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Saline Characteristics of Waters in old Canal Colonies of West Pakistan

By

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Introduction :

Geologists believe that geotectonic forces involved in the erection of Himalayas produced a concomitant depression in the northern part of the peninsular foreland at the foot of this mountain. This was occupied by a sea which extends to Attock in the West and Nainital in the east. Prior to these changes a river flowed from the head waters of Bharamputra to enter this sea near Attock and was given a hypothetical name of Indo Braham¹. By differential earth movement this river was dismembered and a net work of river formed. These streams transported silt loads for sedimentation, silting up the sea, thereby resulting in the formation of vast plain of alluvial desposits. The receding sea, however, left saline residues and in many places the soil rested on brakish aquifer. With such a geological back-ground it would be easy to trace the saline characteristics of the ground waters of West Pakistan.

The Indus plains receive water either through rains which vary from 30" in North to less than 4" in South-West or through the surface streams forming the river system of this region. Naturally the origin of salts in these vast plains is atributable to the receding sea or that carried in by rivers or rainfall.

The minerals which form the rocky crust of the earth are apparently insoluble but actually they are not so. The felspars yield their lime or alkalis under the action of water, leaving a residue known as clay. The rain water which generally contains carbon dioxide has hydrolyzing effect on rocks manifesting high dissolving power for Lime-stones. The rain waters dissolve gases from the atmosphere and their chemical action on rocky matter really starts after it comes into contacts with the earth crust and it continues its chemical activities even for longer contacts. These waters emerge as springs or percolate to the rivers directly or stay in the earth crust as ground water. The properties of waters in surface streams are modified due to the chemical reaction between moistures and soil or rock materials. Thus the composition of waters also depends upon the environments in which they stay after having reached the earth through rains.

For a country whose 80% of the population depends for livelihood on agriculture, the greatest necessity is the scientific utilization of all such

resources which are responsible for improving yields of crops. One of the factors is the inadequate water supply available from the rivers of West Pakistan particularly for the area of Old Canal Colonies. Although the rivers have plenty of water during monsoon period but unfortunately due to lack of proper surface reservoirs major portion of this water flows to the sea unutilized. Apparently very little can be done under the present circumstances to increase surface storage facilities. The only source of water which can be tapped to augment the existing water supply is from the ground and for which very little information was known some years ago.

Object :—

The groundwater was considered to be a source which could be termed as potential reservoir of storing water in the absence of other facilities of storage. It was, therefore, considered necessary to investigate the ground water resources and Groundwater Development Organization was set up for the purpose. A number of problems have been studied by this Organization and the study of chemical quality of groundwater is one of the objectives of this programme. In the present paper the authors have tried to deal only with the chemical quality of groundwaters as available in Rechna and Chaj Doabs.

Experimental.

The study of quality of groundwater is a very intricate problem because just as soils differ from place to place in the alluvial plains so variation can be expected within a short distance in the chemical qualities of the groundwater. This problem is still more difficult because the groundwaters are housed in different layers and quality of water may also vary with depth from the ground surface. Sometimes different waters are encountered in lenses of variable sizes. Secondly the groundwaters are perpetually under the influence of hydrologic agencies which play their part in changing their chemical properties.

In the groundwater quality survey the work was sub-divided into three categories :—

- (a) Study of the chemical quality of surface streams.
- (b) Study of the chemical quality of shallow aquifer and,
- (c) Study of chemical quality of deeper aquifer.

(a) The periodical sampling was undertaken at various places along the length of surface streams and the sites are marked in figure 1, (b). A large number of shallow water sources existed in the two doabs and an attempt was made to sample as many sources as possible and correlate the results with those from deeper aquifers. In this programme 6,491,106 acres have been covered which is 63% of the total area of the two doabs.

For the survey of deeper aquifer, 272 test holes were drilled ranging in depth from 300 ft. to 600 ft. and all the water bearing formations were sampled for determining the chemical quality of water. The drilling work was performed by straight rotary rigs. Figure 2 shows the sites of the test holes in the three doabs where drilling has been carried out.

The method of sampling from the deeper aquifer is an intricate operation and it is more so when a representative sample is to be collected. With the facilities available the following procedures were adopted. As soon as drilling of test holes was completed, water sampling work was taken in hand at the earliest to avoid the caving in of hole. Figure 3 shows the lay out of the procedure adopted for water sampling which is described below :—

In a test hole "B" perforated pipe "A" is lowered to the deepest water bearing stratum connected with the other pipe "C" which rises above the natural soil surface with an opening for the exit of water. Another set of pipes "D" which are of smaller diameter are lowered in pipe "C" and is connected with the air compressor through a rubber tubing. Compressed air is pumped into the test hole through the pipe "D" which pushes the water entering through pipe "A" from the bore hole and lifts it up to the surface. The passing of the compressed air is continued till it is considered that the water coming out of the opening of the pipe "C" at the surface is free from any contamination which might have been added during the drilling operation through the drilling mud. As soon as a sample is taken the perforated pipe is pulled up and brought to the level of the next water bearing stratum and the sampling procedure repeated for the collection of the water sample for that depth. This procedure is repeated for the collection of water samples from all the water bearing strata in the length of the test holes drilled.

The water samples are brought into the Central Laboratory of the Soil and Water Testing Wing (G. W. D. O.) and tested for all chemical constituents as Sodium, Potassium, Calcium, Carbonate, Bicarbonate, Sulphate, Chloride, Iron, Silica, Boron total dissolved solids and conductivity. Boron, Silica and dissolved solids are determined as parts per million (ppm). Other ions are calculated as milliequivalent per litre, while conductivity expressed as micromhos per centimeter at 25°C. The method used for analysis are given in appendix A. The results of representative samples from shallow and deep sources are given in Tables I.

RESULTS AND DISCUSSION

Rain Water.

Rain water is of considerable significance to agriculture and impurities brought from the atmosphere are very useful. The quantities of these impurities vary considerably with local conditions and the rain water contaminations in West Pakistan are very much different from that of industrially advanced countries. This region is free from fog and smoke and, therefore, the major contaminations are through solution of carbon dioxide, slight quantities of salts present on dust particles flying in air and traces of ammonical nitrogen and nitric acid. The most important constituent is the dissolved carbon dioxide. It has been reported

by Asghar and co-workers (2) that 126 ppm. of calcium carbonate can be dissolved due to the presence of carbon dioxide in the soil air to a depth of 15 cm. The carbon dioxide in air can help in the formation of calcium bicarbonate in calcareous soil. This of course accounts for the presence of relatively large proportions of calcium carbonate in both ground as well as surface waters in West Pakistan. The rainfall run-off which is often the source of river waters brings calcium bicarbonate present in the moist soil or produced by dissolution from calcareous silt in the streams.

Surface waters.

The areas of three doabs Rechna, Chaj and Sind Sagar now known as Thal are enclosed by River Indus and its tributaries, Jhelum, Chenab and Ravi. These rivers manifest a great variation of flow with the maxima in rainy months of summer and a minima in dry winter. It has been reported by Kirmani (3) that mean annual discharge through the whole system of Indus basin is 168 million acre feet.

The main source through which water is received in the Indus basin are rain and rivers. The ground waters in this region are therefore directly influenced by these sources. The flat nature of the land evidently is a favourable condition for absorption from rivers during peak flow periods and regeneration when rivers are in low flow. The extensive canal systems having their origin from these rivers may also contribute to the quality of ground-waters in a manner some what different to the main river streams.

In summer times the contribution to the river waters is from rainfall run-off and melting of the snow as well as from the underground drainage from surrounding areas. Figure 4 shows seasonal changes in dissolved solids in various rivers and it is observed that during the rainy months of summer there is a decrease in the dissolved salt content. In dry month of winter the dissolved salt content in the river waters shows an increase. Analytical results (Table I) of the river water for the dry month of December have shown that all the river waters are of excellent quality presenting low salinity and alkalinity hazard (Figure 5).

It is observed that Indus water at Attock is least mineralized having 164 parts per million of dissolved solids while Kabul River sample taken at distance of ten miles before union with Indus had 272 parts per million of dissolved solids. The rivers Indus and Jhelum are low in sodium with an S. A. R. Value of 0.5 and 0.30 respectively. Chenab, Ravi and Sutlej have comparatively higher values of S. A. R. 0.9, 1.0 and 1.1 respectively. These differences can partly be attributed to the fact that the point of sampling although situated as much upstream in the country as possible, are such where rivers have reached after traversing some 100 miles of sedimentary materials. The contaminations are therefore through regeneration into the rivers.

The sodium content of the river waters is generally low during rainy seasons gradually increasing in the following months. Although calcium

plus magnesium remain nearly the same but the reduction in other radicals is significant. The seasonal changes are through mixing with rain-fall run-off and quality of river water improves with the rain. Sodium in waters of river Jhelum is reduced to low values 0.13 milli-equivalent per litre while it is 0.20 for the Ravi.

The waters of all the rivers have relatively higher bicarbonates than sulphates or chlorides but it is not in excess of calcium plus magnesium to depreciate the chemical quality for irrigational use.

The analytical data for waters of the Indus River at five sites from Ghazi Ghat an up-stream point to Chacharan within a distance of about 500 miles, show that the total dissolved solids increase double-fold whereas chloride and sulphate increase five times. The increase in sodium is also considerable. The Indus River after passing through Kalabagh salt range collects some sodium chloride and sodium-magnesium-sulphate. There is practically little increase in bi-carbonate and calcium plus magnesium can balance the carbonate. The effect of the Indus waters on the chemical quality of ground-waters in the Region down-stream of Chacharan when it is running as a combined river, is bound to be slightly adverse than in other areas covered by other rivers. The water of combined Indus is of low alkalinity hazard but shows a medium salinity hazard.

Water free from any sediment is essentially a solution of mixed salts and gases. It gets concentrated on evaporation under-going chemical changes subject to the solubilities of salts. Calcium and magnesium salts get precipitated first and are followed by sodium chloride and magnesium sulphate. Ground-waters if influenced by surface water can therefore have composition similar to the evaporated surface waters or somewhat modified through base exchange reactions with soil materials.

Waters of the Indus, the Chenab and the Ravi were evaporated to one-tenth of original volume and their analytical data included in Table below :—

Constituents	Indus		Chenab		Ravi	
	Before evaporation	After evaporation	Before evaporation	After evaporation	Before evaporation	After evaporation
Calcium (Ca) ...	1.07	1.12	1.53	1.12	1.52	1.22
Magnesium (Mg) ...	0.97	3.42	.77	1.58	.64	1.07
*Sodium & Potassium (Na).	.48	4.80	.60	6.19	1.24	12.10
Carbonate (Co ₃) ...	0	1.20	0	1.25	0	2.25
Bicarbonate (HCo ₃)	2.45	1.24	2.25	1.19	2.57	3.89
Chloride (Cl) ...	.30	2.95	.30	2.90	.33	3.35
Sulphate (So ₄) ...	.40	3.95	.35	3.55	.50	4.90
Sum (Milliequivalents /Litre $\frac{\text{Cation}}{\text{Anions}}$)	3.15	9.34	2.9	8.89	3.40	14.39

It is observed that a decrease in mineral content results from partial precipitation of calcium and magnesium carbonate. This data may be of interest in correlating the influence of surface waters on the chemical composition of ground waters in the West Pakistan.

Shallow waters.

The areas under survey possess large number of such water sources which draw water from depths less than 50 ft., from land surface. The present programme included sampling of as many sites and sources as possible which are hand-pumps, open-wells and shallow tubewells. In all

*Sodium was determined by difference and all cation and anions expressed as milli-equivalents per litre.

25,353 samples were collected and 64,91,406 acres have been covered upto September 30, 1959.

The analytical data available for waters from shallow sources do not allow to establish a particular pattern to be expressed on some contour lines, but a general areal picture of water quality can be formed (Figure 6). It is common feature that an abnormally saline source would exist amongst good waters or *vice versa*.

In Rechna and Chaj Doab out of 7.68 and 3.20 million acres 5.30 and 1.20 million acres were completely covered.

It has been observed that the ground waters are effected by absorption from rivers to the extent to which the rivers can over-spill during floods. Figure 7 gives a part of Rechna Doab showing water quality of part of test lines RTLH, RTLG and RTLZ alongwith the quality of water of shallow sources on the basis of electrical conductivity. The line A and B show an approximate demarcation where shallow waters are dilute having electrical conductivity less than 2250 micro-mhos/cm. The area extends from 5 to 16 miles from the river Ravi. This holds good for most of area around other rivers and exceptions are only in the hilly areas.

There is a definite demarcating influence of the subteranian ridge which runs from Sangla to Shahkot, although the effect on demarcating the boundaries between different qualities of shallow water is not sharp. The quality of water on the North-East of the ridge is decidedly better than of South-Western side. It has also been observed that the areas where water table is high having reached points near the surface, the chemical quality of water is such that the waters can be made use of for irrigation with or without diluting with canal water. Such an area mostly lies on the North-East of the ridge of Rechna Doab.

The areas between the high water-table zone and the foot-hill, have also been surveyed and it is observed that most of the shallow waters have low electrical conductivity of the order of less than 2250 micro-mhos/cms. at 25°C.

Briefly stated there are four main zones based on water quality.

Figure 8 shows the chemical compositions of a few representative samples in the shallow aquifer. The compositions of samples from the Ravi and the Chenab are shown alongwith those from the typical of four quality zones.

- (a) It is observed that the modification of composition of ground-water through recharge from rivers is evident from composition of samples from areas where river can over-spill. The quality of waters from such shallow sources adjoining the river has favourably been affected by the rivers. Majority of samples have electric conductivity below 750 micro-mhos/cm. The

percentages of various cations and anions are similar to that of river water. These waters have low S. A. R. ranging 0.4 to 2.0 and also are low salinity and alkalinity hazard waters. Waters falling in this category can safely be used for irrigation.

- (b) The chemical quality of waters from aquifers near the foothills is also such that in most cases it can be used for irrigation as such but in certain cases dilution with canal water in the ratio of 1:1 is needed. The electric conductivity range is 400 to 2250 micromhos/cm. S. A. R. is from 1 to 10. The few places where water of higher concentration is available the same is due to the concentration of surface water during irrigated agriculture and is housed in local small pocket.
- (c) The areas where ground water level has risen, the chemical quality has been favourably effected by the change. The electric conductivity is from 800 to 2250. The waters are of sodium bicarbonate type and in most cases require dilution with canal waters in 1:1 ratio for safe use in irrigated agriculture. The S. A. R. is 2 to 10. There are some areas in this region in the vicinity of major canals where percolations to the shallow aquifer are producing diluting effect and better type of waters having low mineral content would be found.
- (d) Waters of first aquifer in relatively deeper water table area South-West of Lyallpur in Rechan Doab and around Sargodha in Chaj Doab have been observed to be of varying chemical quality. Electric conductivity changes from 2250 to 8000 micromhos/cm. These waters are a mixture of concentrated native water housed at greater depth in this region and the rain water, or river waters which may have percolated from the surface.

The analytical results of 112 samples selected as representative of the general pattern in the area are included in Table II.

A frequency distribution curve has been given (Fig 9) in order to show the possible salinity hazard by using waters of shallow sources. Waters have been divided into five classes with respect to conductivity. The four classes are the same as given in U.S. Salinity Laboratory diagram⁴ but a fifth class has been introduced to sub-divide the conductivity group between 750 to 2250. The experience of workers in West Pakistan has shown that 95% or more of waters below 1800 and above 750 electrical conductivity expressed in micromhos/cm, can effectively be employed for irrigation without any sodium hazard in any short interval of time. It would be observed that 9.71% sources of water sample are of excellent quality having electrical conductivity less than 750 micromhos/cm., 6.56% are above the range of 4000 micromhos/cm, and the use of such waters is only an exception without dilution as only a few instance can be quoted where such water have been used perhaps for more salt

resistance crops. 63.85% waters are between the range 750 to 2250 micromhos/cm, and only 26.43% samples are above this range.

Figure 10 shows the relationship between total dissolved solids and electric conductance. The factor works out to be 0.65 which is established factor for most natural waters.

The chemical character of shallow group water is interpreted by the plottings in Figure 11 and it is observed that the majority of samples have full range of soft waters whose dissolved constituents are mainly sodium and carbonate and also with large non-carbonates or permanent hardness.

The waters in high water table areas generally contain sodium bicarbonate as a major constituent although sulphate and chloride are also present but to a lesser degree. In deep water-table areas on the other hand chloride and sulphate predominate.

Test Holes.

The investigation included sampling and analysis of water from deep aquifers upto 600' through test drilling. Test holes were drilled along test lines conveniently laid out for reasons of better approach and hydrologic consideration. Following Table shows the number of test holes in Rechna and Chaj Doabs where water sampling was done and the number of samples taken from each :—

Test Line	No. of test holes water samples were collected	No. of sample collected
Rechna Doab		
(RTL)		
A	17	52
B	21	63
C	17	48
D	12	40
E	10	28
F	14	45
G	17	64
H	14	52
Z	48	158
Chaj Doab		
(CTL)		
A	9	20
B	8	21
C	10	25
D	19	48
D1	8	27
E	14	30
F	11	32
G	10	33
Z	56	148

$\frac{25D-20400}{3D-67}$ and $\frac{23B-21000}{2C-26}$ of RTLZ-48 and RTLH 14 respectively.

The concentrated native water of this region cannot be used for any purpose irrigational or domestic and shall have to be pumped out and drained. The saline waters in the south of Lyallpur contain more of chloride and sulphate but are low in carbonate and bi-carbonate.

In Chaj Doab the ground waters behave differently as revealed from test holes on line D & E. The water quality deteriorates around Bhalwal and Sargodha.

CTLD 13 and CTLD 14 show ground-water of worst chemical characteristics $\frac{22B-7800}{3D-14}$ and $\frac{25C-5500}{4D-25}$ respectively. The chemical quality of ground-waters improves gradually with the distance from these test holes and is better near Jhelum than Chenab where CTLD 1 and CTLE 2 near Chenab show chemical characteristics $\frac{18D-1030}{11B-3.8}$ and $\frac{18A-1180}{19A-3.6}$ respectively, while CTLD 19 and CTLE 20 near Jhelum show $\frac{16C-510}{4D-2.9}$ and $\frac{24B-860}{23B-4.4}$

Near Sargodha the test holes reveal the existence of very highly saline waters having extremely unfavourable chemical characteristics.

Ground-waters from CTLE 9, 10, 11, 12 and 13 show very high electrical conductivities.

The various chemical characteristics are given in the Table below :—

TABLE

Test Hole No.	Fraction Symbol	Mg/Ca	Cl/So ₄
CTLE—9	25D—15000	3.50	5.41
	1A—59		
CTLE—10	25D—20400	2.70	6.31
	1A—59		
CTLE—11	23C—28000	3.44	8.28
	1C—12		
CTLE—12	25A—17600	2.30	8.18
	1D—39		
Sea Water	23C—53049	5.24	9.70
	1D—59		

There is a clear similarity in chemical composition of the ground-water in this area with the sea-water. Both Mg/Ca and Cl/So₄ possess a striking similarity which is usual only for water having direct relationship with each other.

These native ground-waters have originated by simple mixture of sea and surface water and are housed in a 40 miles long area from Bhalwal to Sillanwali and 20 miles wide with Sargodha as the centre. The major factor responsible for confirming this type of concentrated water of marine origin is the underground barrier formed by Kirana Hills. The saline aquifer is supporting a small fresh water layer which can be used for irrigation and human consumption. Generally the depth of fresh water aquifer is from 10' to about 60' depth from the surface. The saline ground-water cannot be drained out even by pumping as the quantities involved are very large and ground-water may have some link with the nearby salt range.

The test-line F in Chaj Doab passes through an area which shows ground-water of good quality having chemical characteristics

$$\frac{19C-360}{13B-1.8} \text{ and } \frac{25D-6350}{4D-55}$$

The geology of the region shows the existence of a sea which has been filled up through deltaic process. Sea water possess characteristic properties quite different from other natural surface waters having $\frac{\text{Magnesium}}{\text{Calcium}}$ higher than 3 and $\frac{\text{Chloride}}{\text{Sulphate}}$ is also high showing large preponderance of Chloride ion. The following table includes chemical characteristics as well as $\frac{\text{Magnesium}}{\text{Calcium}}$ and $\frac{\text{Chloride}}{\text{Sulphate}}$ ratios for the concentrated native water of this region.

TABLE

Test Hole No.	Fraction Symbol	Mg/Ca	Cl/So ₄
RTLH-10	25D-10600	2.18	.92
	5A-52		
RTLH-12	24C-21100	4.15	2.14
	30-69		
RTLH-13	25D-18500	2.74	2.39
	3D-51		
RTLZ-42	23C-12950	1.52	2.12
	3A-16		
RTLZ-44	24A-16300	0.87	2.10
	3A-19		
RTLZ-45	22B-16600	1.12	1.15
	5B-18		
RTLZ-46	24B-12900	1.35	2.26
	3D-17		
RTLZ-47	19A-12780	1.50	5.44
	1A-7.5		
RTLZ-48	25D-20400	1.42	3.45
	3D-67		
RTLZ-49	23B-12500	1.85	2.25
	3C-22		

It is observed that the Mg/Ca is not exactly similar to the sea-water except for RTLH-10, 12 and 13 which is high enough to suggest dissimilarity with other natural surface waters. The Cl/So₄ is also low showing excess of sulphate than is usually present in sea-waters.

Native saline water from test hole RTLZ-46 shows possessing nearly an average of Mg/Ca and Cl/So₄ of the concentrated native water of test holes along Z line. Table below shows the chemical composition of the hypothetical mixtures of river and sea-waters alongwith that of water from RTLZ-46.

TABLE

Milli-equivalents per litre.

Description of Water	Milli-equivalents per litre.						
	Ca	Mg	Na	HCo ₃	Cl	So ₄	D. S.
Sea Water	19.96	104.6	468.7	2.29	535.25	55.20	34482
River Water	1.68	0.49	0.77	2.28	0.37	0.29	168
RTLZ-46	38.22	51.78	121.03	2.54	145.2	64.21	13325
Hypothetical mixture of Sea-water with River water to get same chloride as RTLZ-46.	6.66	28.70	127.58	2.28	145.32	15.17	
Hypothetical mixture of Sea water with River Water to get same dissolved solids as RTLZ-46.	8.68	40.36	180.00	2.28	205.20	21.30	13325
Gain (+) or Loss (-) with respect to when chloride is kept constant.	+31.56	+23.08	-6.55	+0.26	+0	+49.04	
When Dissolved Solids are kept constant.	+29.54	+11.42	-58.97	-0.26		+60.0	+42.91

It is observed that keeping chloride as same as of water from RTLZ-46 there is a gain of 49.04 in sulphate, 31.5 in calcium, 23.08 in Magnesium while sodium shows a loss of 6.55 expressed in milli-equivalents per litre. In the other case when dissolved solids are kept the same as that of RTLZ-46 the hypothetical mixture shows a gain of 29.54, 11.42, 42.91 and 0.26 milli-equivalents per litre while a loss in sodium and chloride of 58.97 and 60.00 respectively. Both these method of calculating a hypothetical mixture show a gain in calcium, magnesium and sulphate while total dissolved solids are kept constant, loss in sodium chloride is observed.

If the native water of this region had been a simple mixture of sea and river waters, no loss in sodium chloride would have taken place or the gain in calcium and magnesium would have been in proportion to the loss in sodium which could be accounted for on account of a local base exchange. Since there is a loss of sodium chloride so the possibility of the native water being a simple mixture of sea and river waters shall have to be ruled out.

The next possibility which may be examined to trace the origin of such a highly concentrated native water is the evaporation of surface water in a confined basin.

It is observed that in order to get a hypothetical native water resulting from the surface source, the surface water shall have to concentrate many times say 100 to 150 times considering the ranges in concentration of water of the Ravi and the native waters. Composition of surface waters concentrated to a volume of one-tenth of the original are reported in table below. If these waters are further concentrated 10 to 15 times, assuming that Sodium, Sulphate and Chloride would change proportionately we get :—

	Ravi	Chenab
	Conc : 100 times	
Sodium	121	61.9
Chloride	33.5	29.0
Sulphate	49.0	35.5

The chloride sulphate ratio of hypothetically concentrated surface water has no similarity with that of actual native water where Cl/So₄ is higher.

Thus the native water is neither a simple mixture resulting from sea and river water nor evaporated fresh surface water in a closed basin. Since there is no other source of contamination it is highly probable that the native water is a mixture of a residue left behind through the recession of sea and fresh water from rain or surface streams. The gain in calcium, magnesium and sulphate can be explained, that the sea water while receding deposited calcium, magnesium as sulphates which redissolved in native water of the region.

If the sample of RTLZ—46 is taken as average the calculated composition of the residue would be as follows :—

Calcium sulphate	17.36
Magnesium sulphate	13.22
Magnesium chloride	11.32
Sodium chloride	57.98
Calcium carbonate	0.12
	100.00

Presence of sodium sulphate is not established therefore the formation of the native water did not occur during the glacial period but would have been in recent warmer times.

SUMMARY

In the paper chemical quality of waters from surface sources, shallow and deeper aquifers in old canal colonies of West Pakistan has been described. The saline characteristics of waters in different areas manifesting distinct properties have also been traced and their geochemical origin given. The rivers waters are of very good quality and the waters available in high watertable areas are such which can either be used for irrigation directly or by mixing with canal water in ratio of 1:1. The areas near the rivers where over spills often takes place, house good quality water. Seepage from canal also effects the water quality favourably. The saline characteristics of concentrated waters in Rechna Doab are different than those of Chaj Doab. In Chaj Doab the highly mineralised waters bears direct relation with sea waters while those in Rechna Doabs reveal that those are the result of solution of a saline residue and waters from surface sources.

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APPENDIX

Calcium.

Calcium is determined using versenate titration method, ammonium purpurate is used as indicator, usually the strength of versenate solution is .01 N.

Magnesium.

Magnesium is also determined by versenate titration method. In this case Eriochrome Black T is used as indicator.

Sodium & Potassium.

By flame photometry using internal standard method. The instrument is standardized using different standard solutions varying from 0—16 me/l of Na and 0—4 me/l of K and lithium chloride.

Carbonate & Bicarbonate.

By standard sulphuric acid titration method. The strength of sulphuric acid is .02 N. Phenolphthalein and methyl orange are used as indicators for carbonate and bicarbonate respectively.

The strength of the indicators is .5% phenolphthalein in 50% alcohol and .05% methyl orange in distilled water.

Chloride.

The estimation of chloride is carried out by titrating against standard silver nitrate using 5% potassium chromate solution as indicator.

Sulphate.

Sulphate is determined by Gravimetric Method using 10% Barium Chloride solution as precipitating reagent.

Nitrate.

Nitrate is found out by evaporating a specific volume of water sample and treating the residue with phenoldisulphonic acid. The transmittance of the yellow colour developed with the addition of Ammonium Hydroxide, is read by spectrophotometer.

Flouride.

Flouride is estimated by zirconium alizrin colorimetric method. The colour developed is compared visually with the standard flouride solutions.

Silica.

Silica is determined by adding to the acidified sample, Ammonium Molybdate solution and then sodium sulphite solution forming molybdate blue. The intensity of colour is measured by spectrophotometer. The strength of the solutions used is as follows :—

Hydrochloric acid	...	0.248 N
Ammonium Molybdate solution.	...	5%
Sodium sulphite solution	...	17%

Iron.

Iron is estimated colorimetrically by measuring the intensity of the colour developed with the addition of Ammonium thiocyanate solution to the acidified sample. The crystals of Ammonium persulphate crystals are added. The intensity of red brown colour of iron is measured using spectrophoto-meter.

Strength of Ammonium Thiocyanate solution is 2.4% Hydrochloric acid solution is prepared by 1:1 dilution with distilled water.

Boron.

Boron is found out by Carmine red Indicator method. Concentrated sulphuric acid and Carmine red indicator in concentrated sulphuric acid are added to the acid solution prepared by dissolving the residue of sample in 5% Hydrochloric acid. The dark red colour is developed depending upon the concentration of Boron. The optical density of solution is measured by spectrophoto-meter.

TABLE I
CHEMICAL QUALITY OF WATERS FROM 2 RIVERS AT 11 LOCATIONS
DURING DECEMBER, 1957.

Serial No.	Source at Location	Milli-equivalents per Litre						D. S. ppm	EC ₅ × 10 at 25°C	pH	SAR
		Ca	Mg	Na + K	HCO ₃	Cl	SO ₄				
I-1	Indus at Gaziboat Bridge	1.68	0.51	0.06	1.80	0.15	0.30	138	205	7.8	0.16
I-2	Indus at Attock	1.78	.74	.55	2.33	.37	0.37	164	250	7.7	.5
I-3	Indus at Kalabagh	1.88	.69	1.22	3.23	.26	0.30	216	324	7.5	1.1
I-4	Indus at D. I. Khan	1.88	.89	.77	2.43	.53	0.58	226	353	7.5	.6
I-5	Indus at D. G. Khan	1.68	.79	1.58	2.18	.75	1.12	242	364	7.7	1.4
I-6	Indus at Chacharan	1.98	.79	2.00	2.12	.75	1.90	260	389	7.8	1.7
R-5	Ravi at Jassar	2.04	.72	1.04	3.18	.15	0.47	236	360	7.3	1.0
R-6	Ravi at Lahore	1.88	.74	.99	3.00	.15	0.46	228	347	7.9	.9
R-7	Ravi at Balloki	1.68	.49	.77	2.28	.37	0.29	186	247	7.8	.7
R-8	Ravi at Chichawatni	1.73	.44	2.87	2.54	1.00	1.50	300	482	7.6	2.7
R-9	Ravi at Sidnai	1.78	.52	2.06	2.43	.6	1.31	264	395	7.9	1.9

TABLE I—contd.

CHEMICAL ANALYSIS OF 8 RIVERS WATERS AT 2 LOCATION

Serial No.	Sample in 1957	River source and location	Multi-equivalents per Litre						Dissolved solids: ppm.	EC $\times 10^6$ at 25°C	pH	SAR
			Ca	Mg	Na + K	HCO ₃	Cl	So ₄				
J—1	September	Jhelum at Mangla	1.31	0.50	0.13	1.55	0.19	0.20	123	189	7.5	0.13
J—2	October	Jhelum at Mangla	1.78	0.55	0.20	1.78	0.15	0.20	138	205	7.7	0.20
J—3	November	Jhelum at Mangla	1.74	0.46	0.21	1.82	0.15	0.44	140	230	7.6	0.20
J—4	December	Jhelum at Mangla	1.88	0.54	0.38	2.33	0.15	0.32	170	269	7.9	0.3
J—5	January	Jhelum at Mangla	2.04	0.53	0.77	2.49	0.19	0.66	186	270	8.0	0.78
R—1	June	Ravi at Lahore	1.61	0.74	0.20	2.00	0.30	0.25	166	250	8.0	0.2
R—2	August	Ravi at Lahore	1.70	0.31	0.47	2.00	0.30	0.18	166	280	7.5	0.5
R—3	November	Ravi at Lahore	2.20	0.63	0.95	3.20	0.30	0.28	240	352	7.8	0.8
R—4	December	Ravi at Lahore	1.88	0.74	0.99	3.00	0.15	0.46	228	347	7.9	0.9

TABLE I—contd.

CHEMICAL ANALYSIS OF WATERS FROM 6 RIVERS

Serial No.	Sampled in 1957	River source & location	Milli-equivalents per Litre						Dissolved solids ppm	EC × 10 ⁶ at 25°C	pH	SAR
			Ca	Mg	Na + K	HCO ₃	Cl	SO ₄				
1	December	Kabul at Jahangir	1.93	1.33	1.52	3.02	0.84	0.92	272	432	7.6	1.2
2	December	Indus at Attock	1.78	.74	.55	2.33	.37	.37	164	250	7.7	.5
3	December	Jhelum at Mangla	1.88	.54	.38	2.33	.15	.32	170	269	7.4	.3
4	December	Chenab at Marala	1.73	.74	1.05	2.43	.10	.99	224	333	7.6	.9
5	December	Ravi at Jassar	2.04	.72	1.04	3.18	.15	.47	236	360	7.3	1.0
6	November	Sutlej at Ganda Singh-wala.	1.84	.41	1.15	2.18	.40	.82	228	340	7.6	1.1

TABLE II
 Summary of Water Analysis of Shallow and Deep Aquifers

Serial No.	Date sampled	Source and location	Milli-Equivalents per litre						Total cations ----- Anions	D. S. ppm	EC × 10 ⁴ at 25°C	pH	Res. CO ₂	SAR
			Ca	Mg.	Na + K	CO ₃ + HCO ₃	Cl	SO ₄						
1	1-4-58	Pallu H. P.	2.30	1.30	0.66	3.02	.35	.89	4.26	236	375	7.90	.5	
2	15-4-57	698 GB. P.W.W.	.70	1.22	9.34	9.34	.40	1.02	11.26	712	1080	7.8	9.5	
3	17-5-57	695 GB H. P.	3.35	5.20	1.46	7.20	1.40	1.41	10.01	560	850	...	1.0	
4	20-5-57	764 GB H. P.	1.90	1.60	5.83	4.16	1.30	3.87	9.33	560	844	...	5.4	
5	17-6-57	323 GB P. W.	...	...	...	...	...	...	...	...	10500	...	...
6	24-6-57	680 GB Well	3.50	2.85	6.48	6.78	3.66	2.39	12.83	756	1160	7.8	3.6	
7	2-4-57	731 GB T/W.	1.85	.35	.76	1.79	.37	.80	2.96	192	260	...	1.0	
8	25-4-57	314 GB H.P.	2.51	6.29	71.33	20.19	28.47	31.47	80.13	4960	7500	8.00	34	
9	25-4-57	346 GB H.P.	2.13	5.48	52.51	17.61	19.32	23.17	60.13	3540	5400	8.10	27	

10	5-11-57	258 GB H.P.	1.20	1.68	18.61	12.75	2.54	6.20	21.49	1230	1900	...	16
11	9-9-57	556 GB P.W.W.	1.45	3.10	6.64	3.50	2.70	4.99	11.19	744	1100	...	4.4
12	5-11-57	518 GB H.P.	1.32	.85	12.45	9.35	1.27	4.10	14.62	840	1400	...	12
13	8-11-57	164 GB H. P.	...	...	...	...	...	...	...	12000	...	...	...
14	18-10-56	178 GB Well	...	...	...	...	...	...	...	9000	...	...	...
15	19-9-56	221 GB Well	1.17	2.37	39.47	17.93	11.06	14.02	43.01	2800	4100	8.9	30
16	27-7-56	Kalliar Canal	...	...	...	...	...	...	...	200	...	...	...
17	12-7-56	621 GB P. W.	3.99	3.11	.75	5.52	.48	1.85	7.85	478	700	...	.4
18	12-7-56	399 GB H. P	3.20	2.56	13.71	5.15	3.82	19.50	19.47	1130	1700	7.9	8.1
19	6-12-56	Pindi Sheikh Musa T. W.	1.64	1.10	3.15	3.25	.50	2.14	5.89	340	550	7.8	2.7
20	6-9-56	444 GB H. P.	1.00	1.31	15.47	10.07	2.06	5.65	17.78	1120	1740	...	14
21	26-2-57	138 GB O. W.	8.44	6.46	2.46	8.95	6.58	1.53	17.36	1020	1590	...	.9
22	29-10-56	47 GB Well	11.20	10.06	15.99	18.48	17.90	10.89	37.27	2260	3600	...	4.9
23	14-2-57	500 GB H. P.	7.61	9.39	7.95	5.57	3.58	16.00	24.95	1430	2320	...	2.7
24	11-4-57	167 GB Water logged pool	4.82	5.40	35.76	16.80	18.65	10.53	45.98	3020	4400	...	16

TABLE II—contd.

Summary of Water Analysis

Serial No.	Date sampled	Source and location	Milliequivalents per litre							D S. ppm	EC × 10 ⁶ at 25°C.	pH	Res. CO ₃	SAR
			Ca	Mg	Na +K	CO ₃ + HCO ₃	Cl	SO ₄	Total cations ----- Anion					
25	8-1-57	597 GB Well	3.06	3.42	9.29	6.26	2.63	6.84	15.73	848	1350		5.1	
26	4-6-56	63 GB O. W.	2.39	3.56	21.48	8.08	8.33	11.02	27.43	1700	2660		13	
27	2-6-56	113 GB O. W.	.94	.16	40.28	16.83	13.34	11.21	41.38	2300	3750		54	
28	25-1-56	276 GB	1.56	1.54	15.65	8.50	4.67	5.58	18.75	1240	1800		12	
29	19-4-56	377 GB O. W.	2.80	5.48	5.95	7.84	2.69	3.72	14.23	856	1370		3	
30	13-2-56	380 GB H. P.	1.76	5.91	11.48	8.42	4.46	6.27	19.15	1080	1710		6	
31	20-8-55	629 GB H. P.	2.79	.37	8.89	6.79	1.06	4.20	12.05	576	1038		7.0	
32	4-10-55	625 GB H. P.	3.46	6.05	.55	6.21	.89	2.95	10.05	528	928		0.3	
33	25-7-55	370 GB H. P.	0.79	1.18	13.56	8.29	1.71	6.53	15.53	920	1320	8.5	1.4	
34	18-11-55	Nankana Sahib H. P.	2.94	4.45	14.19	3.20	10.13	7.95	21.58	1320	2240	8.4	7.4	

35	28-11-55	Fatta Jhatta H. P.	3.97	7.10	30.56	10.80	20.14	10.69	41.63	2240	3240		13
36	23-8-55	525/11-B	1.90	4.17	8.24	6.50	3.39	4.42	14.31	808	1230		4.3
37	23-9-55	235 GB H.P.	6.03	10.33	16.02	19.36	7.55	5.47	32.38	1640	2800	8.0	6
38	1-3-56	M. No. 124 O.W. Ganjiwal	1.56	4.08	27.88	14.49	9.25	9.78	33.52	2050	3070		17
39	28-12-56	Manawala H. P.	2.49	5.11	25.74	10.53	14.32	8.49	33.54	1810	2890		13
40	2-3-56	Mohd. Shawal- pura (27 No.)	3.70	7.17	8.15	7.80	4.29	6.93	19.02	1140	1820	8.5	3.5
41	5-5-56	Dhilwan Well	1.88	.77	8.74	5.43	2.81	3.15	11.39	720	1070		8
42	31-1-58	Padianwala O.W.	3.70	4.18	7.90	8.36	3.00	4.42	15.78	968	1500	7.5	4
43	31-1-58	Thatta Qadir Shah O.W.	2.92	4.91	31.07	16.34	7.80	17.76	41.90	2580	4000	7.8	17
44	30-1-58	Virka Dath H.P.	2.97	2.68	7.25	8.36	2.30	2.24	12.90	780	1200	7.7	4.3
45	29-1-58	Bhakka H.P.	1.28	2.52	17.00	2.18	3.50	5.12	20.80	1260	1950	7.7	12
46	31-1-58	Kassoke O.W.	2.30	3.26	4.17	7.84	.47	1.42	9.73	624	924	7.6	2.5
47	31-1-58	Hardo Bhun O.W.	2.10	3.75	5.55	7.63	.60	3.17	11.40	700	1070	8.0	3.3
48	11-10-57	Kang Shahali P.W.W.	3.48	2.48	7.99	5.25	3.82	4.88	13.95	1250	1280		5

TABLE II—contd.
FORM C
Summary of Water Analysis

Serial No.	Date sampled	Source and location	Milli-equivalents per litre						Total cations Anions	D. S. ppm.	EC × 10 ₆ at 25°C	pH	Res. CO ₃	SAR
			Ca	Mg	Na + K	CO ₃ + HCO ₃	Cl	SO ₄						
49	1-10-57	Magowal P.W.W.	2.63	1.98	13.62	8.44	2.42	7.37	18.23	960	1500			10
50	11-11-57	Kunjah	3.06	2.62	9.40	9.55	1.10	4.43	15.08	840	1300			5.6
51	,,	Machiana	2.65	1.76	2.14	4.42	.70	1.43	6.55	412	660	8.0		1.4
52	11-10-57	Chakaran Kalan	2.38	3.71	17.54	9.68	5.70	8.25	23.63	1420	2200	2.5		9.5
53	27-1-53	122 NB H.P.	1.97	2.03	6.94	5.30	4.45	1.19	10.94	680	1080	7.5		4.9
54	,,	95 NB H.B.	1.95	2.46	13.43	12.54	1.60	3.70	17.84	1090	1690	7.4		9.0
55	,,	105 NB H.P.	4.47	1.73	3.30	6.30	1.40	1.80	9.50	600	930	7.6		1.8
56	4-3-58	100 NB	1.09	5.56	2.95	4.80	1.70	3.10	9.60	652	950	7.7		1.6
57	1-1-58	50 JB O.W.	2.91	3.10	8.64	7.80	1.60	5.25	14.65	960	1400			4.9
58	,,	54 JB O.W.	2.70	3.83	10.65	7.26	3.30	6.62	17.18	1060	1630			5.9

59	,,	74 JB O.W.									4500		
60	20-10-56	RTLA 2 136'	2.85	1.17	2.79	4.61	.50	1.70	6.81	440	680	8.1	1.
61	18-10-56	RTLA 4 164'	1.65	4.26	14.13	8.21	3.65	8.18	20.04	1140	1780	7.9	9.6
62	23-10-56	RTLT 7 186'	1.25	2.23	8.69	9.72	.85	1.60	12.17	670	1050	8.4	6.6
63	25-10-56	RTLA 8 178'	1.10	.98	4.83	5.31	.40	1.20	6.91	460	700	8.0	4.8
64	27-10-56	RTLA 19 199'	2.75	1.27	2.07	4.93	.37	.79	6.09	316	500	8.0	1.5
65	24-7-57	RTL B 19 100'	1.30	1.67	2.78	4.80	0.40	0.55	5.75	330	500	8.1	1.7
66	30-7-57	RTL C 7 80'	1.50	.74	1.26	2.00	1.00	.50	3.50	231	350	8.0	1.2
67	1-8-57	RTL C 12 100'	1.30	1.81	8.60	8.40	2.22	1.09	11.71	736	1110	7.9	6.9
68	8-1-57	RTL D 3 575'	1.59	.71	6.33	4.47	.88	3.28	8.63	520	810	...	5.9
69	10-1-57	RTL D 4 132'	1.12	1.33	17.40	8.94	4.97	5.94	19.85	1160	1800	...	19
70	,,	RTL D 5 235'	2.04	2.18	3.93	6.08	.83	1.24	8.15	484	700	...	2.7
71	17-1-57	RTL D 16 270'	1.44	2.45	6.94	6.17	1.09	3.57	10.83	636	950	...	4.8
72	5-8-57	RTL D 16 140'	.60	1.34	22.01	13.00	3.23	7.72	23.95	1380	2250	8.1	17

TABLE II—*contd.*
FORM C
Summary of Water Analysis

Serial No.	Date sampled	Source and location	Mill-equivalents per litre							D. S. ppm.	EC X 10 ⁶ at 25°C	pH	Res. CO ₃	SAR
			Ca	Mg	Na + K	CO ₃ + HCO ₃	Cl	SO ₄	Total cations / Anions					
73	24-7-57	RTLD 20 140'	1.60	8.19	25.24	5.4	18.63	11.0	35.03	2210	3400	7.7	11	
74	29-7-57	RTLE 23 140'	1.20	2.07	19.59	11.0	5.7	6.26	22.86	1320	2110	7.9	14	
75	2-8-57	RTLE 27 160'	1.00	2.98	6.15	4.20	1.32	4.61	10.13	596	950	7.8	4.3	
76	24-10-57	RTLF 17 140'	2.65	10.55	50.10	9.00	45.6	8.70	63.30	3700	6200	8.0	19.4	
77	20-11-57	RTLF 26 150'	1.66	2.93	.21	3.0	.6	1.2	4.8	302	450	...	0.1	
78	14-6-56	RTLE 6 350'	.50	1.33	15.79	9.94	1.94	5.66	17.54	1020	1650	7.7	15	
79	8-6-56	RTLK 12 280'	28.5	5.58	89.13	4.66	22.78	2.77	170.21	10000	15000	...	40	
80	26-10-57	RTLK 16 200'	1.45	6.18	30.48	6.04	23.0	9.07	38.11	2280	3400	...	29	
81	20-3-56	RTLH 2 199'	1.26	2.04	1.71	3.55	.6	.87	5.01	328	500	7.8	1.5	

82	20-2-57	RTLH 12 120'	33.50	5.0	15.51	3.0	160.6	40.41	20401	13500	19600	7.6	69
83	20-4-57	RTLZ 27 192'	1.23	3.27	32.32	16.19	2.49	18.14	36.82	2000	3200	8.3	22
84	22-4-57	RTLZ 42 125'	16.64	25.36	100.85	3.72	94.60	44.53	142.85	8200	13300	7.8	45
85	26-4-57	RTLZ 53 200'	13.75	49.0	55.93	4.70	88.0	125.97	118.68	7400	11000	7.8	50
86	20-9-57	CTLA 3 178'	1.77	1.30	3.59	5.25	.38	1.03	6.66	392	600	...	4.1
87	11-11-57	CTLA 15 380	.62	4.84	4.01	5.62	2.87	.98	9.47	592	880	...	2.4
88	9-1-58	CTLD 1 160'	3.67	.93	5.80	3.39	1.37	5.64	10.40	620	1030	7.3	3.8
89	10-1-58	CTLD 4 120'	0.98	1.49	3.43	3.81	.75	2.36	6.90	388	590	7.9	2.7
90	12-12-58	CTLD 14 160'	2.29	5.77	50.28	11.28	31.95	15.16	58.34	3690	5500	...	25.1
91	19-1-58	CTLE 6 180'	.71	2.95	74.33	11.18	53.36	13.45	77.99	4630	7250	8.6	55
92	2-1-57	CTLE 13 176'	11.89	7.11	232.74	5.91	237.51	8.32	251.74	15500	24000	...	75
93	31-3-58	CTLF 1 140'	2.14	2.60	9.36	6.02	2.77	5.31	14.10	1100	1730	...	6.4
94	„	CTLF 7 100'	.63	1.19	7.84	4.5	2.98	2.18	9.66	560	851	...	8.3
95	23-12-57	CTLZ 1 142'	1.17	1.98	13.95	10.45	3.45	3.20	17.10	1330	1680	...	11
96	10-4-57	CTLZ 40 144'	1.95	5.75	259.14	3.58	235.9	27.36	266.84	15100	24600	...	132

TABLE II

Summary

Lab. No.	Date sampled	Source	Milliequivalents per litre								
			Ca	Mg	Na	K	CO ₃	HCO ₃	Cl	SO ₄	NO ₃	F
RTLE 20	140'		1.60	8.19	25.24		0	5.40	18.60	11.0	.03
RTLE 25	200'		2.20	5.66	9.17		0	6.207	3.60	7.14	.09
RTLF 20	100'		.88	3.83	3.40		0	5.00	1.60	1.00	.01
RTLF 21	180'		.98	1.80	2.95		0	2.60	.40	2.72	.01
RTLF 23	160'		1.71	4.63	4.80		0	3.80	.40	6.80	.14
RTLG 13	300'		10.66	28.48	144.36		0	3.60	149.60	30.30	T
RTLG 15	300'		1.50	6.90	42.40		0	6.40	32.00	10.40	0
RTLG 16	200'		1.45	6.18	30.48		0	6.0	23.0	9.07	.04
RTLG 17	220'		1.04	2.57	16.75		0	6.80	5.60	7.96	T
RTLG	2080'		2.65	3.70	4.86		0	3.00	2.80	4.80	.01
RTLH 15	190'		28.60	27.70	105.51		0	2.80	132.0	27.0	.01
RTLZ 38	110'		1.35	2.45	1.55		0	2.98	.30	2.03	.04
RTLZ 42	125'		16.64	25.36	100.85		0	3.72	94.60	44.53	
RTLZ 44	145'		29.12	47.88	102.44		0	1.56	118.80	59.04	
RTLZ 46	270'		38.22	51.78	121.95		0	2.54	145.20	64.21	
RTLZ 53	200'		13.75	49.00	55.93		0	4.70	88.01	25.97	

of water analysis

Parts per Million

Total Cations	Parts per Million				EC × 10 ⁶ at 25°C	pH	%Na found	Res CO ₃ me/l	S.A. R.	Salt Index.
----- Anions	SiO ₂	Fe	B	D.S. (by Evap.)						
35·03	8	0	·36	2210	3400	7·7			11	
17·03	24	·05	·16	1130	1580	7·8				
8·11	26	0	·06	544	800	7·8				
5·73	11	·10	·09	296	550	7·7				
11·14	19	0	·07	655	1050	7·8				
183·50	11	·00	·62	11000	18000	7·8				
50·80	13	·05	·30	3400	5000	7·9				
38·11	12	0	·07	2280	3400	8·1			29	
20·36	13	0	·09	1215	1800	7·9				
11·21	20	·10	·14	665	1010					
161·81	6	0	·26	10000	16000					
5·35	15	0	·04	290	440	7·8				
142·85	20	·10	·95	8200	13300	7·8				
179·40			·55	10600	16900	7·8				
211·95			·39	12500	20500	7·6				
118·68			·13	7400	11000	7·8				

TABLE III

Serial No.	Test Hole No.	Fraction Symbol	Serial No.	Test Hole No.	Fraction Symbol
	RTL			RTL	
1	A-1	20D-675	14	A-18	13D-450
		25C-3·8			23A-1·6
2	A-2	23A-650	15	A-19	13D-500
		23A-4·4			25A-1·5
3	A-3	22B-600	16	A-21	14C-500
		23A-0·9			25A-1·4
4	A-4	23C-2100	17	A-22	14C-530
		12B-9·6			22B-1·4
5	A-5	20D-550	18	B-1	18B-470
		25A-3·2			22D-2·6
6	A-6	23B-2300	19	B-2	17A-770
		25A-11			20D-7·8
7	A-7	23B-1050	20	B-3	23D-550
		23A-6·6			23B-5·3
8	A-8	23A-700	21	B-4	25C-2490
		23A-4·8			20D-12
9	A-9	19B-1510	22	B-5	18C-1520
		18C-2·9			19C-5·7
10	A-10	22B-700	23	B-6	23D-780
		23A-2·5			22B-0·6
11	A-11	6D-640	24	B-7	13B-340
		23A-0·7			22B-1·0
12	A-12	11B-700	25	B-8	20D-910
		22C-1·6			23C-3·3
13	A-14	23D-535	26	B-9	13D-630
		21C-0·2			23A-1·8

Table III—contd.

Serial No.	Test Hole No.	Fraction Symbol	Serial No.	Test Hole No.	Fraction Symbol
27	RTL B-10	14D-570	41	RTL C-3	25B-750
28	B-9	22D-1·7 20D-750	42	C-4	23C-8·2 24C-615
29	B-12	23B-2·8 19A-575	43	C-5	23B-3·8 22B-1310
30	B-13	22C-2·0 19D-630	44	C-6	19A-4·7 14D-3·50
31	B-14	23B-3·1 16C-490	45	C-8	18A-1·2 18B-350
32	B-15	23B-2·1 20A-710	46	C-10	20C-2·2 18C-650
33	B-16	23D-2·4 14C-530	47	C-11	22D-2·4 22B-590
34	B-17	23D-1·6 20B-670	48	C-12	22D-6·4 23B-1160
35	B-18	25A-2·7 19C-640	49	C-13	23D-6·9 23D-580
36	B-19	25D-2·3 14C-530	50	C-19	22D-0·4 24A-1000
37	B-20	25C-1·7 23A-1000	51	C-20	20C-4·7 23C-945
38	B-21	23B-5·9 17A-370	52	C-21	21D-4·5 19D-1020
39	C-1	23D-1·4 24A-620	53	C-22	21C-3·3 19D-1130
40	C-2	20D-3·6 25B-675	54	C-23	20C-4·4 25C-1500
		23B-8·0			20C-11

Serial No.	Test Hole No.	Fraction Symbol	Serial No.	Test Hole No.	Fraction Symbol
55	RTL D-1	23D-810	69	RTL D-23	22B-575
56	D-2	22B-5·9 18B-625	70	E-10-11	23A-3 8 25D-2610
57	D-3	22C-3·3 23D-480	71	E-16	13B-25 25D-2175
58	D-4	23C-6·8 25D-1800	72	E-20	20D-17 25A-3300
59	D-5	19A-19 19C-700	73	E-21	13C-11 22D-2050
60	D-6	23B-2·7 23A-925	74	E-22	19B-6·5 25A-1820
61	D-8/9	20D-4·4 22B-950	75	E-23	20B-16 25C-2100
62	D-12/13	20D-4·7 22D-665	76	E-24	20B-14 23A-1950
63	D-15	22C-4 8 22B-1700	77	E-25	12B-7·2 22B-1665
64	D-16	19A-6·1 22B-950	78	E-26	12B-6 0 25A-2900
65	D-17	20A-4 8 25C-1010	79	E-27	19C-18 22C-950
66	D-18	20C-2·9 23B-1250	80	E-29	21D-4 3 22B-1000
67	D-19	20B-8·0 24A-710	81	F-5	11C-4 8 19A-650
68	D-20	22D-3·6 23B-1110	82	F-9	23B-2·0 23B-1500
		20A-7·7			20D-7·5

Serial No.	Test Hole No.	Fraction Symbol	Serial No.	Test Hole No.	Fraction Symbol
83	RTL F-13	25A-2850	97	RTL G-3	23B-1800
84	F-14	11D-16 25A-2300	98	G-5	5B-9·3 23C-2230
85	F-16	11D-13 23A-680	99	G-6	14A-11 25C-1650
86	F-17	22D-4·2 23C-6200	100	G-7	22D-15 16B-1400
87	F-18	2B-19 25C-2000	101	G-8	8C-11 8B-2800
88	F-20	19A-16 12B-8·00	102	G-11	12A-11 13B-7100
89	F-21	19A-2·4 20D-450	103	G-12	5C-18 20B-15000
90	F-22	21C-3·8 6C-500	104	G-13	3D-40 23B-4370
91	F-23	10B-0·8 20A-1100	105	G-24	13D-30 36C-3600
92	F-24	10B-3·4 11A-580	106	G-15	2A-19 25A-4500
93	F-25	20D-1·2 12B-750	107	G-16	2A-18 25A-2800
94	F-26	11A-1·1 7B-450	108	G-17	16A-29 25C-1675
95	G-1	22D-0·1 18B-1030	109	G-19	14A-16 25C-1325
96	G-2	20C-3·6 18C-1150	110	G-20	18A-1·2 19A-1010
		12B-5·6			18A2·7

Serial No.	Test Hole No.	Fraction Symbol	Serial No.	Test Hole No.	Fraction Symbol
	RTL.			RTL.	
111	G-21	15B-1600	125	H-16	23C-1280
		3B-24			40C-7.0
112	H-1	3C-260	126	H-17	24A-1340
		23A-0.2			13D-4.9
113	H-2	12D-650	127	Z-1	6B-500
		23B-1.5			22C-0.5
114	H-3	17A-720	128	Z-2	13C-525
		23B-2.1			22C-0.9
115	H-4	24C-800	129	Z-3	4C-390
		21C-4.5			23A-0.4
116	H-6	25C-2380	130	Z-4	4C-450
		20C-16			23A-0.6
117	H-7	25A-1250	131	Z-6	2C-200
		20B-1.1			19A-4.3
118	H-8	19B-2400	132	Z-7	14C-680
		20B-7.0			23C-1.6
119	H-9	25D-4110	133	Z-8	14B-670
		6D-5.3			23B-1.8
120	H-10	25D-10600	134	Z-9	14B-600
		5A-52			23B-1.5
121	H-12	25C-21100	135	Z-10	13D-420
		3D-69			22C-1.2
122	H-13	25D-18500	136	Z-11	24A-700
		3D-51			23B-2.4
123	H-14	23B-21000	137	Z-12	14C-580
		2C-26			23A-1.7
124	H-15	23A-4050	138	Z-13	20C-1000
		1A-15			22D-3.3

Serial No.	Test Hole No.	Fraction Symbol	Serial No.	Test Hole No.	Fraction Symbol
	RTL.			RTL.	
139	Z-15	20D-830	153	Z-41	6C-900
		23C-3·2			10D-1·0
140	Z-26	25C-3700	154	Z-42	23C-12950
		12B-23			3A-16
141	Z-27	25C-3200	155	Z-43	21D-12600
		20C-22			3A-12
142	Z-28	23A-2650	156	Z-44	24A-16300
		13B-10			3A-19
143	Z-29	25A-3950	157	Z-45	22B-16600
		12C-19			5B-18
144	Z-30	23B-4630	158	Z-46	24B-12900
		14A-17			3D-17
145	Z-31	25A-5150	159	Z-47	19A-12780
		14D-23			1A-7·5
146	Z-32	23C-4900	160	Z-48	25D-20400
		16D-18			3D-67
147	Z-33	25A-4450	161	Z-49	23B-12500
		3B-17			3C-22
148	Z-34	25A-3000	162	Z-51	20A-13500
		13A-20			2C-12
149	Z-36	23A-1350	163	Z-52	20D-18250
		19C-10			3C-11
150	Z-37	19A-535	164	Z-53	20B-15600
		22A-1·9			7A-50
151	Z-38	13A-355	165	Z-55	20B-13600
		22C-0·9			3A-13
152	Z-39	19B-500	166	Z-56	22B-16000
		23C-1·9			3A-18

Table III—contd.

Serial No.	Test Hole No.	Fraction Symbol	Serial No.	Test Hole No.	Fraction Symbol
	RTL			RTL	
167	Z-57	25D-3200	180	A-10	23A-700
		13A-34			25A-65
168	Z-58	23C-2850	181	A-12	20D-750
		14A-12			22A-3·3
169	Z-59	18C-750	182	A-15	19A-690
		13A-3·7			23D-2·0
170	Z-60	16C-500	183	A-15A	14C-690
		23C-1·6			25D-1·9
171	Z ₁ -A	19A-475	184	B-2	12D-420
		22B-2·1			25C-1·6
172	Z ₁ -D	11C-470	185	B-3	12B-450
		23A-1·1			23B-1·3
173	Z ₁ -E	19A-500	186	B-4	17A-560
		23A-2·0			24A-2·1
174	Z ₁ -F	12D-400	187	B-5	23A-1280
		23B-1·3			20D-6·6
175	A-3	24A-600	188	B-6	23A-1850
		25C-4·1			20B-7·2
176	A-4	22B-850	189	B-7	24B-850
		25A-4·6			23C-5·0
177	A-5	24A-520	190	B-8	23D-1110
		23A-4·3			18-C-9·4
178	A-7	19C-486	191	B-9	22B-1020
		22C-3·0			18C-4·5
179	A-9	19C-400	192	C-1	11C-300
		22D-2·9			25C-0·8

Table III—contd.

Serial No.	Test Hole No.	Fraction Symbol	Serial No.	Test Hole No.	Fraction Symbol
	RTL			RTL	
193	C-2	20A-6·00	197	D ₁ -5	22A-480
		24A-2·1			25D-3·0
194	C-3	22A-745	198	D ₁ -6	11C-610
		22D-3·5			22C-1·2
195	C-4	22C-785	199	D ₈ -A	20B-570
		23C-4·6			19A-3·0
196	C-5	8D-535	200	D ₁ -4A	14B-640
		25B-0·6			23C-1·7
197	C-6	25A-1200	201	D ₁ -B	20D-545
		24A-9·9			20C-3·1
198	C-9	23A-970	202	D ₁ -U	20D-630
		23B-4·9			23A-2·9
190	C-10	14B-580	203	D-2	18D-615
		23B-1·3			19B-3·5
191	C-11	18B-500	204	D-3	18A-400
		13A-3·1			22C-1·6
192	C-12	13A-330	205	D-4A	19A-640
		23A-0·7			22D-1·9
193	D ₁ -1	18D-1030	206	D-5	20C-480
		11B-3·8			25A-2·9
194	D ₈ -2	13B-610	207	D-7	23B-3300
		10B-3·5			13B-10
195	D ₁ -3	24C-540	208	D-8	22C-2000
		22D-3·7			
196	D ₁ -4	23A-1150	209	CTL. D-9	25C-1900
		23C-6·7			20C-18

Table III—contd.

Serial No.	Test Hole No.	Fraction Symbol	Serial No.	Test Hole	Fraction Symbol
	CTL			CTL	
210	D-10	20C-1980	223	E-5	25D-2380
		12D-5·3			14B-22
211	D-11	25C-1856	224	E-6	25D-7200
		20D-18			2A-55
212	D-12	25A-2110	225	E-9	25D-15000
		20D-15			1A-59
213	D-13	22B-7800	226	E-10	25D-20400
		3D-14			1A-59
214	D-14	25C-5500	227	E-11	23C-28000
		4D-25			1C-12
215	D3-15	23C-2070	228	E-12	25A-17600
		19B-11			1D-39
216	D-16	20A-670	229	E-13	25D-24000
		17A-2·9			1D-76
217	D-17	19B-480	230	E-15	25D-1400
		23A-1·8			11D-2·2
218	D9-785	19C-745	321	E-16	25C-6800
		20D-2·6			2B-28
219	D-19	16C-510	232	E-20	24B-860
		4D-2·9			23B-4·4
220	E-2	18A-1180	233	F-1	23A-1690
		19A-3·6			20C-6·0
221	E-3	18A-620	234	F-2	18C-250
		19B-2·4			23D-2·7
222	E-4	18C-1150	235	F-3	25C-1150
		11D-4·2			19C-11

Table III—contd.

Serial No.	Test Hole No.	Fraction Symbol	Serial No.	Test Hole No.	Fraction Symbol
	CTL			CTL	
236	F-4	25D-1730 ----- 12B-9·4	248	G-5	18A-520 ----- 28D-2·4
237	F-6	25D-6350 ----- 4D-55	249	G-4	24A-810 ----- 25D-504
238	F-7	25C-830 ----- 13A-9·4	250	G-6	17A-410 ----- 25D-1·6
239	F-8	24C-600 ----- 13A-5·2	251	G-7	14B-400 ----- 23D-0·9
240	F-9	25D-1190 ----- 13C-16	252	G-8	3D-310 ----- 25C-0·6
241	F-10	25C-970 ----- 20B-13	253	Z-1	13B-1680 ----- 23A-11
242	F-12	19C-360 ----- 13D-1·8	254	Z-3	24A-525 ----- 25C-3·6
243	F-13	23A-680 ----- 12C-5·3	255	Z-4	23B-1380 ----- 20C-7·7
244	G-1	25C-1340 ----- 19D-14·5	256	Z-5	23B-1300 ----- 13C-8·2
245	G-1A	25B-535 ----- 24B-1·0	257	Z-6	23D-1100 ----- 19A-7·7
246	G-2	23D-980 ----- 26B-6·5	258	Z-7	19A-1130 ----- 20B-2·6
247	G-3	24C-550 ----- 25D-4·3	259	Z-8	23-1050 ----- 13A-6·3

Table III—contd.

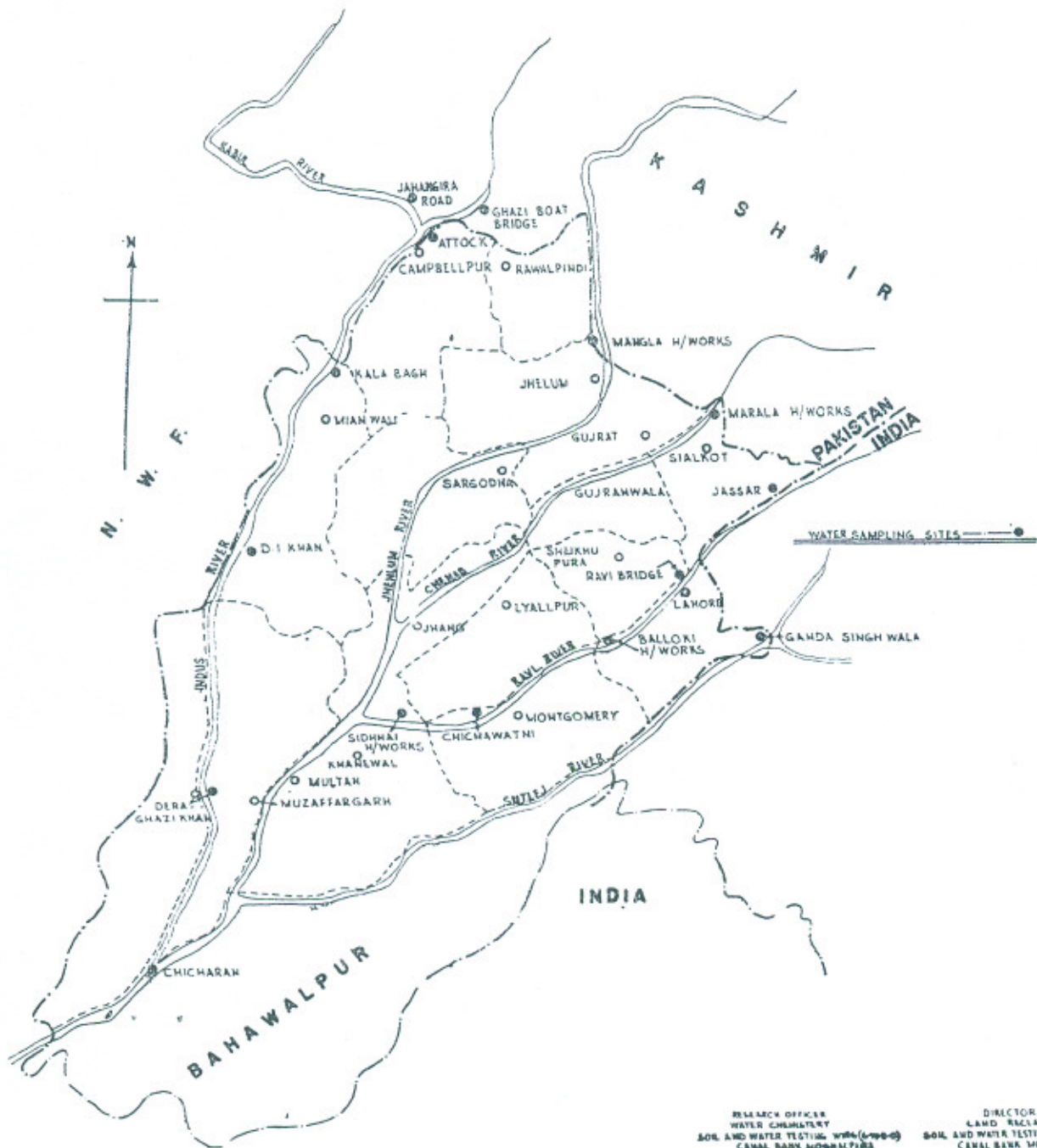
Serial No.	Test Hole No.	Fraction Symbol	Serial No.	Test Hole No.	Fraction Symbol
	CTL			CLT	
260	Z-9	25C-900	274	Z-6	19B-760
		20D-1·0			20C-2·8
261	Z-9A	22C-2950	275	Z-27	20D-1100
		12D-6·2			15C-4·1
262	Z-10	19D-3400	276	Z-28	22C-2200
		8B-7·2			15A-8·5
263	Z-11	13B-450	277	Z-29	22C-4230
		23A-1·4			2A-11
264	Z-12	18C-750	278	Z-30	25A-10200
		23C-3·4			4B-26
265	Z-13	22B-1135	279	Z-33	25A-10750
		15A-4·9			4B-36
266	Z-14	22B-2050	280	Z-34	20D-1930
		15A-8·1			12A-6
567	Z-15	22C-2050	281	Z-35	20B-14500
		18A-8·3			1C-13
268	Z-16	20B-1220	282	Z-36	22B-11500
		6B-3·7			1D-18
269	Z-17	20B-795	283	Z-37	23C-11000
		24C-3·2			9D-28
270	Z-19	20A-880	284	Z-38	25D-4870
		19C-206			2A-32
271	Z-20	21C-1230	285	Z-39	25A-11300
		14B-3·2			1A-36
272	Z-23	20D-1160	286	Z-40	25D-23600
		2B-4·9			1A-132
273	Z-24	19D-1000	287	Z-41	25B-3980
		14B-3·4			13D-56

Table III—concl'd.

Serial No.	Test Hole No.	Fraction Symbol	Serial No.	Test Hole No.	Fraction Symbol
	CTLZ.			CTLZ	
288	Z-42	25D-33000 ----- 1A-45	297	Z-51	25B-2060 ----- 24B-29
289	Z-43	25D-22500 ----- 3D-71	298	Z-52	25C-1310 ----- 19B-15
290	Z-44	25A-9040 ----- 14B-72	299	Z-53	25D-4820 ----- 15A-30
291	Z-45	25A-21360 ----- 1A-55	300	Z-54	23D-5820 ----- 1A-15
292	Z-46	25B-1080 ----- 18A-12	301	Z-55	25A-5150 ----- 15D-18
293	Z-47	25D-3850 ----- 18A-68	302	Z-57	25D-1580 ----- 15B-17
294	Z-47 A	25D-15860 ----- 2B-101	303	Z-58	24D-715 ----- 18D-4.5
295	Z-48	25B-4400 ----- 18B-46	304	Z-59	24A-490 ----- 25D-3.7
296	Z-50	25B-5125 ----- 18B-48			

FIG.-1
PART PLAN
 OF
WEST PAKISTAN
 SHOWING
SAMPLING SITES ON SURFACE STREAMS
 SCALE: 1 INCH = 40 MILES

PAPER No 342



RESEARCH OFFICER
 WATER CHEMISTRY
 SOIL AND WATER TESTING WING (L-1000)
 CANAL BANK AND DAMS
 LAHORE

DIRECTOR
 LAND RECLAMATION
 SOIL AND WATER TESTING WING (L-1000)
 CANAL BANK, MOGHALPURA
 LAHORE

FIG. 2
PART PLAN OF WEST PAKISTAN
SHOWING
TEST HOLE SITES

PAPER No. 342

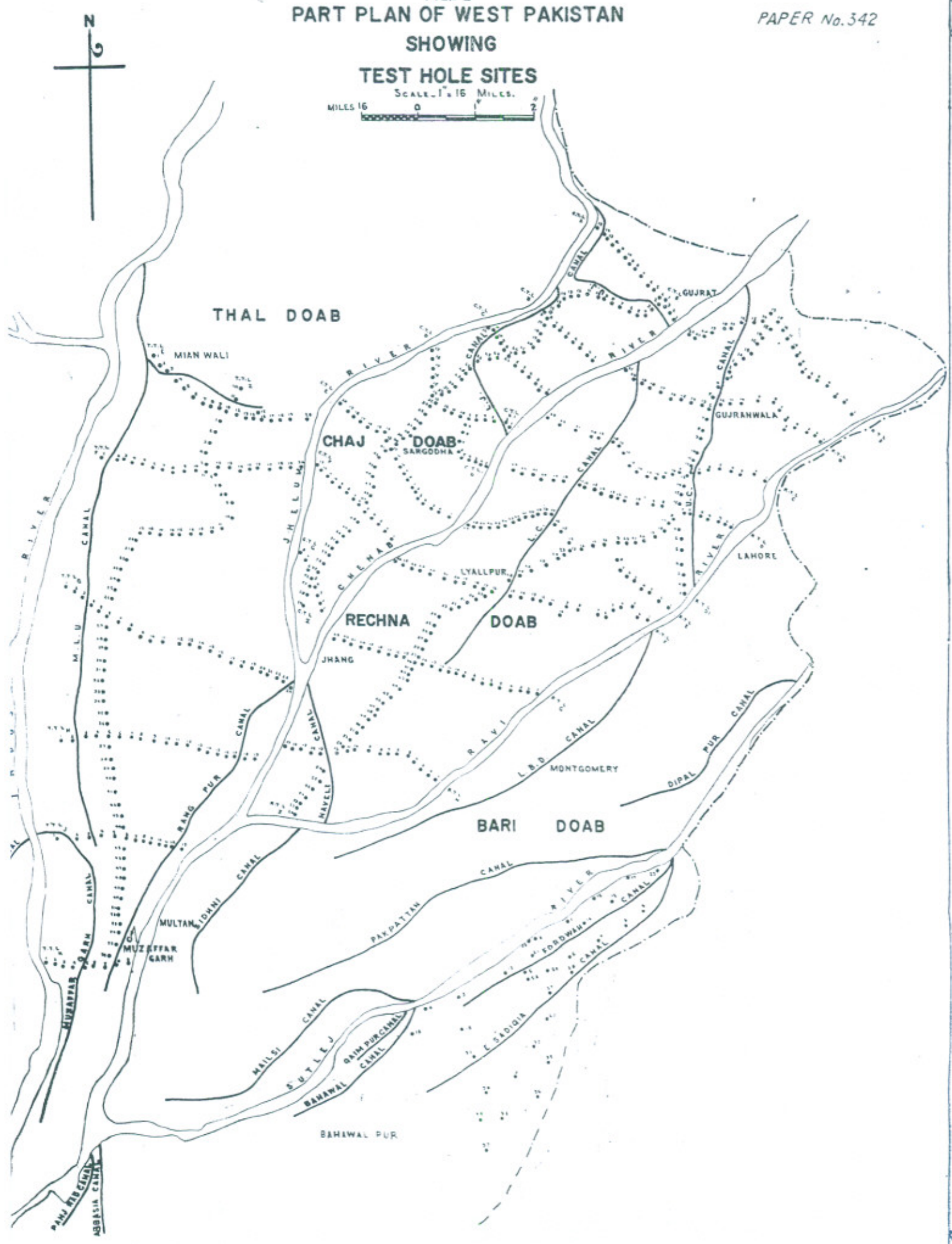


FIG. 2
 PART PLAN OF WEST PAKISTAN
 SHOWING

TEST HOLE SITES

Scale 1" = 16 Miles.

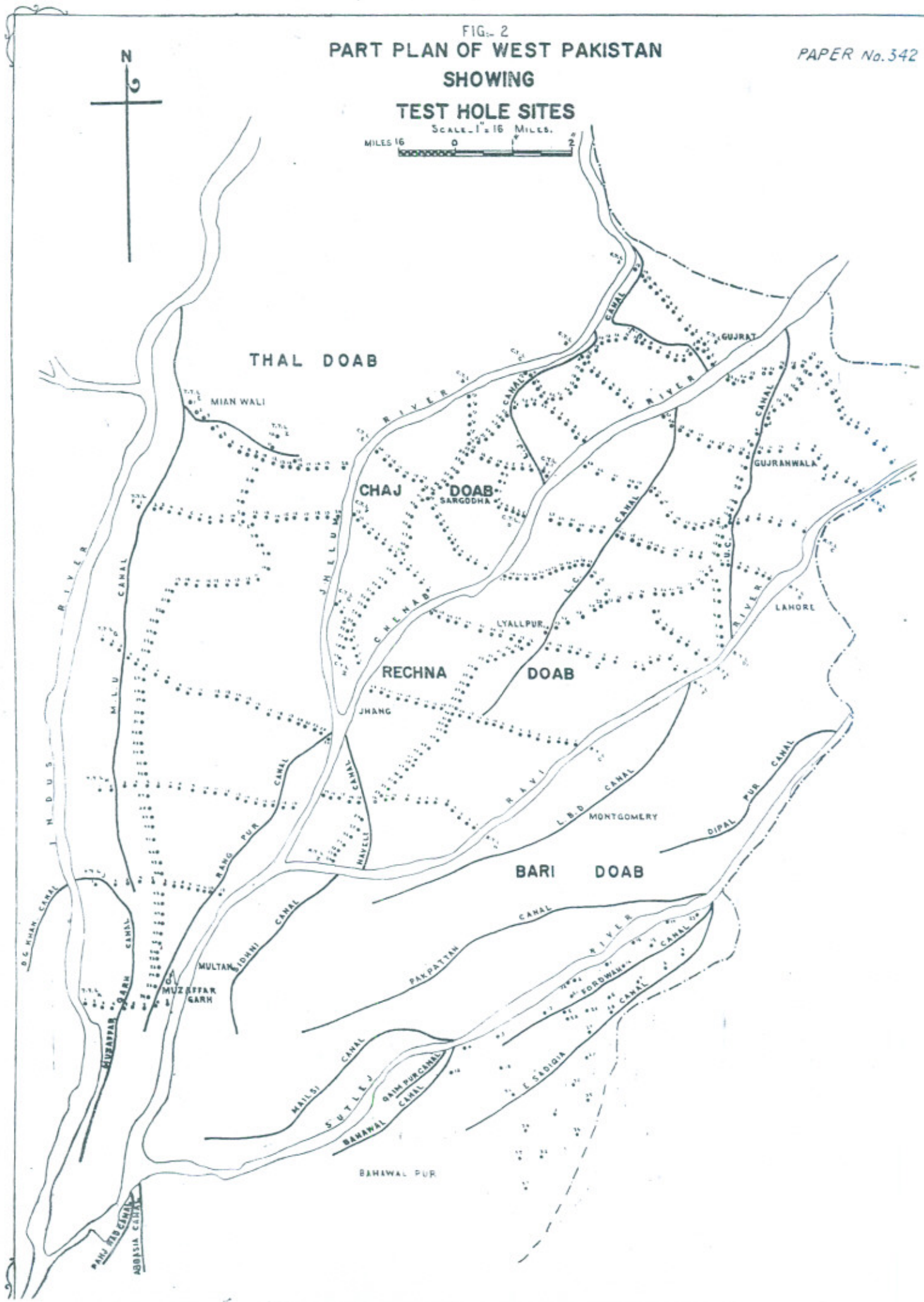


FIG:-3 PAPER No.342
LAYOUT OF THE PROCEDURE ADOPTED FOR
WATER SAMPLING FROM TEST HOLES

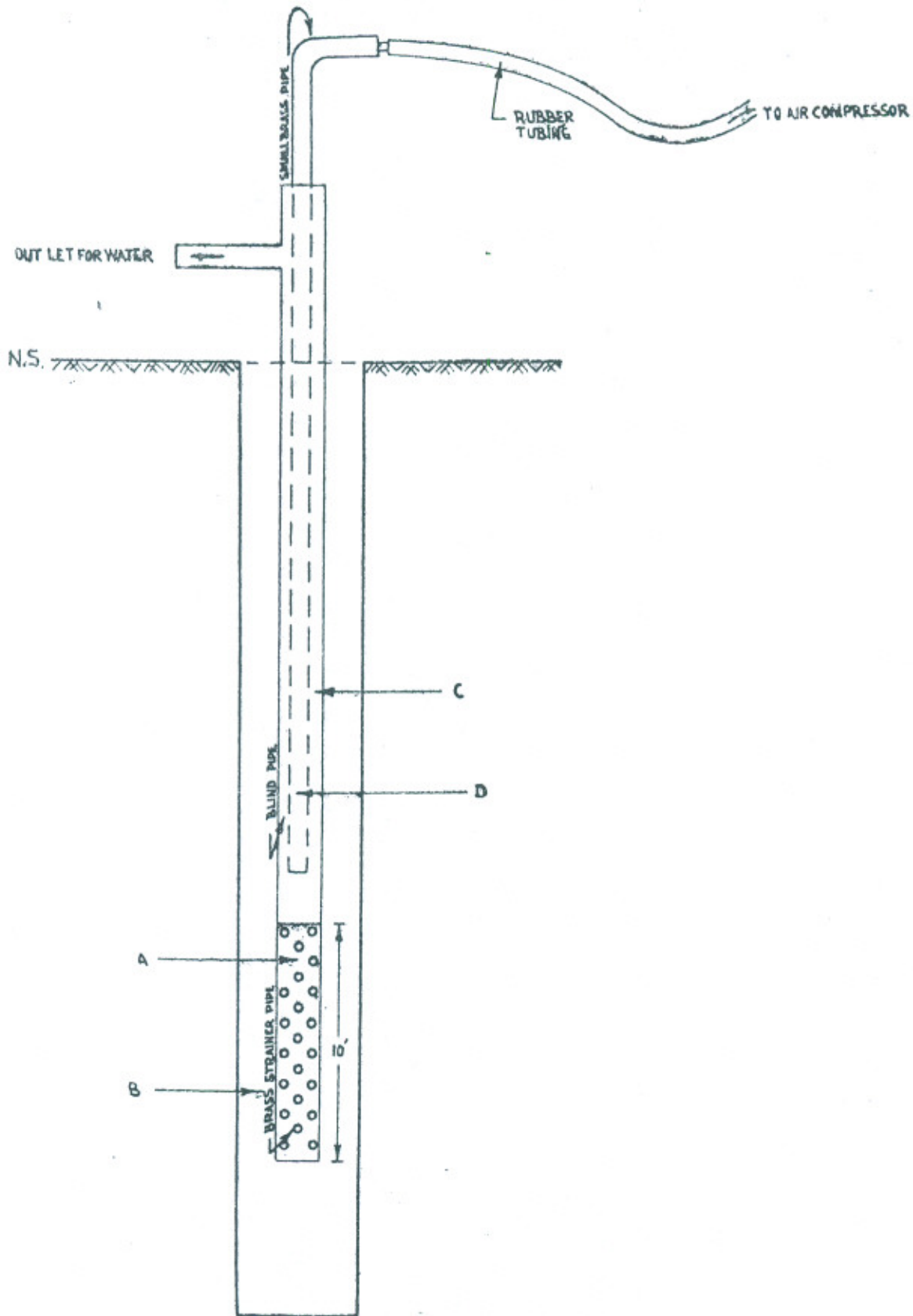


FIG. 4
SHOWING SEASONAL CHANGES IN DISSOLVED SOLIDS

PAPER No. 342

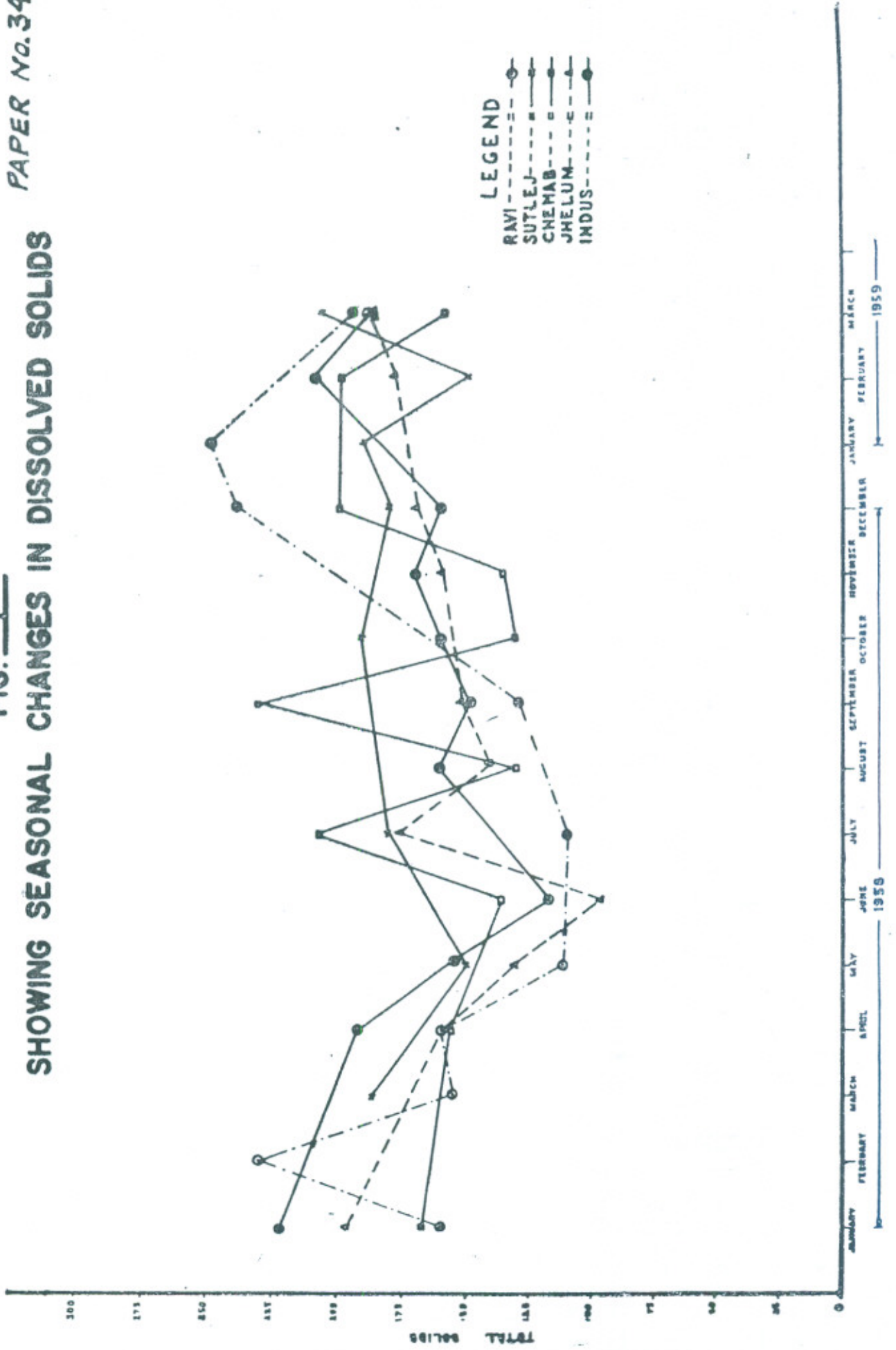
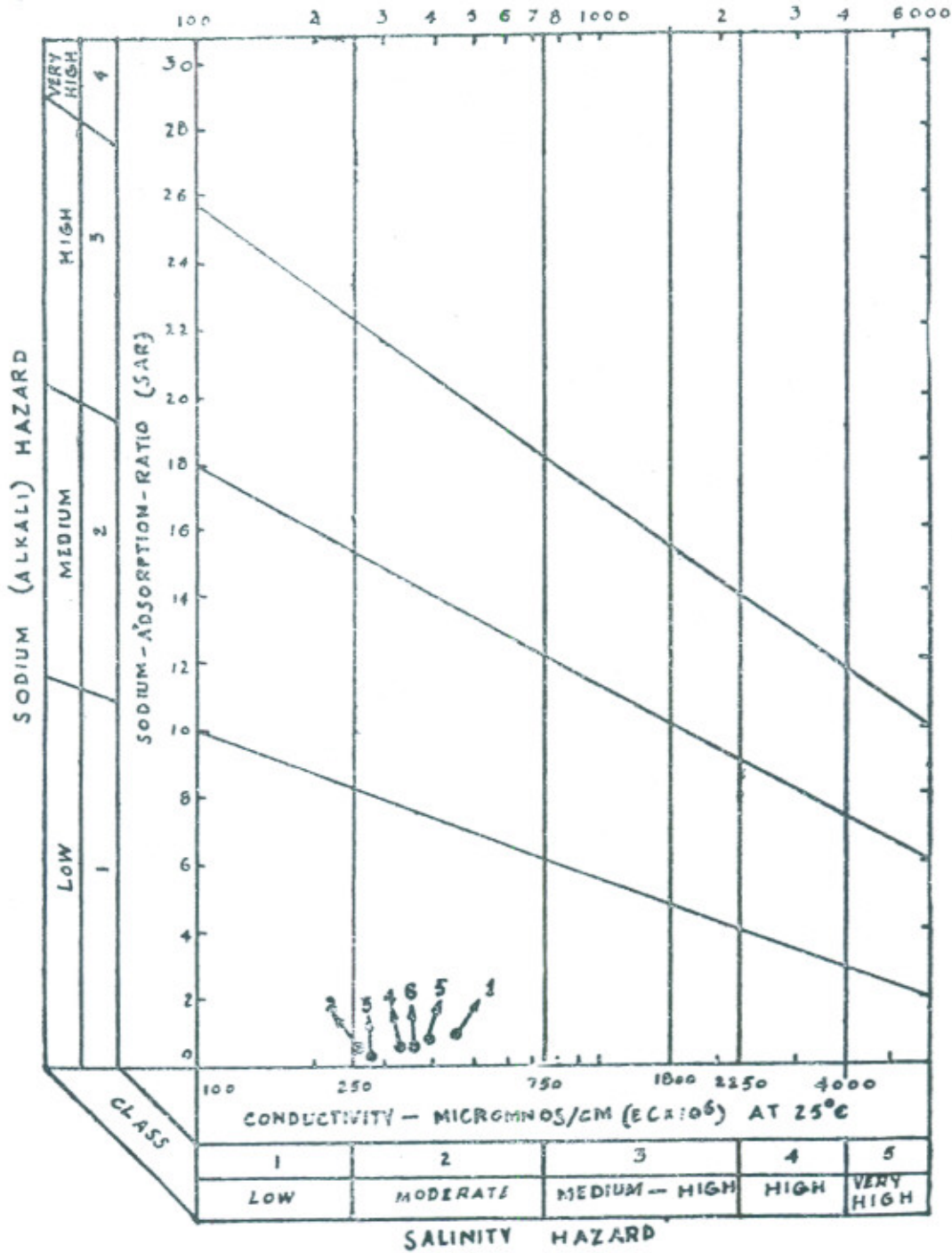


FIG. - 5

SHOWING THE SALINITY AND ALKALINITY HAZARDS OF SURFACE WATERS.



PAPER No. 342

FIG.-6
**PART PLAN OF
WEST PAKISTAN
SHOWING QUALITY OF
SHALLOW WATER**

SCALE 1" = 32 MILES

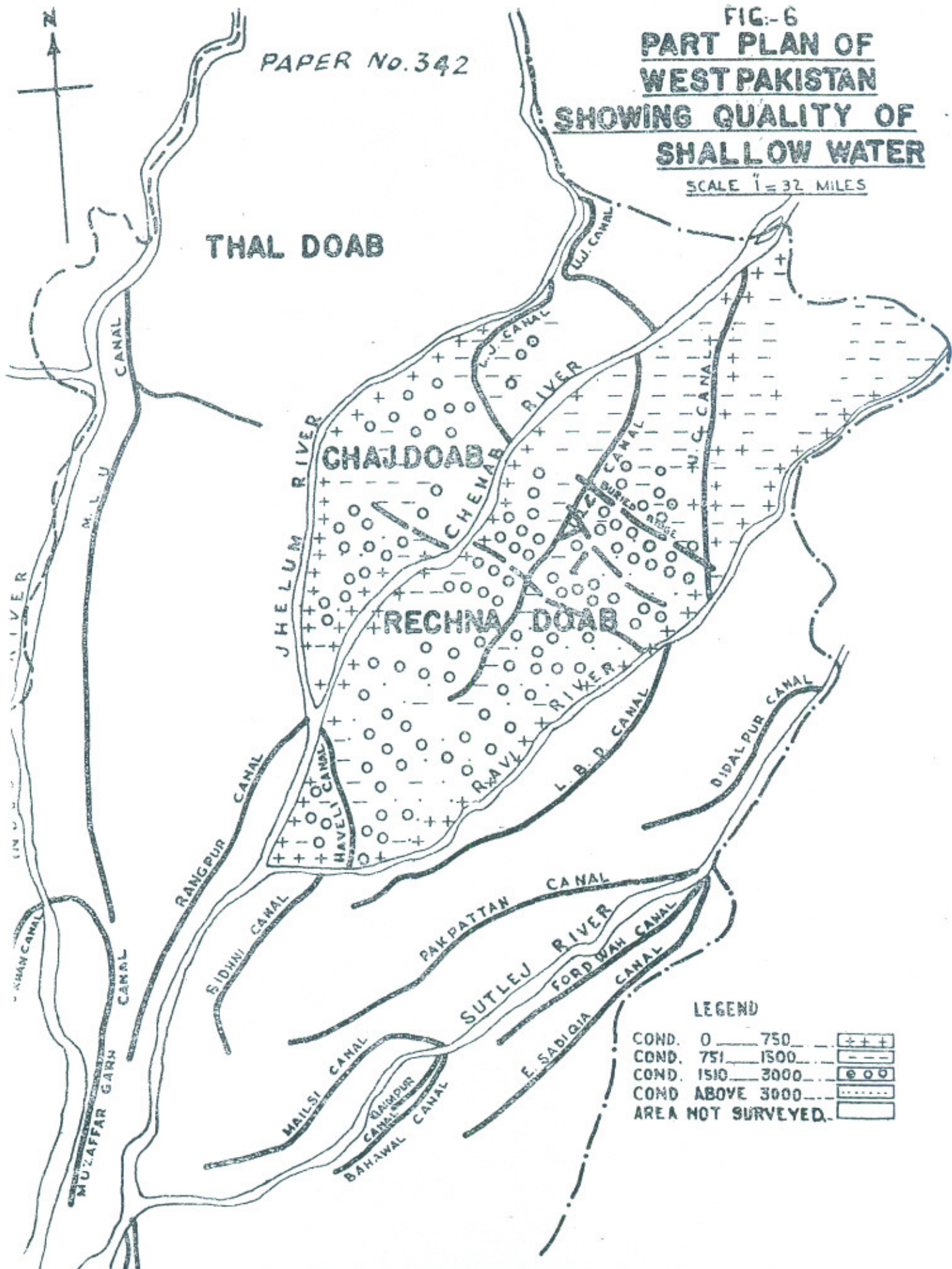
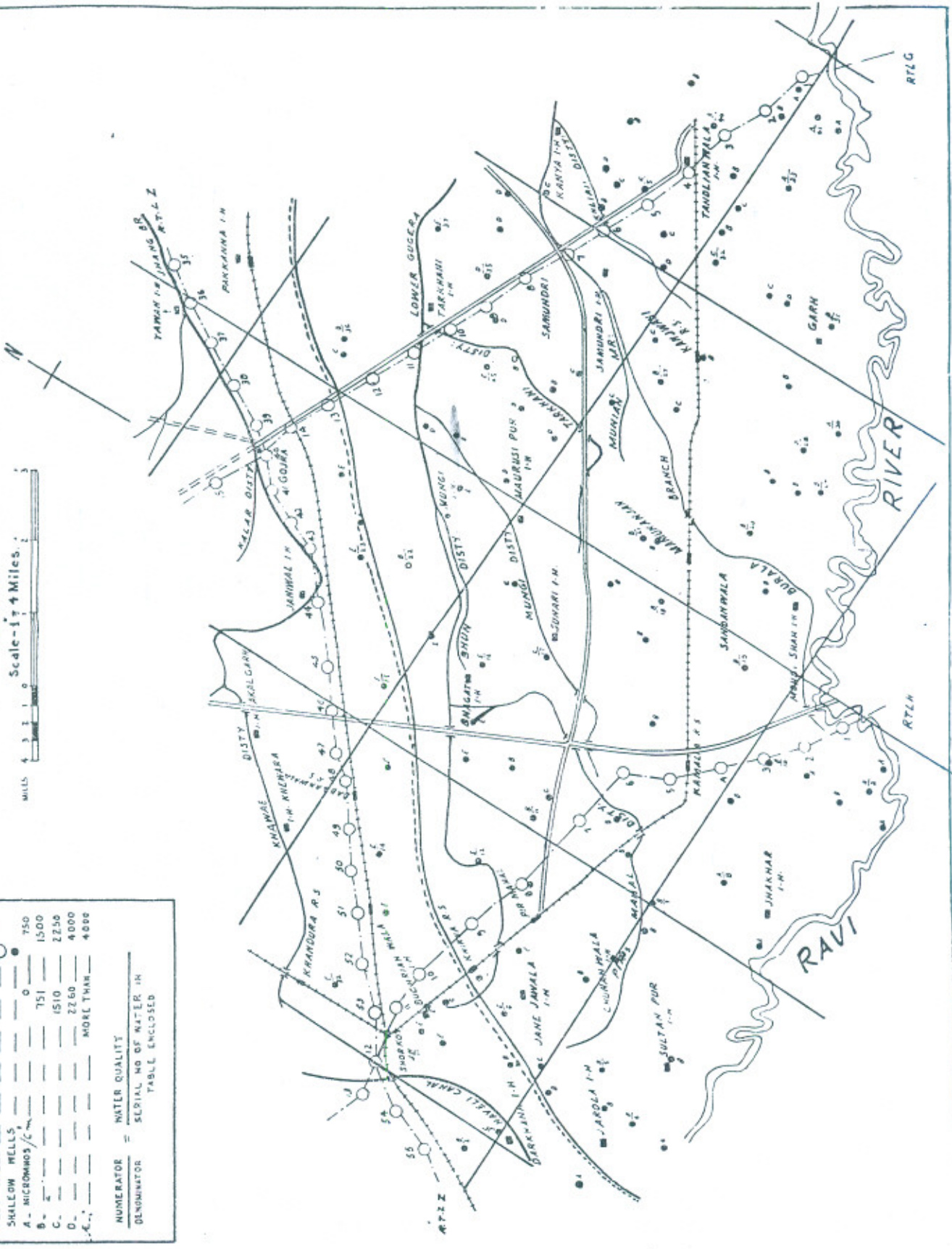


FIG.-7
MAP SHOWING
PART OF TEST LINES OF
R.T.L G.R.T.L H AND R.T.L Z
WITH SHALLOW
SOURCES.



LEGEND	
TEST HOLES	○
SHALLOW WELLS	●
A. MICROMMS / C.M.	0
B.	751
C.	1510
D.	2256
E.	2760
F.	4000
G.	MORE THAN
H.	4000

WATER QUALITY	
NUMERATOR	SERIAL NO OF WATER IN TABLE ENCLOSED
DENOMINATOR	



ME EQUIVALENTS.

MILLIGRAM EQUIVALENTS.

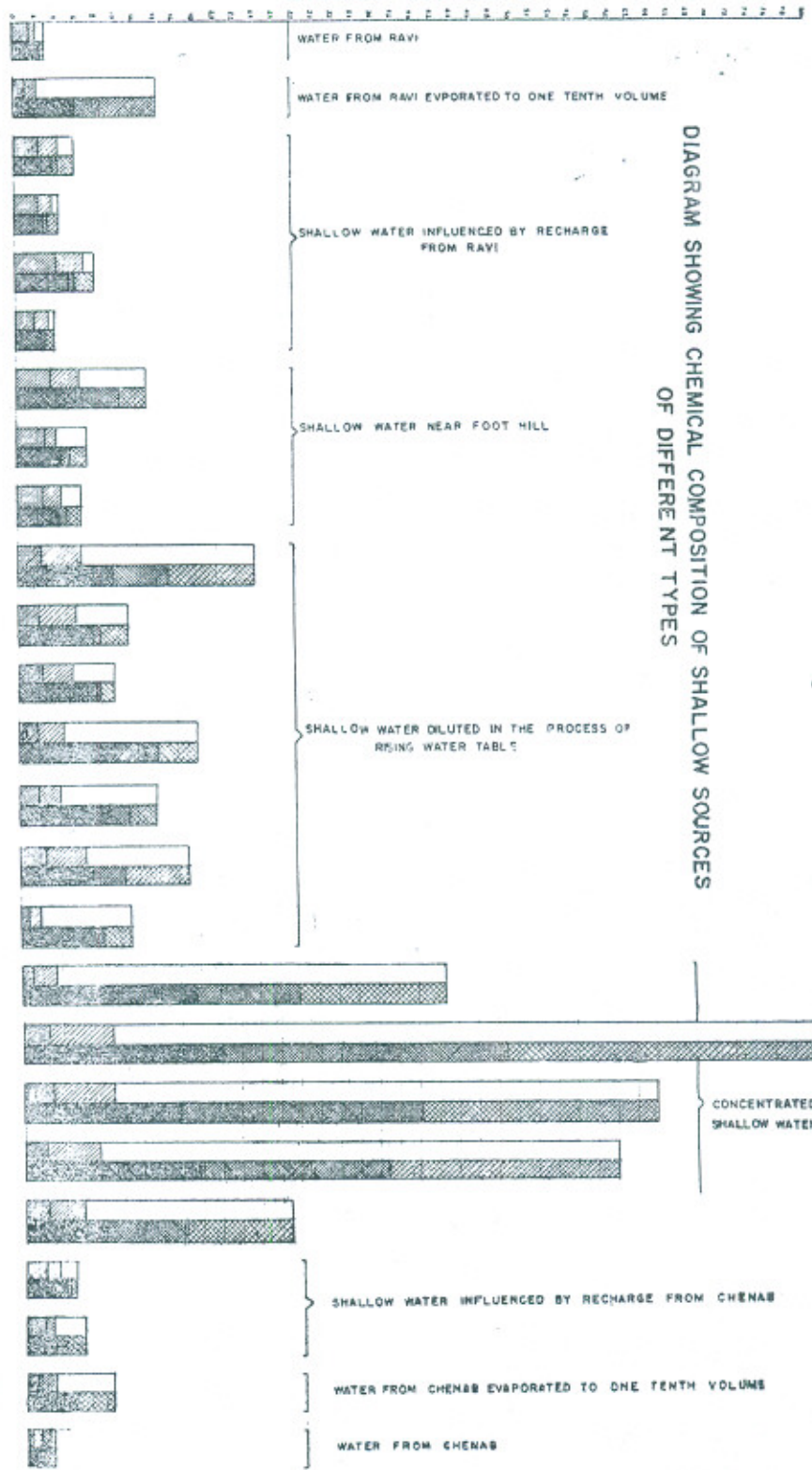
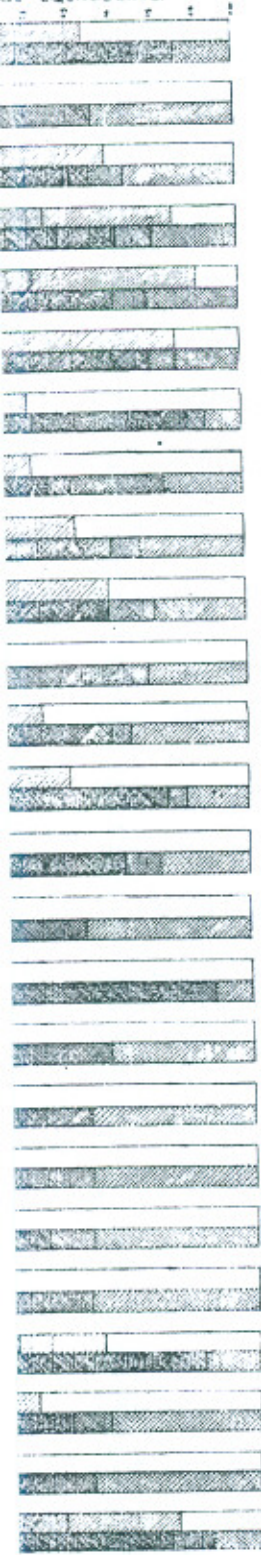


DIAGRAM SHOWING CHEMICAL COMPOSITION OF SHALLOW SOURCES OF DIFFERENT TYPES

- LEGEND
- SODIUM AND POTASSIUM
 - ▨ SULFATE
 - ▩ CHLORIDE AND NITRATE
 - ▧ CALCIUM
 - ▦ BICARBONATE AND CHROMATE
 - ▨ MAGNESIUM

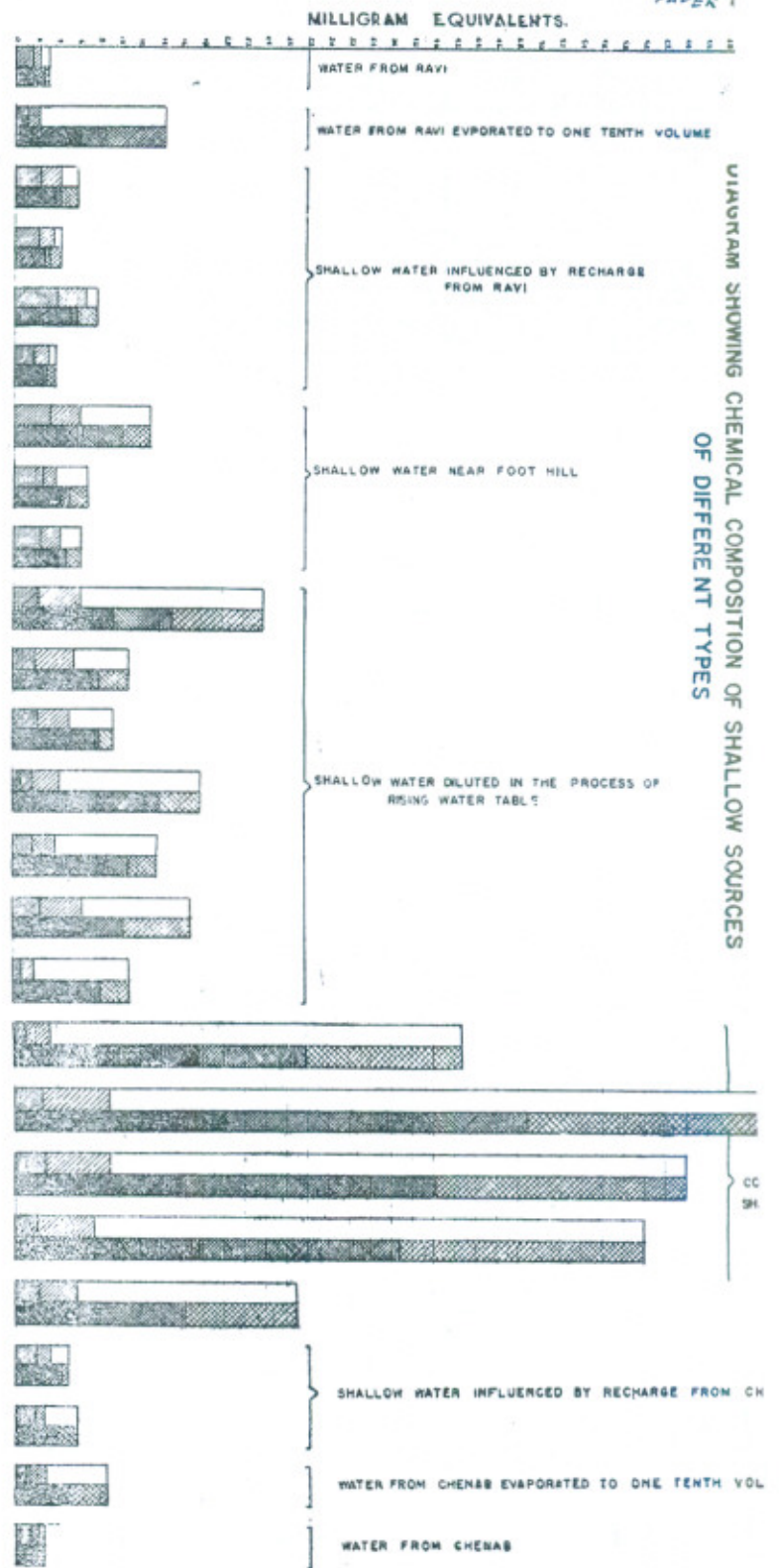
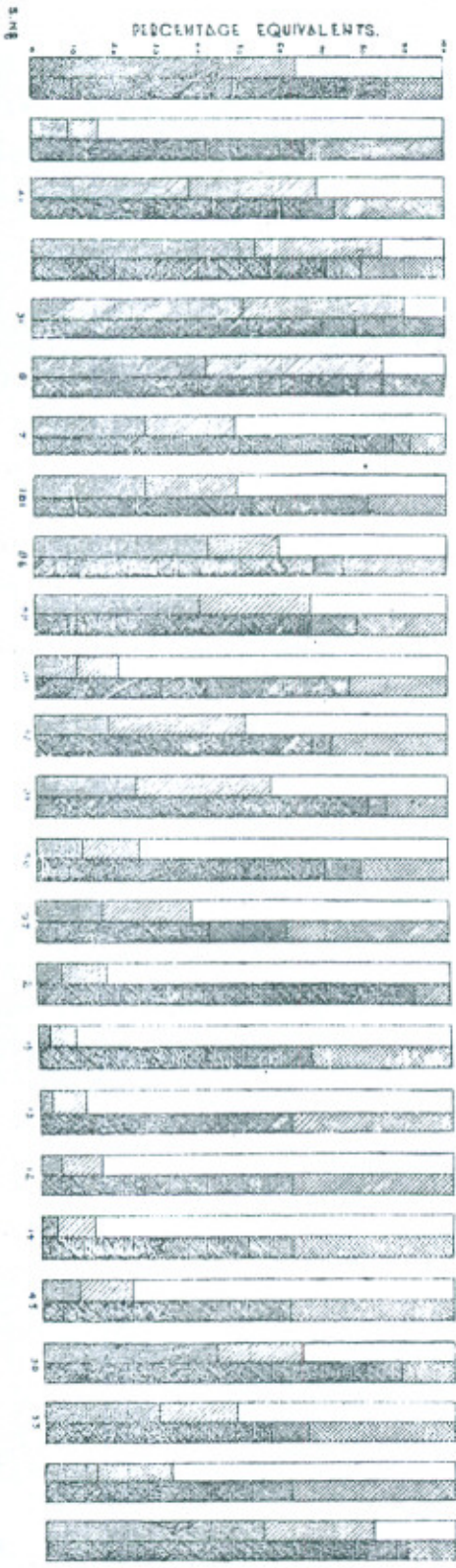


DIAGRAM SHOWING CHEMICAL COMPOSITION OF SHALLOW SOURCES OF DIFFERENT TYPES

LEGEND

	SODIUM AND POTASSIUM		SULFATE
	MAGNESIUM		CALCIUM AND CARBONATE
	CALCIUM		BICARBONATE AND CARBONATE
			CHLORIDE AND NITRATE

FIG:9

FREQUENCY DISTRIBUTION CURVE OF SHALLOW WATERS
IN HYDROLOGIC UNIT NO 1
RECHNA DOAB.

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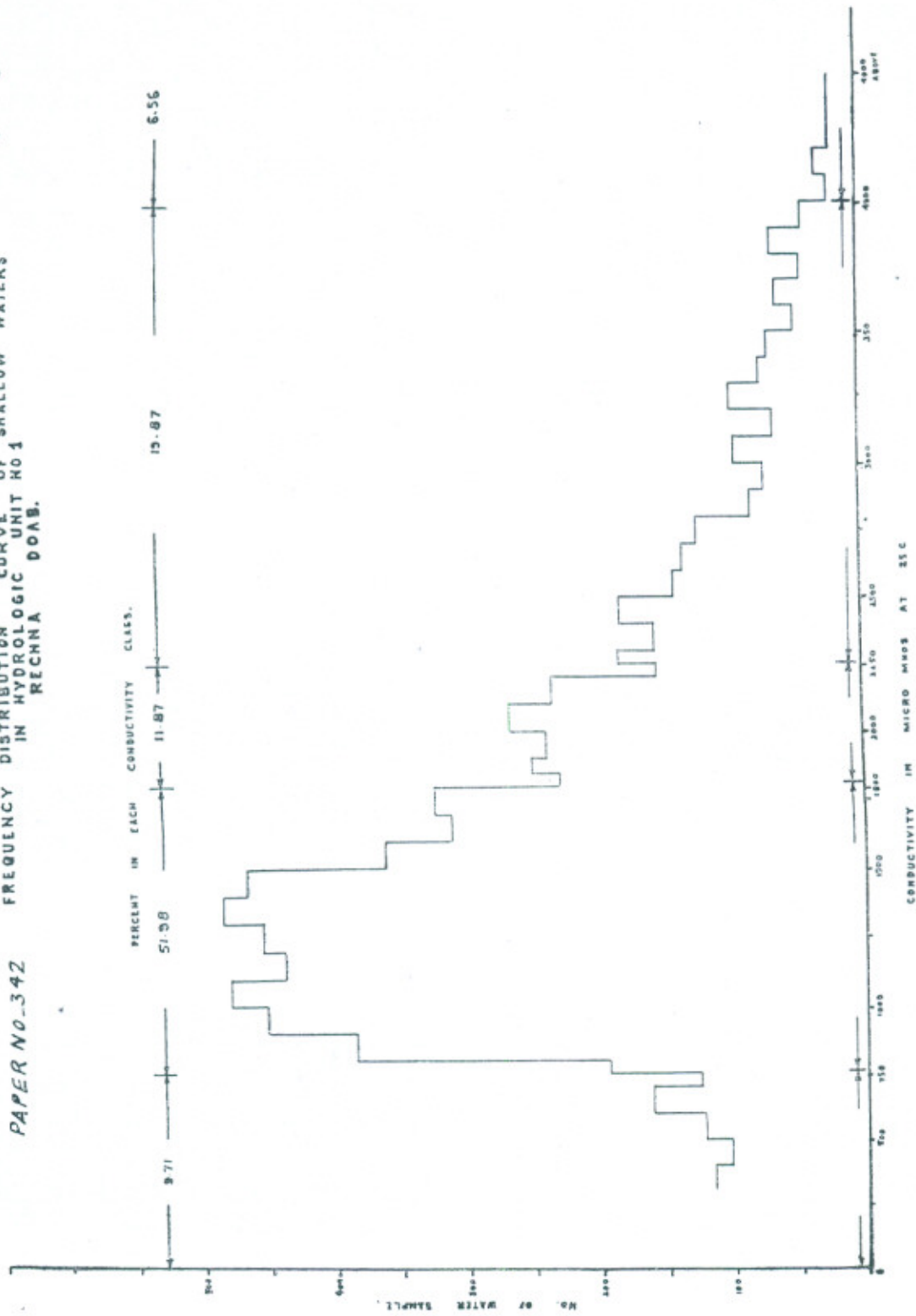
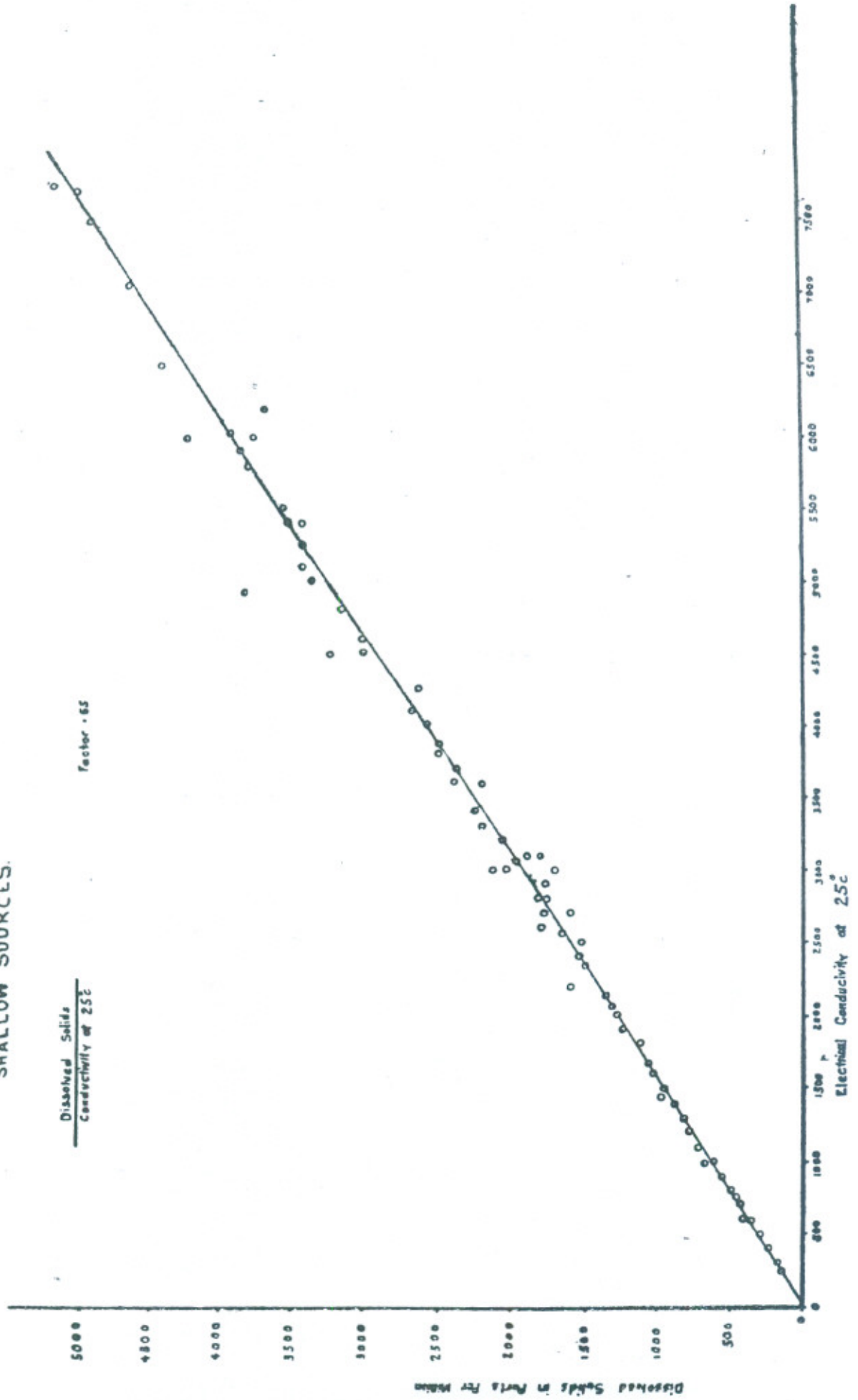


FIG:-10
 Curve Showing Relationship Between Conductivity
 & Dissolved Solids in Waters From
 SHALLOW SOURCES.

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FIG. No. II
DIAGRAM SHOWING GENERAL
CHEMICAL CHARACTER OF SHALLOW
WATER SOURCES.

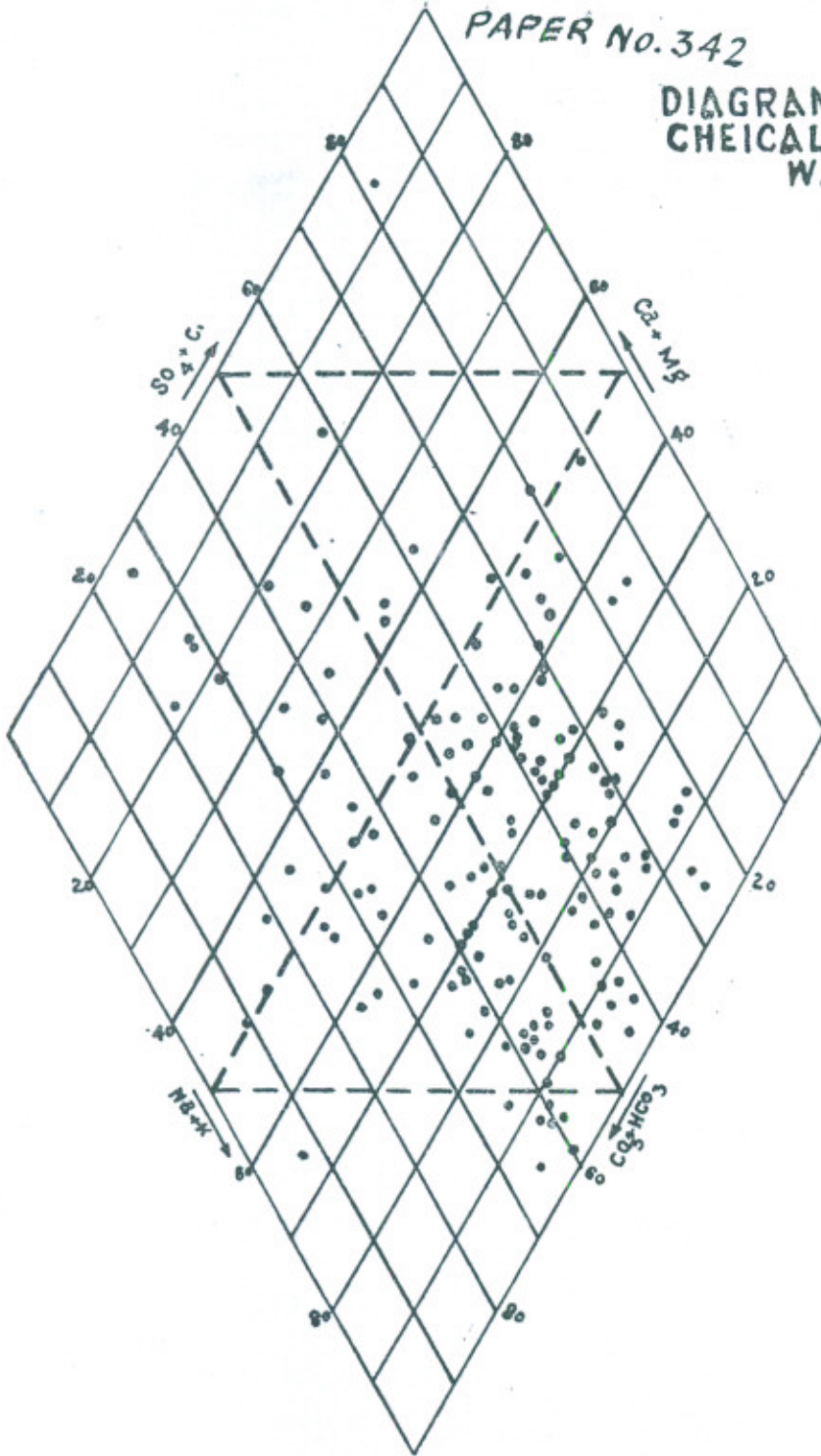
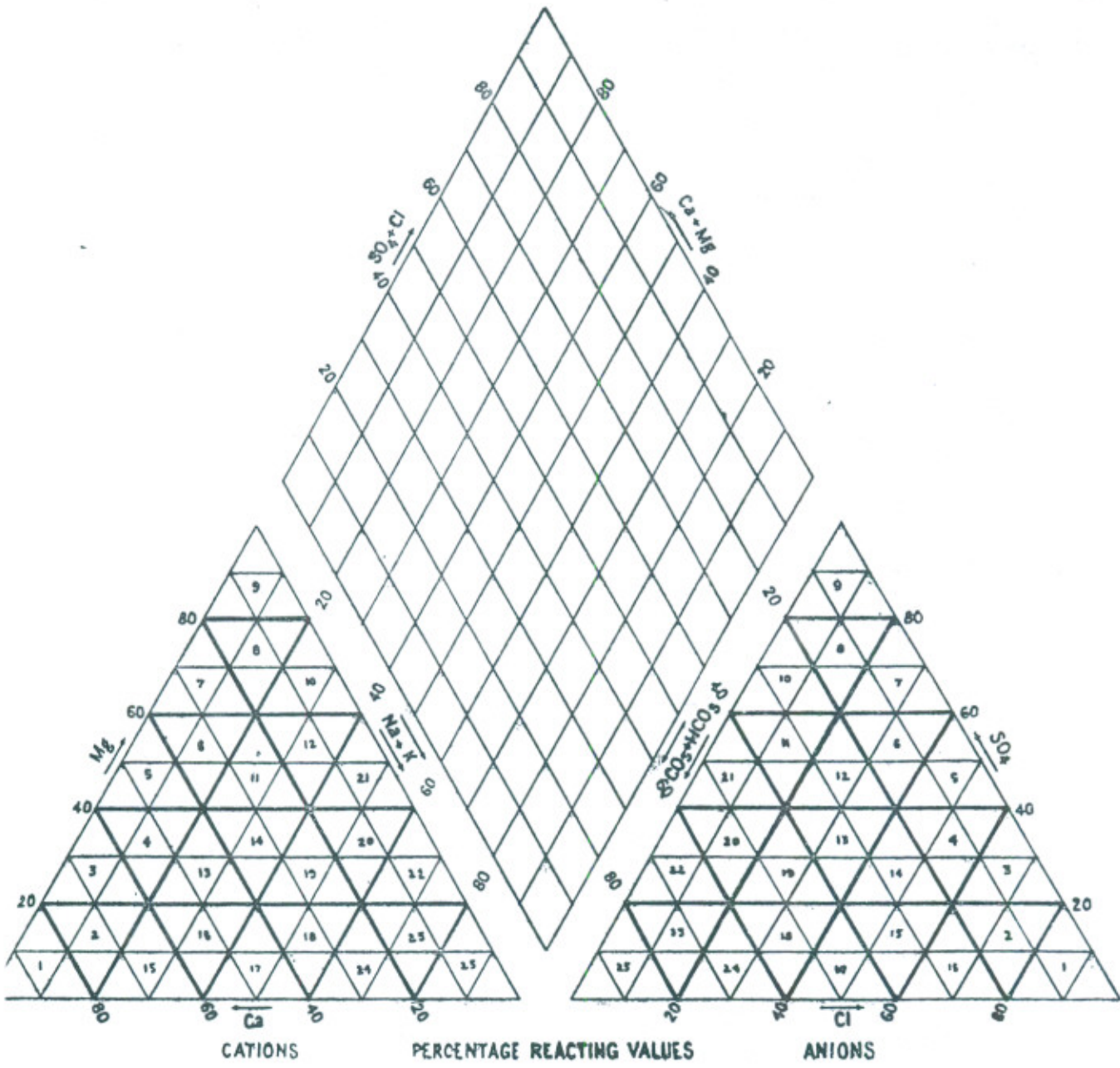


FIG.-12
PIPERS TRIANGULAR DIAGRAM



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FIG:- 13
**PART PLAN OF
WEST PAKISTAN**
SHOWING WATER QUALITY
SCALE 1=32 MILES

