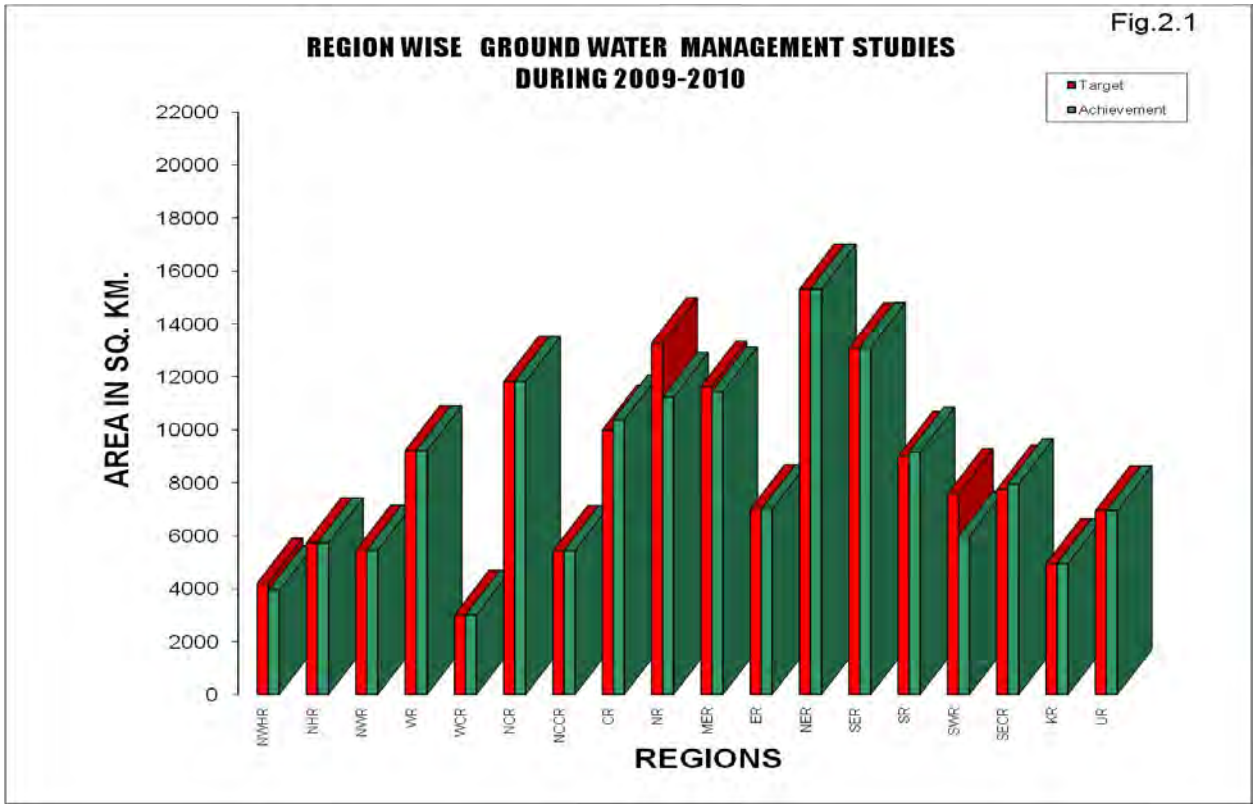
Brief Summary of the Ground Water Management studies during 2009-10

Ground Water Management Studies are being carried by the Board at district level to evaluate the changes in quantity & quality in the ground water regime owing to development and also to identify related issues for future management strategies. A major part of replenishment of ground water is through infiltration from rainfall. Return flow from irrigation and seepage from surface channels and reservoirs also contribute substantially to the ground water recharge. The effect of ground water withdrawals and out-flows are directly measurable through water table. Since all these inputs and outputs frequently change with time, the ground water situation is being periodically reappraised. As the development of resource leads to changes in its regime and water quality therefore planning for further development of the resource is to be done on the basis of findings of the studies, which provide valuable information for reorienting ground water development programme keeping in view the emerging scenarios. During the year 2009-2010, an area of 1.48 Lakh Sq.km. have been covered by the Board under Ground Water Management studies as against target of 1.59 Lakh Sq km. State/District wise target vis-a-vis achievements during the year 2009-2010 is shown in Table 1.1 and fig. 2.1.

Table : 1.1 TARGET AND ACHIEVEMENTS
GROUND WATER MANAGEMENT STUDIES DURING 2009-10

Sl. No.	States	Districts	Target (Sq. km.)	Achievement (Sq. km.)
1	Jammu & Kashmir	Pulwama	1210	1398
		Ramban	2000	1527
		Samba	1000	1000
2	Himachal Pradesh	Kangra	5739	5739
3	Punjab	Nawanshahr	1190	1190
		Amritsar	200	200
4	Haryana	Mewat	1860	1860
		Faridabad	200	200
		Yamuna flood plain area of Haryana(Remote sensing)	2000	2000
5	Rajasthan	Parts of Churu	5897	5897
		Dholpur	3009	3009
		Kota	310	310
6	Gujarat	Mehsana	3000	3000
7	Madhya Pradesh	Umaria	4593	4593
		Anuppur	3258	3258
		Ujjain & Ratlam	2479	2479
		Mandsaur	800	800
		Ujjain	700	700
8	Chhattisgarh	Durg	3000	3000
		Korba	2437	2437
9	Maharashtra	Part of Jalgaon and Aurangabad	3000	3083
		Part of Wardha	3000	3202
		Part of Ahmednagar	3500	3598
		Amravati district	500	500
10	Uttar Pradesh	parts of Kanshi Ram Nagar & Farrukhabad districts	2562	500
		parts of Budaun district	2655	2655
		parts of J P Nagar & Bijnor districts	2677	2677
		parts of Meerut & Muzaffar Nagar districts	1996	1996
		parts of Ghaziabad, Bulandshahar & Aligarh districts	2023	2023
		parts of Sengar River watershed, Kanpur dehat district	1375	1375
11	Uttarakhand	Nainital	3860	3860

Sl. No.	States	Districts	Target (Sq. km.)	Achievement (Sq. km.)
		Almora	3083	3083
12	Bihar	Supaul	2429	2429
		Saharsa-Madhepura	3435	3435
13	Jharkhand	East Singhbhum	4048	3500
		West Bokaro coal field in Hazaribagh district	500	850
		Parts of Darbhanga & Samastipur District	1230	1230
14	West Bengal	Murshidabad district	2000	2000
		Uttar Dinajpur district	2750	2750
		Birbhum district	1250	1250
15	Andaman & Nicobar	Middle & North Andaman	1000	1000
16	Assam	Barpeta & Parts of Baksa district	3300	3300
		Nalbari & Parts of Kanmrup district (Rural)	3000	3000
		Bongaigaon & Parts of Dhubri district	3000	3000
17	Tripura	Dhalai District	2314	2314
18	Meghalaya	East Khasi Hill District	2560	2560
		East Khasi Hill District	1151	1151
19	Orissa	Parts of Sambalpur District	3000	3000
		Anugul District	3000	3000
		parts of Kendrapara, Jagatsingpur and Cuttack	3800	3815
		Parts of Anugul District	3000	3000
		Jajpur district	300	300
20	Andhra Pradesh	E. Godavari	3000	3000
		Chittoor	3500	3650
		Ranga Reddy	110	110
		Mahabubnagar	95	95
		E. Godavari	1600	1600
		Visakapatnam	700	700
21	Karnataka	Hassan district	3150	1550
		Koppal disitrict	2703	2703
		parts of Chikmagalur, Shimoga & Davanagere districts	1100	1100
		In parts of Chitraddurga district	625	625
22	Tamil Nadu	Parts of Nagapattinam and Thiruvarur Districts	2,000	2000
		Ramanathapuram & Sivaganga Districts	2,000	2215
		Parts of Thanjavur & Tiruvarur districts	3132	3132
		Pallikaranai-Chennai Sub urban area	200	200
		Salem(Remote Sensing)	410	410
23	Kerala	Kozhikode district	2344	2344
		Trivandrum	500	500
		Kollam and AAlappuzha	1500	1500
		Trivandrum district	200	200
		Kozhikode (Over-exploited) and Balusseri (Critical blocks)	400	400



SALIENT FEATURES OF DISTRICT GROUND WATER MANAGEMENT STUDIES:

1 NWHR, JAMMU

Ground Water Management Studies were carried out in Pulwama (1398 sqkm), Ramban (1527 sq.km) and Samba districts (1000 sqkm) of Jammu & Kashmir state.. The detailes are given below.

1.1 Pulwama district:

Ground water management studies were carried out in 1398 Sq.km of area covering the entire district of Pulwama of J & K state covering parts of degree sheet No's 43 J,K,N,O. As per the 2001 census, the district has a population of 6, 52,607 persons with density of population 467 persons per Sq.km. The rural areas accounting about 89.5%. The annual average precipitation in Pulwama district varies from 175.40 mm to 1347.8 mm.

The district can be divided into five distinct geomorphological units namely Sharp and high rise Hard Rock Ridges, High table Karewa Plateaus Degraded Karewa Plateus around Pulwama town, Karewa Plains lands and Alluvial plains with Deep River valleys and Channel beds. Rambiara, Romshi and Jhelum Rivers form the main drainage. Pulwama district is one of the well-irrigated districts in J & K state. About 895 Sq.km area is covered by canals irrigating about 35136 ha area. Because of dense network of canals and lack of proper drainage system resulted in water logging problems in canal command areas. Based on depth to water level maps of the district, it is observed that 2.5 sq.km area of Pampore tehsil and 15 sq. km area of Pulwma tehsil are having shallow water levels of less than 2 m throughout the year. About 7.5 Sq.km area in Pampore tehsil and 105 sq.km area in Pulwama tehsil falls in with in 5 m range. A total of 130 sq.km of area is having shallow water levels where remedial measures need to be followed for solving the water logging problems.

Geologically, Pulwama district is underlain Karewa formations and in north and northeastern part and southern part of the district by Triassic limestones and Panjal traps. Thin Alluvium of the thickness of about 5-10 meters is overlying the Karewa Formations of the Quarternary period. The depth of Karewas is extending beyond 300 mts. The geological layers occur up to the top 100 meters as multiple layer dispositions, whereas from the 100-250/300 mts, it occurs as single layer dispositions.

The piedmont zones comprising of scree/talus deposits of limestones, slates, shales and andesites occupies along the foot hills form the potential aquifer system in the northern part resulting in high discharges of tubewells. The Central and southern portions of the district was underlain by the sedimentary deposits of Karewas, comprising of sediments ranging in size from the boulder to clay. The Denuded Karewa Terraces Karewas comprising mainly of boulders gravel, Sand, Silt and clay formed due to erosional activities of Recent rivers viz., Jhelum, Rambiara, Romushi etc. Major part of the district is underlain by the Recent Alluvium and Karewa sedimentaries of Quarternary period. The Occurrences of un-confined aquifers is extensive in the district and being tapped through Dug wells, Hand pumps, and Shallow tube wells. The

Karewas have multiple aquifer dispositions. In Pampore area, it is observed 3-4 aquifers are present normally up to a depth of 110-120 mts. The general thickness of Aquifers available for tapping through tube wells is about 20-25 mts. High table Karewa lands are extensive in their occurrence in Shupiyan area. (Zainapora, Reshipora and surroundings). Prolific aquifers are present extending up to 140 mts. The total thickness is about 60 mts. High discharge tube wells are present in this area (Littar, Zainapora, Reshipora) with discharges ranging about 1500 lpm. The occurrence of ground water under high pressure resulted in the artesian flows in the eastern and southeastern parts of the district. The boulders, cobbles, gravel, sand (coarse) form the main artesian aquifer bed capped by thick clay mixed with silt deposits as confining layer on the top. The free flow discharges ranges in between 300-400 lpm.

The aquifers of Karewas show the low transmissive characteristics when compared to the Transmissivities of Alluvium (Bouldery) and Piedmont zones and Hard rock aquifers. The transmissivity Values of Karewa varies from as low as 39.8 m^2/day to 240 m^2/day. Whereas the Trnsmissivity values are more than 1300 m^2 /day in denuded Karewa terraces and ranges from 60 – 1918 m^2 /day in Hard rock aquifers and more than 5000 m^2 /day in Piedmont Zones. The Specific capacities of tube wells located in the Northern parts of the district varies between 0.16 lpm/m to 87.80 lpm/m. The Sp. Capacities of Auto flow wells are at the range of 15-50 lpm/mts, where as the Sp. Capacity of the well in degraded Karewa Terraces is 117 lpm/mts. The highest Sp. Capacity of the wells is shown by the EWs in Piedmont Zones (2975 lpm/mts) and Hard rock aquifers (2422 lpm/mts). The piedmont zones, the hard rock ridges in the northern and north eastern parts and the degraded Karewa terraces of the southern parts forms the high yielding aquifers of the district. The Karewas in the South eastern and eastern parts (artesian belt) and south central parts of the district forms the moderately yielding aquifers and the Karewas of the North eastern parts of the district (Tral area) forms Low yielding aquifers of the district.

The depth to water level is in between less than 01 mts to 10 mts in Alluvium and Karewa plains, where as it occurs at the range of 15- 20 mts in high Karewa Plateus. In between the hard rock ridges of Panjal traps and Karewa deposits in the northern and north eatern parts of the district, lies the piedmont zone consisting of talus/scree material of lime stone, slates, shales and clay derived from the hard rock ridges (Triassic lime stones). The depth to water level is between 10-60 mts. Deeper water levels are observed in piedmont zones towards hills and become shallower towards Valley. The Depth to piezometric heads varies from 1.50 mts at Gunabal (Karewa Plains) to 44.24 mts at Hayatpur (High table Karewa Plateus). Generally, the water levels of the tube wells drilled in the Karewa table lands are deeper at the range of 20 mts and more. The water levels in the Karewa table land ranging from 19.04 mts at Green-Colony-Wuyan to 44.24 The water table elevations in Pampore area varies from 1600 – 1640 m amsl. The ground water occurs in the artesian conditions in the Eastern and South Eastern parts of the district covering an area of 45 & 60 km^2 respectively. These two artesian belts are associated with the occurrences of springs and surrounded by high table Karewa Plateus. The artesian zone in the southeastern parts of the district is located towards south of Pulwama town around Turk-Wangam, Kigam and Shankarpora and surroundings.

During the present study, 31 No.s of springs are inventoried and chemical quality parameters were analyzed. Fracture type springs are originating from the fractures of Hard rock area generally seen in Tral and Shupiyan areas. These are commonly high discharge springs. Spring of Arapal which is Krastic spring is one such fine example where it originates from Triassic lime stone having a discharge of 1400 lps and is the source for Arapal Nallah draining in Tral area. Contact type Springs occur between the hard rock / piedmont area and Karewas. These springs occur all along the Northern part of the district in Pampore area (e.g. Zewan Khreuh, Zawura etc). Springs of Seepage/depression type occurs all along the southern part of the district in degraded Karewa Terraces/Boulder areas of Pulwama (E.g. Babagund, Kangan, Gudura, Tahab, washbug etc.). Most of the springs in study area falls in Fifth (5^{th}) order classification where discharge at the range from 01-10 liters/second.

The ground water recharge during November to April is estimated as 15494 ha m. The rainfall recharge during May to October is worked out based on rainfall infiltration factor is 8757 Ha.m. The Annual ground water draft is estimated as 1209 ha.m.

The ground water is fresh with Electrical Conductivity ranging from 175 micro-mhos/cm at 25 ^{0}C to 2800 micro-mhos/cm at 25 ^{0}C. Most of the water is very hard in nature (70% of samples analysed) with domination of Calcium and Bicarbonate, Ca-HCO_3 type. About 39.1% wells of shallow ground water is Ca-Mg–HCO_3 type. About 17.4% samples are having mixed type of water comprising of Ca, Mg and Na. The chemical quality data reveals that spring water is acidic to alkaline in nature and pH ranges from 6.95 (Armul) to 8.65 (Ladu Village). Spring water is potable and fresh having specific conductance from 172 µmhos/cm (Thumlahal) to 625 µmhos/cm (Rajpur). In the deeper aquifer maximum Specific Conductance of 587µmhos/cm at 25°C is recorded in the water samples collected from CSB Pampore.

Though the stage of Ground Water development in three tehsils of the district is less than 10%, and in one tehsil Pampore it is more than 25%, The potentialities of denuded Karewa terraces and alluvium in the Southern parts and piedmont zones and hard rocks in the Northern parts along with Karewas has to be developed with sound ground water management strategies. At few places in Karewa terraces, the drawdown in tubewells is so high resulting in pumping head so high it is becoming very difficult to operate pumps throughout the year resulting into failure of pumps and burning of pumps very frequently. The Valley area of the Pampore tehsil is 144 km^2 and the ground water draft was calculated is 579 Hec. Meters per annum. This ground water draft is mainly from the tube wells meant for Public water Supply and is fairly on higher side when compared to the rest of the district. If the present trend goes unabated, without proper precautionary measures, in long run may be after a few more years water levels in Pampore Block may decline at alarming rates.

Two high artesian pressure zones are demarcated in the study area. Zone-I is present around Badrivan, Banderpora. Zone-II is extended from Turk wangam, Shankarpora, Kigam. Exploratory drilling to a desired depth could not be achieved at Badrivan due to high artesian pressure encountered during the time of drilling. Though the construction of deep tubewells in these zones is very difficult, if managed to construct tubewells with proper assembly lowering, they will yield

promising discharges. If artesian condition is encountered at shallow depths, wide diameter casing pipes are lowered to control artesian flow and to drill further in the same bore hole. If successful tubewells are constructed tapping artesian aquifers, the same can be utilized without lowering the pumping devises and thus saving lot of money on energy front.

1.2 Samba district :

Samba district lies is situated in south western part of the state falls in survey of India Degree sheet 43 P & L. District Head Quarter Samba is situated at a distance of forty kilometer from Jammu city on the bank of Basantar river. District Samba is bounded on the southern side by International Border with Pakistan. About two third of the area of Tehsil Samba is Kandi & rain fed. The area on southern side downside the national highway is irrigated through Ravi Tawi Irrigation canal network. Basantar River is major Perennial River flowing in the district and forms a part of the Chenab Basin. Number of other local Nallas & Khads flow in the district and show parallel drainage pattern from north- east to south-west. The rivers/streams have wide channels, shallow depth and flash floods are reported during monsoons.

The district experiences a typical sub- humid to sub-tropical in climate. It experience severe cold in winter when temperature plummets to as low as freezing point in hill and about 6°C in rest of the area. The average annual rainfall of the district is 1150mm, about 85% of the total rainfall is received during monsoon period.As per 2001 Census, the total population is 2.86 lakh, The density of the population is 317 per sq km.

Siwalik Group of rocks of Tertiary period occupy northern half of the district are composed of loosely cemented sand stone, clay and thin beds of boulders, gravels and pebbles. Quaternary alluvium lies over the Siwalik rocks and occupy the southern part of the district called as outer plain. It is further divided into Kandi formation and Sirowal formation.

Ground water occurs in deep water table condition in Kandi region, whereas in Sirowals it is both under water table as well as confined condition. Central Groundwater Board has drilled 45 exploratory wells in the district with a depth ranges from 62.00 m (Mothlikhurd) to 347.00 m bgl (Chamlial). Out of which 18 nos of wells were drilled in Kandi area. Water level in the wells drilled in Kandi formation ranges from 3.20 m (Laoukli) to 71.25 m bgl (Jatwal) with a discharge range from 198 lpm (Paramandal) to 1900 lpm (Raya patti). In Sirowal, formation the water level in the exploratory wells ranges from free flow to 17.63 (Sagaal), with a discharge ranges from 23 lpm (Ghobrahmna) to 2680 lpm (Rajpur).

There are 19 nos of National Hydrograph Network Stations in outer plains of Samba district. Depth to Water level in the district ranges from 1.21 (Didyal) to 21.28 m bgl. (Raiyan). From the last decadal water level data it has been worked out that decline in water level in greater part of the district is less than 20 cm except the eastern margin where the decline is more than 20 to 40 cm per year.

The chemical quality of the ground water samples reveals that water is fresh and suitable for domestic purpose, with its Electrical Conductivity ranging form 463 μs/cm to 1260 μs/cm in Didyal and Bishnah respectively. Ground water in major part of the district shows Electrical Conductivity Value less than 750 μs/cm at 25^0C.Forty-five number key wells were established and pre-monsoon as well as post-monsoon samples were collected.

1.3 Ramban district:

Ground water management studies were carried out in 1527 Sq.km of area covering the entire district of Ramban which is situated in the south-west part of J & K state. As per the 2001 census, the district has a population of 2.15 lakhs persons, with density of population 141 persons per Sq.km and the rural areas accounting about 95%. Cultivation is the main Occupation in Ramban District and Paddy and Maize is the main crop grown in this district with total cropped area of 24,937 ha. The area enjoys Temperate and Sub-Tropical type of climate. The annual average precipitation in Ramban district varies from 86.8 mm to 428.2 mm. The forest area covers about 42.0 percent of the total area of the district.

The district can be divided into three distinct geomorphological units namely Sharp and high rise Hard Rock Ridges, High table Ramban Plateau, and Alluvial plains with Deep River valleys and Channel beds. Chenab is the principal river of Ramban district. Ramban district is one of the well-irrigated districts in J & K state, about 1453 ha is irrigated by canals, springs, and other sources.

Geologically, Ramban district is underlain by Shiwalik and Murree formation. The Shiwalik group is composed of thick succession of sedimentary rocks of fluviatle and lacustrine nature. The chief rocks types are loosely consolidated and poorly badded conglomerites, grits, sandstones, silts and clay. The Shiwalik range exhibits a rugged and restive topography. The Murree group is composed of thick sediments of brakish and fresh water origin. The chief rock types are conglomerate, red clays. The Murree formation constitutes hill range showing comparatively mature topography marked by gentle hill slopes and flat hill tops.

Ground water in the area of investigation occurs in cracks, joints, fractures and secondary openings in hard rocks and voids within alluvium and manifests in the form of springs. In the terraces of flat terrain underlain by the unconsolidated formations, the ground water also occurs under water table conditions. During the present study, 87 No.s of key monitoring stations are inventoried and chemical quality parameters were analyzed, which include 49 springs, 17 Handpumps, 16 Nallahs, 3 Waterfalls, 2 Tubewells. The springs are the principle source of ground water in the area. There are number of springs which are being used for water supply. Fracture type springs are originating from the fractures of Hard rock area generally seen in Batote and Ramban areas. Both cold and hot springs are present in the study area. The discharge of these springs varies from merger to 12 lps. One hot spring Tatapani is inverted during the course of study. The temperature of this hot spring is 41 and 43 ^{0}C respectively during Pre and Post monsoon season. Most of the springs in study area falls in Fifth (5^{th}) order classification where discharge at the range from 01-10

liters/second. During the course of study the discharges of 16 major nallahs are also measured which ranges from 18 to 3220 lps.

The exploratory well at Banihal EW was drilled down to the depth of 79.00 mbgl. The results of the PYT test are:-Static water level : 49.25 mbmp, Duration of pumping : 100 m, Discharge : 9.0 lpm, Drawdown :3.25 mbgl. The well recouped back in 100m after stopping the pump. The exploratory well at IRCON Complex Banihal was drilled down to the depth of 70.12m, the results are:- Static water level : 51.82mbgl, Discharge : 4000 g/h, Drawdown: 3.04mbgl

The spring water is fresh with Electrical Conductivity ranging from 100 micro-mhos/cm at 25 ^{0}C to 980 micro-mhos/cm at 25 ^{0}C. Most of the water is very hard in nature (70% of samples analysed) with domination of Calcium and Bicarbonate, About 9.6% spring water is Ca-HCO_3 type. About 28.2% spring water is Ca-Mg–HCO_3 type. About 22.9% spring water is Ca- Mg-HCO3-SO4 type. The chemical quality data reveals that spring water is acidic to alkaline in nature and pH ranges from 6.92 (Kundapani) to 7.95 (Nal). Spring water is potable and fresh. In the deeper aquifer maximum Specific Conductance of 1980µmhos/cm at 25°C is recorded in the water samples collected from Kanga.

2 NWR, CHANDIGARH

Ground Water Management Studies was carried out 3050 Sq.Km covered in Nawanshahr of Punjab and Mewat districts of Haryana State. The detatis are given below

2.1 Nawanshahr , Punjab

Nawanshahr district, located in the eastern part of the Punjab State, forms a part of the Bist-Doab region, covering a geographical area of 1190 sq.km. Nawanshahr district is divided into 2 tehsils namely Nawanshahr and Balachaur comprising five-development blocks. There are 4 towns and 471 villages, out of which 465 are inhabited and 6 are uninhabited.

Physiographically, the area is bounded by NNW- SSE trending Siwalik hills in the northeast and Sutlej River in the south, which forms the main drainage basin. A number of seasonal streams (''choes'' in local parlance) originate from the Siwaliks, which drain the area during monsoon season. At times these choes bring down flash floods in sub-mountainous region, particularly in Balachaur and Saroya blocks. The deforestation carried out in the Siwalik foothill zones has further aggravated the menace of flash floods as they are causing extensive soil erosion on one hand and deposition of sand and silt in fertile fields on the other. The Sutlej River being snow fed is perennial although the flow varies considerably during the year.

Agriculture constitutes the main source of economy and most of the area is fertile and good land use management is practiced. The land utilization pattern of 2005-06 shows that net area sown is 940 Sq.km. while area under forest cover and land put to non-agricultural uses are 170 Sq.km. and 70 Sq.km. respectively.

The Hydrogeological details are as follows:-

- The Nawanshahr district is covered by Quaternary alluvial deposit except in the northeastern part, where the Siwalik hills of Tertiary age are exposed.
- The Central Ground Water Board has drilled 8 exploratory wells and 2 piezometers to delineate the aquifer geometry and quality of formation water. The wells drilled were in the depth range of 101-451 m bgl.
- Groundwater occurs under both unconfined as wells as confined conditions.
- In unconfined aquifer, the depth to water level varies from 8.8 to 29.7m during pre monsoon and 8.3 to 23.7m during post monsoon season. Deeper water levels are observed in the north eastern part of the district.
- In major part of the district, the water level ranges between 10 and 20 m while the water levels in the western and southern part is within the depth range of 5 to 10 m bgl.
- The long term trend of water level of 10 years shows that there is a decline in water level in major part of the area ranging from 0.25 to 0.86 m /year. 54 no. of key wells were established and monitored for pre and post monsoon ground water levels in the area. Micro level survey of Aur block area of 218 sq.km has been carried out
- The ground water in the district is alkaline in nature with low to medium salinity.
- In the western part of the district, electrical conductivity is slightly higher than 700 microsiemens/cm. While, the maximum value of 940 microsiemens/cm is reported at village Rahon.
- The minor constituents such as iron, nitrate and fluoride, which are essential for plant and animal growth, are found below the permissible limit. Similarly the trace element arsenic is also found below the permissible limit.
- There is need to notify the over-exploited blocks for regulation of construction of all groundwater abstraction structures for sustainability of ground water resources.

2.2 Mewat, Haryana

The Mewat district is having a total area of 1860 sq.km and is situated in southern most part of Haryana state. As per census 2001 the total population of the district is 9,93,603 with population density of 534 persons/sq. km. The district has been divided into two sub divisions and six development blocks for the purpose of administrative control.

Physiographycally, the district is marked by undulating sandy and alluvial plains through which ridges strike trending N-S to NNE-SSW. Arround 140.29 sq. km area is covered by hills of Delhi system. 1740 sq. km area of the district is under

agriculture, out of which 1240 sq.km area is sown more than once. The irrigation in the district is mainly dependent on ground water and canals.The gross irrigated area is 2030 sq.km, and percentage of gross irrigated area to gross cropped area is 67.40%. The climate of the district is semi-arid type with mean annual rainfall of 629 mm.

The main aquifer in the district is unconsolidated alluvium deposits of quaternary age. The hard rock formations also have limited ground water potential. The main source of recharge to ground water is rainfall added with seepage from canals and return flow from irrigation.Depth to water level in the district varries between 2 and 31 m bgl. Deeper water levels are recorded in fresh water areas whereas shallow water levels have been observed in saline areas. Ground water in the area is being exploited mainly through shallow tubewells which are 31669 in numbers and yield ranges from 100-400 lpm.

45 no. of water samples have been collected for ground water quality analysis and got analysed in CGWB laboratory, Chandigarh.The pH value in the area ranges between 7.2 at village Kira to 8.61 at village Bhogipur.The EC values in the area ranges between 511 at village Mahaban to as high as 28100 at village Rampuri.The fluoride concentraton is well within permissible limits except at village Dungri where it is 1.76 mg/l.

A microlevel survey in the Taoru block was carried out covering 225 sq. Km. Area. The area is facing scarcity of water and the water levels are very deep. The depth to water level ranges from 13.29 m bgl at Taoru to 31.75 m bgl at Sahsola. Around 10 numbers of big resort with golf game facility are there in Taoru block and are exploiting water through deep tubewells and are responsible for the depleting ground water resources in the block. It is necessary to regulate the construction of groundwater abstraction structures. The ground water in Taoru block is potable. EC, Nitrate, Chloride and Fluoride are also within permissible limit.

3 WR, JAIPUR

Ground Water Management studies were carried out in Ratangarh and Surajgarh blocks of Churu and Dholpur districts during 2009-10 covering a total of 8906 sq. km area, with the objective to evaluate changes in ground water regime owing to developmental stresses, to identify issues of concern and to suggest future management strategies.

3.1 Churu, Ratangarh and Surajgarh blocks of Churu district

Churu, Ratangarh and Sujangarh blocks of Churu district covering an area of 5897sq.km. and forms south western part of the Churu district which is located on the eastern periphery of Thar desert. The area is covered in the Survey of India Top- Sheet No. 44, 45E, 45I and 45P. The area experiences semiarid to arid type of climate and the vegetation is desertic type. The frequencies of mid and normal type of drought are quite common. The rate of potential evapotranspiration is quite high. The soils in the area are mostly desertic & sandy which are poor in fertility and water retentions capacity.

A total 106 nos. of wells including Dug wells, Piezometers, DCBs and Tube wells, were inventoried for detailed hydrogeological studies. The water samples were also collected for chemical analysis

Practically, the whole of the surface geology of the area is cancealed under wind blown sand. The principal water bearing formations in the area are unconsolidated Quaternary alluvium, semi consolidated Palana sandstone, consolidated Marwar Supergroup of rocks and Post Delhi intrusive. Ground water occurs mainly under unconfined to semi-confined conditions.

Ground water in alluvium occurs under water table condition having average yield of Tube wells & D.C.B ranging from 100 lpm to 650 lpm. In Palana sandstone & Marwar Super Group of rocks, ground water occurs in unconfined to semi-confined condition. Average yield of tube wells range from 50 to 250 lpm.

Depth to water level in the area varies from 10 to 95.50mbgl during pre-monsoon and 10.47 mbgl to 94.00mbgl during post- monsoon.Seasonal water level fluctuation between pre-& post monsoon,2009 were computed and indicates positive fluctuation in the range of 0.02 to 3.54m negative fluctuation from (-)0.01 to (-)4.70 m. Block wise summary of hydro-geological details of the area is given in the table below.

Sl. No.	Name of the Bock	Hydrogeol-ogical formation.	D.T.W. (Pre-Mon.) (mbgl)	D.T.W. (Post-Mon.) (mbgl)	Water level fluctuation (m)	Category
1	Churu	Alluvium	17.80 to 51.12	17.76 to 51.20.	0.02 to 0.95 & -0.01 to - 075	Safe.
2	Ratangarh	Alluvium, Nagaur & Jodhpur Sandston.	28.20 to 95.50	28.24 to 94.0	0.04 to 0.87.& -0.04to– 4.70	Safe.
3	Sujangarh	Alluvium, Marwar Supergroup of rocks &Intrusives	10.90 to 88.50	10.47 to 89.25	0.03 to 0.87 & -0.01 to -.3.39.	Critical

Results of chemical analysis of ground water samples collected during pre–monsoon indicates that ground water is alkaline having pH values from 7.21 to 8.6 and is hard to very hard in major part of the study area. In general, the ground water is brackish to saline having EC values from 880 to 16500 mmhos/cm. at $25C^0$. Fluoride concentration ranges from 0.1 to 9.6 mg/lt. Nitrate content is more than permissible limit in major part of study area. Ground water quality in shallow aquifer is comparatively better and has less salts than deeper aquifer.

The stage of groundwater development in Churu, Ratangarh & Sujangarh blocks is 89%, 59% & 97% respectively. Deep water level, desertic & saline soil, scanty rainfall, poor forest wealth are some of the hazards for the development of the area.

During the hydro geological investigation in the area, an attempt has been made to study the feasibility of integrated approach for conservation and management of water resources in the area. The ground water resources estimation data as on 31-03-2004 reveals that Churu and Ratangarh blocks fall in safe category, thereby giving a scope of future ground water development agriculture purposes (for high tolerant crops). Ground water development may be enhanced through construction of tubewells in these blocks in a phased manner. Combination rig is suitable for drilling tubewell in the area. In alluvial area, tubewells of 8" diametre and depth up to 110m is recommended. In Sujangarh block, no ground water development is recommended since block falls in over-exploited category.

3.2 Dholpur district

Dholpur district is the eastern most district of the Rajasthan state with an area of about 3009 sq. km. comprising Bari, Baseri, Dholpur and Rajakhera tehsils. According to 2001 census, total population in the district is 983258. The area is covered in the survey of India Toposheet No. 54F/6,7,9,10,11,13,14 and 54J/1,2.

During the Pre and Post monsoon studies, a total of 75 number of well (Dugwell, DCB's, and tubewells) were inventoried for detailed hydrogeological studies. The water samples were also collected for chemical analysis.

Declining in water level is due to over exploitation of ground water resources from the potential aquifers. As the major part of the district is characterized by hard rock area (Vindhyan Sandstone), peoples are facing scarcity of water for drinking and other domestic purposes which need attention. As far as groundwater quality is concerned in the area, it is suitable for the drinking and irrigation purposes.

The south western part of the district is hilly covering about 40% area and the rest being alluvial plain. The general land slope is from SW to NE with an average gradient of 1.63 m/km. Parbati river is the tributary of Gambhiri river passes through the central part while Gambhiri river passes through the northeastern part of the district. Chambal river is one of the perennial river in the state passes along the southern border of the district. All these rivers flow from southwest to northeast direction. The climate of the district is of semi arid type being extremely hot in summer and cold in winter. The average annual rainfall is 653.4 mm.

Among different hydrogeological formations, alluvium is the principal groundwater bearing formation. The groundwater in alluvium occurs under water table condition. Depth to water in this formation varies between 12.10 m and 40.12 m bgl (Rajakhera Block) having average yield of the tubewells from 45 m^3/d to 75 m^3/d. The second important aquifer in the district is upper Bhandar sandstone which covers the Bari, Baseri and Dholpur Blocks. The depth to water level in the Vindhyan Sandstone ranges from 6.10 m to 20.22 m bgl (Baseri Block) while the discharge of wells depend upon the joints,fractures and weathering of the formation. However, during the survey, the average discharge of wells has been found in the range of 20 m^3/d to 55 m^3/d. Long term water level fluctuation data (NHS) (between pre monsoon 1999 and pre monsoon 2009) shows that in major part of the district especially toward northern and eastern part (Rajakhera Block), maximum fall (3-5 m) in water level has been recorded. Positive fluctuation or rise in water level is recorded in Vindhyan Sandstone and Shale formation in southern and western part (Baseri Block) of the district where it ranges from 1m to 2.5 m. About 66.67% of wells show negative fluctuation more than 3m during the period (may 1999 –may 2009), whereas 33.33% of wells showing rising fluctuation in the range of 0 to 2m. The summary of hydrogeological details of the area is given in table as follows:-

Table-: Summary of Hydrogeological Details (Blockwise)

Sr. No.	Block	Hydrogeological Formation	Depth to Water Level (mbgl)		Average W.L.Fluctuation (m)	Well Yield (m^3/d)	Category (As on 31.3.2004)
			Pre Monsoon	Post Monsoon			
1	Bari	Alluvium	13.40-40.12	13.57-40.22	0.16	45-75	Semi Critical
		Vindhyan Sandstone	14.65-18.28	14.77-17.68	0.25	20-55	
2	Baseri	Vindhyan Sandstone	6.10-20.22	6.00-20.15	0.35	20-55	Critical
3	Dholpur	Alluvium	12.10-23.30	12.76-22.44	-0.21	45-75	Overexploited
		Vindhyan Sandstone	7.22-17.15	6.34-17.21	-0.15	20-55	
4	Rajakhera	Alluvium	17.25-38.95	17.67-38.70	-0.20	45-80	Overexploited

Chemical analysis of ground water samples indicates that in the district groundwater is alkaline and in major part of the district it is hard to very hard. According to Wilcox's classification, majority of samples lie in the C2S1 & C2S2 categories, indicating that ground water is good to permissible for irrigation purpose. Generally, the ground water is fresh and potable in the area.

Following water management strategies may be applied to the area:

i. As in the area, there is a perennial river Chambal flows through the area so far drinking purpose this water can be used in conjunction with ground water. So the dependence on mainly groundwater can be minimized and declining water level can be checked.
ii. In Dholpur and Rajakhera block, emphasis must be given on the implementation of artificial recharge to ground water technique like construction of small check dam, SSB, contour bunding, plugging etc.
iii. Dug Well Recharge Scheme of Ministry of Water Resource in the district is not pacing up, which needed extra efforts to implementation the scheme.
iv. There are number of village ponds in the Bari and Baseri bloks which can be revived and used to recharge the groundwater of the area and for other domestic purposes.
v. In the district, new improved irrigation techniques such as drip and sprinkler irrigation to be encouraged.
vi. In the overexploited block namely Rajakhera and Dholpur block, construction of new bore well and tubewell should be banned immediately.
vii. To increase the awareness of people/ villagers on water conservation and management issues, mass awareness programme should be conducted.

3.3 Kota Urban & Industrial Area, Kota district (Urban Hydrogeolgical studies)

Kota urban lies in the north western part of Kota district. Area is underlain by sandstone belonging to Upper Vindhyan Group and a patch of limestone occurs in the north eastern part. Physigraphically, area is characterized by gentle plane with undulating plateau. The land slopes from south west to north east and is drained by perennial Chambal river and its tributaries. The soil of the area is brown to dark colour alluvium which is clayey loam to clay in composition and generally non-calcareous.

During premonsoon, 24 wells were inventoried and a total of 20 ground water samples collected from various GW Abstraction structures viz. hand pumps/tubewells for complete analysis and also industrial effluent samples for heavy elements determination. Depth to water level varies from 1.80 to 4.54 mbgl(pre-monsoon). Ground water quality is potable having EC from 270 to 1845 ms/cm at 25^0C and other chemical parameters are also within permissible limits of Drinking Water Standards.

During post-monsoon details survey, 27 Nos. of ground water samples were collected fromn various GW Abstraction structures. Depth to water level varies from 1.10 to 6.90 mbgl(post-monsoon). Ground water quality in general, is suitable for domestic purposes except in the close vicinity of industrial effluents disposal.

4 WCR, AHMEDABAD

4.1 Mahesana district

Ground Water Management studies were taken up in parts of Mahesana district covering an area of about 3000 Sq. Km.

The Rupen, Khari and Puspavati rivers constitute the drainage network in the study area. These rivers are ephemeral in nature and mainly flows in response to the rainfall. The study area experiences an average annual rainfall of 602mm. It experiences a semiarid climate. Extreme temperatures, erratic rainfall and high evaporation are the characteristic features of this type of climate. It is characterized by hot summer, cold winter, scanty rainfall and a general dryness except during short monsoon period. Alluvial plain is the single most prominent geomorphic unit and covers the entire part of the study area and is part of the North Gujarat alluvial plain. The area is characterized by gently sloping, slightly rolling to undulatory topography with gradual slope toward southwest.

Geologically the district is underlain by formations ranging in age from Precambrian to recent. The study area is characterized by the quaternary alluvium, which mainly consists of fine-grained sand, gravel, silt and clay. The alluvium at surface represents the windblown or aeolian deposits. The river alluvium is observed only along the rivers.

The thick alluvial deposit, which mostly occupies the study area, forms the most prolific multi-aquifer system. The thickness of alluvium is less in the north and gradually increases towards south and south-west. Within the explored depth of 600m, the alluvium is underlain by Miocene sediments (Tertiary) and Himatnagar sandstone (Mesozoic). The study area is characterised by multiple aquifer system. Within alluvial plains, two major aquifers have been identified upto the explored depth of about 600m below surface. The upper unit is mainly phreatic, but at places becomes semi-confined to confined and has been designated as aquifer "A". The lower unit comprises a few hundred metres of alternating arenaceous (sandy) and argillaceous beds and forms the confined aquifer system. It is sub-divided into aquifer B, C, D and E contained in post Miocene deposits and aquifer F and G in Miocene sediments. Himatnagar sandstone (Cretaceous) forms local aquifer in north-eastern part and has been designated as aquifer 'H'.

Ground water is extensively developed by dug wells, dug-cum-bore wells and tube wells in the study area. Ground water occurs under unconfined condition in the upper unit i.e. the phreatic aquifer where as in the lower unit of the alluvial formations (deeper aquifer) comprising of few hundred meters of alternate sandy and clayey horizon in semi-confined to confined conditions. Ground water development from phreatic aquifer is low to moderate due to limited saturated aquifer thickness and at place due to low yield and/or salinity.

Water level was monitored in 96 observation wells established, spread over the entire study area and to bring about the change in water level between the pre monsoon and the post monsoon period. The depth to water level during the pre monsoon period ranges between 2.71 to 21.03 mbgl where as during the post monsoon period it varies between 1.74 and 13.11 mbgl. The fluctuation in water level (pre-post) ranges from 0.59m to 8.76m. The depth of tube wells tapping the deeper aquifer varies between 115 mbgl to 390 mbgl and the water level varies between 41 to 163 mbgl during the pre monsoon period where as during the post monsoon period it varies between 35 to 161 mbgl. The fluctuation in water level (pre-post) ranges from 0.51m to 10.93m. Deeper water level is noticed particularly in Unjha and Mahesana taluka. The yield of the dug wells varies between 200 to 300 lpm where as the yield of the tube wells in general is high and ranges from 400- 900 lpm.

Pumping tests conducted in large diameter wells show that the specific capacity value thus calculated varies between 0.019m^3/min/m draw down to 0.065m^3/min/m draw down. The optimum yield value varies between 79.25m^3/day and 219.12m^3/day.

Ground water is the main source of irrigation in the study area. There are no perennial rivers. However, part of the study area is covered by irrigation canals of Dharoi project and Sardar sarovar project that provide irrigation water during the period mid October to the month of February and sometimes even up to March depending on the availability of sufficient storage in the reservoir, which in turn depends on the rainfall.

Drinking water supply in the study area, both urban and rural, is both surface water and ground water dependent. Major part of the study area is covered by the Regional Water Supply Scheme namely, Narmada Canal Based Regional Water Supply Scheme and Dharoi Regional Water Supply Scheme. 119 villages of Kadi taluka, 52 villages of Bechraji taluka and 115 villages of Mahesana taluka are covered by the Narmada canal based drinking water supply where as the Dhoroi regional water supply scheme caters the demand of drinking water in 60 and 28 villages of Visnagar and Unjha talukas respectively.

The groundwater quality of the shallow/phreatic aquifer is generally fresh with EC less than 3000 µS/cm. However, in the western part of Mahesana taluka and southern parts of Kadi talukas, shallow aquifers are brackish to saline; with EC more than 3000µS/cm. Slight deterioration in groundwater quality is observed in the canal command areas. The quality of groundwater in deeper aquifers, down to 300 m depth, is in general good in most parts of the study area. High fluoride concentrations both in shallow and deep aquifers have been reported at many places in the study area.

Many check dams, check dam cum recharge tube wells, percolation tanks in village ponds have been constructed by the irrigation department, GWSSB at different locations on Khari River, Rupen River. 247 percolation tanks have been constructed by the Jilla Panchayat Irrigation division in the entire Mahesana district. However this percolation tanks do not cater the demand of water for irrigation directly. Recharge due to these percolation tanks contribute to the rise in water level in the nearby areas. Thus there is an indirect benefit to irrigation as the water level in the ground water abstraction structures in the nearby areas rises due to recharge. About 2892 Ha area gets benefited by this. Jilla Panchayat Irrigation division has constructed 73 check dams in the entire district till date. 40 check dams have been constructed on cause ways and about 783 Ha area gets benefit for irrigation indirectly.

The western part of Mahesana taluka and southern parts of Kadi talukas, where shallow aquifers are brackish to saline, proper isolation of deeper aquifers by cement seal is necessary while constructing tube wells.

5 NCR, BHOPAL

Ground Water Management Studies were carried out in Umaria, Anuppur and mapping of flood plain aquifer in parts of Kshipra basin (parts of Ratlam & Ujjain districts) covering area of 10330 sq.km.

5.1 Parts of Kshipra water shed (Mapping of flood plain aquifer)

Ground Water Development Studies in parts of Kshipra basin have been carried out in parts of Ujjain and Ratlam District covering and area about 2479 Sq.km in toposheets nos. 46 M/5, M/6, M/9, M/10, M/11 and M/15. The area is mainly covered by Deccan Trap basaltic flows. Consisting weathered, vasicular, hard massive fractured basalts. A few patches around Alot blocks, Vindhyan sandstones are observed in the area. During investigation 74 Nos of key wells has been established and monitored Depth to Water levels of the key wells. Depth range varies from 5.63 to 24.85 mbgl and Depth to water level varies from 5.33 to 24.44 mbgl in the study area. The average yield varies from 2 lps to 5 lps in the study area. Mainly four prominent flows have been encountered during drilling in the study area. The ground water occurs in Phreatic and semi confined aquifer conditions. About 30 Nos. of water samples have been collected to know the chemical quality of ground water in the area which is found inferior, as E.C of 40% samples is higher in the area. Based on detailed survey carried out in the field, post monsoon water levels varies from 2.61 to 20.74 mbgl at Khajuria-Deona (M/9) Moreover Area comes under Kshipra, Chambal sub-basin. Only Alot block comes under Chambal Sub- Basin.

As study area have drinking water problem due to scarcity during summer, suggestions have been given to State authorities to solve the drinking problem in the area. Technical guidance also given to encourage dug well recharge which is being implemented in Semi- critical,critical &OE areas by MOWR.

5.2 Manpur, Karkeli and Pali blocks of Umaria district

Ground Water Management Studies was carried out in parts of toposheet nos. 64A/10, 11, 13, 14, 15, 64E/2 and 3 in Manpur, Karkeli and Pali blocks of Umaria district covering an area of 4593 sq km and 57 key wells were established. In major part of the area, the depth to water level in pre monsoon ranges from 6 mbgl to 9 m bgl. Shallow water level occurs in pockets only. The post monsoon water level ranges from 3 mbgl to 6mbgl in dug wells. About 80% of the area is covered by Barakar sandstone (Gondwana formations). Seven exploratory boreholes have been drilled by CGWB in Gondwana formation. Depth of these wells ranges from 118.2m (Kaudiya Salaiya) to 281.82m (Birsinghpur –Pali). Discharge of the exploratory wells ranges from 1.33 lps to 39 lps. Chemical quality of the water of these wells is good. All the Auto flowing bore holes occur in the Barakar sandstone as coal seams act as confining layer.

5.3 Anuppur District (Study of GW Pollution in and around Amarkantak Thermal Power Station)

GWMS was carried out in the three blocks of the district viz. Anuppur, Pushprajgarh and Jaithari with special emphasis on study of GW Pollution in and around Amarkantak Thermal Power Station (ATPS) due to its operation.

The district falls under two river basins i.e. the Ganga and the Narmada. Almost entire district forms part of Ganga river system except narrow belt along the southwest boundary in Pushprajgarh tehsil, which is drained by Narmada River. The Normal annual rainfall of the district is 1235mm. The district receives

maximum rainfall during south-west monsoon period from June-Sept. Anuppur is predominantly hilly and forested district and is famous for Amarkantak hill station from where two important rivers namely: Narmada & Son Originates. Anuppur district is underlain by various geological formations, forming different type of aquifers in the area. Main geological units in the area are – Archaen, Gondwana, Lameta & Deccan trap formations. Occurrence and movement of ground water in hard rocks is mainly controlled by secondary porosity through joints & fractures. Primary porosity in Gondwana sandstone and vesicular basalts in Deccan Traps play an important role in ground water movement. Ground water in general occurs under unconfined to semi-confined conditions. A total of 60 dug wells have been monitored during the course of study & extensive water sampling has been carried.Depth to water level during Premonsoon ranges from 3.15 mbgl (Merhakhar, Pushprajgarh block) to 15.86 mbgl (Venkatnagar, Jaithari block). Depth to water level during post monsoon ranges from 1.10 (Khatgaon, Pushprajgarh block) to 14.65 mbgl (Venkatnagar, Jaithari block). Ground water fluctuation ranges from –1.65 m (Anuppur, Anuppur block) to 10.18 (Sakra, Anuppur block). Depth to water level during Premonsoon predominantly remains within 5.0 to 10.0 mbgl in the western half whereas it remains within 5.0 to 10.0 mbgl in the eastern half of the district .Depth to water remains more than 10.00 mbgl in the northern part of the district around Anuppur due to urbanization and coal mining activity. Depth to water during post monsoon fallows more or less the same pattern but depth to water becomes shallower. Water table elevation in the area ranges from 467 mamsl to 915 mamsl. Water table elevation coutours reveals that the rivers Son and Narmada in the district are effluent in nature. General Ground water quality in the district is potable and fit for irrigation. Chemical parameters viz. EC, Cl, F, NO_3 etc. largely remain within the permissible limits. At a few locations NO_3 values between 45 and 100 mg/l have been observed which are due to dug well waters being stagnant and not in use. High values of Iron and Manganese around ATPS, Chachai in ground as well as surface water have been observed, which may be due to the influence fly ash disposal sites and / or imperfect treatment of overflow of such sites and discharge from nearby industrial units.

6 NCCR, RAIPUR

Ground Water Management Studies were carried out in parts of Korba and Durg District. Toal area covered under Ground Water Management Studies was 5437 sq.km.

6.1 Korba district (Ground Water Resource Estimation)

Ground Water Management studies includes Ground Water Resource Estimation using field parameter were taken up in Korba and Kartala blocks, which are located in north and eastern part of Korba district. The study area covers an area of about 2437 sq. km. and is a tribal dominated area where tribal population is 45% of the total population. The rural population accounts 69%. The study area has subtropical climate characterized by hot summer and cold winter season. The normal average rainfall ranges from 1089-1473 mm. The area is drained by Hasdeo river and its tributaries like Teti, Aharan, and Tan, Chornai rivers that comes under Mahanadi basinsThe main Geomorphological features and landforms developed in the district are structural plain, plateau, and denudation hill. The study area is underlain by rocks of Chhota Nagpur gneisses, Chhattisgarh and Gondwana Supergroup of Archean to Corboniferous age. The formation comprises Granite, granite gneisses, sandstone and shale with coal seams. Ground water occurs under unconfined condition in the phreatic zone and semi-confined to confined conditions in the deeper formations.

For groundwater regime monitoring in the study area a total of 75 observation wells were established which included both dug wells and bore wells. The pre-monsoon water level ranges between 2.68 mbgl to 15.30 mbgl whereas post monsoon water level ranges between 0.45 mbgl to 9.52 mbgl. Total 49 no. of ground water samples were collected from dug wells and hand pumps for analysis of basic parameters and 8 acidified samples were collected for determination of iron to assess the groundwater quality. The chemical analysis of these samples reveals that in general ground water is potable in nature. No significant change has been observed in the ground water regime when compared with the previous reappraisal survey.

The objective of the study was the determination of field parameter to estimate the ground water resources. The findings are under process and data under refine. The findings can be summarized as under:-

Determination of rate of Infiltration-

Sl.No	Formation	No of Infiltration test conducted	Rate of Infiltration (cm/hrs)
1	Unclassified Granite gneiss	19	1.62
2	Barakar- Arkosic sandstone, shale and coal seams	15	4.44
3	Talchir- Shale, Sandstone, Boulder bed	7	0.97
4	Kampti -Sandstone, ferruginous sandstone	6	3.06
5	Alluvium	2	16
	Total Test	49	

Specific Capacity of large dia well (Dugwell) -By Slichters Method

Sl.No	Formation	No of Pumping test on Dugwell conducted	Average Specific Capacity (lpm / m)
1	Unclassified Granite gneiss	9	41.3
2	Barakar- Arkosic sandstone, shale and coal seams	11	22.59
3	Talchir- Shale, Sandstone, Boulder bed	2	18.66
4	Kampti -Sandstone, ferruginous sandstone	3	31.41
	Total Pumping test on dugwell	**25**	

Determination of Specific Yield- In Julianala Miniwatershed covering 45 sq km, in Granite gneiss specific yield has been calculated as 1.76 using Dry season balance method

6.2 Durg district (Conjunctive use of surface and groundwater)

The study of conjunctive use of surface and groundwater in Tandula Command Area of Seonath sub-basin in Chhattisgarh State was taken. The command area is bounded by Seonath River in the west and Kharun River in the east. The entire Tandula Command Area lies within Durg district, Chhattisgarh

Tandula reservoir complex embodies three reservoirs; salient features are given in table 2. In addition to this, Tandula Reservoir also gets feed from Pt. Ravishankar Reservoir (Gangrel) through the Mahanadi Feeder Canal. Tandula reservoir has a command area of nearly 3000 sq. Km.

A total of 94 key wells were established for the study. The key wells are well- distributed representing head and tail areas of the canals, different geological formations, rural and urban areas etc. All the key wells were monitored every month. As per the data of department of Revenue, in the present year (2009-10), the study area experienced deficit rainfall. Upto 30% deficit in monsoon rainfall was recorded in different blocks of the command area. The catchment of Tandula Reservoir Complex is spread in parts of Raipur, Durg, Kanker, Dhamtari and Bastar Districts. Most of these districts experienced deficit rainfall during monsoon period. The maximum deficit of 41% was recorded for Kanker District. Canal water supply Due to deficit rainfall during the monsoon period, canal water for rabi crop has not been released .

The area is covered by meso to neoproterozoic, unmetamorphosed sedimentary rocks of Chhattisgarh Supergropup The rock types are: Chandarpur Sandstone, Charmuria Limestone, Gunderdehi Shale, Chandi Limestone (with Deodangar Sandstone), Tarenga Shale and Hirri Dolomite. Chandi Limestone and Sandstone cover 50% of the study area.

During pre-monsoon period, the water levels vary from 1 to 16mbgl with the modal class being 5-7 mgl Similarly, during post-mosoon period, the water levels vary from 1 to 11 m bgl with the modal class of 3-5 mbgl. Water table contour map was prepared based on the reduced levels collected by hand held GPS. There are two perennial rivers on both sides of the study area with a water divide at the centre that has an NNE trend. Regional groundwater flow is towards the major rivers i.e. towards east and west from the regional water divide.

7 CR, NAGPUR

Ground Water Management Studies were carried out in parts of Jalgaon and Aurangabad districts, parts of Wardha district (Farmers Distress Area), part of Ahmednagar district and parts of Amravati district covering area of 10433 sq.km.

7.1 Jalgaon and Aurangabad districts (Impact of agricultural pollution on groundwater quality as well as remote sensing studies in hilly areas)

Ground Water Management Studies were carried out in parts of Tapi river basin covering an area of 3000 sq.kms mainly in Jalgaon district and also in parts of Aurangabad, Jalna and Buldhana districts. The theme of study was to assess the impact of agricultural pollution on groundwater quality as well as remote sensing studies in hilly areas of the study area. The plain area surveyed falls Jalgaon, Jamner, Bhusawal, Muktainagar and Bodwad talukas of Jalgaon district. The hilly area in southern and southeastern part forming fringe of the basin area falls in Aurangabad, Jalna and Buldhana districts respectively. The study area comprises of 20 watersheds.

The area forms part of Tapi river basin and drained by the river Purna and major tributary of Tapi river i.e. Vaghur river. There is a general decrease in elevation from south to north from the height of about 750 m amsl to about 250 m amsl.

Basalt is the main hydrogeological unit in the area. Groundwater occurs under phreatic condition in the exposed lava flows and under semi-confined conditions in the subsurface flow. Dug wells are the main ground water abstraction structures in the area and the yield ranges from 20 to 100 m^3/day.

During pre-monsoon 84 key wells (dug wells) were established to monitor the water level in the area and to study the impact of agricultural pollution on groundwater quality. The depth of these dug wells ranges from 5.10 m to 33.8 m. The pre-monsoon depth to water level varied between 2.85 m.bgl and 25.70 m.bgl. During post-monsoon the water levels varied between 0.40 m.bgl and 26.70 m.bgl. Both rise and fall in water level fluctuation were observed in the study area. Out of the 77 key wells were considered for analyzing the water level fluctuation in the study area, 53 wells (69%) has shown the rise in water level and remaining 24 wells (31 %) have shown fall in water level.

During March 2010, thirty water samples were collected from the banana growing areas of the district to study the impact of agricultural pollution viz. sulphate, nitrate and phosphate and other pesticides like Endosulfan, which was reported by the farmers to be using. Data pertaining to pesticides used for the banana growing farms and other crops was collected from the Department of Agriculture in Jalgaon district. The socio-economic data was also collected from the Collector office and District Statistical Officer of Jalgaon and Aurangabad district.

Remote sensing data in the form of imagery available in the office was also analysed with the expert from the North Maharashtra University, Jalgaon and the study revealed that the overall hydrogeological condition in the hilly area is almost similar to that of other part of the study area.

7.2 Wardha district

An area of 3200 sq.kms was covered in northern parts of Wardha district, which includes five talukas namely Wardha, Ashti, Arvi, Karanja and Selu. The area includes 20 watersheds.

The area is underlain by basaltic lava flows with patches of inter-trappean beds. A small pocket of alluvium is also seen in the southwestern part. The district forms part of Godavari basin and the river Wardha is the main river that traverses through the district, which separates Amravati district with Wardha in the western part.

During premonsoon survey, 55 key wells (dugwells) were established to monitor the water level in five talukas of Wardha district viz. Wardha, Ashti, Arvi, Karanja and Selu. The depth of the wells varies from 6.30 m.bgl to 19.31 m.bgl and diameter varies from 1 to 6.80m. The pre-monsoon water level ranges from 4.60 m.bgl to 15.29 m.bgl and the post-monsoon water level ranges from 2.23 to 15.46 m.bgl. The water level fluctuation ranged from -2.86m to 5.85m.

As a part of study in the Farmers Distress area, 23 farmers were selected in different hydrogeomorphological conditions in the above five talukas and their dugwells apart from 55 key wells were studied. The information regarding performance of their dugwells in both pre and post monsoon was collected. The main kharif crops grown in these talukas are cotton and soyabean whereas the main rabi crops are wheat, gram, tur and oranges. About 80-90% of farmers informed that their wells goes dry after 1-2 hour pumping in summer season and the rate of recovery ranges from 4-5 hours and sometimes it took 20-22 hours. Due to failure of monsoon in 2009, the farmers lost their kharif crops and damage to the oranges was noticed.

The overall study reveals that the farmers in all these 5 talukas of Wardha district do not have ground water problems for irrigation and drinking purpose. The Availability of power and laborers are the main problems for the irrigation.

7.3. Amravati district(parameter estimation studies for the refinement of GEC norms)

An area of 549.58 sq. km. was covered in Amravati district covering Amravati, Tivsa and Morshi talukas. The selected area comprises of two watersheds namely WR-4 and WR-5. The theme was parameter estimation studies for the refinement of GEC norms.

The study was carried out based on watershed as a unit hydrogeological feature. The watersheds WR-4 and WR-5 watershed have geographical area of 138.68 and 410.9 sq. kms respectively. The area forms a part of Godavari basin and drained by Wardha river on the eastern boundary of these two watersheds. The maximum elevation of the study area is 405 m amsl near Chikhli in NW part of watershed WR-5 and the minimum elevation is about 314 m amsl near Varkhed in the eastern part of WR-5.

The area is covered by weathered and fractured massive and amygdular basalts. The eastern part of both the watershed falls under the command area of Upper Wardha Project situated at Simbhora near Morshi at about 10 km north of the study area. The right bank canal of the Up. Wardha Project passes through these watersheds. The total command areas in WR-4 and WR-5 is about 33.55 and 75.28 sq. km respectively.

The basalt is the main formation of the area. Ground water occurs under phreatic conditions in the exposed lava flows and in semi-confined to confined state in the subsurface flows. During premonsoon survey, 45 key wells (dugwells) were established to monitor the water level in the area out of which 15 lie in WR-4 and the rest in WR-5 watershed. The depth of the wells varies from 4.3 mbgl to 18.1 mbgl. 32 shallow aquifer water samples from some of the key wells were collected for determination of chemical quality. The monitoring of keywells was done both in pre-monsoon and in post-monsoon periods. Pre-monsoon water level ranged from 2.25 mbgl to 14.35 mbgl and Post-monsoon water level from 1.37 to 14.2 mbgl with the water level fluctuation ranging from 0.9 to 4.5 m.

Infiltration tests were carried out at 18 locations using single ring infiltrometer. The collection of information on ground water draft, unit draft of abstraction structures, yield of dugwells etc., were also done.

7.4 Ahmednagar District :

An area of about 3598 sq.kms was covered under Ground Water Management Studies in parts of Ahmednagar District. The area includes 17 watersheds namely GV- 124, 125, 126, BM 5,14,15,16, & 28, SA- 1, 2, 3,4,5,6,7,8, & 10.

The area is drained by Godavari, Bhima and Sina Rivers and their tributaries. Most part of the area is rain fed and the irrigation in these areas is mainly through ground water structures (Dugwells and Borewells) and rain water abstraction structures (percolation tanks, Nalla Bunds, KT weir etc).
The area is mainly underlain by Deccan traps. Alluvium of Recent age occur along the river courses and valley portions. At places the thickness of the alluvium cover ranges from 3.0 to 15.0 m.

During pre-monsoon, 125 key wells were established. The depth of dug wells varied from 5.1 to 24.40 m.bgl. The DTW during pre-monsoon ranges between 1.60 & 23.8 m.bgl. The DTW during post- monsoon ranges between 0.30 & 14.80 m.bgl. The fluctuation of the water levels ranged between 0.55 & 10.05 m.

The yield cum draft of the dug wells in Deccan traps formations ranges between 5 to 1 00 cubic meter/day where the pumping hours are in the range of 2 to 8 hours/day with the pump sets of 3 to 10 HP, while the yield cum draft of the dug wells in Alluvium areas between 100 to 300 cubic meter/day where the pumping hours are in the range of 8 to 16 hours/day
62 water samples were collected for the study of chemical quality of the ground water. In general, the quality of water is good to brackish. Two industrial areas are located in the study area. Ralegaon Siddi and Hivre Bazar are the two ideal villages developed by the efforts of local Gram Panchayat and NGO"s are located in the study area.

8 NR, LUCKNOW

Flood Plain Aquifer Mapping and hydrogeological investigations along Ganga River with the view to prepare developmental plan to meet out water supply demand of habitations in flood plain areas and for domestic, irrigation & other purposes. Total area covered was 11913 Sq km distributed in parts of Kanshi Ram Nagar, Farrukhabad, Budaun, J P Nagar, Bijnor, Meerut, Muzaffar Nagar, Ghaziabad, Bulandshahar & Aligarh districts. In addition 1375 sq km area was also studied in Sengar river water shed in Kanpur Dehat district & adjoining areas in Hamirpur & Jalaun districts and feasibility study for suggesting measures of run-off control & artificial recharge using remote sensing technique for ravine reclamation.

Ground Water Management Studies were carried out in Hardoi & Shahjahanpur, Kanpur Nagar & Kannauj, Unnao, Lucknow & Barabanki districts .

8.1 In parts of Budaun district District (Flood Plain Mapping)

Ground Water Management Studies in parts of Budaun district has been undertaken for Mapping of flood plains & surrounding area of blocks along Ganga river and potentially assessment of shallow & deeper aquifers & preparation of developmental plan for drinking water supply & irrigation needs

The river Ganga forms the southeren boundary of the Badaun district ,U.P. The part of the study area lies from North West Rajpura block to South East Usawan block falling along the Ganga river, lying in the survey of India toposheet no 54 I/13,54 L/12,54 M 1,5,6. There 8 blocks namely Rajpura ,Gunnaur

,Junawai,Dahigawan ,Sahswan ,Ujhani,Quader chowk and Usawan of Badaun district,U.P.The area lies on the bank of Ganga River ,about 2655 Sq.Km was covered

The area is underlain by a thick pile of Quarternary unconsolidated sediments .The thickness of unconsolidated sediments is likely to be 740 m at Ujhanias per ONGC record.The alluvium consist of clay ,silt,various grades of sand with occasional garvel at depth.The sand is generally fine to medium grained in shallow depth which tends to become coarser with depth.

In the study area most of the dug wells have been gone dry due to the installation of Handpumps (Mark II). The people have stopped using dugwells . During survey of the study area in the pre-monsoon 18 key wells were established and inventoried.

The depth of water level during pre-monsoon-2009 in the area ranges between 3.50 mbgl at Semeri and 10.83 mbgl at Akbarpur. Along the Ganga river ,the depth of water level is more than 10 mbgl in the block Usawan .In this block ,the dug wells have gone dry and water level could not be measured.In total 18 numbers of water samples were collected (near key well established)or from the Hand pump (Mark II)during premonsoon period. The depth of water level during post-monsoon- 2009 in the area ranges-between 3.26 mbgl at Kachha village (Ujhani block) and 10.35mbgl at Akbarpur(block Usawan)The water level is deeper as we go away from the river though water level could not be measured as dug wells were not avilable in the area. The water level fluctuation ranges from 0.01to 1.15m in the study area. In total 15 no water level samples were collected for detailed analysis and 8 numbers of samples are collected for Arsenic (one from each block along Ganga river)

8.2 J P Nagar & Bijnor districts (Flood Plain Mapping)

Mapping of flood plains & surrounding area of blocks along Ganga river and potentially assessment of shallow &Dee per aquifers & preparation of developmental plan for drinking water supply & irrigation needs in parts of J P Nagar & Bijnor districts

The area covering 2677 Sq.km area were studied under Mapping of flood plains & surrounding area of along Ganga river for potentially assessment of shallow &deeper aquifers & preparation of developmental plan for drinking water supply & irrigation needs in parts of J P Nagar & Bijnor districts The Ganeshwari, Hasnpur,Gajraula & Dhanaura blocks of J.P.Nagar district and Mohamadpur-Deomal,Haldaur (Khari Jhalu ,& Jalilpur blocks of Bijnor district were covered under the study.

The Mahawa, Bhagad, Malin and Chhaiya are the major tributaries of the river Ganga forming a dendritic pattern in the alluvial plains of Quaternary age. The area has three tier sub aquifer system upto the inventoried depth 600 mbgl (Gajraula) of which the top " Phereatic Aquifer system "upto an aaverage depth of 50 mbgl is generally unconfined nature having ground water under water table condition which is more dependable in the food plain area and contributing to agriculture productions . The quality of groud water is good for domestic purposes and for irrigation also.

During premonsoon period key wells were established in the study area for water level measurement. About 70 numbers of key wells /Pz/Hand pumps were established and water levels was measured premonsoon & postmonsoon period.. In the area 98 % dug wells are dry pizometeres of GWD department and shallow hand pumps were used for water level measurement.

The pheretic aquifer system has the depth to water level ranging from 2.80mbgl (in the Younger alluvium-in Khader area) to 14.00mbgl (in the older alluvium) in the premonsoon and 2.00 to 13.00 mbgl during the post monsoon seasons respectively except at chandok of Bijnor district.where depth to water level is 17.00mgl in the premonsoon & 9.00 to 10.00 mgl in the post monsoon. For the assessment of water quality in the study area, water samples were collected from the handpump, borewells, tubewells, and Ganges river. In total 30 water samples were collected for the Arsenic study from the study area.
The additional ground water potential existing in the shallow depth to water areas and in the flood plains may also be utilized to meet out irrigation & drinking water needs of the local people. In general the ground water quality of the area is good and potable & fit for domestic & irrigation purposes. The Deeper aquifer system are of semi confined to confined in nature and have ground water under pizometeric pressure head.

8.3 Parts of Meerut & Muzaffar Nagar districts (Flood Plain Mapping)

Mappiing of flood plains & surrounding area of blocks along Ganga river and potentially assessment of shallo & deeper aquifers & preparation of developmental plan for drinking water supply & irrigation needs in parts of in parts of Meerut & Muzaffar Nagar districts

Under Ground water Management studies the blocks covered having an area of 1996 Sq, Km for the purpose of Mappiing of flood plains & surrounding area of blocks along Ganga river and potentially

assessment of shallow &deeper aquifers & preparation of developmental plan for drinking water supply & irrigation needs in Meerut district covering blocks which are Parikshat garh,Hastinapur & Machara,whereas Jansath,Morna & Purkazi blocks in Muzaffer Nagar district.

The Ganga river forms the easteren parts of the district, the area of study.The tract is known as Ganga-Khadar region.and characterized by ravines ,depression and water courses. The study area is the alluvial plain of Indus-Ganga Region of Midle to Upper Pleistocene period. The lithology is alluvial clay and river silt, sand

During pre monsoon period 20 numbers of key wells established in the study area to monitor water level fluctuation . The depth of key wells ranges from 5.56m bgl (Satla village) to 30.00 mbgl at (Seekri village).The water level during premonsoon ranges from 3.38 mbgl (Kharhali, block Parikshat garh)and 16.20 mbgl (Seekri, block Morna) and during postmonsoon it varies from 3.00 mbgl to 16.11mbgl . In total 24 No of water samples were collected for assessment water quality in the study area.

8.4 Parts of Ghaziabad, Bulandshahar & Aligarh districts (Flood Plain Mapping)

Mapping of flood plains & surrounding area of blocks along Ganga river and potentially assessment of shallo & deeper aquifers & preparation of developmental plan for drinking water supply & irrigation needs in parts of Ghaziabad, Bulandshahar & Aligarh districts.

Pre-monsoon Phase: Covered 2023 sq km area under above survey along Ganga river in Garh Mukteshwar block of Ghaziabad district, Dibai, Anup Shahar, Siyana, Unchagaon, B.B. nagar, Danpur and Jahangirabad blocks of Buland Shahar district and Bijauta block of Aligarh district. During pre-monsoon survey took hydrogeological traverses of about 60 villages and fixed 20 key wells additional for water level monitoring in the area. The study area is the alluvial plain of Indus-Ganga Region of Midle to Upper Pleistocene period. The lithology is alluvial clay and river silt, sand. The depth to water level ranges from 1.32 to 11.32 mbgl, the depth of well ranges from 2.40 to 12.80 mbgl, the dia ranges between 0.93 and 2.66m and MP of dug well ranges from G.L. to 1.20 magl. The water samples were also collected from nearest hand pumps and existing dug wells.

Post-monsoon Phase:The post-monsoon water level measurements of key wells completed. The DTW varies from 1.25 to 11.20 mbgl and the seasonal fluctuation ranges between 0.03 to 1.27m . During the detailed survey it is seen that the Simbhawali sugar mill (Garh Mukteshar block of Ghaziabad district affect to village Pawara,Bhadogarh,Sehal & Langa Sarai , the effluents of this sugar mill badely affectsto the villages. The "Gopal Ji Milk Plant " also exist near Simbhawali sugar mill and the effluent of this plant also add the water pollution like sugar mill,all ultimately add the Ganga river with pipe line.In the study it is found alomg the traverse from GarhMukteswar,Pooth ,Paswara, Palwara and Mohammadpur (along Ganga river) ,the water level in KHADAR area range between 2 to 3 mbgl where as in Bangar area it ranges between 5 to 6m bgl (water level increases from Kahdar to Bangar area). During studies along Ganga river in AnoopShahar block traverse taken across Aahar,Awantika temple,Rajghat,Dedh Meel and Niwari places of Dibai block of Buland Shahar district. It is observed in the above areas the water level ranges 3 to 5 mbgl in 'Kahdar'area and 12 to 15 mbgl in Bangar area. In floodplain area the farmers took only single crop either Sugar cane or wheat etc. At Khadar portion the villagers grew tomato etc.

8.5 Parts of Kanshi Ram Nagar & Farrukhabad districts

Mapping of Flood Plains & Surrounding Area of Blocks Along Ganga River and Potentiality Assessment of Shallow & Deeper Aquifers & Preparation of Developmental Plan for Drinking Water Supply & Irrigation Needs in parts of Kanshi Ram Nagar & Farrukhabad districts. Pre- & post-monsoon monitoring and detailed studies in respect of the 2562 Sq Km area in parts of in parts of Kanshi Ram Nagar & Farrukhabad districts completed. Detailed survey was covered for an area of 500 Sq Km.

8.6 Parts of Unnao district

The Ground Water Management Studies were carried out in Unnao District, covering an area of 1496 sq.km. In order to assess the potability of water, the water samples 48 nos. were collected in the blocks (Sikandarpur Sarsoi, Sikandarpur Karaon, Bagamau, Fatehpur, Chourasi, Gan Moradabad, Safipur, Bighapur and Sumerpur) from hand pump (II),and private H.P., Shallow tube well and deeper tube wells. Pre-monsoon the watersamples results of Chemical analysis reveals that the, 6 water samples indicate high fluoride concentration beyond the permissible limits of 1.5 mg/l (BIS-1991). High concentration of Flouride has been found from 1.53(Akbarpur, Bangarmau block) to 2.0(BoniThana, Fatehpur block)

8.7 Kanpur Dehat District (Remote Sensing Studies)

Feasibility of study for demarcating ravenous area in parts of Sengar River watershed, Kanpur dehat district and suggesting measures of run off control & artificial recharge using remote sensing technique

Ground Water Management Studies in parts of Kanpur Dehat, Hamirpur & Jalaun districts covered in S.O.I., Topographic sheet Nos. 54N/15 & 54N/16 by Remote Sensing techniques (Ravine studies in Sengar river water shed in parts of Kanpur Dehat district & adjoining areas in Hamirpur & Jalaun districts).

The special study has been taken up basically with a broad objective to suggest, through remote sensing studies, the measures to conserve and upgrade land and water resources of the area in an integrated manner to restore ecological balance and arrest rapid degradation of land under the Ground Water Management Studies.

The remote sensing interpretation were done on Black & White MSS images and FCC's and currently acquired Satellite data (IRS-1D LISS III Geo- coded 54N/15 & 54N/16) for the mapping of ravine land. The image interpretations were validated through field checks.

The large parts of the area form plain topography with highly undulating surfaces in the vicinity of the trunk river which is resulted due to heavy fluvial erosion. The Yamuna River and its tributary Sengar river flows in meandering pattern with high degree of sinuosity along their courses. The various erosion features identified in the area represent the different stages of fluvial erosion viz. sheet erosion, rill erosion, gully erosion which ultimately transform in to ravines.

The ground water scenario of the area is quite poor in ravenous tracts. The ground water levels of the area rests at deeper levels particularly along the river course where the levee sides are generally developed as ravines. The Depth to Water Levels were monitored at specified interval through out in the area in about 45 dug wells.

The gradual headword erosion leads to upward migration of the ravine in the area which is manifested in terms of widening aerial extent. Such features and locations are identified through imagery data analysis and field survey where excessive erosion leads to develop ravines and need to apply the measure to check the erosion. Various measures in vogue to develop such areas are construction of check dams along first and second order streams, gully plugs, bonding, trenching across the slopes ets. are practiced by Soil Conservation & forest Departments and other organizations and NGO’s working in the area.

9. MER, PATNA

The Ground Water Management Studies were carried out in East Singhbhum district (Jharkhand) & Supaul, Saharsa-Madhepura (Bihar) and area covered 9364 sq.km.

9.1 Supaul district

The District covers an area of 2,420 sq km. It is a part of the Kosi division. The district comprises 4 sub-divisions: Supaul, Birpur, Triveniganj and Nirmali. Supaul sub-division consists 4 blocks: Supaul, Kishanpur, Saraigadh-Bhaptiyahi and Pipra. Birpur sub-division is further divided into 3 blocks: Basantpur, Raghopur and Pratapganj. Triveniganj sub-division has 2 blocks: Triveniganj and Chhatapur. Nirmali sub-division comprises 2 blocks: Nirmali and Maruna. The district has a population of 1,745,069 (2001 census). The urban population constitutes 19% of the total population. The population density is 735/km².

The Kosi River flows through the western boundary of the district. This river is considered as the sorrow of not only this area, but whole of the state of Bihar. The river frequently overtops it banks and causes flooding. Tilyuga Chhaimra, Kali, Tilawe, Bhenga, Mirchaiya, Sursar are the tributaries to it.

The soil is basically sandy and it varies from acidic to basic in nature. The geomorphology of the district and the regional architecture has been carved out by the frequently shifting Kosi River and other misfit channels (groundwater fed) flowing in the abandoned channels of Kosi. The district is situated in the heart of the " Kosi megafan ", known to be the biggest inland delta in the world. The upper 5-9 m of the sub-surface lithology is in general finer (laid down by the shifting Kosi) in nature, below which the lithology is coarser.

Agriculture is the major occupation of this district and paddy is the main crop. Net sown area stands at 55 % of the total geographical area of the district. The agricultural intensity of the district stands at 151 %. The district show an irrigation status of 58 % of the gross area cultivated. Though canal water form a good part of the total irrigation demand, groundwater form the major irrigation source and it fulfills 50-60 % of the gross irrigation demand.

Water level in Supaul district remains largely shallow (<3mbgl) in both pre- as well as post-monsoon period with exceptionally reaching 4 – 5 m bgl at places. As a part of groundwater management study of

the Supaul district, 42 key wells were set and their water level data were collected during pre- as well as the post-monsoon period of the year 2009. Pre-monsoon water levels of the district were found to vary from 1.34 mbgl at Narhi to a maximum of 5.44 mbgl at pipra chowk, whereas the post-monsoon water levels in the district varied from a minimum value of 1.2 mbgl at Narhi to a maximum of 3.6 mbgl at Pipra chowk. In both the seasons the water levels were found to be shallower along the active Kosi channel and deeper towards the west and southwest parts of the district. Few of the important observations during the water level study in the district are summarized below:

- In both the seasons, despite shallow water levels, distinct patterns of ground water flow are evident.
- In both the seasons of water level measurement, the elevation of water table remains within ~ 70 m amsl to > 45 m amsl.
- In general ground water level flows in a NW-SE to north south trend.
- It is interesting note that the active channel of Kosi acts as a recharge source from ground water in the western part of the districts in both the seasons.
- The small streams flowing in the abandoned channels of Kosi are gaining in nature i.e. those are fed from ground water.

Long term water level data have been evaluated for a maximum up to last 24 years. The interpretation of hydrographs indicate both pre- and post-monsoon rising trend of water level up to the year 2007-08 at 7 out of 8 monitoring stations. After 2007, there has been a general falling trend. The rising rates vary from the minimum of 3.11 cm and 2.78 cm per year at Bhimnagar during pre- and post-monsoon respectively to maximum of 9.33 cm and 8.00 cm per year at Bhawanipur during pre- and post-monsoon respectively.

However, during last 3-4 years, the whole of the district faces a water level declining scenario. This may have been due to the deficient rainfall in the district in these years.

9.2 Saharsa-Madhepura district

The study covered 3435 sq. km of Saharsa and Madhepura districts. Quaternary unconsolidated sediments consisting of sand, gravel and pebbles constitute potential ground water repository. Shallow aquifer is about 40-70 meters within a depth of 80 meters. A thin veneer of clay is present overlying the granular zone in the northern part of the district. Though lateral facies changes have been observed, the aquifer system behaves as single continuous one. The aquifers are highly potential and yield 200m^3/hr for nominal drawdown of 2 m. Pre-monsoon depth to water level has been found varying from 2 to 5.5 m bgl while Post-monsoon level was found between 2.12 and 4.10 m bgl. Water samples have been collected from representative wells for analysis of groundwater quality. Groundwater quality of the area is potable except for incidence of high iron in localized pathes.

9.3 East Singhbhum district

Total area covered is 3216 sq. km. Altogether 40 no. Of ground water samples have been collected from Jamshedpur sadar, Patamda, Bahragora, Chakulia, Mosabani, Dhalbhumgarh and Potka blocks of East Singhbhum district. Water samples have been collected both from dug wells and hand pumps to have an idea of shallow and deeper aquifer quality.

Block wise details of East Singhbhum district

Sl. No.	Name of Block	Area (Sq. km.)	Population	Range of Pre-monsoon Water level(mbgl)	Range of Post-monsoon Water level(mbgl)
1	Patamda	511.53	1,31879	7.30-11.60	2.50-8.00
2	Jamshedpur sadar	334.39	1076544	6.00-10.90	1.80-7.90
3	Ghatsila	346.35	115130	5.90-10.05	2.05-5.00
4	Dhalbhumgarh	324.10	72528	2.10-6.65	0.60-4.40
5	Potka	594.22	170657	4.00-9.45	2.10-4.25
6	Mosabani	244.99	104299	6.00-9.05	1.05-2.10
7	Chakulia	427.76	108806	3.70-18.20	2.10-10.00
8	Bahragora	433.31	149530	4.70-9.70	3.50-5.70

The major rock type of the area is mica schist, Schist, phyllite and Quartzite of Singhbhum group.Eastern area of the district is underlain by Tertiary formations consisting of gravel,Pebbles and Sands. Northern area is hilly is of Dalma volcanic consisting of tuffs, hornblende schists, Carbon phyllite, Quartzite etc.

The ground water occurs both under unconfined condition and semi confined to confined condition. The unconfined condition exists in the weathered mantle portion of the rocks. Depth of weathered mantle varies from 15-34 m in general. The general ground water flow is towards southeast. The main potential aquifers are found in the secondary porosity developed by tectonic activities as fractures and joints. The bore wells drilled up to 150 m deep tapping these fractures (2 to 3 numbers) yield 12 to 20 cubic m/hrs. of discharge having 12 to 30 m of draw down.

Ground water quality in the area is potable. All the constituents are within permissible limit of Bureau of Indian standards except Iron and Fluoride. Fe concentrations in these areas are found in the range of 1-5 ppm. Kudada, Parsudih, Baghbera, Ghorabandha and Chota Gobindpur areas have fluoride concentration in hand pump samples (1.5- 2.5 ppm). Some portion of Jamshedpur urban areas like Sidgora, karandih, Parsudih, Baghbera, Kitadih and Chotagobindpur are devoid of fractures so deeper aquifers do not have ground water.potential **.**

Long-term water level data of East Singhbhum indicate that Chakulia, Bahragora and Patamda areas are suitable for artificial recharge. In Jamshedpur urban area, Adityapur, Khasmahal, Karandih, Mango, Pardih areas are suitable for artificial recharge.

10 ER, Kolkata

An area of 7000 sq.km. was covered under Ground Water Management Studies in parts of Middle and North Andaman, parts of Murshidabad, Uttar Dinajpur and parts of Birbhum District.

10.1 Middle and North Andaman Districts(Feasibility of rainwater conservation using Remote sensing technique)

Hydrogeological survey was carried out over an area of 1000 sq km in the Blocks of Diglipur, Mayabander, Rangat of North and Middle Andaman Districts of Andaman & Nicobar island.The objectives of the studies are to to assess the present ground water condition in the water scarce area and to study the feasibility of rain water conservation using Remote sensing technique.

The study area comprises of fine grained sandstone, shale, conglomerate, grit, igneous volcanics and intrusives of Cretaceous age. This is overlained by coralline limestones and limestone of Recent to Sub Recent age. As the sedimentaries are devoid of high porosity and permeability, these are not potential aquifer. Igneous rock Formations are potential aquifer. But its presence in high altitude scope of ground water exploration is very limited. Dug well, ponds and perennial streams are the main sources of irrigation in this area. But during peak summer ground water is the only source of irrigation. Pipe water supply schemes are only dependent on availability of spring water to meet up domestic and drinking needs for the people in the study area. For daily domestic needs dugwells are useful. Due to Tsunami, pipeline water supply was damaged and present water supply is manly based on from intake well constructed in the Kalpong river bed.

A detailed ground water management study was conducted in water scarce areas of North and Middle Andaman Districts. In North Andaman District pre and post monsoon depth to water level ranges from 2.74 to 5.35 mbgl and 1.06 to 3.37 mbgl respectively. In Middle Andaman District pre and post monsoon depth to water level varies from 2.88 to 5.35 and 0.93 to 3.36 mbgl respectively. Remote sensing technique has been used to locate the valley area where construction of ground water abstraction as well as rainwater conservation structure is possible. In Middle Andaman District 14 Valley areas have been located and 8 valley areas have been identified on Diglipur road in North Andaman District.

10.2 Murshidabad district (Flood Plain Aquifer)

An area of 2000 sq. km. including 12 Blocks in parts of Murshidabad district was covered. The Objective are to understand the disposition of flood-plain aquifer along Ganga River.

Geologically the interfluve is represented by huge thickness of Recent to Sub-Recent Alluvium of the Ganga river system (Quaternary age) with presence of basaltic rocks at depth along the northern margin. The study area partly covered by older alluvium & partly by recent alluvium of Quaternay age. The aquifer occurs under unconfined to semi confined condition in unconsolidated sands of various grades within a

depth span of 19.8 mbgl to 143.50 mbgl. Discharge of tubewell ranges from 22.5 to 199.84 m^3/hr. Transmissivity ranges from 75 to 8500 m^2/ day and Stotativity varies from 1.8 X 10^{-2} to 9.9 X X 10^{-4} .

10.3 Uttar Dinajpur district

An area of 2750 sq.km was covered and a detailed study in 'Barind track' of Itahar, Hematabad and Raiganj Block were carried out. The study was conducted through inventory of key observation wells, collected water samples from dugwells & tube wells.The objectives is to to understand the change in ground water regime due to agricultural activity.

The area is covered by alluvium deposits of Recent age. The sediments are thickening towards northern part of the district. The northern part of the area is covered with a broad piedmont alluvium plain overlapping the Older alluvium. The Recent alluvium are fluviatile deposits of sand, silt and clay with occasional gravel beds. Aquifers composed of medium grained to coarse grained sands and gravels are responsible for the ground water development in the district. In the northern part of the study area ground water occurs under water table condition and in southern part of the district groundwater occurs under water table to semi-confined condition. In the central and southern part of the district thin clay layer alternate with fine to medium sand layers occurring 30 to 40 m below ground level. In the study area shallow tube wells are capable to yield 40 m^3/ hr with insignificant drawdown and deep tube wells are capable to yield 150-200 m^3/ hr with a maximum drawdown of 4-5 m only. During hydrogeological survey a total of 52 key observation wells were established. Water level during premonsoon period ranges from 3.050 to 6.80 meter below ground level whereas postmonsoon water level ranges from 1.20 to 5.5 mbgl. Transmissivity value is about 2000 m^2/ day.

Based on the study the following recommendations were given:

- As all the Blocks in the study area falls under "Safe" category large scale ground water development for agricultural use can be feasible for shallow aquifers.
- Close monitoring of depth to water level for both shallow and deep aquifers is essential to know the long term behavoiur of aquifer.
- Shallow ground water abstraction structure is feasible in northern part of study area and deep tube wells can be constructed in southern part of the study area.
- In water logged areas stress has to be given on ground water development and drain out the excess surface water to the adjacent Blocks. (v) Roof top rainwater harvesting and conservation of rainwater can be adopted in southern part of the district. (vi) Modern irrigation practice should be adopted in "Barind"tract areas of Itahar and Hemtabad Blocks.

10.4 Birbhum district (Naturally contaminated Area)

An area of 1250 sq.km was covered in Nalhati II, Rampurhat II, Mayureswar I & II, Saithia and Labpur blocks of Birbhum district. The study was conducted through inventory of key observation wells, collected water samples from dugwells & tube wells. The Objective is to study the high fluoride concentration in ground water.

The area is almost flat terrain with a general gradient is towards southwest direction. Geologically the area is underlain by Quaternary Alluvium deposits of sand, silt and clay, caliche nodules. Basement consists of Chotonagpur Granite gneiss of Archaean age.

Total 93 key observation wells were established in the area for quantitative & qualitative monitoring of ground water. Depth to water level in the key observation wells in the pre monsoon period ranges from 4.92 to 22.65 meter below ground level and that of post monsoon water level ranges from 2.15 to 14.00 mbgl. Exploration in the area reveals that potential granular zones exist in the depth span of 46 - 64 and 125 - 160 mbgl. The deeper aquifer is having fluoride content to the tune of 6 mg/l, whereas the fluoride content in the shallow aquifer is 0.4 mg/l (ie below the permissible limit of 1.5 mg/l). High fluoride concentration can be mitigated by dilution and artificial recharge techniques.

11 NER, GUWAHATI

The Ground Water Management Studies were carried out in Goalpara,Sonitpur,Dibrugarh, Nagaon (Assam), West Tripura (Tripura) and Papumpare (Arunachal Pradesh) and area covered 15000 sq.km.

11.1 Barpeta district & parts of Baksa district of Assam

The study area is located in the northern bank of Brahmaputra river comprises Barpeta district (2645 sq. km) and parts of Baksa district (655 sq. km) in Assam.

The general topography of the study area varies from low-lying plains to highland having small-hillocks. Tropical monsoon climate of the District provides two distinct seasons- summer and winter.

The River Brahmaputra flows from east to west across the southern part of the district. The tributaries of this river that flows through the study area are Beki, Manah, Pohumara, Kaldia, Palla, Nakhanda, Marachaulkhowa and Bhelengi flowing from north to south. Rivers Pohumara and Kaldia join near Barpeta town to form river Nakhanda whereas Palla and Beki join with Nakhanda to ultimately form Chaulkhowa River.

Out of total geographical area of 3300 sq. km approximately 1770 sq.km constitute net sown area forming 53% and of this 620 sq.km constitutes area sown more than once giving cropping intensity of 135%. The main crops of the district are paddy, wheat, rape, mustard, tea, lentil, green gram, black gram, potato, vegetables.

Hydrogeologically, the study area is covered by alluvial sediments of Recent to Sub-recent age. Depending upon hydrogeological set up the study area can be divided into three distinct hydrogeological horizons viz. Bhabar, Terrai and Flood Plain areas.

The Bhabar belt is underlain by pebbles, boulders with gravel and sand in clay matrix in the northern part of the land and is about 8-12 km wide. The second- Terai zone towards south, which is made up of medium to coarse sand down to 20 m and underlain by gravels and pebbles. The third horizon occurring immediately south of Terrai zone constitutes the Flood plain area and is composed of sands of various grades within thin clay intercalations. This zone constitutes almost single horizons with 90% of sand.

Ground water in the area is found to occur under water table condition with some local variations where its occurrences restrict to semi-confined conditions. Average depth to water level varies from 4 to 5 mbgl during lean period in major parts of the flood plain area. However, in a small portion of the northern part of the district immediately below foot hill zone covering Simla Anchali area, water level is less than 4 mbgl, perhaps this is due to occurrence of clay horizon at shallow depth giving rise to perched water table conditions. In the extreme northern parts of the district in the Bhabar zone water levels are generally more than 10 m.

Exploration at Pathsala down to 40 m reveals potential aquifer horizon capable of supporting shallow tube wells of 30 m^3 / hr yield capacity. Tube wells constructed within 170 m at Keotkuchi and Bongaon taps 57 and 53 metres respectively of aquifer horizon and are found to yield more than 100 m^3 / hr for draw down of less than 6 metres. Transmissivity values obtained from the pumping test were found to vary from 5061 m^2 /day to 9942 m^2 / day with permeability of about 70 m/day.

More than 90% populace in the study area is agrarian with only little industrial development / growth. Ground water development in the study area is negligible. The farmers have either very little or no access to irrigation facilities in any form. A network of drinking water supply utilizing ground water sources has been developed by PHED, Govt of Assam at Panchayat / village levels the command area of which is yet to be expanded to about $3/4^{th}$ of the total area.

Analysis of ground water samples collected from the study area with special reference to localities where new industrial set up are coming up and where pesticides are applied in the agricultural fields reveals no deviation from the norm of chemical quality. So far as earlier reports of CGWB refers to occurrence of fluoride in more than permissible limits in certain pockets in the study area, no manifestation of any form of fluorosis has been either observed or reported . However water samples from different sources have been collected for further chemical analysis to determine the present level of fluoride. Possibility of arsenic contamination has so far been withdrawn in the study area.

A network of 57 nos of key observation wells has been established in Barpeta and parts of Baksa Districts to study the water level regime in the study area. A perusal of the water level data shows that there is no depletion of water level so far.

11.2 Nalbari district & parts of Kamrup district (Rural), Assam

Nalbari district:

Physiographically, the study area can be divided into two units which are northern alluvial region and southern swamps or flood plains of river Brahmaputra. The alluvial parts form a flat land of 120 – 140 m above MSL with a gentle local slope towards the river Brahmaputra. The regional gradient is from E-W which is general flow direction of Brahmaputra River. Near the banks of the river, the elevation is only 5 – 10 m above river bed. This area is inundated during flood and the water is retained in swamps even after flood recedes.

Geologically, the area forms part of the great alluvial valley of Brahmaputra river of Assam and West Bengal. The district almost entirely comprise of older and younger alluvium of Quaternary Group of sediments.

Depth to water level ranges between 1.22 m bgl to 3.39m bgl in flood plains. In most of Northern and Southern parts of the district, the depth to water level lies below 2 m bgl. Hydrogeological data of Shallow aquifers in the district is studied in existing dug wells of 7-12 m depth. A thin soil and clay cover generally occurs over sand and gravel mix alluvial aquifers. Water level in the plain ranges from 2-6 m bgl, hence 7-12m deep dug wells have 3- 6 m saturated zones. Hydraulic parameters of shallow aquifers are good, and dug wells can yield ground water of 50-100 m^3 per day. The rate of infiltration is about 34 mm/min in recent alluvium and 0.4mm/min in alluvial fans. Aquifer parameters of shallow aquifers are more or less uniform along northern bank of Brahmaputra River and their hydraulic conductivity value ranges from 25 to 50 m/day.

Data of exploratory tube wells constructed by the Central Ground Water Board and State Agencies show that no hard rock basement is encountered and alluvium occurs down to the depth of 200m. Water level in deeper aquifers varies from 3.00 to 3.92 mbgl and for a drawdown of 4 to 10m, the discharge recorded for the deep tube well is 100 to 150 m^3/hr.

Kamrup district (Rural):

Physiographically, the study area in parts of Kamrup District (Rural) can be broadly sub-divided into three generalized units i.e. hills (hilly tracts of Shillong plateau occurring in southern and eastern parts and sporadic inselbergs), plains (valley fills as well as alluvial tracts with elevation ranging from 45m to 60m amsl) and marshy lands (Low relief areas)

Drainage pattern has been studied by preparing drainage map of the area. Study of drainage patterns shows that apart from the river Brahmaputra, the initial order streams (1^{st} to 3^{rd} order) show three distinct drainage patterns, namely Dendritic, Radial and Directional Trellis Pattern. Based on drainage pattern study, it can be interpreted that hill ranges of the study area are structurally controlled as evidenced by presence of trellis pattern

Based on morphogenetic and hydrogeological properties along with relative ground water potentialities, the subsurface lithology can be broadly grouped into two major hydrogeological units *i.e.* a) Crystalline formations and b) Granular formations. The Crystalline Formations comprising granite gneiss, biotite gneiss, amphibolites *etc.*, are predominant at shallow depth mostly in eastern and southern parts and are sporadic at central and northern parts of the study area. They are characterised by a weathered layer (zone C) at top, followed by a semi-weathered layer (Regolith) containing pebbles and boulders of basement rocks (zone B) and fractured rocks (zone A). Ground water occurs in the weathered zone under water table conditions. Depth to water level ranges from 5-15 m bgl during pre-monsoon period. On the other hand, ground water occurs under semi-confined to confined conditions in the fissured and fractured part of crystalline formations (within Zone A) at various depths.

Pre-monsoon water level varies from 0.95 mbgl (Chamaria) to 5.10 mbgl (Dirgheswari Temple) and that post-monsoon varies from 1.22 (Chamaria) to 6.38 mbgl (Dirgheswari temple) for phreatic aquifer. Pre-monsoon water level for semi confined aquifer varies from 1.02(Panitema) to 6.47 mbgl (South Mandakata) whereas post-monsoon water level varies from 1.28mbgl (Panitema) to 26.47 mbgl (South Mandakata) in the district.

11.3 Bongaigoan district & parts of Dhubri district, Assam

Ground Water Management Studies were carried out in an area of 3511.10 sq. Km in Dhubri and Bongaigoan districts of Assam. The area falls in lower part of Brahmaputra river basin. The study area is drained by major rivers viz, Champamati;Manas; Aie;Gangadhar;Gadhadhar;Sonkosh and Gaurang.

Physiographically, the area forms a part of a alluvial plain with flat topography with isolated hillocks. The general elevation varies from 25 to 455 meter above msl.The area experiences subtropical humid climate and receives a normal annual rainfall in the range from 2062 (Dhubri) to 4021 mm (Bongaigoan) The net sown area covers 52% in Bongaigoan and 55% in Dhubri district. The total irrigated area by all sources is 4364 ha in Bongaigoan district and 6765 ha in Dhubri district.

The area underlain by two distinct formation viz, Pre Cambrian granite gneiss and Quaternary alluvial deposits. Ground water occurs under phreatic, semi confined to confined conditions. Depth to water level during pre monsoon period varies from 4.45 to 17.8o m bgl and 3 to 17.20 mbgl during post mon-soon period.

As per GEC 1997 as on March, 2004, the total annual ground water recharge in Bongaigaon and Dhubri districts are estimated to be 94,774.28 ham and 66,935.91 ham respectively. Out of which the net annual

ground water availability for Bongaigaon and Dhubri districts are estimated 90,030.94 ham and 63,381.24 ham respectively. The existing stage of ground water development is categorized as safe. Ground water in general is good and potable, while in some areas hardness, iron, fluoride and Nitrate contents are high.

11.4 Dhalai district, Tripura state(Mapping of Current availability of ground water of artesian belt)

In course of the survey, artesian zones are found in Salema, Ambasa, Dumburnagar, Manu and Chawmanu blocks of Dhalai district, Tripura. Valley-wise and block-wise brief description of artesian zones has been shown in table

Artesian wells in the district tap mainly deeper granular zones (between 60 – 200 mbgl), except a few artesian wells tap shallow granular zones (within 50mbgl) in Kamalpur valley. Aquifer-wise details of artesian zones are given below:-

- Groundwater occurs under flowing (confined) condition within shallow depths in some areas like Abhanga and Lambucherra of Salema block in Kamalpur valley. In deeper aquifer, groundwater occurring under flowing (confined) condition are found in Bhatkhowri to Bilascherra (eastern bank of Dhalai river); in Ambasa, Jagannathpur area of Kamalpur valley, Harincherra, Jagabandhu para area of Gandacherra valley and Manu, Nepaltila, Khetricherra, Durgapur, Chawmanu areas of Manu valley.
- Artesian wells tapping shallow aquifer (granular zones) are reported to be constructed within a depth range of 35 – 75 mbgl. The piezometric head in wells varies from 0.10 to 4.97 magl. Discharge varies from 0.4 to 2.9 m^3/hr during pre-monsoon and from 0.2 to 3 m^3/hr during post-monsoon.
- Artesian wells tapping deeper aquifer (granular zones) are reported to be constructed within a depth range of 95 – 326 mbgl. The piezometric head in wells varies from 0.25 to 4.10 magl. Discharge varies from 0.1 to 9 m^3/hr during pre-monsoon and from 0.7 to 32 m^3/hr during post-monsoon.

Findings and Recommendations:
The artesian wells are having limited use in Dhalai district for irrigation, drinking, domestic and fishery purposes. Artesian wells with good discharge i.e., 2 to 9 lps is found but most of this water is going unused and flowing through the streams / rivers. As this water is available for 24 hours throughout the year, if arrangements are done to store this water from deep artesian wells then drinking water for another 4000 to 8000 persons (@ 100 lpcd) can be catered or 4 to 8 ha of paddy land can be brought under assured irrigation. Until some measures are taken to use this water properly and to arrest the wastage of water, parapet of the tubewells should be increased, for shallow artesian wells it should be increased by an average of 1.5m agl and for deep artesian wells it may be increased by 2 to 4m agl. This holds good for upcoming tubewells also which are turned out to be free-flowing artesian wells.

Groundwater discharging from the artesian wells contains high concentration of iron. Iron should be removed before put into use.

Rainwater harvesting should be encouraged, particularly in hilly terrains. Rainwater harvesting structures constructed on the boundaries or edges of artesian zones will not only help in maintaining the flow but also providing irrigation water during crisis and can be used for fisheries.

Table : Valley-wise and block-wise salient data of artesian zones in Dhalai district

Block	Shallow artesian zones / wells				Deeper artesian zones / wells			
	Depth of construction (m bgl)	Piezometric head (m agl)	Discharge (m^3/hr)		Depth of construction (m)	Piezo metric head (m agl)	Discharge (m^3/hr)	
			Pre-monsoon	Post-monsoon			Pre-monsoon	Post-monsoon
Kamalpur Valley								
Ambasa	–	–	–	–	125 – 256	0.40 – 4.00	0.1 – 7.2	0.7 – 9.0
	Tubewell with smaller dia 1 to 4 inches				80 – 110	0.15 – 2.05	0.8 – 2.6	0.8 – 3.3
Salema	35 – 75	0.10 – 4.97	0.4 – 2.9	0.2 – 3.0	95 – 219	0.28 – 4.10	4 – 21.6	3.2 – 32.4
Gandacherra Valley								
Dumburnagar	–	0.70	0.3	–	–	0.25	9.1	–
Manu Valley								
Manu	–	–	–	–	119 – 171	0.55	–	–
Chawmanu	–	–	–	–	126 – 326	0.76	0.2	0.1

11.5 Jaintia Hills District, Meghalaya(Hydrology in mining areas)

The study area is located in the Jaintia Hills District about 60 Km. From the State capital of Meghalaya i.e. Shillong.The total area covered under this study is 1151 sq. Km.

Geologically , the area under study consists of Quartzite belonging to Shillong group of rocks and sedimentary rocks belonging to Tertiary group. Coal extraction in the area is done mainly by applying primitive mining method commonly known as "rat hole mining". Most of these mining activities are small scale ventures controlled by individuals who own the land. The main coal bearing areas are Jarain and Shkentalang under Amlaren block. The coal seam are found to be embedded in sedimentary rocks (sandstone and sand) of the Eocene age. Large scale denudation of forest cover, scarcity of water, pollution of air, water and soil and degradation of agricultural land are some of the environmental implications of coal mining.Development of ground water in the district is still in nascent stage. The narrow, linear valleys and intermontane valleys offers scope for development of ground water.The depth to water level varies from 2 m to .50 m bgl and the spring discharge from 5 lpm to 60 lpm.Results of the previous study carried out by different organization reveals that majority of rivers and streams in the mining areas are affected by contamination of acid drainage. The influx of acid water oozing out from mines into the rivers and streams are mainly responsible for degradation of water quality and aquatic habitat. Others parameters which characterized the degradation of water quality are low pH, high conductivity, high concentration of sulphates, iron and toxic metals, low dissoleved oxygen.
Following measures are suggested to mitigate the environmental problem and improvement of water quality:

1) Scientific method of coal mining and disposal of mine water as well as soils.
2) Filling of mine pits, channeling of seepage water for checking " Acid Mines Drainage" contamination of water bodies.
3) Extensive afforestation and vegetation on coal mines areas is an important step of ecorestoration.
4) Conservation of top soil is essential for plant growth and agricultural productivity.

11.6 East Khasi Hills district, Meghalaya(Development of water supply through springs)

During the survey, an area of 2560 sq. km. Has been covered in East Khasi Hills district. The total area of East Khasi hills district is 2748 sq km with a population of 660994 (Census 2001). The district is famous for its picturesque natural beauty, congenial climate attracting large numbers of tourists and immigrants. The water supply is mainly catered by state Government agencies like Shillong Municipal Board (SMB), Public Health Engineering Department (PHED) and local community called *Durbar*. Within the Municipal area, Shillong Municipality supplies water from its seven water sources (both spring and surface water) namely Wahrisa, Wahjalynnoh, Crinoline, Umjasai, Madan laban, Patta khana and Wahdienglieng. PHED provides drinking water through piped water supply scheme (Greater Shillong water supply scheme I and II) and spot sources schemes. Piped water supply schemes can be river pumping, gravity feed spring/stream source and deep tube well, whereas spot sources are hand pumps, ring/dug wells and springs.

Springs are common in East Khasi hill district acting as an important source of water. These are tapped by

a) Constructing a weir and the spring water is conveyed by gravity to a conventional sedimentation, filtration type treatment plant and distributed by network of pipelines and public distribution taps.
b) Constructing a chamber at the mouth of the spring called as spring tapped chamber (STC) and water being collected without treatment.

A total of seventy springs were studied covering all the eight blocks and the discharges of those possible springs were monitored in pre monsoon and post monsoon period. To assess the water quality of the spring, totally thirty-five water samples (for both partial and iron) were collected and submitted to chemical laboratory, NER, Guwahati for analysis. The results of the analysis are awaited.

Findings:

1. There is old age practice of protecting seepages (locally called as *pung*) and springs (referred locally as *sniar*) by constructing concrete weir or chambers.
2. Majority of the springs were spring tapped chambers (STC) type where a concrete chamber is constructed at the mouth of the spring to protect the water from pollution. Some untapped and undeveloped springs are also observed.
3. Springs are developed by state government agencies, missionaries, NGOs, local durbars or through MLA sponsored schemes.
4. The occurrence of spring is observed in various geological formations. Majority of the springs are concentrated types that occur along hillsides in mountain and piedmont areas at points where groundwater emerges naturally from openings of the country rock.

5. In most of the cases, the spring water is used for drinking and washing of clothes. In some, spring water is diverted to the adjacent farms for irrigation.
6. The pre monsoon and post monsoon discharge of the spring varies from (0.03 to 3.0) lps and (0.5 to 3.3) lps respectively.
7. In the dry period, some of the high discharge springs also showed low discharge and some were reported to be dry.
8. There is not much variation in the pre monsoon and post monsoon temperature of the spring. It ranges from 15 to 24°c.
9. There is no proper storage tank for storing the water flowing out from the spring. Most of its flows downstream washing the topsoil cover thereby affecting the fertility of the soil.
10. Washing of clothes is very common in the vicinity of the spring. This poses a threat to the quality of water nearby and further downstream.
11. The chambers of some of the developed spring are not cleaned properly. In come places, there is algal growth or film of detritus is seen deposited. This water when consumed for drinking can cause water borne disease.
12. It has been found that treatment plants like Iron removal plant (IRP) are in use for river, deep tube well water supply schemes, whereas there is no treatment plant for the water that is tapped from spring,
13. Wherever springs are not developed, untapped water is flowing out. This leads to water wastage.
14. Dumping of solid wastes in the surface water adjacent to the spring is observed in Mawpadang (91°52'31", 25°35'11"), Laban (91°52'46", 25°34'02") etc. This trend is mostly reported from the urban areas of Mylliem block that can lead to water pollution.
15. In some catchments areas of spring, shifting cultivation, deforestation is going on unchecked.
16. Some of the high yielding springs are laid with excessive pipes due to water disputes between different communities or adjacent villages. This decreases the water pressure and leakage if any leads to water wastage.
17. Some spring lines are reported in Jongska (91°58'46", 25°28'8") which are already developed whereas in localities like Mawpat Wahtieh under Mylliem block, (91°55' 42", 25°35'44", 91°55' 50"25°35' 57") , Sohryngkham, Mawutieng under Mawkynrew block (91° 58' 19", 25° 32' 59", 91° 58' 04"25° 32' 57") can be developed further.
18. Proper scientific utilization and management of spring can be adopted in some springs. For eg Umsawli, Mawpat pyllun (91°57' 08", 25°36' 43") etc.
19. Commercializations of high yielding springs are taking place where private tankers are supplying water at an exorbitant price to the public. For e.g. is Demthring (91°54' 06", 25°32' 08") along National highway 44, Mawdatbaki Umjan (91°53'37", 25° 36'02") near NEHU, . In some localities, washing and servicing of vehicles are also taking place.
20. There is lack of awareness about management and conservation aspects of spring water among local people.
21. There are many spot and piped water supply schemes that are not working efficiently leading to water scarcity at places.

12 SR, HYDERABAD

The Ground Water Management Studies were carried out in Khammam, Nizamabad, Prakasam, East Godavari, Ranga Reddy and Mahabubnagar districts and area covered 10375 sq.km.

12.1 East Godavari district (Polavaram Irrigation Command)

The objective of the study was to generate base line data and bring out pre project ground water scenario for future evaluation and assessment of impact of the project in the command area.The study are covers Twenty-two Mandals, which forms middle part of the East Godavari district starting from Rajahmundry in the West to Tuni in the East, which also forms part of Polavaram left bank command area. These manadals are; Sithanagaram, Korukonda, Rajanagaram, Rajahmundary (u) & (r), Rangampeta, Gandepalle, Jaggampeta, Kiralampudi, Gollaprolu, Peddapuram, Pithapuram, Prathipadu, Shankhavaram, Tuni, Kadiam, Anaparthi, Biccavolu, Mandapeta, Samalkota, Kotanandru and Rayavaram.

The study area is underlain by granite gneiss, charnockites and khondalites in western part whereas southern part is underlain by soft rocks consisting of sandstone and alluvium.. The depth to water levels (DTWLs) are shallow, <2 meter below ground level (m bgl) in the southern part especially in areas closer to existing Dawleshwaram barrage canal. In the uplands the DTWLs vary from 3 to 6 mbgl. Ground water in the soft rock formation occurs in phreatic conditions with depth of weathering and potential zone extending down to 15 to18 mbgl and yields of the wells range from 5 to 8 lps. In hard rock terrains, which occupy northern part, the DTWLs are moderately deep (8 to 9 mbgl in some cases), depth of weathering is shallow <10 m bgl, fracturing and potential zones extend down to 60 to 80 mbgl, discharges of wells range between 3 and 5 lps. Since the proposed main canal lined there is no possibility of water logging and creating impact on the existing ground water scenario. There could be a rise in DTWL in the range of

0.5 to 1.5 m in upper command areas (present uplands) but possibility of development of water logging condition in Southern parts is very high. In general, ground water quality is good.

12.2 Chittoor district:

The objective was to generate base line data and to evolve at suitable strategies to address the Farmers' distress. The study area consists of 18 over Exploited mandals viz; Nagari, Nindra, Vijayapuram, Palasamudram, S. R. Puram, Vedhurukuppam, Vadmalpet, Puttur, Nagalapuram, Karvet Nagar, Sri Kalahasti, Thottambedu, B. N. Kadiggai, Pitchattur, Narayanavanam, Satayavedu, Varadaiahpalem and K. V. B. Puram of Chittor district covering an area of 3560 Sq. km.

The area is underlain by granites and genisses of peninsular complex of Archean age. Depth of weathering varies from 3 to 15 m bgl. Ground water is being developed by bore wells/dug wells ranging in depth from 60 to 120 mbgl and 8 to 15 m bgl respectively. The yields of the bore wells range from 1 to 5 lps. The upper unconfined aquifer is de-saturated due to over-exploitation. Deepest water levels of 34 m bgl and shallow water levels of 2 to 5 mbgl have been noticed in R.S. Puram and Satyaveedu Mandals respectively.

Ground Water pollution in Nagari Mandal due to textile dyeing industry is identified. Electrical Conductivity of Ground Water varies from 3,500 to 4,000 micro siemens/cm at 25°C. Demarcated the area affected by pollution.

The socio-economic conditions of farmers become worse in the study area due to frequent failure / delayed monsoon/Reduction in crop yield/Dwindling of ground water resources/Failure of bore wells/Re-investment for digging of new/additional bore wells

Mainly the agricultural activities of farmers depend on institutional finance. The loans could not be repaid due to unforeseen worse economic problems. Unfortunately the debt ridden farmers committed suicide. Deterioration of groundwater resources is one of the causes of farmer's distress and suicidal cases. Immediate measures may be taken to control the situation.

1. Before drilling of bore well, the site should be selected scientifically and should be certified by the state ground water department to avoid failures of bore wells.
2. Bore well / crop insurance schemes may be planned.
3. Water conservation techniques like sprinkler / drip irrigation may be implemented.
4. Artificial recharge may be implemented for recharge of ground water.
5. More awareness may be created for adopting artificial recharge of groundwater by media and individual programs
6. farmers participatory program for development/ management of ground water resources in each village may be encouraged and awards / incentives may be given for best agricultural practices, water conservation and recharge.
7. CGWB is constructing artificial recharge structures (Check dams and Percolation Tanks - 20 Nos.) under Central Sector Scheme.

12.3 Ravirala watershed, Maheswaram Mandal, Ranga Reddy district

The objectives was **t**o generate baseline data in the proposed industrial corridor area,to prepare vulnerability map of the area and to suggest appropriate measures, to evolve management strategies for sustainable development of ground water and protecting ground water quality from the probable pollutants and impact on environment. The study covers the Ravirala watershed falling in the Survey of India Toposheet No.56 K/8 & 56 K/12.It forms the part of Maheswaram Mandal, Ranga Reddy District, Andhra Pradesh.

The general slope of the area is towards North-East and the drainage in the area is dendritic to sub-dendritic. The area is drained by Musi river, which is tributary of Krishna river. The average rainfall in the area is 738 mm.The major part of the area is occupied by red and sandy soils. The soil thickness in the area varies between 0.4 and 5.0 m The area is underlain by granites of gneisses of Archaean age.

The pre monsoon DTW varies between 8.05 and 33.42 m bgl. The post monsoon DTW range between 6.412 to 23.99 m bgl. The seasonal fluctuation in the water level ranges between 10.17 and 14.12 m. The weathered position thickness varies from 6.0 to 18.0 m. The depth range of the bore wells ranges between 3.0 and 190.0 m bgl. The piezometric heads in bore wells varies between 8.1 and 27.07 m bgl. The discharge of the wells varies between 2.0 and 5.0 lps. The capacity of the pump lowered ranges between 3 HP to 7 HP and the depth of lowering varies from 24.0 to 50.0 m bgl. The infiltration coefficient ranges from 2.9 to 19.2%.

The quality of ground water is good, in general. pH ranges from 7.28 to 8.25. The EC (µS/cm at 25^0C) of formation water ranged from 404 to 3470. The chloride values range from 14 to 553 mg/l. The

concentration of fluoride ranges from 0.13 to 2.3 mg/l. Fluoride concentration is more than the permissible limit of BIS is recorded at Hardware Park.

12.4 Mahabubnagar district:

The objectives of the Study was to fine-tune/improve the existing groundwater estimation parameter norms/methodology for quantitative assessment of ground water resources of the watershed. The Study area covers MBNR-D-44-Tarnikal watershed (Madharam basin)' consisting of 9 villages in Midjil and Kalwakurthy mandals.

The DTW varies from 11.1 to 31.73 m bgl during pre monsoon and from 4.44 to 25.44 mbgl during post monsoon. The seasonal fluctuation in water levels varies from 6.3 to 6.7 m. Daily rainfall monitored and during the year through outsourcing from the established rain gauge station at Urulonda village. Monthly abstract of the rainfall is given below. The normal annual rainfall is about 620 mm and during the year about 724.5 mm of rainfall occurred which is an increase of about 17% rainfall above the normal.

Water levels were monitored at regular intervals in the irrigation tank at Madharam village which is located at the discharge area of the watershed. The measurement is connected with mean sea level.

Soil consists of sand + silt + clay in varying proportions. Sand % varies from 59 to 75 %, silt from 2.8 to 5.4% and clay from 22.3 to 36% in the study area. The specific yield was calculated by various suitable methods according to the geology of the area. The average specific yield of the area is calculated to be around 0.36%.

Site	Infiltration rate (cm/hr) & (%)	Soil type	Area
Bommarajpally	11.3 (15.2%)	Red clayey sand	Recharge
Urukonda	11 (20%)	Red clayey sand	Recharge
Ramreddipally	9.2 (19%)	Red clayey sand	Transient
Timmanapally	0.1 (0.5%)	Red clayey sand	Transient
Madharam (Tank)-right bank	3.80 (11%)	Red clayey sand	Discharge
Madharam(Tank)-left bank	0.30 (1.2%)	Red Clayey sand	Discharge
Velikatta	1.9 (8%)	Red clayey sand	Discharge

Tracer Studies, in association with NGRI, was conducted. During the study, vertical soil samples, at 20 cm interval (depth-wise), were collected using recovery pipes (Hoffer type augers) of 45 cm diameter up to 3 m during post-monsoon season or after post harvest. Samples were collected from 7 sites only (3 rain fed and 4 Irr. Paddy). The net recharge values obtained are given below.

Natural Recharge (%)		Recharge from Irrigation Return Flow (%) (Through GW) (For A Applied 5750 M^3 Of Ground Water/Acre)	
Recharge Area	Discharge Area	Recharge Area	Transient Area
8 to 14 Avg. 11	2	4 to 24 Avg. 14	6 to 28 Avg. 17

The specific yield (Sy) plays an important role in estimation of ground water resources of any basin/watershed. The average Transmissivity and specific yield determined for the watershed with the pumping tests conducted are given below.

Location	Transmissivity (T) (m^2/day)	Sy (%)	Method used for analysis of the data	Remarks
Bommarajpally Well field-1	107	1.75	Jacob's and Ramsahoye and Lang	Recharge Area Estimation of Sy by other methods is under progress
Bommarajpally Well field-1 (low yield)	58	1.65	Distance Drawdown	Do

Location	Transmissivity (T) (m^2/day)	Sy (%)	Method used for analysis of the data	Remarks
Bommarajpally Well field-2	22	1.4	Distance Drawdown	Do
Urukonda	110	1.96	Jacob's	Shallow Aquifer Estimation of Sy by other methods is under progress
Urukonda	102	1.54	Jacob's	Middle Aquifer Estimation of Sy by other methods is under progress
Urukonda	106	1.3	Jacob's	Deeper Aquifer Estimation of Sy by other methods is under progress
Madharam	50 Average of all	0.36 Average of all	Boulton's, Jacob's, Theis, Distance Drawdown and Ramsahoye and Lang	Discharge Area

Out of 27 samples in 12 samples the fluoride concentration is above the maximum permissible limits of BIS (2003) 1.5 mg/l. The maximum concentration of 3.22 mg/l is encountered at Ramreddi pally village. The NO_3 in 13 wells is beyond the maximum permissible limits of 45 mg/l. The maximum concentration of NO_3 i. e, 270 mg/l is encountered at Urukondapeth village. The total hardness in 2 wells is beyond the maximum permissible limits of 600 mg/l. Magnesium in one well is beyond the maximum permissible limits of 100 mg/l. The other parameters are within the maximum permissible limits of BIS (2003).

12.5 Coastal aquifer management in parts of East Godavari district

The objective was to study Coastal Aquifer Management and to decipher sub-surface geometry and bring out fresh-salt water interface.Ground Water Management Studies in the coastal aquifer in East Godavari district covering 13 mandals viz; with an area of approximately 1642 sq. kms. was continued in the Current AAP. This area covers part of Godavari delta and covers approximately 250 kms. of coast line.

This area is underlain by coastal and deltaic alluvium of Recent age. The ground water occurs under un-confined and confined conditions. Three aquifers were delineated in the area within a depth of 100mbgl. First aquifer which is unconfined in nature extends up to a depth of 18m bgl and the second aquifer is from 20 to 62mbgl and the third aquifer lies between 66 and 95 m bgl.

The pre-monsoon water level lies from 1.58 at S.Yanam to 7.30 m bgl at Lankala Gannavaram. The pre-monsoon ground water temperature varies from 29 to 34°C. In general, the Electric Conductivity(EC) varies from 380 (µS/cm at 25°C) observed at Sarpavaram to 13222, at S.Yanam. The exceptionally high values of EC were observed at Gachchakayala Pora (6630), N. Kothapalli (8010), Gollapalem (6060), Dinda beach Road (7800), S. Yanam (13220), N. Rameswaram (11000), A. Kothapalli (8980). In general the salinity in the area is found to increase during the season.

The post monsoon water levels vary between 1.07 m bgl, at Gachchakayal Pora, and 7.09 m bg,l at L. Gannavaram. The ground water temperature varies from 28 to 31°C. The E C values vary from 370 (µS/cm at 25°C) at Sarpavaram to 16870 at Dinda Beach road. The exceptionally high values of EC are noticed at Gollapalem (9250), Dinda Beach Road (16870), Kandikuppa Light House (12920), S. Yanam (11480), N. Rameswaram (11000), A. Kottapalli (10800). In general, the salinity in the coastal tract has increased.

Even though the groundwater in the area is considered saline, fresh ground water resources are available in the first aquifer which can be abstracted for various uses. Being the command of Major Irrigation Project, the ground water requirement in the area is less. Even then conjunctive use of surface water and ground water may be planned in some parts of the area to prevent the adverse effects of surface water irrigation. Coastal Area being very sensitive in nature, construction of well and heavy abstraction of ground water in the scarce season may be restricted considering the consequential effects.

12.6 Visakhapatnam district

The objective was to assess changes in hydrogeological environment due to intensive urbanization and the impact of climate changes. The study area is a part of Visakhapatnam district which is located in northeastern corner of Andhra Pradesh State. The district is bounded by Bay of Bengal in the East. The

area bordering this urban area are Gajuwaka, Pedagantyada, Visakhapatnam (rural), Bhimunipatnam (part), Pendurti (part) and Paravada (part) mandals.

To know the behavior of ground water level scenario, 59 key wells were established in the study area and water samples collected to know the in chemical quality. Acidified samples were collected in industrial areas. A number of large and medium size industries are located in the area, including Steel Plant, Hindustan Zinc Ltd., BHPV, Coromandal Fertilizers, L.G.Polymers, Visakhapatnam Port Trust and HPCL. The climate of the study area is characterized by high humidity throughout the year. The mean annual rainfall is 982 mm, SW monsoon contributes 65% total rainfall. The area has 4 major hill ranges viz., Kailasa, Yarada, Narava and Kambhalakonda which is characterized by undulating topography. The area is mainly drained by Hanumanthavaka, Narvagedda, Peddagadda and other minor streams which are having their origin in adjoining hills. The area forms a part of Eastern Ghat tectonic complex of Archaean age consisting of Khondalities, Charnockites, and Migmatite group of rocks. These are overlain by laterites of sub-recent age. The un-consolidated sediments of recent age comprise red sediments, stream born Alluvium, Colluvium and coastal sand.

Findings: Ground water occurs under water table conditions in weathered residuum and under semi-confined to confined conditions in deeper fracture zones. The thickness of weathering varies from 4 to 20 m, in general. The weathered zone is porous and extends to deeper levels in Khondalites as compared to other formations. The ground water abstraction is mostly through dug wells or shallow bore wells. The ground water is used mostly domestic purpose. The depth of the dug wells ranges from 2 to 22 mbgl while the general depth in between 7 and 12 mbgl. The depth of bore wells ranges from 15 to 80 mbgl and their yields are between from 0.5 and 3 lps. Higher yields are observed in Khondalites than in quartz-feldspathic gneisses and Charnockites. The unconsolidated sediments in MVP area and Sandy aquifers in old city area are good aquifers. However, the ground water development is restricted to shallow zone only.

In the areas close to Kailasa hills and Waltair highlands the water levels are found to be deeper. The ground water exploitation is done through deep open wells and bore wells. In areas like MVP colony, Isukathota, parts of Lawson's Bay, Mudusarlova valley ground water prospects are good. In industrial areas like R.Venkatapuram (L.G. Polymers), Mindi, Chukkavanipalem (Hindustan Zinc Ltd.,) the ground water is found to be highly contaminated. In port and surrounding areas, the ground water has been contaminated initially due to sea water and subsequently due to industrial effluents. The domestic pollution is high in urban residential localities.

13 SER, BBSR

The Ground Water Management Studies were carried out in Parts of Sambalpur, Anugul, in parts of Kendrapara, Jagatsingpur, Cuttack and remote sensing studies in Jajpur districts and area covered 10115 sq.km.

13.1 Parts of Sambalpur district (Ground Water Resource estimation) :

A detail hydrogeological survey was carried out in 5 blocks – (i) Dhankauda, (ii) Maneswar, (iii) Jujumura,(iv) Kuchinda & (v) Jamankira covering an area of about 3000 sq.km

Physiographically, the area has two divisions Undulating plains with isolated hillocks and mounds occurring in Dhankauda, Maneswar & Jujumura blocks and Hilly terrain with intermittent valleys mainly in Kuchinda and Jamankira blocks. The area falls in Mahanadi basin and tributaries of Mahanadi controls the drainage pattern in this area. Normal Rainfall in the area is 1527 mm and the average annual rainfall as observed from the available data is 1789 mm in the study area.

Geologically, the major part of the area is underlain by Pre-Cambrian formation composed of granite, granite-gneiss, khondalites, charnockites etc. Lower Gondowana formation composed of shale, sandstone etc. occurs at isolated patches. Laterites occur as thin capping over the country rocks mainly in up landed. Recent alluvium occurs along the prominent drainage channels.

To observe the ground water regime, a total of 70 observation key wells (NHS – 35 nos & established key wells – 35 nos.) were monitored during pre and post monsoon periods in 2009. The average pre and post monsoon water levels were found in the study area as 5.84 mbgl and 3.222 mbgl respectively with an average water level fluctuation as 2.62 m.

To evaluate ground water resources through recharges, GEC -97 methodology was adopted which becomes equal to 388.71 MCM in the study area covering 5 blocks.

Based on water level fluctuation method, the ground water resources in the study area is estimated as 226.79 MCM; and based on straightway rainfall infiltration method, it is estimated as 369.39 MCM.

Considering the 'Net' and 'Utilizable'(60% of net) ground water resources for future irrigation development in the study area as 344.58 MCM and 206.75 MCM respectively, the number of feasible ground water structures (dug wells) is determined as 32,300 and thereby creating additional irrigation potential as 426.4 sq. km. at an estimated cropping intensity of 200 percent.
As such, there is no major ground water problems except water logging at a few isolated pockets in the canal command area and fluoride contamination in ground water slightly at higher side, but within permissible limit at one or two places in the study area.

Regarding scope of artificial recharge structures in the water scarce areas during lean period in isolated pockets particularly in hill slopes suitable artificial structures are feasible to increase the ground water storage.

13.2 Parts of Angul district (Mining areas).

Angul district is situated in the central part of Orissa and spread over an area of 6232 sq.km. The district is bounded by Deogarh district in the north; Khondhamal, Nayagarh and Cuttack district in the south. Dhenkanal & Keonjhar in the east and Sambalpur and Suvarnapur in the west.

The area which is covered for the Ground Wayer Mangement studies include Angul, Banarpal & Talcher block covering 3000sq. km. The coal mining activities are centred around Talcher and spread over an area about 1814 sq.km. The anticipated resource is about 44,309,43 million tones comprising of all grades of coal. Out of this reserves of 5,207 million tones have already been proven. There are four underground mines namely Nadire, Handiduha, Deulbera and Talcher and 7 open cast mines at Balanda, Jagannathpur, Ananta, Kalinga, Bharatpur, Lingaraj and Hingua are in the area. 83 key wells have been established and depth to water level data for premonsoon were collected.

13.3 Parts of Anugul district (Industrial areas):

Ground Water Management studies in parts Angul District with special reference to mining areas was assigned during APP 2009-2010. Detailed hydrogeological studies were carried out in 3000 sq.km. area. During Pre-Monsoon 2009 86 no. of observation wells were established and ground water samples were collected for detail as well as trace element analysis. More wells were established in mining areas to study the impact of mining on ground water. The observation wells were monitored during Post-Monsoon. Field data were collected from CMPDI, RWSS, PHED, Minor Irrigation and Irrigation departments. Data were compiled and various maps were prepared. Report writing is under progress.

13.4 Irrigation scheme in Mahanadi in parts of Kendrapara, Jagatsingpur and Cuttack dsitrict

Ground Water Management Studies in Parts of Mahanadi Delta Stage – I Irrigation Command spanning across Cuttack, Jagatsinghpur, Kendrapara districts of Orissa Project was taken up under the sub-head of conjunctive use studies. The above mentioned study area is bounded within the latitudes of 19° 59' to 20° 31' north and longitudes of 85° 46' to 86° 47' east and covers approximately 3815 sq. Kms.

The main objectives of the Ground Water Management study (conjunctive use of surface water and ground water) in the Mahanadi Delta Stage -1 are

i. Evaluation of Hydrogeological situation and quantification of the different components of water balance in the canal command area.
ii. Identification of the critical areas of water logging, water scarcity in tail end areas(if any) and soil salinity
iii. Identification and evolving a suitable plan for controlling the problems of rising water table(if any) in the study area and providing irrigation water to the water scarce areas in the tail end by adopting the technique of conjunctive use of surface water and ground water and proper drainage.
iv. Preparation of suitable plan(sector wise if needed) for development of ground water resources in conjunction with surface water

Problems Reported in the Study Area:

During the course of previous pilot scale studies undertaken by the various State Govt. agencies in collaboration with other scientific agencies like NRSA, Hyderabad(using remote sensing techniques – thermal infrared data) and also from the studies carried out by CGWB, the following problems have been reported to be occurring in the study area

(i) Water Logging : As per the available data the extent of water logging was delineated and classified based on their seasonal occurrence. These water logged areas were classified as perennially water logged, seasonally water logged, marshy lands and mangrove.

(ii) Soil Salinity Affected Areas : As per the pilot scale studies conducted by NRSA, Hyderabad, it has been reported that soil salinity affected areas of the command areas are confined to the coastal plain and adjoining low areas. They have classified them into two kinds – Slightly Saline and Moderately Saline. As per their report the development of soil salinity is basically due to the proximity to the sea. The ingress of saline sea water during high tides through creeks and cyclonic storms impregnate the land with sodium chloride which is the primary cause of soil salinity.

Ground Water Scenario in the Command Area – Current Study

Under the Annual Action plan of 2008 - 10, the Ground Water Management Studies to study Conjunctive use of surface water and ground water in parts of the Mahanadi Delta Stage –1 was taken up.

Regular monthly monitoring have been carried out for the months of - May 2008 to November 2009. Monthly monitoring of water level shows that most of the area remains affected by water logging. Comparing and averaging the water level data of both the years, in the Pre-monsoon about 858.75 sq. km i.e., 22.5% of the total study area is water logged (depth to water level 0 – 2m) and about 1710.45 sq. km. i.e., 44.8 % of the total study area is prone to water logging (depth to water level 2 – 3m). Maximum of this water logging condition is found in the area that lies between the rivers Mahanadi and Kathajodi and few patches near the coast. Where as in the post monsoon however the extent of water logging increases to 2708 sq. km area i.e., around 70.9%(almost the entire Jagatsinghpur district) and area prone to water logging is about 683 sq. km i.e., roughly 17.9% of the study area. The average Pre and post monsoon water level maps are shown in plate.

Depth to Water Level in mbgl	Pre-Monsoon Average		Post-Monsoon Average	
	Area in Sq. Km.	%	Area in Sq. Km.	%
0 - 2	858.80	22.51	2708.00	70.98
2 - 3	1717.00	45.01	683.10	17.91
3 - 5	1134.00	29.72	359.20	9.42
5 - 10	105.20	2.76	64.70	1.70
	3815.00	**100.00**	**3815.00**	**100.00**

Conjunctive Use of Surface water and Ground Water

The major problem in the study area is not any scarcity of water but instead there is plenty. Conjunctive use is planned for optimal usage of surface and ground water and like wise alternate cropping patterns are suggested to avoid stress on any of the components and to prevent water scarcity as well as water logging conditions leading to soil salinization. The depth to water table of the phreatic aquifers in the study area are mostly within 2 metres in the post monsoon season and within 5 metres in the pre monsoon season. More over the irrigation system operates to provide surface water almost all throughout the year and more specifically in the end kharif and entire rabi season. As such there is no dearth of water availability. Since most of the water demand is for agriculture and in the absence of any big industrial unit in the study area there is no problem of water deficit. However certain observations have been made for conjunctive use planning which are as follows:

- The area has very shallow depth to water level with almost non-significant pre and post monsoon fluctuation and suffers from water logging condition – both in terms of surface water as well as ground water. Even the deeper aquifers are under auto flowing conditions almost all through the year. This causes very less amount of recharge to ground water. Most of the water from rain fall infiltration as well as from canal seepage get converted to rejected recharge and adds to the drainage run off component. So in terms of hydrodynamics there is no effective flushing mechanism within the aquifers.
- The topography of the land is very gently sea ward sloping and the master slope of the land is very very low(0.02%). This causes very slow movement of surface run-off.
- The combination of the above causes extensive drainage congestion and increases the risk of flooding and extensive damage to life and property as well as of the crops.
- Hydrogeologically the area is entirely composed of un-consolidated alluvial formation of Quaternary and Recent age underlain. The aquifer disposition is very complex in nature. The porous formations open up, merge and get juxtaposed in a very complex manner.
- There are inherent salinity problems in many of the porous formations due to absence of any flushing mechanism. Some of the wells near the coastal reaches, particularly in the Ersama Block of Jagatsinghpur district, which got affected due to Super Cyclone of 1999 are yet to be restored to its original state in terms of water quality.

- All the wells constructed in the area are production wells tapping a multiple aquifer system. The yield, drawdown, hydraulic parameters etc. represent a composite system. Reliable data on individual aquifers are not available as of present.
- This hampers the interpretation of the system as a whole since the mutual interaction and the hydrodynamics between the individual aquifers are yet to be established in both horizontal as well as in a vertical domain.

Recommendation:

- In most of the Irrigation command areas, cultivators are discouraged to adopt ground water irrigation. As per the existing rules there is no or very bare minimal subsidy / help from the State Government towards individual cultivators for construction of ground water abstraction structures and utilizing them for irrigation purpose. This should be modified suitably to encourage ground water irrigation both from the phreatic as well as from the deeper aquifers wherever possible and feasible.
- For the Community water supply in the semi-urban and rural settlements the source should be ground water.
- There should be extensive development of drainage channels to prevent surface water logging and thus preventing development of soil salinization process.
- Efforts are to be made to reduce the conveyance losses in the system. The current irrigation efficiency is only of the order of 34.7 %.
- If some industrial units come up in the area, they may be permitted to augment their water requirement from the ground water in a controlled and regulated manner in addition to surface water.
- The main essence of all the above mentioned solutions is to create a suitable draw down in the aquifer system. This would ensure periodic recharge in the system and thus an active flushing mechanism would be initiated. This will definitely help to improve the water quality of the areas in proximity to the seas and all those suffering similar problems.
- Desperate problems need desperate cures. If in spite of best efforts, all the above methods fail, suitable measures may be taken to abstract water from these areas and supply them upstream or in water scarce areas as well as constructing large clay screens / dykes near the sea to prevent any additional salinity ingress.
- A lot of people near the coastal sand dunes(allegedly illegal immigrants / settlers) because of the inherent salinity problems and unproductive / barren lands resort to prawn / shrimp cultivation. The so called 'shrimp mafias' pumps the brine inland and thereby further degrades the land. They should be counselled and monitored properly and periodically to prevent the inland salinization menace.
- To properly construct a working simulation flow model, the area may be taken up for extensive ground water exploration with the objective of tapping individual aquifers and testing them individually. They may be kept as sanctuary wells for emergency use, later on and may also be used as ground water observation wells.

14 SWR Bangalore

The ground water management studies have been taken up in Hassan, Koppal, Shimoga, Chikmagalur, Davanagere and Chitraddurga districts.

14.1 Arsikere, Belur and Sakhaleshpur Taluks of Hassan district (Farmers distress district)

An area of 3150 sq. km was covered in the study area during Premonsoon survey. Sixty eight key observation wells were established. Depth to water level ranged from 0.20 to 28mbgl. During Post monsoon studies, Belur and sakleshpur taluks were covered with an area coverage of 1550 sq.km. Postmonsoon depth to water level ranged from 1.0 to 15.0 mbgl.Seasonal fluctuation in the entire area ranged from 0.39 to 13.11m.

The water level in Arsikere taluk have shown rising trend during premonsoon and postmonsoon seasons.In three stations, the trend was falling, while in the remaining stations, both rising and falling trend was observed.

In Belur taluk, all the five wells showed rising trend of water level during pre and postmonsson period.Out of the three stations located in Sakleshpur taluk, two showed rising trend and the remaining one station showed falling trend in water level.

Stage of ground water development in Arsikere taluk is 87.71% categorizing the taluk under over exploited and semi critical. Ground water development is 74.1% in Belur taluk, where as Sakleshpur taluk is categorised as safe.

Ground water quality is generally potable. Localised pockets in the study area shows nitrate concentration above the permissible limit.

14.2 Koppal and Gangavathi Taluks in Koppal district

An area of 2703 sq. km was covered which falls under topo sheet no.48 M and 57A of Survey of India. The study area is underlain by schistose formation in east of Gangavathi taluk,granite in the border of Koppal and Gangavathi taluks in the south and gneiss in the rest of the area. There are three major soil types. The red sandy soil is observed mostly in Granitic and Gneissic terrain particularly in the central and north central part of the study area. The Black cotton soil is observed in north east, east, west and southwest of the study area irrespective of the formation either it is schist or Gneiss. However black cotton soil is mostly not found in granite terrain. Mixed soil is found along the nala course and found as valley fill.

Total forty seven key wells were established and one hundred seventy five ground water structures were monitored during post monsoon period to study the ground water scenario in the area.Details of key wells inventoried in the study area are as below.

Koppal taluk

Type of well	Dug well		Bore well	
Depth range(m bgl)	4.50	17.10	55.00	100.0
DTW range (Pre.)(m bgl)	1.20	14.40	3.40	29.60
Dia range (m)	2.00	5.00	0.15	0.15

Gangavathi taluk

Depth range m bgl)	4.45	14.20	50.0	70.0
DTW range(Pre.)(m bgl)	2.80	5.90	3.48	15.00
Dia range (m)	1.00	10.0	0.15	0.15

Ground water quality problem is the major issue in the study area. The nature / type of the soil play a major role in deciding the quality of ground water.To study the ground water quality problem one hundred twenty five water samples were collected during post monsoon period other than forty five pre monsoon water samples. Ground water samples were collected from the area to study the fluoride content.

Quality problem is observed mainly in black cotton area in the west of the study area around Gudigere, Marlapur, Nilogi, along Bikkanahalli – Alavandi road, along Halgeri – Hire Sindagi road and north east of the study area around Nauli village. Around Belagatti, Gatereddihal,Hatti, Belagatti ground water quality problem is observed even though the area is covered with mixed soil.The ground water quality problem is also observed in the mixed soil area along the nala around the villages Chikka Bommanal, Hiremudihal, Chika Khed, Gudadur, Katapur, Mallapur, Sulekal, Batnarsapur, Kalkeri, Lingadahalli, Guddenahalli etc. Ground water samples were collected to study the fluoride content.

The ground water quality problem is also observed in black cotton soil in canal command area. The intensive irrigation in canal command area reduces the effect of salinity on the crop growth. For eg: Buduguppa, Nandihal, Eliganur, Eliganur camp, Jamapur, Kuntoji, Kakargal etc. . In areas having salinity problem and covered by mixed soil, paddy crop is yielding less. It is observed that, paddy cultivated in red sandy soil area in non-command area is getting wilted, as the water provided does not reach the crop because of the sandy nature of the soil. For eg: Hosur, Idargi, Ingaldal etc

Recommendations

- In areas covered by black cotton soil, particularly west of Koppal taluk and North west of Gangavathi taluk, ground water quality problem is observed. The ground water quality can be improved by implementing artificial recharge structures on large scale.
- In non canal command area covered by sandy soil, less water intensive crops are recommended and the practice of paddy growing should be avoided.

14.3 Shimoga, Chikmagalur and Davanagere districts(Conjunctive use of Surface and Ground Water studies in Bhadra Command area)

The study was continued from previous AAP to carry out long term analysis of quantitative and qualitative aspects of surface and groundwater in Bhadra Command areas. Detailed study was taken up in the whole area of 1100 sq.kms .The command area covers parts of Shimoga, Chikmagalur, and Davangere districts. The Bhadra reservoir having a capacity of 2023 MCM of water irrigate an area of 1100sq.kms through Bhadra Left and Right bank canals, with branch canals like Anveri, Davangere, Malebannur, and Harapanahalli canals.

The area forms part of hard rock crystalline terrain underlain by gneiss, Gneissic granites and granites of Arechean age. The main sources of ground water in the area are precipitation, seepage from canals, and return flow from applied irrigation water. Ground water occurs in weathered / semi weathered formations of granites/gneisses and fractured zones in deep seated formations.

The pre-monsoon depth to water levels ranged from 0.70m to 9.72m with an average of 4.31m. The post monsoon depth to water level ranged from 0.87m to 7.40m with an average of 3.21m. The seasonal water level fluctuation ranged from 0.00 m to 13.77m with an average of 1.43m. The wells showed negative fluctuation adjoining the canals due to discharge in the canal. The analysis of monthly water levels from December-09 to March-10 indicates that the average depth to water level is 3.33m, 3.86m, 3.96m and 4.23m during December-09, January, February, and March-10 respectively. This indicates average monthly fall from Dec to Jan is 0.48m, Jan to Feb is 0.15m and Feb-March is 0.27m respectively, maximum fall in water levels is in between Dec-Jan.

The analysis of long term water levels in 15 NHS maintained by CGWB indicates that the pre monsoon depth to water level ranged from 2.53m to 7.13m and the post monsoon depth to water levels ranged from 1.68m to 5.59m. The seasonal fluctuation ranged from 0.88m to 4.52m.

Water logging conditions are observed in isolated pockets during the period from June to January. This is due to the water being released from the reservoir through canals for irrigation. In addition, monsoon rains also contributes.
Based on monthly water levels, seasonal water logging is observed in the villages viz., Kadaranayakanahalli, Kokkanur, Nanditavare, Kurki, Arasanaghatta and Lakkavalli. Around Chikkakodali, Mangote, Mallapura water logging is observed. This is due to encroachment of tank bed for agricultural activies.

The state government of Karnataka has taken up number of projects on reclamation of waterlogged area through department of Water Shed Development. As a remedial measure, numbers of projects have been taken up to dispose the excess seepage or applied irrigation water through surface and subsurface drains. Forty six villages were covered as per the list provided by Water Shed Development Department, where in about fourteen villages are observed to be permanently water logged and thirty two villages are temporary water logged.

The analysis results indicate that the pH ranged from 7.3 to 8.5, EC ranged from 290 to 3040micro mhos/cm at 25º C. Total hardness ranged from 130 ppm to 1200ppm. Similarly all other parameters are well with in the desirable/permissible limits, indicating that the water is potable for drinking purposes. As per Wilcox classification (based on EC) five samples viz. Arasanaghatta, Kundur, lokikere, Doddapathy and Kakkaragola are falling under u nsuitable class, whose EC values ranged from 2530 to 3040 micro mhos/cm at 25ºC.
For studying seasonal variations in chemical quality due to water logging (seasonal/permanent) 80 water samples were collected. The samples are being analysed.

Findings of detailed surveys:

- Physiographically the study area is plain to undulating topography.
- The depth to water levels ranged from 0.50 to 11.00m.
- Ground water development is negligible and no irrigation dug wells or bore wells are in use.
- Sufficient surface water exists through Bhadra right and left bank canals and with branch canals. However, shortage of irrigation water is observed in tail end areas of the canal and lands on elevated planes in northern parts of the command area around Shingrehalli in Harappanahalli taluk.
- The main crops are paddy and arecanut and water scarcity is felt in some places. W ater management practices like drip/sprinkler irrigation will help to avert the crisis.
- Farmer's suicide cases are mostly related to financial crisis, long illness of farmers, and partly due to crop loss. Crop loss is due to crop diseases, lack of proper crop maintenance and cropping pattern and rarely due to shortage of water.
- Lift irrigation practices are common in adjoining villages of river Bhadra/Thungabhadra.

Conclusions and Recommendations:

- Depth to water level in the Bhadra command areas is not alarming.
- Based on the survey in 46 villages, it is envisaged that the water logging in isolated patches is seasonal, which is mainly due to canal seepage and excess flow during rainy season. At places permanent water logging is observed due to the encroachment of farmland into the village tank bed or the area adjoined to the tank towards down stream directions. Water logging is mostly observed in areca garden, where the crops require continuous water and lack of proper drainage system to drain the excess water.
- Since the farmers in command areas are getting water on rotation basis for irrigation conjunctive use of ground water and surface water will improve the irrigation efficiency.
- Drip/sprinkler irrigation practices are recommended for improved water mangement.
- Farmers should be educated through agricultural scientists regarding protection of crops from crop diseases.

14.4 Chitradurga district (Remote Sensing Studies for impact assessment of artificial recharge structure)

In the present study, Using IRS-ID, LISS-III digital data, surface water body has been mapped. Geomorphology, Geology, Lineament and Landuse/landcover maps have been prepared. These layers were integrated to demarcate the area suitable for the constructing of artificial recharge structures. Surface water body and drainage map has been superimposed for finding the source for the recharge. Geomorphologically, the area mainly consists of pediplain shallow, moderate, and denudational hill. The groundwater prospect is moderate to very good in pediplains and recharge condition is also very good in this landforms. Granite gneisses, granite and metabsalat and tuff are the major formation in the study area. The high fracture aquifer is generally found in the gneissic formation. The lineament is generally trending NW-SE and NE-SW direction. NW-SE direction is parallel to general trend of the rock formation and parallel weaker zones. The landuse practice followed in the area is generally indicating the groundwater conditions in the area. Considering the features, which are favouring for the recharge, all layers were integrated and demarcated zones for the artificial recharge. The artificial recharge zones were superimposed and checked the source for recharge.

15 SECR, Chennai

15.1 Parts of Nagapatnam & Thiruvarur districts (Delineation of alluvial and tertiary fresh water aquifer units, Define recharge & discharge area and Formulation of Aquifer Management Plan

The objective was to delineate alluvial and Tertiary fresh water aquifer units- Sand / Sandstone / Silt / Calc. Sandstone / Limestone and define Recharge Area & Discharge area - Local / distant / Vertical / Lateral

The study area comprise mainly of porous sedimentary formations of Cretaceous, Tertiary and Recent age. A small portion of the western part is occupied by crystalline rocks of Archaean age. The depth of aquifers deciphered based on the study is tabulated below;

Depth range of different aquifers

Sl. No	Formation	Depth (m)	Water Quality
1	Cretaceous aquifers (also Known as Nakkudi Aquifer)	Down to 50	Good
2	Eocene Aquifer	Down to 80 (very limited use)	Good
3	Lower Miocene deep Aquifer System		
a	Orathanadu Aquifer (also Known as Aquitainian Aquifer)	Down to 150	Good
b	Main flowing zone or Burdigalian Aquifer	Deeper aquifer 350	Good
4	Pliocene –Miocene Shallow Aquifer		
a	Pliocene Aquifer (also Known as Podakkudi Aquifer)	Shallow open wells (down to 40) (lesser salinity in the New Delta area)	Good
b	Quaternary aquifer	Shallow open wells (20) & Filter points	Good

Finding

- The aquifers of these porous formations are broadly divided into two group's i.e. shallow aquifer group occurring down to 100 m depth and deeper aquifer group occurring below the depth of 100 to 450 m.
- Ground water in shallow aquifers occurs under phreatic and semi- confined conditions and groundwater occurs in deeper aquifers under confined conditions.
- The comparison of ground water during May 2009 and January 2010 indicates a rise in ground water levels of 0 – 5 m in about 66 percent of wells analyzed. The groundwater level fluctuation of more than 5 m is noticed in the northwestern part.
- The yield of the bore wells in Sedimentary formation varied between 40 and 500 lpm.
- The recharge area for Orathanadu aquifer occurs in the north of kollidam-Mayavaram and south of Thiruvarur-Mannargudi.
- The quality of ground water in the porous formation is generally good and is suitable for both domestic and irrigation. However, saline groundwater exists at shallow depth. The EC values ranges from 430 to 7600 µS /cm. The chloride, Calcium and magnesium in shallow ground water exceeds desirable limit for drinking uses.

15.2 Ramanathapuram & Sivaganga Districts (Delineation of aquifer units, Define recharge & discharge area and Formulation of Aquifer protection and Sustainable Management Plan)

The objective was for delineation of aquifer units, define Recharge Area & Discharge area - Local / distant / Vertical / Lateral and formulation of Aquifer protection and Sustainable Management Plan. The area is underlain by recent alluvium, Gondwana Sandstone, Cuddalore Sandstone (Tertiary) and Cretaceous Sandstone.The depth of aquifer deciphered based on the study is as follows:-

Sl. No	Formation	Depth (m)	Water Quality
1	Recent-Alluvium	Down to 30	Good
2	Gondwana-Sandstones	Down to 100	Good
3	Tertiary- Cuddalore sandstones	Down to 100	Good
4	Cretaceous aquifers (Thiruvadanai aquifer)	100 - 300	Good

Finding

- Ground water occurs under both phreatic and semi- confined conditions in the shallow aquifer, where as in the deeper aquifers it occurs under confined conditions.
- Tank irrigation is more predominant than irrigation by groundwater.
- The depth of the dugwells ranged between 15 and 35m bgl and the tubwells ranged between 70 and 400m bgl.
- The depth to water level varied between 1.4 and 20.56m bgl
- Tank irrigation is more predominant than ground water irrigation.
- Ground water is of bad quality except in Thiruvadanai aquifer and in Tertiary and alluvium aquifers at some places.
- All fresh water aquifers are under stress, especially Tiruvadanai aquifer which is a confined aquifer due to development for the past thirty years. Piezometric head of the aquifer has reduced considerably.
- Artificial Recharge need to be taken up in the recharge area (near Sarugani) of Tiruvadanai aquifer

15.3 Thiruvarur and parts of Thanjavur districts (Conjunctive Use of surface and ground water resources in command area of Cauvery Delta).

The objective of the study was Evaluation of hydrogeological situation and quantification of different components of water balance in the canal command area, Identification of the critical areas in respect of water logging, water scarcity in the tail end areas and soil salinity and Preparation of suitable conjunctive use plan for development of ground water resources in conjunction with surface water.

An area covering 3132 sq.km identified for carrying out conjunctive use in part of cauvery command area of Thiruvarur and parts of Thanjavur districts. 17 administrative blocks falls in the study area. The study area has a hot tropical climate. The average rainfall of the study area is 1150 mm and receives maximum rainfall of about 65% during North East monsoon session and South West monsoon contributes 20% and remaining portions contributed during summer and

winter session. The study area in general is a flat plain terrain with gentle slope towards east with surface elevation of 30 m above msl. The deltaic plain, formed due to major Cauvery River and its tributaries flowing in the region. Sedimentary plain, natural levees marsh lagoon/back water coastal plain, beach and beach ridges are seen in the southern part of the study area. Major river systems in the study area are Vennar, Vettar and Bamni rivers, which are the tributaries of the river Cauvery. There are several canal network systems, which are spread all over the terrain acting as source for ground water system

The area is underlined by Tertiary and Quaternary formations comprising Cuddalore formations, Podakudi formations and Alluvium. The important aquifer systems in the study area are constituted by unconsolidated and semi-consolidated formations.

It is observed that the water level in dug wells during pre-monsoon during May 2008 vary from 1.25 m bgl (Thirukarukkavur) to 13.60 m bgl (Mariamman Koil) and in tube wells 6.0 m.bgl to 15.0 m.bgl. During post monsoon water level during January 2009 vary from 0.48 m bgl (Alankottai) to 4.75 m bgl (Mariamman Koil) and in tube wells 3.80 m bgl to 11.25 m bgl.

The tubewells within the study area tap groundwater from 40m bgl to maximum of 150m bgl. Howere, in Manargudi block, deeper tubewells down to depth of 300m bgl. The yield of the tubewell range between 3 and 17 lps. The transmissivity of the alluvial aquifer varies from 200 to 250 m^2/day.

The Electrical Conductivity (EC) ranged between 750 and 2500 μS/cm. Groundwater with low EC values exists at Cholapuram (416 μS/cm) and High EC values (> 6000 μS/cm) are observed in Thiruturaipoondi and Kumbakonam.

Findings:

1. The major source for irrigation in the study area is through canals. Canal irrigation constitutes 100%, except in Madukkur, Pattukottai and Papanasam blocks, where the ground water contribution is 43%, 40% and 13% respectively. The net sown area of the study area constitutes 71% of the total geographical area.

2. Number of ground water abstraction structures increased by 15 – 20% during the last 5 years.

3. Data on groundwater extraction has been collected and it is noticed that depth of wells for agricultural purpose ranges between 40 to 120 m and few blocks wells tap deeper aquifer down to 350 m.

4. It is observed that the patched saline pockets available blocks of Muthupettai, Thiruthuraipoondi, Kattur and part of Thiruvarur.

5. Water logging (8 – 10 % of the area under study) occurs as localized pockets in Papanasam, Muthupet, Thiruthuraipoondi and Muthupet blocks.

15.4 Pallikaranai-Chennai sub-urban area (Hydrochemistry of Land fill sites)

The main objectives of the study is to assess the Ground water quality around Municipal solid waste disposal in Pallikaranai-site and its adjacent areas, Migration of leachate both vertically and laterally and to find Remedial measures to reduce further groundwater contamination.

Findings

- High concentration of TDS, EC, Hardness, Nitrates, Chlorides, Sulphate, in ground water near landfill
- Leachates have significant impact on groundwater quality near the area of Pallikaranai landfill site.
- Groundwater quality improves with the increase in distance of the well from the pollution source.
- Inadequately controlled landfills leachates escape to the surrounding and underlying ground.

16 Kerala Region, Trivendrum

16.1 Kozhikode district

The total area of the district is 2344 sq km. The district is bounded on the North by Kannur district, on the East by Wayanad district, on the South by Malappuram district and on the West by the Lakshadweep Sea. Kozhikode district is situated between North latitudes 11º08’ and 11º 50’ and East longitudes 75º 30’ and 76º 06’.

The district has a generally humid climate with a very hot season extending from March to May. The main rainy seasons are during the South West Monsoon and the North East Monsoon. The average annual rainfall is 3266 mm.

Topographically the district includes three distinct regions –sandy coastal belt, the rocky highlands formed by the hilly portion of the Western Ghats and lateritic midland. Of the total area of the district 362.85 sq km area comprises of sandy coastal belt, 1343.50 sq kms of lateritic midlands and 636.765 sq kms of rocky highlands. The district has a coastal length of about 80 kms. The highland region accounts for 29.80 percent and the lowland region for 15.55 percent of the total area of the district. The important rivers draining through the district are Mahe river, the Morrad (Kuttiadi river), the Korapuzha, the Kallai river, the Chaliyar and the Kadalundi river.

A total of 117 key wells have been established in this survey out of which 15% represents coastal alluvium, 25% represents bedrock aquifers and the remaining in the lateritic area.

Three major aquifers are identified in the district viz (i) Lateritic aquifers (ii) Weathered Basement complex rock aquifers and (iii) Unconsolidated granular aquifers.

Aquifer characteristics in Kozhikode district

Aquifer	Yield (lps)	Depth of the well (m bgl)	DTWL (m bgl)		Specific capacity (m3/hr/m drawdown)
			premonsoon	postmonsoon	
Laterite	0.5-1.5	4-20	6-13	3-10	1-8
Unconsolidated aquifers					
River plain aquifers		2-10	2-5	1-4	1-2
Coastal sand dune aquifers		2-6	2-4	1-3	1-2
Lacustrine aquifers		3-5	2-3	1-3	2-3

Apart from the above, aquifer system area covered by coastal mangrove swamps are underlain by aquifers of highly saline water without any developmental potential except for the purpose of shrimp and brackish water aqua culture.

Findings

- The major aquifers are Lateritic aquifers, alluvial aquifers shallow aquifers, coastal sand, coastal wetland and estuary deposits , confined regoliths and fractured crystalline aquifers
- Laterite aquifers are dominantly residual weathering products of basement rock. Water quality slightly acidic and is overexploited in urban areas like Kozhikode, Balussery, Vadakara and Quilandy townships. Enhanced levels of nitrates is also observed in urban area.
- The shallower and small alluvial aquifers occur within the alluvial deposits of the minor rivers ansd streams. These aquifers are generally shallow and are directly connected to the surface water in streams and rivers. Even in periods of low surface flow, these aquifers are quickly recharged. These aquifers are exploited to varying degree without experiencing major hazards. A reliable volume of ground water can be extracted from these alluvial aquifer throughout the year.
- Coastal aquifer are unconsolidated dune sands, beach sands and clayey sands of quarternary and Recent age. The Aqufer thickness is upto 25 m. ground Water level is between 2-6 m bgl. High transmissivities upto 2500 m2/day. Highly vulnerable to contanmination from direct infiltration of contaminants from agricultural practices and domestic waste.
- Coastal wetland and estuary deposits have low and highly variable transmissivities between 2 – 80 m2/day. Water quality is often brackish.

Recommendations

- The lateritic aquifers show rapid depletion of ground water resource in the post monsoon phase especially in the urban area and artificial recharge is suggested as a remedial measure.
- Scientific construction of septic tanks are recommended to avoid nitrate contamination of the aquifer under the scenario of increasing population density.

16.2 Trivandrum district

Sea water ingress studies were taken up along the coastal tract and parts of midland area of Thiruvananthapuram district. The coastal tract stretches from Pozhiyur in the south to Edava in the north. The main objective of the study is to identify the areas affected by saline water intrusion by means of hydrogeological, geochemical and geophysical studies.

Physiographically, the study area comprises coastal plain and midland. Coastal plain extends from Pozhiyur to Edava where the elevation is less than 6 m amsl except at Kovalam, Puvar and Varkala where the elevation is more than 6 m amsl. The midland area gently rises from the coastal plain and extends to the foothills zone upto elevation of 80 m amsl characterized by undulating often highly dissected topography. The area is well drained by three rivers Chirayinkil, Karamana Ar and Neyyar river. The region is dotted with backwater lakes (kayal) viz Akkulam, Kadinamkulam and Vellayani (freshwater). Apart from natural water bodies there are man made canals which connects these water bodies viz Parvathy Puthanar. Due to the presence of backwater lagoons a narrow stretch of land is getting sandwiched between the sea and the lagoon. The lagoons are intermittently connected to the sea. The normal rainfall of coastal area is 1885 mm. The area is characterized by wet type of climate. The population density is high in the coastal area. The major soil types of the area are coastal alluvium, riverine alluvium and laterite soil. Red loams are seen in the southern part of Thiruvanthapuram district.

The area is underlain by sedimentary formations ranging in age from Miocene to Recent which overlies the crystalline rocks along the coast. Laterite of sub recent age is encountered along the midland area which also overlies the crystalline rocks. The sedimentary formation encountered in study area belongs to Warkali formation and Quilon formation only in the northern part. The Warkali formation comprises of alternate layer of sand and clay with thin seams of lignite which forms the potential aquifer, Recent formations are represented by alluvium.

Groundwater occurs under phreatic conditions in the coastal alluvium and laterites. Semi-confined to confined conditions exists in underlying deeper sedimentary formations and in fractured crystalline rocks. The present study is restricted only to phreatic aquifers. Coastal alluvium along the coast and riverine alluvium along the river forms the major aquifer in the area.

During the first year of study, preliminary surveys were done to demarcate the area affected by salinity including geophysical survey coupled with groundwater sampling Geophysical survey was carried out from Kappil to Chackai. 76 Soundings (VES) and 15 line km profiling were carried out along several East West traverses perpendicular to the coast using ABEM SAS 300 C terrameter during the summer season. This study has enabled to identify areas which show very low resistivity of less than 10 ohm meter at several locations between Puthukuruchi and Anjengo showing that there is variation in resistivity.

Preliminary hydrogeological survey was conducted during the month of April and 60 key wells were established along the coastal belt. Field EC & PH were monitored. On the basis of field EC, detailed study area were demarcated where EC>500 µs/cm.

In the second year the study was carried out in the affected areas demarcated from the preliminary studies. The detailed study area extends from Vettukad in the south to Vettur in the north covering an area of 500 sq.km. A total of 35 key wells fall in the detailed study area. This is in conformity with geophysical study where the same area showed low resistivity values.

Pre-monsoon and post-monsoon surveys were done. The depth to water level ranges from 0.85 to 18.3 and 0.54 to 17.54 m bgl during pre-monsoon and post-monsoon respectively. Chemical analysis were done only for selected parameters. The EC ranges from 101 to 1800 and 111 to 1952 µsiemens/cm during pre and post-monsoon respectively. In general the EC value is more than 750 µsiemens/cm in the area. The Sodium ranges from 8.5 to 206 and 14 to 204 milligram/litre during pre and post-monsoon and the Chloride value ranges from 16 to 387 and 19 to 394 during pre and post-monsoon seasons.

Groundwater quality is poor in the narrow stretch of land in between the coast and the backwaters, especially in Pudukurichi areas. The ground water quality is affected in the entrapped land due to tidal activity. The resistivity survey also show very low resistivity in these areas.

During the summer season, sea water enters through the coastal inlet and enters into the backwaters. The mixed up water percolates down affecting the ground water quality of the wells located along the fringes of the backwaters especially Pudukurichi, Matanvila and Anjengo coasts. The resistivity values along the fringes of the backwaters were very low and substantiated by the higher conductivity of ground water samples analyzed chemically in the range between 1010 and 3640 microseimens/cm at 25^{o}C.

Field photograph during the Sea Water ingress studies of Kadhinamkulam lake, in Trivandrum district

Field photograph during the Sea Water ingress studies of coir retting in the vicinity of the Kadhinamkulam lake in Trivandrum district

16.3 Kollam district

Sea water ingress studies along the coastal tracts of Kollam and Alleppey districts were carried out under Ground Water Management Studies. The survey was completed in two phases namely; pre-monsoon reconnaitory hydrogeological survey and post-monsoon detailed studies. During pre-monsoon survey, 90 key wells were established to study the ground water behavior and water samples were collected for chemical analysis. During post-monsoon survey, water levels have been monitored from the key wells water samples collected for chemical analysis from key wells and through field traverse carried out demarcation of areas of sea water intrusion.

The study area is located on the south-western part of Kerala State. It is accessible by roads and railways. The NH-47 Kanyakumari-Salem and the Southern Railway line from Kanyakumari to Mumbai and Chennai are passing through the area. The study area comprises (i) the coastal plain, low-lying plain

area adjacent to coast extending inland. The general elevation of coastal plain is less than 6.0 a.msl. and (ii) mid-land. These gently rise from the coastal plains and extend to the foothill zone up to an elevation of 80 m. a.msl. The area is drained mainly by Ithikara and Kallada rivers and their tributary systems. The study area covers the coastal and part of midland in the above said river basins. The coastal and midland area enjoys a humid wet type of climate. The area experiences moderate rainfall during south-western and north-eastern monsoon.

The area is underlain by sedimentary formations ranging in age from Miocene to Recent which overlie the crystalline rocks along the coast. Laterite of sub recent age is found along the midland which again is underlain by crystalline of Archaean age.

Groundwater occurs under phreatic conditions in the coastal alluvium, river alluvium and laterites in the area and under semi confined to confined condition in the deeper sedimentary formations and fractures in the crystallines below laterites. In alluvial formation depth of dug wells ranges from 3.00 to 7.00 m bgl and depth to water level ranges from 0.30 to 5.35 m bgl. In laterites, depth of dug wells ranges from 6.00 to 20.00 m bgl and water level ranges from 5.43 to 18.8 m bgl.

The common groundwater abstraction structures in alluvium are dug wells and filter point wells. In laterites, large diameter wells and in crystallines, dug wells and shallow to deep bore wells are feasible. The quality of ground water is generally good for drinking, irrigation and industrial purposes except in some part of coastal areas.

For the assessment of contamination of ground water due to sea water and tidal back water in the area, an area of about 800 sq.km was selected for detailed study. Pre-monsoon and post-monsoon water levels were monitored in the key wells and water samples collected for chemical analysis. On the basis of analytical results and field traverse areas showing sea water intrusion have been demarcated.

Findings:

1. The study area comprises coastal plain and adjoining midland area.
2. The coastal alluvium forms the major aquifer in the area followed by riverine alluvium and laterite in the midland area
3. In tidal back water limits and certain isolated pockets further inland high EC values were observed
4. In coastal areas and near estuaries the phreatic ground water is showing contamination due to ingress of sea water.
5. Higher concentration of iron content which results in a reddish brown stain is observed around Ochira, Karunagappally and Chavara areas.

16.4 Trivandrum district

Trivandrum urban area is bounded by Kazhakuttam in the north, Karakulam on the northeast, Thirumala on the east, Balaramapuram on the south and Lakshadweep sea on the western side. 17 numbers of key wells were established. Monthly water levels were monitored from April 2009 to March 2010.

Trivandrum district experiences a humid type of climate with an oppressive summer. The district is characterized by very high precipitation which is spread over very few wet days and a long dry season (December – May). The average annual rainfall of the district is 1623.9 mm. The southwest monsoon contributes 48.9 % of the total rainfall followed by northeast monsoon which contributes 28.3%. The normal rainfall of the district is 2001.6 mm.

Trivandrum has a high density of population compared to other cities due to which the built up areas and surface roads are more which reduce the ground water recharge. The area can only withstand low to moderate capacity of bore wells and tube wells. But along the coastal tracts filter point wells are feasible. Reclamation of low lying areas and paddy fields for construction purposes contribute to loss of natural recharge areas.

The area is underlain by sedimentary formations ranging in age from Miocene to Recent which overlies the crystalline rocks along the coast. Laterite of sub recent age is encountered along the midland area which also overlies the crystalline rocks. Recent formations are represented by alluvium.

Groundwater occurs under phreatic conditions in the coastal alluvium and laterites. Semi-confined to confined conditions exists in underlying deeper sedimentary formations and in fractured crystalline rocks. The present study is restricted only to phreatic aquifers. Coastal alluvium along the coast and riverine alluvium along the river forms the major aquifer in the area.

The Trivandrum Urban Water Supply Scheme draws water from Karamana river from the reservoirs at Peppara, Aruvikara and Kundamankadavu near Thirumala. The Southern parts namely Nemon and its

surroundings draw water from the Vellayani Lake. Generally the ground water in urban area is of good quality. The pre monsoon water level in the study area ranges from 2.0 to 17 m bgl and the post monsoon water level ranges from 1.6 to 13.22 m bgl. The fluctuation is in the range of 0.5 to 4.5 m bgl. 17 samples were collected during the study and results of analysis are given below:

The quality of ground water is generally good for both drinking, irrigation and industrial purposes except in some part of coastal areas.
The Specific Electrical Conductance of ground water varies from 89 µs/cm to 737 µs/cm and Total Hardness varies from 18 to 105 mg/l in the area.

Findings

- The study area comprises coastal plain and adjoining midland area.
- Groundwater occurs under phreatic conditions in the coastal alluvium and laterites.
- Semi-confined to confined conditions exists in underlying deeper sedimentary formations and in fractured crystalline rocks
- The hard rock aquifers are low yielding. The formation encountered is Khondalite and most of the fractures are clay filled.

17 UR, DEHRADUN

17.1 Almora district

Ground Water Management Studies have been carried out in Almora district during AAP: 2009-10. Almora district forms part of Kumaon Division of Uttarakhand State. The area is bounded by Chamoli and Bageshwar in the north, Pithoragarh and Champawat in the east, Nainital in the south and Pauri Garhwal district in the west. The geographical area of the Almora district is 3083 km^2. The district comprises of nine tehsils namely, Almora, Ranikhet, Salt, Chaukhutia, Dwarahat, Someshwar, Jaiti, Bhanauli and Bhikiyasain and eleven developmental blocks viz; Syalde, Chaukhutia, Bhikiyasain, Tarikhet, Salt, Dwarahat, Takula, Bhansiya Channa, Hawalbagh, Lamgara and Dhaula Devi. The total population of the district is 630567 (Census, 2001). The density of population is 205 persons per sq. km

The average elevation in the southern part of the district is 6939 m amsl and in northern part is 7603 m amsl. The master slope of the district is to the south. River Saryu in the eastern part, Kosi in central part and River Ramganga along with its tributaries in the western part of the study area comprise the principal drainage. District got a humid and cold climate; temperature ranges from -3.7 to 28.8 ^{0}C and May being hottest month. Annual average rainfall is 1029 mm whose major share is received from S-W monsoon. July receives about 24.8% if total rainfall; November is the driest month and receiving less than 0.6% of total rainfall. The monsoon withdrawal generally is taking place from 19th September. There are average annual normal rainfall at three rain gauge stations has been recorded like 1061 mm at Almora, 1332 mm at Ranikhet and 1597 mm at Kausani.

The agriculture is the main occupation of the habitant of district. Being a hilly terrain, much cultivation is not in practice. The gross cultivated are during 2005-2006 was 181446 hectare and 42461hectare barren land can be sued as agriculture land. The surface water is main source to provide irrigation facilities, source wise irrigation facilities available are Hauze, Hydrums, and Gules etc. In the district there is different type crops has been cultivated like Maize, Rice, Wheat, Barley, Pulses Gram, Potato, Oil seeds, Madra and Tabacco etc.

Geomorphologically, the Almora district is a part of lower Himalayas and characterized by WNS-ESE trending rounded to flattish-topped gently sloping ridges. Except for ridge and narrow inter mountain valley there are no other prominent geomorphic units. The terrain is overall rugged with sudden rise and /or fall in relief and slope.

The Garhwal group occupies a remarkable stratigraphic position in the lesser Himalayan belt. It is tectonically bounded by the two major planes of dislocation, Main Central Thrust in the north and the North Almora Thrust in the south. It extends for a length of about 250 km from the Kali River in the east to Yamuna Valley in the west.

The Almora district may be subdivided into four NW-SE trending zones characterized by distinctive geology. Form south to north, there are (i) Sub Himalayan zone contributed by lower Shivalik sediments forming the south-western fringe area (ii) Outer Sedimentary belt constituted by arenaceous, arglillaceous and calcareous sediments and low grade meta sediments (iii) Central Allothonous belt, the Almora Nappe unit constituted by crystalline rocks as quartzite, Phyllite schist, granite and gneiss (iv) Inner Sedimentary belt formation northern part of the district which are unfossilliferous and constituted by metasediments. The formation exposed over Almora span a considerable length of stratigraphic time scale possibly from

Precambrian to upper Miocene. The stratigraphy is not unequivocally established due to tectonic complication and lack of paleontological evidences.

Hand pumps: The hand pumps were installed by Uttarakhand Jal Sansthan, which are located all along the road sides in the hilly areas. The water levels were monitored in selected hand pumps in both season (Pre & post-monsoon). In pre-monsoon water level ranges from range from 1.32 to 61.84 m bgl with an average value of 20.01 m bgl. The present study reveals that 11% hand pumps shows decline and rest 89% shows the rise in water level in post-monsoon.

Springs: A spring is a concentrated discharge of ground water appearing at the ground surface as a current of flowing water under favaurable geomorphic situation. To be distinguished from spring are seepage areas, which indicate slower movement of groundwater, direct infiltration takes place through the saprolite zone, fractured and joints and then moves along interconnected openings. Despite a good amount of rainfall over district to recharge the groundwater storage, the extreme hilly terrain cause either excessive run off of loosing precious ground water in form of springs seepage to the lower reaches. In Almora district springs are the main source of drinking/ domestic water. Most of the springs are situated at higher altitude, which have been tapped and supplied to near by villages/towns and spring which are situated at lower altitude used for irrigation purpose also. Discharges of springs measured in both season (pre & post-monsoon). In pre-monsoon discharge of springs ranges from <0.5 to 90.0 lpm with an average value of 11 lpm and having temperature between 12^0 and 24^0 C with an average value of 19^0 C. in post monsoon discharge of spring ranges from <0.5 to 129 lpm with an average value of 16.82 lpm.

A total of 194 representative water samples (79 normal, 65 nitric acid treated and 50 hydrochloric acid treated) from these structures (129 from hand pumps and 65 from springs) were collected and sent to the Chemical Lab, North Western Region, Chandigarh for complete chemical, heavy metals and iron analysis in order to know the water quality as these structures are being used for drinking water.

17.2 Nainital district

Ground Water Management Studies have been carried out in Nainital district of Kumaon Division of Uttarakhand State. The district is surrounded by Almora district on north, Champawat on east, Pauri Garhwal on west and Udham Singh ngara districts are southern side. The district comprises of four tehsils namely, Nainital, Dhari, Haldwani and Kosya Kutoli and eight developmental blocks viz., Haldwani, Ramnagar, Kotabagh, Dhari, Betalghat, Ramgarh, Bhimtal and Okhalkanda. The total population of the district is 7,62,909 (Census, 2001). The density of population is 198 persons per sq. km. The geographical area of the district is 3860 km^2.

The district is mainly drained by the Ramaganga, Gola, Kosi, Dabka, Baur and Bhakra rivers. The study area enjoys sub-tropical to sub-humid climate. The maximum temperature in the plain areas ranges from 42ºC to 46ºC and the minimum between 1°C and 9°C. The annual normal rainfall in the district varies from 1200 mm to 2647 mm. The average annual rainfall is 1246 mm. The intensity of rainfall generally increases from north to south. The southern half of the district is primarily an agrarian belt. Besides traditional rain-fed crops, *Kharif* and *Rabi* crops are also cultivated taking the advantage of the available irrigation facilities in certain parts of the hilly terrains. The principal crops are wheat and paddy and mandua.

Geomorphologically, the study area comprises of three broad physiographic divisions, from north to south viz., i) *Lesser Himalayan Zone*, which comprises of deep valleys and distinct terraces, both of alluvial and glacial origin. The terrain is overall rugged with sudden rise and/or fall in relief and slope with a maximum elevation of 2610 m amsl, ii) *Himalayan Foot Hill Zone*, which runs in NW-SE direction with a maximum elevation of 1677 m amsl. The lower Siwaliks are truncated towards south by major/minor structural discontinuities. The slopes are relatively moderate, with flat-topped hills and iii) *Piedmont Alluvial Tract*, which is corresponding to the major geo-tectonic sub-divisions of the Himalayas. At the Himalayan foothills, extensive zone of Recent sediments were deposited by the streams running downhill and can be broadly classified into two distinct zones namely Bhabar and Tarai.

Geologically, the study area can be classified into three broad geotectonic divisions namely, i) Lesser Himalayas, which comprises of unfossiliferous meta-sedimentary sequences along with low to medium grade metamorphics ranging in age from Precambrian to Palaeogene, and the main rock types are granite, granodiorite, phyllite, slate, quartzite, schist and gneiss. ii) sub Himalayas, which has been classified as Shiwaliks, Middle Shiwaliks and the Upper Shiwaliks. The lower Shiwaliks are characterized by hard, massive, grey to brownish grey sandstones interbedded with grey to maroon clays. The middle Shiwaliks are characterized by massive light grey micaceous sandstones. The Upper Shiwaliks are constituted of pebbles, cobbles, boulders, conglomerates and clay lenses. The pebbles and boulders are mostly quartzitic. Thin lenses of grey to light green colour clays are common and iii) piedmont alluvial plains

(Bhabar), which is mainly comprised of poorly sorted unconsolidated sediments viz, cobbles boulders, gravel, pebbles, sand and silt with intervening clay layers. The lithological constituents are of heterogeneous nature viz., basic, acid and intermediate along with epiclastics and metamorphiclasts. Clay lenses are of limited extent. The belt is elongate with NW-SE trend. Its northern boundary has an abrupt structural contact (Main Boundary Thrust) with lower Shiwaliks.

During the course of Hydrogeological investigation a total of 93 hand pumps and 80 springs/ gadheras were identified, established and measured water level from hand pumps and discharge of springs both in pre-monsoon and post-monsoon seasons, respectively in order to know the change in water level fluctuation and discharge of the springs.

Hand pumps*:* The hand pumps were drilled by Uttarakhand Jal Sansthan, which are located all along the road sides and river terraces in the hilly areas. The water levels were monitored in selected hand pumps, pre-monsoon range from 1.09 (Naukhuchiya Tal) to 92.23 (Duthkhandhar-Cloud 9/Khabrar) m bgl and post-monsoon water level range from 0.19 (Naukhuchiya Tal) to 90.13 (Duthkhandhar-Cloud 9/Khabrar) m bgl. Hand pump exhibited artesian conditions in Matiyala village in both the periods. The discharge of the auto-flow hand pump could not be measured due to much leakage inside the pump. The present study reveals that all the hand pumps shows rise in water level both in pre-monsoon and post-monsoon periods.

Springs*:* Springs are the main source of drinking/domestic water in hilly areas of Nainital district. Most of the springs are situated at higher altitude, which have been tapped and supplied to near by villages, situated at lower altitude through the gravity system. Discharge of springs measured during pre-monsoon ranges from 1.0 to 146.0 lpm (Sipahi Dhara) having temperature between 12° and 24°C. The same structures (springs) were monitored during post-monsoon and the discharge ranges from 1.0 to 688.0 (Sipahi Dhara) lpm. All these 80 springs shows increase in discharge during the post monsoon period. The representative water samples form these structures were collected and sent for complete chemical analysis in order to know the water quality as these structures are being used for drinking water. A total of 56 representative water samples (39 from hand pumps and 17 from springs) were collected for complete chemical analysis and the same were sent to the Chemical Lab, North Western Region, Chandigarh.

Special Studies: Special studies were proposed to study the behaviour of lake districts of India, Nainital. Nainital district consists of Nainital, Bhimtal, Naukhuchiya Tal, Sattal etc. the lake has a tectonic origin and is characterized by dolomites, limestone, shale and silicate rocks. Lithology around Nainital consists of carbonate rocks, calcareous slates, argillaceous limestone, ferruginous shale, algal dolomites, black shale with marlite, greywacke, siltstone etc. of the Krol Formation (Permo-Triassic). The Bhimtal is comprised of metabasites associated with shallow water quartzite, grits, conglomerates, phyllite and rocks of zeolite and greenschist facies. Naukhuchiyatal Lake is surrounded by metavolcanics and quartzite, whereas Sattal Lake is developed in quartzitic country. There are no industrial activities in the catchments of the lakes. The lake waters are mostly used for potable water supply, fish production, irrigation and recreation. Naukhuchiyatal Lake is fed by several underground springs. Among these lakes, Nainital Lake is major tourist destination and has most visiting/floating population, whereas the other three lakes have attracted much attention lately. The hydrological parameters of the major Kumaon Himalayan lakes tabulated in **Table .** A total of 66 representative lake water samples were collected (Normal: 22 samples, HCl treated: 22 samples and HNO_3 treated: 22 samples) to study the behavior, hydrodynamics, recharge and water balance of these lakes.

18 NHR, DHARAMSHALA

The Ground Water Management studies were carried out in Kangra district and area was covered 5739 sqkm.

18.1 Kangra district

Ground Water Management Studies in Kangra district were carried out in pre and post-monsoon season as per AAP 2009-2010. Kangra district occupies the western most part of the state located between latitude 31^{o} 45′ and 32^{o} 28′ and longitudes 75^{o} 35′ and 77^{o} 05′and covers an area of 5739 sq.kms. It is bounded by Chamba and Lahaul & Spiti in the north; Kulu and Mandi in the east, Hamirpur and Una in the south; and Gurdaspur & Hoshiarpur districts of Punjab.

Western Part

The study area occupies the western part of the district Chamba district in the north; Shahpur, Kangra, Baroh covers an area of 2523 sq.kms. It is bounded by tehsils in the east; Una in the south; and

Gurdaspur & Hoshiarpur districts of Punjab in the west. Geologically, the rock formations occupying the study area in age from Tertiary to Quaternary period. The study area can broadly be divided into Tertiary and Post Tertiary(Quaternary deposits). The valley fills occurs mainly in the western part and as isolated deposits along the terraces/rivers/streams and Tertiary in most of the part. All the formation are trending in NE-SW direction. Kangra district is drained by streams/rivers forming part of the drainage basins of the Beas. There are numbers of tributaries of Beas Rivers flows in the district. The northernly flowing tributaries are ephemeral and have flash floods during the monsoons. The important (khads) are Pragpur, Nalsuha, Chanour and Dada .The Beas River has been bounded at Pong reservoir resulting in a vast body of water covering about 26,400 hectares of land at maximum storage level. Hydro-geologically, the unconsolidated valley fill or alluvial formation occurring in the valley area such as Andora-Nurpur-terrace valleyfills, Jassur-Jawali-Dehra valley fills, Pragpur-Dada Siba valley fills and Jawalamukhi Structural Terrace valley fills and semi-consolidated formations belonging to Siwalik Group form aquifer in the Study area. Porous alluvial formation occurring in the valley area forms the most prolific aquifer system where as the sedimentary semi-consolidated formations and hard rocks form aquifer of low yield prospect. Springs are the main ground water structures that provide water for domestic and irrigation in major rural and urban centers in the hilly area. In valley area of Indora-Nurpur, the ground water occurs in porous unconsolidated alluvial formation (valley fills). Ground water occurs both under phreatic & confined conditions. Wells and tube wells are the main ground water abstraction structures. Ground water is being developed in the area by medium to deep tube wells, dug wells, dug cum bored wells. Depth of open dug wells and dug cum bored well in area ranges from 4.00 to 35.00 m bgl wherein depth to water level varies from near ground surface to more then 28 m bgl. Yield of shallow aquifer is moderate with well discharges up to 15 lps.Seasonal artesian flow conditions also occur during and after the rainy season around Andaura. In Andaura area the yield of the tubewell varies from 15 lps to 35 lps for a drawdown of 6 m to 10 meters. In this tract Central Ground Water Board has constructed many exploratory tubewells ranging in depth from 145 m to 429.50m. Yield of these tubewells ranged between 674 lpm and 2574 lpm. Apart from this, State Government has also constructed many tubewells for irrigation and domestic purposes.In the study area, there are 21-hydrograph network stations where depth to water level is monitored four times a year and ground water quality once during pre-monsoon period. Apart from this 110 dugwells has been inventoried and monitored during Pre-monsoon and Post-monsoon period (2009). Depth to water table shows wide variation. During pre-monsoon period (May 2009) it ranged between 1.16 & 28.55 m bgl, while during the post-monsoon period (November 2009) depth to water level ranged from 0.42 to 24.10 m bgl. Deeper water levels are observed mainly in Jassur-Jawali-Dehra valley fills. In major parts of the study area the depth to water level are less than 15.00 m bgl.Ground water is being recharged from rainfall infiltration, seepage from khuls, streams, rivers and water reservoirs. The net ground water resource available in the Indora-Nurpur valley is 9438.70 hect.m. The existing gross ground water draft for all uses being 2915.30 hect.m. The existing ground water draft for irrigation is 2393.30 hect.m. Net Ground Water availability for future irrigation development is 6430.40 hect.m. The stage of ground water development as on November 2009 is 30.88 % and categorized as 'safe'.

Eastern Part

The study area occupies the eastern part of the district covers an area of 3206 sq.kms It is bounded by Chamba and Lahaul & Spiti district in the north; Nurpur, Harchekian, Jawalamukhi and Dehra in the west; Hamirpur in the south, Kullu and Mandi in east. Geologically, the rock formations occupying the study area of the district range in age from Pre-Tertiary to Quaternary period. Hydro-geologically, the unconsolidated valley fill i.e. Fluvio Glacial deposit occupies the foot hills of the Dhauladhar in Kangra and Palampur valley, There are numbers of alluvial fans in the Palampur valley and Jawalamukhi Structural Terrace valley fills and semi-consolidated formations belonging to Siwalik Group form aquifer in the Study area. Porous alluvial formation occurring in the valley area forms the most prolific aquifer system where as the sedimentary semi-consolidated formations and hard rocks form aquifer of low yield prospect. Springs are the main ground water structures that provide water for domestic and irrigation in major rural and urban centers in the hilly area. Springs in the study area are mainly gravity, contact or fracture type and springs located along major thrust/faults or structurally weak planes are high yielding.During the study, total 35 springs and 15 Bawries (Seepage) were inventoried in pre-monsoon season and from the same has been re-monitored in post-monsoon season to know the fluctuation in discharge. The studies shows that 88 % of the springs monitored shows increase in discharge during post-monsoon compared with pre-monsoon season while 3 % of the springs shows decrease in discharge. Three of the springs show no change in discharge.The springs in the district are generally grouped under the category V,VI & VII of Meinzer's classification for springs. The pre-monsoon and post-monsoon fluctuation of spring discharge ranges from <zero to 4.6 lps at Jaisinghpur. Springs located along or at the inter section of faults/fracture zones are yielding upto about 20 lps are indicative of their high potentialities. Phyllites, Quartzites, Limestone, Sandstones exposed in the eastern parts of the district forms comparatively a poor aquifer except in the lower valley areas. Springs in these areas are yielding low quantity of water varying in discharge not more than 10 lps.

Recommendation:

- In valley areas, in addition to traditional ground water structures like dug wells, springs, medium to deep tube wells can be constructed for developing the ground water resource for domestic, agricultural and irrigational use.
- Valley fill deposits and terraces are to be fully explored by constructing test wells for studying the precise distribution of ground water horizons and scope for development.
- In hard rock area all the weak zones, like thrust, faults, fractures, lineaments, and contact of different formation are to be studied in detail for demarcating the aerial extent and vertical distribution of ground water potential zones by micro level hydrogeological/geophysical studies followed by exploratory drilling based on which suitable ground water structures can be constructed for the development of ground water resources.
- In alluvial areas of Indora-Nurpur valley, though there is scope for ground water development as stage of ground water development is only 30.88 %, however, there is need to adopt cautious and phased manner ground water development approach in view of depleting water levels in some parts. This decline can be attributed to fast pace of development in recent years, both in agriculture sector and industrial sector.
- This industrial area is highly prone and vulnerable to surface & ground water pollution thus water quality monitoring at close network is essential.
- Proper waste/effluent disposal measures are required to be adopted by industrial units and state authorities needs to check this.
- There is need to protect traditional water harvesting structures like ponds, tanks, talavs to utilized these for rain water harvesting and recharging shallow aquifers.
- In hilly and mountainous terrain, traditional ground water sources viz., springs, *bowries* etc needs to be developed and protected for better health and hygiene with proper scientific intervention.
- Springs needs to be inventoried & studied for optimum utilisation of their discharge either by fracturing, horizontal drilling or by constructing galleries etc.
- Proper development of springs is essential as it is observed that most of the spring in the district does not have collection chamber or tanks from where water can be distributed under gravity. The objective of spring development should be to collect the flowing water underground, to protect it from surface contamination and store it in sanitary spring box for supply. Similarly, *seepage springs* along hill sides also need to develop for harnessing ground water in such areas.
- Spring water should be tested before and after heavy rains each year for bacteria, pH, turbidity, and conductivity.
- Springs are often contaminated with bacteria during construction or maintenance. All new and repaired water systems should be disinfected using *shock chlorination.*
- Roof top rainwater harvesting practices can be adopted in hilly areas and urban areas, since the district receives fair amount of rainfall. Construction of roof top rain water harvesting structures should be made mandatory in all new construction and rain water harvesting in rural areas should be promoted. Traditional water storage systems need to be revived.
- In Study area valley for most of the households, IPH department supplies water, so the people put their dugwells abandoned without using it. These unused and abandoned dugwells can be used as rainwater harvesting and artificial recharge structure to recharge ground water.
- People's participation is a must for any type of developmental activities. So proper awareness for utilization and conservation of water resources is required.