3rd International Conference on Hydrology & Meteorology
(September 15-16, 2014)

Application of Hydrological and Water Table Data for Preparing Water Budget Model for Mahi-Narmada Inter-stream Area, Gujarat

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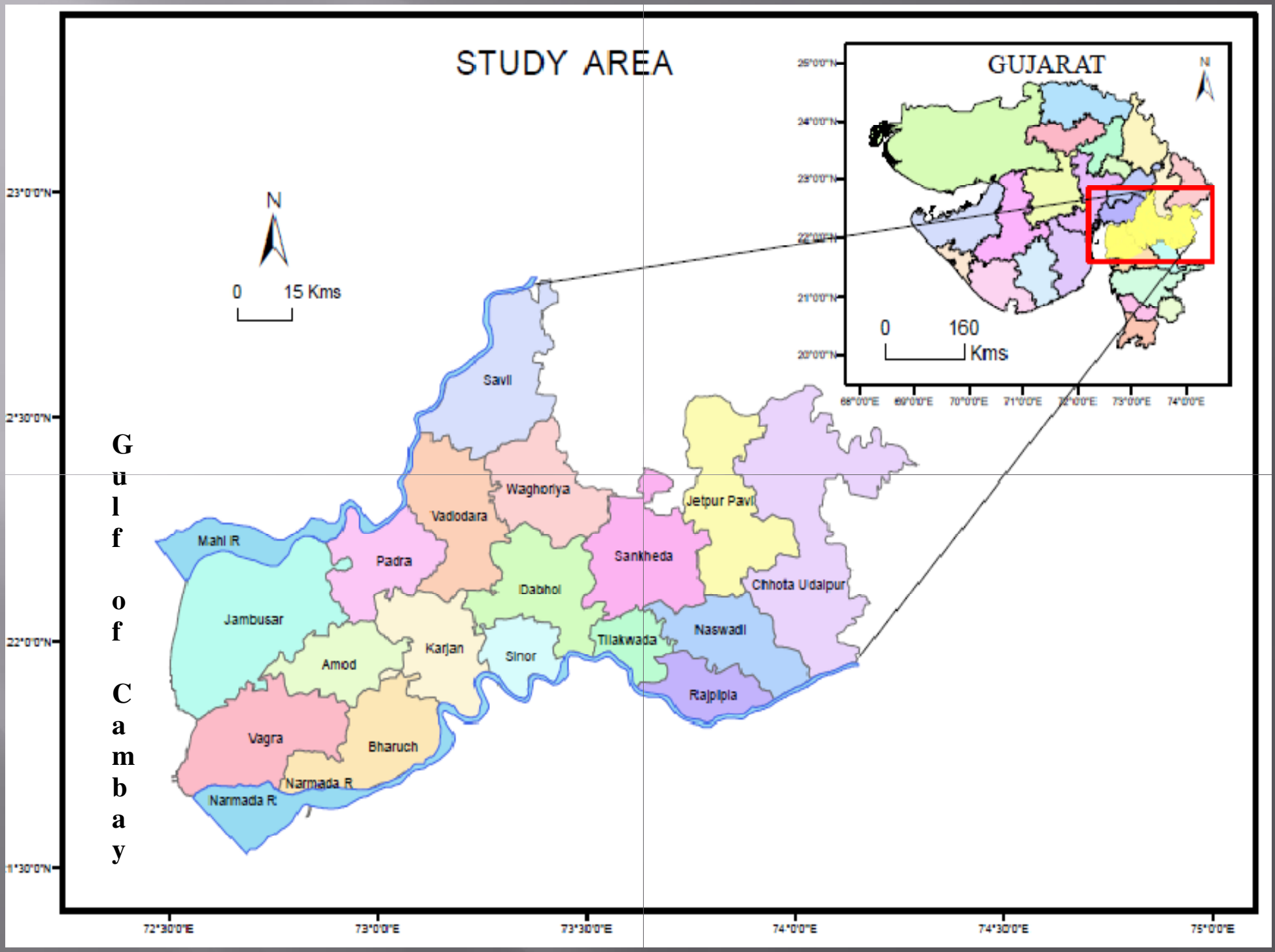
STUDY AREA
GUJARAT
N
0 15 Kms
0 160 Kms
Kms
Savli
Waghoriya
Vadodara
Jetpur Pavi
Mahi R
Padra
Sankheda
Dabhoi
Chhota Udaipur
Jambusar
Naswadi
Tilakwada
Amod
Karjan
Sinor
Rajpipla
Vagra
Bharuch
Narmada R
Narmada R
Gulf of Cambay
23°0'0"N
22°30'0"N
22°0'0"N
21°30'0"N
72°30'0"E
73°0'0"E
73°30'0"E
74°0'0"E
74°30'0"E
75°0'0"E
25°0'0"N
24°0'0"N
23°0'0"N
22°0'0"N
21°0'0"N
20°0'0"N
68°0'0"E
69°0'0"E
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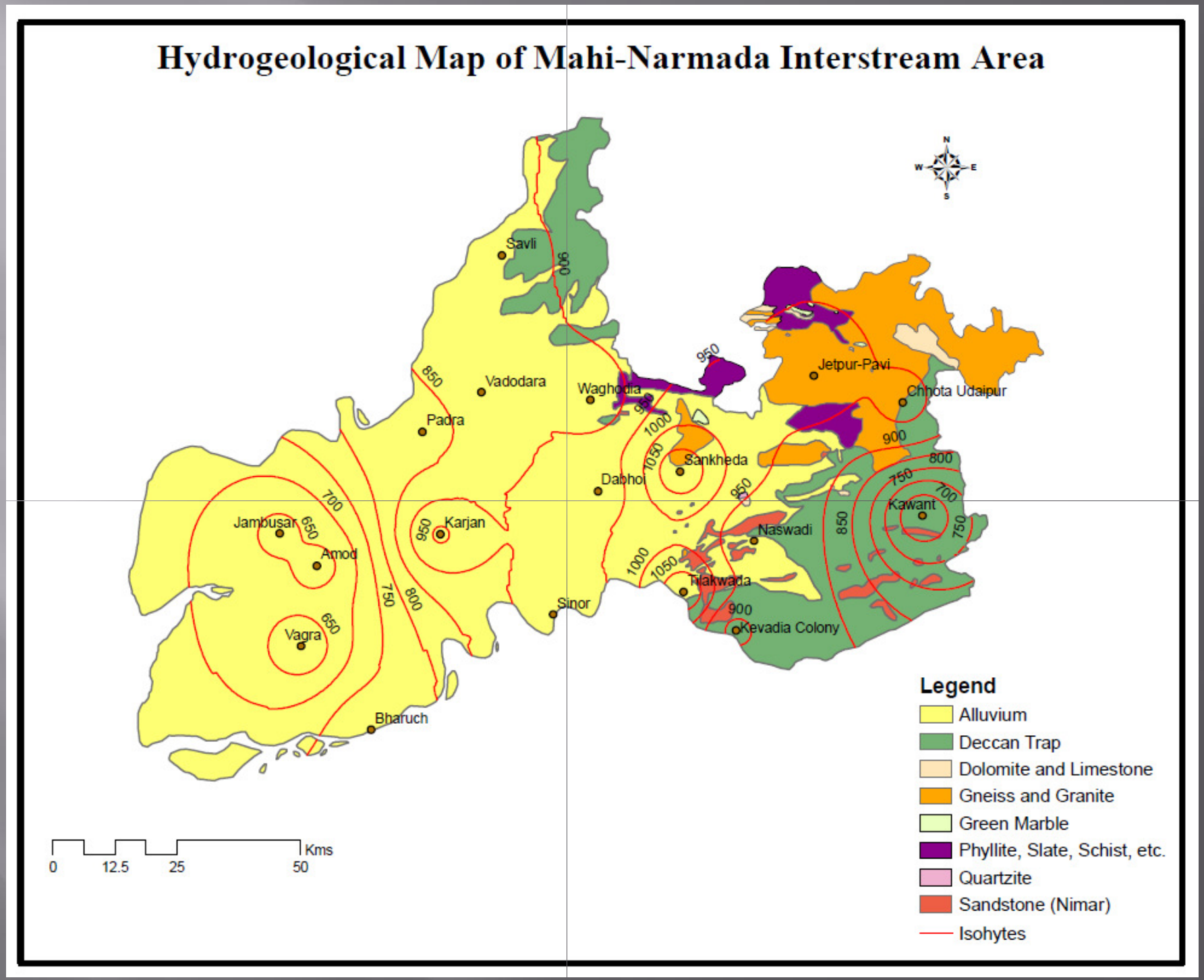
71°0'0"E
72°0'0"E
73°0'0"E
74°0'0"E


Hydrogeological Map of Mahi-Narmada Interstream Area
N
W
E
S
Savli
900
Vadodara
850
Waghodia
950
Padra
1000
1050
Sankheda
Dabhoi
Jetpur-Pavi
Chhota Udaipur
900
800
750
700
Kawant
850
750
Naswadi
950
Jambusar
650
700
Amod
Karjan
950
750
800
Vagra
650
Sinor
1000
1050
Tilakwada
900
Kevadia Colony
Bharuch
Legend
Alluvium
Deccan Trap
Dolomite and Limestone
Gneiss and Granite
Green Marble
Phyllite, Slate, Schist, etc.
Quartzite
Sandstone (Nimar)
Isohytes
0
12.5
25
50
Kms

Geological information

- The region under study; comprises of huge thickness of marine, fluvial and aeolian sediments deposited during the Quaternary period. These sediments consist of intercalations of sand, silt, clay and gravel fractions with the perceived development of clacretised bands.
- These Quaternary deposits, serve as an ideal repository for groundwater in unconfined, semi-confined and confined conditions.
- Geomorphologically the region is mainly, flat terrain which include within itself, recent mudflats, river mouth bars, beach sand ridges, raised mudflats, older alluvial plains, and bets that are formed under fluvial marine environment.
- The coastal belt also shows development of ravines which continues along the banks of Mahi and Narmada rivers in upper reaches.
- The Eastern part of the study area is covered by hard rocks consisting of Deccan Trap, Granite, Gneiss, Quartzite, Phyllite, Slate, Schist, Marble, Sandstone, Dolomite and Limestone.

Rainfall

- SW monsoon from June to September & retreating Monsoon during November month is the main rainfall in the region.
- The average rainfall data for 42 years i.e. from 1961 to 2003 is 858.99 mm
- The main ground water recharge component in the study area is rainfall
- The average maximum rainfall for the study area comes out to be 1699.50mm while lowest is 389.79mm.

(A) Groundwater Recharge by Government Agencies

CGWB, GWRDC and Narmada, water Resources & WS & Kalpsar Department has worked extensively to bring out detail regarding 'Estimation of Groundwater Resources and Irrigation potential in Gujarat state'. The report consists of district wise detail about groundwater assessment. Taluka-wise groundwater recharge is estimated by using the following equation (GWRDC, 1992):

$$\mathbf{Re = (A \times \Delta h \times Sy) + (DW - Rs - RigW - Ris) + Rs + Ris}$$

Where,

Re – Monsoon recharge

A – Area suitable for groundwater recharge (in Sq.kms)

Δh – Change in storage of groundwater between pre & post monsoon (in mts)

Sy – Specific yield formation (%)

DW – Groundwater draft during monsoon (in MCM)

Rs – Recharge from canal seepage during monsoon (in MCM)

RigW – Recharge from recycled groundwater in monsoon (in MCM)

Ris – Recharge from recycled surface water in monsoon (in MCM)

Based on CGWB reports, detail regarding the groundwater recharge in different talukas following in the study area is given in the subsequent Tables.

IMPORTANT OBSERVATIONS

1. The recharge from rainfall during monsoon season comes out to be 1106.63 MCM in the year 1991 and 927. 45 MCM in 2004. Jambusar taluka has not been taken into computational analysis in the year 2004 as the area has been considered into saline category.

2. Since the rainfall in the study area is mainly confined to monsoon period hence recharge during non-monsoon period is considered as zero.

3. In the year 2004, apart from rainfall, recharge from other sources during monsoon season is 92.70 MCM while during non-monsoon season is 151.82 MCM. The higher value of recharge from other sources during non-monsoon period is due to fact that area has extensively being used for irrigation.

4. Talukawise Vagra, Tilakwada, Savli, Chhota-udepur, and Naswadi have more recharge from other sources during monsoon compared to non-monsoon period.

5. Therefore, after computing total recharge from rainfall and from other sources during monsoon and non-monsoon period for the year 2004 the value comes out to be 1171.97 MCM. But due to natural discharge during monsoon and non-monsoon period the net annual groundwater availability comes out to be 1113.36 MCM.

Groundwater resource of the study area for the year 1991

Sr. No.	Assessment		Total Groundwater recharge in MCM/Yr	Utilisable Groundwater recharge in MCM/Yr	Gross Groundwater Draft in MCM/Yr	Net Draft in MCM/Yr (70 % of total draft)	Groundwater balance in MCM/Yr	Level of Groundwater development in %	Category
	District	Taluka							
1	2	3	4	5	6	7	8	9	10
1	Bharuch	Amod	30.05	25.54	35.9	25.13	0.41	98.4	Dark
2		Vagra	30.55	25.96	5.24	3.67	22.3	14.14	White
3		Bharuch	38.01	32.3	24.87	17.4	14.91	53.86	White
4		Nandod	108.28	92.04	34.45	24.11	67.93	26.2	White
5		Jambusar	7.57	6.43	9.65	6.75	-0.32	104.97	White
6	Vadodara	Sinor	78.82	66.99	48.95	34.26	32.73	51.14	White
7		Padra	105.22	89.44	78.95	55.26	34.17	61.78	White
8		Savali	70.24	59.7	42.63	29.84	29.86	49.98	White
9		Jambugam	73.21	62.22	52.68	36.87	25.35	59.25	White
10		Karjan	102.04	86.73	75.02	52.51	34.22	60.54	White
11		Chhota-udepur	73.72	62.66	33.92	23.74	38.92	37.88	White
12		Dabhoi	148.45	126.18	81.3	56.91	69.27	45.1	White
13		Sankheda	48.56	41.27	28.04	19.62	21.65	47.54	White
14		Vadodara	92.44	78.57	95.65	66.95	11.62	85.21	Dark
15		Waghodia	34.57	29.38	15.9	11.13	18.25	37.88	White
16		Tilakwada	22.61	19.22	3.85	2.7	16.52	14.05	White
17		Naswadi	42.29	35.95	9.31	6.52	29.43	18.13	White
	Total		**1106.63**	**940.58**	**676.31**	**473.37**	**467.22**	**67.47**	

Source: Complied from Govt. Data, 1992

Groundwater resource of the Study area for the year 2004

Sr. No.	Assessment		Recharage from rainfall during monsoon season	Recharge from other sources during monsoon season	Recharge from rainfall during non monsoon season	Recharge from other sources during non monsoon season	Total Annual Groundwater Recharge (4+5+6+7)	Natural Discharge during non monsoon season	Net Annual Ground water availability (8-9)
	District	Taluka							
1	2	3	4	5	6	7	8	9	10
2	Bharuch	Amod	28.21	1.43	0	286	32.50	1.63	30.87
3		Vagra	7.01	0.11	0	0.09	7.21	0.36	6.85
4		Bharuch	35.28	1.02	0	2.03	38.33	1.92	36.41
5		Jambusar	SALINE						
6	Narmada	Tilakwada	15.39	2.08	0	0.15	17.62	0.88	16.74
7		Nandod	11.26	2.97	0	9.04	23.27	1.16	22.11
8	Vadodara	Sinor	71.34	6.37	0	7.55	85.26	4.26	81.00
9		Padra	103.19	6.93	0	8.84	118.96	5.95	113.01
10		Savali	66.77	4.43	0	3.90	75.10	3.76	71.34
11		Pavi Jetpur	39.36	13.29	0	52.57	105.22	5.26	99.96
12		Karjan	145.15	8.64	0	16.00	169.80	8.49	161.31
13		Chhota-udepur	33.42	15.40	0	9.72	58.54	2.93	55.61
14		Kavant	27.77	1.39	0	1.75	30.90	1.55	29.35
15		Dabhoi	110.53	6.14	0	13.35	130.02	6.50	123.52
16		Sankheda	52.53	7.79	0	9.43	69.75	3.49	66.26
17		Vadodara	86.87	9.69	0	9.74	106.30	5.31	100.99
18		Waghodia	61.63	2.04	0	3.53	67.20	3.36	63.84
19		Naswadi	31.74	2.98	0	1.27	35.99	1.80	34.19
	Total		**927.45**	**92.70**	**0**	**151.82**	**1171.97**	**58.61**	**1113.36**

Source: Compiled from Govt. Data, 2004

Stage of Groundwater Development

The stage of groundwater development along the coastal belt is computed using the following relations (CGWB, 2004):

$$\text{Stage of GW Development (\%)} = \frac{\text{Gross Ground Water Draft for all uses}}{\text{Net availability of groundwater}} \times 100$$

Stage of Groundwater development

Sr. No.	Stage of Groundwater Development (Percentage)	Water Level Trend	Category
1	<70	Groundwater levels during the last decade does not show a falling trend in water level in any of the period (pre and post monsoon)	Safe/White
2	>70≤90	Water level during only one of the period (Pre monsoon or Post Monsoon) show a falling trend. If no declining trend is observed in the water levels the unit is classified as **Safe**.	Semi-Critical /Grey
3	>90≤100	Both Pre monsoon or Post Monsoon show a declining trend. If declining trend is observed only in one of the period of monitoring the unit is classified as **Semi-Critical**.	Critical
4	>100	The stage of groundwater development is more than 100% and water level during either of period or during both the period show a falling trend.	**Over Exploited**

Over Exploited		Critical		Semi-Critical		Safe		Saline	
1991	2004	1991	2004	1991	2004	1991	2004	1991	2004
Jambusar			Amod	Amod		Bharuch	Bharuch		Jambusar
						Vagra	Vagra		

B) Water Table Fluctuation/Specific Yield Approach Based on Decadal Average Water Table Fluctuation

This approach is widely accepted one and considered to be the most realistic as this encompasses all factors of the terrain and reflect actual contribution from recharge to the groundwater system. The equation to compute groundwater recharge is -

$$R = A \times Sy \times (h_1 - h_2)$$

Where,
R= Groundwater Recharge
A=Area under evaluation
Sy=Specific yield of aquifer
h_1=Post Monsoon groundwater level
h_2=Pre-monsoon groundwater level

Area Under Evaluation (A):

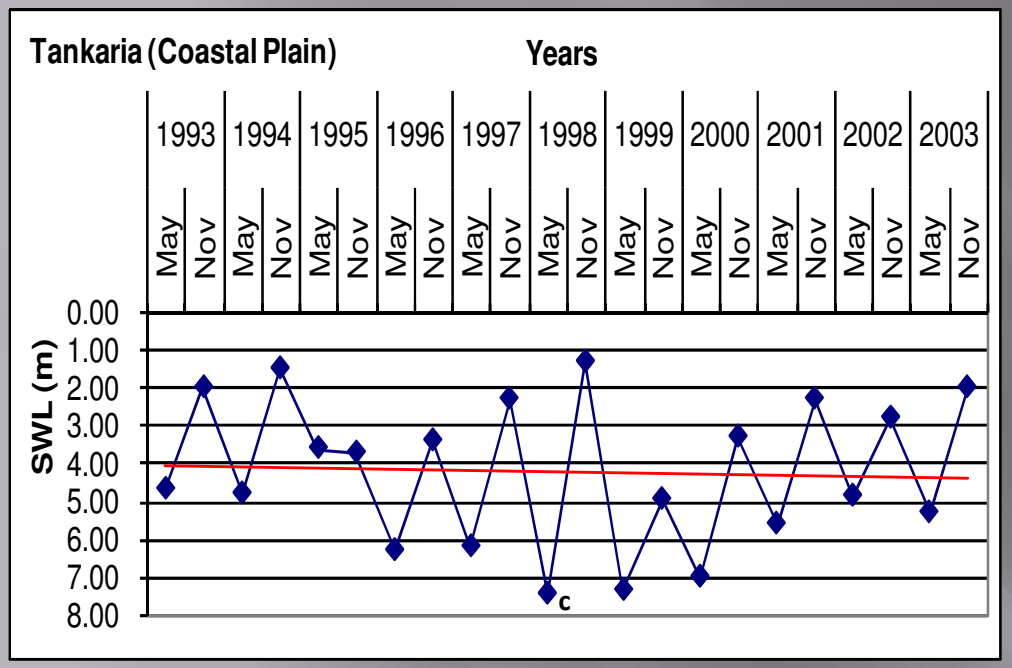
The study area comprises both consolidated and unconsolidated formations. Out-crops of the consolidated formations is mainly confined to the eastern parts of the study area. Whereas, central and western parts are dominated by unconsolidated sediments. Further, at places within the consolidated formations there exits pockets of unconsolidated sediments viz. colluvium and of flood plain deposits. The study area sprawls for about 11101.49 km^2.

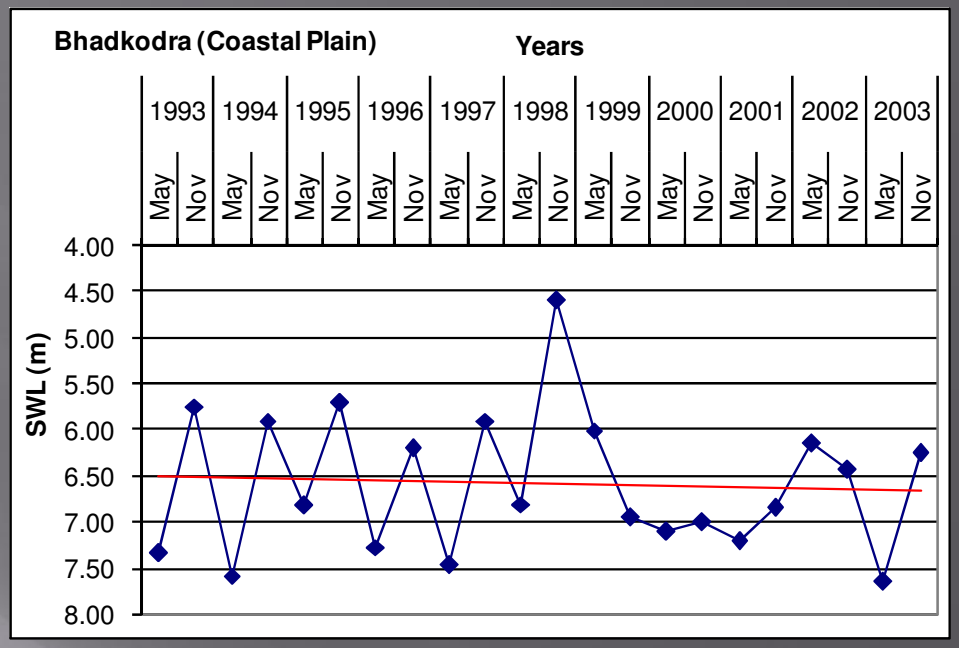
Specific Yield (S_y):

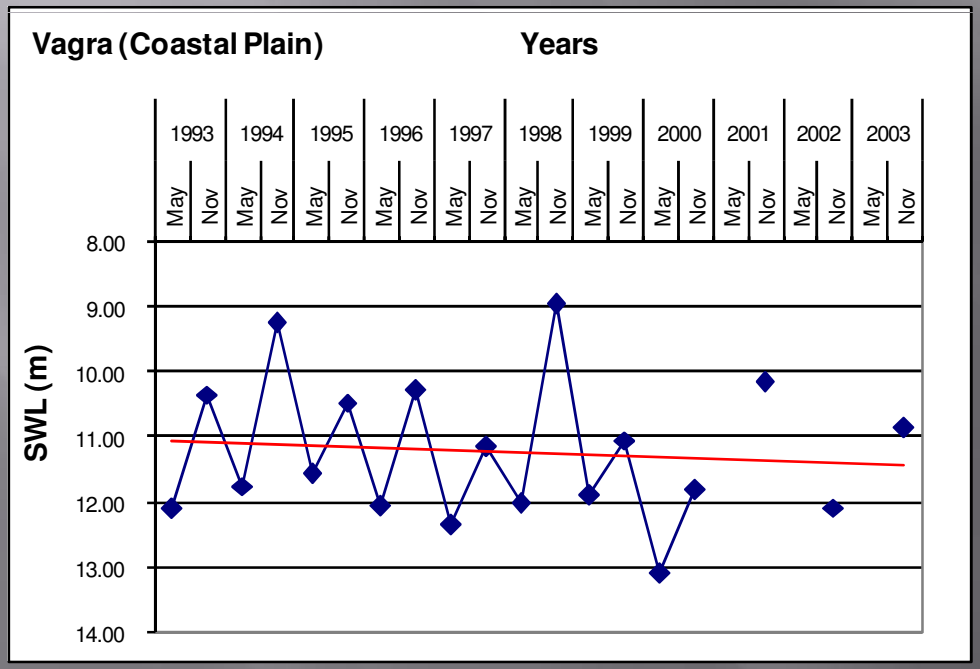
- The specific yield is the ratio of the volume of water that, after saturation, can be drained by gravity to its own volume in water table type of aquifer.
- S_y in the study area depend mainly on grain size, shape, interstitial ratio, compaction of the stratum and time of drainage.
- In unconsolidated sediments the observed heterogeneity in sediment's characteristics, level of compaction and abundance of clay fractions has considerably reduced the specific yield.
- Specific yield values for different formations adopted for the Heran river basin (Tiwari, 1986) are; Metamorphic (3%), Sandstone (2.5%), Basalt (2.5%) and alluvium (10-12%).
- In hard rock area the basic hydraulic properties i.e. porosity and hydraulic conductivity have been modified due to the effect of metamorphism caused by intensive magmatic activities and the rock mass has become more compacted (Dabral, 2009).
- For present study specific yield data have been adopted from GWRDC which is based on pump test results obtained for different formations. Details about the formation specific Sy within the study area are given in Table.

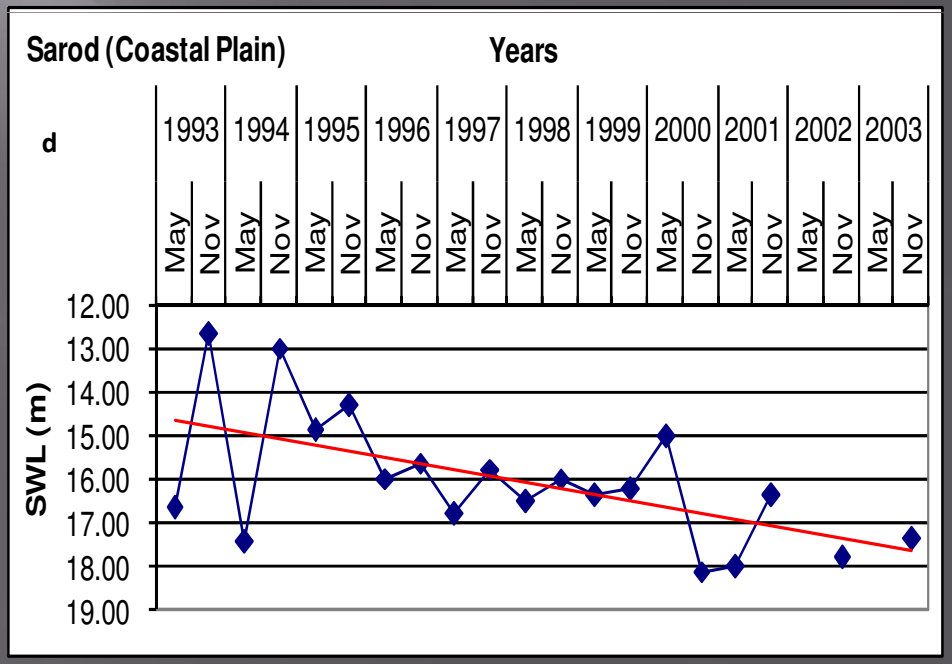
Water Table Fluctuation in Relation to Geo-environment

- In study area water levels from the year 1993-2003 have been studied for it's pre and post monsoon fluctuations.
- The fluctuation values were compared with the corresponding rainfall to deduce the sensitivity of the aquifer to rainfall.
- As the recharge to the aquifers is rainfall dependent, overall water levels are lowest in the month of May (Pre-monsoon) whereas higher in November (Post-monsoon).
- Rainfall begins in the month of June and maximum water level is acquired in October, thereby infiltration is by and large poor especially in alluvium area. In order to develop clear understanding of seasonal behavior of water levels for litho-specific aquifers, well hydrographs has been constructed by considering 1993-2003 pre and post monsoon water levels. Almost all well hydrographs show strong correlation with the rainfall input.

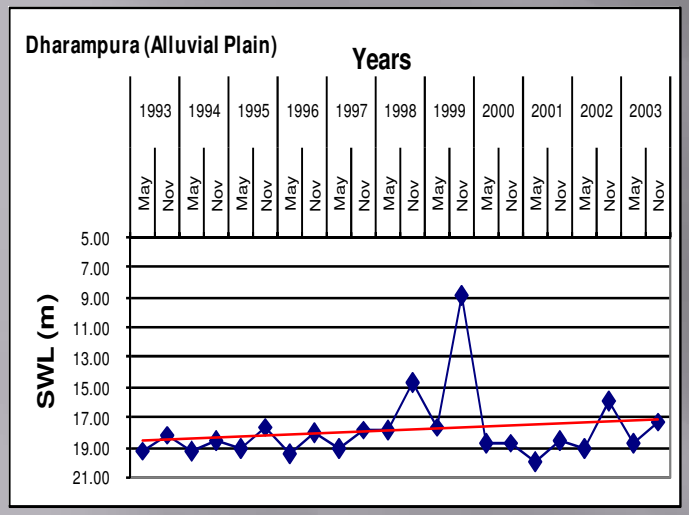


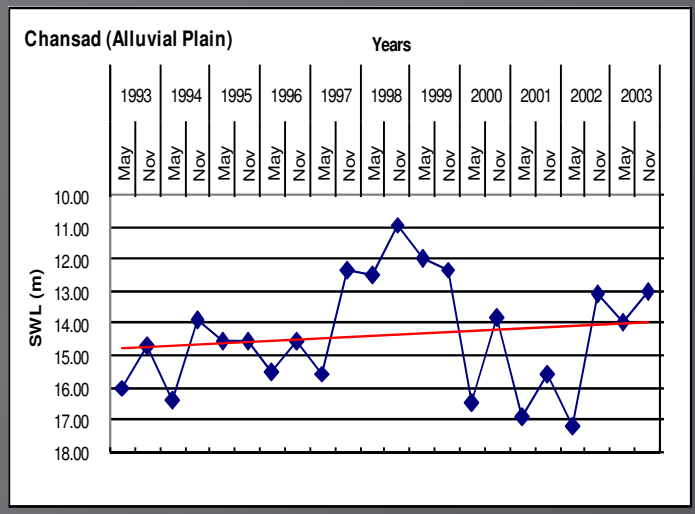


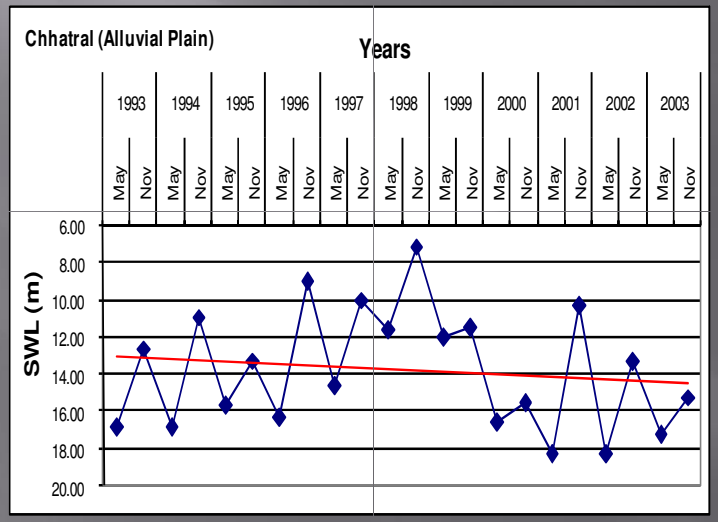


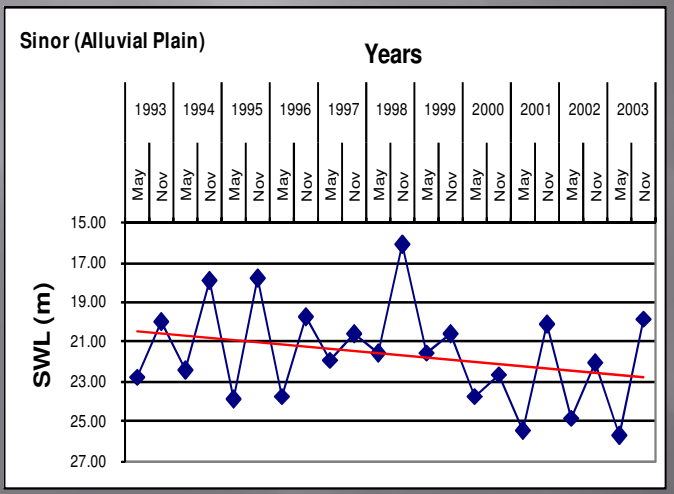


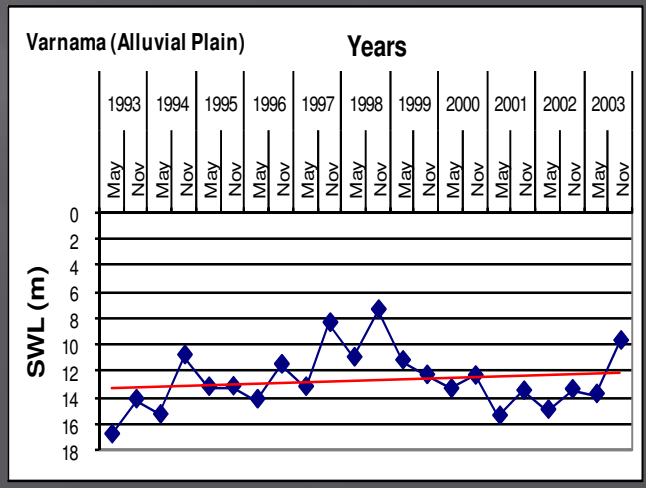
Well Hydrographs of Coastal Plains



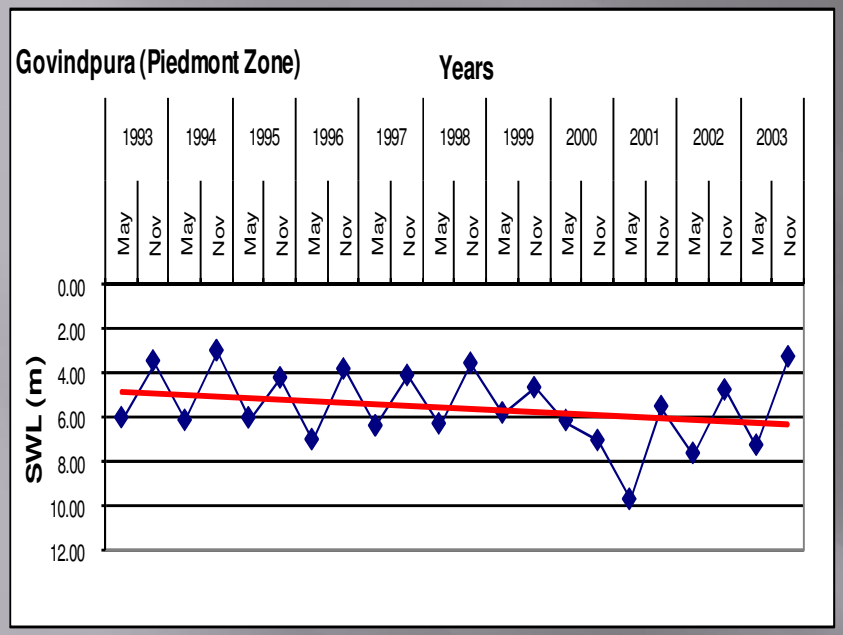


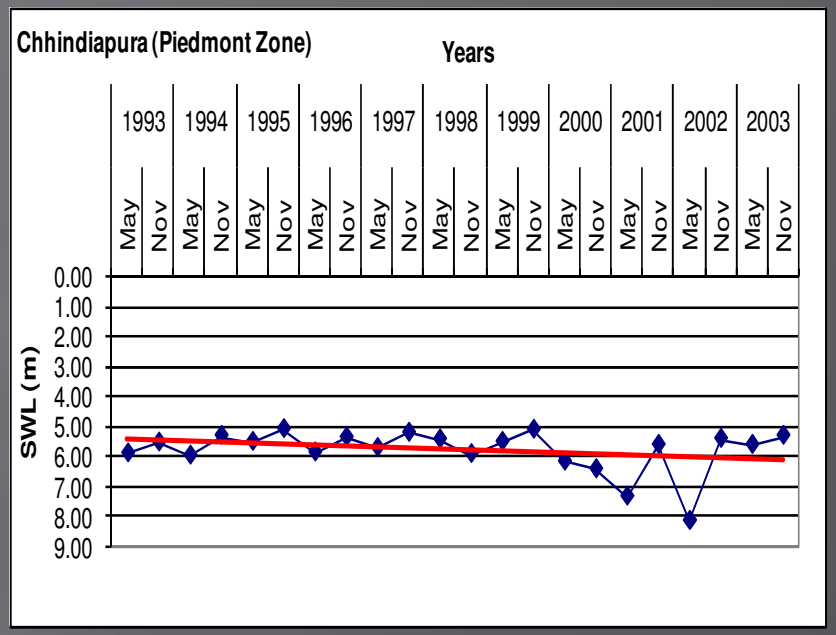


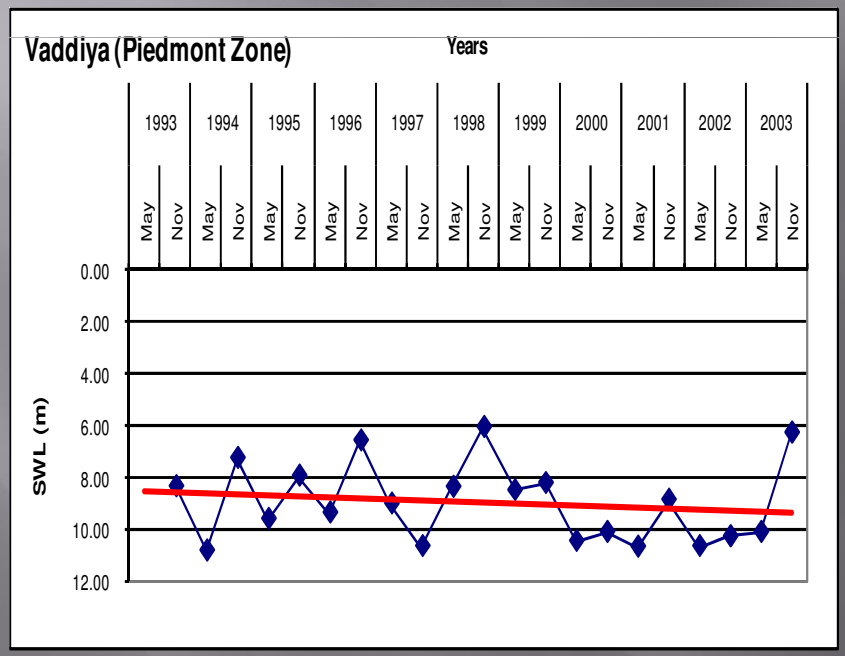


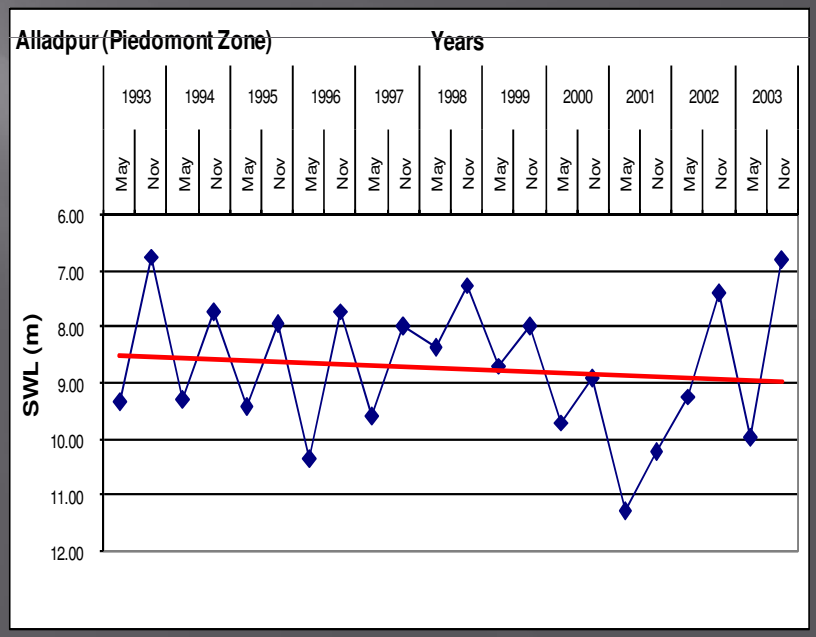


Well Hydrographs of Alluvial Plains.

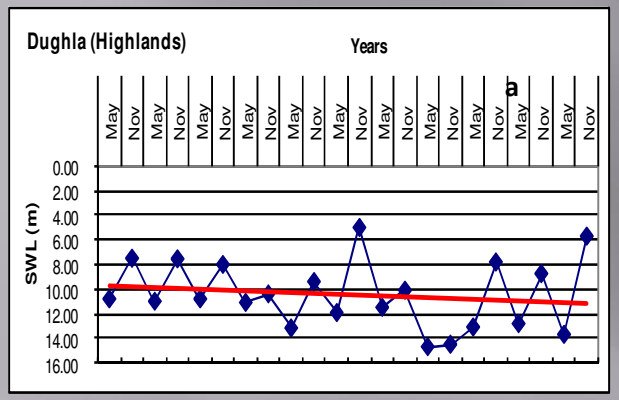


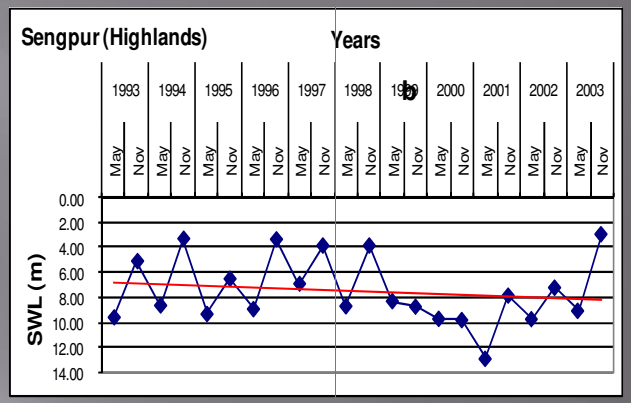


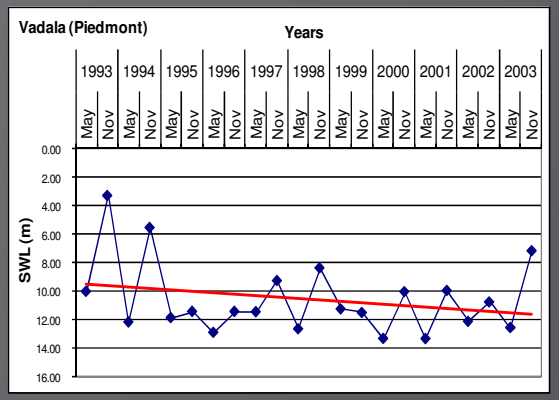


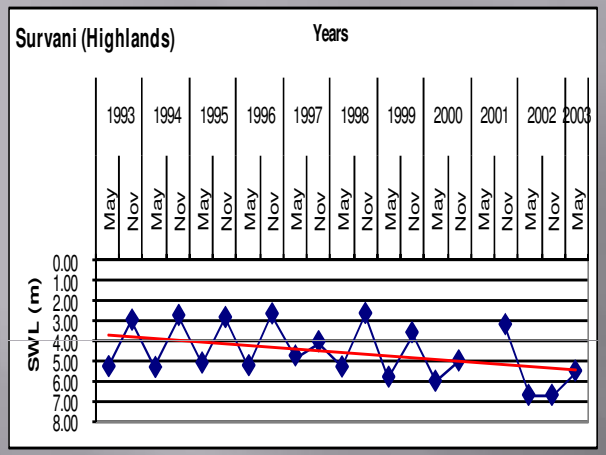


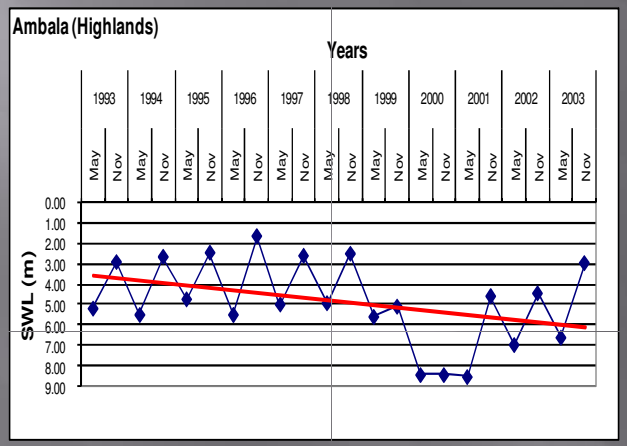
Hydrographs of Piedmont Zone

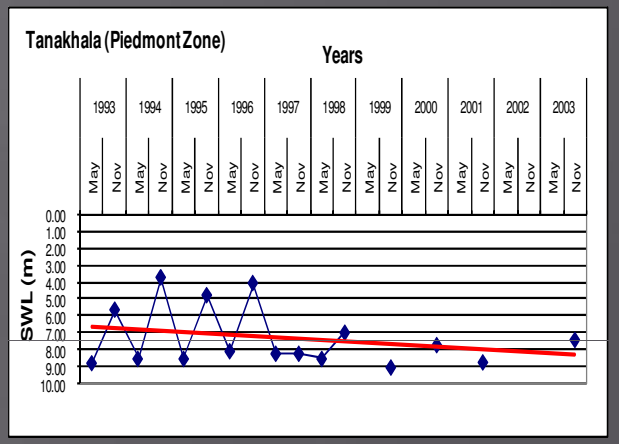


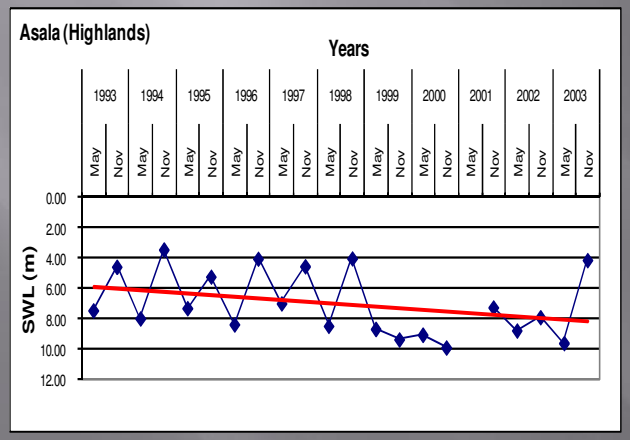


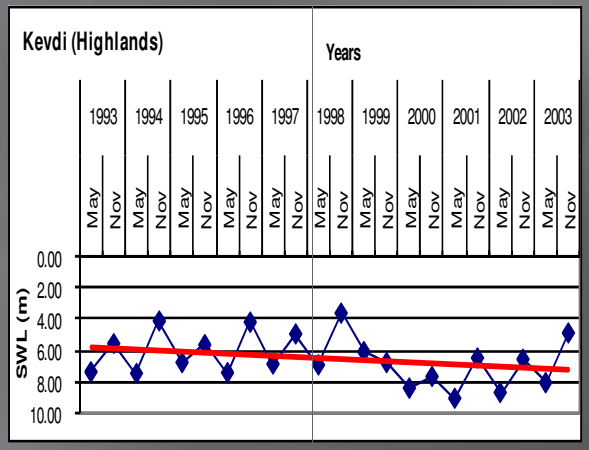


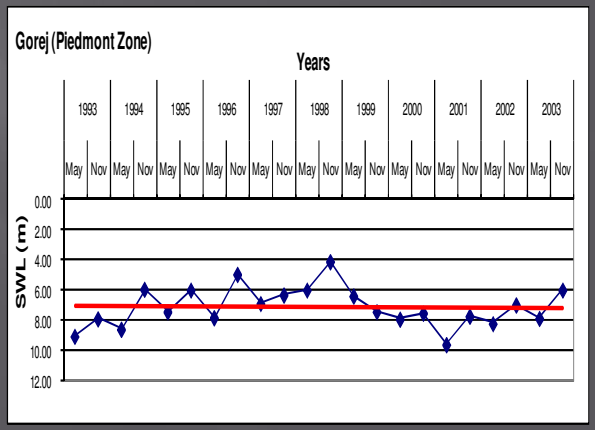




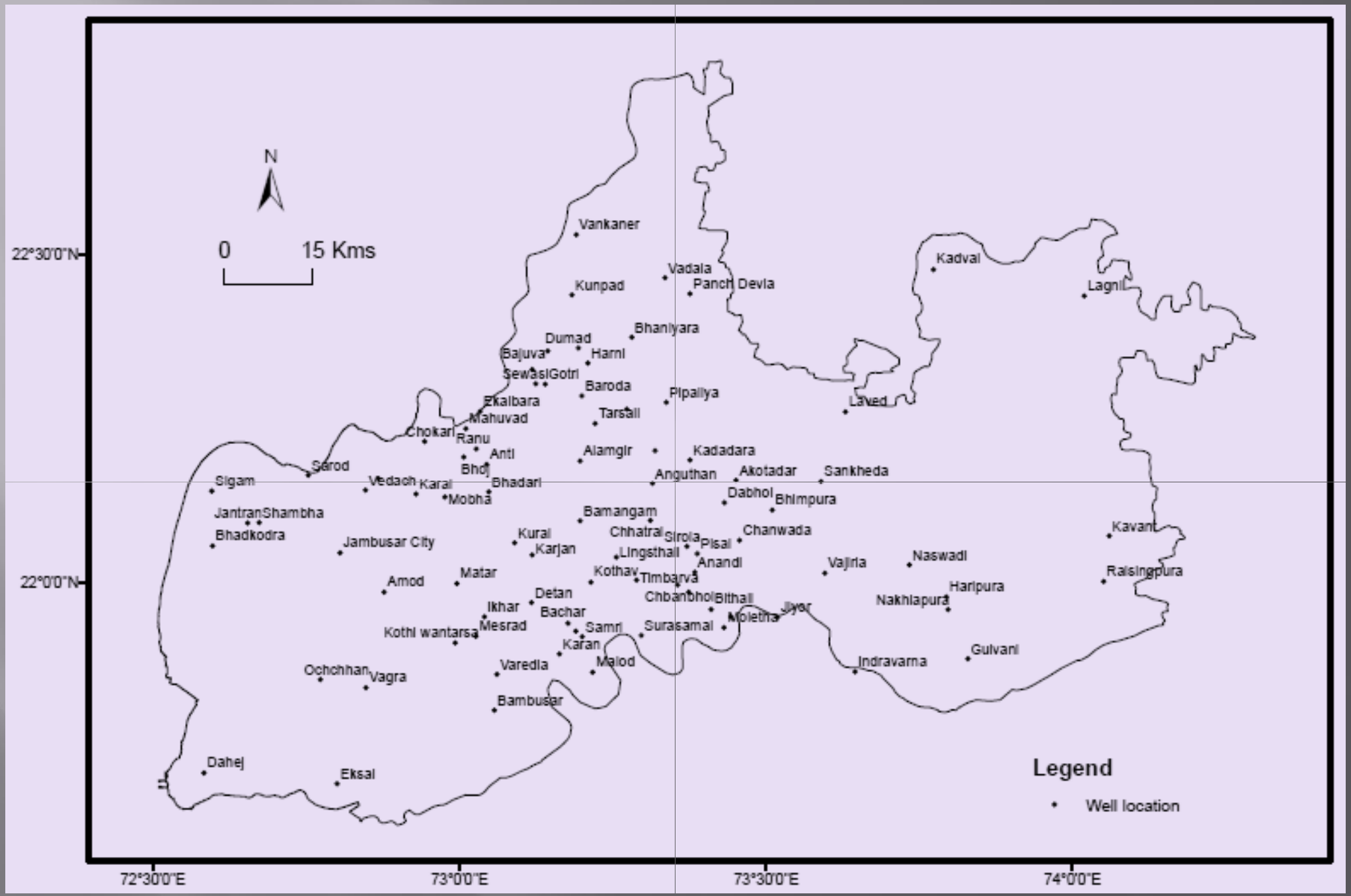




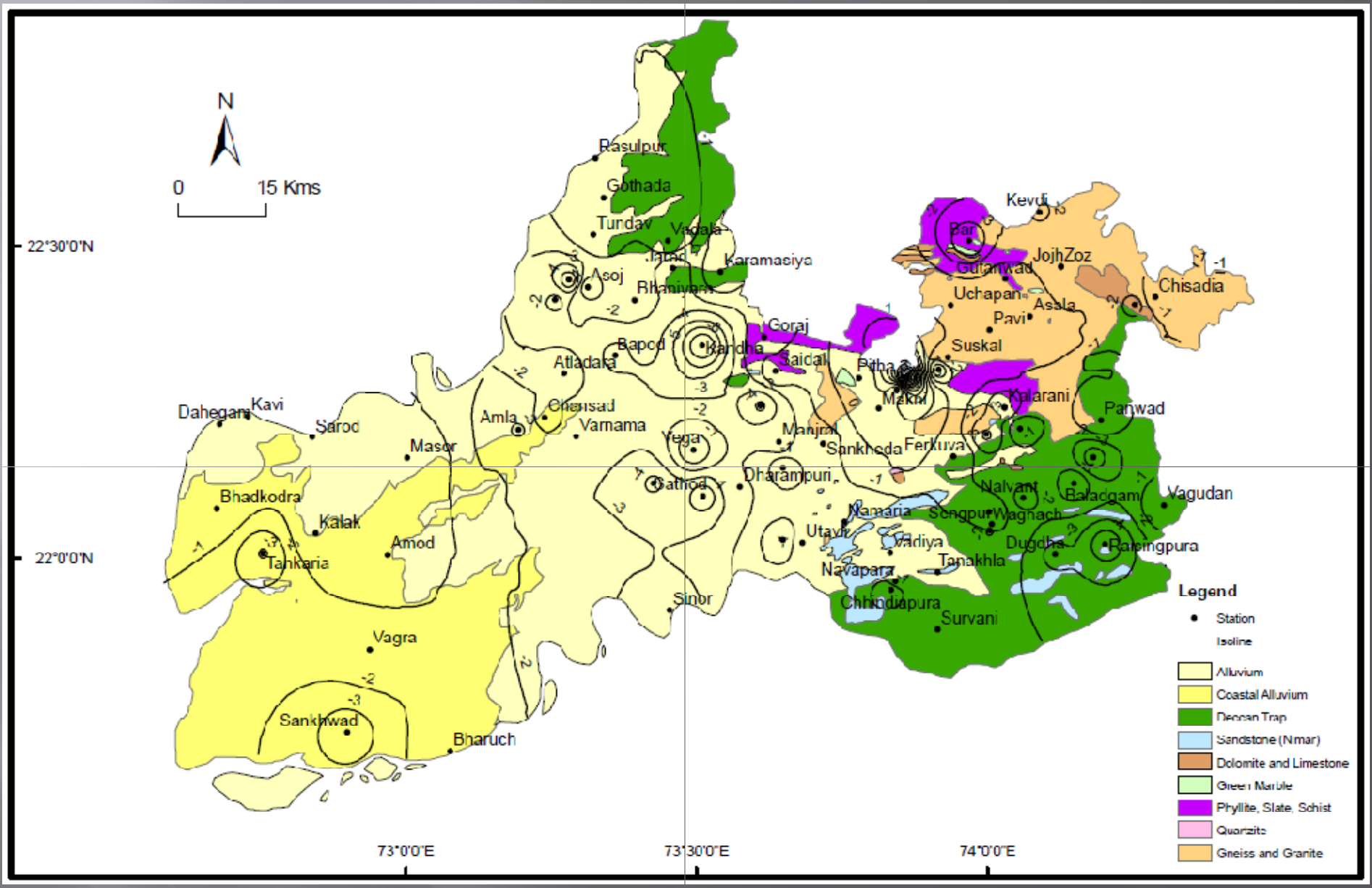




Well Hydrographs of Highland Zone



Location Map of the Samples points for Water Fluctuation Studies



Decadal Change in Water Level of the Study Area.

Recharge to Groundwater Based on Water Table Fluctuation/Specific Yield Approach

Sr. No	Rock Type		Area m^2	Change in Water Table 'm'	Specific Yield	Recharge MCM
1	Alluvium	Flood Plain	4477	2.77	0.14	1736
2		Coastal	3011.86	2.1	0.05	316
3	Deccan Trap		1958920000	2.56	0.02	100.4
4	Dolomite and Limestone		70743000	1.79	0.008	1.01
5	Gneiss and Granite		1079130000	2.24	0.026	62.84
6	Green Marble		13194000	1.68	0.008	0.17
7	Phyllite, Slate, Schist, etc.		308588000	2.49	0.05	38.41
8	Quartzite		2108000	1.8	0.02	0.07
9	Sandstone (Nimar)		180614000	1.79	0.02	6.46
	Total		**11101491000**	**--**	**--**	**2261.3**

Observations

- Water table study forms an important part of watershed development and long term monitoring of water table fluctuation coupled with the hydro-meteorological data can be used to identify groundwater resource potential of any area.

- Study area to a large extent depends upon groundwater for its drinking and agricultural needs.

- The study area receives rainfall due to SW monsoon and is limited to the period between June to September. The period is further extended upto November month due to retreating monsoon. The rainfall data for 42 years i.e. from 1961 to 2003 from 18 rain gauge stations located within the study area was used. The average rainfall for the study area stands at 858.99 mm and the mean annual rainfall gradually increases from west to the east.

- The western and central part of the study area has thick alluvial cover as a result area is under intense use of groundwater. Whereas, in the eastern part due to hard rock formation and less habitation, the development of groundwater resources are not under threat.

- The maximum depth of water table is in central part, while, it is at shallow depth in eastern and western parts.

- Due to influence of sea water in the western part, the area has salinity problem, as a result, exploitation of groundwater resources has not taken place. Overall in the study area, groundwater irrigation, industrial development and urban expansion have stressed the aquifer resources.

- To study water level fluctuation, groundwater level data from year 1993 - 2003 have been utilized.

- Water table contour maps indicates that the water level in the study area ranges between 5 m to 10 m bgl in the eastern and western part of the study area while between 10m to 20m in the central part.

- In the central part deeper levels of groundwater have been observed which is mainly due to over exploitation of groundwater resources particularly in talukas like Vadodara and semi critical talukas like Karjan, Amod and Sinor. However, the western coastal tracks fall in saline category (especially Jambusar Taluka of Bharuch district).

- Net groundwater availability in the study area based on the Government source is computed to be 1113.36 MCM; whereas the adopted approach using the water table fluctuation data is 2261.3 MCM, this mismatch in the values is due to the fact that the Government figure is based on the annual data of the years 1991 and 2004 and the present study has used average figure of 10 year water table fluctuation data.

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- Recharge from rainfall during monsoon season is calculated to be 927.45 MCM/yr in 2004 while in the year 1991 it was 1106.63 MCM/yr (214.46MCM/yr for Coastal areas and 892.17 MCM/yr for rest of the study area). Net draft computed for the study area comes out to be 396.31 MCM/yr in the year 1991 and 525.85 MCM/yr in 2004.

- The stage of groundwater development work out to be 67.47% which fall in safe category

- Safe Category: if the stage of groundwater development is less than 70% and the groundwater levels during the last decade does not show any falling trend in water levels (pre and post monsoon) the area is categorized as safe i.e. white.

- The study focuses on application of rainfall and water table data for preparing water budget model of an inter-stream region.

- We suggest that a grid network of ground water aquifers in the region is created for more realistic water budgeting of the area

THANK YOU