III.2.4 GEOLOGY AND SOIL

1. Introduction

Conservation of the existing farm lands and reclamation of the waste lands for increasing agricultural production under reasonable supply of irrigation water would be a very important prerequisite for successful contribution to the national food security. The Agricultural Development Project with Widening the Pat Feeder Canal will be one of the realizations in response to the nation's request.

New land development must be dealt with sufficient cautions from view-points of the soil degradation that has given rise to the global trouble in food production. In this regard, soil survey of the Project Area in relation with its geological feature will present scientific informations useful for making the development successful. Objectives of the soil survey by the Feasibility Study Team are:

a) to conduct soil profile observations for checking the results of the existing soil surveys, and

b) to investigate problems which will be derived from soil properties and water quality for improving agricultural managements aiming to increase farm products.

2. Geology and Land Form

The Survey Area is composed of the alluvial deposits between the Marri - Bugti Hills and the Indus River. Geological feature including the Area is shown in Fig. III.2-6.

The Piedmont deposits (Qpd) transported from the Hills which are formed with sedimentary rocks of Tertiary (Tpm) cover most part of the eastern area. The flood plain deposits (Qbf) transported by the braided streams from the north spread on more than a half of the Area, mainly west side of the railway (Nuttal - Jacobabad). On this plain, braided streams brought new deposits (Qbr), recently in the Quaternary, which stretch along the eastern part of the Area.

Indus River deposits (Qcm and Qmx), early recent in the Quaternary, from the higher and lower terraces in the marginal south-western part and the most-east part near Guddu Barrage, respectively.

These alluvial covers forming the Kachhi Plain are very thick, thousands of feet at places and have fairly finer textures except the piedmont deposits (Qpd) which are composed of coarse detrital materials from the adjacent high lands.

Table III.2-33 presents brief explanations for material constituents, genesis and topography in relation to the geological era from Tertiary to recent Quaternary.

3. Soil Survey

Soil Survey Project of Pakistan was initiated in 1964 by FAO/UNDP with the help of USA and Netherland. From 1972 Pakistan Government succeeded the Survey to make 1:250,000 scaled soil maps and had covered a half of the country up to 1979.

Considering very short span of the field observation, the survey was focussed to conduct soil profile examination as many as possible and analyse the soil samples in the field. With the survey results obtained, investigations and discussions have been made on the existing results of soil classification and land potentiality.

a) Soil Profile Survey

The survey was carried out in March, 1982 in cooperation with Jhatpat Office of Irrigation and Power Department, Baluchistan Government and Mr. Malik Zahur Ahmad, Research Officer, Soil Salinity and Watertable Surveys, Planning Division, WAPDA, Lahore.

i) Survey Method

The Survey consisted of soil pit observation and soil sample collection for tentative analysis. The pits were made to the depth of 80 to 120 cm from the surface with a width of 100 cm as far as soil compactness allowed digging.

The soil profile descriptions followed the method and terms defined in the FAO Guidelines for Soil Profile Description which is now of wider use in the world.

Boring was tried using a common hand auger (post-hole type) if necessary to observe further the lower layers of the pit. With regard to the field tests, soil harness tester, a kind of cone penetrometer to measure soil compactness, was used. The tester is handy and portable for the field survey. Compactness of the soil layers is of much importance to investigate workability of a land for the potentiality classification as well as to distinguish genetic differences in the soil classification.

In addition, chemical reagent tests were tried with every soil profile. These are:

(1) Dilute hydrochloric acid solution (IN) for detecting carbonates (effervescence)

(2) Benzidin (pp'- diamino - diphenyl salt) solution (one percent in 10 percent acetic acid solution) for detecting active manganese (dark blue color development)

(3) αα'- dipyridyl solution (0.05 percent in 10 percent acetic acid solution) for detecting ferrous iron (Fe^{++}) (pink-red color development)

Selection of the pits was restricted mostly to the sites along the distributaries since besides metaled road from town to town there are no other traffic facilities than the distributary earth roads. Especially on a few days after a heavy rain the sphere of jeep movement was extremely stuck.

ii) Profile Description

The number of pit was 25 only in total because of the limited survey term and the frequent heavy rainfalls which are usually not expected in this season. Locations of the pits are shown in Fig. III.2-7 together with those of water sampling.

Land use and cropping status of the pit sites are summarized in Table III.2-34. Most are fallow plots or unused lands. In the later stage of Rabi, main crops were wheat and grams in pre-maturity.

Table III.2-35 outlines characteristics of the soil profiles are presented in Appendix III.2-5. Name of Soil Series will be referred to the later paragraph.

b) Field Analysis

i) Soil Analysis

About two kg of soil samples were taken from every soil layer distinguished on the profile; three to five samples were collected from each pit. These were air-dried, broken to pieces and sieved to pass two mm-sieve for the analysis in the base camp (Rest House, Jhatpat).

These samples totaling 102 were analysed for pH and electrical conductivity (EC) at 1:2 soil-water ratio. A portable glass electrode pH meter (HM - IK) and a portable EC meter (CM - IK) could nicely be used for these analyses. Data obtained are already given in Table III.2-35, which will be discussed in the next paragraph. No gravels were found throughout the Area.

ii) Water Analysis

Water was sampled at the same time of the pit survey from the Main Canal, distributaries and stagnant pools. Twenty eight samples were subjected to the same analysis as the soil samples.

Analytical data are arranged in Table III.2-36 in the sequence of sampling. Most were taken from canal and Drain System, and only one sample from a tube-well (No.20) nearby RD 238 of Pat Feeder Canal. This tube-well water has an EC of 0.6 mmho, much lower than expected. The water may originate from the groundwater, source of which is considered a seepage of the canal water because soils there are coarse-textured and water permeable.

There have been no other opportunities to collect well water or groundwater samples; in this Area drinking water has been taken from the Canal, and groundwater has been in general considered too high in salt concentration presumably more than 4 mmhos/cm.

Fig. III.2-8 illustrates changes of EC values in the canal irrigation and drain system of the Project Area. It could clearly realize that water from the Indus River is not so contaminated with other salts during its flow along the canal course so far as the barrage gate is opened for irrigation. EC at Guddu Barrage, 323 micro mhos, increased to 392 at Mangsi Distributary, the most far from the Barrage.

c) Laboratory Analysis

Out of all soil samples, 24 samples from 6 soil profiles were sent to the laboratory of Soil Salinity and Watertable Surveys, WAPDA, Lahore for further physical and chemical analysis. The results are given in Table III.2-37 for particle size distribution and moisture equivalent and in Table III.2-38 for chemical properties of the samples. With regard to soil fertility, nitrogen and phosphorus are apparently deficient though they are favored with rich calcium and a high CEC.

Next Table III.2-39 shows examples of water analysis. Both samples were collected in Indus River at the Barrage of Guddu and Sukkur. The water from the Guddu Barrage seems too high in soluble salts and EC as compared with that from the Sukkur and those of water samples in the preceding table.

WAPDA also had conducted its own Soil Survey in the concerned areas under National Irrigation Projects and issued the Atlas in 1981 compiled by its Planning Division, giving many kinds of maps for land use, soil salinity, watertable and so on, based on a survey scale of one examination per one square mile.

Interpretations and discussions of these data will be done in the following paragraphs.

4. Soil Classification

Soils of the Area developed on the Kachhi Plain consist of two different parent materials. Major part of the Area has soils developed in the piedmont sediments brought down by the torrents from the Marri-Bugti and other hills in the north. They are calcareous due to Tertiary materials: mainly shales, sand stones and limestones. The other soils of the Area are derived from the Indus River alluvium, origins of which are calcareous sedimentary, igneous and metamorphic rocks of the Himalayas.

At some places near the border areas the both materials are more or less contaminated each other on the flood plains through frequent stream torrents, resulting in developing a wide variety of the soil types.

a) Great Soil Groups

FAO/UNESCO - Soil Map of the World (VII-1, 1977) classified the soils of Kachhi Plain into one group unit of Yermosols. Haplic Yermosols are dominant and divided into two phases, Yh 27-2a (non-saline) and Yh 26-2/3a (saline). The former occupies most of the Plain while the latter distributes from the eastern part of the Plain to northwards along the Indus River. The boundary line cuts the Command Area of the Pat Feeder Canal at around RD 328 and goes down to Jacobabad side.

Fig. III.2-9 shows distribution of Soil Units along Indus River, which was copied from the FAO Map. Since the Unit symbol is designated with the name of the most dominant Soil Unit in the area, each Unit is generally associated with and/or includes some other Units. This is indicated by suffixing numeral after Unit name. The Yermosols in the Project Area are described as follows:

Map Symbol	Associated Soils	Inclusions	Phase
Yh 26-2/3a (Haplic Yermosols, mediun and fine textured, level to gently undulating)	-	Zo (Orthic Solonchaks)	Saline
Yh 27-2a (Haplic Yermosols, mediun textured, level to gently undulating)	Zo (Orthic Solonchaks)	Jc (Calcaric Flurisoils) Qc (Cambic Arenosols)	-

Yermosols are so called "Desert Soils", defined as sandy, stony and mostly shallow soils with very weak structural development. But they are in some spots deep, yellowish loams. "Haplic" is connotative of soils with a simple, normal horizon sequence. Jhatpat Series, the most dominant soil type in the Area, was identified to be Haplic Yermosols by Soil Survey of Pakistan, and Rojhan Series to be Orthic Solonchaks.

b) General Soil Features

As was already pointed out, the soils in the Project Area have developed on the flat alluvial plains, and they are mostly medium to fine texrured except small areas of sand dune and its vicinity. Soil color is very pale brown (10YR 7/3) to pale brown (6/3) when dry with almost no accumulation of humus under the hot and arid climate. Structural development is very weak in geenral; platy (stratified) or blocky (homogenized) structure are observed more or less according to the frequency and age of the depositions. Consistency when dry is extremely high; the compactness ranges 20 to 30 as expressed as index of the Soil Hardness Tester. Its value more than 23 (10 kg pressure per square centimeter) could stop the root elongation (Takijima, Y., 1969). Overall high clay content of swelling property gives an excellent feature of hexagonal surface cracks every where the soil is dried up on the fallow fields. The cracks, 10 to 20 cm wide, stretch down into the subsoil, probably influencing initial intake of irrigation water. This property of soil is characteristic to Vertisols in former and popular soil nomenclature.

pH ranges from 8.5 to 9.3, moderately alkaline due to the calcarious nature of the soils derived from the calcium-rich parent materials. Laboratory analysis shows the $CaCO_3$ content in the extent from 8 to 18 percent; almost all profile layers give a strong effervescence with dilute HCL solution. Almost all layers of the profile give moderately distinct color development with Benzidin reagent solution, indicating the presence of active manganese in the soil.

In some profiles very fine gypsum crystallines and oxized iron mottles appear, assuming the genetic characteristics of calcareous and ex-reduced potential status, respectively.

Varying salt status is noteworthy in the Area; it ranges from non-saline to strongly saline not only in the surface soil but also in the subsoil. Salinity differences in the soils can present important informations for the soil improvement as well as for the soil classification.

Vegetation is also quite characteristic to the Area of arid soil conditions with a scarce rainfall and a variant soil salinity. More over, long-continued uncontrolled grazing and felling have considerably deteriorated the vegetation cover both in density and quality.

Around the cultivated areas, trees, mainly Acasia arabica (Kikar), Zizyplus jujulea (Bes) and Calotropis procera (Akk-milk weeds) are found only here and there. Uncultivated sandy loam lands (29) along Pat Feeder Canal support also a sparse vegetation comprising Aeroa Javanica (Bui) and Calotropis procera (Akk).

Tamarix sp. (Lai) is the dominant member of the plant community on highly saline soils, for example as described of the soil profile No.10. Arid wastes of the piedmont plain are devoid of any vegetation other than scattered, stunted shrubs of Tamarix sp., too.

Kikar and Eucalyptus sp. trees have been planted not only along the town to village roads but also on the canal bank, aiming to provide shady spots and to avoid soil erossion, respectively. Panicum antidotale (Gum) growing in short bunches is the only grass along the stream courses, being quite palatable to the animals of the nomads. It must be thought of the globally progressing soil degradation that has been believed partly due to the overgrazing. The Area is not an exception.

c) Soil Series Classification

According to the Soil Survey of Pakistan, Ministry of Forestry and Agriculture, that followed the comprehensive soil classification system, USDA (7th Approximation, 1969), soils in Jacobabad - Usta Mohammad Area are divided into 34 Soil Series excluding sand dune (35), marshland (36), river-bed (37) and urban land.

Soil Map of Jacobabad - Usta Mahammad Area scaled at 1:2501000 was printed by them in 1972 at a reconnaissance survey level. The mapping unit is Soil Association composed of a few Soil Series, which is given the name of dominant Series.

Out of 34 groups 16 Soil Association are found in and around the Command Area. Table III.2-40 gives the classification process of the existing Soil Series based on the difference in parent materials, grade of soil formation, salinity, texture and so on. Following the FAO system, Bolan and Rojhan Series are to be classified to Calcaric Fluvisols and Orthic Solonchaks, respectively.

As is clear from the Map they made, only several Associations are major and the others are minor in area; Jhatpat Assoc. ranks first forming almost 80% of the total area, followed by Katchar Assoc. (28) and Kundi Assoc. (34). Chhater Assoc. (29), stratified coarse-textured soil, appears rather frequently contiguous to dune lands in the eastern part of the Area though areal extent is very small.

Results of the pit survey this time are summarized in Table III.2-41 following similar classification system. Six Soil Series were identified totally among the pit profiles. Jhatpat Series reasonably maintains predominance over the other Series. It might be inevitable that these profiles did not always give same locations as those illustrated in the Soil Map because of the Soil Association level in so far as at least two or three Seires are included in one Association. This is quite so in Jhatpat Association which comprises Jhatpat Series as main and other associating Series of Kundi, Katcher, Kandhkot and Bolan. Jhatpat Series (31) is characterized by fine textured soils (SiC) of subrecent piedmont alluvium, calcareous and of moderately well structure development.

Results of WAPDA Survey, however, gave subsoil textural groups map in the Atlas which realized a predominant existence of moderately fine texture (SiCL) with less medium and without any fine texture (SiC). Structure development also seemed to vary widely in this Series. Therefore, further detailed survey will be needed mostly for the Jhatpat Association areas with additional care of soil salinity in order to extend better soil managements to increase land productivity.

d) Mapping and Area of Soil Associations

Soil Map of the Project Area in Fig. III.2-10 has been drawn by partly correcting the Map of Soil Survey of Pakistan; boundaries of some Associations are changed with the identified Soil Series above mentioned. Extent of each Soil Association, though not so differnt from that of the original map, was measured and shown in Table III.2-42; there is reasonably almost no change in the sequence of areal extent among Soil Associations.

5. Land Capability Classification

In spite of major technological advances in agricultural production, the alarming rate of deterioration of agricultural land and water resources through land degradation and soil erosion, especially in developing countries has been pointed out at the global scale.

In case of Pakistan, many of the Irrigation Projects could have developed lands and brought a bumper yield of crops. While at places, improper drainage and water management have led to extremes, either waterlogging or salinization. The problems have often been reported and discussed by the government authorities concerned.

According to Provisional Map of Soil Degradation Risks, recently compiled by FAO (see Fig. III.2-11), the Kachhi Plain Area down to Manchar Lake (Yh 27-2a) and the flood and river deposit area along Indus River (Yh 26-2/3a) are designated as W2 S3 and S2 W2 Pw2, respectively. These symbols are explained as follows:

- W2 - Wind erosion, 50 - 200 tons/ha/year
- S2 - Salinization, 3 - 5 mmhos/cm/year
- S3 - Salinization, >5 mmhos/cm/year
- Pw2 - High physical depradation by waterlogging and irrigation.

These assessments may be reliable at some places, but seem a little overestimated in the whole area upon comparison with the present analytical data of soils. It must be understood, however, that an urgent motion has been emphasized on the land reservation by appraising properly the soil potential. Moreover, in order to reclaim the land economically and cultivate rationally, the land should be subjected to the suitable crops and farm managements according to its soil potentials.

a) Classification by Soil Survey of Pakistan

As already described, soils in the Command Area have more or less limitations in general agricultural uses of the land. Land capability is evaluated with these limitations and the lands are classicied with their relative suitability for sustained field crops or for grazing.

i) Classification Method

Soil Survey of Pakistan has established a classification method designed to suit the agricultural conditions of Pakistan. It has basically similar structure to the USDA Land Capability Classification (USA - Soil Conservation Service, 1961). The method has two level of generalization: Land Capability Class and Land Capability Subclass.

The first grouping, Class, is indicated by Roman numerals I - VIII. The numerals are prefixed with "ir" or "d" on the assumption of irrigation or non-irrigation, respectively. Setting Class I at the best land that has least limitations for crop production, Class II to VIII have progressively increasing limitations. In general, Class V to VIII are regarded as unsuitable for economic agricultural use of the land.

The second grouping, Subclass, is designated by the kinds of limitations which are expressed as the small letter following the Class numeral. The following designations have been used in the surveyed area:

e - Soils restricted in use due to erosion hazard.

w - Soils restricted in use due to excess water because of poor drainage, high watertable or overflow.

s - Soils restricted in use due to limitations inherent in the soil profile such as shallow soil depth, slowly permeable layers or low moisture-holding capacity.

a - Soils restricted in use due to salinity/alkali.

x - Soils restricted in use due to hazard of river erosion or burial by fresh sediments.

c - Soils restricted in use due to unfavourable climate.

The dominant limitation determines the assignment of soils to Subclasses to which priority is given according to the seqence of the above list. More than two limitations will have a cumulative effect on the land, each lowering its capability by one Class.

ii) Land Classes in the Project Area

A land capability classification conducted by Soil Survey of Pakistan on Soils of Jacobabad - Usta Mahammad Area has been reported in 1972. The soils generally are fairly better evaluated for irrigated agriculture and supposed to support good crops provided the irrigation water is made available.

Table III.2-43 excerpts the results in land classification of the soils occurring in the Project Area. It provides a brief interpretation in case of irrigated agriculture considering the most popular culture method at the present time and in the future as well. Only Pacca variant (9), Nabipur (16), Bolan and its variant (27) are rated at Class I though their extents are very small. Most lands of the Area classed to irIIs since the dominant Soil Series, Jhatpat (31), is estimated to have a tilth limitation due to fine texture and slow permeability. Katchar (28) and Kundi (34) Series are also rated at the same Class. The other Series, all having very small extents, belong to Class III or IV owing to the limitations of texture, drainage and/or salinity.

Anyhow, these results show a very simple pattern that almost all lands of the Area are ranked at Class II with minor limitations. This does not seem to supply informations enough to conduct extension work for farmers. As a matter of fact not a few lands have been observed to assume saline phase to an extent as affecting the crop growth. In this regard, project surveys more recently carried out by WAPDA may provide more intensive informations of soil hazard distribution though they are not formal soil surveys but rather objective ones aiming at soil improvement or land reclamation.

b) Salinity Classification by WAPDA Data

WAPDA has surveyed the Indus Basin since 1977 and has released data pertaining to the selected projects/survey units totaling 21 million acres of irrigated areas. Subsequently, they have issued "Atlas of Soil Survey Results for Province-wise Projects" in 1981. It comprises many areal maps scaled at 1:250,000 on soil salinity, watertable depth, groundwater quality and soil textural groups, which are compiled form the original 1:50,000 scale maps. The Command Area of the Pat Feeder Canal Project extends over three maps, 34 p-39 D-39 H, of the Atlas. These maps are of necessity very useful to grasp overall features of the Project, but appearing not enough to get more precise informations.

The present Study Team has attempted, therefore, to analyze the original data supported by laboratory analysis for the better land evaluation of the Project Area. These data have been copied and presented to the Team at the time of their return to Japan.

i) Survey Method and Class Criteria

Boring technique has been adopted for soil sampling, by and large, at a density of one bore per one square mile in the sites which were pre-determined on the grid of aerial photograph. Soil samples were collected in four depth sections from each bore:

Sample No.	Sampling Depth (inch)	Sampling Depth (cm)
1	0 - 6	0 - 15
2	6 - 18	15 - 45
3	18 - 36	45 - 90
4	36 - 72	90 - 180

For checking watertable and collecting shallow groundwater, augering was done to 10 feet depth.

All soil and water samples were analyzed in three laboratory units set up at Hyderabad, Lahore and Mona Project, for their pH, electrical conductivity (ECe), sodium adsorption ratio (SAR) and residual sodium carbonate (RSC - water only). These data have also been coded for computerization to ensure their permanent preservation for the future use.

The soil is classified according to standard parameters of the analyzed items, individually or in combination. The classification criteria of each item are listed in Table III.2-44.

ii) Surface Salinity

Based on the summarization by WAPDA, 30 percent areas out of the total 21 million acres surveyed in Indus Basin are more or less salt affected. In the vicinity of Pat Feeder Canal Area, the ratios of salt affected areas are almost similar in the surface salinity as is shown in Table III.2-45. The salinity problem is comparatively more serious in Sind Province portion; where 55 percent of the gross surveyed area are affected.

Fig. III.2-12 illustrates the distribution of surface salinity in the Canal Command Area, which is excerpted from WAPDA Atlas. Extents of the four categories are computed in Table III.2-46. Around 23 percent of the total area have the saline surface (0 - 6 inches) having ECe more than 4 mmhos at 25°C (S2), 2.4 percent being strongly saline exceeding 15 mmhos (S4).

On the other hand, the original data of the Project Area and its vicinity, which provided analytical values on the soil samples taken from thousands of bores, have been re-examined this time and a distribution map has been drawn by patching each one square-mile bore area of same surface salinity. The map is presented in Fig. III.2-13 which is comparable with Atlas map of Fig. III.2-12; categorical extent is arranged in the lower column of Table III.2-46, similarly comparable with that of the ATlas.

Any discrepancy should not be recognized in both comparisons, but there are actually not a few differences in ditribution and extent between the two results: 12 percent disparity in the extent of salt free area (S1) and many small different locations of saline patch areas that are designated as S2 to S4.

It is very difficult to understand why such diversities appear. Because, so far as the same data are used, gaps in location can not be expected though extent may differ depending on the mapping method. This problem must be further checked.

iii) Profile Salinity

Next concern is on the soil profile salinity and sodicity. According to WAPDA Atlas where soils are classified into four groups by combining salinity (>4 mmhos) and SAR (>13), only 36 percent of the total profiles are free of salinity/sodicity harzard in the Command Area. The figures were obtained by computing their extents on the map (see right column of Table III.2-48). In other words, about two third of the whole area are more or less saline and/or sodic throughout or at some depths of the soil profile.

This classification itself is quite significant to give overall information on the problem sites. For the agricultural extension, however, more intensified informations will be required. Because the above classification process only considers hazardous values of ECe and SAR irrespective of the depths in their occurrences. So far as the crop growth is concerned, problem is the affected depth of the profile from view point of the root zone ranging 12 to 18 inches from the soil surface depending on the crop species.

Taking into account the prevailing salinity problem, an intensive classification on the profile salinity has been intended as is shown in Table III.2-47. Five categories, I to V, are set up considering the present influence of surface salinity and the future risk of surface salinization by upward movement of salts accumulated in the lower layers below 18 inches from the surface. Designations of a, b and c in Subclasses express progressively increasing grades of these hazards.

WAPDA original data of about 1,200 bores have been subjected to this classification process and a distribution map is drawn in Fig. III.2-14 for the Project Area. The extents of each category are given in Table III.2-48.

iv) Profile Sodicity

Further consideration has been taken to signify the severity of sodicity for the upper layer of the profile (0 - 18 inches).

As was noted in Table III.2-47, notations, x and y were used to express sodicity of SAR 13 - 23 and more than 23, respectively for average values of sample 1 and 2 of the profile. The reason why sodicity of the lower layer is not dealt with is due to its less influence and to excluding complication in classification. The depiction of sodicity on the map is omitted, but extent in each Sub-class was measured and presented in Table III.2-48. their occurrence is closely related to the Salinity Subclass in the ascending order though their extents are very small.

Owing to the difference in classification process, fairly big difference in area percent between the two methods is conspicuous in the Table. Anyway, the new classification method can of no doubt reflect more precisely the profile salinity of the soil.

c) Classification Using Profile Salinity Proposed

i) Classification Process

One trial has been intended to classify the land by involving the profile salinity proposed above. Classification method used by Soil Survey of Pakistan has no problem in its process but seems not enough to evaluate the soil salinity particularly in such salt-affected area as the Project Area.

For instances, Rojhan Series and its phases were classified to irIIIa because of moderate to strong salinity. These lands should be ranked lower since in fact most of them have been abandoned for long years. Jhatpat Association was classified to irIIs without regard to salt accumulation.

As is clear in the map of surface and profile salinity (Fig. III.2-13 and 2-14), there bave been observed so many patches having high ECe value more than 8 or 15 mmhos within the area of Jhatpat association (31).

Table III.2-49 is a tentative process aiming to reclassify the land capability as involved with the proposed criteria for profile salinity. Groups, A to D, are set up to estimate actual salt damage in the crop production. In this process, lands of IIa or IIIw of former classification are partly rated at IIIa if they have patches of C group of the profile salinity. In case of D, that is, Va and Vb (ECe, more than 15 mmhos) are all classified newly to Va because the land must be subjected to intense leaching management.

ii) Mapping and Area of Land Classes

Land Capability Classes thus decided for the Project Area are shown in Fig. III.2-15. Table III.2-50 gives the extents of Sub-classes as well as limitation explanation. The lands ranked at irI to irIII are considered good irrigated to irrigable. The Classes are largely followed by the profile salinity status though it is somewhat apprehended if the soil salinity would be overrated. Nevertheless, the estimation may be reasonable in view of the difficulty in leaching the soil.

The proposed land capability classification method is still tentative but will more fit to the actual soil conditions of the area concerned.

An additional caution must be taken for the presence of gypsum in the soil on its effect to control the sodium accumulation. WAPDA original data were available to check the distribution of gypsum in the soil profile. Fig. III.2-16 has been thus drawn by classifying the profile gypsum presence into four groups though some places were lack of data. Table III.2-51 gives the gypseous profile divisions and the extent of each groups. More than a half of the whole area is occupied by the soils containing gypsum almost throughout the profile. As compared with the profile salinity distribution, gypsum appears to be in no apparent correlation with the increasing salinity.

At the present, gypseous status may not necessarily be added to the land classification criteria with the following reasons:

(1) No quantitative data are available, as needed to evaluate the gypsum activity for desalinization.

(2) Judging from the lower SAR (< 2) of the irrigation water, severe alkalinization may not occur for the time being in this Area.

6. Problems and Recommendations

Soils of the Kachhi Plain are in general non-fertile and more or less have a saline and/or alkaline property, since they have developed near recently on the frequent alluvial deposits with very weak structural differenciation and almost no accumulation of organic matter under the supply of weathered products derived from basic rocks and the arid climatic conditions. those found in the Project Area are not an exception, being unable to escape from the following problems.

a) Soil Classification

Jhatpat Soil Association destributes in almost 80% of the Area. According to the report of Soil Survey of Pakistan, this association is composed of three Soil Series of Jhatpat and associated Kundi and Katchar including Jhatpat slightly saline phase at the percentage of 85 and 15, respectively. These soils are all clayey and different only in structural development.

It is uncertain, however, if Jhatpat Soil Series, fine textured (SiC) with moderately good structure development, is the most dominant all over in its extent. Because most of the extent areas rather show moderately fine texture (SiCL) together with medium texture (SiL).

WAPDA Soil Survey also illustrated that almost all soil profiles of the river flood plain area had a moderately fine texture (SiCL) but not a fine texture (SiC) except for a few profiles.

Since the texture was just judged by skillful finger technique in the field, the data should be once checked with laboratory analysis. Nevertheless, in view of the present analytical data (Table III.2-37), it may admit of no doubt that this association could be contaminated with other associations. This is understandable for the reconnaissance survey level.

A further detailed soil survey for Jhatpat Soil Association will produce a good result in the more accurate classification.

b) Soil Salinity

i) Salinity Analysis

Saline status of the land has become one of the global concerns on the soil degradation. Usually most of its interpretation has been made on the basis of electrical conductivity measured with water-saturated extract of the soil.

For routine work, however, particularly in the field test, this requires more or less tredious procedure, and so 1:2 to 5 water additions have often been used because the extract is more easily prepared by decantation. Problem is how to estimate ECe (saturation) values from the EC_{2-5} measurements.

According to the theory of ion adsorption equilibrium in the soil, nearly a linear correlation should be obtained. Yet, if some gypsum is present, the line will remarkably change its angle because of the increased solved amount of the salt with the increasing soil to water ratio. Fig. III.2-44 is made on a double logarithmic graph using the data of Table III.2-35 and III.2-38, showing largely a linear relation between ECe and EC_2, which is expressed in the formula:

$$\log ECe = \log 3.54 + 1.10 \log EC_2 \quad (r = 0.97)$$

Since the ratio of ECe/EC_2 may differ with the defferent saturation percentage and cation exchange capacity in relation to the soil texture, another rough estimations are possible as follows:

SL - SiL	ECe/EC	≑ 5.0
SiCL		≑ 3.0
SiC - C		≑ 2.5

Anyway, to convert the EC measured at high soil to water ratio into the ECe, the convertion coefficients must be obtained from similar curves prepared for each textural group of the soils.

ii) Salinity Distribution

Around the Command Area, five soil series have been reported to be saline but non-alkali. These are very minor in extent except Rojhan Series (24) which distributes on the land between Jhatpat and Jacobabad. According to the spot analysis in the present survey, not only in saline Soil Series but also some profiles in non-saline ones showed a strong salinity much higher than 4 mmhos which is designated as a harmful limit to the crop growth.

Furthermore, soil profile salinity maps of the WAPDA Atlas where EC and sodium adsorption ratio are graded by the hazardous values found within 6 feet depth, gave a more serious presence of saline and saline-sodic nature of the soils. The circumstances are as already analysed on the WAPDA original data in the preceding paragraph.

Although these group lands actually scatter each other and can not be separated as a large area, special consideration should be taken into the selection of crops, soil reclamation, and proper irrigation and drainage method as well, for each of the patches.

As was often reported on the Irrigation Projects in this country, soil salinity problem has become of paramount importance because unsatisfactory irrigation and drainage systems are apt to cause salinity hazard to the field crops by accumulating salts and sometimes by withdrawing them from the saline groundwater to the surface especially in the areas of hot and arid climate. In the Command Area fairly broad barren lands are located from Jhatpat to Jacobabad and/or to Usta Mohammad, where white salt efflorescences are visible. It is more common to abandon cultivation in the marginal strip lands where irrigation or seepage water are standing in part and evaporated to develop salt films.

In addition, as mentioned above, more significant lands than expected before show a soil profile where a saline subsoil is overlaid with non-saline surface soil. Although no growth damage happens in this condition, the lands might get into danger state for crop growth at any time when upward movement of the salts occurs. The advantage gained through irrigation may be more than offset by salinity damage unless the proper managements are taken.

Behaviour of salts in the soil under irrigation and drainage management should be studied in the concerned field. Saline barren lands would be first subjected to leaching management which also need some field experiments. The management will take time because of lower permeability of the dominant clayey soil.

A periodical monitoring of soil salinity by means of EC measurement with water extracts of soils must be scheduled as has been carried on the Punjab Doab Regions.

c) Soil Alkalinity

Alkali soil may be a second problem in the Area because the decrease in water permeability of the clayey soils usually accompanies the irrigation procedures. Its incidence is not restricted to Solonetz soil. Clayey soils having pH values higher than 8.5 or SAR higher than 13 more or less become less permeable, when irrigated, due to dispersion of fine particles resulting in the collapse of structure and poor system.

The present survey as well as WAPDA data observed many high-pH profiles some of which were strongly alkaline, more than pH 9. This evidence should be paid with much concern in the irrigated agriculture in the Command Area in view of the prevalency of low-matured clay-type soils. This will arise more difficulties in extension of the future mechanized farming.

In so far as the Canal Command Area, the extent of surface sodic soils are not yet so prevalent as 10 percent of the total, being much less than outside of the Area.

d) Irrigation Water Quality

Quality of irrigation water is essential in the irrigated agriculture together with its quantity. The water quality is usually measured as EC value in place of salt content.

As was illustrated in Fig. III.2-8, a slight increase in EC values is recognized along the water flow from Guddu Barrage to Canal terminal and from Canal to Distributaries. These range form 320 to 420 micro mhos and around 400 - 600 micro mhos when stagnant. The water quality of the Canal thus has no trouble for irrigation use because only salt sensitive crops may be adversely affected by use of 250 - 750 micro mhos water.

The quality is ranked at C2 - S1 of USDA criteria (1969). Sediments in the water having around 3,000 ppm on the average are also being transported by the canal flow. These arise another problem of sand arrestation and so on, which will be referred to the chapters concerned. Fairly portions of silt and clay particles are flowing into the crop fields. This may not cause any trouble because of their nature of calcareous and swelling clay minerals.

Drain system was also checked with water quality giving much higher conductivity from 8 - 9 mmhos, 20 to 30 times of those of canal water.

In view of a tremendous amounts of salts, however, transported into the crop fields annually by irrigation both system should be in good linkage so as to control salt accumulation. In this regard monitoring survey system must be established including soil salinity survey.

Another problem somewhat prevailing in this Area is waterlogging which has been caused by seepage or excess use of irrigation water. The problem itself might not become so serious if the proper canal maintenance and farm managements are realized in future.

There is almost no tubewell available for irrigation in the Area since the groundwater is so deep as out of reach and extremely saline, more than 2,500 ppm.

e) Soil Fertility

Soil fertility is also one of the important properties of the soil. According to the profile observation and analytical data of Soil Survey of Pakistan, soils of the Area are extremely deficient in nitrogen due to the rapid decomposition of organic matter under the arid climate condition. While they are rich in calcium and magnesium because of the calcareous parent materials. Potassium may be no problem in the presence of weatherable minerals in the soil. Available phosphorus, however, seems to be deficient, too, based on the field trials conducted in Sukkur District in which a positive response to application of phosphate fertilizer was observed as combined with nitrogen supply. The present laboratory analysis also indicated some apprehension for phosphorus deficiency (see Table III. 2-35).

Anyway, a higher crop yield without proper fertilization will not be expected in overall the Area. Considering extremely high pH of the calcaric soils prevailing over the Project Area, physiologically acidic fertilizers, e.g. ammonium sulfate and superphosphate, can be better used.

Not only chemical fertilizers but also organic fertilizers, that is, compost and green manures are highly recommended. In connection with this, deep-rooting legume crops or grasses are quite effective not only on the organic matter supply but also on subsoil improvement especially of its physical condition.

Content of active manganese seems moderate as estimated by the reagent test in the survey. Until now no systematic studies have been performed in the minor nutrient elements. The studies need to be carried out in the near future for this Area.

In addition, clayey soils of the Area are very hard when dry and very sticky when wet because of the swelling property of the clay mineral (montmollilonite). This also gives difficulties in the field preparation particularly for the mechanized farming, arising further study in soil management.

f) Land Capability Classification

In land capability evaluation, Class and Subclass were decided for irrigated agriculture because it has been the most popular culture method here. The Subclass irIIs with some inherent hazards such as fine texture covered almost 90% of the whole area, the other units being minor in extent according to the Land Class Map made by Soil Survey of Pakistan.

Due to the same reason as for the soil classification, soils in these clayey Soil Associations should be re-surveyed in detail with a view to get more accurate presence of soil hazards in this Area. Attempt was made in this report to classify the lands further with the profile salinity distribution which was drawn from WAPDA original survey data. The results were already discussed and arranged thus producing a revised Land

Class Map. Needless to say the map must be further investigated in the near future by conducting the detailed soil survey for the Area.

g) Soil Managements

After commissioning of the Tarbela Dam, the annual summer flooding in the Area due to Indus River seems to have ceased except small floods under locally heavy rains which submerge the land on a narrow extent. Instead of decreased prevention to any summer cropping, natural provision of residual moisture for cultivation of winter crops and also natural leaching of any major salinity-alkali hazard from the land would not have been expected as before. These newly developing problems must be dealt with adequate use of irrigation water system and proper soil managements.

Clayey and very compact nature of the soils prevailing all over the Area have many kinds of tillage problem, requiring intense managements as follows:

(1) Ploughing at an optimum moisture level for the preservation of good physical structure in the topsoil.

(2) Application of stable or green manures to improve the physical conditions as well as nutritional status of the soil.

(3) Avoidance of frequent ploughing and excessive irrigation which may corrupt soil structure and create temporary waterlogging.

(4) Deep ploughing once several years to loosen or destroy the dense or laminated subsoils to improve permeability.

(5) Adequate leaching management taken for the lands soil salinity of which exceeds 16 mmhos.

Areas suffering seepage from the Canal and Disty such as Lower Uch, where cultivation has been inevitably subjected to rice, will be reclaimed in the course of the canal-widening project now under planning. With regard to wind erosion for the high-lying, sandy dune areas, complete control of grazing the scanty natural vegetation may be helpful to regenerate and form a protective cover.

h) Irrigation Method

As was partly discussed, the irrigation water being taken from the Indus River has no problem on its salt constituents as well as its concentration for irrigated agriculture. Therefore, method of irrigation is so important to increase the productivity in relation to the soil properties. It may be here examined for two subjects, irrigation technique and irrigation season.

For irrigation technique, continuous care must be taken not to cause the surface salt accumulation since the downward movement of water is considerably limited due to the laminated or less developed structure of the clayey soil. Drip or spray irrigation should be avoided in this regard though these are the best way in economic use of water. Consequently, intermittent trickle irrigation or basin irrigation are recommendable in view of the technical easiness under the present level of farming and status of farmer's finance.

Next subject is concerned with the selection of irrigation in connection with the cropping pattern. Traditionally in this Area, the canal water has been used dividedly largely for rice in Kharif and wheat in Rabi, both fields, Dubari and Bosi, being left fallow in the other season with a result of very low cropping intensity. The allocated supply of water should be continued to attain the maximum cropping intensity and return by the products even if water quantities can be increased by widening the Pat Feeder Canal with increased discharge of the Indus River water. The desirable cropping patterns will be discussed to be proposed in this report.

In view of the soil characteristics, perennial irrigation is not suitable to the crop fields in this Area even in case of rice culture owing to the following main reasons:

(1) Structural development in the solum may be accelerated by alternating wet and dry condition resulting in porous, blocky or granular structure which will improve the water permeability through

the soil profile. To realize this condition seasonal irrigation must be scheduled according to the reasonable cropping program together with saving the water quantity. At the same time drainage system is required to leach out the excess salts brought by the irrigation.

The Soils in the Area, having high clay content of swelling property, are apt to become so compact when dried to form many soil surface cracks which derive the tilth difficulties. This is a characteristic phenomenon, common to Vertisols. Ploughing at earlier stage of the fallow season will be helpful in producing the finer cracks and consequently the more increased aeration in the subsoil.

(2) The second reason is avoidance of the influence of groundwater. The groundwater found in this Area has a so deep table as more than 10 feet with the increasing distance from the Indus River. Among many analytical data of the well water or the underground water, those obtained by WAPDA Survey gave the results that most of the water sampled by boring in Lower Uch area showed a higher concentration of soluble salts, more than 3,000 ppm, that is, more than C3 S4 in water quality. These are not suited to irrigation use. In other words it is very dangerous if the soil water is connected with the groundwater. Perennial irrigation will finally cause salinization of the solum through capillary upward movement of the saline groundwater.

Irrigation itself is effective as one of leaching procedures, but it can not functionate unless its percorating water press down the groundwater or pass through to the drain without contacting it.

Surface drainage has no meaning in desalinization and in aeration effect on the crop root zone as well. In addition, faulty irrigation practices including excess irrigation and imperfect ridges of the field plot have entailed considerable wastage of irrigation water. As a result at many places around the lower field plots, the water has stayed in a pool followed by the salt accumulation through evaporation to an extent to form salt crusts on the surface. Strict guidance are thus required to farmers for the proper use of irrigation water.

i) Recommendations

From view points of pedology and soil conservation, following items are recommendable for agricultural development of the Project Area:

(1) Detailed soil survey to classify further Jhatpat Soil Association for about 500,000 acres into some Soil Series and Land Classes.

(2) Study on the salt movement in the soil to find the proper irrigation managements of the clayey field.

(3) Field trials to improve soil physical conditions by such methods as admixture of organic materials and/or sand into the soil.

(4) Field trials with different times and amounts of fertilizer application to know the proper dose needed for higher yield of the crops.

(5) Monitoring Survey on the soil salinity and sodicity.

Items from (2) to (4) should be conducted in the fields of the Pilot Project Area with the detailed designs of the trials.

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Table III.2 -33 Geological Feature around Pat Feeder Canal Project Area

Geological Era	Map Symbol	Topography	Genetic Form	Constituents
Tertiary				
Paleocene	Tp	Mountains	Sedimentary rocks	Mostly shale and sandstone, some limestone, conglomerate
Eocene	Te, Tek	Mountains	Sedimentary rocks	Mostly limestone, some marl and shale
Pliocene and Miocene	Tpm	Mountains	Sedimentary rocks	Shale, sandstone and conglomerate
Quaternary				
Early Recent	Qpd	Piedmonts	Piedmont deposits	Coarse detrital material from adjacent high lands
	Qsp	Subpiedmonts	Subpiedmont deposits	Ibid., finer detrital material
	Qbf	Flood-plains	Sheet flood and flood-plain deposits	Material by braided streams
Early Recent	Qcm	Older terraces	Middle terrace deposits	Loess and flood-plain deposits
	Qmx	Extinct streambeds (Lower terrace)	Streambed and meanderbelt deposits	River deposits
	Qfx		Flood-plain deposits	River deposits
Recent	Qbr	Recent streambeds	Braided stream deposits	River deposits
	Qm		Streambed and meanderbelt deposits	
	Qf		Flood-plain deposits	
Pleistocene and Early Recent	Qsc	Relief < 100 feet	Older eolian deposits	Eolian sand and deposits of extinct streams
	Qs	Complex dunes		Eolian sand

(Cited from Geological Map of Pakistan, Geological Survey of Pakistan, 1964)

Table III.2-34 Land Use and Crop Yield of the Soil Pit Examined Areas (1)

Pit No.	Location	Land Use	Crop Yield (mounds/ac)
1	Mitta - Rind, 3 miles down Ballan D.	Fallow, wheat, next	Wheat : 50
2	Dost Ali Khan, 10 miles down Ballan D.	Fallow, rice	IR 6 : 30
3	Doda Khan Brohi, 6 miles down Bari D.	Fallow after sorghum	Moderately poor
4	Shamir Khan Mastyi, 19 miles down Bari D.	Fallow	Poor
5	Falih Mohammed Umaseni, 8 miles down Umrani D.	Fallow after rape seeds	Sorghum, oil seed : 5 due to insect damage
6	Ali Madid, 16 miles down Umrani D.	Fallow, wheat next	Moderately poor
7	Haji Bakhtiar, 1 mile down Jhatpat D.	Fallow after sorghum	Very poor
8	Haji Araz Mohammed, 8 miles down Mangsi D.	Fallow after sorghum	Poor
9	Ali Akhan Khan, 14 miles down Mangsi D.	Fallow after rape seeds; wheat, next	Poor
10	Barren Land, 2 miles south of Jhatpat Station	Unused	-
11	Haji Aliar Khan, 14 miles down Jhatpat D.	Fallow after sorghum	Poor
12	Haji Khan Umarani, 7 miles north of Jhatpat Station	Fallow, joar next	Poor
13	Mir Mohammad, 15 miles down Judher D.	Fallow	Poor

Table III.2-34 Land Use and Crop Yield of the Soil Pit - Examined Areas (2)

Pit No.	Location	Land Use	Crop Yield (maunds/ac)
14	Jaggar Khan Umarani, 6 miles down Judher D.	Grams after rice	Poor
15	8 miles down Temple D.	Fallow	Poor
16	Haq Nawaz Khoso, 3 miles upstream of Nasirabad D. end	Fallow after sorghum	Wheat: 16-20; grams decrease to 1 (insect)
17	Terminal water course, 0.5 miles down Nasirabad D.	-	-
18	Barren Land, 6.5 miles upstream of RD 418	Unused	-
19	Upland, 9 miles north-east of Jhatpat	Wheat	Very poor, 10-15 (sparse growing)
20	Rashid Khan, 15 miles north-west of Jhatpat	Grams, rice next	Poor, 5-7 (sparse growing)
21	Sohbat Pur, 15.5 miles north-west of Jhatpat	Unused, rice next?	(formerly,rice)
22	Rojhan, 8 miles south-west of Jhatpat	Wheat (matured)	Very poor, 10-15 (sparse growing)
23	Ghaffar Khan Jamali, 14 miles s-w of Jhatpat	Fallow (grasses)	(formerly, vegetables)
24	Land, south of Pat Feeder Canal (RD 238)	Unused	No plant growth
25	Land, south of Pat Feeder Canal (RD 109)	Unused	No plant growth

Table III.2-35 Properties of Pit Soils and Their pH and Salinity

Pit No.	Location	Layer No.	Depth (cm)	Texture	Soil Color Dry	Soil Color Moist	Mottlings[1/]	Structure[2/]	Compactness[3/]	pH (1:2)	EC(1:2) (mmhos/25°C)
1*	Mitta Rind, left side of Ballan D. (3 miles)	1	0-6	SiCL	10YR6/3	-	-	crumb	28	8.75	0.17
		2	6-20	SiCL	(10YR6/3)	10YR4/3	-	m.f.platy	21	8.90	0.18
		3	20-30	SiC	(10YR6/3)	7.5YR4/3	-	m.f.platy	21	8.92	0.21
		4	30-140+	SiCL-SiC	(10YR6/3)	10YR5/4	Fe++	m.m.platy	18	8.80	0.27
2	Dost Ali Khan, Jamali, right side of Ballan D. (10 miles)	1	0-5	SiCL	10YR6/3	-	-	m.m.blocky	35	8.60	0.23
		2	5-27	SiCL	(10YR6/3)	10YR4/4	-	m.m.blocky	17	8.90	0.21
		3	27-48	CL	(10YR6/3)	10YR4/4 (5Y5/1)	Fe+	m.m.blocky	14	8.28	1.16
		4	48-120+	CL	(10YR6/3)	10YR4/4 (5Y5/1)	(clay)	s.f.blocky	18	8.30	1.50
3	Doda Khan Brohi, right side of Bari D. (6 miles)	1	0-13	SiCL	10YR7/3	-	-	w.c.blocky	30	8.70	0.31
		2	13-22	SiCL-CL	(10YR6/3)	10YR6/3	-	m.m.bl.& pl.	32	8.72	0.26
		3	22-42	SiCL	(10YR6/3)	10YR6/3	Gy+	m.m.bl.& pl.	32	8.70	0.32
		4	42-120+	SiCL	(10YR6/4)	10YR6/3	Gy+	m.vf.platy	26	8.70	0.54
4*	Shamir Khan Mastyi, left side of Bari D. (19 miles)	1	0-10	SiCL	10YR7/3	-	-	crumb	22	8.75	0.26
		2	10-21	SiCL	(10YR6/3)	10YR5/3	-	m.m.blocky	22	9.15	0.14
		3	21-45	SiCL(SiL)	(10YR6/3)	10YR5/4	Gy+	s.m.platy	27	8.30	0.84
		4	45-110+	SiCL	(10YR6/3)	10YR5/4 (2.5Y5/2)	Gy+(clay)	s.m.platy	25	8.25	3.03

(Cont'd)

Pit No.	Location	Layer No.	Depth (cm)	Texture	Soil Color Dry	Soil Color Moist	Mottlings[1/]	Structure[2/]	Compactness[3/]	pH (1:2)	EC(1:2) (mmhos/25°C)
5	Falih Mohammed Umaseni, right side of Umrani D. (8 miles)	1	0-17	SiCL	10YR7/4	-	-	cumb, c.bl.	25	8.45	0.78
		2	17-25	SiL	(10YR6/3)	10YR6/4	(clay)	m.vf.platy	22	8.50	1.04
		3	25-45	SiL	(10YR6/3)	10YR6/4	(clay)	m.vf.platy	25	8.60	0.95
		4	45-60	FSL	(10YR6/3)	10YR6.5/4	-	massive	16	8.78	1.20
		5	60-110+	SiCL	(10YR6/3)	10YR5/4	Fe+	massive	22	9.23	0.31
6*	Ali Madid, left side of Umrani D. (16 miles)	1	0-13	SiC	10YR7/3	-	-	massive	32	8.95	0.20
		2	13-22	SiC	(10YR7/3)	10YR5/4	-	w.c.blocky	20	9.05	0.24
		3	22-42	SiC	(10YR6/3)	10YR5/4	-	m.f.granular	20	8.60	0.76
		4	42-120+	SiC(SiL)	(10YR6/4)	10YR5/4	(clay)	m.m.bl.& pl.	19	8.60	1.31
7	Haji Bakhtiar, left side of Jhatpat D. (1 miles)	1	0-21	SiCL	10YR7/3	-	-	crumb, c.bl.	21	8.55	0.65
		2	21-42	SiCL	(10YR7/3-6/3)	10YR6/3	Fe++	m.m.platy	24	8.62	0.59
		3	42-60	SiCL	(10YR7/3)	10YR6/3	Fe+, Gy+	m.m.platy	24	8.55	0.79
		4	60-120+	SiCL-CL	(10YR6/2)	10YR5/3	Gy+	c.pl.& bl.	22	8.40	1.76
8	Haji Araz Mohammed, left side of Mangsi D. (8 miles)	1	0-14	SiC	10YR7/3	-	-	crumb, c.bl.	28	8.70	0.66
		2	14-30	SiC	(10YR6/3)	10YR6/4	-	w.c.blocky	32	8.82	0.53
		3	30-100+	SiC	(10YR6/3)	10YR6/4	Gy+	m.f ~ m.bl ~ gr.	28	8.45	2.22

(Cont'd)

Pit No.	Location	Layer No.	Depth (cm)	Texture	Soil Color Dry	Soil Color Moist	Mottlings 1/	Structure 2/	Compactness 3/	pH (1:2)	EC(1:2) (mmhos/25°C)
9*	Ali Akbar Khan, left side of Mangsi D. (14 miles)	1	0-18	SiC-SiCL	10YR6/3	-	Gy+	w.m.blocky	23	8.90	0.26
		2	18-35	SiC-SiCL		10YR5/4	-	w.m.granular	18	9.25	0.20
		3	35-67	SiC		10YR5/4	-	w.m.platy	17	9.05	0.28
		4	67-100+	SiC		10YR5/4	-	w.f.platy	16	9.32	0.27
10*	Barren Land, Jhatpat Town west side of railway, 2 miles south of station	1	0-12	SiCL	(10YR6/3)	10YR4/4	Salt++	w.m.platy	23	8.20	35.95
		2	12-23	L	(10YR6/3)	10YR4/4	Salt++, Gy+	massive	20	8.25	13.75
		3	23-80	LS	(2.5Y6/2)	2.5Y6/3	-	single	17	9.00	2.78
		4	80-120+	SiL(FSL)	(10YR6/2)	10YR5/3	-	massive	20	9.05	4.34
11*	Haji Aliar Khan, left side of Jhatpat D. (14 miles)	1	0-13	SiCL	10YR7/3	-	-	m.c.blocky	25	7.95	5.45
		2	13-35	CL	(10YR7/3)	10YR4/4	-	w.c.blocky	20	7.95	5.48
		3	35-80+	SiCL	(10YR7/3)	10YR4/4	-	w.c.blocky	16	7.93	6.28
12	Hajh Khan Umarani, east side of railway, 7 miles north of Jhatpat station	1	0-11	SiCL	10YR7/3	-	-	massive	23	8.90	0.20
		2	11-23	SiC	(10YR7/3)	10YR4/3	-	m.m.blocky	25	9.20	0.25
		3	23-42	SiC	(10YR7/3)	10YR4/4	-	m.c.blocky	24	9.10	0.51
		4	42-100+	SiC	(10YR7/3)	10YR4/4	-	m.c.blocky	22	8.92	0.84
13	Mir Mohammad, left side of Judher D. (15 miles)	1	0-14	CL	10YR6/3	-	-	massive	19	8.92	0.20
		2	14-38	SiL-SiCL	(10YR7/3)	10YR5/4	-	w.c.blocky	14	9.12	0.23
		3	38-70	SiCL	(10YR7/3)	10YR4/4	-	w.c.blocky	16	9.32	0.58
		4	70-110+	SiC	(10YR6/3)	10YR5/4	-	w.c.blocky	13	9.30	0.87

(Cont'd)

Pit No.	Location	Layer No.	Depth (cm)	Texture	Soil Color Dry	Soil Color Moist	Mottlings[1/]	Structure[2/]	Compactness[3/]	pH (1:2)	EC(1:2) (mmhos/25°C)
14*	Jaggar Khan Umarani, left side of Judher D. (6 miles)	1	0-14	SiC	10YR6/3	-	-	massive	27	8.60	0.29
		2	14-29	SiC	(10YR7/3)	10YR4/4	-	m.m.platy	19	8.90	0.18
		3	29-59	SiC	(10YR6/3)	10YR4/4	-	m.c.platy	20	9.20	0.17
		4	59-100+	SiC	(10YR6/3)	10YR5/4	-	m.c.platy	20	9.30	0.19
15	Left side of Temple D. (8 miles)	1	0-10	CL	10YR6/3	-	-	massive	22	8.70	0.24
		2	10-22	SiCL	(10YR6/3)	10YR5/4	-	w.c.sa.blocky	20	9.80	0.18
		3	22-63	SiCL	(10YR6/3)	10YR5/4	L+	w.c.sa.blocky	22	8.10	1.67
		4	63-100+	SiCL	(10YR6/3)	10YR4/4	Gy+	w.c.sa.blocky	21	8.12	1.59
16	Jaq Nawaz Khoso, 3 miles upstream from end of Nasirabad D. (right side)	1	0-15	SiCL	10YR7/3	-	-	crumb-mas.	24	8.88	0.21
		2	15-25	SiL	(10YR7/3)	10YR6/4	-	m.f.pl.& bl.	22	8.88	0.20
		3	25-32	SiC	(10YR7/3)	10YR4/4	-	m.m.granular	24	8.70	0.28
		4	32-60	SiL	(10YR7/3)	10YR6/4	(clay)	m.f.platy	20	8.70	0.33
		5	60-110+	SiC-SiCL	(10YR7/3)	10YR5/4	Fe++	m.c.pl.& bl.	18	8.30	0.92
17	Terminal water course, left side of Nasirabad D. (0.5 mile)	1	0-33	SiCL	(10YR7/2)	10YR4/4	-	w.c.granular	15	8.90	0.12
		2	33-50	SiCL	(10YR7/2)	10YR5/4	-	w.c granular	18	8.80	0.24
		3	50-60	FSL	(10YR7/2)	10YR6/4	-	single	20	-	-
		4	60-100+	SiL	(10YR7/2)	10YR4/4	-	w.c.gr.	21	8.60	0.21

(Cont'd)

Pit No.	Location	Layer No.	Depth (cm)	Texture	Soil Color Dry	Soil Color Moist	Mottlings [1/]	Structure [2/]	Compactness [3/]	pH (1:2)	EC(1:2) (mmhos/25°C)
18	Barren land, 6.5 mile up-stream of RD418, (inside)	1	0-10	SL	10YR6/4	-	-	single	14	9.15	0.11
		2	10-60	LS	10YR6/4	-	-	single	18	9.30	0.09
		3	60-75	SiCL-CL	(10YR6/4)	10YR5/4	-	w.m.granular	25	8.70	0.48
		4	75-140+	SL	(10YR6/4)	10YR6/3	-	massive	17	9.05	0.27
19	Upland (wheat), 9 miles north-east of Jhatpat, left side	1	0-17	SiCL	(10YR6/3)	10YR4/3	-	m.m.blocky	21	8.38	0.57
		2	17-50	SiCL	(10YR6/4)	10YR4/4	-	m.c.blocky	16	8.47	0.43
		3	50-100+	SiCL	(10YR6/3)	10YR4/4	-	w.c.blocky	17	8.50	0.48
20	Rashid Khan (Gram), 2 miles northwest from the point, 13 miles from Jhat-pat on the Jhat-pat - Sohbat Pur road	1	0-20	SiC	10YR6/3	-	Fe+	w.c ~ m.blocky	18	8.45	0.69
		2	20-40	SiC	(10YR7/3)	10YR5/3	-	m.m.blocky	19	8.70	0.56
		3	40-100+	SiC	(7.5YR6/3)	7.5YR4/3	-	m.c.blocky	19	8.70	0.61
21	Sohbat Pur, for-mer paddy land, 15.5 miles north-east of Jhatpat	1	0-21	SiCL	(10YR5/2)	10YR4/2	Fe+++	s.f.sa.blocky	23	8.26	4.80
		2	21-32	SiCL	(10YR5/2)	10YR5/2	Fe+++	s.m ~ c.blocky	20	8.20	4.08
		3	32-47	SiL	(10YR7/3)	10YR4/4	Fe+	w.c.blocky	18	8.58	3.15
		4	47-88	SiL	(10YR7/2)	10YR4/3	Fe+	w.c.blocky + platy	17	8.62	2.72
		5	88-110+	SiL	(10YR6/3)	10YR5/4	Fe+	s.m.granular	16	8.65	3.50

(Cont'd)

Pit No.	Location	Layer No.	Depth (cm)	Texture	Soil Color Dry	Soil Color Moist	Mottlings 1/	Structure 2/	Compactness 3/	pH (1:2)	EC(1:2) (mmhos/25°C)
22	Rojhan (wheat), 8 miles south-west of Jhatpat (left side)	1	0-15	SiC	(10YR6/3)	10YR4/3	Gy+	s.m.blocky	25	8.10	2.70
		2	15-37	SiC	(10YR6/3)	10YR4/4	Gy+	s.m.blocky	26	8.32	4.52
		3	37-100+	SiC	(10YR6/3)	10YR4/4	Gy+	m.c.blocky	25	8.50	5.63
23	Ghaffar Khan Jamali, fallow, 14 miles south-west of Jhatpat (left side)	1	0-17	SiC	(10YR6/3)	10YR4/3	-	m.m.blocky	21	8.72	0.29
		2	17-47	SiC	(10YR6/3)	10YR4/4	-	w.m ~ c.blocky	16	9.08	0.76
		3	47-80+	SiC(SiCL)	(10YR6/3)	10YR4/4	Gy+	w.m ~ c.blocky	16	8.02	4.40
24	Barren land, 100 m south (inside) of Pat Feeder Canal at RD238	1	0-7	CoSL	(10YR7/3)	10YR6/3	-	single	12	8.00	0.21
		2	7-25	CoSL	(10YR6/3)	10YR4/4	bog, wood	single	14	7.46	1.30
		3	25-70	SL	(10YR6/3)	10YR6/4	bog, wood	massive	14	7.47	0.78
		4	70-120+	SiL	-	10YR6/4	-	massive	-	-	-
25	Barren land, 200 m south (inside) of Pat Feeder Canal at RD109	1	0-13	SiL	(10YR6/3)	10YR5/3	-	w.f.platy	20	8.35	0.41
		2	13-27	SiL	(10YR6/3)	10YR5/4	Gy+	massive	16	8.15	1.28
		3	27-80	SiCL	(10YR6/3)	10YR5/4	Gy+	massive	17	8.15	2.15
		4	80-110+	SiCL	-	10YR5/4	-	w.c.blocky	-	-	-

Remarks : 1/ Mottlings: Fe — oxidized iron, Gy — fine gypsum crystals, L — lime pecks, + — +++ give grade, few to many. (clay) shows inserted clay laminations.

2/ Strucutre: First w.m.s. — weak, moderate, strong (development); second f.m.c. — fine, medium, coarse (size).

3/ Compactness: values of index as measured by Soil Hardness Tester.

* Soil samples were further analyzed in the Laboratory of WAPDA, Lahore.

Table III.2-36 Analysis of Water Samples Taken in the Pat Feeder Canal Project Area

Sample No.	Water Flow	Location	pH	EC (mmhos/cm 25°C)	Salt** Content (ppm)
1	Indus River	Guddu Barrage (lower stream)	7.70	0.32	207
2	Ballan Distributary	near Pit No.2, RD53	8.05	0.32	205
3	Ballan D.(standing)	near Pit No.1, RD16	8.12	0.27	175
4	Bari D.(terminal)	near Pit No.4, RD100	8.18	0.35	223
5	Umrani D.(lower)	near Pit No.6, RD84	8.22	0.42	268
6	Jhatpat D.(starting)	near Pit No.7, RD5	8.16	0.34	218
7	Mangsi D.(lower)	near Pit No.9, RD74	8.15	0.39	251
8	Jhatpat D.(lower)	near Pit No.11, RD74	8.42	0.33	211
9	Jhudher D.(terminal)	near Pit No.13, RD79	8.35	0.34	218
10	Jhudher D.(upper)	near Pit No.14, RD32	8.22	0.35	225
11	Nasirabad D.(lower)	2 mile upper P.16, RD49	8.25	0.35	224
12	Pat Feeder Canal	RD418	8.35	0.34	218
13	Stagnant Water	near Pit No.19	8.23	0.82	525
14	Pond Water	Village near P.20	8.50	3.00	1,920
15	Stagnant Water	near Pit No.21	8.18	4.92	3,150
16	Pat Feeder Canal	RD558*	8.40	0.44	282
17	Stagnant Water	near Pit No.22	7.50	2.26	1,450
18	Pond Water	near Pit No.23	8.60	0.74	475
19	Mohabat Pur D.*	Bridge on road from Jhatpat, RD68	8.40	0.43	275
20	Tube-well Water (50f)	beside RD342	7.82	0.63	402
21	Pat Feeder Canal*	RD238	8.30	0.45	285
22	Faizabad D.*	RD0	8.20	1.24	794
23	Pat Feeder Canal*	RD109	8.32	0.60	384
24	Drain System	RD78, Bridge to Jacobabad	8.80	8.16	5,220
25	Drain System	RD60	8.92	7.85	5,020
26	Flood Area of Drain	Ibid, north flood	8.72	13.34	8,540
27	Drain System	Pump Station, RD2	8.50	9.12	5,840
28	Khirtar Canal	Bridge to Usta Mohammad	8.22	0.51	326

Remarks : Most samples were taken in March, 1982, but those marked with * were from stagnant places after supply of canal water was stopped on 15th, March.
** EC x 640 ppm

Table III.2-37 Mechanical Analysis and Moisture Equivalent of the Soil Sample in the Project Area

Profile No.	Layer No.	Depth (cm)	Clay (%)	Silt (%)	Sand (%)	Texture of Soil	Moisture Equivalent at pF 2.7 (%)
1	1	0 - 6	35.0	63.8	1.2	SiCL	22.7
	2	6 - 20	35.5	62.9	1.6	SiCL	25.9
	3	20 - 30	48.0	51.6	0.4	SiC	27.5
	4	30 - 140	35.0	62.4	2.6	SiCL	25.9
4	1	0 - 10	35.0	61.2	3.8	SiCL	24.0
	2	10 - 21	35.0	60.5	4.5	SiCL	24.0
	3	21 - 45	30.5	65.2	4.3	SiCL	25.1
	4	45 - 110	35.0	61.3	3.7	SiCL	27.0
6	1	0 - 13	40.5	41.3	18.2	SiC	25.2
	2	13 - 22	49.0	41.4	9.6	SiC	23.5
	3	22 - 42	54.5	41.0	4.5	SiC	27.5
	4	42 - 120	40.0	56.5	3.5	SiC	24.6
9	1	0 - 18	53.0	46.3	0.7	SiC	25.4
	2	18 - 35	52.0	47.7	0.3	SiC	25.7
	3	35 - 67	46.5	52.7	0.8	SiC	23.1
	4	67 - 100	49.0	48.2	2.8	SiC	23.3
10	1	0 - 12	35.0	47.2	17.8	SiCL	25.5
	2	12 - 23	27.0	43.2	29.8	L	19.4
	3	23 - 80	1.1	41.0	57.9	FS	8.6
	4	80 - 120	12.0	79.3	8.7	SiL	19.2
14	1	0 - 14	42.5	53.2	4.3	SiC	24.4
	2	14 - 29	45.0	50.0	5.0	SiC	25.4
	3	29 - 59	44.0	48.2	7.8	SiC	23.5
	4	59 - 100	46.0	45.5	8.5	SiC	24.1

Note: Samples were analysed by Soil Laboratory of WAPDA, Lahore in April 1982.

Table III.2-38 Chemical Analysis of the Soil Samples in the Project Area

Pit No.	Depth (cm)	Saturation Percentage	pH of Saturation Paste	ECe mmhos/cm at 25°C	Soluble Cations me/ℓ Ca+Mg	Na	K	Soluble Anions me/ℓ CO_3	HCO_3	Cl	SO_4	Sodium Adsorption Ratio S.A.R.	Cation Exchange Capacity me/100g C.E.C.	Gypsum	$CaCO_3$ (%)	Organic Matter (%)	Available Phosporus (ppm)
1	0 - 6	47	8.3	0.5	3.0	1.5	Nil	-	1.5	1.5	1.5	1.2	17.2	Nil	16.0	0.20	< 1
	6 - 20	52	8.3	0.4	2.5	1.6	Nil	-	1.5	1.0	1.6	1.4		Nil	16.0	0.08	< 1
	20 - 30	59	8.2	0.5	3.5	1.5	Nil	-	1.5	1.5	2.0	1.1		Nil	16.0	0.08	< 1
	30 - 140	50	8.2	0.7	5.0	2.3	Nil	-	1.5	1.5	4.3	1.5		Nil	16.4	0.04	< 1
4	0 - 10	53	8.2	0.8	5.5	2.4	Nil	-	2.0	4.5	1.4	1.4		Nil	17.6	0.20	< 1
	10 - 21	46	8.2	0.4	2.5	1.3	Nil	-	1.5	1.5	0.8	1.2		Nil	18.0	0.12	< 1
	21 - 45	48	8.0	3.6	37.0	8.0	0.5	-	1.0	14.0	30.0	1.9		Traces	18.0	0.08	ppt
	45 - 110	59	8.1	9.5	64.0	48.0	0.5	-	1.0	23.5	88.0	8.5		Traces	16.8	0.04	ppt
6	0 - 13	46	8.1	0.5	3.0	2.1	-	-	2.0	2.0	1.1	1.7		Nil	18.0	0.16	ppt
	13 - 22	54	8.1	3.5	21.5	17.2	0.5	-	1.0	32.5	5.7	5.2		Traces	13.2	0.16	ppt
	22 - 42	66	8.1	2,5	16.5	11.3	0.3	-	1.0	4.0	23.1	3.9	25.4	Traces	13.2	0.08	ppt
	42 - 120	50	8.2	5.0	31.0	29.6	0.4	-	1.0	11.5	48.5	7.5		Traces	11.2	0.08	ppt
9	0 - 18	58	8.2	0.7	3.5	3.5	-	-	2.0	3.0	2.0	2.6		Nil	15.2	0.16	< 1
	18 - 35	54	8.3	0.5	2.0	2.5	-	-	2.0	2.0	0.5	2.5		Nil	15.2	0.12	< 1
	35 - 67	50	8.2	0.7	3.5	3.9	-	-	1.5	2.0	3.9	2.9		Nil	16.0	0.08	< 1
	67 - 100	52	8.2	1.4	5.0	9.3	-	-	1.5	8.5	4.3	5.8		Nil	15.2	0.08	< 1
10	0 - 12	48	8.1	120.0	346.0	975.0	5.2	-	1.0	1,280.0	45.2	74.1		Traces	13.2	0.23	ppt
	12 - 23	35	8.0	65.0	193.0	520.0	4.0	-	1.0	690.0	26.0	52.9	10.0	Traces	9.0	0.04	ppt
	23 - 80	32	8.3	14.0	54.0	120.0	1.0	-	1.0	120.0	54.0	23.1		Traces	7.6	0.04	ppt
	80 - 120	42	8.6	29.0	79.0	240.0	1.6	-	1.0	210.0	109.6	38.2		Traces	8.8	0.04	ppt
14	0 - 14	55	8.2	0.7	4.5	2.1	-	-	1.5	3.0	2.1	1.4		Nil	15.2	0.20	< 1
	14 - 29	60	8.2	0.4	2.5	1.3	-	-	1.5	1.5	0.8	1.2		Nil	13.6	0.08	< 1
	29 - 59	56	8.2	0.4	1.5	2.3	-	-	2.0	1.5	0.3	2.7		Nil	15.6	0.08	< 1
	59 - 100	56	8.2	0.7	2.0	4.5	-	-	1.5	3.0	2.0	4.5	19.8	Nil	16.4	0.04	6.50

Note: Sample were analysed by Soil Laboratory of WAPDA, Lahore in April 1982.

Table III.2-39 Quality Analysis of Water Samples Taken from the Indus River

Sampling Site	Sampling Year	Cations me/ℓ			Anions me/ℓ			pH	S A R	EC mmhos/cm at 25°C
		Ca	Mg	Na	HCO_3	Cl	SO_4			
Guddu 1/ Barrage	1982	1.90	1.45	2.18	2.77	1.62	1.14	7.6	1.68	0.53
Sukkur 2/ Barrage	1962	2.12	0.86	0.88	3.00	0.69	0.25	-	0.72	0.37

Note : 1/; Analyzed by Water and Soil Laboratory of Hydrogeology Directorate WAPDA, Quetta.

2/; Analyzed by U.S. Salinity Laboratory Research River side, California, U.S.A.

Table III.2-40 Soil Series Distributing in the Command Area of the Pat Feeder Canal Project (1)

Parent Material Soil Stratum Form Salinity and Alkalinity Texture and Others	Series Name	Map Symbol No. (Association)
A. River Alluvium Deposits		
1. Stratified Soils		
2. Homogenized Soils		
2-1 Non-saline, non-alkali, without mottles		
2-1-2 Loams	Nabipur	(16)*
2-1-3 Silt loams and v.f. sandy loams	Sultanpur	(12)*
2-2 Non-saline, non-alkali, with mottles		
2-2-2 Silt loams and v.f. sandy loams	Bagh	(4)*
2-2-4 Silty clay loams	Bahalike	(18)*
2-2-6 Silty clays	Pacca	(9)
2-3 Saline, non-alkali, without mottles		
2-3-2 Silt loams and v.f. sandy loams	Jarwar	(21)*
2-4 Saline, non-alkali, with mottles		
2-4-2 Silt loams and v.f. sandy loams	Rojhan	(24)
2-4-4 Silty clays, gypsum specks	Jacobabad	(6)*
B. Piedmont Alluvium Deposits		
1. Stratified soils		
1-1 Loamy sands and sands, excess-drained	Chhater	(29)
1-3 Silt loams and v.f. sandy loams	Bolan	(27)
1-4 Silty clay loams, mod.f.variant	Katchar	
1-5 Silty clays	Katchar	(28)
2. Homogenized Soils		
2-1 Non-saline, non-alkali		
2-1-1 Clay, not underlain by river al.	Kundi	(34)

(Cont'd)

Table III.2-40 Soil Series Distributing in the Command Area of the Pat Feeder Canal Project (2)

Parent Material Soil Stratum Form Salinity and Alkalinity Texture and Others	Series Name	Map Symbol No. (Association)
2-1-2 Calys, not underlain by river alluvium, structured to more than 90 cm depth	Jhatpat	(31)
2-1-3 Clays, underlain by r.a.below 60 cm	Kandohkot	(32)
2-2 Saline, non-alkali		
2-2-1 Clays, not underl.by r.a.	Guddu	(30)*
2-2-2 Clays, underl.by r.a. below 60 cm	Kashmor	(33)
C. Miscellaneous Areas		
Dune Land		(35)

* Distribution is very small in area.

Table III.2-41 Outlines of the Pit Soils Examined in the Command Area of the Pat Feeder Canal (1)

Pit No.	Horizon Sequence	Texture Sequence	Mottlings 1)	Structure 2)	pH 3)	EC 4)	Soil Series	Map Symbol No. (Association)
1.	Ap-B1-B2-B3-C1	SiCL-SiCL-SiCL-SiC	Fe+	m.f.pl.	8.8-8.9	0.2-0.3	Jhatpat	(31)
2.	Ap-B1-IIB2-IIIB3	SiCL-CL	Fe+	m.m.bl.	8.9-8.3	0.2-1.5	Jhatpat	(31)
3.	Ap-B1-B2-B3	SiCL-CL-SiCL	Gy+	m.m.bl+pl.	8.7	0.3-0.5	Jhatpat	(31)
4.	Ap-B1-B2-IIC1	SiCL-SiCL-SiCL	Gy+	m.m.bl+pl	9.2-8.3	0.3-3.0	Jhatpat	(31)
5.	Ap-C1-IIC2-IIIC3-IVC4	SiCL-SiL-FSL-SiCL	Fe+	m.f.pl.	8.5-9.2	0.8-1.2-0.3	Bolan	(27)
6.	Ap-B1-B21-IIB22	SiC-SiC-SiC	(c)	m.m.bl+gr.	9.1-8.6	0.2-1.3	Jhatpat	(31)
7.	Ap-C1-C2-IIB2	SiCl-SiCL-CL	Fe,Gy+	m.m.pl.	8.6-8.4	0.6-1.8	Katchar	(28)
8.	Ap-B1-B2	SiC-SiC	Gy+	m.c.bl+gr	8.8-8.5	0.7-2.2	Jhatpat	(31)
9.	Ap-B1-B2-B3	SiC-SiC-SiC	Gy+	w.m.bl.pl.	8.9-9.3	0.2-0.3	Kundi	(34)
10.	A-C-IIC1-IIIC2	SiCL-L-LS-SiL	Sa,Gy+	massive	8.2-9.1	36.0-2.3	Rojhan	(24)
11.	Ap- B1-B2	SiCL-CL-SiCL	-	w.c.bl.	8.0-7.9	5.5-6.3	Jhatpat	(31)
12.	Ap-C1-C2-C3	SiCL-SiC-SiC	-	m.m.bl.	8.9-9.1	0.2-0.8	Katchar	(28)
13.	Ap-B1-IIB2-IIB3	CL-SiCL-SiC	-	w.c.bl.	8.9-9.3	0.2-0.9	Jhatpat	(31)
14.	Ap-B1-B2-B3	SiC-SiC-SiC	-	m.m.pl.	8.6-9.3	0.3-0.2	Jhatpat	(31)
15.	Ap-B1-B2-B3	CL-SiCL-SiCL	L.Gy+	w.c.bl.	8.9-8.1	0.2-1.7	Jhatpat	(31)
16.	Ap-B1-B2-C1	SiCL-SiL-SiC-SiL	(c)Fe+	m.f.gr+pl.	8.9-8.3	0.2-0.9	Jhatpat	(31)
17.	A-C1-IIC2-IIIC3	SiCL-SiCL-FSL-SiL	-	w.c.gr.	8.9-8.6	0.1-0.2	Kandhkot	(32)
18.	AG-IIC1-IIIC2-IVC3	SL-LS-SiCL-SL	-	Single	9.2-8.7	0.1-0.5	Chhater	(29)
19.	Ap-B1-B2	SiCL-SiCL-SiCL	Fe+	m.m.bl.	8.4-8.5	0.6-0.5	Jhatpat	(31)
20.	Ap-B1-B2	SiC-SiC-SiC	Fe+	m.m.bl.	8.5-8.7	0.7-0.6	Jhatpat	(31)
21.	Ap-B1-IIC1-IIC2	SiCL-SiCL-SiL-SiL	Fe+++	s.m.bl+gr	8.3-8.7	4.8-3.5	Kandhkot	(29)

(Cont'd)

Table III.2-41 Outlines of the Pit Soils Examined in the Command Area of Pat Feeder Canal (2)

Pit No.	Horizon Sequence	Texture Sequence	Mottlings[1)]	Structure[2)]	pH[3)]	EC[4)]	Soil Series	Map Symbol No. (Association)
22.	Ap-B1-B2	SiC-SiC-SiC	Gy+	s.m.bl.	8.1-8.5	2.7-5.6	Jhatpat	(31)
23.	Ap-B1-B2	SiC-SiC-SiC	Gy+	w.m.bl.	8.7-9.1	0.3-4.4	Jhatpat	(31)
24.	A-C1-IIC2-IIIC3	CoSL-SL-SiL	-	Single-ma	8.0-7.5	0.2-1.3	Chhater	(29)
25.	A-C1-IIC2-IIC3	SiL-SiL-SiCL-SiCL	Gy+	w.pl+ma	8.4-8.2	0.4-2.2	Bolan	(27)

Remarks : 1) Fe-oxidized iron mottles ; Gy- fine crystals of gypsum ; L-lime specks ; Sa-Salt efflorescence. +-+++give abandance of mottles, few to many.

2) First w.,m.,s. --- weak,moderate,strong(grade) ; second f.,m.,C. ---fine,medium, coarse(size) ; last bl.,gr.,pl.,ma --- blocky,granular,platy,massive(shape)

3) Of the 1:2 soil - water suspension.

4) Electrical Conductivity expressed as mmhos/cm at 25°C of the 1:2 Soil - Water extract.

Table III.2-42 Area of Soil Associations in the Pat Feeder Canal Command Area

Symbol No.	Soil Association	Acreage (acre)	Hectarage (ha)	Distribution Ratio (%)
6	Jacobabad	4,920	1,990	0.7
9	Pacca	7,400	2,990	1.1
16	Nabipur	3,140	1,270	0.5
24	Rojhan	7,590	3,070	1.1
27	Bolan	15,520	6,270	2.3
28	Katchar	51,390	20,760	7.5
29	Chhater	20,220	8,170	2.9
31	Jhatpat	530,720	214,450	77.1
32	Kandhkot	8,690	3,510	1.3
34	Kundi	29,790	12,040	4.3
35	Dune Land	8,620	3,480	1.2
Total		688,000	278,000	100.0

Table III.2-43 Land Capability Classification of Soils in the Pat Feeder Canal Command Area

Class	Sub-class	Limitations	Soil Series, Variant	Acreage (acre)	Percent (%)
I	irI	No or only slight limitations	Pacca anthropic surface variant (9) Nabipur (16) Bolan (27) Bolan loam variant (27)	14,740	2.1
II	irIIs	Minor limitations; fine textured; rather slowly permeable; or slightly surface saline	Pacca (9) Pacca moderately deep (9) Pacca slightly saline (9) Nabipur fine surface (16) Nabipur moderately coarse variant (16) Bolan moderately coarse variant (27) Katchar (28) Katchar moderately fine variant (28) Jhatpat (31) Jhatpat overwash (31) Jhatpat slightly saline (31) Kandhkot (32) Kundi (34)	620,370	90.2
	irIIa	Slightly saline/ sodic	Nabipur slightly saline (16)	-	-
III	irIIIw	Imperfectly drained; fine tex.; slightly saline	Pacca imperfectly drained (9) Pacca imperfectly drained slightly saline (9)	6,900	1.0
	irIIIa	Moderately saline/sodic or strongly saline but with gypsum; high water table within 10f	Jacobabad (6) Jacobabad imperfectly drained (6) Rojhan (27) Rojhan fine surface (27) Rojhan imperfectly drained (27)	12,530	1.8
IV	irIVw	Fine tex.; seepage	Pacca pooly drained (9)	-	-
	irIVs	Sandy;see page	Chhater (29)	23,200	3.4
VIII	VIIIe	Undulating; erosion	Shifting sand (35)	10,260	1.5
			Total	688,000	100.0

Source: Reconnaissance Soil Survey, Jacobabad-Usta Mohammad, Soil Survey of Pakistan, 1972.

Table III.2-44 Criteria of Soil Characteristics for Land Suitability Evaluation

Item	Symbol (value)	Class	Range
1. Texture			
	1	Coarse	S, LS
	2	Moderately coarse	SL,FSL
	3	Medium	L,SiL,Si
	4	Moderately fine	SCL,SiCL,CL
	5	Fine	SC,SiC,C
2. pH of Saturation Paste			
	1	Slightly alkaline	7.5 - 8.0
	2	Alkaline	8.0 - 8.5
	3	Moderately to strongly alkaline	> 8.5
3. EC x 10^3 at 25°C			
	1	Non-saline	< 4
	2	Slightly saline	4 - 8
	3	Moderately saline	8 - 15
	4	Strongly saline	> 15
4. SAR (Sodium Adsorption Ratio)			
	1	Non-sodic	< 13
	2	Slightly sodic	13 - 23
	3	Moderately sodic	23 - 53
	4	Strongly sodic	> 53
5. Gypsum			
	-	Nil	
	+	Present	

Source : Project-Wise Data of Indus Basin Vol.1, WAPDA (1979), except for pH.

Table III.2-45 Overall Saline Status of Soils in and around the Pat Feeder Canal Area (Baluchistan Portion)

1. Surface Salinity

Project/ Units	Survey period	Total acreage	Salt free S1	Slightly saline S2	Moderately saline S3	Strongly saline S4
Jacobabad	1977-78	42,321	27,191	2,563	7,059	5,452
Thul		%	64	6	17	13
Kandkot	1953-54	42,321	20,349	7,173	8,132	6,621
		%	48	17	19	16
Pat Feeder	1978-79	635,736	476,556	101,702	25,934	28,887
Hairdin		%	75	16	4	5
	1953-54	635,736	493,173	62,706	31,038	47,885
		%	77	10	5	8
Kirthar	1977-78	195,234	142,889	45,289	6,040	315
		%	73	23	3	1
	1953-54	195,234	90,702	60,760	23,770	19,301
		%	47	31	12	10
Total	1977-79	873,291	646,636	149,554	39,033	34,654
		%	74	17	5	4
	1953-54	873,291	604,224	130,639	62,940	73,807
		%	69	15	7	9

2. Profile Salinity/Sodicity

Project/ Units	Survey period	Total profiles	Non-saline non-sodic	Saline	Saline sodic	Non-saline sodic
Jacobabad	1977-78	71	35	13	23	-
Thul		%	49	18	33	-
Kandkot						
Pat Feeder	1978-79	1,018	360	300	351	7
Hairdin		%	35	29	35	1
Kirthar	1977-78	313	102	52	154	5
		%	33	17	49	1
Total	1977-79	1,402	497	365	528	12
		%	35	26	38	1

Source : Project-Wise Data of Indus Basin, Vol.2, Soil Salinity and Water Table Survey, WAPDA (1981)

Table III.2-46 Area of Soil Surface Salinity in the Pat Feeder Canal Project

Map Symbol	ECe (mmhos/cm)	Area (acre)	Area (ha)	Distribution Ratio (%)
1. Measured of WAPDA - ATLAS (1981)				
S1	< 4	530,600	214,420	77.1
S2	4-8	112,100	45,280	16.3
S3	8-15	19,900	8,030	2.9
S4	> 15	16,200	6,540	2.4
Others*	-	9,200	3,730	1.3
Total		688,000	278,000	100.0
2. Measured of WAPDA - DATA (1977-1979)				
S1	< 4	447,100	180,650	65.0
S2	4-8	113,200	45,740	16.5
S3	8-15	55,500	22,410	8.1
S4	> 15	33,200	13,440	4.8
Unknown**	-	39,000	15,760	5.6
Total		688,000	278,000	100.0

Note : Depth of soil surface is 15 cm.

* Sand dune areas not sampled.

** Areas where samples were lost or not analysed.

Table III.2-47 New Class Criteria for Soil Profile Salinity Evaluation

Soil Depth (cm)	Soil Sample No.	Class and Sub-class of Salinity										
		I		II			III			IV		V	
		a	b*	a	b	c	a	b	c	a	b	a	b
0- 45	1-2	1	1	1	1	2	2	2	3	3	3	4	4
45- 90	3	1	1-2	1-2	3-4	1-2	1-2	3-4	1-2	1-2	3-4	1-3	4
90-180	4	1	1-2	3-4	1-4	1-2	3-4	1-4	1-2	3-4	1-4	1-4	1-4

Note : 1) Salinity numbers, 1-4, see Table III.2-44.

2) Salinity of 0-45cm soil shows average value of sample 1 and 2.

3) SAR is further evaluated only for average value of sample 1 and 2 by designating x as its value is 13-23, and y as more than 23. For examples, IIcx: Vay.

* This b does not include 1-1-1 soils.

Table III.2-48 Area of Soil Profile Salinity in the Pat Feeder Canal Project

1. Measured of WAPDA-DATA (1977-1979)

Class	Sub-class	Area (acre)	Percent (%)	Frequency of high SAR (%)
I	a	225,400	32.8	0.2x+0.1y
	b	137,100	19.9	
	Sub-total	362,500	52.7	0.2x+0.1y
II	a	56,500	8.2	
	b	34,400	5.0	
	c	43,900	6.4	0.3x
	Sub-total	134,800	19.6	0.3x
III	a	12,200	1.8	0.3x
	b	56,200	8.2	0.6x
	c	12,200	1.8	0.8x+0.1y
	Sub-total	80,600	11.8	1.7x+0.1y
IV	a	2,700	0.4	0.1x
	b	42,000	6.1	2.3x+0.2y
	Sub-total	44,700	6.5	2.4x+0.2y
V	a	11,900	1.7	0.8x+0.7y
	b	22,200	3.2	1.0x+1.8y
	Sub-total	34,100	4.9	1.8x+2.5y
Unknown		31,300	4.5	
Total		688,000	100.0	

2. Measure of WAPDA-ATLAS (1981)

Group No.		Area (acre)	Percent (%)
1	(Non-saline non-sodic)	244,500	35.6
2	(Saline non-sodic)	214,700	31.2
3	(Saline sodic)	217,000	31.5
4	(Non-saline sodic)	5,700	0.8
Unknwon		6,100	0.9
Total		688,000	100.0

Note: Expression, Saline or sodic, in Atlas include the soils whenever they had any layer high in ECe more than 4 mmhos or SAR more than 13 in the profile examination.

Source: WAPDA original data for Atlas, 34P, 39D and 39H, Planning Division (1977-1979).

Table III.2-49 Re-Classification of Land Capability as Involved with Proposed Soil Profile Salinity Class for Irrigated Agriculture

Land Capability Class and Subclass	Limitation	Proposed class and subclass of profile salinity: I (a, b) A(Non-saline)	II (a, b, c), III (a) B(Slightly saline)	III (b, c), IV (a, b) C(Moderately saline)	V (a, b) D(Strongly saline)
I	-	I	IIa	IIIa	IVa
IIs	Fine textured	IIs	IIa	IIIa	IVa
IIa	Slightly saline	-	IIa	IIIa	IVa
IIIw	Imperfectly drained	IIIw	IIIw	IIIa	IVa
IIIa	Moderately saline	-	-	IIIa	IVa
IVw	Poorly drained	IVw	IVw	IVw	IVa
IVs	Sandy-seepage	IVs	IVs	IVs	IVa

Note: For profile salinity, see Table III.2-47.

Table III.2-50 Land Capability Classification with Profile Salinity of the Soil in the Pat Feeder Canal Project Area

Map Symbol No.	Class Sub-class	Main limitations	Soil Series, variant, phase or other area	Area (acre)	Percent (%)
1	irI	None or only slight limitations	Bolan, Bolan loam variant (27)	11,390	1.7
2	irIIs	Fine textured, slowly permeable	Pacca (9), Nabipur (16), Bolan mod.Co., (27), Katchar (28), Jhatpat (31), Kandhkot (32), Kundi (34)	222,510	32.3
3	irIIa	Fine textured, slightly saline/ sodic	Nabipur slightly saline (16), Jhatpat slightly saline (31)	335,790	48.8
4	irIIIw	Fine textured, poorly drained	Pacca poorly drained (9)	5,440	0.8
5	irIIIs	Fine sandy, rapidly permeable	Pacca imperfectly drained and slightly saline (9)	-	-
6	irIIIa	Mod. to fine tex., moderately saline	Jacobabad (6), Jhatpat (31), Katchar (28)	51,740	7.5
7	irIVs	Sandy textured, seepage	Chhater (29)	16,630	2.4
8	irIVa	Mod. to fine tex., strongly saline	Jhatpat (31), Katchar (28), Kundi (34) Rojhan (24)	33,110	4.8
9	Viic-s	Topography, sandy/saline/ poorly drained	Chhater (29)	2,360	0.4
10	VIII	Undulating, sandy, wind erosion	Dune land (35)	9,030	1.3
			Total	688,000	100.0

Note: The map was drawn by combining Land Capability Map (Soil Survey of Pakistan) and WAPDA original data of soil salinity/sodicity (see Table III.2-49).

Table III.2-51 Group of Gypseous Soil Profiles and Their Extent in the Pat Feeder Project Area

Soil Depth (cm)	Presence(+) or absence(-) of gypsum in the Profile, Group No. 1	2	3	4	Unknown	Total
0- 15	-	- - -	+ - +	+ + + - - - + + +		
15- 45	-	- - -	- + +	- - - + + + + + +		
45- 90	-	+ - +	- - -	+ - + + - + + - +		
90-180	-	- + +	- - -	- + + - + + - + +		
Acreage (acre)	108,100	135,500	16,400	379,400	46,600	688,000
Hectarage (ha)	43,700	55,600	6,600	153,300	18,800	278,000
Distribution ratio (%)	15.7	19.9	2.4	55.2	6.8	100.0

Source: WAPDA original data for Atlas, 34P, 39D and 39H, Planning Division (1977-1979)

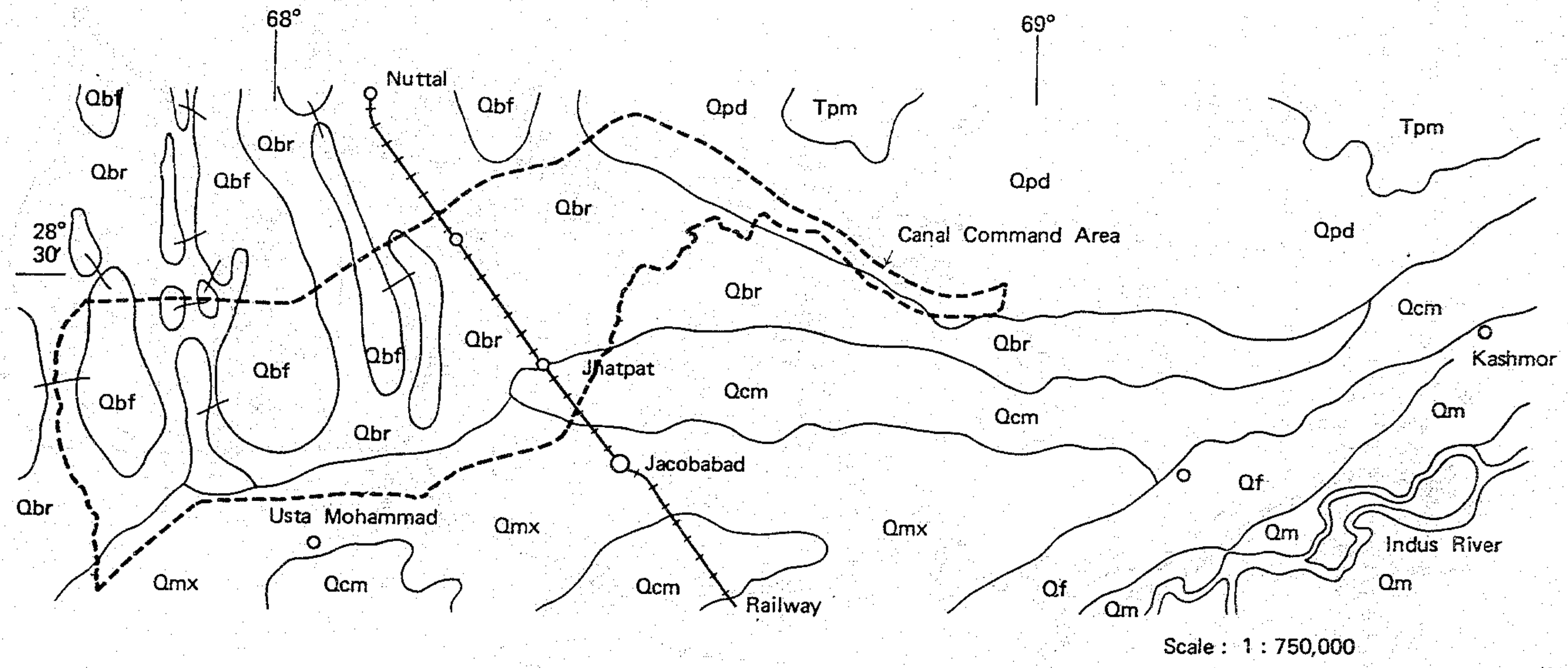


Fig. III.2-6 Geological Map around the Pat Feeder Canal Command Area

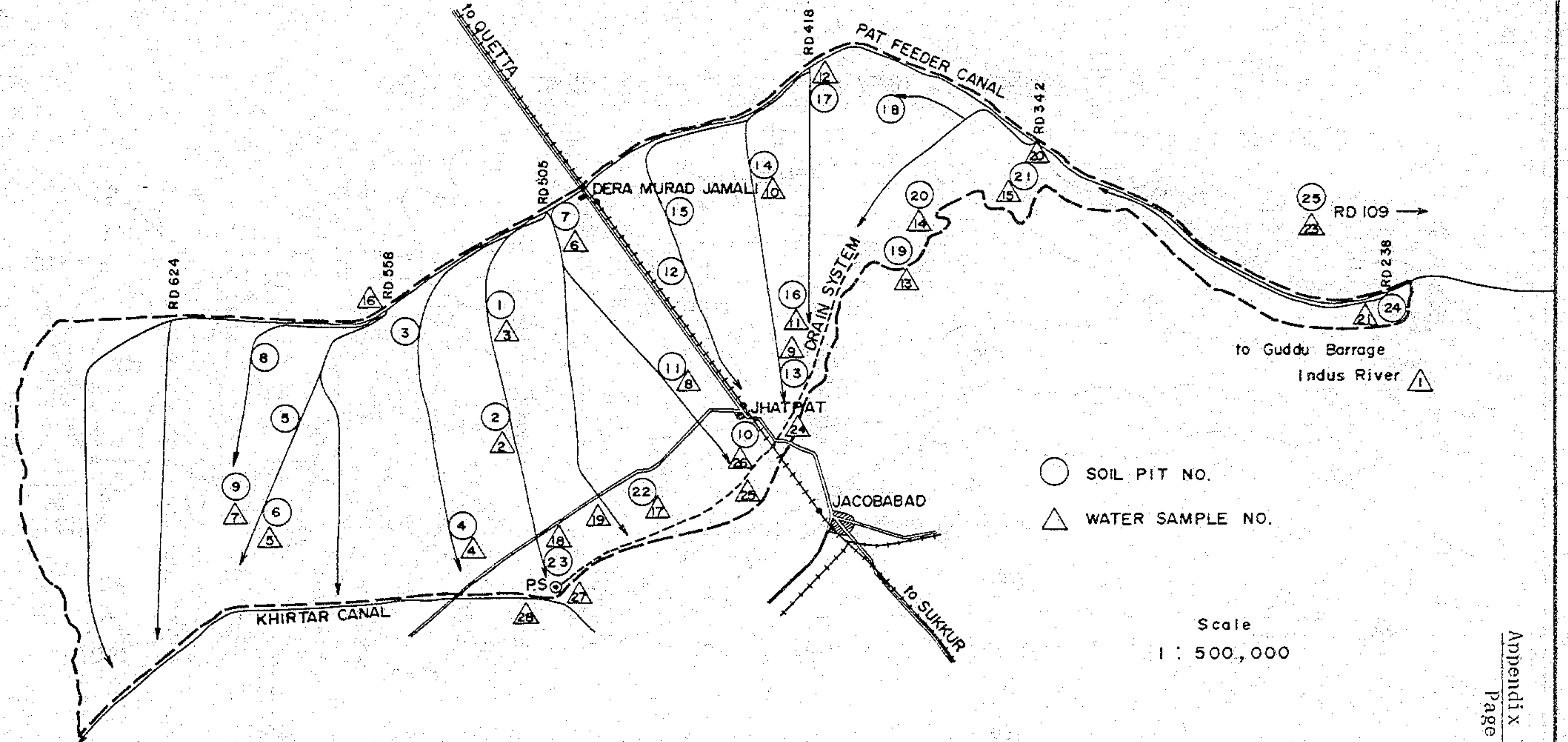


Fig. III. 2-7 Location of Pits Examined in the Command Area of the Pat Feeder Canal Project

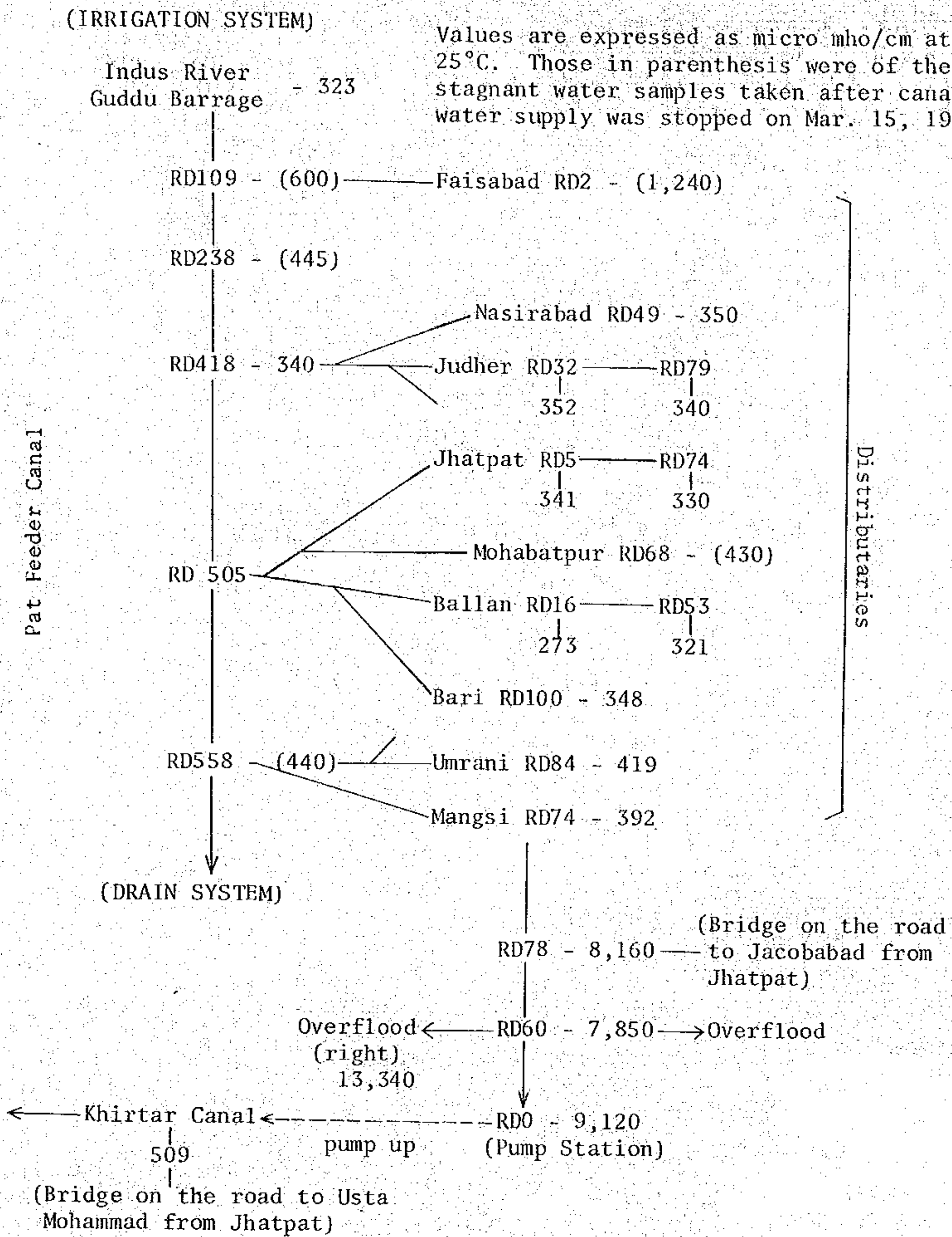


Fig.III.2-8 Distribution of EC Values of the Water Samples Taken from the Irrigation and Drain System of Pat Feeder Canal Project.

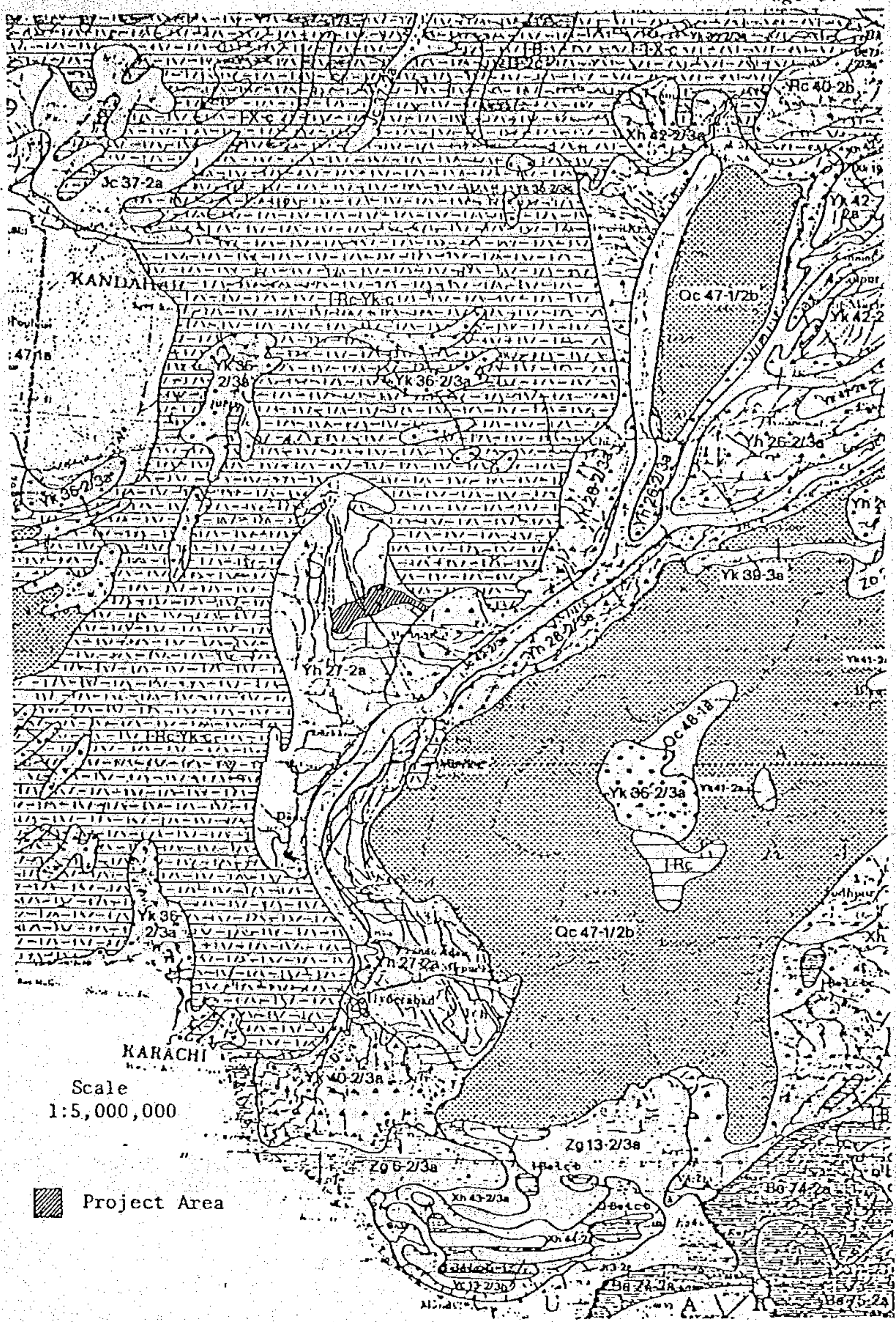


Fig. III.2-9 FAO-UNESCO: Soil Map of the World
(Pakistan)

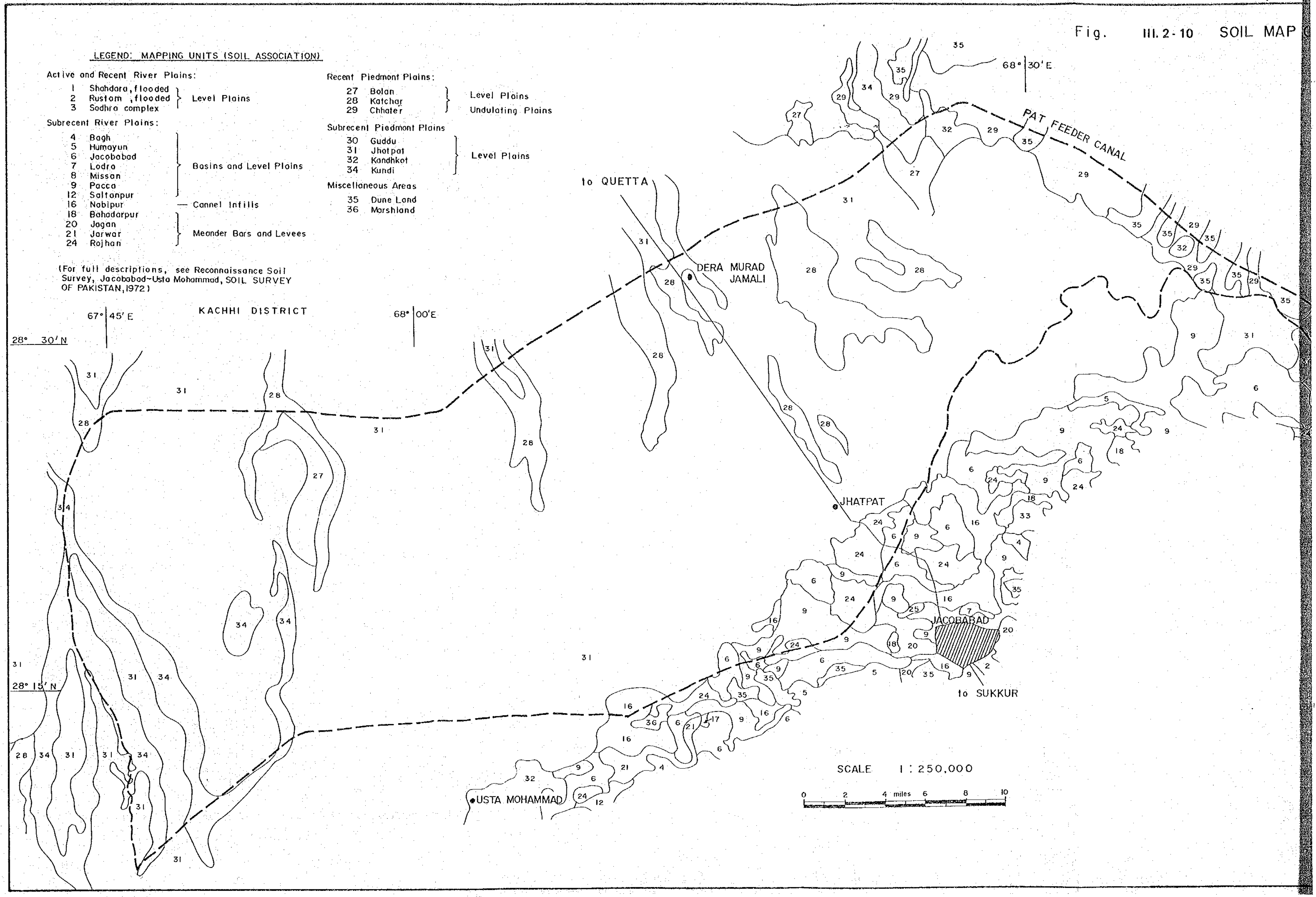
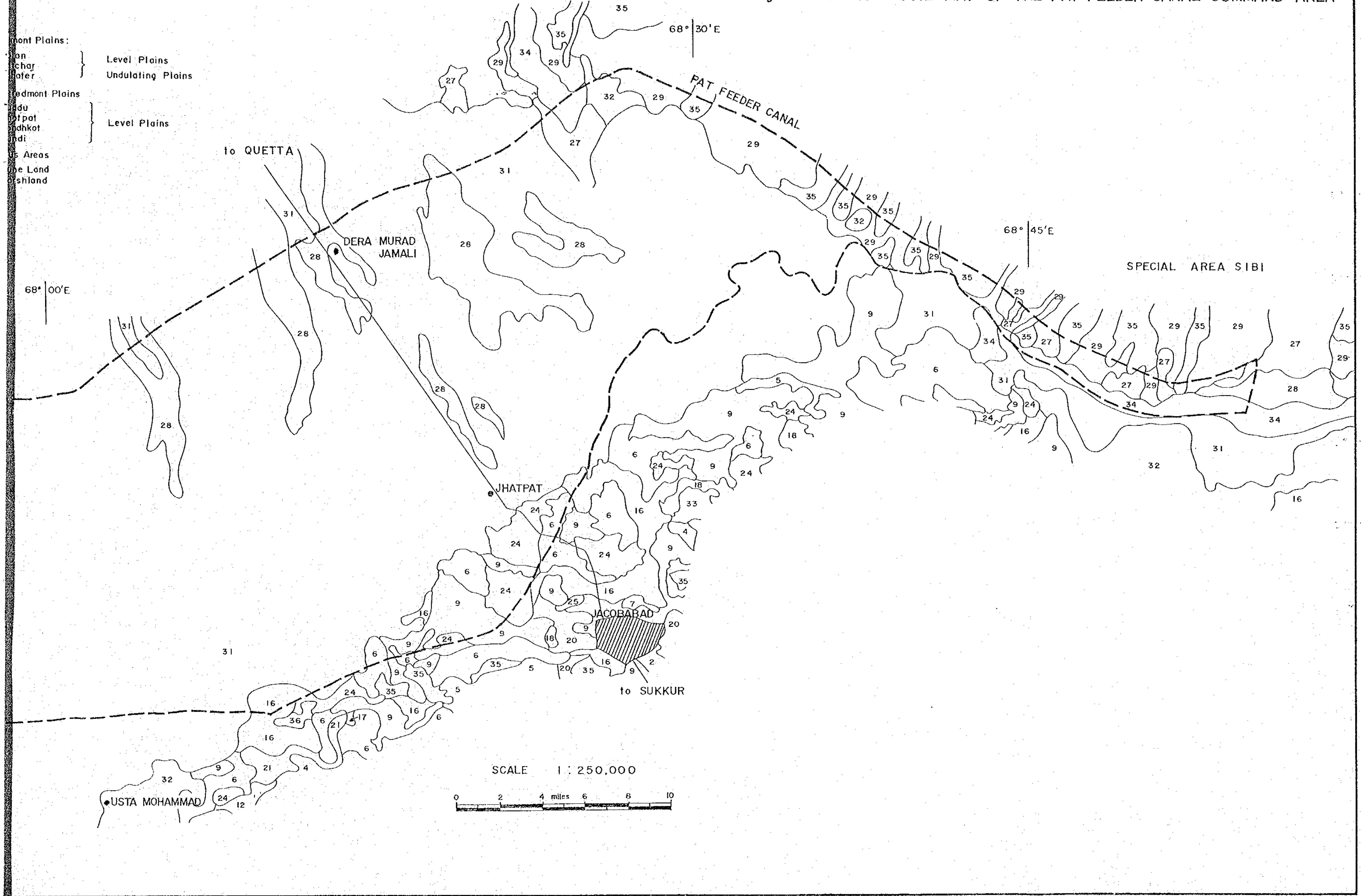


Fig. III.2-10 SOIL MAP

Fig. III.2-10 SOIL MAP OF THE PAT FEEDER CANAL COMMAND AREA



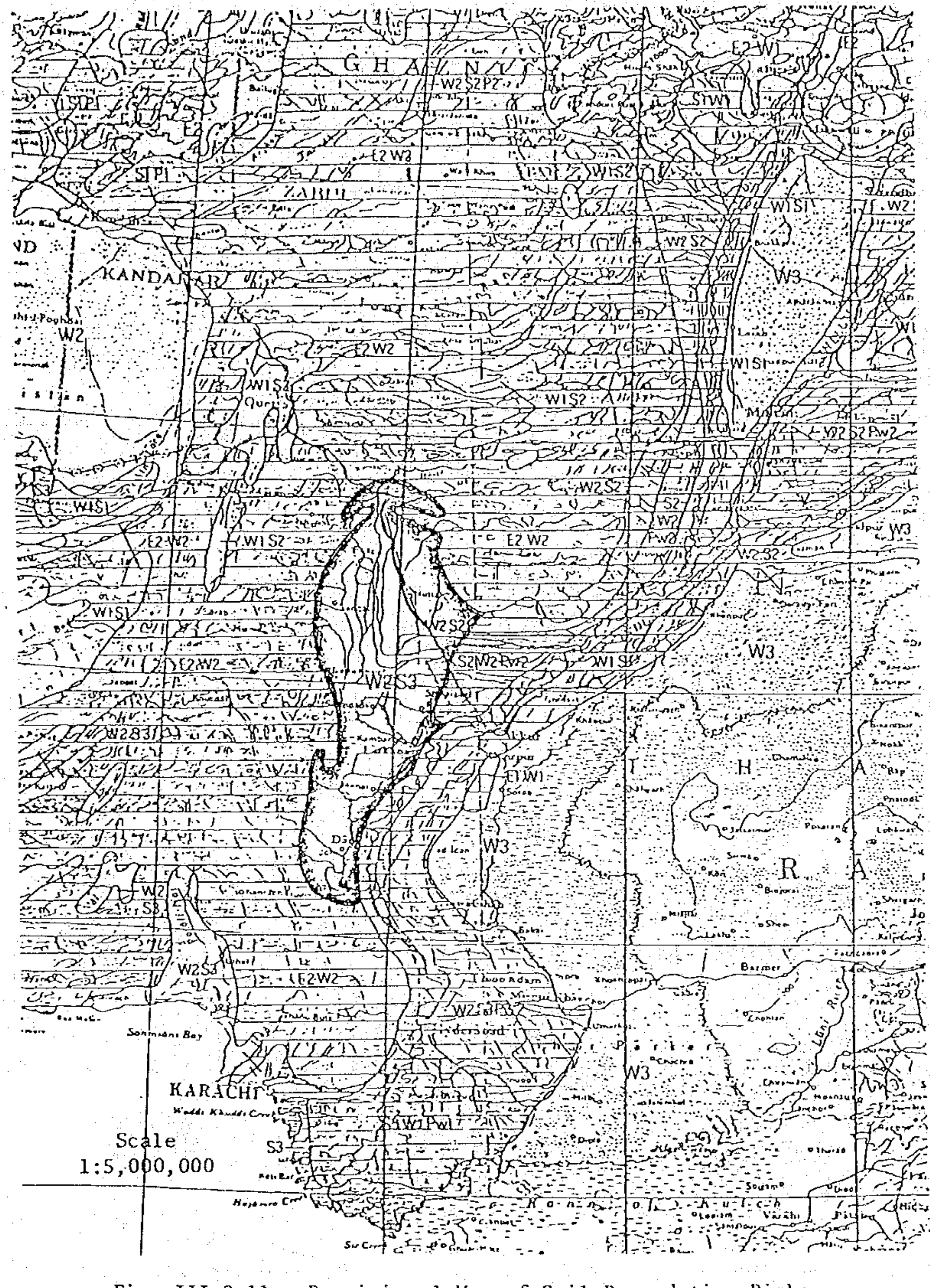


Fig. III.2-11 Provisional Map of Soil Degradation Risks
(Pakistan)

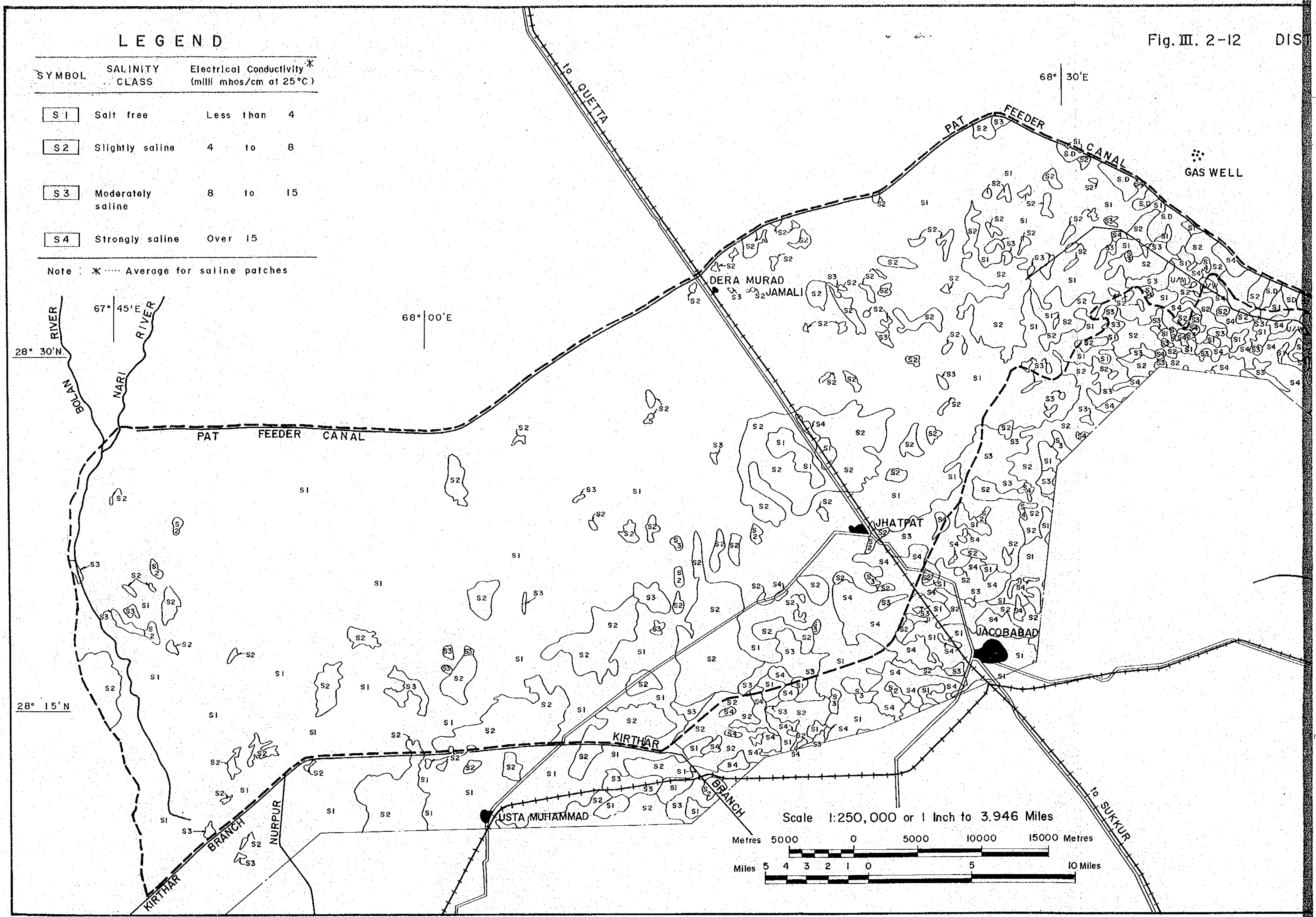


Fig. III. 2-12 DIS
LEGEND
SYMBOL
SALINITY CLASS
Electrical Conductivity*
(milli mhos/cm at 25°C)
S1 Salt free Less than 4
S2 Slightly saline 4 to 8
S3 Moderately saline 8 to 15
S4 Strongly saline Over 15
Note : * ····· Average for saline patches
67° 45'E
68° 00'E
68° 30'E
28° 30'N
28° 15'N
BOLAN RIVER
NARI RIVER
to QUETTA
PAT FEEDER CANAL
GAS WELL
DERA MURAD JAMALI
JHATPAT
JACOBABAD
USTA MUHAMMAD
KIRTHAR BRANCH
NURPUR
to SUKKUR
Scale 1:250,000 or 1 Inch to 3.946 Miles
Metres 5000 0 5000 10000 15000 Metres
Miles 5 4 3 2 1 0 5 10 Miles

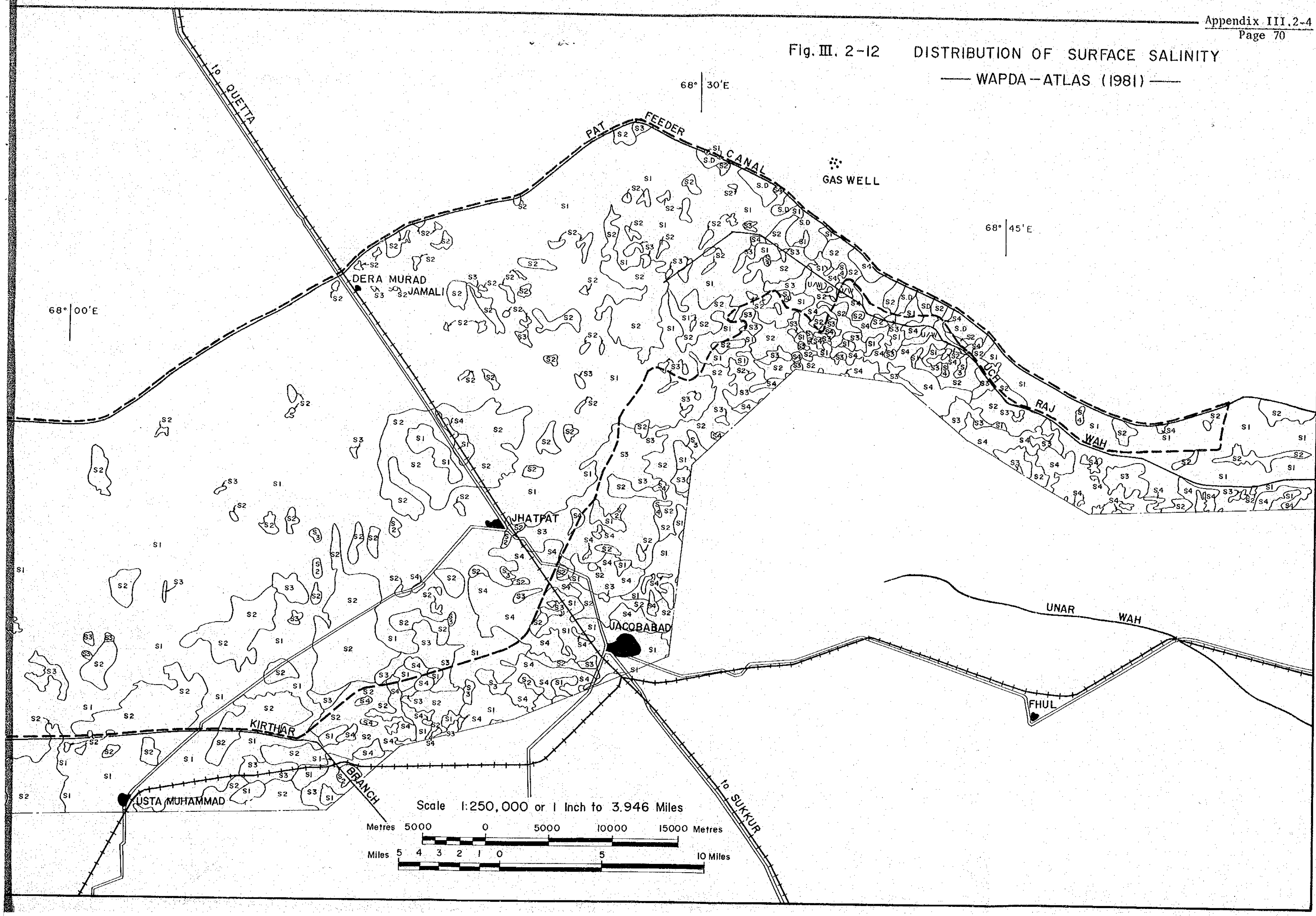


Fig. III. 2-12 DISTRIBUTION OF SURFACE SALINITY
—— WAPDA – ATLAS (1981) ——

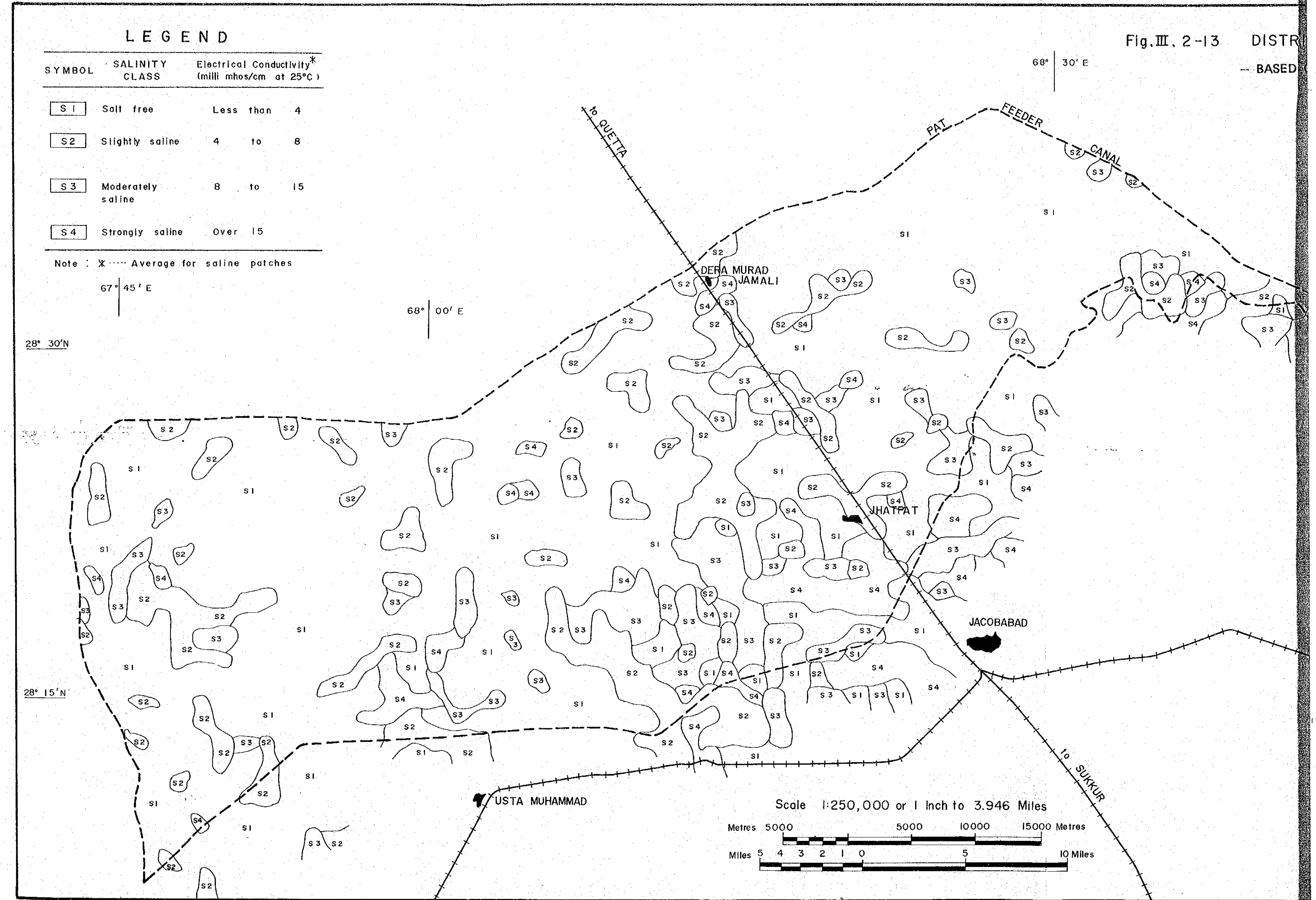
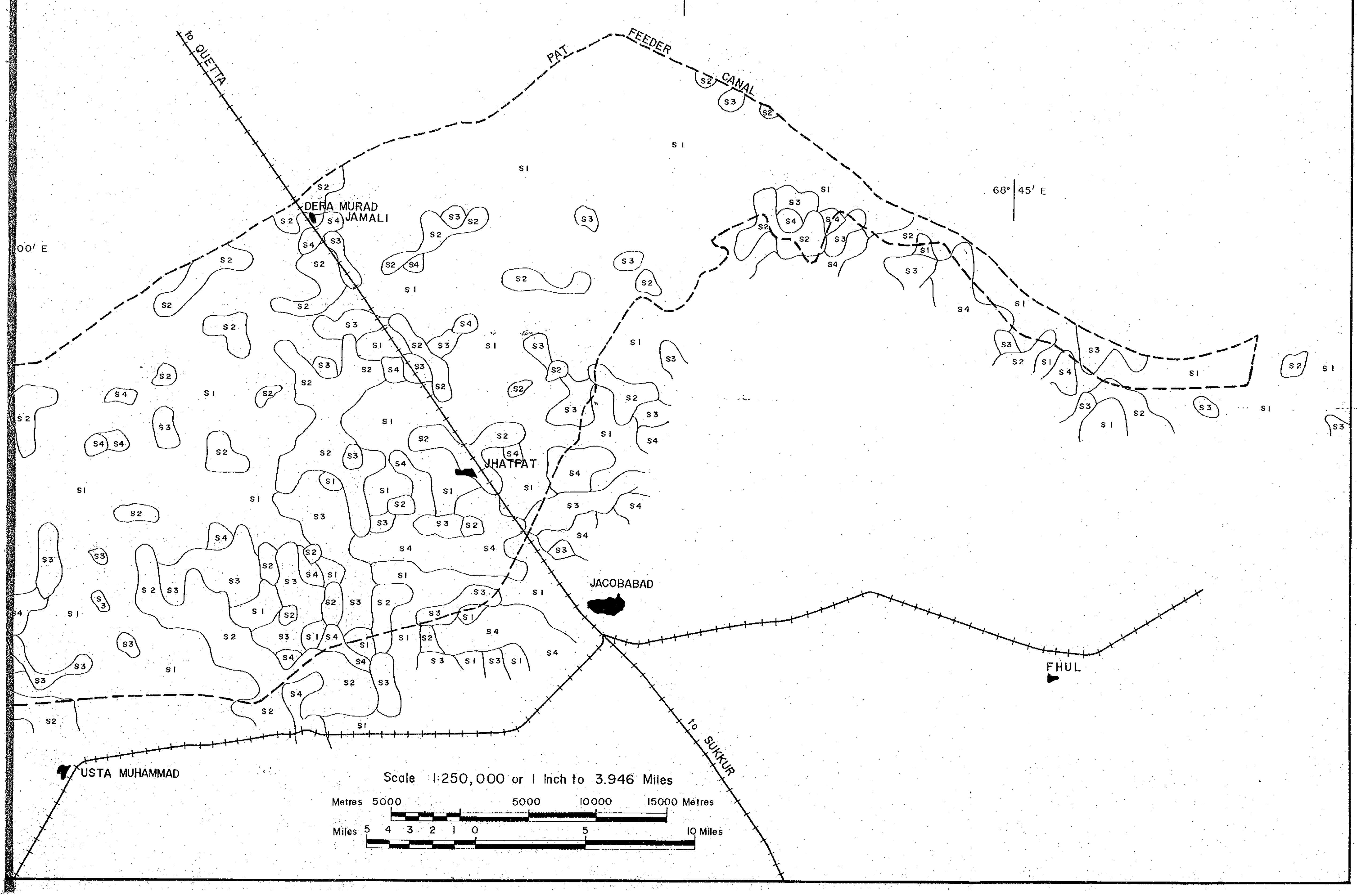


Fig. III. 2-13 DISTR
– BASED

Fig.III. 2-13 DISTRIBUTION OF SURFACE SALINITY

– BASED ON WAPDA ORIGINAL DATA (1977 – 1979) –



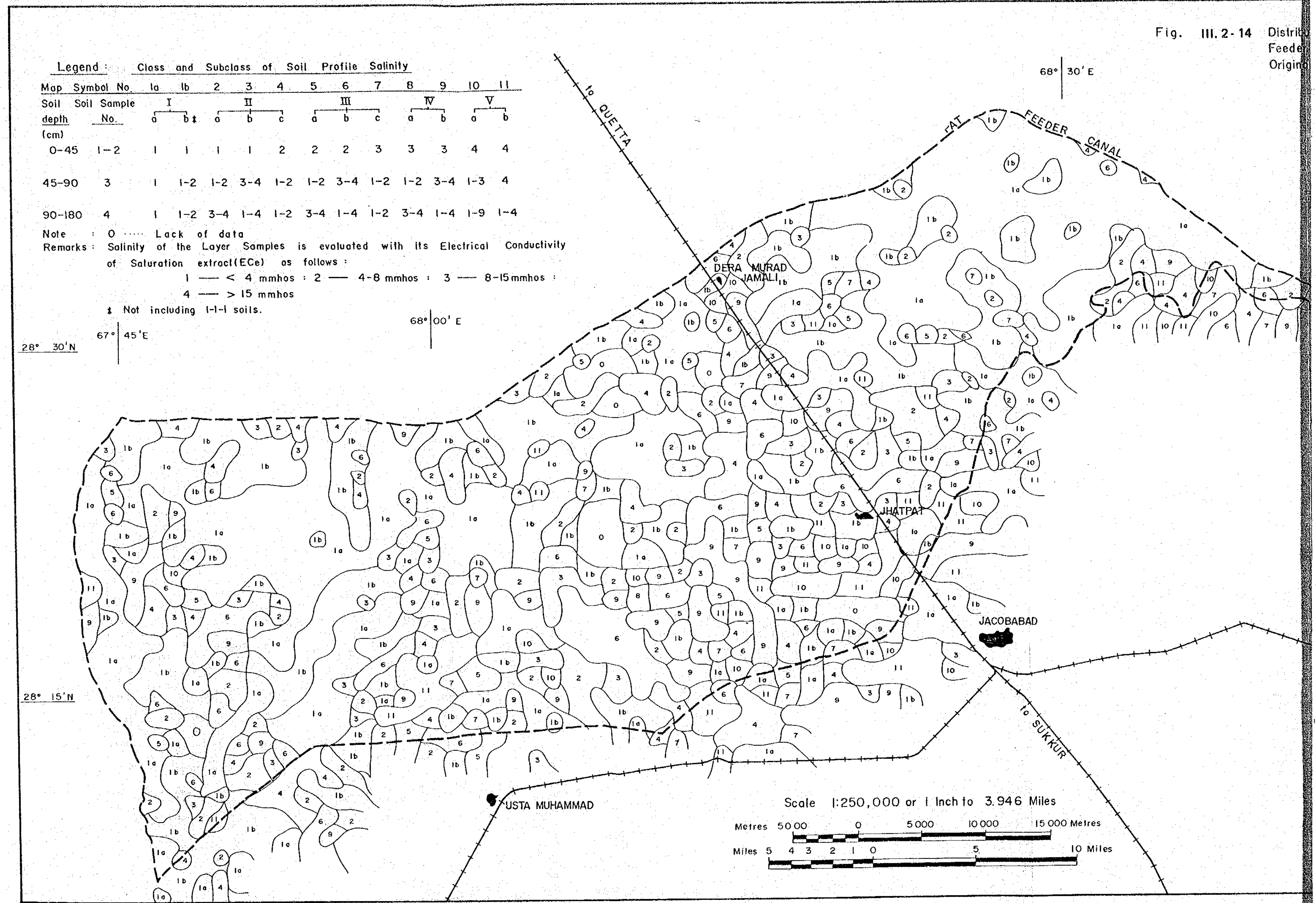


Fig. III. 2-14 Distrib Feeder Origin

Fig. III.2-14 Distribution of Soil Profile Salinity in the Pat Feeder Canal Project Area, Based on WAPDA Original Data. (1977-1979)

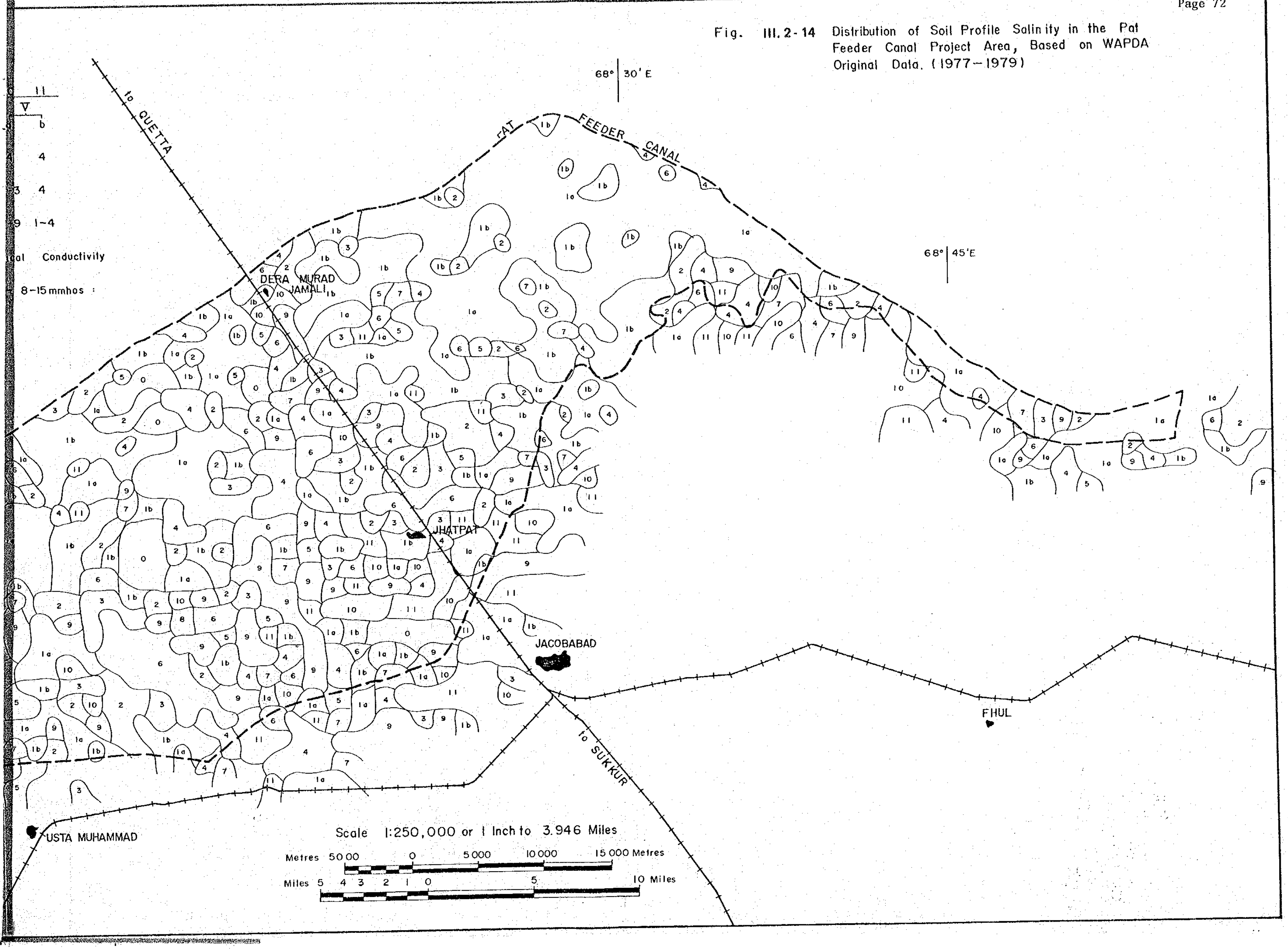
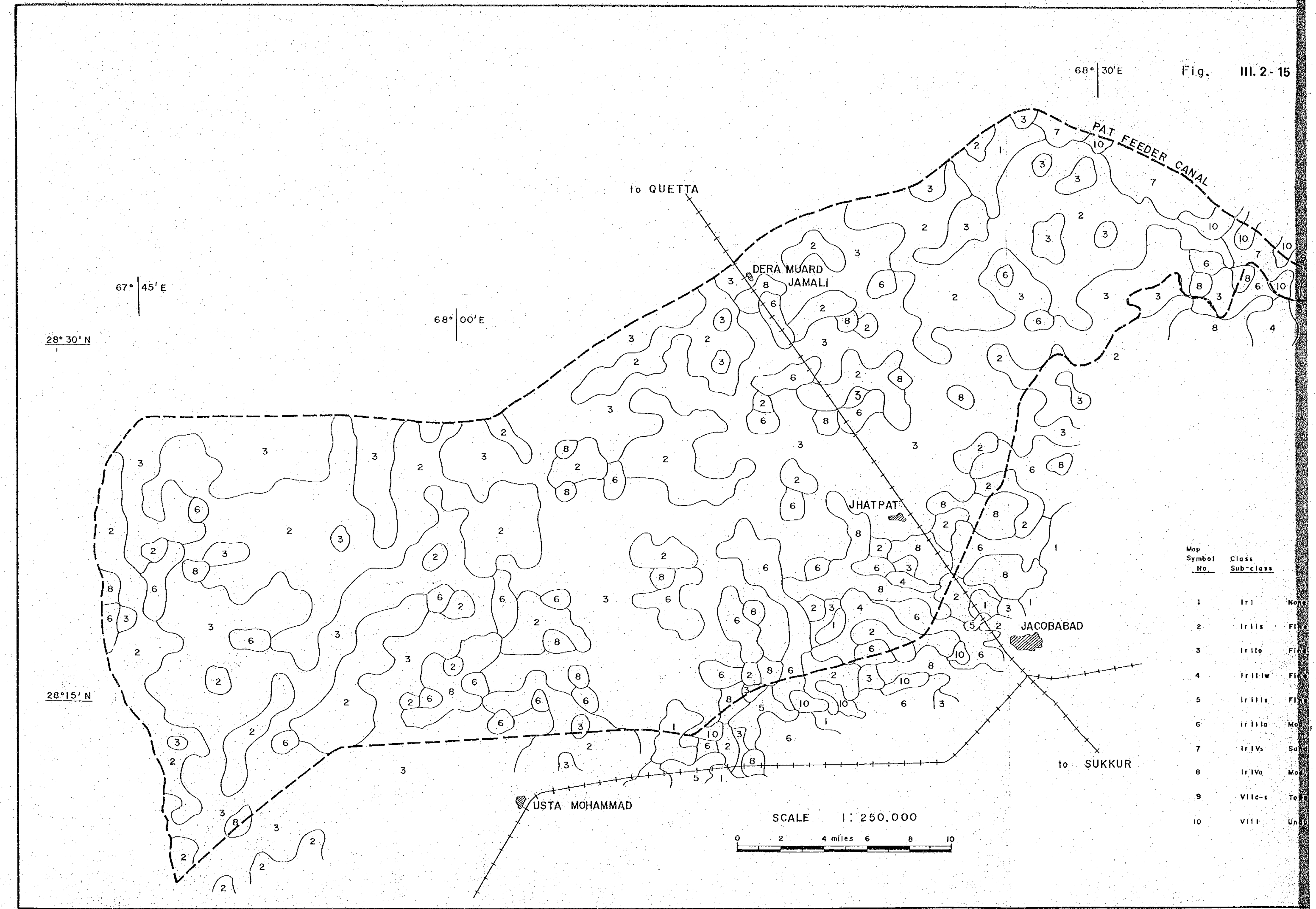
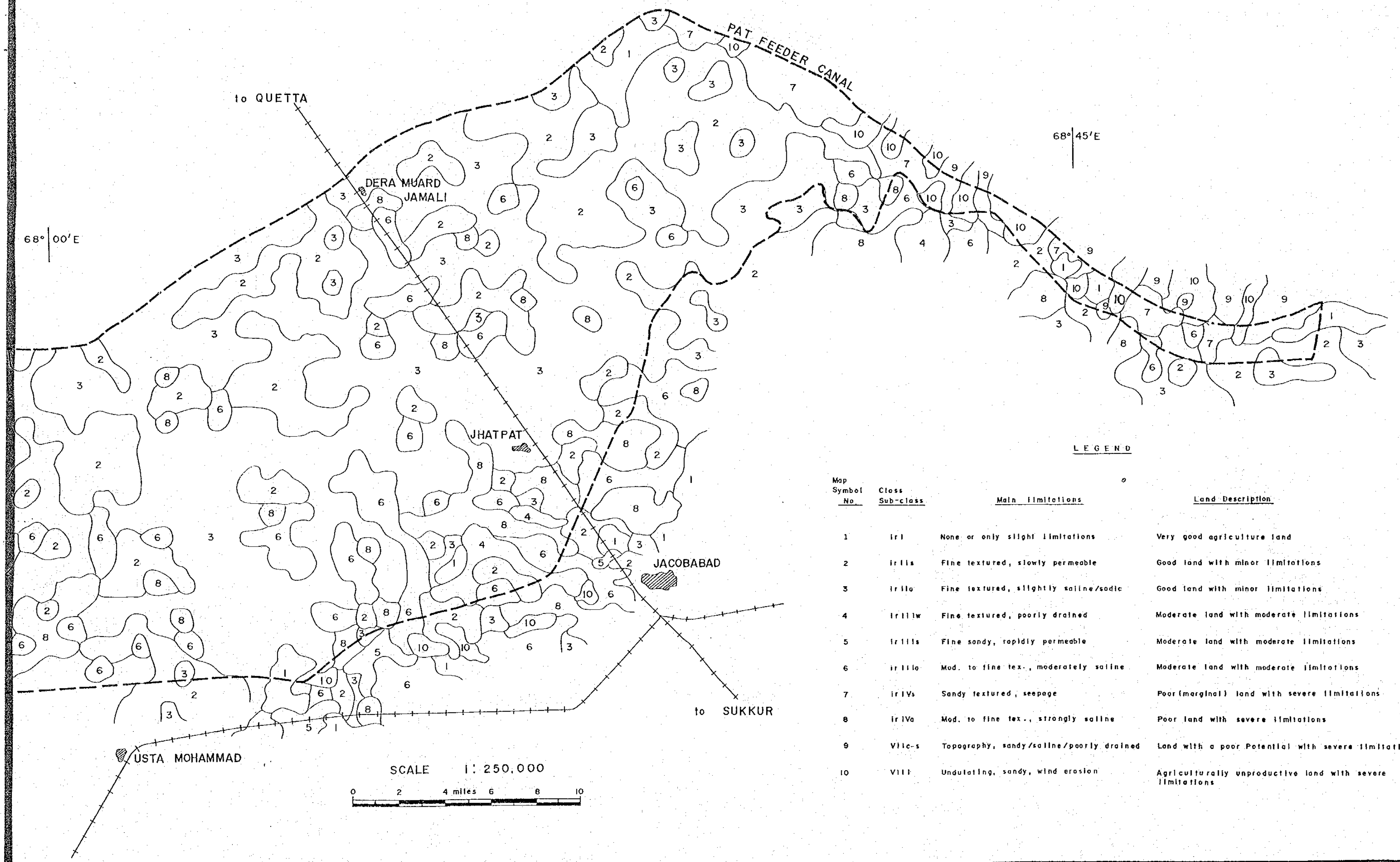


Fig. III. 2- 15



68° 30'E
67° 45'E
68° 00'E
28° 30'N
28°15'N
PAT FEEDER CANAL
to QUETTA
DERA MUARD JAMALI
JHATPAT
JACOBABAD
USTA MOHAMMAD
to SUKKUR
SCALE 1: 250,000
0 2 4 miles 6 8 10
Map Symbol No.
Class Sub-class
1 Ir I
2 Ir IIs
3 Ir IIo
4 Ir IIIw
5 Ir IIIs
6 Ir IIIa
7 Ir IVs
8 Ir IVa
9 VIIc-s
10 VIII

Fig. III. 2- 15 Land Capability Classes in the pat Feeder Canal Project Area, Combined with Soil Profile Salinity



LEGEND

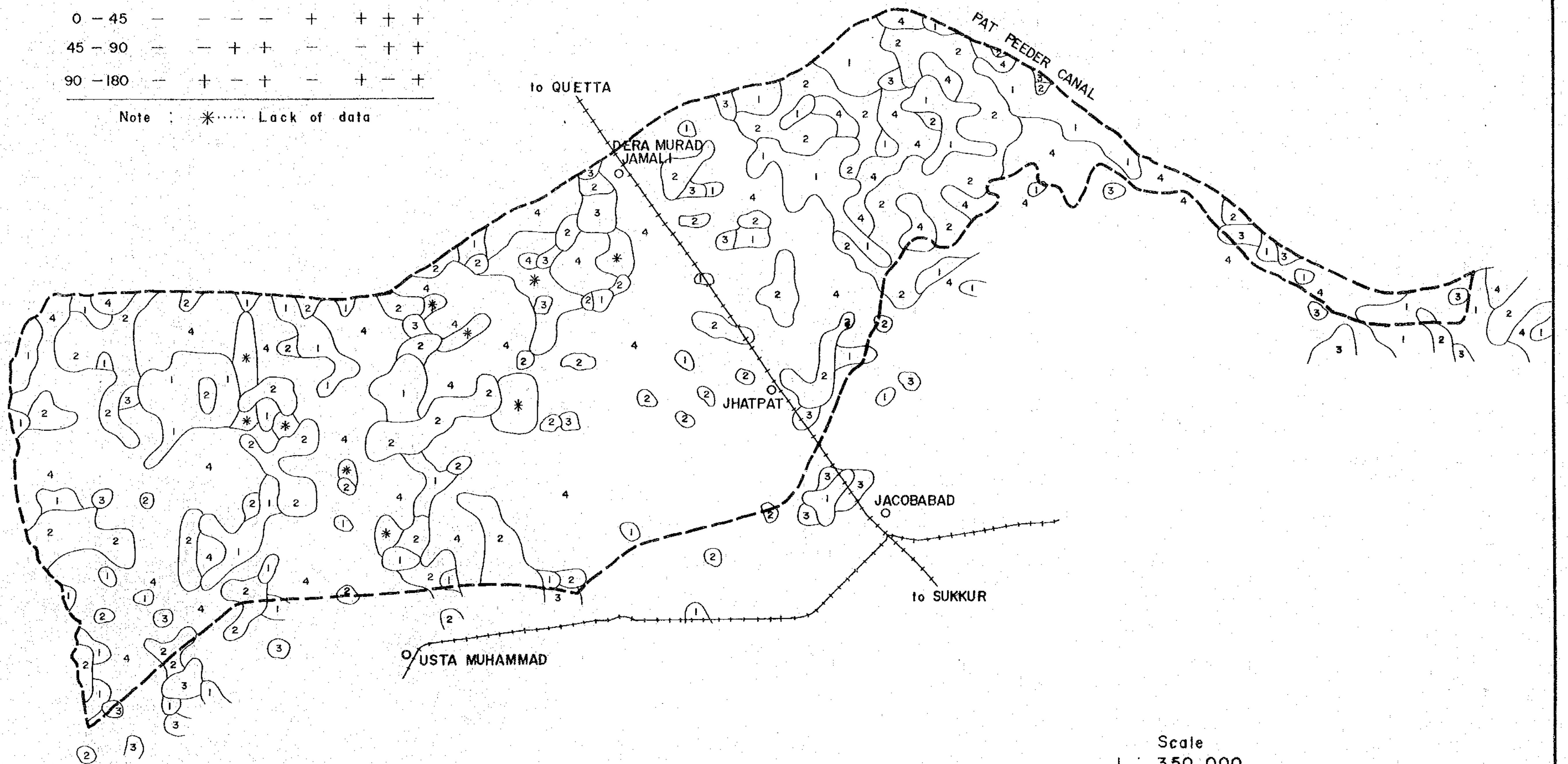
Map Symbol No.	Class Sub-class	Main limitations	Land Description
1	irI	None or only slight limitations	Very good agriculture land
2	irIIs	Fine textured, slowly permeable	Good land with minor limitations
3	irIIa	Fine textured, slightly saline/sodic	Good land with minor limitations
4	irIIIw	Fine textured, poorly drained	Moderate land with moderate limitations
5	irIIIs	Fine sandy, rapidly permeable	Moderate land with moderate limitations
6	irIIIa	Mod. to fine tex., moderately saline	Moderate land with moderate limitations
7	irIVs	Sandy textured, seepage	Poor (marginal) land with severe limitations
8	irIVa	Mod. to fine tex., strongly saline	Poor land with severe limitations
9	VIIc-s	Topography, sandy/saline/poorly drained	Land with a poor Potential with severe limitations
10	VIII	Undulating, sandy, wind erosion	Agriculturally unproductive land with severe limitations

Fig. III.2-16 GYPSEOUS STATUS MAP OF THE PAT FEEDER CANAL COMMAND AREA

LEGEND

Soil Depth (cm)	Presence (+) or absence (–) of gypsum in the profile — Group NO. 1	2	3	4
0 – 45	–	– – –	+	+ + +
45 – 90	–	– + +	–	– + +
90 – 180	–	+ – +	–	+ – +

Note : ✳······ Lack of data



Scale
1 : 350,000

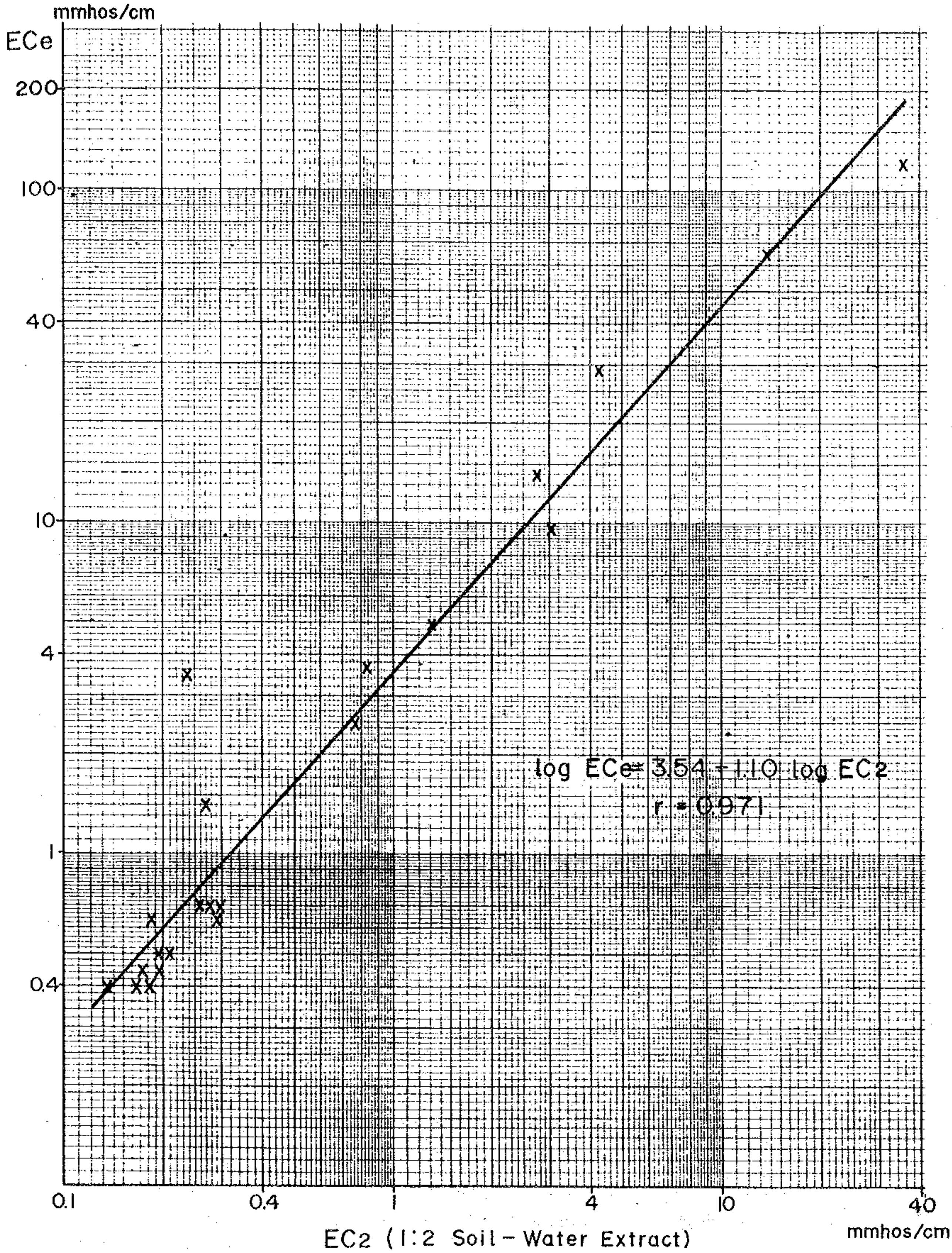


Fig III.2-17 Correlation of 1:2 Soil-Water Extract EC and Saturation Extract EC for Soils of the Project Area.

RICE CULTIVATION IN PAT FEEDER AREA

Dr. M. Bashir Choudhri
Director General, Soil Survey of Pakistan, Lahore

The Pat Feeder command area forms a part of the lower tip of the piedmont plain commonly known as the Kachhi plain. The land surface is almost flat, although traversed at a few places by hill torrents. The land slopes very gently from north to south and gradually merges near Jacobabad with the Indus floodplain which is lower than the Kachhi plain.

Soils

The soils in the entire command are formed in deep deposits of clay. Their clay content ranges from 50 to 60 per cent. The remaining portion is made up of mainly silt particles, whereas sand forms an insignificant part of the soil mass. Being rich in clay, the soils shrink and crack on drying and swell on wetting. Also, they are difficult to till. Soil-plant-air-water relationships are not quite favourable in these soils, rendering them suitable for only a narrow range of agricultural crops like rice and sorghum.

The soils are deep and the understrata are also made up of dense layers of clay with very slow permeability. There is, therefore, a remote possibility of developing true water table in this area. When a dry field is irrigated, the water fills the soil cracks extending to a depth of about four feet. On moistening the soil mass swells and the cracks disappear. There is very little downward movement of water. Under these conditions the aeration of the root zone becomes perfect. Such a root environment suits only a few crops, like rice, sorghum, jantar (Sesbania) etc. In fact these soils are ideally suited to growing rice. The clayey nature of these soils and their occurrence in a dry climate make them in inberently fertils - a condition favourable for rice cultivation.

Salinity

The soils in the Pat Feeder command are generally slightly saline on account of a peculiar made of their deposition and arid climate. The salt content increases with depth. Under seasonal canal irrigation, the salt in the subsoil is likely to come up if a dry crop like cotton is grown. So it would be necessary to grow rice at least for a few years as a reclamation crop. The nature of salts in the soil is, however, favourable and there is no likelihood of sodicity problem.

The salt content of the irrigation water is low and the main component is calcium bicarbonate which on drying precipitates in the soil as insoluble calcium carbonate and no longer remains as effective salt. So there is no danger of salinity by the salt added to the soil through irrigation water even under conditions of slow permeability of the soils if rice is grown with copious irrigation or if periodic leaching is practised by heavy irrigations.

Waterlogging

It has been already mentioned that there is no true watertable in this area,nor is it likely to develop due to very deep clayey strata beneath these soils restricting downward movement of water. However, there is a problem of soil drainage because the soils are such that they get excessively wet after each irrigation, especially in the lower part of the root zone. Because there is very little water penetration beyong the root zone, the evacuation of the these soil water takes place either by direct evaporation from the soil surface, transpiration from crops, or through lateral movement of water from the soil surface and subsoil layers into low laying areas.

The irrigation water in excess of the capacity of root zone finds its way as surface run-off to the low-lying, unused land and borrow pits along rail roads and highways. The presence of such water ponds gives an impression to administrators and the public that the area is waterlogged. The seasonally ponded areas grow marshy vegetation and impart a characteristic look of poor drainage to the landscape. If the irrigation water is properly distributed and managed, the formation of the wet areas could be minimized. But the problem can be controlled by constructing drains according to a proper design, taking into consideration the type of crops, the water input per unit area and the soil conditions.

Soil water can move more freely within the root zone both laterally and vertically than in the substratum due to the presence of drainable pores produced by the decay of plant roots. So the excess soil water moves within the root zone from slightly higher parts of the land to depressional areas, imparting a waterlogged appearance.

Water supply

The water allocation in the Pat Feeder area is 15 cusecs per thousand acres. It is quite sufficient to grow rice but too much if dry crops like cotton or sorghum are grown. So the situation is favourable for rice cultivation.

Conclusion

The soil, draiange and climate conditions in the Pat Feeder command are highly suitable for rice cultivation. Considering the copious water supplies during kharif season, the farmers' demand for rice cultivation seems to be genuine and justified. Rice cultivation would not created salinity problem but would in fact help to remove the salts present in the virgin soil. The drainage problem of low areas there excess irrigation water collects and forms ponds, must be tackled by constructing surface drains according to a suitable design. It may be mentioned that widely spaced drains would be sufficient for rice but if cotton is grown, closely spaced field drains would be a must, besides special soil management.

If rice is established as the main crop in this area, the soil will become completely non-saline after a few years. Then gram can be grown on residual moisture present in the soil after rice harvest.

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