Chapter 6

Water Harvesting Technology and Management Practices in Garhkot Watershed of Tehri Garhwal, U.P. Hills, India[1]

R. Babu, J.S. Samra, P.B. Joshi, B.L. Dhyani, R. Singh and C. Prakash

1. Introduction

The Kumaon and Garhwal Himalayas and the hills of Uttar Pradesh (UP) are geologically young, seismically active, fragile, inaccessible, and marginalised areas with biotic and ecosystem diversity. In spite of heavy rainfall and the fact that they are the source of perennial rivers, there is acute scarcity of water for domestic and agricultural uses as well as for wild- life during most of the year. These areas exercise a tremendous off-site effect by determining weather and being the source of floods and sediment deposition in the plains, reservoirs, and natural water bodies.

The UP Hills lie between 28°60'-31°28'N latitude and 77°49'-80°60'E longitude and are comprised of twelve districts, six in Garhwal Division: Dehra Dun, Pauri Garhwal, Tehri Garhwal, Rudra Prayag, Uttar Kashi, and Chamoli and six in Kumaon Division: Almora, Bageshwar, Champawat, Nainital, Udham Singh Nagar, and Pithoragarh; altogether covering a geographical area of 5.11 million ha. The population density in 1991 was 115/km^2 with a literacy percentage of 55.7 (Table 6.1). About 64% of the working population are engaged in agriculture and nearly 78% of the population live in villages. The average holding size in the region is 0.94 ha. Out of the total area, 64% area is under forest and only 12.4% is under agriculture. Orchard and other vegetation account for four per cent. Agriculture is largely rainfed making it especially prone to the vagaries of weather. Only about 11% of the net sown area is irrigated and that too is mostly confined to lower altitudes.

The most alarming development in the populated Lesser Himalayan belt is the drying up of springs and their increasing seasonality. A study in the catchment of Gaula River in lesser Himalayan River in south central Kumaon in UP demonstrated that in 40% of the villages, the extent of decline in spring discharges in the last five to 50 years ranged between 25 to 75% (Bartarya and Valdiya 1989). This clearly indicates that the Himalayan villages are heading for a serious water shortage. The soils of the area are shallow, gravelly, and

1 The views expressed in this report are those of the authors and not those of the Central Soil and Water Conservation Research and Training Institute.

Table 6.1: **Development indicators of the hill region of UP**

S.N.	Item	Unit	Year	UP Hill Region
1.	Area	sq.km.	1981	51125
2.	Population	million	1991	5.874
3.	Density of population	per sq.km.	1991	115
4.	Decennial growth rate of population	per cent	1981-91	21.49
5.	Literacy rate	per cent	1991	55.67
6.	Female per thousand males	no	1991	974
7.	Percentage of rural population to total population	per cent	1991	78.00
8.	Percentage distribution of main workers			
	1. Cultivators	per cent	1981	63.78
	2. Agricultural labourers	per cent	1981	5.54
	3. Household industry	per cent	1981	1.49
	4. Others	per cent	1981	29.19
9	Average size of operational holdings	per cent	1990-91	0.94
10.	Percentage of small and marginal holdings to total holdings	per cent	1980-81	78.50
11.	Area under forest	per cent	1992-93*	63.95
12.	Area under agriculture	per cent	1992-93*	12.36
13.	Area under orchard and other vegetation	per cent	1992-93*	4.10
14.	Net sown area	per cent	1992-93*	12.9
15.	Irrigation (%) of net sown area	per cent	1992-93*	11.1
16.	Total cropped area	'000 ha	1987	1102.80
17.	Cropping intensity	per cent	1987	164.27
18.	Fruit production	'000 tonnes	-	398
19.	Food grain production	million tonnes	-	1.53
20.	Average yield			
	a. Wheat	kg/ha	1989-90	1465
	b. Rice	kg/ha	1989-90	2116
	c. Potatoes	kg/ha	1989-90	18380
21.	Total number of problem villages suffering drinking water shortages	no		11642
22.	Percentage of village having drinking water facility to total problem villages	per cent	1990	90.90
23.	Employment per lakh of population in organised sector	no	1987	4712

* Agricultural Report, UP, 1995
** Agricultural Census, UP, 1990-91
Source: 'Rumbling in the Mountain' by Chand Joshi. The Hindustan Times, August 22, 1992

impregnated with unweathered fragments of parent rock, occurring within a few centimetres at elevated spots to within about two metres in the valleys. The soils are brown to greyish brown and dark grey in colour, generally non-calcareous and neutral to slightly acidic in reaction.

The region is difficult to approach because of its unique topographical features, and this has resulted in poor impact of development programmes. The people of the region, although primarily depending on agriculture, are relatively unaware of modern crop production and forestry and pasture management practices. Application of modern crop production, animal husbandry, fruit and vegetable production, and forestry and pasture management practices is needed. Application of modern technological methods are indispensable for maximising production per unit area. Due to the mountainous nature of the terrain with steep slopes, coarse and shallow soils, denuded vegetational cover, and heavy precipitation, the zone is extremely vulnerable to landslides, soil erosion, and runoff. Thus ecologically sound innovative development approaches need to be adopted for sustainable development of the area with the least deleterious impact on the mountain ecosystem as well as the foreland.

The climate of the UP hill region is extremely varied, ranging from sub-tropical to temperate and hosting diverse flora and fauna. The area has a different rainfall pattern from the rest of the country. There are two distinct rainfall seasons: July-September and December-March. The isopleths for these two periods are given in Figures 6.1 and 6.2. The variation is great in the monsoon and ranges from 500 to 2,000 mm, but most of the area receives between 750 and 1,500 mm (Srivastava *et al.* 1998). In addition to the normal monsoon precipitation, the region also receives about 200 mm of rainfall in winter with the exception of some pockets near Chakrata and the hills near Uttarkashi. Thus, the region receives plenty of water during the monsoon season. However, during the rest of the period drought prevails. During winter and summer, there is a scarcity of water for drinking purposes as well as for livestock consumption. The average annual rainfall of the Garhwal Himalayas varies from 826 to 2,115 mm, out of which 80% is received during the monsoon season (Table 6.2). Weekly rainfall and rainfall received at probability levels of 70 and 50% (7 and 5 years out of 10 years) for 16 stations in the UP Himalayas are given in Tables 6.3a and 6.3b. During the monsoon (July-September), most of the stations received weekly rainfall of 50 mm or more. During October to December, scanty rainfall is received. However, from January to March, the region receives winter rainfall of about 25 mm per week. The average temperature in the valleys varies from 3° to 30°C, while the higher hills (more than 3,000 masl) are covered with snow in winter.

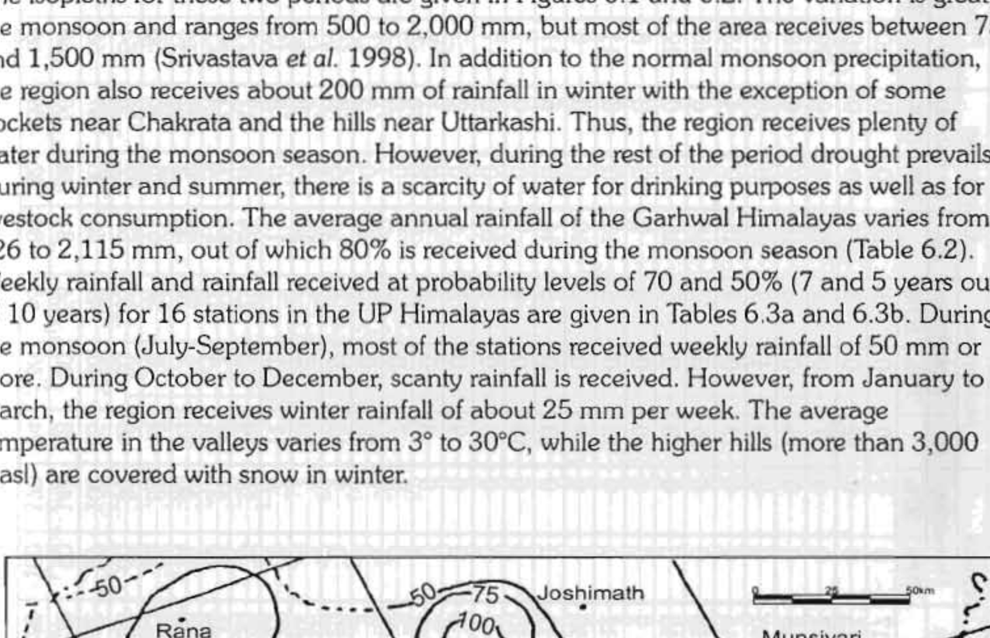


Figure 6.1: **Monsoon (July-Sept) precipitation (cm) over Garhwal-Kumaon Himalayas**

Table 6.2: **Average monthly and annual rainfall (mm) in the area**

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Pauri	61	67	55	32	52	132	326	360	148	34	8	28	1303
Srinagar	55	56	37	22	43	118	244	223	97	25	6	22	948
Devprayag	39	54	50	22	37	89	204	208	89	4	3	27	826
Bironkhal	63	72	44	31	63	166	316	264	132	37	5	27	1220
Lansdown	67	73	45	29	53	202	624	628	316	45	6	27	2115

Source: Compiled from various sources, 1998

Table 6.3a: **Weekly rainfall (mm) and at probability levels of 70 and 50% for selected stations in the UP Hills**

Week	Almora			Ranikhet			Kausani			Nainital			Mukeshwar			Champawat			Pithoragarh			Berinag		
	Av.	Probability		Av.	Probability		Av.	Prob.Level		Av.	Probability		Av.	Probability		Av.	Probability		Av.	Probability		Av.	Probability	
		70%	50%		70%	50%		70%	50%		70%	50%		70%	50%		70%	50%		70%	50%		70%	50%
1	9	0	0	11	0	1	11	0	0	17	0	0	10	0	1	15	0	0	10	0	0	11	0	0
2	10	0	0	14	0	5	17	0	0	15	0	0	12	0	3	14	0	0	10	0	0	11	0	0
3	8	0	1	11	0	0	6	0	0	17	0	0	11	0	3	12	0	0	10	0	0	12	0	0
4	13	0	4	15	0	7	17	0	0	16	0	0	15	0	6	18	0	6	12	0	2	15	0	4
5	16	0	7	19	1	11	26	0	0	23	0	0	20	1	9	23	0	10	19	0	7	20	0	12
6	11	0	4	12	0	3	9	0	0	16	0	0	13	0	4	15	0	4	13	0	3	13	0	2
7	12	0	7	16	0	7	6	0	0	18	0	0	16	0	7	18	0	6	13	0	5	17	0	7
8	11	0	3	14	0	3	10	0	0	18	0	0	13	0	5	15	0	0	12	0	0	13	0	3
9	8	0	2	11	0	2	9	0	0	9	0	0	10	0	3	9	0	0	8	0	0	10	0	3
10	12	0	4	14	0	5	7	0	0	12	0	0	13	0	5	13	0	3	11	0	3	13	0	3
11	8	0	0	7	0	0	8	0	0	10	0	0	9	0	0	10	0	0	8	0	1	9	0	0
12	10	0	4	12	0	5	13	0	0	11	0	0	13	0	6	14	0	6	11	0	4	15	0	8
13	8	0	2	8	0	2	8	0	0	10	0	0	10	0	4	7	0	0	7	0	0	10	0	0
14	6	0	2	8	0	2	0	0	0	7	0	0	0	0	3	10	0	0	7	0	1	9	0	3
15	5	0	1	7	0	1	4	0	0	6	0	0	9	0	2	8	0	2	7	0	1	8	0	1
16	7	0	0	8	0	1	7	0	0	6	0	0	8	0	2	6	0	1	5	0	0	8	0	0
17	5	0	1	6	0	1	8	0	0	6	0	0	7	0	2	5	0	0	7	0	1	8	0	2
18	7	0	1	8	0	3	6	0	0	9	0	1	10	0	3	10	0	3	11	0	5	15	0	5
19	15	0	8	15	1	8	9	0	0	20	0	9	15	0	8	14	0	8	16	0	9	23	0	13
20	10	0	4	10	0	5	7	0	0	22	0	7	13	2	7	13	0	6	13	0	7	14	0	5
21	8	0	3	10	0	5	10	0	0	17	0	6	11	1	5	11	0	8	15	0	6	14	0	8
22	17	1	8	15	1	8	18	0	0	30	0	18	19	0	13	24	6	17	27	0	16	34	3	20
23	22	3	12	22	5	15	20	0	0	43	10	31	21	4	12	21	4	14	27	7	21	40	7	29
24	25	5	14	33	5	18	21	0	10	70	14	40	33	3	19	33	9	22	40	9	28	62	19	43
25	43	13	29	48	16	32	29	0	9	125	55	89	49	8	32	61	25	40	58	25	42	90	42	70
26	42	18	30	43	14	30	49	9	28	135	60	97	48	20	33	53	22	36	54	24	38	79	35	55
27	51	24	37	61	29	45	65	35	59	142	67	106	65	16	49	65	30	47	65	33	53	100	51	81
28	64	32	53	80	44	63	121	73	114	178	90	143	78	30	56	81	38	60	68	35	57	103	63	96
29	61	30	51	83	49	73	94	53	83	185	100	170	74	36	65	84	42	69	69	40	60	118	68	102

Table 6.3a: Cont....

Week	Almora			Ranikhet			Kausani			Nainital			Mukeshwar			Champawat			Pithoragarh			Berinag		
	Av.	Probability		Av.	Probability		Av.	Prob.Level		Av.	Probability		Av.	Probability		Av.	Probability		Av.	Probability		Av.	Probability	
		70%	50%		70%	50%		70%	50%		70%	50%		70%	50%		70%	50%		70%	50%		70%	50%
30	64	30	47	84	43	70	113	87	96	164	88	150	72	43	57	77	36	55	76	41	70	132	78	117
31	60	32	53	86	46	80	110	59	96	197	113	168	70	35	61	73	44	67	71	42	62	124	75	115
32	61	30	49	89	45	75	101	81	90	169	91	157	79	41	73	77	39	65	74	39	66	134	81	123
33	56	26	42	85	45	76	95	47	78	165	82	136	69	42	55	61	31	51	74	38	62	120	64	110
34	56	26	42	75	35	54	73	47	66	184	87	137	75	34	52	72	32	51	64	28	45	110	54	87
35	29	12	20	46	21	32	61	12	44	102	45	70	45	33	32	45	15	30	46	20	33	82	38	63
36	37	12	25	50	22	35	55	24	43	99	45	69	50	21	35	43	18	30	42	19	32	78	37	58
37	33	10	24	44	14	30	56	16	37	94	25	66	54	22	36	54	13	38	40	17	29	56	23	40
38	23	3	13	33	4	16	27	5	18	80	11	39	34	22	20	43	1	16	26	2	14	41	8	29
39	31	0	11	34	2	14	34	0	8	57	4	26	43	7	17	36	0	10	24	0	11	34	7	24
40	14	0	0	19	0	1	75	0	35	42	0	3	24	3	4	27	0	0	21	0	3	21	0	7
41	5	0	0	5	0	0	96	0	0	12	0	0	6	0	0	11	0	0	7	0	0	11	0	0
42	6	0	0	7	0	0	4	0	0	6	0	0	4	0	0	11	0	0	8	0	0	8	0	0
43	1	0	0	2	0	0	4	0	0	1	0	0	2	0	0	3	0	0	2	0	0	1	0	0
44	2	0	0	2	0	0	0	0	0	5	0	0	3	0	0	1	0	0	3	0	0	2	0	0
45	1	0	0	2	0	0	0	0	0	2	0	0	1	0	0	1	0	0	2	0	0	1	0	0
46	2	0	0	2	0	0	0	0	0	4	0	0	3	0	0	5	0	0	3	0	0	3	0	0
47	1	0	0	1	0	0	1	0	0	2	0	0	2	0	0	2	0	0	1	0	0	2	0	0
48	1	0	0	2	0	0	0	0	0	2	0	0	2	0	0	2	0	0	1	0	0	2	0	0
49	1	0	0	2	0	0	0	0	0	3	0	0	2	0	0	1	0	0	2	0	0	2	0	0
50	7	0	0	8	0	0	3	0	0	8	0	0	7	0	0	10	0	0	7	0	0	7	0	0
51	6	0	0	6	0	0	7	0	0	7	0	0	7	0	0	8	0	0	7	0	0	7	0	0
52	5	0	0	6	0	0	1	0	0	6	0	0	7	0	0	6	0	0	4	0	0	7	0	0
Total	1026			1311			1531			2604			1286			1351			1238			1879		

Table 6.3b: **Weekly rainfall (mm) and at probability levels of 70 and 50% for selected stations in the UP Hills**

Week	Pauri			Srinagar			Bironkhal			Joshimath			Karanprayag			Rudraprayag			Dehradun			Mussoorie		
	Av.	Probability		Av.	Probability		Av.	Probability		Av.	Probability		Av.	Probability		Av.	Probability		Av.	Probability		Av.	Probability	
		70%	50%		70%	50%		70%	50%		70%	50%		70%	50%		70%	50%		70%	50%		70%	50%
1	10	0	0	8	0	0	10	0	0	7	0	0	8	0	0	12	0	0	11	0	0	14	0	3
2	13	0	6	10	0	2	13	0	0	17	0	7	11	0	4	12	0	2	12	0	1	14	0	4
3	14	0	5	12	0	3	14	0	5	13	0	5	14	0	0	11	0	0	15	0	1	14	0	4
4	16	0	7	16	0	5	19	0	4	17	0	7	17	0	7	21	0	9	14	0	1	18	0	2
5	19	0	9	20	1	7	20	0	7	23	0	10	21	0	10	22	0	9	20	0	6	26	0	12
6	15	0	6	11	0	3	18	0	2	17	0	7	16	0	5	16	0	5	16	0	1	16	0	7
7	16	0	8	12	0	4	16	0	5	16	4	11	14	0	5	16	0	9	14	0	0	19	0	6
8	16	0	4	13	0	0	18	0	4	20	0	8	19	0	7	23	0	7	17	0	0	17	0	4
9	12	0	2	8	0	0	12	0	0	21	2	11	14	0	6	12	0	5	9	0	0	11	0	1
10	13	0	4	8	0	0	12	0	2	22	2	10	14	0	5	16	0	5	10	0	0	17	0	4
11	9	0	0	9	0	0	7	0	0	16	1	9	7	0	2	10	0	0	5	0	0	9	0	1
12	14	0	6	10	0	3	12	0	4	23	4	13	19	0	9	16	0	9	6	0	0	13	0	7
13	11	0	4	6	0	0	6	0	0	16	1	9	10	0	4	11	0	3	7	0	0	12	0	3
14	8	0	3	6	0	0	6	0	0	14	1	7	10	0	4	12	0	7	5	0	0	11	0	3
15	7	0	0	4	0	0	7	0	1	11	0	5	8	0	3	9	0	4	2	0	0	6	0	0
16	7	0	0	4	0	0	7	0	0	11	0	6	9	0	2	10	0	6	5	0	0	5	0	0
17	6	0	0	4	0	0	7	0	0	6	0	1	8	0	0	9	0	3	3	0	0	5	0	0
18	8	0	2	4	0	0	12	0	3	7	0	3	9	0	2	12	0	7	4	0	0	8	0	1
19	14	0	6	10	1	3	15	0	9	12	0	6	12	0	6	14	0	7	8	0	0	15	0	6
20	10	0	4	8	0	3	12	0	4	7	0	2	12	0	7	18	0	8	8	0	0	10	0	4
21	11	0	4	7	0	2	10	0	0	6	0	2	11	0	6	14	2	7	5	0	0	11	0	4
22	15	0	8	13	0	5	19	0	10	7	0	4	21	2	11	19	2	11	18	0	3	19	0	10
23	19	2	10	13	0	7	21	2	12	10	2	7	18	0	10	26	7	18	19	0	6	24	0	11
24	22	6	16	20	3	14	34	6	19	18	5	12	29	5	20	47	16	32	34	0	13	39	5	21
25	37	9	26	34	10	23	54	17	37	27	9	18	47	19	32	62	26	42	48	12	31	54	11	30
26	51	16	35	38	10	27	55	18	38	28	12	19	58	25	42	80	41	70	68	28	53	87	26	58
27	57	25	40	42	14	29	58	25	41	34	16	26	66	31	50	94	44	71	118	60	97	142	77	121
28	74	37	59	50	21	34	75	35	55	36	21	32	92	46	75	107	64	90	136	88	123	156	85	133
29	79	42	70	58	27	43	80	38	61	43	21	35	86	52	60	127	88	107	153	98	135	198	121	174
30	82	41	68	60	28	45	75	35	54	49	24	39	105	53	87	163	95	140	150	88	130	179	101	154

Table 6.3b: Cont....

Week	Pauri			Srinagar			Bironkhal			Joshimath			Karanprayag			Rudraprayag			Dehradun			Mussoorie		
	Av.	Probability		Av.	Probability		Av.	Probability		Av.	Probability		Av.	Probability		Av.	Probability		Av.	Probability		Av.	Probability	
		70%	50%		70%	50%		70%	50%		70%	50%		70%	50%		70%	50%		70%	50%		70%	50%
31	97	48	77	66	31	49	68	37	54	50	26	40	119	61	92	156	115	141	174	115	157	210	136	190
32	83	40	66	50	23	38	66	34	56	49	26	40	112	56	90	141	102	125	163	95	140	179	88	143
33	95	56	84	47	22	36	69	32	51	38	21	30	81	40	65	138	95	124	170	88	135	176	101	153
34	74	40	68	48	23	37	54	25	41	36	19	28	77	40	60	127	76	107	145	78	123	176	110	158
35	58	26	40	36	11	25	34	11	24	33	15	24	74	33	51	109	59	86	116	58	94	126	57	100
36	40	17	28	23	5	16	34	9	24	25	11	18	60	24	41	74	40	69	94	37	68	95	37	70
37	43	11	30	29	5	21	33	3	20	21	8	14	49	21	35	71	31	51	77	28	56	90	30	63
38	22	1	10	13	0	6	19	0	5	15	3	10	28	6	16	35	14	24	41	3	21	45	4	19
39	24	0	10	15	0	4	21	0	5	17	1	8	26	0	14	29	6	20	35	0	7	52	0	19
40	12	0	0	8	0	1	16	0	0	10	0	2	13	0	33	15	0	4	23	0	0	22	0	3
41	4	0	0	7	0	0	12	0	0	4	0	0	5	0	9	6	0	0	14	0	0	6	0	0
42	6	0	0	5	0	0	7	0	0	5	0	0	4	0	0	9	0	0	6	0	0	6	0	0
43	2	0	0	1	0	0	2	0	0	2	0	0	1	0	0	3	0	0	7	0	0	4	0	0
44	2	0	0	2	0	0	1	0	0	4	0	0	2	0	0	3	0	0	2	0	0	3	0	0
45	2	0	0	1	0	0	2	0	0	2	0	0	2	0	0	1	0	0	2	0	0	4	0	0
46	2	0	0	1	0	0	2	0	0	3	0	0	2	0	0	2	0	0	2	0	0	2	0	0
47	2	0	0	2	0	0	2	0	0	3	0	0	1	0	0	2	0	0	2	0	0	2	0	0
48	2	0	0	1	0	0	1	0	0	2	0	0	1	0	0	4	0	0	2	0	0	3	0	0
49	2	0	0	2	0	0	3	0	0	3	0	0	1	0	0	3	0	0	2	0	0	6	0	0
50	7	0	0	6	0	0	8	0	0	6	0	0	6	0	0	5	0	0	7	0	0	10	0	0
51	7	0	0	7	0	0	10	0	0	8	0	0	5	0	0	6	0	0	7	0	0	8	0	0
52	9	0	0	6	0	0	7	0	0	9	0	0	8	0	0	8	0	0	7	0	0	10	0	0
Total	1280			894			1195			899			1462			1968			2038			2404		

Source : Indian Meteorological Department (IMD) 1995

The runoff data from three experimental watersheds (with areas ranging from 286 to 370 ha) in Garhwal Himalayas (Table 6.4) reveal that runoff volume under different land uses varies from 15 to 42% (Dhyani *et al.* 1997 and Joshi *et al.* 1998).

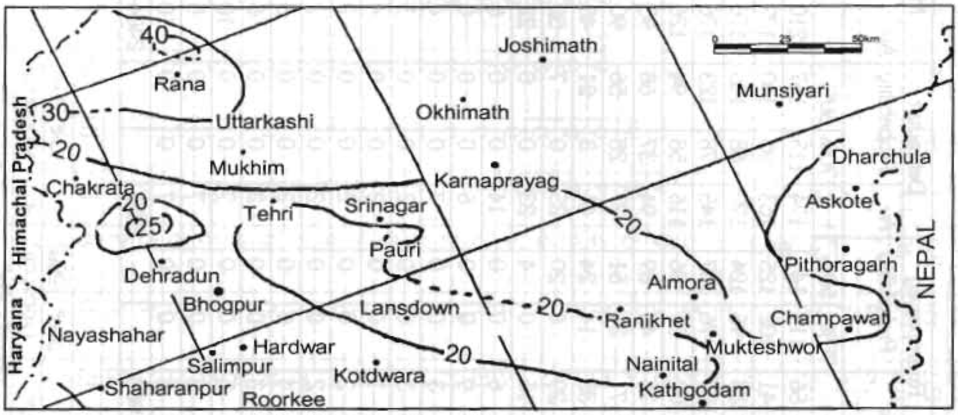


Figure 6.2: **Winter (Dec-March) precipitation (cm) over Garhwal-Kumaon Himalayas**

Table 6.4: **Runoff volume in small watersheds in Garhwal Region of the UP Hills**

	Name of the Watershed		
	*Fakot (Tehri Garhwal)	**Dugar Gad (Pauri Garhwal)	**Srikot Gad. (Pauri Garhwal)
Location	23°13'N and 78°20'E	30°11'N and 78°48'E	30°5'N and 78°46'E
Watershed area (ha)	370	306	286
Elevation range (m)	650 to 2015	1460 to 1900	1060 to 1980
Av. annual rainfall (mm)	1900	1698	2365
Land Use (%)			
Cultivation	22	38	38
Forest	36	9	50
Wasteland	42	53	12
Runoff (%)	42 (Before treatment)	41.3	18.1
	15 (After treatment)		

* Dhyani, et al. (1997)
** Srivastava, et al. (1998)

The hill economy predominantly operates on a subsistence level and is mostly self-contained. Women contribute more than 80% of labour input every day, whereas males migrate elsewhere to supplement family incomes. About 50% of the male population migrate from the area in search of employment. About 74% work in agriculture (82% in crop activities and 69% in livestock activities) is performed by female workers who have little decision-making power (Singh and Sharma 1987). In addition, collection of fodder, fuel, and water is generally considered as women's work and women are subjected to extreme drudgery in carrying out these tasks. Farm equipment suitable for women farmers is non-existent. At the same time, farm mechanisation is not possible because of topographical constraints and a preponderance of marginal and scattered operational landholdings. Bullocks are the main source of draught power.

Transport and communication systems are rudimentary. The marketing and institutional infrastructures are grossly inadequate. There are tremendous potentials for floriculture, off-season vegetables, mushroom production, and Angora rabbit rearing, but they remain unexploited because of the communication constraints. The amount of rich inherent diversity also results in slow adoption of improved technologies.

The UP Himalayas gained popularity as a tourist attraction because of pilgrimages, natural beauty, and recreation and adventure sports. During 1990, more than 15 million tourists (Swaroop 1991 and 1993) visited different places in the UP Hills. The number is increasing rapidly. This is going to aggravate the problem of acute water shortage in the region.

2. Water Problems in the Hills

Despite the fact that the Himalayas are the largest storehouse of fresh water at lower altitudes, for the bulk of people inhabiting these mountains, water is extremely scarce all year round. They receive either too much during the few months of monsoon or too little for the rest of the year (Chalise 1996). This is also true for the UP Hills. Therefore, the following issues need to be addressed and appropriate methods of and techniques for water harvesting and management of local water resources in the region assessed and identified.

- The water requirements of mountain communities in the region need attention and the inhabitants should be provided with a fair share of local downstream benefits from harnessing upstream mountain resources.
- The wide variations and seasonality in water supplies need to be considered and matched with the ever-increasing year round demands for water.
- The systems for harvesting and sustainable management of local water resources need to be better understood.

3. Selection of the Study Area

In the UP hills, the largest population (more than 60%) residing in 55% of the villages is concentrated in the middle altitude zone (1,000-1,500 m) where there are 15°-30° (27% to 60%) slopes, 0-5 km of road accessibility, southern and eastern aspects, and where it is most suitable for habitation with the maximum amount of land under all types of land use. As a result of the heavy population pressure, the region is short of water (for drinking, domestic, and irrigation purposes) all year round except for the four months (July to October) of the south-west monsoon. The Garhkot watershed (elevations range from 840 to 1,700 m) in Hindolakhal block of Dev Prayag 'tehsil' sub-district in Tehri Garhwal district was selected for the study (Figure 6.3). The Garhkot watershed is short of water for drinking, domestic uses, and irrigation. The watershed also has all possible land uses and associated problems for land, water, and vegetation. The watershed is situated on the Devprayag - Tehri road and is easily approachable for the purposes of survey and investigation. (Plate 1)

4. Methodology

The study was based on an intensive field survey and investigation. The investigation covered six 'gram sabha' having five villages and seven hamlets. Forty-five households comprising of 15 families in each altitude zone (upper - greater than 1,500 m, middle – 1,000-1,500 m, and lower - below 1,000 m) were selected randomly. All the families

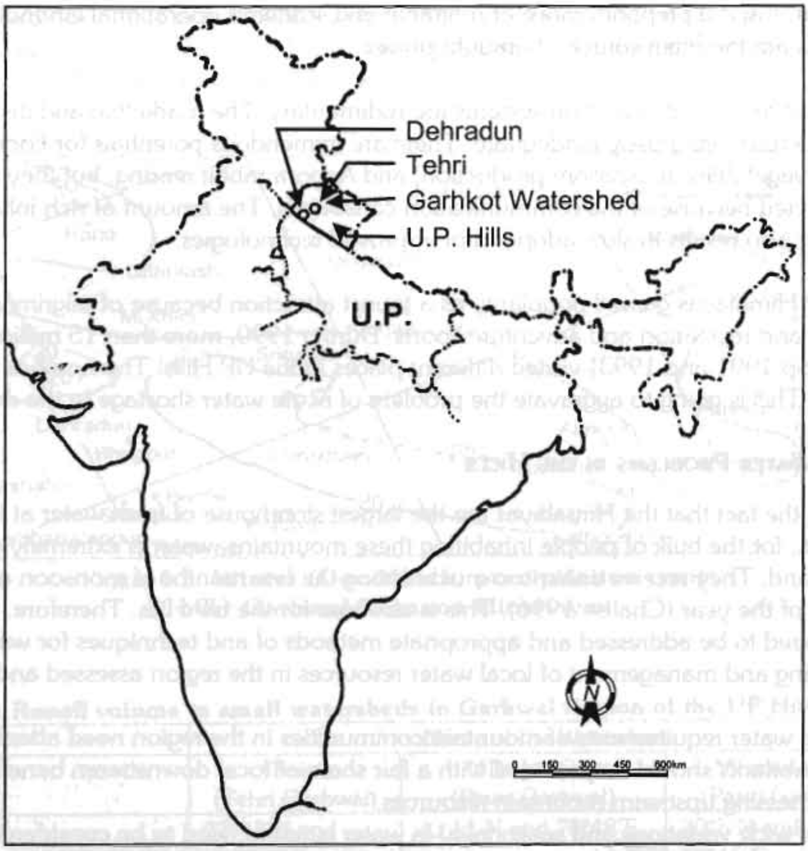


Figure 6.3: **Location map of Garhkot watershed-Tehri Garhwal**

selected were interviewed and an inventory made using a well-structured schedule designed for the study to understand the socioeconomic structure, productivity of land, and arrangements for management of existing water resources in the watershed. Much of the information, both quantitative and qualitative, was gathered using the diary method; thus a mixed approach was used as suggested by Jodha (1995). This was necessary in order to record cross-sectional information linked with water resource issues such as local history, farmers' perspectives and strategies, their perceptions of public policies and programmes, and future vision. Information was generated through group discussions involving farmers of all age groups and from both sexes. The opinions of the village 'Pradhan' (headman), President of the Watershed Association, social workers, and key persons regarding various aspects of local water-harvesting technologies and management systems were also taken into consideration. Various public departments and NGOs were contacted to learn about their different programmes.

A multi-disciplinary team comprising of social scientists, water resource specialists , and a soil scientist extensively carried out a transact survey in each village to collect the actual observations on various aspects pertaining to water resources, socioeconomics, soil, and vegetation. Actual measurements were recorded at each site.

Participatory Rural Appraisal (PRA) was carried out with the villagers. Further, vein diagrams of water resources in the villages were also prepared by a group residing in the village. Water samples from various springs were collected and analysed for physio-chemical characteristics using the 'Standard Method' to monitor water quality. The statistics on humans, livestock population, revenue records, and other related information were obtained from published records, The Tehsil headquarters at Devprayag and the Block Development Office, Hindolakhal, were also visited.

5. BACKGROUND AND INFORMATION ON THE STUDY AREA

Location

The 348 ha watershed is situated on the south-eastern aspect of the Alaknanda River catchment between 13.6 to 16 km from Dev Prayag and two km before Hindolakhal (Block Office). The ridge line forming the boundary of the watershed is well defined and drains into the 'Garhkot Gad' stream. The mean elevation of the watershed is approximately 1,200 masl. The highest ridge point of the watershed is at 1,690 m and the lowest is at 840 m near the bridge below Garhkot village. There are two well-defined drains that join at 'Garhkot Gad' (Figure 6.4).

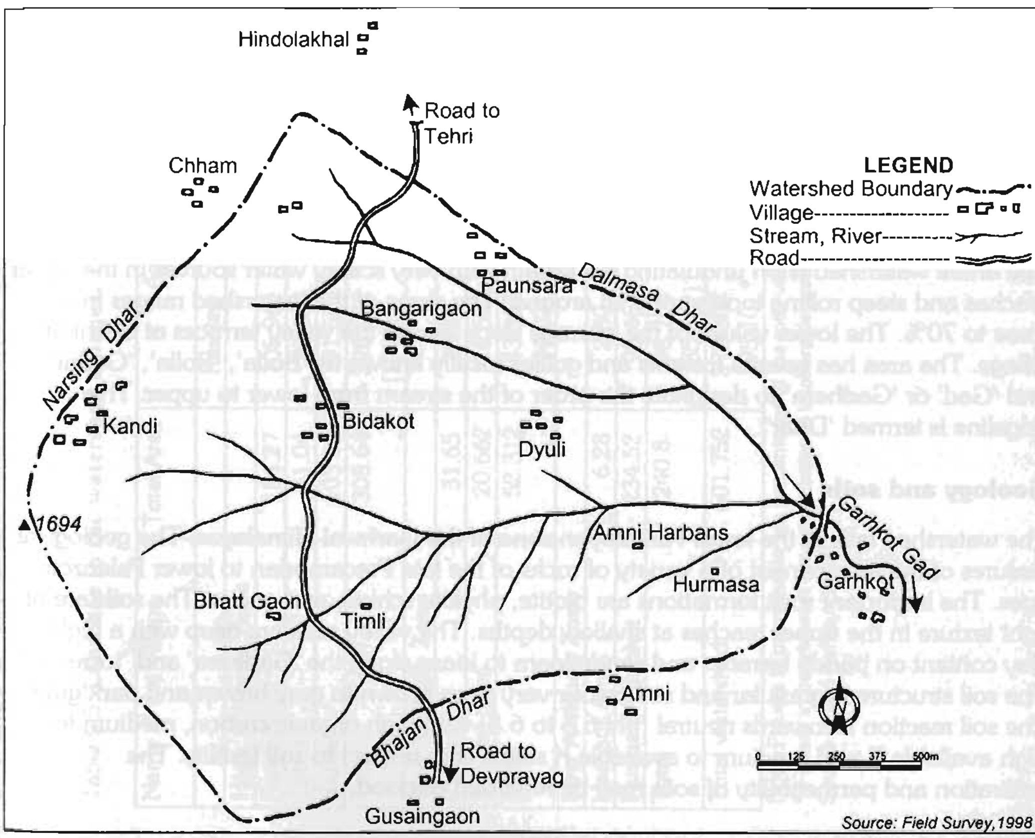


Figure 6.4: **Map of Garhkot watershed, block-Hindolakhal, District-Tehri Garhwal**

The watershed is located at 78°-30'E longitude and 30°-15'N latitude. The area consists of a cluster of twelve hamlets: Kandi Bagri, Chham, Bidakot, Pausada, Bangarigoan, Dyuli, Bhat gaon, Timli, Amni Harbans, Hurmasa, and Garhkot.

Climate

The watershed has a variable climate because of the variation in altitude (840 to 1,690 m). The maximum temperature during summer ranges from 25 to 38°C, while in winter it rarely exceeds 20°C. The minimum temperature touches freezing point when snowfall occurs around the highest peak adjacent to Hindolakhal village. The average rainfall in the area varies from 826 to 2,115 mm (Table 6.2), 80% of which is confined to the three months of the rainy season brought by the south-west monsoon. Winter rain is received as a result of the western disturbances and sustains the meagre rabi (winter) crops. Because of the rolling topography and steep slopes the runoff is rapid, resulting in soil loss (> 18 t/ha/yr) exceeding the permissible limit of 7.5 t/ha/yr and scanty infiltration (Singh and Gupta 1982). This results in poor soil moisture and little recharge. The runoff data; from three identical watersheds (Fakot in Tehri Garhwal and Dugar Gad and Srikot Gad in Pauri Garhwal) located in the vicinity having identical areas, latitudes, altitude variations, and aspects; revealed that runoff volumes vary from 18 to 42% (Dhyani *et al.* 1997 and Srivastava *et al.* 1998) depending on the amounts of annual rainfall (Table 6.4).

Area

The gross area of the watershed is 348 ha. The cultivable, non-arable lands, wastelands, and forest lands in and around the village have been listed in Table 6.5. Although the main motorable road crosses the middle reaches of the watershed, all the villages (except Bidakot) are accessible through trails ranging from 0.5 to 3 km. across the fields. During inclement weather, accessibility from one village to another decreases.

Topography and physiography

The entire watershed is on undulating hill terrain with very scanty water sources in the upper reaches and steep rolling topography all around. The slope of the watershed ranges from three to 70%. The lower values of the average slope are on the valley terraces at Garhkot village. The area has several torrents and gullies locally known as 'Bolla', 'Rolla', 'Gadni' and 'Gad' or 'Gadhera' to designate the order of the stream from lower to upper. The ridgeline is termed 'Dhar'.

Geology and soils

The watershed falls in the lower Himalayan zone of the Garhwal Himalayas. The geological features of the area consist of a variety of rocks of the late Precambrian to lower Paleozoic ages. The important rock formations are biotite, phyllite schists, and gneiss. The soils are of light texture in the upper reaches at shallow depths. The valley soils are deep with a high clay content on paddy terraces and sandy loam to loam along the 'Gadhera' and 'torrents.' The soil structure is granular and soil colour vary from brown to gray brown and dark gray. The soil reaction is towards neutral (pH 6.5 to 6.8) with high organic carbon, medium to high available P, and medium to available K status with respect to soil fertility. The infiltration and permeability of soils may be regarded as good.

Drainage

The drainage in the watershed area is characterised by a number of small seasonal streams flowing along the south-east slope which ultimately form the main flowing stream called

Table 6.5: **Land use in the watershed villages, 1998**

(in ha)

Name of the Village	Total Area	Agricultural Area			Civil Soyam	Forest Panchayat	Water Covered	Wasteland
		Rainfed	Irrigated	Total				
High Altitude Zone								
Kandi Bagri	154.27	105.961	-	105.961	47.145	-	0.015	-
Chham	51.04	30.664	-	30.664	8.828	10.620	0.069	-
Bidakot	103.33	91.527	-	91.527	11.051	-	0.018	-
Total	308.64	228.152 (100*)	-	228.152 (73.92)	67.024 (21.72)	10.620 (3.44)	0.102 (0.03)	-
Mid Altitude Zone								
Pausada	31.65	26.8	2.0	28.8	1.014	-	0.036	0.60
Bangari goan	20.662	16.592	0.760	17.252	0.243	-	0.026	3.143
Total	52.312	43.392 (94.02) *	2.760 (5.98)	46.152 (88.22)	1.257 (2.40)	-	0.052 (0.1)	3.743 (7.16)
Low Altitude Zone						-		
Harbans Amni	6.28	2.30	3.12	5.42	-	0.86	-	-
Hurmasa/Garhkot	234.52	96.463	13.17	109.633	34.728	30.601	0.248	58.10
Total	240.8	98.763 (85.84*)	16.29 (14.16)	115.053 (47.78)	34.728 (14.42)	31.461 (13.06)	0.248 (0.1)	58.10 (24.13)
Total watershed	601.752	370.307 (95.10) *	19.05 (4.90)	389.357 (64.64)	103.009 (17.12)	42.081 (6.99)	0.402 (0.07)	61.843 (10.28)

Note: Figures in parentheses are percentages of the total village area

* Figures in parentheses are percentages of total arable area.

Source : Field Survey (1998)

'Garhkot Gad'. This 'Gad', after flowing about four km towards the south-east merges with the River Alaknanda. These small seasonal streams play an important role for the natural springs, locally known as naula. The drainage pattern is generally of the Dendritic type.

Local water sources/water bodies

Surveys and discussions with the inhabitants of all the villages situated in the project area revealed that there is a scarcity of water in the entire upper reaches, and people have to fetch water from remote springs even for drinking purposes. Although the ridge is a dividing line between two prominent snowfed rivers–the Bhagirathi and Alaknanda, the people and the fields remain thirsty during the rainless period. These perennial rivers with abundance of water are far below (1,400 to 1,500 m vertically). Most of the villagers insisted on the need for some water-lifting device to pump the water from the Bhagirathi to the highest point on the ridge to supply water to the dry tracts and to humans and cattle. Whatever small quantity of rain water or snowmelt recharges the underground aquifers, it emerges in natural springs or streams in the lower reaches. The streams (Dhara), springs (Srot), and covered percolation tanks (naula) are the main sources of water for drinking and minor irrigation purposes. The streams are either perennial or ephemeral depending upon the source and location of the recharge area. Lakes and ponds are few in the region. On the advice of certain development agencies, a few dugout ponds were established in the middle reaches below Garhkot village along the side of a natural drain, but these were silted up in the very first season due to heavy debris flow and suspended sediments. On the rocky terrain in Kandi Bagri village, an embankment type runoff storage pond, shaped like a horseshoe on three sides with a wall constructed on the downstream side, contains water for livestock use and other consumption (Plate 2). A similar tank exists in Chham village. Collection of low discharge spring water into tanks through unlined channels ('Ghul') for irrigation purposes is an old practice in the area. The existing water resources and those dried up in different years have been depicted on the Water Resource Map of the area (Annex I).

Availability of water

In most of the villages situated in the upper reaches of the watershed, there is an acute shortage of water, whereas in certain pockets in the valley, stream water flows in abundance. The drinking water source situated between the two villages is shared on a roster system all twenty-four hours. For example, Bidakot village receives water up to 10 p. m. and Amni village receives it from 10 p. m. to 3 a. m. A watchman paid by the Village Panchayat is engaged to supervise water distribution.

Rain water collection from roof tops through sheet metal gutters and down pipes with funnels has already been adopted by a few progressive farmers in the villages of Chham and Hindolakhals (Plate 3). One resident from Chham village has constructed a cement lined tank of 1.7 m x 1.2 m x 1.0 m to collect about two cubic metres of runoff at a time from the roof; the area of the roof is 18 m x 8 m, i.e., 144 sq m. Because of the undulating topography the underground water table is not uniform and there are perched water tables in certain pockets: the sources of natural springs oozing out the recharged rain water. Details are given in Chapter 3.

Natural vegetation

The natural vegetation in the watershed presented is variable because of variations in altitude and landscape. Lower altitudes have sub-tropical vegetation species, while higher altitudes are dominated by pine (*Pinus roxburghii*) in patches. Because of human and biotic interference, vegetation is poor and far below the desired density (50%) of the area in the hilly region. In general multi-purpose trees (MPT) are grown on risers in the fields by the farmers themselves. Civil 'Soyam' land (Forest land - an open access resource : no one's property or everyone's property) is devoid of shrubs and trees. The characteristic species of forest trees, shrubs, and grasses found in the watershed are *Toona ciliata* (Tun), *Grewia optica* (Bhimal), *Melia azedaragh* (Bakain), *Ficus religiosa* (Pipal), *Acacia catechu* (Khair), *Ficus roxburghii* (Timal), *Embelica officinalis* (Aonla), *Ficus palmata* (Bad), *Pinus roxburghii* (Chir), *Quercus incana* (Banj), *Dendrocalamus strictus* (Bans), *Arundo donax* (Narkul), *Celtis tetrandia* (Kharik), *Punica granatum* (Anar), *Juglans regia* (Akhrot), *Berberis asiatica* (Kilmora), *Ricinus communis* (Arandi), *Agave americana* (Ram Bans), *Lantana camara* (Lantana), *Rosa sinensis* (wild rose), *Urtica parviflora* (suin), *Artensia vulgaris* (Hill bamboo), *Juniperus macropoda* (Dhup) ; *Solanum indicum* (Bhat kataiya), *Cyperus rotundus* (Motha), *Cynodon dactylon* (Doob), and *Panicum spp.*

Fruit trees and plants

There are no systematically planted orchards in the watershed. However, fruit plants are scattered throughout the area. Some farmers have planted fruit trees near their homesteads as well as in the fields. Among the fruit plants, *Mangifera indica* (mango), *Psidium guajava* (guava), *Citrus spp* (Nimbu), *Punica granatum* (Pomegranate), *Musa paradisica* (Banana), and *Carrica papaya* (Papaya) are mainly grown in the valley (lower altitudes); while *Prunus persica* (Peach), *Citrus spp* (Nimbu), *Juglans regia* (Walnut), and *Prunus communis* (Plum) are grown at higher altitudes on the upper ridge of the watershed. Most farmers in the area prefer plantations of mango and bananas in the lower reaches and walnuts in the upper reaches because of favourable soil and climatic conditions.

Land use

The total area of the villages is 602 ha, out of which about 348 ha fall within the watershed and the rest outside the watershed. Land-use statistics for whole villages within the watershed are presented in Table 6.5. The watershed is a dry-land agricultural watershed where 64.6% of the total watershed is under agriculture and nearly 95% of arable land is rainfed. In the high hills, all the arable land (228 ha) is rainfed. In the middle altitude zone, about six per cent of the area is irrigated out of total agricultural land of 46 ha. In the low altitude zone, 14% of the area is irrigated out of agricultural land of 115 ha (Table 6.5). Civil soyam land constitutes a second important land use (17%), followed by wasteland (10.3%). Forests constitute only seven per cent of the total geographical area of the villages; and this is far below the requirements (60%), as per the New Forest Policy, (1988) and a matter of great concern. The land use map of the study area indicating the land-use pattern in different villages is appended to the report (Annex II). A sharp decline in the vegetation cover decreased the recharging capacity of acquifers on the one hand and high intensity storm floods caused a lot of soil and water erosion on the other. Similarly, observations were recorded in various studies conducted in the middle altitude zone of the UP hills (Dhyani *et al.* 1997). Consequently, the area is suffering from severe shortages of water for drinking as well as for irrigation for more than six months in a year. The problem becomes acute during summer when people have to pay a high price for water, about one rupee per litre in the case of water transported from Devprayag, and when they have to wait for long hours (1-4 hours) to get 20-25 litres of water. Although the watershed lies between two big rivers – the Alaknanda and Bhagirathi—joining at Devprayag and forming the sacred River Ganges, the area has acute water shortage.

Agriculture (crops and cropping pattern)

Only 4.9% of agricultural land in the watershed area is irrigated and the remaining area is rainfed. The agriculture in the watershed is limited to cultivation of a few crops. It has a low cropping intensity of 140% (normal-200%) due to small landholdings, lack of irrigation, the vagaries of the weather, and lack of modern technology, and all these lead to uncommercial and unremunerative types of farming. Fertilizer consumption is very low, resulting in poor crop yields. The main problem for agriculture is the lack of water and sloping land, as a result of which crops suffer from inadequate moisture. Agricultural fields are not well terraced on the high slopes and are subjected to soil erosion. The lower area of the watershed in the valley is irrigated and terraces have been constructed scientifically.

Agriculture is mainly looked after and governed by women, except for ploughing the fields which is carried out by men. All packages of practices for agriculture are carried out by women for the most part. Because of the lack of locally-based income- generating opportunities, difficult accessibility, and low productivity, young men move to the cities in search of jobs.

The watershed is vulnerable to soil erosion (>18t/ha/yr) and this creates ecological imbalances caused by a decline in productivity, water scarcity, and floods downstream. Therefore, a watershed management approach needs to be followed and soil conservation measures on agricultural land should be adequately supported by infrastructure to make agriculture more productive and sustainable on a long-term basis.

The main crops grown in the watershed are *Elucine coracana* (*mandua*[a millet]), followed by *Oryza sativa* (paddy), *Glycine max* (soybean), *Zea mays* (maize), *Paspalum scorbiculatum* (jhingora), *Vigna mungo* (black gram), *Phaseolus mungo* (green gram), and *Cajanus cajan* (pigeon pea) in *kharif* (summer) and *Triticum spp* (wheat), *Hordeum vulgare* (barley), *Brassica nigra* (mustard), *Pisum sativum* (pea), and *Sessamum indicum* (til[sesame]) in rabi (winter).

In addition, seasonal and off-season vegetables are also grown under rainfed as well as irrigated conditions. The vegetable crops grown are *Solanum tuberosum* (potatoes), *Brassica spp* (cauliflowers and cabbages), *Lycopersicum esculentum* (tomatoes), *Allium cepa* (onions), *Allium sativum* (garlic), *Capsicum spp* (chillies), *Solanum melongena* (aubergine), *Phaseolus spp* (beans), *Hibiscus esculentum* (okra[lady fingers]), *Zingiber officinale* (ginger), *Cucumis spp* (cucurbits) *Spinacia oleracea* (spinach), *Amaranthus spp* (amaranths), and *Raphnus sativa* (radishes).

The present cropping pattern in the watershed is generally monoculture, and double cropping is carried out in a year. The main crop rotations are given below.

Paddy - wheat - one year (irrigated)
Pigeon pea - fallow - one year (rainfed)
Mandua - fallow - one year (rainfed)
Maize - fallow - one year (rainfed)
Soybean - lentil/pea - one year (rainfed)
Ginger - vegetable/potato - one year (irrigated)
Potato + soybean - one year (irrigated)

Wildlife

The watershed and surrounding area is suitable only for a few wildlife species because the forest is not dense. The wild animals found and reported to be seen in the area are the fox, jackal, boar, monkey (black mouth and red mouth), panther, mongoose, wild cat, and porcupine. The birds found are the owl, pigeon, cuckoo, crow, eagle, vulture, sparrow, parrot, bat, kite, partridge, magpie, and nightingale.

Socioeconomic aspects

Garhkot watershed covers six Gram Sabha (a village-level political body) with five villages and seven hamlets. The details are given below.

Gram Sabha, Villages and Hamlets in Garhkot Watershed

Gram Sabha Covered	Villages	Hamlet
Kandi Bagdi	Kandi Bagdi	-
Durogi	Chham	-
Bidakot	Bidakot	Bangarigaon
Pausada	Pausada	-
Amni	-	Hurbansamni, Bhatt gaon, Amni Timli
Garhkot	Garhkot	Hurmasa, Dyuli, Lwadla

A detailed survey of 45 farmers comprising of 15 members from each altitude zone (high, middle, and valley) was conducted with a pre-designed schedule in order to understand the socioeconomic structure, productivity of land, and arrangements for management of various water resources in the watershed.

The total human population of the watershed is 1,958 and it is distributed in 415 households (Table 6.6). Thus the average family size is about 4.71. However, average family size was maximum (5.20) in the middle hills followed by 5.04 in the low altitude zone and at least 4.4 in the high altitude zone. More than 54% of the total watershed population reside in the high altitude zone, while the corresponding figures for the middle altitude zone and lower altitude zone are 19 and 27% respectively. The female population is higher than the male in the watershed with a sex ratio of 1,075 women to a 1,000 men. The literacy rate is quite low (36.6%). There is a wide gap in the literacy rate of men and women. About 56% of men are literate while the figure is only 19% for women.

Social structural analysis revealed that the watershed is dominated by Rajputs who account for 78.7% of the total human population, followed by Brahmins 12.7%, and Scheduled Castes and Scheduled Tribes (SC and ST), 8.6%. In all the villages it was observed that the upper castes, i.e., Brahamins and Rajputs, are clustered in parts, while the SCs are settled in a separate group. Both upper castes had common traditions and mingled together, except for marriages. Most of the inhabitants are cultivators and follow the same agricultural practices. There are a few caste-based traditions, e. g, . worshipping of a god and goddess by the Brahmins and blacksmith work still carried out by Scheduled Castes. No other distinction is prevalent with respect to job opportunities. One common point that unites the whole village, however, is the worship of the village deity ('Gram Devta'). All the villagers worship this deity and perform their duties as per their caste traditions.

Land distribution

The land distribution pattern in the villages and watershed as a whole is presented in Table 6.7.The overall holding size in the watershed is 0.94 ha. The majority (63.3%) of farm

Table 6.6: **Basic information about villages in the watershed (1991)**

Name of Village	Altitude Range (m)	No. of House holds	Average Family Size	Human Population			Literacy			S.C and S.T. Population		
				Male	Female	Total	Male	Female	Total	Male	Female	Total
High Altitude Zone												
Kandi Bagri	1500-1690	100	3.91	181	213	394	99	43	142 (36.0)	22	16	38 (9.8)
Chham	1500-1600	27	5.11	62	76	138	39	28	67 (48.5)	8	4	12 (8.6)
Bidakot	1380-1500	99	4.65	238	222	460	119	19	138 (30.0)	10	10	20 (7.4)
Total		226 (54.5)	4.39	481	511	992	257	90	347 (34.5)	40	30	70 (7.1)
Mid Altitude Zone												
Pausada	1180-1380	52	4.92	118	138	256	81	54	135 (52.7)	7	9	16 (6.25)
Bangarigoan	1180-1340	27	5.74	71	84	155	45	15	60 (38.7)	Nil	Nil	Nil
Total		79 (19.0)	5.20	189	222	411	126	69	195 (47.4)	7	9	16 (3.89)
Low Altitude Zone												
Harbans-Amni Hurmasa	890-1180	6	4.5	15	12	27	10	8	18 (66.67)	Nil	Nil	Nil
Garhkot	860-1180	104	5.08	247	281	528	128	28	156 (29.5)	46	36	82 (15.5)
Total		110 (26.5)	5.04	262	293	555	138	36	174 (31.35)	46	36	82 (14.7)
Total Watershed	840-1690	415	4.71	932	1026	1958	521 (55.9)	195 (19.0)	716 (36.56)	93	75	168 (8.6)

Note: Figures in parentheses are percentages of the total population of the village.
Source: District Statistical Report of Tehri Garhwal, U.P. (1991).

families have marginal landholdings of less than 0.5 ha with an average holding size of 0.38 ha. No farmer has large holdings (> 10 ha) in this watershed. The number of small (> 2 ha), medium (4-10 ha), and semi-medium (2-4 ha) farmers has declined. Further, the average holding size varies significantly between altitudes. The lowest average holding size was 0.55 ha in Pausada (in the mid-altitude zone) and the maximum 1.13 ha in Chham village (in the high altitude zone). Thus the analysis revealed that there are disparities within as well as between the villages with respect to distribution of arable land.

Fragmentation

Scattered smallholdings pose severe problems to adoption of improved technologies, on the one hand, and have rendered agriculture uneconomical on the other (Table 6.7a). The watershed villages also exhibit the same characteristics in which smallholdings are distributed over five to nine locations situated from 0.4 to 1.5 km apart (Table 6.7b). Thus, the effective operational holding in one place ranges between 0.09 to 0.21 ha. Fragmentation consumes maximum time in travelling from one place to another for both humans and livestock. Realising the curse of fragmentation, farmers have tried to consolidate their landholdings by either legal sale purchase or the *Satwara* (a barter system comprising of exchange of land for land) system. *Satwara* land transactions have no legality as the land is not transferred in the records. People adopted the *Satwara* system to avoid the payment of duty for legal transfer and save their meagre financial resources.

Livestock

Livestock are an integral and vital part of the hill economy and the number of livestock is more or less equal to the human population. Garhkot watershed is no exception. The total livestock population in the watershed is about 1,900, almost equal to the human population in 1958 (Table 6.8). Cows constitute about one-third of the livestock population, followed by sheep and goats (32%). Buffaloes constitute about 24% of the total livestock population. Sheep, goats, and hens are kept primarily for commercial purposes, female buffaloes and cows for milk, and oxen for draught purposes. Increasing livestock population on the one hand and shrinking vegetative cover on the other compell farmers to travel as far away as eight km from the villages to collect grass from the forest (Plate 4).

Time-line analysis of watershed villages

The historical event analysis of villages in the Garhkot watershed is presented in Table 6.9.It is evident from the table that all these villages were settled by migrant people from far away places during the 9th - 10th centuries. It is further evident that settlements started in the higher reaches and slowly moved towards the lower altitude zone. Titles of land were given to the cultivators in 1951 after abolition of the feudal landlord system. Water harvesting in dug-out ponds is quite an old practice in the area, and the oldest existing one was built in 1945. Roof-top water harvesting, although a normal casual practice in the area, has been adopted into regular practice only in one village (Chham) since 1970. A water mill was established in Garhkot village in 1940. Other development activities started very late. All the villages and hamlets have electricity except for the hamlets of Hurmasa and Dyuli.

Women's dairy development cooperative society

To boost farm incomes from livestock, PARAG-a cooperative dairy development organisation in Uttar Pradesh started a Women's Dairy Development Cooperative Society in Bidakot during 1996-97.It is run completely by women. The Society is headed by the

Table 6.7a: **Distribution of farmers as per holding size (1991)**

Name of Village	Marginal < 0.5 ha			Small 1-2 ha			Semi- medium 2-4 ha			Medium 4-10 ha			Av. Holding Size (ha)
	No.	Area (ha)	Avg. holding (ha)	No.	Area (ha)	Avg. holding (ha)	No.	Area (ha)	Avg. holding (ha)	No.	Area (ha)	Avg. holding (ha)	
High Altitude Zone													
Kandi Bagri	50 (50)	8.22	0.164	23 (23)	24.389	1.061	23 (23)	55.27	2.40	4 (4)	18.082	4.52	1.06
Chham	15 (55.6)	6.678	0.445	9 (33.3)	14.667	1.629	3 (11.1)	9.319	3.106	-	-	-	1.13
Bidakot	57 (57.6)	18.625	0.327	32 (32.3)	38.192	1.194	8 (8.1)	19.826	2.478	3 (3.0)	14.889	4.963	0.925
Total	122 (54.0)	33.523	0.275	64 (28.0)	77.248	1.207	34 (15.0)	84.415	2.48	7 (3.0)	32.971	4.71	1.01
Mid Altitude Zone													
Pausada	48 (92.3)	23.6	0.49	4 (7.7)	5.2	1.3	Nil	-	-	-	-	-	0.55
Bangari goan	20 (74.1)	7.252	0.36	7 (25.9)	10.00	1.43	Nil	-	-	-	-	-	0.64
Total	68 (86.1)	30.852	0.453	11 (13.9)	15.2	1.38	Nil	-	-	Nil	-	-	0.58
Low Altitude Zone													
Harbans Amni	3 (50.0)	1.32	0.44	3 (50.0)	4.10	1.37	-	-	-	-	-	-	0.90
Hurmasa Garhkot	70 (67.3)	34.83	0.49	31 (29.8)	61.5	1.98	2 (1.9)	5.803	2.902	1 (1.0)	7.50	7.50	1.05
Total	73 (66.4)	36.15	0.49	34 (30.9)	65.60	1.93	2 (1.8)	5.803	2.902	1 (0.9)	7.50	7.50	1.05
Total Watershed	263 (63.3)	100.525	0.382	109 (26.2)	158.048	1.45	36 (8.6)	90.218	2.506	8 (1.9)	40.471	5.05	0.94

Figures in parentheses are percentages of respective totals
Source : Revenue Records (1991). Devprayag Tehsil, Tehri Garhwal District, U.P.

Table 6.7b: **Fragmentation of arable land**

Name of Village	Number of Fragments in Each Family	Av.Size of Fragment (ha)	Av. Distance between Fragments (km)
Kandi Bagri	5	0.21	0.5
Chham	9	0.12	1.0
Bidakot	7	0.13	0.4
Pausada	6	0.09	0.8
Bangari gaon	4	0.16	0.5
Hurbans Amni	6	0.11	1.2
Hurmasa Garhkot	8	0.13	1.5

Table 6.8: **Livestock population (No) of selected villages in the watershed (1997-98)**

Name of Village	Ox	Cow	She Buffalo	He Buffalo	Sheep	Goat	Hen	Dog	Total
High Altitude Zone									
Kandi Bagri	102	20	71	1	-	93	29	9	325
Chham	70	81	128	9	26	55	46	9	424
Bidakot	60	27	91	1	-	81	21	9	290
Total	232 (22.3)	128 (12.3)	290 (27.9)	11 (1.1)	26 (2.6)	229 (22.0)	96 (9.2)	27 (2.6)	1039 (100)
Mid-Altitude Zone									
Pausada	-	51	-	-	-	37	-	2	90
Bangari gaon	24	30	29	-	17	67	2	3	172
Total	24 (9.2)	81 (30.9)	29 (11.1)	-	17 (6.5)	104 (39.6)	2 (0.8)	5 (1.9)	262 (100)
Low Altitude Zone									
Harbans Amni	12	8	2	-	-	12	16	1	51
Hurmasa Garhkot	102	35	122	1	36	184	55	13	548
Total	114 (19.0)	43 (7.2)	124 (20.7)	1 (0.2)	36 (6.0)	196 (32.7)	71 (11.9)	14 (2.3)	599 (100)
Total for Watershed	370 (19.5)	252 (13.3)	443 (23.3)	12 (0.6)	79 (4.1)	529 (27.8)	169 (8.9)	46 (2.5)	1900 (100)

Source : Agricultural Census, UP, 1997

honorary President (elected from among the members), assisted by a paid secretary (nominated by the members) and a board of members (five). PARAG has deputed a woman worker from their organisation to assist in monitoring the day to day progress. Payment of Rs 300 per month is given to the Secretary by PARAG. Membership is open to all the women on payment of a one time membership fee of Rs 11 only. Each member is entitled to sell milk at the milk booth close to the road within a specified time, twice a day. The Secretary inspects the quality of milk in terms of fat percentage and records it in the presence of the members. The minimum criterion for accepting the milk is that it should have a fat content of more than six per cent, and milk having more than 6.9% fat receives a higher price. The milk collected is transported by the PARAG dairy people to the processing plant. The Village Women's Society has a joint account in the names of its President and

Table 6.9: **Historical timeline analysis of selected villages**

Events	Time period of their first occurrence					
	Kandi Bagri	Chham	Bidakot	Bangarigoan	Pausada	Garhkot
Establishment	9th Century	9th Century	9th Century	9th Century	9th Century	10th Century
Water mill	No	No	No	No	No	1940
Abolition of landlord system	1951	1951	1951	1951	1951	1951
First *Kuchha* pond dug out	1948	1948	1972	1960	1945	1965
Roof-top water harvesting	No	1970	No	No	No	No
High unprecedented rainfall	April, 1978	April, 1978	April, 1978	April, 1978	April, 1978	April, 1978
Kachha road to village	No	No	1960	No	No	No
Electrification	1985	1985	1985	1985	1986	1983
Primary school	1989	1898	1973	No	1973	1940
Junior High School	-	-	-	-	-	1995
Tap water facility from Bagwan-Alaknanda (42 km away) through lift	1986	1986	1986	1986	1990	1994
SWC works started	1982	1982	1982	1982	1982	1982
Cooperative Dairy	No	No	1996	1996	1996	No
Telephone	1997	1997	1997	1997	1997	1997
Distance to Hindolakhal	4 km	3 Km	3 km	3.5 km	3 km	5 km

1962 Block Development Office shifted from Devprayag to Hindolakhal where various facilities were developed

1948	Co-educational Private Junior High School	Collectively developed by all the villagers of nearby villages and headed by board of management - an elected body
1970 1972 1974-75	Co-educational High School Co-educational Intermediate Public School	Collectively developed by all the villagers of nearby villages and headed by board of management - an elected body Adopted by Govt. of U.P.
1965	Primary Health Centre and Veterinary Hospital	
1960	Post Office	
1982	Mettalled Roads	
1964	Cooperative Society	
1973	Nationalised Bank	

Secretary in the bank, and PARAG makes monthly or bi-monthly payments to the Society by cheque. The amount is then distributed to its members according to the quantity and quality of the milk. PARAG also provides free medical or health consultancies to its members for animals and also supplies feed on the basis of payment. There has been a positive growth in the number (increased from 18 to 50) of members, quantity of milk, and income for members. The quantity of milk sold daily depends on the season. It is highest (about 250 lit/day) during the rainy and lowest (60 lit/day) during the summer season.

Workforce

From the field survey it was fond that about 60% of the total watershed workforce is available within the watershed and 40% migrate outside in search of employment. This is because of the lack of off-farm employment opportunities in the area and predominance of rainfed farming. It was also found that the work force available in the villages is dominated by women. About 97% of the total women's work force is found in the village itself, while the corresponding figure for men is 29%, indicating that about 71% of men of working age migrate outside the watershed. It can be concluded that hill agriculture is predominantly dependent on women and the policy implication is that women extension workers may provide quick and better results than men (Plate 5).

Income generation

Family income includes return over variable costs from agriculture and net amount of remittances contributed by family members who have out-migrated. Contributions made by a permanent employee ¶are called income through service, while contributions made by seasonal migrants are called labour income. Average annual family income in the watershed is calculated on 1998 prices and ranges from 41,000 to 43,700 per annum with an average of Rs 42,500 (Table 6.10). The highest per family income is obtained in the high altitude zone (Rs 43,700) followed by the mid-altitude zone (Rs 42,823) and the least in the agriculturally dominant part of the watershed, i.e., the low altitude zone (Rs 41,016). Per capita average annual income is highest (Rs 9,925/) in the high altitude zone followed by 8,235 in the mid-altitude zone, and by 8,138 in the low altitude zone with an average of 9,043 for the watershed as a whole.

Table 6.10: **Annual net income (Rs/family) pattern of sample farmers at 1998**

Attitude Zone	Agriculture			Off farm			Total income
	Crop	Livestock	Sub total	Service	Labour	Sub total	
High-altitude zone	6000 (13.7)	3200 (7.3)	9200 (21.0)	24000 (55.0)	10468 (24.0)	34468 (79.0)	43668 (100)
Mid-altitude zone	5000 (11.7)	2500 (5.8)	7500 (17.5)	19600 (45.8)	15723 (36.7)	35323 (82.5)	42823 (100)
Low-altitude zone	14600 (35.6)	1000 (2.4)	15600 (38.0)	15200 (37.1)	10216 (24.9))	25416 (62.0)	41016 (100)
Overall for whole watershed samples	8533 (20.0)	2233 (5.3)	10766 (25.3)	19600 (46.1)	12136 (28.6)	31736 (74.7)	42502 (100)

Note: Figure in parentheses are percentages of the total
Source : Field Survey 1998

Composition of family income presented in Table 6.10 shows that the economy of the watershed is totally dependent on remittances received from family members who have out-migrated. Contribution of remittances varied significantly in the three zones. It is lowest (62%) in the low altitude zone and highest in the mid-altitude zone (83%) with an average of 75% for the watershed as a whole. Remittances made by seasonal migrants, i.e., labour, contribute about 29% to family incomes, about 17% less than the contribution made by the service group in the migrant population (46%). The agricultural sector contributes only one fourth of the family income in the watershed. Its contribution is lowest in the mid altitude zone (17.5%) and highest in the low altitude zone (38.6%). Thus, agriculture in the hills, particularly in the high and mid-altitude zones, is not profitable under current conditions. An efficient land-use management system with diversified enterprise combinations and improved technology packages are required. This will lead to economic prosperity and environmental security in the area.

Expenditure pattern

Annual family expenditure of the sample watershed was studied for different altitude zones for 1997 and is presented in Table 6.11. Farmers consume about 97% of their total family income in meeting their family's subsistence requirements. Thus, they are left with about Rs 1,120 per annum for investment activities. However, there is a marginal difference in expenditure/savings at different altitudinal zones. Mid-altitude zone farmers consume all their family income (99.5%), while farmers from lower altitudes save about 4.5% of their income. Most of the expenditure is on food (65%). The proportion of expenditure on food items was maximum (70%) in the mid-altitude zone, followed by 65% in the high altitude zone and a minimum (59%) in the lower altitude zone. Clothes are the second major item of expenditure, and their share varied from seven to nine per cent with an overall average of eight per cent. Lower altitude zone farmers spend about 50% more on medicine and treatment of their families. This is primarily due to topographical aspects and inaccessibility of the village. Education expenditure ranked fourth in family expenditure and it ranges from 4.7 to 8.2% with an average of 6.8%. Expenditure for improvement of land is least in priority and constitutes about 1.3% of the total expenditure.

Table 6.11: **Annual expenditure pattern (Rs/family) of sample farm group at 1998 prices**

Altitude Zone	Food etc	Clothes	Ceremonies	Medicines	Education (fee+book+rent)	Land Treatment and Agril. Dev.	Others	Total
High altitude zone	27440 (64.7)	3567 (8.4)	3860 (9.0)	2415 (5.7)	3500 (8.2)	40 (1.1)	1200 (2.8)	42432 (100)
Mid altitude zone	27900 (70.2)	3930 (9.2)	2750 (6.5)	2215 (5.2)	2000 (4.7)	300 (0.7)	1500 (3.5)	42595 (100)
Low altitude zone	22960 (58.7)	2879 (7.4)	3261 (8.3)	3620 (9.2)	3000 (7.7)	900 (2.3)	2500 (6.4)	39120 (100)
Overall	26767 (64.7)	3459 (8.4)	3290 (8.0)	2750 (6.6)	2833 (6.8)	550 (1.3)	1733 (4.2)	41381 (100)

Note: Figures in parentheses indicate per cent of total expenditure.
Source : Field Survey 1998

It is interesting to note that lower altitude zone farmers invest twice more than high altitude and thrice more than mid-altitude zone farmers in land improvement. This is attributed to the fact that high and mid-altitude zone farmers receive less income from agriculture and, therefore, do not care much about land improvement.

Temporal distribution of water resources

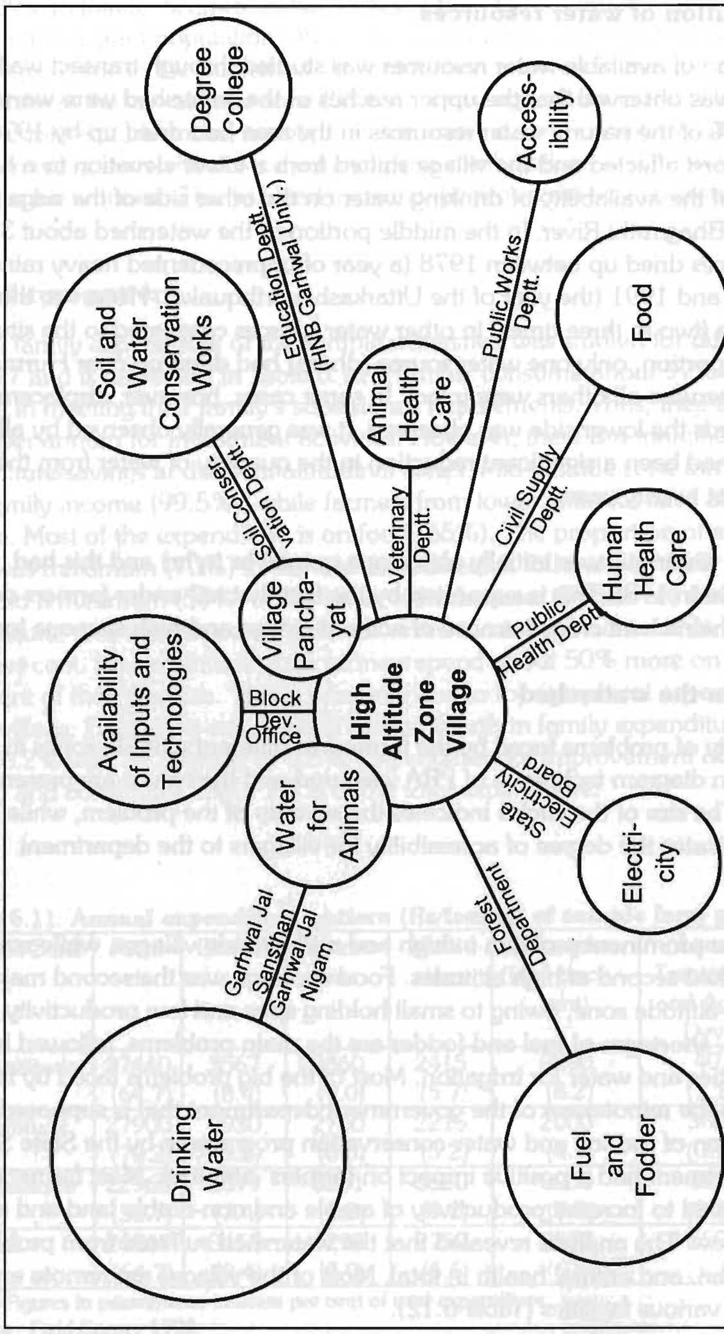
Temporal distribution of available water resources was studied through transect walks with elderly villagers. It was observed that the upper reaches of the watershed were worst affected. About 83% of the natural water resources in the area had dried up by 1976.Kandi Bagri village was worst affected and the village shifted from a lower elevation to a higher elevation because of the availability of drinking water on the other side of the ridge forming a catchment of the Bhagirathi River. In the middle portion of the watershed about 35% of the total water sources dried up between 1978 (a year of unprecedented heavy rainfall in the month of April) and 1991 (the year of the Uttarkashi earthquake). However, there was a significant reduction (two to three times) in other water sources compared to the situation in 1950. In the valley portion, only one water source (dhara) had dried up near Hurmasa hamlet in 1991, otherwise all others were intact. In some cases, however, displacement of water courses towards the lower side was observed. It was generally observed by all the villagers that there had been a significant reduction in the quantity of water from these sources over the past twenty years.

The capacity of the water mill was initially about one quintal/hr (q/hr) and this had decreased to 0.6 q/hr in 1988.This is supported by the fact that tail-ender farmers do not demand water for their wheat crops because of acute shortage and high seepage losses.

Major problems in the watershed

To assess the severity of problems faced by the farmers in different altitude zones in the watershed, the Venn diagram technique of PRA was used and the results are presented in Figures 6.5 to 6.7.The size of the circles indicates the severity of the problem, while distance from the village indicates the degree of accessibility for villagers to the department concerned.

Drinking water is the prominent problem in high and mid-altitude villages, while scarcity of fuel and fodder ranked second at high altitudes. Food shortage was the second major problem in the mid-altitude zone, owing to small holding sizes and low productivity. In the lower altitude areas, shortages of fuel and fodder are the main problems, followed by lack of human health facilities and water for irrigation. Most of the big problems faced by farmers are primarily due to the remoteness of the government department that is supposed to solve them. Implementation of the soil and water conservation programme by the State Soil Conservation Department had a positive impact on farmers' attitudes. Most farmers felt that this programme helped to increase productivity of arable and non-arable land and augment lean period water flow. The analysis revealed that the watershed suffered from problems related to soil, human, and animal health in total. Most of the villages are remote and have little accessibility to various facilities (Table 6.12).



Source: Field Survey, 1998

Figure 6.5: **Venn diagram showing problems and accessibility to the related Institute in the high-altitude zone village**

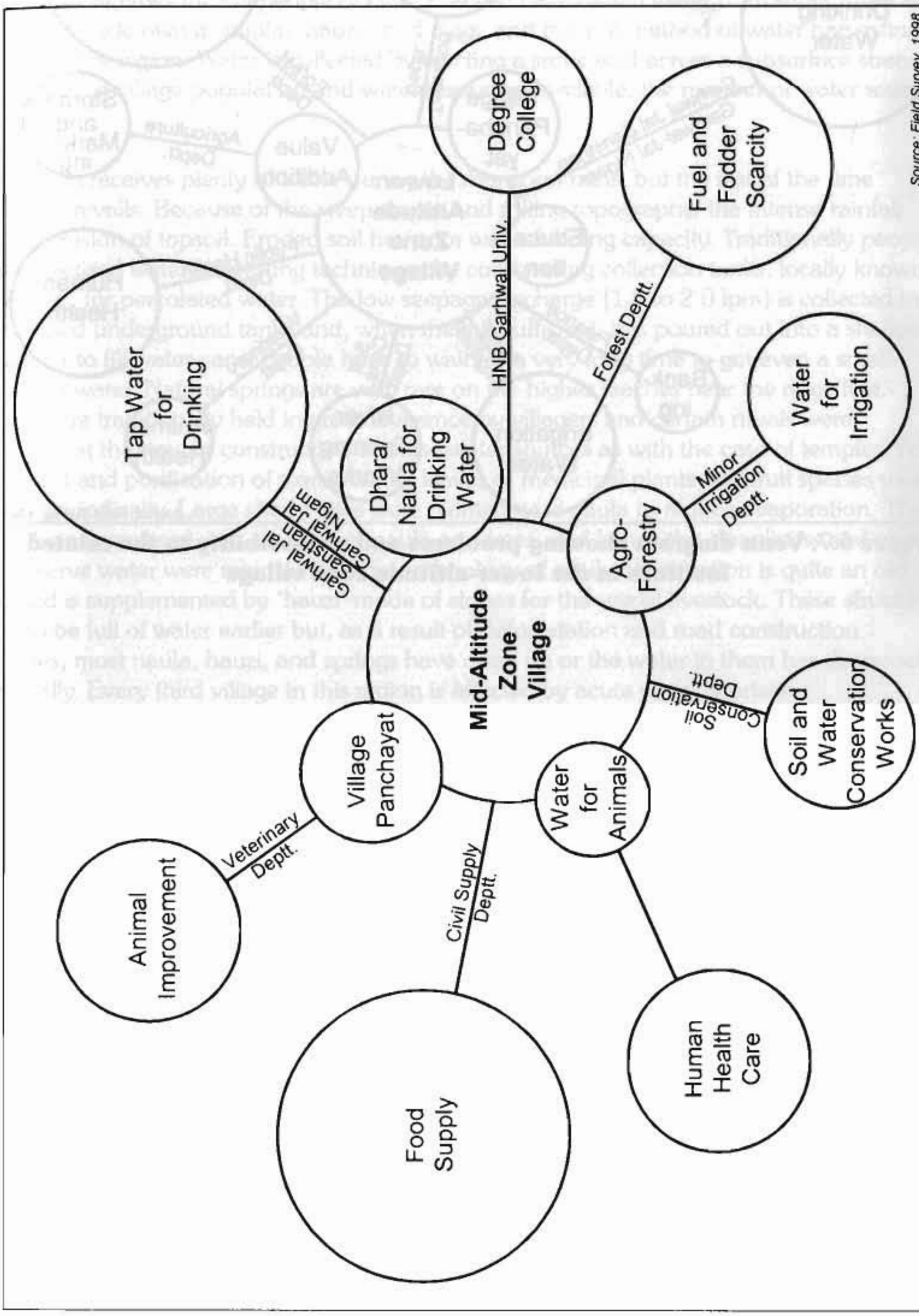


Figure 6.6: **Venn diagram showing problems and accessibility to the related Institute in the mid-altitude zone village**

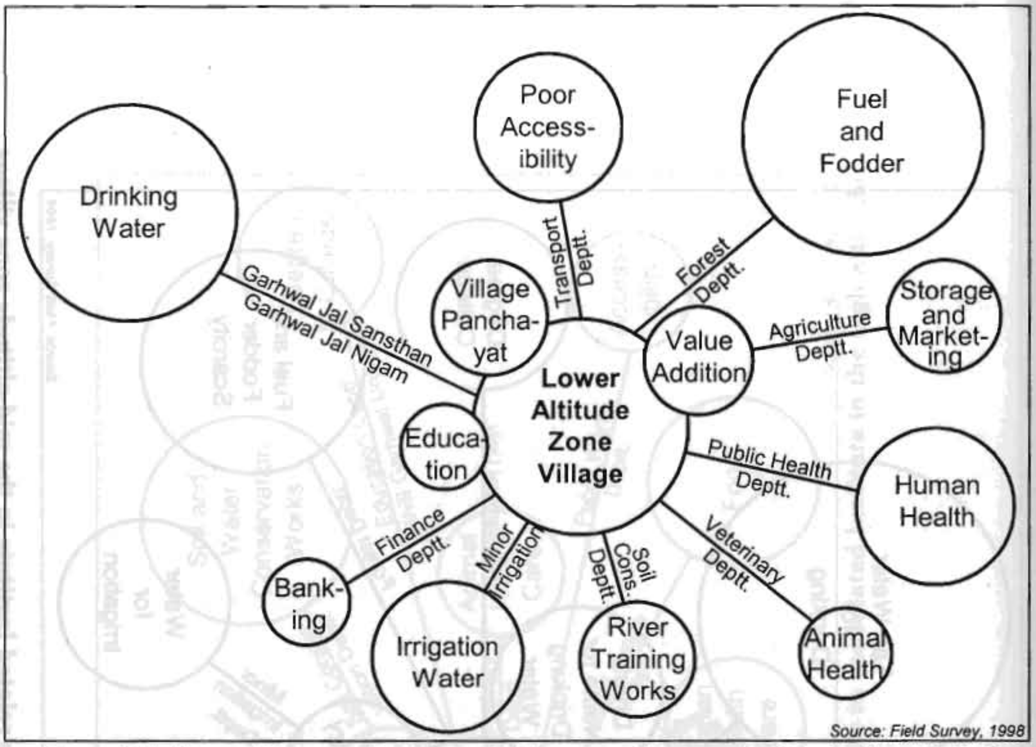


Figure 6.7: **Venn diagram showing problems and accessibility to the related institute in the lower-altitude zone village**

Table 6.12: **Accessibility of selected villages from nearest infrastructure distance from the village**

Facility	High-altitude Zone		Mid-altitude Zone			Low-altitude Zone	
	Kandi Bagri	Chham	Bidakot	Banga-rigaon	Pausada	Hurmasa	Garhkot
Electricity	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Distance from motarable road (km)	3	1.5	0	0.5	0.5	3	3.5
Fair price shop (km)	4.0	3.0	3.0	3.5	3.0	3	3.5
Primary school	0	0	0	0.5		0.5	0
Junior High School	4.0	3.0	3.0	3.5	3.0	0.5	0
Inter College	4.0	3.0	3.0	3.5	3.0	4.5	5
Degree College	28	27	26	26.5	26.5	26	26.5
Bank	4	3.0	3.0	3.5	3.0	4.5	5
Post Office	4	3.0	3.0	3.5	3.0	4.5	5
Water mill	No	No	No	No	No	1.0	0.5
Flour mill	4	3	3.0	3.5	3.0	3.0	3.5
Primary health centre	3	1.5	1.5	2.0	1.5	4.0	4.5
Block Development Office	4.0	3.0					
Veterinary							

Source: Field survey, 1998

6. Local Water Harvesting Technology, Practices and Knowledge : Status and Critical Review

Traditional/indigenous knowledge, methods, and practices for assessing and using water at the local level

Since ancient times the hill people of Uttar Pradesh have drawn water from small, shallow ponds locally known as naula, 'hauzi', and *diggi*, and this is a method of water harvesting typical of this region. Water is collected by erecting a stone wall across a subsurface stream. Based on the village population and water resources available, the number of water sources varies.

The region receives plenty of water during the monsoon rains, but the rest of the time drought prevails. Because of the steep slopes and rolling topography, the intense rainfall causes erosion of topsoil. Eroded soil has poor water-holding capacity. Traditionally people have practised water-harvesting techniques by constructing collection tanks, locally known as 'naula', for percolated water. The low seepage discharge (1.5 to 2.0 lpm) is collected in stone-lined underground tanks and, when there is sufficient, it is poured out into a shallow container to fill water cans. People have to wait for a very long time to get even a small bucket of water. Natural springs are very rare on the higher reaches near the ridge line. Naula were traditionally held in great reverence by villagers and certain rituals were observed at the time of construction of these water sources as with the case of temples. For treatment and purification of stored water, leaves of medicinal plants and fruit species were added periodically. Large shady trees were planted near naula to reduce evaporation. This is still being practised, i.e., worship of naula and trees, and hence the cleanliness and effort to conserve water were maintained. The technology of naula construction is quite an old one and is supplemented by 'hauzi' made of stones for the use of livestock. These structures used to be full of water earlier but, as a result of deforestation and road construction activities, most naula, hauzi, and springs have dried up or the water in them has decreased drastically. Every third village in this region is affected by acute water shortage.

In the middle reaches, the availability of water improves slightly as the recharge area increases, resulting in longer concentration time for runoff water. Consequently, the opportunity for infiltration time increases, and there is an increase in the number of streams and discharge in Pausada, Amni, Harbans, Dyuli, and Garhkot villages. The discharge from dhara (springs) during the summer peak is from five to 20 litres per minute depending on the recharge area and the location. The residents in the area state that many water sources dried up and disappeared after the disastrous Uttarkashi earthquake in October 1991.

Ponds are very rare in this area and most of the water storage structures are cement-plastered tanks constructed in stone masonry. Almost 60-70% of these tanks are defunct as a result of sub-standard construction or wrong site selection or because cracks have developed following soil subsidence/settlement in the filling area. Ms Shakuntala Raturi, Pradhan of Pausada; stated that out of 12 cement tanks constructed in this area, only four are storing surplus water from springs and the eight remaining are defunct as the water sources have dried up in some cases and the tanks need repair also. This situation is prevalent not only in the study area, but also in the entire hilly region. Since water sources are Common Property Resources (CPR), no one looks after their maintenance and upkeep. However, during scarcity, a roster for water distribution is prepared based on family units: a practice going back three generations. On the outskirts of the village on the north-eastern ridge. there are two springs locally called *Magron Ka Dhara,* one giving a lean period discharge of 10 litres per minute (lpm) and the other, on the left side of the village school, discharging 18 litres of clean drinking water per minute. The overflow from the second spring is being diverted through a 193-metre long, unlined eastern channel with an approximate cross-section of 50 cm x 20 cm, locally called a guhl. The excess discharge of overflow from the spring is conveyed through the channel in a stone masonry, cement-plastered tank of 10 m in length, 6 m in width, and 2 m in depth (inside dimensions), i.e., with a capacity of 120 cubic metres. Another similar tank with less capacity (80 m^3) is positioned near the other spring.

On the other side (south-east) of the ridge below Pausada village, two springs with a lean season discharge of 5 lpm and 9 lpm are also used to collect drinking water. In addition to these, one spring at Bangarigaon village has a discharge of 18 lpm and one at Dyuli village has a maximum discharge of 6 lpm; the overflow from this is untapped and it flows into the Garhkot Gad to be finally used in Mulyagaon village situated outside the watershed on the downstream side.

The former Pradhan of Bangarigaon village stated that there are five water sources in this village and only one in the lower village, Hurmasa. Water is primarily used for drinking purposes and the overflow is collected in cement tanks overnight to irrigate small vegetable plots. Rotational distribution of water was fixed family-wise in 1946 and prior to that, before independence, when this was a part of the kingdom of the then Maharaja of Tehri. One villager (Mr. Bihari Lal Bhatt) stated that many streams had dried up as a consequence of the 1991 earthquake. An old perennial water source called *Amni Ka Dhara* had dried up eight years previously. This was feeding surplus water to a cement-lined tank of 12 m x 4 m x 1.25 m: i.e., 60 m^3. This tank has no water at all now. Most of the existing tanks have been constructed under the National Watershed Development Programme for Rainfed Agriculture (NWDPRA). Through the Watershed Development Project, the renovation of naula (percolation water storage tanks) has been carried out by the state soil conservation unit of the Department of Agriculture. Water channels, locally called guhl, have been constructed to channel the overflow from streams of runoff water from seasonal torrents for aquatic crops, e. g. , rice in the rainy season. A small reach of these channels is lined and the remainder is left unlined. This has resulted in a drastic reduction in efficiency (approx. 30%). The Pradhan of Garhkot village (Mr. Hukam Singh) is presently constructing lined channels by assigning jobs to village people on a daily wage basis of Rs 60. The total length of the channel is 250 metres with a cross section of 30 cm x 20 cm.

Gender aspects

Women are the hub of all activities in this neglected and backward region. Apart from routine household chores, all the agricultural and livestock raising activities are being carried out primarily by women. Only ploughing with bullock pairs is carried out by men. Collecting or fetching water for domestic use is the sole responsibility of women. In the case of irrigation, women take charge in the absence of men. Women are totally responsible for collecting fuel and fodder from distant places. They have to travel up to 12 km up and down to do so. Thus most of the time women are kept busy in routine duties. Drudgery is a way of life in this difficult and backward region, irrespective of caste or economic status. Women hardly get time to participate in meetings about water or forest management. Most adult women are illiterate and unexposed to water management activities. Consequently, they simply carry out routine work as dictated by their spouses.

Ethnicity and indigenous knowledge about water and water harvesting

The importance and utility of water has been understood by the inhabitants of hilly region since time immemorial. Originally the habitations were settled near and around the sources of perennial water, e. g. , springs, water falls, seepage/percolated water or streams or rivers. With the increasing population (human and cattle) and better standards of living, the demand for water increased. Biotic interference, environmental degradation, and increase in roads and buildings have led to a dwindling away of natural water sources.

The survey team observed that people in remote areas were very conversant with water-harvesting techniques as these were very much a part of their adaptation to life in the mountains. Rain water was collected in rocky natural depressions for miscellaneous and livestock needs; naula were constructed to collect low discharges through seepage/percolation; and in the upper reaches roof-top water harvesting had been practised for a 100 years as a means of supplementing supplies from springs and erratic tap water supplies. Rain water is free and can be stored in the house and used for domestic purposes, livestock, and kitchen gardening. This was the practice during British times. These same practices were carried out in Champawat district of Kumaon hills as far back as 1917.

Local water-harvesting technologies (indigenous and recent)

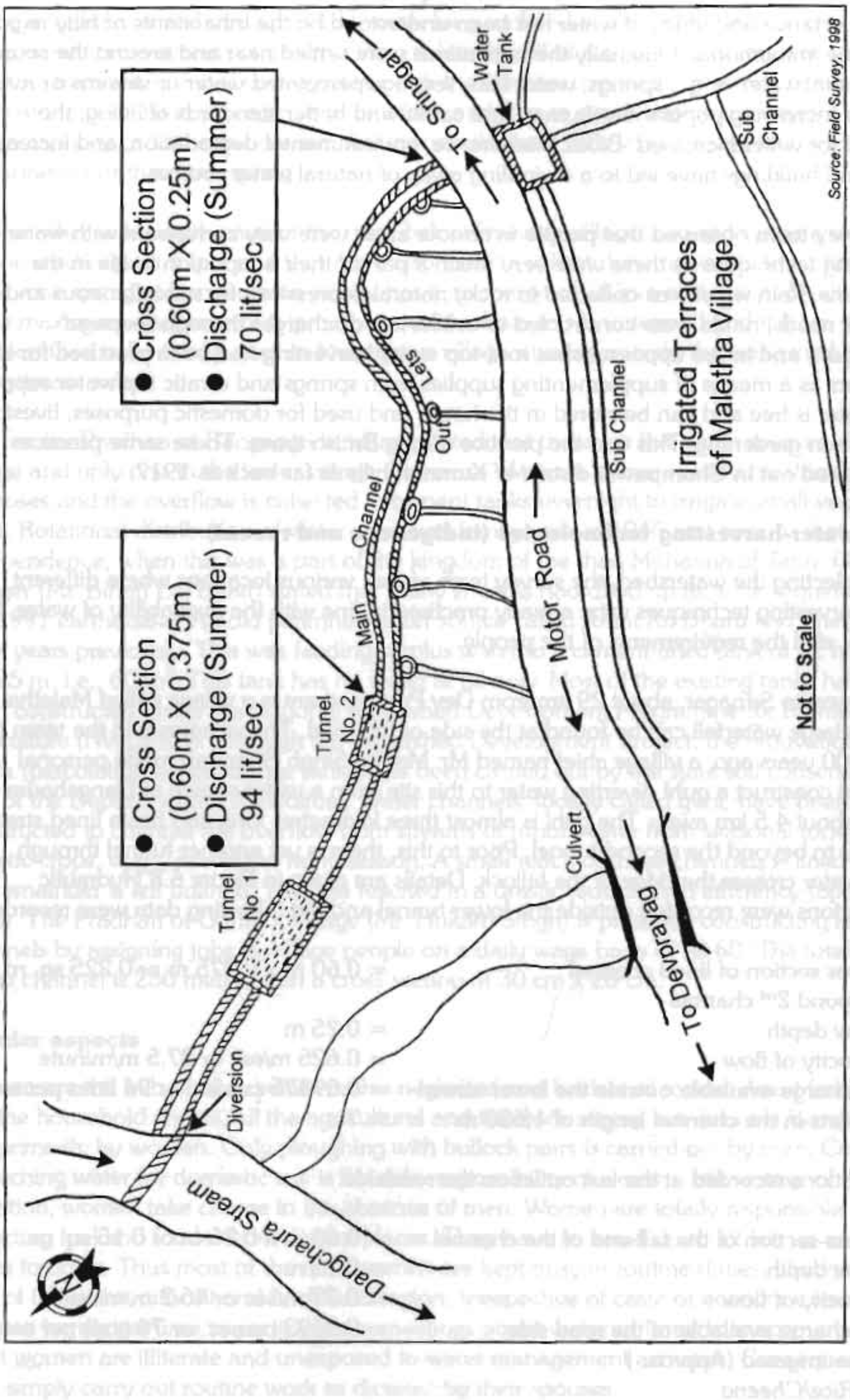
While selecting the watershed, the survey team visited various locations where different water-harvesting techniques were already practised in line with the availability of water, the location, and the requirements of the people.

On the way to Srinagar, about 29 km from Dev Prayag, there is a village called Maletha where a large waterfall can be found at the side of the road. The villagers told the team that, about 300 years ago, a village chief named Mr. Madho Singh Bhandari made personal efforts to construct a guhl diverting water to this site from a water source at Dangchaura village about 4.5 km away. The guhl is almost three kilometres long and has a lined stretch of 1,650 m beyond the second tunnel. Prior to this, there is yet another tunnel through which water crosses the ridge of the hillock. Details are given in Figure 6.8.Hydraulic observations were recorded outside the lower tunnel and the following data were recorded.

• Cross section of lined channel (beyond 2nd channel	= 0.60 m x 0.375 m or 0.225 sq. m.
• Flow depth	= 0.25 m
• Velocity of flow	= 0.625 m/sec or 37.5 m/minute
• Discharge available outside the lower tunnel	= 0.09375 cumec. or 94 litres per sec.
• Outlets in the channel length of 1,650 m	= 7

Observations recorded at the last outlet on the roadside.

• Cross-section of the tail end of the channel	= 0.60 m x 0.25 m or 0.15 sq. m.
• Flow depth	= 0.15 m
• Velocity of flow	= 0.77 m/sec or 46.2 m/minute
• Discharge available of the road side	= 0.0693 cumec. or 70 litres per sec.
• Area irrigated (Approx.)	
(i) Rice/*Cheena*	
(ii) Wheat/Potato	= 50 ha = 70 ha



Source: Field Survey, 1998

Figure 6.8: **Local water harvesting techniques, Maletha village (Tehri Garhwal district)**

On the same road at Bagwan (16 km from Dev Prayag) towards Srinagar, there is yet another perennial water source with a discharge of approximately 35 litres per second. This discharge is diverted to irrigate crops of rice, potatoes, wheat, and onions. This practice of constructing lined channels is adopted at several locations in the region.

In the middle reaches there are several dhara and naula which primarily supply drinking water and the excess water, i.e., overflow, is diverted to cement-lined tanks for small-scale collection; and the water collected in this way can be crucial in times of drought. Renovation of naula and construction of small unlined ponds have been carried out by the State Soil Conservation Unit, while tanks and channels, locally called hauz and guhl, have been constructed by the Watershed Development Project.

In the upper reaches, embankment-type rain water collecting ponds could be seen in natural depressions where the bases were rocky. One was observed in Kandi Bagri village and another was observed just below Chandrabadni temple in Naukhari village at an altitude of almost 2,500 masl.

The specifications of the two rain-water collection ponds in the vicinity of the watershed are as follow.

- **Location** : **Kandi Bagri Village**
  - Elevation : 1,650 masl
  - Dimensions : Average observations
    - Length - 60 m
    - Width (embankment) - 35 m
    - Depth - Maximum- 4 m, minimum-1.5 m
  - Inlet : Runoff collection
  - Surplussing arrangement : Yes
  - Use of water stored : Livestock and washing
  - Year of construction : 1986
- **Location** : **Naukhari Village (below Chandrabadni Temple)**
  - Elevation : 2,480 masl
  - Dimensions : Average observations
    - Length - 100 m
    - Width - 30 m
    - Depth - Variable (1.5 to 2.5 m)
  - Inlet : Runoff collection
  - Outlet : Seepage flow
  - Use of water : Drinking water for animals and groundwater recharge
  - Year of construction : 1975

This kind of pond is usually found at high altitudes (beyond 1,500 m).

In the same upper reaches, it is the practice to collect rain water from slanting roof tops by diverting the flowing rain water through sheet metal drains placed horizontally across the roof and diverting it into a tin funnel and a vertical drainpipe opening into a water container (tank/drum). Even in recently constructed houses with cemented rooves, villagers place pipes to collect rain water. Twelve households are collecting water from the roof in cement tanks. On average, a roof of 150 sq. m. is enough to provide about two cubic metres of water with one hour of moderate rainfall (15 mm/hr). The local people think that this water can not be stored for a long period, and they avoid using it for human consumption.

Bench terraces are constructed for soil and runoff conservation. Cultivation on benched terraces is predominant in the region and steep slopes are transformed into relatively level, narrow steps across the slope. The cultivators in the hills use irrigated, level bench terraces and attain a high rate of productivity. The vertical interval between two adjacent bench terraces should normally not exceed two metres to maintain stability; the width should not be less than three metres to facilitate farming operations and uniform distribution of water. Water moves down from terrace to terrace. The excess water from the last terrace is usually safely disposed of through a well-vegetated grass waterway. Specifications for bench terraces in the UP hills have been calculated by Juyal and Katiyar (1990) and are given in Table 6.13.

Table 6.13: **Specifications for irrigated bench terraces in the hills of UP**

Land Slope (%)	Vertical Interval (m)	Bench Width (m)	Soil Depth (m)
10	0.8	7.5	0.7
20	1.0	5.0	0.8
30	1.2	4.0	0.9
40	1.5	3.7	1.0
50	1.8	3.5	1.2

Source : Juyal and Katiyar 1990

Quality of spring water

In the Garhwal Himalayas where a large population is dependent on natural springs for drinking water, the importance of spring water quality cannot be neglected. The main problems confronting the users of spring water are chemical and biological contamination through infiltration. In the watershed area, almost all the springs discharge water under gravity and the groundwater is in unconfined aquifers. This means that there are increased possibilities of leaching out of surface water into the springs through percolation. If surface water receives sufficient treatment within soil layers, the quality of water will not be poor. But, in the hills, cracks and joints present in the rock can cause short-circuiting and untreated waste water can enter the groundwater body and pollute it. Therefore, to ascertain the degree of subsoil water contamination, the quality of spring water was assessed.

Methodology

The methodology followed during the study included a preliminary survey, in depth monitoring, and data analysis. A preliminary survey was conducted in the watershed to monitor the springs. After surveying, twelve springs/ naula situated in the watershed were selected for water sampling to determine the physico-chemical characteristics. Water samples were collected during the summer of 1998.These samples were analysed by standard methods.

<u>Physio-chemical characteristics</u>

The water samples collected from different springs were colourless; transparent without any turbidity. No specific taste and odour were observed, indicating that water samples were odourless and unremarkable with respect to taste and odour.

The various parameters with respect to water quality are presented in Table 6.14. The pH of spring water ranged between 6.7 to 7.3. The minimum pH value (6.7) was observed in spring water from Kandi Bagri and Pausada and the maximum value (7.3) was observed in spring water from Bangarigaon, Amni Dhara, and Garhkot. Such a slight variation in pH may be ascribed to the varying chemical composition of underground rocks from where water passes out to form springs. Considering the standards for pH laid down by the World Health Organisation (WHO) for drinking water, the spring water is well within permissible limits. Electrical Conductivity (EC) is considered to be a direct indicator of concentration of total dissolved ions in water. In the watershed, spring water had a wide range of EC from 28.3 to 290 micro mhos/cm (Table 6.14). The water from Garhkot had the highest EC of 290 micro mhos/cm followed by Kandi Bagri (200-230 micro mhos/cm) and Amni springs. A possible reason for the high EC could be the dissolution of salts from the bedrock. The water could be taken as safe for drinking purposes as far as EC is concerned.

Sulphates in groundwater are found naturally due to dissolution of calcium sulphate from bedrock. The concentration of sulphate in spring water ranged from 8.4 to 52.21 ppm. The highest value of 52.21 ppm was observed in the Garhkot spring, followed by Amni Dhara (13.66 ppm) and Bidakot spring water (11.25 ppm). The other spring water had the same value of 8.4 ppm. The concentration of sulphate in spring water is within desirable limits (250 ppm) for drinking water (as specified by WHO in their guidelines). Concentration of chlorides was observed in traces and therefore cannot be quantified, and thus there is no fear of chloride toxicity in using spring water for drinking purposes. The carbonate and bicarbonate ions ranged from 1.5 to 15.0 ppm and 73.20 to 147.92 ppm respectively in the water samples analysed. The lowest value of carbonate (1.5 ppm) was obtained in Bidakot and the highest value (15 ppm) in Bangarigaon spring. Similarily, bicarbonate was also minimum (73.20 ppm) in Bidakot and maximum (147.92 ppm) in Bangarigaon springs.

Nitrate is one of the important criterion for the quality of drinking water. Its high concentration is toxic for infants and creates lethal effects (Steel and Meghee 1984). Concentration of nitrate in watershed springs ranged from 17.3 to 47.0 ppm (Table 6.14). About 60% of water samples were found to have a concentration of nitrate as high as 30 ppm. These results are in line with those reported by Kumar and Rawat (1996) who observed that concentrations of nitrate ranged from 11.6 to 68.4 ppm (60% of the samples had more than 50 ppm) in the natural spring water near Almora in the UP hills. Considering an upper limit of 10 ppm as a criterion fixed for nitrate concentration in drinking water by the World Health Organisation (WHO), and 30 ppm as laid down by the Ministry of Health, Government of India, 60% of the spring water in the study area is not suitable for human consumption. However, no case of blue babies (children born with rhesus negative blood) caused by nitrate toxicity has been reported so far. It is, therefore, suggested that these springs be protected against further contamination if they are used for drinking as there is no other option for the villagers.

Calcium and magnesium salts in the water make it hard. In domestic water, hardness is not desirable as it results in excess soap consumption. The concentration of calcium and magnesium in spring water in the watershed ranged from 16.0 to 30.0 ppm and 6.0 to 43.2 ppm, respectively. The minimum concentration of 16.0 ppm calcium was observed in Bangarigoan and Bidakot and the maximum value of 30.0 ppm was found in Garhkot and Kandi Bagri springs. The concentration of magnesium ions was minimum (6.0 ppm) in Kandi Bagri spring (A) and maximum (43.2 ppm) in Bangarigaon spring. This could be due to variation in baseflow conditions through the bedrock. The concentrations of both calcium

Table 6.14: **Physical and chemical characteristics of spring water of Garhkot watershed**

Characteristics	Springs											
	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}
	Kandi Bagri	Kandi Bagri	Pausada	Pausada	Pausada	Dyuli	Bangari gaon	Amni Harbans	Hurmasa	Garhkot (Dhara Aam)	Amni Dhara	Bidakot
	(A)	(B)	(A)	(B)	(C)							
1. Colour	----- Permissible Colourless ----											
2. Taste and Odour	Nothing and No*	No	No	No	No	No	No	No	No	No	No	No
3. Ph	6.7	6.7	6.7	6.8	6.8	6.8	7.3	6.8	6.9	7.3	7.3	6.8
4. Ec (micro mhos/cm)	230	200	73	200	200	140.3	128.3	28.3	66.3	290	210	164.3
5. Cl (ppm)	-	-	-	-	-	-	-	-	-	-	-	-
6. SO_4 (ppm)	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	52.21	13.66	11.25
7. CO_3	6.0	6.0	4.5	13.5	6.0	6.0	15.0	9.0	4.5	7.5	9.0	1.5
8. HCO_3 (ppm)	99.12	99.12	96.07	134.20	94.55	76.25	147.92	108.27	83.87	102.17	94.55	73.20
9. NO_3	37.10	17.30	32.10	29.00	29.70	17.30	39.60	37.10	26.00	32.10	42.10	47.00
10. Ca (ppm)	30.0	26.0	22.0	26.0	24.0	26.0	16.0	26.0	20.0	30.0	20.0	16.0
11. Mg (ppm)	6.0	26.4	18.0	13.2	9.6	8.4	43.2	8.4	19.2	18.0	42.0	10.8
12. Fe (ppm)	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
13. Cu (ppm)	0.003	0.001	0.003	0.002	0.003	0.004	0.001	0.002	0.002	0.004	0.003	0.002
14. Mn (ppm)	Nil	Nil	0.001	0.004	Nil	0.002	Nil	Nil	0.002	Nil	Nil	Nil
15. Zn (ppm)	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	0.004	0.001

*No - Not objectionable

Source : Field Survey 1998

and magnesium were well within the permissible limits laid down by the World Health Organisation (WHO) for the quality of drinking water.

The concentration of copper ranged from 0.001 to 0.004 ppm, zinc from nil to 0.004 ppm, manganese from nil to 0.004 ppm, and iron was not found in the spring water. Thus, the water was found to be within safe limits of 0.1 ppm for iron, 0.05 ppm for copper, and 5.0 ppm for zinc as per the guidelines of the WHO for drinking water. Thus, spring water in general can be stated to be quite suitable and fit for use by aquatic plants and other life forms. However, these springs must be maintained and protected to collect quality water on a sustainable basis.

Efficiency of the local water use system

Most of the local water conveyance systems are unlined over a highly permeable soil mass. Only about two per cent of the channels, locally called guhl, are lined with cement plaster over local stone masonry work. The condition of lined guhl was not satisfactory, mainly because of the ignorance of villagers and apathy of the department. In some villages, it was also found that guhl were constructed and lined with concrete and cement, but there was no water to flow in these guhl.

The storage tanks in most cases are cement lined, otherwise they would not be able to hold water. The siltation rate in the tanks was found to be quite high (1.2 to 3.2 $kg/m^2/yr$). The main losses are during conveyance from the source to the field and during application and storage in the soil profile. As much as 70% of the water is lost and only about 30% is made use of in this already water-starved region. Even if the channels *(guhl)* are lined, they become defunct as a result of debris slides from above, disruption caused by toe-cutting, and gravelly sediment in naturally flowing water. The unlined channels (guhl) are most inefficient in conveying water. The dhara are fed by natural springs. They are a common and popular source of drinking water, but yet huge amounts of scarce water get wasted through inefficient water use.

7. Local Water Supply and Management Systems

Water sources

The study area is situated between two major snowfed river systems, namely, the Bhagirathi in the North-West and the Alaknanda in the South East. The rivers join together at Dev Prayag and thereafter are known as the Ganges. Both rivers flow 800-900 m vertically below the highest point in the watershed. The watershed selected is a catchment of the River Alaknanda. The elevation range is far below that of the permanent snow line. Thus, all the water sources available in the watershed depend on rainfall and groundwater recharge. Chham and Kandi Bagri villages are in the upper reaches and experience few snowfall events. When snow does occur, it melts within a week. Groundwater potential in the watershed has not yet been assessed. Thus rainfall, surface flow, and oozing out of groundwater in places locally called dhara (if water is available in larger quantities and used as a fountain) and naula (if trickling or oozing water) are collected in a very small ditch protected with stone or a wooden roof). Unlined dug-out ponds for collection of excess runoff during rainy season are common in the upper reaches. At mid-altitude the lean base flow is channellised through earthen diversions and carried to cement-lined water storage devices—tanks or hauz— through unlined small channels, guhl. The valley areas had plenty of water in the past, and it was used directly by constructing earthen or cement-lined guhl.

With the increase in demand, on one hand, and declining water availability in the stream on the other, farmers have been forced to line the guhl and tanks with cement as far as possible. In order to avoid excess withdrawal of water from a guhl at its head, resulting in less water for downstream users, a simple inexpensive device can be adopted. At the opening of a turn out, a small boulder is placed with clay sealing it so that the largest stone obstructs the mouth of each but the last turn out, the sizes of the stones obstructing successive turn out mouths become progressively smaller. Some measure of equity in water distribution is thus ensured.

In the region twice a year, the villagers jointly undertake the cleaning and repair of the irrigation system of tanks and channels by removing silt and obnoxious weeds. Those unable to take part in the work provide hired labour. Widows, the infirm, and handicapped persons are exempted. Most of the villagers are of the opinion that the irrigation department and government agencies need not interfere in their arrangements. They believe that if a guhl were to be handed over to the government, it would be destroyed. Even if a new guhl were to be made, there would be no one to maintain it.

Water is diverted at the head of each system by means of a temporary embankment through which enough water is permitted to flow into the system. As per the typical cross sections reported, limited capacity of the guhl ensures that only a certain quantity of water can pass into it. The diversion structure is washed away frequently during monsoon, but it is promptly repaired by the beneficiaries who act collectively. Maintenance and cleaning of the channel within one's field is the responsibility of each farmer. For paddy irrigation, water is allowed to flow from the higher to the lower fields, and establishment of an extensive network of field channels is avoided.

Overexploitation of available vegetation in the region and faulty land-use practices together with natural disasters such as earthquakes and landslides, have contributed significantly to a decrease in water supplies. Time-line analysis of water sources in the watershed showed that a lot of water sources in the area have dried up during the past 20 to 30 years (Annex I). Kandi Bagri villagers shifted to the upper reaches because of the dhara in the old village were drying out and hence water was scarce. Diminishing availability was observed at many water sources. All the villagers of the Hindolakhal Development Block and Dev Prayag Tehsil joined forces to agitate against the government, demanding provision of soft drinking water. The State government established a lift scheme from the Alaknanda River for drinking water, and tap water was provided to the villages.

The tap water system

Water is lifted from the Alaknanda River near Bagwan village on the Devprayag-Srinagar road at government expense. Garhwal Jal Nigam, a state government organisation, is responsible for construction of water collection and distribution systems. The system is handed over to another sister organisation, namely, Garhwal Jal Sansthan, for distribution, minor maintenance, and collection of revenue. The system has been in operation since 1980. It reached the selected watershed villages in 1986, 1990, and 1994 only. The total length of this lift system is about 30 km and water reached the highest point near Chandrabadani in three phases. At the end of each phase, there is a water collection tank, a pump for lifting water, and a distribution system. Distribution of water from a tank at lower elevation reduces the discharge and water pressure at higher elevation. The whole distribution system is practically managed by a water-box man. Each water-box man covers about 60-80 villages within a radius of 20 km. Inaccessibility and paucity of maintenance funds are the main constraints faced by the water-box man in maintaining the system.

Drinking water supplies

Various drinking water supply systems are present in the villages selected. Dhara are the most prominent sources of drinking water and are found in all elevation ranges followed by the tap-water supply system. There is only one naula present in the watershed and this is situated in the mid-altitude zone. People in the low-altitude zone are forced to drink polluted stream water owing to the scarcity of other sources of drinking water. Seasonal distribution/ availability of water from these revealed that there is no scarcity of drinking water during the rainy season. In the winter, water scarcity occurs in high altitude villages and villagers queue for water. On the other hand, at mid-altitude and in the valley plenty of water is available. During summer, drinking water is scarce in all three zones and common in the whole Development Block. People have to travel long distances to fetch water (Table 6.15).

Table 6.15: **Distance travelled and waiting time for drinking water during summer by the villagers**

Parameter/Source	High-altitude Zone	Mid-altitude Zone	Low-altitude Zone (Valley)
Dhara			
Distance travelled (km)	3 to 3.5	0.5 to 1.0	0.5 to 1.0
Waiting time (hour)	2 to 4	2 to 3	0.3
Tap Water			
Average frequency observed			
Rainy season	Twice a week	Daily	Twice a week
Winter season	Once in a week	Once in a week	Once in a week
Summer	Not available (not sure)	Fortnightly	Not available
Waiting time (hours) winter	4 to 6	4 to 6	6 to 8
Waiting time (hours) summer	8 to 10	6 to 8	Not available
Water transported from Devprayag			
Average price paid (Rs/lit)	0.75	0.50	Not purchased
Availability	Erratic	Erratic	-

Source: Field Survey 1998

Water supplies for domestic purposes and cattle

Pond and roof-top water harvesting are prevalent in the high altitude zone, while tanks and guhl are used widely in the mid-altitude and valley (Table 6.16). Water availability from them decreases with the advancement of time from rainy season to summer. Animals have to travel four to eight km for water, particularly from high and mid altitudes. Three continuous ponds constructed on the other side of Kandi Bagri provide drinking water for animals and water for washing. Chham villagers have to travel four to six km away. Mid-altitude farmers travel downstream about two to three km away to get water for their animals.

Irrigation

Water is not available for irrigation in the high-altitude zone. Tanks and guhl are the common water-harvesting and recycling devices at mid-altitude and in the valley. Water from these sources is sufficient during rainy season. During winter, discharge decreases drastically and the command area is reduced by 70% in the mid-altitude zone and 40% in

Table 6.16: **Water sources and availability of water for human uses**

Sources	High Altitude				Mid-altitude				Low Altitude			
	Pre-sence	availability during			Pre-sence	availability during			Pre-sence	Availability during		
		R	W	S		R	W	S		R	W	S
Drinking purposes												
Tap	Yes	L	M	M	Yes	L	M	M	Yes	L	M	M
Dhara	Yes	A	M	M	Yes	A	A	M	Yes	A	A	A
Naula	No	-	-	-	Yes	L	M	M	No	-	-	-
Stream	No	-	-	-	No	-	-	-	Yes	A	A	A
Other purposes (washing & cattle)												
Pond	Yes	A	L	M	No	-	-	-	No	-	-	-
Tank	No	-	-	-	Yes	A	L	M	Yes	A	L	L
Roof top water harvesting	Yes	L	M	No	Yes	L	M	No	Yes	A	L	No
Guhl irrigation	No	-	-	-	Yes	L	M	No	Yes	L	M	M
Stream irrigation	No	-	-	-	No	-	-	-	Yes	A	A	L

R= Rainy season, WS= Winter season, S = Summer, L = Low, M = Meager, A = Adequate
Source : Field Survey 1998

the valley. All the farmers have realised this and, by mutual agreement, tail-ender farmers do not ask to share the water. The normal irrigated crops are wheat and potatoes in winter (rabi) and paddy in the rainy ('kharif') season. During winter, one to two waterings are available rather than three to four during the rainy season, along with adequate rainfall from July to September. For winter crops, water is required in October for pre-sowing irrigation and again between December to February based on the availability of winter rains. During rainy season, two waterings are needed in July and August for transplanting and thereafter continuously up to the end of September.

Water mills

The steep gradients of hill rivers provide ample scope for generation of electricity through micro-hydropower generation techniques. Local people are using this potential for water mills. Water mills have been used for more than a hundred years in the region. There were many water mills in the UP Himalayas in the past. Some of them have been replaced by diesel/electric motor engine mills. Yet, at present, there are more than hundred thousand operational water mills in the region. Most of the water mills are owned by higher caste people belonging to low-income groups. Ownership of a water mill is restricted because one has to own land near a potential site for hydropower. There is a complete, cohesive interdependency between various ethnic groups. People of all castes use the mill on a first come first served basis and pay equally for milling. The mill owner pays only a nominal amount of revenue (Rs 16 per year) for setting up a mill. Uniform charges of Rs 0.80/kg or 12% of input is charged by the mill owner from all customers irrespective of caste and religion. Technological improvements in water mills have increased their efficiency by a 100%, one water mill owner stated at a meeting of the UP Hill Water Mill Association held on 2nd November 1998 in Dehradun. It was also observed that the number of water mills is decreasing over time because of scarcity of water (Bartarya and Valdiya 1989). A water mill owner (Mr. Hukum Singh) in the selected watershed revealed that there is about a 40% reduction in grinding efficiency of his mill compared to 1970. This is because of decreased water flow. Downstream from Garhkot Gad, there were four water mills within a span of four km until 1970, and today there is only one. This is partially due to the lack of water for generating the power required and partly to the replacement of water mills by electric/diesel motor mills that are more efficient.

Traditional water-management systems

The water scarcity in the region is acute during summer. Discharges from dhara and naula decrease significantly. Tap water supplies are erratic and insufficient. The seriousness of the scarcity can be seen from the fact that one man was killed in the summer of 1998 over a water dispute. People have had to devise their own methods of water distribution from available sources.

Traditional water-harvesting systems still continue in this region and are managed by the village communities themselves. The Gram Sabha (village assemblies) manage their own water resources. Based on the population and on water requirements, rosters for water use are maintained.

Most of the area in these hills is rainfed, however a small percentage of cultivated area is irrigated. Wherever a perennial source of water is available, streams are harnessed by temporary diagonal obstructions, made of boulders, trees, or logs, diverting the flow into contour channels along the hillsides. Well construction is very rare except near perennial streams. Canals receive supplies from local springs or streams. Masonry canals, unless lined with lime and stone, deteriorate very rapidly. Large tracts are infested with land crabs which, to get to the water, bore through the ordinary boulder masonry set in white lime. This causes extensive damage to canals.

Some canals are built from hill torrents and from perennial streams and rivers by individuals. Usually the streams almost sink underground on reaching the base of the hill. Large rivers are torrential in nature and follow very steep slopes in descent. The irrigating capacity of the canals varies according to the extent to which they are lined and also according to the type of soil used to build them. A tract of good quality land may not produce as much as one of poorer quality with irrigation facilities. Availability of water also determines the cropping pattern.

Hill farmers harness even the most insignificant water sources that can be diverted to the field. The water source may not carry enough volume outside the monsoon period to support a good winter crop but farmers will still harness it. Villagers who own sufficient irrigated land do not migrate to the plains. Development of irrigation in the hills has been left to the cultivators and has not been considered a government responsibility. After independence, the irrigation department in the hills modernised some of the traditional irrigation systems in the early 1950s and created a few new ones. Some experts are of the opinion that farmer-managed irrigation systems are on the verge of extinction in this region. In fact, there is not enough data about their existence (being small-sized systems), and they are so simple in design that they may go unnoticed by someone looking for sophisticated engineering structures.

Management of drinking water

Locally available water sources, i.e., dhara or naula are cleaned by villagers once a year through '*Yuwak Mangal Dal*' (Village Youth Welfare Groups) without any payment. Sometimes (once in five years), these dhara require major repairs, and these are carried out by all the villagers/beneficiaries on a voluntary basis. All the beneficiary families contribute equal amounts of labour and money to accomplish the job. Sometimes they receive the funds needed from the Block Development Office. Farmers believe that the amounts sanctioned are less than required and beneficiaries have to contribute to maintenance. Maintenance of the tap-water system is the responsibility of the state government department, the Garhwal Jal Sansthan. The present management situation is inadequate. Distribution of drinking water is by roster. The first-in-first out (FIFO) rule is followed in distribution. All the sources of drinking water are busy for 15 to 20 hours a day, particularly during summer. In cases of acute shortage, no family can fetch more than 40 litres at a time and this restriction is imposed in the high and mid-attitude zones especially. If water is available, it is used according to the same rules (Plate 6).

For special ceremonies like marriages, each family contributes its first quota of water to the family in question. In case tap water is available, the whole amount will be used by the family celebrating the marriage. Conflicts about distribution of water often arise between villagers. Most of these are resolved by the village elders on the spot, but, if an amicable solution is not reached, the Village Panchayat, with the advice and cooperation of elderly villagers, will resolve the conflict. Most resolutions are modifications in norms or suggestive in nature. Financial or other restrictions are not within the purview of these committees.

Drinking water is common property between two villages also and managed by a water users' society ('Pani Panchayat') consisting of both villages. For example, a dhara between Amni and Bidakot villages is a common source to both villages. The Pani Panchayat decided that Bidakot villagers can fetch water between 3a. m. and 10p. m. and the rest of the time, i.e., from 10p. m. to 3a. m. Amni village folk will fetch water. The first-in-first-out (FIFO) rule is followed. For efficient functioning of the system, a paid watchman is engaged by the Pani Panchayat. For this, the Pani Panchayat collects a nominal amount of Rs 20 per family per month to pay the watchman. For repair and maintenance, all the beneficiary villagers contribute one day's labour or equivalent wage payment to the Pani Panchayat. The water source between Pausara and Bangari gaon is jointly shared in a similar by both the villages without fixing any time schedule, but the FIFO rule is followed. Maintenance is carried out through voluntary contribution of labour by all the beneficiaries once a year.

Ethnicity and drinking water sources

Drinking water sources, either dhara or tap, are separate for upper caste and lower caste people. Every village is caste-based, i.e., upper caste consisting of Brahamins and Rajputs and lower castes. Scheduled caste clustering is a common feature. Upper castes have different drinking water sources than lower castes (Plate 7). No-one can use the water sources of another caste, particularly for drinking. If water is available from other caste sources, generally from the lower caste sources, it is used by higher castes for washing and animals. The FIFO rule is followed in all cases. Maintenance of these sources lies within the purview of each group. However, in some cases, the village *panchayat* gets a special grant for socially weaker sections for rehabilitation of water sources and to accomplish the job with the cooperation of that community. In very adverse situations, particularly in high altitude villages like Kandibagdi and Chham, when water scarcity is faced by socially weaker sections, they are given water by the upper castes to drink at the source. In this case also, they have to wait in a queue (though separately) for their turn. The upper caste person in the corresponding position in the queue next to them will fetch water and supply it to them.

Gender aspects

It is normal practice in the hills that all jobs, such as collection of water, fodder, fuel, animal grazing, and washing, which require continual and persistent labour for maintenance of the household and farm, are carried out by women. Men do engage in hard labour such as ploughing and construction as well as in conflict resolution, but these are occasional in the agricultural year and do not represent continual drudgery. However, no hard and fast distinction is followed. Most of the work is carried out by women. Women's representation in the Pani Panchayat is a new concept only after reservation of seats for women under the new Panchayati Raj Institution Act (PRI Act). Women hardly contribute to planning, managing, and decision-making with respect to water sources. They simply carry out the decisions made by the male-dominated Pani Panchayat.

Irrigation management system

Water for irrigation is available at mid altitude and in the valley only. Surplus water, either as surface flow or base flow, i.e., oozing out, is diverted through a water channel guhl and collected in a cement-lined tank. It is distributed through a number of unlined guhl. Each water collection tank has a defined command area and all the land owners of the defined area prior to 1950 are members of informal groups for the tank or irrigation system. All those who owned land at the time of abolition of kingship, i.e., 1950, are known as 'thok'. Any subsequent division of land within the thok is not considered as an independent unit. Only the head of the thok is a member of an informal group.

Water-harvesting structures and conveyance systems were initially constructed by local people through contributions in cash as well as in kind based on the area to be irrigated. Regular repair and maintenance of the system is done collectively, prior to the onset of the monsoon and wheat sowing by the beneficiaries as per thok and area to be benefited. Members can contribute in the form of labour or cash. If there is no major breakdown of the system, routine cleaning of guhl and the system is carried out by the person watering the fields. The informal group mainly consists of men from each thok, but there is no restriction on women participating.

Each informal group prepares its estimates for repair/maintenance and extension of irrigation facilities in order to seek financial assistance from government financial sources. All these estimates are checked and prioritised by the village council or Gram Sabha decisions are made on the basis of considerations of social justice and the needs of the people. Projects receiving high priority are then submitted to the Block Development Office, Hindolakhal, by the Head of the village council, the Pradhan. The Minor Irrigation Department prioritises all the applications and allocates the budget for sanctioned projects after completing formalities. The sanctioned budget finally allotted to the village Pradhan to accomplish the job. Since the probability of approving the project from the minor irrigation department is very poor, many times the village Pradhan diverts the 'Jawahar Rojgar Yojna' (JRY) funds for this purpose with the approval of the village council. All the work is completed under the supervision of the village Pradhan. Since funds available to the village council are limited, most of the work cannot be done. Many times there are technical as well as financial lapses in such programmes. Thus the village Pradhan becomes the contractor for all the programmes financed by the government. This has eased the social ties, on one hand, and resulted in poor cooperation and mistrust in village-level institutes on the other. Therefore, local institutions have a more adverse impact on social attitude, behaviour, and community development programmes than before.

Distribution of water for irrigation

All the beneficiaries from a water distribution system form an informal group. The number of beneficiaries is determined as the number of families at the time of abolition of the landlord or kingship system, i.e., in 1950. Paddy is the major kharif (rainy season) crop grown under irrigated conditions. Paddy nurseries are raised close to the water source in the month of May. Each thok is allotted water for 24 hours. If there are sub-divisions within a thok the distribution of water for 24 hours among themselves is the responsibility of the head of the thok as the representative of the water users' group. Thok owning fields closest to the water source receive water first followed by the next owner and so on. This is carried out with minimum seepage and conveyance losses. During summer, water is very limited and, to make efficient use of it, people raise paddy nurseries close to the water sources by mutual consent without payment. Lean flows of water are first collected in a tank and opened for irrigation only after it is completely filled. In most cases, early morning or late evening irrigation is followed to minimise evaporation losses. The same practice is followed when paddy is transplanted. Normally paddy is transplanted jointly by all the beneficiaries from the source. In the remaining area water for irrigating paddy increases, and there are no shortages when annual precipitation is normal. Bartering for water within the group is permitted, but not outside the group.

After harvesting paddy, all the farmers receive water once through the same roster system prior to planting wheat. From the month of December onwards, water supplies decrease drastically and nearly 70 and 30% of the beneficiaries at mid-altitude and in the valley do not get water. Tail enders are well aware of the scarcity and do not demand water. They do not contribute to the maintenance of the system during this period. In the valley people cultivate potatoes and onions. These activities are mostly restricted to those who have landholdings very close to water-harvesting structures or water sources. Thus locational advantages are used to good advantage by the farmers. All farmers have equal rights to water for irrigation, and it is distributed without any disparity based on caste, sex, or economic status. Disputes are resolved in informal group meetings involving all the beneficiaries, and group decisions are strictly followed. Thus formulation of norms for water use, contributions for upkeep of the system, and so on are subjected to revision from time to time depending on the availability of water and the amount required for maintenance.

Civil soyam and forest panchayat management system

Civil soyam land (owned by the forest department and managed by villagers) and Forest panchayat ('Van Panchayat' - owned and managed by villagers) are the two main categories of common property resources in the study area. These two categories of forest land are given to local people primarily to strengthen local institutions and ensure that they have a stake in it so that local demands for fuel, fodder, and timber for agricultural implements will be met. All the villages in the selected watershed have civil soyam land except Harbans and Amni villages. Van Panchayat(s) are limited to Chham, Harbans, Amni, and Garhkot. Civil soyam land is not managed by any set rules or norms. These lands are used by everyone without a management system. In fact, all the civil soyam land is turned into open access resources and ultimately this land becomes wasteland, devoid of vegetation.

The Van Panchayat in the study area has been in existence since 1958.It is managed by a Committee headed by the village Pradhan. There are four to five elected members on the Committee. No effort has been made to rejuvenate the degraded Van Panchayat by the local people. The only restriction currently in place followed strictly in Garhkot and Chham

Van Panchayat is a complete ban on cutting down trees. The State Soil Conservation Unit, Kirtinagar, implemented a watershed management plan in the selected watershed during 1992-95 under the National Watershed Development Project in Rainfed Areas (NWDPRA). Efforts were made to rejuvenate civil soyam as well as the Van Panchayat by adopting soil conservation measures, e. g. , trenching, planting, and loose boulder and gabion check dams. Due to the open grazing practices adopted by villagers and the low participation of local people, these measures have been not been very successful. Therefore, people's participation is an important element in making these CPRs self sustainable.

Recent demands for increased water supply

As the population of both people and livestock increased in the watershed the demand for water also increased. Human population figures for the three altitude zones were collected for the years 1981, 1991, and 1998 from secondary sources and converted into standard human population units. The human population for the next 22 years in the watershed was projected through fitting a trend equation and this is presented in Table 6.17.Daily water requirements for the human population were worked out at two rates, i.e., 150 lit. /day and 175 lit/day per standard human units (Tables 6.18 and 6.19). The estimated water demand is presented in Tables 19 and 20. Based on the recorded discharge from various drinking water sources in each altitude zone, the supply of water from these sources will be enough to cater for human needs even in summer, provided water is collected 24 hours a day. The remoteness of water sources and lack of infrastructural facilities to store water during the night have created a shortage of drinking water in the region.

Table 6.17: **Standard human population of Garhkot watershed**

	Year	Standard Human Population (No)			
		High Altitude	Mid Altitude	Low Altitude	Total Watershed
Actual	1981	72	77	70	219
	1991	96	111	88	295
	1998	120	130	103	353
Projected	2000	124	137	106	367
	2010	152	169	126	447
	2020	180	200	145	525

Table 6.18: **Water requirement (00 lpd) for human consumption @ 150 lpd (litre per day)**

Year	Standard Human Population (No)			
	High Altitude	Mid Altitude	Low Altitude	Total Watershed
1981	108	116	105	329
1991	144	167	132	443
1998	180	195	155	530
2000	186	206	159	551
2010	228	254	189	671
2020	270	300	218	788

Table 6.19: **Water requirements (00 lpd) for human consumption @ 175 lpd**

Year	Standard Human Population (No)			
	High Altitude	Mid Altitude	Low Altitude	Total Watershed
1981	126	135	123	384
1991	168	194	154	516
1998	210	228	180	618
2000	217	240	186	643
2010	266	296	221	783
2020	315	350	254	919

Source : Field Survey 1998

The standard livestock populations for 1987 and 1997 were used to estimate livestock populations for 2000 and 2010 by fitting a trend line (Table 6.20) and water requirements were estimated as per the technical coefficient observed in the area and presented in Table 6.21.By comparing the requirements for people and livestock, it became clear that twice as much water is needed for livestock in the high altitude zone, nearly half in the mid-altitude zone, and almost equal in the valley.

The total water requirements for people and livestock in the watershed are presented in Table 6.22. Past experience and available statistics suggest that the water shortage can mainly be attributed to the poor structural and management system rather than availability in gross terms.

Table 6.20: **Standard livestock population in different zones of the watershed**

Year	Standard Human Population (No)			
	High Altitude	Mid Altitude	Low Altitude	Total Watershed
1987	813	120	340	1273
1997	913	198	434	1545
2000	943	222	435	1600
2010	1043	300	439	1782
2020	1143	378	533	2054

Table 6.21: **Water requirements (00 lpd) for livestock purposes @ 50 lpd**

Year	High Altitude	Mid Altitude	Low Altitude	Total Watershed
1987	407	60	170	637
1997	457	99	217	773
2000	472	111	278	800
2010	522	150	220	892
2020	572	189	267	1029

Table 6.22: **Total projected water requirements for human and livestock in the watershed (00 lpd)**

Year	Water Requirements (00 lpd)
2000	1443
2010	1675
2020	1948

Source : Field Survey 1998

Local water supplies: the main problems

Water scarcity in the region is attributed to many factors. These factors can be grouped into biophysical and socioeconomic aspects and as such have been presented in Figure 6.9. Under the biophysical factors, erratic rainfall, topography (steep slope, gravelly soil), heavy runoff, and soil erosion caused by ineffective vegetative cover are listed. As far as socioeconomic factors are concerned, faulty land use, low adoption of soil and water conservation techniques, and poor water-harvesting and management systems are the main constraints to augmenting water supplies. Increased human and livestock populations, poor economic conditions, the land tenure system, the fact that women are alone in carrying out most of the agriculture, over-grazing, and subsistence agriculture are the major socioeconomic constraints.

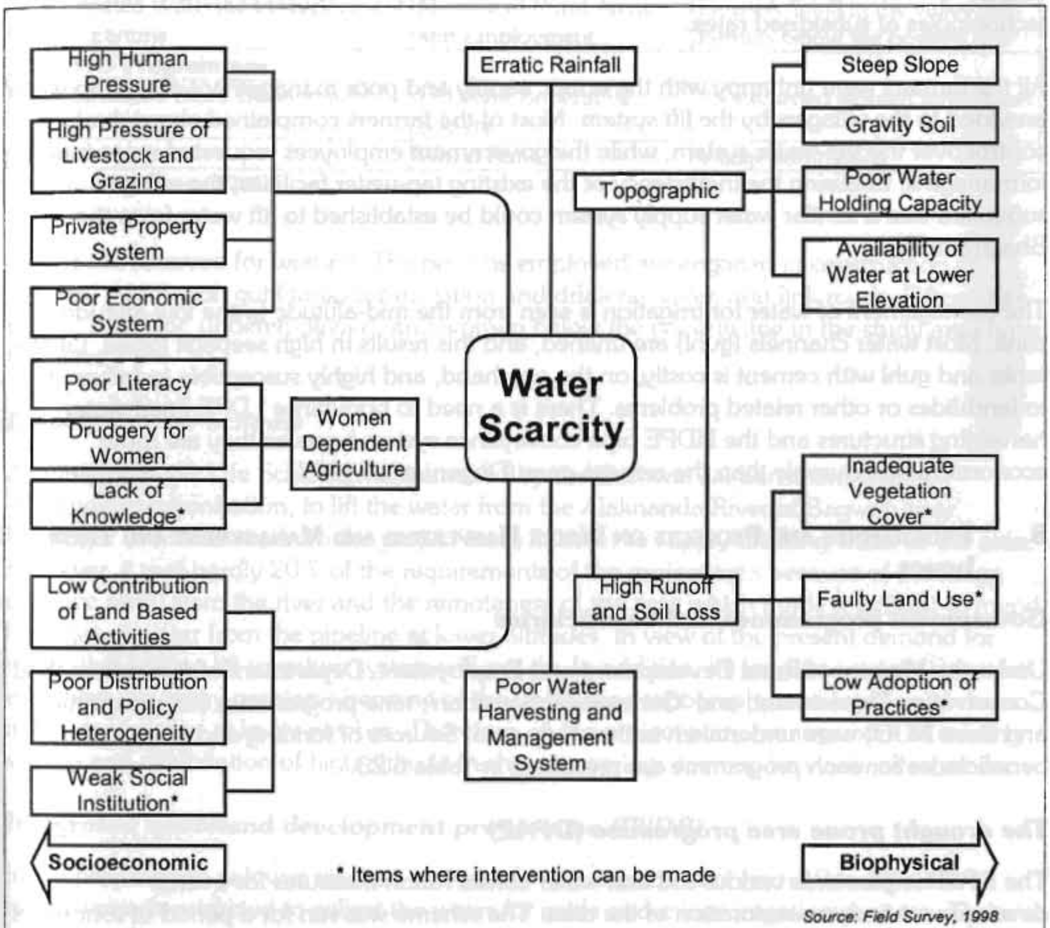


Figure 6.9: **Problems caused: diagram of water scarcity**

Critical issues

Analysis of the watershed and discussions with inhabitants revealed that there were areas in which government intervention (financial or technical or both) could increase water supplies and prosperity in the region. These interventions include creating awareness about the water-management system among the rural masses through various extension methods, improving the economic status of local people through improved crop production technologies, and establishment of agro-based cooperative industries.

All the inhabitants in the watershed realised that denudation of the area caused by ineffective vegetative cover, faulty land-use systems, and lack of proper soil and water conservation measures are the main reasons for depletion of water resources. Mid-altitude and valley zone farmers have perceived a significant increase in the water supplies after implementation of a watershed management programme by the state government in the area. Absence of proper water-harvesting and recycling structures and poor management of available structures are the key issues and require government intervention. Most farmers want to fence in the common land and carry out large-scale plantation of fuel and fodder species with staggered contour trenching on these lands. High-altitude farmers favoured construction of dug-out ponds on common land and adoption of roof-top water harvesting technologies at subsidised rates.

All the farmers were unhappy with the erratic supply and poor management of the tap water provided to the villagers by the lift system. Most of the farmers complained about dual control over the tap-water system, while the government employees requested more funds to manage it. Realising the inefficiency of the existing tap-water facilities, the villagers suggested that a similar water supply system could be established to lift water from the Bhagirathi River.

The management of water for irrigation is seen from the mid-altitude to the low-altitude zone. Most water channels (guhl) are unlined, and this results in high seepage losses. Lining tanks and guhl with cement is costly, on the one hand, and highly susceptible to failure due to landslides or other related problems. There is a need to popularise LDPE-lined water-harvesting structures and the HDPE pipe conveyance system because they are more economical and durable than the cement ones (Dhyani *et al.* 1997).

8. PROGRAMMES AND PROJECTS ON WATER HARVESTING AND MANAGEMENT AND THEIR IMPACT

Government programmes and beneficiaries

Under the Ministry of Rural Development and Employment, Department of Agriculture, Soil Conservation Department, and 'Garhwal Jal Sansthan', nine programmes (six government, and three NGO) were undertaken in the study area. Sources of funding and target beneficiaries for each programme are presented in Table 6.23.

The drought prone area programme (DPAP)

The DPAP implements various soil and water conservation measures for overall development and eco-restoration of the area. The scheme was run for a period of four years (1988-92) with development costs of Rs 4,000 per hectare. The Soil Conservation Department, Govt. of Uttar Pradesh, carried out in situ moisture conservation, construction and repair of ponds and guhl, and construction and renovation of terraces. A large number of families benefited from this programme.

Jawahar rojgar yojna (JRY)

The JRY scheme is totally financed by the Government of India. It provides employment to poor and underemployed villagers who live below the poverty line. Under the scheme, 30%

Table 6.23: **Projects, programmes and target beneficiaries in the area**

Programme	Source of Funds	Target Beneficiaries
A. Government Programmes		
1. Drought Prone Area Programme (DPAP)	Ministry of Agriculture	All cultivators
2. *Jawahar Rojgar Yojna* (JRY)	Ministry of Rural Area and Employment	Community resource, rehabilitation, and weaker sections
3. Drinking Water Scheme	*Garhwal Jal Sansthan* (Govt. of U.P.)	All farmers
4. Integrated Rural Development (IRDP)	Ministry of Rural Areas and Environment	All villagers
5. Million Well Scheme	World Bank	Small and marginalised farmers
6. Integrated Watershed Development Programme	Ministry of Rural Areas and Employment	Farmers living in the valley. All farmers below the poverty line
B. NGO Programmes		
1. Cooperative Dairy Development	PARAG Cooperative Society	All interested women inhabitants
2. *Swajal Yojna*	World Bank	Village community

Source : Field Survey 1998

of jobs are reserved for women. The persons employed are engaged in construction of schools, *panchayat*, guhl tanks for irrigation and drinking water, and link roads. Fifteen per cent of the poor, underemployed, and women below the poverty line in the study area have benefited.

Drinking water scheme

A Drinking Water Life Scheme was launched by the Garhwal Jal Sansthan, a State government organisation, to lift the water from the Alaknanda River at Bagwan near Kirtinagar (35 km away from the project area) in order to supply drinking water to the area. However, it met hardly 20% of the requirements of the project area because of the long distance away from the river and the remoteness of the area which made it difficult to mend leakages of water from the pipeline at lower altitudes. In view of the present demand for water, the existing lift irrigation system will not do. In addition, lift irrigation is cost intensive and there are many problems because of the undulating topography and location of rivers in the deep valley at lower reaches. Therefore, in the project area, management of existing springs and exploitation of high-altitude fresh water springs seem to be viable alternatives.

Integrated wasteland development programme (IWDP)

In the project area at lower reaches, two ponds with capacities of from 10 to 20 cubic metres were constructed to collect the water for cattle and minor irrigation purpose. These tanks have been constructed under the IWDP by the Soil Conservation Department of the government of Uttar Pradesh. These tanks are maintained by the local people. During 1996-97, 12 hectares were planted by the Forest Department in the denuded catchment area of the pond near Kandi Bagri village. A 25% survival rate was observed in the area.

Million well scheme

The million well scheme is meant to create employment for small and marginalised farmers living below the poverty line. Preference is given to bonded labourers for employment. The main objective of the scheme is to create irrigation facilities by constructing ponds, irrigation channels, water-harvesting structures, and bio-engineering measures, thereby reducing runoff and soil loss. The work is strictly carried out through muster rolls and not by contract under any circumstances. Under the schemes, two masonry structures and a half kilometre channel was constructed to benefit the villagers in the watershed.

Integrated rural development programme (IRDP)

The IRDP provides loans and subsidies to those farmers whose annual income from all sources is below Rs 10,000. This money is to be used for establishment of any subsidiary enterprise to boost farming income without adversely affecting the ecology of the area.

NGO Programmes and beneficiaries

PARAG: the cooperative dairy development organisation

A Cooperative Dairy Development Society (named PARAG) is working in the study area to collect milk, process, and distribute it. PARAG provides loans for purchase of good quality animals. The organisation also provides free medical or health consultations for animals to the members of the society and also supplies feed on a payment basis. One such Women's Dairy Development Cooperative Society was started in Bidakot village during 1996-97.It is totally run by the women of Bidakot and nearby villages. Membership increased from 18 in 1996-97 to 50 in 1998-99.

Swajal yojna

Swajal *Yojna* (UP Rural Supply and Environmental Sanitation Project) was started with the assistance of the World Bank in 1996-97 in 650 villages in the UP hills at an approximate cost of Rs 2.5 billion (US $ 60 million). The project was implemented over a period of five years (1996-2000) in four batches (100,150,200, and 200). The scheme is implemented by NGOs only, with the following main objectives.

i) To assist the government of UP to develop and implement a long-term strategy to improve overall water resource management in the state
ii) To deliver sustainable health and hygiene benefits to the rural population through improvements in water supply and environmental sanitation
iii) To improve rural income through time-saving and income-earning opportunities for women
iv) To test alternatives to the current government-led service delivery mechanism

The scheme is functioning in a participatory fashion. Ten per cent of the contribution comes from the beneficiaries (in cash or kind) and 90% is met by the government. *Shri Bhubaneshwari Mahila Ashram* (SBMA) and *Anjanisen* (an NGO) have taken five villages near the study area in which to develop drinking water supply systems. In the near future, it is hoped that the scheme will be extended in the villages in Garhkot watershed.

Water-harvesting measures

The 'Himalaya Paryavaran Evam Gram Vikas Sangathan' has taken on an ambitious programme for developing water-harvesting measures in 22 villages in Khirsue Development Block of Pauri Garhwal district close to the study area.

Impact of programmes on the local ecology and economy

The various government and non-government programmes in the project area have resulted in favourable as well as undesirable impacts on the ecology, economy, and equity in the study area. Impacts as perceived by the beneficiaries and the villagers are summarised in Table 6.23. All rural development programmes in the hills focus primarily on eco-restoration and economic upliftment of the weaker (social or economic) sections of society. Thus, most programmes include soil and water conservation or income-generating activities. All the development programmes have had a favourable impact on the local ecology. Farmers perceive that all the programmes have helped to increase water supplies, reduce runoff, and increase natural vegetation. However, farmers believe that the IRDP programme has had an adverse impact on ecology. This is thought to be primarily because of the increase in livestock in the area, consequently an increase in demand for fodder; and hence reduced vegetative cover. Marginal improvements in the economic status of target families have been realised through these programmes, with the exception of the drinking water scheme. The JRY and IRDP helped to reduce economic disparity.

Some of the programmes described have helped to increase the incomes of small and marginalised farmers (43% of the total population) (Table 6.24).

Table 6.24: **List of Organisations/Institutions Presently Working in the Study Area**

1. Soil and Water Conservation Unit, Deptt. of Agriculture, Govt. of UP
2. Department of Agriculture, Govt. of UP
3. Department of Horticulture and Food Processing, Govt. of UP
4. Department of Animal Husbandry, Govt. of UP
5. Department of Rural Development, Govt. of UP
6. Department of Health and Family Welfare, Govt. of UP
7. Department of Minor Irrigation, Govt. of UP
8. Department of Rural Engineering and Survey, Govt. of UP
9. UP Jal Nigam, Govt. of UP
10. Garhwal Jal Sansthan, Govt. of UP
11. Public Works' Department, Govt. of UP
12. *Garhwal Mandal Vikas Nigam*, Govt. of UP
13. Department of Education, Govt. of UP
14. Department of Forest, Govt. of UP
15. Department of Revenue, Govt. of UP
16. *Parag* Cooperative Dairy Development Organisation
17. *Shri Bhubaneshwari Mahila Ashram, Anjani sain* Tehri - Garhwal (NGO)
18. *Himalaya Paryavaran Evam Gram Vikas Sangathan* (NGO)
19. Central Soil and Water Conservation Research and Training Institute, 218, Kaulagarh Road, Dehradun (UP) (ICAR)

Under the DPAP and IWDP programmes, soya beans were introduced into the high and mid altitude zones, while improved varieties of paddy and wheat were introduced throughout the watershed. These crops are cultivated in the area. Soya bean has become an important cash crop. An afforestation programme undertaken in the area also helped to increase vegetative cover. Stall-feeding practices are being adopted by members of the cooperative dairy project in the area. Increases in vegetative cover and the productivity of natural grass land were observed in the area where social fencing has been established and stall feeding is practised. A list of all the organisations and institutions presently working in the study area is provided below.

Impact with reference to women and marginalised farmers

The impact of the Cooperative Dairy Development Programme financed by PARAG (a Cooperative Dairy Development Organisation of UP Govt.) increased the average family income of each member to Rs 1,400 per month. This programme was taken up exclusively by women. Further investigation revealed that, on average, 20% of this income is kept at the disposal of the women of the family as their personal money and the rest is used for family purposes. The society has thus shown a path of self-help and awakening to the women.

With 20-30% tap water availability in the villages through lifting devices, the pressure of work on women has been reduced to a considerable extent and women are devoting more time to other meaningful activities.

Comparison of modern and traditional systems

Traditionally, the villagers were meeting their drinking and other domestic requirements directly from natural springs, naula, and, perennial streams as well as river water by carrying water as head loads. Besides this, water collected in earthern ponds was also used for domestic purposes and cattle. During monsoon, rain water was also used. One of the methods that involved connecting *kuchha guhl* with streams located at higher reaches was also adopted to meet water needs.

Considering a minimum consumption of 15 litres only per capita per day (which is much below the standard consumption of about 150 litres/day fixed by the Ministry of Health [GOI]) in view of the scarcity of water in the area, women (on average a family has five members) were using 115 days of work to carry water from springs located one kilometre away. These days could have been used for other work if water had been available on the doorstep. Thus, these traditional methods are energy consuming.

In the recent past, tap water was provided to the villages at some point by lifting water from the River Alaknanada located at about 35 km away. The tap water, however, hardly met 20% of the requirements and people are still dependent on natural springs (naula and dhara). Under the Village Development Programme, a water tank (from 10,000-12,000 litres in capacity) was constructed during 1990-91 to collect the spring water and supply it to the villagers. However, this pond was not in use because it was not properly maintained. In view of the current demand for water to meet drinking and domestic requirements, it is not possible to meet the needs from the existing lift water supply and natural springs. Therefore, management of existing springs and exploitation of new springs seem to be viable alternatives.

9. HUMAN AND INSTITUTIONAL CAPACITIES AT LOCAL LEVEL : TECHNOLOGY, OPERATIONS AND MANAGEMENT

Considering water supplies through existing water resources in the study area, drinking and domestic water needs can be met by proper management of water resources as well as by regulating water supplies properly. Awareness needs to be created among the villagers concerning the importance of conserving water by not leaving taps running, by not putting it to unnecessary use in building construction, and so forth. This will reduce the pressure on the ongoing supply of water to distant locations. Thus water will be conserved by avoiding such activities, particularly during dry season, with the help of local people and the authorities.

Though the River Alaknanda, flowing to the south-east, and the River Bhagirathi, flowing towards the north-west of the study area, are located deep inside the valley, it is difficult and expensive to develop lift systems for water supplies that will meet the demands of future populations; and this is because of the undulating topography. Therefore, in the study area, management of fresh existing springs and exploitation of springs in the upper reaches seem to be along with the measures given in the following passages, viable alternatives.

Water-lifting scheme

A water-lifting scheme is already in operation, but it meets only 20% of the demand because of tampering and leakage on the way. Further, whatever water supply is available to the villagers is lavishly used by head-reach villagers, without considering the needs of others. Therefore, the villagers' cooperation should be solicited.

Rejuvenation of natural springs

Most of the natural springs in the study area are of the open type and very unhygienically maintained. Therefore, the water in them is not used by villagers for drinking. Such springs need to be managed properly by constructing covered tanks and providing pipe outlets to ensure hygienic water supplies for drinking. In addition, the algae and bacteria in the springs should be cleaned and water should be treated with a suitable disinfectant. Similarly, water tanks and ponds should also be maintained and protected to avoid contamination. Proper distribution of water should be undertaken with the help of the local people.

Construction of tanks for capacity building

It was observed during the survey that some of the natural streams are perennial. Water from these streams could be diverted to the tanks if they were constructed along the streams. Water collected in such tanks could be used for domestic purposes as well as for a limited amount of irrigation by connecting them with a pipeline to the lower reaches.

Roof-water harvesting

During winter (December - March) about 200 mm of rainfall is expected in the area. Therefore, during these months water from the roof can be collected and used for cattle and domestic purposes to supplement water needs.

Improving spring discharge

Since spring water is an important source of water to meet the demands of people in the study area, decline in spring discharge is one of the main problems and needs immediate action due to increasing demographic pressure. Discharge in springs can be improved by developing 'spring sanctuaries' in the recharge area along with their protection from degradation. Infiltration of rain water can be increased through engineering and vegetative measures. A series of shallow, saucer-shaped dug-out ponds could help to recharge the springs.

Table 6.25: **Impact of Various Programmes on Local Ecology, Economy and Social Equity**

Programme	Major Works	Perceived Benefits by Farmers on		
		Ecology	Economy	Social Equity
Government Programme				
DPAP	All watershed management related works	1. Marginally reduced runoff through construction of terraces 2. Perenniality of water in stream/pond increased due to rejuvenation and soil conservation works	About 5-10 per cent increase in crop yield	No change
JRY	All rural development works as approved by Village Panchayat	Improvement in water quality through improvement in existing water resources	Increased employment opportunities to weaker sections	Disparity in income between weaker and upper sections of society decreased
Drinking Water Scheme	Construction of drinking water facility	Availability of quality drinking water	No change	No change
IWDP	All watershed management works	1. Availability of water is increased 2. Marginal increase in the vegetative cover 3. Increase in crop diversity	Productivity, production and income from agriculture enhanced upto 20%	Sharing of resources increased harmonious relations between different ethnic group
Million Wells Scheme	1. Water resource development 2. Soil and water conservation works	Yet to be realised	Employment opportunities enhanced	Income of weaker sections increased
IRDP	Institutional subsidised financial assistance to improve income of the weaker sections	Ecology was adversely affected by increase in livestock population	Nutritional status and income of families increased	Economic disparity decreased
NGO Programme Cooperative dairy development	Formation of outside assistance to voluntary organization to boost milk production	Ecology improved through adoption of stall feeding practices	Economy improved	Women's status and independence increased.

Source : Field Survey 1998

10. POLICIES ON WATER HARVESTING AND THEIR IMPACTS

The water supply situation in hilly areas is quite different from that in the plains because of the undulating topography and rugged geological formation. Groundwater is available only in the form of natural springs in these areas, and it is used as the main source of water for drinking and domestic purposes by the local population. Rivers flowing in deep valleys can hardly serve the purpose as far as domestic water supplies are concerned. The scarcity of water in the area was felt long back, and policies on water were made and modified from time to time to suit the local requirements.

The water rules of 1917 were modified in 1930 and the traditional practices prevalent in the region were codified. The rules confirmed the then prevailing practice of allowing development of irrigation without the government actively participating in the process. Water rights remained largely with the irrigators, and the principle of prior water use was safeguarded by the rules. Later, it was found that these rules sometimes prevented the government from implementing irrigation and drinking water schemes in the hills. The need to provide drinking water to the hills was considered to be a matter of priority.

Enactment of the *Zamindari* Abolition Act of 1950 confirmed that ownership of private wells (i. e., ponds, naula and hauzi) was vested in the owner of the land on which it was located. The rules established this by giving the right of transfer of the pond to the owner of the land who would not be liable to eviction and should have the right to use the site of the water body for any purpose. The act also envisages that tanks, ponds, ferries, and water channels belonging to the state should be managed by the Gram Sabha (Village Assembly) or any other local authority.

The state government enacted the Kumaon and Garhwal Water (collection, conservation, and distribution) Act of 1975 which terminated the current and customary rights of individuals and village communities. The state took over the power to frame the rules for collection, conservation, and distribution of water and control of water sources. There was, however, provision for giving priority to such village communities from whom the powers had been withdrawn. The state also empowered itself to create a water system, pond, or reservoir and establish a pump set or pipeline on land belonging to any person. One was allowed, without receiving prior written permission of the competent authority, to set up an irrigation system.

The Act of 1975 took away the jurisdiction of individuals and village communities over all water sources and vested these in the government. Thus, there is a conflict between the legislations of 1950 and 1975 and this has not been settled even today. New irrigation systems serving a moderately large area cannot be planned and constructed by village communities because of several reasons. In this region, the irrigation department has expanded at a rapid pace. Private minor irrigation works, which are generally created by individuals and cater to areas of less than one hectare, are supported by the department of minor irrigation which itself has grown substantially.

The Act has not made any difference to the overall picture of irrigated agriculture in the area. Even though a major change was introduced in water rights in the 1975 legislation, the users have not been affected in a majority of cases in which individual or community irrigation systems were already operative. Changing water rights has, however, influenced the irrigation behaviour of farmers served by some new state irrigation systems.

11. Critical Issues and Recommendations

Issues and recommendations

From the point of view of critical issues the following aspects need consideration.

- This area is hydrologically a 'high rainfall and a seasonally dry region' resulting in surplus water during three months of the monsoon and acute scarcity during the remaining nine months of the year, except for a brief spell of winter rain.
- Practically there is no vegetative cover in the whole watershed. From the point of view of sustainability, massive efforts should be made to increase vegetation (trees, shrubs, and grasses) in combination with engineering measures (staggered contour trenching).
- Livestock population (5 animals per hectare) is high and beyond the carrying capacity of the area as well as uneconomical. Therefore, a shift in livestock composition from local to high-yielding breeds, in combination with management techniques, is required along with provision of concentrates and feeds.
- In the upper reaches water scarcity is acute compared to the middle reaches and valley areas.
- All unprotected springs need to be covered with regulated outlets and continuous monitoring of water quality is needed to prevent the outbreak of epidemics.
- Plantation of broad-leaved (*Quereus incana*) species around naula and the sources of springs will help recharge good quality water in future.
- It is also important to explore the possibilities of locating new sources of water.
- Roof-water harvesting should be encouraged in view of the heavy rainfall in winter and during monsoon.
- In situ and surface runoff and underground (seepage and percolation) water need scientific as well as judicious storage and use.
- People's participation was more effective in the past and is almost absent at present, particularly in planning and management; nevertheless people play an active role in water distribution.
- A Water Users' Society needs to be created and made functional in each micro-watershed giving due representation to all inhabitants.
- Low Density Polyethylene (LDPE) sheets, 1,000 gauge thick and High Density Polyethylene (HDPE) pipes could be useful for arresting seepage losses and for laying out in difficult/unstable reaches.
- Most of the spring water is not suitable for human consumption because of a high concentration of nitrate (NO_3). It is suggested that precautions be taken in using it as there is no option for the villagers.
- Women are the main work force. Efforts should be made through women extension workers to motivate them to take an active part in planning, implementation, and management of the system.
- Considering the important role played by women in the hills, their training and participation need to be ensured.
- The UP hills have a great potential for development of tourism for pilgrimage, recreation, and adventure sports. It is obviously expected that additional quantities of water will be needed to boost tourism in the region.

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Plates

Plate 1: A general view of the Garhkot watershed

Plate 2: Rain water-harvesting pond built through the 'Self help' programme by the villagers of 'Kandi Bagri' with a provision to collect the seepage flow in another pit at the lower end

Plate 3: Roof-water harvesting being practised by the farmers in a traditional way from the slanting slated roof of a house

Plate 4: The topmost portion of the watershed under reserved forest is devoid of vegetation and cattle are grazing freely

Plate 5: Women are the main workers in the villages and are engaged in agricultural activities apart from all household chores

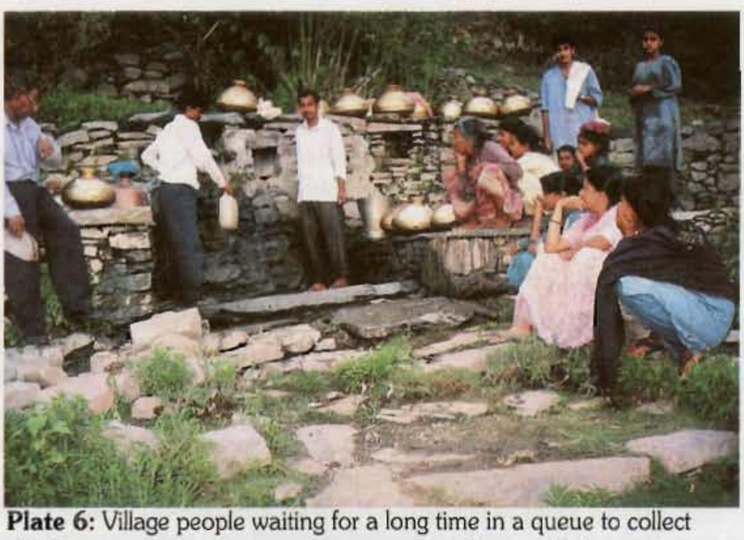

Plate 6: Village people waiting for a long time in a queue to collect drinking water in brass cans—measurement of water discharge during the lean period is in progress

Plate 7: Twin sources of water (dhara) earmarked on a caste basis-water quality samples are being collected