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BASELINE DATA FOR IMPROVEMENT OF A DISTRIBUTARY CANAL SYSTEM

By:

Kafr El-Sheikh and
Cairo Office Design Team

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EGYPT WATER USE AND MANAGEMENT PROJECT

22 El Galaa St., Bulak. Cairo, Egypt

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ABSTRACT

The Egypt Water Use and Management Project conducted an irrigation research and development program from 1978 to 1984 in the Abu Raya area served by the Daqalt Canal in an effort to improve irrigation water management. Using an interdisciplinary effort, the program included the design, construction and operation of the Daqalt Canal system to deliver water to all farms in sufficient quantity at appropriate times to meet all water needs; to deliver water at an adequate and equitable flow rate and head and to minimize surface losses to drains. The original system was designed, constructed and operated under certain physical and operational assumptions that would minimize the use of water while maximizing crop yields for all individual users.

The following technical report describes the physical characteristics of the existing system including the water supply, canal structures, canal and mesqa surveys, soil conditions, crop patterns, water table levels, on-farm irrigation and water delivery requirements. The socio-economic characteristics of the existing system were also evaluated to assist in developing an equitable water user management program.

In general, the Daqalt Canal does not meet its original objectives due to water shortages, inadequate and inequitable flow rates and heads, and large surface losses to drains. These problems are caused by ineffective physical structures operation, conflicts existing with irrigation timing preferences, and poor canal maintenance. As such, the performance of the system falls short of that desired due to incorrect assumptions and improper system management, and the entire water delivery system requires renovation within the context of the larger irrigation system.

It is recommended that a complete hydraulic model of the existing Daqalt system should be developed under the constraint of available water levels in the Mit Yazid Canal, and the design re-evaluated in light of this model. The renovation process should continue, and water users themselves amalgamated into the design and operation of the water management plan.

نبذة

أنجز مشروع تطوير الرى دراسة متطورة للرى لمنطقة أبوريا والتى تروى من ترعة دقلتا وذلك فى الفترة من عام ١٩٧٨ الى عام ١٩٨٤ وذلك بغرض تطوير نظام الرى فى هذة المنطقة وذلك بالأستعانة بالمجهودات المشتركة وتضمنت الدراسة طريقة التصميم والأنشاءات وأسلوب تشغيل ترعة دقلتا وذلك لتوصيل المياة الى الحقول بكميات كافية وفى الأوقات المناسبة لسد الأحتياجات المائية بمعدل وضغط مناسب وأيضا لتقليل كمية المياة الفاقدة فى الصرف ولذلك عمل التصميم على أساس أن يدار بطريقة بحيث تحد من الأستخدام للمياة وتزيد أنتاجية المحاصيل للأفراد.

هذا التقرير يوضح الخواص الطبيعية للنظام الحالى ويتضمن مسح لكل من مصادر المياة والمنشآت على الترع والمساقى وخواص التربة والتركيب المحصولى ومنسوب المياة فى باطن التربة ونظام الرى الحقلى وكذلك أحتياجات التوزيع وتم أيضا تقييم النظام الأقتصادى الأجتماعى الحالى وذلك لأمكانية تطوير أسلوب أستخدام المياة.

وعموما ان قناة دقلتا لا توفر الأحتياجات المطلوبة وذلك بسبب قلة المياة المتوفرة مما نتج عنة أنخفاض معدل التصرف والمنسوب فيها وأيضا بسبب تسرب كميات كبيرة من المياة الى المصارف

كل هذه العوامل سببت مشاكل كثيرة لنظام تشغيل
وأدارة الترع والمنشآت مما أدى الى عدم توفر
المياة بالكميات الكافية وفى الأوقات المناسبة بالأضافة
إلى مشاكل عدم صيانة الترع والمنشآت عليها. ونظرا
لسوء التقدير لكفاءة نظام توزيع المياة الحالى وسوء
التشغيل والأدارة يتطلب الأمر أن يعمل نموذج
كامل لتوزيع المياة فى ترعة دقلتا وذلك لتطوير
طبقا لمعدل ومنسوب المياة فى ترعة ميت يازيد
وعلى ضوء هذا النموذج يتم تصميم ترعة دقلتا وإن
عمليات التجديد لابد أن تستمر وأن يشارك المنتفعين
فى التصميم والأدارة لنظام توزيع المياة

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-1-

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INTRODUCTION

The Daqalt Distributary Canal serves an area of about 6300 feddans (2650 hectares) located in the north central delta region of Egypt. The Egypt Water Use and Management Project (EWUP) conducted an irrigation research and development program from 1978 to 1984 in the Abu Raya area served by the Daqalt Canal in an effort to improve irrigation water management. Both the on-farm and the water delivery systems were studied. An interdisciplinary effort was essential: engineering, agronomic, economic, and sociological aspects of the system were considered. Problem identification; solution search and testing; and implementation stages were conducted. As part of EWUP's research and development studies, evaluation and improvement of the Daqalt Canal was initiated.

An irrigation and drainage project formulation process including determination of objectives; resource inventory; and development and evaluation of alternative plans was outlined by Baumli (1982). Based on the general format presented in this publication, EWUP developed the following procedures for evaluating and redesigning distributary canal systems (Gates, et al., 1984a):

1. Baseline Data Survey,
2. Baseline Data Summary and Analysis,
3. Identification of System Objectives, Constraints, and Problems,
4. Development of Feasible Alternatives for System Improvement,
5. Evaluation of Alternatives, and
6. Preparation of Plans, Specifications, and Recommendations.

Basic to this set of procedures was a survey of the existing system to be investigated to provide information about the characteristics of that system. The data acquired by such a survey was referred to as baseline data because it composed the basic pool of information to be referenced in developing and evaluating alternative structural and operational designs (Gates, et al., 1984a). The procedures were originally tested during renovation of the Abyuha Canal in upper Egypt (Gates, et al., 1984a). A new system was designed to provide gravity flow of water to all farms served by Abyuha Canal. The Daqalt study followed procedures similar to those presented above.

The original Daqalt Canal system was designed, constructed, and operated under certain assumptions to achieve certain objectives. Preliminary investigations by EWUP revealed that system performance had fallen short of its objectives, resulting in problems for water users and for the officials charged with responsibility of water delivery (Egyptian and American Field Team, 1980). System improvement should be aimed at bringing system performance closer to its objectives. The purposes of the Daqalt Canal System study were as follows:

1. to present physical and socio-economic data describing the Daqalt Distributary Canal System,
2. to evaluate system performance in light of stated system objectives and assumptions, and
3. to identify necessary considerations in selecting improvement alternatives.

SYSTEM OBJECTIVES AND ASSUMPTIONS

The purpose of the Daqalt delivery system is to supply sufficient water to produce high-yielding, healthy crops in the served area and to meet all water needs of the area's human and animal population. Each water user is intended to have fair access to water and water is not to be unduly wasted. Stated objectives of the Daqalt Distributary Canal system were not found. However, the desired conditions for the Daqalt area described above imply the following system objectives:

1. to deliver water to all farms in sufficient quantity at appropriate times to meet all water needs,
2. to deliver water at an adequate and equitable flow rate and head, and
3. to minimize surface losses to drains.

The original Daqait Canal system was designed, constructed, and operated under certain assumptions. During system design and construction, it was assumed that on-farm water losses and canal seepage losses would be less for a lift system than for a gravity fed system, especially in the case of rice cultivation. Consequently, farmers were required to lift water from canals and mesqas in order to irrigate their crops. Vertical lift was to typically range between 0.50 and 1.00 m. Other assumptions included:

1. Physical structures as designed and installed would be appropriate for meeting system objectives.
2. Physical structures installed in the system would not be altered by water users (Abdel Hamid, et al., 1977).
3. Canals and mesqas would be well maintained (Abdel Hamid, et al., 1977). The design slope and cross-sectional shape would be maintained in the Daqalt Canal.
4. Irrigation would take place during all hours of the day and night while water was in the canal and mesqas.
5. Water lifting machines such as saqias or pumps would be installed by water users and with Ministry of Irrigation authorization (Abdel Hamid, et al., 1977). The number of machines would not be excessive.
6. Crops would be planted according to recommended and published planting dates and in areas for each crop as required by the cooperative.
7. The system would be well maintained.

The validity of each of the above listed assumptions was tested by the Project study. A comparison between water losses from lift systems and gravity fed systems was not conducted for the Daqalt area.

DAQALT CANAL SYSTEM CHARACTERISTICS

PHYSICAL CHARACTERISTICS

Water Supply

The Daqalt Canal takes its water from the third and last reach of the Mit Yazid Branch Canal with flow controlled at the head of Daqalt by a sluice headgate. The water source for the Mit Yazid Canal is the Bahr Shibin Canal which in turn takes water from two sources: El-Minoufy Raya and El-Abassy Raya. The two Rayas (primary canals) take water from upstream of the Delta Barrage on the Nile River and upstream of the Zifta Barrage on the Damietta Branch of the Nile, respectively.

The Daqalt Canal is operated on a rotation water delivery schedule by opening and closing the headgate. At the beginning of the on-period the headgate is opened and left open for the entire period without flow reduction at night. During the off-period, the headgate is closed. A typical rotation schedule is shown in Table 1. During the summer season a double rotation is typical: 4 days on and 4 days off. Triple rotations are typical during winter: 5 days on and 10 days off. During gate operation, gate opening width is set to achieve a desired downstream head in the Daqalt Canal. Flow rate through the headgate is generally not measured during system operation.

The water level in the Mit Yazid Canal at the Daqalt Canal headgate varies during the year in response to the release rates at the Aswan Dam and also varies daily because of the opening and closing of headgates for other distributary canals which take water from the Mit Yazid Canal. Figure 1 shows daily water levels upstream of the Daqalt headgate during 1978. Comparison with water levels in 1979 and 1980 is given in Table 2. Water levels were highest during the months of June, July and August to provide larger flow rates to meet anticipated high water demand for irrigating summer crops, especially rice.

Structures

The Daqalt Canal headgate has two sluice gates each 2 meters wide. They are equipped with hand operated lift screws. The headgate was calibrated by taking current meter measurements of the flow rate in the Daqalt Canal and measuring the gate opening heights and the water level difference across the gate. The flow rate coefficient determined from these measurements was 0.62. The equation for flow rate through the Daqalt headgates is:

TABLE 1 A Typical Rotational Schedule for Daqalt Canal.

AREAS WITH SUGAR BEETS

Dates	Rotations Days on-off	Influencing Crop
Oct. 15 to Closure[a/]	5-5	Sugar Beets
Closure		
Closure to Mar. 15	5-10	Cotton & Sugar Beets
Mar. 15 to May 25	7-7	
May 15 to Oct. 15	4-4	Rice
AREAS WITHOUT SUGAR BEETS		
Oct. 15 to Closure	5-10	
Closure		
Closure to Mar. 15	5-10	
Mar. 15 to May 25	7-7	Cotton Planting
Apr. 15 to May 25	5-10	
May 15 to Oct. 15	4-4	Rice

a/ Closure means the annual canal closure period when water releases from the Aswan Dam are curtailed for a period of approximately 3 weeks to one month so that repairs, maintenance and cleaning operations can be done on structures and watercourses. For Daqalt the closure period is generally from January 20 to mid-February. Often a general irrigation period (no rotation) of ten days to two weeks follows the closure.

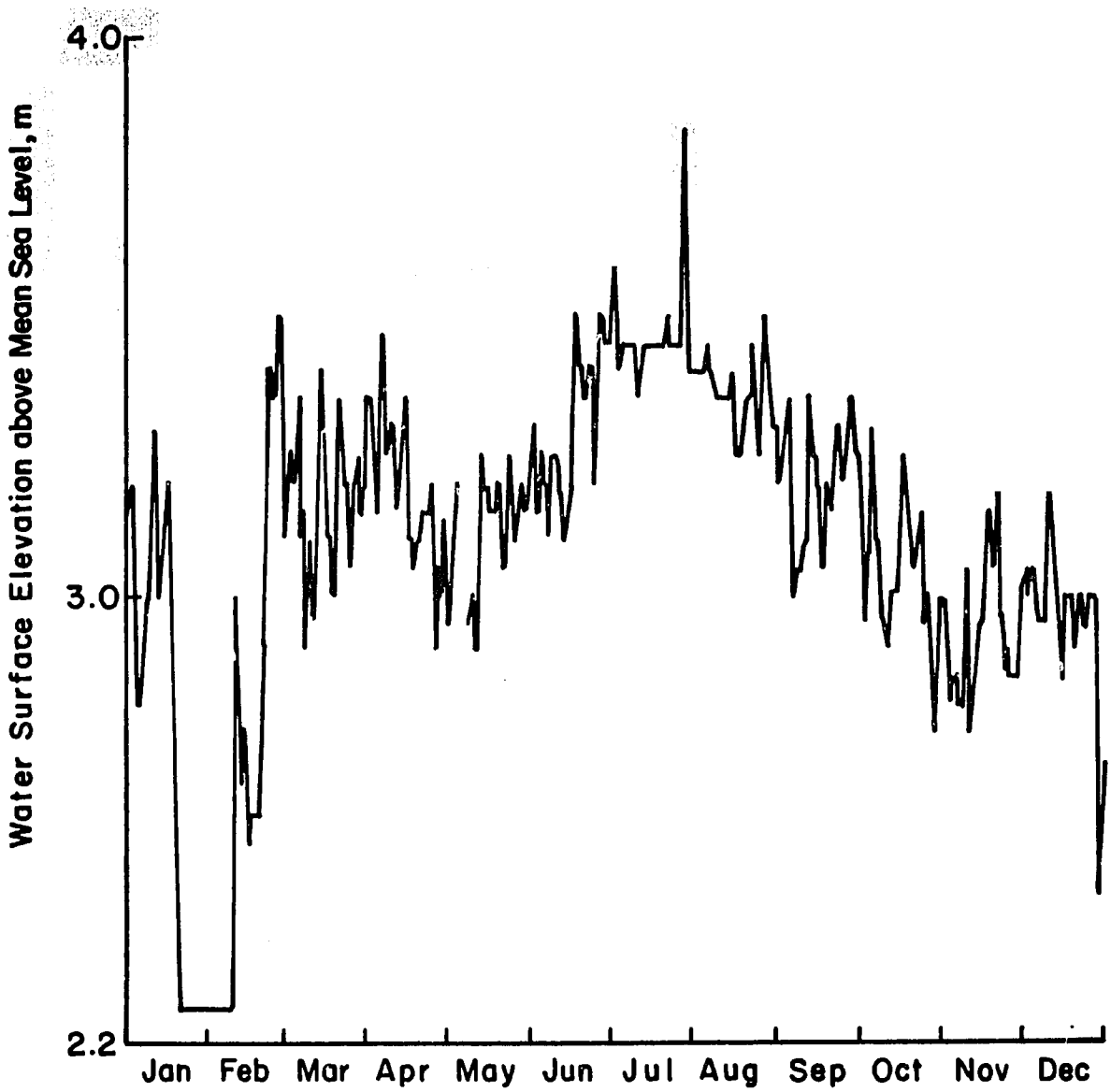

Figure 1. Daqalt Headgate Upstream Water Levels, 1978.

TABLE 2 Average Monthly Water Levels In The Mit Yazid Canal At The Daqalt Headgate

Month	Water Surface Elevation Above Mean Sea Level, m		
	1978	1979	1980
January	2.82		2.75
February	2.84	2.92	2.95
March	3.16	3.07	3.03
April	3.19	3.02	3.05
May	3.12		3.05
June	3.30		3.39
July	3.46		
August	3.36		
September	3.20		
October	3.04	2.89	
November	2.93	2.82	
December	2.96	2.97	

$$Q_{hg} = cwy\,(2gh)^{1/2} = 0.62(4)\,y\,(2gh)^{1/2} = 11.0y(h)^{1/2} \qquad (1)$$

where

Q_{hg} = flow rate, m^3/sec,
c = flow rate coefficient,
w = gate width, m,
y = average gate opening, m,
g = the gravitational constant, 9.8 m/sec^2, and
h = the difference between the upstream and downstream water levels, m.

Figure 2 shows constant flow rate curves for various combinations of water level difference and gate openings.

Two regulators control the flow along the canal and divide the canal into 3 reaches. The Wizaria regulator, 2865 m from the headgate, has a single sluice gate 3 m wide. The Helal regulator, 5575 m from the headgate, has a 2 m wide sluice gate. The regulators were not calibrated. The same coefficient found for the canal headgate was used for these gates since they appeared to be similar to the headgate in construction, orientation in the canal, and physical condition.

Eight concrete bridges span the canal. Their abutments barely intrude into the flow cross-section and cause little disturbance to the flow. There are three other crossings near the downstream end of the canal. One, a pipe culvert, is a source of significant head loss.

A tail escape (end check structure) at the downstream end of the canal provides for the release of excess canal flow into Drain No. 7. It has a circular drop inlet with a crest diameter of 1.44 m, and the crest elevation is 1.12 m. The flow rate constant for the tail escape was assumed to be 0.385. The head-flow rate relationship was estimated as:

$$Q_{the} = cw\,(E-1.12)\,[2g\,(E-1.12)]^{1/2} = (0.385)\,[(3.14)\,(1.44)]\,(E-1.12)$$

$$[(2)\,(9.8)\,(E-1.12)]^{1/2} = 7.72\,(E-1.12)^{3/2} \qquad (2)$$

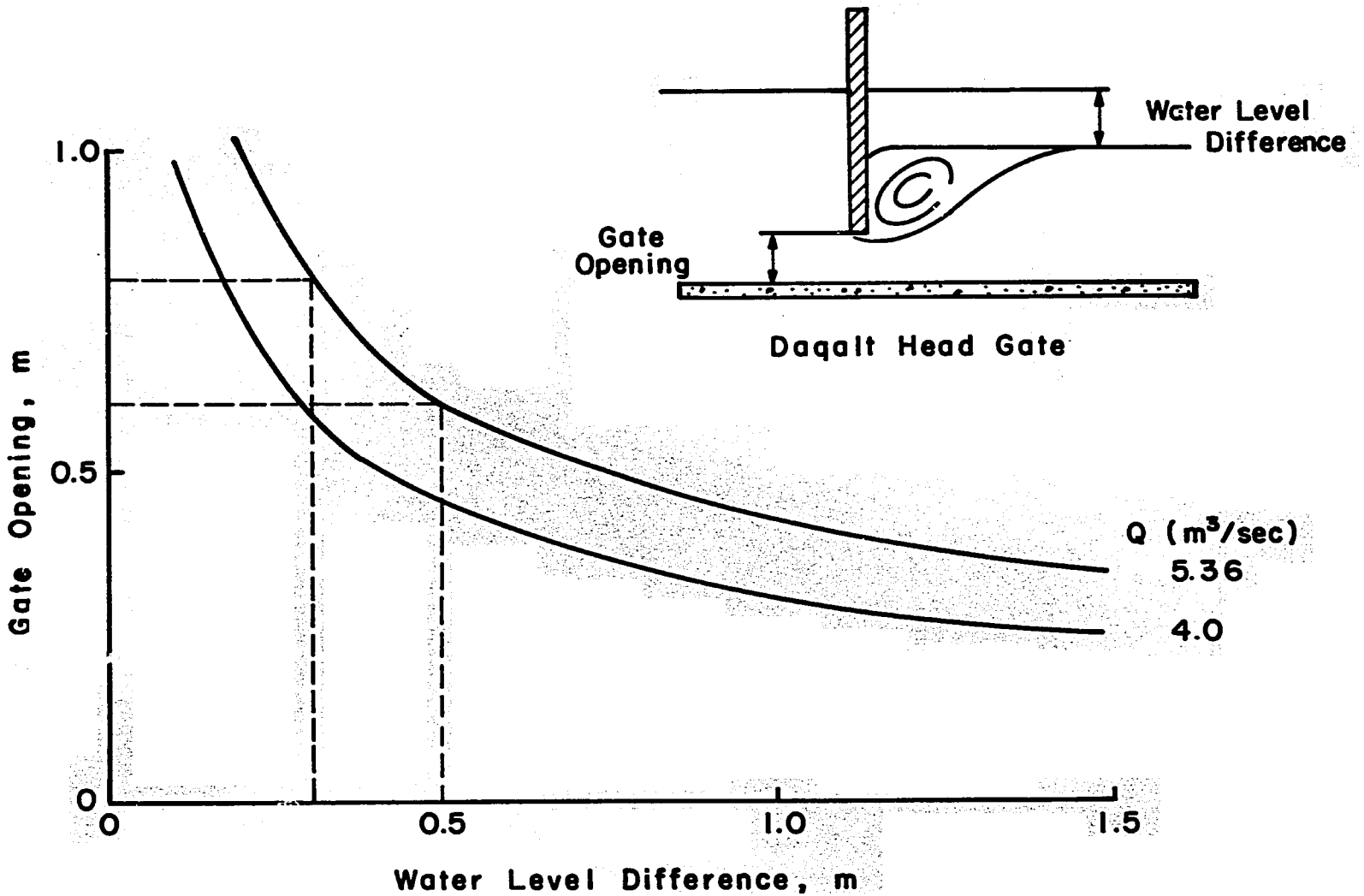

Figure 2. Constant Flow Rate Curves For Various Combinations of Gate Opening and Water Level Difference for Daqalt Headgate.

where

Q_{the} = flow rate over tail escape, m^3/sec,
c = flow rate constant,
w = crest length, ($w = \pi d$, where d is the crest diameter), m,
E = elevation above msl of water in canal at tail escape, m, and
g = the gravitational constant, 9.8 m/sec^2

Canal and Mesqa Surveys

From the head at Mit Yazid Canal, the Daqalt Canal extends northward for 11,400 m and ends at Drain No. 7 (El Asfal Drain). Twenty four mesqas take off from the canal, 10 on the left side and 14 on the right side. In addition to the mesqas there are 76 saqias and 3 diesel pumps taking water directly from the Daqalt Canal. Eight of the saqias are on the first reach of the canal, 15 are located on the second reach, and 53 are on the third reach, downstream of the Helal regulator. The pumps are located on the first reach. The land served by the canal slopes about 0.3 m/km (0.03%) in the direction of flow. Figure 3 is a map of the area. The Daqalt Canal is unlined except for a few locations protected with mortared pitching. Figure 4 shows the canal bottom width and longitudinal profile as originally designed. The design bottom width ranges from 6 m to 1 m. The design bottom slopes are 0.0038% in the first reach; 0.0074% in the second reach; and 0.056% and 0.0% in the third reach. The canal has changed from the design (and presumably the originally constructed) cross-section and profile. Widening and silting of the canal has taken place. Figure 5 shows two typical cross-sections taken from a 1980 survey (unpublished data, Ministry of Irrigation, Kafr El-Sheikh, Egypt). The cross-section at station 6500 m has widened considerably whereas the one at 9000 m has narrowed slightly. The 1980 survey indicated that most sections have widened.

Water flow from the Daqalt canal to mesqas is through pipe turnouts. Traditionally in Egypt turnout size has been based on a flow rate of 50 m^3 per feddan per on-day with turnouts operating under a head of 0.25 m. Based on this design flow rate, a survey of outlets downstream of the Helal Regulator revealed that 72% of the mesqas had either over-sized pipes or extra pipes (Hanson, et al., 1984). Later, design flow rates at Daqalt were determined through the use of the following empirical equation based on percentage of land planted to rice (unpublished data, Ministry of Irrigation, Kafr El-Sheikh, Egypt):

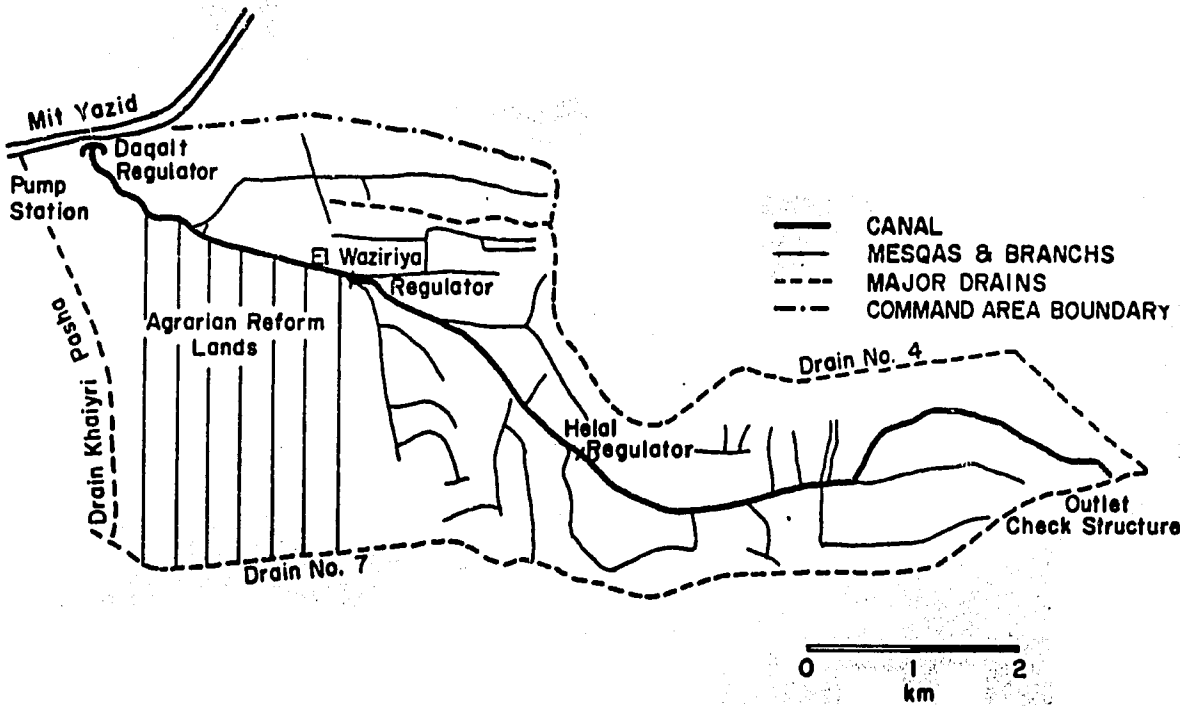

Figure 3. Daqalt Canal and Mesqas.

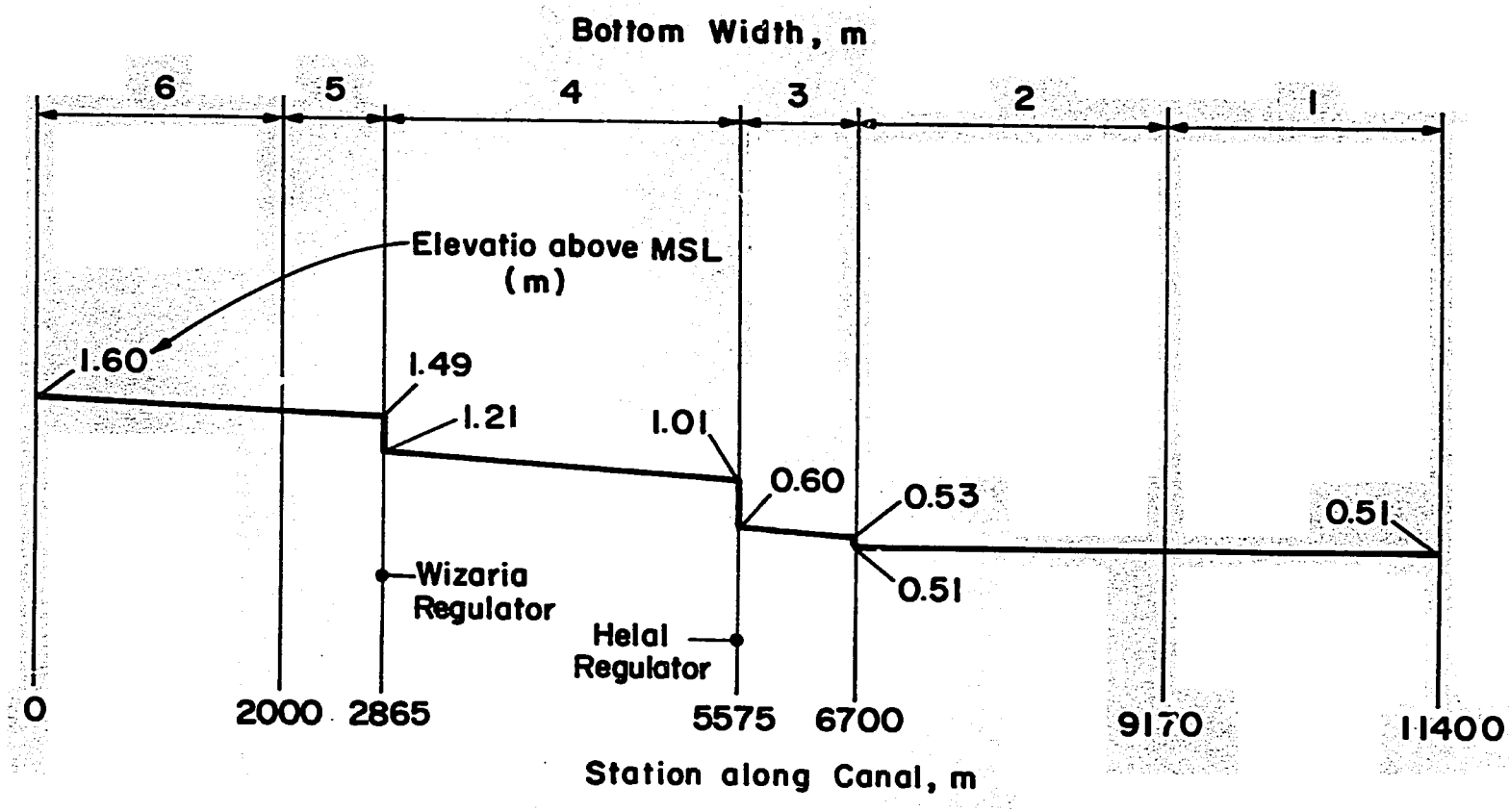

Figure 4. Daqalt Canal Profile and Bottom Widths, Original Design.

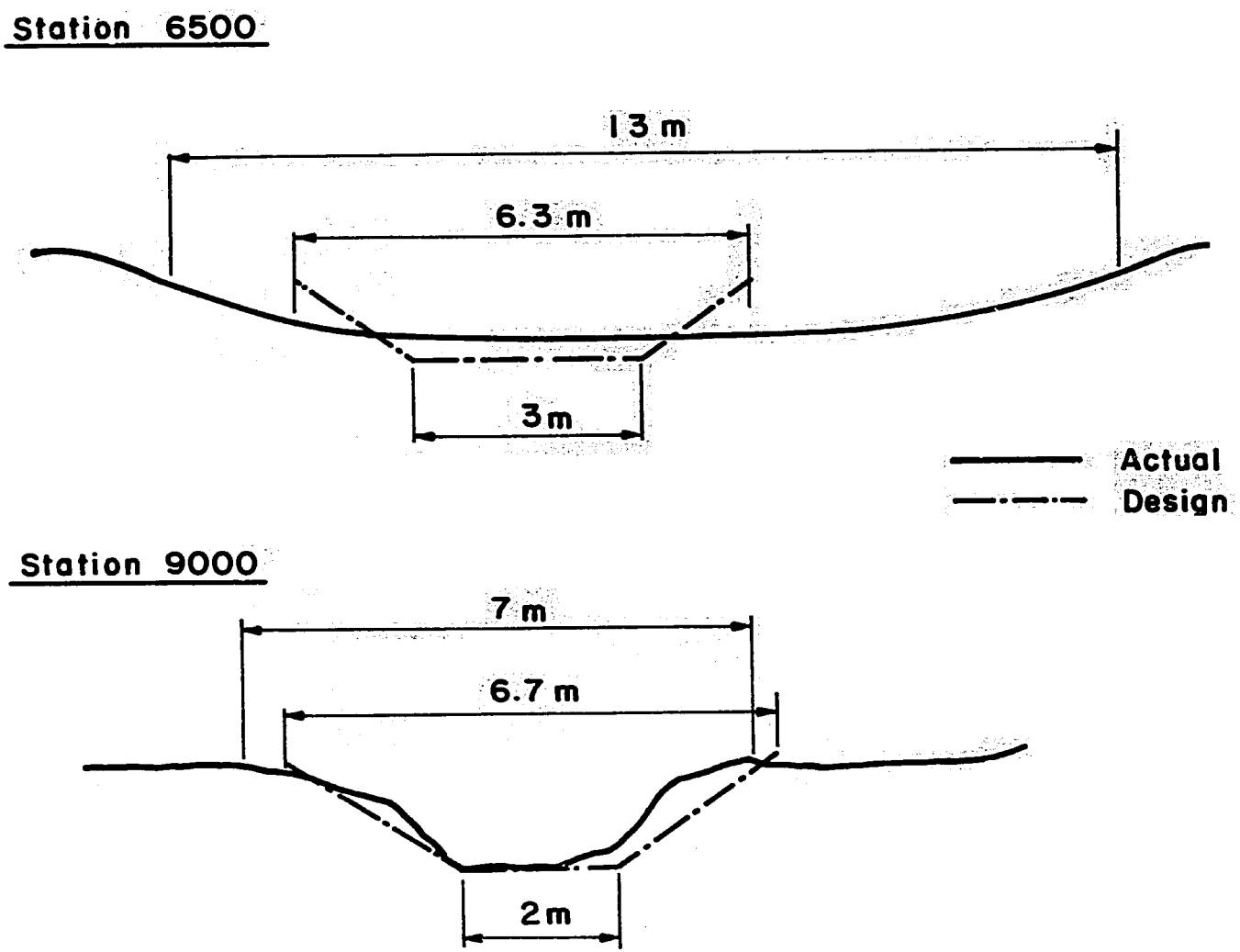

Figure. 5. Comparison of Actual Cross-Section With The Original Design Cross-Section For Two Stations on Daqalt Canal.

$$Q_{to} = 0.00607 (R_p) + 0.607 \quad (3)$$

where

Q_{to} = flow rate through turnouts during on-days, m^3/sec/(1000 feddans), and

R_p = rice percentage, %.

Assuming a rice percentage of 65%, design flow rate based on Equation 3 would be 1.00 m^3/sec/(1000 feddan) or 86.5 m^3/day/feddan, an increase of 73% over the previous design value.

Design turnout diameter for a given pipe length and operating head depends on design flow rate and crop area served.

Longitudinal and cross-sectional surveys were taken of all mesqas served by Daqalt. Mesqa data are given in Tables 3a and 3b. Mesqas are close-ended having no direct outlets from 0.0% to 0.03%. Mesqas vary widely in length and area served. El-Ghait El-Gahari mesqa has three branches with a total length of 6800 m and serves 663 feddans. El-Wizaria mesqa has three major branches of approximately equal size with a total length of 4360 m and serves 305 feddans. El-Desouki mesqa is 1027 m long but serves only 27.7 feddans.

Mesqa cross-sections are larger than design so that considerable channel storage is available. Estimates of channel storage in the Daqalt Canal and its mesqas are shown in Table 4. Flow obstructions such as trees, weeds, pipe culverts, and bridges were observed to be common. Mesqas which were just cleaned were judged to have a Manning n value of 0.03. Appropriate n values for others which were weed infested ranged from 0.08 to 0.10.

Several mesqas also received water from sources other than Daqalt canal. The first three mesqas on the right side of Daqalt (El-Baida, El-Hododa, and Edraga El-Balad) receive water from a pumping station. El-Shait El-Bahari mesqa is connected at its tail to another distributary canal system.

Soils

The soils in the area served by Daqalt Canal are mostly in the vertisol soil order. These soils have 35% or greater clay in all horizons to a depth of 0.50 m and develop deep vertical cracks between irrigations (Selim, et al., 1983). Irrigation of vertisols presents special challenges. Application depths at the

TABLE 3a Daqalt Canal Mesqas

Mesqa Name	Side	No.	Station on Daqalt, M.	Area Served, Fed.	Length 1/ m	Flow 2/ Rate M^3/S	Turnout Pipe		
							Level 3/ M.	Dia. cm	Length M.
El-Ghait El-Bahary	Left	1	1450	662.7	6800	0.66	2.485	60	12
El-Wizaria	Left	2	2980	304.8	4360	0.31	1.53	40	11
El-Far El Ali	Left	3	4200	423.3	3142	0.42	1.60	50	11
Sabatasher	Left	4	4950	40.0	210	0.04			
El-Manshia	Left	5	5700	246.5	2439	0.25	1.22	40	10
Hema	Left	6	7675	69.0	586	0.07	0.81	25	10
El-Gamaeia	Left	7	7840	72.5	710	0.07	0.79	25	10
El-Desouki	Left	8	8175	27.7	1027	0.03	0.77	15	10
Shams El-Din	Left	9	8195	58.5	800	0.06	0.76	20	10
Fathi	Left	10	10033	10.0	400	0.01	0.60	15	10
			TOTAL	1915.0	20474				

1/ Total Length of mesqa and its branches.
2/ Flow rate is the Equation 3 figure for 65% of area in rice.
3/ Level of the pipe is taken on the top of the pipe.

TABLE 3b Daqalt Canal Mesqas (Continued)

Mesqa Name	Side	No.	Station on Daqalt	Area Served, Fed.	Length 1/ M.	Disch. 2/ Rate M^3/S	Turnout Pipe		
							Level 3/ M.	Dia. cm	Length M.
El-Baida	Right	1	775	275.5	3997	0.28	2.615	60	14
El-Hododa	Right	2	1112	182.0	3000	0.18	2.625	60	14
Edraga El-Balad	Right	3	1420	178.2	2375	0.18	2.250	40	14
Fdraga El-Bahari	Right	4	1800	220.1	1900	0.22	2.480	40	14
Ghugar	Right	5	2100	124.8	1050	0.12	2.290	50	13
El-Samenein	Right	6	2410	168.4	2840	0.17	2.190	50	14
Sirhan	Right	7	2660	75.8	2780	0.08	2.350	40	14
El-Khalifa	Right	8	2980	504.5	4600	0.51	2.130	55	14
El-Tayara	Right	9	4800	230.7	3180	0.18	1.520	35	14
Helal	Right	10	5630	143.5	1500	0.14	1.450	35	14
El-Shahina	Right	11	6950	41.2	854	0.14	0.330	17.5	14
El-Gabana	Right	12	7400	98.5	995	0.10	0.970	25	13
Hamad 4/	Right	13	8150	205	1710	0.21	0.640	40	13
Om Sen 4/	Right	14	8450	205	1710	0.21	0.640	40	13
			TOTAL	2667.2	32991				

1/ Total Length of mesqa and its branches.
2/ Flow rate is the Equation 3 figure for 65% of area in rice.
3/ Level of the pipe is taken on the top of the pipe.
4/ Has Cutthroat flume at entrance.

TABLE 4 Estimation of Channel Storage Capacity in the Daqalt Canal System

Channel	Total Length m	Average Top Width m	Maximum Acceptable Water Surface Elevations Fluctuation, m	Storage Available m^3
Daqalt Canal	11400	10	0.50 1/	57,000
24 Mesqas	53465	4	0.50 1/	107,000
TOTAL				164,000

1/ Based on water surface elevation in canal and mesqas fluctuating between 0.50 and 1.00 m below the land surface.

first irrigation of the season need to be very large due to large initial infiltration rates resulting from dry soil conditions and the deep vertical cracks. As cracks close during irrigation, infiltration rates decrease dramatically and sealing could occur leading to undesirable ponding of water on the soil surface. Precision land leveling and/or surface drainage is required to prevent detrimentally long ponding (Litwiller, et al., 1984b). A typical infiltration curve for the first irrigation of wheat is shown in Figure 6.

Typical soil water deficit depths for various crops for initial irrigations of the season and subsequent irrigations are shown in Table 5. The largest application depths are not required during the periods of greatest evaporative demand by the crops. The critical demand periods for all crops at Abu Raya occur during the first irrigation and not during the peak evaporative demand periods (Ley, 1983).

Crop Pattern

The primary summer crops at Daqalt are rice, cotton, and maize. Winter crops include clover, wheat, and sugar beets. Crop surveys taken during the summer season 1983 and the winter season 1983-84 are shown in Table 6a and 6b. The first 7 mesqas on the right bank of Daqalt Canal are land reform lands with a carefully regulated cropping pattern. During summer season, rice, cotton, and maize crops occupy equal areas. For the other 18 mesqas on Daqalt Canal, rice percentages ranged from 1% to 84%. Crops are often planted later than recommended due to machinery and labor shortages. Recommended and actual planting dates are contrasted in Table 7.

Water Table Levels

The water table is very high at Abu Raya, with monthly average depths to the water table ranging from 0.2 m to 0.8 m (Helal, et al., 1984). These high levels represent salinity and waterlogging hazards. A water table balance study explored which interventions had the best potential for maintaining desirable lower water table levels for optimal crop production at Abu Raya (Litwiller, et al., 1984a). The study revealed that water table contribution to evapotranspiration was significant. The lining of the Mi Yazid branch canal, the Daqalt canal, and the 24 mesqas served by Daqalt Canal would have negligible effect on water table levels. Improving on-farm efficiencies including lining of on-farm channels would maintain the water table at lower

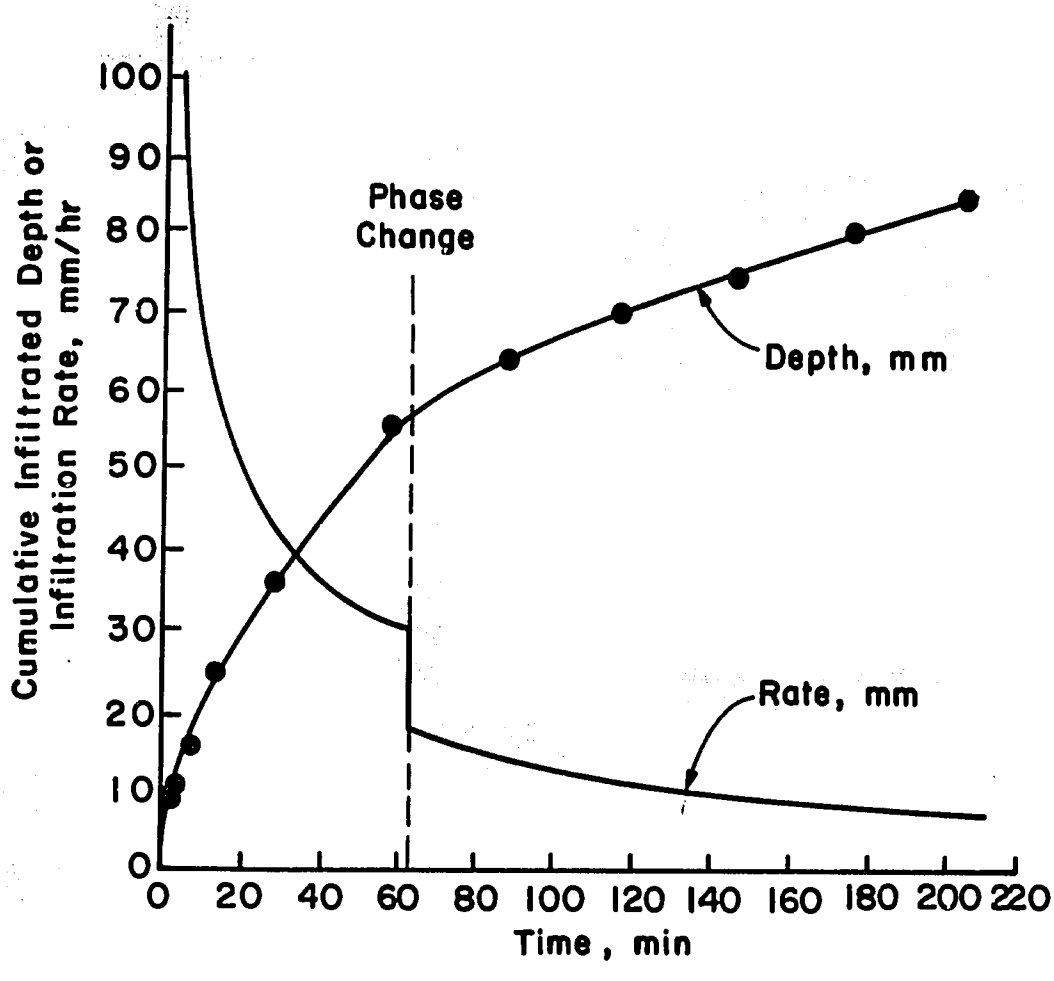

Figure 6. Cumulative Infiltrated Depth and Infiltrated Rate As Functions of Time For a Two-Phase Cylinder Infiltration Test, Rectangular coordinates. (The two phases represent multi-dimensional infiltration from soil cracks and subsequent vertical infiltration into wetter, lower soil layers).

TABLE 5 Measured Soil Water Deficits at Initial and Succeeding Irrigations on Farms on Daqalt Canal.

Site	Crop	Season	Measured Soil Water Deficit at First Irrigation, cm	Average Soil Water Deficit at Succeeding Irrigations, cm
3-01a	Wheat	79-80 Winter	11.8	5.6 1/
3-02a	Wheat	79-80 Winter	8.0	6.7 1/
3-08a	Wheat	79-80 Winter	1.3	8.1 1/
3-09a	Wheat	79-80 Winter	8.5	5.9 1/
3-10a	Wheat	79-80 Winter	6.8	10.4 1/
3-11a	Wheat	79-80 Winter	5.1	4.3 1/
3-12a	Wheat	79-80 Winter	14.9	6.5 1/
3-16A1	Cotton	80 Summer	10.0	6.0
3-17A1	Cotton	80 Summer	8.0	6.3
3-13A1	Cotton	80 Summer	13.0	8.4
3-14A1	Cotton	80 Summer	18.0	8.7
3-15(a)A1	Cotton	80 Summer	18.0	9.4
3-15(b)A1	Cotton	80 Summer	14.0	8.3
3-02	Wheat	80-81 Winter	17.2	10.6 1/
3-19	Wheat	80-81 Winter	13.9	7.6 1/
3-19	Beans	80-81 Winter	20.0	3.5 1/
3-10(A)	Wheat	80-81 Winter	12.0	4.6
3-10(B)	Wheat	80-81 Winter	12.0	5.0
3-10(B)	Flax	80-81 Winter	10.0	5.4
3-22	Wheat	80-81 Winter	11.0	5.0
3-21	Wheat	80-81 Winter	15.9	4.6
Mean ± std. dev.			12.4 ± 4.0 (C.V. = 32.3%	6.5 ± 1.8 2/ (C.V. = 28.1%)

1/ Second Irrigation Only

2/ For Sites With Seasonal Data Only

TABLE 6a Percentage of Area Planted to Each Crop, Summer Season, 1983

Mesqa		Percentage of Area in Crop			
		Rice	Cotton	Maize	Other
Left	1	65	24	9	2
	2	69	24	7	0
	3	64	24	12	0
	4	--	--	--	--
	5	65	21	14	0
	6	1	89	9	1
	7	82	5	11	2
	8	36	36	28	0
	9	75	17	3	5
	10	--	--	--	--
Right	1	33	33	33	0
	2	33	33	33	0
	3	33	33	33	0
	4	33	33	33	0
	5	33	33	33	0
	6	33	33	33	0
	7	33	33	33	0
	8	79	13	7	1
	9	50	27	22	1
	10	60	28	10	2
	11	48	27	17	8
	12	71	20	5	4
	13	84	0	13	3
	14	61	22	14	3
TOTAL		50	31	18	1

TABLE 6b Percentage of Area Planted to Each Crop, Winter Season, 1983-1984

Mesqa		Percentage of Area in Crop			
		Clover	Wheat	Sugar Beets	Other
Left	1	55	16	29	0
	2	69	24	7	0
	3	73	18	9	0
	4	80	17	3	0
	5	79	7	13	1
	6	62	18	16	4
	7	56	29	13	2
	8	49	19	31	1
	9	67	12	21	0
	10	--	--	--	--
Right	1	33	33	33	0
	2	33	33	33	0
	3	33	33	33	0
	4	33	33	33	0
	5	33	33	33	0
	6	33	33	33	0
	7	33	33	33	0
	8	83	5	12	0
	9	65	17	11	7
	10	69	16	12	3
	11	72	15	14	0
Daqalt Canal	12	59	24	10	6
	13	66	23	10	1
	14	54	6	9	2
TOTAL		57	22	20	1

TABLE 7 Recommended and Actual Planting Dates At Daqalt
(from Farouk Abdel-Al, et al., 1984)

CROP	RECOMMENDED PLANTING DATE	ACTUAL PLANTING DATES	
		RANGE	AVERAGE
Rice (Nursery Trans-plant.)	5/1 6/1	5/8 to 5/24 6/12 to 6/29	5/18 6/20
Cotton	3/16	3/25 to 4/13	4/6
Malze	5/15	5/20 to 6/8	5/29
Clover	11/1	9/7 to 10/28	10/24
Wheat	11/25	11/1 to 12/9	11/27

levels than those measured. However, desirable lower water table levels could not be achieved by on-farm irrigation improvements while using surface irrigation methods. Desirable lower water table levels could be maintained by increasing drainage outflows but corresponding increases in water delivery would be required (Litwiller, et al., 1984a).

On-Farm Irrigation

Farmers divide their land into small basins because of field surface elevation irregularities and small available flow rates (Ley, et al., 1984). For efficient irrigation of larger basins of 100 m length and 20 m width, a flow rate of about 25 l/sec is required. On-farm conveyance losses averaged 40% of water lifted at Abu Raya (Ley, 1983). A flow rate of about 42 l/sec is therefore required at the diversion point to the farm, typically a saqia. Flow depths required at the head of the field at Abu Raya typically range from 0.04 to 0.08 m (Litwiller, et al, 1984b). Head losses occur in extensive and poorly maintained on-farm conveyance systems. Water surface elevations at the farm diversion point need to be between 0.20 and 0.30 m above the field elevation to provide adequate head for channel and field losses.

The most common method of lifting water from the Daqalt Canal and its mesqas is the saqia. Saqias are powered by cattle or buffalo and raise water by scooping it from the canal and discharging it from an opening around the central axis. The typical saqia diameter is 3 m with 6 kados or scoops (Ley, 1983). Larger or smaller diameters are observed in areas of unusually large or small lifting conditions, respectively. Saqias are installed so that their axes are 0.20 to 0.30 m above the field elevation in order to provide the head required at the field. Flow rates from saqias are heavily dependent upon vertical lift. Saqia lift can be estimated by the vertical distance between the water surface elevation in the supply canal and the saqia axis neglecting head losses in the turnout pipe between the canal and the saqia well. Figure 7 shows the relation between saqia lift and flow rate for three diameters of saqias. Data were collected at the Ministry of Irrigation Delta Barrage Hydraulic Laboratory using saqias in good condition with constant radial speed, kado width, and vertical lift (Hashim, 1968). In each case the shut-off head corresponded to the saqia radius. For a vertical lift of greater than 1.0 m, the flow rate decreased rapidly with small increases in lift. In the field, saqia flow rate depends on saqia condition and draft conditions such as the

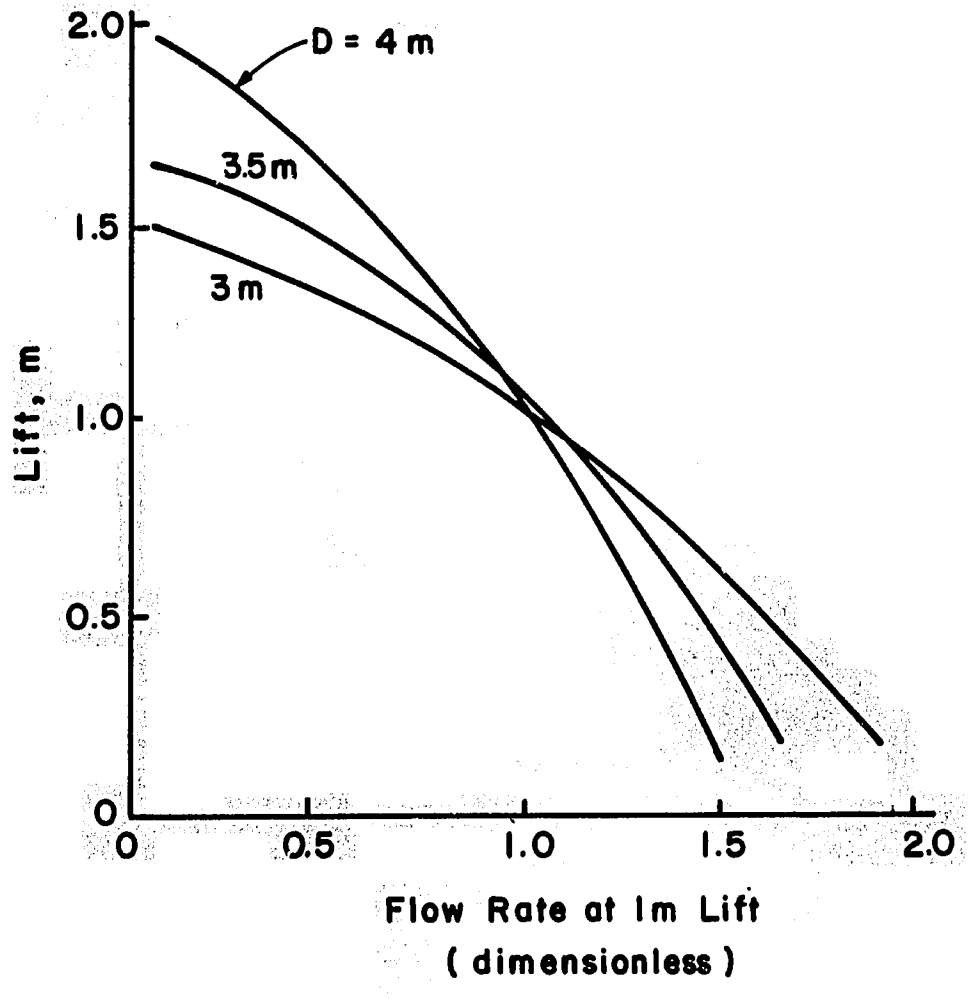

Figure 7. Relation Between Height of Lift and Flow Rate for Saqias at Daqalt (adapted from Hashim, 1968).

strength, age, and freshness of the draft animal, as well as on saqia lift. Lift conditions change continuously as water surface elevation fluctuates in the canal. Ley (1983) presented values for measured variations in saqia flow rates for 1) seasonal average saqia flow rates, 2) average flow rates for individual irrigations during a season, and 3) mean flow rates for many saqias during one irrigation. A wide variation was observed although the average flow rate was between 31 and 38 l/sec in each case. Saqias typically serve between 5 and 10 feddans. There are the 34 saqias on the Omsen mesqa serving 219 feddans and 27 saqias on the Hammad mesqa serving 205 feddans (Egyptian and American Field Team, 1980).

Flows from centrifugal pumps used at Abu Raya were observed to be less sensitive to changes in water surface elevation in the canal. Pumps could be used under vertical lift conditions where saqias could no longer operate because the vertical lift had exceeded the saqia radius. However, a minimum flow rate in the canal was required to maintain pump prime. Under certain conditions where lifts were not excessive and canal flow rates were very small, saqias could be operated while pumps could not.

On-farm losses occur due to on-farm channel leakage, seepage, and dead storage; deep percolation below the root zone in the field; and run-off from fields to drains (Ley, 1983; Ley, et al, 1984). Estimates of various on-farm efficiencies are shown in Table 8.

Water Delivery Requirements

The determination of total water needed in the system during the year required many types of data. Figure 8 displays how various data were combined to arrive at required water delivery volumes for each period during the year. Climatic data were used to estimate potential evapotranspiration (Doorenbos and Pruitt, 1977). The crop and management practices such as planting and harvest dates determined the crop coefficient. Crop evapotranspiration could then be estimated from potential evapotranspiration and crop coefficients. Calculated values of evapotranspiration were compared with data for crops in lower Egypt as presented by Nabawy, et al. (1981). Data on water users irrigation practices were used to predict volumes of water required of non-evapotranspiration purposes such as rice puddling and cotton pre-irrigations (Farouk Abdel Al, et al., 1984; Ley and Tinsley, 1983;

TABLE 8 On-Farm Efficiency Parameters Under Conventional and Improved Water Management Practices at Daqalt.

Conditions/Practices			e_{cf} 2/	e_a 3/	e_{if} 4/	α
PLL 1/	Conveyance Channels	Field Basins				
No	Unimproved	Conventional	0.60	0.65	0.39	0.75
Yes	Reshaped	Redesigned	0.80	0.80	0.64	1.0
Yes	Lined	Redesigned	1.00	0.80	0.80	1.0

1/ PLL - Precision land leveling of fields

2/ e_{cf} - On-farm conveyance efficiency, the ratio of water delivered to the field to water diverted by saqia or pump.

3/ e_a - Application efficiency, the ratio of water stored in the root zone during irrigation to water delivered to the field during irrigation.

4/ e_{if} - On-farm irrigation efficiency, the ratio of water stored in the soil to water diverted by saqia or pump ($e_{if} = e_{cf} \times e_a$).

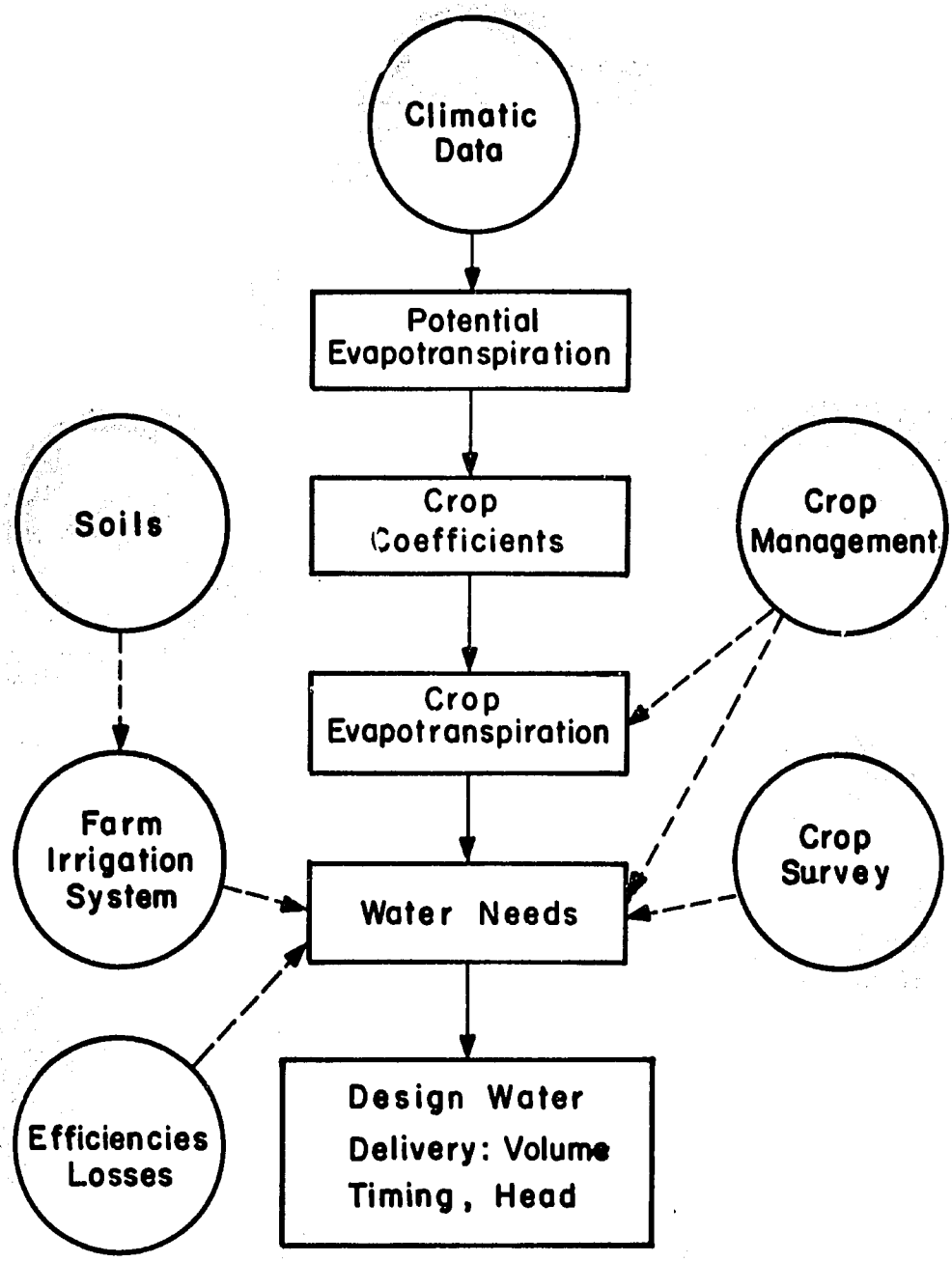

Figure 8. Procedure for Determination of Water Delivery Needs.

Ley, 1983). Soils information served to predict infiltration characteristics and depths of irrigation to be applied at various times during the season (Litwiller, et al., 1984; Moustafa and Tinsley, 1984).

Farm irrigation system design depended on infiltration characteristics and application depths (Ley, 1984). Appropriate designs determined the required values of flow rate and head at the farm level. Saqia lift-flow rate relations could then be used to determine required water surface elevation in the canal. Predicted losses and water table contribution to evapotranspiration needed to be considered in estimating the volume of water needed at the farm diversion point throughout the year. Crop surveys were used to determine the aggregate water needs from individual crop needs. Figure 9 is a representation of relative water delivery needs as determined from actual farmer irrigation practices (unpublished data, Magdy Awad, Kafr El-Sheikh, Egypt). Water needs for domestic use were assumed to be negligible in comparison to irrigation needs. The highest demand periods are during the transplanting of rice, the period following the winter canal closure, and the planting of cotton. The peaks could be flattened by increasing the time interval during which transplanting or planting takes place or by decreasing the area planted to rice or cotton, respectively. Periods of low demand for irrigation water occur in May and again in September and October. Water deliveries must be curtailed during those periods in order to avoid water wastage.

SOCIO-ECONOMIC CHARACTERISTICS

Any physical alteration to an irrigation system is performed within a socio-political environment. The success of any physical alteration depends on the proper management of that alteration by the irrigation water delivery planners and by the water users. Alternative solutions involving any physical alteration need to take into consideration the socio-political environment in order to make the management of the alteration most effective. Necessary socio-economic considerations in the Daqalt Canal system baseline survey include the basic socio-economic parameters of the Daqalt Canal, the present management patterns of water users, and the water users perceptions about the system.

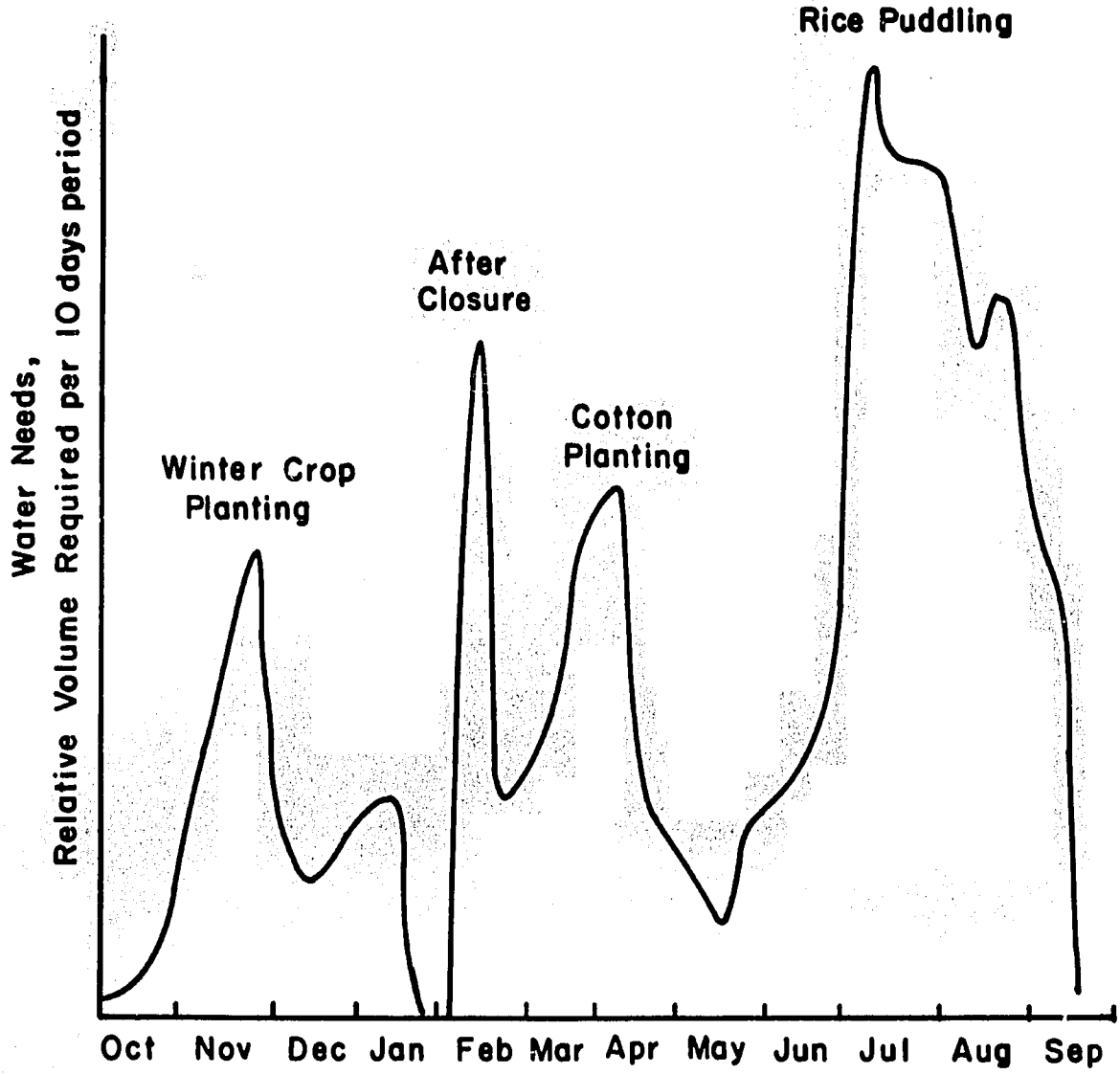

Figure 9. Water Delivery Needs At Daqalt.

Socio-Economic Parameters

The Daqalt Canal is served by 5 cooperatives which provide inputs and marketing facilities as well as regulate the areas planted to certain crops. The cooperatives serving the canal, the area each cooperative serves, the number of land owners in each cooperative, and the average ownership size are shown in Table 9. The area served by the cooperatives is greater than the area served by the Daqalt Canal indicating that cooperative boundaries do not coincide with canal service boundaries. Farms along a single mesqa could be divided into two separate cooperatives.

Several villages could also lie along a single mesqa presenting special challenges to organizing water users on the mesqa level. Canal-wide organization would be even more difficult. Average land ownership on the Daqalt Canal is about 2.5 feddans.

Ownership of buffalo and cattle is shown in Table 10. The animal density of 0.94 buffalos and cows per feddan is reflected in the area planted to clover during the winter season. (See Table 6b). Farm machinery in the Daqalt area includes tractors, trailers, threshing machines, winnowing machines, irrigation pumps, and spraying machines (Table 11). There is approximately one tractor per 119 feddans and approximately one irrigation pump per 55 feddans. Under the Abu Raya cooperative the number of tractors and pumps has increased by 33% and 344%, respectively, from 1979 to 1983 (Table 12). Apparent trends are for animal draft power to be replaced by tractors and pumps. Consequently, animal working hours for farm operations have decreased (Table 13). Livestock meat and milk production per feed expenses have increased as buffalo and cattle work fewer hours.

Water User Management Practices

There are limited group cooperative efforts in managing the water along Daqalt Canal. Water users join together in groups of 2 to 10 to share the use of a single water lifting machine, typically a saqia. Water users informally schedule turns within the saqia units by either agreeing in advance on who should irrigate when, or by negotiating turns at the saqia site.

There is virtually no direct cooperation among water users along a mesqa or between mesqas in the canal. In fact, the water users understand that it is the government's responsibility to manage the water along the canal. The ability of the water users to cooperate among themselves along the mesqa differs with each mesqa.

TABLE 9 Land Ownership Information From Daqalt Cooperatives

Coops Name	Area Feddan	No. Of Ownership	Average Of Ownership Feddan
Daqalt	1500	550	2.73
Enriga	1500	560	2.68
Wizaria	1850	850	2.18
Athaibit	1017	485	2.1
Abu Raya	2827	933	3.03
TOTAL	8694	3378	2.57

TABLE 10 Cattle and Buffalo Ownership in the Daqalt Area.

	Small	Large	Total
CATTLE	1264	4030	5294
BUFFALO	584	2264	2848
TOTAL			8142 1/

1/ 8142 animals/8694 feddans = 0.94 animals/feddan

TABLE 11 Farm Machinery Inventory for Daqalt Area

Machine	Number	Feddans/Machine[1/]
Tractors	73	119
Trailers	13	669
Threshing Machine	70	124
Winnowing Machine	48	181
Irrigation Pumps	158	55
Spraying Motors	30	290

1/ Based on total area served by cooperatives, 8694 feddans.

TABLE 12 Estimation of Increase in Numbers of Tractors and Pumps at Daqalt. Data Taken from Abu Raya Cooperative.

Machine	Number		Increase
	1979	1983	
Tractor	21	28	33%
Pumps	9	40	344%

TABLE 13 Average Annual Animal Working Hours for Various Operations and Livestock Production/Feed Expense Ratio, 1978-1982

Year	Average Annual Animal Hours For Each Operation						Livestock Production
	Transportation	Plowing	Leveling	Puddling	Irrigation	Total	Feed Expenses
1978-1979	600	97	46	4	606	1353	0.39
1979-1980	880	45	8	8	323	1264	0.45
1980-1981	796	18	6	6	365	1191	0.37
1981-1982	572	11	9	9	93	894	1.5

The Daqalt system is in a process of evolution from its original design and construction. Extra and larger turnout pipes have been installed by water users at mesqa inlets (Hanson, et al., 1984). Extensions have been constructed to the Wizaria, Khalifa, and Helal mesqas in order to take water upstream of the Wizaria and Helal regulators. This modification increased the available head in the Wizaria mesqa and allowed for gravity irrigation on its lower reaches. The Helal and El-Shahina mesqas are joined at their tails forming a looping system. Obstructions are installed and removed in mesqas in order to create desirable lift conditions for saqias and pumps.

Water User Perceptions

Several studies addressed specific water management issues. The major issues which were studied included the time at which water users preferred to irrigate, the opinions of water users concerning a proposed new cropping design, and the major problems of the system as viewed by the water users.

An irrigation timing preference study conducted on Omsen mesqa addressed the question of when water users prefer to irrigate. Results displayed in Figure 10 reveal that irrigation begins in the morning about 4 a.m. and continued until about noon. Evening and night irrigation was rare except during critical periods when sufficient water was not available during the morning hours. Similar irrigation timing patterns were observed for other mesqas. At the end of the morning irrigation session, the water in the mesqas and the canal is much lower than at the beginning. Excessive lift conditions sometimes develop in the late morning and early afternoon due to many water users irrigating at one time. In El-Ghait El-Bahari mesqa one observation revealed that the water level at noon was 1 m lower than that in the early morning hours. When irrigation pumping stops, the water level rises. Water levels are much higher during the evening and night when only a few farmers irrigate. Excess water is lost from the Daqalt System by overflow through the Daqalt tail escape or from mesqas through field drains to main drains.

Another study evaluated water user responses to a proposed plan of planting individual mesqas to only one crop and implementing a rotation at the mesqa level. Mesqas would be equipped with gates and larger pipes. This would allow for the isolation of rice and cotton crops during the summer season. Potential benefits of the proposed plan included more adequate water deliveries during critical periods; water savings; efficiency of inputs supply and farm operations; enhanced water table control; and yield increases. Fifty

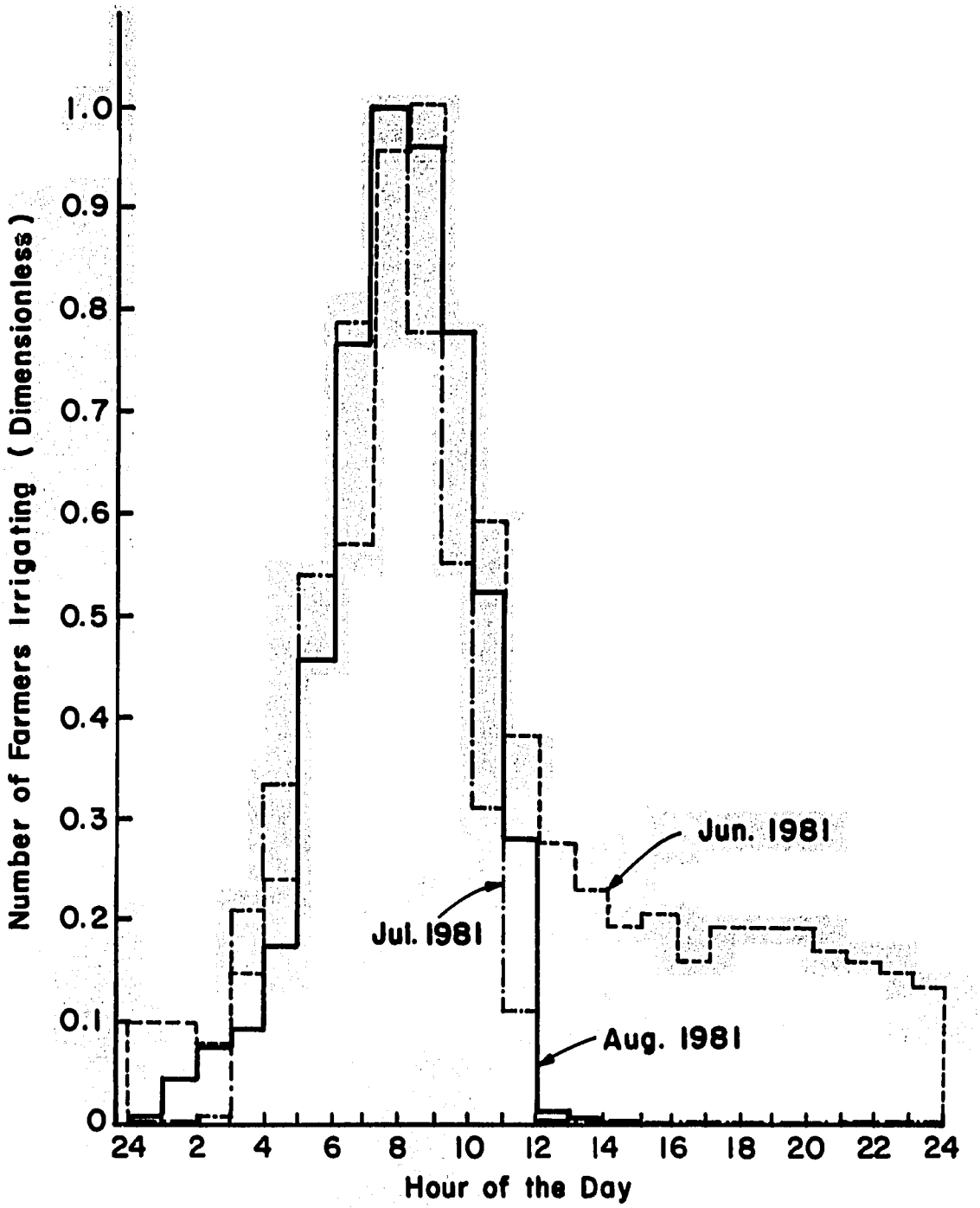

Figure 10. Om Sen Farmers' Preferred Irrigation Timing Histogram for June, July and August, 1981.

water users from nine mesqas were interviewed. A majority of water users felt that the plan would solve the problem of water shortages during critical periods. However, almost all water users saw major problems with planting only one crop on their land. A mixture of crops are needed to feed livestock and family members. Vegetables require frequent irrigations and would be adversely affected by implementation of the plan. With an entire mesqa planted to one crop only, farm operations and irrigations would tend to occur at the same time causing severe labor shortages. Disputes could also develop over irrigation scheduling on saqia units and along the mesqa because of the circumstances created by the consolidation of irrigation times.

The major problems of the canal as perceived by the water users include weeds in the canal and mesqas; a fluctuating water level in the canal; lack of equitable distribution of irrigation water along canals and mesqas in the system; and inadequately sized mesqa turnout pipes. The water users view the insufficient amount of water available during the rice transplanting period as a critical problem.

The water users through the years have learned to manipulate the physical system. However, the water delivery planners have not taken into consideration the changes the water users have made as they attempt to manage the system. As a result, system management has been based on incorrect assumptions and system performance has fallen short of desired levels.

SYSTEM PERFORMANCE AND NEED FOR IMPROVEMENT

Evaluation of system performance was based on data collection, field observations, and hydraulic modeling of the system. A water surface profile program was developed based on:

1. Backwater curve computation using the standard step method proceeding in the upstream direction.
2. A force-momentum balance to calculate the water surface elevation immediately upstream from a flow diversion station.
3. Friction loss calculation based on the Manning formula.[1/]

[1/] Unpublished Temporary Duty Report, W. O. Ree, Jan., 1983.

The program was employed to calculate water surface profiles for the Daqalt Canal. Work has begun on mesqa profiles, however, irregularities in mesqa shape and bottom elevation caused discontinuous water surface profiles. A considerable amount of time would be required to identify the flow controls and calculate the profiles accordingly. Determining water surface profiles for mesqas would be further complicated by branching channels. Hydraulic modeling of the entire system has not been completed to date. However, general observations have been made and conclusions drawn.

OBSERVED PROBLEMS

The Daqalt Canal does not meet its objectives of delivering sufficient water at adequate head and flow rates and minimizing surface losses to drains. Various inadequacies in water delivery were observed during collection of baseline data and related studies.

Water Shortages

Flow through legally sized turnouts is inadequate to supply water to meet peak evapotranspiration requirements (Hanson, et al., 1984). Most turnouts have been replaced by larger or more numerous turnouts. Nevertheless, water users experience shortages during the critical periods of planting or transplanting irrigations. Inadequate water deliveries during those periods cause water users to irrigate later than desired.

Inadequate and Inequitable Flow Rate and Head

Flow rates through legally sized turnouts are insufficient to allow efficient irrigation of large basins (Hanson, et al., 1984). The flow rate of approximately 42 l/sec required at the farm diversion point for efficient on-farm irrigation is often not available. At times, water users need to stop irrigating because vertical lifts exceed the radii of their saqias and flow rate is reduced to negligible levels. The water in the mesqas is often more than 1.0 m below the field elevation.

Both gravity irrigation and lifts exceeding 1 m have been observed. Saqia diameter varies depending on the lift conditions of the respective location in the system. These conditions indicate that water is not delivered to all water users at an equitable head and flow rate.

Surface Losses to Drains

During non-critical periods of water use, large volumes of water accumulate in the lower reaches of the Daqalt System and need to be released to main drains through the Daqalt Canal tail escape or through shallow on-farm surface drains (Tinsley, et al., 1984). Flows to drains also occur at night when little irrigation takes place. At Omsen mesqa, less than 50% of the water delivered is used for evapotranspiration (Helal, et al., 1984).

REASONS FOR PROBLEMS

The system does not perform as designed due to invalid design assumptions and inadequate system management. The management of water delivery to Daqalt does not always take into consideration the existing conditions.

Ineffective Physical Structures Operation

The Daqalt Canal headgate is operated to achieve a predetermined downstream water surface elevation. As indicated by Figure 2 many flow rates are possible for a given downstream head condition depending on gate opening width and upstream water surface elevation.

Physical structures as designed cannot ensure adequate and equitable water distribution due to system alteration by water users; differences in mesqa length and area served; inadequate canal and mesqa maintenance; mesqas which benefit from water sources other than Daqalt Canal; water user irrigation timing preference; large numbers of lifting machines; delayed planting of crops; and excessive areas planted to rice. Water users at tail ends of long, poorly maintained, branching mesqas experience inadequate flow rates and excessive lift conditions during daylight hours when they desire to irrigate. This situation is due in part to increasing numbers of water lifting devices on the mesqas. Centrifugal pumps cause the greatest difficulties due to larger flow rate capacities which are relatively independent of pumping lift. Crops are also planted late due to delays in inputs supply and labor and tractor shortages. This causes large volumes of delivered water to flow to the drain. Water could be saved by altering the canal rotation to match aggregate irrigation water needs (Tinsley, et al., 1984). The percentage of crop lands planted to rice along mesqas often exceeds the assumed 65% maximum value resulting in water shortages.

Irrigation Timing Preference

Most irrigation takes place during morning hours with little during the evening and night. Consequently, turnouts on mesqas do not operate under a constant 24 hour head as designed. Flows in the Daqalt system during on-periods follow non-steady state patterns rather than steady state conditions as assumed. The level of water in the canal and mesqas changes in response to irrigation practice. An analysis of a period of fall and rise in the third reach of Daqalt Canal showed a channel storage change rate equal to about ± 16% of the inflow rate to the reach. The effect would be greater in mesqas where larger changes in water surface elevation and channel storage were observed. this storage effect needs to be taken into consideration in irrigation design.

Poor Maintenance

Canals and mesqas are not well maintained. Water flow is impeded by weeds, tree roots, and floating debris (Egyptian and American Field Team, 1980). In some cases obstructions are deliberately placed in channels. Small dams are constructed across channels during office periods in order to trap fish and are not removed.

Design cross sections are not maintained in Daqalt Canal. Mechanical cleaning and sedimentation cases wider and shallower cross sections than designed (Figure 5). Design and actual bottom elevations are shown in Figures 11a and 11b. Profiles were calculated for the Daqalt Canal for both the original design cross sections and the actual 1980 cross sections. These are also shown in Figures 11a and 11b. For the calculation of these profiles the flows into the mesqa were assumed to be equal to the rates calculated from Equation 3. It was also assumed that every third saqia was pumping at a rate of 0.35 m^3/sec and all diesel pumps had a flow rate of 0.050 m^3/sec. Mannings n was set equal to 0.03.

Sediment deposition was observed to be created in the first reach, and one hundred meters downstream from the headgate it was 0.65 m deep, which raised the water surface profile an estimated 0.20 m. A higher tail water on the Daqalt headgate reduces the possible inflow to the Daqalt Canal. Canal cleaning would be most beneficial in the first reach. In the second reach the sediment deposition averaged 0.20 m deep. The estimated profile for the actual cross section is the same as for the design. Sedimentation has no apparent effect on the water surface profile in this reach, with the widening of the canal offsetting the loss of flow depth. For much of the third reach the

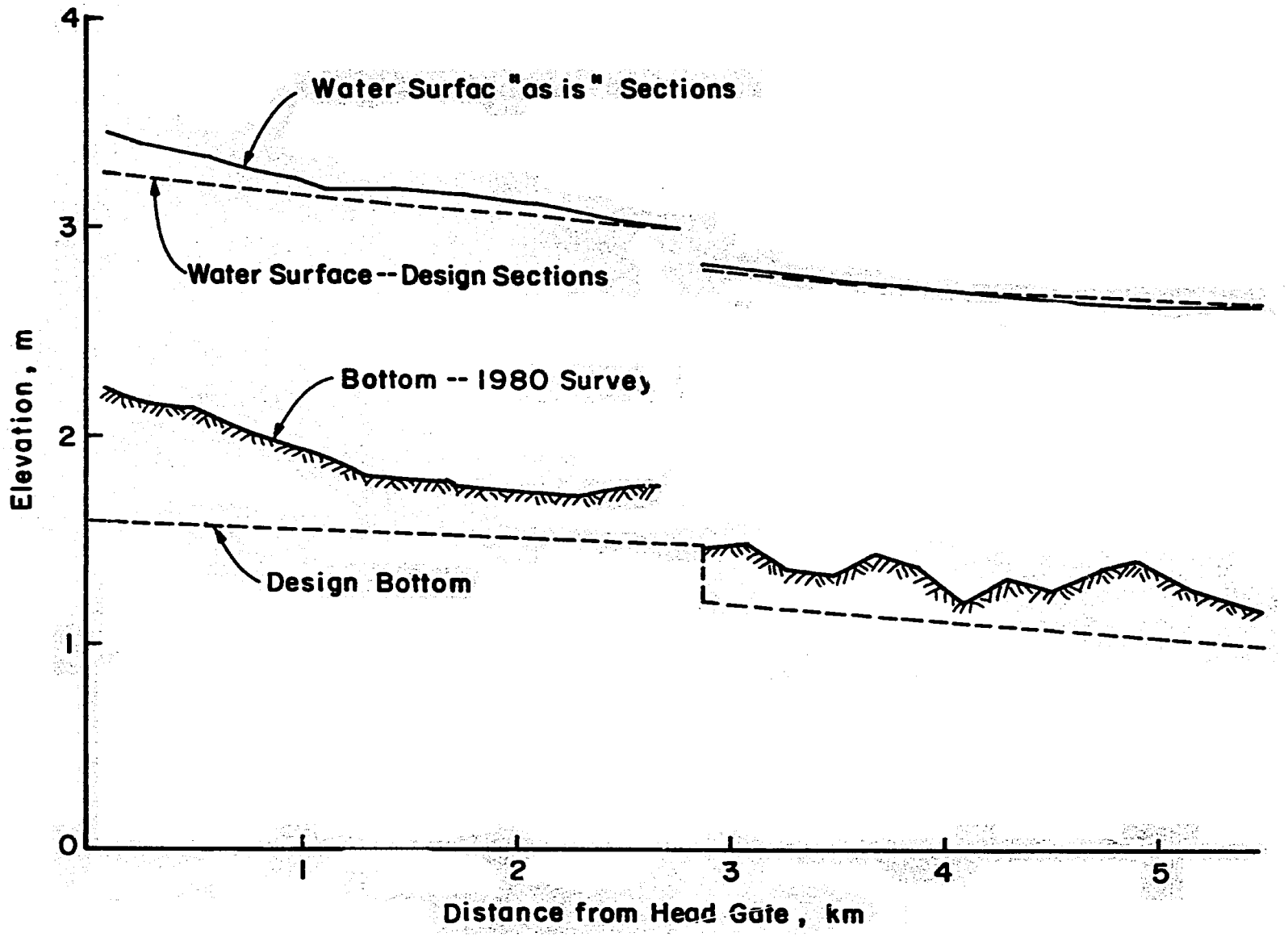

Figure 11a. Daqalt Canal Water Surface Profiles, With Original Design Cross-Sections and With Actual Cross-Sections.

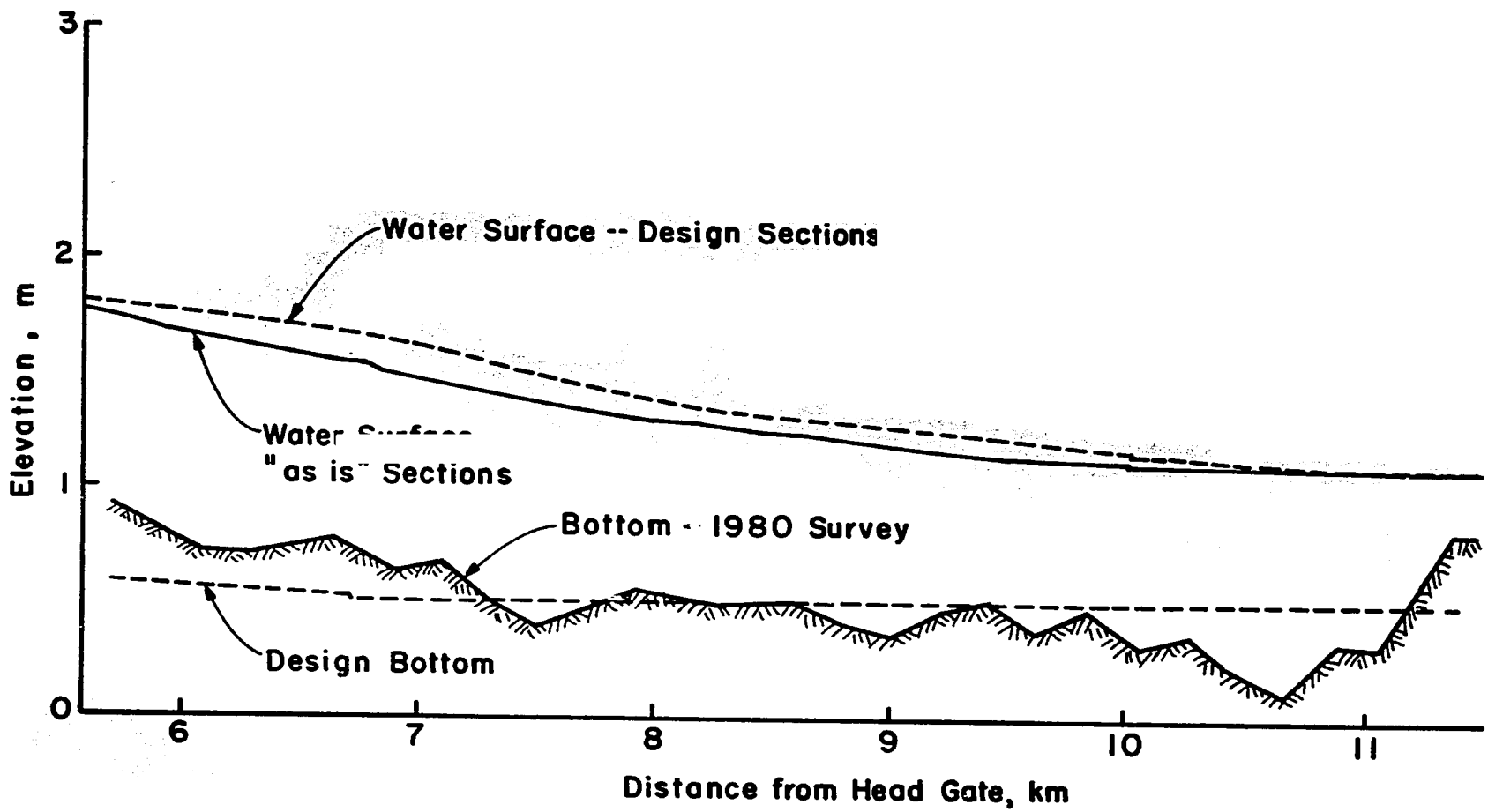

Figure 11b. Daqalt Canal Water Surface Profiles, With Original Design Cross-Sections and With Actual Cross-Sections.

actual bottom elevation is lower than the design elevation. The estimated water surface profile for the actual cross sections is lower than for the design cross sections. This was attributed to the lower bottom elevation and wider cross sections. Sediment has not moved into the downstream end of the canal since the last cleaning.

The Daqalt Canal water delivery system requires renovation to improve its performance. Improved system performance would benefit both water users and water delivery planners. The Canal is part of a larger water delivery network and proposed changes to Daqalt need to consider the impact on the larger system. Improved performance could be achieved by better management of the existing physical structures and increased water user involvement. Interventions which require greater financial and management resources such as construction of a new system with new structures and reshaped and/or re-aligned channels could also be warranted. the goal in either case would be to enable the Daqalt system to achieve its stated objectives in order to produce a bountiful harvest.

SUMMARY AND CONCLUSIONS

The Daqalt Canal water delivery network is a complex physical and socio-economic system. Water levels in the Mit Yazid Canal supplies the Daqalt Canal on a monthly and daily basis. Flow through the Daqalt headgate depends on both water level differences across the gate and the gate opening width. However, prevailing headgate operation is based upon downstream head only. achieving design flow rates through the gate is a difficult process. The canal has three reaches and supplies 24 mesqas of widely varying length, cross section, quality of maintenance, number of branches, and cropped area. The majority of mesqas have illegal turnouts: either extra pipes or oversized pipes.

Irrigation of cracking clay soils requires very large application depths, especially during the pre-planting and/or planting irrigations. Water delivery requirements are large due to excessive land areas planted to rice during the summer season. Water table levels are high and water table contribution to evapotranspiration is significant. A flow rate of about 42 l/sec is required at the farm level in order to irrigate large basins. Flow rates from saqias, the primary means of water lifting, are strongly dependent on the water surface

elevation in the mesqa. Widely fluctuating saqia flow rates were observed between saqias for a season, for one saqia for individual irrigations during a season, and for individual saqias during an irrigation. Saqia flow rate variation is attributed to variation in water surface elevations in the mesqas as well as changing animal draft conditions. A trend was observed for water users to replace saqias and animal drawn tillage by centrifugal pumps and tractors, respectively. The largest demand on the irrigation system is during the transplanting irrigation of rice.

The Daqalt Canal is served by 5 cooperatives whose boundaries do not match irrigation system boundaries. Water users along a single mesqa may be divided into several villages. Water users informally schedule irrigations on saqia units but not on the mesqa or canal levels. Water users prefer to irrigated during morning hours and need to grow a variety of crops. In response to perceived problems, water users make modifications to the physical system which in turn affects system operation.

Problems were observed with the system operation including water shortages, inadequate and inequitable flow rate and head, and large surface losses to drains. System performance falls short of that desired due to incorrect assumptions and improper system management.

The Daqalt Canal water delivery system requires renovation within the context of the larger irrigation system. Appropriate scale of intervention in terms of physical alterations and cost needs to be determined.

RECOMMENDATIONS

The Daqalt Canal renovation process should continue. The existing system should be completed modeled. Renovation efforts should continue to follow the procedures outlined by Gates, et al., (1984a) in identifying, evaluating, and ranking improvement alternatives. Evaluation of alternatives must include a careful comparison of financial and management resources which are required for implementation and those which are available in the implementing organizations.

A complete hydraulic model of the existing Daqalt system should be developed to aid in evaluating management options. The model should be tested with field data. Specifically, the following hydraulic analyses are required:

1. Determine the effect of the water level in the Mit Yazid Canal on the possible inflow rate to the Daqalt Canal.
2. Calculate water surface profiles in the mesqas for actual and design cross sections. Determine head available at the mesqa entrance. If it is insufficient to create the needed flow through the turnout, consider increasing the turnout size or installing a pump at the mesqa inlet.
3. Calculate profiles in a branching system. Consider pipe control or weir control to obtain the desired flow division.
4. Investigate the hydraulics of an unsteady state system. Adapt flood routing methods to the study. Storage characteristics of canals can be developed from a series of steady state profiles.
5. Develop a headgate operation system based on:
   a. Increased flow during irrigation period (morning).
   b. Decreased flow during non-irrigating period (evening and night).
   c. Use of the storage potential with a 0.5 meter variation in water level in the canals and mesqas.
6. Consider making mesqas wider to increase storage potential.

Water delivery planners should carefully evaluate their whole procedure in managing the canal. One of the necessary steps planners need to take is to involve the water users in any management scheme. Water user involvement must be done in a serious and equitable manner. Water users have specific skills which are placed in an extremely important position in the management network. This necessitates their inclusion in any plan which can be deemed successful (Layton, et al., 1984).

REFERENCES

Abdel Hamid Amin Abdallah, et al., 1975. Law No. 74, for the year, 1971, Relative to Irrigation and Drainage. Presented at the International Conference on Global Water law Systems, Valencia, Spain, September.

Baumli, G. R. (ed.), 1982. Principals of Project Formulation for Irrigation and Drainage Projects. American Society of Civil Engineers, New York.

Doorenbos, J. and W.O. Pruitt, 1977. Crop Water Requirements. Irrigation and Drainage Paper 24, Food and Agriculture Organization of the United Nations, Rome.

Egyptian and American Field Team. 1980. Problem Identification Report for Kafr El-Sheikh Study Area. Technical Report 6, Egypt Water Use and Management Project, Cairo, Egypt.

Farouk Abdel Al, D. Martella, and R. L. Tinsley, 1984. Irrigation Practices of EWUP Study Cases - Abyuha and Abu Raya Sites for 1979-1980, 1980-81, and 1981-82. Technical Report #45, Egypt Water Use and Management Project, Cairo, Egypt.

Gates, T. K., J. Andrew, J. Ruff, D. Martella, J. Layton, M. Helal, and A. Nasr. 1984a. Design and Evaluation of Water Deilvery System Improvement Alternatives. Technical Report 55, Egypt Water Use and Management Project, Cairo, Egypt.

Hanson, E., M. El-Kady, K. E. Litwiller, and A. Early, 1984. Impact of Turnout Size and Condition on On-Farm Water Management. Technical Report #71, Egypt Water Use and Management Project, Cairo, Egypt.

Hashim, Abd El-Salam. 1968. The Controlling and Distribution of Irrigation Water in Egypt. Ministry of Irrigation, Cairo, Egypt (In Arabic).

Helal, M., A. Nasr, M. Ibrahim, T. K. Gates, W. O. Ree, and M. Semaika, 1984. Water Budgets for irrigated Regions in Egypt. Technical Report #47, Egypt Water Use and Management Project, Cairo, Egypt.

Layton, J., Mohamed Sallam, Mohamed Naguib, Abdallah Saber, Abdel Fattah El Masry, Ahmed El Attar, Essam Ezz El Din, Farouk Abdel Al Omar, Farouk Hassanein, Hoda Hussen, and Sohair Kamal Yousef. Experiences in Developing Water Users' Associations. Technical Report #65, Egypt Water Use and Management Project, Cairo, Egypt.

Ley, T. W. (ed.), 1983. Farm Irrigation System Design, Kafr El-Sheikh, Egypt. Technical Report #35, Egypt Water Use and Management Project, Cairo, Egypt.

Ley,T.W. & R.L. Tinsley, 1983. Irrigation and Production of Rice in Abu Raya, Kafr El-Sheikh Governorate. Technical Report 9, Egypt Water Use and Management Project, Cairo, Egypt.

Ley, T. W., M. El-Kady, K. Litwiller, E. G. Hanson, W. W. Braunworth, A. El-Falaky, and E. Wafik, 1984. The Influence of Farm Irrigation System Design and Precision Land Leveling on Irrigation Efficiency and Irrigation Water Management. Technical Report 41, Egypt Water Use and Management Project, Cairo, Egypt.

Litwiller, K. E., M. El-Kady, T. K. Gates, and E. Hanson, 1984a. The Relation Between Irrigation Water Management and High Water Tables in Egypt. Technical Report #61, Egypt Water Use and Management Project, Cairo, Egypt.

Litwiller, K. E., R. L. Tinsley, H. H. Deweeb, and T. W. Ley, 1984b. Infiltration Studies on Egyptian Vertisols. Technical Report #57, Egypt Water Use and Management Project, Cairo, Egypt.

Moustafa, A. T. A., and R. L. Tinsley, 1984. Influence of Soil Properties on Irrigation Management in Egypt. Technical Report #64, Egypt Water Use and Management Project, Cairo, Egypt.

Nabawy, Samir (ed.), 1981. Consumptive Use of Major Field Crops in Egypt. Water Master Plan Technical Report No. 17, United Nations Development Program and Ministry of Irrigation, Cairo, Egypt.

Selim, A., M. El-Nahal, M. Assal, and F. Hawela, 1983. Soil Survey Report for Abu Raya Area, Kafr El-Sheikh Governorate. Technical Report #34, Egypt Water Use and Management Project, Cairo, Egypt.

Slack, R., H. Wahby, W. Clyma, and D. Sunada, 1983. Discharge and Mechanical Efficiency of Egyptian Water-Lifting Wheels. Technical Report #36, Egypt Water Use and Management Project, Cairo, Egypt.

Tinsley, R. L., A. Ismail, & M. El-Kady. A Method for Evaluating and Revising Irrigation Rotations. Technical Report #48, Egypt Water Use and Management Project, Cairo, Egypt.

AMERICAN EQUIVALENTS OF EGYPTIAN ARABIC TERMS AND MEASURES COMMONLY USED IN IRRIGATION WORK

LAND AREA	IN SQ METERS	IN ACRES	IN FEDDANS	IN HECTARES
1 acre	4,046.856	1.000	0.963	0.405
1 feddan	4,200.833	1.038	1.000	0.420
1 hectare (ha)	10,000.000	2.471	2.380	1.000
1 sq. kilometer	100×10^4	247.105	238.048	100.000
1 sq. mile	259×10^6	640.000	616.400	259.000

WATER MEASUREMENTS	FEDDAN-CM	ACRE-FEET	ACRE-INCHES
1 billion m^3	23,809,000.000	810,710.000	
1,000 m^3	23.809	0.811	9.728
1,000 m^3 /Feddan (= 238 mm rainfall)	23.809	0.781	9.372
420 m^3 /Feddan (= 100 mm rainfall)	10.00	0.328	3.936

OTHER CONVERSION		METRIC	U.S.
1 ardab	=	198 liters	5.62 bushels
1 ardab/feddan	=		5.41 bushels/acre
1 kg/feddan	=		2.12 lb/acre
1 donkey load	=	100 kg	
1 camel load	=	250 kg	
1 donkey load of manure	=	0.1 m^3	
1 camel load of manure	=	0.25 m^3	

EGYPTIAN UNITS OF FIELD CROPS

CROP	EG. UNIT	IN KG	IN LBS	IN BUSHELS
Lentils	ardeb	160.0	352.42	5.87
Clover	ardeb	157.0	345.81	5.76
Broadbeans	ardeb	155.0	341.41	6.10
Wheat	ardeb	150.0	330.40	5.51
Maize, Sorghum	ardeb	140.0	308.37	5.51
Barley	ardeb	120.0	264.32	5.51
Cottonseed	ardeb	120.0	264.32	8.26
Sesame	ardeb	120.0	264.32	
Groundnut	ardeb	75.0	165.20	7.51
Rice	dariba	945.0	2081.50	46.26
Chick-peas	ardeb	150.0	330.40	
Lupine	ardeb	150.0	330.40	
Linseed	ardeb	122.0	268.72	
Fenugreek	ardeb	155.0	341.41	
Cotton (unginned)	metric qintar	157.5	346.92	
Cotton (lint or ginned)	metric qintar	50.0	110.13	

EGYPTIAN FARMING AND IRRIGATION TERMS

fara = branch
marwa = small distributer, irrigation ditch
masraf = field drain
mesqa = small canal feeding from 10 to 40 farms
qirat = cf. English "karat", A land measure of 1/24 feddan, 175.03 m^2
qarla = village
sahm = 1/24th of a qirat, 7.29 m^2
saqia = animal powered water wheel
sarf = drain (vb.), or drainage. See also masraf, (n.)

EGYPT WATER USE AND MANAGEMENT PROJECT

PROJECT TECHNICAL REPORTS

NO.	TITLE	AUTHOR
PTR#1	Problem Identification Report for Mansuriya Study Area, 10/77 to 10/78.	Egyptian and American Field Teams.
PTR#2	Preliminary Soil Survey Report for the Beni Magdul and El-Hammami Areas.	A. D. Dotzenko, M. Zanati, A. A. Abdel Wahed, & A. M. Keleg.
PTR#3	Preliminary Evaluation of Mansuriya Canal System, Giza Governorate, Egypt.	American and Egyptian Field Teams.
PTR#4	On-farm Irrigation Practices in Mansuriya District, Egypt.	M. El-Kady, W. Clyma & M. Abu-Zeid
PTR#5	Economic Costs of Water Shortage Along Branch Canals.	A. El Shinnawi M. Skold & M. Nasr
PTR#6	Problem Identification Report For Kafr El-Sheikh Study Area.	Egyptian and American Field Teams.
PTR#7	A Procedure for Evaluating the Cost of Lifting Water for Irrigation in Egypt.	H. Wahby, G. Quenemoen & M. Helal
PTR#8	Farm Record Summary and Analysis for Study Cases at Abu Raya and Mansuriya Sites, 1978/1979.	F. Abdel Al & M. Skold
PTR#9	Irrigation & Production of Rice in Abu Raya, Kafr El-Sheikh Governorate.	Kafr El-Sheikh Team as Compiled by T. W. Ley & R. L. Tinsley
PTR#10	Soil Fertility Survey in Kafr El-Sheikh, El Mansuriya and El-Minya Sites.	M. Zanati, P. N. Soltanpour, A.T.A. Mostafa, & A. Keleg.
PTR#11	Kafr El-Sheikh Farm Management Survey Crop Enterprise Budgets and Profitability Analysis.	M. Haider & F. Abdel Al
PTR#12	Use of Feasibility Studies and Evaluation of Irrigation Projects: Procedures for Analysing Alternative Water Distribution System in Egypt.	R. J. McConnen, F. Abdel Al, M. Skold, G. Ayad & E. Sorial

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PTR#13	The Role of Rural Sociologists in an Interdisciplinary, Action-Oriented Project: An Egyptian Case Study.	J. Layton and M. Sallam
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PTR#15	Village Bank Loans to Egyptian Farmers.	G. Ayad, M. Skold, & M. Quenemoen.
PTR#16A	Irrigation System Improvement By Simulation and Optimization: 1. Theory.	J. Mohan Reddy & W. Clyma
PTR#16B	Irrigation System Improvement By Simulation and Optimization: 1. Application.	J. Mohan Reddy & W. Clyma
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PTR#20	The Rotation Water Distribution System vs. The Continual Flow Water Distribution System.	M. El-Kady, J. Wolfe, & H. Wahby
PTR#21	El-Hammami Pipeline Design.	Fort Collins Staff Team
PTR#22	The Hydraulic Design of Mesqa 10, An Egyptian Irrigation Canal.	W.O. Ree, M. El-Kady, J. Wolfe, & W. Fahim
PTR#23	Farm Record Summary and Analysis for Study Cases at Abyuha, Mansuriya and Abu Raya Sites, 79/80.	F. Abdel Al, & M. Skold
PTR#24	Agricultural Pests and Their Control: General Concepts.	E. Attalla
PTR#25	Problem Identification Report for El-Minya	R. Brooks

NO.	TITLE	AUTHOR
PTR#26	Social Dimensions of Egyptian Irrigation Patterns.	E.C. Knop, M. Sallam, S.A. Knop & M. El-Kady
PTR#27	Alternative Approaches in Extension and Rural Development Work: An Analysis of Differing Perspective In Egypt.	M. Sallam & E. C. Knop
PTR#28	Economic Evaluation of Wheat Trials at Abyuha, El-Minya Governorate 79/80-80/81.	N. K. Farag, E. Sorial, & M. Awad
PTR#29	Irrigation Practices Reported by EWUP Farm Record Keepers.	F. Abdel Al, M. Skold & D. Martella
PTR#30	The Role of Farm Records in the EWUP Project.	F. Abdel Al & D. Martella.
PTR#31	Analysis of Farm Management Data From Abyuha Project Site.	E. Sorial, M. Skold, R. Rehnberg & F. Abdel Al
PTR#32	Accessibility of EWUP Pilot Sites.	A. El-Kayal, S. Saleh, A. Bayoumi & R. L. Tinsley
PTR#33	Soil Survey Report for Abyuha Area Minya Governorate.	A. A. Selim, M. A. El-Nahal, & M. H. Assal
PTR#34	Soil Survey Report for Abu Raya Area, Kafr El-Sheikh Governorate	A. A. Selim, M. A. El-Nahal, M. A. Assal & F. Hawela.
PTR#35	Farm Irrigation System Design, Kafr El-Sheikh, Egypt.	Kafr El-Sheikh Team as compiled by T. W. Ley
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PTR#38	Precision Land Leveling On Abu Raya Farms, Kafr El-Sheikh Governorate, Egypt.	EWUP Kafr El-Sheikh Team, as compiled by T. W. Ley
PTR#39*	On-Farm Irrigation Practices for Winter Crops at Abu Raya.	A. F. Metawie, N. L. Adams, & T. A. Tawfic

NO.	TITLE	AUTHOR
PTR#40	A Procedure For Evaluation Crop Growth Environments For Optimal Drain Design.	D. S. Durnford, E. V. Richardson & T. H. Podmore
PTR#41	The Influence of Farm Irrigation System Design and Precision Land Leveling on Irrigation Efficiency and Irrigation Water Management.	T. W. Ley, M. El-Kady K. Litwiller, E. Hanson W. S. Braunworth, A. El-Falaky & E. Wafik
PTR#42	Mesqa Renovation Report.	N. Illsley & A. Bayouml
PTR#43	Planning Irrigation Improvements In Egypt: The Impact of Policies and Prices on Farm Income and Resource Use.	M. Halder & M. Skold
PTR#44	Conjunctive Water Use - The State of the Art and Potential for Egypt.	V. H. Scott & A. El-Falaky
PTR#45*	Irrigation Practices of EWUP Study Abyuha and Abu Raya Sites for 1979-1980, 1980-1981, 1981-1982.	F. Abdel Al, D. Martella, & R. L. Tinsley
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PTR#47	Water Budgets for Irrigated Regions in Egypt	M. Helal, A Nasr, M. Ibrahim, T. K. Gates, W. O. Ree & M. Semaika
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PTR#53*	Crop Management Studies by EWUP.	M. Abdel Naim
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NO.	TITLE	AUTHOR
PTR#55*	Design and Evaluation of Water Delivery System Improvement Alternatives.	T. K. Gates, J. Andrew, J. Ruff, D. Martella, J. Layton, M. Helal & A. Nasr.
PTR#56	Egyptian Canal Lining Techniques and Economic Analysis	M. El-Kady, H. Wahby, J. Andrew
PTR#57	Infiltration Studies on Egyptian Vertisols.	K. Litwiller, R. L. Tinsley H. Deweeb, & T. W. Ley
PTR#58*	Cotton Field Trials, Summer, 1980 Abu Raya.	Kafr El-Sheikh Team as compiled by M. Awad & A. El-Kayal
PTR#59*	Management Plan for a Distributary Canal System	A. Saber, E. Wafik, T. K. Gates, & J. Layton
PTR#60	Hydraulic Conductivity and Vertical Leakage in the Clay-Silt Layer of the Nile Alluvium in Egypt.	J. W. Warner, T. K. Gates, W. Fahim, M. Ibrahim, M. Awad, & T. W. Ley.
PTR#61	The Relation Between Irrigation Water Management and High Water Tables in Egypt.	K. Litwiller, M. El-Kady T. K. Gates & E. Hanson
PTR#62*	Water Quality of Irrigation Canals, Drains and Groundwater in Mansuriya, Kafr El-Sheikh and El-Minya Project Sites.	A. El-Falaky & V. H. Scott
PTR#63	Watercourse Improvement Evaluation (Mesqa #26 and Mesqa #10)	R. McConnen, E. Sorial, G. Fawzy
PTR#64	Influence of Soil Properties on Irrigation Management in Egypt.	A.T.A. Moustafa & R. L. Tinsley
PTR#65	Experiences in Developing Water Users' Associations.	J. Layton and Sociology Team
PTR#66	The Irrigation Advisory Service: A Proposed Organization for Improving On-Farm Irrigation Management in Egypt.	J. Layton and Sociology Team
PTR#67	Sociological Evaluation of the On-Farm Irrigation Practices Introduced in Kafr El-Sheikh.	J. Layton, A. El-Attar H. Hussein, S. Kamal & A. El-Masry
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PTR#69	The Administrative and Social Environment of the Farmers in an Egyptian Village.	J. B. Mayfield & M. Naguib

NO.	TITLE	AUTHOR
PTR#70*	Factors Affecting the Ability of Farmers to Effectively Irrigate: A Case Study of the Mansuriya Mesqa, Kafr El-Sheikh.	M. Naguib & J. Layton
PTR#71*	Impact of Turnout Size and Condition on Water Management on Farms.	E. Hanson, M. El-Kady & K. Litwiller
PTR#72	Baseline Data for Improvement of a Distributary Canal System.	K. Ezz El-Din, K. Litwiller, & Kafr El-Sheikh Team
PTR#73	Considerations of Various Soil Properties For The Irrigation Management of Vertisols	C. W. Honeycutt & R. D.Heil
PTR#74	Farmers' Irrigation Practices in El-Hammami Sands	T. A. Tawfic, & R. J. Tinsley
PTR#75	Abyuha Farm Record Summary 1979-1983	EWUP Field Team
PTR#76	Kafr El Sheikh Farm Record Summary	EWUP Field Team
PTR#77	El Hammami Farm Record Summary & Analysis	M. Haider & M. Skold
PTR#78	Beni Magdul Farm Record Summary	EWUP Field Team
PTR#79	Analysis of Low Lift Irrigation Pumping	H. R. Horsey, E. V. Richardson M. Skold & D. K. Sunada

EGYPT WATER USE AND MANAGEMENT PROJECT MANUALS

NO.	TITLE	AUTHOR
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