Use of Network Analysis for Planning one of the Main Drainage Projects in Egypt

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1. INTRODUCTION

The Arab Republic of Egypt has decided to improve drainage conditions in the whole country. The first project, the largest single tile drainage project that had ever been undertaken, was executed in the Nile Delta area. This project started in July 1970 and will be completed by the end of 1978. The project comprises the provision of an area of 950,000 feddans (1 feddan = 1.04 acres) in the Delta with an adequate field tile drainage system. Use is made of the critical path method in planning part of the project, i.e. field tile drainage as indicated in the attached Annex.

The second drainage project (Upper Egypt Drainage Project I) started in 1973 and covers an area of 300,000 feddan in Upper Egypt. This project is expected to be completed by the end of 1979.

The third project, which is the main subject of this report, is the Upper Egypt Drainage Project II. This differs from the previous projects in two respects: the use of PVC instead of cement pipes, and the drainage work carried out by contractors selected by international tender.

The project is financed by the World Bank and its affiliate, the International Development Association (IDA), $50 million, and the United States Aid programme (USAID), $30 million. The total cost of the project is $282 million. The objective of the project is to carry out installation of field drainage over 500,000 feddans (210,000 hectares). Execution of the project will be the responsibility of the Egyptian Public Authority for Drainage Projects, Ministry of Irrigation.

The network and critical path are drawn up for the main activities in this project. Figures are based on best estimates obtained from experience in previous projects. This report is a result of a joint effort in network planning of this project, with Mr. Van Kampen (3).

2. PHYSICAL WORKS OF THE PROJECT

Installing about 40,000 km covered field (tile) drains of PVC corrugated pipes and 6000 km of covered collector cement pipes in the selected areas totalling 500,000 feddans.

Deepening and widening about 1226 km existing open drains and excavating about 346 km new open drains involving approximately 23 million m^3 of earth works.

Constructing one pumping station with a capacity of 3.5 m^3/sec including electric transmission lines.

Reclaiming, by leaching, about 12,000 feddans of saline soil distributed throughout the area to be drained, including subsoiling and gypsum applications.

Three PVC pipe-making factories have to be constructed: one in Beni-Suef, one is Assuit and the third in Qena.

3. AREA OF THE PROJECT

The area (500,000 feddans) is situated along about 1000 km of the River Nile. The area is subdivided into seven sub-areas according to the organization of the Egyptian Public Authority for Drainage Projects (EPADP) (seven directorates as shown in Table 1).

TABLE 1. *Area distribution and physical works required*

Tender No.	Directorate	Area (feddans)	No of sub units	Tile drains length (km)	New drains (m^3)	remo-delling (m^3)
1 A	Giza, Fayoum	85,000	14	6 800	-	2,900,000
2 B	Beni - Suef	70,000	12	5 600	-	4,800,000
3 C	El Minya	105,100	17	8 408	2,900,000	2,500,000
4 D	Asyout	61,400	10	4 912	264,000	850,000
5 E	Sohag	65,600	11	5 248	1,130,000	1,200,000
6 F	Quena	79,900	13	6 392		
7 G	Esna, Kom Ombo	33,000	5	2 640	6,000,000	620,000
TOTAL		500,000	82	40 000	10,294,000	12,870,000

Each subunit covers, on average, 6000 feddans. The average length of tile drains per feddan is 80 m, but this may be changed after detailed studies have been carried out.

4. DESCRIPTION OF THE NETWORK

4.1. *Tasks and Organization*

The project is divided into clearly defined tasks or activities. An activity represents a job or a task that has to be carried out and which forms an integral part of the network. The activities and the organizations which will carry them out are as follows.

4.1.1. *Field drainage (tile drainage)*

Activity description	Organization
Investigations and design preparation of tender approval (World Bank, EPADP)	Egyptian Public Authority for Drainage Projects (EPADP)
Advertising and information bidders	EPADP
Analysis lowest bid, work plan discussions	EPADP
Final approval	World Bank and EPADP
Execution tile drainage (transport PVC pipe drains, gravel filter collectors, backfilling, flushing)	Contractors

The tile drainage must be completed 48 months after letters of intent have been sent to the contractors (see Fig. 1).

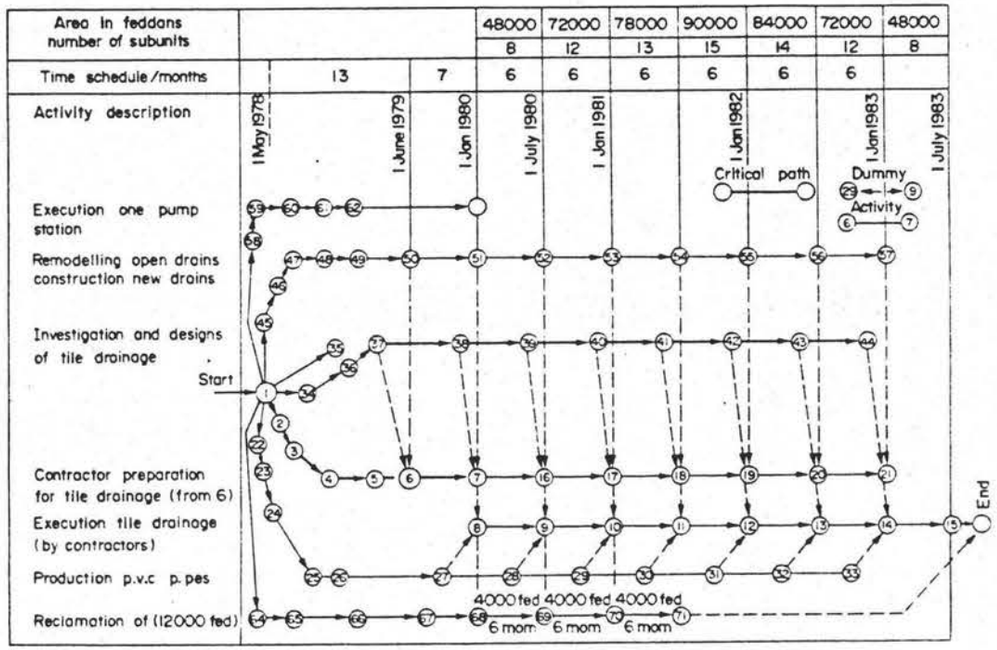

Fig. 1. Network Diagram for Upper Egypt Drainage Project II (area: 500,000 feddans).

The tile drainage work in the seven directorates should be started and completed simultaneously. Production is measured in feddans and subunits. The average length of tile drains is 80 m per feddan, so the average length in a subunit area of 6000 feddans is 490 km.

4.1.2. *Production of the PVC pipes*

Construction of three PVC pipe-making factories will be carried out by a contractor. The three factories will be located at Beni Suef, Assuit and Qena. The EPADP will run the factories and supply the corrugated plastic pipes to the international constructors working on the tile drains.

The following are the description of activities:

Activity description	Organization
Prepare tender and specifications	EPADP
Approval	USAID & EPADP
Advertising and information bidders	EPADP
Analysis lowest bid, work plan	EPADP
Final Approval	USAID & EPADP
Installation PVC plants	Contractors
Tenders for raw materials PVC	EPADP
Production of PVC pipes	EPADP

In the tender a supply of raw material for two years is included (8000 tons). During production a stock of PVC pipes for one month should be available (300 km per plant).

4.1.3. *Remodelling open drains and construction of new drains*

Activity description	Organization
Design open drainage	EPADP
Preparation of tender	EPADP
Advertising, bidding	EPADP
Analysis lowest bid, work plan	EPADP
Execution of open drainage	Contractors

The design of open drainage should be ready 6 months before tile drainage in that area starts.

Open drainage on 200 feddans will be completed by December 1978.

4.1.4. *Construction of one pumping station*

Prepare designs		
Prepare tender		
Advertising and bidding		
Analysis for lowest bid		
The above activities	by	EPADP
Award the contract and preparation period	by	the contractor
Execution of the pump station	by	the contractor

4.2. *The Network Analysis*

The main activities are drawn according to the time schedule shown in Fig. 1 and the activities are listed and written as shown in Annex 1. The duration of each activity is determined through the experience of the planners. The activities are then arranged in working sequence. Data for construction of the network are based on relationships with the preceding, succeeding and concurrent activities and logical requirements. Dashed arrows are sometimes inserted to connect events, such as activity (37-6), (38-7), shown in Fig. 1. These are called dummy activities. A dummy activity requires neither time nor resources. For a complete description of the network, the reader is referred to reference (2) and the annex.

The main activities of the programme are:

(1)	Field Drainage Works:	
	(a) Investigations and designs	1-34, 35 ... to 44
	(b) Execution of tile drainage	1-2 ... to 7-15 and 1-2 ... to 7-21
(2)	Production of PVC pipes	1-22 ... to 33
(3)	Remodelling of open drains and constructing new drains	1-45 ... to 57
(4)	Construction of one pumping station	1-58 ... to 63
(5)	Reclamation of 12,000 feddans	1-64 ... to 71

Under the network is shown a time scale indicating some important dates and productions based on average time production estimates.

4.2.1. *Field drainage works*

The field drainage network is divided into four main parts. 1-7 activities are for preparation before the execution of tile drainage (1-6 are the responsibility of EPAD, and 6-7 the responsibility of the contractor). 1-34, 35 – 44 activities are for investigation and design necessary before construction. Details of these activities will be explained later.

7-8 – 15 Execution of tile drainage, which is the responsibility of the contractor.

1-22 – 26 Preparation required before the construction of three PVC pipe-making factories (26-27 – 33) Production of PVC pipes. The factories are run by EPADP and the pipes are supplied to the contractor.

(a) *Investigation and Design (1-34, 35 – 44)*

Investigating and designing the tile drainage of a certain area requires 9 months, on average. The larger part of this period covers surveying jobs and the preparation of the 1 : 10,000 map (7 months). The design for the 8 subunits to be executed in the period 1 January 1980 to 1 July 1980 (activity 8 - 9) should be ready at 6 when the contractor starts his preparations (activity 6 - 7). As the average start of activity 6-7 is after 13 months, this shows that the average floating time for the first designs is 13 - 9 = 4 months. During the tile drainage work it is assumed that designs will be completed 6 months before the start of drainage construction in that area, so that the contractor has sufficient time to prepare his work. For example, the design activity (37 - 38) for the drainage of the 12 subunits

(activity 9 - 10) must be completed before 7 (dummy 38 - 7). The contractor's preparation periods are shown in activity (7 - 16) and dummy (16 - 9).

(b) *Execution of tile drainage:*

The preparation of the tender documents and the analysis of the tile drainage contract, until approved by both the World Bank and the Egyptian public Authority for Drainage Projects (EPADP), (1 - 6) will take 13 months.

So the average starting time of the contractors at 6 is 13 months from the outset; while the earliest start time (E.S.T.) is 10 months and the latest is 16 months from the outset.

At 6 the two activities should be stated, i.e. remodelling open drains (dummy act. 50-6) and investigation and design (dummy act. 37-6) for the 8 subunits to be constructed with tile drains (act. 8 - 9).

It is clear, however, that completion of these two activities a few months later will not prevent the contractors starting their preparation (act. 6-7).

Activity 6-7 includes all the contractor's work prior to the actual tile drainage construction, such as buying, importation and transportation of 32 pipe laying machines and 10 collector laying machines and other supporting equipment (e.g. tractors, trailers), establishment of workshops, making collector pipes and manholes, crushing and handling of gravel, and organization in the field. The estimated average length of the preparation period is 7 months (varying between 6 and 9 months). This period seems fairly short, particularly if one considers the time required for import, transportation and preparing the machines for operation.

Dummies 7-8 and 27-8 (from PVC pipes) lead to activity 8-9 — 15, the actual tile drainage construction.

For the execution of tile drainage, according to the tender, the available preparation period is 42 months (49 - 7). For planning purposes this period is divided into 6 periods of 6 months.

The construction of the drains will be slower at the beginning and end of the period, while a peak is expected in the middle.

The duration of activities during tile drainage construction is therefore assumed as follows:

Activity No.	(8-9)	(9-10)	(10-11)	(11-12)	(12-13)	(13-14)	(14-15)
Duration	6	6	6	6	6	6	6
No of subunits	8	12	13	15	14	12	8

4.2.2. *Production of PVC pipes*

Three factories for corrugated plastic pipes have to be constructed in three different towns, namely Beni-Suef, Assuit, and Qena. The capacity of each factory is about 300 km per month.

The three factories must start production before the tile drainage construction commences, as shown by Dummy 27-8. Starting time PVC pipe production is here assumed to have started when a stock of at least one month's production is available.

Comparing the starting times for PVC pipe production and tile drainage construction (in months after start):

	Tile drainage	Pipe production
Average starting time	20	17
Earliest starting time	16	14
Latest starting time	25	20

So the production of PVC pipes will commence, on average 3 months prior to the start of the drainage construction.

If one month's stock is required before construction work on the 8 subunits (activity 8 - 9), then it is necessary to store 3 months' supply, i.e. 2700 km pipes. Storing so many pipes would be impractical because of large area required. Consequently the plants should start production about 2 months ahead of drainage construction, i.e. 1st November 1979.

4.2.3. *Remodelling of open drains and constructing new drains (Activities 1-45 - 57)*

Preparation of tender documents, advertising, and analysis until award of contract and the start of the work takes, on average, 9 months (earliest start time 8 months, latest 11 months).

Work on 200,000 feddans has been carried out with available equipment, so the open drains will be constructed on time. New excavating equipment will have to be bought for the remaining work. This will take 16 months, on average, so the new equipment should be obtained as soon as possible.

4.2.4. *Reclamation of 12,000 feddans (activities 1-64 — 71)*

Reclamation activities as shown in Annex 1 have to be carried out by the Ministry of Agriculture. However, it is considered here since it is part of this project. Preparation for this work will take 11 months, on average (1-22 — to 67).

	Tile drainage	Reclamation
Average starting time	20	11
Earliest starting time	16	8
Latest starting time	25	14

It can be seen that a 9-month "float" period is available. However, reclamation work should start after the tile drainage construction. Therefore, the starting time of preparation activities can be delayed 9 months, i.e. Activity 1-64 — 67 can start on 1st February 1979.

The total reclaimed areas are divided into 3 units of 4000 feddans each. Each unit should be completed in 6 months. Work on the first 4000 feddans can start 2 months after the construction of tile drainage (act. 8-9)

4.2.5. *The critical path*

The critical path as defined is the longest chain or path of activities through the network. It is the amount of time needed to complete the project. Until the start of the field tile drainage the critical path is shown to follow activities

1-2-3-4,-5-6-7-8, i.e. tendering, bidding, analysis of bids, negotiations with contractors and contractors' preparation. Other simultaneous activities have sufficient floating time: open drains (dummy 50-6: 4 months), design (dummy 37-6 : 4 months), PVC pipe production (dummy 27-8 : 3 months).

This shows that an attempt should be made to shorten activities 1-2-3-4-5-6-7-8 from an average of 20 months to approximately 16 months. In this case the designs for the first 8 sub units (particularly the preparation of 1:10,000 maps) should be ordered at once.

Assuming that the contractors fulfill their obligations (act. 8-15) the critical path will probably be decided by the investigation and design activities (37-44).

5. DETAILED PROGRAMME

A detailed programme should be drawn up of the 4 main activities, which are:

I Construction of one pump station

II Field drainage works

III Remodelling of open drains

IV Reclamation of 12,000 feddans

A breakdown of the tasks or activities is important for precise planning.

For the purpose of showing how the main activities could be broken down, only field tile drainage investigation and design will be considered (activities 1-35 — to 36).

This breakdown is explained clearly in the annex. The critical path method is used in planning, scheduling and controlling the field drainage works.

The techniques of the CPM are carried out by a computer programme.

The time schedule is based on the average times in the network diagram. From the additions (total) per year the required manpower for designing and supervising can be decided.

6. SUMMARY AND CONCLUSION

The Arab Republic of Egypt has decided to improve drainage conditions in the whole country. The third project (Upper Egypt drainage project II) is under preparation.

This project comprises the installation of field tile drainage system in an area of 500,000 feddans, the remodelling of existing open drains and the construction of a new pumping station. This differs from previous projects in two respects: the use of PVC instead of cement pipes, and the construction of the tile drainage system by international contractors.

A network planning of the preparation and construction of the project is drawn up. Figures are based on experience gained from previous drainage projects. The main activities in the network are:

Activity 1-35 — 44 :	Investigation and design of tile drainage system
Activity 1-6 :	Preparation for contracts
Activity 6-7 — 15 : 7 — 21	Preparation and execution by contractor
Activity 1-22 — 33 :	Construction of PVC pipe factories, and pipe production
Activity 1-45 — 57 :	Remodelling open drainage
Activity 1-58 — 63 :	Construction of one pumping station
Activity 1-64 — 71 :	Reclamation of an area of 12,000 feddans

The contractors must complete the field drainage system construction within 48 months from the contract being assigned.

The work in the 7 directorates must start and end simultaneously.

The critical path is formed by activities 1-2-3-4-5-6. The average starting time of activity 6-7 (preparation by contractors) is 13 months from the outset; the E.S.T. and L.S.T. are 10 and 16 months respectively.

Activity 6-7 takes 7 months, on average. The average starting time of the tile drainage construction is 20 months from the outset (E.S.T. and L.S.T.: 16 and 25 months respectively). Average completion time of the overall works will be after 61 months (E.S.T. and L.S.T. 57 and 66 months respectively).

After starting tile drainage construction the critical path will follow through 7-38 - 44 (designing) as a shortage of investigating and designing engineers will probably occur.

More detailed planning is required for the main activities mentioned above. An example of the breakdown of activity 1-35 — 44 (investigation and design of tile drainage system) is shown in the Annex. The whole area is divided into 82 subunits (6000 feddans each) in 7 directorates. Special attention should be paid to the preparation activities (1-7) which are all situated on the critical path, as lengthening or shortening of any activity will result in a longer or shorter total work period. Designing for the first 8 subunits should start immediately.

The three PVC pipe-making plants will be idle for 3 months, and attempts should be made to utilize them during this period, perhaps for producing pipes for use in areas outside the project.

A more detailed planning system is required for all the 7 directorates by planners in the directorates (regional level).

Training programmes in planning techniques are urgently required.

REFERENCES

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2. Armstrong-Wright, A. T., *Critical Path Method Introduction and Practice*, Longmans, Green & Co., London, 1979

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Annex 1. *Duration of activities for the drainage programme of Upper Egypt II*

Remarks

For 1978 the work plan is already being carried out. The time estimate starts from 1 May, 1978 (in months) L = longest time, S = shortest time, A = average, R = ready or completed.

Activity 1-2 represents the preparation of a tender document for field drainage. Similarly, other activities are described, as follows:

Activity description	Duration months L	S
I. *Construction Pumping Station:*		
1-58 Prepare designs	2	1
58-59 Prepare tender	2	1
59-60 Advertise and bidding	2	1
60-61 Analysis for lowest bid	2	1
61-62 Award contract; preparation by the contractor	2	1
62-63 Execution by the contractor	18	12
	30	17
Average A	24	
II. *Field Drainage Works:*		
a- Investigation and Design:		
1-35 Preparation of survey maps (1 : 10,000)	8	6
1-34 Dummy	0	0
34-46 Investigation	2	1
36-37 Design	2	1
Average:	12	8
37-38, 38-39, 39-40, 43-44 Repetitions for 6 months' execution drainage period (i.e. activity (37-38) with duration 10 months, and other activities, will be repeated for every subunit	A = 10	
b- Execution of Tile Drainage		
1-2 Preparation of tender document	R	R
2-3 Approval (World Bank, EPADP)	2	1
3-4 Advertising and information bidders	6	4
4-5 Analysis lowest bid, workplan discussions	6	4
5-6 Approval (W.B., EPADP)	2	1
6-7 Award of contract; preparation of work and import of machines by contractor	9	6
Start total:	25	16
Average	A = 20	

Annex 1 (cont.)

Activity description	Duration months L	S
7-16 Contractor preparation for execution of drainage in sub-units for a 6-month period	A = 6	
16-17, 17-18, 18-19, 19-20, 20-21 same as activity 7-16.		
7-8, 16-9, 17-10 21-14 Dummies	0	
Total Average	A = 62	
c- Production of PVC pipes:		
1-22 Prepare tender documents for 3 pipe-making factories	R	R
22-23 Approval (USAID, EPADP)	R	R
23-24 Advertising, information bidders	R	R
24-25 Analysis lowest bid, workplan	6	3
25-26 Approval	2	2
26-27 Award of contract, import, construction	12	9
27-8, 28-9 ----(33-14) Dummy	20	14
Average	A = 17	
IV. *Reclamation of 12,000 fed.*		
1-64 Design and layout	3	2
64-65 Prepare tender	2	1
65-66 Advertise	2	1
66-67 Analysis	4	2
67-68 Award of contract and preparation	3	2
	14	8
68-69 Execution	6	6
TOTAL:	20	14
Average	22	
(69-70), (70-71) Repetitions of (68-69)		

Activity description	Duration months S	L
8-9 Tile drainage construction in 6 months' period. A = 42		
9-10 ----(14-15) same as (8-9)		
27-28, --- 32-33 production in 6 month period		
III- *Remodelling open drains and Constructing new drains:*		
1-45 Design open drainage	R	R
45-46 Preparation of tender	3	2
46-47 Advertising; for bidding	4	2
47-48 Analysis for lowest bid, work plan	2	1
48-49 Award of contract; preparation by contractor	2	1
Subtotal:	11	8
49-50 Execution	12	12
Total:	23	18
Average	A = 20	
(50-51),.....(56-57) repetition of (1-65) to 50		1

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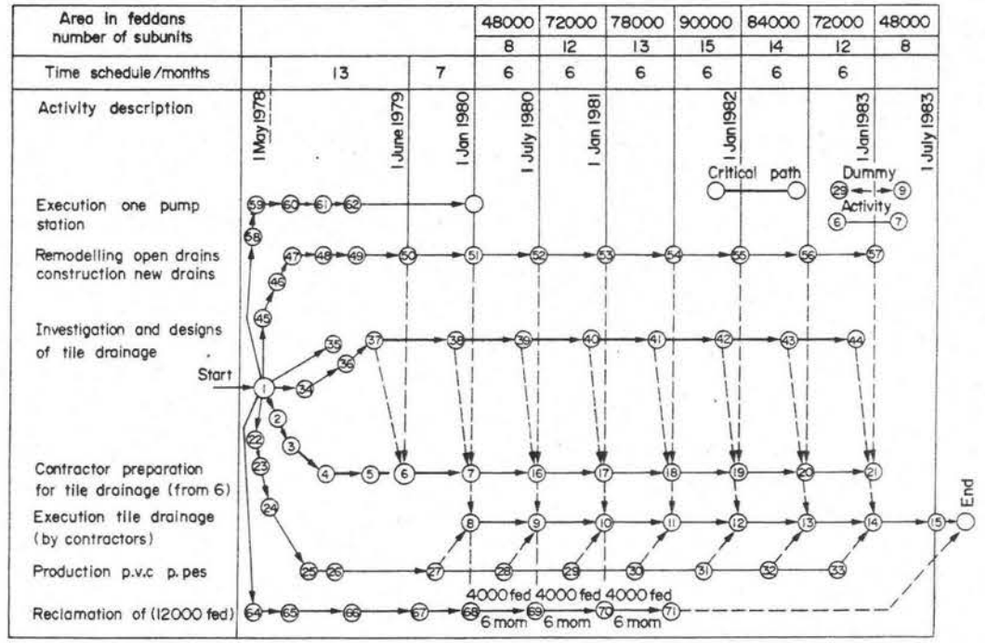

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Advertising, bidding	EPADP
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The main activities are drawn according to the time schedule shown in Fig. 1 and the activities are listed and written as shown in Annex 1. The duration of each activity is determined through the experience of the planners. The activities are then arranged in working sequence. Data for construction of the network are based on relationships with the preceding, succeeding and concurrent activities and logical requirements. Dashed arrows are sometimes inserted to connect events, such as activity (37-6), (38-7), shown in Fig. 1. These are called dummy activities. A dummy activity requires neither time nor resources. For a complete description of the network, the reader is referred to reference (2) and the annex.

The main activities of the programme are:

(1)	Field Drainage Works:	
	(a) Investigations and designs	1-34, 35 ... to 44
	(b) Execution of tile drainage	1-2 ... to 7-15 and 1-2 ... to 7-21
(2)	Production of PVC pipes	1-22 ... to 33
(3)	Remodelling of open drains and constructing new drains	1-45 ... to 57
(4)	Construction of one pumping station	1-58 ... to 63
(5)	Reclamation of 12,000 feddans	1-64 ... to 71

Under the network is shown a time scale indicating some important dates and productions based on average time production estimates.

4.2.1. *Field drainage works*

The field drainage network is divided into four main parts. 1-7 activities are for preparation before the execution of tile drainage (1-6 are the responsibility of EPAD, and 6-7 the responsibility of the contractor). 1-34, 35 — 44 activities are for investigation and design necessary before construction. Details of these activities will be explained later.

7-8 — 15 Execution of tile drainage, which is the responsibility of the contractor.

1-22 — 26 Preparation required before the construction of three PVC pipe-making factories (26-27 — 33) Production of PVC pipes. The factories are run by EPADP and the pipes are supplied to the contractor.

(a) *Investigation and Design (1-34, 35 — 44)*

Investigating and designing the tile drainage of a certain area requires 9 months, on average. The larger part of this period covers surveying jobs and the preparation of the 1 : 10,000 map (7 months). The design for the 8 subunits to be executed in the period 1 January 1980 to 1 July 1980 (activity 8 - 9) should be ready at 6 when the contractor starts his preparations (activity 6 - 7). As the average start of activity 6-7 is after 13 months, this shows that the average floating time for the first designs is 13 - 9 = 4 months. During the tile drainage work it is assumed that designs will be completed 6 months before the start of drainage construction in that area, so that the contractor has sufficient time to prepare his work. For example, the design activity (37 - 38) for the drainage of the 12 subunits

(activity 9 - 10) must be completed before 7 (dummy 38 - 7). The contractor's preparation periods are shown in activity (7 - 16) and dummy (16 - 9).

(b) *Execution of tile drainage:*

The preparation of the tender documents and the analysis of the tile drainage contract, until approved by both the World Bank and the Egyptian public Authority for Drainage Projects (EPADP), (1 - 6) will take 13 months.

So the average starting time of the contractors at 6 is 13 months from the outset; while the earliest start time (E.S.T.) is 10 months and the latest is 16 months from the outset.

At 6 the two activities should be stated, i.e. remodelling open drains (dummy act. 50-6) and investigation and design (dummy act. 37-6) for the 8 subunits to be constructed with tile drains (act. 8 - 9).

It is clear, however, that completion of these two activities a few months later will not prevent the contractors starting their preparation (act. 6-7).

Activity 6-7 includes all the contractor's work prior to the actual tile drainage construction, such as buying, importation and transportation of 32 pipe laying machines and 10 collector laying machines and other supporting equipment (e.g. tractors, trailers), establishment of workshops, making collector pipes and manholes, crushing and handling of gravel, and organization in the field. The estimated average length of the preparation period is 7 months (varying between 6 and 9 months). This period seems fairly short, particularly if one considers the time required for import, transportation and preparing the machines for operation.

Dummies 7-8 and 27-8 (from PVC pipes) lead to activity 8-9 — 15, the actual tile drainage construction.

For the execution of tile drainage, according to the tender, the available preparation period is 42 months (49 - 7). For planning purposes this period is divided into 6 periods of 6 months.

The construction of the drains will be slower at the beginning and end of the period, while a peak is expected in the middle.

The duration of activities during tile drainage construction is therefore assumed as follows:

Activity No.	(8-9)	(9-10)	(10-11)	(11-12)	(12-13)	(13-14)	(14-15)
Duration	6	6	6	6	6	6	6
No of subunits	8	12	13	15	14	12	8

4.2.2. *Production of PVC pipes*

Three factories for corrugated plastic pipes have to be constructed in three different towns, namely Beni-Suef, Assuit, and Qena. The capacity of each factory is about 300 km per month.

The three factories must start production before the tile drainage construction commences, as shown by Dummy 27-8. Starting time PVC pipe production is here assumed to have started when a stock of at least one month's production is available.

Comparing the starting times for PVC pipe production and tile drainage construction (in months after start):

	Tile drainage	Pipe production
Average starting time	20	17
Earliest starting time	16	14
Latest starting time	25	20

So the production of PVC pipes will commence, on average 3 months prior to the start of the drainage construction.

If one month's stock is required before construction work on the 8 subunits (activity 8 - 9), then it is necessary to store 3 months' supply, i.e. 2700 km pipes. Storing so many pipes would be impractical because of large area required. Consequently the plants should start production about 2 months ahead of drainage construction, i.e. 1st November 1979.

4.2.3. *Remodelling of open drains and constructing new drains (Activities 1-45 - 57)*

Preparation of tender documents, advertising, and analysis until award of contract and the start of the work takes, on average, 9 months (earliest start time 8 months, latest 11 months).

Work on 200,000 feddans has been carried out with available equipment, so the open drains will be constructed on time. New excavating equipment will have to be bought for the remaining work. This will take 16 months, on average, so the new equipment should be obtained as soon as possible.

4.2.4. *Reclamation of 12,000 feddans (activities 1-64 — 71)*

Reclamation activities as shown in Annex 1 have to be carried out by the Ministry of Agriculture. However, it is considered here since it is part of this project. Preparation for this work will take 11 months, on average (1-22 — to 67).

	Tile drainage	Reclamation
Average starting time	20	11
Earliest starting time	16	8
Latest starting time	25	14

It can be seen that a 9-month "float" period is available. However, reclamation work should start after the tile drainage construction. Therefore, the starting time of preparation activities can be delayed 9 months, i.e. Activity 1-64 — 67 can start on 1st February 1979.

The total reclaimed areas are divided into 3 units of 4000 feddans each. Each unit should be completed in 6 months. Work on the first 4000 feddans can start 2 months after the construction of tile drainage (act. 8-9)

4.2.5. *The critical path*

The critical path as defined is the longest chain or path of activities through the network. It is the amount of time needed to complete the project. Until the start of the field tile drainage the critical path is shown to follow activities

1-2-3-4,-5-6-7-8, i.e. tendering, bidding, analysis of bids, negotiations with contractors and contractors' preparation. Other simultaneous activities have sufficient floating time: open drains (dummy 50-6: 4 months), design (dummy 37-6 : 4 months), PVC pipe production (dummy 27-8 : 3 months).

This shows that an attempt should be made to shorten activities 1-2-3-4-5-6-7-8 from an average of 20 months to approximately 16 months. In this case the designs for the first 8 sub units (particularly the preparation of 1:10,000 maps) should be ordered at once.

Assuming that the contractors fulfill their obligations (act. 8-15) the critical path will probably be decided by the investigation and design activities (37-44).

5. DETAILED PROGRAMME

A detailed programme should be drawn up of the 4 main activities, which are:

I Construction of one pump station

II Field drainage works

III Remodelling of open drains

IV Reclamation of 12,000 feddans

A breakdown of the tasks or activities is important for precise planning.

For the purpose of showing how the main activities could be broken down, only field tile drainage investigation and design will be considered (activities 1-35 – to 36).

This breakdown is explained clearly in the annex. The critical path method is used in planning, scheduling and controlling the field drainage works.

The techniques of the CPM are carried out by a computer programme.

The time schedule is based on the average times in the network diagram. From the additions (total) per year the required manpower for designing and supervising can be decided.

6. SUMMARY AND CONCLUSION

The Arab Republic of Egypt has decided to improve drainage conditions in the whole country. The third project (Upper Egypt drainage project II) is under preparation.

This project comprises the installation of field tile drainage system in an area of 500,000 feddans, the remodelling of existing open drains and the construction of a new pumping station. This differs from previous projects in two respects: the use of PVC instead of cement pipes, and the construction of the tile drainage system by international contractors.

A network planning of the preparation and construction of the project is drawn up. Figures are based on experience gained from previous drainage projects. The main activities in the network are:

Activity 1-35 – 44 :	Investigation and design of tile drainage system
Activity 1-6 :	Preparation for contracts
Activity 6-7 – 15 :	Preparation and execution
7 – 21	by contractor
Activity 1-22 – 33 :	Construction of PVC pipe factories, and pipe production
Activity 1-45 – 57 :	Remodelling open drainage
Activity 1-58 – 63 :	Construction of one pumping station
Activity 1-64 – 71 :	Reclamation of an area of 12,000 feddans

The contractors must complete the field drainage system construction within 48 months from the contract being assigned.

The work in the 7 directorates must start and end simultaneously.

The critical path is formed by activities 1-2-3-4-5-6. The average starting time of activity 6-7 (preparation by contractors) is 13 months from the outset; the E.S.T. and L.S.T. are 10 and 16 months respectively.

Activity 6-7 takes 7 months, on average. The average starting time of the tile drainage construction is 20 months from the outset (E.S.T. and L.S.T.: 16 and 25 months respectively). Average completion time of the overall works will be after 61 months (E.S.T. and L.S.T. 57 and 66 months respectively).

After starting tile drainage construction the critical path will follow through 7-38 - 44 (designing) as a shortage of investigating and designing engineers will probably occur.

More detailed planning is required for the main activities mentioned above. An example of the breakdown of activity 1-35 – 44 (investigation and design of tile drainage system) is shown in the Annex. The whole area is divided into 82 subunits (6000 feddans each) in 7 directorates. Special attention should be paid to the preparation activities (1-7) which are all situated on the critical path, as lengthening or shortening of any activity will result in a longer or shorter total work period. Designing for the first 8 subunits should start immediately.

The three PVC pipe-making plants will be idle for 3 months, and attempts should be made to utilize them during this period, perhaps for producing pipes for use in areas outside the project.

A more detailed planning system is required for all the 7 directorates by planners in the directorates (regional level).

Training programmes in planning techniques are urgently required.

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Annex 1. *Duration of activities for the drainage programme of Upper Egypt II*

Remarks

For 1978 the work plan is already being carried out. The time estimate starts from 1 May, 1978 (in months) L = longest time, S = shortest time, A = average, R = ready or completed.

Activity 1-2 represents the preparation of a tender document for field drainage. Similarly, other activities are described, as follows:

Activity description	Duration months L	S
I. *Construction Pumping Station:*		
1-58 Prepare designs	2	1
58-59 Prepare tender	2	1
59-60 Advertise and bidding	2	1
60-61 Analysis for lowest bid	2	1
61-62 Award contract; preparation by the contractor	2	1
62-63 Execution by the contractor	18	12
	30	17
Average A	24	
II. *Field Drainage Works:*		
a- Investigation and Design:		
1-35 Preparation of survey maps (1 : 10,000)	8	6
1-34 Dummy	0	0
34-46 Investigation	2	1
36-37 Design	2	1
Average:	12	8
	A = 10	
37-38, 38-39, 39-40, 43-44 Repetitions for 6 months' execution drainage period (i.e. activity (37-38) with duration 10 months, and other activities, will be repeated for every subunit to be constructed in six		

Activity description	Duration months L	S
b- Execution of Tile Drainage		
1-2 Preparation of tender document	R	R
2-3 Approval (World Bank, EPADP)	2	1
3-4 Advertising and information bidders	6	4
4-5 Analysis lowest bid, workplan discussions	6	4
5-6 Approval (W.B., EPADP)	2	1
6-7 Award of contract; preparation of work and import of machines by contractor	9	6
Start total:	25	16
Average	A = 20	
7-16 Contractor preparation for execution of drainage in sub-units for a 6-month period	A = 6	
16-17, 17-18, 18-19, 19-20, 20-21 same as activity 7-16.		
7-8, 16-9, 17-10 21-14 Dummies	0	
Total Average	A = 62	
c- Production of PVC pipes:		
1-22 Prepare tender documents for 3 pipe-making factories	R	R
22-23 Approval (USAID, EPADP)	R	R
23-24 Advertising, information bidders	R	R
24-25 Analysis lowest bid, workplan	6	3
25-26 Approval	2	2
26-27 Award of contract, import, construction	12	9
27-8, 28-9 ----(33-14) Dummy	20	14
Average	A = 17	
IV. *Reclamation of 12,000 fed.*		
1-64 Design and layout	3	2
64-65 Prepare tender	2	1
65-66 Advertise	2	1
66-67 Analysis	4	2
67-68 Award of contract and preparation	3	2
	14	8
68-69 Execution	6	6
TOTAL:	20	14
Average	22	
(69-70), (70-71) Repetitions of (68-69)		
(71-15) Dummy		

Annex 1 (cont.)

Activity description	Duration months S	L
8-9 Tile drainage construction in 6 months' period. A = 42		
9-10 ----(14-15) same as (8-9)		
27-28, --- 32-33 production in 6 month period		
III- *Remodelling open drains and Constructing new drains:*		
1-45 Design open drainage	R	R
45-46 Preparation of tender	3	2
46-47 Advertising; for bidding	4	2
47-48 Analysis for lowest bid, work plan	2	1
48-49 Award of contract; preparation by contractor	2	1
Subtotal:	11	8
49-50 Execution	12	12
Total:	23	18
Average	A = 20	
(50-51),.....(56-57) repetition of (1-65) to 50		1