Hydrogeology Assessment Report

Wakal River Basin, Rajasthan, India

Integrated Management of Coastal and Freshwater Systems Program

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1 ABOUT RAJASTHAN

1.1 Rajasthan: Location

Rajasthan, the second state of India (3,42,239 sq.km.) situated in the northwestern part of the Indian Union (23^0 30' and 30^0 11' North latitude and 69^0 29' and 78^0 17' East Longitude) is largely an arid state for most of its part (Map 1.1). The Tropic of cancer passes through south of Banswara town (Map 1.2). Presenting an irregular rhomboid shape, the state has a maximum length of 869 km. from west to east and 826 km. from north to south. The western boundary of the state is part of the Indo-Pak international boundary, running to an extent of 1,070 km. It touches four main districts of the region, namely, Barmer, Jaisalmer, Bikaner and Ganganagar. The state is girdled by Punjab and Haryana states in the north, Uttar Pradesh in the east, Madhya Pradesh in the south- east and Gujarat in the south-west.

Rajasthan has exhibited spectacular progress in several areas like agricultural production, harnessing of mineral resources, development of means of transport and communication, and the production of energy resources but the rate of progress and plans of economic development have showed to a large extent by a parallel growth of human population and livestock. Human resources are, therefore, to be geared into the channel of economic progress while taking care to arrest their future growth-rate.

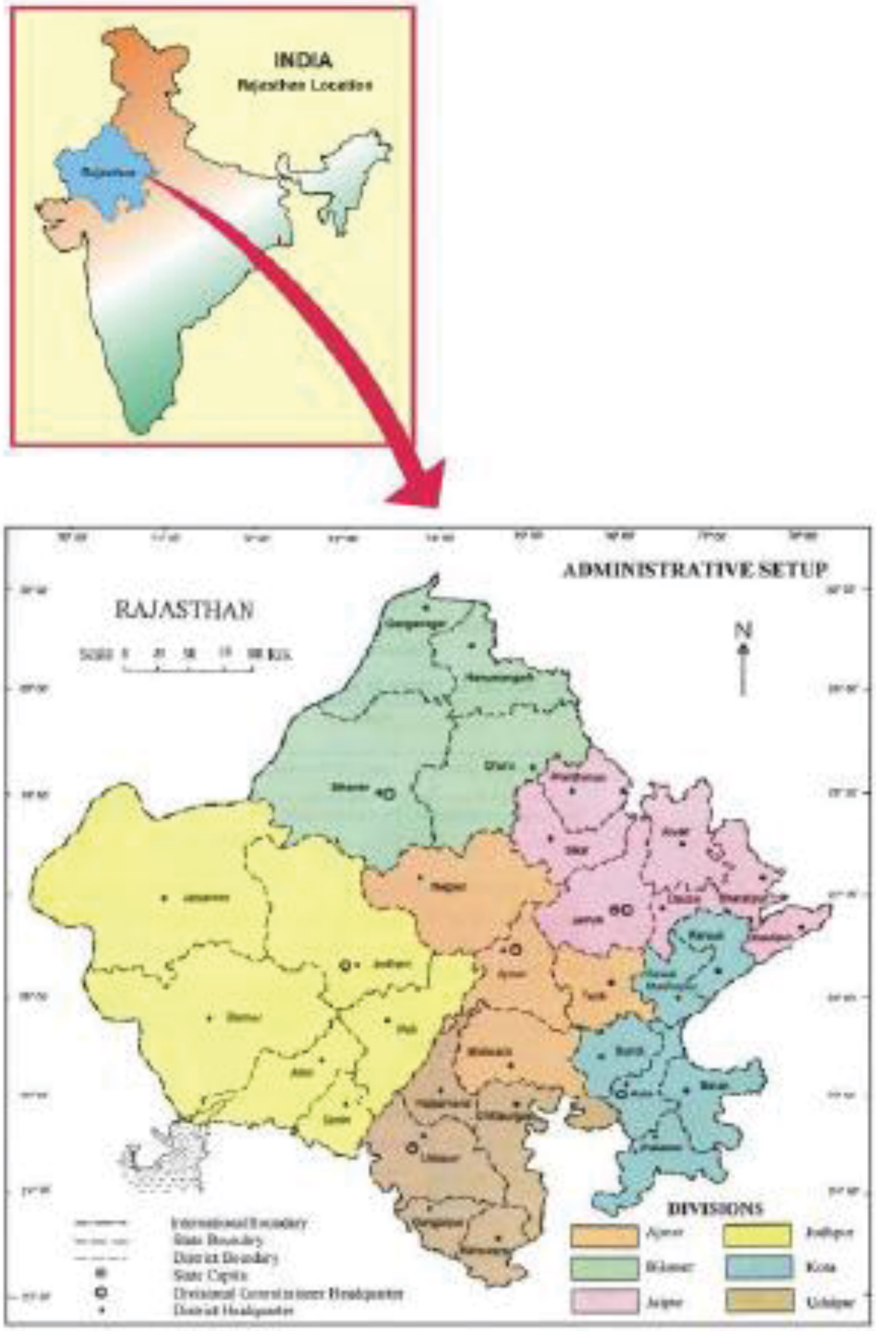
The rich wealth of non-renewable resources is yet to be explored and exploited. Their judicious exploitation can make the state economically self-sufficient. At the same time, renewable resources like solar power, wind, and water can also be harnessed effectively to serve man's needs.

ADMINISTRATIVE SET-UP

The state is divided into six divisions Map-1.1 each being headed by Divisional Commissioner with a view to provide for successful implementation of government policies. These divisions are - Ajmer, Bikaner, Jaipur, Jodhpur, Kota and Udaipur. Besides these divisional commissioners, there are three Area Development Commissioners heading three Command Area

Map No. 1.1

Map Showing the Location of Rajasthan and Udaipur Division



(Source - Ground water Atlas of Rajasthan ([illegible]) DST, Govt. of Rajasthan, Jodhpur

2

Map No. 1.2

Political Map of Rajasthan State Showing Geographical Co-ordinates

(Source: - Roy & Jhaltan, 2002)

Development Programmes viz. Command Area Development, Bikaner; Command Area Development, Chambal, Kota; Tribal Area Development, Udaipur. There are, in all 32 districts. The number of districts in each division varies. The largest among all Division's Jaipur and Kota division has seven districts respectively. Bikaner and Ajmer divisions has only four districts respectively. The districts very greatly in area and population. The western districts are generally much bigger in size than the eastern and southern ones. However, this position is reversed when human population within the district is considered. for carrying out all developmental activities in the district, the Collector as, District Development Officers is supported by Additional Collector (Development) at district level and Vikash Adhikaris at Panchayat Samiti level.

TEHSILS

A Tehsil is a small administrative unit for collecting land revenues and is administered by a Tehsildar. The number of Tehsils in a district is largely determined on the basis of its population. The maximum number of tehsils is in Jaipur district (13) and the minimum is in Jaisalmer (2) (Map 1.3).

PANCHAYAT SAMITIES

A Gram Panchayat extends over an area of about 8 sq.km. covering a group of villages with the population ranging from 2,000 to 5,000. Gram Panchayat is an elected body having 8 to 11 Panchs, one of whom is a Sarpanch, the executive head for rural development. It is mandatory to have the required representation of people of Schedule Castes, Scheduled Tribes and women members in the Panchayat, who, if not elected are co-opted by the Panchayat.

A cluster of Gram Panchayats form a 'Panchayat Samiti' (Map 1.4) which is headed by a Pradhan, elected by the Sarpanchs, who looks after the development work of the Panchayat Samiti. The Block Development Officer, a government official is the executing head of the Samiti.

Map No. 1.3

Tehsil Map of Rajasthan

(Source - Ground water Atlas of Rajasthan (1991) DST, Govt. of Rajasthan, Jodhpur

Map No. 1.4

Panchayat Samities Map of Rajasthan

(Source - Ground water Atlas of Rajasthan (2005) DST, Govt. of Rajasthan, Jodhpur

Parishad', one in each district. The Pradhans elect from amongst themselves a 'Zila Pramukh'. Each Zila Parishad has a senior government officer as the Chief Executive Officer. These 'Parishads' discuss the Panchayat Samiti Plans that are executed after their approval. The normal period of functioning of these institutions is three years after which fresh elections are held.

No. of Panchayat Samities in Udaipur District-

1. Gogunda,
2. Bargaon
3. Mavli
4. Kotra
5. Girwa
6. Bhinder
7. Jhadol
8. Sarada
9. Salumber
10. Dhariawad
11. Kherwara

1.2 Relief

The physiography of Rajasthan is the product of long years of erosional and depositional processes. The present landforms and drainage systems have been greatly influenced and determined by the geological formation and structures. Four major physiographic regions can be identified within the state. These are (1) The Western Desert (Thar), (2) The Aravalli hill region, (3) The eastern plains and (4) The south-eastern plateau region (Map 1.5a & b). The Aravalli hill ranges, running from north-east to south-west, divides the state approximately into the western arid and eastern semi-arid regions. It is also a major water divide. The area, to its east, is well drained by several integrated drainage systems, while the area, to the west, has only one integrated

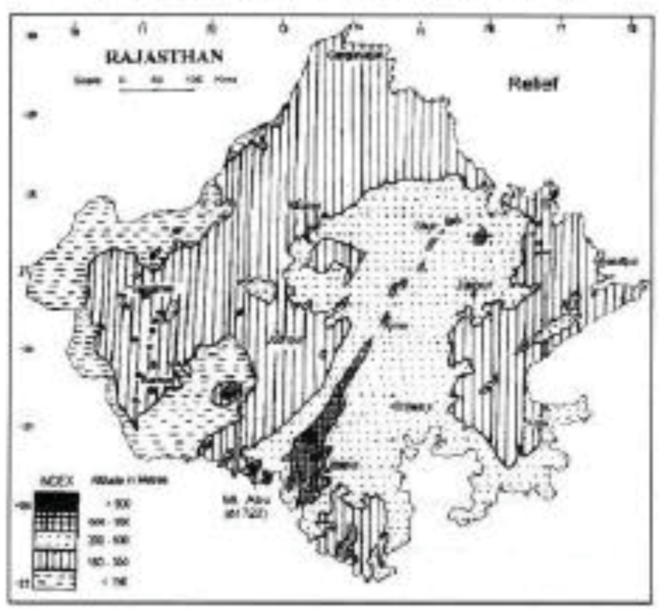
Map No. 1.5

Physigraphic Map of Rajasthan Showing main Geomorphic Segments

A

Map of Rajasthan Showing Relief

B



(Source – Roy & Jhakhar, 2002)

in the south-eastern part of the desert.

DRAINAGE PATTERN:

The Aravalli Mountains, which runs across the State from the southwest to the northeast direction, from the main water divide in Rajasthan. While a major part of western Rajasthan has inland drainage system, the southern, southeastern and the eastern parts have a well developed drainage system. The rivers of Rajasthan, except the Chambal, are ephemeral and flow only during the rainy season. The drainage pattern in the entire part of Rajasthan is generally dendritic.

The river system of the State can be conveniently divided into two major groups-

i) The rivers, which drain their run off to the Bay of Bengal, and

ii) The rivers flowing to the Arabian Sea.

Two other important rivers which flows to the Arabian sea are the West Banas and Sabarmati. The West Banas originates from the western slope of the Aravalli Mountains and drains some parts of Sirohi District, finally draining its run off in the Rann of Kachchh. The Sabarmati originates as the Wakal river from the low hills of Gogunda in the Udaipur District. It drains part of Udaipur and Sirohi Districts before meeting the Gulf of Cambay (Roy & Jakhar, 2002).

Aravalli Hills-

The Aravalli hill ranges constitute the most dominant hilly area of Rajasthan. The ranges run diagonally across the state from north-east Delhi to south-west upto the plains of Gujarat, covering a distance of about 690 kms. Within Rajasthan, the ranges run from Khetri in the north-east to Khed Brahma in the south-west for a length of about 550 kms. In the north-east, the hill ranges become more prominent near Khetri and Alwar. Towards the south-west, the ranges become more prominent with peaks upto 1055 m above MSL. Quartzite, being very resistant, form most of the hills in the northern and central parts. Granite forms the high hills in the south near Abu. Apart from the hills, the other major landforms within this region are the rocky uplands, shallow to moderately deep colluvial plains and narrow alluvial plains at few locations.

The Aravalli Mountains:

The Aravalli Mountains, which crosses the state of Rajasthan diagonally for a distance of about 800 km. lies east of the Thar Desert. It is a typical ensialic mountain range of olden Proterozoic rocks having an age span between 2500 and 850 million years from today. The Archaean rocks, which form the foundation of the mountain, have a history of one billion years; the oldest rocks are believed to have originated earlier to 3300 million years ago. Although Heron (1953) described the Aravalli Mountains as 'being perhaps the oldest mountain range in the world', it is doubtful if the present relief can be ascribed entirely to the Precambrian orogenesis.

References to the Aravalli Mountains are traceable in ancient literatures as a mountain that stands askew to the east-west trending Himalaya and the Vindhyan ranges (known as the Satpura Mountains in geological literatures). The mountain not only prevented the sand movement to the east, but also formed a formidable barrier for the ancient people to cross over particularly in the southern part. In spite of being an ancient geomorphic 'welt', the mountain has very prominent relief features, which normally characterises the much younger mountain chains, like the Appalachians in the eastern North America, or the Urals that joins Europe with Asia.

Heron's (1953) description of the main component of the geomorphic mountain as a syncline or synclinorium ("Main Delhi Syncline") is naively simplistic. Detailed studies subsequent to the publication of the Heron's classical memoir helped in erecting an evoluntary history comprising three successive Proterozoic cycles of basin evolution, magmatism, metamorphism and tectonic inversion, on an Archaean basement.

The Aravalli Mountains can be subdivided into the following geographical belts:

i) Alwar Hills,

ii) Eastern Shekhawati Hills including Sambhar Basin

iii) Central Aravalli (Merwara) Hills,

iv) Mewar Hills, and

v) The Abu Block

Mewar Hills:

Reliefwise the highest elevation of the Aravalli Mountains is in the triangular area lying south of Desuri-Ki-Nal. Known as the Mewar Hills, this high-hilly tract is bounded by the Eastern Mewar and Chappan plains in the east, Cambay Graben in the south, and the extension of the Kui-Chandravati Fault in the west. The northern part of the triangle between the Fort of Kumbalgarh (25^{0}05':73^{0}35') and Gogunda (24'46':73^{0}32') is a region of high elevation, locally called the Bhorat Pathar (plateau). Lying at a level of nearly 1000m, the plateau has a steep and precipitous western fall. There are a number of peaks, which rise over 200m above the average 1000m level. The highest peak of the Bhorat Pathar is the Jarga Parvat rising to 1316m. This is the second highest point in Rajasthan after the Guru Shikhar (1722m) in Mount Abu. The Fort of Kumbalgarh is perched majestically at 1075 m high overlooking the plains of western Rajasthan Bagar. The Bhorat Pathar is made of several subparallel bold ridges of quartzite separated by valleys underlain by phyllite and clacareous schists.

From south of Gogunda, sets of subparallel ridges branch in the southwesterly, southerly, and southeasterly directions. The southwesterly branch of the southern Mewar Hills runs straight upto the Gujarat border where the ridges undergo abrupt truncation. Because of this, the highly mountainous Aravalli landscape is taken over by the low-lying alluvial plain of Cambay Graben. The abrupt termination of Aravalli ridges is a major geomorphic feature that also constitutes the southern boundary of outcrops of the Rajasthan. Another prominent feature in the geomorphology of this part of the Aravalli ranges is the presence of number of circular and semi-circular relief features, possibly related to intrusions that shoved astride the tectonic pattern of the host rocks.

The middle branch of the Aravalli ridges, which runs more or less in the north-south direction, makes its appearance from east of Gogunda. These are very prominent ridges of quartzites in a milieu of phyllites, all belonging to the Aravalli Supergroup. All the ridges of the Aravalli Mountains described earlier, geologically belong to the Delhi Supergroup. The angular relationship between the two trails of the Aravalli Mountains that run southwesterly and southerly respectively, mark an important tectonic feature presumably representing the trace of unconformity between two geological formations. The angular relationship appears very prominently in the satellite imageries. The ridges trend southward upto Kherwara (23^{0}59':73^{0}37') and Rishabdev (24^{0}05':73^{0}42'), where from starts a gradual southeasterly swing of the bold quartzite ridges. On a plan view, the ridges assume queer patterns particularly in the region between south of Dungarpur and Lunavada (23^{0}32':73^{0}35') in northern Gujarat. The ridges become more subdued until these get covered under Deccan basalts in the east. The highest elevation in this part of the Mewar Hills is in the region west and northwest of the city of Udaipur, where there are a number of peaks rising above 900m. The highest point is 1073 m near Jharol (24^{0}24':73^{0}29').

The most easterly trail of ridges, which runs in southeasterly direction, starts from the upland north of Udaipur. The city itself is surrounded by chains of hills. The valley where the city of lakes is situated is called Girwa. The continuity of southeasterly ridges, which are traceable beyond Salumber, is breached at the Jaisamand Lake. Some hills in the neighbourhood of Jaisamand Lake rise upto 820m, whereas the highest level of lake water stands at 300m. These easterly and terminal Aravalli ridges present a bold geomorphic outline bordering the Eastern Plains of Banas and Mahi Basins (Roy & Jhakhar, 2002).

The Aravalli ranges are the most prominent hill features extending from Sirohi, Udaipur and Dungarpur districts in the south-west to Jaipur and Alwar districts in the north-east. They rise to their highest summit at Mount Abu (1772m above MSL) in Sirohi district. These ranges form a Labyrinth of low hills in Udaipur, Dungarpur and Banswara districts, and stretch North-eastwards in the form of undulating low hills through parts of Ajmer, Tonk, Sawai Madhopur, Jaipur and Alwar Districts, Isolated outcrops of Aravallies occur in Jhunjhunun, Sikar and Nagaur districts.

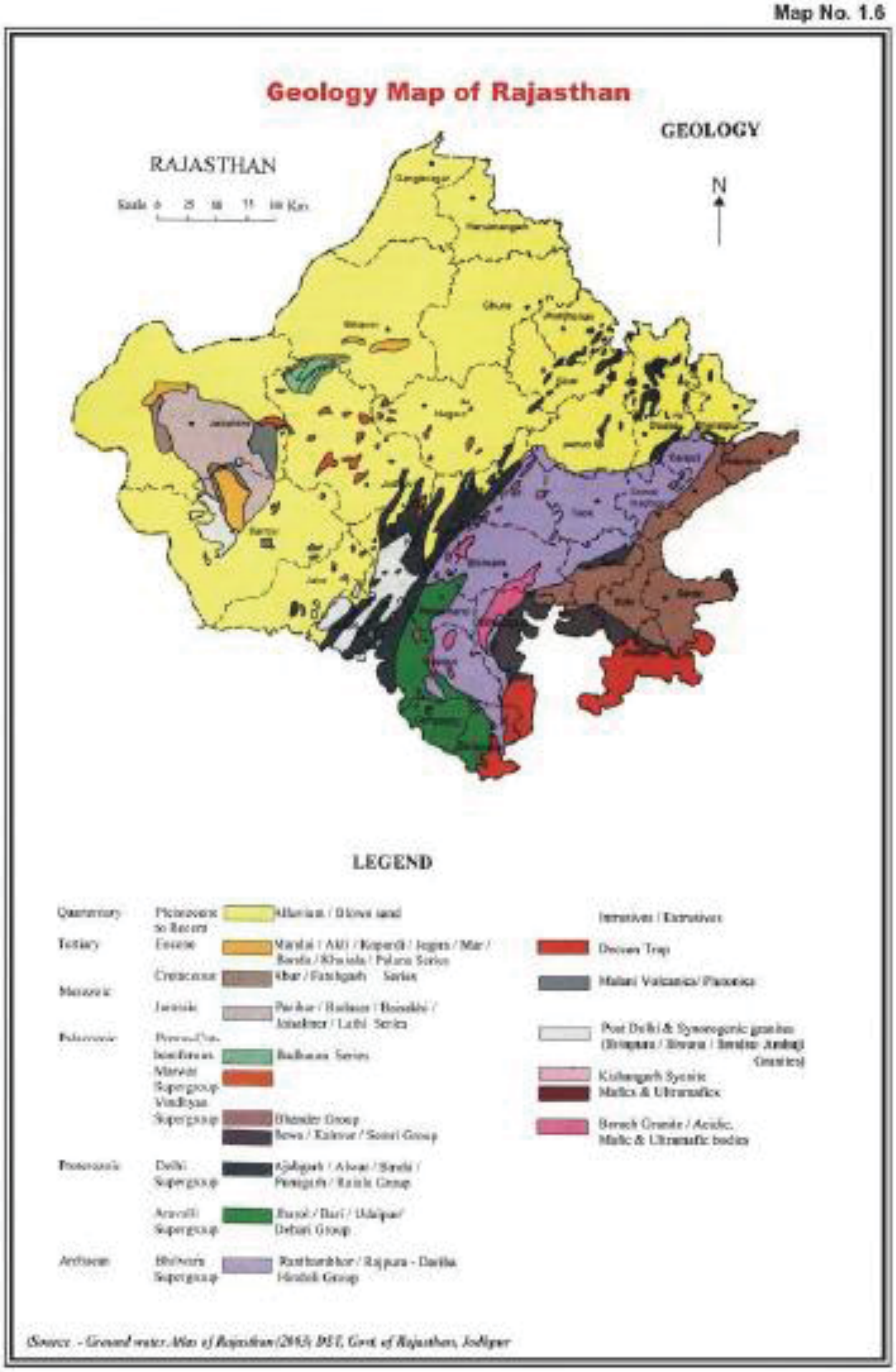
1.3 Geology:

Rajasthan is endowed with a continuous geological sequence of rocks from the oldest. Archaean Metamorphics, represented by Bhilwara Super Group (more than 2,500 million years old) to sub-recent alluvium and wind blown sand. The western and north-western parts of the state are covered by vast blanket of young unconsolidated deposits including the blown sand of the Thar Desert (Marusthal) of Western Rajasthan. The remaining area exposes wide variety of hard rocks which include various types of metamorphic schists, quartzites, marbles and gneisses of Pre-Cambrian age with associated acid and intrusive rocks. The formations include the rocks of Aravalli Super Group, Delhi Super group upper Precambrian Vindhyan Super group and of Cambrian to Jurassic, Cretaceous and Teritary ages. The south-eastern extremity of the state is occupied by a pile of basaltic flows of Deccan Traps of Cretaceous age. Several mineral deposits of economic importance occur in association with the above rock units (Map 1.6).

The geological sequence of the state is highly varied and complex, revealing the co-existence of the most ancient rocks of Pre-Cambrian age and the most recent alluvium as well as wind-blown sand. The Aravallis, one of the most ancient mountains in the world, have the oldest granitic and gneissic rocks at their base. Delhi Super Group, the Vindhyan Super group and younger rocks are highly metamorphosed at certain places and show rich occurrences of minerals of great commercial importance.

The characteristic feature of the geology of Rajasthan is the presence of several groups of rocks belonging to Archaean and Pre-Cambrian ages. They form the Aravalli mountain system which runs across the state from the north of Delhi in the north-east to the Gulf of Cambay in the south-west. The central part of the

Map No. 1.6



Aravalli ranges is occupied by a great synclinorium composed of Aravalli and Delhi rocks. Because of the thin deposits of sand in this region, the rock exposures are good but in the west and the south-west, they are often engulfed in sandy alluvium and desert sands.

The Archaeans consists of the Bhilwara Super group (Bundelkhand Gneiss and the Banded Gneissic complex). The Aravallis, an enormously thick series of argillaceous rocks, came into existence at the close of the Archean era when the sediments which were deposited in the seas of that age, underwent an upheaval by orogenic activities. These vast mountains were peneplaned in pre-cretaceous time but were again rejuvenated in later ages. The Aravallis Super Group is a vast formation composed of basal quartzites, shale's, conglomerates, composite gneisses and slates.

The Delhi Super group overlies the Aravallis. Delhi Super group is divided into lower Railo group, middle Alwar group and upper Ajabgarh group. Railo group is rich in crystalline limestones, grits, schistose rocks and quartzites. The famous marble of Makrana (Nagaur district) belongs to this group. Alwar group and Ajabgarh group consist mostly of calc-silicates, quartzites, grits and schistose rocks.

The other important lithological formations consist of a thick series of sedimentary rocks comprising sandstone, limestone and shales. These have been classified as upper and lower Vindhyans in the east and Marwar in the west. The deposition of these rocks in western Rajasthan was preceded by igneous activity which included a thick pile of lava, mostly of an acidic nature. The plutonic equivalent of these lava are seen in the form of granite bosses and sills in Jalor, Siwana, Mokalsar and Jodhpur areas. Rocks of the above mentioned igneous activity has been designated as Erinpura granite and Malani igneous suit.

There was an encroachment of an arm of the sea from the South-Westernly direction into western Rajasthan during the Jurassic period. Jurassic formations are distinctly noticeable in a vast area around Jaisalmer and some of the fossils of this age are found in these rocks. The outcrops of these rocks are, partly, covered by wind-blown desert sands. Of special interest are the Bap (Jodhpur district) and Pokran (Jaisalmer district) beds of upper Carboniferous age which have now been exploited for ground water. They are composed of boulders of Malani rhyolites showing effects of glaciation. Violent volcanic activity in the form of fissure eruptions marked the close of Mesozoic era in the lower Cretaceous age. The main characteristic of this was a stupendous outburst of covered volcanic energy, resulting into eruption of thick streams of lava over vast areas. These rocks, known as Deccan traps, are found in southern and south-eastern Rajasthan. The Deccan trap, extending over a vast area in southern Jhalawar and in the eastern parts of Chittorgarh and Banswara districts, are notable formations of Upper Cretaceous to Lower Eocene age when a large area of peninsular India was also covered with fissure eruptions of black lava.

During Eocene times, marine transgression seems to have inundated a large part of western Rajasthan with the deposition of thick beds of fossiliferous limestone. To the north of Jaisalmer, the Jurassics are overlapped by nummulitic limestone.

Pleistocene alluvium, blown sand, kankar (calcium nodules), carbonate beds and evaporate deposits of recent and sub-recent age are found over a large area of western and eastern Rajasthan.

The Great Boundary Fault through which the River Chambal has carved its course, passes through south-eastern parts of the state. This fault is visible in Begun (Chittorgarh district) and northern parts of Kota. It reappears again in Sawai Madhopur and Dhaulpur districts. Besides this, several mega lineaments also traverse in the state.

1.4 Soils:

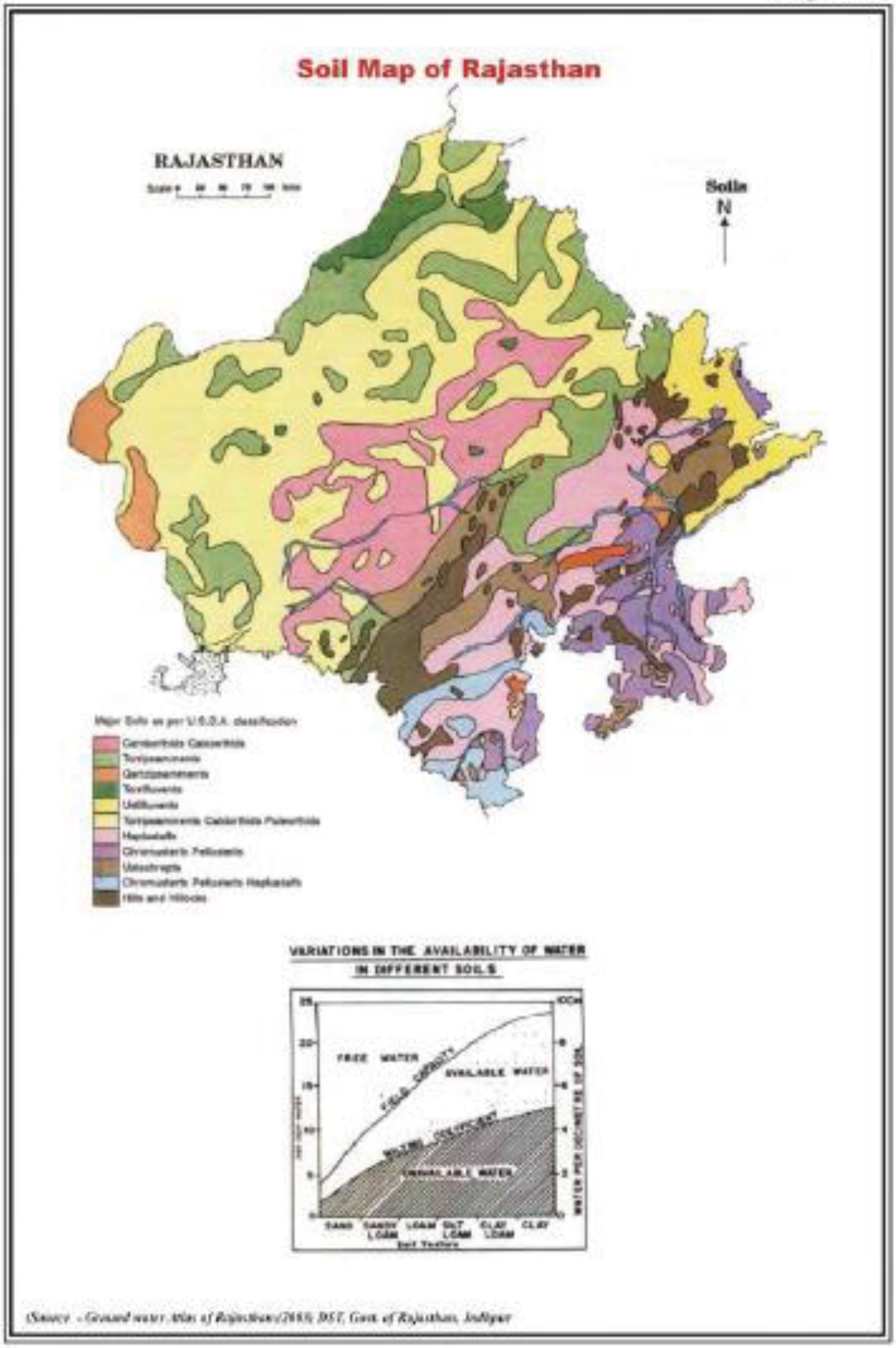
Despite the recent great strides in technology and mechanization, agriculture has remained the world's most important primary industry, in which the soil plays pivotal role. About 66 per cent of the global population, comprising of farmers derives its living directly from the soil. There are no natural resources more important than soil resource.

Whatever its production capacities, whether high in some places of irrigated pockets or low in major areas of dry land and desert, due to inherent limitations, the soil resource of Rajasthan, as a medium of growing crops, has furnished directly or indirectly, a significant share in the income of the state. Rajasthan, being geographically the second largest state in India, has proportionately a greater soil resource. Therefore, the soil resource in the state needs to be used extensively and efficiently so that the state finds an appropriate place in the national food, fiber and fodder production and the state economy is sustained without any depletion through erosion, degradation or overuse. The information and knowledge of soils of the state which could be gained through the study of their physical and chemical properties and their geographically distribution pattern is an essential prerequisite for their proper utilization, management and conservation. It also helps in proper selection of crops and better land use.

When seen in detail at the village level, the soils of Rajasthan are complex, and highly variable reflecting a variety of differing parent materials, physiographic land features, range of distribution of rainfall and its effects, etc. However, broadly, the soils can be put in five major groups, based on the basic fabric of soils i.e. soil texture which governs its many other properties. They are, (1) sandy soils or light soils, (2) sandy loam or light medium soils (3) loan or medium soils, (4) clay loam to clay or heavy soils and (5) skeletal soils or shallow rocky and hilly soils (Map 1.7).

The soils are generally evaluated for their production capacity through study of their ability to supply plant growth requirements in terms of water, nutrient and rooting media. The capacity to retain, as also to conduct soil

Map No. 1.7



moisture in profile, depends upon the soil texture, soil porosity and soil structure. For example, heavy soils due to their fine texture and porosity, provide effective capillary tubes for moisture movement. In loose sandy soils, due to big particles and pores, with fewer fine capillary pores, there is lesser soil moisture movement. Further, heavy soils are more difficult to work with implements than in light soils. during dry hot periods, however, heavy soils that get compacted, resist wind erosion, but under heavy rainfall, due to their low infiltration rates, they generate high surface run off and thus cause extensive soil erosion through water. On the other hand, the sandy or light soils that are loose and single grained are more prone to wind erosion and are often subject to sand drift, but due to their coarse and open texture, coarse pores and resultant high infiltration capacity, they are not susceptible to water erosion, even during heavy cloud bursts. Medium textured soils have moderate condition between the above extremes. As such, these different soils create different types of habitats for plant growth and therefore, the crop choice and cropping patterns on such kind of soils greatly vary.

Soils are thus, variable in their soil-water-plant relationship, conservation needs and production potentials. To assess the potential of agricultural development and to plan proper conservative land use, soil survey is the basic requisite. The knowledge of soils gathered through soil such surveys is not only useful in finding out agriculturally potential areas but also those areas which have remained unnoticed under on or the other soil degradation process for a long period and are now considered as problematic areas. Further, the agronomical and soil moisture conservation technologies, developed for crop production, are often more suitable, particularly for one or the other kinds of soils. Therefore, the distribution of such differing soils depicted through soil survey maps, is useful for easy and proper transfer of such technologies to suitable areas.

Soil resource is also a malleable environment moulded by the agriculturist in many ways e.g. its production capacity per se can be improved through improvements of its fertility by use of organic manures and fertilizers. Its sustainability can also be maintained by its conservation against damages through erosion, preventing salinization, alkalinization, compaction, depletion in nutrient level, etc. These are all known soil degradational processes which lessen the current or potential capability of soils to produce crops or biomass. Many technologies are available to check this and conserve soils for sustained productivity.

1.5 Rainfall Pattern:

The climate of Rajasthan sate varies from arid to sub-humid. To the west of the Aravalli range, the climate is characterised by low rainfall with erratic distribution, extremes of diurnal and annual temperatures, low humidity and high wind velocity. The climate is semi-arid to sub-humid in the east of the Aravalli range, characterised by more or less the same extremes in temperatures but relatively lower wind velocity and high humidity with better rainfall. The entire state is characterised by hyperthermic conditions.

The annual rainfall in the state varies significantly. The general trend of Isohytes is from north-west to south-east. There is a very rapid and marked decrease in rainfall west of the Aravalli range, making western Rajasthan the most arid part. The average annual rainfall in this part ranges from less than 10cm in north-west part of Jaisalmer (lowest in the state), to to 30cm in Ganganagar, Bikaner and Barmer regions, 30 to 40cm in Nagaur, Jodhpur, Churu and Jalore regions and more than 40cm in Sikar, Jhunjhunun and Pali regions and along the western fringes of the Aravallis range. On the eastern side of the Aravalli range, the rainfall ranges from 55cm in Ajmer to 102cm in Jhalawar. In plains, Banswara (92.0cm) and Jhalawar (102 cm) districts receive the maximum annual rain. Mount Abu (Sirohi district) in the south-west, however, receives the highest rainfall in the state (163.8 cm). The yearly total rainfall is highly variable at different places all over the state and it is most erratic in the western half with frequent spells of drought, punctuated occasionally by heavy downpour in some years, associated with the passing low pressure systems over the region.

The south-west monsoon which has its beginning in the last week of June in the eastern parts, may last till mid-September. Pre-monsoon showers begin towards the middle of June and post monsoon rains occasionally occur in October. In the winter season also, there is sometimes, a little rainfall associated with the passing westerns distribution over the region. At most places, the highest normal monthly rainfall is during July and August.

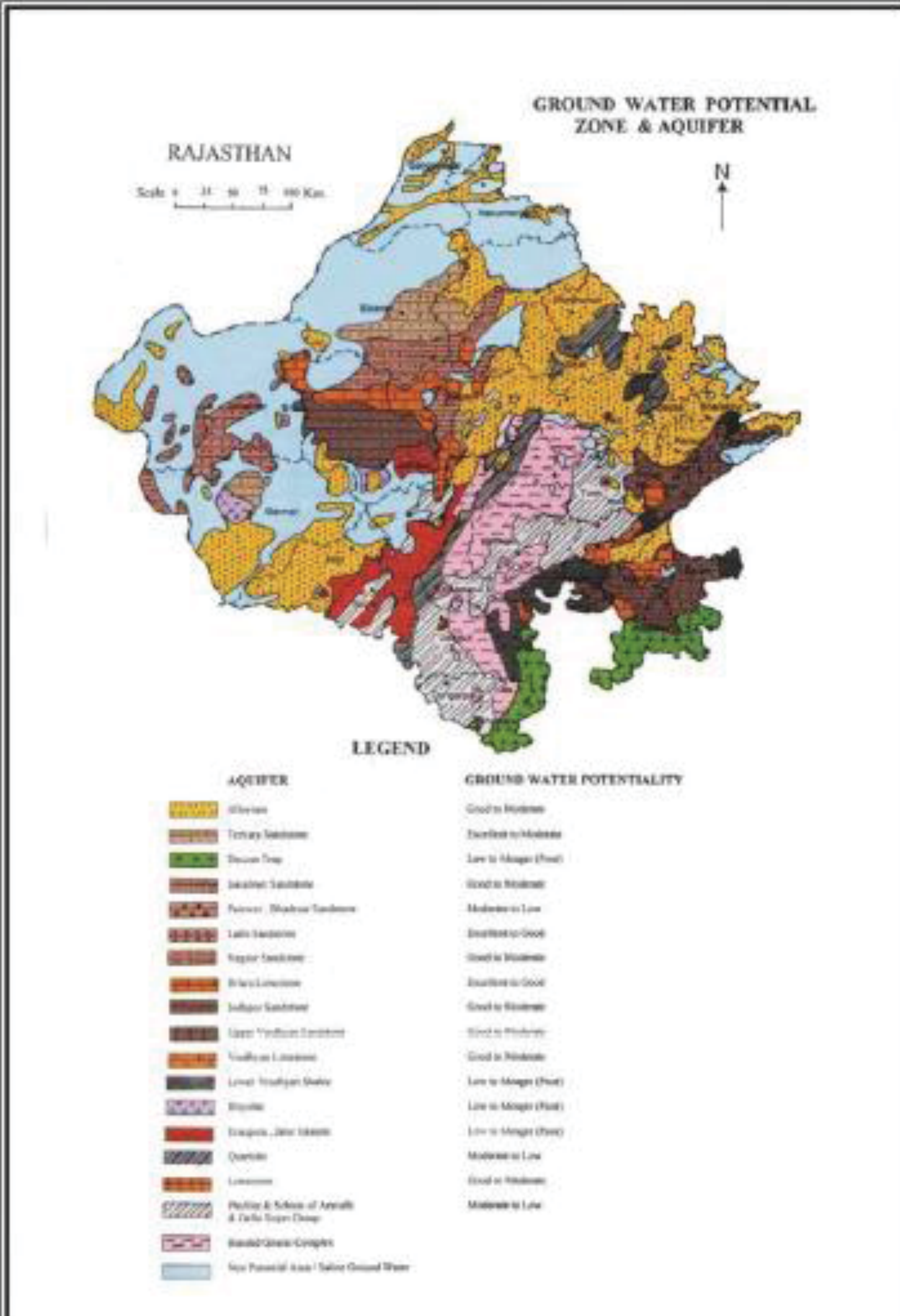
1.6 Ground Water Resources:

Due to scarcity of surface water, Rajasthan has to depend on ground water resources to a great extent.

The availability of ground water depends upon the nature of rocks and their water bearing characters. Approximately, 40 per cent area of Rajasthan is occupied by hard rocks consisting of the Archaean crystallines, Aravalli Super-group and Delhi Super-group, the Erinpura Granites, Malani suite of igneous rocks, their equivalents the Vindhyans and the Deccan Traps. The crystallines (igneous and metamorphic rocks), ranging in age from Archaean to Upper Proterozoic, have negligible primary porosity. Significant secondary prosity is introduced into them locally due to weathering and fracturing. In the crystallines, the yield of wells generally ranges from 10,000 to 50,000 lph. Vindhyan sandstones and limestones occupying parts of Kota, Baran, Jhalawar, Bundi, Chittorgarh and those of Marwar super group in Jodhpur and Nagaur districts, are promising aquifers with moderate to high discharge, due to their porous and permeable nature. The discharge in limestones varies from 30,000 to 1,00,000 lph in Bilara and Borunda (Jodhpur) area. Similarly, discharge in sandstone ranges from 20,000 to 80,000 lph in Mathania and Osian area of Jodhpur district (Map 1.8).

The Deccan traps show low to medium permeability depending on the primary and secondary porosities and their variation from place to place. In the hard rock terrains, the valley fills consisting of river and stream laid deposits, often contain highly productive aquifers, with limited groundwater resources. The alluvium and the blown sand which occupy the major part of the state and the semi-consolidated formation comprising the Tertiaries and the Mesozoic rocks.

Map No. 1.8



(Source – Ground water Atlas of Rajasthan (2013) DST, Govt. of Rajasthan, Jodhpur

Ground water development is significantly high in the eastern part of

Rajasthan as compared to the western part. The annual ground water recharge is relatively less in western Rajasthan, due to low and erratic rainfall, absence of surface water resources, and high evapotranspiration. However, in some of the thick aquifers, the storage is many times and annual recharge and hence, sustained pumpage can be achieved even during a dry spell, without causing adverse effects.

The depth of water varies widely throughout the state. To the east of Aravalli, the depth to water is comparatively shallower than in the west. It generally varies between less than 10 to 25 meters in the eastern part, whereas in the western part, it ranges between 20 to 80 meters.

The state has been divided into 594 ground water potential zones. Out of these, 322 zones fall in the 'White' category where ground water development is less than 65 per cent, 71 zones fall in the 'Grey' category, having 65 per cent to 85 percent stage of development. The remaining 201 zones have been categorised as 'Dark', where the stage of ground water development is more than 85 percent. Out of these, 173 zones are over exploited, having a stage of development that is more than 100 per cent.

1.7 Change In Ground Water Level:

Rajasthan has not been endowed with the natures bounty of water in abundance, surface water sources are scarce, which endorses ground water to assume the role of supplying water for all most all development activities.

The effect of variability in the rainfall pattern is more clearly reflected in the surface water resources. However, a careful and long term study is needed for interpreting the corresponding change in ground water storage. The change in water level have been evaluated on the basis of data collected from a network of over 6,700 key wells comprising of dug wells and piezometers spreaded throughout the state. A map has been prepared showing change in water level between pre monsoon 1984 and 1997 (Map 1.9).

Out of 237 development blocks of Rajasthan, only 60 blocks are those where rising trend of water level has been observed whereas remaining 177 blocks are those where the water level shows an average declining trend.

This reveals that the depletion in water levels happens to be in almost 67% area and rise in that of 33%.

There may be some villages having local (spot) values of high depletion which are being indicated in their related district and theme map. In general the depletion in the ground water table is 1m/ year in the area. This necessititates judiceous use of ground water in irrigation, water supply and industries coupled with artificial recharge, rain water harvesting and conjunctive use of ground water mixing with surface water in canal command area.

2 ABOUT UDAIPUR DISTRICT

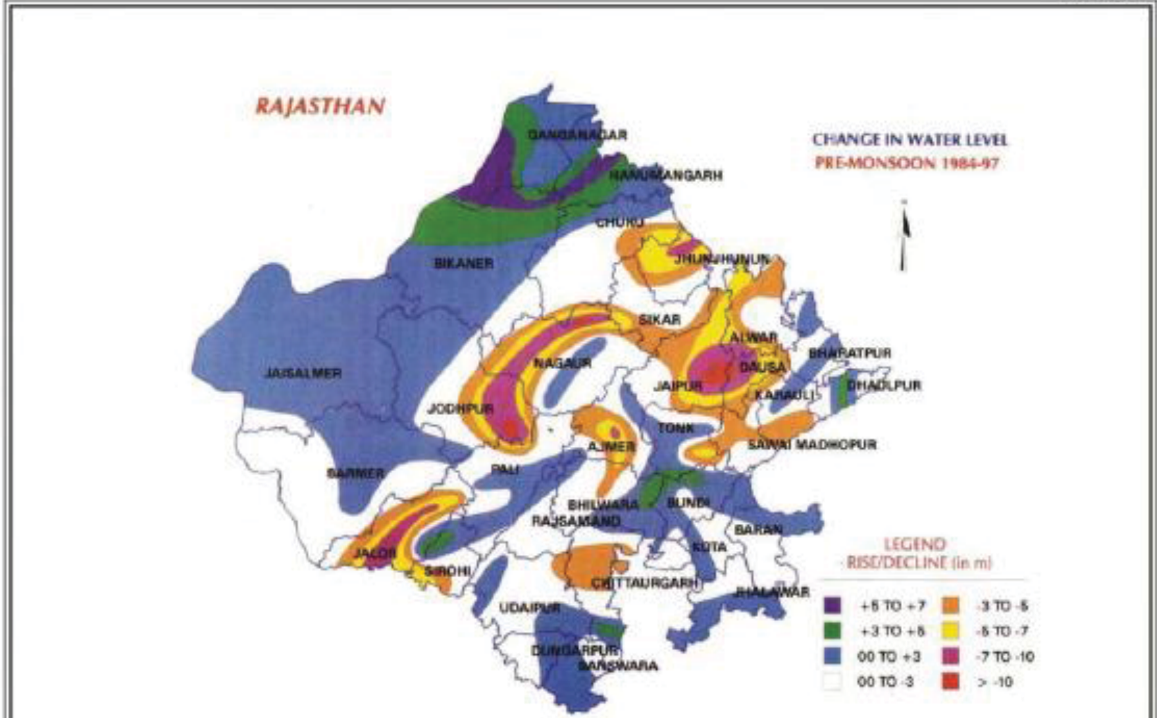
2.1 Location and Administrative Set-up:

Udaipur district is situated in the southern part of the state. It lies between $23^0$45' and $25^0$10' North latitude and $73^0$0' and $74^0$35' East longitude covering geographical area of about 12590 Sqkm. It is bounded on the north by Rajsamand district, north west by Pali district, west partly by Sirohi and Gujarat state, south by Dungarpur and partly by Banswara and east by Chittorgarh district.

Administrative Setup:-

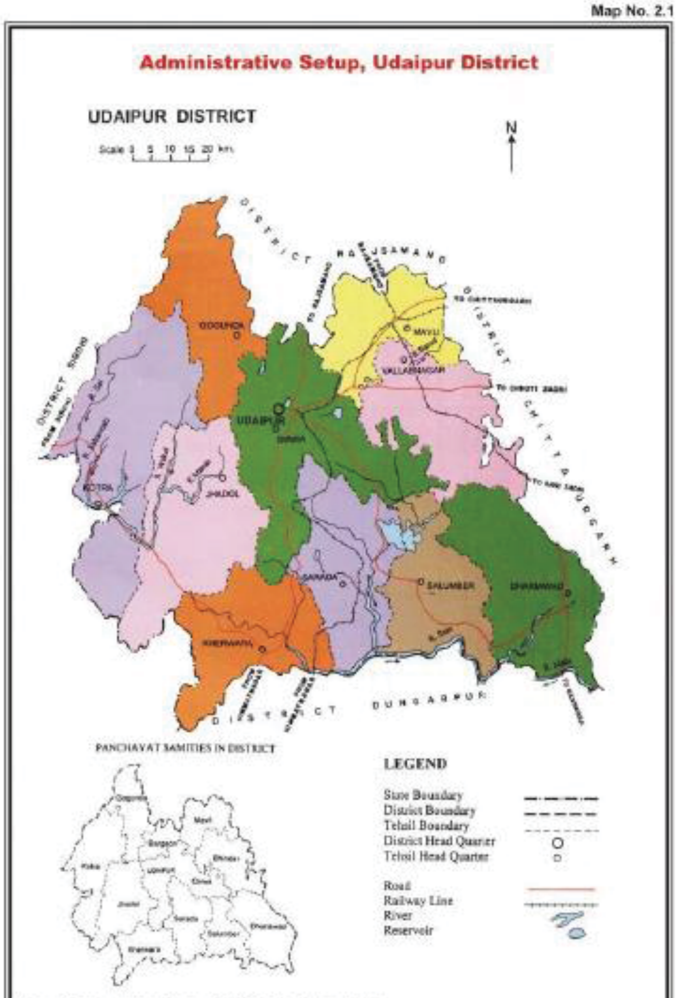
Administratively Udaipur is a part of Udaipur division. The district is divided into 10 tehsils namely:- (1) Kotra, (2) Jhadol, (3) Salumber, (4) Kherwara, (5) Sarada, (6) Girwa, (7) Gogunda, (8) Dhariawad, (9) Mavli and (10) Vallabhnagar (Map 2.1). The district is divided into 11 panchayat samities namely:- (1) Gogunda, (2) Bargaon, (3) Mavli, (4) Kotra, (5) Girwa,

Map No. 1.9



(Source - Ground water Atlas of Rajasthan (2003) DST, Govt. of Rajasthan, Jodhpur

Map No. 2.1



(Source - Ground water Atlas of Rajasthan (2003) DST, Govt. of Rajasthan, Jodhpur

(6) Bhinder, (7) Jhadol, (8) Sarada, (9) Salumber, (10) Dhariawad, (11) Kherwara.

2.2 Climate:-

The district has on the whole moderate and healthy climate without significant seasonal variations, January is the coldest. The minimum and maximum temperature are 03^{0}C and 45^{0}C respectively. The average rainfall of is about 624.5mm. Generally rainfall decreases from the south west to the north east, on an average there are 31 rainy days in a year.

2.3 Geology and Minerals:-

Aravalli Super Group covers the major parts of the district, the general stratigraphic sequence of the rock in the district is classified as under (Map 3.7):-

Post Delhi		-	Erinpura Granites
Delhi Super Group	Ajabgarh Group	-	Schist, gneiss, marble, amphibolite
	Alwar Group	-	Quartzite
Aravalli Super Group		-	Phyllites, Schist, quartzite, dolomite, conglomerate, marble, metavolcanics.
Pre-Aravalli		-	Schist, gneiss and migmatites.

Udaipur district is particularly rich in mineral resources, as a large variety of important minerals are found in the district. Important metallic and non metallic minerals found in the district are ores of copper, lead, zinc and silver, among rock phosphate, asbestos, calcite, lime stone, barytes, emerald and marble etc. are important.

PALAEOPROTEROZOIC ARAVALLI FOLD BELTS:

Regional Distribution:

The Aravalli Supergroup of the Palaeoproterozoic age is the oldest cover succession, which evolved as ensialic rift basin-fills over the Archaean basement rocks. Considered to be geologically interesting with bountiful of mineral deposits, the rocks of the Aravalli Supergroup (described by Heron, 1953, and other contemporary geologists as 'system') attracted attention of a large number of geologists for the last hundred years or so. Nevertheless, the geologists working in this region are divided on the questions of age, aerial extent, internal stratigraphy and the basement-cover relationship.

The regional distribution of the Aravalli rocks is shown in Fig. for the convenience of tectonostratigraphic description, the terrain where the rocks of the Aravalli Supergroup occurs, is divided into three contiguous sectors: i) the northeastern Bhilwara Sector, ii) the central Udaipur Sector; and iii) the southern Lunavada Sector. Each of these three sectors is characterised by distinctive deformational and metamorphic features inspite of the fact that there is no district line of separation between these sectors. Out of these three sectors, the central sector, which includes the Udaipur region, between Nathdwara and Dungarpur, exposes the best sections showing complete succession of the Aravalli Supergroup. As mentioned before, this is the region, which is also known as the 'type area' of the Aravalli Supergroup. By contrast, the northeastern Bhilwara Sector is geologically the least understood region, metaphorically speaking a *"terraincognita"*. About the Lunavada Sector, most workers (Gupta, 1934; Gupta and Mukherjee, 1938; Gupta et al., 1980; Heron, 1953; Gopinath et al., 1977) seem to agree on the extent and distribution of the lithostratigraphic units; although confusions prevail in regard to the interpretation of geology, primarily due to the extremely complex deformation pattern that characterises the region. It is, however, evident that some of the fold phases, which affected the rocks of the Lunavada Sector, may not be related to the presently known Aravalli and Delhi Orogenic Cycles (cf. Mamtani et al., 1999b, 2001, Roy, 1988b, 2000a).

In view of the fact that the rocks of the Aravalli Super group are best exposed in the Udaipur Sector, the type area, a detailed discussion on the stratigraphy of the rocks of the region would be in order Stratigraphic sequence of rocks erected in the type area would be useful not only for an inter-belt correlation of the rocks but also for the elucidation of basin tectonics, from the stage of basin evolution to that of basin inversion (cf. Verma and Greiling, 1995). Mention may be made here of the fact that the Aravalli

Supergroup, defined from the Udaipur Sector (cf. Gupta et al., 1980; Roy et al., 1988) not only includes all the outcrops of the 'Aravalli system', but also the 'outliers of the Delhi system' and the 'Raialo marbles and mica schists' described by Heron (1953).

Gupta et al. (1980) classified the Aravalli rocks of the Udaipur belt into three groups: Debari Group, Udaipur Group, and Jharol Group. Earlier Banerjee (1971a & b) classified the Aravalli rocks ('Group') into three units: the Debari Formation, the Matoon Formation and the Udaipur Formation. In the southern Sector, which is physically continuous with the Central Udaipur Sector, a Lunavada Group has been recognised as an equivalent of the Jharol Group (Gupta et al., 1980). On the assumption of uniform westerly younging of rocks, the Debari Group ('outliers' of Delhi system of Heron, 1953) has been conceived as the oldest unit, whereas the Jharol or its equivalent, the Lunavada Group, is thought to be the youngest.

Lateral correlation between lithostratigraphic units helped in the erection of stratigraphic succession of the Aravalli Supergroup in the Udaipur Sector. The succession comprises three groups separated by prominent unconformities.

The serpentinite bodies, which occur quite extensively in the Udaipur and the Lunavada Sectors need special mention in the context of stratigraphic correlation of the Aravalli rocks. Studies indicate that these are emplaced as contemporaneous lavas in the deep-sea facies zone and as intrusive bodies in the Aravalli rocks of Kherwara ($23^{0}59'$:$73^{0}35'$) and Dungarpur. It may also be worth mentioning here that a number of tectonic models on the evolution of the Aravalli Fold Belts have been postulated on the assumption that the serpentinite bodies truly represented a dismembered ophiolite succession (Banerjee and Bhattacharya, 1994; Deb and Sarkar, 1990; Sen, 1980; Sugden et al., 1990; Schanthavong and Desai, 1977).

Deep-Sea Facies: Jharol Formation:

The rocks constituting the Jharol Formation cover a wide triangular area bounded by the shelf-facies rocks of the Aravalli Supergroup in the east and the outcrops of the Delhi Supergroup in the west. In the south, the formation is in contract with diverse lithological/stratigraphic units including the young granite and gneiss (Godhra Granite and associated gneisses), the Archaean basement rocks the Cretaceous beds and the Deccan Traps. The Jharol Formation, described here, includes both the Jharol Group and the Lunavada Group of Gupta etal. Lithologically, the Jharol Formation is dominantly an argillaceous unit interbedded with thin hands of quartzite. Gupta et al.(1980) referred to this formation as shaly flych-like clastogenic sequence (distal turbidities). However, the preserved sedimentary features in this argillites do not indicate that these are flych-type of deposits. Quartzite which generally stands out as high ridges because of their lithological competence, ranges from less than a meter to over 50 meters in thickness. Many quartzite bands show duplication due to coalescing of successive limbs of isoclinal folds. In the northern part of the Jharol belt, the rocks show a general increase in the grade of metamorphism to the west. Locally, the grade of metamorphism shows an increase up to amphibolite facies. The metamorphism referred to above is related to the post-Aravalli deformation, synchronous with F_2 folding. A number of shear zones developed in the Jharol belt. All the rocks, the pelites and quartzites, have undergone extensive degradation and myloitisation. Thus, some of the phyllite-looking rocks are actually phyllonites from diapthoresis and mylonitisation. An interesting lithological unit in the Jharol Formation is the quartz-garnet rich bed. Being thin and competent (relative to the pelitic rocks which surround it), this quartz-garnet bed displays spectacular buckle folding of complex geometry. Except at Bagdunda where a quartzite- amphibolite (metavolcanic) succession overlies the domal basement gneisses, the Jharol Formation is totally devoid of mafic metavolcanic units. There are, however, a number of thin conformable bands of altered ultramafic units represented by talc-chlorite schist and talc-serpentinite. Lithology of these ultramafic rocks is described separately .

Ultramafic Rocks:

The ultramafic rocks in the Aravalli Supergroup occur only in the belt south of Nathdwara, traversing the belt of type Aravalli rocks. Large outcrops of ultramafic rocks occur in the region between Rishabhdev ($24^0$05' : 73^0 40') and Dungarpur. In the north, the occurrence of ultramafic bodies coincides roughly with the "lineament")popularly known as the Rakhabdev Lineament), marking the boundary between the shelf and the deep-sea association. In the south, the ultramafic rocks crosscut this boundary. The ultramafic rocks also occur as thin conformable bands within quartzite, phyllite and mica schist in the Jharol belt between Gogunda ($24^0$46' : $73^0$32') and Jharol ($24^0$24':73^0 29'). Lithologically, the ultramafic rocks are represented by talc-chlorite (antigorite) schist and serpentinite with variable proportions of actinolite-tremolite, talc-tremolite, asbestos and dolomite. Magnetite (as well as chrome-spinel) is a common accessory mineral. These intrusive (and locally extrusive) bodies have been deformed along with the enclosing metasediments of the Aravalli Supergroup. The inner parts of the thicker bodies are generally massive or irregularly fractured (Chattopadhyay and Gangopadhyay, 1984). Antigorite is the main mineral developed in the serpentinites, occuring as sheafs and plates. Chrysotile veins frequently cut across the crisscross meshwork of antigorite (Chattopadhyay and Gangopadhyay, 1984).

The linear track of serpentinite occurrences between Kherwara ($23^0$59' : 73^0 35') and Dungarpur follows a well defined lineament, which separates the two belts of contrasting sedimentary associations, at least for some distance. Examination of satellite imageries of the Udaipur Sector reveals the presence of a prominent lineament (Bakliwal and Sharma 1980; Drury, 1990) marked by a very strong zone of shearing between the shallow-water shelf facies rocks and the deep-water facies. This lineament (Rakhabdev Lineament' in literatures) is described as an ophiolite-decorated suture zone by a number of authors (Deb and Sarkar, 1990; Sen, 1981;Sinha-Roy et al.,1998; Sugden et al., 1990; Sychanthavong and Desai, 1977).

Barkatiya and Gupta (1983) based on the study of satellite imageries traced continuity of the lineament (as a zone of fracture-faulting) from near Udaipur across the entire southern region of the Aravalli mountains. Bodies of talc-serpentinite, which occur in the Udaipur and Lunawala Sectors neither have any characteristics of ophiolite association nor do these appear to follow any tectonostratigraphic boundary. In the Jharol region, west of Udaipur, the ultramafic bodies occur as contemporaneous metavolcanics (Abu-Hamateh et al., 1994; Sharma et al., 1988). By contrast, a clear intrusive relationship is decipherable in the southern Lunavada belt (Heron, 1953; Gupta, and Mukherjee, 1938; Patel and Merh, 1967). According to Chattopadhyay and Gangopadhyay (1984), the serpentinite bodies occur as fault bounded intrusions into the Aravalli rocks. Earlier, Gupta and Mukherjee (1938) mapped discontinuous lenses of talc-serpentinite as intrusive 'dykes' into the Aravalli rocks of the region. The intrusive relationship is also evident in the geological map of Gupta et al., (1980), which shows occurrence of linear bodies of a talc-serpentinites crosscutting the fold trends. At Kherwara, the talc-serpentinite occurs as intrusive bodies, causing thermal reaction in the adjacent carbonate and silicate rocks. Another feature, which indicates that the ultramafic bodies are parts of intrusive masses is proved by the local occurrences of 'skarn' minerals in the carbonates that surround the serpentinities in the region around Kherwara and Rishabhdev. It is, however, difficult to decipher how far late the instructions are, but certainly, these are later than the complex folding of the Aravalli rocks in this region. This relationship alone is enough to lay aside the theory that the serpentinites are dismembered bodies of obducted ophiolite succession. Petrologically also, the serpentinites do not appear as components of an ophiolite succession. Quite significant in this respect is the absence of any 'Subduction Zone Signature' in the chemistry of the mafic-ultramafic rocks of the Jharol belt (Abu-Hamattech et al., 1994).

DEFORMATION PATTERN:

Udaipur Sector:

The Aravalli Basins in the three belts are characterised by a complex pattern of deformation, which is well documented in a number of studies during the last three decades. Most of these studies were carried out in the central region of the Aravalli Fold Belts (see Naha and Mohanty, 1990, for details and references). Compared to that a very few studies have been made in the northern Bhilwara and the southern Lunavada Sectors respectively.

The Aravalli rocks of the Udaipur Sector exhibit a complex polyphase deformation pattern resulting from three major phases of folding, F_1, F_2, and F_3^1 (Banerjee et al., 1998; Chauhan et al., 1996; Ghosh,1983; Mohanty and Naha,1986; Mookerjee, 1965; Mukhopadhav and Ghosh, 1980; Mukhopadhav and Sengupta, 1979; Naha and Halyburton, 1974a, 1977; Naha and Mohanty, 1988; Roy 1972, 1973, 1978, 1985, 1995a; Roy and Jain, 1974; Roy et al. 1971,1980,1981, 1998; sharma et al. 1998; Singh,1988). In addition to the three major phases of folding and associated shearing, flat-lying small-scale folds and crenulations have locally developed in the Aravalli rocks. Appressed isoclinal folds having reclined geometry are the earliest deformation structures (F_1) in the Aravalli rock. A set of axial planar schistosity (S_1), almost invariably accompanies these early folds. The most commonly developed lineation in the rocks produced during this deformation phase is the intersection of bedding and the penetrative schistosity (S_1) F_1 is locally involved in coaxial upright at some places. The lineation (L_1) related to f_1 folding extensional type, defined by stretched pebbles and boulders, and mineral lineation. Another feature, which indicates that the L_1 lineation is of extensional type is the development of cross joints across these features. These cross joints are, at places, filled up with minerals showing growth features perpendicular to the wall of the joints. Extreme variation is observed in the shape of these F_1 folds from almost elasticus geometry to highly falttened parallel type with thickened hinges (Roy, 1978). F_1 folds are generally asymmetric showing thinning of shorter limbs. Detachment of the thinned limbs have, in certain instances, led to formation of typical 'fishhook type' geometry.

Like F_1 folds, S_1 planes show morphological variations from typically mylonitic type to relatively weakly developed feacture type planes. In regions of high strain,the schistosity and lineation together define LS fabric.

Over a large area, the plunge of early folds and corresponding lineations either is down dip or has high pitch angle. Diverse orientation of F_1 fold axes and L_1 is noticed where the early formed folds are refolded by F_2 folds. F_2 folds are upright with steep or vertical axial surfaces and relatively open geometry. A characteristic feature of superimposition of F_2 over F_1 is the deformation of early lineation over the hinges of $F_{2.}$ Strong subvertical crenulation cleavage planes are commonly associated with F_2 folds (Fig.5.48). The dominant trend of F_2 folds is roughly N-S. A continuous swing in the plunge and trend of the small scale F_2 fold hinges are noticed where the latter folds have developed over the limbs and hinges of large f_1 folds. Superimposition of two phases of folding is a common feature.

Axial plane folding being the common process of superimposition of F_1 the most prevalent outcrop pattern is the mushroom type. Under special situation, the superposed folds assume 'eyed-fold' geometry (Sengupta, 1976). Geological map prepared by Mukhopadhyay and Sengupta (1979) show a complex geometry of outcrop due to superimposition of two phases of folding. A spectacular eyed fold geometry is revealed by the small outcrop of marble near Deola, south of Salumbar. A very large eyed fold has developed bordering the northern outcrop of the Ahar River Granite, northwest of Udaipur. In certain instances, F_1 folds have undergone coaxial refolding prior to superimposition of the F_1 folds (cf.Naha and Mohanty, 1990).

F_3 folds, which refolded both F_1 as well F_1 folds, are generally upright having subvertical axial planes with east-west or west northwest-east southeast strikes. Unlike the early formed folds, F_3 folds are generally in the from of broad and open folds having steep axes (Roy et.al.,1980). in many regions, the F_3 structures are represented by small kinks and chevron folds

(Naha and Halyburton, 1974b; Roy, 1973). These structures have developed in rocks, Which show strong development of early schistosity. F_3 folds in certain, as in the reign around the Zawar mines, show excellent development of fold and cleavage mullions and crenutation or fracture cleavages. Orientation of quartz-filled fracture cleavages locally simulate a 'ladder vein' type appearance.

Besides the three phases of folding mentioned above, a fourth set structure has developed, at places, particularly where the early planar structure (S_0,S_1, and/or S_2) show steep or sub vertical attitudes. Described by some author as F_4 structure, these small-scale recumbent/reclined folds, king bands and crenulations (Roy,1973, 1995; Naha and Halyburton, 1974b) are characterised by spectacular development of crenulation cleavage, S_4.

Detailed structural mapping by a number of working in different of the Udaipur Sector reveals formation of complex outcrop patterns due to superimposition of a number of fold phases (F_1, F_2 and F_3) (Roy & Jakhar, 2002).

METAMORPHISM:

Variation in the grade and pattern of metamorphism over the entire belt of the Aravalli Supergroup is the key to the understanding of tectonothermal history of the early Precambrian rocks. Unlike the detailed studies made on the stratigraphic relationship and the structure (at least in the Udaipur Sector), metamorphism received only a scant attention. Sharma (1988) made a strenuous attempt to collate all the available information related to metamorphism of the Aravalli supracrustal rocks.

The entire belt of the Aravalli Supergroup in the Udaipur and Lunavada Sectors is characterised by a low to very low grade of metamorphism (Roy, 1988b, see also Sharma, 1988). Locally the Aravalli rocks of this belt witnessed middle amphibolite facies metamorphism, and the corresponding partial melting of rocks. The lowest grade of metamorphism is observed in the rocks around the valley of Udaipur and in some parts of Iswal and Zawar in the south. So low is the metamorphic transformation that in some parts the rocks virtually retained their detrital character.

The high-grade rocks in the Udaipur and Lunavada Sectors are found in areas, which either fringe the Delhi Fold Belts in the west (as around Katar, and west of Bagunda and Jharol) or in the southeastern region around Salumber (Mohanty and Naha, 1986) and Bhukia (Grover and Verma, 1993, 1995) or in the region around Mando-ki-Pal and Sagwara in the districts of Dungarpur and Banswara. No detail accounts are available on the metamorphic condition of these areas. However, from the available description of rocks, it appears that the higher grade of metamorphism reaching up to upper amphibolite facies metamorphism and corresponding partial melting of rocks a the result of superimposition of a later thermal imprint on an earlier low-grade metamorphism. It is difficult to guess the time relation between the metamorphic superimposition and the deformation. Studies by Ghosh (1978) suggest that the high-grade of metamorphism in the Katar region bordering the Delhi Food Belts are related to F_2 phase of folding (Roy & Jakhar, 2002).

MIDDLE UPPER PROTEROZOIC:

The Middle to Upper Proterozoic rock sequences in Rajasthan are confined to an important fold belt, the Delhi fold belt which roughly divides the Rajasthan Craton into two parts. The eastern part is composed dominantly of basement rocks, Aravalli Supergroup and its equivalent cover sequences, while the western part is essentially a volcanic province (Malani), with Late Proterozoic cover sequences (Marwar) and Mesozoic-Cenozoic sedimentary basins.

Form and Distribution:

The main orographic axis of the Aravalli hill range is defined by a narrow linear fold belt in central Rajasthan. This fold belt which fans out in the north, northeast and south is known as the Delhi Fold Belt (DFB) (Sinha-Roy, 1984) or the Main Delhi Synchnorium (Heron, 1953). The DEB in the north-east contains rock sequences disposed in several nearly isolated and independent fault-bound basins. In the Central part, i.e. south of Ajmer, the litho-units show a fair degree of continuity, although these are truncated at many places by shear zones.

The DEB contains a number of granite plutons occurring from Khetri in the north to Godhra in the South.

South Delhi Fold Belt:

The main Delhi Synclinorium (Heron, 1953), confined to the central part of the Aravalli hill range, contains rock sequences distributed in two synclines entrenched in the underlying pre-Aravalli gneisses. A long narrow strip of inlier of basement rocks separates the outcrops of the two synclines. On the outer flanks of each syncline, unconformable relations of the Delhi rocks with the pre-Delhi gneisses are represented by the Barr and the Srinagar Conglomerates. Along the margin of the inlier, shearing at the contact has produced mylonitic and gneissose fabric in the basement rocks. The southwestern continuation of the inlier is delimited by a thrust juxtaposing the two synclines.

A correlation of the stratigraphy established in Alwar area (NDFB) of northeastern Rajasthan with that of the main Delhi Synclinorium (SDFB) is uncertain. Although Heron (1953) used the stratigraphic nomenclatures of the Alwar and the Ajabgarh Groups in the main Delhi Synclinorium without establishing the younging polarity, Sen (1980) identified multiple tectonic units in central and southern Rajasthan with westward younging. This composite unit is overlain in the west by younger sequences comprising the Barr Conglomerate and the Ras Marble. Gupta et al (1981) subdivided the Delhi Supergroup of the main Delhi Synclinorium into Gogunda and Khumbalgarh Groups and correlated them with the Alwar and the Ajabgarh Groups, respectively, of the Alwar sub-basin. The status of the rocks occuring west of the main Delhi synclinorium is still debated. These are considered basement rocks by Heron (1953), high-grade variants of the Ajabgarh Group by

Sychanthavong and Desai (1977) and migmatised younger sediments by Gupta et al (1981).

Stratigraphy:

The Delhi Supergroup of central Rajasthan (South of Ajmer) is contained in two separate sub-basins, namely, the western (Barotiya-Sendra) and the eastern (Rajgarh-Bhim) sub-basins, separated by the basement inlier (Gupta et al. 1955). Accordingly the Delhi rocks are divided into Barotiya, Sendra, Rajgarh and Bhim Groups, on the basis of mutual stratigraphic and structural interrelations, and on their relations with the basement rocks (Gupta et al. 1955).

Delhi Supergroup:

In the main Delhi Synclinorium Heron (1953) identified only the major lithological groups. The stratigraphy of the Delhi Supergroup in this fold belt has been worked out in detail by later workers.

Gogunda Group:

The Gogunda Group, comprising an arenaceous sequence of quartzite and interbanded schist and meta basics, extends from Kishangarh in the north to Richer in the south from where eastwards these rocks take a sinistral swing near Antalia and then continue southward from Antalia to Himmatnagar in Gujarat (Gupta et al. 1992). The eastern margin of the Gogunda sequence is marked by a prominent shear zone which brings it against the Jharol sequence of the Aravalli Supergroup. Opinion varies regarding the stratigraphic status of the Gogunda sequence. Although some workers (Gupta et al. 1992) considered it as the basal sequence of the Delhi Supergroup, Gupta et al. (1995) suggested a pre-Delhi status (Roy & Jakhar, 2002).

Structure and Tectonics:

The pre-Delhi rocks record the imprints of five phases of folding (Gupta et al. 1995). The first generation of mesoscopic folds are rootless and isoclinal that are superimposed by tight to isoclinal second and third generation of folds. The fourth generation of folds are large scale open dextral and sinistral folds, while the last deformation produced broad warps. The Devgarh Group rocks are involved in four phases of folding, the last phase producing conjugate set of axial planes(Roy & Jakhar, 2002).

Metamorphism:

It has been concluded by Sharma (1988) that the rocks of the South Delhi fold belt indicate medium-grade (amphibolite facies) regional metamorphism, although there is a spatial variation in the development of metamorphic assemblages. The grade of metamorphism increases westward from staurolite-kyanite zone in the east near the contact with BGC to sillimanite-muscovite zone in the west with the isograds running almost parallel to the compositional layering. Retrograde and also contract metamorphic assemblages with wollastonite are also recorded. The P-T estimates for regional metamorphism are found to be 5-6 kb and 500^0-600^0C for the Delhi rocks near Ajmer and Beawar (Sharma, 1988).

Near the southern extremity of the South Delhi fold belt in Deri-Ambaji area, the regional metamorphism has been over-printed by thermal metamorphism. Deb (1980) suggested that in this area the first event was a regional metamorphism under greenschist facies conditions. Plutonic intrusions associated with the second phase of folding caused thermal metamorphism producing cordierite-anthophyllite assemblage and hornfelsic texture in the rocks. Siliceous marble developed diopside-forsterite assemblage and amphibolites developed hornblende-labradorite $\pm$diopside assemblage. The P-T estimates for the thermal metamorphism are suggested to be 3 kb and 575^0C (Deb, 1980) (Roy & Jakhar, 2002).

2.4 Physiography and Soil:-

The district is enriched by Aravalli ranges from north to south. The northern part of the district consists generally of elevated plateau, while the eastern part has vast stretches of fertile plains. The southern part is covered with rock, hills and dense forest while as the western portion known as the hilly tracks of Mewar is composed of Aravalli range.

Except hard or partically weathered rocks, all types of soils in the district are deep to moderately deep. Clay loam soil is available in tehsil Gogunda, Kotra, Jhadol, Girwa, Mavli and Vallabhnagar while red loam soil is available in Kherwara, Sarada, Salumber and Dhariawad. Generally soils in the western part of the district are stony while yellowish brown soil is met in small portions of eastern and southern part.

Som, Jhakham, Wakal, Sei, Sabarmati and Berach are the main rivers of the district, which are non perennial and flow during the rainy season only. Besides, there are several tanks and lakes in the district. Among them Jaisamand, Fatehsagar and Pichhola at Udaipur are lovely and important places from tourist point of view.

Soils of the area are medium to heavy textured having brown to greyish brown colour. The fertility of these soils is medium and soils have good water retention capacity. In the foot hills soils are shallow to moderately deep. In the vallies soil are deep to very deep (Map 3.3).

2.5 Forests

Udaipur district major Portion is covered with rocks and hills, which are well stocked with forest. Forest covers about 240047.86 hectares of land which in about 23.43 per cent of the total area of district. The Forest of the district fall under northern tropical decidous type.

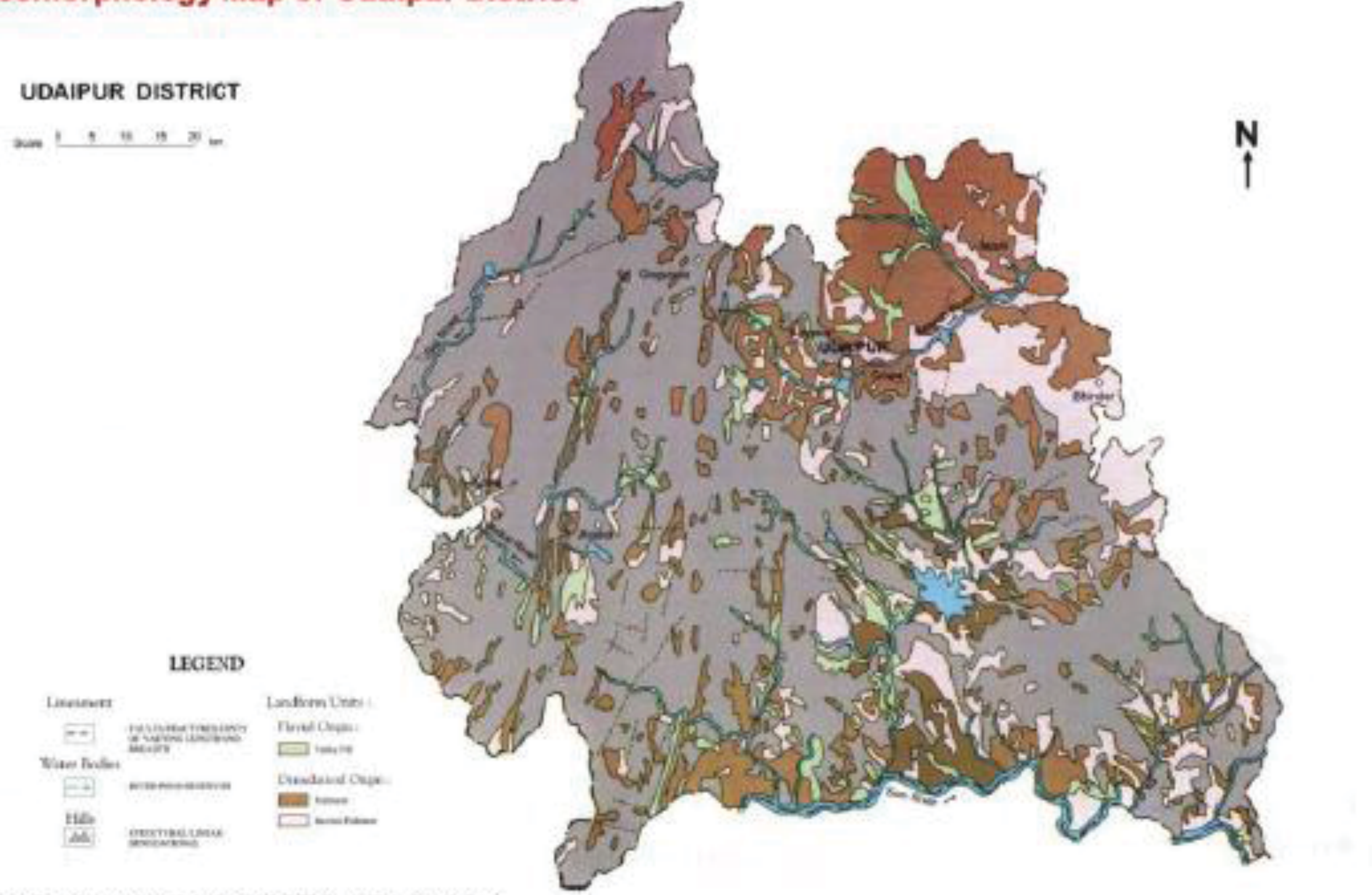
2.6 Geomorphology:

DISTRICT- UDAIPUR

Landform	Symbol	Lithology/Description	Occurrence	Land use/Land cover
Fluvial Origin Valley fill	VF	Formed by fluvial activity, usually at lower topographic locations, comprising of boulders, cobbles, pebbles gravels, sand silt and clay. The unit has consolidated sediment deposits.	Scattered in entire district in between structural hill.	Double crop, single crop(Rabi).
Denudational Origin Pediment	P	Broad gently sloping rock flooring, erosional surface of low relief between hill and plain, comprised of varied lithology, criss crossed by facture & faults.	Main concentration in north east and scattered in the entire district.	Marginal double crop, single crop (Kharif),open scrup, fallow
Burrid pediment	BP	Pediment covered essentially with relatively thicker alluvial or weathered materials.	Main concentration in east and scattered in entire district.	Double crop, single crop (Rabi / Kharif), fallow, open scrub.
Hill Structural Hill	SH	Linear to arcuate hills showing definite trend-lines with varying lithology associated with folding, faulting etc.	Covers entire district except north east.	Forest, mining.

(Please see Map 2.2, 3.5 & 3.6)

Geomorphology Map of Udaipur District



(Source - Ground water Atlas of Rajasthan (2003) DST, Govt. of Rajasthan, Jodhpur

2.7 Hydrogeology:

DISTRICT- UDAIPUR

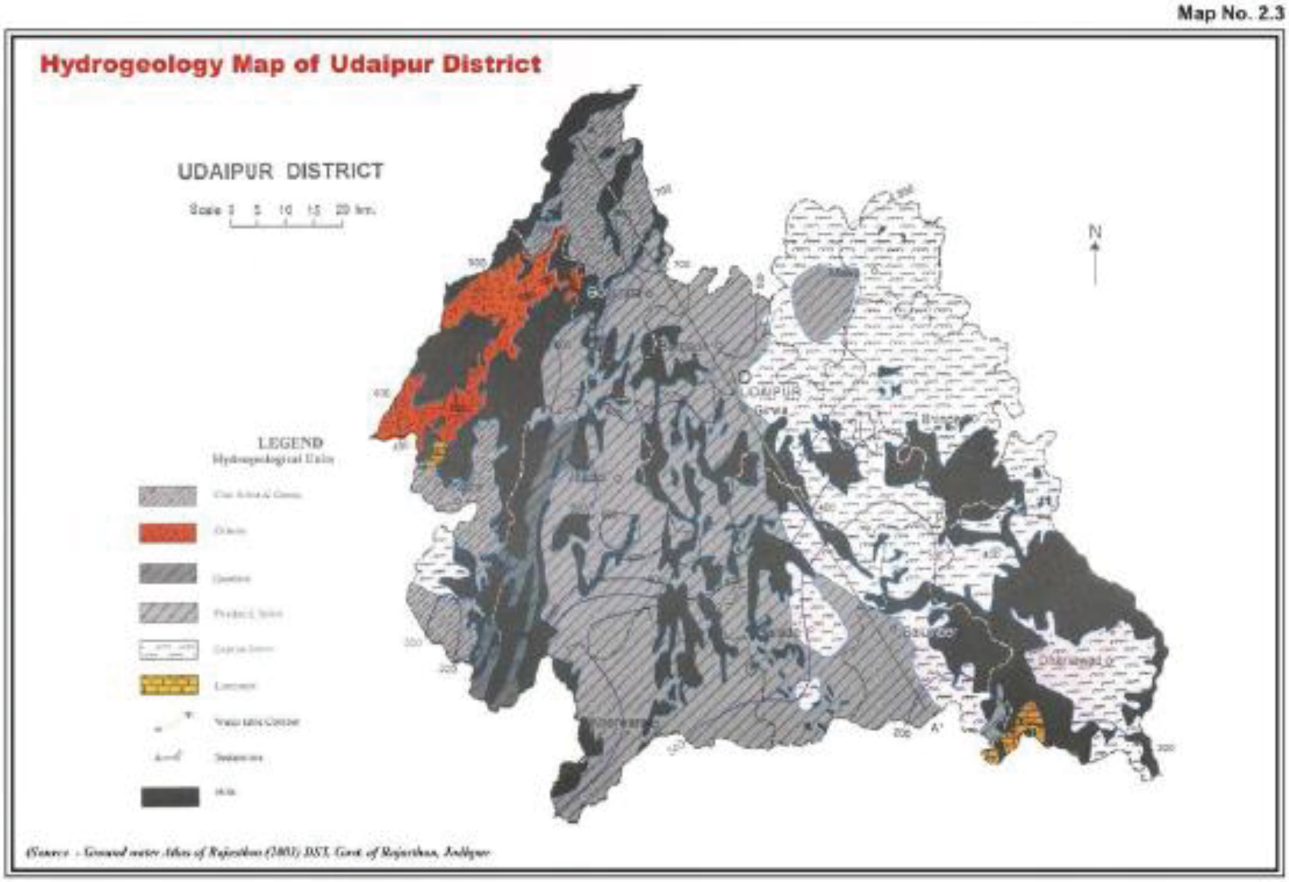
Hydrogeological units	Description of the unit/Geological section	Occurrence	Ground Water flow
Granite (post Delhi Intrusive)	It is grey coloured, medium to coarse grained rock mainly composed of quartz, feldspar with biotite and hornblende as minor constituents.	The litho unit encompasses western peripheral part within the limit of kotra block.	General direction of ground water flow varies considerably. In Mavli and Bhinder blocks, flow direction varies from NW to SE or W to E, or N to S, in Salumber and Kherwara blocks, SE to NW or E to W, in Dhariawad block, while in other remaining blocks NE to SW or N to S. Hydraulic gradient varies from 5.00 to 11.40 m/km.
Calc schist and Gneiss (Delhi super Group)	The litho units are hard and compact, fine to medium grained and characterised by alternating bands of light and drak colour ferromagnesian minerals.	These cover small area in parts of Gogunda and Kotra blocks.	
Quartzite (Delhi super Group)	It represents Alwar group of sediments and characterised by arenaceous facies comprising mainly quartzites of varied colour. Quartzites are grey, pink, pale and light green.	The litho occupies south western part of the district and confined to Jhadol block.	
Phyllite and Schists (Aravalli Super Group)	These represent argillaceous sediment and grades from shale. slate, Phyllite, to mica schist. The litho units are soft and friable.	The formations are most wide spread and cover western half of the district. A localised pocket occupied by the aquifer has been demarcated near Mavli.	

Cont.........

Hydrogeological units	Description of the unit/Geological section	Occurrence	Ground Water flow
Granite and Gneiss (Pre Aravalli)	These comprise Porphyritic and non Porphyritic gneissic complex associated with aplite, amphibolite, schist and augen gneiss. Schist and gneisscs are grey to dark colored, medium to coarse grainted rocks.	These rocks occup eastern part in Bhinder, Dhariawad, Girwa, Mavil, Salumber & Sarada blocks.	

(Please see Map No. 2.3, 3.9, 3.10 & 3.11

Map No. 2.3



2.8 Ground Water Potential Zones and Development Prospects:

DISTRICT- UDAIPUR

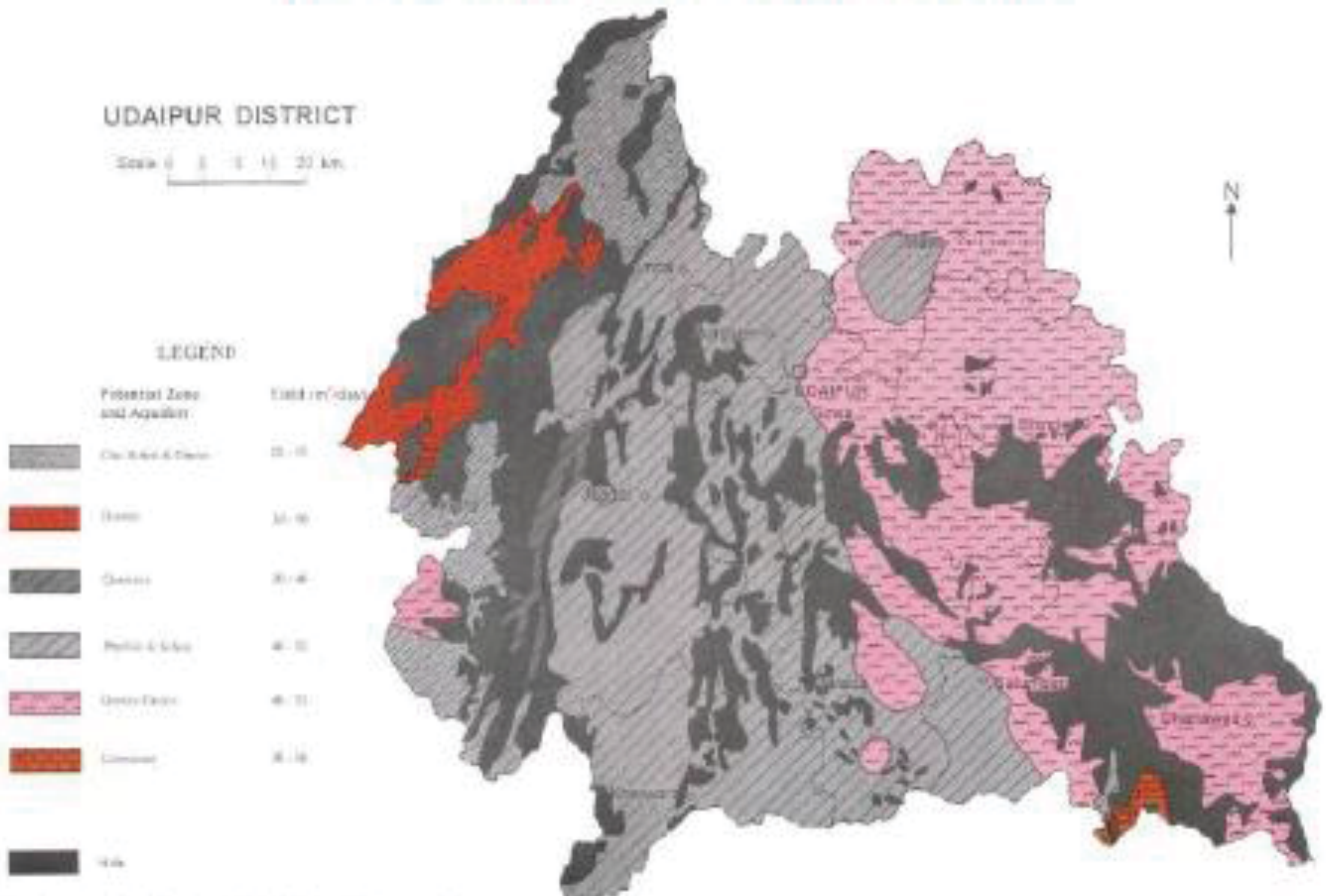
Aquifer in the potential Zone (Area in Km^2)	Occurrence *block (Area in Km^2)	Water Level (1997) in m.	Well Parameters			E.C. X10^3μ siem/cm	Development Prospects
			Type	Proposed depth in m	Discharge in m3/ day		
Calc Shist & Calc Gneiss (825.83)	• Gogunda (451.14)	<15	DW	15-20	40-60	<2	Safe
	• Kotra (374.69)	<15	DW	15-20	40-50	<2	Safe
Granite (253.11)	• Kotra (253.11)	<15	DW	20-25	35-50	<2	Safe
sQuartzite (151.67)	• Jhadol (151.67)	<20	DW	20-25	25-35	<2	Safe
Phyllite & Schist	• Bargaon (262.84)	<20	DW	15-20	40-60	<2	Safe
	• Girwa (695.980)	<25	DW	25-30	50-80	<2.2-4	Safe
	• Gogunda (176.62)	<20	DW	20-25	50-80	<2	Safe
	• Jhadol (604.76)	<25	DW	25-30	40-60	<2	Safe
	• Kherwara (807.12)	<15	DW	20-25	40-60	<2	Safe
	• Kotra (84.47)	<15	DW	20-25	40-60	<2	Safe
	• Mavli (168.10)	<20	DW	25-30	40-60	<2,2-4	Semi Critical
	• Salumber (307.89)	<10	DW	15-20	40-60	<2	Safe
	• Sarada (620.93)	<10	DW	15-20	40-60	<2	Safe
Granite & Gneiss (3300.82)	• Bhinder (906.15)	<25	DW	15-20	35-50	<2	Semi Critical
	• Dhariawad(806.70)	<20	DW	15-20	50-80	<2	Safe
	• Girwa (311.82)	<15	DW	20-25	35-45	<2,2-4	Safe
	• Mavli (615.47)	<25	DW	20-30	35-45	<2,2-4	Safe
	• Salumber (452.98)	<15	DW	20-25	35-45	<2	Safe
	• Sarada (207.70)	<10	DW	15-20	35-45	<2	Safe

DW-Dug wells **Safe-**<65% stage of development **Semi Critical-**65-85%develoment **Critical-**85-100%develoment
over exploited > 100%develoment

(Please see Map No. 2.4, 3.11 & 3.12)

Map No. 2.4

Ground Water Potential Zones of Udaipur District



(Source - Ground water Atlas of Rajasthan (2003) DST, Govt. of Rajasthan, Jodhpur

2.9 Water Level Trends :

DISTRICT- UDAIPUR

DEPTH TO WATER LEVEL		CHANGE IN WATER LEVEL (1984-1997)	
Range in m	**Area**	**Range in m**	**Area**
10 to 15	Mavli and Girwa blocks in north-eastern part Kotra and Gogunda blocks in western part of the district have depth to water level between the range.	0 to 4	Kotra, Dhariawad blocks and pockets scattered in Kherwara, Salumber, Bhinder & Gogunda blocks exhibit rise in water level upto 4m.
		0 to –2	Major part of the district, excluding Kotra, Dhariawad blocks and scattered pocket in different parts, show marginal depletion in water level less than 2m.

(Please see Map No. 3.10 to 3.12)

2.10 Ground Water Potability:

DISTRICT UDAIPUR

The ground water in Udaipur district is fresh to slightly saline. It is mostly bicarbonate type with dominance of calcium and magnesium ions. 68.9% of water has bicarbonate type of character associated with either Ca+Mg (51.8%) or Na+ (12.1%) as dominant cation. 23% well water show mix type of character which are transitional in nature and lies in between bicarbonate and chloride type of water. Rest 12.9% waters are of chloride type. The fresh bicarbonate type water generally have TDS below 1000 mg/L whereas the chloride type of water are more mineralised and have TDS more than 1500 mg/L.

Salinity depicted as electrical conductivity expressed in µS/cm varies from 370 to 7800 with an average of 1240 µs/cm. 79.1% ground water of the district have electrical conductivity within 1500 µs/cm.

The salinity map depicts that 88.8% ground water with electrical conductivity value within 2000 µs/cm is found occurring in almost whole of the district except two big patches one in eastern part covering parts of Mavli and Bhinder blocks and second in southern part covering parts of Salumber and Sarada blocks. These patches have ground water in the range of 2000-4000 and 4000-6000 µs/cm. Some localised scattered patches in Badgaon, Dhariawad, Girwa and Jhadol blocks have ground water with electrical conductivity in the range of 2000-4000 µs/cm (Map 2.5 to 2.7).

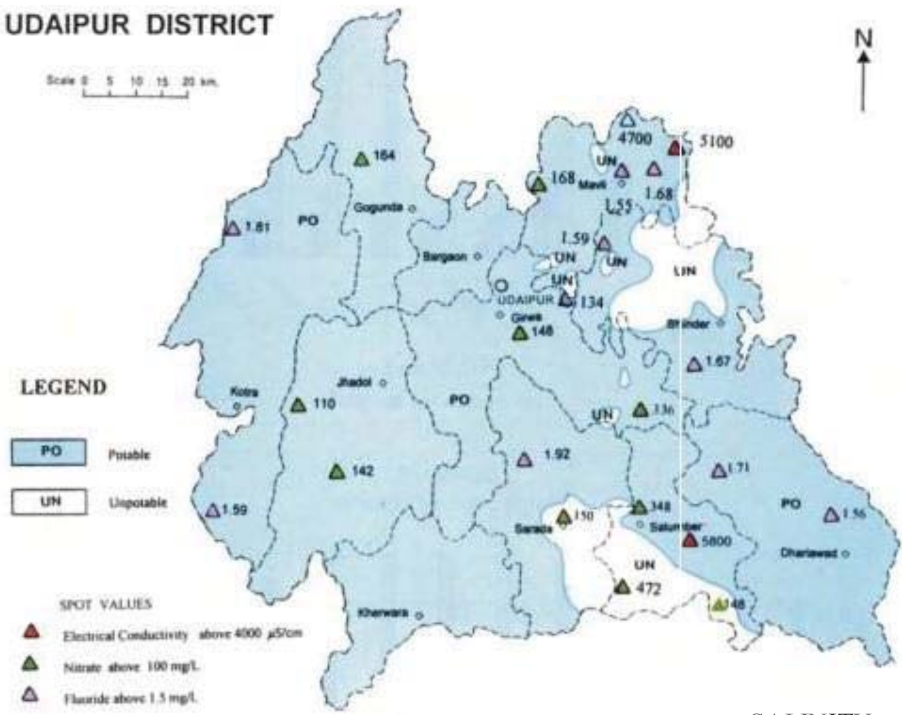
Salinity depicted as total dissolved solids (TDS) in ground water varies from 228 to 4480 mg/L with an average of 730 mg/L. 39.8% of ground water have TDS within 500 mg/L, whereas 54.2% have TDS in the range of 500-1500 mg/L. Only 60% ground water have TDS beyond 1500 mg/l.

Total hardness as calcium carbonate in ground water of the district varies from 120 mg/L to 1605 mg/L as CaCo3 with an average of 363 mg/L. 45.8% ground water have total hardness within 300 mg/L whereas 45.5% ground water have total

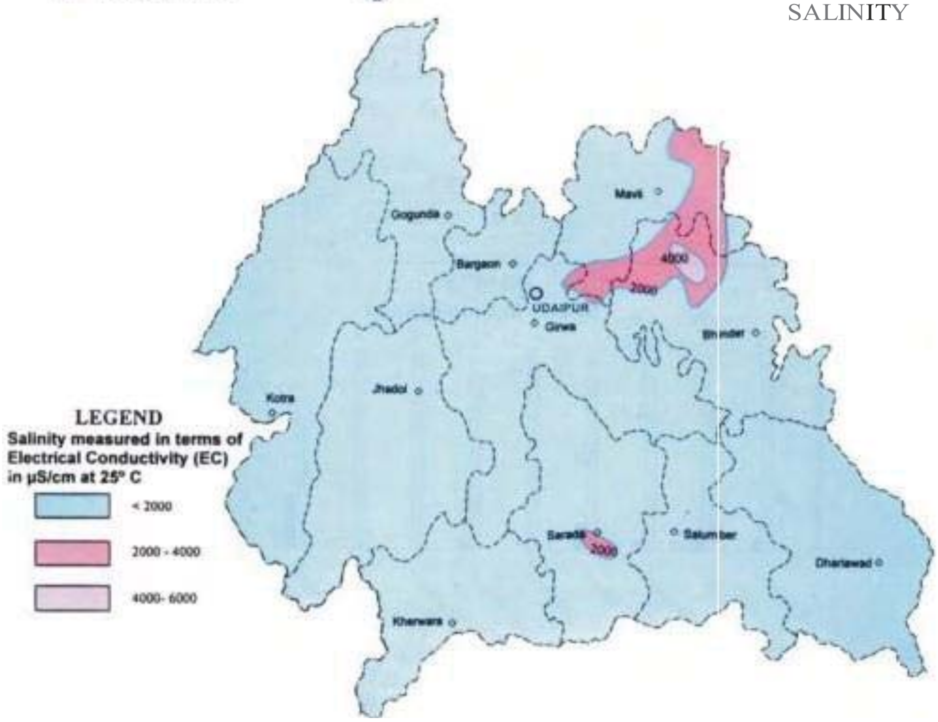
Map No.2.5

A) Map Showing Ground Water Potability in Udaipur District
B) Map Showing Distribution of Salinity in Illdaipur District

GROUND WATER POTABILITY A



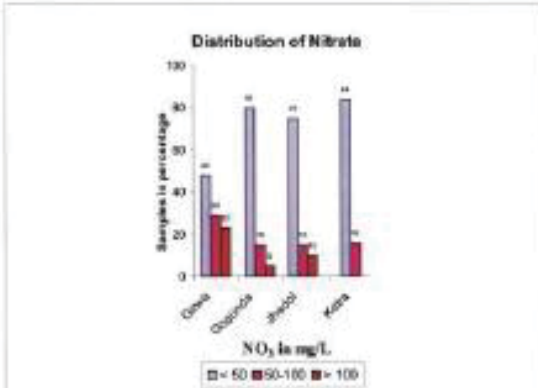
SALINITY B

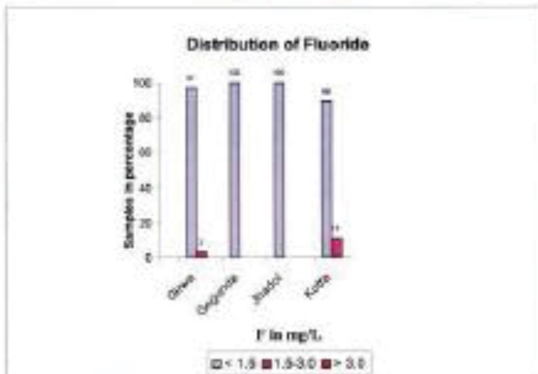


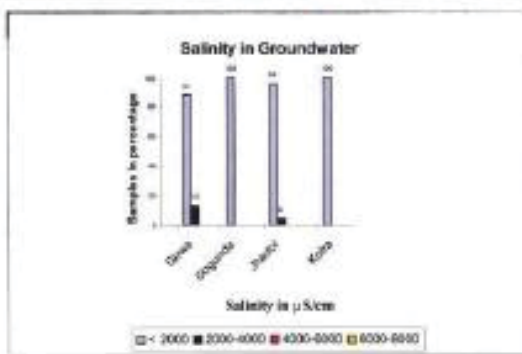
(Source - Ground water Atlas of Rajasthan (2003) DST, Govt. of Rajasthan, Jodhpur

Map No. 2.6

Wakal River Basin

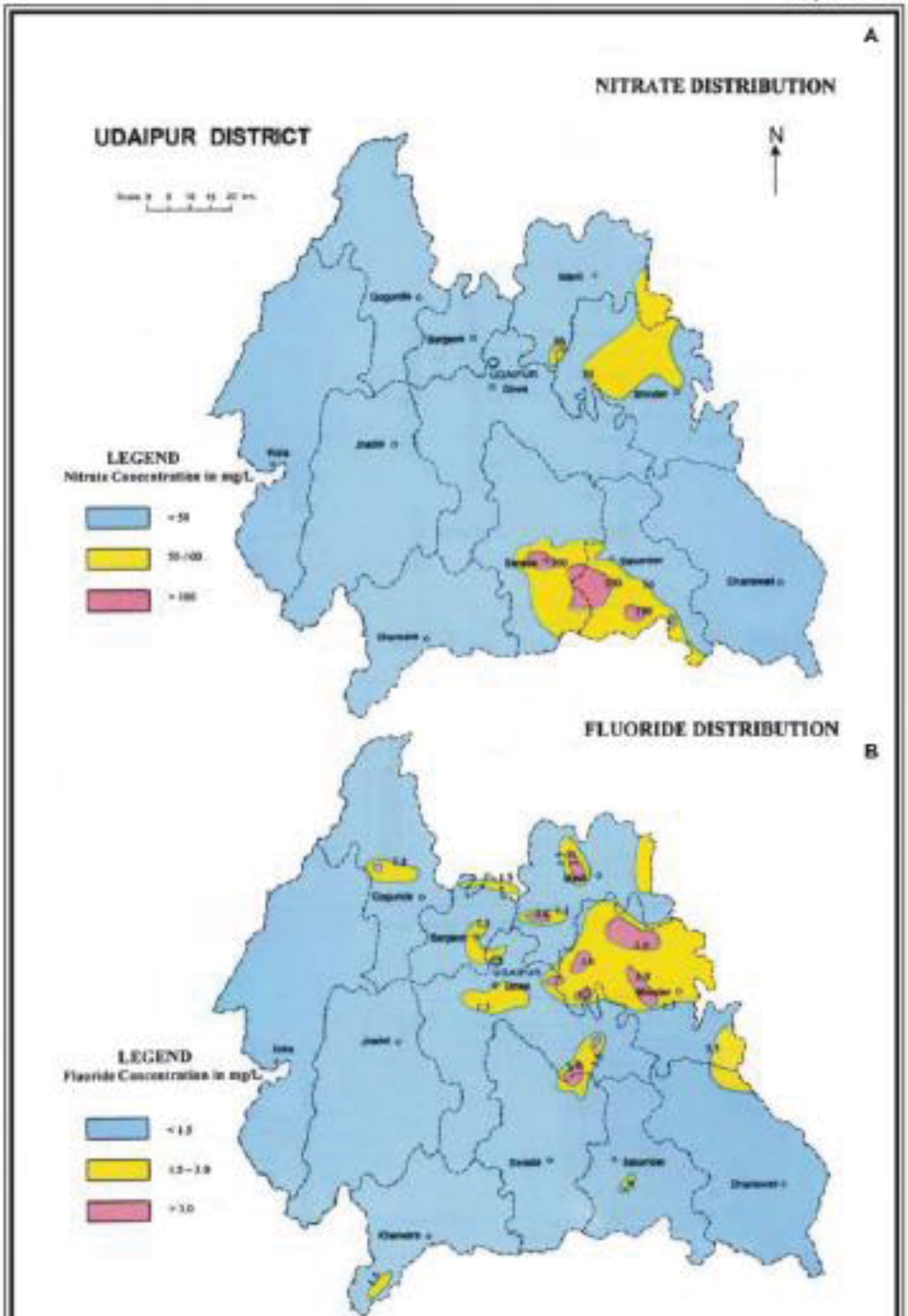






(Source – Ground water Atlas of Rajasthan (2003) DST, Govt. of Rajasthan, Jodhpur

Map No. 2.7



(Source – Ground water Atlas of Rajasthan (2003) DST, Govt. of Rajasthan, Jodhpur

hardness in the range of 300-600 mg/L. Only 8.8% water samples have total hardness above 600 mg/L.

Nitrate concentration in ground water of the district varies from traces to 472 mg/L with an average of 51 mg/L. The diagram for nitrate distribution shows that 68.7% of ground water have nitrate concentration within 50 mg/L and found in almost all the blocks. In western half of the district the ground water have nitrate within 50 mg/L except a patch in block Gogunda and a few scattered localised patches having nitrate in the range 50-100mg/L. In eastern half of the district, the nitrate concentration is mostly in the range of 50-100 mg/L and above, covering parts of the block Mavli, Girwa, Bhinder in the north-east and Sarada and Salumber blocks in south-east. 21.3% of ground water in the district have notrate value in the range of 50-100 mg/L and 10.0% have nitrate value above 100 mg/L (Map 2.7a & b).

The fluoride concentration in ground water of the district varies from 0.24 mg/L to 4.9 mg/L with an average of 1.01 mg/L. 84.7% of ground water have fluoride within 1.5 mg/L mainly in blocks Bhinder, Salumber and Sarada (Map 2.5, 2.6 & 2.7).

On viewing the map showing distribution of fluoride in ground water of the district, it is seen that most part of the district has ground water with fluoride values within 1.5 mg/L except the two big patches, one in eastern part (block Bhinder) having fluoride in the range of 3.0 mg/L and another in southern part covering parts of blocks Salumber and Sarada having fluoride values in the range of 1.5-3.0 mg/L and above 3.0 mg/L. Around 11% ground water in blocks Mavli, Kotra, Dhariawad and 3% in block Girwa also have fluoride in the range of 1.5-3.0 mg/L (Map 2.5 to 2.7).

96.8% of the ground water having EC within the limit of 4000 µS/cm is suitable for irrigation as far as salinity criteria is concerned to the soil of the district. of course, the depth to water should not be below 1.5 metres at any time of the year. water is free from sodium hazard as 98% ground water have sodium within 70% of total cations. Residual sodium carbonate above 2.0 meq/L whish may turn soil hard and difficult for germination of seeds popularly Known as alkali is found only in 9.2% of ground water of the district.

The potability map of the district indicates that the most part of the district have potable ground water. Ground water unsuitable for drinking is observed in two big patches, one in north- eastern part covering part of Mavli and Bhinder blocks, on account of salinity and another in southern part covering part of salumber and Sarada blocks having high fluoride content. small patches showing ground water unsuitable for drinking are also seen in block Girwa, Mavli and Bhinder blocks .

3 WAKAL RIVER BASIN

3.1 Introduction:

River Wakal originates northwest of Udaipur, near Suran Village. The river flows in a generally south direction up to Manpur village in Udaipur District, where it turns northwest and after a distance of about 90 km. leaves Rajasthan near the Goupipli village and joins Sabarmati river near Eitarwar village in Gujarat. The catchment in Rajasthan is situated in Udaipur District latitudes $24^{0}9'$ and $24^{0}46'$ and longitudes $73^{0}7'$ and $73^{0}36'$ and covers 1923.85 sq.km. The main tributaries of Wakal are Manshi and Parvi rivers (Map 3.1, 3.2).

TABLE 3.1 DISTRICTS AND TEHSILS WITHIN WAKAL RIVER BASIN

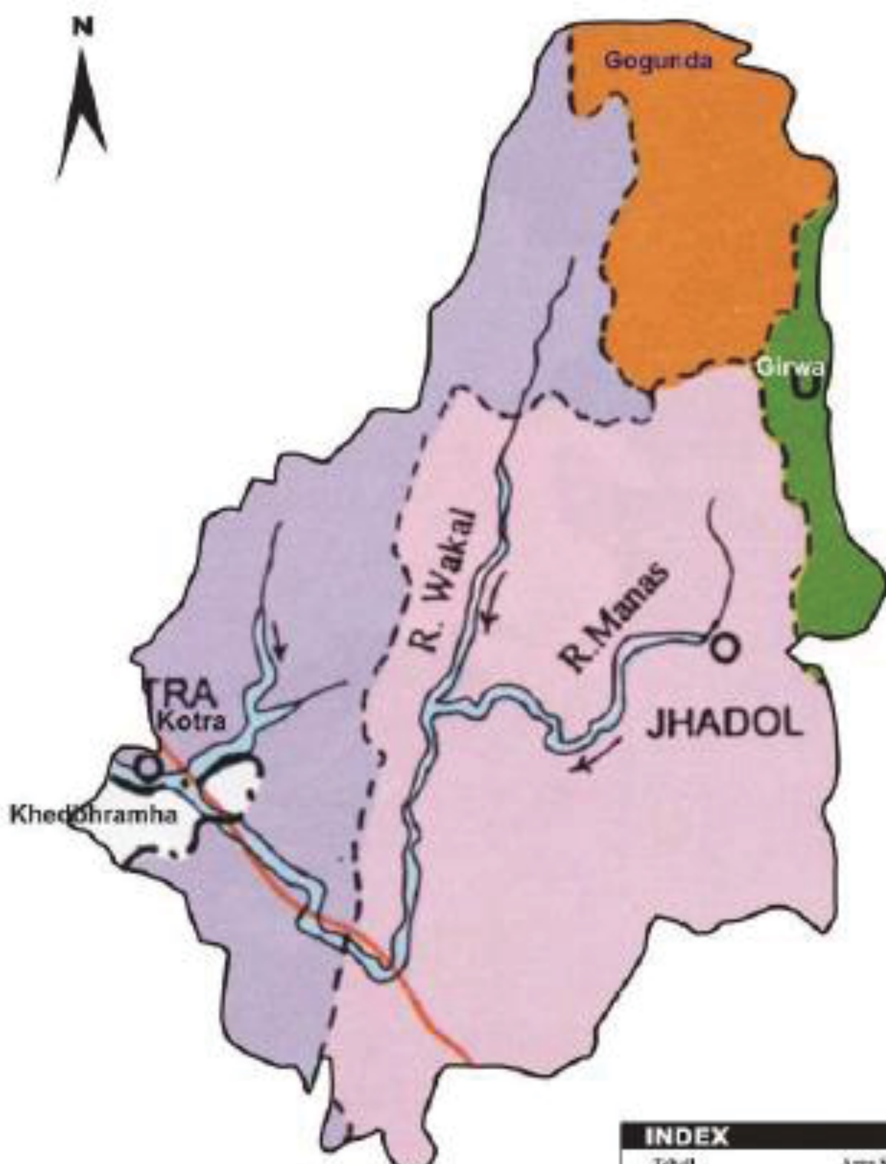
District	Tehsil	Area in Km^2	% of Basin
Udaipur	**Gogunda**	**226.040**	11.74
	Jhadol	**1008.59**	52.42
	Kotra	**563.515**	29.29
	Girwa	**88.808**	4.62
Gujarat	**Khedbhrahma**	**36.896**	1.92
	TOTAL	1923.850	99.99

Orographically, the western part of the Basin is marked by hilly terrain belonging to the Aravalli chain.

The Basin consists of highlands between the foothills of the Aravalli range, with scattered local mounds. The Basin is not served by rail or air services.

Map No. 3.1

Area Covered by Wakal Reiver Basin of Different Tehsils

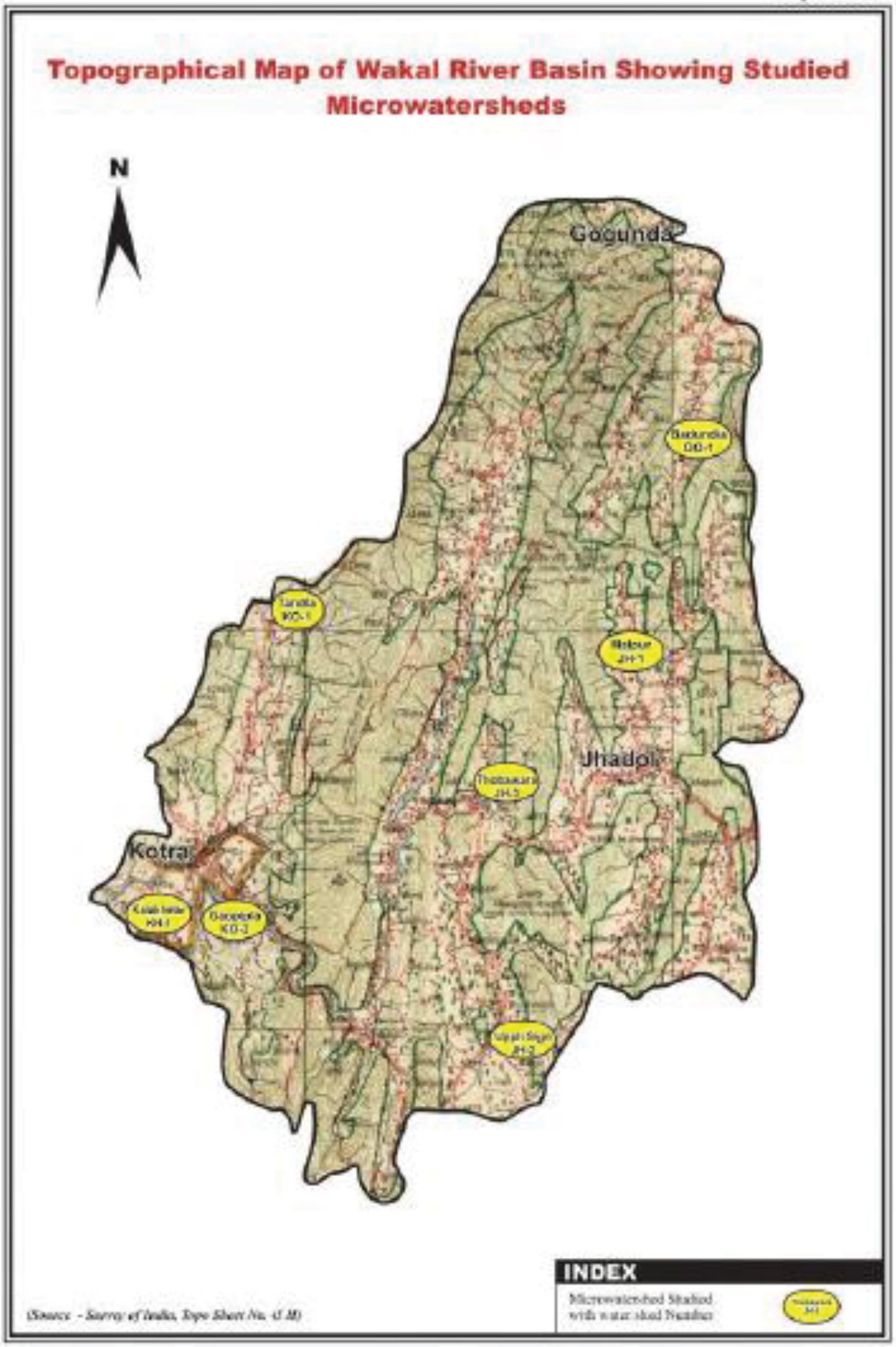


INDEX

Tehsil	Area Sq. Km
• Gogunda	226.040
• Girwa	88.808
• Jhadol	1008.591
• Kotra	563.515
• Khedbhrama	36.896
Total	**1923.850**

Source – Ground water Atlas of Rajasthan (2005) DST, Govt. of Rajasthan, Jodhpur

Map No. 3.2



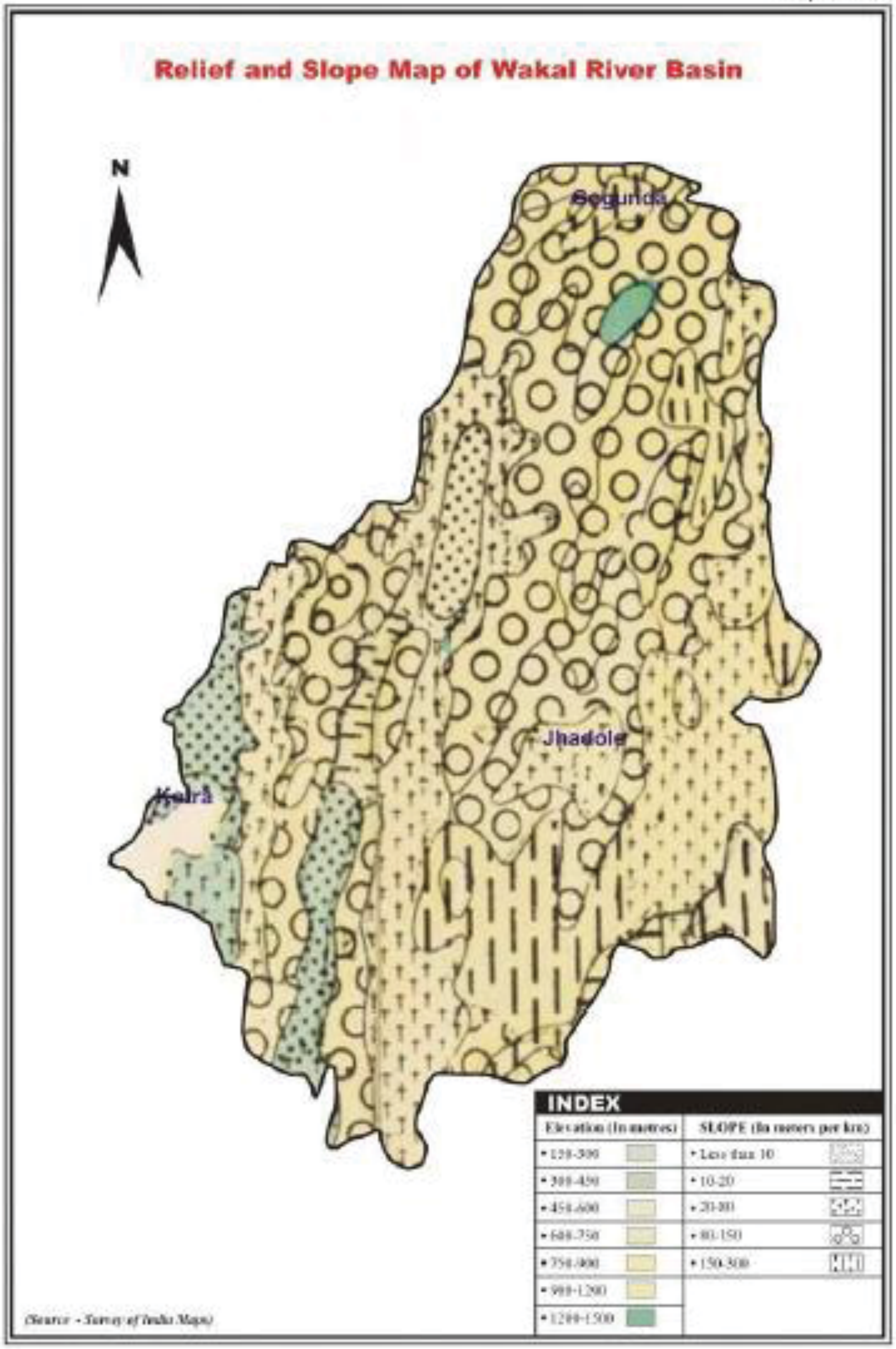
3.2 Geology And Soils:

3.2.1 Drainage:

Drainage patterns in this River Basin are defined by the Wakal river and its tributaries, which drain the slopes of the Aravalli hills in Udaipur District.

Wakal river rises in the Aravalli hills, which roughly mark the western boundary of Udaipur District and flows in a south westerly direction. The main tributaries of the Wakal river are Parvi river and the Mansi Nadi, which also rise in the Aravalli hill range west of Udaipur and flow south-westwards.

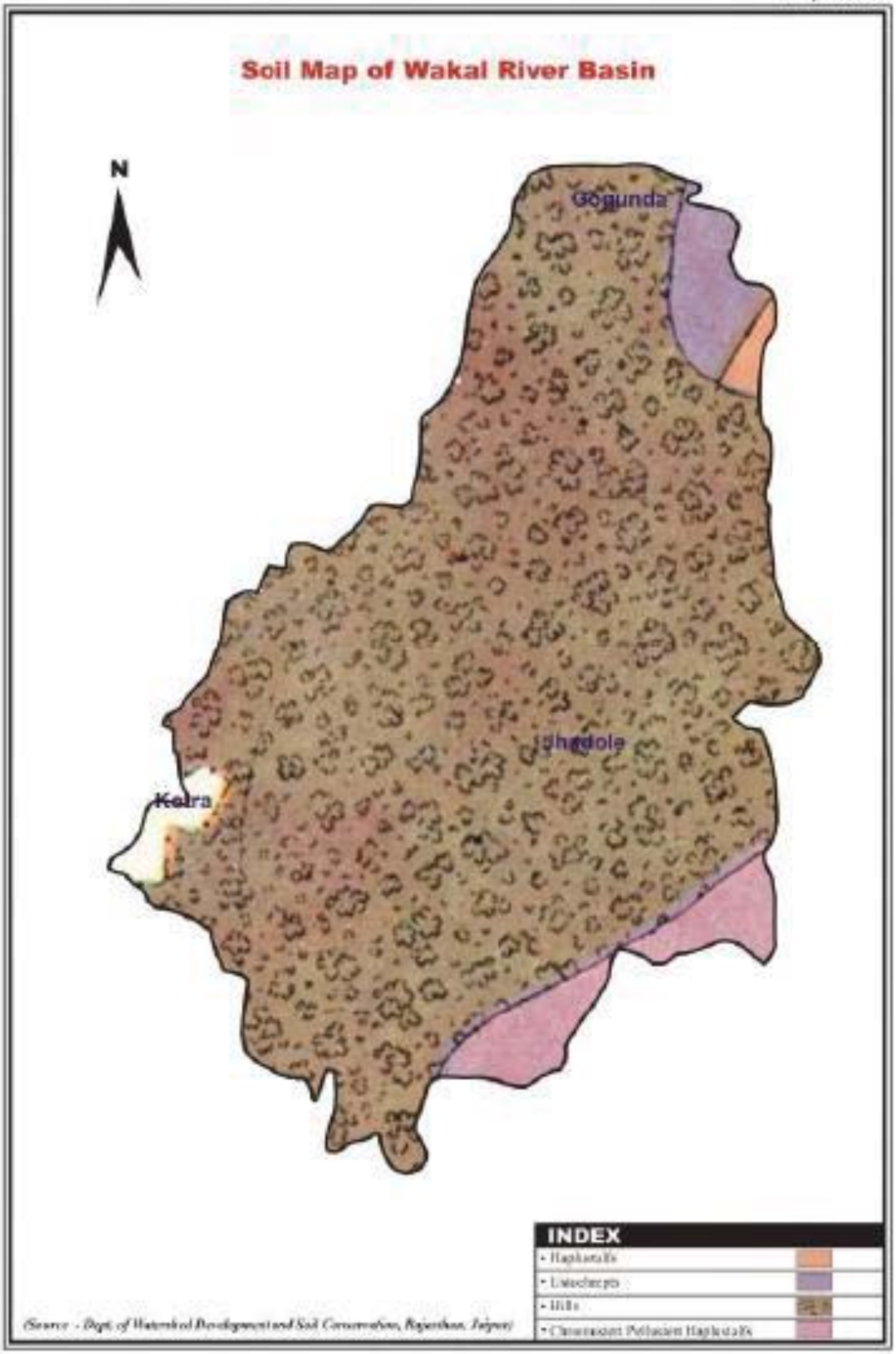
Map No. 3.3



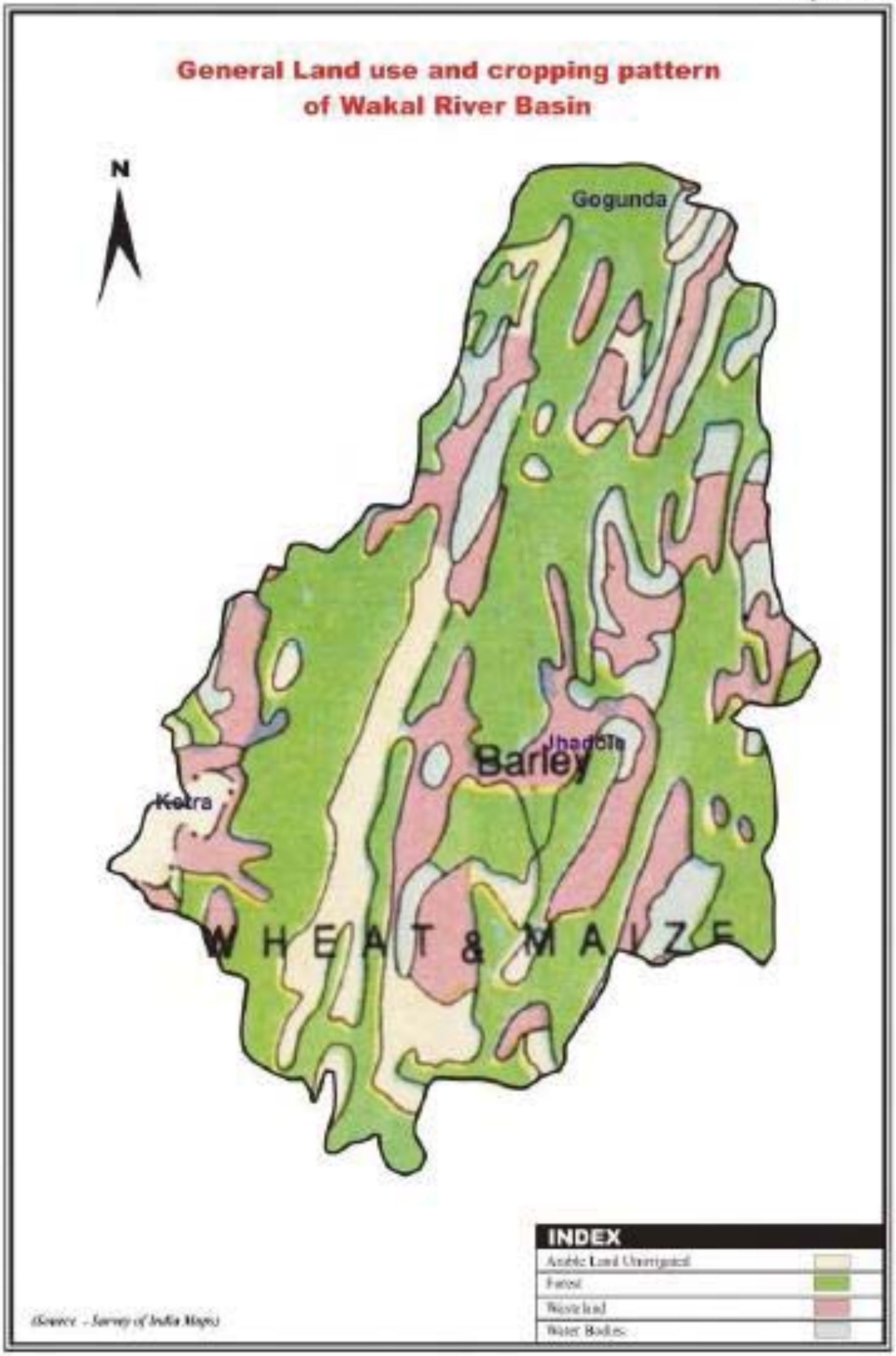
The area has mostly a sub-parallel to parallel type of drainage, with the first order tributaries of the rivers all being of the consequent type. (Map. 3.2)

3.2.2 Land Forms :

Map No. 3.4



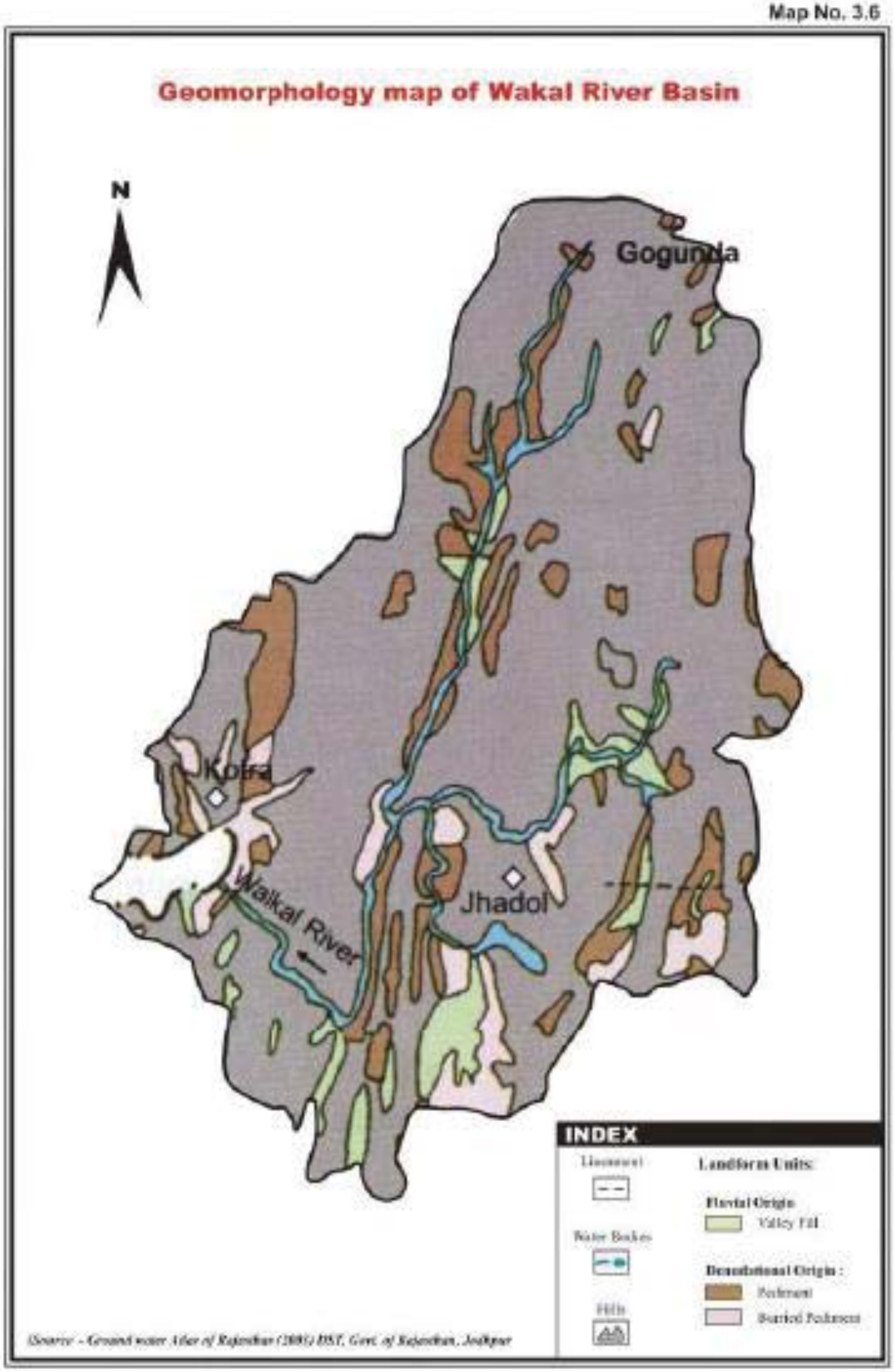
A) HILLS**:** These are part of the Aravalli range, and in conformity with the general trend in the range, run mostly northeast-southwest as a broken chain of hills elongated in shape and parallel to each other. Almost the entire western half of the Basin is made up of these sub-ranges. In addition there are isolated hillocks, the eroded remnants of earlier hill ranges, aligned parallel to the sub-



ranges. The maximum elevation in the hilly terrain is more than 1183m, the highest peak near the source of the Wakal being about 1183 m above mean sea level (amsl) and at its exit from Rajasthan-less than 285m amsl. (Map 3.2, 3.3, 3.4, 3.5 & 3.6).

VALLEYS**:** The parallel sub-ranges of the above hills are interrupted by narrow longitudinal strike valleys in the form of erosional drainage channels. The valley fills are comprised of fluvial sediments mixed with talus and form the valley floors, which are flat to gently sloping and which in their lateral extensions may abut pediment surfaces at the base of the hills enclosing them.

Map No. 3.6



Both the hills and valleys in the Wakal Basin appear to be structurally controlled land forms conforming to the Aravalli strike and lineaments. (Map 3.2 to 3.6).

3.2.3 Geology :

Structure: Since the Basin area consists of the Delhis and the Aravalli's, most of it is essentially rocky terrain. The general strike of the rock formations is northeast-southwest, with local modifications where folding has occured. This has given rise to antiforms, synforms and isoclinal folds of variable dimensions with two main axes, namely northeast-southwest and northwest-southeast. (Map 3.7)

One major lineaments pass through the Basin:

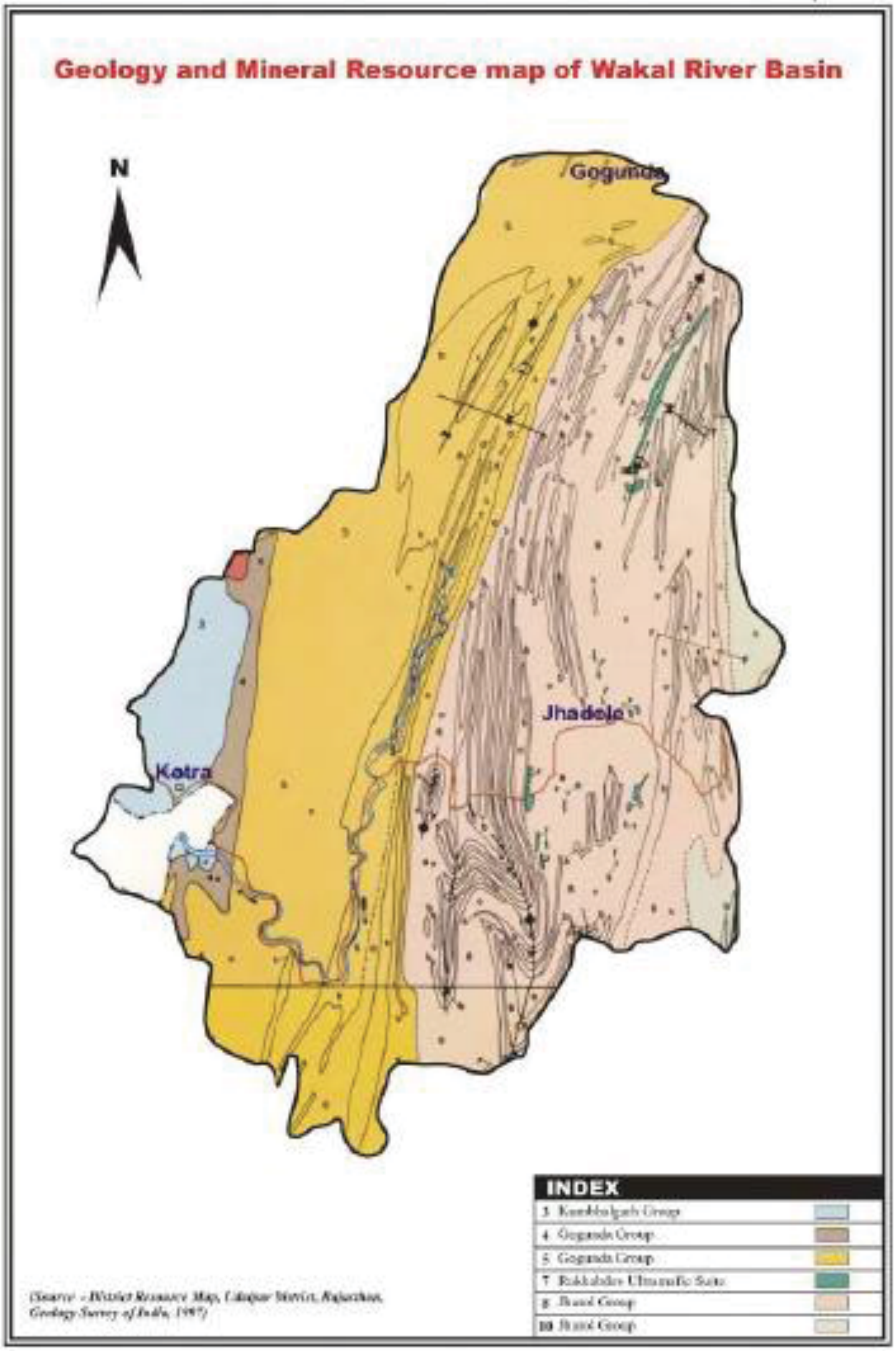
- Kali-Guman Lineament, which passes through the Jharol group of rocks in the Wakal Basin. It virtually forms a boundary between the Delhi's and the Aravallis in this Basin.

(Please see Geology described point no. 1.3 & 2.3)

3.2.4 Soils :

Major soils of the basin have been developed insitu on Aravalli metamorphic and alluviums. The hills and ridges of the district are mostly characterised by rock out crops associated with very shallow, well drained, skeletal soils occurring on steep slopes and are prone to soil erosion hazard . The soils on foot slopes and pediments are shallow to moderately to severely eroded. The soils are sandy loam in nature well drained, fine textured occurring on gently sloping plain. Salinity and sodeicity in patches developed in the depressions and basin like land forms. (Map 3.4).

Map No. 3.7



Geology and Mineral Resource map of Wakal River Basin
N
Gogunda
Jhadole
Kotra
INDEX
3 Kumbhalgarh Group
4 Gogunda Group
5 Gogunda Group
7 Rakhabdev Ultramafic Suite
8 Jharol Group
10 Jharol Group
(Source - District Resource Map, Udaipur District, Rajasthan, Geology Survey of India, 1997)

3.3 Climate

3.3.1 General

The Indian Meterological Department (IMD) has divided Rajasthan into two meterological sub-divisions, i.e. West Rajasthan and East Rajasthan, with the Wakal Basin falling within the East Rajasthan sub division.

Based on Koppen's classification of climatic patterns, the Wakal Basin may be classified as tropical steppe, semi-arid and hot (Bsh). The year may be divided into four seasons. The winter season from mid-November to the beginning of March is followed by the hot summer season from March to June, including the Pre-Monsoon season from April to June. The period from July to mid-September constitutes the southwest Monsoon season and the period from the latter half of September to October the post-Monsoon season.

3.3.2 Cloudiness :

Skies are generally moderately to heavily clouded during the southwest Monsoon season, especially in July and August, being overcast on some days. During the rest of the year, skies are normally clear to lightly clouded, although cloudiness sometimes occurs during the winter due to passing western disturbances. During the months of July-August mean cloudiness (in Oktas) is usually more than 5, being generally higher in the evening than the mornings.

3.3.3 Winds :

Winds are generally light to moderate except in the latter half of summer and during the southwest Monsoon season. In summer, winds blow from directions ranging from west to south. Westerly to south-westerly winds prevail during the Monsoon season. In the post-monsoon and winter months, winds are mostly from directions varying between northwest and northeast.

Mean wind speed is highest in June (8.8 km/ hr) and lowest in November (2.6 km/hr). In June 1962 the mean maximum wind speed was 8.2 km/hr. and in November 1974 the mean minimum wind speed was 0.3 km/hr. *(Source: Ground Water Resources of Udaipur District (1999) Volume-I, Govt. of Rajasthan, GWD, Jodhpur)*.

3.3.4 Rainfall :

Most of the rainfall in the district is received during the southwest monsoon period from last week of June till end of September, August being the rainiest month in the year. The normal annual rainfall in the basin is 675.788 mm (1901-98). Bifurcation of monthly rainfall for monsoon and non-monsoon cycle from 1990-91 to 1998-99 of different blocks within basin or near by basin are given in Table 3.3.1 to 3.3.4 (*Source: Ground Water Resources of Udaipur District(1999) Volume-I, Govt. of Rajasthan, GWD, Jodhpur*)

3.4 Ongoing and Proposed Surface Water Projects : Domestic and Industrial

Two dams (Masi_ and Wakal-I and III), one on river Mansi, a tributary of river Wakal, near the village Gorana with a live storage capacity of 27 mcm and another on river Wakal, downstream of confluence with Mansi river, with a live storage capacity of 71 mcm have been proposed for water supply to Udaipur city in Banas Basin. It was proposed to divert 13 mcm /yr and 50 mcm/ yr of water through Mansi-I and Wakal-I and III dams, respectively. (Map 3.8)

3.5 Groundwater Resources

3.5.1 Groundwater Occurrence

General: The aquifers in the Basin include:

- Alluvium
- Delhi Super-Group of rocks, including intrusives

Geotechnical Projects and Natural Hazards of Wakal River Basin

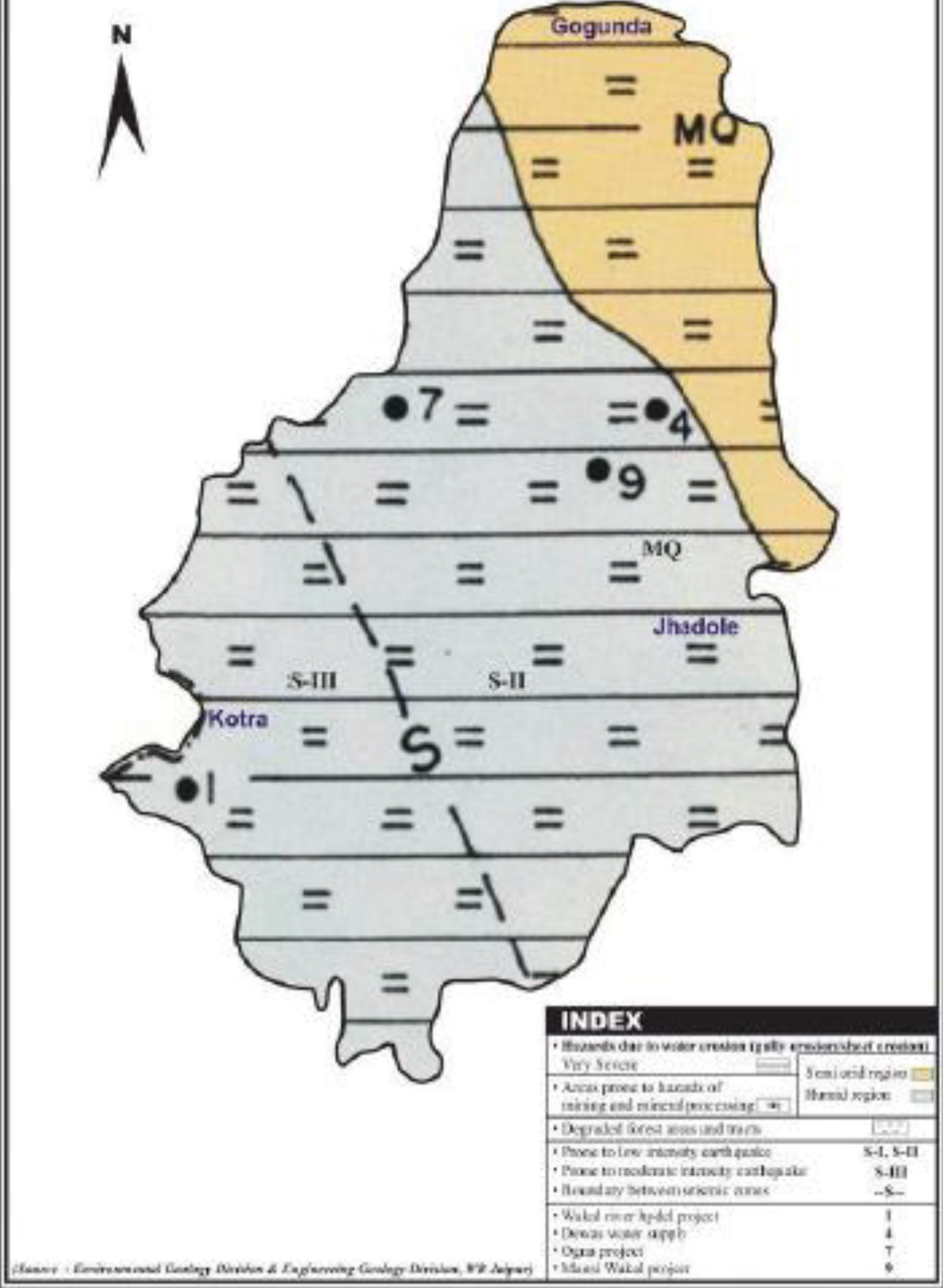


Table: 3.3.1

BIFURCATION OF MONTHLY RAINFALL FOR MONSOON AND NON-MONSOON CYCLE FROM 1990-1998

BLOCK : GOGUNDA **DISTRICT : UDAIPUR**

(in mm)

MONTHS	**MONSOON PERIOD**					**NON-MONSOON PERIOD**								
YEARS	JUNE	JULY	AUG.	SEPT.	**TOTAL**	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	**TOTAL**
1990-91	77.00	105.00	356.00	192.00	**730.00**	13.00				1.00		27.00		**41.00**
1991-92		367.00	108.00	49.00	**524.00**		5.00		4.00				20.00	**29.00**
1992-93	17.00	505.00	222.00	205.00	**949.00**	41.00	14.00			8.00			7.00	**70.00**
1993-94	110.00	327.00	33.00	110.00	**580.00**	2.00			32.00			1.00	1.00	**36.00**
1994-95	193.00	248.00	299.00	167.00	**907.00**				27.00				4.00	**31.00**
1995-96		257.00	137.00	64.00	**458.00**	10.00		20.00	9.00			2.00		**41.00**
1996-97	112.00	204.00	252.00	135.00	**703.00**	15.00						22.00	53.00	**90.00**
1997-98	46.00	134.00	210.00	161.00	**551.00**							14.00		**14.00**
1998-99	137.00	92.00	91.00	181.00	**501.00**	90.00								**90.00**
TOTAL	**692.00**	**2239.00**	**1708.00**	**1264.00**	**5903.00**	**171.00**	**19.00**	**20.00**	**72.00**	**9.00**	**0.00**	**66.00**	**85.00**	**442.00**

Average Annual Rainfall (in mm) = 706.56
(1990 to 1998)

Normal Annual Rainfall (in mm) =
611.14
(1991 to 1998)

Table: 3.3.2

BIFURCATION OF MONTHLY RAINFALL FOR MONSOON AND NON-MONSOON CYCLE FROM 1990-1998

BLOCK : GIRWA **DISTRICT : UDAIPUR**

(in mm)

MONTHS	**MONSOON PERIOD**					**NON-MONSOON PERIOD**								
YEARS	JUNE	JULY	AUG.	SEPT.	**TOTAL**	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	**TOTAL**
1990-91	31.00	120.00	383.00	247.00	**781.00**	33.00						11.00		**44.00**
1991-92	20.00	386.00	84.00		**490.00**		12.00		3.00				14.00	**29.00**
1992-93	75.00	389.00	178.00	181.00	**823.00**	15.00	3.00			7.00	4.00	11.00		**40.00**
1993-94	92.00	294.00	56.00	22.00	**464.00**				8.00			4.00	12.00	**24.00**
1994-95	150.00	166.00	255.00	169.00	**740.00**				28.00					**28.00**
1995-96	42.00	231.00	65.00	36.00	**374.00**	1.00		1.00	8.00	1.00				**11.00**
1996-97	172.00	245.00	101.00	137.00	**655.00**	7.00						11.00	28.00	**46.00**
1997-98	101.00	166.00	163.00	134.00	**564.00**	40.00						49.00		**89.00**
1998-99	67.00	78.00	156.00	222.00	**523.00**	106.00								**106.00**
TOTAL	**750.00**	**2075.00**	**1441.00**	**1148.00**	**5414.00**	**202.00**	**15.00**	**1.00**	**47.00**	**8.00**	**4.00**	**86.00**	**54.00**	**417.00**

Average Annual Rainfall (in mm) = 652.44
(1990 to 1998)

Normal Annual Rainfall (in mm) =
632.57
(1991 to 1998)

Table: 3.3.3

BIFURCATION OF MONTHLY RAINFALL FOR MONSOON AND NON-MONSOON CYCLE FROM 1990-1998

BLOCK :
JHADOL **DISTRICT : UDAIPUR**

(in mm)

MONTHS	**MONSOON PERIOD**					**NON-MONSOON PERIOD**								
YEARS	JUNE	JULY	AUG.	SEPT.	**TOTAL**	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	**TOTAL**
1990-91	51.00	264.00	380.00	227.00	**922.00**									**0.00**
1991-92	13.00	493.00	70.00	13.00	**589.00**		4.00							**4.00**
1992-93	27.00	402.00	191.00	241.00	**861.00**	6.00	15.00			8.00	4.00			**33.00**
1993-94	87.00	398.00	14.00	58.00	**557.00**				12.00			16.00		**28.00**
1994-95	176.00	188.00	377.00	110.00	**851.00**	4.00			27.00					**31.00**
1995-96	23.00	362.00	108.00	62.00	**555.00**							4.00		**4.00**
1996-97	90.00	265.00	323.00	131.00	**809.00**							3.00	13.00	**16.00**
1997-98	235.00	168.00	206.00	51.00	**660.00**		26.00							**26.00**
1998-99	64.00	139.00	163.00	207.00	**573.00**	93.00								**93.00**
TOTAL	**766.00**	**2679.00**	**1832.00**	**1100.00**	**6377.00**	**103.00**	**45.00**	**0.00**	**39.00**	**8.00**	**4.00**	**23.00**	**13.00**	**235.00**

Average Annual Rainfall (in mm) = 739.77
(1990 to 1998)

Normal Annual Rainfall (in mm) =
654.12
(1991 to 1998)

Table: 3.3.4

BIFURCATION OF MONTHLY RAINFALL FOR MONSOON AND NON-MONSOON CYCLE FROM 1990-1998

BLOCK : KOTRA **DISTRICT : UDAIPUR**

(in mm)

MONTHS	**MONSOON PERIOD**					**NON-MONSOON PERIOD**								
YEARS	JUNE	JULY	AUG.	SEPT.	**TOTAL**	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	**TOTAL**
1990-91	72.00	408.00	427.00	147.00	**1054.00**									**0.00**
1991-92	8.00	711.00	125.00	10.00	**854.00**		14.00						3.00	**17.00**
1992-93	42.00	375.00	283.00	524.00	**1224.00**		9.00			10.00				**19.00**
1993-94	65.00	621.00	8.00	89.00	**783.00**				2.00			11.00	7.00	**20.00**
1994-95	159.50	451.00	415.00	299.00	**1324.50**				20.00					**20.00**
1995-96	19.00	354.00	128.00	53.00	**554.00**	26.00						87.00		**113.00**
1996-97	95.00	208.00	136.00	78.00	**517.00**							25.00	20.00	**45.00**
1997-98	96.00	111.00	250.00	235.00	**692.00**	57.00	1.00							**58.00**
1998-99	146.00	172.00	167.00	155.00	**640.00**	125.00								**125.00**
TOTAL	**702.50**	**3411.00**	**1939.00**	**1590.00**	**7642.50**	**208.00**	**24.00**	**0.00**	**22.00**	**10.00**	**0.00**	**123.00**	**30.00**	**417.00**

Average Annual Rainfall (in mm) = 896.17
(1990 to 1998)

Normal Annual Rainfall (in mm) =
775.29
(1991 to 1998)

- Aravalli Super-Group of rocks

Hydrogeological map of Wakal River Basin has been prepared and shown in Map 3.9 & 3.10.

Groundwater in the alluvial aquifer is usually under phreatic (water table) conditions, whereas in the consolidated rocks, semi-confined to confined conditions have been encountered as well. The alluvial aquifer, however, is very limited, and of local importance only. There are no defined alluvial Potential Zones in the Basin. (Map 3.9, 3.10 and 3.11)

Groundwater occurrence in the various aquifers is described in detail below:

3.5.1.2 Alluvium Aquifer: The alluvial aquifer occurs in the form of discontinuous elongated terraces along the banks of rivers. The deposits are very limited in lateral extent.

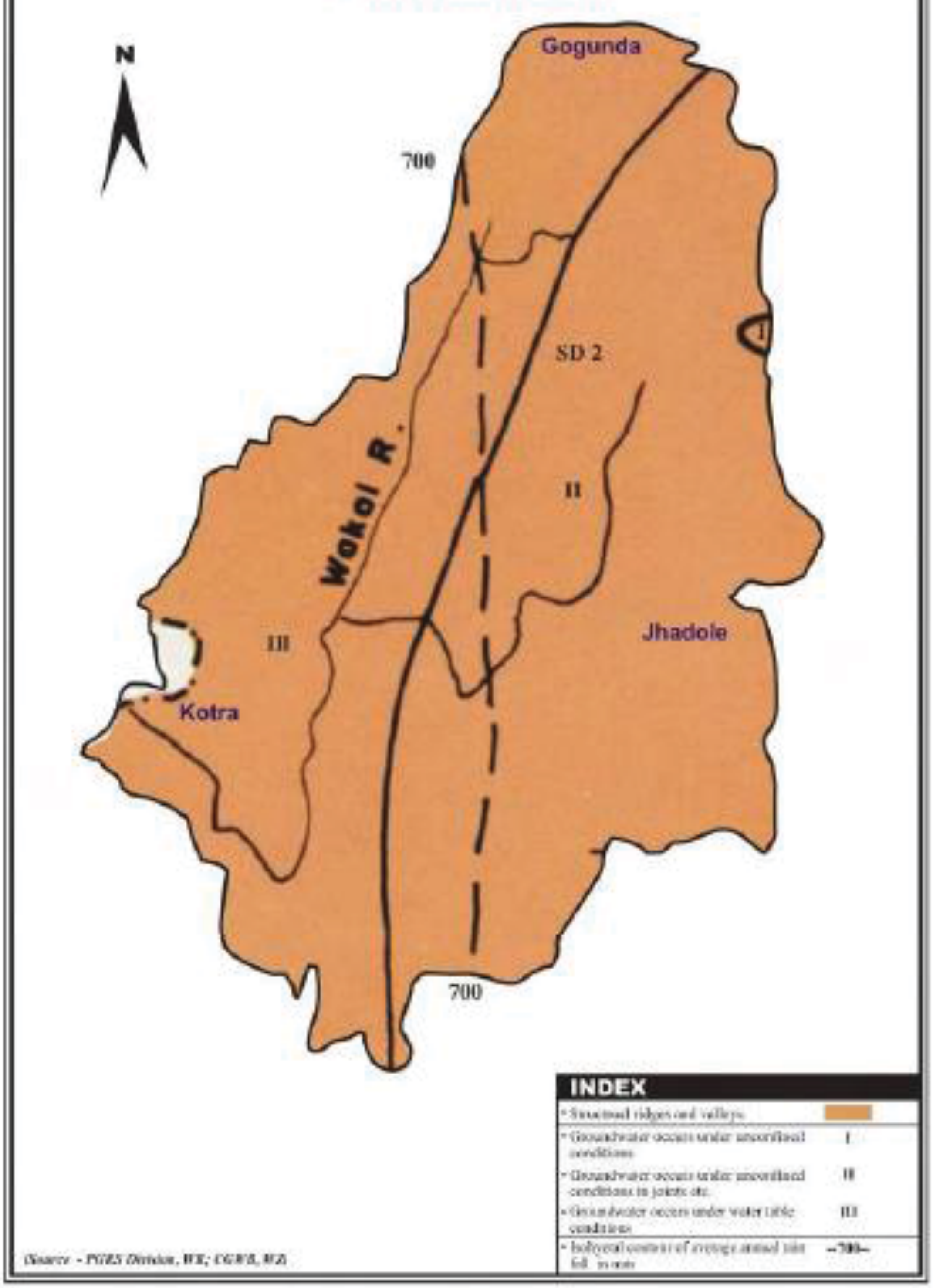
3.5.1.3 Delhi Super-Group Aquifer: This includes the Kubhalgarh and Gogunda rock formations - quartzites, calc-schists and clac-gneisses etc. with the Sandra Ambaji intrusives of granites, gneisses and migmatites (Map 3.7).

Groundwater in these rocks occurs in the weathered zone and in the joints and cracks. It is under water table conditions except locally, where it might be under smi-confined conditions. The depth to water table is between 5 and 15m.

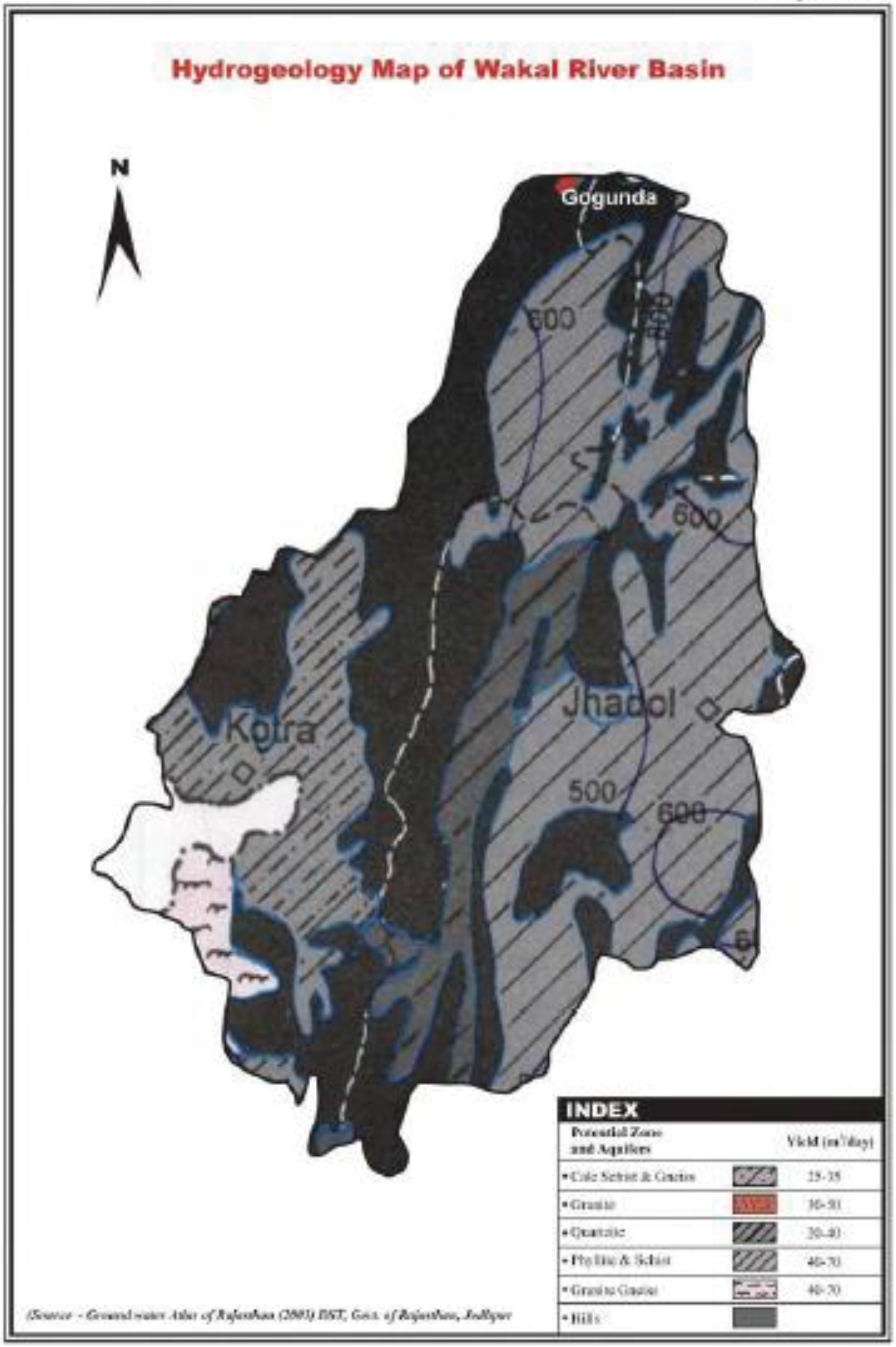
3.5.1.4 Aravalli Super Group Aquifers: These comprises mainly phyllite, schists and quartzites, Groundwater occurs in the weathered and jointed portion of the rock. Phyllite and quartzite from locally important aquifers, being generally well jointed. Groundwater is under water table conditions. The depth to water varies from 5m to more than 15m (Table 3.5).

The depth of water in different hydro-geological formations during pre-monsoon 2007 has been illustrated in Annexure 1.1 to 1.7 for different micro-

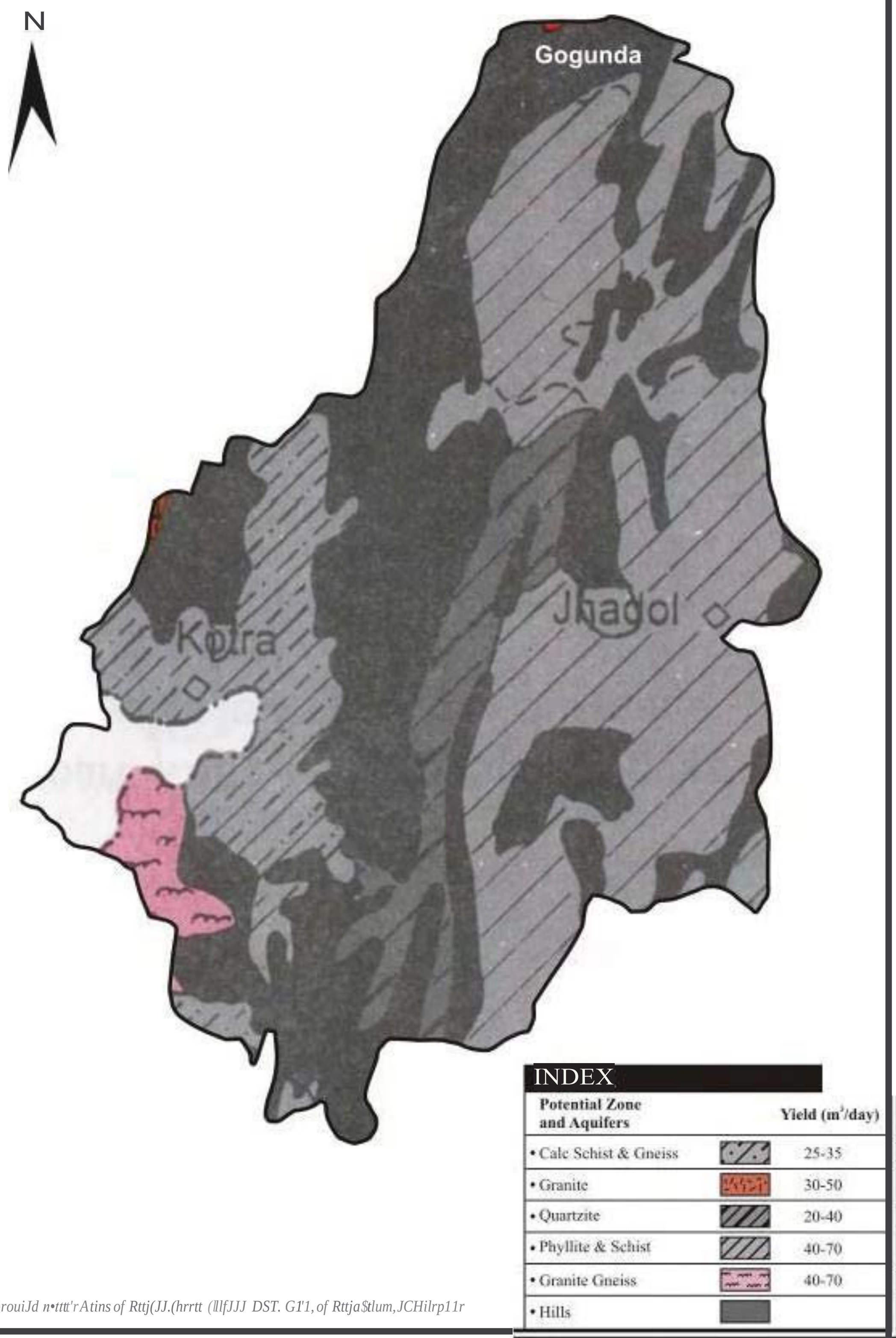
Geomorphology and Geohydrology of Wakal River Basin



Map No. 3.10

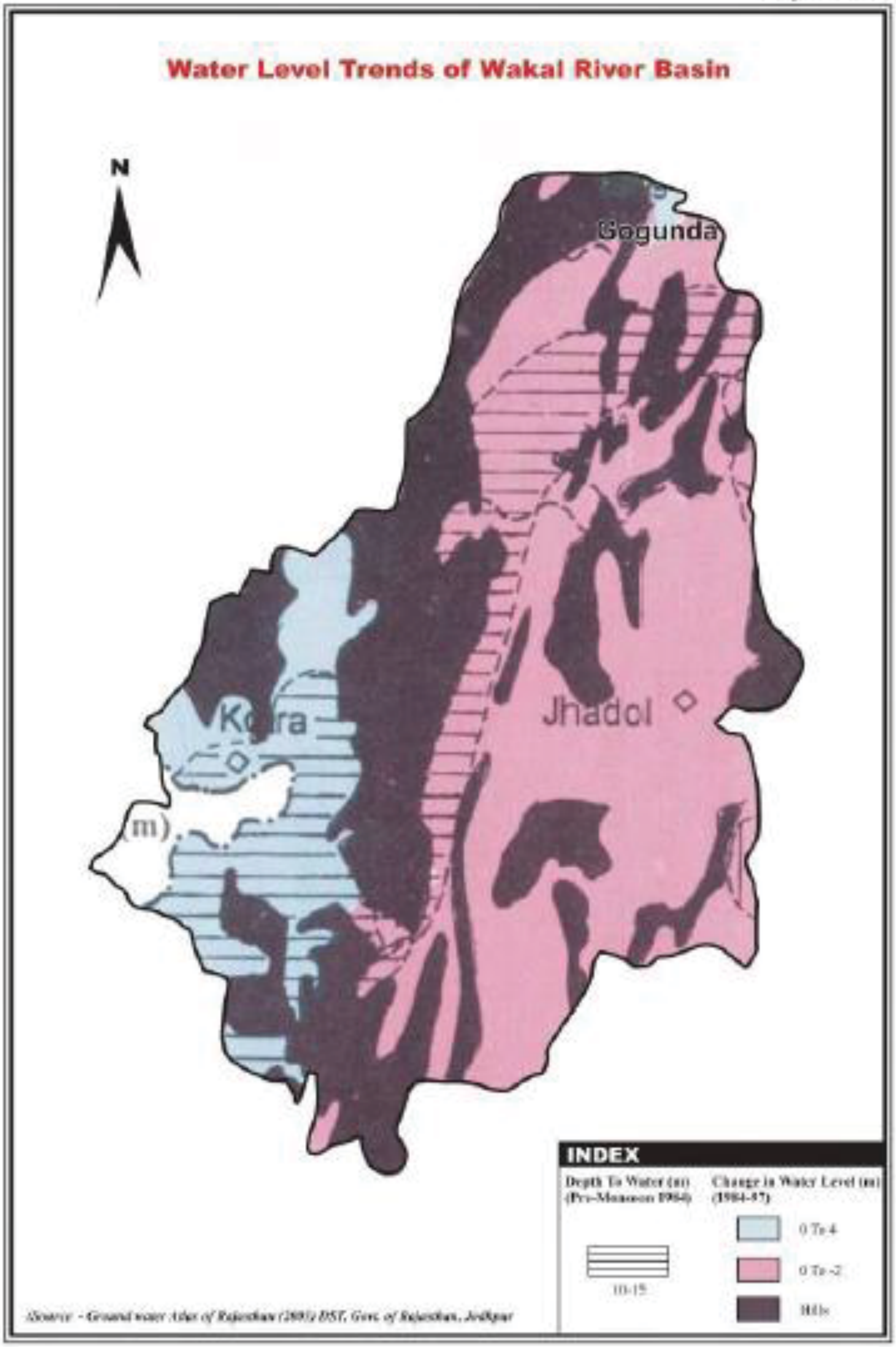

Hydrogeology Map of Wakal River Basin
N
Gogunda
600
600
600
Kotra
Jhadol
500
600
INDEX
Potential Zone and Aquifers
Yield (m³/day)
Granite
Quartzite
Phyllite & Schist
Hills

Ground Water Potential Zones of Wakal River Basin



(Sourr:e- •GrouiJd n•tttt'r Atins of Rttj(JJ.(hrrtt (llfJJJ DST. G1'1, of Rttja$tlum, JCHilrp11r

Map No. 3.12



Source - Ground water Atlas of Rajasthan (2001) DST, Govt. of Rajasthan, Jodhpur

TABLE - 3.5

DEPTH TO WATER IN DIFFERENT HYDROGEOLOGICAL FORMATIONS AS OBSERVED IN PREMONSOON 98 & POSTMONSOON 98 IN WAKAL RIVER BASIN

DISTRICT: UDAIPUR

S.No.	Hydrogeological Formations	(Pre) Depth to Water in Mts. (bgl.) (Post)			
		Minimum	Maximum	Minimum	Maximum
1	2	3	4	5	6
1	Phyllite & Schist	1.72 (Rani) Block Kherara	16.23 (Chatiyakheri) Block Gogunda	0.70 (Baghpura) Block Jhadol	12.70 (Chatiyakheri) Block Gogunda
2	Quartzite	10.00 (Kyaria) Block Jhadol	15.85 (Birothi) Block Jhadol	7.60 (Kyaria) Block Jhadol	12.90 (Berothi) Block Jhadol
3	Granite	4.70 (Deola) Block Kotra	15.13 (Sulab) Block Kotra	1.43 (Khajooria) Block Kotra	13.80 (Sulao) Block Kotra

watershed. While pre-monsoon and post-monsoon 1998 has been illustrated in Table 3.5.

3.5.1.5 Deep Confined to Semi-confined Acquifer: The only data on the deeper aquifer encountered in the consolidated rock formations in the Basin are from 7 exploratory tube wells and 9 piezometers drilled by department. Details of exploratory tube wells and piezometers constructed in Wakal Basin are given in Table 3.5.1 (*Source: Ground Water Resources of Udaipur District(1999)Volume-I, Govt. of Rajasthan, GWD, Jodhpur*).

During the course of Investigations 3 long duration pumping tests were conducted at village Ogana, Jhadol and Nandoda. The details of pumping tests and aquifer parameters are given in Table 3.5.2.

3.6 Groundwater Quality:

Groundwater quality in the Basin is good at times even excellent for the purpose of determining the suitability of ground water for irrigation in different types of soil, its quality is usually expressed in terms of electrical conductivity EC µs/cm at 25^0C For potability the chloride (Cl) content is used as the principal indicator. The EC values, all below 2000 µs/cm in the Wakal River Basin, which is suitable for irrigation for all types of crops. (Map 2.5a, 2.5b and Map 3.12: please see Plate 1 to 7)

Indian Council of Medical Research (ICMR)-1975) has prescribed acceptable limits and maximum permissible limits for various electrical constituents dissolved in water. The electrical conductivity ranging from 0-2000 µs/cm is safe for drinking and basin area is covered in this range.

The basin area is covered by nitrate constituents range in from 0-50 mg/1 and are safe for drinking (Map 2.7a and Fig. 2.6).

The most of the area is covered by water samples showing fluoride concentration 0-1.50 mg/1 and is safe for drinking water. The area around

TABLE - 3.5.1

DETAILS OF PIEZOMETERS CONSTRUCTED UNDER A.D.P., SABARMATI BASIN

(Source : Ground water Department, Govt. of Rajasthan, 1999)

DISTRICT : UDAIPUR

S. No.	Village	Block	Location & Coordinate	Type of BH	Year of Tgt.	Date of Compl.	Drilling Unit	Size of BH	Depth of BH	Size of Assembly	Length of Assembly	Hydrogeo form	S.W.L.	Discharge	EC	NO3	Cl	F	S/F
								mm	m	mm	m		m	lph	us/cm		(mg/l)		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	JHADOL	JHADOL	IN VIDHYAPEETH	PZ	95-96	10/8/1995	DTHS	100	50	125	12.4	Sc	9	5000	1020	22	177	0.74	S
			N24 24 32 E73 28 21																
2	KOLYARI	JHADOL	Nr. LAMPS BLDG.	PZ	95-96	10/8/1995	DTHS	100	50	125	12.4	Sc	9	5000	1020	22	177	0.74	S
			N24 20 11 E73 21 36	PZ	95-96	9/19/1996	DTHS	100	50	125	12.4	Sc	7	2000	3000	368	475	0.42	S

(Source: Report, GWD, Jodhpur, 1999).

TABLE - 3.5.2

DETAILS OF PUMPING TESTS IN WAKAL RIVER BASIN

S. No.	Name of Pumping Test Site	Block	Aquifer	SWL in Mts.	Total Depth of B/H in Mts.	Draw Down in Mts.	Discharge in Cum/day	Total Pumping Hrs.	Specific capacity Cum/hr/ mts. of draw down	Transmissibility (MF/day) & storage Coefficient determined by different methods					
										Jacob time draw down method		Theiss time draw down		Theiss recovery method	
										T	S	T	S	T	S
1	Ogana	Jhadol	Schist	8.89	96.00	1.59	766.80	1420.00	20.09	369.52	-	321.32	-	401.19	-
2	Jhadol (Pumping Well)	Jhadol	Schist	6.15	100.00	14.99	34.24	1330.00	0.10	4.82	-	3.89	-	11.40	-
3	Jhadol (Observation Well)	Jhadol	Schist	5.39	10.00	0.69	-	-	-	26.12	0.00	23.70	0.00	15.69	-

(***Source: Report, Sabarmati basin, GWD Govt. of Rajasthan, 1999)***

Jhadol, Phalasia, Khakhad in Jhadol block of Udaipur district where the fluoride concentration ranges from 1.5-3.0 mg/1 which is unsafe for drinking purpose (Map 2.7b and Fig. 2.6).

3.5.2 Hydrochemistry:

Hydrochemical data based on chemical analysis results of water samples collected during pre-monsoon 2007 are interpreted to arrive at its final quality in 2007. The analysis were further grouped, interpreted and classified for their suitability with respect to agriculture and domestic utilisation. Water sample have been collected from all 7 microwater sheds (Map. 3.13 to 3.19), (Table 3.6.1. to 3.6.7, Annexure 1.1 to 1.7).

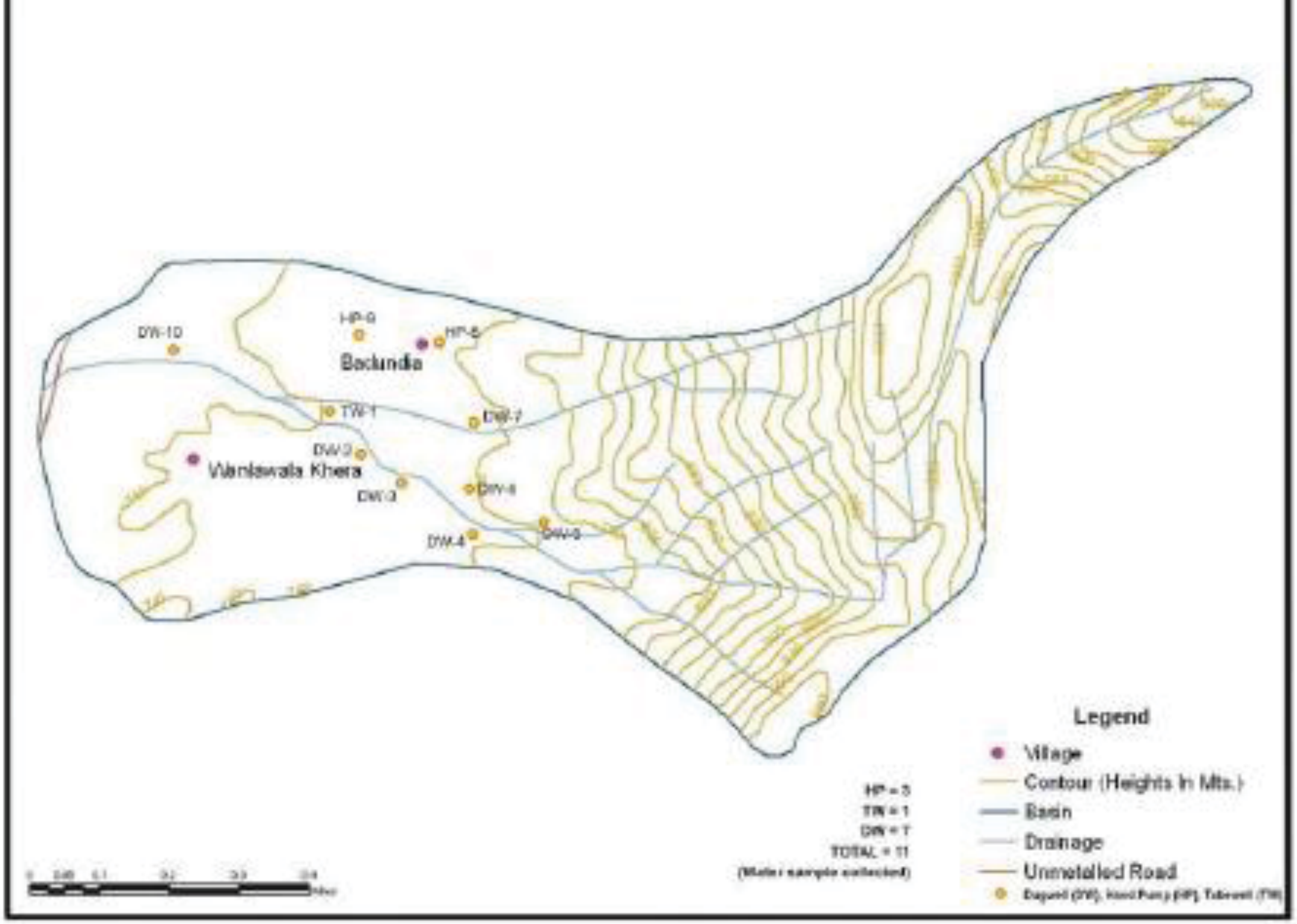
To achieve the above aim the major ions viz. Sodium, Potassium, Calcium, Magnesium, Carbonate, Bicarbonate, Chloride, Sulphate, Nitrate and Fluoride were estimated. pH and specific conductance were also determined. The important parameters like total hardness (as $CaCO_3$), and sodium percentage (Na%) were calculated for adjudging the suitability of phreatic and deeper aquifer water for irrigation. The chemical quality of phreatic aquifer (shallow wells) were compared with tube well waters (deeper aquifers). The Chemical analysis data are furnished in Annexure-1.1 to 1.7

QUALITY OF GROUNDWATER: In Wakal River Basin (Selected Microwater shed Study).

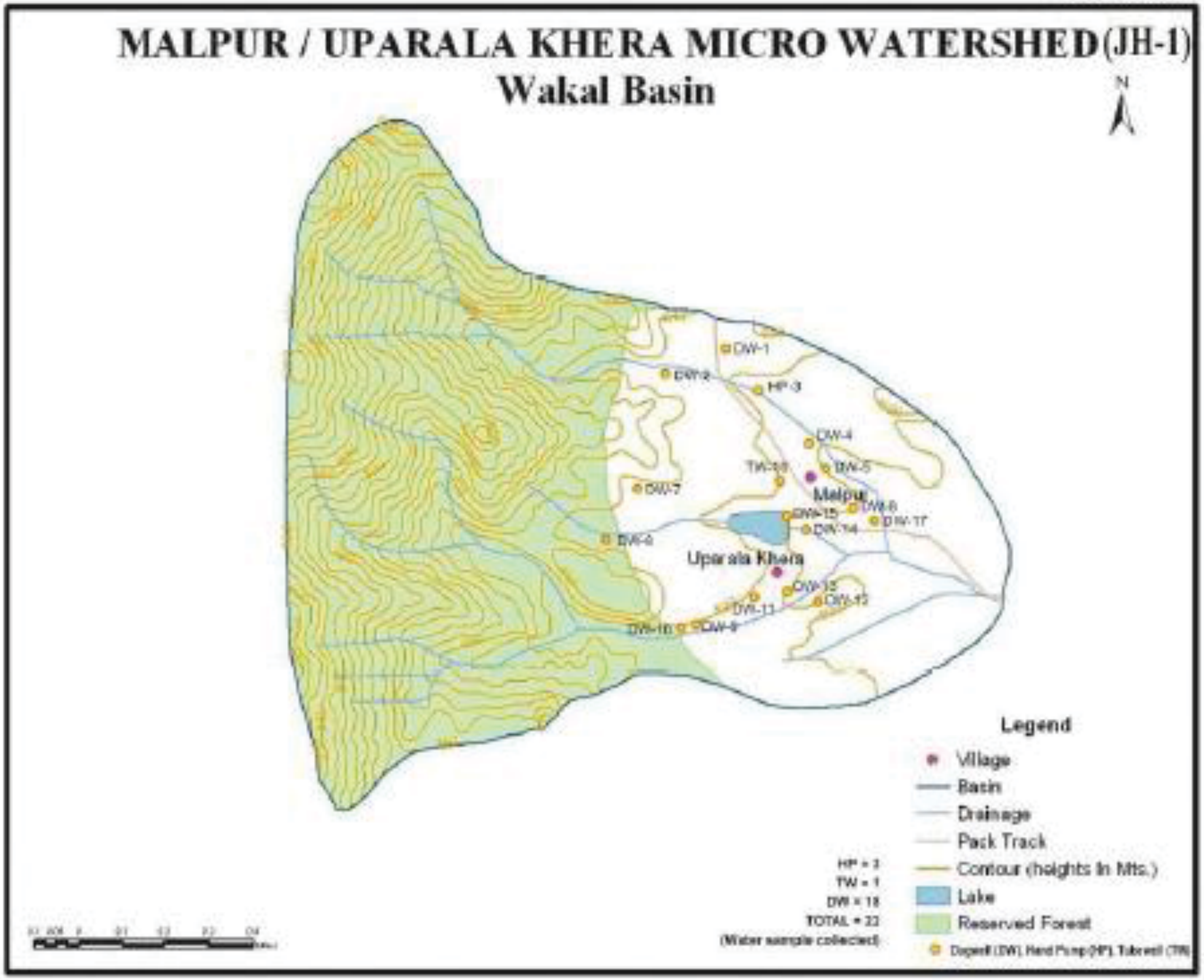
SALINITY AND WATER TYPE: Fresh to moderately saline water is observed in the Fresh Water has low conductivity mostly below 2000µs/cm, whereas slightly saline water is of EC value in between 2000-4000µs/cm. As the concentration of ion increases, electrical conductivity of the solution also increases. Ionic concentration or salinity of water depends on hydrogeological, geomorphological and climatic conditions and water bearing formations in the region along with time of contact of water with the water bearing formation.

Map No. 3.13

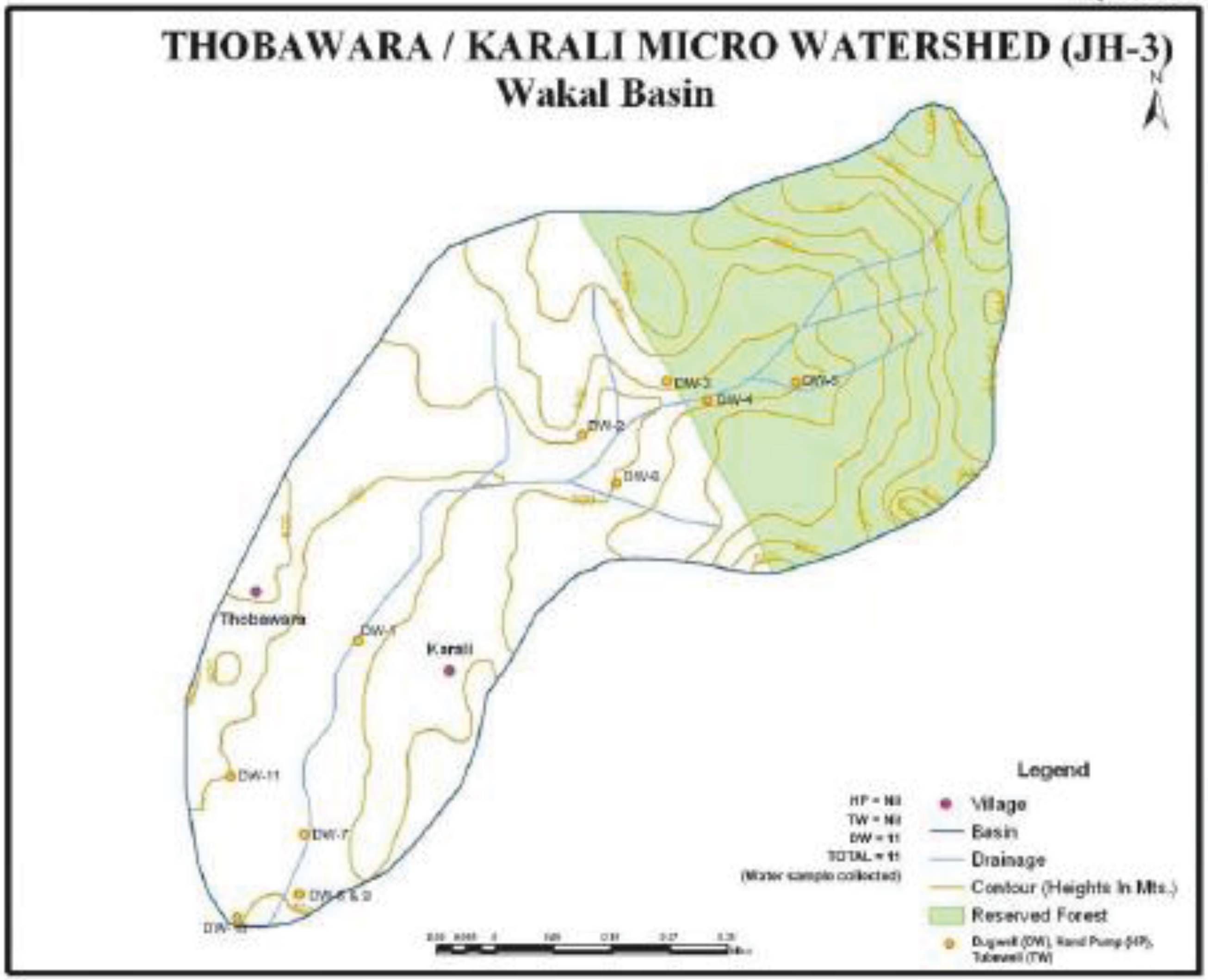
BADUNDIA MICRO WATERSHED (GO-1)
Wakal Basin



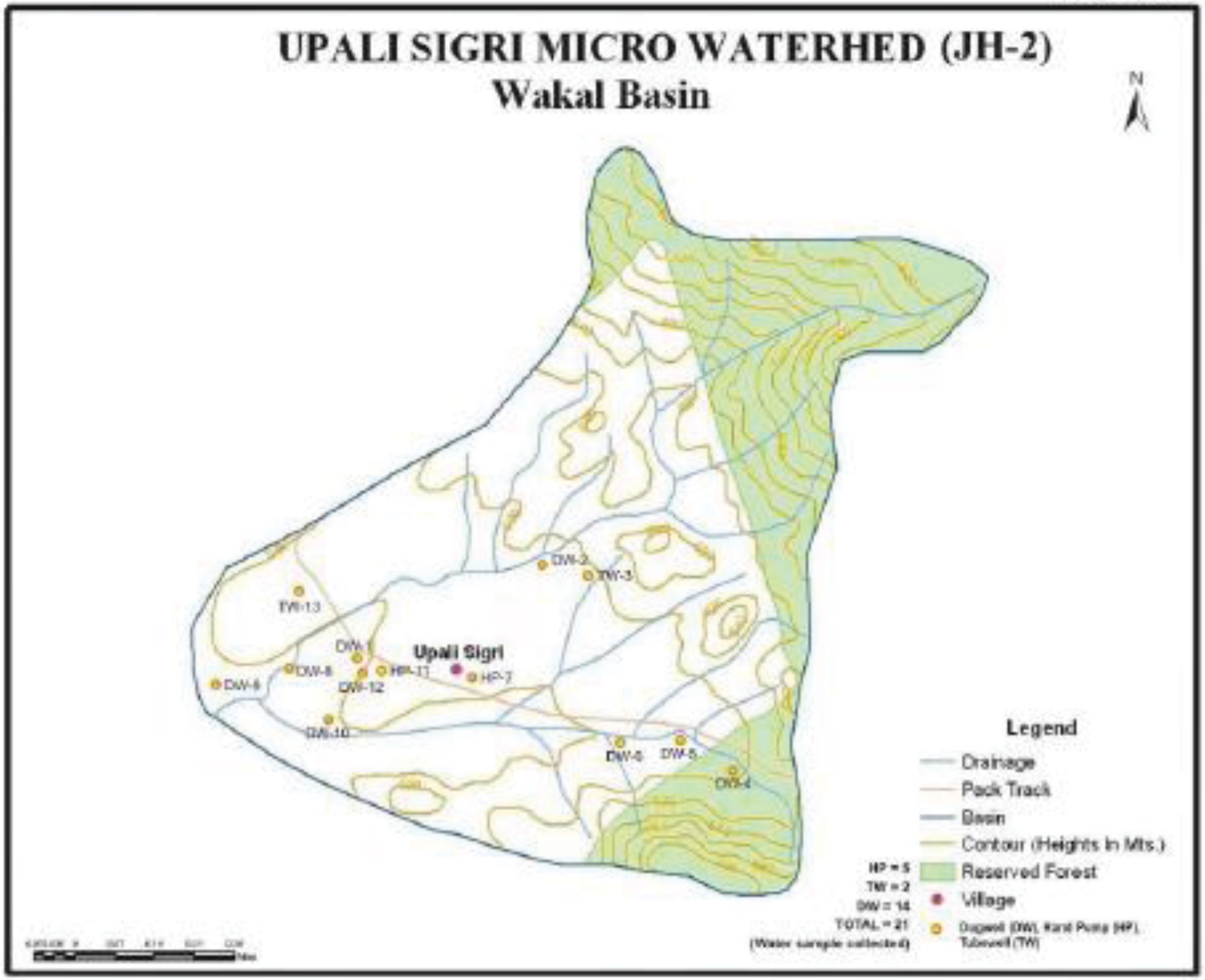
Map No. 3.14


MALPUR / UPARALA KHERA MICRO WATERSHED(JH-1)
Wakal Basin
N
DW-1
DW-2
HP-3
DW-4
DW-5
DW-7
Malpur
DW-17
DW-14
Uparala Khera
DW-11
DW-9
DW-10
Legend
Village
Basin
Drainage
Pack Track
Contour (heights In Mts.)
Lake
Reserved Forest
HP = 3
TW = 1
DW = 18
TOTAL = 22
(Water sample collected)

Map No. 3.15

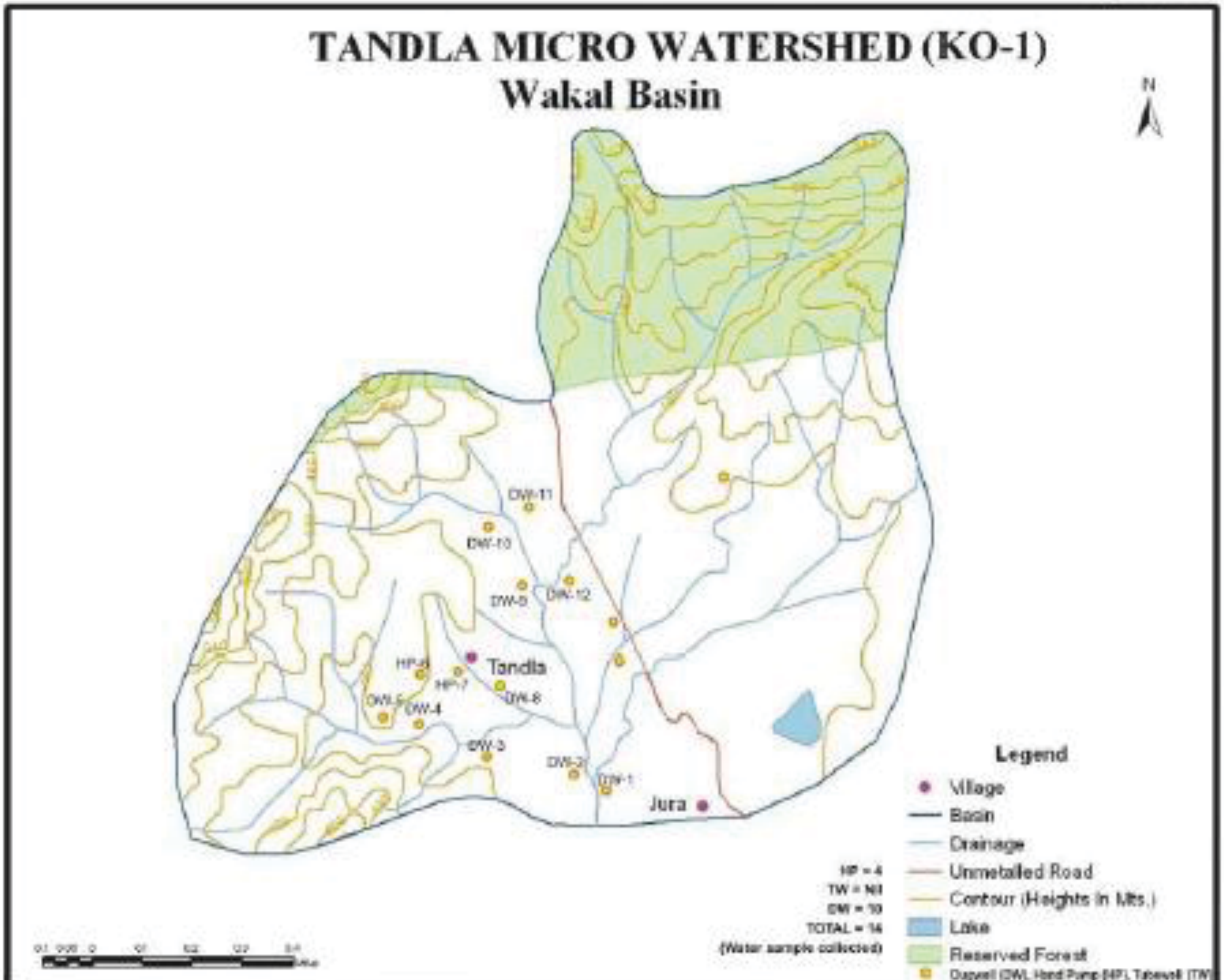

THOBAWARA / KARALI MICRO WATERSHED (JH-3)
Wakal Basin
N
DW-3
DW-4
DW-5
DW-2
DW-6
Thobawara
DW-1
Karali
DW-11
DW-7
DW-8 & 9
Legend
HP = Nil
TW = Nil
DW = 11
TOTAL = 11
(Water sample collected)
Village
Basin
Drainage
Contour (Heights In Mts.)
Reserved Forest
Dugwell (DW), Hand Pump (HP), Tubewell (TW)

Map No. 3.16


UPALI SIGRI MICRO WATERHED (JH-2)
Wakal Basin
N
Upali Sigri
DW-2
TW-3
TW-13
DW-1
DW-8
HP-11
HP-7
DW-9
DW-12
DW-10
DW-6
DW-5
DW-4
Legend
Drainage
Pack Track
Basin
Contour (Heights In Mts.)
Reserved Forest
Village
HP = 5
TW = 2
DW = 14
TOTAL = 21
(Water sample collected)

Map No. 3.18

TANDLA MICRO WATERSHED (KO-1)
Wakal Basin



Map No. 3.19

KALAKHETAR MICRO WATERSHED (KH-1)
Wakal Basin

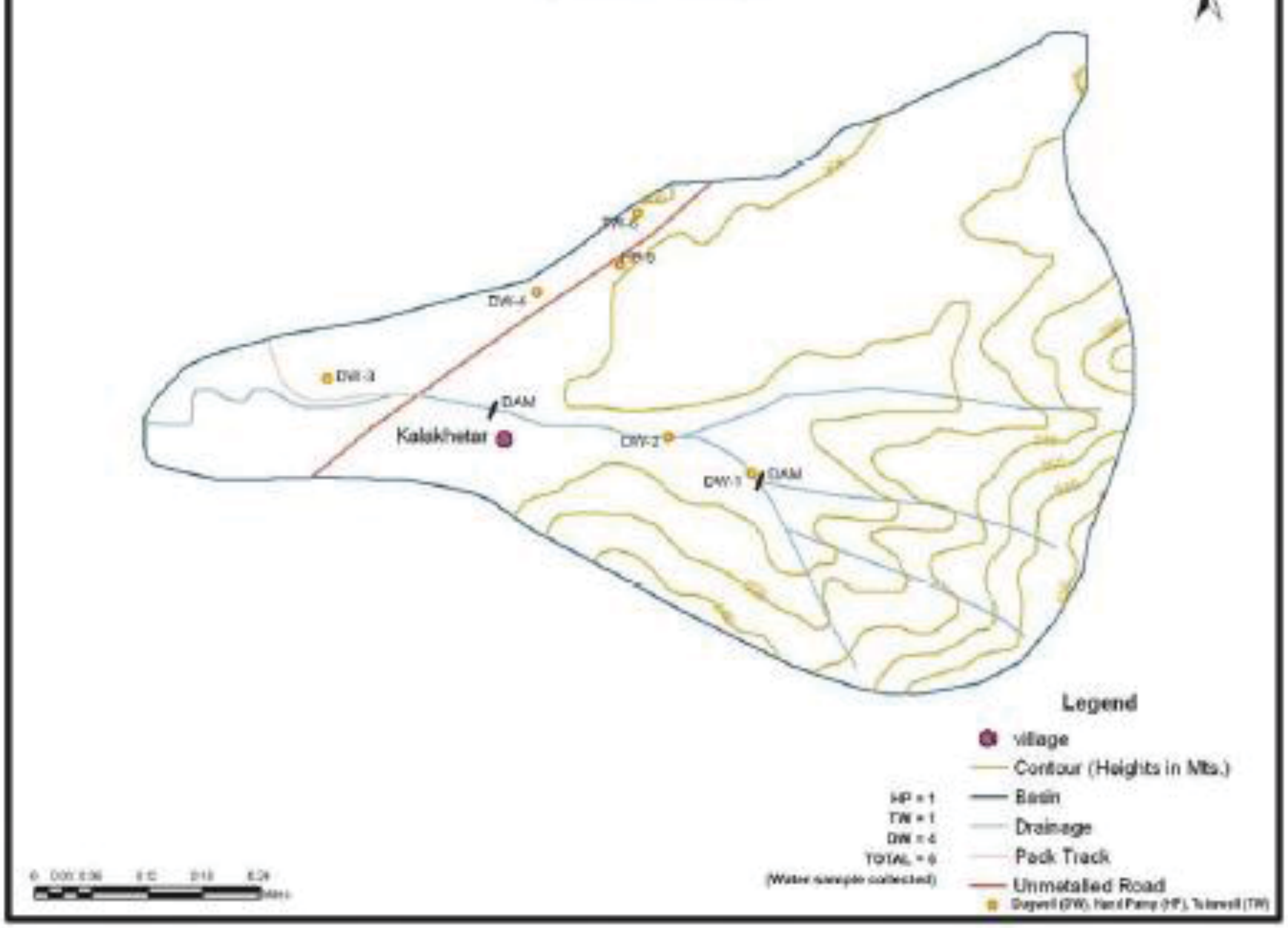


Table: 3.6.1 Hydrochemistry of water sample collected from micro-watershed selected in Gogunda Tehsil (GO-1) at Badundia village.

Parameters	**Permissible Limit**	**GO-1 TW-1**	**GO-1 DW-2**	**GO-1 DW-3**	**GO-1 DW-4**	**GO-1 DW-5**	**GO-1 DW-6**	**GO-1 HP-8**	**GO-1 HP-9**	**GO-1 DW-10**
Color	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less
Odour	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless	Odourless
pH at 25^{o}C	6.5 to 9	7.22	7.39	7.88	7.40	7.30	7.42	7.25	7.40	7.38
Total Alkalinity	100 mg/l	80.0	52.5	65.0	69.2	70.0	75.0	67.5	70.0	62.5
Carbonate Alkalinity	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Bicarbonate Alkalinity	Nil	80.0	52.5	65.0	69.2	70.0	75.0	67.5	70.0	62.5
Conductivity in μs/cm	750 μs/cm	1520	1510	1130	1480	940	1150	1400	1488	1020
Chloride	200 mg/l	210	270	136	230	110	125	155	190	140
Sulphate	200 mg/l	98	130	68	112	58	65	78	92	73
Fluoride	1.00 mg/l	0.58	0.48	0.81	0.83	0.81	0.91	0.93	0.92	0.63
Nitrate-Nitrogen	45.0 mg/l	61	**21**	**38**	49	**21**	**35**	79	68	**30**
Total Dissolve Solids	500 mg/l	836	830	572	785	517	644	770	789	562
Total Hardness	300 mg/l	580	380	400	360	280	300	460	520	360
Calcium Hardness	200 mg/l	340	210	220	200	160	160	280	320	220
Calcium Ion	75 mg/l	136	84	88	80	64	64	112	128	88
Magnesium Hardness	125 mg/l	240	170	180	160	120	140	180	200	140
Magnesium Ion	30 mg/l	58.2	41.2	43.6	38.8	29.1	33.9	43.9	48.5	21.3
Sodium	200 mg/l	80.0	107.5	72.5	110.0	75.0	102.5	70.0	67.5	52.5
Potassium	5.0 mg/l	5.0	2.5	2.5	5.0	2.5	2.5	15	17.5	2.5

Table : 3.6.2 Hydrochemistry of water sample collected from micro-watershed selected in Jhadole Tehsil (JH-1) at Malpur village.

Parameters	**Permissible Limit**	**JH-1 DW-1**	**JH-1 DW-2**	**JH-1 HP-3**	**JH-1 DW-4**	**JH-1 DW-7**	**JH-1 DW-8**	**JH-1 DW-9**	**JH-1 DW-11**	**JH-1 DW-12**	**JH-1 DW-14**	**JH-1 TW-16**	**JH-1 NW-17**
Color	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less
Odour	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less
pH at 25°C	6.5 to 9	7.24	7.52	7.41	7.39	8.11	7.51	7.30	7.56	7.82	7.72	7.96	7.45
Total Alkalinity	100 mg/l	40	20	45	45	95	50	27.5	55	75	65	20	55
Carbonate Alkalinity	Nil	Nil	Nil	Nil	5	10	Nil	7.5	Nil	5	5	Nil	Nil
Bicarbonate Alkalinity	Nil	40	35	45	40	85	50	20	55	70	60	20	55
Conductivity in µs/cm	750 µs/cm	950	640	940	880	1710	1260	360	1070	1190	1020	**9800**	1250
Chloride	200 mg/l	137.5	92.5	87.5	105	187.5	165	40	120	100	87.5	230	187.5
Sulphate	200 mg/l	68	46	43	51	82	76	23	61	48	40	115	88
Fluoride	1.00 mg/l	0.4	0.32	0.41	0.33	0.81	0.31	0.30	0.31	0.30	0.30	0.31	0.29
Nitrate-Nitrogen	45.0 mg/l	49	**42**	**38**	51	62	59	39	57	62	51	110	**40**
Total Dissolve Solids	500 mg/l	482	325	490	436	936	638	191	540	585	512	4980	635
Total Hardness	300 mg/l	320	240	340	320	620	360	140	380	340	340	1740	320
Calcium Hardness	200 mg/l	200	160	200	180	360	180	80	240	200	180	880	200
Calcium Ion	75 mg/l	80	64	80	72	144	72	32	96	80	72	352	80
Magnesium Hardness	125 mg/l	120	80	140	140	260	180	60	140	140	160	860	120
Magnesium Ion	30 mg/l	29.1	19.4	33.9	33.9	63.1	43.6	14.5	33.9	33.9	38.8	208.7	29.1
Sodium	200 mg/l	210	250	170	180	230	180	110	185	165	140	1370	450
Potassium	5.0 mg/l	5	5	5	10	5	5	5	5	15	15	15	15

Note: All values are in mg/l except pH & conductivity is in µs/cm.

Table : 3.6.3 Hydrochemistry of water sample collected from micro-watershed selected in Jhadole Tehsil (JH-2) at Upplisigri village.

Parameters	**Permissible Limit**	**JH-2 DW-1**	**JH-2 DW-3**	**JH-2 DW-4**	**JH-2 DW-6**	**JH-2 DW-99**	**JH-2 DW-8**	**JH-2 DW-9**	**JH-2 DW-10**	**JH-2 HP-11**	**JH-2 DW-12**	**JH-2 DW-13**
Color	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less
Odour	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less
pH at 25°C	6.5 to 9	70.65	7.4	7.20	7.90	7.62	7.6	7.56	7.85	7.81	7.90	7.45
Total Alkalinity	100 mg/l	47.50	48	30	5.0	60.0	45	60	65	75	60	45
Carbonate Alkalinity	Nil	Nil	Nil	Nil	7.5	5.0	Nil	5.0	5.0	Nil	Nil	Nil
Bicarbonate Alkalinity	Nil	47.5	48	30	42.5	55	45	55	60	75	60	45
Conductivity in µs/cm	750 µs/cm	810	1060	650	740	940	800	940	1300	1740	1020	680
Chloride	200 mg/l	95.0	152.5	97.5	60.0	81.0	95	80	145	239	102.5	62.0
Sulphate	200 mg/l	47.0	76.0	46.8	32.6	40.2	46.5	40.8	72.0	108	56.8	33.8
Fluoride	1.00 mg/l	0.70	0.55	0.40	0.62	0.56	0.49	0.55	0.35	0.30	0.70	0.55
Nitrate-Nitrogen	45.0 mg/l	48	**45**	**40**	**25**	**30**	**41**	**31**	**42**	64	60	**42**
Total Dissolve Solids	500 mg/l	415	522	340	368	458	421	460	680	810	518	345
Total Hardness	300 mg/l	220	280	140	285	220	200	222	280	460	260	210
Calcium Hardness	200 mg/l	120	185	80	160	140	110	140	188	255	165	120
Calcium Ion	75 mg/l	48	74	32	64	56	44	56	75.2	102	60	48
Magnesium Hardness	125 mg/l	100	95	60	125	80	90	82	92	205	95	90
Magnesium Ion	30 mg/l	24.3	23.0	14.6	30.3	19.4	21.8	19.9	23.3	49.7	23.0	21.8
Sodium	200 mg/l	221	236	209	198	256	218	255	2619	262	236	219
Potassium	5.0 mg/l	3	3	2	3	2	2	2	3	2	2	3

Note: All values are in mg/l except pH & conductivity is in µs/cm.

Table : 3.6.4 Hydrochemistry of water sample collected from micro-watershed selected in Jhadole Tehsil (JH-3) at Thobawara/Karali village.

Parameters	**Permissible Limit**	**JH-3 DW-1**	**JH-3 DW-2**	**JH-3 DW-3**	**JH-3 DW-4**	**JH-3 DW-5**	**JH-3 DW-6**	**JH-3 DW-7**	**JH-3 DW-8**	**JH-3 DW-9**	**JH-3 DW-10**	**JH-3 DW-11**
Color	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less
Odour	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less
pH at 25°C	6.5 to 9	7.85	7.96	7.65	7.75	7.21	7.95	7.55	7.60	7.66	7.92	7.16
Total Alkalinity	100 mg/l	120	100	90	90	120	98	88	70	83	88	33
Carbonate Alkalinity	Nil	10	10	5	5	5	8	3	5	3.0	8	3
Bicarbonate Alkalinity	Nil	110	90	85	85	115	90	85	65	80	80	30
Conductivity in µs/cm	750 µs/cm	**2100**	1230	1270	1280	1340	1930	1340	1180	1160	1420	580
Chloride	200 mg/l	380	140	135	125	115	160	120	110	105	130	60
Sulphate	200 mg/l	185	72	67	61	56	81	59	53	51	62	32
Fluoride	1.00 mg/l	**1.05**	**1.32**	**0.95**	**0.86**	0.90	**1.41**	0.88	0.85	0.89	0.49	0.54
Nitrate-Nitrogen	45.0 mg/l	49	59	46	**34**	**42**	**41**	**44**	**42**	56	57	**45**
Total Dissolve Solids	500 mg/l	1083	622	632	598	681	972	681	579	584	706	282
Total Hardness	300 mg/l	420	390	400	340	440	360	340	400	420	340	180
Calcium Hardness	200 mg/l	240	220	220	180	260	200	180	210	230	200	100
Calcium Ion	75 mg/l	96	88	88	72	104	80	72	84	92	80	40
Magnesium Hardness	125 mg/l	180	170	280	160	180	160	160	190	190	140	80
Magnesium Ion	30 mg/l	43.6	41.2	67.9	33.8	43.6	38.8	38.8	46.1	46.1	33.9	19.4
Sodium	200 mg/l	315	195	285	190	130	375	275	200	310	270	180
Potassium	5.0 mg/l	5	5	10	20	15	10	10	10	15	10	5

Note: All values are in mg/l except pH & conductivity is in µs/cm.

Table : 3.6.5 Hydrochemistry of water sample collected from micro-watershed selected in Kotra Tehsil (KO-1) at Tandla village.

Parameters	**Permissible Limit**	**KO-1 DW-1**	**KO-1 DW-2**	**KO-1 DW-3**	**KO-1 DW-4**	**KO-1 HP-6**	**KO-1 HP-7**	**KO-1 DW-8**	**KO-1 DW-9**	**KO-1 DW-10**	**KO-1 DW-11**	**KO-1 DW-12**	**KO-1 HP-13**	**KO-1 DW-14**	**KO-1 HP-15**
Color	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less
Odour	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less
pH at 25^{o}C	6.5 to 9	7.30	7.25	7.33	7.45	7.20	7.60	7.45	7.66	7.30	7.38	7.40	7.45	7.21	7.85
Total Alkalinity	100 mg/l	85	75	80	85	90	90	90	75	100	95	95	80	70	65
Carbonate Alkalinity	Nil	15	10	5	5	Nil	Nil	15	10	20	10	10	Nil	5	Nil
Bicarbonate Alkalinity	Nil	70	65	75	80	90	90	75	65	80	85	85	80	65	65
Conductivity	750 µs/cm	1150	1180	1100	1270	1160	1200	1230	1160	1240	1150	1280	1160	1060	770
Chloride	200 mg/l	115	110	90	110	100	115	120	110	110	95	120	**110**	**110**	**60**
Sulphate	200 mg/l	73	55	46	55	51	58	62	56	58	46	63	58	57	29
Fluoride	1.00 mg/l	0.60	0.56	0.54	0.61	0.51	0.54	0.51	0.40	0.42	0.33	0.41	0.43	0.24	0.34
Nitrate	45.0 mg/l	**65**	**63**	**49**	56	**54**	**56**	49	43	44	42	43	**51**	**49**	**39**
TDS	500 mg/l	632	615	620	638	590	599	620	588	635	585	530	590	585	362
Total Hardness	300 mg/l	**380**	**380**	**350**	**380**	**310**	**370**	**400**	**380**	**370**	**290**	**300**	**330**	**310**	**260**
Calcium Hardness	200 mg/l	190	30	220	200	200	180	220	210	150	180	170	170	190	140
Calcium Ion	75 mg/l	76	92	88	80	80	72	88	84	60	72	68	68	76	56
Mg. Hardness	125 mg/l	190	150	130	180	110	190	180	170	120	110	130	160	120	120
Magnesium Ion	30 mg/l	46.1	36.4	31.5	43.6	26.6	46.1	43.6	41.2	29.1	26.6	31.5	38.8	29.1	29.1
Sodium	200 mg/l	155	125	120	170	130	120	135	115	225	190	205	160	135	85
Potassium	5.0 mg/l	2	5	5	5	10	5	10	5	5	10	10	10	5	Nil

Note: All values are in mg/l except pH & conductivity is in µs/cm.

Table : 3.6.6 Hydrochemistry of water sample collected from micro-watershed selected in Kotra Tehsil (KO-2) at Gaopipla village.

Parameters	**Permissible Limit**	**GP/KO2 /DW-1**	**GP/KO2 /DW-2**	**GP/KO2 /DW-3**	**GP/KO2 /HP-4**	**GP/KO2 /DW-5**	**GP/KO2 /HP-6**	**GP/KO2 /DW-7**	**GP/KO2 /HP-8**	**GP/KO2 /DW-9**	**GP/KO2 /DW-10**	**GP/KO2 /DW-11**	**GP/KO2 /DW-12**
Color	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less	Color less
Odour	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less
pH at 25°C	6.5 to 9	7.85	7.76	7.45	7.55	7.39	7.28	7.20	7.33	7.45	7.22	7.32	7.22
Total Alkalinity	100 mg/l	90	178	98	102	100	125	120	125	105	110	120	100
Carbonate Alkalinity	Nil	5	3	3	3	5	5	Nil	Nil	5.0	10	10	5
Bicarbonate Alkalinity	Nil	85	175	95	100	95	120	120	125	100	100	110	95
Conductivity	750 µs/cm	1020	1240	1010	1280	1320	1310	1440	1390	1570	1380	1340	1230
Chloride	200 mg/l	82.5	122.5	130	108	140	150	125	165	160	140	165	**190**
Sulphate	200 mg/l	40	61	65	53	63	72	58	80	76	69	81	92
Fluoride	1.00 mg/l	0.6	0.45	0.35	0.65	0.61	0.56	0.42	0.49	0.48	0.47	0.45	0.46
Nitrate	45.0 mg/l	**32**	**42**	**36**	50	**36**	**40**	53	55	65	50	49	**42**
TDS	500 mg/l	509	615	511	635	670	635	850	765	862	782	732	656
Total Hardness	300 mg/l	**320**	**420**	**304**	**400**	**400**	**420**	**430**	**540**	**540**	**400**	**580**	**420**
Calcium Hardness	200 mg/l	180	240	180	220	230	220	260	260	240	220	300	280
Calcium Ion	75 mg/l	72	96	72	88	92	88	104	104	96	88	120	112
Mg. Hardness	125 mg/l	140	180	160	180	170	200	170	280	300	180	280	140
Magnesium Ion	30 mg/l	33.9	43.6	38.8	43.6	41.2	48.5	41.2	67.9	72.8	43.6	67.9	33.9
Sodium	200 mg/l	175	180	165	195	225	195	195	210	195	255	230	190
Potassium	5.0 mg/l	10	12	10	10	15	15	15	20	10	18	10	12

Note: All values are in mg/l except pH & conductivity is in µs/cm.

Table : 3.6.7 Hydrochemistry of water sample collected from micro-watershed selected in Khedbhrahma District (KH-1) Gujarat at Kalakhetar village.

Parameters	Permissible Limit	KK/KH 1- DW-1	KK/KH 1- DW-2	KK/KH 1- DW-4	KK/KH 1- TW-5	KK/KH 1- HP-6
Color	Color less	Color less	Color less	Color less	Color less	Color less
Odour	Odour less	Odour less	Odour less	Odour less	Odour less	Odour less
pH at 25°C	6.5 to 9	7.31	7.35	7.33	7.20	7.25
Total Alkalinity	100 mg/l	95	100	90	90	90
Carbonate Alkalinity	Nil	05	15	05	Nil	Nil
Bicarb. Alkalinity	Nil	90	85	85	90	90
Conductivity	750 µs/cm	780	780	830	1270	1280
Chloride	200 mg/l	90	**74.0**	87.5	95	95
Sulphate	200 mg/l	42	38	42	55	58
Fluoride	1.00 mg/l	0.20	0.19	0.21	0.22	0.23
Nitrate	45.0 mg/l	**36**	**39**	**41**	52	**41**
TDS	500 mg/l	426	430	448	639	692
Total Hardness	300 mg/l	**340**	**420**	**320**	**570**	**460**
Ca. Hardness	200 mg/l	280	260	280	320	300
Calcium Ion	75 mg/l	112	104	112	128	120
Mg. Hardness	125 mg/l	60	160	40	180	160
Magnesium Ion	30 mg/l	14.5	38.8	9.7	43.6	38.8
Sodium	200 mg/l	85	80	85	110	180
Potassium	5.0 mg/l	5	5	5	5	5

Note: All values are in mg/l except pH & conductivity is in µs/cm.

The analysis also indicate that the electrical conductivity of 360μs/cm is observed in ground water at village Malpur (Dug well) and maximum of 9800 ms/cm at village Malpur in Tube well depth 550' (JH-1/TW-16).

The low salinity in the water shed may be attributed to the fast movement of water through fractures in the aquifer getting less time of contact with formation resulting low level of mineralisation and less salinity. The medium salinity is observed in the Wakal River basin. (Please see the Table 3.6.1 to 3.6.7 for chemical parameters of different water sheds).

NITRATE: Nitrate is among the poisonous ingredient of mineralised waters, with potassium nitrate being more poisonous than sodium nitrate. Nitrogen in the form of dissolved nitrate in groundwater can be attributed to the following reasons:-

1. By rain water
2. Return flow of irrigation,
3. Leaching of nitrogenous fertilizers
4. Human and animal wastes and the product of decay of animal and vegetable proteins.

Analysis have indicated that waters with higher concentration of nitrate, also contain high potassium contents. It is attributed to leaching of residual nitrogenous fertilizers (mineral of potash), or pollution of groundwater by other sources.

Table- Distribution of Nitrate in groundwater.

S.No.	Range of Nitrate (mg/l)	Percent Sample
1.	0 - 50	37 (50%)
2.	51 - 100	37 (50%)
3.	> - 100	0 (-)
	TOTAL	74 (100%)

Above table indicates that most of the area is free from nitrate problem i.e. 50% area is having nitrate less than 50 mg/l. The nitrate content more than 50 mg/l is observed in 50% covering parts of all the studied micro-water sheds).

FLUORIDE: In general fluoride in groundwater occurs through mineral fluorite (CaF_2) occurring both in igneous and sedimentary rocks. The importance of fluoride in forming of human teeth and its intake from drinking water in controlling the characteristics of tooth and bone structure and specially enamel of tooth have been realised only since past 50 years. Though the element is usually present in small amount, its content in natural water has been very extensively studied:-

Table- Distribution of Fluoride in groundwater.

S.No.	Range of Nitrate (mg/l)	Percent Sample
1.	0 - 1	71 (93.42%)
2.	1.0 to 2.0	3 (6.57%)
3.	> - 2.0	0 (-)
	TOTAL	74 (100%)

Fluoride content in groundwater more than 1.00 mg/l observed in Thobawara/ Karali watershed area (Sample No. JH-3/DWI; JH-3/DW-2 and JH-3/DW-6) please see Table 3.6.1 to 3.6.7) Jhadol Tehsil.

HARDNESS, CHLORIDE AND SULPHATE: Hardness in water caused by calcium and magnesium ions is denoted by equivalent CaCO3 concentration. The hardness in the well waters of the district varies from 50 mg/l at Surkhand Khera to 1370 mg/l at Jeewana both of Mavli block.

Total hardness in the range of 0-300 mg/1 is observed in 21.62% of well waters whereas rest 75.67% and 2.70% have 301 to 600 and above 600 mg/1 respectively.

The chloride content in groundwater varies from 40 mg/l at JH-1/DW-9 Malpur, Jhadol Tehsil to 380 mg/l at JH-3/DWL/Thombawara (Jhadol block) Its range of 0-200 mg/1 is observed in 91.89% of well waters while 8.11% well waters fall in the range of 200-1000 mg/l.

The sulphate content in the range of 0-200 mg/1 is observed in 100% of well waters (Please see table 3.6.1. to 3.6.7).

The sulphate content in groundwater varies from 29 mg/l at Tandla (HP-15) to 185 mg/l at JH-3/DW-1 at Thobawara, Jharole Tehsil.

3.5.3 Drinking Water Quality:

The potability of the water has been judged on the basis of "Drinking Water Standard" laid down by Indian Council of Medical Research (1975), which has proposed the acceptable limits and maximum permissible limits in respect of concentrations of various chemical constituents dissolved in water. (Table: 3.6.8).

Water samples of the Wakal River Basin has been grouped in three categories with respect to their potability range as 'A', 'B' and 'C' as per ICMR (1975) standards.

The standards adopted are as follows:-

	A	B	C
Constituents	Acceptable	Tolerable	Excessive
F (mg/l)	0 - 1.0	1.0 - 1.50	Above 1.50
NO_3 (mg/l)	0 - 50	51 - 100	Above 100
EC in microsiemens/cm	0 - 2000	2001 - 4000	Above 4000
Cl (mg/1)	0 - 200	201 - 1000	Above 1000
TH (mg/l as $CaCO_3$)	0 - 300	301 - 600	Above 600

Water having all the parameters in accpetable limits is classified as group 'A', that having all parameters upto tolerable limit as group 'B' water, the one with any one of the parameters beyond tolerable limits, is classified as group 'C' water. If any parameter is above particular group then such water is placed in subsequently higher group. Thus, group 'A' water is safe for all purposes, whereas water under group 'B' is to be used if good quality of water is not available. Group 'C' waters should be avoided for drinking. In all the studied microwatershed samples, except one or two sample can be categorized in Group 'C' which should be avoided for drinking. (Table 3.6.1 to 3.6.7)

3.5.4 Agriculture Quality:

Waters used for irrigation purpose contain varying amounts of dissolved chemical substances, some of these substances improve the soil conditions and plant growth while other constituents present even in traces may be harmful to plant growth. Irrigation waters having excess dissolved salts increase soil salinity and alkalinity effecting adversely the crop productivity. Other factors like climate, topography of the area, soil characteristics/ texture, soil water plant management practices, salt tolerance of crops and effect of fertilizers should also be considered alongwith the chemical quality of water. While rating groundwater quality for irrigation purposes following parameters have been considered.

1. Total soluble salts present in water as determined in terms of electrical conductivity.
2. The proportion of sodium over other cations.
3. The relation of bicarbonate to alkaline earth as residual sodium carbonate (RSC).

The recommendations for irrigation waters is therefore, based on water rating criteria proposed by Anonymous (1972). Irrigation water containing high Na (Sodium) damage the soil characteristic and texture. Soils become impermeable and hard creating serious drainage problem in the area and it also restricts the plant growth. Sodium percentage above 70 creates serious alkali problem in the soils. Application of gypsum directly to the soils is found to be effective in such cases.

The soil of the Wakal River Basin is mostly loamy hence groundwater having EC upto 4000 µs/cm can safely be used for irrigation with proper soil water plant management practices. General quality of groundwater in the district in within the EC range of 2000 µ/cm. (*Source:- Groundwater resource of Udaipur District, GWD, Govt. of Rajasthan, Volume-I, Jodhpur (1999)).*

3.6 GROUNDWATER ASSESSMENT:

Ground water assessment of Sabarmati River Basin (Includes Wakal River Basin) as on 01.01.98 has been carried out as per guidelines of Ground Water Estimation Committee (*Source: Report GWD, Govt. of Rajasthan, 1999)*. The groundwater potential was updated by considering zonewise average water level fluctuations from the year 1993-97, specific yield and rainfall infiltration factor. A separate report of which has already been published. The main points of methodology adopted for groundwater assessment are summarised below:-

- Gross Ground water recharge has been estimated based on GEC guidelines (1984).
- The Ground water potential was updated by considering zonewise average water level fluctuations from the year 1993-1997 and specific yield and rainfall infiltration factor (Please see Table 3.3.1 to 3.3.4, Annexure 1.1 to 1.7 & Plate 1 to 7).
- Recharge from rainfall has been calculated on the basis of normal monsoon and non-monsoon rainfall of the district.

TABLE - 3.7.1

BLOCKWISE AND ZONEWISE SPECIFIC YIELD AND RAINFALL INFILTRATION FACTOR IN WAKAL RIVER BASIN

DISTRICT : UDAIPUR

S.No.	Name of Block	Zone	Specific Yield	Rainfall Infiltration Factor
1	Girwa	Ph./Sc	0.0200	0.08
2	Gogunda	Sc Ph/Sc	0.0150 0.0200	0.08 0.08
3	Jhadol	Ph/Sc Q	0.0200 0.0100	0.08 0.06
4	Kotra	Sc Ph/Sc G	0.0150 0.0200 0.0175	0.08 0.08 0.08

(***Source: Report, Sabarmati basin, GWD Govt. of Rajasthan, 1999)***

- The specific yield and rainfall infiltration factor for assessment purpose have been taken as norms recommended by Groundwater Estimation Committee (Table 3.7.1, Abstract from *Source: Report GWD, Govt. of Rajasthan, 1999)*.

- Annual gross recharge has been computed by adding accepted value of monsoon recharge to total recharge during non-monsoon period.

- Groundwater draft for irrigation has been estimated by comparing the draft obtained by following method.

  a) Number of well in use

  b) Based on crop water requirement

  c) Depletion of water level post-monsoon 1996 and pre-monsoon 1997 *(Please see the Report on Ground Water Resource of Sabarmati River Basin, 1999)*.

- Annual gross draft has been computed by considering annual ground water draft for irrigation and annual ground water draft for domestic and industrial use.

- Net annual ground water draft has been estimated by adding 70% of annual ground water irrigation draft to existing ground water draft for domestic and industrial use.

- Present groundwater balance has been computed by subtracting net annual ground water draft from gross recharge.

- Stage of ground water development has been computed considering net annual ground water draft for all uses against the gross recharge.

- Category of potential zones is decided based on long term trend of water level during pre-monsoon to post-monsoon to pre-monsoon period with considering of stage of ground water development.

- Water requirement for domestic and industrial use as on 2025 is reserved separately instead of keeping 15% of gross recharge.

- Balance future water requirement for domestic and industrial use has been calculated by subtracting ground water draft for domestic and industrial use from water requirement projected for domestic and industrial use as on 2025.

Blockwise and zonewise average yield of wells in Wakal River Basin are presented in Table 3.7.2 and selected microwatershed details as per Annexure 1.1 to 1.7 and Plate 1 to 7.

Potential zonewise hydrographs were prepared on the basis of average water levels of key wells in non-command area to know the long term water level trend. General trends of these hydrographs is similar, showing rise in response to precipitation and decline in response to withdrawal. The study of hydrographs reveals that during the year 1994 due to monsoon rainfall being more than the normal monsoon rainfall, the water level rises considerably and as a consequence, pre-monsoon 1995 water levels are also relatively shallow, whereas in the year 1995 monsoon rainfall was less than the normal monsoon rainfall, the post-monsoon water levels of 1995 show relatively less rise and consequently pre-monsoon 1996 water level shows depletion trend. *(Source: Report on Ground Water Resource of Sabarmati River Basin, 1999)*.

3.7 Artificial Recharge Prospects:

Due to geology, hydrogeology and groundwater regime in nearly all of the basin are, which is occupied by hard rocks, there is very little possibility of incorporating large scales artificial recharge structure. However at few places on the local nalas construction of low cost water relay system may be useful for groundwater recharge. (Table 3.8)

TABLE - 3.7.2

BLOCKWISE AND ZONEWISE AVERAGE YIELD OF WELLS IN SABARMATI RIVER BASIN

DISTRICT : UDAIPUR

S.No.	Name of Block	Zone	NC/C	Mode of Lift	Average yield in Lpd
1	Girwa	Ph./Sc	NC	Without Pump	45000
				With Pump	65000
				T/W	80000
2	Gogunda	Sc	NC	Without Pump	30000
				With Pump	38000
				T/W	60000
		Ph/Sc	NC	Without Pump	45000
				With Pump	60000
				T/W	80000
3	Jhadol	Ph/Sc	NC	Without Pump	48000
				With Pump	60000
		Q	NC	Without Pump	25000
				With Pump	35000
4	Kotra	Sc	NC	Without Pump	25000
				With Pump	35000
		Ph/Sc	NC	Without Pump	30000
				With Pump	45000
		G	NC	Without Pump	30000
				With Pump	40000

(***Source: Abstract Table Report, Sabarmati basin, GWD Govt. of Rajasthan, 1999)***

TABLE - 3.8

GROUND WATER POTENTITAL OF SABARMATI RIVER BASIN (Selected Blocks only which forms the part of Wakal River Basin) AS ON 01.01.98

ESTIMATION OF GROUND WATER RECHARGE IN MONSOON PERIOD BY WATER TABLE FLUCTUATION METHOD

Block	Type of Area	Potentital Zone (Sq.Km.)	Potential Zone Area (m)	Average Water Level fluctuation %	Specific Yield	Change in Ground Water Storage Volume (S)	Gross Ground Water Draft in Monsoon (DW) (mcm)	Monsoon Recharge from Canal (Rc) (mcm)	Monsoon Recharge from SWIG (RSW) (mcm)	Recharge from G.W. Irrigation (Rigw) (mcm)	Rainfall Recharge in Monsoon (Rj) (mcm)	N.F.	Normal Recharge in Monsoon (W.L.F.) (mcm)
1	2	3	4	5	6	7	8	9	10	11	12	13	14
GIRWA	NC	Ph/Sc	71.87	4.37	0.02	6.28	0.92	0.00	0.00	0.21	6.99	1.04	7.27
GOGUNDA	NC	Sc	36.75	6.19	0.02	3.41	0.28	0.00	0.00	0.08	3.62	0.90	3.25
	NC	Ph/Sc	92.87	5.96	0.02	11.07	1.02	0.00	0.00	0.29	11.80	0.90	10.62
JHADOL	NC	Ph/Sc	478.89	3.18	0.02	30.46	3.30	0.00	0.00	0.90	32.85	0.90	29.57
	NC	Q	151.65	2.72	0.01	4.13	0.61	0.00	0.00	0.16	4.57	0.90	4.12
KOTRA	NC	Ph/Sc	84.87	3.68	0.02	6.25	0.48	0.00	0.00	0.13	6.60	0.96	6.33
	NC	G	253.11	2.70	0.02	11.96	1.28	0.00	0.00	0.36	12.88	0.96	12.36
	NC	Sc	374.69	2.74	0.02	15.40	1.63	0.00	0.00	0.45	16.58	0.96	15.92
TOTAL			**1544.70**			**88.96**	**9.52**	**0.00**	**0.00**	**2.58**	**95.89**		**89.44**
Non Command Total			**1544.70**			**88.96**	**9.52**	**0.00**	**0.00**	**2.58**	**95.89**		**89.44**
Command Total			**0.00**			**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**		**0.00**

Cont. ……….

Cont. Table 3.8

ESTIMATION OF GROUND WATER RECHARGE IN MONSOON PERIOD BY WATER TABLE FLUCTUATION METHOD

Block	Type of Area	Potential Zone	Potentital Zone Area (Sq.Km.)	R.I. Factor (m)	Normal Monsoon Rainfall (mcm)	Monsoon Recharge by R.I.F. Approach (mcm)	Recharge from Canal Seepage (Rs.) (mcm)	Recharge from SWIG (Rs.) (mcm)	Normal Recharge in Monsoon (RIF) (mcm)	Normal Recharge in Monsoon (WLF) (mcm)	Variation Factor %	Accepted value of Monsson Recharge (mcm)	R.I. Factor (m)
15	16	17	18	19	20	21	22	23	24	25	26	27	28
GIRWA	NC	Ph/Sc	71.87	0.08	0.58	3.35	0.00	0.00	3.35	7.27	117.03	3.35	0.08
GOGUNDA	NC	Sc	36.75	0.08	0.57	1.69	0.00	0.00	1.69	3.25	92.96	1.69	0.08
	NC	Ph/Sc	92.87	0.08	0.57	4.26	0.00	0.00	4.26	10.62	149.30	4.26	0.08
JHADOL	NC	Ph/Sc	478.89	0.08	0.62	23.77	0.00	0.00	23.77	29.57	24.39	23.77	0.08
	NC	Q	151.65	0.06	0.62	5.65	0.00	0.00	5.65	4.12	-27.09	4.12	0.06
KOTRA	NC	Ph/Sc	84.87	0.08	0.74	5.04	0.00	0.00	5.04	6.33	25.54	5.04	0.08
	NC	G	253.11	0.08	0.74	15.04	0.00	0.00	15.04	12.36	-17.80	12.36	0.08
	NC	Sc	374.69	0.08	0.74	22.27	0.00	0.00	22.27	15.92	-28.51	15.92	0.08
TOTAL			**1544.70**			**81.07**	**0.00**	**0.00**	**81.07**	**89.44**	**335.82**	**70.51**	
Non Command Total			**1544.70**			**81.07**	**0.00**	**0.00**	**81.07**	**89.44**	**335.82**	**70.51**	
Command Total			**0.00**			**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	

Cont. ....

Cont. Table 3.8

ESTIMATION OF GROUND WATER RECHARGE IN MONSOON PERIOD BY WATER TABLE FLUCTUATION METHOD

Block	Type of Area	Potential Zone	Potentital Zone Area (Sq.Km.)	Normal Monsoon Rainfall (mcm)	Normal Non-monsoon Rainfall (mcm)	Non Monsoon recharge from canal (Rs.) (mcm)	Non Monsoon Recharge from SWIG (Rs.) (mcm)	Recharge from Tanks & Ponds (Rs.) (mcm)	Total Recharge in Monsoon (WLF) (mcm)	Recharge from SWT area (Potentital Recharge) %	Annual Gross Recharge (mcm)	Annual Gross Recharge (m)	Annual G.W. Draft for Irrigation (mcm)
29	30	31	32	33	34	35	36	37	38	39	40	41	42
GIRWA	NC	Ph/Sc	71.87	0.05	0.29	0.01	0.02	0.14	0.46	0.00	3.81	3.81	2.86
GOGUNDA	NC	Sc	36.75	0.04	0.11	0.10	0.01	0.01	0.22	0.00	1.91	1.91	1.00
	NC	Ph/Sc	92.87	0.04	0.28	0.02	0.06	0.01	0.38	0.00	4.64	4.64	3.83
JHADOL	NC	Ph/Sc	478.89	0.03	1.29	0.20	0.41	0.71	2.61	0.67	27.04	27.04	12.04
	NC	Q	151.65	0.03	0.31	0.00	0.13	0.00	0.44	0.00	4.55	4.55	2.09
KOTRA	NC	Ph/Sc	84.87	0.03	0.22	0.00	0.00	0.08	0.30	0.00	5.34	5.34	1.69
	NC	G	253.11	0.03	0.66	1.33	0.03	1.15	3.18	0.00	15.54	15.54	4.80
	NC	Sc	374.69	0.03	0.98	0.00	0.13	0.53	1.63	0.00	17.54	17.54	6.04
TOTAL			**1544.70**		**4.14**	**1.66**	**0.79**	**2.63**	**9.22**	**0.67**	**80.37**	**80.37**	**34.35**
Non Command Total			**1544.70**		**4.14**	**1.66**	**0.79**	**2.63**	**9.22**	**0.67**	**80.37**	**80.37**	**34.35**
Command Total			**0.00**		**0.00**	**4.97**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Cont. ....

Cont. Table 3.8

ESTIMATION OF GROUND WATER RECHARGE IN MONSOON PERIOD BY WATER TABLE FLUCTUATION METHOD

Block	Type of Area	Potential Zone	Potentital Zone Area (Sq.Km.)	Annual G.W. Draft for Dom. & Indust. Use (mcm)	Annual Gross Draft (mcm)	Net Annual Ground Water Draft for All user (mcm)	Present Ground water Balance as on 1.1.98 (mcm)	Stage of G.W. Developm ent. (mcm)	Whether significant decline pre-monsoon Water level (Yes/No)	Whether Significant Decline in Post-monsoon Water Level (Yes/No)	Category	Water Reqd. for Dom. & Ind. As on year 2025 (mcm)	Balance future water req. for Dom. & Ind. Use (mcm)
43	44	45	46	47	48	49	50	51	52	53	54	55	56
GIRWA	NC	Ph/Sc	71.87	0.63	3.49	2.63	1.17	69.18	No	No	SAFE	1.21	0.57
GOGUNDA	NC	Sc	36.75	0.09	1.09	0.79	1.12	41.29	No	No	SAFE	0.30	0.21
	NC	Ph/Sc	92.87	0.19	4.02	2.87	1.77	61.84	No	Yes	SAFE	0.76	0.57
JHADOL	NC	Ph/Sc	478.89	0.87	2.91	9.30	17.74	34.39	No	No	SAFE	3.91	3.04
	NC	Q	151.65	0.26	2.34	1.72	2.84	37.68	No	Yes	SAFE	1.24	0.98
KOTRA	NC	Ph/Sc	84.87	0.16	1.85	1.34	4.00	25.15	No	No	SAFE	0.65	0.49
	NC	G	253.11	0.24	5.04	3.60	11.94	23.17	No	No	SAFE	1.95	1.70
	NC	Sc	374.69	0.38	6.42	4.60	12.94	26.25	No	No	SAFE	2.88	2.50
TOTAL			**1544.70**	**2.82**	**27.16**	**26.85**	**53.52**	**318.95**				**12.90**	**10.06**
Non Command Total			**1544.70**	**2.82**	**27.16**	**26.85**	**53.52**	**318.95**				**12.90**	**10.06**
Command Total			**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**				**0.00**	**0.00**

(***Source: Abstract Table Report, Sabarmati basin, GWD Govt. of Rajasthan, 1999)***

4 SUMMARY AND CONCLUSION:

Wakal River Basin covers an area of 1923.85 sqkm along the southern border of Rajasthan, and drains into Gujarat. It is bounded on the north by the Banas and Luni basins, in the east by Banas and Mahi, on the west by west Banas basin. In fact the Wakal basin consists of a separate drainage systems, joining Sabarmati river inside Gujarat.

Result of chemical analysis of groundwater samples collected during the survey indicates groundwater is generally suitable for drinking and irrigation. Few localised patches in Jhadol block have high fluoride contents (Annexure 2.1 to 2.7).

Geochemically analyses of sample collected during Pre-monsoon 2007 from selected 7 microwatersheds (Please see Plate 1 to 7 & Map 3.13 to 3.19).

Normally all the zones in the basin are feasible for construction of dugwells at suitable sites. Dugwell of 3 to 5m diameter and 15 to 20m depth may yield 30,000 to 60,000 litres water per day. Deepening of existing wells by blasting may yield additional 10,000 litres of water per day.

Low duty tubewells can be constructed at suitable sites on the basis of spot hydrogeological survey, which may yield water in the range of 5,000 to 15,000 litres per hour.

The groundwater resources estimation is based on various norms and assumptions. The actual conditions in the field may vary locally. The availability of ground water depends on the local conditions and prevailing hydrogeological environment. Thus it is utmost important to give due consideration to actual field conditions of area while planning and executing Groundwater Development Programme. Moreover all the estimated groundwater balance may not be available for development as major part of it goes to subsurface outflow in hard rock and undulating area.

Due to geology, hydrogeology and groundwater regime in nearly all of the basin area which is occupied by hard rocks, there is very little possibility of incorporating large scales artificial recharge structure. However at few places on the local nalas construction of low cost water relay system may be useful for groundwater recharge. *(Source: Report on Ground Water Resource of Sabarmati River Basin, 1999)*.

5 REFERENCES:

1. Chauhan N.K., Bhu Harsh, Somani R.L. and Raj Sanjay: Hydrogeochemistry and Quality of Ground Water of Bichhiwara Block, Dungarpur District, Rajasthan. Env. Persp. Min. Resour. Utiliz. (MINENV-95), Udaipur. pp 47-54.

2. Chauhan N.K., Nahar T.S. & Porwal C.P. (2001): Abnormal Rise in Water Level in Granite & Rhyolite Terrain Sankra Block District Jaisalmer.

3. Collusion, A.I. 1933. The Geology of Sirohi State, Rajputana Mem. Geol. Surv. India. 63(1), 166p.

4. Garg, S.P. Ground Water and Tubewells. 1993 Oxford and IBH Publishing Co., New Delhi, 344p.

5. Ground Water Atlas of Rajasthan (2003), SRSAC, DST, Govt. of Rajasthan, Jodhpur.

6. Ground Water Resources of Sabarmati River Basin, Aug. 1999, Govt. of Rajasthan, G.W.D. Jodhpur.

7. Ground Water Resources of Udaipur District (1999) Volume-I, Govt. of Rajasthan, GWD, Jodhpur.

8. Ground Water Resources of Udaipur District (1999) Volume-II, Govt. of Rajasthan, GWD, Jodhpur.

9. Gupta, B.C. (1934): The geology of Central Mewar, Mem. Geol. Surv. India. 65, 107-168.

10. Gupta, S.N., Arora, Y.K., Mathur, R.K., Iqballuddin, Prasad, B., Sahai, T.N. and Sharma, S.B. (1980): Lithostratigraphy map of Aravalli region. Geol. Surv. India. Hyderabad.

11. Gupta, S.N., Arora, Y.K., Mathur, R.K., Iqballuddin, Prasad, B., Sahai, T.N. and Sharma, S.B. (1997). Memoirs of the Geological Survey of India. Vol.-123. pp 16-69.

12. Heron, A.M. (1953): The Geology of Central Rajputana. Mem. Geol. Surv. India, 79, 389p.

13. Khatik, K.C. (2001). Hydrogeological Study of Sarada Tehsil, District Udaipur, Rajasthan. A Dissertation Report submitted under supervision of Dr. N.K. chauhan, M.L.S.U., Udaipur.

14. Roy, A.B. and Jakhar, S (2002), Geology of Rajasthan (NW India), Scientific Publishers (India), Jodhpur.

15. Sinha, Roy S.; Mohanty, M. and Malohotra, G. (1998): Geology of Rajasthan, Geol. Soc. India, 1998.

16. Todd, D.K. 1980. Ground Water Hydrology. John. Willey and Sons, 433p.

Annexure 1.1

Hydro geological Data of representative well of selected micro-watershed in Wakal River Basin Project, Udaipur

Watershed No. JH-1 Jharol Tehsil Village : Malpur

S. No.	Name of Well	Co-ordinate	RL in mts.	Depth in mts. (m)	Dimension circular/ Rectangular Diameters	Depth to W.L. in mts. Pre. 07	Hydro-geological formations	USE	Mode of lift	Power of motor	Recouping hours	Remarks (Winter crop)
1	2	3	4	5	6	7	8	9	10	11	12	13
01.	Hamer S. Laxman Singh M/JH-1/DW-1	N 24 29 14.3 E 73 27 13.4	643 m	19.10 m	5 x 2½ m	16.70 m	Q + G MS	I/D	DPS	3HP	2 days	one beegha wheat
02.	Pratap Singh Thakur M/JH-1/DW-2	N 24 29 11.7 E 73 27 9.2	658 m	20 m	4 x 3 m	18.10 m	Q + G MS	I/D	Rehant/ EMS	-	7 days	one beegha wheat
03.	Govt. School, Malpur M/JH-1/HP-3	N 24 29 4.9 E 73 27 18	637 m	200[1]	-	100[1]	Mica schist	D	-	-	-	-
04.	Ganga r. Meghwal M/JH-1/DW-4	N 24 29 9.2 E 73 27 21.9	628 m	21.20 m	5 x 3 m	12.10 m	Mica schist	I/D	Rehant	-	4-5 days	Two beegha wheat
05.	Mohan Meghwal M/JH-1/DW-5	N 24 29 6 E 73 27 22.9	622 m	10.40 m	5 x 3 m	8.70 m	Mica schist	I	DPS on Rent	5 HP	4-5 days	one beegha wheat
06.	Chatan Singh M/JH-1/DW-6	N 24 29 2.1 E 73 27 24.9	621 m	15.20 m	5 x 2 m	10.30 m	Mica schist	I	Rehant	-	Slow 2 days	one beegha wheat
07.	Iswar Prata Thakur M/JH-1/DW-7	N 24 28 59 E 73 27 14.3	629 m	15.40 m	4 x 3 m	6.40 m	Mica schist	I	DPS	5 HP	3-4 days	two beegha wheat
08.	Bhopjee Ba M/JH-1/DW-8	N 24 28 41.3 E 73 27 6.6	634 m	16.70 m	4 mt dia.	7.50 m	Mica schist	I	DPS	5 HP	over night	good discharge

S. No.	Name of Well	Co-ordinate	RL in mts.	Depth in mts. (m)	Dimension circular/ Rectangular Diameters	Depth to W.L. in mts. Pre. 07	Hydro-geological formations	USE	Mode of lift	Power of motor	Recouping hours	Remarks (Winter crop)
1	2	3	4	5	6	7	8	9	10	11	12	13
09.	Samuhik Seva Mandir M/JH-1/DW-9	N 24 28 41.3 E 73 27 7.1	629 m	14.00 m	7 mt dia.	7.60 m	G MS	I	DPS	10 HP	over night	20-25 beegha wheat
10.	Pema Vakta M/JH-1/DW-10	N 24 28 41.6 E 73 27 8.6	634 m	16.70 m	4 m dia.	8.70 m	G MS	I/D	Rehant	-	-	½ beegha wheat
11.	Chatra Vardha M/JH-1/DW-11	N 24 28 43 E 73 27 13.2	634 m	16 m	3 x 3 mt.	10.40 m	GMS	I	Chadas	-	over night	two beegha wheat
12.	Soma Megha M/JH-1/DW-12	N 24 28 44.2 E 73 27 21.6	625 m	15.70 m	5 x 3 mt.	9.90 m	GMS	I/D	DPS	5 HP	2-3 days	wheat 10
13.	Kalu Bhoda M/JH-1/DW-13	N 24 28 46.7 E 73 27 21.2	625 m	11 m	3 mt dia.	7.90 m	GMS	I/D	DPS	5 HP	2-3 days	wheat 2 beegha
14.	Pratap Singh Ji M/JH-1/Dw-14	N 24 28 53.6 E 73 27 23.4	601 M	15.50 m	4 x 5 mt	1.50 mt.	GMS	I/D	EPS	5 HP	NA affected	wheat 15 beegha
15.	Malpur Public Kudi M/JH-1/DW-15	N 24 28 55.8 E 73 27 21.9	621 mt.	19.30 mt.	4 mt dia.	6.30 mt.	GSM	D	-	-	-	-
16.	Shambhu S. Ranawat M/JH-1/TW-16	N 24 28 59.4 E 73 27 22.5	627 mt.	550^{1}	6^{11}	350^{1}	GMS	D	Electrical sub mersible	2 HP	4 Hour	Runnin 30 minitus
17.	Chattar Singh Ranawat M/JH-1/DW-17	N 24 28 55.8 E 73 27 34.5	616 m	17.30 m	5 m dia.	8.70 m	GMS	I/D	Elec. moter	3 HP	3-4 days	wheat 3 beegha

Gran- Granite, Peg- Pegmatite, Sch- Schist, Gn- Gneiss, Amp- Amphibolite, Um- Ultramaphic, GMS- Garnet mica Schist, VQ- Vein quartz

Annexure 1.2

Hydro geological Data of representative well of selected micro-watershed in Wakal River Basine Project, Udaipur

Watershed No. JH-2 Jharol Tehsil Village : Upplisigri

S. No.	Name of Well	Co-ordinate	RL in mts.	Depth in mts. (m)	Dimension circular/ Rectangular Diameters	Depth to W.L. in mts. Pre. 07	Hydro-geological formations	USE	Mode of lift	Power of motor	Recouping hours	Remarks (Winter crop)
1	2	3	4	5	6	7	8	9	10	11	12	13
01.	Kavajee Khokaria U/JH-2/DW-1	N 24 12’ 30.9” E 73^0 24’ 11.5”	588 m	10.40	4 mt. dia.	6 m	GMS	I/D	DPS	5 HP	12 hrs.	1.5 Beegha wheat
02.	Sardarjee U/JH-2/DW-2	N 24 12 33 E 73 24 19.8	594 m	10.70 m	6 m dia.	8 m	GMS	D	-	-	-	-
03.	Laxman Kalal U/JH-2/TW-3	N 24 12 28 E 73 24 16.5	595 m	210’ ft	4½”	80’ ft	GMS	I/D	EPS	1.5 HP sub mersible	12 hrs	-
04.	Sarvajanik Khokharia Phalan U/JH-2/DW-4	N 24 12 19.1 E 73 24 31	587 m	9 m	3 x 3 mt.	7 m	Phyllite	I/D	DPS	12 HP	12 hours	2 Beegha wheat 4 hours running
05.	Kavajee Khokharia U/JH-2/DW-5	N 24 12 18.1 E 73 24 27.6	591 m	15 m	4 x 3 m	7.50 m	Hard Phyllite	I/D	DPS	5 HP	12 hours	wheat 5 beegha
06.	Gambhir L. Khokharia U/JH-2/DW-6	N 24 12 18.5 E 73 24 22.6	599 m	14 m	4 mt. dia	8.50 m	Hard Phyllite	I/D	DPS	2 HP	12 hours	wheat 2 beegha
07.	Samuhaik Gol Amba Bhagora Phala U/JH-2/DW-8	N 24 12 23.9 E 73 23 55.1	580 m	6.60 m	10 mt. dia	6.30 m	Mica Shist	I	DPS	8 HP	over night	3 hours in winter wheat 2 beegha

S. No.	Name of Well	Co-ordinate	RL in mts.	Depth in mts. (m)	Dimension circular/ Rectangular Diameters	Depth to W.L. in mts. Pre. 07	Hydro-geological formations	USE	Mode of lift	Power of motor	Recouping hours	Remarks (Winter crop)
1	2	3	4	5	6	7	8	9	10	11	12	13
08.	Kavaji Bhagora U/JH-2/DW-9	N 24 12 20.5 E 73 23 48.4	580 m	11.40 m	4 mt. dia.	5.0 m	GMS	I	DPS	5 HP	over night	wheat 2 beegha
09.	Rupajee & Broths U/JH-2/DW-10	N 24 12 20.7 E 73 23 59.4	589 m	13.60 m	3 x 3 m	7.50 m	GMS	I/D	DPS	10 HP	over night	4 hours running wheat 5 beegha
10.	World vision U/JH-2/HP-11	N 24 12 22.6 E 73 24 3.7	589 mt.	200’ ft	-	100’ ft	GMS	D	-	-	-	-
11.	Nagji Poonam Chauhan U/JH-2/DW-12	N 24 12 23.9 E 73 24 1.9	578 m	12 m	6 m dia.	9 m	Phyllite	I/D	DPS	2 HP	over night	wheat 4 beegha yield enough
12.	Shambhu Nanama U/JH-2/TW-13	N 24 12 36.3 E 73 24 3.7	597 m	420’ ft	-	-	Phyllite	I/D	EPS	2 HP	over night	2 hours morning & evening wheat 3 beegha

Gran- Granite, Peg- Pegmatite, Sch- Schist, Gn- Gneiss, Amp- Amphibolite, Um- Ultramaphic, GMS- Garnet mica Schist, VQ- Vein quartz

Annexure 1.3

Hydro geological Data of representative well of selected micro-watershed in Wakal River Basine Project, Udaipur

Water shed No. JH-3 **Jharol Tehsil** **Village : Thobawara / Karali**

S. No.	Name of Well	Co-ordinate	RL in mts.	Depth in mts. (m)	Dimension circular/ Rectangular Diameters	Depth to W.L. in mts. Pre. 07	Hydro geological formations	USE	Mode of lift	Power of motor	Recouping hours	Remarks (Winter crop)
1	2	3	4	5	6	7	8	9	10	11	12	13
01.	Vasha Bhera Th/JH-3/DW-2	N 24 24 26.4 E 73 22 50.3	478 m	12 m	4 m dia.	7 m	GMS	I/D	DPS	5 HP	over night	Wheet 1 beegha
02.	Ratnajee Megha Th/JH-3/DW-2	N 24 24 36.1 E 73 22 57.2	491 m	8 m	4 x 3 m	3.5 m	Amph / GMS	I	DPS	2 HP	over night	Wheet 2 beegha
03.	Ratnajee Megha Th/JH-3/DW-3	N 24 24 37.6 E 73 23 2.7	494 m	3.80 m	4 m dia	1.20 m	Amph / bio Gn.	I/D	DPS	5 HP	over night	Wheet 4 beegha
04.	Khumajee Shantajee Th/JH-3/DW-4	N 24 24 37.6 E 73 23 4.9	491 m	2.70 m	3 m dia.	0.90 m	Ampt / GMS	I/D	Persian wheel	Manual	-	Wheet 1 Acre
05.	Ratnajee Roopajee Th/JH-3/DW-5	N 24 24 30.7 E 73 23 14.6	519 mt	5.10 m	3 x 3 mt.	2.10 m	Q/A / GMS	D	Persian wheel	Manual	-	-
06.	Dhanna Hamerajee Th/JH-3/DW-5	N 24 24 26.3 E 73 22 55.9	491 m	5.20 m	3 x 3 mts	3.10 m	A / GMS	I	DPS	5 HP	24 hours	one hours after 12 hours whet 3 beegha
07.	Jalmaji Annaje Th/JH-3/DW-7	N 24 24 18.4 E 73 22 44.5	480 m	9.40 m	5 x 2 mt	4.50 mt.	GMS / Gneiss	I/D	DPS	5 HP	12 hours	Wheet 16 beegha (In Nallah)

S. No.	Name of Well	Co-ordinate	RL in mts.	Depth in mts. (m)	Dimension circular/ Rectangular Diameters	Depth to W.L. in mts. Pre. 07	Hydro geological formations	USE	Mode of lift	Power of motor	Recouping hours	Remarks (Winter crop)
1	2	3	4	5	6	7	8	9	10	11	12	13
08.	Bhuta Lalajee Th/JH-3/DW-8	N 24 24 13.2 E 73 22 45.9	484 m	12 m	5 x 2 m	7.40 m	GMS	I/D	DPS	5 HP	12 hours	Wheet 2 beegha
09.	Jhalu Veerma Th/JH-3/DW-10	N 24 24 11 E 73 22 40.5	484 m	4.70 m	7 x 3 m	2.70 m	Bio-Schist	I	DPS	5 HP	12 hours	Wheet 4 beegha
10.	Khatur Arjan Th/JH-3/DW-11	N 24 24 20.5 E 73 22 40.8	486 m	7.0 mts	5 x 2 m	5 mts.	GMS	I	DPS	5 HP	over night	Wheet 5 beegha

* Sample No. Th/JH-3/DW-9 repeated for sample No. DW-8 for chemical analyses.

Gran- Granite, Peg- Pegmatite, Sch- Schist, Gn- Gneiss, Amp- Amphibolite, Um- Ultramaphic, GMS- Garnet mica Schist, VQ- Vein quartz

Annexure 1.4

Hydro geological Data of representative well of selected micro-watershed in Wakal River Basin Project, Udaipur

Water shed No. GO-1 Gogunda Tehsil Village : Badundia

S. No.	Name of Well	Co-ordinate	RL in mts.	Depth in mts. (m)	Dimension circular/ Rectangular Diameters	Depth to W.L. in mts. Pre. 07	Hydro geological formations	USE	Mode of lift	Power of motor	Recouping hours	Remarks (Winter crop)
1	2	3	4	5	6	7	8	9	10	11	12	13
01.	Keshar S. Jhala B/GO-1/TW-1	N 24 38 19.8 E 73 31 12.1	745 m	350’ ft	4½ TW	120’ ft	GMS + VQ	I/D	EMS	5 HP	Full day	enough water due to canal command area
02.	Bherulal Gameti B/GO-1/DW-2	N 24 38 18.8 E 73 31 12.1	751 m	13 m	4 x 3½ m	9 m	GMS + VQ	I	Rehant	-	-	Not used due to canal
03.	Shiv Singh Jhala B/GO-1/Dw-3	N 24 38 16.7 E 73 31 18.0	755 m	9.80 m	3 x 3 m	4.80 m	GMS	------ Not used due to canal ------				
04.	Mithalal Gameti B/GO-1/DW-4	N 24 38 14.5 E 73 31 20	758	8.25 m	5 x 2 m	6.25 m	GMS	------ Not used due to canal ------				
05.	Shankar L. Nangarsi B/GO-1/DW-5	N 24 38 15.4 E 73 31 24.2	751 m	17.35 m	3½ x 5 m	11.50 m	UM + GMS	I	------ No yield ------			
06.	Mangilal Gameti B/GO-1/DW-6	N 24 38 17 E 73 31 20.8	762 m	12.45 m	3 x 3 mt.	8.70 m	GMS + Phyllitic	------ Not used due to canal ------				

S. No.	Name of Well	Co-ordinate	RL in mts.	Depth in mts. (m)	Dimension circular/ Rectangular Diameters	Depth to W.L. in mts. Pre. 07	Hydro geological formations	USE	Mode of lift	Power of motor	Recouping hours	Remarks (Winter crop)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
07.	Gulab S. Devra B/GO-1/DW-7	N 24 38 19.7 E 73 31 17.9	764 m	14.40 m	3½ x 5½ m	8.10 m	Phyllitic	------ Used only on demand ------				
08.	In Village B/GO-1/HP-8	N 24 38 22.6 E 73 31 15.6	762 m	150' ft	-	100' ft	Phyllitic	D	Hand Pump	-	-	Good yield
09.	Govt. School B/GO-1/HP-9	N 24 38 23.2 E 73 31 12.9	756 m	150' ft	-	100' ft	Phyllitic	D	Hand Pump	-	-	working in all seasons
10.	Pratap S Jhala B/GO-1/DW-10	N 24 38 23.5 E 73 31 6.8	727 m	19 m	3 x 2 mt	6.0 m	Phyllitic	I/D	EMS	5 HP	2 hrs.	fast recouping enough water

Gran- Granite, Peg- Pegmatite, Sch- Schist, Gn- Gneiss, Amp- Amphibolite, Um- Ultramaphic, GMS- Garnet mica Schist, VQ- Vein quartz

Annexure 1.5

Hydro geological Data of representative well of selected micro-watershed in Wakal River Basin Project, Udaipur

Water shed No. KO-1 (Kotra) Kotra Tehsil Village : Tandla

S. No.	Name of Well	Co-ordinate	RL in mts.	Depth in mts. (m)	Dimension circular/ Rectangular Diameters	Depth to W.L. in mts. Pre. 07	Hydro geological formations	USE	Mode of lift	Power of motor	Recouping hours	Remarks (Winter crop)
1	2	3	4	5	6	7	8	9	10	11	12	13
01.	Jeeta Bhana Unaria T/KO-1/DW-1	N 24 30 30.8 E 73 13 07.8	454 m	6.10 m	dia 3 mt	2.60 m	G/Peg.	I/D	DPS	5 HP	2 days	½ beegha wheat
02.	Public Well T/KO-1/DW-2	N 24 30 30.4 E 73 13 4.5	454 m	5.50 m	dia 4 mt.	1.30 m	G/Peg.	I/D	DPS	5 HP	- NA -	2 beegha wheat
03.	Hansa Khema T/KO-1/DW-3	N 24 30 33.6 E 73 12 57.4	457 m	12.00 m	3 x 2 mt.	6.00 m	Calc Sili/G/Peg.	I/D	DPS	5 HP	Two hous	5 beegha wheat
04.	Rupa Bhera Chauhan T/KO-1/DW-4	N 24 30 34.8 E 73 12 49.3	455 m	10.55 m	3 x 2 mt.	5.40 m	GP/Bio.Sch.	D	-	-	-	-
05.	Rupa Chauhan T/KO-1/DW-5	N 24 30 37.9 E 73 12 47.6	467 m	10.50 m	2 x2 mts.	9.70 m	Peg/skarn	Not used	-	-	-	-
06.	Govt. School T/KO-1/HP-6	N 24 30 38.8 E 73 12 52.4	456 m	200[1] ft	-	50-60[1] ft	G/P/Skan	D	-	-	very good yield	-
07.	Govt. H. P. near Lakharm Chouhan T/KO-1/HP-7	N 24 30 33.2 E 73 12 55.8	449 m	150[1] ft	-	40-50[1] ft	G	D	-	-	very good yield	-
08.	Resma Galbajee Chauhan T/KO-1/DW-8	N 24 30 37.6 E 73 12 57.5	459 m	9.00 m	dia 4 mt.	4.40 m	G/Amph.	I/D	DPS	5 HP	3 hours	2 beegha wheat

S. No.	Name of Well	Co-ordinate	RL in mts.	Depth in mts. (m)	Dimension circular/ Rectangular Diameters	Depth to W.L. in mts. Pre. 07	Hydro geological formations	USE	Mode of lift	Power of motor	Recouping hours	Remarks (Winter crop)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
09.	Deeta Kalaji Chauhan T/KO-1/DW-9	N 24 30 41.5 E 73 12 58.1	459 m	10.60 m	5 x 2 mt.	7.60 m	G/Peg.	I/D	DPS	10 HP	over night	45 minutes running only one beegha wheat
10.	Vesha Ram Chauhan T/KO-1/DW-10	N 24 30 55.8 E 73 12 50.2	465 m	4.40 m	6 mt dia	240 m	Bio/Gn/ Gram	D	-	-	-	Insufficient depth
11.	Rama Dhora Damore T/KO-1/DW-11	N 24 30 54.9 E 73 13 3.4	465 m	15.70 m	5 mt. dia	6.20 m	Amp/Gr.	D/I	DPS	10 HP	one day	sufficient depth two beegha wheat
12.	Rafeek Khan Pathan T/KO-1/DW-12	N 24 30 49.1 E 73 13 5.1	459 m	10.80 m	6 mt. dia.	7.40 m	Sch/gneiss	D/I	DPS	10 HP	fast	very good discharge 40 beegha wheat
13.	Govt. HP T/KO-1/HP-13	N 24 30 49.5 E 73 13 10.9	463 m	150[1] ft	-	50-60[1] ft	Weath Peg.	D	-	-	-	-
14.	Govt. well T/KO-1/DW-14	N 24 30 45.9 E 73 13 9.5	457 m	6 mt.	4 mts dia.	1.90 mt.	Weath Peg.	D	-	-	-	-
15.	Govt. School Ghata School T/KO-1/HP-15	N 24^0 30[1] 59.4" E 73 13 21.3"	478 m	200[1] ft	-	60-70[1] ft	Gran/Peg.	D	-	-	-	-

Gran- Granite, Peg- Pegmatite, Sch- Schist, Gn- Gneiss, Amp- Amphibolite, Um- Ultramaphic, GMS- Garnet mica Schist, VQ- Vein quartz

Annexure 1.6

Hydro geological Data of representative well of selected micro-watershed in Wakal River Basin Project, Udaipur

Water shed No. KO-2 (Kotra) **Kotra Tehsil** **Village : Gaopipla**

S. No.	Name of Well	Co-ordinate	RL in mts.	Depth in mts. (m)	Dimension circular/ Rectangular Diameters	Depth to W.L. in mts. Pre. 07	Hydro geological formations	USE	Mode of lift	Power of motor	Recouping hours	Remarks (Winter crop)
1	2	3	4	5	6	7	8	9	10	11	12	13
01.	Bhimraj Ratta Pargi GP/KO-2/DW-1	N 24 19 35.5 E 73 11 22.7	324 m	10.90 m	6 mt. dia.	6.40 m	Calc silicates	I/D	DPS	10 HP	24 Hrs.	Running 1 hr. only ½ beegha wheat
02.	Rata Jeeva Pargi GP/KO-2/DW-2	N 24 19 35.9 E 73 11 26.5	328 m	9.20 m	4 mt. dia.	5.70 m	Calc silicates	I/D	DPS	8 HP	24 Hrs.	Running 1 hr. only one beegha wheat
03.	Chhapru Lal Pargi GP/KO-2/GW-3	N 24 19 26.7 E 73 11 17.4	327 m	13.50 m	4 mt dia.	4.80 m	Calc silicates	I/D	DPS	10 HP	24 Hrs.	Running 1 hr. only ½ beegha wheat
04.	Govt. GP/KO-2/HP-4	N 24 19 11.3 E 73 11 11.5	337 m	200[1] ft	-	35[1] ft	Calc silicates	D	-	-	-	Running well
05.	Babu Pitha GP/KO-2/DW-5	N 24 19 4.2 E 73 11 11.6	343 mt.	11.70	4 mt dia.	3.70 m	Peg/ Bio Sch.	I/D	DPS	8 HP	48 Hrs.	Running 2 hrs. only one beegha wheat
06.	Gujra Deeta Gamar GP/KO-2/DW-6	N 24 19 4.9 E 73 11 13.4	340 mts	14.80 mts	3 mt dia.	3.65 m	Calc silicates	I/D	DPS	8 HP	3 days	Running 2 hrs. only 10 beegha wheat

S. No.	Name of Well	Co-ordinate	RL in mts.	Depth in mts. (m)	Dimension circular/ Rectangular Diameters	Depth to W.L. in mts. Pre. 07	Hydro geological formations	USE	Mode of lift	Power of motor	Recouping hours	Remarks (Winter crop)
1	2	3	4	5	6	7	8	9	10	11	12	13
07.	Nana Bada Gamar GP/KO-2/DW-7	N 24 18 59.1 E 73 11 17.2	342 mts	12.20 mts.	4 mts. dia.	5.60 m	Calc silicate + G + P	I/D	DPS	10 HP	3 days	Running 2 hrs. only 2 beegha wheat
08.	Govt. GP/KO-2/HP-8	N 24 19 06 E 73 11 19	344 mts	200[1] ft		40.50[1] ft	Calc silicale + G + P	D	-	-	-	-
09.	Ganpat Veerma GP/KO-2/DW-9	N 24 19 12.4 E 73 11 22.4	331 mts	19.20 m	5 mt. dia.	10.50 m	Bio Sch. + Gn + VQ	I/D	DPS	10 HP	7 days	2 hrs running only 2 beegha wheat
10.	Suniya Hankra GP/KO-2/Dw-10	N 24 19 16.6 E 73 11 22.1	330 mts	10.70 m	4 mts. dia	6.70 m	Bio Sch. + Gn + VQ	I/D	DPS	10 HP	Next day	2 hrs. only 5 beegha wheat
11.	Khatra Bada Gamar GP/KO-2/DW-11	N 24 19 16.8 E 73 11 12.2	332 m	12 mt.	5 mt. dia.	4.20 mt.	Bio/Sch.	I/D	DPS	10 HP	48 hrs.	2 hrs only 2 beegha wheat

Gran- Granite, Peg- Pegmatite, Sch- Schist, Gn- Gneiss, Amp- Amphibolite, Um- Ultramaphic, GMS- Garnet mica Schist, VQ- Vein quartz

Annexure 1.7

Hydro geological Data of representative well of selected micro-watershed in Wakal River Basin Project, Udaipur

Water shed No. KH-1 (Khedbhrahma) (Gujarat) **Village : Kala Khetar**

S. No.	Name of Well	Co-ordinate	RL in mts.	Depth in mts. (m)	Dimention circuler/ Rectangular Diameters	Depth to W.L. in mts. Pre. 07	Hydro geological formations	USE	Mode of lift	Power of motor	Recouping hours	Remarks (Winter crop)
1	2	3	4	5	6	7	8	9	10	11	12	13
01.	Punma Bhagta Gamar KK/KH-1/DW-1	N 24 20 32.2 E 73 8 58.8	305 m	10 mt.	5 mt. dia	6.50	Calc silicate	I/D	DPS	10 HP	Next day	Running 2 hours 3 beegha wheat
02.	Lakha Hanja Gamar KK/KH-1/DW-2	N 24 20 33.3 E 73 8 55.8	301 m	8 mt.	2 x 2 mt.	7.30 mt.	Calc silicate	I/D	DPS	10 HP	2-3 days	Running 2 hours one beegha wheat
03.	Govt. Bavari KK/KH-1/DW-3	N 24 20 35.9 E 73 8 50	299 m	9 mt.	2.50 mt. dia,	8.70 mt.	Field/ Calc silicate	not used	-	-	-	not used since 20 yrs.
04.	Bheekha Rewa KK/KH-1/DW-4	N 24 20 40.5 E 73 8 54.6	303 n	11.80 m	3 mt. dia.	6.90	Calc silicate	I/D	DPS	10 HP+ 10 HP	2-3 days	Running 2-3 hours only 5 beegha wheat
05.	Vasta Poona KK/KH-1/TW-5	N 24 20 45.8 E 73 8 55.7	297 m	300' ft	6½"	150' ft	Calc silicate	I	EPS Gene-rater	8 HP	2-3 days	2-3 hours only two beegha wheat
06.	Govt. in village KK/KH-1/HP-6	N 24^0 20' 42.6" E 73^O 09' 05'	306 mt.	300' ft	6½"	70' ft	Calc silicate	D	-	-	-	Dry in summer

Gran- Granite, Peg- Pegmatite, Sch- Schist, Gn- Gneiss, Amp- Amphibolite, Um- Ultramaphic, GMS- Garnet mica Schist, VQ- Vein quartz

BADUNDIA G0-1OW6C

BADUNDIA G0-1TW1

BADUNDIA G0-1DW7A

BADUNDIA G0-1HP9A

BADUNDIA G0-1DW4A

BADUNDIA G0-1DWSA

BADUNDIA FIELD PHOTO

BADUNDIA G0-1DW3

BADUNDIA G0-1

MALPUR JH1DW10

MALPUR JH1DW9A

MALPUR JH1DW8C

MALPUR JH1DW7

MALPUR JH1DW6A

MALPUR JH1DWSA

MALPUR JH1DW4A

MALPUR JH1DW2

MALPUR/UPARALA KHERA JH-1


MALPUR JH1JH1DW6


MALPUR JH1HP3A


MALPUR JH1DW17


MALPUR JH10W15A


MALPUR JH10W14A


MALPUR JH10W13A


MALPUR JH1DW12


MALPUR JH1DW11

MALPURIUPARALA KHERA JH-1

UPPLISIGRI JH1HP11

UPPLISIGRI JH1TW3

UPPLISIGRI JH1OW1

UPPLISIGRI JHI1OW2

UPPLISIGRI JH10W4

UPPLISIGRI JHI1 OW6

UPPLISIGRI JH1DW9

UPPLISIGRI JH1DW8B

UPALISIGRI JH-2

THOBAWARA JH3DW8A

THOBAWARA JH3DW7

THOBAWARAJH3DW6A

THOBAWARA JH3DW4

THOBAWARA JH3DW3

THOBAWARA JH3DW2

THOBAWARA JH3DW11

THOBAWARA JH3DW1OA

THOBAWARA JH-3

Plate - 5

GAOPIPLA GPK02DW10

GAOPIPLA •GPK02HP4

GAOPIPLA GPK02DW7A

GAOPIPLA <>PK02DW9

GAOPIPLA GPKO2DW6A

GAOPIPLA GPKO2DW1A

GAOPIPLA GPKO2DW5

GAOPIPLII, GPK02DW2A

Plate - 6 A

TANDLA KO1HP13

TANDLA K01HP7

TANDLA K01DIN14A

TANDLA K01DW10B

TANDLA K01[)W11

TANDLA KO1DW12

TANDLA K01DW9

TANDLA K01DW8


TANDLA K010W5


TANDLA K01OW4A


TANDLA K01OW3


TANDLA KO1DW2


TANDLA K01OW1


TANDLA K01 OW10


TANDLA FIELD


TANDLA KO1DW4

TANDLA K0-1


KALAKHETAR KKKH1TW5A


KALAKHETAR KKKH1TW5


KALAKHETAR KKI<H1HP6


KALAKHETAR KKKH10W4


KALAKHETAR KKKH1DW3


KALAKHETAR KKKH1OW2


KALAKHETAR KKI<H10W1


KALAKHETAR FIELD

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