CHAPTER - 4

DATA COLLECTION AND ANALYSIS

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4.1 GENERAL

Kakrapar Left Bank Main Canal of Kakrapar weir consists of eight branch canals having sixty six minors as mentioned in Tables 4.1 and 4.2. The index map of Kakrapar Left Bank Main Canal command area is given in Plate 1. The branchwise index map showing the details of distributaries, minors and subminors are given in Plates 2 to 7 Main crops grown in command area of Kakrapar Left Bank Main Canal are sugarcane, banana, paddy, mango, cabbage, and grass. Detailed information about the command area is given in appendix I.

Table 4.1: Thirty Five Minors of Four Branch Canals of Kakrapar Left Bank Main Canal under Surat Canal Division

Name of branch canals	Surat		Bardoli	Chaltan	Umbhrat upto 58 R.D.
Minors	1. Bhairav	10. Puna Subminor	1. Baleswar	1. Bhesthan	1. Mahuwa
	2. Dumas Distributary	11. Sania	2. Ena Distributary	2. Chalthan Branch	2. Malekpur
	3. Kalsad	12. Saroli Subminor	3. Gangadhara	3. Devdha	3. Nizar
	4. Katargam Distributary	13 Segwa	4. Kareli	4. Lajpur Distributary	4. Pera Distributary
	5. Khajod	14. Simada	5. Kharwasa	5. Talangpur	
	6. Kholwad	15. Surat Branch	6. Palsana Distributary	6. Udhna Distributary	
	7. Nagod Distributary	16. Umbhel	7. Tundi	7. Vanj	
	8. Palsod	17. Vihan			
	9. Pasodra				

Table 4.2: Thirty One Minors of Four Branch Canals of Kakrapar Left Bank Main Canal under Ambika Division

Name Of branch canals	Umbhrat beyond 58 R.D.	Navsari	Amalsad	Valsad
Minors	1. Bhinar	1. Dandeswar	1. Abrama	1. Bamanvel
	2. Borsi	2. Dandi	2. Arda	2. Chanvai Distributary
	3. Kalkachka	3. Machhad	3. Chijgam	3. Dhakawad
	4. Kasba	4. Onjal	4. Devdha	4. Dhamadachi
	5. Maroli	5. Sadlav	5. Masa	5. Gadat
	6. Nagod	6. Vachnarvad	6. Mandher	6. Khambada
	7. Umrath	7. Veraval	7. Panar	7. Khapariya
				8. Matvad
				9. Minkachh
				10. Pati

4.2 DATA COLLECTION

For the formulation of mathematical model, data regarding Kakrapar irrigation project (surface water data), ground water data, crop data, meteorological data, topography, geohydrological data and electric supply data are required. These data are collected from various Government and Private agencies. Detailed data collected are represented and analyzed in Appendices I,II and III and in next sections of this chapter. The data are collected for the years 1990-1991 to 1999-2000, and the model is run for the year 1999-2000. The sensitivity analysis is carried out using the entire data. The various data collected and source of data are enlisted as follows

Data Regarding Kakrapar Left Bank Main Canal Command Area

(1) Details of command area, including following maps

(a) Index map of the project

(b) Key map for Kakrapar Left Bank Main Canal

(c) Village maps

(2) Reservoir storage and its capacity

(3) Details of surface water distribution system including discharge carrying capacity of canal and whether lined/unlined

(4) Existing release policy

(5) Phasewise total expenditure (capital investment) of the project

(6) Details regarding operation, maintenance and repair cost of the project

Source

1. Surat Irrigation Circle, Surat
2. Ambika Division, Navsari

Ground Water Data

(1) Ground water potential of the command area

(2) Depth of water table and pre & post monsoon water table data

(3) Quality of ground water

(4) Number of open wells and tube wells in the command area and thei discharge capacity

(5) Capital costs of the open wells and tube wells

(6) Operation, maintenance and repair cost of the wells

Source

1. Gujarat Water Resources Development Corporation, Surat
2. Ambika Division, Navsari
3. Gujarat Engineering Research Institute, Vadodara
4. Field Survey

Crop Data

(1) Existing cropping pattern

(2) Crop yield data

(3) Market value and production cost for different crops

Source

1. Department of Agriculture, Krishi Bhavan, Ahmedabad
2. Surat Irrigation Circle, Surat
3. Ambika Division, Navsari

Meteorological Data

(1) Evaporation, rainfall, relative humidity, temperature, wind velocity, etc.

Source

1. Surat Irrigation Circle
2. Meteorological Department, Surat

Topography, Soil and Geohydrological Data

(1) Topography of the command area

(2) Soil characteristics and it's quality

(3) Aquifer characteristics including details of log tests in the command area and information regarding the water bearing strata

Source

1. Surat Irrigation Circle
2. Department of Geohydrology, Surat

Electric Supply (Power)

(1) Cost of power including capital cost of power generation, transmission, distribution and staff charges, etc.

(2) Number of average hours of power availability in the command area

(3) Power of pumps (kW) in the command area

Source

1. Gujarat electricity Board, Surat.

Field Data Collected

Some of the field data are also collected for the discharge of wells and for the measurement of the electric conductivity of the surface and ground water in the command area. The data for the expenditure of wells and the duration for running the wells are also taken. The collected data are as follows

1) From Kakrapar Irrigation Project Report, GERI available ground water salinity range is 750 to 2,250 micromhos/cm so average value of salinity is taken as 1,500 micromhos/cm.

2) The requirement of water for leaching is calculated from Tables 4.3 and 4.4 for surface water and ground water.

Table 4.3: Electrical Conductivity of Surface Water

Name	Temperature	Ec
Khapariya Minor	35^0c	0.28 m mhos
Amalsad Branch	38^0c	0.24 m mhos
Navsari Branch	38^0c	0.24 m mhos

Table 4.4: Details of Wells

Name of Village	Bamanvel	Bamanvel	Navsari
Name of Farmer	Muhamad Ahmad Lunat	Gulam Ahmad Lunat	Dhansukhbhai Raghubhai Lad
Type of Well	Open well	Tube well	Tube well
Construction Time	15 years	13 – 14 years	5 years
Duration for Running Pump	10 h per day	12 h per day	11 h per day
Cost of Construction	Rs.1,15,000	Rs.45,000	Rs.50,000
Diameter of Pipe	0.0635 m	0.0762 m	0.0762 m
Temperature	35 ^{0}c	35 ^{0}c	35 ^{0}c
Ec	0.85 m mhos	0.78 m mhos	0.58 m mhos
X	0.1778 m	0.1778 m	0.3048 m
Y	0.3048 m	0.254 m	0.4572 m
Area, A	0.0032 m^2	0.004558 m^2	0.004558 m^2
Velocity, V	0.713 m/s	0.7813 m/s	0.998 m/s
Discharge,Q	0.0022816 m^3/s	0.00356 m^3/s	0.004549 m^3/s
Ec of surface water	0.24 m mhos measured at the site of canal for canal water		

LR_s = Eci / Ecd ... ... (4.1)

where,

LR_s = Additional surface water requirement for leaching, %

Eci = Electric conductivity of irrigated water, m mhos

Ecd = Electric conductivity of drained water, m mhos

LR_s = (0.24 x 1,000) / 1,500

= 0.1600

= 16.00%

LR_g = Eci / Ecd ... ... (4.2)

where,

LR_g = Additional ground water requirement for leaching, %

Eci = Electric conductivity of irrigated water, m mhos

Ecd = Electric conductivity of drained water, m mhos

LR_g = (0.850 x 1,000) / 1,500

= 0.5667

= 56.67%

3) Farm-harvesting price data are taken from the horticulture information service bulletin, for the year 1999-2000.

Table 4.5: Farm Harvesting Price for the Year 1999-2000

For the year 1999

Jan	Week		Banana	Cabbage	Feb	Week		Banana	Cabbage
	1	P	400.00	750.00		1	P	400.00	500.00
		A	378.00	689.00			A	523.00	1,075.00
	2	P	425.00	700.00		2	P	380.00	200.00
		A	476.00	819.00			A	736.00	1,568.00
	3	P	425.00	500.00		3	P	350.00	200.00
		A	374.00	858.00			A	759.00	1,469.00
	4	P	380.00	500.00		4	P	370.00	200.00
		A	430.00	1,040.00			A	512.00	988.00
	AVG.	P	407.50	612.50		AVG.	P	375.00	275.00
		A	414.50	851.50			A	632.50	1,275.00
Mar	**Week**		**Banana**	**Cabbage**	**Apr**	**Week**		**Banana**	**Cabbage**
	1	P	375.00	175.00		1	P	400.00	460.00
		A	569.00	1,050.00			A	375.00	537.00
	2	P	380.00	200.00		2	P	380.00	350.00
		A	635.00	1,270.00			A	596.00	765.00
	3	P	400.00	300.00		3	P	380.00	425.00
		A	735.00	1,068.00			A	587.00	715.00
	4	P	350.00	300.00		4	P	380.00	430.00
		A	618.00	728.00			A	482.00	624.00
	AVG.	P	376.25	243.75		AVG.	P	385.00	416.25
		A	639.25	1,029.00			A	510.00	660.25
May	**Week**		**Banana**	**Cabbage**	**Jun**	**Week**		**Banana**	**Cabbage**
	1	P	400.00	500.00		1	P	460.00	600.00
		A	567.00	564.00			A	823.00	369.00
	2	P	400.00	500.00		2	P	400.00	550.00
		A	600.00	585.00			A	515.00	455.00
	3	P	400.00	600.00		3	P	400.00	550.00
		A	461.00	522.00			A	445.00	394.00
	4	P	400.00	600.00		4	P	400.00	650.00
		A	480.00	495.00			A	422.00	265.00
	AVG.	P	400.00	504.25		AVG.	P	415.00	587.50
		A	527.00	541.50			A	551.25	370.75
Jul	**Week**		**Banana**	**Cabbage**	**Aug**	**Week**		**Banana**	**Cabbage**
	1	P	450.00	600.00		1	P	400.00	1,200.00
		A	464.00	241.00			A	505.00	221.00
	2	P	425.00	650.00		2	P	450.00	1,200.00
		A	606.00	319.00			A	597.00	240.00
	3	P	400.00	650.00		3	P	400.00	1,200.00
		A	586.00	209.00			A	461.00	232.00
	4	P	380.00	1,200.00		4	P	400.00	1,200.00
		A	685.00	208.00			A	534.00	262.00
	AVG.	P	413.75	775.00		AVG.	P	412.50	1,200.00
		A	585.25	244.25			A	524.24	238.75
Sep	**Week**		**Banana**	**Cabbage**	**Oct**	**Week**		**Banana**	**Cabbage**
	1	P	450.00	1,150.00		1	P	400.00	750.00
		A	498.00	280.00			A	754.00	470.00
	2	P	400.00	900.00		2	P	400.00	700.00
		A	539.00	435.00			A	789.00	560.00
	3	P	400.00	800.00		3	P	400.00	700.00
		A	825.00	531.00			A	891.00	520.00

	4	P	400.00	800.00		4	P	380.00	1,100.00
		A	710.00	464.00			A	874.00	434.00
	AVG.	P	412.50	912.50		AVG.	P	395.00	812.50
		A	643.00	427.50			A	827.00	496.00
Nov	**Week**		**Banana**	**Cabbage**	**Dec**	**Week**		**Banana**	**Cabbage**
	1	P	400.00	800.00		1	P	400.00	2,600.00
		A	794.00	459.00			A	560.00	90.00
	2	P	350.00	800.00		2	P	400.00	2,500.00
		A	696.00	514.00			A	525.00	129.00
	3	P	350.00	700.00		3	P	350.00	2,400.00
		A	818.00	615.00			A	582.00	100.00
	4	P	350.00	600.00		4	P	400.00	2,300.00
		A	615.00	620.00			A	526.00	92.00
	AVG.	P	362.50	725.00		AVG.	P	387.50	2,450.00
		A	730.75	552.00			A	548.25	102.75

From the above table the average values for banana and cabagge are as follows

		Banana	Cabbage
AVG.	P	395.21	792.86
	A	594.42	565.77

For the year 2000

Jan	**Week**		**Banana**	**Cabbage**	**Feb**	**Week**		**Banana**	**Cabbage**
	1	P	400.00	500.00		1	P	350.00	700.00
		A	570.00	675.00			A	500.00	607.00
	2	P	400.00	680.00		2	P	400.00	700.00
		A	440.00	621.00			A	604.00	696.00
	3	P	400.00	600.00		3	P	400.00	700.00
		A	417.00	480.00			A	802.00	675.00
	4	P	400.00	650.00		4	P	400.00	600.00
		A	569.00	643.00			A	423.00	500.00
	AVG.	P	400.00	607.50		AVG.	P	387.50	675.00
		A	499.00	604.75			A	582.25	619.50
Mar	**Week**		**Banana**	**Cabbage**	**Apr**	**Week**		**Banana**	**Cabbage**
	1	P	400.00	700.00		1	P	400.00	900.00
		A	491.00	650.00			A	463.00	485.00
	2	P	370.00	500.00		2	P	400.00	900.00
		A	463.00	720.00			A	533.00	511.00
	3	P	350.00	800.00		3	P	400.00	700.00
		A	586.00	653.00			A	567.00	622.00
	4	P	350.00	900.00		4	P	400.00	950.00
		A	760.00	570.00			A	390.00	475.00
	AVG.	P	367.50	725.00		AVG.	P	400.00	862.50
		A	552.08	648.25			A	488.25	523.25
May	**Week**		**Banana**	**Cabbage**	**Jun**	**Week**		**Banana**	**Cabbage**
	1	P	350.00	950.00		1	P	350.00	700.00
		A	585.00	465.00			A	665.00	455.00
	2	P	400.00	1,000.00		2	P	380.00	700.00
		A	546.00	485.00			A	648.00	494.00
	3	P	400.00	1,000.00		3	P	350.00	1,100.00
		A	686.00	510.00			A	895.00	424.00

	4	P	400.00	1,050.00		4	P	350.00	980.00
		A	578.00	531.00			A	752.00	367.00
	AVG.	P	387.50	1,000.00		AVG.	P	357.50	870.00
		A	598.75	497.75			A	740.00	435.00
Jul	**Week**		**Banana**	**Cabbage**	**Aug**	**Week**		**Banana**	**Cabbage**
	1	P	400.00	1,100.00		1	P	450.00	900.00
		A	732.00	330.00			A	565.00	378.00
	2	P	400.00	1,300.00		2	P	450.00	750.00
		A	854.00	263.00			A	630.00	544.00
	3	P	450.00	1,400.00		3	P	425.00	600.00
		A	665.00	253.00			A	733.00	530.00
	4	P	400.00	1,100.00		4	P	400.00	600.00
		A	760.00	343.00			A	694.00	604.00
	AVG.	P	412.50	1,225.00		AVG.	P	431.25	712.50
		A	752.75	297.25			A	655.50	514.00
Sep	**Week**		**Banana**	**Cabbage**	**Oct**	**Week**		**Banana**	**Cabbage**
	1	P	400.00	700.00		1	P	450.00	750.00
		A	590.00	548.00			A	675.00	406.00
	2	P	350.00	800.00		2	P	400.00	700.00
		A	860.00	623.00			A	800.00	540.00
	3	P	400.00	800.00		3	P	450.00	900.00
		A	885.00	541.00			A	706.00	465.00
	4	P	400.00	750.00		4	P	400.00	1000.00
		A	736.00	484.00			A	527.00	426.00
	AVG.	P	387.50	762.50		AVG.	P	425.00	837.50
		A	767.75	549.00			A	677.00	459.25
Nov	**Week**		**Banana**	**Cabbage**	**Dec**	**Week**		**Banana**	**Cabbage**
	1	P	400.00	1,100.00		1	P	400.00	800.00
		A	558.00	390.00			A	615.00	395.00
	2	P	400.00	1,100.00		2	P	400.00	950.00
		A	662.00	447.00			A	710.00	597.00
	3	P	400.00	1,000.00		3	P	400.00	750.00
		A	610.00	546.00			A	850.00	663.00
	4	P	400.00	900.00		4	P	425.00	600.00
		A	599.00	463.00			A	720.00	729.00
	AVG.	P	400.00	1,025.00		AVG.	P	406.25	775.00
		A	607.25	461.50			A	723.75	596.00

From the above table the average values for banana and cabagge are as follows

		Banana	**Cabbage**
AVG	P	396.88	839.79
	A	638.94	517.13

N.B. P = Price, Rs./Quintal

A = Arrival, million tones

4.3 DATA ANALYSIS

4.3.1 Calculation of Benefits

Outputs from the agricultural products are calculated to determine gross benefits from the project. For the model requirements, benefits from selling agricultural products are considered in Rs./ha for a particular crop. Production cost of each crop is deducted from gross return to obtain net benefit. Calculated net benefits are given in Table 4.6.

Table 4.6: Cropwise Net Benefits for the Year 1999-2000

Sr. No.	Name of crop	Yield	Farm harvest price	Gross returns	Production cost		Net benefits
					Percentage of gross returns	Cost	
		Quintal/ha	Rs./Quintal	Rs./ha	%	Rs./ha	Rs./ha
1	Banana	750.00	395.21	2,96,407.50	40	11,856.30	1,77,844.50
2	Cabbage	250.00	792.86	1,98,215.00	30	59,464.50	1,38,750.50
3	Cotton	3.18	2,656.80	8,448.63	35	2,957.02	5,491.61
4	Grass	750.00	100.00	75,000.00	20	15,000.00	60,000.00
5	Groundnut	13.20	1,717.08	22,665.41	40	9,066.17	13,599.25
6	Jowar	8.30	517.34	4,293.90	55	2,361.64	1,932.25
7	Mango	63.00	1,289.70	81,250.00	23	18,687.50	62,562.50
8	Paddy	50.00	640.39	32,019.50	44	14,088.58	17,930.92
9	Sugarcane	903.75	74.03	66,904.60	70	46,833.22	20,071.38
10	Wheat	24.36	707.19	17,227.26	60	10,336.36	6,890.91

4.4 YEARLY AVAILABILITY OF CANAL WATER FOR MINORS 1 to 7 OF NAVSARI BRANCH CANAL

Maximum possible surface water available for the command area of the different minors should be determined. For this purpose share of different minors is determined with the help of the actual reservoir storage for the year 1999 – 2000. Considering seepage losses, evaporation losses and carry-over, 75% of actual storage is considered as a usable potential for a particular year.

C.C.A of the project = 2,04,080 ha

C.C.A of Navsari branch canal = 6,262.95 ha

Factor of equitable share of Navsari branch = 6,262.95 / 2,04,080

= 0.0307

C.C.A. and factor of equitable share of different minors of Surat branch canal are given in Table 4.7, in the enclosed C.D.

C.C.A. and factor of equitable share of different minors of Bardoli branch canal are given in Table 4.8, in the enclosed C.D.

C.C.A. and factor of equitable share of different minors of Chalthan branch canal are given in Table 4.9, in the enclosed C.D.

C.C.A. and factor of equitable share of different minors of Umbhrat branch canal upto 58 R.D. are given in Table 4.10, in the enclosed C.D.

C.C.A. and factor of equitable share of different minors of Umbhrat branch canal beyond 58 R.D. are given in Table 4.11, in the enclosed C.D.

C.C.A. and factor of equitable share of different minors of Navsari branch canal are given in Table 4.12.

C.C.A. and factor of equitable share of different minors of Amalsad branch canal are given in Table 4.13, in the enclosed C.D.

C.C.A. and factor of equitable share of different minors of Valsad branch canal are given in Table 4.14, in the enclosed C.D.

Table 4.12: C.C.A. and Factor of Equitable Share of Minors 1 to 7 of Navsari Branch Canal of K.L.B.M.C. Command Area

Sr. no.	Minor	C.C.A. ha	C.C.A of the project ha	C.C.A of the branch ha	Factor of equitable share of branch	Factor of equitable share of minor
(a)	(b)	(c)	(d)	(e)	(f)=(e/d)	(g)=(c/e)
1	Dandeswar	465.81	2,04,080	6,262.95	0.0307	0.0744
2	Dandi	2,044.00	2,04,080	6,262.95	0.0307	0.3264
3	Machhad	579.00	2,04,080	6,262.95	0.0307	0.0924
4	Onjal	1,360.00	2,04,080	6,262.95	0.0307	0.2172
5	Sadlav	580.71	2,04,080	6,262.95	0.0307	0.0927
6	Vachnarvad	847.65	2,04,080	6,262.95	0.0307	0.1353
7	Veraval	385.78	2,04,080	6,262.95	0.0307	0.0616

Yearly available surface water of different minors of Surat branch canal are given in Table 4.15, in the enclosed CD.

Yearly available surface water of different minors of Bardoli branch canal are given in Table 4.16, in the enclosed CD.

Yearly available surface water of different minors of Chalthan branch canal are given in Table 4.17, in the enclosed CD.

Yearly available surface water of different minors of Umbhrat branch canal upto 58 R.D. are given in Table 4.18, in the enclosed CD.

Yearly available surface water of different minors of Umbhrat branch canal beyond 58 R.D. are given in Table 4.19, in the enclosed CD.

Yearly available surface water of different minors of Navsari branch canal are given in Table 4.20.

Yearly available surface water of different minors of Amalsad branch canal are given in Table 4.21, in the enclosed CD.

Yearly available surface water of different minors of Valsad branch canal are given in Table 4.22, in the enclosed CD.

Table 4.20: Yearly Available Surface Water for Minors 1 to 7 of Navsari Branch Canal of K.L.B.M.C. Command Area

Sr. no.	Minor	Actual reservoir storage ha.m	Available reservoir storage considering efficiency ha.m	Equitable share for Surat branch ha.m	Equitable share for minor ha.m
(a)	(b)	(c)	(d) = (c x 0.75)	(e)=(d x 0.0668)	(f) = (e x F.E.S.)
1	Dandeswar	1,38,350	1,03,763	3,184.37	236.84
2	Dandi	1,38,350	1,03,763	3,184.37	1,039.26
3	Machhad	1,38,350	1,03,763	3,184.37	294.39
4	Onjal	1,38,350	1,03,763	3,184.37	691.49
5	Sadlav	1,38,350	1,03,763	3,184.37	295.26
6	Vachnarvad	1,38,350	1,03,763	3,184.37	430.98
7	Veraval	1,38,350	1,03,763	3,184.37	196.15

N.B. F.E.S. = Factor of equitable share of Minor

4.5 CARRYING CAPACITY OF THE CANAL

Monthly maximum carrying capacity of the canal is determined, as monthly distribution of surface water is considered in the mathematical model. Considering that for two or three months of peak water requirements canal can be run for 15 days of a month. Monthly carrying capacity is determined by taking 15 days per month. Main canal and branch canals are lined with concrete and considering 80% efficiency of these canals; volume of water at the head of minor is determined.

Volume of water at the head of different minors of Surat branch canal are given in Table 4.23, in the enclosed CD.

Volume of water at the head of different minors of Bardoli branch canal are given in Table 4.24, in the enclosed CD.

Volume of water at the head of different minors of Chalthan branch canal are given in Table 4.25, in the enclosed CD.

Volume of water at the head of different minors of Umbhrat branch canal upto 58 R.D. are given in Table 4.26, in the enclosed CD.

Volume of water at the head of different minors of Umbhrat branch canal beyond 58 R.D. are given in Table 4.27, in the enclosed CD.

Volume of water at the head of different minors of Navsari branch canal are given in Table 4.28.

Volume of water at the head of different minors of Amalsad branch canal are given in Table 4.29, in the enclosed CD.

Volume of water at the head of different minors of Valsad branch canal are given in Table 4.30, in the enclosed CD.

Table 4.28: Volume of Water at the Head of Minors 1 to 7 of Navsari Branch Canal of K.L.B.M.C. Command Area

Sr. No.	Minor	Designed carrying capacity of minor ha.m/day	Monthly carrying capacity of minor ha.m	Volume of water at the head of minor ha.m
(a)	(b)	(c)	(d) = (c x 15)	(e)=(d / 0.80)
1	Dandeswar	2.99	44.86	56.07
2	Dandi	25.48	382.17	477.72
3	Machhad	6.93	104.02	130.02
4	Onjal	6.46	96.83	121.03
5	Sadlav	7.22	108.34	135.43
6	Vachnarvad	7.02	105.26	131.58
7	Veraval	9.72	145.75	182.19

4.6 RECHARGE CALCULATIONS

Total annual recharge through Surat branch canal is given in Table 4.31, in the enclosed CD.

Total annual recharge through Bardoli branch canal is given in Table 4.32, in the enclosed CD.

Total annual recharge through Chalthan branch canal is given in Table 4.33, in the enclosed CD.

Total annual recharge through Umbhrat branch canal upto 58 R.D. is given in Table 4.34, in the enclosed CD.

Total annual recharge through Umbhrat branch canal beyond 58 R.D. is given in Table 4.35, in the enclosed CD.

Total annual recharge through Navsari branch canal is given in Table 4.36

Total annual recharge through Amalsad branch canal is given in Table 4.37, in the enclosed CD.

Total annual recharge through Valsad branch canal is given in Table 4.38, in the enclosed CD.

Table 4.36: Total Annual Recharge Through Navsari Branch Canal

TOTAL ANNUAL RECHARGE		
A. Monsoon Recharge		
a. Area, sq.km		
(i) Geographical area		343.45
(ii) Hilly Area having >20% slopes		51.52
(iii) Saline Area		89
(iv) Net suitable Area		202.93
b. Water Table Fluctuation (WTF)		3
c. Specific yield (Sy), (%)		9
d. Rainfall		
(i) Long term Average Annual Rainfall, mm	Years: 1965 to 1999	1550
(ii)Short term Average Annual Rainfall, mm	Years: 1995 to 1999	1410
(iii) Normalization Factor (NF) (i/ii)		1.10
e. Gross Kharif Draft (Dw), Mcm/year		0.01
f. Monsoon Recharge, Mcm/year		
[{(AxWTFxSy)+Dw-(Rs+Rigw+Ris)}xNF]+Rs+Ris		58.17
AxWTFxSy	Suitable Area ,sq.km x WL Rise,m x Specific yield,%	54.79
Dw	Gross Kharif Draft (Dw), Mcm/year	0.01
Rs+Rigw+Ris		20.83
Rs	Monsoon seepage from canals and tanks,Mcm/year	1.94
Rigw	Monsoon seepage from irrigation, Mcm/year	0.00
Ris	Monsoon seepage from surfacewater irrigation, Mcm/year	18.89
NF	Normalization factor	1.10

B. RECHARGE FROM SURFACE SOURCES

1. Recharge from canals

Applied seepage factor			Unlined	2.5 Cumec /M sq. m			
			Lined	0.3 Cumec/M sq.m			
Name of Scheme	Wetted Area M sq.m		Average Running days	Seepage Mcm/year			Total
	Unlined	Lined	Non-Monsoon	Monsoon	Non-Monsoon	Monsoon	
Navsari Branch Canal	0.14		120	60	3.63	1.81	5.44

2. Recharge from surface water irrigation

Irrigation Water Applied = Area Irrigated x Average depth of water applied

Seepage factor: 35% of the Irrigation Water applied (40% for paddy)

Name of scheme	Area Irrigated ha		Average water Depth applied m		Seepage Mcm/year		Total
	Non-Monsoon	Monsoon	Non-Monsoon	Monsoon	Non-Monsoon	Monsoon	
Navsari Branch Canal	3987	2860	4.141	1.651	57.78	18.88	76.67

3. Recharge from Surface Water Bodies

Type of Structure	Total Nos.	Average Water Spread Area, sq. km	Seepage Factor m	Seepage Mcm/year		Total
				Non-Monsoon	Monsoon	
Tanks, Percolation tanks and Check dams	21	0.01	0.6	0	0.12	0.12

C. POTENTIAL RECHARGE

1. Recharge from Flood-prone Area, Mcm/year

a. Yearly flooded area, sq. km	0.76
b. Duration of flooding, days	12
c. Seepage factor, m	0.6
d. Potential Recharge, Mcm/year	5.47

2.Recharge from Shallow Water Table (Water logged Area)

a. Geographical Area, sq. km	75
b. Pre-monsoon Depth to Water Table, m. bgl	3
c. Permissible Depth to Water Table (5 m. bgl)	5
d. Adopted Specific yield (%)	9
e. Potential Recharge from Shallow Water Table Areas, Mcm/year,(5-b x a x d)	13.50

D. TOTAL RECHARGE			
Type of recharge	**From rainfall**	**From irrigation sources**	**Total**
Monsoon Recharge, Mcm/year	37.35	20.83	58.17
Non-Monsoon Recharge, Mcm/year		61.41	61.41
Potential Recharge, Mcm/year		18.97	18.97
TOTAL, Mcm/year	37.35	101.21	138.56

4.6.4 Total Annual Ground Water Recharge Including Recycled Irrigation Water

Total annual ground water recharge through different minors of Surat branch canal including calculations for recycled irrigation water is given in Table 4.39, in the enclosed CD.

Total annual ground water recharge through different minors of Bardoli branch canal including calculations for recycled irrigation water is given in Table 4.40, in the enclosed CD.

Total annual ground water recharges through different minors of Chalthan branch canal including calculations for recycled irrigation water is given in Table 4.41, in the enclosed CD.

Total annual ground water recharges through different minors of Umbhrat branch canal upto 58 R.D. including calculations for recycled irrigation water is given in Table 4.42, in the enclosed CD.

Total annual ground water recharges through different minors of Umbhrat branch canal beyond 58 R.D. including calculations for recycled irrigation water is given in Table 4.43, in the enclosed CD.

Total annual ground water recharges through different minors of Navsari branch canal including calculations for recycled irrigation water is given in Table 4.44.

Total annual ground water recharges through different minors of Amalsad branch canal including calculations for recycled irrigation water is given in Table 4.45, in the enclosed CD.

Total annual ground water recharges through different minors of Valsad branch canal including calculations for recycled irrigation water is given in Table 4.46, in the enclosed CD.

Table 4.44: Total Annual Ground Water Recharge Including Recycled Irrigation Water Through Different Minors of Navsari Branch Canal

Sr. No.	Minor	C.C.A. ha	Total annual recharge ha.m
(a)	(b)	(c)	(d)
1	Dandeswar	465.81	1,030.55
2	Dandi	2,044.00	4,522.12
3	Machhad	579.00	1,280.97
4	Onjal	1,360.00	3,008.85
5	Sadlav	580.71	1,284.76
6	Vachnarvad	847.65	1,875.33
7	Veraval	385.78	853.49

4.7 MINIMUM DESIRABLE GROUND WATER EXTRACTION FOR DRAINAGE REQUIREMENTS

According to INCID guidelines, minimum necessary and maximum permissible additional recharge caused due to project is decided.

Just after monsoon, the water table depth in the command area is around 5.0 m. Water table rises at an average of 15 cm per year. Thus water table trend can be considered as steady – rising.

Therefore, minimum necessary and maximum permissible additional withdrawal are considered as 60% and 90% of the additional recharge caused by project respectively, which represents values corresponding to "rising" water table trend (refer Table 2.2). Intermediate 75% of the additional recharge value is also considered to study the variation of ground water proportion.

Additional recharge caused due to project = Total annual recharge – Rainfall recharge

Percentage of additional recharge, ha.m

Minimum necessary = 60 %

Intermediate value = 75 %

Maximum permissible = 90 %

Minimum necessary and maximum permissible additional withdrawal through different minors of Surat branch canal is given in Table 4.47, in the enclosed CD.

Minimum necessary and maximum permissible additional withdrawal through different minors of Bardoli branch canal is given in Table 4.48, in the enclosed CD.

Minimum necessary and maximum permissible additional withdrawal through different minors of Chalthan branch canal is given in Table 4.49, in the enclosed CD.

Minimum necessary and maximum permissible additional withdrawal through different minors of Umbhrat branch canal upto 58 R.D. is given in Table 4.50, in the enclosed CD.

Minimum necessary and maximum permissible additional withdrawal through different minors of Umbhrat branch canal beyond 58 R.D. is given in Table 4.51, in the enclosed CD.

Minimum necessary and maximum permissible additional withdrawal through different minors of Navsari branch canal is given in Table 4.52.

Minimum necessary and maximum permissible additional withdrawal through different minors of Amalsad branch canal is given in Table 4.53, in the enclosed CD.

Minimum necessary and maximum permissible additional withdrawal through different minors of Valsad branch canal is given in Table 4.54, in the enclosed CD.

Table 4.52: Minimum Necessary and Maximum Permissible Additional Withdrawal through Different Minors of Navsari Branch Canal

Sr. No.	Minor	Total annual recharge ha.m	Rainfall recharge ha.m	Additional recharge caused due to project ha.m	60% of additional recharge (min. necessary) ha.m	75% of additional recharge (Intermediate) ha.m	90% of additional recharge (max. permissible) ha.m
(a)	(b)	(b)	(c)	(d)=(b - c)	(e)=(0.60 x d)	(d)=(0.75 x d)	(d)=(0.90 x d)
1	Dandeswar	1,284.76	539.40	745.35	447.21	559.02	670.82
2	Dandi	1,875.33	787.35	1,087.98	652.79	815.98	979.18
3	Machhad	1,030.55	432.67	597.88	358.73	448.41	538.09
4	Onjal	853.49	358.34	495.16	297.09	371.37	445.64
5	Sadlav	1,280.97	537.81	743.16	445.90	557.37	668.84
6	Vachnarvad	4,522.12	1,898.60	2,623.52	1,574.11	1,967.64	2,361.17
7	Veraval	3,008.85	1,263.26	1,745.59	1,047.35	1,309.19	1,571.03

4.8 PUMPING CAPACITY OF WELLS

In the command area of minors 1 to 7, of the Navsari branch canal the number of wells, i.e. shallow tube wells and open wells are given in Table 4.60. The average discharging capacity of a shallow tube well / open well is 210 l.p.m. Quantum of water available for pumping is calculated as follows:

Yield of shallow tube well / open well = 210 l.p.m

= 0.0035 cumecs.

Having the total discharge capacity of one cumec, volume of water that can be lifted per day is,

1 cumec = 1 x 60 x 60 x 11 (h/day)

= 39600 m^3/day

= 3.96 ha.m/day

Average No. of days per month for pumping operation, considering power availability and other constraints = 25 days.

Pumping capacity of wells per month in different minors of Surat branch canal is given in Table 4.55, in the enclosed CD.

Pumping capacity of wells per month in different minors of Bardoli branch canal is given in Table 4.56, in the enclosed CD.

Pumping capacity of wells per month in different minors of Chalthan branch canal is given in Table 4.57, in the enclosed CD.

Pumping capacity of wells per month in different minors of Umbhrat branch canal upto 58 R.D. is given in Table 4.58, in the enclosed CD.

Pumping capacity of wells per month in different minors of Umbhrat branch canal beyond 58 R.D. is given in Table 4.59, in the enclosed CD.

Pumping capacity of wells per month in different minors of Navsari branch canal is given in Table 4.60.

Pumping capacity of wells per month in different minors of Amalsad branch canal is given in Table 4.61, in the enclosed CD.

Pumping capacity of wells per month in different minors of Valsad branch canal is given in Table 4.62, in the enclosed CD.

TABLE 4.60 : Pumping Capacity of Wells per Month in Different Minors of Navsari Branch Canal

Sr. no.	Minor	No. of shallow tube wells	No. of open wells	Yield cumecs	Total quantum of water available for pumping cumecs	Volume of water that can be lifted ha.m/day	Tota! of water that can be lifted ha.m/day	Pumping capacity of wells per month ha.m
1	Dandeswar	0	3	0.0035	0.0105	3.9600	0.0416	1.0395
2	Dandi	0	0	0.0035	0.0000	3.9600	0.0000	0.0000
3	Machhad	0	4	0.0035	0.0140	3.9600	0.0554	1.3860
4	Onjal	0	0	0.0035	0.0000	3.9600	0.0000	0.0000
5	Sadlav	0	7	0.0035	0.0245	3.9600	0.0970	2.4255
6	Vachharvad	0	7	0.0035	0.0245	3.9600	0.0970	2.4255
7	Veraval	0	3	0.0035	0.0105	3.9600	0.0416	1.0395

4.9 CROP PERIOD AND CROP CALENDER FOLLOWED IN THE COMMAND AREA

Crops grown in the command area and suggested for designed cropping pattern with their crop periods are given in Table 4.63.

For the model requirements area occupied by each crop for each month of a year is required to be calculated. For this purpose crop calendar, which gives coefficient to be multiplied with area under a particular crop, is considered, to obtain total area under cultivation for a particular month. Value of the coefficient is determined depending upon number of days for crop activity in the particular month. The value of the coefficient is 1, if crop activity exists for the whole month. The crop calendar is given in Table 4.64.

Table 4.63: Crop Period

Sr. no.	Crop	Crop period	No. of days
1	Banana	01/07 to 30/06	365
2	Cabbage	12/11 to 15/03	120
3	Cotton	21/06 to 06/12	168
4	Grass	07/11 to 25/02	110
5	Groundnut	01/02 to 23/05	112
6	Jowar	15/12 to 30/03	105
7	Mango	01/12 to 01/03	120
8	Paddy	16/06 to 15/10	122
9	Sugarcane	05/02 to 04/02	365
10	Wheat	15/11 to 15/03	120

Table 4.64: Crop Calendar

Month	Sugarcane (A_1)	Banana (A_2)	Mango (A_3)	Cabbage (A_4)	Paddy (A_5)	Jowar (A_6)	Wheat (A_7)	Cotton (A_8)	Groundnut (A_9)	Grass (A_{10})
Jan	1	1	1	1	-	1	1	-	-	1
Feb	1	1	1	0.75	-	1	1	-	1	0.9
Mar	1	1	-	-	-	1	0.5	-	1	-
Apr	1	1	-	-	-	-	-	-	1	-
May	1	1	-	-	-	-	-	-	0.7	-
Jun	1	1	-	-	0.5	-	-	0.3	-	-
Jul	1	1	-	-	1	-	-	1	-	-
Aug	1	1	-	-	1	-	-	1	-	-
Sep	1	1	-	-	1	-	-	1	-	-
Oct	1	1	-	-	0.5	-	-	1	-	-
Nov	1	1	-	0.75	-	-	0.5	1	-	0.75
Dec	1	1	1	1	-	0.5	1	0.3	-	1

4.10 WATER REQUIREMENT OF THE CROPS

Water requirement for each crop is calculated on the basis of fortnightly evapotranspiration and crop co-efficient data for the region. The monthly water requirement is calculated by adding the water requirement for the two fortnights of the month, for the model requirements. Calculations are given in Table 4.65. Net irrigation requirement is calculated by subtracting effective rainfall from consumptive use.

ETc=Crop Evapotranspiration

Table 4.65: Monthly Crop Water Requirement for Crops Sugarcane and Banana

Month / Fortnight	Sugarcane(A_1)		Month / fortnight	Banana(A_2)	
	Consumptive use ETc mm	Monthly water requirement mm		Consumptive use ETc mm	Monthly water requirement mm
Jan / 01	34.00		Jan / 01	48.00	
Jan / 02	0.00	34.00	Jan / 02	56.00	104.00
Feb / 01	42.00		Feb / 01	76.00	
Feb / 02	46.00	88.00	Feb / 02	83.00	159.00
Mar / 01	71.00		Mar / 01	98.00	
Mar / 02	76.00	147.00	Mar / 02	105.00	203.00
Apr / 01	92.00		Apr / 01	113.00	
Apr / 02	109.00	201.00	Apr / 02	120.00	233.00
May / 01	113.00		May / 01	101.00	
May / 02	109.00	212.00	May / 02	98.00	199.00
Jun / 01	95.00		Jun / 01	76.00	
Jun / 02	83.00	178.00	Jun / 02	64.00	140.00
Jul / 01	69.00		Jul / 01	26.00	
Jul / 02	60.00	129.00	Jul / 02	23.00	49.00
Aug / 01	58.00		Aug / 01	22.00	
Aug / 02	63.00	121.00	Aug / 02	24.00	66.00
Sep / 01	67.00		Sep / 01	29.00	
Sep / 02	71.00	138.00	Sep / 02	30.00	59.00
Oct / 01	81.00		Oct / 01	39.00	
Oct / 02	64.00	145.00	Oct / 02	40.00	79.00
Nov / 01	59.00		Nov / 01	45.00	
Nov / 02	53.00	112.00	Nov / 02	40.00	85.00
Dec / 01	48.00		Dec / 01	42.00	
Dec / 02	34.00	82.00	Dec / 02	40.00	82.00

Table 4.66: Monthly Crop Water Requirement for Crops Mango and Cabbage

Month / Fortnight	Mango(A_3)		Month / Fortnight	Cabbage(A_4)	
	Consumptive use ETc mm	Monthly water requirement mm		Consumptive use ETc mm	Monthly water requirement mm
Jan / 01	300.00	600.00	Jan / 01	62.00	127.00
Jan / 02	300.00		Jan / 02	65.00	
Feb / 01	300.00	600.00	Feb / 01	70.00	139.00
Feb / 02	300.00		Feb / 02	69.00	
Mar / 01			Mar / 01		
Mar / 02			Mar / 02		
Apr / 01			Apr / 01		
Apr / 02			Apr / 02		
May / 01			May / 01		
May / 02			May / 02		
Jun / 01			Jun / 01		
Jun / 02			Jun / 02		
Jul / 01			Jul / 01		
Jul / 02			Jul / 02		
Aug / 01			Aug / 01		
Aug / 02			Aug / 02		
Sep / 01			Sep / 01		
Sep / 02			Sep / 02		
Oct / 01			Oct / 01		
Oct / 02			Oct / 02		
Nov / 01			Nov / 01	15.00	45.00
Nov / 02			Nov / 02	30.00	
Dec / 01	300.00	600.00	Dec / 01	36.00	89.00
Dec / 02	300.00		Dec / 02	53.00	

Table 4.67: Monthly Crop Water Requirement for Crops Paddy and Jowar

Month / Fortnight	Paddy(A_5)		Month / Fortnight	Jowar(A_6)	
	Consumptive use ETc mm	Monthly water requirement mm		Consumptive use ETc mm	Monthly water requirement mm
Jan / 01			Jan / 01	27.38	76.14
Jan / 02			Jan / 02	48.76	
Feb / 01			Feb / 01	52.29	100.98
Feb / 02			Feb / 02	48.69	
Mar / 01			Mar / 01	61.11	113.15
Mar / 02			Mar / 02	52.04	
Apr / 01			Apr / 01		
Apr / 02			Apr / 02		
May / 01			May / 01		
May / 02			May / 02		
Jun / 01		73.00	Jun / 01		
Jun / 02	73.00		Jun / 02		
Jul / 01	63.00	124.00	Jul / 01		
Jul / 02	61.00		Jul / 02		
Aug / 01	63.00	130.00	Aug / 01		
Aug / 02	67.00		Aug / 02		
Sep / 01	71.00	144.00	Sep / 01		
Sep / 02	73.00		Sep / 02		
Oct / 01	76.00	76.00	Oct / 01		
Oct / 02			Oct / 02		
Nov / 01			Nov / 01		
Nov / 02			Nov / 02		
Dec / 01			Dec / 01		15.50
Dec / 02			Dec / 02	15.50	

Table 4.68: Monthly Crop Water Requirement for Crops Wheat and Cotton

Month / Fortnight	Wheat(A_7)		Month / Fortnight	Cotton(A_8)	
	Consumptive use ETc mm	Monthly water requirement mm		Consumptive use ETc mm	Monthly water requirement mm
Jan / 01	52.91	100.04	Jan / 01		
Jan / 02	47.14		Jan / 02		
Feb / 01	40.47	85.42	Feb / 01		
Feb / 02	44.95		Feb / 02		
Mar / 01	35.41	35.41	Mar / 01		
Mar / 02			Mar / 02		
Apr / 01			Apr / 01		
Apr / 02			Apr / 02		
May / 01			May / 01		
May / 02			May / 02		
Jun / 01			Jun / 01		14.37
Jun / 02			Jun / 02	14.37	
Jul / 01			Jul / 01	23.57	54.22
Jul / 02			Jul / 02	30.65	
Aug / 01			Aug / 01	44.28	96.17
Aug / 02			Aug / 02	51.89	
Sep / 01			Sep / 01	62.61	135.48
Sep / 02			Sep / 02	72.87	
Oct / 01			Oct / 01	67.64	123.97
Oct / 02			Oct / 02	56.34	
Nov / 01		16.45	Nov / 01	44.51	82.80
Nov / 02	16.45		Nov / 02	38.30	
Dec / 01	24.20	61.83	Dec / 01	15.33	15.33
Dec / 02	37.63		Dec / 02		

Table 4.69: Monthly Crop Water Requirement for Crops Groundnut and Grass

Month / Fortnight	Groundnut(A_9)		Month / Fortnight	Grass(A_{10})	
	Consumptive use ETc mm	Monthly water requirement mm		Consumptive use ETc mm	Monthly water requirement mm
Jan / 01			Jan / 01	150.00	
Jan / 02			Jan / 02	100.00	250.00
Feb / 01	25.87	65.71	Feb / 01	120.00	
Feb / 02	39.85		Feb / 02	130.00	250.00
Mar / 01	73.80	158.71	Mar / 01		
Mar / 02	84.90		Mar / 02		
Apr / 01	72.86	132.14	Apr / 01		
Apr / 02	59.28		Apr / 02		
May / 01	58.17	82.62	May / 01		
May / 02	24.45		May / 02		
Jun / 01			Jun / 01		
Jun / 02			Jun / 02		
Jul / 01			Jul / 01		
Jul / 02			Jul / 02		
Aug / 01			Aug / 01		
Aug / 02			Aug / 02		
Sep / 01			Sep / 01		
Sep / 02			Sep / 02		
Oct / 01			Oct / 01		
Oct / 02			Oct / 02		
Nov / 01			Nov / 01		
Nov / 02			Nov / 02	150.00	150.00
Dec / 01			Dec / 01	140.00	
Dec / 02			Dec / 02	110.00	250.00

These values of monthly water requirement of crops A_1 to A_{10} can be expressed in meters as given in Table 4.70.

Table 4.70 : Monthly Water Requirement of Crops A_1 to A_{10}, m

Month	Sugarcane	Banana	Mango	Cabbage	Paddy	Jowar	Wheat	Cotton	Groundnut	Grass
	(A_1)	(A_2)	(A_3)	(A_4)	(A_5)	(A_6)	(A_7)	(A_8)	(A_9)	(A_{10})
Jan	0.03	0.10	0.60	0.13	0.00	0.08	0.10	0.00	0.00	0.25
Feb	0.09	0.16	0.60	0.14	0.00	0.10	0.09	0.00	0.07	0.25
Mar	0.15	0.20	0.00	0.00	0.00	0.11	0.04	0.00	0.16	0.00
Apr	0.20	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00
May	0.21	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00
Jun	0.18	0.14	0.00	0.00	0.07	0.00	0.00	0.01	0.00	0.00
Jul	0.13	0.05	0.00	0.00	0.12	0.00	0.00	0.05	0.00	0.00
Aug	0.12	0.07	0.00	0.00	0.13	0.00	0.00	0.10	0.00	0.00
Sep	0.14	0.06	0.00	0.00	0.14	0.00	0.00	0.14	0.00	0.00
Oct	0.15	0.08	0.00	0.00	0.08	0.00	0.00	0.12	0.00	0.00
Nov	0.11	0.09	0.00	0.05	0.00	0.00	0.02	0.08	0.00	0.15
Dec	0.08	0.08	0.60	0.09	0.00	0.02	0.06	0.02	0.00	0.25

4.11 EFFECTIVE RAINFALL

Effective rainfall is the useful portion of the rainfall, which is directly available to the root zone and satisfies the crop water needs. Effective rainfall mainly depends on rainfall characteristics, land slope, characteristics of soil, ground water characteristics, deep percolation and consumptive use of the crop.

For this study, indirect method based on evaporation precipitation ratio method, which provides value of effective rainfall by correlating normal monthly rainfall and consumptive use of the month, is used, which is given in Table 4.71.

Table 4.71: Normal Monthly Effective Rainfall as Related to Normal Monthly Rainfall and Average Monthly Consumptive Use

Monthly Normal Rainfall	Average Monthly Consumptive Use, mm													
	25	50	75	100	125	150	175	200	225	250	275	300	325	350
	Normal Monthly Effective Rainfall, mm													
25	15	17	18	18	19	20	21	22	25	25	25	25	25	25
50	25	33	35	36	37	40	41	44	48	50	50	50	50	50
75		47	51	54	56	58	61	65	69	74	75	75	75	75
100		50	65	69	73	75	79	83	88	95	100	100	100	100
125			75	83	89	91	96	102	108	116	123	125	125	125
150				97	104	106	113	120	127	136	144	150	150	150
175				100	117	120	128	136	143	154	166	172	175	175
200					125	131	140	148	158	169	184	191	197	200
225						142	152	162	175	189	200	210	220	225
250						148	164	175	192	206	216	226	236	245
275						150	164	188	205	223	233	242	255	265
300							173	195	215	235	246	258	273	288
325							175	199	220	242	258	275	290	304
350								200	224	245	265	285	303	320
375									225	248	270	292	310	328
400										250	273	296	317	335
425											275	298	320	340
450												300	322	343
475													324	350
525	25	50	75	100	125	150	175	200	225	250	275	300	325	350

Under every branch canal command, there are number of rain gauge stations whose data have been obtained for the year 1999 – 2000. The index map of the area under study is used whereon the location of rain gauge stations given in Plate 8, have been plotted. The procedure for drawing theissen polygon is used for knowing exactly, upto what extent each rain gauge station effects. Then, one can exactly know how much rainfall should be taken into consideration, as the location of rain gauge station and the place through which the minor passes are evident. So, under Navsari branch canal

command area the Satem, Aat and Onjal rain gauge stations are to be considered. The rainfall, at these rain gauge stations are given in Table 4.72.

Table 4.72 : Rainfall in 1999-2000 at Various Rainguage Stations Under Navsari Branch Canal

Month	Rainfall mm		
	Satem	Aat	Onjal
Jun	44.00	700.00	342.50
Jul	495.00	563.00	358.00
Aug	243.00	212.00	96.00
Sep	354.00	372.00	251.00
Oct	32.00	47.00	111.00
Nov	43.00	11.00	0.00

For the present study, effective rainfall is calculated for the months of June to October, as in the remaining months significant rainfall does not occur regularly in the command area.

Consumptive use (ET_C) values are referred from the Table 4.70. Referring this Table, effective rainfall considered for various crops for different months is given in Table 4.73.

Table 4.73 : Effective Rainfall in 1999-2000 for Different Crops

Raingauge Station	Month	Effective rainfall for different crops m			
		Sugarcane	Banana	Paddy	Cotton
Satem	Jun	0.0410	0.0390	0.0350	0.0144
	Jul	0.1290	0.0490	0.1240	0.0542
	Aug	0.1210	0.0660	0.1300	0.0962
	Sep	0.1380	0.0590	0.1440	0.1355
	Oct	0.0260	0.0240	0.0230	0.0250
	Nov	0.0370	0.0360	0.0000	0.0360
Aat	Jun	0.1780	0.1400	0.0730	0.0144
	Jul	0.1290	0.0490	0.1240	0.0542
	Aug	0.1210	0.0660	0.1300	0.0962
	Sep	0.1380	0.0590	0.1440	0.1355
	Oct	0.0400	0.0350	0.0350	0.0370
	Nov	0.0090	0.0080	0.0000	0.0080
Onjal	Jun	0.1780	0.1400	0.0730	0.0144
	Jul	0.1290	0.0490	0.1240	0.0542
	Aug	0.0730	0.0580	0.0730	0.0690
	Sep	0.1380	0.0590	0.1440	0.1355
	Oct	0.0830	0.0700	0.0680	0.0810

Therefore, the net monthly water requirement for crops A_1 to A_{10} considering effective rainfall is given in Table 4.74(a), 4.74 (b) and 4.74 (c).

Table 4.74(a) : Net Monthly Water Requirement, of Crops A_1 to A_{10} Considering Effective Rainfall at Satam

Month	Sugarcane	Banana	Mango	Cabbage	Paddy	Jowar	Wheat	Cotton	Groundnut	Grass
	(A_1)	(A_2)	(A_3)	(A_4)	(A_5)	(A_6)	(A_7)	(A_8)	(A_9)	(A_{10})
Jan	0.0340	0.1040	0.6000	0.1270	0.0000	0.0805	0.1000	0.0000	0.0000	0.2500
Feb	0.0880	0.1590	0.6000	0.1390	0.0000	0.1010	0.0853	0.0000	0.0656	0.2500
Mar	0.1470	0.2030	0.0000	0.0000	0.0000	0.1132	0.0354	0.0000	0.1608	0.0000
Apr	0.2010	0.2330	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1568	0.0000
May	0.2120	0.1990	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1151	0.0000
Jun	0.1370	0.1010	0.0000	0.0000	0.0380	0.0000	0.0000	0.0000	0.0000	0.0000
Jul	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Aug	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sep	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oct	0.1190	0.0550	0.0000	0.0000	0.0530	0.0000	0.0000	0.0990	0.0000	0.0000
Nov	0.0750	0.0490	0.0000	0.0450	0.0000	0.0000	0.0165	0.0468	0.0000	0.1500
Dec	0.0820	0.0820	0.6000	0.0890	0.0000	0.0155	0.0618	0.0153	0.0000	0.2500

Table 4.74(b) : Net Monthly Water Requirement, of Crops A_1 to A_{10} Considering Effective Rainfall at Aat

Month	Sugarcane	Banana	Mango	Cabbage	Paddy	Jowar	Wheat	Cotton	Groundnut	Grass
	(A_1)	(A_2)	(A_3)	(A_4)	(A_5)	(A_6)	(A_7)	(A_8)	(A_9)	(A_{10})
Jan	0.0340	0.1040	0.6000	0.1270	0.0000	0.0805	0.1000	0.0000	0.0000	0.2500
Feb	0.0880	0.1590	0.6000	0.1390	0.0000	0.1010	0.0853	0.0000	0.0656	0.2500
Mar	0.1470	0.2030	0.0000	0.0000	0.0000	0.1132	0.0354	0.0000	0.1608	0.0000
Apr	0.2010	0.2330	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1568	0.0000
May	0.2120	0.1990	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1151	0.0000
Jun	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Jul	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Aug	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sep	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oct	0.1050	0.0440	0.0000	0.0000	0.0410	0.0000	0.0000	0.0870	0.0000	0.0000
Nov	0.1120	0.0850	0.0000	0.0450	0.0000	0.0000	0.0165	0.0748	0.0000	0.1500
Dec	0.0820	0.0820	0.6000	0.0890	0.0000	0.0155	0.0618	0.0153	0.0000	0.2500

Table 4.74(c) : Net Monthly Water Requirement, of Crops A_1 to A_{10} Considering Effective Rainfall at Onjal

Month	Sugarcane	Banana	Mango	Cabbage	Paddy	Jowar	Wheat	Cotton	Groundnut	Grass
	(A_1)	(A_2)	(A_3)	(A_4)	(A_5)	(A_6)	(A_7)	(A_8)	(A_9)	(A_{10})
Jan	0.0340	0.1040	0.6000	0.1270	0.0000	0.0805	0.1000	0.0000	0.0000	0.2500
Feb	0.0880	0.1590	0.6000	0.1390	0.0000	0.1010	0.0853	0.0000	0.0656	0.2500
Mar	0.1470	0.2030	0.0000	0.0000	0.0000	0.1132	0.0354	0.0000	0.1608	0.0000
Apr	0.2010	0.2330	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1568	0.0000
May	0.2120	0.1990	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1151	0.0000
Jun	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Jul	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Aug	0.0480	0.0080	0.0000	0.0000	0.0570	0.0000	0.0000	0.0272	0.0000	0.0000
Sep	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oct	0.0620	0.0090	0.0000	0.0000	0.0080	0.0000	0.0000	0.0430	0.0000	0.0000
Nov	0.0000	0.0000	0.0000	0.0450	0.0000	0.0000	0.0165	0.0000	0.0000	0.1500
Dec	0.0820	0.0820	0.6000	0.0890	0.0000	0.0155	0.0618	0.0153	0.0000	0.2500

4.12 UPPER LIMIT OF THE AREA FOR DIFFERENT CROPS

Depending upon soil characteristics, cropping pattern suggested by the irrigation department, socio – economical considerations and traditions followed in the command area considering feasibility of modifications in cropping pattern and availability of land, maximum designed irrigation intensity of 310% is possible if enough water is available to satisfy the crop water requirement. For the different crops taken in the command area upper limit for each crop is decided, with a consideration of increment of 10 % irrigation intensity.

Actual irrigation intensity achieved in the command area with only surface water application ranges from 10% – 322%. Considering harmonized use of ground water, irrigation intensity can be increased to an optimum. Upper limits for each crop for different irrigation intensities are given in the Table 4.75.

Table 4.75 : Area Allocated to Each Crop, ha for Different Irrigation Intensities for Cropping Pattern of Minors 1 to 7 of Navsari Branch Canal of K.L.B.M.C. Command Area

Minor	Dandeswar								
Irrigation Intensity %	Existing	Designed							
	275	270	260	250	240	230	220	210	200
A_1	151.00	148.25	142.76	137.27	131.78	126.29	120.80	115.31	109.82
A_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_3	11.00	10.80	10.40	10.00	9.60	9.20	8.80	8.40	8.00
A_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_5	845.00	829.64	798.91	768.18	737.45	706.73	676.00	645.27	614.55
A_6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_{10}	274.00	269.02	259.05	249.09	239.13	229.16	219.20	209.24	199.27

Minor	Dandi								
Irrigation Intensity %	Existing	Designed							
	10	10	20	30	40	50	60	70	80
A_1	9.00	9.00	18.00	27.00	36.00	45.00	54.00	63.00	72.00
A_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_3	3.00	3.00	6.00	9.00	12.00	15.00	18.00	21.00	24.00
A_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_5	123.00	123.00	246.00	369.00	492.00	615.00	738.00	861.00	984.00
A_6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_{10}	60.00	60.00	120.00	180.00	240.00	300.00	360.00	420.00	480.00

Minor	Machhad								
Irrigation	Existing	Designed							
Intensity %	50	50	60	70	80	90	100	110	120
A_1	69.00	69.00	82.80	96.60	110.40	124.20	138.00	151.80	165.60
A_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_5	32.00	32.00	38.40	44.80	51.20	57.60	64.00	70.40	76.80
A_6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_{10}	191.00	191.00	229.20	267.40	305.60	343.80	382.00	420.20	458.40

Minor	Onjal								
Irrigation	Existing	Designed							
Intensity %	17	20	30	40	50	60	70	80	90
A_1	7.00	8.24	12.35	16.47	20.59	24.71	28.82	32.94	37.06
A_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_3	7.00	8.24	12.35	16.47	20.59	24.71	28.82	32.94	37.06
A_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_5	157.00	184.71	277.06	369.41	461.76	554.12	646.47	738.82	831.18
A_6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_{10}	54.00	63.53	95.29	127.06	158.82	190.59	222.35	254.12	285.88

Minor	Sadlav Branch								
Irrigation	Existing	Designed							
Intensity %	322	320	310	300	290	280	270	260	250
A_1	165.00	163.98	158.85	153.73	148.60	143.48	138.35	133.23	128.10
A_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_5	1,400.00	1,391.30	1,347.83	1,304.35	1,260.87	1,217.39	1,173.91	1,130.43	1,086.95
A_6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_{10}	304.00	302.11	292.67	283.23	273.79	264.35	254.91	245.47	236.24

Minor	Vachnarvad								
Irrigation Intensity %	Existing	Designed							
	237	240	250	260	270	280	290	300	310
A_1	548.00	554.94	578.06	601.18	624.30	647.43	670.55	693.67	716.79
A_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_3	34.00	34.43	35.86	37.30	38.73	40.17	41.60	43.04	44.47
A_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_5	1,140.00	1,154.43	1,202.53	1,250.63	1,298.73	1,346.84	1,394.94	1,443.04	1,491.14
A_6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_{10}	285.00	288.61	300.63	312.66	324.68	336.71	348.73	360.76	372.78

Minor	Veraval								
Irrigation Intensity %	Existing	Designed							
	312	310	300	290	280	270	260	250	240
A_1	230.00	228.53	221.15	213.78	206.41	199.04	191.67	184.29	176.92
A_2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_3	31.00	30.80	29.81	28.81	27.82	26.83	25.83	24.84	23.85
A_4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_5	765.00	760.10	735.58	711.06	686.54	662.02	637.50	612.98	588.46
A_6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
A_{10}	177.00	175.87	170.19	164.52	158.85	153.17	147.50	141.83	136.15

4.13 LOWER LIMIT OF THE CROP AREA

For the socio – economic needs and conditions prevailed in command area, minimum necessary cultivated area under food grain crop is decided. Considering various socio – economical aspects, for food grain crops, minimum area decided for paddy and grass are given in Table 4.76.

Table 4.76 : Lower Limit for the Crop Area, ha of Minors 1 to 7 of Navsari Branch Canal of K.L.B.M.C. Command Area

Minor	Dandeswar								
Irrigation Intensity, %	Existing	Designed							
	275	270	260	250	240	230	220	210	200
Paddy	126.75	124.45	119.84	115.23	110.62	106.01	101.40	96.79	92.18
Grass	41.10	40.35	38.86	37.36	35.87	34.37	32.88	31.39	29.89

Minor	Dandi								
Irrigation Intensity, %	Existing	Designed							
	10	10	20	30	40	50	60	70	80
Paddy	18.45	18.45	36.90	55.35	73.80	92.25	110.70	129.15	147.60
Grass	9.00	9.00	18.00	27.00	36.00	45.00	54.00	63.00	72.00

Minor Irrigation Intensity, %	Machhad								
	Existing	Designed							
	50	50	60	70	80	90	100	110	120
Paddy	4.80	4.80	5.76	6.72	7.68	8.64	9.60	10.56	11.52
Grass	28.65	28.65	34.38	40.11	45.84	51.57	57.30	63.03	68.76

Minor Irrigation Intensity, %	Onjal								
	Existing	Designed							
	17	20	30	40	50	60	70	80	90
Paddy	23.55	27.71	41.56	55.41	69.26	83.12	96.97	110.82	124.68
Grass	8.10	9.53	14.29	19.06	23.82	28.59	33.35	38.12	42.88

Minor Irrigation Intensity, %	Sadlav								
	Existing	Designed							
	322	320	310	300	290	280	270	260	250
Paddy	210.00	208.70	202.17	195.65	189.13	182.61	176.09	169.57	163.04
Grass	45.60	45.32	43.90	42.48	41.07	39.65	38.24	36.82	35.40

Minor Irrigation Intensity, %	Vachharvad								
	Existing	Designed							
	237	240	250	260	270	280	290	300	310
Paddy	171.00	173.16	180.38	187.59	194.81	202.03	209.24	216.46	223.67
Grass	42.75	43.29	45.09	46.90	48.70	50.51	52.31	54.11	55.92

Minor Irrigation Intensity,%	Veraval								
	Existing	Designed							
	312	310	300	290	280	270	260	250	240
Paddy	114.75	114.01	110.34	106.66	102.98	99.30	95.63	91.95	88.27
Grass	26.55	26.38	25.53	24.68	23.83	22.98	22.13	21.27	20.42