GEOENVIRONMENTS AND WATER RESOURCES OF BANASKANTHA DISTRICT, GUJARAT STATE.

Summary of the Thesis
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BY

ANANDI MEHRA

Department of Geology
Faculty of Science
M.S. University of Baroda
VADODARA- 390 002.

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SUMMARY

INTRODUCTION

The district of Banaskantha presents an ideal case of diversity of geological environments manifested which infact, gives a bird eye view of the whole state in a relatively a much smaller geographic area of just 12700 sq. km.

The district has been divided into three geoenvironmental units based on terrain attributes and water resource regime; as Eastern Rocky Highland(ERH), Central Alluvial Plain(CAP) and Western Rocky Highland (WSW). The distinct characters in terms of the terrain attributes and water regime is observed. Along the E-W axis, the changes in the determining factors like physiography, geology, climate and water regime are so well defined that each of the three geoenvironmental units has its own independent identity (Table 1).

EASTERN ROCKY HIGHLAND

The Eastern Rocky Highland is located at the southeastern end of the Aravalli mountain chain that provides a distinct and advantageous geoenvironmental setting in respect of its natural resource potential of land, water and vegetation. The land is bestowed with rich mineral resources like base metals, marble, limestone, granite and good quality of the construction materials. The elevations of the neighbouring terrain including Mt. Abu and other high rising hills have played a dominant role in obstructing the northwest monsoon clouds. This has produced a pocket of high average precipitation in the unit.

The structural framework of the metasedimentary rocks and the geometry of the large scale granite emplacement has produced a specific type of the drainage pattern of the rivers of Sipu, Banas, Saraswati providing a large scale surface runoff from the Abu-Jesor-Ambaji hills. The district gets exceptional benefit of hydrogeomorphic conditions of this unit for augmenting its water resources. It is quite interesting to observe that the adjoining districts of Jalor and

Table 1. SUMMERISED INFORMATIONS OF GEOENVIRONMENTAL UNITS OF THE DISTRICT

Characters	Unit	Eastern Rocky Highland (ERH)	Central Alluvial Plain (CAP)	Western Saline Wasteland (WSW)	District Total /Average
GENERAL INFORMATION					
Area	Sq km (%)	3800 (30)	4800 (38)	4100 (32)	12703 (100)
Talukas	-	Danta, Vadgam and parts of Dhanera and Palanpur	Deesa and parts of Dhanera,Deodar, Kankrej and Tharad.	Vav, Santalpur and parts of Tharad and Radhanpur	11 Nos
Population (1991)	Lakh (%)	8.9 (41)	7.3 (34)	5 4 (25)	21.6 (100)
Density (rural)	person/ sq km	195	202	107	211
Total villages	No (%)	609 (45)	377 (27)	382 (28)	1368 (100)
Density	vill. /100 sqkm	16	8	9	11
Towns	Nos.	03	02	03	08
GEOLOGY					
Stratigraphy Exposed	-	Metasedimentaries of Delhi Supergroup and Post-Delhi intrusives and fluvial Quaternary	Gujarat Alluvium of Quaternary period	Mudflats and recent sands of Quaternary sedimentaries of Tertiary and Mesozoic.	Precambrian Tertiray, Mesozoic and Quaternary.
Subsurface	-	-	Precambrians and Mesozoics	Wagad sst, of Mesozoic and sedimentaries of Tertiary	Precambrian, Mesozoic and Tertiary
Structure& Tectonics	-	Folds of 3 generations Delhi-Aravalli orogeny (NE-SW faults), (Delhistrike) and (E-W Post Delhi)	Sanchor-Patan block of Cambay basin and Neotectonism	Eastern part of Kachchh basin and Neotectonism	Precambrian Orogeny, Mesozoic rifting and Neotectonism

1	2	3	4	5	6
CLIMATE					
Aridity Index	%	15 to 25	20 to30	30-40	20-30
Temperature					
Annual Mean	°C	26	28	33	24
Maximum	°C	34	44	46 5	46
Minimum	°C	20	19.5	15	15
Extremes					
Maximum	°C	44	46 (1958)	48 (1886)	48
Minimum	°C	4	2.9 (1954)	1.1 (1929)	1.1
Relative Humidity	%	29	49	50	40
Rainfall					
Average Annual	mm	704	526	462	555
Annual Maximum	mm	1688	1358	1177	1688
Annual Min imum	mm	160	125	21	21
Heaviest in 24 hrs	mm	409 (1893)	532 (1960)	307 (1905)	532
Rainy days	Nos.	31	23	20	24
Dependibility	(%)	50-60	40-50	< 50	40-60
Wind speed	km\hr	5 to 10	11.4	12.1	7 0
WATER REGIME					
Surface Water	-	Banas, Sipu, Saraswati	Banas	Banas	Banas
Rivers					
Runoff	mm	121	62	62	79
Ponds	No.	55	374	391	820
Area	ha	150	913	2117	3240
Storage	ha-m	146	804	2057	3007

Groundwater Occurance Aquifer		Hard rock Unconfined	Alluvium Unconfined & Confined	Alluvium Unconfined & Confined (artesioan)	Quaternary Alluvium, Mesozoic sedimentary.
Recharge Index	(%) Of rainfall	12	15	13	13
Quality	TDS ppm	300-500	500-2000	2000-4000	300-4000
SOILS		Inceptisols and Entisols	Inceptisols and Entisols	Aridsols, Entisols and Inceptisols	Inceptisols,Entisols and Aridisols
NATURAL HAZARDS		Land Erosion	Flood, drought, duststorms, Gully erosion	drought, flood, inundations and duststorms, seismicity zone vi & v	-Easternpart prone to erosion, central part by flood and western part by drought .
ANTHROPOGENIC IMPACT		Mining and Deforstation	Overexploitation of groundwter and Intensive Agriculture	Salinity spread and Dustsrorms	Deforestation, Nining in eastern part, Groundwater mining and Intensive Agriculture in Central part and Desertification in Westernpart.
NATRUAL RESOURSES		Forests,Mineral deposits and surface water	- Soil and groundwater	Pasture	Forest, Ninerals, Soils and Water reosurces.

Sirohi (Rajasthan) in the north and Mehsana in the south does not have this advantage of either rainfall or surface runoff. The ERH unit, thus plays a crucial role in not only producing high rainfall, but it forms the source area for the surface water and groundwater potential for the other two units. Almost entire water resources of the district is predominated and influenced by the Banas and other related river basins, thus justifying the name of the district. A slight change in structural pattern of ERH would have turned the course of the Banas towards Sabarmati. Under that condition, the two adjoining units of CAP and WSW would have been almost like deserts.

The heavy rainfall in ERH unit produces surplus runoff which drains to the adjoining unit of CAP. The steeper bed gradient of ERH suddenly becomes flat and at the junction of the two units the discharge velocity and the carrying capacity of the Banas river reduces considerably. Its bank heights also reduce resulting into the overflow of flood waters in CAP unit and widespread inundation of WSW unit.

In 1972 there was a long wet spell coupled with heavy rainfall in ERH and its upper catchment. Dantiwada dam overflowed with incoming floods. The upper Banas dam (Dhebaria lake) in Rajasthan breached which caused flash floods in Banas. The reservoir rim on the left bank composed of loess sediments gave way to the escaped reservoir water and carved out a new water course for more than 25 km which then joined the Banas downstream of Deesa. This phenomenon caused great loss to the land and property; fortunately there was no loss to life.

In the design of Dantiwada dam, reservoir sedimentation rate from Banas catchment was provided as 361 MCM/km^2. But since its commencement of impounding in 1965, after about 25 years it was observed to have increased to 514 MCM/km^2 (Singh et. al., 1983). The rate increased nearly 1.5 times. This has not only adversely affected the life of reservoir but it increased rate of sedimentation. The average silt loss works out as 1.95 MCM/Yr. with proportional loss of fertile soils which is also significant.

The piedmont zone in the western part of the unit is covered predominantly by thick sheets of loess deposits. The land of the area is favourable sandy texture forms fertile agricultural soils. The soil readily drains away with the flowing water causing large scale gully erosion and ravine formation. Such erosion also extends in the loess covered land in the adjoining CAP unit. Sharma et. al.,(1981) estimated some 155 sq. km area affected by ravine formation in the district which is more than 6% of the total ravine land of Gujarat.

It has total 835 MCM surface water potential. Of this more than 70% has been already harnessed in the major and medium size dam projects but major benefits go to the downstream area. There is an ever growing demand for irrigation, industry and domestic needs. The unit suffers from a paradoxical situation of chronic shortage among plenty of potential.

Hydrogeologically it is a suitable area for large scale groundwater storage. The recharge rate is low in the exposed rocky parts of the area which is also subjected to outflow under gravity. Thus, the resource is not a dependable source for local needs on sustainable basis. This has made designing of large size pipe supply schemes essential for providing drinking water to a majority of villages.

The piedmont zone of the ERH unit due to its hydrogeological conditions of thick granular deposition provides an extraordinary type recharge conditions. The zone has got the highest rate of recharge in the state. It is shared by the local phreatic aquifers and the confined aquifer system of the adjoining CAP unit. Formation of such a common recharge zone in the ERH unit has a great bearing on the groundwater potential of the other two units. It has also a favourable combination of geoenvironmental factors like land, soil, drainage and the water resources. This has helped in the high agricultural production without any adverse problems and the high agricultural productivity have in turn provided a strong economic support to the local population.

CENTRAL ALLUVIAL PLAIN

The Central Alluvial Plain has got a unique combination of favourable geoenvironmental features and rich water resources. The unit is made up of thick cover of Quaternary deposits which produces rich aquifer system. It is endowed with fertile soil cover, rich aquifer system and relatively narrow range of climatic extremes. Moreover it receives large scale of the surface runoff from upper catchment of ERH unit. These are the major favourable geoenvironmental features for this unit. The higher density population and greater concentration of economic activities is the consequence.

Due to ideal combination of land and water resources of the unit, it has become agriculturally the most productive part of the district. A large area of the land is arable with a greater part having irrigation facilities. The terrain factors, especially soil types are most suitable for agricultural purpose.

The environmental factors and parameters are predominantly controlled by the structural features related to the Cambay Basin and the geological history of the Quaternary period. The limits of the CAP unit are marked by the Sanchor Patan Block of the Cambay Basin. Its eastern and western boundaries are delineated by the EMCBF and WMCBF while the northern and southern boundaries are marked by the Luni-Sukri Fault and Banas Fault. The thick Quaternary deposition in the structural basin has produced formation of an ideal aquifer system. The sudden break of steep gradient of ground slope in CAP has proved to be favourable factor for erosion control. The rich nutrient laden sediments received from ERH also get deposited in this unit.

It is interesting to observe that inspite of the low average rainfall , the surface water potential is very high. The large scale surplus runoff from the ERH through several rivers like

Bargaon, Rel, Sipu, Banas, Umardashi, etc. is received by this unit. Banas is the only major river that traverses through the unit, and a major part of its flow is absorbed into this unit and the water of the several smaller rivers is discharged into the unit.

Flood is one of the environmental hazard of the area, but its causes lie in the adjoining unit of ERH. The heavy rainfall in the ERH unit generates greater amount of runoff which causes the dams to overflow. During heavy rainfall, the gates of the dams upstream are opened to regulate the incoming flow and keep the dam free from overflow stresses. The release increases the intensity of flow but in adjoining CAP unit the carrying capacity of rivers reduces due to the falling gradient, thus overbanking floods spread over larger areas. The flood water management in ERH unit paradoxically, creates adverse effects in the adjoining CAP unit.

The major dams built on the Banas (Dantiwada) and Sipu located in the upstream have the irrigation command in this unit. The overall drainage network in the area is sparse. However, the gently undulating terrain has provided excellent sites for waterpool collection fed by runoff from the local drainage, which has given rise to the distribution of surface water bodies as ponds and tanks all over the unit. Although the unit has large surface water potential, its development is relatively rather low since the physiographic conditions do not provide suitable sites for large surface storage.

The surface water bodies in the form of village ponds and tanks which were earlier used to be maintained by the local people are now being neglected, and the local initiative at village level is missing. The geomorphic features are most favourable for small scale storage of surface runoff as ponds and tanks. The fast migrating courses of the streams also have resulted in providing suitable sites for numerous fresh water bodies scattered all over the unit. These water bodies were mainly the source to meet domestic needs. Today, this source has been almost lost.

In respect of groundwater resource the it is an exceptionally a favoured unit. Its geology, has produced a thick aquifer system extending to considerable depth. The large runoff and underflow seepage from the ERH keep the aquifer charged. The average recharge index for the unit is also very high, which is stored in the upper unconfined aquifer system upto the depth of about 150 m. The confined system is more than 400 m thickness and has a very high storage capacity. Considering the average aquifer thickness of the water yielding of the aquifer system with specific yield of 12% for the total area of the CAP unit, the total drainable reserve is rather substantial. The gross storage capcity of the aquifer system upto 500 m depth is nearly five times the storage capacity of the Narmada dam. This underground storage is more than sixty times the average annual recharge potential for the whole of the district.

Since last 30 years, the confined storage is being withdrawn through progressively increasing number of tubewells. The drawl rate has much exceeded the recharge and the piezometric level in the aquifers are dropping at an alarming rate, resulting into 'groundwater' mining condition the adverse of this is observed now turned non-functional openwells and tubewells. The water quality progressively deteriorating. This also had its economic as well as social impacts. Construction and maintenance of deep tubewells being very costly, the smaller and marginal farmers whose shallow wells have dried up cannot afford to own a tubewell. Resource rich farmers and other well-to-do individuals construct tubewells and sell the water to the smaller farmers on exploitative terms and conditions. The government policy of charging electricity at a flat rate encourages the tubewell owners for maximum pumping. A monopolized water market has developed in the area thus having adverse social implications. Shah (1992) has extensively studied the issue and the tubewell owners are described as 'Waterlords' in North Gujarat. The costly water is generally being used for cash crop growing which is provided high doses of chemical fertilizers in order to get higher returns on investments; as a consequence, the soil fertility of the unit has been adversely affected.

WESTERN SALINE WASTELAND

The water resource occurrence is of special nature and its relationship with environment is also unusual in this unit. The unit has almost negligible surface water potential generation related to its own rainfall. The runoff index and its average rainfall are low. Though the adjoining unit of CAP also has the same runoff index, its average rainfall is higher than that of WSW unit. Thus is indicative of the unfavourable terrain conditions of the WSW unit in respect of surface potential generation.

Difference in the pattern of rainfall and topography of the WSW from the other two units located in its upstream have interestingly favourable environmental impacts on WSW unit. The high average rainfall in the ERH and its very high runoff index generates surplus water in Banas river. This surplus water before reaching the Little Rann of Kachchh, spread in the southwestern part of the unit and the entire area gets inundated by a sheet of water of few tens of cm to about a meter depth. The period of inundation ranges from one to four weeks. The salinity of the land gets suppressed by the fresh water and is a benefit for the agriculture and bumper kharif crop was produced. The products were sold in the Marketing Yard of Harij, the nearest taluka headquaters of the Mehsana district. Harij used to receive maximum agricultural produce among all other Marketing Yards of the state. This is an evidence of the agricultural prosperity. Thus monsoon inundation was the gift of Banas to WSW unit. In the past, the inundation used to take place very frequently except during some lean rainfall years, inundation based agriculture was a special favourable environmental feature. In the year 1965, however, a reservoir dam across Banas for irrigation, was constructed at Dantiwada located in the upstream and the inundation phenomenon eventually disappeared. It affected the agricultural production and increase drought occurrence and sudden divesting floods. The Dantiwada dam also resulted in increasing drought occurrences and sudden divesting floods.

In a normal rainfall year, the Banas flow gets stored in the upstream reservoir and the river downstream remains almost dry round the year. Even the climatic and physiographic conditions of the adjoining units are such that, with normal rainfall, no substantial amount of flow is produced to generate any inundation in this unit. Thus for a majority of years no inundation is generated. Contrary to this, during the years of heavy rainfall, the dam overflows but during the days of cloud-burst, the gates are opened for dam safety and to arrange for the incoming floods. During such period of heavy rainfall, the WSW area, which is already flooded all over, there is extra addition of floods intensifies the effects in the area. There were deviasting effects of the 1972 and 1992 floods in the area. Similarly the droughts of 1985-86-87 were very severe. This has affected the agricultural lands by high salinity due to loss of fresh water supply.

Infact, this unit is charactersied by a large number of surface water bodies. Villagers used to collect large quantities of rainfall and the storage was the source for all needs, drinking, domestic and cattle. Vegetables growing in the dried tank beds was a source of income for the rural poor. These water bodies have now greatly reduced in size and number because of siltation and illegal occupancy.

Till late fifties, this unit was dominantly a grassland area and the cattle-rearing was the main occupation of the people. There used to be light rainfed agriculture. During early sixties, irrigation was introduced. Intially it gave boost to agricultrual production but in couple of decades, the groundwater from unconfined aquifers and underground storages over-exploited. The recharge rate also declined drastically due to reduce Banas flow resulting in the depletion of fresh water storages in the shallow aquifers. The consequence was most of the shallow wells went dry. Thus since last more than a decade this unit has almost lost its major water resources of surface as well as underground. The shallow depth aquifers of confined system are all saline and even shallow borings in open well bottom does not help to meet the fresh water needs.

This has wide spread environmental impact in terms of salinity increase, moisture loss, freshwater scarcity and vegetation degradation.

Recently, deep tubewells drilling is on an increase and the selective tapping of the Miocene aquifers of tolerable salinity is done which is partly meeting the irrigation and domestic needs. But the unit is heading for environmental degradation for water resources with an alarming rate.

In the context of the dam construction at Dantiwada and related environmental degradation, the people against the Government for release of dam water and restore the Banas flow to protect their Riparian rights. Government realised the environmental damage and an agreement has been reached for regular release of water from the dam directly, and also through canal outlets, back into the river downstream. The Government has also been persuaded for providing regular release in the river and not to use the storage reservoir for irrigation so the water reaches this unit. WSW region has been also included into the Narmada Project Irrigation Command. But till, the Narmada water reaches this unit the released water from Banas and Sipu will continue to protect the environment in western parts of Banaskantha. This provides a good example of the need of the public awareness and the Government's realisation of the water-related environmental issues.

An Overview

The district comprising such diverse geoenvironmental setup also presents a rare case of natural balancing mechanism such that adverse effects of each unit are controlled and extremes and are maintained within reasonable limits. It is observed that the units when traced a little away from their locations within the district, the extremities of the environmental factors and parameters become harsh and more hazardous. The ERH as traced in its axial direction of northeast towards Rajasthan gets progressively dry and unpleasant while in the CAP unit towards north in its axial extention in Rajasthan, the productive potential of the land and water resources decreases and climatic conditions become more oppressive and the region grades into desert. The WSW, beyond its western border abruptly falls into the saline waste of the Ranns of Kachchh. These short range geographic variations of the environmental features are indicative of rather unique conditions that of the three units of the district. This diversity is predominantly due to the water resource distribution in space and time that marks the environmental conditions of the three units and that for the entire district more favorable to habitation. Water resources of the district therefore, play a key role in the prevailing environments.

On the basis of the studies carried out by the present author on the various terrain characteristics of the Banaskantha district, an interesting scenario of environmental diversity has emerged. Her findings have been summarized in Table 2

TABLE 2: GEOENVIRONMENTAL DIVERSITY AND WATER RESOURCES IN BANASKANTHA DISTRICT.

1	2	3	4	5
Geoenviron-mental factors	Eastern Rocky Highland (ERH)	Central Alluvial Plain (CAP)	Western Saline Wasteland (WSW)	Overall Picture of the District
(A)	**PRIMARY COMPONENTS**			
Geology	Exposed crystalline rocks of Delhi Supergroup and associated intrusives NNE-SSW regional strike, superimposed foldings and three generation faults: NNE-SSW (Delhi-Aravalli strike), E-W (Post Delhi) and NNW-SSE sympathetic to EMCBF margin.	Northern part of Gujarat Alluvium, Quaternary 500 m thick fluvio-marine sequence with aeolian blanket. The boundaries of the unit approximately mark the Sanchor-Patan Block of Cambay Basin. The alluvial plain is subjected to neotectonic activities.	Quaternary deposits upto 150 m thickness of predominantly marine origin with fluvial channel deposits and cover of aeolian sands The Quaternaries underline by thick (>400 m) Tertiary and Jurassic sedimentaries. The unit predominantly forms the eastern part of the Kutch Basin where the Chorar island occurs as horst. The WMCBF marks the eastern limit The unit is neotectonically active	The eastern part comprises Precambrian crystallines, the Central part marks a structural block in Cambay basin filled by thick Quaternary Alluvium and the western part forms the eastern extention of Kutch Basin filled by Tertiary and Quaternary deposits. The Central and western parts are neotectonically active.
Physiography	SW extension of Aravalli mountain chain Erosional landforms of hills and valleys in elevation range of 200 m to about 1000 m. Steep ground slopes (1:25 to 1:100). Close drainage network. Higher order streams are structurally controlled while lower order are lithology controlled. The unit manifests a picturesque landscape	Alluvial flood plain topography superimposed by stabilised sand dunes, in the elevation range of 50 m to 200 m with very gentle ground slope (1:100 to 1:1000) due west. The ERH drainage system enters the area and except Banas all get lost in its sandy plains. The western part is devoid of drainage. The ancient prominent drainage has topographic impressions.	The low level topography (50 m-20 m) represents an ancient esturarine delta The ground is almost plain (1:1000 to 1 5000), except the solitary outcrop of the Chorar horst locally breaking the monotony of flat ground. Drainage is almost absent except the presence of Banas mouth distributary network in SW part of the unit..	The central Alluvial plain on one side flank against the Aravalli hills and merge into saline wasteland on the other side. The ground has a westerly slope (Av. 1:250). The close drainage of the eastern part gets lost in the central part while the western part shows almost desertic characters.

1	2	3	4	5
Climate	Semi-arid with high average rainfall	Semi-arid to arid, and moderate rainfall. Part of the unit is drought -prone.	Arid-desertic, low average Entire unit is drought prone.	High variations from hilly temperate in E to desertic conditions in W.
Hydro-geology	Phreatic aquifer system of Precambrian crystallines Groundwater restricted to shallow (20 to 50 m) depth of low yield (50 to 100 lpm) and of good quality (500 ppm TDS). Piedmont zone has greater aquifer depth (upto 150 m). It forms common recharge zone for aquifers of unconfined in ERH and confined of CAP. The EMCBF forms the hydraulic boundary.	Compound aquifer system of unconfined (upto 150 m) and confined (150-700 m) formed of Quaternary alluvium and Tertiary sedimentaries. The confined aquifers have high yield (800-1500 lpm) with variable quality. The aquifer system is structurally controlled by Sanchor-Patan block of the Cambay basin. The yield and quality reflect the conditions of depositional environment.	Compound aquifer system Unconfined (upto 150 m Quaternary) and confined (150 to 600m Tertiary). The unconfined aquifers are mostly saline with low yield (20-100 lpm) and mostly saline. Shallow sandy aquifers restricted to buried river channels have moderate yield (200-500 lpm) of good quality. The confined aquifer have moderate yield (700 - 1000 lpm) but quality is generally is poor. Yield and quality reflect the environments of deposition. The structural elements of eastern part of Kutch basin and in WMCBF mark the boundary conditions.	Represents an interesting setup of hardrock and alluvial aquifer system controlled by structural pattern related to Precambrian trends and tectonism of N. Cambay basin and E. Kutch Basin The Central part related to Cambay basin has very rich aquifer system of high yield and good quality. The Western part related to Kutch basin has moderate yield of poor quality.

1	2	3	3	4
(B)	**NATURAL RESOURCES**			
Surface Water Potential	High average rainfall and exposed rocky topography generate high runoff (121 mm). Additional runoff from upper catchment enters the unit. Of the total potential, quite substantial unutilised part flows down to adjoining CAP unit.	Medium rainfall average and sand covered plain topography produces lower runoff (62 mm) which produces low potential but it is substantially increased due to downflows from ERH and the unutilsed surplus flows down to CAP and WSW unit	Low rainfall, and flat topography produces lower runoff (62 mm). But the surplus received from CAP unit raises the potential to a significant extent The untapped runoff flows down to the Ranns of Kachchh.	The variable annual rainfall and diverse topography produce low average runoff (83 mm). Quite substantial runoff is received from upper catchment. Majority of the potential has been developed in ERH. The CAP and WSW do not provide good condition for surface storages on a large scale
Groundwater Potential	Low recharge rate (8-15%) in exposed rocky area and high (20-32%) recharge rate in piedmont zone. Both areas have high outflow losses. Total potential 476 MCM/Yr.	Higher rate (22-38%) recharge potential and practically no losses due to outflows. Total potenital 413 MCM/Yr.	Moderate to low recharge (16-27%) rate and outflow losses are almost nil. Total potential 138 MCM/Yr.	Recharge rate varies greatly within (8 to 38%). Total potential 1027 MCM/Yr.
Soils	Inceptisols of hilly terrain and piedmont zone , loamy-skeletal, neutral shallow excessively drained low AWC.	Entisols of alluvial plains; sandy loam, deep, well drained, with medium AWC,	Inceptisols and Aridisols of Paleo-mudflats and aeolian plain; fine clayey loam , deep, slightly drained, saline, alkaline, calcareous, low to medium AWC.	Transitial soils of hills, piedmont, alluvial plain (fluvial aeolian) and palaeo-mudflat. Neutral in central parts and saline in the west.
Minerals	Base metals, marble, limestone, granite, gravel and sand.	Building sands and brick clays.	Building sands and brick clays.	Rich resource of mineral surface water in eastern part, rich land and groundwater in central part and poor resource in western part.

1	2	3	4	5
(C)	**ANTHROPOGENIC**	**FACTORS**		
Main Occupation	Forest products, light agriculture, mines and industry	Intensive agriculture, industry, cattle breading and trading	Pasture, cattle breading, light agriculture	Agriculture cattle breading light industry mining and trading.
Developmental activities	Surface water development by dam construction, stone quarries, metal mining, tourism, pilgrim centers and agro-research activities.	Groundwater extraction by deep tubewells, canal irrigation from Dantiwada dam.	Canal construction of Narmada project, border roads, other transport activities related to Kandla port and Kachchh mines	Dam, stone quarries and industry in the east, groundwater and canal irrigation and industry, in the center and transport and canal proposed in west.
Other factors	Development of industrial growth centers at almost all towns Major concentration along SH 41 and 53	Original pastoral activities changed to irrigated agriculture and agro-industries mainly by outside entrepreneurs.	Original monsoon inundation agriculture is almost vanished and marginalised farmer migrate out or turn to labour jobs Irrigated agriculture through groundwater lift is being introduced.	A transitional phase of large scale pastoral activities changing over to irrigated agriculture Introduction of industrial growth centers and agro-research activities.

1	2	3	3	5
(D)	ENVIRONMENTAL	RISKS AND HAZARDS :	NATURAL CAUSES	
Flood / Inundation	The river channels have sufficient carrying capacity and floods are generally confined within banks. The Dam spillover generate floods in the downstream.	The river channels are flat with lower carrying capacity and floods from upper catchment overbank covering large areas. Dam spills increase the flood intensity and frequency.	Banas, the only drainage has braided mouth and the incoming flood inundate large expense of area. The other flat areas devoid of drainage and clayey substratum also produce local inundation conditions. However inundation is blessings in disguise for the agriculture in this unit.	The ERH flow generates floods for the CAP. The CAP has limited absorbing capacity. The unabsorbed CAP floods create large scale inundation in WSW.
Erosion	The highest erosion rate. Large scale fluvial erosion in rocky parts and gully formation in foothill piedmont zone. The dam reservoirs have remarkably high sedimentation rate.	Moderate erosion rate. The floods cause river bank erosion. Though it is localised, it is quite intense. There is limited but extensive wind erosion affecting top soils.	The meandering curves of streams erode convex bank erosion only, wind also cause limited soils erosion.	The eastern part has highest rate of land and soil erosion while it is least in the western part.
Deposition	Very limited and restricted to only concave river banks as flood terrace pockets. The ancient arid phase has made large scale aeolian deposits as obstruction dunes.	The large scale fluvial load brought in by the Banas and other rivers gets deposited here as flood terraces, levee and channel bars. Most of the present landscape represent cut the blanket of aeolian sand deposition of Quaternary arid phase. Even today some wind blown sand depositions are quite common.	There is large scale fluvial sand deposition in the braided network of Banas mouth zone. There are several other ancient channel sand deposition in the other parts. The entire unit represent a depositional site of estuarine delta of late Quaternary the very recent past.	The eastern part has least deposition while in the central part it is moderate and the maximum deposition is in the western part.

Soil Salinity	All soils are neutral and unit is almost free form salinity hazard.	The soils are mostly neutral but towards western part gradually the salinity increases. The salt laden winds form Rann add to soil salinity	Almost entire unit is covered by saline, alkaline soils, representing inherent salinity of ancient esturarine deposition The salt laden winds from Rann appreciably add to the salinity.	The salinity hazard is almost restricted to WSW, but it is progressively encroaching towards CAP
Drought	Draught is less frequent in the unit generally twice in ten years.	The unit is generally affected by draught situation three times in ten years.	The entire unit is draught prone. More than five years in a decade are dry.	The western part of the district is chronically draught prone.
Seismicity zone	The unit forms a part of Precambrian shield are falling in zone II and III.	The entire unit forms a structural fault block in north Cambay basin falling in zone IV	The unit comprises of eastern part of kutch basin and lying on the western border of Cambay basin falling in zone IV and V.	The zoning progressively increases form II in the east to V in the west

1	2	3	4	5
E)	**ENVIRONMENTAL RISKS**	**AND HAZARDS: HUMAN**	**INDUCED CAUSES**	
Dam construction	Dam construction on major rivers impound normal rainfall runoff in their reservoir, but overspill during high rainfall year. Reservoirs suffer heavy evaporation losses and subjected to high rate of sedimentation.	The high rainfall year receive extra flood from Dam over spill increasing the intensity of flood, resulting greater damage. Dantiwada breach of 1972 caused heavy damage. All post dam floods are always heavy.	The normal rainfall year the area does not receive any inundation due to ERH runoff got stored in dam. Above average year dam spills get absorbed in CAP. During high rainfall years, the dam spills reach to the unit when there is already monsoon inundation. The two combine waters create flood. Thus, the unit lost its age old rainfed agriculture. The soil salinity aggravated and the area turn into Rann like conditions.	Natural flood conditions related to rainfall changed due dam storage. small scale floods and usual inundation disappeared, which intensified the draught conditions. The high rainfall flood got further intensified in the CAP and WOW units. It caused in enhancing the desertification process in the western parts.
Deforestation	Degradation of forests causes reduction in vegetal canopy which increases the rates of soils erosion and intensity of steam flows. It decreases groundwater recharge, which affects soil moisture and crop growth and water scarcity in summer.	The high erosion and speedy runoff in ERH generate flash floods in CAP. River beds get more sediment deposition cause faster bank erosion and shifting the courses causing loss of land and damage to property.	The original grassland changed to agricultural land which enhanced land erosion and also degraded the soils.	Degradation of forests in ERH and grass cover in WSW enhanced soil erosion and gave rise to flash floods in downstream areas.
Irrigation	Groundwater lift caused water level depletion and chronic summer scarcity of drinking water	Overdraft resulted in water level depletion and progressive quality deterioration. Large scale wastage in Dantiwada canal command	Poor quality groundwater use degrades the soils due to continuos addition of salt	Lift irrigation leads to groundwater mining conditions. Canal irrigation results in large scale wastage of scarce fresh water resource.

(F)	FUTURE SCENARIO			
Land Erosion	Loss of soils and nutrients adversely affecting to agriculture, vegetation and groundwater recharge	Convex river bank areas run greater risk.	Convex river banks areas run greater risk	Extensive risk in eastern parts while in other areas it is restricted to only river bank areas
Reservoir Sedimentation	Life reduction due to high rate of sedimentation	Nutrients laden silt supply is reduced with soil degradation.	Nutrients laden silt supply is reduced with soil degradation.	Reduction in reservoir life and soil degradation in downstream.
Dam Failure	Greater risk of hydraulic and seismic failure.	Failure of major dams in upstream will be disastrous in the unit.	Failure of major dams in upstream will be disastrous in the unit.	The alluvial areas have greater risk .
Ponds and Tanks	Not Significant	High rate siltation and reduce storage.	High rate siltation and reduce storage. Progressive reduction in discharge, waterlevel fall and quality deterioration	The central and eastern part face the problem.
Groundwater Recharge	Progressive reduction in recharge rate and water level fall leading to chronic summer scarcity of water supply.	Progressive reduction, in discharge, waterlevel fall and quality deterioration.	Intensity increases due to dam slipover in upstream	Progressive reduction in discharge, water level fall and quality deterioration
Flood	Intensity and frequency increasing due to increasing land erosion in catchment.	Intensity increases due to dam spillover in upstream.	Disappearance of inundation is leading to increasing salinity of soil and groundwater .	Frequency increase in rocky areas and intensity increase in alluvial areas.
Inundation and Salinity	Insignificant	-	Frequency and intensity are increasing with much higher pace leading to desertification	The problem is spreading in western part intensifying desertification.
Drought	Frequency and intensity progressively increases.	Frequency and intensity progressively is on an increase.		Frequency and intensity are on increase which is more cospicuous in the western part

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(G)	SUGGESTED	APPROACH FOR	SUSTAINABLE	DEVELOPMENT
	(APPROPRIATE TO	GEOENVIRONMENTAL	CONDITIONS)	
Rainwater Harvesting	To take advantage of drainage and topography and create large number of surface storage structures.	To revive the old existing ponds and harness the available rainfall to optimum.	To revive the old existing ponds and harness the available rainfall to optimum.	Inset rainwater harvesting by constructing new structures in ERH and revival of ponds in CAP and WSW, taking integrated watershed development approach.
Catchment development and soil conservation.	Catchments of all water harvesting sites be developed by soil conservation and vegetation stabilisation.	Catchment treatment for runoff diversion to pond storage and in situ soil conservation and vegetation stabilization.	Catchment treatment for runoff diversion to pond storage and in situ soil conservation and vegetation stabilisation.	Total watershed development approach for insitu soil conservation and runoff collection in local storages.
Groundwater Recharge	To design all surface storage structures in view of taking best advantage of hardrock hydrogeological conditions.	Regular desiltation of ponds to increase percolation and create groundwater mounds. Sandy stream beds to take advantage for enhancing recharge.	Regular desiltation of ponds to increase percolation and create groundwater mounds. Sandy stream beds to develop as phreatic aquifers.	Design of surface storage structures with a view to take best and advantage of local hydrogeological conditions and to achieve greater recharge. Even the existing storage projects be partly converted into recharge schemes.

Conjuctive use and integrated development of surface water and groundwater resources	Design of irrigation command be made in view of hydrogeological conditions of hard rock terrain. The piedmont zone be taken for best advantage to take available runoff for maximising groundwater recharge.	The canal commands of Dantiwada and Sipu projects should include available groundwater and accordingly cropping be designed. It will increase benefit area. All available surplus surface flows be used for recharging the depleting aquifer systems. Sipu and Dantiwada dam storages be used for augmenting the aquifer recharge.	The unit is included in Narmada canal command. The fresh water supply be planned for salinity control. The local groundwater potential could be developed by taking advantage of ancient buried drainage. Surplus fresh water flows could be utilised for salt flushing from the saline soils.	Eastern and Central parts have good scope with local sources while in western part the external Narmada canal water use by planned in conjunctive with local groundwater. A new approach be developed for maximising the groundwater recharge all over the district. All surface sources be developed with this in view.
Agricultural Practices	Agro-forestry development approach with local conservation of soil and water.	Discouraging water intensive cropping, introduction to modern technique of saving on irrigation water.	Adopting modern technology for saving in irrigation water, and discouraging the water intensive cropping.	Adoption of agro-forestry in hilly areas and discouraging water intensive cropping in alluvial areas. Change over to organic forming form the present practice of physico-chemical approach.