CHAPTER 5

TECHNIQUES AND METHODS OF SEDIMENT STUDIES

In order to evaluate various sediment properties, experiments were conducted in the field as well as in the laboratory. On the basis of these investigations, the nomenclature and classification of the various sediment groups were arrived at and their connection with the problem of inundation correlated.

Field study included:

(i) observable field phenomena, such as capillarity, efflorescence and areas flooding and water stagnation,

(ii) variation of sediment types and their relation to the geomorphology of the area,

(iii) field experiments at different seasons to determine the moisture variation along profiles, sediment cohesion and degree of infiltration.

Laboratory studies entailed detailed investigations of the various index properties of the sediments.

COLLECTION OF SAMPLES

Reconnaissance survey was initially undertaken and the samples collected. They were subjected to a preliminary examination in order to enable the author to fix-up traverses to collect typical samples in required number suitable for detailed laboratory investigations. On this basis, the final traverses were taken and detailed sampling was carried out. It was observed that the geomorphology and the sediment types showed a definite correlation and on this basis, the samples were collected. Sampling was done only where variation or some special feature were observed. Depth of sampling also depended on the nature of the terrain. Samples were collected from appropriate locations in following areas.

(i) Bets: These features are distinctly elevated units on the Rann surface which never get submerged. Analysis of bet sediments also helped to differentiate it from the Rann sediments. A study of sediments from more than one bet, was carried out to find out the differences and variations.

(ii) Inter-bet channels: Sampling was also done from affected low lying areas between the bets which are inundated during wet seasons.

(iii) The area susceptible to sea-water influx: Here sampling was conducted along an east-west axis (Lakhpat-Kuar Bet). Main difficulty in collecting samples in this region was inaccessibility, as it remains wet throughout the year.

(iv) The fringes of Rann with the rocky mainland: These present a transition zone where material washed down from the mainland intermingles with the Rann sediment.

(v) The Great Rann depression which does not receive sea water: Samples were obtained from all accessible spots with a view to study the phenomenon of water stagnation.

In the course of his traverses, the author made a systematic record of the distribution of salt crystals (season-wise) along soil profiles and thickness of salt encrustations. Depth of sampling varied from 30 cm to 3 metres depending on the location. In most cases digging was carried out upto depths of sub-surface water level, to obtain profiles (Chapter 4). The sediment samples were subjected to several laboratory tests.

METHODS OF ANALYSIS

(A) Field methods

(1) Field moisture coefficient (seasonwise).
(2) Cone Penetrometer (seasonwise).
(3) Field permeability.
(4) Variation of moisture with depth.

(B) Laboratory methods

(1) Grain-size analysis
(2) Atterberg's Limit (PL,LL,PI)
(3) Moisture Absorbing capacity
(4) Thixotropic values
(5) Hygroscopic coefficient
(6) Permeability
(7) Total soluble salts

(8) Mineral Analysis

(9) Properties of leached and unleached sediments.

Field Methods

(1) Field moisture coefficient: Measurement of field moisture coefficient was carried out by using a portable field moisture meter. A compact and useful instrument for carrying out 'on the spot' readings, it operates on the principle of pressure built-up by the moisture present in the sediment interacting with calcium carbide. The pressure value is read on a dial. Value on dial gives direct value of moisture percentage. Greater the moisture percent of the sediment, higher the value on the dial. The values were obtained during various seasons so as to give an insight on the variation of moisture during wet and dry periods.

(2) Variation of moisture with depth: Sampling was carried out along the profile and the moisture coefficient was calculated for samples from various depths. The values were obtained during different seasons to observe the change in the moisture content. The relation of moisture content to depth was then computed on centimeter graph.

(3) Cone Penetrometer Tests: A cone penetrometer is essentially an instrument to determine the compaction of sediments at various depths. For quick and on the spot reading, a portable cone penetrometer was used. This instrument gives the strength of the sediment, read on a guage, and these values, known as Cone Index Values, are directly proportional to the pressure applied for affecting penetration. The values for penetration at intervals of 3" or 6" (depending on the sediment condition) were recorded. The Cone Index Values reflect the degree of sediment cohesion at respective depths. For the sake of comparision, the values of Cone Index, were calculated during wet and dry seasons.

Laboratory Methods

Grain-size Analysis: In any form of sediment study, the knowledge of grain-size is essential, and the purpose of this grain-size analysis is to obtain the proportion of the different grain-sizes as they were deposited. This analysis was rather difficult because of the fine-ness of the sediment, pressure of clay minerals, and on account of their flaky character and surface electrical charge. All these tend the grains to cluster together. Furthermore dispersion and removal of organic matter from the organic clays especially the black boggy clay, was very tedious and time consuming. The average grain size of the Rann sediment being always smaller than 0.062 mm, the technique of pipette analysis had to be followed. As it was difficult to separate clay lumps into individual particles of which size-measurement was to be done, dispersion of clay particles, as per following procedure was found essential.

Dispersion was effected by treating

(i) the soil with hydrogen peroxide to oxidise organic matter,

(ii) destroying the carbonate with acid,

(iii) washing with hot water, adding a quantity of sodium hydroxide and converting the sediment into a sodium sediment.

The fractionation into textural units was achieved by making use of Stokes law (differences in settling velocity). 10 gm of air-dried sediment was taken and 30 cc of 10% hydrogen peroxide added and the solution kept overnight. Next day, the solution was warmed upto 60°C. Effervescence subsided after sometime. Excess hydrogen peroxide was added to ensure complete oxidation of organic matter. The content then was cooled and 25 cc of 2N hydrochloric acid was added and 25 cc extra was added to ensure complete change. After filtering through a funnel using No.1 Whatman filter paper, the residue was washed free of hydrochloric acid and tested by litmus paper. The filter paper was spread over a watch glass and the residue washed down a 0.2 mm sieve held over a 500 cc beaker. This residue was washed down very carefully with a fine jet of water. The residue left behind which represented the coarse sand fraction (X gm). The percentage of coarse sand was calculated from the following formula:

$$\frac{X}{10} \times 100$$

To the residual solution was added distilled water to make a volume of 1000 c.c. Temperature of suspension was noted. This sediment suspension was transferred into a cylinder, and the contents were shaken and placed under a pipette. The suspension was allowed to settle for a period of time as per the standard I.S.I. chart. The pipette was then lowered to a depth of 10 cm from the surface and 20 cc of liquid was slowly withdrawn taking 20 seconds to fill it, and collected in a silica porcelain dish weighing (W_1 gm). It was weighed again (W_2 gm) after evaporating the suspension to dryness.

$$\text{Silt + Clay in sample} = \frac{(W_2-W_1)}{20} \times 1000 \times \frac{100}{10}$$

$$= (W_2-W_1) \times 500 = Y\ \%$$

Again the contents of the cylinder were shaken and after appropriate time, the pipette was again lowered to a depth of 10 cm. The suspension from the pipette was collected into a previously weighed dish (W_3). On evaporation to dryness, weight was (W_4 gm)

$$\therefore \text{ Wt of clay} = (W_4-W_3) \text{ gm.}$$

$$\therefore \text{ Clay in sample} = \frac{(W_4-W_3)}{20} \times 1000 \times \frac{100}{10}$$

$$= \underline{(W_4 - W_3) \times 500 = Z \text{ gm } \%}$$

$$\therefore \underline{\text{Silt } \% = (Y - Z)\ \%}$$

For fine sand, about 3/4th of the suspension in the cylinder was poured out and the remainder was transferred to a tall beaker. Water was added to a depth of 10 cm shaken and allowed to settle. The supernatant liquid was decanted and again the beaker was filled upto 10 cm. This process was repeated till all the clay and silt fractions were decanted away, leaving behind the fine-sand fraction. The sediment was transferred to a previously weighed dish. It was dried and cooled and weighed subsequently.

Wt of fine sand = 5 gm

$\therefore$ Fine sand in sample = $\frac{S \times 100}{10}$ %

(2) Atterberg's Limits: An important feature of sediments, because their behaviour depends on it, is their consistency. This property has been recorded by determining their water content. Atterberg advocated two stages in the wetting of a sediment, (a) when it is just sufficiently wet to be plastic and (b) when it is just liquid enough to flow for a given distance if shaken 25 times under standard conditions. The two critical points are named Plastic (or lower plastic Limit and Liquid (or higher plastic) Limit and the difference between the water percentages at the two points is termed Plasticity Index.

The procedure for determining the Plastic Limit (PL) is as follows:

Material passing B.S. Sieve No. 36 is air dried by the same procedure that is followed in tests for Moisture and Liquid Limits. The air-dried sample is thoroughly mixed with distilled water on a glass plate unit it becomes sufficiently plastic to be shaped in a ball. The ball is then rolled between the palm and the glass until a thread 1/8" in diameter is formed. With further kneading the thread gets progressively elongated and a gradual decrease in moisture content takes place. If kneading is continued, at one stage crumbling of the thread takes place. The moisture content of the crumbled material is then determined.

The upper plastic limit (Liquid Limit) is determined by preparing air-dried sample of sediment in the same way as above. Water is then added and the sediment-water mixture placed in a standarised brass-cup (Casagrande's apparatus), levelled off to a maximum depth of 1 cm and divided into two equal halves by a standard V-grooving tool. The number of shocks, required to make the two parts of the mixture come in contact at the bottom of the groove along a distance of 1.3 cm is recorded and the moisture content of the sample when this occurs is determined. This operation is repeated at least four times, using the same sample to which is added increasing quantities of distilled water. A flow curve is obtained by plotting on a semi-logarithmic paper, the moisture values corresponding to 25 shocks.

The Rann sediments were subjected to these tests and flow curves obtained. Special care was taken in the case of the highly plastic variety of Rann sediments, in which case, the wet sediment was made to stand for about two hours before the tests, to allow the water to permeate through the soil. The values of Atterberg's limits for sediments at various locations are given in Chapter 6.

Atterberg's values were calculated for both unleached as well as leached sediments. The differences in the values are given in Chapter 6.

Hygroscopic coefficient: The ability to suck in or 'sorb', moisture from the vapour in the atmosphere is a characteristic property of sediments and other dispersed bodies and is known as hygroscopity. The moisture thus absorbed is called hygroscopic moisture.

Hygroscopic moisture is calculated by taking a weighed portion of air-dried sample. Air drying is effected by leaving the samples in the laboratory for appropriate number of days, during dry seasons only. The soil mass is then heated to a temperature slightly above boiling point (105°). The crucible is weighed from time to time. A progressive decrease weight is observed upto a certain minimum after which the weight remains constant. The same sediment sample is again dried at 105° for half an hour to ensure complete depletion of the held moisture, and is left in the open in the laboratory. After some days, there is a conspicuous increase in weight to a certain maximum by absorbing moisture from the atmosphere. The hygroscopic moisture is calculated for various values of relative humidity.

In case of Rann, this property was determined only of the samples collected during the driest period of the year. In the laboratory, the values were obtained at different relative humidity values. Graphs were drawn to show the relation between relative humidity and the moisture absorbed (gm/litre) for sediments of different grain sizes.

<u>Moisture Absorbing Capacity</u>: The ability of sediments to absorb moisture is a well known fact. Whereas the ability to absorb atmospheric moisture is generally, known as '<u>hygroscopity</u>', the term <u>moisture absorbing capacity</u> is defined as the ability of the sediment type to absorb free water.

The procedure to determine this property consists of air-drying a known quantity of sediment which is placed over a blotting paper of known weight to which water is added drop by drop, until it is observed that the sediment mass no longer absorbs any water. The sediment and water mass is then allowed to rest for some time to enable the water to permeate through the entire mass. A few more drops of water are added to ensure that the process of absorption is complete. The difference in weight between the dried (W_1) and saturated sediment (W_2) gives the weight of water absorbed.

$$\text{Wt of water absorbed} = (W_2 - W_1) \text{ gm.}$$

$$\% \text{ of water absorbed} = \frac{W_1 \times 100 \text{ gm}}{(W_2 - W_1)}$$

Though, this procedure cannot be regarded as very accurate, it is quick, and serves the purpose well especially where high values of water absorbing capacity are involved. To overcome effects of evaporation during the course of experiment it is advisable to work in a cool and dark place.

The various samples of Rann sediments were subjected to this test and their values for moisture absorbing capacity are given in Chapter 6.

Thixotropy: The term 'Thixotropy' first put forth by Peterfi (1927) in consultation with Freundlich, and pertains to the isothermal, reversible, gel/sol/gel transformation induced by shaking and subsequent rest. This property is particularly displayed by suspensions of finely powdered substances in liquids. The thixotropic values for various Rann sediments were determined with the main purpose of evaluating their behaviour under wet conditions. This property was found very useful in explaining the behaviour of clays and silts under such conditions in relation to other allied properties like plasticity, fineness of grain-size etc. For the purpose of calculating thixotropic values, use of 'Inverted Tube' Experiment (Boswell, 1961) is preferable. It is a comparatively easy experiment to conduct, and can even be carried out in the field. The equipment consists of a series of test-tubes about 1 cm in diameter and about 15 cm long, a 20 cc pipette and a few fine long stirring rods. For evaluating this property, undisturbed sediment samples are ideal, but in practice, to get such samples is rather difficult. But Boswell (1961) has stated that in highly thixotropic sediments, the error is marginal. The samples are air-dried and allowed to 'mature' i.e. to exercise as fully as possible their capacity for sorbing water before being tested.

The thixotropic values after momentary rest (i.e. at the most 1 second), 1 minute's rest and for longer periods are then determined. The system is then left to stand for 24 hours, stirred thoroughly to ensure mixing of phases and thixotropy is retested with some addition of water, if necessary.

Sometimes it is observed that if the mixture has been left to stand for one or more days, and remixed, it flows sluggishly when the tube is inverted, and requires several tapping for the movement. In such case, more water is added before the system becomes no longer thixotropic. This limit at which it just starts flowing is known as the upper thixotropic limit after stirring.

Once the upper thixotropic limit after stirring has been recorded, the mixture is tested for the upper thixotropic values after shaking. This is achieved by a gradual addition of water and shaking (no stirring) till the thixotropy is achieved.

The thixotropic values of the various Rann sediments were determined, with the main purpose of evaluating their behaviour under wet conditions. This property was found very useful in explaining the behaviour of the clays and silts under wet conditions in relation to other allied properties like plasticity and fineness of grain size. The various values of thixotropy for Rann sediments are given in Chapter 6.

<u>Total soluble salt content</u>: The Rann sediments contain a considerable amount of salt in varying proportions, and this salt content has been found to be an important cause for the wetness of the sediment. The author has calculated the total soluble salts for sediment samples collected from different locations. The total soluble salt content is described as under.

50 gm of air dried sediment sample is taken to which 100 cc of distilled water is added. The whole system is thoroughly shaken with an electric stirrer for half an hour. 20 cc of the stirred mixture is extracted by means of a pipette and placed in a porcelain beaker. The beaker is slowly heated and the solution evaporated to dryness. Care should be taken to see that no water boils over. Salt is left behind. The crucible, previously weighed (W_1 gm), is reweighed (W_2 gm). The difference in weight gives the total soluble salts in the specimen. The percentage is expressed as

$$\frac{(W_2-W_1)}{20} \times 100$$

$$= 5 \times (W_2-W_1)\ \%.$$

Salt contents at various levels in profiles were calculated to obtain an idea of the salt variation with depth.

Permeability

Flow of water, ground or surface is governed by certain established hydraulic principles. Permeability which is a measure of the ease of flow through the media, is an important constant in the flow equation (Todd, 1959). Direct determination of permeability can be made from laboratory or field measurements.

For calculating permeability two methods are generally used: (i) Constant head and (ii) Falling head method. The constant head test is performed on relatively permeable sediments, whereas the falling head test is conducted for less permeable sediments, for which the rate of flow is not large. For determining the permeability of Rann sediments the falling head principle was utilised using a Jodhpur permeameter.

In the experiment, water is added to a tall column, where it flows upward through a cylinder and is collected as overflow. The test consists of noting the time at which the water level lowers to various graduations in the tube.

Sediments in situ show a certain amount of stratification because of which field permeability values are higher in the vertical direction. Thus for dependable results it was necessary that the overall sediment structure was not disturbed. The author therefore while investigating the peremeability of Rann sediments took special precaution to keep the overall structure intact. Luckily, Rann sediments being fine-grained, clayey it was possible to attain compact cores. By way of further precaution, the samples were kept in plastic bags and kept away from any form of direct heat. The permeability values were obtained for the representative samples from the main sediment groups.

The coefficient of permeability (K) was calculated from the following equation:-

$$K = 2.3 \frac{ah}{At} \quad \log.10 \frac{h_1}{h_2}$$

where K = coefficient of permeability (am/sec)

t = time interval (seconds)

h_1 = initial head , h_2 = final head

L = Length of specimen (6 cm)

A = Area of cross-section (50 cm^2)

Mineral Analysis

Mineral analysis of sediments though not always essential, are advisable in special cases. In case of the present study, the author made a study of the mineral content of the sediments mainly with a view to understand the origin of the Rann sediments. The minerals present in the various sediments, have revealed much about the evolution of the Rann surface and the probable provenance of sediments. The following procedure was followed:-

10 gms of each of sample, collected from various locations were placed in a test tube containing distilled water shaken and allowed to settle. The top finer fraction was poured off and water added again and decanted. The process was repeated several times. The coarser fractions left at the bottom were scrutinized under a binocular microscope and the

identifiable minerals noted down.

Special Experiments

For the purpose of explaining certain phenomena in the Rann more clearly, especially the role of salts in the sediments, the author carried out some special experiments to observe changes in the values of Index properties of salt-free sediments. He specially removed the soluble salt content from various samples and then conducted experiment for determining various paramters as Atterberg's limit, Hygroscopic coefficient and Water Absorbing Capacity for the salt free sediments.

Simple Field Tests for Identification Purpose

For the description of profiles, some field tests for identification purpose were carried out. The following is a list of comparatively simple field tests which allowed a reasonable facility of fairly identification.

(1) Visual examination of the grain-size and grain shape of coarse-grained sediments, and of texture and colour of fine-grained sediments.

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

(3) Determination of the mobility of the pore water obtained by shaking a piece of sediment horizontally in the hand to bring absorbed water to the surface if possible and then gently squeezing in the specimen (if on shaking, water appears on the surface, producing a glossy appearance, it indicates high mobility. It surface shows no change on shaking or squeezing, then mobility is low). For this test the sample should contain sufficient water and if it is too dry, water must be added.

In addition, numerous field observations supplemented the above methods. These included (i) Relative compaction of an undisturbed sediment, (ii) stratification and (iii) the rise and fall of ground-water level during various seasons.