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Research Paper

HYDROMETEROLOGICAL STUDY OF KUTHALERU RIVER BASIN, ANANTAPUR DISTRICT, ANDHRA PRADESH, INDIA

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The Kuthaleru River Basin comes under semi-arid zone. The rainfall data for 13 years (2001-02 to 2013-14) of the study area reveal that only four years (2001-02, 2007-08, 2008-09 and 2010-11) had sufficient rainfall and rest of the 9 years are drought-prone with varying intensities. Out of the 9 drought years, 3 years (2003-04, 2007-08 and 2008-2009) experienced disastrous type of drought and only 1 year (2002-03) comes under severe type. The rest of the six years have experienced moderate to slightly drought conditions. The area receives maximum amount of rainfall from southwest monsoon. The seasonal variations in the ground water also correlate with the data of the rainfall. The water level has shown a rise during November-December months due to the rainfall percolation during October to December months. The water levels start to decline from the month of February and reaches maximum in the month of June. This is mainly due to the depletion of rainfall and groundwater withdrawals for irrigation.

Keywords: Hydrometeorology, Rainfall ratio, Drought and hydrograph

INTRODUCTION

Geological factors, soils and vegetation influence the distribution of water. However, it is mainly weather and climate that form and sustain lakes and rivers create deserts and produce floods and droughts. This is because the source of all fresh water is the rain and snow, which falls from the clouds and the main loss of water, is what returns to the atmosphere through the process of evaporation. These are some of the facts of the hydrological cycle that accounts for the never-ending movement of water from the atmosphere to the ground by precipitation, then to rivers, lakes and underground reservoirs and to the sea. Most of the water vapor present in the atmosphere is derived from the salty seas by evaporation. The hydrological cycle is nature's great desalinization plant by which saline seawater is converted into water vapor and then into fresh waters that fall on the ground as rain, and snow.

STUDY AREA

The Kuthaleru River rises from Pulikunta hill ranges flows in a South-East direction and joins with Penna River. Kuthaleru River Basin (Figure 1), covering an area of 180 sq. km., in Anantapur District, lies between North latitude 14° 352 and 14° 472 and East longitude 77° 422 and 77° 512

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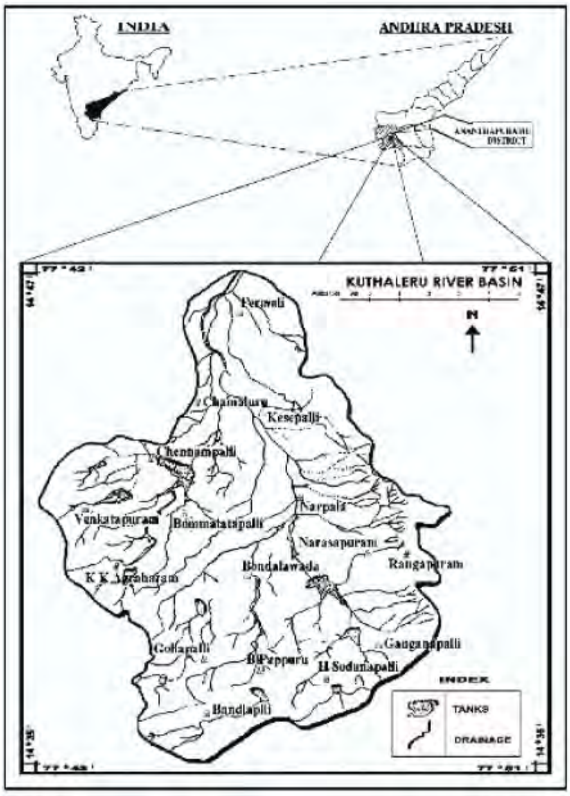
Figure 1: Location of the Study Area



in the Survey of India Toposheet No. 57 F/10, 13, 14.

METHOD

The rainfall data are collected from the Indian meteorological department of Anantapur and analyzing spatial distribution of the rainfall to know the hydro-meteorological conditions like type of drought in the study area by using the rainfall ratio mentioned by Bhargava.

RESULTS

Hydrometeorological Elements

Hydrometeorology is the science that deals with the application of meteorology to water problem. Hydro-meteorological conditions mainly deal with the climatalogical conditions, which affect groundwater of an area.

Climate

The area is a part of the chronically drought-affected district (Anantapur) of Andhra Pradesh lying in the semi-arid tract of the country and falling in the rain-shadow region of Peninsular India. The study area receives erratic and scanty rainfall. The normal rainfall map based on the four rain gauge stations in and around the area, indicates that the rainfall decreases from northeast to southwest from about 660 mm to less than 550 mm.

This area experiences hot summers and mild winters. November to February is the winter period for comfortable living. During December-January the temperature is the lowest touching 20 ^{o}C and during April-May the temperature shoots up to 42 ^{o}C. The onset of southwest monsoon during the first or second week of June brings down the temperature gradually. Humidity varies from 75 to 85% in rainy season and is almost dry (20 to 25%) during May and June.

Wind speeds are generally light to moderate, but become stronger during the southwest monsoon period. During this period the average wind velocity varies from 18 km/h to 28 km/h, whereas it lowers to 8 to 12 km/h during October and November (northeast monsoon period).

Precipitation

Groundwater has close relation to rainfall. Groundwater recharge over any region takes place as a result of a) lateral flow of groundwater from adjoining regions, b) percolation process in rivers, lakes canals, drains and other water courses in the region and c) infiltration of rain water into the ground. The contribution to groundwater from the first two sources is however, more or less a continuous process in varying magnitudes but slower than the rate of contribution from the third factor, if and when it operates.

Rainfall data is collected for four rainguage stations in and around the study area from the meteorological department of Anantapur. The minimum, maximum and mean rainfall data is presented for the four rainguage stations in Table 1. The monthly and annual rainfall data of the study area station from 2001-02 to 2013-14 is given in the Table 2. The deviation of rainfall from the mean annual rainfall is shown in Figure 2. The annual rainfall at study area station ranges from 1125 mm (in 2007-08) to 424 mm (in 2002-03) with a mean value of 615 mm. From Figure 2 it is observed that the rainfall is deviated positively the years 2002-03, 2007-08 and 2010-11, but it shows negative deviation in the rest of the eleven years. The minimum rainfall in the month of January and maximum in the months of August to September are noticed (Table 2). The southwest monsoon during June to August contributes to 62% of the rainfall. The northeast monsoon, which breaks in the month of September, brings 27% of rainfall until December (Tabel 3). The heavy rainfall is due to the cyclone depressions and storms caused in the Bay of Bengal during the period of northeast monsoon. Precipitation range distribution for 13 years (i.e., from 2001-02 to 2013-14) is given in the Table 4.

Table 1: Annual Rainfall Data in and Around the Study Area for 13 years (2001-02 - 2013-14)

S. No.	Year	Narpala (in mm)	Singanamala (in mm)	B. K. Samudram (in mm)	Putluru (in mm)
1	2001-02	727.2	563	760.6	724
2	2002-03	423.8	275.8	321	280
3	2003-04	610	362.2	498.2	621.8
4	2004-05	505.4	351	409	432.6
5	2005-06	642	475.4	742.6	711.8
6	2006-07	490.6	413.8	328.4	470
7	2007-08	1125.8	924	831.8	982
8	2008-09	708.8	879.8	966.4	777.2
9	2009-10	436.2	372.6	517.2	471.4
10	2010-11	725.4	663	730.6	712.2
11	2011-12	505.8	283.6	446.4	576.8
12	2012-13	505.4	359.6	434.4	555.4
13	2013-14	588.6	317.8	372	449.8
Maximum		1125.8	879.8	966.4	982
Minimum		423.8	275.8	321	280
Total		7995	6241.6	7358.6	7765
Mean		615	480	566	597.3

Table 2a: Monthly Rainfall of the Narpala Raingauge Station (2001-02 to 2013-14)

S. No.	Year	Normal	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Min	Max	Total	Mean
1	2001-02	577	28.4	9.4	104.8	309.4	219.8	8.4	--	--	--	--	6.6	40.4	0	309.4	**727.2**	**60.6**
2	2002-03	577	31.8	27.4	145.8	67.4	135.8	15.6	--	--	--	--	--	--	0	145.8	**423.8**	**35.3167**
3	2003-04	577	21.2	27.6	85	22	205	--	--	--	--	29	121.6	98.6	0	205	**610**	**50.8333**
4	2004-05	577	26	135.2	9.4	195.6	36.8	10	-	3.2	-	-	31.6	57.6	0	195.6	**505.4**	**42.1167**
5	2005-06	577	30	206	74.2	86.2	142.4	18.6	16.2	-	-	30.8	--	37.6	0	206	**642**	**53.5**
6	2006-07	577	69.2	14.2	18	207.8	61.2	86.8	--	--	--	--	6.2	27.2	0	207.8	**490.6**	**40.8833**
7	2007-08	577	290.4	72.2	173.4	399.8	71.8	1.2	--	--	32	39.4	--	45.6	0	399.8	**1125.8**	**93.8167**
8	2008-09	577	81.4	120.2	104.6	160.2	83.4	69	--	--	--	--	--	90	0	160.2	**708.8**	**59.0667**
9	2009-10	577	65.4	24.8	83.4	87	36.2	73.6	16	1	--	--	5.2	43.6	0	87	**436.2**	**36.35**
10	2010-11	577	74.2	145.2	155.2	48.2	98	100.4	2.6	--	--	--	37.4	64.2	0	155.2	**725.4**	**60.45**
11	2011-12	577	76.4	67	111.4	45.8	106	9	1.2	15.2	--	--	23.6	50.2	0	111.4	**505.8**	**42.15**
12	2012-13	577	17.6	97	162.4	71.8	55.6	55.6	13.2	--	2	--	8.6	21.6	0	162.4	**505.4**	**42.1167**
13	2013-14	577	31	74.8	33.2	304.4	48.6	2.4	--	--	--	31.6	21	41.6	0	304.4	**588.6**	**49.05**
		Total	**843**	**1021**	**1260.8**	**2005.6**	**1300.6**	**450.6**	**49.2**	**19.4**	**34**	**130.8**	**261.8**	**618.2**	**0**	**2650**	**7995**	**666.25**
		Mean	**64.85**	**78.54**	**96.98**	**154.3**	**100**	**34.7**	**3.8**	**1.5**	**2.6**	**10.1**	**20.1**	**47.6**	**0**	**203.85**	**615**	**51.25**

Table 2b: Monthly Rainfall of the Singanamala Raingauge Station (2001-02 to 2013-14)

S. No.	Year	Normal	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Min	Max	Total	Mean
1	2001-02	546	6.8	14.6	52	261.6	170.8	8.2	--	--	–	–	14.2	34.8	0	261.6	563	46.916667
2	2002-03	546	20.8	15	81.8	45.8	107.2	52	--	--	–	–	--	--	0	107.2	275.8	22.983333
3	2003-04	546	39.4	7.4	85.2	21	109.8	–	--	--	–	11.6	11.8	76	0	109.8	362.2	30.183333
4	2004-05	546	2.8	152	52	126.8	49.2	-	-	-	-	-	1	14	0	152	351	29.25
5	2005-06	546	44	80	48	105.4	103.6	14.6	5.6	-	-	29	--	45.2	0	105.4	475.4	39.616667
6	2006-07	546	82.4	12.4	21.6	103.6	76	58.6	--	--	–	–	10	49.2	0	103.6	413.8	34.483333
7	2007-08	546	147	117.2	203.4	275.8	70	–	--	--	4.6	66.6	--	39.4	0	275.8	924	77
8	2008-09	546	147	68.4	165.6	238	113.6	68.6	--	--	–	–	--	78.6	0	238	879.8	73.316667
9	2009-10	546	50.2	5.4	68.2	95	34.4	42.2	--	27.2	–	–	16	34	0	95	372.6	31.05
10	2010-11	546	109	190.6	114.6	62.8	79.8	50.8	2.2	0	–	–	15.6	37.6	0	190.6	663	55.25
11	2011-12	546	23.6	37.4	57	13.2	91.4	9.6	--	10.4	–	13.2	18	9.8	0	91.4	283.6	23.633333
12	2012-13	546	18.2	96.8	96	71.4	36.6	31	3.2	--	5.2	–	1.2	0	0	96.8	359.6	29.966667
13	2013-14	546	22.6	19.6	13.4	190.2	17.4	6.6	--	--	–	26.4	16.6	5	0	190.2	317.8	26.483333
		Total	713.8	816.8	1012	1610.6	1059.8	295.4	11	37.6	9.8	146.8	104.4	423.6	0	2017.4	**6241.6**	520.13333
		Mean	54.9	62.83	77.8462	123.89	81.523	22.72	0.85	2.89	0.75	11.3	8.031	32.58	0	155.185	**480.123**	40.010256

Table 2c: Monthly Rainfall of the B K Samudram Raingauge Station (2001-02 to 2013-14)

S. No.	Year	Normal	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Min	Max	Total	Mean
1	2001-02	544	12.4	8.2	80.2	306.6	265.8	4.6	--	4.2	–	–	--	78.6	0	306.6	760.6	63.383
2	2002-03	544	21.2	3.2	29.6	26.6	229.6	10.8	--	--	–	–	--	--	0	229.6	321	26.75
3	2003-04	544	8.6	19.8	65.8	80.4	150.8	–	--	--	–	4.2	15.4	153.2	0	153.2	498.2	41.517
4	2004-05	544	20.8	114.4	6	132	60.4	-	-	-	-	-	6	69.4	0	132	409	34.083
5	2005-06	544	72.6	128.6	150.2	115.4	123.8	24	6.4	-	-	37.2	8.4	76	0	150.2	742.6	61.883
6	2006-07	544	53.4	–	33.2	88	20	93.4	--	--	–	–	--	40.4	0	93.4	328.4	27.367
7	2007-08	544	151.4	49.4	202.8	222.8	42.2	3.4	--	--	–	109	--	50.8	0	222.8	831.8	69.317
8	2008-09	544	84.6	97.4	266.6	297	45.4	26	--	--	–	–	--	149.4	0	297	966.4	80.533
9	2009-10	544	35.2	5.2	58.8	155.6	69.4	72.4	--	28.6	–	–	16.6	75.4	0	155.6	517.2	43.1
10	2010-11	544	58.4	217	132.4	19.4	45.6	91.6	4.2	--	–	–	67.2	94.8	0	217	730.6	60.883
11	2011-12	544	84	91.2	83	15.4	121.8	5	--	--	–	7.4	37.4	1.2	0	121.8	446.4	37.2
12	2012-13	544	45.2	148	68.6	91.2	46	26.2	5.2	--	4	0	0	0	0	148	434.4	36.2
13	2013-14	544	63.4	38.6	–	234.4	10.6	–	--	--	–	14.6	6	4.4	0	234.4	372	31
		Total	711.2	921	1177.2	1784.8	1231.4	357.4	15.8	32.8	4	172.4	157	793.6	0	2461.6	**7358.6**	613.22
		Mean	54.708	70.846	90.55	137.3	94.72	27.492	1.215	2.523	0.308	13.262	12.077	61.046	0	189.4	**566**	47.171

Table 2d: Monthly Rainfall of the Putluru Raingauge Station (2001-02 to 2013-14)

S. No.	Year	Normal	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Min	Max	Total	Mean
1	2001-02	565	31.2	17.8	153.6	223.8	204.4	20	--	--	–	–	--	73.2	0	223.8	724	60.3333
2	2002-03	565	15.8	8.2	83.8	44.6	91.2	25.2	--	--	–	3.6	7.6	--	0	91.2	280	23.3333
3	2003-04	565	3.4	43.8	108.4	96.6	199.6	–	--	35.4	–	12.2	26.8	95.6	0	199.6	621.8	51.8167
4	2004-05	565	-	155.4	22.6	137	38.6	-	-	-	2.2	-	30.6	46.2	0	155.4	432.6	36.05
5	2005-06	565	29.2	148.4	59.2	180	202.8	21.2	12	-	-	8	16	35	0	202.8	711.8	59.3167
6	2006-07	565	117.8	–	32.2	151.2	102.2	22.6	--	--	–	–	15	29	0	151.2	470	39.1667
7	2007-08	565	245	26.2	184	295.2	78.8	4		--	–	86.4	--	62.4	0	295.2	982	81.8333
8	2008-09	565	71.8	42	209.6	155	152	28.8	--	--	–	–	7	111	0	209.6	777.2	64.7667
9	2009-10	565	50.2	–	74.2	159.6	27.8	103.4	--	10.6	–	–	12.4	33.2	0	159.6	471.4	39.2833
10	2010-11	565	82.2	160	132.2	50.8	138.4	90	8.4	--	–	–	13.2	37	0	160	712.2	59.35
11	2011-12	565	36.6	125.4	124	2	168	26.4	4.6	--	–	–	43.8	46	0	168	576.8	48.0667
12	2012-13	565	16	87.6	243.2	66.6	94	32	4	--	12	–	--	--	0	243.2	555.4	46.2833
13	2013-14	565	27.6	43.8	46	229.4	39.4	9.2	--	--	–	36.8	8	9.6	0	229.4	449.8	37.4833
		Total	726.8	858.6	1473	1791.8	1537.2	382.8	29	46	14.2	147	180.4	578.2	0	2489	**7765**	647.083
		Mean	55.91	66.05	113.3	137.83	118.2	29.45	2.231	3.538	1.092	11.308	13.877	44.477	0	191.5	**597**	49.7756

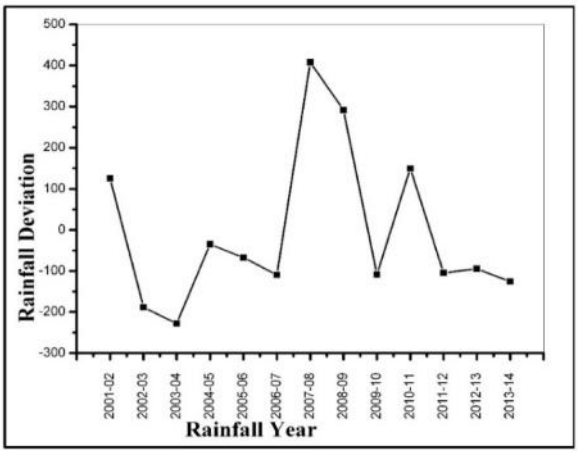
Table 3: Percentage Precipitation in the Study Area (in mm)

S. No.	Period	Percentage of Precipitation
1	South-west Monsoon (Jun, Jul, Aug and Sept.)	58.88%
2	North-east Monsoon (Oct, Nov and Dec.)	27.33%
3	Torential (Hot) Weather (Feb to May)	11.62%

Table 4: Precipitation Range Distribution of Study Area (in mm)

S. No.	Range	No. of Years
1	<500	3
2	500 – 600	4
3	600 –700	2
4	700 – 800	3
5	800 – 900	-
6	900 – 1000	-
7	>1000	1

Figure 2: The Deviation of the Rainfall from the Mean Annual Rainfall



Rainfall Ratio

According to Bhargava (1977) the rainfall ratio is defined as the abnormalities in the occurrence of rainfall at any location. It can be obtained from the formula given below:

$$Rainfall\ \ Ratio = \frac{Px - Pmx}{Pn} \times 100$$

where

Px = Maximum yearly rainfall

Pm = Minimum yearly rainfall

Pn = Average yearly rainfall

The high rainfall ratio indicates high abnormalities, whereas low ratio indicates greater stability of rainfall. The rainfall ratio of the study area shows very high values (i.e., 26 to 666) denoting that there is much variation in annual rainfall from the normal rain of year (Table 5). It confirms the erratic nature of rainfall in the study area.

Table 5: Rainfall Deviation and Rainfall Ratiofor the Study Area

Rainfall Deviation and Rainfall Ratio for the Study Area			
Year	Deviation	% of Deviation	Rainfall Ratio
2001-02	126	22.5	476
2002-03	-188.25	-33.75	520
2003-04	-228	-41	382
2004-05	-35	-6.75	418
2005-06	-67.5	-24	267
2006-07	-109.75	-24	388
2007-08	408	72.75	371
2008-09	292.25	53	306
2009-10	-108.75	-19.5	331
2010-11	149.75	27	302
2011-12	-104.75	-19	323
2012-13	-94.5	-16	369
2013-14	-125.75	-23	666

DISCUSSION

Identification of Drought Types

The Indian Meteorological Department (IMD) has taken deviation from the mean annual rainfall for describing the drought intensity. It is considered that if the deviation

From the mean lies between

10% and 20% — Slightly Drought

20% and 30% — Moderate Drought

30% and 40% — Severe Drought and

above 40% — Disastrous

From the Table 2 it is observed that in the 13 years period only four years (2001-02, 2007-08, 2008-09 and 2010-11) are positive and rest of the 9 years are drought-prone with varying intensities. Out of the 9, 3 years (2003-04, 2007-08 and 2008-2009) experienced disastrous type of drought with more than 40% of deviation from the mean annual rainfall. Only 1 year 2002-03 comes under severe type with 34% and the rest of the six years have experienced moderate to slightly drought conditions.

WATER TABLE CHARACTERISTICS

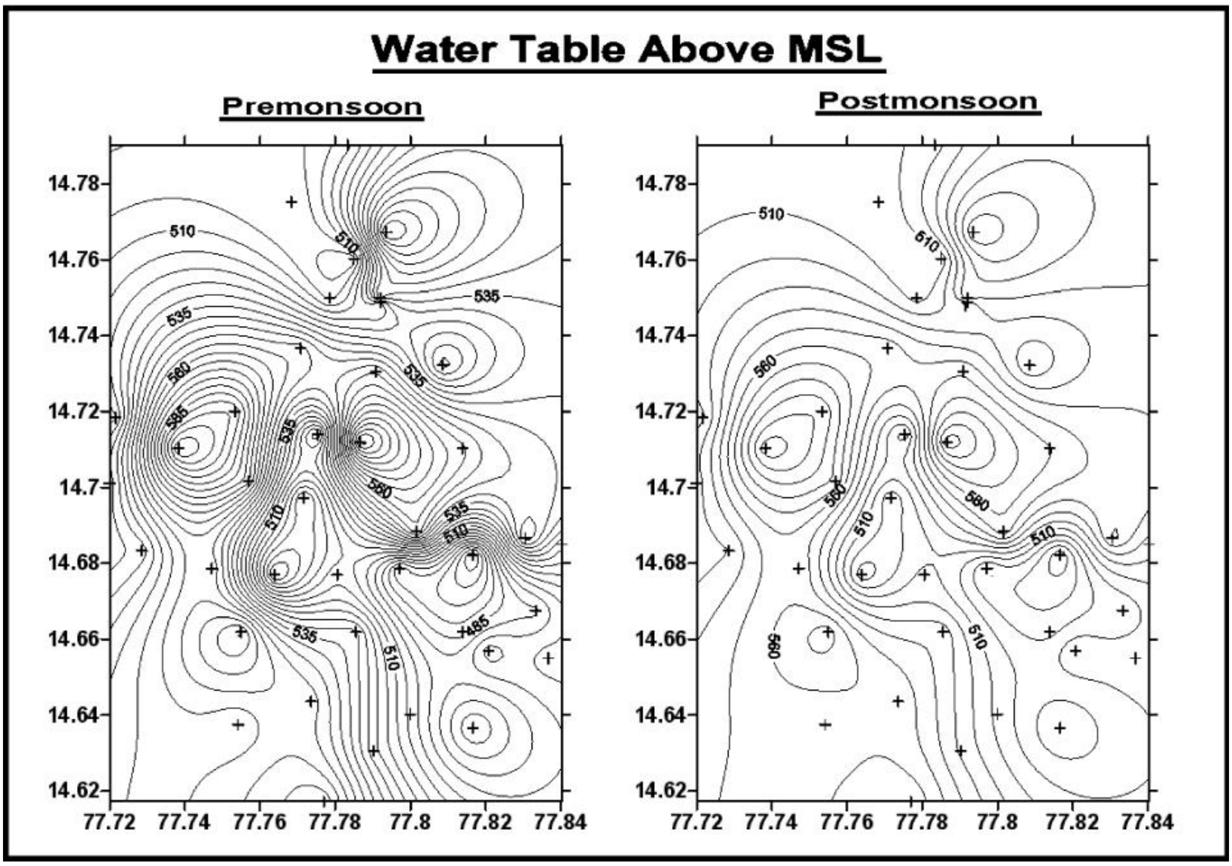
The movement of groundwater in the weathered and fractured rocks is dependent on the degree of inter-connecting interstices, topography, and conditions of recharge and discharge. The thickness of the zone of saturation is also dependent on the said factors. The zone of saturation generally follows the configuration of the topography of the area. In general, the water level starts to rise from the month of July, and continues up to December depending on the amount of precipitation, while it starts to decline from the month of January and continues up to the end of June.

An inventory of 40 wells in the study area enables us to understand the hydrodynamic characteristics of the study area. The depth to

Table 6: Water Table Fluctuations of the Study Area (in m.)

S. No.	Location	Well Depth	Water Table in Pre-Monsoon	Water Table in Post-Monsoon	Difference in Water Table
		(in m.)	Above MSL	Above MSL	(in m.)
1	Peravali	8	499.6	503.8	4.2
2	Peravali	6	513.2	515.8	2.6
3	Chamaluru	9	500.2	503.6	3.4
4	Chamaluru	6	496.2	500.8	4.6
5	Niluvarai	10	503.2	506	2.8
6	Nadimidoddi	8	577	580.6	3.6
7	Nadimidoddi	11	546.9	551	4.1
8	Kesepalli	8	514.5	517.8	3.3
9	Kesepalli	11	555	558.8	3.8
10	Chennampalli	10	553.2	557.4	4.2
11	Chennampalli	12	594.4	598.2	3.8
12	Narpala	7	604.4	608.8	4.4
13	Narpala	8	506.6	509.8	3.2
14	Narpala	6	556.2	560.8	4.6
15	Bommalatapalli	9	572.4	577.6	5.2
16	Venkatapuram	10	611.4	617.2	5.8
17	Venkatapuram	9	514.2	517.4	3.2
18	Venkatapuram	11	521.8	524.9	3.1
19	K KAgraharam	8	526.9	529.7	2.8
20	Sanjivapuram	10	554.3	558.9	4.6
21	Sanjivapuram	12	477.2	482.4	5.2
22	Bondalawada	11	487.8	492.6	4.8
23	Bondalawada	8	509.1	513.2	4.1
24	Dugumarri	9	554.8	557.8	3
25	Dugumarri	7	475.2	478	2.8
26	Narasapuram	6	457.5	460.4	2.9
27	Narasapuram	9	550.7	553.2	2.5
28	Rangapuram	11	521	524.7	3.7
29	Jangam	12	488.7	492.6	3.9
30	Ganganapalli	8	502.7	505.9	3.2
31	Thumpera	11	482.4	486.7	4.3
32	Thumpera	19	503.4	509.2	5.8
33	H Sodanapalli	10	474.1	478.9	4.8
34	H Sodanapalli	8	503.6	507.2	3.6
35	B Pappuru	16	521.6	527.8	6.2
36	Malavandlapalli	14	531.7	536.1	4.4
37	Gollapalli	18	571.4	575.2	3.8
38	Gollapalli	8	553	557.2	4.2
39	SiddeCherla	14	544.8	550.4	5.6
40	Bandlapalli	12	564.3	568.9	4.6
Min.		6	474.1	478	2.6
Max.		19	611.4	617.2	6.2

Figure 3: Water Table Fluctuation Map of the Study Area



water table is recorded for all the wells. The altitude of the wells is determined by using GPS. While collecting the data, sufficient care is taken to avoid perched aquifers. The water table levels are recorded during the pre-monsoon (June, 2012) season and post-monsoon (January, 2013) seasons (Table.6). The fluctuations in the water table levels are represented in the form of iso-contour map (Figure 3).

The water table contours indicate that the direction of the groundwater flow is in concentric manner, i.e., flow direction towards the central portion, coinciding with topography. Depth to water table ranges from 474.1 to 611.4 m in pre-monsoon and from 478.0 to 617.2 m in post-monsoon seasons. The fluctuations in water table levels vary from 2.6 to 6.2 m with a mean value of 4.01 m. Most of the wells present in the study area are large diameter dug wells with depths varying from 6 to 19 m.

Water level variations in the study area depend on the amount of precipitation, influent and effluent nature of the streams, geology of the area, slope and infiltration capacity of the soils. The seasonal variations in the ground water also correlate with the data of the rainfall. The water level has shown a rise during November -December months due to the rainfall percolation during October to December months. This clearly reveals that there is a net recharge of groundwater due to the influence of rainfall only. The water levels start to decline from the month of February and reaches maximum in the month of June. This is mainly due to the depletion of rainfall and groundwater withdrawals for irrigation.

The fluctuations in the water table level have direct relationship with rainfall in the study area. The factors like intensity of rainfall and its variation with time and place, temperature, surface and sub-surface soil characteristics and vegetation cover play an important role in the water level fluctuations besides topography.

HYDROGRAPH

The hydrograph of mean water level data for igneous (granites) rocks show that the water levels were falling from November 2001 to May 2005. The water levels were in steadily improving from May 2007 to June 2010, then once again falling from November 2010 to May 2014 in the study area (Figure 4).

The monthly water table levels in observation wells of the study area for a period of 13 years (2001-02 to 20013-14) correlate with the monthly values of rainfall data for four stations (Figures 5-8). The hydrographs of each mandal prepared with mean depth to water levels of constituent villages show similar pattern and water levels exhibit a decline trend in all the mandals though at varying rate and with different water level disposition in the study area.

Continuous steady fall in water levels is noticed in B.K.Samudram mandal hydrograph from 5 m in November 2001 to 18 m in August 2006, and again declining from September to May 2014 (Figure 5). The hydrograph of Singanamala mandal, which is represented by highest number (27) of observation wells, is having relatively lesser fluctuation than other mandals (Figure 6). The water levels in general have between 5 and 10 m range. Steep fall in water levels has

Figure 4: Hydrograph of the Study Area

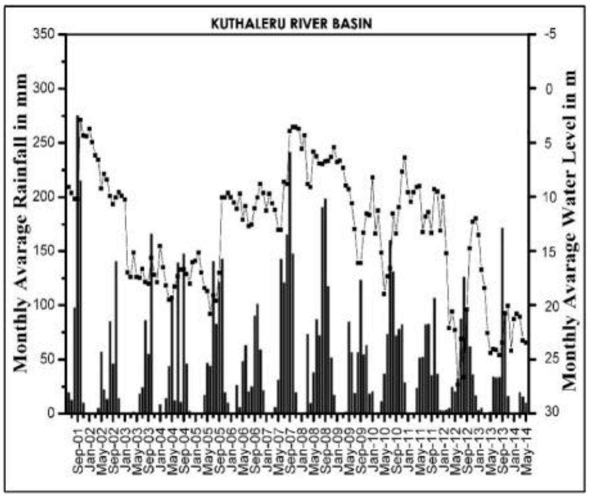
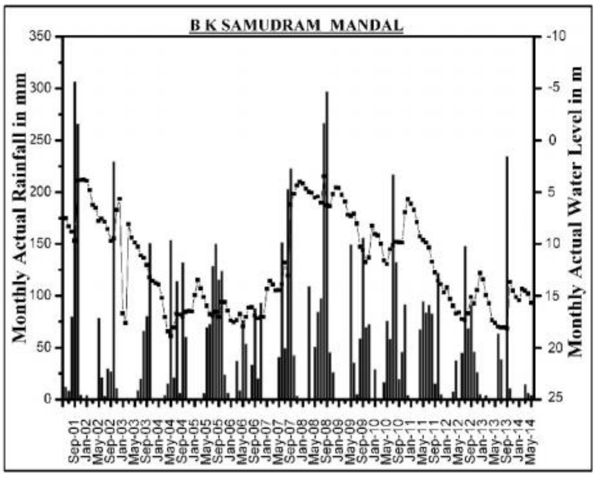


Figure 5: Hydrograph of the B K Samudram Mandal Area



occurred between May 2005; in June 2012 and in June to September 2013 in Putluru mandal (Figure 7). The Narpala mandal, which has canal command and underlain by granite formation, exhibits fall in water levels from 4 to 16 m in the same period (Figure 8). Same trend was observed by Reddy in 2012 for B.K.Samudram, Singanamala and Narpala mandals.

Water Level in Relation to Rainfall

The water levels have direct bearing to the

Figure 6: Hydrograph of the Singanamala Mandal Area

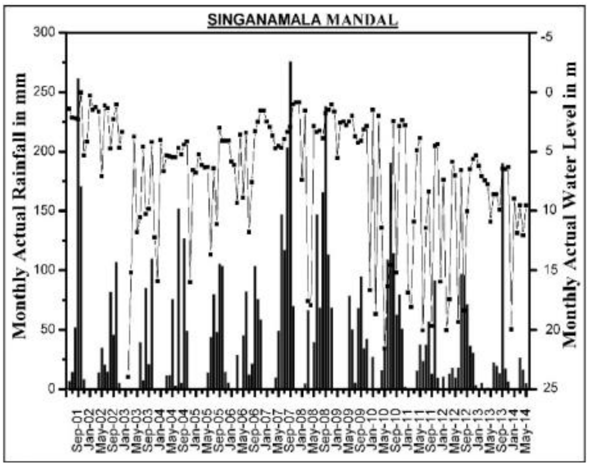


Figure 7: Hydrograph of the Putluru Mandal Area

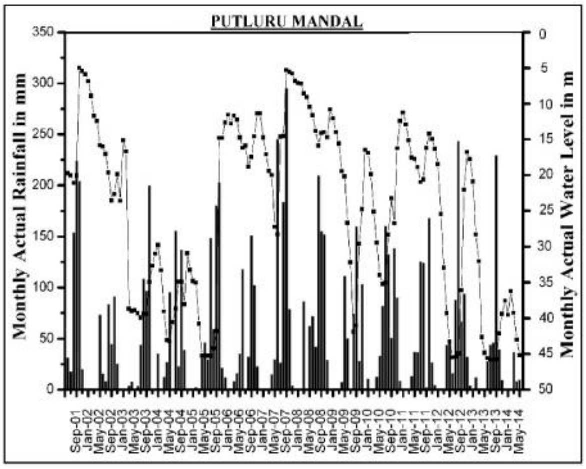


Figure 8: Hydrograph of the Narpala Mandal Area

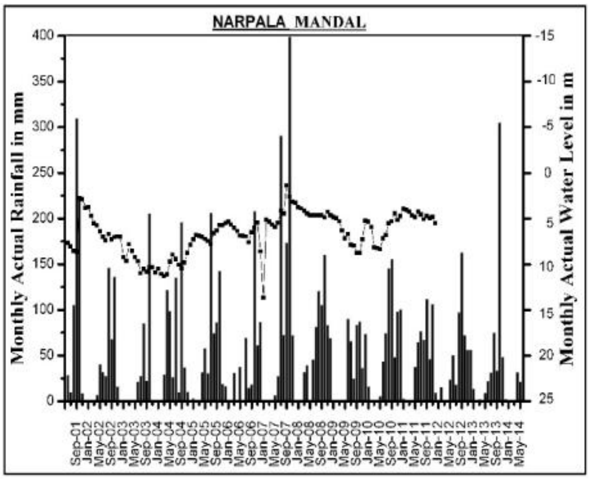
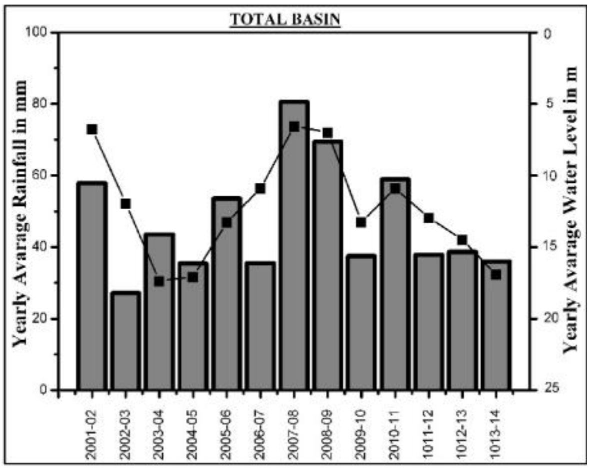


Figure 9: Yearly Hydrograph of the Study Area



incidence of precipitation as it is the maximum contributor of water to the aquifers. Response of water levels to the incidence of rainfall varies depending on the various hydrodynamic properties of the underlying rock formations. The occurrences of heavy rains result in flood and also improvement in groundwater system (Varadaraj, 2006). The groundwater levels of a well may rise sharply when rain starts falling in the watershed of the well. The monthly rainfall and water level data plots indicate positive correlation and quick response to incidence of rainfall. The wells of Narpal manadal, which represent granite terrain, show a raise of 8 m from September to October 2001 in response to 300 mm rainfall in September 2001 (Figure 8). Decreasing rainfall led to steady fall in water level in following months. The wells of B.K.Samudram show a similar trend and water levels have not only stabilized but also increased in response to rainfall of 200 to 220 mm between August and September months of 2008 (Figure 5). In the years 2002-03 and 2003-04 for the of annual rainfall of about 450 mm the shallow (minimum) water levels were consistent but the deeper water levels (maximum) resulted in a steep fall of 15 m which could be due to increasing extraction through bore wells from deeper aquifer for irrigation (Figure 9). Rddy (2012) observed that the deeper water level conditions and its declining feature is directly related to groundwater development in the form of increased agriculture activity, reduced area under rain-fed crops, high horticulture development.

The increase of rainfall in 2008-09 has resulted in stabilizing the deeper water levels and raising shallow water level by 2 to 6 m. Good amount of rainfall helps in rising or stabilizing water levels by enhanced recharge and reduces dependence on groundwater.

CONCLUSION

The study area comes under semi-arid zone. The rainfall data for 13 years (2001-02 to 2013-14) of the study area reveal that only four years (2001-02, 2007-08, 2008-09 and 2010-11) had sufficient rainfall and rest of the 9 years are drought-prone with varying intensities. Out of the 9 drought years, 3 years (2003-04, 2007-08 and 2008-2009) experienced disastrous type of drought with more than 40% of deviation from the mean annual rainfall. Only 1 year 2002-03 comes under severe type with 34% and the rest of the six years have experienced moderate to slightly drought conditions. It is also observed that the water table gradually increases during the June to December (post-monsoon) and decreases during January to June (pre-monsoon). The fluctuations in water table vary from 2.6 m to 6.2 m with a mean value of 4.01 m. The area receives maximum amount of rainfall from southwest monsoon. The seasonal variations in the ground water also correlate with the data of the rainfall. The water level has shown a rise during November-December months due to the rainfall percolation during October to December months. This clearly reveals that there is a net recharge of groundwater due to the influence of rainfall only. The water levels start to decline from the month of February and reaches maximum in the month of June. This is mainly due to the depletion of rainfall and groundwater withdrawals for irrigation. Wide variations in water levels in space and time could be due to uneven distribution of rainfall, varied hydro-geological setup and different aquifer characteristics.

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