Surface Water Resources Assessment Report

Wakal River Basin, Rajasthan, India

Integrated Management of Coastal and Freshwater Systems Program

Surface Water Resources Assessment Report

Wakal River Basin, Rajasthan, India

Funding for the Surface Water Resources Assessment Report for the Wakal River Basin, Rajasthan, India was provided by the people of the United States of America through the U.S. Agency for International Development (USAID), as a component of the Integrated Management of Coastal and Freshwater Systems Leader with Associates (LWA) Agreement No. EPP-A-00-04-00015-00. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Agency for International Development of the United States Government or Florida International University.

Global Water for Sustainability Program

Florida International University

Biscayne Bay Campus 3000 NE 151 St. ACI-267

North Miami, FL 33181 USA

Email: glows@fiu.edu

Website: www.globalwaters.net

For bibliographic purposes, this document should be cited as:

GLOWS-FIU. 2008. Surface Water Resources Assessment Report: Wakal River Basin, India. 2008. Global Water Sustainability Program, Florida International University. 36p.

ISBN:

Cover Photograph: Tributary of Wakal River, Rajasthan, India. (John M. Steifel).

Table of Contents

1 INTRODUCTION

The rivers of India are classified as Himalayan, peninsular, coastal, and inland-drainage basin rivers. Himalayan rivers are snow fed and maintain a high to medium rate of flow throughout the year. The heavy annual average rainfall levels in the Himalayan catchment areas further add to their rates of flow. During the monsoon months of June to September, the catchment areas are prone to flooding.

India is endowed with a rich and vast diversity of natural resources, water being one of them. Its development and management plays a vital role in agriculture production. Integrated water management is vital for poverty reduction, environmental sustenance and sustainable economic development. National Water Policy (2002) envisages that the water resources of the country should be developed and managed in an integrated manner.

India is a land of rivers. There are 14 major, 44 medium and 55 minor river basins in the country. Major rivers have a catchment area of 20,000 square kilometres or above, medium between 2,000 and 20,000 square kilometres and minor systems have a catchment area of 2,000 square kilometres or less. But, in some dry areas of Rajasthan, every inch of land contributes water through runoff to these rivers.

The major river basins constitute about 83-84% of the total drainage area. This, along with the medium river basins, accounts for 91% of the country's total drainage. Though only the last 4,000 kilometres of the Brahmaputra pass through Indian territory, the river carries 31% of all the water carried by Indian rivers. By contrast, the Ganges carries about 30%. In all, a total of 1,645 cubic kilometres of water flows through our river system every year. Given this extensive river system, our country's planners have been justified in storing the water for hydroelectric power generation as well as irrigation. Consequently, India ranks amongst the most important dam-building nations in the world. The Register of Large Dams in India lists 3,600 completed dams, and between 300-400 in varying stages of construction.

Rajasthan is the most dry state of the country and surface water resources form only 1.16 percent of the countries resources. The groundwater resources of the state are most precious and it contributes only 2.9 percent of the total groundwater resources of the country. In Rajasthan, 90 per cent of the population is dependent on groundwater for drinking and 60 per cent for irrigation purposes. The groundwater table is going down at the rate of approximately one meter per year due to scanty rainfall and the situation has reached alarming proportions in some part of the state. The per capita water availability is only 900 m^3 and it is expected that by the year 2045 it will reduced upto 436 m^3 only.

1.1 Present Scenario

Wakal River originates northwest of Udaipur near Sran village. The river flows in a generally south direction up to Manpur village in Udaipur district, where it turns northeast and after a distance of about 90km leaves Rajasthan near the Gaupipli village and joins Sabarmati river near Eitarwar village in Gujrat. The Wakal River Basin lies on the Western part of India between latitudes 24°8' 49.41" N to 24°46' 34.65" N and longitudes of 73°6' 23.41" E to 73°35' 54.18" E and spread across the state of Rajasthan and Gujrat. Total catchment area of Wakal River Basin is 1914.32 km^2 in which 98 per cent of the total area falls in the Udaipur district of Rajasthan. The main tributaries of Wakal are Manshi and Parvi rivers. The total length of the basin is 71.22 km whereas the maximum width is 41.01 km. The location map of the basin is shown in Fig. 1.

The Wakal River Basin lies in Rajasthan state of India's most water-stressed regions. For example, the principle city of Udaipur receives 630 mm of average rainfall in a year, and 95% of precipitation occurs during monsoon season between the months of June to September. This extreme seasonal to drought and flood conditions; long-term records suggest that region has experienced 41 drought conditions during past 50 years. Because most rivers or streams in the region are ephemeral, groundwater provides the main source of supply for human communities.

Looking to the magnitude of the problem of land degradation and water scarcity in the Wakal River Basin, World Vision India and GLOWS, U.S.A. has taken initiative to conduct water resources study of the basin which will provide a guide line to mitigate the drought and also to enhance the crop yield of the area through sustainable interventions of surface water management. They have identified various institutions to address various problems of the region including College of Technology and Engineering, MPUAT, Udaipur.

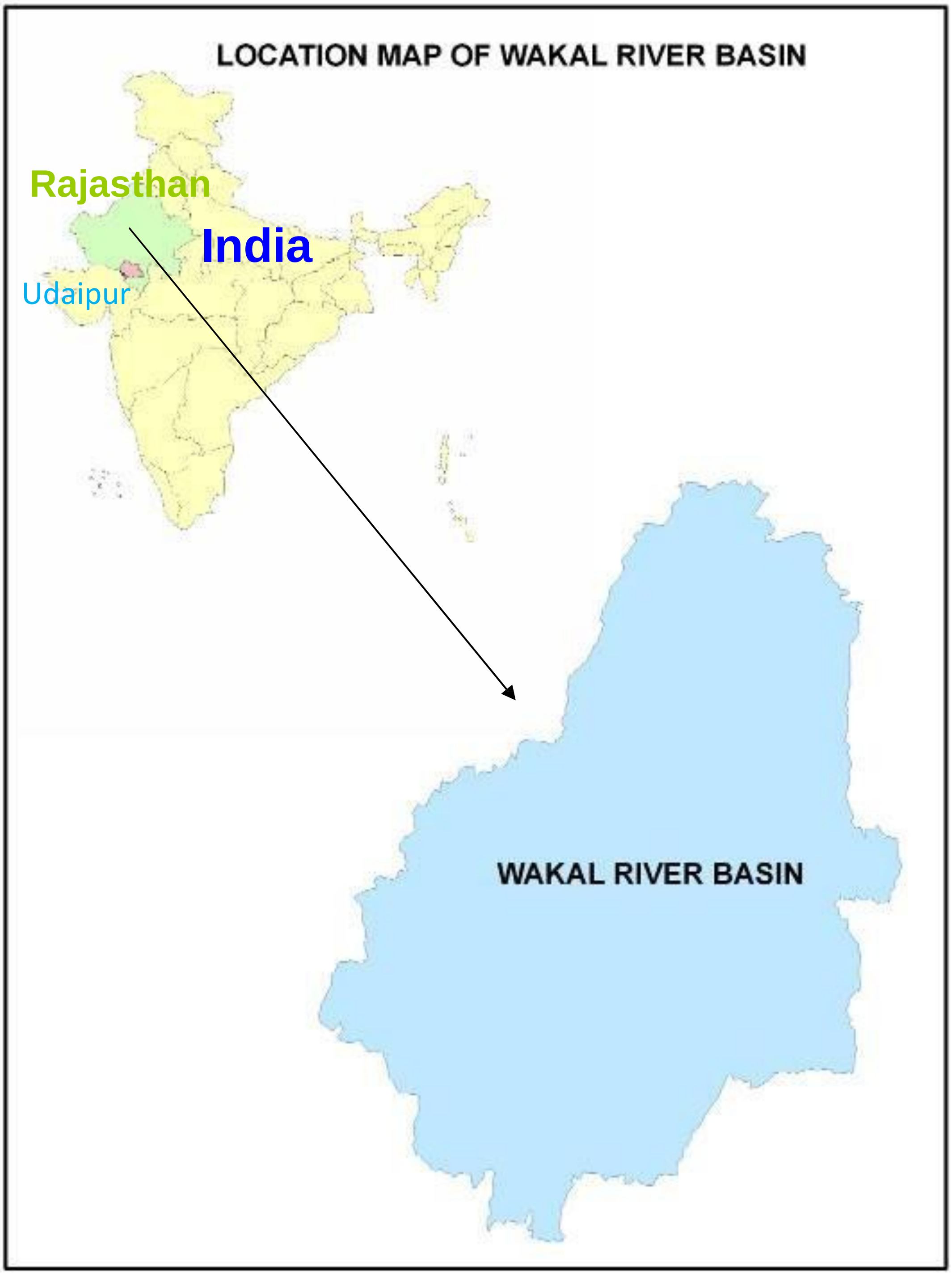

Fig. 1: Location Map of Wakal River Basin

1.2 Need of the study

Rivers of the inland system, centered in Rajasthan state, are few and frequently disappear in years of scant rainfall. The problems that river basin institutions in the developed world successfully address-such as pollution, sediment buildup in rivers and the degradation of wetlands-are not the top priorities for Indian policy makers and people. The items that do top Indian agendas-providing access to water for drinking and growing food, eradicating poverty, and stopping groundwater overexploitation-are either unresolved in the developed world or have become irrelevant due to their economic development. At Independence, only 6% of rural India had access to safe drinking water. This figure has gone up to 82%. The water table is rapidly falling with unregulated over-exploitation of groundwater. By 2025, water scarcity in India will be acute. Big dams, mega river-linking projects or privatized water distribution may not help to solve water scarcity problem.

With an average annual rainfall of 1,170 mm, India is one of the wettest countries in the world. At one extreme are areas like Cherrapunji, in the north-east, which is drenched each year with 11,000 mm of rainfall, and at the other extreme are places like Jaisalmer, in the west, which receives barely 200 mm of rain. Though the average rainfall is adequate, nearly three-quarters of the rain pours down in less than 120 days, from June to September. The country gets about 420 million hectare-meters (mha-m) of precipitation annually, of which 20 mha-m is contributed by rivers flowing in from neighboring countries. Net evapo-transpiration losses are nearly 200 mham. About 135 mha-m is available on the surface and the remaining recharges groundwater.

Water stress is becoming acute in both urban and rural situations. Not only the quantity but also the quality of water supplied or available is being questioned. At one extreme, water is being wasted in urban areas and by industries; at the other, the rural poor lack access to safe water. According to experts, the usable water resources in several river basins will eventually be exhausted, most surface water will be polluted, and environmental deprivation will be universal. Water scarcity has led to the emergence of the bottled water industry worth over Rs 1,000 Crores.

Water scarcity presents an immense threat to the lives and livelihood of communities in the Wakal River of southern Rajasthan. Subsistence frequently experience crop failure and livestock kills as a result of insufficient water supply for agriculture. Workers of the region have to walk several kilometers daily just to obtain water for household uses, leaving them little time to their income-generating activities. In sufficient control over groundwater pumping has resulted in an inequitable access to water as well as rapid depletion of existing supplies. Problems were water quality, are also common parts of the region. Low annual rainfall in the Wakal Basin of southern Rajasthan has resulted in scarce surface water and declining groundwater levels. People rely on groundwater for the bulk of their domestic water supplies. Groundwater quality problems, such as elevated concentrations of fluoride and high salinity in the water supplies, also occur in the area. Baseline surveys and research to determine the quantity and quality, as well as the sustainability of water resources in the program area are therefore, crucial to water resources exploitation and management in the area.

2 OBJECTIVES OF THE STUDY

- Assessment of surface water resources of Wakal river basin.
- To study the design details and description of different rainwater harvesting structures used in the basin.
- To analyze rainfall records and demarcate the location of gauging station.
- To study the water quality of surface water resources.
- To study erosion status of Wakal river basin.

3 SITUATIONAL ANALYSIS

3.1 Climate

The Indian Meteorological Department has divided Rajasthan into two meteorological sub divisions i.e. West Rajasthan and East Rajasthan, with the Wakal basin falling within the East Rajasthan sub division. There is no any existing meteorological station in Wakal basin. The nearest station being Udaipur located outside the basin.

3.1.1 Temperature

The period from March to June is marked by a continuous increase in temperatures, May is generally the hottest month of the year with a mean daily maximum and minimum temperature of 39.5°C and 27.3°C respectively. The summer is milder than in the desert regions. January is the coldest month with daily maximum and minimum temperature of 22.2°C and 7.3°C respectively.

3.1.2 Humidity

Relative Humidity during the southwest monsoon is generally about 70% or more. During the rest of the year, air is normally dry.

3.1.3 Cloudiness

Skies are generally moderately to heavily clouded during the southwest monsoon season especially in July and August, being overcast on some days. During the rest of the year, skies are normally clear to highly clouded.

3.1.4 Winds

Winds are generally light to moderate except in the latter half of summer and during the southwest monsoon season. In summer winds blows from directions running from west to south. Mean wind speed is highest in June (8.8 km/hr) and lowest in November (2.6 km/hr).

3.1.5 Rainfall

The area is characterized by sub-humid climate with an average annual rainfall of 630 mm. Kharif crops are mainly dependent on the rainfall and thereby subjected to either complete or partial failures in either case of excessive or shortage of rainfall during monsoon. More than 95% of the rainfall received during monsoon months of June to September. Uneven and erratic rainfall distributions marked by prolong rain less days is a common phenomenon is this region.

3.1.5.1 Location of raingauge stations

In Wakal River Basin there are five raingauge stations which are located in Gogunda, Jhadol, Gorana, Kotda and Ogana. On these stations daily rainfall is measured using non recording type raingauges. The daily rainfall data of last fifteen years (1992-2006) were collected from these stations. The raingauge station of Gogunda is situated at outside near the basin boundary. The locations of all the raingauge stations are shown in Fig. 2.

3.1.5.2 Rainfall variation at different station

The annual rainfall variation of various raingauge stations (1992-2006) presented in the Fig. 3 reveals that Kotda received the highest annual rainfall whereas Gorana received the lowest annual rainfall in the Wakal Basin. Maximum 1564mm rainfall was recorded in the Kotda during the year 2006 while minimum rainfall of 175mm was recorded at Gorana during the year 2000. Annual rainfall of different raingauge stations along with weighted average is shown in Table 1.

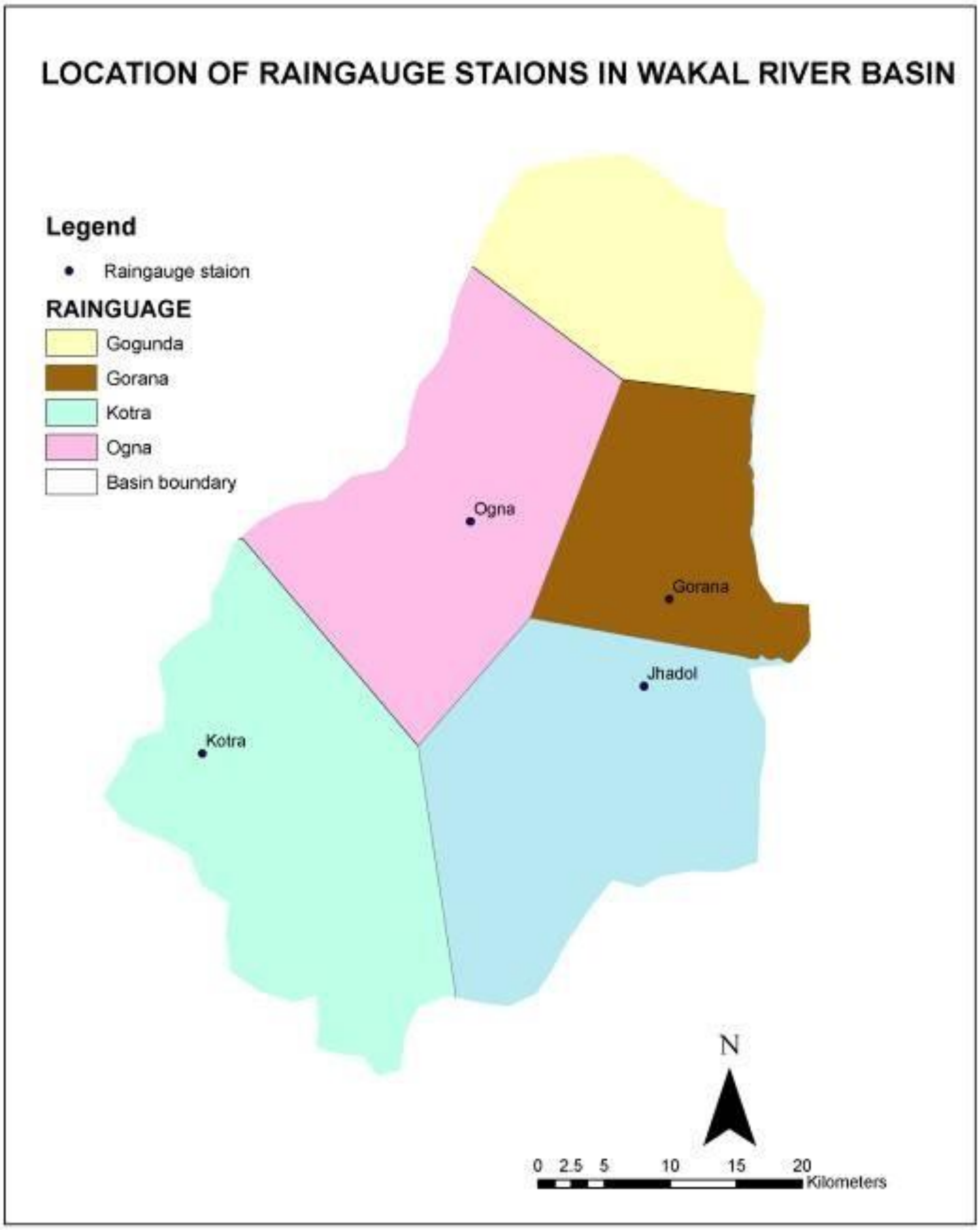

Fig. 2: Location of Raingauge Stations in the Basin

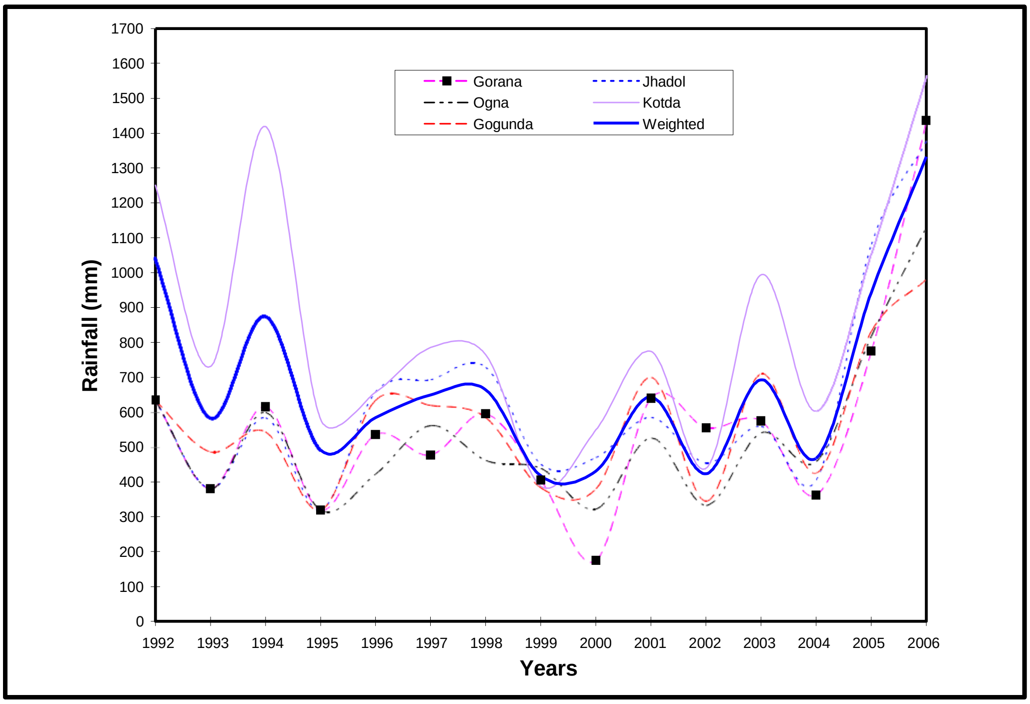

Fig. 3: Annual rainfall variations at different station

3.1.5.3 Probability analysis

Rainfall data of 15 years from 1992 to 2006 for Wakal River Basin, Udaipur were collected and analysed for probability distribution of rainfall at different levels using Weibull's (1939) technique. Weekly data were compiled on the basis of standard meteorological weeks from 23 to 38. The maximum weekly rainfall data of 15 years during the weeks from 23 to 38 were arranged in the descending order and various plotting positions 'P' and return period 'T' for Wakal River Basin, Udaipur were found out and the same are tabulated in Table 2. At 75 per cent probability level the maximum expected weekly rainfall was found to be 105.0 mm. It is also revealed from the analysis that maximum weekly rainfall of 80mm will occur once in a year.

Table 1: Annual rainfall of different rain gauge stations at Wakal river basin

S. No.	Year	Rainfall (mm)					
		Dewas (Gorana)	**Jhadol**	**Ogna**	**Kotda**	**Gogunda**	**Weighted**
1	1992	635	NA	NA	1250.4	NA	**1041.7**
2	1993	380.6	NA	NA	731	487	**583.7**
3	1994	615	584	NA	1418.5	544	**874.8**
4	1995	319	NA	NA	580	NA	**491.5**
5	1996	536	658	422	657	634	**584.1**
6	1997	477	693	562	785	620	**649.2**
7	1998	NA	729	462	765	585	**664.1**
8	1999	405	451	439	388	384	**416.9**
9	2000	175	470	NA	549	380	**430.7**
10	2001	640	585	526	774	700	**643.9**
11	2002	555	454	333	439	345	**423.2**
12	2003	575	560	541	994	710	**692.8**
13	2004	362	406	459	603	426	**467.5**
14	2005	775	1081	818	1054	832	**941.4**
15	2006	1436	1377	1131	1564	982	**1331.9**

Table 2 Weekly rainfall data and probability percentage for the period 1992-2006 (Weibll's Technique) at Wakal River Basin

Year	Max Weekly Rainfall	Descending order	Rank (m)	Plotting Position (m/n+1)	Probability (%)	Recurrence Interval
1992	271.0	290.4	1	0.063	6.25	16.00
1993	206.9	289.4	2	0.125	12.50	8.00
1994	138.5	271.0	3	0.188	18.75	5.33
1995	160.4	206.9	4	0.250	25.00	4.00
1996	110.7	173.7	5	0.313	31.25	3.20
1997	115.5	160.4	6	0.375	37.50	2.67
1998	82.3	148.7	7	0.438	43.75	2.29
1999	132.4	138.5	8	0.500	50.00	2.00
2000	101.3	132.4	9	0.563	56.25	1.78
2001	148.7	115.5	10	0.625	62.50	1.60
2002	90.6	110.7	11	0.688	68.75	1.45
2003	173.7	105.0	12	0.750	75.00	1.33
2004	105.0	101.3	13	0.813	81.25	1.23
2005	290.4	90.6	14	0.875	87.50	1.14
2006	289.4	82.3	15	0.938	93.75	1.07

3.2 Topography

The General topography of the area is hilly and undulating. Most of the cultivated lands are located in the valleys. Surface drainage of the area is generally good due to slight undulations in the topography. About 96,625 ha of the land falls under the slope group of 30 to 50%. Water flows through seasonal nala with high velocity which is a main cause of erosion in the area. Small and scattered land holding situated on varying slope gradient is also a measure cause of soil erosion in the area. The drainage map of the basin is given is Fig. 4.

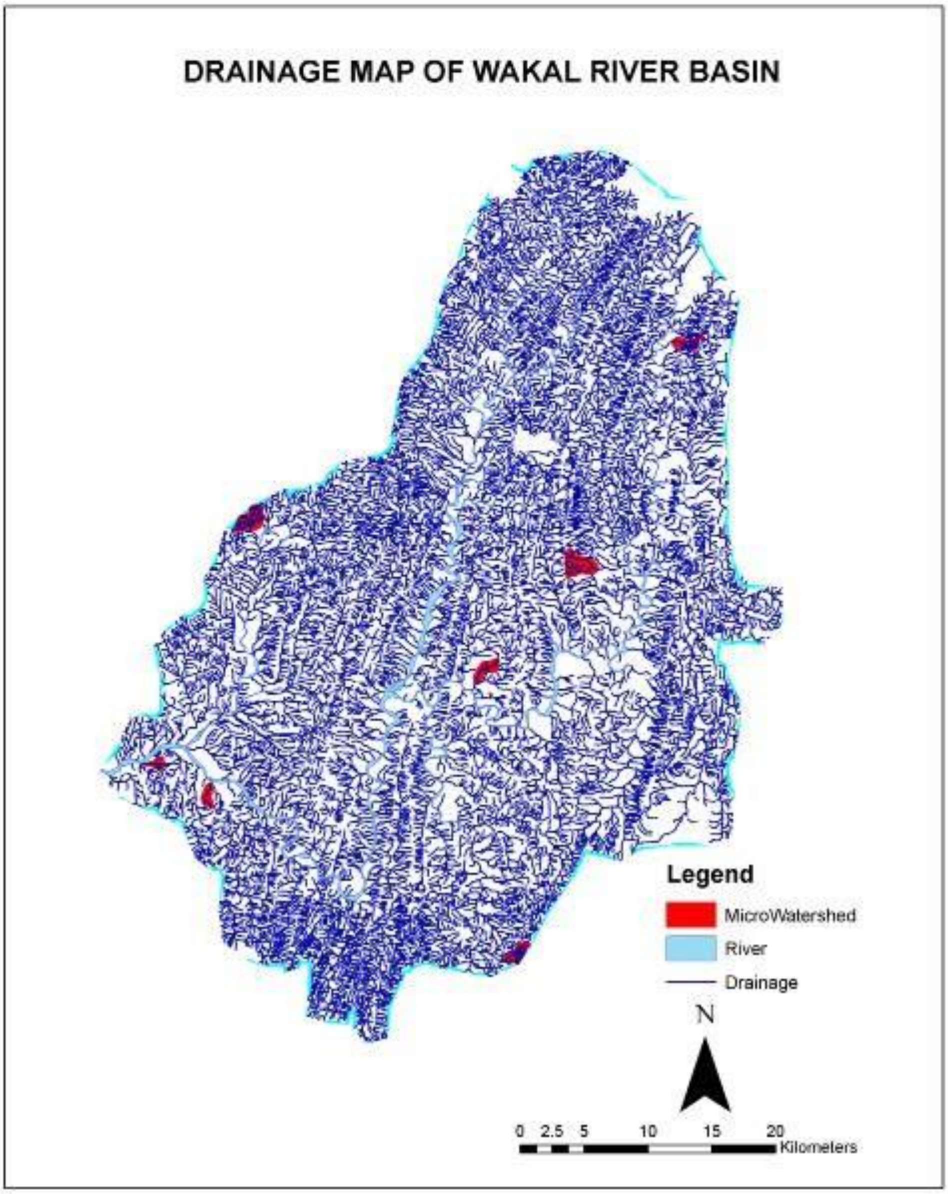

Fig. 4 Drainage map of Wakal River Basin

3.3 Land use/land cover

The land use/land cover map of the basin is prepared under the GIS environment and hole area of the basin was categorized in for measure classes viz. agriculture, open scrub, degraded forest and fairly dense forest. The land use map of the basin is shown in Fig. 5.

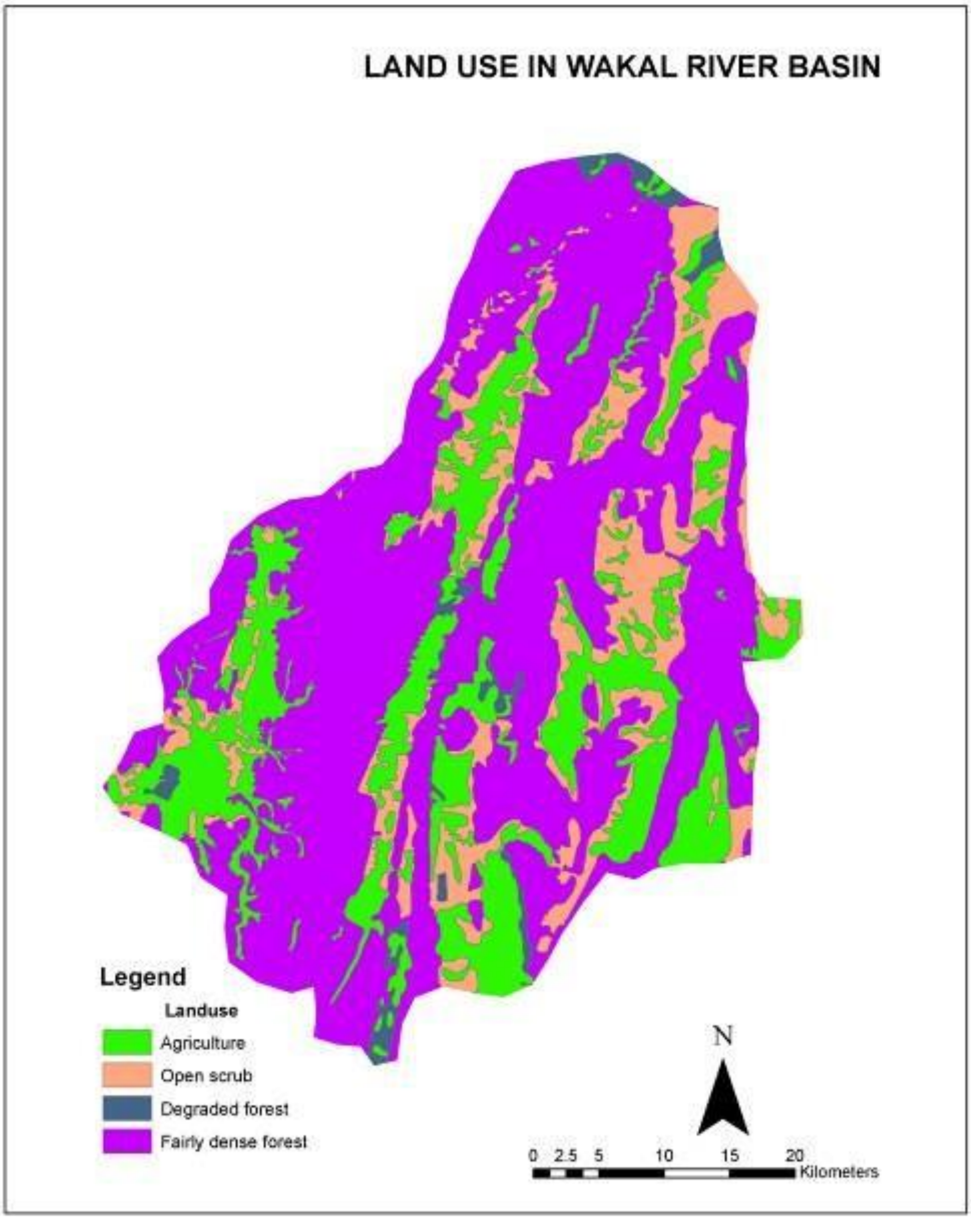

Fig. 5. Land use/ land cover map of Wakal River Basin

3.4 Soils of the basin

Most of the area of the basin falls under rocky soil group, in which soil depth and slope are the limiting factors. Average soil depth varies between 30 to 50 per cent. These soil group falls under hydrologic soil group D which indicates the high runoff potential. In some valleys, fine loam and clay soils are dominating which are having moderate slope of less than 8 per cent and soil depth up to 100 cm. The soil map of the basin is shown in Fig 6 where as the details of different soil groups is presented in Table 3.

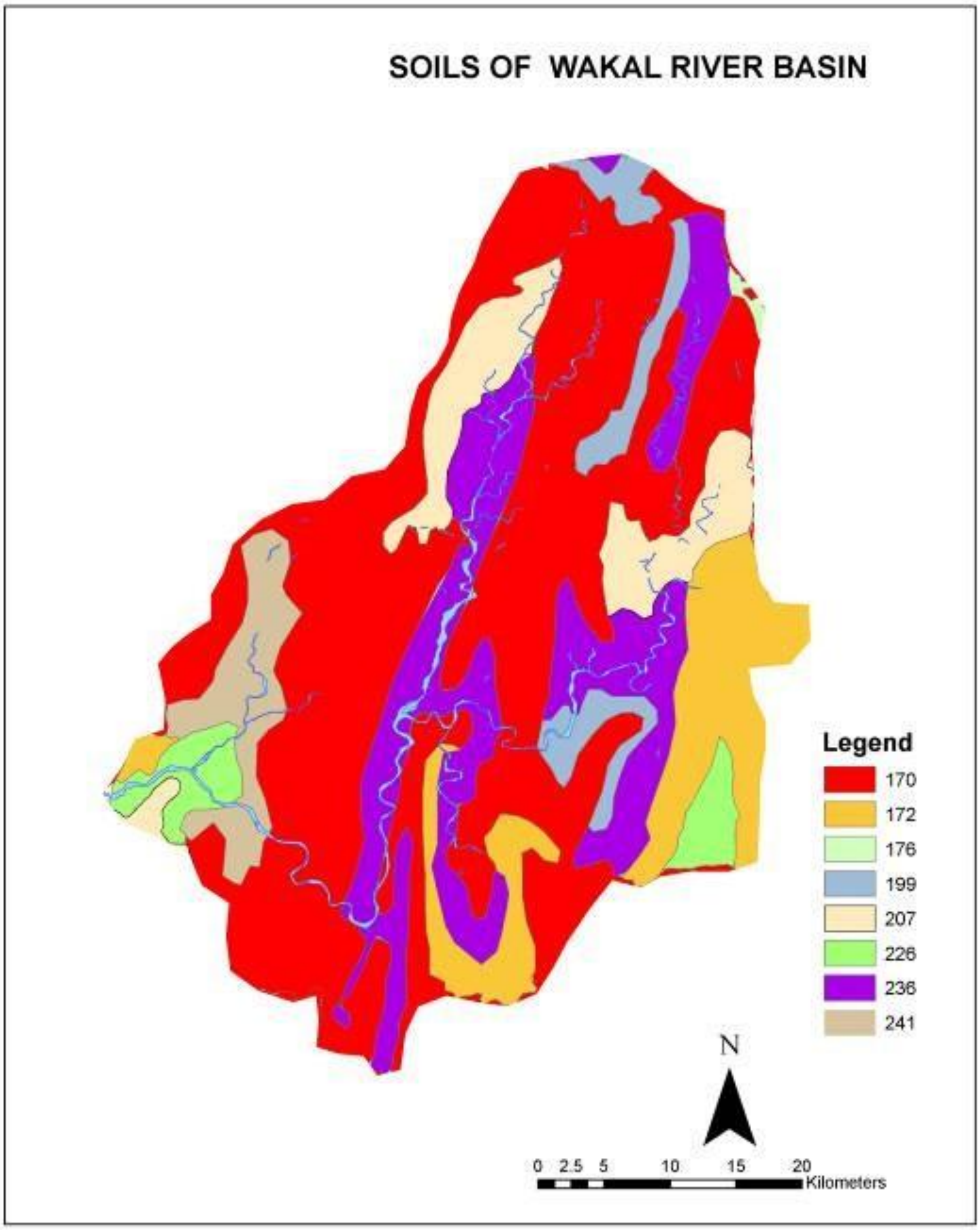

Fig. 6: Soil Map of the Basin

Table 3: Soil details of the basin

S.No.	Soil Unit	Slope %	Soil Depth (cm)	Soil Type	Hydrological Unit	Area (ha)
1	170	30-50	25-50	LSK - R	D	94624.54
2.	172	3-8	50-75	FL - R	C	9007.15
3.	176	1-3	>100	LSK	C	433.37
4.	199	5-15	50-75	FL	B	7193.06
5.	207	8-15	<25	FL - LSK	B	6925.23
6.	226	3-12	50-75	FL - CL	B	5916.47
7.	236	2-8	50-100	FL	A	30894.50
8.	241	3-15	10-100	FL - CL	B	13916.83

LSK- Gravelly Skelton, R – Rocky, FL – Fine Loam and CL - Clay

3.5 Status of soil and water conservation measures

Some of the farmers have minimized soil erosion and attempted for in situ moisture conservation in their arable lands with small earthen/stone bunds, which are stabilized by naturally occurring grasses. The area needs suitable soil and water conservation measures both on arable and non arable areas and extensive efforts are required to be done for extending improved dryland agriculture practices. Non-arable lands are completely devoid of any kind of *in-situ* moisture conservation measures. Very limited treatment measures are done on drainage lines.

4 SURFACE RUNOFF

The surface runoff of Wakal River Basin is estimated using SCS-Curve Number Technique using the daily rainfall data of last 15 years (1992-2006). For determination of Curve Numbers land use and hydrologic soil group map were prepared in GIS environment. The hydrologic soil group map of the basin is shown in Fig. 7. The percentage runoff varies from minimum 4.37 to maximum of 37.89 for the year 1999 and 2005 respectively. The maximum runoff yield of 714.73 million m^3 was found during the year 2006. Rainfall-Runoff relationship is presented in Fig. 8 and the yearly runoff yield is shown in Table 4.

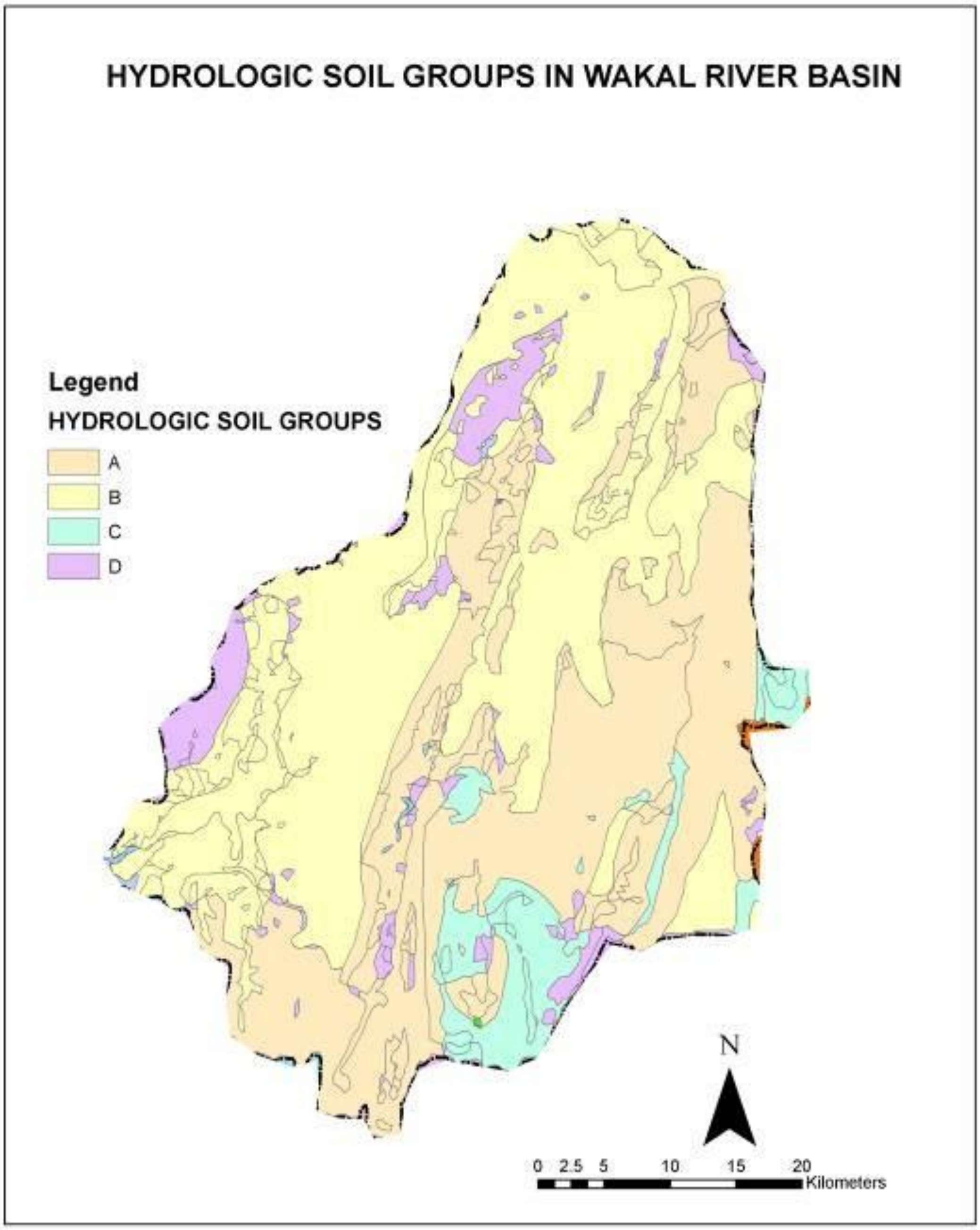

Fig. 7: Hydrologic Soil Group of the basin

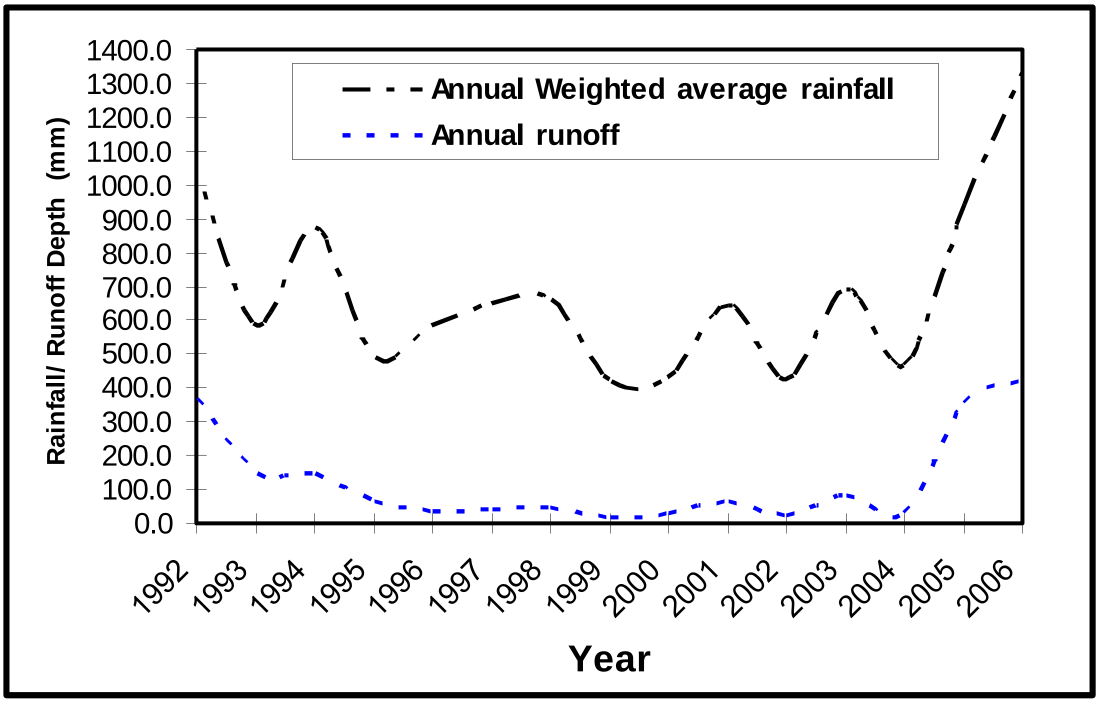

Fig. 8: Rainfall-Runoff relationship in the basin

Table 4 Rainfall and runoff relationship

S.No.	Year	Rainfall (mm)	Runoff (mm)	% Runoff	Runoff Yield (Million m³)
1	1992	1041.7	366.3	35.16	381.57
2	1993	583.7	147.2	25.22	85.92
3	1994	874.8	149	17.03	130.35
4	1995	491.5	64.2	13.06	31.55
5	1996	584.1	32.5	5.56	18.98
6	1997	649.2	43.8	6.75	28.43
7	1998	664.1	46.1	6.94	30.62
8	1999	416.9	18	4.32	7.50
9	2000	430.7	27.7	6.43	11.93
10	2001	643.9	63.7	9.89	41.02
11	2002	423.2	24.1	5.69	10.20
12	2003	692.8	81.8	11.81	56.67
13	2004	467.5	27.9	5.97	13.04
14	2005	941.4	356.7	37.89	335.80
15	2006	1331.9	423.2	31.77	563.66

5 SURFACE WATER STORAGE

To store the surface water potential of the Wakal River Basin various rainwater harvesting structures has already been constructed by Govt. and Non-Govt. Organizations. Presently Irrigation Department, Watershed Development Department, Rural Development Department and NGO's are constructing low and medium height earthen dams/anicuts.

5.1 Location of water storage reservoirs

In the Wakal River Basin 17 major rainwater harvesting structures were constructed by Irrigation Department and Rural Development Department. Mansi Wakal Dam is the biggest dam constructed in the basin which is having the gross storage capacity of 863 MCFt. This dam was mainly constructed to fulfill the drinking water need of the Udaipur City. The location of the different dams is shown in Fig. 9. The water storage capacity along with ownership of the various dams is given in Table 5. The longitude and latitude of the water storage reservoirs are taken using GPS.

5.2 Description of different rainwater harvesting structures

The rainwater harvesting structures constructed in the basin are mostly used for irrigation, ground water recharging and drinking purposes for human and live stock. Most of the measure dams in the basin is managed by village panchayat/ irrigation department. Masonry Anicut of one meter to four meter height is vary popular rainwater harvesting structure that has been constructed in the basin by various government and non government organizations. Earthen Nadi/ Sunken pond and low cost dry stone masonry type rainwater harvesting structure are also common and it is being constructed in the basin by various organizations.

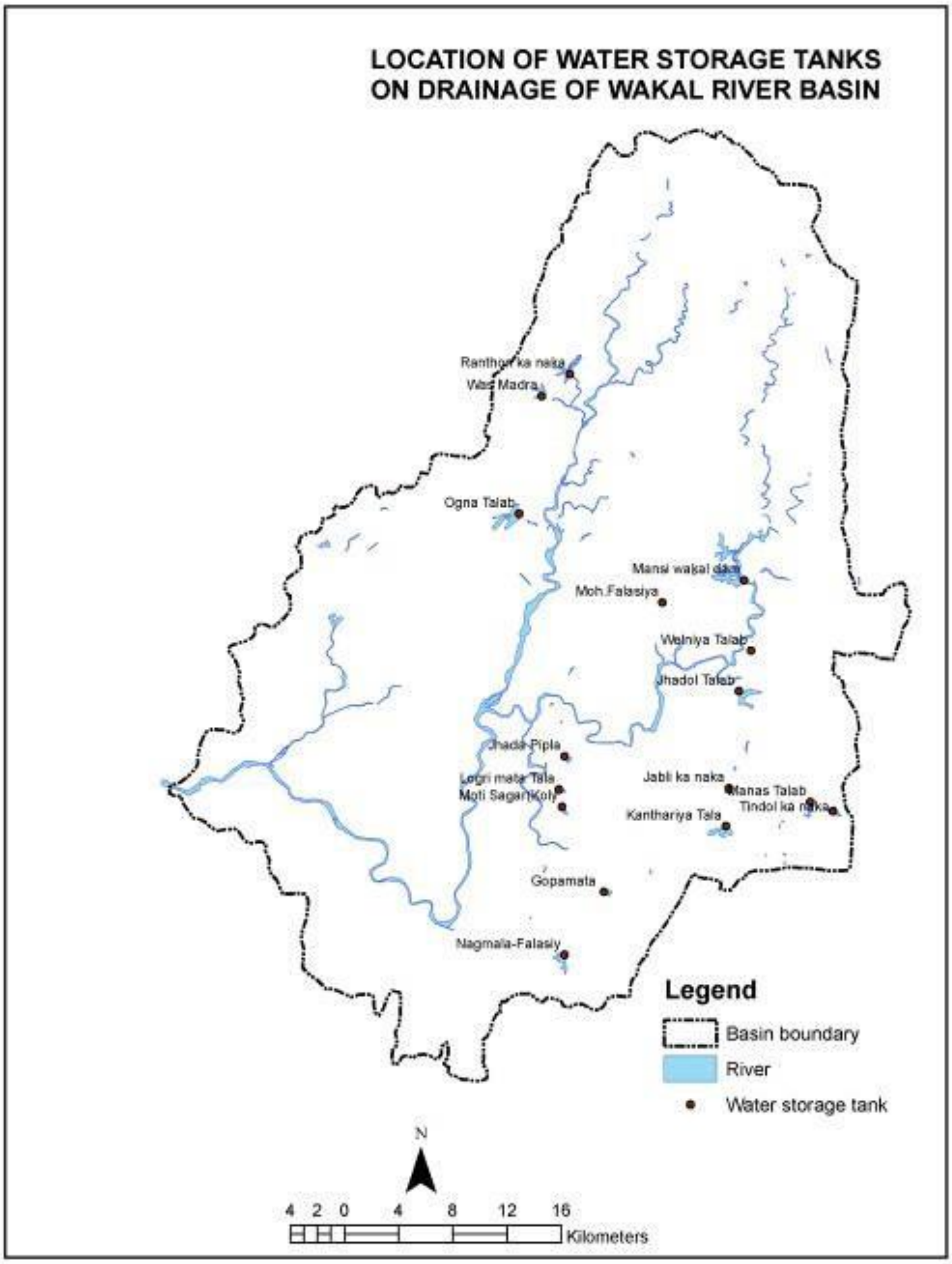

Fig. 9: Location map of the water storage tanks in the basin

Table 5: Water storage tanks situated in Wakal river basin

S. No.	Name of Tank	Village	Year of construction	Storage capacity (MCFt)	Ownership
1.	Jhadol	Jhadol	1961-62	88	Irrigation
2.	Kanthariya	Kanthariya	1980-81	88	Irrigation
3.	Nagmala	Nagmala-Falasiya	State time	90	Panchayat
4.	Jhadapipla	Jhadapipla	1990-91	25.5	Panchayat
5.	Moti Sagar	Kolyari	1990-91	23.7	Panchayat
6.	Ogna	Ogna	1988-89	274	Irrigation
7.	Manas	Manas	1973-74	32.7	Panchayat
8.	Nal	Nal	1994-95	5.5	Panchayat
9.	Welniya	Welniya	1993-94	6.2	Panchayat
10.	Jabli ka naka	Jabli ka naka	1999-2000	35	Panchayat
11.	Gopamata	Bichhiwara	1999-2000	19	Panchayat
12.	Logrimata	Kolyari	1999-2000	12.16	Panchayat
13.	Tindol ka naka	Tindol	2005-06	24.58	Irrigation
14.	Mohammad Falasiya	Mohammad Falasiya	2004-05	40	Irrigation
15.	Ranthon ka naka	Ranthon ka naka	2005-06	142	Irrigation
16.	Was Madara	Was Madara	1997-98	53.17	Panchayat
17.	Mansi Wakal	Gorana	2005-06	863	HZL

5.3 Design parameter of water harvesting structures

The rainwater harvesting structures are designed to intercept the water from local catchment and store it for optimum utilization. In Wakal basin masonry Anicuts were constructed at large scale by the various agencies only due to its wide range utility for agricultural and domestic purposes during and after the monsoon. These structures are designed keeping in view the hydrologic, hydraulic and structural design parameters. The most commonly used design parameters of Anicut is given in Table 6.

Table 6: Design parameters of water harvesting structure-Anicut constructed in the basin

Height of Structure (m)	Catchment Area (ha)	Crest Length (m)	Top Width of Head Wall (m)	Bottom Width of Head Wall (m)	Cost (Rs)
1	50-100	20	0.6	1.2	92,495
2	100-200	20	0.6	2.2	1,90,272
3	200-300	20	0.7	3.0	3,08,177
4	300-500	20	0.8	4.0	4,83,951
5	>500	20	1.0	5.2	6,92,868

5.4 Management aspect and water withdrawals

The dams located in the basin are being managed by irrigation department and gram panchayat. There is no any systematic regulatory mechanism for the withdrawal of water through the canals. Members of the gram panchayat and officials of irrigation department meet once in a year to decide canal operation period according to the availability of water in the reservoir.

6 SURFACE WATER QUALITY

In Rajasthan water is the most limiting resource in intensification of agriculture. As there are considerable variations in the composition of water within the same block, therefore, the study was undertaken to judge the water quality of Wakal river basin. Surface water of the basin is one of the major source of water to fulfill the agricultural as well as domestic need of the people. To examine surface water quality pH, Electrical conductivity, TDS, CO_3, HCO_3 etc. were analyzed from the samples collected at different locations. The water quality is one of the major reason of acquiring water born diseases in the tribal peoples living in the basin. Health hazard due to poor quality water is becoming a major issue in the area.

6.1 Collection of Water Samples

The pre monsoon surface water samples were collected from major 16 dams situated in the basin and these were analyzed in the laboratory to find out different quality parameters. Three samples were collected from each reservoir at different locations.

6.2 Water Quality Parameters

The analysis of water samples for pH, Electrical Conductivity (EC), TDS, $CO_{3,}^{-\,-}$ HCO_3^- etc. was done following the standard methods. The variations in different surface water quality parameters are shown in Fig 10a to Fig 10k. The TDS and EC were found highest in Jabli ka Naka reservoir (TDS - 1050 & EC - 3.14) followed by Manas reservoir (TDS – 629 & EC – 1.802). The BOD_5 and COD were found highest in Tindol ka Naka (BOD_5 4.6 and COD 42) whereas it was found lowest in Ranthon ka Naka (BOD_5 1.7 and COD 10). The different water quality parameters of the reservoirs located in the basin is given in Table 7.

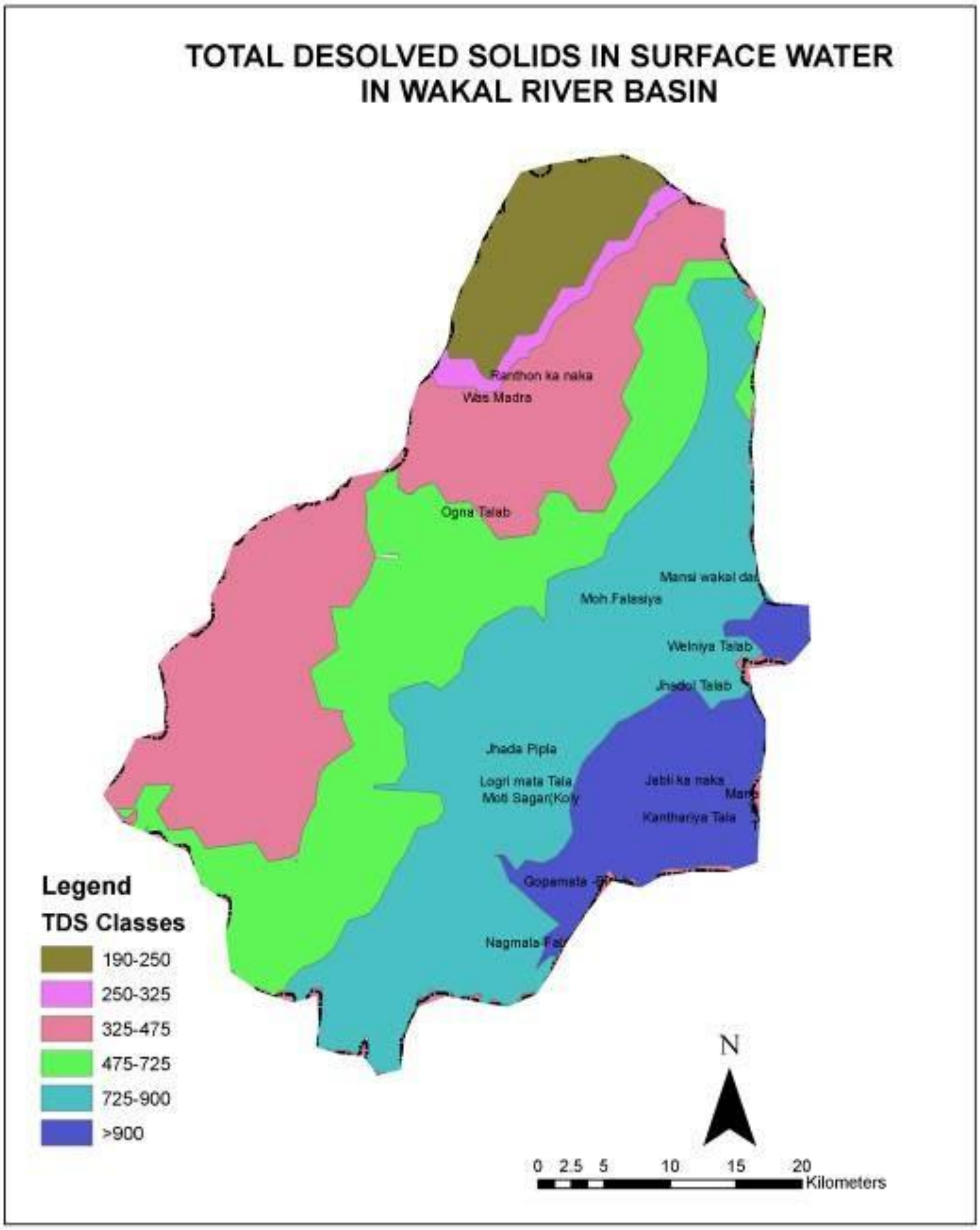

Fig. 10a: Variation in TDS throughout the basin

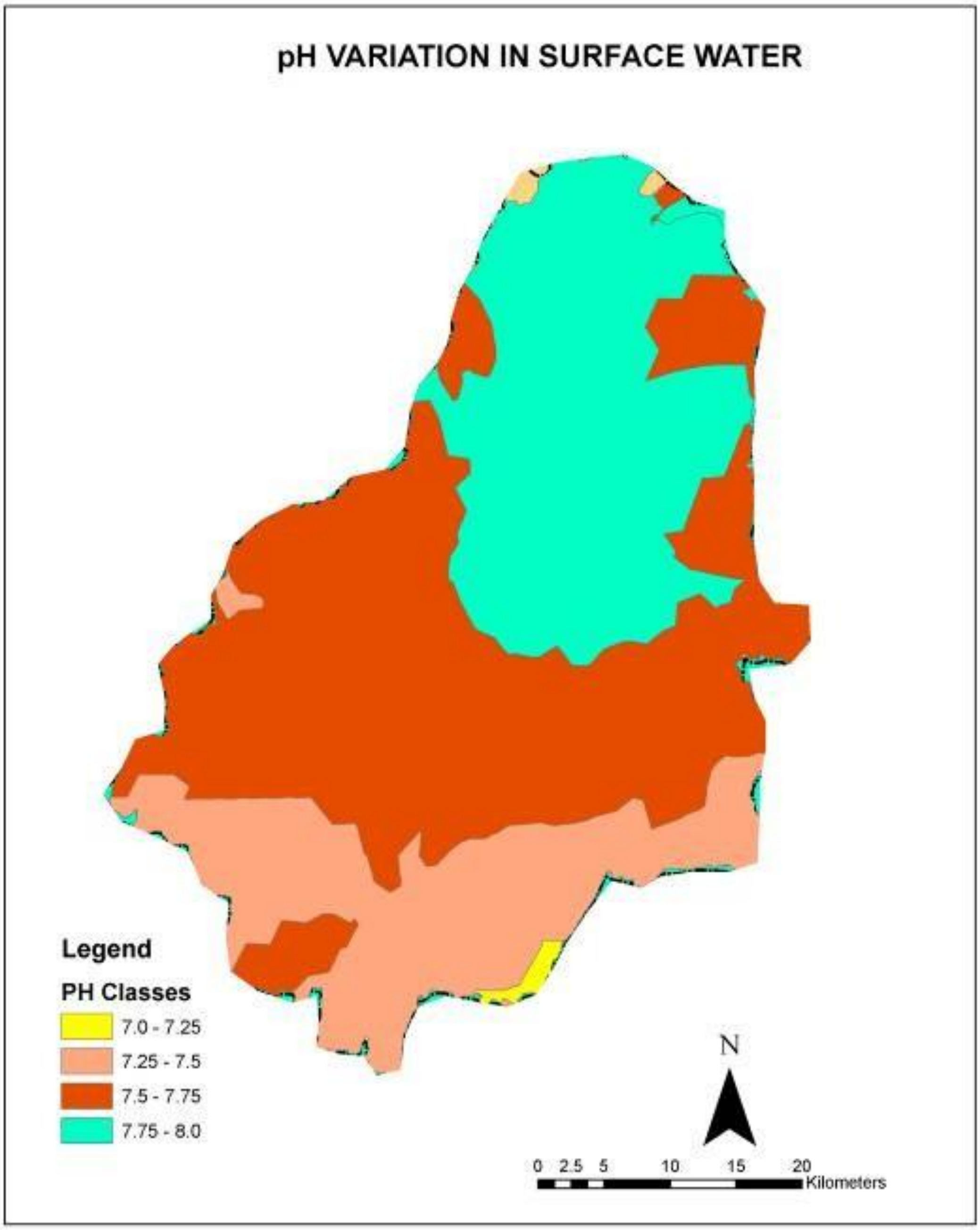

Fig. 10b: Variation in pH throughout the basin

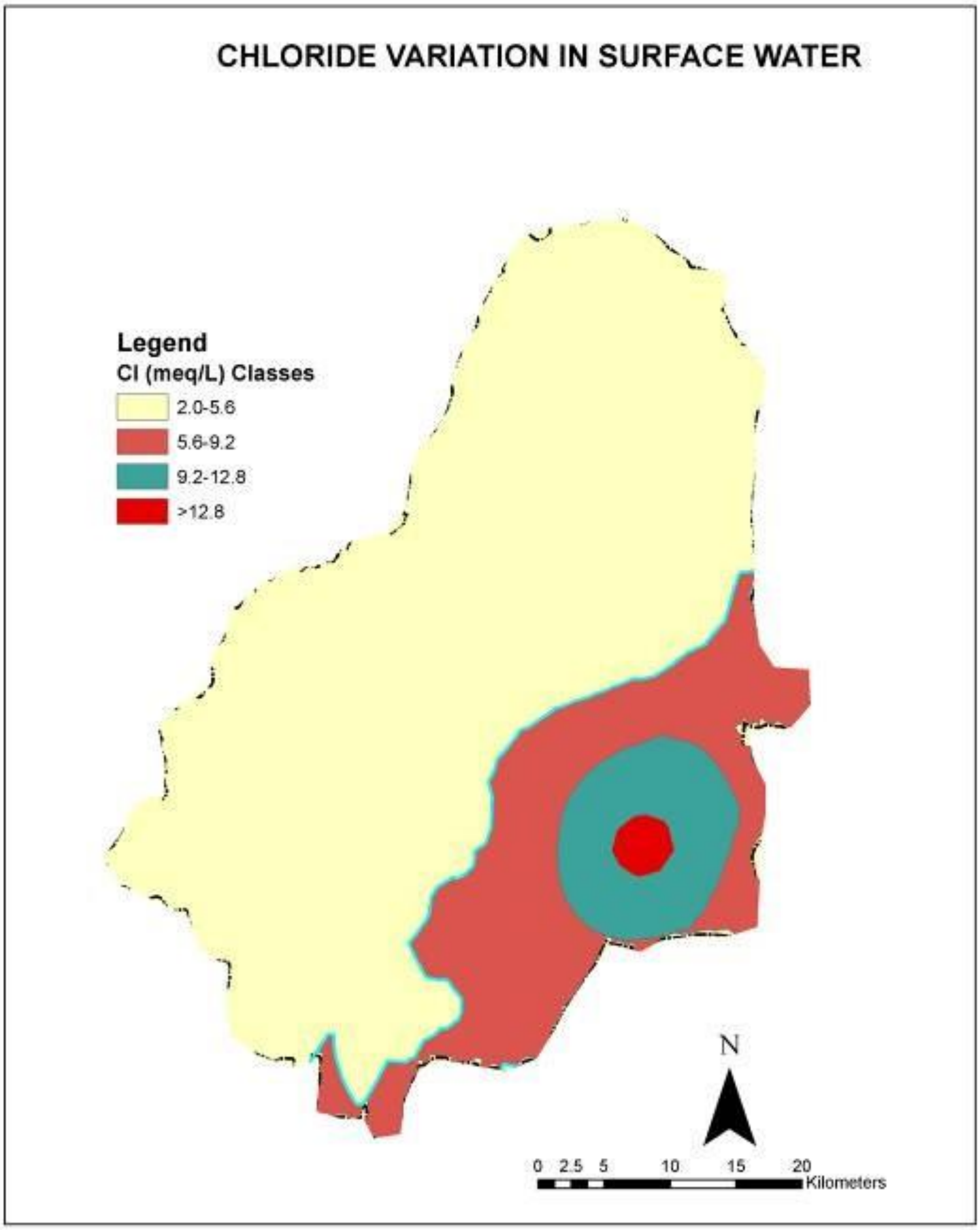

Fig. 10c: Variation in Chloride throughout the basin

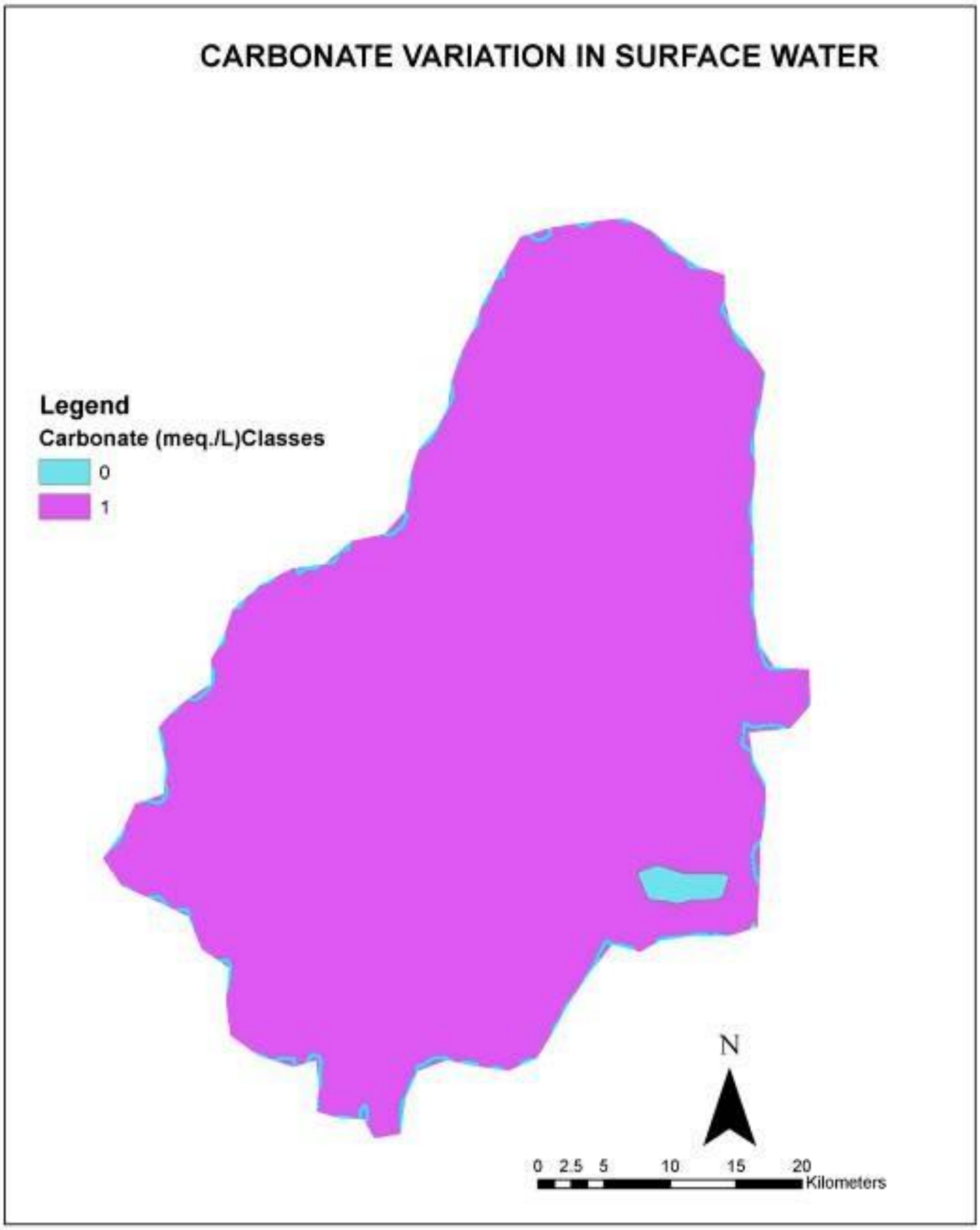

Fig. 10d: Variation in Carbonate throughout the basin

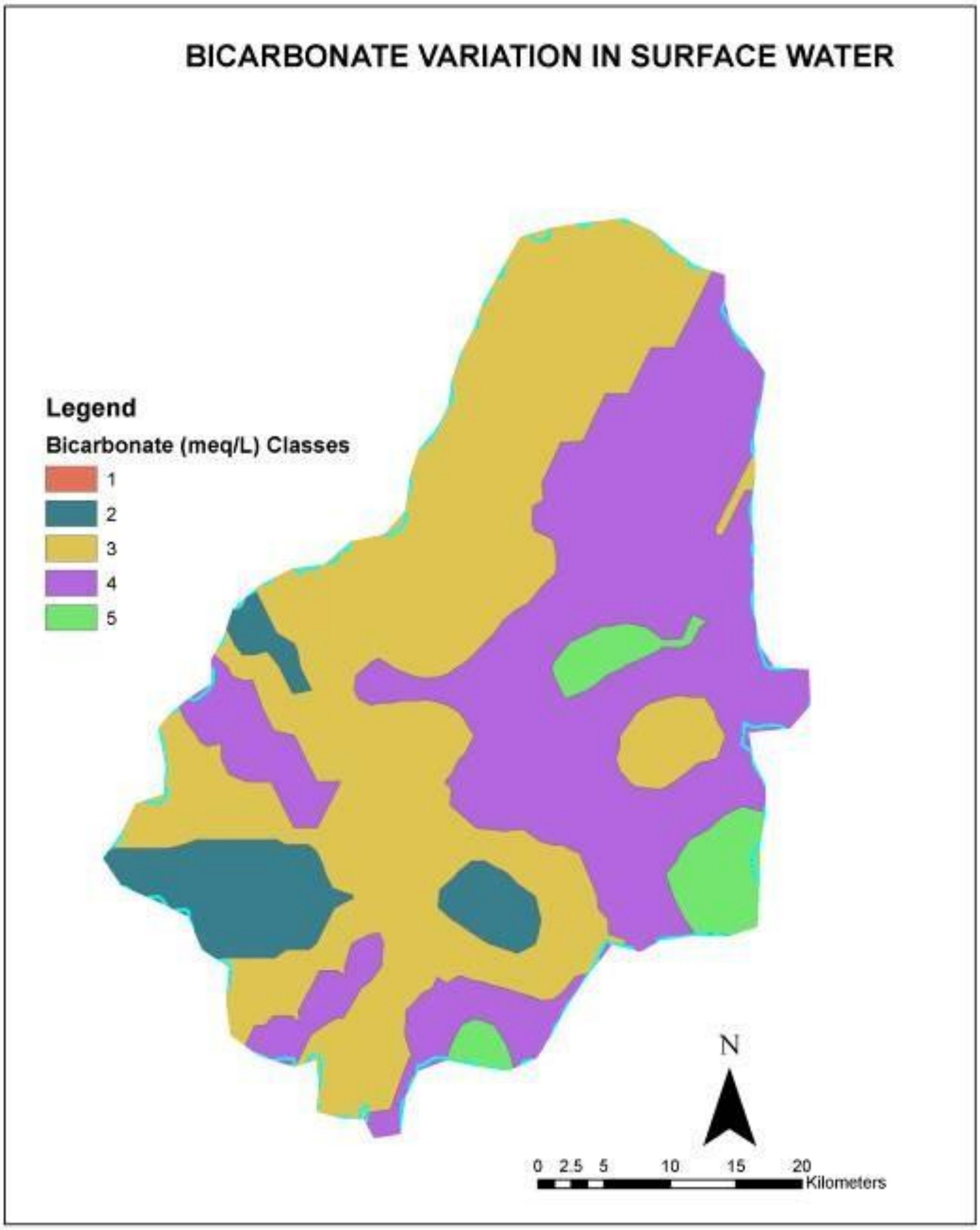

Fig. 10e: Variation in Bicarbonate throughout the basin

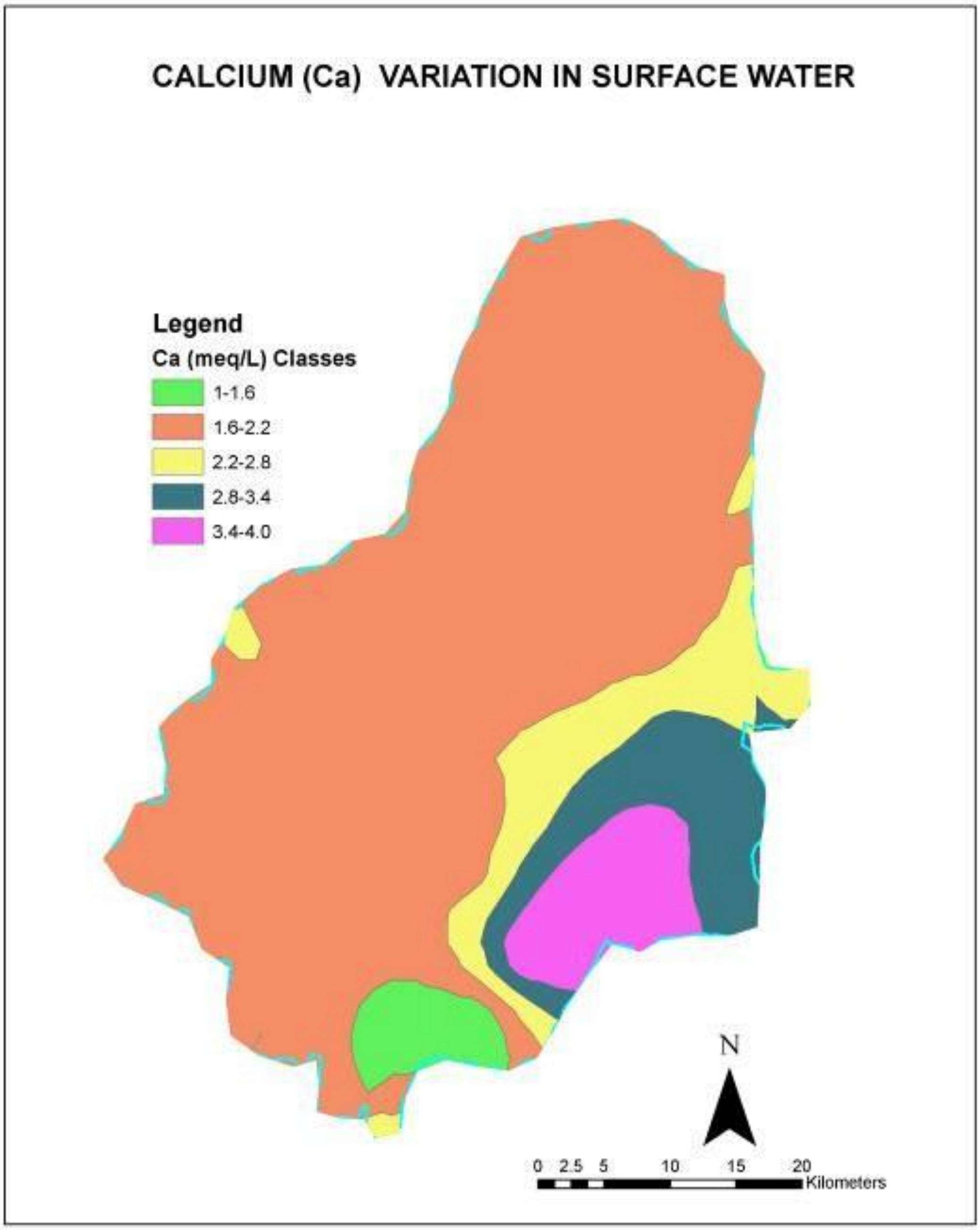

Fig. 10f: Variation in Calcium throughout the basin

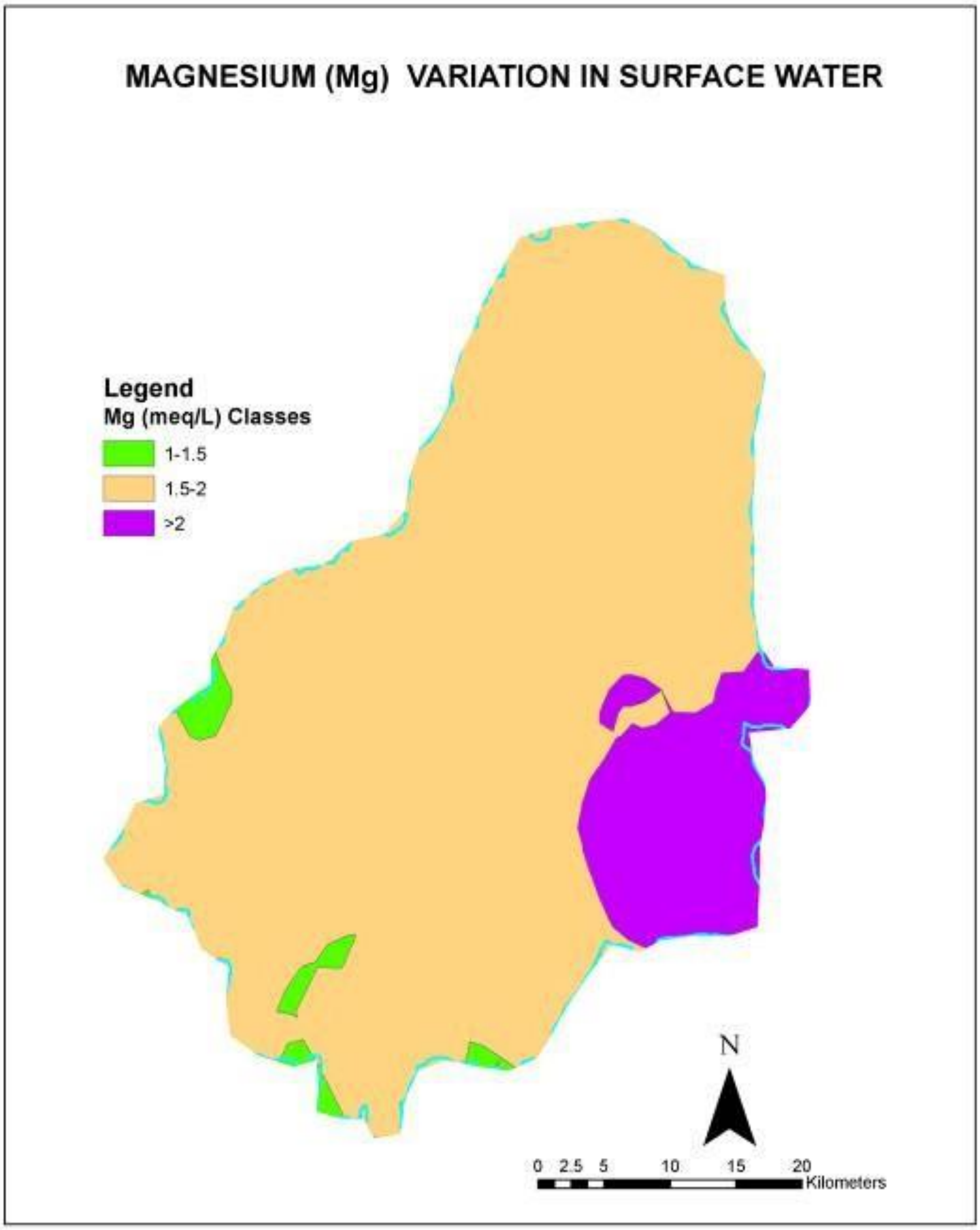

Fig: 10g: Variation in Magnesium throughout the basin

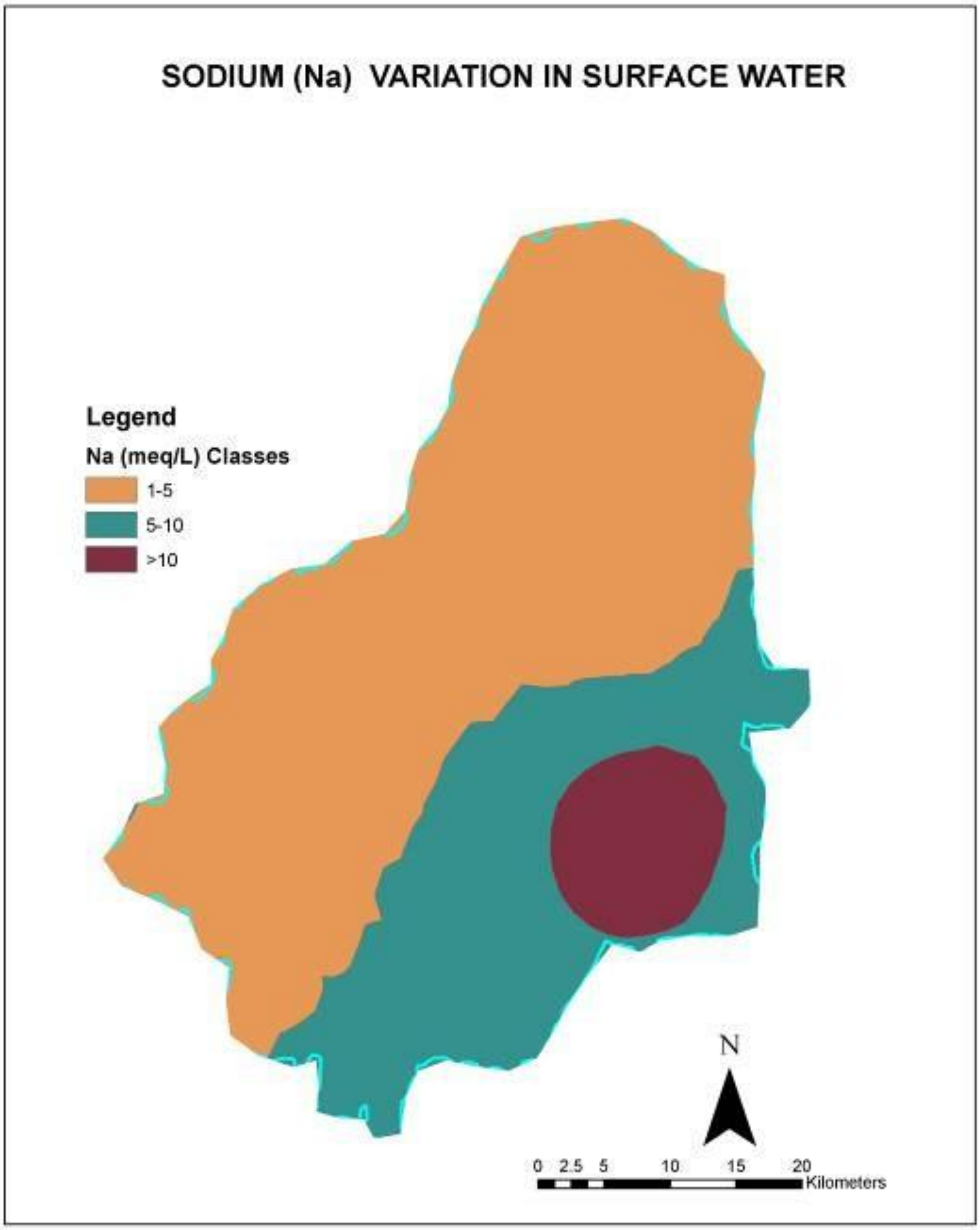

Fig. 10h: Variation in Sodium throughout the basin

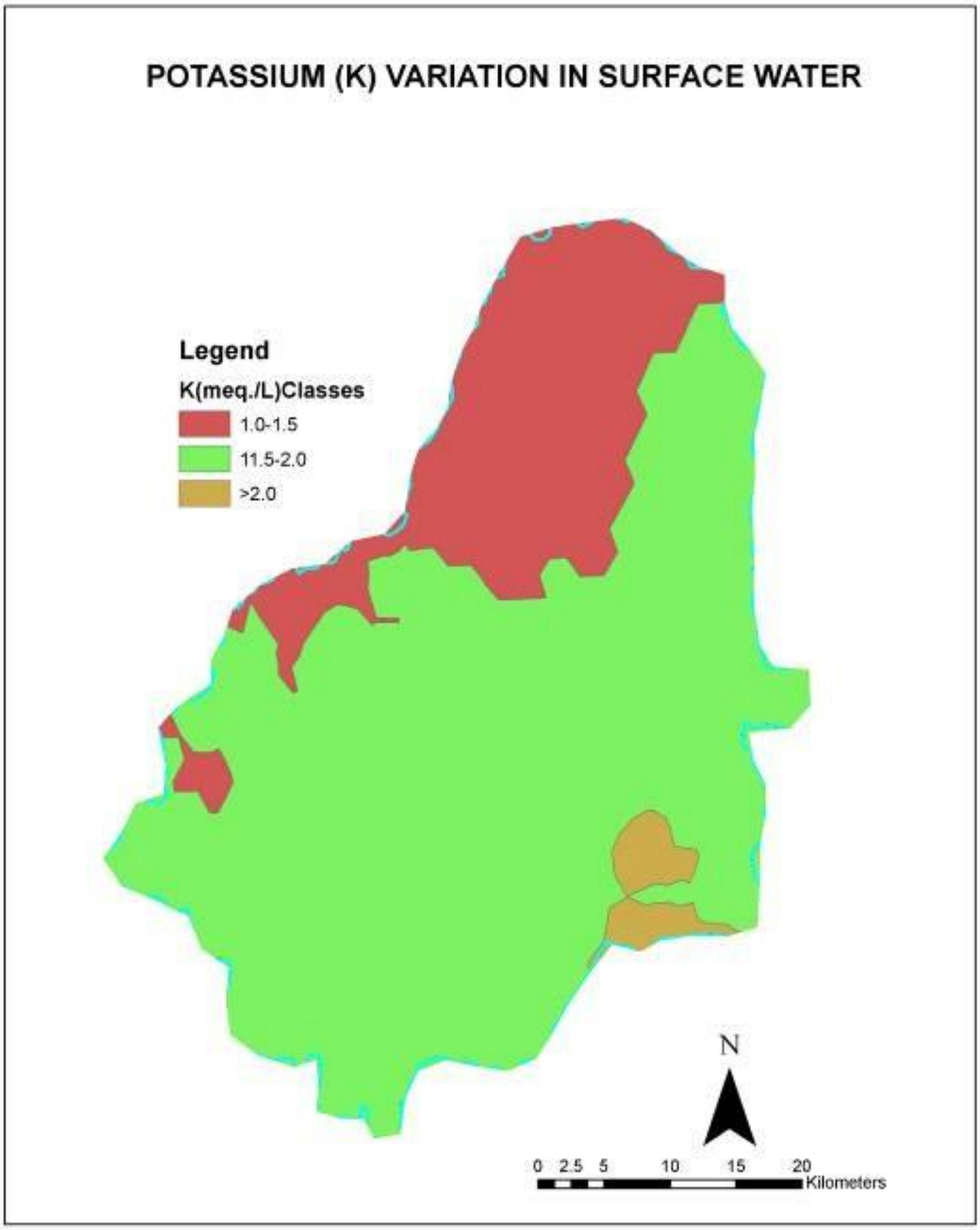

Fig. 10i: Variation in Potassium throughout the basin

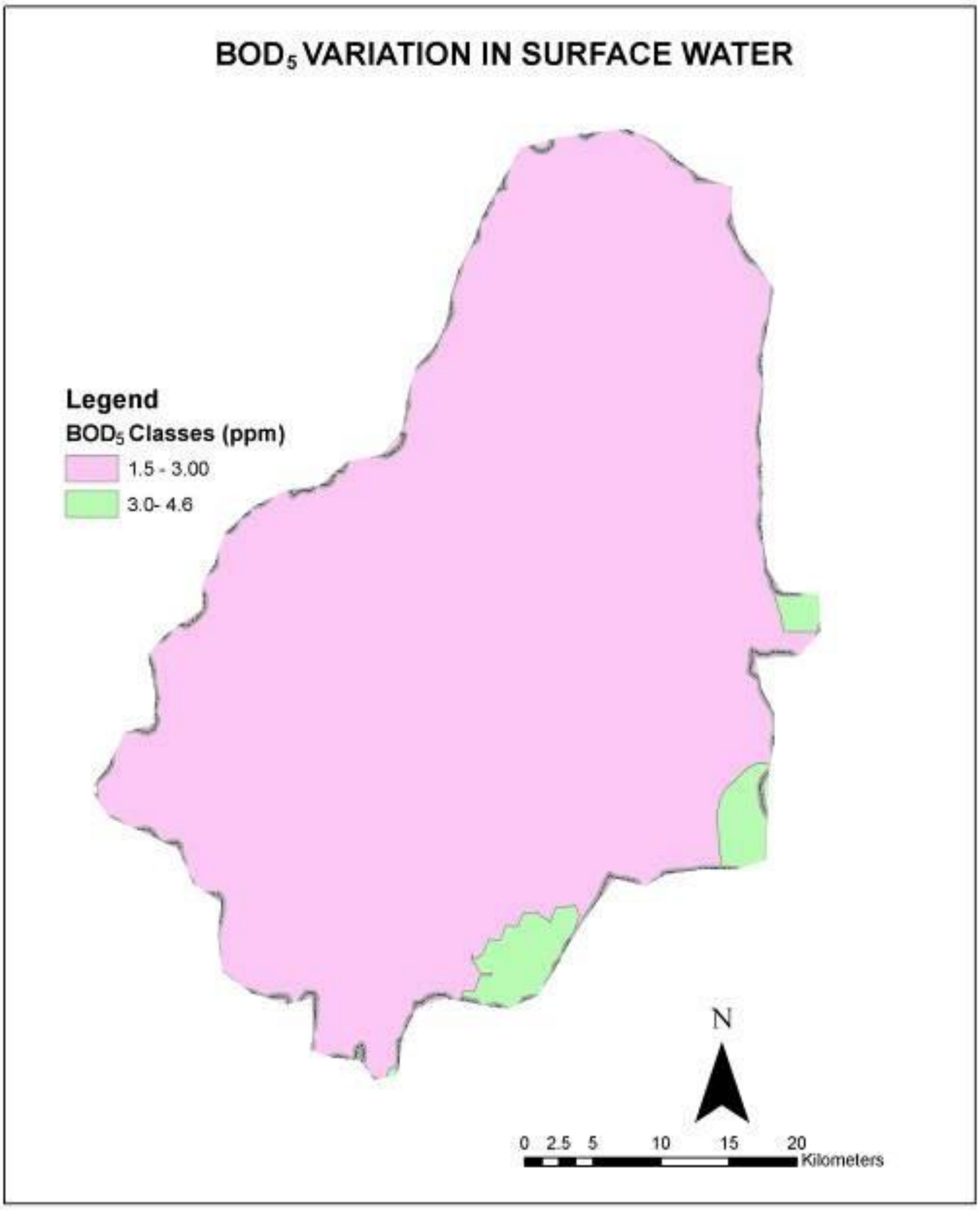

Fig. 10j: Variation of BOS_5 throughout the basin

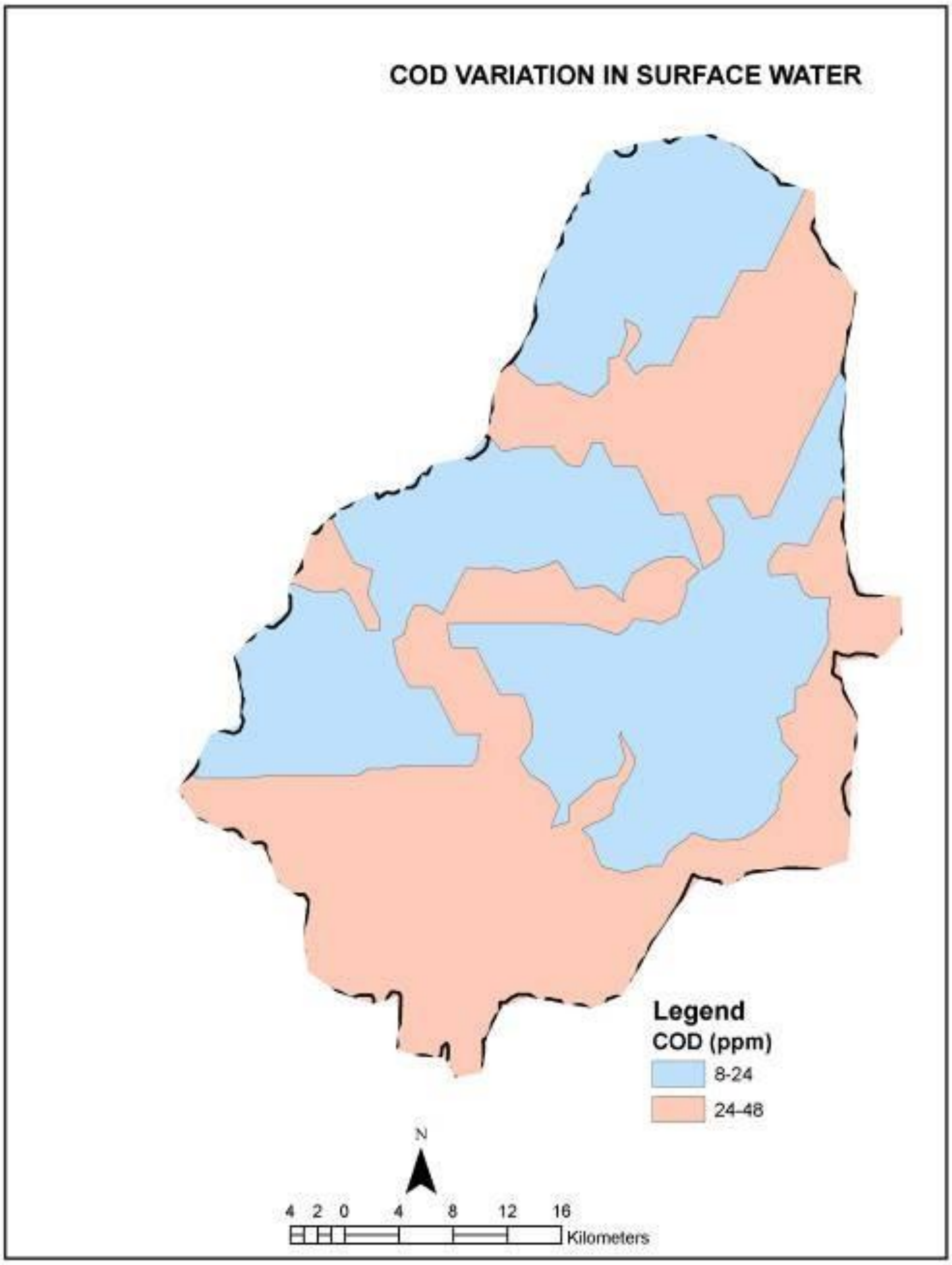

Fig. 10k: Variation of COD throughout the basin

Table 8 Water quality parameters of different water storage tanks

S. No.	Name of Tank	TDS (ppm)	Ph	EC (dS/m)	Cl^- (meq/L)	CO_3^{--} (meq/L)	HCO_3^{--} (meq/L)	Ca^{++} (meq/L)	Mg^+ (meq/L)	Na^+ (meq/L)	K^+ (meq/L)	BOD	COD
1	Jhadol	580	7.4	1.45	9	2	2	3.0	2.0	9.1	2.0	2.1	17
2	Kanthariya	511	7.8	1.496	9	0	4	3.8	1.8	7.6	1.4	1.7	9.0
3	Nagmala	304	7.1	0.835	5	0	5	1.4	0.2	4.8	1.6	3.3	29
4	Jhadapipla	362	7.6	1.003	4	2	4	2	2	4.6	1.2	1.8	13
5	Moti Sagar	306.5	7.5	0.848	5	2	1	2.4	1	4.2	0.7	3.5	36
6	Ogna	191	7.5	0.551	2	2	2	1.8	1.2	1.8	0.5	1.8	13
7	Manas	629	7	1.802	12	0	5	2.6	2.8	10	2.2	3.5	35
8	Nal	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
9	Welniya	597.5	7.6	1.719	10	2	2	3.2	2.2	9.3	2.1	1.6	8
10	Jabli ka naka	1050	7.1	3.14	20	0	4	3.6	2.8	20.2	4	1.5	8
11	Gopamata	459	6.9	1.241	7	2	2	3.6	1.6	5.8	1	3.2	27
12	Logrimata	492.5	7	1.361	6	2	3	2.4	1.4	7.9	1.2	1.7	11
13	Tindol ka naka	252.5	7	0.69	3	0	5	2.6	0.8	2.2	1	4.6	42
14	Mohammad Falasiya	328.5	7.8	0.901	4	0	5	1.8	1.8	4	1.2	3.3	34
15	Ranthon ka naka	193.5	7.6	0.538	3	2	3	2.2	1.2	1.5	0.2	1.7	10
16	Was Madara	223	7.2	0.529	3	2	3	1.8	2	1	0.2	3.4	31
17	Mansi Wakal	223	7.3	0.612	3	0	5	1.8	1.4	2.2	0.3	2.8	24

7 STATUS OF SOIL EROSION

Due to high intensity of rainfall over a period of four monsoon months, variation in slope gradient and scarce vegetative cover, the problem of soil erosion by water is acute in Wakal basin. Existing field bunds on arable lands provide small protection against soil loss but it is not very effective to check the erosion because farmer does not construct it on contours due to small and scattered land holdings. The non arable lands having undulating topography are mostly eroded and degraded because of non availability of *in-situ* moisture conservation measures. Most of the runoff is passing through the valleys and in lower part of the area dominated by agricultural lands, which also cause erosion problem. In most of the part of Wakal basin erosion is severe (25-50 Tonnes/ha/yr) but in few areas problem of erosion is extremely severe (75 Tonnes/ha/yr). The soil erosion map of the basin is shown in Fig 11.

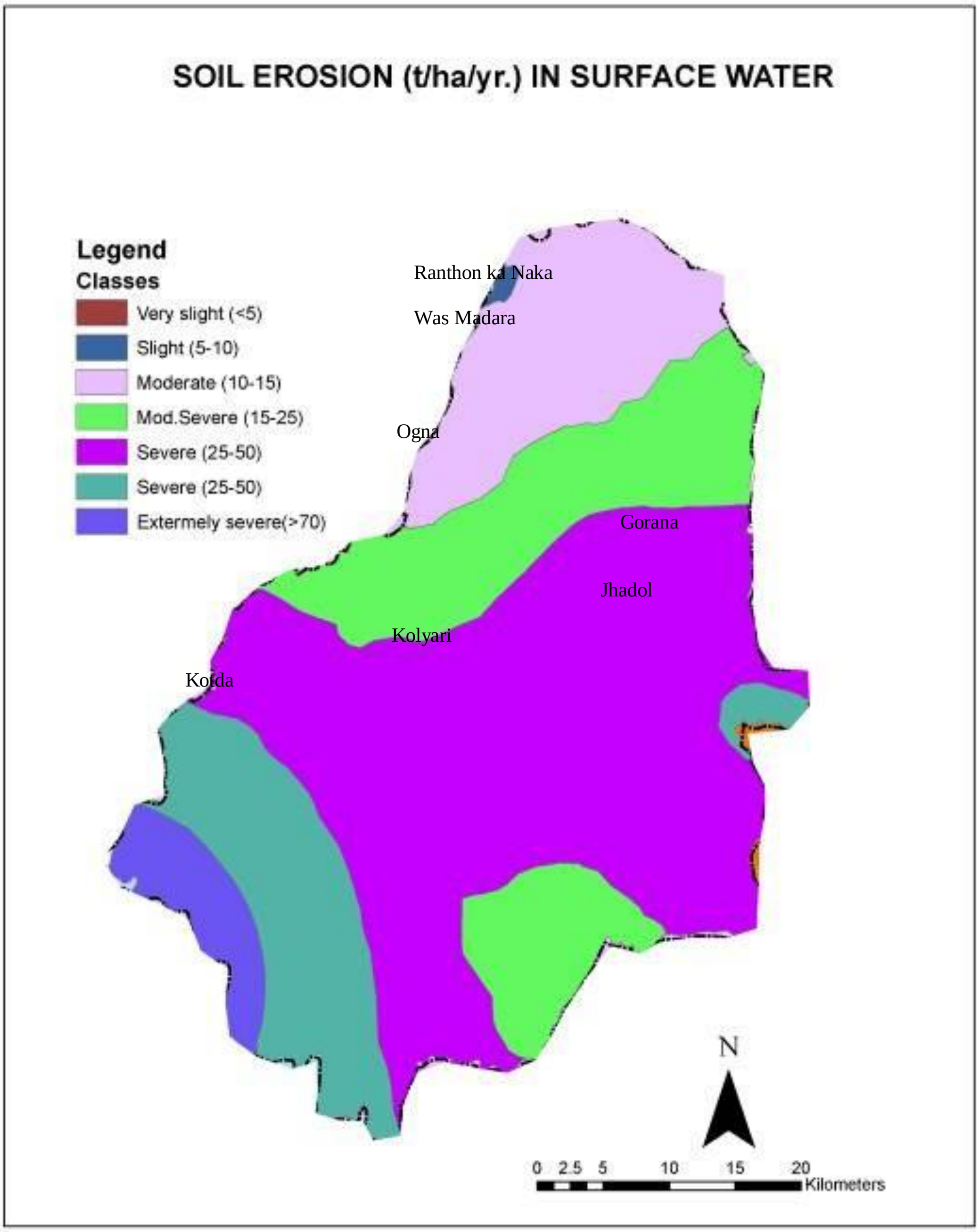

Fig. 11: Erosion map of the basin

8 CONCLUSIONS

- In Wakal river basin there are five raingauge stations which are located in Jhadol, Gorana, Ogna, Gogunda and Kotda.
- The daily rainfall data of last 15 years (1992-2006) were analyzed and it was found that the maximum weekly rainfall probability at 75per cent probability level is 105 mm.
- There is significant variation in the annual rainfall of Gogunda and Kotda while these variations are non significant for rest of three raingauge stations.
- Surface drainage of the area is generally good due to slight undulations in the topography. About 1,07,241 ha of the land falls under the slope group of 30 to 50%.
- The main tributaries of Wakal are Manshi and Pamri rivers. The total length of the basin is 71.22 km, whereas the maximum width is 41.01 km. The total catchment area of the basin is 1914.32 km^2.
- The whole area of the basin is divided in four land use classes viz. agriculture, open scrub, degraded forest and fairly dense forest.
- Most of the area of the basin falls under rocky soil group, in which soil depth and slope are the limiting factors. Average soil depth varies between 30 to 50 per cent.
- The percentage runoff varies from minimum 4.37 to maximum of 37.89 for the year 1999 and 2005 respectively. The maximum runoff yield of 714.73 million m^3 was found during the year 2006.
- In the Wakal River Basin 17 major rainwater harvesting structures were constructed. Mansi-Wakal Dam is the biggest dam constructed in the basin which is having the gross storage capacity of 863 MCFt.
- In Wakal river basin Anicuts, Sunkan pond/ Nadi and low cost dry stone masonry ponds are commonly used rainwater harvesting structures. The height of these structures is varies from 1m to 5m.
- The twelve standard parameters of water quality were analyzed to find out the suitability of surface water collected in the reservoirs. The TDS and EC were found highest in Jabli ka Naka reservoir (TDS - 1050 & EC - 3.14) followed by Manas reservoir (TDS – 629 & EC – 1.802). The BOD_5 and COD was found highest in Tindol ka Naka (BOD_5 4.6 and COD 42) whereas it was found lowest in Ranthon ka Naka (BOD_5 1.7 and COD 10).

- In most of the part of Wakal basin, erosion is severe (25-50 Tonnes/ha/yr) but in few areas problem of erosion is extremely severe (75 Tonnes/ha/yr).
- The erosion problem is extremely severe in the areas near Kotda and Kalakhetar where Wakal River joins to Sabarmati River.
- There is urgent need to check the erosion by providing treatment measures of the area using watershed approach.
- In Wakal River Basin surface rainwater harvesting seems to be the only alternative by which water scarcity problem can be mitigated and agricultural production can be increased.

9 RECOMMENDATIONS

- There is a need to find out causes of pollution of water storage tank situated at Jabli ka Naka because at this site TDS and EC are much high as compared to permissible limits.
- It is required to follow a suitable irrigation schedule for withdrawal of water through canals from the storage reservoirs for better scheduling and management of surface water and its availability throughout the year.
- The erosion rate of the Wakal basin is very high therefore, to check the siltation and also controlling erosion, there is an urgent need to put different kinds of vegetative as well as engineering measures.

Global Water for Sustainability Program

Florida International University

Biscayne Bay Campus

3000 NE 151St. ACI-267

North Miami, FL 33181 USA

Phone: (+1-305) 919-4112