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Effect Of Oil Refinery Effluent On The Shallow Gravel Aquifer in Zerqa Area-Jordan

By

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The Jordan Refinery is located within the Sukhna Refinery Groundwater Province 30km. northeast of Amman and about 5km east of the Sukhna Village. Zerqa River flows and drains the area west of the province. The Sukhna Refinery Groundwater Province is one of the largest developed areas in Jordan. New industries, farms, irrigational projects and municipal schemes are being directed to this area. Groundwater represents most of the water supplies to the entire province.

Groundwater occurs in three main aquifers, namely the shallow gravel aquifer, the Campanian - Maestrichtian chert-limestone aquifer and the Turonian limestone aquifer. The principal sources of recharge to the aquifers include precipitation and runoff. The area receives recharge from the south, northeast, and east. The River Zerqa, Wadi Sueida and possibly the Amman Syncline seem to be the main recharging sources from the south, while wadi Dhuleil and Wadi Es-Sayih area the main recharging sources from the northeast and east respectively.

Waste effluent from the Jordan Oil Refinery is the source of a complex pollution problem. An average daily flow of about 2500 cubic meters of industrial refuse is discharged from the Refinery into a separating pool in a nearby wadi (Wadi Sueida), where oil is separated and returned for processing, and waste water is discharged into the wadi bed. The effluent has high concentration of hydrogen sulphide, sodium sulphide, sodium hydroxide, phenol, and crude oil.

The discharge of this effluent has contaminated the shallow gravel aquifer in the area. Frequent analysis of the groundwater drawn from wells tapping this aquifer indicates a continuous increase in total dissolved solids with the most contamination in the wells nearest to the separating pool. Phenol concentration in eight wells detected at various time intervals in 1972, ranged between 0.07 and 0.15ppm, while a concentration of 0.55ppm was detected at the mouth of the separating pool. These phenol concentrations are beyond the international allowable standards.

A small number of people living in the lower wadi Sueida draw domestic supplies from the wells. Farming has also been affected by this situation, with the result that two citreous orchards were nearly abandoned for a period of time. Moreover, drinking water in the area has acquired a foul smell and taste.

Rainfall in the area has a mean of 130mm per year, an amount that is insufficient to flush the contaminated gravels, and heavy pumping of the municipal wells may result in conditions that could allow drawdown through the contaminated zone. Various waste disposal schemes, in which waste water is treated after separation from oil and before discharging it to the wadi bed have been suggested to the Refinery Company.

INTRODUCTION

Location

The Refinery area is situated about 30 kilometers northeast of Amman, the capital of Jordan.

The area is part of a groundwater province which is considered to be one of the largest developed areas in Jordan. New industries, farms, irrigational projects are being directed to the area. Eight wells have been drilled purposely to meet the refinery water demands other five producing wells were drilled in the same field about 800-950 meters east of the refinery (Figure 1).

Purpose and Scope of Work

The purpose of this paper is to examine the information available on the hydrochemistry of the shallow gravel aquifer in the area in order to evaluate the degree of contamination by certain contaminants. It is also the objective of this study to investigate other contaminating sources. To achieve such objectives, the recorded data on the water chemistry have been reviewed./ Further sampling and chemical analysis have been done. Detailed hydrochemical analyses were made. A number of wells have been sampled at intervals to observe any possible change in the water quality.

The recent data were correlated with the previous ones. The final objective is to find out a means by which treatment of contaminants and pollutants, discharging into the gravel aquifer, is possible. Thence flushing and purifying the aquifer contaminated by the above contaminating flows and giving rise to further development and appraisal of the aquifer.

Description of the Area

The area is drained by two main wadis (non-perennial streams), Wadi Husiya and Wadi Sueida in the south and Wadi Dhuleil in the north. The three wadis join to form lower Wadi Dhuleil which discharges into River Zerqa and thence to River Jordan (Figure 1). The eastern part of the area is a gentle rolling plateau with a slope ranging between 0.8% - 1.2%. The topographic relief increases westwards where the topographic slope becomes about 2%. The western part of the area is characterized by a rugged mountainuous features.

Vegetation

The vegetation in the study area is of two types:-
(a) Steppe-desertic in the eastern part of the area. This type occurs in valleys and gullies. It includes Pistcia Atlantica and some other species. (b) Cultivated high-land type in the western part of the area. It is mesophytic vegetation occurs in areas with minimum rainfall of 150-200mm. The most common species is Malva Parviflora.

HYDROGEOLOGY

Climate

The climate in the study area is that of arid-cool to arid-warm with an average annual rainfall of 75-175mm. Figure 2 shows a mean annual rainfall map of the study area for the ten year period from 1962 to 1972. The highest rainfall zone correspond to the north-western part of the area. The average rainfall decreases gradually eastwards. Thus the average rainfall varies from more than 200mm to less than 100mm.

Geology

The marine rocks of dolomitic limestone, marl, lithographic limestone, and chert cover the area. These sediments are of Cenomanian-Turonian age. Plateau gravels ranging in thickness between 7-40 meters lie on top (Fig. 3). In some places basaltic flows, originated outside the area, are present. The gravel and the basalt are recent. The gravel is mainly concentrated at and along the wadi courses.

Minor structures such synclines, anticlines and faults are recognised in the area (Figure 4).

Hydrology

The study area is considered part of the Amman-Zerqa subcatchment of River Zerqa drainage basin. Runoff in the study area is measured through stream gauging stations installed on two wadis in the study area. The main station at Wadi Dhuleil is fully equipped for flood measurements. Runoff volumes and sediment loads were measured as:-

Period Of Record	Base-flow (MCM)	Runoff (MCM)	Sediment Load (MCM)
1971 - 1972	1.24	17.768	.025
1972 - 1973	1.70	7.656	.0013

There are several springs in the study area. Their waters are used for domestic, agricultural and municipal purposes.

Name Of Spring	Location East	Location North	Elevation (m)	Mean Annual Discharge (m3/hr.)
Zerqa	254.2	162.3		200
Nimra	247.7	172.9	440	244
Sukhna	250.5	171.0	490	880
W. Husiyeh	251.6	173.4	450	33.0

Groundwater

The thick gravel deposits in the study area form very good aquifer. This aquifer is recharged mainly from rainfall, runoff in the wadis and subsurface flow from the adjacent groundwater fields. The aquifer has been overdeveloped all through the area. The gravel overlies highly fractured chert of 70-80 meters thick. There are 42 producing wells in the study area. They range in depth between few meters to about 40 meters. The yield of these wells ranges between 5 cubic meters per hour (m^3/hr) to more than 170m^3/hr. The amount of water withdrawn from this aquifer through these wells totals up to about 3 million cubic meters per annum. This quantity of water irrigates about 1500 dunums (one dunum = one thousand square meters). The main products of which are vegetables and fruits especially citrus and grapes.

Two water table contour maps were constructed. (Figures 4,5) The first represents the water table situation in 1962. The other was drawn to represent the water table shape in 1972. No major difference has been noted. The hydraulic gradient is steeper in the northwestern part of the area. The direction of water movement from the east, where groundwater discharges from the rich groundwater field of Dhuleil, and from the south where water as subsurface flow enters the aquifers from Amman region.

Floods in the wadis during the wet season forms an important source of recharge. Immediate response of the water table to flood occurrence has been noted by means of an observation well during a long term pumping test (Figure 6). This indicates that the gravel aquifer is immediately affected by any additional effluent in the wadi.

HYDROCHEMISTRY

Waste effluent from the Jordan Oil Refinery is the source of a complex pollution problem. An average daily flow of about 2500 cubic meters of industrial refuse is discharged from the Refinery into a separating pool in a nearby wadi (Wadi Sueida), where oil is separated and returned for processing, and waste water is discharged into the wadi bed. The effluent is contaminated by oil and chemical by-products, consisting mainly of sodium hydroxide, sodium sulphide, phenols and hydrogen sulphide.

The data upon which this report is based were collected at intermittent periods of time, throughout the last ten years. The samples were obtained directly from the wells concerned, and were analyzed for the common ions, copper, lead, oil traces, phenol, electric conductance and hydrogen ion concentration.

The first set of sample analysis is shown in Table 1-a. These samples were collected and analyzed in November 1962 before the rainy season. Table 1-a shows the chemical analysis of ten sampling sources (9 wells and 1 waste discharge pool) while table 1-b shows the chemical analyses of 5 sampling sources (4 wells and 1 waste discharge pool), these samples were collected and analyzed in February 1963, during the rainy season.

The following is a discussion of the main polluting ions in the groundwater of the shallow gravel aquifer.

Electric Conductance (E.C.) and Total Dissolved Solids

Water analysis before the rainy season in November 1962 indicates that the lowest electric conductance encountered was 420 mmhos and the highest was 1448 mmhos. The mean value was 708.3 mmhos.

In February 1963 after the rainy season marked increase in electric conductance values was revealed (Table 1-b). The lowest electric conductance value was 490 and the highest value was 5580, recorded at the waste water pool. The mean value was 1702 mmhos. These figures show that there has been an increase in dissolved solids in the groundwater of the shallow gravel aquifer wells in a real short period of time. No distinct trend in dilution is seen in the well samples before and after recharge. A variation of E.C. in waste water pond sample can be seen. An increase in dissolved solids from 797 ppm in November 1962 to 3570 in March 19663 was recorded.

Table 1-b shows that the sample derived from the waste pond is heavily contaminated with alkali, probably derived from caustic soda used in refinery operations.

In 1960 and before the Oil Refinery started operating, total dissolved solids in wells Nos. 6/25/17/27, and 6/25/17/22 were in the order of 425ppm and 640ppm respectively. In 1963, however, an increase in total dissolved solids continued until 1965. Nevertheless, a salinity decrease started after 1965.

Hydrogen Ion Concentration pH

The pH value of most groundwaters is controlled by the amount of dissolved carbon dioxide gas and the dissolved carbonates and bicarbonates in the mineral salts.

pH values of groundwater and waste water are shown in the tables enclosed. In Table 1-a, pH values of the samples taken in November 1962 ranged between 7.7 to 8.0. On the other hand pH values that were recorded in February 1963 ranged between 7.2 and 12.2.

An increase in alkalinity is very well noticed in the waste water pool sample (7.7 - 12.2).

pH values of wells Nos. 6/25/17/27, 28 and 6/25/17/3 and the waste water pool range between 7.8 - 8.6, it is more alkaline at the waste discharge stream. These pH values indicate a definite infiltration of alkaline materials from the waste water effluent.

Bicarbonates

The concentration of bicarbonates in natural and polluted waters is a function not only of the bicarbonates added, but also the temperature, pH and concentration of other dissolved solids. Bicarbonates in most of the samples analyzed have shown an increasing trend together with high values that may reach 349.5ppm (Well No 6/25/17/22). On the other hand the carbonate content has minimal values, depending on the pH value. Hence the concentration of bicarbonates is directly dependant on the pH value and the concentration of carbonates.

Excessive bicarbonates add to the salinity and total solids content of water. Direct contribution to alkalinity by hydroxides is rare in nature, and their presence can usually be attributed to water treatment or to contamination through industrial waste discharge. Hydroxides used in oil refinery are obviously directly contributing to the alkalinity of the groundwater.

Sulphates

Sulphates are dissolved from most sedimentary rocks or derived from the discharge of many of the various industrial waste products. The U.S. Public Health Service (1962) recommends that the sulphate concentration not to exceed 250ppm.

Sulphates concentration in the groundwater samples in the study area exhibit a variation in values with time, however the highest recorded value was 204ppm in Well No. 6/25/17/28 and 283ppm in the waste discharge stream, near Well No.6/25/17/27.

Chlorides

Chlorides are found in practically all natural waters, or they may be derived from industrial effluents, among which are oil refineries. Water for public supply is usually classified as "acceptable" if the chloride concentration is less than 125 mg/l "doubtful" if between 125 and 250 mg/l, and "unsatisfactory" above 250 mg/l (Water Quality Criteria 1963, p. 159).

Chloride limits, vary over a wide range. The source of the chlorides may be a more important factor for drinking water than their quantity. Any sudden increase in the chloride content of a supply should be suspected as a possible indication of pollution. In the present case, the source of excessive chloride is obviously the oil refinery effluent. The effect of chloride concentration on plant life is more pronounced. They are generally more toxic than sulphates to most plants and a tolerance limit of 100 mg/l of chlorides in irrigation water has been set.

Chloride concentration in the shallow gravel aquifer wells in the refinery area has been reported as ranging from as low as 137.38 to as high as 607.05ppm. The highest concentrations are found in the waste pools in surface water samples taken at Wadi Sueida and in nearby shallow wells.

Sodium

Owing to the fact that most sodium salts are extremely soluble in water, any sodium that is leached from soil or discharged to streams by industrial wastes will remain in solution. However some sodium may be removed by ion-exchange in the passage of groundwaters through certain soils. This is well explicit in the study area. Water samples taken from the waste discharge stream in Wadi Sueida, the waste ponds and the seepages to the wadi contain high concentrations of sodium reaching values as high as 368 ppm, while sodium concentration in the surrounding wells is far below this value. The attached tables show the sodium concentration in the above mentioned sampling sources. A remarkable sodium concentration of 460.00 is found in Well No. 6/25/17/22.

Sodium to Total Cations (Na%)

The extent to which an irrigation water might promote the loss of exchangeable Ca^{++} and Mg^{++} from the soil can be approximately predicted on the basis of the sodium percentage and the total concentration of dissolved solids.

Soils which have taken up sodium in exchange for calcium or magnesium are impaired in tilth and permeability. Groundwater in the Refinery area have extremely high Na%. The water of Wadi Sueida stream near Well No. 6/25/17/27 showed a Na% of 85.9 while groundwater of the well had a Na% concentration of 52.83. On the other hand Wadi Sueida water sampled near Well No. 6/25/17/22 had a Na% of 88.9 while water drawn from the well itself had a Na% of 84.03.

Copper and Lead

Traces of copper and lead have been found in groundwater and waste discharge samples. Copper was detected as traces and in certain cases in concentrations not exceeding 0.05 ppm. Table 1-b shows the concentration of copper in five sampling sources the highest value detected is 0.05 and the lowest is 0.01 while the mean is .02. These values are far below the tolerance limits set by the United States Public Health Services Drinking Water Standards (1.0 mg/l) and the World Health Organisation (W.H.O.). Drinking water standards WHO set a "permissible " limit of 1.0 mg/l and an "excessive" limit of 1.5 mg/l.

On the other hand lead was found in higher concentrations, but not exceeding 0.1 ppm. However "there is a feeling that 0.1 mg/l may cause chronic poisoning of the water if used continuously, especially among hypersensitive persons" (Water Quality Criteria, 1963, p. 207). The mandatory limits for lead in the United States Public Health Standards (USPHS) has been lowered to 0.05 mg/l in 1962, while, the WHO Internation Standards and WHO European standards, have set a tolerance limit of 0.1 mg/l.

Phenols

Phenols are waste products of oil refineries. Concentrations in the order of 0.01 - 0.1 ppm are detectable by taste and odour. Trace amounts approaching 1 ppb are detectably by taste and odour. Trace amounts approaching 1 ppb can impart an objectionable taste to water following marginal chlorination. Phenolic compounds can affect health, when present in concentrations above 0.05 ppm.

The presence of phenol in groundwater is indicative of its contamination by oil products. Samples from Waste Ponds No.2 and 8 and wells Nos. 6/25/17/27 and 6/25/17/22 were analyzed in 1968. It was noticed then that the concentration of phenol in waste pond No.2 from which waste water used be discharged directly to the wadi reached a concentration as high as 3.12ppm. On the other hand phenol concentration in Pond No. 8 was 0.07ppm. Wells Nos. 6/25/17/27 and 6/25/17/22 contained negligible concentrations of phenol.

In 1972, a number of sources were analyzed, among which was the waste pond. The highest phenol concentration was obviously detected in the waste pond water while the lowest was found in well No. 6/25/17/7. From the above discussion it can be noted that there has been a dilution of phenolic compounds as the surface water percolates through the soil to the very permeable aquifer material. On the other hand, phenol concentrations above 0.05ppm are present, thus rendering the groundwater unsuitable for domestic purposes. Traces of oil have been detected in certain sampling points, the amounts ranged from trace to fair amount.

As a result of this contamination two citreous orchards, irrigated by wells tapping this aquifer had to be abandoned and the Oil Refinery Company had to buy the farms in compensation .

The Effect of Main Supply Stream on the Groundwater Quality of the Shallow Gravel Aquifer.

The alkalinity content of groundwater drawn from the shallow gravel aquifer in the Refinery area can be attributed to the amount of hydroxides, carbonates, bicarbonates and certain mineral radicals. It is well known that alkalinity is dependant on pH, temperature and other prevailing conditions. As an example, the HCO_3^- content of the groundwater of wells No. 6/25/17/27 and 28 has increased by more than twoforld from 1962 to 1968. The CO_2

out of the Refinery processes and other carbon gases sources. Carbon dioxide dissolves in water to form HCO_3 according to the following reaction:-

$$H^+ + CO_3^{--} \longrightarrow HCO_3^{--} + H_2O$$

The increase in bicarbonate is probably due to the increased value of hydroxide from the Refinery treatment and their presence is indicative of contamination.

The pH values of the groundwater samples from wells tapping the shallow gravel aquifer is unstable, and value may reach about 0.45 pH units. This is probably due to the refiltration of certain minerals at times.

Unfortunately, dissolved oxygen and C.O.D. tests have not been performed, however, it is suspected that some organic matter is present in the wells surrounding the Wadi Sueida stream. Nevertheless, traces of oil have been detected in certain groundwater samples, this is obviously a direct contribution from the waste effluent.

In the absence of dissolved oxygen, sulphate ions may serve as a source of oxygen or as a hydrogen accepter for biochemical oxidation produced by anaerobic bacteria. Variations in sulphate ions in the groundwater of the study area may help in this case to explain this phenomenon, because when sulphates oxidise the organic matter, it produces sulphur and carbon-dioxide according to the following:-

$$SO_4^{--} + \text{Organic Matter} \ \frac{\text{Anaerobic}}{\text{Bacteria}} \ S^{--} + H_2O + CO_2$$

$$S^{--} + 2H \longrightarrow H_2S$$

Since the pH of the water is above 7.5 in all the groundwater samples, the formation equilibrium of H2S shifts rapidly towards the formation of unionized H_2S. Under such conditions, i.e. pH below 8, the partial pressure of H_2S becomes great enough to cause serious odour problems whenever sulphate reduction yields a significant amount of sulphide ion.

The discharge of some industrial waste into streams or groundwater reservoirs may considerably increase their chloride content. The increasing chloride content in the groundwater of the shallow gravel aquifer can be attributed to the waste effluent of the refinery. As can be seen from certain samples, the amount of chloride has been doubled (Wells Nos. 6/25/17/27 and 6/25/17/28) in a period of less than 5 years. This phenomennon indicates possible direct chloride contamination of the shallow gravel aquifer in the refinery area.

Chloride concentration can act as a tracer to check whether there has been a direct contribution from the polluting sources (waste ponds) to the shallow gravel aquifer.

Figure 8 represents the Chloride content from 1960 - 1968 in the waste pond, and groundwater samples taken from two shallow wells 6/25/17/27 and 6/25/17/22. There is a direct and parallel increase in chloride content in the three samples points.

Analysis of waste ponds water and groundwater show that chloride was the main anion while sodium was the main cation, and whenever there was an increase in total dissolved solids, there has always been a parallel increase in sodium chloride. This suggests that sodium chloride is used in the Refinery operations.

WASTE DISPOSAL AND TREATMENT

Waste water ponds of the Refinery constitute the main polluting sources in the area. There is a chain of eight ponds, two of which were built prior to 1965 and the rest of them after that date. The ponds serve the purpose of disposing of a great amount of petroleum compounds present in the waste effluent. The first pond is supposed to separate the sludge from the waste water, which then passes through the rest of the ponds. This process aerates the waste water and disintegrates the petroleum compounds without getting rid of the soluble salts. As mentioned earlier, the waste effluent flows in Wadi Sueida, with the result that the groundwater in the shallow gravel aquifer is badly affected. The rainfall in the area is rather low, 25-120mm per annum. The possibility of flushing the aquifer by local floods in the wadi is little.

As a solution to this problem, the Refinery had to buy the vicinity of the plant. Waste effluent after being freed from oil, is used for irrigation. It was noted that the trees surrounding the Refinery area, have attained average growth rate.

Recent analyses for phenols indicated its presence in amounts ranging from 0.06 to 0.55 ppm, which renders the water unsuitable for domestic purposes.

A very important side effect of this problem is that heavy pumping of the municipal wells tapping the deeper B2 (chert-limestone) aquifer has resulted in a reversal of the groundwater flow in the vicinity of the waste ponds. Thus, contamination of the deeper aquifer has indirectly occured. Moreover, contamination of the deeper aquifer due to direct percolation or seepage through the alluvium has also taken place.

It is recommended that a pumping set be installed at the A.P.I. separator, to pump the waste water through a steel pipeline to an evaporating pan to be installed at an appropriate place about 15kms. away from the plant, where the waste water is allowed to evaporate. The toxic effect of phenolic compounds should be destroyed through an efficient chemical and biochemical treatment involving oxidation by chlorine or ozone, or by a more efficient filteration and aeration process. These processes should be implimented at a very early stage right after separation.

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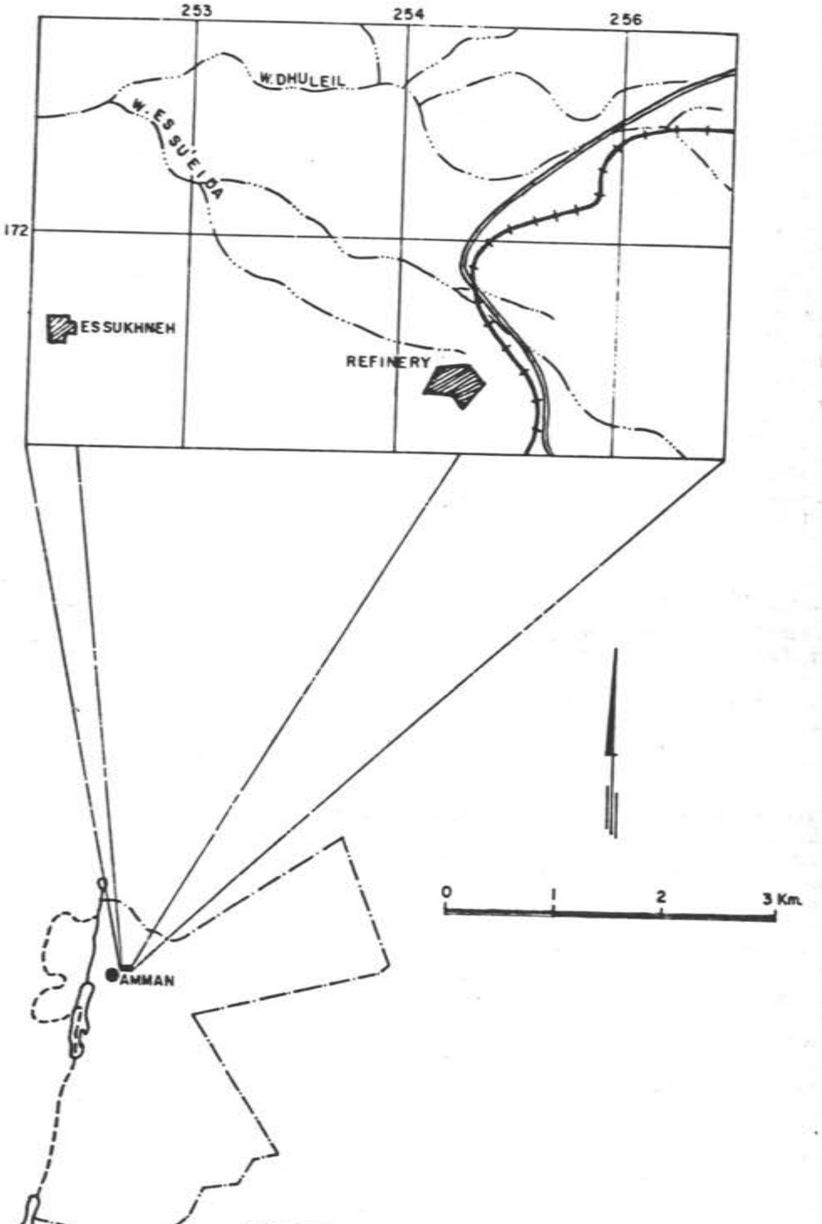
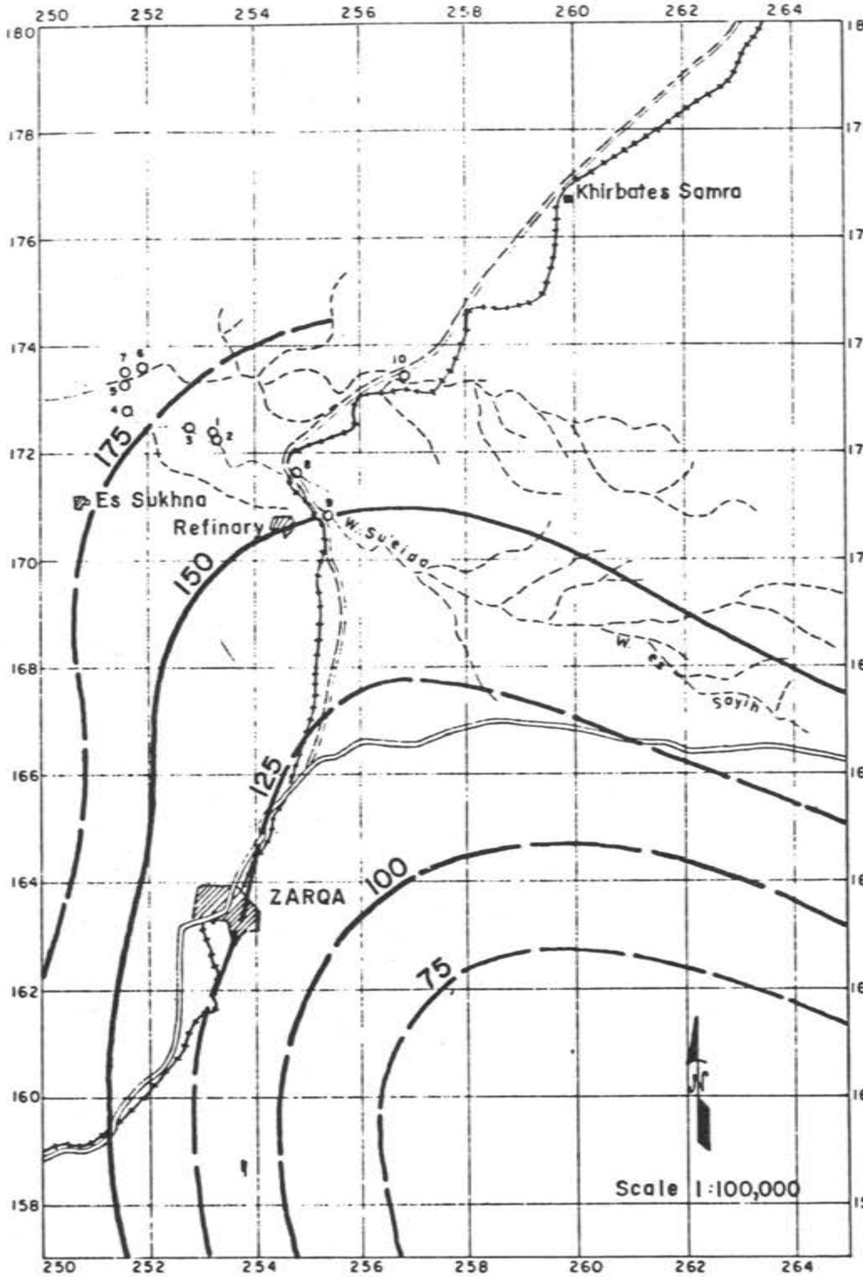
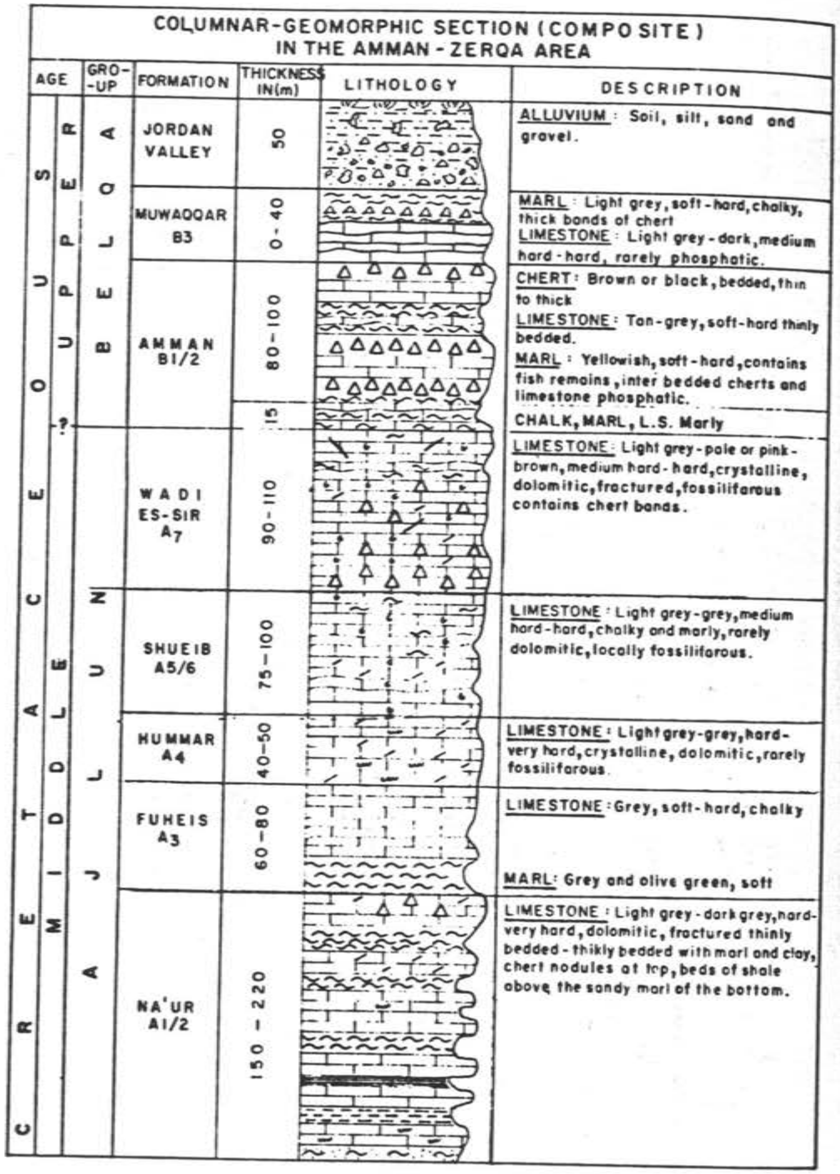


FIGURE 1. LOCATION MAP OF STUDY AREA



ISOHYETS OF 10 YEAR AVERAGE ANNUAL RAINFALL 1962 – 1972

FIG. 2

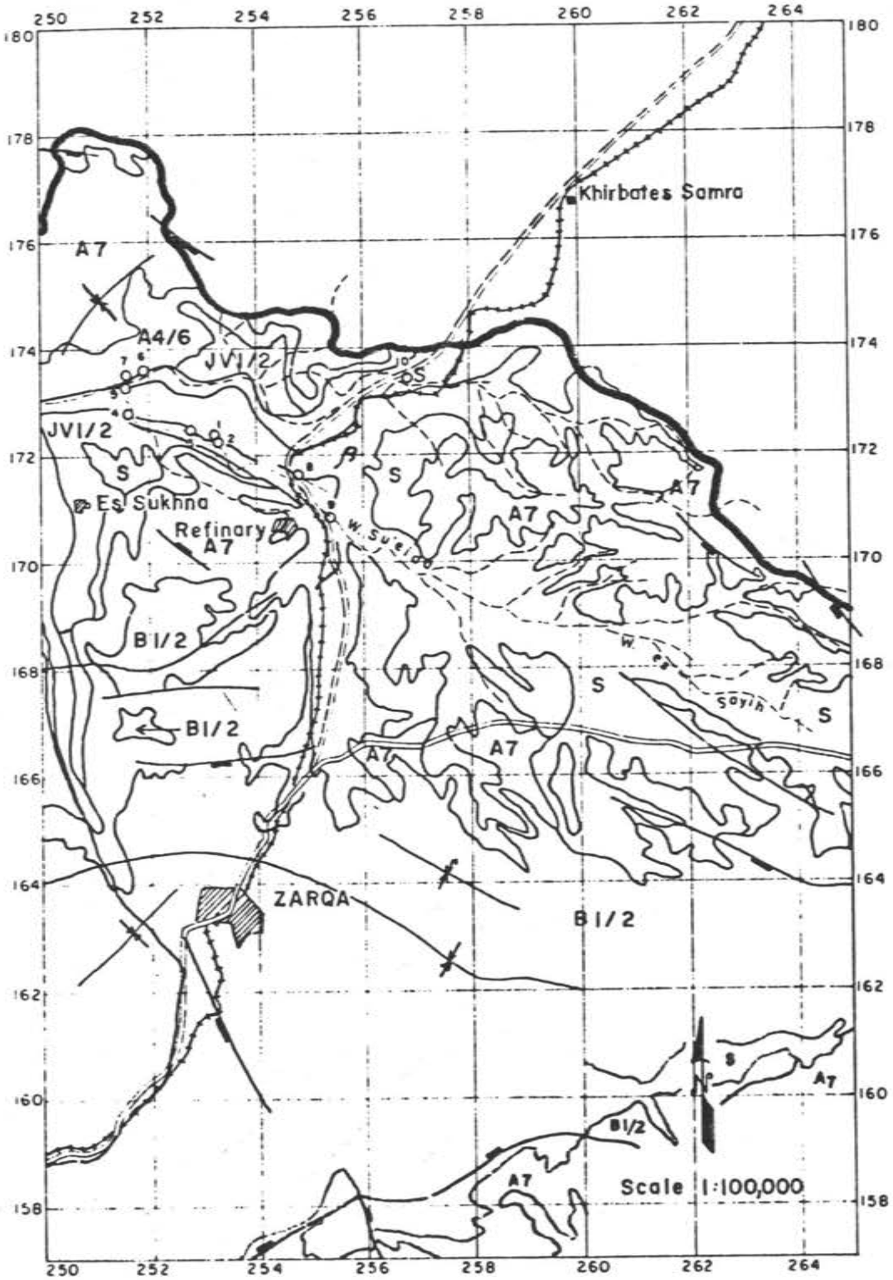


COLUMNAR-GEOMORPHIC SECTION (COMPOSITE)
IN THE AMMAN - ZERQA AREA

AGE		GROUP	FORMATION	THICKNESS IN(m)	DESCRIPTION
CRETACEOUS	UPPER	BELQA	JORDAN VALLEY	50	**ALLUVIUM** : Soil, silt, sand and gravel.
			MUWAQQAR B3	0 - 40	**MARL** : Light grey, soft-hard, chalky, thick bonds of chert **LIMESTONE** : Light grey - dark, medium hard - hard, rarely phosphatic.
			AMMAN B1/2	80 - 100	**CHERT** : Brown or black, bedded, thin to thick **LIMESTONE** : Tan-grey, soft-hard thinly bedded. **MARL** : Yellowish, soft-hard, contains fish remains, inter bedded cherts and limestone phosphatic.
	?			15	CHALK, MARL, L.S. Marly
	MIDDLE	AJLUN	WADI ES-SIR A_7	90 - 110	**LIMESTONE** : Light grey - pale or pink-brown, medium hard - hard, crystalline, dolomitic, fractured, fossiliferous contains chert bands.
			SHUEIB A5/6	75 - 100	**LIMESTONE** : Light grey-grey, medium hard-hard, chalky and marly, rarely dolomitic, locally fossiliferous.
			HUMMAR A4	40-50	**LIMESTONE** : Light grey-grey, hard-very hard, crystalline, dolomitic, rarely fossiliferous.
			FUHEIS A_3	60 - 80	**LIMESTONE** : Grey, soft-hard, chalky **MARL**: Grey and olive green, soft
			NA'UR A1/2	150 - 220	**LIMESTONE** : Light grey - dark grey, hard-very hard, dolomitic, fractured thinly bedded - thikly bedded with marl and clay, chert nodules at top, beds of shale above the sandy marl of the bottom.

V. SCALE 1:3000

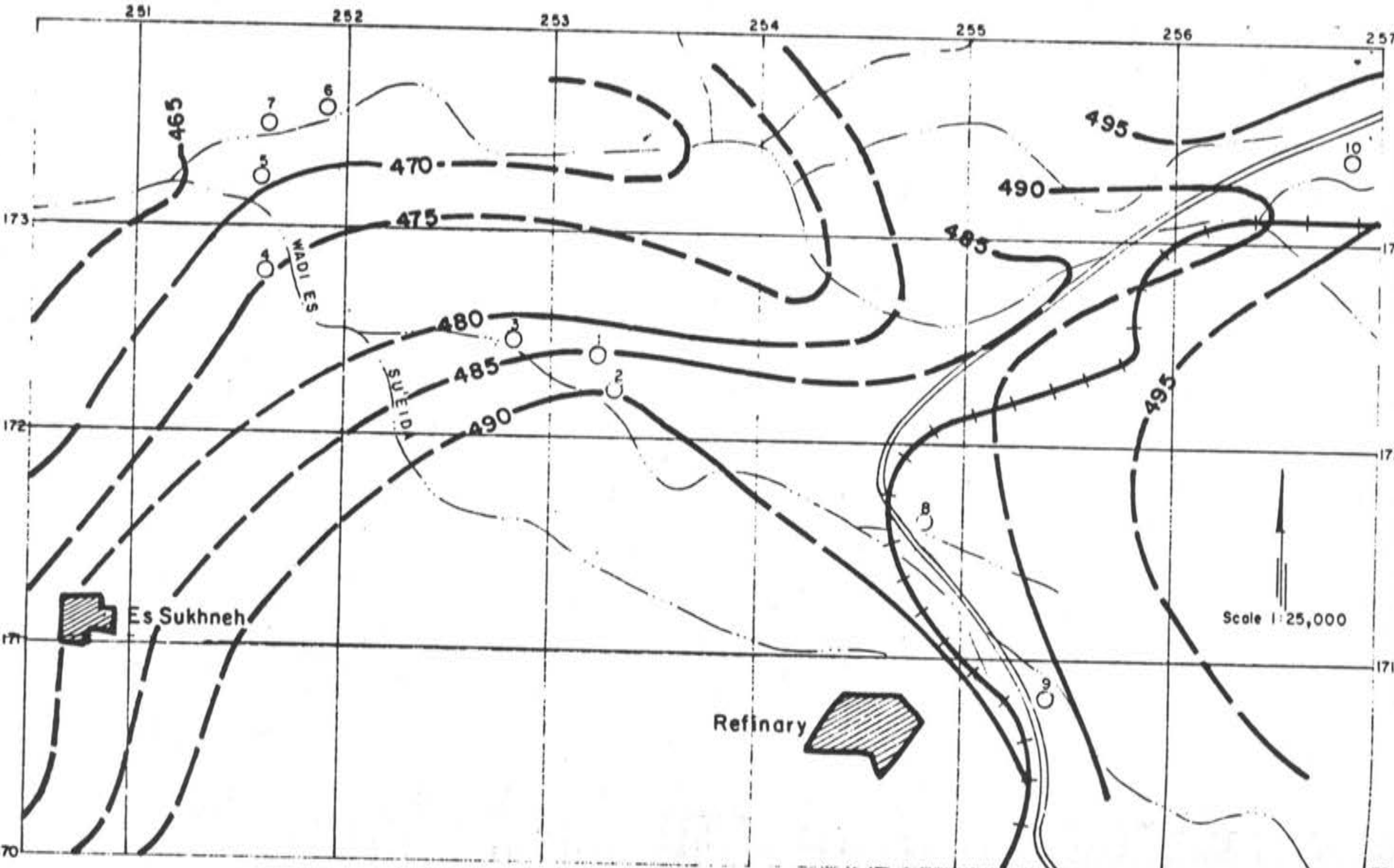
FIG. 3



GEOLOGICAL MAP

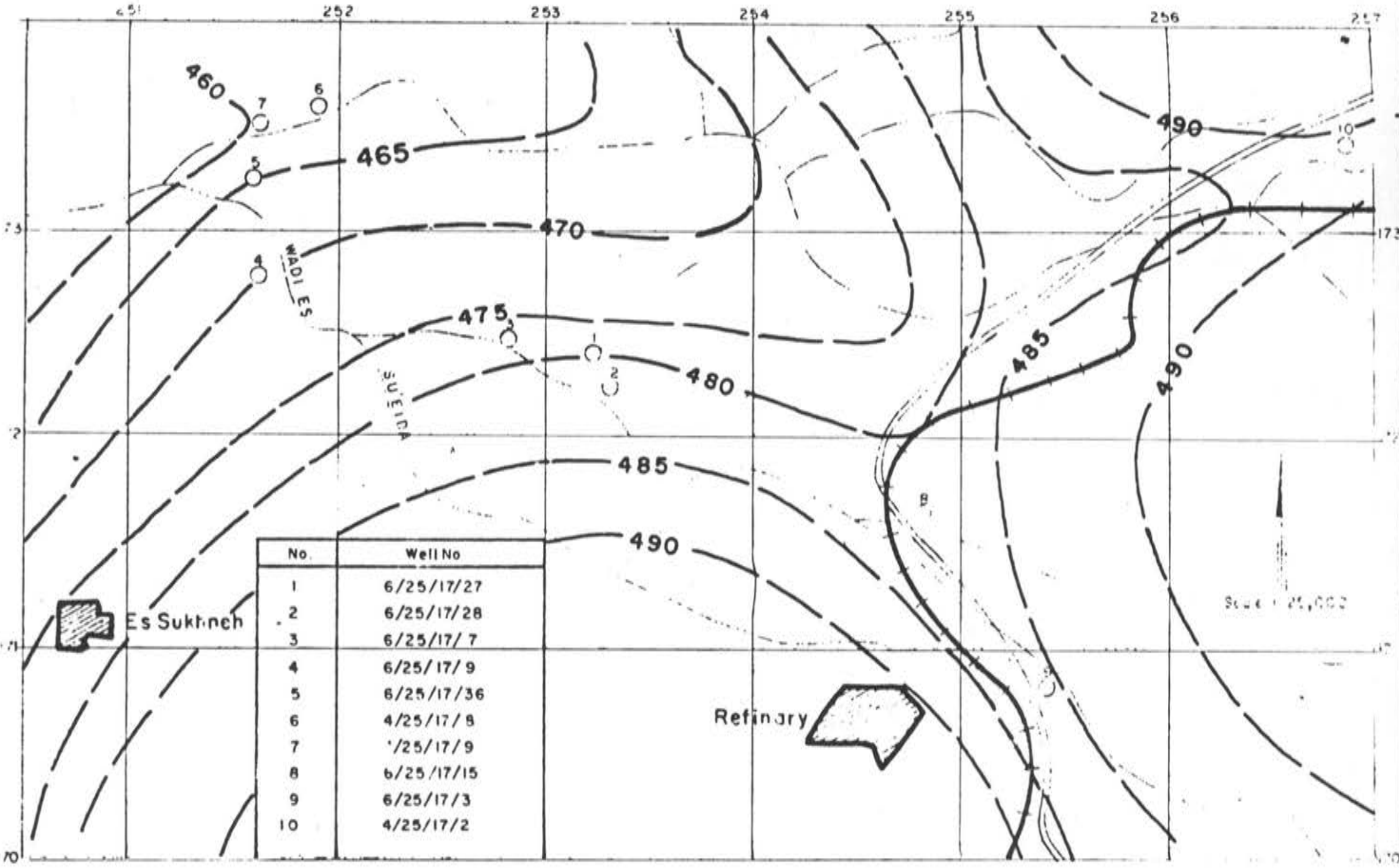
FIG. 4

Refis to Fig.3 for Explanation.



WATER TABLE CONTOUR MAP 1962

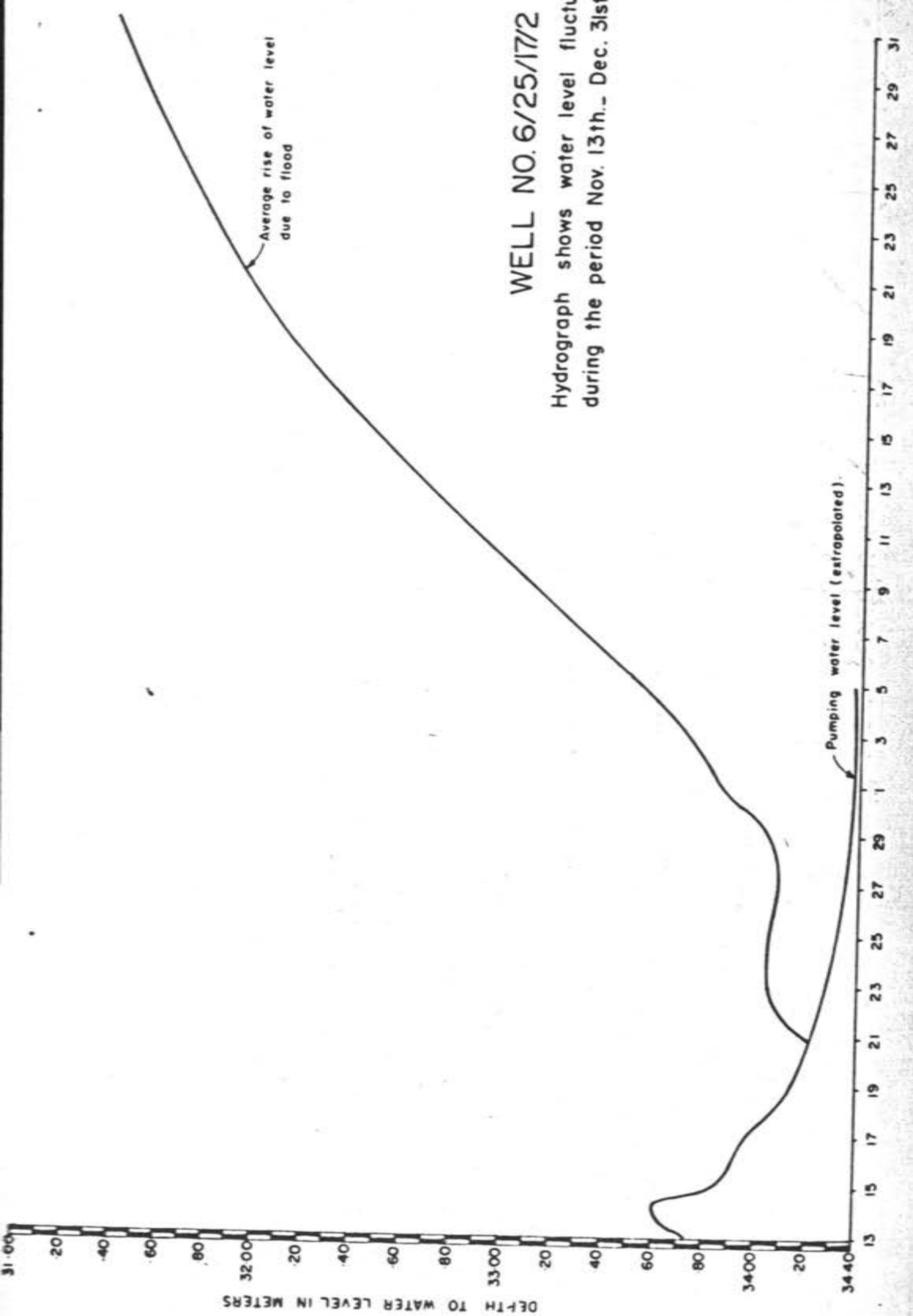
FIG. 5



No.	Well No
1	6/25/17/27
2	6/25/17/28
3	6/25/17/ 7
4	6/25/17/ 9
5	6/25/17/36
6	4/25/17/ 8
7	'/25/17/9
8	6/25/17/15
9	6/25/17/3
10	4/25/17/2

WATER TABLE CONTOUR MAP 1972

FIG. 6



WELL NO. 6/25/17/2

Hydrograph shows water level fluctuati
during the period Nov. 13th.– Dec. 31st. 19

FIG. 7

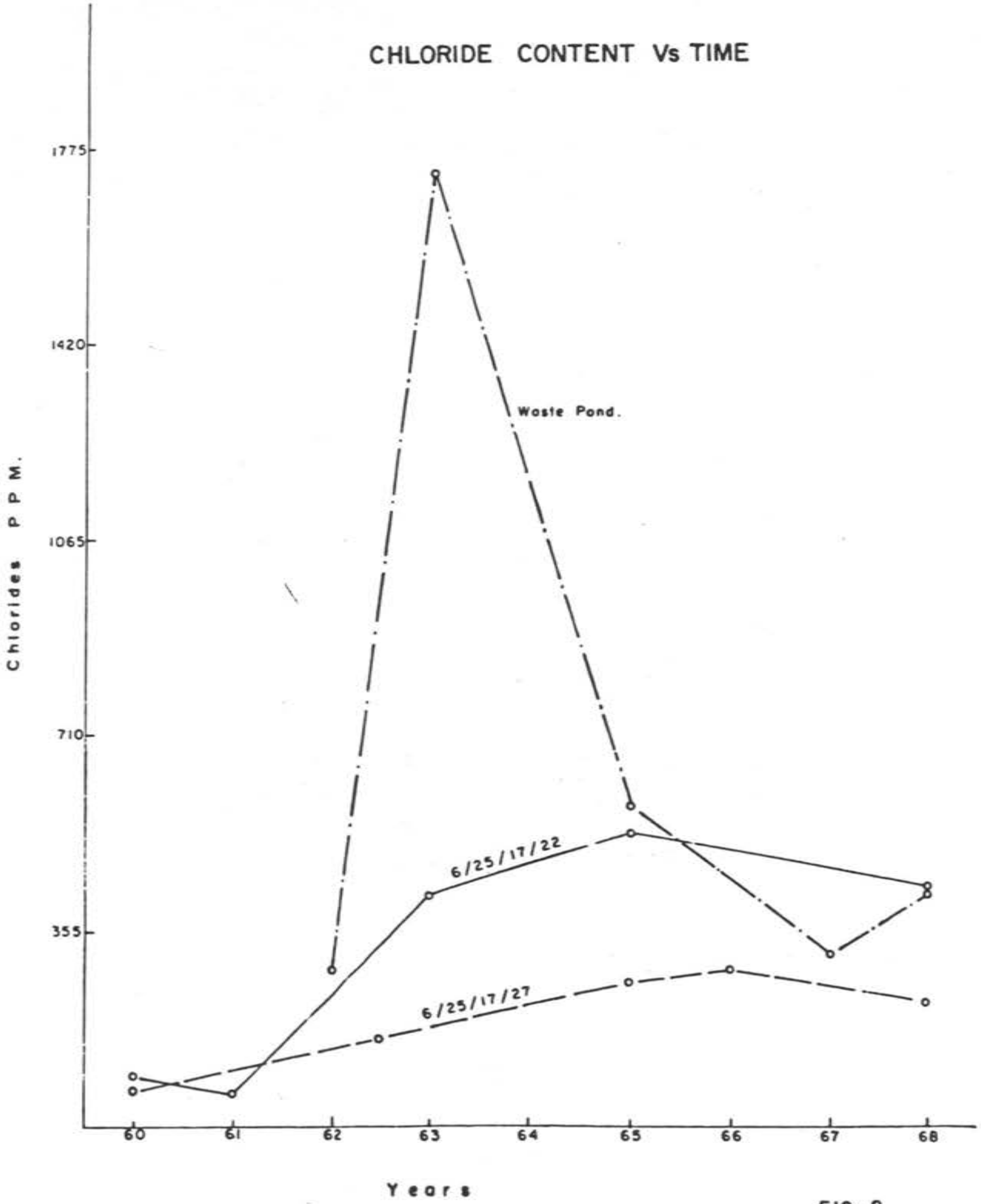


FIG. 8

Groundwater Analysis Before Rainy Season November 1962

Table 1-a

Well Number	E.C.	pH	CO_3	HCO_3	Cl	Ca	Mg	SO_4	Oil
4/25/17/9	475	7.7	5.0	188.0	61.0	38.0	18.0	38.0	Trace
4/25/17/8	433	8.0	-	151.0	54.0	26.0	17.0	31.0	Fair Amount
6/25/17/16	420	8.0	-	149.0	51.0	26.0	17.0	30.0	Fair Amount
6/25/17/36	539	8.0	-	178.0	78.0	57.0	12.0	41.0	Fair Amount
6/25/17/9	455	8.0	-	171.0	50.0	38.0	18.0	32.0	Small Amount
6/25/17/7	842	8.0	Trace	183.0	190.0	61.0	30.0	78.0	Fair Amount
6/25/17/28	758	8.0	Trace	159.0	160.0	57.0	29.0	76.0	Small Amount
6/25/17/22	1448	7.7	2.0	178.0	430.0	127.0	63.0	45.0	Fair Amount
Waste Pond	1246	7.7	-	200.0	240.0	39.0	18.0	116.0	Fair Amount
Hassiyah Spring	467	8.0	2.0	168.0	60.0	40.0	21.0	37.0	Fair Amount

Ground Analysis After Rainy Season March 1963

Table 1-b

Well Number	E.C.	pH	CO_3	HCO_3	Cl	Ca	Mg	SO_4	Cu	Pb	Suspended Solids	Oil
6/25/17/36	558	7.9	-	166.0	79.0	51.0	16.0	43.0	0.01	0.01	Fair Amount	Trace
6/25/17/9	490	7.2	-	208.0	50.0	43.0	15.0	34.0	0.02	0.1	Fair Amount	Trace
6/25/17/27	916	7.8	-	200.0	167.0	62.0	28.0	79.0	0.01	0.1	Small Amount	Trace
Waste Pond	5580	12.2	365.0	1016.0	1704.0	17.0	1.0	127.0	0.05	0.1	Fair Amount	Large Amount
6/25/17/7	966	8.1	-	186.0	197.0	63.0	27.0	76.0	0.01	0.1	Small Amount	Trace

Chemical Analysis of Groundwater in the Refinery Area

Table 2

Well No.	Date	E.C.	T.D.S.	Ca	Mg	Na	K	Cl	SO_4	CO_3	HCO_3	Na (%)	S.A.R.	pH
6/25/17/3	29-5-66	550	352	54.00	18.24	54.05	9.36	71.35	69.12	0.00	175.07			7.90
6/25/17/3	25-8-66	580	371	43.20	9.24	51.75	8.58	59.64	72.00	0.00	149.45	41.73	1.87	7.80
6/25/17/3	4-4-67	620	397	34.00	23.10	52.90	6.24	85.91	38.88	0.00	181.17	37.85	1.71	7.70
6/25/17/27	1960	611	391	44.00	17.02	-	-	64.00	67.20	-	176.90	-	-	-
6/25/17/28	1960	562	360	44.00	17.02	-	-	80.50	88.80	-	74.40	-	-	-
6/25/17/28	Nov. 62	758	-	57.00	29.00	-	-	160.00	76.00	Trace	159.00	-	-	8.00
6/25/17/27	March 63	916	-	62.00	28.00	-	-	167.00	79.00	-	200.00	-	-	7.80
6/25/17/27	8-11-65	1155	992	80.00	42.50	184.00	-	279.95	143.60	-	268.40	51.61	4.10	7.90
6/25/17/28	8-11-65	1600	1024	80.00	42.50	193.20	-	284.00	168.00	-	268.40	52.83	4.35	7.80
6/25/17/27	1966	1580	1011	85.20	86.50	156.40	11.70	254.90	110.40	-	414.80	47.00	3.50	7.90
6/25/17/27	1966	1610	1030	83.20	40.50	173.60	15.60	268.40	168.00	-	276.30	48.90	3.90	7.90
6/25/17/27	1966	1620	1037	87.40	40.50	173.60	13.60	272.90	206.40	-	262.90	48.40	3.80	7.80
6/25/17/27	1966	1610	1030	85.20	40.50	205.80	13.60	272.60	220.80	-	256.20	52.90	4.60	7.80
6/25/17/29	1966	1360	870	63.10	42.50	147.20	10.92	326.60	79.20	0.00	175.07	-	-	-
6/25/17/27	7-5-68	1280	819	69.40	36.11	143.75	7.80	226.80	146.40	-	214.11	-	-	7.57
6/25/17/7	Nov. 62	842	-	61.00	30.00	-	-	190.00	78.00	Trace	183.00	-	-	8.00
6/25/17/7	14-3-66	810	518.4	22.40	6.42	71.30	-	20.94	22.56	-	159.82	-	-	7.60
6/25/17/7	21-8-66	990	634	82.00	22.37	65.55	7.80	137.38	139.60	0.00	187.27	-	-	7.70
6/25/17/7	26-1-67	1000	640	72.00	38.48	71.30	6.24	163.99	83.50	0.00	214.24	-	-	7.70
6/25/17/7	3-4-67	1060	672	78.00	34.65	79.35	7.80	191.70	74.80	0.00	211.02	-	-	7.70
6/25/17/7	11-2-69	840	538	47.40	28.30	77.05	7.41	130.64	57.60	0.00	204.96	-	-	7.60
6/25/17/22	1960	1038	640	100.00	33.40	-	-	122.80	36.70	0.00	375.10	-	-	-
6/25/17/22	16-4-61	554	397	56.00	21.70	21.80	-	46.10	25.90	0.00	225.70	17.10	-	6.80
6/25/17/22	8-11-65	2400	1536	48.00	17.64	460.00	-	514.75	204.00	0.00	308.05	84.03	14.50	7.80
6/25/17/22	8-11-65	2600	1664	80.00	36.48	425.50	-	607.05	175.20	3.00	283.65	72.55	9.78	8.10
6/25/17/22	7-5-68	2020	1293	59.40	32.46	333.50	10.92	400.79	165.60	-	349.50	71.45	8.64	7.50

Chemical Analysis of the Polluting Sources in the Refinery Area

Table 3

Stream by 6/25/17/22	8-11-65	2780	1750	30.00	18.20	552.00	-	603.50	264.00	18.00	274.50	88.89	19.50	8.60
Stream by 6/25/17/28	8-11-65	2300	1472	32.00	19.45	448.50	-	472.10	283.20	12.00	189.10	85.90	15.40	8.50
Main Supply Stream	25-1-67	1320	845	36.00	21.80	217.35	18.72	209.45	194.40	7.50	173.85	69.16	6.80	7.90
Waste Water Pool No. 8	25-1-67	2020	1293	28.00	15.80	368.00	15.21	395.11	213.60	33.60	150.60	83.81	13.75	9.10
Waste Water Pool No. 8	25-1-67	2000	2000	26.00	18.24	368.00	16.77	390.50	206.40	29.70	166.53	83.64	13.50	9.02
Waste Water Pool No. 8	7-5-68	2000	1280	37.60	19.33	368.00	10.14	424.93	136.80	-	297.07	81.10	9.70	7.68
Waste Water Pool No. 8	7-5-68	1600	1024	41.60	17.99	276.00	7.80	318.79	115.20	-	281.82	76.71	9.00	7.48
Seepage to Valley	8-7-67	1540	985.6	33.60	17.87	264.50	21.45	266.25	187.20	12.00	210.45	75.65	9.20	8.90

Table 4

Phenol Concentration in Groundwater in the Vicinity of the Oil Refinery

Well No.	Date of Analysis	Phenol (ppm)
6/25/17/3	19-2-72	-
6/25/17/3	29-2-72	0.07
6/25/17/3	7-3-72	-
6/25/17/15	9-2-72	0.12
6/25/17/15	29-2-72	0.13
4/25/17/2	19-2-72	0.10
4/25/17/2	29-2-72	0.078
6/25/17/7	29-2-72	0.068
6/25/17/7	7-3-72	0.13
6/25/17/9	19-2-72	0.12
Saleh Ahmed	19-2-72	0.10
Saleh Ahmed	29-2-72	0.15
Waste Pond	29-2-72	0.55

LE PROGRES TECHNOLOGIQUE DU DESSALEMENT DE L'EAU DE MER AU KOWEIT

par

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L'absence totale d'aucune source naturelle d'eaux de surface et la disponibilité limitée des eaux souterraines propres à la consomation signifient que le Koweit a du s'en remettre presque entièrement au dessalement de l'eau de mer pour satisfaire ses besoins en eau potable.

Cette dépendance pour la survie de l'Etat a conduit à la construction par étapes successives du plus grand complexe mondial de dessalement de l'eau de mer par le procédé "Flash", avec une capacité installée de 52 millions IGPD. En outre, un projet de 2 unités de 5 millions IGPD doit être commissionné fin 1975.

Après des années d'expérience opérationnelle dans le domaine du dessalement de l'eau de mer, le Ministère de l'Electricité et de l'Eau a pu ainsi former une équipe d'ingénieurs spécialisés. Les spécifications techniques des installations de distillation du Ministère prévoient l'intégration de tous les perfectionnements possibles, permettant ainsi d'équiper les unités en service de fournitures à haute fiabilité et d'une grand efficacité.

Prévoyant le développement considérable des projets pour la satisfaction des besoins en eau à Koweit, Le Ministère de l"Electricité et de l'Eau, en coopération avec l'Organisation des Nations Unies, a établi en 1968 un "Centre pour le Developpement des Ressources en Eau".

Ce Centre se trouve concerné par les différents projets actuellement entrepris, les études économiques de calcul du coût du dessalement de l'eau de mer, la rédaction des programmes pour le contrôle par ordinateur des performances thermales de toutes les installations existantes, le calcul de la capacité optimum à installer au Koweit, l'extraction de la saumure dégagée par le dessalement, des sous-produits chimiques et minéraux et enfin le contrôle en laboratoire de la pollution de l'eau de mer.

Le Centre a rassemblé des données fiables et opérationnelles et établi des comptes rendus par l'installation pilote à osmose inverse, il a en outre une expérience dans le domaine des installations à l'Electrodialyse, il a enfin entrepris des études théoriques sur les possibilités de l'énergie solaire en matière de distillation de l'eau.

Le Centre a exécuté des essais sur le traitement à l'échelle industrielle de l'eau de mer destinée a l'alimentation des installations, en vue de réduire l'incidence de l'encrassement "et de l'entartrage" des surfaces d'échanges calotifiques des évaporateurs MSF. Le contrôle de la corrosion a toujours été un problème important, c'est pourquoi les essais continuent sur de nouveaux matériaux, sur les peintures métalliques et les procédés l'enduction du métal, etc.