

CHAPTER-5

REGIONALIZATION OF THE STUDIED AREA & ITS GEOMORPHIC CHARACTERISTICS

"Things which we see are not by themselves what we see..... it remains completely unknown to us what the objects may be by themselves and apart from the receptivity of our senses. We know nothing but our manner of perceiving them". (Aristotle)

Little Rann of Kutch, roughly triangular in shape is a monotonously saline flat surface with annual inundation, have executed the Rann a mysterious piece of terrain. Lyell (1855) has portrayed the Rann as a singularly flat region which is neither land nor sea which dries up during some part of a year and again inundated by saline water from the sea side and fresh water from the adjoining land area during monsoon. The Rann of Kutch was a gulf of the sea with surrounding coastal towns (Frere, 1870). Rann of Kutch, a marshy plain, without a equivalent in the globe has been previously associated with the channels of Indus giving existence & richness to the region in the history have left no alive trace of the numerous generations that once settled and it owes its present relief because of the geological process of the Pleistocene. Geological stratification (from top to bottom) is: 1) Quaternaries & Tertiaries, 2) Mesozoic & 3) Pre Cambrian. Little Rann of Kutch is the southward extension of the great Rann and is similar in Physiography, edaphic conditions, ecoclimatic and vegetation but differs in inundation regime. The Little Rann act as a dry land and wet land in different period of the year i.e.

the area experiences a seasonal reversal of geomorphic process. Though the Rann considered being a single unit but still there is variation in terms of its geomorphology and surface configuration and land cover. The tidal mud flat and salt marshy tract of Little Rann of Kutch is encompassed from all sides by well formed ridges.

“The earliest attempt to comprehend all landforms over a wide area into a general classification seems to have been that of Passarges, S. (1919). His scheme was hierarchical and remains one of the most comprehensive produced. It includes (category level; Types (coastal, fluvial landforms etc.) Class (forms suffering from aggradations, erosion etc.), Order (identified main type of process such as tectonic, volcanic etc.), Families (e.g. faulted, fractured) & Kind (degree of family, symmetrical, asymmetrical etc.)”⁴⁹.

In line with the Passarges classificatory scheme and looking to geo-ecological balance of the area, considering prevailing climatic, geomorphological and ecological condition, four geomorphic regions has been identified in and around (two miles of buffer and extending upto gulf of kutch) the Little Rann of Kutch .viz, 1) Fringe Area, two miles of frontier around the study area 2) Dry Rann, Eastern and Central part, 3) Wet Rann with numerous creeks, western part & 4) Islands. (Table- 5.1 & Map-5.1)

⁴⁹ Colin W. Mitchal, (1991) “Terrain Evaluation” Longmans, London (2nd Edition), p-50.

5.1 FRINGE ZONE, TWO MILES OF FRONTIER AROUND THE LITTLE RANN OF KUTCH

This geomorphic region encompasses parts of seventy eight villages of twelve talukas of Kachchh, Patan, Surendranagar, Rajkot and Jamnagar. The entire area act as a transition zone between the main land and the Rann, where both mingle together, losing their characteristics. However there is great deal of variation in terms of the relief of the Rann and the fringe area and thereby giving a different color altogether to vegetation type, soil characteristics and as a whole to ecology of the area. There is not much change in the climatic characteristics but unavailability of the vegetation resulting out of relief and soil type, imparts extreme climate to the Rann. Rivers flowing in the entire surrounding area ultimately drains itself into the centrally lying depression that is the Little Rann of kutch. The rivers draining this area from north to east and towards south and south west are Banas, Saraswati, Rupen, Okaro, Umai, Chandrabhaga, Phulka, Godra, Kankavati, Brahmini, Machchhu and many more minor streams (PlateNo.12-14). The entire fringe area has been rilled (Map-5.2) by these streams and is severely affected by water erosion (Map-5.3). This geomorphic region contrasts more with the Rann than inland area lying out of its boundary. Fringe zone has sharp contrast in terms of land cover as compared with the Rann. Within this fringe zone again there are differences up to some extent in terms of soil type and drainage systems which ultimately gave rise to different type of land cover. The water divides that is Wagad, Radhanpur-Barmer and Saurashtra (Map-5.4) lying in the north-west, east and south respectively reveals that the entire fringe area slopes towards the Little Rann of Kutch but with varying degree (Map-5.5), guiding the perpendicular orientation of the streams. The entire boundary of Rann is almost evenly breached by streams from all sides. However, the major rivers draining this area join Rann only along its eastern and

southern boundary. Fringe zone to the east of Rann has more of biodiversity as compared to its counter part to the south and north-west. Southern part of fringe is moderately covered with the vegetation whereas the north western has least vegetative cover. The eastern part is mainly drained by river Rupen and Banas and the southern part is drained by river Phulka and Bambhan, other streams in this area are very minor.

The entire area has similar geological history, the present surfacial configuration owes to the sub-recent (Holocene) that is prehistoric period between 20,000 to 50,000 years ago, during which area was deposited with newer alluvium. Whatsoever may be the past, at present the surface patterns differ from one area to other. The southern fringe area is characterized by unconsolidated sediments. In the south eastern and along the eastern marginal area, coastal dune dominates. Further in the north eastern area silty sand can be well seen. The entire fringe area is either unconsolidated or is loosely compacted with an exception of Dhrangdhara. Etymologically, 'Dhrang' means strong or tough, 'Dhara' means earth, it means Dhrangdhara is an area of tough rocks. The availability of sand stone may have lead to such nomenclature. Strong Solid rock is often not always solid. Sandstone of Dhrangdhara might have started out as a sand dune or a beach, which got buried and compressed to form hard sandstone. Sandstone of this area is of red colour.

As per the Gujarat Hazard Risk and Vulnerability assessment atlas, this fringe zone share three type of classification on the basis of peak ground acceleration. It is to be noted that the intensity of peak ground acceleration decreases away from the coastal area. Since this earthquake hazard risk zonation was done on taluka level and therefore the fringe area lying within the talukas of Rapar, Bhachau, Maliya are seismically very active while the area lying within Santalpur, Sami, Halvad and

Dhrangadhra is moderate while areas lying within Dasada is less seismically active. The same atlas also divides the area into various cyclone hazard risk zone. In line with the seismicity, the wind speed is also maximum along the coastal area and decreases further towards the inland area. Here speed of wind ranges from 34 to more than 55 m/sec. The variation in the wind speed guides the intensity of aeolian processes.

The fringe area receives rainfall ranging between 625 mm to 375 mm. The entire patch lying in the south and south east receives relatively higher amount of rainfall than its counterpart lying in the west and north east. Owing to meager amount of rainfall in the area the probability of dam flow recorded is less than 20 percent. As per the flood hazard risk zonation map, only the area lying under Sami taluka falls under the flood prone area. However, the area lying within the Dasada and Dhrangadhra taluka also faces the problem of flood. The situation of flood arises not because of the excessive rainfall in the area but rather spasmodic rainfall and the flat topography with shallow, wide and ill defined channel character. As it is evident from the map showing the streams (Map-5.2) and map showing the area affected by water erosion (Map-5.3), there are numerous streams which dissect the area, and this is just because of the relief less topography of the entire fringe zone. Erosional work associated with running water is comparatively maximum in the eastern and southern part of fringe area while it is almost absent in the western fringe zone. However, as per the planning atlas, intensity of fluvial erosion is moderate throughout the fringe area (Map-5.6). The maximum erosional work associated with fluvial action can be seen in the Sami Taluka followed by Santalpur taluka, both of Patan district. This is the area which is drained by two rivers Banas and Saraswati aligning in the direction from north to south. Particularly the Banas branches off into distributaries before entering

into the Little Rann of Kutch. There are some twelve villages in this taluka which adjoins the Little Rann.

District Surendranagar offers a maximum boundary to the Little Rann of Kutch with twenty three villages, extending into three talukas, i.e, Dasada, Dhrangadhra and Halvad. This entire patch is drained by eight streams. Of these three talukas, Halvad and Dhrangadhra is drought prone (Map-5.7).

The condition of non availability of water is not so grim in Dasada largely because of the River Rupen and resultant ground water availability. There are many ponds also in this area. Village Degam gets disconnected from the surrounding area only to become an island during monsoon season. Similarly the area lying within the Maliya and Jodiya of Rajkot and Jamnagar district do not have crunch of water because of the availability of rivers such as Machchhu (Maliya); Jhijhoda, Demi, Aji, Dhadhiaria, Und and Kankavati in Jodiya and this is the reason why intensity of fluvial erosion is high to very high in this area (Map-5.6). The adjoining villages of Rapar and Bhachau, to the north west of Little Rann also comes under drought prone area (Map-5.7). Virtually there are no streams of significance in the area also the catchment area lying to the north of it is too small in its dimension. The entire Little Rann of Kutch including the western fringe shows a high aridity, whereas northern, eastern and southern fringe exhibits semi-arid (medium) climatic condition (Map-5.8). The Bio-climatic zones (Map-5.9) also overlaps over aridity map, showing the Rann and western fringe to be a part of Desert (Kutch) and rest of the study area as a part of Semi Arid Gujarat. On the basis of agro-climatic zones, as devised by Gujarat Ecology Commission (Map-5.10), the fringe area can be divided into three zones that is North West Arid (area lying in Kachchh

district), North Gujarat (area lying in Patan district) and North Saurashtra (area lying within Surendranagar, Rajkot and Jamnagar districts).

Geo-Environmentally, the triangular Little Rann of Kutch and its three fringes (along the sides) are identified into four different regions (Map-5.11) i.e, the Rann (Little Rann of Kutch), the Kutch (western fringe), the Northern alluvial plain (eastern fringe) and the Saurashtra (southern fringe). Geomorphological character (Map-5.12) of the fringe area reveals that in its northern part, elevated and uninundated silty sand nonsaline is available. The south eastern fringe is dominated by old coastal dunes. The southern fringe is identified by the availability of unconsolidated sand, silt and clay in most of the area except in the Dhrangadhra, where sandstone dominates its surfacial configuration. Along the northern fringe of the gulf younger tidal flat and saline flat waterlogged geomorphic character can be well seen. In the northwestern fringe the area shows a rolling surface. There is an acute problem of soil salinity in the entire surrounding area (Map-5.13), except in some patches that is in the area where there is relatively less moisture available in the soil profile. The groundwater salinity in the area is also as high as 2000 parts per million (Map-5.14). The problem of soil salinity is sever in the entire northern, eastern, western, southwestern and southeastern part of the fringe. Salinity in the southern central part is restricted because of the presence of hard sand stone rock surface.

Salinity is one of the most prevalent soil degradation processes on the Earth. Globally, the total area under salt affected is about one billion hectares. Problem of salinity crop up mainly in the arid-semiarid regions of the world. Salt affected soils often have a white or grey salt crust on the ground. The pH of the soil is around 8.5 and the salt interferes with the growth of almost all types of plants.

Following are the factor identified, which are the cause for accumulation of salt in the sediment:

- (i) Poor and limited vertical or horizontal drainage conditions
- (ii) Dynamic force regulating movement of water;
 - (a) Imperceptible Relief element that regulates the surface runoff.
 - (b) Dimension of pores that accomplishes Capillary action.
- (iii) Negative water balance that is, when evapo-transpiration surpasses the amount of precipitation.

The climatic condition (aridity) and the morphology of the Rann and fringe area up to some extent have favored accumulation of salts in many different forms. Salt accumulation in the fringe area is in scattered patches. Several types of salt were identified during the field visit, of which the most common is efflorescence. Such salts are characterized by the deposition of the thin layer of salt as a result of evaporation of moisture brought to the surface through the available pores by capillary action. Needle like salt crystals are also present beneath the surface layer. Such phenomenon is more conspicuous in the fine grained sediments of the Rann and surrounding areas of the Rann having fine grained sediments, which favors moisture rise through capillary action. Efflorescence is very often affected by deflation winds and is easily carried for miles through strong gale. Also, sometimes, they themselves are covered by the layers of fine loessic deposits as a result of erosion and deposition processes by the wind. The thin covering of salt crumbles easily even under little pressure.

Profile wise description:

ZAINABAD

Location: zainabad, a village, 8 km north of Patri town.

Geomorphology:

The area exhibits a flat surface characteristic with slight disruption locally, mainly in the form of many minor shallow streamlets which otherwise remains dry during most part of the year. The streams draining this region discharge their water in the Little Rann of the Kutch, north of Kharghoda. The streams in the region do not have a well defined channel and therefore during rainy seasons the area gets flooded and water remains stagnant in the depression areas. To the north and west of this village, a large part of the area remains a wet land for four to five months after monsoon. During the dry season the area gets veiled under the thin layer of inland sebkhas and efflorescence. The denudational process is negligible in the area because of imperceptible relief. However, on a microlevel erosional processes during rainy season and aeolian deposits in the form of loess and salt cannot be ruled out.

Vegetation:

The geomorphology of the area and water availability supports relatively adequate amount of vegetation, even in this extreme climatic condition. The area shows sharp contrast with the surrounding barren Rann. The density of the vegetal cover decreases westward. Types of vegetation in the area are low rise tufted thorny shrubs with numerous arms, covering a larger part of area. Such physiological adaptation reduces the direct loss of soil moisture. Other vegetations are small cactus plants, grasses (along the water bodies, resembling to the other marginal grassland areas), sankhpuspi, Accasia etc.

Description of soil profile:

The soil profile of the area indicates mixed characteristics of soil owing to the work of different depositional agents during different period. The soil profile is not very consolidated and shows thin layers of varying characteristics. Merely a visual inspection reveals that the concentration of sand particles are more in the area than in the Rann. The top soils of the relatively lowlying area is encrusted with thin film of salt and exhibits minor cracks when dried.

The sample of Soil profile collected in the specified location was taken at an interval of 10 inches, including top soils; total 3 samples were collected for all tests except for mechanical analysis where 4 samples were collected at an interval of 6 inches, including one of the surface, usually a thin salt encrusted layer. Laboratory test shows the percentage of moisture content increases with increasing depth. The moisture content increased to almost three times at a depth of 20 inches. However, water content was slightly low in the top profile. Water holding capacity does not show a particular trend, it was maximum at a depth of 10 inches and decreased further below, it was minimum in top profile. The sediment analysis shows there is a presence of coarse sand even at 20 inches though at a very less amount. The fineness of the texture increases with increasing depth. The percentage of silt and clay increases with increasing depth whereas sand particles decreased with depth. Overall, the soil type is loam with plastic index of 17 %. Natural volume decreases with increasing depth. Natural volume and compact volume is maximum at the top profile. Porosity in percentage was maximum (35.6) at a depth of 20 inches. Porosity reduced to one sixth for the top profile. The figures of bulk density reveal the relatively more compactness of the upper soil profile.

RIGHT BANK OF RUPEN

Location: Close to bank of river Rupen, 5 km. north of Visnagar

Geomorphology:

The area is plain with rolling imperceptible slope from Visnagar town towards the west and merges with Rann. The surrounding area is adequately drained by river Rupen and many streamlets. The streams in this area are numerous and are very shallow, wide and without any particular stream line. Roads in this area are so designed that there is no need of bridge. The roads are made depressed in order to drain the water of streams during rainy seasons, which other wise remains dry through out the year. Apart from the Rann in continuum in the west, there are many small patches of saline waste to the north of river Rupan. The maximum and minimum height in the vicinity ranges from 79 feet in the south east to 42 feet in the northwest. There is sharp decrease in the height towards west because after a few Km. the river merges to the Rann. Here the boundary of Little Rann is very irregular. A good volume of water remains in the river through out the year. Volume of water depends upon the amount of rainfall received and the water stored in the reservoir at upstream area. The fine sediments brought by the river during flash floods get deposited in the surrounding area along the both bank of river in the form of very thin layer above the loamy sand, which gets separated during dry season forming thin flakes of clay. The river bed and bank is usually sandy with a thin layer of mud on the top, which makes the water turbid (muddy) even with the little disturbance. Looking to the soil characteristics it is apparent that infiltration rate will be much pronounced in the area. Owing to the presence of loamy sand, cracks do not develop at all. During the rainy season the percolation of the water is uniform from top to bottom. Processes of deposition and erosion is limited by its low relief, however, there is an exchange of finer particles through channel water during rainy season.

Vegetation:

With the availability of water and moisture present in the area, there is ample coverage of vegetation. The xerophytes in the area show luxuriant growth. There are various layers of vegetation in the area. There is sharp contrast in terms of land-cover of this area and the Rann.

Description of soil profile:

The soil profile of the area does not show much variation with the depth. Merely with visual identification one can say that the soil is sandy. The soil in this area is of loamy sandy type with a very high percentage of fine sand. The top soil is encrusted with thin film of salt but in patches. The salt formed here are coarser than that of found in the Rann.

The sample of soil profile collected in the specified location was taken at an interval of 10 inches, including top soil; total 3 samples were collected for all tests except for mechanical analysis where 4 samples were collected at an interval of 5 inches. Laboratory test shows the percentage of moisture content was higher in the area and shows a very slow decreasing trend. The higher moisture content may be attributed to the water holding capacity of the finer sediment. Water holding capacity also shows a similar trend, it was maximum on top and decreased further below. The percentage of coarser sand was maximum on the top of the profile and decreased very high in this sample. Overall, the percentage of sand in the entire sample is around 80 % which is highest amongst the sample. There was no substantial variation in the sediment size properties at different depths. The soil type here is loamy sand with plastic index of 14 %. Natural volume is highest of upper section of the profile and decreases further below and is because of the superincumbent load. Porosity in percentage was maximum (38.7) at a depth of 20 inches.

Porosity reduced to one sixth at upper section of the profile. The water holding capacity was maximum at top layer and therefore moisture was also higher. The figures of bulk density reveal the relative less compactness of the soil. The hygroscopic absorbing capacity of the sample of the similar areas remained low at varied level of humidity percentage. Hygroscopic absorbing capacity ranges from 5.23-7.73 % with changes in humidity from 40-80%.

Photographs covering various aspect of the fringe area have been shown in Plate no. 1-5.

5.2 DRY RANN, EASTERN AND CENTRAL PART OF LITTLE RANN OF KUTCH

Dry Salt Rann accounts for maximum area running from eastern part of Little Rann of Kutch to the central and even upto some extent the western parts too. This part of Little Rann of Kutch is largely affected by the extreme of aridity. The area remain dry and barren with high ambient temperature reaching upto 48°C leading to the aeolian geomorphic process at large in the summer season. "At least two generations of buried Aeolian deposits alternating with marine (beach) sediments are inferred" (Wardha, S.K.). Lithologically the areas top most layer is comprises of fine wind blown pale brown sand (Aeolian origin) followed by the coarse to medium grained reddish brown sand with Quartz and Calcareous rocks (Fluvio-marine origin), which implies the transgression & regression of sea level in sub recent era. Peninsular India witnessed the fluctuation in the sea level in the coastal areas during Jurassic, Lower Cretaceous & Miocene times. Drifting may have caused the temporary incursion of sea. The general Characteristics of this part of Little Rann are not different to that of the north and northwest of Khavada hill of great Rann of Kutch. This is the reason why at certain point of discussion, the Great Rann of Kutch is being referred. The extreme of high temperature in this area leads to the

occurrence of storm leading to upliftment and movements of sand particles further towards the eastern side resulting to the geomorphic processes like attrition, abrasion, deflation and desertification. Whereas during monsoon season numerous minor & major streams discharge their water into the Rann depression.

The worked out aridity Index of Kutch (1970-1994) is 2.86, which is significantly low but not so low as in case of extreme desert climate (Relation: Lower the Aridity index higher is the absolute aridity). The Humidity index for the same period is 19.48 (Agricultural Handbook, Gujarat, 2000) again it is significantly high but not so high as in case of extreme desert (Relation: higher the humidity index lower is the absolute Humidity) and that is why a combined process of fluvial as well as aeolian that is fluvio-aeolian process are very much active giving a characteristics of fluvio-aeolian origin to the lithology. The whole area is affected by strong winds and occasional rain from May to October and frequently flooded to the depth of 60 cm (Report on Wild Ass Sanctuary, Gujarat Ecological Society) on an average. Most of this water is inland water from the rivers like Rupan, Saraswati, Banas, Jhijhora, Machhu, Godadhroi and local streams and also marine water driven by the south west wind, relatively lesser in its volume and extent (Map-5.15, 5.16). The flood water when they dry up leaves a hard flat surface covered with gravels, pebbles, sand and salt. The fineness of the debris increases with the distance from the fringe towards the Rann. With the onset of summer the ground is baked and blistered by the sun and shines with dazzling whiteness of the salt as the heat increases. Eastern margin is dotted by several isolated permanent sand dunes known locally as Thali i.e. heap of sand.

In the interior of Rann, the surface exhibits itself in terms of dark brown surface configuration with wide and deep cracks with veneer of salt.

Generally in the semi arid regions of the tropics and sub tropics, there is pre dominance of deep dark coloured clay soil, particularly in the flat topographical areas. Such deep and dark coloured clay are called Vertisols. Dark colour of soil is related to either parent material or presence of manganese oxides. The dark brown-black color of the Rann sediment is attributed to the parent material lying in its catchment area of basaltic geological structure.

Vertisols are formed under multiple genetic processes which are multifaceted. In general, soil forming processes that lead to the formation of Vertisols are those which manage the development and stability of expansion in the soil. However, secondary processes, such as fluctuations in the moisture condition, accretion of organic matter, carbonates, gypsum or soluble salts and acidification processes through leaching, result in the variability within the Vertisols.

The cracks of the Rann remain open for more than 90 cumulative days per year and hence are known as Usterts (based on the classificatory scheme considering duration of open cracks and soil structure). Globally, this suborder is the most extensive of the Vertisols order, encompassing the Vertisols of the tropics and monsoonal climates in India, U.S., Australia and Africa.

The shrinking and swelling of vertisols can damage buildings and roads, leading to extensive subsidence, and therefore inspite of huge traffic engaged in the salt mining, road connectivity is in poor shape. Areas characterized by availability of vertisols are generally used for grazing of cattle or sheep. Many a time, livestock get injured through falling into cracks in dry periods. However, the shrink-swell activity allows rapid recovery from compaction.

The surface of the Rann ranges from granular to dense massive, with angular blocky structures. Such surface configuration is the result of the

pressure developed as a result of expansion and contraction of the clay with response to drying and wetting of the soil. With the increase in the wetness, peds develop slickensides i.e, shiny surface which appears as one ped slips over another during expansion. The contraction, resulting out of loss of moisture in the soil results to the contraction and thereby leads to the formation of wide and deep cracks.

The more interior area of the Little Rann of Kutch has proportionately very high content of clay and at the same time becomes very dry during the summer and excessively wet during the monsoon season. Such extremity in the weather phenomenon around the year is absent in the fringe area.

The Rann sediment also underwent self mulching or self swallowing through the process of pedoturbation or churning, a process which homogenizes the soil profile through the infilling of the cracks by surficial material during dry season.

The lateral swelling pressures in the Rann is much larger than vertical swelling pressures, as the latter is substantially reduced by the overburden pressure.

The distinctive microrelief features of the Little Rann of Kutch are the presence of knolls (mounds) and basins (depressions). The moisture content in the basins is always higher comparatively because of the accumulation of water during rainy season. These basins often exhibit higher salinity and organic content. These microbasins and microknolls show a repetitive but irregular pattern on the Rann surface. Such topography related to clayey soil with higher plasticity is called ' Gilgai micro-topography.

The occurrence of flooding in the Rann leads to a complex combination of the dampness of the Rann sediments, surface movement and the sub surface movement of water over them. Whatever the source, surface water, sea, river or rain, the conduct of the Rann sediment is really fascinating. However, the transfer of water horizontally or vertically leading to the wetness of the Rann is regulated by two important properties, that is field moisture capacity (infiltration capacity) and permeability of the sediment.

Talking on the absorption capacity of the sediment at given condition, Horton (1933) suggested that infiltration capacity would decrease exponentially in time from a maximum initial value to a constant rate. This movement or hydraulic conductivity has also been defined by Buckman and Brady (1967). They were in the opinion that as the difference in moisture content varies from one area to another area, the moisture adjustment starts working in order to equate them, and this process increases in terms of rapidity within the area with greater variation. The hydraulic conductivity or the ability to transmit water through sediment was found to be highly variable and is in relation to the available field moisture.

Also, the same above process is directly related to the sediment characteristics and property, as for example, well sorted gravels and sand, allows a very higher conductivity, whereas the conductivity is absolutely low in case of heavy fine grained compact sediment like as those of the sediments of the Little Rann of Kutch.

Factors that emerge to control the infiltration capacity of Rann sediment includes:

- (i) Amount of water applied
- (ii) Available field moisture capacity

- (iii) Infiltration capacity of sediment
- (iv) Moisture conductivity of the upper and subsequent lower horizon of the profile and thereafter
- (v) Texture and structure of the various sediment horizon

All the above factors influence the percolation of moisture down the sediment profile. Sediments having fine texture, as that of the Little Rann of Kutch, have very low percolation rates. Infiltration rate in the Rann sediment is exceedingly high initially because the deep and wide cracks holds enormous amount of water. However gradually the infiltration rate slows down and ultimately made to almost halt because those cracks are choked by the swelling loose sediments lying on the surface (Figure- 5.1). Moreover, infiltration rate is slower in the clay dominant sediments.

Water infiltration is the movement of water from the soil surface into the soil profile. Soil texture, soil structure, and slope have the largest impact on infiltration rate. Water moves by gravity into the open pore spaces in the soil, and the size of the soil particles and their spacing determines how much water can flow in. Wide pore spacing at the soil surface increases the rate of water infiltration, so coarse soils have a higher infiltration rate than fine soils but they can not hold water for long.

Soil texture refers to the comparative proportions of sand, silt, and clay. As for example; A loamy sand soil contains larger amount of sand as compared to the content of silt and clay when combined together. loam soil contains these three types of soil particles in roughly equal proportions. Where as silty clay loam contains a larger amount of silt followed by clay and a very small amount of sand. Other types of texture can be referred from the table 5.2

Table-5.2 Soil texture designations ranging from coarse to fine at various identified Geomorphic Regions:

	Texture Designation	Geomorphic Regions
	Coarse-textured	Along the fringe zone, coarseness increases towards northern and western part
	Sand	
	Loamy Sand	
	Sandy loam	
	Fine Sandy loam	
	Loam	
	Silty loam	
	Fine-textured	Rann sediment, clay content increases towards center
	Silt	
	Silty Clay loam	
	Clay loam	
	Clay	

Soil structure is distinct from soil texture in a way that it refers to the clumping together or "aggregation" of sand, silt, and clay particles into a still bigger secondary cluster. When a handful of the soil crumbles easily in the hand then it is considered to be a good soil. Such behavior indicates that the sand, silt, and clay particles are aggregated into granules.

Both soil texture and soil structure determine pore space for air and water circulation, erosion resistance, looseness, ease of tillage, and root penetration. Texture is related to the minerals in the soil and does not change with agricultural or other anthropogenic activities; whereas structure can be altered by human interferences.

With increases in moisture, compactibility and bulk density of the sediment increases, as that of Rann sediment at lower horizon, till the moisture content is approximately at the field capacity point, than a condition known as the optimum moisture content for compaction is reached. Nevertheless, compactibility of the lower horizon Rann sediment is also attributed to the pressure of overlying sediment. At still higher

moisture content, the soil becomes increasingly incompactible as water fills ever more pore space. The compaction of an overloaded wet soil becomes minimal and thus plastic flow may result in the complete destruction of soil structure and macro-pores. However, referring to the latter case, even if there is appreciable increase in the moisture, plastic flow is limited only upto the filling of cracks and not the mud flow from one area to another in the Little Rann of Kutch, largely because of its flat topography.

It was observed that the dimension of the cracks were proportional to the amount of clay present in the sediments. Sediments with heavy clay had deeper cracks and vice versa in case of medium to low clay sediments. In the sandy loam, and loamy sand, cracks were completely absent. The rate of infiltration was found to be rapid in the horizon upto the depth of cracks while infiltration rate decreased quickly further below owing to the characteristics of the sediment (clayey and compaction) and also greater moisture content of the sediment below.

The infiltration rate of a given sample at given point of time is also the function of moisture content of the sediment prior to its exposure to the rain or subjected to wetting. Hence infiltration rate is slowed down in accordance with the field storage capacity. Similar relationship between available field moisture and infiltration phenomenon can be well seen in the works of Blake, Hartge, Brasher, Davidson, Cresswell and Mc. Kenzie. It was observed that the sediments showing higher field moisture takes relatively more time in the infiltration processes as compared to the sediments having lesser field moisture. This relationship was revealed through the lab test after adding water to the same samples with varied amount of moisture content within them.

One more reason for the slow infiltration is the puddling of the Rann sediment owing to the falling drops of rainfall which strikes on the bare

ground, resulting into churning and increases in the turbidity, which chokes up the opening, which allows downward movement of water. Bennet (1955) has stated that clear water penetrates into the sediment much faster than muddy water because of the fine suspended material which tends to choke the openings and impedes downward movement. This phenomenon is ideally seen in the Little Rann of Kutch where the climatic condition does not allow growth of vegetation, and therefore the barren ground is adversely affected by falling drops of rain, which in turn do not allow surface water to percolate downward. The above discussions also throw light on why the dry Little Rann of Kutch gets inundated even with very scanty amount of rainfall.

Though the tests for permeability is not carried out, however looking to the nature, composition and porosity of sediments a clear picture can be deduced. Soil porosity refers to the space between soil particles, which consists of various amounts of water and air. Porosity depends on both soil texture and structure. For example, a fine soil has smaller but more numerous pores than a coarse soil. A coarse soil has bigger particles than a fine soil, but it has less porosity, or overall pore space. Water can be held tighter in small pores than in large ones, so fine soils can hold more water than coarse soils. However, the rate of permeability in the fine soil will be much slower as compared to the coarse soil.

Permeability depends upon the grain size of sediments and therefore the permeability is low to very low, often designate as impervious for the samples taken from the Little Rann (Eastern, central and western wet zone). The sediment sample collected from the fringe zone shows more porosity and permeability, which increases with the depth. However, the top section of the profile shows a very low porosity, owing to the availability of the fine wind blown particles veiling the fringe area. The

pudding, as discussed in the above paragraph, also reduces the porosity and thus permeability.

It is also apparent from the works of Davis (1967), that the suspended clay particles makes a coating on the surface when settles, interceding the gaps of sediments and thereby rendering imperviousness to the sediments. The permeability within the sediments reduces with the increase in the clay. And thus, the abundance of clay in the Rann sediments increases the imperviousness.

The sample analysis also reveals that the porosity of the dark coloured clay is very less, as for example the samples collected from west of Kharaghoda, near Surajbari Bridge and Gagodar shows relatively very less porosity and is true with permeability. Since the amount of clay in the soil is lesser in case of the fringe area and bet and therefore, the porosity is very high and so is permeability. There is a fundamental relationship in between the abundance of clay and stagnation of water in the depression area. The water could not find its way down quickly because clay chokes the gaps, at the same time stagnation of water fastens the clay forming processes. Roy (1973), in his work also mentioned the absence of seepage in the sediments of Great Rann of Kutch. Roy observed that even though standing water was present less than 200mtrs away, a pit dug showed dry base.

Photographs covering various aspect of the eastern dry Rann have been shown in Plate no. 6-8.

Lack of permeability coupled with imperceptible gradient, poor drainage and runoff enables the water of varied sources to remain stagnant for long, especially in the depression area and shallow channels.

The results of the various test conducted with the sample sediments are as follows:

- (i) The proportion of Clay is dominantly very high as compared to other.
- (ii) The plasticity index is very high
- (iii) High Water holding capacity.
- (iv) Low Porosity.
- (v) Higher surface salinity
- (vi) There is no significant difference in Natural volume and Compact volume.
- (vii) Higher hygroscopic absorption capacity.

Properties of the sediments of the Little Rann of Kutch thus inferred are:

- (i) The soil is compact and firm.
- (ii) The field moisture is higher and it increases with the depth.
- (iii) Process of infiltration is much slow as compared to the sediments of the fringe zone.
- (iv) The sediment is impermeable.
- (v) Rann sediment shows hyper sensitivity to the humidity present in the air. It is evident from the field and laboratory test that the Rann soil becomes moist even with the slightest of moisture in the air, through hygroscopic absorption. Hygroscopic absorption for a given relative humidity increases with increasing amount of clay associated with salt.

Profile wise study:

KHARAGHODA

Location: 7 km west of Khadaghoda old station/ town towards the Rann.

Geomorphology:

The area is monotonously plain. There is a rolling imperceptible slope from Kharaghoda town and other surrounding marginal area towards the Rann. Small streams drain their water in the Rann from all marginal areas around. Infact the entire Rann gets inundated with water, coming from inland area and sea. However, this part of Rann is relatively at higher height than that of its counter parts lying west of it and therefore remains drier during most part of the year. By and large this area gets inundated only through river water during rainy season. There are a few mounds of low height scattered around. Inter bet channels were relatively wet during field visit (October, 2008). Fresh foot prints of birds; barely a week old was testimony to it. With the onset of summer season, the rising temperature dries up the soft mud to brittle state passing through plastic state and solid state, forming huge deep cracks. Development of cracks indicates the characteristics of soil that is, presence of clay in higher amount and also its plastic behavior owing to the presence of clay. These cracks are later filled by the fine loose material through winds. During the rainy season the percolation of the water is not uniform from top to bottom. The deep crack portion gets saturated faster than the top. Processes of deposition and erosion is limited by its flat topography, however, there is an exchange of finer particles through wind. Because of the moisture content in the area, weathering process is pronounced. During the rainy season the area gets flooded even with a very small quantity of rain because of slow percolation rate in the clayey soil. Also, hygroscopic behavior of the soil is as such that it absorbs water from the air and therefore, the area becomes soggy even with increase in the humidity in the air.

Vegetation:

Though the area is not to far from the surrounding mainland but the area is absolutely barren with no vegetation at all, and is because of the saline character of soil and lack of moisture during most part of the year.

There is sharp contrast in terms of land-cover of the Rann and the surrounding area of the Rann.

Description of soil profile:

The soil profile of the area indicates different depositional agents and period. The top soil exhibits the properties of vertisols, with huge deep cracks. The top soil is encrusted with thin film of salt which easily cracks down while walking. Physically the surface appears to be dissected hexagonally as far as one can see.

The sample of Soil profile collected in the specified location was taken at an interval of 10 inches, including top soil; total 3 samples were collected for all tests except for mechanical analysis where 4 samples were collected at an interval of 6 inches, including one of the surfaces, usually a thin salt encrusted layer. Laboratory test shows the percentage of moisture content increases with increasing depth. The moisture content increased to almost three times at a depth of 20 inches. However, water holding capacity does not show a particular trend, it was medium on top maximum at a depth of 10 inch and decreased further below. The percentage of coarse sand was nil beyond 12 inches. The fineness of the texture increases with increasing depth. The percentage of silt and clay increases with increasing depth whereas sand particles decreased with depth. Overall, the soil type is clay with plastic index of 58 %. Natural volume is low at the middle and deepest part of profile. Porosity in percentage was maximum (22.8) at a depth of 10 inches and so the water holding capacity; porosity reduced to one fourth at a depth of 20 inches; whereas it was 14.7 % at the top soil. The figures of bulk density reveal the compactness of the soil. The hygroscopic absorbing capacity of the sample remained high at varied level of humidity percentage, of all the samples. Hygroscopic absorbing capacity ranges from 10.30-14.85 % with changes

in humidity from 40-80%. During the month of December to April The visibility even during day time is brought to zero because of the fine dust resulted out of vehicular movement during salt mining, Vehicles has to use fog light even during day time. The entire area remains veiled under fine dust, as far as it can reach.

GAGODAR

Location: Saline inorganic clay, Approx. 5 km east of Gagodar village

Geomorphology:

The area is dismally plain. There is a rolling imperceptible slope from north and west towards the Rann. Small streams drain their water in the Rann from all marginal areas around. There is relatively wider stream to the south of Gagodar which also discharges its water in the Rann, south of the location of the sample. To the north of the location, there is a hill rising upto a height of 104 feet. This part of Rann is relatively at lower height than that of its counter parts lying east of it and therefore remains wet during most part of the year. This area gets inundated even during spring tides. The area remains inundated upto a greater depth and for longer duration of time during monsoon and post monsoon respectively. Foot prints of birds, barely a few week old can seen. With the onset of summer season, the rising temperature dries up the soft mud to brittle state passing through plastic state and solid state, forming huge deep cracks. Development of cracks indicates the characteristics of soil that is, presence of clay in higher amount and also its plastic behavior owing to the presence of clay. These cracks are later filled by the fine loose material through winds. During the rainy season the percolation of the water is not uniform from top to bottom. The deep crack portion gets saturated faster than the top. Processes of deposition and erosion is limited by its flat topography, however, there is an exchange of finer particles through wind. Because of

the moisture content in the area, weathering process is pronounced. During the rainy season the area gets flooded even with a very small quantity of rain because of slow percolation rate in the clayey soil. Also, hygroscopic behavior of the soil is as such that it absorbs water from the air and therefore, the area becomes soggy even with increase in the humidity in the air.

Vegetation:

Though the area is not too far from the surrounding mainland but still it is absolutely barren with no vegetation at all, and is because of the saline character of soil and lack of moisture during most part of the year. There is sharp contrast in terms of land-cover of the Rann and the surrounding area of the Rann.

Description of soil profile:

The soil profile of the area indicates different depositional agents and period. The top soil exhibits the properties of vertisols, with huge deep cracks. The top soil is encrusted with thin film of salt which easily cracks down while walking. Physically the surface appears to be dissected hexagonally as far as one can see.

The sample of Soil profile collected in the specified location was taken at an interval of 10 inches, including top soil; total 3 samples were collected for all tests except for mechanical analysis where 4 samples were collected at an interval of 6 inches, including one of the surfaces usually a thin salt encrusted layer. Laboratory test shows the percentage of moisture content increases with increasing depth. The moisture content increased to almost twice at a depth of 20 inches. However, water holding capacity also shows a similar trend, it increases from top to bottom. The percentage of coarse sand was nil beyond 12 inches. The fineness of the texture increases with increasing depth. The percentage of silt and clay increases

with increasing depth whereas sand particles decreased with depth. Overall, the soil type is clay with plastic index of 45 %. Natural volume is low at the deepest part of profile. Porosity in percentage was maximum (21.06) at a depth of 20 inches and so the water holding capacity; porosity reduced to more than half at the top soil. The figures of bulk density reveal the compactness of the soil at upper layer, which is maximum at top where as it reduces further below. The hygroscopic absorbing capacity of the sample remained high at varied level of humidity percentage, of all the samples. Hygroscopic absorbing capacity ranges from 8-10.57 % with changes in humidity from 40-80%.

It has been observed that the humidity along the ground level even during the dry season is high in the Rann area as compared to the barren fringe area. Moisture along the ground level is increased by the capillary rise in the area. Moreover the fate of water falling on the surface under arid and semi-arid climatic condition is as such that either it is absorbed by the plant root, if any or becomes the part of runoff, which directly evaporates or penetrates only upto a minimum depth only to come out again in the form of capillary rise, thereby, causing an increase in the overall moisture values of the soil.

Puri (1949) has equated the sediments with a bundle of capillary tubes to which the law of surface tension and capillary could be applied. The capillary pull exerted by a sediment column to raise water, or the negative pressure required to pull water from a saturated column, is approximately equal to the reciprocal of the diameter. This notion is very much applicable to the larger part of study area, which shows fineness of grain size and thereby high capillary action. Though the extent of capillary rise has not been calculated in the laboratory, the field study has sufficiently confirmed the fact.

The calculated values of capillary rise in sediments given by Millar and Turk (1949)⁵⁰, shown in the table-(5.3) gives an idea of the connection that exists between the sediment size and capillary rise.

The work of Hogentogler (1937) also states that "below water table, in the case of sand the moisture content is 20.4 % by weight of dry sand and above the water-table the capillary fringe has a moisture content of 0.6 %. Whereas in silts the moisture content below water table is 40 % and the capillary fringe extends upward from the water table to a distance of 4 meters with a moisture content of 36 %"⁵¹.

Table-5.3 Capillary rise in sediments

Time	Height of rise in inches		
	Sand	Silt loam	Clay
½ hour	13.5	7.3	5.4
1 hour	14.3	11.2	8.0
6 hour	16.6	26.6	15.5
12 hour	17.2	35.3	18.5
1 days	18.4	46.4	21.0
3 days	20.3	65.4	24.7
6 days	21.8	78.5	27.3
9 days	23.0	86.3	28.8
18 days	25.3	99.2	33.2

⁵⁰ Millar, C.E. and Turk, L.M., (1949) Fundamentals of Soil Science. John Wiley and Sons, Chapman & Hall, P-165.

⁵¹ Hogentogler, C.A., (1937), Engineering properties of soil. Mc. Graw Hill book company, p-122.

The above discussed works gives an idea about the intensity of capillary rise in fine grained sediments. In the Rann and adjacent surrounding area, the presence of salt encrustation proves the very extent of capillary rise. These salt deposits are generally known as efflorescence deposits, which results out of the evaporation of subsurface water brought to the surface through capillary action.

Consequently, in view of the various factors acknowledged and discussed above to explain the moisture content of Rann sediments, it is likely that because of the fineness of the sediments, the customary field moisture content is high even during the driest period. Rise of water through Capillary action is very extensive in the Rann sediments and there by increasing the already high soil moisture value. Thus, the whole profile from the surface downwards remains relatively moist even under natural dry conditions.

5.3 WET RANN WITH NUMEROUS CREEKS, WESTERN PART

This region is an intertidal and transitional zone between Gulf of Kutch and the Little Rann of Kutch. This region is exposed to diurnal tides. This region is characterized by the medium fine sediments, with dominating characteristics of fluvio-marine origin. The area remains covered by thin sheet of water or remain damp and wet throughout the year with no significant growth of mangroves particularly in the eastern part of this

region. Its coastal front in the west is dominated by shoreline of submergence characterized by tidal mud flat with scanty mangroves swamps and network of creeks. Rivers like Sui, Jhijhora drains the area while the major portion is drained by Chach creek and Sonsaria creek during the time of tide. Total length of the creek channel in the area is around 25 miles. The northern periphery of this region is badly rilled and gullied by the local small seasonal streams. Since the area is almost covered throughout the year by salt water and hence there is no traces of aeolian activities.

The major tributaries draining the Little Gulf of Kutch are Kandla, Nakti and Hanstal creeks. The three desert rivers, Banas, Rupen and Saraswati, carry annually 140 Cubic Mm water to the Little Rann of Kachchh. The Little Rann of Kutch set up short term connection with the creeks at the head of the Gulf during the south west monsoon, when it gets flooded. The creek receives negligible freshwater inflow during the dry season. Hence, the evaporation exceeds precipitation leading to salinities higher than that of typical seawater (35- 36 ppt). The higher salinities may also result due to the drainage of brine from saltpans and higher evaporation rates in the adjoining creeks. Thus salinities upto 50 ppt have been recorded in the Little Gulf of Kachchh. The mudflat is composed of thick deposits of soft marine clay, which get inundated during high tide.

The coastline along the Gulf of Kutch is highly dissected by the creeks which further have a good criss-cross and jumbled network of creek channels throughout the inland area. From all along the coast, the salt water enters into the area to give a character of wet Rann (wetland). The area is overflowed at spring tide and regularly flowed by the normal diurnal tides. The major creeks are Nakti creek, Khori creek, Kandla, Navi, Morwali

and Kuta Phuri creek. Again, the coastal fronts are dominated by shoreline of submergence characteristics.

The amount of sediment derived from the catchment area is very small because of the extremely low run-off and the reason being is the dams constructed on the rivers draining this area. The major source of sediment in the gulf is considered to be the sediments brought by the River Indus.

Saltpans present here are enclosed system adjoining to creek environment filled with tide water. Saltpans are naturally exposed to a extensive range of environmental stress which manifest itself through salinity changes. Simplicity and stability being the characteristic feature of saline ecosystem makes it a more reliable ecosystem with a very less dynamism.

The salinity increases or decreases with reference to the amount of rainfall received. With excessive rain the salt particles are leached down the soil. Whereas, regular exposure to tidal water brings and adds to the salt content of the soil leading to the thickening of the salt crust.

The tidal mud flats are dominated by mangroves and grasses in the extreme west where coastal low lying area merges with the tidal flat. Mangrove supports to the marine food web through the making of debris by litter fall. They also prevent soil erosion and act as a shield for the mainland from storms to protect the coast from erosion. The mangrove species found in this area are relatively dwarfed in their pattern. The amount of rainfall received is a decisive factor for the differential growth of mangrove in the tidal zone.

General lithology of this area is also of subrecent sediments with coarse and very coarse sands to gritty pebbles, sands quartzose with shell clastic of fluvio-marine origin. Major Rivers draining in this area are Churwa, Sakra and many other small local channels during rainy season.

The constructions of breakwaters and jetties for development of ports and harbors have resulted in the significant change in the shorelines. It would prevent the erosion of the protected coastline thereby depriving the littoral currents of adequate supply of sand and sediments and thus they change the beach morphology. Also, poorly planned coastal, urban and industrial developments, including indiscriminate exploitation of coastal resources as for example, Mangroves and development of harbor and aquaculture facilities has resulted in change of the natural coastline and have changed the landcover.

Owing to the proximity to the Gulf of Kutch, the western most study area has a complex network of tidal creeks and tidal channels. There is a presence of numerous and extensive brackish water bodies. The coastal zone of this region is narrow because of the non availability of any major river draining this area. The mangrove forests in this area is of good height, because of the submerged type of environment, they are diverse and have developed in an environment of extremely arid climate. The average annual rainfall is about 470 mm, which occurs only within the months of July to August, rest of the period is undisputedly dry season. As per the information of Space Application Centre, marine processes are dominant through out the year due to insignificant fresh water discharge in the Gulf. Photographs covering various aspect of the western wet Rann have been shown in Plate no. 9-10.

MARSHY CREEK AREA

Location: Marshy creek area (Saline inorganic clay), south east of Surajbaari Bridge.

Geomorphology:

The area seems to be dissected by numerous veins of back water channels i.e, creeks. The creeks varies much from one another in terms of dimension, there are shallow creeks disbranching from the still larger creeks and some are as large as a wide river valley with considerable volume of saline water. These creeks have imparted the area with the characteristics to remain wet through out year irrespective of seasons. There is virtually no mixing of fresh water in the area except in the monsoon season. This area is predominantly modified by marine forces in its natural form. However, there is much alteration by anthropogenic forces, largely in the form of construction of numerous salt pans scattered through out this inter tidal zone. Such action has tremendously reduced the number of biodiversity in the area. Even the mangroves have been choked to death because of excessive salinity in the enclosed salt pans, not to mention about the other micro flora and fauna. Except for small halophyte grasses, which grow on the bunds of salt pan, nothing can be seen as far as one can see. The entire area along both sides of the bridge makes a band of salt pans. The aerial photograph of the area reveals that These salt pans also extend further east and west along the northern and southern limit of Little Rann of Kutch and the Hudson creek in the form of concavely alignment along both side of the bridge. Infact this bridge (Surajbari, with a length of 1235 m.) is built over Hudson creek, connecting Kutch to Saurashtra. The Hudson creek is shallower in the southern part and

deepens further to north of the bridge and thereby allowing salt mining more prominent in the southern margins. The soil of this area is dominantly clay with very insignificant amount of sand. This soil may develop huge cracks if allowed to dry but such environment is never met in the area. Though the salinity in the area is very high one can not see efflorescence on the soil because of huge moisture content. The efflorescence appears to the far east of bridge where eventually the moisture reduces.

Vegetation:

There is absolutely no vegetation except for some grasses which grows either along the levees of creeks or on the small embankment made enclosing the salt pan. These halophyte grasses grow in the area where there is salinity upto there tolerance limit. The salinity within the salt pans increases so much so that the plants are choked to death and therefore there is less of vegetation. There is sharp contrast in terms of land-cover of this part and the surrounding area to the north and south.

Description of soil profile:

The soil profile of the area indicates single dominant depositional agents. The top soil exhibits the properties of vertisols, with huge deep cracks when allowed to dry. There was enormous shrinkage of the sample when it was dried in the laboratory. There is no encrustation of salt on the surface. Actually the surface seems to be molten plastic with bulging appearance.

The sample of Soil profile collected in the specified location was taken at an interval of 10 inches, including top soil; total 3 samples were collected for all tests except for mechanical analysis where 4 samples were collected at an interval of 5 inches. Laboratory test shows a very high

percentage of moisture content which remains more or less same for each and every sample at different depth. The maximum moisture content in percentage within this profile is 30.86. Similarly, water holding capacity does not show much variation, however, it was maximum at a depth of 20 inches. The percentage of coarse sand was nil beyond 5 inches. The fineness of the texture increases with increasing depth. The percentage of silt also ranges from 2.33 on the top to 0.87 at the bottom of profile. Whereas, the percentage of silt and clay (combined) increased from top to bottom of the profile. Overall, the soil type is clay with plastic index of 61%. Again there is no much change in the natural volume; it ranges from 3.2 on the top to 3.1 at the bottom of profile. Comparatively, Porosity in percentage is very low in this profile to that of its counter parts. The top sample exhibits maximum porosity of only 7.9 whereas it decreases to 3.4 at a depth of 20 inches. Water holding capacity of this sample is maximum i.e, ranging between 0.825 – 0.852 for all three samples. The figures of bulk density reveal the relative compactness of the soil. Lower bulk density reveals more amount of moisture content within them. The hygroscopic absorbing capacity of the sample remained high at varied level of humidity percentage. Hygroscopic absorbing capacity ranges from 7.85-9.80% with changes in humidity from 40-80%.

5.4 ISLANDS (BET)

The 23 islands can be construed so because of the two facts that is firstly these isolated highlands (though of less height) resembles islands in the mid of salt waste when the Rann is dry and secondly when the area is inundated then the same highlands becomes the islands in the true sense. These islands do not have significant height as it ranges from 30 feet to 179 feet. Nearly all the highlands are steep and scarped on the north slopes. The highest point is 179 feet at Murdakh bet. All the islands are composed of sandstone with flat top covered by columns of basalt. These islands resemble the monadnocks or Inselberg which are the result of differential erosion in an extensive plain area. The main bets of Little Rann of Kutch are Wasraj and its chain islands, Andheri Wen, Khijadiya, Maharajawali, Miyan, Pancham, Pung (largest bet), Dhut, Mardak, Jhilandar, Shedwa and Nanda (Map-5.17).

This Geomorphic unit is of basaltic and sedimentary formation consist of rugged surface with steep slope, subdued hills with smooth surface and gently undulating structural hill of low relief respectively. The horizon of bet gets excessively drained owing to the relative flat topography. Slope of the bet has been divided into freely drained, owing to the free flow of water along the gentler slope; poorly drained, characterized by very steep slope along which waterfalls. To the down of it is coarse sediment accumulation, which remains waterlogged for much of the period and then the spread of fine sediment (Figure- 5.2). Photographs of various aspect of the bet have been shown in Plate no. 11.

Formation of Gypsum Salts is seen in the area of coarse sediments, because coarse sediments provides with the more space for the growth. Infact, there is direct relation in between size of grains and the size of salt crystals. Formations of such salts are the result of evaporation of saline

interstitial water in the relatively less moist soil in the dry season. The required environment is present around the bet.

JALANDAR/ JHILANDAR BET (JHINJHUVADA)

Location: Jalandar, an island in the midst of surrounding Rann, 3 miles south west of Jhinjhuvada village.

Geomorphology:

As it is a bet, it has its own geomorphic identity. Relatively it is a highland with a triangulation height of 112 feet in the east to 60 feet in the west. This bet is in elongated shape running east-west in direction. Side of the bet rises abruptly from floor to top, giving a character of vertical cliff. The top of the bet resembles to the plateau, with undulating characteristics, where the depressions are occupied by water bodies. The bet is also known as *Jhilandar* owing to the numerous *jhil*. The impermeable nature of the rocks does not allow water percolation and therefore, water (fresh water) remains in the lake through out the year, with fluctuation in the quantity. Processes of denudation can be well seen here. Both physical and chemical weathering is dominant owing to the vegetal cover, water availability and diurnal fluctuation of temperature. Sides of the bet were rilled by the rain water. Within the bet there were variations in the top soil cover, in some parts soil existed up to more than 20 inches and in some cases the surface configuration was of broken sandstone, mostly on the summit. The bet area never gets submerged fully. Water marks along the margin of bet indicates that the water during the rainy season stagnates up to a height of 2 feet.

Vegetation:

The geomorphology of the bet and water availability supports adequate amount of vegetation, even in this extreme climatic condition.

The area shows sharp contrast with the surrounding barren Rann. The density of the vegetal cover decreases outward from the lake vicinity. Types of vegetation on the bet are low rise tufted thorny shrubs with numerous arms, covering a larger part of area. Such physiological adaptation reduces the direct loss of soil moisture. Other vegetations are small cactus plants, grasses (along the water bodies), resembling to the type present in the marginal grassland areas, sankhpuspi, Accasia etc.

Description of soil profile:

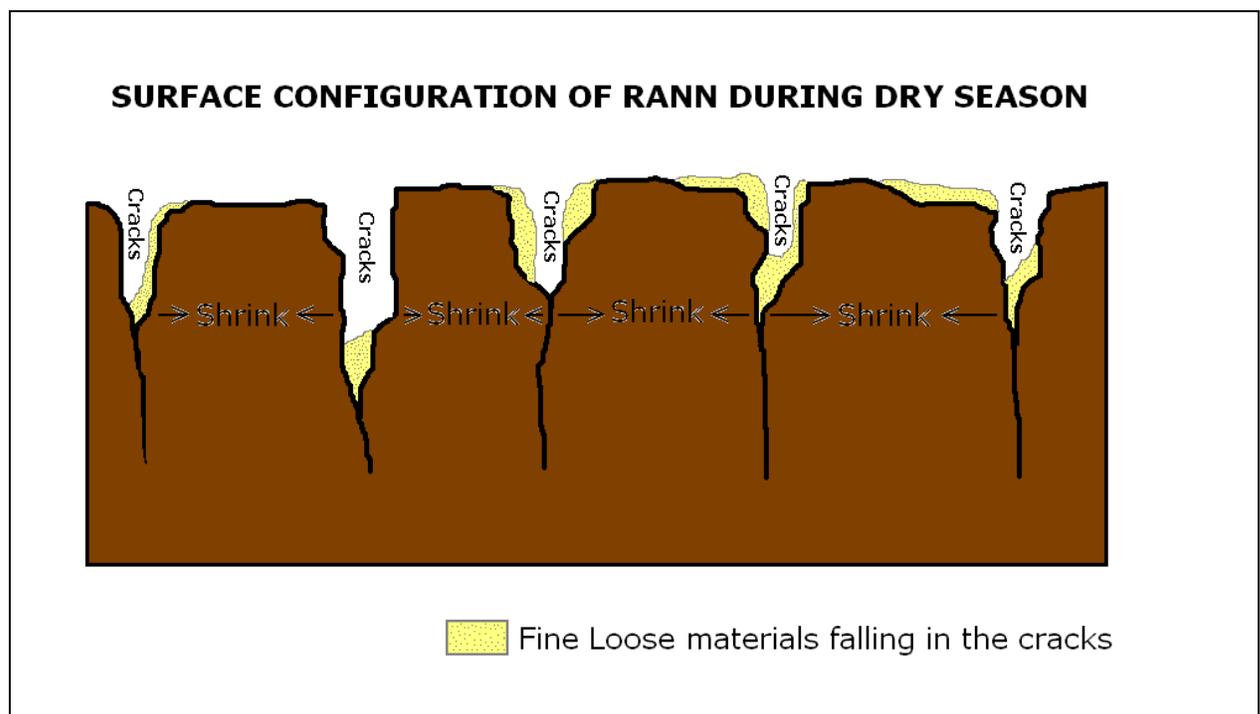
The soil profile of the area indicates the activities of physical, chemical and biological weathering in its formation. The soil exhibits the properties of sandy soil with a considerable amount of silt. The top surface is characterized by soil and broken sandstone, availability of salt is completely absent on the bet.

The colour of bet sediment is lighter, which reveals the different depositional environment from that of the Rann sediments. The organic content in the bet sediment is relatively more.

The sample of Soil profile collected in the specified location was taken at an interval of 10 inches, including top soil; total 3 samples were collected for all tests except for mechanical analysis where 4 samples were collected at an interval of 5 inches. Laboratory test shows the percentage of moisture content increases with increasing depth upto a depth of 10 inches and further reduced at a depth of 20 inches. However, water holding capacity does not show a particular trend, it was maximum on top minimum at a depth of 10 inch and medium further below. The percentage of fine sand was maximum for all the samples followed by silt and clay. Percentage of coarse sand was minimum with decreasing trend from top. The presence of clay also had decreasing trend from top. Overall, the soil

type is silty sand with plastic index of 17%. Natural volume decreases with increasing depth. Porosity in percentage was maximum (20.1) at a depth of 10 inches and so the water holding capacity; porosity reduced to half on the top soil, whereas it was 18-2 % at the depth of 20 inches. The figures of bulk density reveal that the sample is relatively less compact than any other sample. The hygroscopic absorbing capacity of the sample remained lowest at varied level of humidity percentage, of all the samples. Hygroscopic absorbing capacity ranges from 1-4.02 % with changes in humidity from 40-80%.

FIGURE- 5.1



SURFACE CONFIGURATION OF RANN DURING WET SEASON

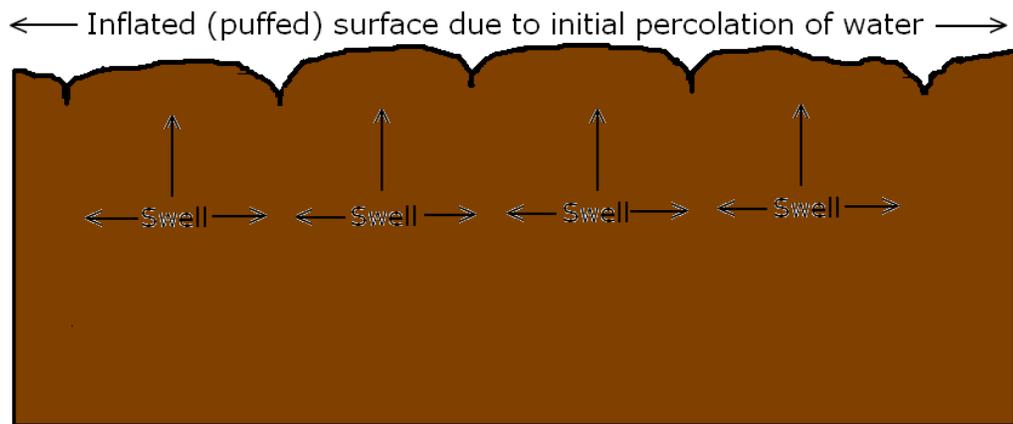
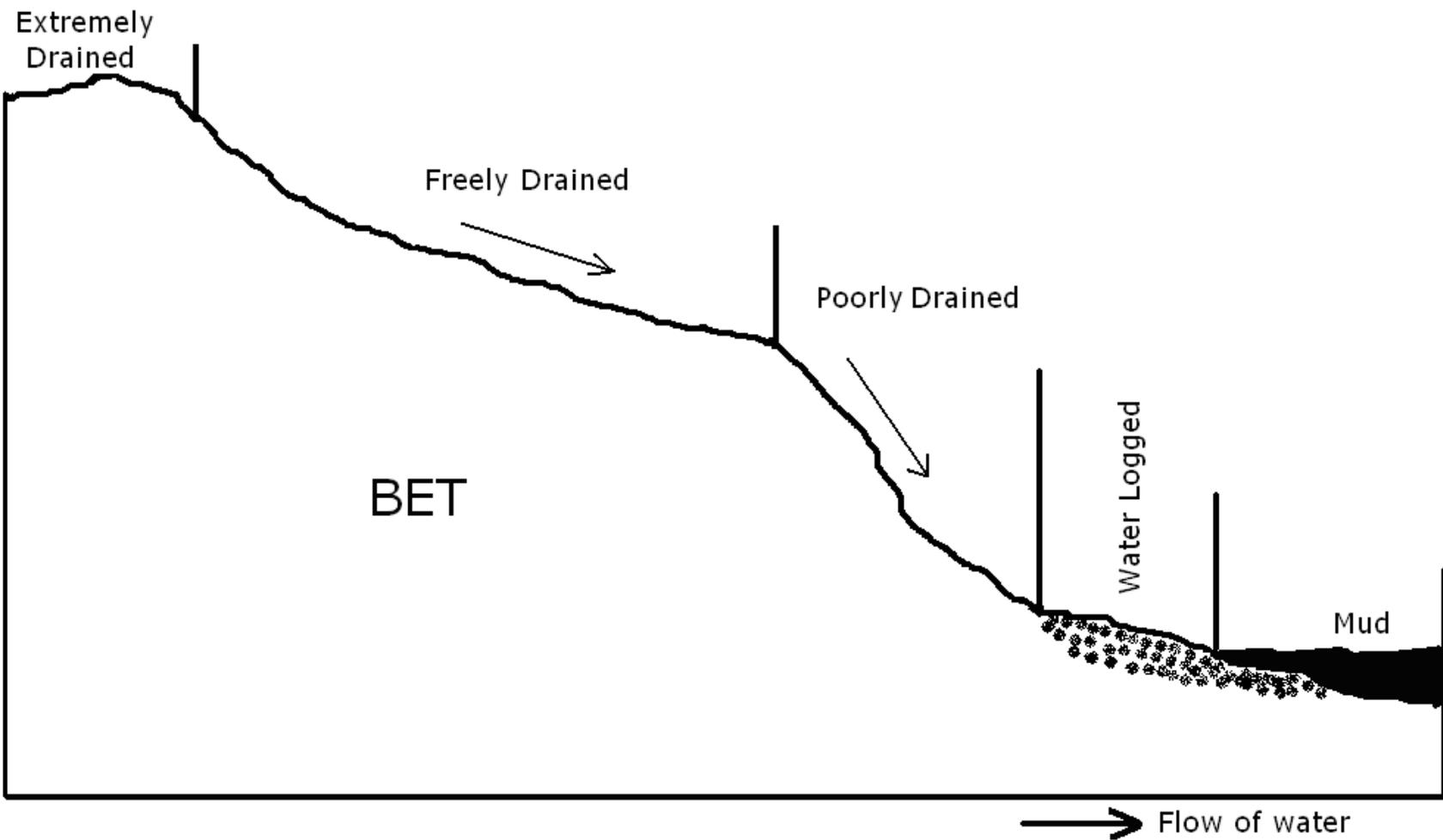


FIGURE-5.2 SLOPE ELEMENT & RELATED DRAINAGE



5.5 FACTORS PROCESSES AND FORMS OF DESERTIFICATION

The entire area under study is either in the process of desertification or is already a desert, with a climatic condition varying from arid to semi-arid. Fringe zone and the bet zone is the vulnerable zone while the Ranns have all the characteristics of desert. The difference in the factors, processes and forms of desertification in different locations are as follows:

Fringe area

Types of landuse: it is purely a semi desert area and is to the verge of attaining a state of arid condition especially in the western fringe of the study area.

Factors: The area suffers with seasonal unevenness of precipitation, with a very high degree of variability, often in the form of spasmodic rainfall and flow. Elimination of vegetation through prolonged drought and overgrazing, cutting of tree for firewood and for making charcoal on a large scale, irrational use of resource.

Processes involved: Rapid erosion through fluvial processes most extensive in eastern and southern fringe. Wind blown sediments gets deposited on the surface, on the leaves and canopy of the shrubs. Capillary action has also advanced the process of desertification by making the area saline. There has been considerable depletion of soil resulting into the reduction of biological activities and thinning of vegetation.

Forms: The area has a characteristic of degraded soil with erosional network of gullies and widespread area of saline waste land along the western fringe and mosaic vegetation in the eastern and southern fringe.

BET/ISLAND

Types of landuse: Desiccated land with semi-desertic type of landuse.

Factors: Deficiency of precipitation with spasmodic type of rainfall and flow, destruction of vegetation through excessive grazing and cutting of shrubs and trees of domestic and commercial use.

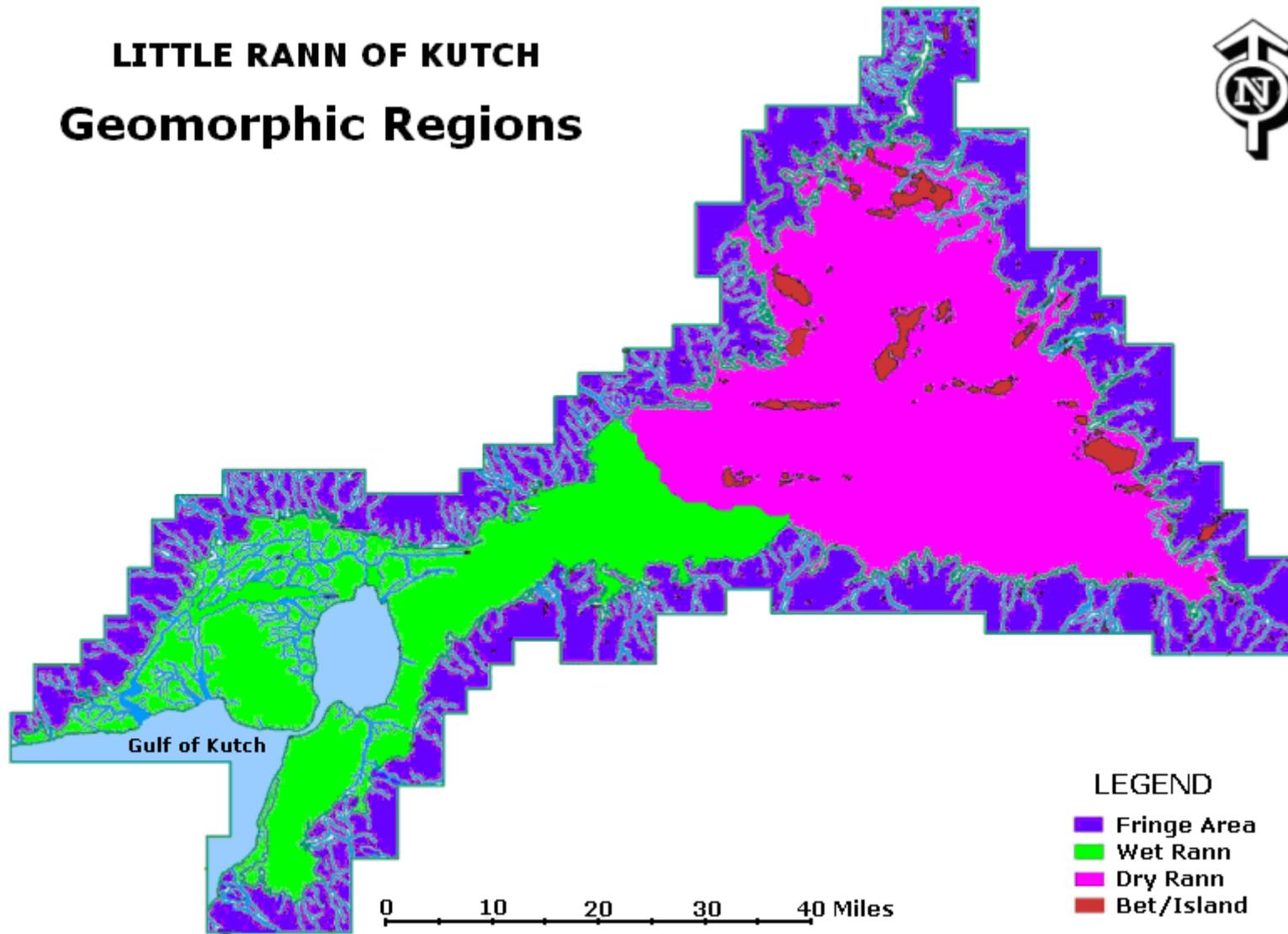
Processes involved: process of erosion in this area is more rapid because of the relative relief. Rate of formation of soil is slow because either it is drained during the rainy season or is blown away with the wind during dry period. Though laying in the midst of the salt desert it is not affected by salinity. Thinning of the vegetation has also accelerated the process of erosion.

Forms: The bets are sedimentary in nature with basaltic top exposed at some places. The surface configuration ranges from stony waste to thin soil. Overall vegetation is also scanty, on the bet except for Jhilandhan bet.

Table: 5.1 - The Classification of study area on the basis of prevailing climate, geomorphological and ecological conditions

SR NO	GEOMORPHIC DIVISIONS	CATEGORIES				
		LEVELS	CLASS	ORDER	FAMILIES	KIND
1	Fringe Area	Fluvial dominant	Degradation	Tectonic	Faulted	Asymmetrical
2	Dry Rann	Fluvio-aeolian dominant	Agradation	Tectonic	Faulted	Symmetrical
4	Wet Rann Western part	Fluvio-marine	Agradation	Tectonic	Faulted	Symmetrical
5	Islands	Fluvio-aeolian dominant	Degradation	Tectonic	Faulted	Asymmetrical

LITTLE RANN OF KUTCH Geomorphic Regions



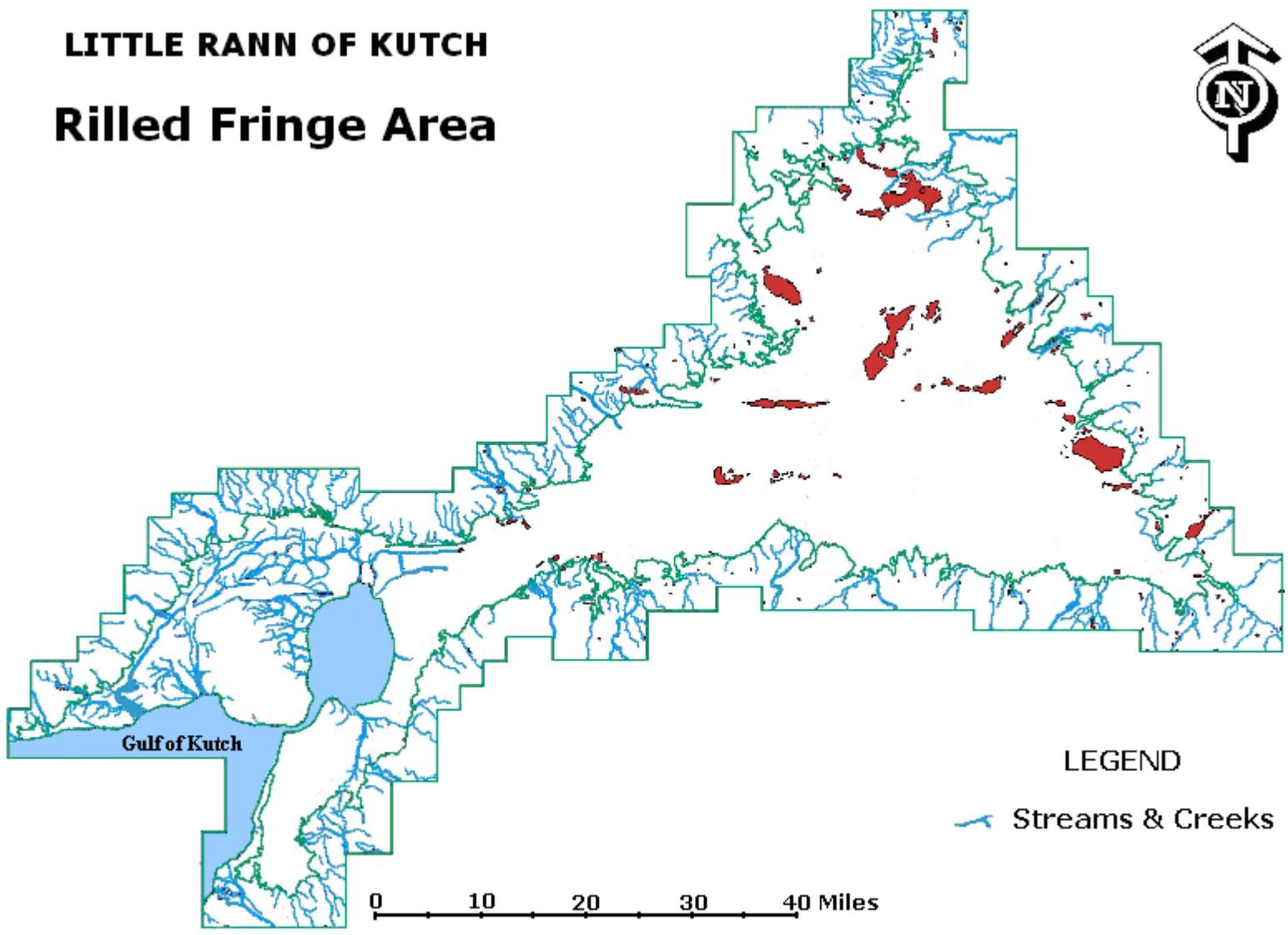
LEGEND

- Blue Fringe Area
- Green Wet Rann
- Yellow Dry Rann
- Red Bet/Island

MAP - 5.1

LITTLE RANN OF KUTCH

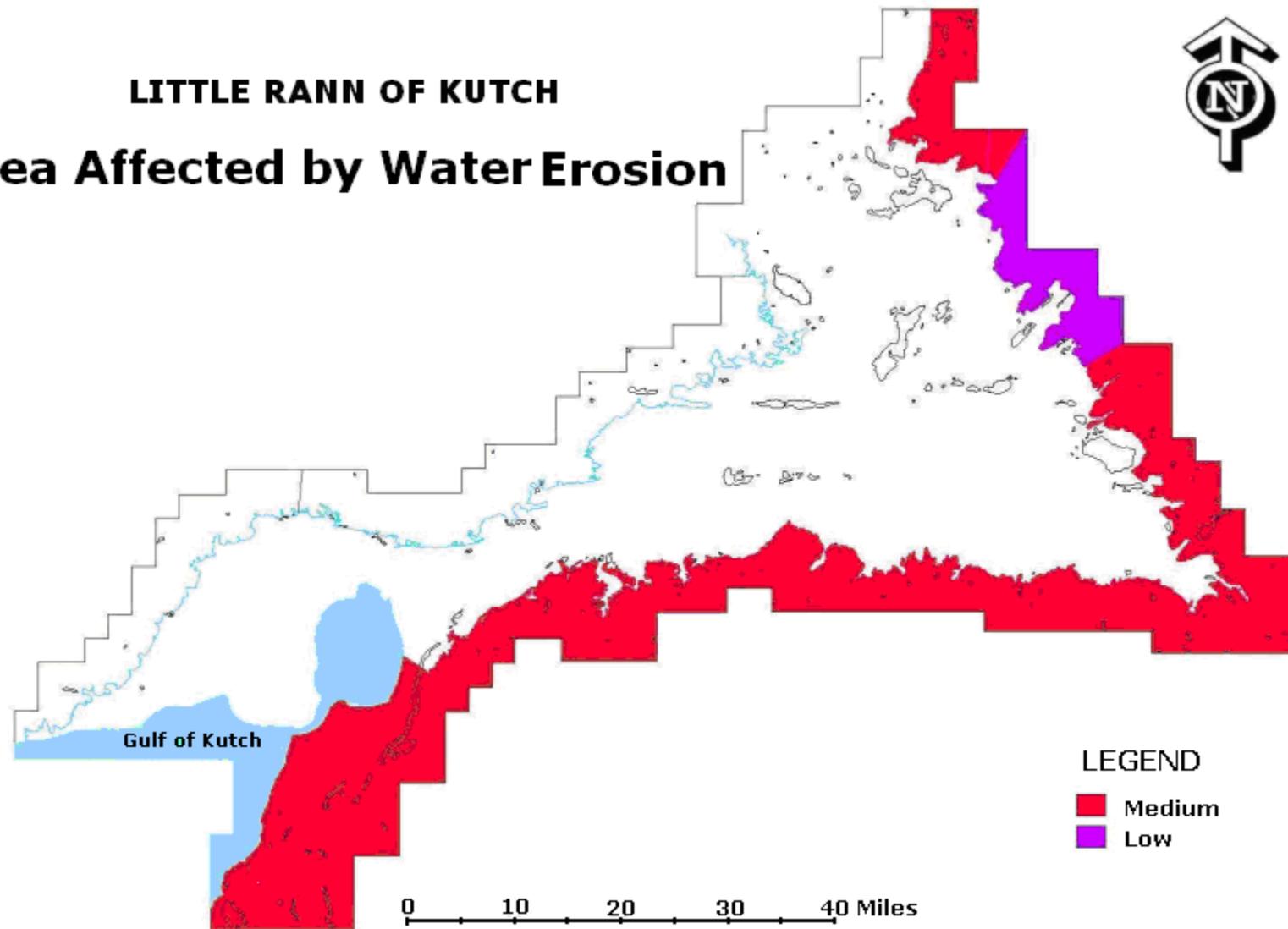
Rilled Fringe Area



MAP - 5.2

LITTLE RANN OF KUTCH

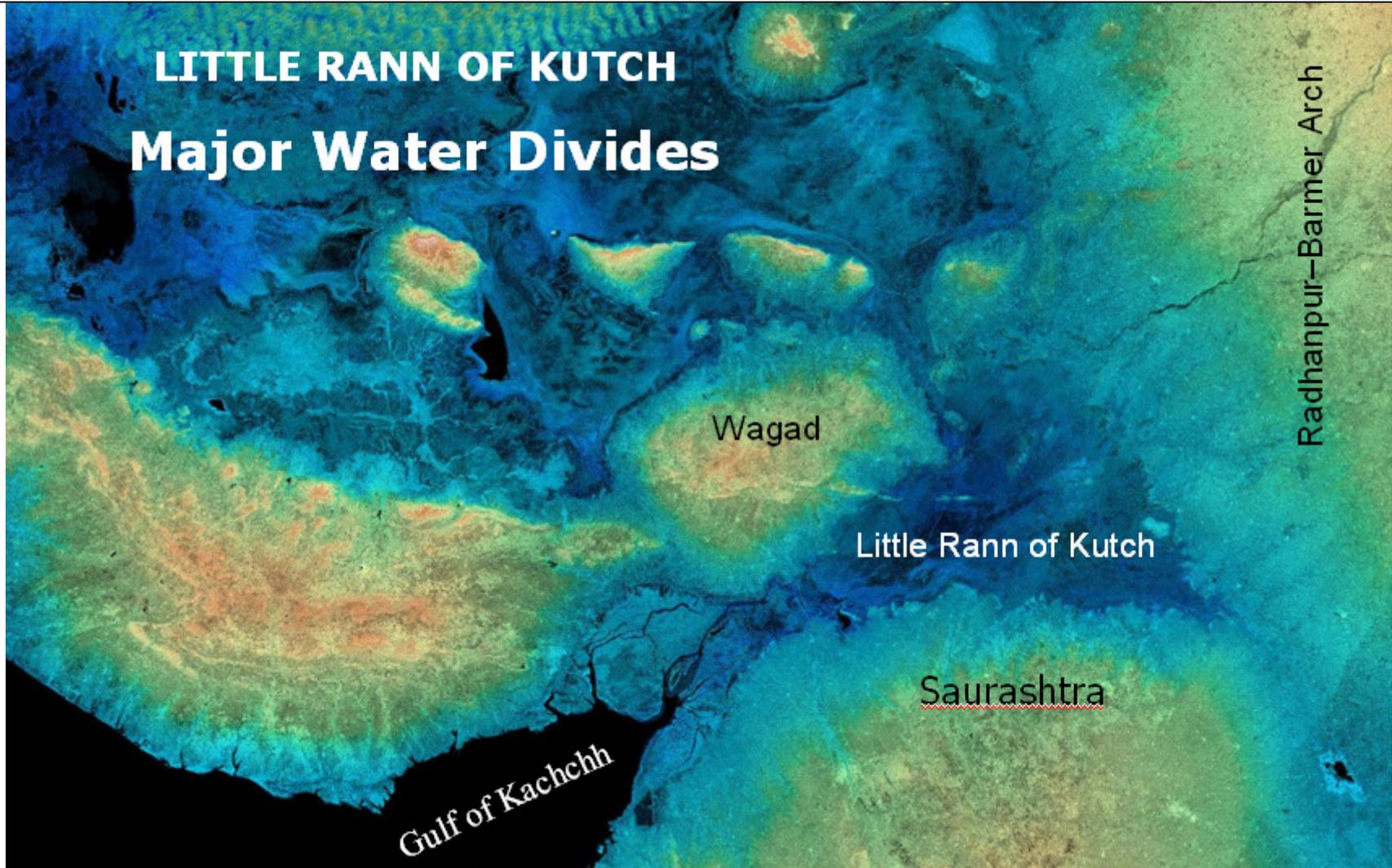
Area Affected by Water Erosion



Source:SEAP Report, Ranns & Desertification, GUIDE, Bhuj, April, 2000 (Modified)

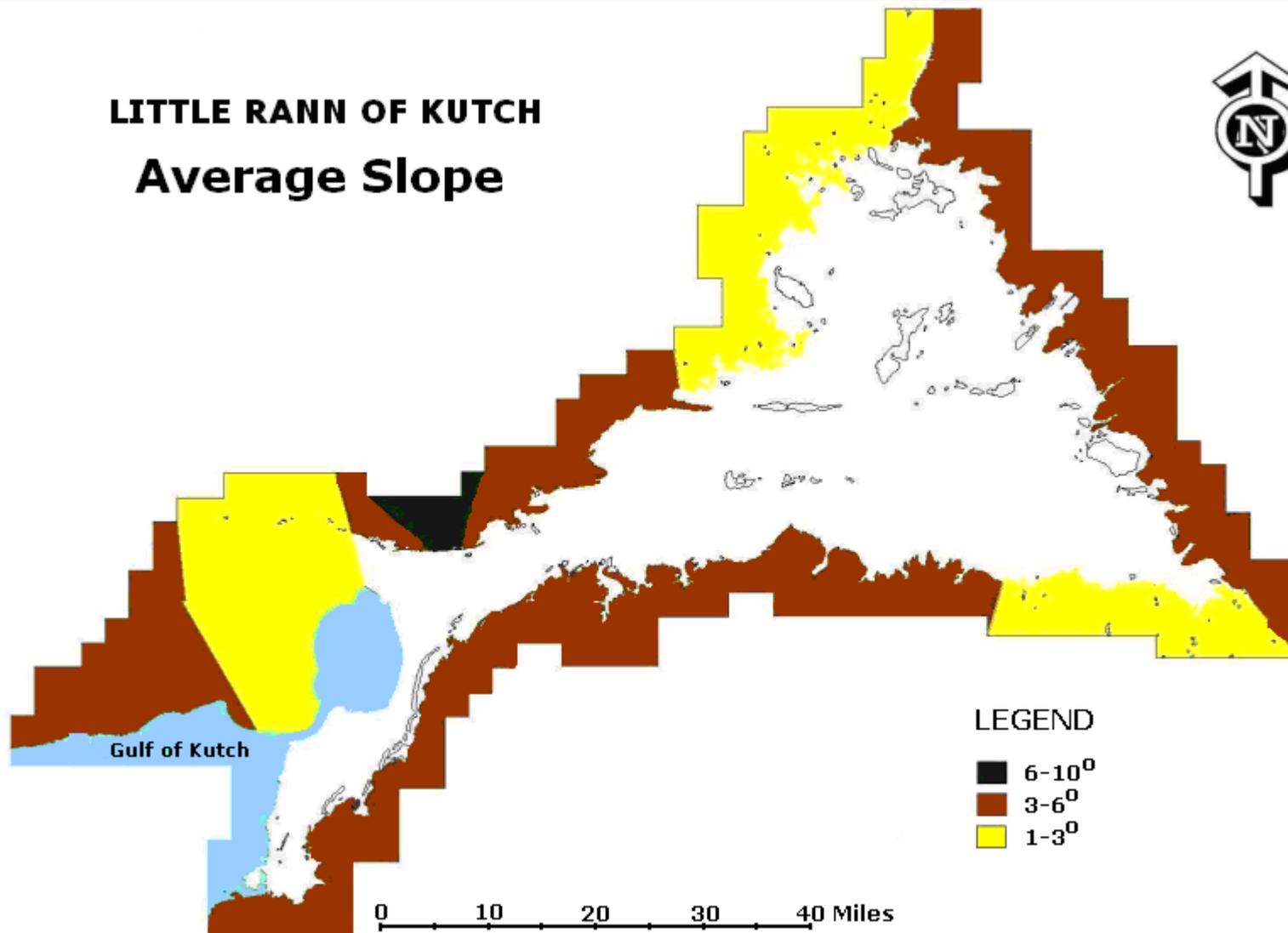
MAP - 5.3

LITTLE RANN OF KUTCH Major Water Divides



MAP -5.4

LITTLE RANN OF KUTCH Average Slope

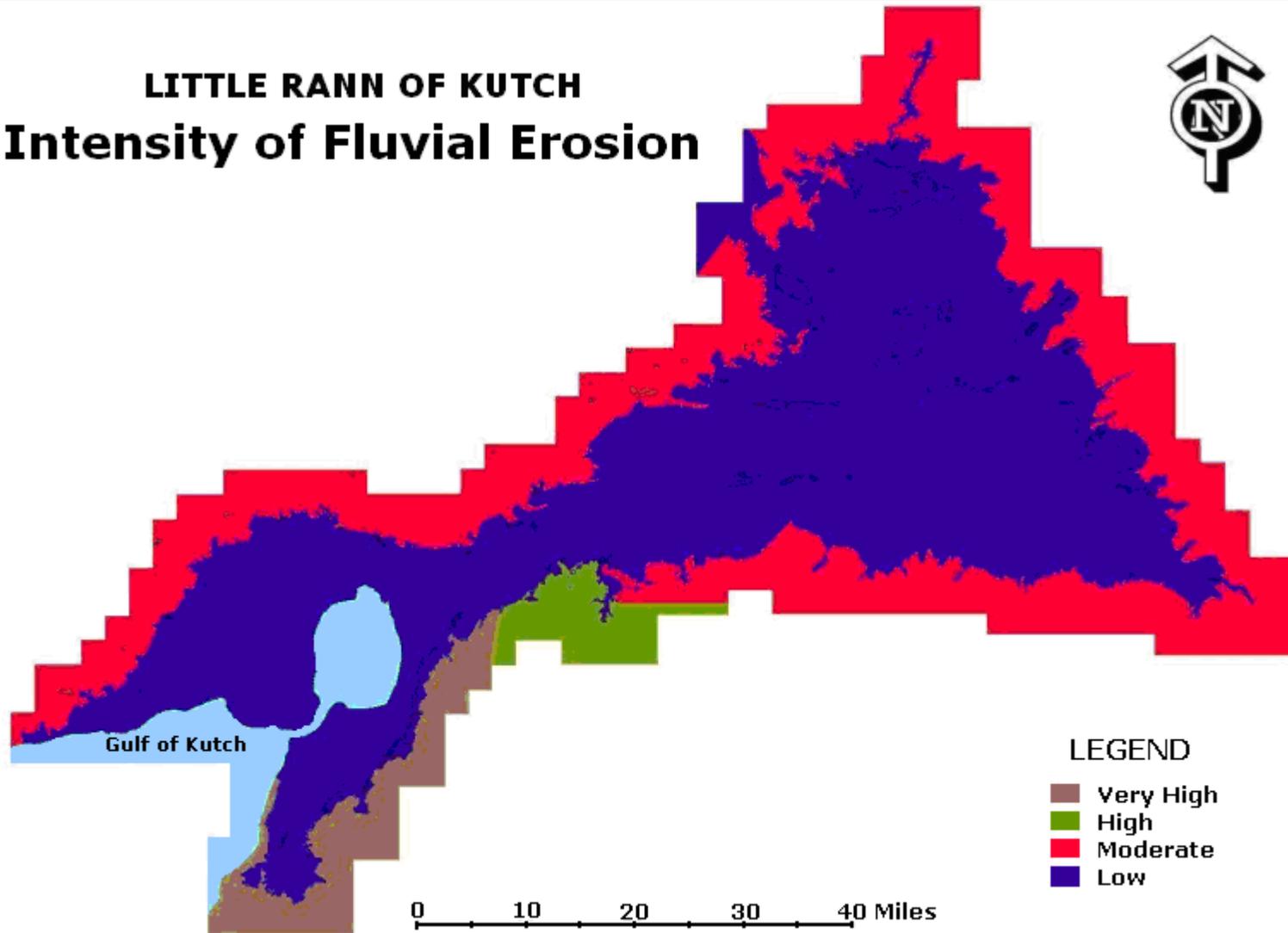


Source: Planning Atlas, Directorate of Economics & Statistics, 1987 (Modified)

MAP -5.5

LITTLE RANN OF KUTCH

Intensity of Fluvial Erosion



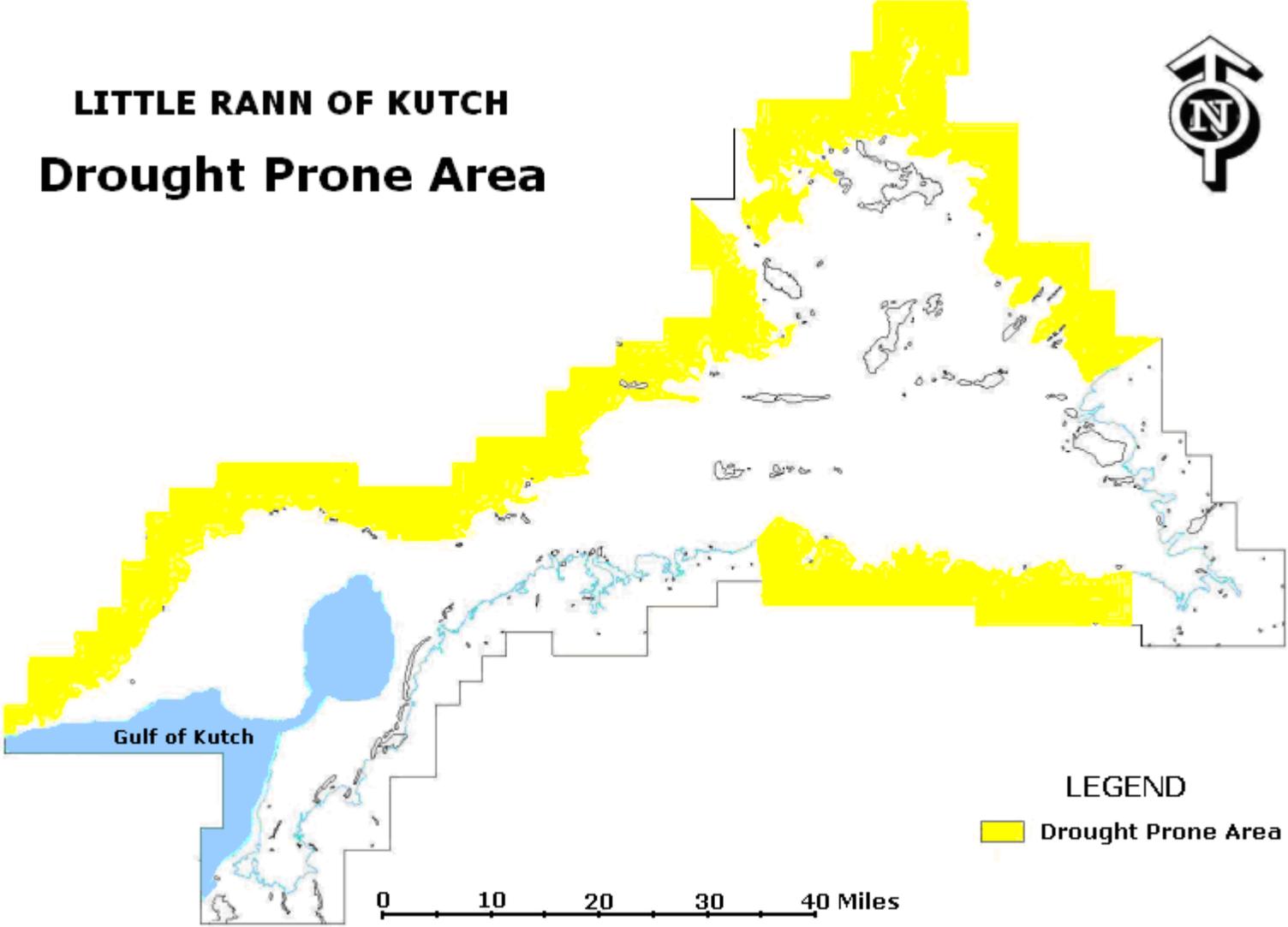
LEGEND

- Very High
- High
- Moderate
- Low

Source: Planning Atlas, Directorate of Economics & Statistics, 1987 (Modified)

MAP - 5.6

LITTLE RANN OF KUTCH Drought Prone Area

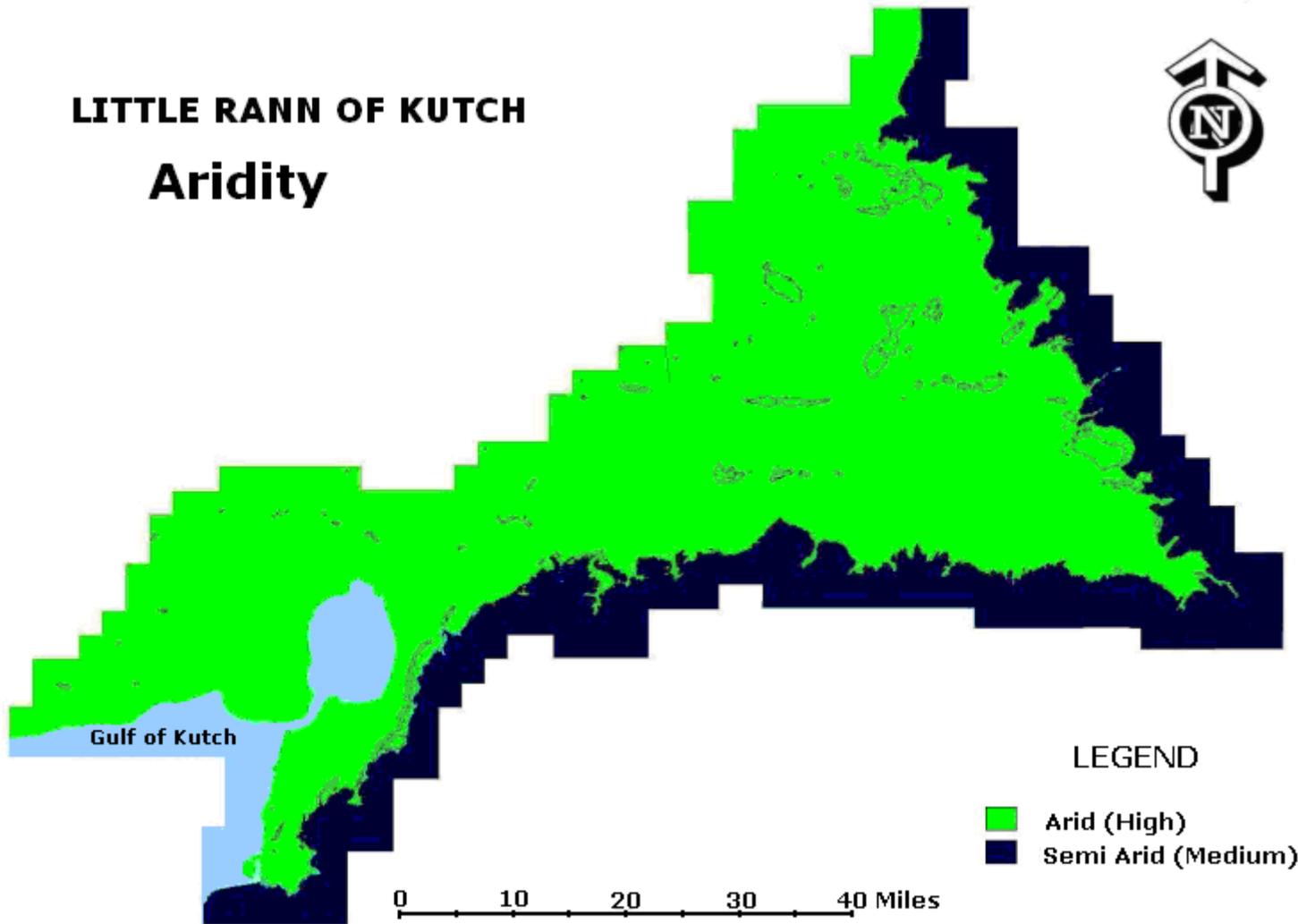


Source: Department of Agriculture, Gujarat State (Modified)

MAP - 5.7

LITTLE RANN OF KUTCH

Aridity

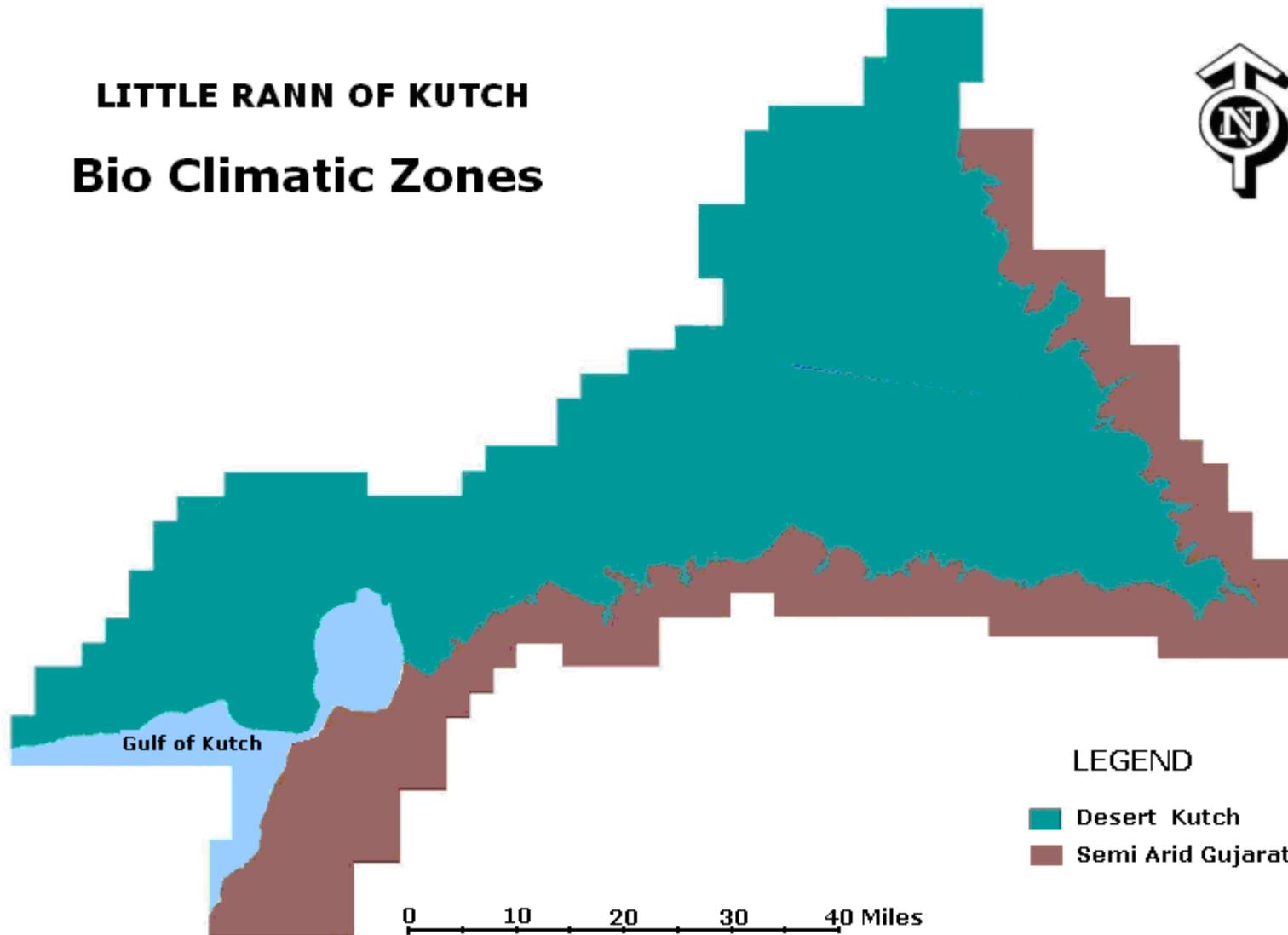


Source: Gujarat Ecology Commission (Modified)

MAP - 5.8

LITTLE RANN OF KUTCH

Bio Climatic Zones

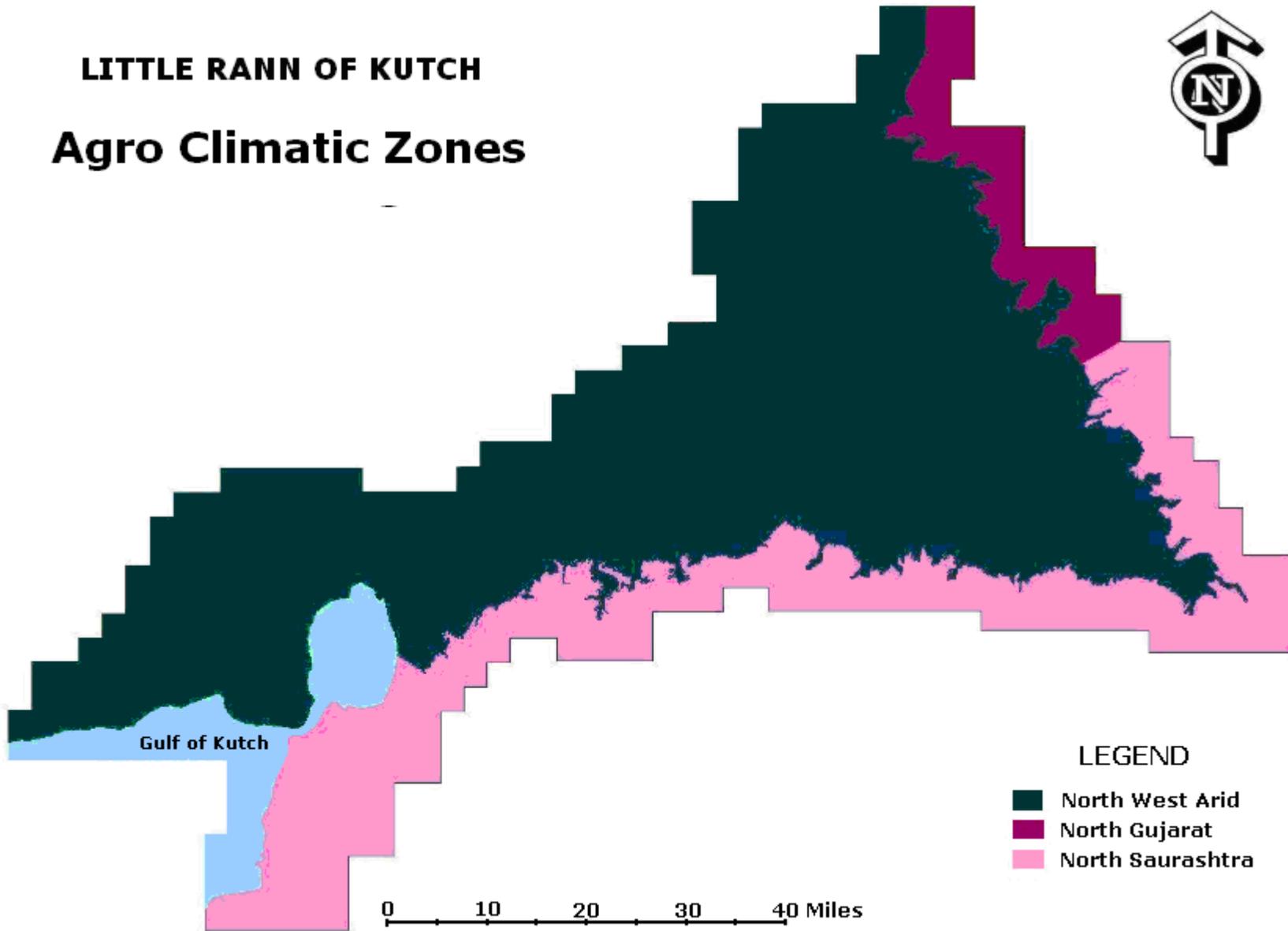


Source:Wetland International South Asia, (2000), State Environment Programme, wetland, GEC, Vadodara (Modified)

MAP - 5.9

LITTLE RANN OF KUTCH

Agro Climatic Zones



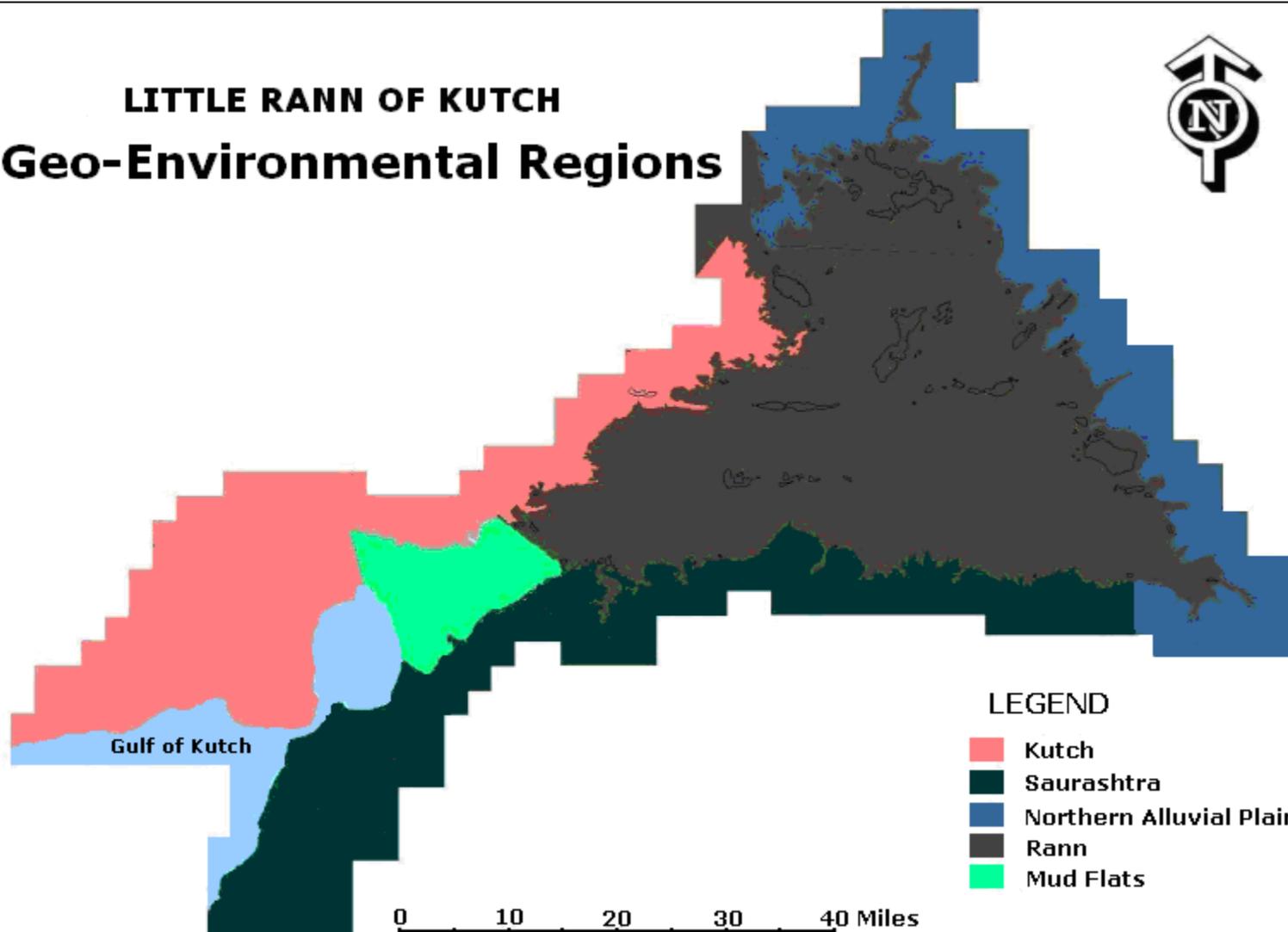
LEGEND

- North West Arid
- North Gujarat
- North Saurashtra

Source: Degraded Lands in Gujarat, Gujarat Ecology Commission (Modified)

MAP - 5.10

LITTLE RANN OF KUTCH Geo-Environmental Regions



LEGEND

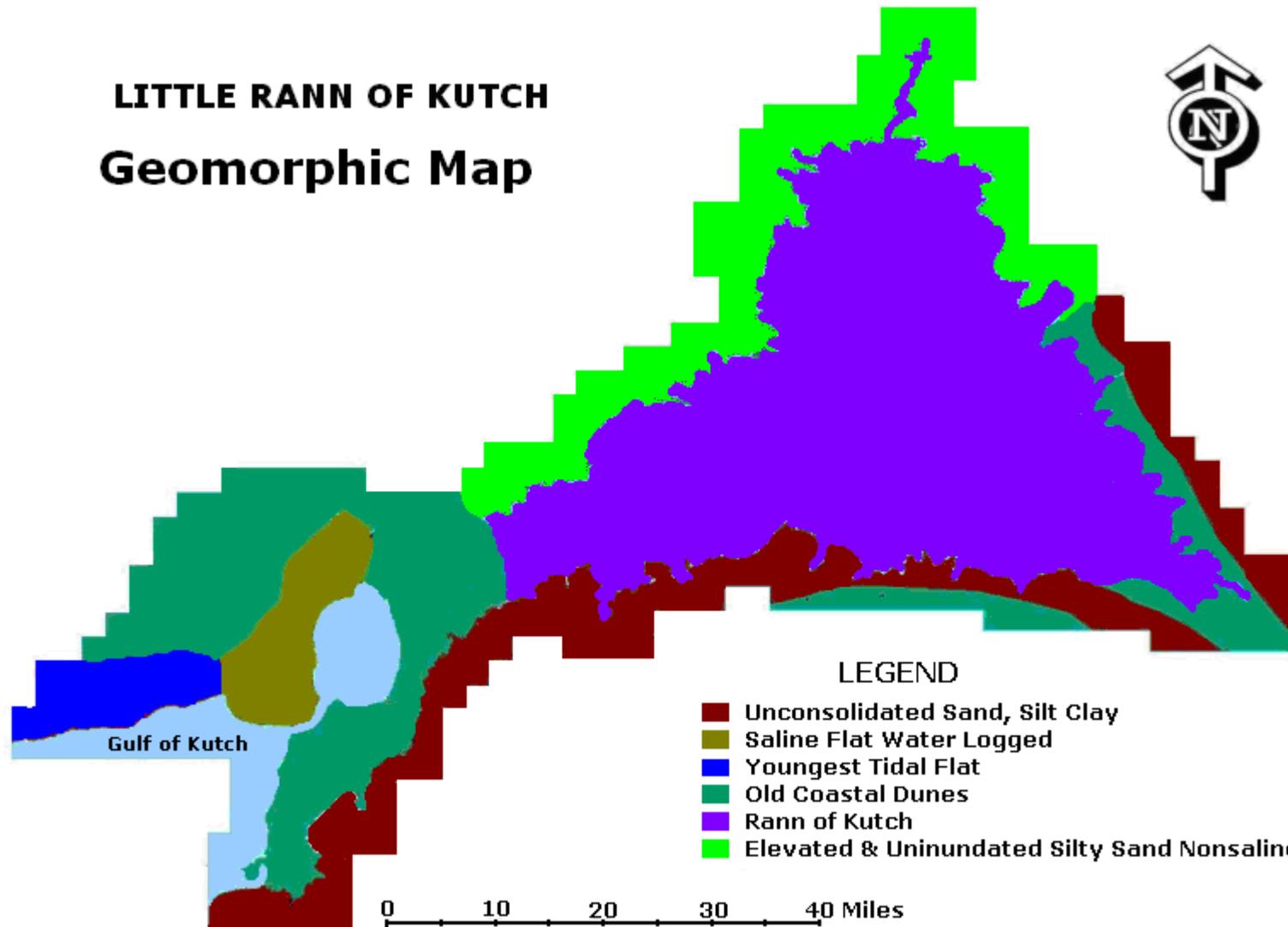
- Kutch
- Saurashtra
- Northern Alluvial Plain
- Rann
- Mud Flats

0 10 20 30 40 Miles

Source: SEAP Report, Ranns & Desertification, GUIDE, Bhuj, April, 2000 (Modified)

MAP – 5.11

LITTLE RANN OF KUTCH Geomorphic Map

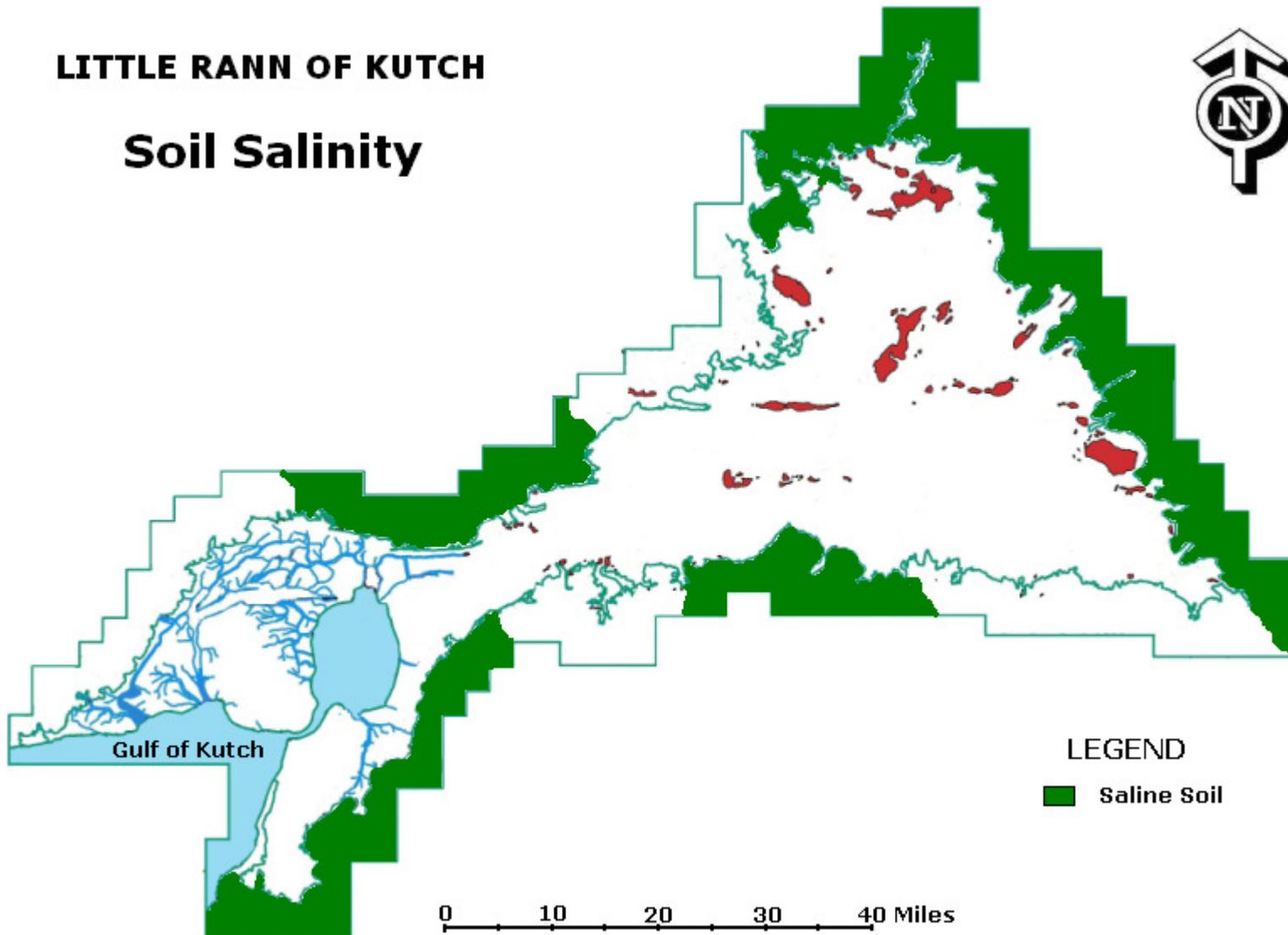


Source: Planning Atlas, Directorate of Economics & Statistics, 1987 (Modified)

MAP - 5.12

LITTLE RANN OF KUTCH

Soil Salinity



LEGEND

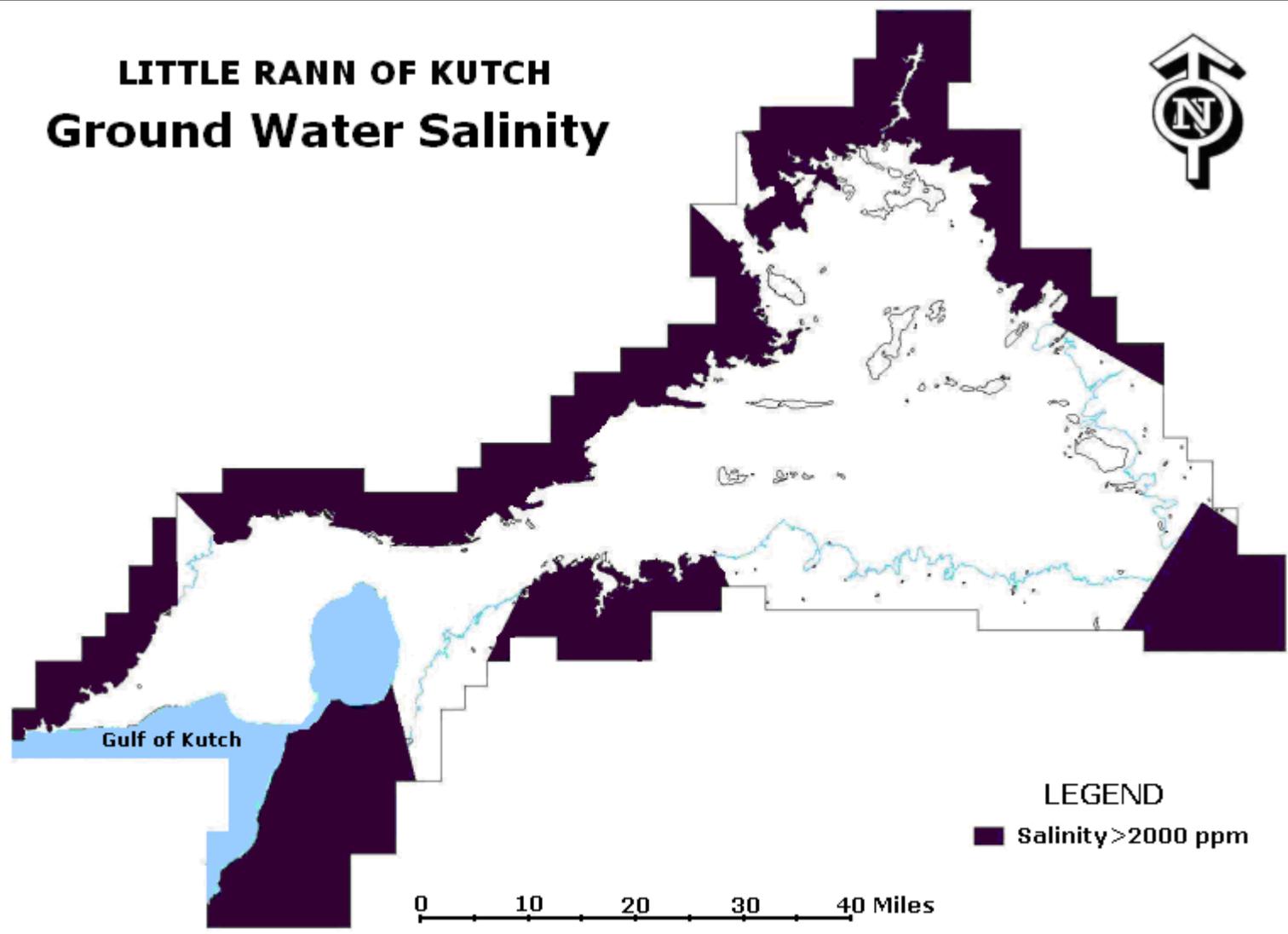
■ Saline Soil

0 10 20 30 40 Miles

Source: National Bureau of Soil Survey & Land use Planning (ICAR), Nagpur (Modified)

MAP - 5.13

LITTLE RANN OF KUTCH Ground Water Salinity

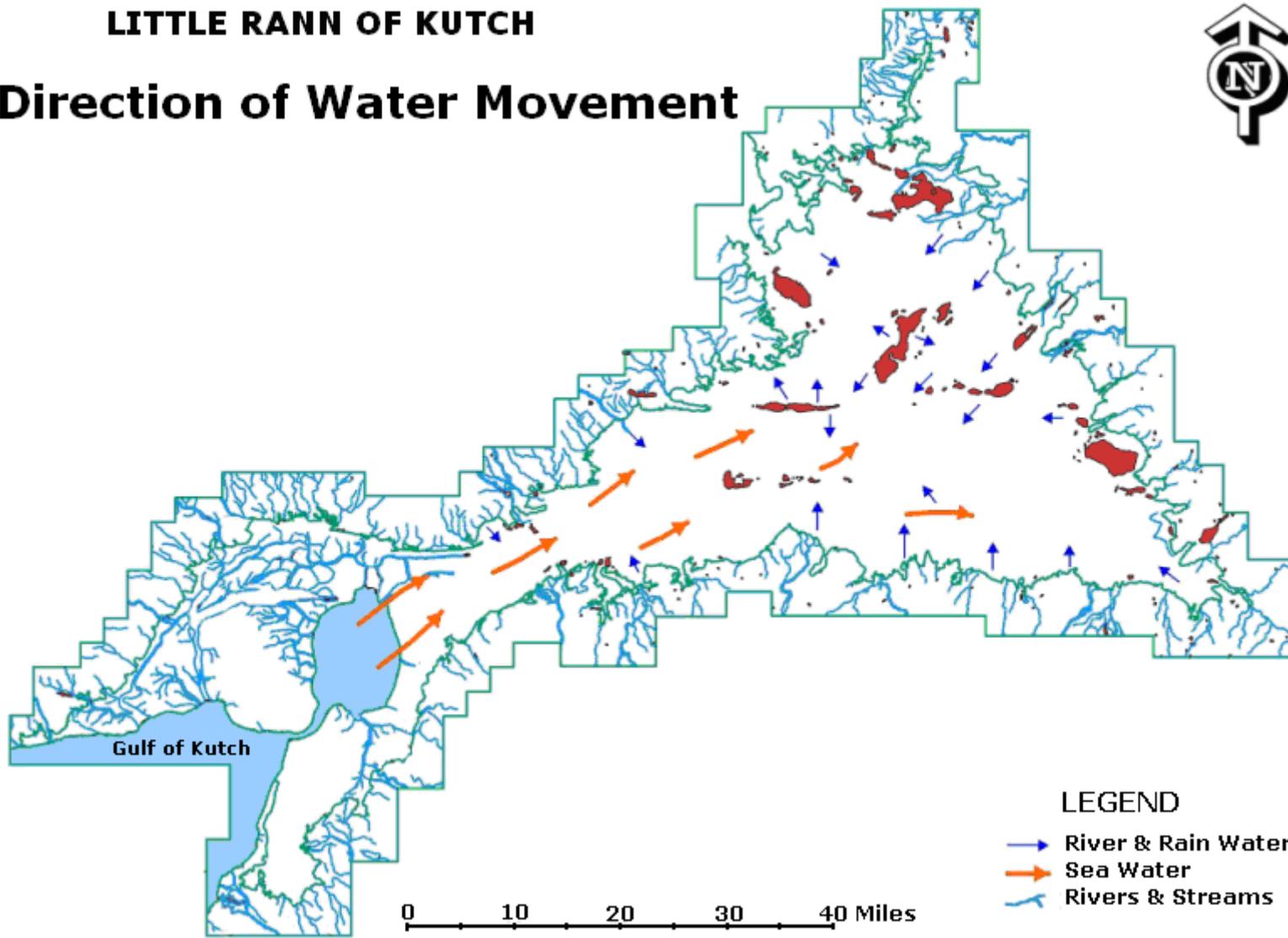


Source: GWRDC, Gandhinagar (Modified)

MAP - 5.14

LITTLE RANN OF KUTCH

Direction of Water Movement

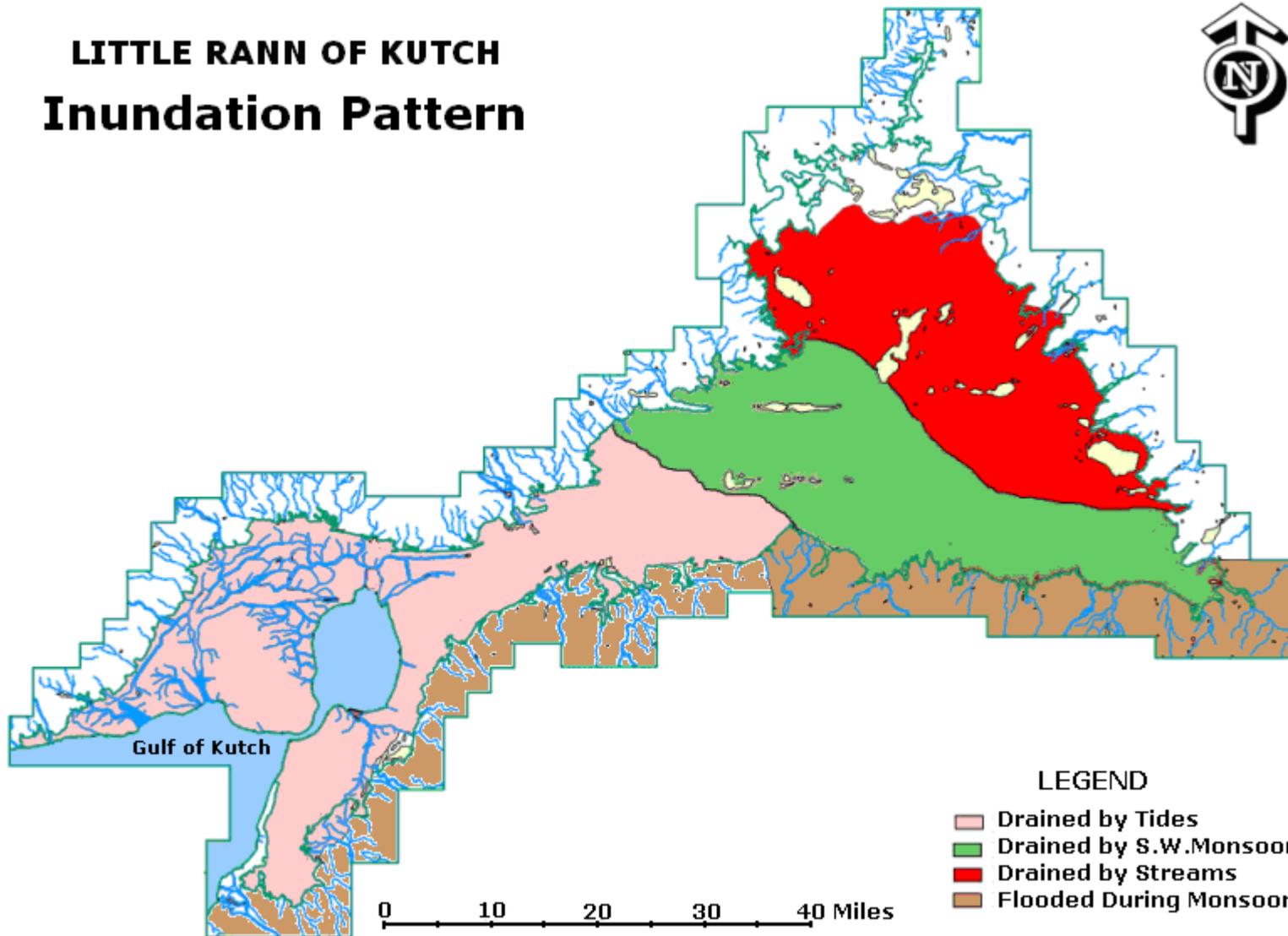


LEGEND

- Blue arrow: River & Rain Water
- Orange arrow: Sea Water
- Blue line: Rivers & Streams

MAP - 5.15

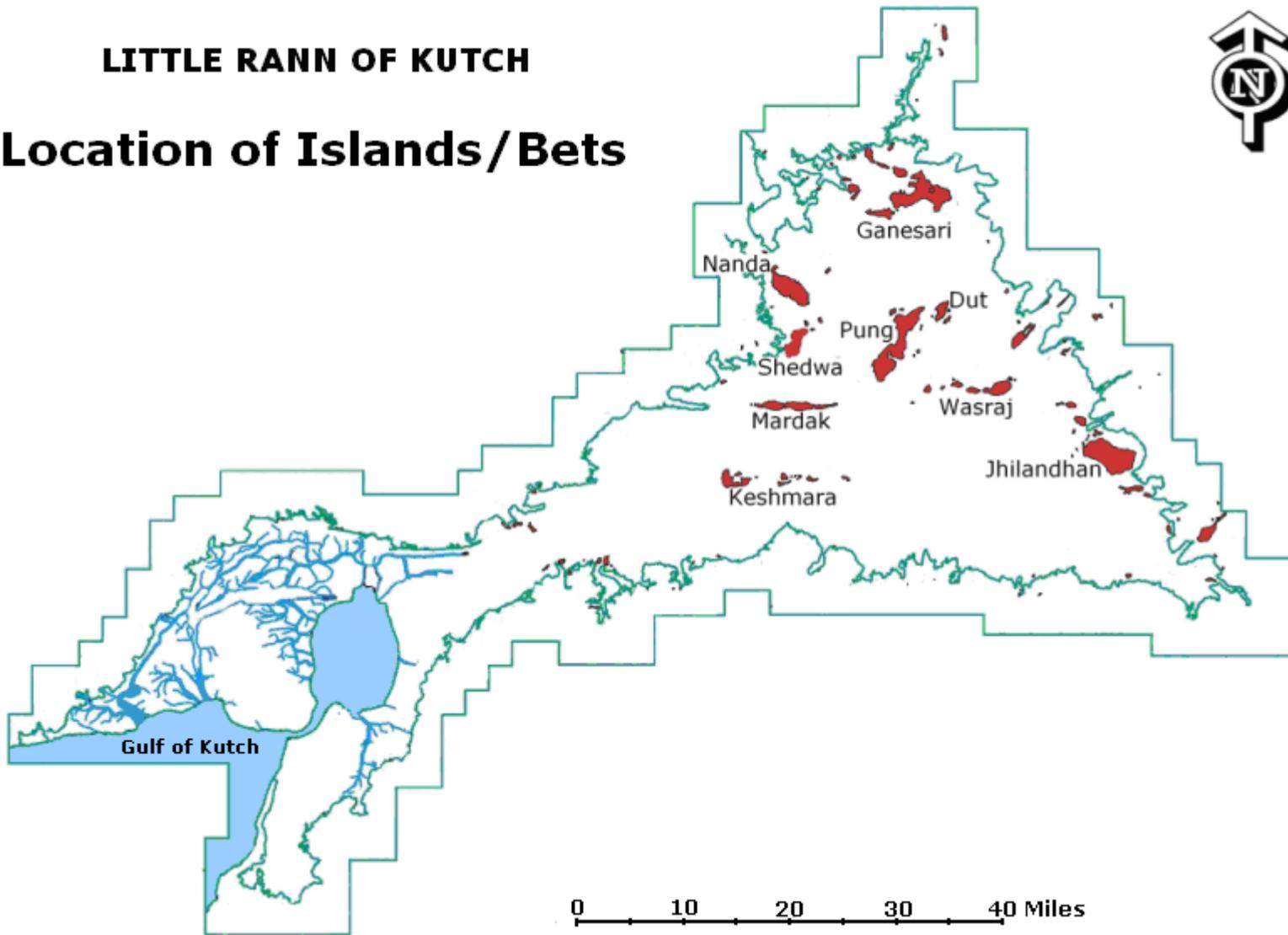
LITTLE RANN OF KUTCH Inundation Pattern



MAP - 5.16

LITTLE RANN OF KUTCH

Location of Islands/Bets



MAP - 5.17