

GEOLOGY , HYDROLOGY AND WATER QUALITY OF DISI – MUDAWARRA AQUIFER SYSTEM IN JORDAN

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Abstract- *The Disi aquifer, which is the sole source of water for Mudawara Area, is one of the most permeable and productive Sandstone aquifers in the Jordan . The aquifer is composed of rock units overlaying the basement complex of the Precambrian ERA are subdivided into two groups :the upper group is called Khreim group ,and the lower group is the Rum group. These formation ,are Saleb ,Burj ,Umm Ishrin ,Disi ,and Umm Sahm formations. The khreim Group consists from bottom to top of Shal Suwaan ,Um Tarifa ,Trabeel ,Batra and Alna Formations .The rock formations constituting theRum group compose the Rum aquifer system , which is dominate fresh water aquifer system in southern Jordan which the rock formations constituting the Khreim group represent the confining layer where sahl suwaan formation occur. The Rum aquifer system represents an unconfined aquifer system in the area in which no deposition of khreim group occurring and it represent a confined aquifer system in the area where khreim group overlies the Rum sandstone deposits. The large transmissivity of the Disi aquifer is indicated between 531-8630 m² /day of yielding wells and the storage coefficient in range 0.0197-0.0249 ,the specific capacity between 163.29-700.70 m³/day/m . The obtained results were found to be correspondent to unconfined nature of in the encountered aquifers in x1,x2,x4, x5,x6,x7,x8 ,and y1 ,y2,y3,y4 wells, and this is clearly indicated in the storage coefficient (specific yield) of this aquifer in these wells. The water quality is excellent and acceptable for drinking purposes, according the Jordanian water standard 2008, and Eu drinking water standard 1998.The Disi aquifer system, which corresponds to Rum aquifer system of recent nomenclature of Natural Resources Authority of Jordan. The different hydraulic characteristics of this aquifer either in the confined or in the unconfined area of the aquifer were summarised the well location, total depth, to static water level, ground elevation, aquifer depth, discharge (m³ /hr) permeability, turbidityand sandcontent ,electrical conductivity . The Khreim group consists of two main parts :The lower most part overlying the Rum Group aquifer consist of Shal suwaan shale forming a confining layer of the Rum aquifer ,and the upper part which consists of a heterogeneous sequence of intrbedded fine grained Sandston, siltstones and silty shale where this part as a result of the constituents represent a leaky layer .The thickness of the second part(leaky layer) ranges between 400 m and 1200 m. The transmissivity ranges between 112 and 4143 m²/d, and the horizontal permeability ranges 0.7 and 4.1 m/d .The water quality of the Khreim leaky aquifer as documented .*

Keywords –: *Aquifer ,Disi ,Mudawarra , storage coefficient ,turbidity , electric conductivity, water quality*

I. INTRODUCTION

DISI –MUDAWARRA AQUIFER SYSTEM .

Based on the outcrop geology of the Mudawarra Southern ground water basin in Jordan ,the different rock units overlying the basement complex of the Precambrian ERA are subdivided into two groups :the upper group is called Khreim group ,and the lower group is the Rum group . These formation ,are Saleb ,Burj ,Umm Ishrin ,Disi ,and Umm Sahm formations. The khreim Group consists from bottom to top of Shal Suwaan ,Um Tarifa ,Trabeel ,Batra and Alna Formations . The rock formations constituting theRum group compose the Rum aquifer system , which is dominant fresh water aquifer system in southern Jordan which the rock formations constituting the Khreim group represent the confining layer where sahl suwaan formation occur . The rest of the formations from a leaky aquitard containing relatively highly saline water. The Rum aquifer system represents an unconfined aquifer

system in the area in which no deposition of khreim group occurring and it represent a confined aquifer system in the area where khreim group overlies the Rum sandstone deposits (haiste and scott Wilson 1995).¹

II. GEOLOGY AND HYDROGEOLOGY OF DISI – MUDAWARRA :

According to the rock formations in southern Jordan fig (1). The Precambrian basement complex represents the base of the Rum aquifer system . The Rum aquifer system presents an unconfined aquifer in the areas between where it directly verlies the basement and it directly underlies the Khreim Group fig (1) . Generally , the Disi –Mudawarra area (fig .1) is bisected by many faults with different directions . The two major directions are Northwest –Southeast and Northeast – Southwest and the two minor fault systems are in the direction of North –South and East –West . The inter – relationship between the aquifer and khreim aquitard is represented in a simplified

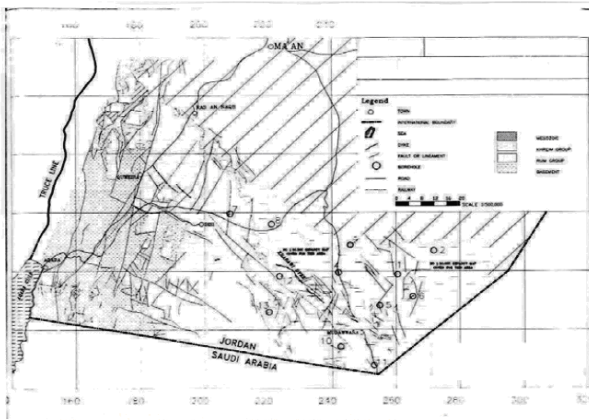


Figure 1: Geology of the Disi-Mudawarra area (Source: Haiste and Scott Wilson, 1995)

Hydrogeological cross section (fig2) . The Rum group is extended to the south where it is exposed in Saudi Arabia and similarly forms unconfined and confined aquifer systems

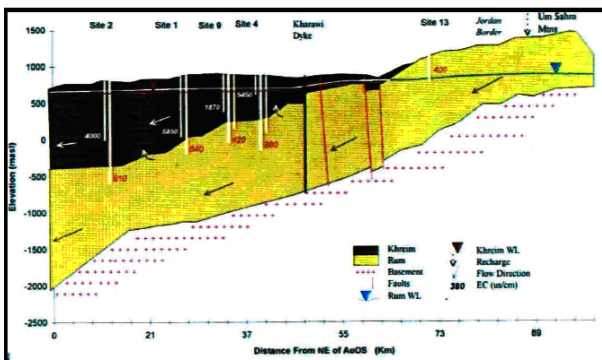


Figure 2: Simplified hydrogeological cross-section showing the inter-relationship between Rum Aquifer and Khreim Aquitard (Source: Haiste and Scott Wilson, 1995)

The Rum aquifer system in southern Jordan is extended into Saudi Arabia where it is known as Sag aquifer system and both actually form one aquifer system . (haiste and scott Wilson , 1995) 2 Generally , the groundwater flows from the Saudi Arabia in the south towards North East Jordan in central Jordan it deviates to north west and lastly towards west where it discharges its water in the dead sea and in the deep Wadis draining the eastern highlands towards the Rift Valley fig (3) .

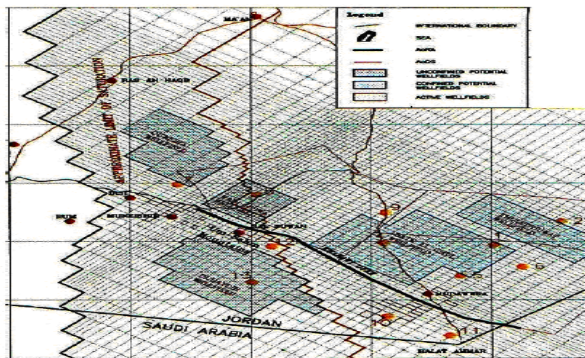


Figure 3: A generalized groundwater flow of the Rum Aquifer in Saudi Arabia, Southern and Central Jordan (Source: Haiste and Scott Wilson, 1995)

The most important feature of the Rum aquifer is its homogeneity in the grain size of different formations constituting the aquifer except local lateral finer grains especially in umm sham formation . The total thickness of the rum aquifer is about 1200m , and this thickness is usually decreased towards its marginal exposure in the west . A confining layer , the Haswa shale of khreim group , overlies the Rum aquifer . The thickness of this confining layer is almost uniform of 50m. The rest of formations of the Khreim group represent a leaky layer of a thickness ranging between 400m and 1200m and normally contain saline water.

III. AQUIFER SYSTEM

In the area located between Disi and Mudawarra there are many wells drilled during the last five decades . Most of these wells were drilled during the last two decades. The abstracted water from these wells are used for domestic industrial purposes for Ababa ,domest local communities distributed all over the area and most of the abstracted amount is used for agricultural purposes utilized by many agricultural companies such as Rum company, Gramco , Wafa and Arab agriculture company presents the total amounts that were abstracted from the wells and distributed all over the area for different purposes during the last 6 years . (scott wilson) . The abstracted amounts from the Disi – Mudawarra area were taken from both the unconfined aquifer in Disi –Sahl Suwaan area , and the confined aquifer in the Mudawarra area.

III.1 Dubaydib well field

Due to the nature of the water quality that occurs in the confining layer of the Rum aquifer , the study conducted by brown and root suggested locating the well field to produce the necessary amount of water in Dubaydib . As mentioned before , the water quality in this area is considered excellent water and there is no deposits of Khreim group present in the area where the water occurs in unconfined conditions

For more emphasis on the nature of the aquifer and water type present in Dubadydib well filed area , three wells were located and drilled under the supervision of (scott Wilson company 2002) . Two wells of these three wells were drilled and tested and the third one is drilled as an observation well in Dubaydib area. A summary of these wells is presented in table (1) .The Disi Mudawarra to Amman Water Conveyance system Project ,were drilled 55

duction wells ,and 9 piezometric wells (observations)in the Dubaydib wells filed.

he hydraulic characteristics of the aquifer encountered in the x1 ,x2, x3 x4, x5, x6, x7, x8 and y1 ,y2 , y3 ,y4 wells were calculated from the well testing -production and observation wells supervised by all companies in project .(2011.2012, 2013) . The obtained results were found to be correspondent to unconfined nature of in the encountered aquifers in x1,x2,x4,x5,x6,x7,x8,and y1 ,y2,y3,y4 wells, and this is clearly indicated in the storage coefficient (specific yield) of this aquifer in these wells . x1,y1(x1 0.0197 and 0.00987 for y1 with the specific yield of Disi unconfined ,which confirmed with the previous studies UNDP (1972) , Humphreys (1976) and Scott Wilson (1995) which were 0.07- 0.1 ,0.001-0.36 and 0.1 respectively and recent studies (Scott Wilson. 2002) , it is noted that the recent values are smaller . This is attributed to the lithological nature of Disi aquifer in the area of Dubaydib where it contains traces of kaolinite and

micaceous silt interrelated the medium to coarse cleanPar sandstone . The x3well is drilled in Dubai did of the area where the aquifer is confined in nature . In the locality of x3 well ,the confining layer of the Khreim Group is the Haswa formation ,which is composed of shale ,sandstone and claystone of about 100 m in thickness. Due to this the calculated storage coefficient of the aquifer in x3 is (0.0200) represents a confined aquifer . The y2 well, containing layer of the Khreim group is Haswa formation consists of mudstone and confines the Rum aquifer in the northeastern of the project area , where there are outcrops

of umm Sahm formation, the aquifer is unconfined. The piezometric surface in the water level depth between 200 m below ground level (8) . The hydraulic conductivity ranges from 1 to 4 m / day . The hydraulic characteristics of the Rum aquifer obtained from the drilled wells . The results on water quality are also consistent with the water quality of the unconfined aquifer of Rum group . The water quality changes of the two production wells (x3 and x4) during SRPT , presented in Tables (2 , 3) water quality changes of x3 during the pumping test .

Table.1 Hydrogeological summary of recently drilled wells in Dubai did Area

wells	Aquifer system	Borehole type	Depth mbgl	Transmissivity m ² /d	Storage coefficient	Specific capacity m ³ /d/m	Water level mbgl	Water aquifer	
								Ec	Ph
X1	Rum un confined	test production	500	5080	0.0197	609.98	117.82	350-400	7
X2	Rum un confined	Test production	511.5	531- 1860		281.66	126.05	508-478	7.53
Y1	Rum un confined	Observation piezometric	400	_____	0.00987	_____	139.33	350-400	7
X3	Rum confined	Test production	500.7	4430-7970	0.0200	580.89	146.62	286	7.83
X4	Rum un confined	Test production	503	5270-8630	0.198	700.70	136.20	323	7.73
Y2	Rum un confined	observation	400	_____	0.00987	_____	158.37	350-459	7
x5	Rum un confined	Test production	502	1927-2454	0.0199	560.51	141.07	310-345	8.075
X6	Rum un confined	Test production	552.9	231.75-1026	0.0249	163.29	126.92	352-383	7.3
Y3	Rum un confined	observation	442.5	_____	0.0140	_____	172.0	1304-383	7.32
X7	Rum un confined	Test production	550.9	356 – 824	0.0247	132.19	117.80	363-369	7.54
X8	Rum un confined	Test production	550.9	1180-1200	0.0247	521.85	99.81	382-384	8
Y4	Rum un confined	Observation	420	_____	0.0118	_____	127.70	625-633	7.92

Table (2) water quality x3 during pumping test

Parameter	Unite	Results	
		1 sample	2 sample
Electrical conductivity	µs/cm	383	352
Temperature	C°	22.1	22.1
PH	-	7.79	8
Turbidity	NTU	2.38	0.3
Ca	Mg\L	37.30	28.40
Mg	Mg\L	6.12	5.22
Na	Mg\L	30.49	16.00
K	Mg\L	1.71	1.20
Cl	Mg\L	28.8	20.8
SO4	Mg\L	17.52	15.63
HCO3	Mg\L	102	94
NO3	Mg\L	8.5	9
Iron	Mg\L	<0.23	<0.1 5

Table (3) water quality x4 during pumping test

Parameter	Unite	Results		Results	
		1 sample	2 sample	1 sample	2 sample
Electrical conductivity	µs/cm	296	276	323	329
Temperature	C°	21.1	21.2	29.2	29.3
PH	-	7.97	8	8.07	7.92
Turbidity	NTU	1.7	0.3	0.3	0.4
Ca	Mg\L	27.3	28.40	30.4	29.4
Mg	Mg\L	4.96	5.22	5.2	5
Na	Mg\L	16.52	16.00	18.67	17.79
K	Mg\L	1.20	1.20	1.3	1.2
Cl	Mg\L	20.8	20.8	24.8	23.4
SO4	Mg\L	15.63	15.63	20.51	18.09
HCO3	Mg\L	92	94	113	109
NO3	Mg\L	9.6	9.5	12.2	12.2
Iron	Mg\L	<0.05	<0.05	<0.05	<0.05

These two tables (2,3) shows that water quality changes of the production wells , during pumping test duration . These two tables (2,3) shows that water quality is excellent and

acceptable for drinking purposes, according the Jordanian water standard 2008, and Eu drinking water standard 1998.

III.2 Disi aquifer system

The Disi aquifer system, which corresponds to Rum aquifer system of recent nomenclature of Natural Resources Authority of Jordan, was intensively explored since mid sixties, during the early stage of exploration; the unconfined aquifer was examined and exploited for local utilization and later for the different uses for Aqaba. In the present time, the Disi- Mudawarra to Amman water conveyance project needs to drill 55 production wells and nine observation wells. The abstracted amounts of water are used for drinking. The total amounts that were abstracted from the wells, Range between 100.10⁶ million m³/ year. The abstracted amount from the Disi- Mudawarra area was taken from both the unconfined and confined aquifer area. Throughout the pumping test of drilled wells during the different periods, the hydraulic properties of this aquifer were determined by studies carried out in the well field, beside the pumping test, laboratory measurements and Geophysical log interpretation. The different hydraulic characteristics of this aquifer either in the confined or in the unconfined area of the aquifer are summaries in table (4)

Table (4) . This table present the well location, total depth, to static water level, ground elevation, aquifer depth, discharge (m³ / hr) permeability or transmissivity.

The water level decline was very changeable as indicate in the observation wells distributed in the unconfined area of the Rum aquifer system. The water level carried in the observation wells 127, 172..37 , 158.37,139.33 are presented in table.4

The piezometric surface in the project area is between 720 and 740 m amsl, which corresponds to water level depths of between 100 and 200 m below ground level. The hydraulic conductivity ranges from 1 to 4 m/day. Groundwater quality in general is good with Total Dissolved Solids (TDS) around 200 – 300 mg/l. These values correspond electrical conductivity (EC) values around 350 – 400 µS/cm, and pH values around 7. The available water level recorded in the observation wells are not the same in figure (4,5)

Table 4

well No	SWI m	Turbidity NTu	EC hs/cm	PH	Discharge l/s	Sand content PPM	Aquifer type
Y1	139.33	-	357 - 395	7.66 - 7.86	5-6 Ll/s	1.77 1.39 0 0	Unconfined
Y2	158.37	48.32 22.50 13.50 0.00	1304-1160 350-459	7	6 l/s Over a period of 9days	37.00 31.00 14.60 8.71 3.40 1.70 0.3300	unconfined
Y3	172.37	47.50 22.70 11.90 6.10 2.79	1304-383	7.32	2.1 and 4.15 l/s Over a time of around 70hrs	0.2, 0.010 0.00, 0.010 0.00	Unconfined
Y4	127.	1.09 0.04 0.00	625- 633	7.92	6.45 and 8.7 l/s	65.0, 25.40 278, 0.55 0.27, 0.22 0.00, 0.44 0.00, 0.00	Unconfined

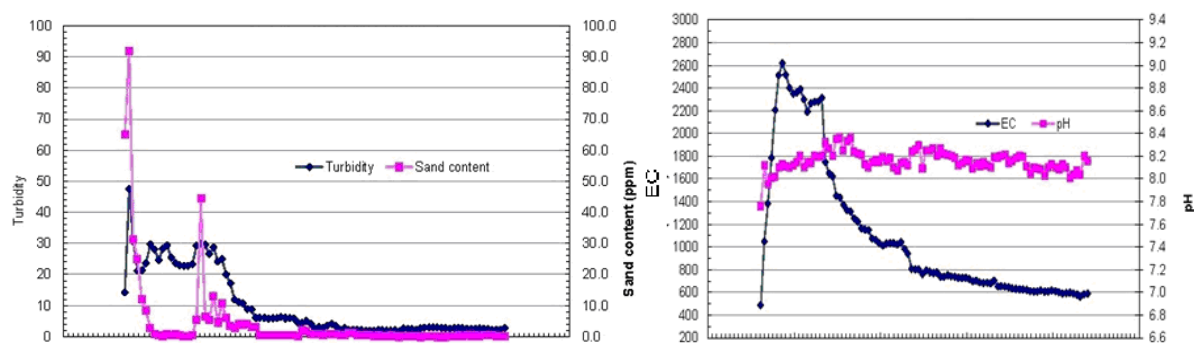


Figure. 4 , 5: EC-pH and Sand content values during the airlift development

Table5: Results of Water Sample Analyses

Parameter	Unit	Laboratory Results			Jordanian Drinking Water Standard 2008	EU Drinking Water Standard 1998
		of sample taken on				
		sample	sample	Sample		
		1	2	3		
Electrical Conductivity	µS/cm	625	633	--	2500	
pH	--	8.28	7.56	--	6.5 – 8.5	
TDS*)	mg/l	450	374	--	1000	
True colour	CU	--	25			
Hardness	mg/l	118	254	--	500	
Alkalinity	mg/l	114	136.5	--	--	
Calcium	mg/l	36.47	35	--	--	
Magnesium	mg/l	6.69	8.18	--	--	
Sodium (Na+)	mg/l	78.89	71.42	--	200	
Potassium (K+)	mg/l	1.17	1.7	--	--	
Ammonium (NH4+)	mg/l	< 0.1	<0.2	--	0.2	
Chloride (Cl-)	mg/l	88.4	91.5	--	500	
Sulfate (SO42-)	mg/l	38.88	34.51	--	500	
Bicarbonate (HCO3-)	mg/l	139.08	167	--	--	
Nitrate (NO3-)	mg/l	4.58	5.9	--	50	
Carbonate (CO32-)	mg/l	0	0	--	--	
Ortho Phosphate	mg/l	0.07	0.07	--	--	
Fluoride (F-)	mg/l	0.33	0.2	--	1.5	
Sulfur (S2-)	mg/l	< 0.2	--	--	--	
Iron (Fe total)	mg/l	0.44	5.64	--	1.0	
Iron (Fe2+)	mg/l	--	1.07	--	1.0	
Manganese (Mn total)	mg/l	0.95	1.18	--	0.1	
Manganese(Mn2+)	mg/l	--	1.06	--	0.1	
Aluminium (Al3+)	mg/l	--	1.06	--	0.1	
Lead (Pb+2)	mg/l	0.01	0.031	--	0.01	
Cadmium	mg/l	< 0.003	< 0.001	--	0.003	
Arsenic	mg/l	< 0.005	--	--	0.01	

The pH is of major importance in determining the corrosivity of water. The value of PH range between 7.56 to 8.28. In general, the lower the pH, the higher the level of corrosion. However, pH is only one of a variety of factors affecting corrosion (3–8). Table(5) Shown electrical conductivity is indicative of the total dissolved solids (TDS 375- 450 mg/l in the water .These values correspond electrical conductivity (EC) values around 625 –633µS/cm, Table. 6 show for the first sample, the sum of anions is 5.69 meq/l and the sum of cations is 5.84 meq/l giving a ionic balance of 1.29 %. The second sample the sum of anions is 6.16 meq/l and the sum of cations is 5.58 meq/l giving an ionic balance of -4.91 %. For details of ionic balance calculation methodology, refer to American Public Health Association (2005). From the inorganic constituents, in both water samples iron and manganese have concentrations above their respective threshold value.

Table6: Sum of meq/l of anions, cations and calculated ionic balance

Sample No	Anions sum (meq/L)	Cations sum (meq/l)	Ionic Balance (%)
1	5.69	5.84	1.29
2	6.16	5.58	-4.91

One of the most important characteristics of the water resources of the Rum aquifer is the limited water quality variation either in the aerial or vertical distribution of the aquifer. The water quality available is presented in table (7). Selected quality of one ground water production wells during development and redevelopment are shown in figure (6)

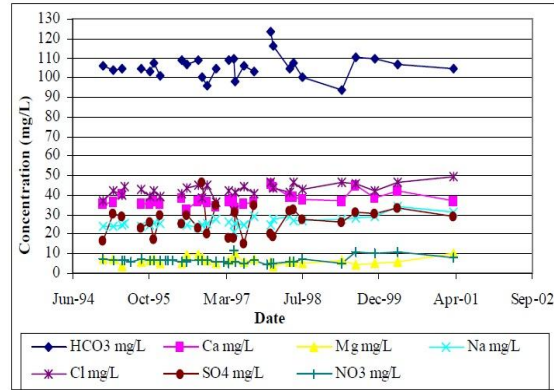


Figure 6 . Water quality of DiSi- Mudawarra ground water resources .

Table (7) Water quality of DiSi- Mudawarra ground water resources

Well No	Samples	EC µs/cm	PH	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Cl mg/l	HCO3 mg/l	SO4 mg/l	NO3 mg/l	CO2 mg/l	TDS
X1	1	343	7.61	35.92	6.28	17.91	1.40	23.50	108.0	18.81	12.50	113	188
	2	366	7.83	33.96	6.14	17.20	1.30	23.0	109.0	23.75	13.80	102	216
X2	3	494	7.61	37.20	6.80	65.30	6.2	68	141	21.52	8.7	130	296
	4	513	7.54	37.8	7	57.3	2.1	57.8	-	21.75	9.9	105	318
X3	5	296	7.97	27.30	4.96	16.52	1.20	20.8	92	15.63	9.6	175	190
	6	276	8	28.40	5.22	16.00	1.20	20.8	94	15.58	9.5	111	166
X4	7	323	8.07	30.4	5.2	18.67	1.3	24.8	113	20.51	12.2	128	222
	8	329	7.92	29.4	5	17.79	1.2	23.4	109	18.09	12.2	125	202
X5	9	345	8.22	35.9	5.64	21.2	1.6	20.7	123	-	10.4	121	209
	10	310	8.51	37.97	5.6	20.72	1.7	20.3	116	-	10.8	111	187
X6	11	383	7.66	37.20	6.12	30.49	1.71	37.55	-	17.52	9.89	80	260
	12	352	7.79	37.33	6.12	23.32	1.83	29.11	-	17.28	9.48	107	227
X7	13	352	7.55	32.84	6.41	31.22	1.5	40.6	49.09	27.24	7.2	104	200
	14	363	7.54	33.44	6.44	30.37	1.5	39.9	50.77	27.14	7.2	101	204
X8	15	372	8.02	37.44	6.34	28.64	1.62	40.19	-	31.18	7.83	119	207
	16	376	7.96	37.40	6.27	28.69	1.52	39.44	-	29.10	7.88	105	208

Measured parameter	Results	Normal range
EC	685 ---- 41.300	2000---- 11.000
PH	6-65___11-5	7.1--- 8.0
temperature	23---- 40	
c0		
ca (mg / L)	20 ___ 40	
Mg (mg\l)	12 ---- 588	
Na(mg\l)	115 ---- 588	
k (mg\l)	8--- 39	
Cl (mg\l)	167—3300	
so4 (mg\l)	43—2980	
Hco3 (mg\l)	92—530	

The water quality of the khreim leaky aquifer varies indicated in. the lowest recorded value of EC and consequently the contents of the other constituents were found to be just above the upper boundary of the Rum group . This is attributed to the dilution effect from the underlying run aquifer , which has a piezometric head much higher than the Khreim leaky aquifer.

IV. CONCLUSION

Disi- Mudawarra area could still be considered a viable area for a ground water demonstration project. The area has an abundance of excellent quality ground water. The ground water supply from the aquifer Disi Mudawarra to Amman Water Conveyance system Project ,were drilled 55 production wells . The electrical conductivity ranged between 329and 494 $\mu\text{s}/\text{cm}$. These values correspond to 227and 318 mg/l of total dissolved solids .Generally ,the EC-values of the ground water resources of the Rum confined and unconfined aquifer range between 276 and 513 $\mu\text{s}/\text{cm}$.

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