Technical Report No. 20

The Rotation Water Distribution System

vs.

The Continual Flow Water Distribution System

April 1982

TECHNICAL REPORT NO. 20

THE ROTATION WATER DISTRIBUTION SYSTEM

VS.

THE CONTINUAL FLOW WATER DISTRIBUTION SYSTEM

Results of an evaluative study
conducted by the Egypt Water
Use and Management Project in
El-Mansuriya, Giza Governorate
1977-1979

MONA EL-KADY, JOHN WOLFE, HASSAN WAHBY

April 1982

EGYPT WATER USE AND MANAGEMENT PROJECT

· 22 El Galaa St., Bulak, Cairo, Egypt

Prepared under support of

WATER DISTRIBUTION RESEARCH INSTITUTE, WATER RESEARCH CENTER

MINISTRY OF IRRIGATION, GOVERNMENT OF EGYPT

UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT
Contract No. AID/NE-C-1351

Contracting agencies

Colorado State University
Engineering Research Center
Ft. Collins, Colorado 80523
USA

Consortium for International
Development
5151 E. Broadway, Ste. 1500
Tucson, Arizona 85711, USA

Abstract

In 1977, the Egypt Water Use Project re-designed and lined the Beni Magdul Canal and introduced the continuous flow water distribution system giving water to farmers on demand. Over the next three years, researchers gathered data on the effectiveness of the new system, using measurements from the Nahia Canal, unimproved and on the old rotation system, as their control.

Because this experiment was conducted in the early days of the Project in Egypt, conditions were not ideal and it was necessary to make large allowances for possible error in the collection of the data. This factor was taken into consideration in the presentation and analysis of the data.

The two systems were compared on nine counts, and results showed that continuous flow irrigation was a marked improvement over the older rotation system. In particular, the new system required smaller cross-sections for the canals and *mesqas*, thereby freeing land. The water table dropped dramatically over the three year period. The new system also eliminated fluctuations in the water table level which used to affect crop yields adversely under the rotation system. Finally, the continuous flow method greatly reduced the amount of water needlessly flowing through the irrigation system.

The experiment showed that, for full benefit from the continuous flow system, it should be directed by an irrigation engineer who regulates the flow in the canals daily. Results also seemed to indicate that it will take farmers some time to adapt to the new system, and make full use of it.

25 pages, 3 figures, 4 tables

مستخلـــــــص

في عام ١٩٧٧ قام مشروع مصر لاستخدام المياه بأعاده تصميم وتبطين ترعه فى مجدول وأدخل نظام التوزيع المستمر للمياه المتدفقة واعطاء المياه للفلاحين عند الطلب . وفى خلال السنوات التالية قام الباحثـون بجمع المعلومات عن تاثير النظام الجديد باستخدام المقاييس التـى أخذت من ترعه ناهية الفير محسنه والتى تتبع النظام القديم للمناوبات وذلك وفقـا لضوابطهم .

ونظرا لان هذة التجربة قد اجريت فى الأيام الأولى من المشروع بمصر فان الأحوال لم تكن نموذجية ، وكان من الضرورى التجاوز الى حد كبير عن الخطا الممكن فى جمع المعلومات . وقد أخذ هذا العامل فى الأعتبار عند تقديم المعلومات وتحليلها .

هذا وقد قورن النظامين فى تسع احصائيات واظهرت النتائج أن الرى بالراحة المستمر كان تحسينا ملحوظا يعلو عن نظام المناوبات الاكثر قدما . وعلى وجة الخصوص فأن النظام الجديد قد تطلب قطاعات أصغر للترع والمساقى ومن ثم فانه يوفر الأرض . كما أن مستوى الماء الأرضى قد هبط بصورة مثمرة خلال فترة الثلاث سنوات . وقد قلل النظام الجديد من تقلبات مستوى الماء الارضى وابت على التاثير على انتاجية المحصول بصورة غير ملائمة فى ظل نظام المناوبات . واخيرا فان نظام التدفق المستمر قد قلل كثيرا من كمية المياه التى تدفق دون حاجة اليها فى نظام الرى .

وقد اظهرت التجربة أن للانتفاع بصورة كاملة بنظام الرى المستمر فانه ينبغى أن يديره مهندس رى يقوم بتنظيم التدفق اليوم الى الترع . كما يبدو أيضا ان النتائج تشير الى أن الفلاحين سوف يستغرقون بعض الوقت للتكيف مع النظام الجديد واستخدامه استخداما كاملا .

عدد ٢٥ صحيفـة – عدد ٣ أشكال – عدد ٤ كشـوف

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

A Comparison of Two Methods for Supplying Water to Egyptian Irrigation Canals*

I. Introduction

During its first years in Egypt, the Egypt Water Use and Management Project (EWUP) conducted a study to determine the relative efficiency of two methods of supplying irrigation water at the farm level. The first was the rotation system, presently in use in Egypt. Under this system, farmers receive irrigation water for a specific number of days (the working period, or "on" period). Working periods alternate with blocks of time during which no water enters the canal (the closure period, or "off" period). In the area studied, the rotation was 8 days off, and four days on. The continuous flow system, on the otherhand, maintains a lower but continuous supply of water in the canal, which is distributed to the farmer upon demand on a modified demand basis. Farmers along the *mesqa* must still take turns because the continuous stream size is often not enough for *saqias* working at once.

The two systems were compared on nine counts:

1. water savings (discharge comparisons)
2. acceptability to farmers
3. equitable distribution of water
4. length of interval between irrigations
5. affect on water table (gauged over a three-year period)
6. land savings
7. effect on seepage from canals and *mesqas*
8. effect on growth of weeds in canals
9. crop yield

* *A version of this paper was presented at the International Congress for Irrigation and Drainage, August-September 1981, Grenoble, France and it appeared in the ICID Bulletin No. 2, 1981.*

II. Specifications of the Study

The site chosen for the study was the Beni Magdul Canal in Mansuriya, just outside Cairo (Giza Governorate). This canal serves 748 *feddans*, and, until 1977, was typical of the majority of branch canals in Egypt. It received water from the Mansuriya Canal on a rotation system of 4-on to 8-off. The canal was unlined, and its cross-section was enlarged. The banks of the canal had deteriorated due to the removal of soil for the making of bricks, trampling by animals to gain access to the canal and by people using the canal for washing. The original cross-section was further affected by an overgrowth of weeds and by accretions of silt.

Water flows eastward by gravity and enters Beni Magdul Canal by a sluice gate. Prior to 1977, water then continued down the canal and entered subsidiary *mesqas* by means of pipes. The Canal serves eleven *mesqas* on its north side, and   on its south side. The size of the pipe was chosen to conform with the amount of land served by each particular *mesqa*, assuming a head of 25 cm over the entrance crest. A smaller canal branches from Beni Magdul to the south, to supply three additional *mesqas*. This canal, too, showed a deteriorated cross-section, and water sometimes overflowed its banks.

In 1977, EWUP carried out the following improvements on the Beni Magdul Canal:

1. the cross-sections were reshaped and lined,
2. a system of continuous flow was introduced to replace the existing rotation distribution system. Under the new system, the flow of water into Beni Magdul was controlled and restricted to reduce the Canal's general water level. Water was supplied to farmers on demand.

An irrigation engineer controlled the inflow of water into the newly-lined Canal. He gave daily instructions to the gatekeeper, adjusting the main gate to maintain a specified water level just downstream from the gate in the morning. The water was cut back to a lower level every evening.

These levels were determined in accordance with measurements taken on a calibrated Nerpic gate below the main gate to obtain a certain stream size. Researchers gauged the "total daily inflow" as equal to the consumptive use of the cropped area plus about 10 percent. An estimated consumptive use was calculated using the Blaney Criddle method, based on weather data from previous years. If any significant spill was observed from the end of the canal or from its branch, or if the level anywhere along the canal was too low to serve the *mesqas*, appropriate adjustments were made on the following day. This procedure permitted the canal to fill completely during the night, so that if farmers on the tail end of remote *mesqas* were in need, they would be able to obtain water at that time.

Experience showed that the presence of the engineer was necessary to the success of the continuous flow method. TABLE 1 shows monthly discharges to the area served by the Beni Magdul canal during the years 1977-1978 and 1978-1979. During the first year, although the continuous flow system was in operation, the Canal did not yet have the services of an irrigation engineer. During the second year, the system described above was followed, resulting in a 1,000,000 m^3/year savings in irrigation water.

It is difficult to make comparative studies of water use in Egypt because of the absence of data concerning irrigation systems in the recent past. No records were available for the amount of water needed per *feddan* in the Beni Magdul area before 1977. It was necessary for the researchers, to work under the assumption that the Canal, before lining, had functioned similarly to existing, unlined canals in the area. The Nahia Canal, which serves 850 *feddans* in Mansuriya, was chosen for purposes of comparison.

Table (1): Monthly Discharges to Beni Magdul Area in Agricultural Years 1977/1978 and 1978/1979

Month	Discharges in m^3/month	
	1977/1978	1978/1979
Oct.	590 932	588 743
Nov.	505 250	444 347
Dec.	340 891	278 485
Jan.	43 986	25 000
Feb.	313 260	360 385
March	406 330	444 123
April	513 276	602 391
May	891 920	549 520
June	679 207	602 392
July	726 192	641 547
Aug.	892 218	476 010
Sept.	468 765	348 892
Total	6 372 227	5 360 840
Water duty per *feddan* in year	8 275	6 962

This is the first canal to the north of the Beni Magdul Canal. Like Beni Magdul before 1977, Nahia Canal is under the 4-on to 8-off system of rotation; it has a large, deteriorated cross-section; and it is so situated that a few fields can occasionally be irrigated by gravity.

At this point it should be noted that this study, conducted in EWUP's first years in Egypt, did not have all of the controls the researchers might have wished. Discrepencies due to inadequate measuring devices or insufficient numbers of readings have been accounted for, however, by allowing generous margins for error.

After analyzing the results of the study, researchers found them to be so dramatic--even with these allowances--that it was decided to present the information for wide distribution, the efficiency of the existing rotation system of irrigation being of key importance to the Egyptian agricultural economy.

III. Methods used to measure discharge

A. Beni Magdul Canal: Continuous Flow System with an improved and lined cross-section

A Nyrpic Gate with seven separate slide gates was used to measure the intake of Beni Magdul Canal. The structure was calibrated against current meter measurements to match several possible combinations of gate openings and upstream heads. Researchers took both weir flow and orifice flow into account in choosing the range of heads for the calibration. Calibration curves were plotted and mathematical equations obtained from them. Since the downstream head was not sufficient to create a submerged discharge at any time, one recorder placed on the upstream side of the Gate was sufficient. Charts from this recorder were then processed on a computer digitizer and the flow calculated by the computer using the calibration equations.

It was estimated that the maximum error in these measurements would not exceed $\pm 10\%$ for the individual 12-day periods, and would be less than that for the 6-mo. total.

B. Nahia Canal: The Rotation System with an unimproved canal (Control data).

The discharge of the Nahia Canal was measured with a current meter near the intake of the Canal. Due to lack of personnel, only one reading was made each day. Although researchers attempted to take measurements for each day of the four-day working periods, this was not always possible. It was therefore necessary to make allowances for any variations which might have occurred over the 4-day period which had gone unrecorded. An arbitrary daily mean for any particular on-period, then, was calculated by taking the mean of all the daily measurements for that period as well as those for the period preceding and that following.

There was also considerable variation in the measured daily flow during off-periods, and researchers were unable to obtain sufficient numbers of measurements to account for these empirically. It was arbitrarily decided to use the mean based on all sixty measurements made during off periods as the "average daily flow" during each off-period. This procedure, by making the daily flow a constant, would mask any variations in off-period flow which were due to seasonal changes.

Another source of error was the diurnal fluctuation of head in the canals. Variations in upstream and downstream head will cause variations in the amount of discharge throughout the day. Since it was not possible to take measurements more than once a day, it was necessary to make some allowance for these fluctuations.

A few kilometers farther north, on the El-Hammami Canal, EWUP had installed a water level recorder. Results from this recorder showed that the measurements taken for the purposes of this experiment--which had all been gathered at approximately 10:00 A.M.--had been taken at a good time for determining the approximate average head. This was later confirmed by information from the level recorder which was installed at Beni Magdul Canal itself. Nahia Canal (which was used as a control and never improved by the PROJECT), did not have a level recorder, but was assumed to follow the same general pattern as its neighbor, Beni Magdul Canal.

Experienced engineers who examined this data judged that the sum of the errors in these measurements, taking into account the compensatory variations, would be less than ±20%.

IV. Results

A. Nine-count comparison

1. Water Savings (discharge comparisons)

The total discharge measured in the Beni Magdul Canal during the last six months of 1979 was 3,815 m^3 per *feddan*. This compares with the 7,107 m^3 per *feddan* discharge from the Nahia Canal. Even given a combined maximum error of as much as ±30%, the measured difference is very great.

Table 2 gives short-term results, each figure representing a 12-day cycle (4-on to 8-off) in the Nahia Canal rotation schedule. The off days were divided in half, four on each side of the on days. Measurements are expressed in both cubic meters per *feddan* and in milimeters.

Table 3 shows the estimated average daily consumptive use during the test period, calculated on the basis of actual weather data and cropping patterns in the Beni Magdul area using the Blaney-Criddle equation.

Table (2): Measured Average Daily Discharge in Nahia and Beni Magdul Canals Per Unit of Net Cropped Area Served During the Last Half of 1979

	Nahia Discharge		Beni Magdul Discharge	
	m^3/*feddan* per day	mm/day	m^3/*feddan* per day	mm/day
June 29 - July 11	35.75	8.15	27.71	6.59
June 12 - July 23	39.98	9.52	29.78	7.09
July 24 - Aug. 4	42.02	10.00	30.25	7.20
Aug. 5 - Aug. 16	44.18	10.51	27.52	6.55
Aug. 17 - Aug. 28	40.02	9.52	21.72	5.17
Aug. 29 - Sept. 9	39.10	9.31	15.14	3.60
Sept 10 - Sept. 21	37.71	8.97	14.43	3.43
Sept 22 - Oct. 3	38.15	9.08	20.16	4.80
Oct. 4 - Oct. 15	38.80	9.23	25.13	5.98
Oct. 16 - Oct. 27	38.32	9.12	23.00	5.47
Oct. 28 - Nov. 9	35.13	8.36	21.61	5.14
Nov. 10 - Nov. 21	37.03	8.81	18.56	4.42
Nov. 22 - Dec. 3	35.27	8.39	15.50	3.69
Dec. 4 - Dec. 14	38.39	9.14	12.44	2.96
Dec. 15 - Dec. 26	36.69	8.73	11.86	2.82

Table (3): Estimated Average Daily Consumptive Use Over the Net Cropped Area in Beni Magdul During July through December, 1979

	m^3 per *feddan* per day	mm per day
July 1-15	21.00	5.00
July 16-31	28.16	6.70
Aug. 1-15	31.87	7.59
Aug. 16-31	30.02	7.15
Sept 1-15	0.46	0.11
Sept 16-30	0.52	0.12
Oct. 1-15	15.11	3.60
Oct. 16-31	19.16	4.56
Nov. 1-15	17.38	4.14
Nov. 16-30	17.06	4.06
Dec. 1-15	16.71	3.98
Dec. 16-31	16.00	3.80

Figure 1 shows the comparison of estimated consumptive use, actual discharge from the Beni Magdul Canal and actual discharge from the Nahia Canal for the last six months of 1979. The reader will notice that canal discharge in Beni Magdul appears to dip below the estimated consumptive use in August and again in November-December. The reason for this is not known, but it was not intentional. It is possible that readings were affected by the fact that the Mansuriya Main Canal sometimes went down after the gate had been set for the day, thereby reducing the flow until it was corrected the following day. The authors are not aware that crops suffered because of insufficient water during these periods. Crops can go long periods of time between irrigations in winter because the water table tends to be somewhat higher, and the low consumptive rate can be supplied by upward capillary flow. In any case, the margin of possible error in the measurement of the amount of water applied, plus the even greater possible error in the estimate of consumptive use, do not permit us to conclude that insufficient water was applied during these periods. If this in fact were the case, however, the major result would be a slight lowering of the water table.

It is clear from the information contained in these figures and tables that, after the introduction of continuous flow, and irrigation on demand, it was possible to reduce the inflow to the area substantially with no apparent adverse effects on the crop.

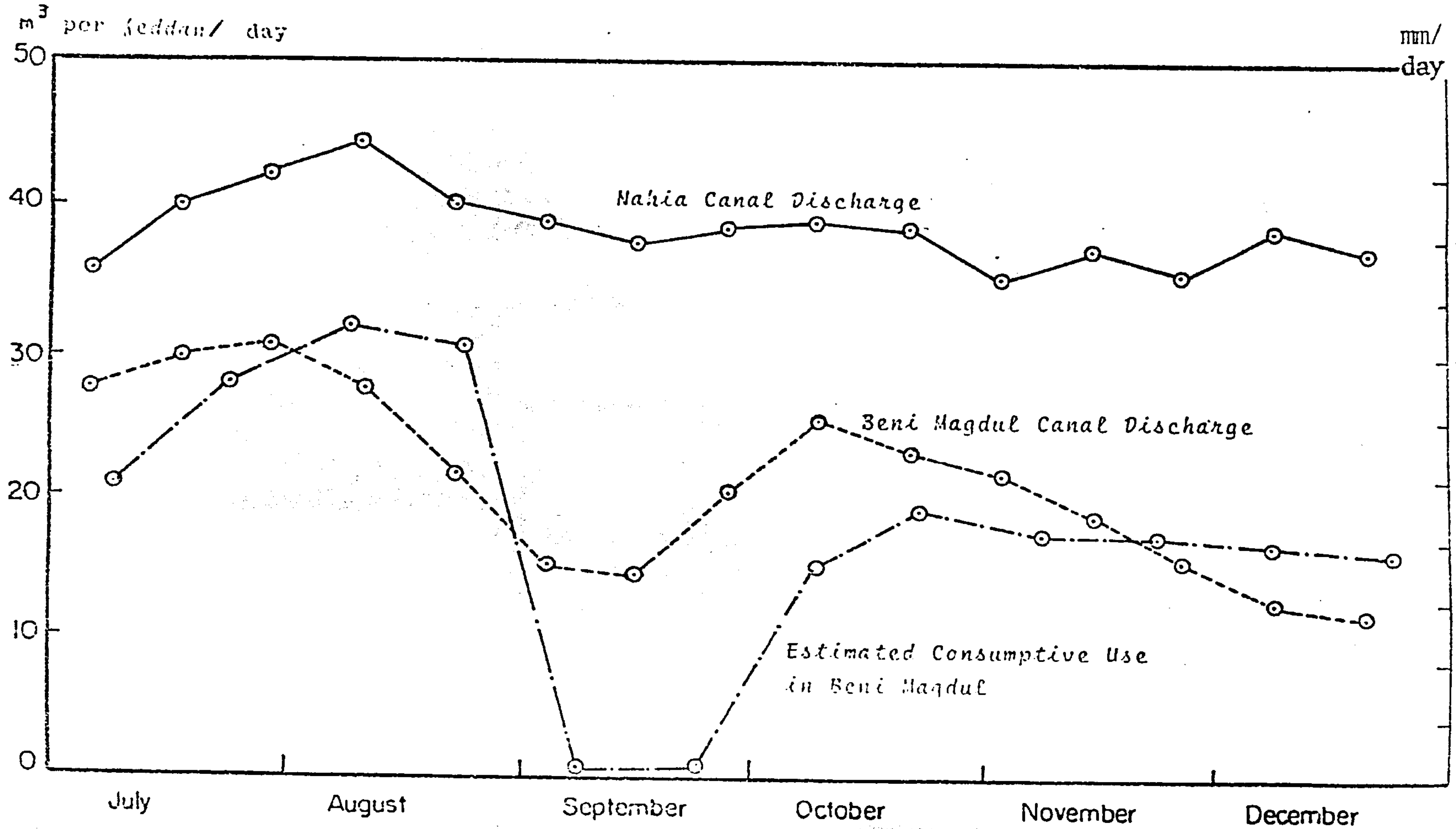
2. Acceptability to Farmers

One measure of the success of a new system is its acceptability to farmers who will use it. The results of a survey carried out by the EWUP sociology team and the on-farm activity team in El-Mansuriya showed:

55% of farmers polled preferred the continuous flow/irrigation on demand system.

45% of farmers polled preferred the rotation system.

FIGURE 1. Discharge in the Beni Magdul Canal as Compared with Discharge in the Nahia Canal: Estimated Consumptive Use in Beni Magdul during the Last Half of 1979



The group of farmers who preferred the rotation system did so, however, with the sole aim of obtaining higher water levels in the Canal during the working periods. Although the Egyptian irrigation system is a lift system by law, higher water levels in the canal would allow farmers with low lying lands to irrigate by gravity flow. It would also mean more water available for farmers at the tail end of the canal and an excessive amount of water for those in the first reach.

One result of the introduction of continuous flow/irrigation on demand in Beni Magdul was that farmers began to think about the need for instituting an irrigation schedule for the first time.

3. Equitable Distribution of Water

One of the major problems identified in the Mansuriya rotation system was that water was not distributed equally among the farms served by the Mansuriya Canal (EWUP Technical Report No. 1, 1979). Figure 2, a graph of the accumulated discharge over six months for the Canal and several of its laterals, illustrates how water available per *feddan* decreases in direct proportion to the distance from the intake of a canal or branch. As a result, lands at the head receive more water than they need, while those at the tail do not receive enough. This was the major complaint of farmers from the last reach of the El Mansuriya Canal.

It should be noted that farmers have registered no official complaints in the Beni Magdul area concerning the inequity of their water shares over three years of experience with the continuous flow system. Complaints did arise, however, from two areas: the first area on the tail of Beni Magdul Branch (El-Ashmawy Branch) and the tail of *Mesqa* No. 3, rights hand side of Beni Magdul Canal.

All curves to the right and below the Mansuriya/Beni Magdul curves represent shortages of water in these Canal reaches. Curves above the Beni Magdul curve represent areas with a surplus of water.

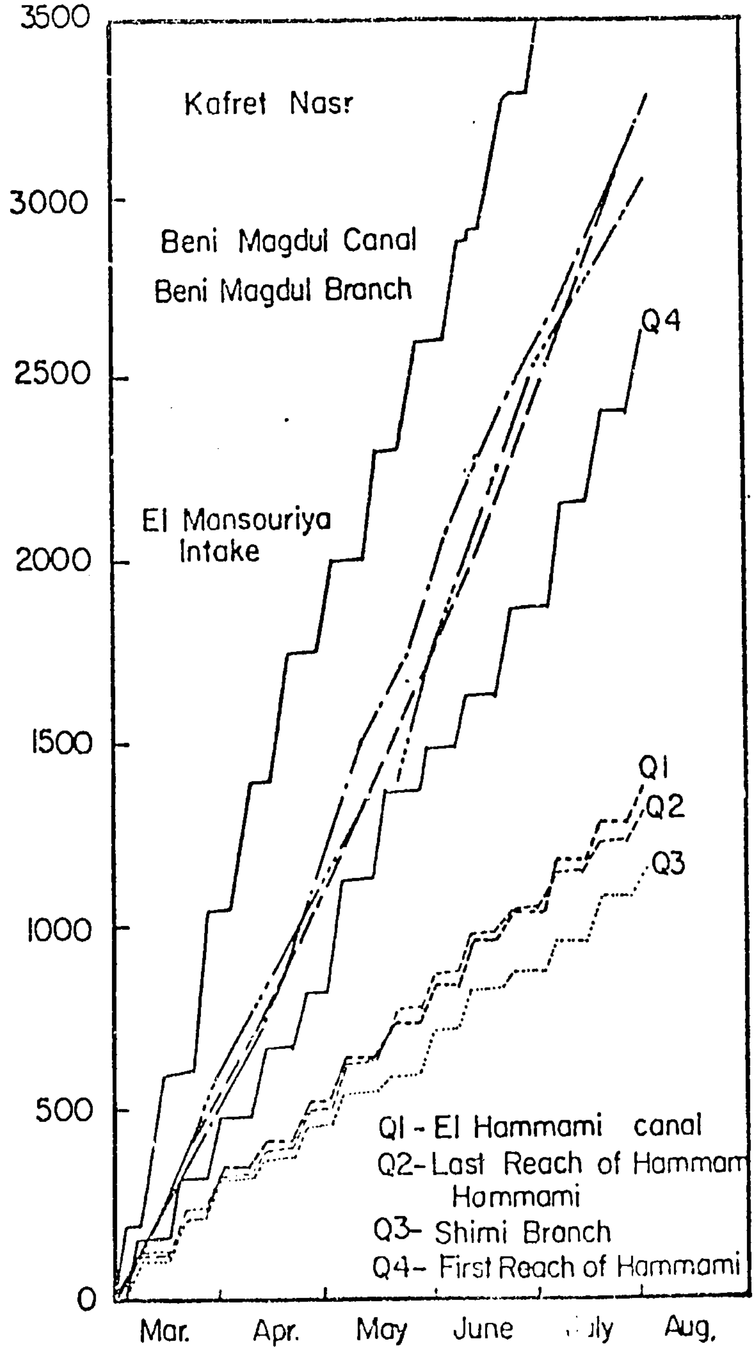


FIGURE 2. Accumulated Discharge as Measured at Upstream Head Gates for the El-Mansuriya Canal and Three of Its Laterals, as a

Farmers in these areas complained that they were not receiving sufficient water, but it was discovered that this was due to the fact that they had not cleaned their private ditches sufficiently to allow the water to reach their lands. These farmers, seeing that the Government of Egypt had funded the lining of the Beni Magdul Branch Canal, felt that it should also undertake the much smaller job of lining their private ditches. Continual complaints about lack of water, therefore, are their attempt to put pressure on EWUP and the GOE to line these ditches.

In the second area, however, *Mesqa* No. 3, the *mesqa* is almost 2 km long, and farmers at the tail cannot be expected to clean the whole length. Since farmers in the first reach of the ditch have sufficient water for their needs, they are not willing to help in keeping the *mesqa* clean. EWUP cleaned this *mesqa* at the beginning of 1980, with the result that farmers at the tail end received the same share as those in the first reach, but the question remains as to how long the farmers will maintain the *mesqa* in a satisfactory state.

Given these facts, it appears that continuous flow irrigation can alleviate the problem of unequal water distribution, but that it must be accompanied with an organized program for ditch cleaning and maintenance to be fully effective.

4. Length of Interval between Irrigations (Table 5)

On a continuous flow system farmers may irrigate whenever they feel their crops need water subject to coordination with neighbors. The median irrigation frequency on Beni Magdul Canal was every 9 to 12 days. The smallest interval between irrigations was five days, since no farmers irrigated with intervals of four days or less. Long intervals between irrigations--17 days or more--which represent 28% of the sample, can be accounted for by conditions which obtained early or late in the cropping season, and by the complete cessation between crops.

On a rotational system of 4-on and 8-off, many farmers on the El Hammami Canal irrigated at the beginning and end of their 4-day working period, so that 25% of the irrigations came at intervals of four days or less. Apparently they were afraid the crop would suffer on a 12-day schedule. At least one third of the irrigations occurred at intervals of 9 to 12 days. In principle, all irrigations on the rotation system should have come at 9 to 12, or 21 to 24-day intervals, since these are the intervals of the irrigation rotation. Since, however, 57% of the irrigations occurred at intervals which were not multiples of 12, water must have been taken unofficially from canal storage, gate leaks, drains, or groundwater reserves. No interval data are available for Nahia. El Hammami is a few kilometers north of Nahia.

Table (4): Intervals between Irrigations, El-Mansuriya, 1978

length of interval in days	BENI MAGDUL CANAL		NAHIA CANAL	
	Continuous flow No. of Irrigation	System canal % of Total Irrigations	Rotational flow No.	System canal %
1-4			31	25
5-8	25	21	17	14
9-12	37	32	41	33
13-16	23	20	19	16
17-20	24	21	3	2
21-24	6	5	8	7
25-28	1	1		
29-32	1	1		
33-36			1	1
37-40				
40			3	2
	117	100	123	100

5. Affect on Water Table (gauged over a three-year period)

Figure 3 shows the average water table levels during the last three years in the Beni Magdul area.

As can be seen in Figure 3, the average level of the water table has been declining since the introduction of continuous flow distribution in 1977. After three years of the new system, the level is an astonishing 30 cm. lower than it was before the system was introduced.

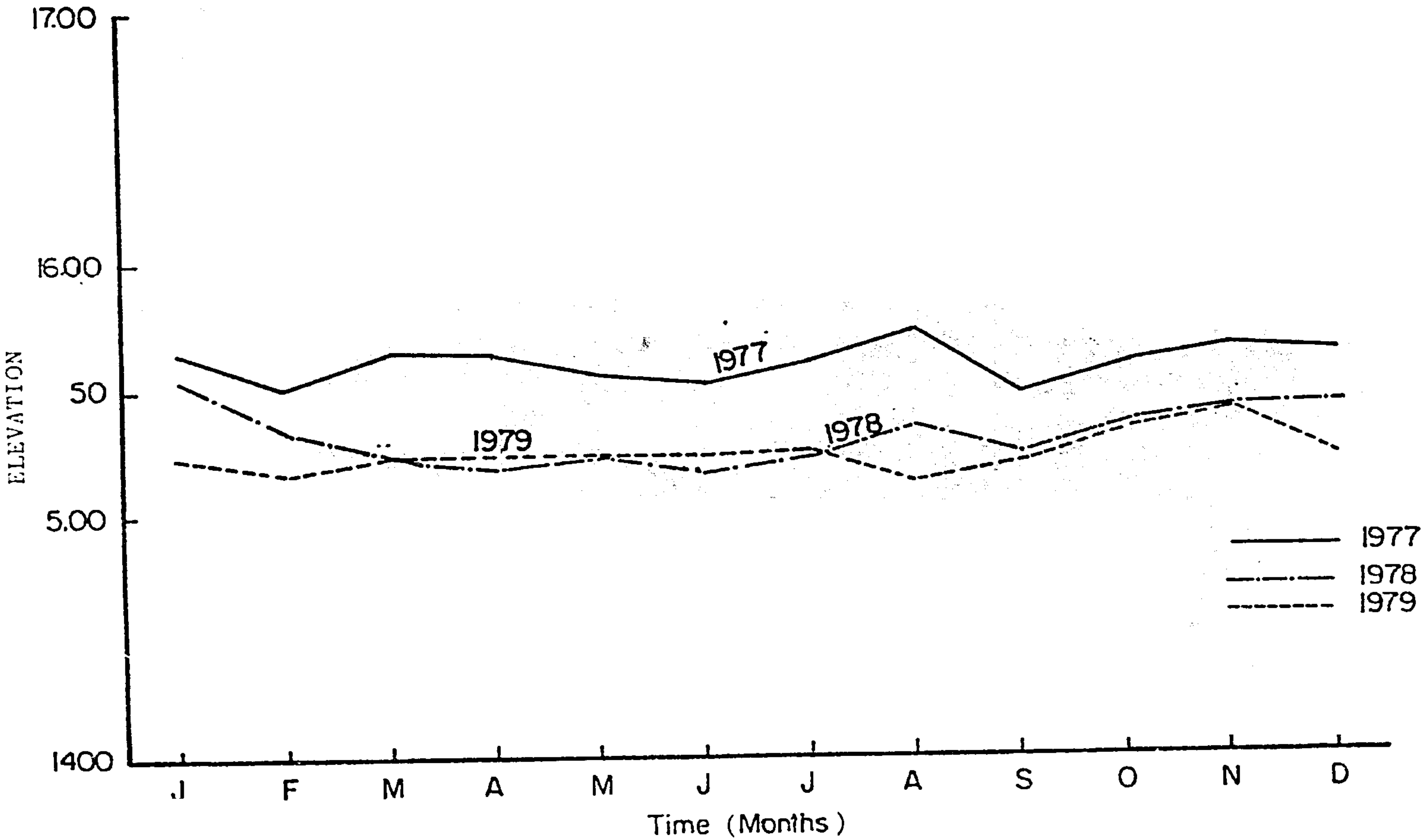
6. Land Savings

With the introduction of the continuous flow system, water enters the canal continually, but at a low rate. There is no need for the massive amounts of water which were required under the rotation system, when all of the fields had to be watered during a 4-day period. It has been possible, therefore, to reduce the cross-section of the Canal by two thirds, thereby freeing a considerable amount of valuable land for cultivation. In Beni Magdul Canal, the cross-section was redesigned and the canal was lined. Smaller cross-sections are also required for the distributary canals, meaning savings in both land and construction costs.

7. Effect on seepage from Canals and *mesqas*

It is reasonable to assume that water loss through seepage will be proportionately greater with an increase of water elevation, and that, therefore, continuous flow irrigation--which in this case reduced the elevation of the water in Canal and *mesqas* at any one time--will also reduce the rate of seepage loss. Since Beni Magdul Canal was lined just before continuous flow irrigation was introduced into the area, it was impossible to isolate the effect of the lining. It is also impossible to isolate the effect of changing to continuous flow from the effect of the arbitrary lowering of the water level in the Canal when it was lined. Continuous flow [illegible] also

FIGURE 3. Average Water Table Levels
in Beni Magdul Area
over the Last Three Years



have the advantage of requiring much smaller cross-sections for both canals and distributary watercourses, which should decrease water loss from seepage.

For studies of this problem in the Mansuriya area, see F. Shahin, M. Saif, et al., 1978.

8. Effect of growth of weeds in canals

The question has been raised as to whether the continuous flow system, which has no drying period, encourages weed growth in the canals.

The rotation system requires larger canal cross-sections, higher levels of water in canals and ditches for short periods, and a drying period. The continuous flow system requires small canal cross-sections, and in this case, low water levels at all times, and no drying period.

Observations of conditions in El-Mansuriya led researchers to conclude that, due to the practice of storing water in the canal after the closure people and also to leakage from the gates, the dry period in the rotation period was, in fact, dry only three out of the eight required days. This period was not sufficient to have any noticeable affect on weed growth.

Since the Beni Magdul Canal was lined before the introduction of continuous flow irrigation, it was impossible to draw conclusions about the effects of the system on weed growth. In distributary canals which were not lined, however, researchers did not notice appreciable differences.

9. Crop Yield

Earlier research by EWUP had determined that it was possible to obtain high crop yields in areas which have high water tables, provided that a) there is a low level of salinity in the groundwater; and b) the level of the groundwater does not fluctuate during the growing season (EWUP, Technical Report No. 1, 1979).

In El-Mansuriya, the quality of the groundwater is good, but, under the rotation system, the level of the water table fluctuated markedly. This situation was partially corrected by the introduction of the continuous flow delivery sytem.

Another advantage of the new system which raised the overall yield was the reclaiming of lands with the reduction in the water table level (see No. 5 above) and the reduction of canal and *mesqa* cross-sections (see No. 6 above).

The following figures show the increase in the maize crop in the Beni Magdul area. Maize is the principal summer crop.

Under the Continuous Flow System, with Lined Canal	Average yield *ardab/feddan*
1977	9.13
1978	10.71

V. Summary and Conclusions

There can be no doubt in analyzing the results of the study conducted by EWUP during the three-year period from 1977 through 1979 in the Beni Magdul Canal area, that the continuous flow distribution system was superior to the rotation system. The two systems were compared on nine counts, and in all areas, the continuous flow system showed an improvement over the older method.

The following is a brief summary of the results:

1. Water savings:
   Total discharge for July-December, 1979
   Rotation system: 3,815 m^3 per *feddan*
   Continuous flow system: 7,107 m^3 *feddan*
   Conclusion: It was apparently possible to reduce water delivery through a branch canal by 86% with the continuous flow system without producing adverse affects on the crops.

2. Acceptability to farmers:
   55% of farmers polled preferred the continuous flow system. 45% of farmers polled wanted to have the rotation system in order to obtain higher water levels. (It may be assumed that, once farmers were properly instructed on the use of the continuous flow system, they would not feel the need for these higher water levels and this percentage would be reduced).

3. Equitable distribution of water:
   Farmers citea inequitable distribution as one of the major problems under the rotation system, had no such complaints under the continuous flow system.

4. Length of interval between irrigations:
   The continuous demand system allowed farmers to institute irrigation schedules in accordance with the needs of their crops, and the median irrigation frequency was 9 to 12 days. Under the rotation system, in a nearby canal, 25% of the farmers irrigated at the beginning and end

of the 4-day working period, regardless of crop requirements, for this was the only time when water was officially available. The rotation system also led farmers to great lengths to circumvent the official irrigation schedule, using water from all possible sources-to irrigate during closure periods.

5. Effect on water table (gauged over a three-year period):
Water table levels decreased by almost 30 cm. during three years after the introduction of continuous flow delivery system.

6. Land Savings:
It was possible to reclaim approximately two-thirds of the area of the canal cross-section when it was re-designed to suit the continuous flow distribution method. Furthermore, some lands which had been lost due to the high water table were recoverable after the water table subsided (see No. 5 above).

7. Effect on seepage from canals and *mesqas*:
Lower water levels brought about by the continuous flow system of distribution should lead to less loss from seepage, but researchers were unable to use data from this experiment for comparisons with the rotation system after the lining and simultaneous lowering of the Beni Magdul Canal.

8. Effect on growth of weeds in canals:
There was no observable difference between the two systems in the matter of weed growth in the canals.

9. Crop Yield:
Data are insufficient to reach conclusions but what is available suggests a slightly higher yield of corn with the lower water table.

VI. Recommendations

On the basis of the results of the experiment conducted by EWUP in the Mansuriya area in 1977-1979, the authors offer the following recommendations:

1. Wherever possible, Egypt's water delivery system should be converted to the continuous flow method, and water issued to farmers on demand or on modified demand.

2. Any new canals should be designed for continuous flow. This means:
   --smaller canal cross-sections
   --the introduction of irrigation schedules among farmers along each *mesqa*, and among *mesqas* along the canal
   --the introduction of various technological improvements by making field trials at the farm level to help farmers adapt to the new distribution system. These might include sprinkler irrigation, drip irrigation, buried pipelines, or less elaborate improvements the farmers can implement by themeselves or with a minimum of help.

3. Tigher control over the discharge and water shares for canals which remain under the rotation system.

4. Improvements in the existing system should include
   --smaller cross-sections
   --introduction of irrigation scheduling
   --better adaptation to crop requirements so that farmers obtain water as needed.

LIST OF REFERENCES

1. Egypt Water Use and Management Project (EWUP). 1979. *Problem Identification,* Technical Report No. 1. Cairo.

2. Shahin, F., M. Saif, *et al.* 1979. *Conveyance Losses in Canals.* Ministry of Irrigation, Government of Egypt. Cairo.

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	0.96335	0.40469
1 *feddan*	4,200.8335	1.03805	1	0.42008
1 hectare (ha)	10,000.00	2.47105	2.38048	1
1 sq kilometer	100×10^4	247.105	238.048	100.00
1 sq mile	259×10^6	640.00	616.4	259.00

Water Measures	*in acre-feet*	*in acre-inches*
1 billion m^3	810,710	
1,000 m^3	0.81071	9.72852
1,000 m^3/*feddan* (= 238 mm of rainfall)	0.781	9.372
420 m^3/*feddan* (= 100 mm of rainfall)		

Other Conversions	*metric*	*U.S.*
1 *ardab*	198 liters	5.62 bushels
1 *ardab*		5.41 bushels/acre
1 kg/*feddan*		2.12 lb/acre

Egyptian Units for Field Crops	*Eg. Unit*	*in kgs*	*in lbs*	*To convert Eg units/fed to tons ha, multiply by:*
Cotton (unginned)	metric *qintar*	157.5	346.97	0.3749
Cotton (lint or ginned)	metric *qintar*	50.0	110.15	0.1190
Sugar, onion, flax straw	*qintar*	45.0	99.12	0.1071
Rice (rough or unmilled)	*dariba*	945.0	2081.50	2.2496
Lentils	*ardab*	160.0	352.42	0.3809
Clover ([illegible])	*ardab*	157.0	345.81	0.3737
Broadbeans, fenugreek	*ardab*	155.0	341.41	0.3690
Wheat, chickpeas, lupine	*ardab*	150.0	330.40	0.3571
Maize, sorghum	*ardab*	140.0	308.37	0.3333
Linseed	*ardab*	122.0	268.72	0.2904
Barley, conttonseed, sesame	*ardab*	120.0	264.32	0.2857
Groundnuts (in shells)	*ardab*	75.0	165.20	0.1785

Egyptian Farming and Irrigation Terms

fara' = branch
marwa = small distributor, 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
qaria = 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.*)