5-2 Tanker traffic forecast

5-2-1 Forecasting method of tanker traffic

This part describes the basic system of forecasting the Canal tanker traffic volume. The principal method of forecast is based on PART V of the Final Report, Technical Cooperation Program to Planning and Research Department, Suez Canal Authority (1978).

The forecasting process consists of four phases, all interrelated for the purpose of making long term forecasts regarding tanker traffic through the Suez Canal.

These four phases are:

a) Route Cost,
b) Route Choice,
c) Tanker Traffic Through the Canal, and
d) Canal Revenue from Tankers.

The process relationships between these phases are shown in Fig. 4-5-2.

A brief description of these phases as follows:

(1) Route cost

Tanker shipping cost may be broken down into two major elements: capital costs and operating costs.

The route cost stage is used to calculate the cost of shipping per ton of cargo on each route and in each tanker size. In the case of tankers, three different route costs are calculated;

a) via Canal both laden and in ballast (s/s),
b) via Canal in ballast but not laden (c/s),
c) not via Canal either laden or in ballast (c/c).

(2) Route choice

The route choice stage is used to determine the proportion of tonnage using the Canal for each category of vessel on each route. In this study, the market condition, route cost, and Canal toll are considered as the main factors of route choice.

(3) Tanker traffic through the Canal

The Oil trade relevant to the Canal, which is forecasted in Chapter 3, is converted to the number of tankers through the Canal by using the volume of oil which can be carried on a voyage by a tanker on each route.

(4) Canal revenue from tankers

Canal tolls for tankers have been set up as unified rates depending on size and loading condition of the tanker. Therefore, the number of tankers through the canal is used to calculate the revenue. In this Chapter, the potential traffic using the Canal in the absence of a capacity constraint is calculated. Therefore, the revenue from tankers is also potential revenue.

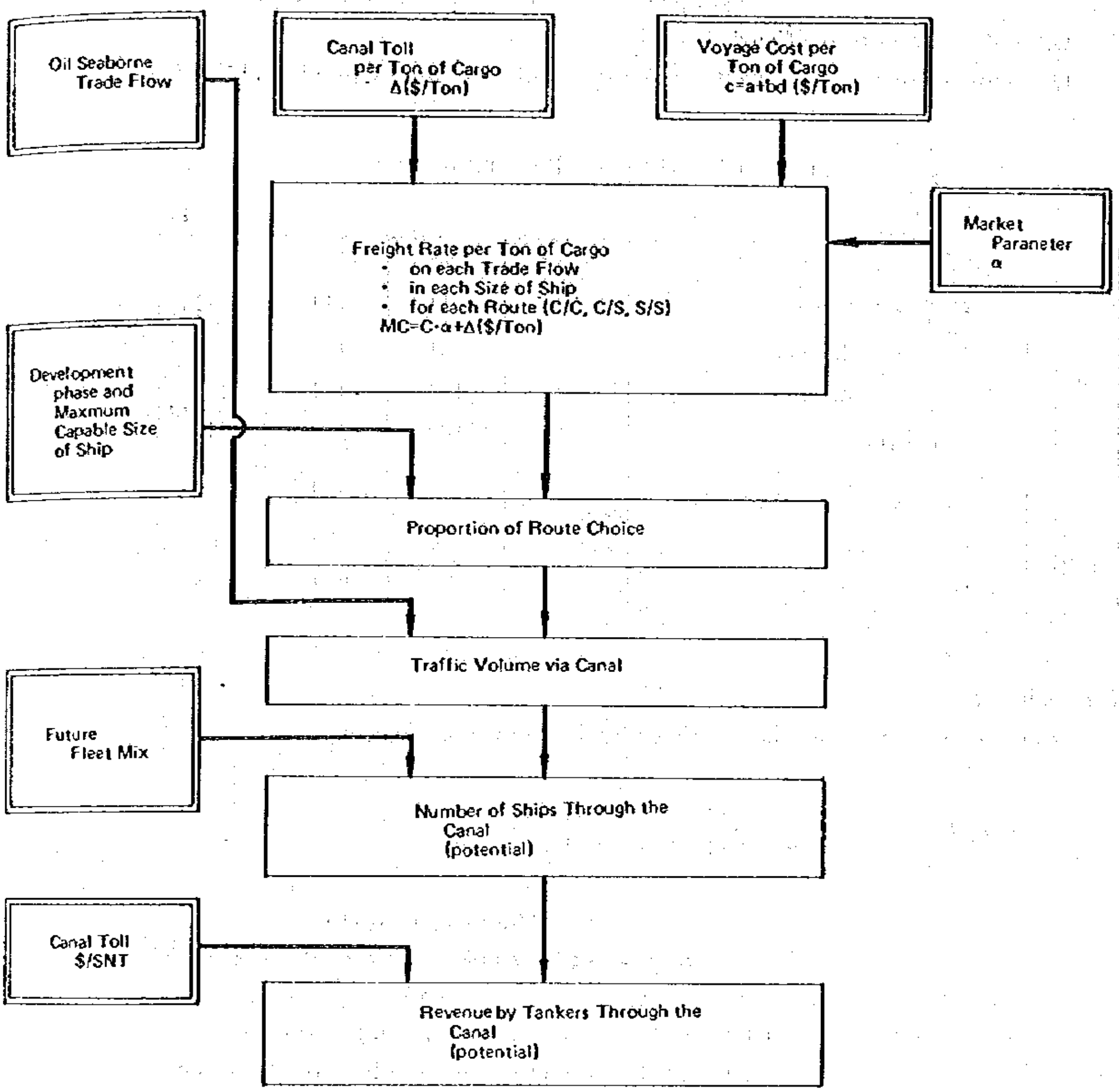


Fig. 4-5-2 Outline of Tanker Forecasting Model

5-2-2 Proposition of tanker traffic forecast

(1) Oil trade relevant to the Canal

Oil Trade is forecasted in Chapter 3 and the results are summarized in Table 4-5-3.

Table 4-5-3 Oil Trade Relevant to Canal

($x10^6$ ton)

Origin → Destination		1980	1985	1990	1995	2000
Oil	A. Gulf → N. W. Europe	242	234	233	233	221
	A. Gulf → Mediterranean	154	141	138	138	132
	A. Gulf → N. America	131	134	141	141	134
	Sub Total	527	509	512	512	487
	Communis Block and Mediterranean → Middle and East Asia	4	4	4	4	4
LNG	A. Gulf N. W. Europe	0	0	8.4	11.1	13.8
	A. Gulf N. America	0	2.9	13.1	18.5	23.9

(2) Route cost

Route cost per ton of cargo is defined by the following equation.

$$\text{Shipping Cost/Ton} = \frac{\text{Annual Shipping Cost (\$)}}{\text{Annual Shipping Volume (Ton)}}$$

$$= \frac{\text{Annual Shipping Cost (\$)}}{\text{Annual Carrying Capacity (Ton/DWT)} \times \text{Ship Size (DWT)}}$$

Annual shipping cost and annual carrying capacity are composed of many cost items. To obtain the shipping cost on each route, the cost data summarized in Table 4-5-4 is collected.

According to the definition of shipping cost, the shipping cost estimation equation is obtained as follows:

$$C = a + b.d \quad \ldots\ldots \quad (1)$$

where d : distance (miles),

a,b: coefficients

$$a = [\frac{(Prc+Cr+Ms+Ad+Lb+Rp)\ (Dt+Do)}{Da} + B_2 . Pb . (Dt+Do)+Tt+To]\ DwR \quad \ldots \quad (2)$$

$$b = [\frac{(Prc+Cr+Ms+Ad+Lb+Rp)}{Da} + B_1 . Pb] \cdot (\frac{1}{S_1} + \frac{1}{S_2}) \cdot \frac{1}{24} \cdot \frac{1}{DwR} \quad \ldots\ldots \quad (3)$$

$$c = (1 + E)\ (Ra+Rr+Ri) \quad \ldots\ldots \quad (4)$$

Table 4-5-4 Necessary Data to Obtain Route Cost

Name	Unit	Symbol
Ship Size	DWT	Dw R
Load Factor	ton/DWT	R
Distance	miles	d
Days in Voyage	days/year	Da
Loading Time	days/voyage	Dt
Unloading Time	days/voyage	Do
Speed in Laden	miles/hour	S_1
Speed in Ballast	miles/hour	S_2
Contract Price	$	Pr
Fitting Out Expense Rate	%	E
Depreciation Rate	%	Ra
Interest	%	Rr
Insurance Rate	%	Ri
Crew Expenses	$/year	Cr
Miscellaneous	$/year	Ms
Administrative Costs	$/year	Ad
Lubrication Costs	$/year	Lb
Maintenance Costs	$/year	Rp
Bunker Oil Price	$/ton	Pb
Bunker Oil Consumption in Voyage	tons/day	B_1
Bunker Oil Consumption at Anchor	tons/day	B_2
Loading Costs	$/voyage	Tt
Unloading Costs	$/voyage	To

The detailed derivation of this equation is shown in PART V of the Final Report of Systems Analysis, Technical Cooperation Program to Planning and Research Department, Suez Canal Authority (1979).

Table 4-5-5 shows the cost estimation equation for each tanker size.

Table 4-5-5 Cost Estimation Equations

Size of Tanker ($\times 10^3$ DWT)	Estimation Equation $C = a + bd$ ($/ton)
30	$C = 1.621 + 3.067d$
100	$C = 1.228 + 1.649d$
200	$C = 0.849 + 1.135d$
275	$C = 0.849 + 1.027d$
325	$C = 0.792 + 0.949d$
375	$C = 0.856 + 0.894d$
425	$C = 0.835 + 0.805d$

Note: d means one way distance on each route, 10^3 mile

By using the cost estimation equation, shipping cost per ton of cargo, including the toll, can be calculated.

Cost/ton of each route in each tanker size

$$= a_i + b_i d + \Delta$$

(a_i, b_i) : cost parameter of i'th category of size

d : route distance (10^3 mile)

Δ : canal toll (\$/Ton)

The results of route costs are shown in Table 4-5-6.

This table shows that the S/S route is the cheapest with respect to shipping cost per ton of cargo.

Table 4-5-6 Shipping Cost per Ton on Each Route

O → D	Size Category (x 10³ DWT)	Route Cost ($/Ton)		
		S/S	C/S	C/C
A. Gulf ↓ N.W. Europe	0 -60	25.61	31.02	36.65
	60 -150	15.13	17.48	20.06
	150-250	11.10	12.34	13.81
	250-300	10.33	11.34	12.58
	300-350	9.72	10.56	11.63
	350-400	9.39	10.11	11.07
	400-	9.02	9.63	10.49
A. Gulf ↓ Mediterranean	0 -60	18.96	26.97	35.22
	60 -150	11.55	15.30	19.29
	150-250	8.63	10.84	13.28
	250-300	8.10	9.98	12.10
	300-350	7.66	9.30	11.19
	350-400	7.45	8.93	10.65
	400-	7.19	8.52	10.09
A. Gulf ↓ N. America	0 -60	30.29	33.93	37.79
	60 -150	17.65	19.04	20.68
	150-250	12.83	13.41	14.24
	250-300	11.90	12.31	12.96
	300-350	11.16	11.46	11.98
	350-400	10.75	10.96	11.40
	400-	10.31	10.44	10.80

Note: Including the Canal Toll
Toll of S/S: 1.204 \$/Ton (Laden) + 0.968 \$/Ton (in Ballast)
Toll of C/S: 0.968 \$/Ton (in Ballast)
Toll of C/C: 0

(3) Route choice

Shipping cost and freight market have a strong effect on the route allocation of tankers. In particular, an increase in the freight rate brings a greater proportion of Suez routes.

To introduce the concept of freight rate, future freight rate is approximated by the fluctuating level of the shipping cost per ton of cargo.

$$FR = [a + bd] \times \alpha + \Delta$$

where FR is the future freight, a and b parameters of shipping cost and α a positive parameter representing market conditions. In this formula, when α = 1.0, FR and the freight level just covers the shipping costs.

By using this freight rate (FR) in each route, a selection among routes, C/C, C/S, and S/S is made depending on the freight rate. Fig. 4-5-3 shows changes of the freight rates corresponding to the three routes (S/S, C/S and C/C) depending on changes in the market condition (α).

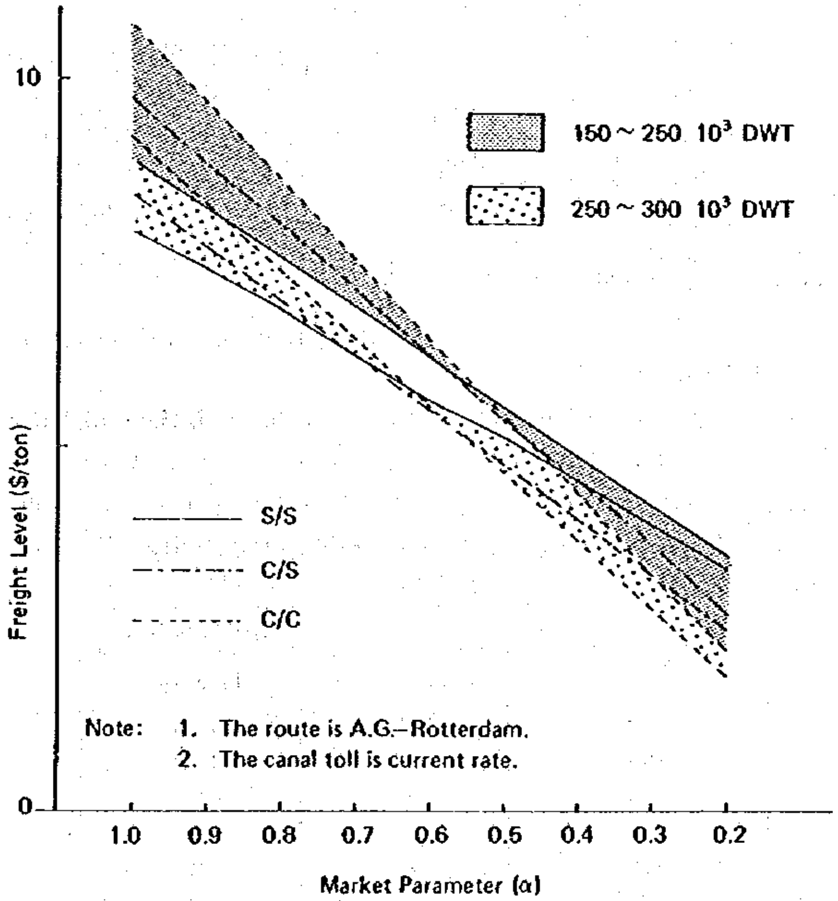


Fig. 4-5-3 Freight Level with respect to Market Parameter

(4) Fleet mix

The fleet mix relevant to the Canal is set up based on the present fleet mixes on each route.

Table 4-5-7 Fleet Mix on Each Trade Flow

(%)

O – D \ Size (000 DWT)	0~60	60~150	150~250	250~300	300~350	350~400	400~	Total
A. Gulf → N. W. Europe	1.4	4.7	33.7	39.2	8.6	6.4	6.0	100
A. Gulf → Mediterranean	22.1	26.7	27.3	25.2	3.3	2.4	2.2	100
A. Gulf → N. America	2.9	15.7	30.8	32.5	7.4	5.7	5.0	100

(5) Canal toll

The canal toll is set by converting the present toll (SDR) to U.S.$ (see Table 4-5-8).

Table 4-5-8 Canal Toll of Tanker

	Toll	
	$/NRT	$/ton
Laden	2.09	1.204
In Ballast	1.68	0.968

Notes: Base Year is 1980.
Conversion rate is 1 SDR = $1.30

(6) Size category and Canal capability

The development stage and size of ships that can pass through the Canal at each stage are shown in Table 4-5-9.

Table 4-5-9 Size Category and Canal Capability

Tanker Size (000 DWT)	Representing Size	Capable or Not		
		Present	1st Stage	2nd Stage
0 – 60	30	L, B	L, B	L, B
60 ~ 150	100	B	L, B	L, B
150 ~ 250	200	B	B	B
250 ~ 300	275	X	B	B
300 ~ 350	325	X	B	B
350 ~ 400	375	X	X	X
400 ~	425	X	X	X

Notes: L, B denotes that tankers in corresponding size category can transit the Canal at corresponding phase, if they are laden and in ballast respectively.
Tanker marked with X can not pass through the Canal.

(7) Market condition

The tanker market is currently going through a depression. As was mentioned in Chapter 4, the gap between supply and demand in shipping is expected to gradually decrease hereafter with prospects of a balance in the latter half of 1980. Accordingly, taking this case as the Base Case, prospects of the tanker market have been ascertained in the three cases with recovery slower than the Base Case as the Low Case and that faster as the High Case.

5-3 Non-Tanker traffic forecast

5-3-1 Forecasting method of non-tranker traffic

This part describes the basic system of forecasting non-tanker traffic.

This outline of this method is shown in Fig. 4-5-4.

The forecasting process consists of the following stages:

a) Set the ship type share for each commodity.

b) Forecast the transiting commodity volume in metric tons according to the growth of seaborne trade relevant to the Canal.

c) Convert the transiting cargo volume to the cargo volume of each ship type by using the ship type share for each commodity.

d) Get the ship NRT by using the load factor for each ship type.

e) Get the NRT for each ship size by using the size distribution for each ship type.

f) Estimate the number of non-tankers by using the representative size of each ship size category.

g) Calculate the revenue corresponding to the number of ships by using the Canal toll.

5-3-2 Proposition of non-tanker traffic forecast

(1) Transit cargo through the Canal

Forecasting of the Suez Canal transit cargo volume is to be based on the rate of increase in cargo by commodity category and by direction analysed in Chapter 3. However, assuming that the economic growth of those countries relating to the future Canal trade will be uncertain, forecasting is to be made in the three cases of High Growth, Medium Growth and Low Growth.

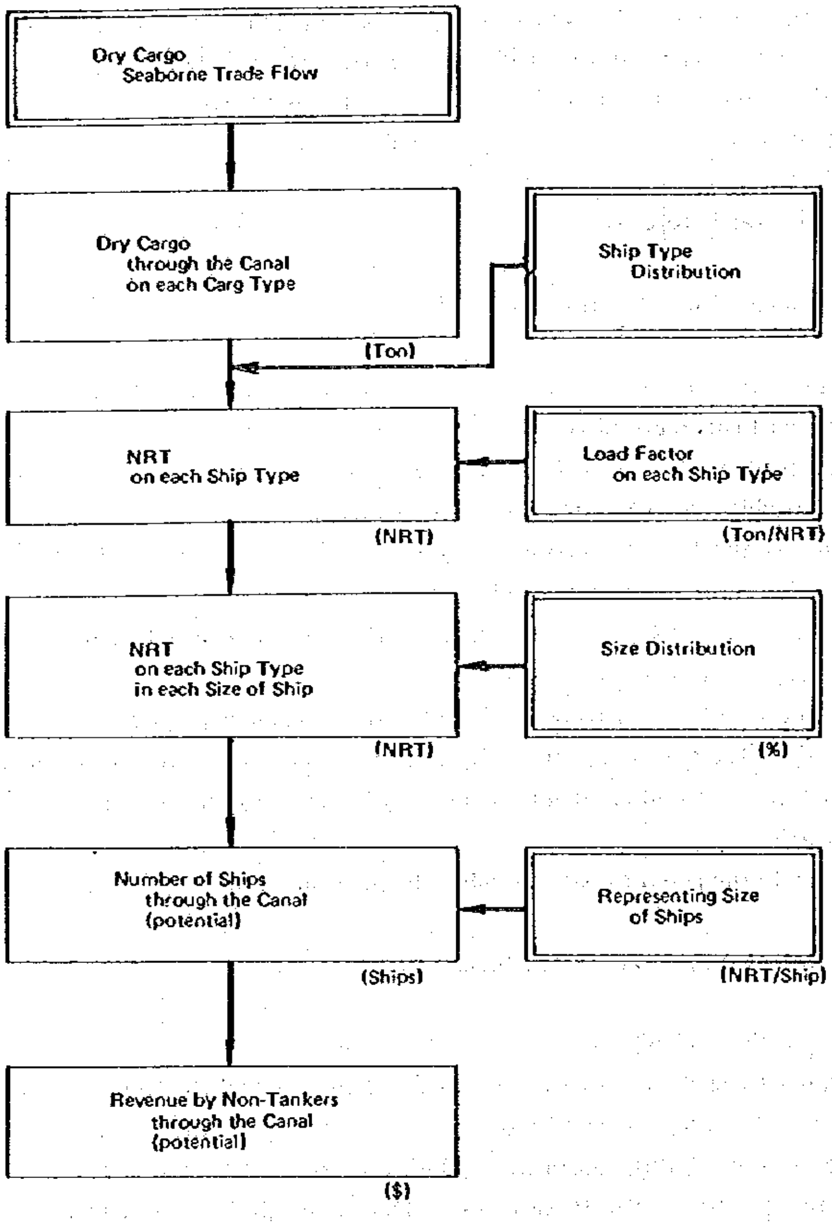


Fig. 4-5-4 Outline of Non-Tanker Forecasting Model

(2) Share of vessel category in each commodity

Table 4-5-10 shows the share of each vessel category in each commodity ascertained from the current data. This information will be used to convert the cargo volume by commodity to that by vessel category.

Table 4-5-10 Share of Ships on Each Commodity

Ship / Cargo	BULK	GCS	CONT	LASH	RORO	CAR	OTRS	TOTAL
Iron	90.0	10.0	0.0	0.0	0.0	0.0	0.0	100.0(%)
Cereals	48.3	51.4	0.0	0.0	0.0	0.0	0.0	100.0
Fab., M	88.2	9.5	2.3	0.0	0.0	0.0	0.0	100.0
Cement	64.8	35.2	0.0	0.0	0.0	0.0	0.0	100.0
Ferti.	62.2	37.8	0.0	0.0	0.0	0.0	0.0	100.0
Coal	90.0	10.0	0.0	0.0	0.0	0.0	0.0	100.0
Others	18.5	61.8	13.3	2.0	2.5	1.8	0.1	100.0

(3) Load factor

Table 4-5-11 Load Factor on Each Ship Type

(TON/NRT)

Ship Type	South Bound	North Bound	Total
1. Bulk Carrier	1.63	1.25	1.41
2. General Cargo	0.93	0.94	0.93
3. Containers	0.38	0.34	0.36
4. Lash Ship	0.81	0.84	0.82
5. RO/RO	0.19	0.22	0.20
6. Car Carriers	0.35	0.09	0.16
7. Others	0.02	0.02	0.02
Total	0.90	0.82	0.87

(4) Distribution of vessel sizes

In order to divide NRT according to vessel sizes, the distribution of sizes was obtained for each vessel category. Table 4-5-12 shows the size distribution after the First Stage Project estimated from the data for 1979. The vessel size distribution in the future is to be obtained by modifying the size structure of each vessel category, anticipating a further increase in big size vessels.

Table 4-5-12 Ship Size Distribution after the First Stage Project

Size $\times 10^3$ NRT	Bulk Carriers	General Cargo	Containers	Lash Ship	RO/RO	Car Carriers	Others
0– 5	0.8 (0.5)	12.1 (7.6)	2.9 (1.8)	0.0 (0.0)	7.7 (4.8)	0.2 (0.1)	36.6 (23.0)
5–10	8.7 (5.7)	72.2 (48.9)	6.2 (4.8)	0.0 (0.0)	44.8 (30.4)	1.7 (1.1)	45.5 (39.4)
10–15	24.8 (18.2)	13.8 (30.8)	8.5 (7.4)	0.0 (1.2)	25.8 (29.9)	4.0 (3.0)	10.4 (22.4)
15–20	24.5 (23.3)	1.5 (9.9)	11.5 (10.2)	1.9 (0.6)	4.7 (13.6)	10.7 (8.0)	0.6 (6.8)
20–25	10.9 (15.8)	0.2 (2.2)	15.9 (14.0)	0.0 (0.1)	4.0 (6.0)	2.7 (5.1)	0.8 (1.8)
25–30	6.4 (9.1)	0.0 (0.4)	5.7 (9.1)	0.0 (0.0)	6.1 (5.6)	20.2 (14.2)	2.4 (1.9)
30–40	9.2 (8.6)	0.1 (0.1)	5.7 (6.4)	95.3 (59.9)	6.9 (6.5)	36.9 (29.4)	1.5 (1.7)
40–50	2.5 (4.8)	0.1 (0.1)	38.1 (26.2)	0.0 (28.1)	0.0 (2.5)	19.5 (24.5)	2.2 (2.0)
50–60	5.4 (4.8)	0.0 (0.0)	5.5 (15.1)	0.0 (6.3)	0.0 (0.5)	1.1 (9.1)	0.0 (0.8)
60–70	3.9 (4.3)	0.0 (0.0)	0.0 (4.2)	0.0 (0.9)	0.0 (0.1)	0.0 (2.0)	0.0 (0.2)
70–80	2.1 (2.9)	0.0 (0.0)	0.0 (0.7)	2.8 (1.9)	0.0 (0.0)	0. (0.3)	0.0 (0.0)
80–	0.8 (1.9)	0.0 (0.0)	0.0 (0.1)	0.0 (1.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note; Figures in brackets show the size distribution in 2000.

(5) Canal toll

The Canal toll per NRT may be determined on the assumption that the current tariff system will be changed in the future. The current toll varies according to Bulk Carrier, Other Vessels and Laden/Ballast (see Table 4-5-13).

Table 4-5-13 Canal Toll ($/NRT)

Size x 10³ NRT	Non Tanker			
	Bulk		Others	
	Laden	Ballast	Laden	Ballast
	$/NRT	$/NRT	$/NRT	$/NRT
2.7	2.156	1.723	2.358	1.886
8.0	1.858	1.486	2.036	1.629
12.5	1.769	1.415	1.941	1.553
17.5	1.724	1.379	1.893	1.514
22.5	1.699	1.359	1.866	1.493
27.5	1.683	1.346	1.849	1.479
35.5	1.667	1.334	1.832	1.466
45.5	1.655	1.324	1.819	1.455
55.5	1.647	1.318	1.810	1.448
65.5	1.641	1.313	1.804	1.444
75.5	1.637	1.310	1.800	1.440
100.0	1.631	1.305	1.793	1.434

5-4 Results of traffic forecast

5-4-1 Forecasting cases and results of traffic forecast

(1) Forecasting cases

The traffic volume was forecast by different methods for tankers and non-tankers. Long-term forecasting was made in three cases of Base, High and Low to ascertain the range of inaccuracy of forecast figures. The factor which affects the number of transit tankers most is the condition of the tanker market. (See Part XII: Sensitivity Analysis of Canal Revenue).

Further, the most important factor of uncertainty with respect to non-tankers lies in the economic growth of Middle East Countries and the trends of their foreign trade (See Chapter 3). Accordingly, forecasting was made by modifying the market condition for tankers and by modifying the marine cargo volume for non-tankers. Table 4-5-14 shows the implications of each case.

Table 4-5-14 Forecasting Cases

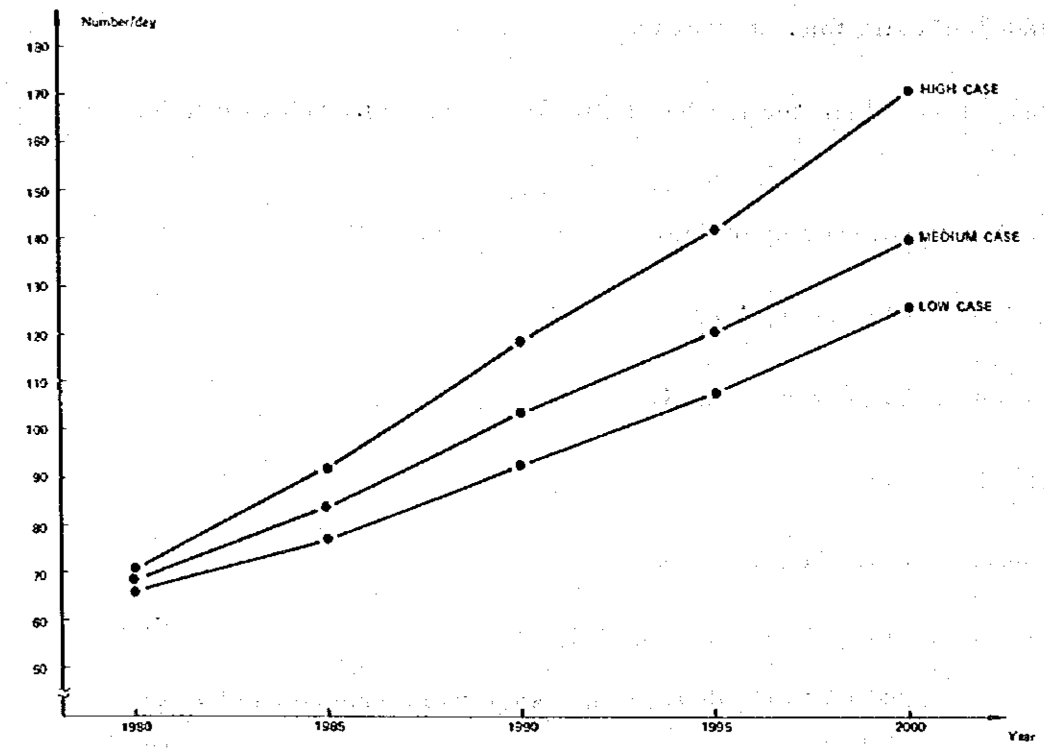
Case	Tanker	Non-Tanker
Base Case	Supply and demand of tankers will be balanced in the latter half of 1980s.	Case of average growth of cargo volume relating to the Middle East Countries
High Case	Case of faster recovery of tanker market.	Case of an increase in cargo volume with fast growth of Middle East Countries.
Low Case	Case of slower recovery of tanker market.	Case of a decrease in cargo volume with slow growth of Middle East Countries.

(2) Results of traffic forecast

Fig. 4-5-5 and Fig. 4-5-6 show the potential number of transits and the potential revenue by case.

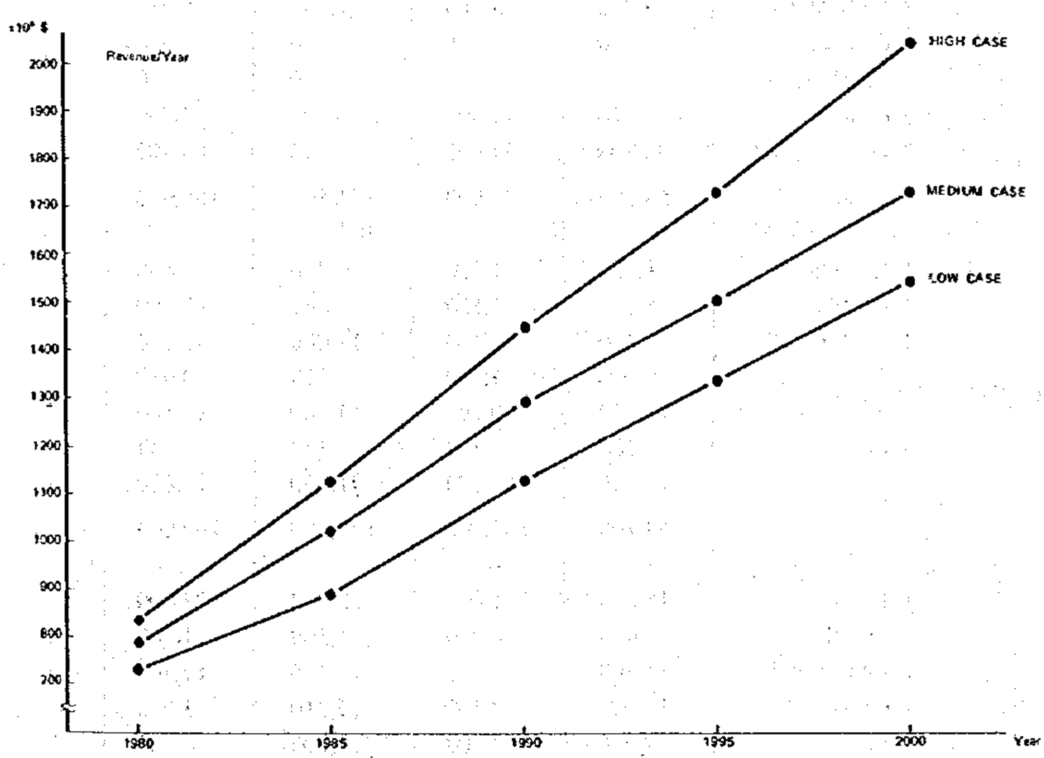
In the Base Case, the number of transits per day after the implementation of the First Stage Project (1980) will be about 68, then almost doubling in 2000.

With the increase in transits the Canal revenue will increase steadily, from 785 million US dollars in 1980 to 1,730 million US dollars in 2000. Forecast figures will be within a ±3% range in 1980, but the degree of uncertainty will increase to +22% – 10% in 2000. If imports of the Arab coastal countries increase, a large increase in the number of non-tanker transits, especially in other cargo vessels, may be expected.



	1980	1985	1990	1995	2000
LOW	66.2	76.5	92.5	107.9	125.3
BASE	68.3	83.9	103.3	120.1	139.6
HIGH	70.3	91.8	118.1	141.5	170.8

Fig. 4-5-5 Number of Ships through the Canal



	1980	1985	1990	1995	2000
LOW	730.5	890.9	1125.5	1336.4	1548.4
BASE	785.2	1021.6	1290.6	1506.7	1730.5
HIGH	835.0	1126.4	1448.1	1723.9	2045.8

Fig. 4-5-6 Canal Revenue

5-4-2 Details of traffic forecast: Base Case

This section will give the details of traffic forecast in the Base Case for each commodity and vessel category.

(1) Goods traffic by category of ships

See Table 4-5-15 and Fig. 4-5-7.

(2) Net tonnage by category of vessels

See Table 4-5-16.

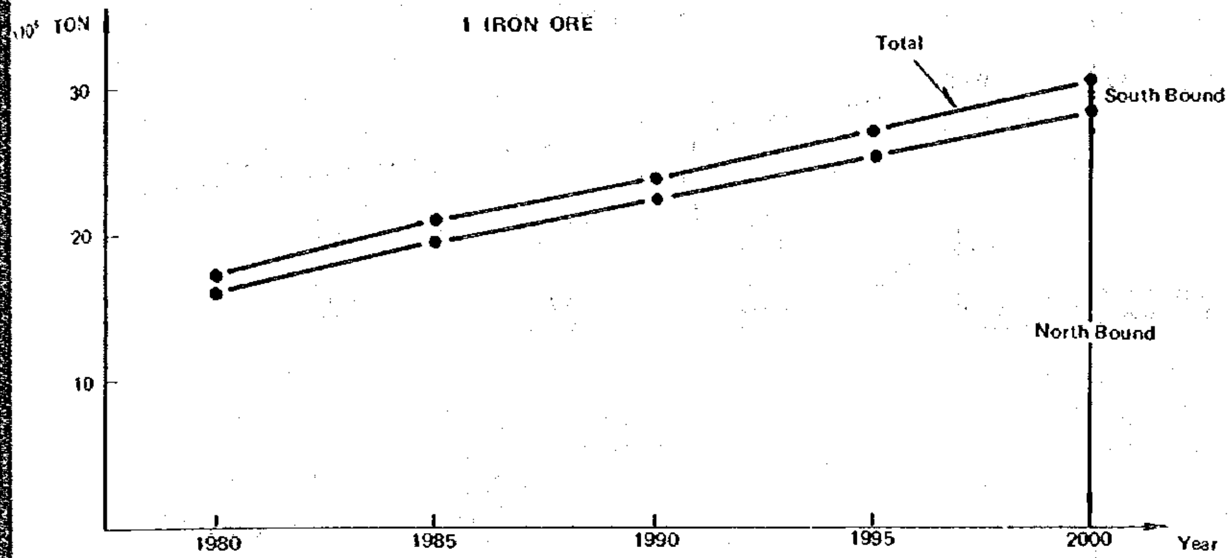
(3) Number of ships and Canal revenue

See Table 4-5-17, Fig. 4-5-8, and Fig. 4-5-9.

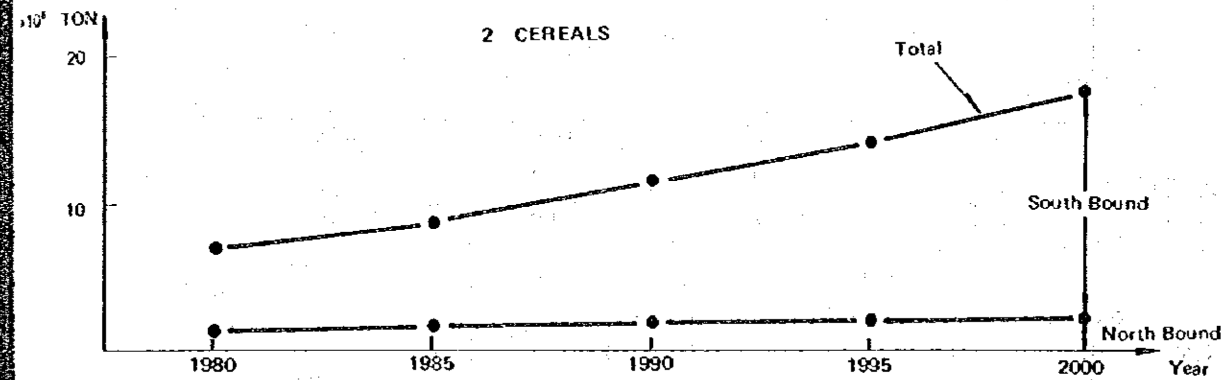
Table 4-5-15 Goods Traffic by Category of Commodities : Base Case

(10^3 Metric Ton)

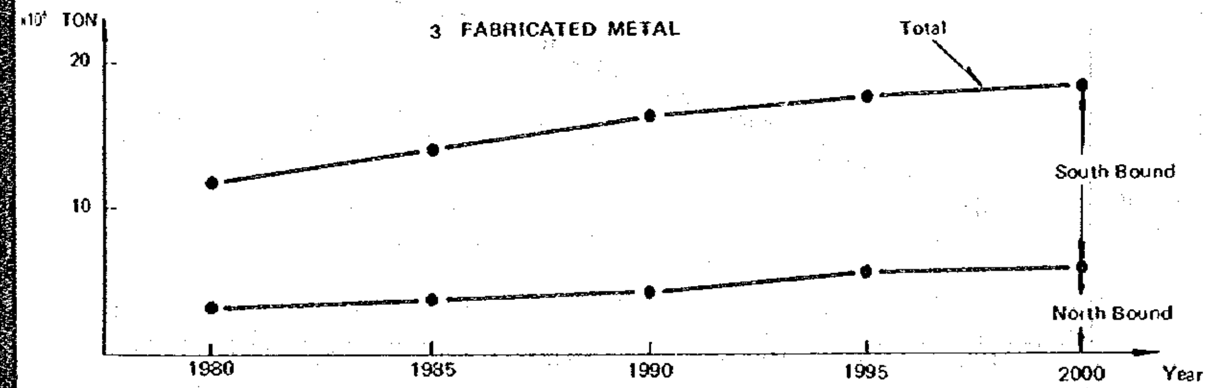
	Cargo Type	1980	1985	1990	1995	2000
North Bound	1 Iron Ore	17,500	19,800	22,400	25,300	28,600
	2 Cereals	1,210	1,400	1,620	1,880	2,180
	3 FAB. Metal	3,240	3,760	4,350	5,050	5,850
	4 Cement	0	0	0	0	0
	5 Fertilizer	0	0	0	0	0
	6 Coal	9,130	14,500	20,200	24,700	30,400
	7 Others	32,700	37,400	42,800	48,900	56,000
	Total	63,800	76,900	91,300	106,000	123,000
South Bound	1 Iron Ore	1,060	1,230	1,430	1,650	1,920
	2 Cereals	5,790	7,520	9,860	12,300	15,400
	3 FAB. Metal	8,460	10,400	12,000	12,700	12,500
	4 Cement	10,000	7,400	5,210	3,080	1,630
	5 Fertilizer	9,550	10,700	13,200	16,500	20,800
	6 Coal	288	334	388	449	521
	7 Others	48,000	67,000	91,300	115,000	146,000
	Total	83,100	105,000	133,000	162,000	199,000
Total	1 Iron Ore	18,500	21,000	23,800	27,000	30,500
	2 Cereals	7,000	8,920	11,500	14,200	17,500
	3 FAB. Metal	11,700	14,100	16,400	17,700	18,300
	4 Cement	10,000	7,400	5,210	3,080	1,630
	5 Fertilizer	9,550	10,700	13,200	16,500	20,800
	6 Coal	9,420	14,900	20,500	25,200	30,900
	7 Others	80,700	104,000	134,000	164,000	202,000
	Total	147,000	181,000	225,000	268,000	322,000



	1980	1985	1990	1995	2000
North Bound	16,200	19,800	22,400	25,300	28,600
South Bound	0,971	1,230	1,430	1,650	1,920
Total	17,200	21,000	23,800	27,000	30,500

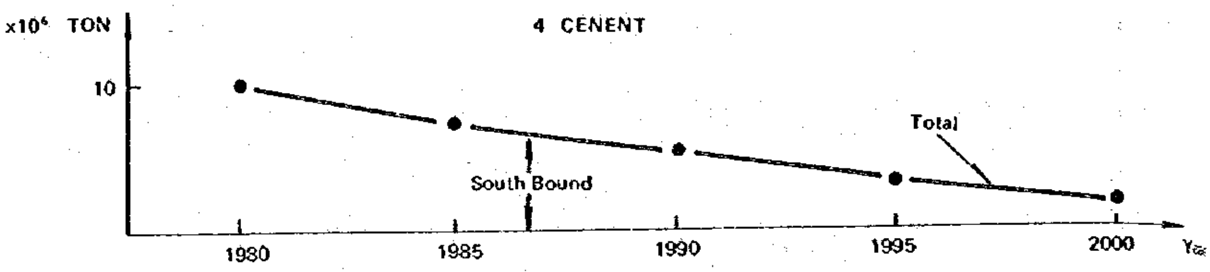


	1980	1985	1990	1995	2000
North Bound	1,210	1,400	1,620	1,880	2,180
South Bound	5,790	7,520	9,860	12,300	15,400
Total	7,000	8,920	11,500	14,200	17,500

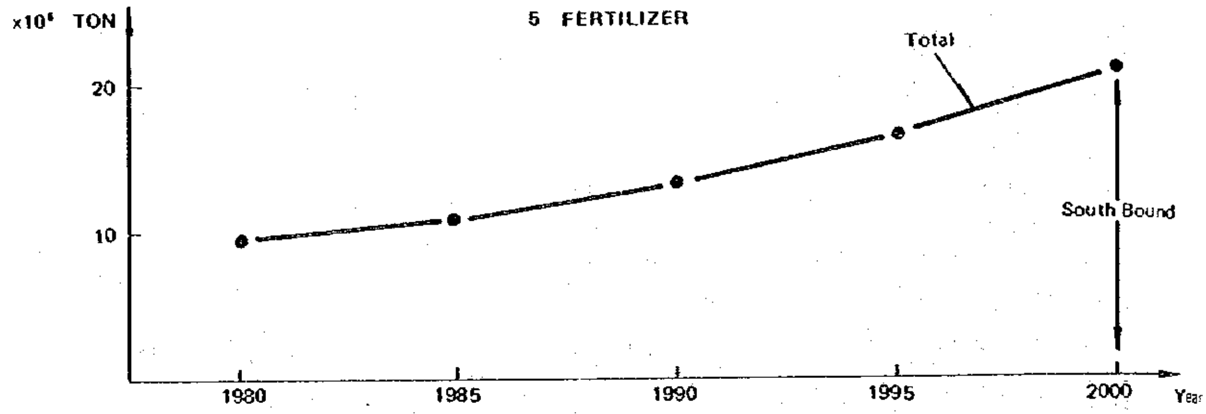


	1980	1985	1990	1995	2000
North Bound	3,240	3,760	4,350	5,050	5,850
South Bound	8,460	10,400	12,000	12,700	12,500
Total	11,700	14,100	16,400	17,700	18,300

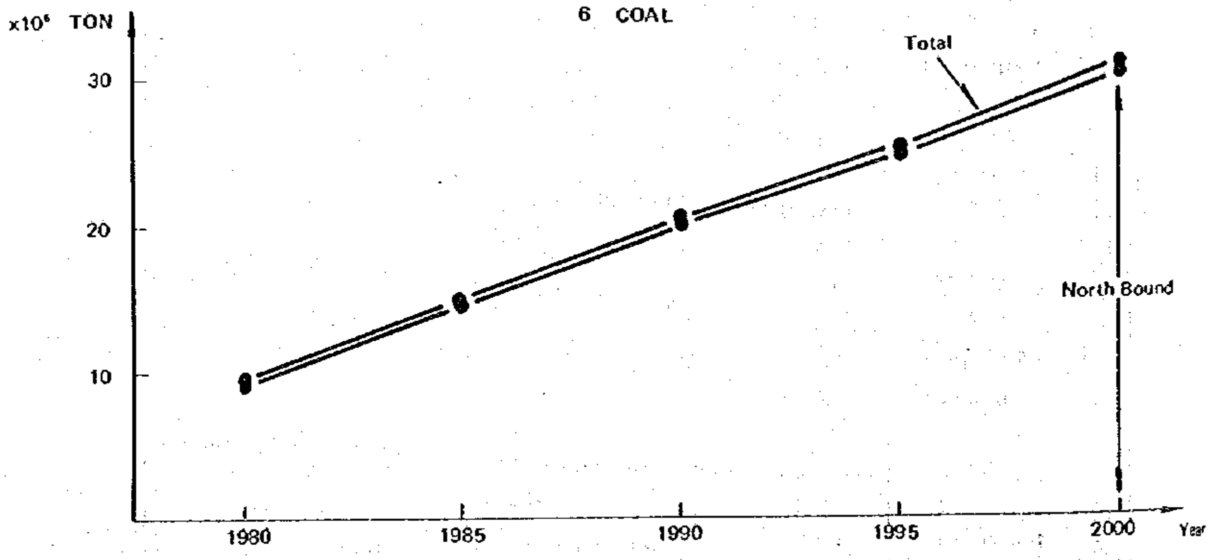
Fig. 4-5-7 Goods Traffic by Category of Commodity (continued)



	1980	1985	1990	1995	2000
North Bound	0	0	0	0	0
South Bound	10,000	7,400	5,210	3,080	1,630
Total	10,000	7,400	5,210	3,080	1,630

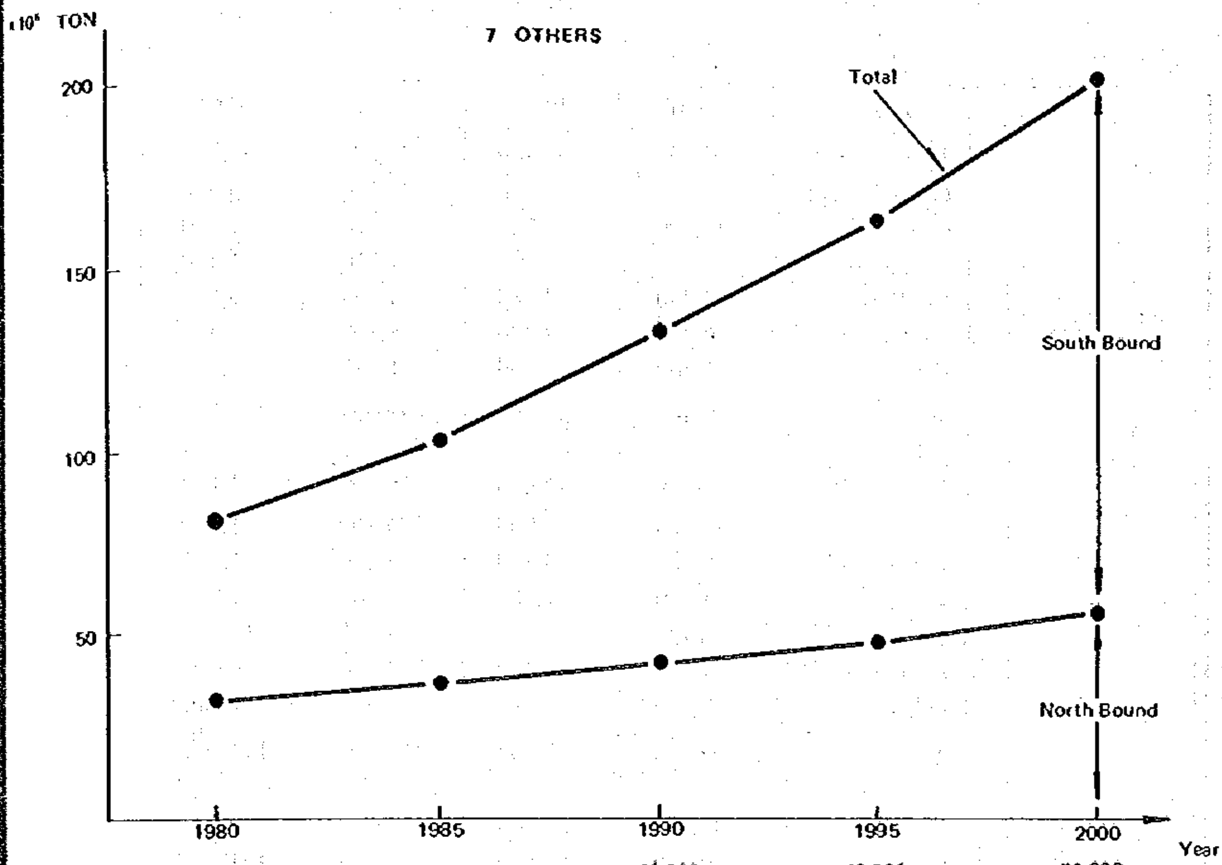


	1980	1985	1990	1995	2000
North Bound	0	0	0	0	0
South Bound	9,550	10,700	13,200	16,500	20,800
Total	9,550	10,700	13,200	16,500	20,800



	1980	1985	1990	1995	2000
North Bound	9,130	14,600	20,200	24,700	30,400
South Bound	288	334	388	449	521
Total	9,420	14,900	20,500	25,200	30,900

Fig. 4-5-7 Goods Traffic by Category of Commodity (Continued)



	1980	1985	1990	1995	2000
North Bound	32,700	37,400	42,800	48,900	56,000
South Bound	48,000	67,000	91,300	115,000	146,000
Total	80,700	104,000	134,000	164,000	202,000

Fig. 4-5-7 Goods Traffic by Category of Commodity (Continued)

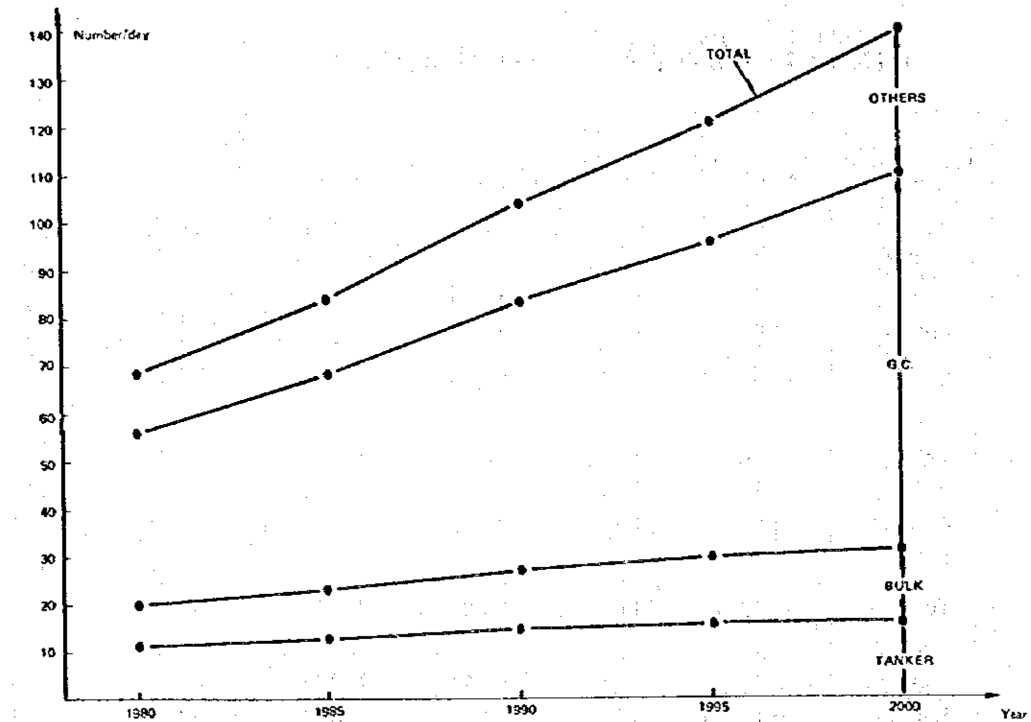
Table 4-5-16 Net Tonnage by Category of Vessels : Base Case

(x 10^3 NRT)

	Year	1980	1985	1990	1995	2000
North Bound	1 Bulk Carriers	26,700	33,400	40,600	47,500	55,700
	2 General Cargo	25,500	29,600	34,300	39,500	45,500
	3 Containers	12,900	14,700	16,800	19,200	22,000
	4 Lash Ship	779	891	1,020	1,170	1,330
	5 RO/RO	3,740	4,280	4,890	5,600	6,410
	6 Car Carriers	6,360	7,270	8,310	9,510	10,900
	7 Others	1,400	1,600	1,830	2,100	2,400
	Total	77,400	91,800	108,000	125,000	144,000
South Bound	1 Bulk Carriers	20,200	23,400	28,000	32,400	37,900
	2 General Cargo	43,800	56,900	74,100	91,100	113,000
	3 Containers	17,500	24,300	33,100	41,700	52,600
	4 Lash Ship	1,190	1,660	2,260	2,850	3,610
	5 RO/RO	6,430	8,970	12,200	15,400	19,500
	6 Car Carriers	2,500	3,490	4,760	6,010	7,600
	7 Others	1,990	2,780	3,780	4,780	6,040
	Total	93,500	122,000	158,000	194,000	240,000
Total	1 Bulk Carriers	46,900	56,800	68,600	79,900	93,600
	2 General Cargo	69,300	86,500	108,000	131,000	158,000
	3 Containers	30,300	39,000	49,900	61,000	74,700
	4 Lash Ship	1,970	2,550	3,280	4,020	4,940
	5 RO/RO	10,200	13,200	17,100	21,000	25,900
	6 Car Carriers	8,860	10,800	13,100	15,500	18,500
	7 Others	3,390	4,380	5,620	6,880	8,440
	Total	171,000	213,000	266,000	319,000	384,000

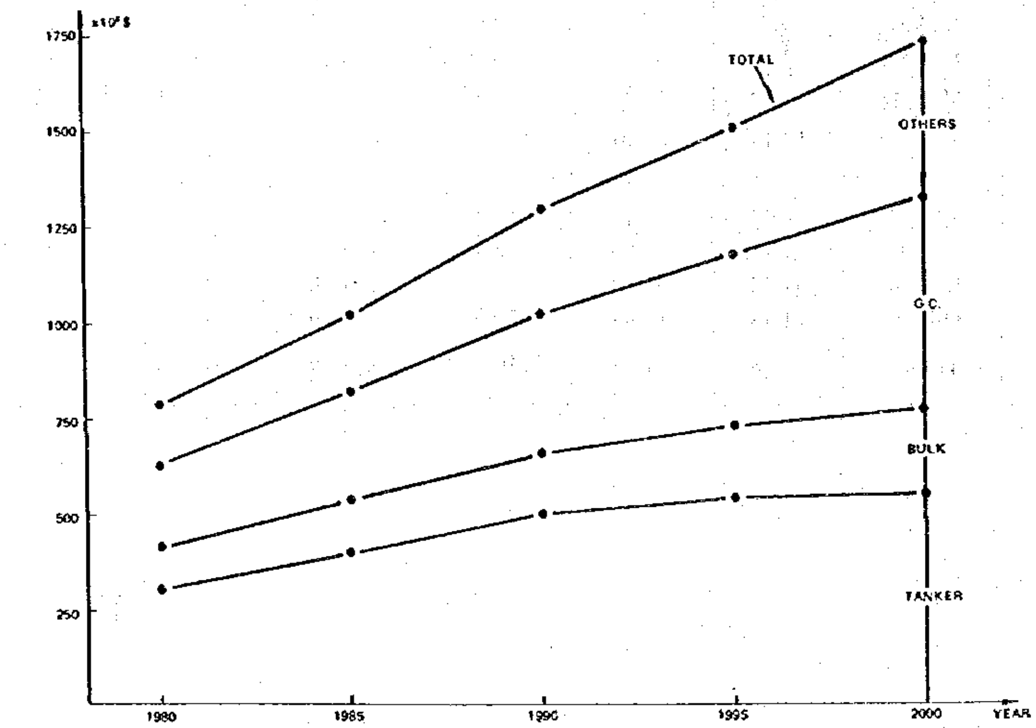
Table 4-5-17 Number of Ships and Canal Revenue : Base Case

Year	Type of Ship	Number of Ship			Canal Revenue		
		North	South	Total	North	South	Total
1980	Tanker	4.60	6.78	11.38	91.80	218.65	310.45
	Bulk.C	4.27	4.26	8.53	59.89	47.89	107.79
	General	18.21	18.22	36.43	122.02	97.64	219.66
	Others	5.96	5.96	11.92	81.85	65.46	147.31
	Total	33.05	35.23	68.28	355.56	429.65	785.20
1985	Tanker	4.78	7.81	12.59	102.05	303.76	405.81
	Bulk.C	5.19	5.19	10.38	74.76	59.71	134.47
	General	22.59	22.58	45.17	157.12	125.71	282.84
	Others	7.88	7.88	15.75	110.30	88.21	198.52
	Total	40.43	43.46	83.89	444.23	577.39	1021.62
1990	Tanker	5.46	8.98	14.44	129.54	369.29	498.83
	Bulk.C	6.14	6.13	12.27	90.73	72.56	163.29
	General	28.10	28.11	56.22	203.05	162.49	365.53
	Others	10.20	10.21	20.41	146.07	116.94	263.01
	Total	49.91	53.43	103.34	569.37	721.27	1290.64
1995	Tanker	5.78	9.52	15.30	142.03	400.58	542.61
	Bulk.C	6.99	6.99	13.98	105.92	84.74	190.67
	General	33.04	33.04	66.08	247.76	198.20	445.96
	Others	12.35	12.36	24.72	181.94	145.51	327.45
	Total	58.17	61.91	120.07	677.66	829.04	1506.70
2000	Tanker	5.86	9.53	15.39	148.35	402.37	550.72
	Bulk.C	7.99	7.99	15.98	124.13	99.30	223.43
	General	39.14	39.14	78.29	304.50	243.62	548.12
	Others	14.98	14.98	29.97	226.80	181.45	408.26
	Total	67.98	71.65	139.63	803.77	926.74	1730.51



	1980	1985	1990	1995	2000
TANKER	11.4	12.6	14.4	15.3	15.4
BULK	8.5	10.4	12.3	14.0	16.0
G.C.	36.4	45.2	56.2	66.1	78.3
OTHERS	11.9	15.8	20.4	24.7	30.0
TOTAL	68.3	83.9	103.3	120.1	139.6

Fig. 4-5-8 Traffic by Category of Vessels: Base Case



	1980	1985	1990	1995	2000
TANKER	310.4	405.8	498.8	542.6	550.7
BULK	107.8	134.5	163.3	190.7	223.4
G.C.	219.7	282.8	365.5	446.9	549.1
OTHERS	147.3	198.5	263.0	327.5	408.3
TOTAL	785.2	1021.6	1290.6	1506.7	1730.5

Fig. 4-5-9 Revenue by Category of Vessels: Base Case

6 Evaluation of Forecast Results

(1) Demand forecasts were made mostly on the Base Case, followed by the High Case and Low Case.

Cargo movement through the Suez Canal is largely influenced by the increase of imports to Middle East countries from regions west of the Suez Canal.

In the Base Case, the increase of imports by Middle East countries is conservatively forecasted against the recent record. Consequently, the forecast values of the Base Case could be considered to be on the lower side for medium values.

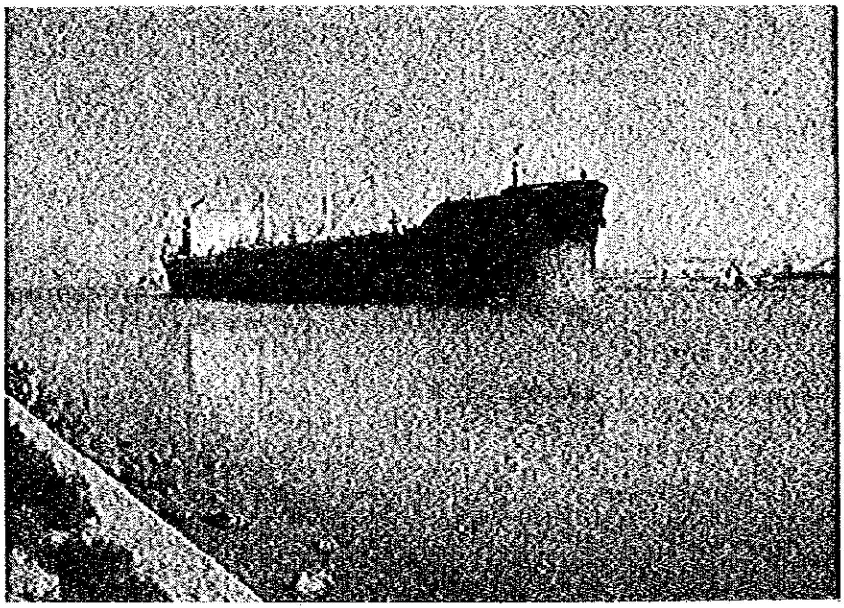
In this sense, the Low Case is rather unlikely barring stagnation in the imports of the Middle East countries from Europe, as well as in the world economy.

(2) The High Case represents the case that the imports of Middle East countries increases at the similar pace to that experienced in the 1970s. There is a possibility that the transit cargo volume of the Suez Canal will increase at the rate of the High Case, in light of the position which the Middle East countries have held in the world economy in recent years.

(3) From the comprehensive analysis of the forecast results in the present study, it will be concluded that the future volume of Suez transits will generally increase at the pace of the Base Case, but *with a high probability of increasing at a higher rate close to the High Case until 1990* and thereafter at a pace approaching the value of the Base Case in 2000.

(4) Following are the points which must be given consideration when applying the results of these forecasts to the development program of the Canal.

a) When making economic and financial analysis, the values of the Base Case should be used as the basis for evaluation to ensure that the evaluation can be made on the safe side.
b) When studying the development program of the Suez Canal, the forecast values in the High Case should be taken up with the view of avoiding congestion and preventing the diversion of large vessels to the Cape route or land transportation due to the congestion.



V. Master Plan

PART V. MASTER PLAN

1. Fundamental Policy

1-1 Policy

It is imperative to formulate a Master Plan in order to develop and/or improve the Canal both effectively and economically. Thus, the Master Plan should be made under the following fundamental policies:

1) To establish an ideal future development guidline under the existing natural environmental, and economic conditions.

2) To prepare the plan to meet the forecast number and size of transit ships for the coming 15 to 20 years.

3) To make an effective investment plan, balanced to the demand for the Canal.

For the Master Plan it is more important to have a basic perspective view rather than detailed plans. The plans to accomplish the Master Plan should be made through economic and technical considerations at each stage. This is because the optimization of one staged plan will not necessarily lead to the development of the best Master Plan, therefore, the individual staged plans must be directed toward an optimum long term plan.

1-2 Objective of plan

The objective of the plans should be based on the concept of planning ideas and policies. With the results of the Study made in the Progress Report of October 1979 and in accordance with the conclusion of the meetings between the SCA and the Team held in October 1979, the following targets have been set up:

1) The Master Plan with the target year of 2000 shall meet the expected transit demand.

2) The design size of ships should be for the largest which will make the expansion of the Canal economically feasible.

3) A rule of "keep right" traffic shall be used with the western channel for the southbound convoy while the east channel for the northbound.

2. General Planning

2-1 Design of Master Plan

The number of ships transiting the Canal per day is forecasted at not less than 100 in 1990, 120 in 1995 and 140 in 2000. According to the examination on the Canal traffic and capacity made in Part VI and Part VII, the Canal will need to be completely doubled in the first half of 1990s.

Accordingly, the total doubling of the Canal is to be the objective of Master Plan for the long term development of the Canal.

2-2 Largest size of vessels for the design of channel section

The largest size of vessels for designing the channel section is based on the size and composition of the existing world tanker fleet. It is very difficult to estimate quantitatively the future size of vessels. The existing fleet of tankers and the total volume of DWT are shown in Table 5-2-1. As clearly seen in the table, the greatest number of the large class vessels are within the range of 200,000 to 250,000 DWT, and the greatest volume of DWT is within the range of 250,000–300,000 DWT class. Therefore, 250,000 or 300,000 DWT ships can be chosen as the size of vessel for the design of the Canal section of the northbound channel. Since the Canal section required for 300,000 DWT vessels is excessively large compared with the section in the First Stage Project from the standpoint of construction cost, the channel size for 250,000 DWT vessels is adopted. Mammoth tankers in the southbound channel are not fully laden, so a smaller section of channel can accomodate all the expected ships, and the size of vessels for the design of this channel section should be for the largest tanker in ballast and for a fully laden container vessel.

Table 5-2-1 World Tanker Fleet

Size Group DWT.	Total	
	No.	DWT.
10,000/ 19,999	447	7,029,680
20,000/ 24,999	303	6,596,496
25,000/ 29,999	245	6,767,544
30,000/ 34,999	259	8,330,602
35,000/ 39,999	159	5,903,374
40,000/ 44,999	68	2,880,176
45,000/ 49,999	78	3,786,724
50,000/ 59,999	147	7,960,325
60,000/ 69,999	120	7,769,763
70,000/ 79,999	136	10,174,027
80,000/ 99,999	241	21,439,902
100,000/149,999	269	33,438,746
150,000/199,999	83	13,729,670
200,000/249,999	313	70,481,434
250,000/299,999	276	73,439,273
300,000/349,999	51	16,213,164
350,000/399,999	30	10,990,128
400,000 & Over	30	13,307,687
Total	3,255	320,238,705

Source: John I. Jacobs & Co., Ltd., World Tanker Fleet Review, As at 31.12.1978.

2-3 Design of the Canal section

(1) East Channel

The figures necessary for the design of a channel are the draught and breadth of a ship. There is an approximate 20% size difference of the vessel with the same tonnage, as shown in Tables 5-2-2 & 3, so it is difficult to determine the section of a vessel by the value of its DWT. In this study, a tanker of 68 feet in draught and 180 feet in breadth is taken as the Design Ship. These figures are slightly greater than average section of 250,000 DWT tankers, thus corresponding to that of a 260,000 DWT tanker.

The underwater side slope gradients are 1:4 to the north and 1:3 to the south of Km 61, the same as of the First Stage project.

A channel section with an area ratio of 4.8 and the lane ratio of 2.6 is used. The section is 240m in width (at −11m) and 24m in depth. On determining the depth, various factors such as squat, trim, under keel clearance and allowance for siltation are taken into account.

The revetment is to be constructed backwards to avoid the necessity of a relocation in case the canal will be widened to 260 meters (at −11m) for a 300,000 DWT tanker.

Table 5-2-2 Dimensions and Draught: Oil Tankers

DIVISIONS IN FEET	NUMBER OF SHIPS IN DIVISIONS OF GROSS TONNAGE 6,000 –9,999	10,000 –19,999	20,000 –29,999	30,000 –39,999	40,000 –49,999	50,000 –59,999	60,000 –69,999	70,000 –79,999	80,000 –89,999	99,000 –99,999	100,000 –109,999	110,000 –119,999	120,000 –129,999	130,000 –139,999	140,000 & above	DIVISIONS IN FEET
OVERALL LENGTH																OVERALL LENGTH
400– 419	4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	400– 419
420– 439	24	...	...	...	...	...	...	...	...	...	...	...	...	...	...	420– 439
440– 459	49	...	...	...	...	...	...	...	...	...	...	...	...	...	...	440– 459
460– 479	98	6	...	...	...	...	...	...	...	...	...	...	...	...	...	460– 479
480– 499	23	...	...	...	...	...	...	...	...	...	...	...	...	...	...	480– 499
500– 519	29	7	...	...	...	...	...	...	...	...	...	...	...	...	...	500– 519
520– 539	3	112	1	...	...	...	...	...	...	...	...	...	...	...	...	520– 539
540– 559	2	252	4	...	...	...	...	...	...	...	...	...	...	...	...	540– 559
560– 579	1	327	5	...	...	...	...	...	...	...	...	...	...	...	...	560– 579
580– 599	...	89	2	...	...	...	...	...	...	...	...	...	...	...	...	580– 599
600– 619	...	93	17	...	...	...	...	...	...	...	...	...	...	...	...	600– 619
620– 639	...	70	26	...	...	...	...	...	...	...	...	...	...	...	...	620– 639
640– 659	...	42	35	...	...	...	...	...	...	...	...	...	...	...	...	640– 659
660– 679	...	15	120	3	...	...	...	...	...	...	...	...	...	...	...	660– 679
680– 699	...	1	69	13	...	...	...	...	...	...	...	...	...	...	...	680– 699
700– 719	...	...	67	4	...	...	...	...	...	...	...	...	...	...	...	700– 719
720– 739	...	...	66	21	...	...	...	...	...	...	...	...	...	...	...	720– 739
740– 759	...	...	18	70	6	1	...	...	...	...	...	...	...	...	...	740– 759
760– 779	...	...	7	109	25	8	...	...	...	...	...	...	...	...	...	760– 779
780– 799	...	...	3	56	49	5	...	...	...	...	...	...	...	...	...	780– 799
800– 819	...	...	...	62	74	3	5	...	...	...	...	...	...	...	...	800– 819
820– 839	...	...	...	6	48	22	...	...	...	...	...	...	...	...	...	820– 839
840– 859	...	...	...	1	21	28	33	1	...	...	...	...	...	...	...	840– 859
860– 879	...	...	...	...	19	29	33	10	...	...	...	...	...	...	...	860– 879
880– 899	...	...	...	...	19	22	27	21	...	...	...	...	...	...	...	880– 899
900– 919	...	...	...	...	2	13	20	26	1	...	...	...	...	...	...	900– 919
920– 939	...	...	...	...	...	1	10	19	15	...	...	...	...	...	...	920– 939
940– 959	...	...	...	...	...	1	1	9	9	6	...	...	...	...	...	940– 959
960– 979	...	...	...	...	...	...	1	4	10	3	1	...	...	...	...	960– 979
980– 999	...	...	...	...	...	...	...	...	3	4	1	...	...	...	...	980– 999
1,000–1,019	...	...	...	...	...	...	1	...	1	2	1	...	...	...	...	1,000–1,019
1,020–1,039	...	...	...	...	...	...	...	...	3	11	6	9	2	...	...	1,020–1,039
1,040–1,059	...	...	...	...	...	...	...	...	2	9	36	38	3	1	...	1,040–1,059
1,060–1,079	...	...	...	...	...	...	...	...	2	30	65	26	26	1	...	1,060–1,079
1,080–1,099	...	...	...	...	...	...	...	...	...	3	16	39	20	11	3	1,080–1,099
1,100–1,119	...	...	...	...	...	...	...	...	...	...	...	35	59	38	6	1,100–1,119
1,120–1,139	...	...	...	...	...	...	...	...	...	...	1	4	17	37	21	1,120–1,139
1,140–1,159	...	...	...	...	...	...	...	...	...	...	...	9	35	4	31	1,140–1,159
1,160–1,179	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6	1,160–1,179
1,180–1,199	...	...	...	...	...	...	...	...	...	...	...	...	...	...	21	1,180–1,199
1,200& above	...	...	...	...	...	...	...	...	...	...	...	...	1	...	43	1,200 & above

Source: Lloyd's Register of Shipping, Statistical Tables 1978

Table 5-2-3 Dimensions and Draught: Oil Tankers

DIVISIONS IN FEET	NUMBERS OF SHIPS IN DIVISIONS OF GROSS TONNAGE															DIVISIONS IN FEET
	6,000 –9,999	10,000 –19,999	20,000 –29,999	30,000 –39,999	40,000 –49,999	50,000 –59,999	60,000 –69,999	70,000 –79,999	80,000 –89,999	90,000 –99,999	100,000 –109,999	110,000 –119,999	120,000 –129,999	130,000 –139,999	140,000 & above	
EXTREME BREADTH																EXTREME BREADTH
50– 54	11	...	...	...	...	...	...	...	...	...	...	...	...	...	...	50– 54
55– 59	36	...	...	...	...	...	...	...	...	...	...	...	...	...	...	55– 59
60– 64	132	8	...	...	...	...	...	...	...	...	...	...	...	...	...	60– 64
65– 69	37	116	...	...	...	...	...	...	...	...	...	...	...	...	...	65– 69
70– 74	19	358	...	...	...	...	...	...	...	...	...	...	...	...	...	70– 74
75– 79	2	165	1	...	...	...	...	...	...	...	...	...	...	...	...	75– 79
80– 84	...	206	30	...	...	...	...	...	...	...	...	...	...	...	...	80– 84
85– 89	...	145	139	7	...	...	...	...	...	...	...	...	...	...	...	85– 89
90– 94	...	10	127	2	...	...	...	...	...	...	...	...	...	...	...	90– 94
95– 99	...	6	59	3	...	...	...	...	...	...	...	...	...	...	...	95– 99
100–104	...	...	71	94	3	...	...	...	...	...	...	...	...	...	...	100–104
105–109	...	...	10	144	18	1	...	...	...	...	...	...	...	...	...	105–109
110–114	...	...	...	20	19	...	...	...	...	...	...	...	...	...	...	110–114
115–119	...	...	1	43	30	2	...	...	...	...	...	...	...	...	...	115–119
120–124	...	...	2	23	91	25	3	...	...	...	...	...	...	...	...	120–124
125–129	...	...	...	9	77	71	16	2	1	...	...	...	...	...	...	125–129
130–134	...	...	...	...	25	19	41	14	...	...	...	...	...	...	...	130–134
135–139	...	...	...	...	...	13	57	10	3	...	...	...	...	...	...	135–139
140–144	...	...	...	...	...	1	13	36	4	4	4	...	...	...	...	140–144
145–149	...	...	...	...	...	1	1	20	23	3	4	6	...	...	...	145–149
150–154	...	...	...	...	...	...	...	...	3	12	25	...	...	...	...	150–154
155–159	...	...	...	...	...	...	...	...	8	39	35	41	...	...	...	155–159
160–164	...	...	...	...	...	...	...	...	...	8	20	27	11	...	...	160–164
165–169	...	...	...	...	...	...	...	...	2	2	11	3	19	4	2	165–169
170–174	...	...	...	...	...	...	...	3	...	...	27	47	82	39	17	170–174
175–179	...	...	...	...	...	...	...	5	2	...	1	32	46	38	22	175–179
180–184	...	...	...	...	...	...	...	...	...	...	...	4	5	11	21	180–184
185–189	...	...	...	...	...	...	...	...	...	...	...	...	...	...	15	185–189
190–194	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	190–194
195–199	...	...	...	...	...	...	...	...	...	...	...	...	...	...	13	195–199
200 & above	...	...	...	...	...	...	...	...	...	...	...	...	...	...	41	200 & above

Source: Lloyd's Register of Shipping, Statistical Tables 1978

(2) West Channel

The deepest draught of ships transiting the southbound channel is 43 feet for 50,000 GT container ships. The existing largest tankers have a draught of 40 feet in ballast. The maximum ULCC has a breadth of 203 feet. Therefore, the design draught shall be at 43 feet, and the design breadth at 203 feet. The channel section with the area ratio of 4.6 and the lane ratio of 2.7 is used. The section is 16m in depth, and has a width of 200m at a depth of 11m.

(3) Port Said Approach Channel

At the final stage of the doubled Canal plan, another bypass is to be developed, running parallel to the New Port Said By-pass on its west side between Km 1.5 – Km 16.0. The approach channels leading to the Mediterranean Sea have been designed considering the meteorological and sea conditions. The dimensions are as below:

	Water Depth	Width (at channel bottom)
East Channel	–25.0 m	Max. 800 m
West Channel	–17.0 m	Max. 880 m

(4) Suez Entrance Channel

Similar to above, the dimensions of the Suez Entrance Channel are designed as below:

	Water Depth	Width (at channel bottom)
East Channel	–24.0 m	390 m
West Channel	–16.0 m	430 m

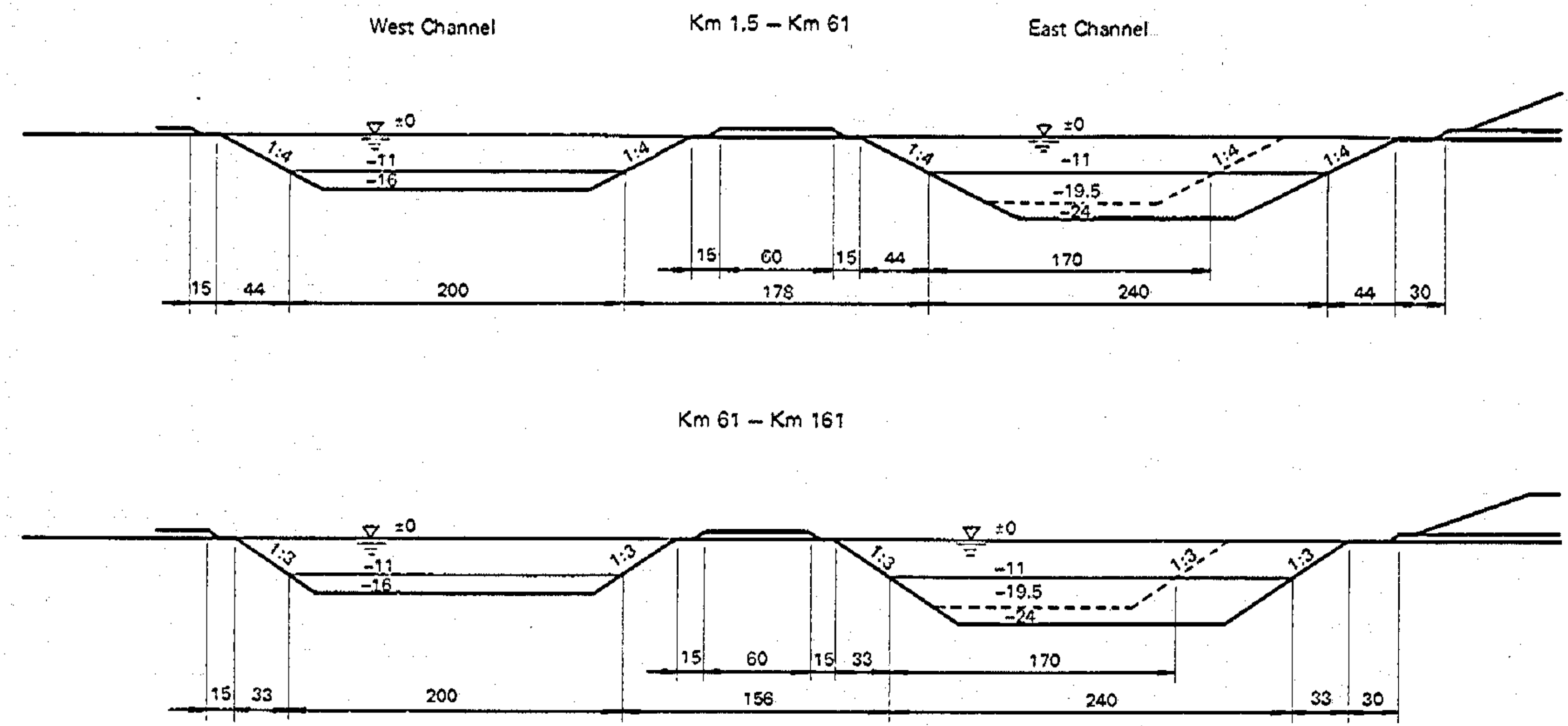


Fig. 5-2-1 Standard Section

(5) Channel in Great Bitter Lake

The channel in the Great Bitter Lake is of the same dimensions as that of the Suez Entrance Channel, but the depth is shallower by 1m.

2-4 Layout of the Canal

The layout of the Canal is made under the following policies:

1) To decrease the curve section as much as possible to increase navigational safety.

2) To utilize effectively the existing channel already expanded in the First Stage Project.

3) To give active consideration to the natural and environmental conditions of the region, such as topography, green belts and town areas, farms, etc.

The completely doubled canal shall be designed under these policies, and is shown in Fig. 5-2-2.

(1) Section between Km 1.5 and Km 16

It is necessary to construct a 3rd channel in addition to the existing channels. If the 3rd channel is not constructed, then the effectiveness of a doubled canal will be reduced considerably from the viewpoint of utilization of the Canal and control of navigation. This channel will be excavated on the west side of the existing by-pass, in view of the route to be choosen by considering the volume of dredging, the location of east breakwater and the total cost.

(2) Section between Km 16 and Km 53

The sweet water channel, roads, and railway are located along the west side of the existing channel in this section; if the new channel is to be excavated on the west side, these existing facilities must be relocated prior to the work.

Relocation requires a long period of time, and may result in the delay of the opening of the new channel and therefore the plan for a new channel on the west side of the Canal is discouraged. The new channel should not necessarily be parallel to the existing one, but the distance between two channels should be increased toward the north from Ballah By-pass. Because the length of new channel will be shorter, the distance between the two channels is less at the junction with Ballah By-pass. At Km 32.5, the existing channel is widened and the revetment is expanded to the east, and therefore the new channel should be developed on the east side, be extended straight, and connect to the Port Said By-pass. As a result, the distance between the two channels is increased at the junction point at Km 16, and thus the problem of flow turbulence due to the hydraulic interaction between the southbound and the northbound convoys will be reduced.

(3) Section between Km 57.5 and Km 73.5

In this section, the roads and railways must be relocated; such a relocation is not difficult because there is no sweet water channel (as in the case of the west side of Km 16 to Km 53), and because of the good soil and topographic conditions.

Furthermore, the volume of soil for dry excavation and dredging is less than that on the east side, and the number of curves will be reduced from 4 to 2. Therefore, the new channel is planned at the west side of the existing one.

(4) Section between Km 72.5 and Km 94.5

In this section the new channel is excavated on the east side of the existing one. If located on the west side, the channel would be longer and have more curved sections, and therefore the east side was chosen.

(5) Section between Km 134.5 and Km 145

The volume of soil for dry excavation and dredging will be smaller for the channel on the west side than on the east, and the excavation of the new channel is possible only on the west side at Km 142, due to the Ahmed Hamdi Tunnel there. For the above two reasons, new channel is to be on the west side.

(6) Section between Km 145 and Km 161

In this section, it is impossible to excavate the new channel on the west side due to the location of Suez City and Suez Port and for this reason the new channel is to be on the east side.

(7) Suez Entrance Channel

The entrance channel has been deepened to 23 meters in the First Stage Project and this channel will be used for the northbound convoy in the future. Thus, the layout of the canal is determined as shown in Fig. 5-2-2.

2-5 Main works

2-5-1 Quantity of works

The quantities of main works are as follows:

1) Dry excavation

As the topographical map necessary to accurately calculate the volume of soil for dry excavation is not available at present, the volume of soil was calculated assuming the topography after the First Stage Project and partially based on the available data of field

Table 5-2-4 Volume of Dry Excavation

Km	Channel	Volume ($10^3 m^3$)
1.5 – 16	West	0
16 – 32.5	East	14,000
32.5 – 52	East	34,000
58 – 73.5	West	37,000
72.5 – 92	East	62,000
134.5 – 145	West	7,000
143.5 – 161.05	East	72,000
Total		226,000

surveys. A dry excavation is to be made along the sides 15 meters from the west revetments of the west channel, and 30 meters from the east revetment of the east channel. The dry excavation is carried out up to D.L. + 2.0m in the section from Km 16 to Km 42, D.L. + 1.0m from Km 42 to Km 145 and ±0.0m from Km 143.5 to Km 161.05 and below those levels the excavation is done by dredging.

2) Bank works

The demolition of revetments is to be done in all the sections of the new channel connecting to the existing channel. When the width of the channel (at –11m) is expanded to 240 meters in future, relocation of revetments will be necessary on the distance between Km 134.5 and Km 145. The length of new revetment in the table below is for those constructed on both sides of new channels. The distance between both revetments on the West channel of the Ballah By-pass will become shorter by about 10 meters on the Master Plan, but this is not included in the table on the extention of the revetments, because another plan can be prepared for securing the required lane and area ratios.

Table 5-2-5 Length of Bank Works

Km	Channel	Demolition	Relocation	Construction
1.5 – 16	West	1.5 km	km	28.0 km
16 – 32.5	East	1.5		28.0
32.5 – 52	East	1.5		36.4
58 – 73.5	West	2.4		31.0
72.5 – 92	East	2.4		40.0
134.5 – 145	West and East	2.1 (W)	11.5 (E)	21.0 (W)
143.5 – 161.05	East	2.1		36.0
Total		13.5	11.5	220.4

3) Dredging

For calculating the dredging volume, the extra dredging is taken as 0.5 meter for the bottom of the new channels and no extra dredging is considered for either widening or deepening, or for the slope cuts.

4) Other works

The other necessary works for developing the Canal are the relocation of railways, roads and sweet water channels along the west side of the section between Km 58 and Km 73.5 and the section between Km 134.5 and Km 145. The extension of sweet water siphon

Table 5-2-6 Volume of Dredging

Km	West Channel	East Channel
	$10^3 m^3$	$10^3 m^3$
1.5 -- 16	61,700	30,200
16 – 32.5	5,300	90,700
32.5 – 52	7,500	116,400
51 – 58	4,300	16,100
58 – 73.5	57,200	24,800
72.5 – 94.5	4,500	117,100
94.5 – 134.5	50,300	70,100
134.5 – 145	40,300	20,100
145 -- 161	5,000	94,800
Port Said Approach	51,600	129,800
Suez Approach	10,500	19,600
Total	298,200	729,800
Grand Total	1,028,000 $10^3 m^3$	

pipes at Km 92.8 will also be required. In the table, the extension of the Port Said breakwaters is not included, as this should be decided only when the necessity of the breakwaters is evaluated after opening of the Port Said By-pass.

Table 5-2-7 Transfer of Related Facilities

Section	Work	Distance
Km 58 – Km 72.5	Relocation of Railways	19 km
	Relocation of Roads	19 km
Km 92.8	Extension of Siphon for sweet water	400 m
Km 134.5 -- Km 145	Relocation of Railways	7 km
	Relocation of Roads	12 km
	Relocation of Sweet Water channel	7 km

2-6 Cost of construction

The construction cost for the Master Plan is estimated as follows:

Table 5-2-8 Cost of Master Plan

Unit	Dry Excavation		Band Works		Dredging		Others		Remarks
	L·C	F·C	L·C	F·C	L·C	F·C	L·C	F·C	
Km	10^6 LE	10^6 \$	10^6 LE	10^6 \$	10^6 LE	10^6 \$	10^6 LE	10^6 \$	
1.5 – 16			11.1	4.6	28.3	16.0			
16 – 32.5	12.4	1.5	11.8	5.0	35.8	20.1			
32.5 – 52	31.2	4.0	15.3	6.4	59.8	33.7			
52 – 58					16.5	9.2			
58 – 73.5	29.4	3.7	12.3	5.2	15.5	111.1	8.4		
72.5 – 94.5	57.0	7.2	15.8	6.6	22.2	157.6			
94.5 – 134.5					32.1	228.1			
134.5 – 145	5.6	.7	15.7	6.6	13.9	98.7	4.1		
145 – 161	66.8	8.4	14.2	5.9	36.0	270.4			
Port Said Approach					41.1	40.4			
Suez Approach					9.2	36.7			
Total	202.4	25.5	96.2	40.3	260.1* 50.3**	944.9* 77.1**	12.5		*Km 1.5–161 Total **Approach Total
Grand Total	L·C F·C 621.5 x 10^6 LE + 1087.8 x 10^6 \$								≒ 2 x 10^9 US\$

The total construction cost for the Master Plan at 1979 prices is estimated at about US\$2 billions (excluding the works of breakwaters at Port Said). This consists of 74% for dredging, 16% for dry excavation, 9% for bank work, and 1% for the other works. The proportion for the local and foreign currency is 45% and 55%, respectively. The proportional cost of dry excavation is larger than that of the First Stage Project. This is due to the increase in the volume of soil, which includes spoil from the First Stage together with a substantial increase in the discharging distance. For the calculation of the dredging cost, the following four items are taken into account:

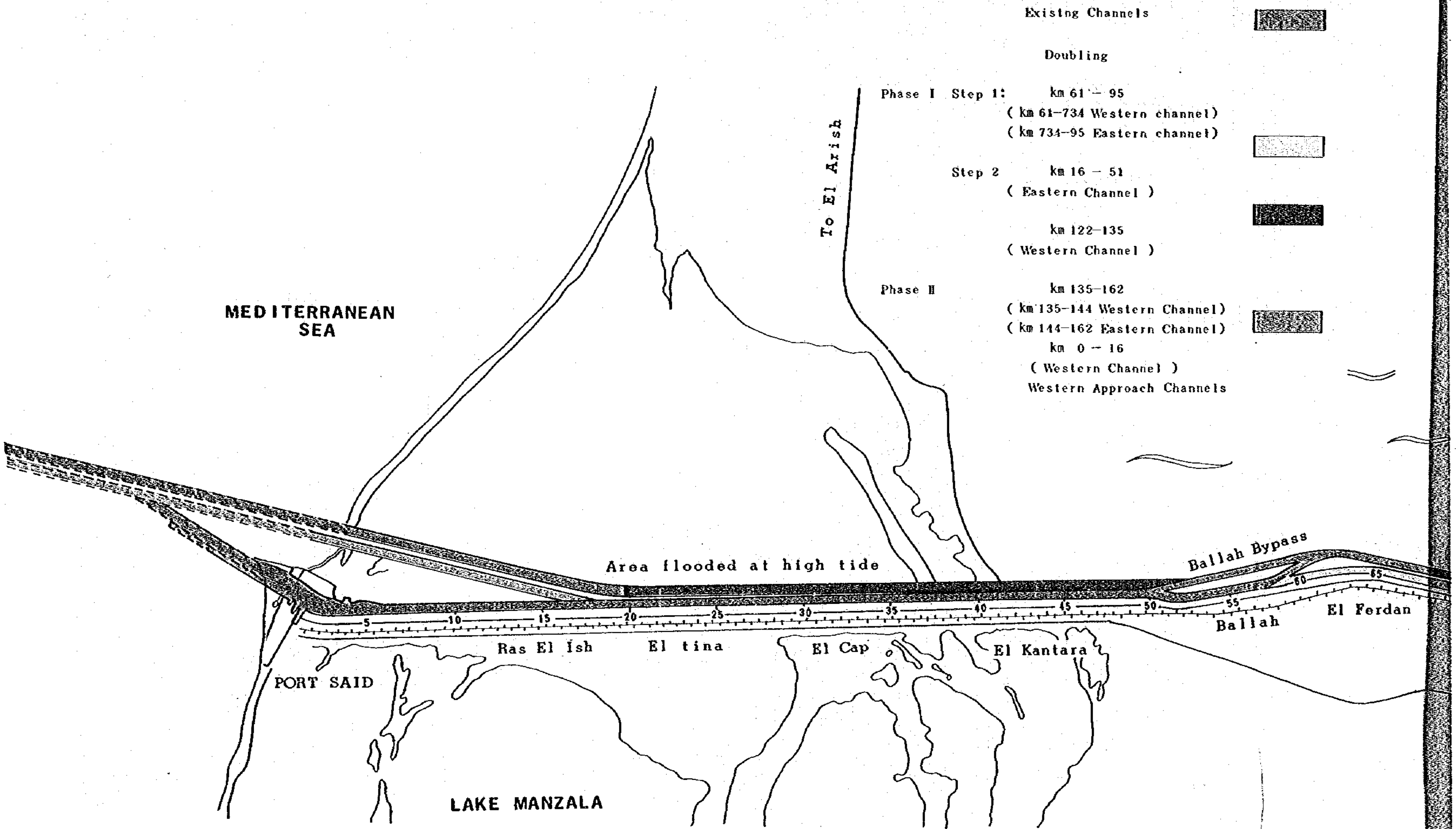
1) The cost of the sections done by SCA and the section committed to contract has been calculated separately. The section undertaken by SCA is from Km 1.5 to Km 61 and outer side of Hm 80 (Hm 50 in the 2nd stage) of the Port Said Approach Channel, with the remainder committed to contract.

2) The dredging cost is estimated by considering the efficiency of the dredger and assuming that the Canal will not be continuously excavated in one stretch to the section planned in the Master Plan, but rather will be excavated first to that in the Second Stage Project and then to that in the Master Plan.

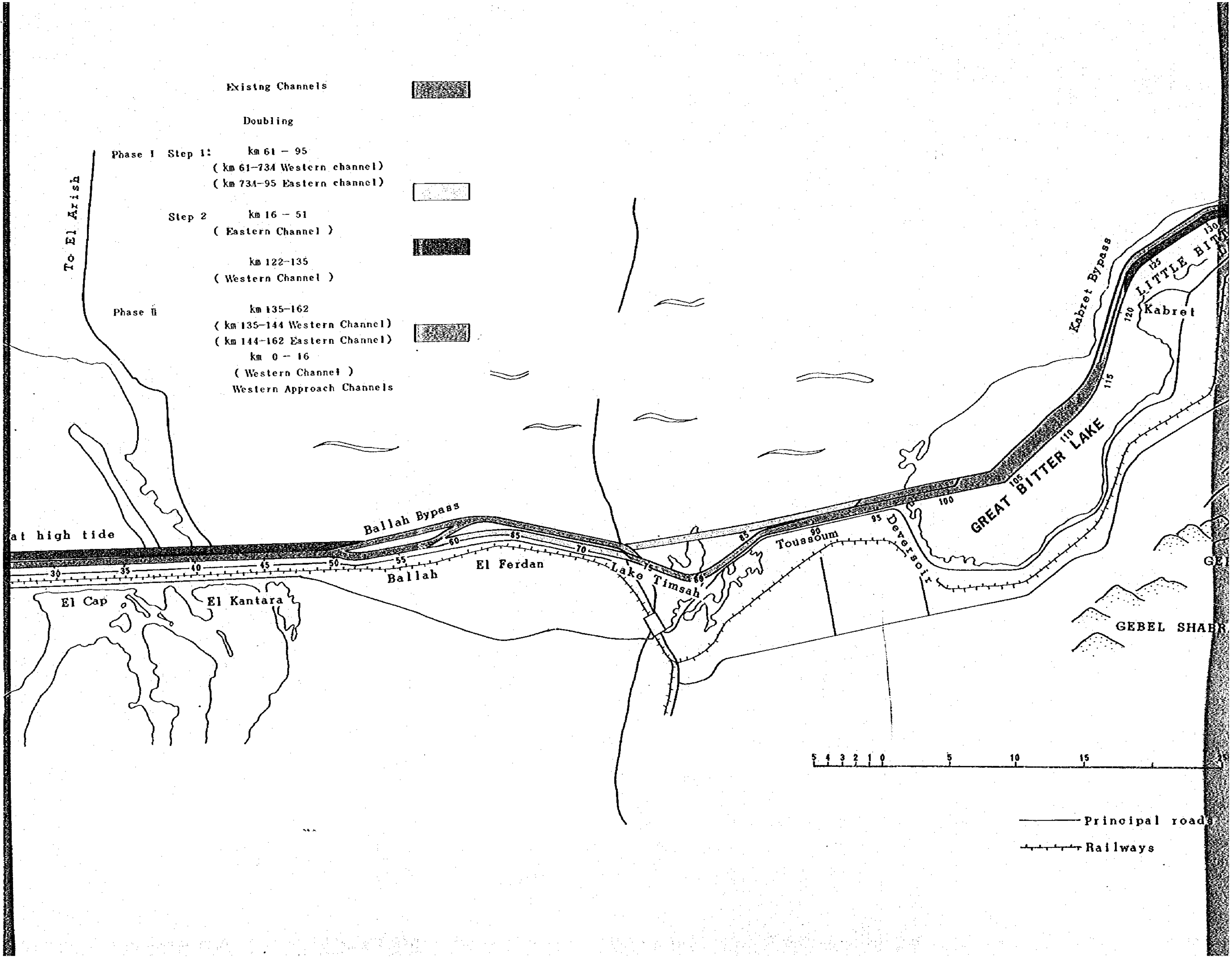
3) The efficiency and unit price of dredging have been estimated from the achievements of dredging work in the First Stage Project.

4) As a result of the soil investigation, a drop in the efficiency of dredging is taken into account for a hard soil layer found below −20 meters.

The total cost for 1,030 million m^3 of dredging is estimated at US$1,470 million. The unit price is $1.43 m^3. The volume and cost of dredging, for the Second Stage (completion of doubling the Canal without deepening) are 556 million m^3 and US$634 million with a unit price of $1.14 m^3. The remaining dredging volume and, its cost after the Second Stage are 472 million m^3 and US$836 million, with a unit cost of $1.77 m^3. The unit price for the latter is about 1.5 times that of the former.



Existng Channels
Doubling
Phase I Step 1: km 61 – 95
(km 61–734 Western channel)
(km 734–95 Eastern channel)
Step 2 km 16 – 51
(Eastern Channel)
km 122–135
(Western Channel)
Phase II km 135–162
(km 135–144 Western Channel)
(km 144–162 Eastern Channel)
km 0 – 16
(Western Channel)
Western Approach Channels
MEDITERRANEAN SEA
To El Arish
Area flooded at high tide
Ballah Bypass
Ballah
El Ferdan
Ras El Ish
El tina
El Cap
El Kantara
PORT SAID
LAKE MANZALA


Existng Channels
Doubling
Phase I Step 1: km 61 – 95
(km 61–73.4 Western channel)
(km 73.4–95 Eastern channel)
Step 2 km 16 – 51
(Eastern Channel)
km 122–135
(Western Channel)
Phase II km 135–162
(km 135–144 Western Channel)
(km 144–162 Eastern Channel)
km 0 – 16
(Western Channel)
Western Approach Channels
To El Arish
at high tide
Ballah Bypass
Kabret Bypass
El Cap
El Kantara
Ballah
El Ferdan
Lake Timsah
Toussoum
Deversoir
GREAT BITTER LAKE
Kabret
GEBEL SHABR
Principal roads
Railways

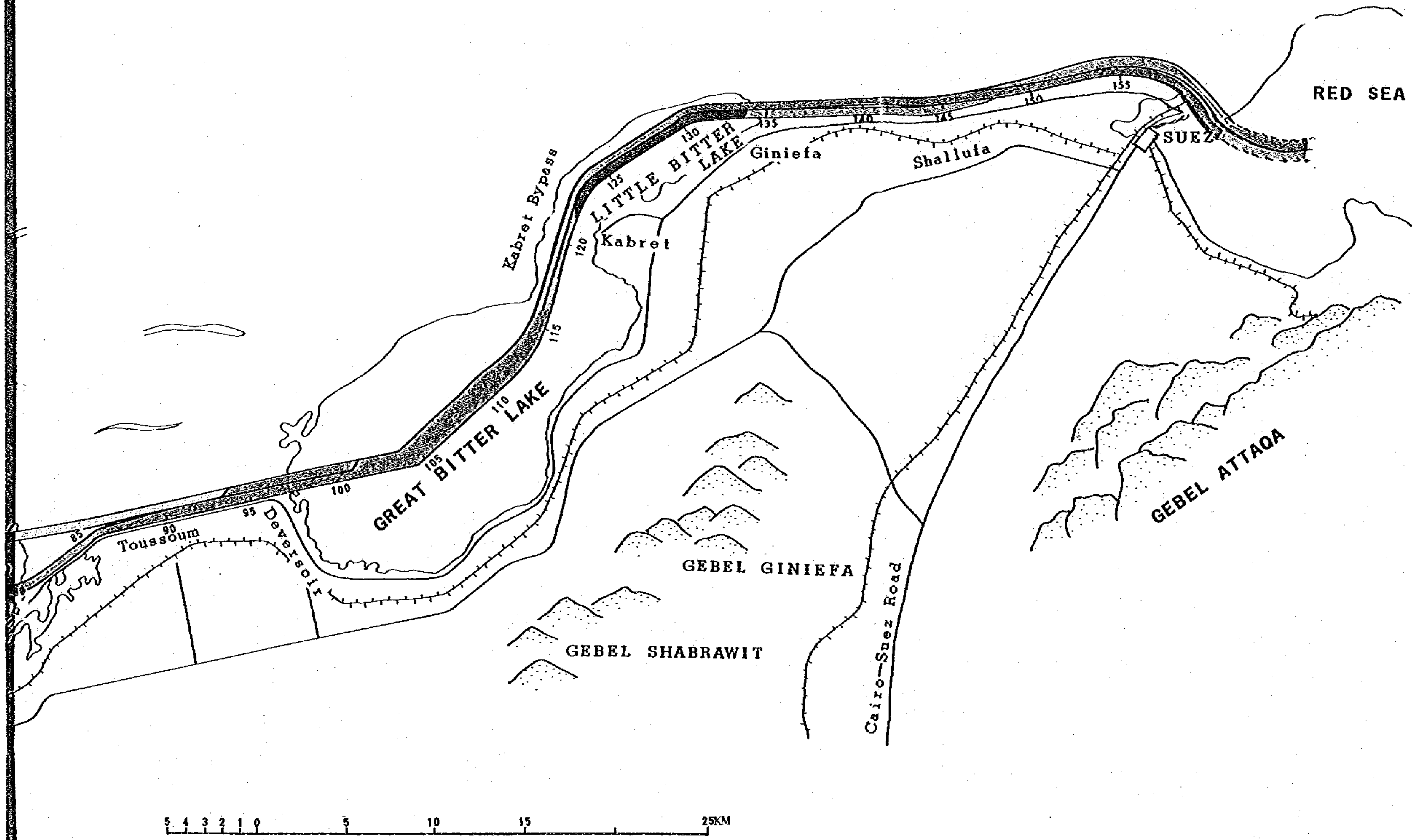
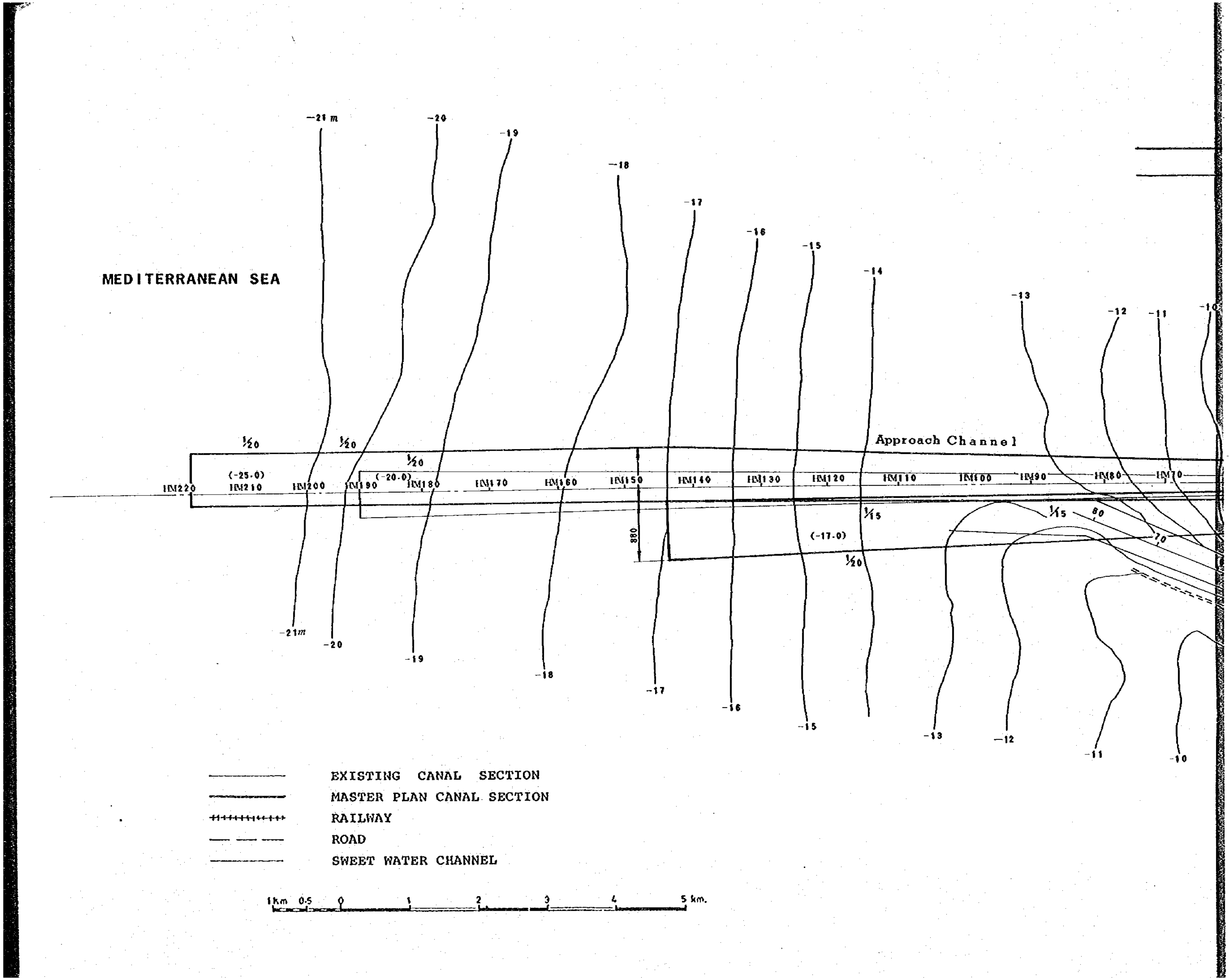


Fig.5-2-2 PLAN OF CANAL

Principal roads
Railways



MEDITERRANEAN SEA
Approach Channel
-21 m
-20
-19
-18
-17
-16
-15
-14
-13
-12
-11
-10
1/20
1/15
(-25.0)
(-20.0)
(-17.0)
HM220
HM210
HM200
HM190
HM180
HM170
HM160
HM150
HM140
HM130
HM120
HM110
HM100
HM90
HM80
HM70
880
80
70
EXISTING CANAL SECTION
MASTER PLAN CANAL SECTION
RAILWAY
ROAD
SWEET WATER CHANNEL
1km 0.5 0 1 2 3 4 5 km.

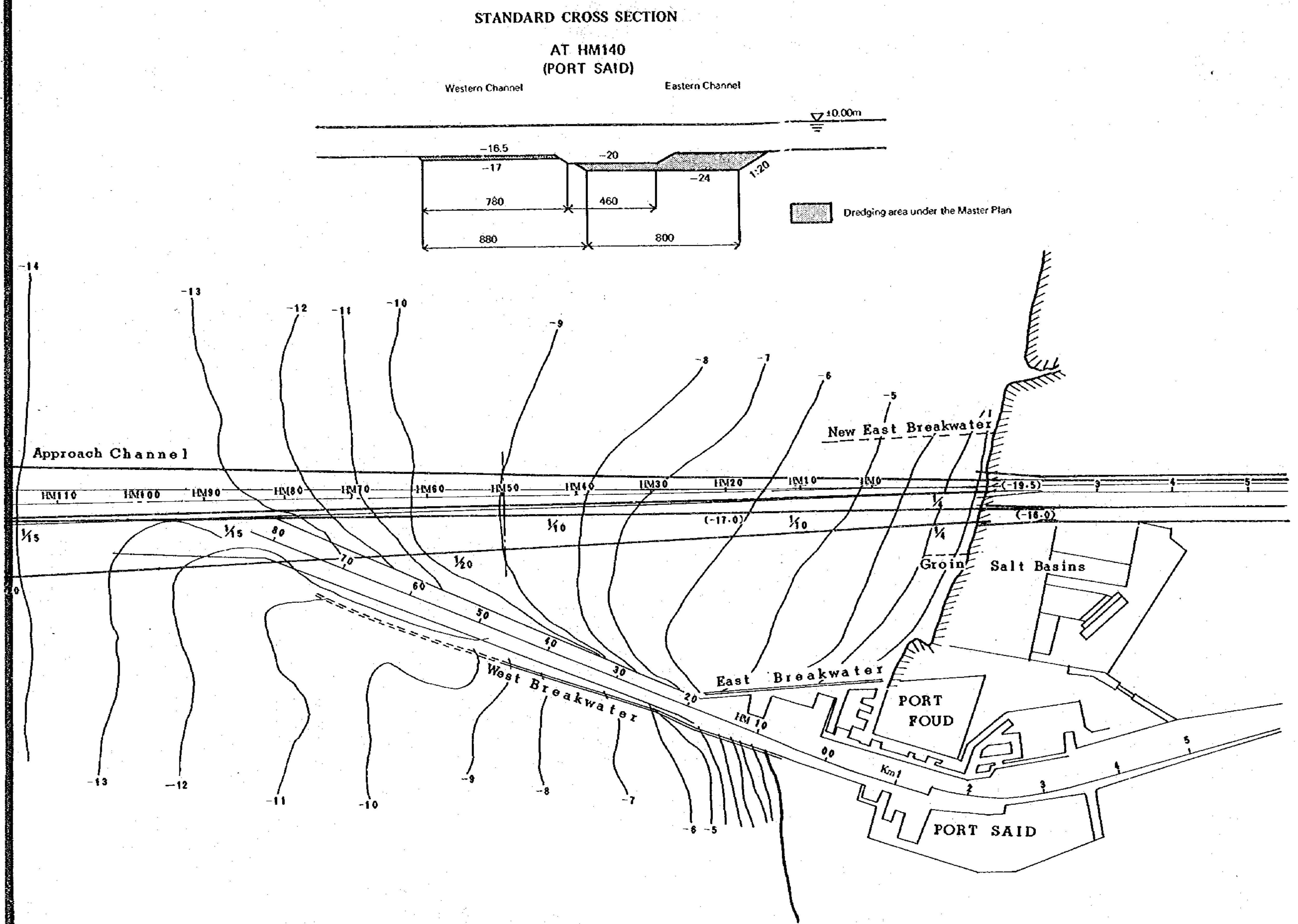
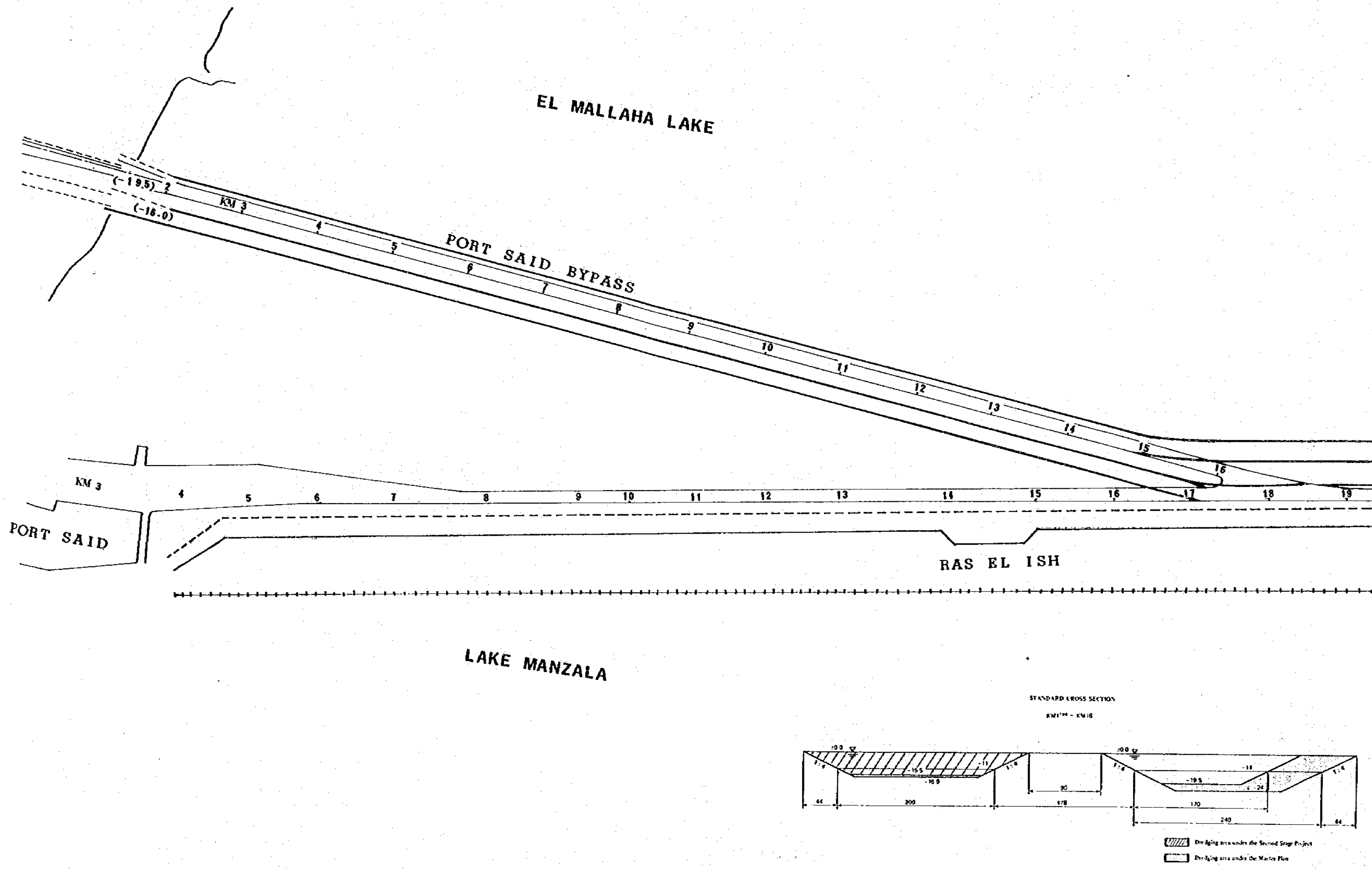
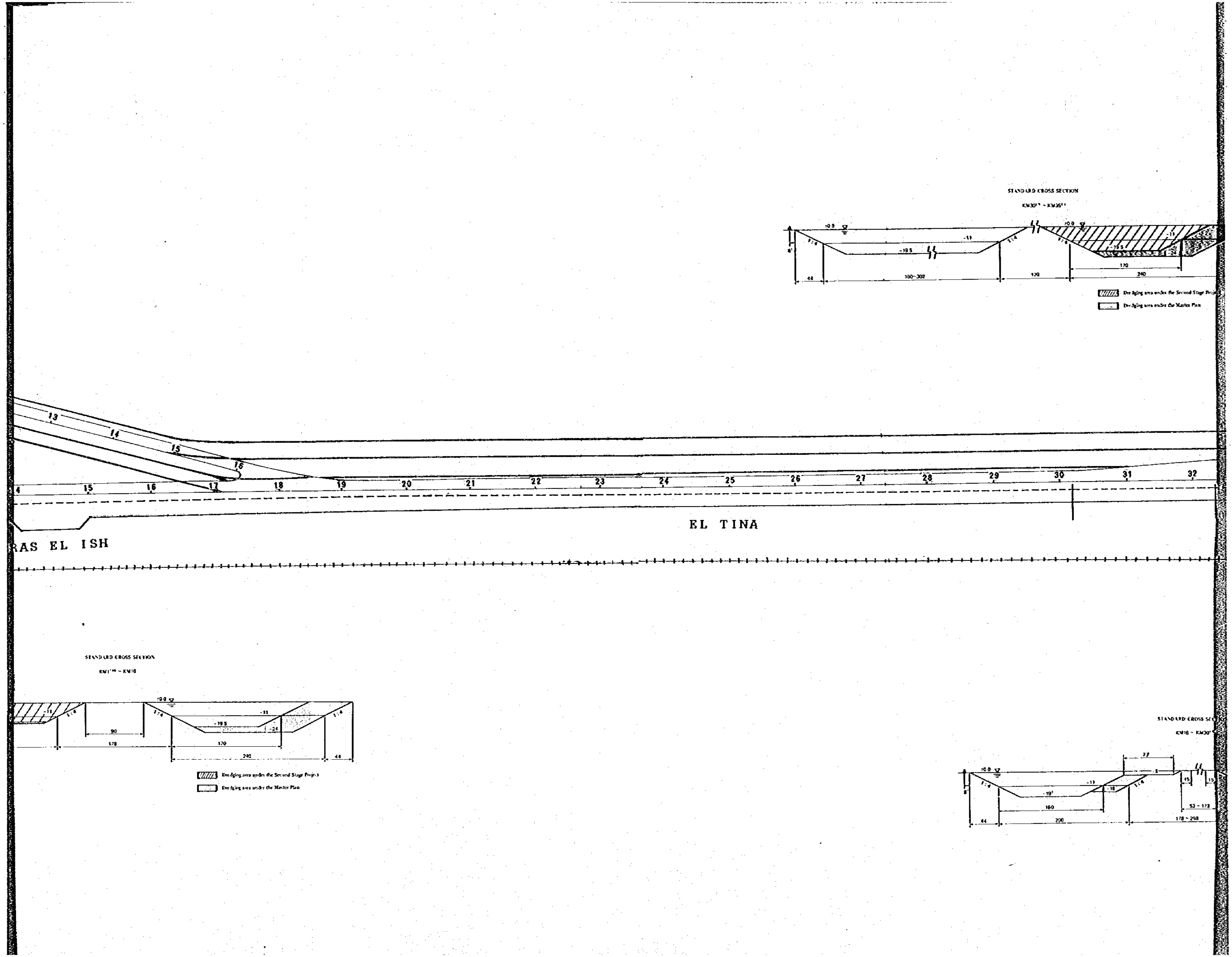


Fig.5-2-3 CANAL LAYOUT PLAN (1) HM220 to KM2


EL MALLAHA LAKE
PORT SAID BYPASS
(-19.5)
(-16.0)
KM 3
PORT SAID
RAS EL ISH
LAKE MANZALA
STANDARD CROSS SECTION
Dredging area under the Second Stage Project
Dredging area under the Master Plan


STANDARD CROSS SECTION
±0.0
-11
-19.5
180~302
44
120
170
240
-24
Dredging area under the Second Stage Project
Dredging area under the Master Plan
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
EL TINA
RAS EL ISH
STANDARD CROSS SECTION
KM16
90
178
44
STANDARD CROSS SECTION
KM16
27
-18
160
200
53 ~ 173
178 ~ 298

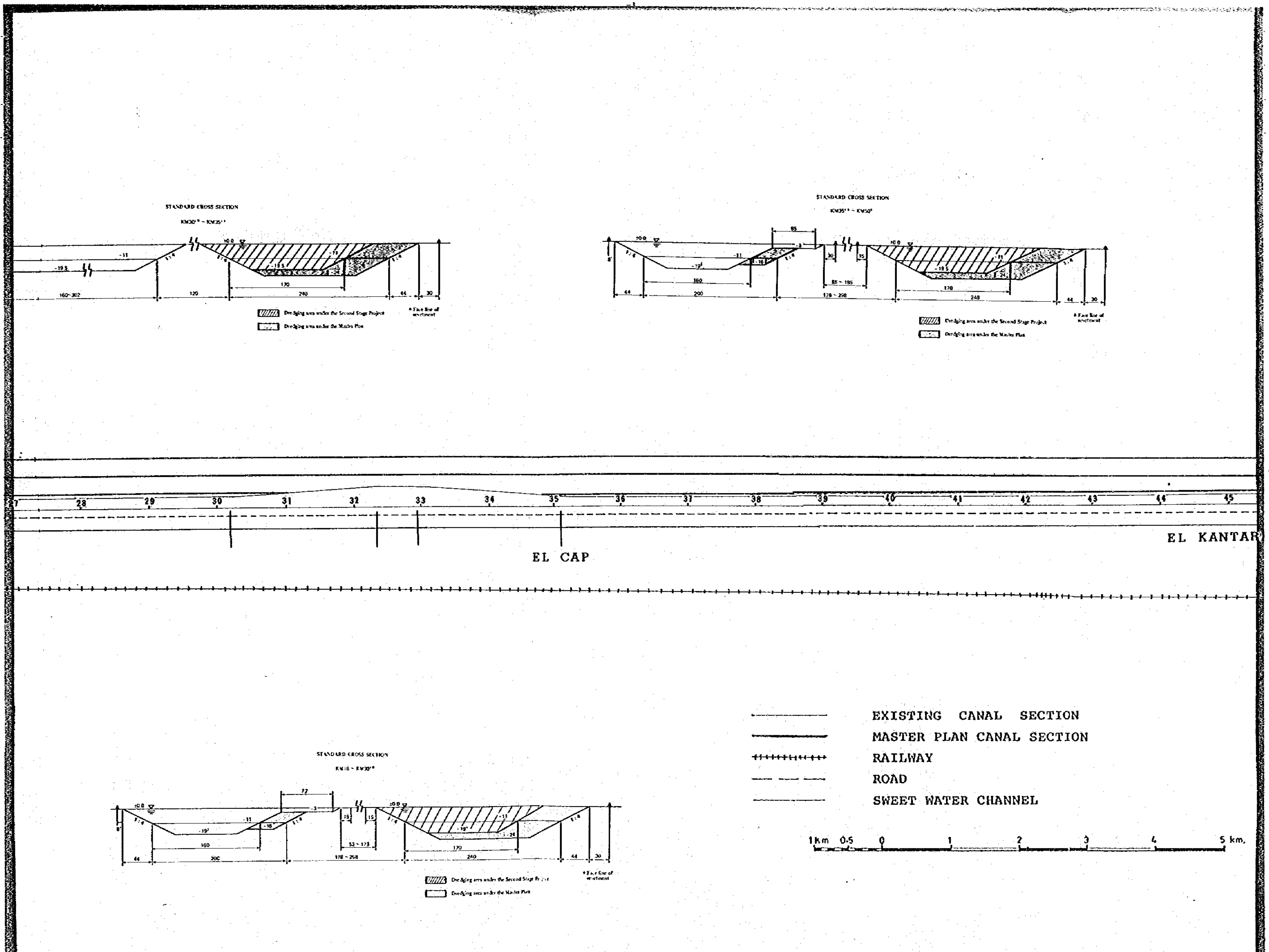
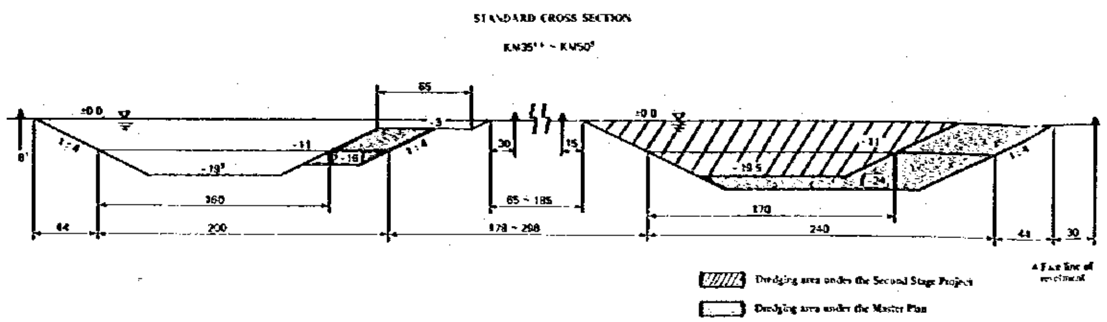
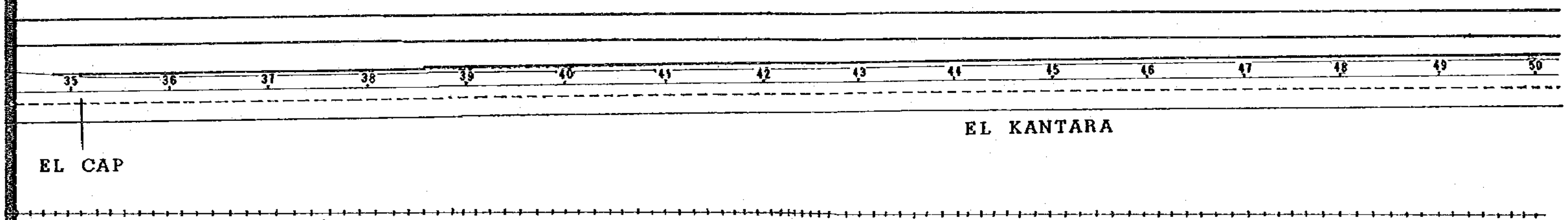
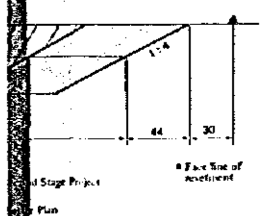


Fig.5-2-3 CANAL LAYOUT PLAN (2)







————	EXISTING CANAL SECTION
━━━━	MASTER PLAN CANAL SECTION
++++++++	RAILWAY
— — —	ROAD
————	SWEET WATER CHANNEL

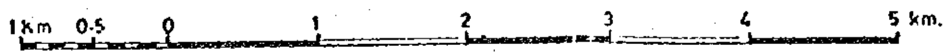
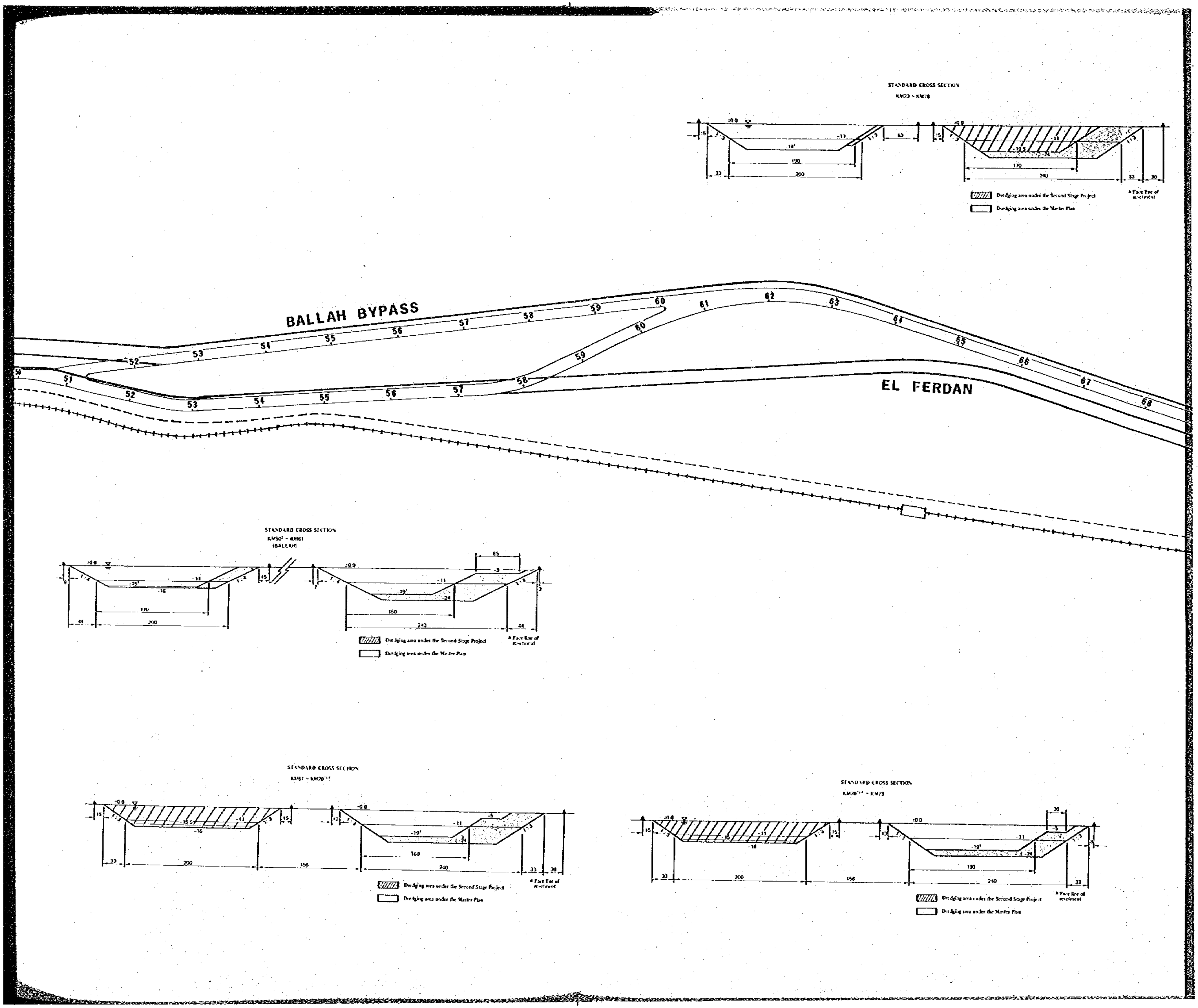
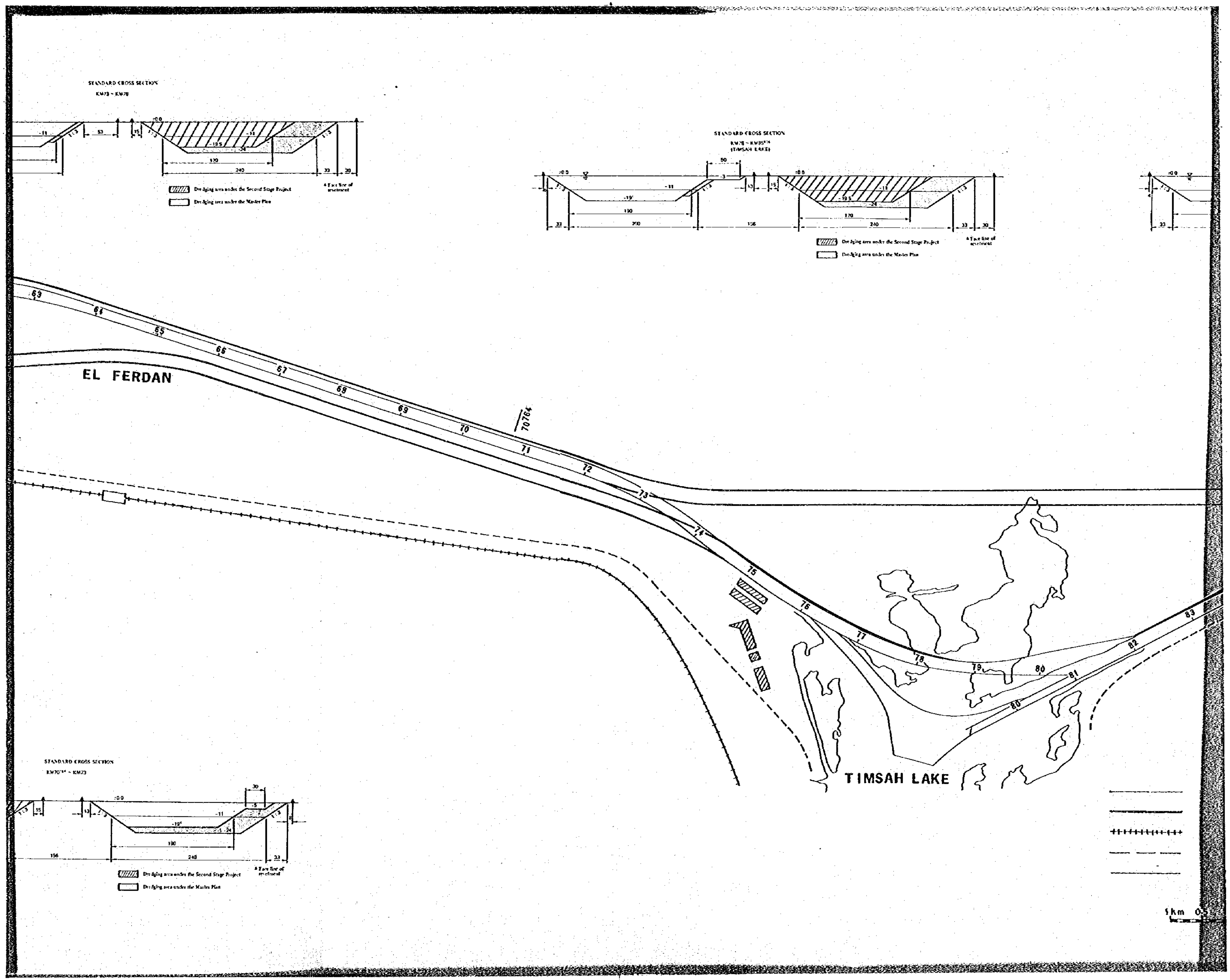


Fig.5-2-3 CANAL LAYOUT PLAN (2) KM0.0 to KM50


STANDARD CROSS SECTION
KM73 ~ KM78
Dredging area under the Second Stage Project
Dredging area under the Master Plan
* Face line of revetment
BALLAH BYPASS
EL FERDAN
STANDARD CROSS SECTION
(BALLAH)
Dredging area under the Second Stage Project
Dredging area under the Master Plan
* Face line of revetment
STANDARD CROSS SECTION
Dredging area under the Second Stage Project
Dredging area under the Master Plan
* Face line of revetment
STANDARD CROSS SECTION
Dredging area under the Second Stage Project
Dredging area under the Master Plan
* Face line of revetment


STANDARD CROSS SECTION
KM73 ~ KM78
Dredging area under the Second Stage Project
Dredging area under the Master Plan
Face line of revetment
STANDARD CROSS SECTION
KM78 ~ KM85
(TIMSAH LAKE)
Dredging area under the Second Stage Project
Dredging area under the Master Plan
Face line of revetment
EL FERDAN
70764
TIMSAH LAKE
STANDARD CROSS SECTION
KM73
Dredging area under the Second Stage Project
Dredging area under the Master Plan
Face line of revetment
1km

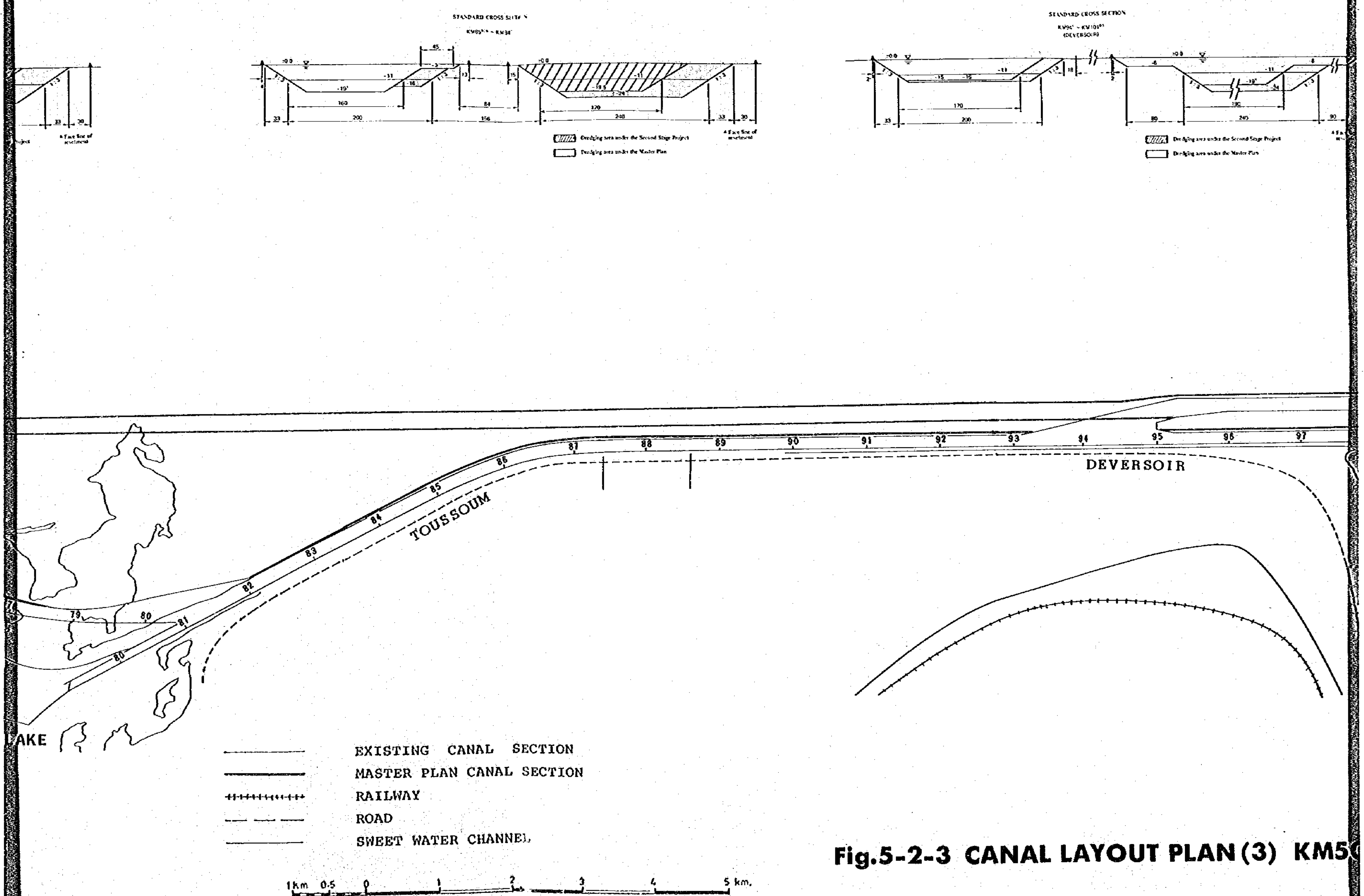


Fig.5-2-3 CANAL LAYOUT PLAN (3) KM5

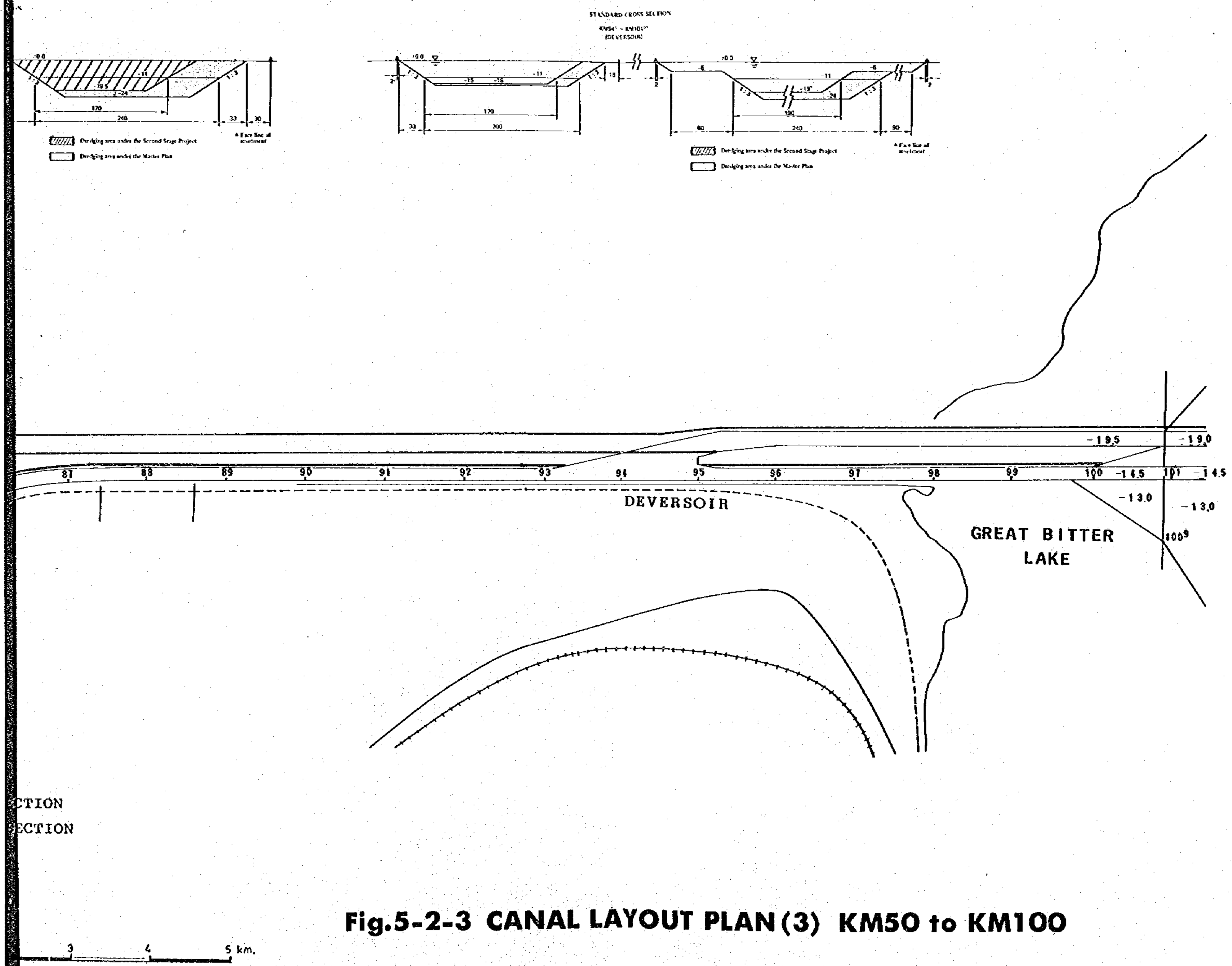
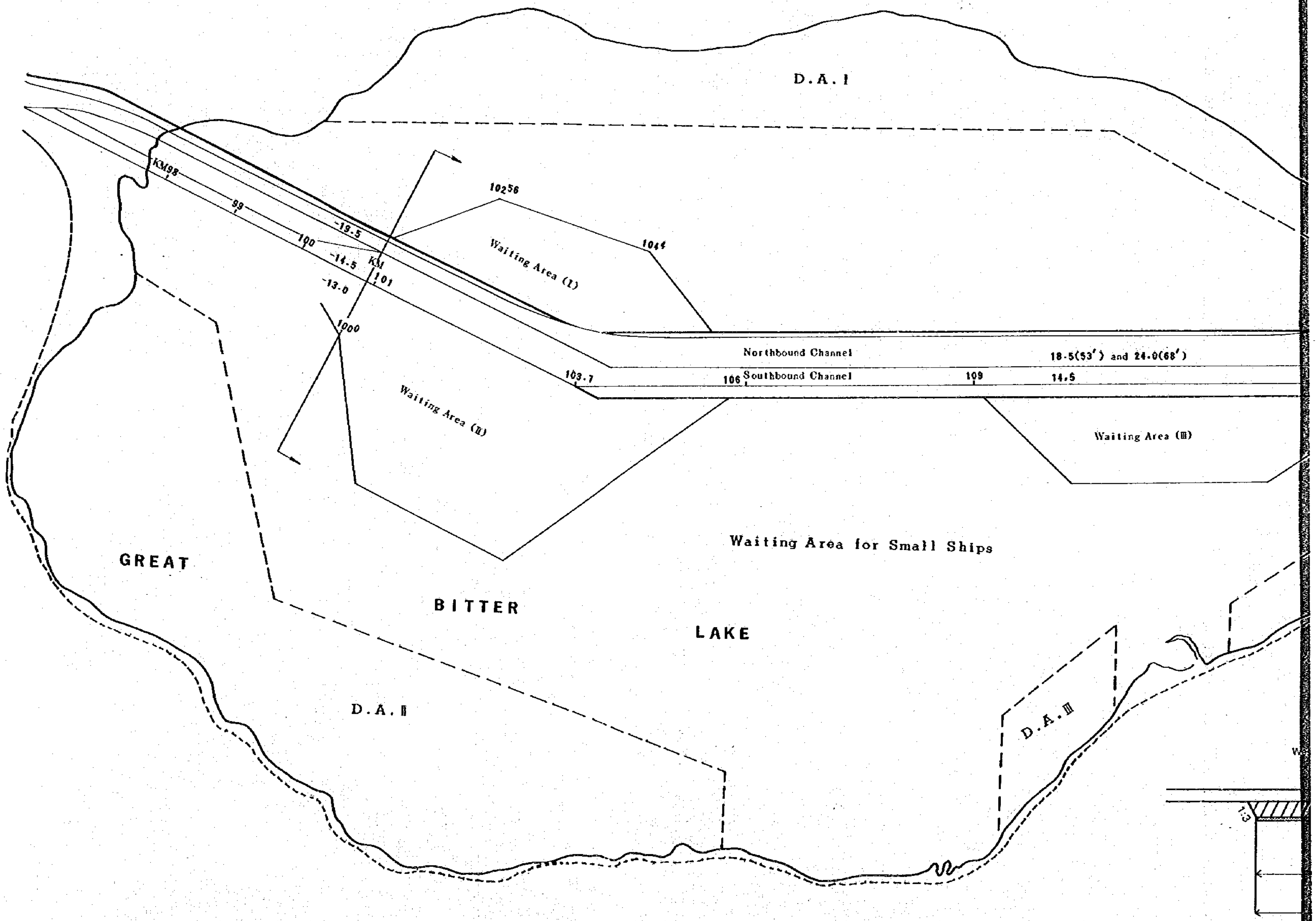
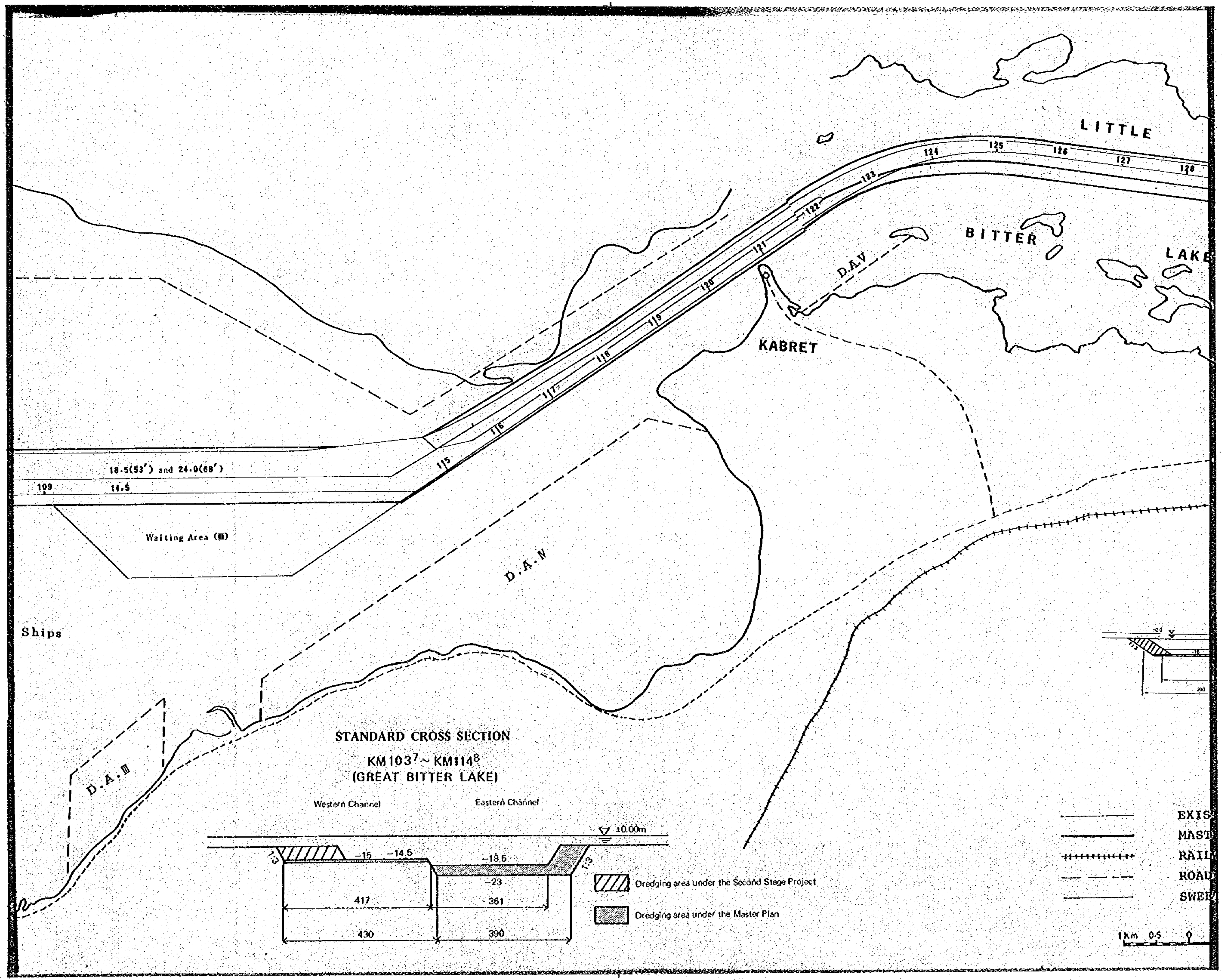


Fig.5-2-3 CANAL LAYOUT PLAN (3) KM50 to KM100


D.A.I
KM98
99
100
-19.5
-14.5
-13.0
KM 101
10256
1044
1000
Waiting Area (I)
Waiting Area (II)
Waiting Area (III)
Northbound Channel
Southbound Channel
18.5(53') and 24.0(68')
14.5
103.7
106
109
Waiting Area for Small Ships
GREAT
BITTER
LAKE
D.A.II
D.A.III
1:3


LITTLE
BITTER
LAKE
KABRET
D.A.V
D.A.IV
D.A.III
Waiting Area (III)
18.5(53') and 24.0(68')
109
14.5
115
116
117
118
119
120
121
122
123
124
125
126
127
128
Ships
STANDARD CROSS SECTION
KM103⁷~KM114⁸
(GREAT BITTER LAKE)
Western Channel
Eastern Channel
±0.00m
1:3
-15
-14.5
-18.5
-23
417
361
430
390
Dredging area under the Second Stage Project
Dredging area under the Master Plan
EXIS
MAST
RAIL
ROAD
SWEP
1Km 0.5 0

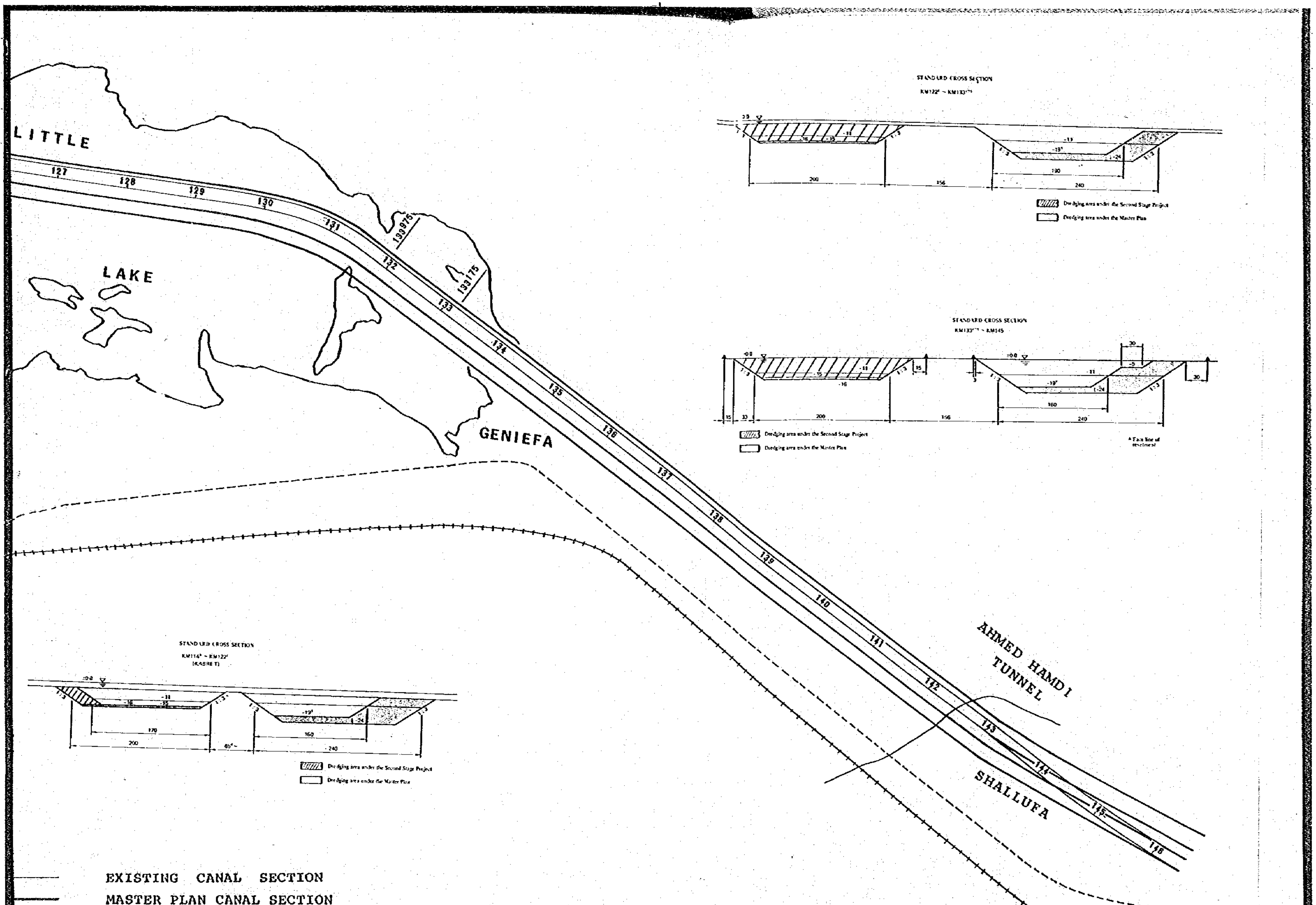
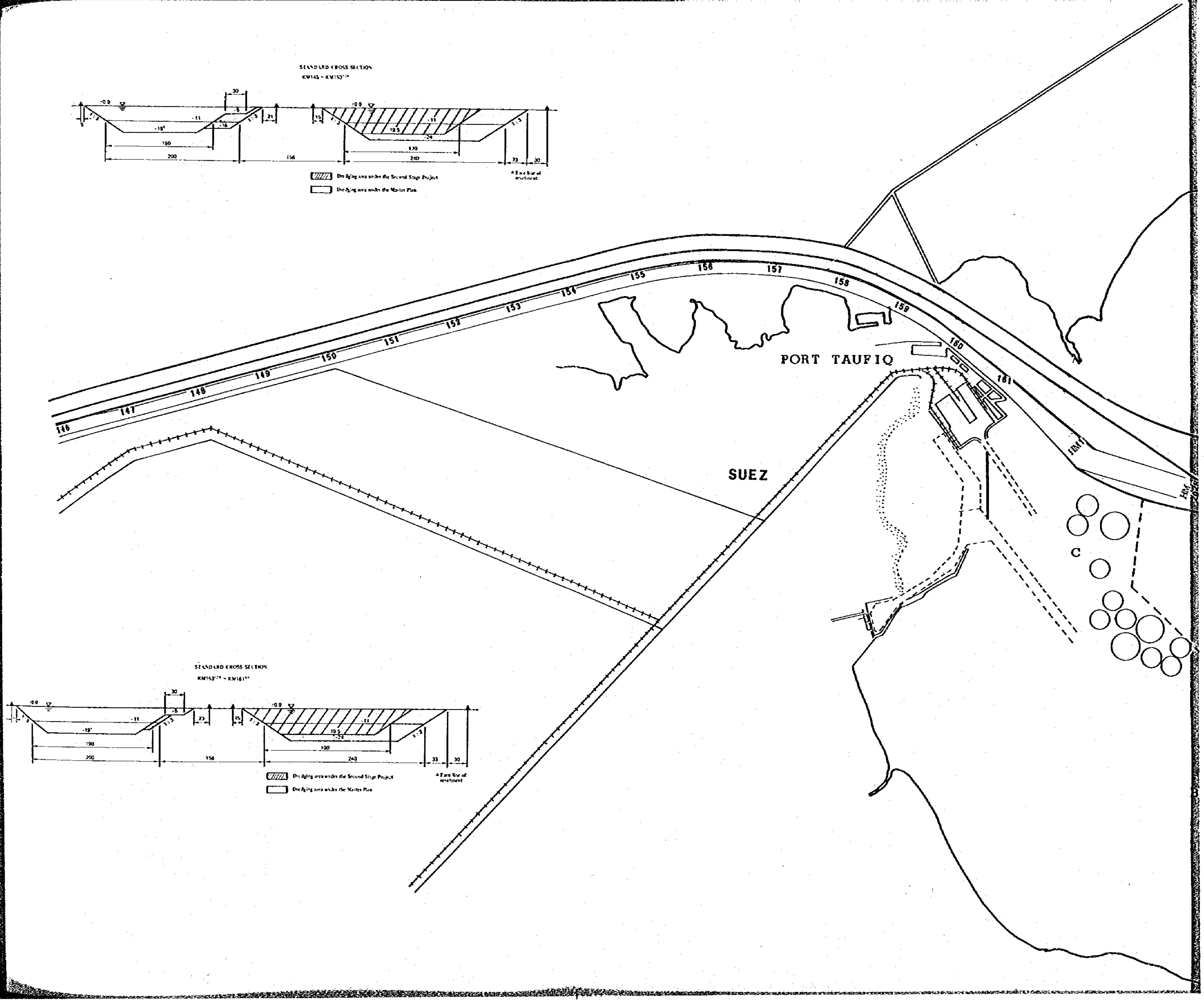


Fig.5-2-3 CANAL LAYOUT PLAN (4)

KM100 to KM145


STANDARD CROSS SECTION
Dredging area under the Second Stage Project
Dredging area under the Master Plan
* Face line of revetment
STANDARD CROSS SECTION
Dredging area under the Second Stage Project
Dredging area under the Master Plan
* Face line of revetment
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
PORT TAUFIQ
SUEZ
C

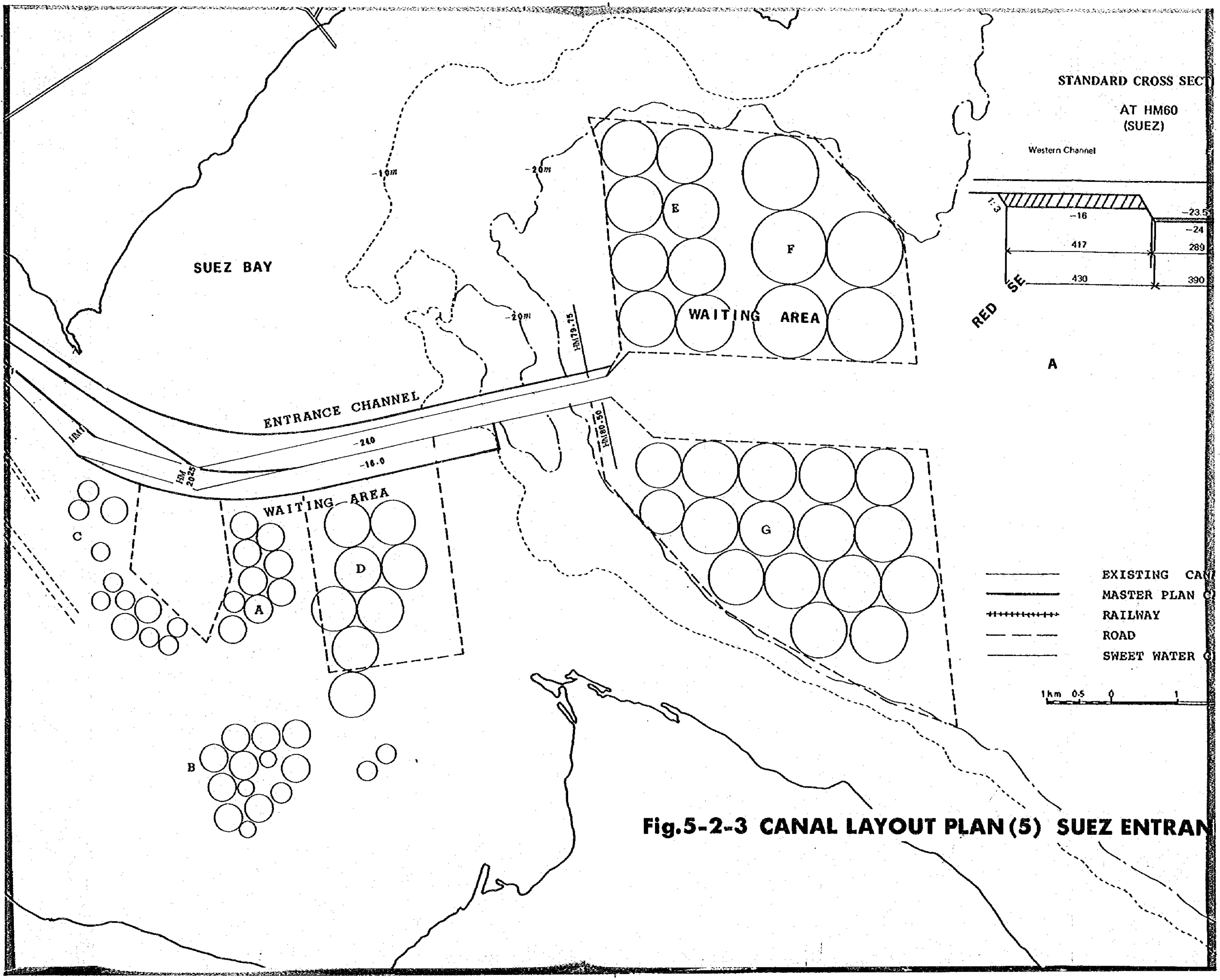


Fig.5-2-3 CANAL LAYOUT PLAN (5) SUEZ ENTRAN

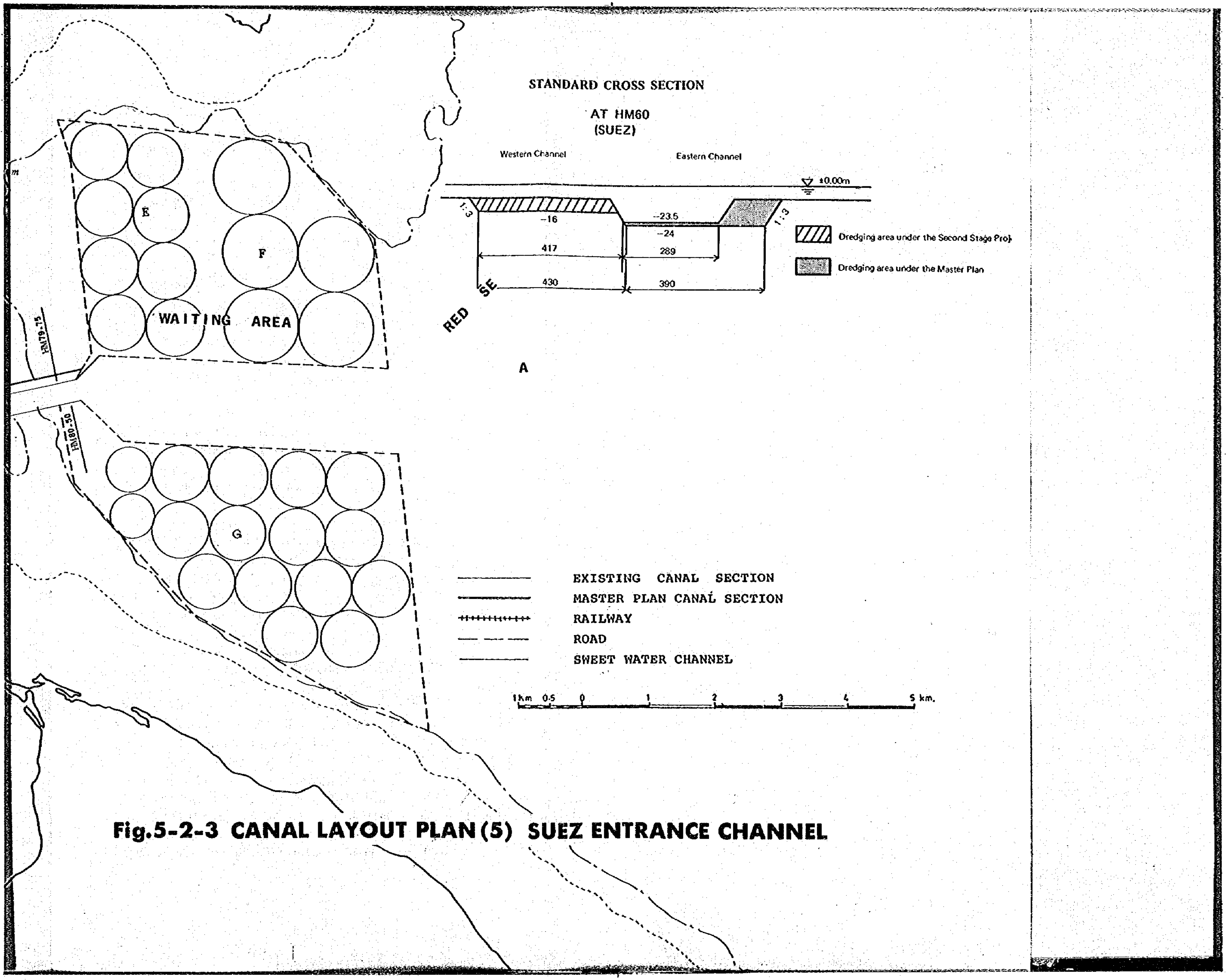


Fig.5-2-3 CANAL LAYOUT PLAN (5) SUEZ ENTRANCE CHANNEL

3. Evaluation

As the steps leading to the Master Plan, either of the following two programs may be used:

1) First Stage Project → Partially Double Channels → Completely Double Channels → Deepening and Widening → Master Plan

2) First Stage Project → Deepening and Widening → Partially Double Channels → Master Plan

To select from the above two programs, one should consider the transit demand, technical, and econimic aspects. The transit demand, discussed in the Progress Report, indicates that the second program is not practical due to the difficulty in forecasting the future demand and supply of oil and tanker market. On the other hand, it is possible to execute the first program because of its reliable demand forecast. The program to meet the transit demand will be explained in the next Part.

Comparing the two programs from technical aspects, the first program can be developed easily and without any trouble as described below. If the second program is adopted, the channel, which has already been expanded under the First Stage Project, will be widened and deepened again. Then, on the implementation of doubling the Canal under the second program, there will be no problems in the section where the southbound channel can be developed on the west of the widened and deepened channel. However, for the sections where the above is impossible, a second channel of the same size as the first must be excavated for laden tankers on the east side. In this case, the first chanel, which served laden tankers initially, will be used only as a southbound channel accommodating ballast tankers, and will leave southbound western channels unnecessarily wider and deeper. Since such sections are very long, the money spent on dredged deeper than 16.0m will be wasted after the Canal is doubled. In the first program, the effect of increasing the transit capacity and the reduction in transiting time will be a result of each partial expansion, while the effect of investment will not appear until the whole reach of the Canal is opened in the second program. The time and the amount of investment for opening the entire reach of the Canal in the second program are considered to be longer and larger than in the first program.

Furthermore, according to the results of soil investigation, a stratum below 20m is found much harder than that dredged under the First Stage Project. This hard layer is expected in the southern section from the point around Km 35. Soil in the southern reach is harder than in the north, and the percentage of hard soil and the degree of hardness both increase with increasing depth. It is questionable whether it would be profitable to dredge the channel below 20m within an appropriate work period.

Therefore, more investigation and study from technical and economic aspects will be required prior to the execution of the second program. From the results of the comparison of the above two programs, the immediate execution of the first program is recommodable as the next step for expanding the Canal after the First Stage Project.

4. Examination of Long-term Plan

4-1 Technical consideration

(1) Re-examination of datum

The present datum along the Canal is determined based on the smaller canal section of the past, but when the expansion plan is completed and the inflow and outflow of water increase, the water level in the Canal will change. Therefore, the reexamination of datum will be necessary. It may not be affected by the small tidal variation of the Mediterrannean Sea side, but it is greatly affected by the Red Sea side of large tidal variation. If the lowest water level drops below datum, it is imperative to redetermine the local datum along the Canal and to increase the dredging depth. If the Canal is to be dredged additionally in the future, it will increase costly, therefore it is necessary to examine well the future tidal conditions beforehand.

(2) Safe navigation at the junction points

Through the steps toward the final stage, two channels are connected at points around Km 16, Km 94.5 and Km 145 without any separation zone. By utilizing these sections, a single lane navigation can be achieved when one of the channels is closed due to some trouble. Also, these location will be convenient for crossing the Canal will tugboats or local ferries.

On the other hand, this endangers navigation when two ships passing at such sections as a result of hydraulic interaction. A large amount of money is needed for constructing a separation dike, therefore some other plans, by which a dike will be unnecessary, should be developed. For example, widening, or deeping the canal may decrease the degree of hydraulic interaction.

(3) Port Said Breakwater

The required length, layout, etc. of Port Said Breakwaters on both sides of the approach channel should be determined, based on the result of analysis on various data of waves, longshore current, sand drift, and also the navigation conditions after opening of Port Said By-pass. But the data necessary for designing the breakwater, such as a siltation rate along the by-pass, etc. are not available, and for this reason the plan can not be advanced further than the past studies. Therefore, it is essential to collect necessary data for analysis.

(4) Dredging of hard layers

In the First Stage Project, the construction encountered a inefficient dredging operation of hard layer at Lot C. A greater amount of this hard layer must be dredged to increase the depth from 19.5m to 24m under the Master Plan. The Canal can not be fully utilized if a single spot is left unfinished, which would allow only ships of shallower draft to transit. Therefore, it is essential to have distinct plans that the entire reach of the Canal will be dredged to the required depth within the planned period and cost. For this purpose, it is necessary to complete the investigation and examination beforehand.

Unit dredging cost was examined as below by estimating the distribution of hard stratum on the basis of the actual record of the First Stage Project.

(5) Unit dredging cost for the section Km 145 – 161

Dredging at Lot C until the end of September, 1979, under the First Stage Project is summarized as below:

Dredger SURUGA (8,000 ps), SUEZ No. 3 (8,000 ps), TAISEI (5,200 ps), NIPPON (4,000 ps), SUEZ (5,000 ps)
Total 5 Dredgers

Operating hours: 52,414 hrs

Operating hours converted to 8,000 ps: 43,085 hrs

Dredged volume: 28,197 x $10^3 m^3$

Table 5-4-1 Dredged Volume per Hour by Hardness

Type of soil	Dredged volume	%	Dredged hours	%	Volume/hr
Very hard	1,551,000 m^3	5.5	6,020 hr	14.0	258 m^3/hr
Hard	3,543,000 m^3	12.6	9,092 hr	21.1	390
Common	23,103,000 m^3	81.9	27,973 hr	64.9	824
Total	28,197,000 m^3	100.0	43,085 hr	100.0	654

Table 5-4-2 Dredging Hours per Month

Type of soil	Dredging volume per one set of cutter head	Durable hours of cutter head	Dredging hours per month
Very hard	1,200 m^3	4.65 hr.	456 hr.
Hard	2,250	5.77	474
Common	17,400	21.07	527

Dredging hours per month are calculated on the assumption that the time required to replace the cutter is 50 min.

Table 5-4-3 Unit Cost of Dredging by Hardness

Type of soil	Dredging volume per hours	Dreding hours per month	Dredging volume per month	Efficiency ratio	Unit Cost of Dredging	
					L·C	F·C
	m^3/hr	hr	m^3/month	%	LE	Yen
Very hard	258	456	117,648	36	0.900	1,500
Hard	390	474	184,860	56	0.580	960
Common	826	527	435,302	132	0.245	410
Average	654	506	330,924	100	0.3222	537.3

Efficiency ratio was obtained by taking the percentage ratio of the dredging volume per month to the average dredging volume per month (100). Unit cost was adjusted from the average unit cost by efficiency ratio.

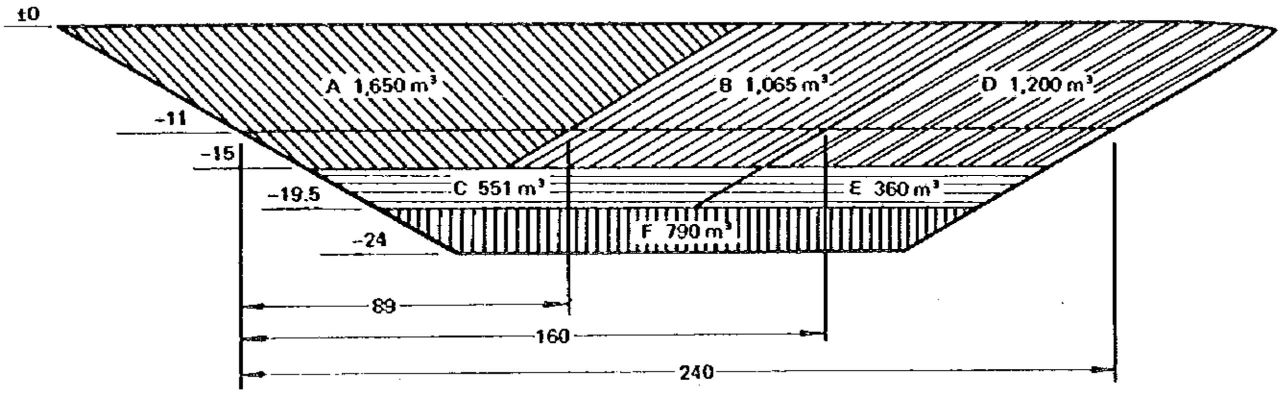


Fig 5-4-1 Dredging Sections Divided

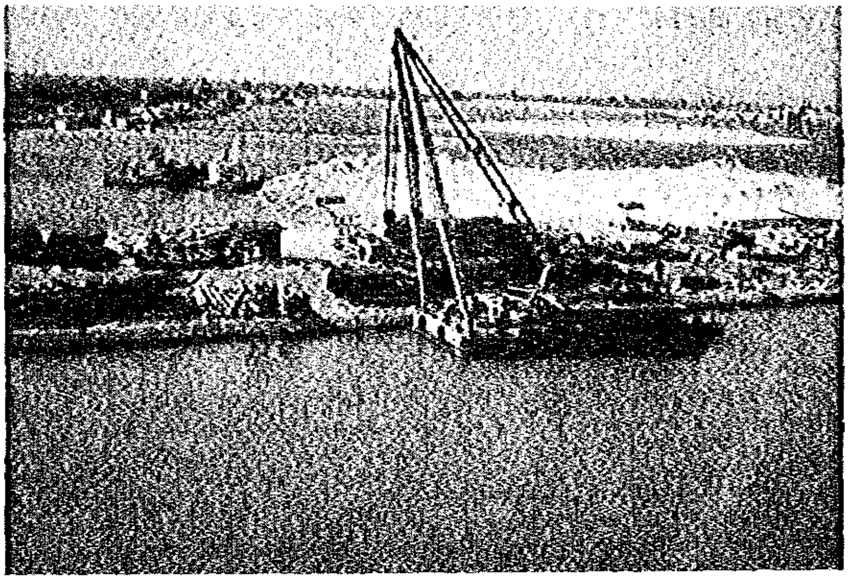
Table 5-4-4 Soil Volume Ratio by Hardness

Type of soil	A, B, D	C, E	F
Very hard	1 %	15 %	30 %
Hard	4 %	30 %	30 %
Common	95 %	55 %	40 %

Table 5-4-5 Soil Volume of Each Designed Section by Hardness

Project	Volume (per 1 m)	Soil Composition by Hardness		
		Very hard	Hard	Common
First Stage	B + C 1616 m³	89 m³	204 m³	1323 m³
		5.5 %	12.6 %	81.9 %
Second Stage	A+B+C 3266 m³	115 m³	240 m³	2911 m³
		3.5 %	7.3 %	89.2 %
Master Plan	D+E+F 2350 m³	300 m³	400 m³	1650 m³
		12.8 %	17.0 %	70.2 %

Unit dredging cost may be obtained for each section from the dredging volume above. With the First Stage Project as the base (100), the Second Stage Project will be 93 and the Master Plan 140. Under the Second Stage Project, as it covers A-section having a small ratio of very hard or hard stratum, the unit cost is smaller than that under the First Stage Project. The average unit dredging cost from the Second Stage Project through the Master Plan increases since the E and F-sections contain hard or very hard stratum. The difference in cost between the Second Stage Project and the Master Plan is 1.5 times. It may be mentioned that annual price increase is not considered in this comparison.



Ⅵ. Second Stage Development Project

PART VI. SECOND STAGE DEVELOPMENT PROJECT

1. Basic Policy

1-1 Basic principles

The Master Plan is to develop a two-lane Canal with the east channel serving 250,000 DWT tankers fully laden and the west channel for 500,000 DWT tankers in ballast as the final form of the Canal expansion. Accordingly, in order to implement the Master Plan, it is necessary not only to double the Canal but also to increase the depth of the east channel.

The necessity of increasing the depth of the channel to serve over 150,000 DWT tankers is related to the recovery of tanker market. Judging from the current tanker market, it is difficult to ascertain the necessity and the economy of this plan; it is in fact economically disadvantageous to increase the depth of the Canal prior to doubling the Canal as described in Chapter 3 Evaluation Part V: Master Plan. Current problems necessitating two-lane waterways are outlined below:

a) In view of the marked increase in Canal traffic after the reopening of the Canal, and the rapid economic growth of the Middle East countries, which are the major users of the Canal, traffic demand is expected to reach Canal capacity in the near future, thereby necessitating an increase in the Canal traffic capacity or a loss in potential revenue.
b) Under the current transit system, northbound convoys make non-stop transit, whereas southbound convoys have to stop either at the Ballah By-pass or at Great Bitter Lake to allow northbound vessels to pass, which require an additional 7 – 8 hours. Accordingly, it is desirable to reduce the transit hours for efficient shipping.
c) Under the current transit system, there are many points where northbound and southbound convoys meet each other, since they alternately utilize the single-lane provided, causing difficulties in navigation. Accidents and troubles have in fact occurred since the reopening of the Canal, and improvement in navigational safety is desired.

In view of the international role played by the Suez Canal, these needs should be met urgently. It is desirable to increase the capacity by partially doubling the Canal before the traffic demand reaches capacity, thereby providing a situation for smooth Canal transit operation. Accordingly, doubling the Canal has to be developed under the Second Stage Project continuously after the completion of the First Stage Project.

In this Chapter, therefore, phased development plans to be implemented as the Second Stage Project under the Master Plan are to be formulated.

1-2 Project objectives

Prior to the formulation of the phased development plans under the Second Stage Project, the objectives of the Second Stage Project are set out below:

a) Under the Second Stage Project, aimed at completely doubling the Canal, the plan of a partially doubled Canal is to be implemented immediately as the First Phase Plan (hereinafter referred to as Phase I), with 1990 as the target year. The next stage is to be the Second Phase Plan (hereinafter referred to as Phase II). Though the target year for Phase I is 1990, the phased development plans are to be formulated by including plans to meet the demand after 1990, so that an evaluation from a long-term viewpoint may be carried out.

b) The traffic capacity is to be increased by providing two lanes so that an increase in demand may be met and shorter transit hours and improvement in navigational safety may be realized. In formulating the phased plans for the two waterways, each plan is to be formulated in such a way as an increase of about 10 vessels per day in the traffic capacity may be expected. The New West Port Said Bypass, paralleling the New Port Said Bypass completed under the First Stage Project, is to be constructed at the final stage when the Canal is completely doubled.

   Consequently, the existing Port Said channel is to be utilized as the west channel of the section Km 0 – 16 until the New West Port Said Bypass is completed.

c) The largest navigable size of transit vessels is to be identical to that acceptable after the completion of the First Stage Project. So, the east channel will handle around 150,000 DWT tankers fully laden, and west channel will handle around 300,000 DWT tankers in ballast and 50,000 G/T container vessels.

   "Around" 150,000 DWT tankers does not mean that all of 150,000 DWT tankers can navigate the Canal. All tankers under 130,000 DWT can navigate, but only some 140,000 – 150,000 DWT class tankers can navigate the Canal. In the case of "around" 300,000 DWT tankers, all tankers less than 300,000 DWT and some of 300,000 – 350,000 DWT tankers are able to make transits.

2. Phased Development Plans

2-1 Canal design

2-1-1 Design of Canal section

(1) Canal

The section of the Canal was designed referring to Part VIII: Technical Examination as in the case of the Master Plan.

1) East channel

The design draft is to be 53′, set under the First Stage Project for around 150,000 DWT tankers fully laden. The channel section was designed considering that most of the tankers with less than this draft will be navigable in the east channel. The maximum breadth and length of tankers were determined based on the data shown in Table 6-2-2, taking into account the specifications of the Japanese tankers of less than 53′ (16.2 m) in draft. The section of the east channel is designed as described below, on the basis of the specifications.

Depth

As a part of the east channel has been dredged to a depth of 19.5 m for the First Stage Project, the new section of the east channel under the Second Stage Project is also to have the same depth. The depth of 19.5 m has been determined on the basis of the depth design as shown in Table 6-2-1.

Table 6-2-1 Canal Depth Design (Second Stage Project)

	East Channel		West Channel	
	Km 0 ~ 60	Km 60 ~ 162	Km 0 ~ 60	Km 60 ~ 162
Draft	16.2m	16.2m	13.1m	13.1m
Squat	0.9	0.9	0.9	0.9
Trim	0.2	0.2		
Siltation	1.2	0.6	0.8	0.4
Underkeel Clearance	0.8	0.8	0.7	0.7
Total	19.3 ≒ 19.5	18.7 ≒ 19.5	15.5	15.2 ≒ 15.0

Note: Compiled by Maunsell's Report

The squat of 150,000 DWT tankers fully laden is about 1 m, in the light of the figures obtained from the study of Part VIII: Technical Examination. Normally, an extra depth of 1.5 – 2.0 times the diameter of the cooling intake part of the main engine is desirable for underkeel clearance. However, as a tanker usually switches over to a higher intake in shallow waters, the depth of 1.5 – 2.0 times the diameter is not absolutely necessary, and an allowance of about 5% of the draft will be adequate.

The depth may thus be computed as below:

$$D = \underset{16.2}{\text{(draft)}} + \underset{1.0}{\text{(squat and trim)}} + \underset{0.8}{\text{(underkeel clearance)}} = 18.0 \text{ m}$$

The above figure leaves a difference of 1.5 m with the design depth of 19.5 m. This difference is for siltation, and is adequate in view of the fact that if a dredger is to be employed for maintenance dredging, a dredging depth of more than 1.0 m is required for economy. Accordingly, the depth of 19.5 m, set under the First Stage Project can be adopted under the Second Stage Project.

Section

The section was designed according to the results of the examination in Chapter 2, Part VIII with the target area ratio (R_a) of 4.8 and the lane ratio (R_l) of 2.6. Computation followed the procedure given below.

Midship area = 712.8 m^2 (150,000 DWT fully laden)

Channel area needed = 712.8 x 4.8 = 3,421.4 m^2

Channel width at 11.0 m	= 165.5^m	(Grade of Slope 1:4 Section)
ditto	= $168.0^m \rightarrow 170^m$	(" 1:3 Section)
Lane ratio R_l	= 2.7 > 2.6	(" 1:4 Section)
	= 3.0 > 2.6	(" 1:3 Section)

Accordingly, 170 m is to be secured for the width of the east channel at a depth of 11.0 m. Details of the section are given in Fig. 6-2-1 and Table 6-2-2.

Of those sections of the east channel already dredged under the First Stage Project, the section Km 135 – 145 has the width of only 160 m at a depth of 11.0 m. The area ratio of this section is less than 4.6 below the target of 4.8. However, it is extremely uneconomical to expand the width by only 10 m because of the inadequate area ratio. As a part of the berm of this section was excavated excessively to a width of 30 m at a depth of 5 m, the area ratio including this part is 4.8. Accordingly, this section is not to be extended under the Second Stage Project; additional caution will therefore be required in navigation after the completion of the First Stage Project.

The grade of slope is to be 1:4 for the section Km 0 – 60 and 1:3 for the section Km 60 – 162, as in the case of the First Stage Project.

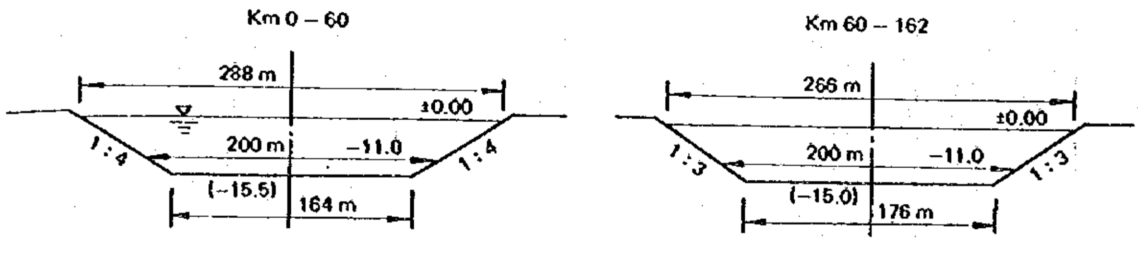
2) West channel

The design draft is to be 43′ (13.0 m) as in the case of the First Stage Project intended for 50,000 G/T container vessels. The maximum breadth of vessels was determined from the section Km 16 – 51 and Km 145 – 153 completed under the First Stage Project, which will form the west channel under the Second Stage Project. These sections are 160 m wide at a depth of 11.0 m. In view of the area ratio of 4.6 and the lane ratio of 2.7, as in the case of the Master Plan, the lane ratio of these sections restricts the width of the acceptable vessel size to 54.8 m, corresponding to the maximum 350,000 DWT tankers.

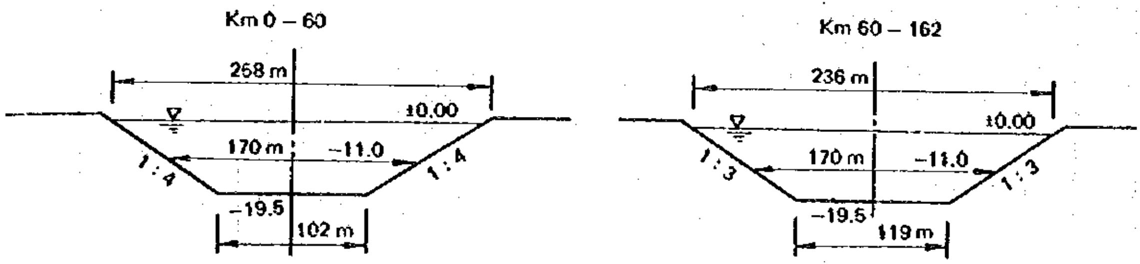
If the west channel is to accommodate most of those tankers under the above size, the projected vessel length may be obtained on the basis of the Japanese tanker specifications, as shown in Table 6-2-2.

1. Canal Itself

1) West Channel



2) East Channel



2. Port Said Approach Channel

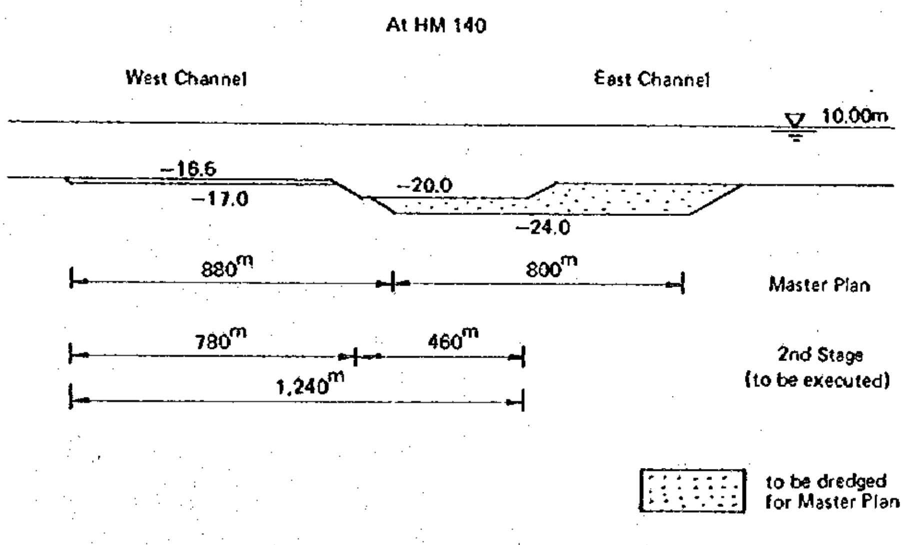


Fig. 6-2-1 Standard Cross Section of the 2nd Stage Development Project (1)

Table 6-2-2 Standard Channel Cross Section in the 2nd Stage Project

	Canal Dimensions					Navigable Ships				Design Conditions		
	Area (m^2)	Depth (m)	Width (m) Surface	Width (m) −11.0m level	Width (m) Bottom	Size (DW or GT)	Draught (m)	Breadth (m)	Length (m)	Grade of Slope	Area Ratio (Target)	Lane Ratio (Target)
Canal												
East Channel												
Km 0 ~ 60	3,510	19.5	258	170	102	Around 150,000DW (fully laden)	16.2	44	280	1:4	4.8	2.6
Km 60 ~ 162	3,416	19.5	236	170	119		(53')	(145')	(920')	1:3	4.8	2.6
West Channel												
Km 0 ~ 60	3,503	15.5	288	200	164	Around 300,000DW (in ballast) or	13.0	54.8	341	1:4	4.6	2.7
Km 60 ~ 162	3,313	15.0	266	200	176	50,000 G/T (container ship)	(43')	(180')	(1,120')	1:3	4.6	2.7
Port Said												
Approach Channel												
East Channel		20.0			max. 700	same as east channel of Canal						
West Channel		16.5			max. 840	same as west channel of Canal						
Suez												
Entrance Channel												
East Channel		19.5			289	same as east channel of Canal						
West Channel		16.0			417	same as west channel of Canal						
Great Bitter Lake Channel												
East Channel		18.5			361	same as east channel of Canal						
West Channel		14.5			417	same as west channel of Canal						

The section of the western channel may thus be designed according to the projected dimensions shown below:

Depth

The west channel is to be completed under the First Stage Project at the following depths:

Ballah west channel: 15.5 m

Deversoir west channel: 15.0 m

Great Bitter Lake: 14.5 m

In the light of the above, the depth of the west channel under the Second Stage Project is to be 15.5 m in the Section Km 0 – 60, 15.0 m in the section Km 61 – 162 (excluding the channel in Great Bitter Lake, which is to be 14.5 m).

The depths under the First Stage Project seem to have been determined on the basis of the design shown in Table 6-2-1.

These design depths are reviewed below as in the case of the east channel.

The channel depth may be computed from the draft, squat, trim and underkeel clearance with respect to the 50,000 G/T container vessels (draft 13.0 m).

$$DW = \underset{13.0}{\text{(draft)}} + \underset{1.0}{\text{(squat and trim)}} + \underset{0.6}{\text{(underkeel clearance)}} = 14.6 \text{ m}$$

This leaves 0.9 m at Ballah Bypass and 0.4 m at Deversoir Bypass for clearance; but it results in a deficiency of 0.1 m at Great Bitter Lake. However, as practically no siltation is expected in Great Bitter Lake and the squat and trim are estimated to be about 0.8 m at most because of an unrestricted waterway, the depth of 14.5 m is expected to cause no problems.

As regards Ballah Bypass and Deversoir Bypass, it is desirable to have about 1.5 m for clearance as in the case of the east channel, in view of the economy of maintenance dredging. In this respect, it may be necessary to dredge the channel under the Second Stage Project to the design depth of 16.0 m planned in the Master Plan. However, as dredging has nearly finished under the First Stage Project, the channel depth of the Second Stage Project should perhaps be geared to the line followed by the former.

Section

The section was designed as in the case of the Master Plan with the projected area ratio (R_a) of 4.6 and the lane ratio (R_l) of 2.7.

As has been described, dredging is in progress under the First Stage Project on the section Km 16 – 61 and Km 145 – 153 to a depth of 19.5 m with a width of 160 m. The section thus formed will determine the acceptable vessel size corresponding to around 300,000 DWT tankers in ballast. The section of the west channel to be newly constructed may be computed as below.

Midship area: $54.8 \times 12 = 657.8$ m²

Canal area needed: $657.8 \times 4.6 = 3{,}025.9$ m²

Canal width at –11.0 m: 160 m (Section Km 0–60)

" 181 m (Section Km 60–162*)

*except in Great Bitter Lake

The width will then be about 160 m on the Ballah west channel and about 180 m on the Deversoir west channel.

Accordingly, it is not necessary to expand the Ballah Bypass located in the section Km 51 – 61. On the other hand, the projected width of the Deversoir Bypass is 170 m under the First Stage Project, about 10 m too narrow. It is necessary to expand the section of the Deversoir west channel under the Second Stage Project.

Accordingly, under the Second Stage Project the width of that secton shall be 200 m at a depth of 11.0 m, as planned in the Master Plan. Details of the section are given in Fig. 6-2-1 and Table 6-2-2.

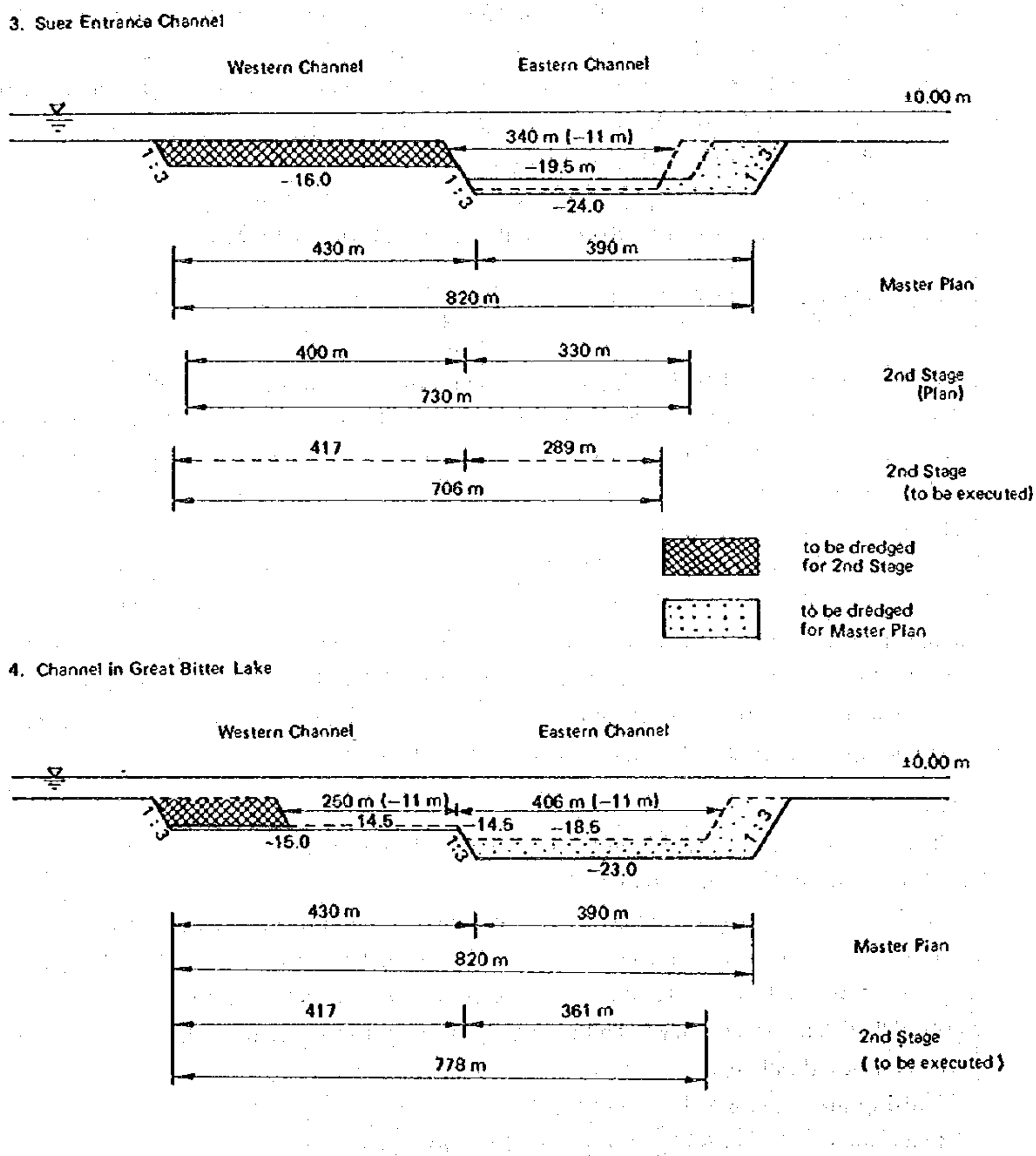


Fig. 6-2-1 Standard Cross Section of the 2nd Stage Development Project (2)

(2) Approach Channels

1) Port Said Approach Channel

The approach channel was designed to accommodate the acceptable vessel size projected in designing the channel section.

As for the Port Said Channel (west), since a further increase in depth and width will be difficult, the New West Port Said Bypass is planned to be constructed adjacent to the New Port Said Bypass when the Canal goes into full two-way operations.

In this case, the Mediterranean section of the approach channel is to be doubled at the same time.

Depth

Though roughly the same concept as that of the Canal sections was applied, consideration was given to the points below for the approach channel constructed in open sea:

a) Squat

The squat of the vessel decreases in the open sea compared with a restricted waterway, for the same speed. However, the speed is expected to be higher in the approach channel. In the case of an 150,000 DWT tanker, the squat is about 40 cm at 6 kt in shallow waters of h/d* = 1.2; it increases to nearly 80 cm at 10 kt. (See Fig. 6-2-2). As the vessel is expected to run at a fairly high speed in the approach channel, the squat will not differ much compared with that in the Canal.

* h: water depth, d: draft of the vessel

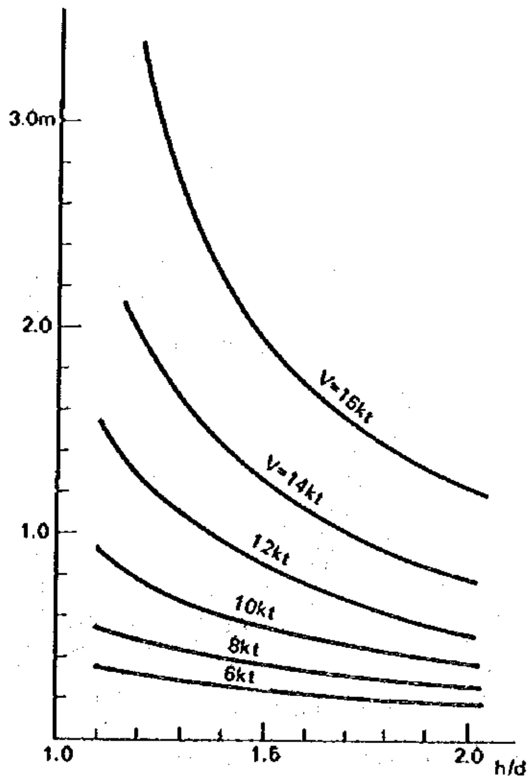


Fig. 6-2-2 Squat and Ship Speed (150,000 DWT Tanker)

b) Marine conditions

It is unavoidable for a vessel to be subjected to waves of about 2.0 m in the vicinity of Port Said when entering or leaving the Canal. It is therefore necessary to consider the sinkage of the bow and bilge due to oscillation. Below are listed the factors constituting the sinkage due to oscillation:

(a) Maximum sinkage of the bow due to head sea

(b) Maximum sinkage of the bow due to diagonal head sea and diagonal following sea

(c) Maximum sinkage of the bilge when synchronized with rolling

Assuming that an 150,000 DWT tanker (L=280 m, B=44 m, D=24 m and d=16.2 m) runs at a speed of 10 kt in the waters where the wave length is 100 m and the wave height 2 m, the sinkage in the above three cases may be computed as below:

(a) Maximum sinkage of the bow due to head sea.

The maximum sinkage of the bow may be obtained from the aggregate of heaving and pitching at a vessel's descent.

$$\text{Sinkage of the bow} = Z_G + \frac{L}{2} \sin \psi \qquad (6.1)$$

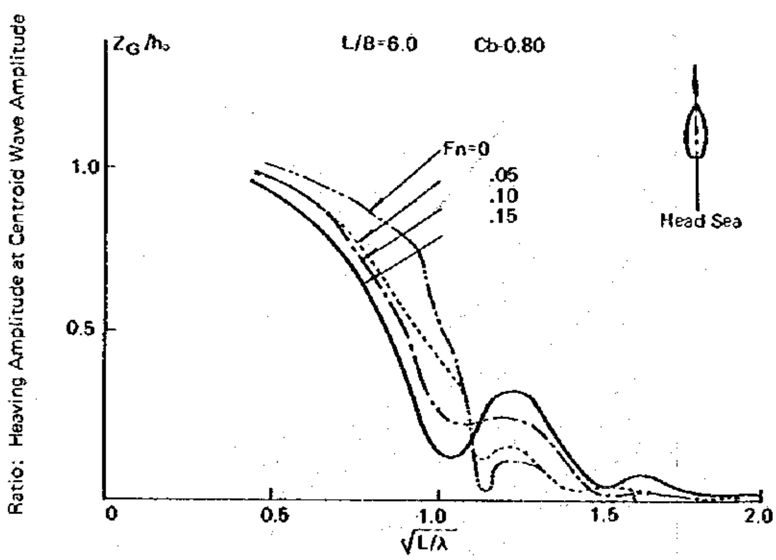
Here, Z_G is the maximum heaving at the vessel's center of gravity and ψ the pitching angle.

If the speed of the vessel is 10 kt (5.14 m/s), the Froude number may be obtained as below:

$Fn = V/\sqrt{L \cdot g} = 5.14/\sqrt{280 \times 9.8} = 0.098$

Also, $\sqrt{L/\lambda} = \sqrt{280/100} = 1.67$

$Z_G/h_o = 0.15$ may be obtained from Fig. 6-2-3.



Source: Guidance of Maneuvering of VLCC

Fig. 6-2-3 Heaving caused by Head Sea

Accordingly,

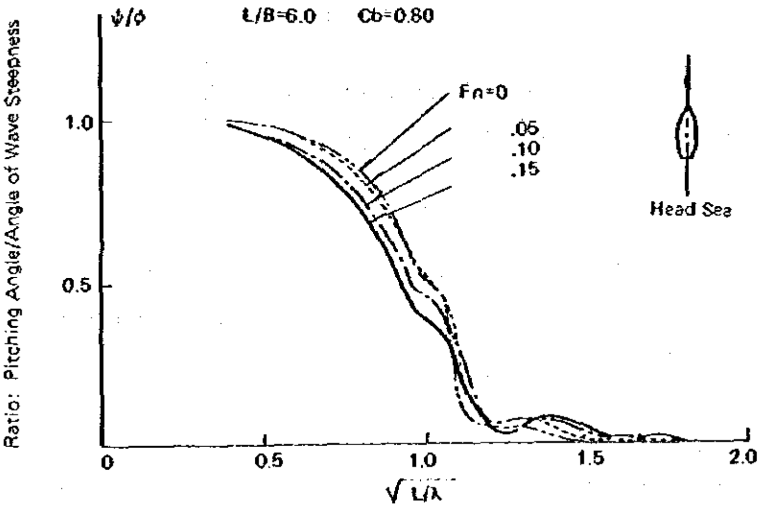
$$\text{Heaving } Z_G = ho \times 0.15 = \frac{Hw}{2} \times 0.15 = 0.15 \text{ m}$$

Similarly, $\psi/\phi = 0.1$ may be obtained from Fig. 6-2-4 for the amplitude of the pitching angle.

$$\text{Amplitude of pitching angle } \psi = \phi \times 0.1 = 180^\circ \times \frac{Hw}{\lambda} \times 0.1 = 0.36^\circ$$

Since $\sin \psi = 0.0063$

$$\text{Maximum heaving} = Z_G + \frac{L}{2} \sin \psi = 0.15 + \frac{280}{2} \times 0.0063 = 1.03 \text{ m}$$



Source: Same as Fig. 6-2-3

Fig. 6-2-4 Pitching Angle caused by Head Sea

(b) Maximum sinkage of the bow due to diagonal head sea and diagonal following sea. In both cases of dagonal head sea (θ = 45°) and of diagonal following sea (θ = 135°),

$Z_F/h_o = 0.2$ in the vicinity of $\sqrt{L/\lambda} = \sqrt{280/100} = 1.67$

(See Fig. 6-2-5)

Accordingly,

$$\text{Maximum heaving of bow} = ho \times 0.2 = \frac{Hw}{2} \times 0.2 = 0.2 \text{ m}$$

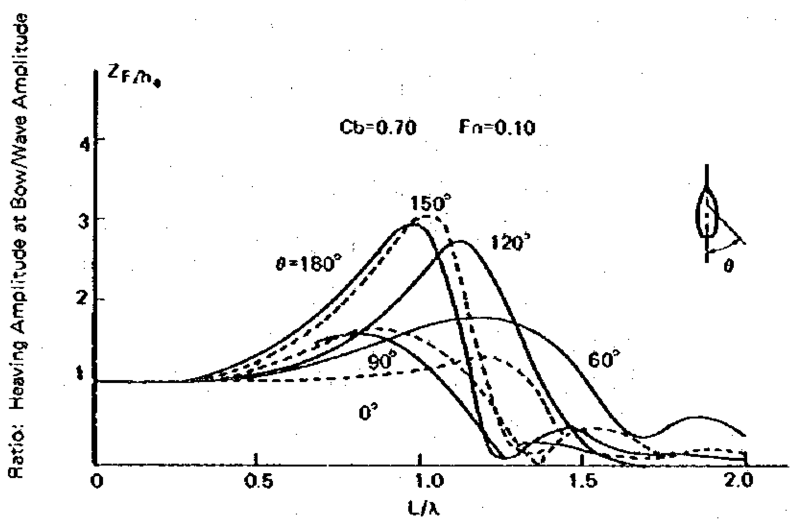


Fig. 6-2-5 Heaving and Diagonal Wave

(c) Maximum sinkage of the bilge when synchronized with rolling.

The course of simultaneous oscillation may be shown by the equation below (6.2).

$$\cos\theta = \frac{1}{V_S}\cdot\left(1.25\sqrt{\lambda} - \frac{\lambda}{T_R}\right) \qquad (6.2)$$

Here, Vs is the speed, λ = wave length, T_R is the rolling period.

If Vs = 5.14 m/s, λ = 100 m and T_R = 13 sec in the equation (6.2),

$$\cos\theta = \frac{1}{5.14}\cdot\left(1.25\sqrt{100} - \frac{100}{13}\right) = 0.935$$

Thus, synchronization begins with following sea of 20.8° from the stern resulting in sin θ = 0.355.

Further, effective wave steepness coefficient may be obtained from the equation (6.3).

$$\gamma = 0.73 + 0.6 \times \frac{OG}{d} \qquad (6.3)$$

Here, OG is the vertical distance from the water surface to the centre of gravity: OG = 0.4 D – d. (D: depth of vessel, d: draft)

From the equation (6.3),

$$\gamma = 0.73 + 0.6 \times \frac{0.4 \times 24 - 16.2}{16.2} = 0.49$$

The maximum sinkage of the bilge may be obtained from the equation (6.4).

Maximum sinkage of the bilge = $\frac{B}{2} \times \sin\Theta$

Here, $\Theta = 5\gamma\phi\sin\theta$ $\qquad \phi = 180° \times Hw/\lambda$

γ : effective wave steepness coefficient

B : breadth
θ : angle to waves causing synchronized rolling
Hw : wave height
λ : wave length

Therefore, the maximum rolling angle in synchronization:

$$\Theta = 5\gamma\psi\sin\theta$$
$$= 5 \times 0.49 \times 180^\circ \times 2/100 \times 0.355 = 3.13^\circ$$

Accordingly, the maximum sinkage of the bilge in synchronization may be obtained from equaton (6.4).

$$\frac{B}{2} \times \sin\Theta = \frac{44}{2} \times 0.05 = 1.1\text{m}$$

Judging from the above results, sinkage of the bilge due to rolling in synchronization is the largest.

On the basis of these results the depth of the eastern channel may be determined as below:

$$\text{East channel} = \underset{16.2}{\text{(draft)}} + \underset{0.8}{\text{(squat)}} + \underset{2.2}{\text{(rolling)}} + \underset{1.0}{\text{(siltation)}}$$
$$+ \underset{0.8}{\text{(underkeel clearance)}}$$
$$= 19.9 \rightarrow 20.0\text{ m}$$

The depth of the western channel may be computed similarly. Heaving of the bilge of the 50,000 G/T container vessel in synchronized rolling is thus 0.8 m, squat 0.8 m and underkeel clearance 0.7 m.

$$\text{West channel} = \underset{13.0}{\text{(draft)}} + \underset{0.8}{\text{(squat)}} + \underset{0.8}{\text{(rolling)}} + \underset{1.0}{\text{(siltation)}}$$
$$+ \underset{0.7}{\text{(underkeel clearance)}} = 16.3 \rightarrow 16.5\text{ m}$$

Section

The width to be planned under the Second Stage Project was computed as below for the projected vessel size for the east and west channels, by means of equation (6.5).

East approach channel: 150,000 DWT tanker fully laden.

draft:	16.2 m
breadth:	44 m
length:	280 m

West approach channel: 300,000 DWT tanker in ballast

draft:	12.0 m
breadth:	54.8 m

length: 341 m

The width required for two-lane traffic on the Port Said Approach Channel may be obtained from the equation below (6.5).

$$W = 2 \times (Wx + Wy) \qquad (6.5)$$

Here, $Wx = 0.02d + 0.9Bx + 1.8Bx + (Cx \cdot Vax + Vcx) \cdot Tx$

$Wy = 0.02d + 0.9By + 1.8By + (Cy \cdot Vay + Vcy) \cdot Ty$

where
- d : distance to a steering object
- B_x, B_y : ship breath
- C_x, C_y : constant (dependent upon type of ships)
- V_{ax}, V_{ay} : wind speed
- V_{cx}, V_{cy} : current speed
- T_x, T_y : maneuverability index

Here, W, Wx and Wy denote the width of channel bottom

If d = 2,000 m, Bx = 44 m, By = 54.8 m, Cx = 0.01, Cy = 0.015, Tx = Ty = 360 sec., Va = 10 m/s and Vc = 0.5 m/s, W may be obtained from the equation (6.5).

$$W = 2 \cdot (Wx + Wy) = 2Wx + 2Wy = 600 + 840 = 1{,}440 \text{ m}$$

It is thus necessary to secure 2Wy = 840 m for the east channel and 2Wx = 600 m for the west channel. However, as shown in Fig. 6-2-1, the approach channel newly dredged under the First Stage Project is to be used for the east channel and only the west channel is to be dredged under the Second Stage Project. As a result, the width of the eastern channel at HM 140 will be 460 m and that of the western channel 780 m.

2) Suez Entrance Channel

Depth

The depth was determined by employing the same concept as that for the Port Said Approach Channel, with the exception of the effect of siltation, which can be ignored.

The depths of the eastern and of western channels were obtained as below.

$$\text{East channel} = \overset{\text{(draft)}}{16.2} + \overset{\text{(squat)}}{0.8} + \overset{\text{(rolling)}}{1.1} + \overset{\text{(Keel clearance)}}{1.4} = 19.5 \text{ m}$$

A keel clearance was set at 1.4 m because of an additional allowance of 0.6 m in addition to the 5% of the draft as the bottom of the Suez Entrance Channel is assumed to be rock.

$$\text{West channel} = \overset{\text{(draft)}}{13.0} + \overset{\text{(squat)}}{0.8} + \overset{\text{(rolling)}}{0.8} + \overset{\text{(keel clearance)}}{1.3} = 15.9 \rightarrow 16.0 \text{ m}$$

Section

In the case of the Suez Entrance Channel, the width of the channel which allows two-way passage may be obtained from the equation (6.6).

$$W = Wx + Wy + Ly \qquad (6.6)$$

Here $W_X = 0.02d + 0.9\ B_X + 1.8\ B_X + C_X \cdot V_{aX} \cdot T_X$

$W_y = 0.02d + 0.9\ B_y + 1.8\ B_y + C_y \cdot V_{ay} \cdot T_r$

L_y = maximum length of transit vessels

where d : distance to a steering object

B_x, B_y : ship breath

C_x, C_y : constant (dependent upon type of ships)

V_{ax}, V_{ay} : wind speed

V_{cx}, V_{cy} : current speed

T_x, T_y : maneuverability index

If $d = 2{,}000$ m, $B_X = 44$ m, $B_y = 54.8$ m, $L_y = 341$ m, $C_X = 0.01$, $C_y = 0.015$, $T_X = T_y = 360$ sec. $V_a = 5$ m/s,

$W = W_X + W_y + L_y = 170\ m + 215\ m + 341\ m = 726\ m \rightarrow 730\ m$

As shown in Fig. 6-2-1, if the west channel is dredged to a width of 730 m, about 20 m will be left undredged on the west channel according to the Master Plan. Accordingly, it is to be dredged under the Second Stage Project to the section designed under the Master Plan.

As regards the east channel, expansion by 45 m will be required to secure the planned width. However, as it is possible to secure a width of about 290 m without expansion, no dredging is to be carried out under the Second Stage Project; it is to be carried out including that portion planned for the Second Stage Project when expansion in depth and width is carried out under the Master Plan.

As a result, the width of the Suez Entrance Channel will be 289 m for the east channel and 417 m for the west channel, totalling 706 m.

3) Channels in Great Bitter Lake.

Depth

As no effects of waves and of siltation are expected in the Great Bitter Lake, the depth may be determined without taking them into consideration. This is the reason why the east and west channels were designed to be shallower than the Canal section by 1.0 m and 0.5 m respectively under the First Stage Project.

Accordingly, under the Second Stage Project, the depth is to be 18.5 m for the east channel and 14.5 m for the west channel taking account of the First Stage Project.

Section

The planned width is the same as that of the Suez Entrance Channel. As regards the west channel, if it is dredged to the planned width, about 20 m will be left undredged according to the Master Plan as in the case of the Suez Entrance Channel. Accordingly, it is to be dredged under the Second Stage Project to the section designed under the Master Plan.

The east channel width designed under the First Stage Project is sufficient to secure the width designed under the Second Stage Project.

Accordingly, the width of the channel in the Great Bitter Lake will be 361 m for the east channel and 417 m for the west channel, totalling 778 m.

2-1-2 Design of alignment

The design of alignment under the Second Stage Project is to be based on the concept employed for the Master Plan. The channel section for the Second Stage Project is to be secured by bringing the west side of the channels in line with that of the Master Plan, and the east side is to be extended to expand the section to that designed under the Master Plan.

In the Great Bitter Lake and the Suez Entrance Channel, the west channel under the Master Plan is to be dredged completely under the Second Stage Project as shown in Fig. 6-2-1.

For the east channel, the section required under the Second Stage Project is to be secured on the west side under the Master Plan, and the east side is to be extended to expand the section to that designed uner the Master Plan.

2-1-3 Design of anchorage area

(1) Great Bitter Lake

Two anchorage areas (north and south anchorages are provided in the Great Bitter Lake for northbound and southbound convoys east and west of the channel respectively, as shown below:

Depth	Anchorage for northbound convoys number of berths	Anchorage for southbound convoys number of berths
14.5 m		3
14.0	3	
13.0		5
12.0	7	3
11.0	2	23
9.0	8	
	20	34

For northbound VLCCs, emergency anchoring space for four tankers is available in the eastern channel at Deversoir.

As the number of vessels anchored in the Great Bitter Lake is decided based on the single anchoring system, it is difficult to increase the number so long as this method is employed. When a non-stop transit operates, no anchorage area for southbound vessels will be required in the Great Bitter Lake, except in emergencies. The question is, therefore, whether the existing number of anchoring points will be sufficient for southbound vessels until the commencement of non-stop operations in both directions. However, the anchorage area in the Great Bitter Lake will not be extended under the Second Stage Project due to the following reasons:

a) The present single anchoring system may be changed to mooring with two anchors so that the anchorage area may be used more efficiently 33% with 15,000 DWT freighters, 26% with 30,000 DWT freighters and 20% with 100,000 DWT tankers. This will increase the anchoring capacity proportionately.

b) As swinging areas in the anchorage can overlap to some extent, the anchoring capacity may be increased by over 50%. Though the anchorage along the channel at the south anchorage area will be reduced by about 180 m with the extension of the west channel, no expansion will be necessary if mooring with two anchors is made as compulsory for those vessels stopping at the anchorage area or if anchoring point are clearly marked.

(2) Suez Anchorage Area

In regards to the anchorage area at Suez, the SCA has the accommodation plans as shown below: (See Fig. 5-2-2)

	Number of Ships	Area No.
General cargo ships, passenger ships	13	C
Tankers (small tankers)	13	A
(up to 50,000 DWT)	15	B
(up to 100,000 DWT)	10	D
(up to 150,000 DWT)	8	E
(up to 250,000 DWT)	5	F
Ships, for a limited time	17	G
	81	

In view of the small area for general cargo vessels, if they are accommodated in the area (A) for small tankers, the capacity will be sufficient. However, a part of the anchorage area along the channel will be shared by the channel under the Second Stage Project, causing some reduction in the swinging area; but the anchoring capacity will be affected only slightly.

(3) Port Said Anchorage Area (Outer Waiting Area).

Those tankers of over 38' and container vessels unable to wait in the anchorage area in the Port Said Harbour are to wait in the Outer Waiting Area which is to be provided along the west side of the New Port Said Approach Channel in the outer offing at a depth of 14.0 m. However, dredging will not be particularly required. This is to be positioned off Hm110.

2-2 Formulation of Phased Development Plans

2-2-1 Principles of planning

Various phased development plans may be roughly classified as below according to the objectives set under the Second Stage Project:

a) For increasing the transit capacity:

As the two-lane sections are extended, the transit capacity will increase. Of the single-lane sections, Km 40 between Km 122 and Km 162 and Km 79 between the section

Km 16 and Km 95 (though the section Km 16 – 95 includes the doubled Ballah channel, it is not effective for S-1 convoy) the latter section restricts the transit capacity. Accordingly, the capacity may be increased by reducing the length of the single-lane section. If the length north of the Bitter Lake becomes shorter than 40 km the capacity will be restricted by the single-lane section south of Bitter Lake. Accordingly, in order to increase the capacity for the time being, either one end or both ends of the Km 16–95 section may gradually be doubled.

b) For reducing transit hours:

Under the present transit system, southbound convoys have to wait at the Ballah Bypass and the Great Bitter Lake to allow a northbound convoy to pass, requiring longer hours than the latter. In order to reduce this loss due to waiting, it will be ultimately required to operate non-stop transits for southbound convoys. For that purpose, either restricting the number of single-lane section to one or doubling a long central section of the canal with single-lane sections provided at both ends of the two-lane section may be considered. If the length of the double channel section increases to a certain extent, it will be possible to operate a non-stop transit for a part of a southbound convoy. (See Fig. 6-2-6.)

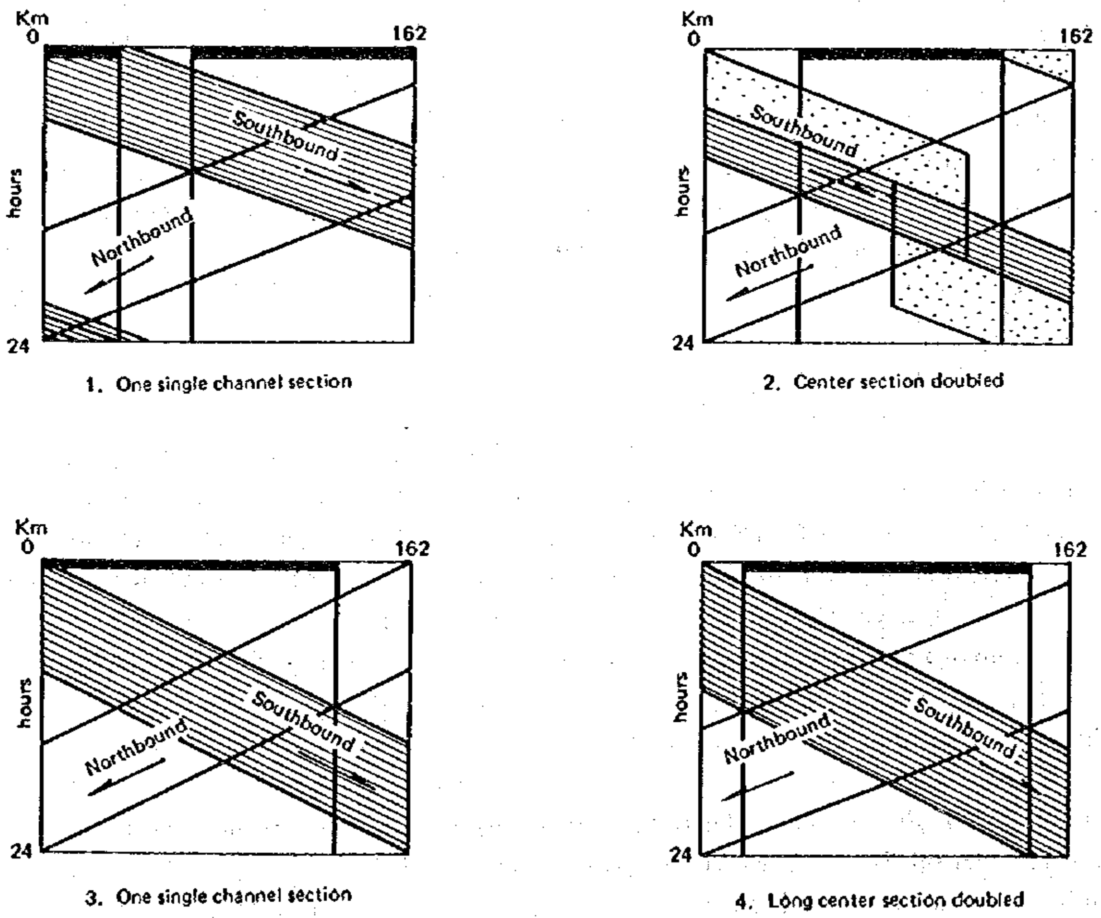


Fig. 6-2-6 Variations of Doubling the Canal

c) For improving navigational safety:

In order to improve navigational safety with respect to the transit method, it will be necessary to reduce the meeting of northbound and southbound convoys. This will prevent accidents which may occur at meeting and eliminate the dangers of manoeuvering, and thereby the safety of navigation may be secured.

In order to reduce meeting points, therefore, it will be necessary to secure a long doubled channel section; meeting may be eliminated completely in the end by providing two lanes for the entire length of the canal. For the above objectives, the phased development plans capable of responding gradually to an increase in demand are to be formulated. On the assumption that the Canal will be doubled in units of 10–20km to increase the capacity, the two cases below may be conceived.

(a) When doubling of the Km 16–51 section procedes: (See Fig. 6-2-7.)

If the expansion proceeds according to the order shown in Fig. 6-2-7, the capacity is expected to increase gradually. However, even if a step to be implemented later precedes, it will have no effect on the capacity.

If doubling of the Km 16–51 section precedes, it will not be necessary to expand the channel south of Bitter Lake before the section Km 16–51 is entirely doubled.

(b) When doubling of the Km 61–95 section precedes: (See Fif. 6-2-7.)

In this case, too, unless the entire length of the Km 61–95 section is doubled, doubling of the section south of Great Bitter Lake before other sections has no merit of increasing the capacity.

In this case, however, there is a possibility of operating non-stop transits for southbound convoys, and thereby reduction in transit hours may be expected.

If doubling in units of 10–20km is to be executed in parts as outlined above, connection channels will be required for connecting the two-lane and single-lane sections. These connection channels will not only become redundant when the single-lane sections are doubled, but also have to be shut off with dikes in view of hydraulic interferences expected when northbound and southbound convoys pass each other. In view of the cost of the dikes, it is desirable to carry out doubling considerably long sections rather than short sections.

Accordingly, it is advisable to double the section Km 16–51 or Km 61–95, north of the Bitter Lake, at one time. For the section south of the Bitter Lake, in view of the fact that the point Km 135 roughly corresponds to the end of the Little Bitter Lake and the characteristics of the two-lane route, expansion in units of about 10km is not expected to be wasteful.

2-2-2 Formulation of plans

On the basis of the principles described above, the phased plans for the Second Stage Project were formulated for eight cases shown in Fig. 6-2-8.

These plans are outlined below:

Plan 0 : Of the section Km 16–51, the section Km 16–32.5 is to be doubled for the east channel. The length of single-lane part of the section Km 16–95 will thus be

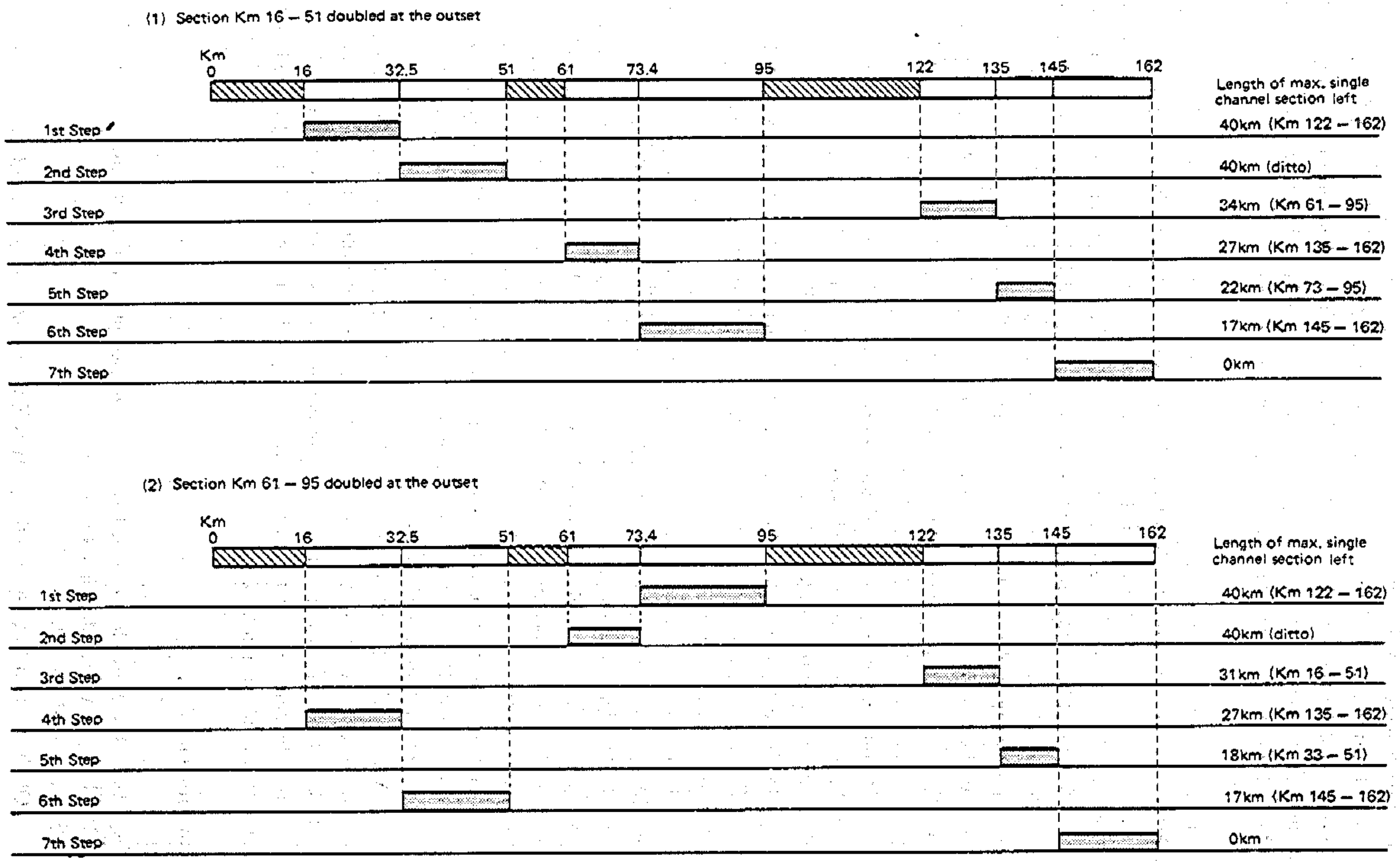


Fig. 6-2-7 Order of Doubling the Canal

reduced from 79km to 62km, and thereby the capacity will be increased. This is, however, a tentative plan to respond to an increase in demand on a short-time basis, thus requiring no expansion on other sections.

Plan 1 - 1 : In Plans 1-1 ~ 1-3 no expansion is planned for the section south of the point Km 122 of the Bitter Lake. With the expansion of either Km 16–51 or Km 61–95, the longest single-lane part will be the 40km between Bitter Lake and Suez which will restrict the capacity.

Plan 1-1 is intended to double the section Km 16–51 and also to widen the western channel of the two-lane section Km 95–122 which requires improvement.

Plan 1 - 2 : Plan 1-2 is to double the section Km 61–95 and also to widen the west channel of the two-lane section Km 95–122 which requires improvement. The section Km 51–122 will then be a two lane channel allowing two-lane traffic for southbound and northbound convoys with the possibility of operating a nonstop transit for a southbound convoy.

Plan 1 - 3 : This combines Plans 1-1 and 1-2 to provide two lanes for the section Km 0–122. It will then be possible to operate a non-stop transit for a southbound convoy as well as northbound one, and thereby a marked reduction in transit hours may be expected.

Plan 2 : In addition to Plan 1-2, the section Km 122–135 south of the Little Bitter Lake will be made two-lane, and thereby the section Km 51–135 will entirely be a two-lane channel. The capacity will then increase more than Plan 1-2 and more reduction in transit hours may be expected.

Plan 3 : In addition to Plan 2, the section Km 16–51 will be made two-lane, and thereby the section Km 0–135 will entirely be a two-lane channel. The capacity will then increase proportionately compared with Plan 2.

Plan 4 : In addition to Plan 3, the section Km 135–145 will be made two-lane, and thereby the section Km 0–145 will be entirely a two-lane channel. The capacity will then increase proportionately compared with Plan 3.

Plan 5 : This is a plan to expand the entire route to a two-lane canal. In this case a channel for southbound convoys will be provided on the west side of the New Port Side Bypass so that the section Km 0--16 will be made two-lane. Further, the Suez Entrance Channel and the Port Said Approach Channel will also must be made two-lane. With the entire section expanded to a two-lane Canal, non-stop transits may be made without waiting for the formation of convoys at Suez and Port Said.

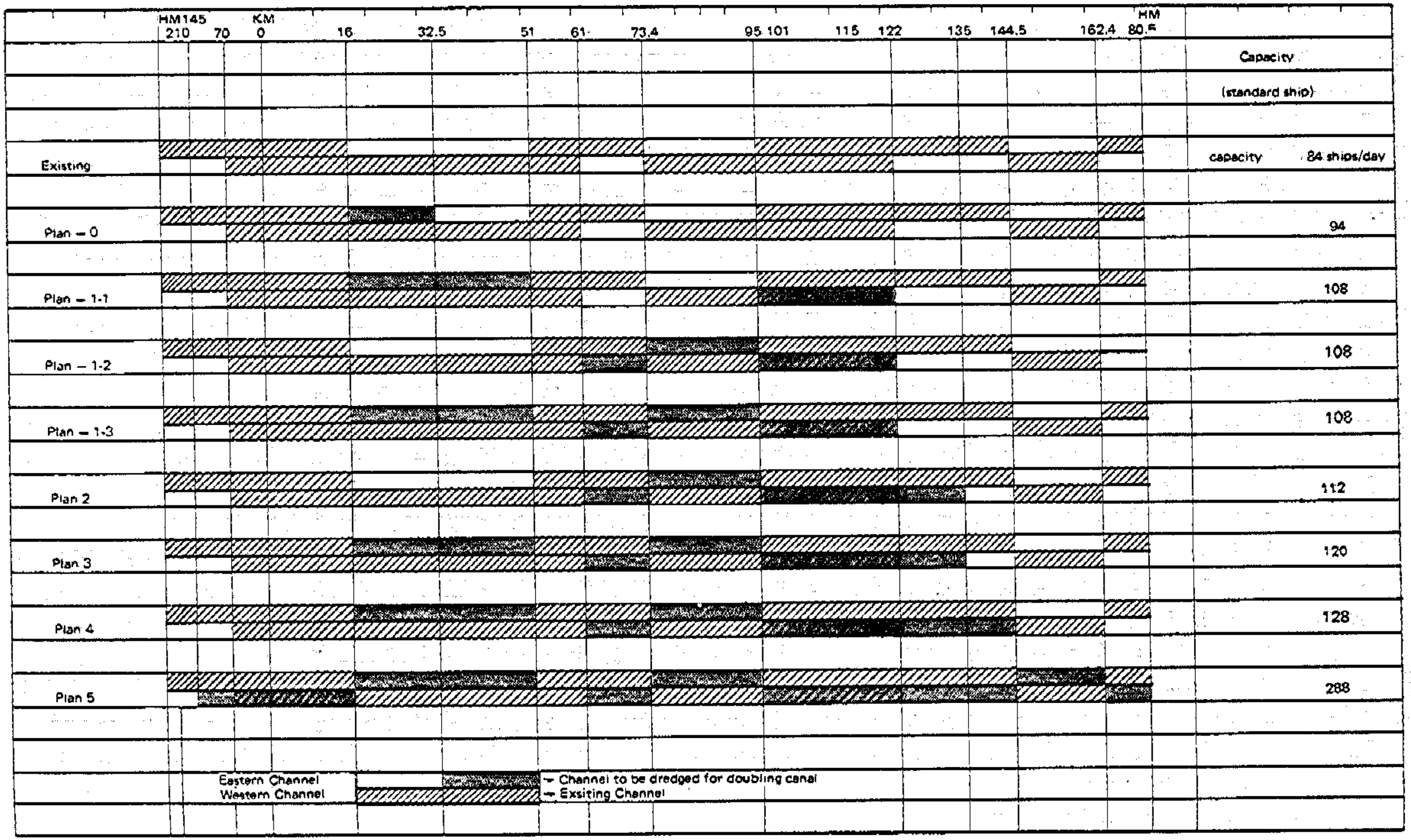


Fig. 6-2-8 Phased Development Plans

3. Order of implementation of the Second Stage Project

3-1 Method of evaluation

This chapter is intended to evaluate the above eight phased plans on the basis of the basic principles so that the order of implementation of the Second Stage Project may be examined.

As regards the aspect of evaluation, firstly, a degree of variation in profitability among the phased plans is to be studied. On the basis of the results, the order of implementation of the Second Stage Project will be proposed, by taking into account the various factors, including the demand for canal transits, the transit capacity and improvement in navigational safety.

The evaluation flow for the order of implementation of the Second Stage Project is as shown in Fig. 6-3-1. As the purpose of work here is to ascertain whether there is an extreme degree of variation in evaluation among the phased plans, a quantitative study is made only to the extent to achieve the purpose.

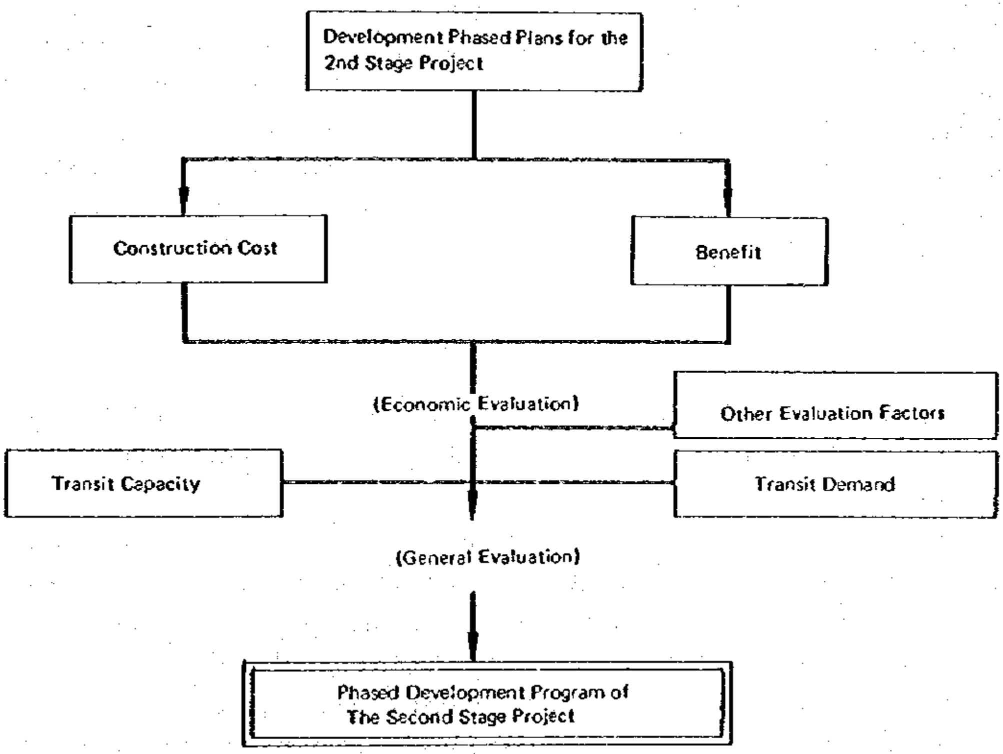


Fig. 6-3-1 Evaluation Flow for the Phased Development Program