CHAPTER-4

STUDIED VARIABLES OF THE GEOMORPHOLOGICAL PHENOMENON

4.1 MORPHODYNAMIC ENVIRONMENT

Detailed analysis of any geomorphic landscape essentially demands to identify and review the study area in the light of morphoclimatic region. Each morphoclimatic region has its own characteristics assemblages of landforms and set of geomorphic processes which sculptors them. The study of role of climate on geomorphic processes and landforms can be seen in the classical work of J. Budel (1948), L. C. Peltier (1950), C. Troll (1969), W. F. Tanner (1961), P. Birot (1968), D. R. Stoddart (1969), L. Wilson (1969), J. Tricart and A. Cailleux (1972) etc. These scholars have emphasized that the pace and nature of weathering and erosional processes, surface runoff, vegetation type and mechanism of landform process differs significantly from one climatic region to the other.

According to the famous geomorphologist Stoddart, D.R. (1969)[47], the concept of geomorphology is based on the following three major themes:

(1)Landforms differ significantly in different climatic regions.

(2)Spatial variations of landforms are due to different climatic parameter (example: Temperature, humidity, precipitation etc.) and their influences on weathering, erosion and runoff.

(3)Quaternary climatic changes could not obscure relationships between landforms and climates. In other words, there are

[47] Stoddart, D.R., (1969) Climatic Geomorphology: Review & Reassessment. Progressive Geographer-1, Pp- 161-222.

certain diagnostic landforms which clearly demonstrate climate landforms relationships.

Apart from the major diagnostic landforms the formation and composition of crust do differ in different morphogenetic regions.

The Kutch district falls under the semi-arid climatic conditions, which belongs to the “Steppe-Bush type” as per the Koppen’s classification. The climatic characteristics of area shows transitory phase between the arid and semi humid type in the west and east respectively. The intensity of heat goes on increasing from east to west in the district accept in the coastal zones. The area experiences a typical arid climate may be because the tropic of cancer passes through the Kutch.

The region experiences four main seasons namely winter, summer, South-west monsoon and post monsoon seasons. During winter season (December to February) winds are N-NE and rough sea conditions may prevail because of western disturbances characterized by chilly winds from the N-NE due to high pressure zone in the north of Himalayan ranges. Summer season (March to mid June) is characterized by high temperature and high humidity with the maximum air temperatures often reaching 40-45°C. Southwest monsoon (mid June to mid September) has weak monsoon mainly due to monsoon low centered around more inland part making it a low rainfall area with strong winds with S -SW directions. Post monsoon season (mid September to November) is a transition period between monsoon and winter when the climate is pleasant with relatively calm periods.

The following are the climatic characteristics of the selected study area:

- **(i)** The region is characterized by a high aridity index of over 40 percent.
- **(ii)** The mean annual temperature is 26°C.
- **(iii)** Average temperature of the coolest month (January) is 10°C.
- **(iv)** The mean maximum and minimum temperature is 30°C and 10°C respectively.
- **(v)** Maximum temperature during summer month sometimes reaches upto 48°C.
- **(vi)** There are three rainy months i.e., June to August of which July is the wettest month, receives almost 80 percent of the total rainfall received in the area.
- **(vii)** There is definite dry period starting from October to May within which there is insignificant amount of rainfall.
- **(viii)** Average annual rainfall for the area is 320 mm with dependability less than 40 percent.
- **(ix)** Total rainy days are less than 15.
- **(x)** Annual rainfall is variable, the coefficient of variability being 14.01 percent in Kutch, 9.46 percent in Surendranagar and 7.84l Percent in Rajkot.
- **(xi)** The average humidity of the year is less than 25 percent.
- **(xii)** Humidity during rainy and post rainy season that is from June to October even goes upto 80 percent.
- **(xiii)** Strong summer winds, which blow from SW and W and often carry salts from dried salt encrustation of the Ranns towards the land, is also one of the factors contributing salinity to the area.

In general the study area receives very low mean annual precipitation with a moderate mean annual temperature while the mean annual potential Evapo-transpiration (the amount of water that could be evaporated and transpired if there was sufficient water available) is maximum in the Little Rann of Kutch.

High temperature in May leads to the development of very low pressure cells. During this period violent storms are very common. These violent storms or winds are of less duration and occurs in the afternoon regularly because by that time the low pressure develops to its fullest. A very harsh northerly and easterly wind prevails in winter season, followed by strong South-Western steady winds. The moving air masses remains always loaded with dust and salt and are carried to more inland part of the India and Pakistan. The area do not experiences a very cold climate but is associated with occasional cold waves. Here the unavailability of obstruction of required height reduces the amount of rainfall received in the area.

The above facts largely conform to the criteria of alternating wet and extreme dry season. The study area fall under the semi-arid type of climatic conditions, which belongs to steppe-Bush type as defined by Thornthwaite, Koppen, Trewartha, Miller, Nieuwolt etc. the above designation to the region can also be proved from the climate, vegetation and soil type.

The dry type (steppe-Bush) of environment is also reflected in the socio-cultural practices, such as pastoral, lumbering (of mangroves) and salt mining in the area. The complete absence of agriculture in most area and seasonal pastoral; related movement of the people is strongly related to the absence of rainfall and type of soil (saline soil) available in the region. Salt mining is also done only in the specific part of year that is dry period, which otherwise gets inundated and during wet season remains wet for longer period.

4.2 STUDY OF SEDIMENT PROPERTIES AND TECHNIQUES OF ANALYSIS

The entire area undertaken for research work seems to be assemblage of various types of physiographic units in microcosm. The study area encompasses highlands which rises upto the height of 112 feet above mean sea level to the areas which are at par with the sea level. The highland bets in the midst of the Rann appear to be the offshoots of the Kutch mainland peninsula. Minute geomorphic features such as structure, form, silts, deposits, salts etc. of the area have been analyzed because of the fact that precipitous variation in the relief is a rare phenomenon except the bets (islands). After the evaluation of such details, the area will be categorized in the chapters to follow.

The characteristics of sediments not only discloses the pedogenesis processes but also plays an important role in the movement of water, exhibits various physical and chemical properties such as porosity, permeability, plasticity, water holding capacity etc., which in a way divides themselves from one another in terms of homogeneity and heterogeneity. And therefore, it is essential to have a systematic study of the profiles from the different geomorphic facets. These profile wise systematic study will be generalized in the discussion of various geomorphic regions. The profile wise study will not only give an insight to the variation but also the nature of distribution of phenomenon.

The characteristics and role of sediments in terms of erosional and depositional characteristics, their plasticity, facilitating capillary rise, their hygroscopic absorption capacity, infiltration capacity, permeability etc. gives both short term and long term implication to the area. Apart from the above concern, the soil has a great deal to play in terms of the vegetal and faunal cover.

Still many people regard soil as “simple and lifeless”, as used by Sir. J. Rusell. but beyond any doubt, the plants, animals and soil comprise a harmonious whole. This entity is the ecosystem, being essentially a microcosm of the more familiar systems studied by the geographer, including many features applicable to human being at different scale and levels. With this, again we encounter the concept of feed back mechanism in that both structures and flows are interdependent. Such mutual relationships are never static but inevitably in a state of dynamic equilibrium.

By understanding a little about the soil's physical properties and its relationship to soil moisture, one can make better soil-management decisions. Soil texture and structure greatly influence water infiltration, permeability, and water-holding capacity.

Soil texture refers to the composition of the soil in terms of the proportion of small, medium, and large particles (clay, silt, and sand, respectively) in a specific soil mass. For example, a coarse soil is sand or loamy sand, a medium soil is a loam, silt loam, or silt, and a fine soil is a sandy clay, silty clay, or clay.

Soil structure refers to the arrangement of soil particles (sand, silt, and clay) into stable units called aggregates, which give soil its structure. Aggregates can be loose and friable, or they can form distinct, uniform patterns. For example, granular structure is loose and friable, blocky structure of six-sided and can have angled or rounded sides, and plate like structure is layered and may indicate compaction problems.

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.

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.

Permeability refers to the movement of air and water through the soil, which is important because it affects the supply of root-zone air, moisture, and nutrients available for plant uptake. A soil's permeability is determined by the relative rate of moisture and air movement through the most restrictive layer within the upper 40 inches of the effective root zone. Water and air rapidly permeate coarse soils with granular subsoils, which tend to be loose when moist and don't restrict water or air movement. Slow permeability is characteristic of moderately fine subsoil with angular to sub-angular blocky structure. It is firm when moist and hard when dry.

In the process of evaluation of sediments of different locations, simple experiments were done in the field as well as in the laboratory. The investigation of properties of sediment thus enabled to give nomenclature and classification and to arrive on their connection and correlation with the geomorphodynamic processes and morpho-ecological characteristics of the area.

Field study includes:

(1) Observation of general terrain characteristics of the area in different seasons.

(2) Observable field phenomenon such as capillary, efflorescence, vegetal cover and areas with flooding during tides and water stagnant areas.

(3) To make a note of variation of sediments types and their relation to the geomorphology of the Rann and land cover.

(4) Field experiences at different seasons to make a note of the extent of flooding in the area. Water marks along the slope of bet also revels the last extent of flooding in the Rann.

(5) Collection of samples for detailed quantitative investigation of the various index properties.

(6) Profile wise study of soil sediment characteristics in terms of plasticity, sediment size, degree of infiltration, permeability, moisture content etc.

(7) Statements by natives which reveled a sea change in the area since 13^{th} century. Several evidences were also encountered during the field work, which will be explained at the appropriate place.

A framework was devised in order to collect required number of samples from suitable locations. It was observed that geomorphology and sediment types showed a definite correlation and on this basis samples were collected. Samples were collected from all those area having spatial variation. Depth of sampling also varied from place to place depending upon the nature of terrain. Profile samples were collected mostly from the existing pit, along the channel banks, sides of the bet. Only at few places soil was dug because of the scarcity of resources. Samples were collected from appropriate locations in following areas.

(i) Transition zone, the fringe of Rann with the rocky mainland, where sediments from the mainland intermingles with the Rann Sediment.

(ii) The Rann depression which remains dry for larger part of the year.

(iii) The central part of Rann depression which relatively remains wet for larger part of year except for January to April.

(iv) The area having highest density of creeks lying along the western fringe of Little Rann of Kutch. The area is susceptible to sea water influx.(this area has been considered looking to its physical affinity with the Little Rann of Kutch.)

(v) Bets (islands): this geomorphic features stands distinctly on the flat Rann depression, which never gets submerged completely. Sediments from two bets were collected and studied in order to find differences if any.

(vi) Channels: samples were also collected from inter bet channels and channels which ultimately drains the water out of the Rann depression gradually in the dry periods.

In the course of field visit during two different seasons, a systematic record of the distribution of salts, vegetation, thickness of salt encrustations etc. were done. However, the soil analysis was done on one time collected samples.

Depth of sample varied from 1 foot to 3 feet depending upon the terrain condition. Samples collected from the field were subjected to various laboratory tests. All test except grain size and plasticity test were done personally.

Methods of Analysis:

(a)*Field Methods*

Some simple field tests for identification purpose were carried out in order to describe the profiles, for it facilitates a fair identification of the sediment characteristics. Following is the list of field tests:

(i) Visual inspection of the grain size and grain shape, texture, color.

(ii) Comparative compaction of uninterrupted sediment.

(iii) Determination of the feel of sediment by rubbing between two fingers, whether soapy or gritty.

(iv) Stratification of the profile of soil.

(v) Thickness of salt encrustations.

(vi) Assessment of the mobility of water within the pores. Through this test, water absorbed in the sediment can be brought to its surface by shaking a piece of sediment horizontally or by simply squeezing. If water appears on the surface with glossy appearance, it means high mobility while in case of vice-versa the sediment has low mobility. For this test the sediment should contain sufficient water and if it is too dry, water must be added to the sample.

(vii) The Hand Test, a quick method of determining moisture is known as the "Hand Test". Pick up a handful of soil, Squeeze it and then open your hand. If the soil is powdery and will not retain the shape made by your hand, it is too dry. If it shatters when dropped, it is too dry. If the soil is moldable and breaks into only a couple of pieces when dropped, it has the right amount of moisture for proper compaction. If the soil is plastic in your hand, leaves traces of moisture on your fingers and stays in one piece when dropped, it has too much moisture for compaction.

(viii) Relevant photography was done in order to strengthen the statements.

Description of the above field tests is discussed in the chapter-5 with reference to the various locations within study area.

(b)Laboratory Methods

(i) Grain Size Analysis:

Grain-size analysis, also known as particle-size analysis or granulometric analysis is perhaps the most basic sedimentological technique to characterize and interpret sediments and sedimentary rocks. The purpose of this lab analysis is to analyze grain-size measurements of samples from the various locations of Little Rann of Kutch which shows some fundamental differences in terms of land cover. The samples were collected from distinctly different environments. The grain-size measurements were carried out by means of the classical sieve-pipette technique (i.e., sieving of the sand fractions; pipette extraction of the mud fractions using settling tubes). This analysis was difficult because of the fineness of the sediments. Presence of clay, black boggy clay material and salts also tends the grain to cluster together. Nowadays, grain-size analysis is commonly performed with high-tech instruments like laser particle sizers. It is widely known that different measurement techniques provide different results; this is a particularly important issue when samples measured by different techniques are to be compared.

The size of sediment particles can be measured by visual estimation or by use by a set of sieves. With experience, most geologists can visually measure grain size within accuracy of the Wentworth grade scale at least down to silt grade. Silt and clay can be differentiated by whether they are crunchy or plastic between one's teeth.

Soil is most generally measured by sieving. The basic principle of this technique is as follows. A soil sample of known weight is passed through a set of sieves of known mesh sizes. The sieves are arranged in downward decreasing mesh diameters. The sieves are mechanically vibrated for a fixed period of time. The weight of sediment retained on each sieve is measured and converted into a percentage of the total sediment sample. This method is quick and sufficiently accurate for most purposes. Essentially it measures the maximum diameter of a sediment grain. This method is useful in analysis of terrigenous sediment.

Every soil type behaves differently with respect to maximum density and optimum moisture. Therefore, each soil type has its own unique requirements and controls both in the field and for testing purposes. Soil types are commonly classified by grain size, determined by passing the soil through a series of sieves to screen or separate the different grain sizes. Soil classification is categorized into 15 groups, a system set up by AASHTO (American Association of State Highway and Transportation Officials). Soils found in nature are almost always a combination of soil types. A *well-graded* soil consists of a wide range of particle sizes with the smaller particles filling voids between larger particles. The result is a dense structure that lends itself well to compaction. There are three basic soil groups:

1. Cohesive

2. Granular

3. Organic (this soil is almost nil in the study area and hence forth will not be a part of discussion).

Cohesive soils have the smallest particles. Clay has a particle size range of .00004" to .002". Silt ranges from .0002" to .003". Clay is used in embankment fills and retaining pond beds. Cohesive soils are dense and tightly bound together by molecular attraction. They are plastic when wet and can be molded, but become very hard when dry. Proper water content, evenly distributed, is critical for proper compaction. Silt has a noticeably lower cohesion than clay. However, silt is still heavily dependent on water content.

Granular soils range in particle size from .003" to .08" (sand) and .08" to 1.0" (fine to medium gravel). Granular soils are known for their water-draining properties. Sand and gravel obtain maximum density in either a fully dry or saturated state.

Grain size analysis of the sample sediment is shown in Table-4.1. Figure-4.1 and 4.2 shows the Sheppard's triangle diagram of sediment classification and Sediment classification of Rann and surrounding area repectively. Map-4.1 depicts the location from where samples were collected and their identified types.

Table-4.1 Mechanical analysis of sediments

Location -1 7 Km. West of Kharaghoda

Soil Profile Depth (inch)	Coarse Sand	Fine Sand	Silt	Clay
0-1	Salt encrusted surface			
1-6	2.31	4.30	33.73	59.65
6-12	0.50	2.96	35.50	61.02
12-20	Nil	1.74	37.12	61.14

Location -2 Jalandar Bet (Jhinjhuvada)

Soil Profile Depth (inch)	Coarse Sand	Fine Sand	Silt	Clay
0-5	7.34	51.15	29.45	12.00
5-10	6.10	58.45	28.65	6.52
10-15	4.50	60.23	25.43	9.81
15-20	2.60	49.67	40.30	7.43

Location -3 Zainabad

Soil Profile Depth (inch)	Coarse Sand	Fine Sand	Silt	Clay
0-1	Salt encrusted surface			
1-6	4.68	7.83	37.42	50.08
6-12	4.30	9.61	38.15	47.94
12-20	2.89	9.27	36.94	50.88

Location -4 Right bank of Rupen

Soil Profile Depth (inch)	Coarse Sand	Fine Sand	Silt	Clay
0-5	23.59	57.12	14.62	4.67
5-10	24.10	53.39	17.34	5.11
10-15	28.36	50.30	15.79	5.56
15-20	28.71	50.46	15.90	4.93

Location -5 5km east of Gagodar

Soil Profile Depth (inch)	Coarse Sand	Fine Sand	Silt	Clay
0-1	Salt encrusted surface			
1-6	1.93	4.69	34.53	58.85
6-12	0.56	3.13	37.21	59.02
12-20	Nil	2.27	37.98	59.80

Location -6 South-East of Surajbaari bridge

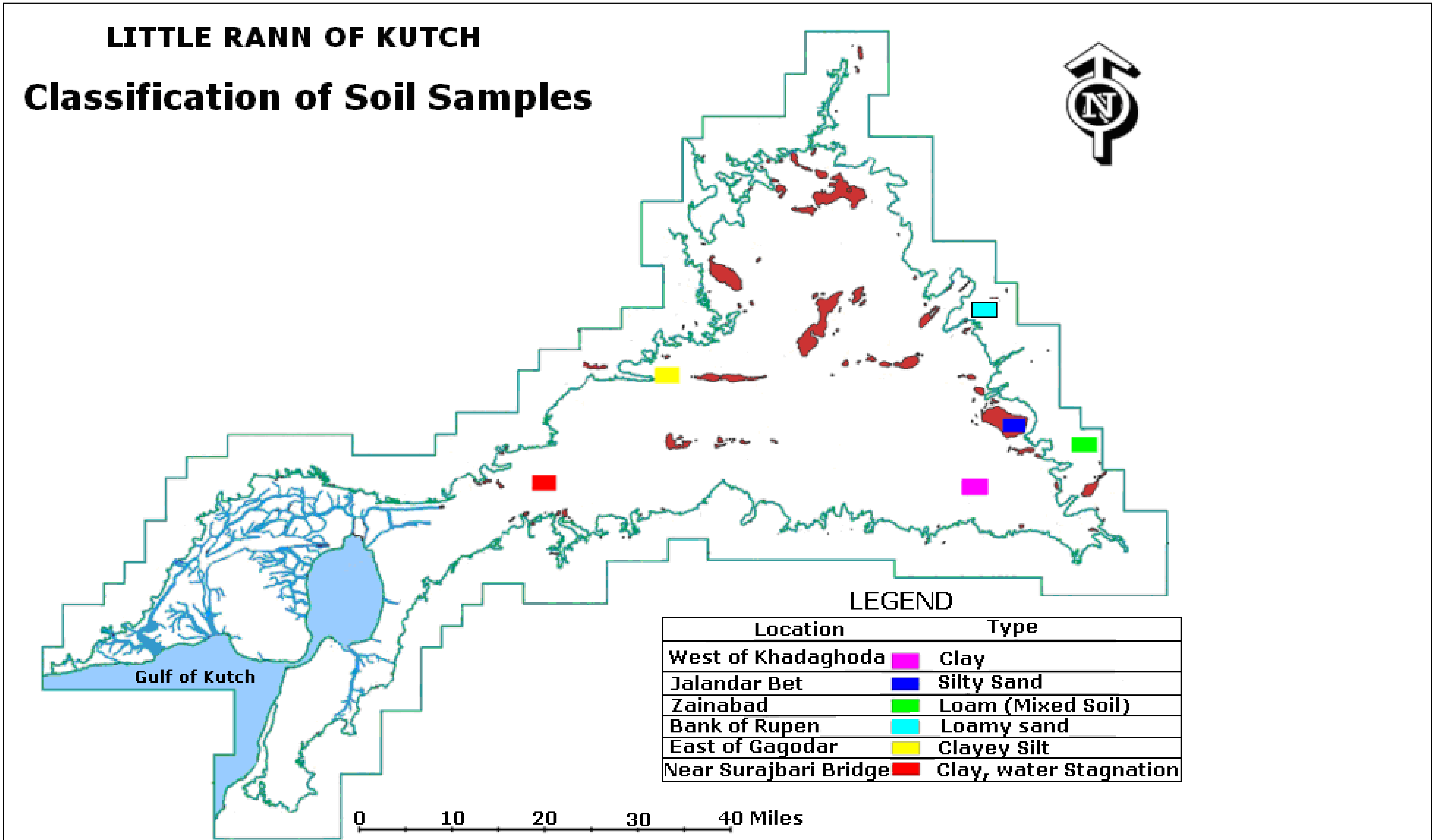
Soil Profile Depth (inch)	Coarse Sand	Fine Sand	Silt	Clay
0-5	0.47	2.33	40.19	57.00
5-10	Nil	2.17	38.62	59.20
10-15	Nil	1.64	44.95	53.41
15-20	Nil	0.87	45.41	53.72

(ii) Plasticity of Soil:

These are basic measure of the nature of a fine grained soil, depending on the water content of the soils; it may appear in four state; solid, semisolid, plastic, and liquid. In each state the consistency and behavior of a soil is different and so is its mobility (Table- 4.2).

Thus, the boundary between each state can be defined based on a change in the soil's behavior. The Atterberg limits can be used to distinguish between silt and clay, and it can distinguish between different types of silts and clays. These limits were created by Albert Atterberg, a Swedish chemist. They were later refined by Arthur Casagrande.

The plastic limit (PL) is the water content where soil starts to exhibit plastic behavior. After significant reduction of its moisture content, soil obtains characteristics of a brittle material, and when exposed to strain it fails. This state is called stiff consistency. By further reduction of moisture content, the state of genuine brittle behavior of soil is reached. The transitory moisture content between its stiff and solid consistency is called the shrinkage limit. The shrinkage limit is determined by a test during which a soil sample, mostly prism-shaped, is exposed to slow drying, and its moisture content is measured in relation to shrinkage. At the moment when the soil practically stops shrinking, its shrinkage limit has been reached.


LITTLE RANN OF KUTCH
Classification of Soil Samples
N
Gulf of Kutch
LEGEND
Location | Type
West of Khadaghoda | Clay
Jalandar Bet | Silty Sand
Zainabad | Loam (Mixed Soil)
Bank of Rupen | Loamy sand
East of Gagodar | Clayey Silt
Near Surajbari Bridge | Clay, water Stagnation
0 10 20 30 40 Miles

MAP – 4.1

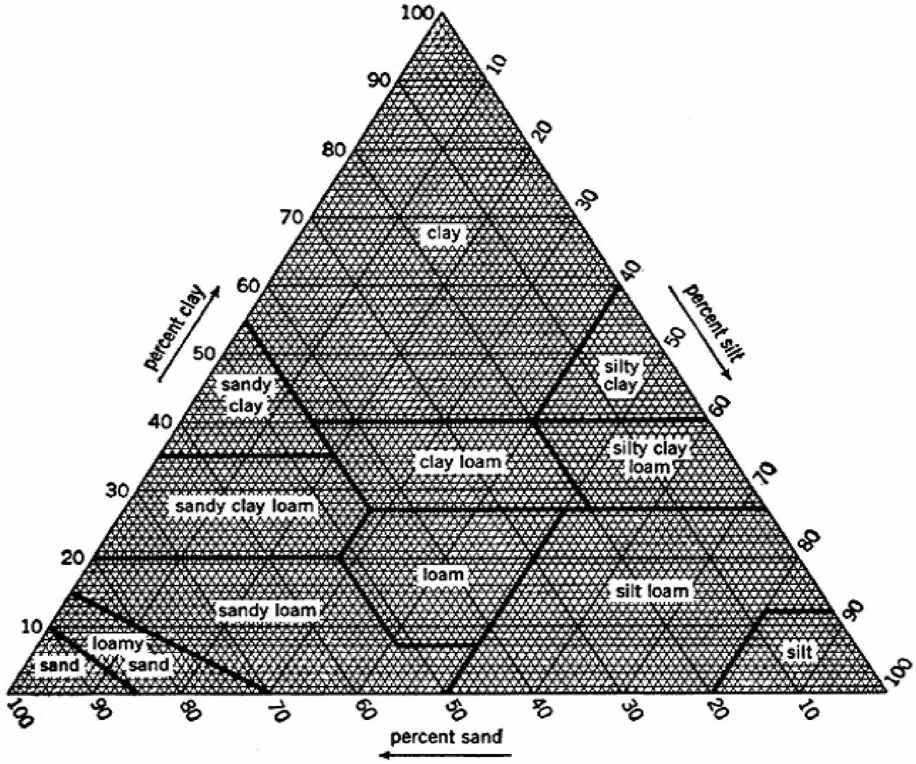


Fig. 4.1 Sheppard's triangle diagram showing the sediment classification

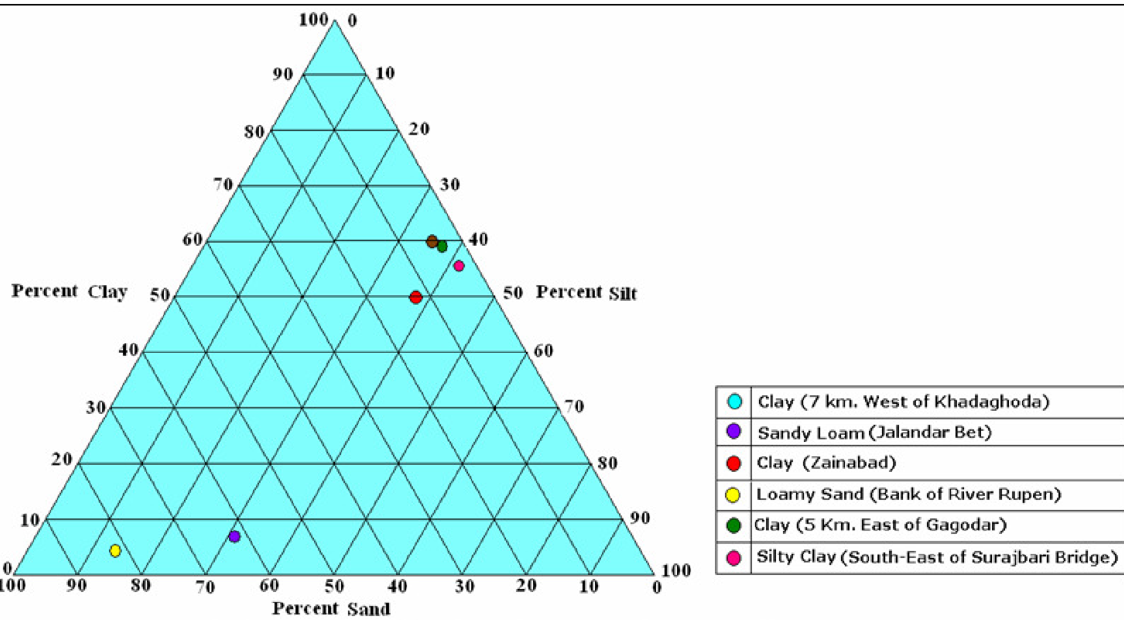


Fig. 4.2 Sediment classification of Rann and surrounding area

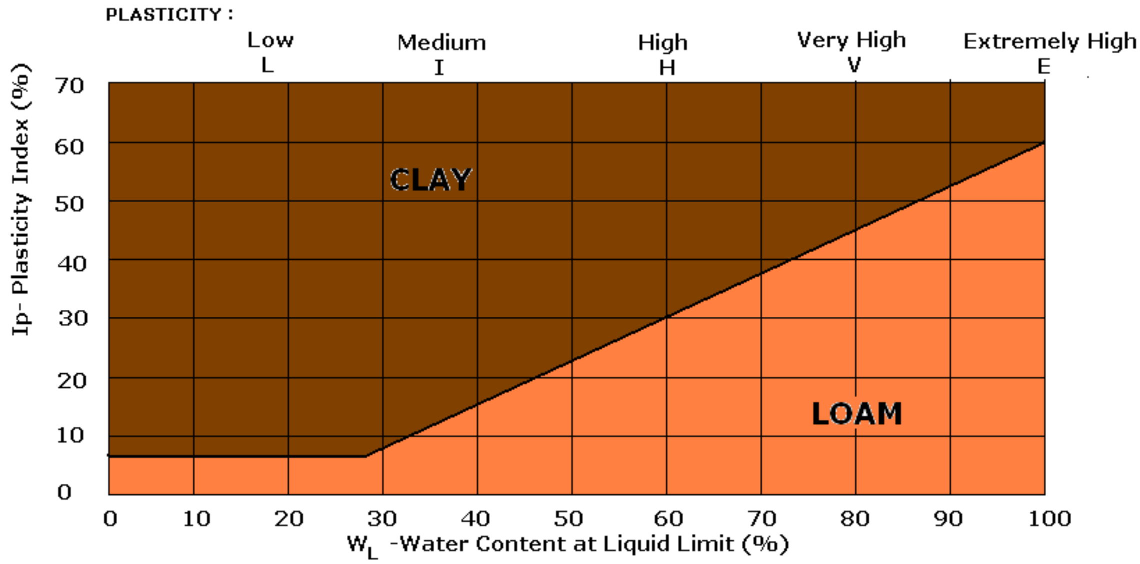


Fig. 4.3 Casagrande Plasticity Diagram

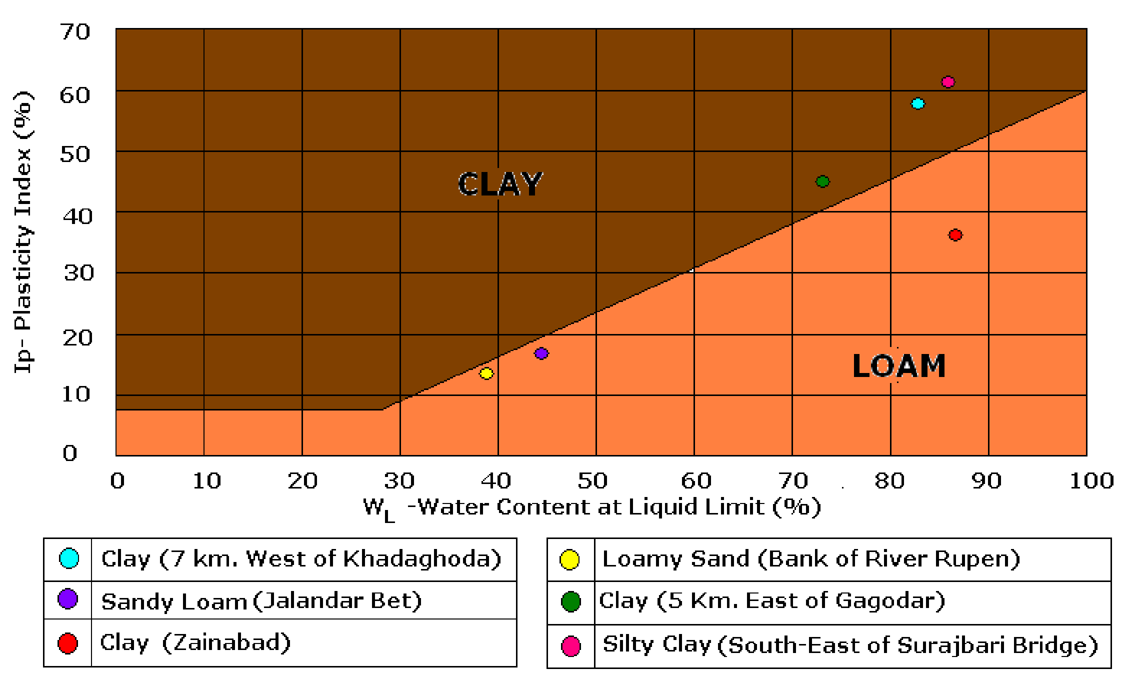


Fig. 4.4 Plastic Behaviour of the Rann and Surrounding Sediment

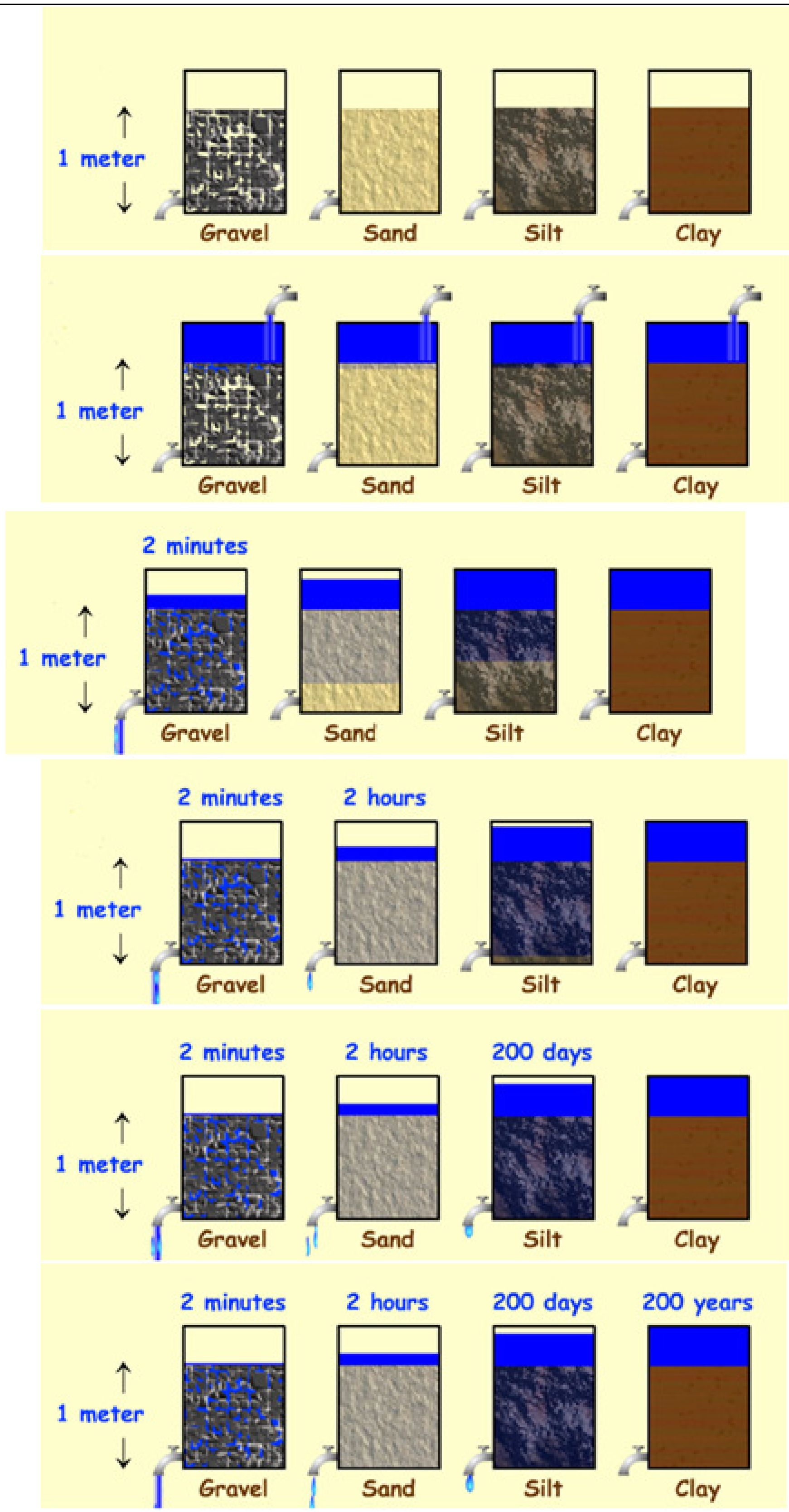


Fig. 4.5 Permeability in Different Soil Type

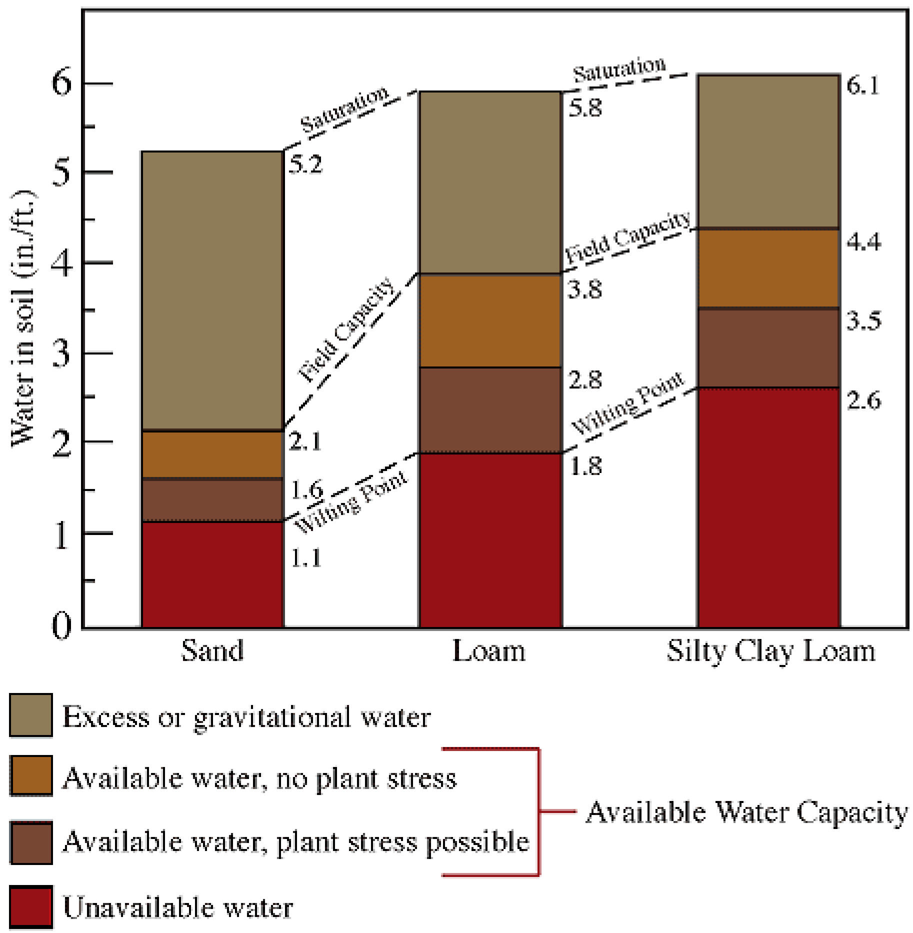


Fig. 4.6 Water Holding Capacity

The liquid limit (LL) is the water content where a soil changes from plastic to liquid behavior. The behavior of cohesive soil depends on its moisture content. With high moisture content, silty clay becomes slurry to liquid. Liquid consistency corresponds to the case when soil shows

Practically no resistance to shear strain. The moisture content at which soil already shows some shear strain is considered to be the boundary between liquid and plastic consistency. It is called the liquid limit w_L.

The original liquid limit test of Atterberg's involved mixing a pat of clay in a little round-bottomed porcelain bowl or metal cup of 10-12cm diameter, and a groove is made down its center with a standardized tool. The cup is repeatedly dropped onto a hard rubber base until the groove is closed for 13 mm (½ inch). The moisture content at which it takes 25 drops of the cup to cause the groove to close is defined as the liquid limit.

Depending on their liquid limit, soils may be further specified as soils showing the following plasticity:

L – low w_L below 35 %

I – medium w_L = 35 – 50 %

H – high w_L = 50 – 70 %

V – very high w_L = 70 – 90 %

E – extremely high w_L exceeding 90 %

Another method for measuring the liquid limit is the Cone Penetrometer test. It is based on the measurement of penetration into the soil of a standardized cone of specific mass. Despite the universal prevalence of the Casagrande method, the cone penetrometer is often considered to be a more consistent alternative because it minimizes the possibility of human variations when carrying out the test. In the present study values for plasticity index was derived through original liquid limit test of Atterberg's (get it done from the private laboratory and not done personally).

The values of these limits are used in a number of ways. There is also a close relationship between the limits and properties of a soil such as compressibility, permeability, and strength. This is thought to be very useful because as limit determination is relatively simple, it is more difficult to determine these other properties. Thus the Atterberg limits are not only used to identify the soil's classification, but it also allows for the use of empirical correlations for some other properties.

Bentonite, which is abundantly found in the study area, is a sealing element, the range of its plasticity state is a very important property. Bentonite with high plasticity is used to fill in and seal the cracks and joints in the engineered barrier's construction and also to fill the vacuum oilwells.

The plasticity index (PI) is a measure of the plasticity of a soil. The plasticity index is the size of the range of water contents where the soil exhibits plastic properties. The PI is the difference between the liquid limit and the plastic limit (PI = LL-PL). Soils with a high PI tend to be clay, those with a lower PI tend to be silt, and those with a PI of 0 tend to have little or no silt or clay.

The liquidity index (LI) is used for scaling the natural water content of a soil sample to the limits. It can be calculated as a ratio of difference between natural water content, plastic limit, and plasticity index: LI=(W-PL)/(LL-PL) where W is the natural water content. The relation between the plasticity index and moisture content at the liquid limit is expressed in the Casagrande plasticity diagram Figure 4.3. The plasticity measurement of the sample sediment is given in Table 4.3 and is represented in Figure-4.4.

Table-4.3 Plasticity measurement

Location	Soil type	Liquid limit (LL)	Plastic limit (PL)	Plastic Index (PI)
7 km.west of Kharaghoda	Clay	83	25	58
Jalandar Bet (Jhinjhuvada)	Sandy loam	45	28	17
Zainabad	Clay	87	51	36
Right bank of Rupen	Loamy sand	39	25	14
5km east of Gagodar	Clay	73	28	45
South-East of Surajbaari bridge	Silty, water stagnation	86	25	61

(iii) Total moisture content:

Water content or moisture content is the quantity of water contained in a material, such as soil (called soil moisture), rock, ceramics, or wood on a volumetric or gravimetric basis. The property is used in a wide range of scientific and technical areas, and is expressed as a ratio, which can range from 0 (completely dry) to the value of the materials' porosity at saturation. Primary field testing was done through shaking and squeezing the lump of soil in hand to have a qualitative idea of mobility and moisture content of the soil.

Volumetric water content, θ, is defined mathematically as:

$$\theta = \frac{V_w}{V_T}$$

Where V_w is the volume of water and $V_T = V_s + V_w + V_a$ is the total volume (that is Soil Volume + Water Volume + Void Space). Water content may also be based on its mass or weight, thus the gravimetric water content is defined as:

$$u = \frac{m_w}{m_b}$$

Where m_w is the mass of water and m_b (or m_s for soil) is the bulk material mass.

Moisture content is also defined as the ratio of m_w (water weight in soil) to m_d (dry weight of soil), unit: %.

The method of moisture content determination in laboratory conditions specifies the amount of water contained in soil. It has been done by drying the soil sample at 105 - 110° C. Moisture content is calculated from the relation of weight loss in percentage after drying of samples (Table-4.4)

Table-4.4 Moisture content

Location	Soil profile	weight after drying (5gms. sample)	Total moisture content in (Perentage)
7 Km. West of Kharaghoda	Top soil	4.727	5.46
	Soil at 10 inch depth	4.540	9.20
	Soil at 20 inch deep	4.218	15.64
Jalandar Bet (Jhinjhuvada)	Top soil	4.437	11.26
	Soil at 10 inch depth	4.307	13.86
	Soil at 20 inch deep	4.485	10.30
Zainabad	Top soil	4.806	3.88
	Soil at 10 inch depth	4.824	3.52
	Soil at at 20 inch deep	4.537	9.26
Right bank of Rupen	Top soil	3.874	22.52
	Soil at 10 inch depth	3.937	21.26
	Soil at 20 inch deep	4.008	19.84
5km east of Gagodar	Top soil	4.412	11.76
	Soil at 10 inch depth	4.128	17.44
	Soil at 20 inch deep	3.936	21.28
South-East of Surajbaari bridge	Top soil	3.457	30.86
	Soil at 10 inch depth	3.552	28.96
	Soil at 20 inch deep	3.512	29.76

(iv) Porosity and Permeability:

The capacity of earth materials to circulate and transmit fluids (water, solutions, air etc.) through their pores and fractures and measured as the fluid volume passing through a unit cross-section area. Sand and gravel are highly permeable, clay does not allow water to pass through it, and so it is impermeable.

Porosity is a measure of the void spaces in a material, and is measured as a fraction, between 0–1, or as a percentage between 0–100 %. The term is used in multiple fields including ceramics, metallurgy, materials, manufacturing, earth sciences, construction, geology, hydro-geology and soil science. The porosity of a porous medium (such as rock or sediment) describes the fraction of void space in the material, where the void may contain, for example, air or water. Symbols φ and n are used to denote porosity.

Porosity is a fraction between 0 and 1, typically ranging from less than 0.01 for solid granite to more than 0.5 for peat and clay, although it may also be represented in percent terms by multiplying the fraction by 100. Just as the porosity of a soil affects how much water it can hold, it also affects how quickly water can flow through the soil.

The ability of water to flow through a soil is referred to as the soil's permeability. As one can probably guess, the permeability of gravel is higher than that of clay. Time taken by water to travel 1 meter deep profile in different soil types are as follows: gravel - 2minute, sand - 2hour, silt - 200day, clay – not even in 200years (Fig.- 4.5).

Porosity can be calculated by dividing the volume of water that was able to be poured into it by the total volume of the material. Then express this result as a percentage. For example if 50ml of water was added to 300ml of gravel, the porosity would be:

$$\frac{50ml}{300ml} = .1666 = 16.66\%$$

Another way of calculating porosity is by adopting the following formula: Porosity (%)= $\left[1 - \frac{Bulk\ Density}{Particle\ Density}\right] \times 100$

The porosity of the sample sediment is given in Table 4.5

Table-4.5 Porosity

Location	Soil profile	Bulk density (gm/ cm^3)	Particle density (gm/ cm^3)	Porosity (%)
Kharaghoda;	Top soil	1.152	1.350	14.7
	Soil at 10 inch depth	1.008	1.297	22.8
	Soil at 20 inch deep	1.171	1.240	5.6
Jalandar Bet (Jhinjhuvada)	Top soil	1.431	1.584	9.7
	Soil at 10 inch depth	1.435	1.794	20.1
	Soil at 20 inch deep	1.359	1.661	18.2
Zainabad	Top soil	1.501	1.602	6.4
	Soil at 10 inch depth	1.461	1.608	8.9
	Soil at 20 inch deep	1.008	1.564	35.6
Right bank of Rupen	Top soil	1.047	1.106	5.4
	Soil at 10 inch depth	1.193	1.357	12.1
	Soil at 20 inch deep	0.910	1.484	38.7
5km east of Gagodar	Top soil	1.452	1.587	8.5
	Soil at 10 inch depth	1.279	1.459	12.3
	Soil at 20 inch deep	1.098	1.391	21.06
South-East of Surajbaari bridge	Top soil	1.347	1.463	7.9
	Soil at 10 inch depth	1.172	1.231	4.7
	Soil at 20 inch deep	1.108	1.071	3.4

(v) Total soluble salt content:

The purpose of salinity analysis is to evaluate the size and extent of salt contamination; therefore, the samples should represent the salt affected areas only, instead of the entire field. The aridity and morphology of the Rann has favored accumulation of salts in varying forms in scattered patches.

Efflorescence is the common form of salt deposits in the study area, which are the result of evaporation of moisture brought to the surface by capillary action. The salt encrustations usually due to efflorescence occur as thin coating like crusts on the surface which always crumble easily under pressure. The undersurface of these crust, very often consist of the needle like salt crystals. This phenomenon is more conspicuous in the area of fine sediments which allows soil moisture to rise up through capillary action and not in the area of coarse sediments. This sheet of salt crust tends to disappear from the area of formation due to the action of wind or at certain places they are covered under the veil of loess during desert storms, also lots of salts are often carried to a large distance inland during the storms.

Another type of salt crystal development was seen mostly along the foot zone of bet, where the sedimentary characteristic is different from that of the Rann interior. The salt crystals developed here are of larger size than that of the area of efflorescence. It has been observed that there is close relation between grain size of sediments and salt crystals. Larger the grain size more is the intermediate space between them, where these salts crystal develops. Such type of crystal formation is the result of evaporation of saline water cleaves to the sediments. The crystals formed are mainly gypsum and are best seen during dry season.

Sebkhas are another type of brine deposits of significant thickness, formed by the evaporation of stagnant saline water bodies, resulting in the formation of salt playas. There are two types of sebkhas, one is inland and another is marine. They are differentiated on the basis of source of water in the depression which ultimately leaves behind damp salt encrusted sediments.

Total soluble salts (TSS), is referred to the total amount of salt dissolved in the soil extract expressed in parts per million (ppm) or milligram/ Kilogram. The salts include substances that form common table salt (sodium and chloride) as well as calcium, magnesium, potassium, nitrate, sulfate and carbonates. Total soluble salt contain in the samples were tested through electrical conductivity in mS (milli Simens) unit (Table-4.6)

Formula:

T.S.S.= Conductivity (mS i.e, milli Simens) x 640 (constant)
Measured in ppm (parts per million or milligram/kilogram)

Weight of soil sample: 10 gms. each
Volume of water added to the samples: 50ml.

Table-4.6 Total soluble salt contain (TSS)

Location of Samples.	Conductivity (mS)	TSS (ppm)
Stream between Patdi and Shavada	0.44	281.6 {0.44 X 640 (constant)}
Foot zone of Jalandar Bet	3.79	2425.6
Dry channel bed, midst of Rann	18.9	12096
Rann floor 10 km west of Kharaghoda	0.76	486.4
Rann top dried flakes, 2km north of Kuda.	10.6	6784

(vi) Natural volume and Compact volume:

Soil compaction is the term for the deterioration of soil structure (loss of soil features) by mechanistic pressure. The compaction process can be initiated by both natural and anthropogenic processes. Soil compaction is a form of physical degradation resulting in densification and distortion of the soil where biological activity, porosity and permeability are reduced, strength is increased and soil structure partly destroyed. Compaction can reduce water infiltration capacity and increase erosion risk by accelerating run-off. Measurement of volumes both natural and compact (Table-4.7) is desirable to understand the properties of soil.

Table-4.7 Natural volume and Compact volume

Location	Soil profile	Natural volume of 5gms. Sample (cm^3)	Compact volume of 5gms. Sample (cm^3)
7 Km. West of Kharaghoda	Top soil	3.4	3.1
	Soil at 10 inch depth	3.1	3.0
	Soil at 20 inch deep	3.1	3.0
Jalandar Bet (Jhinjhuvada)	Top soil	4.4	3.7
	Soil at 10 inch depth	4.1	3.5
	Soil at 20 inch deep	3.9	3.4
Zainabad	Top soil	3.8	3.4
	Soil at 10 inch depth	3.5	3.2
	Soil at 20 inch deep	3.4	3.2
Right bank of Rupen	Top soil	4.7	3.5
	Soil at 10 inch depth	4.2	3.5
	Soil at 20 inch deep	4.0	3.4
5km east of Gagodar	Top soil	4.6	3.9
	Soil at 10 inch depth	4.1	3.7
	Soil at 20 inch deep	3.9	3.6

South-East of Surajbaari bridge	Top soil	3.2	3.1
	Soil at 10 inch depth	3.2	3.1
	Soil at 20 inch deep	3.1	3.1

(vii) Bulk density:

The relationship of the mass of a soil or sediment to its volume, typically expressed in gm/cubic cm, using either a naturally damp or oven dried sample.

"Bulk density is a measure of the weight of the soil per unit volume (g/cc), usually given on an oven-dry (110° C) basis. Variation in bulk density is attributable to the relative proportion and specific gravity of solid organic and inorganic particles and to the porosity of the soil. Most mineral soils have bulk densities between 1.0 and 2.0. Bulk densities are important in quantitative soil studies, and measurements are necessary, for example, in calculating soil moisture movement within a profile and rates of clay formation and carbonate accumulation. Even when two soils are compared qualitatively on the basis of their development for purposes of stratigraphic correlation, more accurate comparisons can be made on the basis of total weight of clay formed from 100 g of parent material than on percent of clay alone. To convert percent to weight per unit volume, multiply by bulk density".[48] The determination usually consists of drying and weighing a soil sample, the volume of which is known (Table-4.8).

$$\text{Bulk Density} = \frac{Weight\ After\ Drying}{Volume\ of\ Dry\ Sample}$$

[48] Birkeland, P.W., 1984, Soils and Geomorphology: Oxford University Press, New York, p. 14-15.

Table-4.8 Bulk Density

location	Soil profile	Weight after drying 5gms. sample	Volume of dried sample	Bulk density (gm/ cm^3)
7 Km. West of Kharaghoda	Top soil	4.727	4.1	1.152
	Soil at 10 inch depth	4.540	4.5	1.008
	Soil at 20 inch deep	4.218	3.6	1.171
Jalandar Bet (Jhinjhuvada)	Top soil	4.437	3.1	1.431
	Soil at 10 inch depth	4.307	3.0	1.435
	Soil at 20 inch deep	4.485	3.3	1.359
Zainabad	Top soil	4.806	3.2	1.501
	Soil at 10 inch depth	4.824	3.3	1.461
	Soil at 20 inch deep	4.537	4.5	1.008
Right bank of Rupen	Top soil	3.874	3.7	1.047
	Soil at 10 inch depth	3.937	3.3	1.193
	Soil at 20 inch deep	4.008	4.4	0.910
5km east of Gagodar	Top soil	4.458	3.0	1.452
	Soil at 10 inch depth	4.279	3.3	1.279
	Soil at 20 inch deep	3.973	3.6	1.098
South-East of Surajbaari bridge	Top soil	3.427	2.5	1.347
	Soil at 10 inch depth	3.394	2.8	1.172
	Soil at 20 inch deep	3.306	2.9	1.108

(viii) Water holding capacity

Water-holding capacity is controlled primarily by soil texture and organic matter. Soils with smaller particles (silt and clay) have a larger surface area than those with larger sand particles, and a large surface area allows a soil to hold more water. In other words, a soil with a high percentage of silt and clay particles, which describes fine soil, has a higher water-holding capacity. The table- 4.9 illustrates water-holding-capacity differences as influenced by texture. Organic matter percentage also influences water-holding capacity. As the percentage increases, the water-holding capacity increases because of the affinity organic matter has for water.

Water availability is illustrated by water levels in three different soil types (fig.-4.6). Excess or gravitational water drains quickly from the soil after a heavy rain because of gravitational forces (saturation point to field capacity). Plants may use small amounts of this water before it moves out of the root zone. Available water is retained in the soil after the excess has drained (field capacity to wilting point). Plants can use approximately 50 percent of it without exhibiting stress, but if less than 50 percent is available, drought stress can result. Unavailable water is soil moisture that is held so tightly by the soil that it cannot be extracted by the plant. Water remains in the soil even below plants' wilting point.

It is clear from the Table-4.9 that soil texture greatly influences water availability. The sandy soil can quickly be recharged with soil moisture but is unable to hold as much water as the soils with heavier textures. As texture becomes heavier, the wilting point increases because fine soils with narrow pore spacing hold water more tightly than soils with wide pore spacing.

Soil is a valuable resource that supports plant life, and water is an essential component of this system. Management decisions concerning types of crops to plant, plant populations, irrigation scheduling etc. depends upon the amount of moisture that is available to the crop throughout the growing season. By understanding some physical characteristics of the soil, one can better define the strengths and weaknesses of different soil types. Table-4.10 shows the water holding capacity of the various soil samples.

Table-4.9 Available Water Capacity by Soil Texture

Textural Class	**Available Water Capacity (Inches/Foot of Depth)**
Coarse sand	0.25–0.75
Fine sand	0.75–1.00
Loamy sand	1.10–1.20
Sandy loam	1.25–1.40
Fine sandy loam	1.50–2.00
Silt loam	2.00–2.50
Silty clay loam	1.80–2.00
Silty clay	1.50–1.70
Clay	1.20–1.50

Table-4.10 Water holding capacity

Location	Soil profile	Water holding capacity (ml/gm)
7 Km. West of Kharaghoda	Top soil	0.740
	Soil at 10 inch depth	0.818
	Soil at 20 inch deep	0.640
Jalandar Bet (Jhinjhuvada)	Top soil	0.405
	Soil at 10 inch depth	0.348
	Soil at 20 inch deep	0.401
Zainabad	Top soil	0.330
	Soil at 10 inch depth	0.414
	Soil at 20 inch deep	0.396
Right bank of Rupen	Top soil	0.542
	Soil at 10 inch depth	0.457
	Soil at 20 inch deep	0.474
5km east of Gagodar	Top soil	0.406
	Soil at 10 inch depth	0.712
	Soil at 20 inch deep	0.756
South-East of Surajbaari bridge	Top soil	0.825
	Soil at 10 inch depth	0.831
	Soil at 20 inch deep	0.852

(This test was conducted with oven dried samples)

(ix) Hygroscopic Absorption:

Hygroscopic absorption capacity of the soil has been defined as the ability of the soil to absorb or to suck in moisture from the vapour in the air, depending upon the physical and chemical properties of the soil. The atmospheric moisture absorbed by the soil is called hygroscopic moisture. Apart from the laboratory experiments to calculate the hygroscopic coefficient, field observations during different part of the year also confirm this phenomenon.

It is also clear from the works of Roy (1973) that Hygroscopic absorption capacity of the Rann sediment is very high as compared to its peripheral areas, and this increases the already high moisture content in the Rann sediment. During the moist period the moisture volume of the

Rann sediment increases considerably because of the higher hygroscopic absorption capacity.

The natives on the related area under discussion mistook the phenomenon of sudden dampness in clayey soil as a result of rise in the water table. But, the fact is, the time required for vertical permeability in the one meter deep profile of the clay soil has been estimated to be 200 years, not to mention about the horizontal movement. It has been noticed during the field visit that there is unparalleled increase in the field moisture even during cloudy weather. Sudden dampness develops on the ground hindering the accessibility, and may be attributed to the chemical properties of the soil that is excess of salt contents. This test was done on one time collected soil samples. Hygroscopic absorption for the soil samples (Table-4.11) have been carried out in the laboratory during different part of the year with varying humidity.

Table-4.11 Hygroscopic Absorption capacity

(For dried soil samples (10 grams each))

HUMIDITY (%)	LOCATION (Sediment characteristics)	Weight	Absorbing capacity in percentage
40	Peripheral frontier zone within the range of two miles from the boundary of Rann. (organic Silty clay, less saline)	10.523	5.23
	Eastern dry areas of Rann close to periphery. (saline partly organic clay)	11.030	10.30
	Central semi dry areas of Rann away from periphery and bet. (saline Inorganic clay)	10.800	8.00
	Western most peripheral, Marshy creek areas. (saline inorganic clay)	10.785	7.85
	Bet sediment	10.100	1.00
	Foot zone of bet (organic clay)	10.987	9.87

60	Peripheral frontier zone within the range of two miles from the boundary of Rann. (organic Silty clay, less saline)	10.676	6.76
	Eastern dry areas of Rann close to periphery. (saline partly organic clay)	11.282	12.82
	Central semi dry areas of Rann away from periphery and bet. (saline Inorganic clay)	10.951	9.51
	Western most peripheral, Marshy creek areas. (saline inorganic clay)	10.895	8.95
	Bet sediment	10.270	2.70
	Foot zone of bet (organic clay)	11.166	11.66
80	Peripheral frontier zone within the range of two miles from the boundary of Rann. (organic Silty clay, less saline)	10.773	7.73
	Eastern dry areas of Rann close to periphery. (saline partly organic clay)	11.485	14.85
	Central semi dry areas of Rann away from periphery and bet. (saline Inorganic clay)	11.057	10.57
	Western most peripheral, Marshy creek areas. (saline inorganic clay)	10.980	9.80
	Bet sediment	10.402	4.02
	Foot zone of bet (organic clay)	11.346	13.46

Table- 4.2 BEHAVIOUR OF CLAY SOIL (VERTISOLS)

(IN DIFFERENT MOISTURE REGIME)

	SHRINKAGE LIMIT	PLASTIC LIMIT	LIQUID LIMIT
STIFF CONSISTENCY (Brittle)	SOLID CONSISTENCY	PLASTIC CONSISTENCY	LIQUID CONSISTENCY

In each state the consistency, behaviour and mobility of soil is different.