WATER BALANCE STUDY WITH INADEQUATE HYDROLOGIC DATA - A CASE STUDY OF DANG VALLEY IN NEPAL

A DISSERTATION

submitted in partial fulfillment of the
requirements for the award of the degree
of
MASTER OF ENGINEERING
in
WATER RESOURCES DEVELOPMENT

By

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DECEMBER, 2001

CANDIDATE'S DECLARATION

I hereby declare that the dissertation entitled **"WATER BALANCE STUDY WITH INADEQUATE HYDROLOGIC DATA - A CASE STUDY OF DANG VALLEY IN NEPAL"**, being submitted by me in partial fulfillment of the requirement for award of the degree of Master of Engineering in Water Resources Development at the Water Resources Development Training Centre, Indian Institute of Technology, Roorkee is an authentic record of my own work carried out during the period from July 16, 2001 to December, 2001 under the supervision of **Dr. U.C.Chaube**, Professor, WRDTC, Indian Institute of Technology, Roorkee.

The matter embodied in this dissertation has not been submitted by me for the award of any other degree or diploma.

Dated: Dec. ,2001

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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(KRISHNA PRASAD SUVEDI)

SYNOPSIS

The dissertation study "Water Balance Study with Inadequate Hydrologic Data- A Case Study of Dang Valley in Nepal " is intended to develop regional approach for planning of micro/medium level water resource development schemes in an ungaged basin. Dang Valley in the inner Terai is part of mid-western development region , Rapti Zone , Nepal. It is the largest valley of Nepal.

The main objective of the water balance study of Dang valley is:

(i) to analyse various methods and evolve appropriate procedure to assess the availability of surface water resources with inadequate hydrologic data.

(ii) To assess existing and future water demand for various purposes.

(iii) To quantify the water surplus/deficit with geographic variation for irrigation development through minor and medium projects.

(iv) To prepare a regional approach for pre-feasibility study of minor irrigation schemes.

The main river in the valley is Babai river. The catchment area of the river in the valley is about 1431 km^2. It is estimated that 29% of the catchment is agriculture land, 51% forest land and 20% non vegetated land at present . Babai river originates in south east part of the valley from Churiya hill. It flows east to west following the southern boundary of the valley. It's own contribution for irrigation development in the valley is negligible due to topographical constraints. All the major tributaries of Babai river originate from Mahabharat mountain in the north and flow to south merging with Babai river. These streams are the main sources of water for development of micro/medium irrigation schemes.

National Water Development Agency (NWDA,India) guidelines for basin water balance study have been followed for estimation of water requirement for various purposes. There is about 42000 ha of agricultural land in the valley. The existing irrigation water requirement is computed as per existing cropping pattern in the valley. The future irrigation water requirement is estimated considering the changes in cropping pattern in future and possible irrigation area in future. Existing domestic water requirement in the valley has been computed based on the population of 2001 census, whereas future domestic water requirement is estimated for the projected population of 2050 AD. In the absence of data for industrial water need , the future industrial water requirement is adopted as being equal to the future domestic water requirement as per NWDA guidelines. The annual existing water requirement for irrigation and domestic purpose is estimated as 618.9 MCM and 7.9 MCM respectively. Whereas the estimated future annual requirement for irrigation, domestic and industrial use is 644.9 MCM, 24.9 MCM and 39.7 MCM respectively.

Water availability in the valley is computed using Regional Multiple Regression method , Regional Hydrograph method and Mock model . Comparative study of the methods shows that Mock model is more reliable for the estimation of monthly runoffs in ungaged catchments. The annual water available in the valley for irrigation diversion is estimated as 581.5 MCM

For irrigated agriculture, rainfall deficit is an indication of irrigation requirement. Rainfall deficit is defined as the difference of potential evapotranspiration (for albedo 0.25) and 80% dependable rainfall. It is therefore an important parameter in the planning of an irrigation scheme. Isopleth map of dependable rainfall, coefficient of variation of rainfall and rainfall deficit have been prepared. These maps are useful in estimating irrigation requirement in project command area for which observed climatic data are not available.

It is estimated from the surface water balance study of Dang valley that there is annual surplus of 22.9 MCM in existing condition and deficit of 11.82 MCM in future condition respectively.

It is concluded from the study that Mock model can be satisfactorily used to estimate the water availability of an ungaged catchment with meteorological data. The accuracy of the results depend on the calibration of model parameters such as soil moisture capacity, infiltration factor , ground water storage and ground water recession constant. Regional approach for planning of minor irrigation projects with the help of rainfall deficit maps and surface water availability estimation for ungaged catchment can be adopted for pre- feasibility type of study.

Following strategy is recommended for irrigation development in minor tributary sub-basins.

(i) Supplementary irrigation in the months of June and October when moisture availability index is less than 1.33 so that kharif crop production can be made reliable.

(ii) Water should be transferred from tributary sub-basin not having sizeable agriculture command area to other tributary sub-basins with sizeable command area so that irrigated food crop such as rice could be grown.

(iii) Present study be followed up for identification and quantification of water surplus/ deficit condition in each minor tributary sub-basin and suitable project sites for the purpose of planning of minor irrigation schemes as illustrated by one case study.

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CHAPTER – 1

INTRODUCTION

1.1 GENERAL

Water is the most precious gift of nature. It is the most critical need for sustaining life and is a resource input in almost all the activities of man, for drinking and municipal use, for irrigation to meet the growing food and fiber needs, for industries, power generation, navigation and recreation. The development, conservation and use of water, therefore, forms one of the main elements in the country's development planning. However, the rainfall in south Asian countries is confined to the monsoon season and is unevenly distributed both in space and time even during the monsoon season. At present Nepal is on the developing stage for irrigated agriculture. Major part of the country's agricultural land has no reliable irrigation system. As a result, the country is affected by frequent droughts. Hence, the available water resources needs to be harnessed in a scientific and efficient manner.

1.2 OBJECTIVE AND SCOPE OF STUDY

The main objective of water balance study of Dang Valley is :

(i) to analyse various methods and evolve appropriate procedure to assess the availability of surface water resources with inadequate hydrologic data.

(ii) to assess existing and future water demand for various purposes .

(iii) to quantify the water surplus/deficit with geographic variation through minor and medium projects.

A graphic procedure showing geographic variation of rainfall deficit in the valley will be developed for preparing maps. The maps will be useful tool for planning of minor irrigation projects under the condition of non availability or inadequate availability of data at first instance for pre-feasibility study. The study is expected to reveal the status of water availability and its uses in the valley, which will be useful for further planning of water resources development projects.

The study comprises the assessment of water yield in the valley, existing uses, the reasonable requirements in the foreseeable future and the determination of order of surplus /deficit.

1.3 THE STUDY AREA

1.3.1 Location

Babai basin in Dang valley lies in Dang district , Rapti zone , mid- western development region of Nepal.It is located between 27° 56′ 37 ″N to 28° 15′ 16″ N Latitude and 82° 0′ 37″ E to 82° 35′ 34″E Longitude. The valley is stretched from east to west and is about 62 Km long and the average width of valley is about 10 Km from north to south (Figure- 1.).

1.3.2 Topography and Physiography

Dang valley is stretched east to west bounded in north , east and west by Mahabharat range of mountain and south by Churiya hills.The hills on the northern side is covered with thick forest while on the south hill is covered with thin forest. The valley topography is plain and well drained. Babai river originates at the south east part of the valley from Churiya hill and flows along the southern boundary of the valley. It's tributaries originate from the Mahabharat Mountain in the north and flow south meeting the valley plain and merging into the Babai river. The elevation varies from 500 m at the outlet point of the valley to 2200 m at northern boundary.

1.3.3 Land Resources

Forest land , agriculture land and non vegetated land forms the land resources in the valley. The distribution of land is estimated as 51 % forest, 29 % agriculture and 20 % non- vegetated land respectively. The bounding hills of the valley comprises the main forest. Where as the valley land forms the agriculture land.

The land profile of the valley consists of undulating terraces near the foot hills with the soil texture varying sandy loam to silty clay loam.The major part of the valley land is gently sloping with fine loamy soil. The land profile and soil is suitable for irrigation in the valley.

1.3.4 Climate

The area falls within subtropical and warm temperate climatic zones of Nepal.Most part of the study area has subtropical climate except the mountaineous northern part, which has warm temperate climate.

1.3.4.1 Rainfall

Average annual rainfall of the area is 1700 mm. The basin receives about 85 % of the total annual rainfall in the monsoon season from June to September. The three meteorological station in the valley are: Nayabasti , Tulsipur and Ghorahi. The other two adjacent rain gauge station of the valley are at Kusum in Banke district and Luwamjula Bazar in Salyan district. The rainfall data at these station from the year 1971 to 1996 are given in Table - 1.1 to 1.5. The areal average of rainfall is computed from Thiessen polygon method and is given in Table-1. 6

1.3.4.2 Temperature and Humidity

The monthly mean temperature and relative humidity recorded at Ghorahi station is given in Table - 1.7 The maximum temperature 35°C occurs in the month of April and the minimum temperatures falls to 5°C in the month of January.

1.3.4.3 Wind Velocity

The monthly mean wind velocity data at Ghorahi is given in Table - 1.8.

1.3.4.4 Sunshine Hours

The monthly sunshine hours per day measured at Tulsipur is given in Table - 1.9

TABLE - 1.1

RAINFALL (MM)

STATION : NAYABASTI ($28^{0}13'$ N , $82^{0}07'$ E)
STATION NUMBER : 0507
ELEVATION : 698 M

Month → / Year ↓	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total
1971	18	31	25	147	111.4	280	324	283.8	119.6	75.6	0	0	1415.4
1972	0	21.6	0	0	0	116	269	175	236.9	8	4	0	830.5
1973	101	38	10	3	36	397	307	448	290	64	7	0	1701
1974	0	0	0	4	3	5	81.6	107.9	68.3	8	3	0	280.8
1975	7	0	0	0	3	126	474.8	489.6	170.8	40.6	0	0	1311.8
1976	0	0	0	0	90.2	163.5	354.3	304.4	158.3	15	0	0	1085.7
1977	0	13	0	34	82.5	133.5	499.1	262.1	85.8	28.2	0	55	1193.2
1978	23.8	48.9	13.5	18	56	373.4	320.2	319	331.7	11.3	0	0	1515.8
1979	6.3	62.1	7.7	6.3	98.3	313.4	421.3	517.4	19.4	30.2	0	50.8	1533.2
1980	2	22.9	24.9	0	61	302	661.3	445.6	510.5	12	0	0	2042.2
1981	62.2	10.1	30.4	3.4	109	264.1	228.4	305	494.1	0	110.4	23.3	1640.4
1982	48.6	22.2	87.1	10.2	76.5	168.2	416.1	631.6	498.6	74.7	85.1	6.1	2125
1983	27.3	7.1	0	11	201.7	69.1	312.1	376.1	307.1	252.8	0	29.2	1593.5
1984	44.3	8.3	0	0	13.5	587	922.1	240.1	414.6	17.3	0	7.1	2254.3
1985	17.6	0	0	35.1	61.6	318.2	595	527	501.2	189.6	0	29.9	2275.2
1986	0	52.7	7.2	45.7	145.6	255.3	422.3	460.9	396.2	62.3	14.5	61.7	1924.4
1987	8.2	0	7.1	13.8	84.5	104.8	717.4	469.4	186.5	71.4	0	13.1	1676.2
1988	0	10.7	40	25.8	91.4	208.2	578.8	634.5	104.3	5.5	0	37.1	1736.3
1989	72.2	0	13.4	0	51.5	243.3	747.8	561.2	372.7	3	21.6	7.5	2094.2
1990	0	100.9	82.2	1.5	155.9	414.9	563.7	417.6	361.1	56.4	0	26	2180.2
1991	60.2	10.3	72.9	25.8	16.6	271.4	334.2	431	349.8	0	0.1	71.2	1643.5
1992	33.2	11	0	9.7	60.3	78.9	331.3	263.6	377.3	1.5	7.1	0	1173.9
1993	4.3	9.7	73.7	60.9	121.8	268.2	384.5	475.8	327.2	0	0	0	1726.1
1994	49.4	36.9	0	4.5	60.8	328.8	348.2	501.8	239	0	0	0	1569.4
1995	39.3	27.1	34.7	0	82.2	338	401.8	845.2	210.8	2.2	93.1	0.9	2075.3
1996	39	65.7	0.4	22.2	0	323.6	556.5	611.6	210.8	139.1	0	0	1968.9
Total	663.9	610.2	530.2	481.9	1874.3	6451.8	11572.8	11105.2	7342.6	1168.7	345.9	418.9	42566.4
Mean	25.53	23.47	20.39	18.53	72.09	248.15	445.11	427.12	282.41	44.95	13.30	16.11	1637.17
S.D	27.58	25.31	28.20	30.74	51.11	129.02	183.10	163.05	143.95	62.79	31.18	22.26	468.83
C.V	1.08	1.08	1.38	1.66	0.71	0.52	0.41	0.38	0.51	1.40	2.34	1.38	0.29
n	26	26	26	26	26	26	26	26	26	26	26	26	26

TABLE - 1.2
RAINFALL (MM)

STATION : TULSIPUR ($28^0 08'$ N , $82^0 18'$ E)
STATION NUMBER : 0508
ELEVATION : 725 M

Month ► / Year ▼	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total
1971	18.3	25.4	23	133	90.8	420.6	398.8	462.4	231.8	138.6	32	0	1974.7
1972	0	38	0	5.3	0	102.2	431.9	186.9	347.2	26.1	3.6	0	1141.2
1973	142.2	44.2	13.9	5.4	65.6	638.6	344	383.9	409.7	178.6	23.8	0	2249.9
1974	24.3	5.4	11.9	0.6	12.7	124	404.7	527.6	205.5	20.6	0	3.5	1340.8
1975	62.2	8.6	5.2	0	37.5	330	634.2	398.6	234.7	98.9	0	0	1809.9
1976	16.7	11.7	0.4	10.9	91.2	246.9	459.2	597.6	238.3	8.2	0	0	1681.1
1977	0.6	0	0	49.7	71.6	108.6	498.9	309.2	148.2	99.1	0.5	14	1300.4
1978	22.3	72.9	32.3	8.5	49.7	396	471.9	340.6	311.9	42.5	0	8.4	1757
1979	25.4	96.1	0.8	10.1	136.2	442.4	541.1	327.4	55.1	84.5	8.5	54.1	1781.7
1980	5	21	10.5	0	134.2	412.9	567.9	368.8	432.5	29.5	0	0	1982.3
1981	25.7	0.7	12.1	37.4	187.9	385.8	488.2	314.4	569.2	0	55.8	10.6	2087.8
1982	39.3	2.9	82	6.7	111.2	343.4	208.2	539.9	419.9	69.1	22.2	8.9	1853.7
1983	25	7.1	1.1	2.6	97.7	71.1	348.9	423.9	460.5	303.5	0	45.3	1786.7
1984	40	1.8	0	4	51.6	433.2	562.1	260.5	465.6	31.6	0	17	1867.4
1985	8.5	4	0	16	73.7	169	442.4	536.7	405.5	181.9	0	41.8	1879.5
1986	0	45.8	0	23.2	103.9	350.7	462.1	263.4	225	34.7	2.1	48.2	1559.1
1987	1.8	1.7	8.5	22.4	75.9	161.1	475.5	551.4	148.5	59.3	0	14	1520.1
1988	2	2.5	43.9	44.4	44.3	247.4	799.2	488.9	175	6.1	0	33.5	1887.2
1989	63.4	0.6	6.1	0	118.4	176	506.8	562.5	211	39.5	26.2	3.5	1714
1990	0	57.1	69	0	98.3	322	429.3	294.9	103.4	51.9	0	0	1425.9
1991	15	0	20.4	29.7	24.1	216.6	285.2	317.6	364.8	0	0	41.7	1315.1
1992	22.1	9.5	0	28.4	25.8	161.4	168.2	315.7	255.2	123.3	6.2	6.2	1122
1993	10.1	7.4	55.1	48.1	140.2	346.4	188.4	579.5	210.6	1.5	0	0	1587.3
1994	40.8	34	0	0.6	32.5	196.4	263.2	251	173.4	0	0	0	991.9
1995	23.3	0	14.5	0	115.6	331.8	411.5	692	174.5	9.4	111.6	1.7	1885.9
1996	40.8	51	4.6	10.6	0	426.4	509.7	520.3	166.6	94.1	0	0	1824.1
Total	674.8	549.4	415.3	497.6	1990.6	7560.9	11301.5	10815.6	7143.6	1732.5	292.5	352.4	43326.7
Mean	25.95	21.13	15.97	19.14	76.56	290.80	434.67	415.98	274.75	66.63	11.25	13.55	1666.41
S.D.	29.78	26.09	22.60	28.17	47.76	137.52	140.47	132.19	130.50	72.22	24.64	18.05	316.37
C.V	1.15	1.23	1.41	1.47	0.62	0.47	0.32	0.32	0.47	1.08	2.19	1.33	0.19
n	26	26	26	26	26	26	26	26	26	26	26	26	26

TABLE - 1.3
RAINFALL (MM)

STATION : GHORAHI (MASINA) (28°03' N , 82°30' E)
STATION NUMBER : 0509
ELEVATION : 725 M

Month▶ Year▼	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total
1971	11.6	1.2	30.4	173.4	52.6	378.7	475.6	392.1	242.1	109	0	0	1866.7
1972	0	42.8	10.4	2.6	0	99.8	503.4	180.4	280.4	28.4	12.8	0	1161
1973	86.6	47.4	8.8	0	114.4	709.6	263.2	304.4	349	206.4	22.6	0	2112.4
1974	12.4	25.6	6.8	0	20.4	206.4	418.6	541.4	163.4	22.8	0	2.4	1420.2
1975	70.2	10.6	8.6	0	35.2	368.2	823.6	471.6	497.4	154.8	0	0	2440.2
1976	12.4	8.8	4.8	32.2	124	371.4	765.2	582.4	660.8	108	0	2.4	2672.4
1977	2	4	6.2	40.6	92.8	112	448	490	220.4	64.8	0	8.8	1489.6
1978	10	16.4	30.8	24.4	44.2	289.2	395.2	275	226	0	0	6.4	1317.6
1979	17	56.6	0	10.4	92	166.4	482	488	46	138	6	36	1538.4
1980	0	12	0	0	87	209.4	587	474.8	444.6	138	0	0	1952.8
1981	49.6	0	9	0	141.2	244.2	505.2	441	767.6	0	46.6	0	2204.4
1982	29.4	26.6	66.2	32	181.8	268.8	259.4	610.6	333.5	41.5	42.7	2.6	1895.1
1983	0	0	0	40	237	124.1	576.2	527.3	770.9	320.1	0	52.8	2648.4
1984	32.4	6.7	2.6	57.1	77.3	721.3	865.1	642.9	430.8	40.1	0	34	2910.3
1985	36.1	0	0	6.6	12	407.1	530.7	554.1	464.8	179.9	0	33.3	2224.6
1986	0	70.6	2.3	41.1	183.9	315	559.3	630.1	311.1	266.2	13.7	54.2	2447.5
1987	2.3	9	7.1	26.3	85.2	172.1	637.7	753.7	343.9	81.5	0	26.3	2145.1
1988	0	7.6	83.4	31.6	11.9	151.3	649.1	684.6	136.8	7.7	3.8	36.3	1804.1
1989	76.7	6.5	16.4	0	175.2	360.6	739.5	423	332.7	40	19.5	2.1	2192.2
1990	0	52.3	75.6	6.9	29.5	181.8	667.3	369.1	73.6	139.9	0	3.4	1599.4
1991	13.8	24.8	43	24.7	91.9	326.2	261	447.4	458.1	0	0	29.3	1720.2
1992	44.5	0	0	7.2	42.3	270.6	303.3	412.2	470.3	117.5	1.3	0	1669.2
1993	1.3	2.2	74.5	6.8	71.8	204.7	399.1	510.3	296.6	31.7	0	0	1599
1994	50	43.5	0	0	61.2	262.6	318.4	237.5	157.5	0	0	0	1130.7
1995	40.4	43	90.9	0	47.9	428	400	380.1	270.9	23.5	94.1	0	1818.8
1996	41	77.1	3.4	2.3	0	321.7	590.5	625	256.7	158.8	0	0	2076.5
Total	639.7	595.3	581.2	566.2	2112.7	7671.2	13423.6	12449	9005.9	2418.6	263.1	330.3	50056.8
Mean	24.60	22.90	22.35	21.78	81.26	295.05	516.29	478.81	346.38	93.02	10.12	12.70	1925.26
S.D.	26.13	23.57	29.92	35.33	62.39	155.26	171.84	139.84	187.52	86.30	21.43	18.01	467.54
C.V	1.06	1.03	1.34	1.62	0.77	0.53	0.33	0.29	0.54	0.93	2.12	1.42	0.24
n	26	26	26	26	26	26	26	26	26	26	26	26	26

TABLE - 1.4
RAINFALL (MM)

STATION : KUSUM ($28^{0}01'$ N , $82^{0}07'$ E)
STATION NUMBER : 0407
ELEVATION : 235 M

Month ▶ Year ▼	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total
1971	33.6	29	19	177.6	125.6	150.8	248.6	769.4	732.6	202.8	0	4.8	2493.8
1972	22.8	143.2	33.4	50	10	314.2	665.4	276	774.4	173	21	6	2489.4
1973	168.6	69.4	68.9	0	94.6	386.2	178.2	257.8	129.6	148	0	0	1501.3
1974	8	15	7	0	12.5	32.3	300.5	288.2	161.8	0	0	2	827.3
1975	0	6	0	0	1	94	473.4	296	90	76.5	0	0	1036.9
1976	**10.1**	**10.7**	**4.3**	**11.4**	**97.8**	**217.0**	**457.7**	**441.8**	**280.9**	**35.7**	**0.0**	**0.6**	**1567.825**
1977	0	0	0	0	58	28	101.5	216.7	51	0	0	5	460.2
1978	8.2	10.4	8	3.6	2.3	91.1	332.2	163.5	195.8	0	0	0	815.1
1979	0	9.8	0	0	55	67	61.5	209.1	24.8	57.5	0	49	533.7
1980	0	7.2	29	0	46	223.6	399.4	201.7	426	9	0	0	1341.9
1981	25.6	2	27.3	29.4	151.2	142.4	438.5	371.4	**551.45**	0	69.4	6.4	1815.05
1982	34.4	4	8	0	57.3	149	213	163.2	318	35	11.7	0	993.6
1983	0	6.3	2	14	169.9	74	198.3	196	394.8	3.2	0	46.8	1105.3
1984	51.2	2	5.2	51	164.4	214.2	498.8	80.2	167.6	36.1	0	7.1	1277.8
1985	3	0	0	3	66.4	141.5	272.5	460.1	213.4	145.5	0	0	1305.4
1986	0	17.5	0	13	31	282.5	244.3	146.6	123.7	46	4.2	73.4	982.2
1987	0	14.7	26.7	47.2	4.1	12.5	414.8	181.9	156.5	58.4	0	6.1	922.9
1988	2.1	15.8	35.9	14.1	33	140.1	578.7	492.8	70.8	13.3	0	22	1418.6
1989	92	11	5.9	0	30.7	252.1	587.7	271.2	347.9	33.9	0	12.3	1644.7
1990	0	106	68.4	3.5	268	146.6	399.8	170.1	109.8	21.3	0	35.3	1328.8
1991	41.4	10.3	22.1	14.4	38	132.7	160.1	367	187.5	0	0	28.8	1002.3
1992	69.6	0	0	0	0	140.9	195.3	327.5	515.7	208.1	8	10.9	1476
1993	4.1	7.7	77.6	22	119.7	227.3	349.1	688.8	268.3	0	0	0.1	1764.7
1994	48.3	39.9	1.3	4.5	40.1	215.4	456.7	391.5	366	0	0	0	1563.7
1995	11.4	26.4	17	0	176.4	357.9	337.3	563.3	149.6	0.5	76	3.2	1719
1996	37	75.5	0	36.5	0.7	414.5	338.9	443.3	339.1	86.4	0	0	1771.9
Total	671.4	639.8	467.0	495.2	1853.7	4647.8	8902.2	8435.1	7147.1	1390.2	190.3	319.8	35159.4
Mean	25.82	24.61	17.96	19.05	71.29	178.76	342.39	324.43	274.89	53.47	7.32	12.30	1352.28
S.D.	127.39	121.15	87.68	96.55	343.40	851.00	1624.40	1541.52	1312.65	260.63	39.51	60.94	501.23
C.V.	4.93	4.92	4.88	5.07	4.82	4.76	4.74	4.75	4.78	4.87	5.40	4.95	0.37
n	26	26	26	26	26	26	26	26	26	26	26	26	26

TABLE - 1.5
RAINFALL (MM)

STATION :LUWAMJULA BAZAR ($28^{0}18'$ N , $82^{0}17'$ E)
STATION NUMBER : 0512
ELEVATION : 885 M

Month ► / Year ▼	January	February	March	April	May	June	July	August	September	October	November	December	Annual Total
1971													
1972	6.4	29.7	39.9	16.3	0	116.1	260.2	119.2	196.6	43.3	5	0.7	833.4
1973	145.1	67.1	30.8	3.5	34.9	342	387.4	239.3	133.9	247.5	40.4	0	1671.9
1974	24.8	16.3	40.2	6.2	25	152.8	459.1	244.7	43.7	2.2	0	9.5	1024.5
1975	74.5	39.2	30.9	0	70.8	348.1	438.4	318.3	276.1	15.2	0	0	1611.5
1976	11.2	22.1	11.8	2.4	85.6	86.2	252.1	282.7	66.3	11.7	0	0	832.1
1977	9	10.4	1.6	54.9	41.3	288.3	322.6	202.7	72.6	10.9	0	29.7	1044
1978	11.8	73.8	86.5	32.6	54.1	352.5	367.2	296.2	145.2	0	3.5	9.4	1432.8
1979	22.4	83.4	12.9	73.8	215.3	119.8	349	205.4	7.2	39.2	6.2	115.9	1250.5
1980	0	43.4	69	0	94.4	239.7	456.3	250.2	253	5.5	0	0	1411.5
1981	52.6	4.2	48.5	39.8	102.7	188.7	292.5	229.6	374.9	0	73.6	14.6	1421.7
1982	64	12.1	173.4	20.2	126.9	114.6	274.5	253.7	273.1	6.1	14.9	10.6	1344.1
1983	36.6	5.3	5.9	36.5	152.8	123.2	229.6	243.1	308	205.4	0	27.2	1373.6
1984	58.4	0	5.6	10.7	5.5	198.5	467.8	73.7	310.7	24.5	0	32.3	1187.7
1985	0.1	0.1	0.3	15.6	75.2	130.7	340.5	309.5	243.9	169.5	0	64.5	1349.9
1986	1	29.1	17.1	55.5	15.6	362.3	182.9	113	199.9	14	0	75.7	1066.1
1987	9.2	14.8	0	61.9	67.5	139.4	341.7	200.9	55	111.9	3.2	18.2	1023.7
1988	3	15.5	57.3	39.8	63.8	167.4	399.1	372.9	82.6	8.2	0	52.5	1262.1
1989	68.6	7.5	40	0	91.9	134.1	345.8	214.5	170.8	50.5	33.8	0.3	1157.8
1990	0	121.4	134.9	0.2	124.2	131.9	165.7	57.5	87.8	8.2	0	33.4	865.2
1991	66.8	34.2	45.8	47.2	31.7	155.6	119.5	330.9	62.3	0	15.6	42.9	952.5
1992	35.3	22.6	0	0	39.5	57	97.2	225	118.8	84.9	0	0	680.3
1993	21.7	55.6	94	40.1	95.1	170.8	197.2	386.1	118.1	0	0	0	1178.7
1994	52.6	44	8.8	3.4	78.5	120.1	144.5	253	73.6	0	0	0	778.5
1995	31.5	40.1	43.6	0	3.6	178.1	99	416.6	155.2	0	20.7	7.2	995.6
1996	52.2	123.9	6.7	19.5	6.6	200.5	391.7	162.6	174.8	56.9	0	0	1195.4
Mean	34.35	36.63	40.22	23.20	68.10	184.74	295.26	240.05	160.16	44.62	8.68	21.78	1157.80
S.D.	33.28	33.75	42.91	22.62	50.75	86.23	114.09	88.92	96.53	67.17	17.08	28.79	254.13
C.V.	0.97	0.92	1.07	0.97	0.75	0.47	0.39	0.37	0.60	1.51	1.97	1.32	0.22
n	25	25	25	25	25	25	25	25	25	25	25	25	25

TABLE - 1.6

AREAL AVERAGE RAINFALL

Station No. →	Station (5)	Station (4)	Station (3)	Station (2)	Station (1)	Average
Place →	Luwamjula Bazar	Kusum	Ghorahi	Tulsipur	Nayabasti	Rainfall
Thiessen Weight →	0.049	0.052	0.333	0.371	0.194	
Month ↓						
January	34.4	25.8	24.6	26.0	25.5	25.8
February	36.6	24.6	22.9	21.1	23.5	23.1
March	40.2	18.0	22.4	16.0	20.4	20.2
April	23.2	19.0	21.8	19.1	18.5	20.1
May	68.1	71.3	81.3	76.6	72.1	76.5
June	184.7	178.8	295.0	290.8	248.1	272.6
July	295.3	342.4	516.3	434.7	445.1	451.8
August	240.1	324.4	478.8	416.0	427.1	425.3
September	160.2	253.7	346.4	274.8	282.4	293.1
October	44.6	53.5	93.0	66.6	45.0	69.4
November	8.7	7.3	10.1	11.3	13.3	10.9
December	21.8	12.3	12.7	13.6	16.1	14.1
Total						1702.9

TABLE - 1.7

TEMPERATURE AND RELATIVE HUMIDITY

STATION :GHORAHI

Month	Mean Temp.		Average	RH Mean (%)		Average RH
	1998	1999	Temperature	1998	1999	(%)
January	12.55	13.1	12.8	81.15	79	80.08
February	15.95	17.4	16.7	72.9	77.2	75.05
March	18.45	21.15	19.8	67	67.4	67.20
April	24.3	26.9	25.6	58.9	66.1	62.50
May	28.25	26.85	27.6	66.15	72.25	69.20
June	29.45	26.35	27.9	70.25	74.2	72.23
July	25.95	25.7	25.8	89.7	86.2	87.95
August	26.15	25.3	25.7	92	89.15	90.58
September	25.85	24.5	25.2	89.55	89.55	89.55
October	23.85	22.1	23.0	91.25	88.5	89.88
November	19.4	17.4	18.4	89.55	85.7	87.63
December	14.75	13.9	14.3	89.05	84.6	86.83

TABLE -1.8
WIND SPEED AND WIND FUNCTION

STATION :GHORAHI

Month	Wind speed (km/hr.)	Wind speed at 2.0 m height (km/hr.)	Wind speed (km/day)	f(U)
January	3.7	3.06	73.44	0.47
February	5.2	4.31	103.44	0.55
March	8.1	6.71	161.04	0.70
April	8	6.62	158.88	0.70
May	7.9	6.54	156.96	0.69
June	7.95	6.58	157.92	0.70
July	4.6	3.81	91.44	0.52
August	4.55	3.77	90.48	0.51
September	4.3	3.56	85.44	0.50
October	3.65	3.02	72.48	0.47
November	3.15	2.61	62.64	0.44
December	3.1	2.57	61.68	0.44

Remarks :Wind speed recorded is at 7.5 m height.

TABLE - 1.9
DAILY SUNSHINE HOURS AND f (n/N)

STATION :TULSIPUR

Month	Daily Sunshine hours(n)	Maximum daily Sunshine hours(N)	n/N	f(n/N)
January	7.7	10.7	0.72	0.75
February	7.6	11.3	0.67	0.71
March	8	12	0.67	0.71
April	8.5	12.7	0.67	0.71
May	7.9	13.3	0.59	0.64
June	6.1	13.7	0.45	0.51
July	3.7	13.5	0.27	0.35
August	5.1	13	0.39	0.45
September	5.25	12.3	0.43	0.49
October	7	11.6	0.60	0.64
November	8.9	10.9	0.82	0.83
December	5.9	10.6	0.56	0.61

FIGURE – 1·0

LOCATION MAP

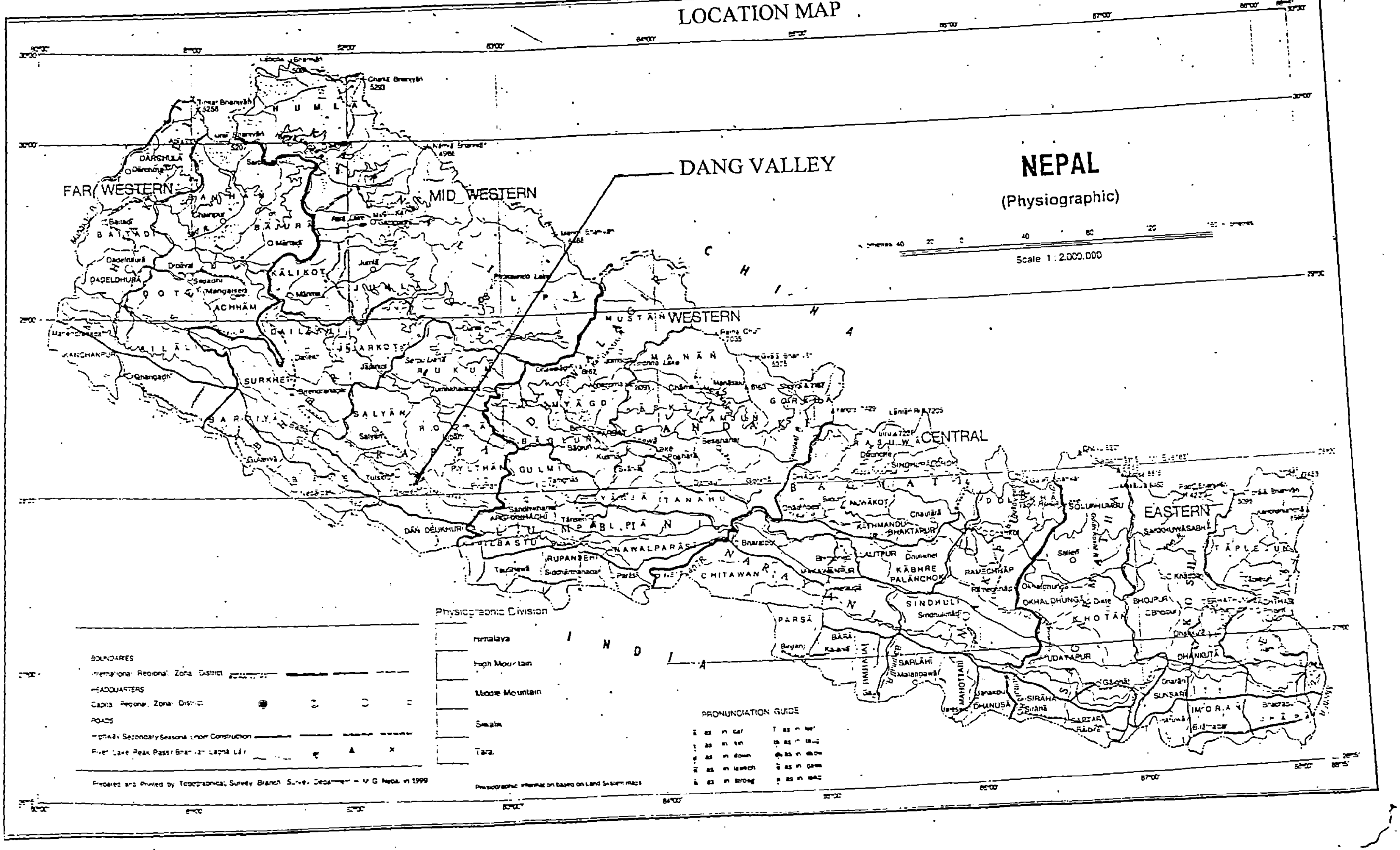
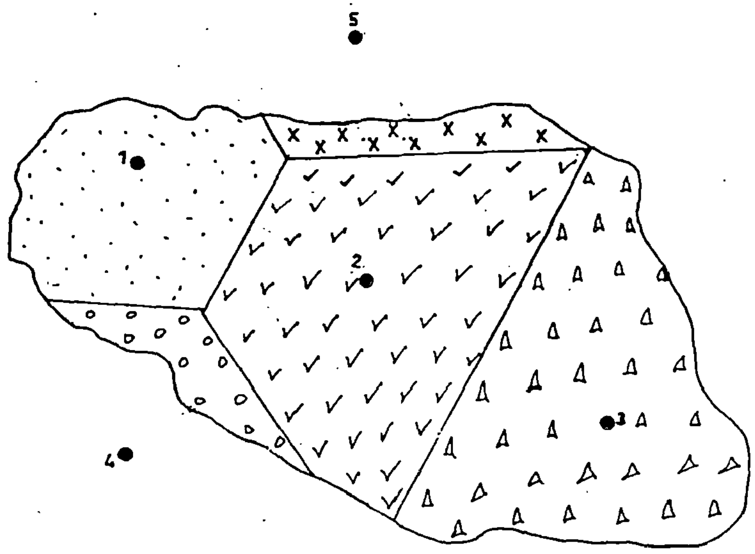


FIGURE – 1.1

THIESSEN POLYGON



SCALE 1:500000

TOTAL CATCHMENT AREA 1431 km^2

STATION		STATION No	THIESSEN POLYGON AREA	WELGHTAGE
NAYABASTI	1	0507	277.6	0.194
TULSIPUR	2	0508	530.9	0.371
GHORAHI (MASINA)	3	0509	476.1	0.333
KUSUM	4	0407	74.4	0.052
LUWAMJULA	5	0512	72	0.050

CHAPTER-2

ESTIMATION OF EXISTING AND FUTURE WATER DEMAND

2.1 GUIDELINES

Detailed guidelines for basin studies are not available in Nepal. However, irrigation water requirement is computed on climatological approach using modified Penman method. Domestic water requirement in practice is computed taking 45 liters per capita per day and 140 liters per capita per day for rural and urban water supply respectively. Therefore, guidelines evolved by National Water Development Agency (NWDA) for basin studies in India have been followed to compute water demands for basin water balance study.

NWDA Guidelines

Technical Advisory committee for NWDA has made following recommendations :

2.1.1 NWDA Guidelines-Irrigation Water Requirement

(1) The water requirement for irrigation should be worked out on climatological approach and reasonable provisions made for the field and transmission losses as well as evaporation from the storages.

(2) . The NWDA may adopt a figure of 60% for irrigation efficiency for the water balance studies in respect of major and medium projects.

(3) The evaporation losses may be based on the available data for the existing major and medium reservoirs in and around the basin. It was also decided that any figure for evaporation losses which is accepted in Tribunal Awards or agreements between the states may be taken for the NWDA studies for the concerned basin/sub-basin.

(4) Adopt 20% of the withdrawls from the reservoir as evaporation losses in the absence of actual data. TAC recommended same figure for minor schemes also.

(5) An irrigation efficiency of 55 % for major and medium irrigation projects with a regeneration value of 10% and an irrigation efficiency of 70% for minor projects without considering any regeneration.

(6) The intensity of irrigation in the case of existing and on going projects will be as per the present use. Under peninsular river development component for the future projects, the intensity may be assumed as 150% for major projects, 125% for medium projects and 100% for minor projects. The studies should also consider possibility of augmentation in the existing storage to increase the present intensity of irrigation, wherever this is less than the percentages indicated above for the future projects.

(7) Any surplus surface water for transfer considering the water needs of the basin for extending irrigation to 60% of net cultivable area.

(8) In water deficit area, the first attempt should be to cover at least 30% of the cultivable area of the basin/sub-basin by irrigation from surface water.

(9) In case of deficit basin/sub-basis where the percentage of existing irrigation from surface water is about 30% of the culturable area, extending irrigation facilities to 60% of the culturable area may be considered where the additional area to be brought under irrigation would be for a single dry crop without considering any high water consuming crop like sugarcane and paddy.

(10) Extension of irrigation from 30% to 60% of the culturable area in the deficit areas by way of transfer from other basins should also stand the scrutiny of economic criteria.

(11) In the water balance studies, value of 10% for regeneration from utilization by all major, medium and minor projects should be adopted.

(12) Before diversion of water , irrigation level of at least 60% of the culturable area as annual irrigation is being followed.

2.1.2 NWDA Guidelines -Domestic Water Requirement

(1) Consumptive use of domestic water use is 20% of the surface water diverted or lifted from the rivers, reservoirs, storages, canals etc.

(2) The per capita consumption for rural and urban population may be assumed as 70 litres and 200 litres respectively and for livestock population is 50 litres per livestock per day.

(3) The 50% of the rural water requirement and entire livestock water requirement is proposed to be met from ground water sources. The urban water requirement in full and 50% of the rural water requirement is to be met from surface water sources.

(4) In order to update the water balance studies, it was decided that while revising the studies, population projections may be made for 2050 A.D.

2.1.3 NWDA Guidelines -Industrial Water Requirement

(1) Consumptive use of industrial use is 2.5% of the surface water diverted or lifted from the rivers, reservoirs, storages, canals etc.

(2) Entire industrial water requirement is to be met from surface water sources.

2.2 IRRIGATION WATER REQUIREMENT

2.2.1 Crop Water Requirement

Crop water requirements are defined here as " the depth of water needed to meet the water loss through evapotranspiration (Etcrop) of a disease free crop , growing in large fields under non restricting soil conditions including soil water and fertility and achieving full production potential under the given growing environment".

For estimating the surface water needs for irrigation, an assessment has been made of the area that can be brought under irrigation and the reasonable requirement for irrigating the area. The total command area that can be brought under irrigation by surface water is 42000 ha. The existing and future cropping pattern is given in fig. 2.1 and 2.2 respectively. The existing cropping pattern is based on the information from

District Agriculture Office , Dang . The proposed cropping pattern is based on present trend of agriculture in the valley and to meet the future requirement. It is assumed that new projects will be implemented to meet the irrigation water demand for the proposed area in the future. Irrigation water requirement is calculated on the basis of climatological approach for each crop.

As the study area has measured data on temperature, humidity, wind speed and sunshine duration, Modified Penman method is used to estimate the crop water requirement
The temperature , relative humidity and wind speed data is from Ghorahi station and the daily sunshine duration is taken from Tulsipur station for computation. The areal average rainfall for the valley is used for effective rainfall computation.

2.2.2 Irrigation Water Needs for Crops

The irrigation water need (IN) for all field crops except paddy is determined as follows :

IN = Etcrop - Pe

Where ,

Etcrop =ETo*Kc

ETo = reference crop evaopotranspiration

Kc = crop coeffcient

Pe = effective rainfall

= 0.8 P -25 , if monthly precipitation (P) ≥ 75 mm , and

Pe = 0.6 P -10 , if monthly precipitation (P) <75 mm for paddy.

Effective rainfall for other crops has been computed using USDA method.

Paddy rice, growing with "its feet in the water " is an exception .Not only has the crop water needs (Etcrop) to be supplied by irrigation or rainfall , but also water is needed for:

- Saturation of the soil before planting (saturation water)
- Percolation and seepage loss
- Establishment of a water layer

Saturation water:

For nursery field preparation :

Soil moisture content at saturation = 30 %

Current soil moisture content =15 % (for clay loam soil)

Root zone depth = 1000 mm

Bulk density = 1.3

∴ Saturation water =(30-15)/100*1000*1.3

= 195 mm

Seepage and percolation losses 6 mm/day for 7 days =6*7 = 42 mm

Evaporation 6 mm/day for 7 days =6*7 = 42 mm

Ponding water = 100 mm

Total water needed for nursery field preparation =195+42+42 +100

=379 mm

For nursery, 1/20 th area is required

∴ Saturation water required for nursery field preparation = 379/20 = 18.95 mm

For transplantation field preparation :

It is presumed that soil moisture would increase by 5 %

∴ Saturation water = (30-20)/100*1000*1.3 = 130 mm

Seepage and percolation = 42 mm

Evaporation = 42 mm

Ponding water = 100 mm

∴ Total water =130+42+42+100

=314 mm

Water requirement for various crops from modified Penman method is given in Table - 2.1 to 2.8 The total crop water requirement in existing and future conditions for each month has been given in Table -2.9 and 2.10.

2.2.3 Existing and Future Irrigation Demand

Based of the existing cropping pattern and future cropping pattern, existing and future Irrigation demand has been computed. The monthly existing and future requirement is given in Table 2.9 & 2.10. The annual existing and future irrigation water requirement for Dang Valley is estimated as 618.9 MCM and 644.9 MCM respectively.

2.3 DOMESTIC WATER REQUIREMENT

The following guidelines (National Water Development Agency) have been followed for computing domestic water requirements:

- Consider consumptive use of domestic water as 20 % of the surface water diverted or lifted from the rivers, reservoirs, storages, canals etc.
- The per capita consumption for rural and urban population may be assumed as 70 litres and 200 litres respectively .
- The 50 % of the rural water requirement is proposed to be met from ground water sources. The urban water requirement in full and 50 % of rural water requirement is to be met from surface water sources.

The requirement of water for domestic consumption in the rural and urban areas as well as for the livestock has been obtained by projecting the rural , urban and livestock population of the study area to 2050 A.D.

Population

The population and livestocks have been projected from 2001 to the year 2050 A.D. using the formula ,

$P2050 = P2001\ [1+R/100]^n$

Where ,

P2050 = Population in the year 2050 A.D.

P2001 = Population (known) in the year 2001 A.D.

R = Compound rate of growth of population

n = number of years.

Population of the area as per 2001 census is 300895. Taking average compound growth rate of population as 2.4 %, Population projected for the year 2050 is :

$P2050 = 300895\ [1+2.4/100]^{49}$

$= 961862$

The population trend shows that 22 % of the population comprises urban population and 78 % that of rural population. The population growth rate in 1991 census was 2.85 % and in 2001 census is 2.7 %. There is falling trend of population growth rate , hence 2.4 % growth rate has been adopted.

Live stock:

In absence of a reliable data on live stock , an assumption has been made in case of animals based on bullock requirement and traditional living structure in the project area.

Average number of bullocks /cows /buffaloes per family = 3.5

Total number of families estimated in 2001 A.D. = 49300

Hence , total number of livestock = 49300*3.5

=172550

The projected live stocks for the year 2050 A. D.

P_{2050} (live stock)= $172550[1+1/100]^{49}$

= 280972

The present and future domestic surface water requirement has been given in Table 2.11. The annual existing and future domestic water requirement for Dang valley is estimated as 7.9 MCM and 24.9 MCM respectively.

2.4 INDUSTRIAL WATER REQUIREMENT

In the absence of actual data on the existing, on going and future industries, the industrial water requirement was assumed to be the same order as the total domestic water requirement. The entire industrial water requirement is proposed to be met from surface water sources.

The annual future industrial water requirement for Dang valley is estimated as 39.7 MCM .

2.5 WATER DEMAND IN 2001 AD & 2050 AD

Water demand for irrigation, domestic and industrial purposes has been estimated in previous section of this chapter. The estimated annual water demand in existing condition (2001AD) and in future condition (2050AD) is summarised below:

Water Demand	Existing (2001AD)	Future (2050 AD)
Irrigation water demand	618.9 MCM	644.9 MCM
Domestic water demand	7. 9 MCM	24.9 MCM
Industrial water demand	_	39.7 MCM
Total	626.8 MCM	709.5 MCM

TABLE - 2.0

CALCULATION OF(ETo)REFERENCE CROP EVAPOTRANSPIRATION

Month	Temp.(^{0}C)	RH(%)	ea (mbar)	ed (mbar)	f(U)	Ra	n/N	Rs= (.25+.5n/N)Ra	f(T)	f(ed)	f(n/N)	Rnl= f(T)*f(ed)*f(n/N)	Rn= (.75Rs-Rnl)	W	C	Eto=C(W*Rn+(1-W)*f(U)*(ea-ed))
January	12.8	80.08	14.8	11.85	0.47	9.24	0.82	6.10	13.26	0.19	0.75	1.89	2.68	0.61	1	2.18
February	16.7	75.05	19.04	14.29	0.55	11.05	0.83	7.35	13.94	0.18	0.71	1.78	3.73	0.66	1	3.35
March	19.8	67.2	23.12	15.54	0.70	13.36	0.8	8.68	14.52	0.16	0.71	1.65	4.86	0.7	1	5.00
April	25.6	62.5	32.84	20.53	0.70	15.29	0.81	10.01	15.8	0.14	0.71	1.57	5.94	0.76	1	6.58
May	27.6	69.2	36.96	25.58	0.69	16.5	0.67	9.65	16.22	0.12	0.64	1.25	5.99	0.78	1	6.40
June	27.9	72.23	37.59	27.15	0.70	16.83	0.45	7.99	16.28	0.11	0.51	0.91	5.08	0.78	1	5.57
July	25.8	87.95	33.22	29.22	0.52	16.71	0.46	8.02	15.85	0.1	0.35	0.55	5.46	0.76	1	4.65
August	25.7	90.58	33.03	29.92	0.51	15.7	0.57	8.40	15.83	0.1	0.45	0.71	5.59	0.76	1	4.63
September	25.2	89.55	32.08	28.73	0.50	14.07	0.48	6.89	15.7	0.11	0.49	0.85	4.32	0.75	1	3.66
October	23	89.88	28.1	25.26	0.47	11.95	0.65	6.87	15.2	0.12	0.64	1.17	3.99	0.74	1	3.30
November	18.4	87.6	21.16	18.54	0.44	9.85	0.8	6.40	14.28	0.15	0.83	1.78	3.02	0.68	1	2.43
December	14.3	86.83	16.37	14.21	0.44	8.73	0.82	5.76	13.55	0.18	0.61	1.49	2.83	0.63	1	2.14

TABLE 2.1
CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Rice **Soil Type: Clay Loam** **Planting date: 1 July**

Period	ETo(mm/day)	ETo(mm)	Kc	ETc(mm)	S&P(mm)	ETc+S&P	Rain(mm)	Pe(mm)	NIR(mm)	FIR (mm)	GIR(mm)
May 25-31	field preparatory water Nursery water								18.95	25.27	31.58
June1-30	5.57	167.1	1.1	183.81	180	363.81	272.6	193.08	170.73	227.64	284.55
	Field preparation for transplantation			(20 % in June and 80 % in July)					314.00	418.67	523.33
July 1-15	4.65	69.75	1.1	76.725	90	166.73	451.6	168.14	82.66	110.21	137.76
July 16-31	4.65	74.4	1.1	81.84	96	177.84		168.14	93.77	125.03	156.28
August 1-15	4.63	69.45	1.3	90.285	90	180.29	425.1	157.54	101.52	135.35	169.19
August 16-31	4.63	74.08	1.3	96.304	96	192.30		157.54	113.53	151.38	189.22
September 1-15	3.66	54.9	1.3	71.37	90	161.37	293	104.7	109.02	145.36	181.70
September 16-30	3.66	54.9	1	54.9	90	144.90		104.7	92.55	123.40	154.25
October 1-15	3.3	49.5	1	49.5	90	139.50	69.3	15.79	131.61	175.47	219.34
									1228.33	1637.77	2047.22

Remarks :

S&P=Seepage and Percolation

Pe=Effective Rainfall(mm) ,Pe=0.8P-25, if P $\geq 75mm$ and $Pe=0.6P-10$, if $P<75mm$

ETo= Evapotranspiration of a reference crop (mm)

Kc= Crop coefficient for evapotranspiration=ETc/ETo

ETc=Evapotranspiration of crop (mm)

Pe=Effective rainfall(Rain stored in the root zone) mm,USDA method

NIR=Net Irrigation Requirement[(ETc+Seepage and Percolation) - Pe]

FIR= Field Irrigation requirement (NIR/AE)

AE= Application efficiency ranging between 50-75% I.e. water stored in root zone /water applied to field

GIR= Gross Irrigation Requirement (mm) I.e. FIR/ Conveyance efficiency

CE= Conveyance efficiency ranging between 70-80% I.e. water received at field gate/water released at project head

TABLE - 2.2
CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Maize **Soil Type: Clay Loam** **Planting Date:May 15**

Period	ETo(mm/day)	ETo(mm)	Kc	ETc(mm)	Rain(mm)	Pe(mm)	NIR(mm)	FIR (mm)	GIR(mm)
May 15-31	6.4	108.8	0.28	30.46	76.5	24.74	5.72	7.63	9.54
June 1-15	5.57	83.55	0.65	54.31	272.6	54.31	0.00	0.00	0.00
June 16-30	5.57	83.55	0.65	54.31		54.31	0.00	0.00	0.00
July 1-15	4.65	69.75	1.05	73.24	451.8	73.24	0.00	0.00	0.00
July 16-31	4.65	74.4	1.05	78.12		78.12	0.00	0.00	0.00
August 1-15	4.63	69.45	1.05	72.92	425.3	72.92	0.00	0.00	0.00
August 16-31	4.63	74.08	0.55	40.74		40.74	0.00	0.00	0.00
September 1-15	3.66	54.9	0.55	30.20	293.1	30.20	0.00	0.00	0.00
September 16-20	3.66	18.3	0.55	10.07		10.07	0.00	0.00	0.00
Total							5.72	7.63	9.54

Remarks :

ETo= Evapotranspiration of a reference crop (mm)

Kc= Crop coefficient for evapotranspiration=ETc/ETo

ETc=Evapotranspiration of crop (mm)

Pe=Effective rainfall(Rain stored in the root zone) mm,USDA method

NIR=Net Irrigation Requirement[(ETc+Seepage and Percolation) - Pe]

FIR= Field Irrigation requirement (NIR/AE)

AE= Application efficiency ranging between 50-75% I.e. water stored in root zone /water applied to field

GIR= Gross Irrigation Requirement (mm) I.e. FIR/ Conveyance efficiency

CE= Conveyance efficiency ranging between 70-80% I.e. water received at field gate/water released at project head

TABLE - 2.3
CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Wheat **Soil Type: Clay Loam** **Planting Date: 20 November**

Period	ETo(mm/day)	ETo(mm)	Kc	ETc(mm)	Rain(mm)	Pe(mm)	NIR(mm)	FIR (mm)	GIR(mm)
November 20-30	2.43	26.73	0.4	10.69	10.9	0	10.69	14.26	17.82
December 1-15	2.14	32.1	0.75	24.08	14.1	4.39	19.69	26.25	32.81
December 16-31	2.14	34.24	0.75	25.68		4.68	21.00	28.00	35.00
January1-15	2.18	32.7	1.05	34.34	25.8	8.63	25.71	34.27	42.84
January16-31	2.18	34.88	1.05	36.62		9.21	27.41	36.55	45.69
February 1-15	3.35	50.25	1.05	52.76	23.1	8.89	43.87	58.50	73.12
February 16-28	3.35	43.55	1.05	45.73		7.71	38.02	50.69	63.36
March 1-15	5	75	0.25	18.75	20.2	6.09	12.66	16.88	21.10
March 16-20	5	25	0.25	6.25		2.03	4.22	5.63	7.03
Total							203.27	271.02	338.78

Remarks :

ETo= Evapotranspiration of a reference crop (mm)
Kc= Crop coefficient for evapotranspiration=ETc/ETo
ETc=Evapotranspiration of crop (mm)
Pe=Effective rainfall(Rain stored in the root zone) mm,USDA method
NIR=Net Irrigation Requirement[(ETc+Seepage and Percolation) - Pe]
FIR= Field Irrigation requirement (NIR/AE)
AE= Application efficiency ranging between 50-75% I.e. water stored in root zone /water applied to field
GIR= Gross Irrigation Requirement (mm) I.e. FIR/ Conveyance efficiency
CE= Conveyance efficiency ranging between 70-80% I.e. water received at field gate/water released at project head

TABLE - 2.4
CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Pulses **Soil Type: Clay Loam** **Planting Date:October 20**

Period	ETo(mm/day)	ETo(mm)	Kc	ETc(mm)	Rain(mm)	Pe(mm)	NIR(mm)	FIR (mm)	GIR(mm)
October 20-31	3.3	39.6	0.4	15.84	69.4	14.19	1.65	2.20	2.75
Nov 1-15	2.43	36.45	0.4	14.58	10.9	0.00	14.58	19.44	24.30
Nov 16-30	2.43	36.45	0.7	25.52		0.00	25.52	34.02	42.53
December 1-15	2.14	32.1	0.7	22.47	14.1	4.51	17.96	23.95	29.93
December 16-31	2.14	34.24	1.05	35.95		4.82	31.13	41.51	51.89
January1-15	2.18	32.7	1.05	34.34	25.8	8.63	25.71	34.27	42.84
January16-31	2.18	34.88	1.05	36.62		9.21	27.41	36.55	45.69
February 1-15	3.35	50.25	1.05	52.76	23.1	8.76	44.00	58.67	73.34
February 16-28	3.35	43.55	0.75	32.66		7.60	25.06	33.42	41.77
March 1-15	5	75	0.75	56.25	20.2	7.16	49.09	65.45	81.82
Total							262.11	349.48	436.85

Remarks :

ETo= Evapotranspiration of a reference crop (mm)
Kc= Crop coefficient for evapotranspiration=ETc/ETo
ETc=Evapotranspiration of crop (mm)
Pe=Effective rainfall(Rain stored in the root zone) mm,USDA method
NIR=Net Irrigation Requirement[(ETc+Seepage and Percolation) - Pe]
FIR= Field Irrigation requirement (NIR/AE)
AE= Application efficiency ranging between 50-75% I.e. water stored in root zone /water applied to field
GIR= Gross Irrigation Requirement (mm) I.e. FIR/ Conveyance efficiency
CE= Conveyance efficiency ranging between 70-80% I.e. water received at field gate/water released at project head

TABLE - 2.5
CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Potatoes **Soil Type: Clay Loam** **Planting Date:October 15**

Period	ETo(mm/day)	ETo(mm)	Kc	ETc(mm)	Rain(mm)	Pe(mm)	NIR(mm)	FIR (mm)	GIR(mm)
October 15-31	3.3	52.8	0.4	21.12	69.4	18.92	2.20	2.93	3.67
Nov 1-15	2.43	36.45	0.4	14.58	10.9	0.00	14.58	19.44	24.30
Nov 16-30	2.43	36.45	0.7	25.52		0.00	25.52	34.02	42.53
December 1-15	2.14	32.1	0.7	22.47	14.1	4.50	17.97	23.96	29.95
December 16-31	2.14	34.24	1.05	35.95		4.81	31.14	41.52	51.90
January1-15	2.18	32.7	1.05	34.34	25.8	8.31	26.03	34.70	43.38
January16-31	2.18	34.88	0.7	24.42		8.87	15.55	20.73	25.91
Total							132.98	177.30	221.63

Remarks :
ETo= Evapotranspiration of a reference crop (mm)
Kc= Crop coefficient for evapotranspiration=ETc/ETo
ETc=Evapotranspiration of crop (mm)
Pe=Effective rainfall(Rain stored in the root zone) mm,USDA method
NIR=Net Irrigation Requirement[(ETc+Seepage and Percolation) - Pe]
FIR= Field Irrigation requirement (NIR/AE)
AE= Application efficiency ranging between 50-75% I.e. water stored in root zone /water applied to field
GIR= Gross Irrigation Requirement (mm) I.e. FIR/ Conveyance efficiency
CE= Conveyance efficiency ranging between 70-80% I.e. water received at field gate/water released at project head

TABLE - 2.6
CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Mustard **Soil Type: Clay Loam** **Planting Date:October 10**

Period	ETo(mm/day)	ETo(mm)	Kc	ETc(mm)	Rain(mm)	Pe(mm)	NIR(mm)	FIR (mm)	GIR(mm)
October 10-15	3.3	19.8	0.4	7.92	69.4	7.09	0.83	1.11	1.38
October 16-31	3.3	52.8	0.4	21.12		18.92	2.20	2.93	3.67
Nov 1-15	2.43	36.45	0.7	25.52	10.9	0.00	25.52	34.02	42.53
Nov 16-30	2.43	34.02	1.05	35.72		0.00	35.72	47.63	59.54
December 1-15	2.14	32.1	1.05	33.71	14.1	4.52	29.19	38.91	48.64
December 16-31	2.14	34.24	0.75	25.68		4.82	20.86	27.81	34.77
January1-10	2.18	21.8	0.75	16.35	25.8	5.40	10.95	14.60	18.25
Total							125.26	167.01	208.77

Remarks :

ETo= Evapotranspiration of a reference crop (mm)
Kc= Crop coefficient for evapotranspiration=ETc/ETo
ETc=Evapotranspiration of crop (mm)
Pe=Effective rainfall(Rain stored in the root zone) mm,USDA method
NIR=Net Irrigation Requirement[(ETc+Seepage and Percolation) - Pe]
FIR= Field Irrigation requirement (NIR/AE)
AE= Application efficiency ranging between 50-75% I.e. water stored in root zone /water applied to field
GIR= Gross Irrigation Requirement (mm) I.e. FIR/ Conveyance efficiency
CE= Conveyance efficiency ranging between 70-80% I.e. water received at field gate/water released at project head

TABLE - 2.7
CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Winter vegetables **Soil Type: Clay Loam** **Planting Date:September- 25**

Period	ETo(mm/day)	ETo(mm)	Kc	ETc(mm)	Rain(mm)	Pe(mm)	NIR(mm)	FIR (mm)	GIR(mm)
September 25-30	3.66	21.96	0.4	8.78	293.1	8.78	0.00	0.00	0.00
October 1-15	3.3	49.5	0.4	19.80	69.4	19.80	0.00	0.00	0.00
October 16-31	3.3	52.8	0.7	36.96		24.35	12.61	16.81	21.02
Nov 1-15	2.43	36.45	0.7	25.52	10.9	0.00	25.52	34.02	42.53
Nov 16-30	2.43	36.45	0.95	34.63		0.00	34.63	46.17	57.71
December 1-15	2.14	32.1	0.95	30.50	14.1	4.58	25.92	34.55	43.19
December 16-31	2.14	34.24	0.95	32.53		4.88	27.65	36.86	46.08
January1-15	2.18	32.7	0.95	31.07	25.8	8.32	22.75	30.33	37.91
January16-31	2.18	34.88	0.8	27.90		8.87	19.03	25.38	31.72
February 1-15	3.35	50.25	0.8	40.20	23.10	8.66	31.54	42.05	52.57
Total							199.63	266.18	332.72

Remarks :

Pe=Effective Rainfall(mm) ,Pe=0.8P-25 if P
ETo= Evapotranspiration of a reference crop (mm)
Kc= Crop coefficient for evapotranspiration=ETc/ETo
ETc=Evapotranspiration of crop (mm)
Pe=Effective rainfall(Rain stored in the root zone) mm,USDA method
NIR=Net Irrigation Requirement[(ETc+Seepage and Percolation) - Pe]
FIR= Field Irrigation requirement (NIR/AE)
AE= Application efficiency ranging between 50-75% I.e. water stored in root zone /water applied to field
GIR= Gross Irrigation Requirement (mm) I.e. FIR/ Conveyance efficiency
CE= Conveyance efficiency ranging between 70-80% I.e. water received at field gate/water released at project head

TABLE - 2.8
CROP WATER REQUIREMENT CALCULATION SHEET

Crop : Summer vegetables **Soil Type: Clay Loam** **Planting Date:February- 16**

Period	ETo(mm/day)	ETo(mm)	Kc	ETc(mm)	Rain(mm)	Pe(mm)	NIR(mm)	FIR (mm)	GIR(mm)
February 16-28	3.35	43.55	0.4	17.42	23.1	6.69	10.73	14.31	17.88
March 1-15	5	75	0.4	30.00	20.2	6.92	23.08	30.77	38.47
March 16-31	5	80	0.7	56.00		7.39	48.61	64.81	81.02
April 1-15	6.58	98.7	0.7	69.09	20.1	9.14	59.95	79.93	99.92
April 16-30	6.58	98.7	0.95	93.77		9.14	84.63	112.83	141.04
May 1 -15	6.4	96	0.95	91.20	76.5	30.60	60.60	80.80	101.00
May 16 -31	6.4	102.4	0.95	97.28		32.65	64.63	86.17	107.72
June 1-15	5.57	83.55	0.95	79.37	272.6	79.37	0.00	0.00	0.00
June 16-30	5.57	83.55	0.8	66.84		66.84	0.00	0.00	0.00
Total							352.23	587.04	782.72

Remarks :

ETo= Evapotranspiration of a reference crop (mm)
Kc= Crop coefficient for evapotranspiration=ETc/ETo
ETc=Evapotranspiration of crop (mm)
Pe=Effective rainfall(Rain stored in the root zone) mm,USDA method
NIR=Net Irrigation Requirement[(ETc+Seepage and Percolation) - Pe]
FIR= Field Irrigation requirement (NIR/AE)
AE= Application efficiency ranging between 50-75% I.e. water stored in root zone /water applied to field
GIR= Gross Irrigation Requirement (mm) I.e. FIR/ Conveyance efficiency
CE= Conveyance efficiency ranging between 70-80% I.e. water received at field gate/water released at project head

TABLE- 2.9

TOTAL CROP WATER REQUIREMENT (EXISTING)

Month →		January		February		March		April		May		June	
		1	2	1	2	1	2	1	2	1	2	1	2
Crop ▼	Crop Area (ha)												
Maize	14750										84370	0	0
Rice (Paddy)	27250										516388	116317	1827617
Wheat	7500	192825	205575	329025	285150	94950	31650						
Pulses	15000	385650	411150	660000	375900	736350							
Mustard	12000	131400											
Potatoes	1200	31236	18660										
Winter vegetables	700	15925	13321	22078									
Summer vegetables	150				1609.5	3462	7291.5	8992.5	12694.5	9090	9694.5	0	0
Total water (ha-mm)		757036	648706	1011103	662660	834762	38941.5	8992.5	12694.5	9090	610452	116317	1827617
Net water in (l.p.s.)		5841.33	5005.45	7801.72	5113.11	6441.06	300.47	69.39	97.95	70.14	4710.28	897.50	14101.98
Net water in (m^3/sec)		5.84	5.01	7.80	5.11	6.44	0.30	0.07	0.10	0.07	4.71	0.90	14.10
Total water requirement taking 75 % A.E. and 80 %C.E.		9.74	8.34	13.00	8.52	10.74	0.50	0.12	0.16	0.12	7.85	1.50	23.50

TABLE- 2.9
TOTAL CROP WATER REQUIREMENT (EXISTING)

Month →		July		August		September		October		November		December	
		1	2	1	2	1	2	1	2	1	2	1	2
Crop ↓	Crop Area (ha)												
Maize	14750	0	0	0	0	0	0						
Rice (Paddy)	27250	5675085	5977833	2766420	3093693	2970795	2521988	3586373					
Wheat	7500										80175	147675	157500
Pulses	15000								24750	218700	382800	269400	466950
Mustard	12000							9960	26400	306240	428640	350280	250320
Potatoes	1200								2640	17496	30624	21564	37368
Winter vegetables	700							0	8827	17864	24241	18144	19355
Summer vegetables	150												
Total water (ha-mm)		5675085	5977833	2766420	3093693	2970795	2521988	3596333	62617	560300	946480	807063	931493
Net water in (l.p.s.)		43789.24	46125.25	21345.83	23871.08	22922.80	19459.78	27749.48	483.16	4323.30	7303.09	6227.34	7187.45
Net water in (m^3/sec)		43.79	46.13	21.35	23.87	22.92	19.46	27.75	0.48	4.32	7.30	6.23	7.19
Total water requirement taking 75 % A.E. and 80 %C.E.		72.98	76.88	35.58	39.79	38.20	32.43	46.25	0.81	7.21	12.17	10.38	11.98

TABLE- 2.10

TOTAL CROP WATER REQUIREMENT (FUTURE)

Month →		January		February		March		April		May		June	
		1	2	1	2	1	2	1	2	1	2	1	2
Crop ↓	Crop Area (ha)												
Maize	14000										80080	0	0
Rice (Paddy)	28000										530600	119518	1877918
Wheat	13500	347085	370035	592245	513270	170910	56970						
Pulses	11500	295665	315215	506000	288190	564535							
Mustard	12000	131400											
Potatoes	2000	52060	31100										
Winter vegetables	1500	34125	28545	47310									
Summer vegetables	700				7511	16156	34027	41965	59241	42420	45241	0	0
Total water (ha-mm)		860335	744895	1145555	808971	751601	90997	41965	59241	42420	655921	119518	1877918
Net water in (l.p.s.)		6638.39	5747.65	8839.16	6242.06	5799.39	702.14	323.80	457.11	327.31	5061.12	922.21	14490.11
Net water in (m^3/sec)		6.64	5.75	8.84	6.24	5.80	0.70	0.32	0.46	0.33	5.06	0.92	14.49
Total water requirement taking 75 % A.E. and 80 %C.E.		11.06	9.58	14.73	10.40	9.67	1.17	0.54	0.76	0.55	8.44	1.54	24.15

TABLE- 2.10
TOTAL CROP WATER REQUIREMENT (FUTURE)

Month →		July		August		September		October		November		December	
		1	2	1	2	1	2	1	2	1	2	1	2
Crop ↓	Crop Area (ha)												
Maize	14000	0	0	0	0	0	0						
Rice (Paddy)	28000	5831280	6142360	2842560	3178840	3052560	2591400	3685080					
Wheat	13500										144315	265815	283500
Pulses	11500								18975	167670	293480	206540	357995
Mustard	12000							9960	26400	306240	428640	350280	250320
Potatoes	2000								4400	29160	51040	35940	62280
Winter vegetables	1500							0	18915	38280	51945	38880	41475
Summer vegetables	700												
Total water (ha-mm)		5831280	6142360	2842560	3178840	3052560	2591400	3695040	68690	541350	969420	897455	995570
Net water in (l.p.s.)		44994.44	47394.75	21933.33	24528.09	23553.70	19995.37	28511.11	530.02	4177.08	7480.09	6924.81	7681.87
Net water in (m^3/sec)		44.99	47.39	21.93	24.53	23.55	20.00	28.51	0.53	4.18	7.48	6.92	7.68
Total water requirement taking 75 % A.E. and 80 %C.E.		74.99	78.99	36.56	40.88	39.26	33.33	47.52	0.88	6.96	12.47	11.54	12.80

TABLE - 2.11
DOMESTIC WATER REQUIREMENT

EXISTING

		Rural	Urban	Total
Population		234698	66197	300895
Water requirement per capita per day in litres		70	200	
Total water requirement per day in litres for population		16428860	13239400	29668260
Livestock population				172550
Water requirement per capita per day for livestock in litres.				50
Total water requirement per day in litres for livestock				8627500
Total water requirement per day	Litres	16428860	13239400	38295760
	m^3	16428.86	13239.4	38295.76

FUTURE

		Rural	Urban	Total
Population		750252	211610	961862
Water requirement per capita per day in litres		70	200	
Total water requirement per day in litres for population		52517640	42322000	94839640
Livestock population				280972
Water requirement per capita per day for livestock in litres.				50
Total water requirement per day in litres for livestock				14048600
Total water requirement per day	Litres	52517640	42322000	108888240
	m^3	52517.64	42322	108888.24

TABLE - 2.12

POPULATION OF DANG VALLEY (1991 CENSUS)

S.No.	Village / Town Development Committee	Total No. of Households	Population		
			Male	Female	Total
1	Amritpur	1725	4762	4918	9680
2	Baghmare	1075	2911	3054	5965
3	Bijauri	1599	4883	4846	9729
4	Dhanauri	1905	6165	6238	12403
5	Dharna	961	2699	2828	5527
6	Dhikpur	1112	4030	4055	8085
7	Duruwa	1408	4882	4839	9721
8	Goltakuri	659	2204	2129	4333
9	Halwar	1339	4071	4111	8182
10	Hapur	1788	5173	5251	10424
11	Hekuli	1139	4272	4240	8512
12	Laximipur	1493	4379	4696	9075
13	Manpur	1449	4972	4990	9962
14	Narayanpur	1143	4238	4408	8646
15	Panchakule	1019	3151	3119	6270
16	Pawan Nagar	1961	5621	5807	11428
17	Phulbari	745	2198	2264	4462
18	Purandhara	2033	6025	5956	11981
19	Rampur	1576	4532	4890	9422
20	Sudiyar	1067	3984	4068	8052
21	Tarigaon	1087	3733	3952	7685
22	Tribhuvan Nagar	5235	14888	14162	29050
23	Tulsipur	2540	6982	6833	13815
24	Urahari	1288	4331	4433	8764
Total		37346	115086	116087	231173

Remarks : Population as per 2001 census of Dang district is 462916.Population details oı could not be available.
Population of Dang valley estimated is 300895.

TABLE - 2.13

EXISTING CULTIVATED LAND AND IRRIGATION SITUATION

Agriculture Service Centre	Name of V.D.C.	Cultivated land		Total Cultivated Land (ha)
		Irrigated (ha)	Rainfed (ha)	
Tulsipur	Bijauri	1250	300	1550
	Tulsipur	1980	540	2520
	Malwar	1390	110	1500
	Manpur	1168	182	1350
Narayanpur	Narayanpur	1407	640	2047
	Hapur	757	927	1684
	Dhikpur	1558	475	2033
	Duruwa	1360	715	2075
Panchakule	Panchakule	320	1112	1432
	Purandhara	1704	1408	3112
Santi Nagar	Shanti Nagar	870	310	1180
	Baghmare	562	455	1017
	Pavan Nagar	1095	255	1350
Hekuli	Dhanauri	1015	485	1500
	Shrigaon	735	541	1276
	Hekuli	785	689	1474
Urhari	Urhari	1200	500	1700
	Tarigaon	1100	540	1640
	Goltakuri	750	800	1550
	Phulbari	600	700	1300
Saudiyar	Tribhuvan Nagar	2716	1495	4211
	Saudiyar	882	282	1164
	Dharna	427	305	732
Rampur	Rampur	1309	456	1765
	Laxmipur	324	520	844
Total		27264	14742	42006

Source : District Agriculture Development Office , Agriculture Development Programme And Achievement (1999/2000).

FIGURE - 2.1
CROPPING PATTERN (EXISTING)

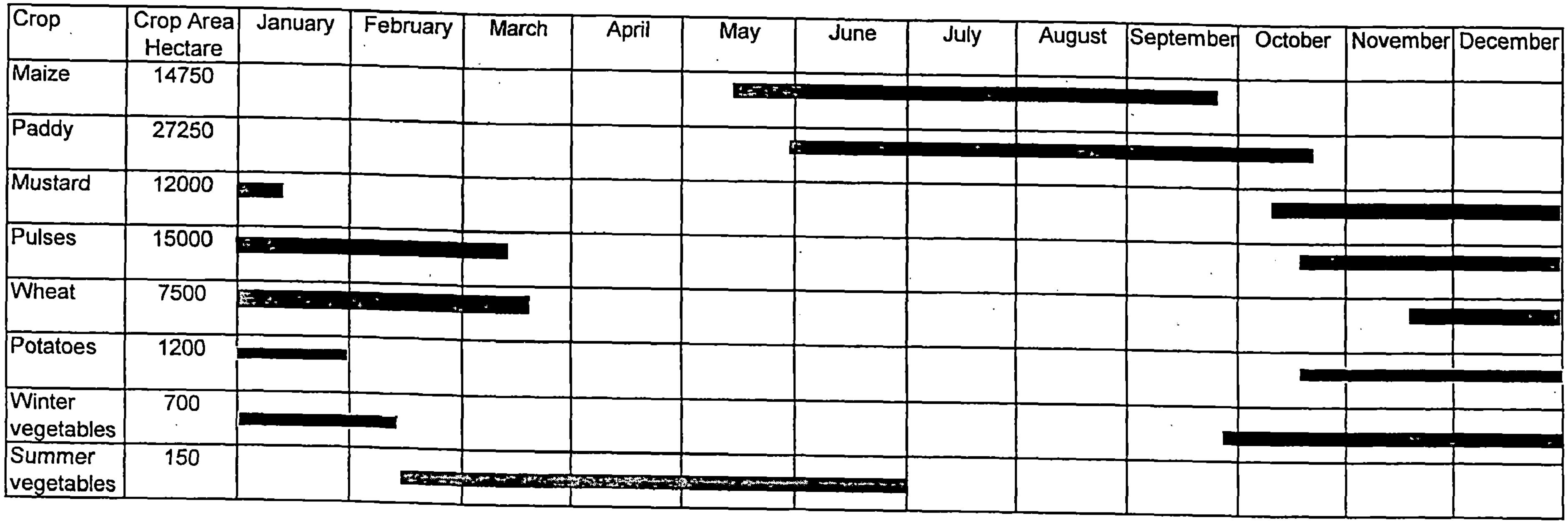
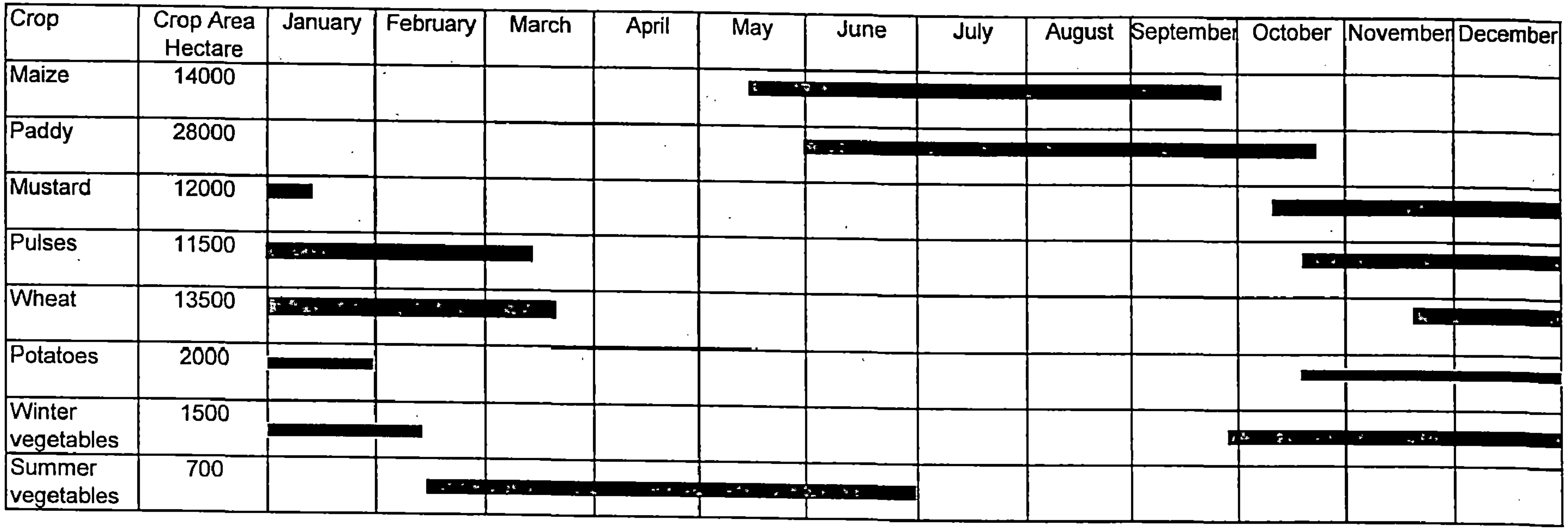


FIGURE - 2.2

CROPPING PATTERN (FUTURE)



CHAPTER - 3

ESTIMATION OF MONTHLY RUNOFF WITH INADEQUATE HYDROLOGIC DATA

There is no gauge and discharge site on Babai river and its tributaries in Dang Valley. The gauge and discharge site on Babai river is located about 85 km d/s from the outlet point of valley at Bargada in Bardiya district (Figure- 3.1). Dang Valley comprises about 48% of the total catchment area (3000 km^2) at this gauge and discharge site. The average fortnightly discharge at outlet point of the valley is computed from the observed discharge at Bargada on catchment area proportion basis. The fortnightly observed discharge is given in Table-3.12. However for planning of minor irrigation schemes in the valley, water availability needs to be assessed in the catchments of these schemes.

As the catchment area of Babai river and its tributaries in the valley is ungauged the following approaches have also been used to compute the availability of water and select the most appropriate method for further analysis.

⇒ Regional Multiple Regression Method (WECS, 1989)

⇒ Regional Hydrograph of Monthly Flows

⇒ Mock Model

3.1 REGIONAL MULTIPLE REGRESSION METHOD

A study was carried out in 1989 (WECS-1989) utilising flow records of gauges. Observed flows for catchments ranging from 4 km^2 to 54100 km^2 were utilised for regional multiple variables regression study. After detailed checking of data quality, the monthly data was used in a multiple regression analysis involving up to 14 catchment parameters such as : basin area, main stream length, area of catchment below 5000 m elevation, etc. Sets of 12 regression equations were derived which can be used to predict the mean flow in each month of the year. These equations are given in Table-3.1 and are of the form:

Q_{mean}(month) = coefficient x (basin area)^{A1} x (basin area below 5000 m + 1)^{A2} x (mean monsoon precipitation) ^{A3}.

These equations cover the whole country and require the designer to measure the catchment area below 5000 m from 1:250000 maps. The average monsoon rainfall for a catchment is estimated from the isohyetal map.

Table -3.1 Coefficients of Regional Regression Equations for Monthly Flows:

Month	Constant Coefficient	Power of Area of Basin (Km^2)	Power of Area of Basin in Km^2) below (5000+1)	Power of Mean monsoon precipitation	Coefficient of Determination
	C	A1	A2		R2
January	0.01423	0	0.9777	0	0.945
February	0.01219	0	0.9766	0	0.966
March	0.009988	0	0.9948	0	0.983
April	0.007974	0	1.0435	0	0.079
May	0.008434	0	1.0898	0	0.959
June	0.006943	0.9968	0	0.2610	0.932
July	0.2123	0	1.0093	0.2523	0.938
August	0.02548	0	0.99663	0.2620	0.955
September	0.01677	0	0.9894	0.2878	0.968
October	0.009724	0	0.9880	0.2508	0.953
November	0.001760	0.9605	0	0.3910	0.973
December	0.001485	0.9536	0	0.3607	0.968

Notes: 1. Units of flow are m^3/sec

2. Example equation for july is Q_{max} (July) = 0.02123 (area below 5000 m $+1)^{1.0093}$ x (mean monsoon precipitation)$^{0.2523}$

3. A power of 0 indicates that the particular parameter does not enter into the equation for that month.

3.2 REGIONAL HYDROGRAPH METHOD

A method for estimating divertable flows at ungauged sites was derived in the MIP Design Manual (MMP, 1982). The data base was spot measurements. Department of Meteorology and Hydrology carry out a number of spot gaugings every year during routine circuits of major stations. These occasional measurements cover a large number of small catchments in the hills. The current metering (velocity) is done by wading and therefore does not cover flood flows. The flows measured are residual flows after upstream abstractions, i.e. they do not represent the natural conditions but they give an indication of available water. The measurements cover streams draining both rain shadow areas and areas facing the approaching monsoon, and as expected when plotted as hydrographs of specific discharge (l/s per km^2), show a wide scatter of points. Initial work with this data identified 7 regional groups, see fig. 3.2. The hydrological regions of Nepal (MIP) and non dimensional hydrographs were then drawn up for each region.

These hydrographs present monthly flows as a ratio of the flow in April. The lowest flows occur in March/April and where these have been measured at an off take site, the hydrograph can be adjusted to match the ratio of predicted to observed dry season flow.

The mean monthly hydrographs for the region 2, where the basin lies are given in fig.3.3. This indicate flow rates (l/s per Km^2)for each month.

The method was intended to be used in conjunction with spot measurements taken for a particular proposed project and to incorporate as much local information as possible. The method permits mean monthly flows to be estimated anywhere in Nepal.

3.3 MOCK MODEL

In ungauged streams, precipitation and evapotranspiration data along with basin characteristics (vegetation cover, soil type, infiltration, soil moisture and ground water storage characteristics) can be used to estimate stream flows. Thornthwaite proposed a method of water balance which can be applied on fortnight or monthly basis. Thornthwaite considered potential evapotranspiration in the water balance calculations. F.J. Mock proposed a rainfall runoff simulation model by considering actual evapotranspiration instead of potential evapotranspiration. Mock also suggested a procedure to recalculate and adjust the runoff on the basis of observed runoff. The method is specifically useful in assessing flows of small catchments having limited or no stream flow records. The water balance method mimics key hydrologic processes, infiltration of water in soil profile, actual evaporation, change in soil moisture, water surplus and direct run off. This method is more popular in Japan , Philipines and Indonesia .

Data Requirement

- Rainfall data (fortnightly) from at least one representative station for the catchment.
- Evapotranspiration data estimated or observed (fortnightly).
- Number of rainydays in fortnight. Runoff data for the evaluation of the computed run off.
- Average catchment area not covered by green vegetation in different fortnights. It depends mainly on season, land use and erosion conditions.
- Soil moisture holding capacity.
- Infiltration factor, ground water recession constant.
- Storm runoff factor (proportion of monthly rainfall which contribute to storm runoff).

Procedure

Main steps involved in Mock Rainfall runoff model are explained below:

(i) Soil Moisture

Initial soil moisture storage + areal average rainfall – actual evapotranspiration.

(ii) Water Surplus

Soil moisture – soil moisture capacity. If soil moisture is less than soil moisture capacity, then water surplus is set equal to zero and infiltration is zero and direct runoff is zero.

(iii) Infiltration

Water surplus x infiltration factor. Infiltration factor is proportion of excess rainfall that infiltrates to ground water.

(iv) Ground Water Storage at End of Period

G. Store (t-1) x RC+ (1+RC)/2 x Infiltration,

where,

G.store. (t-1) is groundwater storage at beginning of period, RC is monthly flow recession constant.

(v) Base flow

Infiltration- G.W storage at end of period + G.W. storage at beginning of period = Infiltration-change in storage.

(vi) Direct Runoff

Water surplus x (1-Infiltration factor)

(vii) Storm Runoff

Rainfall x percentage factor. Percent factor is proportion of monthly rainfall which contributes to storm runoff.

(viii) Total Runoff

Base flow+ Direct runoff + Storm runoff. In wet season when there is water surplus, storm runoff component is not included separately. In dry season water surplus is zero, hence direct runoff is zero. Storm runoff is included to account for small amounts of run off in dry season where rainfall intensity exceeds soil infiltration rate. Mock Model computation table is explained as below:

Col.1 - Average rainfall in catchment.

Col.2 - Potential evapotranspiration estimated by Penman or any other method depending upon availability of climatic data.

Col.3 - Number of rainy days.

Col. 4 - Percent of catchment area not covered by vegetation.

Col.5 - Reduction in potential evapotranspiration (Eto) due to rainfall and surface factors = Eto x m/20* (18-n). Where, m is fraction of surface area not covered by green vegetation and n is number of rainy days.

Col.6 - Actual evapotranspiration = Col (2) - Col.5.

Col.7 - Change in soil moisture = P- actual evapotranspiration i.e. Col.1 – Col.6.

Col. 8 - Soil moisture at end of the period = soil moisture at end of previous period + change in soil moisture subject to upper limit of soil moisture capacity which is 150 mm.

Col.9 - Value of Col. 7 if value in Col.8 is 150 mm otherwise = 0

Col.10 - Col 7 x Infiltration factor (0.2) when Col. 7 is positive otherwise zero.

Col.11 - Storage volume Vn = (1+k)/2 x INFIL +kVn-1, where INFIL is percolation to ground water (Col.10), k is ground water recession c constant(0.9), Vn-1 is groundwater storage volume at beginning of period i.e. Col.(11) in volume of previous period.

Col.12 - Change in g.w. storage= current volume of Col.(11) – Vol. of Cool (11) in pervious row.

Col.13 - Col. 10 – Col. 12 i.e. infiltration – change in g.w. storage.

Col.14 - Water surplus (1-infiltration factor) = Col.9 (1- 0.2) =0.8 x Col.9

Col. 15 Col.13 + Col 14.

Col.16 - Rainfall x Run off factor. Here run off factor (PF) is assumed to be 0.1. Storm run off is computed for dry season only. For wet season (water surplus positive) storm run off is zero, (included in water surplus).

Col. 17. - It corresponds to revision of Col. 8 i.e. change in soil moisture = (Rain – Storm run off)- Actual evapotranspiration) = (Col. 1 – Col. 16) – Col 6. And soil moisture at end of period SMSE = SMS at beginning + change in soil moisture

Col. 18. - Revised water surplus similar to Col. 9 but with revised soil moisture.

Col. 19 - Similar to Col. 10 but with revised soil moisture.

Col.20 to 26 are similar to earlier calculations with revised data.

Col. 27 - Total run off expressed in equivalent discharge

$$= \frac{Col.26}{10\ x\ 100}\ x\ \frac{Catchment\,(m^2)}{24\ x\ 60\ x\ 60 x 15 (No.\ of\ days\ in\ fortnghtly}$$

3.4 COMPARATIVE STUDY OF METHODS

The catchment area of Babai basin in Dang valley is estimated as 1431 Km^2. Water availability is computed from Regional Multiple Regression method, Regional Hydrograph method and Mock model. The monthly discharge estimated at the outlet point of the valley from these methods is given in Table - 3.2, 3.3 and 3.4 respectively. The fortnightly rainfall and rainy days data required for Mock model have been computed from the daily rainfall data from the year 1972 to 1986 and are tabulated in Table - 3.5 and 3.6. The water availability computation from Mock model is given in Table- 3.7

Monthly discharge computed from Regional Multiple Regression method, Regional Hydrograph method and Mock model are compared in Table-3.8. Annual water estimated from Regional Multiple Regression method, Regional Hydrograph method and Mock model are 1620 MCM, 1221 MCM and 1455 MCM respectively. The discharge obtained from Regional Hydrograph method yielded less discharge and Mock model almost match with the observed discharge, whereas Regional Multiple Regression method has yielded higher discharges. Comparing with the annual volume computed from the observed discharg at G&D site for the same catchment, Regional Multiple Regression method yielded 4.1% more, Regional Hydrograph method 21.5% less and Mock model 6.5% less.

3.5 WATER AVAILABILITY - EXISTING AND FUTURE CONDITIONS

Existing water availability in the valley is based on the following land use pattern of the catchment :

Forest land	51%
Agriculture land	29%
Non vegetated land	20%

Catchment area of each tributaries have been computed from the topographical map considering the intake point for irrigation diversion. Monthly water available for irrigation on 75 % dependability is given in different tributaries in the valley is given in Table-3.9. The water availability in future will depend on change in land use pattern of the catchment. The surface run off varies with the land use type. A well managed forest yield less surface run off and more infiltration during a storm compared to agricultural and non vegetated land. Whereas non vegetated land yield more surface run off and less infiltration than forest land during a storm. The water availability in the future will depend on the catchment land use pattern. However, it is expected that the present forest cover is maintained in the future also and accordingly future water availability has been assessed.

3.6 RESULTS AND DISCUSSIONS

The monthly water available from three different methods as mentioned above is shown in Table - 3.8 . It is observed from the result that :

(1) The flow from Regional Multiple Regression method is on higher side. The annual yield is 4.1% more than the average observed value. The discharge in the month of April has been increased from the month of March. The rainfall data shows that there is no significant rainfall during April contributing run off, hence the discharge increment in this month does not occur. The increase in discharge during April and May in absence of rainfall generally applicable in snow-fed river. This method is based on the analysis of major river discharges of the whole country. It is applicable for rough estimation purposes in ungauged site and is used for reconnaissance and pre-feasibility level studies related to water resources developments in Nepal.

(2) Discharge computed from Regional Hydrograph method is 21.5% less than the observed discharge. As mentioned earlier while developing the regional hydrograph, flood flow and u/s abstractions were not included while taking the spot measurement. Hence the flows predicted do not represent the natural conditions but they give an indication of available water.

(3) The discharge obtained from Mock model is matching with the observed discharge. The Model is based on precipitation, evapotranspiration and basin characteristics such as vegetation cover, soil type, infiltration, soil moisture, initial ground water storage and ground water recession constant. The parameters infiltration factor, initial ground water storage and ground water recession constant has been estimated by trial and error. The model is very sensitive to these

parameters. The accuracy of the method depends on the actual value of these parameters and may vary from one basin to other. The procedure of Mock model is applicable for water availability computation in Dang Valley. Hence the water availability computed from the Mock model has been adopted for water balance study.

TABLE - 3.2

COMPUTATION OF DISCHARGE - REGIONAL MULTIPLE REGRESSION METHOD

Month	Coefficients	Basin Area Km^2	Basin area below (5000 m +1) Km^2	Mean monsoon precipitation (mm)	A1	A2	A3	Average Discharge (m3/sec)
January	0.01423	1431	1432	25.86	0	0.9777	0	17.33
February	0.01219	1431	1432	23.14	0	0.9766	0	14.73
March	0.009988	1431	1432	20.26	0	0.9948	0	13.77
April	0.007974	1431	1432	20.1	0	1.0435	0	15.66
May	0.008434	1431	1432	76.48	0	1.0898	0	23.19
June	0.006943	1431	1432	272.59	0.9968	0	0.261	41.95
July	0.02123	1431	1432	451.62	0	1.0093	0.2523	152.07
August	0.02548	1431	1432	425.11	0	0.9963	0.262	173.43
September	0.01677	1431	1432	293.05	0	0.9894	0.2878	114.03
October	0.009724	1431	1432	69.33	0	0.988	0.2508	36.95
November	0.00176	1431	1432	10.96	0.9605	0	0.391	4.82
December	0.001485	1431	1432	14.13	0.9536	0	0.3607	3.94

TABLE - 3.3
COMPUTATION OF DISCHARGE -
REGIONAL HYDROGRAPH METHOD

Month	Monthly flow rate (l/sec/km2)	Average monthly flow (m3/sec)
January	7.6	10.9
February	5.7	8.2
March	4.4	6.3
April	3.4	4.9
May	3.9	5.6
June	21	30.1
July	62	88.7
August	92.5	132.4
September	68	97.3
October	31	44.4
November	13	18.6
December	9.75	14.0

TABLE - 3.4
COMPUTATION OF DISCHARGE - MOCK MODEL

Year → / Month ↓	1973	1974	1977	1978	1975	1976	1979	1980	1981	1982	1983	1984	1985	1986	Average monthly discharge (m^3/sec)
June	140.12	5.86	20.4	44.44	11.22	7.46	10.89	18.34	32.83	7.79	5.77	116.62	6.60	24.74	32.36
July	87.08	39.41	173.45	128.34	231.45	172.29	149.27	203.35	138.25	57.49	58.34	265.08	164.00	153.19	144.36
August	111.79	136.33	288.35	89.17	145.07	178.46	133.85	135.04	107.93	191.95	139.31	122.76	181.56	132.76	149.60
September	124.08	38.38	63.2	92.62	111.18	134.40	15.55	175.28	234.32	163.05	203.90	169.30	165.81	98.86	127.85
October	65.12	10.70	27.55	13.80	37.82	18.77	12.78	20.51	20.29	17.04	106.67	22.68	73.66	39.67	34.79
November	15.89	8.93	11.2	11.51	16.27	15.67	10.86	16.47	17.39	14.22	18.35	18.93	18.90	14.24	14.92
December	12.49	7.02	8.4	9.05	12.79	12.32	8.60	12.94	13.80	11.18	14.48	14.88	14.87	11.24	11.72
January	10.49	5.69	6.5	7.33	10.36	9.98	7.16	10.48	11.18	9.08	11.89	12.09	12.10	9.12	9.53
February	10.07	5.09	5.4	6.57	9.28	8.93	6.41	9.05	10.01	8.21	10.65	10.54	10.83	8.17	8.52
March	7.41	3.73	3.55	4.81	6.80	6.54	4.70	6.88	7.33	6.01	7.80	8.02	7.94	5.99	6.25
April	6.19	3.12	2.85	4.02	5.67	5.46	3.92	5.74	6.12	5.02	6.51	6.69	6.63	5.00	5.21
May	4.86	2.45	8.75	3.16	4.46	4.29	3.15	4.51	4.89	4.35	5.26	5.26	5.21	3.95	4.61

TABLE - 3.5

AVERAGE RAINFALL (FORTNIGHTLY)

Month	January		February		March		April		May		June		July		August		September		October		November		December		Total
Year	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	
1972	0.1	1.5	41.5	0.0	7.1	0.0	3.8	2.5	0.3	0.2	26.3	89.7	184.2	243.3	98.9	84.9	249.7	69.2	12.2	19.7	0.0	7.7	0.3	0.0	1143.2
1973	45.0	72.4	3.7	42.8	15.2	0.0	0.0	2.8	46.8	29.1	212.1	374.6	73.7	229.8	150.5	206.0	201.2	136.7	166.5	0.5	19.7	0.0	0.0	0.0	2029.1
1974	7.5	7.3	12.0	0.0	0.0	9.0	0.5	0.8	8.5	5.4	34.4	90.0	132.2	210.8	197.0	226.4	53.5	101.0	1.8	15.1	0.6	0.0	0.1	2.6	1116.4
1975	21.5	29.8	6.9	2.0	3.6	2.7	0.0	0.0	8.9	20.8	66.3	224.7	304.9	342.2	147.1	284.0	146.2	156.8	94.6	5.9	0.0	0.0	0.0	0.0	1869.0
1976	0.0	11.4	4.2	4.7	1.9	0.7	0.9	14.5	40.5	61.3	157.1	105.0	293.1	236.0	263.7	247.8	153.7	201.8	39.2	4.8	0.0	0.0	0.0	0.8	1842.9
1977	0.0	1.3	4.3	0.0	0.0	2.1	24.6	16.7	66.6	11.9	26.4	92.7	254.7	197.8	183.9	165.5	71.2	79.7	49.9	14.4	0.2	0.0	2.0	18.8	1284.7
1978	4.9	12.4	18.0	28.4	16.2	13.3	0.0	16.5	23.7	23.1	103.9	262.6	183.0	221.4	190.9	112.3	137.7	135.5	18.1	0.0	0.0	0.2	5.7	0.0	1527.7
1979	5.1	12.3	42.7	28.5	2.1	0.3	2.5	9.6	32.4	81.4	105.4	185.2	112.2	351.2	221.7	183.5	24.0	17.2	87.8	0.0	0.0	5.4	4.0	46.3	1560.8
1980	2.3	0.0	18.1	0.7	9.6	4.2	0.0	0.0	62.4	35.3	189.4	116.3	292.7	285.4	205.7	198.4	323.6	119.0	48.2	11.3	0.0	0.0	0.0	0.0	1922.4
1981	18.5	23.5	2.0	0.6	3.0	14.2	3.1	15.1	54.7	96.3	8.1	284.7	173.4	257.2	86.2	266.9	427.8	152.3	0.0	0.0	65.1	0.0	9.6	0.0	1962.1
1982	0.7	38.1	14.8	0.1	67.3	11.0	0.0	16.0	99.4	26.1	188.2	74.8	96.9	172.3	339.1	208.1	374.0	20.3	18.7	37.5	22.5	17.9	0.0	5.9	1849.9
1983	0.0	16.5	0.0	4.6	0.1	0.7	3.2	15.7	62.7	107.7	58.0	32.8	184.0	218.6	215.8	211.8	303.6	218.0	265.0	13.3	0.0	0.0	0.0	43.8	1976.0
1984	0.0	39.8	3.0	1.6	0.0	1.4	0.7	22.8	3.9	52.5	283.9	251.1	212.8	511.6	164.7	198.9	357.0	63.7	8.0	23.5	0.0	0.0	11.2	9.7	2221.8
1985	16.7	1.9	1.5	0.0	0.0	0.0	6.5	9.5	18.3	32.4	48.3	225.0	248.6	238.8	146.6	378.8	285.6	140.0	179.1	1.1	0.0	0.0	0.0	35.6	2014.2
1986	0.0	0.0	43.6	9.4	2.2	0.8	3.1	31.5	45.6	84.6	58.9	258.3	265.1	196.0	135.4	273.8	122.2	158.1	105.0	10.8	0.0	8.4	33.4	22.1	1868.3

TABLE - 3.6

AVERAGE RAINYDAYS (FORTNIGHTLY)

Month	January		February		March		April		May		June		July		August		September		October		November		December		Total
Year	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	
1972	0	0	3	0	0	0	1	0	0	0	2	3	8	9	7	8	10	4	1	1	0	2	0	0	59
1973	4	4	0	1	2	0	0	1	3	3	8	12	4	9	8	10	11	6	7	0	2	0	0	0	97
1974	1	1	1	0	0	1	0	0	1	1	2	5	7	11	8	8	5	6	0	1	0	0	0	0	60
1975	2	2	1	0	0	0	0	0	1	2	4	9	11	12	8	9	8	8	5	1	0	0	0	0	84
1976	0	1	1	1	0	0	0	1	2	3	8	3	10	9	11	12	7	6	2	1	0	0	0	0	78
1977	0	0	1	0	0	0	2	2	5	1	2	3	9	9	7	8	5	3	2	2	0	0	0	2	65
1978	1	1	2	1	2	1	0	2	2	2	5	9	8	9	12	7	8	7	1	0	0	0	1	0	80
1979	0	2	3	3	0	0	0	1	2	1	5	8	6	10	9	8	1	1	4	0	0	1	0	2	67
1980	0	0	2	0	1	1	0	0	2	3	6	6	9	10	8	8	6	4	2	1	0	0	0	0	69
1981	1	2	0	0	1	1	1	1	3	6	1	9	9	9	5	9	9	6	0	0	2	0	1	0	76
1982	0	3	2	0	4	1	0	2	4	1	8	4	5	9	11	11	8	2	1	1	2	1	0	1	81
1983	0	1	0	1	0	0	0	1	4	5	3	2	6	9	9	8	9	10	7	1	0	0	0	2	78
1984	0	1	1	0	0	0	0	2	1	2	10	10	10	11	6	10	11	3	1	1	0	0	1	1	82
1985	2	0	0	0	0	0	1	1	2	2	4	8	8	9	6	11	11	9	7	0	0	0	0	2	83
1986	0	0	3	1	0	0	1	4	3	6	2	9	11	10	6	10	5	7	4	1	0	1	1	2	86

TABLE - 3.7 (i)

ESTIMATION OF RUNOFF
MOCK MODEL

LOCATION: OUT-LET POINT OF DANG VALLEY
Year:1973

Column No. →		1	2	3	4	5	6	7	8	9	10	11	12
		Average rainfall (mm)	Evapo -transpiration (mm)	Number of rainy days No.	Area not covered by vegetation %	Reduction in Eto due to rain fall and surface factors Eto*m/20*(18-n)	Actual Eto (Eto-e) (mm)	Change in soil moisture (P-Aeto) i.e.col(1)-col(6) (mm)	Soil moisture at the end of period (mm)	Value of col(7) if value in col(8) is 150mm otherwise zero (mm)	Col.(7)* infiltration factor 0.2 when col (7) is +ve otherwise zero	Storage volume Vn = (1+k)/2 * INFIL +k*Vn-1 (mm)	Change in ground water storage col(11)-col(11)of previous row
Symbol →		P	Eto	n	m	e	Aeto	EP	SMSe	WS	INFIL	Vn	GSTOR
Month ↓									0			55	
June	1	212.1	83.55	8	49	20.47	63.08	149.02	149.02	0	29.80	77.81	22.81
	2	374.6	83.55	12	20	5.01	78.54	296.06	150.00	295.08	59.21	126.28	48.47
July	1	73.7	69.75	4	20	9.77	59.99	13.72	150.00	13.72	2.74	116.26	-10.02
	2	229.8	74.4	9	20	6.70	67.70	162.10	150.00	162.1	32.42	135.43	19.17
August	1	150.5	69.45	8	20	6.95	62.51	88.00	150.00	88	17.60	138.61	3.18
	2	206	74.08	10	20	5.93	68.15	137.85	150.00	137.85	27.57	150.94	12.33
September	1	201.2	54.9	11	20	3.84	51.06	150.14	150.00	150.14	30.03	164.37	13.43
	2	136.7	54.9	6	20	6.59	48.31	88.39	150.00	88.39	17.68	164.73	0.36
October	1	166.5	49.5	7	20	5.45	44.06	122.45	150.00	122.45	24.49	171.52	6.79
	2	0.5	52.8	0	20	9.50	43.30	-42.80	107.20	0	0.00	154.37	-17.15
November	1	19.7	36.45	2	20	5.83	30.62	-10.92	96.29	0	0.00	138.93	-15.44
	2	0	36.45	0	20	6.56	29.89	-29.89	66.40	0	0.00	125.04	-13.89
December	1	0	32.1	0	20	5.78	26.32	-26.32	40.08	0	0.00	112.53	-12.50
	2	0	34.24	0	20	6.16	28.08	-28.08	12.00	0	0.00	101.28	-11.25
January	1	45	32.7	4	20	4.58	28.12	16.88	28.88	0	3.38	94.36	-6.92
	2	72.4	34.88	4	20	4.88	30.00	42.40	71.28	0	8.48	92.98	-1.38
February	1	3.7	50.25	0	20	9.05	41.21	-37.51	33.77	0	0.00	83.68	-9.30
	2	42.8	43.55	1	20	7.40	36.15	6.65	40.43	0	1.33	76.58	-7.10
March	1	15.2	75	2	20	12.00	63.00	-47.80	0.00	0	0.00	68.92	-7.66
	2	0	80	0	49	35.28	44.72	-44.72	0.00	0	0.00	62.03	-6.89
April	1	0	98.7	0	49	43.53	55.17	-55.17	0.00	0	0.00	55.83	-6.20
	2	2.8	98.7	1	49	41.11	57.59	-54.79	0.00	0	0.00	50.24	-5.58
May	1	46.8	96	3	49	35.28	60.72	-13.92	0.00	0	0.00	45.22	-5.02
	2	29.1	102.4	3	49	37.63	64.77	-35.67	0.00	0	0.00	40.70	-4.52

Remarks:
Soil moisture capacity =150 mm
Infiltration factor =0.2
Initial ground water storage =55 mm
Ground water recession coefficient (k) =0.9
Dry season storm runoff factor =0.1

13	14	15	16	17	18	19	20	21	22	23	24	25	26
Base flow =col(10) -col(12) i.e. infiltration -change in storage (mm)	Direct runoff (DR) = col(9) * (1-0.2) (mm)	Total runoff (BF+DR) (mm)	Storm runoff (mm)	Change in soil moisture	Soil moisture at the end of period (mm)	Water surplus (mm)	Percolation to ground water	Storage volume Vn= INFIL * (1+k)/2+ k*Vn-1 (mm)	Ground water balance (mm)	Base flow (mm)	Direct runoff (mm)	Total runoff (mm)	Total runoff m3/sec
BF	DR	TR	Qs		SMSe	WS	INFIL	Vn	GSTOR	BF	DR	TR	TR
					0			55					
6.99	0.00	6.99	0	149.02	149.02	0	29.80	77.81	22.81	6.99	0	6.99	7.72
10.74	236.06	246.81	0	296.06	150.00	295.08	59.21	126.28	48.47	10.74	236.0662	246.81	272.52
12.77	10.98	23.74	0	13.72	150.00	13.72	2.74	116.26	-10.02	12.77	10.972	23.74	26.21
13.25	129.68	142.93	0	162.10	150.00	162.10	32.42	135.43	19.17	13.25	129.6768	142.92	147.95
14.42	70.40	84.82	0	88.00	150.00	88.00	17.60	138.61	3.18	14.42	70.396	84.82	93.65
15.24	110.28	125.52	0	137.85	150.00	137.85	27.57	150.94	12.33	15.24	110.2771	125.52	129.93
16.60	120.11	136.71	0	150.14	150.00	150.14	30.03	164.37	13.43	16.60	120.1144	136.71	150.95
17.32	70.71	88.03	0	88.39	150.00	88.39	17.68	164.73	0.36	17.32	70.7104	88.03	97.20
17.70	97.96	115.66	16.65	105.80	150.00	105.80	21.16	168.36	3.63	17.53	84.636	102.17	112.81
17.15	0	17.15	0.05	-42.85	107.15	0	0.00	151.52	-16.84	16.84	0	16.84	17.43
15.44	0	15.44	1.97	-12.89	94.27	0	0.00	136.37	-15.15	15.15	0	15.15	16.73
13.89	0	13.89	0	-29.89	64.38	0	0.00	122.73	-13.64	13.64	0	13.64	15.06
12.50	0	12.50	0	-26.32	38.06	0	0.00	110.46	-12.27	12.27	0	12.27	13.55
11.25	0	11.25	0	-28.08	9.98	0	0.00	99.41	-11.05	11.05	0	11.05	11.43
10.30	0	10.30	4.5	12.38	22.36	0	2.48	91.82	-7.59	10.07	0	10.07	11.11
9.86	0	9.86	7.24	35.16	57.52	0	7.03	89.32	-2.50	9.53	0	9.53	9.87
9.30	0	9.30	0.37	-37.88	19.64	0	0.00	80.39	-8.93	8.93	0	8.93	9.86
8.43	0	8.43	4.28	2.37	22.02	0	0.47	72.80	-7.59	8.06	0	8.06	10.27
7.66	0	7.66	1.52	-49.32	0.00	0	0.00	65.52	-7.28	7.28	0	7.28	8.04
6.89	0	6.89	0	-44.72	0.00	0	0.00	58.97	-6.55	6.55	0	6.55	6.78
6.20	0	6.20	0	-55.17	0.00	0	0.00	53.07	-5.90	5.90	0	5.90	6.51
5.58	0	5.58	0.28	-55.07	0.00	0	0.00	47.77	-5.31	5.31	0	5.31	5.86
5.02	0	5.02	4.68	-18.60	0.00	0	0.00	42.99	-4.78	4.78	0	4.78	5.27
4.52	0	4.52	2.91	-38.58	0.00	0	0.00	38.69	-4.30	4.30	0	4.30	4.45

TABLE - 3.7 (ii)

ESTIMATION OF RUNOFF
MOCK MODEL

LOCATION: OUT-LET POINT OF DANG VALLEY

Year:1974

Column No. →		1	2	3	4	5	6	7	8	9	10	11	12
		Average rainfall (mm)	Evapo (mm)	Number of rainy days No.	Area not covered by vegetation %	Reduction in Eto due to rain fall and surface factors Eto*m/20*(18-n)	Actual Eto (Eto-e) (mm)	Change in soil moisture (P-Aeto) i.e.col(1)-col(6) (mm)	Soil moisture at the end of period (mm)	Value of col(7) if value in col(8) is 150mm otherwise zero (mm)	Col.(7)* infiltration factor (0.2) when col (7) is +ve otherwise zero	Storage volume Vn = (1+k)/2 * INFIL +k*Vn-1 (mm)	Change in ground water storage col(11)-col(11)of previous row
Symbol →		P	Eto	n	m	e	Aeto	EP	SMSe	WS	INFIL	Vn	GSTOR
Month ↓									0			55	
June	1	34.4	83.55	2	49	32.75	50.80	-16.40	0	0	0	49.50	-5.50
	2	90	83.55	5	20	10.86	72.69	17.31	17.31	0	3.46	47.84	-1.66
July	1	132.2	69.75	7	20	7.67	62.08	70.12	87.43	0	14.02	56.38	8.54
	2	210.8	74.4	11	20	5.21	69.19	141.61	150.00	79.04	28.32	77.65	21.27
August	1	197	69.45	8	20	6.95	62.51	134.50	150.00	134.05	26.90	95.44	17.79
	2	226.4	74.08	8	20	7.41	66.67	159.73	150.00	159.73	31.95	116.24	20.80
September	1	53.5	54.9	5	20	7.14	47.76	5.74	150.00	5.74	1.15	105.71	-10.53
	2	101	54.9	6	20	6.59	48.31	52.69	150.00	52.69	10.54	105.15	-0.56
October	1	1.8	49.5	0	20	8.91	40.59	-38.79	111.21	0	0	94.63	-10.51
	2	15.1	52.8	1	20	8.98	43.82	-28.72	82.49	0	0	85.17	-9.46
November	1	0.6	36.45	0	20	6.56	29.89	-29.29	53.20	0	0	76.65	-8.52
	2	0	36.45	0	20	6.56	29.89	-29.89	23.31	0	0	68.99	-7.67
December	1	0.1	32.1	0	20	5.78	26.32	-26.22	0.00	0	0	62.09	-6.90
	2	2.6	34.24	0	20	6.16	28.08	-25.48	0.00	0	0	55.88	-6.21
January	1	7.5	32.7	1	20	5.56	27.14	-19.64	0.00	0	0	50.29	-5.59
	2	7.3	34.88	1	20	5.93	28.95	-21.65	0.00	0	0	45.26	-5.03
February	1	12	50.25	1	20	8.54	41.71	-29.71	0.00	0	0	40.74	-4.53
	2	0	43.55	0	20	7.84	35.71	-35.71	0.00	0	0	36.66	-4.07
March	1	0	75	0	20	13.50	61.50	-61.50	0.00	0	0	33.00	-3.67
	2	9	80	1	49	33.32	46.68	-37.68	0.00	0	0	29.70	-3.30
April	1	0.5	98.7	0	49	43.53	55.17	-54.67	0.00	0	0	26.73	-2.97
	2	0.8	98.7	0	49	43.53	55.17	-54.37	0.00	0	0	24.05	-2.67
May	1	8.5	96	1	49	39.98	56.02	-47.52	0.00	0	0	21.65	-2.41
	2	5.4	102.4	1	49	42.65	59.75	-54.35	0.00	0	0	19.48	-2.16

Remarks:

Soil moisture capacity =150 mm

Infiltration factor =0.2

Initial ground water storage =55 mm

Ground water recession coefficient (k) =0.9

Dry season storm runoff factor =0.1

TABLE - 3.7 (ii)

13	14	15	16	17	18	19	20	21	22	23	24	25	26
Base flow =col(10) -col(12) i.e. infiltration -change in storage	Direct runoff (DR) = col(9) * (1-0.2)	Total runoff (BF+DR)	Storm runoff	Change in soil moisture	Soil moisture at the end of period	Water surplus	Percolation to ground water	Storage volume Vn= INFIL * (1+k)/2+ k*Vn-1	Ground water balance	Base flow	Direct runoff	Total runoff	Total runoff
(mm)	(mm)	(mm)	(mm)		(mm)	(mm)		(mm)	(mm)	(mm)	(mm)	(mm)	m3/sec
BF	DR	TR	Qs		SMSe	WS	INFIL	Vn	GSTOR	BF	DR	TR	TR
					0			55					
5.50	0	5.50	0	-16.40	0	0	0	49.50	-5.50	5.50	0	5.50	6.07
5.12	0	5.12	0	17.31	17.31	0	3.46	47.84	-1.66	5.12	0	5.12	5.66
5.49	0	5.49	0	70.12	87.43	0	14.02	56.38	8.54	5.49	0	5.49	6.06
7.05	63.23	70.29	0	141.61	150.00	79.04	28.32	77.65	21.27	7.05	63.23	70.29	72.76
9.11	107.24	116.35	0	134.50	150.00	134.50	26.90	95.44	17.79	9.11	107.60	116.71	128.86
11.14	127.78	138.92	0	159.73	150.00	159.73	31.95	116.24	20.80	11.14	127.78	138.92	143.81
11.68	4.59	16.27	0	5.74	150.00	5.74	1.15	105.71	-10.53	11.68	4.59	16.27	17.97
11.10	42.15	53.25	0	52.69	150.00	52.69	10.54	105.15	-0.56	11.10	42.15	53.25	58.79
10.51	0	10.51	0.18	-38.97	111.03	0	0	94.63	-10.51	10.51	0	10.51	11.61
9.46	0	9.46	1.51	-30.23	80.80	0	0	85.17	-9.46	9.46	0	9.46	9.80
8.52	0	8.52	0.06	-29.35	51.45	0	0	76.65	-8.52	8.52	0	8.52	9.40
7.67	0	7.67	0	-29.89	21.56	0	0	68.99	-7.67	7.67	0	7.67	8.46
6.90	0	6.90	0.01	-26.23	0.00	0	0	62.09	-6.90	6.90	0	6.90	7.62
6.21	0	6.21	0.26	-25.74	0.00	0	0	55.88	-6.21	6.21	0	6.21	6.43
5.59	0	5.59	0.75	-20.39	0.00	0	0	50.29	-5.59	5.59	0	5.59	6.17
5.03	0	5.03	0.73	-22.38	0.00	0	0	45.26	-5.03	5.03	0	5.03	5.21
4.53	0	4.53	1.2	-30.91	0.00	0	0	40.74	-4.53	4.53	0	4.53	5.00
4.07	0	4.07	0	-35.71	0.00	0	0	36.66	-4.07	4.07	0	4.07	5.19
3.67	0	3.67	0	-61.50	0.00	0	0	33.00	-3.67	3.67	0	3.67	4.05
3.30	0	3.30	0.9	-38.58	0.00	0	0	29.70	-3.30	3.30	0	3.30	3.42
2.97	0	2.97	0.05	-54.72	0.00	0	0	26.73	-2.97	2.97	0	2.97	3.28
2.67	0	2.67	0.08	-54.45	0.00	0	0	24.05	-2.67	2.67	0	2.67	2.95
2.41	0	2.41	0.85	-48.37	0.00	0	0	21.65	-2.41	2.41	0	2.41	2.66
2.16	0	2.16	0.54	-54.89	0.00	0	0	19.48	-2.16	2.16	0	2.16	2.24

TABLE - 3.7 (iii)

ESTIMATION OF RUNOFF
MOCK MODEL

LOCATION: OUT-LET POINT OF DANG VALLEY
Year:1975

Column No.		1	2	3	4	5	6	7	8	9	10	11	12
		Average rainfall (mm)	Evapo -transpiration (mm)	Number of rainy days No.	Area not covered by vegetation %	Reduction in Eto due to rain fall and surface factors Eto*m/20*(18-n)	Actual Eto (Eto-e) (mm)	Change in soil moisture (P-Aeto) i.e.col(1)-col(6) (mm)	Soil moisture at the end of period (mm)	Value of col(7) if value in col(8) is 150mm otherwise zero (mm)	Col.(7)* infiltration factor 0.2 when col (7) is +ve otherwise zero	Storage volume Vn = (1+k)/2 * INFIL +k*Vn-1 (mm)	Change in ground water storage col(11)-col(11)of previous row
Symbol		P	Eto	n	m	e	Aeto	EP	SMSe	WS	INFIL	Vn	GSTOR
Month									0			55	
June	1	66.3	83.55	4	49	28.66	54.89	11.41	11.41	0	2.28	51.67	-3.33
	2	224.7	83.55	9	20	7.52	76.03	148.67	150.00	10.08	29.73	74.75	23.08
July	1	304.9	69.75	11	20	4.88	64.87	240.03	150.00	240.03	48.01	112.88	38.13
	2	342.2	74.4	12	20	4.46	69.94	272.26	150.00	272.26	54.45	153.32	40.44
August	1	147.1	69.45	8	20	6.95	62.51	84.60	150.00	84.6	16.92	154.06	0.74
	2	284	74.08	9	20	6.67	67.41	216.59	150.00	216.59	43.32	179.81	25.75
September	1	146.2	54.9	8	20	5.49	49.41	96.79	150.00	96.79	19.36	180.22	0.41
	2	156.8	54.9	8	20	5.49	49.41	107.39	150.00	107.39	21.48	182.60	2.38
October	1	94.6	49.5	5	20	6.44	43.07	51.54	150.00	51.54	10.31	174.13	-8.47
	2	5.9	52.8	1	20	8.98	43.82	-37.92	112.08	0	0.00	156.72	-17.41
November	1	0	36.45	0	20	6.56	29.89	-29.89	82.19	0	0.00	141.05	-15.67
	2	0	36.45	0	20	6.56	29.89	-29.89	52.30	0	0.00	126.94	-14.10
December	1	0	32.1	0	20	5.78	26.32	-26.32	25.98	0	0.00	114.25	-12.69
	2	0	34.24	0	20	6.16	28.08	-28.08	0.00	0	0.00	102.82	-11.42
January	1	21.5	32.7	2	20	5.23	27.47	-5.97	0.00	0	0.00	92.54	-10.28
	2	29.8	34.88	2	20	5.58	29.30	0.50	0.50	0	0.10	83.38	-9.16
February	1	6.9	50.25	1	20	8.54	41.71	-34.81	0.00	0	0.00	75.04	-8.34
	2	2	43.55	0	20	7.84	35.71	-33.71	0.00	0	0.00	67.54	-7.50
March	1	3.6	75	0	20	13.50	61.50	-57.90	0.00	0	0.00	60.79	-6.75
	2	2.7	80	0	49	35.28	44.72	-42.02	0.00	0	0.00	54.71	-6.08
April	1	0	98.7	0	49	43.53	55.17	-55.17	0.00	0	0.00	49.24	-5.47
	2	0	98.7	0	49	43.53	55.17	-55.17	0.00	0	0.00	44.31	-4.92
May	1	8.9	96	1	49	39.98	56.02	-47.12	0.00	0	0.00	39.88	-4.43
	2	20.8	102.4	2	49	40.14	62.26	-41.46	0.00	0	0.00	35.89	-3.99

Remarks:
Soil moisture capacity =150 mm
Infiltration factor =0.2
Initial ground water storage =55 mm
Ground water recession coefficient (k) =0.9
Dry season storm runoff factor =0.1

TABLE - 3.7 (iii)

13	14	15	16	17	18	19	20	21	22	23	24	25	26
Base flow =col(10) -col(12) i.e. infiltration -change in storage	Direct runoff (DR) = col(9) * (1-0.2)	Total runoff (BF+DR)	Storm runoff	Change in soil moisture	Soil moisture at the end of period	Water surplus	Percolation to ground water	Storage volume Vn= INFIL * (1+k)/2+ k*Vn-1	Ground water balance	Base flow	Direct runoff	Total runoff	Total runoff
(mm)	(mm)	(mm)	(mm)		(mm)	(mm)		(mm)	(mm)	(mm)	(mm)	(mm)	m3/sec
BF	DR	TR	Qs		SMSe	WS	INFIL	Vn	GSTOR	BF	DR	TR	TR
					0			55					
5.61	0.00	5.61	0	11.41	11.41	0	2.28	51.67	-3.33	5.61	0.00	5.61	6.20
6.65	8.06	14.72	0	148.67	150.00	10.08	29.73	74.75	23.08	6.65	8.06	14.72	16.25
9.88	192.02	201.90	0	240.03	150.00	240.03	48.01	112.88	38.13	9.88	192.03	201.90	222.93
14.01	217.81	231.82	0	272.26	150.00	272.26	54.45	153.32	40.44	14.01	217.81	231.82	239.97
16.18	67.68	83.86	0	84.60	150.00	84.60	16.92	154.06	0.74	16.18	67.68	83.85	92.59
17.57	173.27	190.84	0	216.59	150.00	216.59	43.32	179.81	25.75	17.57	173.27	190.84	197.55
18.95	77.43	96.38	0	96.79	150.00	96.79	19.36	180.22	0.41	18.95	77.43	96.38	106.42
19.10	85.91	105.01	0	107.39	150.00	107.39	21.48	182.60	2.38	19.10	85.91	105.01	115.95
18.78	41.23	60.01	9.46	42.08	150.00	42.08	8.42	172.33	-10.27	18.68	33.66	52.34	57.79
17.41	0.00	17.41	0.59	-38.51	111.49	0	0.00	155.10	-17.23	17.23	0.00	17.23	17.84
15.67	0.00	15.67	0	-29.89	81.60	0	0.00	139.59	-15.51	15.51	0.00	15.51	17.13
14.10	0.00	14.10	0	-29.89	51.71	0	0.00	125.63	-13.96	13.96	0.00	13.96	15.41
12.69	0.00	12.69	0	-26.32	25.39	0	0.00	113.07	-12.56	12.56	0.00	12.56	13.87
11.42	0.00	11.42	0	-28.08	0.00	0	0.00	101.76	-11.31	11.31	0.00	11.31	11.70
10.28	0.00	10.28	2.15	-8.12	0.00	0	0.00	91.59	-10.18	10.18	0.00	10.18	11.24
9.26	0.00	9.26	2.98	-2.48	0.00	0	0.00	82.43	-9.16	9.16	0.00	9.16	9.48
8.34	0.00	8.34	0.69	-35.50	0.00	0	0.00	74.18	-8.24	8.24	0.00	8.24	9.10
7.50	0.00	7.50	0.2	-33.91	0.00	0	0.00	66.77	-7.42	7.42	0.00	7.42	9.45
6.75	0.00	6.75	0.36	-58.26	0.00	0	0.00	60.09	-6.68	6.68	0.00	6.68	7.37
6.08	0.00	6.08	0.27	-42.29	0.00	0	0.00	54.08	-6.01	6.01	0.00	6.01	6.22
5.47	0.00	5.47	0	-55.17	0.00	0	0.00	48.67	-5.41	5.41	0.00	5.41	5.97
4.92	0.00	4.92	0	-55.17	0.00	0	0.00	43.80	-4.87	4.87	0.00	4.87	5.37
4.43	0.00	4.43	0.89	-48.01	0.00	0	0.00	39.42	-4.38	4.38	0.00	4.38	4.84
3.99	0.00	3.99	2.08	-43.54	0.00	0	0.00	35.48	-3.94	3.94	0.00	3.94	4.08

TABLE - 3.7 (iv)

ESTIMATION OF RUNOFF
MOCK MODEL

LOCATION: OUT-LET POINT OF DANG VALLEY
Year:1979

Column No.		1	2	3	4	5	6	7	8	9	10	11	12
		Average rainfall (mm)	Evapo -transpiration (mm)	Number of rainy days No.	Area not covered by vegetation %	Reduction in Eto due to rain fall and surface factors Eto*m/20*(18-n)	Actual Eto (Eto-e) (mm)	Change in soil moisture (P-Aeto) i.e.col(1)-col(6) (mm)	Soil moisture at the end of period (mm)	Value of col(7) if value in col(8) is 150mm otherwise zero (mm)	Col.(7)* infiltration factor 0.2 when col (7) is +ve otherwise zero	Storage volume Vn = (1+k)/2 * INFIL +k*Vn-1 (mm)	Change in ground water storage col(11)-col(11)of previous row
Symbol		P	Eto	n	m	e	Aeto	EP	SMSe	WS	INFIL	Vn	GSTOR
Month									0			55	
June	1	105.4	83.55	5	49	26.61	56.94	48.46	48.46	0	9.69	58.71	3.71
	2	185.2	83.55	8	20	8.36	75.20	110.01	150.00	8.47	22.00	73.74	15.03
July	1	112.2	69.75	6	20	8.37	61.38	50.82	150.00	50.82	10.16	76.02	2.28
	2	351.2	74.4	10	20	5.95	68.45	282.75	150.00	282.75	56.55	122.14	46.12
August	1	221.7	69.45	9	20	6.25	63.20	158.50	150.00	158.5	31.70	140.04	17.90
	2	183.5	74.08	8	20	7.41	66.67	116.83	150.00	116.83	23.37	148.23	8.19
September	1	24	54.9	1	20	9.33	45.57	-21.57	128.43	0	0.00	133.41	-14.82
	2	17.2	54.9	1	20	9.33	45.57	-28.37	100.07	0	0.00	120.07	-13.34
October	1	87.8	49.5	4	20	6.93	42.57	45.23	145.30	0	9.05	116.66	-3.41
	2	0	52.8	0	20	9.50	43.30	-43.30	102.00	0	0.00	104.99	-11.67
November	1	0	36.45	0	20	6.56	29.89	-29.89	72.11	0	0.00	94.49	-10.50
	2	5.4	36.45	1	20	6.20	30.25	-24.85	47.26	0	0.00	85.04	-9.45
December	1	4	32.1	0	20	5.78	26.32	-22.32	24.94	0	0.00	76.54	-8.50
	2	46.3	34.24	2	20	5.48	28.76	17.54	42.47	0	3.51	72.22	-4.32
January	1	5.1	32.7	0	20	5.89	26.81	-21.71	20.76	0	0.00	65.00	-7.22
	2	12.3	34.88	2	20	5.58	29.30	-17.00	3.76	0	0.00	58.50	-6.50
February	1	42.7	50.25	3	20	7.54	42.71	-0.01	3.75	0	0.00	52.65	-5.85
	2	28.5	43.55	3	20	6.53	37.02	-8.52	0.00	0	0.00	47.38	-5.26
March	1	2.1	75	0	20	13.50	61.50	-59.40	0.00	0	0.00	42.64	-4.74
	2	0.3	80	0	49	35.28	44.72	-44.42	0.00	0	0.00	38.38	-4.26
April	1	2.5	98.7	0	49	43.53	55.17	-52.67	0.00	0	0.00	34.54	-3.84
	2	9.6	98.7	1	49	41.11	57.59	-47.99	0.00	0	0.00	31.09	-3.45
May	1	32.4	96	2	49	37.63	58.37	-25.97	0.00	0	0.00	27.98	-3.11
	2	81.4	102.4	1	49	42.65	59.75	21.65	0.00	0	4.33	29.29	1.32

Remarks:
Soil moisture capacity =150 mm
Infiltration factor =0.2
Initial ground water storage =55 mm
Ground water recession coefficient (k) =0.9
Dry season storm runoff factor =0.1

TABLE - 3.7 (iv)

13	14	15	16	17	18	19	20	21	22	23	24	25	26
Base flow =col(10) -col(12) i.e. infiltration -change in storage (mm)	Direct runoff (DR) = col(9) * (1-0.2) (mm)	Total runoff (BF+DR) (mm)	Storm runoff (mm)	Change in soil moisture	Soil moisture at the end of period (mm)	Water surplus (mm)	Percolation to ground water	Storage volume Vn= INFIL * (1+k)/2+ k*Vn-1 (mm)	Ground water balance (mm)	Base flow (mm)	Direct runoff (mm)	Total runoff (mm)	Total runoff m3/sec
BF	DR	TR	Qs		SMSe	WS	INFIL	Vn	GSTOR	BF	DR	TR	TR
					0			55					
5.98	0.00	5.98	0	48.46	48.46	0	9.69	58.71	3.71	5.98	0.00	5.98	6.61
6.97	6.78	13.75	0	110.01	150.00	8.47	22.00	73.74	15.03	6.97	6.77	13.74	15.17
7.88	40.66	48.54	0	50.82	150.00	50.82	10.16	76.02	2.28	7.88	40.66	48.54	53.59
10.43	226.20	236.63	0	282.75	150.00	282.75	56.55	122.14	46.12	10.43	226.20	236.63	244.95
13.80	126.80	140.60	0	158.50	150.00	158.50	31.70	140.04	17.90	13.80	126.80	140.60	155.25
15.17	93.46	108.64	0	116.83	150.00	116.83	23.37	148.23	8.19	15.17	93.46	108.63	112.45
14.82	0.00	14.82	0	-21.57	128.43	0	0.00	133.41	-14.82	14.82	0.00	14.82	16.37
13.34	0.00	13.34	0	-28.37	100.07	0	0.00	120.07	-13.34	13.34	0.00	13.34	14.73
12.46	0.00	12.46	8.78	36.45	136.52	0	7.29	114.99	-5.08	12.37	0.00	12.37	13.66
11.67	0.00	11.67	0	-43.30	93.22	0	0.00	103.49	-11.50	11.50	0.00	11.50	11.90
10.50	0.00	10.50	0	-29.89	63.33	0	0.00	93.14	-10.35	10.35	0.00	10.35	11.43
9.45	0.00	9.45	0.54	-25.39	37.94	0	0.00	83.83	-9.31	9.31	0.00	9.31	10.28
8.50	0.00	8.50	0.4	-22.72	15.22	0	0.00	75.44	-8.38	8.38	0.00	8.38	9.26
7.83	0.00	7.83	4.63	12.91	28.12	0	2.58	70.35	-5.09	7.67	0.00	7.67	7.94
7.22	0.00	7.22	0.51	-22.22	5.90	0	0.00	63.32	-7.04	7.04	0.00	7.04	7.77
6.50	0.00	6.50	1.23	-18.23	0.00	0	0.00	56.99	-6.33	6.33	0.00	6.33	6.55
5.85	0.00	5.85	4.27	-4.28	0.00	0	0.00	51.29	-5.70	5.70	0.00	5.70	6.29
5.26	0.00	5.26	2.85	-11.37	0.00	0	0.00	46.16	-5.13	5.13	0.00	5.13	6.53
4.74	0.00	4.74	0.21	-59.61	0.00	0	0.00	41.54	-4.62	4.62	0.00	4.62	5.10
4.26	0.00	4.26	0.03	-44.45	0.00	0	0.00	37.39	-4.15	4.15	0.00	4.15	4.30
3.84	0.00	3.84	0.25	-52.92	0.00	0	0.00	33.65	-3.74	3.74	0.00	3.74	4.13
3.45	0.00	3.45	0.96	-48.95	0.00	0	0.00	30.28	-3.36	3.36	0.00	3.36	3.72
3.11	0.00	3.11	3.24	-29.21	0.00	0	0.00	27.26	-3.03	3.03	0.00	3.03	3.34
3.01	0.00	3.01	8.14	13.51	13.51	0	2.70	27.10	-0.16	2.86	0.00	2.86	2.96

TABLE - 3.7 (v)

ESTIMATION OF RUNOFF
MOCK MODEL

LOCATION: OUT-LET POINT OF DANG VALLEY
YEAR: 1984

Column No.		1	2	3	4	5	6	7	8	9	10	11	12
		Average rainfall (mm)	Evapo -transpiration (mm)	Number of rainy days No.	Area not covered by vegetation %	Reduction in Eto due to rain fall and surface factors Eto*m/20*(18-n)	Actual Eto (Eto-e) (mm)	Change in soil moisture (P-Aeto) i.e.col(1)-col(6) (mm)	Soil moisture at the end of period (mm)	Value of col(7) if value in col(8) is 150mm otherwise zero (mm)	Col.(7)* infiltration factor 0.2 when col (7) is +ve otherwise zero	Storage volume Vn = (1+k)/2 * INFIL +k*Vn-1 (mm)	Change in ground water storage col(11)-col(11)of previous row
Symbol		P	Eto	n	m	e	Aeto	EP	SMSe	WS	INFIL	Vn	GSTOR
Month									0			55	
June	1	283.9	83.55	10	49	16.38	67.17	216.73	150.00	66.73	43.35	90.68	35.68
	2	251.1	83.55	10	20	6.68	76.87	174.23	150.00	174.23	34.85	114.71	24.04
July	1	212.8	69.75	10	20	5.58	64.17	148.63	150.00	148.63	29.73	131.48	16.77
	2	511.6	74.4	11	20	5.21	69.19	442.41	150.00	442.41	88.48	202.39	70.91
August	1	164.7	69.45	6	20	8.33	61.12	103.58	150.00	103.58	20.72	201.83	-0.56
	2	198.9	74.08	10	20	5.93	68.15	130.75	150.00	130.75	26.15	206.49	4.66
September	1	357	54.9	11	20	3.84	51.06	305.94	150.00	305.94	61.19	243.97	37.48
	2	63.7	54.9	3	20	8.24	46.67	17.04	150.00	17.04	3.41	222.81	-21.16
October	1	8	49.5	1	20	8.42	41.09	-33.09	116.92	0	0.00	200.53	-22.28
	2	23.5	52.8	1	20	8.98	43.82	-20.32	96.59	0	0.00	180.48	-20.05
November	1	0	36.45	0	20	6.56	29.89	-29.89	66.70	0	0.00	162.43	-18.05
	2	0	36.45	0	20	6.56	29.89	-29.89	36.81	0	0.00	146.19	-16.24
December	1	11.2	32.1	1	20	5.46	26.64	-15.44	21.37	0	0.00	131.57	-14.62
	2	9.7	34.24	1	20	5.82	28.42	-18.72	2.65	0	0.00	118.41	-13.16
January	1	0	32.7	0	20	5.89	26.81	-26.81	0.00	0	0.00	106.57	-11.84
	2	39.8	34.88	1	20	5.93	28.95	10.85	0.00	0	2.17	97.97	-8.60
February	1	3	50.25	1	20	8.54	41.71	-38.71	0.00	0	0.00	88.18	-9.80
	2	1.6	43.55	0	20	7.84	35.71	-34.11	0.00	0	0.00	79.36	-8.82
March	1	0	75	0	20	13.50	61.50	-61.50	0.00	0	0.00	71.42	-7.94
	2	1.4	80	0	49	35.28	44.72	-43.32	0.00	0	0.00	64.28	-7.14
April	1	0.7	98.7	0	49	43.53	55.17	-54.47	0.00	0	0.00	57.85	-6.43
	2	22.8	98.7	2	49	38.69	60.01	-37.21	0.00	0	0.00	52.07	-5.79
May	1	3.9	96	1	49	39.98	56.02	-52.12	0.00	0	0.00	46.86	-5.21
	2	52.5	102.4	2	49	40.14	62.26	-9.76	0.00	0	0.00	42.17	-4.69

Remarks:

Soil moisture capacity =150 mm
Infiltration factor =0.2
Initial ground water storage =55 mm
Ground water recession coefficient (k) =0.9
Dry season storm runoff factor =0.1

TABLE - 3.7 (v)

ESTIMATION OF RUNOFF
MOCK MODEL

LOCATION: OUT-LET POINT OF DANG VALLEY
YEAR: 1984

13	14	15	16	17	18	19	20	21	22	23	24	25	26
Base flow =col(10) -col(12) i.e. infiltration -change in storage	Direct runoff (DR) = col(9) * (1-0.2)	Total runoff (BF+DR)	Storm runoff	Change in soil moisture	Soil moisture at the end of period	Water surplus	Percolation to ground water	Storage volume Vn= INFIL * (1+k)/2+ k*Vn-1	Ground water balance	Base flow	Direct runoff	Total runoff	Total runoff
(mm)	(mm)	(mm)	(mm)		(mm)	(mm)		(mm)	(mm)	(mm)	(mm)	(mm)	m3/sec
BF	DR	TR	Qs		SMSe	WS	INFIL	Vn	GSTOR	BF	DR	TR	TR
					0			55					
7.67	53.38	61.05	0	216.73	150.00	66.73	43.35	90.68	35.68	7.67	53.38	61.05	67.41
10.81	139.38	150.19	0	174.23	150.00	174.23	34.85	114.71	24.04	10.81	139.39	150.20	165.84
12.96	118.90	131.86	0	148.63	150.00	148.63	29.73	131.48	16.77	12.96	118.90	131.86	145.60
17.57	353.93	371.50	0	442.41	150.00	442.41	88.48	202.39	70.91	17.57	353.93	371.50	384.56
21.28	82.86	104.14	0	103.58	150.00	103.58	20.72	201.83	-0.56	21.28	82.87	104.14	114.99
21.49	104.60	126.09	0	130.75	150.00	130.75	26.15	206.49	4.66	21.49	104.60	126.09	130.52
23.71	244.75	268.46	0	305.94	150.00	305.94	61.19	243.97	37.48	23.71	244.75	268.46	296.43
24.57	13.63	38.20	0	17.04	150.00	17.04	3.41	222.81	-21.16	24.57	13.63	38.20	42.17
22.28	0.00	22.28	0.8	-33.89	116.12	0	0.00	200.53	-22.28	22.28	0.00	22.28	24.60
20.05	0.00	20.05	2.35	-22.67	93.44	0	0.00	180.48	-20.05	20.05	0.00	20.05	20.76
18.05	0.00	18.05	0	-29.89	63.55	0	0.00	162.43	-18.05	18.05	0.00	18.05	19.93
16.24	0.00	16.24	0	-29.89	33.66	0	0.00	146.19	-16.24	16.24	0.00	16.24	17.93
14.62	0.00	14.62	1.12	-16.56	17.10	0	0.00	131.57	-14.62	14.62	0.00	14.62	16.14
13.16	0.00	13.16	0.97	-19.69	0.00	0	0.00	118.41	-13.16	13.16	0.00	13.16	13.62
11.84	0.00	11.84	0	-26.81	0.00	0	0.00	106.57	-11.84	11.84	0.00	11.84	13.07
10.77	0.00	10.77	3.98	6.87	6.87	0	1.37	97.22	-9.35	10.73	0.00	10.73	11.10
9.80	0.00	9.80	0.3	-39.01	0.00	0	0.00	87.50	-9.72	9.72	0.00	9.72	10.73
8.82	0.00	8.82	0.16	-34.27	0.00	0	0.00	78.75	-8.75	8.75	0.00	8.75	10.35
7.94	0.00	7.94	0	-61.50	0.00	0	0.00	70.87	-7.87	7.87	0.00	7.87	8.69
7.14	0.00	7.14	0.14	-43.46	0.00	0	0.00	63.78	-7.09	7.09	0.00	7.09	7.34
6.43	0.00	6.43	0.07	-54.54	0.00	0	0.00	57.41	-6.38	6.38	0.00	6.38	7.04
5.79	0.00	5.79	2.28	-39.49	0.00	0	0.00	51.67	-5.74	5.74	0.00	5.74	6.34
5.21	0.00	5.21	0.39	-52.51	0.00	0	0.00	46.50	-5.17	5.17	0.00	5.17	5.70
4.69	0.00	4.69	5.25	-15.01	0.00	0	0.00	41.85	-4.65	4.65	0.00	4.65	4.81

TABLE - 3.8
COMPARISION OF DISCHARGE

Month	Regional Multip Regression Method (m3/sec)	Regional Hydrograph Method (m3/sec)	Mock Model (m3/sec	Observed (m3/sec)
January	17.33	10.9	9.53	9.5
February	14.73	8.2	8.52	7.7
March	13.77	6.3	6.25	6.5
April	15.66	4.9	5.21	4.2
May	23.19	5.6	4.61	7.0
June	41.95	30.1	32.36	36.2
July	152.07	88.7	144.36	151.0
August	173.43	132.4	149.6	152.7
September	114.03	97.3	127.85	139.1
October	36.95	44.4	34.79	45.4
November	4.82	18.6	14.92	17.3
December	3.94	14	11.72	11.3

Remarks : Observed value has been computed from the observed discharge at G &D site located at about 85 Km. D/S from the discharge computed site, i. e. outlet point of Dang Valley.

TABLE -3.9

MONTHLY IRRIGATION WATER AVAILABLE IN STREAMS OF DANG VALLEY (75 % DEPENDABILITY)

Month → / Name of Tributaries ↓	Catchment Area (Km^2)	June	July	August	September	october	November	December	January	February	March	April	May
Toang Khola	47.69	0.205	2.725	3.727	2.634	0.450	0.378	0.297	0.242	0.217	0.159	0.133	0.102
Chyanti Khola	25.77	0.111	1.473	2.014	1.423	0.243	0.204	0.160	0.131	0.117	0.086	0.072	0.055
Gurjung Khola	20.86	0.090	1.192	1.630	1.152	0.197	0.165	0.130	0.106	0.095	0.070	0.058	0.045
Bahula Khola	48.33	0.208	2.762	3.777	2.669	0.456	0.383	0.301	0.246	0.220	0.161	0.135	0.103
Kala Khola(Chire Gad)	37.3	0.160	2.132	2.915	2.060	0.352	0.296	0.232	0.189	0.170	0.124	0.104	0.080
Bhamake Khola	35.34	0.152	2.020	2.762	1.952	0.334	0.280	0.220	0.180	0.161	0.118	0.099	0.076
Patu Khola	132.23	0.568	7.557	10.334	7.304	1.248	1.049	0.823	0.672	0.602	0.441	0.369	0.283
Gwar Khola	272.97	1.173	15.600	21.334	15.077	2.577	2.165	1.700	1.387	1.244	0.910	0.761	0.584
Chauwa Khola	11.5	0.049	0.657	0.899	0.635	0.109	0.091	0.072	0.058	0.052	0.038	0.032	0.025
Sangram Khola	33.3	0.143	1.903	2.603	1.839	0.314	0.264	0.207	0.169	0.152	0.111	0.093	0.071
Patri Phalne Khola	27.47	0.118	1.570	2.147	1.517	0.259	0.218	0.171	0.140	0.125	0.092	0.077	0.059
Hapur Khola	44.96	0.193	2.569	3.514	2.483	0.424	0.357	0.280	0.228	0.205	0.150	0.125	0.096
Gurje Khola	33.21	0.143	1.898	2.596	1.834	0.314	0.263	0.207	0.169	0.151	0.111	0.093	0.071
Sewar Khola	43.43	0.187	2.482	3.394	2.399	0.410	0.344	0.270	0.221	0.198	0.145	0.121	0.093
Katwa Khola	48.54	0.209	2.774	3.794	2.681	0.458	0.385	0.302	0.247	0.221	0.162	0.135	0.104
Sisne Khola	37.89	0.163	2.165	2.961	2.093	0.358	0.301	0.236	0.192	0.173	0.126	0.106	0.081
Balim Khola	28.53	0.123	1.630	2.230	1.576	0.269	0.226	0.178	0.145	0.130	0.095	0.080	0.061
Total	929.32	3.99	53.11	72.63	51.33	8.77	7.37	5.79	4.72	4.23	3.10	2.59	1.99

TABLE - 3.10
75 % DEPENDABLE WATER IN DEPTH (MM) PER UNIT CATCHMENT AREA

Month ►	June				July				August				September			
Year ▼	Water depth in mm	Water depth in decending order	Rank	% of time water equals or exceeded	Water depth in mm	Water depth in decending order	Rank	% of time water equals or exceeded	Water depth in mm	Water depth in decending order	Rank	% of time water equals or exceeded	Water depth in mm	Water depth in decending order	Rank	% of time water equals or exceeded
1973	253.80	253.80	1	6.67	166.66	503.36	1	6.67	210.34	355.51	1	6.67	224.74	424.43	1	6.67
1974	10.62	211.25	2	13.33	75.77	433.72	2	13.33	255.63	345.34	2	13.33	69.52	369.33	2	13.33
1975	20.33	80.50	3	20.00	433.72	380.01	3	20.00	274.70	345.34	2	13.33	201.39	317.49	3	20.00
1976	13.52	59.47	4	26.67	321.25	321.25	4	26.67	333.21	333.21	4	26.67	243.45	306.66	4	26.67
1977	10.67	33.21	5	33.33	170.50	306.35	5	33.33	199.66	274.70	5	33.33	68.63	300.33	5	33.33
1978	80.50	20.33	6	40.00	240.89	306.35	5	33.33	164.70	260.35	6	40.00	167.76	300.33	5	33.33
1979	19.73	19.73	7	46.67	285.17	285.17	7	46.67	249.23	255.63	7	46.67	28.16	295.33	7	46.67
1980	33.21	14.11	8	53.33	380.01	260.62	8	53.33	252.23	252.23	8	53.33	317.49	243.45	8	53,33
1981	59.47	13.52	9	60.00	260.62	240.89	9	60.00	206.33	249.23	9	60.00	424.43	224.74	9	60.00
1982	14.11	11.95	10	66.67	109.84	170.50	10	66.67	355.51	230.23	10	66.67	295.33	201.39	10	66.67
1983	10.45	11.95	10	66.67	112.34	166.66	11	73.33	260.35	210.34	11	73.33	369.33	167.76	11	73.33
1984	211.25	10.67	12	80.00	503.36	112.34	12	80.00	230.23	206.33	12	80.00	306.66	69.52	12	80.00
1985	11.95	10.62	13	86.67	306.35	109.84	13	86.67	345.34	199.66	13	86.67	300.33	68.63	13	86.67
1986	11.95	10.45	14	93.33	306.35	75.77	14	93.33	345.34	164.70	14	93.33	300.33	28.16	14	93.33
75 % dependability in (mm)		11.15				153.06				209.33				143.16		

TABLE -3.10

75 % DEPENDABLE WATER IN DEPTH (MM) PER UNIT CATCHMENT AREA

October				November				December				January			
Water depth in mm	Water depth in decending order	Rank	% of time water equals or exceeded	Water depth in mm	Water depth in decending order	Rank	% of time water equals or exceeded	Water depth in mm	Water depth in decending order	Rank	% of time water equals or exceeded	Water depth in mm	Water depth in decending order	Rank	% of time water equals or exceeded
119.00	194.43	1	6.67	28.79	34.29	1	6.67	23.32	27.78	1	6.67	19.60	22.58	1	6.67
19.98	134.67	2	13.33	16.18	34.24	2	13.33	13.11	27.76	2	13.33	10.62	22.58	1	6.67
69.57	134.67	2	13.33	29.47	34.24	2	13.33	23.87	27.76	2	13.33	19.33	22.57	3	20.00
35.04	119.00	4	26.67	28.38	33.24	4	26.67	22.99	27.03	4	26.67	18.62	22.19	4	26.67
22.89	69.57	5	33.33	16.41	31.49	5	33.33	13.29	25.76	5	33.33	10.77	20.86	5	33.33
25.75	42.33	6	40.00	20.86	29.83	6	40.00	16.89	24.16	6	40.00	13.68	19.60	6	40.00
23.87	38.24	7	46.67	19.66	29.47	7	46.67	16.06	23.87	7	46.67	13.37	19.57	7	46.67
38.24	37.87	8	53.33	29.83	28.79	8	53.33	24.16	23.32	8	53.33	19.57	19.33	8	53.33
37.87	35.04	9	60.00	31.49	28.38	9	60.00	25.76	22.99	9	60.00	20.86	18.62	9	60.00
31.81	31.81	10	66.67	25.76	25.76	10	66.67	20.87	20.87	10	66.67	16.95	16.95	10	66.67
194.43	25.75	11	73.33	33.24	20.86	11	73.33	27.03	16.89	11	73.33	22.19	13.68	11	73.33
42.33	23.87	12	80.00	34.29	19.66	12	80.00	27.78	16.06	12	80.00	22.57	13.37	12	80.00
134.67	22.89	13	86.67	34.24	16.41	13	86.67	27.76	13.29	13	86.67	22.58	10.77	13	86.67
134.67	19.98	14	93.33	34.24	16.18	14	93.33	27.76	13.11	14	93.33	22.58	10.62	14	93.33
	25.28				20.56				16.68				13.60		

TABLE -3.10
75 % DEPENDABLE WATER IN DEPTH (MM) PER UNIT CATCHMENT AREA

February				March				April				May			
Water depth in mm	Water depth in decending order	Rank	% of time water equals or exceeded	Water depth in mm	Water depth in decending order	Rank	% of time water equals or exceeded	Water depth in mm	Water depth in decending order	Rank	% of time water equals or exceeded	Water depth in mm	Water depth in decending order	Rank	% of time water equals or exceeded
16.99	18.47	1	6.67	13.83	14.96	1	6.67	11.20	12.12	1	6.67	9.08	9.82	1	6.67
8.60	18.29	2	13.33	6.97	14.82	2	13.33	5.64	12.00	2	13.33	4.57	9.82	1	6.67
15.66	18.29	2	13.33	12.69	14.82	2	13.33	10.28	12.00	2	13.33	8.32	9.72	3	20.00
15.08	17.97	4	26.67	12.22	14.56	4	26.67	9.90	11.79	4	26.67	8.02	9.72	3	20.00
8.72	16.99	5	33.33	7.07	13.83	5	33.33	5.72	11.20	5	33.33	4.64	9.13	5	33.33
11.08	16.90	6	40.00	8.98	13.69	6	40.00	7.27	11.09	6	40.00	5.89	9.08	6	40.00
10.83	15.85	7	46.67	8.77	12.84	7	46.67	7.10	10.40	7	46.67	5.89	8.42	7	46.67
15.85	15.66	8	53.33	12.84	12.69	8	53.33	10.40	10.28	8	53.33	8.42	8.32	8	53.33
16.90	15.08	9	60.00	13.69	12.22	9	60.00	11.09	9.90	9	60.00	9.13	8.13	9	60.00
13.86	13.86	10	66.67	11.23	11.23	10	66.67	9.09	9.09	10	66.67	8.13	8.02	10	66.67
17.97	11.08	11	73.33	14.56	8.98	11	73.33	11.79	7.27	11	73.33	9.82	5.89	11	73.33
18.47	10.83	12	80.00	14.96	8.77	12	80.00	12.12	7.10	12	80.00	9.82	5.89	11	73.33
18.29	8.72	13	86.67	14.82	7.07	13	86.67	12.00	5.72	13	86.67	9.72	4.64	13	86.67
18.29	8.60	14	93.33	14.82	6.97	14	93.33	12.00	5.64	14	93.33	9.72	4.57	14	93.33
	11.02				8.93				7.23				5.73		

TABLE - 3.11

DISCHARGE OF BABAI RIVER (M3/SEC) FORTNIGHTLY

LOCATION : OUT-LET POINT OF DANG VALLEY
CATCHMENT AREA : 1431 KM^2

Month / Year		January	February	March	April	May	June	July	August	September	October	November	December
1973	1	12.2	11.8	12.1	4.9	5.0	28.7	46.5	144.8	114.4	133.7	16.1	9.7
	2	23.5	12.0	4.9	4.6	7.1	162.5	236.9	98.5	147.1	28.4	10.5	8.3
1974	1	7.1	6.0	5.7	4.5	4.1	4.0	76.1	185.7	45.3	15.5	13.4	8.4
	2	6.5	5.8	4.5	4.4	4.9	46.6	103.0	114.9	38.6	12.2	13.0	7.8
1977	1	6.8	5.5	3.8	2.9	10.8	4.7	134.7	162.3	86.1	35.1	11.9	8.6
	2	6.2	5.3	3.3	2.8	6.7	36.1	212.2	414.4	40.3	20.0	10.5	8.2
1978	1	7.5	9.1	4.1	2.8	4.2	10.2	234.8	297.8	150.2	76.4	39.6	12.8
	2	6.0	8.6	5.3	2.7	2.2	134.3	614.9	94.1	127.7	47.7	24.7	11.3
1979	1	8.9	8.9	5.6	2.6	2.4	9.9	30.8	99.3	69.4	23.7	8.4	12.6
	2	9.3	7.5	5.1	1.9	22.9	11.5	371.0	121.9	94.8	16.0	8.7	13.7
1980	1	12.9	8.0	6.8	5.6	0.6	15.3	30.6	8.9	341.4	32.7	16.1	9.6
	2	9.5	6.7	5.9	5.6	6.7	22.7	29.0	50.0	91.1	22.7	12.7	7.2
1981	1	4.8	6.0	4.3	4.5	7.9	5.5	67.2	161.1	317.3	62.5	33.7	14.8
	2	7.9	4.7	4.5	5.5	8.7	95.9	173.0	234.5	120.1	24.2	20.3	12.9
1982	1	10.7	12.2	31.0	6.4	9.3	17.5	24.5	110.3	145.1	23.3	18.5	11.8
	2	11.4	9.9	7.7	5.0	9.8	24.7	20.8	45.5	49.0	23.7	15.3	9.9
1983	1	8.8	8.2	5.6	4.0	5.3	6.9	24.1	54.4	293.5	137.1	20.1	12.0
	2	9.6	6.8	4.6	5.3	10.3	6.6	46.5	61.7	60.1	61.9	14.3	9.1
1984	1	4.6	4.4	3.7	1.8	1.9	7.4	122.0	179.3	383.4	20.8	16.5	14.6
	2	17.1	6.3	2.4	1.7	3.2	68.6	631.9	115.4	184.5	18.9	15.4	13.4
1985	1	11.3	9.1	8.3	7.3	14.2	49.9	127.2	145.6	163.9	137.4	24.9	14.9
	2	10.2	8.7	7.9	7.1	10.2	43.6	101.1	370.2	151.9	36.8	16.5	8.7
1986	1	9.4	7.0	4.8	3.0	3.3	6.8	52.3	74.9	81.0	45.7	18.8	14.9
	2	6.3	6.1	3.8	4.2	11.0	47.9	113.4	319.3	41.9	34.0	15.1	16.5
Average discharge		9.5	7.7	6.5	4.2	7.0	36.2	151.0	152.7	139.1	45.4	17.3	11.3

TABLE - 3.12

OBSERVED DISCHARGE OF BABAI RIVER AT G &D SITE DEDUCTING DISCHARGE OF SARADA KHOLA (M^3/SEC)

CATCHMENT AREA :2063 KM^2

Month / Year		January	February	March	April	May	June	July	August	September	October	November	December
1973	1	17.59	16.97	17.47	7.01	7.20	41.43	67.05	208.76	164.89	192.70	23.24	13.93
	2	33.89	17.28	7.12	6.66	10.21	234.21	341.46	141.94	212.00	40.98	15.13	11.92
1974	1	10.30	8.61	8.15	6.48	5.90	5.78	109.68	267.69	65.24	22.41	19.36	12.05
	2	9.41	8.40	6.50	6.29	7.08	67.25	148.50	165.59	55.66	17.60	18.71	11.29
1977	1	9.85	7.93	5.45	4.17	15.50	6.81	194.26	233.92	124.07	50.61	17.18	12.44
	2	8.88	7.66	4.79	4.02	9.69	52.07	305.89	597.41	58.05	28.85	15.20	11.79
1978	1	10.88	13.10	5.86	3.97	5.99	14.70	338.53	429.25	216.53	110.09	57.07	18.40
	2	8.66	12.40	7.62	3.94	3.18	193.66	886.49	135.66	184.11	68.78	35.60	16.28
1979	1	12.85	12.82	8.05	3.78	-3.47	14.29	44.39	143.14	100.11	34.21	12.13	18.18
	2	13.40	10.77	7.32	2.67	33.05	16.55	534.83	175.74	136.63	23.09	12.55	19.73
1980	1	18.53	11.58	9.74	8.01	0.81	22.01	44.11	12.79	492.19	47.14	23.17	13.79
	2	13.68	9.68	8.55	8.06	9.69	32.68	41.74	72.15	131.27	32.73	18.35	10.38
1981	1	6.98	8.63	6.15	6.56	11.40	7.92	96.85	232.31	457.39	90.13	48.58	21.36
	2	11.40	6.78	6.43	7.97	12.58	138.24	249.38	338.08	173.18	34.88	29.23	18.54
1982	1	15.37	17.62	44.67	9.29	13.37	25.27	35.39	159.07	209.25	33.57	26.71	17.06
	2	16.47	14.26	11.04	7.15	14.06	35.58	29.99	65.55	70.65	34.17	22.09	14.31
1983	1	12.72	11.87	8.05	5.73	7.61	9.97	34.77	78.43	423.09	197.69	28.98	17.31
	2	13.89	9.76	6.63	7.71	14.82	9.56	67.03	88.92	86.61	89.24	20.58	13.13
1984	1	6.67	6.40	5.27	2.65	2.75	10.61	175.82	258.47	552.75	29.98	23.78	21.07
	2	24.67	9.07	3.46	2.51	4.58	98.92	910.91	166.43	265.95	27.31	22.18	19.31
1985	1	16.32	13.11	11.92	10.49	20.54	71.99	183.42	209.97	236.34	198.15	35.96	21.49
	2	14.64	12.54	11.39	10.25	14.73	62.83	145.72	533.65	219.03	53.04	23.84	12.51
1986	1	13.51	10.12	6.95	4.39	4.69	9.79	75.37	107.93	116.77	65.90	27.16	21.44
	2	9.13	8.85	5.50	5.99	15.81	69.02	163.50	460.31	60.40	49.07	21.74	23.73
Average		13.74	11.09	9.34	6.07	10.07	52.13	217.71	220.13	200.51	65.51	24.94	16.[illegible]

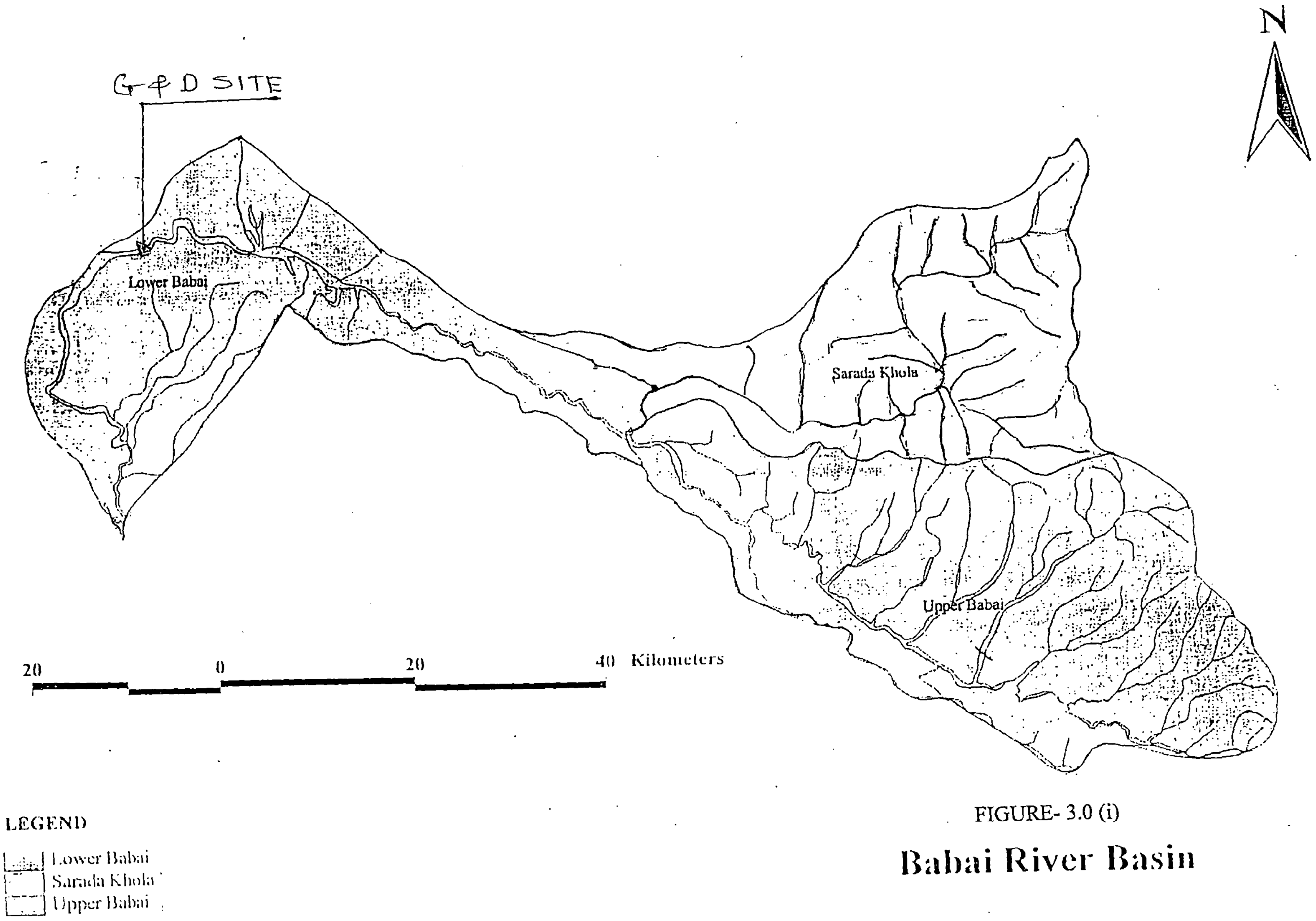


FIGURE- 3.0 (i)

Babai River Basin

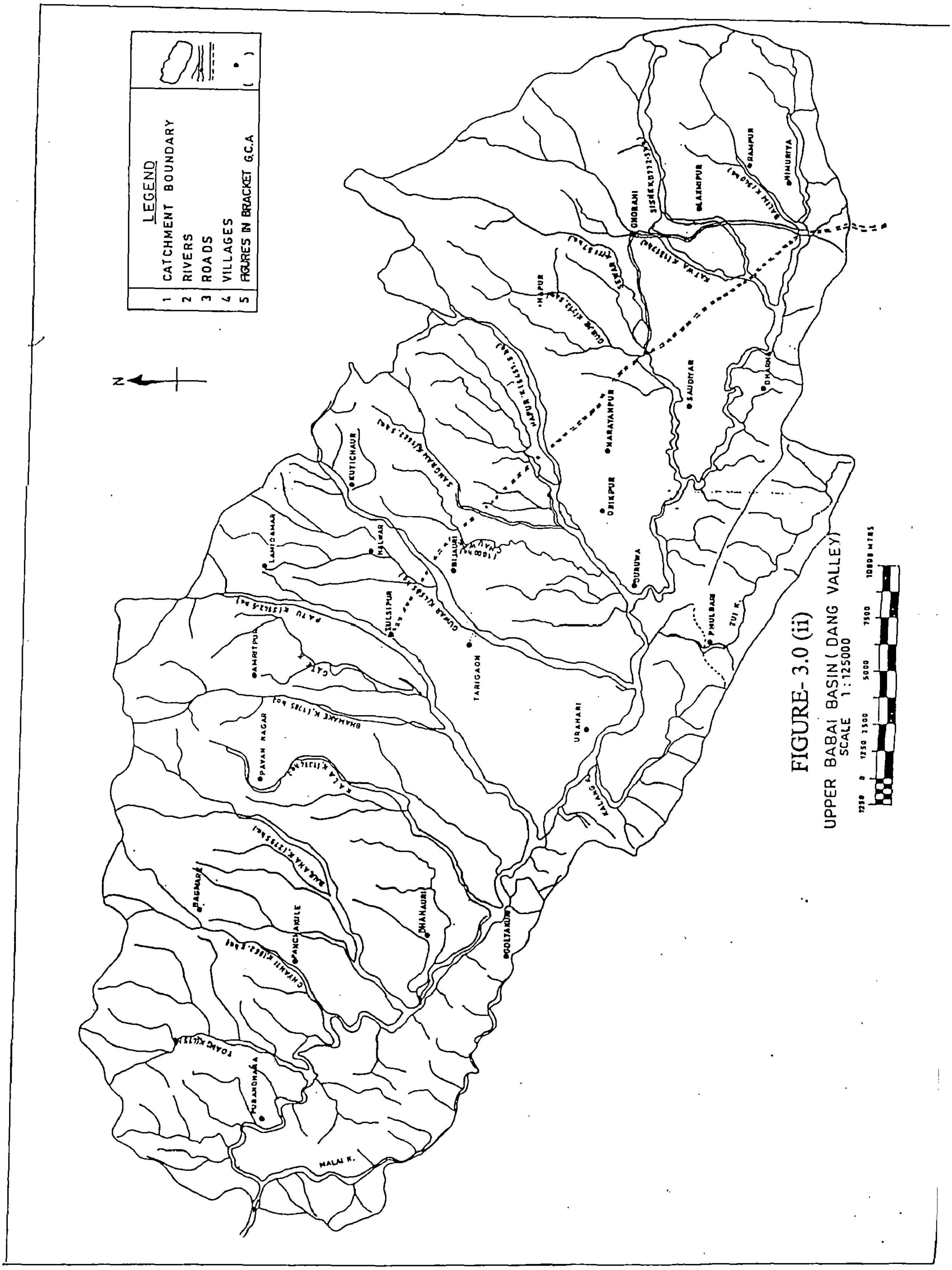
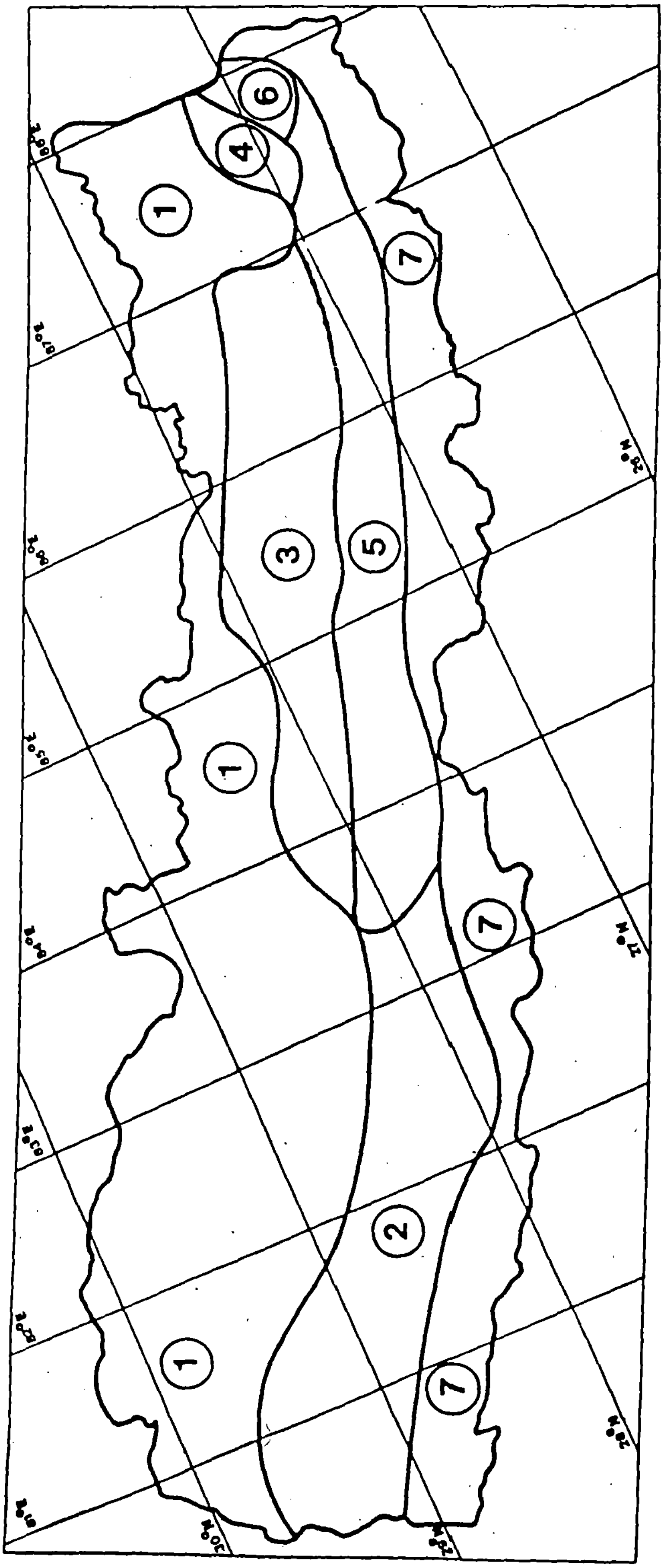


FIGURE- 3.0 (ii)
UPPER BABAI BASIN (DANG VALLEY)
SCALE 1 : 125000

Figure 3.1

The Hydrological Regions of Nepal



ey:

. Mountain catchments.

Hills to north of Mahabarats, rivers rising north of Siwaliks, inner Terai.

Pokhara, Nuwakot, Kathmandu, Sun Kosi tributaries.

Lower Tamur valley.

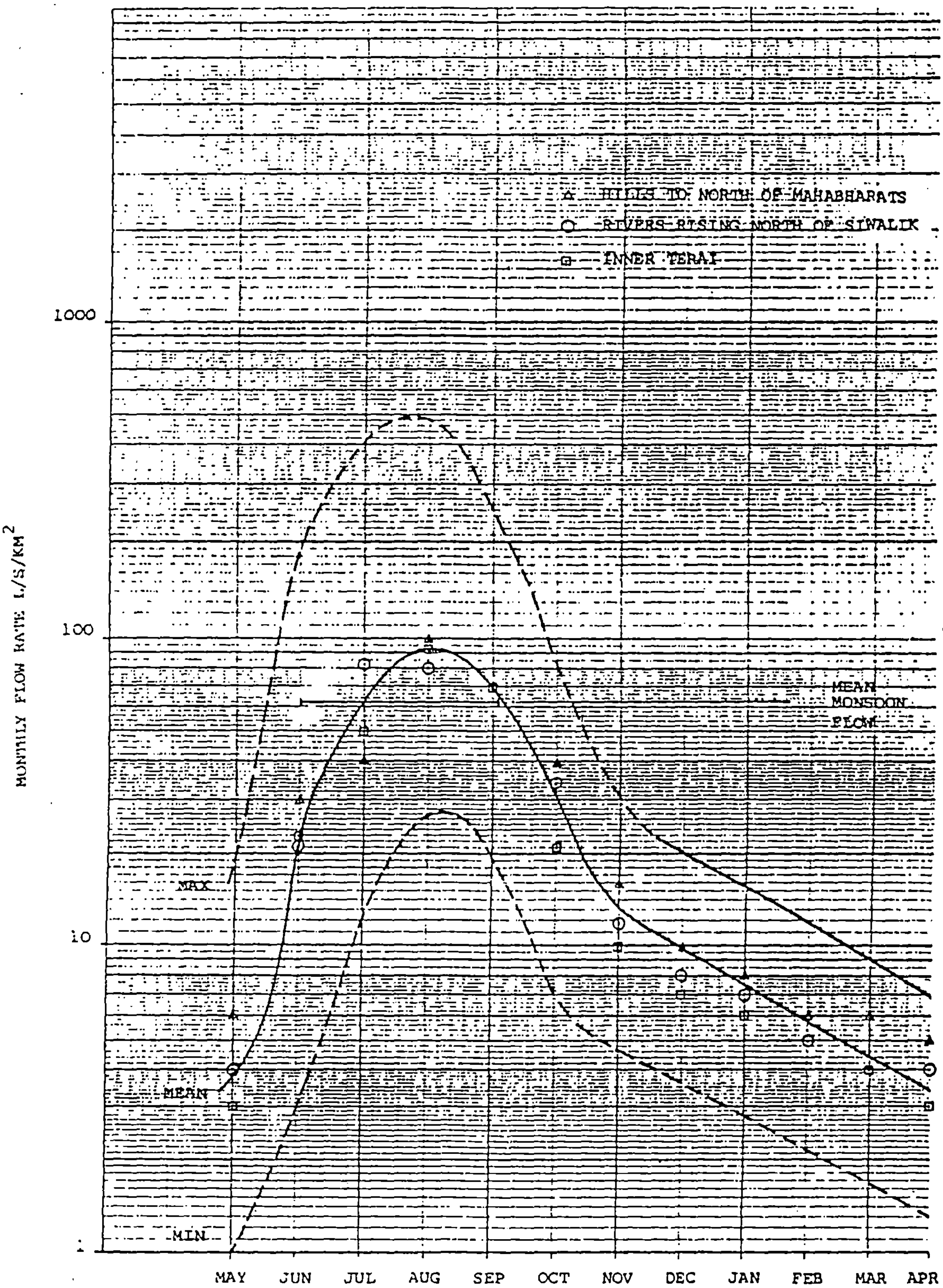
Rivers draining Mahabarats.

Kankai Mai basin.

Rivers draining from Churia range to the Terai.

Figure 3.2

Mean Monthly Hydrograph - Region 2



CHAPTER - 4

REGIONAL APPROACH FOR PLANNING OF MINOR IRRIGATION

4.1 GENERAL

Climatic inventory of a region such as temperature and moisture regimes are useful to assess crop water requirements. Usefulness of any climatic inventory is dependent on how far the climatic requirements are used in the inventory. Accordingly, data on climatic requirements of crops is an essential prerequisite to the compilation of any climatic inventory to be used for assessment of agro-climatic crop suitability. In this chapter main emphasis is on analysis of moisture condition. Temperature throughout the year in the study area is suitable for crop growth.

The climate of Dang Valley is sub-tropical . Rainfall occurs during monsoon months from June to September and 85% of annual rainfall occurs in these months. There are about 42000 ha of cultivated land out of which 27260 ha is irrigated and 14740 ha is rainfed. Some 87 number of existing irrigation schemes supplement irrigation water in the valley.

4.2 SCOPE OF ANALYSIS

Crop water needs can be fully or partly met by rainfall . For this purpose 80% dependable rainfall is generally considered to be effective in meeting crop water needs on monthly basis for irrigation planning. However, the degree of shortage below this dependable level during the dry periods should be analysed since loss in crop yields during the period may significantly affect the projects economic viability.

A higher level of dependable rainfall (say 90%) may need to be selected during the periods when crops are germinating or are most sensitive to water stress and yields are severely affected. In this chapter the recorded monthly rainfall and climatic data for the stations distributed in the valley have been analysed to estimate the following:

(1) Mean and 80 percent dependable rainfall, standard deviation and coefficient of variation on monthly basis of three rain gauge stations.

(2) Isohyets of mean annual rainfall and isopleth of coefficient of variation of annual rainfall to study regional characteristics.

(3) Isohyetal map of 80 percent dependable rainfall for the 12 calendar months to assess effective rainfall in a proposed command area.

(4) Monthly potential evapotranspiration estimate (for different albedo values r= 0.25, r= 0.15 and r = 0.05) for three meteorological stations in the valley.

(5) Isohyetal maps for monthly rainfall deficit defined as difference of 80 % dependable rainfall and potential evapotranspiration (for r = 0.25) to assess the need for irrigation.

4.3 ANALYSIS OF STATION RAINFALL

Monthly rainfall data at three stations in the valley and two adjacent to the valley are available for the year 1971 to 1996. Table 4.1 shows the results of the analysis of monthly data. Each table shows number of data, mean rainfall, standard deviation, coefficient of variation and 80 percent dependable rainfall for each of the 12 calendar months. 80 percent dependable rainfall values are obtained by carrying out a probability analysis of monthly rainfall data.

4.4 ANNUAL RAINFALL ISOHYETS

Annual rainfall isohyet have been plotted using mean annual rainfall at five stations (Table 4.1) and are shown in fig.4.1 . The highest rainfall occurs at eastern part of the valley, which is 1925 mm at station Ghorahi and decreasing in the west to 1667mm and 1637 mm at Tulsipur and Nayabasti respectively. The station located at northern mountain adjacent to the valley recorded the minimum of 1158 mm and the station in the south of valley in Terai is 1332 mm. So, the valley gets more rain, which is between Churiya and Mahabharat hill than north of Mahabharat and south of Churiya hill.

Fig.4.2 shows isopleth of coefficient of variation of annual rainfall. Coefficient of variation of annual rainfall ranges from 0.19 to 0.37 . The annual rainfall characteristics in the valley indicate that rainfed cultivation during the month July, August and September may not be affected to draught.

Similarly, isopleths of coefficient of variation of monthly rainfall can be drawn to study variability of monthly rainfall. C.V. values for monthly rainfall have been worked out for five stations and are shown in Table-4.1. C.V. for monthly rainfall are significantly large for all months ranging from 0.3 to 2.3. This indicates that rainfed cultivation may not be reliable for rice crop.

4.5 DEPENDABLE RAINFALL ISOHYETAL MAPS

One in five years reliable monthly rainfall values are frequently required for calculation of irrigation water requirements in the design of irrigation schemes . 80 percent dependable monthly rainfall in each of the twelve calendar months have been computed for the five stations and are shown in table -4.1

Twelve isohyetal maps of dependable rainfall have been prepared using these results are shown in fig.- 4.3 to 14 for the months of January to December. Dependable rainfall is more in the eastern part of valley decreases in the west, south and north respectively. The network of raingauge station for the computation of dependable rainfall in the area is adequate.

4.6 EVAPORATION AND EVAPOTRANSPIRATION

Evaporation is the process in which a liquid changes to the gaseous state at the free surface, below the boiling point through the transfer of heat energy .The loss of moisture from land area in which plants stand by transpiration and by the evaporation of water from soil and water bodies is the evapotranspiration . If sufficient moisture is always available to completely meet the needs of vegetation fully covering the area, the resulting evapotranspiration is called potential evapotranspiration (PET).

Estimates of open water evaporation and potential evapotranspiration (PET) are required for the following studies and therefore form an important component of irrigation planning.

(I) Assessment of rainfall deficit (potential evapotranspiration - effective rainfall)being an indicator of irrigation water requirement.

(2) Assessment of moisture availability index (MAI) being an indicator of rainfed rice cultivation.

(3) Assessment of average annual runoff from catchments which have rainfall data but no flow records using water balance techniques.

Evapotranspiration Equations

The lack of reliable field data and the difficulties of obtaining reliable evapotranspiration data have given rise to a number of methods to predict PET by using climatological data. Penman's equation is one of the method which is based on sound theoretical reasoning and is obtained by a combination of the energy-balance and mass-transfer approach . Penman's equation, incorporating some of the modifications suggested by other investigations is

$$PET = \frac{\Delta Hn + Ea\gamma}{\Delta + \gamma} \quad ....(A)$$

Where,

PET = daily potential evapotranspiration in mm/day

Δ = slope of the saturation vapour pressure vs. temperature curve at the mean air temperature, in mm of mercury per^{0}C. Table- 4.2

Hn = Net radiation in mm of evaporable water per day

Ea = parameter including wind velocity and saturation deficit.

γ = Psychrometric constant = 0.49mm of mercury/^{0}C

The net radiation is the same as used in the energy budget and is estimated by the following equations:

$$Hn = Ha(1\text{-}r)[a + b\, n/N] - 6Ta^4 (0.56 - 0.092\sqrt{ea})[0.1 + 0.9\, n/N] \quad ...(B)$$

Where,

Ha = incident solar radiation outside the atmosphere on a horizontal surface, expressed in mm of a evaporable water per day (it is a function of the altitude and period of the year as indicated in (Table 4.3).

a = a constant depending upon the latitude ϕ and is given by a = 0.29 Cosϕ.

b = a constant with an average value of 0.52

n = actual duration of bright sunshine in hours.

N = maximum possible hours of bright sunshine (it is a function of latitude as indicated in Table- 4.4

r = reflection coefficient (albedo). Usual range of values of r are given below:

Surface	Range of r Values
Close ground crops	0.15 – 0.25
Bare lands	0.05 – 0.45
Water Surface	0.05
Snow	0.45 –0.95

σ = Stefan- Boltzman constant = 2.0 x 10^{-9}mm/day

Ta = mean air temperature in degrees Kelvin = 273+^{0}C

ea = actual mean vapour pressure in the air in mm of mercury. The parameter Ea is estimated as

$$Ea = 0.35\left[1 + \frac{42}{160}\right](ew - ea) \text{........ (C)}$$

in which.

u_2 = mean wind speed at 2 m above ground in km/day

cw = saturation vapour pressure at mean air temperature in mm of mercury Table 4.2

ew = Actual vapour pressure, defined earlier.

For the computation of PET, data on n, ea, u_2 , mean air temperature and nature of surface (i.e. value of r) are needed. These can be obtained from actual observations or through available meteorological data of the region. Equations (A), (B) and (C) together with Table. 4.2, 4.3 and 4.4 enable the daily PET to be calculated. It may be noted that Penman's equation can be used to calculate evaporation from a water surface by using r= 0.05. Penman's equation is widely used in India, the U.K. , Australia and in some parts of U.S.A.

On the basis of the mean monthly climatological data, the monthly potential evapotranspiration computations have been carried out and are shown in Table-4.5 to 4.7 For the three meteorological stations of Dang valley for different albedo or reflection coefficient.

4.7 MOISTURE AVAILABILITY INDEX (MAI)

Moisture availability index is defined as the ratio of 80% probability rain (R80) to monthly potential evaporatranspiration (PET)

$$MAI = \frac{R80}{PET}$$

Hargreaves suggests suitability for rainfed rice if three consecutive months have excessive precipitation. A month of excessive precipitation was defined as one with a value of MAI exceeding 1.33. Table-4.8 shows the monthly estimates of parameters for rainfed and irrigated agriculture in the valley. MAI exceeded in the month of July, August and September. Hence rice crop could be an important Kharif crop with provision of irrigation.

4.8 RAINFALL DEFICIT

Potential evapotranspiration estimate indicate crop water requirements of rice crop for full growth potential. Actual rates of evapotranspiration fall below the potential rate when the availability of mositure in the soil is limited. This occurs in prolonged dry spells where rooting depth is not sufficient to draw on reserves of moisture deep in the soil. A soil moisture deficit then occurs and this can lead to moisture stress if prolonged. Thus in areas with high rainfall, no marked dry season and in deep rooted vegetation such as forest cover, actual evaporation rates will always be at or very near to the potential rate. However in dry areas with a marked dry season and shallow rooted vegetation, actual evaporation will fall considerably below the potential rate.

For irrigated agriculture, rainfall deficit i.e. difference of potential evapotranspiration and 80 percent dependable rainfall (considered to be available for crop growth) is an indication of irrigation requirement. It is therefore an important parameter in the planning of an irrigation scheme.

Table 4.1 Shows the monthly values of average rainfall (Rav), 80 percent dependable rainfall (R80) and potential evapotranspiration for flooded rice field(Et 0.05), for growing rice crop (Et.0.25) and for forest or plantation (Et 0.15).

Monthly rainfall deficit for each station are shown in Table-4.1. Rainfall deficit isopleths for each month are plotted and shown in fig 4.15 to 4.26.

Rain fall deficit values shows that there is no rainfall deficit during the months of July to September. In other months rainfall deficit is there.

4.9 APPLICATION OF REGIONAL APPROACH FOR IRRIGATION PLANNING

Example:

Project : Gwar Khola Irrigation Project

Location : 82.35^0 E, 28.12^0 N

Culturable command area – 700 ha
Catchment area at diversion point from topographical map – 190 Km^2

WATER AVAILABILITY

75% dependable water available at diversion point on monthly basis (from Table 3.10)

Month	75% dependable water in mm per unit catchment area	Water available at diversion point (m3/sec)
January	13.6	0..965
February	11.02	0.865
March	8.93	0.633
April	7.23	0.53
May	5.73	0.406
June	11.15	0.817
July	153.06	10.858
August	209.33	14.849
September	143.16	10.494
October	25.28	1.793
November	20.56	1.507
December	16.68	1.183

Water Requirement

Water requirement is calculated on cropping pattern during Kharif and Rabi season. In this case, full area is used for Kharif and Rabi crops.

The net crop water requirement in each month is the rainfall deficit. Rainfall deficit isopleth map is used to know the rainfall deficit for the project as given in Chapter -4

For Gwar khola project, from the isopleth map of Rainfall deficit ,crop water requirement is calculated as below.

Month Wise Crop Water Requirement

Month	Cropping Period	Water deficit in mm	Total net water requirement m^3/sec	Total crop water requirement taking 75% A.E and 80 % C.E.
January	Rabi	37.0	0.097	0.162
February		61.0	0.176	0.293
March		108.9	0.285	0.475
April		-	-	-
May		-	-	-
June	Kharif (Rice)	-	-	-
July		-	-	-
August		-	-	-
September		-	-	-
October		76	0.199	0.332
November	Rabi	54.1	0.146	0.243
December		33.3	0.087	0.145

Water Balance Table

Month	Water Available m^3/sec	Water Requirement m^3/sec	Surplus (+) Deficit (-)
January	0..965	0.162	(+)
February	0.865	0.293	(+)
March	0.633	0.475	(+)
April	0.53	0	(+)
May	0.406	0	(+)
June	0.817	0	(+)
July	10.858	0	(+)
August	14.849	0	(+)
September	10.494	0	(+)
October	1.793	0.332	(+)
November	1.507	0.243	(+)
December	1.183	0.145	(+)

From the water balance table, it is observed that the project can be planned for year round irrigation for Kharif and Rabi crop. Maximum diversion requirement is 0.475 m^3/sec for C.C.A. of 700 ha.

TABLE - 4.1
RAINFALL ANALYSIS

STATION : NAYABASTI - (0507)

Month	January	February	March	April	May	June	July	August	September	October	November	December	Annual
n	26	26	26	26	26	26	26	26	26	26	26	26	26
Mean	25.5	23.5	20.4	18.5	72.1	248.1	445.1	427.1	282.4	45.0	13.3	16.1	1637.2
S.D	27.6	25.3	28.2	30.7	51.1	129.0	183.1	163.0	143.9	62.8	31.2	22.3	468.8
C.V	1.1	1.1	1.4	1.7	0.7	0.5	0.4	0.4	0.5	1.4	2.3	1.4	0.29
R80	0.0	0.0	0.0	0.0	14.7	120.0	315.3	271.7	135.1	1.8	0.0	0.0	858.6

STATION : TULSIPUR - (0508)

Month	January	February	March	April	May	June	July	August	September	October	November	December	Annual
n	26	26	26	26	26	26	26	26	26	26	26	26	26
Mean	26.0	21.1	16.0	19.1	76.6	290.8	434.7	416.0	274.8	66.6	11.3	13.6	1666.4
S.D.	29.8	26.1	22.6	28.2	47.8	137.5	140.5	132.2	130.5	72.2	24.6	18.0	316.4
C.V.	1.1	1.2	1.4	1.5	0.6	0.5	0.3	0.3	0.5	1.1	2.2	1.3	0.19
R80	1.9	1.1	0.0	0.0	28.5	161.2	308.7	261.7	169.3	6.9	0.0	0.0	939.3

STATION : GHORAHI (MASINA) - (0508)

Month	January	February	March	April	May	June	July	August	September	October	November	December	Annual
n	26	26	26	26	26	26	26	26	26	26	26	26	26
Mean	24.6	22.9	22.4	21.8	81.3	295.0	516.3	478.8	346.4	93.0	10.1	12.7	1925.3
S.D.	26.1	23.6	29.9	35.3	62.4	155.3	171.8	139.8	187.5	86.3	21.4	18.0	467.5
C.V.	1.1	1.0	1.3	1.6	0.8	0.5	0.3	0.3	0.5	0.9	2.1	1.4	0.24
R80	0.0	0.0	0.0	0.0	24.0	168.7	349.1	373.5	186.2	13.7	0.0	0.0	1115.2

TABLE - 4.1
RAINFALL ANALYSIS

STATION : KUSUM - (0407)

Month	January	February	March	April	May	June	July	August	September	October	November	December	Annual
n	26	26	26	26	26	26	26	26	26	26	26	26	26
Mean	26.5	25.2	18.5	19.4	70.2	177.2	337.8	319.7	263.1	54.2	7.6	12.8	1332.1
S.D.	38.0	35.3	22.8	36.3	69.3	108.2	151.9	168.8	193.9	66.5	19.8	18.9	501.2
C.V.	1.4	1.4	1.2	1.9	1.0	0.6	0.4	0.5	0.7	1.2	2.6	1.5	0.37
R80	0	2.4	0	0	2.4	77.4	195.9	172.5	109.8	0	0	0	560.40

STATION : LUWAMJULA BAZAR - (0512)

Month	January	February	March	April	May	June	July	August	September	October	November	December	Annual
n	25	25	25	25	25	25	25	25	25	25	25	25	25
Mean	34.4	36.6	40.2	23.2	68.1	184.7	295.3	240.1	160.2	44.6	8.7	21.8	1157.8
S.D.	33.3	33.8	42.9	22.6	50.8	86.2	114.1	88.9	96.5	67.2	17.1	28.8	254.1
C.V.	1.0	0.9	1.1	1.0	0.7	0.5	0.4	0.4	0.6	1.5	2.0	1.3	0.22
R80	1.4	8.1	5.7	0.0	17.5	119.9	169.1	170.3	67.6	0.0	0.0	0.0	559.60

TABLE 4.2 SATURATION VAPOUR PRESSURE OF WATER

Temperature (^{0}C)	Saturation vapour pressure e_w (mm of Hg)	A (mm/^{0}C)
0	4.58	0.30
5.0	6.54	0.45
7.5	7.78	0.54
10.0	9.21	0.60
12.5	10.87	0.71
15.0	12.79	0.80
17.5	15.00	0.95
20.0	17.54	1.05
22.5	20.44	1.24
25.0	23.76	1.4
27.5	27.54	1.61
30.0	31.82	1.85
32.5	36.68	2.07
35.0	42.81	2.35
37.5	48.36	2.62
40.0	55.32	2.95
45.0	71.20	3.66

$e_w = 4.584 \exp [17.27\, t/(237.3 + t)]$ mm of Hg, where t = temperature in ^{0}C

Table 4.3 MEAN MONTHLY SOLAR RADIATION AT TOP OF ATMOSPHERE, H_a IN MM OF EVAPORABLE WATER/DAY

North latitude	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0^0	14.5	15.0	15..2	14.7	13.9	13.4	13.5	14.2	14.9	15.0	14.6	14.3
10^0	12.8	13.9	14.8	15.2	15.0	14.8	14.8	15.0	14.9	14.1	13.1	12.4
20^0	10.8	12.3	13.9	15.2	15.7	15.8	15.7	15.3	14.4	12.9	11.2	10.3
30^0	8.5	10.5	12.7	14.8	16.0	16.5	16.2	15.3	13.5	11.3	9.1	7.9
40^0	6.0	8.3	11.0	13.9	15.9	16.7	16.3	14.8	12.2	9.3	6.7	5.4
50^0	3.6	5.9	9.1	12.7	15.4	16.7	16.1	13.9	10.5	7.1	4.3	3.0

TABLE 4.4 MEAN MONTHLY VALUES OF POSSIBLE SUNSHINE HOURS N

North latitude	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0^0	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1
10^0	11.6	11.8	12.1	12.4	12.6	12.7	12.6	12.4	12.9	11.9	11.7	11.5
20^0	11.1	11.5	12.0	12.6	13.1	13.3	13.2	12.8	12.3	11.7	11.2	10.9
30^0	10.4	11.1	12.0	12.9	13.7	14.1	13.9	13.2	12.4	11.5	10.6	10.2
40^0	9.6	10.7	11.9	13.2	14.4	15.0	14.7	13.8	12.5	11.2	10.0	9.4
50^0	8.6	10.1	11.8	13.8	15.4	16.4	16.0	14.5	12.7	10.8	9.1	8.1

TABLE - 4.5

COMPUTATION OF POTENTIAL EVAPOTRANSPIRATION

Month		Mean Temperature	e_w	RH	e_a	u_2	Δ	l	n	H_a	b	a	σ	T_a	r	$\sigma * T_a^4$	H_n	E_a	PET
	Unit	^0C	mm of mercury	%	mm of mercury	km/day	mm of mercury / ^0C	hours	hours	(mm / day)			mm/day	^{0}Kelvin			mm/day	mm/day	mm/day
January		12.8	11.09	80.08	8.88	73.51	0.8	10.7	7.7	8.9	0.52	0.26	$2.01*10^{-9}$	285.8	0.25	13.41	1.34	1.13	1.26
February		16.7	14.27	75.05	10.71	103.32	0.9	11.3	7.6	10.8	0.52	0.26	$2.01*10^{-9}$	289.7	0.25	14.16	2.32	2.05	2.23
March		19.8	17.33	67.2	11.65	160.94	1.04	12	8	12.9	0.52	0.26	$2.01*10^{-9}$	292.8	0.25	14.77	3.29	3.99	3.51
April		25.6	24.64	62.5	15.40	158.95	1.45	12.7	8.5	14.9	0.52	0.26	$2.01*10^{-9}$	298.6	0.25	15.98	4.52	6.45	5.00
May		27.6	27.71	69.2	19.18	156.98	1.62	13.3	7.9	15.9	0.52	0.26	$2.01*10^{-9}$	300.6	0.25	16.41	5.10	5.92	5.29
June		27.9	28.2	72.23	20.37	157.99	1.65	13.7	6.1	16.4	0.52	0.26	$2.01*10^{-9}$	300.9	0.25	16.48	4.80	5.45	4.95
July		25.8	24.93	87.95	21.93	91.39	1.47	13.51	3.7	16.1	0.52	0.26	$2.01*10^{-9}$	298.8	0.25	16.02	4.09	1.65	3.48
August		25.7	24.78	90.58	22.45	90.41	1.46	13	5.1	15.3	0.52	0.26	$2.01*10^{-9}$	298.7	0.25	16.00	4.38	1.28	3.60
September		25.2	19.7	89.55	17.64	85.42	1.19	12.3	5.3	13.7	0.52	0.26	$2.01*10^{-9}$	298.2	0.25	15.89	3.59	1.11	2.86
October		23	21.08	89.88	18.95	72.53	1.27	11.6	7	11.6	0.52	0.26	$2.01*10^{-9}$	296	0.25	15.43	3.37	1.09	2.74
November		18.4	15.88	87.6	13.91	62.59	0.98	10.9	8.9	9.5	0.52	0.26	$2.01*10^{-9}$	291.4	0.25	14.49	2.23	0.96	1.80
December		14.3	12.23	86.83	10.62	61.61	0.8	10.59	5.9	8.3	0.52	0.26	$2.01*10^{-9}$	287.3	0.25	13.69	1.25	0.78	1.07

Remarks :

PET = Potential Evapotranspiration in mm/day

$= \Delta H_n + E_a \gamma / (\Delta + \gamma)$

Δ = Slope of the saturation vapour pressure vs. temperature curve at the mean air temperature, in mm of mercury per ^{0} C.

H_n = net radiation in mm of evaporable water per day.

E_a = Parameter including wind velocity and saturation deficit.

γ =Psychrometric constant = 0.49 mm of mercury/^{0}C

a= a constant depending uopn the latitude Φ and is given by 0.29*COS Φ

b = a constant with an average value of 0.52.

n = actual duration of bright sunshine hours.

r = reflection coefficient (albedo).

σ = Stefan- Boltzman constant = mm/day

T_a = mean air temperature in ^{0} kelvin =273+^{0}C.

e_a = actual mean vapour pressure in the air in mm of mercury .

$E_a = 0.35 * (1+u_2/160)* (e_w-e_a)$.

ew = saturation vapour pressure at mean air temperature in mm of mercury.

TABLE - 4.6

COMPUTATION OF POTENTIAL EVAPOTRANSPIRATION

Month		Mean Temperature	e_w	RH	e_a	u_2	Δ	N	n	H_a	b	a	σ	T_a	r	$\sigma * T_a^4$	H_n	E_a	PET
	Unit	^{0}C	mm of mercury	%	mm of mercury	km/day	mm of mercury / ^{0}C)	hours	hours	(mm / day)			mm/day	^{0}Kelvin			mm/day	mm/day	mm/day
January		12.8	11.09	80.08	8.88	73.51	0.8	10.7	7.7	8.9	0.52	0.26	$2.01*10^{-9}$	285.8	0.15	13.41	1.90	1.13	1.61
February		16.7	14.27	75.05	10.71	103.32	0.9	11.3	7.6	10.8	0.52	0.26	$2.01*10^{-9}$	289.7	0.15	14.16	2.98	2.05	2.65
March		19.8	17.33	67.2	11.65	160.94	1.04	12	8	12.9	0.52	0.26	$2.01*10^{-9}$	292.8	0.15	14.77	4.06	3.99	4.04
April		25.6	24.64	62.5	15.40	158.95	1.45	12.7	8.5	14.9	0.52	0.26	$2.01*10^{-9}$	298.6	0.15	15.98	5.42	6.45	5.68
May		27.6	27.71	69.2	19.18	156.98	1.62	13.3	7.9	15.9	0.52	0.26	$2.01*10^{-9}$	300.6	0.15	16.41	6.00	5.92	5.98
June		27.9	28.2	72.23	20.37	157.99	1.65	13.7	6.1	16.4	0.52	0.26	$2.01*10^{-9}$	300.9	0.15	16.48	5.60	5.45	5.57
July		25.8	24.93	87.95	21.93	91.39	1.47	13.51	3.7	16.1	0.52	0.26	$2.01*10^{-9}$	298.8	0.15	16.02	4.73	1.65	3.96
August		25.7	24.78	90.58	22.45	90.41	1.46	13	5.1	15.3	0.52	0.26	$2.01*10^{-9}$	298.7	0.15	16.00	5.08	1.28	4.13
September		25.2	19.7	89.55	17.64	85.42	1.19	12.3	5.3	13.7	0.52	0.26	$2.01*10^{-9}$	298.2	0.15	15.89	4.24	1.11	3.33
October		23	21.08	89.88	18.95	72.53	1.27	11.6	7	11.6	0.52	0.26	$2.01*10^{-9}$	296	0.15	15.43	4.04	1.09	3.21
November		18.4	15.88	87.6	13.91	62.59	0.98	10.9	8.9	9.5	0.52	0.26	$2.01*10^{-9}$	291.4	0.15	14.49	2.87	0.96	2.23
December		14.3	12.23	86.83	10.62	61.61	0.8	10.59	5.9	8.3	0.52	0.26	$2.01*10^{-9}$	287.3	0.15	13.69	1.71	0.78	1.36

Remarks :

PET = Potential Evapotranspiration in mm/day

$= \Delta H_n + E_a \gamma / (\Delta + \gamma)$

Δ = Slope of the saturation vapour pressure vs. temperature curve at the mean air temperature, in mm of mercury per ^{0}C.

H_n = net radiation in mm of evaporable water per day.

E_a = Parameter including wind velocity and saturation deficit.

γ =Psychrometric constant = 0.49 mm of mercury/^{0}C

a= a constant depending uopn the latitude Φ and is given by 0.29*COS Φ

b = a constant with an average value of 0.52.

n = actual duration of bright sunshine hours.

r = reflection coefficient (albedo).

σ = Stefan- Boltzman constant = 2 mm/day

T_a = mean air temperature in ^{0} kelvin =273+^{0}C.

e_a = actual mean vapour pressure in the air in mm of mercury .

$E_a = 0.35 * (1+u_2/160)*(e_w-e_a)$.

ew = saturation vapour pressure at mean air temperature in mm of mercury.

TABLE - 4.7

COMPUTATION OF POTENTIAL EVAPOTRANSPIRATION

Month		Mean Temperature	e_w	RH	e_a	u_2	Δ	N	n	H_a	b	a	σ	T_a	r	σ $* T_a^4$	H_n	E_a	PET
	Unit	^{0}C	mm of mercury	%	mm of mercury	km/day	mm of mercury / ^{o}C)	hours	hours	(mm / day)			mm/day	^{0}Kelvin			mm/day	mm/day	mm/day
January		12.8	11.09	80.08	8.88	73.51	0.8	10.7	7.7	8.9	0.52	0.26	$2.01*10^{-9}$	285.8	0.05	13.41	2.46	1.13	1.96
February		16.7	14.27	75.05	10.71	103.32	0.9	11.3	7.6	10.8	0.52	0.26	$2.01*10^{-9}$	289.7	0.05	14.16	3.63	2.05	3.07
March		19.8	17.33	67.2	11.65	160.94	1.04	12	8	12.9	0.52	0.26	$2.01*10^{-9}$	292.8	0.05	14.77	4.84	3.99	4.57
April		25.6	24.64	62.5	15.40	158.95	1.45	12.7	8.5	14.9	0.52	0.26	$2.01*10^{-9}$	298.6	0.05	15.98	6.32	6.45	6.35
May		27.6	27.71	69.2	19.18	156.98	1.62	13.3	7.9	15.9	0.52	0.26	$2.01*10^{-9}$	300.6	0.05	16.41	6.90	5.92	6.67
June		27.9	28.2	72.23	20.37	157.99	1.65	13.7	6.1	16.4	0.52	0.26	$2.01*10^{-9}$	300.9	0.05	16.48	6.40	5.45	6.18
July		25.8	24.93	87.95	21.93	91.39	1.47	13.51	3.7	16.1	0.52	0.26	$2.01*10^{-9}$	298.8	0.05	16.02	5.38	1.65	4.45
August		25.7	24.78	90.58	22.45	90.41	1.46	13	5.1	15.3	0.52	0.26	$2.01*10^{-9}$	298.7	0.05	16.00	5.79	1.28	4.65
September		25.2	19.7	89.55	17.64	85.42	1.19	12.3	5.3	13.7	0.52	0.26	$2.01*10^{-9}$	298.2	0.05	15.89	4.90	1.11	3.79
October		23	21.08	89.88	18.95	72.53	1.27	11.6	7	11.6	0.52	0.26	$2.01*10^{-9}$	296	0.05	15.43	4.70	1.09	3.69
November		18.4	15.88	87.6	13.91	62.59	0.98	10.9	8.9	9.5	0.52	0.26	$2.01*10^{-9}$	291.4	0.05	14.49	3.52	0.96	2.67
December		14.3	12.23	86.83	10.62	61.61	0.8	10.59	5.9	8.3	0.52	0.26	$2.01*10^{-9}$	287.3	0.05	13.69	2.16	0.78	1.64

Remarks :

PET = Potential Evapotranspiration in mm/day

$= \Delta H_n + E_a \gamma / (\Delta + \gamma)$

Δ = Slope of the saturation vapour pressure vs. temperature curve at the mean air temperature, in mm of mercury per ^{0}C.

H_n = net radiation in mm of evaporable water per day.

E_a = Parameter including wind velocity and saturation deficit.

γ =Psychrometric constant = 0.49 mm of mercury/^{0}C

a= a constant depending uopn the latitude Φ and is given by 0.29*COS Φ

b = a constant with an average value of 0.52.

n = actual duration of bright sunshine hours.

r = reflection coefficient (albedo) .

σ = Stefan- Boltzman constant = 2. mm/day

T_a = mean air temperature in ^{0} kelvin =273+^{0}C.

e_a = actual mean vapour pressure in the air in mm of mercury .

$E_a = 0.35 * (1+u_2/160) * (e_w - e_a)$.

ew = saturation vapour pressure at mean air temperature in mm of mercury.

TABLE - 4.8

MONTHLY ESTIMATES OF PARAMETERS FOR RAINFED AND IRRIGATED AGRICULTIRE (ALL FIGURES IN MM)

Description of Item	January	February	March	April	May	June	July	August	September	October	November	December
Mean monthly rainfall (RM)	25.86	23.14	20.26	20.1	76.48	272.6	451.6	425.11	293.05	69.33	10.96	14.13
80 % Probability rain (R80)	0.7	0.9	0.3	0.0	22.2	149.5	312.2	295.9	160.8	7.7	0.0	0.0
Potential Evapotranspiration (PET)	67.58	93.8	155	197.4	198.4	167.1	144.2	143.53	109.8	102.3	72.9	67.58
Potential Evapotranspiration Deficit (PET-R80)	66.9	92.9	154.7	197.4	176.2	17.6	-168.0	-152.4	-51.0	94.6	72.9	67.6
Moisture Availability Index (MAI)	0.01	0.01	0.00	0.00	0.11	0.89	2.17	2.06	1.46	0.08	0.00	0.00
Gross Water Surplus (RM - PET)	-41.72	-70.66	-134.74	-177	-121.9	105.5	307.5	281.58	183.25	-32.97	-61.94	-53.45
Where , RM > PET												

TABLE - 4.9

Rainfall Deficit

Month	PET (mm)	R80 at Rain Gauge Station (mm)			Rainfall Deficit (mm)		
		Nayabasti	Tulsipur	Ghorahi	Nayabasti	Tulsipur	Ghorahi
January	39.1	0	1.9	0	39.1	37.2	39.1
February	62.3	0	1.1	0	62.3	61.2	62.3
March	108.9	0	0	0	108.9	108.9	108.9
April	150.1	0	0	0	150.1	150.1	150.1
May	164.0	14.7	28.5	24	149.3	135.5	140.0
June	148.5	120	161.2	168.7	28.5	0.0	0.0
July	108.0	315.3	308.7	349.1	0.0	0.0	0.0
August	111.6	271.7	261.7	373.5	0.0	0.0	0.0
September	85.9	135.1	169.3	186.2	0.0	0.0	0.0
October	84.8	1.8	6.9	13.7	83.0	77.9	71.1
November	54.1	0	0	0	54.1	54.1	54.1
December	33.3	0	0	0	33.3	33.3	33.3

FIGURE - 4.1

ANNUAL ISOHYETAL MAP OF DANG VALLEY

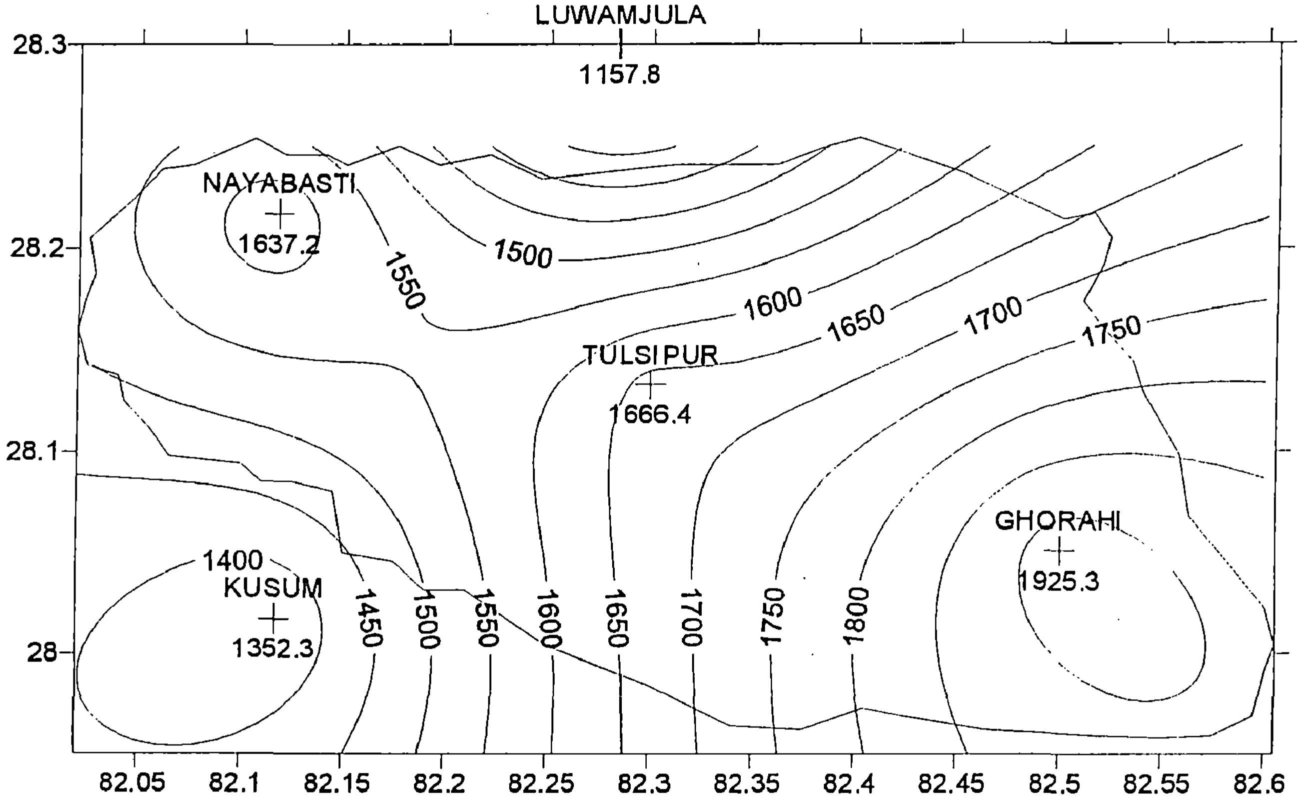


FIGURE - 4.2

ANNUAL ISOPLETH OF C.V. OF RAINFALL

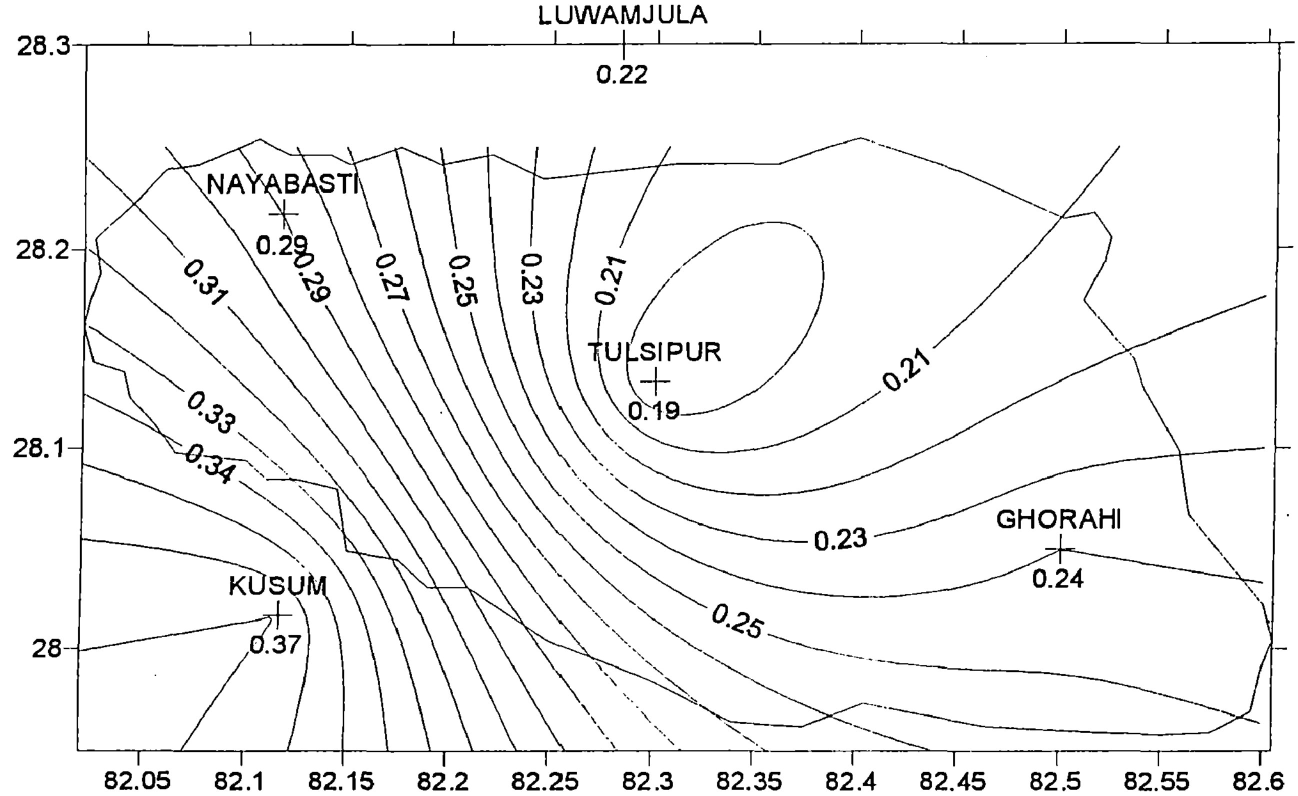


FIGURE - 4.3

ISOHYETAL MAP OF R80 FOR JANUARY

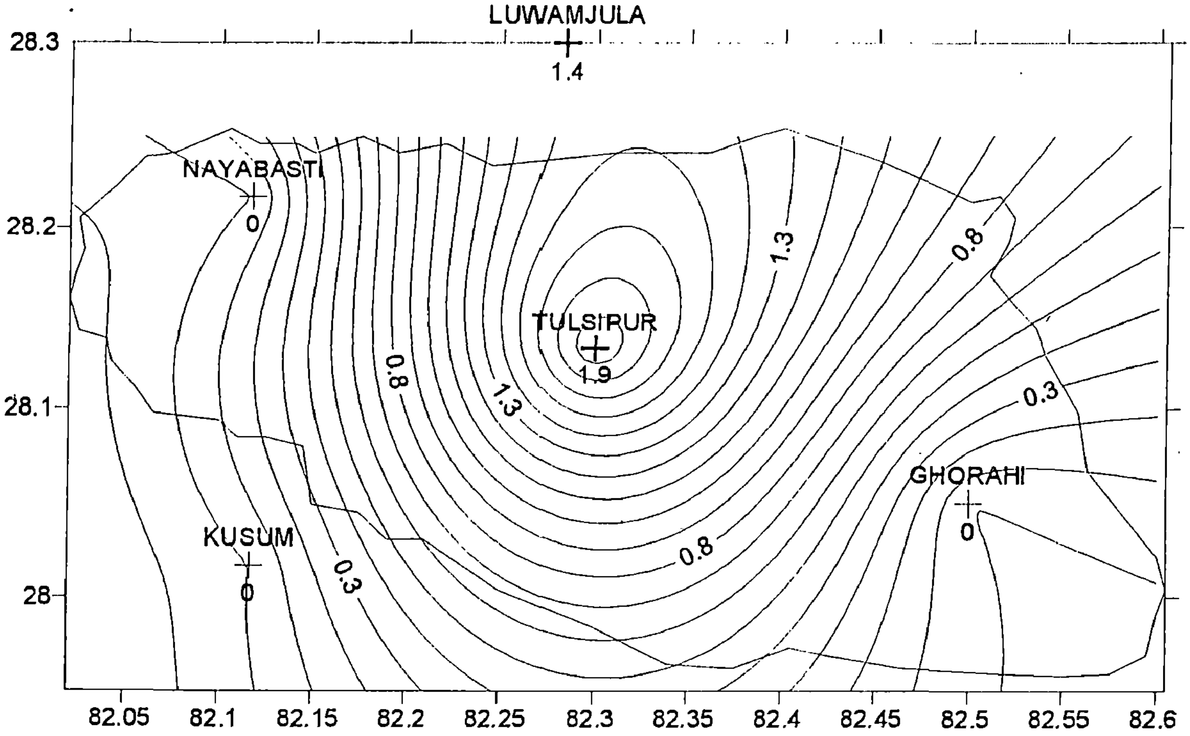


FIGURE - 4.4

ISOHYETAL MAP OF R80 FOR FEBRUARY

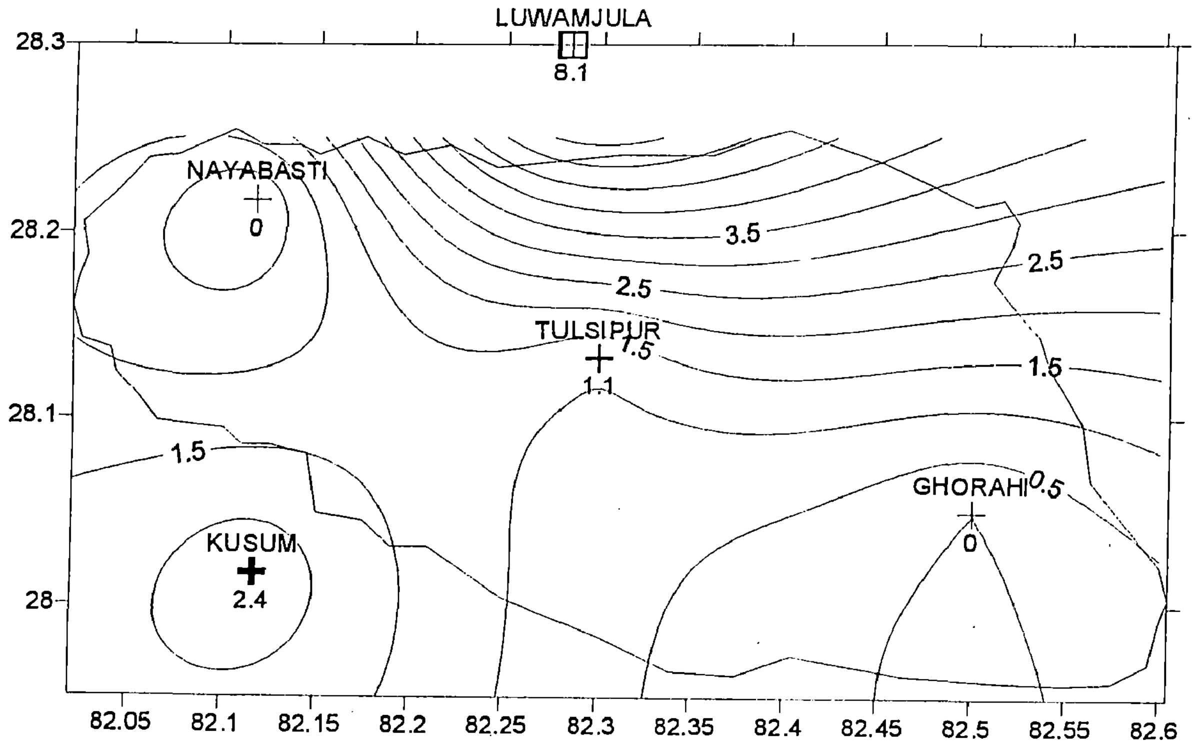


FIGURE - 4.5

ISOHYETAL MAP OF R80 FOR MARCH

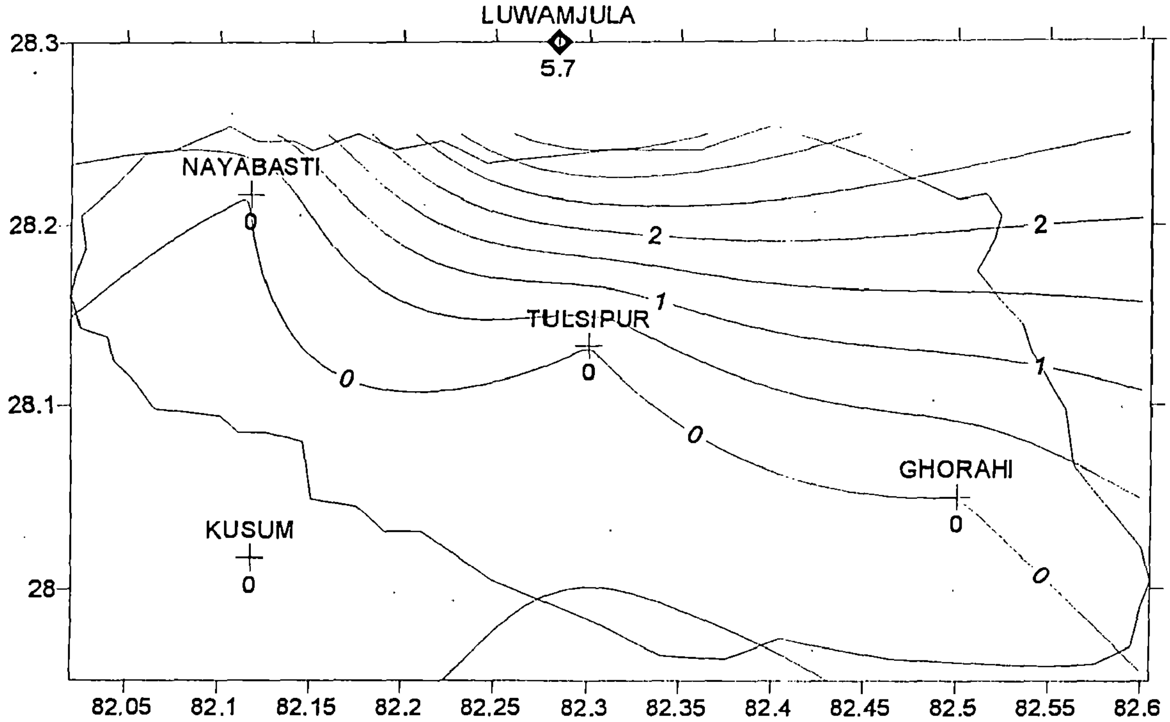


FIGURE - 4.6

ISOHYETAL MAP OF R80 FOR APRIL

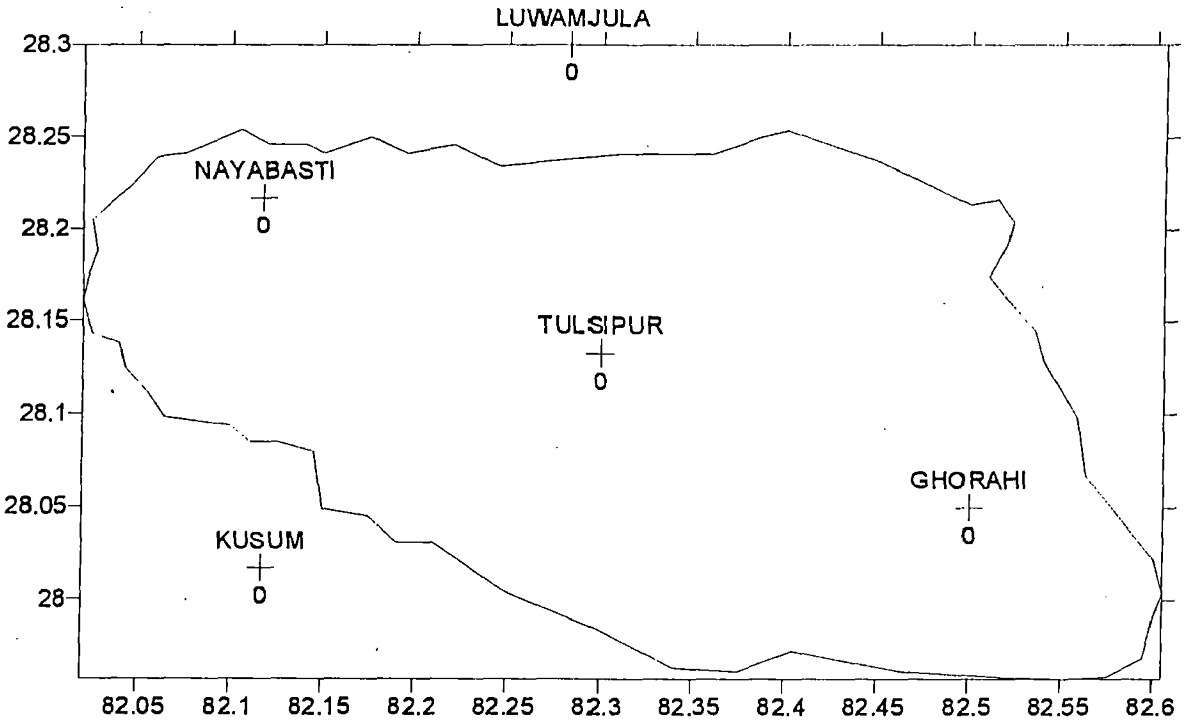


FIGURE - 4.7

ISOHYETAL MAP OF R80 FOR MAY

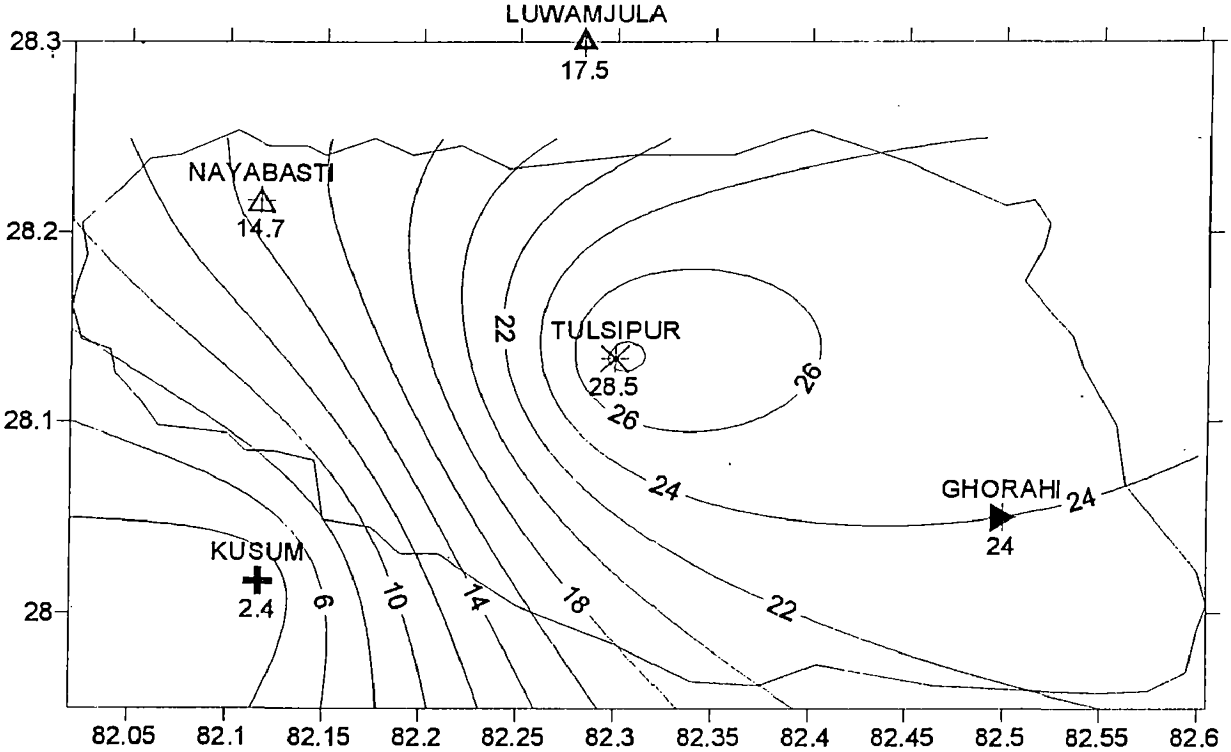


FIGURE - 4.8

ISOHYETAL MAP OF R80 FOR JUNE

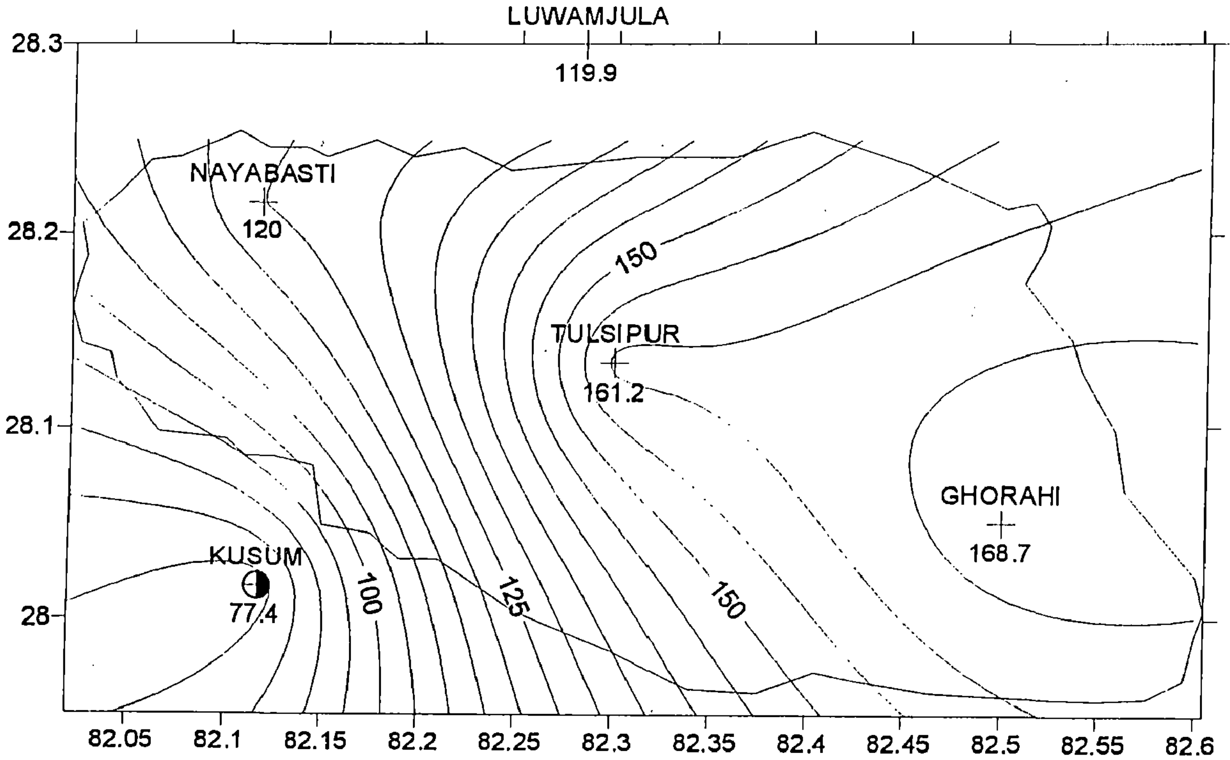


FIGURE - 4.9

ISOHYETAL MAP OF R80 FOR JULY

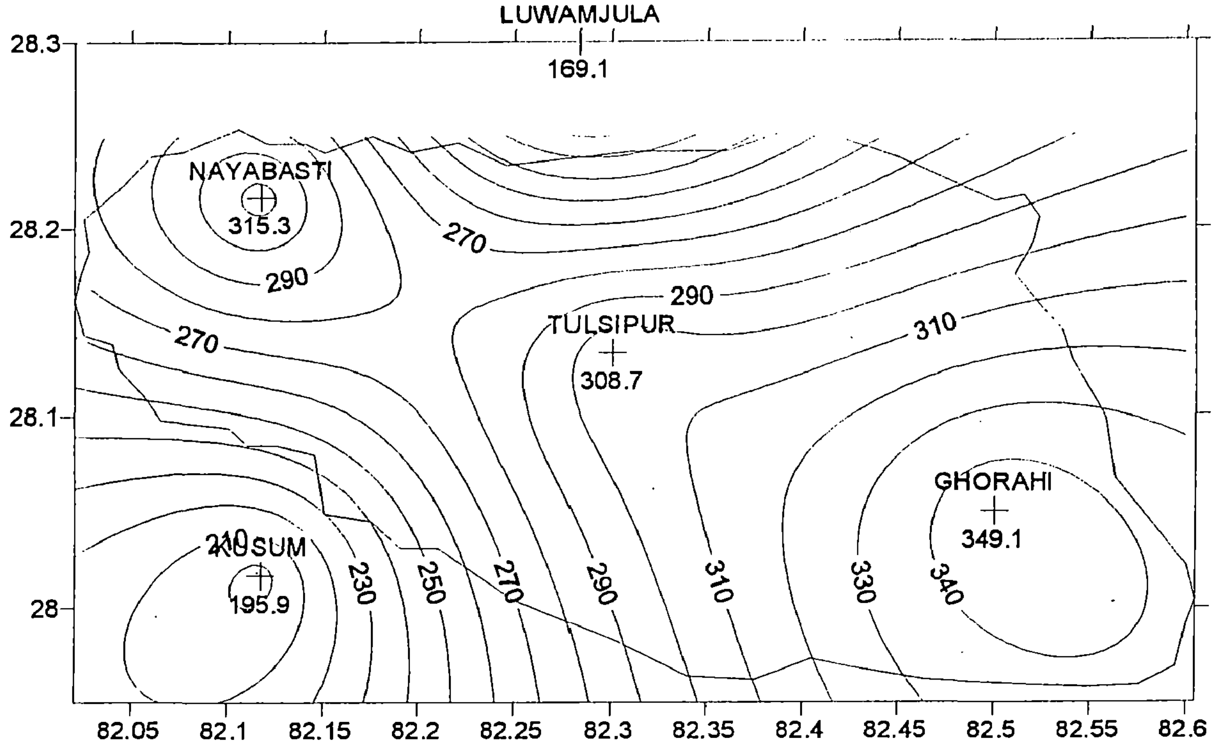


FIGURE - 4.10

ISOHYETAL MAP OF R80 FOR AUGUST

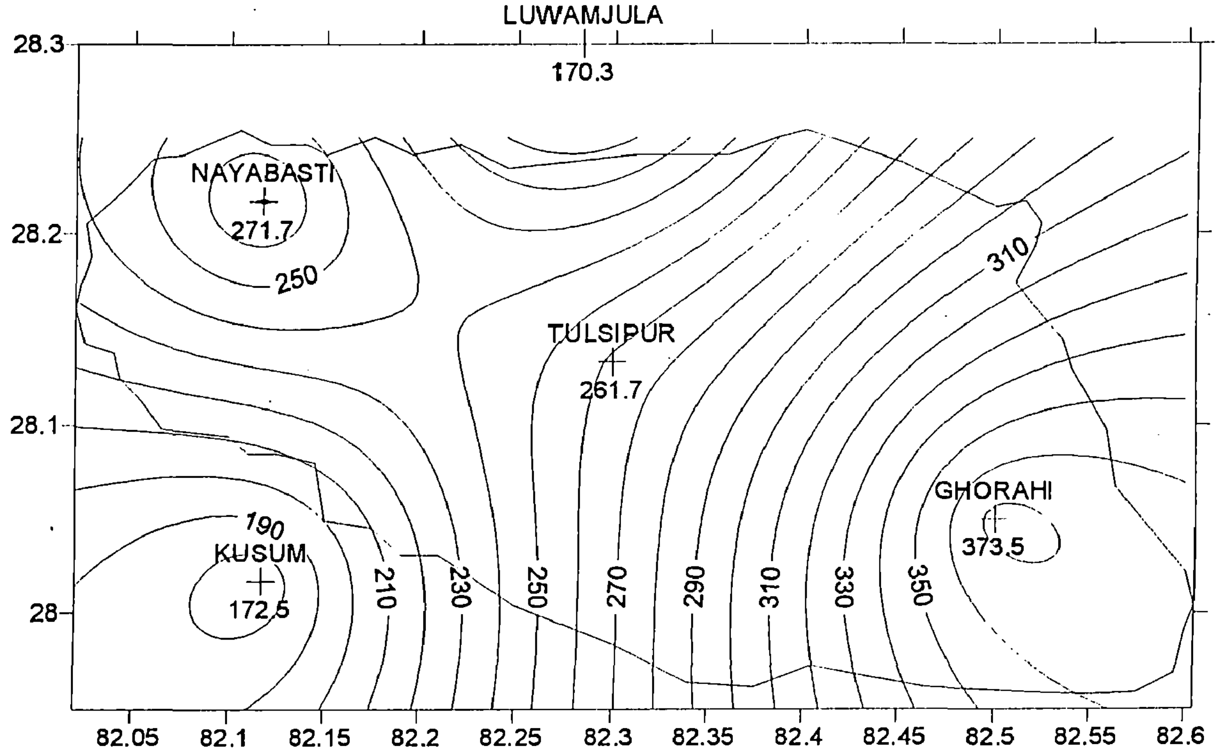


FIGURE - 4.11

ISOHYETAL MAP OF R80 FOR SEPTEMBER

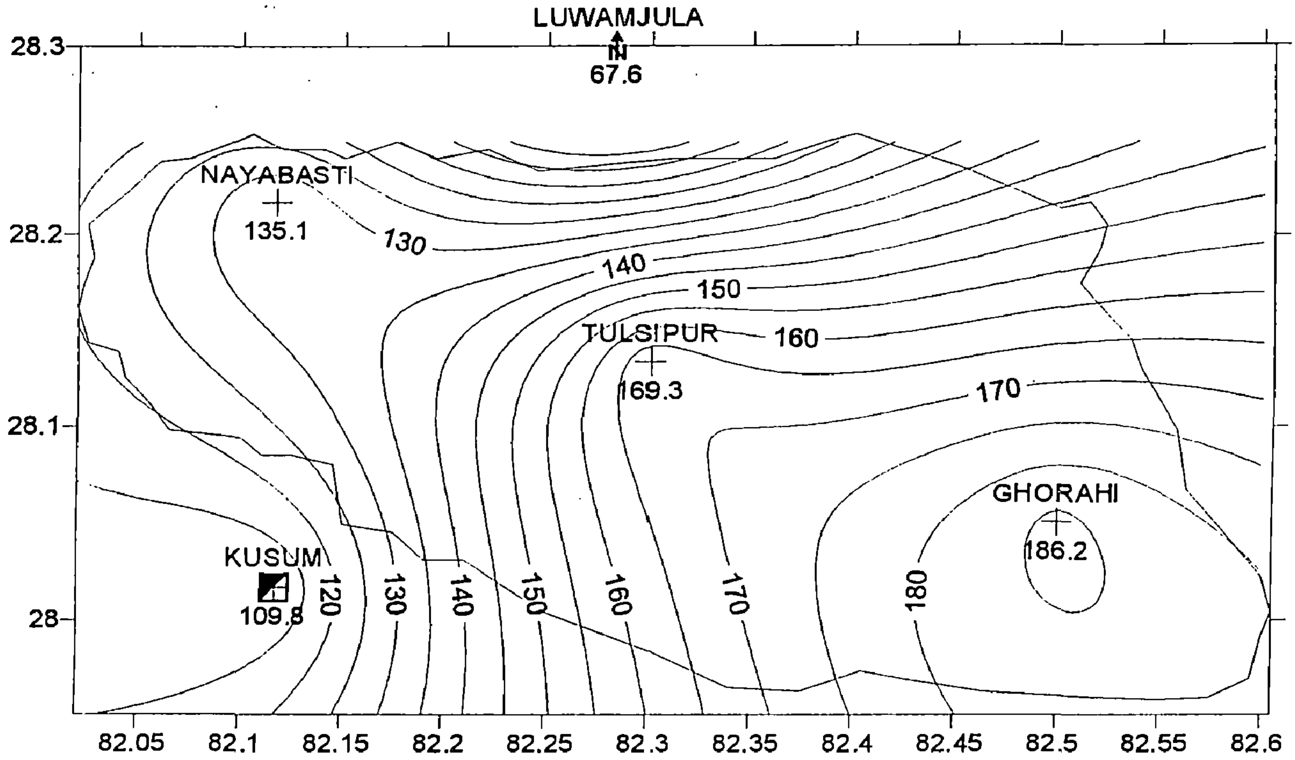


FIGURE - 4.12

ISOHYETAL MAP OF R80 FOR OCTOBER

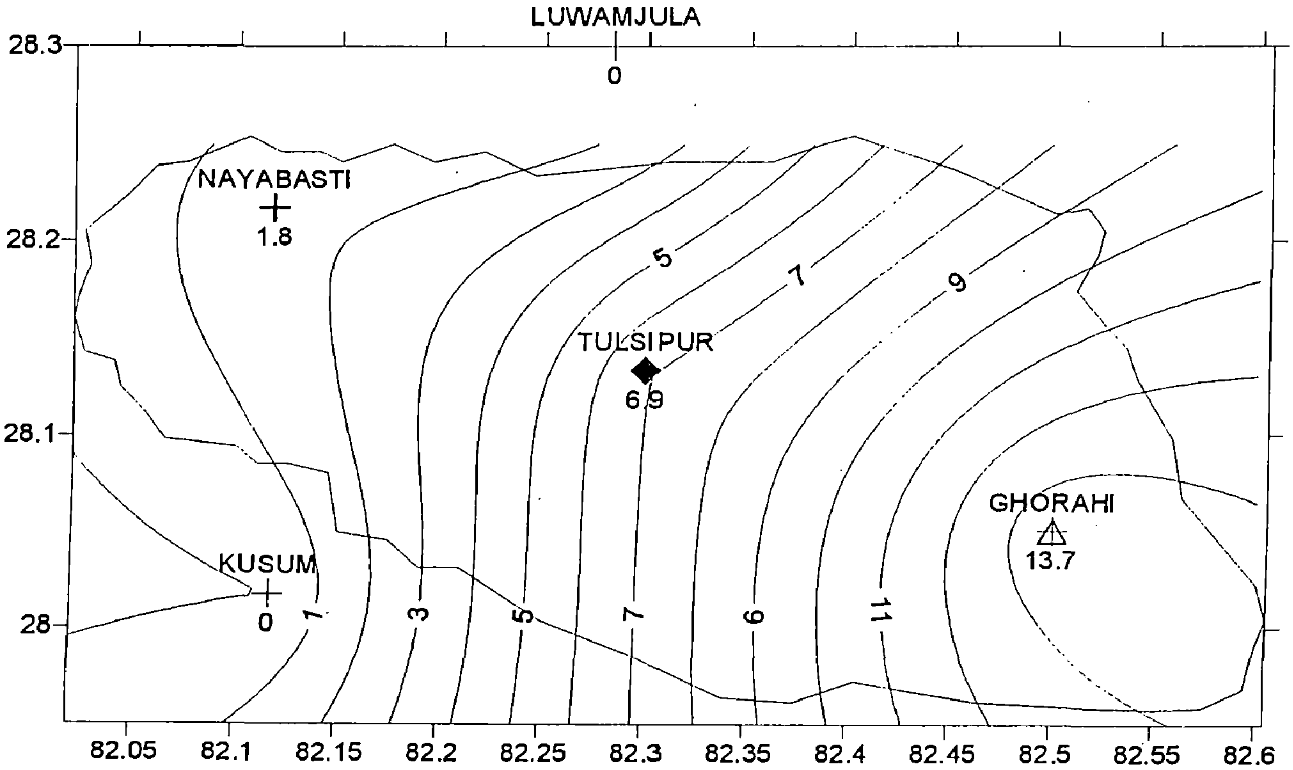


FIGURE - 4.13

ISOHYETAL MAP OF R80 FOR NOVEMBER

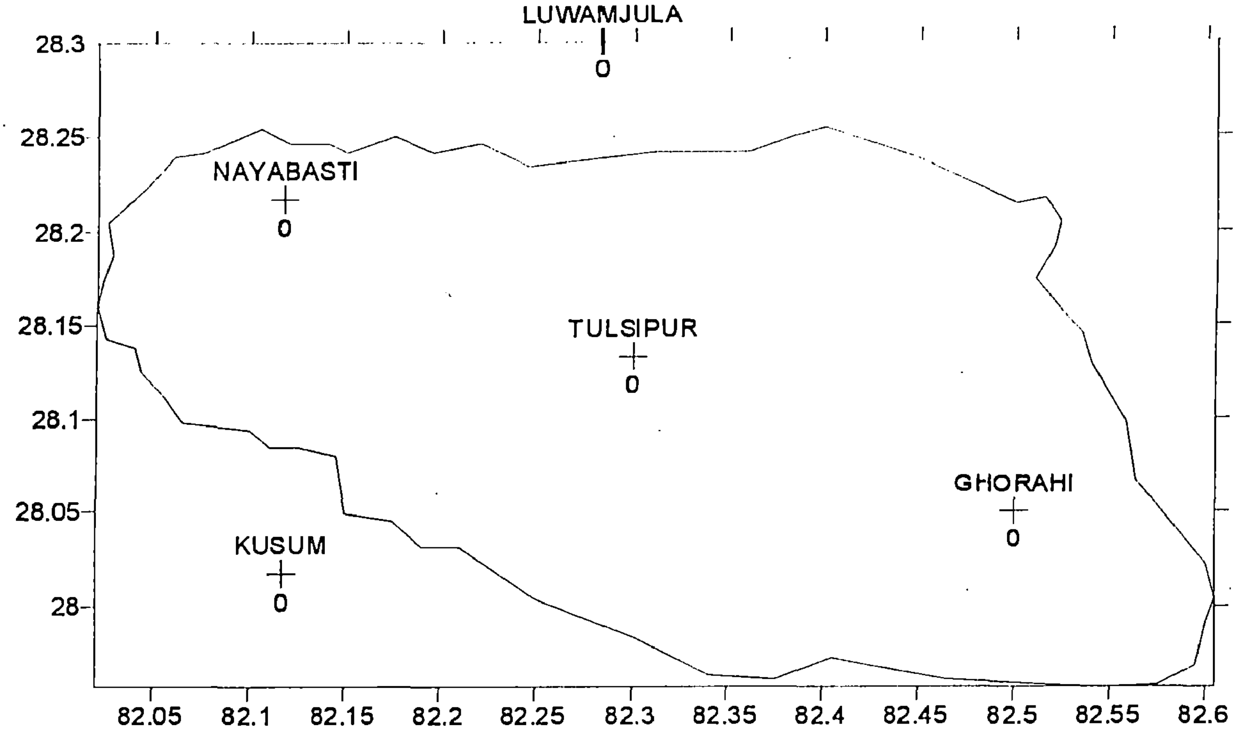


FIGURE - 4.14

ISOHYETAL MAP OF R80 FOR DECEMBER

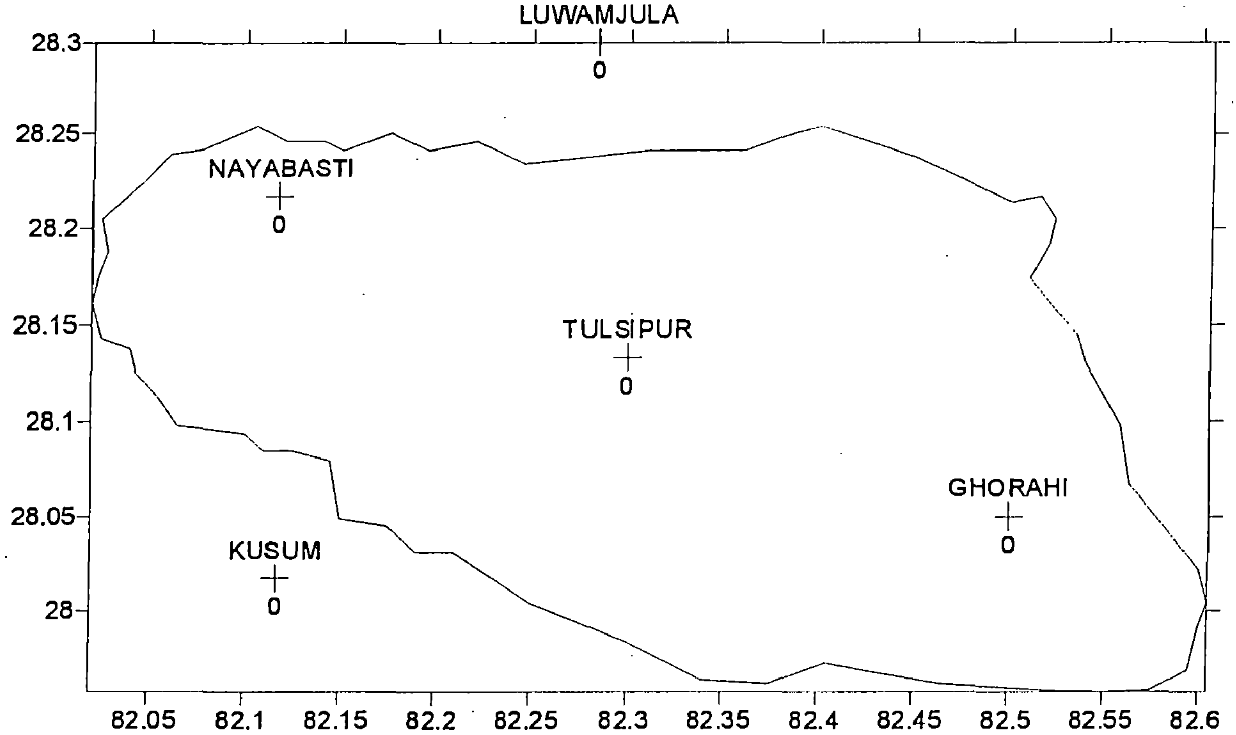


FIGURE - 4.15

ISOPLETH MAP OF RAINFALL DEFICIT FOR JANUARY

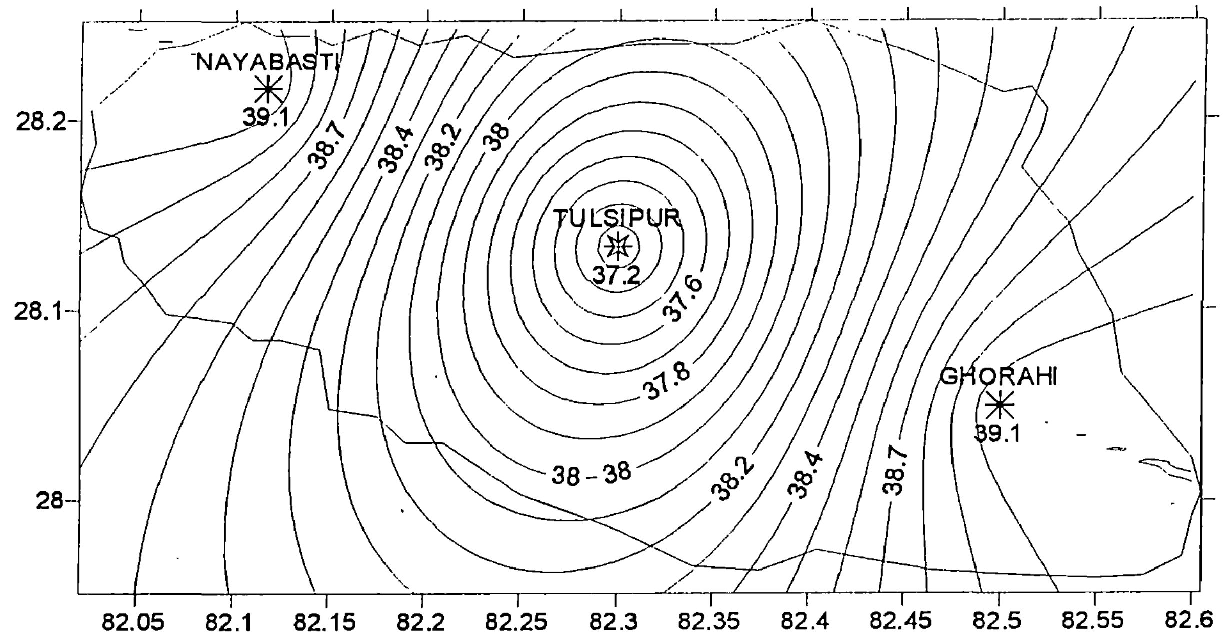


FIGURE - 4.16

ISOPLETH MAP OF RAINFALL DEFICIT FOR FEBRUARY

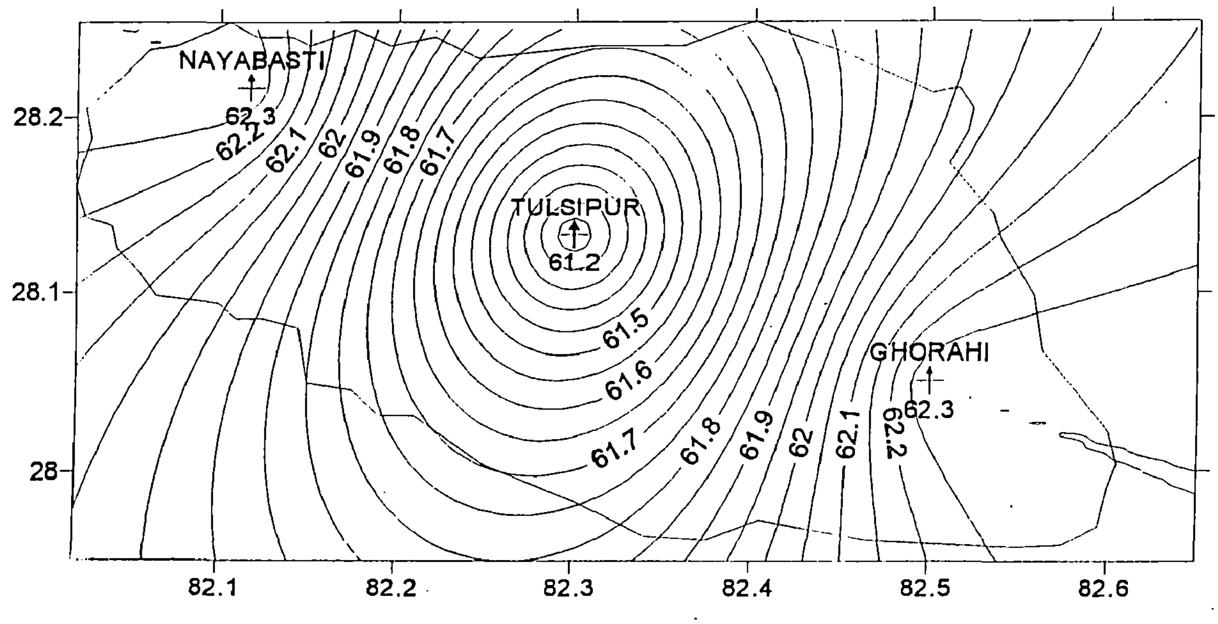


FIGURE - 4.17

ISOPLETH MAP OF RAINFALL DEFICIT FOR MARCH

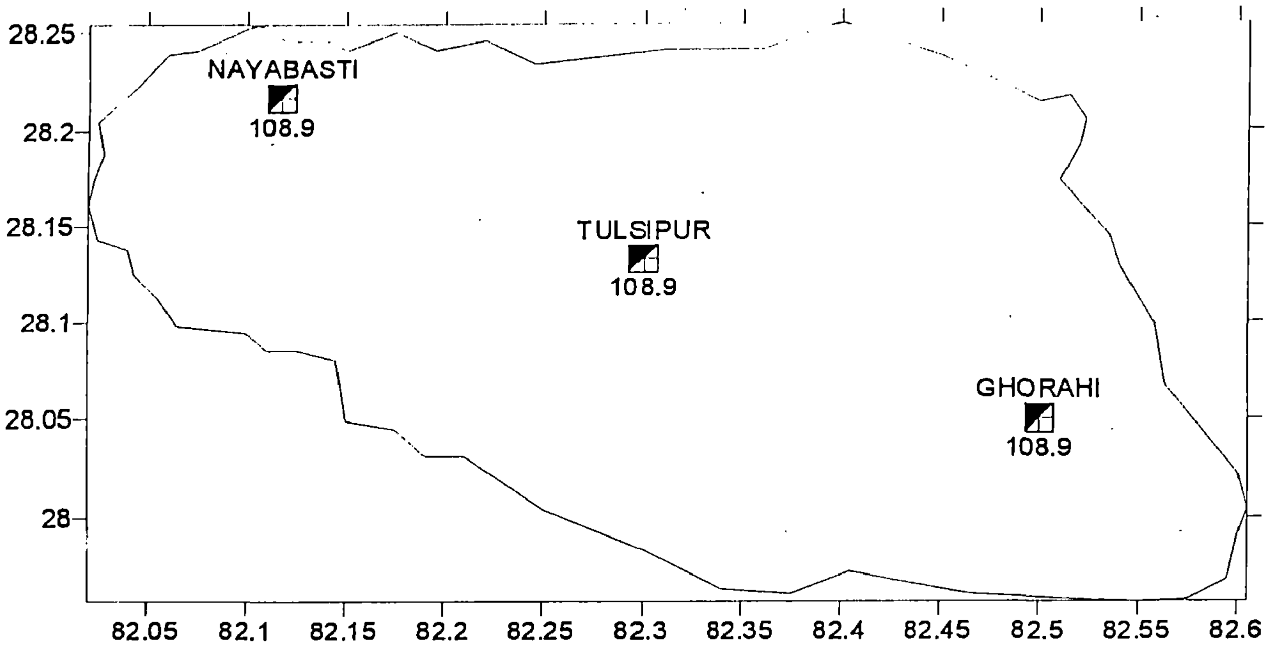


FIGURE - 4.18

ISOPLETH MAP OF RAINFALL DEFICIT FOR APRIL

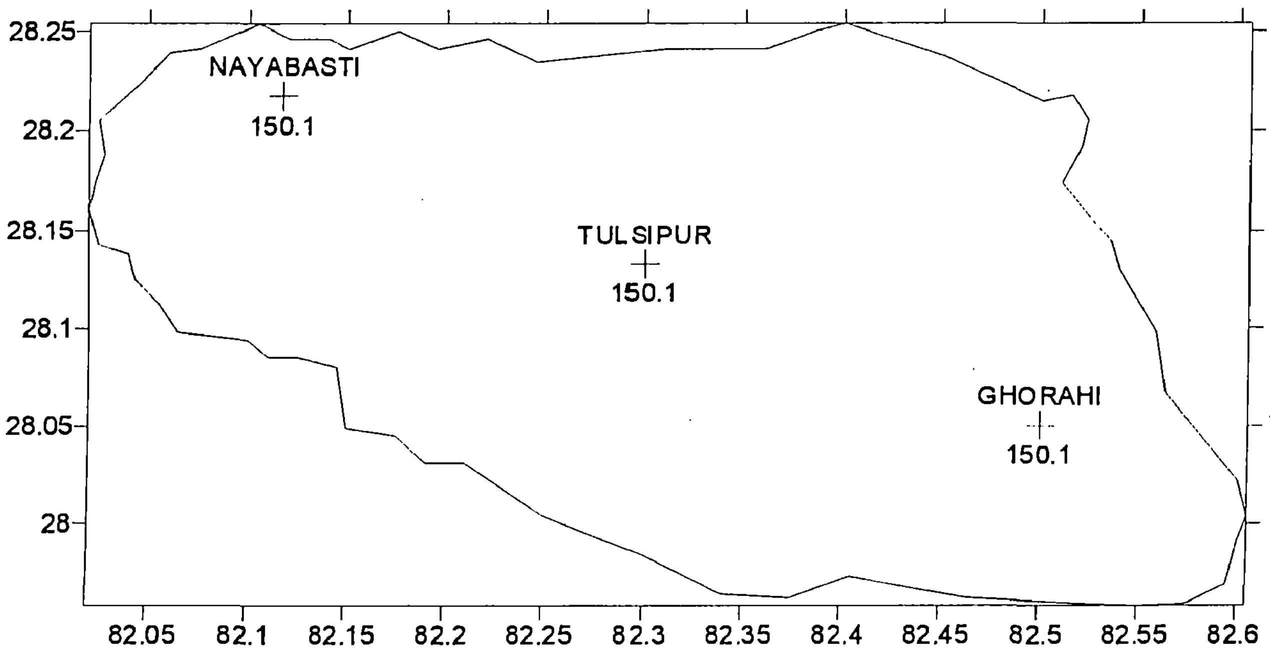


FIGURE - 4.19

ISOPLETH MAP OF RAINFALL DEFICIT FOR MAY

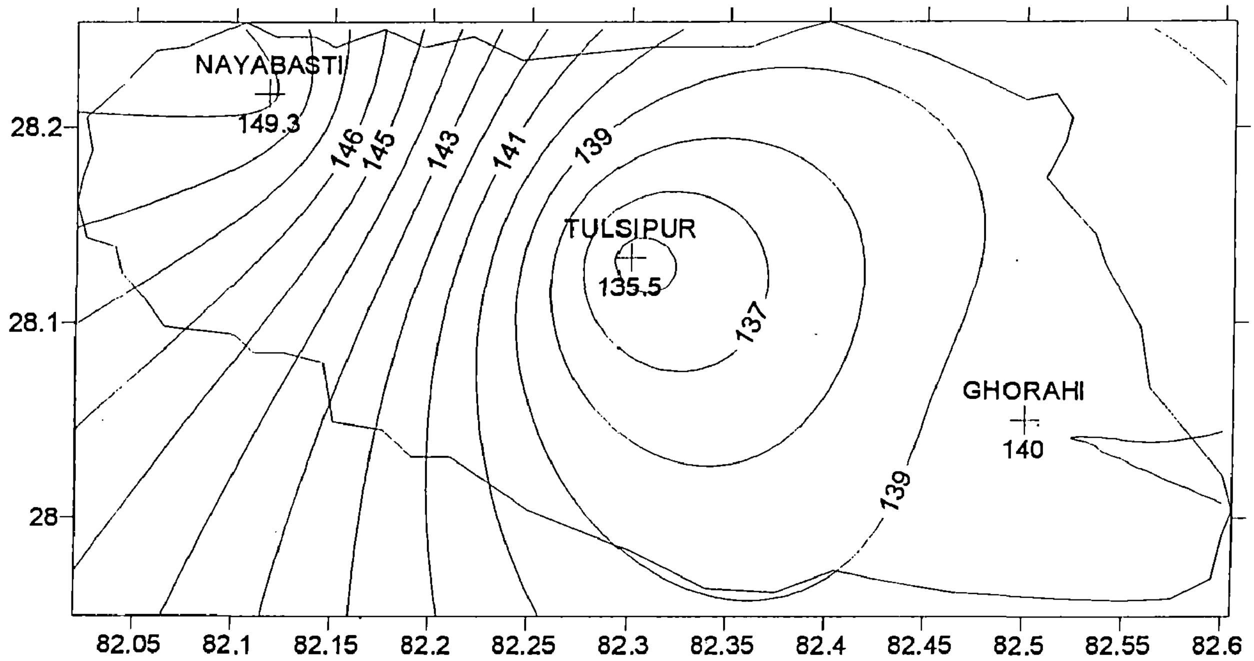


FIGURE - 4.20

ISOPLETH MAP OF RAINFALL DEFICIT FOR JUNE

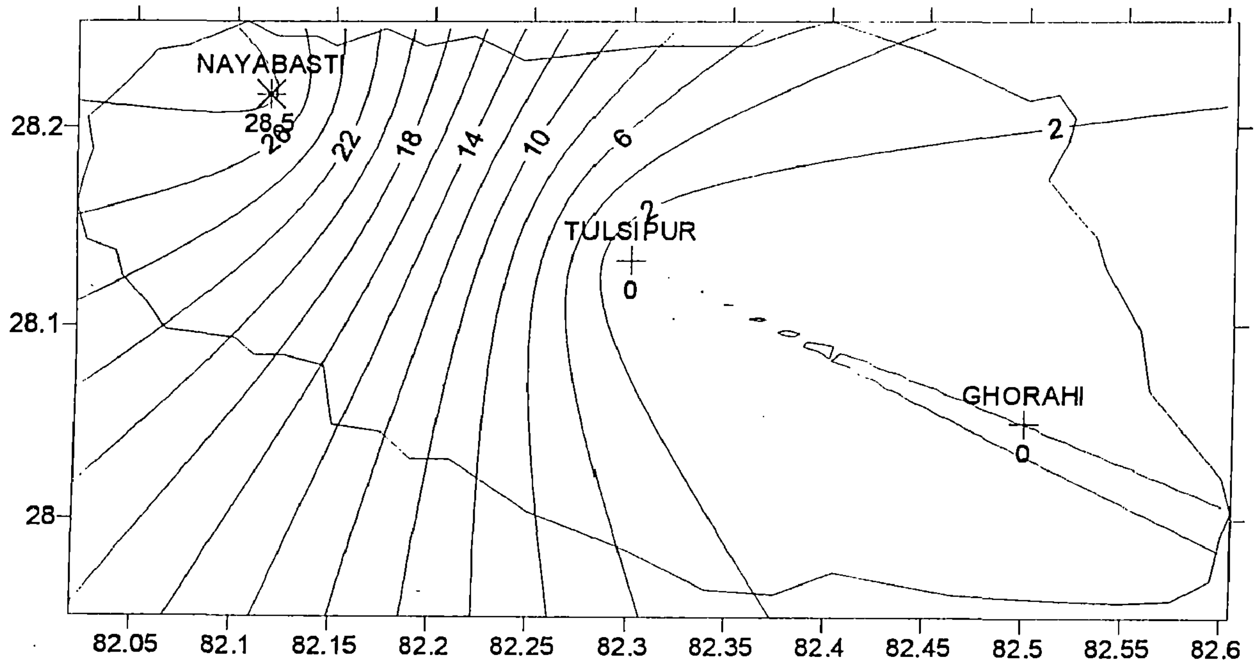


FIGURE - 4.21

ISOPLETH MAP OF RAINFALL DEFICIT FOR JULY

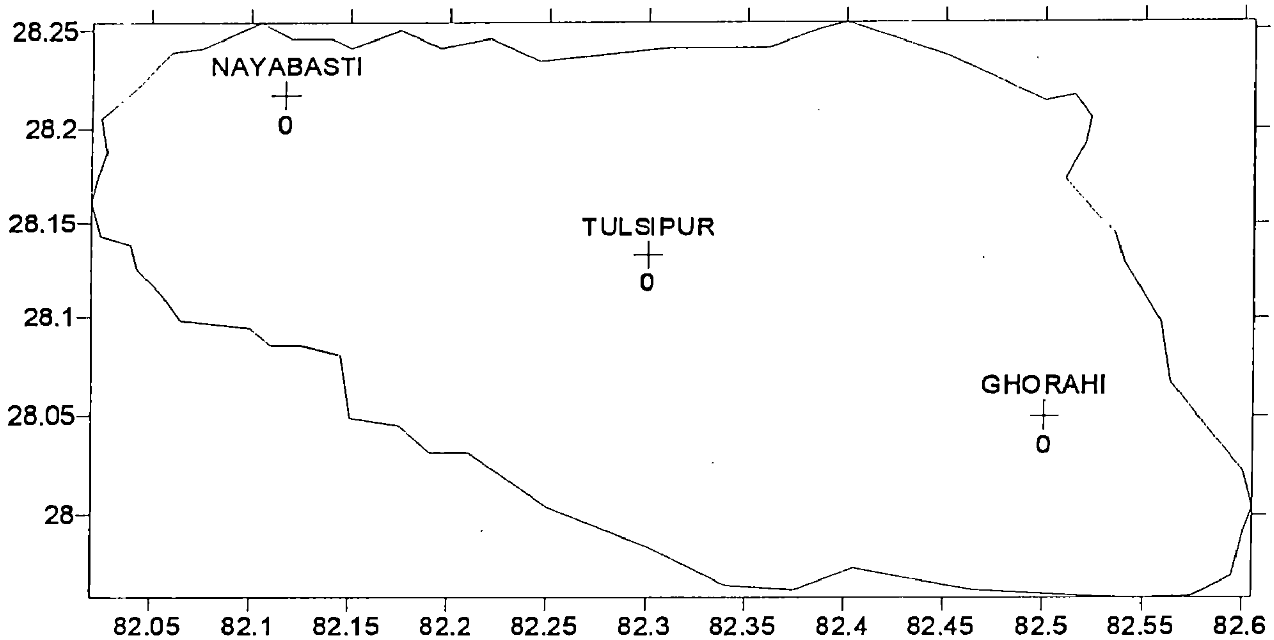


FIGURE - 4.22

ISOPLETH MAP OF RAINFALL DEFICIT FOR AUGUST

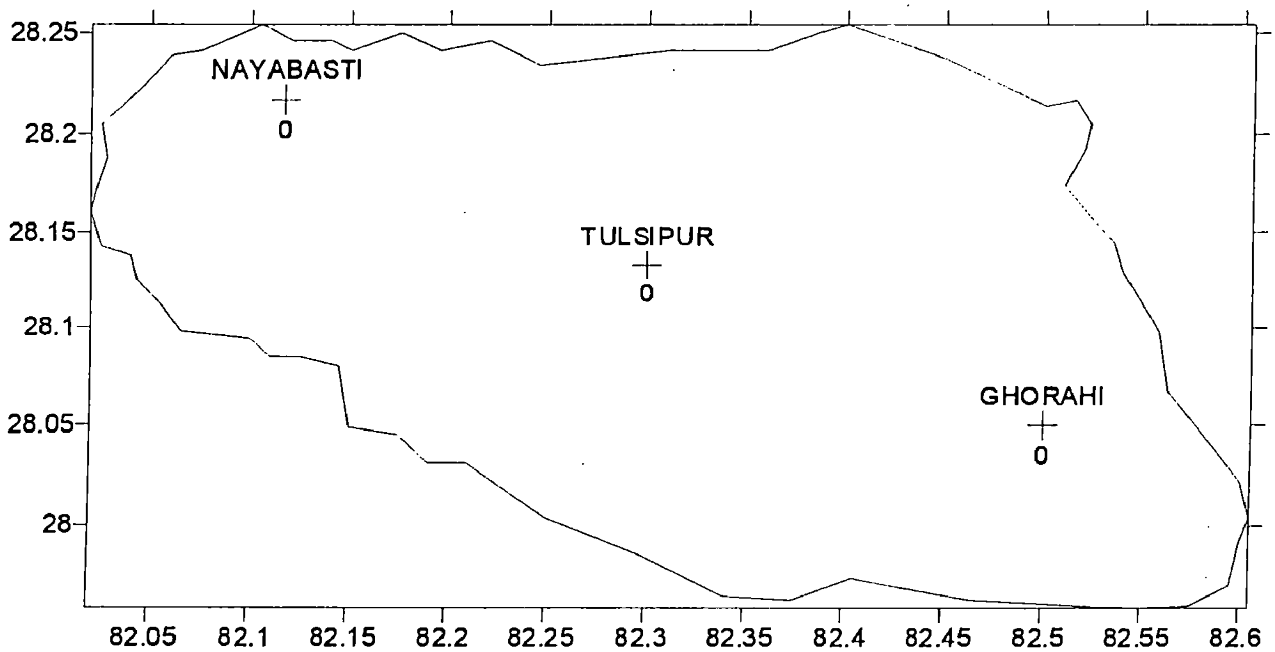


FIGURE - 4.23

ISOPLETH MAP OF RAINFALL DEFICIT FOR SEPTEMBER

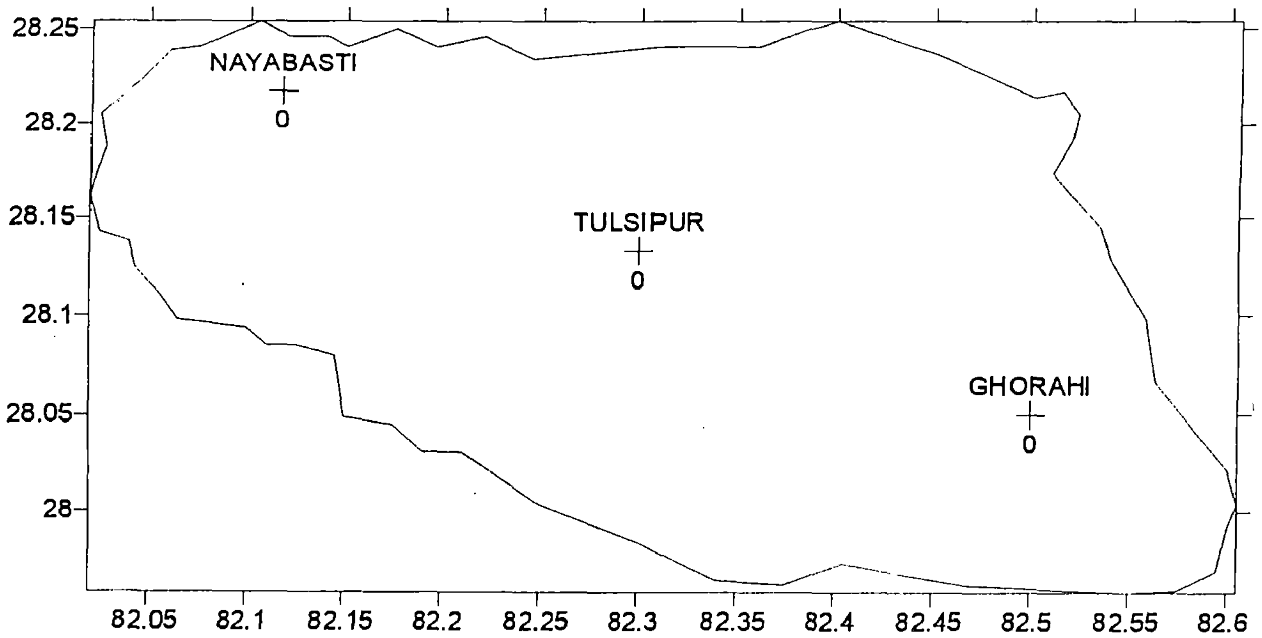


FIGURE - 4.24

ISOPLETH MAP OF RAINFALL DEFICIT FOR OCTOBER

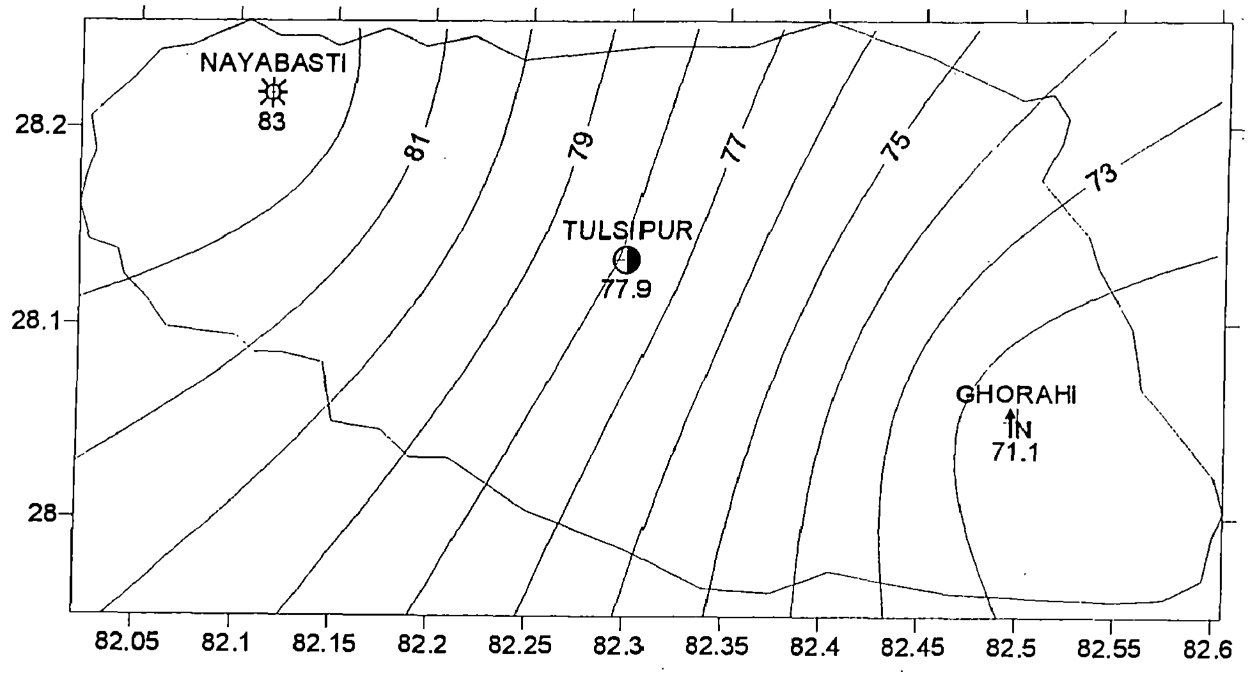


FIGURE - 4.25

ISOPLETH MAP OF RAINFALL DEFICIT FOR NOVEMBER

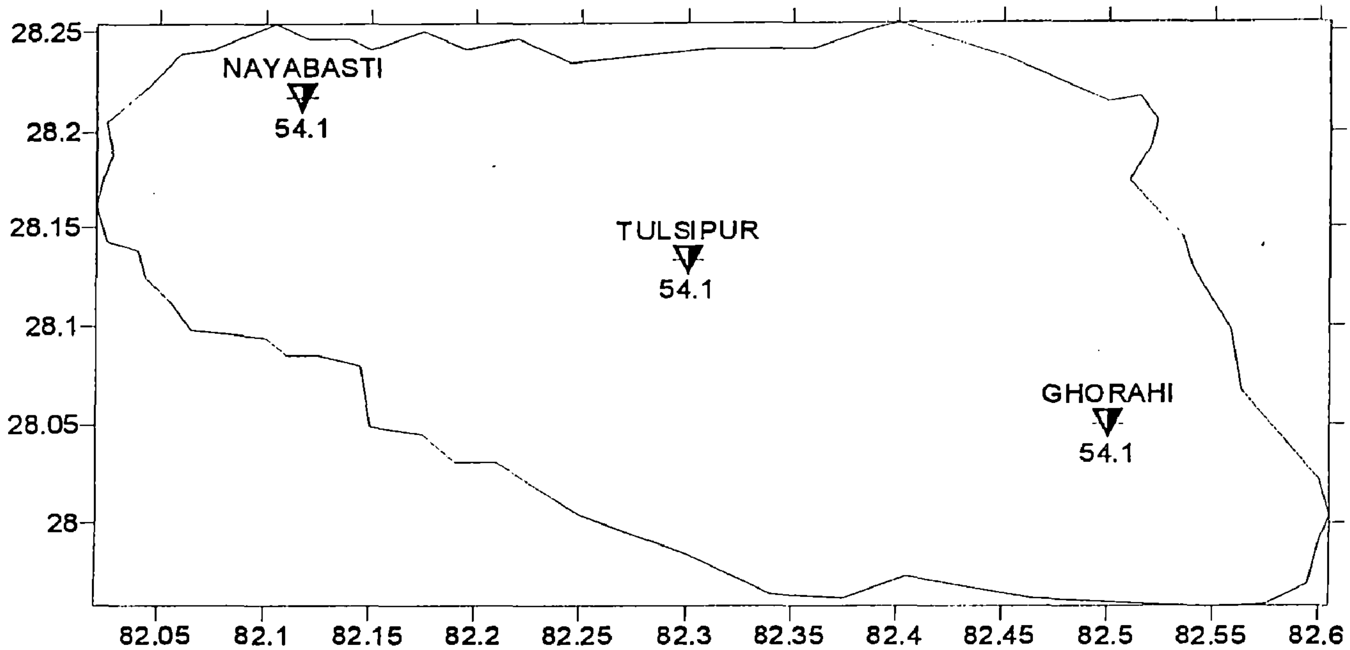
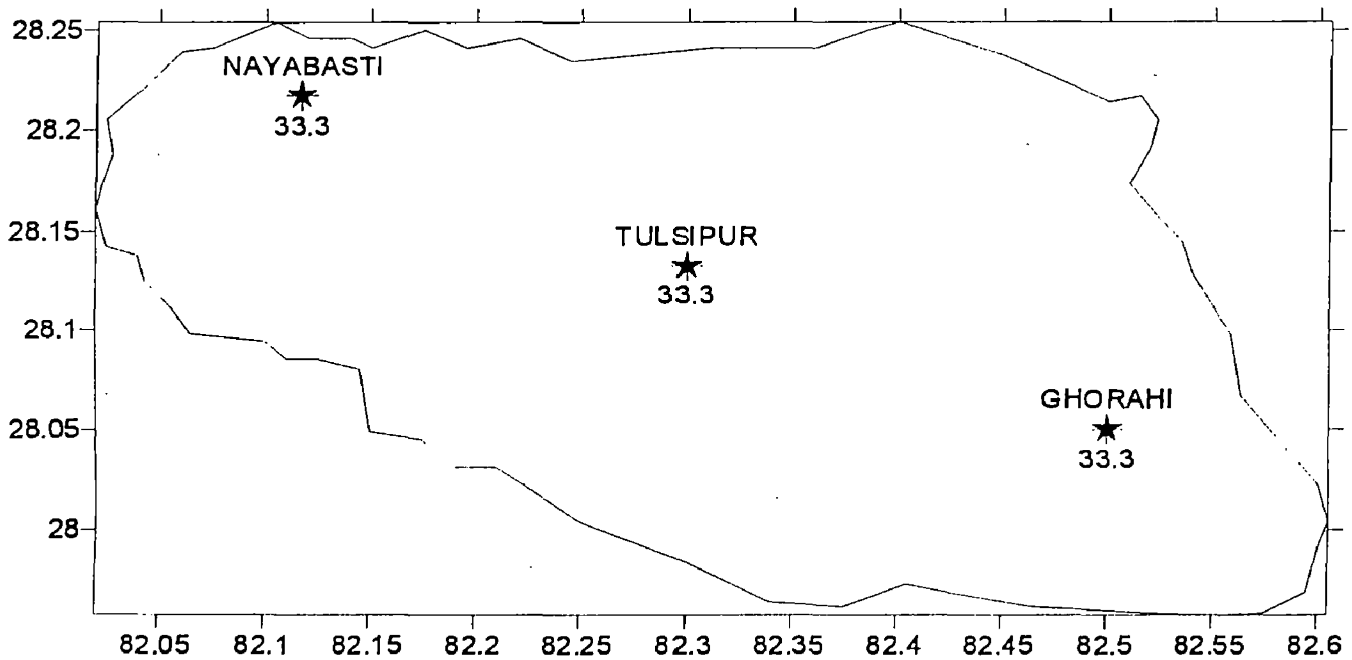


FIGURE - 4.26

ISOPLETH MAP OF RAINFALL DEFICIT FOR DECEMBER



CHAPTER - 5

WATER BALANCE STUDY

5.1 GENERAL

The water balance computation is one technique used in analysing the hydrologic response of a catchment to rainfall in terms of stream flow , evapotranspiration , soil moisture storage and ground water recharge and storage . Awareness is increasing to make full use of water resources for meeting the progressively increasing requirement of water, a continuing inventory must be developed and maintained. This will show the quantities of water passing through each phase of hydrologic cycle and will permit a periodic accounting of the water storage in soil, in surface reservoirs, groundwater reservoir and evapotranspiration etc. With this quantitative information and the application of sound hydrologic principles, optimal development and management of surface and ground water can be achieved. In case of ground water, full development is achieved when the average replenishment is balanced by the average discharge and the discharge for non-beneficial purposes has been reduced to minimum. In most years, however, such a balance will not be achieved. When recharge is large, the precipitation and stream flow are also likely to be above normal. So that the need for ground water may be less.

In order to find out present status of water resource utilization and to make assessment of available surface and ground water resources in future, water balance study of an area is necessary. In the present study, water balance approach has therefore been adopted to assess quantitatively the various components of hydrologic cycle in order to evaluate the water resources of the area.

Water balance study of the study area has been carried out to evaluate net available surface water resources and to assess the existing water utilization pattern and practices. The information will help in planning optimal and efficient management of water resources.

5.2 HYDROLOGICAL WATER BALANCE

Natural sources of water to any area is precipitation, which is not uniform over the area and occurs only in some parts of the year. The precipitated water may be intercepted or transpired by plants, may run over ground surface into the stream or may infiltrate in to the ground.

Part of the intercepted water and transpired water and some of the surface runoff return to the atmosphere through evaporation and evapotranspiration. The infiltrated water may percolate downward into groundwater reservoir which may later seep out into rivers or streams.

The hydrologic cycle thus undergoes various processes. The estimation of water in the various components of hydrologic cycle over certain period helps ultimately in the estimation of utilizable water.

The basic concept of a balance equation is that change in storage in the system is equal to the difference of input to the system and outflow from the system, which is based on the concept of continuity equation given as follows:

[Input to the system] – [outflow from the system] = [Change in storage in the system]

The various components of the above continuity equation can be represented in equation form as:

$$P + \text{Input} = Q + E_T + \text{Export} + Sm + Sg + Sd + L$$

Or,

$$P + (Ic+Ig) = Q + E_T + (Oc + Og) + Sm + Sg + Sd + L$$

Where,

P = Precipitation

Ic = Surface supplies through rivers, canals and drainage from outside the basin.

Ig = Inflow to the groundwater from other basins.

Q = runoff

E_T = Evaporation and Evapotranspiration

Et = E+E'+E"

E = Evaporation from water surface

E' = Evapotranspiration from irrigated crops

E" = Evapotranspriation from un-irrigated crops

Oc = Surface supplies going out to other basin

Og = Ground water outflow from the basin to other basins

Sm = Change in soil moisture

Sg = Change in ground water storage

Sd = Change in depression storage

L = Loss through deep percolation

Changes in surface storage are determined from the changes in the reservoir or lake levels and their capacity curves. The changes in the stream storage are of minor importance in a long time or yearly budget. Changes in soil moisture storage (Sm) are of minor importance if balance is prepared on yearly basis because the beginning and the end of the study period is at about the same season of the year and the change in soil moisture can be usually ignored. For seasonal balance, soil moisture storage change may be significant, which may be determined from the soil moisture profiles at the beginning and the end of the period. This is done at various locations to determine the weighted average for the area. Change in ground water storage, Δsg can be determined from contour maps of the water table or piesometric surface and the storativity of the aquifer at the beginning, during and at the end of the study period or periods.

The precipitation is measured at selected points by means of either automatic or non automatic rain gauges stations. The weighted average depth of precipitation over the whole study area is found by constructing Thiessen polygons or plotting isohyetals.

Surface flow components Ic, the inflow into the area and Oc, the outflow from the area can be estimated from the discharge data of the canal . Where surface and ground water basins boundries do not coincide, ground water flows may be major factors. Groundwater flow component Ig, underflow from and Og, the under flow to the adjacent basins can be estimated by determining the width of the flow path from the knowledge of the aquifer dimensions ,the gradient from the water level contour maps and the transmissivity.

5.3 WATER BALANCE OF DANG VALLEY

Water balance of Dang valley is estimated as per NWDA guide lines. The water requirement for various purposes as estimated in chapter 2 is considered for computations . Due to non-availability of ground water data, only surface water is accounted while computing. The water balance computation is based on the following points:

1. The existing cropping pattern is adopted as per the data available from District Agriculture Office, Dang .Total crop water requirement is calculated as per cropping patter based on climatological approach by Modified Penman method.
2. Future cropping pattern has been suggested as per needs of the area based on present cultivation trend.
3. There is no industrial use of water at present situation . In absence of data , future industrial water requirement has been taken as the total domestic water requirements.
4. The total domestic water requirement at existing and future is calculated as per NWDA guide lines. Future water requirement is estimated projecting the population for the year 2050 A.D. based on the population of year 2001.
5. There is no possibility of hydropower development in the valley. No water has been accounted for this purpose at present and future.
6. Total water availability has been assessed as the total water available from all the streams which can be diverted for gravity irrigation in the valley. 75% dependable flow is considered as the water available for computing the water balance.
7. Regeneration of 10% , 80% and 80% from irrigation, domestic and industrial water use is taken as the additional water available.

Based on these points, the monthly water balance is computed. The total water balance statement of the valley in the existing and future condition is given in Table 5.1 and 5.2

From the monthly water balance statement , it is observed that there is water deficit in all the months except for the month of August and April in existing and future condition. It is also observed that there is rainfed cultivation at existing conditions from the cropping pattern . The total annual water in existing and future condition is +22.9 MCM and -11.82 MCM respectively.

5.3.1 Existing Water Balance

Existing water balance is computed with existing demands as estimated in Chapter- 2. The total monthly water balance statement is given in table-5.1. There is 22.9 MCM of water surplus in existing condition.

5.3.2 Future Water Balance

Water availability in the future will depend on catchment land use pattern. Deforestation and conversion of forest land to agriculture land would change the water availability in the catchment. However, it is expected that the forest cover in the catchment is maintained in future also. Future water balance based on the future requirement for irrigation, domestic and industrial purposes as per NWDA guidelines have been computed and given in Table-5.2 There is 11.82 MCM of water deficit in future.

TABLE - 5.1

MONTHLY WATER BALANCE STATEMENT (EXISTING) Mm^3

Month	Water Requirement (Mm^3)					Water Availability (Mm^3)						Monthly water balance
	Irrigation use	Domestic use	Hydropower use	Industrial use	Total	Regeneration from uses				Surface water yields	Total water available	
						Irrigation	Domestic	Industrial	Total			
June	32.400	0.648	0	0	33.048	3.240	0.518	0	3.758	10.342	14.100	-18.948
July	200.853	0.670	0	0	201.523	20.085	0.536	0	20.621	142.250	162.871	-38.652
August	101.270	0.670	0	0	101.940	10.127	0.536	0	10.663	194.532	205.195	103.255
September	91.549	0.648	0	0	92.197	9.155	0.518	0	9.673	133.047	142.721	50.523
October	61.068	0.670	0	0	61.737	6.107	0.536	0	6.642	23.490	30.132	-31.605
November	25.116	0.648	0	0	25.764	2.512	0.518	0	3.030	19.103	22.133	-3.631
December	30.025	0.670	0	0	30.694	3.002	0.536	0	3.538	15.508	19.046	-11.648
January	24.213	0.670	0	0	24.882	2.421	0.536	0	2.957	12.642	15.599	-9.283
February	26.418	0.605	0	0	27.022	2.642	0.484	0	3.126	10.233	13.359	-13.664
March	14.597	0.670	0	0	15.267	1.460	0.536	0	1.995	8.303	10.298	-4.968
April	0.363	0.648	0	0	1.011	0.036	0.518	0	0.555	6.713	7.268	6.257
May	11.008	0.670	0	0	11.678	1.101	0.536	0	1.637	5.330	6.967	-4.711
Total	618.881	7.884			626.765	61.888	6.307		68.195	581.494	649.689	22.924
Annual water balance												22.924

TABLE - 5.2

MONTHLY WATER BALANCE STATEMENT (FUTURE) Mm^3

Month	Water Requirement (Mm^3)					Water Availability (Mm^3)						Monthly water balance
	Irrigation use	Domestic use	Hydropowe use	Industrial use	Total	Regeneration from uses				Surface water yields	Total water available	
						Irrigation	Domestic	Industrial	Total			
June	33.307	2.048	0	3.266	38.621	3.331	1.638	2.613	7.582	10.342	17.924	-20.697
July	206.371	2.116	0	3.375	211.861	20.637	1.693	2.700	25.030	142.250	167.279	-44.582
August	103.895	2.116	0	3.375	109.386	10.390	1.693	2.700	14.782	194.532	209.314	99.928
September	94.090	2.048	0	3.266	99.403	9.409	1.638	2.613	13.660	133.047	146.707	47.304
October	62.808	2.116	0	3.375	68.299	6.281	1.693	2.700	10.673	23.490	34.163	-34.136
November	25.194	2.048	0	3.266	30.508	2.519	1.638	2.613	6.770	19.103	25.873	-4.634
December	32.650	2.116	0	3.375	38.140	3.265	1.693	2.700	7.658	15.508	23.165	-14.975
January	27.588	2.116	0	3.375	33.078	2.759	1.693	2.700	7.151	12.642	19.793	-13.285
February	30.772	1.911	0	3.048	35.732	3.077	1.529	2.439	7.045	10.233	17.278	-18.454
March	14.142	2.116	0	3.375	19.633	1.414	1.693	2.700	5.807	8.303	14.110	-5.523
April	1.685	2.048	0	3.266	6.998	0.168	1.638	2.613	4.419	6.713	11.133	4.134
May	12.374	2.116	0	3.375	17.865	1.237	1.693	2.700	5.630	5.330	10.960	-6.905
Total	644.876	24.913		39.735	709.525	64.488	19.931	31.788	116.207	581.494	697.700	-11.824
Annual water balance												-11.824

CHAPTER –6

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The following conclusions are drawn from the water balance study of Dang valley.

(i) Mock model can be applied for water availability computation in an ungaged catchment with meteorological data. The accuracy of the method depends on the accurarcy of calibration of the model parameters such as soil moisture capacity, infiltration factor, ground water storage and ground water recession constant. The data requirement for the Mock model are evapotranspiration data, precipitation, number of rainy days, area not covered by vegetation and soil type.

(ii) Mock model can be used to find run off depth per unit area under various land use conditions such as forest land, agriculture land and non-vegetated land. Thus it is possible to assess runoff in minor tributary sub-basins having different land use pattern. It is also possible to estimate runoff due to change in land use pattern in future.

(iii) Regional approach for planning of minor irrigation projects with the help of rainfall deficit maps and surface water availability estimation for ungaged catchment can be adopted under the condition of non-availability/ inadequate hydrologic data for pre-feasibility type of study.

(iv) Detailed guidelines have not yet been evolved for basin water balance studies in Nepal. Guidelines followed by National Water Development Agency(INDIA) for estimation of multipurpose water demand under existing and future conditions can be utilised as socio-economic and climatic conditions are similar in Himalayan regions of India and Nepal.

(v) The annual surface water availability in the valley for the purpose of irrigation is estimated to be 581.5 MCM

(vi) On the basis of existing and future cropping pattern, the annual existing and future irrigation water requirement are 618.9 MCM and 644.9 MCM respectively.

(vii) The Dang valley as a whole is water deficit even for the purpose of meeting irrigation water demand. Irrigation water deficit is 37.4 MCM under existing condition (2001 AD) and it may become 63.4 MCM in future (2050AD).

(viii) The annual existing and future domestic surface water requirement is 7. 9 MCM and 24.9 MCM respectively.

(ix) In the existing condition, there is no significant industrial water requirement in the valley. It is estimated that industrial water requirement in future may be 39.7 MCM per year.

(x) Water deficit condition exists in all the months except August, September and April. It is estimated that there is annual surplus of 22.9 MCM in existing condition and deficit of 11.82 MCM in future condition for meeting various demands.

6.2 RECOMMENDATIONS

Dang valley is one of the food grain producing valley in Inner Terai region of Nepal. The population of the valley is increasing at 2.7% growth rate annually. There is increasing trend of migration from hill districts into the valley and also from valley to outside. Due to limitation on available land area for cultivation , crop yield has to be increased to meet the food demand in the future. Irrigation water is one of the major resource input without which increment in crop yield cannot be significant.

It is concluded from the basin water balance study that there is deficit of irrigation water even under existing conditions for entire basin. However within the basin (Dang Valley) there are a large number of minor tributaries sub-basins exhibiting local surplus/deficit conditions.

Following strategy is recommended for irrigation development in minor tributary sub-basins.

(i) Supplementary Irrigation in the months of June and October when moisture availability index is less than 1.33 so that Kharif crop production can be made reliable.

(ii) Water should be transfered from tributary sub-basin not having sizeable agriculture command area to other tributary sub-basins with sizeable command area so that irrigated food crop such as rice could be grown.

(iii) Present study be followed up for identification and quantification of water surplus/ deficit condition in each tributary sub-basin and suitable project sites for the purpose of planning of minor irrigation schemes as illustrated by one case study.

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