Table B.1.4 Rainfall Data of Tank Station

(in mm)

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Daily max
1961	0.5	3.0	7.9	55.4	15.2	10.7	231.9	10.9	0.8	0.0	1.5	0.8	338.6	94.0
1962	5.8	26.9	30.7	20.1	2.0	7.1	55.9	64.3	5.6	2.0	13.2	10.4	244.1	38.1
1963	0.0	8.9	28.2	37.1	64.3	1.3	2.5	63.2	15.7	0.0	3.3	0.0	224.5	43.2
1964	19.6	6.1	33.8	9.1	44.7	18.3	100.6	92.7	0.5	0.0	0.0	0.8	326.1	63.5
1965	7.6	10.4	28.4	51.3	49.0	3.3	36.1	34.8	1.3	0.0	10.9	4.6	237.7	25.4
1966	0.0	35.1	14.2	48.8	7.9	0.0	82.6	19.6	35.6	2.0	0.0	0.0	245.6	26.7
1967	0.0	5.6	82.3	19.6	15.5	3.3	44.2	78.7	2.3	4.6	4.1	110.5	370.6	20.8
1968	11.2	36.6	19.6	27.9	12.4	0.0	25.9	116.6	0.0	0.0	0.0	3.3	253.5	76.2
1969	3.0	31.5	5.3	10.9	32.8	3.6	69.3	50.8	9.1	0.0	9.4	0.0	225.8	48.5
1970	11.4	34.8	16.8	0.0	8.1	0.0	99.6	3.8	11.4	0.0	0.0	0.0	185.9	53.3
1971	0.0	1.5	3.0	4.8	24.1	0.8	54.4	0.8	48.8	0.0	0.0	0.0	138.2	38.1
1972	30.5	7.6	6.1	43.9	16.0	15.2	49.8	29.7	9.1	0.0	8.9	22.4	239.3	38.1
1973	0.0	28.7	24.4	0.0	52.6	0.0	27.7	36.8	8.6	0.0	0.0	0.0	178.8	26.2
1974	6.4	34.3	8.1	45.2	31.5	0.0	86.1	34.3	3.3	0.0	0.0	20.1	269.2	45.2
1975	7.6	52.3	42.4	23.1	6.4	13.5	60.5	38.4	40.6	0.0	0.0	8.4	293.1	39.4
1976	1.0	21.8	33.0	26.7	13.5	158.8	1.8	132.6	50.8	1.5	0.0	0.0	441.5	97.8
1977	22.6	0.0	0.0	44.7	3.8	0.5	224.5	51.8	73.4	2.5	5.1	0.0	429.0	98.3
1978	21.3	5.3	36.6	12.4	0.0	3.3	142.0	41.9	49.8	0.0	0.0	0.0	312.7	61.0
1979	15.2	33.8	80.3	14.0	8.6	3.0	0.0	85.1	32.5	1.3	13.5	26.7	313.9	40.6
1980	N.D	N.D	N.D	N.D	N.D	N.D	57.7	17.0	11.4	1.8	7.1	3.3	N.D	N.D
1981	24.6	19.1	98.6	26.2	10.9	0.3	108.5	72.1	9.4	26.4	0.0	0.0	396.0	33.0
1982	34.0	19.6	31.0	0.5	63.8	3.3	8.6	109.5	0.0	7.9	4.3	19.6	302.0	39.4
1983	0.0	43.2	33.3	94.5	16.0	0.0	28.7	96.3	42.9	0.0	0.0	0.0	354.8	40.1
1984	0.0	6.1	25.7	23.1	0.0	0.0	100.1	36.8	15.2	0.0	3.3	10.2	220.5	26.9
1985	2.5	18.5	1.5	48.8	0.0	8.4	103.6	48.3	0.0	0.0	0.0	8.1	239.8	69.1
1986	0.0	50.8	95.3	21.8	11.4	26.9	211.3	120.4	0.0	25.1	14.0	13.2	590.3	99.1
1987	0.0	39.4	99.8	1.0	25.9	46.7	91.2	48.3	4.6	0.0	0.0	0.0	356.9	43.2
1988	5.1	4.6	109.5	0.0	0.0	0.0	3.6	71.4	22.4	6.1	0.0	29.2	251.7	34.5
1989	0.0	1.5	73.9	0.0	0.0	17.0	72.6	19.8	0.0	0.0	0.0	35.3	220.2	34.5
1990	13.5	15.0	86.4	12.7	35.6	0.0	14.7	57.4	27.9	0.0	0.0	0.0	263.1	82.6
1991	0.0	46.7	61.7	84.6	14.7	27.9	20.3	27.9	3.8	0.0	0.0	5.8	293.6	33.0
1992	95.3	41.9	129.8	51.1	2.5	7.6	12.4	17.8	78.0	0.0	4.8	0.0	441.2	38.1
1993	0.0	7.1	13.5	16.8	0.0	0.0	159.5	11.9	0.0	0.0	0.0	0.0	208.8	77.5
Mean	10.6	21.8	42.5	27.4	18.4	11.9	72.4	52.8	18.6	2.5	3.1	10.1	292.1	

N.D: no data are available.

Table B.1.5 Rainfall Data of Chaudwan Station

(in mm)

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Daily max
1985	7.9	5.1	5.1	45.0	N.D	14.7	44.5	N.D	N.D	N.D	N.D	N.D	122.2	N.D
1986	N.D	N.D	12.2	8.6	29.2	27.9	50.3	61.0	N.D	3.0	3.8	N.D	196.1	N.D
1987	N.D	132.8	42.7	N.D	N.D	2.0	N.D	N.D	N.D	N.D	N.D	N.D	177.5	68.6
1988	10.2	N.D	10.2	19.3	15.5	N.D	166.4	18.3	5.1	11.2	2.0	24.4	282.4	49.8
1989	2.0	N.D	62.7	6.4	N.D	3.8	130.8	77.5	5.1	N.D	N.D	31.8	320.0	43.2
1990	8.9	15.5	82.6	17.5	2.5	5.1	25.4	55.9	N.D	N.D	N.D	24.1	237.5	38.1
1991	N.D	15.5	14.0	33.0	33.5	12.7	77.2	19.1	3.0	4.6	N.D	N.D	212.6	58.9
1992	38.1	15.7	34.0	45.2	17.8	26.7	83.1	73.7	60.7	5.8	2.5	N.D	403.4	46.2
1993	8.9	6.4	26.7	30.0	9.4	29.0	176.8	14.2	5.8	2.3	N.D	N.D	309.4	74.9
Mean	12.7	31.8	32.2	25.6	18.0	15.2	94.3	45.6	16.0	5.4	2.8	26.8	251.2	

N.D: no data are available.

Table B.1.6 Rainfall Data of Lar Station

(in mm)

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Daily max
1941	0.5	0.0	8.9	2.5	10.2	38.1	101.6	5.1	N.D	N.D	N.D	N.D	166.9	50.8
1942	38.1	35.6	0.0	0.0	28.2	19.1	93.2	40.4	0.0	0.0	0.0	10.4	264.9	38.1
1943	5.3	0.0	11.2	10.4	2.5	0.0	N.D	0.0	N.D	N.D	N.D	0.0	29.5	10.4
1944	11.2	58.9	20.3	26.4	10.2	10.2	10.2	0.0	91.4	0.0	0.0	0.0	238.8	38.1
1945	22.9	0.0	0.0	12.7	4.6	8.9	7.4	0.0	19.1	0.0	0.0	0.0	75.4	22.9
1946	0.0	7.6	0.0	0.0	1.3	17.0	43.9	65.5	6.6	6.4	0.0	0.0	148.3	43.2
1947	6.1	9.9	30.2	0.0	0.0	0.0	34.0	24.9	0.0	0.0	0.0	14.7	119.9	24.9
1948	10.2	38.4	8.6	12.2	0.0	10.2	74.4	64.8	0.0	0.0	0.0	27.9	246.6	44.7
1949	0.0	13.7	22.6	0.0	0.0	8.1	189.5	29.5	0.0	0.0	0.0	0.0	263.4	50.8
1950	43.2	15.2	5.6	58.4	0.0	5.8	25.4	38.1	19.1	0.0	0.0	0.0	210.8	38.1
1951	5.1	0.0	65.0	10.2	7.9	9.1	87.1	63.5	0.0	0.0	5.1	0.0	253.0	40.6
1952	0.0	2.8	22.6	13.5	0.0	20.3	10.9	19.1	5.1	0.0	0.0	2.5	96.8	19.1
1953	24.1	22.1	0.0	5.3	0.0	22.9	178.6	82.3	18.8	0.0	0.0	0.0	354.1	86.4
1954	32.0	104.9	13.5	6.9	3.3	0.0	30.2	22.9	48.3	0.0	0.0	0.0	261.9	69.9
1955	0.0	0.0	33.8	4.3	6.6	0.0	60.5	127.8	25.4	0.0	0.0	37.1	295.4	50.8
1956	8.4	12.7	86.1	97.0	0.0	0.0	108.2	46.7	0.0	4.3	0.0	0.0	363.5	88.9
1957	32.0	0.0	10.2	31.0	35.8	9.7	71.1	27.9	4.6	0.0	16.0	12.7	251.0	25.4
1958	3.3	0.0	9.7	N.D	0.0	2.8	18.5	39.6	0.0	0.0	0.0	46.7	120.7	31.8
1959	24.9	26.7	1.5	31.8	9.1	0.0	120.7	15.5	0.0	4.1	30.5	0.0	264.7	38.6
1960	2.5	0.0	31.0	0.0	0.0	0.0	63.8	0.0	38.1	0.0	0.0	25.4	160.8	45.7
1961	10.2	15.2	38.1	29.7	5.1	19.1	56.6	8.6	35.6	0.0	0.0	0.0	218.2	35.6
1962	5.1	6.4	24.6	0.0	27.9	4.1	17.5	41.9	13.0	6.6	4.3	7.6	159.0	22.9
1963	0.0	19.1	45.7	50.3	44.5	0.0	0.0	75.7	0.0	0.0	5.1	2.5	242.8	51.1
1964	14.0	3.3	12.7	0.0	6.4	0.0	59.7	38.1	11.4	0.0	0.0	4.8	150.4	24.1
1965	0.0	7.6	48.3	45.2	54.1	0.0	34.3	37.8	0.0	0.0	0.0	0.0	227.3	40.6
1966	0.0	55.1	0.8	42.7	0.8	0.0	115.8	35.3	12.2	0.0	0.0	0.0	262.6	58.4
1967	0.0	0.0	130.8	31.5	5.1	9.7	1.0	54.4	49.5	34.5	0.0	35.6	352.0	49.5
1968	19.8	44.5	21.6	5.1	0.0	3.0	48.8	0.0	0.0	0.0	0.0	0.0	142.7	20.3
1969	0.0	16.8	5.8	9.1	19.1	10.2	17.8	8.9	11.9	4.1	0.0	0.0	103.6	12.7
1970	6.1	27.7	19.3	0.0	0.0	0.0	45.0	0.0	0.0	0.0	0.0	0.0	98.0	30.5
1971	3.8	2.5	0.0	0.0	18.8	62.2	65.0	22.1	25.9	0.0	0.0	0.0	200.4	45.7
1972	17.8	6.4	0.0	7.1	0.0	0.0	12.4	36.8	38.1	0.0	6.1	39.4	164.1	38.1
1973	0.0	14.2	19.8	0.0	0.0	0.0	124.2	72.4	1.3	0.0	0.0	3.0	235.0	80.0
1974	4.3	22.9	4.3	33.8	21.6	15.7	137.2	34.3	22.9	0.0	0.0	6.4	303.3	58.4
1975	0.0	12.2	35.6	10.9	20.1	40.9	43.2	23.9	0.0	0.0	0.0	0.0	186.7	30.5
1976	7.6	22.9	24.1	21.6	24.1	12.7	229.9	257.3	30.5	31.8	0.0	0.0	662.4	63.5
1977	31.8	0.0	0.0	24.1	2.5	0.0	102.9	139.7	45.7	0.0	8.9	0.0	355.6	76.2
1978	21.6	0.0	47.8	0.0	15.2	0.0	158.8	72.4	22.9	0.0	0.0	0.0	338.6	69.9
1979	58.4	41.9	55.9	0.0	7.6	13.5	88.9	31.0	58.2	35.6	10.2	38.1	439.2	58.4
1980	13.5	20.3	62.2	7.6	0.0	73.8	29.2	54.9	16.3	7.6	57.2	0.0	342.5	57.2
1981	13.6	21.6	55.9	30.4	42.2	0.0	259.1	162.7	0.0	0.0	0.0	0.0	585.5	152.4
1982	38.1	19.1	47.0	8.9	6.4	5.9	0.8	120.3	0.0	49.5	0.0	19.1	314.9	53.6
1983	5.6	10.2	17.8	110.1	53.3	6.4	24.9	154.9	55.9	0.0	10.2	0.0	449.2	77.5
1984	0.0	12.7	40.6	40.6	0.0	0.0	58.4	48.3	41.9	0.0	0.7	0.2	243.3	30.5
1985	0.2	1.0	14.2	2.3	0.0	0.0	3.3	0.7	0.0	1.8	0.0	25.7	49.1	14.2
1986	0.0	26.1	3.2	0.6	15.3	0.9	1.5	3.3	0.0	1.5	0.0	0.9	53.2	25.4
1987	0.0	25.4	78.5	15.9	116.1	0.0	50.8	0.0	0.0	0.0	0.0	0.0	286.6	68.6
1988	12.5	0.0	28.5	9.5	0.0	0.0	86.7	113.4	9.7	0.0	0.0	2.1	262.4	78.3
1989	0.2	0.0	40.3	0.0	0.0	29.0	57.6	133.0	24.0	0.0	0.0	38.0	322.1	64.1
1990	0.0	27.3	60.8	9.0	0.0	2.0	92.0	111.1	0.5	0.0	0.0	44.0	346.7	57.0
1991	0.0	1.0	46.0	87.0	8.0	2.0	53.0	40.0	53.0	12.0	0.0	0.0	302.0	40.0
1992	48.0	33.0	58.0	49.0	0.0	8.0	99.1	0.0	150.0	0.0	18.0	7.0	470.1	54.0
1993	4.0	15.0	32.0	21.0	10.0	0.0	234.0	0.0	75.0	0.0	0.0	0.0	391.0	74.0
Mean	10.2	16.1	33.9	21.3	15.9	9.7	73.0	58.6	24.4	5.6	3.7	8.3	280.6	

N.D: no data are available.

Table B.1.7 Rainfall Data of Griser Station

(in mm)

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Daily max
1941	0.0	0.0	21.3	3.8	30.2	8.9	56.1	6.4	0.0	0.0	0.0	9.1	135.9	33.0
1942	0.0	16.5	0.0	0.0	15.7	15.0	94.0	67.6	0.0	0.0	0.0	14.2	223.0	62.2
1943	6.9	0.0	15.5	29.2	7.1	10.4	0.0	0.0	0.0	0.0	0.0	0.0	69.1	20.3
1944	10.9	61.5	8.9	33.0	0.0	8.9	2.5	0.0	44.5	0.0	0.0	1.3	171.5	31.8
1945	29.5	0.0	0.0	25.1	2.5	5.1	15.7	0.0	0.0	0.0	0.0	0.0	78.0	17.8
1946	0.0	18.3	0.0	0.0	8.6	8.9	0.0	22.4	0.0	34.3	0.0	0.0	92.5	34.3
1947	7.4	10.2	27.2	0.0	0.0	0.0	11.4	5.1	11.4	0.0	0.0	1.8	74.4	11.4
1948	53.3	25.9	7.6	9.7	0.0	0.0	78.0	57.2	0.0	0.0	0.0	17.0	248.7	57.2
1949	0.0	15.7	26.7	0.0	0.0	0.0	39.6	62.7	0.0	0.0	0.0	0.0	144.8	29.2
1950	48.3	12.7	10.2	59.2	0.0	12.4	15.7	53.1	0.0	0.0	0.0	0.0	211.6	53.1
1951	1.3	0.0	49.3	24.6	11.4	11.4	18.8	39.4	43.2	0.0	6.4	0.0	205.7	43.2
1952	0.0	4.1	19.8	11.2	20.3	5.1	39.1	57.9	0.0	0.0	0.0	4.1	161.5	33.8
1953	24.1	16.0	0.0	8.9	3.6	36.8	197.6	19.1	12.2	0.0	0.0	0.0	318.3	69.9
1954	31.5	85.3	6.1	3.8	0.0	5.3	13.2	0.0	32.3	0.0	0.0	0.0	177.5	61.0
1955	0.0	0.0	55.1	0.0	23.4	0.0	62.2	129.3	37.6	6.1	0.0	34.3	348.0	43.7
1956	3.0	16.5	98.0	88.6	0.0	12.7	87.9	91.4	19.1	0.0	0.0	0.0	417.3	66.0
1957	59.2	0.0	14.2	43.2	24.6	20.3	83.6	99.6	7.6	2.8	22.1	14.7	391.9	45.7
1958	11.4	0.0	8.6	0.0	0.0	2.8	82.3	17.0	13.2	0.0	0.0	55.6	191.0	68.6
1959	25.7	42.2	30.2	34.5	9.1	0.0	232.4	0.0	0.0	20.3	43.2	0.0	437.6	66.0
1960	30.2	0.0	33.0	12.7	0.0	15.5	76.2	15.5	18.3	0.0	0.0	15.2	216.7	33.0
1961	31.2	13.7	18.8	33.5	5.1	13.2	109.0	6.1	26.7	0.0	0.0	0.0	257.3	41.1
1962	3.8	15.0	34.5	0.0	0.0	0.0	0.0	52.3	24.1	7.6	6.4	11.2	154.9	26.7
1963	0.0	20.6	18.0	32.0	31.0	5.3	21.1	42.2	0.0	0.0	3.8	0.0	174.0	24.1
1964	19.6	4.8	16.5	0.0	0.0	0.5	102.1	59.4	7.1	0.0	0.0	3.0	213.1	45.2
1965	3.0	4.3	32.5	44.2	126.2	2.0	7.9	62.0	0.0	0.0	4.1	0.0	286.3	101.6
1966	0.0	38.4	12.4	33.3	17.8	8.9	81.8	15.5	55.1	1.3	0.0	0.0	264.4	50.8
1967	0.0	8.1	143.8	10.4	4.3	0.0	53.3	58.9	48.3	17.8	1.3	53.6	399.8	48.3
1968	29.7	50.0	54.1	7.6	17.8	22.9	30.5	3.6	0.0	0.0	0.0	0.0	216.2	29.2
1969	0.0	25.9	12.7	10.7	21.1	0.0	24.6	90.2	15.7	0.0	0.0	0.0	200.9	37.6
1970	8.4	57.4	32.8	0.0	8.9	0.0	102.4	0.0	0.0	0.0	0.0	0.0	209.8	63.5
1971	0.0	11.4	0.0	2.8	53.6	16.5	17.0	21.3	23.1	0.0	0.0	0.0	145.8	29.7
1972	24.6	9.4	2.3	2.8	3.6	68.3	34.8	40.6	40.6	0.0	6.6	49.5	283.2	66.0
1973	0.0	7.6	11.4	5.1	9.7	7.6	123.2	30.7	1.8	0.0	0.0	0.0	197.1	53.3
1974	0.0	18.0	3.3	24.6	31.8	17.0	72.1	15.0	4.1	0.0	0.0	14.2	200.2	31.8
1975	2.8	14.2	28.4	15.0	7.6	63.5	20.3	32.0	0.0	0.0	3.8	1.8	189.5	22.9
1976	12.7	44.5	18.8	10.2	14.0	33.3	25.4	90.2	16.5	0.0	0.0	0.0	265.4	38.1
1977	27.9	0.0	0.0	52.8	8.9	3.8	39.4	71.1	22.9	0.0	4.3	0.0	231.1	64.8
1978	20.3	0.0	53.8	15.2	0.0	0.0	99.1	5.1	29.0	0.0	0.0	0.0	222.5	50.8
1979	49.5	27.9	58.4	15.2	7.6	0.0	54.6	53.3	19.1	20.3	15.2	20.3	341.6	25.4
1980	26.7	41.9	72.4	6.4	0.0	16.7	43.0	35.5	12.7	0.0	33.0	7.6	295.8	33.0
1981	25.4	25.4	67.3	33.0	22.9	15.2	239.9	52.1	0.0	4.4	0.0	0.0	485.7	38.1
1982	39.4	20.1	81.3	6.3	33.0	6.4	0.0	113.0	0.0	27.9	12.7	19.1	359.1	35.6
1983	0.0	25.5	21.6	115.6	37.5	8.9	49.5	82.6	12.7	0.0	0.0	0.0	353.9	30.5
1984	0.0	6.4	36.8	24.1	0.0	5.8	44.5	40.7	0.0	0.0	10.2	0.0	168.5	25.4
1985	6.4	11.3	20.4	47.0	0.0	0.0	24.1	0.0	0.0	47.0	0.0	25.9	182.2	21.6
1986	0.0	30.5	70.4	40.6	8.9	25.3	130.8	87.5	0.3	0.0	0.0	8.9	403.2	55.7
1987	0.0	43.2	105.8	6.4	62.2	25.4	57.2	0.0	0.0	0.0	0.0	0.0	300.1	34.3
1988	0.0	0.0	55.9	0.0	0.0	0.0	43.2	37.4	0.0	0.0	0.0	2.1	138.6	19.1
1989	0.0	0.0	50.0	0.0	0.0	14.0	88.9	38.2	0.0	0.0	0.0	58.4	249.5	24.1
1990	29.2	61.0	47.0	0.0	17.8	24.1	59.3	42.0	16.5	0.0	0.0	43.2	340.1	34.3
1991	0.0	30.3	66.9	40.2	19.9	0.0	20.3	48.3	12.7	10.2	0.0	3.8	252.6	25.4
1992	21.6	0.4	36.8	73.7	6.4	19.1	44.5	0.4	131.5	0.0	10.2	0.0	344.5	101.6
1993	0.0	10.2	25.4	21.6	0.0	11.4	94.0	0.0	10.2	0.0	0.0	0.0	172.8	25.4
Mean	11.6	20.5	39.7	22.1	17.5	13.2	59.3	40.2	16.1	4.1	3.4	9.8	257.6	

N.D: no data are available.

Table B.1.8 Rainfall Data of Kotla Station

(in mm)

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Daily max
1941	7.6	0.0	15.2	2.5	26.7	29.2	70.4	17.8	51.1	0.0	0.0	0.0	220.5	24.1
1942	24.1	35.6	0.0	0.0	33.0	46.2	78.5	14.0	0.0	0.0	0.0	20.3	251.7	37.3
1943	20.3	0.0	24.1	11.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	55.9	11.4
1944	10.7	48.5	24.1	33.0	0.0	14.5	21.6	0.0	114.3	0.0	0.0	0.0	266.7	68.6
1945	27.2	0.0	0.0	28.4	0.0	20.3	43.2	14.2	5.6	0.0	0.0	0.0	138.9	23.4
1946	0.0	11.4	0.0	0.0	2.5	3.8	3.8	43.2	11.4	0.0	11.4	0.0	87.6	31.8
1947	11.4	5.8	19.1	0.0	0.0	0.0	0.0	39.6	0.0	2.5	0.0	6.6	85.1	27.9
1948	39.4	31.0	21.1	3.8	0.0	8.4	98.6	119.6	2.5	0.0	0.0	2.5	326.9	81.5
1949	0.0	10.2	8.9	8.9	0.0	5.1	73.2	81.8	5.8	0.0	0.0	0.0	193.8	50.8
1950	33.3	17.8	13.2	13.2	62.7	0.0	31.0	12.7	2.5	0.0	0.0	0.0	186.4	50.8
1951	12.7	0.0	33.5	33.5	24.9	2.5	51.6	114.3	0.0	0.0	7.6	0.0	280.7	88.9
1952	0.0	1.3	13.5	6.4	0.0	30.5	15.2	27.7	0.0	0.0	0.0	0.0	94.5	24.1
1953	22.9	16.8	0.0	0.0	0.0	2.5	149.1	53.3	34.0	0.0	0.0	0.0	278.6	44.5
1954	26.9	55.1	20.3	3.3	17.8	0.0	55.6	38.9	11.7	0.0	0.0	0.0	229.6	41.4
1955	0.0	0.0	78.2	4.3	15.5	0.0	54.9	45.2	26.4	0.0	0.0	24.6	249.2	34.5
1956	8.4	12.7	95.3	85.1	0.0	0.0	197.1	51.6	0.0	27.9	0.0	0.0	478.0	92.7
1957	37.8	0.0	14.5	36.8	26.7	17.8	108.0	87.6	46.5	14.0	24.4	19.1	433.1	49.5
1958	10.9	0.0	8.1	0.0	0.0	3.6	5.8	200.9	9.9	0.0	0.0	59.9	299.2	69.9
1959	26.2	38.6	10.7	35.6	24.1	0.0	166.6	42.4	53.8	0.0	21.1	0.0	419.1	52.1
1960	5.3	0.0	44.7	8.4	0.0	26.2	80.8	0.0	30.5	0.0	0.0	20.3	216.2	48.3
1961	38.9	6.6	20.3	32.5	12.2	29.0	55.1	27.4	56.4	14.0	0.0	0.0	292.4	56.4
1962	4.6	10.4	27.9	0.0	12.7	4.6	6.4	57.4	27.4	7.1	3.8	8.4	170.7	20.6
1963	0.0	15.2	26.9	56.1	35.1	0.0	25.4	85.1	5.6	0.0	5.1	3.8	258.3	34.0
1964	20.6	4.6	25.9	0.0	7.6	0.0	70.6	1.3	30.7	0.0	0.0	3.8	165.1	30.5
1965	8.9	9.7	18.3	72.6	20.3	17.8	33.0	86.4	11.4	0.0	0.0	0.0	278.4	40.1
1966	0.0	39.4	3.6	63.5	16.5	0.0	165.9	40.1	13.5	0.0	0.0	0.0	342.4	43.4
1967	0.0	0.0	77.0	6.4	1.8	25.4	0.0	21.6	17.8	16.3	4.1	50.0	220.2	26.7
1968	23.4	37.6	37.8	9.7	0.0	0.0	50.8	0.0	0.0	0.0	0.0	0.0	159.3	24.1
1969	0.0	11.7	2.0	9.1	21.8	0.0	22.6	17.5	6.4	1.3	0.0	0.0	92.5	14.0
1970	3.8	30.5	34.0	1.3	0.8	0.0	22.1	22.6	0.0	0.0	0.0	0.0	115.1	15.5
1971	2.5	17.8	12.4	0.0	11.7	28.7	76.2	34.8	8.4	0.0	0.0	0.0	192.5	63.5
1972	30.7	6.4	4.3	3.8	1.8	1.3	13.5	34.8	22.9	0.0	0.0	50.5	169.9	34.3
1973	0.0	0.0	21.1	0.0	2.0	0.0	146.1	76.2	2.5	0.0	0.0	0.0	247.9	78.7
1974	5.1	19.6	5.8	25.7	10.2	24.1	195.6	35.6	25.4	0.0	0.0	13.0	359.9	69.9
1975	2.5	6.4	28.2	10.2	6.6	36.8	77.5	10.2	43.2	0.0	0.0	0.0	221.5	61.0
1976	7.6	13.5	24.6	13.2	0.0	12.7	5.1	212.1	12.7	5.1	0.0	0.0	306.6	63.5
1977	31.8	0.0	1.8	12.7	5.1	0.0	44.5	108.0	80.0	38.1	6.4	0.0	328.2	71.1
1978	10.2	0.0	102.1	5.1	0.0	0.0	174.0	70.4	25.4	0.0	0.0	0.0	387.1	76.2
1979	29.2	40.6	58.2	0.0	10.2	0.0	41.9	27.9	43.2	35.6	19.1	38.1	343.9	38.1
1980	7.6	11.4	61.5	6.4	0.0	101.6	30.4	53.1	50.8	0.0	38.1	10.1	371.0	50.8
1981	22.8	20.3	66.2	27.9	14.2	0.0	288.3	118.1	0.0	0.0	0.0	0.0	557.9	165.1
1982	43.2	9.4	60.3	40.6	14.0	13.7	0.0	83.3	5.1	39.4	25.4	14.0	348.3	50.8
1983	0.0	31.8	17.8	135.9	58.4	12.7	35.6	174.5	144.8	0.0	0.0	0.0	611.4	69.9
1984	7.6	0.0	45.7	12.7	0.0	12.7	54.6	71.4	33.0	0.0	15.2	0.1	253.2	41.9
1985	0.0	0.6	14.2	1.4	0.0	0.0	63.5	52.4	0.0	6.4	0.0	38.1	176.5	55.0
1986	0.0	25.2	80.7	22.2	15.9	25.8	88.8	69.1	0.0	31.8	0.0	6.4	365.8	43.7
1987	0.0	25.4	114.3	0.0	0.0	0.0	57.2	0.0	0.0	0.0	0.0	0.0	196.9	44.5
1988	0.0	0.0	73.0	0.5	0.0	0.0	76.2	101.6	0.0	0.0	0.0	0.9	252.2	50.8
1989	0.2	0.0	1.3	0.5	0.0	0.5	38.1	25.4	0.0	0.0	0.0	31.8	97.7	25.4
1990	0.0	44.5	38.1	1.6	0.0	0.0	63.5	241.3	57.2	0.0	0.0	25.4	471.6	88.9
1991	0.0	22.2	25.4	82.6	0.0	6.4	57.2	25.4	63.5	6.4	0.0	0.0	289.0	38.1
1992	19.1	25.4	57.2	25.4	0.0	0.0	9.5	50.8	88.9	0.0	12.7	3.2	292.2	38.1
1993	0.0	25.4	22.2	12.7	15.9	0.0	158.8	12.7	88.9	0.0	0.0	0.0	336.6	38.1
Mean	9.7	15.5	36.7	21.0	8.9	10.7	68.1	62.1	29.2	6.1	3.9	9.0	281.0	

N.D: no data are available.

Table B.1.9 Rainfall Data of Chashma Station

(in mm)

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total	Daily max
1941	9.9	2.0	21.3	15.5	5.1	30.5	43.7	29.2	N.D	N.D	N.D	N.D	157.2	31.0
1942	45.7	47.5	2.5	9.9	15.7	23.4	42.7	33.8	2.8	0.0	0.0	4.3	228.3	37.1
1943	8.1	1.8	12.7	6.4	0.8	17.8	N.D	37.1	0.0	N.D	N.D	N.D	84.6	26.7
1944	30.0	52.6	26.2	33.0	3.0	9.4	120.7	N.D	68.6	N.D	0.0	0.0	343.4	57.9
1945	29.2	0.0	2.5	3.8	13.5	74.9	21.6	68.6	31.8	0.0	0.0	0.0	245.9	58.4
1946	N.D	18.8	8.6	0.0	27.9	11.4	31.5	34.5	30.0	4.1	0.0	2.5	169.4	20.8
1947	5.3	5.8	28.4	0.0	0.0	0.0	2.5	53.3	0.0	0.0	0.0	2.0	97.5	53.3
1948	1.0	12.7	8.1	2.5	0.0	15.2	125.2	128.8	26.7	0.0	0.0	20.3	340.6	45.2
1949	0.0	7.6	41.7	0.0	0.0	5.1	41.9	74.4	0.0	0.0	0.0	0.0	170.7	30.5
1950	27.9	8.9	22.9	48.3	6.4	27.9	55.6	27.9	2.8	0.0	0.0	0.0	228.6	36.1
1951	7.6	14.0	45.7	45.2	8.4	13.7	11.7	29.0	0.0	0.0	16.3	0.0	191.5	33.0
1952	0.0	9.7	26.7	0.0	0.0	21.1	39.1	12.2	17.8	0.0	0.0	10.2	136.7	37.1
1953	26.7	10.9	0.0	5.3	1.3	11.9	119.9	16.5	11.7	13.2	0.0	0.0	217.4	37.1
1954	38.6	65.5	15.2	4.3	7.6	3.0	58.9	55.9	43.2	0.0	0.0	0.0	292.4	36.8
1955	0.0	0.0	88.9	0.0	1.8	0.0	62.2	30.5	20.1	15.7	0.0	30.5	249.7	61.0
1956	3.8	12.7	66.5	21.6	0.0	23.4	137.4	54.6	26.4	18.5	0.0	0.0	365.0	63.5
1957	20.3	1.5	21.6	28.2	16.5	2.5	61.0	34.8	10.9	19.6	33.3	14.0	264.2	25.4
1958	3.8	0.0	14.0	0.0	7.9	0.0	23.4	106.9	38.1	0.0	0.0	59.7	253.7	61.0
1959	32.5	27.7	30.5	20.6	17.3	0.0	216.9	142.5	10.7	6.6	18.8	0.0	524.0	94.0
1960	6.4	0.0	29.5	0.0	1.3	6.4	37.3	1.3	3.6	0.0	0.0	28.2	113.8	19.1
1961	28.7	16.5	2.8	37.3	0.0	31.2	22.4	4.3	132.1	10.9	4.3	4.3	294.9	82.6
1962	3.8	0.0	35.3	14.0	2.5	1.5	17.3	84.3	39.4	0.0	21.6	5.3	225.0	34.3
1963	0.0	15.0	14.0	28.4	25.4	19.6	34.3	33.5	5.6	0.0	2.5	3.3	181.6	25.4
1964	21.8	5.3	5.1	6.4	2.5	0.0	47.5	10.4	47.8	0.0	0.0	12.7	159.5	38.1
1965	2.5	22.4	24.1	37.6	22.1	11.4	24.1	26.2	0.0	0.0	0.0	0.0	170.4	22.9
1966	0.0	29.5	4.1	21.6	2.5	0.0	27.4	80.0	42.4	3.8	0.0	0.0	211.3	38.1
1967	0.0	3.8	87.1	40.6	4.3	20.3	17.8	92.2	21.3	11.4	17.8	48.0	364.7	34.3
1968	30.5	33.0	71.6	0.0	7.1	17.8	11.2	34.3	0.0	0.0	0.0	0.0	205.5	22.9
1969	0.0	11.7	35.1	22.9	17.8	0.0	156.7	16.0	4.3	0.0	0.0	0.0	264.4	69.9
1970	1.8	25.7	20.8	2.0	2.5	0.0	63.2	102.9	11.4	1.5	0.0	0.0	231.9	50.8
1971	0.0	0.0	0.0	3.3	7.1	6.9	28.4	0.0	5.1	0.0	0.0	0.0	50.8	19.8
1972	18.0	11.4	0.0	13.5	0.0	34.5	62.2	45.7	3.8	0.0	1.0	12.7	202.9	38.6
1973	2.5	15.5	19.3	0.0	9.9	27.9	95.3	198.1	26.7	0.0	0.0	0.0	395.2	110.5
1974	0.0	8.9	12.7	16.5	11.2	13.0	54.4	74.7	49.5	0.0	0.0	5.8	246.6	58.4
1975	0.0	10.7	49.8	21.6	11.4	0.0	89.2	22.4	11.9	0.0	0.0	0.0	216.9	34.5
1976	0.0	19.8	10.9	38.6	10.2	40.6	45.7	238.3	22.4	0.0	0.0	0.0	426.5	127.0
1977	19.8	0.0	0.0	22.9	2.5	0.0	184.2	161.8	52.1	3.8	4.6	0.0	451.6	80.0
1978	8.9	1.8	56.1	5.6	0.0	0.0	127.0	85.1	35.6	0.0	0.0	0.0	320.0	64.8
1979	53.3	19.1	111.8	12.7	0.0	0.0	48.8	82.6	31.8	7.1	5.6	38.1	410.7	53.3
1980	2.5	20.3	98.6	0.0	0.0	49.4	119.6	20.3	106.7	0.0	0.0	0.0	417.4	96.5
1981	3.8	10.2	87.6	63.5	25.4	0.0	218.4	47.0	0.0	0.0	0.0	0.0	455.9	114.3
1982	44.5	6.4	79.6	38.1	8.9	12.7	40.7	14.5	3.8	10.2	6.4	10.2	275.7	38.1
1983	0.0	16.5	19.1	118.1	33.0	0.0	40.6	205.8	116.8	0.0	0.0	0.0	550.0	76.2
1984	0.0	0.0	22.9	10.2	0.0	38.1	76.2	2.4	33.0	0.0	0.7	0.0	183.4	25.4
1985 *	1.2	0.0	0.5	0.8	0.0	0.4	6.3	0.4	0.4	0.8	0.0	2.3	13.1	6.3
1986 *														
1987 *														
1988 *														
1989 *														
1990 *														
1991 *														
1992 *														
1993 *														
Mean	9.8	12.1	34.8	23.0	8.3	13.0	66.4	67.3	32.2	2.0	2.6	5.7	277.0	

N.D : no data are available.

* : Data from 1985 are not raliable.

Table B.1.10 Evaporation Data of Tank Station

(in mm)

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1970	N.D	N.D	139.7	257.0	414.8	335.8	404.6	378.0	337.8	324.1	240.0	185.9	N.D
1971	113.3	94.0	139.7	245.4	395.7	428.0	370.1	254.0	241.0	191.5	156.2	132.3	2,761.2
1972	115.6	82.0	130.8	223.8	261.9	449.6	569.5	N.D	195.8	251.0	161.5	N.D	N.D
1973	N.D	99.8	155.4	268.7	413.8	445.5	N.D	N.D	224.8	220.0	151.1	102.4	N.D
1974	104.1	N.D	214.1	N.D	396.5	N.D	410.5	393.7	307.3	249.9	172.2	93.7	N.D
1975	75.4	80.5	140.2	196.3	381.3	403.1	415.3	278.4	212.6	195.1	114.6	N.D	N.D
1976	N.D	N.D	N.D	N.D	266.7	271.0	363.5	308.6	258.1	213.1	171.5	90.7	N.D
1977	77.5	92.5	159.3	227.1	N.D	N.D	433.3	405.4	335.0	210.1	125.0	N.D	N.D
1978	64.3	90.4	119.1	241.8	391.2	455.9	317.0	256.0	227.3	167.1	118.4	80.0	2,528.6
1979	69.3	77.0	125.7	222.0	300.7	408.7	451.6	407.7	274.3	224.0	124.2	98.6	2,783.8
1980	N.D	N.D	N.D	N.D	N.D	N.D	359.4	322.3	272.8	208.3	180.6	87.9	N.D
1981	73.9	58.2	87.1	202.2	337.1	384.6	397.0	332.2	261.1	184.2	149.1	143.5	2,610.1
1982	127.3	109.7	133.1	200.9	184.7	322.1	365.3	352.6	304.0	295.9	192.8	127.0	2,715.3
1983	130.0	130.8	164.6	176.5	254.5	271.0	282.2	253.0	248.2	206.0	156.0	123.4	2,396.2
1984	136.7	144.0	183.6	213.1	294.1	281.2	256.3	252.2	204.7	179.6	144.8	136.9	2,427.2
1985	133.6	135.9	174.5	189.7	205.0	224.5	267.7	251.7	256.3	196.1	160.0	132.3	2,327.4
1986	108.7	109.0	136.1	178.8	273.8	304.3	316.2	298.7	274.6	209.6	163.6	152.7	2,526.0
1987	152.9	133.9	127.3	173.2	257.8	304.5	359.7	353.3	328.7	239.3	153.9	134.4	2,718.8
1988	125.5	125.7	147.1	199.4	209.6	254.8	262.4	229.4	207.0	198.1	174.5	137.4	2,270.8
1989	155.4	138.2	154.2	181.9	206.0	242.1	179.3	191.5	240.0	187.2	126.2	121.2	2,123.2
1990	132.3	138.2	160.8	186.4	229.1	228.6	206.5	211.8	153.7	142.7	164.1	110.0	2,064.3
1991	121.9	89.9	100.6	127.5	197.6	348.5	382.8	292.6	222.0	192.8	126.2	107.7	2,310.1
1992	92.7	121.9	137.9	108.5	178.1	225.6	226.1	209.6	154.2	199.6	158.8	130.0	1,942.8
1993	99.3	132.1	118.4	161.3	227.6	243.8	217.9	281.2	214.1	199.6	143.0	138.9	2,177.3
Mean	110.5	109.2	143.3	196.2	279.2	324.9	336.8	292.2	244.2	207.0	151.7	119.0	2,514.2

N.D: no data are available.

Table B.1.11 Evaporation Data of Arid Zone Station

(in mm)

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1983	64.5	70.6	115.3	132.0	258.9	322.5	322.4	223.8	227.4	158.4	75.0	67.0	2,037.7
1984	48.7	84.8	134.9	178.5	327.1	325.8	220.7	188.8	169.5	135.5	80.4	60.5	1,955.0
1985	59.2	89.6	153.8	171.0	297.9	341.7	294.2	288.0	207.6	124.0	78.0	53.9	2,158.9
1986	58.9	67.2	98.0	177.6	278.4	302.1	247.7	214.8	192.9	128.7	83.7	53.6	1,903.5
1987	67.9	70.0	84.0	182.4	221.7	282.0	291.4	312.2	225.3	169.0	83.4	52.4	2,041.6
1988	N.D	N.D	N.D	N.D	N.D	N.D	233.4	221.7	189.9	132.1	76.8	37.2	N.D
1989	60.8	93.0	84.3	157.5	301.0	311.7	287.7	251.7	232.2	137.6	74.4	39.7	2,031.6
1990	45.3	56.0	98.0	210.0	310.0	331.8	304.4	250.2	203.4	155.0	92.7	48.1	2,104.8
1991	62.0	63.3	104.8	144.0	268.2	300.0	273.4	257.6	180.9	133.9	91.2	43.7	1,923.0
1992	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	N.D	40.0	N.D
1993	55.5	83.7	99.8	204.0	290.2	360.0	253.6	238.4	210.0	170.5	82.5	53.3	2,101.5
Mean	58.1	75.4	108.1	173.0	283.7	319.7	272.9	244.7	203.9	144.5	81.8	49.9	2,015.7

N.D: no data are available.

Table B.2.1 Observed Peak Discharge

Year	Tank Zam Jandola		Gomal Zam Kot Murtaza		Gomal Zam Khajuri Kach		Daraban Zam Zam Tower	
	(CUSECS)	(CUMECS)	(CUSECS)	(CUMECS)	(CUSECS)	(CUMECS)	(CUSECS)	(CUMECS)
1929			29,440	834				
1930			12,060	342				
1931			no data					
1932			63,300	1,793				
1933			no data					
1934			no data					
1935			18,000	510				
1936			5,000	142				
1937			7,000	198				
1938			18,000	510				
1939			18,000	510				
1940			8,400	238				
1941			8,400	238				
1942			9,400	266				
1943			5,300	150				
1944			45,000	1,274				
1945			3,200	91				
1946			3,900	110				
1947			3,500	99				
1948			6,100	173				
1949			6,100	173				
1950			14,000	396				
1951			14,000	396				
1952			4,200	119				
1953			3,420	97				
1954			11,110	315				
1955			105,300	2,982				
1956			77,120	2,184				
1957			8,310	235				
1958			31,750	899				
1959			42,000	1,189				
1960			19,800	561				
1961	29,000	821	20,100	569				
1962	12,600	357	24,200	685	34,100	966		
1963	9,900	280	27,900	790	17,200	487		
1964	12,700	360	22,300	632	24,000	680		
1965	15,500	439	28,200	799	17,100	484		
1966	5,270	149	18,100	513	21,100	598		
1967	16,700	473	19,900	564	12,300	348		
1968	21,530	610	7,360	208	20,720	587		
1969	14,700	416	6,390	181	20,710	587		
1970	15,700	445	27,600	782	21,020	595		
1971	10,600	300	20,700	586	20,920	592		
1972	11,600	329	19,800	561	20,910	592		
1973	8,490	240	47,000	1,331	21,320	604		
1974	13,320	377	5,140	146	20,690	586		
1975	11,930	338	42,400	1,201	21,250	602		
1976	27,160	769	14,000	396	20,820	590		
1977	15,770	447	14,800	419	20,830	590		
1978	17,290	490	67,000	1,897	21,150	599		
1979	15,400	436	5,840	165	20,700	586		
1980	18,300	518	11,600	329	15,400	436		
1981	4,430	125	14,100	399	5,520	156	1,450	41
1982	1,430	40	7,230	205	5,800	164	8,510	241
1983	14,250	404	20,900	592	12,900	365	6,000	170
1984	7,440	211	15,400	436	23,800	674	3,520	100
1985	5,370	152	17,400	493	16,100	456	4,050	115
1986	23,400	663	24,700	700	23,600	668	2,900	82
1987	3,750	106	18,400	521	16,400	464	1,800	51
1988	30,100	852	35,100	994	15,500	439	3,370	95
1989			30,000	850				
1990			35,000	991				
1991			38,000	1,076				
1992			126,000	3,568				

Table B.3.1 Results of Water Quality Test

Surface Water

Site No.	Water Temp (°C)	pH	EC x10^6	++ ++ Ca+Mg meq/l	" CO3 meq/l	' HCO3 meq/l	' Cl meq/l	Na + meq/l	Sod. Abs. Ratio SAR	Total Dissolved Solids (ppm)	Total Suspended Solids (ppm)	Water Class
SW1	26	8.6	188	1.60	Nil	1.32	0.74	0.30	0.327	120.0	Nil	C1S1
SW2	35	8.5	200	1.70	Nil	1.39	0.68	0.28	0.300	128.0	51	C1S1
SW3	35	8.2	898	2.75	Nil	2.02	1.90	6.23	5.310	574.0	77	C3S1
SW4	34	8.3	1,163	4.99	Nil	1.87	2.39	6.53	4.132	719.0	127	C3S1
SW5	34	8.4	300	2.78	Nil	2.35	0.68	0.98	0.825	192.0	1,568	C2S1

Ground Water

Site No.	Water Temp (°C)	Stage Ground Water(M)	pH	EC x10^6	++ ++ Ca+Mg meq/l	" CO3 meq/l	' HCO3 meq/l	' Cl meq/l	Na + meq/l	Sod. Abs. Ratio SAR	Total Dissolved Solids (ppm)	Total Suspended Solids (ppm)	Water Class
GW1	28	50	8.5	800	1.73	Nil	2.34	1.14	6.28	6.923	512.0	102	C1S1
GW2	30	70	8.0	7,975	25.03	Nil	5.17	18.22	54.80	15.493	5,104.0	Nil	C4S2
GW3	30	85	8.1	9,375	49.13	Nil	3.05	39.63	41.53	8.381	6,000.0	Nil	C4S1
GW4	28	25	8.1	9,250	29.33	Nil	3.51	40.01	63.18	16.490	592.0	85	C4S2
GW5	28	117	8.4	4,500	20.75	Nil	1.62	2.63	24.23	7.540	2,880.0	88	C4S1

FIGURES

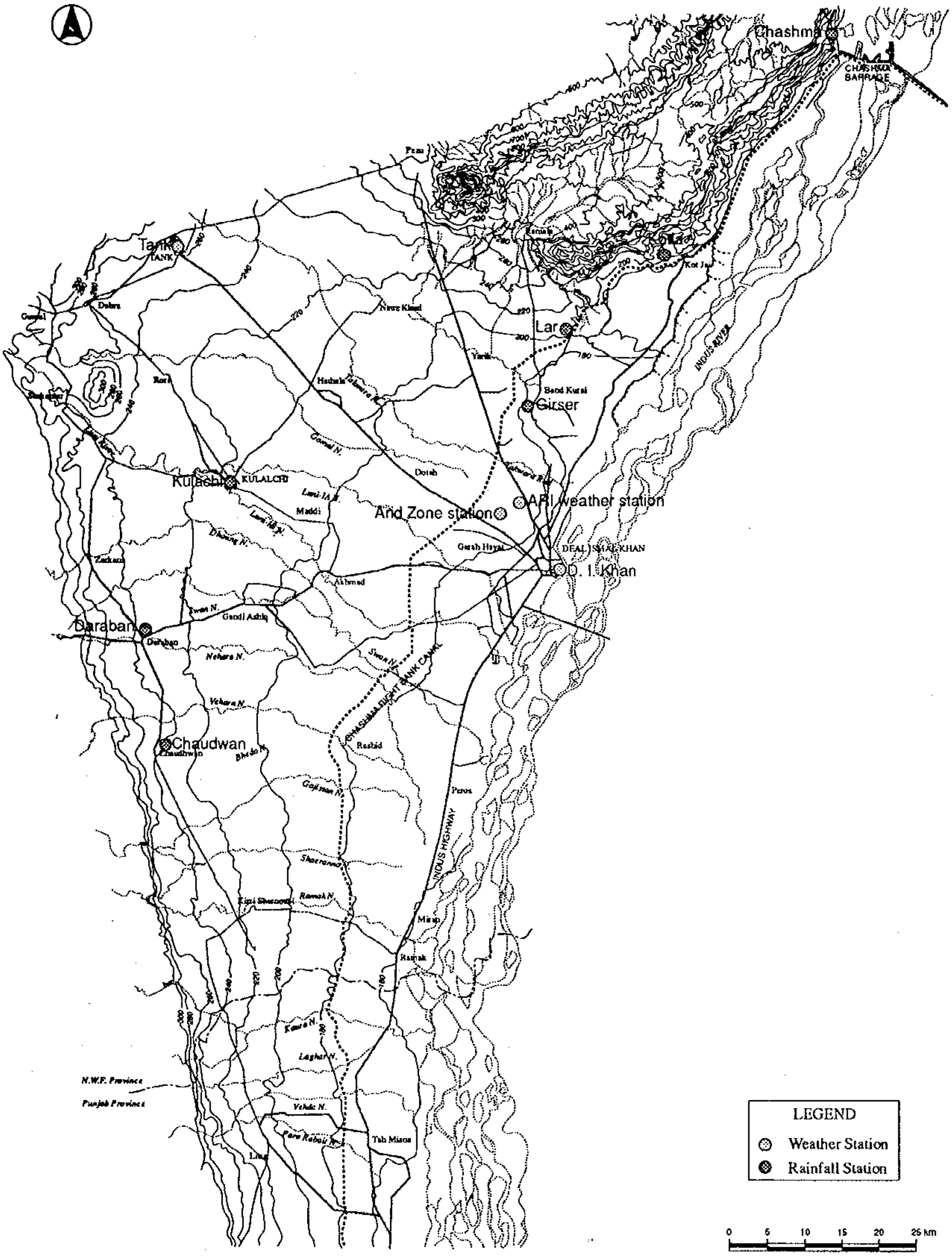
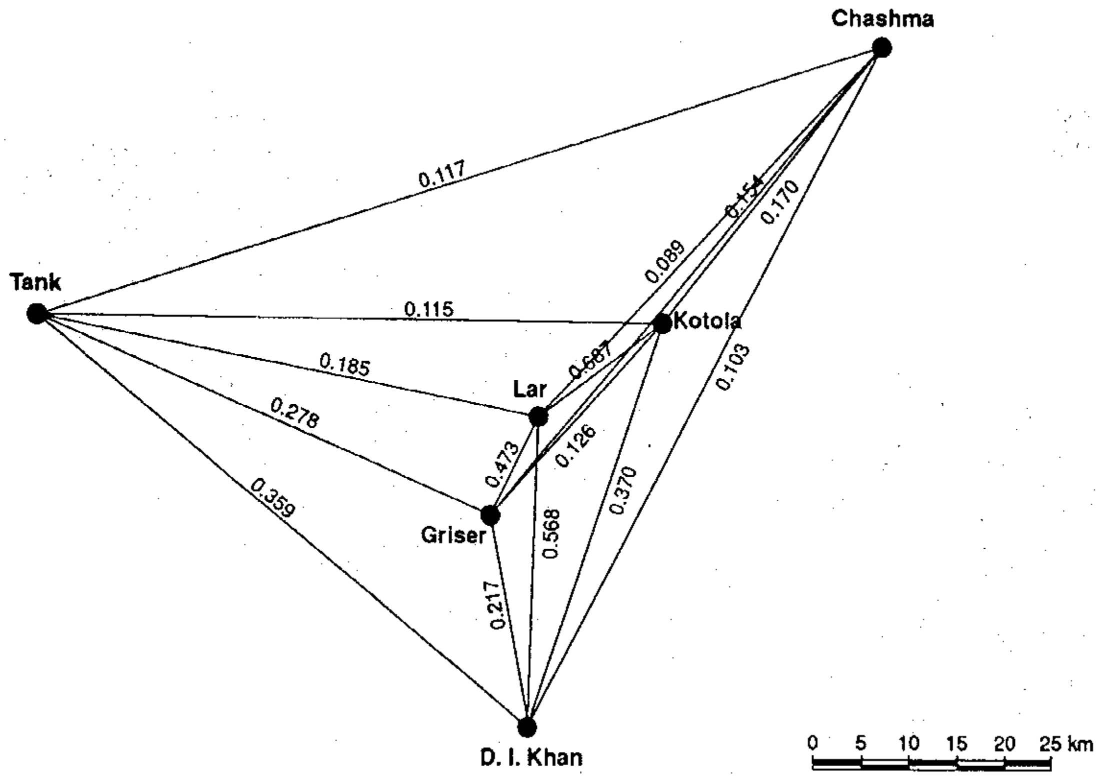


Fig. B.1.1 Location of Meteorological Stations



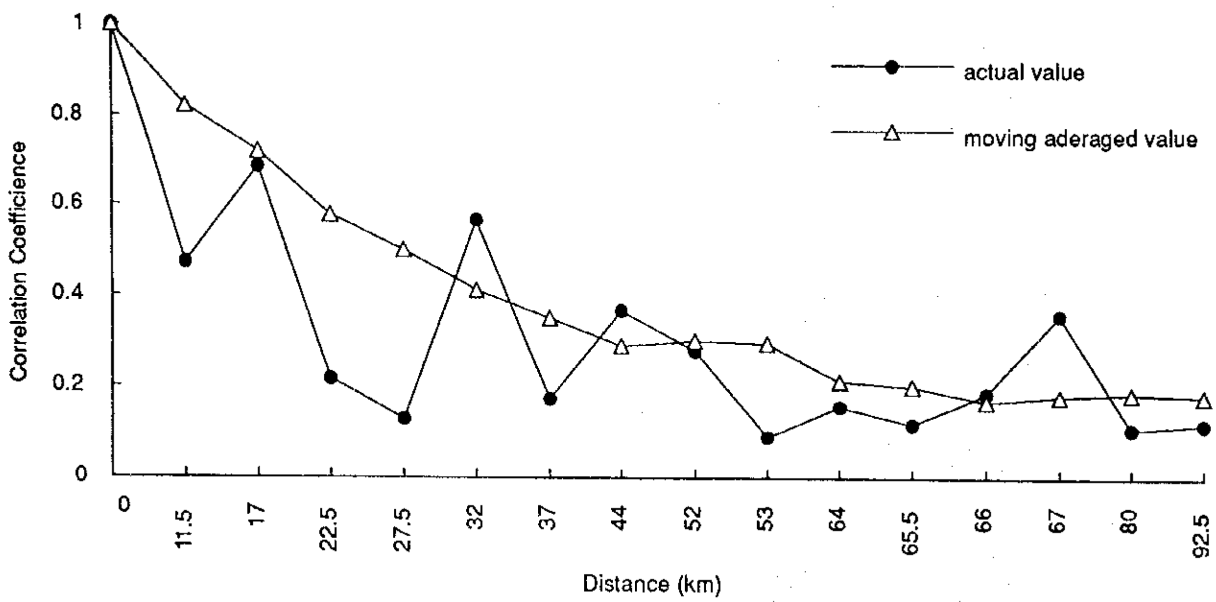


Fig. B.1.2 Correlation Relation between Rainfall and Distance

(mm/day) (mm)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
ETo estimated by PENMAN Method	1.92	2.52	3.69	5.31	6.75	7.10	6.50	5.83	4.89	3.66	2.48	1.57	1,590.6
ETpan of ARID ZONE Station	1.87	2.69	3.49	5.77	9.15	10.66	8.80	7.89	6.80	4.66	2.73	1.61	2,015.7

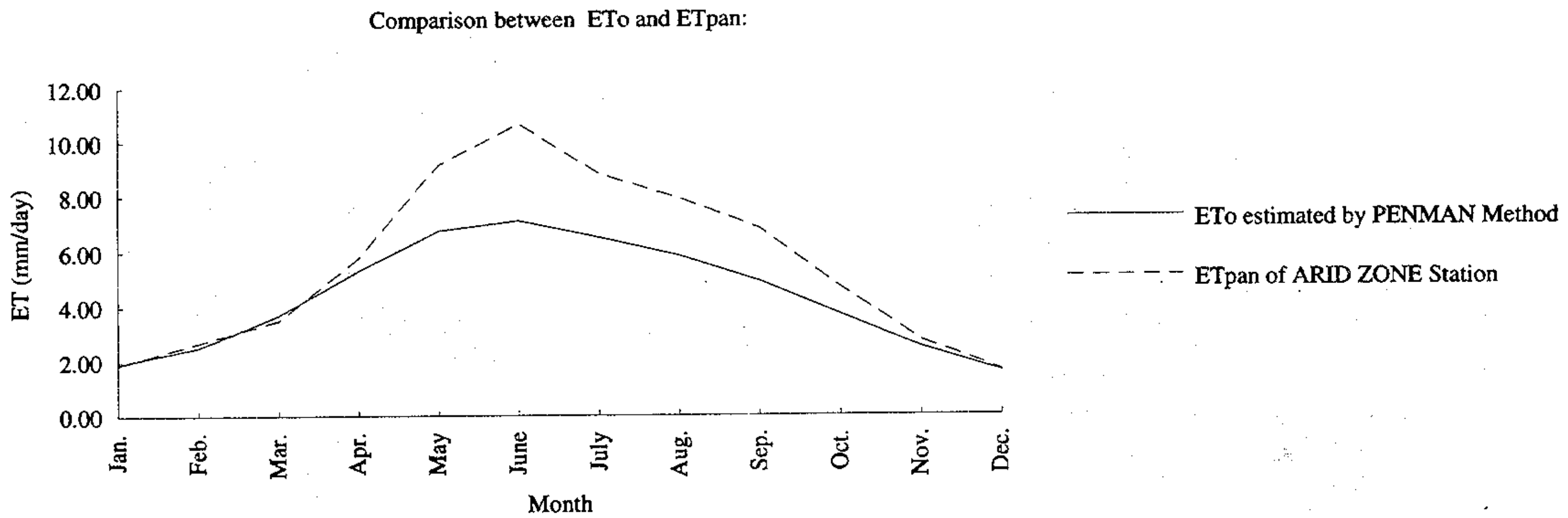
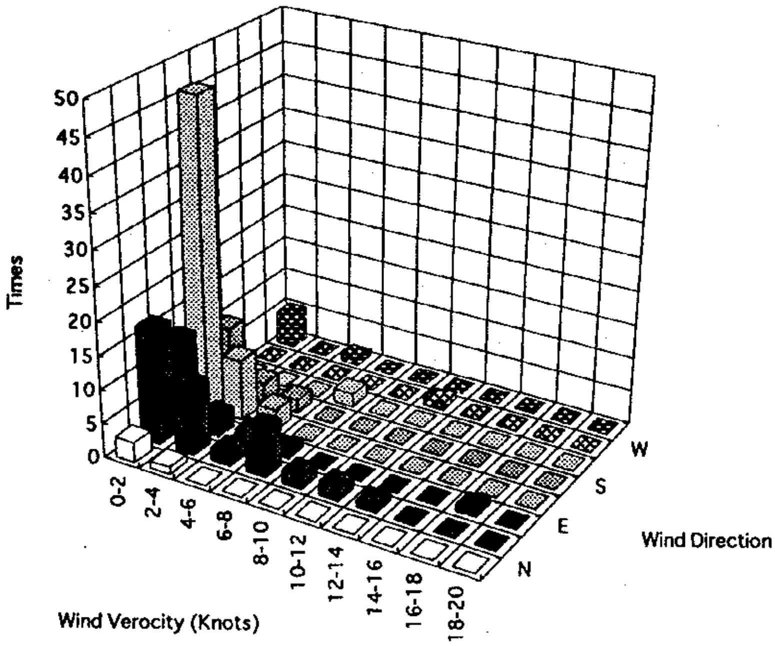


Fig. B.1.3 Comparative Figure of ETo and ETpan

Wind Condition (Kharif)



Wind Condition (Rabi)

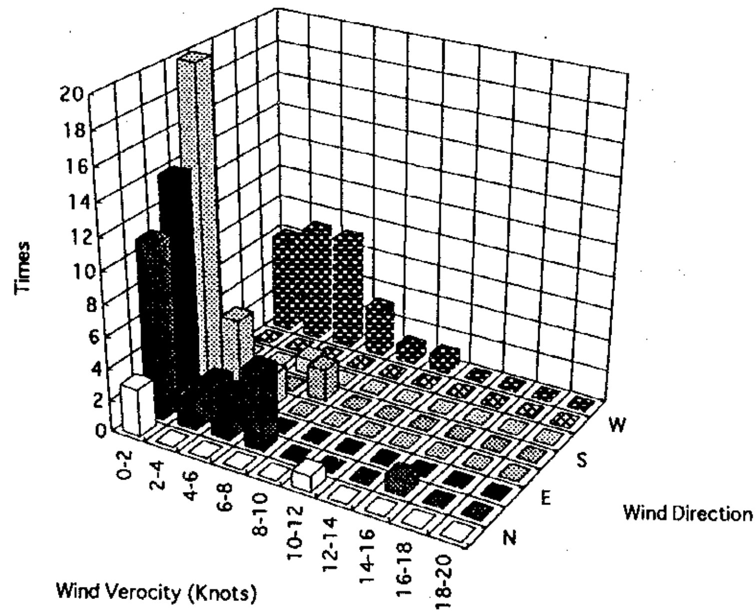


Fig. B.1.4 Wind Direction and Speed in Each Season

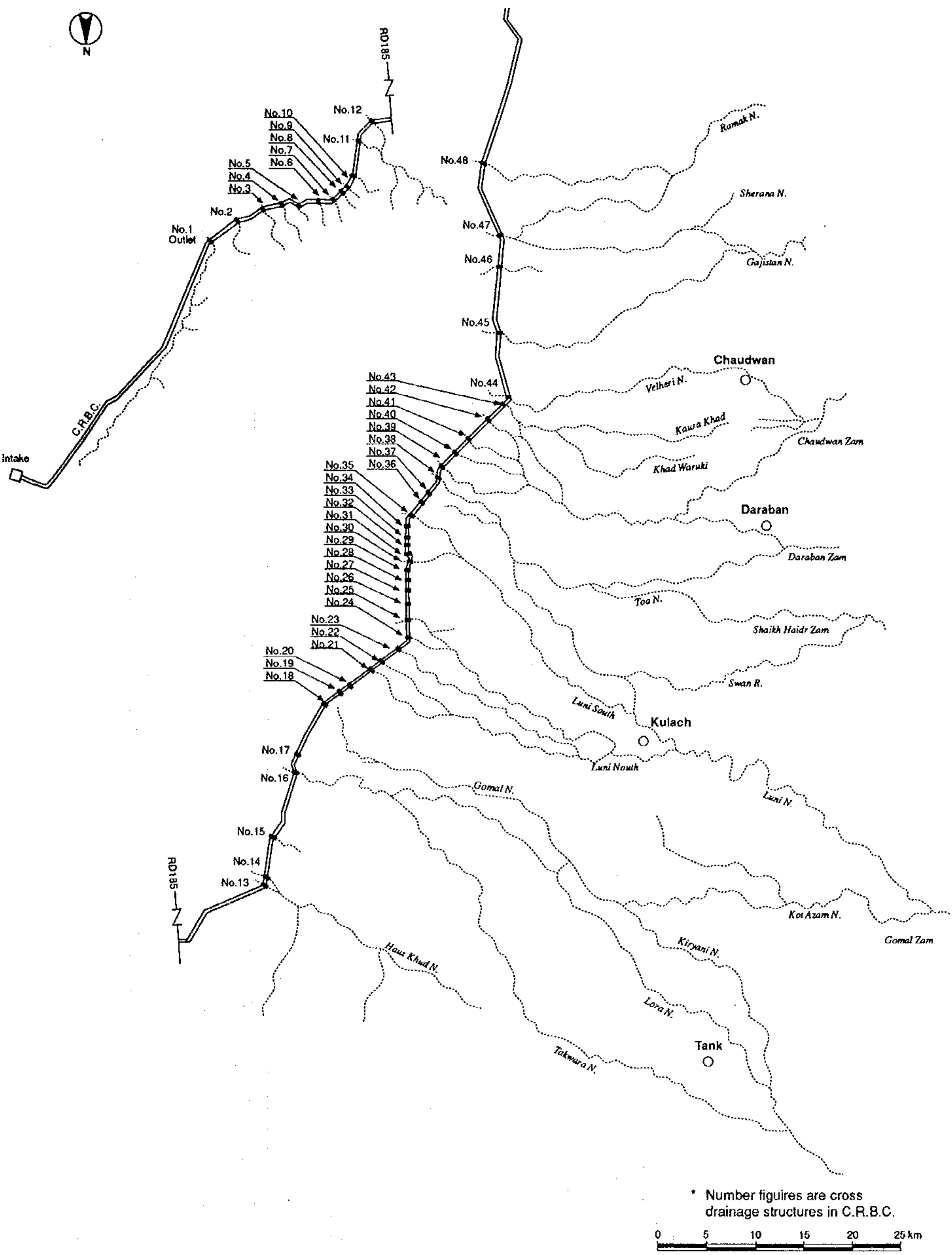


Fig. B.2.1 Present River System

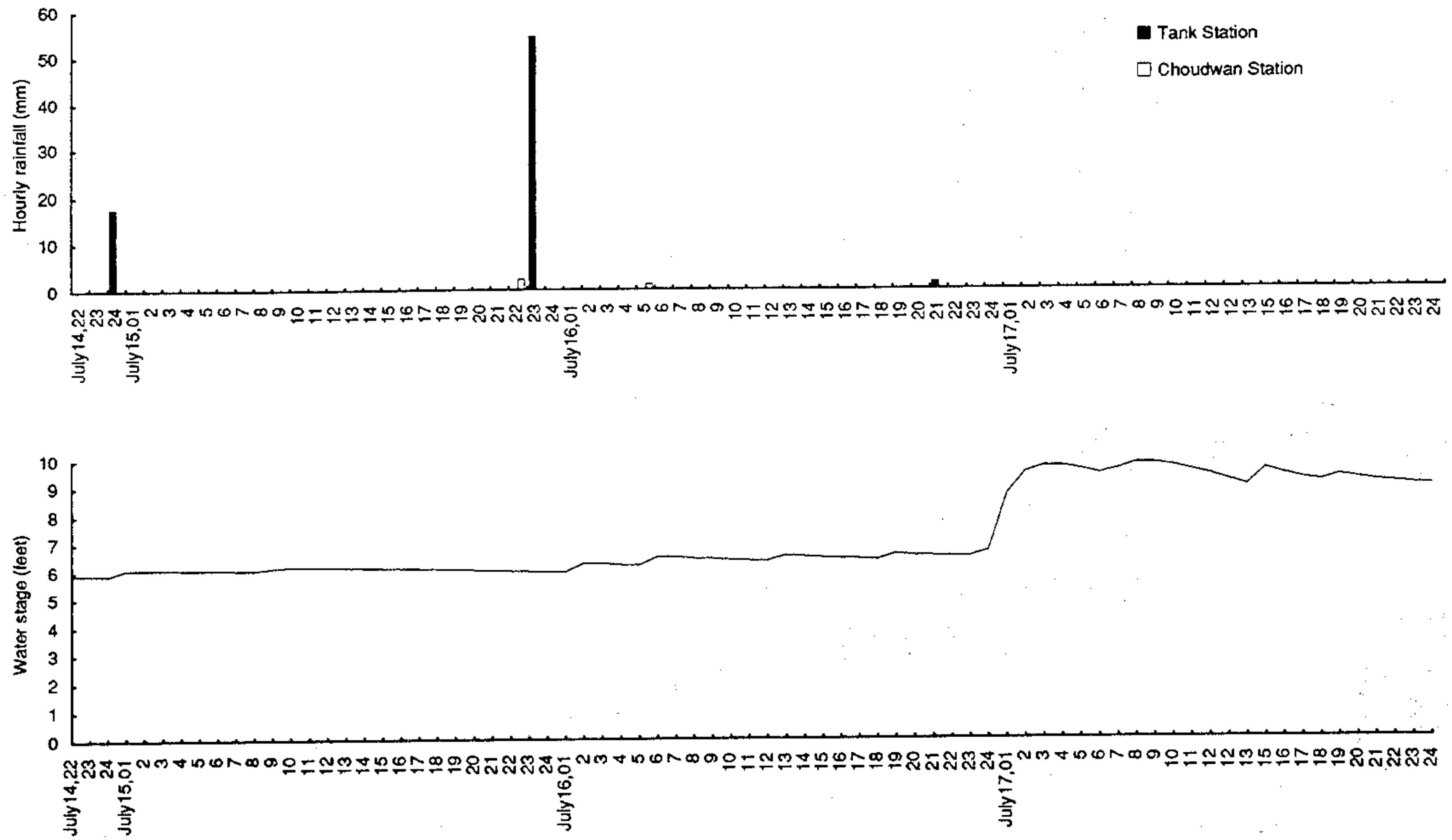


Fig. B.2.2 Comparative Diagram of Discharge and rainfall (July 14 - 17, 1993)

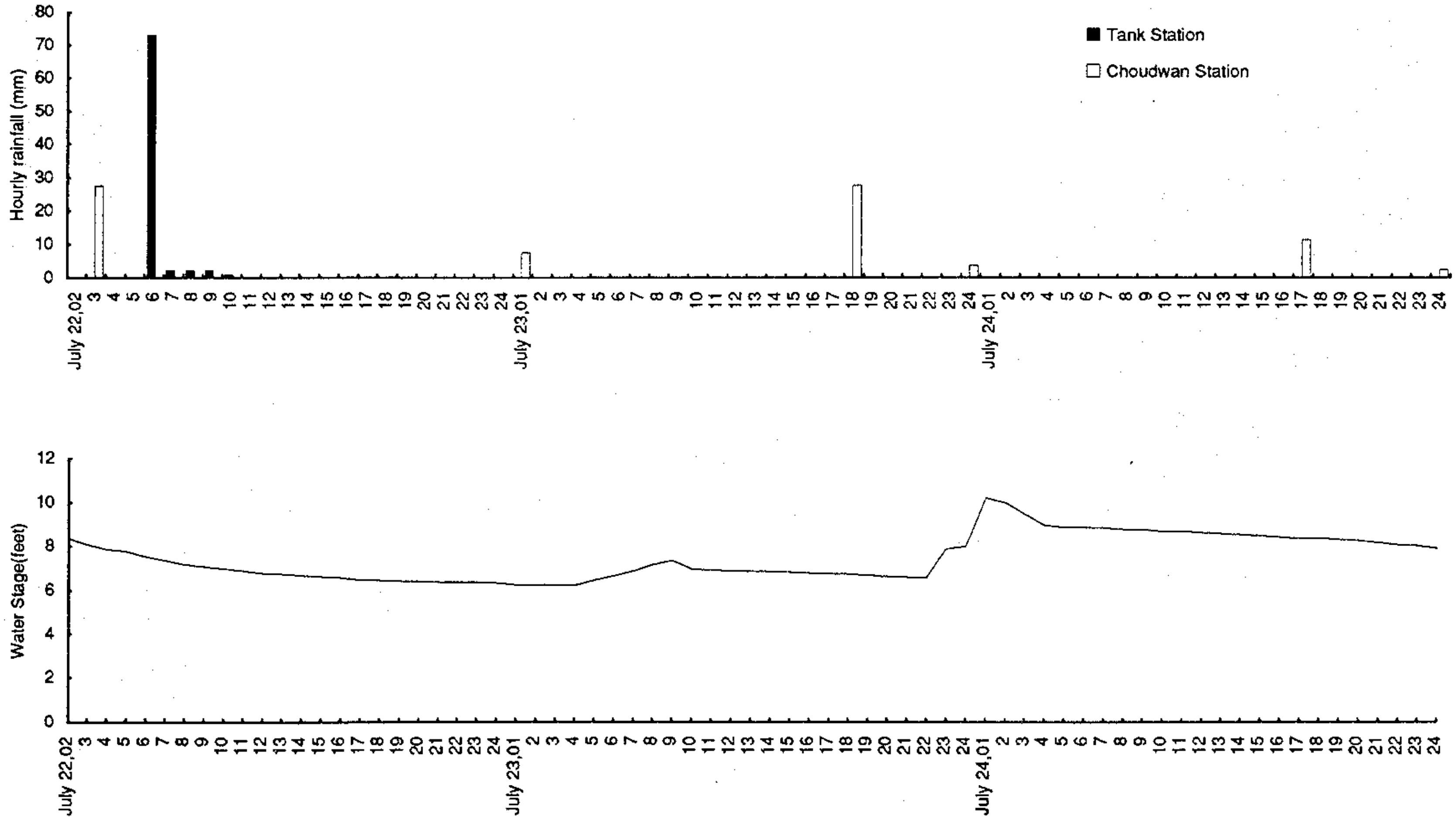


Fig. B.2.3 Comparative Diagram of Discharge and rainfall (July 22 - 24, 1993)

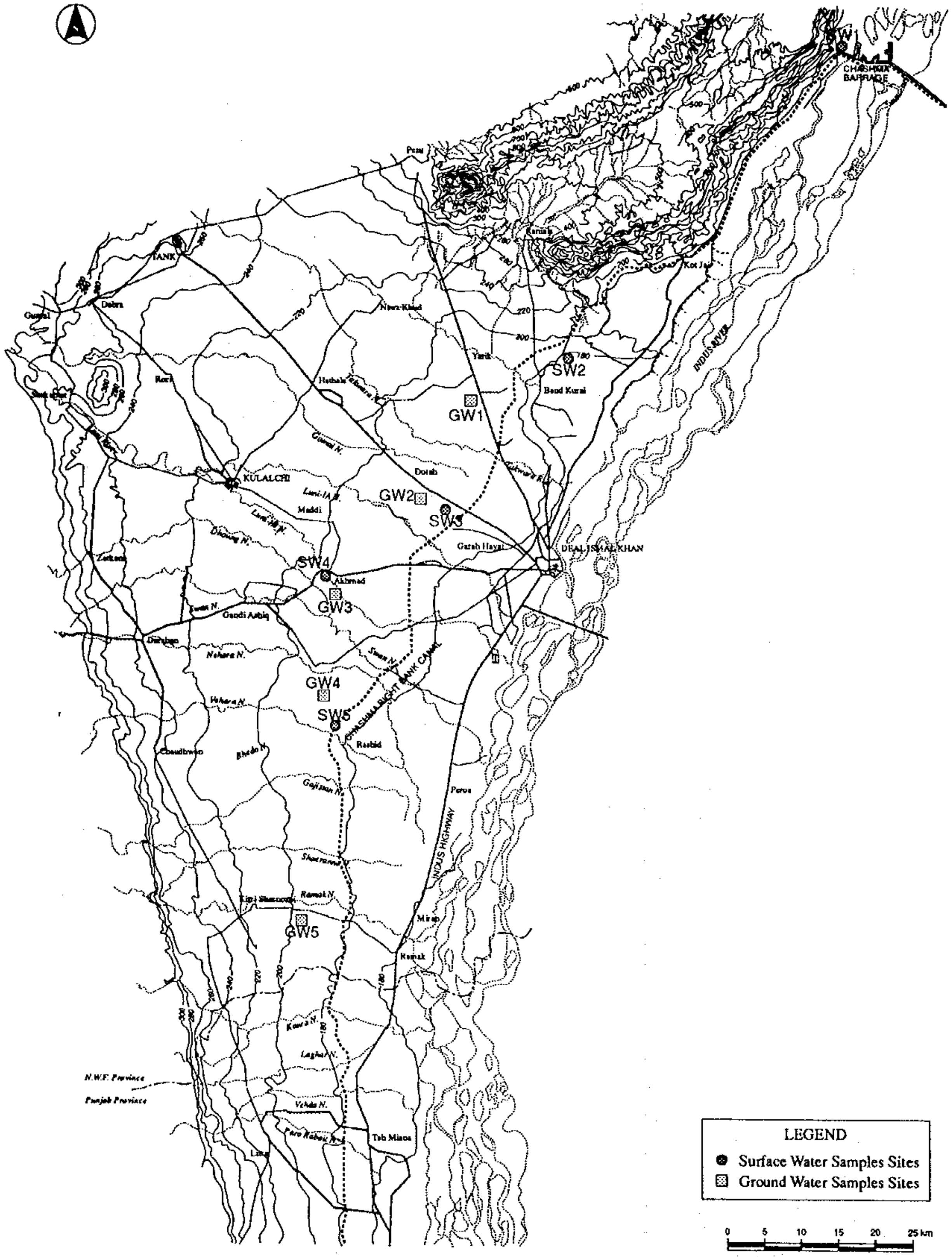


Fig. B.3.1 Sampling Site for Water Quality Test

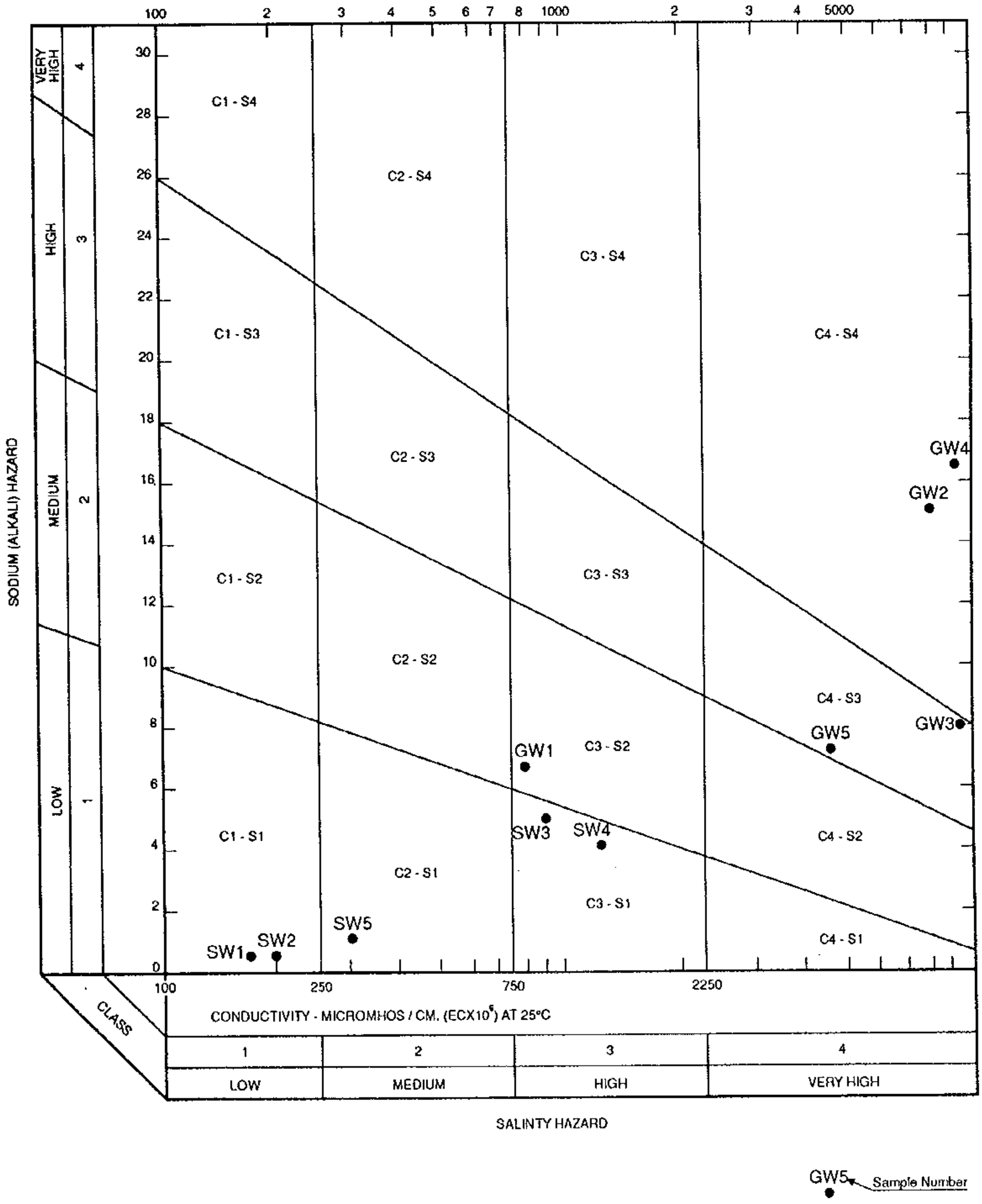


Fig. B.3.2 Classification of Irrigation Water

ANNEX C

IRRIGATION AND DRAINAGE

ANNEX-C

IRRIGATION AND DRAINAGE

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ANNEX C IRRIGATION AND DRAINAGE

C.1 Irrigation

C.1.1 Flood Irrigation

(1) Irrigation practice

Flood irrigation has for long been practiced in the Study Area utilizing flood flows which occur in short period but with high peak during summer and with relatively moderate flood in winter. Method to divert flood flow in the river channel (so-called Zam) is to erect at suitable intervals earthen and gravel embankments (so-called Ganji) extending about half to full way, depending on the scale of zam, across a river bed to head up flood water and lead it to distributary channels which open immediately above the embankments. There are approximately 40 number of such embankments within the Study Area.

Flood water in the distributary channel is head up by earthen bund and guided into the farm field surrounded by embankments (also called Bund), often at a height of less than 1m but sometimes as high as 2m. As soon as the field is filled with water at full height of surrounding bund, the bund at the channel is cut open and the water is allowed to flow into the next field located at downstream. The water in the field is impounded until the ground is sufficiently saturated then the seed is sown.

(2) Water right

The site of each embankments across the river and distributary channels, the order and sometimes the proportional rate of water intake are registered in the water rights. The area having water rights for flood irrigation is shown below.

Area Having Water Right in Each Zam

Tank Zam	900 ha
Gomal Zam	8,600
Sheikh Haider Zam	5,300
Daraban Zam	11,600
Ramak Zam	700
Total	27,100

(3) Field size

The size of field plot irrigated by flood water can be measured on aerial photographs.

The Study Area is roundly divided into 12 sub-areas in accordance with river course of major zams as shown in Fig. C.1.1.1. Taking one to two sample area of about 1,000 ha in these sub-areas, field plot size was measured at each sample area. Average size of farming field was estimated at about 2.6 ha. Condition of these sampling areas are shown in Fig. C.1.1.2.

Histogram of Farming Plot Size

Plot size(ha)	Percentage	Accumulated percentage	
0 - 0.5	2.0	2.0	
0.5 - 1.0	7.9	9.9	
1.0 - 1.5	10.5	20.4	
1.5 - 2.0	15.6	36.0	
2.0 - 2.5	11.4	47.4	
2.5 - 3.0	10.5	57.9	average
3.0 - 3.5	7.1	65.0	
3.5 - 4.0	9.6	74.6	
4.0 - 4.5	6.4	80.9	
4.5 - 5.0	3.6	84.5	
5.0 - 5.5	3.8	88.3	
5.5 - 6.0	2.4	90.8	
6.0 - 6.5	2.1	92.9	
6.5 - 7.0	1.5	94.4	
7.0 - 7.5	1.6	96.0	
7.5 - 8.0	1.3	97.3	
8.0 - 8.5	0.5	97.8	
8.5 - 9.0	0.6	98.5	
9.0 - 9.5	0.7	99.2	
9.5 - 10.0	0.3	99.5	
10.0 - 10.5	0.1	99.6	
10.5 - 11.0	0.1	99.7	
11.0 - 11.5	0.2	99.9	
11.5 - 12.0	0.1	100.0	

C.1.2 Tube-well Irrigation

Tube-well irrigation is practiced in the Study Area but limited in scale and area , and mostly privately owned. The tube-well irrigation area is located along the Bannu road and at west of Ramak. Total benefit area is 130 ha in Kharif and 940 ha in Rabi. The number of tube-wells operated is 20, and shown below.

Tube-wells in the Study Area

Category	Power of motor	number	Irrigation area
Private Operation	50 HP	3	198 ha
	40 HP	0	-
	30 HP	1	40 ha
	25 HP	7	260 ha
	20 HP	6	303 ha
	15 HP	1	69 ha
Governmental Operation	40 HP	1	12 ha
	20 HP	1	58 ha
		20	940 ha

Tube-well irrigation areas are well facilitated by concrete lined watercourses which were constructed under the Program of "On Farm Water Management on Special Watercourse in NWFP". Intensive and elaborate farming are practiced in the tube-well benefit area. Irrigation methods such as furrow, basin, border irrigation etc. are selected to meet with the cultivated crops.

C.1.3 Land Availability for Irrigation

According to the soil investigation in CRBC command area, curve of accumulated intake rate in each soil had been analyzed as shown below and Fig. C.1.3.1.

Curve of Accumulated Intake rate in D. I. Khan

Soil	Intake family*	Accumulated intake curve**
Sandy Loam(D. I. Khan)	3.75	$D= 6.10\ T^{0.60}$
Sandy Loam(CRBC)	5.0	$D= 8.26\ T^{0.68}$
Loam(D. I. Khan)	2.5	$D= 5.46\ T^{0.45}$
Loam(CRBC)	1.25	$D= 2.24\ T^{0.58}$
Silt Loam(D. I. Khan)	1.25	$D= 4.01\ T^{0.52}$
Silt Loam(CRBC)	1.25	$D= 3.81\ T^{0.37}$
Silty Clay Loam(D. I. Khan)	0.25	$D= 1.07\ T^{0.47}$
Silty Clay Loam(CRBC)	0.25	$D= 0.94\ T^{0.46}$

*: Intake families are significant rate at which water enters these soils (one to two hours after initial applications) expressed in centimeters per hour.

**: D--cm/hr, T--hr

In the Study Area, Loam and Silt Loam of soils are dominant soil. In view point of irrigation practice, every kind of surface irrigation methods may be applicable. Sand dune area is found in northern and southern portions of the Study Area. It is classified as Sandy Loam, which limits the application of ordinal surface irrigation method.

C.1.4 Notable Knowledge on CRBC Project

After completion of the implementation of CRBC Stage-I and Stage-II, notable and useful information was obtained through the post project evaluation and investigations especially on operation and maintenance aspects.

(1) Water losses from irrigation canal

IIMI has made field investigations on water losses from distributaries of CRBC. The result of the study indicates that an average seepage loss rate at 1.5 l/s per 1,000m2 of wet area of canal, which is lower than the design value at 2.4 l/s as unlined canal. Considering the soil classification in the Study Area dose not differ greatly from that of CRBC command area, design value of irrigation efficiency derived from smaller conveyance losses may be taken greater than the CRBC design value of 0.53.

(2) Water shortage

According to the special study for post evaluation on CRBC Project by ADB, it was concluded that actual discharge of canal in wet season was increased up to 50 % of design value while the discharge in dry season was decreased by 20 ~ 50 % of design value.

Reasons to describe the difference of discharge between actual operation and the design were estimated as follows:

- higher estimation of water requirement in wet season
- inaccurate estimation of water requirement
- lower estimation of effective rainfall in wet season
- inadequate water management
- difference with cropping pattern and intensity between actual and designed ones

(3) Keen desires for crop based irrigation

Farmers used to select their cultivating crops in consideration with momentary conditions even though those are not recommended in the proposed clopping pattern. Water shortage mentioned above has caused by this difference between designed cropping pattern and farmers' intention at the moment. Forcing farmers to cultivate in line with fixed cropping pattern sometimes hinders liberal agricultural activities of farmers.

In addition to the above, it should be noted that the *Warabandi* system is practiced in the CRBC command area. It is the rotation system of canal water with fixed turn and time intervals.

Farmers are willing to hold certain applicability in selecting their crops, having sense of saving water as applying *warabandi.*

C.1.5 Irrigation Planning

(1) Irrigation method

Stage I, stage II and also stage III of CRBC are based on on-farm irrigation using level-basin flood irrigation method, that is equally named as level border irrigation method. The border irrigation is a method controlling surface flooding. The field is divided into strips or basins by parallel bunds or border ridges. Each strip is irrigated separately.

The level border irrigation method is more appreciable in the fields of which soil is low intake rate less than 1 cm of intake family. In order to save irrigation water, other irrigation methods are preferable such as furrow irrigation method, sprinkler method and trickle method. As intake family of soils in the Study Area is assumed 1.0 to 2.0, another irrigation method rather than the border irrigation method is recommended. Flood irrigation method has been widely applied in the Study Area. Taking account of farmers' unfamiliarity for canal irrigation into consideration, it seems to be easy for them to adopt surface irrigation. Accordingly, furrow irrigation method is the most suitable method for the Study area so as to save water and to adopt former themselves to the same.

The effects of regular Rod Kohi irrigation have led to the development of a much-modified topography because of the construction of Rod Kohi bunds and floodways, and resulting from differential siltation of irrigated fields.

Moreover, special consideration has been given to how the transition from existing practices to canal irrigation will be carried out in regular Rod Kohi areas. Irrigation development in the regular Rod Kohi areas should not involve massive earth leveling operations with consequent disruption to the existing socio-economic system, but rather should be tackled in such a way that canal irrigation water and the necessary distribution systems should progressively replace the existing Rod Kohi system, and that the necessary additional financial provision be made to allow this to happen.

Whole project area excluding sandy soil land has been adopted uniform irrigation efficiency. As to irrigation for the sandy land, complicated irrigation method such as sprinkler or drip is not recommendable for adoption due to higher cost. It is recommended to adopt surface irrigation with care of control for percolation. According to the experience on sandy land in CRBC, it has been observed that such lands have become productive because of mixing of fine sediments brought by canal water with sandy soil.

(2) Irrigation efficiency

Irrigation efficiency is an overall scheme efficiency composed of each item enumerated below.

Transfer Efficiency for Main Canal..................	Seepage losses Evaporation losses Wastage
Conveyance Efficiency for Watercourse..	Seepage losses Evaporation losses Wastage
Field Application Efficiency.	Evapotranspiration Infiltration Wastage

The overall efficiency of CRBC was applied at 0.53 (0.86 x 0.82 x 0.75). Transfer efficiency for main canal of 0.86 was on the assumption that seepage rates are 8 cfs per million sq. feet of wetted area for unlined canals and 4 cfs for lined canals, and evaporation rate is 200 mm per month. Conveyance efficiency for watercourse of 0.82 was on the assumption that 70 % of the watercourse length were lined. Adopted the field application efficiency of 75 % assumed applying level border irrigation method and precision land leveling over at least 70 % of the CCA.

In this Project, some modification of efficiencies in comparison with these CRBC's figures should be taken considering differences of conditions.

Transfer efficiency for main canal is applicable at 0.90 which is considered the fact that actual seepage losses of CRBC canals measured by ADB and IIMI are smaller than the designed figures. Conveyance efficiency for watercourse should be applied at 0.86 considering the ratio of proposed figure to former CRBC's figure for the case of main canal. Field application efficiency is applied at 0.75. Though the efficiency can be taken greater than CRBC's figure of 0.75 due to being proposed furrow irrigation method instead of the level border irrigation method, 0.75 as same as CRBC is proposed considering small parentage of area applying precision land leveling to the CCA.

Therefore, an irrigation efficiency of 0.58 (0.90 x 0.86 x 0.75) is proposed for area having ordinal soil.
The soil survey of sandy area under CRBC indicate that a layer deeper than 6-20 cm indicated low percolation rate due to this phenomena. For the sandy land, field application efficiency is assumed at 0.40. Therefore, overall irrigation efficiency for sandy land of 0.30 (0.90 x 0.86 x 0.40) is proposed.

(3) Effective rainfall

Actual irrigation requirement is the quantity of water required to produce a crop minus effective rainfall. Effective rainfall should be estimated based upon rainfall records considering other physical factors such as water holding capacity of soil, soil moisture and rainfall intensity and so on.

Daily rainfall record of D. I. Khan Meteorological Station during 1961 to 1992 is used for calculation of effective rainfall in this Study. On the CRBC project, effective rainfall has been estimated multiplying rainfall by a constant of 90 % when 10 days' rainfall is less than 16.7 mm, 85 % when more than. Since the constant is not always qualified where come from, another methodology of estimation for effective rainfall should be taken in this Study.

The water budget calculation taking into account of holding capacity of soil and soil moisture when rain occurs are carried out. Notation of the water budget calculation is explained as follows:

- Holding capacity of soil is generally given at 30 mm
- Initial soil moisture is set at same as holding capacity
- Soil moisture is calculated by subtracting crop water requirement equivalent to evapotranspiration from the previous soil moisture content
- When it rains, rainfall supplements water to soil depend upon empty room of the holding capacity of soil. The volume of rainfall to hold water to the soil is an effective rainfall. If soil moisture contents full of the holding capacity, rainfall flows away ineffectively.
- The calculation is conducted in daily base.

The result of the calculation is shown in Table C.1.5.1 comparing with effective rainfalls analyzed so far. Results of calculation shows that the effective rainfall in the Study is 86 % of actual rainfall in volume.

(4) Water requirement

Applying proposed cropping pattern, effective rainfall and parameters for irrigation, specific water requirement for irrigation is calculated. Water requirement for irrigation is calculated at 10 days bases. Conditions and assumptions for calculation are enumerated below.

- Evapotranspiration for each crop requirement is based upon ETo presented in Fig. B.1.3.
- Crop coefficient (Kc) is referred FAO technical paper, as shown in the results of calculation.
- For each upland crop, land soaking water at totally 50 mm is required during 10 days before cropping.
- Effective rainfall mentioned above is applied in each cropping area among whole irrigation area.
- Irrigation efficiency composed of conveyance losses, operation losses and application losses as explained above are applied.

Applying proposed cropping patterns, water requirements is calculated as attached Table C.1.5.2, C.1.5.3 and C.1.5.4. The results are summarized below.

Land category	Area (CCA)	Volume of water requirement Kharif	Rabi	Peak discharge
PC-1	110,500ha	787.9MCM	674.5MCM	66.17cum.s
Ordinary land	108,640ha	619.3MCM	544.3MCM	63.33cum.s
Sandy land	6,960ha	76.7MCM	67.4MCM	7.84cum.s
Sub-total	115,600ha	696.0MCM	611.7MCM	71.17cum.s
Loss for Feeder Canal		44.8MCM	44.5MCM	(74 cum.s)*
Total		740.8MCM	656.2MCM	

*: The design discharge at Chashma Intake is estimated as 74 cum/s including water conveyance loss in the feeder canal.

(5) Distribution system

Distribution system of the Project have components holding each significant function mentioned below.

Components	Facilities	Functions
Intake	Intake structures	to take water effectively and correctly from the Indus river
Conveyance	Feeder canal	to convey water from the intake structures to the pumping station
Lift	Pumping station	to lift conveyed water through the feeder canal to the beginning point of main canal
Transmission	Main canal	to transmit and to divert lifted water for command area
conveyance	Distributary	to convey water timely and correctly to each *mogha*

Each component consists of major facilities above and other related structures.

Institutional set up for implementation of the Project could be conducted through the authority and farmers organization newly established so that crop-based irrigation is introduced. Along with the institutional preparation, irrigation system which consists of components above shall be devised for responding to water without waste of water and time.

- Intake structure shall be independent of existing intake gate for the C.R.B. Canal gravity system, avoiding rivalry of both water uses.
- Combination of pump shall be decided so that water supply can respond economically to fluctuation of water demand through operating of different numbers of pumps .
- Main lift canal shall be designed to have sufficient velocity of water for prompt response to request of each distributary.
- Regulating pond adjusting water supply to actual water requirement shall be equipped at the head of each distributary (The regulating pond should be multipurpose , such as water regulation, domestic water supply, environment improvement etc.)

(6) Command area development (CAD) system

Command area development (CAD) system includes all aspects downstream of the *mogha*. Diverted water at the *mogha* flows into main watercourse, and finally introduce to each field at *pucca nacca* .

Command area of *mogha* is subject to the capacity of *mogha*. Capacity of main watercourse should be smaller than 2.5 -3.0 cfs (0.071 - 0.0848 cms) so that farmers can easily do water management by themselves. The command area of *mogha* is, therefore, decided at 160 ha at best, applying specific peak discharge for irrigation of 0.554l/s. GCA of the command area is fixed at 174 ha which is obtained dividing 160 by 0.92 of conversion ratio between CCA and GCA.

Along the main watercourse, water diverts to several watercourses. Command area of *mogha* is divided into modal farm units which be commanded by *pucca nacca* . The *pucca nacca* locates along the watercourse. Consulting the information regarding turning irrigation so that number's of the modal farm units is recommended to be multiples of six, modal farm unit is laid down around 7.25 ha obtained dividing 174 by 24.

Typical layouts should be divided into two groups, one is the case that *mogha* is equipped along distributary directly (Distributary to Watercourse[DTM] system), and another is the case that the same locates in minor distributary (Minor canal to Watercourse[MTW] system).

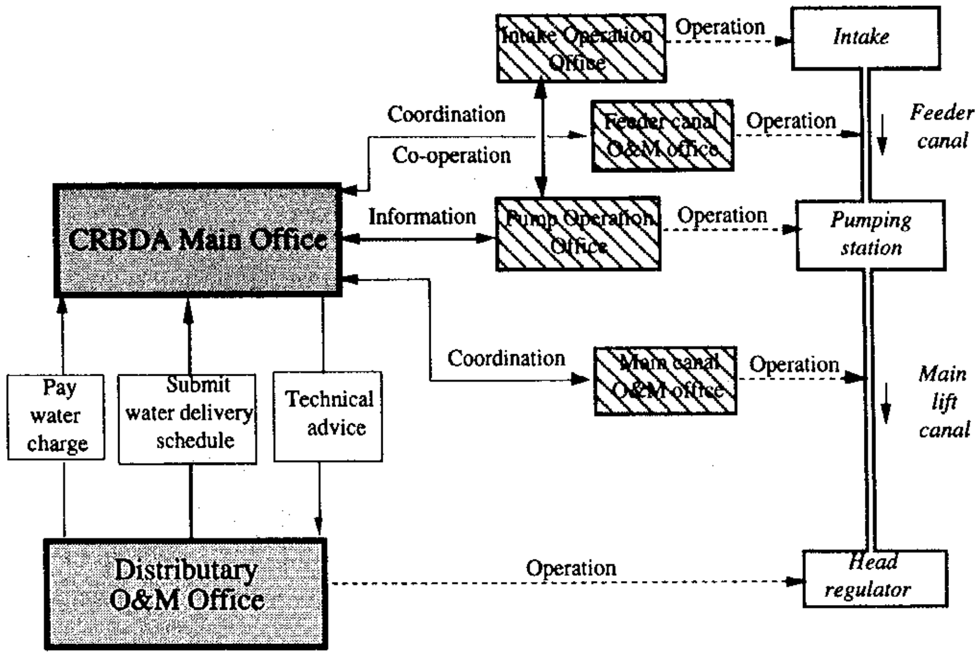
(7) Operation and maintenance

Fig. C.1.5.1 shows complication of O&M activities taken by agencies concerned in CRBC. According to the figure, many agencies are involved in each work for operation and maintenance(O&M). Its constraint is an essential cause for thinking of innovating present institution on O&M in irrigation as described in the paragraph of "Institution" in detail. Planning of O&M in this Project shall be devised in line with proposal on the institutional issues.

Basic strategy for O&M is simply defined as follows:

- Proposed CRBDA Main Office shall handle and manage all administrative matters as well as technical supporting with full responsibility.
- Actual operation and maintenance for the facilities downstream of head regulator shall be subject to the Distributary O&M Office which is an active body for O&M of a proposed Distributary Farmers Association (DFA). The office will plan water management in accordance with farmer's request for irrigation water supply.
- CRBDA Main Office and Distributary O&M Office shall function harmoniously in order to realize "Demand Based Irrigation".

The relation among proposed offices on the operation and maintenance are schematically presented as follows:



Relation among Proposed Offices on the Operation and Maintenance

C.1.6 Introduction of Crop-based Irrigation

(1) Definitions

'**Demand**' irrigation comprises operation of farm offtakes by farmers, such that they can turn on, adjust or turn off their water supply without giving notice or having to obtain permission. A demand system must respond automatically to user demands (like a town drinking water supply), right back to the headworks with no constraint on cropping pattern.

'**Semi-demand**' is a demand system modified to avoid a 'free-for-all'; e.g. such a system could limit the number of farmers taking water simultaneously.

In a '**Supply-based irrigation**' system, deliveries are controlled by the Department of Irrigation in line with their schedule and canal capacity. The releases may be in response to farmer's request, or may be at the discretion of the supply authority.

'**Crop-based irrigation**' comprises water supply to the crop in accordance with, or close to, actual crop water requirement at the particular stage of growth achieved, thus minimizing water stress and the corresponding yield reductions.

Where there are constraints on farmer ability to determine accurately the crop water requirements, or constraints upon the maximum discharge available, a semi-demand and/or crop-based system is recommended to be applied based on calculated or indented crop water requirements.

(2) Necessity to Change Supply-based Irrigation to Crop-based Irrigation

During field survey on the Feasibility Study, a series of interviews with the farmers were made in order to know farmers' opinion and intention for the Project. Farmers expressed their strong desire for the Project through the interview. One hundred percent of interviewees agreed to pay costly *abiana* for lift irrigation if water was available when they needed it.

Farmers' consent for the Project and self-reliance effort on the Project is essential for the success of the Project. Furthermore, providing irrigation water as farmers need is the most important condition in order to obtain full farmers' consent to the Project. It is also necessary to supply water according to the crop water requirements to realize maximum productive capacity of the Project.

(3) Basic concept of Crop-based Irrigation

Farmer can not always be provided water 'free-for-all' at any time and as much as he likes, because of limitation of resources and sense of economy. User demands of water supply can not exceed certain limitation, for instance, irrigation water releases for the Project must be within Water apportionment accord of Indus river. In view of this limitation, it is necessary to introduce a crop-based irrigation that is a semi-demand irrigation in line with crop-demand. Proposed crop-based irrigation is not demand-based system under which farmer turn on and off his water supply freely, but an irrigation system in which water supply is made in accordance with actual crop water requirement. Further, the farmer or a group of farmers will have to follow a certain cropping pattern which responds to the water releases in conformity with the water accord.

It is, therefore, absolutely necessary to establish certain rules on water management that water user must be subjected to. Concept of crop-based irrigation of the Project is to build irrigation system and such rules which easily supply water to any farmer in accordance with proposed crop water requirement.

(4) Methodology of Crop-based Irrigation

Crop-based irrigation will function successfully under well facilitated circumstances as follows:

- Establishment of a realistic cropping pattern

- Elaborate water delivery schedule
- Systematic and well-trained operation
- Closed communication on operation
- Accurate and timely measurement of discharge
- Reasonable water charge system and fair collection
- Adequate and useful technical advice system

Basic institutional organization of the Project is proposed in the Institutional Improvement Plan. Every functions above should be facilitated in line with the proposed organization.

"Water delivery schedule" will be made in consideration with proposed cropping schedule prepared by each DFA through Distributary O&M Office keeping in view of the overall cropping pattern for the Project. CRBDA will analyze water requirement of whole project area, and make operation schedule. After the yearly schedule is approved, CRBDA will watch and accept alternation if absolutely necessary of water requirement of each DOMO on monthly, and weekly basis.

"Operation" within command area of a distributary including head regulator operation will be done by DFA under the support of CRBDA. Each proposed office will be equipped with communication system so as to communicate adequately among the organizations.

"Measurement of discharge" will be done by means of facilitating necessary measuring devices and deployment of necessary staff.
"Water fee (Abiana)" is collected by CRBDA through DFA. Abiana will be appropriated directly to O&M expenditure. Payment for water use as Abiana is on a volume basis because other criteria for determining payment (e.g. per cropped acre, as at present), will not motivate the farmer to limit his water uptake to the requirements of his crops.

'Technical advice" will be given to DFA by CRBDA through Agriculture Extension Advisor assigned to each DFA.

(5) Development Plan for Crop-based Irrigation

For elaborate water delivery schedule:

Water delivery schedule must be based upon farmers desires of cultivation. A month before the start of hydrological year (from April to March), DFA shall submit yearly cropping schedule for their distributary command through collecting and summing up cropping schedule of each farmer along with estimate of water requirement for the distributary. The CRBDA will check the discharge of water requirement with the available water taking from Indus river, and flowing capacity of facilities of the Project. If it is excessive, the proposal on cropping schedule and water demand will be sent back to DFA. After fixing yearly cropping schedule in whole project area, yearly water delivery schedule will be made in CRBDA.

During the month, the DFA could ask for modification which should be considered by the CRBDA and accommodate the demand, If possible within the overall system. Water delivery is basically constant in each 10 daily period. A few days before the next period, CRBDA will inform the DFA of any negative change. Similarly, the DFA can request CRBDA to change the discharge of their distributary. Response for the request on the change of discharge will be expected immediately, depending upon the distance between intake and head gate of requesting distributary. The flow on confirmation of water delivery schedule is shown in Fig. C.1.6.1

For systematic and well-trained operation

Operation of major facilities such as pumping station, facilities on main canal etc. shall be done by CRBDA staff. They will be trained in their duty through CRBDA's original training program.

Facilities downstream of head gate of distributary, shall be operated and maintained by DOMO staff. CRBDA shall train farmers through DFA, providing operation manual and holding training seminar.

For closed communication on operation

Transmission of information such as cropping schedule, water delivery schedule, and alternation of discharge shall be smoothly and correctly done through communication system. Wireless system is provided in the Project. All proposed offices in the Project will be linked with the wireless system.

In case of stoppage of the wireless system, vehicles equipped in each office is available for the communication use.

For accurate and timely measurement of discharge

Measurement of discharge for delivered water must be done at predetermined important points and on scheduled time. Staff gauge shall be installed at the point of gates. Personnel who have the duty reading such staff gauge are trained for handling the staff. On the other hand, rating curve which can change the stage to discharge at the staff gauge, must be provided through measuring discharge at several water stage.

For reasonable water charge system and fair collection

Farmers can select cultivating crop in accordance with information for adaptability of their fields, latest market price, water consumption, and required labor force etc., as far as peak discharge is less than the flowing capacity of facilities, and total volume of water is available for taking from Indus river.

Water fee shall be charged to farmers on a volume basis which relate with crop variety farmers chose. Abiana price at cubic meter is decided in consideration with all expenditure for operation and maintenance.

Abiana shall be collected by CRBDA through DFA from every beneficiaries on the basis of consumed water recorded by DOMO staff.

For adequate and useful technical advice system

Farmer will play the leading role on management, operation and maintenance of the Project. Farmers association named Distributary Farmers Association is an acting body such activities. CRBDA shall fully support and train the association so as to function well. Agricultural extension advisor who is assigned to every DFA will act a leader and technical supporter for the DFA. The agricultural extension advisor should be an agronomist or a senior engineer to be able to deal with any matters regarding farmers association.

Technical support on irrigation practice and facilities repairing can be given by CRBDA through despatching engineer from the authority.

C.2 Drainage

C.2.1 Present Drainage System

During the field survey, investigation and reconnaissance was made the present conditions of the rivers more clear.

The rivers in the Study area have some peculiar characteristics as given below.

- The courses of rivers are neither distinct nor permanent. These change and silt up due to heavy sediment during flood flows.
- The uncontrolled and random diversions for the propose of flood irrigation by the people known as Rod Kohi result into a phenomena of no fixed stream courses

and unnatural run-off characteristic.

- There are 48 cross drainage structures across the C.R.B. gravity canal running parallel at about 10 kilometers west and 60 feet below the lift canal. No well defined flood channels exist flowing into these outlets from the Study area. The flood capacity flowing away from the Study area is thus limited to the designed capacities of these outlets to avoid inundation in the Study area.

Location and design capacity of each existing cross drainage structure in the C.R.B. gravity canal has been given as per actual flooding situation. If there were mismatches between present stream courses and location of existing cross drainage structures, the river system might be modified so as to match with condition of such existing structures. Accordingly, the present river system must be considered with its implication on the these existing cross drainage structures. The present river system is schematized in Fig. C.2.1.1.

C.2.2 Design Capacity for Drainage

(1) Design discharge of nullahs

Scale of design flood in each river concerning the Study Area should be 40 years return period in consonance with CRBCs' criteria. In that case, design flood discharge in each nullah(river) could be referred in the Fig. C.2.1.1. These design discharges have been estimated by means of several methods below.

Catchment area	Land condition	Method for peak run-off estimation	Remarks
small than 10 sq.miles	including hill area	Rational Method	
greater than 10 sq.miles	including hill area	Synthetic Unit Hydrograph	
greater than 1000 sq.miles	mountainous area	Statistical estimation	Observed data exist

Note : 1) Flood from plain area located behind hill area is considered within the figures of discharge in the Fig. C.2.1.1

2) Peak discharge is decreased by flood wave reduction, when length of river from gorge to the cross point with CRBC exceeds 10 miles (16 km).

3) General formations for run-off estimation mentioned above were taken in the Report of "Review of Cross Drainage Works and Sheet Flow Protection of Chashma Right Bank Canal" by ACE in 1984, then feasibility study reports on CRBC have been basically followed it.

Design capacity of proposed cross drainage structure in the proposed main lift canal should be estimated with reference to the discharge at the proposed crossing point on the Fig. C.2.1.1. When the discharge is mitigated by flood wave reduction, design capacity should be estimated according to the distance from the gorge (Rate of flood wave reduction seems to be an exponential function of flowing length.).

(2) Design discharge for plain area

As to estimation of run-off from plain area sandwiched between proposed main lift canal and C.R.B. gravity canal, careful attention needs to be paid. In the feasibility study report of stage III of CRBC, run-off from plain area has been overlooked due to long time of peak (greater than 35 hours). As long as each field has water storage function by peripheral bund as it is, run-off component from plain area may be neglected. However in case of any change in the farm management in the plain area, run-off condition from the plain area such as shortening of time of peak, and increasing of peak discharge is likely to be experienced.

Assuming that uniform sheet flow occurs in the plain area, run-off discharge from the plain has been estimated with Kinematic Wave Method during the field survey. The result is shown in Fig. C.2.2.1 and be summarized in the following table.

	Length of plain (km)	Slope of plain	Time of peak (hr)	Specific peak discharge (cms/sq.km)
Case 1	8.0	1/400	6.6	1.86
Case 2	17.5	1/850	21.1	0.74

(3) Design capacity for proposed cross drain

For the case of existing cross drainage outlets of C.R.B. gravity canal concerning Gomal zam that is the biggest zam having time of peak flood of more than 50 hours, run-off component from plain area may be overlooked because of no overlapping of both peak discharges. However as to medium and small zams having time of peak flood from 2 hours to 10 hours, both peak discharges flooding from such zams and from plain must overlap at the outlets of C.R.B. gravity canal.

Accordingly, the capacities of cross drainage structures in the main lift canal, for zams other than Gomal zam, may be designed as the capacity discharge of the corresponding structure of C.R.B. gravity canal less peak discharge of plain area between the two canals pertaining the same basin.

C.2.3 Basic Concept for Drainage Planning

Basic concept for drainage planning for the Project are:
to drain flood water crossing the proposed main canal promptly through existing CRBC cross drainage structures.

and, not to allow exceed flood flowing into the Project area through proposed cross drainage structures in the proposed main canal. Capacity of the proposed cross drainage in the main canal should be related with the capacity of existing CRBC cross drainage (40 years return period). Exceed flood water coming from zams in excess of such capacity shall be inundated at the out of the Project area in an allowable short term.

In accordance with the basic concept, four(4) components of drainage are conceived as follows:

1) *Cross drainage structures* in the proposed main canal so as to drain flood water safely
2) *Flood carrier channel* to carry flood to the outlets of cross drainage in CRBC. Existing Nullah will be utilized as the channel with remodeling if necessary.
3) *Supplemental flood drainage channel* to complementary flow flood water. It is newly constructed.
4) *Open collector drain* to drain ordinal flood water caused in the Project area facilitating along each main watercourse.

C.2.4 Routine Study at Proposed Outlet of Lift Irrigation Canal

In order to know the flooding situation around proposed cross drainage structure when flood come, flood routine study is carried out. Crossing point with Budh nullah is selected as a typical site in consideration with magnitude of discharge, topographical condition, type of cross drainage structure.
For the routing study, information in items below is required.

- Relation between water stage and water volume (H-V relation) in and around upstream of the site
- Run-off hydrograph of the Nullah in each return period
- Flowing capacity of proposed cross drainage structure flowing flood down below main canal

Result in each item is described followed paragraph.

(1) H-V relation

H-V relation in and around upstream of the site is identified by topographic map. The H-V relation is given as shown below. The water volume in each water stage in the table may regard as inundated volume of water upper potion of the site.

Water stage (m)	Inundated area (m2)	Water volume (m3)
201.67	0	0
202.00	4,700	517
202.70	270,000	96,660
203.00	486,000	210,060
204.20	2,645,000	2,088,660
205.75	12,772,000	14,036,840

(2) Run-off hydrograph of Budh Nullah

The hydrograph is required so as to obtain rough discharge distribution in time scale for the purpose of carrying out this routine study. In order to meet this purpose, unit graph is applied for estimation of the hydrograph because of formulating easily.
Budh nullah is a tributary of Tank Zam. Unit hydrograph is formulated for Tank Zam on the grounds that there is sufficient information about characteristic of run-off on Tank Zam , then hydrograph at the site is calculated. Characteristic of Tank Zam at Zam post is as follows:

Catchment area		2,311 sq.km
Length of river		84.5 km
Height	(Max.)	8,500 ft
	(Min.)	1,260 ft
Time of concentration		8.26 hr
Time to peak		5.51 hr

Giving average probable rainfall intensity applying probable rainfall intensity curve proposed in ANNEX B, hydrograph at the site in each return period is obtained as shown in Fig. C.2.4.1.

(3) Flowing capacity of proposed cross drainage structure

As to the cross drainage structure at the site, culvert type is applied. Considering dimension of the structure, flowing capacity is calculated by formula below.

Discharge = $225.4 \times (H - 202.17)^{1.5}$
H: water stage in upper side

(4) Result of routine study

Utilizing above condition, routine study is conducted. Table C.2.4.1 shows the result of the analysis. According to the result, maximum water stage of inundation on upper potion of the proposed cross drainage structure at Budh Nullah is assumed at 204.32m even in the case of 100 year return period flood.

C.2.5 Design Discharge on Drainage Components

(1) Cross drainage structure

Design discharge for cross drainage structure is estimated in 40 years return period in accordance with run-off discharge in nullah. Run-off discharge for nullah is normally given at two points, upper stream of proposed site of cross drainage structure and crossing point with CRBC. design discharge of the proposed cross drainage structure located between points is estimated considering flood wave reduction as flood flowing down. As such flood wave reduction can be assumed to represent by exponential function, it is estimated through exponential function which fixed using discharge at both points. As to the discharge, run-off from plain area should be considered to subtract. Table C.2.5.1. is a summary for this estimation.

(2) Flood carrier channel

Flood carrier channel links with proposed cross drainage structure of lift main canal and existing cross drainage facilities in CRBC. Though both structures were designed at 40 years return period flood, design discharge of both don't always coincide due to flood wave reduction and increasing of discharge from plain area during flowing down. Flood carrier channel should be designed at 40 years return period as same as the capacity of the proposed cross drainage facilities. Considering present condition of existing nullah, flood carrier channel is excavated having capacity at 2 years return period, and embanked so as to flow for 40 years return period flood.

Estimated discharge in each year return period utilizing observed data is available in Tank Zam and Gomal Zam only. Other information regarding probable discharge besides these is required. For this purpose, an attempt to obtain such information by rainfall data is made. In ANNEX B, probable rainfall intensity curve was formulated. Utilizing those rainfall intensity curve, magnitude of peak discharge in each return period can compare with. Following table is calculation of probable effective rainfall.

Probable Effective Rainfall in Each Return Period

(mm)

Return	Distributed rainfall				Distributed effective rainfall				
period	1 hr	2 hr	3 hr	~	1 hr	2 hr	3 hr	~	total
2	32.14	2.31	1.42	-----	27.06	0	0	-----	27.06
5	48.94	6.01	2.34	-----	43.86	0.93	0	-----	44.79
10	60.22	6.45	2.47	-----	55.14	1.37	0	-----	56.51
20	70.47	6.98	2.65	-----	65.39	1.90	0	-----	67.29
30	77.05	7.00	2.63	-----	71.97	1.92	0	-----	73.89
40	78.25	8.84	2.75	-----	73.17	3.76	0	-----	76.93
50	84.57	7.34	2.74	-----	79.49	2.26	0	-----	81.75
80	91.60	7.57	2.80	-----	86.52	2.49	0	-----	89.01
100	94.67	7.82	2.90	-----	89.59	2.74	0	-----	92.33

Distributed rainfall is calculated by rainfall intensity curve so as to hold relation between mean rainfall intensity and rainfall duration. 0.2 inch/hr is constantly lost for effective rainfall calculation.

According to the result above, effective rainfall of 2 years return period is assumed at 35.2% of the same of 40 years return period. As peak discharge having good relation with such effective rainfall, peak discharge of 2 years return period can regard as 35.2% of the peak discharge of 40 years return period.

Therefore, design capacity of flood carrier channel to be excavated is proposed at 35.2% of the design discharge of related cross drainage structure in lift main canal.

(3) Open collector drain

This should be drain excess water without flooding. Peak discharge of the related *mogha* is applied as the design capacity of open collector drain.

TABLES

Table C.1.5.1 Estimated Effective Rainfall

(mm/10 days)

Month	Jan.			Feb.			Mar.			Apr.			May			Jun.		
10 days	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
PC-1	3.8	2.8	2.5	4.3	7.1	4.1	6.1	9.4	9.9	10.7	5.6	4.1	3.3	4.3	1.8	0.8	1.3	4.3
CRBC	3.0	3.7	4.0	4.3	5.4	6.1	8.0	8.9	8.1	7.1	6.4	5.8	4.4	3.7	3.4	3.2	4.3	5.2
Comparative plan	2.4	1.7	4.9	3.6	7.3	5.6	7.7	10.7	12.3	8.1	7.8	4.5	5.1	6.4	4.9	2.3	4.7	5.3
Proposed	2.7	2.0	5.7	4.1	8.3	5.7	7.6	12.5	13.4	9.4	8.7	5.1	5.7	6.3	4.6	2.6	5.5	5.1

Month	Jul.			Aug.			Sep.			Oct.			Nov.			Dec.		
10 days	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
PC-1	19.1	25.1	21.1	11.9	14.5	6.9	6.9	3.6	1.5	1.3	0.5	8.6	1.5	0.3	0.8	0.3	2.5	4.3
CRBC	18.8	25.1	20.7	14.2	11.6	9.4	6.2	4.6	2.9	1.4	0.8	0.7	0.8	0.7	0.8	1.5	1.9	2.2
Comparative plan	12.3	18.8	18.8	21.2	14.2	15.4	10.3	4.6	2.2	0.5	1.9	2.6	0.5	1.1	0.5	1.5	2.2	4.6
Proposed	13.7	14.7	19.1	18.0	12.5	13.9	8.1	5.0	2.5	0.5	2.1	3.0	0.5	1.2	0.5	1.8	2.4	4.7

Comparative plan : applyed constant ratio of 90 % when 10 dats' rainfall is less than 16.7 mm,
85 % when more than

Proposed : estimated by water budjet calculation

Table C.1.5.2 Result of Water Requirement (1 of 4)

Crop No. 1 (Cotton 10 %)

(Unit : mm/day)

Month		May		Jun.			Jul.			Aug.			Sep.			Oct.			Nov.			Dec.	
10 Days		2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2
							0.35	0.37	0.44	0.59	0.78	0.94	1.08	1.11	1.12	1.12	1.12	1.12	1.10	1.05	0.94	0.83	0.72
						0.35	0.37	0.44	0.59	0.78	0.94	1.08	1.11	1.12	1.12	1.12	1.12	1.10	1.05	0.94	0.83	0.72	
					0.35	0.37	0.44	0.59	0.78	0.94	1.08	1.11	1.12	1.12	1.12	1.12	1.10	1.05	0.94	0.83	0.72		
				0.35	0.37	0.44	0.59	0.78	0.94	1.08	1.11	1.12	1.12	1.12	1.12	1.10	1.05	0.94	0.83	0.72			
			0.35	0.37	0.44	0.59	0.78	0.94	1.08	1.11	1.12	1.12	1.12	1.12	1.10	1.05	0.94	0.83	0.72				
		0.35	0.37	0.44	0.59	0.78	0.94	1.08	1.11	1.12	1.12	1.12	1.12	1.10	1.05	0.94	0.83	0.72					
		0.35	0.36	0.39	0.44	0.51	0.58	0.70	0.82	0.94	1.03	1.08	1.11	1.12	1.11	1.08	1.03	0.96	0.93	0.89	0.83	0.78	0.72
Area %		0.17	0.33	0.50	0.67	0.83	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.83	0.67	0.50	0.33	0.17
ET (mm)		6.75	6.75	7.10	7.10	7.10	6.50	6.50	6.50	5.83	5.83	5.83	4.89	4.89	4.89	3.66	3.66	3.66	2.48	2.48	2.48	1.57	1.57
Req. (1)		0.39	0.81	1.37	2.07	2.99	3.76	4.55	5.35	5.46	5.98	6.31	5.44	5.45	5.40	3.93	3.76	3.51	1.91	1.46	1.03	0.41	0.19
Soaking	0.83	0.83	0.76	0.83	0.83	0.83																	
Eff. rain	0.57	0.63	0.42	0.26	0.55	0.51	1.37	1.47	1.74	1.80	1.25	1.26	0.81	0.50	0.25	0.05	0.21	0.27	0.05	0.12	0.05	0.18	0.24
Req. (2)	0.03	0.06	0.11	0.19	0.24	0.33	0.24	0.31	0.36	0.37	0.47	0.50	0.46	0.50	0.52	0.39	0.35	0.32	0.19	0.13	0.10	0.02	0.00

632mm

Crop No. 2 (Pulses 5 %)

(Unit : mm/day)

Month		Jun.		Jul.			Aug.			Sep.			Oct.			Nov.		
10 Days		2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
							0.35	0.37	0.48	0.66	0.87	1.05	1.09	1.10	1.10	1.10	1.06	0.85
						0.35	0.37	0.48	0.66	0.87	1.05	1.09	1.10	1.10	1.10	1.06	0.85	
					0.35	0.37	0.48	0.66	0.87	1.05	1.09	1.10	1.10	1.10	1.06	0.85		
				0.35	0.37	0.48	0.66	0.87	1.05	1.09	1.10	1.10	1.10	1.06	0.85			
			0.35	0.37	0.48	0.66	0.87	1.05	1.09	1.10	1.10	1.10	1.06	0.85				
		0.35	0.37	0.48	0.66	0.87	1.05	1.09	1.10	1.10	1.10	1.06	0.85					
		0.35	0.36	0.40	0.47	0.55	0.63	0.75	0.88	0.98	1.05	1.08	1.05	1.04	1.03	1.00	0.96	0.85
Area %		0.17	0.33	0.50	0.67	0.83	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.83	0.67	0.50	0.33	0.17
ET (mm)		7.10	7.10	6.50	6.50	6.50	5.83	5.83	5.83	4.89	4.89	4.89	3.66	3.66	3.66	2.48	2.48	2.48
Req. (1)		0.41	0.85	1.30	2.01	2.96	3.67	4.39	5.10	4.78	5.14	5.30	3.84	3.18	2.51	1.24	0.79	0.35
Soaking	0.83	0.83	0.83	0.83	0.83	0.76												
Eff. rain	0.26	0.55	0.51	1.37	1.47	1.74	1.80	1.25	1.26	0.81	0.50	0.25	0.05	0.21	0.27	0.05	0.12	0.05
Req. (2)	0.03	0.03	0.06	0.04	0.07	0.10	0.09	0.16	0.19	0.20	0.23	0.25	0.19	0.15	0.11	0.06	0.03	0.02

205mm

Crop No. 3 (Maize 20 %)

(Unit : mm/day)

Month		Jun.		Jul.			Aug.			Sep.			Oct.			Nov.	
10 Days		2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2
							0.35	0.37	0.52	0.74	0.95	1.07	1.10	1.10	1.10	1.08	0.85
						0.35	0.37	0.52	0.74	0.95	1.07	1.10	1.10	1.10	1.08	0.85	
					0.35	0.37	0.52	0.74	0.95	1.07	1.10	1.10	1.10	1.08	0.85		
				0.35	0.37	0.52	0.74	0.95	1.07	1.10	1.10	1.10	1.08	0.85			
			0.35	0.37	0.52	0.74	0.95	1.07	1.10	1.10	1.10	1.08	0.85				
		0.35	0.37	0.52	0.74	0.95	1.07	1.10	1.10	1.10	1.08	0.85					
		0.35	0.36	0.41	0.50	0.59	0.67	0.79	0.91	1.01	1.07	1.05	1.05	1.03	1.01	0.97	0.85
Area %		0.17	0.33	0.50	0.67	0.83	1.00	1.00	1.00	1.00	1.00	1.00	0.83	0.67	0.50	0.33	0.17
ET (mm)		7.10	7.10	6.50	6.50	6.50	5.83	5.83	5.83	4.89	4.89	4.89	3.66	3.66	3.66	2.48	2.48
Req. (1)		0.41	0.85	1.34	2.14	3.17	3.89	4.62	5.32	4.94	5.22	5.13	3.19	2.52	1.85	0.80	0.35
Soaking	0.83	0.83	0.83	0.83	0.83	0.76											
Eff. rain	0.26	0.55	0.51	1.37	1.47	1.74	1.80	1.25	1.26	0.81	0.50	0.25	0.05	0.21	0.27	0.05	0.12
Req. (2)	0.11	0.14	0.23	0.16	0.30	0.44	0.42	0.67	0.81	0.83	0.94	0.98	0.63	0.46	0.32	0.15	0.05

390mm

Crop No. 4 (Kharif Fodder 10 %)

(Unit : mm/day)

Month		Jun.			Jul.			Aug.			Sep.			Oct.		
10 Days		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
							0.79	0.96	0.95	0.95	0.95	0.95	0.77	0.00	0.00	0.00
						0.79	0.96	0.95	0.95	0.95	0.95	0.77	0.00	0.00	0.00	
					0.79	0.96	0.95	0.95	0.95	0.95	0.77	0.00	0.00	0.00		
				0.79	0.96	0.95	0.95	0.95	0.95	0.77	0.00	0.00	0.00			
			0.79	0.96	0.95	0.95	0.95	0.95	0.77	0.00	0.00	0.00				
		0.79	0.96	0.95	0.95	0.95	0.95	0.77	0.00	0.00	0.00					
		0.79	0.88	0.90	0.91	0.92	0.93	0.92	0.91	0.91	0.89	0.86	0.77	0.00	0.00	0.00
Area %		0.17	0.33	0.50	0.67	0.83	1.00	1.00	0.83	0.67	0.50	0.33	0.17	0.00	0.00	0.00
ET (mm)		7.10	7.10	7.10	6.50	6.50	6.50	5.83	5.83	5.83	4.89	4.89	4.89	3.66	3.66	3.66
Req. (1)		0.93	2.07	3.20	3.95	4.98	6.01	5.37	4.42	3.54	2.18	1.40	0.63	0.00	0.00	0.00
Soaking	0.76	0.83	0.83	0.83	0.83	0.83										
Eff. rain	0.42	0.26	0.55	0.51	1.37	1.47	1.74	1.80	1.25	1.26	0.81	0.50	0.25	0.05	0.21	0.27
Req. (2)	0.03	0.15	0.24	0.35	0.34	0.43	0.43	0.36	0.32	0.23	0.14	0.09	0.04	0.00	0.00	0.00

321mm

Table C.1.5.2 Result of Water Requirement (2 of 4)

Crop No. 5 (Sugarcane 10 %)

(Unit : mm/day)

Month		Jan.			Feb.			Mar.			Apr.			May			Jun.		
10 Days		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
		0.72	0.72	0.72	0.70	0.66	0.62	0.58	0.57	0.58	0.58	0.59	0.66	0.73	0.79	0.86	0.92	0.98	1.04
		0.72	0.72	0.72	0.70	0.66	0.62	0.58	0.57	0.58	0.58	0.59	0.66	0.73	0.79	0.86	0.92	0.98	1.04
Area %		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ET (mm)		1.92	1.92	1.92	2.52	2.52	2.52	3.69	3.69	3.69	5.31	5.31	5.31	6.75	6.75	6.75	7.10	7.10	7.10
Req. (1)		1.38	1.38	1.38	1.76	1.66	1.56	2.14	2.10	2.14	3.08	3.13	3.50	4.93	5.33	5.81	6.53	6.96	7.38
Eff. rain	0.21	0.27	0.20	0.52	0.41	0.83	0.71	0.76	1.25	1.22	0.94	0.87	0.51	0.57	0.63	0.42	0.26	0.55	0.51
Req. (2)	0.00	0.11	0.12	0.09	0.14	0.08	0.09	0.14	0.09	0.09	0.21	0.23	0.30	0.44	0.47	0.54	0.63	0.64	0.69

Month	Jul.			Aug.			Sep.			Oct.			Nov.			Dec.		
10 Days	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
	1.07	1.10	1.13	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.14	1.09	1.04	0.99	0.94	0.88	0.83	0.77
	1.07	1.10	1.13	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.14	1.09	1.04	0.99	0.94	0.88	0.83	0.77
Area %	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ET (mm)	6.50	6.50	6.50	5.83	5.83	5.83	4.89	4.89	4.89	3.66	3.66	3.66	2.48	2.48	2.48	1.57	1.57	1.57
Req. (1)	6.96	7.15	7.35	6.70	6.70	6.70	5.62	5.62	5.62	4.21	4.17	3.99	2.58	2.46	2.33	1.38	1.30	1.21
Eff. rain	1.37	1.47	1.74	1.80	1.25	1.26	0.81	0.50	0.25	0.05	0.21	0.27	0.05	0.12	0.05	0.18	0.24	0.43
Req. (2)	0.56	0.57	0.56	0.49	0.55	0.54	0.48	0.51	0.54	0.42	0.40	0.37	0.25	0.23	0.23	0.12	0.11	0.08

1,229mm

Crop No. 6 (Fruits/Vegetable 5 %)

(Unit : mm/day)

Month		Jan.			Feb.			Mar.			Apr.			May			Jun.		
10 Days		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
		0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
		0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Area %		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ET (mm)		1.92	1.92	1.92	2.52	2.52	2.52	3.69	3.69	3.69	5.31	5.31	5.31	6.75	6.75	6.75	7.10	7.10	7.10
Req. (1)		1.44	1.44	1.44	1.89	1.89	1.89	2.77	2.77	2.77	3.98	3.98	3.98	5.06	5.06	5.06	5.33	5.33	5.33
Eff. rain	1.25	0.27	0.20	0.52	0.41	0.83	0.71	0.76	1.25	1.22	0.94	0.87	0.51	0.57	0.63	0.42	0.26	0.55	0.51
Req. (2)	0.00	0.06	0.06	0.05	0.07	0.05	0.06	0.10	0.08	0.08	0.15	0.16	0.17	0.22	0.22	0.23	0.25	0.24	0.24

Month	Jul.			Aug.			Sep.			Oct.			Nov.			Dec.		
10 Days	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Area %	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
ET (mm)	6.50	6.50	6.50	5.83	5.83	5.83	4.89	4.89	4.89	3.66	3.66	3.66	2.48	2.48	2.48	1.57	1.57	1.57
Req. (1)	4.88	4.88	4.88	4.37	4.37	4.37	3.67	3.67	3.67	2.75	2.75	2.75	1.86	1.86	1.86	1.18	1.18	1.18
Eff. rain	1.37	1.47	1.74	1.80	1.25	1.26	0.81	0.50	0.25	0.05	0.21	0.27	0.05	0.12	0.05	0.18	0.24	0.43
Req. (2)	0.18	0.17	0.16	0.13	0.16	0.16	0.14	0.16	0.17	0.13	0.13	0.12	0.09	0.09	0.09	0.05	0.05	0.04

954mm

Crop No. 7 (Wheat 45 %)

(Unit : mm/day)

Month		Oct.		Nov.			Dec.			Jan.			Feb.			Mar.			Apr.			May		
10 Days		2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
							0.35	0.41	0.57	0.79	0.99	1.07	1.10	1.10	1.10	1.10	1.10	1.07	1.00	0.79	0.56	0.32	0.00	0.00
						0.35	0.41	0.57	0.79	0.99	1.07	1.10	1.10	1.10	1.10	1.10	1.07	1.00	0.79	0.56	0.32	0.00	0.00	
					0.35	0.41	0.57	0.79	0.99	1.07	1.10	1.10	1.10	1.10	1.10	1.07	1.00	0.79	0.56	0.32	0.00	0.00		
				0.35	0.41	0.57	0.79	0.99	1.07	1.10	1.10	1.10	1.10	1.10	1.07	1.00	0.79	0.56	0.32	0.00	0.00			
			0.35	0.41	0.57	0.79	0.99	1.07	1.10	1.10	1.10	1.10	1.10	1.07	1.00	0.79	0.56	0.32	0.00	0.00				
		0.35	0.41	0.57	0.79	0.99	1.07	1.10	1.10	1.10	1.10	1.10	1.07	1.00	0.79	0.56	0.32	0.00	0.00					
		0.35	0.38	0.44	0.53	0.62	0.70	0.82	0.94	1.03	1.08	1.10	1.10	1.08	1.03	0.94	0.81	0.75	0.67	0.56	0.44	0.32	0.00	0.00
Area %		0.17	0.33	0.50	0.67	0.83	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.83	0.67	0.50	0.33	0.67	0.00	0.00
ET (mm)		3.66	3.66	2.48	2.48	2.48	1.57	1.57	1.57	1.92	1.92	1.92	2.52	2.52	2.52	3.69	3.69	3.69	5.31	5.31	5.31	6.75	6.75	6.75
Req. (1)		0.21	0.46	0.55	0.88	1.29	1.09	1.29	1.47	1.97	2.07	2.10	2.76	2.72	2.59	3.46	2.98	2.31	2.37	1.49	0.78	1.44	0.00	0.00
Soaking	0.83	0.83	0.76	0.83	0.83	0.83																		
Eff. rain	0.05	0.21	0.27	0.05	0.12	0.05	0.18	0.24	0.43	0.27	0.20	0.52	0.41	0.83	0.71	0.76	1.25	1.22	0.94	0.87	0.51	0.57	0.63	0.42
Req. (2)	0.35	0.38	0.43	0.60	0.72	0.93	0.41	0.47	0.47	0.76	0.84	0.71	1.06	0.85	0.84	1.21	0.78	0.49	0.64	0.28	0.12	0.00	0.00	0.00

297mm

Table C.1.5.2 Result of Water Requirement (3 of 4)

Crop No. 8 (Oil Seeds 10 %)

(Unit : mm/day)

Month		Sep.		Oct.			Nov.			Dec.			Jan.			Feb.			Mar.			Apr.		
10 Days		2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
							0.35	0.35	0.36	0.39	0.45	0.58	0.76	0.90	1.03	1.07	1.10	1.10	1.10	1.10	1.09	1.06	0.86	0.60
						0.35	0.35	0.36	0.39	0.45	0.58	0.76	0.90	1.03	1.07	1.10	1.10	1.10	1.10	1.09	1.06	0.86	0.60	
					0.35	0.35	0.36	0.39	0.45	0.58	0.76	0.90	1.03	1.07	1.10	1.10	1.10	1.10	1.09	1.06	0.86	0.60		
				0.35	0.35	0.36	0.39	0.45	0.58	0.76	0.90	1.03	1.07	1.10	1.10	1.10	1.10	1.09	1.06	0.86	0.60			
			0.35	0.35	0.36	0.39	0.45	0.58	0.76	0.90	1.03	1.07	1.10	1.10	1.10	1.10	1.09	1.06	0.86	0.60				
		0.35	0.35	0.36	0.39	0.45	0.58	0.76	0.90	1.03	1.07	1.10	1.10	1.10	1.10	1.09	1.06	0.86	0.60					
		0.35	0.35	0.35	0.36	0.38	0.41	0.48	0.57	0.69	0.80	0.91	0.99	1.05	1.08	1.09	1.09	1.05	0.97	0.94	0.90	0.84	0.73	0.60
Area %		0.17	0.33	0.50	0.67	0.83	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.83	0.67	0.50	0.33	0.17
ET (mm)		4.89	4.89	3.66	3.66	3.66	2.48	2.48	2.48	1.57	1.57	1.57	1.92	1.92	1.92	2.52	2.52	2.52	3.69	3.69	3.69	5.31	5.31	5.31
Req. (1)		0.29	0.57	0.65	0.88	1.16	1.03	1.19	1.42	1.08	1.25	1.42	1.91	2.02	2.08	2.76	2.75	2.65	3.57	2.90	2.22	2.23	1.29	0.53
Soaking	0.83	0.83	0.83	0.83	0.83	0.76																		
Eff. rain	0.81	0.50	0.25	0.05	0.21	0.27	0.05	0.12	0.05	0.18	0.24	0.43	0.27	0.20	0.52	0.41	0.83	0.71	0.76	1.25	1.22	0.94	0.87	0.51
Req. (2)	0.00	0.06	0.12	0.14	0.15	0.16	0.10	0.11	0.14	0.09	0.10	0.10	0.16	0.18	0.16	0.23	0.19	0.19	0.28	0.16	0.10	0.13	0.04	0.00

312mm

Crop No. 9 (Rabi Pulses 10 %)

(Unit : mm/day)

Month		Sep.		Oct.			Nov.			Dec.			Jan.			Feb.			Mar.			Apr.		
10 Days		2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
							0.35	0.35	0.37	0.42	0.53	0.66	0.80	0.93	1.05	1.08	1.10	1.10	1.10	1.10	1.10	1.10	0.99	0.85
						0.35	0.35	0.37	0.42	0.53	0.66	0.80	0.93	1.05	1.08	1.10	1.10	1.10	1.10	1.10	1.10	0.99	0.85	
					0.35	0.35	0.37	0.42	0.53	0.66	0.80	0.93	1.05	1.08	1.10	1.10	1.10	1.10	1.10	1.10	0.99	0.85		
				0.35	0.35	0.37	0.42	0.53	0.66	0.80	0.93	1.05	1.08	1.10	1.10	1.10	1.10	1.10	1.10	0.99	0.85			
			0.35	0.35	0.37	0.42	0.53	0.66	0.80	0.93	1.05	1.08	1.10	1.10	1.10	1.10	1.10	1.10	0.99	0.85				
		0.35	0.35	0.37	0.42	0.53	0.66	0.80	0.93	1.05	1.08	1.10	1.10	1.10	1.10	1.10	1.10	0.99	0.85					
		0.35	0.35	0.36	0.37	0.40	0.45	0.52	0.62	0.73	0.84	0.94	1.01	1.06	1.09	1.10	1.10	1.08	1.04	1.03	1.01	0.98	0.92	0.85
Area %		0.17	0.33	0.50	0.67	0.83	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.83	0.67	0.50	0.33	0.17
ET (mm)		4.89	4.89	3.66	3.66	3.66	2.48	2.48	2.48	1.57	1.57	1.57	1.92	1.92	1.92	2.52	2.52	2.52	3.69	3.69	3.69	5.31	5.31	5.31
Req. (1)		0.29	0.57	0.65	0.91	1.23	1.11	1.29	1.53	1.15	1.32	1.47	1.94	2.04	2.09	2.76	2.77	2.73	3.84	3.16	2.48	2.60	1.63	0.75
Soaking	0.83	0.83	0.83	0.83	0.83	0.76																		
Eff. rain	0.81	0.50	0.25	0.05	0.21	0.27	0.05	0.12	0.05	0.18	0.24	0.43	0.27	0.20	0.52	0.41	0.83	0.71	0.76	1.25	1.22	0.94	0.87	0.51
Req. (2)	0.00	0.06	0.12	0.14	0.15	0.17	0.11	0.12	0.15	0.10	0.11	0.10	0.17	0.18	0.16	0.24	0.19	0.20	0.31	0.19	0.13	0.17	0.08	0.02

337mm

Crop No. 10 (Rabi Fodder 10 %)

(Unit : mm/day)

Month		Sep.		Oct.			Nov.			Dec.			Jan.			Feb.			Mar.			Apr.		
10 Days		2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
							0.76	1.00	0.95	0.95	0.95	0.95	0.95	0.95	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
						0.76	1.00	0.95	0.95	0.95	0.95	0.95	0.95	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
					0.76	1.00	0.95	0.95	0.95	0.95	0.95	0.95	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
				0.76	1.00	0.95	0.95	0.95	0.95	0.95	0.95	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00			
			0.76	1.00	0.95	0.95	0.95	0.95	0.95	0.95	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00				
		0.76	1.00	0.95	0.95	0.95	0.95	0.95	0.95	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00					
		0.76	0.88	0.90	0.92	0.92	0.93	0.96	0.95	0.91	0.90	0.89	0.87	0.84	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area %		0.17	0.33	0.50	0.67	0.83	1.00	1.00	1.00	1.00	0.83	0.67	0.50	0.33	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ET (mm)		4.89	4.89	3.66	3.66	3.66	2.48	2.48	2.48	1.57	1.57	1.57	1.92	1.92	1.92	2.52	2.52	2.52	3.69	3.69	3.69	5.31	5.31	5.31
Req. (1)		0.62	1.43	1.65	2.23	2.81	2.30	2.38	2.36	1.43	1.18	0.93	0.84	0.54	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Soaking	0.83	0.83	0.83	0.83	0.83	0.76																		
Eff. rain	0.81	0.50	0.25	0.05	0.21	0.27	0.05	0.12	0.05	0.18	0.24	0.43	0.27	0.20	0.52	0.41	0.83	0.71	0.76	1.25	1.22	0.94	0.87	0.51
Req. (2)	0.00	0.10	0.20	0.24	0.29	0.33	0.22	0.23	0.23	0.13	0.09	0.05	0.06	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

224mm

Crop No. 11 (Oilseeds 5 %)

(Unit : mm/day)

Month		Feb.		Mar.			Apr.			May			Jun.
10 Days		2	3	1	2	3	1	2	3	1	2	3	1
					0.35	0.42	0.66	0.93	1.08	1.10	1.10	1.10	0.85
				0.35	0.42	0.66	0.93	1.08	1.10	1.10	1.10	0.85	
			0.35	0.42	0.66	0.93	1.08	1.10	1.10	1.10	0.85		
		0.35	0.42	0.66	0.93	1.08	1.10	1.10	1.10	0.85			
		0.35	0.39	0.48	0.59	0.77	0.94	1.05	1.10	1.04	1.02	0.98	0.85
Area %		0.25	0.50	0.75	1.00	1.00	1.00	1.00	1.00	1.00	0.75	0.50	0.25
ET (mm)		2.52	2.52	3.69	3.69	3.69	5.31	5.31	5.31	6.75	6.75	6.75	7.10
Req. (1)		0.22	0.49	1.32	2.18	2.85	5.00	5.59	5.81	7.00	5.15	3.29	1.51
Soaking	1.25	1.25	1.56	1.25									
Eff. rain	0.41	0.83	0.71	0.76	1.25	1.22	0.94	0.87	0.51	0.57	0.63	0.42	0.26
Req. (2)	0.04	0.03	0.07	0.09	0.05	0.08	0.20	0.24	0.27	0.32	0.23	0.14	0.06

365mm

Table C.1.5.2 Result of Water Requirement (4 of 4)

Crop No. 12 (Spring Maize 5 %)

(Unit : mm/day)

Month		Feb.			Mar.			Apr.			May		Jun.
10 Days		2	3	1	2	3	1	2	3	1	2	3	1
					0.36	0.45	0.74	1.01	1.10	1.10	1.10	0.98	0.57
				0.36	0.45	0.74	1.01	1.10	1.10	1.10	0.98	0.57	
			0.36	0.45	0.74	1.01	1.10	1.10	1.10	0.98	0.57		
		0.36	0.45	0.74	1.01	1.10	1.10	1.10	0.98	0.57			
		0.36	0.41	0.52	0.64	0.83	0.99	1.08	1.07	0.94	0.88	0.78	0.57
Area %		0.25	0.50	0.75	1.00	1.00	1.00	1.00	1.00	1.00	0.75	0.50	0.25
ET (mm)		2.52	2.52	3.69	3.69	3.69	5.31	5.31	5.31	6.75	6.75	6.75	7.10
Req. (1)		0.23	0.51	1.43	2.36	3.04	5.24	5.72	5.68	6.33	4.47	2.62	1.01
Soaking	1.25	1.25	1.56	1.25									
Eff. rain	0.41	0.83	0.71	0.76	1.25	1.22	0.94	0.87	0.51	0.57	0.63	0.42	0.26
Req. (2)	0.04	0.03	0.07	0.10	0.06	0.09	0.22	0.24	0.26	0.29	0.19	0.11	0.04
												347mm	

Table C.1.5.3 Result of Water Requirement : (per 1,000ha of ordinary land) (1 of 2)

SUMMARY TABLE : (Unit : m3/s)

Month	10 Days	Kharif						Rabi						Total
		Cotton 100ha	Pulses 50ha	Maize 200ha	Fodder 100ha	Sugarcane 100ha	Fruits 50 ha	Wheat 450 ha	Oil Seeds 100ha	Pluses 100ha	Fodder 100 ha	Oilseeds 50ha	Maize 50ha	
Jan.	1					0.022	0.012	0.152	0.033	0.033	0.011			0.264
	2					0.024	0.012	0.168	0.036	0.037	0.007			0.283
	3					0.017	0.009	0.142	0.031	0.031	0.000			0.231
Feb.	1					0.027	0.015	0.211	0.047	0.047	0.000	0.008	0.008	0.363
	2					0.017	0.011	0.169	0.038	0.039	0.000	0.006	0.006	0.287
	3					0.017	0.012	0.169	0.039	0.040	0.000	0.013	0.014	0.303
Mar.	1					0.028	0.020	0.242	0.056	0.061	0.000	0.018	0.019	0.444
	2					0.017	0.015	0.155	0.033	0.038	0.000	0.009	0.011	0.279
	3					0.018	0.015	0.098	0.020	0.025	0.000	0.016	0.018	0.211
Apr.	1					0.043	0.030	0.129	0.026	0.033	0.000	0.041	0.043	0.344
	2					0.045	0.031	0.055	0.008	0.015	0.000	0.047	0.048	0.251
	3					0.060	0.035	0.024	0.000	0.005	0.000	0.053	0.052	0.228
May	1	0.005				0.087	0.045	0.000				0.064	0.057	0.259
	2	0.012				0.094	0.044	0.000				0.045	0.038	0.233
	3	0.023			0.007	0.107	0.046	0.000				0.029	0.022	0.234
Jun.	1	0.039	0.006	0.023	0.030	0.125	0.051					0.012	0.008	0.293
	2	0.047	0.007	0.028	0.047	0.128	0.048							0.304
	3	0.066	0.012	0.047	0.070	0.137	0.048							0.380
Jul.	1	0.048	0.008	0.032	0.068	0.111	0.035							0.302
	2	0.061	0.014	0.060	0.087	0.113	0.034							0.369
	3	0.072	0.020	0.088	0.085	0.112	0.031							0.408
Aug.	1	0.073	0.019	0.083	0.071	0.098	0.026							0.370
	2	0.094	0.031	0.134	0.063	0.109	0.031							0.463
	3	0.101	0.038	0.162	0.045	0.109	0.031							0.486
Sep.	1	0.092	0.040	0.165	0.027	0.096	0.029		0.000	0.000	0.000			0.449
	2	0.099	0.046	0.188	0.018	0.102	0.032		0.012	0.012	0.019			0.529
	3	0.103	0.050	0.195	0.007	0.107	0.034		0.023	0.023	0.040			0.583
Oct.	1	0.078	0.038	0.125	0.000	0.083	0.027	0.070	0.029	0.029	0.049			0.527
	2	0.071	0.030	0.092	0.000	0.079	0.025	0.075	0.030	0.031	0.057			0.490
	3	0.065	0.022	0.063	0.000	0.074	0.025	0.086	0.033	0.034	0.066			0.468
Nov.	1	0.037	0.012	0.030		0.050	0.018	0.120	0.019	0.021	0.045			0.353
	2	0.027	0.007	0.009		0.047	0.017	0.143	0.021	0.023	0.045			0.339
	3	0.020	0.003			0.046	0.018	0.186	0.027	0.030	0.046			0.375
Dec.	1	0.005				0.024	0.010	0.082	0.018	0.019	0.025			0.183
	2	0.000				0.021	0.009	0.094	0.020	0.022	0.019			0.185
	3					0.016	0.007	0.093	0.020	0.021	0.010			0.167

Irrigation efficiency of 58% is applyed.

Table C.1.5.3 Result of Water Requirement : (per 1,000ha of sandy land) (2 of 2)

SUMMARY TABLE :

(Unit : m3/s)

Month	10 Days	Cotton 100ha	Pulses 50ha	Kharif Maize 200ha	Fodder 100ha	Sugarcane 100ha	Fruits 50 ha	Wheat 450 ha	Oil Seeds 100ha	Pluses 100ha	Rabi Fodder 100 ha	Oilseeds 50ha	Maize 50ha	Total
Jan.	1					0.043	0.023	0.295	0.063	0.064	0.022			0.510
	2					0.046	0.024	0.324	0.070	0.071	0.013			0.548
	3					0.033	0.018	0.275	0.060	0.061	0.000			0.446
Feb.	1					0.052	0.029	0.408	0.090	0.091	0.000	0.016	0.016	0.702
	2					0.032	0.020	0.328	0.074	0.075	0.000	0.012	0.012	0.554
	3					0.033	0.023	0.326	0.075	0.078	0.000	0.026	0.026	0.586
Mar.	1					0.053	0.039	0.468	0.109	0.119	0.000	0.035	0.037	0.859
	2					0.033	0.029	0.300	0.064	0.074	0.000	0.018	0.021	0.539
	3					0.036	0.030	0.189	0.039	0.049	0.000	0.031	0.035	0.408
Apr.	1					0.083	0.059	0.249	0.050	0.064	0.000	0.078	0.083	0.665
	2					0.087	0.060	0.107	0.016	0.029	0.000	0.091	0.094	0.485
	3					0.116	0.067	0.047	0.001	0.009	0.000	0.102	0.100	0.441
May	1	0.010				0.168	0.087	0.000				0.124	0.111	0.500
	2	0.023				0.181	0.086	0.000				0.087	0.074	0.451
	3	0.044			0.013	0.208	0.090	0.000				0.055	0.042	0.453
Jun.	1	0.075	0.011	0.044	0.058	0.242	0.098					0.024	0.015	0.566
	2	0.091	0.013	0.054	0.091	0.247	0.092							0.588
	3	0.128	0.023	0.090	0.136	0.265	0.093							0.735
Jul.	1	0.092	0.015	0.062	0.132	0.215	0.068							0.584
	2	0.119	0.027	0.116	0.168	0.219	0.066							0.714
	3	0.139	0.038	0.169	0.165	0.216	0.060							0.788
Aug.	1	0.141	0.036	0.161	0.138	0.189	0.050							0.715
	2	0.182	0.061	0.260	0.122	0.210	0.060							0.896
	3	0.195	0.074	0.314	0.088	0.210	0.060							0.940
Sep.	1	0.178	0.077	0.319	0.053	0.186	0.055		0.000	0.000	0.000			0.869
	2	0.191	0.090	0.364	0.035	0.198	0.061		0.024	0.024	0.037			1.023
	3	0.199	0.097	0.377	0.014	0.207	0.066		0.044	0.044	0.078			1.127
Oct.	1	0.150	0.073	0.242	0.000	0.160	0.052	0.136	0.055	0.055	0.094			1.018
	2	0.137	0.057	0.178	0.000	0.153	0.049	0.145	0.058	0.059	0.110			0.947
	3	0.125	0.043	0.122	0.000	0.143	0.048	0.166	0.064	0.066	0.127			0.904
Nov.	1	0.072	0.023	0.058		0.098	0.035	0.231	0.038	0.041	0.087			0.682
	2	0.052	0.013	0.018		0.090	0.034	0.276	0.041	0.045	0.087			0.656
	3	0.038	0.006			0.088	0.035	0.359	0.053	0.057	0.089			0.725
Dec.	1	0.009				0.046	0.019	0.159	0.035	0.037	0.048			0.353
	2	0.000				0.041	0.018	0.182	0.039	0.042	0.036			0.358
	3					0.030	0.014	0.181	0.038	0.040	0.019			0.323

Irrigation efficiency of 30% is applyed.

Table C.1.5.4 Total Water Requirement of the Project

Month	10 Days	Ordinary Land	Sandy Land	Total (m3/sec)	Total (MCM)
Jan.	1	28.639	3.547	32.186	27.81
	2	30.771	3.811	34.582	29.88
	3	25.089	3.108	28.197	26.80
Feb.	1	39.468	4.888	44.356	38.32
	2	31.139	3.857	34.995	30.24
	3	32.939	4.080	37.018	25.59
Mar.	1	48.286	5.981	54.266	46.89
	2	30.262	3.748	34.010	29.38
	3	22.924	2.839	25.764	24.49
Apr.	1	37.376	4.629	42.006	36.29
	2	27.230	3.373	30.603	26.44
	3	24.805	3.072	27.877	24.09
May	1	28.095	3.480	31.575	27.28
	2	25.347	3.139	28.487	24.61
	3	25.429	3.150	28.578	27.16
Jun.	1	31.819	3.941	35.761	30.90
	2	33.023	4.090	37.114	32.07
	3	41.278	5.113	46.391	40.08
Jul.	1	32.795	4.062	36.857	31.84
	2	40.114	4.968	45.083	38.95
	3	44.299	5.487	49.786	47.32
Aug.	1	40.182	4.977	45.159	39.02
	2	50.327	6.233	56.561	48.87
	3	52.841	6.545	59.386	56.44
Sep.	1	48.809	6.045	54.855	47.39
	2	57.460	7.117	64.577	55.79
	3	63.328	7.844	71.171	61.49
Oct.	1	57.224	7.088	64.312	55.57
	2	53.205	6.590	59.795	51.66
	3	50.817	6.294	57.111	54.28
Nov.	1	38.300	4.744	43.044	37.19
	2	36.864	4.566	41.429	35.80
	3	40.729	5.045	45.774	39.55
Dec.	1	19.844	2.458	22.302	19.27
	2	20.139	2.494	22.633	19.55
	3	18.147	2.248	20.395	19.38
					1,307.7

Table C.2.4.1 (1) Routine Study of Budh Nullah (40 years return period)

hour	Discharge (m3/s)	Drainage (m3/s)	Water stage (m)	Water volume (m3)	Inundated area (ha)
0	1.00	1.00	202.20	27,574	7.90
1	1.00	1.00	202.20	27,575	7.90
2	1.00	1.00	202.20	27,575	7.90
3	4.97	4.34	202.24	34,391	9.60
4	71.61	71.58	202.64	88,133	24.60
5	214.06	184.60	203.05	287,013	56.80
6	426.41	318.32	203.43	887,867	125.70
7	626.12	507.39	203.89	1,606,860	208.30
8	721.46	648.57	204.19	2,082,210	263.20
9	702.09	660.30	204.22	2,252,940	275.80
10	604.33	646.60	204.19	2,066,200	262.50
11	484.78	540.33	203.96	1,710,840	221.50
12	369.47	433.43	203.72	1,323,780	177.50
13	285.28	343.87	203.50	979,823	137.70
14	221.95	274.18	203.31	687,213	104.30
15	170.53	217.18	203.15	432,628	74.80
16	130.86	172.19	203.01	213,921	49.60
17	97.65	103.01	202.76	119,526	31.60
18	75.47	75.87	202.65	89,688	25.30
19	59.14	59.00	202.58	79,831	22.40
20	47.45	47.47	202.52	72,124	20.30
21	37.07	36.97	202.47	64,735	18.30
22	26.70	26.96	202.41	56,590	16.10
23	21.74	21.61	202.38	52,325	14.90
24	16.94	17.04	202.35	47,999	13.70
25	12.69	12.89	202.32	43,711	12.50
26	10.26	10.19	202.30	40,966	11.70
27	7.89	8.08	202.28	38,230	11.00
28	5.96	6.12	202.26	35,765	10.30
29	4.63	4.84	202.25	33,831	9.80
30	3.31	3.46	202.23	31,878	9.30
31	2.92	3.04	202.23	31,053	9.10
32	2.92	2.84	202.22	31,193	9.00
33	2.87	2.84	202.22	31,294	9.00
34	2.87	2.84	202.22	31,395	9.00
35	2.87	2.84	202.22	31,496	9.00
36	2.87	2.84	202.22	31,597	9.00
37	2.87	2.84	202.22	31,698	9.00
38	2.81	2.84	202.22	31,585	9.00
39	2.81	2.84	202.22	31,470	9.00
40	2.81	2.84	202.22	31,355	9.00
41	2.81	2.84	202.22	31,240	9.00
42	2.81	2.84	202.22	31,125	9.00
43	2.76	2.84	202.22	30,832	9.00
44	2.76	2.65	202.22	30,731	8.90
45	2.76	2.65	202.22	31,136	8.90
46	2.76	2.65	202.22	31,546	8.90
47	2.70	2.84	202.22	31,407	9.00
48	2.70	2.84	202.22	30,901	9.00
49	2.70	2.65	202.22	30,704	8.90
50	2.70	2.65	202.22	30,898	8.90

Table C.2.4.1 (2) Routine Study of Budh Nullah (100 years return period)

hour	Discharge (m3/s)	Drainage (m3/s)	Water stage (m)	Water volume (m3)	Inundated area (ha)
0	1.00	1.00	202.20	27,574	7.90
1	1.00	1.00	202.20	27,575	7.90
2	1.00	1.00	202.20	27,575	7.90
3	5.96	5.47	202.25	35,751	10.10
4	86.00	85.66	202.70	96,440	26.80
5	257.06	205.77	203.11	391,217	68.60
6	512.07	380.76	203.59	1,138,910	154.50
7	751.90	617.70	204.13	1,983,480	251.60
8	866.39	688.82	204.28	2,705,770	314.10
9	843.13	720.82	204.34	3,202,300	356.40
10	725.73	722.07	204.34	3,220,680	358.00
11	582.16	696.76	204.29	2,763,280	324.60
12	443.69	615.07	204.12	1,963,290	250.60
13	342.59	441.08	203.73	1,353,900	180.70
14	266.53	335.40	203.47	946,948	133.80
15	204.79	260.93	203.27	631,237	97.60
16	157.15	205.25	203.11	373,622	68.30
17	117.27	137.79	202.89	167,293	40.70
18	90.63	94.71	202.73	106,575	29.20
19	71.02	71.05	202.63	87,124	24.50
20	56.98	56.88	202.57	78,464	22.00
21	44.52	44.64	202.51	70,059	19.80
22	32.07	32.09	202.44	60,970	17.20
23	26.10	26.28	202.41	56,065	16.00
24	20.34	20.52	202.37	51,108	14.60
25	15.24	15.33	202.34	46,347	13.20
26	12.32	12.47	202.32	43,290	12.40
27	9.47	9.52	202.29	40,160	11.50
28	7.16	7.41	202.27	37,292	10.80
29	5.57	5.77	202.26	35,181	10.20
30	3.98	4.08	202.24	32,944	9.50
31	3.51	3.64	202.23	32,039	9.30
32	3.51	3.42	202.23	32,198	9.20
33	3.45	3.42	202.23	32,293	9.20
34	3.45	3.42	202.23	32,387	9.20
35	3.45	3.42	202.23	32,481	9.20
36	3.45	3.42	202.23	32,575	9.20
37	3.45	3.42	202.23	32,669	9.20
38	3.38	3.42	202.23	32,513	9.20
39	3.38	3.42	202.23	32,355	9.20
40	3.38	3.42	202.23	32,197	9.20
41	3.38	3.42	202.23	32,038	9.20
42	3.38	3.42	202.23	31,880	9.20
43	3.31	3.22	202.23	31,715	9.10
44	3.31	3.22	202.23	32,049	9.10
45	3.31	3.22	202.23	32,386	9.10
46	3.31	3.42	202.23	32,519	9.20
47	3.25	3.42	202.23	31,900	9.20
48	3.25	3.22	202.23	31,670	9.10
49	3.25	3.22	202.23	31,794	9.10
50	3.25	3.22	202.23	31,921	9.10

Table C.2.5.1 Design Discharge at Proposed Cross Drainage Structures

No of Cross Drainage	Name of Crossed River	Q1 (Discharge at upper mesured point)	Q2 (Discharge at CRB Canal)	L1 (Dist.between points of Q1 and CRBC:km)	L2 (Dist.between points of Q1 and Lift canal:km)	Catchment Area (km2)	Pattern of Run-off for Plain area *	q (Discharge from Plain Area:(cfs))	Q2' (=Q2-q)	a (=-1/L1xLn(Q2'/Q1))	Q (=Q1exp(-aL2))	Proposed Design Discharge (cfs)	Proposed Design Discharge (cms)
1	Paniala River	-	12,500	-	-	64.5	B	1,685	10,815	0.000	10,815	10,800	306
2	Hauz Khud	52,000	28,000	23.2	11.0	109.3	B	2,856	25,144	0.031	36,975	37,000	1,048
3	Takwara N.	54,600	21,600	68.5	47.6	147.0	B	3,841	17,759	0.016	25,494	25,500	722
4	Gomal diversion	5,000	5,000	-	-	57.6	B	1,505	5,000	0.000	5,000	5,000	142
5	Gomal N.	21,000	18,500	23.0	10.7	97.3	-	-	18,500	0.006	19,691	19,700	558
6	Luni Nouth (1)	7,000	7,000	-	-	77.5	-	-	7,000	0.000	7,000	7,000	198
7	Luni Nouth (2)	2,500	2,500	-	-	29.8	-	-	2,500	0.000	2,500	2,500	71
8	Luni Nouth (3)	5,500	5,500	-	-	82.4	-	-	5,500	0.000	5,500	5,500	156
9	Luni South (1)	32,200	32,200	-	-	117.2	-	-	32,200	0.000	32,200	32,200	912
10	Luni South (2)	24,900	12,200	16.0	6.0	59.6	-	-	12,200	0.045	19,008	19,000	538
11	Toa N.	17,800	17,800	-	-	21.9	B	572	17,228	0.000	17,228	17,200	487
12	Daraban Zam	35,800	35,800	-	-	49.7	B	1,299	34,501	0.000	34,501	34,500	977
13	Chaudwan Zam	60,200	41,200	11.6	7.9	99.3	B	2,594	38,606	0.040	43,889	43,900	1,243
14	Khad Waraki	4,850	4,850	-	-	29.8	A	1,957	2,893	0.000	2,893	2,900	82
15	Kaura Khad	8,820	8,820	-	-	19.9	A	1,307	7,513	0.000	7,513	7,500	212
16	Velheri N.	8,520	5,960	34.0	23.6	64.6	A	1,200	4,760	0.017	5,704	5,700	161
17	Gajistan N.	13,220	15,000	-	-	69.5	A	4,565	10,435	0.000	10,435	10,400	295
18	Sherana N.	14,460	14,460	-	-	34.8	A	2,286	14,460	0.000	14,460	14,500	411
19	Ramak diversion	8,000	2,540	19.2	14.6	24.8	A	1,629	911	0.113	1,540	1,500	42
20	Ramak N.	24,000	19,000	20.4	13.8	59.5	A	3,908	15,092	0.023	17,473	17,500	496

* : Specific discharge of plain area of pattern A, B are applied at 1.86 m3/s/km2 and 0.74 m3/s/km2, respectively.

FIGURES

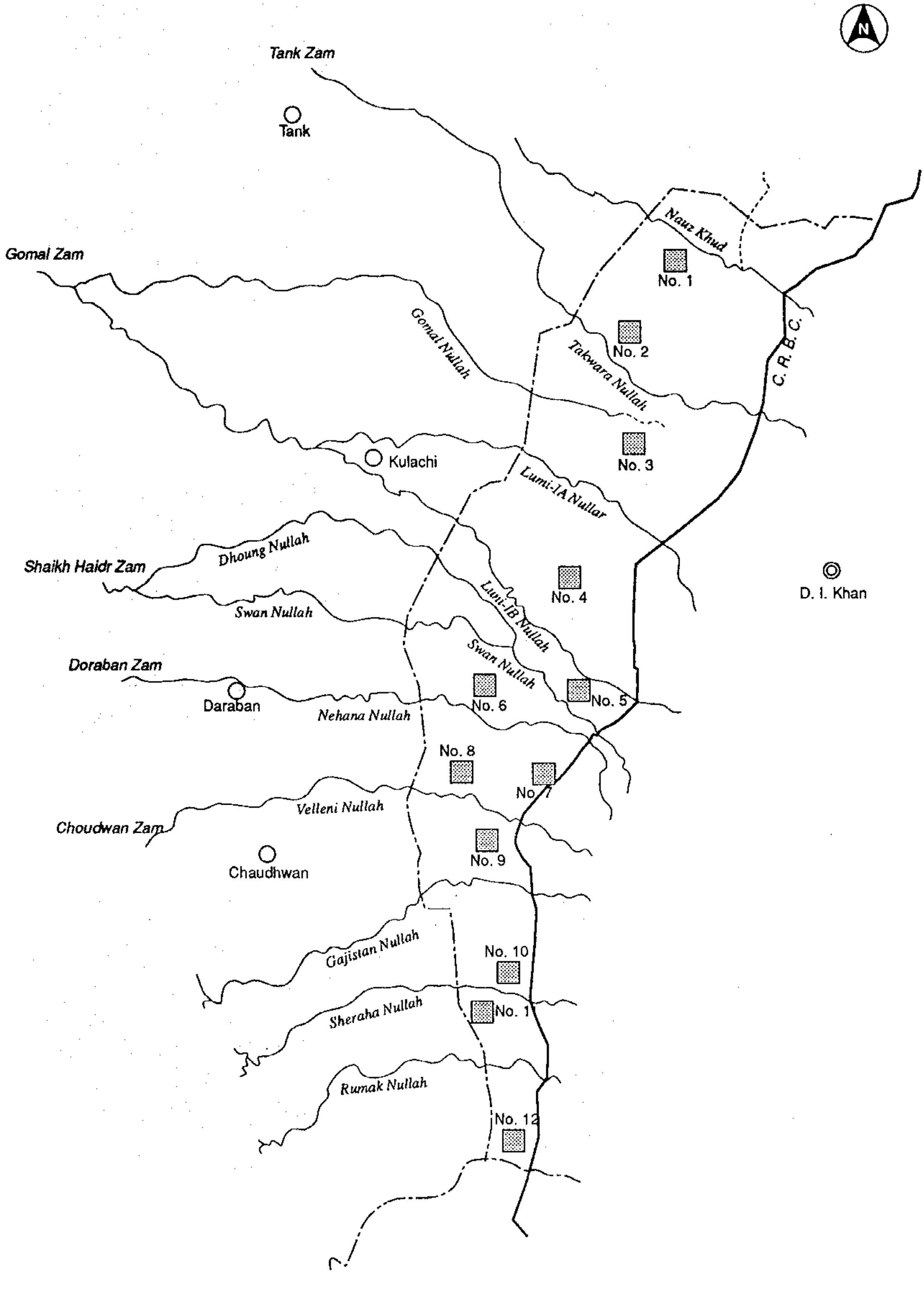


Fig. C.1.1.1 Location of Sample Areas for Farm Size Measurement

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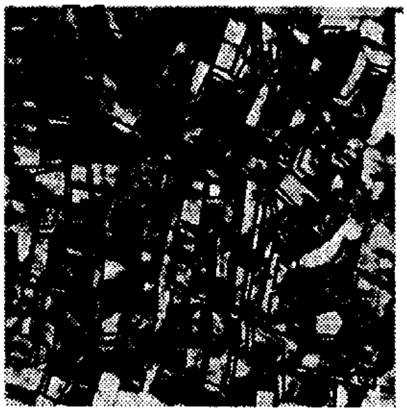

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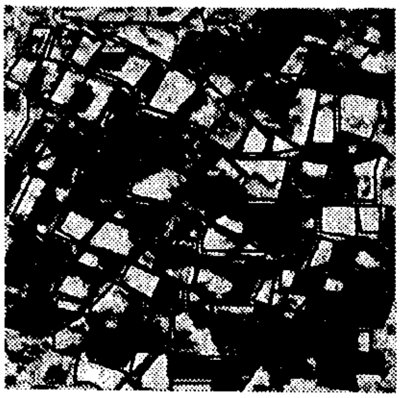

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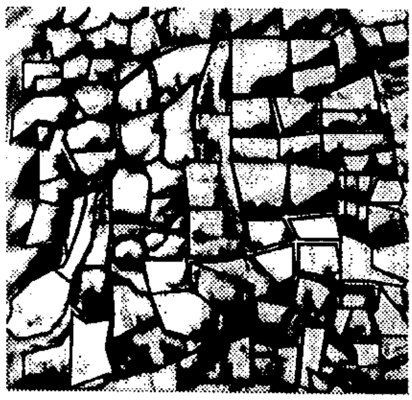

Fig. C.1.1.2 (1) Sampling Area for Farm Size Measurement

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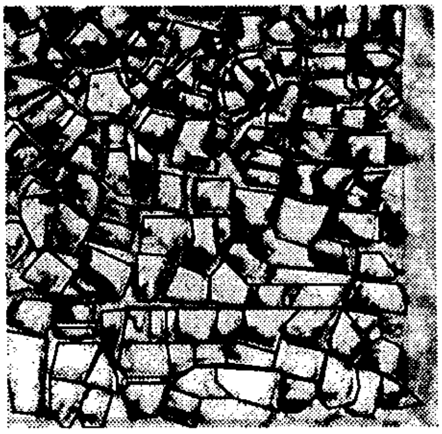

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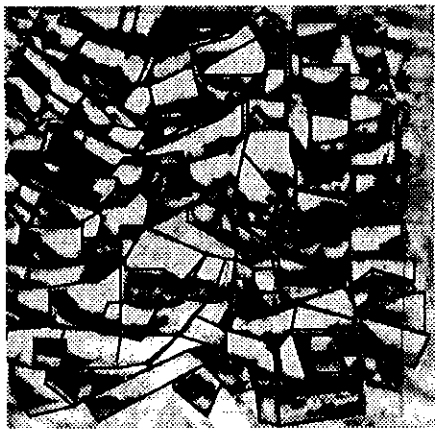

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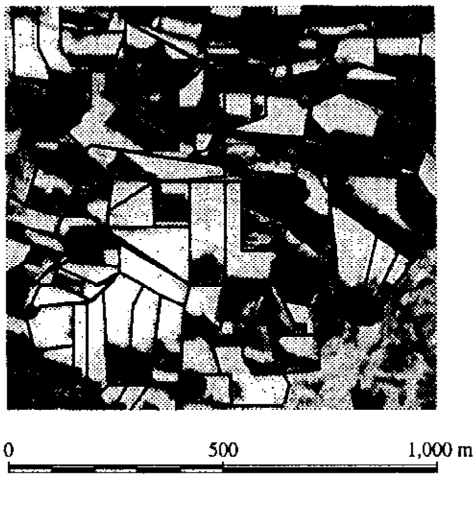
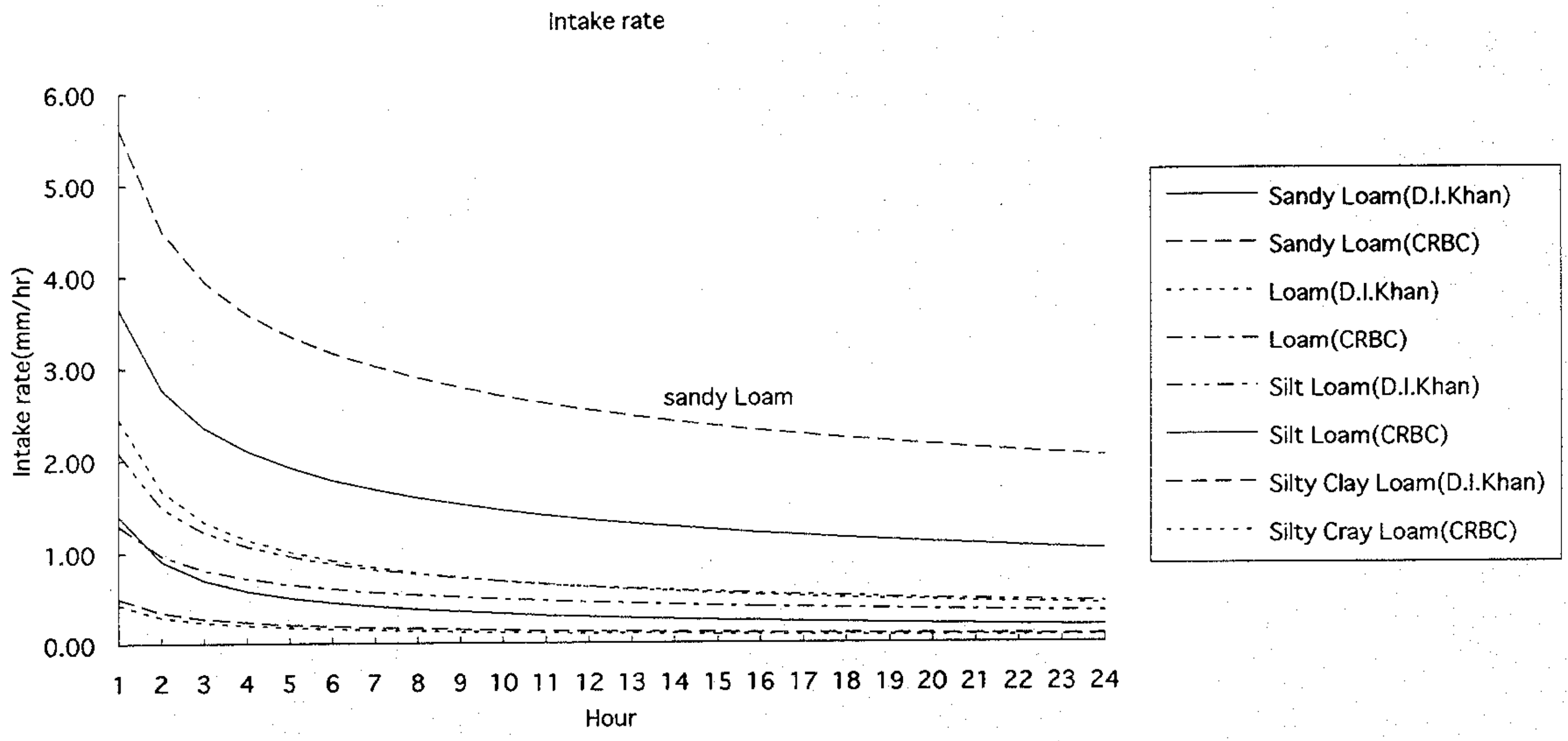


Fig. C.1.1.2 (2) Sampling Area for Farm Size Measurement



Source: Sub-soil Irrigation, CRBC Soil & Concrete Labs., 1988-1989

Fig. C.1.3.1 Typical Intake Rate Curve in D. I. Khan

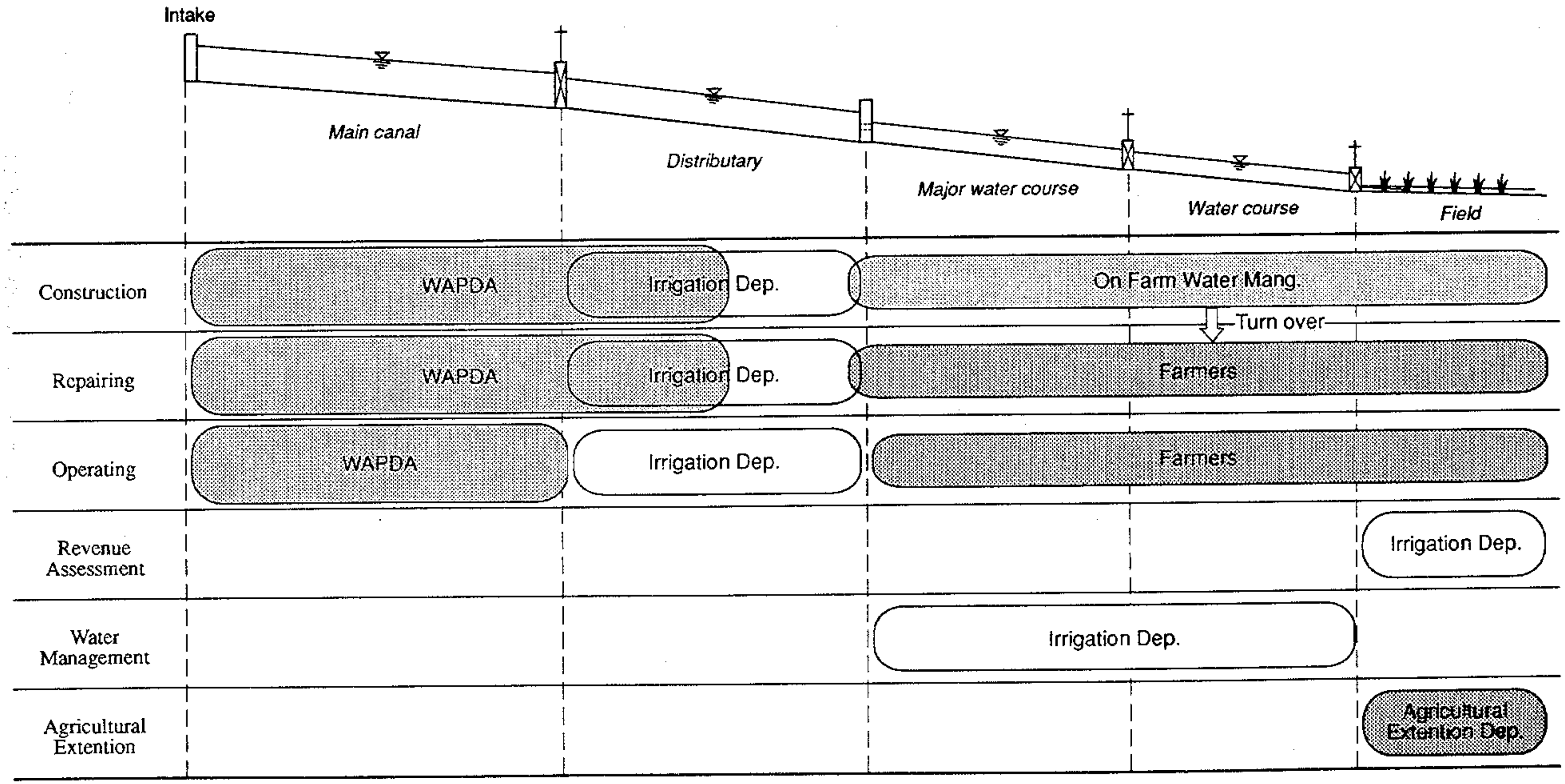


Fig. C.1.5.1 Complicated Performance of Each Agency on O & M in CRBC

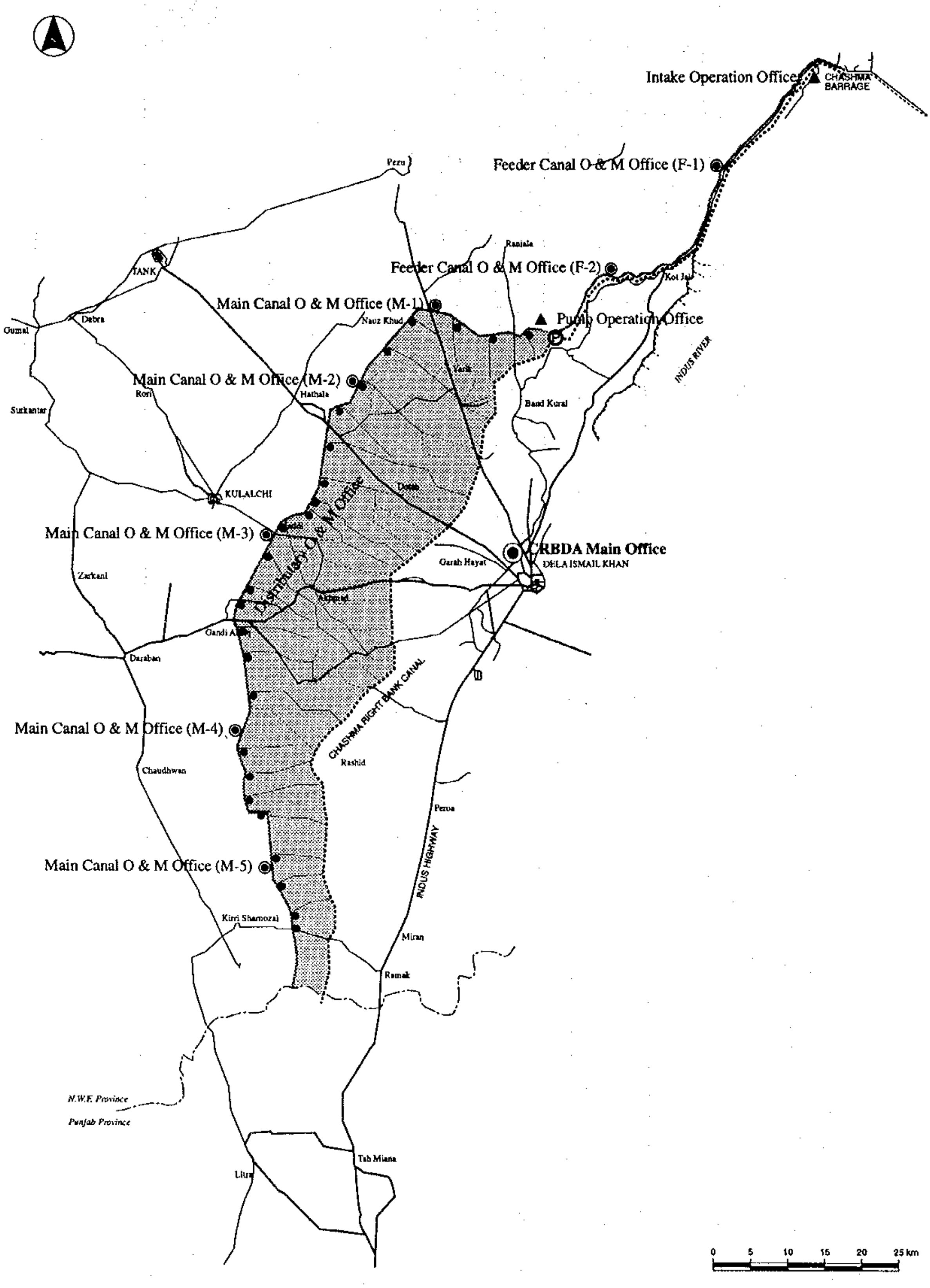


Fig. C.1.5.2 Proposed Organization for O&M

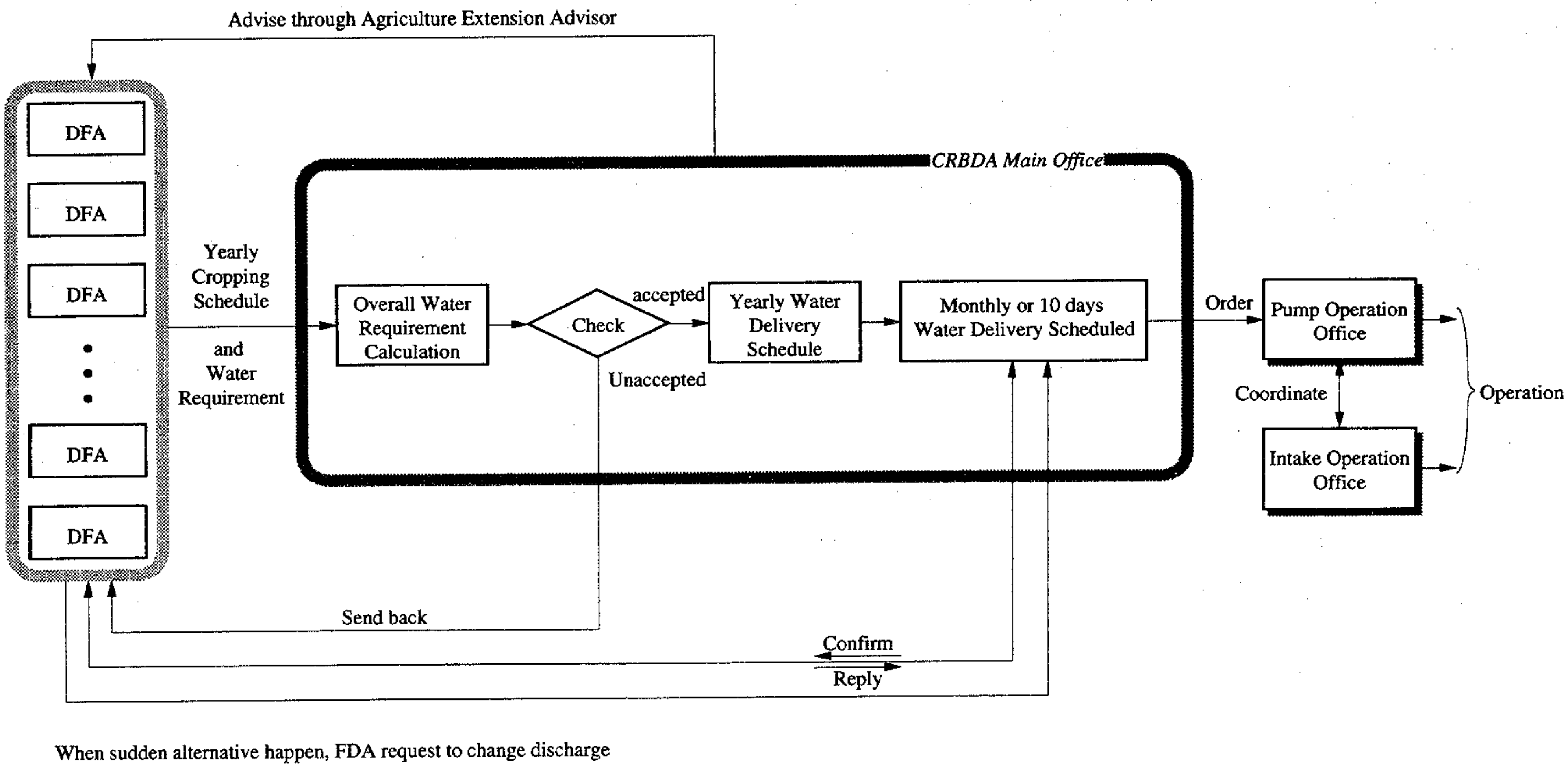


Fig. C.1.6.1 Flow on Confirmation of Water Delivery Schedule

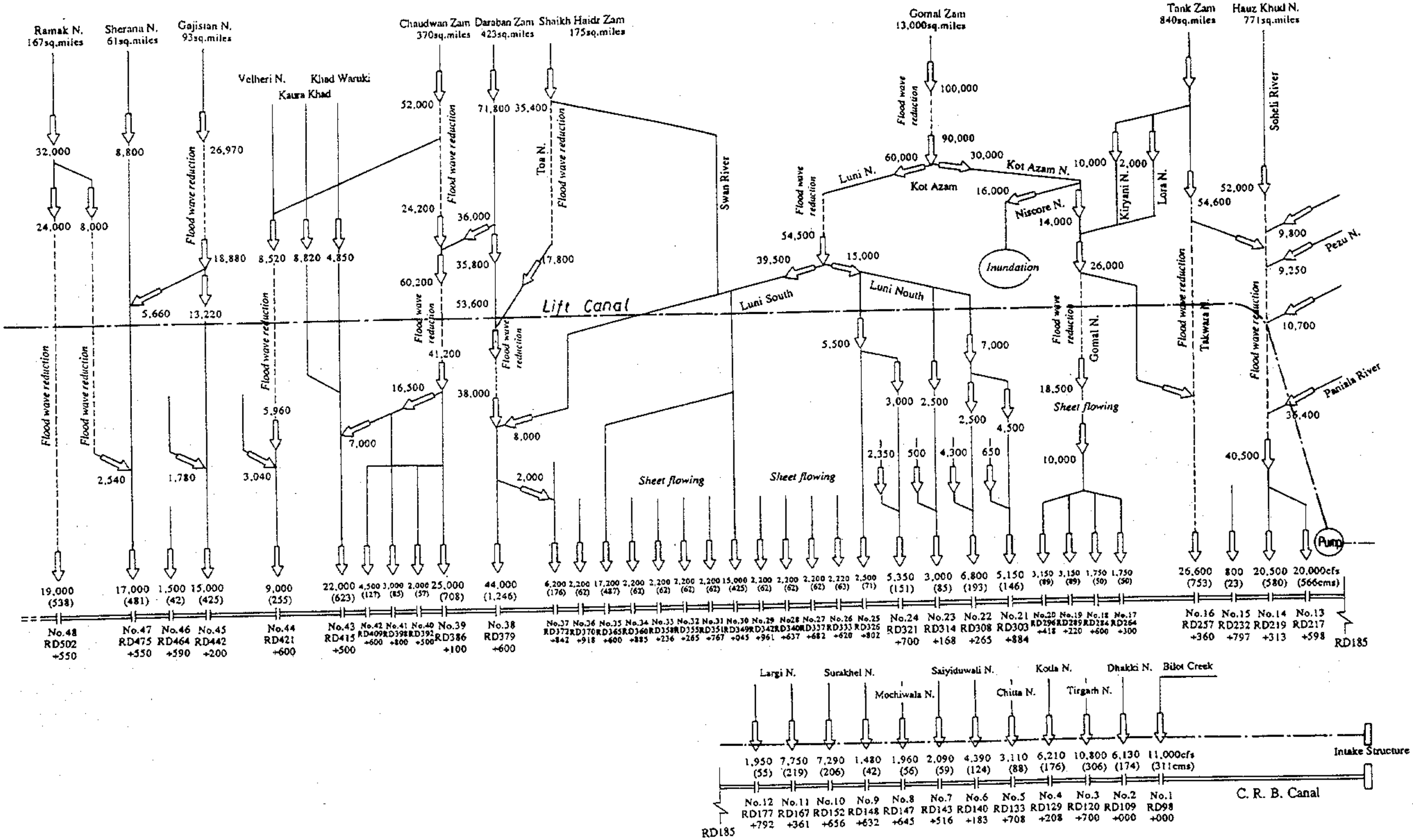
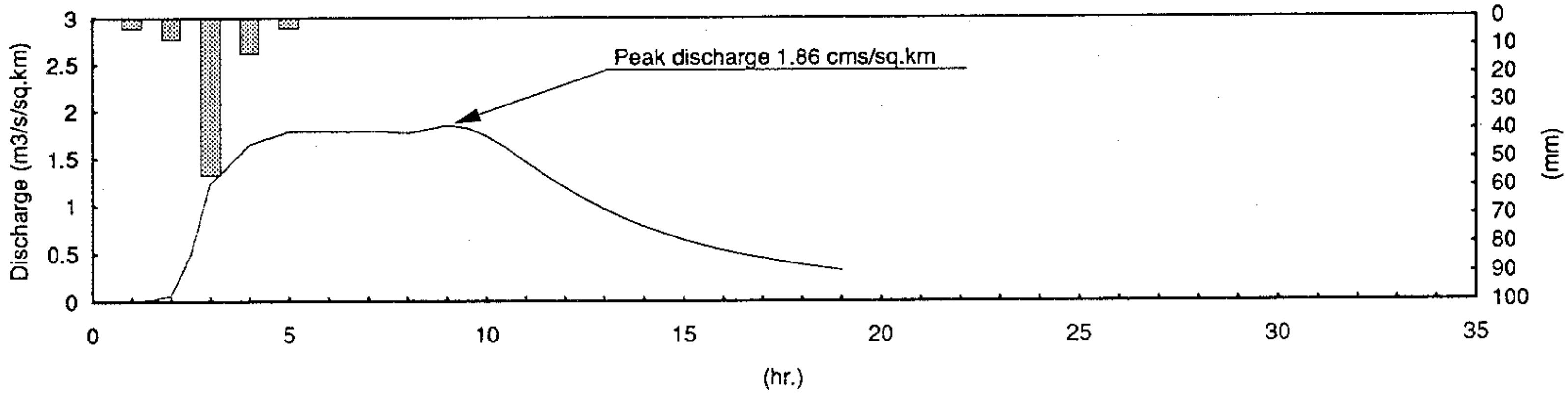
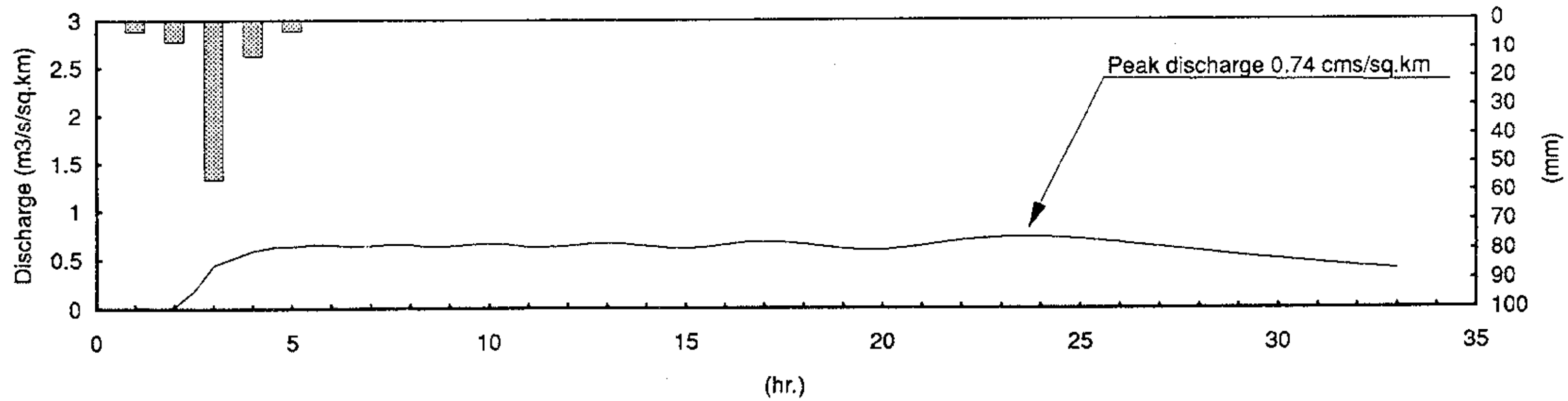


Fig. C.2.1.1 Schematic Diagram of Present River System



Case 1: for steep plain with slope of 1/400 having slope length of 8,000 m



Case 2: for flat plain with slope of 1/850 having slope length of 17,500 m

Fig. C.2.2.1 Estimated Run-off Discharge from Plain Area by Kinematic Wave Method

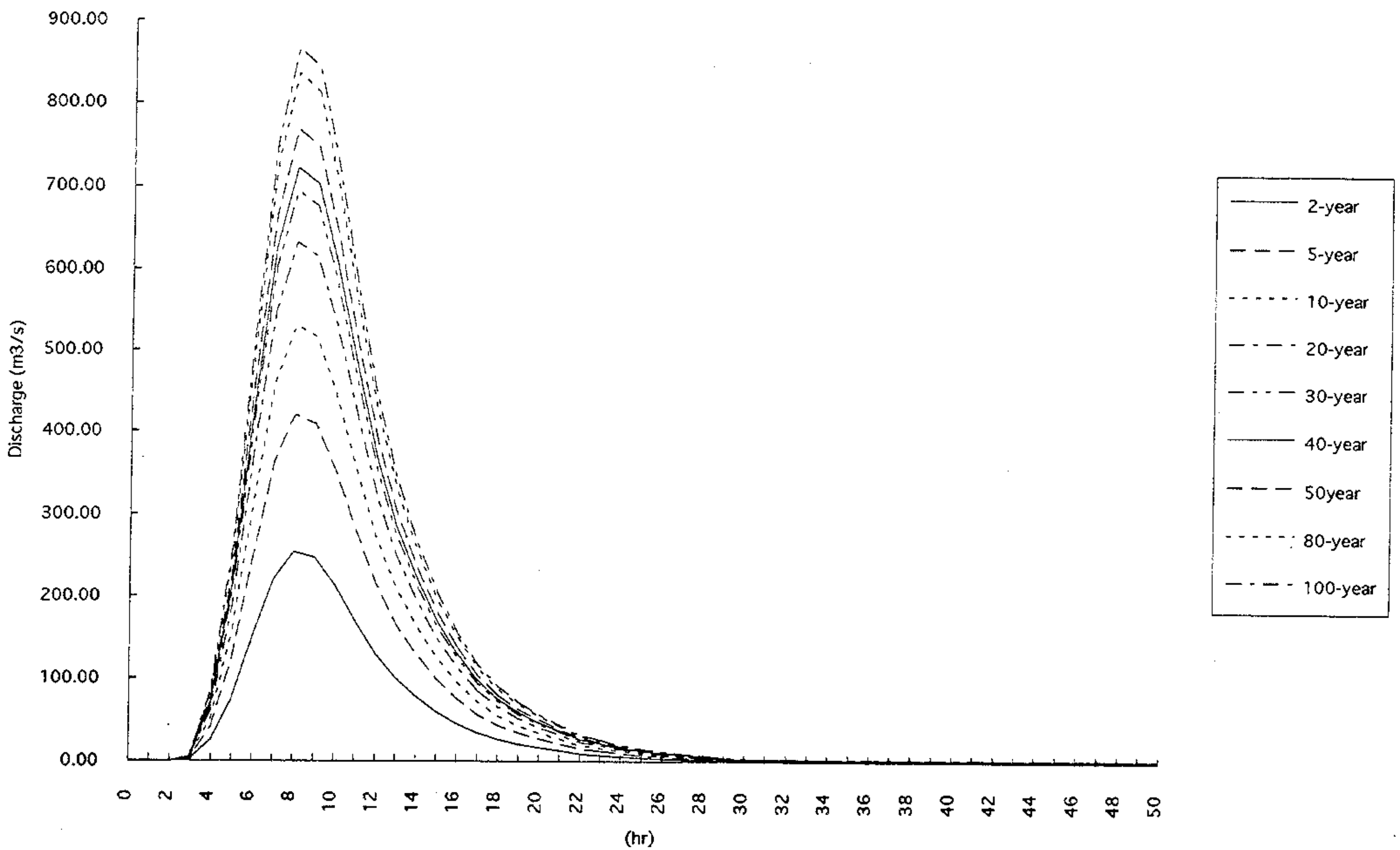


Fig. C.2.4.1 Unit Hydrograph of budh Nullah

ANNEX D

SOIL AND LAND USE

ANNEX-D

SOIL AND LAND USE

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ANNEX D SOIL AND LAND USE

D.1 The Soil Survey

D.1.1 Previous Studies

(1) Reconnaissance soil survey

The Study Area has been surveyed by the Soil Survey of Pakistan (SSP) at reconnaissance level (1969), and a soil map was prepared at a scale of 1:125,000. In this survey, the soils were grouped into 22 soil associations. The survey covers whole area of D. I. Khan District and the soil map is very general, however the report is the most authoritative soil data of the area.

(2) CRBC command area

The CRBC command area has been surveyed by the Central Monitoring Organization (CMO) of WAPDA (1975). Subsequently more detailed studies were undertaken by Harza/NESPAK consultants in the course of their CRBC System Performance Monitoring (1988). Of the 31 profiles' studies, 9 were located in the Stage II area and 22 in Stage III. These studies included infiltration tests on seven different soil types at twelve locations. The Harza/NESPAK investigations were supplementary undertaken on the Zindani soil association by the Planning Directorate (Water) North, WAPDA (1983), and of the series of reconnaissance level studies on permeability and hydraulic conductivity carried out.

D.1.2 Objectives and Procedure of the Soil Survey

The soil survey was conducted to explore and evaluate the land and soil resources of the Study Area aiming at the following points;

1) To review the existing data and check the validity of the existing soil map for use in irrigation agriculture planning,
2) To make the supplementary soil survey to identify, classify and describe properly the major kinds of soils occurring in the area, and
3) To evaluate the soils in terms of land suitability taking account of canal irrigation conditions.

In consideration with above points, the following works were carried out by the Study team.

a) Review and evaluation of existing data
b) Interpretation of aerial photographs of the area

c) Supplementary field survey
   - Auger boring 500 sites
   - Test pit digging 100 sites

d) Preparation of maps
   - Soil map
   - Land capability map
   - Present land use map

Prior to the field survey, the existing soil survey reports were studied in detail. On this basis, a provisional soil map on the scale of 1:50,000 was prepared and used as field map. Aerial photographs as well as soil associations map of SSP were taken into consideration in the study. The soils were studied along the selected traverses with distance between observation points depending upon the complexity of the soil and generally varying from 1 to 2 km. The intensity of observation was one per 220 ha approximately. At each observation site, information recorded including soil texture, dry and moist Munsell color, depth and thickness of horizons or layers, structure, consistency, porosity, carbonates, salinity and moisture status. The location of auger holes and soil pits were recorded by a GPS receiver. The field work was started on 11th August 1993 and completed on 30th September 1993.

Auger boring

Five hundred field auger observations were made upto 1m depth in the area as required by change in soils and terrain conditions. At each auger hole, morphological and physical characteristic of the soils were studied and described. Soil pH was determined by thymol blue in the field and the electrical conductivity was measured by a portable EC meter. Associated features like physiography, micro relief, drainage conditions, natural vegetation and land use were also noted at each observation point.

Test pit

One hundred soil test pits upto 1m depth were excavated in the selected locations representing the soil mapping units for detailed morphological description and sampling of different horizon or layers. The profiles of the pits were described according to the USDA guidelines. The basic unit of classification was soil series constituting the soil mapping units as soil association that has two or more components. List of the test pits is shown in Table D.1.1.

Soil sampling

One hundred soil samples of the representative horizons were taken from 33 soil pits for physical and chemical characterizations in laboratory. These samples were sent to the NARC (National Agricultural Research Centre) laboratory in Islamabad for the analysis.

D.1.3 Methods of the Soil Analysis

The one hundred samples collected from the different layers of thirty-three soil pits were analyzed in the NARC laboratory. The methods adopted for the analysis are described below. USDA Hand Book No. 60 was also used as guideline during analysis of the soil samples;

D.1.3.1 Physical Properties

(1) Soil texture

The soil texture was determined in the laboratory by hydrometer method and the texture class was determined also using "Texture triangle" of USDA.

(2) pF

The undisturbed core samples were prepared to determine pF-moisture retention relationship by using pressure plate method. The test was carried out at 0.3 and 15 bar pressure and moisture was determined gravimetrically.

(3) Bulk density

Bulk density was determined by core sampling volume displacement by paraffin coating in laboratory.

(4) Permeability

Soil permeability was measured by constant head permeameter. The constant head well permeameter estimates Kfs by measuring the steady-state rate of water flowing out of a cylindrical well in which a constant depth of water is maintained.

D.1.3.2 Chemical Properties

(1) pH

The pH of soils was determined by pH meter using 1:2.5 soil-water suspension.

(2) Electrical conductivity (EC)

The electrical conductivity of soils was determined in the field at each auger hole observation point and at each of the 100 pit locations by portable EC meter using 1:5 suspension. While in the laboratory, both 1:5 suspension and saturation extract were used.

(3) Total Nitrogen

Micro Kjeldahl method was used to measure total nitrogen.

(4) Total Carbon

Total carbon was analyzed for both organic and inorganic origins separately. Organic carbon was determined by Walkely Black method, and inorganic carbon was determined by CO_2 liberated by HCl.

(5) Available phosphorous

Olson method of bicarbonate extraction.

(6) Gypsum ($CaSO_4$)

Gypsum was determined by Bower and Hess method. Amount of calcium absorbed by the soil (A) was calculated as follows;

A = (Initial Ca in solution) - (Ca+Mg in solution after equilibration with soil)

(7) Calcium carbonate ($CaCO_3$)

Calcium carbonate was determined by acid treatment (HCl method).

(8) Cation Exchange Capacity (CEC)

Cation Exchange Capacity of soils was determined by NH_4HCO_3 absorption method.

D.2 The Characteristics of the Soils

D.2.1 General

The Study Area consists of piedmont plain formed through wide spread flooding by torrents originating from the Suleiman range predominantly. The land forms in the area are divided into two major geomorphological units on the basis of surface configurations, nature of sediments and age of land surfaces. These units are a) recent piedmont plain and b) sub-recent piedmont plain, and described as follows.

Recent piedmont plain

The recent piedmont plain is mapped along the torrent streams and is received outwash sediments until quite recently in the area. The original relief and configuration have been obliterated due to leveling for torrent watered cultivation. The soils are young and lacking the sign of development. They are level to nearly level and have laminated material in the sub-soil. The soils near the torrents are very thin and have wider range of texture. This unit consists of level plains and gently undulating sand plains.

a) Level plains : The area along the channel margins contains silt loam and very fine sandy loam (Tikken series), and flat to level areas are occupied by silty clay loam (Zindani series).
b) Gently undulating sand plains : The soils of these areas are of limited extent and have been mapped in the north and south edge of the boundary of the Study Area. The soils consist of thin sandy deposit (Wajan series). The soils are mainly loamy sand or sand and are generally used for grazing and rainfed farming for wheat and gram.

Sub-recent piedmont plain

A considerable Study Area has been mapped as sub-recent piedmont plain that is level to nearly level, exposed in some places where younger deposits have been removed by sheet erosion. The soils show varying degree of development. Silty clay loam (Gishkori series) and silty clay (Saggu series) soils have a profile development of 50-70 cm. Some clayey soil such as Ramak series has profile development of one meter or more. A thin cover of recent stratified sediments occurs on these soils. Some gently undulating concave areas with sand ridges have also been mapped in the northern side of boundary of the Study Area. These soils are mainly sandy loam (Banda series) having structure development upto 50 cm depth. They have a thin cover of loam sand and are usually far from flooding by hill torrents.

D.2.2 Principal Characteristics of the Major Soil Series

Seven major soil series have been found in the area through the Study, which are classified according to the USDA classification.

Soil series	Order	Sub-group
Tikken	Entisol	Typic Torrifluvents
Zindani	Entisol	Typic Torrifluvents
Gishkori	Aridsol	Fluventic Camborthids
Saggu	Aridsol	Fluventic Camborthids
Banda	Aridsol	Fluventic Camborthids
Ramak	Aridsol	Vertic Camborthids
Wajan	Entisol	Typic Torripsamments

The principal characteristics of each soil series are described as follows;

Tikken soil series

This soil series is the most dominant in the Study Area which covers 36,800 ha (26.9%). The soil is stratified silty loam, loam or very fine sandy loam. The value of pH ranges from 8.0 to 9.0 with the average of 8.6. Electrical conductivity (ECe) is generally low which average is 0.21 mS/cm. The crop suitability of the soil is rated as "S1" (well suited) for almost all crops except for paddy and sugarcane. The soil is easily workable and has little limitation for crop cultivation.

Zindani soil series

Zindani soil series is also dominant in the area, and covers 34,900 ha (25.5%). This soil is stratified silty clay loam. The soil pH ranges from 8.2 to 9.0 with the average of 8.6. The average ECe of the soil is 0.42 mS/cm. The crop suitability of the soil is also rated as "S1" for almost all crops except for cotton and paddy. The soil has a little limitation for crop cultivation. However, the soil is prone to water logging in case of over irrigation due to its somewhat clayey nature.

Gishkori soil series

This soil series covers 20,800 ha (15.2%), and its texture is silty clay loam. The pH ranges from 8.3 to 9.0 with the average of 8.4, and ECe is 0.45 mS/cm on average. The soil is suitable for almost all crops except for cotton and paddy. The soil has a little limitation for crop cultivation.

Saggu soil series

Saggu soil series is silty clay or clay soil which covers 26,800 ha (19.6%). The pH ranges from 7.9 to 9.0 with the average of 8.3. ECe of the soil is 0.67 mS/cm on average. The crop suitability of the soil is rated as either "S2" or "S3" for almost all crops. The soil is prone to water logging in case of over irrigation.

Ramak soil series

Ramak is silty clay or clay soil which covers 7,300 ha (5.3%). The pH ranges from 7.8 to 8.2 with the average of 7.9, and ECe is 1.58 mS/cm on average. The soil is slightly saline due to lack of leaching water and its clayey nature. The crop suitability of the soil is rated as either "S2" or "S3" for almost all crops. The soil is also prone to water logging in case of over irrigation.

Banda soil series

This soil series covers 2,500 ha (1.8%), and its texture is sandy loam. Because of its coarse texture, this soil has poor water holding capacity. The pH ranges from 8.4 to 8.9 with the average of 8.6, and ECe is 0.10 mS/cm. The soil is not suitable for cotton, paddy, sugarcane and berseem, and needs special care when canal irrigation is introduced.

Wajan soil series

Wajan is loamy sand soil and its water holding capacity is low. The soil covers 7,800 ha (5.7%). The pH ranges from 8.4 to 8.6 with the average of 8.5. ECe of the soil is 0.10 mS/cm on average. The soil is not suitable for cotton, maize, paddy, sugarcane and berseem.

Wajan soil series also needs special care when canal irrigation is introduced.

D.2.3 Physical and Chemical Properties of the Soils

D.2.3.1 Physical Properties

Results of the tests for soil texture, bulk density, pF-moisture retention and permeability are shown in Table D.2.1. Detailed description of physical properties of the soils is as follows;

(1) Soil texture

Particle size analysis is used to determine the proportions of different sized particle in a soil and hence its texture class. These measurements are used as basic indicators of soil physical and chemical properties. Soil texture affects plant growth by its influence on aeration, water intake rate, available water capacity, CEC, permeability, erodibility and workability. The result shows the soil texture of the Study Area varies from sand to clay, but silty clay loam is the dominant texture of the area.

(2) pF-moisture retention

The amount of water that soil can hold as available water for plant use is an important property for developing water budgets, predicting drought and crop yields, and designing and operating irrigation systems. The results are presented in the table for 0.3 and 15 bar pressure. The difference between the moisture percentage at the two pressures is considered to be the plant available moisture. As expected the pits where sandy soil was found have lower water holding capacity, while clayey soils hold more water. Since the soils of the area are predominantly moderately fine or medium textured, available water capacity (AWC) would favor the major crops of the survey area. AWC of 1m soil depth is shown for each soil series in TABLED.2.2.

(3) Bulk density

Bulk density measurements are made as a guide to soil compaction and porosity, results are overall indications of problems of root penetration and soil aeration in different soil horizons. It is evident from the result that generally bulk density of clayey soils range from 1.51 to 1.70 while those of sandy soils range from 1.34 to 1.64. The bulk density of fine silty and loamy soils vary from 1.36 to 1.70. The result indicates that all the soils of the study area except clayey soils are porous and do not pose any severe problem of aeration and can safely be used for a variety of crops using modern management and techniques.

(4) Permeability and saturated hydraulic conductivity

There are many factors that affect hydraulic conductivity. Among them, the interaction between the porous medium and the fluid, and the occupancy of pores are two of the most important. Other important factors are water quality, exchangeable cations, cracks, roots, and worm holes which affect the movement of the water through soil and cause difficulty in hydraulic conductivity carried out both in the laboratory and in the field. The result shows that Kfs in loamy sand and very fine sand varies from 7 to 115 cm/h, in silty loam it varies from 0.65 to 17.28 cm/h, in silty clay loam it varies from 0.18 to 3.96 cm/h, and in silty clay it varies from 0.1 to 1.55 cm/h. Therefore, the Kfs values are strongly correlated with texture. The soils in the pit No. 5, 10, 20, 27 and 32 were light textured, therefore Kfs values are very high. In these soils, flood irrigation or surface irrigation may not be very efficient as applied water will drain out of root zone and will not be available for plant use. On the other hand, Kfs values in the pit No. 11, 12, 13, 14, 19, 21, 22 and 23 were low falling in the range of 0.5 to 0.1 cm/h. In this case, heavy irrigation may cause stagnation of water on the surface or heavy run off. In some situation where a horizon with higher Kfs exists over a horizon with low Kfs may result in a perched water table. The pit No. 2 and 33 are quotable examples in this case.

D.2.3.2 Chemical Properties

Results of the chemical analysis of 100 soil samples collected from field and analyzed by NARC laboratory, are shown in Table D.2.3. To have an idea of chemical characteristics of the soils, interpretation for each property has been made to assess their suitability for irrigation and for the development of agriculture. The results are interpreted for farming level, capability class and crop suitability rating of the soils which may be used for the formulation of cropping pattern, availability as well as optimum use of irrigation water for different crops.

(1) pH

The principal value of the soil pH measurement is the knowledge about soil characteristics like nutrient's availability. It is evident from the table that generally pH of the soils varies from 8.0 to 8.5 while some soils have been above 8.5 which indicates that most of the soils of the survey area are calcareous and moderately alkaline in nature. Nitrogen will be readily available in soils with pH less than 8.5. However, inadequate availability of iron, manganese, copper, zinc, boron and phosphorous may occur in soils with pH more than 8.5.

(2) Electrical conductivity (EC)

Electrical conductivity of a solution is an index of the total concentrations of ionized constitute of solutions. It is related to sum of cations and anions, and usually correlates with total dissolved solids therefore are used to indicate the existence of saline soils. The results show the soils are generally non saline.

(3) Total nitrogen

Total nitrogen in soils infer the application of nitrogenous fertilizers. The results obtained show that the soils are generally poor in plant available nitrogen and the soils will benefit from any nitrogen fertilizer's application. The total nitrogen is generally very low and is less than 0.02% in all cases which indicates the lack of any application of such fertilizers. Detailed trials may be made for different doses of fertilizers for different crops grown in the area.

(4) Total carbon

Organic carbon influences physical and chemical properties of soils far out of proportion to the small quantities present. It accounts for at least half the CEC and is responsible for the aggregate's stability of soil. Organic matter of clayey soils varied from 0.08 to 0.16% while that of loamy soils is also less than 0.2%. Soils of the Study Area therefore low in organic matter content.

(5) Available phosphorous

The available phosphorous of surface horizon is 3 to 12 ppm and that of subsurface horizon is moderate to low which indicates that these soils will show a good response to phosphoric fertilizer. Limits are less than 3 ppm is efficient, 11-20 ppm is moderate, 20-30 ppm is sufficient, and more than 30 ppm is high.

(6) Gypsum ($CaSO_4$)

Amount of calcium adsorbed by the soil is a measure of the gypsum requirement of the soil. The results show that the gypsum is not present in the soils. As the soils are generally non-saline and non-sodic, there seems no need of adding gypsum for reclamation purposes.

(7) Calcium carbonate ($CaCO_3$)

Carbonates are natural constituent of soils occurring as $CaCO_3$ (calcite) or as $CaCO_3MgCO_3$ (dolomite) and influences phosphorous fertilization. Soils with more than 15% of $CaCO_3$ would require more phosphoric fertilizer because of fixation. The results shown in the table indicate that the soils are moderately to strongly calcareous.

(8) Cation exchange capacity (CEC)

Cation exchange capacity is sum of exchangeable cations of soil expressed as me/100g of soil. Amount of CEC varies with nature and amount of clay. The CEC of clayey soils of the Study area varies from 27 to 63 me/100g of soil while that of silty and loamy soils varies from 11.2 to 50.6 me/100g of soil. These are indicative of high fertility level and it can be predicted that soils of the Study area would have satisfactory production of crops in response to irrigation.

(9) Exchangeable cations - Na, K, Ca and Mg

Exchangeable cations indicate the reserves of exchangeable bases and determine the fertility status of the soils. The results show that the exchange complex of soils is loaded with Ca and there is no problem of sodicity as in all cases exchangeable sodium is less than 30%. The exchangeable K indicates the availability of this nutrient. The criteria are; less than 60 is deficient, 60-120 is moderate, 120-180 is sufficient and more than 180 is high. In most cases, in the surface horizon there is sufficient amount of plant available K in these soils. It appears that crops will not benefit from any potash fertilizers if applied, because these soils contain appropriate amount of weatherable K minerals. Similarly, plants will not benefit from Mg application. The soils are seemed to be fertile and will have good response to application of irrigation water for major crops.

D.2.4 Recommendations for Soil Improvement of the Area

A productive soil must have favorable physical properties to get maximum crop yield. Physical properties such as texture, structure and permeability greatly affect the crop suitability and management of soil.

The soils of the Study Area can easily be grouped as;

1) Silty or loamy soils (Tikken)
2) Fine silty soils (Gishkori and Zindani)
3) Silty clay soils (Saggu and Ramak)
4) Sandy soils (Banda and Wajan)

Most of the soils of the area are light textured (Tikken). They are fertile and have little problem of physical properties. After irrigation, these soils are likely to be improved after a few years intensive irrigated cropping. The soils are easily workable and have little limitation for roots, air and water penetration. Their available water holding capacity is good. With modern management, including adequate irrigation supplies and improved agronomic practices (such as quality seeds and balanced dose of fertilizers), high yields of crops can be attained. Green manuring and addition of farm yard manure should be included in the cropping system to increase nutrient level and soil structure.

The soils having clay loam texture stratified or homogenized in the subsoil (Gishkori and Zindani series) need a little management effort. Due to their somewhat clayey nature and stratification in subsoil, there is danger of temporary water logging in case of over irrigation, so special care is needed in the application of irrigation water.

However, these soils are not very suitable for deep rooted crops, because compactness of stratified layer may restrict the root and water penetration.

Clayey soils of the Study Area (Saggu and Ramak series) will create relatively difficult workability and seed bed preparation because of their clayey nature. These are comparatively rich in organic matter. With modern management including adequate drainage measure, high to very high yield of suitable crops could be obtained. The management practices should include the followings;

1) Ploughing at optimum moisture level for preservation of good tilth
2) Green manuring and addition of farm yard manure to improve physical properties of the soil, and
3) Occasional (once in 4-5 years) deep ploughing to break plough pan.

These soils should not be heavily and frequently irrigated, because they are likely to develop perched water table.

Sandy soils (Banda and Wajan series) of the Study area need some management measures for arable cropping. Due to coarse texture and sandy nature, these soils have rapid intake and permeability. They are prone to wind and water erosions and bury the adjacent land if not protected. In general, these lands are not very suitable for irrigation by canal, and need special cares in terms of irrigation systems, crop selection and fertilizer application.

D.2.5 Description of Soil Mapping Unit

Soil mapping unit No. 1

Tikken association : Nearly level recent piedmont of the Suleiman Range.

Major soils;

Tikken	Very gently sloping	60-70%	Stratified silt loam, loam and very fine sandy loam.
Gishkori	Extensively level high area	10-15%	Silty clay loam, weak or moderate subangular blocking.
Zindani	Very gently sloping, slightly higher parts	5-10%	Stratified silty clay loam.
Wajan	Locally undulating	0-5%	Stratified sand or loamy sand.

Soil mapping unit No. 2

Zindani association : Nearly level recent piedmont plains.

Major soils;

Zindani	Very gently sloping	65-75%	Stratified silty clay loam.
Tikken	Gently sloping lower area	15-25%	Stratified silt loam, loam and very fine sandy loam.
Wajan	Locally un-dulating	10%	Stratified sand or loamy sand.

Soil mapping unit No. 3

Saggu association : Piedmont alluvium, subrecent piedmont plains, gently sloping plains.

Major soils;

Saggu	Mainly level	65-75%	Clay or silty clay.
Zindani	Very gently sloping, low area	15-25%	Stratified silty clay loam.
Ramak	Level to gently	10%	Clay or silty clay.

Soil mapping unit No. 4

Gishkori association : Level subrecent piedmont of the Suleiman Range.

Major soils;

Gishkori	Extensively level high area	65-75%	Silty clay loam.
Saggu	High level area	15-25%	Clay or silty clay.
Zindani	Very gently sloping	10%	Stratified silty clay loam.

Soil mapping unit No. 5

Banda association : Gently undulating subrecent piedmont plains of the Marwat Range.

Major soils;

Banda	Extensively gently sloping	70%	Sandy loam.
Wajan	Sloping	20%	Stratified loamy sand or sand.
Shifting sand	Rolling	10%	loamy sand.

Soil mapping unit No. 6

Wajan association : Undulating recent piedmont plains of the Suleiman and Marwat Ranges.

Major soils;

Wajan	Undulating	85%	Stratified sand or loamy sand.
Shifting sand	Convex slope	15%	Shifting sand.

Soil mapping unit No. 7

Ramak association : Level subrecent piedmont plains.

Major soils;

Ramak	Level	70-75%	Clay.
Zindani	Nearly level,	15-20%	Stratified silty clay loam.
		slightly higher area	
Saggu	Level to nearly level	10%	Clay or silty clay.

D.2.6 Soil Profile Description of the Major Soil Series

Tikken soil series

Pit No.	27
Location	31° 33' 04" N
	70° 33' 32" E
Physiography	Sub-recent plain
Parent Material	Piedmont alluvium
Topography	Flat
Land use/vegetation	Poor grazing
Profile Drainage	Moderately well
Permeability	Slow
Erosion	Nil
Moisture	Dry
U.S.D.A.	Classification Typic Torrifluvent

Horizon	Depth	Description
A	0-13	Brown/dark brown (10 YR 4/3) moist, and pale brown (10 YR 6/3) dry, loam, massive, slightly sticky, slightly plastic, friable moist, hard dry, few fine tubular pores, moderately calcareous, clear smooth boundary.

pH=8.0, EC=0.1 mS/cm.

C1	13-70	Brown (10 YR 4/3)moist, and pale brown (10 YR 5/4) dry, silt loam, massive breaking into very weak sub-angular blocky, slightly sticky, slightly plastic, friable moist, soft dry, few fine tubular pores, moderately calcareous, few fine roots, clear smooth boundary. pH=8.2, EC=0.1 mS/cm.
$2C_2$	70-110	Brownish gray (2.5 YR 5/2) moist, brownish gray (2.5 YR 6/2) dry, loamy sand single grain, non sticky, slightly plastic, very friable moist, soft dry, no pores, moderately calcareous, no roots. pH=8.3, EC=0.1 mS/cm.

Zindani soil series

Pit No.	2
Location	32° 00' 49" N 70° 49' 34" E
Physiography	Sub-recent plain
Parent Material	Piedmont alluvium
Topography	Flat
Land use/vegetation	Shrubs (Uncultivated)
Profile Drainage	Moderately well
Permeability	Slow
Erosion	Nil
Moisture	Dry
U.S.D.A. Classification	Typic Torrifluvent (sodic)

Horizon	Depth	Description
A	0-13	Brown/dark brown (10 YR 4/3) moist, and pale brown (10 YR 6/3) dry, silty clay loam, massive, weak thin platy, sticky, plastic, firm moist, hard dry, few fine tubular pores, moderately calcareous, few fine roots, clear smooth boundary. pH=8.3, EC=0.2 mS/cm.
C1	13-60	Dark yellowish brown (10 YR 3/4)moist, and yellowish brown (10 YR 5/4) dry, silty clay loam, weak thin platy,

		sticky, plastic, firm moist, hard dry, few find tubular pores, moderately calcareous, no roots, abrupt smooth boundary. pH=8.2, EC=0.2 mS/cm.
C_2	60-120	Brown (10 YR 5/3) moist, and pale brown (10 YR 6/3) dry, silt clay loam, weak thin platy, slightly sticky, slightly plastic, friable moist slightly hard dry, very few fine tubular pores, moderately calcareous, no roots. pH=8.3, EC=0.2 mS/cm.

Gishkori soil series

Pit No.	12
Location	32° 00' 25" N 70° 41' 25" E
Physiography	Sub-recent plain
Parent Material	Piedmont alluvium
Topography	Flat
Land use/vegetation	Wheat, Millet
Profile Drainage	Moderately well drained
Permeability	Slow
Erosion	Nil
Moisture	Dry
U.S.D.A. Classification	Fluventic Camborthids

Horizon	Depth	Description
Ap	0-17	Brown/dark brown (10 YR 4/3) moist, and very pale brown (10 YR 6/4) dry, silty clay massive, sticky, plastic, firm moist, hard dry, common fine and very find tubular pores, gypsum specks, present moderately calcareous, few fine roots, clear smooth boundary. pH=8.4, EC=0.2 mS/cm.
B1	17-61	Brown (10 YR 5/3) moist, and pale brown (10 YR 6/3) dry, silty clay loam, weak coarse and medium sub-angular blocky, sticky, plastic, firm moist, hard dry, gypsum specks present, common fine and very fine tubular pores, moderately calcareous, few fine roots, clear smooth boundary.

		pH=8.4, EC=0.2 mS/cm.
C_1	61-110	Brown/dark brown (10 YR 4/3) moist, and pale brown (10 YR 6/3) dry, silt clay loam, massive in upper part and weak run platy, gypsum specks, few fine tubular pores, moderately calcareous, no visible roots. pH=8.2, EC=0.2 mS/cm.

<u>Saggu soil series</u>

Pit No.	14
Location	31° 56' 32" N 70° 43' 59" E
Physiography	Sub-recent plain
Parent Material	Piedmont alluvium
Topography	Flat
Land use/vegetation	Wheat, Sorghum
Profile Drainage	Moderately well drained
Permeability	Slow
Erosion	Nil
Moisture	Dry
U.S.D.A. Classification	Fluventic Camborthids

Horizon	Depth	Description
A	0-11	Brown/dark brown (10 YR 4/3) moist, and pale brown (10 YR 6/3) dry, silty clay massive sticky, plastic, firm moist, hard dry, common fine tubular pores, moderately calcareous, few fine roots, clear smooth boundary. pH=8.6, EC=1.2 mS/cm.
C1	11-62	Brown (10 YR 5/3)moist, and pale brown (10 YR 6/3) dry, silty clay loam, weak coarse sub-angular blocky, sticky, slightly plastic, firm moist, slightly hard dry, few fine and very fine tubular pores, moderately calcareous, few fine roots, clear smooth boundary. pH=8.2, EC=0.2 mS/cm.
C_2	62-110	Brown/dark brown (10 YR 4/3) moist, and pale brown (10 YR 6/3) dry, silty loam, massive, slightly sticky, slightly plastic, firm moist slightly hard dry, no visible

pores, moderately calcareous, no visible roots.
pH=9.0, EC=2.8 mS/cm.

Ramak soil series

Pit No.	25
Location	31° 36' 47" N 70° 35' 14" E
Physiography	Sub-recent plain (Tenable)
Parent Material	Piedmont alluvium
Topography	Flat
Land use/vegetation	Uncultivated
Profile Drainage	Moderately well drained
Permeability	Moderately slow
Erosion	Nil
Moisture	Dry
U.S.D.A. Classification	Vertic Camborthid

Horizon	Depth	Description
A	0-12	Brown/dark brown (10 YR 4/3) moist, and pale brown (10 YR 6/3) dry, silty clay loam, massive, (cloddy), very sticky, very plastic, very firm moist extremely hard dry, common very fine and few fine tubular pores, no roots, moderately calcareous. pH=8.3, EC=0.2 mS/cm.
B2	12-30	Brown (10 YR 5/3) moist, and pale brown (10 YR 6/3) dry, silty clay very weak coarse sub-angular blocky, very sticky, very plastic, very firm moist, extremely hard dry, continuous distinct slicken sides, few fine and very fine tubular pores, moderately calcareous, few very fine roots. pH=8.2, EC=3.7 mS/cm.
B_2b	30-110	Brown (10 YR 5/3) moist, and pale brown (10 YR 6/3) dry, silty clay, weak coarse sub-angular blocky, very sticky, very plastic, very firm moist, extremely hard dry, few distinct slicken sides, lime coating, few fine tubular pores, moderately calcareous, few fine roots.

pH=8.3, EC=0.2 mS/cm.

Banda soil series

Pit No.	20
Location	32° 46' 18" N 70° 35' 44" E
Physiography	Recent plain
Parent Material	Piedmont alluvium
Topography	Flat
Land use/vegetation	Sorghum
Profile Drainage	Moderately well
Permeability	Rapid
Erosion	Very slight
Moisture	Moist
U.S.D.A. Classification	Fluventic Camborthids

Horizon	Depth	Description
Ap	0-20	Brown/dark brown (10 YR 4/3) moist, and pale brown (10 YR 6/3) dry, silty clay loam, massive, sticky, plastic, firm moist, hard dry, few fine and very fine tubular pores, moderately calcareous, common fine and very fine roots, clear smooth boundary. pH=8.0, EC=0.1 mS/cm.
C1	20-46	Brown/dark drown (10 YR 4/3)moist, and pale brown (10 YR 6/3) dry, sandy loam, very weak sub-angular blocky, sticky, common fine and very fine tubular pores, moderately calcareous, few fine and common very fine roots, clear smooth boundary. pH=8.2, EC=Nil mS/cm.
C_2	46-120	Brown (10 YR 5/3) moist, and pale brown (10 YR 6/3) dry, loamy fine sand, massive, non sticky, non plastic, very friable moist, slightly hard dry, no visible pores, moderately calcareous, few fine roots. pH=8.0, EC=Nil mS/cm.

Wajan soil series

Pit No.	32
Location	31° 22' 35" N 70° 35' 04" E
Physiography	Recent piedmont plain
Parent Material	Piedmont alluvium
Topography	Gently undulating
Land use/vegetation	Poor grazing (Gram)
Profile Drainage	Extremely to moderately drained
Permeability	Rapid
Erosion	Slight wind erosion
Moisture	Moderately dry
U.S.D.A. Classification	Typic Torripsamments

Horizon	Depth	Description
A	0-12	(10 YR 4/3) moist, and pale brown (10 YR 6/3) dry, loamy sand, massive, non sticky, non plastic, loam moist, soft dry, no pores, moderately calcareous, very few roots, clear smooth boundary. pH=8.0, EC=0.06 mS/cm.
C1	12-60	Brown (10 YR 5/3) moist, and pale brown (10 YR 5/4) dry, loamy sand, massive, and very weak coarse sub-angular blocky, slightly sticky, slightly plastic, friable moist, slightly hard dry, no visible pores, moderately calcareous, common fine and medium roots, clear smooth boundary. pH=8.0, EC=0.7 mS/cm (few cobbles present).
C2	60-120	Brown (10 YR 5/3) moist, and pale brown (10 YR 6/3) dry, coarse sand, massive, non sticky, non plastic, loam moist, soft dry, no pores, common fine and very fine roots. pH=8.0, EC=0.05 mS/cm.

D.3 Crop Suitability

D.3.1 Outline of Crop Suitability Classification

Crop suitability classification is a method of rating soils in terms of their relative suitability for the sustained production of specified crops. Sustained production does not necessary mean that the same crop should be produced on the same piece of land year after year. In most cases, the crop should be produced in rotation with other crops. The ratings are called crop suitability classes and range from Class 1 (S1) for the most suitable soils to Class 4 (NS) for the least suitable.

These ratings are similar to land capability classes, but two important differences should be noted. A crop suitability class is a rating for individual crops, whereas a land capability class is a rating for overall crop production. Moreover, a crop suitability rating takes into account only the most favorable season of the year for the soil- crop combination under consideration, whereas a land capability rating is based on the limitations of a soil for crop production throughout the year.

Each soil has certain physical and chemical characteristics that affect its response to management and influence yields. For instance, soils best suited for cotton production are well drained, medium textured and fertile or responsive to fertilizer applications. Other crops such as paddy has different requirements. Therefore, soils in the same land capability class may be differently rated for crop suitability.

The soils are rated according to their present condition or that expected to exist for the next ten years or so under traditional or modern management. Whenever capital improvements are made, for example, by providing drainage or large scale irrigation, then a revised rating of crop suitability will be needed for the new situation. Similarly, changes may need to be made with improvement in agricultural technology, for instance, the introduction of drought resistant varieties of crops.

D.3.2 Definition of the Class

The four classes are defined as follows;

<u>Class 1 (S1) : well suited</u>

Under traditional management, the crops grow well and produce high yields. For the crops under consideration, the soil has favorable physical, chemical and drainage characteristics; a moderate or high fertility level; and is responsive to good management. Under modern management, the crops would produce high or very high yields.

Class 2 (S2) : moderately suited

Under traditional management, the crops produce moderate to poor yields or are subject to occasional hazard of failure. For the crops under consideration, the soil has somewhat unfavorable physical or drainage characteristics; a medium or low level fertility level. Under modern management, the crop yields would be moderately high. Except where climate is limiting, moderate expenditure to overcome limitations and/or a relatively high intensity of management would enable the crop to produce very high yields.

Class 3 (S3) : poorly suited

Under traditional management, the crops produce poor yields or would be subject to great hazard of failure For the crops under consideration, the soil has unfavorable drainage; unfavorable physical or chemical characteristics; low fertile, not easy corrected. The response to management is generally low. Intensive modern management together with major expenditure for drainage, erosion control and/or correction of unfavorable soil conditions would be required for the crops to give moderate to high yields. If the climate is unsuitable, high yields can not be obtained. Generally, the crop must be considered as marginal and is not recommended for the soil under consideration.

Class 4 (NS) : not suited

Under traditional management, little production may be expected from the crops. The soil has severe physical, chemical or drainage limitations for the crops under consideration or a severe erosion hazard. Only with prohibitive expenditure foe major improvements and under very intensive or special management, moderate or good crop yield could be expected in some cases. This would be uneconomical.

Crop suitability classification of the soils in the Study Area is described in Table D.3.1. On the basis of the classification, the suitability was rated crop-wisely and result is shown in Table D.3.2.

D.4 Land Capability Classification

D.4.1 Method of Classification

Land capability classification is a method of grouping the soils of an area to show their relative suitability for sustained production of common agriculture crops, or for grazing or forestry. It takes into account general agricultural use, but not special crops or the urban or industrial uses.

The classification outlined below is designed to suit the agricultural conditions of Pakistan. It is similar in basic structure to the U.S. Soil Conservation Service Classification, U.S.D.A. (1961), but the definition of the classes has been modified and the number of subclasses extended to suit the conditions of Pakistan. Soils placed in the highest class (I) have the least limitations for agriculture use and relatively little effort is required to produce high crop yields. In successively lower classes there are increasingly severe limitations for agricultural use and increasingly greater effort is required to produce high crop yields Soils in the lowest class are unfit for agricultural use.

D.4.2 Outline of Classification

Two levels of generalization are recognized; land capability class and land capability subclass. The first and broadest grouping, land capability class, are identified by the Roman numerals I to V. The letters "ir" or "d" preceding the class number are indicated "irrigation" or "dry farming", respectively. The soils within each land class have limitations of about the same degree. Class I has the least limitations for crop production. Class IV is considered unfit for economic production of agricultural crops. The kinds of limitations may vary, however, within each class.

The land capability subclass is designated by small letters following the class number, which shows soils having the same kinds of limitations for agricultural use. The following subclasses are recognized.

e : Soils restricted in use due to erosion hazard or past erosion.

w : Soils restricted in use due to excess water because of poor drainage, high water table or overflow.

s : Soils restricted in use due to limitations inherent in the soil profile such as shallow soil depth, stoniness, slowly permeable layers or low moisture holding capacity.

a : Soils restricted in use due to salinity and/or alkalinity.

c : Soils restricted in use due to unfavorable climate.

D.4.3 Description of the Land Capability Classification

Class I. Good irrigable land

Soils in this class have little or minor limitations for crop production throughout the year and have the widest range of agricultural use. The limitations of this class are as follows;

a) irIs (clayey) soils

Soils in this subclass are either moderately fine to fine textured or medium textured and rather slowly permeable. With sufficient irrigation water and under modern management, they are capable of giving high yields of a wide range of crops.

b) irIs (sandy) soils

Soils in this subclass are moderately coarse textured or medium textured, and a higher permeability and lower water holding capacity.

Class II. Moderate irrigable land

Soils in this class have moderate limitations for crop production throughout the year, or severe limitations during one season, or have a very limited range of suitable crops.

a) irIIs soils

Soils in this subclass are moderately coarse textured, moderately deep over sand. They have relatively rapid permeability.

b) dIIw soils

This subclass comprises moderately coarse to moderately fine textured dry-farmed soils that are seasonally flooded. Under modern management, including selection of good variety and use of fertilizers, this land could produce high yields of winter crops.

Class III. Marginal irrigable land

Soils in this class have severe limitations for crop production and may have very narrow range of agricultural use. These limitations are mainly due to shortage of soil moisture because of their coarse texture and arid climate, which make crop production very hazardous.

a) dIIIs soils

Soils in this subclass are mainly level to gently undulating, rapidly permeable;

medium textured with coarse textured topsoil.

b) dIIIc soils
Soils in this subclass are level to gently undulating, moderately coarse textured and occur in an arid climate. Their overriding limitation is lack of sufficient soil moisture.

Class IV. Unproductive land
Land in this class dose not have a potential for agriculture, grazing or forestry. Some parts may need afforestation or other measure to protect adjoining agricultural and, but this is not expected to yield economic returns of wood or other products.

a) IVe soils
This subclass comprises bad lands subject to erosion by water as well as coarse textured dune land which is subject to severe wind erosion.

b) IVs soils
This subclass comprises level to nearly level, medium to fine textured soils under an arid climate. The land supports very scarce natural vegetation.

D.5 Land Use

D.5.1 General

Land use survey was carried out through the review of existing reports, aerial photograph interpretation and additional field trips. The aerial photograph for the area was taken in 1992, which brought comprehensive and detailed information to the Study. Special emphasis was placed in the survey to understand seasonal change in the land use and to delineate each land use category. Major land use categories encountered in the area were cultivated area, grazing area, cultivable waste land, residential area and unproductive land. Cultivated area consists of tube well irrigation area, flood irrigation (Rod Kohi) area and rainfed agriculture (Barani) area. Unproductive land is mainly gullies, torrent water beds and their surroundings.

D.5.2 Present Land Use

The land in the Study Area is mainly used for crop production, grazing and residential area depending upon physiographic position, soil properties and irrigation water availability. Torrent-watered cultivation (Rod Kohi) is the dominant land use in the area, which is practiced near the mountain and along large nullahs (seasonal rivers). Cropped area, however, varies from year to year according to water availability. A part of the cultivated area is irrigated by tube wells, which covers only small patches. Rainfed agriculture is practiced mainly in the northern part of the area where receives relatively higher amount of rainfall. The major crops grown in the area are sorghum and millet in Kharif, and wheat, oilseed and gram in Rabi season.

Some land is unused or rarely used for cultivation, because the land is either too high or too distant to be irrigated by the torrents. Such land is covered with sparse natural vegetation, like *Prosopis spicigera* (Jand), *Acacia nilotica* (Kiker), *Zyzuphus* spp. (Ber), *Tamarix* spp. (Frash), *Capparis aphylla* (Karir), *Saueda fruticosa* (Lana) and *Calotropis* spp. (Ak). The major land use of this area is livestock grazing, firewood collection and/or cultivable waste. The remaining area is not used for agriculture due to irregular relief or higher elevation, which includes gullies, torrent beds, residential area, roads and others.

The various kinds of land use described are often combined in the Study Area so that it is not possible to distinguish each kind on a map as a pure unit. The present land use therefore is mapped as land use association containing small portions of other types of land use in addition to the major constituents. The land use map is shown in Fig. D.1.3, and land use associations are described as follows;

a) General cropping with tube well irrigation

Small patches of the area are irrigated by tube wells. They mainly occur in north-eastern part of the study area and are scattered near the D. I. Khan-Bannu road. Small patches are also found in southern end of the Study Area, which lies around Sarra Garra village. However, the groundwater quality of the area is rather poor in general, which may cause salinity problem in future. Most of the EC value of well water is as high as 2-4 mS/cm (1,500-3,000 ppm).

b) Restricted cropping with torrent flooding

This category is one of the major land use in the Study Area, which occurs on piedmont plain along torrents and nullahs. This land use partly includes rainfed cultivation area and cultivable waste. The acreage of torrent flooding fully depends on the amounts of rainfall and flood, and varies year to year. The area where flood water is not available is either rainfed cultivation area or waste land. The major crops of the area are millet and sorghum in Kharif and wheat in Rabi season.

c) Restricted cropping with rainfed cultivation

This area is cultivated without irrigation by canals, wells, torrent water nor river spills. A low rainfall is the only source of moisture. Some part of this category also includes flood irrigation area and cultivable waste as mentioned in the previous paragraph.

d) Poor grazing

This category of land use is mapped in scattered patches or belts of land throughout the Study Area. It also includes cultivable waste land. The area is not cultivated and has sparse vegetation of scrub and grasses which are grazed. Due to the lack of other natural grazing lands, most of the area is overgrazed.

e) Rarely used for restricted cropping

This unit is inaccessible to torrent water, due to either large distance from the torrent bed or higher elevation of the land. Some part of this area is embanked and prepared to receive torrent water, which fails in most of years. Normally the area is too dry to be cultivated with rainfall alone.

f) Not used

This unit consists of torrent beds, gullies and eroded lands which are not suitable for any kind of agriculture.

D.5.3 Future Land Use

The implementation of the Project will introduce revolutionary change in future land use in the area. Huge land where traditional cultivation is practiced with unreliable water resource will be converted into modern canal irrigated land. Under the "With Project" conditions, Rod Kohi area, Barani area and grazing and/or cultivable waste land will be irrigated. The extents of these areas are 27,100 ha, 73,700 ha and 26,900 ha, respectively. Some 10,000 ha out of these areas, however, will not be cultivated, because they will be used as irrigation and drainage canals, farm roads and field borders. Unproductive land such as gullies and torrent beds will remain uncultivated area in future land use. River training work, however, will be done to control flood water, and some of the torrents will be used as drainage channel. Residential area will be increased along with the Project implementation.

Another major beneficial impact of the Project on land use is reducing grazing pressure. Currently, most of the grazing land in and out of the Project area is overgrazed. It is anticipated that the Project will generate plenty of animal fodder, so that the need to graze the upper areas of the piedmont and the higher rangelands will be significantly reduced.

TABLES

Table D.1.1 List of Test Pits

No.	Location		Soil series	No.	Location		Soil series
1	31° 59' 19" N	70° 50' 05" E	Zindani	51	31° 40' 37" N	70° 35' 42" E	Zindani
2	32° 00' 49" N	70° 49' 34" E	Zindani	52	31° 39' 52" N	70° 36' 25" E	Gishkori
3	32° 01' 57" N	70° 49' 10" E	Gishkori	53	31° 40' 31" N	70° 37' 21" E	Tikken
4	32° 05' 52" N	70° 48' 48" E	Tikken	54	31° 42' 40" N	70° 37' 18" E	Tikken
5	32° 07' 25" N	70° 46' 07" E	Wajan	55	31° 41' 55" N	70° 31' 00" E	Gishkori
6	32° 01' 25" N	70° 50' 53" E	Zindani	56	31° 43' 33" N	70° 33' 21" E	Saggu
7	32° 02' 43" N	70° 51' 34" E	Zindani	57	31° 43' 09" N	70° 40' 42" E	Zindani
8	32° 04' 15" N	70° 51' 21" E	Zindani	58	31° 42' 34" N	70° 33' 55" E	Tikken
9	32° 05' 27" N	70° 52' 00" E	Gishkori	59	31° 45' 39" N	70° 33' 27" E	Saggu
10	32° 00' 49" N	70° 49' 34" E	Banda	60	31° 47' 27" N	70° 37' 21" E	Saggu
11	32° 04' 15" N	70° 42' 35" E	Gishkori	61	31° 45' 32" N	70° 39' 05" E	Saggu
12	32° 00' 25" N	70° 41' 25" E	Gishkori	62	31° 44' 58" N	70° 41' 37" E	Zindani
13	31° 56' 28" N	70° 41' 23" E	Zindani	63	31° 46' 33" N	70° 41' 25" E	Zindani
14	31° 56' 32" N	70° 43' 59" E	Saggu	64	31° 46' 45" N	70° 39' 41" E	Saggu
15	31° 52' 23" N	70° 45' 29" E	Tikken	65	31° 48' 05" N	70° 41' 55" E	Gishkori
16	31° 53' 41" N	70° 39' 15" E	Tikken	66	31° 52' 07" N	70° 43' 31" E	Zindani
17	31° 48' 25" N	70° 36' 38" E	Tikken	67	31° 48' 32" N	70° 33' 38" E	Zindani
18	31° 48' 55" N	70° 40' 59" E	Zindani	68	31° 50' 06" N	70° 33' 47" E	Gishkori
19	31° 46' 35" N	70° 31' 44" E	Saggu	69	31° 47' 39" N	70° 37' 57" E	Gishkori
20	31° 46' 18" N	70° 35' 44" E	Banda	70	31° 51' 36" N	70° 36' 18" E	Tikken
21	31° 48' 52" N	70° 40' 00" E	Zindani	71	31° 52' 57" N	70° 37' 37" E	Gishkori
22	31° 46' 57" N	70° 42' 02" E	Saggu	72	31° 52' 34" N	70° 42' 00" E	Zindani
23	31° 42' 04" N	70° 39' 57" E	Zindani	73	31° 54' 39" N	70° 35' 18" E	Tikken
24	31° 41' 00" N	70° 42' 50" E	Saggu	74	31° 54' 39" N	70° 37' 18" E	Zindani
25	31° 36' 47" N	70° 35' 14" E	Ramak	75	31° 54' 49" N	70° 41' 32" E	Tikken
26	31° 36' 14" N	70° 31' 08" E	Tikken	76	31° 53' 55" N	70° 42' 29" E	Zindani
27	31° 33' 04" N	70° 33' 32" E	Tikken	77	31° 56' 11" N	70° 39' 38" E	Gishkori
28	31° 33' 42" N	70° 36' 01" E	Ramak	78	31° 57' 32" N	70° 38' 26" E	Zindani
29	31° 30' 46" N	70° 35' 09" E	Wajan	79	31° 53' 32" N	70° 46' 11" E	Tikken
30	31° 26' 57" N	70° 34' 09" E	Tikken	80	31° 58' 32" N	70° 39' 57" E	Zindani
31	31° 23' 55" N	70° 35' 24" E	Gishkori	81	31° 01' 24" N	70° 39' 56" E	Saggu
32	31° 22' 35" N	70° 35' 04" E	Wajan	82	31° 00' 19" N	70° 41' 59" E	Tikken
33	31° 20' 26" N	70° 35' 29" E	Zindani	83	31° 58' 00" N	70° 41' 06" E	Zindani
34	31° 20' 45" N	70° 33' 41" E	Zindani	84	31° 57' 05" N	70° 45' 11" E	Saggu
35	31° 21' 26" N	70° 32' 19" E	Wajan	85	31° 57' 32" N	70° 47' 07" E	Saggu
36	31° 22' 24" N	70° 32' 41" E	Wajan	86	31° 55' 41" N	70° 48 11" E	Zindani
37	31° 22' 56" N	70° 36' 26" E	Gishkori	87	31° 58' 13" N	70° 49' 07" E	Zindani
38	31° 22' 45" N	70° 36' 29" E	Wajan	88	31° 59' 32" N	70° 49' 07" E	Tikken
39	31° 24' 45" N	70° 32' 23" E	Saggu	89	31° 59' 55" N	70° 46' 17" E	Zindani
40	31° 25' 58" N	70° 41' 59" E	Tikken	90	31° 01' 37" N	70° 44' 19" E	Zindani
41	31° 27' 58" N	70° 35' 37" E	Ramak	91	32° 02' 10" N	70° 39' 56" E	Saggu
42	31° 28' 25" N	70° 33' 24" E	Ramak	92	32° 02' 17" N	70° 44' 41" E	Tikken
43	31° 31' 45" N	70° 35' 49" E	Tikken	93	32° 03' 11" N	70° 42' 05" E	Tikken
44	31° 32' 29" N	70° 35' 44" E	Ramak	94	32° 01' 15" N	70° 46' 35" E	Zindani
45	31° 33' 49" N	70° 32' 00" E	Ramak	95	32° 02' 51" N	70° 46' 00" E	Zindani
46	31° 35' 11" N	70° 33' 46" E	Tikken	96	32° 05' 31" N	70° 43' 41" E	Gishkori
47	31° 38' 37" N	70° 36' 07" E	Gishkori	97	32° 07' 32" N	70° 44' 55" E	Tikken
48	31° 38' 40" N	70° 33' 49" E	Saggu	98	32° 05' 37" N	70° 50' 57" E	Gishkori
49	31° 38' 47" N	70° 30' 11" E	Saggu	99	32° 06' 42" N	70° 55' 06" E	Wajan
50	31° 37' 52" N	70° 33' 41" E	Saggu	100	32° 08' 37" N	70 '46' 34" E	Wajan

Table D.2.1 Results of Physical Analysis (1/3)

Pit No.	Depth (cm)	Soil Texture Clay (%)	Silt (%)	Sand (%)	Bulk Density (g/cc)	pF moisture 0.3 bar (%)	15 bar (%)	Kfs (cm/s)	om (cm2/s)	a (cm)	Kfs (cm/hr)
P1-1	0-13	41.5	43.7	14.8	1.70	25.4	10.2	0.00015	0.0012	8.000	0.54
P1-2	13-60	47.0	27.5	25.5	1.49	12.8	4.6	0.00031	0.0026	8.387	1.12
P1-3	60-120	21.8	26.7	51.5	1.45	20.4	5.3	0.00140	0.0120	8.571	5.04
P2-1	0-13	36.8	51.7	11.5	1.52	27.1	10.5	0.00085	0.0071	8.353	3.06
P2-2	13-60	32.1	53.8	14.1	1.35	32.8	17.6	0.00024	0.0020	8.333	0.86
P2-3	60-120	37.0	54.9	8.1	1.63	26.3	10.3	0.00040	0.0033	8.250	1.44
P3-1	0-15	33.8	49.4	16.8	1.53	21.0	7.9	0.00072	0.0060	8.333	2.59
P3-2	15-60	42.0	33.9	24.1	1.61	12.1	6.6	0.00210	0.0180	8.571	7.56
P3-3	60-110	32.1	20.9	47.0	1.69	13.3	8.6	0.00025	0.0020	8.000	0.90
P4-1	0-20	43.3	17.6	39.1	1.52	21.2	11.3	0.00033	0.0027	8.182	1.19
P4-2	20-60	16.0	11.9	72.1	1.45	11.9	4.2	0.00064	0.0053	8.281	2.30
P4-3	60-110	19.0	29.9	51.1	1.45	14.0	5.7	0.00055	0.0046	8.364	1.98
P5-1	0-20	7.7	12.8	79.5	1.54	1.6	0.4	0.03200	0.2600	8.125	115.20
P5-2	20-30	11.3	4.6	84.1	1.34	6.0	3.4	0.00110	0.0090	8.182	3.96
P5-3	30-60	17.5	17.7	64.8	1.40	-	-	0.00110	0.0087	8.182	3.96
P6-1	0-12	24.0	39.9	36.1	1.55	-	-	0.00025	0.0020	8.000	0.90
P6-2	12-55	31.0	24.3	44.7	1.58	-	-	0.00072	0.0060	8.333	2.59
P6-3	55-80	33.0	34.9	32.1	1.68	-	-	0.00048	0.0040	8.333	1.73
P7-1	0-11	34.8	30.4	34.8	1.54	19.2	9.9	0.00035	0.0029	8.286	1.26
P7-2	11-50	31.0	17.9	51.1	1.45	18.4	7.9	0.00120	0.0100	8.333	4.32
P7-3	50-75	17.8	10.4	71.8	1.47	-	-	0.00160	0.0130	8.125	5.76
P8-1	0-17	32.0	27.2	40.8	1.67	-	-	0.00010	0.0009	8.500	0.36
P8-2	17-53	28.0	31.9	40.1	1.41	-	-	0.00026	0.0021	8.077	0.94
P8-3	53-90	19.0	42.9	38.1	1.41	-	-	0.00072	0.0060	8.333	2.59
P9-1	0-15	31.0	21.3	47.7	1.60	-	-	0.00049	0.0041	8.367	1.76
P9-2	15-30	32.4	18.4	49.2	1.39	-	-	0.00110	0.0094	8.545	3.96
P9-3	30-52	30.2	21.3	48.5	1.42	-	-	0.00041	0.0034	8.293	1.48
P10-1	0- 5	7.8	2.4	89.8	1.54	-	-	0.01900	0.1600	8.421	68.40
P10-2	5-60	12.0	8.3	79.7	1.43	-	-	0.00410	0.0340	8.293	14.76
P10-3	60-120	15.0	8.3	76.7	1.41	-	-	0.00410	0.0340	8.293	14.76
P11-1	0-15	53.8	32.4	13.8	1.56	-	-	0.00010	0.0008	8.367	0.35
P11-2	15-60	40.8	30.4	28.8	1.33	-	-	0.00009	0.0008	8.370	0.33
P11-3	60-110	21.0	34.0	45.0	1.41	-	-	0.00340	0.0290	8.529	12.24
P12-1	0-17	42.0	44.9	13.1	1.57	-	-	0.00009	0.0007	8.295	0.32
P12-2	17-30	51.0	34.9	14.1	1.61	-	-	0.00003	0.0002	8.148	0.10
P12-3	30-110	57.0	27.3	15.7	1.53	-	-	0.00008	0.0007	8.333	0.28
P13-1	0-18	65.8	33.4	0.8	1.45	-	-	0.00048	0.0040	8.333	1.73
P13-2	18-65	51.0	38.5	10.5	0.99	-	-	0.00006	0.0005	8.387	0.22
P13-3	65-110	61.5	28.7	9.8	1.56	-	-	0.00002	0.0002	8.261	0.08

Table D.2.1 Results of Physical Analysis (2/3)

Pit No.	Depth (cm)	Soil Texture Clay (%)	Silt (%)	Sand (%)	Bulk Density (g/cc)	pF moisture 0.3 bar (%)	15 bar (%)	Kfs (cm/s)	om (cm2/s)	a (cm)	Kfs (cm/hr)
P14-1	0-11	71.0	24.9	4.1	1.59	32.7	23.0	0.00007	0.0006	8.333	0.26
P14-2	11-62	74.8	19.4	5.8	1.64	28.3	17.4	0.00011	0.0009	8.545	0.40
P14-3	62-110	31.0	23.3	45.7	1.63	23.8	16.0	0.00078	0.0065	8.333	2.81
P15-1	0-13	13.8	6.7	79.5	1.50	17.0	8.4	0.00010	0.0010	8.636	0.40
P15-2	13-33	15.0	10.5	74.5	1.38	25.8	10.9	0.00250	0.0210	8.400	9.00
P15-3	33-60	13.8	12.7	73.5	1.36	22.7	7.7	0.00510	0.0430	8.431	18.36
P16-1	0-12	28.0	31.9	40.1	1.37	25.4	13.4	0.00089	0.0074	8.315	3.20
P16-2	12-33	19.0	23.3	57.7	1.55	24.5	13.0	0.00010	0.0001	8.500	0.36
P16-3	33-60	11.0	4.4	84.6	1.42	28.0	15.4	0.00190	0.0160	8.421	6.84
P16-4	60-90	28.0	25.3	46.7	1.57	-	-	0.00190	0.0160	8.421	6.84
P17-1	0-11	37.0	36.3	26.7	1.28	18.6	6.4	0.00110	0.0092	8.364	3.96
P17-2	11-33	43.0	33.9	23.1	1.40	9.5	2.5	0.00250	0.0200	8.000	9.00
P17-3	33-80	19.5	54.7	25.8	1.44	17.2	14.5	0.00050	0.0042	8.400	1.80
P18-1	0-15	46.0	31.9	22.1	1.56	25.1	17.0	0.00007	0.0006	8.333	0.26
P18-2	15-43	37.0	31.3	31.7	1.51	24.7	16.8	0.00860	0.0720	8.372	30.96
P18-3	43-75	0.0	19.9	80.1	1.46	24.9	16.2	0.00029	0.0024	8.276	1.04
P19-1	0-15	47.2	29.3	23.5	1.54	23.8	17.5	0.00006	0.0014	24.561	0.21
P19-2	15-40	41.2	27.3	31.5	1.69	26.7	17.9	-	-	-	0.00
P19-3	40-68	29.9	48.0	22.1	1.68	-	-	-	-	-	0.00
P20-1	0-20	22.0	31.3	46.7	1.38	12.1	8.5	0.00310	0.0260	8.387	11.16
P20-2	20-50	12.0	14.3	73.7	1.34	9.8	4.6	0.00270	0.0220	8.148	9.72
P20-3	50-100	9.1	4.9	86.0	1.40	7.6	2.4	0.00840	0.0700	8.333	30.24
P21-1	0-20	31.0	40.3	28.7	1.34	24.9	15.5	0.00018	0.0015	8.333	0.65
P21-2	20-59	47.0	23.3	29.7	1.50	24.0	20.5	0.00002	0.0002	8.500	0.07
P21-3	59-90	47.0	34.3	18.7	1.49	26.9	20.1	0.00004	0.0003	8.293	0.15
P22-1	0-15	50.0	33.3	16.7	1.51	31.2	23.9	0.00007	0.0006	8.333	0.26
P22-2	15-28	59.0	28.3	12.7	1.56	-	-	0.00002	0.0002	8.261	0.08
P22-3	28-75	28.0	51.3	20.7	1.43	27.3	23.1	0.00006	0.0005	8.364	0.20
P23-1	0-13	52.0	31.9	16.1	1.65	-	-	0.00007	0.0006	8.406	0.25
P23-2	13-30	37.0	43.3	19.7	1.38	-	-	0.00660	0.0006	8.333	0.24
P23-3	30-50	30.0	50.3	19.7	1.45	-	-	0.00040	0.0034	8.500	1.44
P24-1	0-12	61.0	36.9	2.1	1.65	-	-	0.00006	0.0050	8.276	0.21
P24-2	12-40	56.0	33.3	10.7	1.40	-	-	0.00056	0.0047	8.393	2.02
P24-3	40-80	59.0	38.5	2.5	1.43	-	-	0.00100	0.0087	8.700	3.60
P25-1	0-12	69.0	24.9	6.1	1.64	-	-	0.00020	0.0017	8.500	0.72
P25-2	12-30	65.0	18.9	16.1	1.68	-	-	0.00043	0.0036	8.372	1.55
P25-3	30-100	66.0	20.9	13.1	1.70	-	-	0.00043	0.0036	8.372	1.55

Table D.2.1 Results of Physical Analysis (3/3)

Pit No.	Depth	Soil Texture Clay	Silt	Sand	Bulk Density	pF moisture 0.3 bar	15 bar	Kfs	om	a	Kfs
	(cm)	(%)	(%)	(%)	(g/cc)	(%)	(%)	(cm/s)	(cm2/s)	(cm)	(cm/hr)
P26-1	0-12	37.0	48.3	14.7	1.60	-	-	0.00051	0.0043	8.431	1.84
P26-2	12-35	23.0	13.3	63.7	1.44	-	-	0.00150	0.0130	8.667	5.40
P26-3	35-70	28.0	14.3	57.7	1.66	-	-	0.00037	0.0031	8.378	1.33
P27-1	0-13	20.0	9.9	70.1	1.50	-	-	0.00480	0.0400	8.333	17.28
P27-2	13-70	22.0	12.3	65.7	1.36	-	-	0.00290	0.0240	8.276	10.44
P27-3	70-100	29.0	32.5	38.5	1.41	-	-	0.00640	0.0530	8.281	23.04
P28-1	0-20	37.0	31.9	31.1	1.69	-	-	0.00012	0.0010	8.333	0.43
P28-2	20-60	23.5	49.7	26.8	1.56	-	-	0.00093	0.0077	8.280	3.35
P28-3	60-90	55.0	24.9	20.1	1.61	-	-	0.00006	0.0005	82.281	0.23
P29-1	0-16	15.8	4.7	79.5	1.64	-	-	0.00200	0.0017	8.500	7.20
P29-2	16-50	25.8	7.4	66.8	1.64	-	-	0.00170	0.0140	8.235	6.12
P29-3	50-90	14.2	11.0	74.8	1.49	-	-	0.00560	0.0470	8.393	20.16
P30-1	0-15	29.8	12.7	57.5	1.51	-	-	0.00028	0.0023	8.214	1.01
P30-2	15-52	24.0	13.3	62.7	1.57	-	-	0.00140	0.0120	8.571	5.04
P30-3	52-90	14.0	8.3	77.7	1.35	-	-	0.00049	0.0041	8.367	1.76
P30-4	90-105	9.0	4.9	86.1	-	-	-	-	-	-	-
P31-1	0-13	43.8	18.7	37.5	1.70	25.5	16.0	0.00054	0.0045	8.333	1.94
P31-2	13-55	50.0	22.3	27.7	1.61	26.9	15.1	0.00180	0.0150	8.333	6.48
P31-3	55-87	41.0	20.7	38.3	1.40	13.6	11.8	0.00220	0.0190	8.636	7.92
P32-1	0-12	9.0	4.9	86.1	1.58	-	-	0.00820	0.0680	8.293	29.52
P32-2	12-60	13.8	4.7	81.5	1.60	-	-	0.01300	0.1100	8.462	46.80
P32-3	60-88	7.8	1.4	90.8	1.60	-	-	0.01300	0.1100	8.462	46.80
P33-1	0-13	35.3	12.6	52.1	1.42	-	-	0.00039	0.0032	8.205	1.40
P33-2	13-55	29.0	22.3	48.7	1.47	-	-	0.00180	0.0150	8.333	6.48
P33-3	55-85	34.0	28.3	37.7	1.55	-	-	0.00005	0.0004	8.367	0.18

Table D.2.2 Available Water Content of Major Soil Series

Soil series	Soil texture	Depth (cm)			pF moisture (%)			Bulk	Available water	
					0.3 bar	15 bar		Density	in 10cm	in 1m
		(a)	(b)	(b-a)	(c)	(d)	(c-d)	(g/cc)	(mm)	(mm)
TIKKEN		0	20	20	21.2	11.3	9.9	1.52	30.1	
	silty loam	20	60	40	11.9	4.2	7.8	1.45	45.0	
		60	100	40	14.0	5.7	8.3	1.45	47.9	123.0
TIKKEN		0	13	13	17.0	8.4	8.6	1.50	16.8	
	silty loam	13	33	20	25.8	10.9	14.9	1.38	41.0	
		33	100	67	22.7	7.7	15.0	1.36	136.9	194.6
ZINDANI		0	13	13	25.4	10.2	15.2	1.70	33.6	
	silty clay loam	13	60	47	12.8	4.6	8.2	1.49	57.2	
		60	100	40	20.4	5.3	15.2	1.45	87.9	178.7
ZINDANI		0	13	13	27.1	10.5	16.6	1.52	32.8	
	silty clay loam	13	60	47	32.8	17.6	15.3	1.35	96.8	
		60	100	40	26.3	10.3	16.0	1.63	104.3	233.8
GISHKORI		0	15	15	21.0	7.9	13.1	1.53	30.1	
	silty clay loam	15	60	45	12.1	6.6	5.4	1.61	39.3	
		60	100	40	13.3	8.6	4.7	1.69	31.9	101.3
GISHKORI		0	13	13	25.5	16.0	9.5	1.70	21.1	
	silty clay loam	13	55	42	26.9	15.1	11.8	1.61	79.7	
		55	100	45	13.6	11.8	1.8	1.40	11.3	112.0
SAGGU		0	11	11	32.7	23.0	9.7	1.59	16.9	
	silty clay	11	62	51	28.3	17.4	11.0	1.64	91.7	
		62	100	38	23.8	16.0	7.8	1.63	48.3	156.9
BANDA		0	20	20	12.1	8.5	3.7	1.38	10.1	
	sandy loam	20	50	30	9.8	4.6	5.2	1.34	20.8	
		50	100	50	7.6	2.4	5.2	1.40	36.7	67.5
WAJAN		0	20	20	1.6	0.4	1.2	1.54	3.7	
	loamy sand	20	30	10	6.0	3.4	2.6	1.34	3.5	
		30	100	70	6.0	2.4	3.6	1.40	35.4	42.6

Table D.2.3 Result of Chemical Analysis (1/5)

Pit No.	Depth	pH	EC 1:5	ECe	Total	Carbon			Available	CaSO4	CaCO3	CEC	Exchangeable Cations			
					Nitrogen	Organic	Inorganic	Total	phosphorous				Na	K	Ca	Mg
	(cm)		(mS/cm)	(mS/cm)	(%)	(%)	(%)	(%)	(ppm)	(%)	(%)	(meq/100g)	(meq/100g)	(meq/100g)	(meq/100g)	(meq/100g)
P1-1	0-13	8.46	0.05	0.18	0.016	0.14	1.32	1.46	5.57	Nil	11.0	29.94	2.70	0.51	24.40	2.33
P1-2	13-60	8.65	0.08	0.32	0.016	0.10	1.32	1.42	3.04	Nil	11.0	25.67	3.91	0.36	19.40	2.00
P1-3	60-120	8.98	0.08	0.43	0.009	0.13	2.52	2.65	1.50	Nil	21.0	12.75	2.26	0.15	10.00	0.33
P2-1	0-13	8.74	0.02	0.05	0.014	0.13	1.80	1.93	4.81	Nil	15.0	27.39	0.61	0.72	25.40	0.67
P2-2	13-60	8.56	0.04	0.20	0.013	0.12	2.04	2.16	4.05	Nil	17.0	22.49	2.78	0.31	18.40	1.00
P2-3	60-120	8.22	0.09	0.47	0.012	0.05	1.92	1.97	2.74	Nil	16.0	43.26	2.96	0.31	38.00	2.00
P3-1	0-15	9.02	0.02	0.07	0.013	0.16	1.80	1.96	4.98	Nil	15.0	25.52	0.78	0.67	23.40	0.67
P3-2	15-60	8.55	0.06	0.33	0.015	0.11	1.56	1.67	8.96	Nil	13.0	46.08	3.65	0.36	40.40	1.67
P3-3	60-110	8.34	0.08	0.45	0.014	0.16	1.56	1.72	1.74	Nil	13.0	22.42	2.61	0.41	18.40	1.00
P4-1	0-20	8.71	0.02	0.08	0.010	0.12	1.68	1.80	6.72	Nil	14.0	19.75	0.87	0.62	17.60	0.67
P4-2	20-60	8.02	0.06	0.32	0.010	0.09	1.86	1.95	6.84	Nil	15.5	17.84	0.96	0.15	16.40	0.33
P4-3	60-110	8.00	0.07	0.40	0.010	0.09	1.86	1.95	5.82	Nil	15.5	33.08	1.48	0.21	30.40	1.00
P5-1	0-20	8.44	0.01	0.03	0.002	0.02	0.60	0.62	7.60	Nil	5.0	11.36	0.09	0.21	10.40	0.67
P5-2	20-30	8.86	0.01	0.02	0.002	0.03	0.66	0.69	1.74	Nil	5.5	22.39	0.17	0.15	21.40	0.67
P5-3	30-60	8.40	0.01	0.03	0.002	0.13	1.20	1.33	6.23	Nil	10.0	32.61	0.96	0.26	30.40	1.00
P6-1	0-12	8.86	0.02	0.06	0.019	0.32	1.74	2.06	12.70	Nil	14.5	31.57	0.87	0.56	28.80	1.33
P6-2	12-55	8.68	0.02	0.09	0.010	0.24	1.86	2.10	6.47	Nil	15.5	27.39	0.87	0.26	24.60	1.67
P6-3	55-80	8.66	0.03	0.18	0.011	0.13	1.92	2.05	4.48	Nil	16.0	36.05	1.04	0.21	32.80	2.00
P7-1	0-11	8.28	0.05	0.18	0.015	0.06	1.62	1.68	9.37	Nil	13.5	35.86	1.57	0.90	32.40	1.00
P7-2	11-50	8.65	0.02	0.06	0.007	0.09	1.92	2.01	3.24	Nil	16.0	22.45	0.61	0.31	20.20	1.33
P7-3	50-75	9.00	0.02	0.04	0.011	0.13	1.80	1.93	27.64	Nil	15.0	14.48	0.96	0.26	12.60	0.67

Table D.2.3 Result of Chemical Analysis (2/5)

Pit No.	Depth (cm)	pH	EC 1:5 (mS/cm)	ECe (mS/cm)	Total Nitrogen (%)	Carbon Organic (%)	Carbon Inorganic (%)	Carbon Total (%)	Available phosphorous (ppm)	CaSO4 (%)	CaCO3 (%)	CEC (meq/100g)	Exchangeable Cations Na (meq/100g)	Exchangeable Cations K (meq/100g)	Exchangeable Cations Ca (meq/100g)	Exchangeable Cations Mg (meq/100g)
P8-1	0-17	8.81	0.04	0.18	0.015	0.27	1.68	1.95	6.23	Nil	14.0	19.62	2.26	0.56	15.80	1.00
P8-2	17-53	8.93	0.04	0.18	0.012	0.17	1.92	2.09	5.82	Nil	16.0	26.91	2.09	0.36	22.80	1.67
P8-3	53-90	8.67	0.06	0.23	0.011	0.20	2.04	2.24	2.79	Nil	17.0	20.87	2.26	0.21	17.40	1.00
P9-1	0-15	8.71	0.02	0.07	0.011	0.09	0.96	1.05	5.48	Nil	8.0	23.81	0.70	0.51	21.60	1.00
P9-2	15-30	8.62	0.14	0.06	0.013	0.07	0.85	0.92	4.58	Nil	9.2	18.74	0.69	0.45	21.00	0.98
P9-3	30-52	8.50	0.14	0.06	0.010	0.06	0.73	0.79	5.25	Nil	10.7	15.21	0.72	0.51	22.50	0.96
P10-1	0- 5	8.48	0.01	0.02	0.001	0.10	0.42	0.52	5.32	Nil	3.5	11.75	0.26	0.15	11.00	0.33
P10-2	5-60	8.51	0.01	0.02	0.003	0.05	0.48	0.53	5.02	Nil	4.0	21.83	0.09	0.21	21.20	0.33
P10-3	60-120	8.43	0.01	0.02	0.003	0.13	0.54	0.67	4.98	Nil	4.5	24.91	0.09	0.15	24.00	0.67
P11-1	0-15	8.46	0.02	0.10	0.014	0.08	1.56	1.64	4.56	Nil	13.0	32.46	1.30	0.82	29.00	1.33
P11-2	15-60	8.62	0.03	0.56	0.010	0.18	2.16	2.34	3.80	Nil	18.0	25.39	1.83	0.56	22.00	1.00
P11-3	60-110	8.26	0.04	0.21	0.010	0.14	1.92	2.06	5.82	Nil	16.0	19.76	2.43	0.26	16.40	0.67
P12-1	0-17	8.59	0.03	0.13	0.020	0.15	1.62	1.77	9.96	Nil	13.5	43.64	1.30	0.51	40.20	1.67
P12-2	17-30	8.75	0.02	0.05	0.013	0.06	1.62	1.68	5.48	Nil	13.5	19.20	1.30	0.56	16.00	1.33
P12-3	30-110	8.77	0.03	0.08	0.014	0.09	1.56	1.65	11.70	Nil	13.0	27.20	2.09	0.51	22.60	2.00
P13-1	0-18	8.63	0.06	0.23	0.022	0.25	1.50	1.75	10.13	Nil	12.5	18.18	3.39	0.72	13.40	0.67
P13-2	18-65	8.27	0.22	0.78	0.021	0.10	1.56	1.66	6.84	Nil	13.0	33.84	7.04	0.46	25.00	1.33
P13-3	65-110	8.24	0.08	0.60	0.018	0.20	1.44	1.64	5.82	Nil	12.0	36.28	7.13	0.62	26.20	2.33
P14-1	0-11	7.91	0.19	0.64	0.030	0.16	1.50	1.66	10.63	Nil	12.5	50.16	7.13	0.62	40.20	2.67
P14-2	11-62	8.08	0.11	0.14	0.013	0.28	1.32	1.60	7.34	Nil	11.0	37.09	6.52	0.77	27.80	2.00
P14-3	62-110	8.61	0.13	0.58	0.014	0.16	1.74	1.90	6.72	Nil	14.5	30.01	4.87	0.41	23.40	1.33

Table D.2.3 Result of Chemical Analysis (3/5)

Pit No.	Depth	pH	EC 1:5	ECe	Total	Carbon			Available	CaSO4	CaCO3	CEC	Exchangeable Cations			
					Nitrogen	Organic	Inorganic	Total	phosphorous				Na	K	Ca	Mg
	(cm)		(mS/cm)	(mS/cm)	(%)	(%)	(%)	(%)	(ppm)	(%)	(%)	(meq/100g)	(meq/100g)	(meq/100g)	(meq/100g)	(meq/100g)
P15-1	0-13	8.80	0.02	0.08	0.007	0.06	2.10	2.16	10.71	Nil	17.5	13.88	0.43	0.51	12.60	0.33
P15-2	13-33	8.98	0.01	0.05	0.004	0.01	1.68	1.69	6.47	Nil	14.0	11.22	0.43	0.26	10.20	0.33
P15-3	33-60	8.69	0.02	0.05	0.018	0.09	1.80	1.89	3.04	Nil	15.0	20.79	0.52	0.21	19.40	0.67
P16-1	0-12	8.31	0.03	0.13	0.017	0.10	1.62	1.72	10.63	Nil	13.5	17.45	0.96	0.36	14.80	1.33
P16-2	12-33	8.73	0.02	0.06	0.013	0.10	1.74	1.84	5.98	Nil	14.5	23.77	0.78	0.26	21.40	1.33
P16-3	33-60	8.75	0.01	0.06	0.003	0.04	1.86	1.90	4.73	Nil	15.5	24.66	0.43	0.15	23.40	0.67
P16-4	60-90	8.37	0.03	0.17	0.015	0.12	1.62	1.74	5.98	Nil	13.5	21.59	0.78	0.21	19.60	1.00
P17-1	0-11	8.58	0.03	0.13	0.020	0.23	1.68	1.91	3.49	Nil	14.0	25.39	0.70	0.56	22.80	1.33
P17-2	11-33	8.69	0.03	0.10	0.016	0.03	1.62	1.65	5.57	Nil	13.5	20.80	1.04	0.36	17.40	2.00
P17-3	33-80	8.65	0.04	0.20	0.014	0.17	1.86	2.03	1.99	Nil	15.5	27.12	1.30	0.15	24.00	1.67
P18-1	0-15	8.56	0.03	0.14	0.024	0.07	1.44	1.51	1.25	Nil	12.0	44.94	1.65	0.36	40.60	2.33
P18-2	15-43	8.31	0.03	0.14	0.019	0.12	1.62	1.74	5.32	Nil	13.5	18.97	0.78	0.26	16.60	1.33
P18-3	43-75	8.54	0.02	0.12	0.003	0.22	1.68	1.90	4.05	Nil	14.0	33.94	0.87	0.21	31.20	1.67
P19-1	0-15	8.29	0.03	0.14	0.013	0.06	1.74	1.80	4.73	Nil	14.5	25.90	0.87	0.56	22.80	1.67
P19-2	15-40	8.50	0.02	0.08	0.012	0.17	1.86	2.03	5.73	Nil	15.5	21.25	1.30	0.41	18.20	1.33
P19-3	40-68	7.99	0.08	0.23	0.014	0.06	1.74	1.80	7.73	Nil	14.5	26.41	2.17	0.31	21.60	2.33
P20-1	0-20	8.89	0.02	0.08	0.001	0.23	1.68	1.91	7.47	Nil	14.0	21.54	0.70	0.51	19.00	1.33
P20-2	20-50	8.76	0.01	0.05	0.002	0.16	1.80	1.96	4.23	Nil	15.0	21.86	0.35	0.31	20.20	1.00
P20-3	50-100	8.48	0.01	0.05	0.004	0.20	1.74	1.94	2.24	Nil	14.5	19.69	0.35	0.21	17.80	1.33
P21-1	0-20	8.52	0.03	0.21	0.015	0.25	1.50	1.75	2.74	Nil	12.5	31.02	0.96	0.46	27.60	2.00
P21-2	20-59	8.45	0.03	0.12	0.010	0.13	1.50	1.63	7.22	Nil	12.5	28.61	1.57	0.31	24.40	2.33
P21-3	59-90	8.46	0.03	0.01	0.009	0.10	1.26	1.36	5.98	Nil	10.5	26.80	1.30	0.36	22.80	2.33

Table D.2.3 Result of Chemical Analysis (4/5)

Pit No.	Depth	pH	EC 1:5	ECe	Total Nitrogen	Carbon Organic	Carbon Inorganic	Carbon Total	Available phosphorous	CaSO4	CaCO3	CEC	Exchangeable Cations Na	Exchangeable Cations K	Exchangeable Cations Ca	Exchangeable Cations Mg
	(cm)		(mS/cm)	(mS/cm)	(%)	(%)	(%)	(%)	(ppm)	(%)	(%)	(meq/100g)	(meq/100g)	(meq/100g)	(meq/100g)	(meq/100g)
P22-1	0-15	8.24	0.04	0.19	0.013	0.11	1.20	1.31	7.97	Nil	10.0	26.00	1.30	0.36	22.00	2.33
P22-2	15-28	9.02	0.02	0.09	0.003	0.02	1.56	1.58	5.73	Nil	13.0	27.77	1.83	0.62	23.00	2.33
P22-3	28-75	8.58	0.02	0.10	0.012	0.04	1.32	1.36	5.23	Nil	11.0	29.18	1.30	0.51	24.20	3.17
P23-1	0-13	8.25	0.03	0.09	0.023	0.10	1.32	1.42	6.84	Nil	11.0	14.77	0.87	0.56	12.00	1.33
P23-2	13-30	8.51	0.01	0.06	0.019	0.08	1.20	1.28	10.21	Nil	10.0	26.93	0.61	0.26	24.40	1.67
P23-3	30-50	8.78	0.02	0.07	0.023	0.23	1.20	1.43	6.23	Nil	10.0	21.95	0.96	0.26	19.40	1.33
P24-1	0-12	8.03	0.08	0.45	0.018	0.21	1.80	2.01	5.23	Nil	15.0	41.52	2.52	0.46	36.20	2.33
P24-2	12-40	8.11	0.06	0.30	0.017	0.09	2.04	2.13	0.75	Nil	17.0	26.99	1.74	0.51	22.40	2.33
P24-3	40-80	8.31	0.02	0.09	0.019	0.19	2.28	2.47	3.98	Nil	19.0	22.83	0.61	0.36	20.20	1.67
P25-1	0-12	8.19	0.02	0.09	0.018	0.03	1.20	1.23	9.87	Nil	10.0	27.04	0.78	1.13	23.80	1.33
P25-2	12-30	7.99	0.08	0.30	0.016	0.08	1.20	1.28	1.25	Nil	10.0	39.67	1.04	0.56	36.40	1.67
P25-3	30-100	7.87	0.13	0.36	0.008	0.07	1.32	1.39	5.80	Nil	11.0	31.53	2.26	0.67	26.60	2.00
P26-1	0-12	8.59	0.02	0.07	0.006	0.04	2.88	2.92	5.73	Nil	24.0	24.70	0.61	0.36	22.40	1.33
P26-2	12-35	8.78	0.01	0.07	0.010	0.11	2.88	2.99	5.73	Nil	24.0	21.98	0.52	0.26	20.20	1.00
P26-3	35-70	8.54	0.01	0.08	0.005	0.04	2.40	2.44	3.74	Nil	20.0	30.11	0.70	0.41	27.00	2.00
P27-1	0-13	8.33	0.01	0.03	0.003	0.06	1.80	1.86	5.32	Nil	15.0	19.64	0.17	0.67	17.80	1.00
P27-2	13-70	8.76	0.01	0.03	0.008	0.18	1.92	2.10	5.48	Nil	16.0	30.46	0.26	0.46	28.40	1.33
P27-3	70-100	8.36	0.02	0.14	0.011	0.04	2.04	2.08	2.28	Nil	17.0	22.75	0.61	0.21	20.60	1.33
P28-1	0-20	7.84	0.18	1.36	0.017	0.14	1.80	1.94	4.81	Nil	15.0	63.02	7.39	0.36	51.60	3.67
P28-2	20-60	7.86	0.30	1.41	0.014	0.11	1.56	1.67	3.24	Nil	13.0	55.73	5.13	0.67	47.60	2.33
P28-3	60-90	7.80	0.24	1.54	0.018	0.16	2.04	2.20	5.98	Nil	17.0	46.82	6.78	0.31	37.40	2.33

Table D.2.3 Result of Chemical Analysis (5/5)

Pit No.	Depth	pH	EC 1:5	ECe	Total	Carbon			Available	CaSO4	CaCO3	CEC	Exchangeable Cations			
					Nitrogen	Organic	Inorganic	Total	phosphorous				Na	K	Ca	Mg
	(cm)		(mS/cm)	(mS/cm)	(%)	(%)	(%)	(%)	(ppm)	(%)	(%)	(meq/100g)	(meq/100g)	(meq/100g)	(meq/100g)	(meq/100g)
P29-1	0-16	8.54	0.01	0.03	0.005	0.16	1.68	1.84	6.33	Nil	14.0	20.26	0.26	0.46	19.20	0.33
P29-2	16-50	8.57	0.01	0.03	0.007	0.07	1.44	1.51	3.54	Nil	12.0	27.95	0.52	0.56	25.20	1.67
P29-3	50-90	8.51	0.01	0.05	0.007	0.13	1.80	1.93	4.30	Nil	15.0	29.14	0.35	0.46	27.00	1.33
P30-1	0-15	8.40	0.01	0.05	0.014	0.15	1.20	1.35	7.34	Nil	10.0	22.51	0.17	0.67	21.00	0.67
P30-2	15-52	8.47	0.01	0.03	0.010	0.14	1.56	1.70	7.47	Nil	13.0	25.43	0.43	0.46	23.20	1.33
P30-3	52-90	8.60	0.01	0.03	0.005	0.14	1.32	1.46	3.49	Nil	11.0	21.53	0.09	0.31	19.80	1.33
P30-4	90-105	8.85	0.01	0.05	0.002	0.03	1.56	1.59	7.47	Nil	13.0	12.35	0.17	0.31	11.20	0.67
P31-1	0-13	5.57	0.01	0.04	0.021	0.16	1.44	1.60	5.48	Nil	12.0	20.52	1.04	0.87	17.60	1.00
P31-2	13-55	8.64	0.01	0.04	0.016	0.14	1.20	1.34	3.74	Nil	10.0	21.84	0.26	0.51	19.40	1.67
P31-3	55-87	8.42	0.01	0.04	0.007	0.14	2.16	2.30	8.10	Nil	18.0	36.17	0.43	0.21	33.20	2.33
P32-1	0-12	8.48	0.01	0.04	0.004	0.07	1.80	1.87	3.80	Nil	15.0	23.44	0.26	0.31	22.20	0.67
P32-2	12-60	8.43	0.01	0.07	0.003	0.03	1.68	1.71	5.06	Nil	14.0	14.87	0.35	0.10	14.00	0.33
P32-3	60-88	8.53	0.01	0.04	0.000	0.02	1.80	1.82	2.79	Nil	15.0	16.63	0.35	0.10	15.60	0.67
P33-1	0-13	8.40	0.01	0.05	0.014	0.16	1.68	1.84	4.56	Nil	14.0	18.93	0.43	0.56	16.60	1.33
P33-2	13-55	8.40	0.01	0.03	0.011	0.03	1.44	1.47	5.23	Nil	12.0	25.56	0.09	0.41	23.40	1.67
P33-3	55-85	8.38	0.01	0.03	0.011	0.08	1.68	1.76	4.23	Nil	14.0	26.03	0.09	0.21	23.40	2.33

Table D.3.1 Crop Suitability Classification of the Soils in the Study Area under Irrigating (1/3)

Soil series	Area (ha)	Land type	Slope	Texture	Drainage	Permeability	Effective soil depth	Consistency	Soil reaction (pH)	Crops	Suitability
Tikken	30,700	Level land	Level to nearly level	Silt loam, loam very fine sandy loam	Moderately well	Moderate	<50cm	Slightly sticky	8.2	Wheat	S1
										Cotton	S1
										Maize	S1
										Oilseeds	S1
										Gram	S1
										Millet	S1
										Sorghum	S1
										Paddy	S2
										Sugarcane	S3
										Berseem	S1
Zindani	32,420	Level land	Level to nearly level	Silty clay loam (stratified)	Moderately well	Moderate to slow	>50cm	Sticky	8.4	Wheat	S1
										Cotton	S2
										Maize	S1
										Oilseeds	S1
										Gram	S1
										Millet	S1
										Sorghum	S1
										Paddy	S2
										Sugarcane	S1
										Berseem	S1
Gishkori	13,310	Level land	Level to nearly level	Silty clay loam (structured)	Well drained	Moderate	>50cm	Sticky	8.4	Wheat	S1
										Cotton	S1
										Maize	S1
										Oilseeds	S1
										Gram	S1
										Millet	S1
										Sorghum	S1
										Paddy	S1
										Sugarcane	S1
										Berseem	S1

Table D.3.1 Crop Suitability Classification of the Soils in the Study Area under Irrigating (2/3)

Soil series	Area (ha)	Land type	Slope	Texture	Drainage	Permeability	Effective soil depth	Consistency	Soil reaction (pH)	Crops	Suitability
Saggu	18,560	Level land	Level to nearly level	Silty clay (homogenized)	Well drained	Moderately slow	>60cm	Sticky to very sticky	8.4	Wheat	S1
										Cotton	S3
										Maize	S2
										Oilseeds	S3
										Gram	S3
										Millet	S3
										Sorghum	S2
										Paddy	S2
										Sugarcane	S2
										Berseem	S2
Ramak	6,510	High land	Level to nearly level	Silty clay (homogenized)	Well drained	Moderately slow	>100cm	Very sticky	8.4	Wheat	S1
										Cotton	S3
										Maize	S2
										Oilseeds	S3
										Gram	S3
										Millet	S3
										Sorghum	S2
										Paddy	S2
										Sugarcane	S2
										Berseem	S2
Banda	1,780	High land	Irregular	Sandy loam (weakly homogenized)	Excessively drained	Rapid	<50cm	Very slightly sticky	8.4	Wheat	S2
										Cotton	NS
										Maize	S3
										Oilseeds	S2
										Gram	S1
										Millet	S1
										Sorghum	S2
										Paddy	NS
										Sugarcane	NS
										Berseem	NS

Table D.3.1 Crop Suitability Classification of the Soils in the Study Area under Irrigating (3/3)

Soil series	Area (ha)	Land type	Slope	Texture	Drainage	Permeability	Effective soil depth	Consistency	Soil reaction (pH)	Crops	Suitability
Wajan	5,820	High land	Rolling	Loamy sand	Excessively drained	Very rapid	-	Non sticky	8.2	Wheat	S3
										Cotton	NS
										Maize	NS
										Oilseeds	S2
										Gram	S2
										Millet	S2
										Sorghum	S3
										Paddy	NS
										Sugarcane	NS
										Berseem	NS

Table D.3.2 Crop Suitability rating of the Soils under Irrigation

Soil Series (Texture)	Area(ha) (%)	Wheat	Cotton	Maize	Oilseeds	Gram	Millet	Sorghum	Paddy	Sugarcane	Berseem
Tikken	34,500	S1	S1	S1	S1	S1	S1	S1	S2	S3	S1
(silty loam)	(27%)	26.5	26.5	26.5	26.5	26.5	26.5	26.5	21.2	13.3	26.5
Zindani	34,000	S1	S2	S1	S1	S1	S1	S1	S2	S1	S1
(silty clay loam)	(26%)	26.1	20.9	26.1	26.1	26.1	26.1	26.1	20.9	26.1	26.1
Gishkori	20,200	S1	S2	S1	S1	S1	S1	S1	S2	S1	S1
(silty clay loam)	(16%)	15.5	12.4	15.5	15.5	15.5	15.5	15.5	12.4	15.5	15.5
Saggu	25,400	S1	S3	S2	S3	S3	S3	S2	S2	S2	S2
(silty clay)	(20%)	19.5	9.8	15.6	9.8	9.8	9.8	15.6	15.6	15.6	15.6
Ramak	6,600	S1	S3	S3	S3	S3	S3	S2	S2	S2	S2
(silty clay)	(5%)	5.1	2.6	2.6	2.6	2.6	2.6	4.1	4.1	4.1	4.1
Banda	2,400	S2	NS	S3	S2	S1	S1	S2	NS	NS	NS
(sandy loam)	(2%)	1.4	0.0	0.9	1.4	1.8	1.8	1.4	0.0	0.0	0.0
Wajan	7,000	S3	NS	NS	S2	S2	S2	S3	NS	NS	NS
(loamy sand)	(5%)	2.7	0.0	0.0	4.3	4.3	4.3	2.7	0.0	0.0	0.0
Total Score		94.1	72.1	87.2	81.8	82.2	82.2	89.2	74.2	74.5	87.8
Rating		A	C	B	B	B	B	B	C	C	B

Note : Crop suitability was scored as S1=100, S2=80, S3=50, and NS=0. Then crop suitability score(CSS) was calculated by following equation;

CSS = (Crop suitability x Soil series area / Total area)

According to the total of CSS, general crop sutability was rated for each crop as follows; >=90 is "A", 90-80 is "B", and <80 is "C".

FIGURES

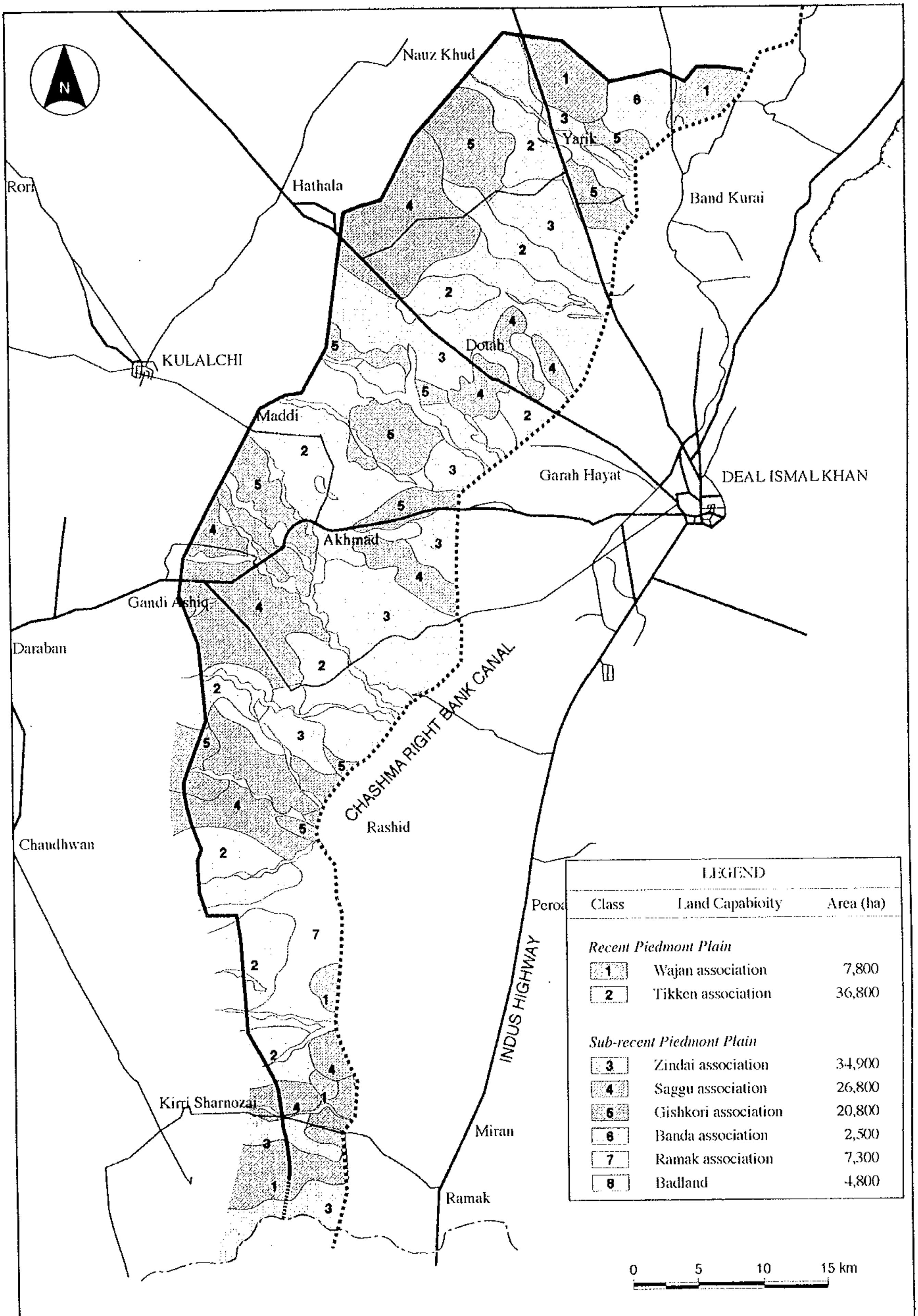

Fig. D.1.1 Soil Map of the Study Area

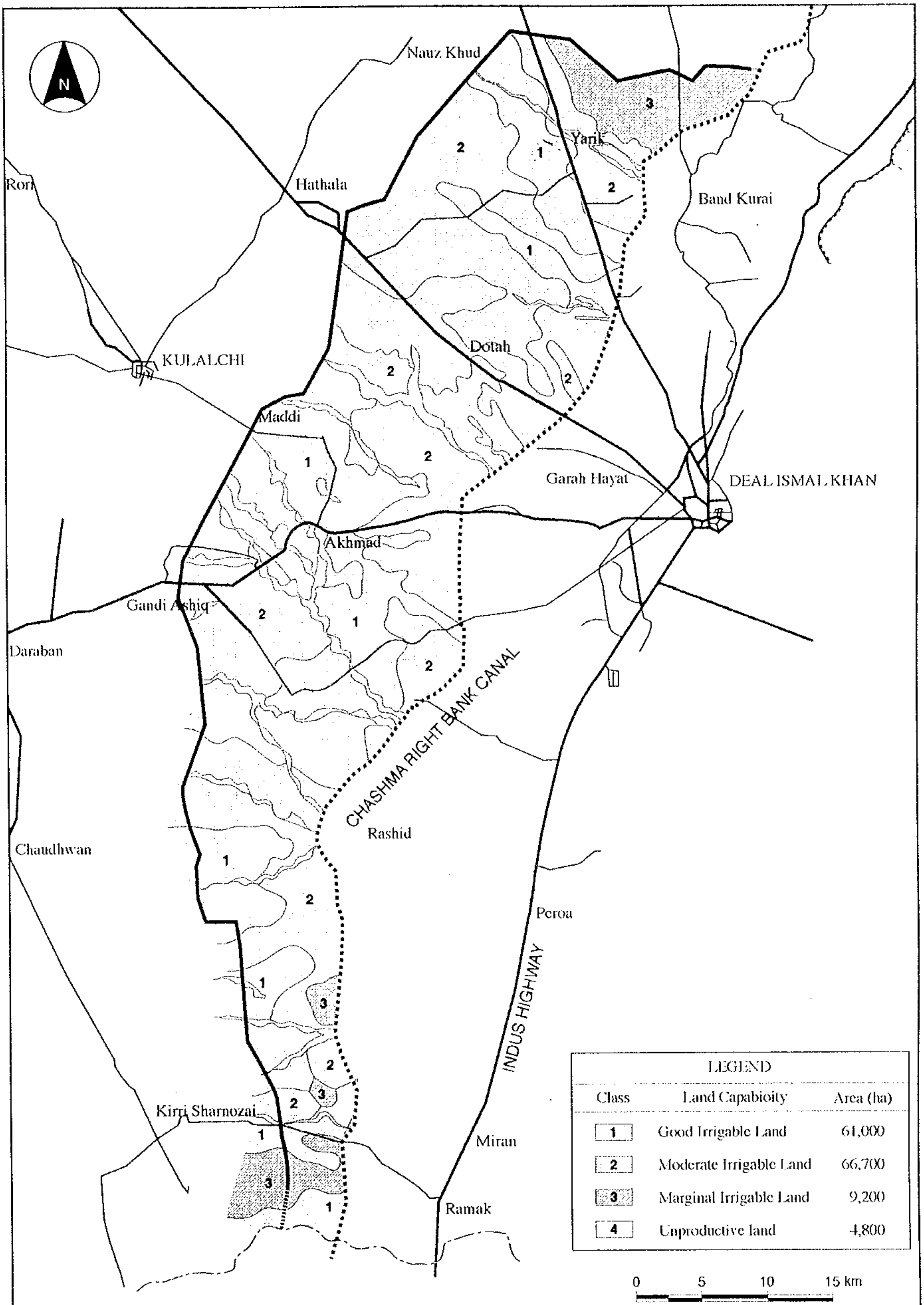

Fig. D.1.2 Land Capability Map of the Study Area

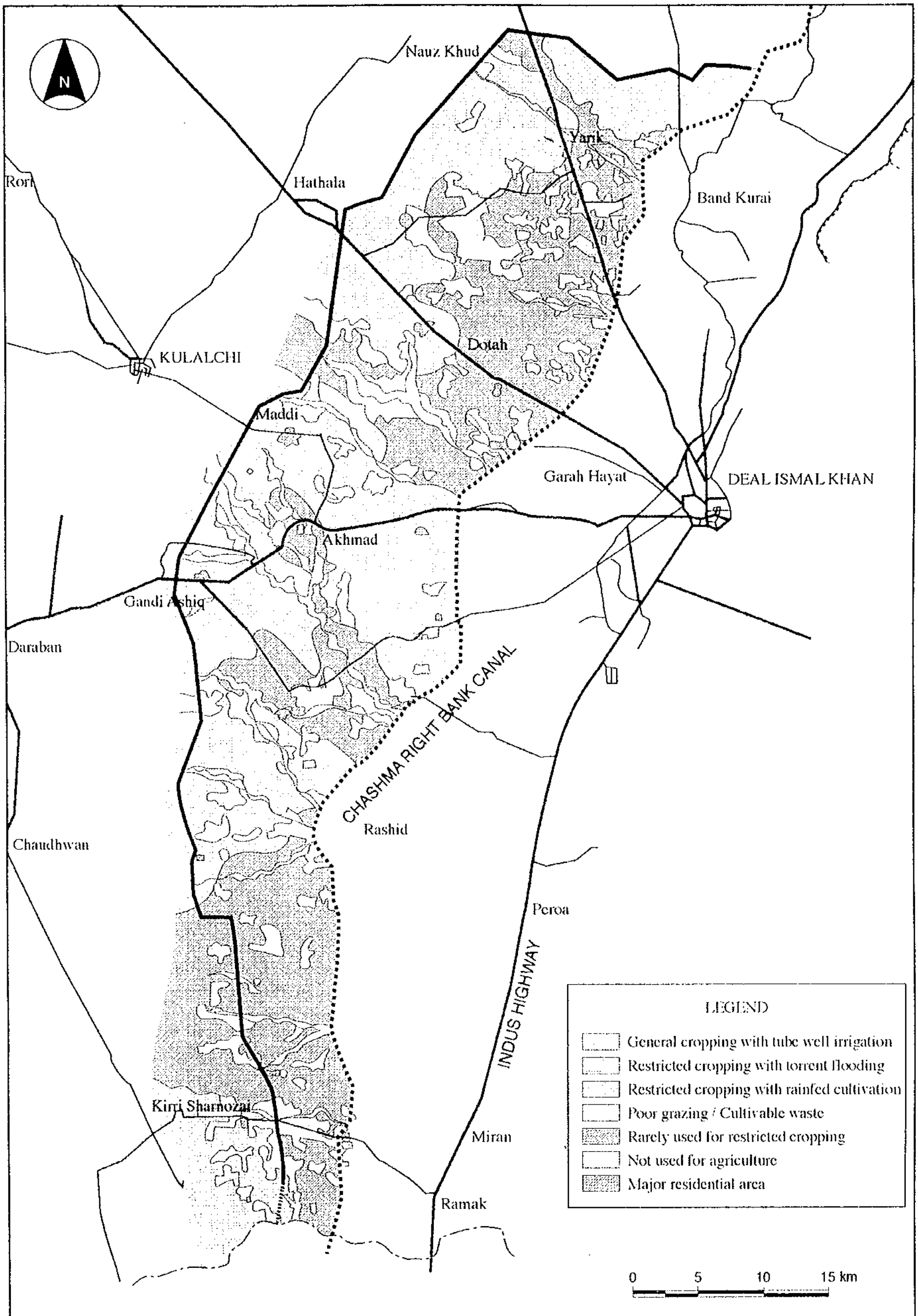

Fig. D.1.3 Present Land Use Map of the Study Area