Chapter - 7

Results, Conclusions & Recommendations

7 RESULTS, CONCLUSIONS AND RECOMMENDATIONS

RESULTS

7.1 IMPACT OF CHECK DAMS ON THE STORAGE OF BHADAR RESERVOIR

7.1.1 Bhadar basin

Bhadar basin is the biggest basin in Saurashtra region. Out of seven districts, part of six districts fall in this basin. There are three hydrological divisions of Bhadar basin. The comparison areas are presented in Table 7.1.

Table 7.1 Details of Bhadar (s) Basin

Sr. No.	Details	Bhadar-I	Bhadar-II	Lower Bhadar	Total
1	Topographical area	2467 km^2	2054 km^2	2586 km^2	7076 km^2
5	Average yield Available	193 Mm^3	198 Mm^3	281 Mm^3	673 Mm^3
6	Yield at 50% reliability	177 Mm^3	178 Mm^3	245 Mm^3	593 Mm^3
7	Surface water (utilised)	38 Mm^3	168 Mm^3	202 Mm^3	408 Mm^3
8	Utilisable G. W. Recharge	195 Mm^3	236 Mm^3	238 Mm^3	669 Mm^3
12	Surface water irrigation	9802 ha	14785 ha	14077 ha	38664 ha
13	Ground water irrigation	128711 ha	80087 ha	109287 ha	318085 ha
14	Total irrigation	138513 ha	94872 ha	123364 ha	356749 ha

7.1.2 Bhadar I irrigation scheme

Bhadar I is the major irrigation scheme constructed in 1965, which is situated between Bhadar-I basin and Bhadar-II basin boundary. Its gross storage is 238 Mm^3. There are 188 villages situated in Bhadar-I catchment area. Gujarat State Water Resources Department launched a scheme 'Sardar Patel Sahabhagi Jal Sanchai Yojna' on dated 17.1.2000. The Bhadar-I catchment villages have also constructed 905 number of check dams in last six years. The design storage of the check dams is 18.59 Mm^3. The surface area storage of these check dams is 27.27 Mm^2. Impact of check dams in Bhadar-I storage has been analyzed and additional water receive if there is no check dam scenario is given in Table 7.2

Table 7.2 Additional water received in Bhadar-I reservoir (without check dams)

Week /Month	Qty of stored in check dams (Mm^3)	Check dam water available at Bhadar-I reservoir considering 17 % runoff (Mm^3)	Water available at Bhadar-I reservoir as per new formula (Mm^3)
Year 2003-2004			
3 / June	8.622	1.466	1.000
1 / July	0.865	0.147	0.160
2 / July	3.012	0.512	0.550
4 / July	5.000	0.850	0.920
1 / August	10.575	1.800	1.930
2 / August	3.012	0.510	0.550
Total	**31.086**	**5.285**	**5.11**
Year 2004-2005			
3/June	7.688	1.310	0.890
1/July	0.865	0.150	0.110
1/August	11.380	1.970	1.870
2/August	2.984	0.510	0.490
4 / September	2.225	0.380	0.580
Total	**25.145**	**4.32**	**3.94**
Year 2005-2006			
4 / June	18.587	3.160	2.286
1 / August	15.690	2.670	10.900
2 / September	12.075	2.050	2.790
3 / September	6.512	1.100	0.250
Total	**52.864**	**8.98**	**16.226**

7.1.3 Additional irrigation by check dams water in Bhadar-I command

Increase in irrigation due to check dam water is presented both for the new formula scenario and 17% runoff scenario (Table 7.3). The variation between the two scenarios is marginal except in 2005-06 when it is considerable.

Table 7.3 Check dam Additional Water Impact (New Formula Scenario)

Sr. No.	Year	Actual storage (Mm3)	Actual canal releases (Mm^3)	% of canal release with respect to storage	Actual Irrigation (ha)	Estimated new storage (no check dam condition) adding new formula runoff (Mm^3)	Estimated new canal releases (Mm^3) w.r.t % as per column 5	Estimated New irrigation (no check dam condition) (ha)	Estimated Increase in irrigation by check dam water (ha) (no check dam condition)
1	2003-04	149.453	72.29	48.37	14686	154.5697	74.7651	15188.8	502.82
2	2004-05	99.002	31.304	31.62	5508	102.942	32.5498	5727.2	219.2
3	2005-06	232.244	118.64	51.08	18352	248.473	126.9283	19634.4	1282.42
	Average	: 160.23				168.66 (105%)			668.14

Table 7.4 Additional irrigation in Bhadar command by check dam water (17 % runoff scenario)

Sr. No.	Year	Actual storage (Mm^3)	Actual canal releases (Mm^3)	% of canal release with respect to storage	Actual irrigation (ha)	Estimated new storage (no check dam condition) adding new formula runoff (Mm^3)	Estimated new canal releases (Mm^3) w.r.t % as per column 5	Estimated new irrigation (no check dam condition) (ha)	Estimated increase in irrigation by check dam water (ha) (no check dam condition)
1	2003-04	149.453	72.29	48.37	14686	154.7377	74.8464	15205.33	519.33
2	2004-05	99.002	31.304	31.62	5508	103.32	32.67	5748.34	240.34
3	2005-06	232.244	118.64	51.08	18352	241.224	123.2253	19061.6	709.60
	Average	: 160.23				166.43 (104%)			489.75

As seen from the above the average reduction in Bhadar-I storage due to check dams is only 5% and average reduction in irrigation is 668 ha.

7.1.4 Abstract of additional irrigation due to check dam water in Bhadar-I command

From the analysis of the data obtained from the Irrigation Department field offices, the benefits of 7498 wells because of 905 check dams are quite evident (Table 7.5 and Table 7.6).

Table 7.5 Additional irrigation area potential in check dams vicinity

Sr. No.	Year	Total storage in check dams (Mm^3)	Evaporation losses in check dams (Mm^3)	Net utilization of check dams Storage (Mm^3)	Area irrigated by check dams (ha)	Protective irrigation (ha) (two waterings)
1	2003	31.086	7.633	23.453	5746	11720
2	2004	25.142	5.996	19.226	4710	9600
3	2005	52.864	12.37	40.49	9921	20240
	1. Duty 245 ha/ Mm^3 for five waterings					
	2. Duty 500 ha/ Mm^3 for two waterings					

Table 7.6 gives area irrigated with check dams water and area irrigated without check dam.

Table 7.6 Area irrigated

Year	Check dam irrigation (ha)	Canal command irrigation (ha)
2003-04	5746	520
2004-05	4710	240
2005-06	9921	1282
Average	6792	680

The above results indicate that the average area of irrigation through check dams water is 6792 ha against reduction 680 ha in average irrigation in Bhadar-I command.

7.2 IMPACT OF CHECK DAMS ON SEDIMENTATION IN BHADAR RESERVOIR

Impact of check dams on sedimentation in Bhadar reservoir through years 1965 to 2004 is presented in Table 7.7. Between 1965 and 1986, the loss in reservoir capacity was maximum as corroborated by silt rate. In later years, there had been reduction in silt rates and also in losses of reservoir capacity because of interception by check dams. The design silt rate was 3.57 ha.m/ 100 km^2 /year. The actual silt rate was 7.085 ha.m/ 100 km^2 /year. Which was reduced to 3.717 ha.m/ 100 km^2 /year after construction of check dams in catchment.

Table 7.7 Year wise sedimentation of Bhadar-I reservoir

Sr. no	Year of survey	Capacity (Mm^3)			Loss in Capacity (Mm^3)			Silt rate (ham./ 100 km^2 /year)	Annual % loss
		Dead	Live	Gross	Dead	Live	Gross		
1.	1965 (Original)	14.16	223.70	237.86	-	-	-	3.57	-
2.	1986 (DBS)	1.27	199.09	200.36	12.89	24.61	37.50	7.085	0.72
3.	2000 (DBS) (FRL107.90m)	0.226	187.814	188.04	13.93	35.89	49.82	5.752	0.58
4.	2004 (FRL106.46 m)	0.327	145.983	147.31	13.833	18.697	32.53	3.379* 4.25**	0.455
5.	2004 (FRL 107.90m)	0.327	201.753	202.08	13.83	21.95	35.78	3.717	0.376

Note :-

* Without considering interception of 460 km^2 C.A. of check dams.

** With considering interception of 460 km^2. C.A. of check dams.

Taluka wise impact of check dams for the year 2005 is presented in Table 7.8. In general, the check dams were effective in interception of sediments but there were variations among the talukas which is understandable due to presumed differently in soil and other erosive parameters.

Table 7.8 Talukawise sedimentation in check dams in Bhadar basin (Year 2005)

Sr. No	Name of village	Nos. of check dam	Catch ment area (km^2)	Initital storage capacity (m^3)	Storage capacity at the time of survey (m^3)	Sedime ntation (m^3)	Year for impoun ding	Siltation (m^3/year)	% Sedim entati on /year
1	2	3	4	5	6	7	8	9	10
	Taluka Gondal								
1	Gondal	12	7.79	259740	253800	5940	2002	1980	0.76
2	Ghoghavadar	7	0.67	22400	21812	588	2003	294	1.31
3	Devchadi	4	1.07	35712	34902	810	2004	810	2.27
4	Moviya	11	1.89	63140	60665	2475	2003	1237.5	1.96
5	Shrinathghadh	7	0.65	21560	21140	420	2000	84	0.39
6	Karmadhiya	3	12.96	431883	431545.5	337.5	2004	337.5	0.08
7	Deradi	9	1.51	50400	49738.5	661.5	2000	132.3	0.26
	Taluka Kotada Sanghani								
8	Ardoi	3	0.63	21000	20892	108	2003	54	0.26
9	Kotada Sanghani	12	15.12	504000	502650	1350	2000	270	0.05
10	Ramod	13	19.5	650000	645125	4875	2000	975	0.15
11	Satapara	21	31.5	1050000	944412	105588	2003	52794	5.03
	Taluka Jasdan								
12	Juna Pipadiya	18	2.16	72000	66600	5400	2000	1080	1.50
	Total	**120**	**95.45**	**3181835**	**3053282**	**128553**		**60048.3**	
Total Bhadar Catchment		**905**	**567**	**18590000 m^3 18.59 Mm^3**	**17620000 m^3 17.62 Mm^3**	**970000 m^3 0.97 Mm^3**		**0.4563 Mm^3/ year**	**2.45 %**

The average sedimentation Rate in check dams is 6.16 ha.m/100 km^2/year. Due to interception of silt in check dams, the siltation in Bhadar-I reduced. Removal of silt from check dams is easy compared to silt removal from Bhadar reservoir.

7.3 RESULTS OF COMPARISON OF EVAPORATION LOSSES IN CHECK DAMS WITH BHADAR RESERVOIR

Evaporation losses in Bhadar-I reservoir are presented in Table 7.9. While the trend of proportionality is apparent between the total yield and the evaporational loss, the magnitude of evaporational loss has been relatively larger with the lower yield level of the reservoir as in the year 2004-05. In case of the other losses (Table 7.10), there was a reversed trend.

Table 7.9 Evaporation loss in Bhadar-I reservoir

Sr. No.	Year	Total yield in reservoirs (Mm^3)	Evaporation losses (Mm^3)	% of evaporation losses relative to total yield
1	2002-03	164.91	45.23	27.42
2	2003-04	149.45	42.0267	28.12
3	2004-05	99.02	33.105	33.44
4	2005-06	232.24	60.70	27.14
	Average	161.40	45.26	28.05

Table 7.10 Analysis of other losses (i.e. losses in gate leakage, filter etc.)

Sr. No.	Year	Losses (Mm^3)
1	2002-03	15.45
2	2003-04	9.87
3	2004-05	8.52
4	2005-06	15.48
Average		12.33 Mm^3/year

7.3.1 Evaporation Losses in Check dams

There are 905 check dams in Bhadar catchment. The surface area of these check dams is 27.27 Mm^2. The evaporation losses in these check dams for the year 2003-04 to year 05-06 are analysed and results are presented in Table 7.11.

Table 7.11 Evaporation losses in check dams

Sr. No.	Year	Total storage in check dam (Mm^3)	Total evaporation losses (Mm^3)	% losses
1	2003-04	31.086	7.633	24.55
2	2004-05	25.142	5.916	23.53
3	2005-06	52.864	12.37	23.40
	Total	37.364	8.64	23.76

The results show that the evaporation losses in Bhadar dam are more compared to that in check dams. Further, the other losses in Bhadar dam due to leakages are 12.33 Mm^3/year. Hence, the total losses every year in Bhadar reservoir are 57.59 Mm^3. The bottom bed of Bhadar reservoir is already silted below RL 97.5 m. There is no significant ground water recharge due to this siltation. In case of check dams even after evaporation losses, 75% water percolates as ground water recharge.

7.4 FLOOD ROUTING OF BHADAR DAM DUE TO CHECK DAMS IN CATCHMENT

Flood reports of Bhadar reservoir of various years have been analyzed. It is seen that there was a flood in Bhadar reservoir in June 2002 because of 250 mm rainfall in the catchment. Similar type of rainfall was received in catchment in June 2005. Relevant data are presented in Table 7.12 and Table 7.13.

Table 7.12 Weekly rain fall in June-2002 (mm)

Rain gauge station	June-I	June-II	June-III	June-IV	Total June
Adiya	0	0	25	144	**169**
Amarnagar	0	0	0	296	**296**
Bhadar-I	0	7	0	263	**270**
Gondali	0	25	0	260	**285**
Ishvariya	0	19	14.5	381.5	**415**
Jasdan	0	7	8	190	**205**
K.Sanghani	0	0	8	219	**227**
Kamadhia	0	36	0	403	**439**
Rajwadala	0	0	12	133	**145**
Vachhapari	0	40	0	217	**257**
Total	**0**	**134**	**68**	**2507**	**2708**
Average	**0**	**13**	**7**	**251**	**271**

Table 7.13 Weekly rain fall in June-2005 (mm)

Rain gauge station	June-I	June-II	June-III	June-IV	Total June
Adiya	0	0	70	275	**345**
Amarnagar	0	10	67	212	**289**
Bhadar-I	0	0	14	248	**262**
Gondali	0	0	105	280	**385**
Ishvariya	0	0	5	347	**352**
Kamadhia	0	0	3	237	**240**
Rajwadala	0	0	85	250	**335**
Vachhapari	0	0	77	173.5	**250.5**
Total rainfall	**0**	**10**	**426**	**2023**	**2459**
Average	**0**	**1**	**47**	**225**	**273**

The Bhadar reservoir scenario for both these years has been analyzed and the results are presented in Table 7.14, Table 7.15 and Table 7.16.

Table 7.14 Water release from spillway in June-2002

Month & Fort-night	Reservoir level beginning (m)	Reservoir level end (m)	Capacity at beginning (Mm^3)	Capacity at end (Mm^3)	Difference of capacity (Mm^3)	Canal releases (Mm^3)	Water supply (Mm^3)	Flow over the spillway (Mm^3)	Evaporation losses (Mm^3)	Run off (Mm^3)
Jun1 2002	96.50	97.840	0.0734	0.707	0.6336				0.0646	0.6983
Jun2 2002	97.84	107.29	0.7070	161.734	161.027		0.046	**130.28**	1.7505	**293.10**

Table 7.15 Water release from spillway in June-2005

Month & Fort-night	Reservoir level beginning (m)	Reservoir level end (m)	Capacity at beginning (Mm^3)	Capacity at end (Mm^3)	Difference of capacity (Mm^3)	Canal releases (Mm^3)	Water supply (Mm^3)	Flow Over the spillway (Mm^3)	Evapo-ration losses (Mm^3)	Run off (Mm^3)
Jun1 2005	99.30	98.900	5.162	3.3110	-1.8510		1.160	-	0.472	
Jun2 2005	98.90	105.95	3.311	112.566	109.255		1.140	-	1.670	**112.07**

Table 7.16 Flood routing in June 2005

	Average rainfall (mm)	Quantity of water received (Mm^3)	Spillway water (Mm^3)	Initial storage (Mm^3)
Year June 2002	271	293	130.28	0.70
Year June 2005	273	112	---	3.31

Table 7.17 Rise of Ground Water Level in Catchment of Bhadar

Sr. No.	Bhadar catchment taluka	District	Ground water level rise in October 2002 (m)	Ground water level rise in October 2005 (m)
1	Gondal	Rajkot	3.83	10.31
2	Jasdan	Rajkot	1.39	11.34
3	Kotda Sangani	Rajkot	3.05	8.67
4	Rajkot	Rajkot	4.81	10.63
5	Babra	Amreli	7.34	14.46
6	Kunkavav	Amreli	4.30	11.04
		Average	**4.12**	**11.08 (268%)**

The results show that there is similar rainfall in June 2002 and June 2005. Even though there was flood in Bhadar-I during June 2002 and 130.28 Mm^3 water was released. However in June 2005, there was no flood release from Bhadar-I. There is 11.08 m ground water rise in October 2005, where as in October 2002 the ground water rise is only 4.12 m.

7.5 CHECK DAMS IN GROUND WATER RECHARGE IN THE CATCHMENT OF BHADAR DAM

The catchment area of Bhadar dam is 2436 km^2. There are 4 talukas viz. Gondal, Jasdan, Rajkot & Kotdasangani in Rajkot Dist and Babra & Kukavav Taluka in Amreli Dist & very small portion of Chotila taluka of Surendranagar Dist. The total basin is highly weathered and fractured in top 30 to 40 m depth. In Bhadar catchment, 905 check dams have been constructed between year 2000 to year 2006. The ground water level and recharge estimation of six talukas for the year 1997 as well as for the year 2006 in the entire Bhadar catchment area has been presented in Table 7.17 and Table 7.18.

Table 7.18 Ground water recharge for year 1997 & year 2006

Sr. No.	Taluka	Geographical area (km^2)	Area falling in Bhadar basin (km^2)	Gross recharge for entire taluka (Mm^3)		Gross Recharge for area falling in Bhadar basin (Mm^3)	
				1997	2006	1997	2006
1.	Jasdan	1321	495	118	254	94	96
2.	Gondal	1193	683	135	257	77	147
3.	Kotadasangani	447	326	58	62	42	45
4.	Rajkot	1005	146.50	108	222	16	32
5.	Kunkavav	546	400	124	84	91	62
6.	Babra	793	375	92	94	43	44
Total		**5304**	**2425**	**635**	**973**	**313**	**426**

The details of average rainfall of the year 1991 to year 1997 & year 2003 to year 2006 & annual draft are given in Table no.7.19 and 7.20.

Table 7.19 Average rainfall of year 1997 & 2006.

Sr. No.	Taluka	Total rainfall (mm)		Weighted average rainfall (mm)	
		1997	2006	1997	2006
1.	Gondal	678	628	193	177
2.	Rajkot	595	882	36	53
3.	Jasdan	509	662	104	135
4.	Kotadasangani	625	681	84	92
5.	Babra	489	754	75	116
6.	Kankavav	596	677	98	111
Total				**590 mm**	**685 mm (16%)**

Table 7.20 Details of annual draft

Annual draft (Mm^3)		Taluka wise draft (Mm^3)		For area falling within Bhadar-I basin (Mm^3)	
Sr. No.	**Taluka**	**1997**	**2006**	**1997**	**2006**
1.	Gondal	81	69	46	40
2.	Rajkot	61	111	9	16
3.	Jasdan	73	96	27	36
4.	Kotadasangani	29	45	21	33
5.	Babra	40	53	19	25
6.	Kankavav	68	41	50	30
Total		**352**	**415**	**172**	**415**

It can be seen from the above that the taluka wise ground water recharge for 1997 was 635 Mm^3. In the year 2006, the ground water recharge in all these 6 talukas was 973 Mm^3. The ground water recharge exclusively by in Bhadar catchment for all the 6 talukas has been analyzed and it is seen that in the year 1997, the ground water recharge in Bhadar catchment is 313 Mm^3, whereas in the year 2006, the ground water recharge is 426 Mm^3. Hence because of check dams, the ground water recharge has increased by 36% in year 2006 compared to that in year 1997 (rainfall 16% more).

It can be seen from the above data that the average rainfall of the year 2006 is 685mm whereas for the year 1997 is 590 mm. 16% more rainfall occurred in year 2006 whereas there is 36% increase in the ground water recharge in the year 2006. The ground water utilization in 2006 is 415 Mm^3, where as in 1997 it is 172 Mm^3. hence there is 243 Mm^3 more water used in irrigation, the estimated increase ground water irrigation is 60000 ha.

7.6 IMPACT OF CHECK DAMS ON GROUND WATER REGIME OF VARIOUS TALUKAS OF RAJKOT DISTRICT

Taluka wise data for years 1997, 2002 and 2006 are presented with respect to average rainfall (Table 7.21), check dams (Table 7.22), water table rise (Table 7.23), total ground water recharge (Table 7.24) and total ground water draft (Table 7.25). Summary of results for Rajkot district as a whole is presented in Table 7.26. Comparison of results has been presented for most benefited talukas and less benefited talukas (Table 7.27, Table 7.28 and Table 7.29)

Table 7.21 Taluka wise average rainfall (mm) of three different years scenario

Sr. No.	Taluka	1991-1997 average	1998-2002 average	2003-2006 average
1	Rajkot	595	406	882
2	Wankaner	465	310	514
3	Gondal	678	445	628
4	Jasdan	624	505	730
5	Paddhari	460	320	618
6	Jetpur	588	399	679
7	Upleta	583	512	850
8	Morbi	496	340	754

Sr. No.	Taluka	1991-1997 average	1998-2002 average	2003-2006 average
9	Kotada Sangani	625	483	681
10	Lodhika	558	428	692
11	Jam Kandorana	509	467	663
12	Dhoraji	556	459	764
13	Tankara	Part of Morbi	282	507
Rajkot District		561	422	705
% with respect to year 1997		-	**75 %**	**125 %**

Table 7.22 Taluka wise details of check dams over years

Sr. No.	Taluka	Year 1997	Year 2002	Year 2006
1	Rajkot	47	532	634
2	Wankaner	29	417	630
3	Gondal	49	357	522
4	Jasdan	39	414	450
5	Paddhari	38	280	399
6	Jetpur	23	287	361
7	Upleta	19	120	307
8	Tankara	-	248	275
9	Morbi	39	191	231
10	Kotada Sangani	28	166	222
11	Lodhika	35	185	219
12	Jam Kandorana	24	138	178
13	Dhoraji	14	125	165
14	Maliya	0	50	77
Total		**308**	**2561**	**3406**

Table 7.23 Average rise in water level (WTF) in various talukas

Sr. No.	Taluka	1991 to 1997 average	1998 to 2002 average	2003 to 2006 average
1	Rajkot	4.31	4.29	8.81
2	Wankaner	3.62	4.25	7.33
3	Gondal	5.33	4.12	8.23
4	Jasdan	3.46	2.97	8.37
5	Paddhari	4.80	4.19	12.3
6	Jetpur	5.35	2.84	7.98
7	Upleta	4.4	3.29	6.94
8	Morbi	3.73	2.39	3.29

Sr. No.	Taluka	1991 to 1997 average	1998 to 2002 average	2003 to 2006 average
9	Kotada Sangani	6.14	4.09	6.60
10	Lodhika	5.00	3.37	10.59
11	Jam Kandorana	4.70	4.14	7.17
12	Dhoraji	5.43	2.45	9.87
13	Tankara	Part of Morbi	3.94	5.79
	Average	**4.69**	**3.56**	**7.94**
	%		**76%**	**170%**

Table 7.24 Taluka wise total ground water recharge over years (Mm^3)

Sr. No.	Taluka	1997	2002	2006
1	Rajkot	108.09	106.91	215.27
2	Wankaner	108.05	133.03	134.80
3	Gondal	152.49	127.49	217.00
4	Jasdan	117.50	114.30	251.67
5	Paddhari	79.37	81.45	194.16
6	Jetpur	113.92	75.72	130.51
7	Upleta	111.14	117.39	154.35
8	Kotada Sangani	57.60	57.14	75.37
9	Lodhika	44.17	39.59	98.76
10	Jam Kandorana	79.08	79.08	95.68
11	Dhoraji	55.35	55.89	128.05
12	Morbi	120.05	111.41	138.92
13	Tankara	Part of Morbi	81.80	103.08
	Total	**1146.81**	**1181.20**	**1937.62**
	%		**103%**	**169%**

Table 7.25 Taluka wise total draft (Mm^3)

Sr. No.	Taluka	1997	2002	2006
1	Rajkot	60.62	53.01	91.70
2	Wankaner	57.00	69.72	80.92
3	Gondal	80.80	105.79	62.17
4	Jasdan	73.07	71.31	88.59
5	Paddhari	50.97	52.59	89.80
6	Jetpur	59.57	44.21	45.21
7	Upleta	67.72	78.91	75.71
8	Morbi	72.62	64.34	72.33
9	Kotada Sangani	29.15	33.26	43.25

Sr. No.	Taluka	1997	2002	2006
10	Lodhika	27.63	28.5	56.57
11	Jam Kandorana	50.53	51.2	40.72
12	Dhoraji	55.26	35.93	63.04
13	Tankara	-	37.77	57.07
	Total	**684.94**	**726.54**	**867.08**
	%		**106%**	**127%**

Table 7.26 Average rainfall, WTF, and impact of check dams results in Rajkot district over years

Rajkot district	**1997**	**2002**	**2006**
Average rainfall (mm)	561	422	705
Check dams (Nos.)	384	3510	4670
Average water table fluctuation (WTF) (m)	4.69	3.56	7.94
Monsoon recharge (Mm^3)	954	944	1707
Total ground water recharge (Mm^3)	1147	1187	1937
Total ground water draft (Mm^3)	685	726	867
% ground water draft v/s recharge	59 %	61 %	45 %
% total recharge with respect to total recharge of 1997	-	103 %	168 %
% monsoon recharge v/s monsoon recharge of 1997	-	98 %	179 %
% average rainfall with v/s average rainfall in 1997	-	75 %	126 %
% check dams v/s check dams of 1997	-	831 %	1105 %
% water table fluctuation v/s water table fluctuation of 1997	-	76 %	170 %

Table 7.27 Comparison of taluka wise benefited in ground water recharge due to check dams in most benefited talukas

Details	**Rajkot taluka**	**Wankaner taluka**	**Gondal taluka**
Check dams in Year 2006 (Nos)	**634**	**630**	**522**
Average rainfall in 2006 (mm)	882	514	628
% rainfall in 2006 v/s 1997	148 %	110 %	92 %
% water table fluctuation (WTF) in 2006 v/s 1997	204 %	202 %	154 %

% ground water recharge in 2006 v/s 1997	199 %	124 %	142 %
% ground water draft in 2006 v/s 1997	151 %	141 %	77 %

Table 7.28 Comparison of talukas less benefited in ground water recharge in less benefited talukas (Mm^3)

Ground water recharge Year	Jetpur taluka	Kotda Sangani taluka	Jam Kandorana taluka
1997	113.92	57.60	79.08
2002	75.72	57.14	79.08
2006	130.51	75.37	95.68

Table 7.29 Comparison of results of talukas less benefited

Details	Jetpur taluka	Kotda Sangani taluka	Jam Kandorana taluka
Average rainfall in 2006 (mm)	673	681	663
Average rainfall in 1997 (mm)	588	625	509
% rainfall in 2006 v/s 1997	115 %	108 %	130 %
Check dams in 2006 (Nos)	361	222	178
Check dams in 1997 (Nos)	23	28	24
% check dams in 2006 v/s 1997	1570 %	792 %	741 %
Average water table fluctuation (WTF) in 2006 (m)	7.98	6.60	7.17
Average water table fluctuation (WTF) in 1997 (m)	5.35	6.14	4.70
% water table fluctuation (WTF) in 2006 v/s 1997	149%	107%	152%
Total ground water recharge in 2006 (Mm^3)	130.51	75.37	95.68
Total ground water recharge in 1997 (Mm^3)	113.92	57.60	79.08
% total ground water recharge in 2006 v/s 1997	115%	131%	121%
Total ground water draft in 2006 (Mm^3)	45.21	43.25	40.72
Total ground water draft in 1997 (Mm^3)	59.57	29.15	50.53
% Total ground water draft 2006 v/s 1997	49 %	148 %	80 %

The rainfall increased in year 2006 is 25% with respect to year 1997. However the WTF rises is 70% and ground water recharge is also 70% increased. Ground water recharge impact of check dams in Rajkot, Wankaner and Jasdan is more. In case of Jetpur, Kotda Sangani and Jam Kandorna had less impact.

7.7 IMPACT OF CHECK DAMS ON CROP YIELD & PRODUCTION

Area, production and yield of crops are presented in Table 7.30. While the data show wide variations among the years particularly in respect of crop yield and production, they have been averaged in two groups; (i) 1998 to 2003, and (ii) 2003 to 2005 to bring out the impact of check dams since most of the check dams were constructed by the year 2003.

Compared to the pre-check dam years average to the post-check dam years average, there were remarkable increase in the latter, in crop yields of ground nut (2.78 times) and cotton (3.87 times) which were aptly reflected correspondingly in crop production of ground nut (2.67 times) and cotton (4.35 times). The increases in crop productions were largely mediated through the increases in crop yields, since the differences in crop areas were relatively marginal.

Table 7.30 Area, production & yield of crops from year 1998-99 to 2004-05 (groundnut and cotton)

Sr. No.	Year	Area ('00 ha)	Production ('00 tons)	Yield (ton / ha)
GROUNDNUT				
1	1998-1999	4133	5148	1.25
2	1999-2000	4090	270	0.07
3	2000-2001	3748	218	0.06
4	2001-2002	3919	4958	1.27
5	2002-2003	4191	530	0.13
	Average	**4016**	**2225**	**0.56**
1	2003-2004	3707	8583	2.32
2	2004-2005	4202	3307	0.79
	Average	**3955**	**5945**	**1.56**

COTTON				
1	1998-1999	1612	6105	3.79
2	1999-2000	1510	2357	1.56
3	2000-2001	1777	691	0.39
4	2001-2002	1831	2112	1.15
5	2002-2003	1720	690	0.4
	Average	**1690**	**2391**	**1.46**
1	2003-2004	1681	10118	6.02
2	2004-2005	2028	10683	5.27
	Average	**1855**	**10401**	**5.65**

7.8 GROUND WATER QUALITY IN RAJKOT DISTRICT (MAY-2006)

The ground water quality data assessed in terms of TDS, ALK, HDs, NO_3 and F are presented in Table 7.31. The data reflect an improvement in ground water quality of the villages where the check dams are constructed.

Table 7.31 Chemical analysis data of the water samples collected by GWSSB

Sr. No	Village	Taluka	Ground water quality				
			TDS (PPM)	Al K (PPM)	HDs (PPM)	NO_3 (PPM)	F (PPM)
1	Mahika	Wankaner	1460	400	440	17.72	1.2
2	Sartanpar	Wankaner	1290	160	400	70.88	1.4
3	Pipali	Morbi	2740	280	1000	8.6	0.2
4	Luntavadar	Morbi	510	200	280	0	0.4
5	Jasapar	Maliya	2840	480	1080	17.72	0.1
6	Khirai	Maliya	974	320	240	14.18	1.4
7	Lajai	Tankara	2540	160	800	3.54	0.1
8	Mitana	Tankara	500	200	240	14.18	0.1
9	Gauridad	Rajkot	620	160	200	1.77	0.1
10	Kasturba Dham	Rajkot	1310	200	600	3.14	0.1
11	Nyara	Paddhari	460	160	240	8.86	0.2
12	Khamta	Paddhari	590	280	200	0.89	1.2
13	Atkot	Jasdan	1580	400	400	70.88	1.4
14	Hingolgadh	Jasdan	1780	200	720	0.89	0.1
15	Mekha Timbi	Upleta	2008	640	640	0.89	0.2
16	Arni	Upleta	530	600	200	1.77	0.2
17	Supedi	Dhoraji	5410	240	1760	17.72	0.4
18	Jamnavad	Dhoraji	1200	280	320	17.72	0.4
19	Jetalsar	Jetpur	1814	260	680	70.88	0.2
20	Virpur	Jetpur	700	240	200	17.72	0.4
21	Khajurda	Jam	520	120	280	70.88	0.2

Sr. No	Village	Taluka	Ground water quality				
			TDS (PPM)	Al K (PPM)	HDs (PPM)	NO_3 (PPM)	F (PPM)
		Kandorana					
22	Dholidhar	Jam Kandorana	2478	280	1160	88.6	0.2
23	Dahiya	Gonadal	1640	200	600	17.72	0.2
24	Moviya	Gonadal	2270	600	720	53.16	0.2
25	Bhadva	Kotda Sanghani	2136	120	800	17.72	0.4
26	Nani Menghni	Kotda Sanghani	780	280	400	17.72	0.2
27	Pardi	Lodhika	830	120	300	14.18	0.2
28	Khirsara	Lodhika	860	240	200	17.72	0.2

CONCLUSION

The data presented in Table 7.32 indicate that the average water stored in 905 check dams is only 2.33% (average of 1.87%, 1.86% and 3.71%) of the total quantity of rain water in Bhadar catchment area.

Table 7.32 Comparison of total rainwater in catchment area of Bhadar-I project with water stored in check dams

Details	Year 2003	Year 2004	Year 2005
Average rainfall (mm)	670	546	673
Quantity of rainwater in Bhadar catchment (Mm^3)	1657	1351	1665
Water stored in Check dams (Mm^3)	31.08	25.14	52.86
% of water stored in check dams with respect to total rainfall.	1.87	1.86	3.71

From the results presented in Table 7.33, it can be concluded that the average water stored in the check dams, average water overflown from the check dams is 1 : 2.37, which indicate that the check dams intercept only a small fraction of the total runoff of a catchment area.

Table 7.33 Quantity of water stored and overflown from check dams

Details	Year 2003	Year 2004	Year 2005	Total
Quantity of water stored in check dams (Mm^3)	31.08	25.14	52.86	109.09
Quantity of water over flown from check dams (Mm^3)	81.949	44.145	132.91	259.00

From the results presented in Table 7.34, it can be concluded that the impact of check dams constructed in the catchment area of Bhadar-I reservoir in lowering the yield of Bhadar-I reservoir is limited to only 3% to 7%.

Table 7.34 Comparison of water stored in check dams with yield of Bhadar-I reservoir

Details	Year 2003	Year 2004	Year 2005
Quantity of water stored in check dams (Mm^3)	31.08	25.14	52.86
Additional maximum quantity of water if stored in Bhadar reservoir without check dams (Mm^3)	5.285	4.32	16.226
Total yield of Bhadar-I reservoir (Mm^3)	149.45	99.02	232.24
% of check dam water with respect to yield of Bhadar-I reservoir	3.53	4.36	6.98

The average area of irrigation in command area for the Bhadar-I project of last three years is 12848 ha, without check dams scenario (Table 7.35). The estimated maximum additional irrigation in the command of Bhadar-I project with the use of water stored in the check dams is 680 ha. i.e. 5.30% of average irrigation of 12848 ha, whereas the estimated average minimum irrigation due to check dams is 6792 ha. Thus it can be concluded that the check dams can cover about 10 times area compared to the area irrigated by the use of the same quantity of water through the reservoir in the command area of Bhadar-I project.

Table 7.35 Irrigation due to check dams

Details	Year 2003	Year 2004	Year 2005	Average of 3 year
Actual irrigation in command of Bhadar-I project (ha)	19686	5508	18352	14515
Estimated maximum additional irrigation in command of Bhadar-I project with use of water stored in check dams (ha)	520	241	1283	680
Groundwater Potential due to check dams (Mm^3)	23.45	19.23	40.49	28
Estimated minimum irrigation due to check dams (ha)	5746	4710	9921	6792

- The dead storage of Bhadar-I reservoir was designed for 42 years. The dam was completed in year 1965. The average silt per year was estimated as 0.37 Mm^3 / year and accordingly, provision of dead storage of 14.16 Mm^3 was kept with sill at R.L. 97.54 m in design. In year 2007, i.e. after 42 years of operation of reservoir, actual siltation is observed as 35.78 Mm^3 against estimated volume of silting of 14.16 Mm^3. Thus the actual siltation in the reservoir is about 2.5 times higher than the estimated.

- Due to silt entrapped in check dams, the siltation rate of Bhadar-I reservoir has reduced to 3.717 ha./100 sq.km./year in year 2004 against observed silt rate of 5.756 ha./100 sq.km./year. As per sedimentation survey conducted in the year 2000. The result leads to/conclude that the construction of small check dams in the catchment area of an irrigation project plays a very important role in enhancing the life of irrigation projects.

- The result analysis indicates that siltation also occurred in live storage of Bhadar-I reservoir and its volume was 24.61 Mm^3 which is twice the volume of dead storage (12.89 Mm^3).

- The total yield in Bhadar-I reservoir for year 2003-04 to year 2005-06 is 480.71 Mm^3. The water is actually used for irrigation and drinking purpose. The irrigation water released for the above mentioned three years was 72.29 Mm^3 , 31.304 Mm^3 and 51.08 Mm^3 respectively i.e. total release of 154.67 Mm^3 for irrigation and release for water supply purpose was 25.26 Mm^3, 26.07 Mm^3 and 22.19 Mm^3 respectively i.e. total release of 73.52 Mm^3 for domestic supply. Hence from Bhadar-I reservoir in three years, out of 480.71 Mm^3 of water yield, the water actually utilized is 228.19 Mm^3 (48%). Remaining water is lost (52%) due to evaporation (136.83 Mm^3) and other losses (116.69 Mm^3.) Whereas the losses in check dams is only due to evaporation which is about 23.76% only, the actual utilization of water in check dams for irrigation / domestic purpose is 76.24% ,which is higher than 48% utilization in dam. This reveals that even though the evaporation loss in the check dams is not substantially less than that in the large reservoir, overall benefits of storage of water in underground reservoir is far better.

- From the analysis of rain water, runoff and flood for June 2002 & June 2005, it can be concluded that the check dams can route the flood partially. Further with the same quantity of flood water, if stored in check dams, the groundwater recharge will be increased. Hence, it is concluded that the check dams convert the surface water runoff / flow to groundwater flow which benefits environmentally to a wider area compared to surface flow in small river width.

- The results of total groundwater recharge of year 1997 (without check dams) and that of year 2006 with check dams clearly suggest that the recharge of year 2006 is increased by 36% whereas the rainfall was only 16% more.

- Due to check dams, average 6.19 Mm^3 quantity of water is reduced in Bhadar reservoir. However, groundwater potential has increased by 62 Mm^3 (assume same rainfall year 1997 - year 2006). This leads to suggest that the check dams actually enhances the total water resources of the entire Bhadar Basin.

Table 7.36 Groundwater estimation of Rajkot district

Details	Year 1997	Year 2002	Year 2006
Average rainfall (mm)	561	422	705
Check dams (nos)	384	3560	4670
Total ground water recharge (Mm^3)	1147	1187	1937
Average water table rise (m)	4.69	3.56	7.94

- The results presented in Table 7.36 clearly indicate that the rate of groundwater recharge is increased due to check dams. The results also suggest that there was 40 Mm^3 of more ground recharge in bad year 2002 compared to that of good year 1997, which benefited farmers at the right moment, when rain water had reduced considerably in year 2002. This is one safety net among others for protective irrigation of kharif crops to poor farmers.

The ground water recharge for the year 2006 was 1937 Mm^3 which is 790 Mm^3 more than that of year 1997. Considering the duty of ground water irrigation as 245 ha/Mm^3, estimated additional irrigation would be about 1.70 lakh ha. Hence, the check dams appear to be the real crisis management tools for kharif crops protection.

Further rise in watertable due to recharge of check dams enhances the discharge / HP and saves the electricity which plays a very important role for present global warming and other water and air related environmental issues.

- The kharif is the main season for survival of farmers depending on rainfed and groundwater irrigation. In Rajkot district, the ground water, surface water, and rainfed irrigation are 144600 ha, 50000 ha, and 543600 ha, respectively. Because of increase in ground water recharge, more wells are being dug in the region and more and more rainfed area is converted to ground water based irrigation and thereby irrigation efficiency is also improved. Further, the results also show that due to the presence of unconfined aquifers in the region, farmers of the command area using surface irrigation also take benefit of ground water in winter season, when there is less availability of surface water resources. Hence, check dams increase ground water recharge benefit to all sections of water users.

RECOMMENDATION

- River basin-wise planning of overall water resource potential and utilization have to be examined. The focus should be on the overexploited and the ground water quality problem areas. In the basin, surface water, ground water & recycle water should be estimated, and considered in water resources development planning. Similarly on utilization side, domestic, agricultural & industrial water requirements should be worked out. If the availability of total water resource in basin is less than the utilization requirement, inter-basin transfer of water may have to be planned. Simultaneously conservation sustainable and efficient utilization of water resource has to be promoted.

- The surface water availability considering average series of 30 to 40 years with respect to 50% dependability need to be estimated. Against the available surface water resources. the present storing facility in major, medium, minor and other small structures like check dams, percolation tanks, ponds, etc. should be examined. If the present storage capacity is less than the available surface water, then small rain harvesting structures should be planned in a systematic manner, using appropriate technical inputs.

- The rain water harvesting structures like check dams are required to be planned considering the existing of drain / rivulet in each village. The villages where the check dams are not been constructed till now should be given priority. Even in villages, if check dams are less than 10 in number, that should also be covered gradually.

- The target area for construction of rain water harvesting structures should also be on the basis of consideration of surface water scarcity and quality deterioration in ground water villages. Minimum one check dam with 2 km^2 catchment area with a storage capacity of 10000 m^3 to 30000 m^3 can safeguard the Kharif crop and also such check dams allow sufficient overflow so that there is no significant storage loss to the downstream dams.

- The region where the farmers take only Kharif crops are mainly depend on ground water supply and where the rainfall is erratic, check dam type of rain water harvesting structures can safeguard the crop productivity. In Saurashtra, the crop productivity has increased 2 to 3 times wherever check dams are constructed. In this region, the total surface water resource even at 50% dependability is 3300 Mm^3 while the present storage in major -medium and minor dams are only 2200 Mm^3, At present, all small rain water harvesting structures store maximum of 300 Mm^3 to 400 Mm^3 of water. Hence there is an ample scope of further construction of check dams, so that 800 Mm^3 to 1000 Mm^3 water can be conserved in ground water regime.

- In Bhadar catchment, out of 188 villages, 43 villages have not yet reaped the benefit of check dams. Even 66 villages have less than 5 check dams. These villages are required to be given priority by allowing situation-based reduction in the farmer's contribution amount from present 20% to 10%.

- The construction of check dams needs to be promoted taking cognizance of the benefits of ground water recharge, ground water quality improvement, flood routing, reduction in reservoir siltation and reduced evaporation. Moreover, for the construction of check dams, the land acquisition problem is not to be encountered. By and large, the benefits far outweigh the disadvantage ascribable to the sharing of small proportion of runoff by check dams.

- The present water availability per capita in Saurashtra is only 540 m^3 against minimum requirement of 1000 m^3/person/year. Therefore, it is essential to manage the water resources keeping equity, efficiency and sustainability concept. This can be achieved by conserving surface water resource as much as feasible by way of constructing check dams and other rain water harvesting structures.

- The check dams hold great promise in Gujarat since even after utilizing total surface water and ground water resources, irrigation is possible for maximum of 65 lakh ha only, which is 52% of the total agricultural area. To mitigate the water deprivation of the remaining 48 % area, the check dams provide one of the most feasible solutions.

- Two-third of Gujarat area is rocky and undulating and due to which canal surface water benefit of major-medium surface water schemes is technically difficult. In such areas, creating and enhancing ground water resource through check dam-mediated water harvesting is a most plausible option.

- People participatory scheme, introduced by Govt. of Gujarat on 17.1.2000, provides opportunity to get the feedback from the beneficiary farmers groups and take corrective steps. There should be flexibility particularly in respect of location, type of material, height of check dam and contribution methodology from farmers with respect to labour, material or money which can be attractive to the deprived farmers for getting involved.

- In Saurashtra, the success stories of the participatory construction and operation of water harvesting check dams in Rajsamadiara (Rajkot District) and Kopala (Bhavnagar District) was inspiring to the farmers for similar attainment under the participatory scheme launched by Gujarat Government in the year 2000. The spirit of participation needs to be kept alive in deprived villages.

- ❖ Details with respect to location, design, type, construction, as well as operation and maintenance of check dams should be handed over to beneficiaries so that after construction of check dams any minor repair or de-silting can be carried out by them.

- ❖ In a basin, if the surface water availability is already exhausted and there are problems of ground water availability and ground water quality, then the option of converting the surface stored water into ground water storage needs attention in view of the advantages of reduced evaporation losses as well as conveyance losses in the latter.

- ❖ In Bhadar-I basin, the ratio of surface water utilization between the catchment and the command is 1:7, although, the percentage of agricultural land in the catchment is more or less similar to that in the command area. The catchment villages are not benefited due to their situation in the upper reach where there is no movement of ground water from the lower lying basin to the upper basin. The solution lies in the catchment itself in the form of check dams which can be planned to convert the surface water as much as desirable into the ground water so that the upper and the lower reaches of the basin may get the equal benefits, and the evaporation and conveyance losses can be minimized.

- ❖ In Rajkot district, after construction of 4670 check dams, the total ground water storage increased from 900 Mm^3 to 1600 Mm^3 in 2006 accompanied with increase in ground water irrigation to the tune of 1.0 to 1.5 lakh ha, which diminished the possibility of failure of Kharif crops such as groundnut, cotton and bajra even in case of prolonged dry spells. Similarly review of other districts of state is advisable to know the importance of check dams in ground water regime.

- In medium & minor Irrigation dams of Saurashtra, the dead storages are already filled up by sedimentation. Even the live storages are reduced considerably. The water stored below canal bed level in reservoir gets evaporated in summer without any utilization. Further, because of huge siltation, the ground water recharge from such reservoir is also negligible. Silt removal in major and medium irrigation projects is cost inhibitive so much so that the demolition of such dams and dozing of silt in the river may be a preferred option. To avoid such situation to happen, preventive measures of silt loading in the reservoir by constructing rain water harvesting structures in the catchment/watershed is a desirable proposition.

- Check dams also decreases soil erosion and improve socio-economic condition of farmers and are also environmental friendly. Therefore, wherever the technically suitable sites are available particularly in arid and semi-arid water scarcity region, check dams should be planned.

- It is pertinent to point out that the major share of benefits of the construction of check dams has been reaped by progressive villages. Ways and means need to be adopted to bring the downtrodden and backward villages into the realm of Government sponsored development initiatives of constructing check dams so as to provide the benefit of indispensable water resource to all sections of the society as equally as possible.