6. FORMULATION OF MASTER PLAN

6.1 Planning Concept and Criteria

Planning concept and design criteria which aims to propose the economical, practical and sustainable Urban Drainage Master Plan are established as follows:

6.1.1 Target Year

The target completion year of the Urban Drainage Master Plan is set at 2020 on the premise that the proposed project implementation will be taken up at least 20 years. Consequently, all plans are to be prepared to meet the population and land use in the target year 2020. The present and projected future population and land use in the study area are shown in Table E.3.1 and Figs. E.3.3 (1/2) and (2/2).

6.1.2 Identification of Objective Catchment Areas and Canal Systems

As described in Section 3, the objective catchment areas and canal systems in Master Plan area were identified as follows:

OBJECTIVE CATCHMENT AREAS AND CANALS

Drainage Zone	Objective Canal system for Master Plan		
	Number of Canal System	Total Catchment Area (km^2)	Total Canal Length (km)
Central (C-zone)	4	98.53	55.474
Northern (N-zone)	2	127.44	44.105
Western (W-zone)	1	72.91	17.732
Southern (S-zone)	5	69.09	55.191
North-Eastern (NE-zone)	5	57.03	24.437
South-Eastern (SE-zone)	10	95.13	60.728
Total	27	520.13	257.667

6.1.3 Scope of Measures

Considering the level of current structure of the city related to socio-economy, urbanization, and urban drainage and sewerage infrastructures, the Study area is broadly classified into the following four (4) areas:

(a) Area A: existing urbanized areas with a combined sewerage system (inner city area)
(b) Area B: existing urbanized areas with a channel and canal drainage system (inner city and a part of surrounding areas)
(c) Area C: projected future urbanized areas with a channel and canal drainage system (high and low land areas in surrounding areas)
(d) Area D: areas to be preserved as agricultural land and green open space where has rainwater storage potential (mainly low-lying areas in surrounding area)

The area and location of the above classification from A to D by each drainage zone are shown in Table E.6.1 and Fig. E.6.1.

As mentioned in Section 5, a large number of areas in the inner city (Area A & B) have seriously flooded several times a year. These floods cause from a high intensity rainfall, high water level of the canals and rivers affected by the high tide of South China Sea, and overage and poor capacity of urban drainage pipes and channels.

The surrounding areas; particularly the northern and northeastern areas from the inner city (Area B &C) have being rapidly urbanized and drastically changed of their land use from a paddy field to a residential or industrial area. As shown in Fig. E.6.2, the peak discharge of storm water run-off has being increased, due to lowering of infiltration and storage potential in low lands, increasing run-off coefficient of the basin and decreasing of the time of concentration of run-off. Consequently, serious flood areas have being expanded toward the surrounding areas.

On the other hand, the drainage improvement and rehabilitation works by PCHCMC have been behind due to the financial constraint of the city. In addition, no Integrated Urban Drainage Master Plan has been formulated so far.

Considering the above situation, the integrated urban drainage measures shown in Fig. E.6.3, which consist of structural and non-structural measures, are proposed in this Master Plan, in order to minimize the project cost and to facilitate the smooth implementation of the project. Basic policy of selecting measures is as follows:

(a) In the existing urbanized area, where property and assets concentrate without open space, storm water is to be drained promptly as much as possible by structural measures.

(b) In the future urbanized area, flood damages are to be minimized by the combination of structural and non-structural measures.

(c) In the agricultural land and green open space, water storage potential is to be preserved by non-structural measures.

For the above four (4) classified areas, the following measures are employed as a result of the flood mechanism study summarized in Fig. E.6.4.

PROPOSED DRAINAGE IMPROVEMENT MEASURES

Drainage Area		Structural Measure	Non-structural Measure
A	High Land	Rehabilitation of existing sewer pipe & construction of additional pipe	-
	Low Land	Filling up of low-lying area or Construction of retaining wall, gate and pumping station with retarding pond including rehabilitation of sewer pipe	-
B	High Land	Improvement of drainage ditch, channel and canal (widening, deepening and bank protection)	-
	Low Land	Improvement of drainage ditch, channel and canal, Filling up, or Construction of polder dike, gate and pumping station with retarding pond	-
C		Sustainable low cost urban drainage system consist of retarding basin, improvement of channel and canal	Land use regulation Flood proofing Flood forecasting and warning Communication system of flood information
D		-	Preservation of storage function Development & land use regulation Flood forecasting and warning Communication system of flood information

Concept of the proposed measures for each area is illustrated in Fig. E.6.5.

6.1.4 Design Scale

Design scale for the Urban Drainage Master Plan is generally applied to meet 2 to 10 year frequency floods, taking into consideration of the economical and political position of the city, the size of catchment area, land use and asset conditions in the area, a importance of drainage facilities, etc. Most of the capitals and major cities in the developing Southeast Asia countries including Ha Noi city, the capital of Viet Nam adopt the almost same design scale as shown in table below:

DESIGN SCALE FOR URBAN DRAINAGE IN ASIA COUNTRIES

Name of Country and City	Population ($x10^3$ person)	Design Scale(Frequency)		Remarks
		Sewer Line	Canal	
Japan, Tokyo	12,000	3	7 - 30	capital
Philippine, Manila	6,500	5	10	capital
Thailand, Bangkok	5,000	2	5	capital
Indonesia, Jakarta	8,000	5	10	capital
Malaysia, Kuala Lumpur	1,390	2 - 5	10	capital
Indonesia, Semarang	1,000	2 - 5	5 - 10	city
Indonesia, Ujunpandang	1,000	2 - 5	5 - 10	city
Bangladesh, Dacca	5,000	5	5	capital
Laos, Vienchang	300	2	5	capital
Viet Nam, Ha Noi	2,200	5	10	capital

In HCMC, 1 to 3-year and 5-year frequency floods have been applied for the design of sewer line (Grade 2,3,4) and the canal (Grade 1) respectively. Considering that HCMC is the largest city of the nation as well as the socio-economic center in the southern region of the country, the design scale is proposed as follows:

DESIGN SCALE FOR DRAINAGE FACILITIES

Urban Drainage facility	Catchment Area (km^2)	Design Flood (year return period)
Sewer Line (Grade 3,4)	-	2
Sewer Line (Grade 2)	-	3
Canal (Grade 1)	less than 30	5
Canal (Grade 1)	More than 30	10
Drainage Pumping Station	-	5

In accordance with the above design scale, the canals to be planned on 10-year return period flood are as follows:

(a) Central City Drainage Zone (C-Zone)
- C-C.1: Nhieu Loc - Thi Nghe canal (A=31.668 km^2)
- C-C.3: Ta Hu - Ben Nghe canal (A=31.668 km^2)
- C-C.4: Doi - Te canal (A=31.668 km^2)

(b) Northern City Drainage Zone (N-Zone)
- C-N.3: Tham Luong - Ben Cat canal (A=107.569 km^2)

(c) Western City Drainage Zone (W-Zone)
- C-W.1: Rach Chua - Rach Nuloc Len (A=40.064 km^2)
- C-W.4: Ben Cut River (A=50.554 km^2)
- C-W.5: Can Giuoc River (A=72.908 km^2)

(d) Southern City Drainage Zone (S-Zone)
- C-S.5: Rach Tan - Rach Roi - Rach Tom - Muong Chuoi (A=34.511 km^2)

(e) North-Eastern City Drainage Zone (NE-Zone)
- C-NE.5: Rach Nhu - Rach Cau - Rach Go Cone (A=34.380 km^2)

(f) South-Eastern City Drainage Zone (SE-Zone)
- Tac River (A=59.258 km^2)

6.1.5 Design Rainfall

Four (4) design rainfalls have been developed for preparation of the improvement plan of sewers and canals, and the pump drainage plan. These are as follows: (Details are presented in Appendix C: Meteorology and Hydrology.)

(1) For Sewer Line Improvement

Rainfall intensity-duration with 2-year and 3-year return period are employed for planning of sewer line improvement for Grade 3 and 4, and Grade 2 respectively.

2-year Return Period: for Grade 3 and 4 : $I = 13,567/(t^{1.18} + 89)$: $t < 3$ hours

3-year Return Period: for Grade 2 : $I = 17,439/(t^{1.20} + 107)$: $t < 3$ hours

Where, I: Point rainfall intensity (mm/hr)
t: Duration (minutes)

The applied design rainfall and duration curves are shown in Fig. E.6.6.

(2) For Canal Improvement

For canal improvement, the following 5-year and 10-year frequency rainfall-duration formulas are employed.

5-year Return Period : $I = 22,294/(t^{1.22} + 128)$: $t < 3$ hours
$I = 2,020/(t^{0.84} - 15)$: 3 hours $< t < 24$ hours

10-year Return Period : $I = 29,125/(t^{1.25} + 154)$: $t < 3$ hours
$I = 1,669/(t^{0.80} - 16)$: 3 hours $< t < 24$ hour

Where, I: Point rainfall intensity (mm/hr)
T: Duration (minutes)

The above design rainfall intensity and duration curves are shown in Figs. E.6.6.

These design rainfalls are prepared by the series of point rainfall data. Accordingly, for the estimation of the design discharge, the area reduction factor shown in Fig. E.6.7 is to be considered to convert the basin average rainfall intensity.

(3) For Pump Drainage Plan

Six (6) hours consecutive rainfall with 5-year return period (R_{24} = 113.47 mm) is proposed to employ as the design rainfall for the pump drainage plan considering the correlation with the design scale of sewer line and canal improvements. Fig. E.6.8 shows the rainfall depth and its distribution. This design rainfall was made analyzing the typical daily rainfall pattern for the current 10 major rainfalls (over 100 mm/day).

6.1.6 Design Water Level

According to the water level analysis for five (5) stations in and around the Study area; Thu Dau Mot, Phu An, Nha Be, Bien Hoa and Ben Luc, the design flood water levels of the Saigon, Dong Nai, Nha Be and Ben Luc rivers are proposed as the following table:

DESIGN FLOOD WATER LEVEL IN THE STUDY AREA

River Section	H.H.W.L	H.W.L (D.F.W.L)	M.W.L	L.W.L	L.L.W.L
A: Nha Be River From confluence with Muong Chuoi River to confluence of Saogon and Don Nai rivers (about 14 km)	1.75	1.39	0.27	-2.12	-1.61
B: Saigon River From confluence with Don Nai River to confluence with Doi canal (about 11 km)	1.75	1.39	0.27	-2.12	-1.61
C: Saigon River From confluence with Doi canal to confluence with Rac Ba Hong (about 34.5 km	1.56	1.32	0.23	-2.11	-2.40
D: Dong Nai River From confluence with Saigon River to confluence with Tac River (about 22.5 km)	1.91	1.47	0.54	-1.78	-2.04
E: Ben Luc River At crossing point with west boundary of the Study area	1.56	1.32	0.23	-2.11	-2.40
F: Can Guioc River and Rach Ben Lac At crossing point with south boundary of the Study area	1.75	1.39	0.27	-2.12	-2.42

For formulation of pump drainage plan and execution of the dynamic hydraulic simulation by MIKE 11 and MOUSE, design 24 hours consecutive water level variation of the above river sections are also developed as shown in Fig. E.6.9.
(Details of this Section refer to Appendix C: Meteorology and Hydrology.)

6.1.7 Run-off Formula

The first step estimation for design discharge (peak run-off) of the canal will be carried out by Rational formula mentioned below:

$$Q = (1/360) * C * f * I * A$$

Where, Q : *Peak run-off* (m^3/s) C : *Run-off coefficient*
F : *Area reduction factor* I : *Rainfall intensity (mm/hr)*
A : *Catchment area (ha)*

Rainfall intensity (I), as expressed by the equations of the IDF curves, is a function of time of concentration (Tc), which represent as followings:

$$Tc = Ti + Tf$$

Where, Ti: Time of inlet to manhole of sewer or canal (min.)
Tf: Time of flow in sewer or canal (min.)

The proposed run-off coefficient by land use category are shown in the table below:

PROPOSED RUN-OFF COEFFICIENT BY LAND USE CATEGORY

Land Use Category Grouped by Study Team	C	Original Land Use Category in Master Plan Prepared by UPI
Commercial Area	0.8	Commerce, Services
Industrial Area	0.9	Industrial Area, Garbage Treatment Site, Ware House
Residential Area (High)	0.8	Inner City, Suburban Residential Town
(Medium)	0.7	Suburban Residential Area
(Low)	0.6	Existing Residential Area (Existing)
Institutional Area	0.5	City and District Center, Education and Culture, Tourism, Miritary
Green Open Space	0.3	Green Park, Ecological Forestry
Agricultural Area	0.4	Agriculture
Water Bodies	1.0	River, Canal

6.1.8 Demarcation Criteria for Employment of Gravity or Pump Drainage System

The gravity drainage system is most economical and applicable for urban drainage. However, the pump drainage system is to be employed, in case that the ground elevation of the area is not enough for the external water level of the river or canal. The demarcation criteria for employment of the gravity or pump drainage system is proposed as follows:

$GE > DWE + hl$: Gravity drainage system is applicable.
$GE < DWE + hl$: Pump drainage system is to be employed.

Where, *GE* : Ground elevation of low-lying area in the basin (m above MSL)
DWE : Design water level at outlet of drainage pipe, channel or canal (m above MSL)
hl : Hydraulic head loss of drainage pipe, channel or canal (0.3 to 0.5 m)

Considering the proposed DWL, most areas located along the Saigon and Nha Be rivers, of which the ground elevation are below about 1.7 m above MSL, will be required to apply the pump drainage system or to fill up more than 1.7 m to apply the

gravity drainage system. The critical ground elevation for the inland areas situated far from the rivers will be more than 2.0 m due to the hydraulic loss of inner canals.

6.1.9 Drainage Criteria

Since the proposed design rainfall intensity in short duration of HCMC is very high, it is proposed that internal inundation having very low flood loss are to be allowable in short duration for some low lying areas, considering that the capital cost of the project is to be more reasonable. Duration of pump drainage for design rainfall is proposed to be within 12 hours (half day).

6.1.10 Freeboard and Roughness coefficient

Manning's roughness coefficient (n) for sewer pipe, culvert, channel and canal improvement plan and freeboard for channel and canal improvement plan are applied as follows:

PROPOSED COEFFICIENT OF ROUGHNESS AND FREEBOARD

Item	Material and Bank Protection Type	Manning's Roughness Coefficient	Freeboard (cm)
Sewer Line	Concrete Pipe	0.0013	-
	Box Culvert	0.0015	-
Channel/Canal	Bank: sod protection	0.0030	40
	Bank: stone masonry	0.0025	40
	Bank: concrete	0.0022	40
	Bank: concrete Bottom: concrete	0.0015	40

6.1.11 Specific Pump Capacity and Storage Requirement

Specific pump capacity and storage requirement by channel/canal, retarding pond and temporary inundation area are estimated at 2.01 m^3/s /km^2 and 69,000 m^3/km^2 respectively, assuming the duration of pump operation is 12 hours. Calculation is made by the following formula:

$$\Sigma Qin - \Sigma Qout = \Sigma S$$
$$Qin = r \times R \times A$$
$$Qout = 60 \times q \times T$$

Where, *Qin:* *Run-off volume (m^3)* *Qout:* *Pump drainage volume*
r: *Run-off ratio (0.8)* *R:* *Rainfall during T (mm/min.)*
A: *Area (1.0 km^2)* *q:* *Pump capacity (m^3/s)*
T: *Calculation time (30 min.)*

Calculation result is shown in Fig. E.6.10.

6.1.12 Specific Onsite Storage Requirement due to Urbanization

As mentioned in 6.1.3, any development (urbanization) will give a hydraulic impact for the surrounding areas to increase an amount of flood run-off and a peak discharge. So, any developer shall be necessary to consider by itself how to control a flood run-off increased due to its development. In case that onsite detention pond is considered as flood run-off control facility, required specific storage volume, which is the same volume as the increased one due to urbanization, has been estimated based on Rational method. Applying time to inlets of 10 and 5 minutes and overland flow velocities of 0.5 and 1.0 m/s, time of concentrations for overland flow through unit length of 1.0 km due to existing agricultural and future urbanized areas are calculated as 51.67 and 25.83 minutes respectively. Applying Rational method, overland flow runoff hydrographs for 5 and 10 year return periods have been constructed for different land use conditions for unit catchment area of 1.0 km^2 and are presented in Fig. E.6.11. Required specific storage volume ($m^3/s/km^2$) for each scenario of urbanization has been calculated and the results are plotted as shown in Fig. E.6.12. For ease in application, two equations have been proposed for 5 and 10 year frequency:

$$V = 76852 \times (\Delta C)^{0.7612}; \qquad \textit{5-year return period}$$
$$V = 85679 \times (\Delta C)^{0.7620}; \qquad \textit{10-year return period}$$

Where, V = *required specific storage volume* ($m^3/s/km^2$) *and*
ΔC = *increase in runoff coefficient by urbanization*

6.2 Alternative Study

6.2.1 Utilization of Low-lying Agricultural Land as Natural Retarding Basin

Even if almost 70 % of the existing paddy field in Dai Han catchment area is planned to preserve in the future as shown in Fig. E.3.3 (1/2) and (2/2), a large scale improvement of Tham Luong - Ben Cat canal receiving the discharge from Dai Han canal will be necessary. In order to propose more economical improvement plan of these canals, the following alternative are studied.

(a) Alternative I-I: Dai Han and Tham Luong - Ben Cat canals are planned on 5 and 10-year frequency flood respectively.

(b) Alternative I-II: Dai Han canal is planned on 5-year frequency flood with an allowable inundation and Tham Luong – Ben Cat canal is planned on 10-year return period.

If the low-lying paddy fields along Dai Han canal are allowable to practically use as a natural retarding basin with an allowable inundation (area: within 10 % of the basin, depth: max. 0.4 m, and duration: within one day), it was found that about 75 % of peak run-off

can be decreased as shown in Fig. E.6.13. Alternative 1-II will be more economical canal improvement as shown in the table below:

COST COMPARISON OF ALTERNATIVES 1-I AND 1-II (unit: billion VND)

Alternative / Item	Alternative 1-I		Alternative 1-II	
	Quantity	Cost	Quantity	Cost
1. Canal Improvement Cost				
(1) Excavation/Dredging	4,027,900 m^3	326.3	2,516,700 m^3	203.9
(2) Construction of O/M Road	327,500 m^3	134.1	327,500 m^3	134.1
(3) Bank Protection	942,200 m^2	266.7	742,500 m^2	189.6
(4) Slope Reformation	87,500 m^2	4.7	128,400 m^2	6.9
Sub-total		731.8		552.8
2. Land Acquisition Cost	1,150400 m^2	22.2	924,500 m^2	18.3
Total		754		552.8

Note: 1. Hydraulic design and bill of quantities of canal improvement for alternatives 1-I and 1-II are shown in Table E.6.2 and E.6.3 respectively.
2. Detailed cost comparison is shown in Table E.6.4.

Utilization of low-lying paddy field as a natural retarding basin is applicable for N.1 catchment (Ben Da - Ba Hong canal) in N zone and W.1 catchment (R. Cua - R. Nuoc Len canal) in W zone as shown in Fig. E.6.14. In order to realize a land use regulation to preserve the low-lying paddy fields as a natural retarding basin, PCHCM is necessary to prepare as soon as possible a local law and to strengthen the governmental organization in charge of it.

6.2.2 Tham Luong - Ben Cat and R. Chua - R. Nuoc Len Canal Improvement

At present, Tham Luong - Ben Cat canal (N.2) and R. Chua - R. Nuoc Len canal (W.1) are actually blocked at the middle stream reaches of May 19 canal, however, both canals were originally connected each other. Flood run-off from R. Dai Han catchment area of 34.65 km^2 is discharged to Saigon River through N.2 canal. For preparation of improvement plan for both canals, the following alternatives are studied:

(a) Alternative 2-I: Existing drainage system (discharge to Saigon River through Tham Luong - Ben Cat canal) shown in Fig. E.6.15.

(b) Alternative 2-II: Discharge to R. Cua - R. Nuoc Len canal shown in Fig. E.6.15 in W zone, which is connected with Ben Luc and Can Giuoc rivers

As the result of cost comparison of both alternatives shown in the table below, Alternative 2-I (existing drainage system) was recommended, because of lower canal improvement cost and land acquisition area than Alternative 2-II.

COST COMPARISON OF ALTERNATIVES (billion VND)

Item	Alternative 2-I	Alternative 2-II
1. Construction		
(1) Excavation	336.6	522.9
(2) O/M Road	285.8	297.6
(3) Bank Protection	418.8	418.8
(4) Slope Reformation	11.1	11.1
Sub-total	1,052.3	1,250.4
2. Land Acquisition	33.4	42.6
Total	1,085.7	1,293.0

Note: 1. House compensation cost is excluded.
2. The proposed canal section and required improvement works are shown in Tables E.6.5 and Table E.6.6 respectively.
3. Details of construction cost are shown in Table E.6.7.

Alternatives 2-I is recommendable because of lower construction cost and less land acquisition area than Alternative 2-I.

6.2.3 Drainage System of Newly Developed Area in Low Land

According to the AMP prepared by UPI, vast paddy fields in W, S, SE and other low lying areas are expected to develop as residential, institutional and industrial areas. PCHCM has provided the guideline for the new development program in low lying areas that a new ground elevation is to be preserved more than 2.0 m above MSL and maintained the gravity discharge for urban drainage. This guideline may be made in view point of technical and economical considerations. In order to confirm the justification of the guideline, alternative study for applicable drainage system in low-lying area has been made.

According to AMP, the low-lying paddy fields in W, S and SE zones would be widely developed as a residential, institutional and industrial area. UPI has prepared a guideline that a land development in low-lying area shall be filled up to EL.2.0 m to maintain easily a separated gravity discharge system from a technical and economical point of view. In order to confirm the justification of the guideline, alternative study for applicable drainage system in low lands has been made.

(a) Alternative 3-I: Low land is filled up more than 2.0 m above MSL and the gravity discharge system is employed for storm water drainage.

(b) Alternative 3-II: Low land is protected from the external flood by a polder dike and the pump drainage system is applied.

Construction and O/M costs of the above alternatives are estimated for the following 12 cases:

(a) Development area: four (4) cases: 1.0, 3.0, 6.0 and 10.0 km^2
(b) Existing average ground elevation: three (3) cases: 0.6, 0.9 and 1.2 m

Costs of these alternatives by each case are estimated as follows:

COST COMPARISON OF ALTERNATIVES 3-I AND II

Case	Development Area (km^2)	Existing Ground Elevation (EL. m)	Alternatives 3-I (billion VND)	Alternative 3-II (billion VND)
1	1.0	0.6	370.0	675.4
2	1.0	0.9	293.8	665.1
3	1.0	1.2	215.9	656.1
4	3.0	0.6	1,001.4	1,669.2
5	3.0	0.9	813.5	1,651.2
6	3.0	1.2	611.8	1,635.7
7	6.0	0.6	1,738.4	2,761.4
8	6.0	0.9	1,454.9	2,736.0
9	6.0	1.2	1,122.9	2,714.0
10	10.0	0.6	2,309.4	4,344.7
11	10.0	0.9	2,062.0	4,322.9
12	10.0	1.2	1,679.6	4,283.5

Note: 1. Cost of Alternative 3-I includes only land development cost for filling up to 2.0 m above MSL.
2. Cost of Alternative 3-II includes land filling cost, construction costs of dike and pumping station with retarding pond, O/M cost for 50 years and land acquisition cost for dike and pumping station with retarding pond.
3. Cost of the canal, channel, ditch and drainage pipe improvement in the new development area is omitted because of same value for both alternatives.
4. Bill of quantities of each work and detailed cost comparison are shown in Tables E.6.8 and 6.9 respectively.

Cost comparison led Alternative 3-I is to be recommended. Because it was found that the cost of Alternative 3-II including its O/M cost during the project life of 50 years, was estimated at 1.6 to 3 times of that of Alternative 3-I as shown in Figs. E.6.16 and E.6.17. This justification was confirmed by the same study for Long Truong development plan with an area of about 9.0 km^2 in SE zone as shown in Table E.6.10 and Fig. E.6.18.

In addition, considering the merit and demerit of both alternatives shown below, it can be said that Alternative 3-I is comprehensively recommendable.

(a) Alternative 3-I
(Merit)
* Permanent solution from the external flood
* No O/M works will be required after completion

* It will be free to decide a development area and less prior investment for development
* Everywhere can use after completion of land filling

(Demerit)

* A large quantity of filling material is required
* Temporary relocation will be required for land filling.

(b) Alternative 3-II

(Merit)

* A large development area can be protected easily from the external and internal floods without a large filling material.
* It will not be necessary to have a large number of relocation.

(Demerit)

* There is some flood risk to collapse the dike due to bank erosion or to cut off a power supply.
* Land acquisition for dike, pumping station and retarding pond will be required.
* O/M works for drainage facilities, such as dike, pumping station and retarding pond.

However, assuming the average filling height will be 1.5 m for the future development of about 88 km^2 in low-lying paddy field of W, S and SE zones, it is estimated the total required filling materials of about 132 million m^3. It is necessary to solve the problems how and where can be found the source of filling materials.

In addition, for some low-lying areas located on the fringe of C zone, where has being already developed, land filling to apply the gravity discharge system will be difficult due to a large number of relocation of the existing houses and buildings. Pump drainage system by a polder dike has to employ for these areas regardless of its little wasteful system.

6.2.4 Drainage System of Newly Developed Area in High Land

As shown in Table E.3.3, almost 50% of the agricultural lands in Thu Duc area (NE.3, 4 and 5 basin of about 44 km^2) situated on high land of NE zone would be expected to rapidly developed to residential, institutional and industrial areas. The future development on upstream high land will give the hydraulic impact increasing the peak run-off and flood risk to the downstream low-lying areas as shown in Fig. E.6.19. Accordingly, a large scale of canal improvement will be required in future. As reference of NE.5 Canal (R. Nhum - R. Cau - R. Go Gone), the following countermeasure alternatives for flood run-off increased due to urbanization are studied.

(a) Alternative 4-I: Increased flood run-off due to urbanization will be met by only

canal improvement

(b) Alternative 4-II: Canal improvement is designed on the existing condition and future increased run-off will be met by onsite detention pond.

Construction costs of these alternatives are given as follows:

COST COMPARISON OF ALTERNATIVES 4-I AND 4-II (unit: billion VND)

Item	Alternative 4-I	Alternative II
1. Canal Improvement		
(1) Construction	615.8	497.3
(2) Land Acquisition	13.8	9.6
Sub-total	629.7	506.9
2. Onsite Detention Pond		
(1) Construction	-	70.8
(2) Land Acquisition	-	4.8
Sub-total	-	75.6
Total	629.7	582.4

Note: 1. The proposed canal section and required canal improvement works of both alternatives are shown in Tables E.6.11 and E.6.12 respectively.
2. Specific storage requirement of onsite detention pond is estimated at 17,000 m^3/km^2 based on the increased run-off coefficient (from 0.45 to 0.57) due to the future urbanization (refer to Fig. E.6.12).
3. Detailed construction costs are shown in Table E.6.13.

Alternative 4-II is recommended because of lower construction cost than Alternative 4-I. This means that PCHCM will require to prepare a guideline for regulating on new development in high land that developers shall construct the required onsite detention pond to control the flood run-off increased due to their activity. This conclusion is able to apply for the new development in NE. 3 (R. Thu Duc) and NE. 4 (R. Truong Tho) basins.

6.3 Optimum Drainage Plan

6.3.1 Outline of the Proposed Plan (see Fig. E.6.19)

Outline of the optimum drainage plan in each drainage zone is as follows:

(1) C-Zone

C zone is situated on high land and overcrowded with a population of about 3.19 million corresponding to about 75 % of total population in the study area. Only few open space and green area are found. Flood damaged areas are estimated at 21.2 km^2 equivalent to almost 60 % of total flood area (34.6 km^2) in built-up one. For C zone drainage improvement, it is proposed to drain out the storm water collected to the

surrounding rivers as soon as possible by the following structural measures:

(a) Rehabilitation and construction of drainage pipes (Grade 2,3,and 4)
(b) Canal improvement for Nhieu Loc - Thi Nghe, Tan Hoa - Lo Gom and Tau Hu - Ben Nghe canals
(c) Drainage improvement for low-lying areas (Thanh Da, Ben Me Coc) by pump drainage system consisting of dike and pumping station with retarding pond, canal improvement, and drainage pipe facilities

It is recommended that the above measures is to be implemented as a short term program taking into account of urgency of the drainage improvement of C zone.

(1) N-Zone

N zone having a population of 422,000 equivalent to about 10 % of that in the study area has been suffered from the flood with an area of 7.5 km^2 equivalent to about 21 % of the total flood area in built-up one. This zone is projected to increase in about 2.6 times population and to expand into about 1.7 times development area in 2020. For the drainage improvement of N zone expecting a rapid urbanization, the following combination with structural and non-structural measures are proposed to decrease a total project cost.

(a) Utilization of low-lying paddy fields as a natural retarding basin and land use regulation for these areas
(b) Rehabilitation and construction of secondary/tertiary drainage channel, drain and pipe in the right bank basin of Tham Luong - Ben Cat canal
(c) Canal improvement for Tham Luong - Ben Cat and Ben Da - Ba Hong canals
(d) Construction of secondary/tertiary drainage channel and drain for the left bank basin of Tham Luong - Ben Cat canal and Ben Da - Ba Hong basin

It is recommended that the above item (a) & (b) , and (c) & (d) are to be implemented as the short and mid. term program respectively, considering the present and future urbanization and flood conditions in N zone.

(2) W-Zone

Population, future developments and flood area in built-up one in West zone are about 50 % of these in N zone. The proposed measures are almost same as that of N zone.

(a) Utilization of low-lying paddy fields as a natural retarding basin and land use regulation for these areas
(b) Rehabilitation and construction of secondary/tertiary drainage channel, drain and pipe improvement in the eastern region neighboring C zone
(c) Canal improvement for R. Cua - R. Nuoc Len and other canals

(d) Construction of secondary/tertiary drainage facilities in new development areas

It is recommended that the above item (a) & (b), and (c) & (d) are to be executed as the short and mid. term program respectively. Because the urbanization and flood conditions in W zone is almost same as that of N zone.

(3) S-Zone

About 110,000 peoples (3% of a total population in the study area) are living in the existing built-up area of 11.37 km^2 equivalent to about 6% of a total one in the study area, which is mostly southern parts of Doi - Te canal. However, Saigon South Development Project will change the land use from the southern low-lying agricultural land to residential, institutional and industrial park. The following structural and non-structural measures are proposed.

(a) Preservation of land along the existing rivers/canals and land use regulation of low-lying paddy field
(b) Construction of secondary/tertiary drainage channel, drain and pipe in the existing built-up area
(c) Partial improvement of main canals
(d) Construction of secondary/tertiary drainage facilities in newly developed areas

The above items (a) & (b), and (c) & (d) are recommended to implement in short term and mid. or long term programs respectively. Drainage improvement of newly developed areas in Saigon South will be expected by the private investment.

(4) NE-Zone

Almost 120,000 peoples equivalent to 4 % of a total population in the study area are living in Thu Duc region, of which built-up area is about 7 % of a total one in the study area. Up to 2020, about 21 km^2 of high land agricultural area (about 50 % of Thu Duc region) is expected to develop as a residential, institutional, industrial and recreation/refresh area. Some parts have being developed and it is feared to increase the flood risk for the downstream low lands. The proposed measures are as follows:

(a) Land use regulation for high land development and flood control regulation (construction of on-site detention pond) for developers
(b) Land use regulation for low-lying agricultural land and preservation for future requirement of land along the existing canals
(c) Construction and rehabilitation of secondary/tertiary drainage facilities in the existing urbanized areas
(d) Canal improvement adjusting the urbanization
(e) Construction of secondary/tertiary drainage facilities in newly developed areas

It is recommended that the above items (a), (b) & (c), and (d) & (e) are to be executed in short tem and mid. or long term program in view of the flood condition and economic view of non-structural measures.

(5) SE-Zone

The present population of about 160 thousand and urbanized area of about 13.0 km^2 in SE zone is almost same situation as that of NE zone, however topography and land use of SE zone is prominently different because of almost all low flat paddy field. However, inland low-lying areas of about 31 km^2 is projected to develop up to 2020 as a residential, institutional and industrial, which is equivalent to 2.3 times of the existing developed area. Combination with the following structural and nonstructural measures is proposed.

(a) Land use regulation for low-lying paddy field and preservation for future requirement of land along the existing canals
(b) Construction and rehabilitation of secondary/tertiary drainage facilities in the existing urbanized areas
(c) Canal improvement adjusting the urbanization
(d) Construction of secondary/tertiary drainage facilities in newly developed areas

The above items (a) & (b), and (c) & (d) are proposed to implement in short and mid. or long term program respectively. Because the new development in SE zone is expected to start relatively early period, but it takes much time to be fully developed.

6.3.2 Proposed Canal Improvement Plan

(1) Design Discharge

27 drainage catchment areas are divided into several sub-catchment areas based on the existing topographic conditions, road and canal networks as shown in Fig. E.6.20. The design discharges for canal improvement are estimated by the Rational Formula according to the short duration design rainfall of 5-year and 10-year return periods and the projected land use in 2020.

The estimated design discharges for each canal improvement are shown in Tables E.6.14 (1/2) and (2/2), and Figs. E.6.21(1/3) to (3/3).

(2) Proposed Canal Improvement

Most of 27 main canals may be required to have some canal improvements by widening and deepening to increase their conveyance capacity and to maintain the smooth waterway transport, and to have the existing bank reforming to improve the city environment.

Planning concepts for the formulation of optimum plan are summarized as follows:

(a) Target canals for improvement in M/P are identified as 27 canal systems indicated in Table E.3.5.

(b) Main canals with a catchment area of more than 30 km^2 are proposed to improve for 10-year frequency flood. However, the objective canals in suburban area are to be improved in two (2) stages from the economical point of view. In first stage, the canal improvement of 5-year return period is to be executed as a short-term plan. 10-year return period one is to be implemented in second stage on the progression of urbanization as a long-term plan. Main canals in inner city and having a basin of less than 30 km^2 are to be improved at one stage.

(c) Tau Hu canal and the downstream reaches of Tan Hoa - Lo Gom in C zone have to be improved in line with the city environmental improvement program and the water transportation program proposed in the pre-feasibility study conducted by Dept. of Transportation and Public Works (DTAPW). The other canal improvements have to be planned based on the drainage requirement to minimize the project cost. Improvement plans for other drainage systems are designed on only the urban drainage requirements.

(d) Operation and maintenance (O/M) road is to be installed both banks of proposed canals. According to the Vietnamese standard established by Ministry of Transportation (MOT), the required width of O/M roads are stipulated as follows:

* Rural area: 10 m (20 m for newly developed area)
* Urban area: 5 m (10 m for newly developed area)

While for this M/P, O/M road with a minimum width of 5 m including shoulders and excluding a bank slope will be proposed to install on both banks from the technical and economical point of view.

(e) Water surface gradient of the canal will be designed same as the existing ground slope as much as possible. Bed slope of the canal is designed to be same as the proposed water surface gradient.

(f) Considering a design discharge, topography, development situation and difficulty of land acquisition/house compensation, the following five (5) type canal cross sections are proposed.

- Type A: This type will be applied in case that the existing discharge capacity is bigger than the design one. Basically, no improvement works are executed except the construction of O/M road to be provided along

both banks. Reformation of the bank and a grass/sod slope protection will be implemented adjoining the urbanization in view point of the hydraulic and city environmental improvements.

- Type B: This type forms trapezoidal shape with 1:2 slope lined by grass/sod. This type will be mainly applicable for the canal improvement in suburban area, in where land acquisition is relatively not difficult. O/M road is provided along both banks.

- Type C: This type forms trapezoidal shape with 1:1 to 1:1.5 slope lined by stone masonry. This will be applied for the canal improvement in the existing urbanized area where can be acquired the expected land. O/M road is also provided along both banks.

- Type D: This type forms trapezoidal shape with 1:0.5 slope or rectangular shape protected by the reinforced retaining wall. This type will be employed in the existing urbanized area, in where land acquisition is expected to be rather difficult.

- Type E: This is a reinforced concrete box culvert. This type will be applied at the road crossing if the bridge construction is more expensive than this. This type is also employed for the improvement of upstream reaches, which is expected to cover due to bad smell and other environmental problems.

Typical cross section of each type is illustrated in Figs. E.6.22 (1/2) and (2/2).

(g) Since no existing road and railway bridges have had sufficient structural evaluation due to lack of data and information, reconstruction of these bridges will be proposed if the existing bridge length is shorter than the proposed width of the canal.

The proposed longitudinal and cross sections of the 27 canal systems are shown in Tables E.6.15 (1/4) to (4/4). Typical drawings of canal improvement are shown in Figs. E.6.23 (1/6) to (6/6). Summary and breakdown of the proposed canal improvement works are shown in Table E.6.16 and Tables E.6.17 (1/5) to (5/5) respectively.

6.3.3 Proposed Pump Drainage Plan

(1) Pump Drainage Area

As mentioned in the previous section, it was recommended that the gravity discharge system is to be employed for newly developed areas in flood plain of W, S, NE and SE zones by land filling. However, some low-lying areas located at fringe of C-zone,

where are mostly urbanized and difficult to fill up without house relocation, are expected to apply the pump drainage system.

The proposed pump drainage plan covers the following three (3) pump drainage areas.

(a) Thanh Da in C.a catchment area: $A = 0.154\ km^2$
(b) Ben Me Coc (1) in C4 catchment area: $A = 0.709\ km^2$
(c) Ben Me Coc (2) in C4 catchment area: $A = 0.460\ km^2$

(2) Requirement of Pumping Station and Retarding Pond

In order to economize on total pump drainage cost, it is proposed to consider the effect of the retarding basin, which is expected to reduce the required pump capacity. The required pump capacity and storage volume of the retarding pond can be estimated by the specific pump capacity and storage requirement mentioned in Sub-section 6.1.11. The calculation results are as follows:

REQUIREMENT OF PUMP CAPACITY AND STORAGE VOLUME

Item	Pump Drainage Area		
	Thanh Da	Ben Me Coc (1)	Ben Me Coc (2)
Drainage Area (km2)	0.495	0.709	0.460
Specific Pump Capacity (m3/s/km2)	2.1		
Specific Storage Volume (m3/km2)	69,000		
Required Pump Capacity (m3/s)	1.04	1.49	0.97
Required Storage Volume (m3)	34,000	48,900	31,700
(1) Storage Volume of Temporary Inundation Volume (m3)	11,100	15,900	10,300
(2) Storage Volume of Retarding Pond (m3)	22,900	33,000	21,400

Note: Almost 15% of pump drainage area including roads and streets is allowed to have temporary inundation at below 15 cm in depth under the non-flood damage condition.

As shown in Fig. E.6.24, locations of three (3) pumping stations with retarding pond are proposed as follows:

(a) Thanh Da P.S.: Right bank of the Saigon River near the existing retarding pond, which locates at almost center of the drainage area.
(b) Ben Me Coc (1) P.S.: Left bank of Doi canal near the existing pond connected between Doi and Tau Hu canals
(c) Ben Me Coc (2) P.S.: Right bank of Rach Lo Gom canal near the center of drainage area

Fig. E.6.24 shows the typical structural drawing of the proposed pumping station.

(3) Related Structures

The construction of related structures are proposed to bring the following purposes:

(a) Water Gate: to maintain a gravity discharge while the outer water level is lower than inner water level
(b) Dike/Revetment: to prevent from the external flood
(c) Drainage pipe/ditch: to collect the rainwater and convey it to the canal and pumping station

Bill of quantities for the related structures are summarized in Table E.6.18.

6.3.4 Proposed Onsite Detention Pond Plan

For new developments of the high land in three (3) catchment areas (NE.3, NE.4 and NE.5) located on Thu Duc region in NE zone, any developer has to construct a detention pond to regulate flood run-off increased. The specific and total storage requirements of the detention pond in these areas are estimated at 17,000 - 19,000 m^3/km^2 and 50,000 - 530,000 m^3 respectively. Since no concrete development plan is now prepared, assuming that the storage capacity of one detention pond will be 30,000 – 40,000 m^3/pond, the required number of the pond foe each catchment area is estimated at 4, 2 and 12 ponds as shown in the table below:

ONSITE DETENTION POND PLAN IN THU DUC REGION

Item / Zone	Drainage	NE.3	NE.4	NE.5
Drainage Area (km^2)		7.15	2.65	34.38
Development Area (km^2)	1997	2.39	1.50	5.13
	2020	6.25	2.48	21.46
	Difference	3.86	0.98	16.33
Run-off Coefficient (C)	1997	0.50	0.57	0.45
	2020	0.64	0.73	0.57
	Difference	0.14	0.16	0.12
Specific Storage Requirement of Detention Pond (Vs) (x 1,000 m^3/km^2)		17.2	19.0	15.3
Total Storage Requirement of Detention Pond (V = Vs x A) (x 1,000 m^3)		123.0	50.5	526.1

Fig. E.6.25 shows the proposed typical structural drawing of the detention pond. Bill of quantities of the proposed detention pond is shown in Table E.6.19.

6.3.5 Proposed Drainage Pipe Improvement Plan

The principal of drainage development plan is to utilize the existing combined sewer

network to minimize the investment cost and allocate a budget effectively. According to the survey of the existing combined sewer system, most of the system is still functioning well. The development plan of drainage pipe and channel systems to mitigate flooding also takes into account the factors consisting of sewerage development plan, existing combined sewer area and existing/future land use.

Consequently, respective countermeasures are proposed for four (4) area types, which are classified in the forgone section, as shown in the table below and Fig. E.6.27.

DRAINAGE PIPE/CHANNEL SYSTEM DEVELOPMENT PLAN

Area Type	Factor					Proposed Countermeasures
	Sewerage Development Area	Sewerage Collection System	Existing Combined Sewer Area	Land Use		
				Existing	Future	
(A)	Yes	Combined	Fully Covered	Urbanized Area	Urbanized Area	Rehabilitation existing main/ secondary/tertiary combined sewer
(B)-1	Yes	Combined	Partially Covered	Rural / Urbanized Area	Urbanized Area	Install additional main/ secondary/tertiary combined sewer
(B)-2	Yes	Separate	Not Exist	Rural / Urbanized Area	Urbanized Area	Mostly Install open channel for new urbanized part Partially Install drainage pipe for existing urbanized part
(C)	No	-	Not Exist	Rural / Urbanized Area	Urbanized Area	ditto
(D)	No	-	Not Exist	Rural Area	Rural Area	Utilize existing natural drainage system

Based on the above-mentioned criteria of the delineation, the length of the proposed drainage pipe/channel for area without existing combined sewer is estimated as Table E.6.20. The assumption of the estimation is based on the existing condition of the drainage system in District 1 which has been fully covered by drainage system.

The area of type (A) is included in C zone and has the combined sewer system at present. Therefore the rehabilitation plan was made based on the results of the evaluation stated in section 3.6.2. The purpose of the rehabilitation was to improve the drainage capacity of main sewer. In consequence, additional sewers were proposed as shown in Table E.6.21 and Fig. 6.28. The total length of the proposed sewer is estimated at approximately 15 km. Most of them are proposed to be install parallel to the existing sewers having an insufficient capacity.

The length of the proposed drainage pipe/channel by each zone is summarized as the table below

ESTIMETED LENGTH OF DRAINAGE PIPE/CHENNEL

Drainage Zone		Length of Proposed Drainage Pipe/Channel (m)					
Zone Name	Area (ha)	Rehabilitation of Existing Sewer	Main Combined Sewer	Secondary /Tertiary Combined Sewer	Stormwater Sewer	Open Channel	Total
C-Zone	10,641	15,181	375,846	162,528	11,792	214,400	779,747
N-Zone	13,620	-	265,179	114,672	59,697	1,085,400	1,524,948
W-Zone	7,291	-	53,280	23,040	19,536	355,200	451,056
S-Zone	8,174	-	149,073	64,464	33,836	615,200	862,573
NE-Zone	6,491	-	255,855	110,640	35,354	642,800	1,044,649
SE-Zone	11,936	-	294,261	127,248	47,146	857,200	1,325,855
Total	58,153	15,181	1,446,774	625,632	207,361	3,770,200	6,065,148

Note : The length of drainage pipe per area are assumed as follows;

Main Combined Pipe	: 111 m/ha
Secondary/Tertiary Combined Pipe	: 48 m/ha
Stormwater Sewer	: 11 m/ha
Open Channel	: 100 m/ha x both side of road

6.3.6 Proposed Non-structural Measures

(1) Necessity of Non-structural Measures

According to the city master plan in 2020, the present population of about 4.3 million in the study area is projected at about 7 million in 2020, then the existing built-up area of about 170 km^2 will be expanded at almost 2 times of 340 km^2. Urbanization of high lands at northeast and northwest parts and low-lying agricultural areas at west, south and southeast parts in the study area will increase an amount of flood run-off and peak discharge. It can be easily forecasted that flood risk occurring in the central city zone will be expanded to newly developed areas in suburbs. Since structural measures will take much investment and time in rapidly urbanizing city of HCM, it is recommended to employ the comprehensive urban drainage plan including non-structural measures. The proposed non-structural measures are described below.

(2) Identification and Publication of Flood Area

Inundation map is the essential tool for the publication of information on floods. This serves as a guide for stabilizing living conditions for the peoples and future urban development, resulting in mitigation of flood damages. Several inundation maps identified in the past including this study are proposed to distribute the government

agencies and publish to the peoples directly and in directly.

(3) Preservation of Low-lying Area

Low-lying agricultural lands have essentially the potential for storage of rainwater and the function to decrease the peak discharge of storm run-off. A large scale filling-up of these areas for land development will impact instantly to deteriorate the surrounding drainage condition and bring the necessity of much investment for drainage improvement by structural measures. Consequently, it is proposed to preserve the low-lying areas for land development as much as possible and utilize these areas as a natural temporary retarding basin. So, PCHCM has to prepare the appropriate guideline of land use regulation for low-lying areas and to provide the administrative organization suitable as a practical agency.

(4) Preservation of Future Land Requirement of Canal Improvement

Most of the canals in C, N, W and NE zones will require a large scale improvement by widening and dredging including bank protection and O/M road constructions. So, the future land requirement of canal improvement shall be preserved as fast as possible to reduce the cost and time for the land acquisition and house compensation. In addition, any reduction of the existing widths of canals situated in S and SE zones, most of which will not necessary to improve except bank protection and O/M road constructions, shall be strictly controlled and regulated. PCHCM will need to prepare an appropriate guideline and organization.

(5) Flood Proofing Measures of Future Development in Flood Plain

UPI has made a guideline for future development in low-lying areas that the minimum ground elevation after filling up shall be maintained at more than 2 m to employ the gravity discharge system and to prevent from the external flood of surrounding rivers. This will be reasonable guideline in the technical and economical points of view. PCHCM shall guide to the peoples, who live in flood prone areas that houses/buildings shall provide individual flood-proofing measures such as a partial land fill, flood-proof wall, a piloti style house, etc to mitigate flood damage by themselves. Because it will take much time to complete the drainage improvement works.

(6) Flood Control Regulation for New Development in High Land

New developments in high lands, such as Hoc Mon district in N-zone and Thu Duc district in NE-zone, will increase a flood risk for downstream low-lying areas and a cost of canal improvement. So, these developers shall construct a retarding pond, of which requirement varies 17,000 -- 19,000 m^3/km^2, to regulate flood run-off increased by the new development. PCHCM shall prepare a regulation law of flood control for

new development in high land and establish an organization having technical development, investigation and inspection sections.

(7) Strengthening of the existing standing office for flood prevention

The branch office of Water Management and Flood Prevention/Fighting was established in Department of Agriculture and Rural Development in 1996 as a standing office to support the Steering Committee of Flood and Storm Prevention in PCHCM. Organization of this office shall be strengthen to carry out sufficiently his function and responsibilities including the smooth implementation of the proposed non-structural measures.

(8) Flood Forecasting and Warning System

Establishment of appropriate flood forecasting and warning system will be necessary to mitigate a flood damage in the city. The existing hydrological monitoring system in and around the Study area by Southern Region Hydro Meteorological Center (SRHMC) is proposed to improve as follows:

(a) Manual rain gauge of six stations, such as Hoc Mon, Le Minh Xuan, Binh Chanh, Nha Be, Ha Tien and Long Son shall be replaced to the automatic one.
(b) Additional five (5) new automatic rain gauge station shall be established.
(c) Nine (9) water level stations for inland main rivers/canals shall be established.

Details of the proposed hydrological monitoring system are mentioned in Chapter C.

7. PRIORITY PROJECT AND IMPLEMENTATION SCHEDULE

7.1 Priority Sequence and Implementation Schedule

Priority sequence of drainage zone will be decided through comparison of the following factors:

(a) Beneficial population
(b) Required project cost per one beneficial population
(c) Flood condition
(d) Damage to Commercial and institutional activity
(e) Required land acquisition area per one beneficial population
(f) Land use grade
(g) Not duplicate and conflict with other on-going projects

The factors of beneficial population, project cost and land acquisition area can be compared by the common indicators showing efficiency of financial and land resources expenditures; per capita project cost and land acquisition area.

The integrated comparison viewing all the factors is shown the following table:

PRIORITY COMPARISON

Factor \ Zone	C	N	W	S	NE	SE
(a) Beneficial population (1997)	I	III	II	III	IV	IV
(2020)	I	II	III	III	III	III
(b) Required project cost (1997)	I	IV	II	III	IV	IV
(2020)	I	II	I	I	II	I
(c) Present flood condition	I	II	II	II	III	II
(d) Damage to commercial and institutional activity	I	II	III	IV	III	IV
(e) Require land acquisition(1997)	I	III	IV	III	IV	III
(2020)	I	II	II	II	III	II
(f) Land use grade (1997)	I	II	III	III	III	III
(2020)	I	II	III	III	II	III
(g) Economic evaluation (EIIR)	13.07	10.63	6.83	8.70	2.19	9.28
Priority Sequence	First	Second	Second	Third	Third	Second

Note: (a) Beneficial population: I > 20,000 person/flood area (km^2), 10,000 < II < 20,000
5,000 < III < 10,000, IV < 5,000

(b) Required project cost per one beneficial population:
I < 10 million VND, 10 < II < 20 million VND,
20 < III < 30 million VND, IV > 30 million VND

(c) Present flood condition: I: Very serious II: serious III: not so serious

(d) Damage to commercial and institutional activity:
I: Large II: Medium III: Small

(e) Required Land acquisition per on beneficial population:
I < 1 m^2, 1 < II < 5 m^2, 5 < III < 10 m^2, IV > 10 m^2

(f) Present land use grade: I: High II: Medium III: Low

It can be recognized easily that every factor of C-zone will be ranked highest because of its most vulnerable population. So, the drainage zone C will be identified the first priority zone for urban drainage improvement, according to the above comparison. W & N zones, and S, NE & SE zones are identified as second and third priority sequence zones respectively.

(a) First Priority Zone: C
(b) Second Priority Zone: N, W, and SE
(c) Third Priority Zone: S and NE

7.2 Implementation Schedule

An implementation schedule consisting of three (3) phases is tentatively proposed in conformity with the priority sequences mentioned above, project cost of each zone and progression of urbanization of each zone. It is shown in the table below:

TENTATIVE IMPLEMENTATION SCHEDULE

Phase	Zone	1996 - 2000	2001 - 2005	2006 - 2010	2011 - 2015	2016 - 2020
I	C-zone					
II	N-zone					
	W-zone					
	SE-zone					
III	S-zone					
	NE-zone					

7.3 Priority Project Identified for Feasibility Study

The priority drainage zone, C-zone consists of seven catchment areas, C.1 to C.4 and C.a to C.c. As shown in the table below, C.4 catchment is most serious and high priority area because of the largest number of beneficiary for urban drainage improvement. The drainage improvement of C.1 and C.3 are ongoing by the assistance of the World Bank, Belgium Government and Asian Development Bank respectively as shown in Fig. E.4.1. Therefore, the possible priority area for the feasibility study is proposed to be C.4 catchment area including remaining catchment area of C.2, C.a and C.b basins. The F/S report of HCMC Sewerage Project assisted by World Bank, however, indicate that southwest low-lying areas of about 1.3 km^2 in C.2 area, which will be required to apply a pump drainage system due to low ground elevation of below +1.5m, includes in its project area. It is noted that urban drainage improvement works for the flood plain area below +2.0m of R. Cau Bong-R. Cau San basin are not included in Phase 1 project considering its future transition of urban development. It is recognized that C.2 and C.b

are to be under the same situation. Some low-lying residential areas have being filled up in cooperation with residents to mitigate the flood damage and to apply the gravity discharge system. Taking into consideration of the above situation, the possible priority projects are recommended as follows:

(a) Improvement of Tau Hu – Ben Nghe canal of about 12.2 km

(b) Pump drainage improvement for the following three (3) low-lying areas:
- Thanh Da area of 0.495 km^2
- Ben Me Coc (1) area of 0.709 km^2
- Ben Me Coc (2) area of 0.460 km^2

(c) Construction and rehabilitation of drainage pipe in C.4 sub-catchment area of about 30.65 km^2

Location of the proposed feasibility study area is shown in Fig. E.7.1.

IDENTIFICATION OF PRIORITY PROJECT

Catchment		Habitual Flood Condition			Flood Vulnerable Population (person)			Remarks
Name	Area (km^2)	Area (km^2)	Depth (cm)	Duration (hour)	Total	Per Catch-ment Area	Per Flood Area	
C.1	31.85	4.81	37.5	7.0	195,629	6,142	40,689	World Bank
C.2	5.14	1.81	33.5	3.0	33,081	6,436	18,327	
C.3	20.22	4.45	35.5	11.2	157,552	7,792	35,373	Belgium/ADB
C.4	41.31	6.19	40.0	6.1	344,210	8,330	55,643	
C.a	4.91	3.73	68.5	4.0	9,839	12,323	29,611	
C.b	1.29	0.22	42.5	3.1	2,880	2,241	12,973	
C.c	1.68	0	0	0	0	0	0	
Total	106.41	21.20	43.0	6.7	745,188	7,003	35,145	

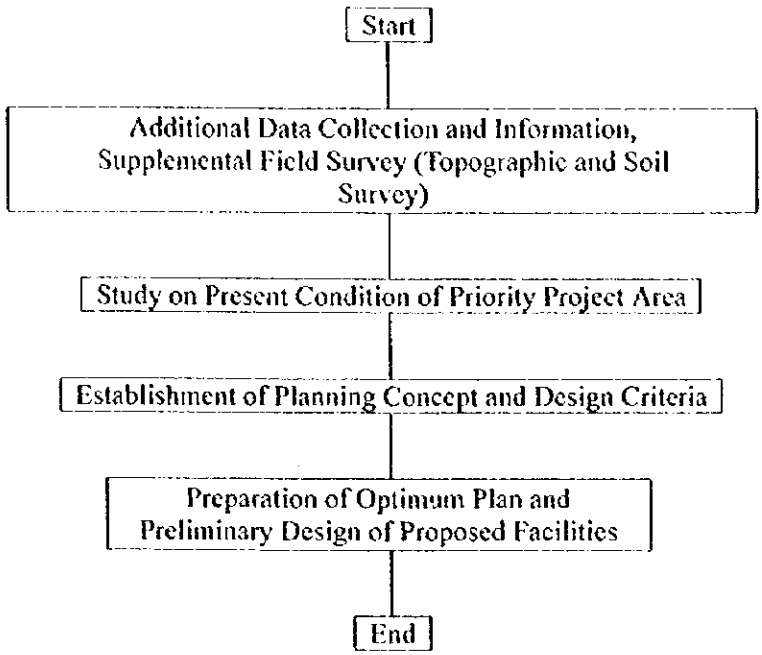
Note: 1. The figures of flood depth and duration mean the average value.

8. FEASIBILITY STUDY OF PRIORITY PROJECT

8.1 General

In Master Plan Study, Tau Hu - Ben Nghe canal improvement, pump drainage improvement for Thanh Da, Ben Me Coc (1) and (2), and drainage pipe development in C4 zone are identified as the priority project for the feasibility study. The feasibility study has been conducted in accordance with the following flow chart.

FLOW CHART OF FEASIBILIY STUDY



8.2 Tau Hu - Ben Nghe Canal Improvement

8.2.1 Present Condition of the Canal

(1) Hydraulic Characteristics

Tau Hu - Ben Nghe canal lies along southern edge of the central business area of HCM City and drains the rainwater, domestic and industrial wastewater from District 1, 4, 5, 6, 8, 10, 11 and Binh Chang District into Saigon River. The canal having a total length of about 12.2 km connects with Ben Luc River to the west and Saigon River to the east. Its hydraulic characteristics (canal bed and bank elevations, width, depth, maximum flow area, wetted perimeter, average hydraulic gradient, velocity and discharge capacity) are updated based on the supplemental canal survey conducted on July 1999. These are shown in Table E.8.1, Fig. E.8.1 and summarized below.

(a) Canal Bed and Dike Crown Elevation

Bed elevation of Ben Nghe canal, which varies from -1.82 to -2.72 m above MSL, is very shallow due to much sedimentation consisting of dumped soil, garbage,

solid waste, debris and organic materials. Tau Hu downstream reaches of about 4.2 km long from Chu Y Bridge to the junction with Ngang No.1 canal are also very shallow. The bed elevation from -1,50 to -2.98 m is almost the same variation as that of Ben Nghe canal. Upstream reaches of Tau Hu canal with elevation from -3.06 to -3.82 m are relatively deep, however, still shallow for navigation of the boat with 300 tons during low tide.

The dike crown elevations of Ben Nghe and Tau Hu downstream reaches vary from +1.3 to +1.9 m, which is almost same or higher than the design high water level (D.H.W.L.) of +1.32 to +1.50m. However, existing dikes in some sections of Tau Hu upstream reaches are lower than D.H.W.L. of +1.50 to +1.6 m. Accordingly, during high tide season from September to January, flood waters have overflowed from some low bank to the low-lying inland.

(b) Canal Width

Average original canal width of Ben Nghe might be about 60 and 70 m in upstream and downstream reaches respectively, according to the topographic map with 1:5000 provided in Saigon Sewerage Feasibility Study in 1972. However, due to the encroachment of more than 7,800 illegal houses and buildings constructed on and along the canal before 1975, the present width from midstream to upstream reaches of Ben Nghe have become narrowed from 30 to 40 m, resulting in a greater hindrance to the smooth navigation.

The width of Tau Hu upstream and downstream reaches might originally be 45 to 50 m and 40 to 60 m respectively. Due to the encroachment of illegal houses and buildings to the water course, the width of some sections has been reduced to about 30 m. Execution of the relocation program is expected for the improvement of storm water drainage, waterway transportation and water environment including landscape.

(c) Velocity and Discharge Capacity

Tau Hu - Ben Nghe canal has always strongly affected by tidal influence from the East Sea. The tide amplitudes are quite high. The average tide amplitudes at Phu An station near the mouth of Ben Nghe canal ranges from 1.7 to 2.5 m. Therefore, flow direction and velocity of the canal always vary based on the water levels of surrounding rivers, especially Saigon and Nha Be rivers. Maximum and minimum velocity is surveyed at about 0.5 and 0.35 m/sec respectively, which are evaluated by the hydraulic dynamic simulation. The existing discharge capacities of Tau Hu - Ben Nghe canals during the high tide are estimated at 30 to 150 m^3/sec under the steady flow condition.

(2) Water Environment

Tau Hu - Ben Nghe canal receives untreated domestic and industrial wastewater with about 300,000 m^3/day from the surrounding districts excluding Tan Hoa - Lo Gom basin and water quality of the canal has been deteriorated to an alarming level. The canal water is black in color and emanates offensive odor. At Chu Y Bridge, Tau Hu canal has BOD as high as 150-250 mg/l and Fecal Coliforms is of the order of 2.1 E+0.5 MPN/100ml. Water quality is comparatively better in Ben Nghe canal due to dilution by Saigon River and BOD is about 100-150 mg/l but still quality of canal is

similar to wastewater. The fecal contamination has already led to higher incidence of water-borne diseases in District 5,6 and 8. Sludge accumulated at the bottom of canal is undergoing an aerobic degradation and emanates offensive odor of CH_4 and H_2S. Investigation of sludge showed that heavy metals are present but still sludge can pass EU regulations and Japanese standards for heavy metals in the sludge to be disposed on land. Present water quality condition of Tau Hu - Ben Nghe canal is shown in Table E.8.2.

Supplemental water quality test at eight (8) sites of Tau Hu - Ben Nghe canal has being made in Environmental Impact Assessment (EIA) study.

(3) Encroachment by Illegal House and Building

According to the 1996 survey data by the Department of Land and Housing, the number of residents on and along Tau Hu - Ben Nghe canal including the tributaries is reported about 65,000 with 7,800 households as shown in the table below. Among them, illegal houses account for 80% and most of them encroach on the canal water. Almost half of them have been living in the low level or temporary houses of this area without electricity and water supply services for more than 20 years. Many houses can be seen constructed on the accumulated garbage in the canal and disturb the storm water drainage and navigation. The part of Tau Hu canal in District 5 has the highest density of houses followed by the Ben Nghe canal on the side of District 1. There are many boats floating on the lower part of Ben Nghe canal of the District 1 and on the side of District 5 of Tau Hu canal. Compared with Ben Nghe canal, Tau Hu canal has more warehouses, small workshop, markets and unloading stations of the shipment. Most of the poor peoples living on and along the canals are labor workers such as porters, cyclo drivers. These jobs are often irregular and have low income. Details of relocation for illegal houses and buildings are mentioned in Appendix I.

SUMMARY OF RESIDENTS ALONG TAU HU - BEN NGHE CANALS

Item	Number
Total Residents (persons)	65,218
Total Households (households)	7,832
Share of Illegal Households (%)	80.8
Houses located in less than 5 m from the bank (houses)	5,921 (80.2%)
Houses constructed before 1975 (houses)	3,679 (49.8%)

Source) Department of Land and Housing (Survey of Households on and Along Canals in Inner City of HCM City, 1996)

(4) Related Structures

There are four (4) relevant structures on and along the canal. These are electric cable, bridge, quay and bank protection/revetment.

(a) Electric Wire

Fourteen (14) power lines in total have been installed over and/or under Tau Hu - Ben Nghe canal including Ngang No.1 to No.3 canals. These are as follows:

Canal	Number of Line	Voltage	Location
Ben Nghe	4	Medium	Over the canal (2 lines) Underground (2 lines)
Tau Hu	7	2 lines: High 2 lines: Medium	Over the canal
Ngang No.1	1	Medium	Over the canal
Ngang No.2	1	Medium	Over the canal
Ngang No.3	1	Medium	Over the canal

Location and dimension of each power line is shown in Fig. E.8.2 and Table E.8.3 respectively.

(b) Bridge

There are fifteen (15) existing and one (1) under constructing bridges on the Tau Hu - Ben Nghe canal and Ngang No.1 to No.3 as shown in Fig. E.8.2. Out of these bridges, seven (7) bridges were constructed by reinforced or pre-stressed concrete. The remaining nine (9) bridges are steel one. Mon and Ong Lanh bridges are not in use, because the superstructure has been damaged. Mon Bridge is being rehabilitated as a historical structure. Main structural features of the existing bridges are shown in Table E.8.4. Replacement of the existing bridges will not be proposed, unless these bridges block or obstruct for flow of the canal.

(c) Quay Structure

According to OWM, seven (7) quays are operating along Tau Hu - Ben Nghe canal, in which two (2) quays is in Ben Nghe canal and the remaining five (5) are along Tau Hu canal. Name, location, length and loading/unloading goods of each quay are summarized in the table below.

SUMMARY OF QUAY ALONG TAU HU - BEN NGHE CANALS

No.	Name	Location	Length (m)	Loading/Unloading Good
Q.1	No.5	Ben Nghe	70	foodstuff, agricultural product
Q.2	No.6	ditto	100	ditto
Q.3	No Name	Tau Hu	30	construction material (sand)
Q.4	No Name	ditto	30	ditto
Q.5	No.2	ditto	120	
Q.6	Tran Van Kieu	ditto	2,000	foodstuff, agricultural product, fertilizer, construction materials
Q.7	Ben Binh Dong	ditto	2,200	ditto

Note: Locations of these quays are shown in Fig. E.8.2.

(d) Bank Protection/Revetment

Ben Nghe canal has no existing sufficient bank protection or revetment except near mouth of the canal. These have been constructed by stone masonry with the slope of 1:3, of which length is about 60 and 160 m for the left and right bank respectively.

Some kinds of bank protection or revetment are fund out along Tau Hu, Lo Gom and Ngang No.2 canals. These facilities have been rehabilitated and newly constructed by OMW based on the navigation requirements. Locations of the existing bank protection/revetment are summarized below and shown in Fig. E.8.2.

- right bank of downstream reaches from Cha Va Bridge: about 400 m
- right bank of downstream reaches from Ngang No.1 canal: about 450 m
- both banks of downstream reaches from Chu U Bridge: about 600 m
- right bank from the confluence of Ngang No.2 canal to Chu U Bridge: about 550 m
- right bank from the confluence of Lo Gom to Ngang No. 2 canals: 1,000 m
- both banks near the confluence of Doi canal: about 200 m

Some sections of these facilities are, however, eroded, damaged and collapsed due to their long use, some poor quality, and collide with boats. These are needed to rehabilitated or replaced to new one. Table E.8.5 shows the summary of existing bank protection/revetment and their structural evaluation.

8.2.2 Related On-going Project

There are two (2) related on-going project for preparation of Tau Hu - Ben Nghe canals improvement plan. These are summarized as follows:

(1) Dredge and Rehabilitation Project on Ben Nghe - Tau Hu - Lo Gom for Navigation

Office of Waterway Management (OWM) has completed the feasibility study on the Project to Dredge and Rehabilitate Ben Nghe - Tau Hu - Lo Gom for Navigation in December 1995. The main objectives of the project are as follows:

- to dredge the canal in order to recover the enough draft for the navigation
- to contribute as much as possible for the improvement of urban drainage condition in the central parts of the city

The proposed project is summarized below:

(a) Name of Project: Improvement if Ben Nghe - Tau Hu - Lo Gom canal
(b) Implementation Agency: Waterway Unit under the management of Transportation and Public Works Service
(c) Location of the Project: District 1, 4, 5, 6 and 8
(d) Main Construction Item
- Length to be Dredged: Ben Nghe canal : L = 3.45 km
  Tau Hu canal : L = 6.30 km
  Lo Gom canal : L = 2.75 km
  Ngang No. 1, 2 and 3 : L = 1.35 km
  Total : L = 13.85 km
- Minimum Width of Canal to be Dredged
  * Ben Nghe canal (Saigon River – Chu Y Bridge) : W = 21.0 m
  * Tau Hu canal (Chu Y Bridge – Ngang No. 1) : W = 21.0 m
  * Tau Hu/Lo Gom canal (Ngang No.1 – Phu Dinh) : W = 22.0 m
- Design Water Level : H = -1.20 m
- Minimum Draft for Boat Navigation : H = 2.1 m and 3.1 m
- Design Canal Bed Elevation
  * Ben Nghe canal (Saigon River – Chu Y Bridge) : EL = -3.30 m
  * Tau Hu canal (Chu Y Bridge – Ngang No. 1) : EL = -3.30 m
  * Tau Hu/Lo Gom canal (Ngang No.1 – Phu Dinh) : EL = -4.30 m
- Total Dredging Volume : V = 1,043,513 m^3

(e) Project Implementation Period : T = 2 years

(f) Project Cost: Construction Cost : C1 =33,246 million VND
Contingency and Others : C2 = 3,200 million VND
Total : C3 =36,446 million VND

(g) Source of Fund: PCHCM City

PCHCM City has approved the proposed project on 9 April 1998. According to OMW, the dredging will be started at August 1999.

(2) Rehabilitation and Widening of Ben Chuong Duong – Ben Ham Tu – Tran Van Kieu Road

In 1995, Department of Transportation and Public Works (DTPW), PCHCM has conducted the feasibility study on the rehabilitation and widening project of Ben Chuong Duong - Ben Ham Tu - Tran Van Kieu Road. The existing road with total length of 9,92 m runs along and close to Tau Hu - Ben Nghe canal through the District 1, 5, 6, 8 and Binh Chang District and mainly functions as a regional road. These roads were constructed in the French colonial time, so the road is very narrow, only 6 to 10 m in width. DTPW has proposed to rehabilitate and widen these roads in order to create a new urban road, to meet with the transport requirement for the communication between Northeast and Southwest regions of the city and to contribute the improvement of city traffic condition.

The proposed project as shown in Fig. E.8.3 is summarized as follows:

(a) Name of Project: Feasibility Study on Ben Chuong Duong - Ben Ham Tu - Tran Van Kieu - Ben Nghe - Ham Tu Road Across Lo Gom Canal Linking With N.H.1A

(b) Implementation Agency: Department of Transportation and Public Works, PCHCM

(c) Location of the Project: District 1, 5, 6,8, and Binh Chang District

(d) Main Construction Item:

- Length to be improved: Ben Chuong Duong Road : L = 2.675 km
  Ben Ham Tu Road : L = 2.795 km
  Tran Van Kieu Road : L = 3.622 km
  Lo Gom Bridge - N. H. No. 1 : L = 4.258 km
  Total : L = 13.350 km
- Proposed width Ben Chong Duong Road : W = 35.5 – 42.5 m
  Ben Ham Tu Road : W = 35.5 – 36.5 m
  Tran Van Kieu Road : W = 23.5 – 42.0 m
  Lo Gom Bridge – N. H. No. 1 : W = 40.0 m
- Bridge Construction: Five (5) bridges (Ba Do, Quoi Duoc, Lo Gom, Rach Cay Canal, and Nuoc Len Canal bridges)
- Other Works: Surface Water Drainage, Canal Bank Protection, Underground Structure, Lighting and Tree Planting System, and Traffic Safety System

(e) Relocation Program

- Number of house to be removed: 4,650 houses
- Number of house to be resettled: 3,745 houses
- Number of house to be resettled by the inhabitants: 905 houses

(f) Project Cost: Construction Cost: 373,600 billion VND
Compensation and Removal Cost: 538,452 billion VND
Total Cost: 912,052 billion VND

(g) Source of Fund:	Construction:	OECF Loan
	Technical and social infrastructures	
	Of the resettlement areas:	OECF Loan
	Compensation, site clearance and	
	Resettlement area construction:	PCHCM City

This project has been short-listed as a priority project by the financial assistance of Japanese Government. Special Assistance for Project Formation (SAPROF) Study has being undertaken by Overseas Economic Cooperation Fund (OECF).

8.2.3 Planning Concept and Design Criteria

(1) Target Year

Target completion year of the canal improvement project is set at 2010 on the premises that the proposed project implementation will be taken up at least 10 years. However, all the plans are to be prepared to meet the city development plan in 2020.

(2) Design Scale

Design scale for Tau Hu - Ben Nghe canal improvement is applied at 10-year frequency flood, because these are main canals with total catchment area of more than 30 km^2.

(3) Design Rainfall

The following rainfall intensity-duration formula is to be employed as a design rainfall for Tau Hu - Ben Nghe canal improvement.

(a) $I = 29{,}125/(t^{1.25} + 154)$: $t < 3$ hours
(b) $I = 1{,}669/(t^{0.80} - 16)$: 3 hours $< t <$ 24 hours
where, I: Point rainfall intensity (mm/hour)
t: Duration (minutes)

For flood run-off analysis, the area reduction factor shown in Fig. E.6.7 is to be considered to convert the basin design rainfall intensity.

(4) Design High Water Level

Design High Water Level (DHWL) at the mouth of Ben Nghe canal is applied at +1.32 m above MSL, which is the average of monthly maximum water levels during August and November. Design 24 hours consecutive water level variation is employed as the same one as that of Master Plan study.

(5) Navigation Requirement

The canal improvement plan of Tau Hu - Ben Nghe have to meet the following waterway transportation requirements proposed by OMW.

NAVIGATION REQUIREMENTS FOR TAU HU - BEN NGHE CANALS

Canal	Section Start	Section End	Min. Canal Width (m)	Design Water Level (m)	Proposed Canal Bed Elevation (m)	Boat Size (ton)
Ben Nghe	Saigon River	Chu Y Bridge	21.0	- 1.20	- 3.30	100 - 200
Tau Hu (Downstream)	Chu Y Bridge	Ngang No.1	21.0	- 1.20	- 3.30	100 – 200
Tau Hu (Upstream)	Ngang No.1	Phu Dinh Port	22.0	- 1.20	- 4.30	300
Ngang No.1 to No.3	Tau Hu Canal	Doi Canal	22.0	- 1.20	- 4.30	300

Note: DWL of -1.20 m corresponding to 90% frequency for the navigation possibility was determined based on the alternative study conducted by OMW.

(6) Other Criteria

Other criteria, such as run-off formula, Manning's roughness coefficient, freeboard, are the same as those of Master Plan study.

8.2.4 Alternative Study

According to the navigation requirements prepared by OMW, the bed elevation of Tau Hu downstream reaches from Chu Y Bridge to Ngang No.1 is proposed to be 1.0 m higher than that of upstream reaches. Considering more steady flow of the downstream reaches, the following alternative study has been carried out.

(a) Alternative I: Minimum bed elevation of Tau Hu downstream reaches is to be -3.30 m, which is proposed by the navigation requirements
(b) Alternative II:Minimum bed elevation of Tau Hu downstream reaches is to be - 4.30 m, which is the same as that of the upstream reaches

Alternative study has been conducted under the following hydrological and hydraulic conditions:

- Canal Network: Ben Nghe - Tau Hu - Lo Gom - Doi - Te canal network including Ngang No.1 to No.3
- Catchment Area: Independent catchment with total area of 61.72 km^2 including Tan Hoa - Lo Gom basin
- DHWL : 1.32 m at the mouth of Ben Nghe and Te canals
- Design Rainfall: 10-year return period
- Status of Canal:
  * Ben Nghe - Tau Hu - Lo Gom canals: after completion of improvement
  * Ngang No.1 to No.3 canals: after completion of improvement
  * Doi - Te canals: existing condition
- Calculation Method: Hydrodynamic simulation model of MIKE 11

Comparative studies of the above Alternatives conclude that Alternative I is more feasible option. Because, the construction cost of Alternative II is estimated at 11.96 billion VND higher than that of Alternative I, even if hydraulic effect of Alternative II can be expected only 1 to 2 cm lower water level than that of Alternative I as shown in

Fig. E.8.4.

COST COMPARISON OF ALTERNATIVES I and II

(unit of cost: billion VND)

Alternative / Item	Alternative I		Alternative II	
	Quantity	Cost	Quantity	Cost
1. Dredging	335,830 m^3	45.34	424,450 m^3	57.30
2. Bank Protection (Type A)	29,709 m^2	16.56	29,709 m^2	16.56
(Type B)	8,720 m^2	12.55	8,720 m^2	12.55
(Type C)	4,200 m^2	15.50	4,200 m^2	15.50
Total		89.95		101.91

Note: Construction cost of O/M road and land acquisition/house compensation cost is excluded.

8.2.5 Proposed Optimum Canal Improvement Plan

(1) Alignment

The alignment of the courses of Tau Hu - Ben Nghe canal is proposed considering the following technical point of view:

(a) to coincide with the existing channel alignment to minimize land acquisition and house evacuation
(b) to ensure the curve within the radius from 200 to 300 m for the smooth navigation
(c) not to reduce the existing canal width
(d) to coincide the road alignment proposed in the pre-feasibility study of Ben Chuong Duong – Ben Ham Tu – Tran Van Kieu Road improvement project

The proposed alignment of Tau Hu – Ben Nghe canal is shown in Fig. E.8.5. More detailed proposed alignments are compiled in Volume 4 "Drawings".

(2) Longitudinal Profile

As mentioned before, the proposed canal bed has to be designed principally to meet the requirements of waterway transportation. The canal bed slope is planned at 1:20,000 to maintain the canal bed and to be more gentle hydraulic gradient of DHWL, which is nearly equal to or lower than the existing ground level in principle so as not create drainage problems inside the embankment.

The proposed longitudinal profile of Tau Hu - Ben Nghe canal is shown in Table E.8.6 and Fig. E.8.6.

(3) Cross Section

A single cross section with some slope protection and/or revetment is employed for the canal improvement to be protected from bank erosion. The proposed cross sections are classified broadly into the following three (3) types:

(a) Type A: Trapezoidal shape channel with 1:1.5 slope lined by stone masonry

(b) Type B: Trapezoidal shape channel with 1:0.5 slope lined by stone masonry

(c) Type C: Rectangular shape channel lined by concrete retaining wall or concrete pile revetment

These types are sub-divided into the following several types considering the combination with the available existing slope protection and revetment.

CLASSIFICATION OF TYPE OF PROPOSED CROSS SECTION

Type	Shape	Slope Protection/Revetment		Remarks
		One Side of Bank	Other Side of Bank	
A.1	Trapezoid	New one having 1:1.5 shape lined stone masonry	New one having 1:1.5 shape lined stone masonry	This is most typical type.
A.2	ditto	ditto	Existing bank having no slope protection or revetment	This type is employed at junction with Doi, I.o Gom and Ngang 1 to 3 canals
A.3	ditto	ditto	Existing bank protected by stone masonry with 1:1.5 shape	This type is employed to some reaches of Tau Hu canal.
A.4	ditto	ditto	Existing bank protected by vertical concrete revetment	This type is also employed to some reaches of Tau Hu canal.
B.1	ditto	New one having 1:0.5 shape lined stone masonry	New one having 1:0.5 shape lined stone masonry	This is applied for some narrow reaches of Tau Hu canal.
B.2	ditto	ditto	Existing bank protected by stone masonry with 1:1.5 shape	ditto
B.3	ditto	ditto	Existing bank protected by vertical stone or concrete pile revetment	ditto
C.1	Rectangle	New one having vertical concrete retaining wall	New one having vertical concrete retaining wall	This type is employed for some very narrow reaches of Tau Hu canal
C.2	ditto	ditto	Existing bank protected by vertical stone or concrete pile revetment	ditto

Figs. E.8.7 (1/2) and (2/2) show the proposed typical cross sections for canal improvement. Table E.8.7 and Figs. E.8.8 (1/5) to (5/5) show the proposed design cross section. Details of the design cross sections are compiled in Volume 4 "Drawings".

(4) Operation and Maintenance Road (O/M Road)

Generally, O/M road has to be provided along the river/canal to supervise and maintain the channels. The existing roads along both banks of Tau Hu - Ben Nghe canals have sufficient structural features for using as public and also O/M road, even though some sections are slightly narrow. Consequently, it is not necessary to provide newly O/M road along the canal.

However, Tau Hu - Ben Nghe canal improvement aims to improve not only urban drainage and waterway transportation, but also water body environment and landscape of the city. So, in order to maintain the amenity of water body environment it is proposed to provide principally open space of maximum 5.0 m in width along both banks of the canal, in which tree planting and installation of some facilities for recreation/relaxation are recommended as shown in Fig. E.8.9.

According to the pre-feasibility report of Ben Chuong Duong - Ben Ham Tu - Tran Van Kieu Road Improvement Project, the proposed boundary line between near Chu Y Bridge to the junction with Tan Hoa - Lo Gom canal is mostly touched with existing edge of the canal. Therefore, in detailed design stage, it will be necessary to coordinate the boundary lines proposed by both projects.

(5) Slope Protection and Revetment Facility

In due consideration of structural and economical aspects and easiness of land acquisition and house evacuation, the following three (3) types of slope protection and revetment are preliminarily designed.

(a) Type A: This is the slope protection lined stone masonry with 1:1.5 slope, which is the most typical type and applied for the channels having no land acquisition and house evacuation problems. Stone with mortar having a thickness of 30 cm is supported with concrete of 10 cm in thickness. Geo-textile sheet is provided to protect outflow of filling materials (red soil) with a thickness of 30 cm. In order to drain out groundwater, PVC pipe with 100mm diameter is provided at interval of 1.2m. Reinforced concrete foundation with width of 60 cm and height of 50 cm is supported by wooden piles of 100 mm in diameter. Riprap with 5.0 m in width and 50 cm in thickness is provided to cope with scouring around the concrete foundation.

(b) Type B: This is the slope protection lined stone masonry with 1: 0.5 slope. This type is applied for channel improvement from Cha Va Bridge to the junction of Ngang No.1 (about 1.2 km) and from Chu U Bridge to Ngang No.2 (about 0.6 km), which have a restriction of land. The structure of this type is basically the same as that of Type A except a thickness of stone masonry (45 cm)/ concrete (15cm), a size of reinforced concrete foundation (800 x 600) and materials of foundation pile (concrete pile).

(c) Type C: This is reinforced concrete revetment lined T-shaped concrete retaining wall of 4.5 m in height. This type is employed for the channel improvement near Cha Quan Hospital of 525 m in length, which has strict limitation of land. Because the canal has a width of only 40m and then the proposed boundary line of road rehabilitation and expansion project is almost the same as that of the existing left bank. There is no space to apply the revetment with some slope and also open space. T-shaped concrete retaining wall is supported by the concrete pile (300 x 300 x 12,000). Riprap is also provided to protect scouring near the base of retaining wall.

Fig. E.8.9 shows the structural design of proposed slope protection and revetment including green open space.

8.2.6 Evaluation of Proposed Canal Improvement Plan by Hydrodynamic Model

(1) Model Set Up

Hydrodynamic simulation has been carried out to evaluate the proposed canal

improvement plan against 10-year return period rainfall event and Design Flood Level condition. Danish Hydraulic Institute's "MIKE 11" software has been used. The canal network for hydrodynamic model is shown in Fig. E.8.10. The hydrodynamic model has been set up for seven canals. They are: Tau Hu - Ben Nghe canal (12.175 km), Doi - Te canal (13.11 km), Ngang 1 canal (0.42 km), Ngang 2 canal (0.43 km), Ngang 3 canal (0.43 km), Xom Cui canal (1.28 km) and Ong Lon canal (1.40 km). Nine runoff hydrographs with total catchment area of 61.72 km^2 have been applied. Details of the sub-catchments with runoff hydrographs are presented in Table E.8.8. Symmetric triangular unit hydrograph with base time of 2*time of concentration which produces peak runoff same as calculated by Rational method has been applied for runoff hydrograph generation. Average specific runoff is calculated to be about 10 $m^3/s/km^2$. Same runoff hydrographs (under future land use condition) have been used for evaluating both existing and proposed canal conditions.

Hydraulic evaluation has been made on both existing and proposed canal conditions. As for existing canal condition, JICA surveyed (June-August, 1999) cross-sections of Tau Hu - Ben Nghe, Ngang 1, Ngang 2 and Ngang 3 canals have been used. As for proposed canal condition, two alternatives have been considered. Compared to Alternative II, Alternative I represent higher canal bed elevation with lesser excavation.

Considering low velocity along the southern canals, a phase lag of one hour has been applied between the amplitudes of dynamic water levels along the Saigon River and the southern canal boundaries.

Manning's roughness co-efficient of 0.035 and 0.025 have been used for existing and proposed canal conditions. A space step of 50 m and a time step of 15 seconds have been applied for hydrodynamic simulation.

(2) Model Cases

In total, four cases with nine sub-cases for existing canal condition and 10 sub-cases for proposed canal condition have been investigated. Detail listing of the cases for hydrodynamic simulation is presented in Table E.8.9. In brief:

Case 1: Represents closed canal system (without interaction with southern canals) with constant water levels at the boundaries.

Case 2: Represents closed canal system with dynamic water levels at the boundaries. Depending on the time lag between the peak rainfall intensity and the amplitude of the dynamic water level, three sub-cases namely Case 2A, 2B and 2C have been investigated.

Case 3: Represents open canal system (with interaction with southern canals) with constant water levels at the boundaries. Depending on whether amplitude of dynamic water level along the Saigon River would be higher or lower than that along the southern canals, two sub-cases namely Case 3A and 3B have been considered.

Case 4: Represents open canal system with dynamic water levels at the boundaries. Depending on the time lag between the peak rainfall intensity and the amplitude of the dynamic water level, three sub-cases namely Case 4A, 4B and 4C have been investigated.

Since, simulation results for Cases 1A and 1B (as will be discussed later) show that proposed canal improvement plan as of Alternative I would be the optimum one, hence, for the Cases 2, 3 and 4, simulation has been carried out only for Alternative I.

(3) Simulation Results

Maximum discharges, water levels and velocities for all the sub-cases at selected locations along all the canals are summarized in Tables E.8.10 and 11 for existing and proposed canal conditions respectively (please refer to Fig. E.8.13 for the locations). Maximum water level profiles for existing and proposed canal conditions for all the sub-cases are shown in Figs. E.8.11 and 12 respectively. Discharge hydrographs under proposed canal improvement plan (Alternative I) at selected locations along the canals for five sub-cases that best represent discharge distribution are presented in Figs. E.8.13 (1/5) to (5/5). Since, the discharge distribution for existing canal condition would be similar to that for proposed canal condition, discharge hydrographs for existing canal condition is not presented.

For any case and under any canal condition, maximum water level is always found to be at the junction of Tau Hu canal with Lo Gom canal. In terms of maximum water level, the following cases are found to be critical:

- Among Cases 2A, 2B and 2C: Case 2B i.e. peak rainfall intensity occurring at 12^{th} hour appears to be critical.
- Among Cases 3A and 3B: Case 3A i.e. amplitude of dynamic water level along the Saigon River higher than that along the southern canals appears to be critical.
- Among Cases 4A, 4B and 4C: Case 4B i.e. peak rainfall intensity occurring at 12^{th} hour appears to be critical.

(a) Existing Canal Condition:

Simulation results (Fig. E.8.11) show that upstream and some part along downstream of Tau Hu canal is expected to be inundated during a 10-year rainfall event. Under the most severe Case 1A, maximum water level (Table E.8.10 (1/2)) is found to be EL. +1.89m. However, under the most practical Case 4B that is found to be EL. +1.68 m. In general, maximum water levels for different cases are found to be 20 cm higher under the existing canal condition than under proposed canal condition.

Maximum discharges (Table E.8.10 (1/2)) along Tau Hu and Ben Nghe canals are found to be +132 m^3/s and +123 m^3/s for Cases 2C and 4C respectively. In general, maximum discharges for different cases are found to be lower under the existing canal condition than under proposed canal condition. Maximum discharges along Doi and Te canals are found to be +522 m^3/s and +691 m^3/s for Cases 2C and 4C respectively

Maximum velocities (Table E.8.10 (2/2)) along Tau Hu - Ben Nghe canal are found to be +1.55 m/s and -0.91 m/s for Cases 2C and 4C respectively. In general, for different cases, maximum positive velocities are found to be higher under the

existing canal condition than under proposed canal condition (due to higher hydraulic gradient) and vice versa.

(b) Proposed Canal Condition:

The results of simulation (Table E.8.11 and Fig. E.8.12) show that the maximum water levels along Tau Hu - Ben Nghe canal for Alternative I (EL. +1.69 m) and Alternative II (EL. +1.67m) are almost the same. Since, Alternative I has a higher bed elevation representing lesser excavation, Alternative I is adopted as the optimum canal improvement plan.

Under the most severe Case 1A, maximum water level (Table E.8.11 (1/2)) is found to be EL. +1.69m. However, for under the most practical Case 4B that is found to be EL. +1.50m. For the Cases 1 and 2 that represent closed canal system (most severe cases), a free board of 30 to 35 cm can be maintained from the proposed dyke level of EL. +2.0m. On the other hand, for the Cases 3 and 4 that represent open canal system (more practical cases), a free board of more than 40 cm can be maintained from the proposed dyke level of EL. +2.0 m.

Maximum discharges (Table E.8.11 (1/2)) along Tau Hu and Ben Nghe canals are found to be +168 m^3/s and +275 m^3/s for Cases 2C and 4C respectively. Maximum discharges along Doi and Te canals are found to be +548 m^3/s and -662 (+654) m^3/s for Cases 2C and 4C respectively.

Maximum velocities (Table E.8.11 (2/2)) along Tau Hu - Ben Nghe canal are found to be +1.00 m/s and --1.21 m/s for Cases 2C and 4C respectively.

Even though, it's quite difficult to identify a generalized flow distribution along the canals, attempt has been made to identify the most probable flow direction under joint probability of high water level with high rainfall intensity and is presented in Fig. E.8.14. The flow distribution has been identified through compilation of hydrodynamic simulation results for different cases.

(4) Conclusion

The hydrodynamic simulation reveals that under the existing canal condition, inundation is expected to occur along the Tau Hu canal for a 10-year rainfall event. However, under the proposed optimum canal improvement plan (Alternative I), a free board of more than 40 cm can be maintained from the proposed dyke level of EL. +2.0 m.

8.3 Pump Drainage Improvement

8.3.1 Present Condition of Pump Drainage Area

(1) Thanh Da Area

Thanh Da drainage area of about 49.5 ha is triangular shape surrounding by Thanh Da River to the west and Saigon River to the north and south as shown in Fig. E.8.15. The area belongs to Ward 27 of Binh Thanh District. Almost 90% of the area have been development before 1975 as a residential area consisting of many high story apartments and few independent houses. Remaining 10% of the area is low-lying and still

undeveloped, however, will be developed as a residential area near future, according to the officials of Binh Thanh District. The present population of 17,700 is projected at 20,900 in the target year of 2020.

Systematic drainage pipe network system in Thanh Da area has been prepared before 1975 as sown in Fig. E.8.15. The northern part of 20.0 ha from Xo Viet Nghe Tinh Road, of which average ground elevation is about 1.30 m above MSL, drains directly into Saigon River through four (4) trunk sewers and has no inundation problems. However the southern area from this road, in which four (4) main sewers of o800 to o1000 mm has constructed, has flooded at least ten times at the high tide between September and January per year, due to low ground elevation of 0.90 to 1.20 m above MSL. Inundation area, depth and duration has been surveyed at about 16 ha, 30 to 50 cm and four (4) hours respectively. In the past, one small pumping station had been constructed and operated, however, it was damaged and broken, due to the budgetary problem for the sufficient operation and maintenance work. The Petro Viet Nam property situated at southwest part of the area is protected from the external and internal flood by own dike and pump drainage system. According to Binh Thanh District, the undeveloped low-lying area along Thanh Da River is planned to fill up and to employ the gravity discharge system. Therefore, the southern low-lying part of 15.4 ha is proposed to apply the pump drainage system to solve the inundation problems.

According to the field reconnaissance together with the officials of Ward 27 and Binh Than District, most of all sewers are blocked by garbage, solid disposal and debris, which is one of the cause of serious inundation. Cleaning of the sewer pipes shall be done immediately. Moreover, some houses and restaurants have occupied on the sewer outlets in the northern drainage area, resulting into the difficulty of sufficient operation and maintenance work. Relocation and resettlement has to be implemented at once.

(2) Ben Me Coc (1)

Ben Me Coc (1) drainage area of 70.9 ha belong to Ward 15 of District 8 located at southwest of the city. The area is rectangular shape surrounded by Tau Hu, Lo Gom, Ngang No.2/No.3 and Doi canals and is divided into two (2) parts, eastern and western parts, by the pond as shown in Fig. E.8.15. The eastern part of the area (32.6 ha) has been fully developed as warehouse and residential areas without satisfactory urban development plan. Secondary and tertiary sewers (o400 - o600) have constructed under the narrow streets by District 8. On the other hand, the western part of the area has not fully developed yet. Many warehouses and residents have been constructed along Lo Gom and Doi canals respectively. Inland areas are used to agricultural land and fishponds. District 8 has planned to develop as residential area including some green and open spaces, but no definitive implementation schedule is yet.

Ben Me Coc (1) area is topographically low from about 0.9 to 1.3 m. During high tide season from September to January, almost all area has inundated at least ten (10) times per year. No sufficient dike around the area and no gate at the sewer outlets make more serious inundation. Inundation depth and duration have surveyed at 30 to 50 cm and 4 to 6 hours respectively, according to the flood survey conducted by the Team.

(3) Ben Me Coc (2)

Ben Me Coc (2) drainage area of 46.0 ha is a part of Ward 15 of District 8. As shown in Fig. E.8.15, the area is surrounded by Lo Gom, Doi and Ngang No.3 canals as same as

Ben Me Coc (1). Even though the area is not so far from Cho Long commercial center and has a potential to develop as a residential area, it is still not fully developed due to insufficient transportation, water supply and drainage system. Almost all houses have been constructed along the ring road, however, a residential development has recently been progressing towards inland low-lying area by filling up.

Ground elevation of the area is low changing from +0.9 to +1,3 m above MSL. Flood condition of the area is almost the same as that of the western parts of Ben Me Coc (1), which is mentioned before.

8.3.2 Planning Concept and Design Criteria

(1) Target Year

Target completion year of pump drainage improvement project is set at 2010 as same as canal improvement project. However, all facilities are to be designed to meet the city development plan in 2020.

(2) Design Scale

The design scale for pump equipment and drainage pipe is applied at 5-year and 2-year frequency flood respectively as mentioned in the M/P.

(3) Design Rainfall

(a) For pumping station

Six (6) hours consecutive rainfall with 5-year frequency (R = 113.47 mm) shown in Fig. E.6.8 is proposed.

(b) Drainage Pipe

The following rainfall intensity and duration formula with 2-year return period is applied.

$$I = 13{,}567/(t^{1.18} + 89) : \quad t < 3 \text{ hours}$$

Where, I: point rainfall intensity (mm/hr)
t: duration (minutes)

(4) Design Water Level

Based on the hydraulic analysis in the M/P study, design water levels at Thanh Da and Ben Me Coc areas are applied as follows:

Location	High Water Level	Mean Water Level	Low Water Level
Thanh Da Area	1.32	0.23	-2.11
Ben Me Coc (1) & (2)	1.50	0.27	-2.12

(5) Other Criteria

Other criteria, such as drainage criteria, specific requirement of pump and retarding pond, are the same as that of Master Plan.

8.3.3 Preliminary Design of Dike

During the high tide season from September to January, Thanh Da, Ben Me Coc (1) and (2) areas have affected about 10 times a year by the serious external flood from Saigon, Tau Hu, Lo Gom and Doi canals, due to lower existing bank elevation than DHWL of these canals. Accordingly, a polder dike system is proposed to apply for these areas as the most suitable and economical external flood mitigation measure.

(1) Thanh Da Area

HCMC has constructed the dike along Saigon River to protect the proposed pump drainage area of 15.4 ha in Thanh Da from the external flood of Saigon River. As shown in Fig. E.8.16 (1/3), however, intermediate section of about 74 m has never been provided any dike, due to the difficulty of construction by some illegal houses. New dike shown in Fig. E.8.17, which is the same type as existing one, is proposed to construct for 74m. According to the supplemental leveling survey, top elevation of the existing dike in western part (L = 130 m) and eastern part (L = 200 m) is about 25 cm in maximum lower than the proposed dike level of +2.00m. It will not be particularly anxious. However, raising work of existing dike will be expected to execute in future.

(2) Ben Me Coc (1) and (2)

At present, the existing ring roads in Ben Me Coc (1) and (2) have two function, transportation and dike to protect from the external flood of Doi, Tau Hu and Lo Gom canals. However, supplemental leveling survey indicates that top elevation of the existing ring roads is 50 to 80 cm lower than the proposed dike of +2.00m as shown in Figs. E.8.16 (2/3) and (3/3). This is a main reason to occur the serious external floods from the surrounding canals in high tide season from September to January in every year. New dikes along Tau Hu, Lo Gom and Ngang No.2 and 3 are proposed to construct simultaneously in the canal improvement work as shown in Fig. E.8.17. However, as Doi canal improvement is excluded in the priority project, temporary dike shown in Fig. E.8.17 is propose to construct along Doi canal. Proposed length of temporary dike is about 1.36 km for Ben Me Coc (1) and 1.35 km for Ben Me Coc (2).

8.3.4 Preliminary Design of Sewers

In order to complete the successful drainage pipe network in Thanh Da area, construction of some new sewers to be connected between the existing sewers and pumping station and/or retarding pond are proposed. Then, in Ben Me Coc (1) and (2) areas, new sewer lines are proposed to construct along the ring road, in order to mitigate flood damages along the ring road and to integrate the existing many small outlets of secondary drains. These sewers have been designed to convey a 2-year flood runoff calculated by Rational Method. Finally, the proposed sewer network system in combination with pump and retarding pond has been evaluated against 5-year frequency flood using hydrodynamic simulation model of MOUSE, which will be mentioned later. Details of the proposed sewers and hydrological calculations for three (3) pump drainage areas are shown in Tables E.8.12 to 17.

The proposed sewers by each pump drainage area are summarized below:

Area	Sewer Size (mm)	Sewer Length (m)
Thanh Da	ø800 to ø1,200	660
Ben Me Coc (1) (East)	ø900 to ø1,500	2,450
Ben Me Coc (1) (West)	ø900 to ø1,650	2,170
Ben Me Coc (2)	ø600 to ø1,650	4,210

Figs. E.8.18 and 19 show the sub-catchment for run-off calculations and proposed sewers for three (3) pump drainage systems respectively. Samples of longitudinal profile for the proposed sewers are shown in Figs. E.8.20 (1/3) to (3/3). All preliminary drawings of the proposed sewers are compiled in Volume 4 "Drawings".

8.3.5 Preliminary Design of Pumping Station with Retarding Pond

(1) Design Condition and Criteria

(a) Proposed Pump Drainage System

The proposed pump drainage areas of Thanh Da, Ben me Coc (1) and (2) are divided into some sub-drainage areas based on the following considerations:

- Topography: All areas are low and flat. Ben Me Coc (1) and (2) areas are very long and narrow shapes, however, Thanh Da is not so slender shape.
- Urbanization: Thanh Da and the eastern part of Ben Me Coc (1) are fully urbanized, however, other areas are not fully developed and have agricultural land or green open space in inland area.
- Pond: Thanh Da and Ben Me Coc (1) have a suitable pond located at almost center of the area to utilize as a retarding pond, however, no pond is found in Ben Me Coc (2).
- Land acquisition: Thanh Da and Ben Be Coc (1) have no problem for getting the land for pumping station and retarding pond, however, Ben Me Coc (2) is necessary to get land for these facilities.
- Phasing: Considering the flood condition and existing urbanization, Thanh Da and Ben Me Coc (1) (East) are recognized to urgently improve.

Taking into the above consideration, only Ben Me Coc (1) area is divided into two (2) pump drainage areas. Other two (2) areas are planned to be one (1) pump drainage basin. Figs. E.8.21 (1/3) to (3/3) show the proposed pump drainage system in combination with dike and sewer network systems.

(b) Hydraulic Requirements of Pumping Station and Retarding Pond

To economize on total pump drainage cost by reducing the required pump capacity, each pumping station is proposed to provide the retarding pond. The specific requirements of pump station and the retarding pond (pump capacity and storage volume) are proposed to be 2.1 $m^3/s/km^2$ and 69,000 m^3/km^2 by the mass curve method in M/P study (refer to Fig. E.6.10).

Required pump capacity and storage volume of retarding pond are estimated as

follows:

$Q = q \times A$
$V = v \times A = Vt + Vr$
where, Q: required pump capacity (m^3/s)
q: specific requirement of pump capacity (2.1 $m^3/s/km^2$)
v: specific requirement of storage volume (69,000 m^3/km^2)
A: pump drainage area (km^2)
Vt: allowable temporary inundation volume including storage volume of drainage pipe (m^3)
Vr: require storage volume of retarding pond (m^3)

Calculation results are shown in Table E.8.18 and summarized below:

Name of Drainage Area	Area (ha)	Required Pump Capacity (m^3/s)	Required Storage Capacity of Retarding Pond (m^3)
Thanh Da	15.4	0.32	7,600
Ben Me Coc (1) (East)	32.6	0.68	16,700
Ben Me Coc (1) (West)	38.3	0.80	19600
Ben Me Coc (2)	46.0	0.97	23,500

These requirements will be finally evaluated by hydrodynamic simulation model, "MOUSE" in combination with the proposed sewer network.

(c) Proposed Location and Soil Condition

Taking into consideration of sufficient combination with sewer network and pump drainage system and easiness of land acquisition, construction sites of these pumping stations are proposed as follows:

- Thanh Da P.S.: Same site as the damaged old pumping station at the existing pond
- Ben Me Coc (1) (East) P.S.: Outlet of the existing pond for Doi canal, where is almost center of the drainage area
- Ben me Coc (1) (West) P.S.: Same site as Ben Me Coc (1) (East) P.S.
- Ben Me Coc (2) P.S.: Near the temple along Lo Gom canal, where is almost center of the drainage area

The Study Team has conducted the soil investigations for the proposed pumping stations from July to August 1999. Location of the boring sites is shown in Figs E.8.22 (1/4) to (4/4) and E.8 24 (3/4). The sub-soil conditions of them are summarized below:

Thanh Da Pumping Station

According to the soil survey results at two (2) sites, the sub-soil consists of the following layers:

Layer	Depth (m)	Thickness (m)	Materials	N-Value	Notation
1	1.5 – 19.0	17.5	Very soft, high plasticity, blackish gray organic clay	0 - 1	OH
2	19.0 – 23.0	4.0	Very loose, blackish gray clayey sand	1	SC
3	18.5 – 22.0	3.5	Loose, greenish gray silty clay sand	2 – 4	SMSC
4	22.0 – 30.0	8.0	Stiff, low plasticity, greenish gray, clay w/ sand	10 - 25	CL

The characteristics of the sub-soil are as follows:

* Natural Moisture Contents (Wn): 20.0 – 88.7 %
* Specific Gravity (Gs): 2.591 – 2.693
* Liquid Limit (Lw): 21.2 – 80.1 %
* Plastic Limit (PW): 13.6 – 42.2 %
* Wet Density (rt): 1.435 – 2.066 g/cm^3
* Dry Density (rd): 0.765 – 1.721 g/cm^3
* Cohesion (C): 0.056 – 0.061 kg/cm^2

Ben Me Coc (1)

The sub-soil is basically the same as that of Than Da site as shown below:

Layer	Depth (m)	Thickness (m)	Materials	N-Value	Notation
1	0.0 – 18.0	18	Very soft, high plasticity, blackish gray organic clay	0 - 1	OH
2	18.0 – 25.0	7.0	Soft, high plasticity, blackish gray organic clay	2 – 3	OH
3	5.0 – 30.0	5.0	Soft, low plasticity, blackish gray sandy clay	2 – 3	CL

The characteristics of the sub-soil are as follows:

* Natural Moisture Contents (Wn) : 33.8 - 80.7 %
* Specific Gravity (Gs) : 2.590 - 2.635
* Liquid Limit (Lw) : 41.7 - 81.4 %
* Plastic Limit (Pw) : 24.6 - 43.2 %
* Wet Density (rt) : 1.388 - 1.472 g/cm^3
* Dry Density (rd) : 0.821 - 1.056 g/cm^3
* Cohesion (C) : 0.079 - 0.120 kg/cm^2

Ben Me Coc (2)

Sub-soil at the proposed pumping station consist of the following layers:

Layer	Depth (m)	Thickness (m)	Materials	N-Value	Notation
1	0.0 - 25.0	25.0	Very soft, high plasticity, blackish gray organic clay	0 - 3	OH
2	25.0 - 30.0	5.0	Soft, high plasticity, blackish gray organic clay	3 - 4	OH
3	23.5 - 27.5	4.0	Soft, yellow, whitish gray clay with silt	11 - 14	CL
4	22.0 - 23.5	1.5	Dense, light brown gray clay sand	12 - 13	SC
	28.0 - 30.0	2.0			
5	24.0 - 30.0	6.0	Medium dense, brownish gray graded sand with silt	12 - 16	SW - SM
6	27.5 - 29.0	1.5	medium dense, brownish gray poorly graded sand w/ silt	2 - 3	CL

The characteristics of the sub-soil are as follows:

*	Natural Moisture Contents (Wn)	:	14.4 - 81.8 %
*	Specific Gravity (Gs)	:	2.597 - 2.676
*	Liquid Limit (Lw)	:	26.2 - 78.6 %
*	Plastic Limit (Pw)	:	15.5 - 41.8 %
*	Wet Density (rt)	:	1.453 - 1.936 g/cm^3
*	Dry Density (rd)	:	0.804 - 1.608 g/cm^3
*	Cohesion (C)	:	0.074 kg/cm^2

Details of soil investigation result refer to Appendix A "Topography and Geology".

(d) Design Water Level and Pump Head

Taking into consideration of DHWL of the surrounding rivers/canals and minimum ground elevation of the residential areas, DHWL and DLWL of these pumping stations are proposed as follows:

Name of P.S.	Inlet side (Land side)		Outlet side (River side)	
	DHWL (m)	DLWL (m)	DHWL (m)	DLWL (m)
Thanh Da P.S.	0.90	-1.00	+1.32	-1.10
Ben Me Coc (1) P.S.	0.90	-1.00	+1.50	-1.10
Ben Me Coc (2) P.S.	0.90	-1.00	+1.50	-1.10

Note: 1. DHWL of inlet side is planned to be the same as minimum ground elevation of residential area.
2. DLWL of inlet side is planned to easily maintain the water level by tidal effect of Saigon River and Doi canal.
3. DHWL and DLWL of outlet side is planned to be average of maximum monthly high water level and low water level of Saigon River and Doi canal respectively.

So, the statistic pump head (Hs) and total pump head (Ht) are estimated as follows:

Hs = DHWL (river side) – DLWL (land side)
Ht = Hs + Hl
Hl: hydraulic losses of pump equipment, valves and sluice way (m)

Hl is roughly estimated to be 0.90 m for pump facility and 0.30 m for valves and outlet facilities. Therefore, design statistic pump head and a total pump head of

each pumping station are shown below:

Name of P.S.	Statistic Pump Head (Hs) (m)	Hydraulic Loss of Equipment (Hl) (m)	Total Pump Head (Ht) (m)
Thanh Da P.S.	2.32	1.20	3.52
Ben Me Coc (1) P.S.	2.50	1.20	3.70
Ben Me Coc (2) P.S.	2.50	1.20	3.70

(3) Preliminary Design of Proposed Pumping Station

(a) Major Mechanical and Electrical Equipment

Pump Type Alternatives

The conventional pump applied for urban drainage system is generally classified into (i) Mixed Flow Pump, (ii) Axial Flow Pump, (iii) Centrifugal Flow Pump, (iv) Screw Pump and (v) Submersible Pump. Their applicable ranges in total pump head and bore size are summarized below:

Pump Type		Applicable Range in Total Pump Head (m)	Available Pump Diameter (mm)
Mixes Flow Pump	Horizontal	Less than 7 m	Less than ø2,000
	Vertical	Less than 9 m	Less than ø4,000
Axial Flow Pump	Horizontal	Less than 3 m	Less than ø2,000
	Vertical	Less than 5 m	Less than ø4600
Centrifugal Flow	Horizontal	Less than 10 m	Less than ø1,600
Pump	Vertical	Less than 10 m	Less than ø2,000
Screw Pump		Less than 8 m	Less than ø3,500
Submersible Motor Pump		Less than 20 m	Less than ø1,800

In consideration of the above applicable ranges, the following three alternative pump types are considered.

- Alternative I: Vertical Shaft Axial Flow Pump
- Alternative II: Horizontal Shaft Axial Flow Pump
- Alternative III: Submersible Motor Pump

As the results of comparative study for these alternatives shown in Table E.8.19, Alternative III, "Submersible Motor Pump" is recommended as the most applicable and economical pump type.

Number of Pump Unit and Its Bore

Considering the most economical point of view and easiness of operation and maintenance, the pump unit number, pump capacity and pump bore for three (3) pumping stations are proposed as follows:

Pumping Station	Pump Capacity (m^3/s)		Number	Bore of Pump
	Total	Unit	of Unit	(mm)
Thanh Da P.S.	0.35	0.35	1	ø 400
Ben Me Coc (1) (East) P.S.	0.70	0.35	2	ø 400
Ben Me Coc (1) (West) P.S.	0.80	0.80	1	ø 750
Ben Me Coc (2) P.S.	1.05	0.35	1	ø 400
		0.70	1	ø 600

The above pump bore is estimated by the following formula:

$D = 1{,}000 \times (0.1 \sim 0.08) \times Q^{0.5}$

D: Pump bore (mm)
Q: Unit pumping capacity (m^3/min.)

Power Source of Pump Operation

The proposed submergible pump is driven by an electric motor. The pump power source is supplied from the existing power line of Electric Company No.2 located near the proposed pump sites, of which voltage is 15 KV. The maximum pump shaft break power of each pump is estimated as follows:

* Thanh Da P.S.: 18.5 kw for ø 400 pump
* Ben me Coc (1) P.S.: 18.5 kw for ø 400 pump
  37.0 kw for ø 750 pump
* Ben Me Coc (2) P.S.: 18.5 kw for ø 400 pump
  37.0 kw for ø 600 pump

Other Major Equipment

The other major mechanical and electrical equipment to be required for the installation, operation and maintenance works of the pumping stations are listed in Table E.8.20.

(b) Civil Works

Layout of Pumping Station

The proposed pumping stations consist of inlet pits, pump pit, discharge basin, sluice way and related structures. The civil works of these structures are composed of earth work, foundation work, reinforced concrete work, masonry and others. The general layouts of these pumping stations are shown in Figs. E.8.22 (1/4) to (4/4). As mentioned later, these pumping stations will be constructed in the following phasing:

Phase I (2001 - 2005): Thanh Da and Ben Me Coc (1) (East) P.S.
Phase II (2006 - 2010): Ben Me Coc (1) (West) and Ben me Coc (2) P.S.

Design concept for the proposed pumping stations, of which drawings are shown in Figs. E.8.23 (1/6) to (6/6), is described below:

Inlet Pit

The inlet pit drains flood water from the existing sewer network into the retarding pond. The pit is constructed with reinforced concrete and designed to provide a sluice gate, which is closed usually and opened before pump operation. Main features of the pit for each pumping station are as follows:

Name of Pumping Station	Inlet Pipe Diameter (mm)	Number of Pit	Sluice Gate Width (m)	Sluice Gate Height (m)
Thanh Da P.S.	ø1,000	1	1,000	1,000
	ø1,200	1	1,200	1,200
Ben Me Coc (1) P.S.	ø1,500	1	1500	1,500
	ø1,800	1	1,800	1,800
Ben Me Coc (2) P.S.	ø1,500	2	1,500	1,500

Pump Pit

The pump pit is a reinforced concrete substructure for the pump equipment. The pump pit is planned to have sufficient length and width not to occur hydraulic loss for pump operation. The top elevation of the pit (pump floor) is designed to be at least 10 cm higher than that of the surrounding area. The bottom elevation of the pump pit is designed to be more than three times deeper of the pump bore from the pump stop level (Lowest Low Water Level: LLWL). As the bearing capacity of sub-soil is not enough for the spread foundation, the pump pit is supported by reinforced concrete pile with section of 300 mm x 300 mm and length of 24.0 m.

Pump House

Since all mechanical and electrical equipment are designed as outdoor type in due consideration of economic point of view, no pump house is designed.

Discharge Basin

The discharge basin to where water is pumped out from pump pit, has a function to convey the pumped water smoothly to sluice way as a surge tank. The discharge basin connecting with pump pit is constructed with reinforced concrete of which the top elevation is designed to be higher than that of DHWL plus hydraulic loss of sluice way (about 30 cm). The discharge basin has entrance with sluice gate, which is able to change from pump discharge to gravity discharge by opening the sluice gate. The discharge basin is also supported by reinforced concrete piles with section of 300 mm x 300 m and length of 24.0 m.

Sluice Way

The sluice way having a gate leaf at outlet is planned with a reinforced concrete box culvert through the flood dike. The maximum velocity in culvert is set at 2.0 m/s. The box culvert is supported by the reinforced concrete pile with section of 250 mm x 250 mm and length of 12.0 m. The dimensions of the designed sluice way are summarized below:

Name of Pumping Station	Design Discharge (m^3/s)	Cross Section Width (m)	Height (m)	No. of Section	Length (m)
Thanh Da P.S.	4.1	1.4	1.4	1	75.3
Ben Me Coc (1) P.S.	8.0	2.0	2.0	1	31.3
Ben Me Coc (2) P.S.	5.4	1.8	1.8	1	24.0

Note: The size of sluice gate to be installed is the same one as the proposed cross section of box culvert.

Operation and Maintenance Office

An operation and maintenance office including store room is provided for each pumping station. Main features of O/M office are mentioned below:

Pumping Station	No. of staff (person)	Width (m)	Length (m)	Height (m)	Area (m^2)
Thanh Da P.S.	4	4.0	10.0	3.5	40.0
Ben Me Coc (1) P.S.	8	5.0	16.0	3.5	80.0
Ben Me Coc (2) P.S.	4	4.0	10.0	3.5	40.0

Note: Details of number of staff for each station are shown in Appendix G: Operation and Maintenance.

Typical design of operation and maintenance office is shown in Fig. E.8.23 (7/7).

(4) Preliminary Design of Proposed Retarding Pond

Each pumping station is proposed to provide with retarding pond at inlet side to reduce the required pump capacity and to economize on total pump drainage cost. Existing ponds in Thanh Da and Ben Me Coc (1) areas are utilized as the retarding pond. However, as no existing pond to be utilized as retarding pond is in Ben Me Coc (2) area, inland possible site of about 12,400 m^2, where is almost 100 m far from the proposed pumping station and is no house to be relocated, is proposed to have land acquisition.

The proposed hydraulic requirement of each retarding pond is shown below:

Retarding Pond	DHWL (m)	DLWL (m)	Effective Depth (m)	Pond Area (m^2)	Storage Cap. (m^3)
Thanh Da R.P.	+0.90	-1.00	1.90	4,050	7,695
Ben Me Coc (1) (East)	+0.90	-0.20	0.70	19,000	13,300
Ben Me Coc (1) (Total)	+0.90	-1.00	1.90	19,000	36,100
Ben Me Coc (2) R.P.	+0.90	-1.00	1.90	12,400	23,560

Note : Ben Me Coc (1) (East) and (Total) mean Phase 1 and Phase 2 requirements respectively.

Layouts and structural design of the proposed retarding ponds are shown in Figs. E.8.24 (1/4) to (4/4).

(a) Thanh Da R.P.

Thanh Da R.P. is planned to improve the pond in existing park. The proposed pond forms rectangular shape with width of 28 m and length of 145 m. The bed elevation of pond is designed at -1.5 m, which is 0.50 m lower than DLWL of -1.0

m to prevent from the growing of trees and plants. Slope of the pond is protected by stone masonry. Sidewalk and fence are provided for maintenance work and security respectively.

(b) Ben Me Coc (1) R.P.

Ben Me Coc (1) R.P. is planned to improve the existing pond in two (2) phases to adjust the storage requirement in each phase. Main works in phase 1 are construction of control gate connecting with reservoir and Lo Gom canal shown in Fig. E.8.25 (3/4), dredging, filling and construction of sidewalk including guard fence. Phase 2 works are additional dredging up to bed elevation of -1.50 m and slope protection by stone masonry.

(c) Ben Me Coc (2) R.P.

Ben Me Coc (2) R.P. is planned to newly construct at inland agricultural land far from about 100 m from the proposed pumping station. The proposed pond forms rectangular shape with width of 95 m and length of 105 m. Top elevation of the pond is designed at +1.50 m, which is 10 cm higher than that of the surrounding areas. Bed elevation is designed at –1.50 m, 50 cm lower than DLWL. Sidewalk and guard fence is provided around the pond. Slope protection works by stone masonry is also proposed. The pond is connected with proposed pumping station by box culvert with section of 1.80 m x 1.80 m (length: L = 127.5 m), and with sewer network by drainage pipe with diameter of 2,000 mm (length (L = 230 m). For construction of these connection pipe/box culvert and operation/maintenance work of the retarding pond, new road construction (width: B = 5.0 m and 7.0 m, length: L = 397 m and 393 m) is planned.

8.3.6 Hydraulic Evaluation by Hydrodynamic Simulation Model

(1) Model Set Up

The proposed pump drainage systems for three (3) areas have been evaluated against 5-year return period rainfall event and Design Flood Level condition. Danish Hydraulic Institute's unsteady sewer flow modeling software called "MOUSE" has been used for hydrodynamic simulation. Runoff hydrographs from the sub-catchments under future land use condition have been generated applying Time-Area Curve method. The main basin parameters (sub-catchment area, runoff coefficient and time of concentration) are presented in Tables E.8.13, 15 and 17. Sub-catchments and the proposed drainage layouts are shown in Figs. E.8.18 and 8.21(1/3) to (3/3) respectively.

Manning's roughness co-efficient of 0.013 has been used for the sewers considering normal concrete condition. A time step varying from 1 to 15 seconds has been applied for hydrodynamic simulation.

(2) Model Cases

Hydrodynamic simulation has been carried out the following three (3) cases:

Case 1	:	Thanh Da pump drainage improvement plan for total area
Case 2	:	Ben Me Coc (1) pump drainage improvement plan has been investigated for two sub-cases

Case 2.A : Represent drainage improvement plan for East area
Case 2.B : Represent drainage improvement plan for the total area
Case 3 : Ben Me Coc (2) pump drainage improvement plan for total area

(3) Simulation Results

As shown in Table E.8.21 and Fig. 8.25 (1/4) and (4/4), hydrodynamic simulation has given the following findings:

(a) High water level of retarding pond varies from about +0.85 to +0.95, which is almost the same or lower than minimum ground elevation of residential area.
(b) Pump operation time for one food will very from 4.0 to 4.5 hours.
(c) Maximum temporary inundation depth will vary from 10 to 15 cm.

Therefore, the proposed pump drainage systems are able to cope with a 5-year flood.

8.4 Main Combined Sewer Improvement

8.4.1 Present Condition of Main Combined Sewer

The priority project for the main combined sewer improvement is focused on the sub-catchments of C.4 and C.c in Central City Drainage Zone (C-zone).

The total length of the existing main combined sewer installed in the project area amounts to 102 km.

The priority area is divided into 5 sewer network zones based on the main combined network as shown in Fig. E.8.26. The length of the sewer by each sewer network zone is presented below.

Sewer Network Zone	Length (km)
A	36.2
B	3.4
C	23.9
D	24.3
E	14.5
Total	102.3

8.4.2 Evaluation of Main Combined Sewer

The main combined sewer network is large and complex one. Furthermore the outlets of the sewers are affected by the tidal time varying water levels.

Thus, for consideration of the network and the hydraulic condition at the outlet, unsteady sewer pipe flow modeling software called "MOUSE" has been applied to Hydrodynamic simulation.

Existing discharge capacity of the main combined sewer was computed based on the collected longitudinal and cross sectional data of the sewers, in addition to the supplementary survey data by the Study Team.

In this study, a minimum diameter of the combined sewer constructed in model was

extended to 600 mm because the model could not identify the sewers to be improved in some habitual inundation area.

The evaluation for the discharge capacity of the main combined sewer has been carried out for the design rainfall of 3 year return period and the design flood water level of 2 year return period under the condition of existing land use.

The simulation concluded the following main combined sewers to be improved because of an insufficient discharge capacity. The location of the sewer to be improved is shown Fig. E.8.27. According to the results of the simulation, an inundation is expected to occur in some area of the zone of the main combined sewer.

The detailed information on the sewers to be improved is shown table below.

Sewer Line No.	Section No.	Road Name	Existing Sewer Diameter (mm) / Conduit Type	Length (m)
Sewer Network Zone B				
1	1-1	Ho Hao Hon	1,200	182
	1-2	ditto	1,200	513
2	2-1	Tran Hung Dao	800	192
	2-2	ditto	K-2	173
	2-3	ditto	800	33
	2-4	ditto	A-2	46
Sewer Network Zone C				
3	3-1	Nguyen Bieu	800	147
	3-2	ditto	Not exist	362
4	-	Le Hong Phong	800	391
5	-	Hung Vuong	800	298
6	6-1	Tran Binh Trong	1,000	932
	6-2	ditto	J-1	25
	6-3	ditto	J-1	363
7	7-1	Dien Bien Phu	800	714
	7-2	3 Thang 2	800	926
Sewer Network Zone D				
8	8-1	3 Thang 2	800	414
	8-2	ditto	600	268
	8-3	Ly Thai To	600	422
	8-4	ditto	600	324
	8-5	Su Van Hanh	600	516
9	9-1	3 Thang 2	800	418
	9-2	Ta Uyen	1,000	712
Sewer Network Zone E				
10	10-1	Nguyen Tat Thanh	800	1,480
	10-2	ditto	800	724

8.4.3 Improvement Plan Proposed by UDC

UDC has an improvement plan of the existing combined sewer based on "Pre-feasibility Study on Environmental Improvement Project of Ho Chi Minh City, 1998". The study proposed the construction of 9 new combined main sewer lines in the priority project area.

The new sewers are planed to densely install along the main road running the north to the south. The sewers are mainly box culvert type with a size of 2,400 mm x 3,000 mm.

8.4.4 Planning Concept and Design Criteria

More than 50 % of the sewer in the sewer network zone A is considered to be old sewer installed in 1980s. However, a sever inundation can not be identified by the flood survey in this zone. It can be said that most of them work well according to the field survey in Master Plan stage.

The existing main combined sewer networks shall be utilized to minimize the project cost and to achieve an immediate improvement of the main combined sewer system.

Consequently, two (2) options for the sewer improvement are considered as follows;

1) In case that the road width is sufficient to install, an additional sewer is proposed to supplement the shortage.
2) In case that the road width is insufficient to install, the existing sewer is proposed to be replaced to a sewer dealing with the full discharge.

8.4.5 Proposed Main Combined Sewer Improvement Plan

The proposed improvement plan is described as follows and the detailed is presented in Fig. E.8.27.

Sewer Network Zone B

Two (2) lines of the existing main combined sewer can be utilized as ever and additional sewers are proposed to be installed parallel to the existing sewers. According to a field survey, the improvement of Sewer Line No. 1 along Ho Hao road and Sewer Line No. 2 along Tran Hung Dao road have been done lately.

Therefore, no improvement plan is considered for this zone.

Sewer Network Zone C

There are 5 lines to be improved in this zone.

1) Sewer Line No. 3 : An additional sewer pipe with a diameter of ϕ 1,200 mm and new sewer pipe with a diameter of ϕ 2,500 mm discharging to Ben Nghe canal are proposed along Nguyen Bieu road.
2) Sewer Line No. 4 : An additional sewer pipe with a diameter of ϕ 1,000 mm is proposed along Le Hong Phong road.
3) Sewer Line No. 5 : An additional sewer pipe with a diameter of ϕ 2,000 mm is proposed along Hung Vuong road.
4) Sewer Line No. 6 : New sewer pipe with a diameter of ϕ 2,000 mm $\sim$ ϕ 2,500 mm is proposed to replace with the existing sewer pipe along Tran Binh Trong road.
5) Sewer Line No. 7 : An additional sewer pipe with a diameter of ϕ 2,000 mm $\sim$ ϕ 2,500 mm is proposed along Dien Bien Phu and 3 Thang 2 roads.

Sewer Network Zone D

There are 2 lines to be improved in this zone.

1) Sewer Line No. 8 : These sewers identified by the simulation can not increase the discharge capacity because the capacity of some part of the downstream sewer in the network is insufficient.
Therefore, a new sewer pipe of box culvert with a dimension of 2m x 2m~2.4m x 2.8m is proposed between Le Dai Hanh and Mac Cuu roads. The total length is estimated at 3.6 km, thus box culvert type is applied to minimize an earth covering depth.

1) Sewer Line No. 9 : There is a same reason as same as No. 8.
Therefore, a new sewer pipe of box culvert with a dimension of 2.4m x 2m~2.4m x 2.4m is proposed along Nguyen Tri Phung road. The total length is estimated at 3.1 km, thus box culvert type is applied to minimize an earth covering depth.

Sewer Network Zone E

According to a field survey, the sewer identified to be improved along Nguyen Tat Thanh road have been done lately.

8.5 New Drainage Pipe for Separate Sewer System Area

The right bank area of Doi -- Te canal is proposed to be developed by separate sewer system according to the Vietnamese standard for a new development area. Hence new drainage pipe system is proposed to be installed in this area. The area consists of Rach Ong, Pham The Hien and Binh Dang areas and the total amounts to 537 ha (refer to Fig, F.15.1).

The drainage pipe system is designed based on a 2-year flood runoff calculated by Rational Method The total length of drainage pipe is 26 km and the pipe diameter ranges from ϕ 600 mm to ϕ 3,000 mm. Main Features of the new drainage pipe are presented in the table below.

Diameter (mm)	Rach Ong (133 ha)	Pham The Hien (196 ha)	Binh Dang (208 ha)	Total
600	-	90	0	90
700	-	99	0	99
800	-	0	181	181
900	-	-	-	-
1,000	801	476	107	1,384
1,100	237	298	-	535
1,200	1,520	1,898	740	4,158
1,300	977	1,069	257	2,303
1,500	872	3,034	3,370	7,276
1,600	331	443	-	774
1,800	1,625	778	2,303	4,705
2,000	211	367	-	578
2,500	602	1,459	2,148	4,209
3,000	-	-	168	168
Total	7,176	10,011	9,273	26,460

TABLE E 3.1

POPULATION & BUILT-UP AREA IN 1997 AND 2020 BY DRAINAGE ZONE

Drainage Zone	Area (km^2)	District	Built-up Area (km^2)		Population ($x10^3$ person)	
			1997	2020	1997	2020
C-Zone	106.41	1,3,4,5,6,7,8 & *5 districts	75.38 (70.8)	87.56 (82.3)	3,185 (75.0)	3,422 (48.6)
N-Zone	136.20	12 and ** 5 districts	46.59 (34.2)	80.34 (59.0)	422 (9.9)	1,127 (16.0)
W-Zone	72.91	6,8, Tan Binh and Binh Chanh	14.39 (19.7)	33.62 (46.1)	176 (4.1)	629 (8.9)
S-Zone	81.74	7,8, Bin Chanh and Nha Be	11.37 (13.9)	39.46 (48.2)	127 (3.0)	475 (6.8)
NE-Zone	64.91	9 and Thu Duc	12.38 (19.1)	44.57 (68.7)	174 (4.1)	537 (7.6)
SE-Zone	119.36	2,9 and Thu Duc	13.52 (11.3)	54.25 (45.4)	160 (3.8)	844 (12.0)
Total	581.53		173.66 (29.9)	339.81 (58.4)	4,245 (100)	7,035 (100)

Note: * : Phu Nhuan, Go Vap, Binh Chanh, Binh Thanh and Tan Binh districts

**: Go Vap, Binh Tanh, Tan Binh, Binh Chanh and Hoc Mon districts

1: The figures in parenthesis of built-up area show the percent of built-up rate in each zone.

2: The figures in parenthesis of the population show the percent of population in total area of zones.

TABLE F.3.2 CATCHMENT AREA BY DRAINAGE ZONE

Zone	Number and Name of Catchment Area		Area (km2)	Remarks
I. Central City Drainage Zone			**106.41**	
	C.1	Nieu Loc - Thi Nghe	31.67	Nhieu Loc Thi Nghe canal (C-C.1)
	C.2	R. Cau Son - R. Lang	5.14	Rach Cau Son - Rach Lang (C-C.2)
	C.3	Tan Hoa - Lo Gom	20.22	Tan Hoa - Lo Gom canal (C-C.3)
	C.4	Tau Hu - Ben Nghe Canal and Doi - Te Canal	41.50	Ba Tang (C-C.6), Rach Ba Long (C-C.7) and Rach Ong Nho (C-C.8)
	C.a	Tanda	4.91	along the right bank of Sai Gon River
	C.b	Van Thanh	1.28	along the right bank of Sai Gon River
	C.c	Ben	1.68	along the right bank of Sai Gon River
II. Northern City Drainage Zone			**136.18**	
	N.1	R. Ban Da - R. Ba Hong	19.87	Rach Ban Da - Rach Ba Hong (C-N.1)
	N.2	Tham Luong - Ben Cat	107.56	Rach Dai Han (C-N.2), Tham Luong - Ben Cat canal (C-N.3),Rach 19-5 (C-N.4), R.achBen Cat (C-N.5), R. Gia (C-N.6), R. Giao Khau - R. Ba Thon - R. Ca Bon (C-N.7)
	N.a	An Phu Dong (along Sai Gon River)	8.75	along the right bank of Sai Gon River
III. Western City Drainage Zone			**72.91**	
	W.1	R. Chua - R. Nhoc Len - Ben Luc R. - Can Giuoc R.	72.91	Rach Chua - Rach Nhoc Len (C-W.1), Rach Nhanh (C-W.2), Rach Cai Trung - Rach Ba Doc (C-W.3), Ben Luc River (C-W.4), Can Giuoc River (C-W.5) and Rach Huong Nhon (C-W.6)
IV. Southern City Drainage Zone			**81.74**	
	S.1	R. Xom Cui - R. Ba Lao	14.32	Rach Ba Lao (C-S.1) and Rach Xom Cui (C-S.2)
	S.2	R. Ong Lon - K. Cay Kho	15.66	Rach Ong Lon - Kinh Cay Kho (C-S.3) and Rach Ong be (C-S-4)
	S.3	R. Tan - R. Ca Cam - R. Roi - R. Tom - Muong Chuoi R.	34.48	Rach Tay Tieu (C-S-6), Rach Dia (C-S.7) and Phuoc Khien R. (C-S.8)
	S.4	R. Cau Kinh	2.36	Rach Cau Kinh (C-S.9)
	S.5	R. AP3 Phu My	2.23	Rach AP3 Phu My (C-S.10)
	S.a	Tan Thuan EPZ	3.46	along the right bank of sai Gon River
	S.b	Phu May	3.86	along the right bank of Nha Be River
	S.c	Phu Xuan	5.33	along the right bank of Nha Be River
V. North-Eastern City Drainage Zone			**64.91**	
	NE.1	R. Ong Dau	3.32	Rach Ong Dau (C-NE.1)
	NE.2	R. Go Dua	9.53	Rach Go Dua (C-NE.2)
	NE.3	R. Thu Duc	7.15	Rach Thu Duc (C-NE.3)
	NE.4	R. Truong Tho	2.65	Rach Truong Tho (C-NE.4)
	NE.5	R. Nhum - R. Cau - R. Go Cong	34.38	Rach Nhum - Rach Cau - Rach Go Cong (C-NE.5)
	NE.a	Hiep Binh Phuoc	3.76	along the left bank of Sai Gon River
	NE.b	Hiep Binh Chanh	2.50	along the left bank of Sai Gon River
	NE.c	Truong Tho	1.62	along the left bank of Sai Gon River
VI. South-Eastern City Drainage Zone			**119.36**	
	SE.1	Rach Binh Khanh	1.98	Rach Binh Khanh (C-SE.1)
	SE.2	R. Ca Tre Nho	2.60	Rach Ca Tre Nho (C-SE.2)
	SE.3	Rach Da Do	1.92	Rach Da Do (C-NE.3)
	SE.4	R. Giong Ong To	7.80	Rach Gion Ong To (C-SE.4)
	SE.5	R. Muong	3.83	Rach Muong (C-SE.5)
	SE.6	R. Ky Ha	5.10	Rach Ky Ha (C-SE.6)
	SE.7	R. Kinh Ong Hong - R. Chiec	14.58	Rach Kinh Ong Hong - Rach Chiec (C-SE.7)
	SE.8	R. Ong Cay - R. Ba Cua - R. Ong Kieu	11.33	Rach Ong Cay - Rach Ba Cua - Rach Ong Kieu (C-SE.8)
	SE.9	R. Tan - R. Ong Nhieu	21.11	Rach Tan - Rach Ong Nhieu (C-SE.9)
	SE.10	Tac River	24.88	Rach Trau Trau (C-SE.10) and Tac River (C-SE.11)
	SE.a	Thao Dien	3.67	along the left bank of Sai Gon River
	SE.b	An Khanh and An Loi Dong	5.16	along the left bank of Sai Gon River
	SE.c	Thanh My Loi	1.82	along the left bank of Sai Gon River
	SE.d	Cat Lai	1.30	along the right bank of Dong Nai River
	SE.e	Long Truong	2.77	along the right bank of Dong Nai River
	SE.f	Long Phuoc	9.52	along the right bank of Dong Nai River
Total			**581.51**	

TABLE E.3.3 URBANIZATION BY DRAINAGE CATCHMENT

Zone	Catch-ment No.	Name of Catchment	Catchment Area (km2)	1997		2020		Remarks
				Area (km2)	%	Area (km2)	%	
C	C.1	Nhieu Loc - Thi Nghe	31.67	29.76	0.94	29.59	0.93	
	C.2	R. Cau Son - R. Tau Vam Tat	5.14	3.81	0.74	4.47	0.87	
	C.3	Tan Hoa - Lo Gom	20.22	12.41	0.61	16.67	0.82	
	C.4	Tau Hu - Ben Nghe and Doi - Te	41.50	25.61	0.62	32.45	0.78	
	C.a	Tanda (along Saigon River)	4.91	1.14	0.23	2.10	0.43	
	C.b	Van Thanh (along Saigo River)	1.28	1.13	0.88	0.75	0.59	
	C.c	Ben Bach Dang (along Saigon R.)	1.68	1.52	0.90	1.53	0.91	
	Sub-total		106.40	75.38	0.71	87.56	0.82	
N	N.1	Rach Ben Da - Rach Ba Hong	19.87	2.88	0.14	6.85	0.34	
	N.2	Tham Luong - Ben Cat Canal	107.57	41.54	0.39	68.81	0.64	
	N.a	An Phu Dong (along Saigon R.)	8.75	2.17	0.25	4.68	0.53	
	Sub-total		136.19	46.59	0.34	80.34	0.59	
W	W.1	Rach Chua - Rach Nuoc Lon	72.91	14.39	0.20	33.62	0.46	
S	S.1	R. Xom Cui - R. Ba Lao	14.33	0.87	0.06	3.71	0.26	
	S.2	R. Ong Lon - K. Cay Kho	15.66	1.53	0.10	5.12	0.33	
	S.3	R. Tan - R. Ca Cam - R. Roi - R. Tom - Muong Chuoi Canal	34.51	3.54	0.10	20.96	0.61	
	S.4	R. Cau Kinh	2.36	1.40	0.59	1.39	0.59	
	S.5	R. AP3 Phu My	2.23	0.18	0.08	1.10	0.49	
	S.a	Tan Thuan EPZ (along Saigon R.)	3.46	2.26	0.65	2.75	0.79	
	S.b	Phu May (along Nha Be River)	3.86	0.42	0.11	1.62	0.42	
	S.c	Phu Xuan (along Nha Be River)	5.33	1.17	0.22	2.81	0.53	
	Sub-total		81.74	11.37	0.14	39.46	0.48	
NE	NE.1	R. Ong Dua	3.32	0.54	0.16	1.93	0.58	
	NE.2	R. Go Dua	9.53	1.97	0.21	8.51	0.89	
	NE.3	R. Thu Duc	7.15	2.39	0.33	6.25	0.87	
	NE.4	R. Truong Tho	2.65	1.50	0.57	2.48	0.94	
	NE.5	R. Nhum - R. Cau - R. Go Gone	34.38	5.13	0.15	21.46	0.62	
	NE.a	Hiep Binh Phuoc (along Saigon R.)	3.76	0.20	0.05	1.97	0.52	
	NE.b	Hiep Binh Chanh (along Saigon R.)	2.50	0.16	0.06	1.02	0.41	
	NE.c	Truong Tho (along Saigon River)	1.62	0.49	0.30	0.95	0.59	
	Sub-total		64.91	12.38	0.19	44.57	0.69	
SE	SE.1	R. Binh Khanh	1.98	0.22	0.11	0.98	0.49	
	SE.2	R. Ca Tre Nho	2.60	0.20	0.08	1.71	0.66	
	SE.3	R. Da Do	1.92	0.13	0.07	1.68	0.88	
	SE.4	R. Giong Ong To	7.80	1.55	0.20	2.23	0.29	
	SE.5	R. Muong	3.83	0.58	0.15	2.51	0.66	
	SE.6	R. Ky Ha	5.10	0.74	0.15	4.35	0.85	
	SE.7	R. Kinh Ong Hong - R. Chuiec	14.58	2.43	0.17	8.36	0.57	
	SE.8	R. Ong Cay - R. Ba Cua - R. Ong Kieu	11.33	1.06	0.09	4.76	0.42	
	SE.9	R. Tan - R. Ong Nhieu	21.11	2.52	0.12	11.46	0.54	
	SE.10	Tac River	24.88	0.98	0.04	7.40	0.30	
	SE.a	Thao Dien (along Saigon River)	3.67	1.09	0.30	2.39	0.65	
	SE.b	An Khanh and An Loi Dong	5.16	1.00	0.19	4.01	0.78	
	SE.c	Tha My Loi (along Saigon River)	1.82	0.16	0.09	0.00	0.00	
	SE.d	Cat Lai (along Dong Nai River)	1.30	0.44	0.34	0.49	0.38	
	SE.e	Long Truong (along Dong Nai R.)	2.77	0.00	0.00	0.00	0.00	
	SE.f	Long Phuoc (along Dong Nai R.)	9.52	0.42	0.04	1.92	0.20	
	Sub-total		119.37	13.52	0.11	54.25	0.45	

TABLE E.3.4 (1/3) HYDRAULIC CHARACTERISTIC AND EXISTING DISCHARGE CAPACITY OF CANALS

Drainage Area	Canal No.	Name of Canal	Catchment Area (km2)	Length L (km)	Width B (m)	Depth H (m)	Flow Area A (m2)	Average Gradient I	Velocity V (m/s)	Discharge Cap. Q (m3/s)
Central City Drainage Zone (C-Zone)	C-C.1	Nhieu Loc - Thi Nghe Canal	31.668	9.376	16.0 - 65.5	1.5 - 7.5	14.8 - 250.6	0.00034 - 0.00201	0.47 - 1.73	7.0 - 430.0
	C-C.2	Rach Cau Son - Rach Tau Vam Tat	5.1400	2.259	46.0 - 58.0	2.3 - 3.6	90.6 - 102.2	0.00065	1.06 - 1.14	103.0 - 109.0
	C-C.3	Tan Hoa - Lo Gom Canal	20.224	7.773	8.0 - 63.0	1.1 - 4.2	8.4 - 210.4	0.00054 - 0.00082	0.51 - 1.45	3.0 - 304.0
	C-C.4	Tau Hu - Ben Nghe Canal	61.726	12.429	28.0 - 92.0	3.0 - 5.0	62.4 - 209.2	0.00008	0.24 - 0.58	21.0 - 96.0
	C-C.5	Doi - Te Canal		13.547	84.0 - 129.0	4.5 - 12.6	81.3 - 1.026	0.00033	0.62 - 2.12	50.0 - 2.175.0
	C-C.6	Rach Ba Tang	2.882	4.737	10.0 - 92.0	0.8 - 5.8	4.1 - 404.9	-0.00042 - 0.0013	0.37 - 2.97	-28.0 - 1.200.0
	C-C.7	Rach Ba Lon	6.518	5.353	15.0 - 74.0	1.9 - 9.4	18.0 - 172.2	0.0004 - 0.0030	0.64 - 3.73	121.0 - 642.0
	C-C.8	Rach Ong Nho	1.705	2.447	20.0 - 46.0	1.4 - 3.4	18.0 - 85.4	0.00050 - 0.00130	0.51 - 1.56	11.0 - 133.0
Northern City Drainage Zone (N - Zone)	C-N.1	Rach Ben Da - Rach Ba Hong	19.866	9.988	20.0 - 47.0	1.6 - 4.4	18.8 - 103.7	0.00023	0.41 - 0.72	8.0 - 75.0
	C-N.2	Rach Dai Han	34.649	9.698	5.0 - 12.0	0.6 - 2.2	3.6 - 17.4	0.00024	0.26 - 0.55	1.0 - 10.0
	C-N.3	Tham Luong - Ben Cat Canal	107.569	14.976	16.0 - 95.0	0.7 - 7.8	8.7 - 262.8	0.00035	0.42 - 1.30	3.0 - 335.0
	C-N.4	Rach 19 - 5	10.983	3.840	7.0 -11.0	1.0 - 2.2	3.9 - 12.8	0.00011	0.19 - 0.36	1.0 - 5.0
	C-N.5	Rach Ben Cat	11.863	5.603	51.9 - 57.2	3.1 - 4.3	94.2 - 126.2	0.00017	0.54 - 0.66	51.0 - 83.0
	C-N.6	Rach Gia	0.718	1.830	18.9 - 38.2	1.9 - 3.3	23.9 - 69.6	0.00036	0.58 - 0.80	14.0 - 55.0
	C-N.7	R. Giao Khau - R. Ba Thon - R. Ba Con	2.901	5.420	10.4 - 39.4	1.9 - 4.3	15.1 - 63.0	-0.00021 - 0.00029	-0.56 - 0.80	-16.0 - 58.0
Western City Drainage Zone (W - Zone)	C-W.1	Rach Chua - Rach Nuoc Len	40.064	13.544	9.0 - 48.0	0.2 - 5.0	2.1 - 109.9	0.00014 -0.00040	0.25 - 1.52	1.0 - 73.0
	C-W.2	Rach Nhanh	3.195	1.528	4.9 - 48.0	0.7 - 4.6	2.5 - 107.8	0.00120	0.60 - 1.67	1.0 - 180.0
	C-W.3	Rach Cai Trung - Rach Ba Doc	6.037	5.085						
	C-W.4	Ben Luc River	50.554	3.657	56.0 - 112.0	4.3 - 13.2	58.6 - 113.9	0.00033	1.02 - 1.61	123.0 - 1.012.0
	C-W.5	Can Giuoc River	72.908	4.188	100.0 - 190.0	4.3 - 11.6	535.1 - 662.1	0.00060	1.61 - 2.04	1.069.0 - 1.139.0
	C-W.6	Rach Huong Nhon	2.282							

TABLE E.3.4 (2/3) HYDRAULIC CHARACTERISTIC AND EXISTING DISCHARGE CAPACITY OF CANALS

Drainage Area	Canal No.	Name of Canal	Catchment Area (km2)	Length L (km)	Width B (m)	Depth H (m)	Flow Area A (m2)	Average Gradient I	Velocity V (m/s)	Discharge Cap. Q (m3/s)
Southern City Drainage Zone (S - Zone)	C-S.1	Rach Ba Lao	14.327	6.850	26.0 - 160.0	1.9 - 11.0	19.3 - 161.1	0.00013 - 0.00058	0.57 - 2.06	11.0 - 1,173.0
	C-S.2	Rach Xom Cui	6.334	7.349	44.0 - 75.0	2.3 - 10.0	70.3 -230.3	-0.00014 - 0.00110	-0.69 - 1.82	-105.0 - 367.0
	C-S.3	Rach Ong Lon - Kinh Cay Kho	13.701	8.390	75.0 - 120.0	6.6 - 9.3	301.5 - 673.4	-0.00020 - 0.00019	-1.31 - 0.98	-883.0 - 502.0
	C-S.4	Rach Ong Be	1.957	2.040	20.0 - 30.0	0.6 - 2.4	2.03 - 42.3	-0.00074 - 0.00118	-0.85 - 1.31	-22.0 - 55.0
	C-S.5	Roi - Rach Tom - Muong Chuoi Canal	34.511	11.923	26.0 - 190.0	2.0 - 21.7	25.2 - 2,312.5	0.00027 - 0.00080	0.83 - 2.42	21.0 - 5,606.0
	C-S.6	Rach Thay Tieu	4.788	3.131	40.0 - 50.0	3.1 - 5.9	67.3 - 133.5	0.00055	0.93 - 1.37	62.0 - 223.0
	C-S.7	Rach Dia	5.752	4.500	98.0 - 125.0	7.5 - 8.9	500.0 - 701.9	-0.00055 - 0.00079	-2.12 - 2.45	-1,487.0 - 1587.0
	C-S.8	Phuoc Khien River - Rach Cay Kho	6.454	6.136	36.0 - 112.6	1.4 - 13.2	82.7 - 594.2	0.00051 - 0.00072	1.20 - 2.27	99.0 - 1,753.0
	C-S.9	Rach Cau Kinh	2.363	2.450	30.0 - 50.0	2.0 - 3.7	24.5 - 103.3	0.00161	1.02 - 1.85	25.0 - 191.0
	C-S.10	Rach AP3Phu My	2.232	2.422	8.0 - 45.0	1.6 - 4.7	6.3 - 132.8	0.00106 - 0.00233	1.15 - 1.90	7.0 - 252.0
	C-S.11	Rach Ben Ro	1.660	2.173	38.0 - 65.0	6.6 - 8.1	115.3 - 248.6	-0.00148 - 0.00057	-2.42 - 1.64	-328.0 - 408.0
	C-S.12	Rach Ong Tu Dinh	-	1.322	32.0 - 38.0	4.3 - 5.2	89.1 - 101.8	0.00035	0.99 - 1.02	90.0 - 104.0
	C-S.13	Rach Tu B4 - B9 and C3 - C7	-	2.850	10.0 - 35.0	1.3 - 3.1	2.4 - 53.3	0.00038 - 0.00133	0.21 - 1.03	1.0 -43.0
	C-S.14	Rach Tu B0 - B3	-	0.900	15.0 - 20.0	1.9 - 2.8	15.6 - 23.5	0.00059	0.64 - 0.87	10.0 - 20.0
	C-S.15	Rach Phu Xuan	-	3.344	125.0 - 150.0	9.7 - 12.8	775.5 - 962.5	0.00086	2.74 - 3.00	2,442.0 - 2,888.0
	C-S.16	R. Ngang - R. Muong Chuoi (Branch)	1.289	3.401	9.0 - 35.0	1.3 - 4.0	6.7 - 80.7	0.00057 - 0.00067	0.60 - 1.16	4.0 - 93.0
	C-S.17	Rach Ong - Rach Ong Ta	0.306	2.101	5.0 - 18.0	1.3 - 2.8	3.7 - 27.1	0.00083 - 0.00117	0.73 - 1.06	3.0 - 29.0
	C-S.18	Rach Ong Doi	1.302	1.500	10.0 - 32.0	1.5 - 4.1	9.0 - 65.3	0.00158	1.02 - 1.80	9.0 - 118.0
	C-S.19	Rach Bang - Rach Thuy Tieu	0.678	1.850	34.0 - 45.0	3.2 - 4.7	55.4 - 112.4	0.00078	1.10 - 1.45	61.0 - 164.0
	C-S.20	Rach Ong Kich	0.615	1.531	26.0 - 40.0	1.5 - 3.2	20.9 - 68.4	0.00073	0.63 - 1.10	13.0 - 75.0
	C-S.21	Rach Tam De	0.829	1.730	9.0 - 20.0	1.6 - 3.8	8.2 - 37.5	0.00100 - 0.00125	0.84 - 1.44	7.0 - 51.0
	C-S.22	Rach Mieu	-	0.900	7.0 - 26.0	2.0 - 3.0	8.2 - 33.5	0.00117	0.98 - 1.24	8.0 - 39.0
	C-S.23	R. Dinh (Phu Xuan)	-	0.600	7.0 - 8.0	1.6 - 2.6	6.7 - 13.3	0.00100 - 0.00200	0.83 - 1.56	6.0 - 21.0

TABLE E.3.4 (3/3) HYDRAULIC CHARACTERISTIC AND EXISTING DISCHARGE CAPACITY OF CANALS

Drainage Area	Canal No.	Name of Canal	Catchment Area (km2)	Length L (km)	Width B (m)	Depth H (m)	Flow Area A (m2)	Average Gradient I	Velocity V (m/s)	Discharge Cap. Q (m3/s)
North-Eastern City Drainage Zone (NE - Zone)	C-NE.1	Rach Ong Dau	3.321	3.856	17.6 - 28.7	1.5 - 3.0	15.9 - 49.3	0.00075	0.83 - 1.28	13.0 - 63.0
	C-NE.2	Rach Go Dua	9.486	3.549	34.0 - 54.0	3.3 - 5.6	65.8 - 154.6	0.00036	0.97 - 1.29	64.0 - 200.0
	C-NE.3	Rach Thu Duc	7.146	3.336	6.6 - 37.2	1.3 - 3.9	5.3 - 67.5	0.00147	1.05 - 1.85	6.0 - 125.0
	C-NE.4	Rach Truong Tho	2.653	1.115						
	C-NE.5	R. Nhum - R. Cau - R. Go Gone	34.380	12.581	7.0 - 64.0	1.2 - 4.8	3.6 - 192.0	0.00029 - 0.00482	0.52 - 2.21	2.0 - 207.0
South-Eastern City Drainage Zone (SE - Zone)	C-SE.1	Rach Binh Khanh	1.977	2.457	33.0 - 54.0	2.9 - 6.8	55.7 - 204.2	0.00059	0.88 - 1.52	49.0 - 310.0
	C-SE.2	Rach Ca Tre Nho	2.596	2.203	16.0 - 42.0	1.1 - 5.4	10.7 - 119.4	0.00064 - 0.00163	0.89 - 2.48	10.0 - 296.0
	C-SE.3	Rach Da Do	1.918	3.672	30.1 - 39.5	3.3 - 4.0	49.6 - 70.7	0.00026	0.74 - 0.80	37.0 - 55.0
	C-SE.4	Rach Giong Ong To	7.803	5.614	20.0 - 58.0	2.7 - 5.4	31.1 - 191.3	0.00039 - 0.00065	0.76 - 1.67	24.0 - 320.0
	C-SE.5	Rach Muong	3.828	2.852	34.0 - 44.0	1.4 - 2.8	36.7 - 63.2	0.00211	1.62 - 2.23	59.0 - 141.0
	C-SE.6	Rach Ky Ha	5.104	5.399	20.0 - 46.0	1.7 - 3.8	23.6 - 95.9	0.0037 - 0.0097	0.80 - 1.01	23.0 - 86.0
	C-SE.7	Rach Chieu - Rach Kinh Ong Hong	15.050	6.752	51.0 - 97.2	1.9 - 8.4	120.6 - 396.6	0.00019 - 0.00025	0.76 - 1.04	95.0 - 399.0
	C-SE.8	R. Ong Cay - R. Ba Cua - R. Ong Kieu	11.328	6.993	19.0 - 70.0	1.9 - 6.9	27.8 - 210.2	0.00024	0.42 - 1.10	12.0 -205.0
	C-SE.9	Rach Tan - Rach Ong Nhieu	21.106	6.946	56.0 - 128.0	4.1 - 8.3	157.7 - 678.4	0.00057	1.37 - 2.05	216.0 - 1.393.0
	C-SE.10	Rach Trau Trau		4.492	48.0 - 85.0	3.2 - 8.7	105.5 - 269.7	0.00032	0.87 - 1.12	91.0 - 302.0
	C-SE.11	Tac River	24.878	13.850	164.0 -214.2	6.9 - 11.0	27.5 - 1.646.	- 0.00046 - 0.0001	- 2.36 - 1.10	-3.893.0 - 1.342.0
	C-SE.12	Rach Ba Nai	0.747	2.740	30.0 - 60.0	3.2 - 3.9	60.3 - 122.1	0.00013	0.44 - 0.52	30.0 - 63.0
	C-SE.13	Rach Ngon Muong	0.877	2.389	24.0 - 42.0	1.5 - 5.1	17.4 - 123.0	0.00063 - 0.00257	0.56 - 2.88	10.0 - 354.0
	C-SE.14	Rach Ngon Ngan	0.785	2.144	22.0 - 37.0	1.6 - 2.6	21.4 - 50.6	0.00020 - 0.00067	0.39 - 1.09	8.0 - 55.0