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A LOGICAL SOLUTION FOR WATER-LOGGING PROBLEMS IN SIWA DEPRESSION, WESTERN DESERT, EGYPT.

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Siwa depression is receiving a considerable attention from the governmental authorities and private sector for agriculture, tourism and social development. It has abundant ground water naturally flowing from more than 150 springs and 1250 shallow and deep wells. The total discharge of water reaches about 250 million m^3 $year^{-1}$. This depression has four main ponds into which excess surface and drainage water flows. The cultivated areas have progressively increased from 2000 ha in the eighties of the last century to about 4500 ha nowadays. Most of the new areas lie at high locations relative to the old ones.

Siwa depression is a closed basin. The excessive irrigation by relatively highly saline water, high soil infiltration rates and high seepage cause persistent water-logging and soil salinity problems.

Two main alternatives have been proposed to solve water-logging problem viz. i) disposing drainage water out of the depression to one of the nearest depressions, such as Qattara or Tabaghbagh. ii) discharging drainage water within the depression by pumping into the existing ponds and salt-flats areas (Sabkhas).

In the current work, SPOT satellite images were used to estimate the areas of the existing ponds, wet and dry Sabkhas and the cultivated land. Water losses via evaporation and evapotranspiration were calculated. The study concluded that the use of the existing ponds and their surrounding wet Sabkhas to evaporate drainage water is the preferable solution, even after horizontal agricultural expansion.

Keywords: Remote sensing, Siwa depression, Water-Logging, evaporation ponds, vertical drainage.

PHYSICAL SETTING

1- Location and Topography

Siwa is a closed depression located at 65 Km east of the Egyptian-Libyian borders and 300 Km south-west of Matrouh city. It lies between longitudes 25° 16′ and 26° 12′ E and latitudes of 29° 06′ and 29° 34′ N. The total area of the depression reaches 1100 Km^2. It is bounded on the north by an escarpment its elevation about 100 m above the depression floor. The great sand sea borders it from the west and the south with an elevation of 25 to 50m. The depression floor lies at 21m bsl where four saline water ponds (lakes) are located at the western portion of the depression .Such ponds are Al-Maraki, Al-Zeiton (the largest one), Aghormi and Siwa. In the far east of the depression there are minor ponds, Timera and Al-Maaser. Agricultural activity in the far east areas is very limited compared to the other areas.

2- Climate

The climate of the depression is hot and dry in the summer and fall seasons whereas it is warm and dry with occasional cold night in the winter. The average maximum temperature is 38°C during August and the average minimum one is 4.6°C during January. Rainfall is negligible (on the average of 10 mm/year). Humidity is low (30-55%). Northern to north-eastern calm wind prevails most of the year. The maximum wind speed is about 11m/sec . Evaporation ranges from 17.5 mm/day in June to 5.20 mm/day in December.

3- Water resources

Ground water is the only water source in Siwa Depression. Mudallal (1991), Abdel-Mogheeth *et al.* (1995) and Gad (1999) stated that ground water comes from three main aquifers; which are under artesian head. Their waters are naturally flowing and can be classified as:

a) The upper limestone aquifer, about 200-250m thick, belongs to the Middle Miocene period. Such aquifer can also be subdivided into three horizons from top to bottom as:
   - Highly weathered limestone, at 5-20m below the surface. Its water salinity is 2500 ppm.
   - Fractured limestone at 70-130m depth. The water salinity is 1700 ppm.
   - highly fissured limestone at 150-250 depth. Its water salinity is ranging from 6500 to 7000 ppm.

b) The lower limestone aquifer, lies directly under the Miocene rocks. Its average thickness is 3500 m. It belongs to the Eocene period. Its water salinity ranges from 6500 to 8000 ppm.

All drilled and dug wells (1250 wells) tap the shallower layers of the Miocene aquifer while spring waters (about 200springs) are naturally formed from the Eocene and / or lower layers of the Miocene aquifers.

c) Nubian sand -stone aquifer

This aquifer has an average saturated thickness of 200m at more than 700m depth. It is characterized by high discharge rate (450m^3/h/well compared to 20 and 35 m^3/h/well for the above two aquifers). Its quality is excellent (200 ppm). Ten deep wells (at 1000-1200m depth) were drilled in this aquifer.

4- Land use and irrigation practices

The cultivated area in depression is continuously increasing owing to the surplus of water and land resources as well as population. In 1962, the cultivated area was 800 ha. It reached 1500 ha in 1977 according to The Arab Organization for Agriculture Development (AOAD), (1977). At present it is estimated to be about 4200 ha according to the Desert Research Center (2003). Olives and Palm orchards occupy 85% of the cultivated area. Few areas are cultivated with citrus, apricot, pomegranate and vegetables, while alfalfa is usually intercropped with the newly cultivated orchards.

Basin irrigation method (4×4 or 5×5m) prevails. Irrigation intervals vary from one to two weeks and the depth of water applied at each irrigation is estimated as 7.5 cm (Shatanawi, 1991). This indicates that the amount of water applied throughout the year reaches about 26000m^3/ha, which is extremely higher than the irrigation requirement for the cultivated crops in the Nile valley area, even under approximately similar conditions to that in the oasis at the depression concerning saline water irrigation and climatic factors. This situation led to excessive deep percolation and water-logging problems.

WATER-LOGGING AND DRAINAGE PROBLEMS

Although the problems of water-logging, drainage and consequently soil salinity are as old as irrigation, they are continuously increasing and became very serious. This situation resulted from the excessive use of ground water via the expansion of drilling wells (more than 1250 well), and the continuous flow of springs with low quality water. Also, the unplanned agricultural expansion especially in areas having relatively higher levels than the old cultivated ones and the excessive application of irrigation water caused seepage and run-off towards the low-lying old lands. These factors, beside the presence of impermeable layer at 2 to 5m depth created a permanent water- table at depths varying between zero and 1.5m. During the period from 1987 and 1998, the average annual rise of water-table in the cultivated areas approached 4cm, (Gad, 1999). This means that water-logging problem is continuously increasing and threatens the agriculture and socio-economic development.

As mentioned above, Siwa depression is a closed one and there is no outlet to discharge the excess water away. The drainage network comprises of arbitrary made open field and sub-main ditchs connected to four main drains. These main drains discharge their water by gravity beside the excess flow of water from springs, wells, and tail irrigation water to the nearest pond of the four main ones, in the depression. In this respect, Abdel Mogeeth *et al.* (1995) estimated the amount of applied water as 152.2×10^6 m^3 y^{-1}. Water consumption by plants and drainage water reaches 107.7×10^6 m^3 y^{-1}. Hence, excess water causes water-logging is 44.5×10^6 m^3 y^{-1}. Therefore, water level in the drains is often very close to the soil surface. This problem is more acute in winter than in summer season owing to the lower evaporation capacity and plant consumptive use during the former than the latter season. Such phenomenon is evident by the considerable fluctuation in water-table level.

PROPOSED SOLUTIONS FOR WATER-LOGGING PROBLEM IN SIWA DEPRESSION

Few alternatives have been proposed to solve the problem of water-logging in Siwa depression. Such proposals are still debatable, they are categorized under two approaches. The first advocates transfer of excess water outside to the nearest depression (Al Qattara), especially Tabaghbagh area in its vicinity which is at -70 m bsl at 80 Km south-east of Siwa depression (Kandil, 2002). This will require the construction of waterway to carry out water, from Siwa, Aghromi ponds and Maraki ponds, to Al-Zeiton ponds, where appropriate lifting station should be established to pump water up-hill (+40 m). Thereafter, water flows via gravity to Tabaghbagh depression. This proposal is opposed owing to its high cost (Fig 1).

Another alternative intends to get red of the excess water inside Siwa depression. Such approach includes:

a) Vertical drainage

This solution has been raised as a result of some observations on the presence of cracks and cavities in geological formation at 300-500m depth. Therefore, it is assumed that drilling wells to such depth could be used to discharge the excess drainage water into this layer. Nevertheless this alternative is raised on the basis of elementary remarks and involves the risk of contaminating the ground water resources. It may also be expensive (Arar, 1991).

b) The use of excess drainage water to irrigate new lands. This proposal based on the fact that the quality of drainage water is not much different from that of the irrigation water (DRC, 1998). Moreover, it can partially blends with the naturally flowing good quality water of the deep wells which tap the Nubian sandstone aquifer. A pilot project including 125 ha has been executed to investigate such alternative in which drainage water

(2500-3000 ppm) feeding Aghormi pond was diverted via a canal to a sump from which water is lifted to a reservoir designed to allow mixing drainage water with fresh water or using such waters on alternative basis (Shatanawi, 1991).

The Desert Research Center (1998) has adopted a biological drainage project aimed to alleviating the water-logging and salinity problems in the oasis. Such approach depends upon cultivating forest trees which are characterized by their extra-ordinary extraction of soil water (250000 trees of selected eucalyptus sp. and other timber sp.) around the drains feeding Aghormi and Siwa ponds. The project also involve the re-use of drainage water either blended or not, for biological stabilization of sand dunes and cultivating field crops in order to reduce the amounts of disposed water. Such approach resulted in minor influence on controlling the level of water-table in the agriculture areas, which is a prerequisite for solving the water-logging problem in the oasis.

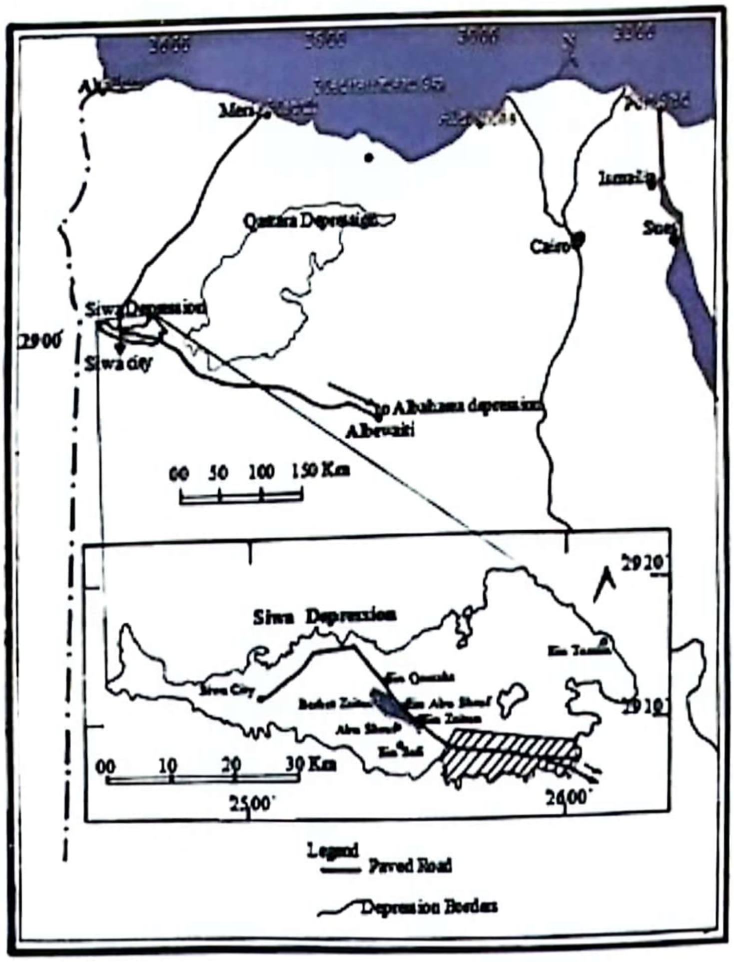

Fig (1). Map Showing Location of Siwa Oasis and Qattara Depression.

c) The use of the existing ponds and their surrounding sabkhas as outlets for discharging the drainage water which is advocated in this investigation as the most suitable solution to solve water-logging problem. It entails pumping the drainage water from the main drains, in the vicinity of the ponds in order to lower the water level in the drains to at least 1.50m below the ground surface. In this way drainage water from field drains, which should control the water-table level at about 1.0m deep, could naturally flow to the main drains and eventually pumped to be evaporated in the ponds. This means that the area of ponds alone or together with their surrounding sabkhas should be sufficient to evaporate the expected incoming drainage water.

To estimate the areas of ponds, Sabkhas and the cultivated land, 1:25000 topographic maps and landsat TM 1998 satellite image, which cover the study area, were used. The topographic maps and the landsat images were enhanced in such a way to discriminate the different terrestrial features. The land cover map was produced from the interpretation of TM 1:100000 landsat image. Their areas were then calculated.

The obtained data reveal that the total cultivated area reaches 4407.3 ha. (Table 1). About 70 to 80% of such area lies along high elevation. The areas of ponds and wet sabkhas are 10625 and 57267 ha aproximately, respectively. The data also indicate that in Maraki and Siwa areas, where the problems of water-logging and salinity are exacerbating, the ratio between the cultivated land and ponds areas reaches 1:1.25 and 1:1.29, respectively. Such ratio reaches 1:4.8 in Aghormi and Al zeiton and 1:3.7 all over the depressions. Evidently the areas of ponds plus wet sabkhas are much more than the agricultural areas.

The potential evapotranspiration (ETo) was estimated from the mean meteorological data for the period from 1931 to 1993 submitted by the Egyptian Meteorological Authority (1993), using the modified Penman formula according to FAO (1977). The consumptive use (ETc) for Palm and Olive orchards which occupy 50 and 35% of the cultivated area, as well as for other crops, e.g. vegetables, alfalfa,…etc., which occupy the rest of the cultivated land were calculated using the recommended crop coefficients for each growth stage of such crops as stated by FAO (1977). The obtained average values of ETc are 4.7, 3.4 and 5.1 mm/day for palm, olive and annual crops, respectively, with a weighted average of 4.3 mm/day.

As for irrigation requirement, it is important to mention that in Siwa depression irrigation water contains relatively high salt levels (2000 to 3000 ppm), which entails high leaching fraction and frequent irrigation resulting in high water losses and hence lower irrigation efficiency to about 45%. Therefore, irrigation requirement approaches 9.6mm/day and the amount of water disposed to the ponds reaches 5.3mm/day since weighted average ETc is 4.3 mm/day. Evidently, such rate is more or less equal to the minimum evaporation rate during December (5.2 mm/day). These results could be confirmed by the studies of Abdel Mogheeth *et al.* (1995) on water budget for Siwa depression. They pointed out that the excess amount of water causing water-logging problem in the cultivated area was estimated at that time for 3800 ha as 44.53×10^6 m^3, indicating that the depth of water to be disposed approaches 3.2mm/day. Now, it is concluded that the area required to evaporate the excess drainage water is equal to the cultivated area.

Table (1). Estimated areas (ha) of ponds, wet & dry sabkhas and cultivated land for different locations of Siwa depression.

Location	West of Siwa oasis				Western portion of Siwa depression								Eastern portion of Siwa depression	Total area (ha)
	Al - Maraki				Siwa				Aghormi and Zeiton				Al-maaser and Temira	
Contour level / Terrestrial feature	Above -15 m	-15 to -18 m	Below -18 m	total	Above -15 m	-15 to -18 m	Below -18 m	total	Above -15 m	-15 to -18 m	Below -18 m	total	Above -15m	
1- Ponds	-	-	917.0	917.0	-	1171.0	1045.60	2216.6	-	668.9	5403.6	6072.5	1419.0	10625.1
2- Wet sabkha (with shallow water cover)	99.5	226.9	131.0	457.4	81.5	657.4	34.6	773.5	345.1	1095.1	138.4	1578.6	2917.3	5726.8
Σ (1) + (2)	99.5	226.9	1048.0	1374.4	81.5	1828.4	1080.2	2990.1	345.1	1764.0	5542	7651.1	4336.3	16351.9
3- Dry Sabkha	252.0	325.9	49.1	625	454.6	688.2		1142.2	3719.7	8857.4	-	12577.1	11693.4	26033.7
4- Cultivated land	536.6	199.5	-	736.1	1339.0	376.1	-	1715	1078.6	514.3	-	1592.9	363.3	4407.3
Ratio between cultiv. Land: ponds	-	-	-	1:1.25	-	-	-	1:1.29	-	-	-	1:3.8	1:3.91	1:2.41
Ratio between cultiv. Land: ponds + Wet Sab	-	-	-	1:1.87	-	-	-	1:1.74	-	-	-	1:7.80	1:11.9	1:3.7

From the above mentioned results, it is evident that the water-logging and salinity problems in Siwa depression is the absence of a suitable drainage network to convey excess water to drains, from which it has to be pumped to the nearby ponds. In some cases, the construction of dykes is required to protect the low-lying cultivated areas in the vicinity of the ponds from becoming inundating wherever the water level rises. It is also needless to mention that if the appropriate drainage network is constructed and the areas of wet sabkhas around the ponds are used as drainage outlets, it is expected that there will be no water-logging problems even after the horizontal expansion of irrigated agriculture provided that such expansion is directed to the east of Al-Zeiton ponds. In addition to the high ratio between the area of the ponds to the cultivated land, Al-Zeiton pond acts as hydraulic barrier and hence protect the low-lying agricultural areas in Aghormi from seepage and tail water losses. In this respect, the estimated maximum areas for horizontal expansion of irrigation agriculture in the oasis ranges between 8000 and 12000 ha.

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الحل الأنسب لمشاكل الغدق بمنخفض سيوة - الصحراء الغربية – مصر

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يعتبر التوسع الزراعي – الرأسي والأفقي – أحد التحديات والمتطلبات الأساسية التي تواجه مصر في سعيها نحو الوفاء بإحتياجات الزيادة المضطردة في اعداد السكان. وفي مجال التنمية الزراعية نالت سيوة وهي إحدى المنخفضات المغلقة في الصحراء الغربية بمصر إهتماما خاصا من كل السلطات الحكومية والقطاع الخاص – وذلك لتوافر كميات كبيرة من المياه الجوفية المتدفقة ذاتيا من أكثر من ١٥٠ عين طبيعية وأكثر من ١٢٥٠ بئرا سطحيا إلى جانب بعض الآبار العميقة – ويقدر إجمالي التصرف من هذه المياه حوالي ٢٥٠ مليون متر مكعب سنويا – ويوجد بالواحة أربع برك رئيسية تنساب إليها الكميات غير المستخدمة من هذه المياه إلى جانب مياه الصرف الزراعي – حيث تتبخر هذه المياه – وتحت هذه الظروف زادت مساحة المناطق المنزرعة من حوالي ٢٠٠٠ هكتار خلال ثمانينيات القرن الماضي إلى حوالي ٤٥٠٠ هكتار حتى الآن ومعظم هذه الزيادات في مساحات الأراضي يقع على منحدرات مرتفعة نسبيا عن مناطق الزراعات القديمة.

وحيث أن سيوة – تعتبر من الناحية الجغرافية والجيولوجية – حوض مغلق أي بدون أي مخرج يسمح بصرف المياه الزائدة لذلك فإن التدفق المستمر للمياه الجوفية والإفراط في كميات مياه الري وقصر الفترة بين الريات بسبب ملوحة المياه والرشح من المناطق المرتفعة قد أدى إلى تفاقم مشاكل غدق وملوحة الأراضي ؛ مما أصبح من المتعذر معه إستدامة الإنتاج الزراعي فضلا عن تداعياته البيئية والإجتماعية الأخرى.

وقد أقترحت حلول كثيرة لحل مشكلة الصرف بالمنخفض منها:

١. نقل المياه الزائدة خارج سيوة إلى أحد المنخفضات الأخرى القريبة ومن أهمها منخفض القطارة أو منخفض تبغبغ.
٢. صرف المياه الزائدة داخل منخفض سيوة إما عن طريق الصرف الرأسي أو الصرف عن طريق الضخ إلى البرك والسبخات بغية التخلص منها عن طريق التبخير .

وفي هذا البحث إستخدمت صور الأقمار الصناعية لحساب مساحات البرك ومساحات السبخات المغمورة بالمياه فضلا عن مساحات السبخات الجافة ومساحات الأراضي المنزرعة كما تم حساب كميات فواقد المياه بالبخر من سطوح البرك والسبخات المغمورة بالمياه وإتضح أنها تكفي للتخلص من المياه الزائدة ومياه الصرف الزراعي من الأراضي المنزرعة حاليا والمساحات التي يمكن زراعتها مستقبلا- كما تضمن البحث مناقشة مزايا وعيوب البدائل الأخرى المقترحة للتخلص من المياه الزائدة.