4. SURFACE WATER POTENTIAL & ANALYSIS

Kutch District has the maximum number of rivers but minimum surface water potential as compared to the other districts of Gujarat. There are 81 rivers and number of small streams flowing through Kutch. However, all the rivers are non-perennial. Some of the rivers keep changing the course and are known by different names in different areas.

4.1 RIVERS OF KUTCH

The rivers of the district have certain characteristics. All the rivers or streams of Kutch start from its central portion and flow towards the sea in the south and the Great Rann in the north and the Little Rann in the southeast. Broadly speaking, the rivers flow northwards or southwards because of the ranges in the central area, which serve as watersheds. There are physical contours varying from 16 km to 32 km length, which create independent flows of water. As a result, there is approximately one river at every 24 km in the district.

The rivers have steep gradients and are flashy. They have therefore formed deep cuts along their courses and rarely spill over their banks. Duration of flow of water in the rivers is a question of a few hours in monsoon. Some rivers are called by different names of villages by which they pass. This is particularly the case with small rivers. Figure 4.1 indicates the major rivers of the Kutch District. The details of some of the main rivers of Kutch have been mentioned here.

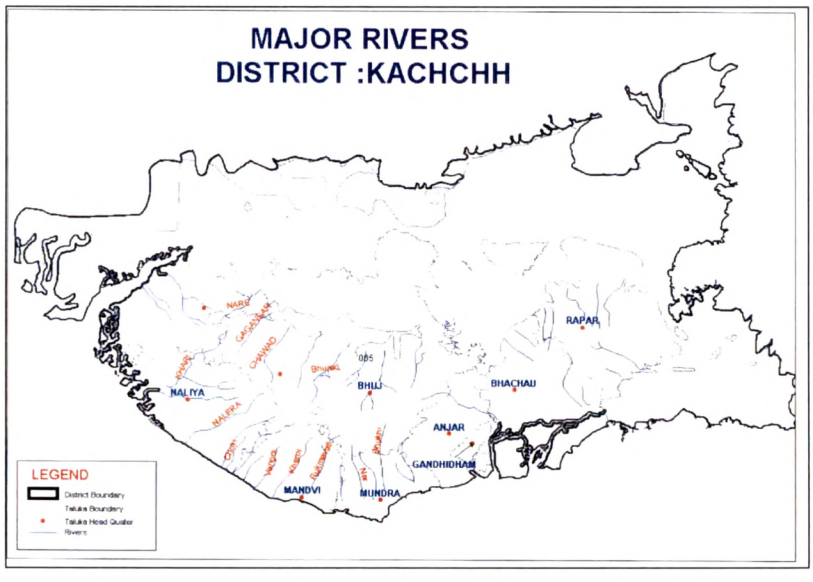


Figure 4.1 Major Rivers of Kutch
(Source: Kutch Irrigation Circle)

4.1.1 Major North Flowing Rivers

Some of the major north flowing rivers are as follows:

Bharud

Rising in the Nanama hills near village Mangwana in the Nakhatrana taluka. The river Bharud flows past Mangwana and Nirona villages. A medium dam was constructed during the second five-year plan on this river. The total length of the river is about 47 km and it finally merges in the Banni grassland area.

Kali

The river Kali rises from the hills northwest of Matano Madh village in the Lakhpat taluka. It flows by the villages of Mindhiari, Pandhro, Sanadhro and Baiyava. Sanadhro dam was constructed on this river during the first five-year plan. The river is 45 km long and meets the Arabian Sea near the Kori creek.

Godhatad

The river Godhatad issues from the hills near Barandha village of Lakhpat taluka. It flows past the villages of Godhatad and Kaiyari. A dam is constructed on this river. The length of the river is 42 km. The river merges in the Kori creek northeast of Koteshwar.

Suvi (Suvai)

The river Suvi originates from the hills west of Badargadh village of Rapar taluka. It flows past the villages of Trambau, Jesda and Suvi. A dam was constructed on this river during the second five-year plan period under the medium irrigation scheme. After traversing a total length of 39 km it merges in the Great Rann of Kutch.

Dhudud

The river Dhudud rises from Manki hills near Jadodar village in Nakhatrana taluka. It flows past Jadodar, Desalpur, Chhari and Fulay villages. It merges in the Banni area after a course of 37 km.

Malan

The river Malan issues from the hills near Dabhunda village in Rapar taluka and flows past Umaiya, Dabhunda and Karuda villages. A minor irrigation dam has been constructed between Karuda-Dabhunda villages of the Rapar taluka. The length of the river is 32 km and it merges in the Great Rann of Kutch.

Chang

The Chang River rises in the Sarsala hills near Gamdau village in the Bhachau taluka. It flows past Torania, Kanthkot, Kakarva, Manfara and Chobari villages. A minor irrigation dam was constructed on this river in first five-year plan. The river is 32 km in length and merges finally in the Great Rann of Kutch.

Nara
The Nara River originates in the hills near Matano Madh village in the Lakhpat taluka. It flows past Paneli, Gugariana and Nara villages. The river after crossing the western end of Banni meets the Great Rann of Kutch. Its total length is about 30 km.

Khari
The Khari starts from Chadwa hills in the Bhuj taluka, south west of Bhuj and flows past Bhuj keeping to north for about 15 km. After receiving Mithi or Pur from the right it flows about 12 km more and then merges in the Banni area in the north. A medium irrigation dam was built near the Rudramata temple during the second five-year plan. Its total length is about 27 km.

Rav
The Rav River issues from Vithroi hills near Badargadh village in the Rapar taluka. It passes by Lilpur and Rav villages and turns into a lake at Lakda vandh. The lake spills over into the Great Rann of Kutch. Two dams called Lilpur (Nilpur)1 and Lilpur (Nilpur)2 have been constructed on the this river. Its total length is about 26 km.

Kaila
The Kaila rises from Varar and Jhura hills. It flows by the villages of Kamaguna and Zurya of Bhuj taluka. A medium irrigation dam has been constructed on this river. The river merges in the Banni after traversing a course of 21 km.

Kaswati (Kans)
The river issues from the Habo hills and flows past the village Lodai of Bhuj taluka. After a course of 20 km, it merges in the Banni area.

4.1.2 Major South Flowing Rivers

Some of the major north flowing rivers are as follows:

Naiero
The river Naiero starts from the Manki hills near Balachod village in the Naliya taluka. It flows past the villages of Mothala, Balachod, Sandhav and Kothara. A minor irrigation dam on this river was built at Balachod in the Naliya taluka during the first five-year plan. After a course of about 55 km, it merges in the Arabian sea.

Kankawati
The river Kankawati rises from the Roha hills south of Gangon village in the Nakhatrana taluka. It flows by Naredi, Nundhatad, Vinzan, Sandhan, Sanosara and Hajapar villages. A medium irrigation dam was constructed on this river during the first five-year plan period. The course of the river is about 51 km. It merges in the Gulf of Kutch.

Kharod
The river rises from the Nanama hills in the Nakhatrana taluka. It flows past the villages of Gadhsisa, Sherdi, Godhra and Layja Nana. A storage tank was constructed on this river during the princely Kutch regime. After a course of 50 km it merges in the Gulf of Kutch.

Khari

The Khari River originates in the hills near Matano Madh village of the Lakhpat taluka. After traversing a course of 39 km, the river meets the Mithi river across the Naliya plain. The Mithi River passes by the Tera village with its course about 50 km. After their confluence at Vadsar both the rivers flow together for about 15 km and then fall into the Gulf of kutch near Jakhau.

Mithi

The river Mithi rises from the Vamoti hills in Naliya taluka. It flows past villages of Bitta and Tera and meets the Khari river near Vadsar. A dam has been constructed on this river near Bitta. The total length of the river is about 50 km.

Sakra

The Sakra River rises from the hills southwest of Mamuyara village of Bhuj taluka. It flows by Kanderai, Dhaneti, Makhana, Kotda, Chandrani, Tappar, Pasuda and Chirai villages. The river has a course of 48 km and meets the Gulf of kutch.

Rukmavati

The river originates from the Chadwa hills in Bhuj taluka. It flows past Kojachora, Rampur, Vekra, Koday and Mandavi. The Vijaysagar dam was constructed on this river near the village Kojachora in Mandvi taluka during the princely Kutch regime. The river flows 46 km and meets the Gulf of Kutch near Mandvi.

Nagmati

The river Nagmati rises from the Lanki hills, south of Naranpur village of the Bhuj taluka. It flows by Kera, Gajod, Beraja and Gelda villages. The medium irrigation dam was constructed on this river near Gajod village during the first five-year plan. The total length of the river is 46 km. It meets the Gulf of Kutch near Bhenslewali creek.

Lakadiawali

The river Lakadiawali rises from the Vithoi hills near Badargadh village of the Rapar taluka. It flows past villages of Badargadh, Shivlakha, Lakadia, Chandrodi, Shikarpur and Surbari. A minor irrigation dam was constructed on this river at Badargadh village during the first five-year plan. After a course of 42 km, it merges in the Little Rann of Kutch.

Bhukhi

The Bhukhi river rises from the Khatrod hills north of Jambudi village of Bhuj taluka. It flows by the villages of Reha, Jambudi, Chakar, Bandhara, Patri, Lakhapar and Mundra. A storage tank called Khengarsagar was constructed on this river by the Kutch state at Patri village of the Mundra taluka. The total length of the river is 40 km. It merges in the Gulf of Kutch near Mundra.

Sakra

This is another Sakra River and it starts from the hills north of Vadli village of Bhuj taluka. It flows past Vadli, Makhiyan, Chandroda and Bhadresar villages. A dam for minor irrigation scheme is under construction on this river at Bharudia village. The river is 36 km in length and it merges in the Gulf of Kutch.

Sang

The Sang River rises from the hills south of Sinugra village of the Kharirohar. A Shinay dam, which provides water to Kandla, has been constructed on this river. The river is 29 km in length and it merges in the Nakti creek.

Sai

The Sai rises near Daha village of the Naliya taluka. It flows past Halapar and Sabharai, Moti village. The total length of the river is 30 km. The river meets the Gulf of Kutch near Bambhadai village.

Rakhdi

The Rakhdi rises in the Naliya taluka. It flows by Vayor and Thumdi villages. A minor irrigation dam on this river was constructed during second five-year plan. The river is 29 km in length and it meets the Arabian sea.

Bhukhi

This is another Bhukhi river in the district. It starts from the south of Khedoi village of the Anjar taluka. It passes through Kumbharia, Bita, Valadia and Naga valadia villages. Its length is about 24 km. The river meets the Gulf of Kutch.

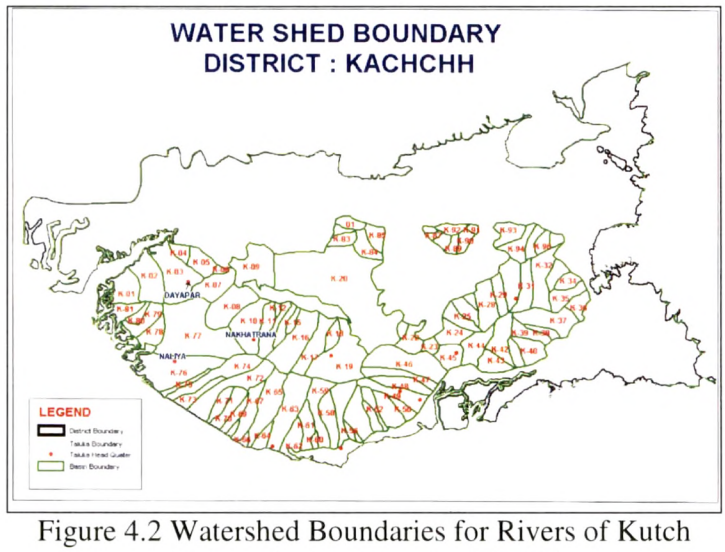


Figure 4.2 Watershed Boundaries for Rivers of Kutch
(Source Kutch Irrigation Circle)

Figure 4.2 shows the catchment plans for 81 rivers of Kutch. However, in order to obtain better accuracy for the purpose estimation of runoff, images from Shuttle Radar Topography Mission (SRTM) data Version 3 (V3) using World Geodetic System (WGS) 84 at 90 m resolution (http://srtm.csi.cgiar.org) have been downloaded and processed for developing the watersheds for the smaller streams of study area which have not been in figure 4.2. This has resulted in obtaining 103 watersheds for north flowing streams and 96 watersheds for south flowing streams, giving a total of 199 streams instead of 81 rivers. Figure 4.3 shows the watersheds for the study area along with the taluka boundaries.

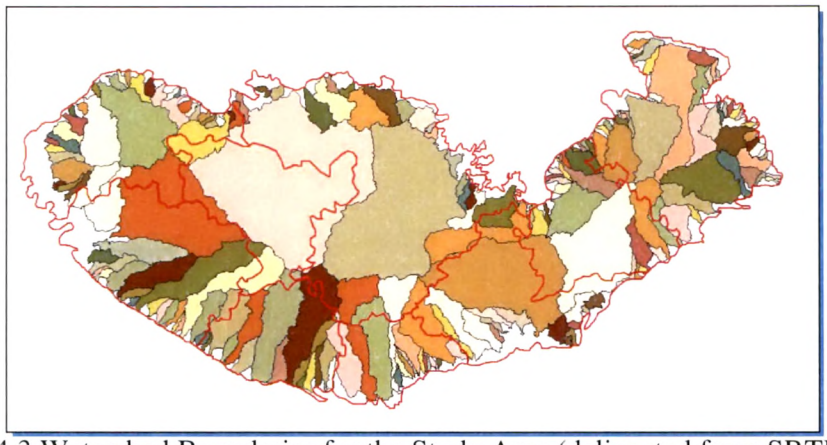


Figure 4.3 Watershed Boundaries for the Study Area (delineated from SRTM data)

4.3 MEDIUM IRRIGATION SCHEMES OF KUTCH

There are about 20 Medium Irrigation Schemes. Most of these schemes have earthen dams with concrete or masonary spillway portion. Most of the irrigation schemes are also used for domestic water supply to surrounding regions whenever required. Out of the 20 medium irrigation schemes, 1 is located in Anjar taluka, 4 in Bhuj taluka, 4 in Lakhpat taluka, 1 in Mandvi taluka, 1 in Mundra taluka, 3 in Nakhatrana taluka, 4 in Naliya taluka and 2 in Rapar taluka. Details of the medium irrigation schemes are given in table Annexure 3 shows the general details of Medium Irrigation Schemes and Annexure 4 shows the storage parameters for Medium Irrigation Schemes.

4.4 MINOR IRRIGATION SCHEMES

There are 166 minor irrigation schemes in Kutch. Out of these, 13 are located in Anjar taluka, 16 in Bhachau taluka, 34 in Bhuj taluka, 15 in Lakhpat taluka, 21 in Mandvi Taluka, 10 in Mundra taluka, 16 in Nakhatrana taluka, 24 in Naliya taluka and 17 in Rapar taluka. The details for the same have been included in Annexure 5 shows the details for Minor Irrigation Schemes.

4.5 CHECK DAMS

In the last decade, the movement for construction of checkdams has gained momentum due to government policies and increased awareness amongst the people. Due to this, there has been a substantial rise in the number of checkdams in Kutch especially after the year 2001. There are about 939 checkdams constructed till June 2008 in the study area. Out of these, 45 are located in Anjar taluka, 34 in Bhachau taluka, 115 in Bhuj taluka, 57 in Lakhpat taluka, 107 in Mandvi taluka, 39 in Mundra taluka, 166 in Nakhatrana taluka, 40 in Naliya taluka and 336 in Rapar taluka. The details for the same have been included in Annexure 6. Construction of underground checkdams has also been practiced in this region. Vivekanand Research and Training Institute (VRTI) has been a pioneer institute for construction of underground checkdams.

4.6 RUNOFF

The runoff for all the watersheds has been calculated using daily rainfall data for the period of 1989 to 2007. The Soil Conservation Service model (USDA-SCS, 1972), which computes the direct runoff through an empirical equation that requires rainfall and basin coefficients as inputs has been used for estimation of runoff. The runoff curve number (CN) represents the runoff potential of the land cover-soil complex. The landuse map was generated using the images derived from Landsat Thematic Mapper (TM) data at 90 m resolution.

It is an established fact that besides precipitation, the distribution of the runoff depends on the morphological characteristics of the landforms and their associated natural resources such as soil, vegetation and landuse / land cover. The digital classification of Landsat TM data of different seasons does not distinguish the major landforms and boundaries of different natural resources due to similar reflectance of the various landforms, their continuous pattern being displayed by similar tones, pattern and shape in the arid regions. As a result, a photo-interpretation technique was preferred over the digital analysis (which is also expensive and available at a few places only).

The Landsat TM data for November 2009 corresponding to post-monsoon season was selected for the purpose of visual interpretation. Boundaries of prominent landforms were delineated and mapped and their morphological features, tonal variations and landuse / land cover were interpreted and demarcated.

From the above map, the hydrological soil groups (A to D), hydrological cover conditions (poor, fair and good) and CN values were determined as per the USDA-SCS (1972) method using five day antecedent rainfall values as mentioned in National Engineering Handbook, Part 630(Hydrology) Appendix A. The available soil map for the district was used to find the Hydrologic Response Units (HRU) for the region. As there were more than one curve numbers for each catchment, the weighted curve numbers were found out and considered for the estimation of runoff. Table 4.1 gives the details of the landuse pattern based on the derived landuse map for the study area in km^2.

Table 4.1 Landuse Pattern for Study Area.

Taluka	Agricultural (km^2)	Forest & Perennial Vegetation (km^2)	Uncultivated / Fallow land (km^2)	Water bodies (km^2)	Total Area (km^2)
Anjar	1029.93	38.95	314.71	197.80	1581.40
Bhachau	1378.97	170.05	574.61	54.96	2178.59
Bhuj	3508.59	571.78	781.29	71.21	4932.87
Lakhpat	620.29	551.55	773.87	147.23	2092.94
Mandavi	1045.89	65.09	411.04	6.19	1528.21
Mundra	498.39	81.12	164.24	19.51	763.26
Nakhatrana	524.65	436.39	795.83	3.83	1760.70
Naliya	1405.67	685.13	330.15	108.79	2529.74
Rapar	1897.65	267.68	905.36	33.39	3104.08
Kutch	11910.02	2867.74	5051.10	642.93	20471.79

Most of the people associated with the calculation of stormwater runoff are not hydrologists yet they calculate the water potential of the taluka. So micro-watershed stormwater runoff is calculated, weighted runoff for each taluka is derived using ArcView GIS 3.2 and the average monthly and annual runoff values for each taluka were obtained. In subsequent chapters, the relationship for groundwater recharge has been developed talukawise in similar manner.

Figure 4.4 shows the schematic procedure of runoff estimation using SCS runoff curve number. It also shows the landuse map, the soil map, the map showing hydrologic response units and the map used for obtaining weighted curve numbers along with a map showing rainfall and the estimated runoff for all the catchments.

The average annual runoff pattern calculated for all the talukas has been shown in the figures 4.5 to 4.23 and the values obtained have been tabulated in Table 4.2. The darker shades indicate higher values of runoff and lighter shades indicate lower values of runoff.

Table 4.2 Average Annual Runoff in mm

Year	Anjar	Bhachau	Bhuj	Lakhpat	Mandvi	Mundra	Naliya	Nakha trana	Rapar
1989	55.65	64.44	72.35	144.45	247.36	53.67	302.35	63.04	39.84
1990	3.74	39.67	28.97	3.76	3.07	32.92	12.35	14.83	93.02
1991	0.00	1.98	0.17	0.00	0.02	3.06	0.00	0.00	3.27
1992	40.19	71.48	222.40	221.44	200.19	188.41	278.86	370.75	30.89
1993	0.32	9.43	0.20	0.02	0.03	0.44	0.00	0.24	32.34
1994	162.95	172.09	343.36	60.29	610.79	400.32	71.91	397.68	108.96
1995	3.91	17.83	4.42	10.81	4.32	16.71	35.53	7.20	2.91
1996	3.91	17.83	4.42	10.81	4.32	16.71	35.53	7.20	2.91
1997	85.39	97.04	65.82	3.03	44.18	198.57	0.99	57.09	181.59
1998	5.70	39.58	36.97	0.00	37.75	45.97	0.91	0.63	119.72
1999	3.51	32.82	0.95	0.00	0.00	0.05	0.00	0.00	1.47
2000	14.98	30.03	12.63	6.74	0.67	21.88	24.62	4.19	32.37
2001	1.92	6.65	4.26	39.89	2.84	6.34	146.96	24.29	19.84
2002	0.67	20.34	1.40	0.64	6.06	9.78	2.17	0.51	50.29
2003	135.57	195.97	530.23	340.81	44.76	332.23	149.84	391.38	375.34
2004	11.25	16.60	20.32	0.77	39.52	67.59	0.97	7.97	27.04
2005	7.44	50.05	96.25	66.57	35.42	81.16	32.55	108.45	72.83
2006	7.36	46.90	12.38	0.66	3.52	94.91	2.21	1.89	43.47
2007	93.93	184.26	140.79	70.10	72.90	113.68	37.64	124.34	253.68

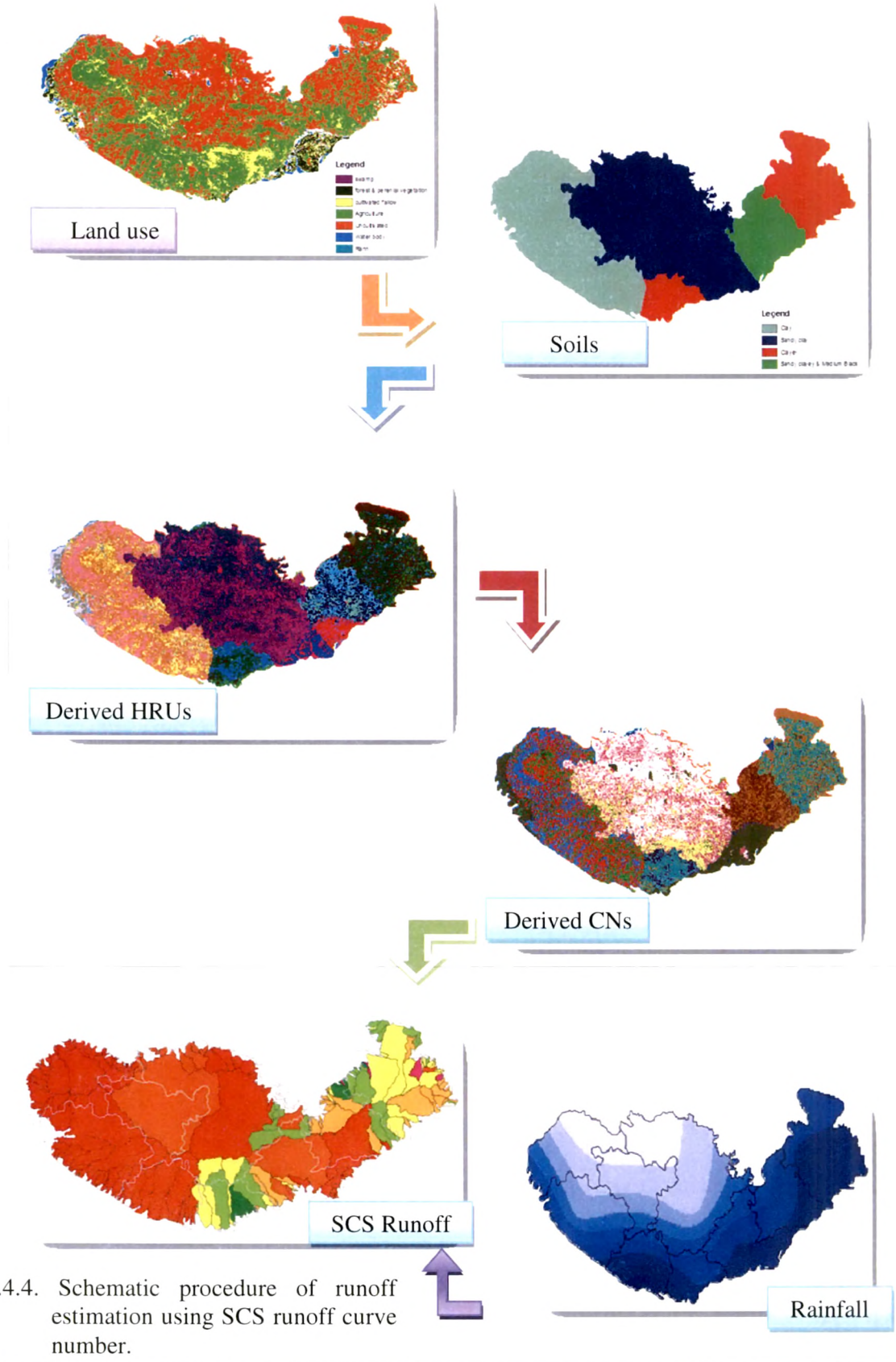


Fig.4.4. Schematic procedure of runoff estimation using SCS runoff curve number.

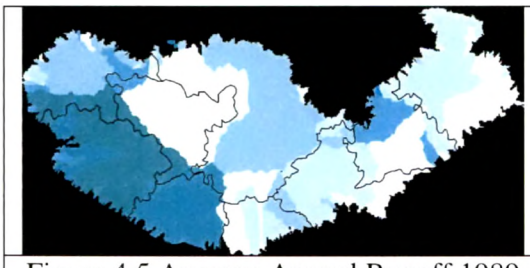


Figure 4.5 Average Annual Runoff 1989

Figure 4.6 Average Annual Runoff 1990

Figure 4.7 Average Annual Runoff 1991

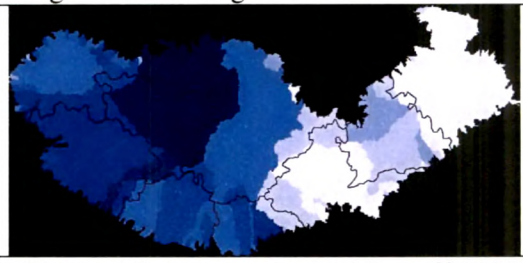


Figure 4.8 Average Annual Runoff 1992

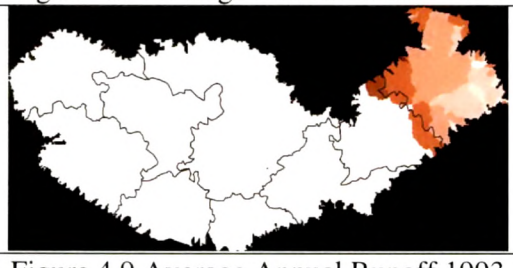


Figure 4.9 Average Annual Runoff 1993

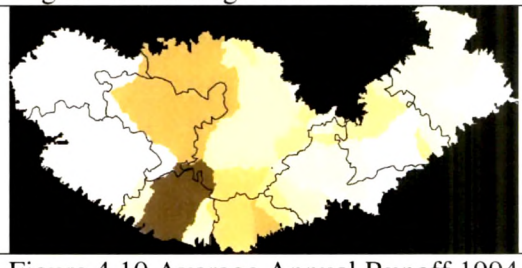


Figure 4.10 Average Annual Runoff 1994

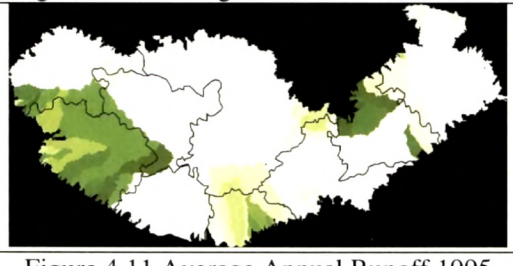


Figure 4.11 Average Annual Runoff 1995

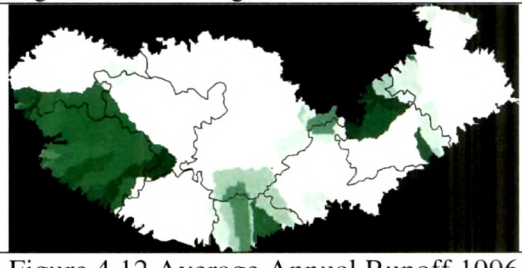


Figure 4.12 Average Annual Runoff 1996

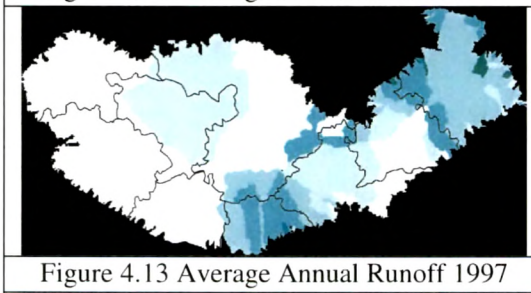


Figure 4.13 Average Annual Runoff 1997

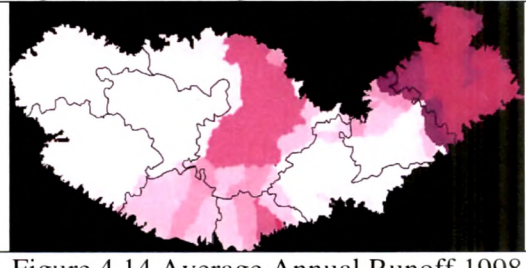


Figure 4.14 Average Annual Runoff 1998

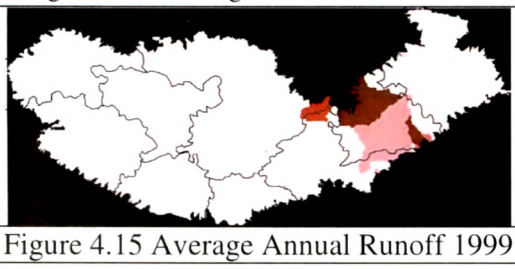


Figure 4.15 Average Annual Runoff 1999

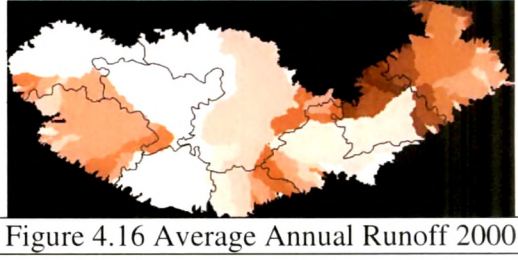


Figure 4.16 Average Annual Runoff 2000

Figure 4.17 Average Annual Runoff 2001

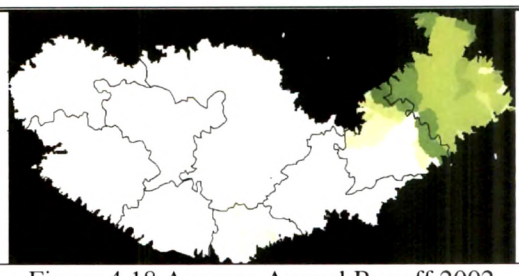


Figure 4.18 Average Annual Runoff 2002

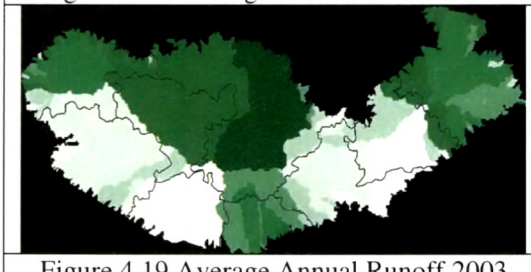


Figure 4.19 Average Annual Runoff 2003

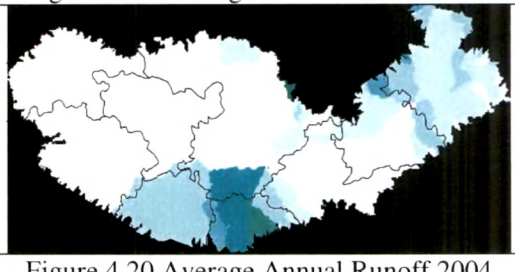


Figure 4.20 Average Annual Runoff 2004

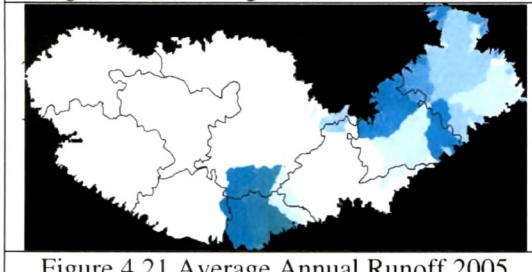


Figure 4.21 Average Annual Runoff 2005

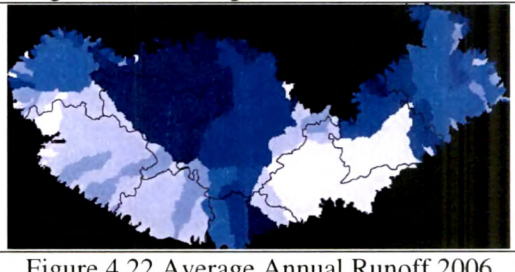


Figure 4.22 Average Annual Runoff 2006

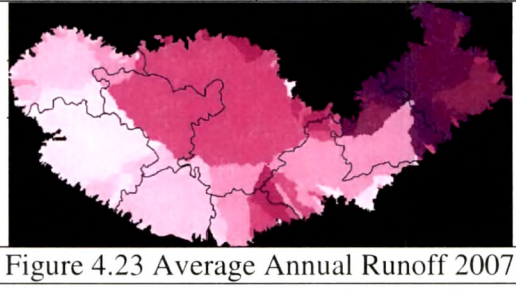


Figure 4.23 Average Annual Runoff 2007

Similarly, the average monthly runoff pattern calculated for all the talukas has been shown in the figures 4.25 to 4.119 and the values obtained have been tabulated in Table 4.4. As the runoff occurs only during the season of monsoon, the values have been tabulated for the months of June to October for all the years. Table 4.3 shows the legends for the plots of monthly runoff. The darker shades indicate higher values of runoff and lighter shades indicate lower values of runoff.

0-25 mm	25-50 mm	50-100 mm	100-200 mm	200-300 mm	300-400 mm	400-500 mm	500-600 mm	600-1000 mm

Table 4.3 Legends for Monthly Runoff in mm

				
Fig. 4.24 Jun-89 Runoff	Fig. 4.25 Jul-89 Runoff	Fig. 4.26 Aug-89 Runoff	Fig. 4.27 Sep-89 Runoff	Fig. 4.28 Oct-89 Runoff
				
Fig. 4.29 Jun-90 Runoff	Fig. 4.30 Jul-90 Runoff	Fig. 4.31 Aug-90 Runoff	Fig. 4.32 Sep-90 Runoff	Fig. 4.33 Oct-90 Runoff
				
Fig. 4.34 Jun-91 Runoff	Fig. 4.35 Jul-91 Runoff	Fig. 4.36 Aug-91 Runoff	Fig. 4.37 Sep-91 Runoff	Fig. 4.38 Oct-91 Runoff
				
Fig. 4.39 Jun-92 Runoff	Fig. 4.40 Jul-92 Runoff	Fig. 4.41 Aug-92 Runoff	Fig. 4.42 Sep-92 Runoff	Fig. 4.43 Oct-92 Runoff
				
Fig. 4.44 Jun-93 Runoff	Fig. 4.45 Jul-93 Runoff	Fig. 4.46 Aug-93 Runoff	Fig. 4.47 Sep-93 Runoff	Fig. 4.48 Oct-93 Runoff
				
Fig. 4.49 Jun-94 Runoff	Fig. 4.50 Jul-94 Runoff	Fig. 4.51 Aug-94 Runoff	Fig. 4.52 Sep-94 Runoff	Fig. 4.53 Oct-94 Runoff
				
Fig. 4.54 Jun-95 Runoff	Fig. 4.55 Jul-95 Runoff	Fig. 4.56 Aug-95 Runoff	Fig. 4.57 Sep-95 Runoff	Fig. 4.58 Oct-95 Runoff
				
Fig. 4.59 Jun-96 Runoff	Fig. 4.60 Jul-96 Runoff	Fig. 4.61 Aug-96 Runoff	Fig. 4.62 Sep-96 Runoff	Fig. 4.63 Oct-96 Runoff
Fig. 4.64 Jun-97 Runoff	Fig. 4.65 Jul-97 Runoff	Fig. 4.66 Aug-97 Runoff	Fig. 4.67 Sep-97 Runoff	Fig. 4.68 Oct-97 Runoff
Fig. 4.69 Jun-98 Runoff	Fig. 4.70 Jul-98 Runoff	Fig. 4.71 Aug-98 Runoff	Fig. 4.72 Sep-98 Runoff	Fig. 4.73 Oct-98 Runoff
Fig. 4.74 Jun-99 Runoff	Fig. 4.75 Jul-99 Runoff	Fig. 4.76 Aug-99 Runoff	Fig. 4.77 Sep-99 Runoff	Fig. 4.78 Oct-99 Runoff

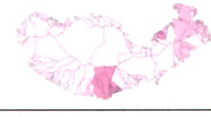
				
Fig. 4.79 Jun-00 Runoff	Fig. 4.80 Jul-00 Runoff	Fig. 4.81 Aug-00 Runoff	Fig. 4.82 Sep-00 Runoff	Fig. 4.83 Oct-00 Runoff
				
Fig. 4.84 Jun-01 Runoff	Fig. 4.85 Jul-01 Runoff	Fig. 4.86 Aug-01 Runoff	Fig. 4.87Sep-01 Runoff	Fig. 4.88 Oct-01 Runoff
				
Fig. 4.89 Jun-02 Runoff	Fig. 4.90 Jul-02 Runoff	Fig. 4.91 Aug-02 Runoff	Fig. 4.92 Sep-02 Runoff	Fig. 4.93 Oct-02 Runoff
				
Fig. 4.94 Jun-03 Runoff	Fig. 4.95 Jul-03 Runoff	Fig. 4.96 Aug-03 Runoff	Fig. 4.97 Sep-03 Runoff	Fig. 4.98 Oct-03 Runoff
				
Fig. 4.99 Jun-04 Runoff	Fig. 4.100 Jul-04 Runoff	Fig. 4.101 Aug-04 Runoff	Fig. 4.102 Sep-04 Runoff	Fig. 4.103 Oct-04 Runoff
				
Fig. 4.104 Jun-05 Runoff	Fig. 4.105 Jul-05 Runoff	Fig. 4.106 Aug-05 Runoff	Fig. 4.107 Sep-05 Runoff	Fig. 4.108 Oct-05 Runoff
				
Fig. 4.109 Jun-06 Runoff	Fig. 4.110 Jul-06 Runoff	Fig. 4.111 Aug-06 Runoff	Fig. 4.112 Sep-06 Runoff	Fig. 4.113 Oct-06 Runoff
				
Fig. 4.114 Jun-07 Runoff	Fig. 4.115 Jul-07 Runoff	Fig. 4.116 Aug-07 Runoff	Fig. 4.117 Sep-07 Runoff	Fig. 4.118 Oct-07 Runoff

Table 4.4 Average Monthly Runoff in mm

Taluka	Anjar	Bhachau	Bhuj	Lakhpat	Mandvi	Mundra	Nakhatrana	Naliya	Rapar
Jun-89	0	0	0	0	0	0	0	0	0
Jul-89	56	64	66	145	247	41	63	302	36
Aug-89	0	1	6	0	0	10	0	0	0
Sep-89	0	0	1	0	0	3	0	0	0
Oct-89	0	0	0	0	0	0	0	0	0
Jun-90	0	0	0	0	0	0	0	0	0
Jul-90	0	0	0	0	0	0	0	0	0
Aug-90	4	39	25	3	3	33	2	12	92

Taluka	Anjar	Bhachau	Bhuj	Lakhpat	Mandvi	Mundra	Nakhatrana	Naliya	Rapar
Sep-90	0	0	0	0	0	0	0	0	0
Oct-90	0	0	0	0	0	0	0	0	0
Jun-91	0	0	0	0	0	0	0	0	0
Jul-91	2	5	1	16	0	3	10	61	18
Aug-91	0	0	0	0	0	0	0	0	0
Sep-91	0	0	0	0	0	0	0	0	0
Oct-91	0	0	0	0	0	0	0	0	0
Jun-92	0	1	0	0	0	0	0	0	1
Jul-92	32	13	184	217	200	186	239	278	28
Aug-92	0	0	0	1	0	1	0	1	0
Sep-92	0	0	0	0	0	2	0	0	0
Oct-92	0	0	0	0	0	0	0	0	0
Jun-93	0	0	0	0	0	0	0	0	0
Jul-93	121	167	473	333	44	299	251	149	307
Aug-93	0	0	0	0	0	0	0	0	0
Sep-93	0	0	0	0	0	0	0	0	0
Oct-93	0	0	0	0	0	0	0	0	0
Jun-94	0	0	0	0	0	0	0	0	0
Jul-94	80	87	206	8	169	348	137	12	20
Aug-94	33	9	6	0	0	20	0	0	4
Sep-94	49	79	83	50	96	33	128	60	82
Oct-94	0	0	0	0	0	0	0	0	0
Jun-95	3	0	1	0	0	2	0	0	0
Jul-95	1	18	4	11	4	14	7	36	2
Aug-95	0	0	0	0	0	0	0	0	0
Sep-95	0	0	0	0	0	0	0	0	0
Oct-95	0	0	0	0	0	0	0	0	0
Jun-96	10	78	3	0	0	4	0	0	132
Jul-96	0	3	0	0	0	0	0	0	8
Aug-96	0	0	0	0	0	0	0	0	0
Sep-96	0	0	0	0	0	0	0	0	0
Oct-96	0	0	0	0	0	0	0	0	0
Jun-97	0	0	0	0	0	0	0	0	0
Jul-97	0	7	5	0	38	6	1	1	17
Aug-97	4	47	1	0	0	3	0	0	114
Sep-97	70	31	45	2	6	180	15	0	12
Oct-97	0	0	0	0	0	0	0	0	0
Jun-98	0	0	0	0	0	0	0	0	0
Jul-98	0	0	3	0	1	19	0	0	0
Aug-98	0	4	0	0	6	0	0	0	0

Taluka	Anjar	Bhachau	Bhuj	Lakhpat	Mandvi	Mundra	Nakhatrana	Naliya	Rapar
Sep-98	0	7	0	0	0	1	0	0	11
Oct-98	5	26	34	0	31	26	1	1	107
Jun-99	0	0	0	0	0	0	0	0	0
Jul-99	0	0	0	0	0	0	0	0	0
Aug-99	0	3	0	0	0	0	0	0	0
Sep-99	0	0	0	0	0	0	0	0	0
Oct-99	4	31	1	0	0	0	0	0	1
Jun-00	0	0	0	0	0	0	0	0	0
Jul-00	15	30	13	7	1	22	4	25	32
Aug-00	0	0	0	0	0	0	0	0	0
Sep-00	0	0	0	0	0	0	0	0	0
Oct-00	0	0	0	0	0	0	0	0	0
Jun-01	0	0	3	23	2	2	14	86	0
Jul-01	2	5	1	16	0	3	10	61	18
Aug-01	0	1	0	0	0	1	0	0	1
Sep-01	0	0	0	0	0	0	0	0	0
Oct-01	0	0	0	0	0	0	0	0	0
Jun-02	0	13	0	0	0	0	0	0	41
Jul-02	0	0	0	0	0	0	0	0	0
Aug-02	1	7	1	1	6	10	0	2	8
Sep-02	0	0	0	0	0	0	0	0	0
Oct-02	0	0	0	0	0	0	0	0	0
Jun-03	0	8	0	0	0	0	0	0	7
Jul-03	121	167	473	333	44	299	251	149	307
Aug-03	14	16	19	2	1	33	1	1	56
Sep-03	0	0	0	0	0	0	0	0	0
Oct-03	0	0	0	0	0	0	0	0	0
Jun-04	1	3	1	0	0	3	0	0	1
Jul-04	0	0	0	0	0	0	0	0	0
Aug-04	11	13	16	0	39	65	1	1	24
Sep-04	0	0	0	0	0	0	0	0	1
Oct-04	0	0	0	4	0	0	2	0	2
Jun-05	1	1	0	0	0	1	0	0	1
Jul-05	4	34	5	0	1	36	0	0	7
Aug-05	0	3	0	0	0	4	0	0	3
Sep-05	3	9	7	1	2	55	0	2	31
Oct-05	0	0	0	0	0	0	0	0	0
Jun-06	0	0	0	0	0	0	0	0	0
Jul-06	5	27	9	15	3	54	3	4	17
Aug-06	3	23	66	49	33	27	26	28	53

Taluka	Anjar	Bhachau	Bhuj	Lakhpat	Mandvi	Mundra	Nakhatrana	Naliya	Rapar
Sep-06	0	0	0	0	0	0	0	0	1
Oct-06	0	0	0	0	0	0	0	0	0
Jun-07	1	0	12	0	0	5	0	0	1
Jul-07	34	34	48	3	1	27	39	0	125
Aug-07	59	147	60	65	72	81	13	38	125
Sep-07	0	1	1	0	0	0	0	0	1
Oct-07	0	0	0	0	0	0	0	0	0

4.7 SUMMARY OF RUNOFF ANALYSIS

The analysis of annual and monthly runoff was done for obtaining the mean values, minimum values, maximum values, variance, standard deviation and the standard error of estimation using the software STATISTICA for Windows version 5.0.

4.7.1 Summary for Analysis of Annual Runoff

The average annual runoff is found to range between 30 to 90 mm. For some of the talukas, the values of minimum rainfall are also found to be zero when the rainfall is extremely less. Mandvi and Mundra talukas have the highest value of the runoff where as Anjar and Lakhpat are found to have less runoff as compared to the other talukas. The results for the analysis of the annual runoff values have been tabulated in Table 4.5.

Table 4.5 Results of Annual Runoff (mm) Analysis

Taluka	Mean	Median	Minimum	Maximum	Variance	Std.Dev.	Standard Error
Anjar	33.60	7.36	0.00	162.95	2492.35	49.92	11.45
Bhachau	58.68	39.58	1.98	195.97	3694.81	60.78	13.95
Bhuj	84.12	20.32	0.17	530.23	19760.86	140.57	32.25
Lakhpat	51.62	6.74	0.00	340.81	8349.94	91.38	20.96
Mandvi	71.46	6.06	0.00	610.79	21717.80	147.37	33.81
Mundra	88.65	45.97	0.05	400.32	13143.42	114.64	26.30
Nakhatrana	59.76	24.62	0.00	302.35	8684.45	93.19	21.38
Naliya	83.25	7.97	0.00	397.68	19586.87	139.95	32.11
Rapar	78.51	39.84	1.47	375.34	9525.08	97.60	22.39

4.7.2 Summary for Analysis of Monthly Runoff

The analysis of the average monthly runoff shows that the maximum runoff usually occurs in the month of July in the monsoon season. Most of the runoff is found to occur during the months of July, August and September. June and October are found to be the months where there is very little runoff or no runoff. However, for most of the months, the value of runoff is between 0 to 25 mm. The results for the analysis of the monthly runoff values have been tabulated in Table 4.6.

Table 4.6 Results of Monthly Runoff (mm) Analysis

Taluka	Mean	Median	Minimum	Maximum	Variance	Std.Dev.	Standard Error
Anjar	3.27	0.00	0.00	120.57	224.14	14.97	0.99
Bhachau	5.55	0.00	0.00	167.06	470.23	21.68	1.44
Bhuj	8.25	0.00	0.00	472.88	2353.52	48.51	3.21
Lakhpat	5.72	0.00	0.00	332.65	1287.79	35.89	2.38
Mandvi	4.62	0.00	0.00	247.05	653.37	25.56	1.69
Mundra	8.61	0.00	0.00	347.86	1659.75	40.74	2.70
Nakhatrana	5.35	0.00	0.00	251.49	965.20	31.07	2.06
Naliya	4.95	0.00	0.00	302.35	901.58	30.03	1.99
Rapar	4.40	0.00	0.00	307.10	526.53	22.95	1.52