 m within unconfined aquifers (Figure 3.3) whereas in confined aquifers it ranges from 100 m to more than 180 m at places.

Based on static water level, the study area has been categorized into four zones viz., (01) Very Shallow zone SWL less than 10 m; (02) Shallow zone SWL 10 to 20 m; (03) Deep groundwater zone SWL ranges from 20 to 100 m and (04) Very deep groundwater zone SWL more than 100 m. Very shallow and shallow zones in study area are in the north, between main canal and Sabarmati river and area around villages of Chackarala, Palari, Haripar, Shekhpar, Jagatpar, Paldi and Guja and small patches around Pudgam, Desaj and Savala villages. Western part of study area is mostly characterized as very deep groundwater zone and rest of the area i.e. middle and eastern part of the study area is of deep groundwater zone. (Fig. 3.6) Comparison between well density and water level shows well density is more in area where groundwater occurs at shallow depth and it decreases as the depth of groundwater level is more.

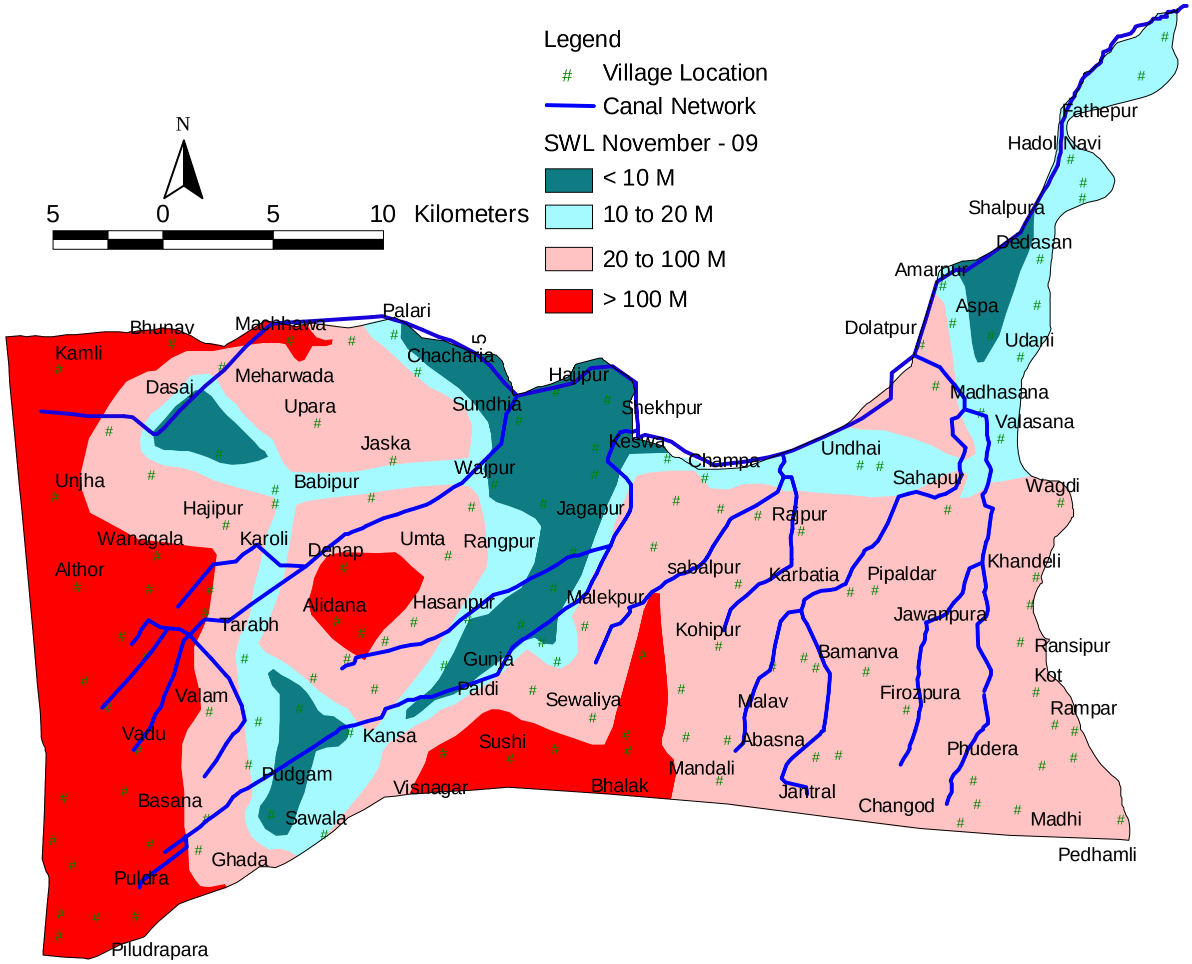



**Fig. 3.6 Static Water Level Based Groundwater Zone in Study Area.**

Source: GoG Irrigation Department (2005), SOI (1965) ACT Field Data, 2009

Changes in water level during irrigation season have been studied during study through static water with monitoring for two seasons i.e. Post monsoon in year 2008 and post winter season 2009. The purpose of this monitoring is to understand the change in water level during winter irrigation (Table 4.2, Fig. 3.7). There was no significant change observed in deep and very deep tube wells whereas in very shallow and shallow area, water level in well has gone down and in some cases wells became dried e.g. in villages Denap (DW 18), Eyasar (DW 22), Kansa (DW 38), Moti Hadol (RW 3) and Chada (RW 5) whereas in villages Ganeshpura (DW 24), Visnagar (DW 26), Gunja (DW 27), Karoli (DW 31) and Masava (DW 34) water level has gone down. The range of depletion is between, 0.7 m to 2.8 m. In some of the wells water level is raised up to about 0.30 m as in case of village Satusan (DW 6). Table 3.6 shows monitored water level data in observation wells.

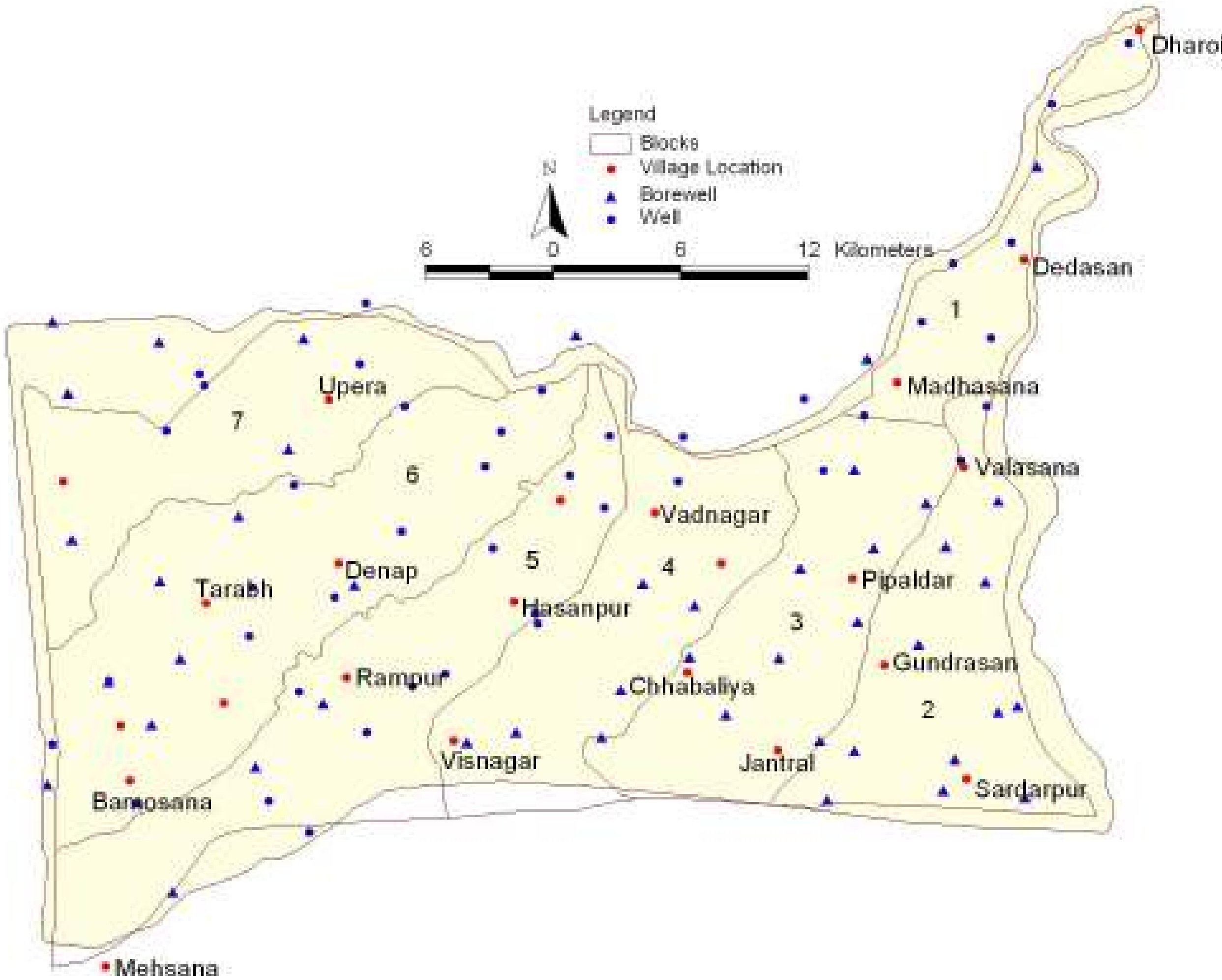



**Fig. 3.7 Locations of Monitoring Wells**

Source: GoG Irrigation Department (2005), SOI (1965) ACT Field Data, 2009

**Table 3.6: Seasonal Changes in Static Water Level in RBMC Area (2008-09)**

| Sr. No. | Sample Code | Village | Type | Depth (m) | Static Water Level (m) | | Use |
|---|---|---|---|---|---|---|---|
| | | | | | Oct-08 | Feb 09 | |
| 1 | DW2 | Babhonsana | Bore well | 283.00 | 183.35 | 183.35 | Irrigation |
| 2 | DW3 | Moti Dau | Bore well | 267.00 | 166.65 | 166.65 | Irrigation |
| 3 | DW4 | Bhandu | Well | 15.00 | 11.70 | 11.5 | Irrigation |
| 4 | DW5 | Vadu | Bore well | 336.00 | 166.70 | 166.70 | Irrigation |
| 5 | DW6 | Satusana | Well | 12.60 | 6.10 | 5.8 | No use |
| 6 | DW6 | Satusana | Bore well | 267.00 | 166.65 | 166.65 | Irrigation |
| 7 | DW7 | Valam | Bore well | 233.00 | 166.70 | 166.70 | Irrigation |
| 8 | DW8 | Gokalpur | Bore well | 267.00 | 183.35 | 183.35 | Drinking |
| 9 | DW9 | Unja | Bore well | 266.00 | 166.70 | 166.70 | Irrigation |
| 10 | DW10 | Kambli | Bore well | 333.00 | 183.30 | 183.30 | Irrigation |
| 11 | DW11 | Biliya | Bore well | 142.00 | 130.00 | 130.00 | Irrigation |
| 12 | DW12 | Bhunav | Bore well | 267.00 | 180.00 | 180.00 | Irrigation |
| 13 | DW13 | Lihoda | Well | 14.20 | 5.10 | 6 | Drinking |

**Table 3.6: Seasonal Changes in Static Water Level in RBMC Area (2008-09) contd…**

| Sr. No. | Sample Code | Village | Type | Depth (m) | Static Water Level (m) | | Use |
|---|---|---|---|---|---|---|---|
| | | | | | Oct-08 | Feb 09 | |
| 14 | DW14 | Lihoda | Well | 15.00 | 7.00 | 8.35 | No use |
| 15 | DW15 | Dasaj | Well | 5.10 | 4.40 | 5.1 | Irrigation |
| 16 | DW16 | Visnagar | Well | 17.90 | 8.50 | 9.55 | ---- |
| 17 | DW17 | Denap | Bore well | 200.00 | 167.00 | 167.00 | Irrigation |
| 18 | DW18 | Denap | Well | 17.50 | 7.00 | Dry | Irrigation |
| 19 | DW19 | Tarap | Well | 12.15 | 6.75 | 8.9 | Irrigation |
| 2 | DW20 | Khansosan | Well | 15.40 | 11.20 | 11.5 | ---- |
| 21 | DW21 | Kausa | ---- | ---- | ---- | ---- | ---- |
| 22 | DW22 | Eyasar | Well | 8.50 | 8.10 | Dry | Drinking |
| 23 | DW23 | Padugam | Bore well | ---- | ---- | ---- | Irrigation |
| 24 | DW24 | Ganeshpura | Well | 11.40 | 4.20 | 4.9 | Irrigation |
| 25 | DW25 | Sawal | Well | 18.60 | 16.60 | 16.8 | Irrigation |
| 26 | DW26 | Visnagar | Well | 10.90 | 4.00 | 6.1 | Irrigation |
| 27 | DW27 | Gunja | Well | 12.60 | 7.50 | 9.95 | ---- |
| 28 | DW28 | Malekpur | Well | 10.00 | 3.00 | Dry | Irrigation |
| 29 | DW29 | Umata | Well | 14.80 | 14.10 | 14.4 | Irrigation |
| 3 | DW30 | Umata | Well | 10.80 | 7.10 | 10.7 | Irrigation |
| 31 | DW31 | Karoli | Well | 14.90 | 13.20 | 14.3 | Irrigation |
| 32 | DW32 | Hajipura | Bore well | ---- | ---- | ---- | Irrigation |
| 33 | DW33 | Upera | Bore well | ---- | ---- | ---- | Irrigation |
| 34 | DW34 | Masava | Well | 12.90 | 11.50 | 14.3 | Irrigation |
| 35 | DW35 | Gokuliyu (N) | Bore well | 113.00 | 103.35 | 103.35 | Irrigation |
| 36 | DW36 | Rampura | Well | 19.40 | 12.20 | 13.9 | Irrigation |
| 37 | DW37 | Jaska | Well | 18.10 | 11.50 | 11.95 | Irrigation |
| 38 | DW38 | Kansa | Well | 18.40 | 12.10 | Dry | Irrigation |
| 39 | DW39 | Sushi | Bore well | 217.00 | 193.30 | 193.30 | Irrigation |
| 40 | DW40 | Salisana | Bore well | 233.00 | 193.30 | 193.30 | Irrigation |
| 41 | DW41 | Bhalak | Bore well | 125.00 | 116.65 | 116.65 | Irrigation |
| 42 | DW42 | Trasvad | Bore well | 133.00 | 116.75 | 116.75 | Irrigation |
| 43 | DW43 | Kahipur | Bore well | 133.00 | 73.35 | 73.35 | Irrigation |
| 44 | DW44 | Vadnagar | Bore well | 133.00 | 66.70 | 66.70 | Irrigation |
| 45 | DW45 | Vadnagar | Bore well | 117.00 | 100.00 | 100.00 | Irrigation |
| 46 | DW46 | Champa | Well | 10.33 | 7.35 | 7.5 | Irrigation |
| 47 | DW47 | Vadnagar | Well | 12.33 | 10.00 | 10.4 | Irrigation |
| 48 | DW48 | Keshimpa | Well | 9.30 | 1.45 | 2.7 | Irrigation |
| 49 | DW49 | Kheralu | Bore well | 127.00 | 113.20 | 113.20 | Irrigation |
| 50 | DW50 | Sundhiya | Well | 9.55 | 8.55 | 9.9 | Irrigation |
| 51 | DW51 | Sundhiya | Well | 18.00 | 2.35 | 11.1 | Irrigation |
| 52 | DW52 | Jagapur | Well | 10.65 | 7.65 | 6.7 | Irrigation |
| 53 | DW53 | Ambavadi (S) | Well | 13.35 | 6.65 | 10.63 | Irrigation |
| 54 | DW54 | Khanpur | Well | 12.67 | 10.65 | 20.7 | Irrigation |
| 55 | DW55 | Unad | Well | 13.35 | 10.70 | 13.7 | Irrigation |

**Table 3.6: Seasonal Changes in Static Water Level in RBMC Area (2008-09) contd…**

| Sr. No. | Sample Code | Village | Type | Depth (m) | Static Water Level (m) | | Use |
|---|---|---|---|---|---|---|---|
| | | | | | Oct-08 | Feb 09 | |
| 56 | DW56 | Rajpur | Well | 11.65 | 9.65 | Dry | Irrigation |
| 57 | DW57 | Bahadurpur | Well | 8.90 | 7.80 | 8.6 | Irrigation |
| 58 | DW58 | Dabu | Bore well | 81.65 | 50.00 | 50.00 | Irrigation |
| 59 | DW59 | Undhai | Bore well | ---- | ---- | ---- | Irrigation |
| 60 | DW60 | Pipaldar | Bore well | 60.67 | 43.35 | ---- | Irrigation |
| 61 | DW61 | Karbatiya | Bore well | 65.00 | 46.65 | 46.65 | Irrigation |
| 62 | DW62 | Ransipur | Bore well | 116.65 | 93.35 | 93.35 | Irrigation |
| 63 | DW63 | Techava | Bore well | ---- | ---- | ---- | Irrigation |
| 64 | RW1 | Dharoi | Well | 15.10 | 10.80 | 11 | Irrigation |
| 65 | RW2 | Khodamali | Well | 12.40 | 10.70 | 11.3 | Irrigation |
| 66 | RW3 | Moti Hadol | Bore well | 33.35 | 10.00 | Dry | Irrigation |
| 67 | RW4 | Dedasan | Well | 16.10 | 10.80 | 14.35 | Irrigation |
| 68 | RW5 | Chada | Well | 9.40 | 3.40 | Dry | Irrigation |
| 69 | RW6 | Aspa | Well | 19.50 | 11.50 | 14 | Irrigation |
| 70 | RW7 | Undani | Well | 21.00 | 11.40 | 12.3 | Irrigation |
| 71 | RW8 | Valasana | Well | 16.80 | 12.10 | 12.6 | Irrigation |
| 72 | RW9 | Valasana | Well | 19.80 | 17.90 | 18.6 | Irrigation |
| 73 | RW10 | Sobhasana | Bore well | ---- | ---- | ---- | Irrigation |
| 74 | RW11 | Navi Vagdi | Bore well | 56.70 | ---- | ---- | Irrigation |
| 75 | RW12 | Sobhasana | Bore well | 60.00 | 30.00 | 30.00 | Irrigation |
| 76 | RW13 | Kot | Bore well | 63.35 | 33.30 | 33.30 | Irrigation |
| 77 | RW14 | Rampur(Kot) | Bore well | 66.65 | 60.00 | 60.00 | Irrigation |
| 78 | RW15 | Sadarpur | Bore well | 125.00 | 50.00 | 50.00 | Irrigation |
| 79 | RW16 | Madhi | Bore well | 73.33 | 58.35 | 58.35 | Irrigation |
| 70 | RW17 | Sundarpur | Bore well | 60.00 | 33.35 | 33.35 | Irrigation |
| 81 | RW18 | Jantral | Bore well | 65.00 | 48.35 | 48.35 | Irrigation |
| 82 | RW19 | Kamalpur | Bore well | 193.35 | 76.75 | 76.75 | Irrigation |
| 83 | RW20 | Kamalpur | Bore well | 183.35 | 76.65 | 76.65 | Irrigation |
| 84 | RW21 | Abasana | Bore well | 163.35 | 76.65 | 76.65 | Irrigation |
| 85 | RW22 | Bamansa | Bore well | 146.65 | 100.00 | 100.00 | Irrigation |
| 86 | RW23 | Gundasan | Bore well | 60.00 | 33.35 | 33.35 | Irrigation |

**Water Quality:** It is important to understand changes in groundwater quality in high groundwater exploitation area since the quality deterioration is parallel impact of water level depletion. GWRDC has categorized Mehasana as Dark zone in their categorization. Groundwater quality in RBMC area can be determined based on various physico -chemical parameters such as Total Dissolved Solids (TDS), pH, hardness and ion content.

**Total Dissolved Solids:** Determination of total dissolved solid is a very efficient tool to draw rapid idea about overall water quality. The specific conductance of water provides measure of the content of dissolved matter, which is popularly known as Total Dissolved Solids.

TDS and pH determination in groundwater of study area has been carried out at 10 sq km grid within RBMCA (Fig. 3.7). The assessment has been carried out for post monsoon and post winter seasons of the year 2008 & 2009 respectively, because during winter most of the farmers intensively use groundwater for irrigation purposes.

To characterize study area from water quality point of view, especially salinity, TDS values have been plotted on study area map and 150 TDS maps were prepared for whole area for both the seasons. There are several use wise standards proposed by different agencies for limits of TDS concentration such as for drinking water. TDS value up to 1500 mg/l is maximum permissible limit by ICMR (1975) where as ISI (1983) has suggested up to 2000 mg/l of TDS permissible for drinking water. Considering such limits the study area has been categorized in to five categories of water quality, which are as per thefollowing:

(01) Excellent water quality (TDS <500 mg/l)
(02) Good water quality (TDS 500-1500 mg/l)
(03) Moderate/ permissible water quality (TDS 1500-2000 mg/l)
(04) Brackish /partial saline water quality (TDS 2000-3000 mg/l)
(05) Saline water quality (>3000 mg/l).

Fig. 3.8 shows changes in TDS concentration before (A) and after (B) winter irrigation in RBMCA area of year 2009.

Following characterization of the study area can be understood based on changes in TDS

- Concentration increases towards western part of the RBMCA and area around villages of Mehasana, Sankhalpur, Champa during pre monsoon time i.e. before winter
- Good to excellent groundwater quality exists in eastern part of RBMCA, and it remains same even after winter irrigation period.
- Village Ganeshpura (5700 mg/l), Bhandu (5500 mg/l), Khandosan (4200 mg/l) and Dela (4100 mg/l) were maximum saline villages during post winter season of year 2009.
- TDS value in groundwater of villages of Moti Dau, Bhanbhanasana, Vadu, Satlasana, Valam, Gokalpura, Bhanau, Dasaj, Visnagar, Kansa, Savala, Gunja, Umta, Karoli, Hajipura, Masva, Salisana, Sundhiya, ranges between 2200 to 3500 mg/l during post winter season (Table 3.7).

Fig 3.8 shows that TDS concentration increases in western part as well as in area around Meshva, Sankhalpur, Champa villages during pre monsoon seasons. The eastern part of command area shows good to excellent groundwater quality from TDS point of view during post monsoon as well as post winter seasons.

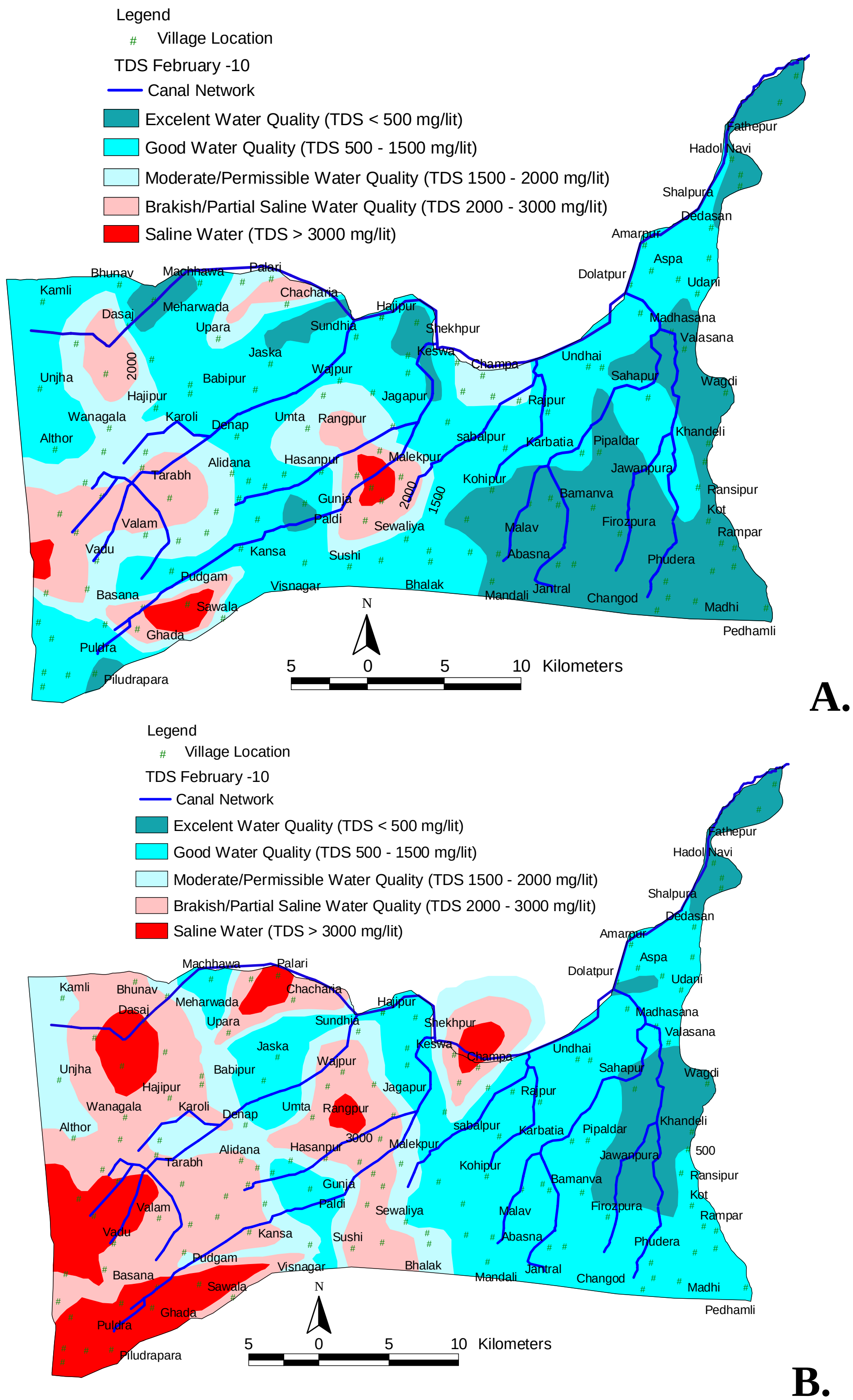



**Fig. 3.8 Change in TDS Concentration During Post monsoon 2008 (A) and Post Winter 2009 (B) Seasons**

Source: GoG Irrigation Department, (2005) SOI, (1965) ACT Field Data, 2009

**Table 3.7 Post Monsoon (2008) and Post Winter (2009) TDS and pH Concentrations in Groundwater of RBMC Area**

| Sr. No. | Code | Village | TDS (mg/lit) | | pH | |
|---|---|---|---|---|---|---|
| | | | Nov'08 | Feb'09 | Nov'08 | Feb'09 |
| 1 | DW1 | Dela | 254 | 4100 | 6.7 | 7.3 |
| 2 | DW2 | Babhonsana | 1690 | 2600 | 6.9 | 7.5 |
| 3 | DW3 | Moti Dau | 1490 | 2400 | 6.9 | 7.3 |
| 4 | DW4 | Bhandu | 3430 | 5500 | 7 | 7.5 |
| 5 | DW5 | Vadu | 1660 | 2600 | 6.5 | 7.6 |
| 6 | DW6 | Satusana | 2540 | 3600 | 7.3 | 7.2 |
| 7 | DW6 | Satusana | 2870 | 3600 | 7.1 | 7.1 |
| 8 | DW7 | Valam | 1470 | 3300 | 7.1 | 7.3 |
| 9 | DW8 | Gokalpur | 1690 | 2400 | 7.2 | 7.5 |
| 10 | DW9 | Unja | 787 | 1500 | 7.3 | 7.7 |
| 11 | DW10 | Kambli | 1060 | 1800 | 7.4 | 7.6 |
| 12 | DW11 | Biliya | 503 | 790 | 7.1 | 7.5 |
| 13 | DW12 | Bhunav | 1470 | 2400 | 7.1 | 7.8 |
| 14 | DW13 | Lihoda | 215 | 330 | 7.4 | 8 |
| 15 | DW14 | Lihoda | 175 | 950 | 7.3 | 7.2 |
| 16 | DW15 | Dasaj | 2580 | 3700 | 6.8 | 7.2 |
| 17 | DW16 | Visnagar | 2170 | 2800 | 6.8 | 7.8 |
| 18 | DW17 | Denap | 1260 | 1840 | 6.7 | 7.3 |
| 19 | DW18 | Denap | 254 | Dry | 6.8 | Dry |
| 20 | DW19 | Tarap | 653 | 1490 | 7.4 | 7.6 |
| 21 | DW20 | Khandosan | 2540 | 4200 | 6.7 | 6.6 |
| 22 | DW21 | Kansa | 1760 | 2600 | 7.1 | 7 |
| 23 | DW22 | Eyasar | 667 | Dry | 7.5 | Dry |
| 24 | DW23 | Padugam | 1100 | 1890 | 7.3 | 7.9 |
| 25 | DW24 | Ganeshpura | 4060 | 5700 | 6.4 | 7 |
| 26 | DW25 | Sawal | 1730 | 2400 | 7.5 | 7.5 |
| 27 | DW26 | Visnagar | 264 | 720 | 7.7 | 7.9 |
| 28 | DW27 | Gunja | 1940 | 2300 | 6.9 | 7.3 |
| 29 | DW28 | Malekpur | 3670 | -- | 6.7 | -- |
| 30 | DW29 | Umata | 2220 | 3300 | 7.2 | 7.4 |
| 31 | DW30 | Umata | 531 | 880 | 7.4 | 7.3 |
| 32 | DW31 | Karoli | 157 | 2200 | 7.5 | 8.3 |
| 33 | DW32 | Hajipura | 1390 | 2400 | 7.6 | 7.5 |
| 34 | DW33 | Upera | 1190 | 1850 | 7.4 | 7.8 |
| 35 | DW34 | Masava | 2540 | 3600 | 6.9 | 7.3 |
| 36 | DW35 | Gokuliyu (N) | 584 | 820 | 7.5 | 7.9 |
| 37 | DW36 | Rampura | 1370 | 1920 | 7.3 | 7.5 |
| 38 | DW37 | Jaska | 313 | 540 | 7.3 | 7.8 |
| 39 | DW38 | Kansa | 858 | -- | 7.1 | -- |
| 40 | DW39 | Sushi | 1230 | 1370 | 6.9 | 7 |
| 41 | DW40 | Salisana | 1800 | 2700 | 6.9 | 6.6 |

**Table 3.7 Post Monsoon (2008) and Post Winter (2009) TDS and pH Concentrations in Groundwater of RBMC Area Contd…**

| Sr. No. | Code | Village | TDS (mg/lit) | | pH | |
|---|---|---|---|---|---|---|
| | | | Nov'08 | Feb'09 | Nov'08 | Feb'09 |
| 42 | DW41 | Bhalak | 618 | 940 | 7 | 7.3 |
| 43 | DW42 | Trasvad | 521 | 860 | 7.5 | 7.2 |
| 44 | DW43 | Kahipur | 426 | 690 | 7.3 | 7.7 |
| 45 | DW44 | Vadnagar | 570 | 860 | 7.2 | 7.3 |
| 46 | DW45 | Vadnagar | 705 | 875 | 7.3 | 7.2 |
| 47 | DW46 | Champa | 563 | 800 | 7.1 | 7.4 |
| 48 | DW47 | Vadnagar | 784 | 1000 | 6.9 | 7.3 |
| 49 | DW48 | Keshimpa | 287 | 640 | 7.5 | 7.7 |
| 50 | DW49 | Kheralu | 633 | 1100 | 7.4 | 7.5 |
| 51 | DW50 | Sundhiya | 1800 | 2600 | 6.5 | 7.4 |
| 52 | DW51 | Sundhiya | 735 | 1230 | 6.8 | 7.5 |
| 53 | DW52 | Jagapur | 542 | 990 | 6.8 | 7.1 |
| 54 | DW53 | Ambavadi (S) | 789 | 1420 | 7.3 | 7.4 |
| 55 | DW54 | Khanpur | 712 | 1140 | 7.4 | 7.4 |
| 56 | DW55 | Unad | 682 | 1170 | 7.4 | 7.5 |
| 57 | DW56 | Rajpur | 584 | Dry | 7.6 | Dry |
| 58 | DW57 | Bahadurpur | 2260 | 4000 | 7 | 7.2 |
| 59 | DW58 | Dabu | 930 | 1530 | 7.4 | 7.4 |
| 60 | DW59 | Undhai | 541 | 790 | 7.2 | 7.2 |
| 61 | DW60 | Pipaldar | 342 | -- | 7.2 | -- |
| 62 | DW61 | Karbatiya | 337 | 700 | 7.2 | 7.3 |
| 63 | DW62 | Ransipur | 247 | 410 | 7.3 | 7.3 |
| 64 | DW63 | Techava | 322 | 510 | 7.1 | 7.6 |
| 65 | RW1 | Dharoi | 283 | 520 | 8.1 | 7.1 |
| 66 | RW2 | Khodamali | 244 | 452 | 8.2 | 7.5 |
| 67 | RW3 | Moti Hadol | 240 | 340 | 8.1 | 7.5 |
| 68 | RW4 | Dedasan | 242 | 800 | 8 | 7.2 |
| 69 | RW5 | Chada | 375 | 610 | 7.8 | 7.4 |
| 70 | RW6 | Aspa | 657 | 1210 | 8 | 7.1 |
| 71 | RW7 | Undani | 572 | 960 | 7.9 | 7.2 |
| 72 | RW8 | Valasana | 287 | 500 | 8.1 | 7.9 |
| 73 | RW9 | Valasana | 241 | 420 | 8.1 | 8.1 |
| 74 | RW10 | Sobhasana | 658 | 600 | 8.1 | 7.4 |
| 75 | RW11 | Navi Vagdi | 249 | 460 | 8.1 | 7.7 |
| 76 | RW12 | Sobhasana | 250 | 440 | 8.2 | 7.9 |
| 77 | RW13 | Kot | 272 | 570 | 8.1 | 7.6 |
| 78 | RW14 | Rampur(Kot) | 338 | 560 | 8 | 7.2 |
| 79 | RW15 | Sadarpur | 294 | 450 | 8.1 | 8 |
| 80 | RW16 | Madhi | 400 | 680 | 8.1 | 7.6 |
| 81 | RW17 | Sundarpur | 457 | 810 | 8 | 7.5 |
| 82 | RW18 | Jantral | 294 | 510 | 8.1 | 7.7 |

**Table 3.7 Post Monsoon (2008) and Post Winter (2009) TDS and pH Concentrations in Groundwater of RBMC Area Contd…**

| Sr. No. | Code | Village | TDS (mg/lit) | | pH | |
|---|---|---|---|---|---|---|
| | | | Nov'08 | Feb'09 | Nov'08 | Feb'09 |
| 83 | RW19 | Kamalpur | 247 | 500 | 7.2 | 8 |
| 84 | RW20 | Kamalpur | 352 | 670 | 7.1 | 7.7 |
| 85 | RW21 | Abasana | 340 | 750 | 7.2 | 7.5 |
| 86 | RW22 | Bamansa | 536 | 950 | 7.1 | 7.3 |
| 87 | RW23 | Gundasan | 280 | 520 | 7.2 | 7.1 |

***pH:*** Another water quality parameter considered for evaluation is Hydrogen Ion Concentration i.e. pH. The pH is a measure of the solvent power of water. The pH value of water represents the overall balance of a series of equilibrium existing in solution (Hem, 1991). The pH of natural water is largely controlled by chemical reactions and equilibrium among the ions in solution. The most important type of reaction affecting pH in natural water is hydrolysis, which is due to predominance of carbonate and bicarbonate salts. Due to this, pH value tends to rise above 7 (Ageno and Valla, 1911). In study area almost all water samples show pH value more than 7 thereby, indicating predominance of hydrolysis reaction due to the presence of carbonates and bicarbonates. The pH value of groundwater in study area ranges from 6.4 to 7.5 (Table no. 3.7).

***Hardness:*** Divalent metallic cations like calcium and magnesium are most abundant in groundwater and are responsible for hardness of the water. As per study done by USEPA (1976), the resistance capacity of community for acceptation of the degree of hard water varies depending on local condition. Calcium carbonate hardness in study area varies from 200 mg/lit to 1820 mg/lit. About 38% of the analyzed water is not safe from hardness point of view.

***Ionic concentration:*** Cations and anions in combination with each other give rise to various chemicals and minerals. To evaluate chemical properties of groundwater in study area, water sampling in sixteen villages have been carried out (Table .3.8). Important cations viz., calcium, magnesium, and sodium while important anions viz., carbonate, bicarbonate, sulfate, and chlorides were determined by standard titration methods (Table 3.8).

**Calcium ($ca^{+2}$)**: Calcium is one of the alkaline earth minerals and normally present in natural water in dissociate form as the bivalent iron $Ca^{++}$. Because of wide spread occurrence in rock and soil, and its ready solubility, calcium is present in nearly all water (Hem, 1959), in case of study area $Ca^{++}$concentration is more than 900 mg/l in Sundarpura, Visnagar, Khandosan, Ganeshpura and Khanpur villages where as it is lowest i.e. 200 mg/l is in Gokaliyu village.

**Magnesium ($Mg^{++}$):** Magnesium is often analyzed with calcium in water analysis, as both contribute to the hardness of water. Carbonate rocks like dolomite and limestone are important sources of magnesium. Magnesium is typical component of the important silicate minerals in the dark colored Ferro Magnesium and ultra basic rocks (Hem, 1959). Mg concentration in groundwater of Chada, Sundarpura and Bamansa villages is almost nil where as it is highest (1584 mg/l) in Bhandu village followed by Khanpur (1488 mg/l) and Ganeshpura villages (1104 mg/l).

**Table 3.8 Groundwater Chemistry in Villages of RBNCA (year 2009) in mg/l**

| Village | TDS | pH | Hardness | Alkanity | Ca | Mg | $CO_3$ | $HCO_3$ | Cl | $SO_4$ |
|---|---|---|---|---|---|---|---|---|---|---|

| | | | as $CaCO_3$ | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Khodamali | 244 | 8.2 | 280 | 430 | 360 | 216 | 600 | 360 | 3899 | 27043 |
| Chada | 375 | 7.8 | 240 | 560 | 560 | 0 | 450 | 450 | 6735 | 23174 |
| Sundarpur | 457 | 8 | 390 | 470 | 920 | 0 | 900 | 300 | 6026 | 37526 |
| Bamansa | 536 | 7.1 | 340 | 600 | 600 | 0 | 1350 | 300 | 5317 | 32842 |
| Bhandu | 3430 | 7 | 1610 | 540 | 640 | 1584 | 750 | 600 | 4608 | 154656 |
| Valam | 1470 | 7.1 | 300 | 850 | 480 | 240 | 300 | 870 | 13471 | 28915 |
| Gokalpar | 1690 | 7.2 | 270 | 710 | 440 | 240 | 300 | 690 | 8153 | 26064 |
| Dasaj | 2580 | 6.8 | 1130 | 860 | 880 | 672 | 750 | 750 | 10635 | 108557 |
| Visnagar | 2170 | 6.8 | 1400 | 740 | 1000 | 912 | 450 | 720 | 9217 | 134486 |
| Khandosan | 2540 | 6.7 | 1260 | 790 | 1440 | 672 | 450 | 600 | 8508 | 121066 |
| Ganeshpura | 4060 | 3.4 | 1820 | 590 | 1920 | 1104 | 300 | 600 | 5317 | 174806 |
| Gokaliya | 584 | 7.5 | 230 | 670 | 200 | 360 | 450 | 660 | 4963 | 22186 |
| Salisana | 1800 | 6.9 | 540 | 570 | 760 | 240 | 150 | 630 | 5672 | 51946 |
| Khanpur | 712 | 7.4 | 280 | 870 | 2000 | 1488 | 300 | 870 | 3190 | 2704 |
| Bahadurpur | 2260 | 7 | 840 | 1000 | 600 | 624 | 300 | 900 | 8153 | 80659 |
| Techva | 322 | 7.1 | 200 | 310 | 440 | 168 | 750 | 360 | 3545 | 19325 |

**Sodium ($Na^{++}$) :** Sodium is one of the alkali metals and is most important and abundant of the group in natural water. Sodium salts are very important in the evaporate sediments. In general sodium when leached from the rocks remains in solution. It takes part in important precipitation reaction like calcium and magnesium because mainly all sodium components are readily soluble (Hem, 1991).

**Carbonate and bicarbonate ($CO_3$ and $HCO_3^{2-}$) :** Carbonate in the form of limestone and dolomite and iron carbonate is widely distributed on the earth surface (Davis and Dewiest, 1967). When pH of the groundwater is below 4.3, the carbonate exists as $H_2CO_3$ however on crossing the limits of the pH above 8.5, the carbonate form changes to the bicarbonate (Hem 1991). Bicarbonate is normally derived from complex atmosphere, hydrosphere, lithosphere, introduction through (01) solubility of $CO_2$ in the water and (02) chemical weathering of rocks by $CO_2$ saturated water (Davis and Dewiest, 1967). The concentration of carbonates ions in groundwater ranges 150 mg/lit to 1350 mg/lit. Bicarbonate ions range from 300 to 900 mg/lit.

***Sulfate ($SO_4^{-2}$):*** Sulfur occurs in water largely as sulfate $SO_4$. High concentration of Sulfate shows a typical characteristic of an arid region. Rainfall in semi arid and arid regions or where soils are gypsiferous, it contains considerable amounts of sulfate as a result of airborne dust, Hem (1959). In the upper oxidized layers of soil and rock, sulfides are largely been converted to sulfates and are gradually leached away by water but in semiarid regions the soils are not fully leached and dissolved salts produced by weathering may tend to accumulate in the soils. Similarly fine grained sediments have poor groundwater circulation, but over a large area they may yield significantly high mineralized seepage having considerable addition of Sulfate to water in adjacent coarse grained aquifers. Sulfate concentration in RBMCA is very high.

***Chloride ($Cl^{-}$):*** Sedimentary rocks especially are more important source of chloride. Normally chloride in groundwater occurs as resistant as a result of inclusion of carbonate water, and is to be expected in any incompletely leached deposit laid down under the sea or in a closed basin where chloride is present (Hem, 1991). When porous rocks submerged by the sea at any time after their formation, they are impregnated with soluble salts. Chloride concentration in study area varies in range from 3190 mg/l to 10635 mg/l.

## 3.5 LANDUSE

Land use pattern in the RBMC area has been studied with the help of remote sensing data of LISS 4 of two different periods viz., year 2003 and year 2008. For both the years images of winter season (Month of December) has been selected for analysis so that estimation of irrigated areas can be carried out. However, it is important to mention here that the resolution of image of year 2003 was of 23 x 23 m pixels whereas that of year 2008 was of 6 x 6 m pixels.

Therefore, the accuracy level of analysis of year 2008 image is more than the image of year 2003. The RBMC area has been classified in to five classes such as (01) Irrigated land; (02) Fallow/Dry Land; (03) Water Logged Areas; (04) Settlements and (05) Water Body. Table 3.9 shows land use wise computed area during year 2008. The dominant land use in the command area is for agriculture followed by water logged and fallow areas. Water bodies in the RBMC area spread over about 1.82 sq.km.

**Table 3.9 Land Use Pattern in RBMC Area**

| Landuse | Area (Ha) |
|---|---|
| Irrigated Agriculture | 52853 |
| Fallow / Dry Land | 28664 |
| Water Logged | 7588 |
| Water Body | 910 |
| Settlement | 3727 |
| **Total** | **93742** |
| Source: Analysis Based on RS Data Year 2008 | |

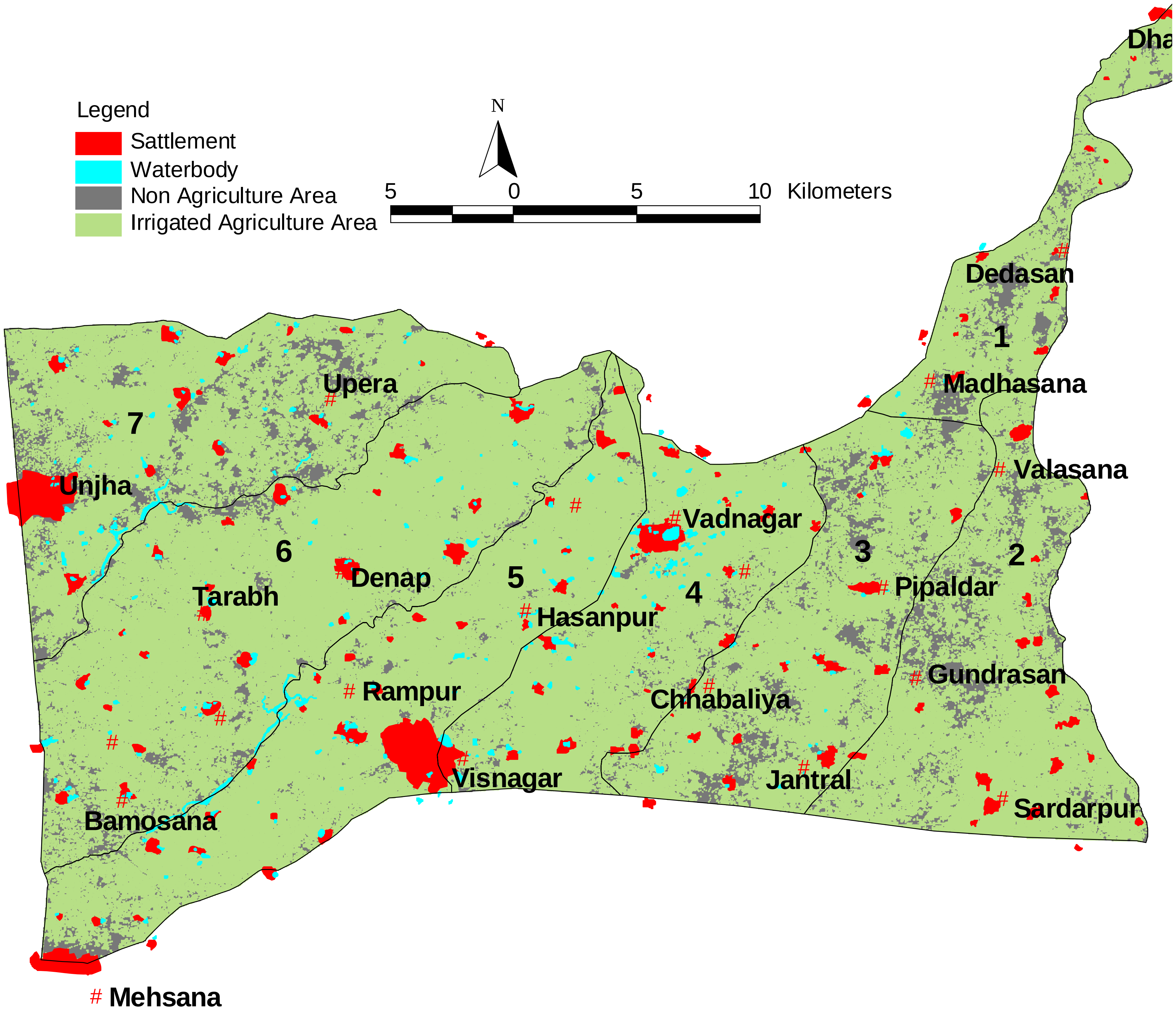



**Fig 3.9 Land Use Classification of RBMC Area Based on Remote Sensing Data (2008)**

Source: NRSA, RS Data (2003) GoG, Irrigation Department (2006), SOI, (1965)

## 3.6 SOIL

The soil is a dynamic natural body on the earth surface, in which plants grow, and is composed of mineral and organic materials and living forms Buckman and Brady (1960). In other words, soil is the uppermost weathered layer of the earth's crust; it consists of rocks that have been reduced to small fragments and have been more or less changed chemically together with the remains of plants and animals that live on it and in it. Soil consists of particle of varying rocks by weathering and erosion processes. Physical properties (mechanical behavior) of a soil greatly influence plant growth. The plant support, root penetration, drainage, aeration, retention of moisture, and plant nutrients are linked with the physical condition of the soil. Physical properties also influence the chemical and biological behavior of all soils. The physical properties of a soil depend on the amount, size, shape, arrangement and mineral composition of its particles. The physical properties also depend on organic matter content and pore-spaces. The important physical properties of soil are soil texture, soil structure, soil density, soil porosity, soil color, soil temperature etc.

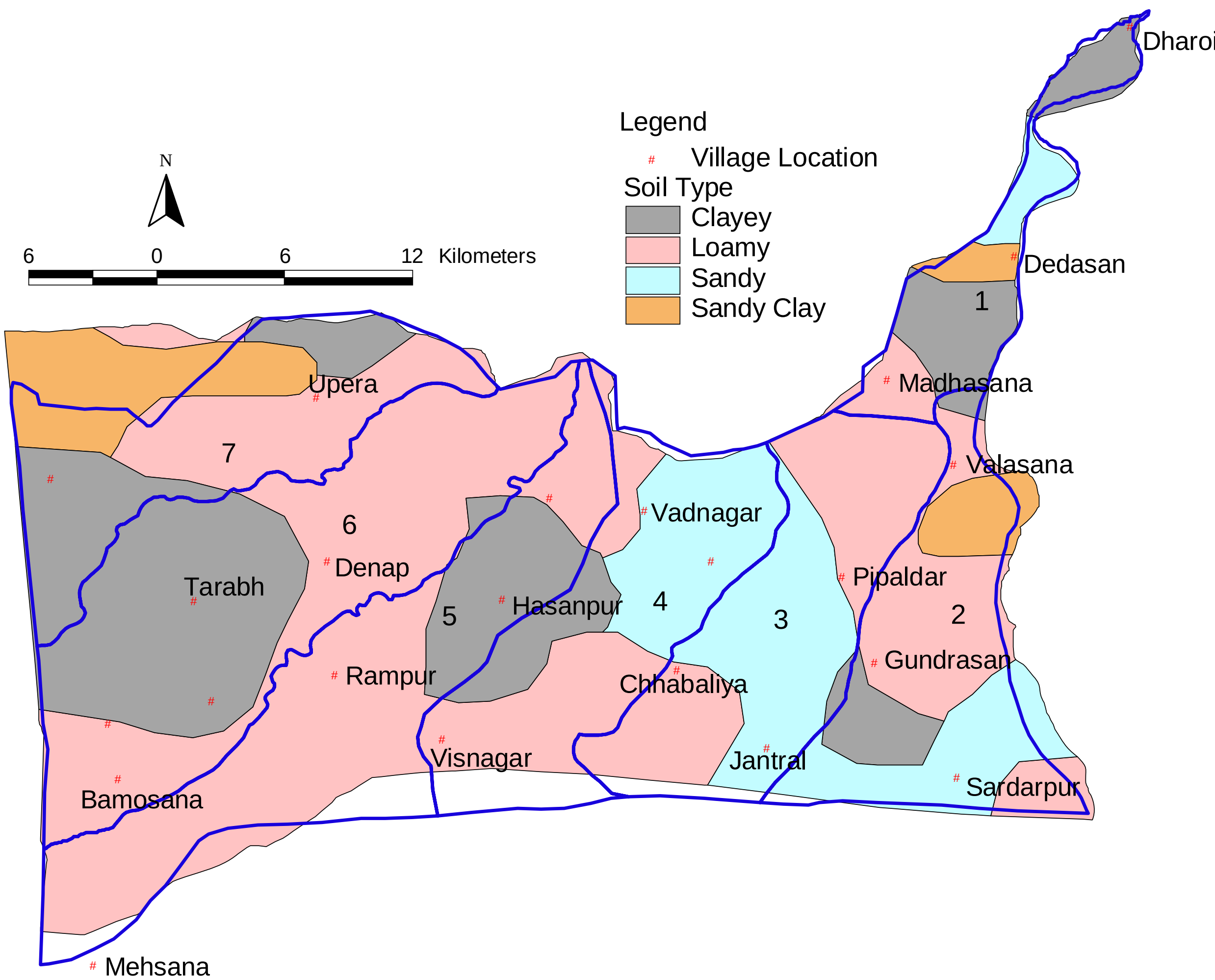



**Fig. 3.10 Soil Map of RBMCA**

Source: GoG, Irrigation Department (2006), SOI, (1965) ACT field Data, (2009)

**Table 3.10 Soil Type wise Range of Saturation Percentages**

| Type | Saturation (%) |
|---|---|
| Clayey | 27 - 32 |
| Loamy | 29 - 31 |
| Sandy Clay | 23 - 37 |
| Sandy | 23 - 26 |

Details of soil types and saturation percentages in different villages of RBMCA are given in annexure 3.3. Maximum saturation percentage of soil was observed in Kansa village i.e. 38.6 % whereas minimum has observed in Pipaldar i.e. 20.6 %. There were Bhandu, Satusana, Kambli, Biliya, Visnagar, Khansosan, Eyasar, Rampura, Vadnagar, Unad, Undai, Sobhasana, Jantral and Kamalpur villages having more than 30 % saturation. Such high saturation percentages of soils reflect good amount of moisture conservation capacity of soil. Table 3.11 shows soil type wise maximum and minimum values of saturation percentages.

## 3.7 Cropping Pattern

Cropping pattern in any area is an adaptation of agro-climatic characteristics of the area and availability of water. Besides this, soil composition and soil health are two important influencing parameters for crop selection as they determine productivity. So far the study area is concerned the cropping pattern has been studied in order to understand change in pattern before and after PIM activities as well as to understand water use efficiency. Table 3.11 shows change in crop sown areas before and after PIM in selected villages of different command areas of RBMCA. (Source-rabi Irrigation data, 2077, DSC) After PIM wheat, Mustard and Caster productions have significantly increased in the command areas whereas slight decrease has been seen in Cumin seed, Isabgool, grass and vegetable crops (Fig 3.11). Table 3.11 clearly shows that there is a significant **increase in total crop sown area from 5263.31 ha before PIM to 9998.5 ha after PIM i.e. about 190 %** in compare to before PIM.

Another major impact seen on crop in the area is change in crop variety such as earlier in most of the areas indigenous cotton and caster were used to saw which are now replaced by BT cotton and hybrid caster.

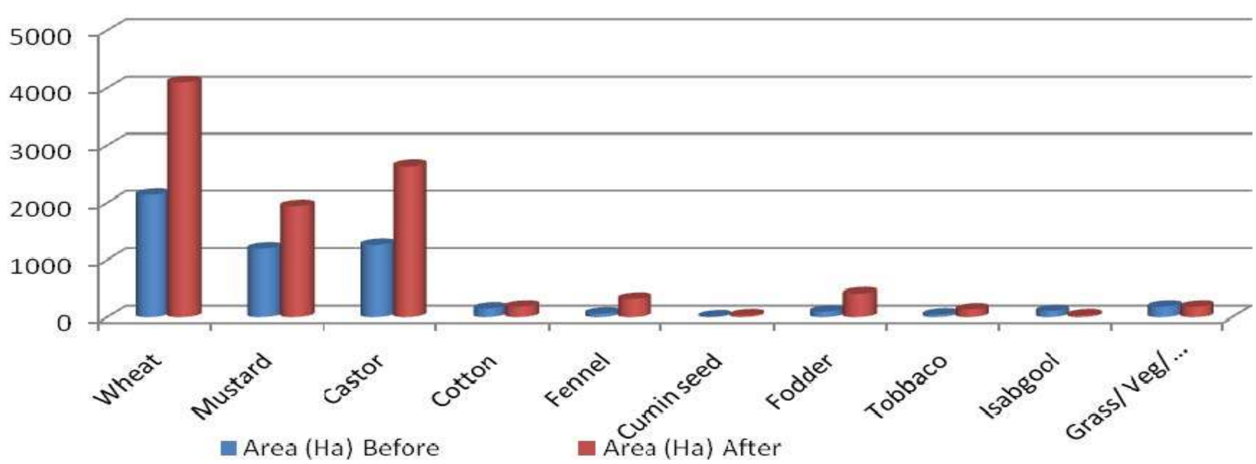



**Fig 3.11 Changes in Crop Pattern Before and After PIM**

**Table 3.11: Change in Cropping Before and After PIM**

| Crop | Period | Canal | | | | Total |
|---|---|---|---|---|---|---|
| | | MAIN | BR 1 | BR 2 | BR 3 | |
| **Wheat** | Before | 123.12 | 286.17 | 1082.31 | 642.20 | 2133.80 |
| | After | 84.41 | 1006.06 | 1566.23 | 1447.43 | 4104.13 |
| **Mustard** | Before | 20.05 | 52.49 | 547.03 | 579.10 | 1198.67 |
| | After | 6.49 | 242.54 | 776.67 | 918.68 | 1944.38 |
| **Castor** | Before | 108.97 | 601.33 | 325.50 | 228.86 | 1264.66 |
| | After | 98.31 | 1539.65 | 530.50 | 468.28 | 2636.74 |
| **Cotton** | Before | 4.85 | 60.29 | 71.15 | 17.55 | 153.84 |
| | After | 7.45 | 73.29 | 63.96 | 41.24 | 185.94 |
| **Fennel** | Before | 9.56 | 19.37 | 11.54 | 22.54 | 63.01 |
| | After | 16.91 | 81.23 | 129.69 | 100.45 | 328.28 |
| **Cumin seed** | Before | 2.45 | 0.00 | 6.50 | 3.56 | 12.51 |
| | After | 0.20 | 3.08 | 13.20 | 13.91 | 30.39 |
| **Fodder** | Before | 5.16 | 17.96 | 60.97 | 12.85 | 96.94 |
| | After | 5.31 | 57.58 | 221.97 | 130.52 | 415.38 |
| **Tobacco** | Before | 11.64 | 28.63 | 3.13 | 1.95 | 45.35 |
| | After | 5.57 | 119.67 | 0.00 | 10.73 | 135.97 |
| **Isabgool** | Before | 25.27 | 60.32 | 20.79 | 1.81 | 108.19 |
| | After | 6.90 | 22.42 | 1.90 | 0.00 | 31.22 |
| **Grass/ Veg. / other crops** | Before | 122.85 | 43.84 | 12.95 | 6.70 | 186.34 |
| | After | 8.83 | 62.57 | 94.12 | 20.55 | 186.07 |
| **Total Crop Area** | **Before** | **433.92** | **1170.4** | **2141.87** | **1517.12** | **5263.31** |
| | **After** | **240.38** | **3208.09** | **3398.24** | **3151.79** | **9998.5** |

Source: DSC, 2007

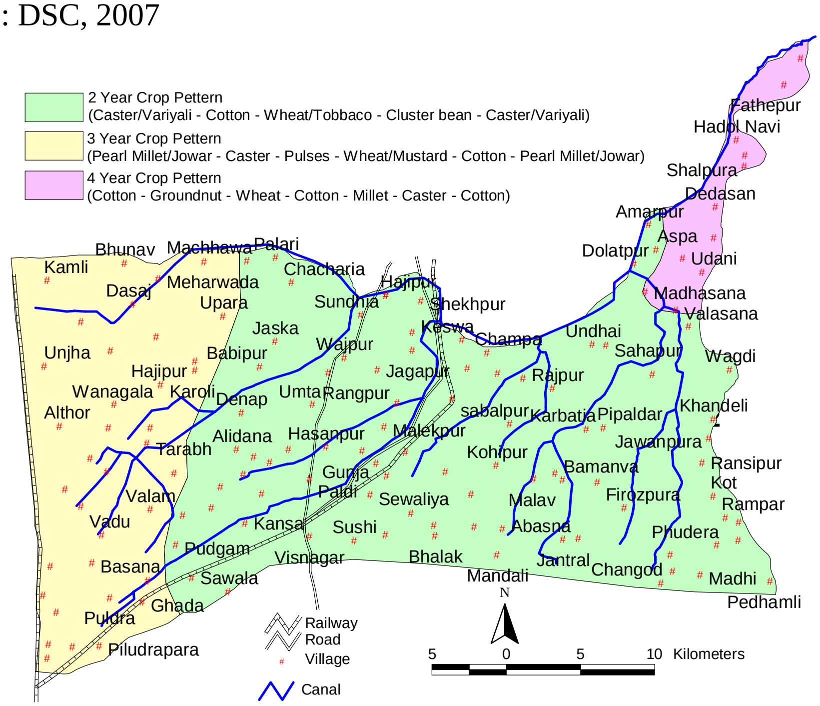



**Fig 3.12: Crop Pattern in RBMC Area**

Source: GoG, Irrigation Department (2006), SOI, (1965) ACT field Data, (2009) To characterize crop pattern in study area, village level consultations with farmers in different parts of command area were carried out. The main objective of the crop pattern evaluation is to understand how farmers practice different crop as per water availability from different sources. Repetition of crop, annual crop cycle and combination / alternative crop were main parameters considered for classification. Crop pattern of the area was classified into three classes such as (01) Two year crop pattern: where main crop cycle is Caster / Fennel - Cotton – Wheat / Tobacco - Cluster Bean – Caster / Fennel; (02) Three year crop pattern where main crop cycle is Pearl Millet /Sorghum - Caster - Pulses - Wheat/Mustard - Cotton - Pearl Millet / Sorghum; (03) Four year crop pattern where main crop cycle is Cotton - Groundnut - Wheat - Cotton - Millet - Caster – Cotton. (Fig 3.12)

***Two Year Crop Pattern:*** To understand the pattern farmers of irrigation cooperatives namely M8 Dedasan Mandli village Dedasa and SM 9 R / D07L Valasana of Valasana villages have been consulted. This pattern is mainly adopted by farmers of the villages of Chada, Aspa, Dabu, Sipor, Jantral, Ganeshpura, Rampur, Fudeda, Kot, and Chhabaliya. Terrain wise this pattern is dominant in undulating terrain and in sandy soil conditions. With respect to command area, this type is popular in immediate command of the dam where minor are designed directly from main canal. There are two sub types noticed in this pattern (Table 3.12 and 3.13). In case of type A, usually in first year farmer saws caster or fennel in later part of monsoon i.e. during month of August whereas in Type B farmers normally saw pearl millet as rain fed crop and then they saw caster that remains up to summer season. In short major difference in both the types is that in case of Type A farmers do not saw any crop in first year during monsoon whereas in Type B in all seasons farmer saws crop. Both types show similarity in sawing during winter and summer of second year. In both the types farmers saw winter and summer cropping up to month of April however, crops are different. In case of Type A there is a single crop mainly cotton while in Type B it may be wheat or mustard depending upon number of irrigation from canal water. Another similarity in both types is that during month of April and May farmers keep their land for drying but occasionally they also saw pearl millet.

**Table 3.12 Two Year Crop Pattern of Study Area Type A**

<table>
<tr><td colspan="5">Type – A</td></tr>
<tr><td>Crop Pattern:</td><td colspan="3">2 Year (Caster / Fennel - Cotton - Wheat/Tobacco - Cluster Bean - Caster/ Fennel)</td><td rowspan="4">Distribution</td></tr>
<tr><td>Village</td><td>Dedasana</td><td>Mandli</td><td>M 8 Dedasan Mandli</td></tr>
<tr><td rowspan="2">Month</td><td colspan="3">Crops</td></tr>
<tr><td>Year I</td><td>Year II</td><td>Year III</td></tr>
<tr><td>June</td><td></td><td rowspan="7">Cotton</td><td rowspan="4">Cluster Bean / Green Manure</td><td>Chada</td></tr>
<tr><td>July</td><td></td><td>Aspa</td></tr>
<tr><td>August</td><td rowspan="9">Caster / Fennel</td><td>Dabu</td></tr>
<tr><td>September</td><td>Sipor</td></tr>
<tr><td>October</td><td rowspan="7">Caster / Fennel</td><td>Jantral</td></tr>
<tr><td>November</td><td>Ganeshpura</td></tr>
<tr><td>December</td><td>Rampur</td></tr>
<tr><td>January</td><td rowspan="3">Wheat / Tobacco</td><td>Fudeda</td></tr>
<tr><td>February</td><td>Kot</td></tr>
<tr><td>March</td><td>Chhabaliya</td></tr>
<tr><td>April</td><td rowspan="2">Land Drying / Millet</td><td></td></tr>
<tr><td>May</td><td>Cotton</td><td></td><td></td></tr>
</table>

**Table 3.13 Two Year Crop Pattern of Study Area Type B**

| Type – B | | | | |
|---|---|---|---|---|
| Crop Pattern | 2 Year (Caster / Fennel - Cotton – Wheat / Tobacco - Cluster Bean - Caster/ Fennel ) | | | Distribution |
| Village | Valasana / Mandli | SM 9 R / D07L Valasana | | |
| Month | Crops | | | |
| | Year I | Year II | Year III | |
| June | Pearl Millet | Cluster Bean / Pearl Millet | Pearl Millet | Ranshipur |
| July | | | | Shobhshan |
| August | | | | Karbatiya |
| September | | | | Dediya |
| October | Caster | Wheat/ Mustard | Caster | Aspa |
| November | | | | Pipaldar |
| December | | | | Madhasan |
| January | | | | Chada |
| February | | | | Rangpur |
| March | | | | Denap |
| April | | Land Drying / Millet | | Gundrasan |
| May | | | | Kamalpur, Kansa |

**Table 3.14 Three Year Crop Pattern of Study Area**

| Crop Pattern: | 3 Year (Pearl Millet/ Jowar - Caster - Pulses - Wheat/Mustard - Cotton - Pearl Millet/Jowar) | | | | Replicability in village |
|---|---|---|---|---|---|
| Village | Kambli | Mandli | D1R, SM5 &6 L Kambli | | |
| Month | Crops | | | | |
| | Year I | Year II | Year III | Year IV | |
| June | Pearl Millet (Optional) | Pulses / Millet / Jowar | Cotton / Caster | Pearl Millet (Optional) | Jetalvasna, Tarabh, Valam, Satusana, Bhandu, Laxmipura, Arnipura, Aidor (Chamundanagar), Khandosan, Udgam, Vadu, Bamansa, Randal, Nani Davu, Gunja, Upera, Kesimpa, Pilodra, Gadha |
| July | | | | | |
| August | | | | | |
| September | | | | | |
| October | Caster | | | Caster | |
| November | | Wheat / Mustard | | | |
| December | | | | | |
| January | | | | | |
| February | | | | | |
| March | | | | | |
| April | | Land Drying | Land Drying | | |
| May | | | | | |

***Three Year Crop Pattern:*** In this case farmers grow Pearl millets in first year followed by long duration corps like caster sown in late monsoon (in October) that remains standing till April in next year. The important characteristic of this pattern is that farmers keep their land dry for one or two months in each year. During third year farmers sow cotton or caster in the beginning of monsoon season that remains until March. This crop pattern is dominant in agriculture areas of western part of study area. According to discussion with farmers the selection of this kind of cropping pattern is mainly due to availability of poor quality of groundwater in this area. Being a tail area of Right Bank Main Canal when they have sufficient number of watering they sow wheat or mustard. Table 3.14 shows season wise crop in this pattern.

**Table 3.15 Three Year Crop Pattern of Study Area**

<table>
<tr><td>Crop Pattern:</td><td colspan="5">4 Year (Cotton - Groundnut - Wheat - Cotton - Millet - Caster - Cotton)</td><td rowspan="4">Replicability in village</td></tr>
<tr><td>Village</td><td>Dharoi</td><td>Mandli</td><td colspan="3">M2L Dharoi Mandli</td></tr>
<tr><td rowspan="2">Month</td><td colspan="5">Crops</td></tr>
<tr><td>Year I</td><td>Year II</td><td>Year III</td><td>Year IV</td><td>Year V</td></tr>
<tr><td>June</td><td rowspan="7">Cotton</td><td rowspan="5">Ground nut</td><td rowspan="7">Cotton</td><td rowspan="10">Caster</td><td rowspan="7">Cotton (Irrigation from Octo to Dec</td><td rowspan="12">Dharoi to Madhasan</td></tr>
<tr><td>July</td></tr>
<tr><td>August</td></tr>
<tr><td>September</td></tr>
<tr><td>October</td></tr>
<tr><td>November</td><td></td></tr>
<tr><td>December</td><td rowspan="4">Wheat</td></tr>
<tr><td>January</td><td rowspan="5">Pre Sowing Ground Nut</td><td></td><td rowspan="5">Pre Sawing Ground Nut</td></tr>
<tr><td>February</td><td rowspan="4">Pearl Millet</td></tr>
<tr><td>March</td></tr>
<tr><td>April</td><td rowspan="2">Land Drying</td><td rowspan="2">Land Drying</td></tr>
<tr><td>May</td></tr>
</table>

***Four Year Crop Pattern:*** Repetition of pre sowing ground nut in month of January is benchmark in this class of crop pattern. This type is dominant in area from adjoining Dharoi dam to Madhasana village. Farmers keep their land for drying for two alternative years i.e. during second and fourth year, while in first and third year's agriculture land remains occupied with crop. Table 3.15 shows year wise crop type in this pattern.

# 4. IMPACT OF PIM IN RBMC

## 4.1 CHANGES IN IRRIGATED AREA

Participatory irrigation management has been promoted since 1995-96 but the intensive spread of PIM activity started after year 2004. Before year 2004 there were only 28 ICs in entire command area. Therefore considering year 2004 as benchmark year the changes in irrigation area as well as land use in RBMCA have analyzed.

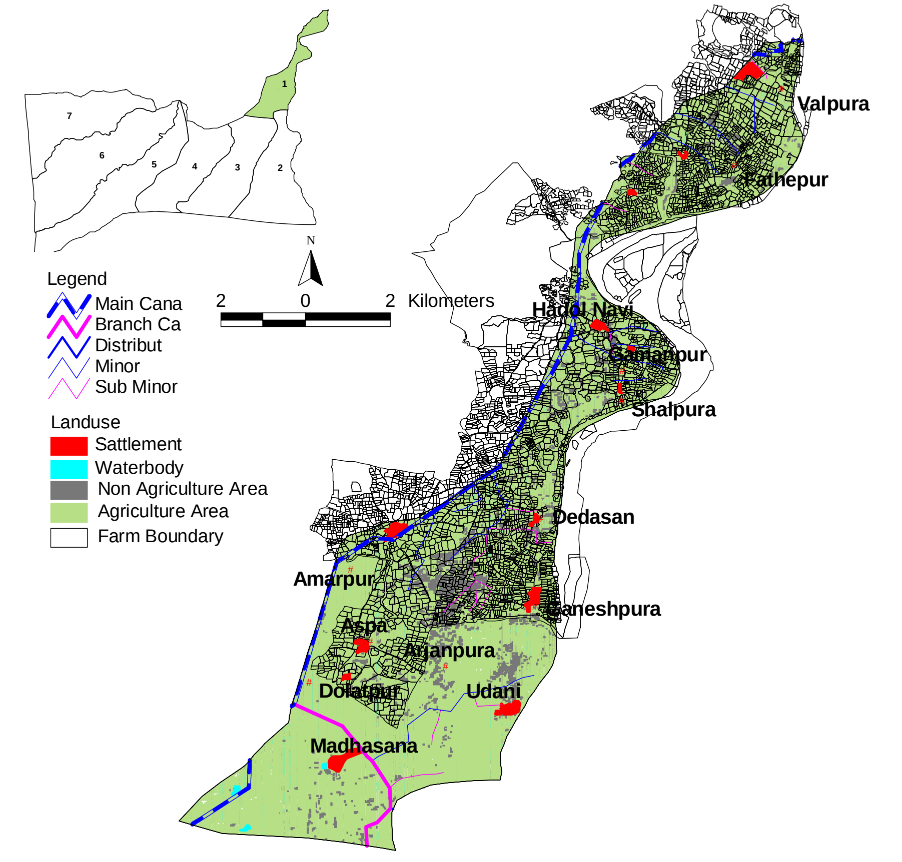
Today about 196 cooperatives manage irrigation in Right Bank Main Canal Command area of Dharoi dam. About 129 Irrigation cooperatives (IC) have been formulated by DSC whereas remaining cooperatives have directly been constituted by Irrigation department directly or by other NGOs. All these cooperatives are managing canal water irrigation. In addition there are several private *mandalis* who are also managing bore well irrigation but source of water is groundwater. ICs established by DSC are spread over about 89 villages and manage about 25,784 ha of irrigation areas. There are about 20,491 farmers who are members of these ICs. There are two federations constituted by these ICs at Branch level, one of them (Branch 2 Federation) has undergone for agreement with Government and has taken charge of water distribution also.

For estimation of change in irrigated area, Rabi season of year 2003-04 has been consider as before PIM and that of year 2007-08 has been considered as after PIM stage. This analysis has been carried out with the help of remote sensing data of respective periods. It is important to clarify that comparative analysis (before and after) of block no. 5, 6 and 7 has not been carried out due to partial data gap in satellite image of Rabi season of year 2003. However, for year 2008 land use pattern has been analyzed for all seven blocks. Table 4.1 and Fig.4.1, 4.2, 4.3, 4.4 shows computed irrigation area of before and after PIM situations. Remote sensing data analysis shows that there are total about 22,512 ha of area under irrigation during Rabi season of year 2003-04 in block no. 1,2,3 and 4 while it was about 36,412 ha during year 2007-08. Total irrigation area in seven blocks is about 63,235 ha. Comparative analysis of first four blocks shows about 61.74% of increase in irrigated area after PIM. To understand reasons of rise in RBMCA, consultation with various ICs and irrigation department's officials had been held. According to them following are main reasons for this rise.

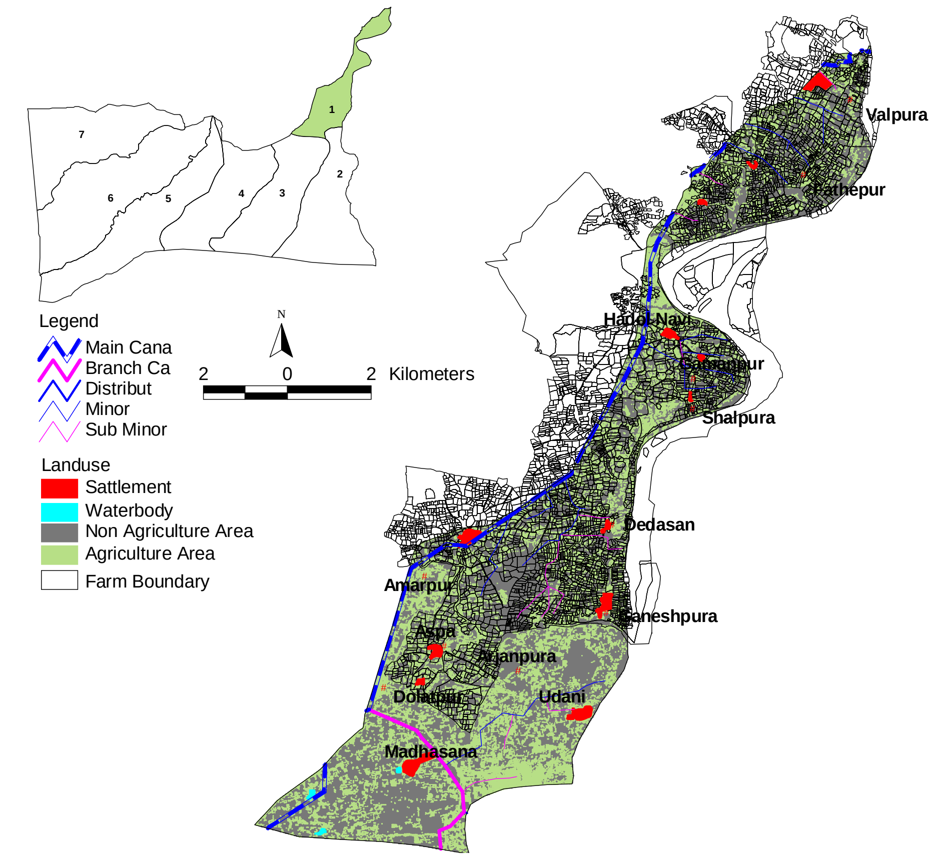
**Table no. 4.1 Block Wise Changes in Irrigated areas Before (Year 2003-04) and After (Year 2007-08) PIM.**

| Block No. | Irrigated Areas (Ha) | | Difference (Ha) | Change (%) |
|---|---|---|---|---|
| | Year 2003-04 | Year 2007-08 | | |
| 1 | 5551 | 3537 | -2014 | -36.30 |
| 2 | 4964 | 7940 | 2976 | 59.95 |
| 3 | 5351 | 7753 | 2402 | 44.90 |
| 4 | 6646 | 8785 | 2139 | 32.20 |
| **Total** | **22512** | **36412** | **13900** | **61.74** |
| 5 | ----- | 11571 | ---- | ---- |
| 6 | ----- | 15252 | ---- | ---- |
| 7 | ----- | 8397 | | |
| **Total** | **-----** | **63235** | | |

Source: NRSA RS Data 2003-04, 2007-08,



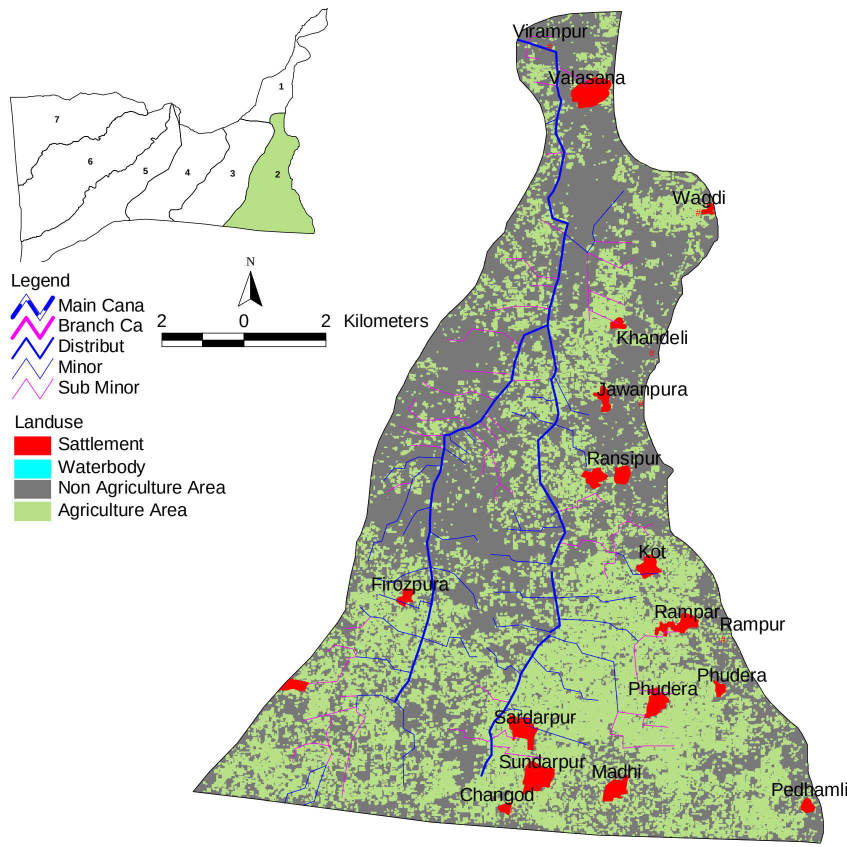

Year 2003-04 Irrigated Areas 5551 (ha)



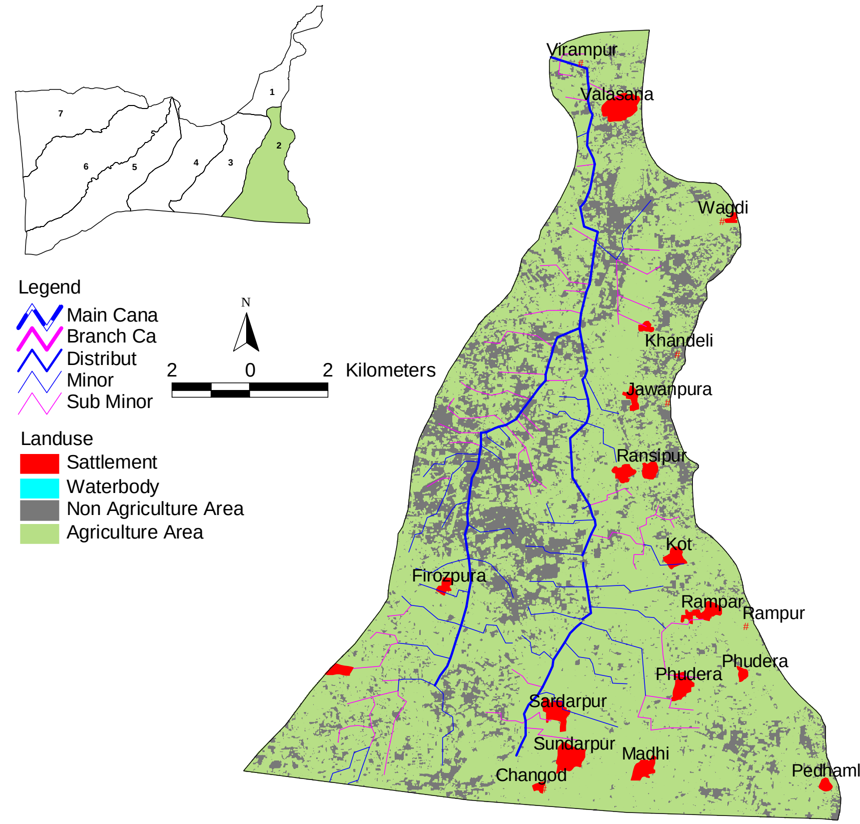

Year 2007-08 Irrigated Areas 3539 (ha)

**Fig. 4.1 Change in Irrigation Areas in Block I of RBMCA**

Source: NRSA RS Data (2003, 04, 07, 08 ) GoG, Irrigation Department (2006), SOI, (1965) ACT field Data, (2009)



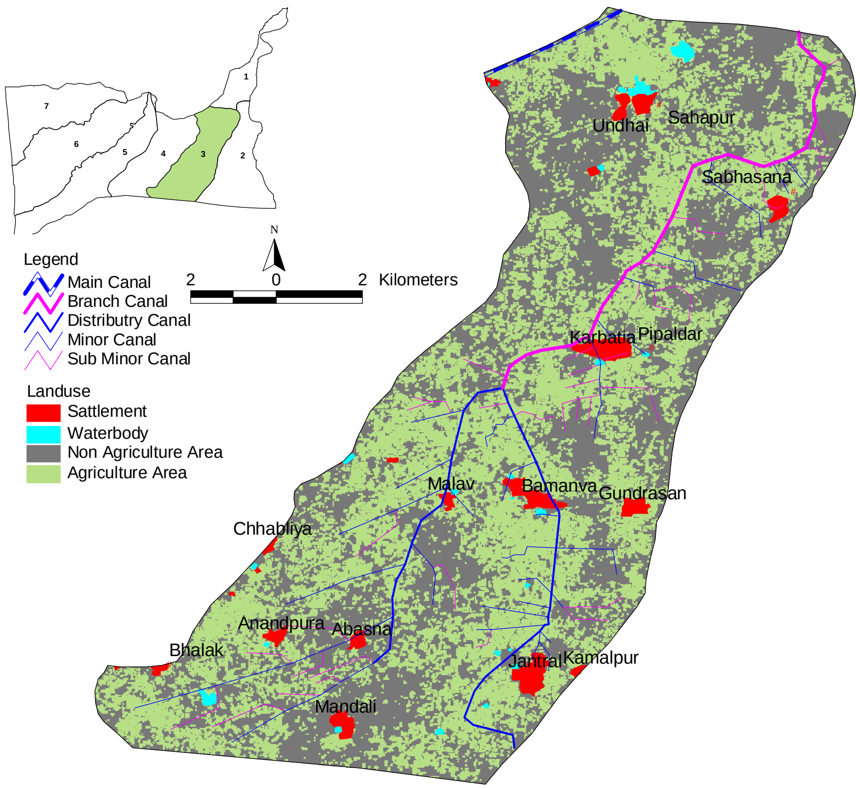

Year 2003-04 Irrigated Areas 4964 (Ha)



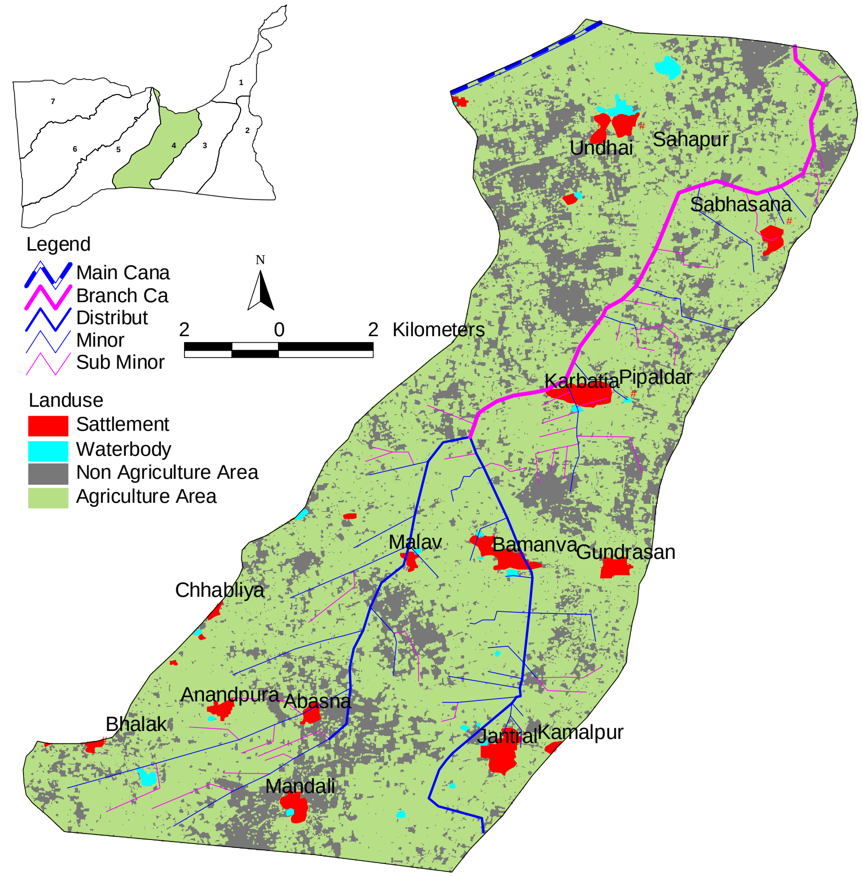

Year 2007-08 Irrigated Areas 7940 (Ha)

**Fig 4.2 Change in Irrigation Areas in Block 2 of RBMCA**

Source: NRSA RS Data (2003, 04, 07, 08 )GoG, Irrigation Department (2006), SOI, (1965) ACT field Data, (2009)




Year 2003-04 Irrigated Areas 5351 (ha)




Year 2008 Irrigated Areas 7753 (ha)

**Fig. 4.3 Change in Irrigation Areas in Block 3 of RBMCA**

Source: NRSA RS Data (2003, 04, 07, 08)GoG, Irrigation Department (2006), SOI, (1965) ACT field Data, (2009)

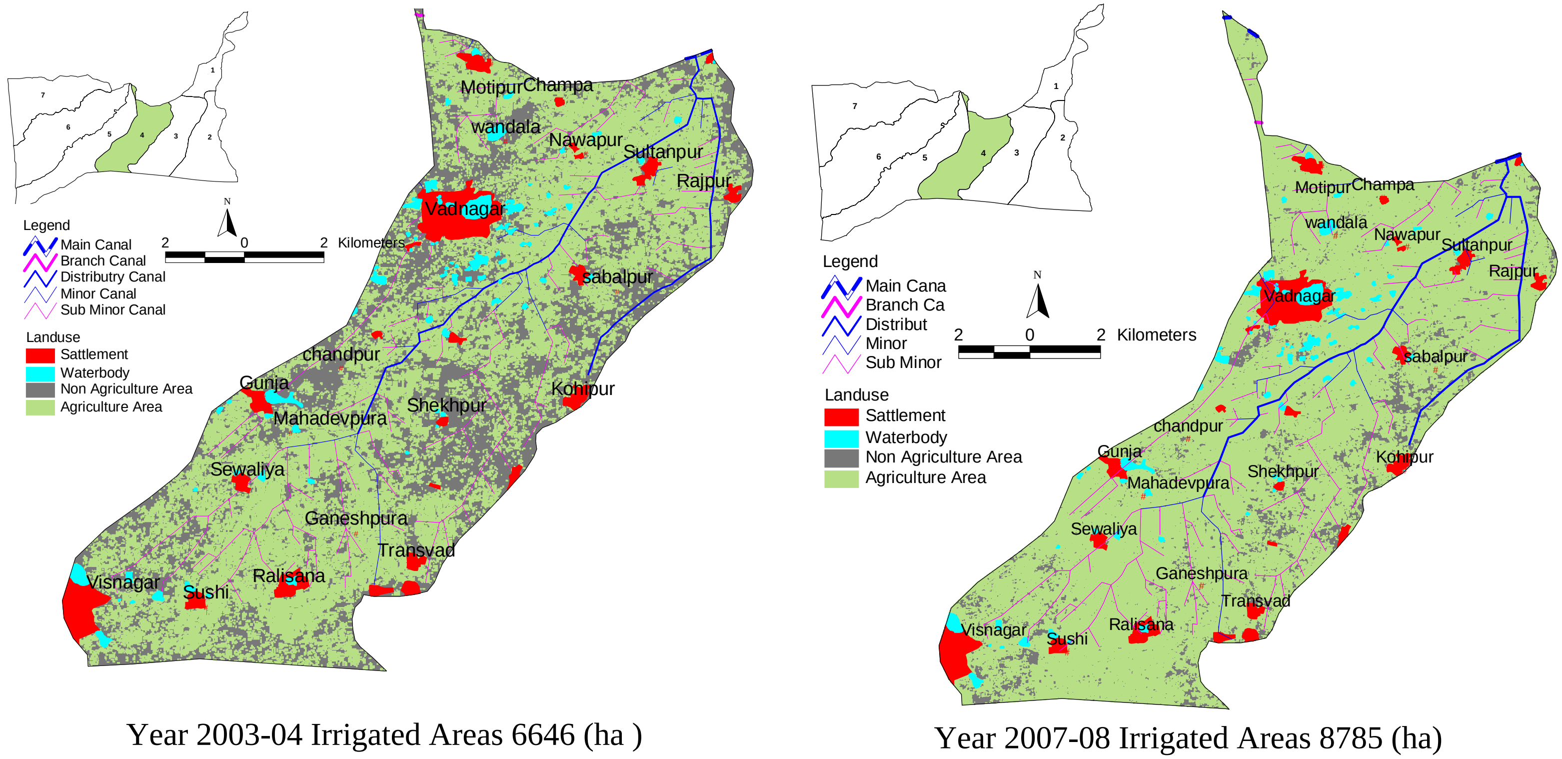



**Fig. 4.4 Change in Irrigation Areas in Block 4 of RBMCA**

Source: NRSA RS Data (2003, 04, 07, 08) GoG, Irrigation Department (2006), SOI, (1965) ACT field Data, (2009) Presently canal lining has taken place at all minor and most of the sub minor levels. That has reduced conveyance lost as well as seepage. Canal rehabilitation works executed by ICs were carried out during this period intensively. Up to year 2009 total about **488 km length of canal had been surveyed** and estimates have been prepared of Rs. 658 lakh. Canal rehabilitation work has significantly decreased seepage and conveyance losses from canal. Department data shows that **about 254 km length of canal rehabilitation work has been completed by 127 WUAs** under DSC's supervision. The WUAs have shared more than 10% of the cost and remaining 90% contributed by Govt. In addition, irrigation department is also executing canal rehabilitation work through WUAs under direct supervision.

Involvement of ICs in irrigation management is another important reason for this increase. It is already described in previous chapter that ICs have developed their regulatory norms for water management and distribution. Today in RBMCA, PIM activities are already spread over about 25,784 ha area which was only about 5100 ha before year 2004. Today there are about 129 ICs in 89 villages managing irrigation water in command area and about 20,491 farmers are member of these WUAs.

Above discussion clearly shows that spread of PIM activities has encouraged important as well as efficient water distribution that ultimately resulted in to overall increase in irrigated area in RBMCA. In addition, increased use of groundwater in irrigation also contributes to increase in irrigated area in RBMCA. However, discussion on use of groundwater in irrigation is mentioned separately in proceeding discussions on intensive or extensive use of canal water section.

Increase in irrigated area is definitely a measure of improvement of overall system but, sustainability of this increase still remains questionable unless positive changes take place in water use efficiency. Keeping this in mind some more aspects affecting the irrigation efficiency have been evaluated based on available data. It is important to clarify that such assessment study requires in depth primary investigation, appropriate data and monitoring as well as resource. Following aspects have been analyzed for this assessment.

- Water use efficiency
- Extensive and intensive use of canal water in RBMCA
- Extension of command area
- Water inflow in dam and catchment yield

## 4.2 WATER USE EFFICIENCY

### 4.2.1 Approaches

Various approaches exist to estimate water use efficiency. The basic concept of irrigation efficiency, $I_e$, was set forth by Israelsen (1950) as the ratio of the irrigation water consumed (evaporated) by crops, $U_{ci}$, to the irrigation water delivered from a surface or groundwater source to the canals or farm head gates, $V_D$:

*Ie = Irrigation Water Evaporated by Crops Water /Diverted, Delivered, or Applied*
*= UV = CropET - PV* (1)

Where, *CropET* is the crop transpiration and evaporation or evapo-transpiration, *ET*, and $P_e$ is the effective precipitation. Water use efficiency estimation by this method is known as Effective Efficiency approach. This early definition, which has been accepted by irrigation scientists worldwide, is appropriate but limited parameter for irrigation design. It applies only to the quantity of water that must be handled (pumped, conveyed, etc.) to accommodate an estimated amount of beneficial use. For design purposes, it is limited because it omits the necessary leaching water.

As irrigation water is transpired by crops and evaporates from the soil surface, salts remain behind and accumulate in the soil. To maintain a favorable salt balance for optimum crop production, these residual salts must be periodically leached from the soil by applying excess water. The ratio of the minimum amount, $V_{LR}$, of the applied irrigation water (in excess of $CropET - P_e$, or $U_{ci}$) that must pass below the crop root zone to maintain a favorable salt balance is called the leaching fraction or requirement, *LR:*

$$LR = V_{LR}/ +Uci+ V_{LR} \qquad (2)$$

The leaching requirement is specific for each combination of irrigation water quality and crop because crops differ in their tolerance to soil salinity. It is also a function of the type of irrigation application system, the frequency of irrigations, and to a limited extent soil texture. Consequently Ayers and Wescot (1985) expand the classical concept of irrigation efficiency in equation (1) to account for leaching requirements (and we designate expanded classical efficiency as $E_i$):

$$Ei = Ie/(1-L_R) \qquad (3)$$

or

$$Ei =( CropET – Pe) + V_{LR}/V_D$$
$$= Uci + V_{LR} / V_D$$
$$= Uci / (1-LR)V_D \qquad (4)$$

Figure 1 shows a schematic view of an irrigation project supplied by diverting water from a river. The relative locations of the data (terms) needed for computing the classical irrigation efficiency $E_i$, by equation (4) are also included in Fig. 4.5.

Irrigation scientists have struggled with the classical irrigation efficiency concepts and tried to tackle such problems as:

- How to deal with application uniformity, effective rainfall, and estimating actual crop evapo-transpiration
- What besides evapo-transpiration and meeting the leaching requirement is a legitimate beneficial use
- How to deal with practical values for conveyance losses, application uniformities, leaching requirements, meeting evapo-transpiration potentials, and irrigation frequency and scheduling

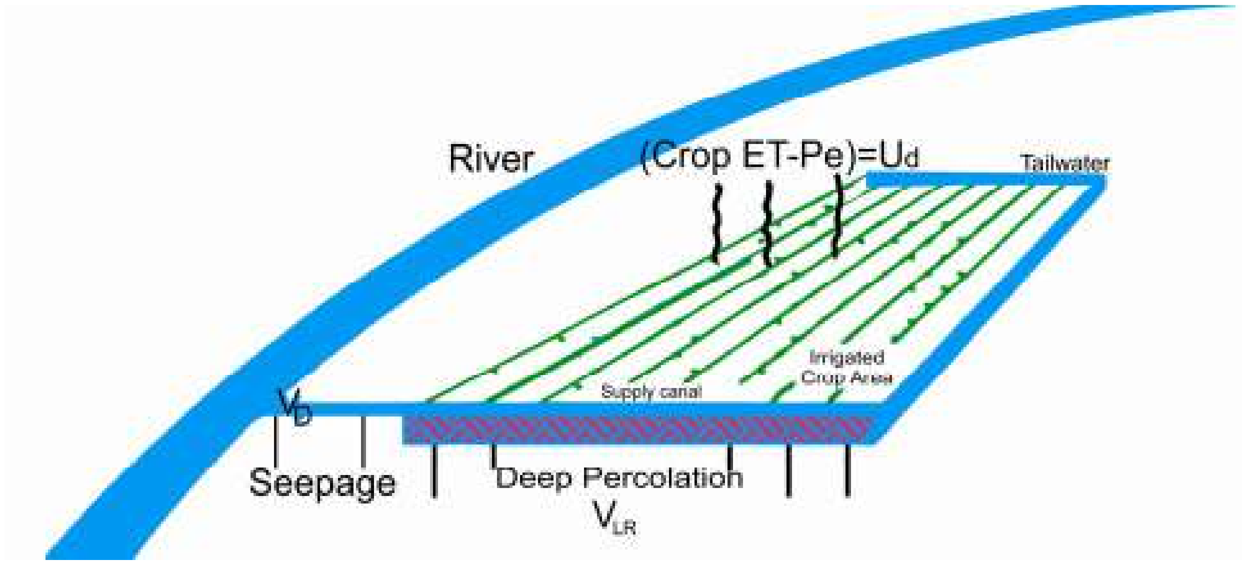



**Fig. 4.5. Schematic View of a Diversion Project and Terms Necessary for Defining Classical Irrigation Efficiency**

Most recently, the American Society of Civil Engineer's Irrigation and Drainage Division Task Committee's draft report *Irrigation Efficiency and Distribution Uniformity* (dated 10 June 1994) suggests a new application efficiency term, *irrigation sagacity (IS):*

*IS = Irrigation Water Beneficially and Reasonably Used / Irrigation Water Applied* (5)

*Beneficial uses* include such items as crop evapo-transpiration, leaching, germination, temperature and humidity control, and soil preparation. *Reasonable uses* include water needed to maintain drainage water quality, some deep percolation due to non-uniformity and uncertainties in salt management, and various losses that may not be economical to avoid.

Using irrigation sagacity (equation 5) provides an interesting approach for system design and a more realistic efficiency concept for evaluating irrigation systems because it justifiably includes beneficial and reasonable uses in addition to crop evapo-transpiration and the leaching requirement. Its authors developed the irrigation sagacity concept out of concern that irrigation is gaining a reputation of being inefficient and a water waster. Yet, irrigation sagacity, while it may put farm irrigation efficiency in a better light, is still a classical irrigation efficiency concept. It includes desired deliverables and reasonable irrigation water inputs, but it ignores reusable return flows. In other words, irrigation sagacity still makes irrigation appear to be a less efficient user of freshwater resources than it actually is. Therefore irrigation sagacity should not be employed for water resource allocation purposes.

Jozef Takac, Pavol Nejedlik and Bernard Siska in 2008 have derived method for water use efficiency based on crop yield. They proposed following methods for water use efficiency assessment.

**Method I:** Water use efficiency WUE [ kg/mm ]

IE= Yi/Yr*100

*Yi* yield of irrigated plant [kg/ha]; *Yr* yield of non irrigated plant [kg/ha]

**Method II:** Irrigation Water Use Efficiency IWUE [kg/mm]

$IWUE=Yi-Yr/I$

*Yi* yield of irrigated plant [kg/ha]; *Yr* yield of non irrigated plant [kg/ha]; *l irrigation amount* [mm]

Jozef et. al. have carried out field experiments on crops like winter wheat, spring barely, maize and sugar beet during year 1973 to 2006. They computed water use efficiency and irrigation water use efficiency for each crop. Based on their experiment following conclusions were made by them.

- Positive effect of irrigation comes mainly at the crops harvested in late summer i.e.maize and sugar beet. Irrigation efficiency was lower at the cereals.
- Irrigation water use efficiency was highest at all crops during dry seasons when low irrigation dosages were applied
- Total Precipitation s during the respective vegetation season, the amount of water flowing into the system is not the only parameter determining the efficiency of water use by the crops. The way and the date of irrigation as well as the nutrition and soil properties and their interactions play the decisive role.

It is true that not all water taken from a source (river, well) reaches the root zone of the plants. Part of the water is lost during transport through the canals and in the fields. The remaining part is stored in the root zone and eventually used by the plants. In other words, only part of the water is used efficiently, the rest of the water is lost for the crops on the fields that were to be irrigated. Figure 4.6 shows the irrigation water losses in canals; these are due to:

1. Evaporation from the water surface
2. Deep percolation to soil layers underneath the canals
3. Seepage through the bunds of the canals
4. Overtopping the bunds
5. Bund breaks
6. Runoff in the drain
7. Rat holes in the canal bunds

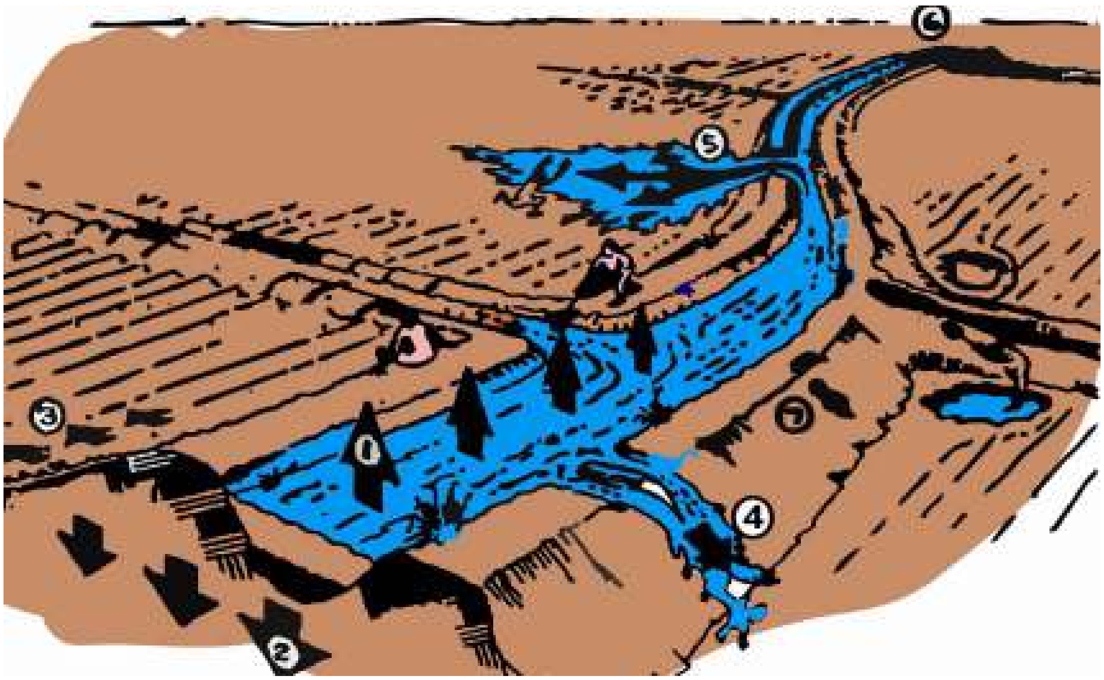


**Fig 4.6. Irrigation Water Losses in Canals**

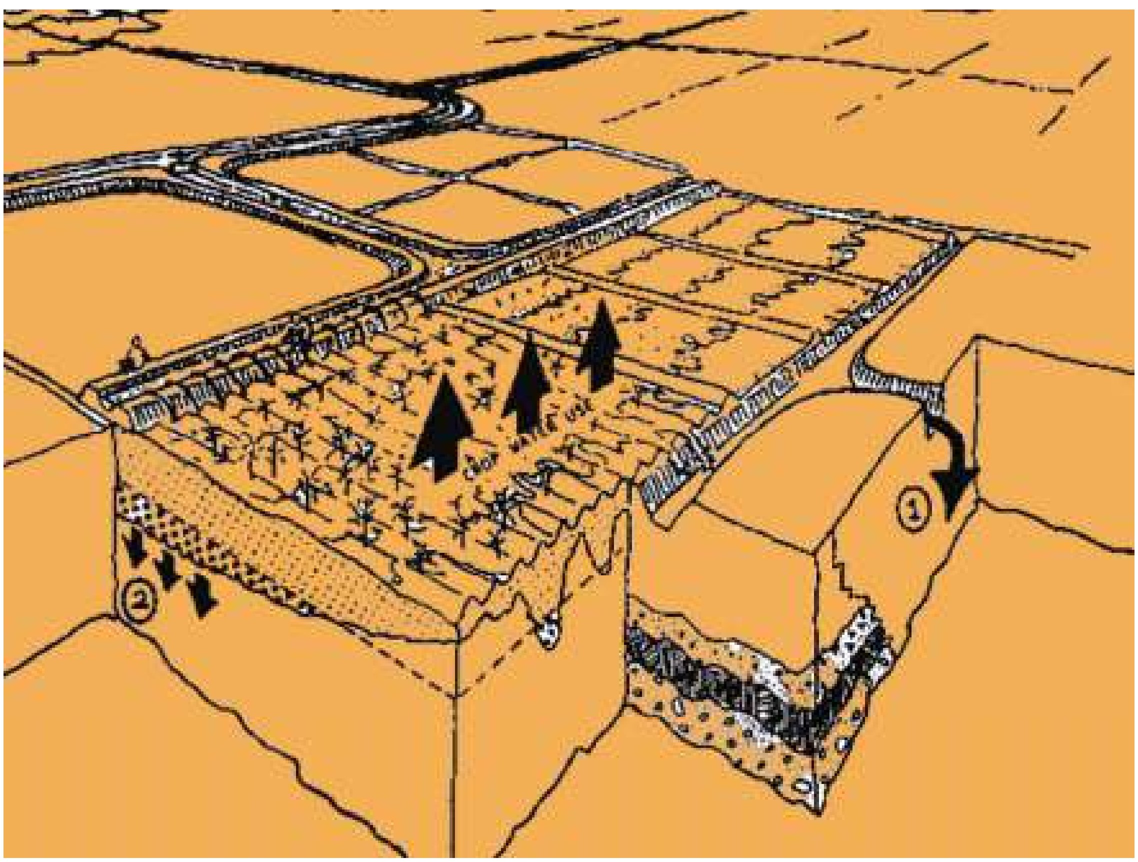


**Fig 4.7. Irrigation water losses in the field**

Figure 4.7 shows the irrigation water losses in the field; these are due to:

1. Surface runoff, whereby water ends up in the drain
2. Deep percolation to soil layers below the root zone

To express what percentage of irrigation water is used efficiently and what percentage is lost; the term **irrigation efficiency** is used.

The **scheme irrigation efficiency** (e in %) is that part of the water pumped or diverted through the scheme inlet which is used effectively by the plants. The scheme irrigation efficiency can be sub-divided into:

The **conveyance efficiency (ec)** which represents the efficiency of water transport in canals, and the **field application efficiency (ea)** which represents the efficiency of water application in the field.

The conveyance efficiency (ec) mainly depends on the length of the canals, the soil type or permeability of the canal banks and the condition of the canals.

In large irrigation schemes more water is lost than in small schemes, due to a longer canal system. From canals in sandy soils more water is lost than from canals in heavy clay soils. When canals are lined with bricks, plastic or concrete only then very little water is lost. If canals are badly maintained, bund breaks are not repaired properly and rats dig holes, a lot of water is lost.

Table 4.2 provides some indicative values of the conveyance efficiency (ec), considering the length of the canals and the soil type in which the canals are dug. The level of maintenance is not taken into consideration: bad maintenance may lower the values of Table 7 by as much as 50%.

**Table 4.2 Indicative Values of the Conveyance Efficiency (ec) for Adequately Maintained Canals**

| **Soil type** | **Earthen canals** | | | **Lined canals** |
|---|---|---|---|---|
| | **Sand** | **Loam** | **Clay** | |
| **Canal length** | | | | |
| Long (> 2000m) | 60% | 70% | 80% | 95% |
| Medium (200-2000m) | 70% | 75% | 85% | 95% |
| Short (< 200m) | 80% | 85% | 90% | 95% |

The **field application efficiency** (ea) mainly depends on the irrigation method and the level of farmer discipline. Some indicative values of the average field application efficiency (ea) are given in Table 4.3. Lack of discipline may lower the values found in Table 4.2.

**Table 4.3 Indicative Values of the Field Application Efficiency (ea)**

| **Irrigation Methods** | **Field Application Efficiency** |
|---|---|
| Surface irrigation (border, furrow, basin) | 60% |
| Sprinkler irrigation | 75% |
| Drip irrigation | 90% |

Once the conveyance and field application efficiencies have been determined, the **scheme irrigation efficiency (e)** can be calculated, using the following formula:

$$e = \frac{ec \times ea}{100}$$

with
e = scheme irrigation efficiency (%)
ec = conveyance efficiency (%)
ea = field application efficiency (%)

A scheme irrigation efficiency of 50-60% is good; 40% is reasonable, while a scheme irrigation efficiency of 20-30% is poor.

### 4.2.2 Water Use Efficiency of RBMC Area

Based on above discussed approaches water use efficiency in RBMC area has been computed by using following methods.

***Scheme Irrigation Efficiency:*** Most of the main, branch, distributary and minor canals of the RBMC area are lined and hence the conveyance efficiency value can be considered about 95% and for field application method is 60 % due to surface irrigation method. Therefore scheme irrigation efficiency by using following equation will be:

E = (ec*eA)/100
= (95*60)/100
= 57 %

According to classification, the **scheme efficiency falls under good category** (50 to 60 %).

***Per Hectare Water Use (Duty):*** Yearly water use per unit (hectare) area has been computed by using irrigation department's data from the year 1979-80 to 2009-2010. Table 4.4 and Fig 4.8 show decrease in per hectare water use from starting year of 1979-80 (0.4031 mcft/ha) to 2009-2010 (0.188 mcft/ha). Minimum water use per ha is in year 1996-97 and maximum is in year 1980-81.

**Table 4.4 Year wise Irrigated Area and Duty**

| Year | Released Water in RBMC (mcft) | Area in Different Season (ha) | | | Total (ha) | Water Use Efficiency (mcft / ha) |
|---|---|---|---|---|---|---|
| | | Kharif | Rabi | Summer | | |
| 1979-80 | 104 | 75 | 183 | 0 | 258 | **0.4031** |
| 1980-81 | 572 | 131 | 502 | 380 | 1013 | **0.5647** |
| 1981-82 | 650 | 16 | 677 | 593 | 1286 | **0.5054** |
| 1982-83 | 1862 | 135 | 4303 | 1685 | 6123 | **0.3041** |
| 1983-84 | 4546 | 0 | 5606 | 2637 | 8243 | **0.5515** |
| 1984-85 | 6862 | 21 | 11432 | 3729 | 15182 | **0.4520** |
| 1985-86 | 4663 | 3711 | 11750 | 2223 | 17684 | **0.2637** |

**Table 4.4 Year Wise Irrigated Area and Duty Contd…**

| Year | Released Water in RBMC (mcft) | Area in Different Season (ha) | | | Total (ha) | Water Use Efficiency (mcft / ha) |
|---|---|---|---|---|---|---|
| | | Kharif | Rabi | Summer | | |
| 1986-87 | 0 | 0 | 0 | 0 | 0 | **----** |
| 1987-88 | 0 | 0 | 0 | 0 | 0 | **----** |
| 1988-89 | 4513 | 0 | 11129 | 2070 | 13199 | **0.3419** |
| 1989-90 | 3189 | 0 | 11600 | 0 | 11600 | **0.2749** |
| 1990-91 | 6700 | 0 | 12344 | 4483 | 16827 | **0.3982** |
| 1091-92 | 7905 | 2989 | 15605 | 5179 | 23773 | **0.3325** |
| 1992-93 | 9545 | 1559 | 17677 | 5942 | 25178 | **0.3791** |
| 1993-94 | 9614 | 4465 | 19377 | 5195 | 29037 | **0.3311** |
| 1994-95 | 10447 | 0 | 20259 | 7175 | 27434 | **0.3808** |
| 1995-96 | 2757 | 6041 | 9059 | 0 | 15100 | **0.1826** |
| 1996-97 | 650 | 6019 | 0 | 0 | 6019 | **0.1080** |
| 1997-98 | 5098 | 0 | 14986 | 4235 | 19221 | **0.2652** |
| 1998-99 | 2627 | 0 | 11797 | 0 | 11797 | **0.2227** |
| 1999-2000 | 0 | 0 | 0 | 0 | 0 | **----** |
| 2000-01 | 0 | 0 | 0 | 0 | 0 | **----** |
| 2001-02 | 5186 | 2523 | 13651 | 0 | 16174 | **0.3206** |
| 2002-03 | 0 | 0 | 0 | 0 | 0 | **----** |
| 2003-04 | 6805 | 0 | 18107 | 0 | 18107 | **0.3758** |
| 2004-05 | 1171 | 0 | 7405 | 0 | 7405 | **0.1581** |
| 2005-06 | 8893 | 0 | 22760 | 0 | 22760 | **0.3907** |
| 2006-07 | 11575 | 0 | 22430 | 4956 | 27386 | **0.4226** |
| 2007-08 | 11798 | 0 | 22205 | 4718 | 26923 | **0.4382** |
| 2008-09 | 4117 | 0 | 16285 | 0 | 16285 | **0.2528** |
| 2009-10 | 2726 | 0 | 14607 | 0 | 14607 | **0.1866** |

Source: Sabarmati reservoir project, Dharoi Dam, Salient features

**Table 4.5 Maximum and Minimum Efficiency Ranges and Before and After PIM Change in Water Use Efficiency**

| Duty | MCFT/ha | Year |
|---|---|---|
| Minimum | 0.108 | 1996-97 |
| Maximum | 0.565 | 1980-81 |
| PIM Impact | | |
| Average Before PIM | 0.340 | 1979-80 to 1994-95 |
| Average After PIM | 0.232 | 1994-95 to 2010 |

To understand impact of PIM on water use efficiency the yearly data has been categorized into three categories such as (01) Before PIM i.e. from year 1979-80 to 1994-95; and (02) After PIM i.e. from year 1994-95 to year 2009-10. Table 4.4 shows that per ha use of water has decreased from 0.340 MCFT to 0.232 MCFT after PIM, whereas average decrease from the year 1978-80 to year 2009-10 is about 0.284 MCFT.

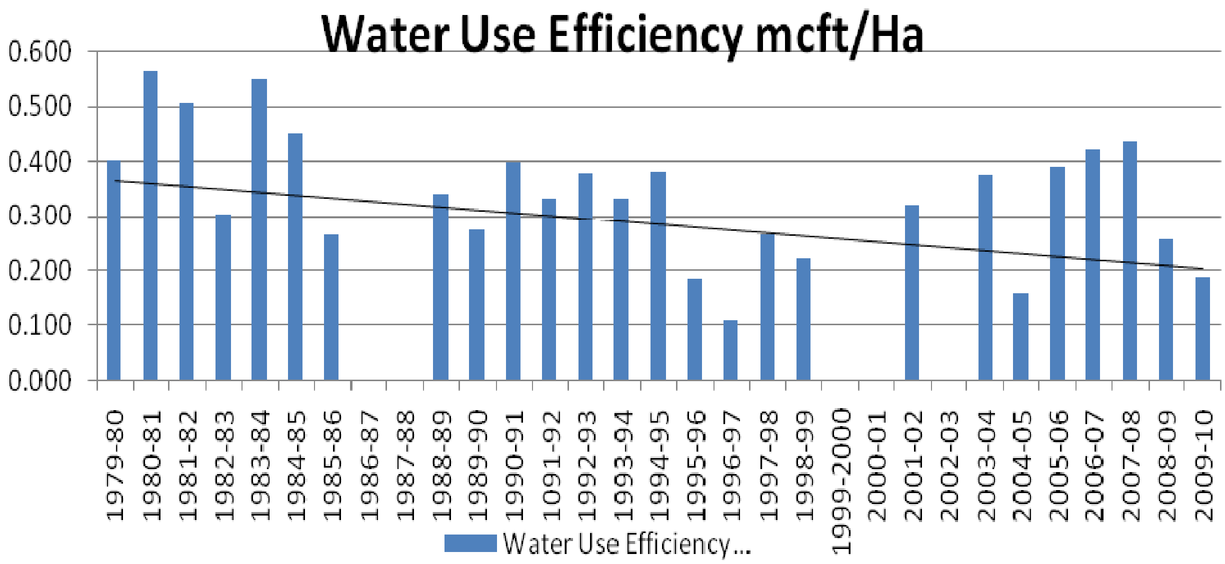



**Fig 4.8 Water Use Trend in RBMC area**

Source : GoG, Irrigation Department, 2010

Per hectare water use efficiency was also computed based on crop area estimated through three methods i.e. (01) Area recorded by irrigation department; (02) Area calculated based on field data and (03) irrigated area computed through remote sensing data. The estimation done for the year 2007-08 and the water allocated during this year was 10923 mcft. Average water use efficiency found during this year was 0.45 mcft/ha. (Table 4.6)

**Table 4.6 Computed Irrigated Area by Different Method/ Source**

| Information Source | Total Irrigated Area (ha) | Duty (mcft/ha) |
|---|---|---|
| Irrigation Department | 22205 | 0.491916 |
| Field Data | 26699 | 0.409116 |
| Remote Sensing Data | 24305 | 0.449414 |
| **Average mcft / ha** | | **0.450149** |

***Yield Base:*** The Water Use Efficiency based on Grain productivity (for 100 kg production) and income (for 1000 Rs) has been carried out based on case studies of 10 minors of command areas. Wheat, Mustard, Cumin, Fennel, Cotton, Caster, Lucerne, and maize crops were irrigated in total 506 ha areas by farmer during year 2007-08 (Table 4.7).

To assess water use efficiency only four main winter crops such as wheat, mustard, cumin and fennel irrigated in 376 were considered. Irrigated water has been estimated based on number of watering and 10 cm water column per watering (Table 4.8). The assumption of water column was mainly based on discussion with a particular farmer and/or members of *mandlis* according to their observation. Grain production of the particular crop was estimated based on average production of respective crop through survey of four farmers in particular Minor command beneficiaries. Water use efficiency based on grain productivity was computed for per 100 kg production. In addition to production base water use efficiency attempt was made to understand water use efficiency for 1000 Rs income from a particular crop. Table 4.6 shows that for 1000 Rs income, wheat crop requires water in range from 128 – 231 cum whereas cumin requires maximum water i.e. 471 cum.

**Table 4.7 Crop Production wise Water Use Efficiency**

| Crop | Water Use Efficiency cum/100kg | Water Use Efficiency cum/1000 Rs. income |
|---|---|---|
| Wheat | 167 – 300 | 128 – 231 |
| Cumin | 2000 | 471 |
| Mustard | 429 – 500 | 238-278 |
| Fennel | 1200 | 133-278 |

DSC has carried out study for water use efficiency from productivity and income point of view for wheat crop in detail through trial with about 10 farmers of the RBMC area in Rabi season of year 2006. Table 4.9 shows farmer wise details of wheat production, gross income, expenditure, net income, along with water use per ha and per unit production. The table clearly shows that water requirement per kg wheat production ranges between 381 - 2038 lit where as gross and net water productivities range between 50 – 258 lit and 20 - 173 lit respectively. Total per ha wheat production varies from 2500 – 5000 kg (Table 4.8).

**Table 4.8 Water Use Association wise Crop Production and Water Use Efficiency Estimation**

| Canal | Total Irrigation Area (ha) | Crop | Cropped Area (ha) | Water Given for Irrigation | | | Unit Production (kg/ha) | Total Production (kg) | Water Use Efficiency (cum/100 kg) Production | Unit Rate Rs./ Kg | Total Income (Rs.) | Water Use Efficiency (cum/ 1000 Rs.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Watering (No) | Water column (m) | Volume (cum) | | | | | | |
| DSM3 | 176 | Mustard | 158 | 6 | 0.1 | 948000 | 1200 | 189600 | 500 | 18 | 3412800 | 278 |
| | | Wheat | 3 | 6 | 0.1 | 20460 | 3600 | 12276 | 167 | 13 | 159588 | 128 |
| | | Fennel | 0.36 | 6 | 0.1 | 2160 | 500 | 180 | 1200 | 90 | 16200 | 133 |
| DSM4 | 25 | Mustard | 7 | 6 | 0.1 | 43320 | 1200 | 8664 | 500 | 18 | 155952 | 278 |
| | | Wheat | 9 | 6 | 0.1 | 52140 | 3600 | 31284 | 167 | 13 | 406692 | 128 |
| DSM5 | 35 | Fennel | 7.00 | 6 | 0.1 | 42000 | 500 | 3500 | 1200 | 90 | 315000 | 133 |
| | | Cumin | 28 | 6 | 0.1 | 168000 | 300 | 8400 | 2000 | 43 | 357000 | 471 |
| DSM6 | 11 | Mustard | 5 | 6 | 0.1 | 32760 | 1200 | 6552 | 500 | 18 | 117936 | 278 |
| | | Wheat | 2 | 6 | 0.1 | 14820 | 3600 | 8892 | 167 | 13 | 115596 | 128 |
| | | Fennel | 0.64 | 6 | 0.1 | 3840 | 500 | 320 | 1200 | 90 | 28800 | 133 |
| M 1 R | 24 | Mustard | 10 | 6 | 0.1 | 57660 | 1200 | 11532 | 500 | 18 | 207576 | 278 |
| | | Wheat | 10 | 6 | 0.1 | 60960 | 3600 | 36576 | 167 | 13 | 475488 | 128 |
| | | Fennel | 1.52 | 6 | 0.1 | 9120 | 500 | 760 | 1200 | 90 | 68400 | 133 |
| M 2 R | 17.2 | Mustard | 4 | 6 | 0.1 | 24660 | 1200 | 4932 | 500 | 18 | 88776 | 278 |
| | | Wheat | 5 | 6 | 0.1 | 27180 | 3600 | 16308 | 167 | 13 | 212004 | 128 |
| | | Fennel | 3.02 | 6 | 0.1 | 18120 | 500 | 1510 | 1200 | 90 | 135900 | 133 |
| D.O | 150 | Mustard | 29 | 6 | 0.1 | 174780 | 1200 | 34956 | 500 | 18 | 629208 | 278 |
| | | Wheat | 47 | 6 | 0.1 | 279000 | 3600 | 167400 | 167 | 13 | 2176200 | 128 |
| M 3 R | 39 | Mustard | 15 | 6 | 0.1 | 90000 | 1400 | 21000 | 429 | 18 | 378000 | 238 |
| | | Wheat | 10 | 6 | 0.1 | 60000 | 3000 | 30000 | 200 | 13 | 390000 | 154 |
| D 2 R | 8.5 | Mustard | 4 | 6 | 0.1 | 24000 | 1400 | 5600 | 429 | 18 | 100800 | 238 |
| | | Fennel | 2.00 | 6 | 0.1 | 12000 | 240 | 480 | 2500 | 90 | 43200 | 278 |
| M 8 L main | 20 | Wheat | 15 | 6 | 0.1 | 90000 | 2000 | 30000 | 300 | 13 | 390000 | 231 |
| Total | 505.7 | | 375.54 | | | | | | | | | |

**Table 4.9 Water Use Efficiency for Wheat Crop in RBMCA (Year 2006)**

| Farmer / Village | Wheat production in KG/ha | Gross income Rs./ ha | Total expenses in Rs./ ha | Net income Rs./ ha | Water used in lakh liters/ ha | Water used Liters per kg of Wheat | Gross Water Productivity (Rs.) | Net Water Productivity (Rs.) |
|---|---|---|---|---|---|---|---|---|
| Natwar (Dedasan) | 3333 | 34167 | 20663 | 13504 | 67.94 | 2038 | 50 | 20 |
| Dayabhai (Hasanpur) | 3583 | 35167 | 14838 | 20329 | 46.64 | 1302 | 75 | 44 |
| Bhathuji (Karbatiya) | 4167 | 35694 | 13469 | 22225 | 24.65 | 592 | 145 | 90 |
| Bharat (Kahipur) | 4467 | 44867 | 14837 | 30030 | 42.30 | 947 | 106 | 71 |
| Ishwar (Khatoda) | 3500 | 34625 | 13225 | 21400 | 26.68 | 762 | 130 | 80 |
| Arvind (Rangpur) | 5474 | 53474 | 16095 | 37379 | 27.76 | 507 | 193 | 135 |
| Rajendra (Kansa) | 4731 | 45204 | 16449 | 28754 | 20.17 | 426 | 224 | 143 |
| Mahesh (Kiyadar) | 4583 | 44167 | 13883 | 30283 | 23.08 | 503 | 191 | 131 |
| Varvaji (Sunhiya) | 5000 | 49166.7 | 16170.83 | 32995.8 | 19.06 | 381 | 258 | 173 |
| Vishnu (Sundhiya) | 2500 | 25833 | 13150 | 12683.3 | 19.79 | 791 | 131 | 64 |

Source: DSC, 2006

## 4.3 EXTENSIVE vs. INTENSIVE AREA

Canal water in RBMC area of Dharoi dam is used as extensive source of water, as there is an availability of other water resource and extension of designed command area. According to study carried out by DSC in November 2003, for tail enders and other deprived in the Canal Irrigation System, for those concerned with equity are in favor of extensive irrigation that would provide adequate water to raise less water intensive crops like millets while banning water intensive crop like paddy, sugarcane and banana. When the command area of Parambikulam Aliyar Project (PAP) in Tamilnadu was extended, the original irrigators protested. A committee, set up to review the performance of PAP, came to the conclusion that extensive irrigation is more desirable because the benefits can be distributed to a large community. The aggrieved farmers – the original irrigators- took the matter to court- right up to the Supreme Court. The Supreme Court decided the state had the right to decide issue and can order extensive or intensive irrigation. In fact, in the design of most of the projects the cropping pattern described is for extensive irrigation over a large area. The problem is that the cropping is ignored in practice, and the irrigation department fails to control the head reach farmers who raised water intensive crops depriving the farmers downstream of their share of water.

The use of groundwater, number of waterings, gradual extension of command and changes in crop type are main factors to characterize use of canal water as extensive or intensive. Because of these factors canal water usage in designed as well as extended command area is now used as extensive source of water. Therefore, to consider any particular part of RBMC area as intensive irrigation command area or extensive irrigation by canal irrigation is very difficult. In spite of these limitations an attempt has been made to define extensive or intensive use of canal water based on source wise irrigation percentages by canal and groundwater in a particular block as well as village. RBMC area has also very good groundwater potential within shallow and deep aquifer systems of loose alluviums. In both kinds of areas people use canal water as extensively as well as intensively depending on number of waterings allocated by department during a particular irrigation season. However, in some areas immediately adjoining the dam i.e. villages around Dharoi, Madhasana, and people use canal water mainly for recharge purpose. In case of deep groundwater areas people use groundwater and canal water supplementary to each other based on crop type and number of watering.

**Table no. 4.10 Block wise Bore wells and Well Base Irrigation during Year 2007-08**

| **Block** | **Village No.** | **Bore well** | | | **Wells** | | | **Irrigation ha** | | | **Irrigation By Diff. Sources (%)** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Total No.** | **Use No.** | **Irri. ha** | **Total No.** | **Use No.** | **Irri. ha** | Total Area | GW Irr. | **Canal Water** | **Ground Water** | **Canal Water** |
| 1 | 6 | 165 | 165 | 554 | 298 | 298 | 1188 | 3537 | **1742** | 1795 | 49.25 | 50.75 |
| 2 | 13 | 498 | 498 | 3678 | 185 | 71 | 383 | 7940 | **4061** | 3879 | 51.15 | 48.85 |
| 3 | 10 | 359 | 331 | 3622 | 200 | 70 | 116 | 7753 | **3737** | 4016 | 48.20 | 51.80 |
| 4 | 12 | 273 | 222 | 3407 | 529 | 322 | 242 | 8785 | **3648** | 5137 | 41.53 | 58.47 |
| 5 | 27 | 461 | 402 | 3922 | 1814 | 1052 | 1343 | 11571 | **5265** | 6306 | 45.50 | 54.50 |
| 6 | 23 | 683 | 672 | 4708 | 1834 | 429 | 1030 | 15252 | **5738** | 9514 | 37.62 | 62.38 |
| 7 | 11 | 567 | 429 | 4440 | 1380 | 893 | 2568 | 8397 | **7008** | 1389 | 83.46 | 16.54 |
| Total | **102** | **3006** | **2719** | **24329** | **6240** | **3135** | **6870** | **63235** | **31199** | **32036** | 49.34 | 50.66 |

Therefore, number of watering, crop type and groundwater availability are three factors deciding extensive or intensive use of canal water. Table 4.10 shows block wise groundwater based irrigation done by farmers in RBMC area during year 2007-08. The table clearly shows that about 31199 ha of irrigation during 2007-08 have been carried out with the help of groundwater in the area. Maximum groundwater based irrigation practices (7008 ha) exists in block no. 7 where as minimum is in block no. 1 (1742 ha.) (Table 4.10) Total groundwater based irrigation is in about 24,329 ha (77.98 %) whereas that of open well based is in about 6870 ha. (22.02 %) Source wise comparison shows that in case of block no. 1 open well based irrigation (68.22 % ha) is higher than the bore well base irrigation (31.78 %). The ratio of well irrigation is very low in case of block no. 2 (9.43 %), 3 (3.10%) and 4 (6.63 %). Table 4.8 clearly shows that the whole command area is using both the source of water almost equally. However, bock no. 6 and 7 can be categorized as intensive groundwater irrigated area and intensive canal water irrigation area respectively whereas rest of the blocks are almost using both the resources equally.

Another attempt has been made to understand extensive vs intensive use of canal water by studying 11 selected cooperatives' irrigation pattern with respect to crop type and number of irrigations given during year 2007 (Table 4.11) .

**Table 4.11 Crop wise Numbers of Irrigation by Different Source**

| WUA | Total Irrigation Area (ha) | Crop | Cropped Area (ha) | Watering (No) | | |
|---|---|---|---|---|---|---|
| | | | | Total | Canal | Bore well |
| DSM3 | 174.52 | Mustard | 158 | 5 | 3 | 2 |
| | | Wheat | 3.41 | 6 | 3 | 3 |
| | | Caster | 12.69 | 8 | 3 | 5 |
| | | Fennel | 0.36 | 6 | 3 | 3 |
| | | Suva | 0.06 | 5 | 3 | 2 |
| DSM4 | 23.95 | Mustard | 7.22 | 5 | 3 | 2 |
| | | Wheat | 8.69 | 6 | 3 | 3 |
| | | Caster | 6.18 | 8 | 3 | 5 |
| | | Fennel | 0.086 | 6 | 3 | 3 |
| | | Cotton | 0.92 | 9 | 3 | 6 |
| | | Maize | 0.85 | 3 | 3 | 0 |
| DSM5 | 35 | Fennel | 7 | 6 | 3 | 3 |
| | | Cumin | 28 | 6 | 3 | 3 |
| DSM6 | 10.62 | Mustard | 5.46 | 5 | 3 | 2 |
| | | Wheat | 2.47 | 6 | 3 | 3 |
| | | Caster | 1.87 | 8 | 3 | 5 |
| | | Fennel | 0.64 | 6 | 3 | 3 |
| | | Cotton | 0.18 | 9 | 3 | 6 |
| M 1 R | 23.89 | Mustard | 9.61 | 5 | 3 | 2 |
| | | Wheat | 10.16 | 6 | 3 | 3 |
| | | Caster | 0.96 | 8 | 3 | 5 |
| | | Fennel | 1.52 | 6 | 3 | 3 |
| | | Cotton | 1.64 | 9 | 3 | 6 |

**Table 4.11 Crop wise Numbers of Irrigation by Different Source contd…**

| WUA | Total Irrigation Area (ha ) | Crop | Cropped Area (ha) | Watering (No) | | |
|---|---|---|---|---|---|---|
| | | | | Total | Canal | Bore well |
| M 2 R | 15.54 | Mustard | 4.11 | 5 | 3 | 2 |
| | | Wheat | 4.53 | 6 | 3 | 3 |
| | | Caster | 1.02 | 8 | 3 | 5 |
| | | Fennel | 3.02 | 6 | 3 | 3 |
| | | Suva | 0.88 | 5 | 3 | 2 |
| | | Cotton | 1.98 | 9 | 3 | 6 |
| D.O. | 146.87 | Mustard | 29.13 | 5 | 3 | 2 |
| | | Wheat | 46.5 | 6 | 3 | 3 |
| | | Caster | 11 | 8 | 3 | 5 |
| | | Fennel | 0.24 | 6 | 3 | 3 |
| | | Cotton | 60 | 9 | 3 | 6 |
| M 3 R | 35 | Mustard | 15 | 4 | 3 | 1 |
| | | Wheat | 10 | 6 | 3 | 3 |
| | | Caster | 5 | 6 | 3 | 3 |
| | | Fennel | 2.5 | 6 | 3 | 3 |
| | | Lucerne | 2.5 | 24 | 3 | 21 |
| D 2 R | 8.5 | Caster | 2.5 | 6 | 2 | 4 |
| | | Mustard | 4 | 3 | 2 | 1 |
| | | Fennel | 2 | 6 | 2 | 4 |
| M 8 L main | 20 | Tobacco | 5 | 8 | 2 | 6 |
| | | Wheat | 15 | 8 | 2 | 6 |
| MR 8 | 75 | Cotton | 10 | 5 | 2 | 3 |
| | | Caster | 30 | 5 | 2 | 3 |
| | | Fennel | 5 | 7 | 2 | 5 |
| | | Tobacco | 30 | 10 | 2 | 8 |
| **Total** | **568.89** | | **568.89** | **300** | **135** | **165** |

The Table 4.11 shows, out of total 300 waterings in 568.89 ha areas only 135 watering have been made available from canal water whereas 168 waterings have been facilitated by groundwater. The fact itself indicates that the command area is now using canal water as extensive source of water.

In most of the cases 5 to 6 waterings were given to different crops whereas maximum number of watering were given to Tobacco, Lucerne and Cotton crops. Table 4.9 shows that during 2007 only 2 to 3 times water has been released through canal, but total watering given by farmers ranges from 5 to 6 in case of wheat, mustard and fennel crops whereas 8 to 10 times to crops like cotton, caster etc. These case studies clearly show difficulties in clear divisions of areas from intensive or extensive use of canal water point of view.

## 4.4 EXTENDED COMMAND AREA

### 4.4.1 Expansion Areas

RBMC area has continuously expanded after the irrigation started. The bases of expansion were gradual development and up-gradation of canal network system. To understand extension in command area, consultation with irrigation department was held during the study and expansion plan from year 2005-06 was discussed. Table 4.12 shows block wise expansion made by irrigation department in different distributaries. Total about 23410 ha area has been added since year 2005 mainly in block no 2, 3, 4, 5, 6 and 7. Besides expansion in different blocks maximum extension of about 12,738 ha area has been added through expansion of right bank main canal along with expansion in branch no. 4 and 5. Irrigation department had planned to expand command area in about 56,695 ha and yet they have achieved expansion to about 41.3 % only. According to irrigation department they have stopped water supply to the cities of Gandhinagar and Ahmedabad since 1997 and the surplus water has been diverted for the expansion and therefore, there will not be any shortage that can arise in existing command area due to this extension. According to them these two cities were supplied 316 cusec water per day (i.e. 115340 cusec/year). Fig. 4.9 shows areas where command has been extended. Extension has mainly taken place towards south and western parts of RBMC.

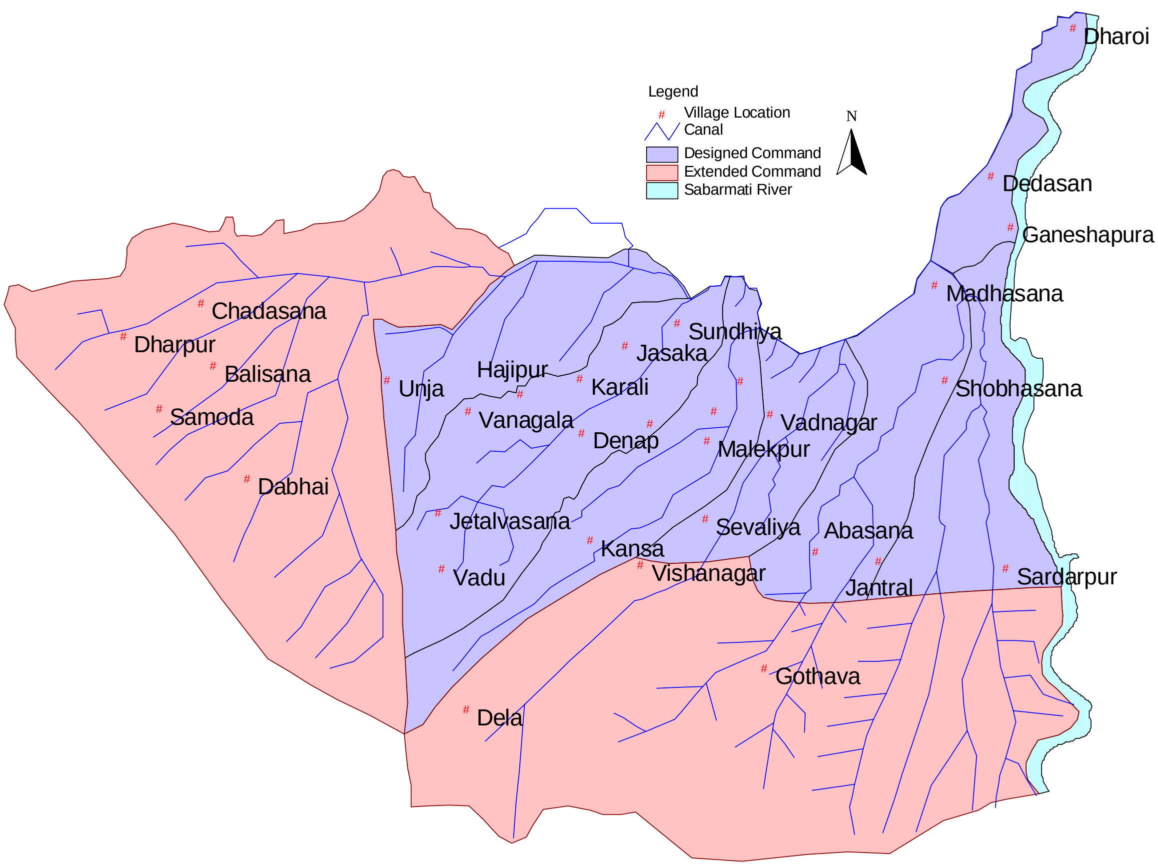



**Fig 4.9 Extended Command Area of RBMC**

Source: GoG, Irrigation Department, 2010

**Table 4.12 Block wise Extended Command Area from Year 2005-06 to 2009-10**

| Block | Branch/Minor | Planned Extensions (ha) | Extension (ha) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 2005-06 | 2006-07 | 2007-08 | 2008-09 | 2009-10 | Total |
| 4 | Right Bank Main | 690 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | Vadnagar Distributaries | 4300 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | Branch – 2 | 7663 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | Sipor Loop Canal | 2100 | 0 | 0 | 0 | 0 | 2100 | 2100 |
| 6 | Branch – 3 | 11652 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | Tail End Distributaries - D2R | 6403 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | Ext. Vadnagar Distributaries | 2336 | 2336 | 0 | 0 | 0 | 0 | 2336 |
| 7 A | Ext. Right Bank Main Canal | 14435 | 0 | 0 | 12738 | 0 | 0 | 12738 |
| | Branch 4 | | | | | | | |
| | Branch 5 | | | | | | | |
| 2 | Extended Kamalpur Distributaries | 805 | 400 | 405 | 0 | 0 | 0 | 805 |
| 2 | Extended Sardarpur Distributaries | 3026 | 1000 | 1000 | 1026 | 0 | 0 | 3026 |
| 3 | Extended Jantral Distributaries | 1080 | 700 | 0 | 0 | 0 | 0 | 700 |
| 3 | Extended Abasana Distributaries | 2205 | 1705 | 0 | 0 | 0 | 0 | 1705 |
| **Total** | | **56695** | **6141** | **1405** | **13764** | **0** | **2100** | **23410** |

Source: GoG, Irrigation Department, 2010

### 4.4.2 Expansion Sustainability Based on Catchment Modification

The sustainability of command area extension has also been understood from catchment characteristics point of view. The total catchment area of Dharoi Dam is about 5540 sq.km out of which about 2361 sq.km area is interrupted by construction of small and big reservoirs such as tank, dam etc. Therefore, only about 58 % of total catchment is directly generating runoff for Dharoi reservoir (Fig. 4.6).

The rainfall records of 4 stations of last 33 years have been analyzed for runoff estimation and inflow water computation in reservoir. Average annual rainfall of the catchment area is 703 mm distributed among 32 days during rainy seasons. Fig.4.10 shows decreasing trend in average annual rainfall from year 1977 as about 800 mm to 2009 as about 700 mm. However, there is no significant change seen in daily intensity of rainfall. Table 4.13 and Annexure 4.1 show total rainfall received in catchment area and volume of water received in reservoir in the form of inflow. Average received inflow of all years is about 16 % however maximum and minimum range of fluctuation varies from 50.5 mcm (in year 1977) to 2.66 mcm (in year 2004-05). The hydrograph has been prepared to understand change in volume of inflow water in reservoir with reference to changes in average annual rainfall (Fig 4.8). It indicates that there was a narrow gap between rainfall and inflow percentage into dam during 1977-78 that has widen over the period of time.

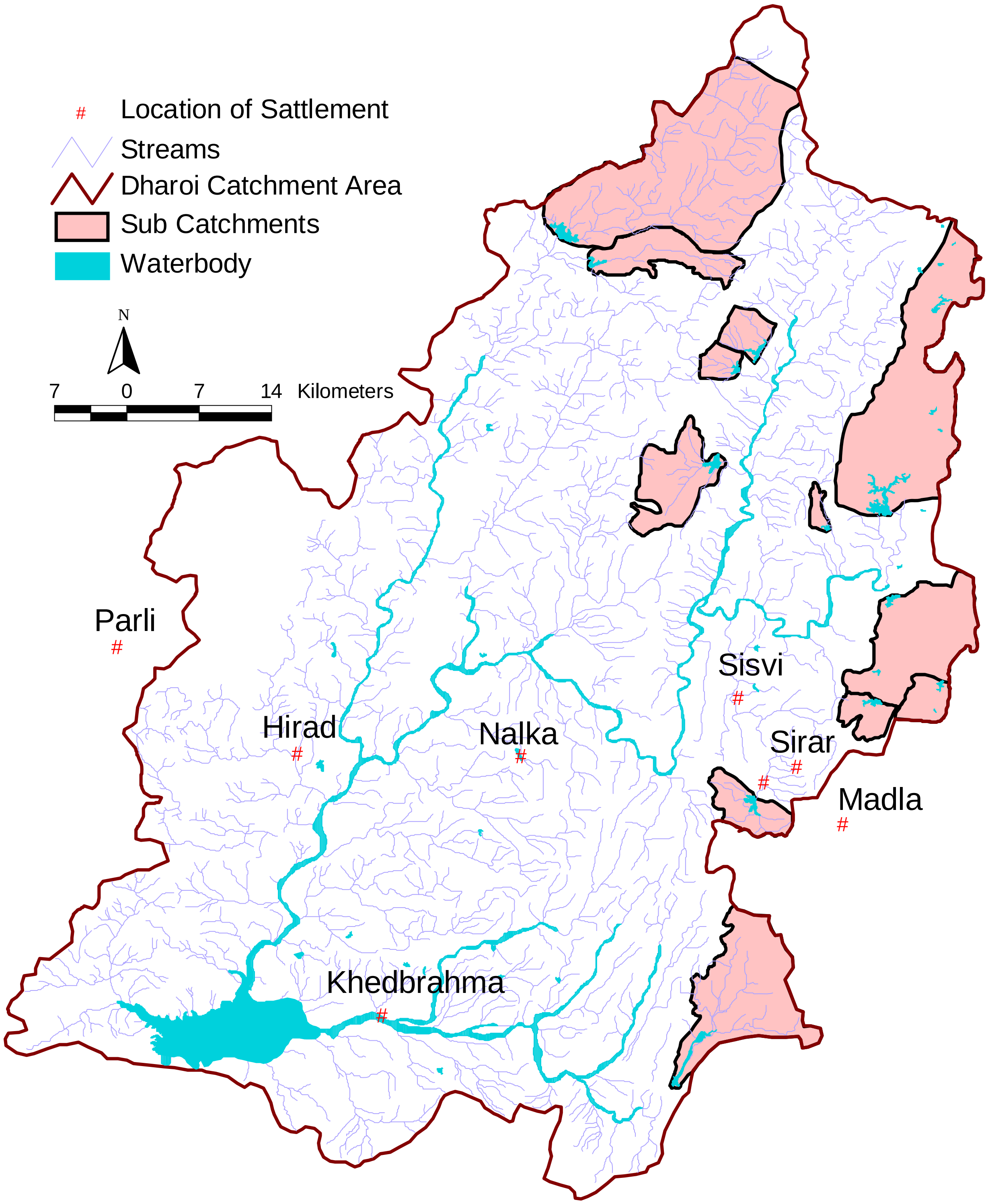



**Fig 4.10 Catchment Area of Dharoi Dam**

Source: GoG, Irrigation Department (2006), SOI, (1965)

**Table 4.13 Estimation of Yearly Inflow in Dharoi Dam Reservoir (Year 1977-2009)**

| Year | Total Irrigation (ha) | Total Inflow (MCFT) |
|---|---|---|
| 1979-80 | 258 | 12949 |
| 1980-81 | 1013 | 44408 |
| 1981-82 | 1286 | 15172 |
| 1982-83 | 6123 | 12717 |
| 1983-84 | 8243 | 45464 |
| 1984-85 | 15182 | 29411 |
| 1985-86 | 17684 | 12757 |
| 1986-87 | 0 | 4792 |
| 1987-88 | 0 | 2018 |
| 1988-89 | 13199 | 27324 |
| 1989-90 | 11600 | 12426 |
| 1990-91 | 16827 | 49779 |
| 1091-92 | 23773 | 22562 |
| 1992-93 | 25178 | 76652 |
| 1993-94 | 29037 | 40531 |
| 1994-95 | 27434 | 85797 |
| 1995-96 | 15100 | 10529 |
| 1996-97 | 6019 | 12804 |
| 1997-98 | 19221 | 22979 |
| 1998-99 | 11797 | 9319 |
| 1999-2000 | 0 | 2203 |
| 2000-01 | 0 | 3491 |
| 2001-02 | 16174 | 12091 |
| 2002-03 | 0 | 3423 |
| 2003-04 | 18107 | 14503 |
| 2004-05 | 7405 | 3727 |
| 2005-06 | 22760 | 31712 |
| 2006-07 | 27386 | 28054 |
| 2007-08 | 26923 | 15476 |
| 2008-09 | 16285 | 14404 |

Based on received rainfall, catchment characteristics and recorded received inflow in reservoir, hydrogrphwas computed and their relationship with irrigated areas has been crosschecked with the help of hydrograph (Fig 4.12) from year 1977 to 2009. Fig 4.9 shows that gradual decrease in inflow change in irrigated areas is not so significant as it was in the years e.g. 1986-87 or during year 1999-2000. Fig 4.13 is a hydrograph showing relationship between rain water inflows and supplied irrigated areas. It clearly reveals that before 1995-96 there was a clear relationship between inflow in dam and irrigated areas whereas in period of year 1995 - 2004 it seems transitional period while from 2004 onwards variation in inflow has not much significant impact over irrigation area which clearly shows an impact of spread of PIM activities in RBMCA.

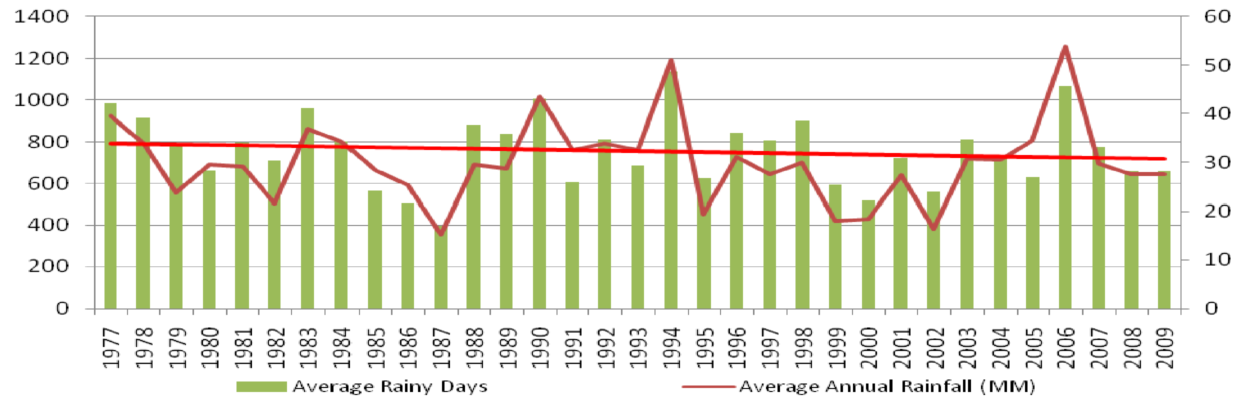



**Fig 4.11 Changing Trend in Average Annual Rainfall in Dharoi Catchment Area**

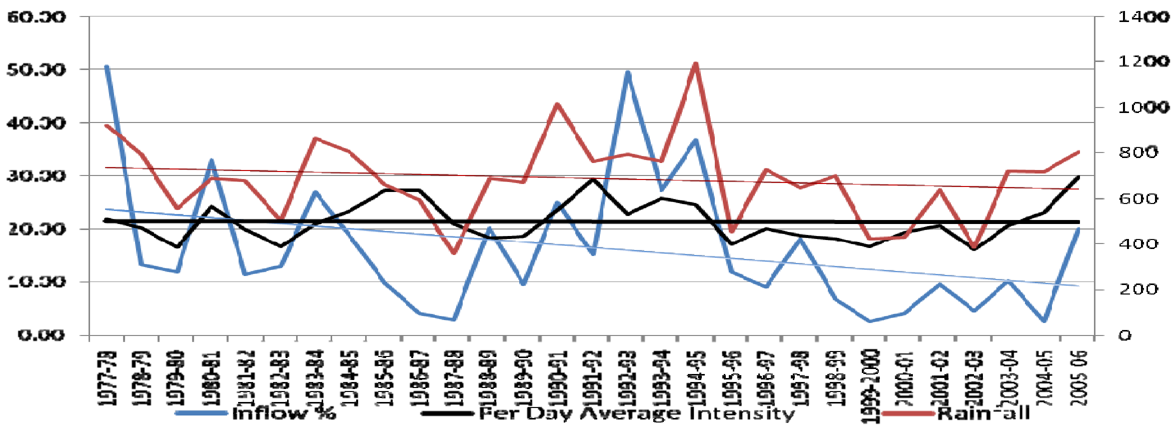



**Fig 4.12 Impact of Rainfall Changes on Inflow**

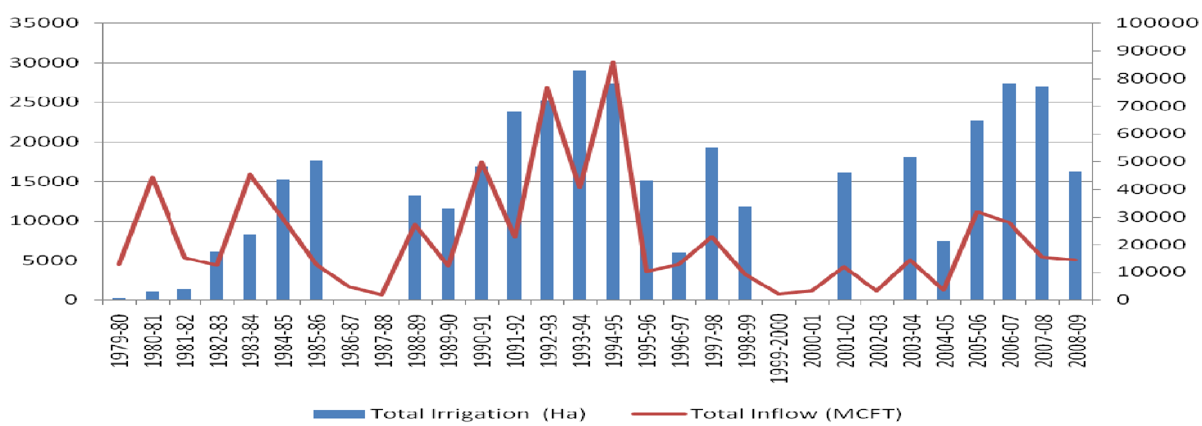



**Fig 4.13 Relationship Between Inflow in Reservoir and Irrigation in RBMC Area**

# 5. RECOMMENDATIONS

Findings of the study have clearly revealed that spread of PIM in RBMCA has resulted into better management practices at almost all the levels i.e. from sub minors to main canal. It has also lead to extension of command area as well as helped in increasing efficiency of the overall system. Besides canal water, groundwater has also played very important role in maintaining and increasing irrigated areas in RBMC. Land use analysis has clearly revealed that both the water resources have almost equal contribution in irrigation. Along with all these positive impacts several threats are also taking place as far as the sustainability is concerned. These threats are at both the levels i.e. catchment and command level.

So far the catchment level threat is concerned run off estimation data has revealed that due to decrease in rainfall and changes in land use pattern inflow of runoff water to the dam reservoir is gradually reducing (Table 4.13, Fig 4.12). Whereas in case of command area extensive use of groundwater has depleted water level as well as degraded water quality. Application of bad quality groundwater has impacted on soil quality. Another command area threat is linked with equitable distribution management in extended command area. With these considerations, geo-hydrological characteristics and popularity of PIM activities in RBMC area four main sets of recommendations have been made for future sustainability and better irrigation management in RBMC area.

1. Recharging local surface and ground water bodies
2. Better Irrigation management practices at main/ distributary canals and below minor canal level
3. On farm irrigation management

## 5.1 Recharging of Local Surface and Ground Water Bodies

These activities can further be categorized into three major strategies such as (01) Pond base irrigation management system; (02) Watershed development and management activities and (03) Use of existing groundwater potential

### 5.1.1 Pond Based Irrigation Management System

There are about 233 small, medium and major water structures already existing in RBMC area. Recharging of at least these medium and major structures by canal water is proposed to make use of such structures for decentralized pond based irrigation management. Block wise distribution of these structures (Table 5.1) shows that about **58 structures are of medium and major size that can be considered for this.** A schematic sketch is shown in Fig 5.1 for how to link these structures and to set up irrigation management system around it.

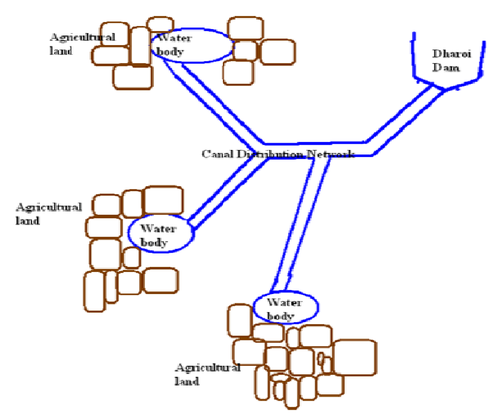



**Fig 5.1 Schematic Sketch Showing Recharge of Local Water Bodies by Canal water**

Major physical activity required for this is to construct feeder canal from nearest outlet or canal network. To establish proper irrigation management with this strategy, initially one should go for two to three pilot projects in each block in first phase then planning of up-scaling in next phase based on experience.

**Table 5.1 Block Size wise Distribution of Water Bodies in RBMC Area**

| Structure Type | Block Wise Distribution (No.) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Block 1** | **Block 2** | **Block 3** | **Block 4** | **Block 5** | **Block 6** | **Block 7** | **Total** |
| Small | 6 | 18 | 29 | 26 | 40 | 40 | 16 | **175** |
| Medium | 5 | 2 | 4 | 10 | 23 | 4 | 7 | **55** |
| Major | 0 | 0 | 0 | 0 | 0 | 0 | 3 | **3** |
| **Total** | **11** | **20** | **33** | **36** | **63** | **44** | **26** | **233** |

### 5.1.2 Watershed Development and Management Activities

There are two major rivers viz., (01) Rupen and (02) Pushpavati that are passing through block no 5, 6 and 7 in western part of RBMC area (Fig 5.2). Watershed Development activities in these two watersheds can help to increase recharge the shallow aquifers of the area.

Village wise well/bore well distribution clearly shows large number of well density exists in this areas (Fig 3.5). Geologically, the area is characterized as loose alluvial area that has high permeability and porosity. Due to unconsolidated nature of formations the area has good recharge potential. Further, the general slope of the area varies between 2 to 5 degrees which permits good sites to recharge structures.

**Table 5.2 Benefited Blocks by Watershed Development Activities in RBMC Area**

| Watershed | Block | Existing Irrigation Potential of Block (ha) | | |
|---|---|---|---|---|
| | | **By Canal** | **By G.W** | **Total** |
| Rupen Watershed | 5 | 5595 | 5265 | 10860 |
| | 6 | 10326 | 5738 | 16064 |
| Pushpavati Watershed | 6 | | | |
| | 7 | 3706 | 7008 | 10714 |
| **Total** | | **19627** | **18011** | **37638** |

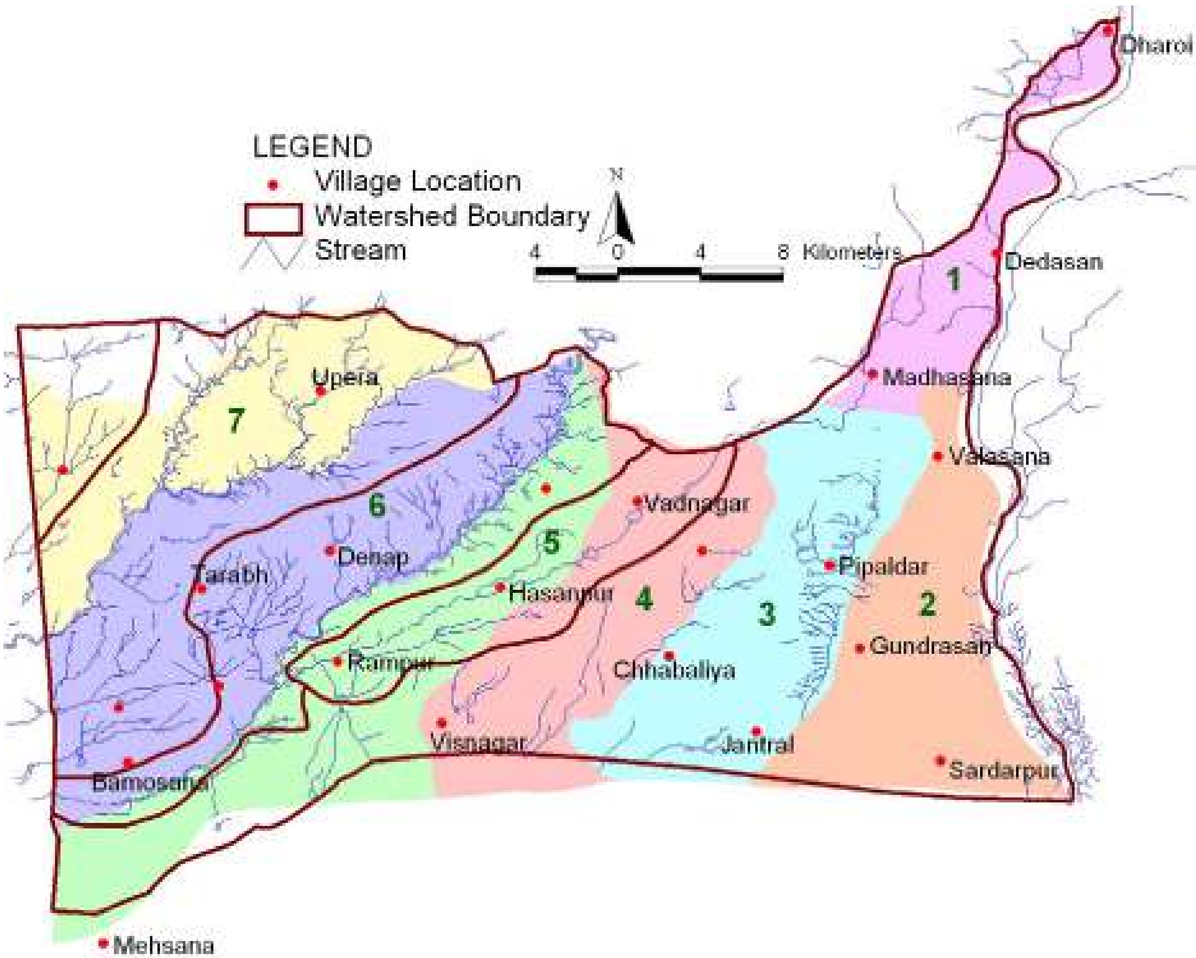



**Fig 5.2 Location of Watershed in RBMC Area**

Source: GoG, Irrigation Department, 2010 SOI, 1965

Watershed development activities in this area can have qualitative and quantitative impacts on groundwater resources of the area. It is already discussed earlier that in block no. 4, 5 and 6 of RBMC area have more than 5000 open wells which can be directly benefited by this activities through improvement of water quality. Activities like construction of new recharge structure, de-silting of existing small sized water harvesting structures, recharge of groundwater through dug wells etc. can be planned to encourage recharge within watershed areas. However, for micro planning of watershed, PRA needs to be held in command area of respective watershed areas. Proposed activities will ultimately decrease over burden on canal water and will increase the water use efficiency in block no. 5, 6 and 7 which will increase the productivity of the area.

### 5.1.3 Considerations of Groundwater Potential for Block wise Distribution

It is already discussed that the RBMC areas have very good potential of surface as well as groundwater resources. Consultations with farmers have shown that some of the areas of RBMCA have regenerated groundwater potential after canal water introduction in the area. It is proven that parallel use of groundwater in RBMC area has played very important role in maintenance of overall sustainability of irrigation. Because of this, categorization of RBMCA as intensive or extensive canal water using area is very difficult and therefore, consideration of groundwater potential in irrigation management is equally important. Keeping this in mind groundwater of RBMCA is categorized based on depth of water level and quality, into four classes as shown in Fig 5.3.

**Table 5.3 Preferred Irrigation Management Strategies Based on Groundwater Class**

| Groundwater Class | Water Level Range (m) | TDS (mg/l) | Strategy |
|---|---|---|---|
| Shallow Good Groundwater Areas | 10 – 20 | <1500 | Re-estimate allocation of water volume according to requirement for groundwater recharge and allocate surplus water to bad quality deep groundwater areas. |
| Deep Good Groundwater Areas | >20 | < 1500 | Promote micro irrigation practices and efforts for change in crop pattern for less water intensive crops. Needs micro level mapping for intensive and/or extensive groundwater and canal water use. |
| Shallow Bad Groundwater Areas | 10 – 20 | >1500 | Use Canal water for recharge and improve groundwater quality |
| Deep Bad Groundwater Areas | >20 | >1500 | Use only canal water intensively |

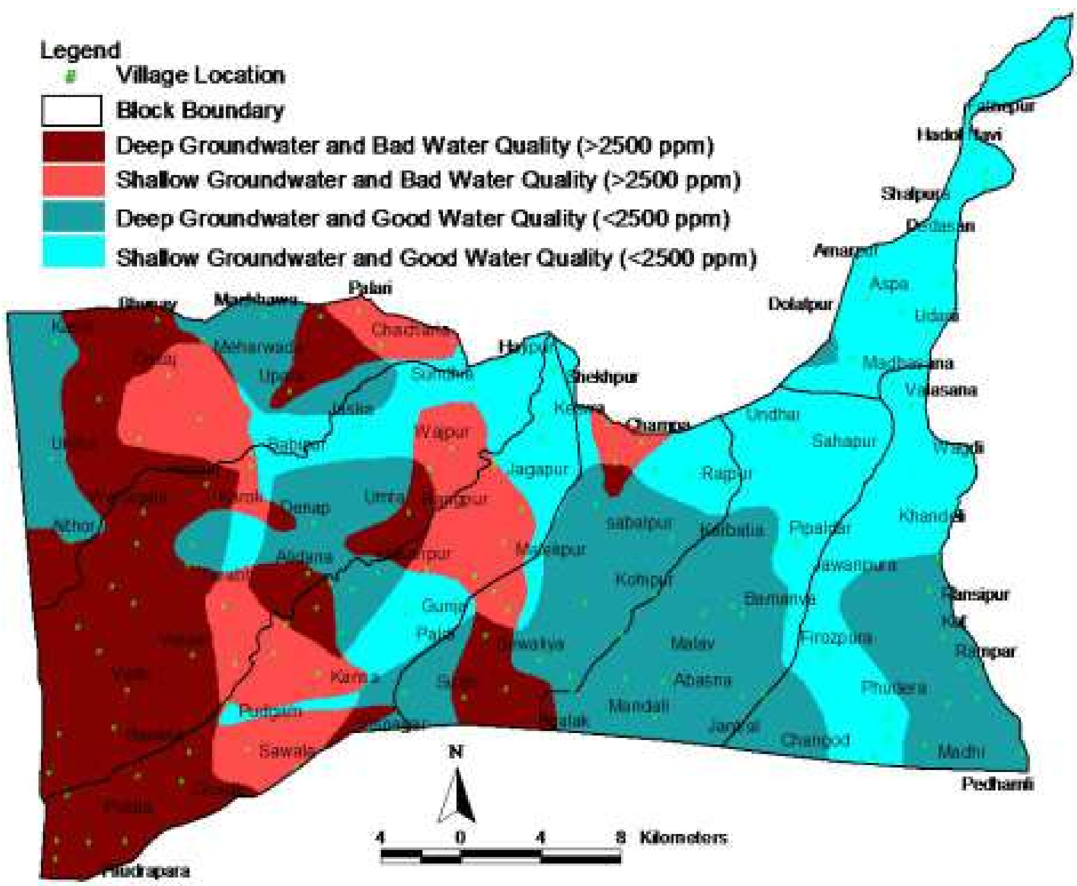



**Fig 5.2 Groundwater Potential Classes in RBMC Area**

Source: GoG, Irrigation Department, 2010 SOI, 1965, ACT Field Data (2008, 09)

## 5.2 BETTER IRRIGATION MANAGEMENT PRACTICES

For better irrigation management practices two levels of recommendations have been made viz., (01) at Main / Distributaries level and (02) Minor / Sub Minor level.

### 5.2.1 Main / Distributaries Level

There needs to be improvement in management at Main and Distributary canal levels through the following,

System infrastructure needs improvement by improving canal lining and measuring structures throughout the length of the main canals and distributaries to control seepage and leakage from the structures. Communication facilities also need to be improved in order to control illegal water lifting from main and branch canals. Watering schedule method needs to be revisited and the schedule planning process should be done in consultations with WUAs and their federations. Wara bandhi / alternate running of canal method should be encouraged within group of farmers or WUAs. This can be planned effectively in consultations with farmers/ users. Further, for conjunctive use of water, possible water saving area should be mapped by holding participatory appraisal.

Decision making and review of irrigation processes also need to be decentralized so that users can be made more responsible. Therefore, roles and responsibilities of different stake holders such as irrigation department, WUAs, federations and NGOs need to be reviewed and redefined.

There should be encouragement system in form of incentives for beneficiaries who judiciously use water. This can be done by introducing schemes like incentive package along with water meter usage, adaptation of low water intensive crop, adaptation of micro irrigation techniques. Similarly disincentives should also be imposed in case of misuse or over use of water, high water intensive crops, water stealing. Department needs to collaborate with federations to execute such scheme.

Most important recommendation for system improvement is computerized record keeping and data management at all levels. This needs a proper capacity building of various stake holders.

### 5.2.2 Minor / Sub Minor Level

As decentralized decision making is important requirement at main and distriubtary level, setting up of performance monitoring of WUAs at minor/sub minor level is one of the important requirements. All minors should be facilitated with volumetric system so that use of water can be controlled. Also farmers should be encouraged / incentivized for adoption of volumetric based water allocation. There is a need to develop mechanism and management of resource for asset management like canals, volumetric infrastructure etc. Improvement is required in communication facilities up to the minor level also to enable continuous easy management by the department or the WUA.

Capacity building of the WUA and the farmers for creation of awareness for their right to get water as per design discharge or from the WUA should develop equitable norms. Department along with NGO should organize a mass awareness program on economics in crop selection and emphasis on return per drop of water. Design a capacity building program for development of at least one Para worker per village with specific capacity skills of irrigation management techniques.

There is a need to make provision of additional facilities like office building/ command area hut/ command area service center and night irrigation facilities with control monitoring system.

## 5.3 ON FARM IRRIGATION MANAGEMENT

For better irrigation management at farm level there is a need to give more emphasis on farmer's education and updating him with latest information on management of irrigation water demand through agriculture extension system. Department should launch specific schemes for modern water saving techniques in specifically targeted areas such as good quality deep groundwater areas, (Fig 5.3) etc. Mapping of such areas and blocks need to be prepared by department so that techniques like drip / sprinkler / PINS can be promoted with large mass.

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# Annexure 1.1

## List of Consulted WUAs

| Block No. | Village | WUA |
|---|---|---|
| 1 | Dharoi | M2L |
| | Khodamali | SM 5 L |
| | Dedasan | M 8 |
| 2 | Valasana | SM 9 R, DO7L |
| | Rampur | M 17 L, |
| | Gundrasan | M 5 R, D 04 R |
| 3 | Karbatiya | SM36L, DO 33, DO 34, DO 35 |
| | Jantral | 25 L, 26 T, 24 R, 23 R, |
| | Chhabaliya | M 8 R |
| 4 | Vadnagar | SM17 |
| | Vadnagar | SM 12 |
| | Gunja | ASM 12, SM 5 R, SM 6 R |
| 5 | Kesimpa | M 0 L, M 1 R, SM 1 R, M 2 R |
| | Kamalpur | M 1 R |
| | Kansa | DS M 3, DS M 4, DS M 5, DS M 6, M 1 R, M 2 R |
| | Gadha | M 5 T |
| 6 | Rangpur | M 5 L, M 3 L |
| | Denap | M 14 |
| | Jetalvasna | D3R |
| | Valam | D 5 T, D 4 L |
| | Upera | M 2 L, D 1 R |
| | Kambli | D1R, SM 5 L, SM 6 L |

# Annexure 2.1

## Salient Features of Dharoi Irrigation Dam Project

| **Location** | Vill : Dharoi, Ta : Kheralu, Dist : Mehsana |
|---|---|
| Purpose | Irrigation & water supply |
| River | Sabarmati |
| Area of catchment | 5475 $km^2$ |
| Mean annual runoff in the catchment | 1052 $mm^3$ |
| Mean annual rainfall | 633 mm |
| Year of commencement of construction work | 1971 |
| Year of completion | 1978 |
| **Dam** | |
| Type | Earthen & Masonry |
| Bed rock | Granite |
| Maximum height above the lowest point of foundation | 45.87 m |
| Length at the top of the dam | 1207 m |
| Total volume content : | |
| Concrete | 0.07 $Mm^3$ |
| Masonry | 0.24 $Mm^3$ |
| Earthwork | 1.58 $Mm^3$ |
| **Spillway** | |
| Type | Ogee |
| Length | 219 m |
| Energy Dissipater | Roller bucket |
| Maximum discharge | 21662 $m^3/s$ |
| Type, number & size of gate | Traintor,12,(14.95m x 10.67m) |
| **Reservoir** | |
| Area at full reservoir level | 107 $km^2$ |
| Gross storage capacity | 907.88 $Mm^3$ |
| Effective storage capacity | 131.99 $Mm^3$ |
| Area under submergence : | |
| (a) Forest | 349.39 ha |
| (b) Waste land | 2727.55 ha |
| (c) Culturable | 7489.87 ha |
| No. of villages under submergence | 19 partial, 28 full |

| **Canal** | |
|---|---|
| Length of canal | 44 km (Right), 29.52 km (Left) |
| Capacity | 20 $m^3/s$ (Right), 5 $m^3/s$ (Left) |
| Gross command area | 81754 ha (Right), 15670 ha (Left) |
| Culturable command area | 70454 ha (Right), 12145 ha (Left) |
| Villages under command | |
| District | Taluka / No. of villages |
| Mehsana | Kheralu / 59 |
| | Visnagar / 28 |
| | Sidhpur / 16 |
| | Mehsana / 7 |
| | Vijapur / 17 |
| Sabarkantha | Idar / 41 |
| | Himmatnagar / 9 |
| | **Total / 177** |
| **Area Irrigated during last five years** | |
| Year | Area Irrigated in Ha |
| 2004-05 | 11839 |
| 2005-06 | 29645 |
| 2006-07 | 33139 |
| 2007-08 | 31393 |
| 2008-09 | 18993 |
| **Power Plant** | |
| Type | Hydro power |
| Hydraulic head | 31.7 m |
| Maximum discharge | 31 $m^3/s$ |
| Capacity | 1.4 MW |
| **Cost** | |
| Estimated cost | Rs. 9600 lacs |
| Expenditure up to March, 1987 | Rs. 8354.94 lacs |

# Annexure 2.2

## Extension of Sabarmati (Dharoi) Right Bank Command Area

<table>
<tr><td>1. Name of project</td><td colspan="4">Extension of Sabarmati (Dharoi) right bank command area</td></tr>
<tr><td>2. Salient features</td><td colspan="4"></td></tr>
<tr><td>i. Location</td><td colspan="4">(A) South and East of Mehsana city<br>(B) North and West of Mehsana city</td></tr>
<tr><td rowspan="4">ii. Benefited Area</td><td>District</td><td>Taluka No.</td><td>Villages No.</td><td>Irrigated Area Ha.</td></tr>
<tr><td>Mehsana</td><td>4</td><td>100</td><td>15087</td></tr>
<tr><td>Patan</td><td>3</td><td>49</td><td>8800</td></tr>
<tr><td>Grand Total</td><td>7</td><td>149</td><td>23887</td></tr>
<tr><td rowspan="3">iii. Availability of water</td><td colspan="2">(1) Reservoir</td><td colspan="2">75.75 Mcm</td></tr>
<tr><td colspan="2">(2) By Shallow Tube well:</td><td colspan="2">36.00 Mcm</td></tr>
<tr><td colspan="2">From command area:</td><td colspan="2">111.76 Mcm</td></tr>
<tr><td rowspan="3">iv. Method of Irrigation</td><td colspan="4">(1) Lift</td></tr>
<tr><td colspan="4">(2) Drip, Drop</td></tr>
<tr><td colspan="4">(3) Sprinkler</td></tr>
<tr><td>v. Length of extended distributaries</td><td colspan="4">79.80 km</td></tr>
<tr><td>vi. Type of canal</td><td colspan="4">Unlined</td></tr>
<tr><td>vii. Benefit cost ratio</td><td colspan="4">1.50</td></tr>
<tr><td>3. Year of A.A</td><td colspan="4">8-1-1999</td></tr>
<tr><td>4. S.O.R. on which A.A. accorded</td><td colspan="4">1998-1999</td></tr>
<tr><td>5. Year of O.T.S. with order No.</td><td colspan="4">N.W.R. & W.S. Deptt.'s letter No. Dharoi/4096/1560/69/K/Dt.8.1.99</td></tr>
<tr><td>6. Amount of A.A.</td><td colspan="4">Rs. 5477.61 Lacs.</td></tr>
<tr><td rowspan="3">7. Expenditure incurred year – wise</td><td colspan="2">1997-98</td><td colspan="2">Rs. 3.70 Lacs.</td></tr>
<tr><td colspan="2">1998-99</td><td colspan="2">Rs. 7.50 Lacs.</td></tr>
<tr><td colspan="2">1999-2000<br>(up to 20-12-99)</td><td colspan="2">Rs. 2.20 Lacs.</td></tr>
<tr><td rowspan="3">8. Total expenditure upto 31.8.99</td><td colspan="4">Rs. 11.20 Lacs.</td></tr>
<tr><td colspan="4">Rs. 13.40 Lacs.</td></tr>
<tr><td colspan="4">Up to 30-11-99</td></tr>
<tr><td>9. Estimated expenditure for the year 1999-2000</td><td colspan="4">Rs. 150 Lacs.</td></tr>
<tr><td rowspan="4">10. Works completed</td><td colspan="4">(1) Survey & investigation of existing area of increasing capacity.</td></tr>
<tr><td colspan="4">(2) Collection of village maps and 7/12 details of extended command area.</td></tr>
<tr><td colspan="4">(3) Finalized discharge of different canals.</td></tr>
<tr><td colspan="4">(4) Tender of Rs. 124 Lacs are invited</td></tr>
</table>

| | | |
|---|---|---|
| 11. Works to be completed | As per Sr. No. 12 | |
| 12. Works in progress and to be completed | (1) Design and fixing of alignment for extension | |
| | (2) Preparation of plan estimates & D.T.P. for raising existing canals | |
| 13. Works not in progress and are to be completed | Project in progress | |
| 14. Physical and financing planning (year wise) | | |
| Years | Physical | Financial |
| 1999-2000 | Raising of canal 20 km. | 150 Lacs. |
| 2000-2001 | Raising of canal 50 km. | |
| | New canal to be extended15 km | 1390 Lacs. |
| 2001-2002 | ----Do---- with C.D. works | |
| | New canal 25 km. | 1600 Lacs. |
| | Raising of canal 5 km. | |
| 2002-2003 | Earth work and C..D. work | 1600 Lacs. |
| 2003-2004 | ----D0---- | 737.61 Lacs. |
| 15. Fund required (year-wise) | 1999-2000 | Rs. 150 Lacs. |
| | 2000-2001 | Rs. 1390 Lacs. |
| | 2001-2002 | Rs. 1600 Lacs. |
| | 2002-2003 | Rs. 1600 Lacs. |
| | 2003-2004 | Rs. 737.61 Lacs. |
| 16. Bar – chat | ---- | |
| 17. Benefits of the project | (1) Irrigation facilities to 23887 Ha. Land of Mehsana & Patan districts . | |
| | (2) Recharge of ground water in the proposed command area. | |
| | (3) Due to recharge of ground water rising of water table lift from existing wells and tube wells will be reduced. | |
| | (4) Saving in electricity. | |
| | (5) Lower temperature of environment in command. | |
| 18. Reasons for delay | N.A. | |
| 19. Head of account | 4701-C.O.on M.&M. irrigation<br>03-Medium Irri. (Comm.)<br>698-Extention of Dharoi Right<br>Bank Command. | |
| 20. Whether included under AIBP/Salinity NABARD Aid | Yes,<br>It is proposed for part finance<br>Under A.I.B.P. | |
| 21. Whether project can be proposed for AIBP/NABARD Aid | It is proposed to get 65 % finance under A.I.B.P. from Central Government. | |

# Annexure 3.1

## Block Wise Distribution of Command Area

| Block No. | GCA of Each Block in (Ha) | | | | GCA of Each Block in (Ha) | | | | GCA of Each Block in (Ha) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Flow Irri. | | Lift Irri. | Total | Flow Irri. | | Lift Irri. | Total | Flow Irri. | | Lift Irri. | Total |
| | PIPC | AIPC | PIPC | | PIPC | AIPC | PIPC | | PIPC | AIPC | PIPC | |
| 1 | ------ | 2343 | 466 | 2809 | ------ | 1578 | 294 | 1872 | ------ | 1438 | 294 | 1732 |
| 2 | 6014 | 3633 | 602 | 10249 | 5447 | 3503 | 347 | 9297 | 4560 | 2680 | 347 | 7687 |
| 3 | 5616 | 5551 | 3230 | 14396 | 3843 | 2794 | 1905 | 8542 | 3768 | 2805 | 1905 | 8078 |
| 4 | 9136 | ------ | ------ | 9136 | 6595 | ------ | ------ | 6595 | 4811 | ------ | ------ | 4811 |
| 5 | 12676 | ------ | ------ | 12676 | 8691 | ------ | ------ | 8691 | 7642 | ------ | ------ | 7942 |
| 6 | 20990 | ------ | ------ | 20990 | 15745 | ------ | ------ | 15745 | 11652 | ------ | ------ | 11652 |
| 7 | 11498 | ------ | ------ | 11498 | 8065 | ------ | ------ | 8065 | 6403 | ------ | ------ | 6503 |
| **Total** | **65929** | **11527** | **4298** | **81754** | **48386** | **7875** | **2546** | **58807** | **38836** | **6923** | **2546** | **48405** |

# Annexure 3.2

## Rainfall Recorded at Various Stations in Mahesana District

| STATION | NO. OF YEARS OF DATA | JAN | FEB | MAR | APR | MAY | JUN | JULY | AUG | SEP | OCT | NOV | DEC | ANNUAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mahesana | 47 a | 2.3 | 0.9 | 2.1 | 0.6 | 4.0 | 63.4 | 252.5 | 164.7 | 105.2 | 5.0 | 2.6 | 1.3 | 604.60 |
| | b | 0.3 | 0.1 | 0.2 | 0.0 | 0.2 | 3.1 | 11.7 | 9.6 | 4.7 | 0.5 | 0.2 | 0.1 | 30.70 |
| Dharoi | 28 a | 2.8 | 1.1 | 1.4 | 0.6 | 2.7 | 83.9 | 276.6 | 258.6 | 130.0 | 11.8 | 10.3 | 2.8 | 782.60 |
| | b | 0.3 | 0.1 | 0.1 | 0.1 | 0.3 | 3.7 | 11.2 | 11.9 | 5.2 | 0.7 | 0.6 | 0.2 | 34.40 |
| Kalol | 45 a | 1.0 | 1.5 | 0.4 | 1.5 | 2.9 | 74.3 | 287.4 | 201.7 | 158.7 | 9.7 | 3.0 | 0.9 | 743.00 |
| | b | 0.1 | 0.1 | 0.1 | 0.2 | 0.3 | 3.7 | 12.7 | 10.0 | 5.3 | 0.5 | 0.3 | 0.1 | 33.50 |
| Patan | 47 a | 2.0 | 1.4 | 4.0 | 0.3 | 4.0 | 62.0 | 262.1 | 167.1 | 102.7 | 8.9 | 5.4 | 2.5 | 622.40 |
| | b | 0.2 | 0.1 | 0.2 | 0.2 | 0.2 | 2.6 | 10.5 | 8.9 | 4.0 | 0.4 | 0.3 | 0.2 | 27.70 |
| Visnagar | 18 a | 1.0 | 0.6 | 1.5 | 0.3 | 2.2 | 66.7 | 236.7 | 191.1 | 146.5 | 18.6 | 2.1 | 0.8 | 668.10 |
| | b | 0.2 | 0.1 | 0.2 | 0.1 | 0.1 | 3.1 | 10.5 | 9.4 | 5.4 | 0.9 | 0.1 | 0.1 | 30.20 |
| Kadi | 17 a | 0.2 | 0.0 | 0.7 | 0.0 | 0.3 | 58.4 | 262.9 | 167.7 | 161.3 | 8.1 | 3.8 | 2.1 | 665.50 |
| | b | 0.1 | 0.0 | 0.1 | 0.0 | 0.1 | 3.8 | 11.1 | 9.2 | 5.3 | 0.8 | 0.2 | 0.1 | 30.80 |
| Kheralu | 18 a | 1.3 | 1.4 | 9.3 | 1.2 | 0.9 | 66.3 | 214.3 | 186.2 | 109.1 | 11.4 | 0.3 | 0.6 | 602.30 |
| | b | 0.1 | 0.1 | 0.4 | 0.1 | 0.1 | 2.7 | 10.7 | 10.1 | 5.1 | 1.1 | 0.1 | 0.1 | 30.70 |
| Sidhpur | 19 a | 0.4 | 0.0 | 5.3 | 0.0 | 0.9 | 61.3 | 208.9 | 147.5 | 75.4 | 10.7 | 0.1 | 1.1 | 511.60 |
| | b | 0.1 | 0.0 | 0.2 | 0.0 | 0.1 | 2.8 | 9.5 | 8.5 | 3.4 | 0.7 | 0.0 | 0.2 | 25.50 |
| Chansama | 19 a | 1.4 | 0.0 | 1.2 | 0.0 | 0.0 | 62.7 | 209.6 | 154.9 | 132.7 | 7.8 | 2.4 | 2.1 | 574.80 |
| | b | 0.1 | 0.0 | 0.2 | 0.0 | 0.0 | 3.1 | 9.4 | 8.2 | 5.1 | 0.5 | 0.2 | 0.1 | 26.90 |
| Sami | 16 a | 1.6 | 0.8 | 1.2 | 0.0 | 0.9 | 37.0 | 200.1 | 126.2 | 109.8 | 3.2 | 1.7 | 0.3 | 482.80 |
| | b | 0.10 | 0.10 | 0.10 | 0.0 | 0.10 | 1.70 | 8.70 | 5.70 | 3.30 | 0.40 | 0.30 | 0.0 | 20.50 |
| Hart/Harij | 17 a | 1.10 | 0.50 | 1.30 | 0.0 | 0.10 | 53.50 | 191.50 | 130.20 | 105.00 | 6.80 | 2.30 | 0.9 | 493.20 |
| | b | 0.1 | 0.1 | 0.2 | 0.0 | 0.1 | 2.7 | 8.7 | 6.6 | 4.5 | 0.7 | 0.2 | 0.1 | 24.0 |
| Vijapur | 19 a | 1.2 | 0.3 | 0.8 | 2.0 | 2.5 | 77.2 | 244.3 | 170.7 | 150.7 | 19.6 | 3.2 | 3.0 | 675.5 |
| | b | 0.1 | 0.1 | 0.2 | 0.1 | 0.2 | 3.8 | 11.2 | 9.5 | 5.3 | 0.7 | 0.2 | 0.2 | 31.6 |
| Mahesana(District) | a | 1.4 | 0.7 | 2.4 | 0.5 | 1.8 | 63.9 | 237.2 | 172.2 | 123.9 | 10.1 | 3.1 | 1.5 | 618.7 |
| | b | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 3.1 | 10.5 | 9 | 4.7 | 0.7 | 0.2 | 0.1 | 28.9 |

Source: GoG, 2008

# Annexure 3.3

## Well Performa

### ગામવાર ભુગર્ભજળ સર્વેપત્રક

ગામનું નામ ______ તાલુકો ______ જિલ્લો ______ તારીખ ______

મંડળીનું નામ ______ સ્થાપના ______ કયા વર્ષમાં કેનાલથી પિયત શરૂ થઇ? ______

સ્થાપના સમયે પિયત માટે નક્કી કરેલ વિસ્તાર કેટલો હતો? ______

પહેલા વર્ષે પિયત વિસ્તાર ______ ગયા વર્ષે (૨૦૦૮-૦૯)માં પિયત વિસ્તાર ______

આ તફાવતના કારણો ______

પિયત માટેના કેનાલ સિવાયના સ્ત્રોતો (સંખ્યા જણાવવી)

કુવા ______ બોર ______ કુવા+બોર ______ અન્ય ______

**કુવા અંગેની માહિતી**

ઉપયોગ (સંખ્યા) પીવા માટે ______ ખેતી માટે ______ અન્ય ______ બંધ ______

વપરાશની નિયમિતતા (સંખ્યા) નિયમિત ______ સીઝન મુજબ ______ અનિયમિત ______

પંપીગ મશીનરી ઇલ. મોટર ______ એચ.પી. ______ ડીઝલ એન્જિન ______ એચ.પી. ______ સબમર્શીબલ ______ એચ.પી. ______

કુલ ઉંડાઇ ______ (અંહી એવરેજ ઉંડાઇ દર્શાવવી. વધારે ફેરફાર હોય તો રેંજમાં દર્શાવવી.)

પાણીનું સ્તર મી. હાલનું ______ ૨૦૦૮ના વરસાદ બાદ ______

પાણીની ગુણવત્તા હાલની મીઠું ______ મોરું ______ ખારું ______

૨૦૦૮ના વરસાદ બાદ મીઠું ______ મોરું ______ ખારું ______

એકવીફર ______ કુલ જાડાઇ મી. ______

છેલ્લા પાંચ વર્ષમાં ભુગર્ભજળના સ્તરમાં અને ગુણવત્તામાં શું ફેરફાર થયા છે? કારણો જણાવો ______

કેનાલ આવ્યા બાદ ભુગર્ભજળના સ્તરમાં શું ફેરફાર થયો છે? ______

કેનાલ આવ્યા બાદ ભુગર્ભજળના ગુણવત્તામાં શું ફેરફાર થયો છે? ______

**બોર અંગેની માહિતી**

ઉપયોગ (સંખ્યા) પીવા માટે ______ ખેતી માટે ______ અન્ય ______ બંધ ______

વપરાશની નિયમિતતા (સંખ્યા) નિયમિત ______ સીઝન મુજબ ______ અનિયમિત ______

પંપીગ મશીનરી ઇલ. મોટર ______ એચ.પી. ______ ડીઝલ એન્જિન ______ એચ.પી. ______ સબમર્શીબલ ______ એચ.પી. ______

કુલ ઉંડાઇ ______ (અંહી એવરેજ ઉંડાઇ દર્શાવવી. વધારે ફેરફાર હોય તો રેંજમાં દર્શાવવી.)

પાણીનું સ્તર મી. હાલનું ______ ૨૦૦૮ના વરસાદ બાદ ______

પાણીની ગુણવત્તા હાલની મીઠું ______ મોરું ______ ખારું ______

૨૦૦૮ના વરસાદ બાદ મીઠું ______ મોરું ______ ખારું ______

એકવીફર ______ કુલ જાડાઇ મી. ______

છેલ્લા પાંચ વર્ષમાં ભુગર્ભજળના સ્તરમાં અને ગુણવત્તામાં શું ફેરફાર થયા છે? કારણો જણાવો ______

કેનાલ આવ્યા બાદ ભુગર્ભજળના સ્તરમાં શું ફેરફાર થયો છે? ______

કેનાલ આવ્યા બાદ ભુગર્ભજળના ગુણવત્તામાં શું ફેરફાર થયો છે? ______

માહિતી આપનારનું નામ ______ માહિતી લેનારનું નામ ______

# Annexure 3.4

## Soil Type and Saturation Percentages in RBMC Area

| Sr. No | Sample code | Village Name | Soil Type | Saturation Percentage % |
|---|---|---|---|---|
| 1 | DS1 | Dela | Loamy | 28.8 |
| 2 | DS2 | Babhonsana | Loamy | 30 |
| 3 | DS3 | Moti Dau | Red loamy | 28.6 |
| 4 | DS4 | Bhandu | Red loamy | 31 |
| 5 | DS5 | Vadu | Clayey soil | 26.2 |
| 6 | DS6 | Satusana | Clayey soil | 32.4 |
| 7 | DS7 | Valam | Clayey soil | 30.2 |
| 8 | DS8 | Gokalpur | Clayey soil | 23.8 |
| 9 | DS9 | Unja | Clayey loamy | 28.8 |
| 10 | DS10 | Kambli | Sandy Clayey | 32.8 |
| 11 | DS11 | Biliya | Sandy Clayey | 36.6 |
| 12 | DS12 | Bhunav | Loamy | 26.2 |
| 13 | DS13 | Lihoda | Sandy | 26 |
| 14 | DS14 | Lihoda | Sandy Clayey | 27 |
| 15 | DS15 | Dasaj | Red loamy | 28.4 |
| 16 | DS16 | Visnagar | Loamy | 32.8 |
| 17 | DS17 | Denap | Loamy | 26.6 |
| 18 | DS18 | Denap | Red loamy | 27.2 |
| 19 | DS19 | Tarap | Clayey loamy | 25 |
| 20 | DS20 | Khansosan | Clayey loamy | 31.6 |
| 21 | DS21 | Kausa | Loamy | 23.2 |
| 22 | DS22 | Eyasar | Loamy | 33.4 |
| 23 | DS23 | Padugam | Loamy | 30 |
| 24 | DS24 | Ganeshpura | Loamy | 24.2 |
| 25 | DS25 | Sawal | Black | 27 |
| 26 | DS26 | Visnagar | Black | 28 |
| 27 | DS27 | Gunja | Black | 27.4 |
| 28 | DS28 | Malekpur | Loamy | 24.6 |
| 29 | DS29 | Umata | Black | 22.8 |
| 30 | DS30 | Umata | Loamy | 27.6 |
| 31 | DS31 | Karoli | ------- | 26.8 |
| 32 | DS32 | Hajipura | ------ | 26.6 |
| 33 | DS33 | Upera | ----- | 22.6 |
| 34 | DS34 | Masava | Loamy | 23.6 |
| 35 | DS35 | Gokuliyu (Nartol) | Clayey loamy | 22.8 |
| 36 | DS36 | Rampura | Sandy Clayey | 32.2 |
| 37 | DS37 | Jaska | Loamy | 26 |
| 38 | DS38 | Kansa | Sandy loamy | 68.6 |
| 39 | DS39 | Sushi | Red Sandy Clayey | 27 |
| 40 | DS40 | Salisana | Loamy | 26 |
| 41 | DS41 | Bhalak | Loamy | 26 |
| 42 | DS42 | Trasvad | Red loamy | 25.6 |

| | | | | |
|---|---|---|---|---|
| 43 | DS43 | Kahipur | Sandy | 28.4 |
| 44 | DS44 | Vadnagar | Sandy Clayey | 25.2 |
| 45 | DS45 | Vadnagar | Sandy | 31.2 |
| 46 | DS46 | Champa | Sandy Clayey | 22.8 |
| 47 | DS47 | Vadnagar | Loamy | 24 |
| 48 | DS48 | Keshimpa | Sandy loamy | 28.4 |
| 49 | DS49 | Kheralu | Sandy loamy | 26 |
| 50 | DS50 | Sundhiya | Salty Sandy | 25.4 |
| 51 | DS51 | Sundhiya | Loamy clayey | 28 |
| 52 | DS52 | Jagapur | Red loamy | 26 |
| 53 | DS53 | Ambavadi (Sundhiya) | Red loamy | 25.8 |
| 54 | DS54 | Khanpur | Loamy | 21.4 |
| 55 | DS55 | Unad | Loamy | 32.4 |
| 56 | DS56 | Rajpur | Loamy | 27 |
| 57 | DS57 | Bahadurpur | Loamy | 23.6 |
| 58 | DS58 | Dabu | Loamy | 27 |
| 59 | DS59 | Undhai | Loamy | 24.8 |
| 60 | DS60 | Pipaldar | Loamy | 20.6 |
| 61 | DS61 | Karbatiya | Sandy loamy | 30 |
| 62 | DS62 | Ransipur | Loamy | 24.4 |
| 63 | DS63 | Techava | Loamy | 27.2 |
| 64 | RS1 | Dharoi | Clayey | 26 |
| 65 | RS2 | Khodamali | Clayey loamy | 27.4 |
| 66 | RS3 | Moti Hadol | Sandy | 27.4 |
| 67 | RS4 | Dedasan | Sandy | 24 |
| 68 | RS5 | Chada | Sandy loamy | 26.6 |
| 69 | RS6 | Aspa | clayey loamy | 22.8 |
| 70 | RS7 | Undani | Clayey loamy | 32.4 |
| 71 | RS8 | Valasana | Clayey loamy | 27 |
| 72 | RS9 | Valasana | Sandy | 23 |
| 73 | RS10 | Sobhasana | ----- | 31 |
| 74 | RS11 | Navi Vagdi | Sandy loamy | 30 |
| 75 | RS12 | Sobhasana | Sandy loamy | 33 |
| 76 | RS13 | Kot | Sandy | 26.2 |
| 77 | RS14 | Rampur (Kot) | Sandy | 26.6 |
| 78 | RS15 | Sadarpur | Sandy | 33.2 |
| 79 | RS16 | Madhi | Red loamy | 23.4 |
| 80 | RS17 | Sundarpur | Sandy | 27 |
| 81 | RS18 | Jantral | Sandy loamy | 31.6 |
| 82 | RS19 | Kamalpur | Loamy clayey | 27.4 |
| 83 | RS20 | Kamalpur | -------- | 31 |
| 84 | RS21 | Abasana | ------- | 27.2 |
| 85 | RS22 | Bamansa | ----- | 27.8 |
| 86 | RS 23 | Gundasan | ------ | 30.4 |

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