CHAPTER 4 SEWAGE MANAGEMENT MASTER PLAN

4.1 Sewage Management Master Plan

As discussed in the previous chapter, the applicability of on- and off-site treatment is evaluated by dividing PPCC into three areas: namely, (i) Cheung Aek Treatment Area, in which off-site treatment is applicable; (ii) Tamok Treatment Area, in which alternative study of on- and off-site treatment is conducted; and (iii) Other Area, in which on-site treatment is applicable.

4.1.1 Cheung Aek Treatment Area

As discussed in **Subsection 3.2.2**, the Cheung Aek Treatment Area is evaluated by applying off-site treatment with the following assumptions.

- Sewage collection system: Combined system (including interceptor)
- Sewage treatment methods: 6 methods are evaluated

(1) Sewage Collection System

As shown in **Table 4.1.1**, the evaluation result shows that the treatment area expands to 4,701.9 ha with the population of 1,093 thousand. Total length of trunk sewer [20] is 34.1 km (diameter from φ250 mm to φ2,200 mm), with estimated construction cost of 130.7 million USD, as shown in **Table 4.1.4**. Branch sewer is not required because the combined system, which utilizes existing pipe network, is adopted in this treatment area. As described in "**4.2.1 Sewer Facilities Plan**", no relay pumping station will be required.

Table 4.1.1 Outline of Cheung Aek Treatment Area

Item	Contents
Area (ha)	4,701.9
Population (year 2035)	1,093,155
Sewage collection system	Combined system
Trunk sewer (km)	34.1 (φ250 mm-φ2,200 mm)
Requirement of installing branch sewer	Not required
Pumping station	Not required
Construction cost of sewer network	See **Tables 4.1.4** and **4.1.5**

Source: JICA Study Team

(2) Sewage Treatment Plant

Based on the population in **Table 4.1.1** and the sewage generation per capita discussed in **Chapter 3**, the design inflow to STP and pollution load are projected as shown in **Tables 4.1.2** and **4.1.3.** Evaluation result of six treatment methods are summarized **in Tables 4.1.4 and 4.1.5**, with the layout plan of the STP in Cheung Aek Lake illustrated in **Fig. 4.1.2**.

[20] Trunk sewer includes (i) Trunk Sewer: Sewer connected to STP, and (ii) Main Sewer: Sewer connected to the trunk sewer or covers whole area of its sewer district.

Table 4.1.2 Design Inflow to Cheung Aek STP

Items	Sewage (m^3/day)	Ground water (m^3/day)	Total (m^3/day)	Design inflow (m^3/day)
Daily average	224,097	35,264	259,361	260,000
Daily maximum	245,960	35,264	281,224	282,000
Hourly maximum	371,673	35,264	406,937	407,000

Note: (Groundwater estimate 1)= 4,701.9 ha×7.5 m^3/day/ha=35,264 m^3/day…..(1)
(Groundwater estimate 2)=Population×(160+95)L/capita/day×0.85×15%=35,541 m^3/day.....(2)
The results show that (1)<(2). Therefore, (Groundwater estimate 1) is adopted.
Source: JICA Study Team

Table 4.1.3 Design Water Quality of Cheung Aek STP

Items	Daily average inflow (m^3/day)	Concentration calculated (mg/L)	Design water quality (mg/L)	Remarks
BOD	260,000	192	195	Total BOD load: 49,935 kg/day Of which domestic and commercial: 49,192 kg/day Industrial: 743 kg/day
TSS	260,000	202	205	BOD×1.05

Note: (Domestic and commercial BOD load)=(Population)×45 g/capita/day×10^{-3}
(Industrial BOD load)=(Population)×8.5 L/capita/day (amount of water use)×80 mg/L×10^{-6}
Source: JICA Study Team

Study results on STP are defined briefly below.

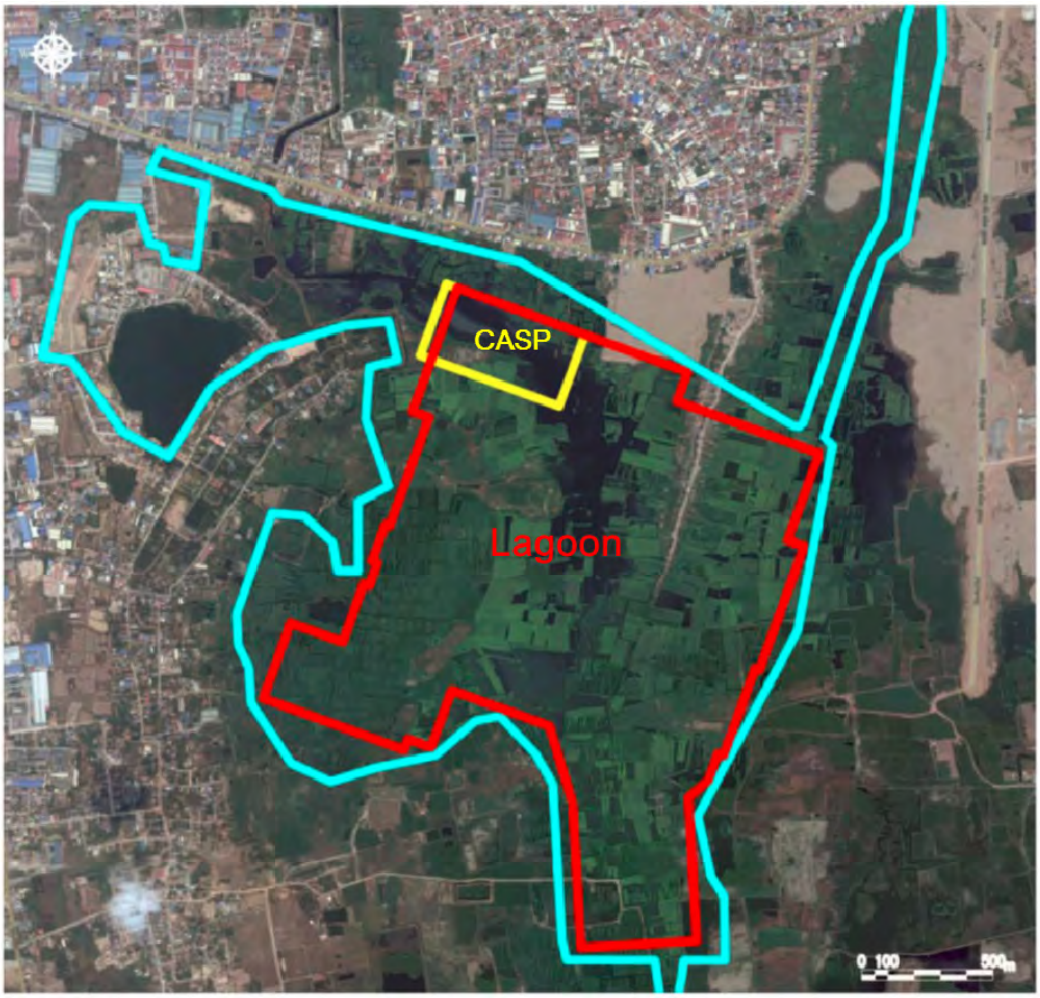
- Land requirement: Land requirements of PTF and SBR are almost the same and smallest among the six methods (PTF:13.0 ha, SBR:13.4 ha). Maximum is Lagoon with 262.4 ha. OD is second-ranked with the area of 43.1 ha.

- Construction cost: OD has the highest (397.9 million USD), followed by TF. Lowest one is 214.2 million USD of Lagoon.

- O&M cost: Lagoon's cost is the lowest (about 1.9 million USD/year) and OD's is highest (about 18.0 million USD/year).

- EIRR: EIRRs in **Tables 4.1.4** and **4.1.5** are estimated as reference, in consideration of loss of social value with the reclamation of Cheung Aek Lake, which is surrounded by large development and housing areas. The tables show that the EIRR of Lagoon is smallest because its reclamation area amounts to more than 10 times of those of the other methods.

- Environmental and social aspects: If applying Lagoon, large-scale resettlement (about 100 households) will be required and almost all Cheung Aek Lake will be reclaimed, as shown in **Fig. 4.1.1**, in which land requirements of the lagoon and typical mechanical method of CASP are depicted for comparison. In addition, control of offensive odour is difficult. As a result, Lagoon will much affect the surrounding environment.



Source: JICA Study Team

Fig. 4.1.1 Comparison of Land Requirement of Lagoon and CASP

In addition to the above discussion, result of quantitative evaluation, focusing on construction cost, O&M cost, easiness of O&M, number of application in large-scale STP and environmental and social aspects due to reclamation and offensive odour, are summarized in the tables. Based on the evaluation, Lagoon is the best option in terms of low construction and O&M cost, as well as easiness of O&M. On the other hand, Lagoon has such disadvantages as (i) social impact due to large-scale resettlement and reclamation is quite large, (ii) the reclaimed land will no longer be used for protected or cultivation area for aquatic plants and (iii) it has a lot of negative environmental impacts such as uncontrolled offensive odour. In consideration of the disadvantages of Lagoon, the application of CASP is recommendable and PTF will also be a good option, although the method has so far not applied to large-scale STP.

Table 4.1.4 Comparison of Wastewater Treatment Method applied to Cheung Aek STP (1/2)

Items	Lagoon	Trickling Filter (TF)	Pre-treated Trickling Filtration (PTF)
Land requirement (ha)	262.4	28.8	13.0
Construction cost (million USD)			
STP in total	214.2	328.5	271.8
Civil (reclamation)	151.3	38.1	18.5
Civil (structures)	36.9	107.3	82.3
Architecture	8.8	15.9	15.9
Machinery	5.9	103.7	93.0
Electricity	11.3	63.5	62.1
Sewer	130.7	130.7	130.7
Sludge dumping site	16.5	16.5	16.5
Total	361.4	475.7	419.0
O&M cost (million USD/year)			
STP in total	1.559	10.979	9.853
Civil (reclamation)	0.996	5.580	4.583
Civil (structures)	0.167	0.237	0.237
Architecture	-	3.933	3.933
Machinery	0.052	0.645	0.589
Electricity	0.344	0.584	0.511
Sewer	0.157	0.157	0.157
Sludge dumping site	0.174	0.174	0.174
Total	1.890	11.310	10.184
EIRR	-0.4%	9.4%	12.1%
Number of resettlements anticipated	• About 100 households	• No resettlement	• No resettlement
Pros and cons	• Large-scale resettlement is required and adverse social impact due to large-scale reclamation is anticipated. • Construction and O&M costs are lowest. • O&M is easy but control of offensive odour by covering is difficult due to the reason that the system has to introduce sunshine into the lagoons for provision of oxidization and disinfection. • This method has strength in coping with fluctuation of water quality but periodical removal of sludge is required so as not to reduce capacity.	• Land requirement is 2nd largest, which is twice as large as that of PTF. • 3rd lowest of O&M cost due to low energy consumption. • Control of offensive odor and outbreak of filter bed flies are difficult. • Application to large-scale STP is small in number.	• Land requirement is the minimum among 6 treatment methods. • 2nd lowest of O&M cost due to low energy consumption. • Periodical mixing of media keeps filter bed clean and thus prevent from out-break of filter flies. • This method has strength in coping with first flush and hence this method is applicable to combined system. • At present, there is no application to large-scale STP. Only in operation in: 1. Demo plant in Da Nang, 300 m^3/day 2. Under construction plant in Hoi An, 2,000 m^3/day 3. Demo plant in Japan, 6,750 m^3/day
Evaluation[1)]			
Construction cost	+++++	+++	++++
O&M cost	+++++	+++	++++
Easiness of O&M	+++++	++++	++++
Number of applications in large-scale STP[2)]	++	++	+
Number of	+	+++++	+++++

Items		Lagoon	Trickling Filter (TF)	Pre-treated Trickling Filtration (PTF)
	resettlements			
	Environmental and social aspects	+	+++	+++++
	Total	+19	+20	+23

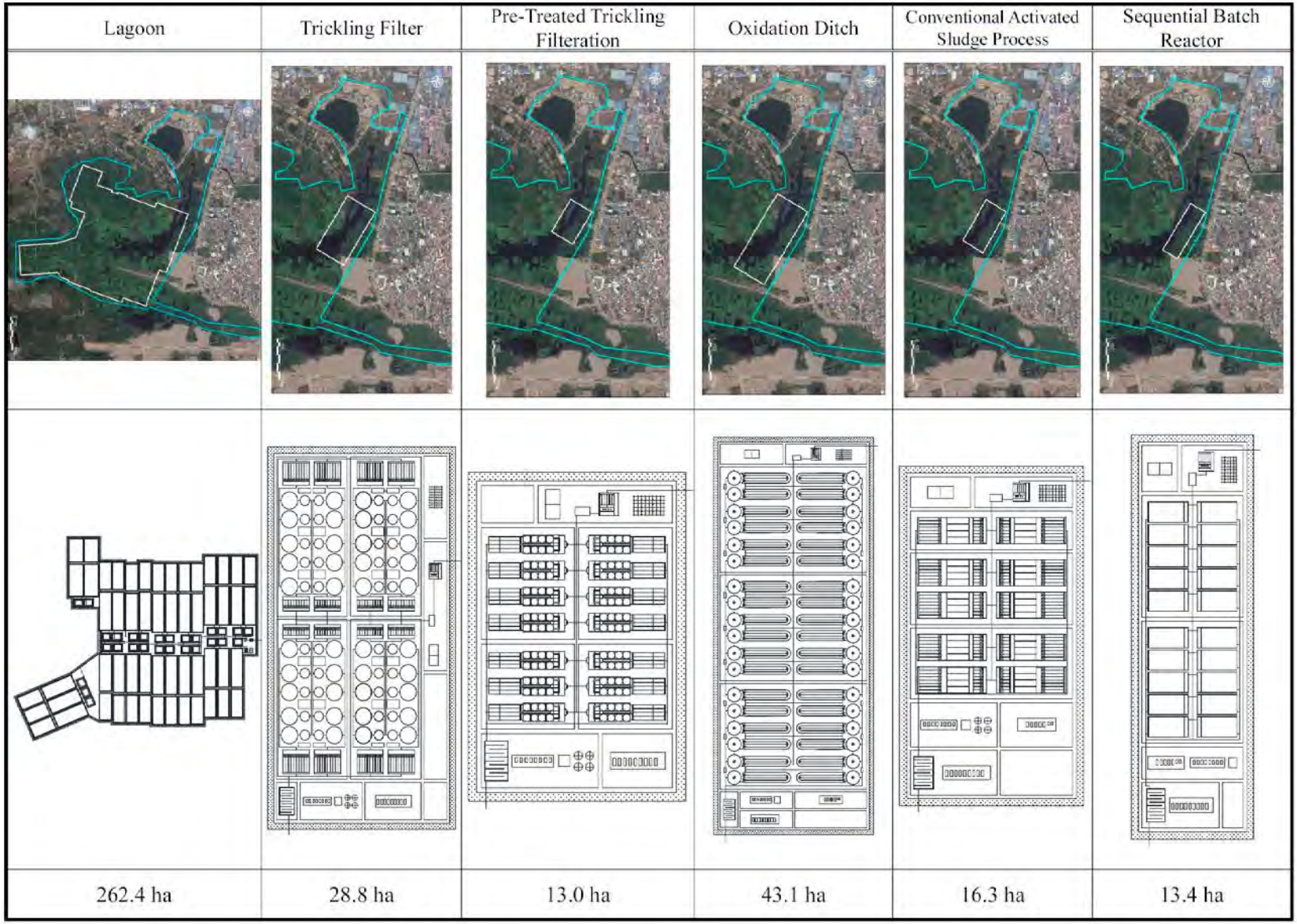
Note1: Scores in "Evaluation" are on a five-level descending system of "+++++" to "+".
Note2: Large-scale STP in the table is defined as the STP with capacity of more than 100,000 m^3/day.
Source: JICA Study Team

Table 4.1.5 Comparison of Wastewater Treatment Method applied to Cheung Aek STP (2/2)

Items		Oxidation Ditch (OD)	Conventional Activated Sludge Process (CASP)	Sequential Batch Reactor (SBR)
Land requirement (ha)		43.1	16.3	13.4
Construction cost (million USD)				
	STP in total	397.9	302.9	260.9
	Civil (reclamation)	57.2	23.8	20.4
	Civil (structures)	176.9	77.0	84.3
	Architecture	18.8	19.8	18.9
	Machinery	83.1	118.7	75.0
	Electricity	61.9	63.6	62.3
	Sewer	130.7	130.7	130.7
	Sludge dumping site	16.5	16.5	16.5
	Total	545.1	450.1	408.1
O&M cost (million USD/year)				
	STP in total	17.711	14.564	16.433
	Civil (reclamation)	13.950	8.968	10.961
	Civil (structures)	0.273	0.721	0.307
	Architecture	2.645	3.933	4.112
	Machinery	0.539	0.368	0.500
	Electricity	0.304	0.574	0.553
	Sewer	0.157	0.157	0.157
	Sludge dumping site	0.174	0.174	0.174
	Total	18.042	14.895	16.764
EIRR		7.1%	10.5%	11.7%
Number of resettlements anticipated		• No resettlement	• No resettlement	• No resettlement
Pros and cons		• O&M is easy because of its simplified structure. On the other hand, land requirement of OD reaches 2.5 times of CASP's. • In general, this method is applicable to STP with capacity of less than 10 thousand m^3/day. • Application of this method to large-scale plant tends to be relatively high in cost.	• Construction cost is higher but O&M is lower than those of SBR. In addition, O&M is easier compared to SBR. • Large in number of application to large-scale plants and operation methods are well-established.	• Construction cost is lower than that of CASP. O&M cost is higher than that of CASP. • Skilled techniques including formulation of appropriate sequence are required, because this method treat wastewater in one reactor. This method is as a whole applicable to a site in which available land is limited.
Evaluation[1)]				
	Construction cost	+++	+++	++++
	O&M cost	+	++	+
	Easiness of O&M	++++	+++	+++
	Number of applications in large-scale STP[2)]	++	+++++	+++

Items		Oxidation Ditch (OD)	Conventional Activated Sludge Process (CASP)	Sequential Batch Reactor (SBR)
	Number of resettlements	+++++	+++++	+++++
	Environmental and social aspects	+++	+++++	+++++
	Total	+18	+23	+21

Note1: Scores in “Evaluation” are on a five-level descending system of “+++++” to “+”.
Note2: Large-scale STP in the table is defined as the STP with capacity of more than 100,000 m^3/day.
Source: JICA Study Team



Source: JICA Study Team

Fig. 4.1.2 Layout Plan of Cheung Aek STP

(3) Financial Analysis

Financial analysis is performed based on the result described above, targeting CASP and PTF, which are first-ranked in the quantitative evaluation, as well as Lagoon which has strength in terms of low-cost.

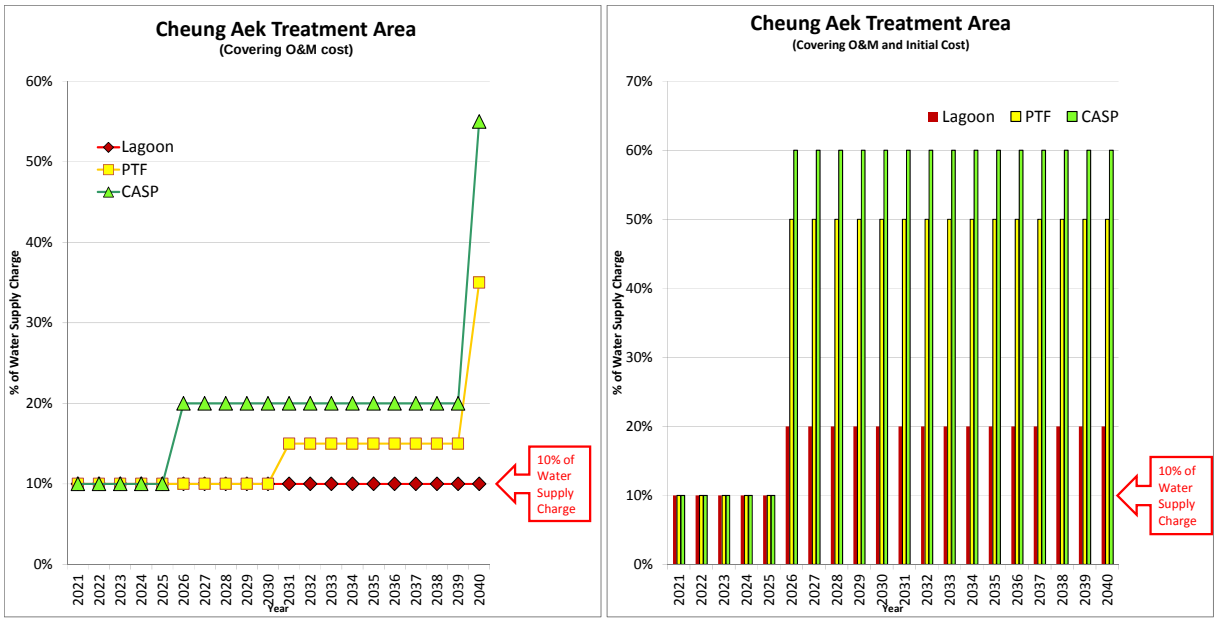
The financial analysis figures out: (i) sewerage fee and (ii) charge on vacuum truck dumping on-site facilities' sludge to the proposed sludge dumping site as detailed in **Subsection 4.3.2,** in order to cover O&M cost only or to cover both O&M and construction cost. The analysis result is summarized in **Table 4.1.6** and the transition of estimated total charge (expressed in percent) is presented in **Fig. 4.1.3**.

As shown in **Table 4.1.6**, for example, current sewerage fee of 10% to water tariff can cover O&M cost of Lagoon system. In contrast, sewerage fee of 10% up to year 2025 will be required to cover O&M cost of the CASP system, and then 20% from year 2026 to 2039 and 55% from 2040, are required.

Table 4.1.6 Summary of Financial Analysis for Cheung Aek Treatment Area

Case	**Cheung Aek Treatment Area is serviced applying Lagoon**		**Cheung Aek Treatment Area is serviced applying PTF**		**Cheung Aek Treatment Area is serviced applying CASP**	
Target	O&M cost only	O&M and construction cost	O&M cost only	O&M and construction cost	O&M cost only	O&M and construction cost
Source of revenue						
Sewerage fee (ratio to water charge)	**10%** (entire period)	**10%** (up to year 2025) ⇓ **20%** (from year 2026)	**10%** (up to year 2030) ⇓ **15%** (up to year 2039) ⇓ **35%** (from year 2040)	**10%** (up to year 2025) ⇓ **50%** (from year 2026)	**10%** (up to year 2025) ⇓ **20%** (up to year 2039) ⇓ **55%** (from year 2040)	**10%** (up to year 2025) ⇓ **60%** (from year 2026)
(Adding to present sewerage and drainage charge of 10%)	(-)	(-) (up to year 2025) ⇓ (10%) (from year 2026)	(-) (up to year 2030) ⇓ (5%) (up to year 2039) ⇓ (25%) (from year 2040)	(-) (up to year 2025) ⇓ (40%) (from year 2026)	(-) (up to year 2025) ⇓ (10%) (up to year 2039) ⇓ (45%) (from year 2040)	(-) (up to year 2025) ⇓ (50%) (from year 2026)
Charge on vacuum truck dumping sludge to the sludge dumping site (USD/truck)	5	5	5	5	5	5

Source: JICA Study Team



Source: JICA Study Team

Fig. 4.1.3 Transition of Sewerage Fee to cover Cost of Cheung Aek Treatment Area

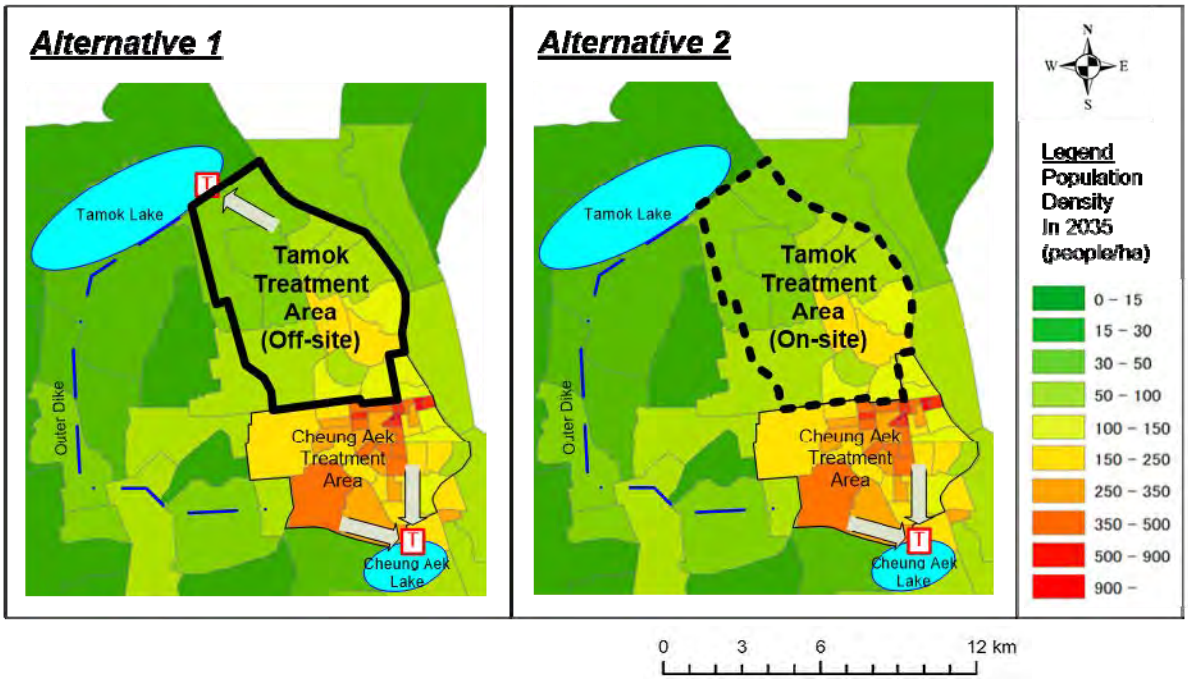
(4) Conclusion

Based on the above discussion, the Lagoon system is not preferable in consideration of social and environmental negative impacts due to extensive land reclamation. Rather, a typical mechanical treatment system of CASP or PTF, which is a new Japanese treatment system being advantageous to O&M cost reduction and minimization of land acquisition, are recommendable. However, when applying the PTF, careful attention should be paid on the risks of the method because the method is not yet applied to large-scale STPs. Additionally, more attention should be paid to PPCC's strategies and priorities for sustainable sewage management when selecting and finalizing wastewater treatment method. Therefore, the selection of wastewater treatment method is finalized through the discussion in T/C and S/C meetings.

In response, CASP was selected for M/P and Pre-F/S for Cheung Aek STP in the discussions of T/C and S/C with PPCC, held in September 2016, because it is too early to apply PTF due to the fact that the method is not yet applied to large-scale STPs.

4.1.2 Tamok Treatment Area

Alternative study on (i) Alternative-1, off-site and (ii) Alternative-2, on-site, are carried out, targeting the area in Tamok basin having the population density of more than 50 persons/ha in the year 2035, as schematically illustrated in **Fig. 4.1.4**[21].



Source: JICA Study Team

Fig. 4.1.4 Alternative Study on Tamok Treatment Area

(1) Study Result of Off-Site Treatment (Alternative 1)

As discussed in **Subsection 3.2.2**, study on off-site treatment is conducted with the following assumptions.

- Sewage collection system: Separate system
- Sewage treatment methods: 6 methods are evaluated

(a) Sewage Collection System

As shown in **Table 4.1.7**, the evaluation result shows that treatment area amounts to 6,019.2 ha with population of 481 thousand. Total length of trunk sewer is 66.1 km (diameter from φ200 mm to φ1,650 mm). Pumping station should be installed at nine locations, of which seven pumping stations are manhole type. Construction cost of sewer system is estimated at 397.7 million USD, higher than that of Cheung Aek Area, as shown in **Tables 4.1.10** and **4.1.11**, because branch sewers are required in entire Tamok Treatment Area, unlike the Cheung Aek Treatment Area.

[21] Thus, area in Tamok basin with population density of less than 50 persons/ha is integrated into "Other Area"

Table 4.1.7 Outline of Tamok Treatment Area

Items	Contents
Area (ha)	6,019.2
Population (year 2035)	481,423
Sewage collection system	Separate system
Trunk sewer (km)	66.1 (φ200 mm-φ1,650 mm)
Requirement of installing branch sewer	Required
Pumping station	Large-scale 2 locations Manhole type 7 locations
Construction cost of sewer network	See **Tables 4.1.10** and **4.1.11**

Source: JICA Study Team

(b) Sewage Treatment Plant

Based on the population in **Tables 4.1.7** and sewage generation per capita discussed in **Chapter 3**, design inflow to STP and pollution load are projected as shown in **Tables 4.1.8** and **4.1.9**. In addition, evaluation results of six treatment methods are summarized in **Tables 4.1.10** and **4.1.11**, and the layout plan of STP in Tamok Lake is illustrated in **Fig. 4.1.5.**

Table 4.1.8 Design Inflow to Tamok STP

Items	Sewage (m^3/day)	Ground water (m^3/day)	Total (m^3/day)	Design inflow (m^3/day)
Daily average	98,692	15,652	114,344	115,000
Daily maximum	108,320	15,652	123,972	124,000
Hourly maximum	163,684	15,652	179,336	180,000

Note: (Groundwater estimate 1)= 6,019.2 ha×7.5 m^3/day/ha=45,144 m^3/day…..(1)
(Groundwater estimate 2)=Population×(160+95)L/capita/day×0.85×15%=15,562 m^3/day..(2)
The results show that (2)<(1). Therefore, (Groundwater estimate 2) is adopted.
Source: JICA Study Team

Table 4.1.9 Design Water Quality of Cheung Aek STP

Items	Daily average inflow (m^3/day)	Concentration calculated (mg/L)	Design water quality (mg/L)	Remarks
BOD	115,000	191	195	Total BOD load: 21,991 kg/day of which domestic and commercial: 21,664 kg/day Industrial: 327 kg/day
TSS	115,000	201	205	BOD×1.05

Note: (Domestic and commercial BOD load)=(Population)×45 g/capita/day×10^{-3}
(Industrial BOD load)=(Population)×8.5 L/capita/day (amount of water use)×80 mg/L×10^{-6}
Source: JICA Study Team

Evaluation results show that Lagoon is the best option in terms of lowest construction and O&M cost. Unlike Cheung Aek Lake, Lagoon requires largest land requirement but negative environmental impact to Tamok Lake is limited because the lake has a considerably large surface area. In addition, resettlement will not be required.

Based on the quantitative evaluation in terms of construction cost, O&M cost, easiness of O&M, number of application in large-scale STP and environmental and social aspects, Lagoon, PTF and CASP are given the highest scores in the evaluation.

Table 4.1.10 Comparison of Wastewater Treatment Method applied to Tamok STP (1/2)

Items	Lagoon	Trickling Filter (TF)	Pre-treated Trickling Filtration (PTF)
Land requirement (ha)	115.0	16.5	8.4
Construction cost (million USD)			
STP in total	109.7	201.3	176.7
Civil (reclamation)	69.4	18.3	11.7
Civil (structures)	20.3	56.8	46.4
Architecture	8.9	15.9	15.9
Machinery	3.5	65.2	58.5
Electricity	7.6	45.1	44.2
Sewer[1)]	397.7	397.7	397.7
Pumping station	1.7	1.7	1.7
Sludge disposal site[2)]	-	-	-
Total	509.1	600.7	576.1
O&M cost (million USD/year)			
STP in total	0.752	5.056	4.549
Civil (reclamation)	0.441	2.468	2.027
Civil (structures)	0.128	0.178	0.178
Architecture	-	1.737	1.737
Machinery	0.033	0.416	0.381
Electricity	0.150	0.257	0.226
Sewer	1.492	1.492	1.492
Pumping station	0.075	0.075	0.075
Sludge disposal site[1)]	-	-	-
Total	2.319	6.623	6.116
EIRR	4.3%	3.2%	3.5%
Number of resettlements anticipated	• No resettlement	• No resettlement	• No resettlement
Pros and cons	• Large-scale resettlement is not required and social impact due to large-scale reclamation is limited, compared to Cheung Aek Lake. • Construction and O&M costs are lowest. • O&M is easy but control of offensive odour by covering is difficult due to the reason that the system has to introduce sunshine into the lagoons for provision of oxidation and disinfection. • This method has strength in coping with fluctuation of water quality but periodical removal of sludge is required so as not to reduce capacity.	• Land requirement is 2nd largest, which is twice as large as that of PTF. • 3rd lowest of O&M cost due to low energy consumption. • Control of offensive odour and outbreak of filter bed flies is difficult. • Adoption in large-scale STP is small in number.	• Land requirement is less than half of TF's. • 2nd lowest of O&M cost due to low energy consumption. • Periodical mixing of media keeps filter bed clean and thus prevent from out-break of filter flies. • This method has strength in coping with first flush, and hence applicable to combined system. • At present, there is no application to large-scale STP. Only in operation in 1. Demo plant in Da Nang, 300 m^3/day 2. Under construction plant in Hoi An, 2,000 m^3/day 3. Demo plant in Japan, 6,750 m^3/day
Evaluation[3)]			
Construction cost	++++	+++	++++
O&M cost	+++++	+++	++++
Easiness of O&M	+++++	++++	++++
Number of applications in large-scale STP[4)]	++	++	+
Number of resettlements	+++++	+++++	+++++
Environmental and	++	+++	+++++

Items		Lagoon	Trickling Filter (TF)	Pre-treated Trickling Filtration (PTF)
	social aspects			
	Total	+23	+20	+23

Note 1: Construction cost includes cost of branch sewer installation.
Note 2: Construction and O&M cost is included in sludge dumping site in **Table 4.1.4** and **Table 4.1.5**.
Note 3: Scores in "Evaluation" are on a five-level descending system of "+++++" to "+".
Note 4: Large-scale STP in the table is defined as the STP with capacity of more than 100,000 m^3/day.
Source: JICA Study Team

Table 4.1.11 Comparison of Wastewater Treatment Method applied to Tamok STP (2/2)

Items		Oxidation Ditch (OD)	Conventional Activated Sludge Process (CASP)	Sequential Batch Reactor (SBR)
Land requirement (ha)		24.1	10.4	8.1
Construction cost (million USD)				
	STP in total	235.3	198.8	168.3
	Civil (reclamation)	25.6	12.5	9.7
	Civil (structures)	86.4	45.2	48.3
	Architecture	18.9	19.8	18.9
	Machinery	52.2	74.6	47.1
	Electricity	52.2	46.7	44.3
	Sewer[1)]	397.7	397.7	397.7
	Pumping station	1.7	1.7	1.7
	Sludge disposal site[2)]	-	-	-
	Total	634.7	598.2	567.7
O&M cost (million USD/year)				
	STP in total	8.039	6.681	7.463
	Civil (reclamation)	6.170	3.967	4.848
	Civil (structures)	0.196	0.253	0.230
	Architecture	1.171	1.737	1.816
	Machinery	0.365	0.467	0.324
	Electricity	0.137	0.257	0.245
	Sewer	1.492	1.492	1.492
	Pumping station	0.075	0.075	0.075
	Sludge disposal site[1)]	-	-	-
	Total	9.606	8.248	9.030
EIRR		3.8%	2.8%	3.1%
Number of resettlement anticipated		• No resettlement	• No resettlement	• No resettlement
Pros and cons		• O&M is easy because of its simplified structure. On the other hand, land requirement of OD reaches 2.5 times of CASP's. • In general, this method is applicable to STP with capacity of less than 10 thousand m^3/day. • Application of this method to large-scale plant tends to be relatively high in cost.	• Construction cost is higher but O&M is lower than that of SBR. In addition, O&M is easier compared to SBR • Large in number of application to large-scale plants and operation methods are well-established.	• Construction cost is lower than that of CASP. • O&M cost is higher than that of CASP. • Skilled techniques including formulation of appropriate sequence are required because this method treat wastewater in one reactor. This method is as whole applicable to the site in which available land is limited.
Evaluation[3)]				
	Construction cost	+++	+++	++++
	O&M cost	+	++	+
	Easiness of O&M	++++	+++	+++
	Number of applications in	++	+++++	+++

Items		Oxidation Ditch (OD)	Conventional Activated Sludge Process (CASP)	Sequential Batch Reactor (SBR)
	large-scale STP[4)]			
	Number of resettlements	+++++	+++++	+++++
	Environmental and social aspects	+++	+++++	+++++
	Total	+18	+23	+21

Note 1: Construction cost includes cost of branch sewer installation.
Note 2: Construction and O&M cost is included in sludge dumping site in **Table 4.1.4** and **Table 4.1.5**.
Note 3: Scores in "Evaluation" are on a five-level descending system of "+++++" to "+".
Note 4: Large-scale STP in the table is defined as the STP with capacity of more than 100,000 m^3/day.
Source: JICA Study Team

Source: JICA Study Team

Fig. 4.1.5 Layout Plan of Tamok STP

(2) Study Result of On-Site Treatment (Alternative 2)

As shown in **Table 2.4.2**, more than 90% of households in Phnom Penh have the pit latrine or septic tank. Most probably, therefore, roughly 90% households in Tamok treatment area have the pit latrine or septic tank.

In order to select the appropriate on-site treatment method for Tamok treatment area, on-site treatment methods of pit latrine, septic tank, Johkasou and community plant are evaluated as shown in **Table 4.1.12**. As the result, Johkasou is selected as the appropriate on-site treatment method in Tamok treatment area with the following reasons. In this evaluation, domestic and commercial wastewater is treated by the facilities but industrial wastewater is treated by each owner of factory to the level of BOD of 80 mg/L.

- On-site treatment facilities, which exceed the capacity of septic tank, is appropriate in consideration of the present deterioration of water environment in Tamok basin under the condition that most of the households install septic tank or pit latrine, and estimated increase in population as well as pollution load generated

- Johkasou and community plant are candidates for the facilities exceeding the septic tank, but in particular Johkasou has advantages over community plant that (i) it can be fabricated in factory and be easily installed on the site; (ii) it has in principle functionality equivalent to community plant; and (iii) it has a wide range of line-up covering community based size.

Table 4.1.12 Comparison of On-Site Treatment Methods applicable to Tamok Treatment Area

Method	Salient features	Evaluation
Pit latrine	・This method is equipped with a pit and cover plate. ・Structure is very simple but it cannot control offensive odour and outbreak of flies because it only deposit faeces and urine. ・Electricity is not required.	・This method is very simple and it can be easily installed with low-cost. However, more advanced method of septic tank are widely installed in Phnom Penn and thus this method is no longer applicable for newly installed facilities in Phnom Penh. Evaluation : +
Septic tank	・This method consists of flush toilet and underground tank in which faeces and urine are partially decomposed by anaerobic digestion. ・This method is widely used in Phnom Penh. ・Electricity is not required.	・This method is widely used in Phnom Penh. Nevertheless water environment in Phnom Penh is deteriorating. It is therefore recommendable to introduce facilities exceeding septic tank Evaluation : ++
Johkasou	・This is an on-site treatment facility device developed in Japan. This device has wide range of line-up, covering a household size to community-based size with capacity for several hundred to several thousand. ・This devise is in principle fabricated in factory and easily installed on site. ・Electricity is required, but, the electric consumption of household size is for example several dozen Wh. ・Removal rate of the device is same as that of mechanical off-site treatment system.	・This device is applicable as alternative of septic tank because (i) the device has advantages in easiness of installation compared with community plant, (ii) phased installation is easy and (iii) it has wide variety of line-up ranging from a household size to community based size equivalent to several hundred to a thousand people. ・Recently, community-based Johkasou has been developed and it becomes alternative of community plant due to the reason of easiness of installation at lower cost. ・Further cost reduction is expected if this device is widely installed in PPCC in the future. Evaluation : +++
Community plant	・This is a system consisting of sewer network in the community and small-scale STP. ・Electricity is required and removal rate of the system is the same as that of mechanical off-site treatment system.	・The system treats wastewater at the same level of mechanical off-site treatment system but on the other hand the system is not simple and costly compared to Johkasou because it requires same configuration of off-site treatment system. Evaluation : ++

Scores in "Evaluation" are on a three-level descending system of "+++" :good; "++":fair; and "+" :not good.
Source: JICA Study Team

Evaluation results applying Johkasou are described briefly as below.

- Construction and O&M cost: Construction and O&M cost is estimated at 396 million USD and 15.8 million USD/year. This construction cost is more than 100 million USD lower than that of Lagoon, which is lowest in construction cost (509 million USD) of off-site treatment system. This result arises from the reason that Tamok basin needs branch sewer installation, unlike Cheung Aek treatment area. On the other hand, O&M cost (14.3 million USD/year) is 1.9 times of CASP's (8.3 million USD/year). However, total cost including construction cost and O&M is lower than that of CASP.

- Others: Johkasou have advantages that phased construction and commission is easy because it is generally installed individually. Moreover, unlike off-site treatment system, reclamation of Tamok Lake is not required and EIRR is higher than those of the other six off-site treatment methods.

Table 4.1.13 Outline of On-Site Treatment System applied to Tamok Treatment Area

Item	Contents
Title of facilities	On-site treatment (Johkasou
Target population	481,423
Quantities of facilities[1)]	Small scale (for 5 persons) : 48,085 units Community-based scale (for 300 persons) : 805 units

Item		Contents
Construction cost (million USD)		396.2
Total O&M cost (million USD/year)		15.797
Electricity		8.266
Inspection		2.020
Desludge and disposal of sludge		4.040
Spare parts and repair		1.471
EIRR		6.5%
Pros and cons		• Construction cost is lower than any other off-site treatment method (6 methods). • O&M cost is higher than that of typical off-site treatment method of CASP. • Phased construction is easy because Johkasou can be commissioned individually. • Reclamation of Tamok Lake is not required.
Evaluation[2)]		
	Construction cost	+++++
	O&M cost	+
	Easiness of O&M	++++
	Number of application	+++
	Number of resettlement	+++++
	Environmental and social aspect	+++++
	Total	+23

Note 1: Number of Johkasou is computed under assumption that 50% of population uses small-scale Johkasou, while others use community-based Johkasou.
Note 2: Scores in "Evaluation" are on a five-level descending system of "+++++" to "+", as with in **Tables 4.1.10 and 4.1.11.**
Source: JICA Study Team

Based on the discussion in **Tables 4.1.10** and **4.1.11**, which summarise the quantitative evaluation of six off-site treatment methods, as well as **Table 4.1.13**, which outlines quantitative evaluation of on-site treatment, off-site treatment applying Lagoon, CASP and PTF or on-site treatment applying Johkasou are preferable as a whole.

(3) Financial Analysis

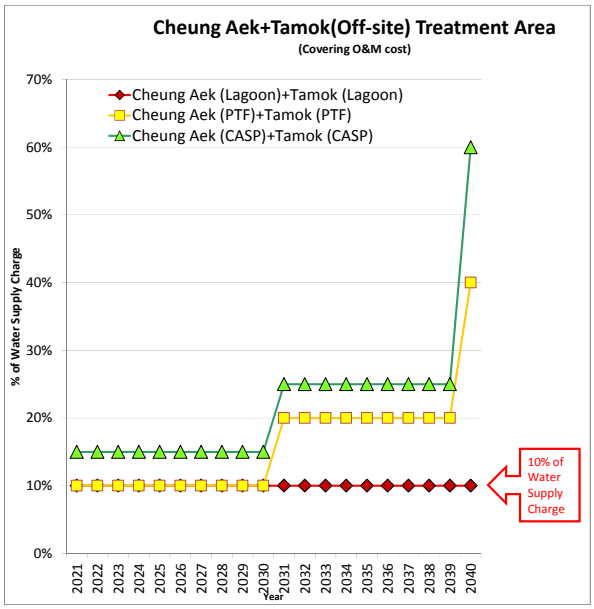
Based on the discussion above, financial evaluation is performed focusing on the off-site treatment by Lagoon, CASP and PTF, as well as the on-site treatment by Johkasou, because the four methods obtained the same score. It is noted that the financial analysis is performed to compute sewerage fee and sludge dumping fee posed to vacuum truck, in order to cover cost of Tamok as well as Cheung Aek Treatment areas, since Cheung Aek Treatment Area is covered by sewerage fee, regardless of selection of treatment method in Tamok Treatment Area. There is a case that investment cost as well as O&M cost in Tamok area is borne only by users in Tamok area but this case is not studied because the financial burden to Tamok Area is too big as shown in **Appendix 2**. Therefore, costs of sewerage in Cheung Aek and Tamok area are combined and is borne together by both users in Cheung Aek and Tamok.

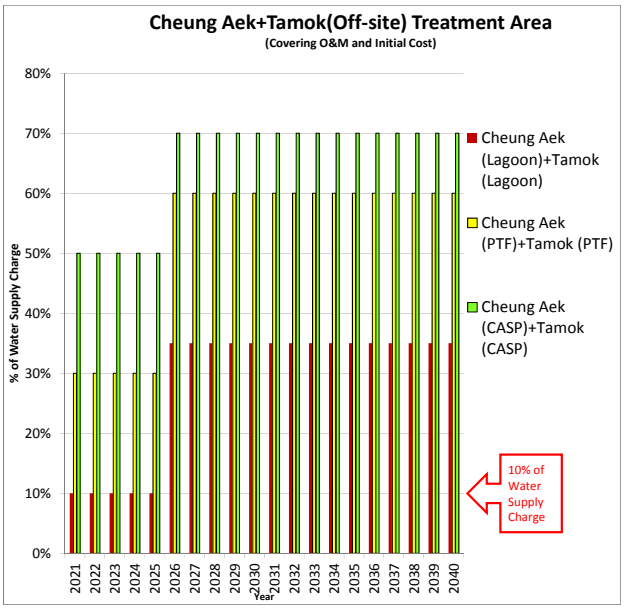
Tables 4.1.14 and **4.1.15** respectively summarizes the financial analyses of: (i) Tamok Treatment Area serviced by applying off-site treatment of Lagoon, PTF and CASP and (ii) Tamok Treatment Area serviced by applying on-site treatment of Johkasou, in cases of application of Lagoon, PTF and CASP in Cheung Aek Treatment Area. In addition, **Figs. 4.1.6** and **4.1.7** present transitions of sewerage fee covering O&M cost only or covering both O&M and construction cost, depending on the case analysis in **Tables 4.1.14** and **4.1.15**.

Table 4.1.14 Summary of Financial Analysis for Tamok Treatment Area applying Off-Site System (including Cost of Cheung Aek Treatment Area)

Case	**Tamok Treatment Area is serviced applying off-site treatment of Lagoon (including cost of Cheung Aek Treatment Area is serviced applying Lagoon)**		**Tamok Treatment Area is serviced applying off-site treatment of PTF (including cost of Cheung Aek Treatment Area is serviced applying PTF)**		**Tamok Treatment Area is serviced applying off-site treatment of CASP (including cost of Cheung Aek Treatment Area is serviced applying CASP)**	
Image of application of on- and off-site	Tamok (off-site) Lagoon Cheung Aek (off-site) Lagoon		Tamok (off-site) PTF Cheung Aek (off-site) PTF		Tamok (off-site) CASP Cheung Aek (off-site) CASP	
Target	O&M cost only	O&M and construction cost	O&M cost only	O&M and construction cost	O&M cost only	O&M and construction cost
Source of revenue						
Sewerage fee (ratio to water charge)	**10%** (entire period)	**10%** (up to year 2025) ⇓ **35%** (from year 2026)	**10%** (up to year 2030) ⇓ **20%** (from year 2031 to 2039) ⇓ **40%** (from year 2040)	**30%** (up to year 2025) ⇓ **60%** (from year 2026)	**15%** (up to year 2030) ⇓ **25%** (from year 2031 to 2039) ⇓ **60%** (from year 2040	**50%** (up to year 2025) ⇓ **70%** (from year 2026)
(Adding to present sewerage and drainage charge of 10%)	(-) (entire period)	(-) (up to year 2025) ⇓ (15%) (from year 2026)	(-) (up to year 2030) ⇓ (10%) (from year 2031 to 2039) ⇓ (30%) (from year 2040)	(20%) (up to year 2025) ⇓ (50%) (from year 2026)	(5%) (up to year 2030) ⇓ (15%) (from year 2031 to 2039) ⇓ (50%) (from year 2040)	(40%) (up to year 2025) ⇓ (60%) (from year 2026)
Charge on vacuum truck dumping sludge to the sludge dumping site (USD/truck)	5	5	5	5	5	5

Source: JICA Study Team





Source: JICA Study Team

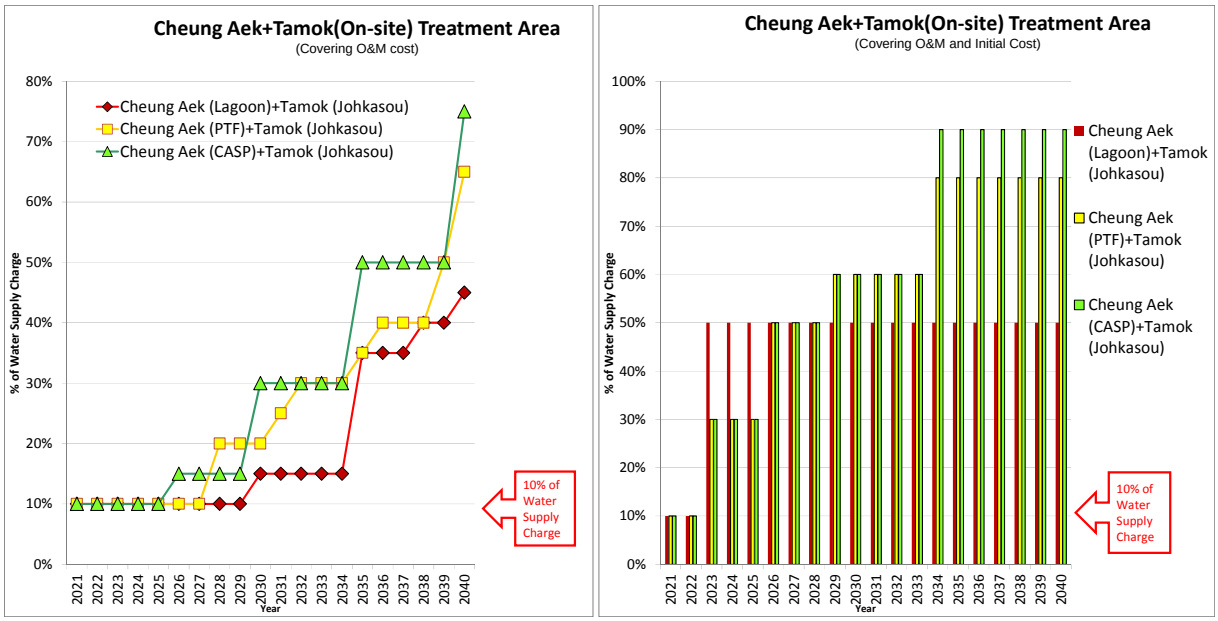
Fig. 4.1.6 Transition of Sewerage Fee to cover Costs for Cheung Aek and Tamok Treatment Area (Tamok Treatment Area: Off-Site)

Table 4.1.15 Summary of Financial Analysis for Tamok Treatment Area applying On-Site System (including Cost of Cheung Aek Treatment Area)

Case	**Tamok Treatment Area is serviced applying on-site treatment of Johkasou (including service cost of Cheung Aek Treatment Area applying Lagoon)**		**Tamok Treatment Area is serviced applying on-site treatment of Johkasou (including service cost of Cheung Aek Treatment Area applying PTF)**		**Tamok Treatment Area is serviced applying on-site treatment of Johkasou (including service cost of Cheung Aek Treatment Area applying CASP)**	
Image of application of on- and off-site	Tamok (on-site) Johkasou / Cheung Aek (off-site) Lagoon		Tamok (on-site) Johkasou / Cheung Aek (off-site) PTF		Tamok (on-site) Johkasou / Cheung Aek (off-site) CASP	
Target	O&M cost only	O&M and construction cost	O&M cost only	O&M and construction cost	O&M cost only	O&M and construction cost
Source of revenue						
Sewerage fee (ratio to water charge)	**10%** (up to year 2029) ⇓ **15%** (up to year 2034) ⇓ **35%** (up to year 2037) ⇓ **40%** (up to year 2039) ⇓	**10%** (up to year 2022) ⇓ **50%** (from year 2023)	**10%** (up to year 2027) ⇓ **20%** (up to year 2030) ⇓ **25%** (up to year 2031) ⇓ **30%** (up to year 2034) ⇓	**10%** (up to year 2022) ⇓ **30%** (up to year 2025) ⇓ **50%** (up to year 2028) ⇓ **60%** (up to year 2033) ⇓	**10%** (up to year 2025) ⇓ **15%** (up to year 2030) ⇓ **30%** (up to year 2034) ⇓ **50%** (up to year 2039) ⇓	**10%** (up to year 2022) ⇓ **30%** (up to year 2025)) ⇓ **50%** (up to year 2028) ⇓ **60%** (up to year 2033) ⇓

Case	**Tamok Treatment Area is serviced applying on-site treatment of Johkasou** **(including service cost of Cheung Aek Treatment Area applying Lagoon)**		**Tamok Treatment Area is serviced applying on-site treatment of Johkasou** **(including service cost of Cheung Aek Treatment Area applying PTF)**		**Tamok Treatment Area is serviced applying on-site treatment of Johkasou** **(including service cost of Cheung Aek Treatment Area applying CASP)**	
	45% (from year 2040)		**35%** (up to year 2035) ⇓ **40%** (up to year 2038) ⇓ **50%** (up to year 2039) ⇓ **65%** (from year 2040)	**80%** (from year 2034)	**75%** (from year 2040)	**90%** (from year 2034)
(Adding to present sewerage and drainage charge of 10%)	(-) (up to year 2029) ⇓ (5%) (up to year 2034) ⇓ (25%) (up to year 2037) ⇓ (30%) (up to year 2039) ⇓ (35%) (from year 2040)	(-) (up to year 2022) ⇓ (40%) (from year 2023)	(-) (up to year 2027) ⇓ (10%) (up to year 2030) ⇓ (15%) (up to year 2031) ⇓ (20%) (up to year 2034) ⇓ (25%) (up to year 2035) ⇓ (30%) (up to year 2038) ⇓ (40%) (up to year 2039) ⇓ (55%) (from year 2040)	(-) (up to year 2022) ⇓ (20%) (up to year 2025) ⇓ (40%) (up to year 2028) ⇓ (50%) (up to year 2033) ⇓ (70%) (from year 2034)	(-) (up to year 2025) ⇓ (5%) (up to year 2030) ⇓ (20%) (up to year 2034) ⇓ (40%) (up to year 2039) ⇓ (65%) (from year 2040)	(-) (up to year 2022) ⇓ (20%) (up to year 2025) ⇓ (40%) (up to year 2028) ⇓ (50%) (up to year 2033) ⇓ (80%) (from year 2034)
Charge on vacuum truck dumping sludge to the sludge dumping site (USD/truck)	5	5	5	5	5	5

Source: JICA Study Team



Source: JICA Study Team

Fig. 4.1.7 Transition of Sewerage Fee to cover Costs for Cheung Aek and Tamok Treatment Area (Tamok Treatment Area: On-Site)

Results in **Tables 4.1.14** and **4.1.15** suggest that it is not realistic to cover construction cost by sewerage fee. In addition, considering sewerage fee after year 2041, sewerage fee is stable to cover only O&M cost but significant raise of sewerage fee is required to cover O&M and construction cost. Therefore, it is recommendable for it to cover only O&M cost and construction cost is borne by subsidy from the government.

To clarify sewerage fee per capita, sewerage fee presented by percentage in **Tables 4.1.14** and **4.1.15,** are converted to O&M cost per capita per month, as shown in **Table 4.1.16**, depending on the case analysis.

As in **Table 4.1.16**, O&M cost per capita per month ranges from 0.23 USD/month to 1.63 USD/month, by which Cheung Aek and Tamok Treatment areas are serviced applying the lagoon in both areas, as well as CASP in Cheung Aek and Johkasou in Tamok, respectively.

Table 4.1.16 also presents construction cost. Considering total cost (construction cost and O&M cost), Case of applying CASP in Cheung Aek Treatment area and Johkasou in Tamok Treatment Area is cheaper comparing the case of applying CASP in Cheung Aek and Tamok treatment areas[22].

Table 4.1.16 O&M Cost per Capita per Month

	Treatment area	Contents					
Population	Cheung Aek	1,093,155					
	Tamok	481,423					
	Total	1,574,578					
Treatment method	Cheung Aek	Lagoon	Lagoon	PTF	PTF	CASP	CASP
	Tamok	Johkasou	Lagoon	Johkasou	PTF	Johkasou	CASP
Construction cost	Cheung Aek	361.4	361.4	419.0	419.0	450.1	450.1
(million USD)	Tamok	396.2	509.1	396.2	576.1	396.2	598.2
(Reference)	Total	757.6	870.5	815.2	995.1	846.3	1,048.3
O&M cost (million USD/year)	Cheung Aek	1.890	1.890	10.184	10.184	14.895	14.895
	Tamok	15.797	2.319	15.797	6.116	15.797	8.248
	Total	17.687	4.209	25.981	16.300	30.692	23.143

[22] It takes about 27 years to balance difference in construction cost of 202.0 (598.2-396.2) million USD and accumulated difference in O&M cost of 7.549 (15.797-8.248) million USD/year.

	Treatment area	Contents					
O&M cost per capita (USD/month)		**0.94**	**0.23**	**1.38**	**0.87**	**1.63**	**1.23**

Source: JICA Study Team

(4) Conclusion

The above discussion reveals that: (i) introduction of off-site treatment system in Tamok Treatment Area has a disadvantage that it is too costly and it takes a long time to install the branch sewer in the entire basin, and thus water environment is not improved immediately; (ii) to introduce off-site treatment system in both Cheung Aek and Tamok Areas should be a financial burden to PPCC, considering the present budgetary allocation for sewage and drainage management sector; and (iii) there is an advantage in introducing the on-site treatment system in Tamok area because the step-by-step implementation approach can easily be applied. Ultimately, selection of on- and off-site treatment in Tamok depends on the strategies and policies on sewerage management of PPCC as with the case of Cheung Aek Area.

Thus, selection of on- and off-site treatment in Tamok Area was discussed in the S/C held in September 2016. As a result, on-site treatment (Johkasou) was applied in Tamok area considering the following advantages.

- On-site treatment system has advantage of total cost reduction. Highest EIRR compared to other six off-site treatment methods also shows the advantage.
- Additional cost reduction will be expected by the competition among the Johkasou suppliers.
- Considering the low population density in Tamok Area, on-site treatment has advantage in easiness of step-by-step implementation.

4.1.3 Other Area

It is not timely to introduce the off-site treatment system and high-grade on-site treatment facilities such as Johkasou, which is proposed in Tamok area, because population projection and population density estimated for the year of 2035 is too low and status of development is immature. Installation of pit latrine or septic tank should be, therefore, promoted in the area (outer area of Cheung Aek and Tamok), especially in households in which no toilet or pit latrine is equipped. Introduction of high-grade on-site treatment or off-site treatment should be discussed after the target year of 2035.

4.1.4 Summary of Application of On-Site and Off-Site Treatment System

Based on the discussion above, study on the sewage management M/P is hereinafter detailed, according to the classification of on- and off-site treatment area in PPCC, as showing in **Table 4.1.17**. Thus Tamok area is detailed, based on the application of on-site treatment in due consideration of reduction of early-stage investment cost and easy phased installation. However, as a reference, the study result on off-site treatment in Tamok area is supplemented in **Subsection 4.2.1**.

In the **Section 4.7**, methodologies for financial evaluations are detailed under the assumption that (i) off-site treatment applying CASP is considered for Cheung Aek Area; and (ii) on-site treatment, applying Johkasou is considered for Tamok Area. The same methodologies are applied to the evaluation in **Tables 4.1.6**, **4.1.14** and **4.1.15**.

Table 4.1.17 Summary of Application of On-Site and Off-Site Treatment

	Treatment system applied
Cheung Aek area	Off-site treatment
Tamok and other area	On-site treatment

Source: JICA Study Team

(1) Reduction of Pollution Load in the Implementation of the Master Plan

Effect of implementation of the Master Plan are evaluated by comparing pollution load at present (year 2015) and the target year (year 2035), based on the classification in **Table 4.1.17** and planning and design conditions described in **Chapter 3** and **Table 4.1.18**.

Table 4.1.18 Conditions for Evaluation of Pollution Load Reduction

Items		Contents	Remark
BOD load per capita (g/capita/day)		45	
Removal rate of septic tank (%)	Without project (at present and target year of 2035)	20	Note 1)
	With project (year 2035)	40	Note 2)
Effluent from the facilities (STP or Johkasou) in Alternative1 and 2 (mg/L)		30	

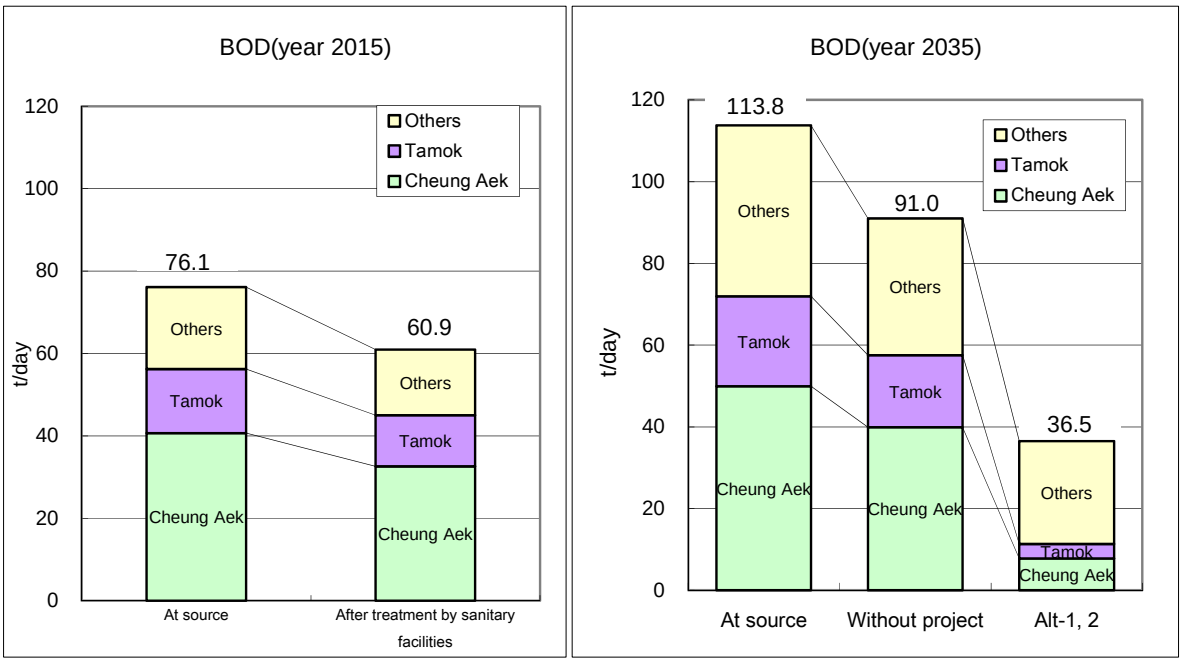
Note 1) Removal rate [(240-200)/240×100×20%] is set up, employing typical value obtained in the monitoring survey (about 200 mg/L at Trabek pumping station) and assumed BOD at the source (240 mg/L=45g/capita/day÷150 L(assumed sewage generation per capita in 2015)×1,000).

Note 2) Removal rate under the condition that desludge is appropriately conducted with reference to “Preparatory Survey Report on the Project for the Improvement of Water Supply, Sewerage and Drainage System in Yangon City in the Republic of the Union of Myanmar”, March 2014, JICA and "Project for Capacity Development of Wastewater Sector through reviewing the Wastewater Management Master Plan in DKI Jakarta", Final Report, March 2012, JICA.

Source: JICA Study Team

As shown in **Fig. 4.1.8**, pollution load of 76.1 t/day, generated at present (year 2015), will increase to 113.8 t/day or 1.5 times of present in the target year 2035 but the pollution load discharged (after treatment) is reduced from 60.9 t/day to 36.5 t/day by implementing the proposed Master Plan[23].

[23] Result of calculation is detailed in **Appendices 3** and **4**.



Source: JICA Study Team

Fig. 4.1.8 Reduction of Pollution Load

(2) Others

Occurrence of water-borne diseases manifested in social survey conducted in the Study, would be reduced and dirty sewage in drainage channels would disappear by the implementation of the M/P.

4.2 Facilities Plan

4.2.1 Sewer Network

(1) Study on Sewer Network

(a) Review of Existing Drainage System

As shown in **Subsection 2.4.3**, drainage pipe are installed mainly inside the inner ring dike, in which Khan Chamkarmon, Khan Daun Penh, Khan 7 Makara and Khan Tuol Kok are located. The drainage flow is discharged into the Cheung Aek Lake at the south and the Tamok Lake at the north of PPCC bordered by the railway. These drainage pipes receive connection from the septic tank installed in each household.

(b) Comparison of Sewer System

Collection system of sewage will be determined considering the topography, meteorology and present condition of drainage system. The collection system of sewage is classified to two (2) types, which are: 1) the combined sewer system and 2) the separate sewer system. Features of these sewer systems are shown in **Table 4.2.1**. The separated sewer system will be preferable from the viewpoint of water environmental management.

Table 4.2.1 Features of Sewer Systems

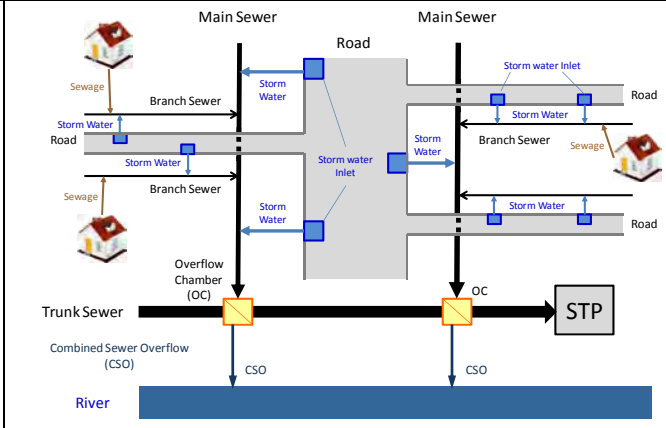
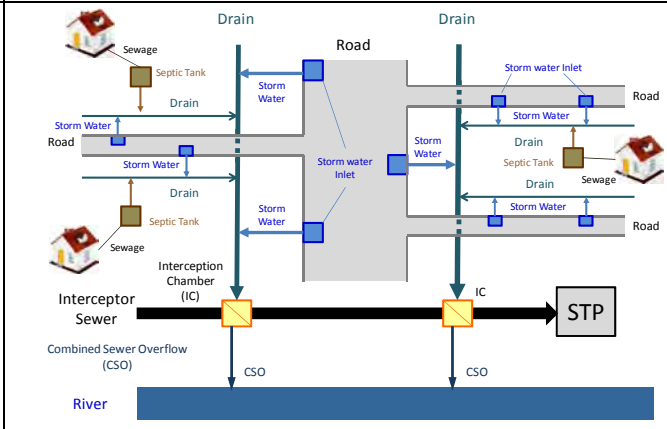
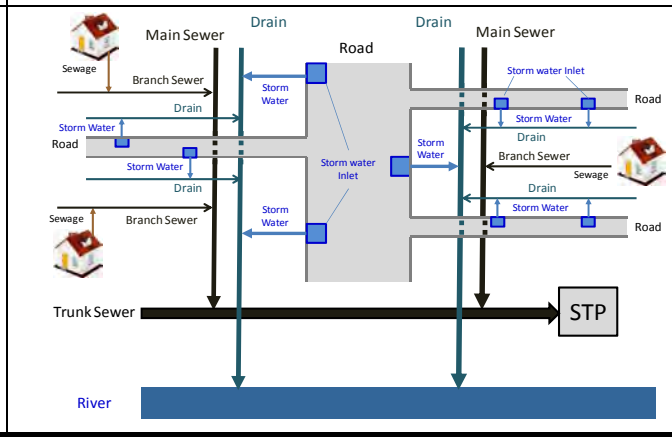
Sewer System	Combined Sewer		Separate Sewer
	Combined Sewer	Interceptor Sewer	
Feature	- To collect sewage with storm water by a same pipe.	- To utilize existing drainage system and to collect sewage	- To collect sewage by a sewer, separately from stormwater.
Construction	- Construction term and cost can be reduced because only one pile is installed. - Pipe diameter of sewer will be larger than that of separate sewer since both sewage and stormwater are collected in one pipe.	- Construction term and cost will be reduced because the existing drainage system is utilized. - Interceptor chambers are required at some discharge points of the drainage system.	- Construction duration and cost will be increased because two (2) pipes to collect sewage and stormwater are required. - Pipe diameter of sewer can be minimized.
Operation and Maintenance	- In the dry season, sedimentation will easily occur inside pipes. - In the rainy season, flashing by stormwater can be expected, but overflow will occur easily. - Regular checking and cleaning will be easier.		- Sediment deposition in sewer pipe is less than that of combined sewer or stormwater pipe. - Management for both of sewer pipe and stormwater pipe is required. - Installation depth of sewer will be deep.
Protection of Water Environment	- Combined sewer overflow (CSO) will be discharged to water bodies without any treatment. - Initial stormwater which contains a lot of pollutants can be treated at STP.		- Sewage will not be discharged to water bodies. - Initial stormwater which contains a lot of pollutants will be discharge to water bodies without any treatment.
House connections	- Not required but disconnection of septic tank will be required under the responsibility of house owner. - If septic tank is not disconnected, house owner will have to desludge septic tank even after the sewerage connection.		- Required.

Source: JICA Study Team

In addition, the interceptor sewer system will be considered as a method of staged sewer development for sewage treatment. This sewer system is a kind of combined sewer system and

utilizes the existing drainage system so that it is effective and economical to improve the sewer covered area faster. In this system, sewage will be collected at discharge point of wastewater from the existing drainage system by installing interception facilities. This interceptor sewer has to be converted into a separate sewer system in the future.

In the case of PPCC, each household must install a septic tank and the septic tanks are connected to the drainage system with a ratio of 71.8 % (as shown in **Table 2.4.2**). Under the present situation in PPCC, it is advantageous to apply the interceptor sewer system. **Fig. 4.2.1** shows each sewer system. In case the sewer system is developed, the septic tank installed at each household can be removed.

Sewer System	Outline of the System
Combined Sewer System (Sewage and stormwater will be collected by the same sewer)	
Interceptor Sewer System (Septic tanks will be removed after development of separate sewer system considering protection of water environment.)	
Separated Sewer System (Sewage and stormwater will be collected separately by each sewer. CSO will not occur.)	

Source: JICA Study Team

Fig. 4.2.1 Outline of Sewer Systems

(c) Sewage Transportation to STP

The transportation system of sewage includes gravity flow and pressured flow. Generally, sewer systems are planned with gravity flow. However, the systems will be selected considering the topographic condition of the sewage treatment area.

In the case of gravity flow, the sewer system will be economical and sewer connection is easy. In addition, its maintenance work will be easier than pressure flow. However, installation depth of sewer will be deep since the length of sewer is long. Therefore, some pumping stations may be required to avoid installation of sewer deeper. On the other hand, in case of pressure flow, installation depth of sewer can be shallow regardless of topography, but the connection of sewers and maintenance work will be more difficult than that of gravity flow system.

The ground elevation of PPCC is almost flat and slightly decline to public water bodies located at surrounding area of the capital. In addition, no pressure pipe is installed in PPCC at present and all drainage pipes collect water by gravity.

Considering the above, gravity flow will be applicable for the sewer system in PPCC, in accordance with the theory, but some pumping stations may be required because of the topographic condition.

(d) Basic Strategy for Developing Sewer Network

A sewer network is planned for areas in which sewage is treated at sewage treatment plants (STPs) considering actual situation and feature of the sewer system. In PPCC, drainage system is mainly developed in high population density area. Therefore, the interceptor sewer system by gravity flow shall be applied to improve the water environment and water quality as early as possible. These interceptors can be converted to the separated sewer system in the future. On the other hand, for areas in which a drainage system has rarely been developed, the separated sewer system will be applied.

The facilities for sewer network will be installed at existing road or public land to avoid land acquisition and resettlement. In addition, the routes of the sewer shall be selected beside existing canals and rivers in order to collect sewage effectively.

(2) Components of Facilities for Sewer Network

Sewer network by interceptor sewer system shall consist of: 1) sewers, 2) manholes, 3) interception facilities and 4) pumping stations.

(a) Sewers

Sewers are classified into 1) trunk sewer, 2) main sewer and 3) branch sewer. In this Master Plan, the following sewers are considered:

- Trunk Sewer: Sewer connected to STP
- Main Sewer: Sewer connected to the trunk sewer or covers whole area of its sewer district
- Branch Sewer: Sewer connects each household and the main sewers

There are several materials for sewer such as concrete, polyvinyl chloride and ductile cast iron. These materials shall be selected considering the characteristics of the each material, required condition for installation (diameter, earth covering depth, etc.) and installation method (open-cut, pipe-jacking, and shield method).

(b) Manholes

Manholes shall be installed for the purpose of sewer maintenance. The location of manhole shall be: 1) starting point of sewer; 2) changing point of sewer direction, diameter and gradient; and 3) connection point of several sewers. The maximum interval of the manholes shall be 200 m, considering workability and safety for maintenance. Main components of manhole shall be as follows:

- Manhole cover
- Ladder
- Intermediate slab (in case of deep manhole) and fence
- Invert to make sewage flow smoothly
- Erosion protection (in case the invert level of sewers connected to a manhole are different and affects the manhole structure and function) by installation of side pipe, protection boards, and drop shaft.

(c) Interception Facilities (Overflow Chamber)

Interception facilities have the purpose to collect sewage from existing drainage system in order to reduce pollution load to public water bodies. The structure of the interception facilities is very important and it shall be designed in accordance with the design sewage flow in sewer. In addition, interception volume shall be determined considering the target water quality in public water bodies because some stormwater will be discharged without any treatment in the rainy seasons. The main components of interception facilities are follows:

- Weir to collect designed sewage flow
- Equipment such as screen to keep large floatables and/or debris entering into sewer

In addition, in case backflow from public water bodies or discharged point of stormwater occur, a facility such as check valve shall be installed at discharge pipe from interception facilities to prevent excessive wastewater from entering the sewer.

(d) Pumping Stations

Pumping stations for sewage are classified into two (2) types. One is located at influent and/or effluent point in STP. The other is the relay pumping station to lift sewage to shallow earth covering depth and to transfer sewage by gravity flow to next pumping station or STP. The relay station is also classified into three (3) types depending on sewage volume and grid removal method as follows:

- Type 1: Pumping station which has grid removal facilities (large-scale pumping station).
- Type 2: Pumping station which has sand pit and simplified screen or comminutor.
- Type 3: Pumping station without any grid and sand removal facilities (manhole pump).

Generally, Type 1 is applied to large- and middle-scale, and Types 2 and 3 are applied to small-scale. However, the type of relay pumping station shall be determined considering not only sewage volume but also volume of debris or sand, neighbouring environment and workability for maintenance. Type 3, manhole pump, is applied in case sewage volume is 3.0 m^3/min or less in general.

Pumping stations require civil facilities, architectural buildings, mechanical and electrical equipment. The main components in case of a large pumping station (Type 1) are shown in **Table 4.2.2**.

Basically, sewer systems are planned as gravity flow to minimize pumping stations to be installed considering O&M works. However, in case that depth of sewer is deep, it is necessary to install pumping stations considering the following points.

- Land availability for pumping station at basically public land at proper location to lift sewage.
- Feasibility in terms of construction and O&M cost in comparison with gravity flow.

Table 4.2.2 Main Components of Pumping Station in Case of Type 1

Items	Purpose of Installation
1. Civil Facilities	
Inlet conduit	- To flow sewage into pumping station.
Grit removal facilities	- To prevent abrasion and damage to pumping equipment.
Pumping well	- To control water level to turn on and off the pump.
Outlet conduit	- To flow sewage into subsequent STP facilities.
2. Architectural Buildings	
Sand trap and screen room	- To install sand trap and screen equipment.
Carry in and out room	- To store grit and screened debris to be carried out by vehicle. - To carry mechanical and electrical equipment into pumping station.
Pump pit	- To operate and maintain pump equipment.
Electrical room	- To install power control panels, incoming and transforming panels and distribution boards.
Control room	- To install supervisory and control equipment.
Generator room	- To install generators.
Staff room	- Standby space and dressing room for staff.
Office (Stack room)	- Working and documentation space for staff and standby room.
Warehouse	- To store equipment for operation and maintenance.
Passage way and stair case	- To access each floor and rooms for operation and maintenance works in pumping station.
Ventilation room	- To install ventilation facilities.
Deodoriser room	- To install deodorisation facilities.
3. Mechanical Equipment	
Inlet gate	- To prevent underground facilities from submerging and to control sewage flow volume.
Course screen	- To catch and remove large floatables and debris in sewage to protect pumping equipment and prevent blockage of pump operation.
Fine screen	- To catch and remove smaller floatables and debris in sewage, which are not removed by course screen.
Sand trap	- To catch grit and sands to prevent blockage, damage and abrasion to pumping equipment.
Lift pump	- To lift sewage and discharge to downstream.
Crane	- To install, remove, transfer equipment
Ventilation facilities	- To ventilate inside pumping station
Deodorisation facilities	- To remove odour inside pumping station to improve environmental condition for maintenance work and neighbourhood of pumping station.
4. Electrical Equipment	
Power supply	- To receive power from power company and supplier.
Transformer	- To transfer electric energy to each alternating current circuit controlling power voltage.
Generator	- To generate electric power to operate pumping station.
Supervisory, control and data acquisition (SCADA)	- To collect and record information of operation and maintenance for staff.
Video monitoring	- To secure safety of pumping station.

Source: JICA Study Team

(3) Design Criteria for Sewer

There are no standards and guidelines to design sewer system in the Phnom Penh Metropolitan Government. Therefore, the design criteria for sewer in this Master Plan are determined as follows to plan and design sewer network.

(a) Design Sewage Volume

The interceptor sewer will be converted to separate sewer in the future. Therefore, the design sewage volume must be minimized. In the case of combined sewer, the design volume is determined to be three times of the hourly maximum sewage flow in dry condition in Japan. However, in the case of PPCC, the sewage volume applied in Japan is too large because meteorology is clearly separated into the dry and rainy seasons. Therefore, the design sewage volume shall be determined considering design examples of regional countries in the South-east Asia.

In the case of Bangkok (Thailand), the applied sewer system is the combined system with five times of hourly maximum sewage flow in dry condition. On the other hand, in the case of Manila (the Philippines) and Yangon (Myanmar), the interceptor sewer system which will be converted to a separated sewer in the future is applied, and the design sewage volume is determined to be the same volume as the hourly maximum sewage flow in the dry condition.

Considering the condition of the existing drainage system, the conversion to separated sewer system in the future and the examples in surrounding countries, the design sewage flow for PPCC shall be determined the same volume as hourly maximum sewage flow in the dry condition.

(b) Equation of Hydraulic Calculation

The Manning's equation to be applied for hydraulic calculation is as follows:

$$V = 1/n \times R^{2/3} \times I^{1/2}$$

Where;

V: velocity (m/s)
n: Manning's roughness coefficient
R: hydraulic radius
I: pipe gradient

Manning's roughness coefficient of 0.013 is applied in the Master Plan.

(c) Water Depth of Sewer (Allowance of Sewage Volume)

Water depth of sewers shall be determined in order to ensure flow capacity to accommodate stormwater unexpectedly entering the sewer from manhole or joint of sewers. However, the interceptor will be converted to separate sewers in the future and hence significant allowance should not be applied to avoid a large diameter and construction cost. Therefore, the water depths of sewer, which is allowance of sewer volume, is determined based on the sewer diameter as follows:

- Diameter is less than 500 mm: 50% of the diameter
- Diameter is 500 mm and less than 1,000 mm: 60% of the diameter
- Diameter is 1,000 and more: 75% of the diameter

(d) Minimum Diameter of Sewer

Diameter of sewer shall be set to prevent sewage from being suspended due to insufficient capacity and unexpected obstruction, and to ease maintenance work. Therefore, the minimum diameter of 200 mm is set in the Master Plan.

(e) Minimum Earth Covering Depth

Interceptor will receive sewage from existing drainage system. Therefore, the earth covering depth must be determined to collect all sewage from the drainage system. In addition, the

interceptor shall be installed along existing roads on which heavy vehicles pass. Therefore, the installation depth of the sewer must be enough to resist the traffic load.

Considering the above, the minimum earth covering depth is determined as 2.0 m for trunk and main sewers. In case of branch sewers which will directly connect with households, the minimum earth covering depth shall be 1.0 m.

(f) Flow Velocity

Flow velocity of sewage should be determined to avoid sediment deposition of sludge and sand in the pipes. On the other hand, too high velocity is not preferable because it damages sewer and manholes. Thus, the minimum and maximum flow velocity shall be determined, as follows:

- Minimum velocity: 0.8 m/sec
- Maximum velocity: 3.0 m/sec

(g) Interval of Manholes

Manhole shall be installed at the following locations in sewer;

- Starting point of sewer
- Changing point of sewer direction, diameter and gradient
- Connection point of several sewers

In addition, manholes shall also be installed at proper intervals in straight position for maintenance as follows:

- Diameter is less than 500 mm: 75 m (at a maximum)
- Diameter is over 500 mm and less than 1,000 mm: 100 m (at a maximum)
- Diameter is over 1,000 mm and less than 1,650 mm: 150 m (at a maximum)
- Diameter is 1,650 mm or more: 200 m (at a maximum)

(h) Summary of Design Criteria for Sewer

Table 4.2.3 shows the comparison between the design criteria applied in this M/P and the other major cities of Bangkok, Yangon and Manila, as a reference.

Table 4.2.3 Design Criteria for Sewer

Cities	Bangkok, Thailand[*1]	Yangon, Myanmar[*2]	Manila, the Philippines[*3]	This Study Phnom Penh
Design Volume	5.0 times of daily average sewage flow.	1.65 times of daily average sewage flow.	1.8 times of daily average sewage flow	1.65 times of daily average sewage flow.
Equation of Hydraulic Calculation	Manning's equation	Manning's equation	Manning's equation	Manning's equation
Water Depth in Sewer	*Not mentioned*	*Not mentioned*	Diameter "D": D≦250: 50% 250＜D＜400: 60% 400＜D＜500: 70% 500≦D: 75%	Diameter "D": D＜500: 50% 500≦D＜1000: 60% 1000≦D: 75%
Min. Diameter	300 mm	200 mm	200 mm	200 mm
Min. Earth Covering Depth	2.0 m at starting point of sewer, 2.0 m under channel and 2.5 m under high way	1.0 m at starting point of sewer, 2.0 m under channel and 2.5 m under high way	2.0 m	2.0 m for trunk and main and 1.0 m for branch sewer
Flow Velocity	Max. is 3.0 m/s and	Max. is 3.0 m/s and	Max. is 3.0 m/s and	Max. is 3.0 m/s and Min.

Cities	Bangkok, Thailand[*1]	Yangon, Myanmar[*2]	Manila, the Philippines[*3]	This Study Phnom Penh
	Min. is 0.6 m/s	Min. is 0.6 m/s	Min. is 0.8 m/s	is 0.8 m/s
Interval of Manholes	Diameter "D": D≦300: 100 m 450≦D＜800: 150 m 800≦D: 200 m	Diameter "D": D＜600: 75 m 600≦D＜1000: 100 m 1000≦D＜1650: 150 m 1650≦D: 200 m	Diameter "D": D＜350: 75 m 350≦D＜500: 100 m 500≦D＜1000: 150 m 1000≦D: 200 m	Diameter "D": D＜500: 75 m 500≦D＜1000: 100 m 1000≦D＜1650: 150 m 1650≦D: 200 m

Source: *1: Preparatory Survey for Bangkok Wastewater Treatment Project in Thailand (2011, JICA)
*2: The Project for the Improvement of Water Supply, Sewerage and Drainage System in Yangon City (2014, JICA)
*3: Preparatory Survey on Water Supply and Sewerage Development in the West Zone of Metro Manila (2013, JICA)

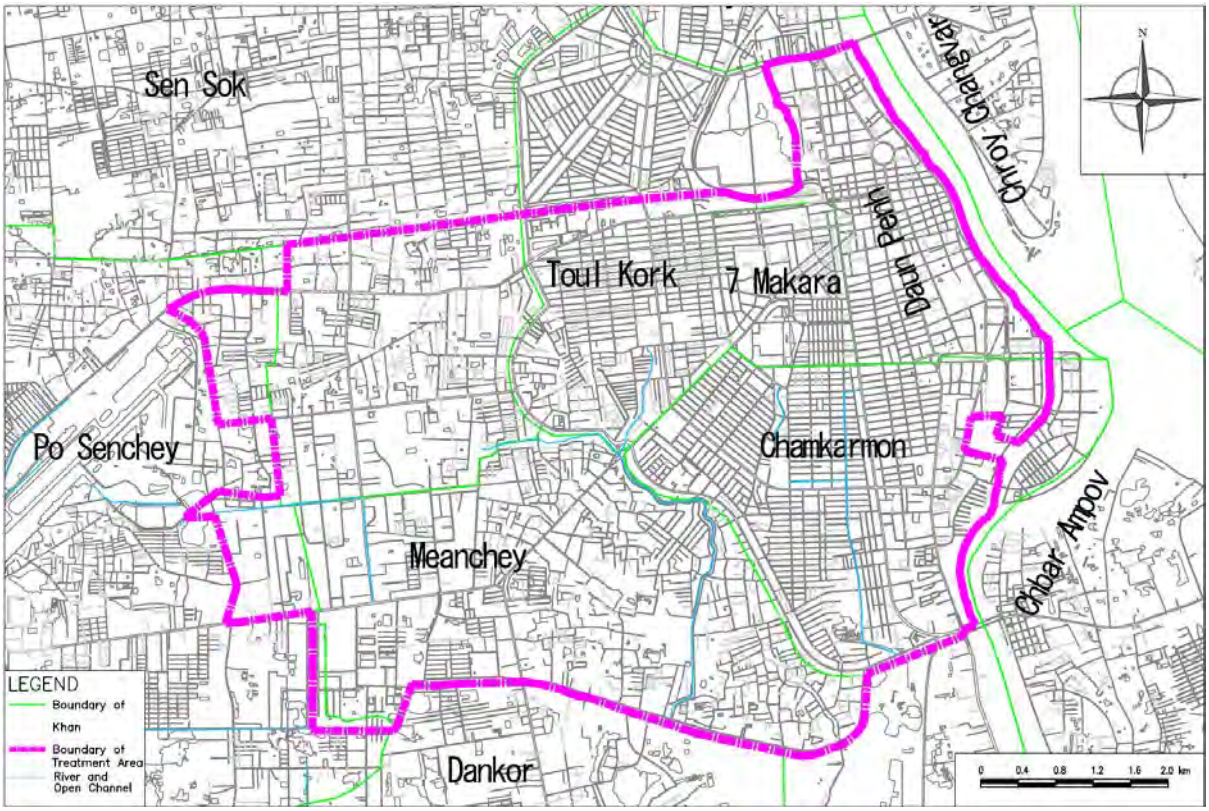
(4) Sewer Network Plan

Population of PPCC is concentrated at the central four khans and the khans surrounding these four khans. On the contrary, population of the outer area of PPCC is very few and the areas are not so urbanised based on the land use in 2035 because the area is as a whole located in protection zone or water bodies. Therefore, the sewer network plan is prepared for the high-density population area. In this Master Plan, two sewage treatment areas were included to formulate the sewer plan.

(a) Cheung Aek Treatment Area

Cheung Aek treatment area is located at the southern part of central PPCC. This area covers the whole area of Khan 7 Makara and a part of the surrounding five khans. The area is 4,702 ha and the total population is 1,093,155 in 2035. **Fig. 4.2.2** shows the Cheung Aek treatment area and **Table 4.2.4** shows the covered area and population of the Cheung Aek treatment area.

The covered population is estimated by prediction of population in 2035 and the covering area of each Sangkat.



Source: JICA Study Team

Fig. 4.2.2 Cheung Aek Treatment Area

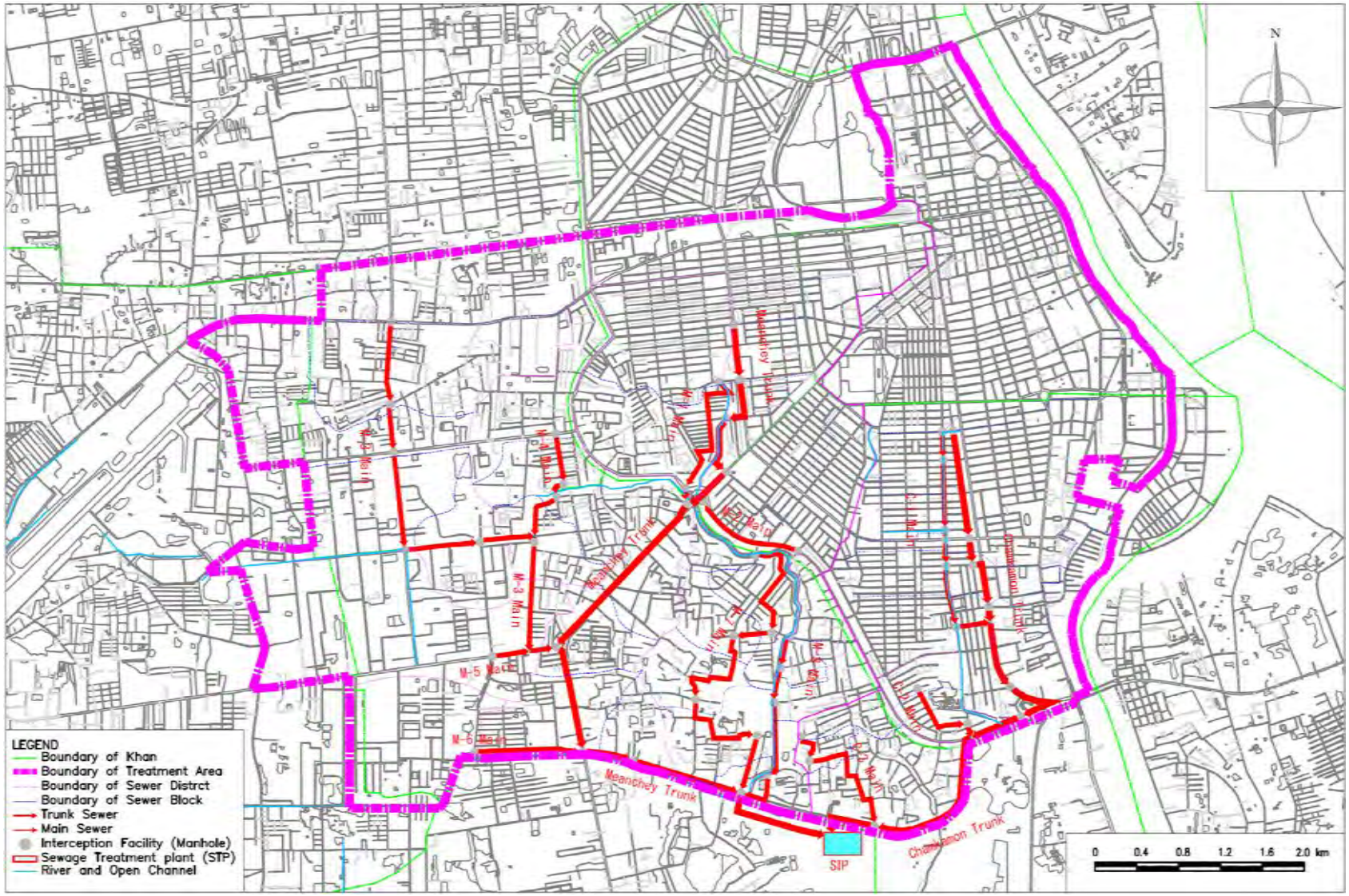
Table 4.2.4 Covered Area and Population of Cheung Aek Treatment Area

Name of Khan and Sangkat		Covered Area (ha)	Covered Population (Cheung Aek Treatment Area)				
			2016	2020	2025	2030	2035
01	**Chamkarmon**	**919.0**	**184,118**	**188,126**	**199,900**	**211,674**	**223,448**
0101	Tonle Basak1	9.3	481	481	481	481	481
0102	Tonle Basak2	104.5	10,036	10,845	13,719	16,593	19,467
0103	Tonle Basak3	155.1	12,000	13,100	16,600	20,100	23,600
0104	Boeng Keng Kang Muoy	99.7	14,000	14,000	15,333	16,667	18,000
0105	Boeng Keng Kang Pir	29.2	11,700	11,700	11,700	11,700	11,700
0106	Boeng Keng Kang Bei	65.8	23,700	24,300	24,967	25,633	26,300
0107	Oulampik	30.3	10,000	10,600	11,100	11,600	12,100
0108	Tuol SvayPreyTiMuoy	58.9	14,700	14,700	15,300	15,900	16,500
0109	Tuol SvayPreyTiPir	35.0	11,600	11,900	12,367	12,833	13,300
0110	Tumnob Tuek	78.6	18,900	18,900	18,900	18,900	18,900
0111	Tuol TumpungTiPir	47.0	11,300	11,300	11,300	11,300	11,300
0112	Tuol TumpungTiMuoy	62.6	13,800	14,400	15,433	16,467	17,500
0113	Boeng Trabaek	45.9	9,600	9,600	10,067	10,533	11,000
0114	Phsar Daeum Thkov	97.1	22,300	22,300	22,633	22,967	23,300
02	**Daun Penh**	**592.1**	**106,336**	**108,438**	**111,535**	**114,631**	**117,728**
0201	PhsarThmeiTiMuoy	16.5	5,300	5,500	5,767	6,033	6,300
0202	PhsarThmeiTiPir	10.7	7,500	7,400	7,200	7,000	6,800
0203	PhsarThmeiTiBei	31.4	10,400	10,400	10,300	10,200	10,100
0204	Boeng Reang	41.6	7,100	7,500	7,767	8,033	8,300
0205	Phsar KandalTiMouy	40.9	11,400	12,300	13,367	14,433	15,500
0206	PhsarKandalTiPir	14.7	7,500	8,400	9,533	10,667	11,800
0207	Chakto Mukh	149.7	12,000	12,000	13,000	14,000	15,000
0208	CheyChummeah	72.9	12,400	12,400	11,900	11,400	10,900
0209	PhsarChas	10.1	6,900	7,100	7,400	7,700	8,000
0210	SrahChak1	75.5	5,707	6,676	7,154	7,633	8,112
0211	SrahChak2	63.7	10,429	9,762	9,580	9,398	9,216
0212	VoatPhnum	64.4	9,700	9,000	8,567	8,133	7,700
03	**7 Makara**	**219.9**	**95,100**	**96,600**	**98,633**	**100,667**	**102,700**

Name of Khan and Sangkat		Covered Area (ha)	Covered Population (Cheung Aek Treatment Area)				
			2016	2020	2025	2030	2035
0301	Ou Ruessei Ti Muoy	8.5	8,300	8,100	7,900	7,700	7,500
0302	Ou Ruessei Ti Pir	8.7	9,200	8,900	8,533	8,167	7,800
0303	Ou Ruessei Ti Bei	4.9	7,800	7,400	6,900	6,400	5,900
0304	Ou Ruessei Ti Buon	8.3	8,600	8,500	8,433	8,367	8,300
0305	Monourom	13.9	11,500	11,400	11,300	11,200	11,100
0306	Mittakpheap	38.7	10,800	11,600	12,367	13,133	13,900
0307	Veal Vong	96.9	28,100	29,100	30,400	31,700	33,000
0308	Boeng Prolit	40.1	10,800	11,600	12,800	14,000	15,200
04	**Toul Kork**	**492.1**	**148,857**	**148,051**	**148,012**	**147,973**	**147,935**
0401	Phsar Depou Ti Muoy	32.4	11,700	12,000	12,333	12,667	13,000
0402	Phsar Depou Ti Pir	20.5	11,500	11,300	11,300	11,300	11,300
0403	Phsar Depou Ti Bei	30.6	8,600	9,200	9,700	10,200	10,700
0404	Tuek L'ak Ti Muoy	90.8	16,300	17,300	18,800	20,300	21,800
0405	Tuek L'ak Ti Pir	42.5	13,600	13,600	13,300	13,000	12,700
0406	Tuek L'ak Ti Bei	117.1	32,900	31,600	30,833	30,067	29,300
0407	Phsar Daeum Kor	69.5	22,257	22,851	23,345	23,840	24,335
0408	Boeng Salang	88.7	32,000	30,200	28,400	26,600	24,800
05	**Po Senchey**	**220.4**	**10,558**	**13,145**	**13,145**	**13,145**	**13,145**
0501	Chaom Chau1	115.7	3,573	4,444	4,444	4,444	4,444
0502	Kakab1	104.6	6,985	8,700	8,700	8,700	8,700
06	**Meanchey**	**1,587.9**	**271,000**	**301,700**	**319,200**	**336,700**	**354,200**
0601	Stueng Mean Chey1	321.9	11,400	13,000	13,767	14,533	15,300
0602	Stueng Mean Chey2	804.7	157,900	178,200	188,733	199,267	209,800
0603	Boeng Tumpun	461.4	101,700	110,500	116,700	122,900	129,100
07	**Sen Sok**	**670.5**	**97,400**	**110,400**	**118,267**	**126,133**	**134,000**
0701	Tuek Thla	670.5	97,400	110,400	118,267	126,133	134,000
	Total	**4,701.9**	**913,369**	**966,459**	**1,008,691**	**1,050,923**	**1,093,155**

Source: JICA Study Team

Fig. 4.2.3 shows the sewer network plan and **Table 4.2.5** summarizes sewer network facilities in the treatment area. This area is divided into two sub treatment area and 14 sewer districts considering the existing drainage system, road and topographic condition. The STP will be located near Tumpun Pumping Station at the Cheung Aek Lake. Design sewage volume in 2035 is 282,000 m^3 at the daily maximum. Relay pumping station will not be required in this treatment area.



Source: JICA Study Team

Fig. 4.2.3 Sewer Network Plan in Cheung Aek Treatment Area

Table 4.2.5 Summary of Sewer Network Facilities in Cheung Aek Treatment Area

Item	Length (m)	Diameter (mm)	Covering (m)	Remark
1. Trunk Sewer				
1) Chamkamon Trunk	5,984	1,000 ~ 1,650	4.36 ~ 10.25	
2) Meanchey Trunk	7,665	900 ~ 2,200	2.47 ~ 10.01	
2. Main Sewer		~	~	
1) C-1 Main	2,201	800 ~ 1,000	3.93 ~ 7.00	Connecting to
2) C-2 Main	843	250 ~ 400	2.70 ~ 10.25	Chamkarmon Trunk
3) C-3 Main	1,544	300 ~ 400	2.64 ~ 11.59	
4) M-1 Main	1,226	600 ~ 800	4.32 ~ 9.33	Connecting to
5) M-2 Main	1,295	500 ~ 700	4.43 ~ 7.69	Meanchey Trunk
6) M-3 Main	4,812	600 ~ 1,350	2.09 ~ 9.30	
7) M-4 Main	1,161	500 ~ 600	2.50 ~ 7.78	
8) M-5 Main	352	600 ~	4.32 ~ 4.32	
9) M-6 Main	1,044	400 ~	4.54 ~ 8.33	
10) M-7 Main	4,100	300 ~ 900	2.64 ~ 12.01	
11) M-8 Main	1,877	300 ~ 600	2.64 ~ 11.72	
Total Length	**34,104**			
Interception Facilities (Overflow Chamber)			Amount	
1) Chamkamon Trunk and connected Main			17	
2) Meanchey Trunk and Connected Main			33	
Total Amount			**50**	

Source: JICA Study Team

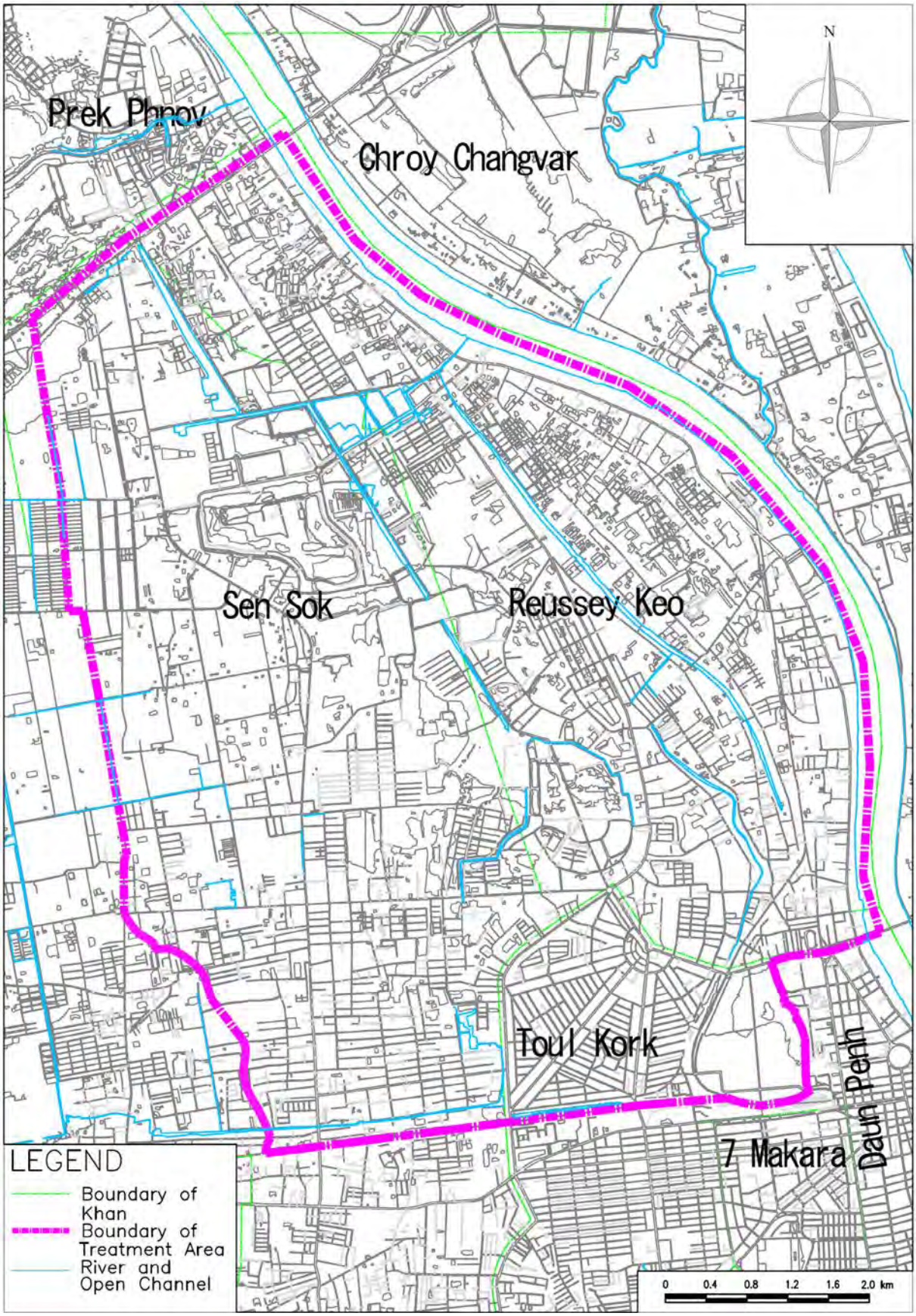
In the Cheung Aek Treatment Area, sewer is about 34 km in length and installation depth is 12 m at maximum considering collection of sewage utilizing existing drainage system. Therefore, relay pumping station will not be required.

(b) (Reference) Tamok Treatment Area[24]

Tamok Treatment Area is located at the northern part of central PPCC. This treatment area covers a part of the whole area of Reussey Keo and a part of the surrounding three khans. The area is 6,019 ha and the total population is 481,423 in 2035. **Fig. 4.2.4** shows the Tamok treatment area and **Table 4.2.6** shows the covered area and population of Tamok treatment area.

The covered population is estimated by prediction of population in 2035 and the covering area of each Sangkat.

[24] As shown in **Subsection 4.1.4**, on-site treatment is applied in Tamok area, so this description is given as a reference to show the detail of alternative study on selection of on- and off-site treatment, conducted for Tamok area.



Source: JICA Study Team

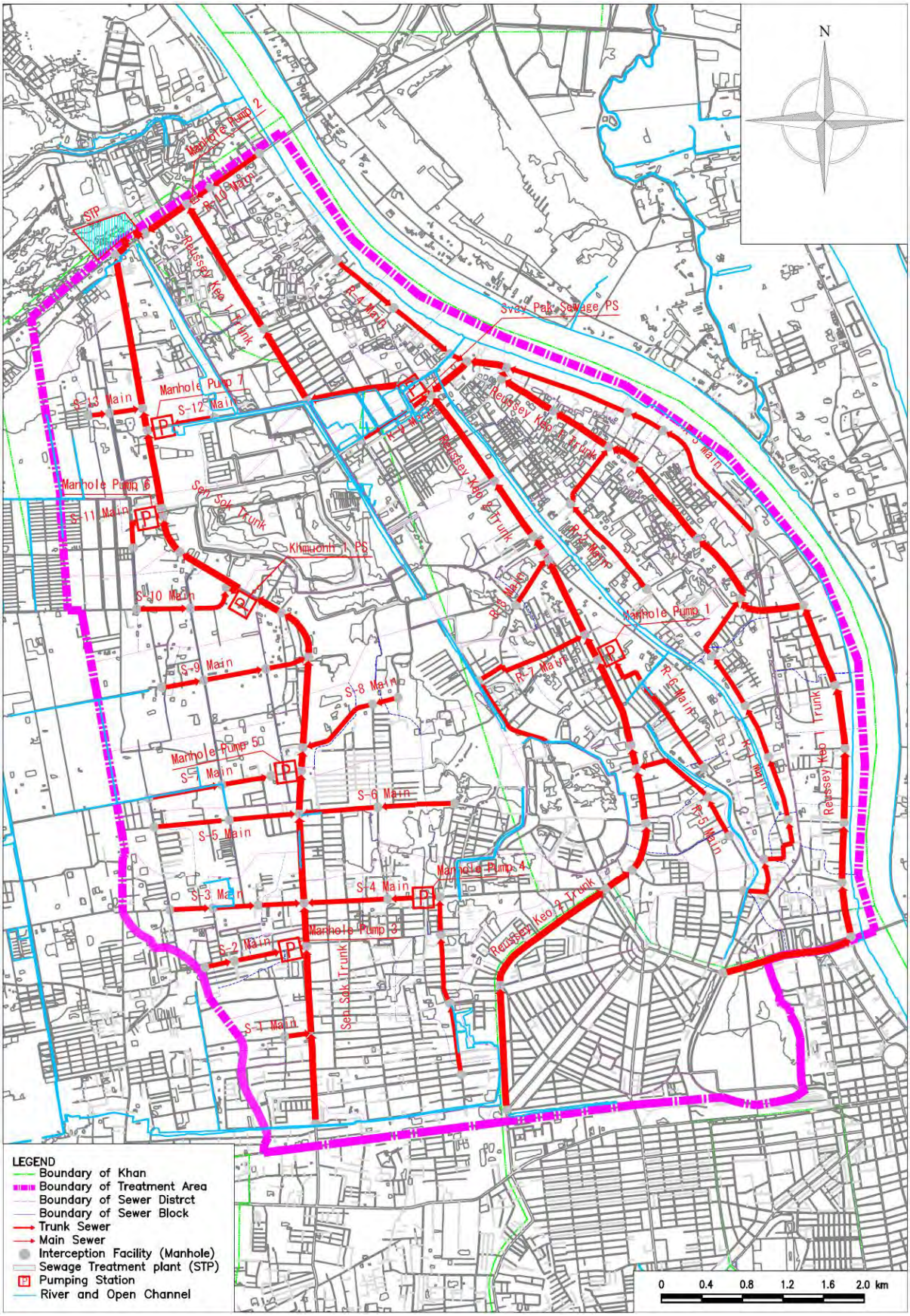
Fig. 4.2.4 Tamok Treatment Area

Table 4.2.6 Covered Area and Population of Tamok Treatment Area

Name of Khan and Sangkat		Covered Area (ha)	Covered Population (Cheung Aek Treatment Area)				
			2016	2020	2025	2030	2035
01	**Daun Penh**	**176.2**	**16,968**	**18,265**	**19,002**	**19,738**	**20,474**
0101	SrahChak1	134.8	10,190	11,921	12,775	13,630	14,485
0102	SrahChak2	41.4	6,778	6,344	6,226	6,108	5,990
02	**Tuol Kok**	**327.2**	**46,300**	**44,500**	**43,367**	**42,233**	**41,100**
0201	Boeng Kak Ti Muoy	159.2	15,900	15,900	15,900	15,900	15,900
0202	Boeng Kak Ti Pir	168.1	30,400	28,600	27,467	26,333	25,200
03	**Reussey Keo**	**2,338.3**	**195,716**	**220,816**	**230,083**	**239,350**	**248,616**
0301	Tuol Sangkae 1	137.9	43,300	49,800	53,400	57,000	60,600
0302	Tuol Sangkae 2	137.9	45,200	52,000	55,767	59,533	63,300
0303	Svay Pak	336.8	20,216	20,216	20,216	20,216	20,216
0304	Kilomaetr Lekh Prammuoy	564.1	25,400	28,200	30,067	31,933	33,800
0305	Ruessei Kaev	517.6	31,200	36,100	36,133	36,167	36,200
0306	Chrang Chamreh Ti Muoy	229.9	13,800	13,800	13,800	13,800	13,800
0307	Chrang Chamreh Ti Pir	414.1	16,600	20,700	20,700	20,700	20,700
04	**Sen Sok**	**3,177.5**	**92,145**	**124,744**	**140,240**	**155,736**	**171,232**
0401	Phnom Penh Thmei	1,428.8	57,192	71,298	80,842	90,385	99,929
0402	Khmuonh1	1,086.8	21,753	27,745	30,865	33,984	37,103
0403	Khmuonh2	662.0	13,200	25,700	28,533	31,367	34,200
	Total	**6,019.2**	**351,129**	**408,325**	**432,691**	**457,057**	**481,423**

Source: JICA Study Team

Fig. 4.2.5 shows the sewer network plan and **Table 4.2.7** summarizes the sewer network facilities in the treatment area. This area is divided into two sub-treatment areas and 33 sewer districts considering the existing drainage system, road and topographic condition. STP will be located near Kop Srov Pumping Station at the Tamok Lake. Estimated sewage volume in 2035 is 124,000 m^3 at the daily maximum.



Source: JICA Study Team

Fig. 4.2.5 Sewer Network Plan in Tamok Treatment Area

Table 4.2.7 Summary of Sewer Network Facilities in Tamok Treatment Area

Item	Length (m)	Diameter (mm)	Covering (m)	Remark
1. Trunk Sewer				
1) Reussey Keo Trunk 1	14,922	600 ~ 1,650	2.00 ~ 20.04	
2) Reussey Keo Trunk 2	8,278	500 ~ 1,200	3.43 ~ 11.63	
3) Sen Sok Trunk	9,495	350 ~ 1,100	2.05 ~ 12.40	
2. Main Sewer				
1) R-1 Main	3,599	400 ~ 600	4.54 ~ 11.65	Connecting to Reussey Keo Trunk 1
2) R-2 Main	1,823	200 ~ 350	4.75 ~ 11.55	
3) R-3 Main	3,058	250 ~ 350	2.00 ~ 20.07	
4) R-4 Main	1,591	200 ~ 350	4.75 ~ 13.17	
5) R-9 Main	822	200 ~ 300	4.75 ~ 11.38	
6) R-10 Main	869	200 ~ 200	4.75 ~ 9.29	
7) R-5 Main	1,287	200 ~ 300	2.75 ~ 9.58	Connecting to Reussey Keo Trunk 2
8) R-6 Main	1,699	200 ~ 350	2.00 ~ 11.76	
9) R-7 Main	2,159	600 ~ 700	4.32 ~ 8.23	
10) R-8 Main	619	300	4.64 ~ 6.99	
11) S-1 main	260	200	4.35 ~ 7.22	Connecting to Sen Sok Trunk
12) S-2 Main	1,020	200 ~ 250	2.00 ~ 11.80	
13) S-3 Main	1,325	250 ~ 350	2.00 ~ 8.28	
14) S-4 Main	3,102	200 ~ 500	3.42 ~ 13.08	
15) S-5 Main	1,434	200 ~ 300	2.00 ~ 10.02	
16) S-6 Main	1,536	400 ~ 450	2.00 ~ 10.97	
17) S-7 Main	1,526	200 ~ 250	2.00 ~ 20.93	
18) S-8 Main	1,101	250 ~ 250	4.70 ~ 11.52	
19) S-9 Main	1,483	200 ~ 300	2.00 ~ 9.90	
20) S-10 Main	1,326	200 ~ 250	2.00 ~ 12.50	
21) S-11 Main	587	200	2.00 ~ 6.91	
22) S-12 Main	672	200	2.00 ~ 8.11	
23) S-13 Main	540	200 ~ 250	2.00 ~ 5.42	
Total Length	**66,133**			

Interception Facilities (Overflow Chamber)	Amount	
1) Reussey Keo Trunk 1 and connected Main	37	
2) Reussey Keo Trunk 2 and connected Main	20	
3) Sen Sok Trunk and Connected Main	45	
Total Amount	**102**	

Pumping Stations	Area (m^2)	Head (m)	Capacity (m^3/s)	
1) Svay Pak Sewage PS	1,000	14.8	1.300	Land is owned by National Institute of Physical Education and Sport
2) Khmuonh 1 Sewage PS	500	9.9	0.582	Land is owned by MOWRAM

Manhole Pumps	Head (m)	Discharged Sewer Diameter (mm)	Capacity (m^3/s)	
1) Manhole No. 1	2.0	350	0.041	R-6 Main
2) Manhole No. 2	1.7	200	0.015	R-10 Main
3) Manhole No. 3	2.0	250	0.018	S-2 Main
4) Manhole No. 4	9.5	450	0.033	S-4 Main
5) Manhole No. 5	9.9	250	0.022	S-7 Main
6) Manhole No. 6	4.0	200	0.009	S-11 Main
7) Manhole No. 7	2.5	200	0.012	S-12 Main

Source: JICA Study Team

In the Tamok treatment area, sewer length is about 66 km and installation depth is as deep as 20 m a maximum considering collection of sewage utilizing existing drainage system and because of small separated sewers. In this treatment area, some pumping stations are required considering length of sewer. As a result of site survey on available land, two relay pumping stations are proposed at Sangkat Pvay Pak and Sangkat Khmuonh 1. The candidate sites of pumping station are selected from public properties. **Photo 4.2.1** shows the candidate site of the two pumping stations. The candidate site in Sangkat Svay Pak is a sports park owned by the National Institute of Physical Education and Sports, while the candidate site in Sangkat Khmuonh 1 is machinery and pumping centre owned by MOWRAM.

Candidate Site for Svay Pak Sewage Pumping Station

Candidate Site for Khmuonh 1 Sewage Pumping Station

Source: JICA Study Team

Photo 4.2.1 Candidates Sites for Pumping Station

In addition, drainage pipes have not been fully installed and separate sewer is as a whole small with diameter of 200 and 250 mm in Tamok treatment area. In order to keep the minimum velocity of the sewage flow, the gradient should be large and installation depth should be deep. Therefore, seven manhole pumps are planned at main sewers considering the maximum capacity of 3.0 m^3/min for the manhole pump.

4.2.2 Sewage Treatment Plan Facilities Plan

As discussed in **Subsections 4.1.1** and **4.1.2**, off-site treatment is applied only for Cheung Aek treatment area. Overview of the Cheung Aek STP is therefore shown in **Table 4.2.8**. Details of the facilities are reorganized after finalization of the Master Plan according to the decision in the discussion with PPCC. Sludge treatment system is simply organized with the configuration of sludge thickener and dehydrator. Sludge digester is not proposed because it has a number of accessories and thus operation of the facilities is not easy, especially in controlling input depending on the condition of sludge. Sludge recycle facilities are not proposed in the Master Plan because no great need in PPCC was recognized in the social survey conducted in the Study. Instead, sludge recycle facilities should be considered in the future. Detail specifications of facilities in the STP are summarised in **Chapter 8**.

As described later, septage treatment facilities to cope with the sludge from on-site treatment area is proposed not in Cheung Aek STP but in another area to be secured by PPCC, because sludge from on-site area is estimated to be about 45% of the sludge (thickened sludge) generated in Cheung Aek STP, and resultantly there is a great concern that the sludge from on-site area will cause overloading and such substances in the sludge as salinity would affect biological degradation of facilities in Cheung Aek STP, although there is an alternative to combine the on-site sludge and STP's sludge and treated together in the sludge treatment facilities in Cheung Aek STP, by installing additional facilities, like digester.

Table 4.2.8 Overview of Cheung Aek STP

Facilities	Items
Pumping station	Grit chamber and pumping equipment
Administration building	Staff's room/laboratory and so on
Wastewater treatment facilities	Primary and final sedimentation tank and reactor and so on
Sludge treatment facilities	Gravity thickener/Mechanical thickener/dehydrator
Disinfection chamber	Chlorine chamber
Others	Distribution chamber/ generator/ receiving and transforming station

Source : JICA Study Team

4.2.3 On-Site Treatment Plan

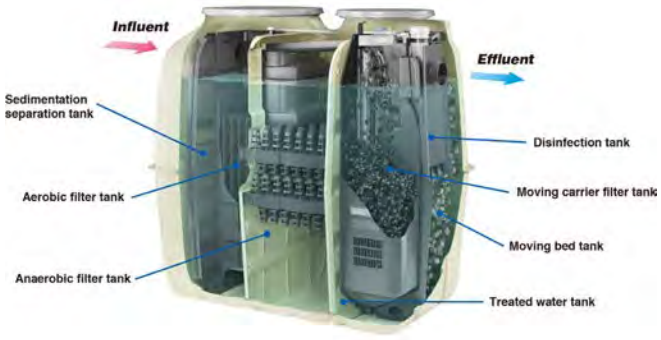
As described in **Subsection 2.4.2**, more than 90% of households have installed sanitary equipment such as septic tank. Households in PPCC, which have already installed septic tanks and require a treatment level exceeding the septic tank, has to, therefore, install Johkasou or community plant.

Johkasou can simultaneously treat black and grey water and have a wide line-up, ranging from household size (for 5 persons[25]: see image of **Fig. 4.2.6**) and community-based size (for several hundred persons: see image in **Figs. 4.2.7** and **4.2.8**) to large-scale type[26] for 1,000 persons. BOD removal rate of Johkasou reaches 90%, which is equivalent to off-site treatment facilities. Moreover, Johkasou can be fabricated in factories and be easily installed on site.

Johkasou has advantages in treating wastewater but it is very costly compared to other on-site treatment facilities such as septic tank. Thus, the Johkasou has not been so popular in developing countries. However, in the recent years a great deal of effort has been made in cost reduction by localizing procurement of parts and material as well as fabrication. For instance, in the neighbouring country of Myanmar, installation of Johkasou has been in progress especially in the capital city of

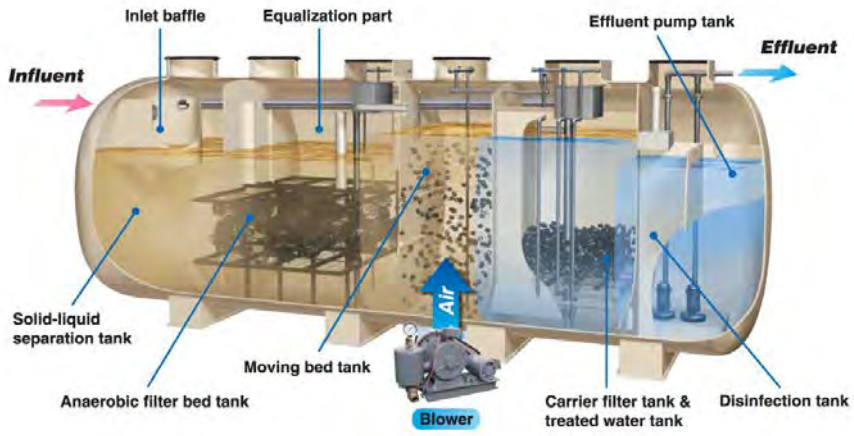
[25] Size: L1.6 m×W1.0 m ×H1.6 m
[26] Size: L(8.2+8.2+7.0) m×W2.5 m ×H2.8 m, in case of Johkasou for 300 persons

Yangon. Considering the status of Johkasou, there exists a great potential for cost-reduction and its dissemination in Phnom Penh if some manufacturers expand their businesses to Cambodia or establish affiliated companies. Therefore, Johkasou is introduced for alternative study in the Master Plan.



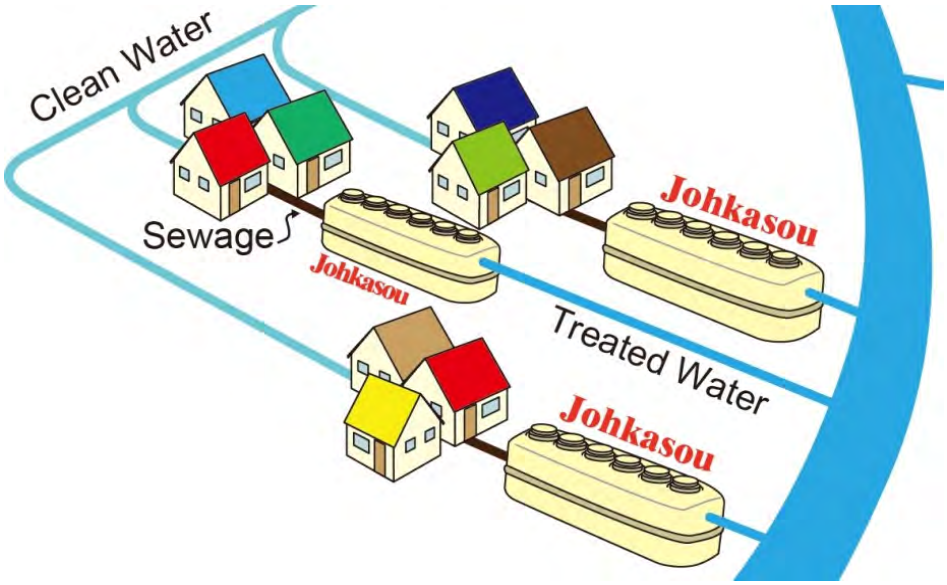
Source: Japanese Manufacturer

Fig. 4.2.6 Image of Johkasou (for 5 persons)



Source: Japanese Manufacturer

Fig. 4.2.7 Image of Johkasou (for 300 persons)



Source: JICA Study Team

Fig. 4.2.8 Image of Community-Based Sewage Treatment applying Johkasou

4.2.4 Sludge Disposal Plan

At present, more than 90% of households in PPCC have on-site facilities such as septic tank, but unfortunately PPCC has no septage disposal site. In addition, the Cheung Aek STP is proposed in the Master Plan as one of the off-site treatment facilities and thus there exist an additional need to dispose sludge generated from the STP. As a solution, a sludge disposal site is proposed in the Master Plan in which septage, sludge withdrawn from the Johkasou and treated sludge from the STP can be disposed. Anaerobic and/or aerobic digestion are candidates for the treatment of septage and sludge from Johkasou but they are as a whole costly in terms of construction and O&M.

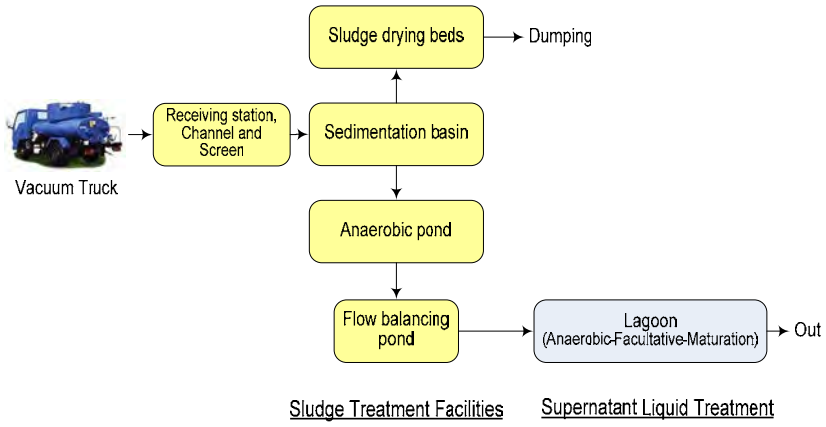
Therefore, the following simple sludge treatment facilities are proposed in the M/P. The treatment facilities consist of (i) the receiving station in which sludge unloaded from vacuum trucks are received, and the sedimentation basin and anaerobic pond in which septage are treated; and (ii) the lagoon consisting of anaerobic, facultative and maturation lagoons, in which overflow water is treated (**Table 4.2.9** and **Fig. 4.2.9**). Treated sludge from the STP is disposed at the disposal site. Land requirement of this sludge disposal site is estimated at 35 ha (i.e., 30 ha for sludge disposal site and 5 ha for septage and Johkasou sludge treatment facilities). Lifetime of the site will be about 15 to 20 years.

Table 4.2.9 Overview of Sludge Disposal Site

Item	Contents	Remark
Area	35 ha Breakdown: Sludge disposal site 30 ha Septage and Johkasou sludge treatment facilities 5 ha	General plan of septage and Johkasou sludge treatment facilities is shown in **Appendix 5** as a reference.
Sludge treatment facilities		
Population	1,773,945 persons (354,789 households) Breakdown: 481,423 persons (Tamok area: Johkasou) ⇒ 96,285 households 1,292,522 persons (Other area: Septic tank) ⇒ 258,504 households	Based on 5 persons per 1 household
Frequency of desludging (Assumed)	Johkasou:1 time/year, Johkasou:1 time/3 years	
Volume of facilities (Assumed)	Johkasou:1.5 m^3/tank, Septic tank:2.0 m^3/tank	
Sludge volume	868 m^3/day	
	Breakdown: From Johkasou: 96,285 households × 1.5 m^3/365day =396 m^3/day Septic tanks: 258,504 households × 1/3 × 2.0 m^3/365day=472 m^3/day	
Sludge density	15,000 mg/L	
Receiving station	W 5.8 m ×L 11.0 m ×D 0.8 m×1 tank	
Sedimentation basin	W 29.0 m ×L 29.0 m ×D 2.0 m×2 ponds	
Anaerobic pond	W 35.0 m ×L 40.0 m ×D 3.0 m×2 ponds	
Regulation pond	W 20.0 m ×L 35.0 m ×D 2.0 m×1 pond	
Sludge drying beds	W 75.0 m ×L 25.0 m ×4 beds	Assumed moisture content is 60%.
Lagoon		
Anaerobic lagoon	W 18.0 m ×L 34.0 m ×D 3.0 m×2 lagoons	
Facultative lagoon	W 40.0 m ×L 88.0 m ×D 1.75 m×2 lagoons	
Maturation lagoon	W 42.0 m ×L 25.0 m ×D 1.25 m×2 lagoons	

Note: W=Width, L=Length and D=Depth
Source: JICA Study Team

If the need to establish a sludge recycle system increases in the future, such sludge recycle system that will use sludge as construction material, aggregate for concrete, agricultural use, and materials for landfill, is to be proposed.



Source: JICA Study Team

Fig. 4.2.9 Treatment Facilities for Septage and Johkasou Sludge

4.3 Operation and Maintenance Plan

4.3.1 Sewer Network

(1) Purpose of Operation and Maintenance

The sewer network is an essential component in a sewerage system. The role of sewer network is to transfer sewage to STP for treatment without any delay and obstruction. Maintenance work is required not only to prevent sand or other sediment from depositing inside sewer but also to protect the sewer network from corrosion and deterioration. Therefore, periodic inspection is very important in the management of sewerage facilities.

The purposes of the operation and maintenance of sewer network are: 1) to maintain the capacity of facilities; 2) to extend depreciation period and reduce lifecycle cost; and 3) to prevent other infrastructure or facilities from being influenced by accidents or troubles of sewer network.

(2) Current Situation of Operation and Maintenance

There are no sewerage facilities in PPCC to date. In this connection, the organization, methodology of operation and maintenance of drainage systems are summarized to formulate the operation and maintenance plan of sewer network.

(a) Organization

As described in **Section 2.6**, the Drainage and Sewerage Division (DSD) in DPWT has the responsibility to operate and maintain the drainage system. Of the 193 employees in DSD, only 30 persons are full-time employees with the responsibility for planning and management of operation and maintenance works. The others are annually contracted and temporary employees to implement maintenance work at the site. The number of annually contracted employees is adjusted depending on the work volume.

(b) Methodology

Maintenance work for drainage facilities is implemented in nine months during the dry season from November to July. Full-time employees of DSD and annually contracted personnel are divided into groups consisting of 10 persons each in general to clean and implement periodical inspection of drainage facilities. This maintenance work is basically implemented once a year for pumping stations and drainage pipes except for some drainage pipes. Maintenance frequency for some drainage pipes is twice a year.

For the cleaning of drainage pipes, water-jet and sludge sucker is utilized to remove garbage and sediment. These maintenance works are recorded on working sheet and registered in the monitoring system in DSD. In addition, the maintenance work is implemented based on working schedule and actual performance is monitored in accordance with the schedule.

A supervisor, a few operators and several workers are dispatched for the operation and maintenance of the pumping station. Among the dispatched staffs, the supervisor and a few operators mainly operate and control the operation of the pumping station. Other workers are engaged in such work as collecting large garbage around the pumping station.

(3) Basic Strategy of Operation and Maintenance for Sewer Network

Operation and maintenance for sewer network is planed based on the same method for drainage system. Since the current strategy of operation and maintenance work, as well as organization structure is successfully functioning, the same strategy of operation and maintenance for drainage system can be easily adapted for sewer network. However, diameter of some sewers will be as small as 200 mm or 250 mm. In this case, television (CCTV camera) inspection will be additionally required. Further, sewer pipe is minimized to collect design sewage flow. Therefore, proper management of large garbage is essential not to allow them to be transported to STP.

(4) Operation and Maintenance for Sewer Networks

It is essential to establish a sewerage ledger and to record the operation and maintenance work in operating and maintaining the sewer network. In the sewerage ledger, it is required to organize such information as sewer length, diameter, manhole depth and dimension of each sewer and manhole. Based on the sewerage ledger, operation and maintenance plan shall be prepared in order to effectively manage sewerage facilities.

In the implementation of operation and maintenance work, it is required to establish a management group for sewerage facilities. At present DSD in DPWT is responsible for the drainage system operation and maintenance work and their performance is good, because the works is conducted in accordance with the work plan prepared by them. Therefore, it is desirable to establish a management group for sewerage facilities in DSD.

(a) Sewers and Manholes

Sewers and manholes will generally be installed under road or in public land. Therefore, immediate operation and maintenance work will be difficult from the technical and economical points of view, because the progress of work largely depends on traffic condition. Therefore, it is important to prepare an operation and maintenance plan utilizing such periodical inspections as daily and monthly. In operation and maintenance, the following works are required:

i) Recording and registration of operation and maintenance works
ii) Conducting daily or weekly site inspection
iii) Checking and cleaning inside of sewers and manholes (1 to 2 times per year)
iv) Periodical inspection inside sewers and manhole by manual or television (CCTV camera)
v) Detailed survey and evaluation of capacity of sewers and function of manholes
vi) Repair or rehabilitation

(b) Interception Facilities (Overflow Chambers)

Interceptor facilities are very important facilities to collect sewage and proper maintenance is required. In addition, screen or other facilities shall be installed to prevent debris or suspended solids from overflowing into public water bodies. Therefore, operation and maintenance is more complicated than normal manholes. If proper maintenance work is not conducted, pollutants

settle in the facilities and flow into public water bodies. Furthermore, design sewage volume is not collected by interceptor sewers due to obstructions. Therefore, frequent inspection and cleaning is required. In inspection, checking the following points is required. Other maintenance operations are same as normal manholes.

i) Situation of sewage collection and water level of sewage
ii) Checking no overflow of sewage in the dry condition
iii) Checking weir and other equipment
iv) Removing suspended solids and debris

(c) Pumping Stations

In the PPCC, 12 drainage pumping stations are in operation. Basically, operation and maintenance for sewage pumping stations is almost the same as drainage pumping stations. However, in the case of sewage pumping stations, settlement of sewage causes corrosion of facilities and deterioration of equipment. In addition, odour treatment and deodorization is required in sewage pumping station. Therefore, operation and maintenance is required not only to keep the pumping capacity but also to consider the surrounding environment. The most important to operate pumping station is to keep the sewage pumping function.

Regarding maintenance, classification management method is effective. The method is divided into three (3) types considering policy of stock management as follows:

- Condition-based management method
- Time-based management method
- Repair-based management method

Condition-based management method is a method to manage and take countermeasures for facilities and equipment based on evaluation of visible corrosion and deterioration by periodical inspection. This method shall be applied to mechanical equipment to predict condition of corrosion and deterioration which will affect the pumping function. In this method, repair and rehabilitation interval can be forecasted by collecting results of periodical inspections. By this method, maintenance work will be effective and maintenance cost will be saved.

Time-based management method is a method to manage from a determined interval for repair and rehabilitation. This method shall be applied to electrical equipment because of difficulties in evaluating corrosion and deterioration by periodical inspection and predicting significant influent to pumping function.

Repair-based management method shall be applied to civil and architectural facilities in which risk to the pumping function is low.

Considering the reduction of lifecycle cost, classification of management method for each facility and equipment is effective. **Table 4.3.1** shows the classifications of management method.

Table 4.3.1 Classification of Management Method in Pumping Station

Items	Condition-based Management	Time-based Management	Repair-based Management
Management Method	- Managing based on condition of equipment	- Managing based on determined interval in advance	- Managing after accidents and corrosion
Policy for Application	- Impact to pumping function is big. - Cost is expensive and impact to budget is big. - Condition of equipment is visible and able to be	- Impact to pumping function is big. - Cost is expensive and impact to budget is big. - Condition of equipment is not visible and cannot be	- Impact to pumping function is small. - Impact to budget is small.

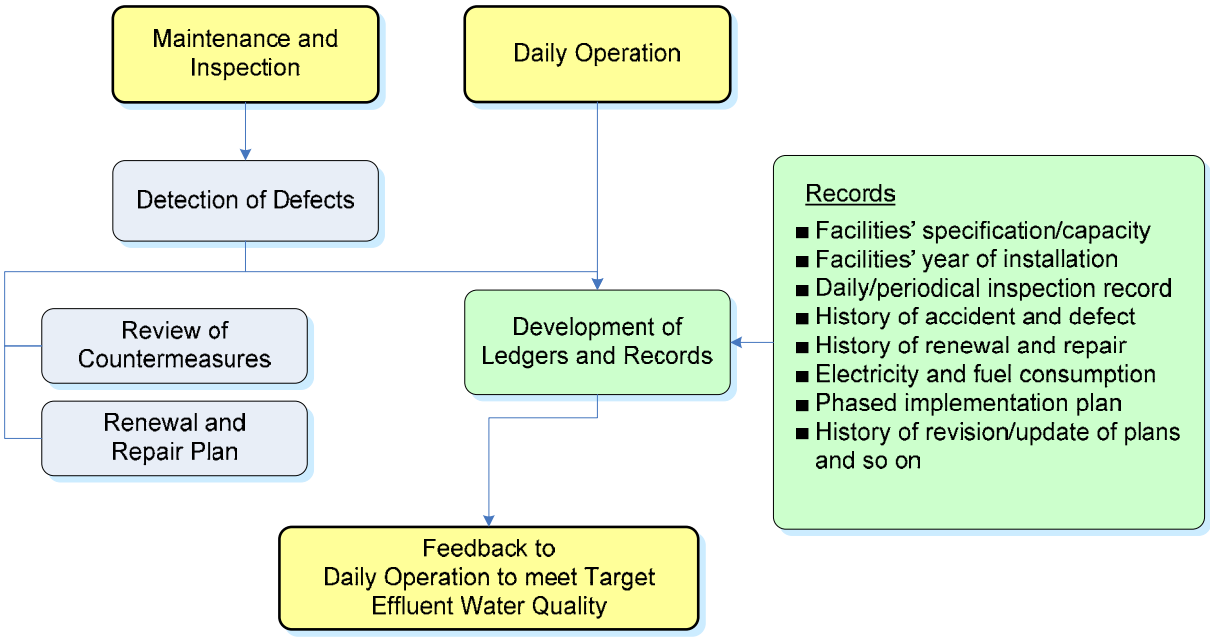
Items	Condition-based Management	Time-based Management	Repair-based Management
	forecasted.	forecasted.	
Applicable Facilities/ Equipment	- Mechanical equipment	- Electrical equipment	- Civil facilities - Architectural facilities
Remarks	- It is important to collect results of periodical inspection in order to forecast corrosion and deterioration.	- It is required to set interval for countermeasures.	- Periodical inspection can save time and cost.

Source: JICA Study Team

4.3.2 Sewage Treatment Plant and Sludge Disposal Site

(1) Sewage Treatment Plant

O&M in STP is implemented with objectives of optimizing the functions of treatment facilities, thereby complying with effluent and targeted standards, improving water environment, and conserving water quality of public water bodies. Flowchart of O&M in STP is shown in **Fig. 4.3.1**.



Source: JICA Study Team, based on Tentative Guidelines for Optimization of Operation and Maintenance of Sewage Works in developing Countries, October 2001

Fig. 4.3.1 Flowchart of O&M in STP

O&M items in STP are summarised in **Table 4.3.2.**

Table 4.3.2 O&M Items in STP

Facilities		Items
Grit chamber/pumping station		・ Removal of debris
Influent channel		・ Record of inflow
Sewage treatment facilities	Sedimentation chamber	・ Removal of scum ・ Control of putrefaction and floatation of sludge ・ Inspection of wearing and putrefaction and sludge collector ・ Control of sludge overflow from overflow weir
	Reactors	・ Control of bulking

Facilities		Items
		・ Prevention of floatation and deflocculation of activated sludge
Sludge treatment facilities	Gravity thickener	・ Check of floatation of sludge and rising of sludge-liquid interface
	Mechanical thickener/dehydrator	・ Check of abnormal vibration and rotation ・ Control of injection ratio of flocculants
Chlorine chamber		・ Check of chlorine consumption
Water quality analysis		・ pH, DO, BOD, TSS, COD, Coliform and so on

Source: JICA Study Team

(2) Sludge Disposal Site

In sludge dumping site, activities such as drying up of sludge and ground levelling in order to extend lifetime of the site, are required. O&M items of septage and Johkasou sludge treatment facilities are listed below.

- Sludge receiving station : Removal of debris
- Lagoon and flow regulation pond : Removal of scum and algae
- Sludge drying bed : Check of sludge thickness and removal of sludge

4.3.3 On-site Treatment Facilities

Septic tank and Johkasou requires periodical desludging. In addition, Johkasou requires periodical operation and maintenance such as control of aeration, circulated water, backwashing, and flushing flow rate in toilets in order to comply with the discharge criteria.

4.4 Review of Organization and Legal Framework of Sewage Management

4.4.1 Review for Proposal of a New Organization to Implement the Sewer Network Service

Based on the issues identified and described in **Section 3.1**, the option of creating a new organization specialized in sewage management in the large, rapidly growing city of PPCC, is discussed in this section. The organization will carry out planning of a sewer network service plan shall have a leadership with strong abilities (authority and organizational strength) to carry out the implementation plan based on the Master Plan while coordinating and negotiating with relevant ministries and agencies and respective authorities of the PPCC, with staff to support the leader and to carry out the service, to set fee schedules and to be responsible for publicity. A phased plan to enhance the organization, following the M/P policy of staged establishment and improvement (short term, medium term, and long term), is also considered[27].

The new organization shall be headed by the Director and shall have at least two divisions as below.

- **Sewerage Project Division**: Responsible for publicity, fee schedule, financial plan, coordination with relevant divisions, and so on.
- **Sewerage Technical Division**: Responsible for formulating service plan, preparing implementation plan, training of engineers to plan and build sewage facilities (sewer, pumping station and sewage treatment plant) and engineers with technical expertise in sewage treatment, and so on.

It is assumed that the Sewerage Project Division will be staffed with selected employees from general accountancy areas in such organizations as MPWT, MEF, and PPCC. The Sewerage Technical Division will need to formulate the sewer network service plan and be engaged in designing and construction of sewage treatment plants alongside installation of pipes and culverts within three to four years of establishment of the organization. Therefore, during the initial stage of the project, the staff requirement for the sewer network service plan, implementation plan, designing and construction of sewer facilities, etc., should be met with sewer policy specialists trained through utilization of the technical cooperation projects, etc. Those specialists will also be responsible for disseminating expertise related to the sewer network service throughout Cambodia, as well as for training of other engineers. For instance, based on the experience with SRSWTPU (Siem Reap Sewerage Works Treatment Plant Unit), it is thought that some 15 to 20 staff members will be required at the initial stage after establishment of the organization.

On the other hand, it has been proposed as an option to carry out the sewer network service in PPCC through collaboration (integration) with PPWSA. PPWSA has developed and expanded a water supply system project for PPCC within just over ten years, and has become a major organization supplying 450,000 m^3 of water daily for over 90% of the entire population of the Capital City, known as "Miracle of Phnom Penh." Therefore, it will be very beneficial in the initial stage of the sewer network service for PPCC to draw on PPWSA's experience and expertise in project implementation and service operation. However, the JICA Study Team has obtained the following information through discussions with relevant people, including the General Director of PPWSA, and other means of information gathering:

- At this point in time, PPWSA considers that the sewer network service body is too immature to collaborate with PPWSA in the sewer network service.
- Although the government is the 85% majority shareholder, PPWSA has already become an independent private corporation and a listed company. Making an investment in a project

[27] The proposed plan should be coordinated with the financial and human resources development plan of PPCC and related organizations

with such little profit potential would not be accepted by its shareholders and other stakeholders.

- PPWSA still has loans to pay back to such donors as JICA, ADB, and AFD. Although loan payments are not currently delayed, it will need to expand water supply service into less profitable areas to address poverty, etc., and its financial condition will be tighter in the future.
- PPWSA has been told by the government (MIH) to consider lowering fees. (It cannot raise fees.)
- As a result, PPWSA would like to continue the current system to collect a 10% sewer user fee alongside the water supply fees.

Aside from the matters listed above, there are other issues such as, similar to Japan, water supply services (MIH) and sewer services (MPWT) are under separate authorities in Cambodia; each project/service body has a different accounting system; drinking water supply and wastewater treatment services have different methods of treatment and particulars of water quality management; and operation including fee collection except for general affairs business, as well as technical matters, differs largely between project/service bodies.

In terms of management, sewer services are greatly different from water supply services as follows:

- Construction cost is high (pipes need to be buried deeply; the diameter of the pipes is large; a large loan needs to be repaid).
- Period of construction is long (it takes a lot of time until charges can be collected; it takes a long time to stabilize management).
- It is necessary to take environmental measures (such as measures against bad smells).
- Charge system is complicated (for well water, groundwater, industrial drainage, and stormwater).
- The period of durability for machinery in treatment facilities is short (the renewal period is short).

Furthermore, although all water supply service clients have signed a contract with PPWSA concerning their water supply use, the contract only covers water supply use, but not sewerage use. If the clients have to pay a sewerage fee to PPWSA, a new contract needs to be signed. In addition, currently no law is available to require users to pay sewerage fees and legislation of such a rule will be politically difficult. At present, there is only a Governor's ordinance for collecting 10% of water supply use fee from the water supply users within the areas subject to the ADB Water Supply and Drainage Project.

However, it is widely known that establishment of a sewer system contributes to improvement of water environment in lakes, swamps, rivers, etc. At PPCC, also, better water quality at Sap Lake, Mekong River, Sap River and so on, will help ensure good sources of water supply, and thus establishment of a sewer system, will sufficiently benefit PPWSA. Furthermore, there are cases in Japan in which water supply and sewer services have separate accounts (even in the administration division which can easily be integrated), with a mechanism to avoid sewerage project negatively impacting the water supply service, and thus water supply and sewer services are effectively operated.

Therefore, in order for both the sewer and water supply project bodies to establish a win-win relationship, it is recommended that a committee, chaired by the Deputy Governor of PPCC or the Director of DPWT for implementing sewage and water supply projects in PPCC, be established to facilitate full discussion before reaching a conclusion.

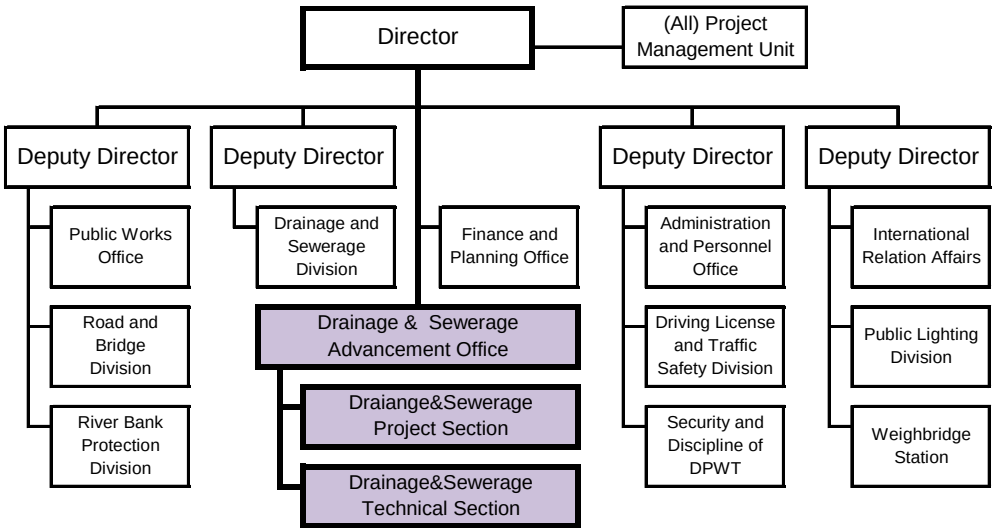
Accordingly, the option to collaborate or integrate with PPWSA shall be considered a review topic in and after the Medium-Term (from year 2021), when the sewer pipes and the sewage treatment plant have been established and the sewer network service will have a certain level of future prospects. In this M/P, the following (proposals) shall be reviewed assuming that the organization to implement the sewer network service will be established within DPWT.

(1) Proposed Organization 1: Sewerage and Drainage M/P Project Advancement Office to be established within DPWT

The Sewerage and Drainage M/P Project Advancement Office shall be established directly under the Director of DPWT, to be initially operated in a two-division structure of the Sewerage Project Division and Sewerage Technical Division, with some 15 staff members.

Its primary tasks will be planning of the sewer network service plan, preparation and implementation of an implementation plan, coordination with relevant divisions and bureaus, publicity, fee schedule, planning and designing for installation of sewer pipes and treatment plants/facilities, management of treatment facilities and so on. As the project progresses such organizations as Project Division, Planning Division, Design Division, Works Division, Facility Management Division, Water Quality Monitoring Division, Operations Division, and Marketing Division will be enhanced and staffed.

Meanwhile, the organizations within DSD that are responsible for maintenance and management of drainage facilities will maintain their current structures. As the project expands, the divisions involved in maintenance and management of wastewater pipes and cannels and sewage treatment plant will be enhanced. **Fig. 4.4.1** shows the organizational structure incorporating the above proposal (Proposed Organization 1).



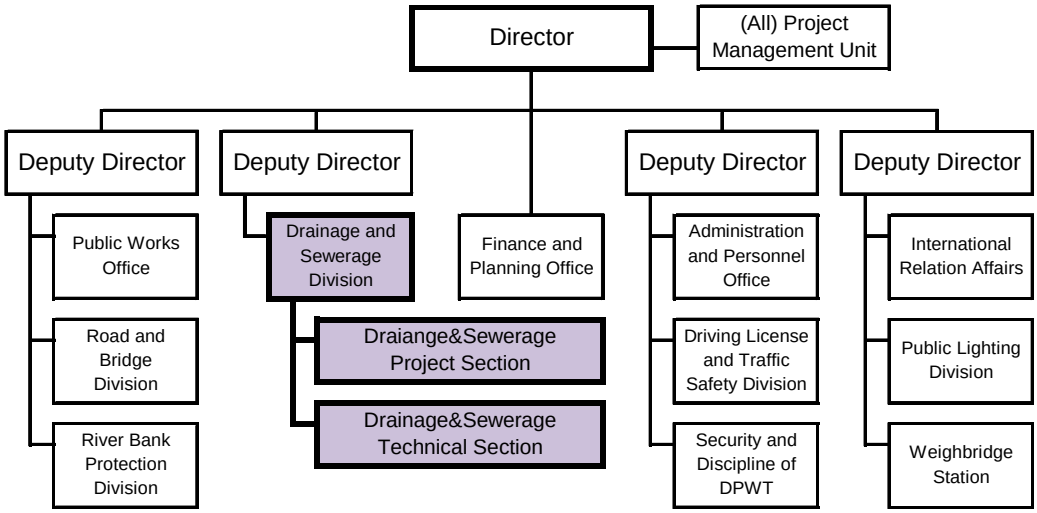
Note 1: Shaded items show the structure not in current organization
Source: JICA Study Team

Fig. 4.4.1 Organizational Structure of DPWT based on the Proposed Organization 1

(2) Proposed Organization 2: DSD is to be divided into Two Enhanced Divisions, one of which will be established as the Sewerage and Drainage M/P Project Division

With this proposal, DSD will be divided into two divisions: the division responsible for the sewerage and drainage M/P project and the division responsible for maintenance and management, for an enhanced organization. In this case, also, the divisions involved in the sewerage and drainage M/P project will be placed under the leadership of the DPWT Director, organized into the project section and the maintenance and management section for better project advancement, to implement the project. Details of their work are as described in the proposed Organization 1.

As the project expands, the posts responsible for maintenance and management will be formed by enhancing the divisions for maintenance and management of wastewater pipes and channels and sewage treatment plant. **Fig. 4.4.2** shows the organizational structure incorporating the above proposal (the proposed Organization 2).



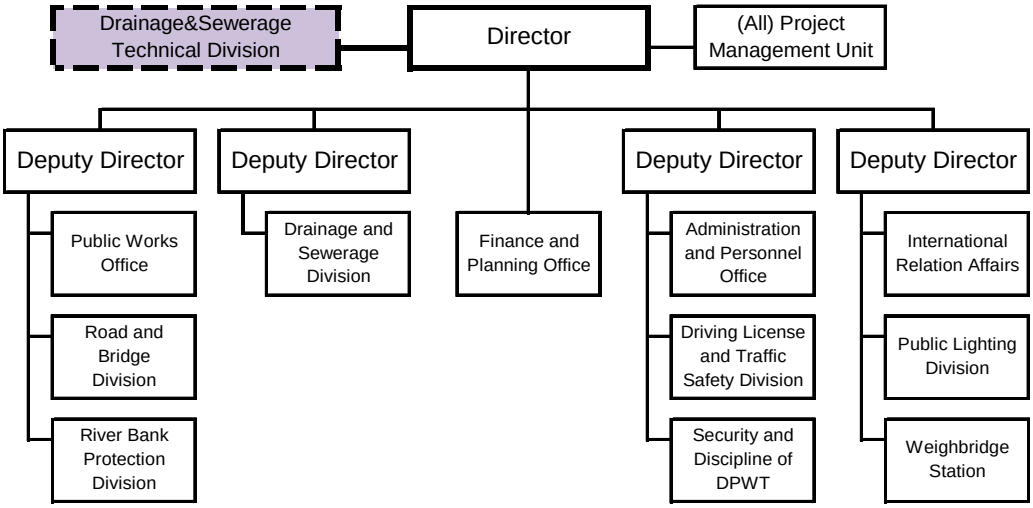
Source: JICA Study Team

Fig. 4.4.2 Organizational Structure of DPWT based on the Proposed Organization 2

(3) Proposed Organization 3: Sewerage and Drainage M/P Project Management Unit to be established within DPWT

In this proposal, the Sewerage and Drainage M/P Project Management Unit will be established within DPWT, under the leadership of the DPWT Director and headed by the Deputy Director, to advance the first stage of M/P (control of wastewater).

This unit will perform such tasks as sewer network service planning necessary in the first, establishment stage (two to three years), preparation of an implementation plan, coordination with relevant divisions and bureaus, fee schedule, publicity, and training of sewer engineers. After this stage, when the M/P implementation policies and directions are clarified, the unit will be dissolved and developed into the proposed Organization 1 or 2. **Fig. 4.4.3** shows the organizational structure incorporating the above proposal (the proposed Organization 3).



Source: JICA Study Team

Fig. 4.4.3 Organizational Structure of DPWT based on the Proposed Organization 3

(4) Policy for Staged Organizational Improvement in the Organizations that Implement the Project

For the new organization to be established within DPWT, according to the M/P Policy for staged streamlining of organizations (Short-Term, Medium-Term, and Long-Term), those posts listed in **Table 4.4.1** shall be established according to the order. (Duties of respective posts are listed in **Table 4.4.2**). It is noted that, for at least ten years until the end of Medium-term, when the sewer network service will start to run its course, technical cooperation projects such as JICA's (for training of sewer project human resources) need to be utilized for continuing human resource training.

Table 4.4.1 Policy for Staged Streamlining of Organizations that Implement the Project

	Short-Term (–2020)	Medium-Term (2021–2030)	Long-Term (2031-)
Posts	Sewerage Project Division	Project Division	Same as the left
		Operations Division	
		Marketing Division	(Marketing branches)
	Sewerage Technical Division	Planning Division	
		Design Division	
		Works Division	(Work offices)
		Facility Management Division	
		Water Quality Monitoring Division	
		Service Division	Drainage Supervision Division

Note 1): The Drainage Supervision Division will be separated from the Water Quality Monitoring Division and will carry out water quality control and supervision of wastewater from commercial facilities and plants and discharged to sewer (while the water directly discharged into public watercourse will be under jurisdiction of MOE).

Note 2): The marketing branches and work offices under Long- term will be established as branch offices of the government in each Khan, according to the progress of sewerage and drainage facilities in the Khans.

Source: JICA Study Team

Table 4.4.2 Posts to implement Projects and their Work

Posts	Work
Project Division	Project implementation plan planning, project policy formulation, and coordination between relevant departments and bureaus
Planning Division	Project implementing plan formulation, monitoring and assessment of development, supervision and training of work contractors
Design Division	Designing standards of wastewater or drainage pipes/culverts, designing of treatment plants, pumping stations, or similar facilities

Posts	Work
Works Division	Management and supervision of sewerage and drainage works, assessment and inspection of drainage facilities (connection to sewer)
Facilities Management Division	Management of facilities and utilities at treatment plants, pumping stations, or similar facilities, facilities design, sludge treatment
Water Quality Monitoring Division	Water quality management at treatment plants, management and supervision of sewerage and drainage (commercial facilities and plants)
Operations Division	Financial planning, management of budget and accounting, asset management, publicity and education for the citizens, dissemination
Marketing Division	Fee conciliation (coordination with PPWSA), levy, management of customer information
Service Division	Connection to sewer, promotion of installation of wastewater treatment facilities such as septic tanks and Johkasou, maintenance and management

Note 1): Standards, guidelines, manuals and so forth are under jurisdiction of respective responsible divisions
Note 2): DSD is responsible for operation and management of treatment plants.
Note 3): Sewerage sludge disposal sites are under jurisdiction of WMD of PPCC.
Source: JICA Study Team

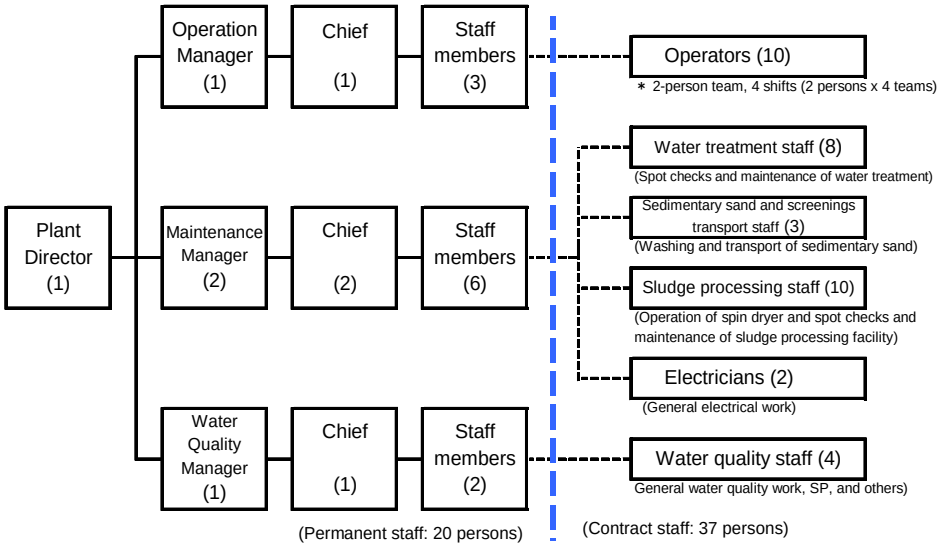
The above three alternatives propose to establish a project organization in DPWT to improve sewerage and drainage management at PPCC. However, considering the current arrangement at PPCC that the WMD (Waste Management Division) of PPCC is managing environmental matters including sewerage and drainage sectors under the leadership of the Deputy Governor, it is imperative to establish a strong partnership between the new organization at DPWT and the WMD of PPCC. Since waste management at PPCC is under the jurisdiction of the WMD of PPCC, strong partnership between the WMD and DPWT of PPCC will also be important in promoting septic tank or Johkasou installation as on-site treatment facilities, formulating manuals for maintenance and management (such as spot checks, disposal of septage, monitoring treated water, etc.) and securing disposal sites to meet the future demand of sewerage sludge.

Considering such external impacts as (i) transparency of activities of the leader and (ii) easiness to recruit staff from other organizations, the above three proposals are ordered, namely, the Organization 1 is 1st ranked, followed by the Organization 3 and Organization 2, because the Organization 2 seems to be just a restructuring of the existing organization and thus it has less impact compared to the others.

It is very important to clarify the roles and functions of (i) organizations that promote the sewerage service and (ii) the organizations in charge of technical support, at the start of establishing the sewer system, because it takes a long period of time to establish them. In addition, considering the present status of PPCC's sewer network service system, there is an option that Organization 3 should firstly be established under the policy of "Start small, let it grow", which was set in consultation with DPWT; then, the Organization 3 should be replaced with Organization 1 in the middle period of phased schedule (from 2021); and a reasonable organization system, like PPWSA, should be built up in order to implementing a full-scale sewerage system.

Fig. 4.4.4 shows the organization and staffing at the sewage treatment plant proposed in Cheung Aek Treatment Area (Capacity: about 280,000 m^3/day, applying combined system), assuming application of CASP, based on the case at the city of Kitakyushu, Japan. (This organization is equivalent to the Wastewater Treatment Plant Unit in **Fig. 2.6.7.**)

Staffing categories are in line with DSD's staffing structure, consisting of fulltime and contractual employees. However, the staffing in sludge treatment work would be changed considerably depending on the method of sludge treatment and disposal. In this chart, the case of Thickener-Digester-Dewatering-Landfill system is considered. However, if the sludge treatment system includes incineration, fuel recovery and sludge recycling system, staffing would increase by 10-15 workers.



Source: JICA Study Team

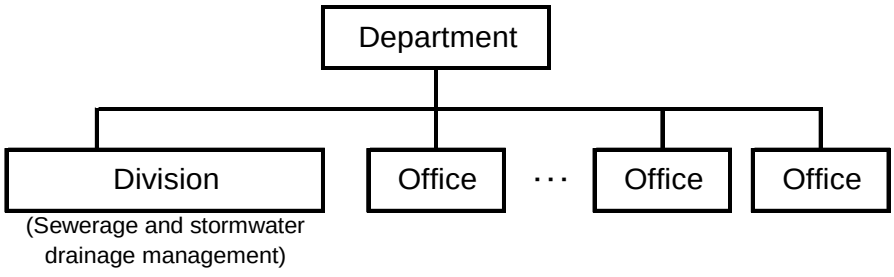
Fig. 4.4.4 Example of Management Organization in STP

4.4.2 Review of Legal Framework

Although the Cambodian legal framework for management of wastewater and stormwater drainage is not yet completed, the interviews at MPWT found that it currently has a plan for rebuilding organizations of sewerage and drainage. Therefore, if the plan is approved and implemented, preparation of a legal framework for sewerage and drainage will be accelerated.

According to the interviews, the new organization is created from an existing department, namely, the Department of National Urban Infrastructure and Engineering (see **Fig. 2.6.2)**, strengthening sewerage and stormwater management capacities. Then a division specialised in sewerage and stormwater drainage will be established. This organizational structure sets up various frameworks and systems concerning sewerage and drainage policies, as well as establishes technical standards, criteria, guidelines, sludge management and human resource training and so forth in Cambodia. The chart below (**Fig. 4.4.5**) shows the concept of the new organization responsible for legal preparation, etc. (with Division being the main driving force).

No stipulation in such regulation as sub-decree is required to establish the offices in the figure. Only the decision of the director is required. The office has the same power as the division.



Source: JICA Study Team

Fig. 4.4.5 Concept of the New Organization of Sewerage and Drainage Management established in MPWT

Under this organization, a Drainage and Sewerage Unit (equivalent to Division) will be established at each Municipality or Province, and will be responsible for sewerage and drainage management in the respective region.

Ideally, the proposed Master Plan should be implemented in PPCC in accordance with the legal framework for sewerage and drainage management and the national policies established by the central government (MPWT and DPWT). However, for the time being, MPWT (DPWT) should consider a special legislative provision to designate areas in which an urgent sewer system is established so as to improve the current status of PPCC where the rapid urbanization and absence of a sewer system accelerates deterioration of the water environment. The proposed organization should be headed by the Deputy Governor through partnership with PPCC.

As previously discussed in **Subsection 2.6.1(3)**, the "Law on Land Use Plan, Urbanization and Construction 940524" clearly states the principle that major development projects and land use in Cambodia must conform to the urban development master plan of the local government, as well as the land use plan based on the urban development master plan. In addition, for construction of a structure larger than a certain scale, a construction permit must be obtained pursuant to Ordinance No. 86 concerning construction permits. However, the reality in PPCC is that its urban development master plan, which would provide the foundation of regulation of developments, is yet to receive final approval. On the other hand, major development projects and private development projects are rapidly progressing.

To develop a sound city and good urban environment, a legal framework must be established to govern major development projects and land use areas, as discussed above. In addition, standards and guidelines on development areas should be formulated in accordance with an urban development master plan and relevant laws, specifying such matters as population size, roads, public facilities or facilities for public benefits, water supply and drainage facilities, disaster resilience and safe facilities, greenbelt plan, etc., to regulate land development. However, in PPCC, standards and regulation on major development areas are particularly obscure, and responsibility of administrative unit(s) for regulation is unclear. Those jurisdictions therefore need to be clarified.

For instance, the City of Kitakyushu in Japan had formulated the "City Planning Master Plan in the City of Kitakyushu," as well as the "Ordinance on Permission for Development Activity in the City of Kitakyushu" and "Rules on Permits, etc., for Development Activities in the City of Kitakyushu," based on the "City Planning Act" (a national statute). The City had developed the "Development Activity Manual" in accordance with the City Planning Master Plan, the Ordinance and the Rule for unified regulation of development areas.

The Development Activity Manual consists of five chapters: Chapter 1 (Principle of Development Permit System); Chapter 2 (Definition of Development Activity); Chapter 3 (Permission for Development Activity); Chapter 4 (Procedure for Development Activity; and Chapter 5 (Criteria of Development Permission). Chapter 5 also lists specific matters subject to regulation in development activities. It also has detailed description of the criteria for permission of drainage facilities and water supply facilities.

Furthermore, concerning the technical standards of sewerage and drainage facilities, the City developed detailed criteria for installation and structure of drainage facilities, pursuant to the ordinance of the city of Kitakyushu on the sewer system. The City implements these technical criteria (standards) on drainage facilities, aiming for technical unification of installation and structure of drainage facilities in the City.

Table 4.4.3 summarizes the organization and legal system options proposed in this section, following **Section 3.1** (Identification of the issues).

Table 4.4.3 Summary of Discussions and Proposals on Organization and Legal System

Current state and issues	Summary of actions to meet the issues (summary of discussions and proposals)
(1) Structure of the project implementing organizations (posts and staffing) to be established	
At present, agencies responsible for planning of projects concerning wastewater is unclear	• Based on the three proposed options in **Subsection 4.4.1**, an organization managing wastewater is established in DPWT. The organization formulates sewage management plan in accordance with the phased schedule of Short-term, Medium-term, and Long-term, aiming for synergic effect with the sewage management Master Plan. • The new organization in DPWT shall be the main body of project plan planning. • A system shall be established, in which the project planning is carried out through a partnership with WMD, which is responsible for the environmental administration in PPCC, while obtaining a consensus with PPCC. • The subject areas need to have wastewater treatment measures, including on-site treatment; therefore, agencies responsible for management of septic tanks, promotion of switching to Johkasou, standards of maintenance and management, and so on are required. • The departments engaged in septic tanks shall be unified, and procedural rules and technical standards shall be established, including those regarding installation, inspection, and maintenance of septic tanks. • The responsibilities of House Owners of septic tanks shall be specified. • Systems for registering and giving companies permission to install, maintain, or inspect septic tanks shall be established and a law shall be enacted so that only registered companies can handle septic tanks.
(2) Determining task descriptions for central and regional organizations	
Task descriptions are not determined for either central (MPWT) or regional organization (DPWT)	• The central organization (MPWT) shall be responsible for establishing policies and legal framework, stipulating technical standards and criteria, medium to long term national project planning, human resource training plan, and coordination with other ministries and agencies on laws, ordinances, ministerial orders, and so on. • In terms of the human resource training plan, in particular, it shall carry out coordination in relation to international technical support programs. • Regional organization (DPWT or provincial) shall be responsible for drawing up manuals and guidelines based on the central legal framework, central technical standards and criteria, and the central project plan, while incorporating regional and geographical features, human resource training, and other aspects. • It shall strive for enhancing partnership (and sharing information) among the organizations in PPCC under jurisdictions of MOI and the organizations under other ministries and agencies so that the project is smoothly implemented. Tasks shall be clarified after reviewing the provisions of No. 425 BrK.SK.BT, Prakas: Article 2 (Jobs of MPWT) and Article 8 (Treatment of wastewater and flood prevention); and No.274 BRK.SK.BT, Declaration: Section 3 of Chapter 4 (Jobs of DPWT) and Section 2 of Chapter 5 (Drainage, pumps, and treatment of polluted water).
(3) Securing technical standards and human resources concerning wastewater management	
Shortage of technicians for management and operation of wastewater treatment facilities	• To cultivate sewerage specialists utilizing technical cooperation projects (for training of sewerage engineers, etc.) and inviting sewerage specialists from other countries. • To establish training program, in which trainees are dispatched to cites with advanced sewer systems in foreign countries for short-term (1-3 months) or long-term (1-2 years), for training of technicians. • Technicians trained in the above program shall establish a human resource training cycle, in central and regional level, to make technicians meet the progress of sewer network service. • To establish a section to administer the training program for cultivating sewerage specialists in the central and regional governments. • To establish a “Sewer Association” (provisional name) or a similar specialized organization on sewer system and to carry out such tasks as research, investigation, development of standards and technologies of sewer systems, training, publicity, securing sewer technicians and continuous training of technicians.

Current state and issues	Summary of actions to meet the issues (summary of discussions and proposals)
(4) Insufficient management for effluent from factories	
MIH, the responsible ministry, has not implemented sufficient monitoring of status at plants/factories such as installation of treatment facilities and compliance with standards	• As well as assess criteria for issuing factory/plan operation permit, the MIH shall make factories report status of wastewater treatment after commission and the water quality monitoring data, and shall work with them to check status. Strict management of the effluent treatment facilities especially in a major source of industrial effluent discharge in such areas as the Special Economic Zone (SEZ), are required. • MIH shall work with the MOE, which is another regulatory authority. • DPWT shall discuss with related ministries (MIH and MOE) to establish regulations on installation of treatment facilities, standards for drainage and monitoring, and to confirm structure and treatment capacity in the factories. • Allocation of responsibilities among the related organizations (MIH, DOE, DLMUPC, DPWT, WMD, and so forth) shall be discussed and protocols and framework of management of factory/plant effluent shall also be discussed.
(5) Pollution control guideline, as well as land use regulation guideline for large-scale development areas, are unclear	
There is no guideline to control wastewater in large-scale development areas, which are rapidly increasing recently. Each development area manage wastewater by themselves since no unified guideline is available in PPCC	• To work with the committee in order that PPCC's Urban Development Master Plan is promptly approved. • To clarify agencies responsible for regulating development, develop a guideline and thoroughly supervise the developer with the guideline. • To clarify agencies responsible for the regulation, as well as the procedures for notification, application and so forth, concerning permission of development.

Source: JICA Study Team

4.4.3 Financial Review

(1) Financing Resources for Sewerage

In general, sewerage operation is based on the user-pay principle. However, the user fee revenues cannot cover the sewerage investment costs. The investment costs are mostly covered by government grants or subsidies. In Japan, most sewerage investments were in the past covered by the local governments' budget and also national government's subsidies. Municipal governments are operating their sewerage facilities with user fee revenues, which are almost equal to water supply use fee revenues (it is said that wastewater is treated to the almost potable extent). While there are a lot of cases that the invoices are common, there are some cases that different separate invoices are issued because the local governments as operational entities are different. In the case of the common invoices, both usage charges are collected by the same methods at the same time. Sewerage departments of municipal governments bear 30 to 40% of the water supply entities' (local public corporations) user fee collection costs. However, there are some financing methods other than user fee in other countries as reference obtained from the Internet as follows.

(a) Wastewater Tax in Europe

A wastewater tax scheme was introduced in France and the Netherlands around 1970, while Germany followed suit with a scheme that took effect in 1981. Denmark introduced a wastewater tax, which took effect in 1997. In other European countries, wastewater taxes are applied at the regional level such as in Flanders (Belgium) and in Italy and Spain.

In the Netherlands, a proposal for large-scale state subsidies to the Water Boards for the construction of local sewage treatment plants was turned down in the House of Representatives in the late 1960s. This resulted in a full-cost recovery scheme based on revenues from emission charges (in accordance with the polluter-pays principle). The levy is imposed on all direct discharges to surface waters as well as on all indirect discharges. The levy covers the costs of sewage treatment and therefore resembles an ordinary user fee. However, in two important respects, it is different from user fee. Firstly, the levy does not cover the costs of the sewer network, which is financed by a separate municipal fee. Secondly, the levy also applies to direct dischargers, i.e. industries and municipal treatment plants which discharge directly to surface waters. The levy applies to discharges of organic material, nitrogen, mercury, cadmium, copper, zinc, lead, nickel, chromium and arsenic. The revenue from the state water levy has been recycled both for support of municipal sewage treatment plants and to support in-house pollution abatement in industry, but this subsidy scheme for industry was abolished in 1996.

In Germany, the wastewater tax affects only direct dischargers, i.e. discharges from industries and municipal sewage outlets. Indirect dischargers are affected by the tax via the ordinary wastewater user fee. The revenue raised by the tax is spent by the local authorities on municipal sewage treatment and on local administration of water quality programs. The practice varies, but in the main, the revenue is recycled for support of investments in municipal sewage treatment plants. The tax is effectively a penalty tax (for non-compliance with standards).

(b) Property tax

In British Columbia, Canada, the City of Victoria historically charged for sewage in two ways – through water bills and through property taxes. The city formerly allocated 2.9% of annual property tax revenue to regional sewage services. The city announced that sewage costs would no longer be levied on the property tax bill and rather, it would be billed separately based on metered water consumption in 2008. The Capital Regional District's (the City is a member) sewage costs would be more transparent and accurately reflect a user-pay relationship. This restructuring of tax was phased-in from 2009 to 2011.

In India, there is no established mechanism for cost recovery of sewerage service. The charging for wastewater collection and treatment is conducted mainly by three methods:

- Levying a tax (sewerage/ drainage tax) – this is a percentage of property tax and varies from 1 per cent to 25 per cent of Annual Ratable Value (ARV) of property.
- Levying a charge per water closet (WC) – this type of charge is common in most urban centers of Haryana and in some urban centers of Punjab and Andhra Pradesh.
- Levying a surcharge on water – this is practiced in four urban centres (Bangalore, Chennai, Hyderabad and Ajmer).

In some cities, the basis of charging is different in all the other urban centres. Calcutta charges a certain percentage of water tax as sewerage tax while in Mangalore the basis of charging is by area.

(c) Other tax

In Korea, from 10% to 70% (mega-cities: 10%, cities: 50% and counties: 70%) of the total expenditures in implementing the sewage treatment facilities initiative is provided through the transfer of national liquor tax revenues to local governments (46.6% of total liquor tax was used for water pollution prevention).

As a result, the proportion of people with access to sewage treatment facilities was doubled in just 10 years (1992: 38% and 2002: 76%).

In January 2004, the law on the Local Subsidy Program was abrogated. Instead, the Special Act on Balanced National Development was enacted so that funds equivalent to what was provided through liquor tax revenues would be earmarked directly from the national general budget from the year 2005 onward.

The financial viability for this initiative has been secured by i) enacting relevant legal mechanisms to provide a stable source of funding for sewage facilities to local governments, ii) providing differentiated rates of support from the national treasury based on the fiscal conditions of the local government, iii) attracting private investors in order to relieve the pressures of financially strained local governments, and iv) institutionally guaranteeing financial returns to the private investors. Furthermore, user fees have been gradually increased within an affordable range to establish a stable flow of revenues from sewage treatment facilities to local governments.

Thus, there are financing resources other than user fees, but the user fee system is usual and fair. The governments with general budget, subsidy or special taxes cover the investment costs.

(2) Sewerage Financing in Phnom Penh

Revenues of the sewerage can be i) rate to the water supply (PPWSA) use payments and ii) other additional rate or new taxes such as property tax or wastewater tax.

i) Rate to water use payments is the present system, but if it becomes official (legalized) and the rate is raised, it will be difficult because every customer has an agreement with PPWSA for use of water and payment and it does not include sewerage payment. However, actually the Governor in January 2015 decided to expand the area from the ADB project area to the entire PPCC area to collect sewerage tariffs and surprisingly no people in the expansion area opposed the decision.

ii) New tax introduction is also difficult similarly to the rate increase above. Customers do not want to pay for sewerage. Therefore, the present 10% of PPWSA's water use charge revenues

payment is inevitably the starting method. However, it may not be enough even for operational costs of the sewerage project.

At first, it is necessary to legalize the sewerage tariffs as rate to the water use charges as well as defining that water use includes wastewater discharge.

Then, campaigns and public relations that wastewater treatment is essential for environmental protection and human health (wastewater without treatment may go to water supply intake of PPWSA and also the downstream people who use downstream river water for drinking) and the user(polluter)-pay principle as the worldwide trend technique should be conducted. Then, after the customers are convinced, the rate will be raised gradually to cover the operational costs. However, the object customers should be those within the new sewerage service coverage areas based on the user-pay principle. In addition, the following are to be considered:

- Sludge disposal costs from the septic tanks etc. can be new revenues for the sewerage treatment entity.

- It may be difficult to cover the investment cost (CAPEX) so that operational cost is aim to be covered with sewerage use revenues.

- The government should shoulder a soft loan for the CAPEX.

(3) Public-Private-Partnership (PPP)

"Financing Metropolitan Governments in Developing Countries" edited by Roy W. Bahl et al. and published in 2013 indicates "During the 1990s and early 2000s, the hope was that private involvement would increase the efficiency of service provision and provide badly needed resources to support urban infrastructure investment. In fact, PPP has added relatively little to urban capital financing in developing countries in the 1990s and 2000s. Less than 10 percent of investment has been in the high-priority water/sewer sector, and an even smaller share has been in the form of full or partial privatization. To the extent that PPP has been used, it has focused more on the energy, telecommunications, and transport sectors."

It also says "the failure to use PPP arrangements as being due to a 'trust deficit' between the public and private sectors. There also is weak institutional capacity for dealing with PPP." PPP requires institution and knowledge and skills of the public side. The private side has a lot of experiences usually and is tough about negotiation so that the public side short of experience at first in addition to incomplete institution is inclined to have disadvantageous agreements with the private. The Indian High Powered Commission on Urban Infrastructure (High Powered Expert Committee 2011) puts it well: "Weak governments cannot rely on private agents to overcome their weaknesses nor can they expect to make the best possible bargains for the public they represent."

In addition, the private seeks profits and the (investment and operation) costs are not necessarily cheap because the operation must be reliable so that the tariffs as revenue source are inclined to be expensive. In addition, the private cannot get soft loans, which the public can, and instead has to get high interest rate commercial loans with shorter tenure without grace period. That is, the private side has higher financial costs.

There are two sewerage PPP cases in Southeast Asia. One is in Malaysia and the other is in the Philippines. It can be said that both do not seem the best practices.

- In Malaysia, a concession for developing sewerage and sanitation throughout the company was awarded to a private company, Indah Water Consortium, in 1993. The concession was based on the principle of financing investment through consumer charges, but consumers objected to the tariffs, the tariff structure was revised, investment needs were found to be

higher than anticipated, and the government had to provide substantial financial support in the form of long-term soft loans. In 2000, the Malaysian government nationalized Indah, thus ending the experiment with private sewerage.

- In Manila, the Philippines, both water supply and sanitation were privatized in January 1997 to two private groups: a Lyonnaise des Eaux-led consortium to operate Maynilad, involving the multinational Suez group, in the western zone of the city; and Manila Water, led by the British company, United Utilities, in the eastern zone. Both concessions took responsibility for water and sanitation, including targets for new sanitation concessions. The regulator, MWSS-Regulatory Office, assessed that Maynilad increased sewerage coverage from pre-privatization levels of 7% to 11% in 2001 (compared to a target of 16% for the same year) and 10% in 2002. Manila Water achieved coverage of 3% in 2001 (meeting its target of 3% for the same year) and 3% in 2002, from pre-privatization levels of 7% (Note: it is estimated that 7% reduced to 3% because the population increased.). A Maynilad executive admitted that the company had fallen short in achieving sewerage and sanitation targets. While Maynilad in charge of the west area failed once, Manila Water in charge of the east area got listed and has given technical assistance in other countries so that the achievements are very different. Ryoichi Mohri described the reasons as follows in his paper, "Virtues and Vices of Water Privatization in Manila: Safe Water Services for the Poor," 'The Journal of Economic Studies, Nihon Fukushi University,' Economics Association and Welfare Social Development Research Institute, Nihon Fukushi University (Feb. 2006).

  - Maynilad was affected much more financially because it burdened 90% of the MWSS's foreign debt and Peso declined against US Dollars after the Asian Currency Crisis.

  - The East Area with less population includes rich districts such as Makati, but the West Area with more population has a lot of poor people.

  - The water supply facilities were much older than expected and leakage and illegal connections caused a lot of non-revenue water.

4.5 Implementation Plan

As discussed in **Subsection 3.2.3**, implementation plan is formulated on a phased schedule of Short-Term, Medium-Term and Long-Term.

4.5.1 Short-Term

As described in **Section 3.1**, priority should be placed on Cheung Aek Treatment Area, because (i) the area is fully urbanized and (ii) water pollution is more serious compared to any other areas in Phnom Penh.

Cheung Aek treatment is further subdivided into Trabek and Tumpun systems, as shown in **Table 4.5.1**. The Cheung Aek Treatment Area, which consists of STP with capacity of 282,000 m^3/day and pipe network totalling 34.1 km, covers a huge catchment area and in particular construction scale of the STP is large. Therefore, based on the overviews of the two systems in **Table 4.5.1**, priority is placed on the improvement of the Trabek system, in which urbanization and water pollution is in progress in comparison with the Tumpun system.

Table 4.5.1 Overview of Trabek and Tumpun System

Item			Trabek System	Tumpun System
Progress of urbanization			This system covers the most urbanised area in Phnom Penh, accommodating a large number of governmental and commercial buildings.	This system is located at the west of Trabek system, and is characterized with on-going and rapid urbanization in the recent years.
Current situation of water pollution			Water pollution is worst in Phnom Penh. In particular, BOD exceeds 250 mg/L in the dry season at the downstream end of Trabek Pumping Station, based on the water quality monitoring conducted in the Study.	Water pollution is second-worst in Phnom Penh, next to Trabek system. For instance, BOD ranges from 150 to 250 mg/L in the dry season at the downstream end of Tumpun Pumping Station, based on the water quality monitoring conducted in the Study.
Conditions in the year 2035				
	Area		1,581 ha	3,121 ha
	Population		394,400 person	702,800 person
	Population density		247 person/ha	225person/ha
	Wastewater generated	Daily ave	80,000 m^3/day	158,000 m^3/day
		Daily max	99,700 m^3/day	181,500 m^3/day
	Estimated reduction of BOD load[1)]		15.1 t/day	27.0 t/day

Note1) Computed by multiplying total reduction of BOD load 42.3 t/day of 1,093,155 people in Cheung Aek area, as shown in **Appendix 4** and ratio of population to the total.
Source: JICA Study Team

As shown in **Fig. 4.5.1**, Trabek system is further subdivided into Trabek East and Trabek West area. Trabek East area encompasses the most urbanised area in Phnom Penh with populations of 237,900 in 2035, while Trabek West is located adjacent to Trabek East with population of 152,500 in 2035. In the implementation plan, Trabek East, which encompasses the most urbanized area in Phnom Penh is entitled as “Phase 1 Project” to be firstly implemented. Then, Trabek West area is entitled as “Phase 2 Project”, followed by “Phase 3 project”, which represents projects in the Tumpun system.

In addition, “Preparatory Project” implemented ahead of “Phase 1 Project”, is proposed in due consideration of (i) institutional and legal framework set-up is urgent need before commencement of full-scale construction and installation of sewerage facilities, (ii) it is therefore recommendable for Phnom Penh to mainly implement non-structural measures focusing on institutional and legal framework set-up and to put them on track particularly in Short-term period, and (iii) it is also essential to accumulate technical stills step-by-step in order to smoothly enter into full-scale construction and installation of sewerage facilities in parallel with establishing institutional and legal

framework. The preparatory project is comprised of small-scale STP and the pipe collects and convey wastewater equivalent to the STP's capacity, as detailed in subsequent **Subsection 4.9**.

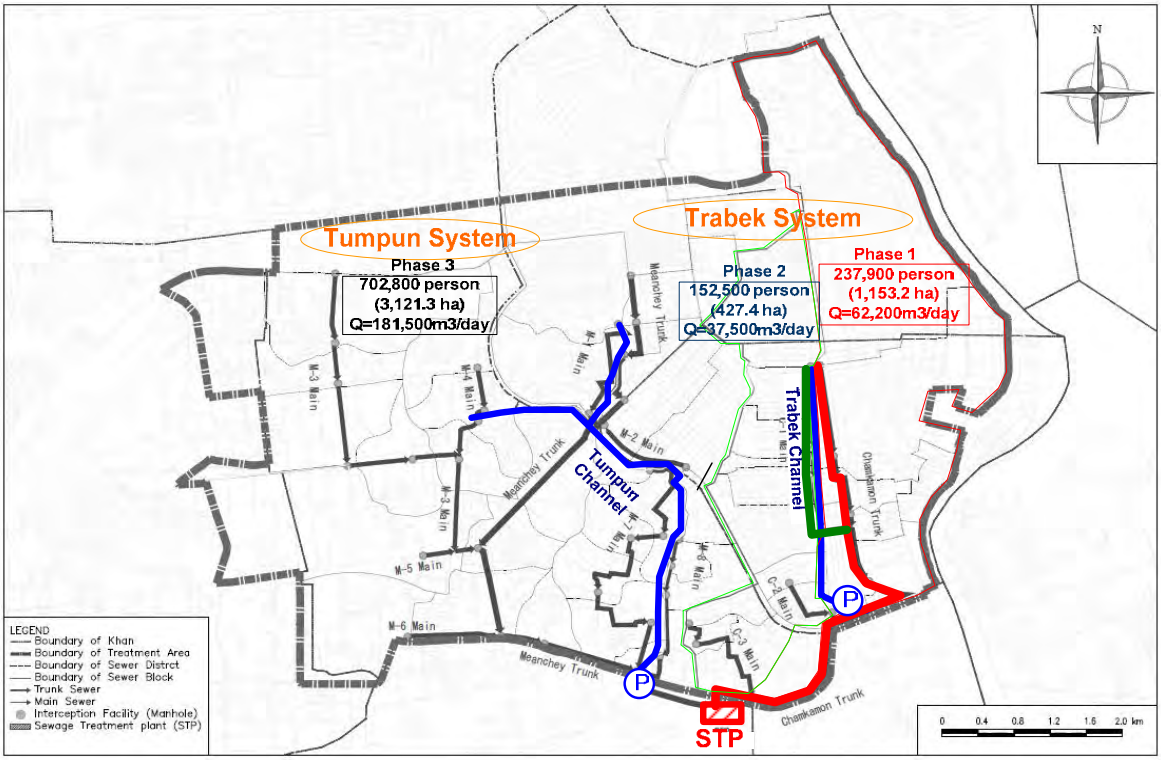


Fig. 4.5.1 Trabek and Tumpun Systems in Cheung Aek Treatment Area

4.5.2 Medium-Term and Long-Term

As described in **Subsection 4.5.1**, a Preparatory Project is proposed to be implemented in the Short-Term period in Cheung Aek Treatment Area. The Phase 1 Project is then implemented together with Phase 2 in Medium-Term period. After that, the Phase 3 Project is implemented in the Long-Term period from 2031 to 2040. The Long-Term period of 10 years is set to equalize the volume of projects implemented in each period. On the other hand, the implementation of projects in Tamok Treatment Area is commenced in the Medium-Term and ended in 2040, the last year of the Long-Term period.

Non-structural measures are continuously implemented, mainly focusing on review and improve of the issues on institutional and legal framework established and operated, throughout the course of medium- and long term period.

Based on the above discussion, the phased implementation plan for sewage management is summarised in **Table 4.5.2**, out of which the construction schedule of facilities is summarised in **Table 4.5.3**.

The construction period in **Table 4.5.4** is elaborated considering similar projects implemented in PPCC or neighbouring countries. Cheung Aek STP is constructed by reclaiming a part of Cheung Aek Lake, and the construction plan is formulated based on meteorological condition peculiar to Phnom Penh. Each project component includes feasibility study, financial preparation and designing study periods of 8, 12 and 10 months, respectively.

Table 4.5.2 Phased Implementation Schedule (Sewage Management)

Items		Short-Term (to year 2020)					Medium-Term (year 2021 to year 2030)										Long-Term (year 2031 to year 2040)										Remarks
Year		2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	
Structural Measures																											
Facilities design and construction																											
Construction of sewage facilities in Cheung Aek area							Design/ Fund arrangement			Construction			Design/ Fund arrangement		Construction												
	Phase 1																										
	Phase 2																		Design/ Fund arrangement			Construction					
	Phase 3		Design/ Fund arrangement		Construction																						
	Preparatory Project																										
Construction of sewage sludge and septage disposal site											Design/ Fund arrangement									Construction							
Installation of sewage facilities in Tamok area																											
Project cost (Million USD)																											Total
Construction of sewage facilities in Cheung Aek area																											
Phase 1	STP							65.9																			65.9
	Sewer pipe							29.5																			29.5
Phase 2	STP												120.8														120.8
	Sewer pipe												12.3														12.3
Phase 3	STP																		157.4								157.4
	Sewer pipe																		109.6								109.6
Preparatory Project	STP			20.9																							20.9
	Sewer pipe			6.0																							6.0
Construction of sewage sludge and septage disposal site				9.1				16.1																			25.2
Installation of sewage facilities in Tamok area												34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2	34.2		478.8
Total				36.0				111.5				34.2	167.3	34.2	34.2	34.2	34.2	34.2	301.2	34.2	34.2	34.2	34.2	34.2	34.2		1,025.0
O&M cost (Million USD/year)																											
Cheung Aek area (including sludge disposal site)							0.38	0.38	0.38	0.38	0.38	2.95	2.98	3.02	3.05	3.09	5.20	5.24	5.28	5.32	5.37	5.37	5.37	5.37	14.90		79.75
Tamok area													0.88	1.75	2.63	3.65	4.78	5.91	7.03	8.39	9.80	11.32	12.70	14.23	15.80	15.80	114.65
Total							0.38	0.38	0.38	0.38	0.38	2.95	3.86	4.77	5.68	6.74	9.98	11.15	12.31	13.71	15.17	16.69	18.07	19.60	21.17	30.70	194.41
Non-structural Measures																											
Legal and institutional set-up																											
Establishment of sewage management body and HRD													HRD is continued														
Establishment of sewage implementation entity																											
Formulation of guideline for sewage treatment													In operation														
Procedures																											
Securing Cheung Aek STP construction site																											
Securing site for sewage sludge and septage disposal site																											
Strengthening of management of industrial wastewater																											
Formulation of guideline and starting of operation													In operation														
Strengthening of management of large-scale development																											
Formulation of guideline and starting of operation													In operation														

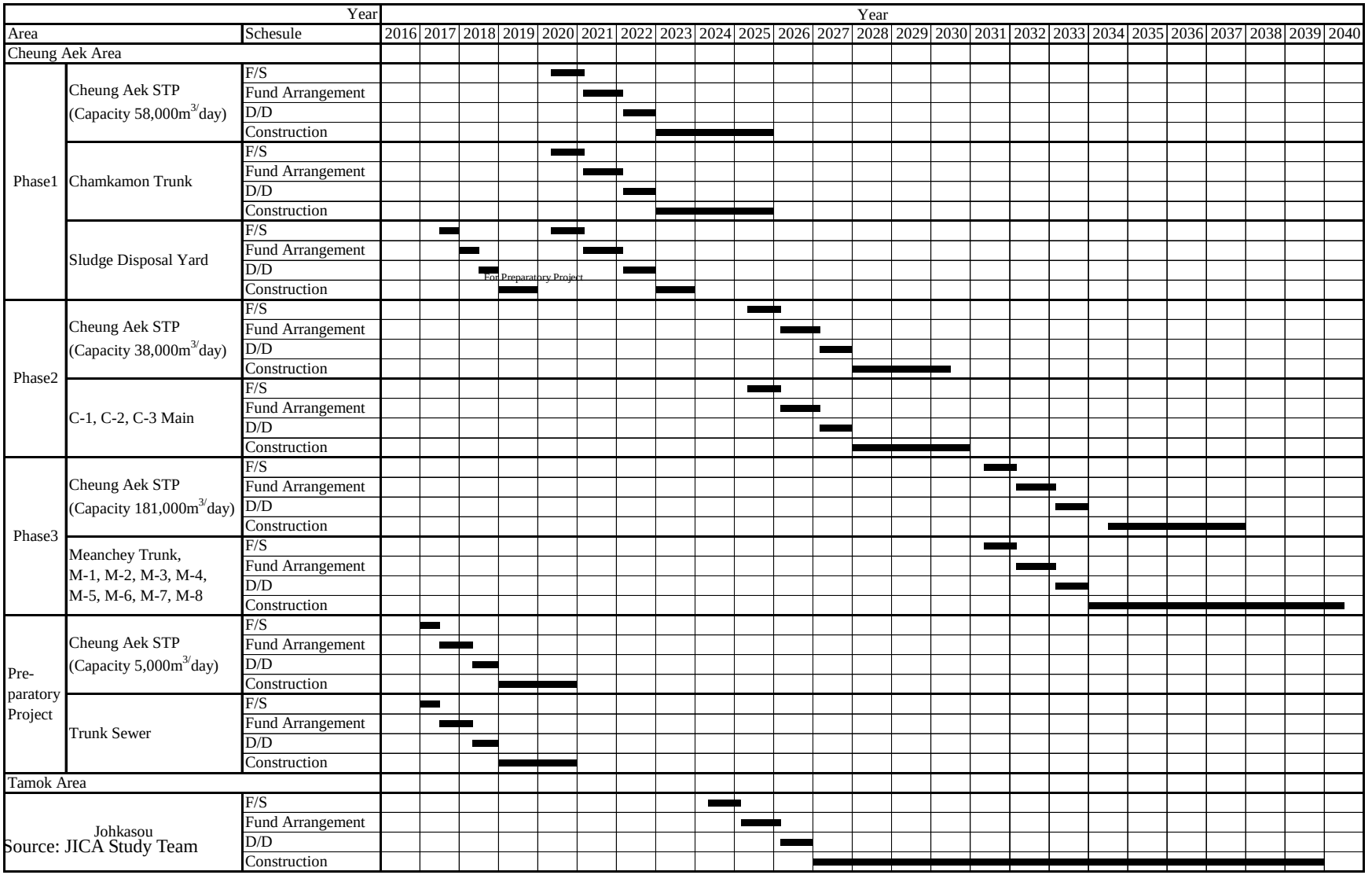
Source: JICA Study Team

Table 4.5.3 Outline of Schedule of Construction of Facilities

Treatment area		Outline of project	Commission (year)	Population in 2035	Ratio to total population of PPCC in 2035
Cheung Aek treatment area					
	Phase1	Construction of STP (Capacity 58,000 m^3/day)	2026	237,848[1)]	8.3%
		Construction of sewer (6.0km)			
		Construction of sludge disposal site (including septage treatment facilities) (for Phase1 and after)			
	Phase2	Construction of STP (Capacity 38,000 m^3/day)	2031	152,541	5.3%
		Construction of sewer (4.6km)			
	Phase3	Construction of STP (181,000 m^3/day)	2040	702,766	24.5%
		Construction of sewer (23.5km)			
	Preparatory Project	Construction of STP (5,000 m^3/day)	2020	19,000	-
		Construction of sewer (2km)			
	Sludge disposal site	Securing of site for Preparatory Project			
Tamok treatment area		Johkasou	From 2027	481,423	16.8%

Note 1) Population includes that covering that of Preparatory Project.
Source: JICA Study Team

Table 4.5.4 Phased Implementation Plan for Construction Works



Source: JICA Study Team

4.6 Cost Estimation

4.6.1 General Conditions

Project cost consists of construction cost, administration cost, engineering cost and land expropriation/compensation cost. These costs are estimated based on the general conditions as shown in **Table 4.6.1** based on the exchange rate of 1USD=119.64JPY, and 1Riel=0.030JYP, as of April 2015.

Table 4.6.1 General Conditions for Cost Estimation

No.	Items	Conditions
1	Construction cost	Material and equipment cost, Labor cost, Transportation cost and so on
2	Administration cost	5% of construction cost
3	Engineering cost	10% of construction cost
4	Physical contingency	5% of construction and engineering cost
5	Land expropriation	Not required in STP construction, and required in sludge disposal site construction

Source: JICA Study Team

Facilities construction costs are estimated based on the following conditions.

- As described in **Subsection 4.1**, in Cheung Aek treatment area, the cost includes installation of interceptors and construction of STP, applying CASP, and in Tamok treatment area, the cost is comprised of the installation cost of Johkasou.
- Civil and architectural material cost, labor cost, construction equipment cost are estimated based on the prices obtained in Cambodia because these are procured in Cambodia. On the other hand, some parts of sewer installation, some steel products and construction equipment cost, are estimated based on the prices obtained in other countries such as Japan because those are not available in Cambodia.
- Mechanical and electrical equipment is in general procured from other countries, considering cost effectiveness, reliability and easiness of operation and maintenance. Cost of the equipment is estimated, referring to a cost function in “Guidelines for Planning of Regional Sewerage System, 2008”, Japan Sewage Works Association.
- Construction cost of new sewage sludge and septage disposal site (including Lagoon type of septage treatment facilities) is included in the cost estimation because there exists no septage disposal site in PPCC.
- As discussed in **Section 4.5**, Preparatory Project in Cheung Aek Treatment Area, is proposed in Short-Term; Phase 1 and Phase 2 projects are implemented in Medium-Term; and Phase 3 project is implemented in Long-Term. In Tamok Treatment Area, the installation of Johkasou starts from the Medium-Term period and ends in year 2040.

4.6.2 Construction Cost (Project Cost)

Based on the above conditions, project cost for sewage management is estimated as shown in **Table 4.6.2**. According to the table, project cost of Cheung Aek treatment area amounts to 450.1 million USD and that of Tamok treatment area amounts to 396.2 million USD. The cost disbursement schedule for sewage management projects is shown in **Table 4.6.3**.

Table 4.6.2 Project Cost for Sewerage Management

Unit: million USD

Items	Foreign currency	Local currency	Total
I. Construction cost (1+2)	512.7	333.6	846.3
1) Cheung Aek treatment area (a+b+c+d+e)	263.5	186.6	450.1
a) Phase1 (i+ii)	52.1	27.0	79.1
i) STP Construction, Total	37.5	17.1	54.6
Civil(Reclamation)	0.1	1.6	1.7
Civil(Structure)	3.4	11.5	14.9
Architecture	0.1	1.4	0.7
Mechanical works	21.5	1.2	23.4
Electrical works	12.4	1.4	13.9
ii) Sewer Pipe Construction	14.6	9.9	24.5
b) Phase2 (i+ii)	57.1	53.5	110.6
i) STP Construction, Total	53.3	47.1	100.4
Civil(Reclamation)	0.1	11.3	11.4
Civil(Structure)	7.5	19.2	26.7
Architecture	0.5	13.5	14.0
Mechanical works	30.8	1.6	32.4
Electrical works	14.4	1.5	15.9
ii) Sewer Pipe Construction	3.8	6.4	10.2
c) Phase3 (i+ii)	137.5	84.1	221.6
i) STP Construction	88.4	42.2	130.6
Civil(Reclamation)	0.0	1.6	1.6
Civil(Structure)	6.7	31.8	38.5
Architecture	0.1	2.9	3.0
Mechanical works	54.1	2.9	57.0
Electrical works	27.5	3.0	30.5
ii) Sewer Pipe Construction	49.1	41.9	91.0
d) Preparatory Project (i+ii)	11.8	10.5	22.3
i) STP Construction	9.8	7.5	17.3
Civil(Reclamation)	0.2	3.3	3.5
Civil(Structure)	0.7	1.9	2.6
Architecture	0.2	1.9	2.1
Mechanical works	5.7	0.2	5.9
Electrical works	3.0	0.2	3.2
ii) Sewer Pipe Construction	2.0	3.0	5.0
e) Sludge Disposal Yard (i+ii)	5.0	11.5	16.5
i) Construction in Short-Term	1.2	5.1	6.3
ii) Construction in Medium-Term	3.8	6.4	10.2
2) Tamok treatment area	249.2	147.0	396.2
II. Administration cost	0.0	42.3	42.3
III. Engineering cost	67.7	16.9	84.6
IV. Physical contingency	29.0	17.5	46.5
V. Land expropriation	0.0	5.3	5.3
Total (Project Cost) (I+II+III+IV+V)	609.4	415.6	1,025.0

Source: JICA Study Team

Table 4.6.3 Disbursement Schedule of Project Cost for Sewerage Management

Unit: million USD

Item	2016			2017			2018			2019			2020			2021			2022		
	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total
A : Cost covered by loan (1+2+3)	0.0	0.0	0.0	0.0	0.0	0.0	16.1	17.0	33.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	66.2	37.0	103.2
1. Construction cost (a+b+c+d)	0.0	0.0	0.0	0.0	0.0	0.0	13.0	15.6	28.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	55.9	33.4	89.3
a) Cheung Aek area: STP							9.8	7.5	17.3										37.5	17.1	54.6
b) Cheung Aek area: Pipe							2.0	3.0	5.0										14.6	9.9	24.5
c) Cheung Aek area: Sludge disposal site							1.2	5.1	6.3										3.8	6.4	10.2
d) Tamok area: Johkasou																					
2. Consultant fee	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.6	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.1	1.8	8.9
3. Phisical contingency	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.8	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	1.8	5.0
B : Cost not covered by loan (4+5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	8.3
4. Administration cost	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	4.5
5. Land expropriation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	3.8
Total (A+B)	0.0	0.0	0.0	0.0	0.0	0.0	16.1	19.9	36.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	66.2	45.3	111.5

Item	2023			2024			2025			2026			2027			2028			2029		
	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total
A : Cost covered by loan (1+2+3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.1	11.7	32.8	90.3	70.1	160.4	21.1	11.7	32.8	21.1	11.7	32.8
1. Construction cost (a+b+c+d)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.8	10.5	28.3	74.9	64.0	138.9	17.8	10.5	28.3	17.8	10.5	28.3
a) Cheung Aek area: STP													53.3	47.1	100.4						
b) Cheung Aek area: Pipe													3.8	6.4	10.2						
c) Cheung Aek area: Sludge disposal site																					
d) Tamok area: Johkasou										17.8	10.5	28.3	17.8	10.5	28.3	17.8	10.5	28.3	17.8	10.5	28.3
2. Consultant fee	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.6	2.9	11.1	2.8	13.9	2.3	0.6	2.9	2.3	0.6	2.9
3. Phisical contingency	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.6	1.6	4.3	3.3	7.6	1.0	0.6	1.6	1.0	0.6	1.6
B : Cost not covered by loan (4+5)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	1.4	0.0	6.9	6.9	0.0	1.4	1.4	0.0	1.4	1.4
4. Administration cost	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	1.4	0.0	6.9	6.9	0.0	1.4	1.4	0.0	1.4	1.4
5. Land expropriation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total (A+B)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.1	13.1	34.2	90.3	77.0	167.3	21.1	13.1	34.2	21.1	13.1	34.2

Item	2030			2031			2032			2033			2034			2035			2036		
	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total
A : Cost covered by loan (1+2+3)	21.1	11.7	32.8	21.1	11.7	32.8	21.1	11.7	32.8	184.1	104.6	288.7	21.1	11.7	32.8	21.1	11.7	32.8	21.1	11.7	32.8
1. Construction cost (a+b+c+d)	17.8	10.5	28.3	17.8	10.5	28.3	17.8	10.5	28.3	155.3	94.6	249.9	17.8	10.5	28.3	17.8	10.5	28.3	17.8	10.5	28.3
a) Cheung Aek area: STP										88.4	42.2	130.6									
b) Cheung Aek area: Pipe										49.1	41.9	91.0									
c) Cheung Aek area: Sludge disposal site																					
d) Tamok area: Johkasou	17.8	10.5	28.3	17.8	10.5	28.3	17.8	10.5	28.3	17.8	10.5	28.3	17.8	10.5	28.3	17.8	10.5	28.3	17.8	10.5	28.3
2. Consultant fee	2.3	0.6	2.9	2.3	0.6	2.9	2.3	0.6	2.9	20.0	5.0	25.0	2.3	0.6	2.9	2.3	0.6	2.9	2.3	0.6	2.9
3. Phisical contingency	1.0	0.6	1.6	1.0	0.6	1.6	1.0	0.6	1.6	8.8	5.0	13.8	1.0	0.6	1.6	1.0	0.6	1.6	1.0	0.6	1.6
B : Cost not covered by loan (4+5)	0.0	1.4	1.4	0.0	1.4	1.4	0.0	1.4	1.4	0.0	12.5	12.5	0.0	1.4	1.4	0.0	1.4	1.4	0.0	1.4	1.4
4. Administration cost	0.0	1.4	1.4	0.0	1.4	1.4	0.0	1.4	1.4	0.0	12.5	12.5	0.0	1.4	1.4	0.0	1.4	1.4	0.0	1.4	1.4
5. Land expropriation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total (A+B)	21.1	13.1	34.2	21.1	13.1	34.2	21.1	13.1	34.2	184.1	117.1	301.2	21.1	13.1	34.2	21.1	13.1	34.2	21.1	13.1	34.2

Item	2037			2038			2039			2040			Total		
	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total
A : Cost covered by loan (1+2+3)	21.1	11.7	32.8	21.1	11.7	32.8	21.1	11.7	32.8	0.0	0.0	0.0	609.4	368.0	977.4
1. Construction cost (a+b+c+d)	17.8	10.5	28.3	17.8	10.5	28.3	17.8	10.5	28.3	0.0	0.0	0.0	512.7	333.6	846.3
a) Cheung Aek area: STP													189.0	113.9	302.9
b) Cheung Aek area: Pipe													69.5	61.2	130.7
c) Cheung Aek area: Sludge disposal site													5.0	11.5	16.5
d) Tamok area: Johkasou	17.8	10.5	28.3	17.8	10.5	28.3	17.8	10.5	28.3				249.2	147.0	396.2
2. Consultant fee	2.3	0.6	2.9	2.3	0.6	2.9	2.3	0.6	2.9	0.0	0.0	0.0	67.7	16.9	84.6
3. Phisical contingency	1.0	0.6	1.6	1.0	0.6	1.6	1.0	0.6	1.6	0.0	0.0	0.0	29.0	17.5	46.5
B : Cost not covered by loan (4+5)	0.0	1.4	1.4	0.0	1.4	1.4	0.0	1.4	1.4	0.0	0.0	0.0	0.0	47.6	47.6
4. Administration cost	0.0	1.4	1.4	0.0	1.4	1.4	0.0	1.4	1.4	0.0	0.0	0.0	0.0	42.3	42.3
5. Land expropriation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.3	5.3
Total (A+B)	21.1	13.1	34.2	21.1	13.1	34.2	21.1	13.1	34.2	0.0	0.0	0.0	609.4	415.6	1,025.0

Source: JICA Study Team

4.6.3 Operation and Maintenance Cost

Annual operation and maintenance cost is summarized in **Table 4.6.4**. According to the table, annual operation and maintenance cost of Cheung Aek and Tamok treatment area in year 2040, in which all the construction of facilities are completed, are estimated at 14.895 million USD, and 15.797 million USD, respectively.

Table 4.6.4 Annual Operation and Maintenance Cost for Sewerage Management

Unit: million USD

Year	2016	2017	2018	2019	2020	2021	2022
a) Cheung Aek area: STP						0.368	0.368
b) Cheung Aek area: Pipe						0.005	0.005
c) Cheung Aek area: Sludge disposal site						0.006	0.006
d) Tamok area: Johkasou						0.000	0.000
Total						0.379	0.379

Year	2023	2024	2025	2026	2027	2028	2029
a) Cheung Aek area: STP	0.368	0.368	0.368	2.858	2.893	2.927	2.962
b) Cheung Aek area: Pipe	0.005	0.005	0.005	0.029	0.029	0.029	0.029
c) Cheung Aek area: Sludge disposal site	0.006	0.006	0.006	0.060	0.060	0.060	0.060
d) Tamok area: Johkasou	0.000	0.000	0.000	0.000	0.876	1.751	2.627
Total	0.379	0.379	0.379	2.947	3.858	4.767	5.678

Year	2030	2031	2032	2033	2034	2035	2036
a) Cheung Aek area: STP	2.996	5.028	5.071	5.115	5.158	5.201	5.201
b) Cheung Aek area: Pipe	0.029	0.050	0.050	0.050	0.050	0.050	0.050
c) Cheung Aek area: Sludge disposal site	0.060	0.117	0.117	0.117	0.117	0.117	0.117
d) Tamok area: Johkasou	3.652	4.779	5.906	7.033	8.386	9.799	11.322
Total	6.737	9.974	11.144	12.315	13.711	15.167	16.690

Year	2037	2038	2039	2040			
a) Cheung Aek area: STP	5.201	5.201	5.201	14.564			
b) Cheung Aek area: Pipe	0.050	0.050	0.050	0.157			
c) Cheung Aek area: Sludge disposal site	0.117	0.117	0.117	0.174			
d) Tamok area: Johkasou	12.700	14.229	15.797	15.797			
Total	18.068	19.597	21.165	30.692			

Source: JICA Study Team

4.7 Financial Analysis

The sewerage M/P in Phnom Penh consists of two systems. One is the Cheung Aek System, south part and the other is the Tamok System, north part. The Cheung Aek System has a sewerage treatment plant and can be operated by a new entity collecting user fee revenue. Therefore, this entity's operation can be analysed financially in a usual way. However, the Tamok System consists of every user's on-site treatment, Johkasou (Japanese septic tank). Thus, the Tamok System cannot be analysed financially in the usual way.

4.7.1 Cheung Aek System

Ten percent (10%) of the PPWSA's revenue in the ADB project area had been paid to PPCC as drainage and sewerage costs until 2014, but from 2015 according to the Governor's decision, this charging system was expanded from the ADB project area to the total Phnom Penh area, However, small garment manufacturers and their landowners contributing to export partially are exempted (4.4% on the 10% of water supply sales revenues basis). It is assumed that this exemption does not exist and 10% of PPWSA's sales revenues are sewerage and drainage revenues for maintenance and management. However, 9% is taken out by PPWSA for management and operation and hence 91% become the sewerage and drainage use revenues. Assuming this is adopted to the 2014 sales revenues of PPWSA, the sewerage and drainage use revenues are calculated as $137{,}018 \times 0.1 \times 0.91 =$ 12.47 billion Riels, but it is less than the actual maintenance and operation costs, 13.03 billion Riels of DSD. In addition, sewerage operation entities cannot cover the investment costs with their user fee revenues usually. Therefore, operational balance is analysed at first.

(1) Revenues

At least it is expected that 10% of PPWSA revenue continue or the revenue start from this. At present, revenues are used for drainage, but they should be considered sewerage use fee revenues. Polluter-Pay principle should be adopted. Similarly, although the sewerage and drainage cost burden was expanded to all the water supply users in 2015, the exempted garment manufacturers should be subsidized in the other way. Tax exemption or other purpose subsidy should be implemented. It is not reasonable for the sewerage and drainage operator to exempt use charges. Therefore, this exemption system should be abolished in the future, by the time when the sewerage operation starts at the latest. Namely, it is assumed that the sewerage use charge revenues start from 10% of PPWSA's sales revenues. However, assuming that PPWSA takes out 9% of 100% (the PPWSA's 10% sales revenues) as a commission (sewerage charge collection costs), the remaining 91% become the sewerage use revenues. It is also supposed that 10% of PPWSA revenues or ratio of water supply revenues (payment) for sewerage user fee payment is legalized and water use is defined as not only water supply but also wastewater. Since the sewerage treatment plant operation is supposed to start in 2021, the campaign and PR will convince the citizens that users or polluters must pay. If 10% is not enough, the ratio is raised until the revenues exceed the expenditures. There is a possibility of water supply tariff raise around 2017, but this analysis is based on constant price, namely real without inflation and the raise may reflect inflation. Thus, tariff raise and inflation are excluded and it is considered how many percent ratio of the sewerage charge revenues to the water supply revenues is necessary. In fact, if water supply tariffs are raised, the ratio (10%) to water supply revenues may be reduced excluding the inflation portion.

In addition, it is assumed that the average water supply user fee revenue per cubic meter will increase because water use per customer per month will increase with the annual household income increase (6.11%). Both of water supply user fee revenue per cubic meter and water use per customer per month are estimated using linear regression analysis result based on **Tables 2.2.3** (values in the table is converted into USD) and **2.6.18**. Thus, revenue related populations and other data are as shown in **Table 4.7.1**.

In addition to the user fee revenues, there are other revenues as sludge disposal fee revenues from the sludge truck services with vacuum hose, which remove sludge from household Johkasou or septic tanks and carry it to sludge disposal site. The disposal fee revenue is supposed to be USD 5 per sludge truck because the cost of desludge is USD 34.5 per household on average based on the Social Survey result and it is supposed that a vacuum car removes sludge of one household. It can be considered that less than one-sixth of the desludge cost is disposal cost. The sludge volumes and sludge truck numbers estimated are shown in **Table 4.7.2**. Since the sludge disposal site will be located far from the city area supposedly and there is a high possibility of illegal dumping, regulation and monitoring reinforcement by WMD are necessary.

Table 4.7.1 Population and Other Data Related to Revenues of Cheung Aek System

Year	2016	2017	2018	2019	2020	2021	2022
Unit Estimate							
US$ HH Income	747	793	842	893	948	1,006	1,068
m^3/C/Month	43.0	43.5	44.1	44.7	45.4	46.1	46.8
US$/$m^3$	0.257	0.259	0.261	0.263	0.266	0.268	0.271
l/c/d	181	184	187	189	192	195	198
Covered Population (Cheung Aek STP)							
Total	913,367	926,641	939,911	953,191	966,463	974,906	983,346
Phase 1	192,696	194,263	195,830	197,400	198,968	201,558	204,151
Phase 2	140,542	141,103	141,663	142,223	142,779	143,431	144,078
Phase 3	580,129	591,275	602,418	613,568	624,716	629,917	635,117
Pop. Covered	0	0	0	0	0	201,558	204,151

Year	2023	2024	2025	2026	2027	2028	2029
Unit Estimate							
US$ HH Income	1,133	1,203	1,277	1,355	1,438	1,526	1,620
m^3/C/Month	47.6	48.4	49.3	50.2	51.2	52.2	53.4
US$/$m^3$	0.274	0.277	0.280	0.284	0.288	0.292	0.296
l/c/d	201	204	207	210	213	217	220
Covered Population (Cheung Aek STP)							
Total	991,802	1,000,249	1,008,691	1,017,134	1,025,590	1,034,032	1,042,479
Phase 1	206,744	209,335	211,930	214,517	217,111	219,705	222,298
Phase 2	144,733	145,387	146,033	146,685	147,337	147,987	148,637
Phase 3	640,325	645,527	650,728	655,932	661,142	666,340	671,544
Pop. Covered	206,744	209,335	211,930	361,202	364,448	367,692	370,935

Year	2030	2031	2032	2033	2034	2035 and after	
Unit Estimate							
US$ HH Income	1,719	1,824	1,936	2,055	2,181	2,315	
m^3/C/Month	54.5	55.8	57.1	58.5	60.0	61.6	
US$/$m^3$	0.300	0.305	0.310	0.315	0.321	0.327	
l/c/d	223	226	230	233	237	240	
Covered Population (Cheung Aek STP)							
Total	1,050,922	1,059,367	1,067,818	1,076,265	1,084,708	1,093,155	
Phase 1	224,886	227,481	230,072	232,663	235,259	237,848	
Phase 2	149,289	149,939	150,591	151,243	151,888	152,541	
Phase 3	676,747	681,947	687,155	692,359	697,561	702,766	
Pop. Covered	374,175	377,420	380,663	383,906	387,147	1,093,155	

Note) "m^3/C/Month" is m^3/customer/month; " Pop." is Population; " l/c/d" is liter/capita/day; and " HH" is Household.
Source: JICA Study Team

Table 4.7.2 Sludge Volume from non-STP Area

Year	2016	2017	2018	2019	2020	2021	2022
Cheung Aek Pop						958,805	967,038
Tamok Pop.						413,199	418,072
Other Area Pop.						1,048,075	1,065,542
Total Pop.						2,420,079	2,450,652
Sludge(m^3/d)						884	895
Trucks/day						196	199
Trucks/year						71,702	72,594

Year	2023	2024	2025	2026	2027	2028	2029
Cheung Aek Pop	975,287	983,527	991,761	802,617	808,479	814,327	820,181
Tamok Pop.	422,945	427,818	432,691	437,564	442,438	447,311	452,184
Other Area Pop.	1,082,993	1,100,453	1,117,918	1,135,382	1,152,832	1,170,297	1,187,757
Total Pop.	2,481,225	2,511,798	2,542,370	2,375,563	2,403,749	2,431,935	2,460,122
Sludge(m^3/d)	906	918	929	868	890	911	933
Trucks/day	201	204	206	193	198	202	207
Trucks/year	73,487	74,460	75,352	70,404	72,189	73,893	75,677

Year	2030	2031	2032	2033	2034	2035	2036
Cheung Aek Pop	826,036	681,947	687,155	692,359	697,561	702,766	702,766
Tamok Pop.	457,057	461,930	466,803	471,677	476,550	481,423	481,423
Other Area Pop.	1,205,221	1,222,683	1,240,139	1,257,598	1,275,062	1,292,522	1,292,522
Total Pop.	2,488,314	2,366,560	2,394,097	2,421,634	2,449,173	2,476,711	2,476,711
Sludge(m^3/d)	957	929	953	979	1,009	1,039	1,059
Trucks/day	213	206	212	218	224	231	235
Trucks/year	77,624	75,352	77,299	79,408	81,841	84,275	85,897

Year	2037	2038	2039	2040			
Cheung Aek Pop	702,766	702,766	702,766	0			
Tamok Pop.	481,423	481,423	481,423	481,423			
Other Area Pop.	1,292,522	1,292,522	1,292,522	1,292,522			
Total Pop.	2,476,711	2,476,711	2,476,711	1,773,945			
Sludge(m^3/d)	1,080	1,102	1,123	868			
Trucks/day	240	245	250	193			
Trucks/year	87,600	89,384	91,088	70,404			

Note) Methodology of calculating sludge volume is shown in **Table 4.2.9**.
Source: JICA Study Team

(2) Expenditures

The estimated operational costs excluding depreciation are shown in **Table 4.7.3**.

Table 4.7.3 Operation Expenditures Excluding Depreciation

Unit: million USD

Year	2016	2017	2018	2019	2020	2021	2022
Phase 1 STP							
Phase 1 sewer pipe							
Phase 2 STP							
Phase 2 sewer pipe							
Phase 3 STP							
Phase 3 sewer pipe							
Preparatory STP						0.368	0.368
Preparatory sewer pipe						0.005	0.005
Sludge disposal site						0.006	0.006
Total						0.379	0.379

Year	2023	2024	2025	2026	2027	2028	2029
Phase 1 STP				2.858	2.893	2.927	2.962
Phase 1 sewer pipe				0.029	0.029	0.029	0.029
Phase 2 STP							
Phase 2 sewer pipe							
Phase 3 STP							
Phase 3 sewer pipe							
Preparatory STP	0.368	0.368	0.368				
Preparatory sewer pipe	0.005	0.005	0.005				
Sludge disposal site	0.006	0.006	0.006	0.060	0.060	0.060	0.060
Total	0.379	0.379	0.379	2.947	2.982	3.016	3.051

Year	2030	2031	2032	2033	2034	2035	2036
Phase 1 STP	2.996	3.031	3.065	3.100	3.135	3.169	3.169
Phase 1 sewer pipe	0.029	0.029	0.029	0.029	0.029	0.029	0.029
Phase 2 STP		1.997	2.006	2.015	2.023	2.032	2.032
Phase 2 sewer pipe		0.021	0.021	0.021	0.021	0.021	0.021
Phase 3 STP							
Phase 3 sewer pipe							
Preparatory STP							
Preparatory sewer pipe							
Sludge disposal site	0.060	0.117	0.117	0.117	0.117	0.117	0.117
Total	3.085	5.195	5.238	5.282	5.325	5.368	5.368

Year	2037	2038	2039	2040			
Phase 1 STP	3.169	3.169	3.169	3.169			
Phase 1 sewer pipe	0.029	0.029	0.029	0.029			
Phase 2 STP	2.032	2.032	2.032	2.032			
Phase 2 sewer pipe	0.021	0.021	0.021	0.021			
Phase 3 STP				9.363			
Phase 3 sewer pipe				0.107			
Preparatory STP							
Preparatory sewer pipe							
Sludge disposal site	0.117	0.117	0.117	0.174			
Total	5.368	5.368	5.368	14.895			

Note) Cost for Preparatory Project in 2026 and after is included in those of Phase 1 project
Source: JICA Study Team

(3) Operational Balance

Based on the above revenues and expenditures, the operational profit or loss is estimated excluding depreciation because IRR calculation deals only cash flow and if investment costs are covered by the government, depreciation should be excluded. The result in the case of the present use charge revenue system that is 10% of water supply use charge revenues as sewerage use revenues is shown in **Table 4.7.4**. Profits continue from 2021 to 2039, but a loss is shown in 2040 when the last phase treatment plant starts to operate. This result indicates that 10% of the total water supply users' charges as sewerage maintenance and management costs may be over-collection till 2039. Concerning this issue, there are four points to be considered.

First, the imposed sewerage use charges at present are without treatment plants and the sewerage is a combined system. Therefore, the costs are for both of sewerage wastewater and stormwater drainage. Originally, only the costs for sewerage should be burdened by use charges and the stormwater drainage costs should be burdened by the government for inundation prevention, that is, countermeasures against disaster. However, the costs are not separated and mixed up. Based on this principle, sewerage and drainage should be separated and sewerage costs should be burdened by use charges.

Taking the above into consideration, even in the case of total water supply users as the objects, a substantial loss is estimated in 2040 when the final phase 3 facilities start to operate so that total water supply users cannot cover the operation costs. In this phase, it is necessary to double the ratio from 10% to 20%. However, profits are estimated annually before 2040 and it becomes an issue how to handle the surpluses. If the surpluses are consumed for stormwater drainage costs, it will be a kind of confusion and not suitable. At least sewerage and drainage costs should be separated clearly and the public (not sewerage operator) should burden the drainage costs with its budget (not the user charges).

Table 4.7.4 Profit and Loss excluding Depreciation (Present System, but without Garment Manufacturers Exemption)

Unit: million USD

Year	2016	2017	2018	2019	2020	2021	2022
Rev. from STP Pr.						4.23	4.39
Rev. from Desludge						0.36	0.36
Total Rev.						4.59	4.75
Expenditure						0.38	0.38
Profit/ Loss						4.21	4.37

Year	2023	2024	2025	2026	2027	2028	2029
Rev. from STP Pr.	4.56	4.73	4.92	5.11	5.31	5.55	5.78
Rev. from Desludge	0.37	0.37	0.38	0.35	0.36	0.37	0.38
Total Rev.	4.93	5.11	5.29	5.46	5.67	5.92	6.16
Expenditure	0.38	0.38	0.38	2.95	2.98	3.02	3.05
Profit/ Loss	4.55	4.73	4.92	2.52	2.69	2.91	3.11

Year	2030	2031	2032	2033	2034	2035	2036
Rev. from STP Pr.	6.01	6.26	6.56	6.84	7.16	7.47	7.47
Rev. from Desludge	0.39	0.38	0.39	0.40	0.41	0.42	0.43
Total Rev.	6.40	6.64	6.94	7.23	7.57	7.89	7.90
Expenditure	3.09	5.20	5.24	5.28	5.32	5.37	5.37
Profit/ Loss	3.32	1.45	1.70	1.95	2.24	2.53	2.53

Year	2037	2038	2039	2040	Total		
Rev. from STP Pr.	7.47	7.47	7.47	7.47	122.25		
Rev. from Desludge	0.44	0.45	0.46	0.35	7.80		
Total Rev.	7.91	7.92	7.93	7.83	130.05		
Expenditure	5.37	5.37	5.37	14.90	79.75		
Profit/ Loss	2.54	2.55	2.56	-7.07	50.30		

Source: JICA Study Team

Second, all the water supply users are imposed on, but the objects are users of sewerage treatment plant in the Cheung Aek system. Essentially, the objects of charges should be sewerage service beneficiaries. Assuming that the sewerage cost burden objects are limited to Cheung Aek system area population and all the area population pay from the start, profit and loss estimated results are shown in **Table 4.7.5**. Profits are estimated from 2021 when the preparatory project starts to operate, but losses are estimated from 2026 when the phase 1 operation starts. The loss changes to a profit in 2030, but next year, in 2031, phase 2 operation starts and losses continue to and after 2040. In order to get profits every year, it is necessary to increase 10% ratio to 20% in 2026 and to 55% in 2040.

Table 4.7.5 Profit and Loss excluding Depreciation (Imposing charges only on Cheung Aek Area Population from the Start)

Unit: million USD

Year	2016	2017	2018	2019	2020	2021	2022
Rev. from STP Pr.						1.69	1.75
Rev. from Desludge						0.36	0.36
Total Rev.						2.05	2.12
Expenditure						0.38	0.38
Profit/ Loss						1.67	1.74

Year	2023	2024	2025	2026	2027	2028	2029
Rev. from STP Pr.	1.81	1.88	1.95	2.01	2.09	2.17	2.25
Rev. from Desludge	0.37	0.37	0.38	0.35	0.36	0.37	0.38
Total Rev.	2.18	2.25	2.32	2.37	2.45	2.54	2.63
Expenditure	0.38	0.38	0.38	2.95	2.98	3.02	3.05
Profit/ Loss	1.80	1.87	1.94	-0.58	-0.53	-0.47	-0.42

Year	2030	2031	2032	2033	2034	2035	2036
Rev. from STP Pr.	2.34	2.43	2.53	2.63	2.74	2.85	2.85
Rev. from Desludge	0.39	0.38	0.39	0.40	0.41	0.42	0.43
Total Rev.	2.73	2.80	2.92	3.02	3.15	3.27	3.28
Expenditure	3.09	5.20	5.24	5.28	5.32	5.37	5.37
Profit/ Loss	-0.36	-2.39	-2.32	-2.26	-2.17	-2.10	-2.09

Year	2037	2038	2039	2040	Total		
Rev. from STP Pr.	2.85	2.85	2.85	2.85	47.37		
Rev. from Desludge	0.44	0.45	0.46	0.35	7.80		
Total Rev.	3.29	3.30	3.30	3.20	55.17		
Expenditure	5.37	5.37	5.37	14.90	79.75		
Profit/ Loss	-2.08	-2.07	-2.06	-11.69	-24.58		

Source: JICA Study Team

Third, although the object is planned sewerage population, it is an issue whether the objects should be changed based on the phased coverage population as beneficiaries or the total planned coverage population from the start of the first phase without considering phases. In a normal thinking way, use charges should be imposed on the first phase coverage users, but it can be considered that the final coverage users pay from the first phase because sewerage is a kind of network service and although it is constructed partially in order, the total network connection is completed finally and the environment is improved with wastewater treatment.

If the objects of sewerage charges are based on the phased coverage population instead of the total planned area population, the estimated profit and loss result is shown in **Table 4.7.6**. Similarly to the case of imposition on the total planned population from the start (**Table 4.7.5**), profits are estimated in the preparatory project phase, but losses are predicted from 2026 when the Phase 1 operation starts and continues to the final year. Of course, the revenues are less than those of **Table 4.7.5**. During the preparatory project phase, the profits are derived from sludge disposal revenues. In order to make profits from 2026, it is necessary to increase the ratio from 10% to 65%.

Fourth, generally speaking, it is considered that users' burden is for operation and maintenance of sewerage, but in the case of total users from the first start (like the governor's present policy implementation including outside of the ADB project area users as the object), there may be surplus because the revenues become much more than the operation and maintenance costs so that it is necessary to analyze whether investment costs should be burdened by the users or it is feasible or not.

Considering the beneficiary's burden principle based on the results, there is some doubt about whether the severe burden like **Table 4.7.6** is appropriate or not. Service users cannot get so much monetary benefits, which may be like no burden of sludge disposal costs. Benefits must be water environmental improvement to every citizen and much more than users monetary benefits.

Thus, it may not be wrong that the total planed population should be the objects of charges from the preparatory project start. Furthermore, it can be considered that all the citizens may be the total water supply users instead of the planned area population. However, at first, the planed area is the Cheung Aek system and so the objects considered should be the planned area population. Next, in the case of integrating the Tamok system, the objects should be the total water supply users, that is, both of system areas users.

Table 4.7.6 Profit and Loss excluding Depreciation (Imposing Charges only on Cheung Aek Area Phased Population)

Unit: million USD

Year	2016	2017	2018	2019	2020	2021	2022
Rev. from STP Pr.						0.03	0.03
Rev. from Desludge						0.36	0.36
Total Rev.						0.39	0.39
Expenditure						0.38	0.38
Profit/ Loss						0.01	0.01

Year	2023	2024	2025	2026	2027	2028	2029
Rev. from STP Pr.	0.03	0.03	0.03	0.42	0.44	0.46	0.48
Rev. from Desludge	0.37	0.37	0.38	0.35	0.36	0.37	0.38
Total Rev.	0.40	0.40	0.41	0.78	0.80	0.83	0.86
Expenditure	0.38	0.38	0.38	2.95	2.98	3.02	3.05
Profit/ Loss	0.02	0.02	0.03	-2.17	-2.18	-2.18	-2.19

Year	2030	2031	2032	2033	2034	2035	2036
Rev. from STP Pr.	0.50	0.86	0.90	0.94	0.98	1.02	1.02
Rev. from Desludge	0.39	0.38	0.39	0.40	0.41	0.42	0.43
Total Rev.	0.89	1.24	1.29	1.33	1.39	1.44	1.45
Expenditure	3.09	5.20	5.24	5.28	5.32	5.37	5.37
Profit/ Loss	-2.20	-3.95	-3.95	-3.95	-3.94	-3.93	-3.92

Year	2037	2038	2039	2040	Total		
Rev. from STP Pr.	1.02	1.02	1.02	2.85	14.08		
Rev. from Desludge	0.44	0.45	0.46	0.35	7.80		
Total Rev.	1.46	1.46	1.47	3.20	21.88		
Expenditure	5.37	5.37	5.37	14.90	79.75		
Profit/ Loss	-3.91	-3.90	-3.89	-11.69	-57.87		

Source: JICA Study Team

(4) FIRR (Financial Internal Rate of Return)

Next, profit and loss including investment costs are estimated although generally it is considered difficult to cover sewerage investment costs. The investment costs are shown in **Table 4.5.3**. If the estimate is stopped in the final year on the way that the invested facilities (assets) are not fully depreciated, profits covering the investment costs can be brought about after that and so the calculation does not reflect that correctly. Therefore, residual value of the investment assets needs to be included into the calculation as negative costs, namely, the positive revenue side, in the final year. (There are other calculation methods such as a selling price of the project operation or a profit of the following year after the final year divided by discount rate as total profits till the asset depreciation completion used in private investment business. However, the residual value is used simply in this study.) Lives for residual value calculation are shown in **Table 4.7.7**. Using these, the result of the case in which sewerage charges are imposed on the total planned area population from the start, namely, **Table 4.7.5** including investment costs and residual values, is shown in **Table 4.7.8**. Even in **Table 4.7.5**, losses are estimated from 2026, the Phase 1 start, and the investment costs are added so that the cash flow becomes much negative naturally. In the case of **Table 4.7.8** with imposition on the total planned population from the start and residual values addition at last, cash flow sum becomes negative, namely, FIRR is negative.

Then, it is estimated how many percent ratio should be raised to cover the investment costs. The

result is that 60% ratio from 10% is necessary from 2026 and FIRR is almost positive zero, namely sum of cash flow becomes zero (**Table 4.7.9**). However, if FIRR is zero and the total investment costs are funded by loans, even interest cannot be paid. In order to pay interest, more than 60% ratio is necessary. It may be difficult to get users' (residents') agreement with more than water supply use charges so that it is appropriate for the government (public) to burden the investment costs.

Table 4.7.7 Lives (Depreciation Terms) of Invested Assets (Construction)

Unit: million USD

	Item		STP			Sewer
			Civil	Mechanical	Electrical	
	Lifetime		50 years	20 years	15 years	50 years
1	Cheung Aek Phase 1 STP	54.6	17.3	23.4	13.9	
2	Cheung Aek Phase 1 sewer pipe	25.4				25.4
3	Cheung Aek Phase 2 STP	100.4	52.0	32.4	16.0	
4	Cheung Aek Phase 2 sewer pipe	10.2				10.2
5	Cheung Aek Phase 3 STP	130.6	43.1	57.0	30.5	
6	Cheung Aek Phase 3 sewer pipe	91.0				91.0
7	Cheung Aek Preparatory STP	17.3	8.2	5.9	3.2	
8	Cheung Aek Preparatory sewer pipe	4.1				4.1
9	Sludge disposal site	16.5	13.1	1.7	1.7	
10	Johkasou	396.2	317.0	79.2		
	Total	846.3	450.7	199.6	65.3	130.7

Source: JICA Study Team

Table 4.7.8 Cash Flow of Sewerage Project (Imposing Charges only on Cheung Aek Area Phased Population)

Unit: million USD

Year	2016	2017	2018	2019	2020	2021	2022
Rev. from STP Pr.						1.69	1.75
Rev. from Desludge						0.36	0.36
Total Rev.						2.05	2.12
Expenditure						0.38	0.38
Profit/ Loss						1.67	1.74
Investment			36.00				111.50
Cashflow			-36.00			1.67	-109.76

Year	2023	2024	2025	2026	2027	2028	2029
Rev. from STP Pr.	1.81	1.88	1.95	2.01	2.09	2.17	2.25
Rev. from Desludge	0.37	0.37	0.38	0.35	0.36	0.37	0.38
Total Rev.	2.18	2.25	2.32	2.37	2.45	2.54	2.63
Expenditure	0.38	0.38	0.38	2.95	2.98	3.02	3.05
Profit/ Loss	1.80	1.87	1.94	-0.58	-0.53	-0.47	-0.42
Investment					133.20		
Cashflow	1.80	1.87	1.94	-0.58	-133.73	-0.47	-0.42

Year	2030	2031	2032	2033	2034	2035	2036
Rev. from STP Pr.	2.34	2.43	2.53	2.63	2.74	2.85	2.85
Rev. from Desludge	0.39	0.38	0.39	0.40	0.41	0.42	0.43
Total Rev.	2.73	2.80	2.92	3.02	3.15	3.27	3.28
Expenditure	3.09	5.20	5.24	5.28	5.32	5.37	5.37
Profit/ Loss	-0.36	-2.39	-2.32	-2.26	-2.17	-2.10	-2.09
Investment				267.00			
Cashflow	-0.36	-2.39	-2.32	-269.26	-2.17	-2.10	-2.09

Year	2037	2038	2039	2040	Total		
Rev. from STP Pr.	2.85	2.85	2.85	2.85	47.37		
Rev. from Desludge	0.44	0.45	0.46	0.35	7.80		
Total Rev.	3.29	3.30	3.30	3.20	55.17		
Expenditure	5.37	5.37	5.37	14.90	79.75		
Profit/ Loss	-2.08	-2.07	-2.06	-11.69	-24.58		
Investment					547.70		
Cashflow	-2.08	-2.07	-2.06	-11.69	-166.04	FIRR=	Minus
Residual value				406.24			

Source: JICA Study Team

Table 4.7.9 Cash Flow of Sewerage Project (Sewerage Use Fee of 60% to Water Use Fee Case)

Unit: million USD

Year	2016	2017	2018	2019	2020	2021	2022
Rev. from STP Pr.						1.69	1.75
Rev. from Desludge						0.36	0.36
Total Rev.						2.05	2.12
Expenditure						0.38	0.38
Profit/ Loss						1.67	1.74
Investment			36.00				111.50
Cashflow			-36.00			1.67	-109.76

Year	2023	2024	2025	2026	2027	2028	2029
Rev. from STP Pr.	1.81	1.88	1.95	12.09	12.52	13.04	13.52
Rev. from Desludge	0.37	0.37	0.38	0.35	0.36	0.37	0.38
Total Rev.	2.18	2.25	2.32	12.44	12.89	13.41	13.90
Expenditure	0.38	0.38	0.38	2.95	2.98	3.02	3.05
Profit/ Loss	1.80	1.87	1.94	9.49	9.90	10.39	10.85
Investment					133.20		
Cashflow	1.80	1.87	1.94	9.49	-123.30	10.39	10.85

Year	2030	2031	2032	2033	2034	2035	2036
Rev. from STP Pr.	14.02	14.55	15.17	15.76	16.44	17.10	17.10
Rev. from Desludge	0.39	0.38	0.39	0.40	0.41	0.42	0.43
Total Rev.	14.41	14.93	15.56	16.16	16.85	17.52	17.53
Expenditure	3.09	5.20	5.24	5.28	5.32	5.37	5.37
Profit/ Loss	11.33	9.73	10.32	10.87	11.53	12.15	12.16
Investment				267.00			
Cashflow	11.33	9.73	10.32	-256.13	11.53	12.15	12.16

Year	2037	2038	2039	2040	Total		
Rev. from STP Pr.	17.10	17.10	17.10	17.10	238.79		
Rev. from Desludge	0.44	0.45	0.46	0.35	7.80		
Total Rev.	17.53	17.54	17.55	17.45	246.59		
Expenditure	5.37	5.37	5.37	14.90	79.75		
Profit/ Loss	12.17	12.18	12.18	2.55	166.84		
Investment					547.70		
Cashflow & IRR	12.17	12.18	12.18	2.55	25.38	FIRR=	0.48%
Residual value				406.24			

Source: JICA Study Team

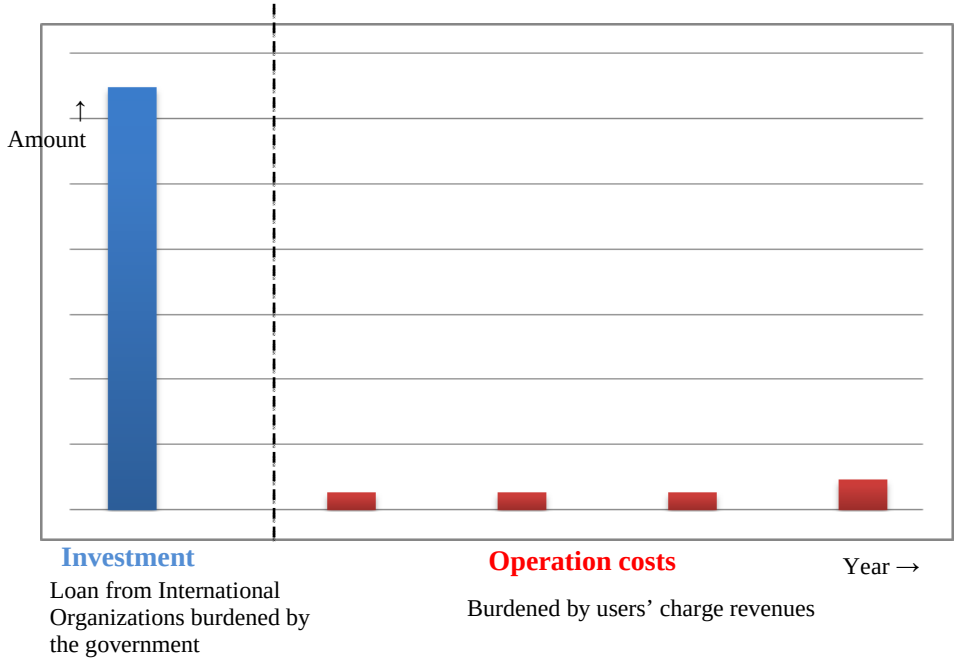
4.7.2 Tamok System

The Tamok Lake basin system is based on the on-site plants such as Johkasou and different from the Cheung Aek basin system. The investment starts from 2026 and finishes in 2039. The annual investment costs (only construction) are constant and USD 28.3 million. The annual operation costs change from USD 0.876 million in 2027 to USD 15.797 million in 2039 and after 2039 they are constant. The annual investment costs, USD 28.3 million, correspond to the population of 25,000 and so the per capita cost is USD 1,132. The annual per capita operation cost is USD 35.04. Assuming the

household size is approximately 5, these costs per household are USD 5,660 and USD 175.2, respectively. The average monthly household income is estimated at USD 793 in 2017 and so the Johkasou investment cost is (5,660÷793=) 7.1 months of income, that is, the burden seems a little too heavy, especially to lower income household.

4.7.3 Financing of Sewerage Systems

The Cheung Aek sewerage system consists of STP and pipes and it seems that the operation costs can be covered by the user fee revenues, but the investment needs to be burdened by the government since it cannot be covered by the user fee revenues which are more than water supply user revenues. The government does not have enough fund by itself and so it depends on soft loans such as the ADB's or JICA's. Such an image of sewerage costs burden can be as shown in **Fig. 4.7.1**. While the operation costs increase in proportion to the accumulated construction amounts by each phase, the final phase investment is large so that the final phase operation costs increase remarkably.



Source: JICA Study Team

Fig. 4.7.1 Image of Sewerage Cost Burden

On the other hand, the Tamok sewage system consists of every user's individual or community's Johkasou and so every user has to finance independently in principle. However, operation costs can be covered by each user although low income users need public support. The investment cost of Johkasou seems too expensive for each user. The government does not have funds and there is a problem whether the government can get soft loans for each user's Johkasou investment. Johkasou belongs to each user and usually soft loans cannot be used for private citizens. If two-step loan can be available, soft loan may be possible, but the second step loan is borrowed by each user (private) from the government (or the central bank) with usual commercial interest rates although the first step loan is between the international organization such as the ADB or JICA and the Cambodian government with long tenure, grace period and low interest rate. In that case, the second step loan is not supportive to each user. If the second step loan conditions are similar to the first step, it will be a problem of competition with commercial loans. If this problem is solved because users need support for Johkasou investment, the next problem that Johkasou users have to cover the investment costs while STP users do not need to cover the investment costs and it can be mentioned that it is unfair. In order to solve this unfair problem, it can be considered that the sewerage user fees in the Cheung Aek system should be a little expensive than necessary to the extent that the users do not refuse and the surplus should be used to reduce the investment costs of Johkasou in the Tamok system. It should be designed at the

implementation stage how much is fair to both system users including some support of operation and investment costs for low income households.

Looking at the Tamok system from a different angle, it can be considered that the Johkasou are supplied by the new sewerage operation entity operating the Cheung Aek system instead of each user's ownership. For example, since there is a limit for individual households to bear the costs of Johkasou, each municipal government in Japan establishes a municipal Johkasou promotion policy introducing a system to view Johkasou as public assets, bear the investment and maintenance costs and collect user charges from the residents instead of a simple subsidy system. Since an STP system for the Tamok basin area is not efficient, an independent on-site Johkasou system is selected and so these Johkasou are operated by the entity instead of STP. If the sewerage use charge revenues are 10% of water supply charge revenues added and imposed on the total planned Tamok system area population as well as the Cheung Aek system area population instead of phase service population, the estimate result is shown in **Table 4.7.10**. Compared with **Table 4.7.5**, which has a similar condition, namely, total planned population objects from the start, the result is the same till 2026 before the Tamok system starts, but in 2027 when the Tamok system begins, losses become less because the Tamok area planned population is included and from 2028 expenditures increase and losses in **Table 4.7.10** become more than those in **Table 4.7.5.** In particular, losses increase in 2031 when the second phase of Cheung Aek system starts and in 2040 when the third phase starts. In order to make profits, the ratio should be 15% from 2026, 30% from 2031, 50% from 2035 and 75% from 2040 like **Table 4.7.11**.

Furthermore, in order to cover the investment costs including the Tamok system, the ratio to water supply charge revenues should be 10% from 2021 to 2022, 30% from 2023 to 2025, 50% from 2026 to 2028, 60% from 2029 to 2033 and 90% from 2034 so that cash flow becomes a little positive shown in **Table 4.7.12**.

Table 4.7.10 Operational Profit or Loss Including Tamok System (10% of Water Use Revenues, imposing Sewerage Fee to Cheung Aek and Tamok Area)

Unit: million USD

Year	2016	2017	2018	2019	2020	2021	2022
Rev. from STP Pr.						1.69	1.75
Rev. from Desludge						0.36	0.36
Total Rev.						2.05	2.12
Expenditure						0.38	0.38
Profit/ Loss						1.67	1.74

Year	2023	2024	2025	2026	2027	2028	2029
Rev. from STP Pr.	1.81	1.88	1.95	2.01	2.99	3.11	3.23
Rev. from Desludge	0.37	0.37	0.38	0.35	0.36	0.37	0.38
Total Rev.	2.18	2.25	2.32	2.37	3.35	3.48	3.61
Expenditure	0.38	0.38	0.38	2.95	3.86	4.77	5.68
Profit/ Loss	1.80	1.87	1.94	-0.58	-0.51	-1.28	-2.07

Year	2030	2031	2032	2033	2034	2035	2036
Rev. from STP Pr.	3.35	3.48	3.63	3.78	3.94	4.10	4.10
Rev. from Desludge	0.39	0.38	0.39	0.40	0.41	0.42	0.43
Total Rev.	3.74	3.86	4.02	4.17	4.35	4.53	4.53
Expenditure	6.74	9.97	11.14	12.31	13.71	15.17	16.69
Profit/ Loss	-3.00	-6.11	-7.12	-8.14	-9.36	-10.64	-12.16

Year	2037	2038	2039	2040	Total		
Rev. from STP Pr.	4.10	4.10	4.10	4.10	63.25		
Rev. from Desludge	0.44	0.45	0.46	0.35	7.80		
Total Rev.	4.54	4.55	4.56	4.46	71.05		
Expenditure	18.07	19.60	21.17	30.69	194.41		
Profit/ Loss	-13.53	-15.05	-16.61	-26.24	-123.35		

Source: JICA Study Team

Table 4.7.11 Profit or Loss Including Tamok (Sewerage Fee of 10% to 75% of Water Use Revenues)

Unit: million USD

Year	2016	2017	2018	2019	2020	2021	2022
Rev. from STP Pr.						1.69	1.75
Rev. from Desludge						0.36	0.36
Total Rev.						2.05	2.12
Expenditure						0.38	0.38
Profit/ Loss						1.67	1.74

Year	2023	2024	2025	2026	2027	2028	2029
Rev. from STP Pr.	1.81	1.88	1.95	3.02	4.48	4.67	4.85
Rev. from Desludge	0.37	0.37	0.38	0.35	0.36	0.37	0.38
Total Rev.	2.18	2.25	2.32	3.37	4.84	5.04	5.23
Expenditure	0.38	0.38	0.38	2.95	3.86	4.77	5.68
Profit/ Loss	1.80	1.87	1.94	0.43	0.99	0.27	-0.45

Year	2030	2031	2032	2033	2034	2035	2036
Rev. from STP Pr.	10.06	10.45	10.90	11.33	11.83	20.52	20.52
Rev. from Desludge	0.39	0.38	0.39	0.40	0.41	0.42	0.43
Total Rev.	10.45	10.83	11.29	11.73	12.24	20.94	20.95
Expenditure	6.74	9.97	11.14	12.31	13.71	15.17	16.69
Profit/ Loss	3.71	0.85	0.15	-0.58	-1.47	5.78	4.26

Year	2037	2038	2039	2040	Total		
Rev. from STP Pr.	20.52	20.52	20.52	30.78	214.08		
Rev. from Desludge	0.44	0.45	0.46	0.35	7.80		
Total Rev.	20.96	20.97	20.98	31.13	221.88		
Expenditure	18.07	19.60	21.17	30.69	194.41		
Profit/ Loss	2.89	1.37	-0.19	0.44	27.47		

Source: JICA Study Team

Table 4.7.12 Cash Flow Including Tamok

Unit: million USD

Year	2016	2017	2018	2019	2020	2021	2022
Rev. from STP Pr.						1.69	1.75
Rev. from Desludge						0.36	0.36
Total Rev.						2.05	2.12
Expenditure						0.38	0.38
Profit/ Loss						1.67	1.74
Investment			36.00				111.50
Cashflow			-36.00			1.67	-109.76

Year	2023	2024	2025	2026	2027	2028	2029
Rev. from STP Pr.	5.44	5.64	5.84	10.07	14.94	15.57	19.39
Rev. from Desludge	0.37	0.37	0.38	0.35	0.36	0.37	0.38
Total Rev.	5.81	6.01	6.21	10.43	15.30	15.94	19.76
Expenditure	0.38	0.38	0.38	2.95	3.86	4.77	5.68
Profit/ Loss	5.43	5.63	5.83	7.48	11.44	11.17	14.09
Investment	0.00	0.00	0.00	34.20	167.40	34.20	34.20
Cashflow	5.43	5.63	5.83	-26.72	-155.96	-23.03	-20.11

Year	2030	2031	2032	2033	2034	2035	2036
Rev. from STP Pr.	20.12	20.90	21.81	22.67	35.50	36.94	36.94
Rev. from Desludge	0.39	0.38	0.39	0.40	0.41	0.42	0.43
Total Rev.	20.51	21.28	22.19	23.06	35.91	37.36	37.37
Expenditure	6.74	9.97	11.14	12.31	13.71	15.17	16.69
Profit/ Loss	13.77	11.30	11.05	10.75	22.20	22.19	20.68
Investment	34.20	34.20	34.20	301.20	34.20	34.20	34.20
Cashflow	-20.43	-22.90	-23.15	-290.45	-12.00	-12.01	-13.52

Year	2037	2038	2039	2040	Total		
Rev. from STP Pr.	36.94	36.94	36.94	36.94	422.96		
Rev. from Desludge	0.44	0.45	0.46	0.35	7.80		
Total Rev.	37.38	37.38	37.39	37.29	430.76		
Expenditure	18.07	19.60	21.17	30.69	194.41		
Profit/ Loss	19.31	17.79	16.23	6.60	236.35		
Investment	34.20	34.20	34.20	0.00	1,026.50		
Cashflow&IRR	-14.89	-16.41	-17.97	6.60	4.89	FIRR=	0.06%
Residual value				795.04			

Source: JICA Study Team

4.8 Economic Analysis

4.8.1 Preconditions for Economic Analysis

(1) Costs

Costs consist of investment cost and operation costs similarly to financial analysis. However, in economic analysis, costs and benefits must be modified from market price to economic price. In particular, prices of imported goods must be border prices excluding customs and results of other trading policies, etc. When monetary amounts are expressed in foreign currency, market prices of imported equipment and materials are converted to border prices with conversion factors, which are specific to the countries. In Cambodia, the conversion factors are shown in ADB's Urban Water Supply Project report. (http://www.adb.org/projects/documents/Cambodia-urban-water-supply-project-rrp)

The conversion factors for capital costs and O&M costs are 0.96 and 0.92, respectively. The operational costs are the same as those in financial analysis.

(2) Benefits

In economic analysis, financial profits are excluded. Instead, social benefits of the project are included in the calculation. Social benefits of sewerage can be considered in several ways. At first, satisfaction of sewerage users can be mentioned. For this benefit, willingness-to-pay prices are surveyed. However, most users cannot imagine the un-existing service effects and additionally, people in developing countries cannot and do not want to pay for environmental purposes such as sewerage or pollution improvement. In this project, Social Survey is conducted, but the willingness-to-pay results are very low, less than USD 1.5 per month accounts for more than 90%. This amount corresponds to 10%-20% of water supply use monthly payments. That is similar to the actual ADB project drainage payments of 10% water supply charge. Since the willingness-to-pay price is too cheap, affordable price, that is, 1.5% of disposable household income for sewerage (or about 97.8% of average household income), based on the World Bank or ADB references is used instead of willingness-to-pay results in this economic analysis.

The benefits of sewerage are environmental improvement or water pollution amelioration, in general. For example, without the sewerage project, wastewater from houses and commercial and some industrial facilities continues to be discharged without appropriate treatment to the Bassac River and Sap River ultimately. The wastewater without treatment may enter the intake of PPWSA's water supply and also the downstream people use the river water for drinking although it may be diluted to some extent[28]. Therefore, there is a possibility of health issue and additionally people may dislike it. However, this impact cannot be expressed in monetary amount suitably. Thus, the main benefits of sewerage project cannot be quantified.

On the other hand, it may be easier to quantify the benefits as land value increase. Since the areas around Trabek, Tumpun and Kop Slov pumping stations smell terribly, the values of these areas for housing may be lower than usual. With the sewerage project, the land values may be raised from the present values if the offensive odor issues are improved. According to the real estate developers, this offensive odor problem solution effect is not so large and the estimate is a few percent. Therefore, it is assumed that the values of surrounding land around the lakes to where wastewater is discharged from the pumping stations can be increased at three percent with the sewerage project. The affected areas are supposed to the land with width of 50 meters facing the lakes such as the Cheung Aek and Tamok.

[28] According to PPWSA's past 10 years (2016-2015) data of water treatment plant, the average annual DO decreased 30%, the average annual ammoniac nitrogen increased 150% and phosphate increased 60%. There is a possibility that these changes relate to water pollution.

The next benefit expected is agricultural harvest improvement of water spinach. Although water spinach is cultivated in dirty water environment, the areas around pumping station exiting without treatment cannot cultivate water spinach. At present, the average productivity or profit of water spinach around the Cheung Aek Lake is USD 1,533/ha/dry season according to "Seasonal Direct Use Value of Cheung Aek Peri-urban Lake, Phnom Penh, Cambodia" (Seila Sar, et al., 2010). On the other hand, lotus is the main product affected by wastewater around the Tamok Lake. Lotus was cultivated in 70 ha, but the area reduced to 50% because of algae increase caused by the wastewater and the lotus yield is three million riels/ha/year according to the officials of Khan Prek Pnov. Rice yields are affected, too. They are damaged at 20% reduction of the yields before the pollution is conspicuous. By the way, average profit of rice is USD 506/ha/ dry season based on the Cheung Aek paper above. According to the interview with the director of the Department of Agriculture, PPCC, rice field area in Prek Pnov during the dry season is 574 ha in 2015. Concerning the Tamok, the Khan officials said, "Fishery for all types of fish is conducted by net and the yields dropped at 30% to 40% in 2015, but usual yield was 10 to 20 kg/day. It decreased to less than 7 to 12 kg/day. The fish evacuated from the dirty water. In monetary terms, 100,000 riels/ day decreased to 30,000 to 50,000 riels /day now. Some fishery people moved to other areas."

According to "Household Baseline and Monitoring Survey Report on Production in Aquatic Peri-urban System in Phnom Penh, Cambodia," (Khov Kuong, et al., 2002), the farmers around the Cheung Aek and Tamok Lakes complain about itchy skin diseases. This is called dermatitis caused by the dirty wastewater. The skin problem complaint rate is 8.8% among the water spinach farmers around the Cheung Aek Lake. Medical care costs are 3,000 riels/person at one time for consultation and pills at referral hospitals in Phnom Penh. It is supposed that a dermatitis patient farmer goes to hospital once in a month during the dry season (6 months). Around the Tamok Lake, some farmers also complain of itchy skin diseases.

4.8.2 Cheung Aek System EIRR

The investment costs are converted as the imported part is converted to border price described above using conversion factor, 0.96. The operation costs are the same as those of the financial analysis.

Concerning the benefits, users' benefits are calculated multiplying water volume and affordable sewerage price instead of sewerage use tariff. However, user numbers can be two alternatives. One is sewerage user numbers similar to those of financial analysis. The other is user numbers, which are final project object user numbers. The former is the actual user number in the year, but the latter is the planned area population in the year. Of course, the latter (benefit) is more than the former. The former concept is that the actual users are the benefit takers, but the latter concept is that the final project area users are the participants to pay for the project from the beginning. The latter seems appropriate, but both are estimated. In addition, since the social survey result shows that willingness-to-pay is 1.5 USD per month, this amount and the case that the final user number is supposed from the start are applied to the calculation model and the result is shown for reference (**Table 4.8.3**).

Land value increase benefit is supposed 3% of land value. The land width is 50 meters and length of the Cheung Aek Lake is 32.3 km. The total land value increases are supposedly fulfilled when the project was completed 100% and so the change at each implementation stage reflects land values. Land value around the Cheung Aek Lake is supposedly USD 320/m^2 based on the web site information. If those sites are developed as housing lots, the land values may be more expensive, but these are adopted as conservative values. However, the land values are estimated to increase as household income increases in the future.

Concerning water spinach in the Cheung Aek, the affected area, where wastewater discharged directly is too dirty to cultivate water spinach, is supposed 10% of the Cheung Aek Lake, that is, (total area – STP area)×0.1=(520 ha-16.3 ha)×0.1= 50.37 ha. Potentially, this area has USD 1,533/ha/dry season, but it is assumed that the productivity is recovered 100% at the project completion and till then it is proportional to the population coverage of the project. Rice fields around both lakes are supposed

outside of the directly affected areas, but since water used for rice cultivation is polluted, rice growth and harvest are affected proportionally to the project coverage.

Medical care costs of farmers for dermatitis are supposed proportional to household income growth yearly. The total farmer numbers are calculated using cultivation areas and producers numbers according to "Spatial Analysis of Human Activities Performed in Cheung Aek inundated Lake, Cambodia" (Phearith Teang and Puy Lim, 2010).

The EIRR result of actual user case by using 1.5% of disposable income in each household is shown in **Table 4.8.1**. Users' benefits are the largest.

Table 4.8.1 Cheung Aek System EIRR (Actual Users)

Unit: million USD

Year	2016	2017	2018	2019	2020	2021	2022
Users' Benefit						0.58	0.62
Land Value Rise						0.34	0.00
Agri. & Fishery						0.01	0.01
Medical Care						0.000	0.000
Operational Costs						0.38	0.38
Investment			35.36				108.85
Cash flow			-35.36			0.55	-108.60

Year	2023	2024	2025	2026	2027	2028	2029
Users' Benefit	0.67	0.72	0.77	10.37	11.14	11.97	12.85
Land Value Rise	0.00	0.00	0.00	5.46	0.02	0.02	0.03
Agri. & Fishery	0.01	0.01	0.01	0.10	0.10	0.11	0.12
Medical Care	0.000	0.000	0.000	0.001	0.001	0.001	0.001
Operational Costs	0.38	0.38	0.38	2.95	2.98	3.02	3.05
Investment					130.43		
Cash flow	0.30	0.35	0.40	12.98	-122.14	9.09	9.94

Year	2030	2031	2032	2033	2034	2035	2036
Users' Benefit	13.80	24.57	26.31	28.16	30.14	32.25	32.25
Land Value Rise	0.03	5.39	0.01	0.01	0.01	0.01	0.00
Agri. & Fishery	0.13	0.22	0.24	0.25	0.27	0.28	0.28
Medical Care	0.001	0.002	0.002	0.002	0.002	0.002	0.002
Operational Costs	3.09	5.20	5.24	5.28	5.32	5.37	5.37
Investment				260.48			
Cash flow	10.87	24.99	21.31	-237.34	25.09	27.18	27.17

Year	2037	2038	2039	2040	Total		
Users' Benefit	32.25	32.25	32.25	90.31	424.23		
Land Value Rise	0.00	0.00	0.00	30.88	42.21		
Agri. & Fishery	0.28	0.28	0.28	0.79	3.77		
Medical Care	0.002	0.002	0.002	0.006	0.030		
Operational Costs	5.37	5.37	5.37	14.90	79.75		
Investment					535.12		
Cash flow	27.17	27.17	27.17	107.09	304.22	EIRR=	4.06%
Residual value				448.85			

Source: JICA Study Team

Medical care costs are negligible. Anyway, EIRR is 4.06% and very small.

However, the EIRR result of total project user case by using 1.5% of disposable income in each household, is shown in **Table 4.8.2**. The EIRR is 28.78%. Although it is usually said that 12% of EIRR is minimum, the calculated EIRR exceeds this 12%. On the other hand, when 1.5 USD per month as willingness-to-pay in the social survey result is used, the total cash flow becomes negative and economic effects become less than the costs (**Table 4.8.3**). After all, 1.5 USD per month is 0.2% of 747 USD household income (in 2016) and considered too cheap.

Table 4.8.2 Cheung Aek System EIRR (Final Users)

Unit: million USD

Year	2016	2017	2018	2019	2020	2021	2022
Users' Benefit						35.01	37.48
Land Value Rise						0.34	0.00
Agri. & Fishery						0.01	0.01
Medical Care						0.000	0.000
Operational Costs						0.38	0.38
Investment			35.36				108.85
Cash flow			-35.36			34.98	-71.75

Year	2023	2024	2025	2026	2027	2028	2029
Users' Benefit	40.12	42.94	45.96	49.18	52.63	56.32	60.26
Land Value Rise	0.00	0.00	0.00	5.46	0.02	0.02	0.03
Agri. & Fishery	0.01	0.01	0.01	0.10	0.10	0.11	0.12
Medical Care	0.000	0.000	0.000	0.001	0.001	0.001	0.001
Operational Costs	0.38	0.38	0.38	2.95	2.98	3.02	3.05
Investment					130.43		
Cash flow	39.75	42.57	45.59	51.79	-80.65	53.44	57.36

Year	2030	2031	2032	2033	2034	2035	2036
Users' Benefit	64.48	68.98	73.79	78.94	84.43	90.31	90.31
Land Value Rise	0.03	5.39	0.01	0.01	0.01	0.01	0.00
Agri. & Fishery	0.13	0.22	0.24	0.25	0.27	0.28	0.28
Medical Care	0.001	0.002	0.002	0.002	0.002	0.002	0.002
Operational Costs	3.09	5.20	5.24	5.28	5.32	5.37	5.37
Investment				260.48			
Cash flow	61.54	69.39	68.80	-186.56	79.39	85.24	85.23

Year	2037	2038	2039	2040	Total		
Users' Benefit	90.31	90.31	90.31	90.31	1,332.37		
Land Value Rise	0.00	0.00	0.00	30.88	42.21		
Agri. & Fishery	0.28	0.28	0.28	0.79	3.77		
Medical Care	0.002	0.002	0.002	0.006	0.030		
Operational Costs	5.37	5.37	5.37	14.90	79.75		
Investment					535.12		
Cash flow	85.23	85.23	85.23	107.09	1,212.36	EIRR=	28.78%
Residual value				448.85			

Source: JICA Study Team

Table 4.8.3 Cheung Aek System EIRR (Willingness-to-Pay, Final Users)

Unit: million USD

Year	2016	2017	2018	2019	2020	2021	2022
Users' Benefit						3.51	3.54
Land Value Rise						0.34	0.00
Agri. & Fishery						0.01	0.01
Medical Care						0.000	0.000
Operational Costs						0.38	0.38
Investment			35.36				108.85
Cash flow			-35.36			3.48	-105.68

Year	2023	2024	2025	2026	2027	2028	2029
Users' Benefit	3.57	3.60	3.63	3.66	3.69	3.72	3.75
Land Value Rise	0.00	0.00	0.00	5.46	0.02	0.02	0.03
Agri. & Fishery	0.01	0.01	0.01	0.10	0.10	0.11	0.12
Medical Care	0.000	0.000	0.000	0.001	0.001	0.001	0.001
Operational Costs	0.38	0.38	0.38	2.95	2.98	3.02	3.05
Investment					130.43		
Cash flow	3.20	3.23	3.26	6.27	-129.59	0.84	0.85

Year	2030	2031	2032	2033	2034	2035	2036
Users' Benefit	3.78	3.81	3.84	3.87	3.90	3.94	3.94
Land Value Rise	0.03	5.39	0.01	0.01	0.01	0.01	0.00
Agri. & Fishery	0.13	0.22	0.24	0.25	0.27	0.28	0.28
Medical Care	0.001	0.002	0.002	0.002	0.002	0.002	0.002
Operational Costs	3.09	5.20	5.24	5.28	5.32	5.37	5.37
Investment				260.48			
Cash flow	0.85	4.23	-1.15	-261.63	-1.14	-1.14	-1.15

Year	2037	2038	2039	2040	Total		
Users' Benefit	3.94	3.94	3.94	3.94	75.51		
Land Value Rise	0.00	0.00	0.00	30.88	42.21		
Agri. & Fishery	0.28	0.28	0.28	0.79	3.77		
Medical Care	0.002	0.002	0.002	0.006	0.030		
Operational Costs	5.37	5.37	5.37	14.90	79.75		
Investment					535.12		
Cash flow	-1.15	-1.15	-1.15	20.72	-44.50	EIRR=	-1.85%
Residual value				448.85			

Source: JICA Study Team

4.8.3 Tamok System EIRR

The method is similar to that of the Cheung Aek system. However, the Tamok system benefits and costs are added. Concerning the Tamok system, the following information is added.

- The length of the Tamok Lake is 29 km. Land value around the Tamok Lake is USD 220/m^2.
- Around the Tamok Lake, lotus cultivation is similar to water spinach in the Cheung Aek and it is assumed that present production is 3 million riels/ha/year×70 ha, but it is at the project completion stage and by then it is proportional to the project population coverage.
- Fishery benefits in the Tamok Lake are assumed similar to the rice cultivation affected.

The EIRR result of actual users case is shown in **Table 4.8.4**. Compared with **Table 4.8.1**, the EIRR, 3.49%, becomes lower than that (4.06%) of **Table 4.8.1** because of the Tamok system inefficiency.

The EIRR result of total project users case is shown in **Table 4.8.5**. The EIRR is 26.31% and also lower than that of **Table 4.8.2**.

Table 4.8.4 Both Systems EIRR (Actual Users)

Unit: million USD

Year	2016	2017	2018	2019	2020	2021	2022
Users' Benefit						0.58	0.62
Land Value Rise						0.34	0.00
Agri. & Fishery						0.01	0.01
Medical Care						0.000	0.000
Operational Costs						0.38	0.38
Investment			35.36				108.85
Cash flow			-35.36			0.55	-108.60

Year	2023	2024	2025	2026	2027	2028	2029
Users' Benefit	0.67	0.72	0.77	10.37	12.42	14.69	17.19
Land Value Rise	0.00	0.00	0.00	5.46	0.56	0.55	0.54
Agri. & Fishery	0.01	0.01	0.01	0.10	0.14	0.15	0.16
Medical Care	0.000	0.000	0.000	0.001	0.002	0.002	0.002
Operational Costs	0.38	0.38	0.38	2.95	3.86	4.77	5.68
Investment				33.36	163.79	33.36	33.36
Cash flow	0.30	0.35	0.40	-20.37	-154.51	-22.73	-21.14

Year	2030	2031	2032	2033	2034	2035	2036
Users' Benefit	20.30	33.66	38.26	43.30	49.52	56.46	60.09
Land Value Rise	0.66	6.06	0.67	0.65	0.82	0.83	0.87
Agri. & Fishery	0.18	0.28	0.30	0.32	0.35	0.38	0.38
Medical Care	0.002	0.003	0.003	0.004	0.004	0.004	0.004
Operational Costs	6.74	9.97	11.14	12.31	13.71	15.17	16.69
Investment	33.36	33.36	33.36	293.84	33.36	33.36	33.36
Cash flow	-18.95	-3.33	-5.27	-261.88	3.63	9.15	11.31

Year	2037	2038	2039	2040	Total		
Users' Benefit	63.98	67.94	71.62	130.08	693.24		
Land Value Rise	0.93	0.95	0.89	30.98	51.78		
Agri. & Fishery	0.39	0.39	0.38	0.80	4.74		
Medical Care	0.004	0.004	0.004	0.012	0.055		
Operational Costs	18.07	19.60	21.17	30.69	194.41		
Investment	33.36	33.36	33.36	0.00	1,002.10		
Cash flow	13.88	16.34	18.37	131.18	378.09	EIRR=	3.49%
Residual value				824.79			

Source: JICA Study Team

Table 4.8.5 Both Systems EIRR (Final Users)

Unit: million USD

Year	2016	2017	2018	2019	2020	2021	2022
Users' Benefit						35.01	37.48
Land Value Rise						0.34	0.00
Agri. & Fishery						0.01	0.01
Medical Care						0.000	0.000
Operational Costs						0.38	0.38
Investment			35.36				108.85
Cash flow			-35.36			34.98	-71.75

Year	2023	2024	2025	2026	2027	2028	2029
Users' Benefit	40.12	42.94	45.96	49.18	75.34	80.68	86.40
Land Value Rise	0.00	0.00	0.00	5.46	0.56	0.55	0.54
Agri. & Fishery	0.01	0.01	0.01	0.10	0.14	0.15	0.16
Medical Care	0.000	0.000	0.000	0.001	0.002	0.002	0.002
Operational Costs	0.38	0.38	0.38	2.95	3.86	4.77	5.68
Investment				33.36	163.79	33.36	33.36
Cash flow	39.75	42.57	45.59	18.44	-91.60	43.27	48.07

Year	2030	2031	2032	2033	2034	2035	2036
Users' Benefit	92.52	99.06	106.05	113.53	121.53	130.08	130.08
Land Value Rise	0.66	6.06	0.67	0.65	0.82	0.83	0.87
Agri. & Fishery	0.18	0.28	0.30	0.32	0.35	0.38	0.38
Medical Care	0.002	0.003	0.003	0.004	0.004	0.004	0.004
Operational Costs	6.74	9.97	11.14	12.31	13.71	15.17	16.69
Investment	33.36	33.36	33.36	293.84	33.36	33.36	33.36
Cash flow	53.26	62.07	62.52	-191.65	75.64	82.77	81.30

Year	2037	2038	2039	2040	Total		
Users' Benefit	130.08	130.08	130.08	130.08	1,806.28		
Land Value Rise	0.93	0.95	0.89	30.98	51.78		
Agri. & Fishery	0.39	0.39	0.38	0.80	4.74		
Medical Care	0.004	0.004	0.004	0.012	0.055		
Operational Costs	18.07	19.60	21.17	30.69	194.41		
Investment	33.36	33.36	33.36	0.00	1,002.10		
Cash flow	79.99	78.48	76.83	131.18	1,491.13	EIRR=	26.31%
Residual value				824.79			

Source: JICA Study Team

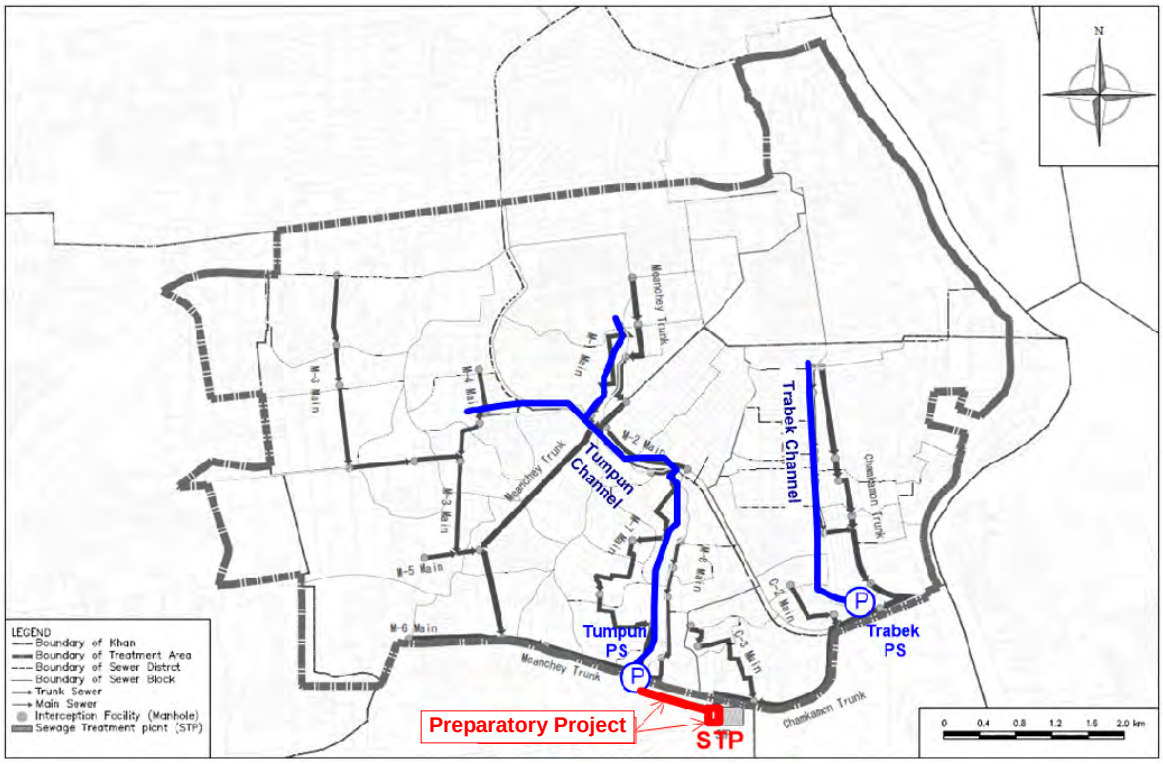
4.9 Selection of Priority Projects for Pre-Feasibility/Study

As described in **Subsection 4.5**, a Preparatory Project in Cheung Aek treatment area is proposed in Short-Term period to achieve technical skills for preparation of full-scale construction and operation of sewage facilities, in parallel with establishing institutional and legal framework, considering current lack of institutional and legal provisions for sewage management in Phnom Penh.

The Preparatory Project is comprised of small-scale STP and sewer pipe to collect and convey wastewater equivalent to the STP's capacity.

Capacity of the STP is set at 5,000 m^3/day, which deems to be the minimum unit to demonstrate the performance of the STP as well as the effectiveness of treatment method applied and to accumulate technical skills and experience covering construction, operation and maintenance work. The sewer pipe for the STP is proposed to collect wastewater from outlet of Tumpun Pumping Station, which is located in the west of construction site of the STP. Thus the STP and sewer pipe, as shown in **Fig. 4.9.1** and **Table 4.9.1**, are provided for the priority projects for Pre-F/S.

Along with the sewage treatment facilities, some measures such as landscaped pond for the people will be proposed in the Pre-F/S to visualize accomplishments and enhance public relations.



Source: JICA Study Team

Fig. 4.9.1 Location Map of Preparatory Project (Priority Project)

Table 4.9.1 Components of Preparatory Project (Priority Project)

Component	Contents
Sewer Pipe	Diameter : φ500 mm Length :about 1,300 m
STP	Capacity:5,000 m^3/dairy maximum

Source: JICA Study Team

CHAPTER 5 STRATEGY FOR FORMULATION OF DRAINAGE MANAGEMENT MASTER PLAN

5.1 Summary of Issues

Based on the study results discussed in **Chapter 2**, the current condition and issues related to drainage improvement in PPCC are summarized below:

- In many parts of the city center (inside of the inner ring dike), the drainage condition has been improved under the Japan's Grant Aid projects for drainage improvement (Phase 1, Phase 2 and Phase 3) and ADB's loan project. These projects were implemented on the basis of the Master Plan for drainage improvement in Phnom Penh City formulated in "The Study on Drainage Improvement and Flood Control in the Municipality of Phnom Penh (1999)". On the other hand, drainage improvement on the northern side of Wat Phnom (eastern half of Sangkat Srah Chak) and most parts of Tuol Kok District have lagged behind other areas. Since these areas are densely-populated and still vulnerable to inundation damage, drainage improvement is important and urgently necessary. The rehabilitation or construction of new pumping stations, rehabilitation of drainage channels and improvement of drainage pipe network are necessary for these areas.

- As described in **Subsection 2.1.2**, in the drainage catchment area of Trabek Pumping Station located in the southern part of the city center, Trabek Pumping Station and Trabek Drainage Channel were improved under the ADB's loan project in 2003 and drainage pipes are being installed under the Japan's grant aid project. Since land development and reclamation have kept encroaching the Trabek regulation pond little by little year by year during 10 years after completion of the ADB project, the capacity of Trabek regulation pond has decreased, resulting in the decreased function of the Trabek drainage system. In addition, the indiscriminate land development in many parts of Phnom Penh metropolitan area has reduced the area of water body which has been functioning as temporary storage of stormwater. It is expected that these circumstances will generate other inundation damage in the near future.

- In the area between the inner ring and outer ring dikes, although urbanization is proceeding vigorously, drainage issues are not so prominent and hence drainage facility development has not been performed sufficiently in this area. However, inundation has increased and has recently become a new problem in the area. There are now strong requests for drainage improvement at the eastern side of Pochentong Airport, Chroy Changvar area and Chbar Ampov area.

- Nine (9) massive satellite city development zones, including completed and undergoing zones, exist in Phnom Penh at present. The respective developers planned and designed drainage facilities by themselves, but not under the unified standard. In addition, impact onto outside of development zone such as increase of ratio of run-off is not generally considered. One of the reasons for the issue above is that MLMUPC and PPCC which issues the permission for development, do not have any standard for drainage facility in large-scale land development. Accordingly, besides the provision that "stormwater drainage should be managed under the responsibility of developer in satellite city" defined in Sub-Decree No. 86, it is necessary to enact a law or set regulations, such as standard for installation of rainwater regulation reservoirs for disaster prevention in satellite city, and strengthen the enforcement capacity.

- As the result of capacity development of DPWT/DSD staff members through assistance from Japan and other countries, the capacity to operate and maintain the drainage facilities of DPWT/DSD has been improving. However, since the number of staff occupying management positions in the organization is still insufficient, it is necessary and important to continue enhancing the capacity development of DPWT/DSD staff.

- Although equipment for operation and maintenance (O&M) work of drainage facilities has been increasing gradually, they are still deficient in covering the whole PPCC area. Although more equipment is necessary for proper O&M work, in parallel with the enhancement of the equipment, it is also necessary to increase the number of personnel and strengthen the organizational structure to operate equipment properly.

5.2 Planning Frame

5.2.1 Target Year

Target year of the M/P should be 2035, same as that of sewage management.

5.2.2 Planning Scale

Planning scale of drainage facilities in the 1999 Master Plan was set with reference to the previous scale or case of similar cities. Since the previous drainage projects in Phnom Penh were implemented based on the planning scale set in the 1999 Master Plan and that the planning scale is considered as adequate, the same conditions shall be adopted for the new Master Plan.

- Major drainage facilities such as pumping stations, floodgates/sluiceways, regulation ponds, drainage mains, canals and channels (catchment area more than 1 km^2) will be designed as 5-year probable rainfall.

- Minor drainage facilities such as secondary or tertiary drainage pipes, channels/canals and sewer pipes will be designed as 2-year probable rainfall.

5.2.3 Drainage Area for Master Plan

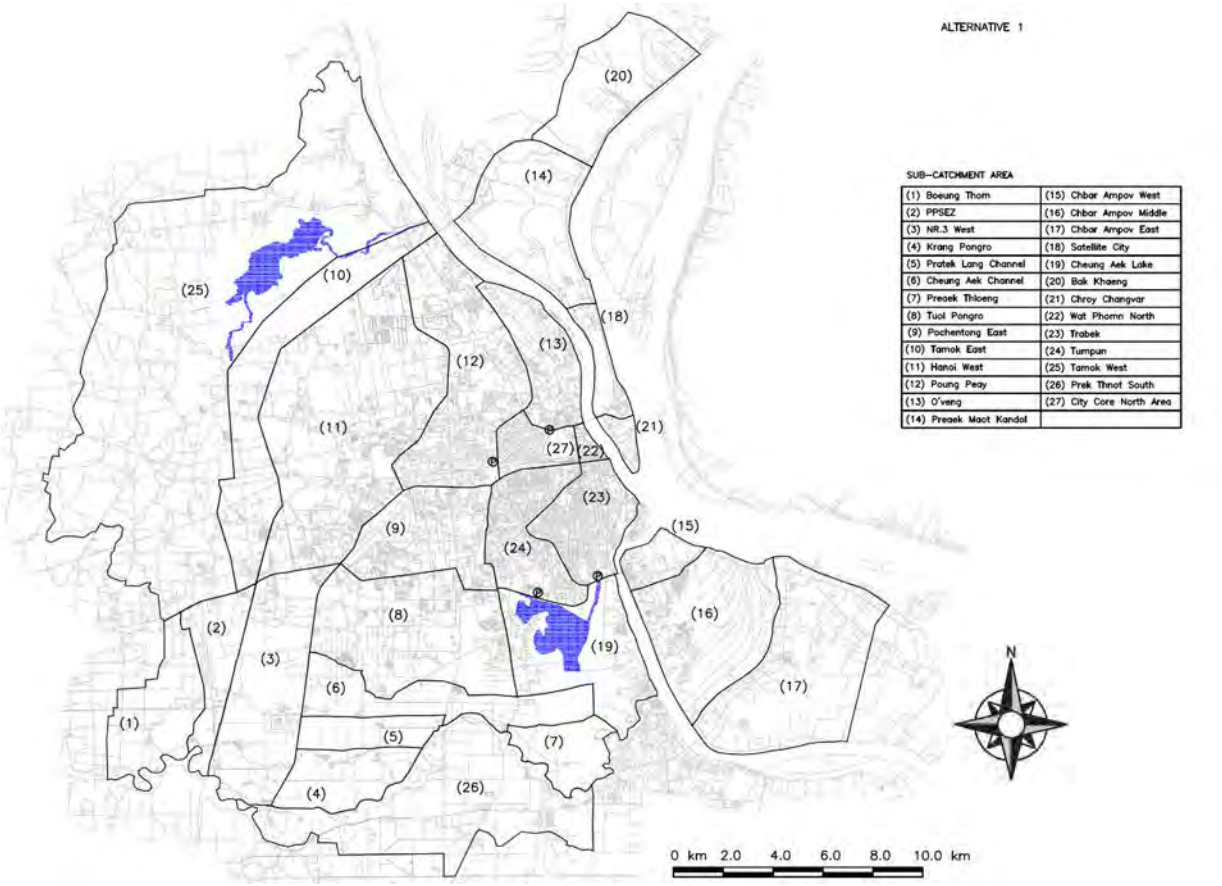
The Study Area, which is the whole administrative area of Phnom Penh Capital City, is divided into 27 drainage areas as shown in **Table 5.2.1** and **Fig. 5.2.1** for the formulation of Master Plan. The drainage plan for each drainage area will be formulated respectively.

Table 5.2.1 List of Drainage Areas

No.	Sub-Catchment Area	Area (km^2)
1	Boeung Thom	15.39
2	PPSEZ	10.56
3	NR.3 West	27.36
4	Krang Pongro	11.01
5	Pratek Lang Channel	7.17
6	Cheung Aek Channel	16.46
7	Preaek Thloeng	8.53
8	Tuol Pongro	32.98
9	Pochentong East	18.23
10	Tamok East	26.60
11	Hanoi West	59.46
12	Poung Peay	31.46
13	O'veng	12.15
14	Preaek Maot Kandol	22.43
15	Chbar Ampov West	4.77
16	Chbar Ampov Middle	25.63
17	Chbar Ampov East	34.32
18	Satellite City	4.63
19	Cheung Aek Lake	23.28
20	Bak Khaeng	18.74
21	Chroy Changvar	2.10
22	Wat Phnom North	1.17
23	Trabek	13.01

No.	Sub-Catchment Area	Area (km^2)
24	Tumpun	14.49
25	Tamok West	133.85
26	Prek Thnot South	39.97
27	City Core North Area	5.80
Total		621.73

Note: Of total area of PPCC (678.46 km^2) (i) water surface of Mekong River, Sap River and Bassac River and (ii) Dach Island, totalling 56.73 km^2, are excluded from the drainage planning area.
Source: JICA Study Team



Source: JICA Study Team

Fig. 5.2.1 Map of Drainage Areas

5.2.4 Drainage Management Plan per Drainage Area

The optimum drainage plan will be formulated with consideration and comparison of alternatives in each drainage area. Tentative alternatives are listed in **Table 5.2.2**.

Table 5.2.2 List of Alternatives (Tentative)

No.	Drainage Area	Tentative Alternatives for Drainage Plan				
		Improvement of Drainage Pipes / Canals/ Channels	Construction / Extension of Drainage Pumping Station	Preservation/ Extension/ Creation of Regulation Pond/ Retarding Basin	No Change	Note
1	Boeung Thom	•	•	•	-	
2	PPSEZ	•	•	•	-	
3	NR.3 West	•	•	•	-	
4	Krang Pongro	•	•	•	-	
5	Pratek Lang Channel	•	-	-	-	

No.	Drainage Area	Tentative Alternatives for Drainage Plan				
		Improvement of Drainage Pipes / Canals/ Channels	Construction / Extension of Drainage Pumping Station	Preservation/ Extension/ Creation of Regulation Pond/ Retarding Basin	No Change	Note
6	Cheung Aek Channel	•	-	-	-	
7	Preaek Thloeng	•	•	•	-	
8	Tuol Pongro	•	•	•	-	
9	Pochentong East	•	•	•	-	
10	Tamok East	•	•	•	-	
11	Hanoi West	•	•	•	-	
12	Poung Peay	•	•	•	-	
13	O'veng	•	•	•	-	
14	Preaek Maot Kandol	•	•	•	-	
15	Chbar Ampov West	•	•	•	-	
16	Chbar Ampov Middle	•	•	•	-	
17	Chbar Ampov East	•	•	•	-	
18	Satellite City	•	-	-		*3
19	Cheung Aek Lake	•	-	-		*3
20	Bak Khaeng	•	•	•	-	
21	Chroy Changvar	•	•	•	-	
22	Wat Phnom North	•	•	•	-	
23	Trabek	•	•	•	-	*2(Phase 1)
24	Tumpun	•	•	•	-	*2(Phase 2)
25	Tamok West	•	-	•	•	*1
26	Prek Thnot South	•	-	-	•	*1
27	City Core North Area	•	•	•	-	

*1) Currently, non-inundation area; future land use is planned to be agriculture field.
*2) Area of ongoing project for flood protection and drainage improvement in the municipality of Phnom Penh.
*3) Area for large-scale development; responsibility for installation of drainage facilities falls under the developer.
Source: JICA Study Team

With the consideration and comparison of the above alternatives, the optimum drainage plan will be formulated. Following items are considered and presented in the Master Plan:

- *Structural Measures*: Preliminary drawings, construction cost estimate, O&M cost estimate and construction plan for drainage channels, pumping stations, drainage pipes and regulation ponds/retarding basin.
- *Non-Structural Measures:* Development of laws regarding standards for installation of stormwater regulation reservoirs in satellite city, environmental education, strengthening organization, human resource capacity development, securing financial resource.
- *Economic and Financial Analysis*

5.2.5 Study on Project Implementation Plan

Based on the drainage plan formulated in the Master Plan, the implementation plan will also be formulated through setting the priorities of alternatives. The following issues shall be considered during the formulation of implementation plan:

- Annual investment scale for drainage facilities (except sewerage facilities)
- Annual cost for operation and maintenance
- Consistency with the related development plans
- Urgency
- Requests from PPCC and local government such as Khan

Implementation schemes in each drainage area should be considered from the budgeting aspect. Budget source considered in the plan shall be the national budget of Cambodia, Japan's grant aid, Japan's loan, other donor's assistance, and others.

5.2.6 Selection of Priority Project

Based on the implementation plan, the Priority Project for the Pre-Feasibility Study will be selected from the projects formulated in the Master Plan.

5.3 Design Criteria

5.3.1 Rainfall

Design rainfall will be prepared by model pattern of center-concentrated type. Design rainfall pattern of 5-year probable rainfall is applied to design main drainage channels and pumping stations. Hourly rainfall and daily rainfall are shown in **Table 5.3.1** as mentioned in **Subsection 2.1.4**.

Table 5.3.1 Design Rainfall

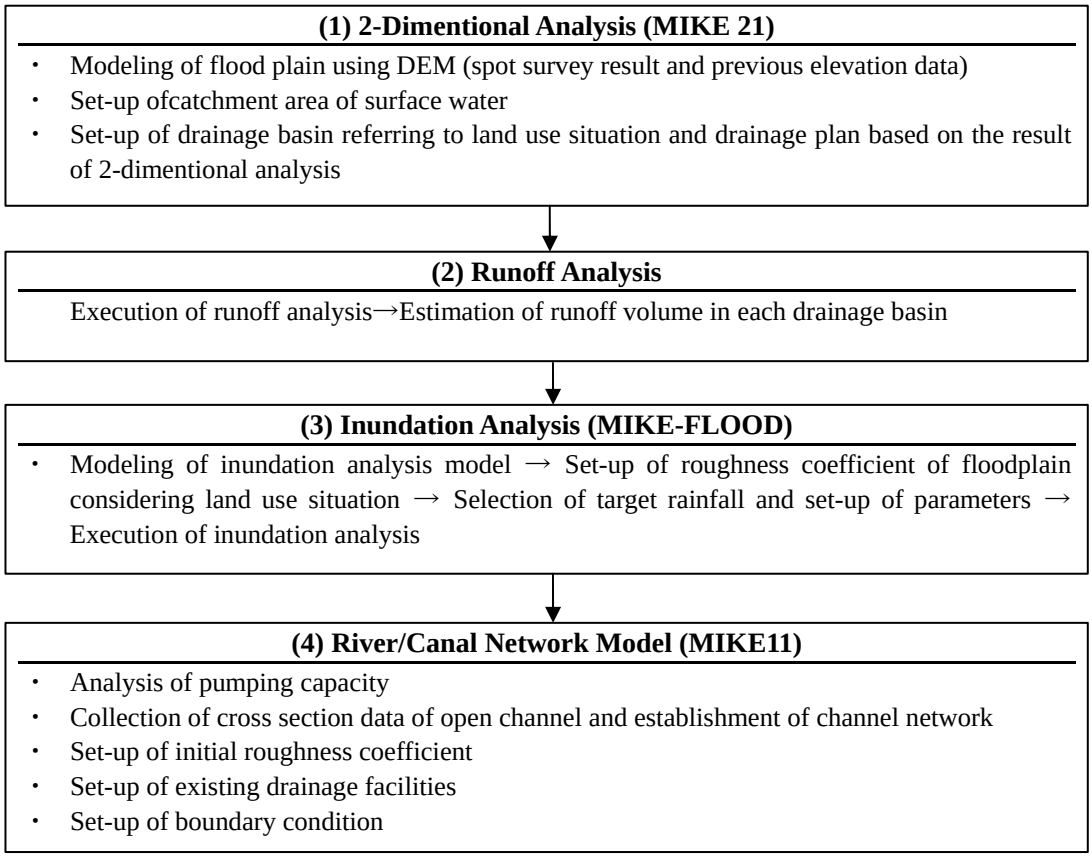
Scale of Probable Year	Hourly Rainfall (mm/h)	Daily Rainfall (mm/day)
2 year	44.8	87.8
5 year	63.2	112.3

Source: JICA Study Team

5.3.2 Catchment Area, Run-off and Inundation Analysis

(1) Methodology

Inland flooding is a very complicated phenomenon influenced by overflow, volume of runoff and topographical condition. Therefore, runoff and inundation analysis model must reappear past inland flooding and predict future flooding area. The procedure for establishing runoff and inundation analysis model and parameter fitting for reproducing flood situations is shown in **Fig. 5.3.1**.



Source: JICA Study Team

Fig. 5.3.1 Procedure of Establishment of Hydrological and Hydraulic Model

(2) Setup of Catchment Area

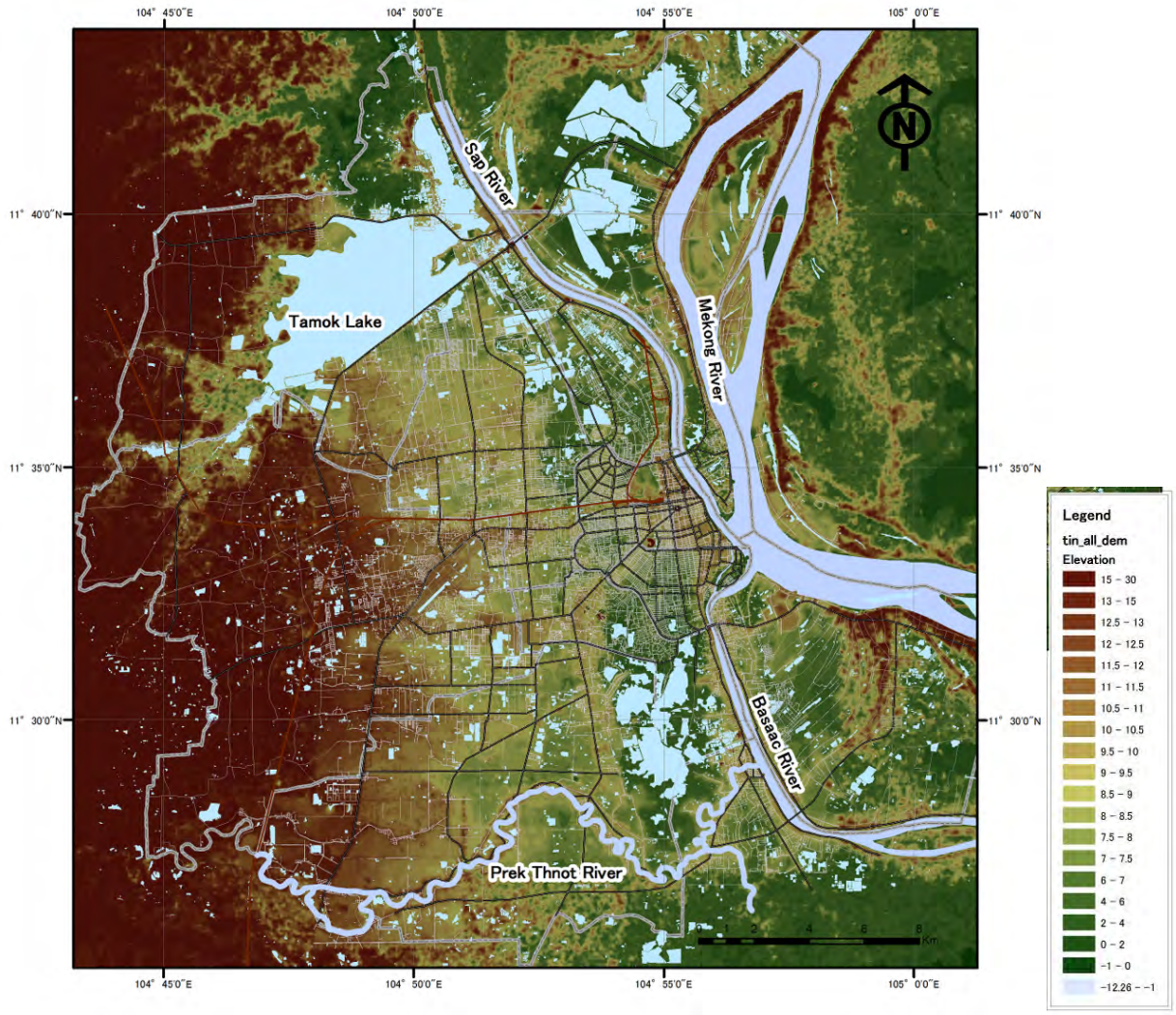
Catchment areas are set considering analysis of behaviour of surface water based on the relations between rainfall and inundation area. The analysis is performed using 2-dimentional unsteady flow model (MIKE 21); its outline is summarized in **Table 5.3.2**.

Table 5.3.2 Outline of Two-Dimensional Unsteady Flow Model (MIKE 21)

Items	Contents
Software	DHI MIKE 21
Grid Size	100 m×100 m
Elevation	Setup based on spot survey result and KOICA's survey result
Roughness Coefficient	Set up based on present land-use
Rainfall Pattern	Actual rainfall pattern of 26 September 2012 (**Fig. 2.1.26**)
Computing Time	24 hrs

Source: JICA Study Team

Elevation data of floodplain is setup based on spot survey result in this Study and previous survey result of KOICA Project (The production of the National Base Map and the Establishment of the Master Plan for the National Spatial Data Infrastructure in Cambodia, KOICA, 2011) and SRTM's (Shuttle Radar Topography Mission) digital elevation data with 90 m resolution. Ground elevation of Phnom Penh metropolitan area is shown in **Fig. 5.3.2**.

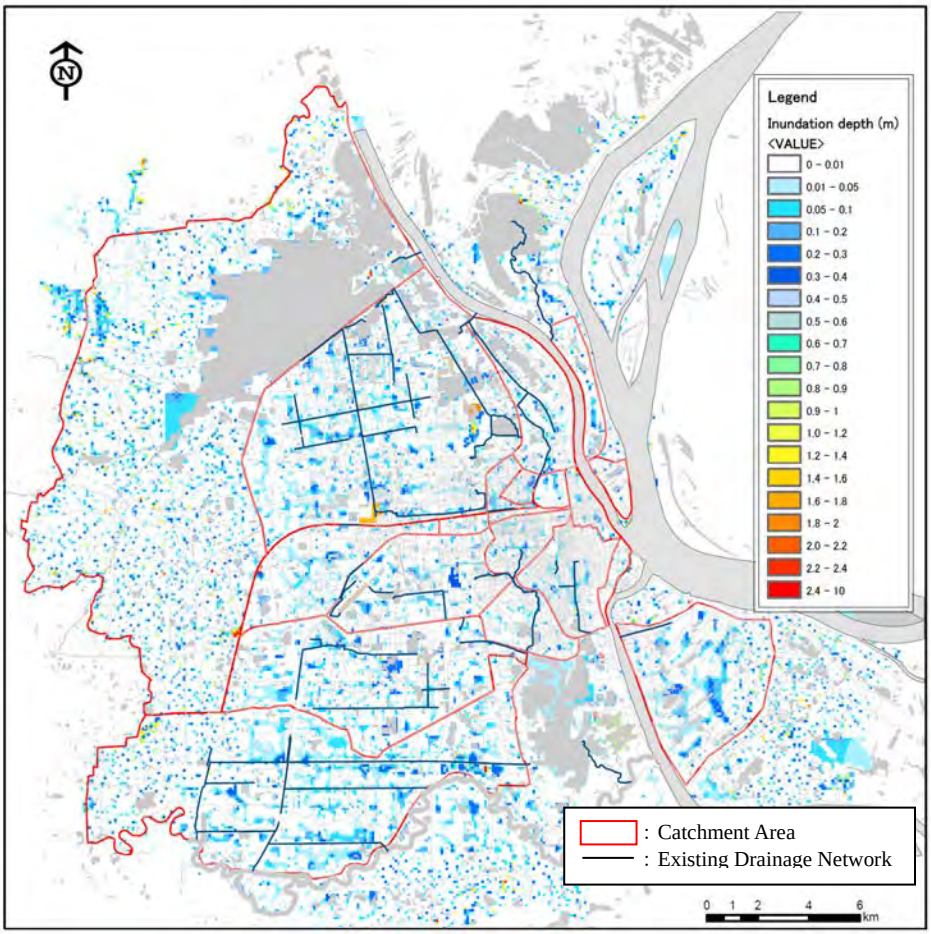


Source: JICA Study Team using data of "The production of the National Base Map and the Establishment of the Master Plan for the National Spatial Data Infrastructure in Cambodia, KOICA" and SRTM (Shuttle Radar Topography Mission 3sec) and topographical survey result in the Study

Fig. 5.3.2 Ground Elevation of Phnom Penh Metropolitan Area

Analysis result of behaviour of surface water, employing actual rainfall pattern is given to target area, as shown in **Fig. 5.3.3**.

The analysis shows that stormwater tends to inundate ponds and low-land (low-elevation area) and do not reach the existing channels. Hence, inundation occurs in PPCC. This phenomenon arises from the following reasons: (i) stormwater cannot easily travel due to gentle slope in the area and thus the stormwater is locally stored in the low-lying area; (ii) drainage channels as a whole have insufficient capacity due to limited gradient.



Source: JICA Study Team

Fig. 5.3.3 Catchment Area and Present Inundation Area (Analysis based on Rainfall on 26 September 2012)

(3) Calculation of Run-off (Run-off Analysis: Rational Formula)

(a) Selection of Run-off Model

Inundation in urban area usually occurs due to insufficient drainage capacity for peak flow caused by high-intensity rainfall in short-time duration. Therefore, the rational formula, with which run-off discharge can be computed on the safe side, is employed in consideration of present and future land-use in the target area, as enumerated below. The rational formula is shown below.

Rational formula $$Q = \frac{1}{360} \cdot C \cdot I \cdot A$$

Where,

Q : Run-off (m^3/s)
C : Run-off coefficient
I : Rainfall intensity (mm/h)
$I=2{,}566.07\times(T+25.48)^{-0.93}$ (2-year return period)
$I=5{,}009.12\times(T+31.38)^{-0.98}$ (5-year return period)
A : Drainage area (ha)

- Topological condition is almost flat, and secondary as well as tertiary drainage channel is not fully installed in the target area. Thus, stormwater tend to inundate ponds and low-land (low-elevation area) and do not reach the existing channels.

- Almost all target areas are developed and transformed into housing, commercial and industrial development, based on the land-use plan for the target year 2035.

- Above development is likely to accompany installation of branch drainage pipe/channel in the area. As a result, stormwater immediately concentrate on the channels evaluated in the analysis.

- Stormwater should quickly be conveyed and discharged to prevent inundation especially in urban area.

(b) Run-off Coefficient

Run-off coefficient is set up based on run-off coefficient by land-use (**Table 5.3.3**) and future land-use and then overall run-off coefficient is computed. Future land-use in the computation is set up based on the following concepts.

【Concepts of Future Land-use Setting】

- Land-use is based on PPCC's Land-use plan of 2035
- All large-scale development are completed by 2035
- Small-scale development is not considered except for development designated in PPCC's Land-use plan of 2035

≪Overall Run-off Coefficient≫

$$C = \sum_{m=1}^{m} Ci \cdot Ai / \sum_{m=1}^{m} Ai$$

where; C : Overall Run-off Coefficient
Ci : Run-off coefficient by land use
Ai : Area by land use
m : Number of land use

Table 5.3.3 Run-off Coefficient by Land Use

Land Use		Run-off Coefficient
Residential Area	Residential area with little unused area	0.80
Suburban Area 1	Suburban area with small gardens	0.65
Suburban Area 2	Suburban area with large gardens	0.40
Industrial Area		0.65
Agricultural Area		0.30
Park		0.25

Source: JICA Study Team

Overall run-off coefficient, which is set up based on the methodology described above, is summarized in **Table 5.3.4**.

Table 5.3.4 Overall Run-off Coefficient

No.	Name of Drainage Area	Area (km^2)	Area (km^2)								Overall Run-off Coefficient
			Residential Area	Sub-urban Area 1	Sub-urban Area 2	Industrial Area	Agri-cultural Area	Park	Pond	Total Area (except pond area)	
1	Boeung Thom	15.39	0.00	0.00	0.00	0.00	15.39	0.00	0.00	15.39	0.30
2	PPSEZ	10.56	0.00	0.00	0.00	3.48	7.08	0.00	0.00	10.56	0.42
3	NR.3 West	27.36	0.00	0.00	3.08	1.82	22.46	0.00	0.00	27.36	0.33

No.	Name of Drainage Area	Area (km^2)	Area (km^2)								Overall Run-off Coefficient
			Residential Area	Sub-urban Area 1	Sub-urban Area 2	Industrial Area	Agri-cultur-al Area	Park	Pond	Total Area (except pond area)	
4	Krang Pongro	11.01	0.00	0.00	0.00	0.00	11.01	0.00	0.00	11.01	0.30
5	Pratek Lang Channel	7.17	0.00	0.00	0.00	0.00	7.17	0.00	0.00	7.17	0.30
6	Cheung Aek Channel	16.46	0.00	0.00	3.52	0.00	12.95	0.00	0.00	16.46	0.32
7	Preaek Thloeng	8.53	0.00	0.00	0.00	0.00	8.53	0.00	0.00	8.53	0.30
8	Tuol Pongro	32.98	3.50	0.00	20.49	3.61	4.77	0.00	0.62	32.36	0.46
9	Pochentong East	18.23	0.00	0.00	18.23	0.00	0.00	0.00	0.00	18.23	0.40
10	Tamok East	26.60	0.00	0.00	0.00	6.72	19.88	0.00	0.00	26.60	0.39
11	Hanoi West	59.46	4.58	0.00	12.41	4.80	35.37	2.31	0.00	59.46	0.39
12	Poung Peay	31.64	7.28	12.18	12.18	0.00	0.00	0.00	0.00	31.64	0.59
13	O'veng	12.15	0.00	12.15	0.00	0.00	0.00	0.00	0.00	12.15	0.65
14	Preaek Maot Kandol	22.43	0.00	0.00	8.92	6.03	7.48	0.00	0.00	22.43	0.43
15	Chbar Ampov West	4.77	4.77	0.00	0.00	0.00	0.00	0.00	0.00	4.77	0.80
16	Chbar Ampov Middle	25.63	1.67	0.00	23.96	0.00	0.00	0.00	0.00	25.63	0.43
17	Chbar Ampov East	34.32	0.00	0.00	0.00	0.00	34.32	0.00	0.00	34.32	0.30
18	Satellite City	4.63	0.00	0.00	4.63	0.00	0.00	0.00	0.00	4.63	0.40
19	Cheung Aek Lake	23.28	3.39	0.00	7.82	0.00	7.84	0.00	4.23	19.05	0.43
20	Bak Khaeng	18.74	0.00	0.00	0.00	0.00	18.74	0.00	0.00	18.74	0.30
21	Chroy Changvar	2.10	0.00	0.00	2.10	0.00	0.00	0.00	0.00	2.10	0.40
22	Wat Phnom North	1.17	1.17	0.00	0.00	0.00	0.00	0.00	0.00	1.17	0.80
23	Trabek	13.01	2.58	10.23	0.00	0.00	0.00	0.00	0.20	12.81	0.68
24	Tumpun	14.49	1.99	3.34	8.82	0.00	0.00	0.00	0.34	14.15	0.52
25	Tamok West	133.85	1.99	0.00	0.00	0.00	0.00	0.00	0.34	1.99	0.80
26	Prek Thnot South	39.97	0.00	0.00	0.00	0.00	39.97	0.00	0.00	39.97	0.30
27	City Core North Area	5.80	1.17	0.00	4.62	0.00	0.00	0.00	0.00	5.80	0.48
Total		621.73	34.08	37.90	130.78	26.46	252.96	2.31	5.72	484.49	—

Source: JICA Study Team

5.4 Evaluation of Inundation (Inundation Analysis: Without-Project)

(1) Methodology

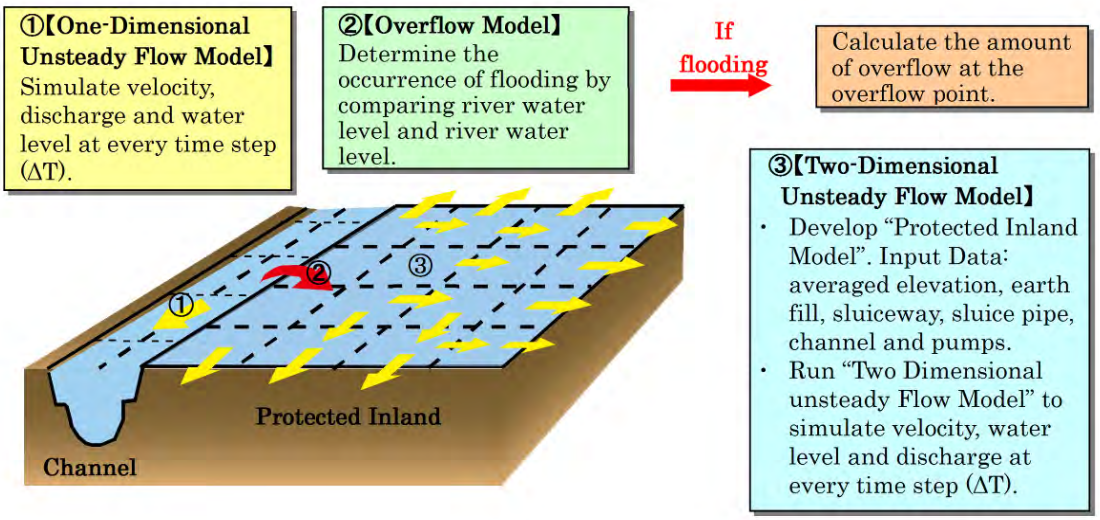
Aforementioned run-off is computed under the assumption that the target area is fully developed, accompanying installation of branch drainage pipe/channel, and the stormwater collected by the pipe/channel immediately concentrate on the channels evaluated in the analysis. On the other hand, in this subsection, inundation condition without implementing project proposed in the M/P is analysed and demonstrated.

For the inundation analysis in floodplain, the two-dimensional unsteady flow analysis model is employed. Outline of inundation analysis model and image of analysis model is shown in **Table 5.4.1** and **Fig. 5.4.1**.

Table 5.4.1 Outline of Inundation Analysis Model

Items	Contents
Software	DHI MIKE-FLOOD
Grid Size	100 m×100 m
Elevation	Setup based on spot survey result and previous survey result
Evaporation	4 mm/day
Roughness Coefficient	Setup based on land-use (2035)

Source: JICA Study Team

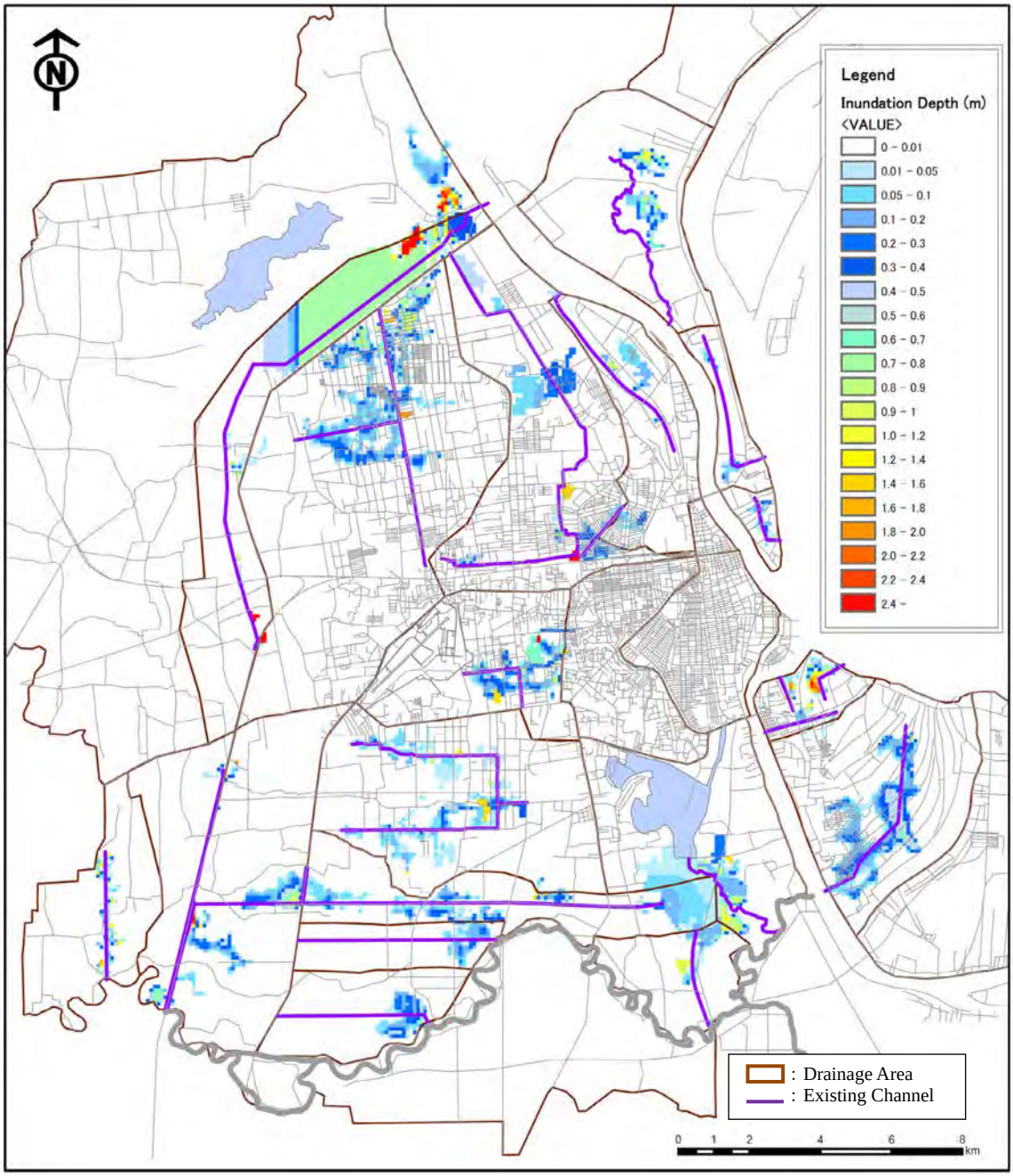


Source: JICA Study Team

Fig. 5.4.1 Image of Inundation Analysis

(2) Result of Evaluation

Result of evaluation (without project) is shown in **Fig. 5.4.2**.



Source: JICA Study Team

Fig. 5.4.2 Inundated Area (Without Project)

CHAPTER 6 DRAINAGE MANAGEMENT MASTER PLAN

6.1 Improvement Plan for Stormwater Drainage Management

In principle, improvement plan for stormwater drainage management is formulated primarily based on the consideration of the following.

- Original flow direction of existing drainage network in each drainage area
- Status of existing drainage facilities (drainage channel, pumping station and so forth)

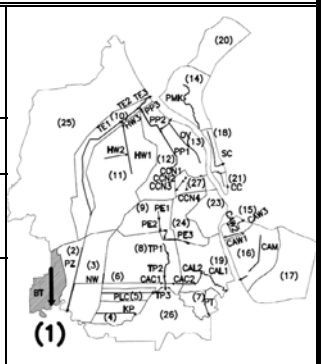
Basic conditions for formulation of drainage management plan are enumerated below.

- One drainage area has one outlet.
- Flow direction of each drainage area is determined in consideration with topographical condition, land-use and status of existing drainage facilities.
- Priorities are placed on improvement of existing drainage facilities to minimize cost.
- Stormwater is in principle collected and conveyed by gravity
- Pumping station and sluiceway are proposed at crossing points of ring dikes and rivers, if necessary.

6.1.1 Improvement Plan for Each Drainage Area

Flow direction in each drainage area is in general determined based on topographical condition, status of existing drainage facilities and land-use. However, the study on alternative on drainage areas, namely, “No.6 Cheung Aek Channel Drainage Area”, “No.8 Toul Pongro Drainage Area”, “No.12 Poung Peay Drainage Area” and “No.13 O’veng Drainage Area”, are conducted whether or not these are combined or separated. The improvement plan for drainage areas other than the above are summarised below.

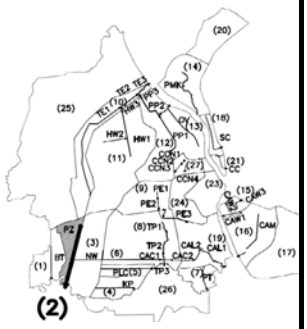
(1) Boeung Thom Drainage Area (Drainage Area No.1)

Item	Contents	
Location	An area located in the southwestern edge of PPCC, and on the west of PPSEZ, bordered by National Road No.4 on the north, Prek Thnot River on the south, PPSEZ on the east and the city boundary of PPCC on the west.	
Land-use	Present: Almost all of the area is farmland. Future: Farmland	
Salient features of drainage area	Ground surface elevation of the area is over 15 meter, gently sloping from west to east. Existing drainage channel of Pratek Lan drains stormwater with flow direction from west to east by gravity.	
Issues	PPSEZ and its adjacent area in the west annually suffer from inundation in about 1 to 5 days in the rainy season, due to the reasons that (i) Pratek Lan channel has a bottleneck at the crossing point of railway and (ii) capacity of Pratek Lan channel is not enough.	
Strategy for improvement	New construction of drainage channel is proposed to drain stormwater by gravity from north to south in order to reduce burden to existing Pratek Lang Channel.	
Structural measures	Drainage channel (Sluiceway)	
Environmental and social considerations	Estimated number of resettlement: No resettlement. Topographical change is anticipated to some extent because proposed drainage channel is constructed in paddy field. Negative impact to fauna, flora and ecosystem is not anticipated.	

Source: JICA Study Team

(2) PPSEZ Drainage Area (Drainage Area No.2)

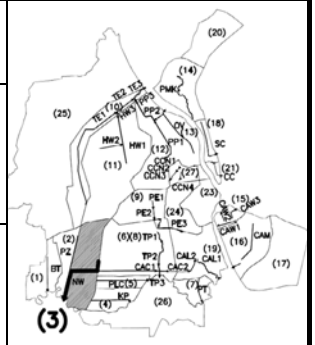
Item	Contents
Location	An area bordered by National Road No. 4 on the north, Prek Thnot River on the south, PPSEZ on the west and railway on the east.
Land-use	Present: Industrial area and farmland Future: SEZ, used as industrial and farmland
Salient features of drainage area	This area is new development area flatly reclaimed. Residential development is in progress along National Road No.4. An existing channel of Pratek Lan, which is utilized for irrigation and drainage drains stormwater by gravity, running from west to east in the premise of PPSEZ.
Issues	PPSEZ and its adjacent area in the west suffer from inundation in about 2 to 5 days in the rainy season once in about 2 years, due to the reasons that (i) Pratek Lan Channel has a bottleneck at the crossing point of railway and (ii) capacity of Pratek Lan Channel is not enough.
Strategy for improvement	Improvement of existing drainage channel is proposed to drain stormwater from PPSEZ and its adjacent area in the east to Prek Thnot River by gravity.
Structural measures	Drainage channel
Environmental and social considerations	Estimated number of resettlement: 5 households. Inundation damages several times per year are mitigated by implementation of the project and thus negative impacts to business activities are mitigated. Negative impact to fauna, flora and ecosystem is not anticipated.



Source: JICA Study Team

(3) NR.3 West Drainage Area (Drainage Area No.3)

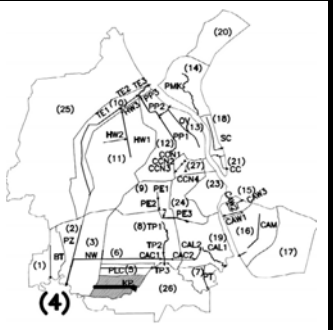
Item	Contents
Location	An area bordered by National Road No.4 on the north, Prek Thnot River on the south, railway on the west and National Road No.3 on the east.
Land-use	Present: About 20% of the total or area along National Road No.4, is industrial and residential area. The other area is farmland. Future: About 30% is urbanized area and SEZ and the other area is farmland.
Salient features of drainage area	Land development is in progress from north to south. Existing channels of Pratek Lan and Cheung Aek is utilized for irrigation and drainage but they have insufficient capacity. There exists another channel along National Road No.3, running from north to south, but being disconnected in spots. Irrigation channels are widely installed in a grid pattern in the southern part of the drainage area (paddy field area). At present no inundation damage is detected.
Issues	The northern part of the area will be developed for residential use and SEZ, and would suffer from inundation. Thus, construction of drainage channel running from west to east is required to drain stormwater of the area.
Strategy for improvement	New construction of drainage channel is proposed to drain stormwater to Prek Thnot River by gravity, since the area is bordered by roads and railway in higher elevation on the north, east and west side.
Structural measures	Drainage channel
Environmental and social considerations	Estimated number of resettlement: 36 households. Topographical change, especially in irrigation network, is anticipated to some extent because existing drainage channel in the irrigation network is rehabilitated. Negative impact to fauna, flora and ecosystem is not anticipated. Detailed survey in the implementation stage is required to evaluate impact to agricultural crops in paddy fields.



Source: JICA Study Team

(4) Krang Pongro Drainage Area (Drainage Area No.4)

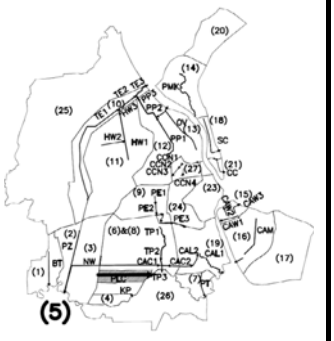
Item	Contents
Location	An area in the catchment area of Krang Pongro Channel, bordered by Prek Thnot River in the south and east.
Land-use	Present: Farmland Future: Farmland and low density residential area
Salient features of drainage area	This area gradually slopes from west to east. A existing channel named Krang Pongro, which is utilized for irrigation and drainage, crosses the area from west to east but has small capacity. At present no inundation damage is detected and the damage in the future will be limited because the area is dominated by farmland.
Issues	Improvement of existing channel is required.
Strategy for improvement	Improvement of existing Krang Pongro Channel is proposed to accommodate stormwater from the area and drain them to Prek Thnot River by gravity.
Structural measures	Drainage channel
Environmental and social considerations	Estimated number of resettlement: 2 households. Topographical change, especially in irrigation network, is anticipated to some extent because existing drainage channel in the irrigation network is rehabilitated. Negative impact to fauna, flora and ecosystem is not anticipated. Detailed survey in the implementation stage is required to evaluate impact to agricultural crops in paddy fields.



Source: JICA Study Team

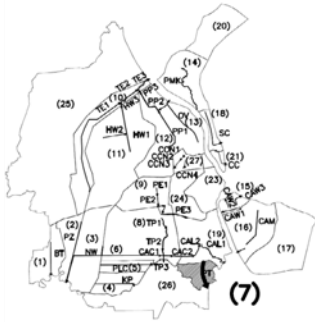
(5) Pratek Lang Channel Drainage Area (Drainage Area No.5)

Item	Contents
Location	A part of Pratek Lang channel's catchment area, covering area along National Road No.3 in the east, bordered by Prek Thnot River on the east.
Land-use	Present: Farmland Future: Farmland and low density residential area
Salient features of drainage area	This area gradually slopes from west to east. An existing channel named Pratek Lang, which is utilized for irrigation and drainage, cross the area from west to east but has small capacity. At present no inundation damage is detected and the damage in the future will be limited because the area is dominated by farmland.
Issues	Improvement of existing channel is required.
Strategy for improvement	Improvement of existing Pratek Lang Channel is proposed to accommodate stormwater from the area and drain them to Prek Thnot River by gravity.
Structural measures	Drainage channel
Environmental and social considerations	Estimated number of resettlement: 10 households. Topographical change, especially in irrigation network, is anticipated to some extent because existing drainage channel in the irrigation network is rehabilitated. Hydraulic consideration for Prek Thnot River is required to discharge stormwater from the area. Negative impact to fauna, flora and ecosystem is not anticipated. Detailed survey in the implementation stage is required to evaluate impact to agricultural crops in paddy fields.



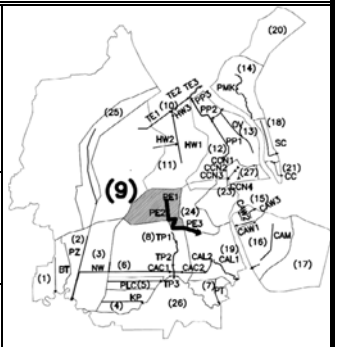
Source: JICA Study Team

(6) Preaek Thloeng Drainage Area (Drainage Area No.7)

Item	Contents	
Location	An area in the south of Cheung Aek lake, bordered by Prek Thnot River on the east, west and south. This area is also a part of large-scale development area of ING City.	
Land-use	Present: Farmland and wetland. Future: Low density residential area.	
Salient features of drainage area	This area is topographically flat and is occupied by wetland in the centre of the area. At present no inundation damage is detected. In the land-use plan for year 2035, this area is categorized into low density residential area but is likely to be developed because the area is included in ING City.	
Issues	Installation of new drainage channel is required for future provisions.	
Strategy for improvement	Specification for the new drainage channel is proposed to drain stormwater to Prek Thnot River by gravity. It is recommendable that the drainage channel should be installed by developer of ING City or be installed by PPCC depending on the progress of development.	
Structural measures	Drainage channel	
Environmental and social considerations	Estimated number of resettlement: 2 households. At present, this area (Cheung Aek Lake), is developed into ING City and drastic change in topographical and hydraulic condition is anticipated with the development. Detailed survey in the implementation stage is required to evaluate impacts. Negative impact to fauna, flora and ecosystem is not anticipated because the Cheung Aek Lake is already polluted heavily by wastewater from the catchment area.	

Source: JICA Study Team

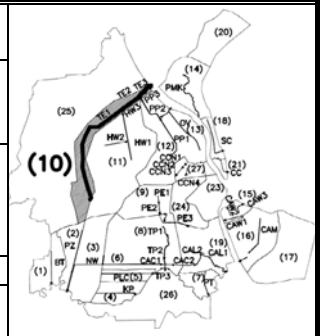
(7) Pochentong East Drainage Area (Drainage Area No.9)

Item	Contents	
Location	An area including Phnom Penh International Airport (former Pochentong International Airport) and its adjacent area in the east and southeast, bordered by National Road No. 4 on the north and west, Veng Sreng road (former BOT road) on the south, and catchment boundary of Tumpun Drainage Area on the east.	
Land-use	Present: high density residential area, commercial and industrial area (factory, shop) Future: high density residential areas, commercial and industrial area, economic development zone	
Salient features of drainage area	This area is topographically flat and is in most urbanized area of Phnom Penh in parallel with expansion of urbanization toward west in recent years.	
Issues	Installation of drainage facilities have not been catching up with rapid urbanization. Inundation occurs especially in the southern part of the area. With the progress of urbanization, inundation damage will be bigger.	
Strategy for improvement	Installation of new box culvert is proposed to connect exiting drainage channels/pipes, and drain stormwater to Cheung Aek Lake, through Veng Sreng road (former BOT road) and new pumping station and Moul drainage channel.	
Structural measures	Box culvert, Pumping station, Regulation pond and Drainage channel.	
Environmental and social considerations	Estimated number of resettlement: 40 households. Mitigation measures are required to minimize adverse impact to the people in this area because this area includes high density residential, commercial and industrial areas. Adverse impact from dredging of existing regulation ponds should be evaluated. Negative impact to fauna, flora and ecosystem is not anticipated because the existing regulation ponds are already polluted. Detailed survey in the implementation stage is required to evaluate impacts.	

Source: JICA Study Team

(8) Tamok East Drainage Area (Drainage Area No.10)

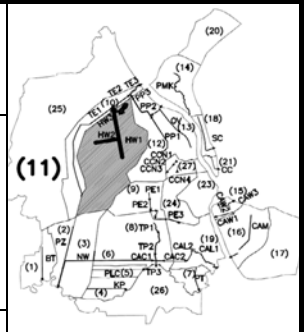
Item	Contents
Location	An area located in the north and west of Kop Srov Dike, which form outer ring dike of Phnom Penh.
Land-use	Present: Farmland, wetland. Future: Economic development zone, farmland and low density residential area.
Salient features of drainage area	Drainage facilities are required to drain stormwater from proposed large-scale development area, which is located in the north of intersection of Kop Srov Dike and National Road No.4. At present no inundation damage is detected,
Issues	Installation of drainage channel is required for future provisions.
Strategy for improvement	Stormwater from the area is drained toward north because National Road No.4 forms watershed dividing Phnom Penh into the north and south. New drainage channel is proposed along Kop Srov Dike, by which stormwater is drained to Sap river via Tamok Lake.
Structural measures	Drainage channel
Environmental and social considerations	Estimated number of resettlement: 40 households. Mitigation measures are required to minimize adverse impact to the people in this area because this area includes high density residential, commercial and industrial area. Adverse impact from dredging of existing regulation ponds should be evaluated. Negative impact to fauna, flora and ecosystem is not anticipated because the existing regulation ponds are already polluted. Detailed survey in the implementation stage is required to evaluate impacts.



Source: JICA Study Team

(9) Hanoi West Drainage Area (Drainage Area No.11)

Item	Contents
Location	An area located inside of Kop Srov Dike, which forms outer ring dike of Phnom Penh, bordered by Kop Srov Dike on the north and west, Hanoi road (or St.1019) on the east and National Road No.4 on the south.
Land-use	Present: High density residential area, commercial and industrial area along National Road No.4 in the south and Hanoi Road in the east. The other area is farmland and low density residential area. Future: Residential area, commercial and industrial area in the south and east, farmland and low density residential area in the north and west.
Salient features of drainage area Issues	This area, including an area in the north-western region of international airport and National Road No.4, is topographically flat and suffers from inundation. Stormwater from the area is drained to Toul Sampov Channel and pumped up by Tuol Sampov Pumping Station (located in the west of Kop Srov Pumping Station), and finally discharged to Tamok Lake. As with Pochentong East Drainage Area, urbanization in the southern part of the area is in progress.
Issues	Installation of drainage facilities has not been catching up with rapid urbanization, and thus inundation occurs in the area. With the progress of urbanization, inundation damage will be bigger.
Strategy for improvement	Drainage channel starting from downstream end is proposed for future provisions. Existing drainage facilities, namely, Tuol Sampov Channel, Tuol Bakha 1 Channel and Tuol Dampov Pumping Station, are augmented to accommodate stormwater from the area. At the same time, the other existing channels are maintained to keep present condition. Additionally, a regulation pond is proposed to reduce initial investment, as well as O&M cost for the pumping station.
Structural measures	Drainage channel, Pumping station and Regulation pond
Environmental and social considerations	Estimated number of resettlement: 28 households. Adverse impact should be mitigated in the southern part of the drainage area because this area includes high density residential, commercial and industrial area. Adverse impact from dredging of existing regulation ponds should be evaluated. Negative impact to fauna, flora and ecosystem

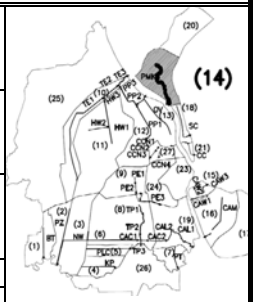


Item	Contents
	is not anticipated because the existing regulation ponds are already polluted. Detailed survey in the implementation stage is required to evaluate impacts.

Source: JICA Study Team

(10) Preaek Maot Kandol Drainage Area (Drainage Area No.14)

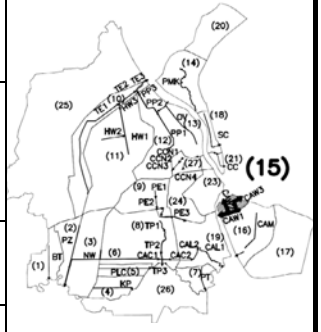
Item	Contents
Location	An area located at the northern peninsular part of Chroy Changvar District, sandwiched between Mekong River and Sap River.
Land-use	Present: Low density residential area along with National Road No.6. The other area is wetland. Future: Economic development zones and low density residential area.
Salient features of drainage area	This area is located on lowland and wetland. Northern part of the area is developed for economic development zone. At present not inundation damage is detected.
Issues	Improvement of existing channel is required for future provision.
Strategy for improvement	In principle the developer should improve existing drainage channels to drain stormwater from the area to Sap River by gravity when present wetland is developed into residential area, or PPCC should install drainage facilities on behalf of the developer, depending on the progress of the development.
Structural measures	Drainage channel
Environmental and social considerations	Estimated number of resettlement: 47 households. Negative impact to fauna, flora and ecosystem should be evaluated because the existing drainage channel originated from natural channel. Adverse impact in the project area should be minimized in the implementation stage because a number of houses are located along the existing channel.



Source: JICA Study Team

(11) Chbar Ampov West Drainage Area (Drainage Area No.15)

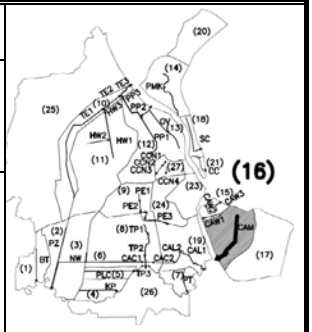
Item	Contents
Location	An area located at the north-western part of Chbar Ampov District and in the north of Barang Channel, sandwiched between Mekong River and Bassac River.
Land-use	Present: Residential and commercial area located on the west half, as well as wetland and future development area on the east half. Future: high density residential area and cluster of high-rise buildings
Salient features of drainage area	This area is topographically flat and the urbanization is in progress, especially in the western part of the area. All of the area will be urbanized in the future
Issues	River water flows back to Barang Channel in the rainy season because of high water level of Bassac. A lot of houses and large amount of garbage are found in and along the Barang Channel. Installation of drainage facilities has not been catching up with rapid urbanization and thus inundation occurs. With the progress of urbanization, inundation damage will be bigger.
Strategy for improvement	Improvement of Barang Channel and new construction of new pumping station is proposed to drain stormwater in the rainy season. Improvement of existing channel is also proposed to drain stormwater from the northern part of National Road No.1 and discharge them to Bassac River and Mekong River by gravity, when the area is developed in the future.
Structural measures	Drainage channel and Pumping station
Environmental and social considerations	Estimated number of resettlement: 179 households. Adverse impact in the project area should be minimized in the implementation stage because a number of houses are located along the existing channel. No negative impact to fauna, flora and ecosystem is anticipated. Hydraulic consideration should be paid to the downstream area of proposed pumping station because volume of discharge through the pumping station increases.



Source: JICA Study Team

(12) Chbar Ampov Middle Drainage Area (Drainage Area No.16)

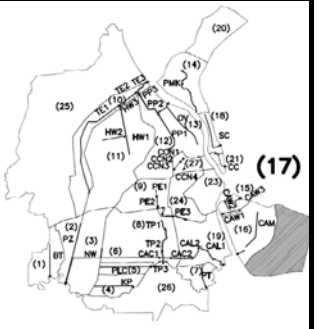
Item	Contents
Location	An area located at the central part of Chbar Ampov District, sandwiched between Mekong River and Bassac River.
Land-use	Present: Residential and commercial area along National Road and dike road in the west, and wetland and farmland in the east. Future : high and low density residential area
Salient features of drainage area	This area is topographically flat and almost all area is in wetland. Urbanization in the western part of the area, being adjacent to city centre, has been in progress, and in the future the area is developed into residential area. On the other hand, the eastern part of the drainage area is wetland in which stormwater is retained.
Issues	In parallel with urbanization, inundation problem has emerged because wetlands in the drainage area have no outlet. With the progress of urbanization, inundation damage will be bigger.
Strategy for improvement	In principle the developer should install drainage channels and pumping station to drain stormwater from the area even to high water level observed in the rainy season, and it should also install regulation pond to reduce initial investment, as well as O&M cost for the pumping station, when the wetlands in the area is developed into residential area, or PPCC should, on behalf of the developer, install drainage facilities depending on the progress of development.
Structural measures	Drainage channel, Pumping Station and Regulation Pond
Environmental and social considerations	Estimated number of resettlement: 17 households. Topological and hydraulic change is anticipated in the northern part of this drainage area because the area is located in existing swamp. Therefore, hydraulic analysis will be required in the implementation stage. Negative impact to fauna, flora and ecosystem is not anticipated because the existing swamps are already polluted. Detailed survey in the implementation stage is required to evaluate impacts.



Source: JICA Study Team

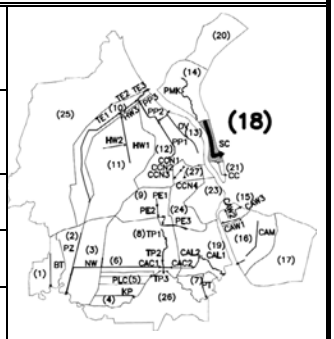
(13) Chbar Ampov East Drainage Area (Drainage Area No.17)

Item	Contents
Location	An area located at the eastern part of Chbar Ampov District, sandwiched between Mekong River and Bassac River.
Land-use	Present: Wetland and low density residential area. Future: No land-use plan
Salient features of drainage area	Almost all area is wetland.
Issues	Not available.
Strategy for improvement	No plan is proposed since at present and in the future no inundation is detected or anticipated. In addition, future land-use plan is not available.
Structural measures	Not proposed.
Environmental and social considerations	Estimated number of resettlement: No resettlement. No negative impact is anticipated because no structural measures are proposed.



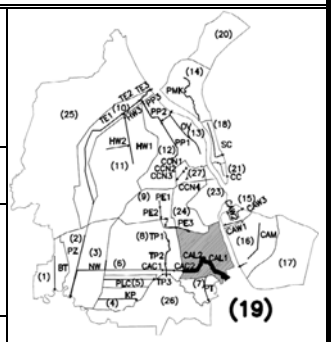
Source: JICA Study Team

(14) Satellite City Drainage Area (Drainage Area No.18)

Item	Contents	
Location	An area located at the central peninsular part of Chroy Changvar District, sandwiched between Mekong River and Sap River.	
Land-use	Present: low density residential area along National Road No.6. The other areas are being developed into residential area. Future: Low density residential area	
Salient features of drainage area	No drainage facilities are installed. Almost all area is located in large-scale development area of Satellite City.	
Issues	Installation of drainage facilities is required in parallel with development.	
Strategy for improvement	In principle the developer should install drainage facilities. Specifications for the drainage facilities are proposed to drain stormwater to Mekong or Sap Rivers by gravity.	
Structural measures	Drainage channel	
Environmental and social considerations	Estimated number of resettlement: 4 households. Topographical change is anticipated to some extent because proposed drainage channel is newly constructed. Negative impact to fauna, flora and ecosystem is not anticipated because the drainage area has no existing drainage channel and swamps.	

Source: JICA Study Team

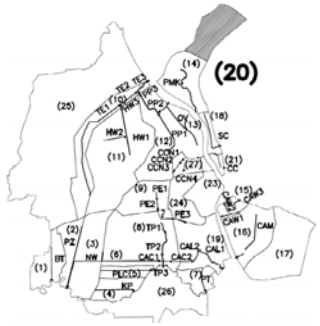
(15) Cheung Aek Lake Drainage Area (Drainage Area No.19)

Item	Contents	
Location	An area including Cheung Aek Lake and its surrounding area, bordered by Tumpun ring Dike (St.371) and St.271 on the north, National Road No.2 on the east, Cheung Aek road on the west, and Prek Thnot River on the southeast. The area is also a part of large-scale development area of ING City.	
Land-use	Present: Farmland, lake and wetland Future: Low and high density residential and commercial area	
Salient features of drainage area	This area is located in ING City. ING City has ownership of the land except for water bodies. All the area under the ING's ownership is reclaimed in the future in parallel with development.	
Issues	In principle ING should install drainage facilities in the area in parallel with land development.	
Strategy for improvement	Specification for the drainage facilities is proposed to drain stormwater to Prek Thnot River by gravity. Based on the specification, ING or PPCC should install the drainage facilities depending on the progress of development	
Structural measures	Drainage channel	
Environmental and social considerations	Estimated number of resettlement: 152 households. At present, this area (Cheung Aek Lake), is developed into ING City and drastic change in topographical and hydraulic condition is anticipated with the development. Detailed survey in implementation stage is required to evaluate impacts. Negative impact to fauna, flora and ecosystem is not anticipated because the Cheung Aek Lake is already polluted heavily by wastewater from the catchment area.	

Source: JICA Study Team

(16) Bak Khaeng Drainage Area (Drainage Area No.20)

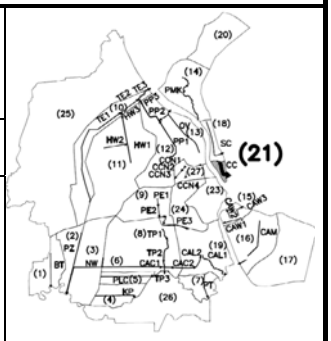
Item	Contents
Location	An area located along National Road No.6 and on the northern edge of Chroy Changvar District.
Land-use	Present: Wetland and low-density residential area along National Road Future: No land-use plan
Salient features of drainage area	Almost all area is wetland.
Issues	Not available.
Strategy for improvement	No plan is proposed since at present and in the future no inundation is detected or anticipated. In addition, future land-use plan is not available.
Structural measures	Not proposed.
Environmental and social considerations	Estimated number of resettlement: No resettlement. No negative impact is anticipated because no structural measures are proposed.



Source: JICA Study Team

(17) Chroy Changvar Drainage Area (Drainage Area No.21)

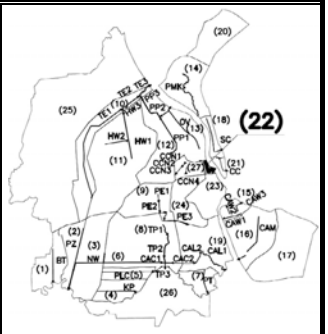
Item	Contents
Location	An area located at the southern edge of peninsular part of Chroy Changvar District, sandwiched between Mekong River and Sap River.
Land-use	Present: Low density residential area and wetland Future: Low density residential area
Salient features of drainage area	Urbanized area is formed on the reclaimed area. Existing residential area located at the centre of peninsula suffers from inundation with the expansion of reclamation in the surrounding area. All the area is developed into low density residential area according to future land-use plan of Phnom Penh.
Issues	Inundation occurs due to the absence of existing drainage channel and outlet to discharge stormwater from the central lowland area. With the progress of urbanization, inundation damage will be bigger.
Strategy for improvement	New construction of drainage channel is proposed to drain stormwater to Mekong River or Sap River by gravity.
Structural measures	Drainage channel
Environmental and social considerations	Estimated number of resettlement: 42 households. Topographical change is anticipated to some extent because a proposed drainage channel is newly constructed. Negative impact to fauna, flora and ecosystem is not anticipated because the drainage area is located in reclaimed area.



Source: JICA Study Team

(18) Wat Phnom North Drainage Area (Drainage Area No.22)

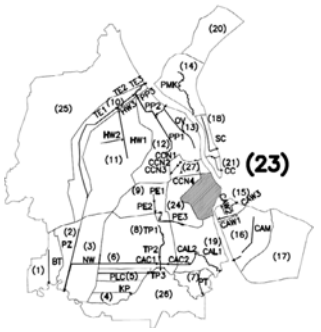
Item	Contents
Location	An area located in the northeast of city centre of Phnom Penh, bordered by the approach road of Japan Bridge on the north, Sap River on the east, Monivong Street on the west and St.102 on the south.
Land-use	Present: High density residential area, commercial and administrative area Future: High density residential area, commercial and administrative area
Salient features of drainage area	Improvement work in the area was requested and studied in Phase 2(*1) but was finally excluded from the project components from viewpoint of project size and priority. Priority of improvement of this area is therefore very high.
Issues	Inundation frequently occurs in the rainy season. Furthermore, lots of facilities like hospital and governmental office situate in the area, so that improvement of drainage facilities is urgent.
Strategy for improvement	Establishment of drainage pipe network is proposed, along with construction of underground reservoir and pumping station to drain stormwater to Sap River. In addition, installation of interceptor is proposed to divert sewage to Trabek Channel in the dry and rainy season.
Structural measures	Drainage channel, Regulation Pond and Pumping Station
Environmental and social considerations	Estimated number of resettlement: No resettlement. Negative impact to fauna, flora and ecosystem, as well as natural end social environment, is not anticipated.



(*1) The Project for Flood Protection and Drainage Improvement in the Municipality of Phnom Penh (Phase 2)
(*2) Underground reservoir is proposed in this drainage area because no swamp/lake appropriate for regulation pond is found in the drainage area.
Source: JICA Study Team

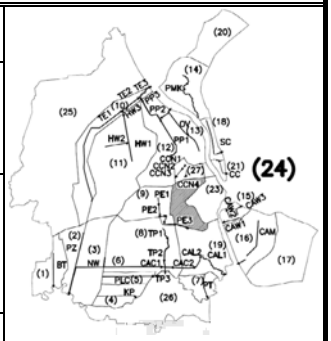
(19) Trabek Drainage Area (Drainage Area No.23)

Item	Contents
Location	An area located at the eastern part of city centre of Phnom Penh.
Land-use	Present: High density residential area, commercial and administrative area Future: High density residential area, commercial and administrative area
Salient features of drainage area	This area is the target area of Phase 2(*1) and Phase 3(*2), and is located in the catchment area of existing Trabek Pumping Station. Urgent and minimum improvement work is done with the implementation of Phase 2 and 3 projects.
Issues	Screens installed in Phase 2 project are not functioning due to clogging triggered by extensive amount of trash than expected.
Strategy for improvement	Improvement of the screen installed in Phase 2 project is proposed.
Structural measures	Mechanical screen (4 locations)
Environmental and social considerations	Estimated number of resettlement: No resettlement. No negative impact is anticipated because the proposed structures are installed only in existing pumping stations.



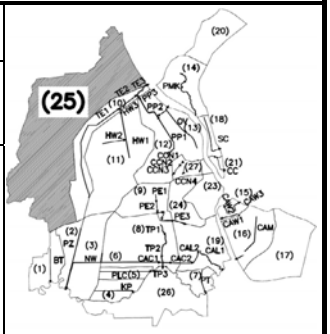
(*1) The Project for Flood Protection and Drainage Improvement in the Municipality of Phnom Penh (Phase 2)
(*2) The Project for Flood Protection and Drainage Improvement in the Phnom Penh Capital City (Phase 3)
Source: JICA Study Team

(20) Tumpun Drainage Area (Drainage Area No.24)

Item	Contents	
Location	An area located in the western part of city centre of Phnom Penh.	
Land-use	Present: High density residential area, commercial and administrative area Future: High density residential area, commercial and administrative area	
Salient features of drainage area	This area is located on the target area of Phase 1(*1) and is in the catchment area of Tumpun Pumping Station. With the implementation of Phase 1 project, urgent and minimum improvement works in the downstream of the drainage area are already done.	
Issues	There exists newly urbanized area in which drainage facilities are not installed.	
Strategy for Improvement	No project is proposed in the M/P.	
Structural measures	Not proposed.	
Environmental and social considerations	Estimated number of resettlement: No resettlement. No negative impact is anticipated because no structural measures are proposed.	

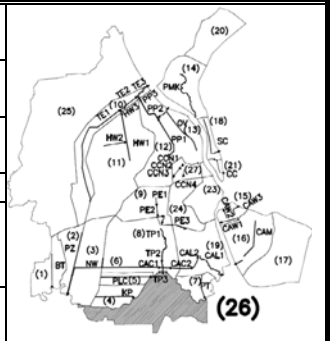
(*1) The Project for Flood Protection and Drainage Improvement in the Municipality of Phnom Penh
Source: JICA Study Team

(21) Tamok West Drainage Area (Drainage Area No.25)

Item	Contents	
Location	An area located at outer area of Kop Srov Ring Dike, bordered by the north-western city boundary.	
Land-use	Present: Farmland, lowland and low density residential area Future: Farmland, lowland, low density residential area. No land-use planning available.	
Salient features of drainage area	This area is located in the catchment area of Tamok Lake with natural river flowing to Tamok Lake. At the outlet of Sap River, a weir is installed with the assistance of Korea to control water level because the area is affected by fluctuation of water level of Sap River. In the rainy season, stormwater is discharged to wetland located in the north of Tamok Lake. Urbanization is not in progress and the drainage area is dominated by farmland except for Tamok Lake and wetland surrounding the lake.	
Issues	Not available.	
Strategy for improvement	No improvement work is proposed because the drainage area gradually slopes from west to east and no inundation is detected at present and in the future.	
Structural measures	Preservation of existing rivers.	
Environmental and social considerations	Estimated number of resettlement: No resettlement. No negative impact is anticipated because no structural measures are proposed.	

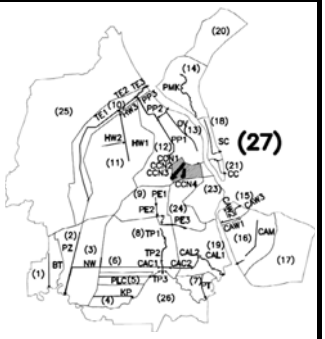
Source: JICA Study Team

(22) Prek Thnot South Drainage Area (Drainage Area No.26)

Item	Contents	
Location	An area located at the southern edge of PPCC, bordered by south bank of Prek Thnot River.	
Land-use	Present: Farmland and low density residential area. Future: No land-use plan.	
Salient features of drainage area	Almost all area is farmland.	
Issues	Not available.	
Strategy for improvement	No plan is proposed since at present and in the future no inundation is detected or anticipated, and future land-use plan is not available.	
Structural measures	Not proposed.	
Environmental and social considerations	Estimated number of resettlement: No resettlement. No negative impact is anticipated because no structural measures are proposed.	

Source: JICA Study Team

(23) City Core North Area Drainage Area (Drainage Area No.27)

Item	Contents	
Location	An area located inside inner ring dike and in the north-western part of city centre, covering the northern part along National Road No. 4 in Tuol Kok District and the reclaimed area of Boeung Kak Lake, bordered by St.598 on the west; St.355, St.273 and St.70 on the north; Monivong Boulevard on the east; and Russian Boulevard on the south.	
Land-use	Present: High density residential and commercial area Future: High density residential and commercial area	
Salient features of drainage area	Improvement of this area is proposed in 1999 M/P but is not yet implemented in viewpoint of priority, so that the priority is very high. The drainage area includes catchment area of Tuol Kork and Tuol Kork 2 Pumping Stations in Tuol Kork District. SHUKAKU reclaimed Boeung Kak Lake and now installing drainage facilities in parallel with the development.	
Issues	Inundation frequently occurs especially in the northern part of Tuol Kok District in the rainy season. The northern part of Tuol Kok District has high population density and a large number of commercial facilities, so that the installation of drainage facilities is urgent.	
Strategy for improvement	Construction of new box culvert and a sluice way is proposed in the northern part of Tuol Kok District to drain stormwater from inside inner ring dike by gravity. On the other hand, SHUKAKU should install drainage facilities in the reclaimed area of Boeung Kak Lake	
Structural measures	Box culvert and Sluiceway	
Environmental and social considerations	Estimated number of resettlement: 18 households. Adverse impact should be mitigated in the drainage area because this area includes high density residential, commercial and industrial area. Hydraulic analysis is required for the construction of sluiceway because hydraulic change is anticipated. Negative impact to fauna, flora and ecosystem is not anticipated.	

Source: JICA Study Team

6.1.2 Alternative Study on Cheung Aek Channel Drainage Area (Drainage Area No.6) and Tuol Pongro Drainage Area (Drainage Area No.8)

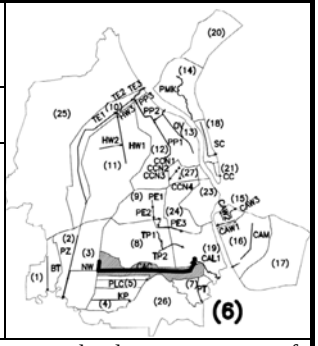
In this sub-section, alternative study on whether or not to combine Cheung Aek Channel Drainage Area (Drainage Area No.6) and Tuol Pongro Drainage Area (Drainage Area No.8) is conducted.

Based on the alternative study detailed later, the two drainage areas are combined in the drainage management M/P.

(1) Alternative Study 1: Cheung Aek Channel Drainage Area (Drainage Area No.6) and Tuol Pongro Drainage Area (Drainage Area No.8) are separated

(a) Cheung Aek Channel Drainage Area (Drainage Area No.6)

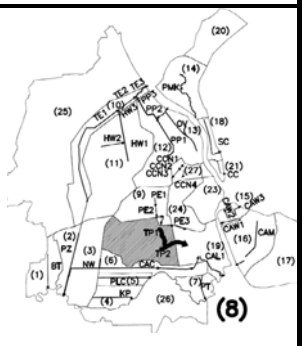
Item	Contents
Location	A slender area that extends from east to west, located in the catchment area of Cheung Aek Channel, bordered by Cheung Aek Lake on the east.
Land-use	Present: Farmland. Future: Farmland and low density residential area.
Salient features of drainage area	This area gradually slopes from west to east. Existing Cheung Aek Channel is utilized for irrigation and drainage but has insufficient capacity. Inundation damage is not so big because the Cheung Aek Channel is mainly utilized for irrigation. Dangkor solid waste disposal site is located in the area.
Issues	Installation of drainage channel is required for future provisions because the downstream part of the area is developed into residential area.
Strategy for improvement	Improvement of Cheung Aek Drainage Channel is proposed to drain stormwater to Cheung Aek Lake by gravity.
Structural measures	Drainage channel
Environmental and social considerations	Estimated number of resettlement: 69 households. Topological change in the existing irrigation network area is anticipated because improvement of existing drainage is proposed in the area. At present, discharge point of this drainage area (Cheung Aek Lake), is developed into ING City and drastic change in topographical and hydraulic condition is anticipated by the development. Detailed survey in the implementation stage is required to evaluate impacts. Negative impact to fauna, flora and ecosystem is not anticipated because the Cheung Aek Lake is already polluted heavily by wastewater from the catchment area.



Source: JICA Study Team

(b) Tuol Pongro Drainage Area (Drainage Area No.8)

Item	Contents
Location	An area located in the south of Pochentong East Drainage Area, bordered by Veng Sreng road (former BOT road) on the north, National Road No.3 on the west, Cheung Aek Road on the east and Prey Sar Road on the south.
Land-use	Present: Farmland, wetland, residential area and factories. Future: low and high density residential area, economic development zone.
Salient features of drainage area	This area gradually slopes from west to east. Existing Tuol Pongro Channel and the other channels are utilized for irrigation and drainage, running from west to east through Moul Channel and discharging stormwater to Cheung Aek Lake. The existing channels cannot drain stormwater especially in the rainy season due to lack of capacity. The stormwater is thus retained in wetlands scattered in the area. Land development in the northern part is in progress and the area is finally developed from farmland into residential area.
Issues	Inundation damage is already detected in the northern part of the drainage area. Almost all drainage area will be highly urbanized in the future, and as a result the inundation damage will be bigger. Drainage facilities in the area should be improved in the early stages.
Strategy for improvement	Preservation of existing Tuol Pongro Channel and its tributaries is proposed. In addition, installation of new drainage channel and box culvert in the downstream is proposed to drain stormwater to Cheung Aek Lake by gravity.
Structural measures	Drainage channel and Box culvert

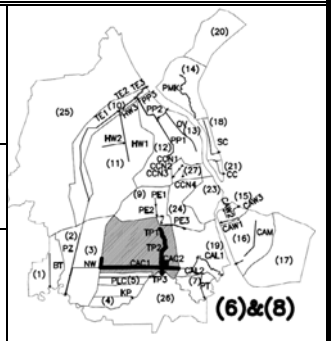


Item	Contents
Environmental and social considerations	Estimated number of resettlement: 89 households. Adverse impact should be minimized in the northern part of this drainage area because a new residential area is being developed. Negative impact to fauna, flora and ecosystem is not anticipated because the discharge point of the drainage area (Cheung Aek Lake) is already heavily polluted by wastewater from the catchment area.

Source: JICA Study Team

(2) Alternative Study 2: Cheung Aek Channel Drainage Area (Drainage Area No.6) and Tuol Pongro Drainage Area (Drainage Area No.8) are combined

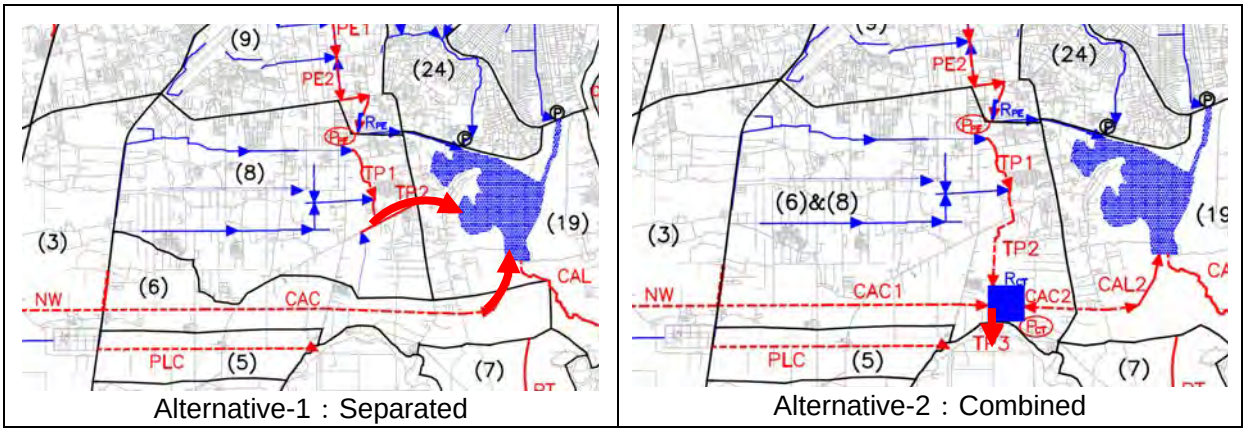
Item	Contents
Location	An area located in the south of Pochentong East Drainage Area and in the catchment area of Cheung Aek Channel, bordered by Veng Sreng road (former BOT road) on the north, National Road No.3 on the west and Cheung Aek Channel on the south.
Land-use	Present: Farmland, wetland, residential area and factories. Future: low and high density residential area, economic development zone.
Salient features of drainage area	This area gradually slopes from west to east. The existing channels cannot drain stormwater especially in the rainy season due to lack of capacity. The stormwater is thus retained in wetlands scattered in the area. Land development in the northern part of the area is in progress and the area will be finally developed from farmland into residential area.
Issues	Inundation damage is already detected in the northern part of the drainage area. Almost all Tuol Pongro Drainage Area will be highly urbanized in the future, and as a result the inundation damage will be bigger. Drainage facilities in the area should be improved in the early stages.
Strategy for improvement	Preservation of existing Tuol Pongro Channel and its tributaries is proposed. In addition, installation of new drainage channel, which runs through wetlands in the eastern part of the drainage area, is proposed to drain stormwater to the downstream end by gravity. New pumping station is also proposed at the downstream end of the new channel to discharge the stormwater to Prek Thnot River. Further, new regulation pond is proposed to downsize the pumping equipment and reduce initial investment and O&M cost. Improvement of existing Cheung Aek Channel is also proposed to connect it to the new regulation pond and drain stormwater to Prek Thnot River.
Structural measures	Drainage channel, Pumping Station, Regulation pond
Environmental and social considerations	Estimated number of resettlement: 81 households. Compared to Alternative 1, the number of resettlement can be reduced in Drainage Area No.8 since the drainage channel can be installed avoiding the congested housing area. Adverse impact can be minimized in the Drainage Area by the same reason. Negative impact to fauna, flora and ecosystem is not anticipated.



Source: JICA Study Team

(3) Summary of Alternative Study on Cheung Aek Channel Drainage Area (Drainage Area No.6) and Tuol Pongro Drainage Area (Drainage Area No.8)

Concepts of the alternative study on Cheung Aek Channel Drainage Area (Drainage Area No.6) and Tuol Pongro Drainage Area (Drainage Area No.8) are illustrated in **Fig. 6.1.1**.



Source: JICA Study Team

Fig. 6.1.1 Alternative Study on Cheung Aek Channel Drainage Area (Drainage Area No.6) and Tuol Pongro Drainage Area (Drainage Area No.8)

Results of alternative study are summarized in **Table 6.1.1**.

Table 6.1.1 Summary of Alternative Study on Cheung Aek Channel Drainage Area (Drainage Area No.6) and Tuol Pongro Drainage Area (Drainage Area No.8)

Item	Alternative-1 : Separated	Alternative-2 : Combined
Flow direction	Each drainage area has outlet to drain stormwater to Cheung Aek Lake located east of the areas	Stormwater from the two drainage areas is drained to Prek Thnot River located south of the areas
Facilities	Drainage channel and Box culvert	Drainage channel, Regulation pond, Pumping Station, Sluiceway
Construction cost	88.6 million USD	48.2 million USD
O&M cost	0.1 million USD/year	0.4 million USD/year
EIRR	11.2%	12.5%
Resettlement	158 households	81 households
Regulation pond	Not required	70 ha
Evaluation	Not adopted	**Adopted**

Source: JICA Study Team

As could be gleaned from **Table 6.1.1**, Alternative-2 is better than Alternative-1 in terms of construction cost and number of resettlements, although it needs land acquisition cost for regulation pond. Therefore, Alternative-2, in which Cheung Aek Channel Drainage Area (Drainage Area No.6) and Tuol Pongro Drainage Area (Drainage Area No.8) are combined, is selected in the M/P.

6.1.3 Alternative Study on Poung Peay Drainage Area (Drainage Area No.12) and O'veng Drainage Area (Drainage Area No.13)

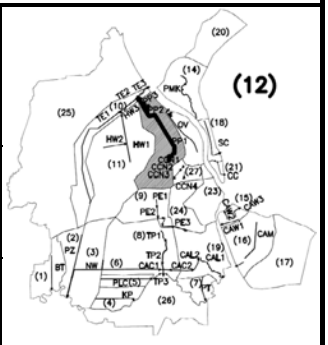
In this subsection, alternative study on whether or not to combine Poung Peay Drainage Area (Drainage Area No.12) and O'veng Drainage Area (Drainage Area No.13) is conducted.

Based on the alternative study detailed later, the two drainage areas are combined in the drainage management M/P.

(1) Alternative Study 1: Poung Peay Drainage Area (Drainage Area No.12) and O'veng Drainage Area (Drainage Area No.13) are separated

(a) Poung Peay Drainage Area (Drainage Area No.12)

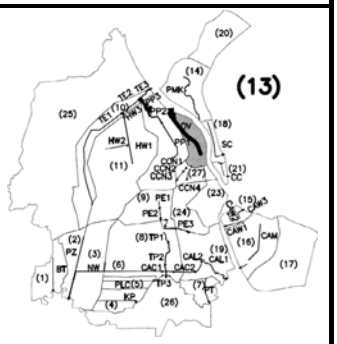
Item	Contents
Location	An area located inside of Kop Srov Ring Dike in the north of Phnom Penh, bordered by Hanoi Street on the west, Kop Srov Dike on the north, St.598 (or Chea Sophara Road) and St.289 (Kim Il Sung Road) on the east and National Road No.4 on the south.
Land-use	Present: Southern half part is high density residential area, commercial and industrial areas, and northern half part is development area and wetland. Future: High density residential, commercial and industrial area.
Salient features of drainage area	This area includes the inundated area sandwiched between National Road No.4 and the railway. Stormwater from the drainage area is conveyed to the north through Poung Peay Lake, pumped up at Kop Srov Pumping Station and then discharged to Tamok Lake. As with Pochentong East Drainage Area, urbanization is in progress especially in the southern part. The area will be finally developed into residential/commercial area in the future.
Issues	Installation of drainage facilities has not been catching up with rapid urbanization and thus inundation occurs. With the progress of urbanization, inundation damage will be bigger.
Strategy for improvement	Drainage channel starting from downstream end is proposed for future provision. Existing drainage facilities, namely, Poung Peay Channel and Kop Srov Pumping Station, are augmented to accommodate stormwater from the area. At the same time, the other existing channels are maintained to keep the present condition. Additionally, regulation pond is proposed to reduce initial investment, as well as O&M cost for the pumping station.
Structural measures	Drainage channel, Pumping station and Regulation pond
Environmental and social considerations	Estimated number of resettlement: 22 households. Adverse impact should be minimized in the construction work in dense residential, commercial and industrial area. Hydraulic analysis is required for the construction of regulation pond. Negative impact to fauna, flora and ecosystem is not anticipated.



Source: JICA Study Team

(b) O'veng Drainage Area (Drainage Area No.13)

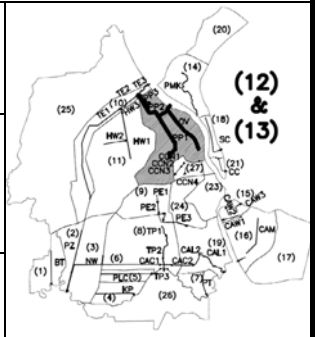
Item	Contents
Location	An area located inside of Kop Srov Ring Dike in the north of Phnom Penh, bordered by St.598 (or Chea Sophara Road) and St.289 (Kim Il Sung Road) on the west; Kop Srov Dike on the north; National Road No.5 on the east; and St.355, St.273 and St.70 on the south.
Land-use	Present: Two-thirds of the southern part and area along National Road No. 5 is high density residential area, commercial and industrial area. The other part is residential development area and wetland. Future: High density residential area and commercial and industrial areas.
Salient features of drainage area	This area is located in hinterland of natural levee is reclaimed. Stormwater is drained through Ou Bak Touk and O′veng Channels and discharged to Sap River through Svay Pak Sluiceway when water level of Sap River is lower than that inside the sluiceway. On the other hand, when water level of Sap River is lower than that inside the sluiceway, the sluiceway is closed and the stormwater is pumped up and discharged to Sap River. However, the pumping station is currently not functioning and thus the stormwater is transferred to Poung Peay Drainage Area and then discharged to Tamok Lake through Kop Srov Pumping Station. So far, there is no serious inundation damage detected.



Item	Contents
Issues	Almost entire area, including wetland is developed into residential and commercial area in the future. With the progress of urbanization, inundation damage will be bigger.
Strategy for improvement	Drainage channel starting from downstream end is proposed for future provision. Existing drainage facilities, namely, O′veng Channel and Svay Pak Pumping Station, are augmented to accommodate stormwater from the area. At the same time, the other existing channels are maintained to keep present condition. Additionally, regulation pond is proposed to reduce initial investment as well as O&M cost for the pumping station.
Structural measures	Drainage channel, Pumping station and Regulation pond
Environmental and social considerations	Estimated number of resettlement: 71 households. Adverse impact should be minimized in the construction work in density residential, commercial and industrial area. Negative impact to fauna, flora and ecosystem is not anticipated because the discharge point of the drainage area (Tamok Lake) is already polluted by wastewater from the catchment area, but negative impact to the new regulation pond should be studied in detail in the implementation stage.

Source: JICA Study Team

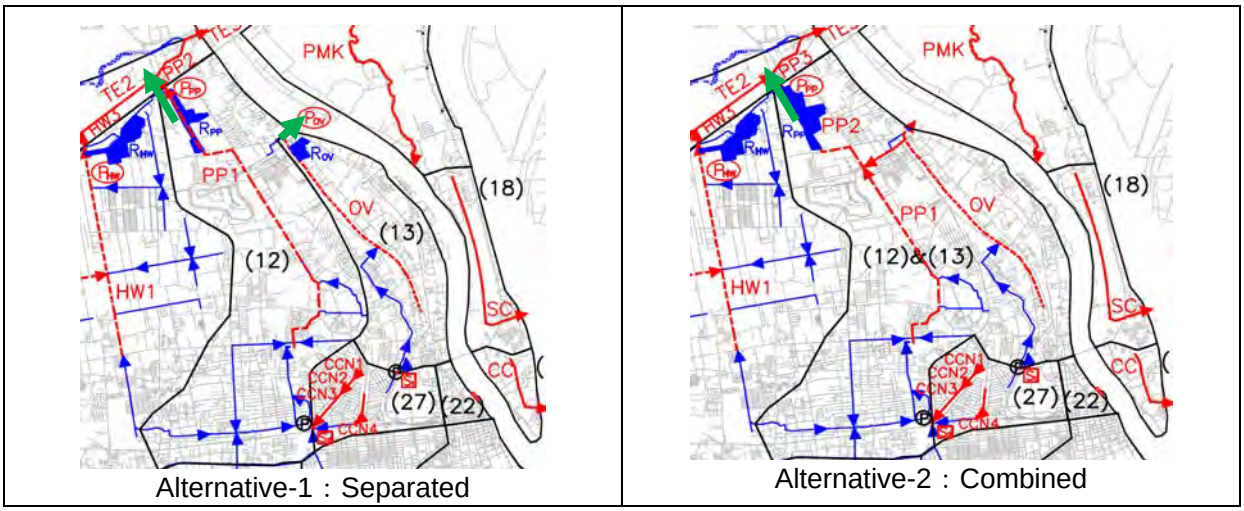
(2) Alternative Study 2: Poung Peay Drainage Area (Drainage Area No.12) and O'veng Drainage Area (Drainage Area No.13) are combined

Item	Contents	
Location	An area located inside of Kop Srov Ring Dike in the north of Phnom Penh, bordered by Hanoi Street on the west; Kop Srov Dike on the north; National Road No.5 on the east; and St.355, St.273 and St.70 on the south.	
Land-use	Present: Southern part of the area is high density residential area, commercial and industrial area, while northern part is residential development area and wetland. Future: High density residential area and commercial and industrial area.	
Salient features of drainage area	This area includes inundated area sandwiched between National Road No.4 and railway. Stormwater from the drainage area is conveyed to the north through Poung Peay and O'veng Channels and discharged through Kop Srov Pumping Station or Svay Pak Sluiceway. Urbanization in the southern part of the drainage area is in progress. Almost entire area, including wetland, is to be developed into residential, commercial area in the future.	
Issues	Installation of drainage facilities has not been catching up with rapid urbanization and thus inundation occurs in the area. With the progress of urbanization, inundation damage will be bigger.	
Strategy for improvement	Improvement of drainage channel starting from downstream end is proposed for future provisions. The improvement work includes (i) connection of Poung Peay and O'veng Channels at the north of Poung Peay Lake, (ii) augmentation of Poung Peay and O'veng Channels to accommodate stormwater from the area, (iii) preservation of the other drainage channels to keep present condition and (iv) construction of regulation pond at Kop Slov Pumping Station to reduce initial investment, as well as O&M cost for the pumping station. On the other hand, improvement of Svay Pak Pumping Station is not proposed in the M/P.	
Structural measures	Drainage channel, Pumping station and Regulation pond	
Environmental and social considerations	Estimated number of resettlement: 90 households. Compared to Alternative 1, the number of resettlement can be reduced to some extent since the drainage channel can be installed avoiding congested housing area. Negative impact can be reduced by combining discharge point. Negative impact to fauna, flora and ecosystem is not anticipated but negative impact to the new regulation pond should be studied in detail in the implementation stage.	

Source: JICA Study Team

(3) Summary of Alternative Study on Poung Peay Drainage Area (Drainage Area No.12) and O'veng Drainage Area (Drainage Area No.13)

Concepts of alternative study on Poung Peay Drainage Area (Drainage Area No.12) and O'veng Drainage Area (Drainage Area No.13) are illustrated in **Fig. 6.1.2**.



Source: JICA Study Team

Fig. 6.1.2 Concepts of Alternative Study on Poung Peay Drainage Area (Drainage Area No.12) and O'veng Drainage Area (Drainage Area No.13)

Results of alternative study are summarized in **Table 6.1.2**.

Table 6.1.2 Summary of Alternative Study on Poung Peay Drainage Area (Drainage Area No.12) and O'veng Drainage Area (Drainage Area No.13)

Item	Alternative-1:Separated	Alternative-2:Combined
Flow direction	Poung Peay Drainage Area drains stormwater to Tamok Lake located northwest of the area, while O'veng Drainage Area drains stormwater to Sap River located northeast of the area	Stormwater from two drainage areas is combined and drained to Tamok Lake located northwest of the areas (Stormwater is drained to Sap River located northeast when water level of Sap River is low.)
Facilities	Drainage channel, Regulation pond and Pumping station (2 locations)	Drainage channel, Regulation pond and Pumping station (1 location)
Construction cost	95.4 million USD	82.0 million USD
O&M cost	1.6 million USD/year	1.4 million USD/year
EIRR	9.9%	12.1%
Resettlement	93 households	90 households
Regulation pond	33 ha (Rpp:18ha + Rov:15ha)	20 ha
Evaluation	Not adopted	**Adopted**

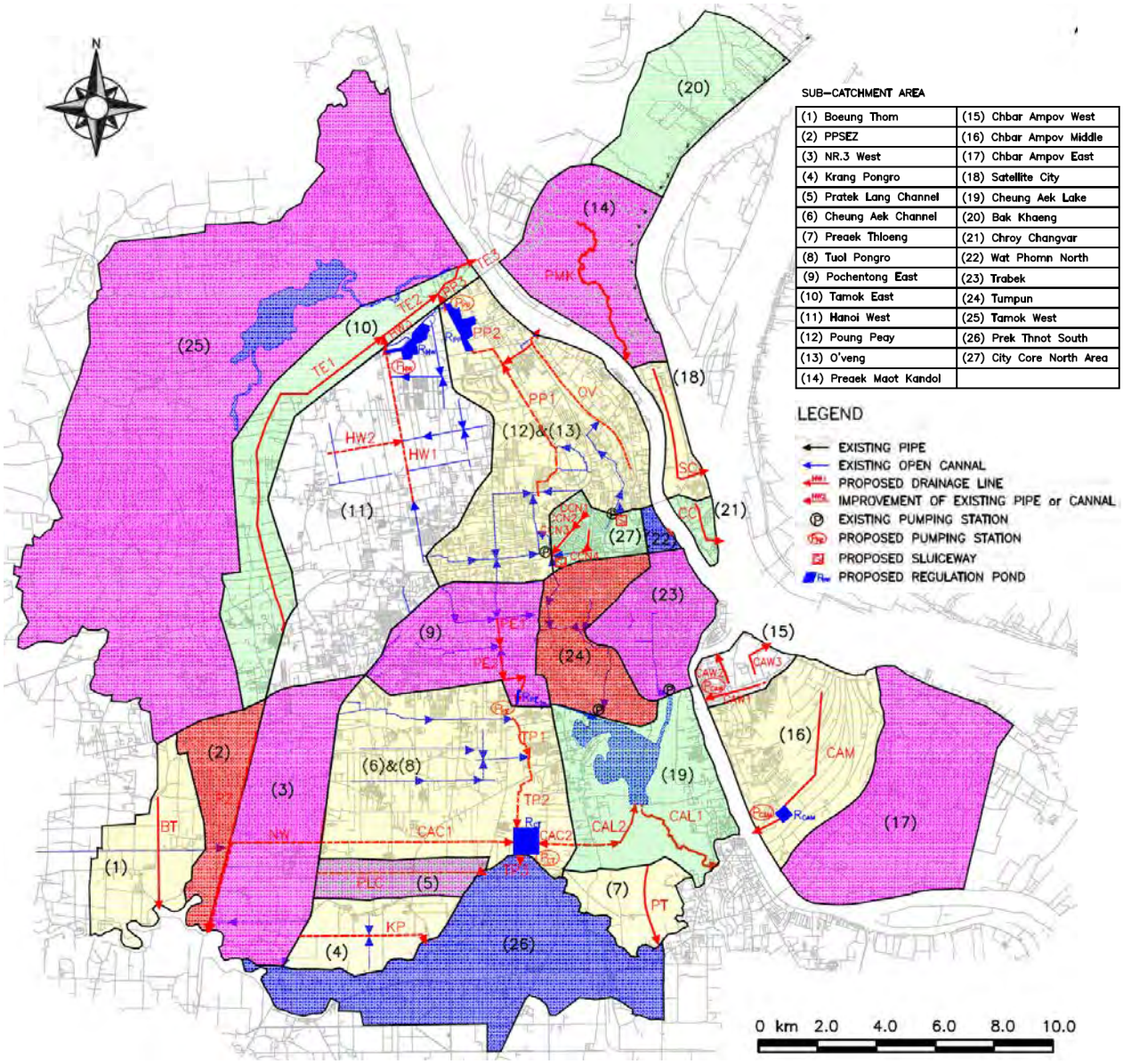
Source: JICA Study Team

As shown in **Table 6.1.2**, Alternative-2 is better than Alternative-1 in all items. Therefore, Alternative-2, in which Poung Peay Drainage Area (Drainage Area No.12) and O'veng Drainage Area (Drainage Area No.13) are combined, is selected in the M/P.

6.2 Drainage Facilities Plan

6.2.1 General Layout of Drainage Management Plan

Based on the above discussion, the general layout of the drainage management plan is as shown in **Fig. 6.2.1**.



Source : JICA Study Team

Fig. 6.2.1 General Layout of Proposed Drainage Management Plan

6.2.2 Run-off Analysis

Results of run-off analysis applying Rational Formula are summarized in **Tables 6.2.1** and **6.2.2**.

Rational formula $$Q = \frac{1}{360} \cdot C \cdot I \cdot A$$

Where,

Q : Run-off (m^3/s)
C : Run-off coefficient
I : Rainfall intensity (mm/h)
$I=5{,}009.12\times(T+31.38)^{-0.98}$ (5-year return period)
A : Drainage area (ha)

Table 6.2.1 Run-off Analysis (1/2)

No.	Sub-Catchment Area	Name of Facilities	Area	Time of Concentration										R_5	Overall run-off coefficient	Run-off calculated	Design Flow	Proposed Works
				Inlet Time					Drain Flow Time				Tc	5-Year Rainfall intencity				
				Li	n: roughness coefficient	Starting point G.L.	End point G.L.	Ti	Ld	Starting point G.L.	End point G.L.	Td						
			km^2	m				min	m			min	min	mm/hr		m^3/s	m^3/s	
1	Boeung Thom	BT	15.39	1,940	0.20	16.90	16.60	180.9	3,670	16.60	16.20	68.0	248.9	20.0	0.30	25.65	26.00	New Construction
2	PPSEZ	PZ	10.56	2,670	0.15	16.30	14.70	133.8	7,010	14.70	12.58	116.8	250.7	19.9	0.42	24.50	25.00	Improvement
3	NR.3 West	NW	27.36	5,560	0.15	13.33	12.29	247.4	7,150	12.29	11.96	132.4	379.8	13.7	0.33	34.46	35.00	Improvement
4	Krang Pongro	KP	11.01	1,430	0.15	13.57	11.71	83.4	4,490	11.71	8.82	74.8	158.3	29.3	0.30	26.93	27.00	Improvement
5	Pratek Lang Channel	PLC	7.17	780	0.15	11.62	11.28	81.1	5,720	11.30	8.86	95.3	176.5	26.8	0.30	16.02	17.00	Improvement
6&8	Cheung Aek Channel & Tuol Pongro	CAC1	10.26	1,010	0.10	12.95	12.37	71.0	7,730	12.37	7.58	128.8	199.9	24.2	0.40	27.55	28.00	Improvement
		CAC2	2.02	1,160	0.10	9.77	9.57	100.4	1,840	9.57	7.58	20.4	120.8	36.4	0.40	8.16	9.00	Improvement
		TP1	11.68	6,110	0.06	13.00	7.90	118.8	2,220	7.90	5.90	37.0	155.8	29.7	0.46	44.33	45.00	Improvement
		TP2	33.00	6,110	0.06	13.00	7.90	118.8	4,560	8.07	7.70	84.4	203.3	23.8	0.46	100.39	101.00	New Construction
		TP3	45.28	6,110	0.06	13.00	7.90	118.8	7,450	7.70	7.63	138.0	256.8	19.5	0.46	112.62	113.00	New Construction
7	Preaek Thloeng	PT	8.53	2,820	0.10	7.91	4.50	96.4	2,740	4.50	4.44	50.7	147.2	31.1	0.30	22.13	23.00	New Construction
9	Pochentong East	PE1	7.57	2,930	0.06	11.40	11.00	128.7	1,010	11.00	9.10	11.2	139.9	32.4	0.40	27.27	28.00	New Construction
		PE2	18.23	2,930	0.06	11.40	11.00	128.7	3,890	11.00	9.60	64.8	193.5	24.8	0.40	50.26	51.00	New Construction
10	Tamok East	TE1	22.52	2,620	0.15	14.60	14.00	166.0	12,460	14.00	7.00	207.7	373.7	13.9	0.39	34.02	35.00	New Construction
		TE2	25.46	2,620	0.15	14.60	14.00	166.0	14,780	14.00	6.30	246.3	412.4	12.8	0.39	45.18	46.00	New Construction
		TE3	26.60	2,620	0.15	14.60	14.00	166.0	16,620	14.00	10.43	307.8	473.8	11.2	0.39	57.36	58.00	New Construction
11	Hanoi West	HW1	59.46	9,460	0.10	14.50	10.30	214.4	5,290	10.30	8.70	88.2	302.6	16.8	0.39	108.53	109.00	Improvement
		HW2	12.20	2,370	0.10	12.90	10.16	89.8	2,560	10.16	8.87	42.7	132.5	33.8	0.39	44.72	45.00	Improvement
12&13	Poung Peay & O'veng	PP1	24.98	5,690	0.06	8.38	7.21	159.4	5,460	7.90	7.20	101.1	260.6	19.2	0.62	82.70	83.00	Improvement
		PP2	49.59	5,690	0.06	8.38	7.21	159.4	8,740	7.90	7.50	161.9	321.3	16.0	0.62	136.41	137.00	Improvement
		OV	15.04	3,580	0.06	8.80	7.80	119.6	7,310	7.80	7.20	135.4	254.9	19.6	0.62	50.74	51.00	Improvement

Source: JICA Study Team

Table 6.2.2 Run-off Analysis (2/2)

No.	Sub-Catchment Area	Name of Facilities	Area	Time of Concentration										R_5	Overall run-off coefficient	Run-off calculated	Design Flow	Proposed Works
				Inlet Time					Drain Flow Time				Tc	5-Year				
				Li	n: roughness coefficient	Starting point G.L.	End point G.L.	Ti	Ld	Starting point G.L.	End point G.L.	Td		Rainfall Int.				
			km^2	m				min	m			min	min	mm/hr		m^3/s	m^3/s	
14	Preaek Maot Kandol	PMK	22.43	2,770	0.06	11.40	7.19	71.4	7,000	7.19	6.54	129.6	201.0	24.0	0.43	64.39	65.00	Improvement
15	Chbar Ampov West	CAW1	1.22	1,060	0.06	11.00	10.60	63.1	2,140	10.60	9.70	35.7	98.8	42.4	0.80	11.49	12.00	Improvement
		CAW2	1.36	990	0.06	10.50	10.40	83.2	1,040	9.51	9.29	19.3	102.4	41.3	0.80	12.51	13.00	Improvement
		CAW3	2.19	730	0.06	10.40	10.20	57.2	1,460	11.00	10.72	27.0	84.2	47.7	0.80	23.24	24.00	Improvement
16	Chbar Ampov Middle	CAM	25.63	2,040	0.06	9.80	8.40	74.5	5,300	7.70	6.80	98.1	172.7	27.3	0.43	83.57	84.00	New Construction
17	Chbar Ampov East																	
18	Satellite City	SC	4.63	720	0.06	9.75	8.76	39.0	4,780	7.11	7.02	88.5	127.5	34.9	0.40	17.96	18.00	New Construction
19	Cheung Aek Lake	CAL1	27.45	4,250	0.10	5.66	4.69	172.4	4,230	4.69	8.80	78.3	250.7	19.9	0.43	65.18	66.00	Improvement
		CAL2	4.05	740	0.10	9.02	8.49	58.3	2,820	8.49	4.69	31.3	89.7	45.5	0.43	22.04	23.00	Improvement
20	Bak Khaeng																	No Proposed Works
21	Chroy Changvar	CC	2.10	870	0.06	10.07	10.00	82.6	1,650	10.72	10.56	30.6	113.1	38.3	0.40	8.92	9.00	New Construction
22	Wat Phnom North																	Phase IV
23	Trabek																	Phase II & Phase III
24	Tumpun		14.49	1,960	0.20			80.7	4,770	7.91	5.50	79.5	160.2	29.0	0.52	60.77	61.00	Phase I
25	Tamok West																	No Proposed Works
26	Prek Thnot South																	No Proposed Works
27	City Core North Area	CCN1 CCN2 CCN3 CCN4 S1	1.84	800	0.06	8.33	8.15	62.5	1,880	8.15	7.83	34.8	97.3	42.9	0.48	10.54	11.00	New Construction
		S2	1.53	720	0.06	8.60	7.57	38.6	580	7.97	7.87	10.7	49.3	67.7	0.48	13.78	14.00	New Construction

Source: JICA Study Team

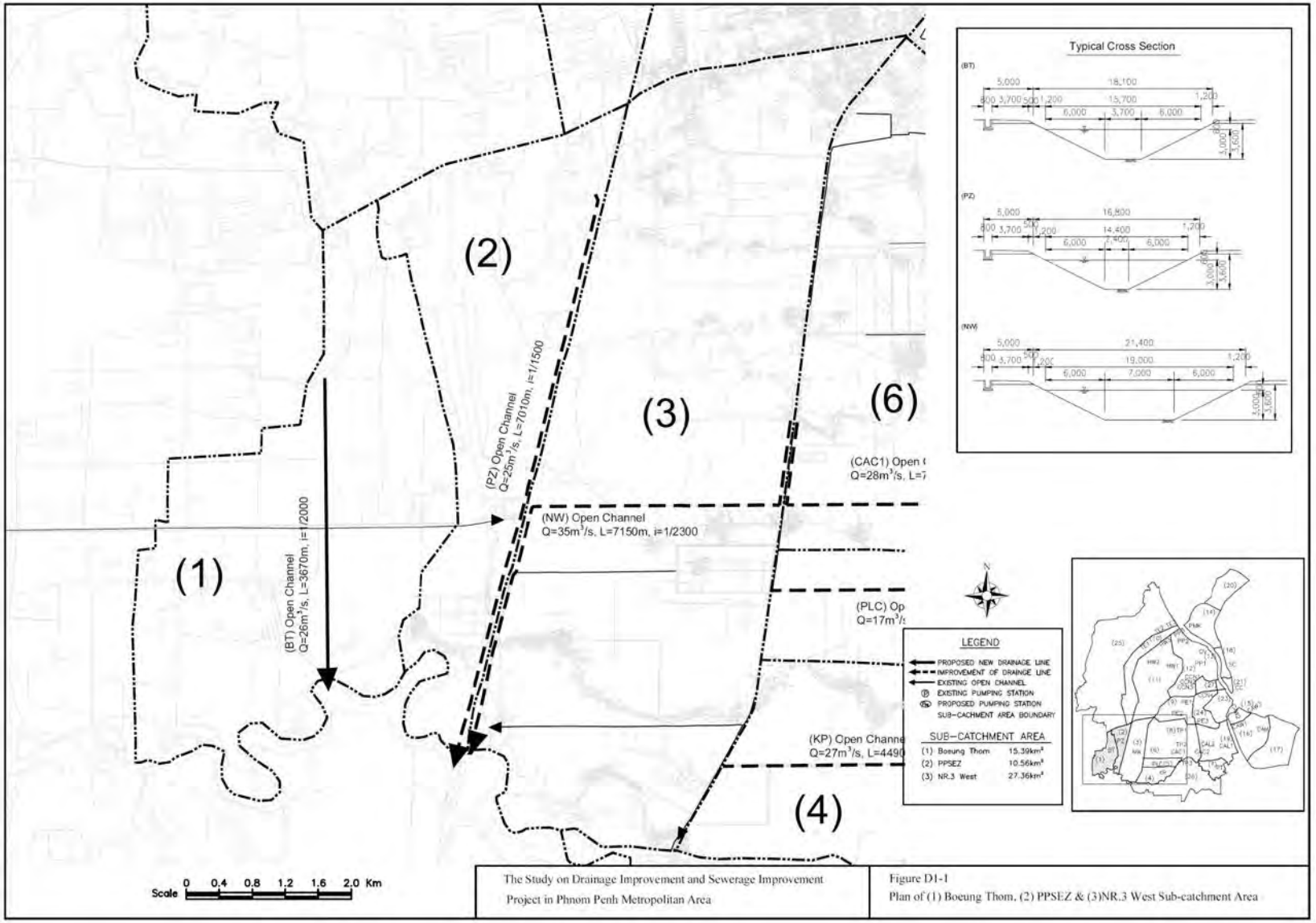
6.2.3 Planning of Drainage Channels and Pipes

Based on the results of run-off analysis, drainage channels and pipes are proposed, as summarised in **Table 6.2.3.** General layouts are shown in **Figs. 6.2.2** to **6.2.8**.

Table 6.2.3 Summary of Proposed Drainage Channels and Pipes

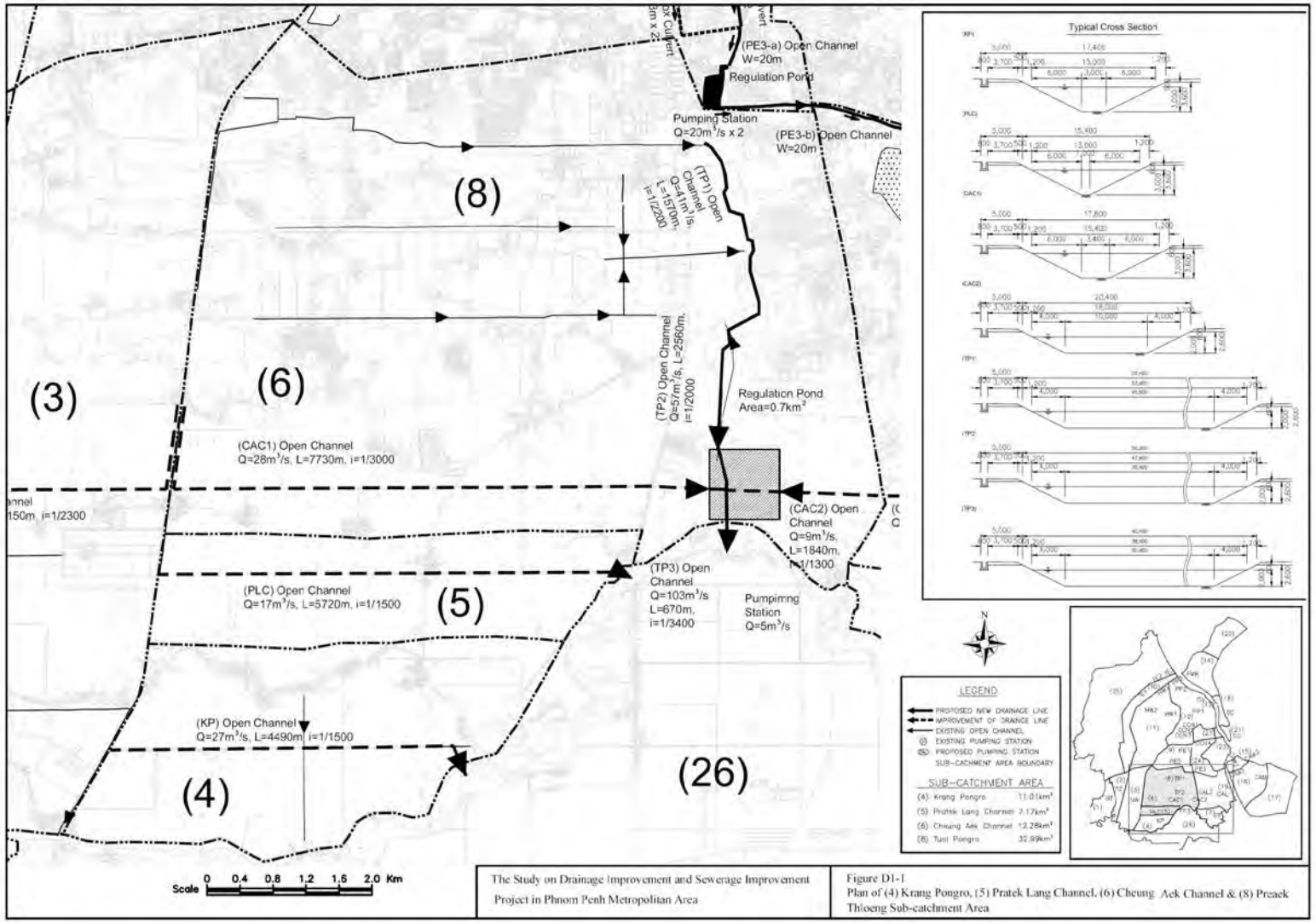
No.	Drainage Area	Name of Facilities	Area km2	R_5 5-Year Rainfall Int. mm/hr	Discharge Q_5 m^3/s	Proposed Works	Facilities	Length m	Slope 1/I	Drainage Channel /Box Culvert Width b m	Depth h m
1	Boeung Thom	BT	15.39	20.0	26.00	New Construction	Open Cannal	3,670	2,000	15.7	3.6
2	PPSEZ	PZ	10.56	19.9	25.00	Improvement	Open Cannal	7,010	1,500	14.4	3.6
3	NR.3 West	NW	27.36	13.7	35.00	Improvement	Open Cannal	7,150	2,300	19.0	3.6
4	Krang Pongro	KP	11.01	29.3	27.00	Improvement	Open Cannal	4,490	1,500	15.0	3.6
5	Pratek Lang Channel	PLC	7.17	26.8	17.00	Improvement	Open Cannal	5,720	1,500	13.0	3.6
6&8	Cheung Aek Channel & Tuol Pongro	CAC1	10.26	24.2	28.00	Improvement	Open Cannal	7,730	3,000	22.0	3.6
		CAC2	2.02	36.4	9.00	Improvement	Open Cannal	1,840	1,300	18.0	2.6
		TP1	11.68	29.7	45.00	Improvement	Open Cannal	2,220	2,200	38.0	2.6
		TP2	33.00	23.8	101.00	New Construction	Open Cannal	2,560	2,000	53.0	2.6
		TP3	45.28	19.5	113.00	New Construction	Open Cannal	670	3,400	47.9	3.6
		P_{CT}				New Construction	Pumping Station				
		R_{CT}				New Construction	Regulation Pond				
7	Preaek Thloeng	PT	8.53	31.1	23.00	New Construction	Open Cannal	2,740	1,800	14.6	3.6
9	Pochentong East	PE1	7.57	32.4	28.00	New Construction	Box Culvert	1,010	2,600	W3.5m x H2.5m x 3 Barrel	
		PE2	18.23	24.8	51.00	New Construction	Box Culvert	2,880	2,600	W4m x H3m x 4 Barrel	
		P_{PE}				New Construction	Pumping Station				
		R_{PE}				New Construction	Regulation Pond				
		PE3						2,660	1,800	20.0	
10	Tamok East	TE1	22.52	13.9	35.00	New Construction	Open Cannal	12,460	3,000	24.5	3.6
		TE2	25.46	12.8	46.00	New Construction	Open Cannal	2,320	2,000	57.0	3.6
		TE3	26.60	11.2	58.00	New Construction	Open Cannal	1,840	2,000	102.0	3.6
11	Hanoi West	HW1	59.46	16.8	109.00	Improvement	Open Cannal	5,290	2,700	42.4	3.6
		HW2	12.20	33.8	45.00	Improvement	Open Cannal	2,560	2,000	21.0	3.6
		HW3				New Construction	RCP	450		φ1800 x 3 Barrel	
		P_{HW}				New Construction	Pumping Station				
		R_{HW}				New Construction	Regulation Pond				
12&13	Poung Peay & O'veng	PP1	24.98	19.2	83.00	Improvement	Open Cannal	5,460	3,200	36.8	3.6
		PP2	49.59	16.0	137.00	Improvement	Open Cannal	3,100	3,600	56.8	3.6
		PP3				New Construction	RCP	310		φ2000 x 4 Barrel	
		P_{PP}				New Construction	Pumping Station				
		OV	15.04	19.6	51.00	Improvement	Open Cannal	7,310	2,800	24.9	3.6
		R_{PP}				New Construction	Regulation Pond				
14	Preaek Maot Kandol	PMK	22.43	24.0	65.00	Improvement	Open Cannal	7,000	3,000	30.1	3.6
15	Chbar Ampov West	CAW1	1.22	42.4	12.00	Improvement	Open Cannal	2,140	1,900	13.0	3.6
		CAW2	1.36	41.3	13.00	Improvement	Open Cannal	1,040	2,100	13.0	3.6
		CAW3	2.19	47.7	24.00	Improvement	Open Cannal	1,460	1,900	14.9	3.6
		P_{CAW}				New Construction	Pumping Station				
16	Chbar Ampov Middle	CAM	25.63	27.3	84.00	New Construction	Open Cannal	5,300	3,200	37.2	3.6
		P_{CAM}				New Construction	Pumping Station				
		R_{CAM}				New Construction	Regulation Pond				
17	Chbar Ampov East										
18	Satellite City	SC	4.63	34.9	18.00	New Construction	Open Cannal	4,780	1,700	13.0	3.6
19	Cheung Aek Lake	CAL1	27.45	19.9	66.00	Improvement	Open Cannal	4,230	3,000	30.5	3.6
		CAL2	4.05	45.5	23.00	Improvement	Open Cannal	2,820	1,500	18.5	3.6
20	Bak Khaeng					No Proposed Works					
21	Chroy Changvar	CC	2.10	38.3	9.00	New Construction	Box Culvert	1,650	1,000	W3.0m x H3.0m	
22	Wat Phnom North		Drainage Pipe Under Ground Reservoir Pumping Station, will be constructed in Phase IV.								
23	Trabek		Implemented in Phase II & Phase III but mechanical screen will be installed in existing Pumping Station.								
24	Tumpun		Implemented in Phase I.								
25	Tamok West					No Proposed Works					
26	Prek Thnot South					No Proposed Works					
27	City Core North Area		Box Culvert and Sluiceway will be constructed in Phase IV.								

Source: JICA Study Team



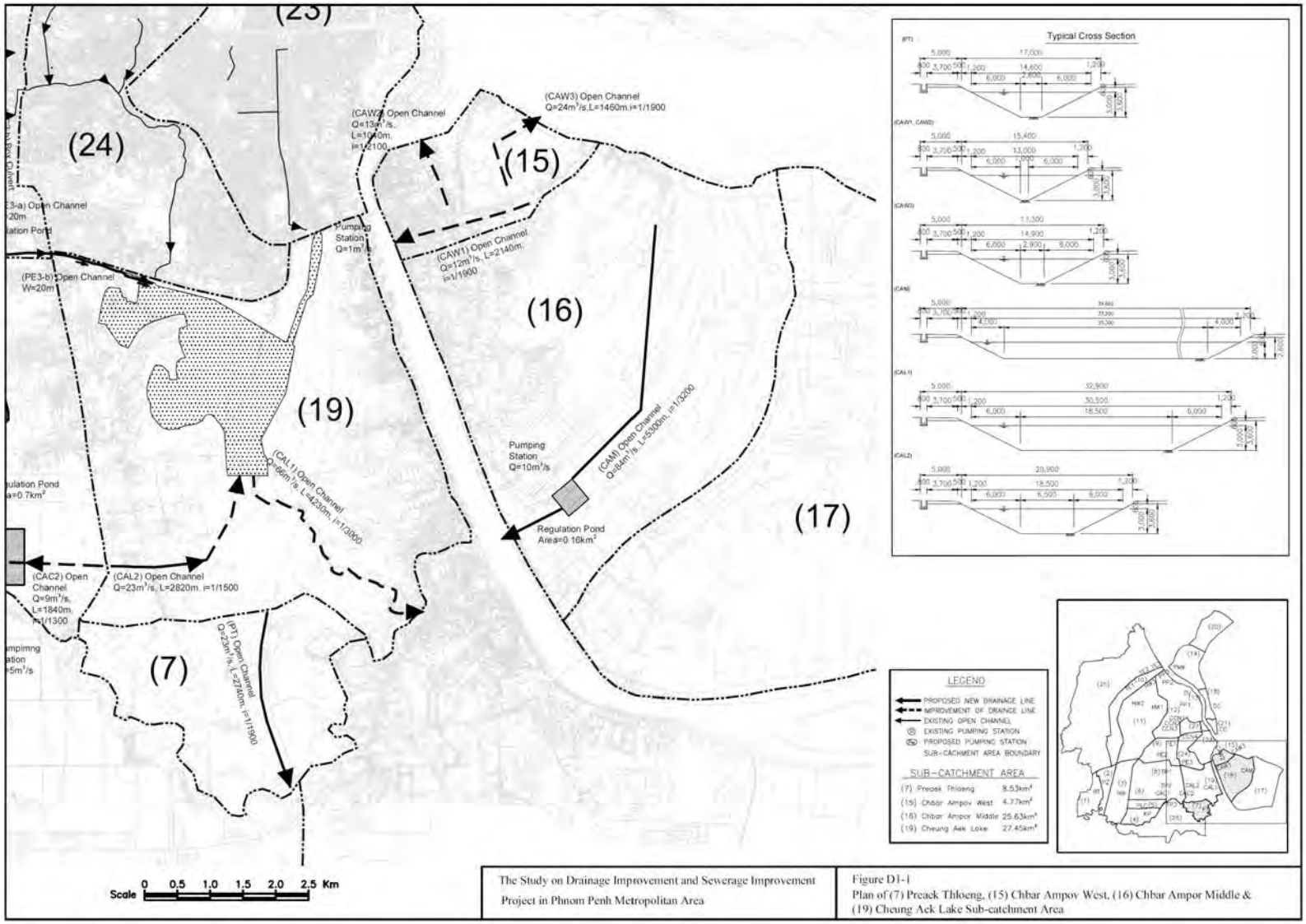
Source: JICA Study Team

Fig. 6.2.2 General Map of Drainage Improvement (1/7) (Boeung Thom/PPSEZ/NR. 3 West Drainage Areas)



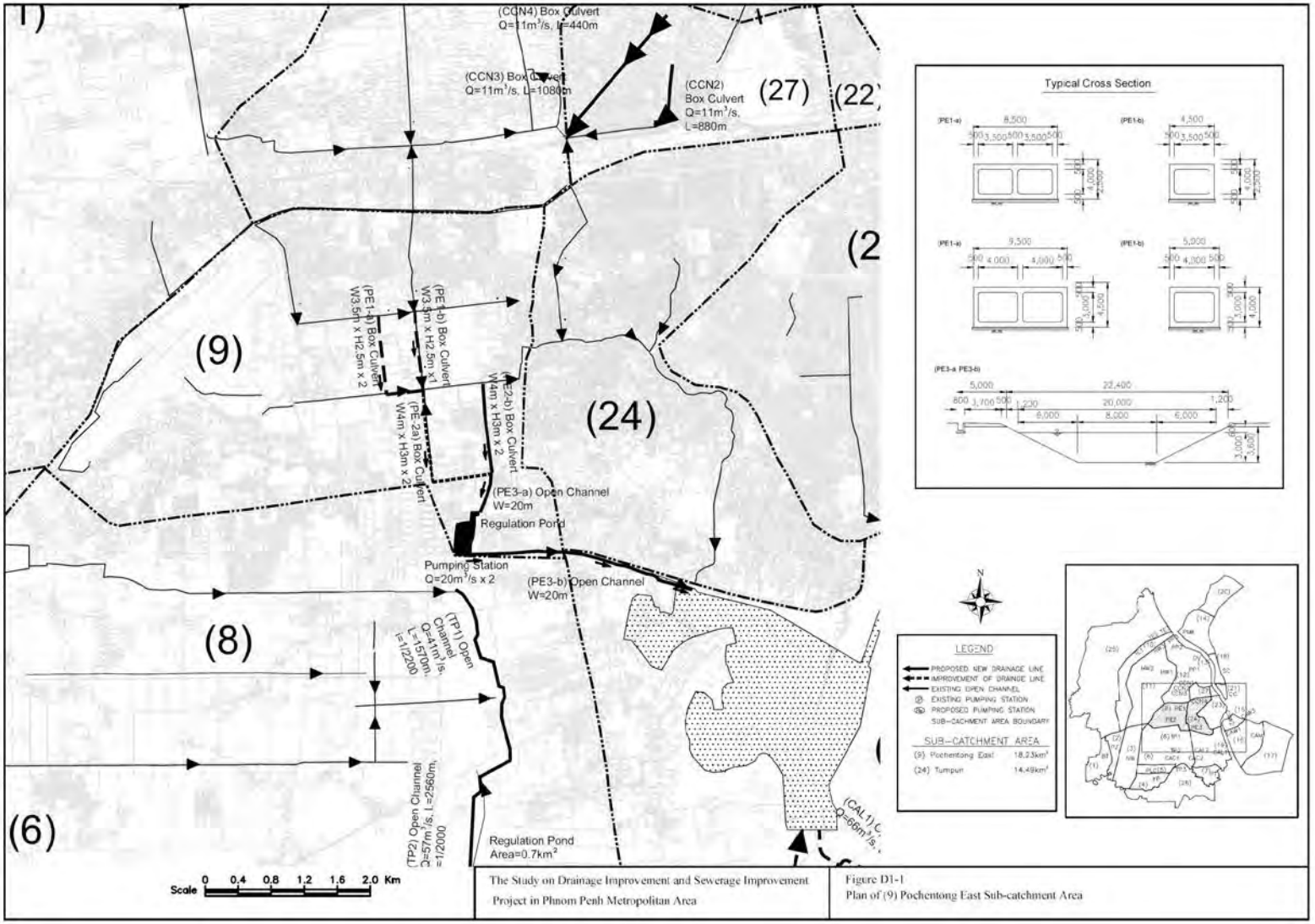
Source: JICA Study Team

Fig. 6.2.3 General Map of Drainage Improvement (2/7) (Krang Pongro/Pratek Lang Channel/Tuol Pongro Drainage Areas)



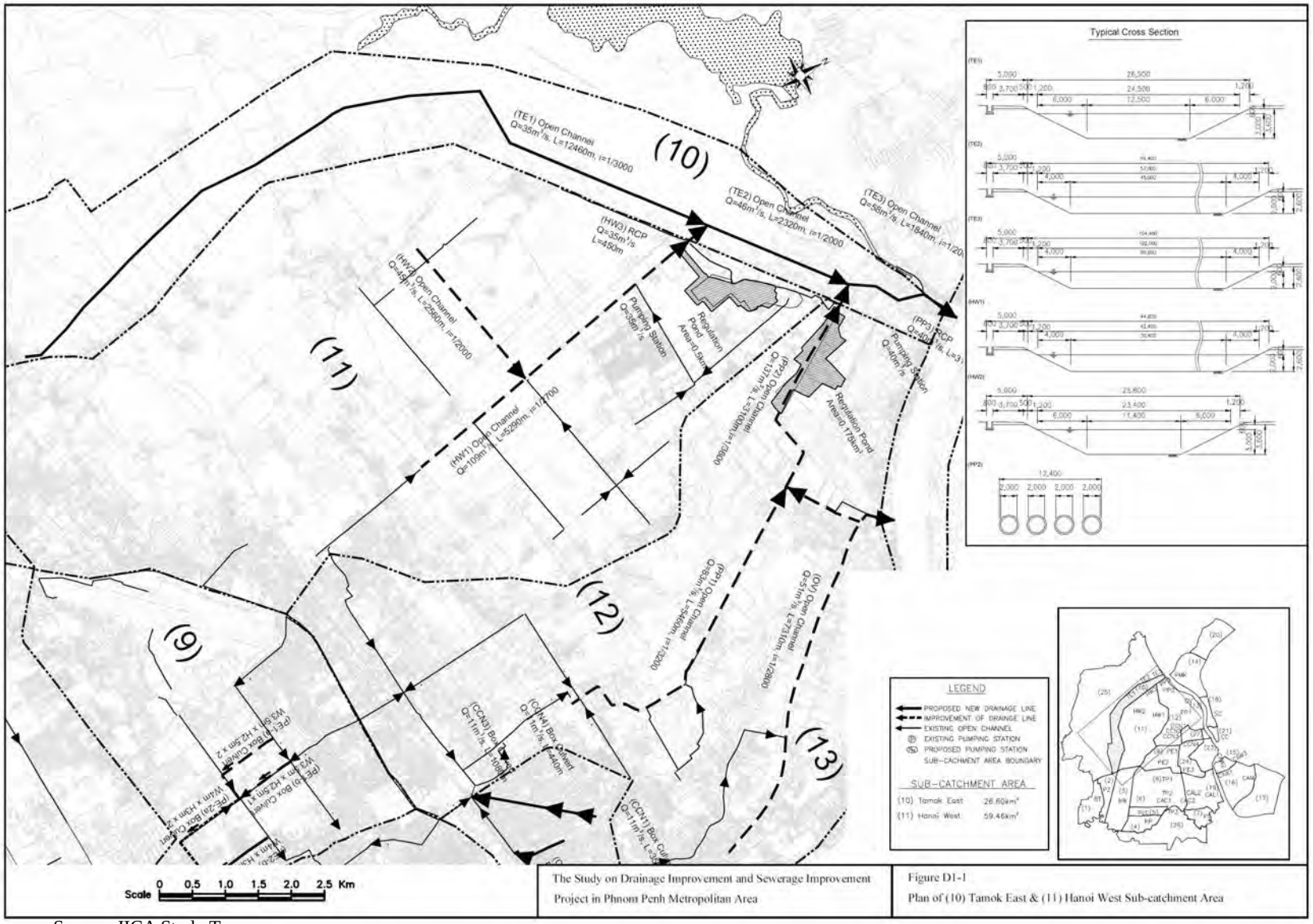
Source: JICA Study Team

Fig. 6.2.4 General Map of Drainage Improvement (3/7) (Preaek Thloeng/Chbar Ampov Middle/Cheung Aek Lake Drainage Areas)



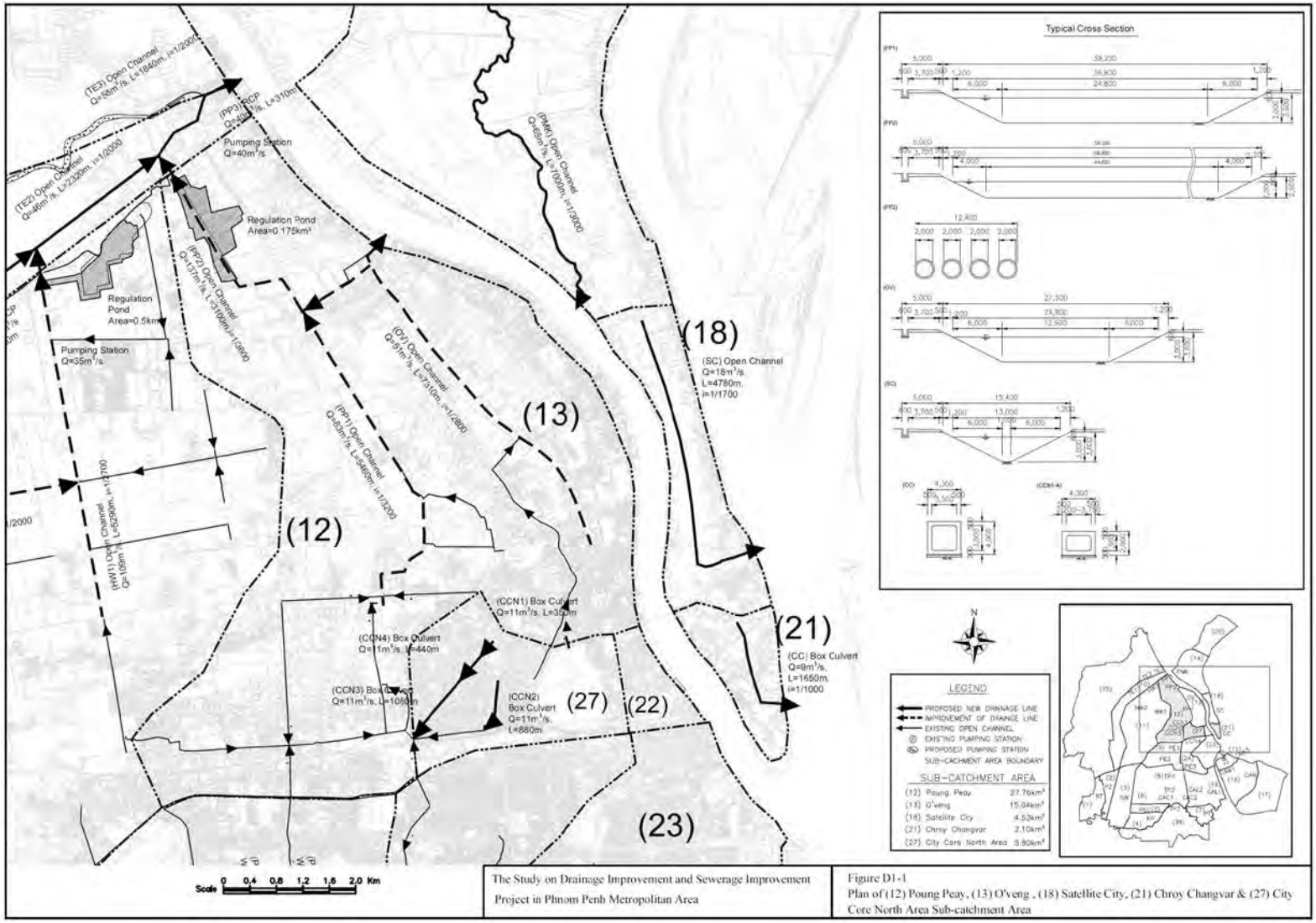
Source: JICA Study Team

Fig. 6.2.5 General Map of Drainage Improvement (4/7) (Pochentong East Drainage Area)



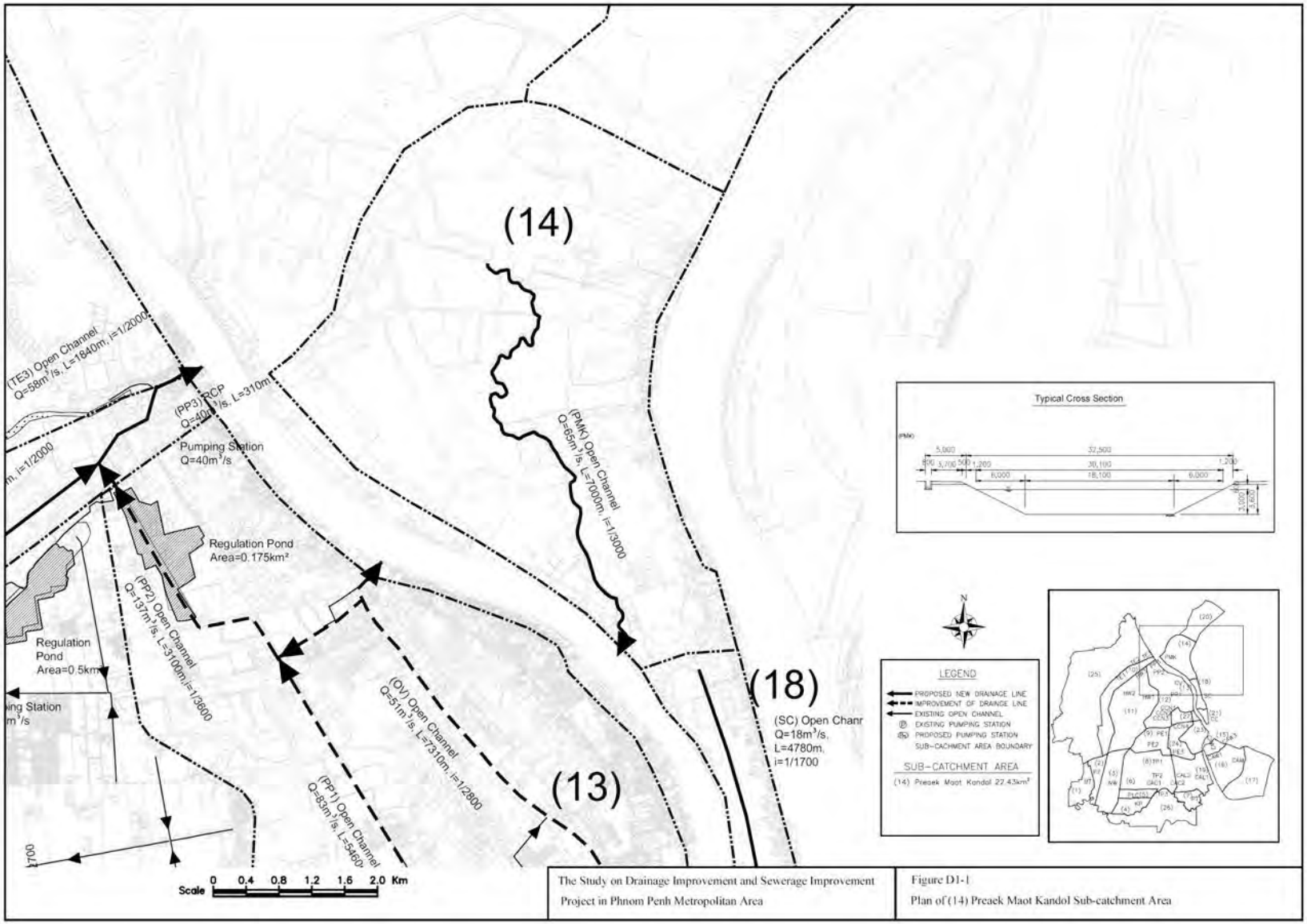
Source: JICA Study Team

Fig. 6.2.6 General Map of Drainage Improvement (5/7) (Tamok East/Hanoi West Drainage Areas)



Source: JICA Study Team

Fig. 6.2.7 General Map of Drainage Improvement (6/7) (Poung Peay/O'veng/Satellite City/Chroy Changvar/City Core North Area Drainage Areas)



Source: JICA Study Team

Fig. 6.2.8 General Map of Drainage Improvement (7/7) (Preaek Moat Kandol Drainage Area)

6.2.4 Planning of Pumping Stations

(1) Calculation of Discharge Capacities (Model of River Channel Analysis: One-Dimensional Unsteady Flow Model)

Flow condition of channels flowing through low-lying areas is influenced by confluences of branch channels, as well as retention in the channels. Therefore, evaluation of fluctuation of water level and flow rate is necessary to estimate capacities of pumping stations. One-dimensional unsteady flow model, which can estimate water level and flow rate for each section, is employed (see **Table 6.2.4**).

Table 6.2.4 Summary of River Channel Analysis Model

Item	Contents
Hydraulic model	One-dimensional unsteady flow model (Dynamic wave model: DHI-MIKE11 HD model)
Drainage network of planning	Determination of drainage network for each alternative
Cross sections	Set according to planned cross sections
Structure	Drainage facilities (Pumping station)
Flow hydrograph	Hydrograph is drawn using synthetic rational formulas, obtaining the same peak flow by shortening or lengthening the graph.

Source: JICA Study Team

(2) Calculation Results of Capacity for Pumping Station

Pumping stations are necessary to pump water from low-land area to the higher outlet located at the downstream end. Discharge capacity of pumping stations is computed employing one-dimensional unsteady flow to consider retention in channels and not to allow the water overflow. The results are summarised in **Table 6.2.5**.

Table 6.2.5 Summary of Capacity of Pumping Station

Catchment No.	Catchment Name	Flow Capacity (m^3/s)	Head (m)	Land Requirement (m^2)	Landowner
6&8	Cheung Aek Channel & Tuol Pongro	5	5	2,500	Private
9	Pochentong East	40	5	6,000	Public
11	Hanoi West	35	5	5,500	Public
12&13	Poung Peay & O'veng	40	5	6,000	Public
15	Chbar Ampov West	1	4	500	Public
16	Chbar Ampov Middle	10	6	4,000	Private

Source：JICA Study Team

(3) Plan of Regulation Pond

Required area and volume of regulation pond at the end of each drainage area are summarized in **Table 6.2.6**.

Table 6.2.6 Features of Regulation Pond

Drainage Area No.	Name of Drainage Area	Area (m^2)	Volume (m^3)	Landowner
6&8	Cheung Aek Channel & Tuol Pongro	700,000	700,000	Private
9	Pochentong East	25,000	100,000	Public
11	Hanoi West	500,000	600,000	Private/ Public
12&13	Poung Peay & O'veng	175,000	350,000	Private/ Public
16	Chbar Ampov Middle	160,000	160,000	Private

Source：JICA Study Team

6.3 Maintenance Plan

6.3.1 Drainage Channels and Pipes

(1) Agency in Charge

DSD/DPWT is responsible for operation and maintenance of the drainage channels and pipes as before.

(2) Methodology for Maintenance

Maintenance of open channels and pipes, which are major facilities of the drainage system, is quite important. However, it is particularly difficult to check damage and abnormalities of pipes because they are buried underground. It is therefore essential to reduce sedimentation of sludge/garbage in the pipes and thereby prevent clogging. The items of maintenance for channels and pipes are shown in **Table 6.3.1**.

Table 6.3.1 Items of Maintenance for Drainage Channels and Pipes

Item	Details	Frequency
Periodical inspection	● Check of amount of sedimentation ● Check of damage of road above pipelines ● Check of damage (crack, penetration of root of street trees) ● Check of infiltration of groundwater ● Check of illegal connection ● Check of status of manhole cover ● Records of inspection work	Once at least every 2 to 3 years
Cleaning/dredging	● Implementation of cleaning or dredging according to results of inspection (Cleaning work is implemented using high pressure cleaning equipment)	Frequency is set based on volume of sedimentation
Repair/rehabilitation	● Repair and rehabilitation of damaged part	

Source : JICA Study Team

6.3.2 Pumping Station and Regulation Pond

(1) Agency in Charge

DSD/DPWT is responsible for operation and maintenance of the drainage channels and pipes as before.

(2) Methodology for Maintenance

Maintenance of pumping stations is essential because malfunctions exert a great impact on the entire drainage system especially in urban areas. Regulation ponds are fundamental to cut peak flow in the rainy events and reduce burden to channels and pumping stations in the downstream. Before the rainy season, it is necessary to clean inside of the regulation ponds in order to ensure storage capacity. Required maintenance items for pumping station and regulation ponds are summarized in **Table 6.3.2**.

Table 6.3.2 Items of Maintenance for Pumping Station and Regulation Pond

Item	Details	Frequency
Pumping station	● Check of current and voltage ● Check of abnormal noise/vibration ● Check of leakage/float switch ● Check of main body ● Check of lubricating oil ● Overhaul	Everyday Everyday Once a month Once every 3 months Once every 3 months (Oil change: once a year) Once every 2 years

Item	Details	Frequency
Regulation pond	● Removal of trash/sludge in the pond	At least once before the rainy season

Source: JICA Study Team

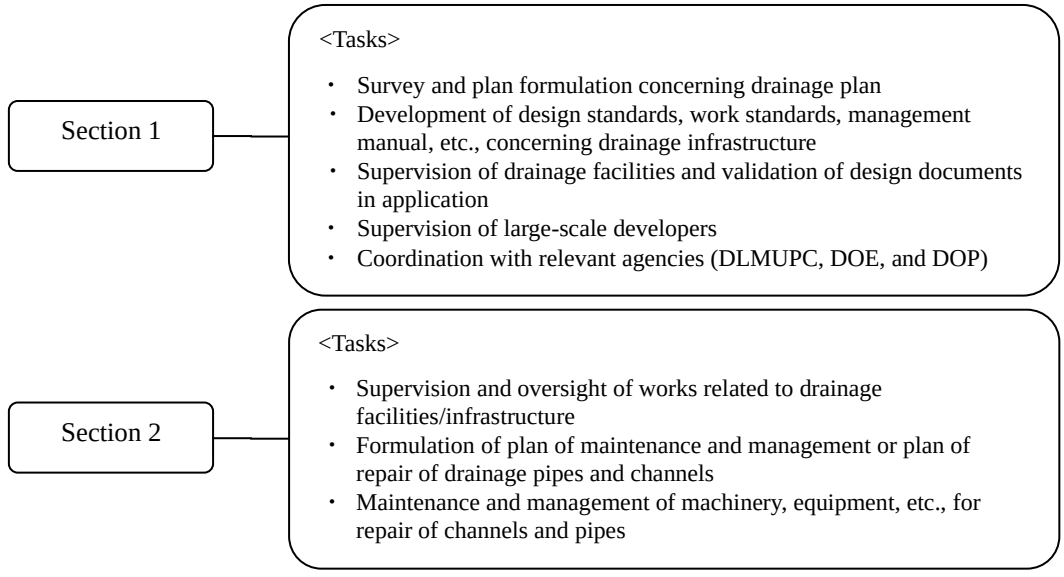
6.4 Review of Organization and Legal Framework of Drainage Management

PPCC had established its drainage facilities in accordance with the details stipulated in "M/P 1999." In the PPCC, in the areas in need of large-scale and systematic work or urgent measures, ADB's financial assistance, the Japanese Grant Aid project (Phases 1-3) and other programs helped in solving the City's drainage issues. As a result, in PPCC, especially in the existing suburban areas, drainage pipes, channels, manholes, and pumping stations were installed and/or established, mitigating flood damage. The total length of drainage pipes installed is increasing year after year.

6.4.1 Review of Organization

As discussed above, stormwater drainage infrastructure has been established in an orderly manner, thanks to donations and aids, and, the DSD, a division within DPWT responsible for maintenance and management of the infrastructure, has been organized and their staffing and assets have been improved. However, the capacity of DSD is still insufficient in manpower and equipment to manage the drainage infrastructure covering the entire PPCC as proposed in this M/P. It is essential to develop their capacities for formulating drainage infrastructure plans and stipulating design standards, in relation to the large-scale development rapidly growing in recent years, as well as to clarify the scope of responsibilities.

Against this backdrop, with the aim to clarify which posts are responsible for the drainage infrastructure establishment/improvement in relation to the large-scale development and development of their abilities, it is proposed that the current DSD Technical Section is divided into two sections to be responsible for respective tasks as presented in **Fig. 6.4.1**. (For information on current organizational structure, refer to **Fig. 2.6.7**, DSD Organization Chart.)



Source: JICA Study Team

Fig. 6.4.1 Proposal to divide the DSD Technical Section

To develop their capacities to carry out work, drainage technicians shall be invited (for 2-3 year term) to enhance those of the available technician workforce. In addition, young staffs shall be dispatched to developed countries for training and become key persons. These key persons shall be the core of the

technicians in DSD. At the same time, an internal training system based such activities as OJT shall be established in DSD.

6.4.2 Review of Legal Framework

In Cambodia, if a master plan for land-use has not been provided, a large-scale residential development or similar project requires MLMUPC's approval, in accordance with Royal Decree No. 86 concerning construction permits. Although Article 31 of the decree provides rules for sewer connection, there is no clear indication of specific permission criteria for stormwater drainage facilities/infrastructure.

To control stormwater drainage for large-scale residential development or similar projects, it is necessary to clarify such matters as the legal criteria and regulation of improving or developing infrastructure in the areas, and obligations and responsibilities of the developer.

As described in **Subsection 4.4.2**, to realize sound development in the City and a good urban environment in the development area in accordance with the Urban Development Master plan and relevant laws, developers engaging in large-scale residential development need to provide a part of the infrastructures such as roads, public facilities, public facilities, waste facilities, water supply facilities, drainage facilities, disaster management and safety facilities, and/or planned green zones as a condition of the development permit, subject to negotiation with the relevant offices (such as MIH, DOE, DLMUPC, DPWT, and WMD). Therefore, the Study Team proposes that the relevant offices collaborate with each other to develop the standards of development, criteria, and guidelines on improving/establishing the infrastructure in the development area, so as to determine a unified process of notifying the development area, condition of permit, obligations of developer, and administrative procedures necessary for development and to ensure thorough supervision of the developers.

In principle, the criteria/standards of development permit closely related to drainage management shall enforce the developers to install drainage facilities to discharge stormwater from entire development area into public water. However, if the drainage capacity of the downstream of the area is not enough, it is proposed that the developer shall create a regulating reservoir within the development area to temporarily retain stormwater.

6.5 Phased Implementation Plan

Phased implementation plan is formulated in consideration of the following preconditions.

(1) Each drainage area is classified into 4 groups by priority.
(2) Four groups are formulated, based on EIRR.
(3) Drainage area located in large-scale development area is categorized into lower group regardless of EIRR, because drainage facilities in the area should be constructed by the developer and progress of the development is unclear.

Based on the above preconditions, priority of each drainage area is set as shown in **Table 6.5.1**.

Table 6.5.1 Priority of Implementation for Each Drainage Area

No.	Sub-Catchment Area	Population in 2035 (person)	Area (km^2)	Population density person/km	Resettle-ment (house)	Land expropriation (m^2)	Con-struction cost M USD	O&M cost M USD	EIRR %	Ranking of EIRR	Priority	Remarks
1	Boeung Thom	19,900	15.39	1,293	0	71,932	5.8	0.028	2.7	14	3	Subsequently implemented after improvement of PPSEZ
2	PPSEZ	13,800	10.56	1,307	5	10,655	10.9	0.047	10.2	7	2	EIRR 10~15
3	NR.3 West	43,100	27.36	1,575	36	54,340	14.4	0.070	2.3	15	4	EIRR<5
4	Krang Pongro	8,100	11.01	736	2	7,184	8.6	0.032	0.0	18	4	EIRR<5
5	Pratek Lang Channel	7,400	7.17	1,032	10	6,864	9.0	0.032	-3.3	19	4	EIRR<5
6&8	Cheung Aek Channel & Tuol Pongro	122,800	49.44	2,484	81	879,943	48.2	0.384	12.9	5	2	EIRR 10~15
7	Preaek Thloeng	29,600	8.53	3,470	2	51,293	3.7	0.019	0.3	17	4	Commercial area developed in medium- or long-term
9	Pochentong East	183,300	18.23	10,055	40	26,915	89.6	1.172	13.3	4	2	EIRR 10~15
10	Tamok East	63,100	26.60	2,372	154	549,374	53.6	0.318	-9.2	20	4	EIRR<5
11	Hanoi West	287,200	59.46	4,830	28	512,273	62.6	1.167	5.7	10	3	EIRR 5~10
12&13	Poung Peay & O'veng	359,000	43.79	8,198	90	182,507	82.0	1.409	10.4	6	2	EIRR 10~15
14	Preaek Maot Kandol	78,100	22.43	3,482	47	20,160	24.8	0.122	3.6	12	4	Commercial area developed in medium- or long-term
15	Chbar Ampov West	67,600	4.77	14,172	179	0	8.8	0.087	8.4	8	3	EIRR 5~10
16	Chbar Ampov Middle	118,200	25.63	4,612	17	355,040	27.0	0.423	0.6	16	4	Commercial area developed in medium- or long-term
17	Chbar Ampov East	61,700	34.32	1,798	-	-	-	-	0	-	-	
18	Satellite City	42,000	4.63	9,071	4	83,363	9.4	0.027	5.4	11	3	EIRR 5~10
19	Cheung Aek Lake	212,800	23.28	9,141	152	50,760	18.3	0.091	3.6	13	4	Commercial area developed in medium- or long-term
20	Bak Khaeng	10,200	18.74	544	-	-	-	-	-	-	-	
21	Chroy Changvar	23,700	2.10	11,286	42	0	6.1	0.002	6.3	9	3	EIRR 5~10
22	Wat Phomn North	20,000	1.17	17,094	0	0	10.3	0.007	15.8	2	1	EIRR>15
23	Trabek	372,400	13.01	28,624	0	0	2.5	0.040	16.1	1	1	EIRR>15
24	Tumpun	471,800	14.49	32,560	-	-	-	-	-	-	-	
25	Tamok West	121,700	133.85	909	-	-	-	-	-	-	-	
26	Prek Thnot South	54,500	39.97	1,364	-	-	-	-	-	-	-	
27	City Core North Area	74,800	5.80	12,897	18	0	9.1	0.002	15.2	3	1	EIRR>15
TOTAL		2,866,800	621.73		907	2,862,603	504.7	5.479				

Note 1) Priority is firstly classified into the following 4 groups based on the EIRR
- Group 1: Drainage area with EIRR of 15% or more
- Group 2: Drainage area with EIRR of 10% to less than 15%
- Group 3: Drainage area with EIRR of 5% to less than 10%
- Group 4: Drainage area with EIRR of less than 5%

Note 2) Boeng Thom Drainage Area falls in Group 3, because the area should be improved immediately after PPSEZ area to optimize the improvement works done in the areas.

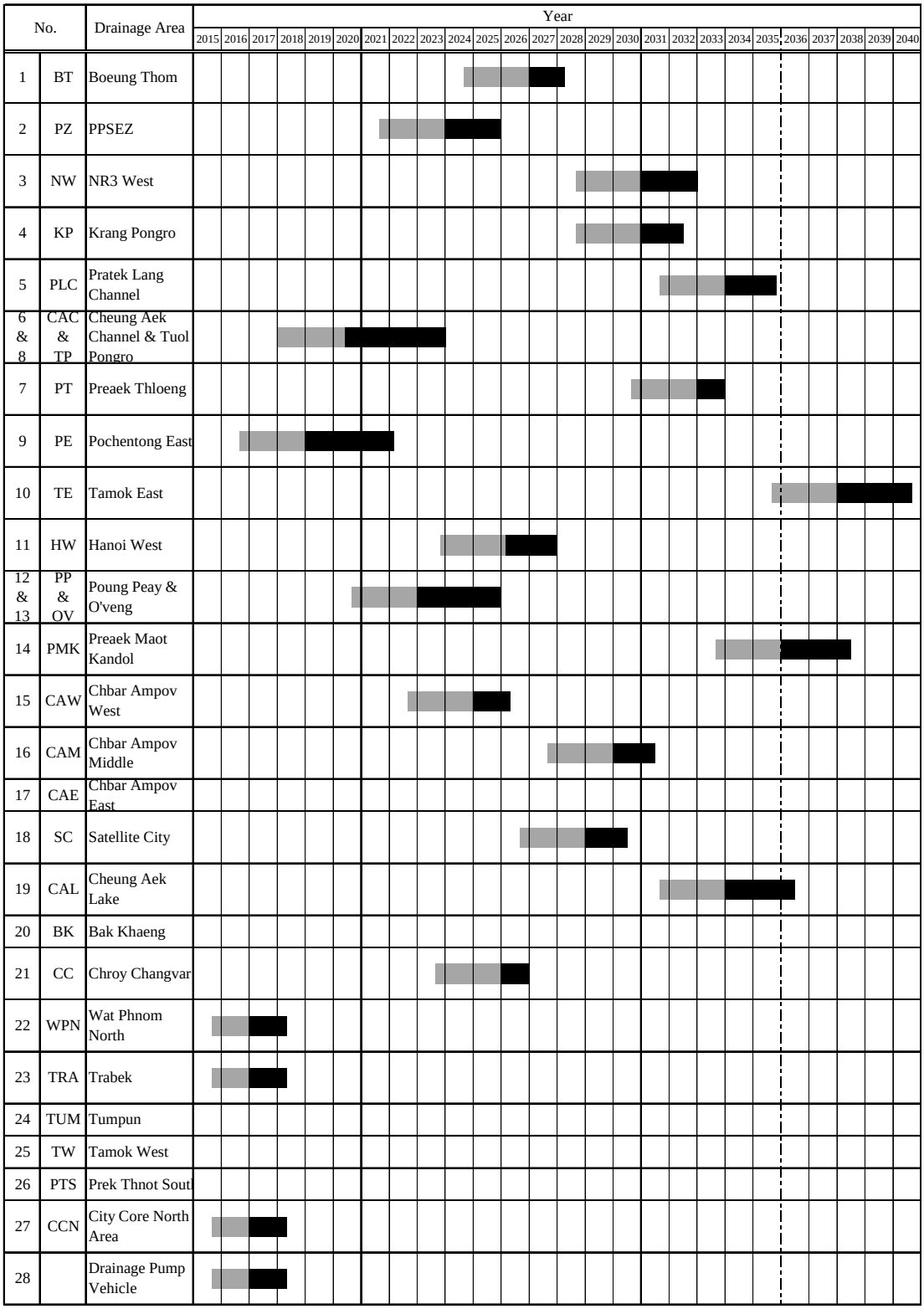
Source: JICA Study Team

Phased implementation plan based on the order of priority in **Table 6.5.1** is shown in **Table 6.5.2**. Construction period in the implementation plan is established based on similar projects implemented in PPCC. Each project component has 28 months of preparation period, including F/S, financial preparation and designing study periods of 8, 12 and 10 months.

In short, the priority of projects is in principle determined based on the economic benefit, which is represented by EIRR. As a result, projects in the city centre of PPCC are to be implemented in the

early stages and then the projects in the drainage area surrounding the city centre are implemented in the next stage depending on the progress of urbanization.

Table 6.5.2 Phased Implementation Plan



Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	Total
Project cost (million USD)	0.0	28.8	0.0	108.8	72.2	0.0	0.0	102.4	13.5	12.4	91.1	8.1	0.0	12.7	38.1	29.1	0.0	5.3	35.4	0.0	30.7	0.0	74.3	0.0	0.0	0.0	662.2
O&M cost (million USD/year)	0.00	0.00	0.00	0.07	0.07	0.07	0.07	1.05	1.24	1.63	1.63	3.14	3.17	4.36	4.37	4.38	4.61	4.83	4.92	4.94	5.07	4.99	5.03	5.10	5.16	5.50	75.38
Non-structural measures																											
Strengthening of O&M capacity											Continued																
Strengthening of regulating large-scale development area														In operation													

F/S/Investment Preparation/Design Study Construction

Source: JICA Study Team

6.6 Cost Estimation

6.6.1 General Conditions

Project cost consists of construction cost, administration cost, engineering cost and land expropriation/compensation cost. These costs are estimated based on the general conditions as shown in **Table 6.6.1** based on the exchange rate of 1USD=119.64JPY, and 1Riel=0.030JYP, as of April 2015.

Table 6.6.1 General Conditions for Cost Estimation

No.	Items	Conditions
1	Construction cost	Material and equipment cost, Labor cost, Transportation cost and so on
2	Administration cost	5% of construction cost
3	Engineering cost	10% of construction cost
4	Physical contingency	5% of construction and engineering cost
5	Land expropriation/ compensation cost	Required in construction of pumping stations and regulation ponds

Source: JICA Study Team

Facilities construction costs are estimated based on the following conditions:

- Construction cost is estimated based on the drainage management plan, targeting 25 drainage areas.
- Construction cost is estimated based on the cost of similar projects implemented by the donors such as JICA and ADB, considering price escalation.
- Civil and architectural material cost, labor cost, construction equipment cost are estimated based on the prices obtained in Cambodia because these are procured in Cambodia. On the other hand, some steel products and construction equipment cost are estimated based on the prices obtained in the other countries such as Japan because these are not available in Cambodia.
- Such mechanical and electrical equipment in pumping station is in general procured from other countries, considering cost effectiveness, liability and easy O&M.
- Construction cost of regulation ponds are estimated considering available land verified in the field survey and simulation results of stormwater run-off.
- House relocations are minimized as much as possible.
- Implementation plan is proposed in consideration of geological, meteorological and related regulations.
- O&M cost is estimated considering the costs for existing facilities.
- Construction plan for pipe-laying under the existing road, is formulated to minimize traffic hindrance and interference to existing drainage channels by establishing temporary facilities such as diversion channel.

6.6.2 Construction Cost (Project Cost)

Cost estimation is summarized in **Table 6.6.2**. As shown in the table, total project cost is estimated at 662.2 million USD, of which construction cost amounts to 506.5 million USD. In addition, cost disbursement schedule for drainage management projects is shown in **Tables 6.6.3** and **6.6.4**.

Table 6.6.2 Summary of Cost Estimation

Unit: million USD

Item	Foreign currency	Local currency	Total
I. Construction Cost	86.4	420.1	506.5
1) Boeung Thom	0.1	5.7	5.8
2) PPSEZ	0.1	10.8	10.9
3) NR.3 West	0.2	14.2	14.4
4) Krang Pongro	0.1	8.5	8.6
5) Pratek Lang Channel	0.1	8.9	9.0
6&8) Cheung Aek Channel & Tuol Pongro	3.6	44.6	48.2
7) Preaek Thloeng	0.0	3.7	3.7
9) Pochentong East	31.4	58.2	89.6
10) Tamok East	0.6	53.0	53.6
11) Hanoi West	19.1	43.5	62.6
12&13) Poung Peay & O'veng	16.8	65.2	82.0
14) Preaek Maot Kandol	0.3	24.5	24.8
15) Chbar Ampov West	0.7	8.1	8.8
16) Chbar Ampov Middle	6.4	20.6	27.0
17) Chbar Ampov East			
18) Satellite City	0.1	9.3	9.4
19) Cheung Aek Lake	0.2	18.1	18.3
20) Bak Khaeng			
21) Chroy Changvar	0.7	5.4	6.1
22) Wat Phnom North	1.1	9.2	10.3
23) Trabek	2.0	0.5	2.5
24) Tumpun			
25) Tamok West			
26) Prek Thnot South			
27) City Core North Area	1.2	7.9	9.1
28) Drainage Pump Vehicle[1)]	1.6	0.2	1.8
II. Administration cost	0.0	25.3	25.3
III. Engineering cost	40.5	10.1	50.6
IV. Physical contingency	6.3	21.5	27.8
V. Land expropriation/ compensation cost	0.0	52.0	52.0
Grand total (I+II+III+IV+V)	133.2	529.0	662.2

Note 1) Drainage pump vehicle is a component not included in specific drainage area but covers all drainage areas for emergency. Similarly, **Tables 6.6.3** and **6.6.4** are formulated including procurement of drainage pump vehicle.

Source: JICA Study Team

Table 6.6.3 Cost Disbursement Schedule (Drainage Management 1/2)

Items	2016			2017			2018			2019			2020			2021			2022			2023			2024			2025			2026			2027			2028		
	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total
A. Cost covered by loan（I+II+III）	8.2	19.2	27.4	0.0	0.0	0.0	40.5	63.0	103.5	7.9	47.9	55.8	0.0	0.0	0.0	0.0	0.0	0.0	24.6	70.1	94.7	1.1	11.6	12.7	1.5	8.7	10.2	26.6	52.8	79.4	0.6	6.1	6.7	0.0	0.0	0.0	0.9	10.0	10.9
I. Construction cost	5.9	17.8	23.7	0.0	0.0	0.0	31.4	58.2	89.6	3.6	44.6	48.2	0.0	0.0	0.0	0.0	0.0	0.0	16.8	65.2	82.0	0.1	10.8	10.9	0.7	8.1	8.8	19.8	48.9	68.7	0.1	5.7	5.8	0.0	0.0	0.0	0.1	9.3	9.4
1 Boeung Thom																															0.1	5.7	5.8						
2 PPSEZ																						0.1	10.8	10.9															
3 NR.3 West																																							
4 Krang Pongro																																							
5 Pratek Lang Channel																																							
6&8 Cheung Aek Channel & Tuol thloeng										3.6	44.6	48.2																											
7 Preaek Thloeng																																							
9 Pochentong East							31.4	58.2	89.6																															
10 Tamok East																																							
11 Hanoi West																												19.1	43.5	62.6									
12&13 Poung Peay & O'veng																			16.8	65.2	82.0																		
14 Preaek Maot Kandol																																							
15 Chbar Ampov West																									0.7	8.1	8.8												
16 Chbar Ampov Center																																							
17 Chbar Ampov East																																							
18 Satellite City																																					0.1	9.3	9.4
19 Cheung Aek Lake																																							
20 Bak Khaeng																																							
21 Chroy Changvar																												0.7	5.4	6.1									
22 Wat Phnom North	1.1	9.2	10.3																																				
23 Trabek	2.0	0.5	2.5																																				
24 Tumpun																																							
25 Tamok West																																							
26 Prek Thnot South																																							
27 City Core North Area	1.2	7.9	9.1																																				
28 Drainage Pump Vehicle	1.6	0.2	1.8																																				
II. Consultant fee	1.9	0.5	2.4	0.0	0.0	0.0	7.2	1.8	9.0	3.9	1.0	4.9	0.0	0.0	0.0	0.0	0.0	0.0	6.6	1.6	8.2	0.9	0.2	1.1	0.7	0.2	0.9	5.5	1.4	6.9	0.5	0.1	0.6	0.0	0.0	0.0	0.8	0.2	1.0
III. Phisical contingency	0.4	0.9	1.3	0.0	0.0	0.0	1.9	3.0	4.9	0.4	2.3	2.7	0.0	0.0	0.0	0.0	0.0	0.0	1.2	3.3	4.5	0.1	0.6	0.7	0.1	0.4	0.5	1.3	2.5	3.8	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.5	0.5
B. Cost not covered by loan（IV＋V）	0.0	2.2	2.2	0.0	14.0	14.0	0.0	4.5	4.5	0.0	6.0	6.0	0.0	0.3	0.3	0.0	9.7	9.7	0.0	4.1	4.1	0.0	2.0	2.0	0.0	0.4	0.4	0.0	3.4	3.4	0.0	7.1	7.1	0.0	0.0	0.0	0.0	1.8	1.8
IV. Administration cost	0.0	1.2	1.2	0.0	0.0	0.0	0.0	4.5	4.5	0.0	2.4	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.1	4.1	0.0	0.5	0.5	0.0	0.4	0.4	0.0	3.4	3.4	0.0	0.3	0.3	0.0	0.0	0.0	0.0	0.5	0.5
V. Land expropriation/compensation cost	0.0	1.0	1.0	0.0	14.0	14.0	0.0	0.0	0.0	0.0	3.6	3.6	0.0	0.3	0.3	0.0	9.7	9.7	0.0	0.0	0.0	0.0	1.5	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.8	6.8	0.0	0.0	0.0	0.0	1.3	1.3
Total（A＋B）	8.2	21.4	29.6	0.0	14.0	14.0	40.5	67.5	108.0	7.9	53.9	61.8	0.0	0.3	0.3	0.0	9.7	9.7	24.6	74.2	98.8	1.1	13.6	14.7	1.5	9.1	10.6	26.6	56.2	82.8	0.6	13.2	13.8	0.0	0.0	0.0	0.9	11.8	12.7

Source: JICA Study Team

Table 6.6.4 Cost Disbursement Schedule (Drainage Management 2/2)

Items	2029			2030			2031			2032			2033			2034			2035			2036			2037			2038			2039			2040			合計		
	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total	F.C.	L.C.	Total
A. Cost covered by loan（I+II+III）	9.0	22.2	31.2	2.2	24.4	26.6	0.0	0.0	0.0	0.3	4.0	4.3	2.6	28.9	31.5	0.0	0.0	0.0	2.4	26.3	28.7	0.0	0.0	0.0	5.1	56.8	61.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	133.2	451.7	584.9
I. Construction cost	6.4	20.6	27.0	0.3	22.7	23.0	0.0	0.0	0.0	0.0	3.7	3.7	0.3	27.0	27.3	0.0	0.0	0.0	0.3	24.5	24.8	0.0	0.0	0.0	0.6	53.0	53.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	86.4	420.1	506.5
1 Boeung Thom																																					0.1	5.7	5.8
2 PPSEZ																																					0.1	10.8	10.9
3 NR.3 West				0.2	14.2	14.4																															0.2	14.2	14.4
4 Krang Pongro				0.1	8.5	8.6																															0.1	8.5	8.6
5 Pratek Lang Channel													0.1	8.9	9.0																						0.1	8.9	9.0
6&8 Cheung Aek Channel & Tuol thloeng																																					3.6	44.6	48.2
7 Preaek Thloeng										0.0	3.7	3.7																									0.0	3.7	3.7
9 Pochentong East																																					31.4	58.2	89.6
10 Tamok East																									0.6	53.0	53.6										0.6	53.0	53.6
11 Hanoi West																																					19.1	43.5	62.6
12&13 Poung Peay & O'veng																																					16.8	65.2	82.0
14 Preaek Maot Kandol																			0.3	24.5	24.8																0.3	24.5	24.8
15 Chbar Ampov West																																					0.7	8.1	8.8
16 Chbar Ampov Center	6.4	20.6	27.0																																		6.4	20.6	27.0
17 Chbar Ampov East																																							
18 Satellite City																																					0.1	9.3	9.4
19 Cheung Aek Lake													0.2	18.1	18.3																						0.2	18.1	18.3
20 Bak Khaeng																																							
21 Chroy Changvar																																					0.7	5.4	6.1
22 Wat Phnom North																																					1.1	9.2	10.3
23 Trabek																																					2.0	0.5	2.5
24 Tumpun																																							
25 Tamok West																																							
26 Prek Thnot South																																							
27 City Core North Area																																					1.2	7.9	9.1
28 Drainage Pump Vehicle																																					1.6	0.2	1.8
II. Consultant fee	2.2	0.5	2.7	1.8	0.5	2.3	0.0	0.0	0.0	0.3	0.1	0.4	2.2	0.5	2.7	0.0	0.0	0.0	2.0	0.5	2.5	0.0	0.0	0.0	4.3	1.1	5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.5	10.1	50.6
III. Phisical contingency	0.4	1.1	1.5	0.1	1.2	1.3	0.0	0.0	0.0	0.0	0.2	0.2	0.1	1.4	1.5	0.0	0.0	0.0	0.1	1.3	1.4	0.0	0.0	0.0	0.2	2.7	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.3	21.5	27.8
B. Cost not covered by loan（IV＋V）	0.0	1.4	1.4	0.0	4.3	4.3	0.0	0.2	0.2	0.0	10.7	10.7	0.0	1.4	1.4	0.0	0.0	0.0	0.0	1.2	1.2	0.0	0.0	0.0	0.0	2.7	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	77.3	77.3
IV. Administration cost	0.0	1.4	1.4	0.0	1.2	1.2	0.0	0.0	0.0	0.0	0.2	0.2	0.0	1.4	1.4	0.0	0.0	0.0	0.0	1.2	1.2	0.0	0.0	0.0	0.0	2.7	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.3	25.3
V. Land expropriation/compensation cost	0.0	0.0	0.0	0.0	3.1	3.1	0.0	0.2	0.2	0.0	10.5	10.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.0	52.0
Total（A＋B）	9.0	23.6	32.6	2.2	28.7	30.9	0.0	0.2	0.2	0.3	14.7	15.0	2.6	30.3	32.9	0.0	0.0	0.0	2.4	27.5	29.9	0.0	0.0	0.0	5.1	59.5	64.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	133.2	529.0	662.2

Source: JICA Study Team

6.6.3 Operation and Maintenance Cost

Annual operation and maintenance cost is summarized in **Table 6.6.5**. According to the table, annual operation and maintenance cost is estimated at 5.5 million USD for the target year 2040.

Table 6.6.5 Summary of O&M Cost

Unit: million USD

Item	Annual O&M cost
1) Boeung Thom	0.028
2) PPSEZ	0.047
3) NR.3 West	0.070
4) Krang Pongro	0.032
5) Pratek Lang Channel	0.032
6&8) Cheung Aek Channel & Tuol Pongro	0.384
7) Preaek Thloeng	0.019
9) Pochentong East	1.172
10) Tamok East	0.318
11) Hanoi West	1.167
12&13) Poung Peay & O'veng	1.409
14) Preaek Maot Kandol	0.122
15) Chbar Ampov West	0.087
16) Chbar Ampov Middle	0.423
17) Chbar Ampov East	
18) Satellite City	0.027
19) Cheung Aek Lake	0.091
20) Bak Khaeng	
21) Chroy Changvar	0.002
22) Wat Phnom North	0.007
23) Trabek	0.040
24) Tumpun	
25) Tamok West	
26) Prek Thnot South	
27) City Core North Area	0.002
28) Drainage Pump Vehicle	0.022
Annual total O&M cost	5.501

Note 1) Drainage pump vehicle is a component not included in specific drainage area but covers all drainage areas for emergency.

Source: JICA Study Team

6.7 Financial Analysis

The drainage project does not have user service fee revenues and so there is no need to make a financial analysis.

6.8 Economic Analysis

6.8.1 Preconditions for Economic Analysis

The investment and operational costs are clarified in **Section 6.6**. However, the investment costs are converted to border prices similar to the economic analysis on sewerage project.

The benefits of drainage project as follows are different from those of the sewerage project. The first benefit of the drainage project is avoidance of inundation. The inundation damage can be estimated based on the Social Survey result and **Table 6.8.1**.

Table 6.8.1 Average House Damages per Household in Three Districts

Relative water depth with average year water level (m)	House Damages in USD per household	Calculated recovery year = Damage/Recovery cost per year	Remarks
0	129.34	0.7	Actual damages in 2006
0.5	162.307	0.9	Potential damages
1	193.20	1.0	Potential damages
1.5	327.23	1.8	Potential damages
2	468.73	2.5	Potential damages

Source: Badri Bhakta Shrestha et al., International Centre for Water Hazard and Risk Management (ICHARM), "Assessment of Flood Hazards and Vulnerability in Cambodian Floodplain," 2013

However, the table above is derived from the rural areas in Cambodia. Therefore, the data above should be converted to damage in Phnom Penh using household income statistics (rural: 931,000Riel/month, Phnom Penh: 2,517,000Riel/month on average in 2013). When the relationship between inundation depth and damage (multiplying 2.7 times = 2,517/931 in order to convert from local damage to Phnom Penh damage) is estimated by linear regression, the regression coefficient, R, is 0.97, but the intercept is -283 so that if the depth is small, the damage becomes negative. Therefore, the depth is transformed logarithmically and the regression analysis is carried out. R becomes 0.99, higher than that of linear regression and an equation, $L_n(\text{Damage})=3.6548+0.0163\times\text{Depth}$, is obtained. Thus, an equation, the average house damage per household = $e^{3.6548+0.0163\times\text{Depth}}$, is obtained. In addition, it is supposed the damages are proportional to household income change year by year. Based on the frequency and depth of inundation in the Social Survey and **Table 6.8.1**, the damages per household in Phnom Penh are estimated as shown in **Table 6.8.2**.

Table 6.8.2 Average House Damage per Household in Phnom Penh

Depth (cm)	Damage (USD/HH)	Frequency		Share		Damage (USD/HH)		
		1/ year (Including heavy rain)	2/ year	1/ year (Including heavy rain)	2/ year	1/ year (Including heavy rain)	2/ year	
	A	B	C	D	E	F = A×D	G = A×2E	Total (2016)
10	45.48	8	4	0.3265306	0.119403	14.85	10.86	225
25	58.03	7.5	19.5	0.3061224	0.582090	17.77	67.57	↑ increase
50	87.12	8	7	0.3265306	0.208955	28.45	36.41	Total (2006)
75	130.78	1	2	0.04081633	0.059702	5.34	15.62	F×B/(B+C)
100	196.34	0	1	0	0.029851	0	11.72	+G×C/(B+C)
Total		24.5	33.5	100: Total sample number		66.41	142.18	110

HH: Household
Source: JICA Study Team

The inundation damage per household and covered population (converted to household number with household size, 5), are multiplied and inundation avoidance benefits can be estimated. The drainage project aims to avoid inundations of once in five years and so it seems that the above Social Survey results can be avoided. (Although some of the frequency answers, "Others" mean the 'occasion of heavy rain', it seems that the occasion of heavy rain occurs more than once in five years and so it is supposed as once in a year.)

The beneficiaries are calculated multiplying population of each drainage district and inundation prevention area ratio to the total district area. Not only residents but also business facilities are damaged by inundation. In this analysis, factories are focused as representative business facilities. The factory statistics described in **Chapter 2** show that there are 684 large-scale factories (Capital investment excluding real estate exceeds 500,000 USD) in Phnom Penh. The factories distribution by districts is shown in **Fig. 2.2.4**. There is also a list of large investment factories and it shows that the number of these large factories is 677, very close to 684 above. Based on the list, the average employee number per factory is 736. Based on **Fig. 2.2.4**, the large-scale factories are distributed to drainage districts and then the factory employee number in each drainage district is calculated multiplying average employee number per factory and factory number. In addition, the beneficiary area ratio is used to obtain beneficiary factory employee number. Since these factories' inundation damages are not clarified, it is assumed that the factory employee's damage is the same as each residential household's damage. These large-scale factories must have invested much more than household and so this estimate may be conservative. Furthermore, small-scale domestic handicraft type factories may be included in households, but medium- and small- scale factories are excluded from both of large-scale and handicraft types. In addition, business facilities other than factories are also excluded and so the large-scale factories damages estimate may be conservative.

The second benefit is avoidance of inundation impacts as work damage such as "Cannot go out for business" or "Cannot open for business" in the Social Survey. Cross-analysis of frequency, duration and troubles in the Social Survey results is shown in **Table 6.8.3**. Multiplying the annual total below, household income (converted to day from month) and covered population (converted to household number with household size, 5), the lost production (avoided production loss) can be estimated.

Table 6.8.3 Production Loss Recovery in Phnom Penh

Duration (day)	Frequency		Share		Annual Total
	1/year (Including heavy rain)	2/year	1/year	1/year (Including heavy rain)	
0.0625	4	1	0.0139	0.00463	0.02315
0.09375	7	7	0.0365	0.04861	0.13368
0.3125	3	12	0.0521	0.27778	0.60764
0.625		3	0	0.1389	0.27778
0.7		1	0	0.05185	0.10370
1	4	3	0.222	0.2222	0.66667
	18	27	0.325	0.74398	0.57625

Source: JICA Study Team

Similarly, large-scale factories production losses are obtained multiplying employee number and the average household income damage above. If damaged residents work for these factories, the damages are double counted, but factories production values may be more than twice the employee salaries (income) and so the estimate may be conservative similarly to the inundation damage above.

The third benefit is khans' cost reduction of discharging water after inundation. According to the interview with Dangkor Khan officials, diesel oil consumption for pumping inundation water is approximately 10,000 L/year. Usually, diesel oil price is 3,800 Riels/l at gas stations. Based on the depth and frequency cross-analysis for each khan of the Social Survey results, the other khans' oil consumptions can be estimated, and the total diesel oil consumption can be summed.

The fourth benefit is medical cost reduction of diseases caused by inundation. There are two diseases. One is diarrhea and the other is itchy skin disease, that is, dermatitis described in the sewerage economic analysis above. There are other water-borne diseases such as hepatitis, typhoid and cholera, but there are no data on how inundation causes these diseases.

Table 6.8.4 provides data on occurrence of diarrhea in children as published in the article, "Water-Borne Diseases and Extreme Weather Events in Cambodia: Review of Impacts and Implications of Climate Change," 'International Journal of Environmental Research and Public Health' 2015, Grace I. Davies et al.

Table 6.8.4 Diarrhea Occurrence in Children Up to Age 14 in Cambodia

Provinces	Study Period	Mean Monthly No. of Diarrhoea Cases in Children up to 14 Years [a]		No. of Months Affected by Flooding [b]	Rainfall [c] (mm)		Mean Temperature [c] (°C)
		Non-flood	Flood		Median (IQR)	Max	
Banteay Meanchey	2001–2012	828	871	13	88.5 (149.3)	452.2	28.4
Battambang	2001–2012	747	845	14	82.6 (142.8)	353.3	28.3
Kampong Thom	2001–2012	620	569	15	99.4 (180.3)	497.2	27.6
Kampot	2001–2012	243	237	11	131.4 (209.1)	629.1	28.1
Koh Kong	2001–2012	101	90	6	197.5 (354.4)	1600.8	27.7
Kratie	2001–2012	267	380	10	126.7 (221.7)	537.8	28.5
Pailin	2007–2012	135	109	6	106.2 (128.3)	374.8	27.6
Phnom Penh	2001–2012	650	705	12	98.0 (168.1)	410.3	28.9
Pursat	2001–2012	180	219	11	105.6 (165.9)	398.6	28.4
Prey Veng	2001–2012	1719	1587	8	108.8 (169.0)	544.8	28.3
Ratanakiri	2004–2008	385	434	3	57.6 (263.3)	746.7	26.8
Siem Reap	2001–2012	885	1517	10	90.5 (197.1)	512.8	28.4
Stung Treng	2001–2012	54	45	8	74.5 (215.2)	552.8	28.4
Svay Rieng	2001–2012	507	524	7	127.5 (211.1)	499.1	28.2
Kampong Cham	2001–2012	2319	1990	10	80.5 (101.0)	170.0	28.2
Preah Sihanouk	2001–2012	152	135	3	86.5 (81.5)	182.0	28.0

Source: Grace I. Davies et al., "Water-Borne Diseases and Extreme Weather Events in Cambodia: Review of Impacts and Implications of Climate Change," 'International Journal of Environmental Research and Public Health' 2015

Diarrheal occurrence of children up to the age of 14 in Phnom Penh caused by inundation above as well as the project covered population can be used to estimate the medical costs of diarrhea.

On the other hand, when other water-borne disease incidence in the Social Survey results is scrutinized, there are many cases of "itchy" symptoms. This seems to be a skin disease (dermatitis) caused by inundation similarly to dermatitis caused by the untreated wastewater above. The itchy skin disease occurrence is 11% based on the Social Survey. Medical care costs for dermatitis can be benefits of the drainage project.

6.8.2 EIRR

The EIRR for the proposed drainage management M/P is 12.6%, as shown in **Table 6.8.5**.

Table 6.8.5 EIRR of Drainage Management Projects

Year	2016	2017	2018	2019	2020	2021	2022
Inundation benefit	0	0	2.73	2.88	3.05	3.23	18.47
Production	0	0	0.32	0.34	0.36	0.38	1.65
Pumping Diesel Oil	0	0	0.01	0.01	0.00	0.00	0.01
Medical Care	0	0	0.005	0.005	0.005	0.005	0.015
Operational Costs		0	0.06	0.07	0.07	0.07	1.05
Investment	28.47	0.00	107.18	71.88	0.00	0.00	101.4
Cash flow	-28.47	0.00	-104.18	-68.73	3.34	3.54	-82.32
Year	2023	2024	2025	2026	2027	2028	2029
Inundation benefit	19.65	40.42	42.97	59.46	63.38	71.81	76.45
Production	1.76	3.32	3.53	4.95	5.29	6.08	6.48
Pumping Diesel Oil	0.01	0.02	0.02	0.02	0.02	0.03	0.03
Medical Care	0.016	0.023	0.024	0.036	0.038	0.046	0.049
Operational Costs	1.24	1.63	1.63	3.14	3.17	4.36	4.37
Investment	13.456	12.34	90.036	8.076	0	12.7	37.7
Cash flow	6.74	29.81	-45.12	53.25	65.56	60.93	40.89
Year	2030	2031	2032	2033	2034	2035	2036
Inundation benefit	81.33	86.95	94.38	102.24	109.00	116.05	126.03
Production	6.90	7.40	8.11	8.78	9.39	10.01	10.90
Pumping Diesel Oil	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Medical Care	0.053	0.057	0.064	0.070	0.075	0.080	0.088
Operational Costs	4.38	4.61	4.83	4.92	4.94	4.94	5.02
Investment	29.012	0	5.288	35.296	0	30.604	0
Cash flow	54.92	89.83	92.45	70.90	113.55	90.62	132.04
Year	2037	2038	2039	2040			Total
Inundation benefit	134.20	142.79	155.06	165.64			1,718.14
Production	11.63	12.39	13.57	14.52			148.05
Pumping Diesel Oil	0.03	0.03	0.03	0.03			0.47
Medical Care	0.094	0.101	0.113	0.122			1.18
Operational Costs	5.06	5.12	5.18	5.29			75.14
Investment	74.096	0	0	0			657.6
Cash flow	66.79	150.18	163.58	175.02		EIRR	**12.6%**
Residual value	-	-	-	-			303.1

Source: JICA Study Team

6.9 Selection of Priority Project for Pre-Feasibility Study

As shown in **Table 6.9.1**, drainage facilities in Pochentong East Drainage Area (Drainage Area No. 9) are tentatively selected as the priority projects for Pre-F/S. Pochentong West Area (Drainage Area No.11) is not included in the priority projects because implementation in the No.11 area is not urgent compared to Drainage Area No.9. On the other hand, implementation plan for (i) construction of drainage facilities in Wat Phnom North Area (Drainage Area No.22) and City Core North Area (Drainage Area No.27) and (ii) installation of mechanical screen at four locations in Trabek Drainage Area (Drainage Area No.23), is to be formulated in "The Project for Flood Control and Drainage Improvement in Phnom Penh Capital City (Phase 4)", as shown in **Table 6.10.1**.

Table 6.9.1 Priority Project for Pre-Feasibility Study

Item	Facilities	Specification/capacity	Remark
Construction of drainage facilities in Pochentong East Drainage Area (Drainage Area No. 9)	Drainage channel	• Box culvert:5,220 m • Inlet channel: 480 m • Rehabilitation of existing channel: 2,660 m	
	Pumping station	• 1 location: Capacity 40 m^3/s	Landowner: Public
	Regulation pond	• 1 location: Area required: 25,000 m^2	

Source: JICA Study Team

6.10 Relations of Components requested for Phase 4 and proposed in the M/P

Table 6.10.1 summarizes the relation of components requested by PPCC for the implementation of "The Project for Flood Control and Drainage Improvement in the Phnom Penh Capital City (Phase 4)" and the components evaluated and proposed for the M/P.

Table 6.10.1 Relation of Components requested for Phase 4 and those proposed in the M/P

Components requested in 2014 for Phase 4 project			Contents		Study results in the M/P			
Item		Pri-ority			No.	Drainage area	Pri-ority	Timing of implementation
Improvement of Wat Phnom Northern area drainage system		1	Facilities	Drainage pipe, Underground reservoir, Pumping station and Interceptor	22	Wat Phnom North	1	Implementation in Phase 4 is recommended.
Improvement of flood control facility to Phnom Penh Special Economic Zone		1	Facilities	Box culvert, Drainage channel, Maintenance road, Sluiceway	2	PPSEZ	2	Implementation after Phase 4 is recommended.
Mechanical screen cleaning facilities to screen pits at pumping stations constructed in Phase 2		1	Facilities	Mechanical screen cleaning facilities	23	Trabek	1	Implementation in Phase 4 is recommended.
Improvement of Tuol Kork area drainage system		1	Facilities	Box culvert and Sluiceway	27	City Core North	1	Implementation in Phase 4 is recommended.
Improvement of Pochenton g drainage system	East area	2	Facilities	Pumping station, Regulation pond, Sluiceway, Drainage channel and Box culvert	9	Pochenton g East	2	Implementation after Phase 4 is recommended.
	West area	3	Facilities	Box culvert and Drainage channel	11	Hanoi West	3	Implementation after improvement in East area is recommended
Procurement of Detention Pond cleaning equipment		5	Equipme nt	Drainage pump vehicle, Regulation pond cleaning equipment(*1)	-	Not applicable	-	Implementation in Phase 4 is recommended.
Boeng Trabek pumping station II		4	Facilities	Pumping station	23	Trabek	Out of scope, because it is implemented by PPCC	

(*1) Regulation pond cleaning equipment : Dredging boat, Floating excavator, Earth and sand barge, Long arm excavator, and Watertight dump truck. Drainage pump vehicle is high in utility and versatility.

Source: JICA Study Team

6.11 Debt Sustainability Analysis (DSA) Addition

The investment costs of sewerage and drainage projects need to be covered by soft loan because the Cambodian Government does not have its own fund. The feasibility of soft loan can be analysed adding foreign currency loan portion of these investment costs to Cambodia Debt Sustainability Analysis published in October 2015 by the IMF, the World Bank and the International Development Association. DSA checks (present value) external public debt-to-GDP ratio, debt-to-export ratio, debt-to-revenue ratio, etc. However, in practice, debt-to-GDP ratio and debt-to-export ratio are mainly focused on.

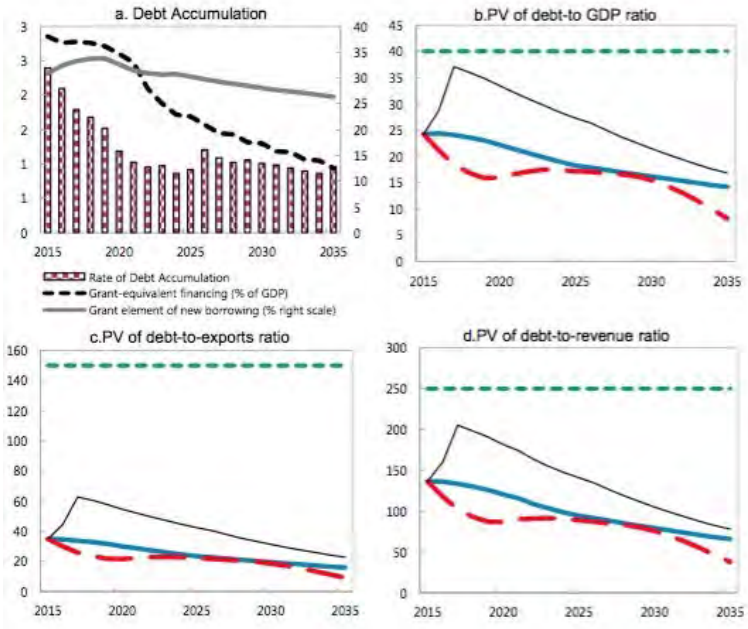
According to IMF and the World Bank, "Revisiting the Debt Sustainability Framework for Low-Income Countries," Jan. 2012, the indicative threshold for each debt burden indicator depends on each country's policy and institutional capacity, as measured by the World Bank's Country Policy and Institutional Assessment (CPIA) index. The specific thresholds are shown in **Table 6.11.1**.

Table 6.11.1 Indicative Policy-dependent Thresholds

	PV of debt in percent of			Debt service in percent of	
	GDP	Exports	Revenue	Exports	Revenue
Weak policy (CPIA ≤ 3.25)	30	100	200	15	25
Medium policy (3.25 < CPIA < 3.75)	40	150	250	20	30
Strong policy (CPIA ≥ 3.75)	50	200	300	25	35

Source: IMF and World Bank, "Revisiting the Debt Sustainability Framework for Low-Income Countries," Jan. 2012

Cambodia Debt Sustainability Analysis indicates Cambodia's policies and institutions, as measured by the World Bank's Country Policy and Institutional Assessment, continue to be classified as "medium performer." The relevant indicative thresholds, applicable to public and publicly guaranteed external debt, for this category are 40% for the net present value (NPV) of debt-to-GDP ratio, 150% for the NPV of debt-to-exports ratio, 250% for the NPV of debt-to-revenue ratio, 20% for the debt service-to-exports ratio, and 20% for the debt service-to-revenue ratio. Cambodia DSA shows the results in **Fig. 6.11.1**.



Source: IMF, World Bank and IDA, "Cambodia DSA," October 2015

Fig. 6.11.1 Cambodia Indicators of Public and Publicly Guaranteed External Debt

The figure indicates that Cambodia can keep the indicators declining under the thresholds. Based on the results above, soft loan feasibility of the sewerage and drainage projects is examined by checking whether the additional necessary foreign debt may make the external debt-to-GDP ratio exceed the threshold.

Usually total investments are not borrowed from the international organizations. For example, approximately 75% of total investments are the object of loan in case of JICA. Therefore, in this study, foreign debt share of the projects are supposed 80% of investments. Additionally, discount rate for present value calculation is 5%. Furthermore, larger investments of the alternatives are selected for the most case. Thus, the addition of sewerage and drainage projects loans is shown in **Table 6.11.2**.

Table 6.11.2 Addition of Sewerage and Drainage Projects to DSA

(Unit: billion USD, %)

Item	2012	2013	2014	2015	2016	2017	2018	2019	2020	2025	2035
GDP (billion USD)	14.1	15.4	16.6	17.6	19.0	20.6	22.5	24.5	26.7	40.8	95.1
Gross workers' remittances	0.1	0.1	0.3	0.4	0.2	0.2	0.3	0.4	0.4	0.8	1.9
PV of PPG external debt			3.8	4.2	4.6	4.9	5.3	5.6	5.9	7.4	13.5
PPG ex.debt/ (GDP+Remitta.)			22.9%	23.7%	24.1%	23.9%	23.3%	22.7%	21.9%	17.9%	13.9%
Sewerage project (Accumulated)							0.036	0.036	0.036	0.1475	0.8897
Drainage project (Accumulated)					0.0296	0.0436	0.1516	0.2134	0.2137	0.4303	0.5983
Debt portion of project total					0.0237	0.0349	0.1501	0.1995	0.1998	0.4622	1.1904
PV of project debt					0.0226	0.0317	0.1297	0.1641	0.1565	0.2838	0.4486
Ex debt incl project/(GDP+R.)					24.6%	24.6%	25.8%	25.6%	24.6%	21.7%	17.2%

Note) The top four rows from GDP are based on the IMF and IDA, "Cambodia Staff Report for the 2015 Article IV Consultation - Debt Sustainability Analysis" Oct. 2015 and the lower rows are this sewerage Master Plan investments, 80% of the investments as debt, present values of debts and added to the external debt above divided by GDP plus remittance. PPG is Public and Publicly Guaranteed.
Source: JICA Study Team

The result shows that external debt-to-GDP ratio is less than 30% or a little higher than the original fourth largest ratio (24.1% in 2016). Therefore, the sewerage and drainage projects loan has no significant problem as long as the government does not make other foreign debts. In "Revisiting the Debt Sustainability Framework for Low-Income Countries" of IMF and World Bank, it is not clarified which projects are included in the future forecast. It is considered that the existing and fixed projects at the analysis time might be included. If other projects with foreign debts increase and the indicator (foreign debt ratio) get closer to the threshold, it will be difficult to get a soft loan as project financing resource. However, it is expected that the Ministry of Economy and Finance will investigate this matter carefully.

CHAPTER 7 ENVIRONMENTAL AND SOCIAL CONSIDERATION OF MASTER PLAN

7.1 Environmental and Social Consideration at Master Plan Formulation Stage Applying Strategic Environmental Assessment

In line with JICA's Guidelines for Environmental and Social Consideration, the study applies the Strategic Environmental Assessment (SEA) for the Master Plan formulation. The approach consists of: 1) information disclosure to the public; 2) reflection of public opinion in the plan; and 3) alternative analysis at the early stage. The information disclosure and collection of public opinion were conducted through a series of stakeholder meetings; namely, workshop on the progress of the study and the socio-economic survey consisting of interview with the residents at the early stage of study.

7.1.1 Tentative Environmental Scoping at Master Plan Stage

(1) Screening of the Project

The project was tentatively designated as Category B in the Detailed Planning Survey for the "Study on Drainage and Sewerage Improvement Project in Phnom Penh Metropolitan Area" (http://www.jica.go.jp/english/our_work/social_environmental/id/asia/southeast/category_a_b_fi.html). Careful study should be required for project selection.

There is no significant change that would merit reclassification of the sewage management projects in the Master Plan stage. However, drainage management projects in which approximately 900 to 1,000 structures will be affected exist close to the project sites in the entire PPCC. Some resettlement may thus be involved, which should be minimized upon further consideration. In case the scale of resettlement is large, reclassification of the category may be considered at the next stage.

In relation to the categorization along with JICA's Guidelines for Environmental and Social Consideration (2010, April), the environmental conditions of projects are as summarized in **Table 7.1.1**. The actual project scheme is finalized in the Master Plan.

Table 7.1.1 Environmental Condition for Project Screening (May 2015)

No.	Environmental Items	Description
1	Permits and approvals, explanations	・ For project implementation, EIA is required.
2	Natural environment	・ Protected area: No legally protected area under the protected area law will be involved in the project area. Wetland area is used for the natural sewage system in the capital. ・ Primeval forests, tropical natural forests: No primeval forest is involved. ・ Ecologically important habitats and endangered species: No particular endangered species has been identified at candidate construction sites (Cheung Aek and Tamok Lakes). The candidate site for the STP has functioned as natural lagoon for sewage treatment (Cheung Aek, Tumpun, Trabek and Tamok Lakes). However, Tamok Lake which contains much larger water surface area had provided water for domestic use of residents nearby and some are complaining about water pollution of the lake.
3	Social environment	・ Resettlement (No physical displacement has been identified at the time of study but some land acquisition may be required): The situation of resettlement and land acquisition will be clarified with the progress of the current study. Approximately 900-1000 structures were identified in potentially project affected area for drainage management. Resettlement should be avoided and land acquisition area to be expropriated from private land should be minimized as much as possible.

No.	Environmental Items	Description
4	Pollution	・ As positive impact, water quality in the wetland in the PPCC will improve. ・ No significant negative impact of pollution is anticipated. However, some earthworks during construction may increase water turbidity. Also, the construction works should be considered to minimize impact to residents.

Source: JICA Study Team

(2) Environmental Scoping at Master Plan Phase

The potential impacts associated with the projects have been identified based on the environmental condition collected above. The scoping matrix is in the Appendix and the major impacts are extracted here.

(a) Potential Impacts of Sewage Management Project

The potential impacts associated with sewage management are as summarized in **Table 7.1.2** (Scoping matrix is shown in **Appendix 6**).

Table 7.1.2 Potential Impacts of Sewage Management Project (May 2015)

Environmental Items	Impact associated with the Project (In case of no consideration)	Remarks
Natural Environment	・ With STP construction, approximately 20-40 ha of wetlands/water bodies which were currently used mainly for agriculture/fishery are to be reclaimed. ・ Agricultural area in the lake area will be reduced. ・ Water quality of the wetland is expected to be improved.	Actual scale of the project is under consideration. This will be clearer as the study progress.
Social Environment	・ There are some residents in the Cheung Aek Lake area. Resettlement and land acquisition should be avoided and minimized. ・ Cheung Aek area which is planned as the STP site is largely used for agriculture. Some residents may lose their income sources partly/fully. ・ Some people live in temporary or permanent structures at areas surrounding the existing ditch in Phnom Penh. With the improvement of existing structures, some residents may be temporarily or permanently resettled. ・ Traffic flow due to construction work (installation of pipeline under existing road) may be disturbed. ・ Pumping station construction at the city area requires new land.	Actual scale of the project is under consideration. This will be clearer as the study progress.
Pollution	・ Offensive odor may be generated at the area surrounding the STP. ・ Offensive odor at existing ditch will be reduced by the improvement of facilities (decreasing sewage water flow). ・ Water turbidity in the area will increase due to the construction work. ・ During construction, water leakage from the old drainage system to new one may temporarily contaminate the area. ・ With the operation of STP, sludge will be generated and it needs to be properly disposed at the designated site.	Actual scale of the project is under consideration. This will be clearer as the study progress.

Source: JICA Study Team

(b) Potential Impacts of Drainage Management Project

The potential impacts associated with drainage management are as shown in **Table 7.1.3** (Scoping matrix is shown in **Appendix 7**).

Table 7.1.3 Potential Impacts of Drainage Management Project (May 2015)

Environmental Items	Impact associated with the project (In case of no consideration)	Remarks
Natural Environment	**<Improvement of Drainage Pipes/Canals/Channels>** ・ As positive impact, flooding problems are expected to be reduced with project implementation. **< Construction/Extension of Drainage Pumping Station>** ・ Construction of new pumping station may require additional land acquisition and sometimes resettlement in city area. **< Preservation/Extension/Creation of Regulation Pond/Retarding basin>** ・ Positive impact to the city area is expected by creating ponds with good condition.	Actual scale of the project is under consideration. This will be clearer as the study progresses. Actual location of the facilities will be determined through the current study.
Social Environment	**<Improvement of Drainage Pipes/Canals/Channels>** ・ Some residents are living close to existing ditches in city area. Approximately 900-1000 structures were identified in the potential project-affected area in the drainage management plan. At the improvement of the existing ditches, impact to the residents should be avoided and minimized based on the adequate survey for the existing ditch at the planning stage. ・ Associated with the installation work of the new pipe under the existing road, traffic hazards such as traffic jam, and accidents, may occur. **< Construction /Extension of Drainage Pumping Station>** ・ Construction of new pumping stations may require additional land and sometimes resettlement. **< Preservation/Extension/Creation of Regulation Pond /Retarding basin>** ・ Construction of new regulation ponds require approximately 16 to 70 ha of additional land and resettlement/land acquisition should be avoided and minimized based on adequate survey at the planning stage. ・ Without adequate instruction to the users, the regulation pond will be a source of the pollution (as with current condition of the water ditches in city area).	Actual scale of the project is under consideration. This will be clearer as the study progresses. Actual location of the facilities will be determined through the current study.
Pollution	**<Improvement of Drainage Pipes/Canals/Channels>** ・ Drainage water flow is planned to be treated separately from the sewage applying separate sewer system and it is expected to improve the water flow in the capital. ・ At the construction stage, associated with disturbance of the river bottom sediment such as bed excavation and foundation works, offensive odor may be generated even if area and period is limited. **< Construction /Extension of Drainage Pumping Station>** ・ Associated with the construction work, water turbidity in the area will increase. ・ During construction, water leakage from the old system to the new system may temporarily contaminate the area. **< Preservation/Extension/Creation of Regulation Pond /Retarding basin>** ・ In operating facilities, people dispose garbage in the sites without routine maintenance of the system/adequate education to the people.	Generally no significant negative impact is anticipated. With the progress of the current study, scale of impact may be clarified.

Source: JICA Study Team

7.1.2 Consideration at the Master Plan Formulation

To evaluate the Master Plan and select the priority projects, items to be considered and the evaluation methods are to be proposed by applying the SEA approach in accordance with both Cambodian environmental related laws and regulations and JICA's Guidelines for Environmental and Social Consideration. **Table7.1.4** shows the points to be considered.

Table 7.1.4 Points to be considered in SEA at the Master Plan Stage

No.	Items	Contents	Implementation Status
1	Set up of development plans and programs	Set up of overall plans and programs in accordance with the policies on management of environment and sanitation.	The development plans were set in the 1st phase.
2	Selection of projects to realize the plans and programs	Selection of projects necessary for realization of the policies on management of environment and sanitation	Overall project scheme was formulated as M/P at the 2nd phase of the study.
3	Implementation of scoping	Proposal on items to be considered and the evaluation methods for selection of the priority projects	Based on the general baseline information, preliminary scoping was conducted.
4	Baseline survey of environmental and social conditions	Confirmation of environmental and social conditions in PPCC	Baseline information was collected to evaluate positive and negative impacts associated with the projects.
5	Confirmation of institutions/regulations in Cambodia	Confirmation of institutions/regulations of EIA, resettlement, public participation, information disclosure and so on	Confirmation was done in the 1st phase.
6	Evaluation of impacts	Evaluation of the results of impact assessment	To contribute stakeholder's feedback, preliminary evaluation was presented at early stage of the M/P formulation.
7	Study on alternatives	Comparative study on a number of alternatives including zero option	Alternatives of master plan were presented to the stakeholders to obtain feedback.
8	Assistance for holding of stakeholder meetings	Assistance for holding stakeholder meetings hosted by the agencies concerned	A range of workshop meetings were planned. The 1st Workshop Meeting was held on 17 March 2015 to share the progress of the study result in the 1st phase.

Source: JICA study Team

7.1.3 Existing Environmental Condition in the Study Area

General features of natural environment and socio-economic condition in the project area are described in **Chapter 2**. Some key issues related to the sewage and drainage management projects are described below.

(1) Social Environment

The projects will cover the entire area of the capital. A summary of the environmental situation in the khans (districts) is shown in **Table 7.1.5**.

Table 7.1.5 Environmental Situation of the Khans (Districts) in PPCC

No.	Khan	Area (km^2)	No. of Sangkats	Population (1,000 persons)	Pop. Density (Persons/ha)	Description
1	Chamkarmon	11.1	12	182.0	164.0	The khan is located inside of the inner dike at the bank of Bassac River, a tributary of the Mekong River, at the center of the city. Trabek Lake as one of the lagoon system of waste water treatment in the city is located in the area.
2	Daun Penh	7.5	11	126.6	168.7	The khan is located inside of the inner dike at the center of the city.
3	7 Makara	2.2	8	91.9	417.7	The khan is located inside of the inner dike at the center of the city.
4	Tuol Kok	8.2	10	171.2	208.8	The khan is located inside of the inner dike at the center of the city.
5	Dangkor	117.8	13	73.3	6.2	The khan is located at the south edge (outside of outer dike) of the city bordering on Kandal Province and includes the western part of the

No.	Khan	Area (km^2)	No. of Sangkats	Population (1,000 persons)	Pop. Density (Persons/ha)	Description
						Cheung Aek Lake.
6	Po Senchey	150.0	10	159.5	10.6	The khan is located at the western edge of the city bordering on Kandal Province. In the khan, the outer dike passes at the middle of the khan in north-south direction and the major National Road No. 4 passes at the east-west direction connecting the capital and Shihanoukville. The international airport is also located in this khan.
7	Meanchey	25.0	4	194.6	77.9	The khan is located at the middle south edge of the capital bordering on Kandal Province. In the khan, the outer dike passes at the north of the khan and includes the area in between Cheung Aek Lake and Bassac River bank. Tumpun Lake as one of the lagoon system of waste water treatment in the capital is located in the area.
8	Chbar Ampov	80.5	8	133.2	16.5	The khan is located at the southeast edge (outside of outer dike) of the capital in between Mekong River and Bassac River.
9	Reussey Keo	24.9	6	115.7	46.5	The khan is located in the area between the outer dike and inner dike at the north of the capital along National Road No. 5 at the Sap River bank.
10	Chroy Changvar	84.0	5	68.7	8.2	The khan is located at the northeast edge (outside of outer dike) of the capital and in between Sap and Mekong River.
11	Sen Sok	51.9	4	137.8	26.5	The khan is located in the area between the outer dike and inner dike. In the area the Hanoi Road passes in north-south direction as main road.
12	Prek Pnov	115.4	5	47.3	4.1	The khan is located at the northwest edge of the capital just outside of the outer dike. (At southwestern part of khan, south of Kouk Roka Sangkat, it is located inside of outer dike). Most of the area is covered by water bodies such as Tamok Lake and Samroung Lake and the area adjacent to Sap River.
	Total	678.5	96	1,501.7		

Source: JICA Study Team

(2) Natural Environment

Since PPCC has already been developed, the environmental situation should concern the general public. The swamp areas closely related to the sewage and stormwater management projects are described below.

(a) Cheung Aek Lake Area

The Cheung Aek Lake basin with approximately 2,600 ha is located in the south-east edge of PPCC and partly belonging to Kandal Province. The area was notified recently as a state public land in Sub-Decree, 2008 No. 124 ANKr. BK, " Identification of area of Cheung Aek Lake and canal in Mean Chey and Dangkor Khan Phnom Penh and Takhmao District Kandal Province as State Public Land" with the area of 520 ha. The area is well known as one of the killing fields, mass grave where people were massacred and buried in the regime of Khmer Rouge.

As a natural wastewater treatment lagoon, the area is used for flood control and wastewater treatment before flowing into the Bassac River. The swamp and the seasonal and permanent water bodies in the lake have been used by people to cultivate aquatic plants, animal husbandry and fisheries.

The lake area has been widely used by farmers, even in permanent water surface. Seasonal wetland can be utilized for the cultivation of water spinach, water mimosa and rice, and water surface can be utilized for aquaculture using floating raft. According to a study conducted by the Royal University of Agriculture in 2009 (PHEARITH TEANG & PUY LIM 2010, International Journal of Environmental and Rural Development), majority of the area was used for water spinach cultivation (43% of the area), as shown in **Table 7.1.6**.

Table 7.1.6 Area occupied by Human Activities at Cheung Aek Lake in the Dry Season

Human Activities	Total area (ha)	Percentage (%)
Water spinach area	429	43.2
Water mimosa area	32	3.2
Dry season rice field	13.5	1.5
Fishing activity	15	1.5
Duck raising	10	1
Other aquatic plant and water surface	492.5	49.6
Total lake surface	992	100

Source: (PHEARITH TEANG2009, Spatial Analysis of Human Activities Performed in Cheung Aek Inundated Lake, Cambodia, International Journal of Environmental and Rural Development (2010)

According to the study (PHEARITH TEANG 2009), commercial fishery in the Cheung Aek Lake is not common and it is limited to domestic consumption. A diverse range of fish *species* is caught such as common carp (*Cyprinus carpio*), silver carp (*Hypophthalmichthys molitrix*), tilapia (*Orechromis niloticus*), Snakehead fish (*Channa striata*) and Walking catfish (*Clarias batrachus*). The fish are sold at local markets or used as a supplemental house diet.

(b) Tamok Lake Area

Tamok Lake is located at the northeastern border of PPCC featuring a comparatively large water body with swamp area. A part of the area named Samraong Lake has been preserved as State Public Land with about 336 ha (the area adjacent to Tamok Lake). Tamok Lake with about 3,270 ha is still in the process of becoming a State Public Land by a Sub-Decree. According to PPCC, PPCC requested the Prime Minister to complete the process but the result of the Committee's investigation has not been released (more than 3 years has passed after request, as of October 2014). The area contained some leased area for quarry of the military and other uses, and the final preserved area may be smaller than the proposed area. The lake is currently receiving wastewater from the northern part of PPCC through two pumping stations and is functioning as natural lagoon (location of the lake is shown in **Fig. 3.2.2**).

Besides, the area is used for fishery and seasonal cultivation land for such as rice and vegetables. Tilapia, Catfish, Gourami, and Channa are common species in the lake. According to the administration record, approximately 100 persons use fishing rods for capturing Channa species and approximately 300 families use the net for capturing tilapia, gourami, and dusky face carp (*Hypsibarbus suvattii* and *Osteochilus hasseltii)*.

Previously, water of Tamok Lake was quite clean and people living in the surrounding area used it for drinking. However, according to the result of water quality monitoring conducted in the study in 2014, the water is slightly polluted and, aside from pH, DO and BOD, average values of most parameters exceed the water quality standard (Water quality standard for lake and pond, **Table 2.5.1**). Comparatively high DO (Average 6.06mg/L, Standard: >2.0mg/L), high TSS (Average 85.8mg/L, Standard: <15mg/L), low BOD (Average 5.17mg/L, Standard: <10mg/L), high COD (Average 9.76mg/L, Standard: <8mg/L), high T-N (Average: 1.74mg/L, Standard:

<1.0mg/L), high T-P (Average 0.30mg/L, Standard: <0.05mg/L) and very high coliforms (Average 90,000MPN/100ml, Standard: <1,000MPN/100ml), were observed.

(c) Trabek Lake

The lake is located south of the city center area in Khan Chamkarmon, inside the outer dike where it functions as lagoon for treating wastewater from the city area (refer to **Fig. 3.2.1**). At its downstream end in the inner area, a drainage pumping station is installed (Trabek Pumping Station).

Although water in the area is quite polluted, most of the area is used for the cultivation of water plants such as water spinach and water mimosa. Approximately 8 ha (200 m×400 m) of surface area still remain swampy without encroachment, but it has not been legally demarcated yet (based on Google Earth image on January 16, 2015).

(d)Tumpun Lake

As with the Trabek Lake, Tumpun Lake is located at the southwest of the city center just inside of the outer dike in Khan Meanchey (refer to **Fig. 3.2.1**). The area is used for cultivating water plants such as water spinach, water mimosa and lotus. A part of the area accommodates tree vegetation of the *Eucalyptus* spp.

Approximately 40 ha (200 m×500 m on the west and 550 m×550 m on the east) of surface area still remain swampy without encroachment, but it has not been legally demarcated yet (based on Google Earth image on January 16, 2015).

7.1.4 Alternative Comparison

Alternatives of the sewage management M/P and the drainage management M/P are compared in **Chapter 4** and **Chapter 6**. Potential impacts associated with the projects of the M/P are as described below.

(1) Environmental Consideration for the Sewage Management Master Plan

In accordance with the M/P alternatives, potential impacts of the plans are as presented in **Table 7.1.7**. The ratings are not based on absolute comparison but on relative comparison.

Table 7.1.7 Comparison of Alternatives of Sewage Management M/P (April 2015)

Alternative		Alternative 1 (2 STPs, one each for Cheung Aek and Tamok Lakes)	Alternative 2 (Combined development plan on-site and off-site treatment; 1 STP at Cheung Aek area and On-site treatment in Tamok area)	Alternative 3 (Without Project) No project implementation
Rating		---	--	Not applicable
Environmental & Social Consideration	Natural Environ-ment	Seasonal wetland area is to be transformed into the STP construction in Cheung Aek Lake and Tamok Lake. Large scale of land reclamation may be required for the Tamok Lake due to the depth of water at the candidate site in the lake, which is adjacent to the existing pumping station.	Seasonal wetland area is to be transformed into the STP area in Cheung Aek Lake.	Water quality in Tamok Lake and Cheng Aek Lake will decline due to the decline of natural purification function; Biological diversity of the lakes may remain poor; Habitat for wildlife may be reduced; Further eutrophication of the lakes in the capital may progress.
	Social Environ-ment	Farmers and fisheries who are working at the lakes are to be affected in both lake area.	Farmers and fisheries who are working at the lakes are to be affected in Cheung Aek Lake area.	Water pollution affects quality of crops from the wetland which may cause some health problems to

Alternative		Alternative 1 (2 STPs, one each for Cheung Aek and Tamok Lakes)	Alternative 2 (Combined development plan on-site and off-site treatment; 1 STP at Cheung Aek area and On-site treatment in Tamok area)	Alternative 3 (Without Project) No project implementation
				consumers. Further eutrophication of the lakes may reduce crop yield in future.
	Pollution	Water quality at Cheung Aek Lake is expected to be improved through STP operation. Water quality flowing into Tamok Lake area is expected to be improved through STP operation.	Water quality of Cheung Aek Lake area is expected to be improved through STP operation. Water quality of Tamok Lake area is expected to be improved through applying on-site treatment and strict control over them.	Poor water quality of the wetland may cause health problems to farmers and fishermen who work at the lakes.

Legend: ---: high negative impact; --: less negative impact)
Source: JICA Study Team

(2) Environmental Consideration for the Drainage Management Master Plan

In accordance with the M/P alternatives, potential impacts of the plans were identified as shown in **Table 7.1.8**. The ratings are not based on absolute comparison but on relative comparison.

Table 7.1.8 Comparison of Alternatives of Drainage Management M/P (April 2015)

Alternative		Alternative 1	Alternative 2	Without Project
		(27 Sub-catchment areas)	(25 Sub-catchment areas)	
		Regulation pond: 5 locations (North 3 and South 2 locations) **Pumping station: 6 locations** (North 3 and South 3 locations) **Channel (Total length): 123 km** New open canal: 33 km Canal improvement: 77 km New box culvert: 12 km RCP: 1 km	**Regulation pond: 5 locations** (North 2 and South 3 locations) **Pumping station: 6 locations** (North 2 and South 4 locations) **Channel (Total length): 123 km** New open canal: 36 km Canal improvement: 78 km New box culvert: 8 km RCP: 1 km	-
Rating		---	--	-
Environmental & Social Consideration	Natural Environment	**<Improvement of Drainage Pipes/Canals/Channels>** ・ As a positive impact, flood problems are expected to be reduced with project implementation. **< Construction /Extension of Drainage Pumping Station>** ・ No significant negative impact is expected. ・ As a positive impact, tentative habitat for wildlife may be provided even in the city area by cleaning currently polluted ditches. ・ Reduction of wetland in the city area may be facilitated by improvement of drainage. **<Creation of Regulation Pond /Retarding basin>** ・ As a positive impact, tentative	**<Improvement of Drainage Pipes/Canals/Channels>** ・ Same as the left. **< Construction /Extension of Drainage Pumping Station>** ・ Same as the left. ・ Same as the left. ・ Same as the left. **<Creation of Regulation Pond /Retarding basin>** ・ Same as the left.	Inundation problems in the city area will continue.

Alternative		Alternative 1	Alternative 2	Without Project
		habitat for wildlife may be provided even in the city area by creating ponds.		
	Social Environment	**<Improvement of Drainage Pipes/Canals/Channels>** ・ Some residents are living close to existing ditches in city area. Approximately 1,000 structures are located at surrounding area of existing ditch which requires improvement. At the improvement of the existing ditches, impact to the residents should be avoided and minimized based on survey for the existing ditched at planning stage. ・ In the installation work of the new pipe under the existing road, road traffic hazards such as traffic jam and accidents may occur. **< Construction /Extension of Drainage Pumping Station>** ・ Construction of new pumping station may require additional land acquisition (sometimes resettlement are required) in city area. ・ Expansion of the existing pumping station may affect the residents nearby without any consideration. ・ Land values in the area may increase. ・ In the rainy season, easy traffic in inundated road will be obtained. **< Preservation/Extension/Creation of Regulation Pond /Retarding basin>** ・ Additional land and resettlement/land acquisition associated with expansion of existing pond, should be avoided and minimized based on detailed survey at the planning stage. ・ Without adequate instruction to the users, the regulation pond will be a source of pollution, as with current condition of water ditches in city area.	**<Improvement of Drainage Pipes/Canals/Channels>** ・ Some residents are living close to existing ditches in city area. Approximately 900 structures are located at surrounding area of existing ditch which requires improvement. At the improvement of the existing ditches, impact to the residents should be avoided and minimized based on survey for the existing ditched at planning stage. ・ Same as the left. **< Construction /Extension of Drainage Pumping Station>** ・ Same as the left. ・ Same as the left. ・ Same as the left. ・ Same as the left. **<Preservation/Extension/Creation of Regulation Pond /Retarding basin>** ・ Same as the left. ・ Same as the left.	Current inundation problems will continue/ worsen. Those are: ・ Drainage improvement in the northern area of Wat Phnom and most parts of Tuol Kok District will lag behind other area. ・ Due to land development and reclamation, the area of Trabek regulation pond has been reduced and capacity of Trabek regulation pond has been decreased and cause inundation problems. Present capacity of existing Trabek pumping station is insufficient. ・ Explosive land developments reduce water body area and cause other inundation damage in near future. ・ In the area between inner ring dike and outer ring dike (especially in drastically urbanized area), drainage facilities are not properly installed and it increases inundation problem (in the area at eastern side of Pochentong airport, Chroy Changvar area and Chbar Ampov area.

Alternative		Alternative 1	Alternative 2	Without Project
	Pollution	**<Improvement of Drainage Pipes/Canals/Channels>** ・ Stormwater will be treated separately from the sewage applying separate sewer system, and water flow in the capital will be purified. ・ At the construction stage, disturbance of river bottom sediment due to bed excavation and foundation works, offensive odor may be generated in limited area and period. **< Construction /Extension of Drainage Pumping Station>** ・ During construction, water turbidity in the area will be increased. ・ During construction, water leakage from the old system to the new system may temporarily contaminate the area **<Preservation/Extension/Creation of Regulation Pond /Retarding basin>** ・ In operating facilities, people dispose garbage in the sites without routine maintenance of the system/adequate education to the people.	**<Improvement of Drainage Pipes/Canals/Channels>** ・ Same as the left. ・ Same as the left. **< Construction /Extension of Drainage Pumping Station>** ・ Same as the left. ・ Same as the left. **<Preservation/Extension/Creation of Regulation Pond /Retarding basin>** ・ Same as the left.	Water pollution at the current existing ditches may cause some health problems such as infectious diseases.

Legend: ---: high negative impact; --: less negative impact)
Source: JICA Study Team

7.1.5 Information Disclosure at Master Plan Formulation

(1) Dissemination for Authorities and Local Communities about Development Projects

Dissemination of the study results to major stakeholders was implemented through a series of seminars/workshops. Seminars/workshops are to be held to promote capacity development and understanding of the study results of the Master Plan and Pre-Feasibility Study, targeting persons from relevant authorities, other donors and NGOs, etc. The seminars/workshops are to be held for at least three times. The 1st workshop was held on 17 March 2015 at the Phnom Penh City Hall. Approximately 80 persons in total participated in the meeting, including 12 local authorities representing 12 khans, local administrations in the city, universities and NGO and private companies.

(2) Results of Public Consultation in the First Workshop

The first workshop chaired by the City Governor was successfully held with 81 participants at the Phnom Penh City Hall. In the workshop, the participants commented about the projects/plan. The main comments from the participants are as shown in **Table 7.1.9** (as a reference, memo of the Workshop is shown in **Appendix 8**).

Table 7.1.9 Comments from Stakeholders in the First Workshop

Comments from Participants of the First Workshop (17 March 2015)
Participants of the workshop were fully aware of the water environment condition in the city. The major comments are as follows. • Reinforcement of strict implementation of the relevant legislation such as: - Construction permit (Anukret 86 ANK/BK/December 19, 1997) for septic tank installation - Lack of sewage management law • Institutional capacity development - DOE for the pollution monitoring - Agencies concerned in sewage management in national and provincial level - Land management office and departments concerned in the control of land-use.

Source: JICA Study Team

(3) Results of public consultation in the Second Workshop

The second workshop chaired by the Deputy Governor of the city was successfully held with 61 participants at the Phnom Penh City Hall on 19 November 2015. In the workshop, the contents of both the master plans of sewage management and drainage management were presented and priority projects proposed in each master plan were explained. Also, one of the case studies on the successful achievement of sewage and drainage development including waterway management in the City of Kitakyushu, Japan, was presented. Representatives from ministries, local governments, universities, government-owned companies and private companies joined the workshop. In the workshop, the participants commented about the projects/plan proposed by the study team. The main comments from the participants are shown in **Table 7.1.10** (as a reference, memo of the Workshop is shown in **Appendix 9**).

Table 7.1.10 Comments from Stakeholders in the Second Workshop

Comments from Participants of the Second Workshop (19 November 2015)
The workshop was concluded by the Chairman in two points as follows: (1) Managing the drainage and sewerage system in PPCC is a big challenge. This M/P has a significant impact on the future of Phnom Penh, so that the M/P should be realistic and sustainable. (2) Implementation of the project after approval of the M/P is also important. The major comments from workshop participants are as follows (refer to the meeting results for details): - The condition of Kitakyushu City 50 years ago is similar to the current condition of Phnom Penh. Many things can be learned from experiences of Kitakyushu City. PPCC has to pay more attention to build environmental-friendly living conditions. - Treatment efficiency of each wastewater treatment method such as BOD, COD, TSS, etc., should be provided. - Treatment method should be selected in consideration of technical and economic views. - It is necessary to confirm the landowner of the proposed sites of treatment plant, pumping station and other facilities. - To set-up the new institution, PPCC need to collaborate with MOE. MOE has already established a new division for wastewater management, especially for regulating water quality (MOE is ready to work with the Study Team and PPCC). - We should learn from the experiences on sewerage management in Kitakyushu City. Flood damage in Phnom Penh became smaller than that of 10 years before, because some drainage improvement projects have been implemented. However, it seems that environmental pollution has become serious, especially in Tamok Lake basin. - We see improvement from flooding. However, we still have inundation in the rainy season. We request JICA to provide more projects in all areas. - Capacity development for the staff is very important. - Wastewater management is very important, - We need to place priority on improving living condition of the people.

Source: JICA Study Team

(4) Results of Public Consultation in the Third Workshop

The third workshop chaired by the Deputy Governor of the city was successfully held with 58 participants at the Phnom Penh City Hall. In the workshop, the study team presented overall result of M/P and Pre-F/S. The participants commented about the projects/plan. The main comments from the participants are as shown in **Table 7.1.11** (as a reference, memo of the Workshop is shown in **Appendix 10**).

Table 7.1.11 Comments from Stakeholders in the Third Workshop

Comments from Participants of the Third Workshop (15 September 2016)
The major comments are as follows. • I would like to know about the methodology of selection of construction site of Cheung Aek STP. • Reclamation of lakes/swamps due to rapid urbanization accelerates inundation in PPCC. • Decrease in impervious surface accelerates inundation in PPCC. • To secure disposal site for sludge from STP is essential. • To provide incentive for people is essential in the on-site treatment area in which Johkasou is installed. • Detailed location of proposed drainage channel should be presented in the M/P. • Decentralised system is a good option the new development area. • I would like to know about cost and lifetime of Johkasou Chairman made closing remarks as follows. • To implement the M/P, legal and institutional set-up is essential to Sewage and drainage management is a challenge of PPCC. The M/P makes impact to the future of PPCC. Therefore, the M/P should be realistic and sustainable. • The M/P should be implemented after approval of PPCC

Source: JICA Study Team

7.2 Assistance for IEE Level Study at Pre-Feasibility Study

A preliminary environmental study at the IEE level for the selected priority project will be conducted at the Pre-Feasibility Study, based on the TOR discussed in **Chapter 2**. The result of the IEE study is detailed in **Chapter 10**. The format and contents of the Study follow the guideline of the MOE.

CHAPTER 8 PRE-FEASIBILITY STUDY ON PRIORITY PROJECT OF SEWAGE MANAGEMENT

8.1 Components of Priority Project

As described in **Section 4.9**, the Preparatory Project is selected as the priority project of sewage management. Components of the "Preparatory Project" are summarised in **Table 8.1.1**.

Table 8.1.1 Components of the "Preparatory Project" of Sewage Management

Component	Contents
Sewer Pipe	Diameter : φ500 mm Length :about 1,300 m
STP	Capacity:5,000 m^3/dairy maximum

Source : JICA Study Team

8.2 Preliminary Design of Sewer Line

8.2.1 Design Sewage Volume

In the Preparatory Project, the proposed capacity of STP is 5,000 m^3/day in daily maximum. Therefore, the sewage volume of sewer shall be designed in accordance with the treatment capacity of STP. Based on the design condition of sewage volume studied in **Subsection 3.3.1**, the design sewage volume of the Preparatory Project is determined at 7,500 m^3/day in hourly maximum, which is equivalent to 0.087 m^3/s.

8.2.2 Study on Sewage Interception and Conveyance

(1) Sewage Interception

In the Preparatory Project, pipeline is planned from discharging point of Tumpun PS to STP. The sewerage facilities will be constructed inside of the Cheung Aek Lake. In this section, location and method of sewage interception are studied.

(a) Location of Sewage Interception

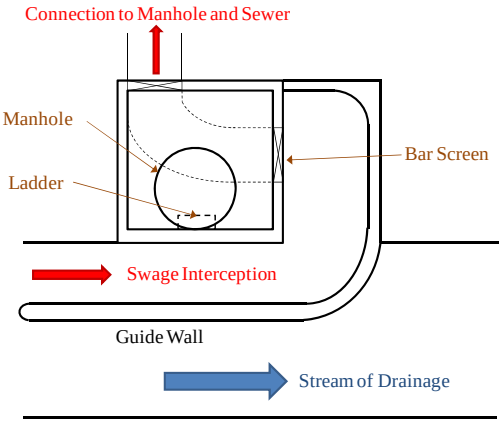
Location of sewage interception will be determined not to disturb drainage stream discharged from Tumpun PS and to ensure intercepting design sewage volume.

In case that the interception point is planned close to the discharge point of Tumpun PS, the interception facilities will be damaged by discharged drainage flow and thus design sewage volume will not be intercepted. On the other hand, in case that the interception point is planned far from the discharge point, the interception facilities will be affected by flood in the rainy season during which the water level of Cheung Aek Lake is high.

Therefore, the location of sewage interception shall be determined at around 80 m distance from the discharge point of the Tumpun PS, considering annual variability of water level in the Lake. The detailed location shall be determined in the Feasibility Study stage.

(b) Method of Sewage Interception

In the interception facilities, sewage is intercepted not to affect drainage flow discharged from Tumpun PS, and not to be affected by the water level of the Lake. The interception facilities with guide wall shall be installed in parallel with water stream. In addition, manhole, ladder and screen shall be installed for maintenance and to prevent garbage from entering the sewer system. **Fig. 8.2.1** shows the method of sewage interception.



Source: JICA Study Team

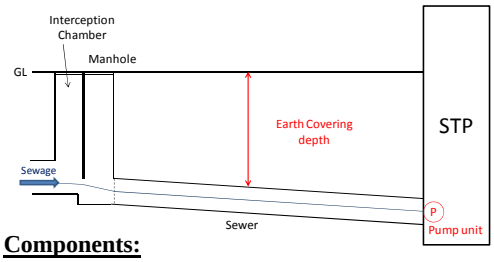
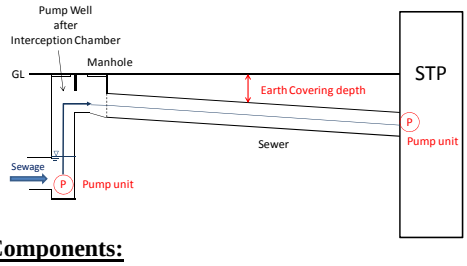
Fig. 8.2.1 Method of Sewage Interception

(2) Conveyance of Sewage to STP

Two (2) methods of sewage conveyance to STP are compared based on the basic policy of applying gravity flow. One is conveyed by gravity in whole stretch of sewer. Another is a combination of gravity flow and pumping equipment.

In case of gravity flow in whole stretch of sewer, O&M is required only for the pipe with low frequency. However, covering depth will be as deep as 7 m to 9 m from the interception facilities to STP. Though reinstallation of sewer to large diameter will be required in future phase, the sewer which is installed in the Preparatory Project will be utilized continuously On the other hand, a combination of gravity flow and pumping equipment, O&M is required for not only pipe but also pump units. Considering design sewage volume, four (4) pump units of which capacity is 2.61 m^3/min will be required including two (2) standby pumps. However, covering depth of sewer will be shallower and reconstruction work in the future will be easy. In addition, standard life period of pump equipment is around 15 years. So, the reconstruction work will be the same period with requirement for renewal of pump units. **Table 8.2.1** shows the results of comparison of sewage conveyance to STP.

Table 8.2.1 Comparison of Sewage Conveyance

Items	Option 1: Gravity flow	Option 2: Combination of Gravity Flow and Pumping equipment
Outline of system and components	 **Components:** Interception facilities, manholes and sewer	 **Components:** Interception facilities, pump well , manholes, sewer
Construction	- Covering depth of sewer ranges from about 7 m to 9 m. - Pump equipment will be required at STP. - Screen to avoid entering garbage is required at interception point or inside inlet chamber. - Open-cut method can be applied as the construction method considering recent ground level of 4.4 m and estimated excavation depth of 3 m.	- Covering depth of sewer is about 2 m to 4 m. - Screen to prevent entering garbage is required at interception point or inside inlet chamber. - Four (4) pump units including two (2) standby pump units will be required. - Pump equipment will be required not only at interception point but also in STP. - Electronic control panel is required on the ground.
O&M	- O&M is easy	- O&M for sewer is easy

Items	Option 1: Gravity flow	Option 2: Combination of Gravity Flow and Pumping equipment
	- Frequency of the O&M work will be less than that of Option 2. - Proper maintenance and cleaning for interception, manholes and sewer is required.	- Frequency of the O&M work will increase because maintenance of pump units as well as sand and scam removal is required. - Proper maintenance and cleaning is required not only for interception facilities but also for mechanical and electrical equipment in the pump well.
Future handling	- Sewer can be continuously utilized as sewer. - Interception facilities will be removed. - Manhole will be reconstructed for installation of sewer of 2,200 mm in a diameter. - Shield method will be applied to reconstruct the sewer for the future provision. - The vertical shafts for shield method will be utilized as manholes after construction.	- Sewer can be converted to drainage pipe and a sewer of 2,200 mm in a diameter shall be installed. - Interception facilities will be removed. - Manhole will be reconstructed for sewer of 2,200 mm in diameter. - Reconstruction of sewer can be conducted at the same period as pump renewal and the shield method will be applied. - The vertical shafts for shield method will be utilized as manholes after construction.
Effectiveness as preparatory project	- Experience of O&M for deep sewer, interception facilities and manholes.	- Experience of O&M for sewer, interception facilities, manholes and pumps. -
Rough cost estimation	- Construction cost is estimated at 2.29 million USD (civil works only). - O&M cost will be lower than that of Option 2 because O&M is required only for sewer and manholes.	- Construction cost is estimated at 2.20 million USD (civil works: 1.82 million USD, mechanical and electrical work: 0.38 million USD). - O&M cost will be higher than Option 1 because the frequency is very high, and electricity fee for the pumping equipment is required.
Evaluation	**Recommended**	

Source: JICA Study Team

Considering O&M works, it is clearly easier and less frequent O&M work for sewer in Option 1 even if sewer will be installed deeper. Based on rough cost estimate, construction cost of Option 2 is cheaper than that of Option 1. However, lifecycle cost including expenditure for O&M in Option 1 is cheaper. This is because expenditure for electricity and high frequency of O&M work will be required in Option 2. Therefore, Option 1 of Gravity Flow is recommended for the Preparatory Project.

(3) Route of Sewer

Proposed sewer will be installed at the southern side of the access road to STP, considering future expansion of the sewer system.

8.2.3 Preliminary Design of Sewer

Preliminary design of the sewer, including interception facilities, sewer and manholes, are outlined below.

(1) Interception Facilities

(a) Location of Sewage Interception

The sewage interception facilities will be located at the point in which drainage flow discharged from Tumpun PS is stable, as shown in **Fig. 8.2.2.** The location shall be studied in more detail in the Feasibility Study stage, based on the annual fluctuation of water level of the Cheung Aek Lake.

Source: JICA Study Team based on Google Earth Pro Image as of Oct.31, 2015

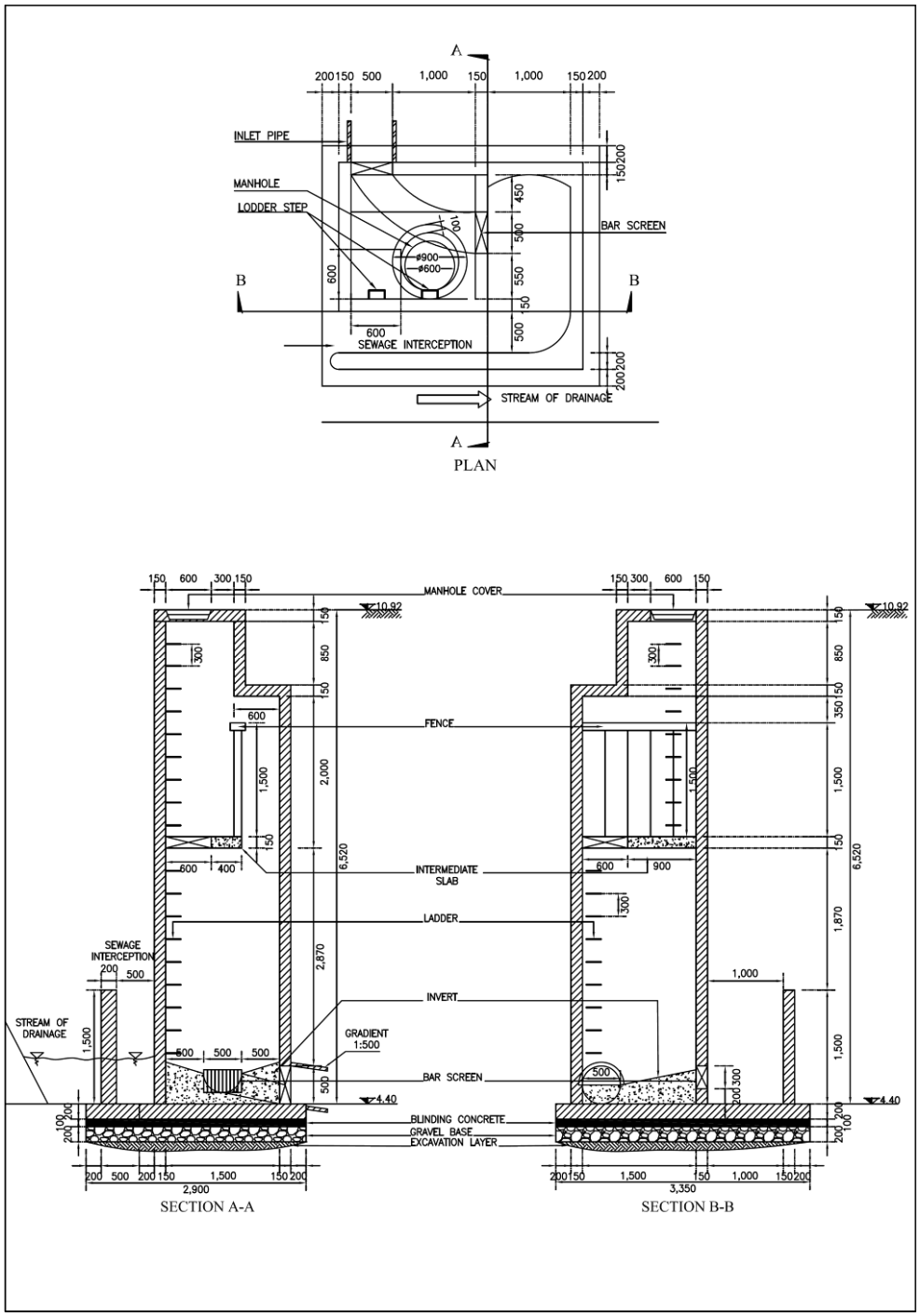
Fig. 8.2.2 Proposed Location of Sewage Interception

(b) Structure of Interception Facilities

Structure of interception facilities will consist of: (i) guide wall to capture sewage and control inlet sewage volume, (ii) bar screen to prevent garbage and large contaminants from entering sewer system. The guide wall will be installed in parallel with drainage stream and inlet of sewage installing bar screen will be installed a right angle with stream of drainage.

In addition, manhole and ladder step shall be installed for maintenance of the interception facilities. Manhole cover shall be easy to open and to be prevented the cover from falling down inside of the facility. Therefore, manhole cover will be circle shape with 600 mm considering a maintenance worker can enter the facilities. Material of the manhole cover will be ductile cast iron. Regarding ladder step, it is required a maintenance person can safely enter the facilities and it shall be resistant to corrosion and have proper interval. Therefore, ladder step will be installed at every 300 mm interval and it will be made of stainless steel with non-slip material.

Furthermore, intermediate slab and fence will be required considering the proposed access road level of 10.50 m and depth of the facilities. The intermediate slab will be installed at 3.0 m deep from ground level. **Fig. 8.2.3** shows the preliminary design of interception facilities.



Source: JICA Study Team

Fig. 8.2.3 Structure of Interception Facility

(2) Sewer and Manhole

(a) Sewer

(i) Selection of Pipe Material

Two (2) options for pipe material are considered. One is concrete pipe (CP) and another is hard vinyl chloride pipe (uPVC). **Table 8.2.2** shows the comparison of characteristics of the pipe materials. Based on the table, uPVC will not be applicable considering covering depth. As a result, concrete pipe is applied to this project.

Table 8.2.2 Characteristics of Pipe Materials

Items	Concrete Pipe (CP)	Hard Vinyl Chloride Pipe (uPVC)
Diameter	- From 150 mm to 3,000 mm	- From 75 mm to 600 mm
Internal Pressure Resistance	- It has sufficient strength on internal pressure in ordinary lying condition	- 6.0 kgf/cm^2
External Pressure Resistance	- It has sufficient strength on external pressure in ordinary lying condition	- Same as CP
Hydraulic Performance	- Coefficient of roughness (n) is 0.013. - Inside face is rough than uPVC. - Friction loss is larger than uPVC.	- Coefficient of roughness (n) is 0.010. - It has smooth inside face and little surface rust. - Friction loss is less than CP.
Corrosion Stability	- It is easy to be corroded by acid, especially hydrogen sulphide released from suspended sewage and particles in anaerobic condition.	- It has high stability to acid, alkali and other chemicals. - It is provided with the complete absence of electrochemical corrosion.
Transportation and Installation	- CP is heavy and it takes time to transport and install than uPVC.	- uPVC is light weight and it is easy to transport and install.
Application for Pipe-jacking method	- Pipe-jacking method is applicable. - Shield method is applicable.	- Pipe-jacking method is applicable, however, available diameter is up to 450 mm with shallow earth covering depth.
Maintenance	- The repair work require much time than uPVC because of difficulty of pipe cutting on site.	- The repair work is easy on site.
Economical Point of View	- Material itself is not expensive, however, work is costly and work duration is long.	- It can be reduced one size of pipe diameter because of coefficient of roughness.
Advantages	- Available diameter is wide up to 3,000 mm. - Resistance to deforming force is high. - Deep earth covering depth is applicable. - Pipe-jacking and shield method is applicable.	- Material is very light. - Workability is very high. - Resistance to corrosion is high. - Pipe-jacking method is applicable up to 450 mm.
Disadvantages	- CP is so heavy that workability is less than uPVC. - Resistance to corrosion is low.	- Applicable diameter is up to 600 mm. - Resistance to deforming force is lower than CP. - Availability is very limited compared with CP.
Evaluation	**Recommended**	

Source: JICA Study Team

(ii) Diameter

Diameter of the sewer is 500 mm based on design sewage volume and hydraulic calculation.

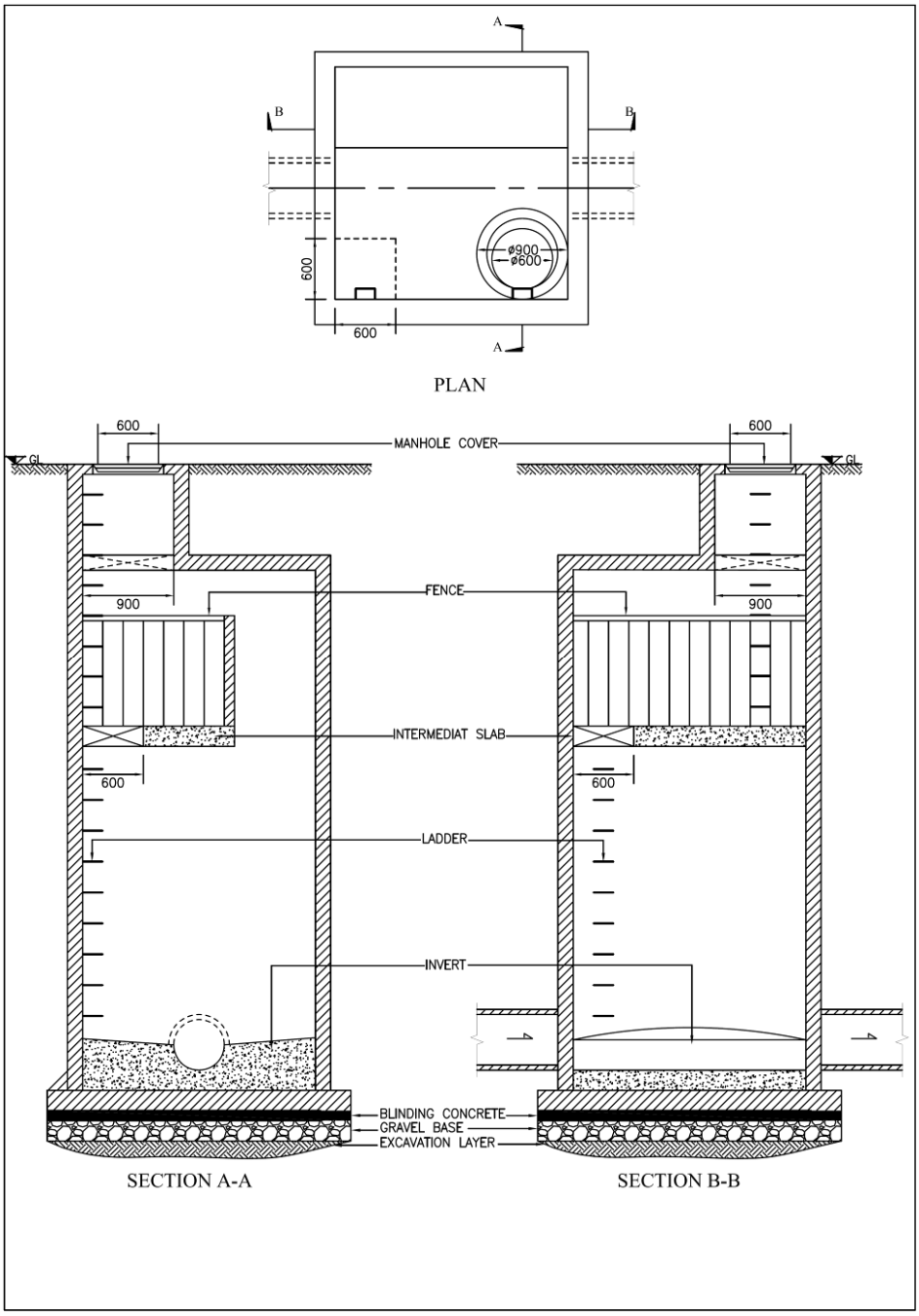
(b) Manholes

(i) Locations of Manhole

Manholes will be installed for proper maintenance of sewer. The manholes shall basically be installed at 100 m interval considering sewer diameter. In addition, manhole will be required at start point of sewer, transition point of sewer direction, changing point of sewer diameter and gradient, and connection point of sewers from various directions. In the Preparatory Project, 14 manholes will be required.

(ii) Typical Structure of the Manholes

Typical structure of manholes will be almost the same as the interception facilities. Components of the manholes will be manhole cover and ladder steps. Considering depth of manholes, intermediate slab and fence will be required. **Fig. 8.2.4** shows the typical structure of manholes in the Project. The dimension of each manhole shall be determined in the Feasibility Study Stage.

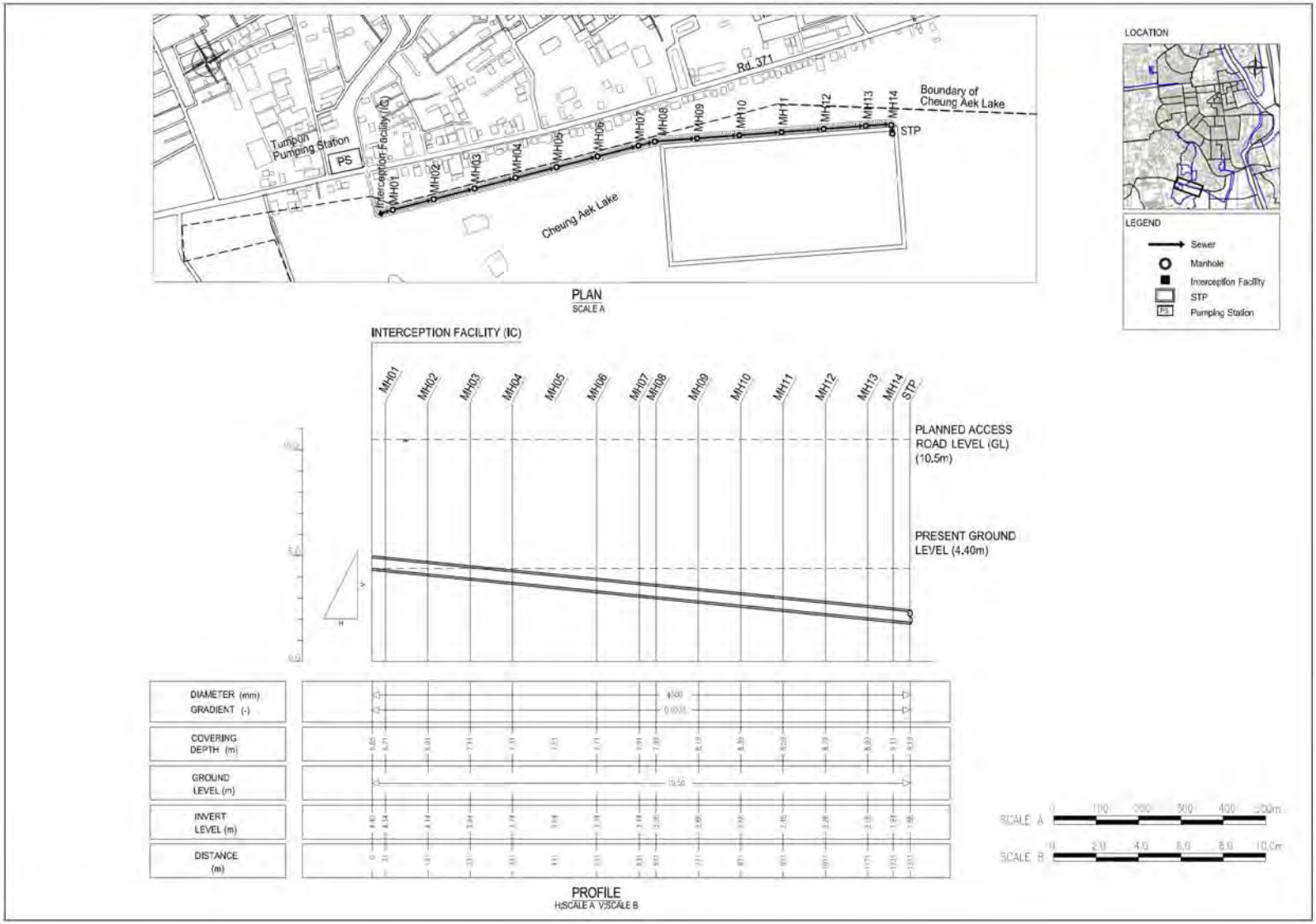


Source: JICA Study Team

Fig. 8.2.4 Typical Structure of Manhole

(3) Preliminary Design of Sewer Line

Fig. 8.2.5 shows the plan and sectional drawing of the sewer line in the Preparatory Project. The length of the sewer is 1,271 m and depth of the sewer line ranges from 6.7 m to 9.2 m.



Source: JICA Study Team

Fig. 8.2.5 Plan and Profile of Sewer Line in the Preparatory Project

8.2.4 Implementation Plan of Sewer Line

Sewer line will be installed under the access road to STP, which will be constructed by landfill of the Cheung Aek Lake. It is recommended to install the sewer line in parallel with construction work of the access road to minimize excavation. Although the depth of the sewer will be 6.7 m to 9.2 m after construction of the access road, excavation depth for sewer installation before the construction of the access road will be 2.6 m at the maximum. Therefore, open-cut method installation method will be applied.

8.2.5 Recommendation for Feasibility Study Stage

(1) Improvement of Discharge Channel from Tumpun PS

Drainage discharged from Tumpun PS flows into natural waterway in the Cheung Aek Lake. After construction of STP, access road and sewer line, area of the Cheung Aek Lake is reduced. In this case, the waterway of discharged stream is limited and flood area might expand to southern area of the Cheung Aek Lake. Therefore, it is recommended to study on flood condition of the Cheung Aek Lake and it may be necessary to improve discharge channel result from the analysis of the flood condition in future, if necessary.

(2) Implementation of Topographic and Geotechnical Survey at Cheung Aek Lake

In order to confirm and determine design condition for sewer line, STP and access road, it is recommended to conduct topographic and geotechnical survey in detail in the Cheung Aek Lake. Topographic condition is closely related to structural design and depth of excavation, landfill and earth covering of sewer line, STP and access road. On the other hand, geotechnical condition including particle size distribution is required to determine scale of structure and requirement to equipment which will be installed in the sewer system such as sand removal, coarse screen and fine screen.

(3) Investigation of Water Level of the Cheung Aek Lake

Annual fluctuation of water level of Cheung Aek Lake will be significant. The area of the Lake is reduced by rapid development with landfill. So, annual variability of water level of the Cheung Aek Lake as well as flood area in the past may be changed. Regarding the Preparatory Project of sewage treatment, sewage is intercepted at discharge point of Tumpun PS and the interception facilities will directly be affected by water level of the Cheung Aek Lake. In addition, sewer line will be affected by increasing groundwater level in case the water level of the Cheung Aek Lake is raised. Therefore, it is important to confirm annual variability for water level of the Cheung Aek Lake in order to confirm and determine the structure of sewer line.

(4) Study on Detailed Soft Components such as Garbage Management

Many households are settling in the Cheung Aek Lake and much garbage is disposed to the Lake. From the viewpoint of environmental protection, garage control by public authorities is essential because uncontrolled garbage increases O&M works and influences sewage conveyance and operation of STP. In addition, edification to residents is essential to control the garbage. The edification shall be conducted not only for the Lake but also other existing water bodies in whole area of PPCC. For drainage and sewerage management, soft components for edification to residences are also recommendable in parallel with construction of drainage and sewerage facilities. Therefore, it is recommended to study soft components such as garbage management in detail along with improvement and development of drainage and sewerage facilities in the Feasibility Study stage.

8.3 Preliminary Design of Sewage Treatment Plant

8.3.1 Construction Site

Construction site of STP is shown in **Fig. 8.3.1**. At present, no access road exists at the STP site; therefore new access road to the STP is constructed in the Project along the boundary of Cheung Aek Lake as shown in **Fig. 8.3.1**. As discussed in **Section 8.2**, a sewer pipe with diameter of 500 mm is installed under the access road to convey wastewater corresponding to the capacity of the STP. Electricity to operate the STP is provided through electric cable derived from high-voltage power cable buried under Road No. 371. The reclaimed area for the "Preparatory Project" is 3.5 ha.

Source : JICA Study Team, based on Google Earth

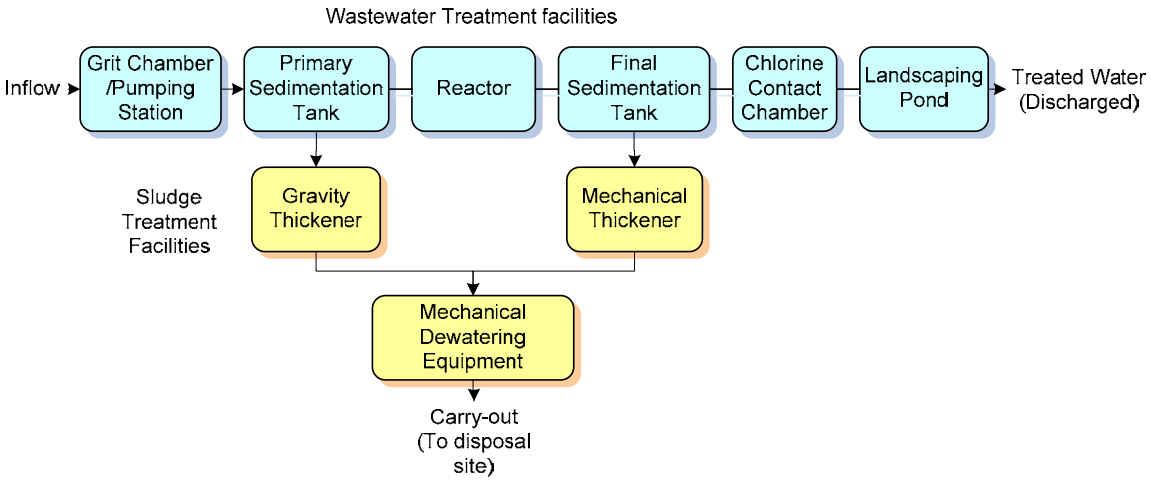
Fig. 8.3.1 Proposed STP Site in Cheung Aek Lake

8.3.2 Treatment Facilities

(1) Processing Flow

Treatment flow is shown in **Fig. 8.3.2**. Applied wastewater treatment method is CASP (Conventional Activated Sludge Process). Treatment facilities consist of: Grit chamber/Pumping station, Wastewater treatment facilities (Primary sedimentation tank, Reactor and Final sedimentation tank) and Chlorine contact chamber, as well as Landscaping pond. Landscaping pond is installed to demonstrate the effect of treatment. Sludge treatment facilites consist of : Gravity thickener, Mechanical thickener and Mechanical dewatering equipment. Dewatered sludge is transported to sludge disposal site.

Prior to implementation of the Preparatory Project, it is prefarable for PPCC to designate the disposal site specialised for sewage sludge disposal, as discussed in **Subsection 4.3.2.** However, as the second best, temporary use of Dangkor waste disposal site can be considered because it may take a long time to secure the new sludge disposal site.



Source: JICA Study Team

Fig. 8.3.2 Processing Flow of STP

(2) Design Flow

Design flow is shown in **Table 8.3.1**. Specifications of treatment facilities are determined in accordance with the design flow.

Table 8.3.1 Design Flow

Item	Design flow for Preparatory Project (m^3/day)	(Reference) Design flow for ultimate stage (m^3/day)
Daily average	4,600	260,000
Daily maximum	5,000	282,000
Hourly maximum	7,300	407,000

Source: JICA Study Team

(3) Specification of Treatment Facilities

Specifications of treatment facilities for the Preparatory Project are summarised in **Table 8.3.2**. Type of mechanical thickener and dewatering equipment is tentatively determined as shown in the remarks of **Table 8.3.2**, and detailed study should be conducted in the Feasibility Study. Landscaping pond is constructed to demonstrate effect of treatment by showing treated water and to strengthen public relations for the people (Image of landscaping pond is shown in **Photo 8.3.1**).

Table 8.3.2 Specification of Treatment Facilities (Preparatory Project)

Item	Specification	Remarks
Grit chamber/pumping station	Grit chamber: W0.80 m×L2.6 m×2 ponds Pumping station: 3.0 m^3/min×3 units (1stand-by)	Generator for pumiping station will be equipped.
Primary sedimentation tank	W3.6 m× L15.0 m× D3.0 m×2 ponds	
Reactor	W7.55 m× L34.0 m× D6.0 m×1 reactor	
Final Sedimentaton tank	W3.6 m× L35.0 m×D3.5 m×2 ponds	
Chlorine contact chamber	W3.0 m× L10.0 m× D4.0 m	
Blower	20 m^3/min×2 units (1 stand-by)	Roots blower type Note 1)
Gravity thickener	Diameter3.0 m×1 unit	
Mechanical thickener	10 m^3/hr×2 units (1 stand-by)	Belt type filteing
Mechanical dewatering equipment	110 kg-DS/hr×2 units (1 stand-by)	High-efficiency screw press type
Others	Administratiion building and landscaping pond	

Note 1) Roots blower is applied in the preparatory project stage. On the other hand, turbo blower is applied in the ultimate stage, as shown in **Table 8.3.3**.
Source : JICA Study Team

Source: Kitakyushu City

Photo 8.3.1 Image of Landscaping Pond

(4) General Layout, Hydraulic Profile and Structural Drawings of Major Facilities

Layout of facilites and hydraulic profile are determined based on the following considerations.

- Design ground level is set at EL.+10.50 m considering that of the surrounding area of STP, namely, ING City's design ground level (EL. +10.50 m).

- Hydraulic profile is set considering the highest water level of Bassac River and Sap River (EL. +10.18 recorded at Chaktmok Station), which affects the discharge level of the STP. After pumping up at the pumping station in the STP, treated water is conveyed and discharged by gravity.

- Facilities constructed in the Preparatory Project (capacity of 5,000 m^3/day) are designed as much as possible not to be useless for next phased construction (ultimate capacity of 282,000 m^3/day).

- Based on the above consideration, administration building, grit chamber/pumping station and wastewater treatment facilities are laid out in accordance with the layout plan in the ultimate stage. Blower and sludge treatment facilities are accommodated in the mechanical equipment building. The mechanical equipment building is however centralised in the blower and mechanical sludge treatment facilities' building constructed in the ultimate stage. The mechanical equipment building constructed in the Preparatory Project is converted to warehouse in the ultimate stage.

Based on the above considerations, general layout plan of the STP and wastewater treatment facilities are depicted in **Figs. 8.3.3** to **8.3.7**. As a reference, specification of STP in ultimate stage is shown in **Table 8.3.3** and also transition from Preparatory Project to ultimate stage (final stage of construction of STP) is illustrated in **Fig. 8.3.8**.

Table 8.3.3 Specifications of Treatment Facilities (Ultimate Stage)

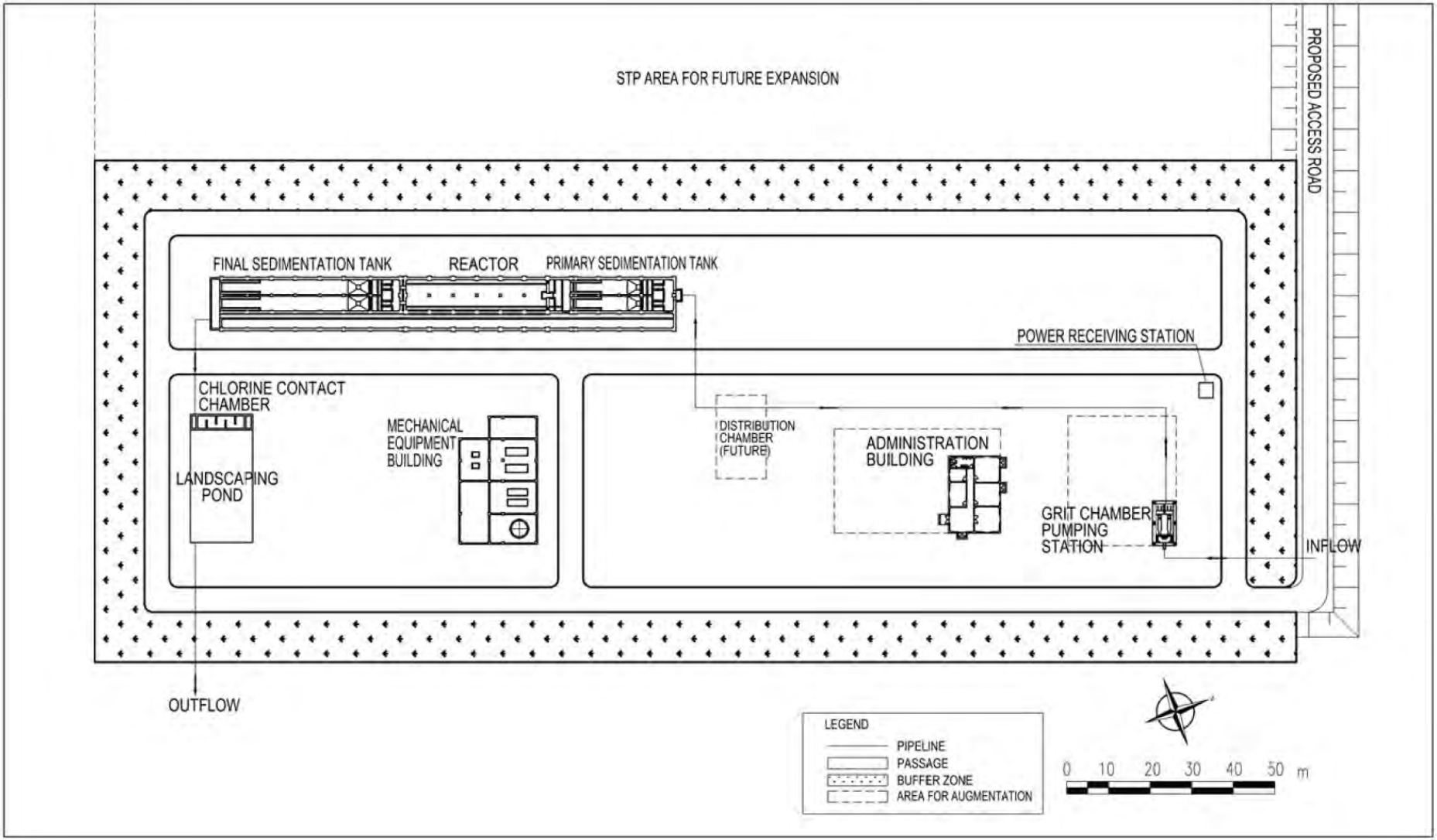
Item	Specifications	Remark
Grit chamber/pumping station	Grit chamber: W3.00 m×L13.0 m×6 ponds Pumping station: 50.0 m^3/min×7units (1stand-by)	
Primary sedimentation tank	W3.6 m×L15.0 m×D3.0 m×8 ponds×2 lanes W5.3 m×L 15.0 m×D3.0 m×8 ponds×8 lanes	
Reactor	W7.55 m×L 34.0 m×D6.0 m×4 ponds×2 lanes W10.95 m×L 34.0 m×D6.0 m×4 ponds×8 lanes	
Final Sedimentaton tank	W3.6 m×L 35.0 m×D3.5 m×8 ponds×2 lanes W5.3 m×L 35.0 m×D3.5 m×2 ponds×8 lanes	
Chlorine contact chamber	W30.0 m×L 50.0 m×D4.0 m×1 pond	

Item	Specifications	Remark
Blower	90 m^3/min × 2 units 180 m^3/min × 5 units (1 stand-by)	Turbo blower
Gravity thickener	Diameter 11.0 m × 4 units	
Mechanical thickener	50 m^3/hr × 8 units (1 stand-by)	Belt type filteing
Mechanical dewatering equipment	840 kg-DS/hr × 9 units(1 standby)	High-efficiency screw press type
Others	Administratiion building, generator, power receiving statiton and landscaping pond	

Source : JICA Study Team

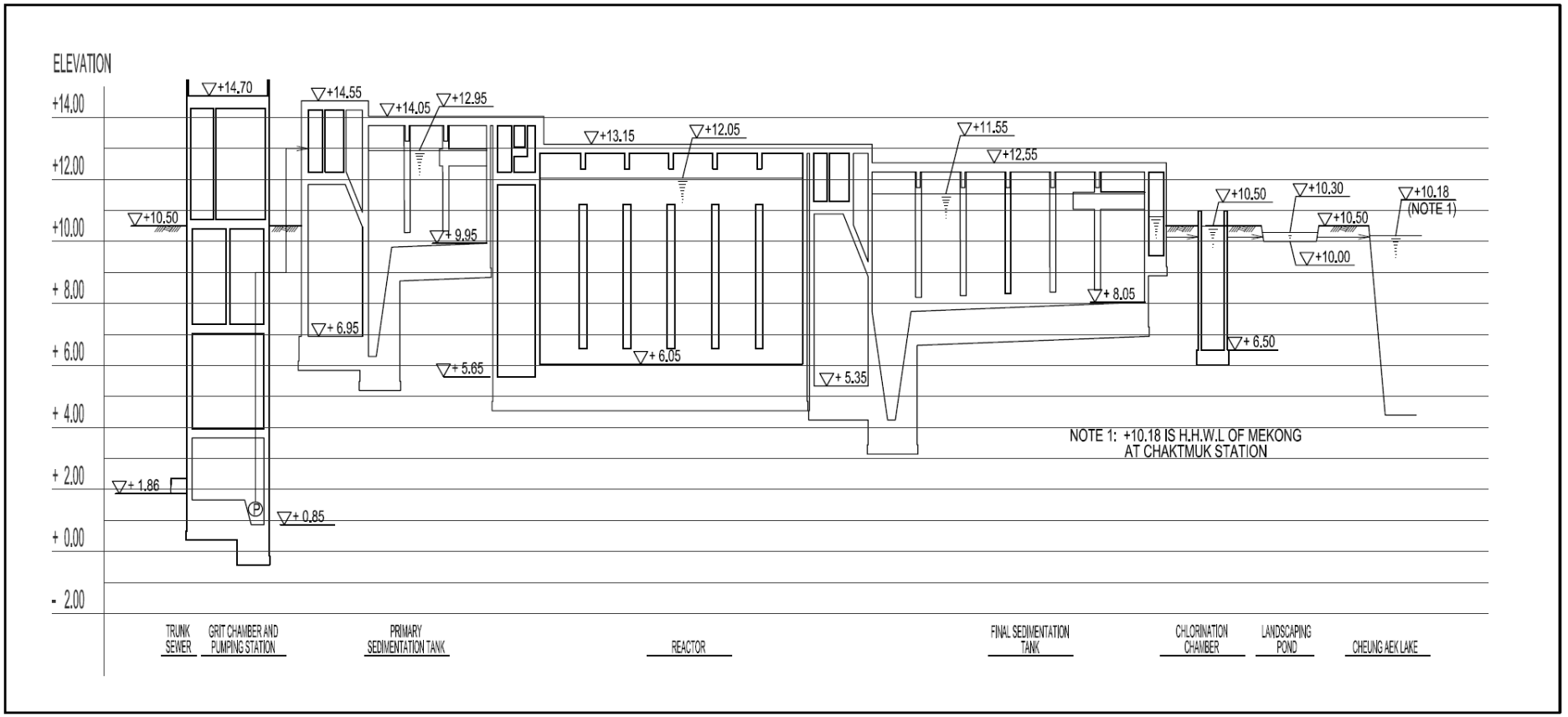
(5) Others (Reference)

In the Pre-F/S, the STP facilities plan is formulated applying CASP but in **Appendix 11**, the layout plan of wastewater treatment facilities (capacity: 5,000 m^3/day) applying PTF is attached as a reference for the next Feasibility Study Stage.



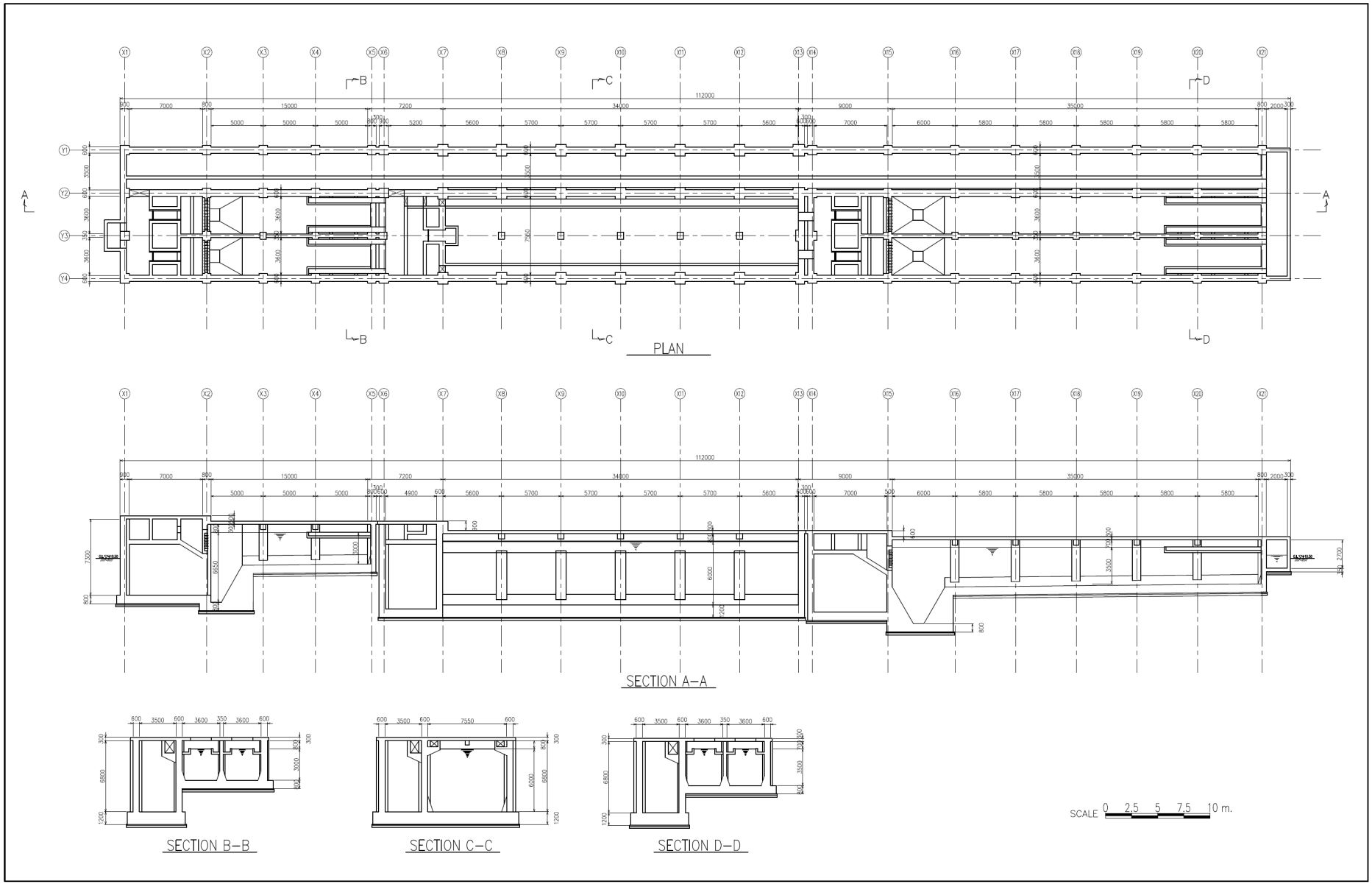
Source: JICA Study Team

Fig. 8.3.3 General Layout of STP constructed in Preparatory Project



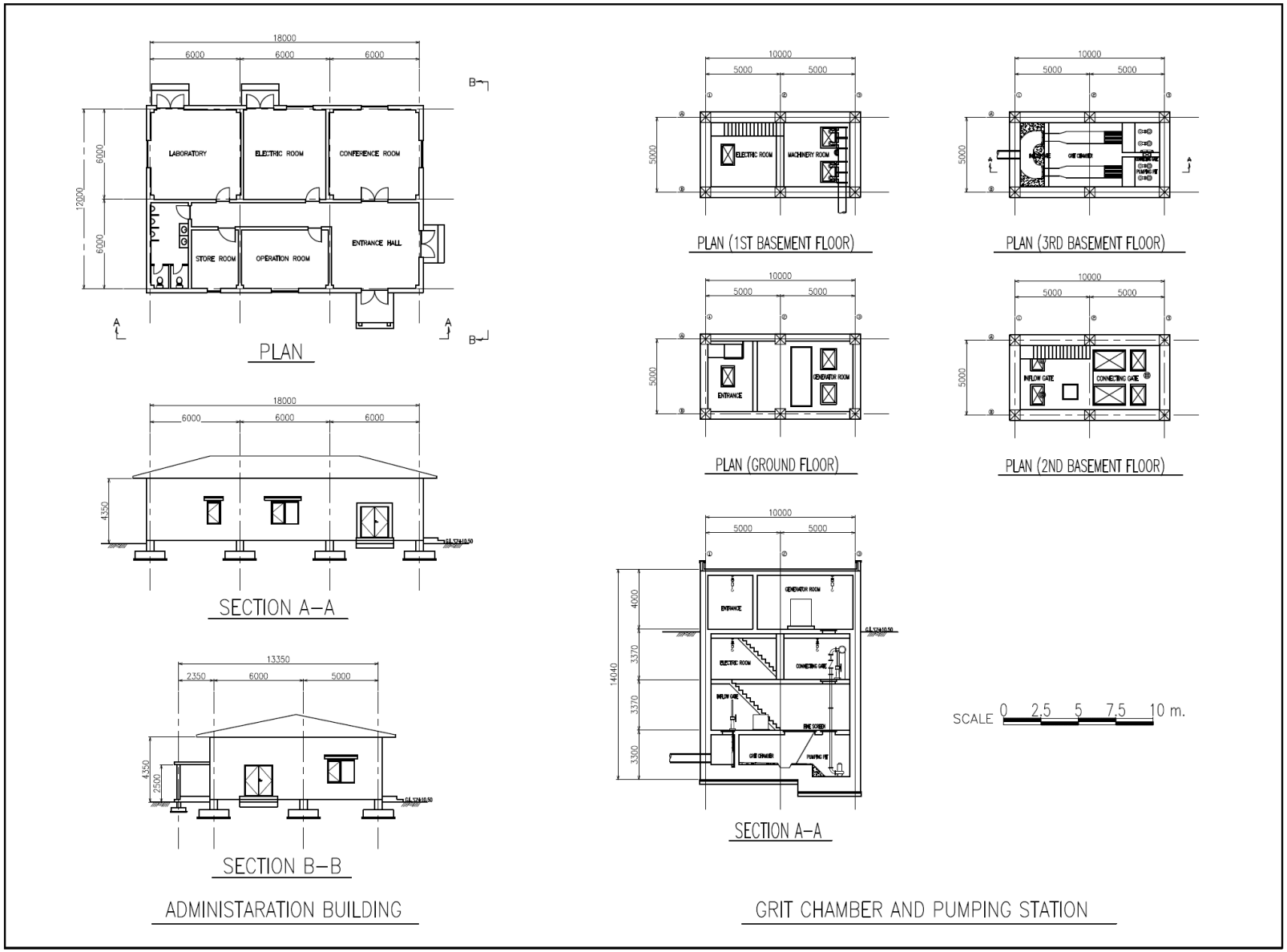
Source: JICA Study Team

Fig. 8.3.4 Hydraulic Profile



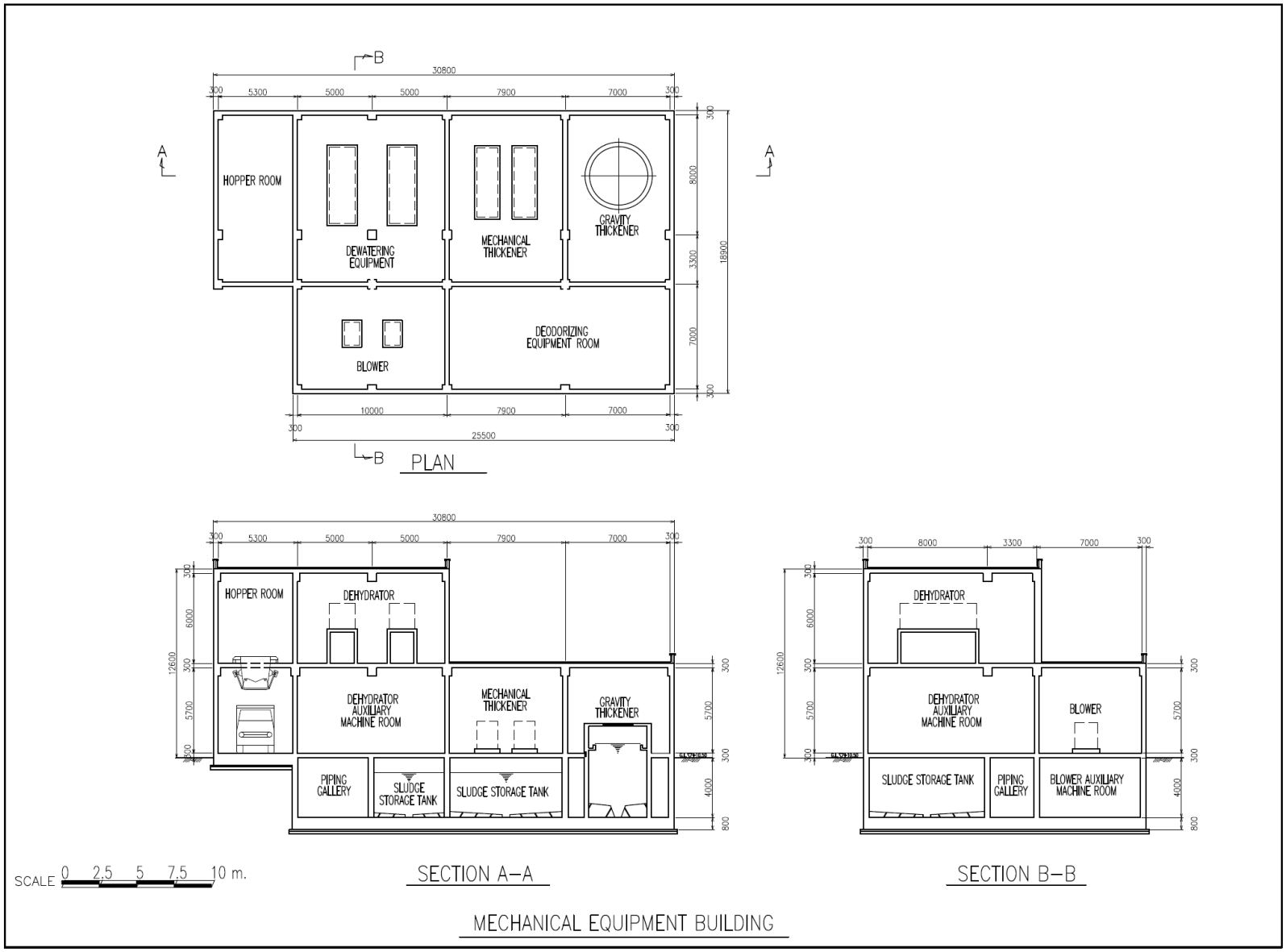
Source: JICA Study Team

Fig. 8.3.5 Plan and Section of Major Facilities (1/3)



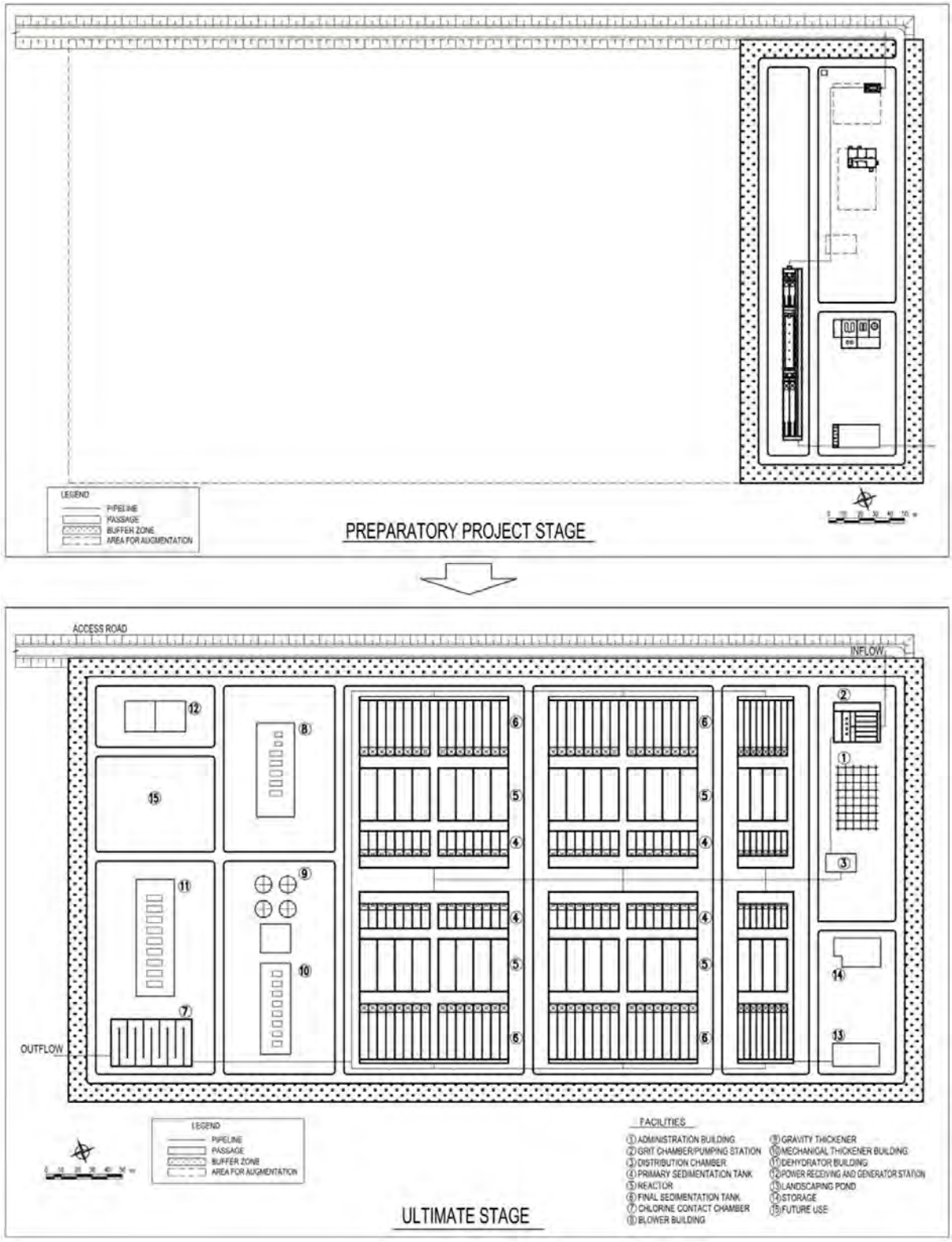
Source: JICA Study Team

Fig. 8.3.6 Plan and Section of Major Facilities (2/3)



Source: JICA Study Team

Fig. 8.3.7 Plan and Section of Major Facilities (3/3)



Source : JICA Study Team

Fig. 8.3.8 Comparison of Layout Plans of Preparatory Stage and Ultimate Stage

8.4 Implementation Framework (including O&M System)

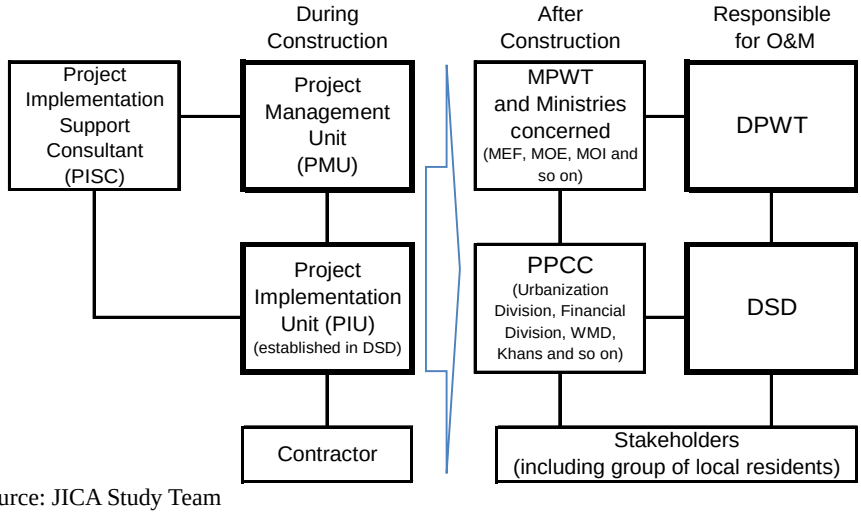
8.4.1 Priority Project Implementation System

Fig. 8.4.1 shows the organization for carrying out the Preparatory Project (construction of STP with treatment capacity of 5,000 m^3/day). The Preparatory Project shall be carried out by the Project Management Unit (PMU), which comprehensively manages the project, the Project Implementation Unit (PIU), which conducts operation related to construction of the STP, the Project Implementation Support Consultant (PISC), which gives total technical support to PMU and PIU, and the contractor, which will be responsible for the construction work.

Operation and Maintenance (O&M) after completion of the Project shall be carried out by the Drainage and Sewerage Division (DSD). With regard to Capacity Development (CD) related to O&M, the parties engaged in the design and construction of the STP shall from time to time carry this out during the construction period on behalf of DSD, including the technical transfer of knowledge regarding the structure, mechanism, and role of the facilities and the preparation of O&M manuals. After operation of the plant begins, they shall develop O&M capacity through the provision of instructions on a practical level and give instructions so that DSD can quickly become able to take leadership in O&M. In addition, during implementation of the Project (design and construction) and after the commission of STP, they shall provide the stakeholders (including civil groups) with explanations about the significance and necessity of sewerage systems. Moreover, they should give information to residents in PPCC through active public relations and awareness-raising activities.

The PMU and PIU shall be established in DPWT and DSD, respectively. Staff assigned to PMU shall be selected by the organizations concerned.

Project plans and technical support (for the design, construction management, and O&M of the plant) necessary for implementation of the Project shall be entrusted to consultants and experts who are thoroughly familiar with this project and have sufficient experience and prior achievements in the planning, design, construction management, and O&M of a sewer network service.



Source: JICA Study Team

Fig. 8.4.1 Implementing System of the Preparatory Project

8.4.2 Organization and Role of the Project Implementation Unit

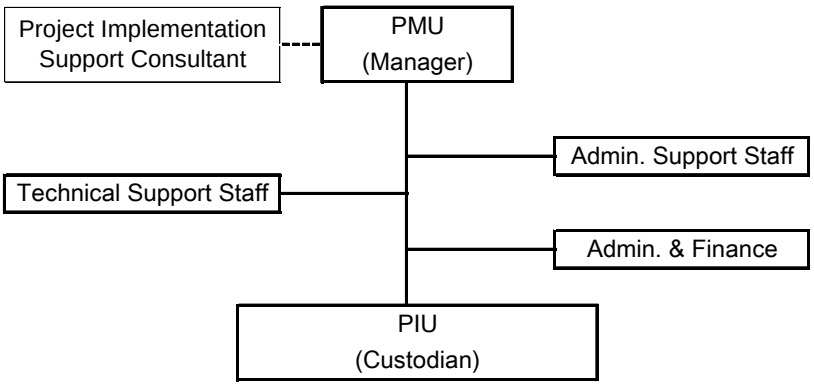
The organization for the implementation of the project, the sharing of roles, and maintenance are detailed as follows:

(1) Organization and Role of the Project Management Unit (PMU)

PMU is in charge of comprehensive management of the Project, including overall coordination with the stakeholdes and management regarding the progress of the project. They mainly carry out the following duties:

- Coordination with the overall plan, budget management, financial management, and general construction management etc.
- Management of approval etc. of work plans, financial plans, and activity plans
- Liaison and coordination with related agencies and interested parties, liaison and coordination with supporting consultants
- Supervision of PIU
- Reporting the progress status of the Project
- Activities for raising awareness among civil groups about the necessity for a sewer network service etc.
- Other necessary matters

The staff of PMU shall be appointed by recommendation of the organizations concerned. **Fig. 8.4.2** shows the organization of PMU, while **Table 8.4.1** shows the staff and their duties.



Source: JICA Study Team

Fig. 8.4.2 Organization of Project Management Unit (PMU)

Table 8.4.1 Staff and Duties of PMU

Position	No. of staff	Duties
Manager	1	Supervision of PMU
Assistant manager	1	Assists the manager, overall coordination with related agencies
Technical support staff	2-4	Technical management of the project
Admin. support staff	2	Management of general administrative affairs for the project, operational liaison
Admin. & finance	2	Financial management for the project

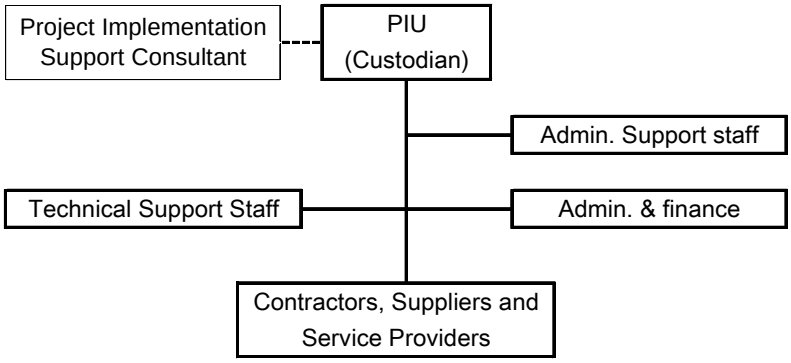
Source: JICA Study Team

(2) Organization and Role of the Project Implementation Unit (PIU)

PIU is in charge of practical affairs for the construction of the STP, and manages and supervises the construction of the plant. After the completion of construction, some staff members shall continue to be in charge of O&M as plant maintenance staff. PIU mainly carry out the following duties:

- Management of the progress in public works and other construction, supervision of construction, and inspection
- Social environment management, implementation and coordination of safety management activities
- Close cooperation with DPWT, PPCC, and the khans
- Report on the progress status of construction of the Project (to PMU)
- Hold explanation meetings with civil groups concerning the Project (civil groups' tours of the plant)
- Technical transfer to DSD staff concerning maintenance
- Other necessary matters

The Manager of PIU shall be appointed from DPWT (DSD). The staff shall be appointed from among the related departments, such as DPWT, DOP, DEF, and DOE, and the related divisions (related khans) of Phnom Penh. **Fig. 8.4.3** shows the organization of PIU, while **Table 8.4.2** shows the staff and their duties.



Source: JICA Study Team

Fig. 8.4.3 Organization of Project Implementation Unit (PIU)

Table 8.4.2 Staff and Duties of PIU

Position	No. of staff	Duties
Manager	1	Supervision of PIU
Assistant manager	1	Assists the Manager, coordination with related agencies concerning construction
Technical support staff	4-6	Technical management of the project
Admin. support staff	2	Operational management of the project, operational liaison
Admin. & finance	2	Financial management of the project

Source: JICA Study Team

8.4.3 O&M of the STP

There is no staff for O&M of the sewage treatment plant because there is no STP in PPCC. However, when the sewerage treatment facilities are built in PPCC, DSD will be the most suitable as the O&M department. This is because DSD is now in charge of O&M of the drainage facilities (including pumping stations) and so has achievements and experience. Therefore, DSD shall take charge of O&M of the STP. **Table 8.4.3** shows the O&M staff. When the plant is in operation, workers will be needed to remove scum, clean sediment, and dispose sludge.

Table 8.4.3 O&M Staff

Type of job	No. of staff	Duties
Custodian	1	Facilities manager
Civil engineer	2	O&M of facilities structures, sewage pipes, etc.
Machinery/electricity engineer	3 - 5	O&M of sewage treatment facilities
Water quality management engineer	2	Water quality sampling, test, analysis
Clerical worker	2	General affairs, public relations
Worker	4 - 6	Removal of scum, disposal of sludge, cleaning of facilities

Source: JICA Study Team

8.5 Cost Estimate

8.5.1 Project Cost

(1) General Conditions

Project cost consists of construction cost, administration cost, engineering cost and physical contingency. No land expropriation/compensation cost is included in this cost estimation since all construction works are done in public land. The costs are estimated based on the general conditions as enumerated below, with exchange rate of 1USD=122.85JPY, and 1Riel=0.030JYP, as of December 2015.

- As described in **Sections 8.2** and **8.3**, the cost is estimated targeting the "Preparatory Project", including construction of STP (Capacity: 5,000 m^3/day) and sewer pipe installation. Applied treatment method is CASP.

- Civil and architectural material cost, labor cost, and construction equipment cost are estimated based on the prices obtained in Cambodia because these can procured in Cambodia. On the other hand, some steel products and construction equipment costs are estimated based on the prices obtained in other countries such as Japan because those are not available in Cambodia.

- Mechanical and electrical equipment is in general procured from other countries, considering cost effectiveness, liability and easiness of operation and maintenance.

- Engineering cost consists of: (i) cost for natural condition such as topological and geological surveys and (ii) consulting service fee in engineering, procurement and construction supervision.

- Administration cost includes cost for project administration and implementation such as review and approval of design documents, construction supervision as project owner (inspection, testing, approval of design changes, office administration and holding meeting). The administration cost is estimated at 5% of construction cost.

- Physical contingency is a cost to cover additional expenditure for construction due to

unforeseeable site condition and uncertainties. The physical contingency is estimated at 5% of construction cost and engineering cost.

(2) Cost Estimation

Based on the above conditions, project cost is estimated as shown in **Table 8.5.1**. According to the table, project cost is 24.05 million USD. Construction cost consists of (i) construction of STP: 15.45 million USD; (ii) construction of sewer pipe: 2.29 million USD; and (iii) construction of access road: 1.94 million USD.

Table 8.5.1 Project Cost (Preparatory Project)

Unit: million USD

Item	Local currency	Foreign currency	Total
I. Construction cost ((1)+(2)+(3))	14.01	5.76	19.77
(1) STP	10.27	5.27	15.54
1) Civil	8.69	0.52	9.21
Reclamation (3.5 ha)	3.37	0.04	3.41
Structure	5.32	0.48	5.80
2) Architecture	1.31	0.04	1.35
3) Mechanical work	0.23	4.39	4.62
4) Electrical work	0.04	0.32	0.36
(2) Sewer	1.97	0.32	2.29
(3) Access road	1.77	0.17	1.94
II. Engineering cost	0.44	1.75	2.19
III. Administration cost	0.99	0	0.99
IV. Physical contingency	0.72	0.38	1.10
Total (I+II+III+IV)	16.16	7.89	24.05

Source : JICA Study Team

8.5.2 Operation and Maintenance Cost

Operation and maintenance cost is 415,440 USD, as shown in **Table 8.5.2**. Personal expense is estimated based on number of O&M staff proposed in **Subsection 8.4.3**.

Table 8.5.2 O&M Cost (Preparatory Project)

Unit: USD

Item	Total	Remark
I. Treatment facilities ((1)+(2)+(3)+(4))	407,119	
(1) Personnel expenses	126,240	Based on estimated number of 5 regulars, including chief of STP and 15 contracted employee
(2) Electricity	175,262	Based on electrical requirements of machinery
(3) Chemicals	72,380	sodium hypochlorite and high-polymer coagulant
(4) Repair and spare parts	23,820	1% of construction cost of machinery
(5) Sludge disposal	9,417	Transportation of sludge
II. Sewer	5,621	
III. Access road	2,700	
Annual O&M total cost (I+II+III)	415,440	

Source : JICA Study Team

8.6 Implementation Schedule

Implementation schedule of the Preparatory Project is shown in **Table 8.6.1** and **Fig. 8.6.1**.

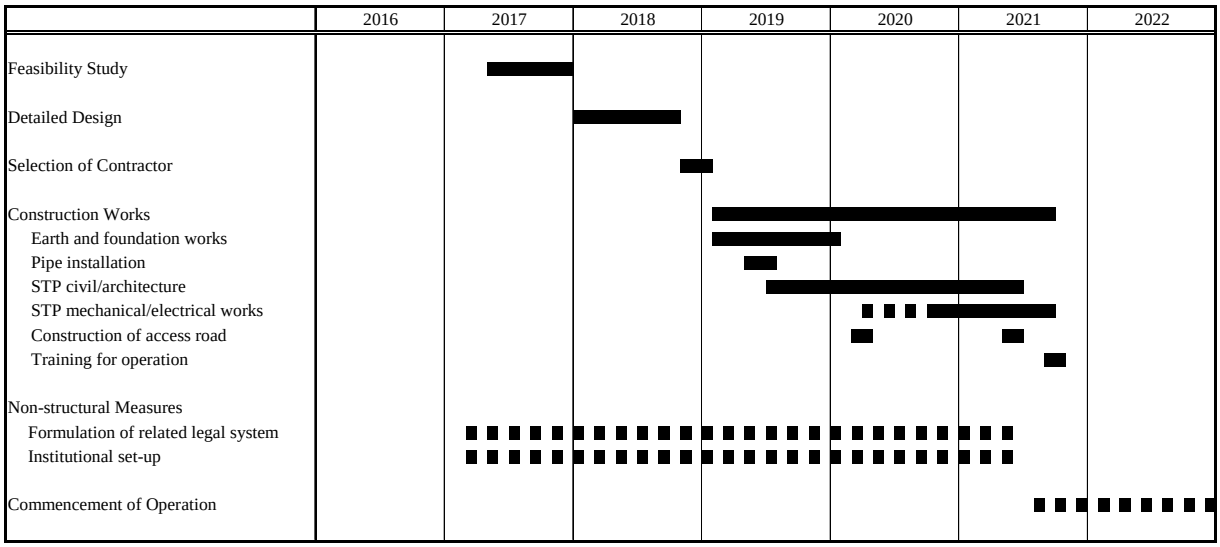
Table 8.6.1 Implementation Schedule of Preparatory Project

Item	Period
Feasibility Study	8 months
Detailed Design	10 months

Item	Period
Selection of Contractor	3 months
Construction Works	32 months
Legal and Institutional Set-up	48 months

Source : JICA Study Team

In the implementation schedule, commencement of STP operation is set in year 2022. As discussed in **Section 4.9**, legal and institutional framework is established before commencement of the STP operation. Period of Feasibility Study and Detailed Design are set based on general ones and hence can be shortened depending on scheme or methodologies provided by the donors.



Source : JICA Study Team

Fig. 8.6.1 Implementation Schedule of Preparatory Project

8.7 Financial Analysis

The financial analysis result of the sewerage Preparatory Project is described as follows, but the methodology is similar to that used in **Section 4.7**. Since this Preparatory Project is included in the M/P, the scale is less than one-tenth of that of the M/P Phase 1 or 2% of the total M/P scale. The beneficiary population (19,000 in 2035) is small and so at first it is analyzed whether 10% of the beneficiary population's water supply use charge revenues (strictly speaking, 91% of those excluding commission) as sewerage use charge revenues can cover the costs or not. Although the scale is small, if it aims to cover the investment costs, 10% of water supply revenues are not sufficient and it is necessary to raise the ratio similarly to the M/P case. Therefore, the government shoulders the investment costs and it is analyzed whether the operation costs without depreciation can be covered by the 10% of water supply revenues. In addition, wastewater to be treated in this Project is part of discharged water from Tumpun Pumping Station. Strictly speaking, beneficiaries are part of Phases 1, 2 and 3 planned population so that they are the total Cheung Aek system area planned population. However, they are too many and so beneficiaries are supposed to be equivalent of treatment capacity or beneficiaries responding to the intake wastewater. Thus, if the direct beneficiaries of this Project cannot cover the costs, then next it is analyzed whether Phase 1 beneficiaries can cover the costs. Further next, the Cheung Aek system area population coverage is the object. Of course, since the total Phnom Penh water supply users are the objects of sewerage and drainage use charges (10% of water supply use charge revenues) at present, it can be examined whether they can cover the operation costs, but it may be unnecessary and Cheung Aek area population may be sufficient. From that viewpoint, it can be analyzed whether the Cheung Aek area population or total Phnom Penh water supply users can cover even the investment costs in addition to the operation costs. Nevertheless, investments of Phases 1 to 3 and Tamok system area continue and so it is useless to cover only this preparatory

project investment costs. Incidentally, this analysis treats only the Preparatory Project and does not include sludge disposal revenues.

At first, profit and loss in the case of 10% of Preparatory Project beneficiaries' water supply use revenues is estimated in **Table 8.7.1**. The sewerage use revenues are very small and cannot cover the operation costs. There is no sludge disposal revenue and so Preparatory Project operation expenditures cannot be covered by sewerage use charges revenues.

Then, the case result including Phase 1 beneficiaries' revenues is shown in **Table 8.7.2**.

Table 8.7.1 Profit and Loss without Depreciation (Revenues of Preparatory Project Beneficiaries)

(Unit: million USD)

Year	2016	2017	2018	2019	2020	2021	2022
Rev. from STP Pr.						0.03	0.03
Total Rev.						0.03	0.03
Expenditure						0.42	0.42
Profit/ Loss						-0.39	-0.39

Year	2023	2024	2025	2026	2027	2028	2029
Rev. from STP Pr.	0.03	0.03	0.03	0.03	0.04	0.04	0.04
Total Rev.	0.03	0.03	0.03	0.03	0.04	0.04	0.04
Expenditure	0.42	0.42	0.42	0.42	0.42	0.42	0.42
Profit/ Loss	-0.39	-0.38	-0.38	-0.38	-0.38	-0.38	-0.38

Year	2030	2031	2032	2033	2034	2035	2036
Rev. from STP Pr.	0.04	0.04	0.04	0.05	0.05	0.05	0.05
Total Rev.	0.04	0.04	0.04	0.05	0.05	0.05	0.05
Expenditure	0.42	0.42	0.42	0.42	0.42	0.42	0.42
Profit/ Loss	-0.38	-0.37	-0.37	-0.37	-0.37	-0.37	-0.37

Year	2037	2038	2039	2040	Total		
Rev. from STP Pr.	0.05	0.05	0.05	0.05	0.81		
Total Rev.	0.05	0.05	0.05	0.05	0.81		
Expenditure	0.42	0.42	0.42	0.42	8.31		
Profit/ Loss	-0.37	-0.37	-0.37	-0.37	-7.50		

Source : JICA Study Team

Table 8.7.2 Profit and Loss without Depreciation (including Revenues of Phase 1 Beneficiaries)

(Unit: million USD)

Year	2016	2017	2018	2019	2020	2021	2022
Rev. from STP Pr.						0.35	0.36
Total Rev.						0.35	0.36
Expenditure						0.42	0.42
Profit/ Loss						-0.07	-0.05

Year	2023	2024	2025	2026	2027	2028	2029
Rev. from STP Pr.	0.38	0.39	0.41	0.42	0.44	0.46	0.48
Total Rev.	0.38	0.39	0.41	0.42	0.44	0.46	0.48
Expenditure	0.42	0.42	0.42	0.42	0.42	0.42	0.42
Profit/ Loss	-0.04	-0.02	-0.01	0.01	0.03	0.05	0.07

Year	2030	2031	2032	2033	2034	2035	2036
Rev. from STP Pr.	0.50	0.52	0.54	0.57	0.59	0.62	0.62
Total Rev.	0.50	0.52	0.54	0.57	0.59	0.62	0.62
Expenditure	0.42	0.42	0.42	0.42	0.42	0.42	0.42
Profit/ Loss	0.08	0.11	0.13	0.15	0.18	0.20	0.20

Year	2037	2038	2039	2040	Total		
Rev. from STP Pr.	0.62	0.62	0.62	0.62	10.15		
Total Rev.	0.62	0.62	0.62	0.62	10.15		
Expenditure	0.42	0.42	0.42	0.42	8.31		
Profit/ Loss	0.20	0.20	0.20	0.20	1.84		

Source : JICA Study Team

In this case, it starts that sewerage use charge revenues are a little less than operational costs, they exceed operation costs meaning profits from 2026. Sum of profit minus loss from the start to 2040 is positive.

Next, the case includes the total Cheung Aek system area beneficiaries and the revenues increase shown in **Table 8.7.3**.

Table 8.7.3 Profit and Loss without Depreciation (including Revenues of Total Cheung Aek System Area Beneficiaries)

(Unit: million USD)

Year	2016	2017	2018	2019	2020	2021	2022
Rev. from STP Pr.						1.69	1.75
Total Rev.						1.69	1.75
Expenditure						0.42	0.42
Profit/ Loss						1.28	1.34

Year	2023	2024	2025	2026	2027	2028	2029
Rev. from STP Pr.	1.81	1.88	1.95	2.01	2.09	2.17	2.25
Total Rev.	1.81	1.88	1.95	2.01	2.09	2.17	2.25
Expenditure	0.42	0.42	0.42	0.42	0.42	0.42	0.42
Profit/ Loss	1.40	1.46	1.53	1.60	1.67	1.76	1.84

Year	2030	2031	2032	2033	2034	2035	2036
Rev. from STP Pr.	2.34	2.43	2.53	2.63	2.74	2.85	2.85
Total Rev.	2.34	2.43	2.53	2.63	2.74	2.85	2.85
Expenditure	0.42	0.42	0.42	0.42	0.42	0.42	0.42
Profit/ Loss	1.92	2.01	2.11	2.21	2.33	2.43	2.43

Year	2037	2038	2039	2040	Total		
Rev. from STP Pr.	2.85	2.85	2.85	2.85	47.37		
Total Rev.	2.85	2.85	2.85	2.85	47.37		
Expenditure	0.42	0.42	0.42	0.42	8.31		
Profit/ Loss	2.43	2.43	2.43	2.43	39.06		

Source : JICA Study Team

8.8 Economic Analysis

The method in this Preparatory Project economic analysis is similar to that described in **Section 4.8.** Concerning the benefits of sewerage users, the method is similar and it is an issue whether the objects are only sewerage users or the total final planned area population from the start because they can get water pollution improvement benefits. In particular, wastewater to be treated in this Project is partially taken in from the total wastewater so that it means all the water supply users relate to this Project wastewater (of course, the total wastewater is not treated, though). At first, the beneficiaries are supposed to be population responding to the treated wastewater volume and the result is shown in **Table 8.8.1**. EIRR is positive 0.47%, but very low.

Next, the case result supposing Phase 1 users as objects is shown in **Table 8.8.2**. Users' benefits become larger responding to Phase 1 users number and EIRR becomes 25.22%, sufficiently high. It will be higher if the beneficiaries are supposed to be the Cheung Aek system area users, but it is not necessary because the Phase 1 users case is sufficient.

Table 8.8.1 Preparatory Project EIRR (Case of Beneficiaries responding to the Capacity)

(Unit: million USD)

Year	2016	2017	2018	2019	2020	2021	2022
Users' Benefit						0.58	0.62
Land Value Rise						0.34	0.00
Agri. & Fishery						0.01	0.01
Operational Costs						0.42	0.42
Investment			23.73				0.00
Cash flow			-23.73			0.51	0.21

Year	2023	2024	2025	2026	2027	2028	2029
Users' Benefit	0.67	0.72	0.77	0.83	0.89	0.96	1.03
Land Value Rise	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agri. & Fishery	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Operational Costs	0.42	0.42	0.42	0.42	0.42	0.42	0.42
Investment					0.00		
Cash flow	0.26	0.31	0.37	0.42	0.48	0.55	0.62

Year	2030	2031	2032	2033	2034	2035	2036
Users' Benefit	1.10	1.18	1.27	1.36	1.46	1.57	1.57
Land Value Rise	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agri. & Fishery	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Operational Costs	0.42	0.42	0.42	0.42	0.42	0.42	0.42
Investment							
Cash flow	0.70	0.78	0.87	0.96	1.06	1.17	1.17

Year	2037	2038	2039	2040	Total		
Users' Benefit	1.57	1.57	1.57	1.57	22.86		
Land Value Rise	0.00	0.00	0.00	0.00	0.37		
Agri. & Fishery	0.01	0.01	0.01	0.01	0.21		
Operational Costs	0.42	0.42	0.42	0.42	8.31		
Investment					23.73		
Cash flow & IRR	1.17	1.17	1.17	1.17	2.05	EIRR=	0.47%
Residual value				10.65			

Source : JICA Study Team

Table 8.8.2 Preparatory Project EIRR (Case of Phase 1 Beneficiaries)

(Unit: million USD)

Year	2016	2017	2018	2019	2020	2021	2022
Users' Benefit						7.24	7.78
Land Value Rise						0.34	0.00
Agri. & Fishery						0.01	0.01
Operational Costs						0.42	0.42
Investment			23.73				0.00
Cash flow			-23.73			7.17	7.37

Year	2023	2024	2025	2026	2027	2028	2029
Users' Benefit	8.36	8.99	9.66	10.37	11.14	11.97	12.85
Land Value Rise	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agri. & Fishery	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Operational Costs	0.42	0.42	0.42	0.42	0.42	0.42	0.42
Investment					0.00		
Cash flow	7.95	8.58	9.25	9.97	10.74	11.56	12.45

Year	2030	2031	2032	2033	2034	2035	2036
Users' Benefit	13.80	14.81	15.90	17.06	18.31	19.65	19.65
Land Value Rise	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agri. & Fishery	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Operational Costs	0.42	0.42	0.42	0.42	0.42	0.42	0.42
Investment				0			
Cash flow	13.39	14.41	15.50	16.66	17.91	19.25	19.25

Year	2037	2038	2039	2040	Total		
Users' Benefit	19.65	19.65	19.65	19.65	286.14		
Land Value Rise	0.00	0.00	0.00	0.00	0.37		
Agri. & Fishery	0.01	0.01	0.01	0.01	0.21		
Operational Costs	0.42	0.42	0.42	0.42	8.31		
Investment					23.73		
Cash flow & IRR	19.25	19.25	19.25	19.25	265.33	EIRR=	25.22%
Residual value				10.65			

Source : JICA Study Team

8.9 Project Evaluation

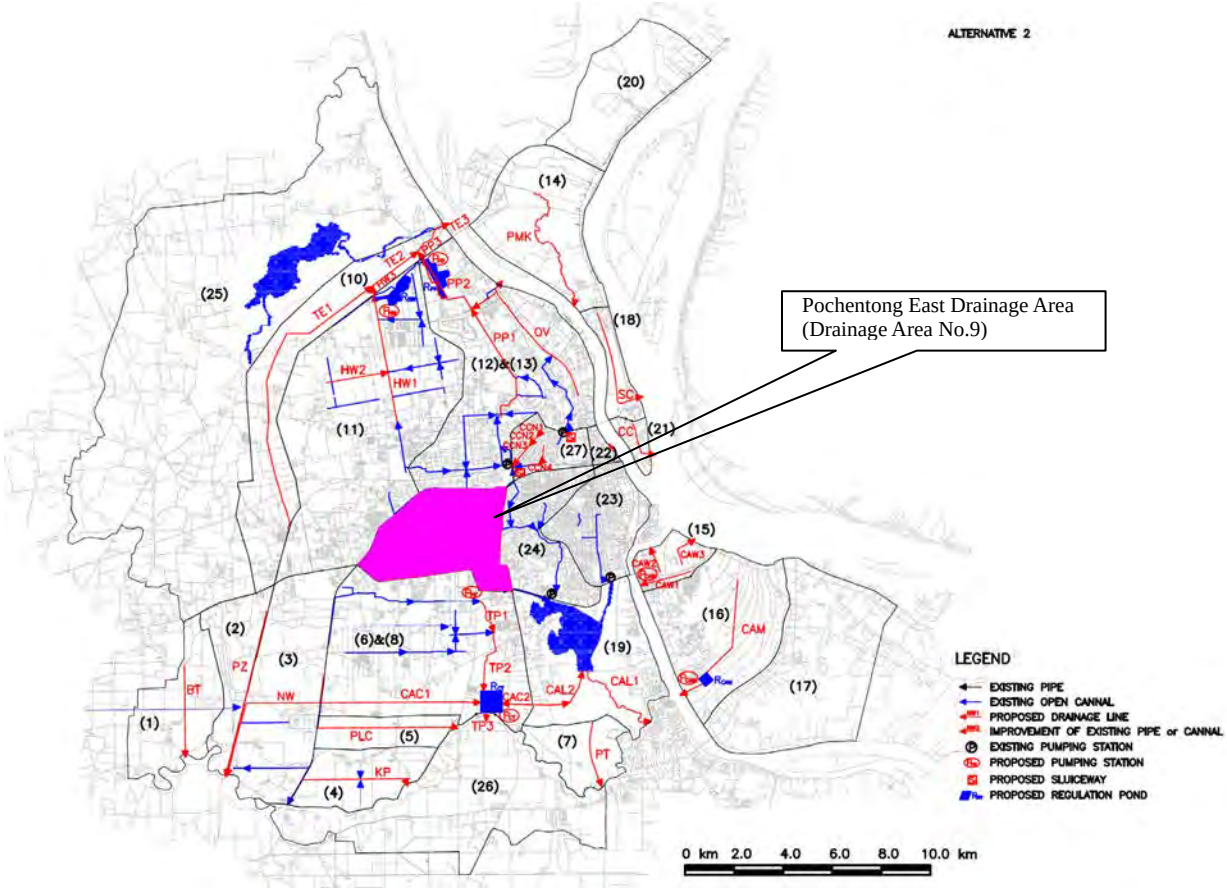
Project evaluation based on the result of Pre-F/S is summarized as follows.

- Preparatory Project contributes accumulation of knowledge and experience for full-operation of the STP because all processes (elements) of STP are equipped in the facilities installed in the Preparatory Project.
- In parallel to implementation of the Preparatory Project, establishment of institutional and legal framework is required to smoothly implement sewerage projects proposed for year 2020 or after.
- Preparatory Project beneficiaries' water supply use revenues (10% of water supply fee) cannot cover operation costs for the Preparatory Project. On the other hand, Phase 1 beneficiaries' revenues (10% of water supply fee) can cover the cost. In other words, sum of profit minus loss from the start to 2040 is positive.
- EIRR of 0.47% is expected depending on population (19,000 people in 2035) equivalent to 5,000 m^3/day, whereas the EIRR of 25.22% is expected depending on entire population of Phase 1 area in Cheung Aek treatment area (238,000 people in 2035).
- Resettlement is not required to implement the Preparatory Project because the STP is constructed in Cheung Aek Lake. Reclaimed area for Preparatory Project stage and ultimate stage are 3.5 ha and 16.3 ha, which are equivalent to 0.67% and 3.1% of total area of the Cheung Aek Lake (520 ha).
- Negative impacts such as traffic interruption, noise, dust and vibration would be unavoidable during the construction stage. However, the impacts could be minimized by introducing countermeasures such as setting up diversion road, sprinkling water and selecting low-noise and/or low-vibration type construction equipment as far as practicable.
- PPCC needs to secure land to dispose dewatered sludge from STP.

CHAPTER 9 PRE-FEASIBILITY STUDY ON PRIORITY PROJECT OF DRAINAGE MANAGEMENT

9.1 Components of Priority Project

In the M/P, PPCC is subdivided into 25 drainage areas. Out of the 25 drainage areas, Pochentong East Drainage Area is selected as Priority Project. The location of the Pochentong East Drainage Area is shown in **Fig. 9.1.1**.



Source : JICA Study Team

Fig. 9.1.1 Location of Pochentong East Drainage Area

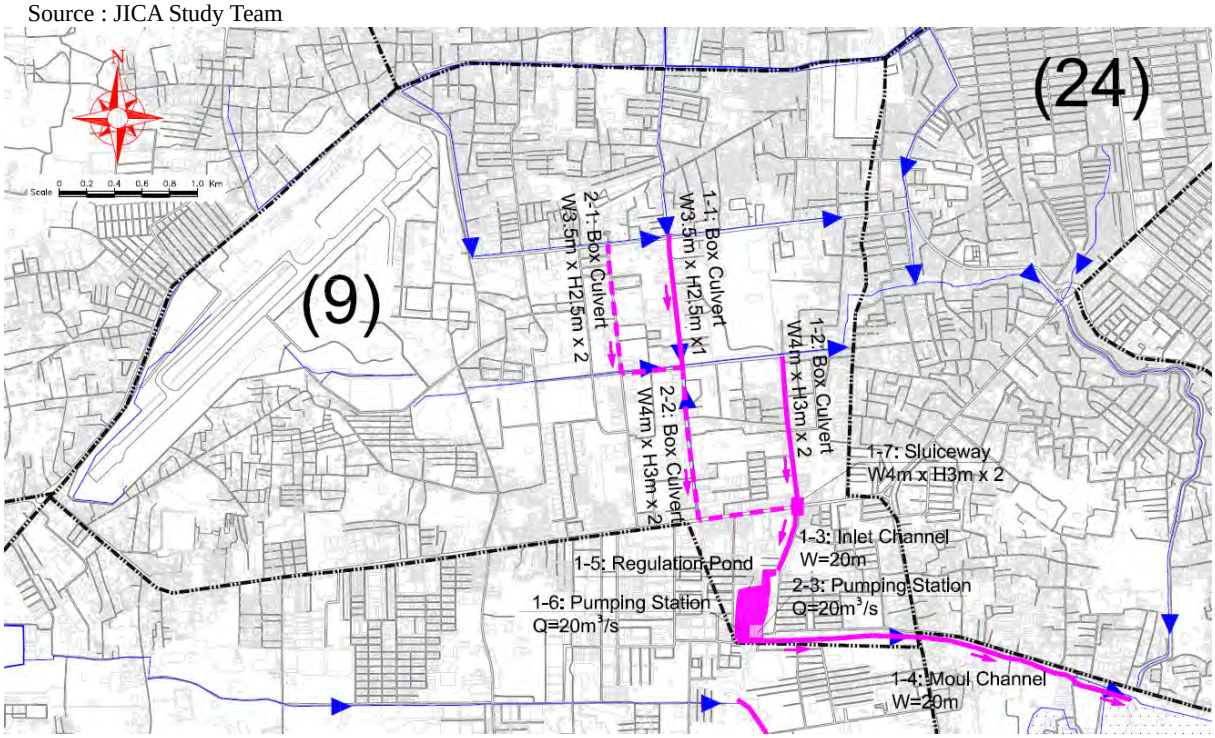
Pochentong East Drainage Area (area 18.23 km^2, Drainage Area No.9), is located west of the city centre and bordered by National Road No. 4 on the north and west, Veng Sreng Road (former BOT Road) on the south, and the catchment boundary of Tumpun Drainage Area on the east. The area is located in a newly urbanized area.

The drainage facilities plan for the Pochentong East Drainage Area is formulated targeting 5 years return period. The facilities plan is subdivided into two components as shown in **Table 9.1.1** and **Fig. 9.1.2**.

Table 9.1.1 Components in Pochentong East Drainage Area

No.	Type	Specification
Component 1		
1-1	Construction of box culvert	W3.5 m×H2.5 m, L=1,010 m
1-2	Construction of box culvert	W4.0 m×H3.0 m×2 lanes, L=1,080 m
1-3	Construction of inlet channel	W20 m, L=480 m
1-4	Rehabilitation of Moul drainage channel	W20 m, L=2,660 m
1-5	Construction of regulation pond	Volume: 100,000 m^3
1-6	Construction of Pochentong East pumping station	Capacity:20 m^3/s
1-7	Construction of sluiceway crossing road	W4.0 m×H3.0 m×2 lanes, L=10 m
Component 2		
2-1	Construction of box culvert	W 3.5 m×H2.5 m×2 lanes, L=1,370 m
2-2	Construction of box culvert	W 4.0 m×H3.0 m×2 lanes, L=1,760 m
2-3	Augmentation of Pochentong East pumping station	Capacity:20 m^3/s

Note : W=Width, H=Height, L=Length
Source : JICA Study Team



Source : JICA Study Team

Fig. 9.1.2 Location of Components in Pochentong East Drainage Area

In Component 1, drainage facilities receiving stormwater from existing channel and then discharge them to southern edge of the drainage area, are constructed. Box culvert running from north to south is constructed to connect existing drainage channels. Stormwater in the area is conveyed under Veng Sreng Street and discharged through regulation pond and pumping station.

In Component 2, drainage facilities constructed in Component 1 is augmented. In the augmentation, box culvert running in parallel with the box culvert of Component 1 is constructed and pumping station of Component 1 is augmented.

9.2 Preliminary Design of Drainage Facilities

9.2.1 Box Culvert and Road Crossing Channel

Land acquisition for construction of open channel is very difficult in northern area of Veng Sreng Street because the area is highly urbanized. Therefore, circular pipe or box culvert is appropriate. In the priority project, box culvert is proposed to carry design flow.

Alignment of box culvert is under the existing road. As shown in **Table 9.2.1**, two lines of box culverts and one road crossing sluice way are constructed in Component 1 and two lines of box culverts are constructed in Component 2.

Table 9.2.1 Specifications of Box Culvert and Sluiceway crossing Road

No.	Facilities	Specifications	Route/Objective
1-1	Box culvert	Design flow : 10 m^3/sec Size : W3.5m × H2.5m Slope : 1/2,600, L=1,010m	Route : From intersection of North Bridge Street and St. 2004 to Barang drainage channel Objective : To discharge stormwater in the northern area of St. 2004 to the south
1-2	Box culvert	Design flow : 26 m^3/sec Size : W 4.0m × H 3.0m × 2lanes Slope : 1/2,600, L= : 1,080m	Route : From Barang drainage channel to Veng Sreng Street Objective : To discharge stormwater collected by Barang drainage channel to the south
1-7	Sluiceway crossing road	Design flow : 26 m^3/sec Size : W 4.0m × H 3.0m × 2lanes Slope : 1/2,600, L= : 20m	Route : Location of Box Culvert 1-1 crossing Veng Sreng Street from north to south Objective : To discharge stormwater of the northern area of Veng Sreng Street to the south
2-1	Box culvert	Design flow : 20 m^3/sec Size : W 3.5m × H 2.5m × 2lanes Slope : 1/2,600, L=1,370m	Route : From St. 2004 to Barang drainage channel of Duong Ngeap II Street, and from Duong Ngeap II Street to Trung Morn Street along Barang drainage channel Objective : To collect stormwater from the northern area of St. 2004 and the western area of North Bridge Street, and discharge the stormwater to Box Culvert 2-2
2-2	Box culvert	Design flow : 26 m^3/sec Size4.0m × H3.0m × 2lanes Slope : 1/2,600, L=1,760m	Route : From Barang drainage channel of Trung Morn Street to Veng Sreng Street, and from Trung Morn Street to inlet channel of Veng Sreng Street Objective : To distribute stormwater from box culvert 1-1&2-1, and Barang drainage channel and then discharge the stormwater to the south

Source: JICA Study team

9.2.2 Drainage Channel (Open Channel)

Planning site of inlet channel to Pochentong East pumping station is located in swamp area and open channel can be constructed. Therefore, open channel is designed to convey design flow. Existing Moul Channel is rehabilitated and augmented to convey design flow. Open channels of Component 1 are constructed in the same alignment of existing channel. Open channels constructed are summarized in **Table 9.2.2**.

Table 9.2.2 Specifications of Open Channels

No.	Facilities	Specifications	Route/Objective
1-3	Construction of inlet channel	Type : Earth channel (Side slope 1:2) Capacity : 51 m^3/sec Width : 20 m, Depth : 2.5m Slope : 1/2,600、L=480 m	Route : From Veng Sreng Street to regulation pond Objective : To discharge stormwater collected by box culvert to regulation pond
1-4	Rehabilitation of Moul drainage channel	Type : Earth channel (Side slope 1:2) Capacity : 51 m^3/sec Width : 20m, Depth : 2.5 m Slope : 1/2,600、L= : 2,660 m	Route : From pumping station to Cheung Aek Lake Objective : To discharge stormwater from pumping station to Cheung Aek Lake

Source: JICA Study team

9.2.3 Pumping Station and Regulation Pond

Pochentong Pumping Station is constructed at the south-eastern edge of the drainage area. The location of the pumping station is at south-eastern edge of the existing swamp. Land requirement of the station is about 6,000 m^2.

Design flow of inlet channel to the regulation pond is 51 m^3/s. The design flow is regulated in the regulation pond and design flow for pumping station is reduced to 40 m^3/s. The pumping station consists of two substations with capacity of 20 m^3/s. Each substation has pumping equipment of 4 m^3/s of 5 units (**Table 9.2.3**).

Table 9.2.3 Specifications of Pumping Station and Regulation Pond

No.	Facilities	Specifications	Location/Objective
1-5	Construction of regulation pond	Structure：Unlined (Slope 1:2) Area： 25,000 m^2 Volume：100,000 m^3 Depth：4 m	Location：Existing swamp Objective：To regulate stormwater and to reduce volume to be pumped
1-6	Construction of Pochentong East pumping station	Pump type：Submersible pump Capacity：20 m^3/sec (4 m^3/sec×5unit) Head：6 m	Location：Southern edge of existing swamp Objective：To discharge regulated water in regulation pond to Moul drainage channel
2-3	Augmentation of Pochentong East pumping station	Pump type：Submersible pump Capacity：20 m^3/sec (4 m^3/sec×5unit) Head：6 m	Location：Southern edge of existing swamp Objective：To discharge regulated water in regulation pond to Moul drainage channel

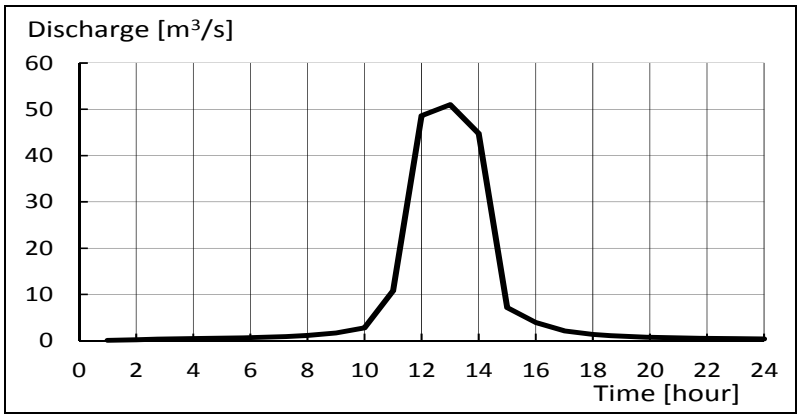
Source: JICA Study Team

(1) Specifications of Pumping Station and Regulation Pond

Pumping station is one of the main facilities in drainage management. In principle, designing of a pumping station to discharge peak flow is not economical. Often, pumping station accompany regulation pond to reduce design flow. The larger the land of regulation pond, the cheaper the construction cost of pumping station.

A swamp area adjacent to Veng Sreng Street is utilized for the construction of regulation pond, because available land of regulation pond for the Pochentong East pumping station is limited due to rapid urbanization. Available land for the regulation pond is about 25,000 m^2.

Based on hydrograph of 5-year return period in Pochentong East Drainage Area (**Fig. 9.2.1**), alternative study on relations between pumping capacity and volume of regulation pond is conducted and result of the study is summarized in **Table 9.2.4**. In the pre F/S, Alternative 4 (pumping capacity of 40 m^3/s and volume of regulation pond is 100,000 m^3), is selected to minimize size of pumping equipment.



Source : JICA Study Team

Fig. 9.2.1 Hydrograph of Pochentong East Pumping Station (5-year Return Period)

Table 9.2.4 Comparison of Construction Cost in Relations between Pumping Capacity and Volume of Regulation Pond

Alternative	Pump capacity (m^3/sec)	Volume of regulation pond (in case of available land of 2.5 ha)		Construction cost (US$ million)
		Volume required (m^3)	Available depth (m)	
1	45	25,000	1.0	24.4
2	42	50,000	2.0	23.1
3	41	75,000	3.0	23.0
4	**40**	**100,000**	**4.0**	**22.8**
Reference(*)	35	200,000	4.0	21.5

(*) In this case, volume of regulation pond under available land of 5.0 ha is analyzed. However, actually it is very difficult to acquire 5.0 ha, so this case is analyzed for reference.

Source: JICA Study Team

Water levels in designing Pochentong Pumping Station are summarized in **Table 9.2.5**.

Table 9.2.5 Water Levels in Designing Pochentong East Pumping Station

Water Level	Elevation (EL.m)	Reasons
(1) Outer side		
(a) Design High Water Level (HWL)	10.0	Design high water level of Tumpun Pumping Station plus 1 m slope of Moul drainage channel
(b) Normal Water Level (NWL)	6.0	Based on topological survey result
(2) Inner side		
(a) Design High Water Level (HWL)	8.0	Based on ground elevation in vicinity
(b) Design Low Water Level (LWL)	4.0	Based on volume of regulation pond

Source: JICA Study Team

(2) Type of Pump

Turbo type pumping equipment is often applied to drainage pumping station because turbo type is applicable to large amount of discharge. Turbo type pump discharges water with rotation of impeller in casing. The turbo type pump is categorised into three types: (i) Centrifugal pump, (ii) Mixed flow pump and (iii) Axial-flow pump. Salient features of the three types are summarised in **Table 9.2.6**.

Table 9.2.6 Comparison of Turbo Type Pumping Equipment

Type	(1) Centrifugal pump	(2) Mixed flow pump	(3) Axial-flow pump
Salient features	Water flow discharged from impeller is conveyed at right angle of main shaft Example (1) Volute Type Pump: Commonly used for wide range of use such as water supply, sewage, and chemical plant. (2) Diffuser Type Pump: Pump with guide vane outside of impeller in order to achieve high pressure. Suitable for high pressure and low-capacity	Water flow discharged from impeller is conveyed in conic surface along center line of main shaft. The Pump has merits of centrifugal and axial-flow pumps. Example (1) Volute Type Mixed Flow Pump: Pump with volute type casing. Suitable for high pump head. Commonly used for sewage pumping station. (2) Diffuser Type Mixed Flow Pump: Pump with guide vane. Commonly used for river water pump and drainage pump.	Water flow discharged from impeller is conveyed in the cylinder of main shaft Suitable for low pump head and high-capacity. Not suitable for high pump head and low-capacity. Suitable for river pump station with total pump head of 5 to 6 m. Example a. Vertical-shaft Traditional Type b. Horizontal-shaft Traditional Type c. Submersible Type
Evaluation			Recommended

Source: JICA Study team

As shown in the table above, axial-flow pump is applied to Pochentong East Pumiping Station because the pump is commonly used for drainage pumping stations.

Axial-flow pump has three types : (i) Vertical-shaft Traditional Type, (ii) Horizontal-shaft

Traditional Type and (iii) Submersible Type. **Table 9.2.7** summarises comparison of the three types of pump. As shown in the Table, submersible type is applied to the Pochentong East Pumping Station in considertation of cost effectiveness, easiness of O&M and constrction work, as well as reduction in construction period.

Table 9.2.7 Comparison of Axial-flow Pumping Equipment

Item	Vertical-shaft Traditional Type	Horizontal-shaft Traditional Type	Submersible Type
1. Civil and Building Works			
1.1 Space Required	Comparatively small in width and length, but relatively higher due to lifting height of crane	Relatively large in width and length, but relatively lower due to lifting height of crane	Comparatively small in width and length
1.2 Substructure and Foundation Work	Costly due to heaviness and requirement of accuracy of the machinery	Costly due to heaviness and requirement of accuracy of the machinery	Comparatively not so costly due to light weight of equipment
1.3 Superstructure/Building Works	Superstructure is required. In case outdoor type generator is applied, building works is not required except an operation building.	Superstructure is necessary.	No superstructure is required. An operation building only is required. Simple structure with smaller area is required.
2. Mechanical and Electrical Works			
2.1 Pump Characteristics (Cavitation)	Less cavitation is concerned commonly since impellers are set below water level.	Pump suction performance is limited, and cavitation may occur if water level becomes low.	No cavitation is concerned commonly since impellers are set below water level.
2.2 Ancillary Equipment	Ancillary equipment for prime action is not required.	Ancillary equipment for prime action is inevitable.	Ancillary equipment for prime action is not required.
2.3 Installation	Not so easy	Difficult	Easy
2.4 Operation	Automation is easily done because prime action is unnecessary.	Prime action is required, accordingly automatization is complicated.	Automation is easily done due to no concerns about priming and cavitation.
2.5 Maintenance and Repair	Difficult because: - main pump components are installed below water level, and - bearing(s) is placed under water.	Easy because: - main components of pump are installed above water level - removal of driver is unnecessary upon disassembly, and - less submerged bearings or no submerged bearings.	Rather easy because: - periodic inspection and maintenance can easily be done by lifting of electric motor and pump from water, and - life of electric motor is generally shorter than other types.
2.6 Noise	Less noise emission than the horizontal-shaft type because of submerged impellers installed, while noisier than submergible type because electric motors are installed on floor.	Noisy because impellers and electric motors are installed on floor	Little noise emission with impellers and electric motors submerged
3. Total Cost	140%	130%	100%
4. Judgement	Not recommended	Not recommended	Recommended

Source: JICA Study Team

(3) Outline of Regulation Pond

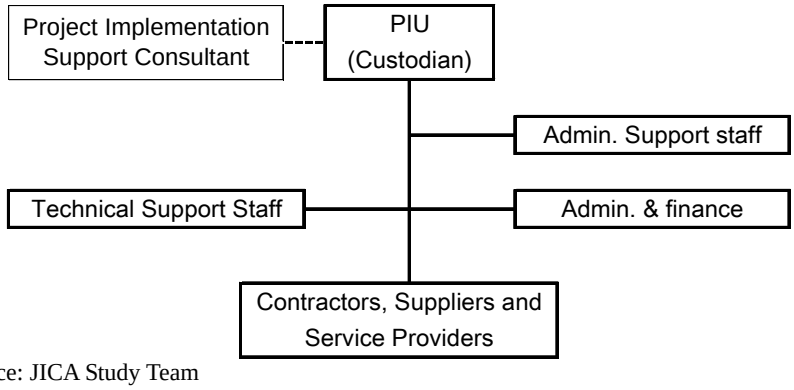
Regulation pond is constructed in the existing swamp located north of Pochentong East Pumping Station. The existing swamp has about 2.5 ha so the regulation pond is constructed in the area. Volume of the regulation pond of 100,000 m^3 is obtained by excavation up to EL. +4.00 m. The regulation pond is unlined and slope of the pond is protected by sodding.

9.3 Framework of Implementation (Including the O&M System)

With regard to the establishment of a stormwater drainage system in Phnom Penh, the Project for Flood Protection and Drainage Improvement in Phnom Penh Capital City (Phases 1 to 3) has already been completed and Phase 4 will be carried out as a priority. The Pochentong East district (PE) has been selected as the priority project in this M/P, because the area suffered flood damage due to rapid urbanization and a delay in carrying out stormwater drainage measures. The following are explanations about the project implementation system in the selected district.

9.3.1 System for Implementing the Priority Project

Stormwater drainage facilities have been established gradually with the assistance from donors. As a result, project implementation know-how has already begun to be accumulated. At present, the facilities are operated and maintained by DSD of DPWT, since the components of the priority project are drainage channels, drainage pipes, regulating reservoirs, and drainage pumping stations, the project shall be carried out by establishing an implementation unit in DPWT (DSD). As described in **Section 8.4**, the unit shall be established through the unification of PMU and PIU. **Fig. 9.3.1** shows the project implementation system. The structure of the staff shall be as shown in **Table 8.4.2**.



Source: JICA Study Team

Fig. 9.3.1 Project Implementation System

9.3.2 O&M System

DSD has established a system for cleaning drainage channels and pipes, and maintaining the cleaning equipment. In addition, the soft components in the Project for Flood Protection and Drainage Improvement in Phnom Penh Capital City (Phase 3) were carried out to improve capacities, such as capacity to clean drainage facilities and maintain equipment according to plan, and capacity to keep management records as to whether cleaning and inspection has been carried out according to the maintenance and inspection manuals.

In this way, technologies concerning the maintenance of drainage facilities have been transferred to DSD. However, the pumping and electric equipment at the drainage pumping facilities has not been regularly inspected or maintained sufficiently due to the shortage of engineers, etc. Drainage pumps must be able to work at any time and in any case. That is, the preventive maintenance of machinery and electric equipment such as daily check, regular inspections and repairs, are very important.

Therefore, when the drainage pumping station is built in the Pochentong East Drainage Area, engineers' preventive maintenance skill for machinery and electric equipment shall be developed on a practical level, including providing training to the engineers concerned with their maintenance. Specifically, engineers in charge of preventive maintenance shall be trained in the Pumping Station & Canal Maintenance Section in **Fig. 2.6.7** (Organization Chart of DSD).

9.4 Cost Estimate

9.4.1 Project Cost

(1) General Conditions

Project cost consists of construction cost, administration cost, engineering cost, physical contingency and land expropriation/compensation cost. The costs are estimated based on the general conditions as enumerated below, with exchange rate of 1USD=122.85JPY, and 1Riel=0.030JYP, as of December 2015. The unit cost and quantities are reviewed and recalculated, based on the ones in **Section 6.6.**

- Construction cost is estimated based on the cost of similar projects implemented by the donors such as JICA and ADB, considering price escalation as of December 2015.

- Civil and architectural material cost, labor cost, construction equipment cost are estimated based on the prices obtained in Cambodia because these are procured in Cambodia. On the other hand, some steel products and construction equipment cost are estimated based on the prices obtained in the other countries such as Japan because those are not available in Cambodia.

- Mechanical and electrical equipment in pumping station is in general procured from other countries, considering cost effectiveness, liability and easy O&M.

- Administration cost includes cost for project administration and implementation such as review and approval of design documents, construction supervision as project owner (inspection, testing, approval of design changes, office administration and holding meeting). The administration cost is estimated at 5% of construction cost.

- Physical contingency is a cost to cover additional expenditure for construction due to unforeseeable site condition and uncertainties. The physical contingency is estimated at 5% of construction cost and engineering cost.

- Land expropriation/compensation cost is the one for land acquisition for facilities construction and establishing diversion channel. The cost is estimated considering past projects implemented in Cambodia.

- O&M cost is estimated considering the costs for existing facilities.

- House relocations are minimized as much as possible.

- Implementation plan is proposed in consideration of geological, meteorological and related regulations.

- Construction plan for pipe laying under the existing road, is formulated to minimize traffic hindrance and interference to existing drainage channels by establishing temporary equipment such as diversion channel.

(2) Cost Estimation

Based on the above conditions, project cost is estimated and summarised in **Table 9.4.1**. According to the table, project cost is 93.01 million USD. Construction cost consists of (i) Component 1: 35.13 million USD; and (ii) Component 2: 40.69 million USD, totalling 75.82 million USD.

Table 9.4.1 Project Cost

Unit: million USD

	Item	Local currency	Foreign currency	Total
I.	Construction cost [(1)+(2)]	51.93	23.89	75.82
	(1) Sub-component 1	23.77	11.36	35.13
	1) Construction of box culvert (W3.5 m×H2.5 m)	5.63	0.71	6.34
	2) Construction of box culvert (W4.0m×H3.0m×2)	9.39	1.18	10.57
	3) Construction of inlet channel (480m)	0.81	0.01	0.82
	4) Rehabilitation of drainage channel (2,660m)	4.50	0.06	4.56
	5) Construction of regulation pond	0.13	0.01	0.14
	6) Construction of pumping station	2.08	9.24	11.32
	7) Construction of sluiceway crossing road	1.23	0.15	1.38
	(2) Sub-component 2	28.16	12.53	40.69
	1) Construction of box culvert (W3.5m×H2.5m×2)	10.79	1.36	12.15
	2) Construction of box culvert (W4.0m×H3.0m×2)	15.29	1.93	17.22
	3) Augmentation of pumping station	2.08	9.24	11.32
II.	Engineering cost	1.68	6.71	8.39
III.	Administration cost	3.79	0	3.79
IV.	Physical contingency	2.68	1.53	4.21
V.	Land expropriation / compensation cost	0	0.80	0.80
	Total (I+II+III+IV+V)	60.08	32.93	93.01

Source: JICA Study Team

9.4.2 Operation and Maintenance Cost

Operation and maintenance cost (targeting all facilities of Components 1 and 2) is 1.23 million USD, as shown in **Table 9.4.2**. Frequency in cleaning of box culvert, drainage channel and regulation pond is set at 5 years.

Table 9.4.2 O&M Cost

Unit: million USD

	Item	Total	Remark
I.	Pumping station	1.19	
	Electricity	0.97	Based on actual unit cost of existing pumping station
	Personnel expenses	0.04	Based on estimated number of 5 regular and 15 contracted employee
	Fuel	0.12	Based on actual unit cost of existing pumping station
	Repair and spare parts	0.05	1% of construction cost of machine and electronic facilities
	Others	0.01	Cleaning and miscellaneous expense
II.	Drainage channel and regulation pond	0.04	
Annul O&M total cost (I+II)		1.23	

Source : JICA Study Team

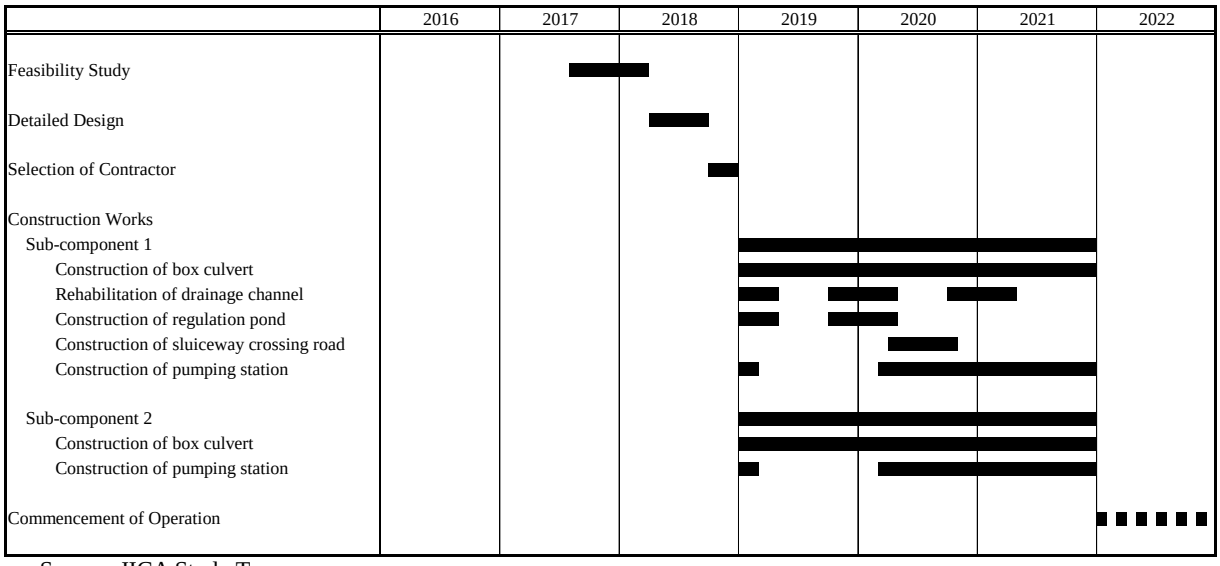
9.5 Implementation Schedule

Implementation schedule of the Preparatory Project is shown in **Table 9.5.1** and **Fig. 9.5.1**. This implementation schedule is formulated on the assumption that Components 1 and 2 are implemented simultaneously. However, the two components can be implemented separately, depending on condition of fund arrangement. When implemented separately, Component 1 work should be done first and then Component 2 work implemented.

Table 9.5.1 Implementation Schedule of Priority Project

Item	Period
Feasibility Study	8 months
Detailed Design	6 months
Selection of Contractor	3 months
Construction Works (Component 1)	36 months
Construction Works (Component 2)	36 months

Source : JICA Study Team



Source: JICA Study Team

Fig. 9.5.1 Implementation Schedule of Priority Project

9.6 Economic Analysis

Based on the supposed socioeconomic indexes and land use in the target year 2040, direct damages related to buildings and assets are estimated.

The average inundation damages in Phnom Penh can be expressed with inundation depths (d in cm) as a variable in an equation, Damage= $e^{3.6548+0.0163\times Depth}$ (in 2006 price) (Source: **Subsection 6.8.1**). In order to convert damage to that in 2016 price, it is multiplied by 2.045, inflation increase rate.

Through the flood inundation analysis by return-period, inundation depths and inundated damage areas actually caused by 2- and 5-year return period floods are estimated. Based on the estimated inundated areas by depths, inundation damages of households per one hectare caused by 2- and 5-year return period are calculated as shown in **Tables 9.6.1** and **9.6.2**, respectively. In addition, indirect damages (such as traffic block and commercial and industrial activities hindrance) are supposed 30% of the direct damages in reference to the set values in 1999 M/P.

Table 9.6.1 Inundation Damages of Households per One Hectare Caused by Two-Year Probability Precipitation

Depth d (cm)		Households' Inundation Damage (US$/HH)		Inundation Area (ha)	Sum of households' damages (USD/HH)*1)
		2006	2016		
A		$B = e^{(3.6548+0.0163d)}$	C = B×2.045	D	E = C×D×1.30
0＜d≦50	Ave.25	58.1	118.8	179	27,652
50＜d≦100	Ave.75	131.3	268.5	35	12,215
100＜d≦150	Ave.125	296.6	606.5	8	6,308
150＜d≦200	Ave.175	670.0	1,370.2	0	0
200＜d≦300	Ave.250	2,275.1	4,652.7	2	12,097
				224	58,271

Note: HH: Household, *1) , including indirect damage (30% of the direct)
Source: JICA Study Team

Table 9.6.2 Inundation Damages of Households per One Hectare Caused by Five-Year Probability Precipitation

Depth d (cm)		Households' Inundation Damage (US$/HH)		Inundation Area (ha)	Sum of households' damages (USD/HH)*1)
		2006	2016		
A		$B = e^{(3.6548+0.0163d)}$	C = B×2.045	D	E = C×D×1.30
0＜D≦50	Ave.25	58.1	118.8	211	32,595
50＜D≦100	Ave.75	131.3	268.5	39	13,611
100＜D≦150	Ave.125	296.6	606.5	9	7,096
150＜D≦200	Ave.175	670.0	1,370.2	1	1,781
200＜D≦300	Ave.250	2,275.1	4,652.7	2	12,097
				262	67,180

Note: HH: Household, *1) : including indirect damage (30% of the direct)
Source: JICA Study Team

While economic benefits are calculated as the difference of damages between the cases with- and without-project, but the facilities construction aims to prevent inundation damages caused by 5-year return periods so that the benefits are regarded as inundation damages caused by less than 5-year return period.

Based on the inundation damages of households per one hectare by return period obtained above, these reduced inundation damages are multiplied by each occurrence probability and the calculated average annual damages by return period are shown in **Table 9.6.3** as average annual damage reduction expected value.

Table 9.6.3 Average Annual Inundation Damage Reduction Expected Value (of households per one hectare in 2016 price)

Average annual exceeding probability		Reduced inundation damages (USD/HH)	Average reduced damages (USD/HH)	Interval probability	Accumulated damage reduction of households (USD/HH)
0.1-year	10	0			
			29,136	9.5	276,788
2-year	0.5	58,271			
			62,726	0.3	18,818
5-year	0.2	67,180			
Average annual damage reduction expected value		**-**	**-**	**-**	**295,606**

Source: JICA Study Team

The annual damage reduction amount is calculated from the average annual damage reduction expected value of households per one hectare obtained above as economic benefits and the economic analysis is carried out. The annual damage reduction amount is deemed proportional to annual changes of household number per one hectare and household income, and so the average annual damage

reduction expected value of households per one hectare is multiplied by changes of household number and household income. The annual household number change per one hectare depends on forecast population and household size is supposed to be five persons per household. The household income change is based on the household income in 2016 and the annual growth rate is supposed to be 6.14%/year, which is obtained from the household income statistics converted to real or constant price. The capital opportunity cost (social discount rate) is supposed to be 10% in reference to the past examples in Cambodia. The evaluation period is 25 years from 2016 to 2040. **Table 9.6.4** shows the cost/benefits and economic analysis results.

The maintenance and management costs are supposed to be those at the total facilities completion but in 2016 price (not discounted), that is 1,230,000 USD, and the annual growth rate is supposed to be 6.14%/ year, the same as household income and it may be higher, but set from the safe side viewpoint.

Table 9.6.4 Costs/ Benefits and Economic Evaluation Result

No.	Year	Household income	Household number	Damage reduction (Benefit)	Construction Cost	Operation & Maintenance (O/M) Cost	B-C
		USD	HH/ha	USD1,000	USD1,000	USD1,000	USD1,000
1	2016	747	-	-	-	-	-
2	2017	793	-	-	-	-	-
3	2018	842	-	-	1,010	0	-1,010
4	2019	893	-	0	31,000	0	-31,000
5	2020	948	21.06	1,580	31,000	624	-30,044
6	2021	1,006	25.51	4,062	30,000	1,325	-27,263
7	2022	1,068	25.75	10,882	0	1,759	9,123
8	2023	1,133	25.99	11,651	0	1,866	9,786
9	2024	1,203	26.23	12,485	0	1,981	10,504
10	2025	1,277	26.46	13,374	0	2,103	11,271
11	2026	1,355	26.70	14,319	0	2,231	12,087
12	2027	1,438	26.96	15,340	0	2,368	12,972
13	2028	1,526	27.20	16,423	0	2,513	13,910
14	2029	1,620	27.43	17,587	0	2,667	14,920
15	2030	1,719	27.67	18,825	0	2,830	15,994
16	2031	1,824	27.91	20,147	0	3,003	17,144
17	2032	1,936	28.15	21,567	0	3,188	18,379
18	2033	2,055	28.39	23,087	0	3,384	19,703
19	2034	2,181	28.63	24,709	0	3,591	21,118
20	2035	2,315	28.87	26,446	0	3,812	22,634
21	2036	2,457	29.11	28,303	0	4,046	24,257
22	2037	2,608	29.35	30,289	0	4,295	25,994
23	2038	2,768	29.58	32,411	0	4,558	27,853
24	2039	2,939	29.82	34,680	0	4,839	29,842
25	2040	3,119	30.06	37,106	0	5,136	31,970
Total		-	-	415,271	93,010	62,118	260,143
Economic Internal Rate of Return		IRR					**12.72%**
Benefit/ cost ratio		B/C					**1.22**
Net Present Value		NPV				**USD**	**17,069,000**

Note: HH; Household
Damage reduction amount = 295,606 (USD/HH) × HH number/ha × HH income growth rate
HH income growth rate: 6.14%/ year
Discount rate used in B/C and NPV calculation is 10%
Source: JICA Study Team

The economic evaluation result of drainage improvement project in Pochentong East Drainage District (No. 9 drainage district) is shown in **Table 9.6.5**.

Table 9.6.5 Economic Evaluation Result of Drainage Improvement Project in Pochentong East Drainage Area (No. 9 Drainage Area)

Item	Unit	Drainage Improvement Project in Pochentong East Drainage Area	(cf.) Case that Components 1 & 2 are implemented in two stages
EIRR	%	12.72	13.54
Benefit/ Cost ratio (B/C)	-	1.22	1.27
Net Present Value (NPV)	USD 1,000	17,069	18,641

Source: JICA Study Team

Based on the result above, the drainage improvement project in Pochentong East Drainage Area (No. 9 Drainage Area) is decided to be appropriate economically.

9.7 Project Evaluation

Project evaluation based on the result of Pre-F/S is summarized as follows.

- Inundation damage to households, commercial and industrial activities, traffic interruption associated with access to Phnom Penh International Airport, are reduced by implementing the project in Pochentong East Drainage Area.
- EIRR of 12.72%, obtained by improvement in Pochentong East Drainage Area (Drainage Area No.9), shows significant economic effect.
- Resettlement of 40 households is anticipated to implement the project for Pochentong East Drainage Area. Detailed survey in the succeeding Feasibility Study will therefore be required to minimize the number of resettlement.
- Negative impacts such as traffic interruption, noise, dust and vibration would be unavoidable during the construction stage. However, the impacts could be minimized by introducing counter measures such as setting up of diversion road, sprinkling water and selecting low-noise and/or low-vibration type construction equipment as far as practicable.

CHAPTER 10 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS OF PRE-FEASIBILITY STUDY

10.1 Environmental and Social Considerations of Pre-Feasibility Study

10.1.1 Priority Project for Sewage Management

Based on the Sewage Management M/P, the Preparatory Project is selected as the priority project as shown in **Table 10.1.1.**

Table 10.1.1 Components of Priority Project in Sewage Management (Preparatory Project)

Component	Contents
Sewer Pipe	Diameter : φ500 mm Length: about 1,300 m
STP	Capacity:5,000 m^3/dairy maximum Conventional Activated Sludge Process (CASP): Approximately 3.5ha (in Cheung Aek)

Source: JICA Study Team

10.1.2 Priority Project for Drainage Management

Based on the Drainage Management M/P, the priority project is proposed as shown in **Table 10.1.2**.

Table 10.1.2 Priority Project of Drainage Project

Name of project	Facilities	Specification/capacity
Construction of drainage facilities in Pochentong East, Drainage Area (Drainage Area No. 9)	Drainage channel	Box culvert: W3.5 m × H2.5 m × 3 cells × 1,010 m Box culvert: W4.0 m × H3.0 m × 4 cells × 2,880 m
	Pumping station	1 location: Capacity 40 m^3/s
	Regulation pond	1 location :Area required: 25,000 m^2

Source: JICA Study Team

10.2 Description of Environmental Resources

10.2.1 Natural Environmental Resource

(1) Physical Resources

The Royal Government of Cambodia has 181,035 km^2 of land. The country borders with Thailand to the north and west, Laos to the northeast, and Vietnam to the east and southeast. The country area is surrounded by the Cardamom Mountains and the Dângrêk Mountains at the west to north bordering with the Thailand and Mondorukiri Plateau at the border with the Vietnam. Most of the country area is below 100 m and the Mekong River and its tributaries flow in the middle of the country. All the area in the country falls into the tropical monsoon climate zone having about 27.7ºC of average temperature and about 1,500 mm of annual rainfall, with the dry season from May to November and the rainy season from December to April.

Phnom Penh is located in alluvial lowland at the right bank of the confluence of Mekong and Sap rivers, and at the fork of Mekong and Bassac rivers. Old Phnom Penh City is located on natural levee, and the suburban residential area is in swampy plain, which is prone to inundation. The area is relatively topographically flat and its elevation is lower than the maximum water level of the Mekong River that reaches more than 10 m in the rainy season. Therefore, the urban and suburban areas of Phnom Penh are highly prone to flooding, despite being surrounded by dikes. Urbanization in the outskirts has been progressing in recent years, and lots of lakes and swamps in and around Phnom Penh have been reclaimed, resulting in the inundation.

(a) Geology

In terms of geological conditions of Cambodia, almost all of the land is situated on relatively-new ground, such as quaternary sedimentary rocks and unconsolidated sediments. Relatively old soil such as the upper Jurassic-cretaceous sedimentary unit, exists in the northeast area. Lower-middle Jurassic sedimentary units are situated in the southwest part of Cambodia. Phnom Penh is mainly located on quaternary sedimentary rocks.

(b) Topography

In the administrative area of PPCC, the topography is relatively flat and its elevation is lower than the maximum water level of the Mekong River during the rainy season. The maximum water level of the Mekong River is more than 10 m, while the ground elevation in the east of Phnom Penh is lower than 7.5 m. Therefore, the urban and suburban areas of Phnom Penh are highly prone to flooding, despite being surrounded by dikes.

(c) Soil Erosion and Sedimentation

Geologic structure of the Mekong Delta region, where the Study Area is situated, had been formed in Precambrian to Holocene ages. Old Alluvium was formed in deltaic shape between the Pliocene and Pleistocene by the Mekong and its tributaries and then Holocene deltaic alluvium was formed. The Holocene Alluvium, mainly consisting of unconsolidated silt and clay with some lenses of sand, virtually blankets the entire delta. The Holocene Alluvium in and around the Study Area generally has a thickness of less than 25 m.

The Holocene Alluvium differs from the Old Alluvium in having a generally finer texture, almost no laterite, and a relative abundance of shell and lignite layers. The surface geological condition of PPCC is characterised by the sandy mud covered on base terrane inclined from west to east, as well as soft clay layer at some places.

(d) Climate

Phnom Penh has a tropical monsoon climate. The average annual rainfall recorded between 2000 and 2010 was 1,500 mm. The minimum annual rainfall was 1,171 mm (in 2006) while the maximum was 2,147 mm (in 2000). The dry season, from December to April, has few rainy days between January and March. On the other hand, the rainy season, from May to November, records more than 80% of the annual rainfall.

(i) Temperature

Phnom Penh experiences high temperature and high humidity. The maximum and lowest monthly average temperatures in Phnom Penh between 2000 and 2010 are 35.4°C and 22°C, respectively, and the seasonal fluctuation of temperature is not large. The temperature from March to May is relatively high, and the highest temperature recorded in the past 11 years was 40°C in May 2010. The annual average humidity between 2000 and 2010 was 76.3%.

(ii) Wind Direction and Speeds

Wind speed tends to be stronger in the dry season than that in the rainy season. The maximum wind speed between 2001 and 2010 was 20 m/s, which was recorded in June 2006. Generally, the wind flows to the northern direction from October to January, south-eastern from February to April, and western to south-western from May to September.

(iii) Evaporation

The daily average evaporation between 2000 and 2010 is 4.6 mm. The daily maximum evaporation in the rainy and dry seasons is 9.5 mm and 43.8 mm, respectively. The seasonal variation of evaporation in the dry season is five times of that in the rainy season.

(e) Hydrology

The water level of the Mekong River is measured at Chrauy Changva Station, while that of the Sap River is measured at Chaktmuk and Phnom Penh Port stations by MOWRAM. The highest water level of Bassac and Sap rivers is generally recorded during August to October. Among annual highest water level in recent 5 years (2009-2013), the highest water level of Bassac River is 9.84 m (2011) and lowest level is 7.47 m (2010). On the other hand, water level during March to May is very low (1.2 m). Annual variation of the river water levels sometimes reaches approximately 8.0 m.

The river flows have seasonal fluctuations: the maximum flow of the Mekong River is more than 30,000 m^3/s during the rainy season when it counterflows towards Sap River.

(f) Water Quality

The JICA study, Drainage and Sewerage Improvement Project in Phnom Penh Metropolitan Area, conducted a range of water quality monitoring in 2014 as their baseline survey, in rivers, lakes and some effluent in 3 times respectively in the dry and rainy season. The result shows water pollution at the surrounding area of the capital, having low concentration of DO, and high concentration of TSS, BOD, COD, T-N and T-P (Detail results are explained in **Chapter 2**).

(g) Air Quality

Available air quality monitoring as secondary information is still limited in Cambodia. Results of the monitoring of ambient air pollution (Project for Comprehensive Urban Transport Plan in Phnom Penh Capital City, 2014,) are shown in **Tables 10.2.1** to **10.2.2**. As shown in the tables, CO, NO_2 and SO_2 values are within the standard. However, the dust parameters of particulate matters (PM 2.5, PM 10) are very high. The trend found in the record in 2001 was high Total Suspended Particles (TSP).

Table 10.2.1 Air Quality along the road NH4 in Phnom Penh

Type	Unit	Point 1 (7 Makara)	Point 2 (Sen sok)	Point 3 (near Hanoi road Junction)	Point 4 (Airport)	Point 5 (near Junction with NH3)	Cambodian Standard	WHO standard
CO	mg/m^3	2.86	1.79	2.86	3.58	3.58	20	
NO_2	mg/m^3	0.057	0.029	0.045	0.056	0.058	0.1	
SO_2	mg/m^3	0.033	0.027	0.027	0.025	0.033	0.3	
PM2.5	$\mu g/m^3$	128	107	284	186	248	n.a.	25
PM10	$\mu g/m^3$	93	68	150	71	169	n.a.	50

Note: The results are average of 24 hours continuous survey
Source: Project for Comprehensive Urban Transport Plan in Phnom Penh Capital City, 2014

Table 10.2.2 Ambient Air Pollution in Phnom Penh

Parameters	2000		2001		2002		2014	
	Mean	Max	Mean	Max	Mean	Max	Mean	Max
CO (mg/m^3)	3.06	7.12	1.98	2.42	3.50	5.71	3.02	3.87
NO_2 ($\mu g/m^3$)	32.08	47.17	2.45	3.77	30.19	56.60	24	71
SO_2 ($\mu g/m^3$)	-	-	2.60	7.80	7.80	13.00	10	27
TSP (mg/m^3)	-	-	0.63	0.84	0.41	1.00	0.128	0.169

CO=Carbon Monoxide: mg/m^3=milligrams per cubic meter; $\mu g/m^3$=micrograms per cubic meter; NO_2=Nitrogen Dioxide; TSP=Total Suspended Particles. Mean Value in the 2014 were received as tentative values.

Source: MOE (2014), ADB 2006 Country Synthesis Report on Urban Air Quality Management, "Research collaboration with Yokohama University from 2000-2002.
Quoted in MOE and Ministry of Health (2006). Country Report: Cambodia, Hang Dara, Chin Chamroeun, Sourn Pun Lork, and Chim Sophan, Paper presented at the Clean Air for Asia Training Course for Developing Countries, Thailand, 24 May-02 from ADB

(2) Biological Resources

(a) Forest

Although there are some patches of tree vegetation remaining in the capital in a private garden or a city park, there is no legally recognized forest area in Phnom Penh capital.

The forest area in the country was managed by the Ministry of Agriculture, Forest and Fisheries (MAFF). According to the FAO (2010), the total forest area in Cambodia in 2010 was estimated at 10,094,000 hectares (ha), which covers 57% of the land area. As a general trend in Cambodia, the extent of forest area has been declining and around 127,000 ha of forest have been converted to other uses or lost through natural causes every year from 2005 to 2010 with the annual deforestation rate of 1.2%.

(b) Biodiversity and Ecology System

Cambodia accommodates more than 135 species of mammals, 599 species of birds, 173 species of reptiles, 72 species of amphibians, 350 species of moths and butterflies, 955 fresh and marine fish and aquatic species, and more than 4,500 vascular plant species (2014, The Fifth National Report to the Convention on Biological Diversity). Located at the middle Cambodia, Phnom Penh also has similar potential for biodiversity. Among the species, 74 vertebrate animal and 23 plant species were listed as endangered species in the Red List in the IUCN at 2011. The status is shown in **Table 10.2.3**.

Table 10.2.3 Status of Endangered Species in Cambodia

Red List Species		Red List Status	
Taxon	Total	Type	Total
Mammal	26	VU	18
		EN	6
		CR	2
Bird	26	VU	9
		EN	10
		CR	7
Reptile	12	VU	7
		EN	3
		CR	2
Amphibians	2	VU	2
		EN	0
		CR	0
Fish	9	VU	0
		EN	6
		CR	3
Plant	23	VU	0
		EN	13
		CR	10

VU:Vulnerable, EN:Endangered, CR:Critical Endangered
Source: National Biodiversity Steering Committee in Kingdom of Cambodia (2014) 5th National Report to the Convention of Biological Diversity based on the IUCN 2011 and Bird Life International Cambodian Program 2013

(c) Protected area

There is no protected area in Phnom Penh Capital. In Cambodia, naturally important environmental features are protected under No. 07 NS/RKM/2008, Protected Areas Law (Royal

Decree No. NS/RKM/2008/007). The protected areas are classified into four types depending on the purpose: 1) Natural Park: Areas reserved for nature and scenic views and to be protected for scientific, educational and entertainment purposes; 2) Wildlife Preserves: Areas preserved in their natural condition to protect wildlife, vegetation and ecological balance; 3) Protected scenic view areas: Areas to be maintained as scenic spots for leisure and tourism; and 4) Multi-purposes areas: Areas necessary for the stability of the water, forestry, wildlife, and fisheries resource, for pleasure, and for the conservation of nature with a view of assuring economic development. Name of protected areas in the country are shown in **Table 10.2.4**.

Table 10.2.4 Protected Areas in Cambodia

National Parks in Cambodia			
	Name	Province	Area (ha)
1	Kirirom	Kampong Speu and Koh Kong	35,000
2	Bokor	Kampot	140,000
3	Kep	Kampot	Originally 5,000 Later amended to 1,152
4	Ream	Kampong Som	150,000
5	Botum Sakor	Koh Kong	171,250
6	Phnom Koulen	Siem Reap	37,500
7	Virachey	Stung Treng and Ratanik Kiri	332,500
Wildlife preserves in Cambodia			
	Name	Province	Area (ha)
1	Phnom Aural	Koh Kong, Pursat, Kampong Chhnang	253,750
2	Peam Krasop	Koh Kong	23,750
3	Phnom Samkos	Koh Kong	333,750
4	Roneam Donsam	Battambang	178,750
5	Koulen Prum Tep	Siem Reap and Preah Vihear	402,500
6	Beng Per	Kampong Thom	242,500
7	Lumphat	Ratanak Kiri and Mondul Kiri	250,000
8	Phnom Prich	Mondul Kiri and Kratie	222,500
9	Phnom Namlear	Mondul Kiri	47,500
10	Snuol	Kratie	75,000
Protected scenic view areas			
	Name	Province	Area (ha)
1	Angkor	Siem Reap	10,800
2	Banteay Chhmar	Banteay Meanchey	81,200
3	Preah Vihear	Preah Vihear	5,000
Multi-purposes areas in Cambodia			
	Name	Province	Area (ha)
1	Dung Peng	Koh Kong	27,700
2	Samlot	Battambang	60,000
3	Tonle Sap	Kampong Chhnang, Kampong Thom, Siem Reap, Battambang and Pursat	316,250

Source: http://www.opendevelopmentcambodia.net/briefing/protected-areas/#1

10.2.2 Socio-economic Resources

About 15 million people consisting of Khmer (90%), Vietnamese (5%), Chinese (1%) and other (4%) of ethnic groups live in the Mekong River basin at the southwestern part of Indochina peninsula. More than 96% of them are Buddhists. The country experienced long politically instable period through civil wars even after independence in 1945 and those ended in 1999. High annual growth rate of the economy in the country keeping more than 7% of GDP growth rate were achieved in recent years. The main industries are garments, construction, agriculture, and tourism. Poverty rate in 2011 was 10.1% (Number of people living below 1.25 USD/day of the international poverty line). The official language is Khmer. The adult literacy rates in 2008 were 75.6% in total, 84.6% for males, and 67.7% for females.

Phnom Penh, located in the middle of the country, currently consists 12 khans (districts). Approximately 1.5 million people live in the area of 678.5 km^2. Poverty rate (which is calculated by

the cost of purchasing food equivalent to 2,200 kilocalories, NSDP) in the whole nation is 17.9% and that in Phnom Penh is 15.3%. Adult literature rate in the capital is 93.8% in the estimation in 2012 and it is higher than those in other urban area (86.4%) and country (79.7%). Household's monthly average income in the capital is approximately 625 USD (in year 2013). It is more than two times higher than the national household's monthly income of approximately 309 USD.

(1) Demography and Settlement

Out of 12 khans in PPCC, Chamkarmon, Daun Penh, 7 Makara and Tuol Kok are located in the city center, having higher population densities of more than 160 persons/ha. Dangkor, Chroy Changvar, Prek Pnov and Chbar Ampov which have been recently incorporated from Kandal Province, have comparatively lower population densities (Detail information is in **Chapter 2**).

(2) Economic Status: Employment and Income

Economic status of households in Cambodia is analysed in **Chapter 2**. The National Institute of Statistics, Ministry of Planning, publishes socio-economic research results every year. Household income is shown in **Tables 2.2.3**.

Although the average total monthly income by household in Cambodia dropped in the year 2011, the income increased as a whole. The average monthly total income by household was 1,236 thousand Riels (approximately 309 USD based on the exchange rate 1UD=4thousand Riels) per household in 2013 with about 20% of annual growth rate (average monthly total income growth by household was 21.3% from 2012 to 2013).

As with the national trend, in PPCC, the average total monthly income by household slightly dropped in 2011 and the average in 2013 was 2,517 thousand Riels (about 625 USD based on the exchange rate 1UD=4thousand Riels). Annual growth rate from 2012 to 2013 was 33.5 %. The total household income in PPCC was about twice as high as that in the national average (Refer to **Chapter 2** for detail).

(3) Education

Literacy rate in the country is improved during last decades, as shown in **Table 10.2.5**.

Table 10.2.5 Literacy Rate [Adult Literacy (15+) by Geographical Domain and Sex (%)]

Years	2008			2012		
Domain	Women	Men	Both sexes	Women	Men	Both sexes
Cambodia	67.7	84.6	75.6	73.2	86.9	79.7
Phnom Penh	88.9	96.9	92.6	89.8	98.4	93.8
Other urban	77.6	89.7	83.2	81.3	91.8	86.4
Other rural	63.2	82.2	72.1	69.2	84.2	76.3

Source: Cambodia Socio-Economic Survey (CSES)

(4) Ethnic Group in the Country

People in Cambodia consist of Khmer (90%), Vietnamese (5%), Chinese (1%) and other ethnic groups (4%). Among the other ethnic groups, Cham, Thai, Lao and Khmer Loeu have comparatively high populations (**Table 10.2.6**). Based on the recent sampling of the Cambodia Socio-Economic Survey (CSES), the population of Khmer shares more than 97% (**Table 10.2.7**).

Table 10.2.6 Ethnic Group in Cambodia (1/2)

Unit: %

	Khmer	Vietnamese	Chinese	other
Ethnic groups	90	5	1	4

Source: CIA (2014), The World Fact Book

Table 10.2.7 Ethnic Group in Cambodia (2/2)

Unit: %

Ethnicity	Geographical domain (2012)			
	Cambodia	Phnom Penh	Other urban	Other rural
Khmer	97.2	97.6	99.2	96.8
Cham	1.6	1.9	0.2	1.8
Chinese	0.0	0.1	-	0.0
Vietnamese	0.4	0.4	0.4	0.4
Thai	-	-	-	-
Lao	-	-	-	-
Other	0.7	-	0.0	1.0
Not stated	0.1	-	0.1	0.1
Total	100	100	100	100

Source: Cambodia Socio-Economic Survey (CSES)

The indigenous people in Cambodia belong to two distinct linguistic families; the main groups are the Austronesian speaking Jarai and the Mon-Khmer speaking Brao, Kreung, Tampuan, Punong, Stieng, Kui and Poar. Over half of the indigenous population is found in the north-eastern provinces of Ratanakiri and Mondulkiri (NGO Forum on Cambodia, 2006 Indigenous Peoples in Cambodia).

(5) Religion

Buddhism is the state religion as embodied in Article 43 of the Constitution (1993) and more than 96% of the population are Buddhists (**Table 10.2.8**). The Constitution also provides freedom of the belief and among the other religions. Muslims and Christians are comparatively more than the others.

Table 10.2.8 Religions in Cambodia

Religions in Cambodia (2008 estimation), %			
Buddhist	Muslim	Christian	Other
96.9	1.9	0.4	0.8

Source: CIA (2014), The World Fact Book

(6) Land Use

The administration area of PPCC was expanded in 2008 from approximately 377 km^2 to approximately 678.5 km^2. Land use in the previous capital (Old Phnom Penh Capital area of about 377 km^2) is shown in **Table 10.2.9** and the land use plan for year 2035 is shown in **Fig. 2.1.10** in **Chapter 2**.

Table 10.2.9 Land Pattern in Old Phnom Penh City Area

Land use	Percentage (%)
Greens and forest	0.15
Lake, swamp, farmland	81.93
Urban area	16.53
Road	1.33
Water way	0.045
Total	100.00

Source: Korean Industry & Technology Institute (2011), Feasibility Study of Sewerage Treatment Plant in Phnom Penh, Kingdom of Cambodia based on Current Socio-Economy and Environment Status in the Kingdom of Cambodia (2009.10, MOE)

(7) Energy Use

Electric power in Cambodia is supplied by EDC (Government Enterprise, Electricite du Cambodia), IPP (Independent Power Producer) or imported from Thailand and Vietnam. Sixty percent of total power is imported. Therefore, in Cambodia, the operation of large-sized

hydroelectric power plants and thermal power plants has started to increase the domestic power generation capacity.

Electricity charges in PPCC is more expensive than those of neighbouring countries (0.15-0.20 USD/kWh for domestic and 0.18-0.22 USD/kWh for commerce, industry and government institutions), because the main power source at present is small-sized diesel power generators or imported.

(8) Traffic Volume

In parallel with the economic development, traffic flow has become heavy in PPCC. The traffic volume in PPCC is 60 to 90 thousand vehicles/day. Seventy-five percent of the traffic consists of motorcycles (Project for Comprehensive Urban Transport Plan in Phnom Penh Capital City, 2014). In the installation of drainage and sewer pipes, traffic flow in the city area may be affected.

(9) Waste Management

There are three waste management companies in PPCC; namely, 1) CINTRI: collection and transport of domestic waste; 2) Carom: collection and dispose of industrial waste; and 3) Red Cross Phnom Penh: burning of hazardous waste (waste from hospitals). PPCC is managing the landfill site in Dangkor District. Capacity of the site is approximately 31.4 ha. The landfill site of industrial waste is managed by the Carom in Po Senchey District in an area of approximately 5 ha.

10.3 Environmental Situation related to the Pre-Feasibility Study

General feature of natural environment and socio-economic condition in the project area are described in **Section 10.2**. Some key issues related to the sewage and drainage management priority projects are described below.

10.3.1 Environmental Situation related to Sewerage Priority Project

In the priority project, namely, "Preparatory Project", construction of STP with capacity of 5,000 m^3/day in Sangkat Dangkor in Khan Dangkor, is proposed. Treatment method is Conventional Activated Sludge Process (CASP). Brief explanation on the project site is given below.

(1) Khan Dangkor

Khan Dangkor is located at the south edge (outside of outer dike) of the capital bordering Kandal Province and it includes the western part of the Cheung Aek Lake. The Khan is divided into 13 sangkats having the population of 73,287 with the density of 6.2 persons/ha.

(2) Cheung Aek Lake area

Cheung Aek Lake originally has approximately 2,600 ha and is located in the south-eastern edge of PPCC partly belonging to Kandal Province. The area has been recently declared as a state public land in Sub-Decree, 2008 No. 124 ANKr. BK, " Identification of area of Cheung Aek Lake and canal in Mean Chey and Dangkor Khan in Phnom Penh and Takhmao District in Kandal Province as State Public Land" with the area of 520 ha. The area is well known as one of the killing fields, mass grave yards where peoples were collectively killed and buried at the regime of Khmer Rouge.

The Lake is used for flood control and natural wastewater treatment lagoon of Phnom Penh before flowing into Bassac River. Swamp area, seasonal land area and permanent water body in the lake have been used by the people for the cultivation of aquatic plants and animal husbandry and fisheries.

The Lake area has been widely used by farmers even in permanent water surface. Seasonal wetland can be utilized for the cultivation of water spinach, water mimosa and rice. Water surface can be utilized for aquaculture using floating raft. According to a study conducted by the Royal University of Agriculture in 2009 (PHEARITH TEANG & PUY LIM, 2010, International Journal of Environmental and Rural Development), majority of the area was used for water spinach cultivation (43% of the area, 992 ha), as shown in **Table 7.1.6**.

According to the study (PHEARITH TEANG 2009), commercial fishery in the Cheung Aek Lake is not common and it is limited to domestic consumption. A wide range of fish species is found in the Lake, including common carp *(Cyprinus carpio*), silver carp *(Hypophthalmichthys molitrix)*, tilapia *(Orechromis niloticus)*, snakehead fish *(Channa striata*) and walking catfish *(Clarias batrachus*).

Photo 10.3.1 shows the condition of the project site.

	
Structure in Cheung Aek Lake near Project Site	Wastewater discharged from existing Pumping Station

Source: JICA Study Team

Photo 10.3.1 Site Condition of Priority Project in Sewage Management (Preparatory Project)

10.3.2 Environmental Situation related to Drainage Priority Project

The sub-catchment area for the priority project includes 4 sangkats in 3 khans in PPCC; namely, Chaom Chau Sangkat and Kakab Sangkat in Khan Po Senchey, Tuek Thla Sangkat in Khan Sensok and Stueng Mean Chey Sangkat in Khan Meanchey. Brief explanations of the site are given below.

(1) Khan Po Senchey

The khan is located at the western edge of the capital, bounded by Kandal Province. An outer ring dike passes at the middle of the khan at the north-south direction, and National Highway No. 4 passes at the east-west direction, connecting the capital and Sihanoukville. The international airport is also located in this khan. The khan is divided into 10 sangkats having the population of 159,455 with density of 10.6 persons/ha.

(2) Khan Sen Sok

The khan is located in the area between the outer and inner ring dikes. In the area, Hanoi Road passes in the north-south direction as the main road. The khan is divided into 4 sangkats having the population of 137,772 with density of 26.5 persons/ha.

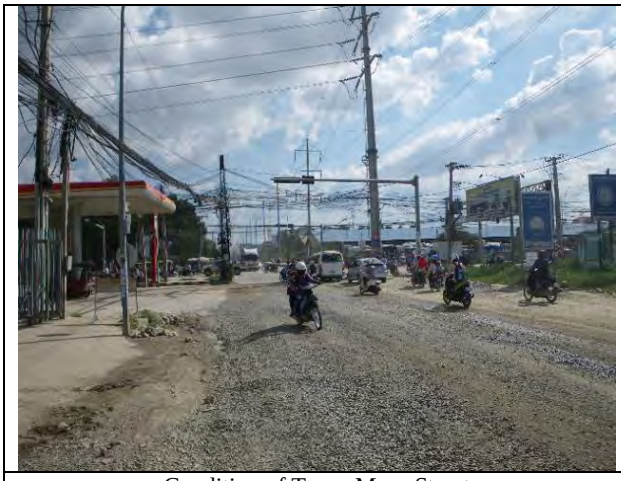
(3) Khan Meanchey

The khan is located at the middle southern edge of the capital, bounded by Kandal Province. An outer ring dike passes at the north of the khan and it includes a part of Cheung Aek Lake and Bassac River bank. The khan is divided to 4 sangkats having the population of 194,636 with density of 77.9 persons/ha. Tumpun Lake functioning as one of wastewater treatment lagoon, is located in the area.

(4) Road Condition in Proposed Sites of Drainage Facilities

(a) Trung Morn Street (North Bridge Street)

The street is connected to the Hanoi Road at the north and Veng Sreng Blvd. at the south, longitudinally crossing the Phnom Penh's western sub-urban area. Currently expansion works are ongoing (as of November 2015). The works will be financed by China in 2016 and it will be completed in 2017. (Based on information from DPWT/PPCC)



Condition of Trung Morn Street
[At intersection of Street 2004 (view from South)]

Condition of Trung Morn Street (view from North)

Source: JICA Study Team

Photo 10.3.2 Site Condition of Trung Morn Street (North Bridge Street)

(b) Veng Sreng Blvd.(Chm Chhoa Street)

Road improvement works such as expansion and concrete paving have been ongoing since 2014. The work has been delayed due to resettlement works (conflict on compensation, the Cambodian Daily, May 14, 2014, Veng Sreng Street Upgrade behind Schedule). Completion of the construction work is scheduled in 2016. The ROW of the road is 30 m (22 m of the road and 4 m×2 walkway at opposite sides according to DPWT/PPCC)

	
Veng Sreng Blvd. at existing bridge (West side)	Veng Sreng Blvd. [At intersection of St. Duong Neap II (East side)]

Source: JICA Study Team

Photo 10.3.3 Site Condition of Veng Sreng Blvd.

(c) Street Duong Neap II

The road is newly paved with concrete. The ROW is 20 m (12 m of main road and 4 m×2 walkway at both sides). The road improvement work has not yet been completed.

	
Street Duong Neap II (View from North of intersection of St. 2004)	Street Duong Neap II (View from South of intersection of Veng Sreng Blvd.)

Source: JICA Study Team

Photo 10.3.4 Site Condition of Street Duong Neap II

(d) Street 2004

Road improvement construction work is still ongoing and is probably completed in 2016. Twin pipelines of 1,500 mm are installed in opposite sides of the road at present.

10.4 Impact Assessment for Pre-Feasibility Study

10.4.1 Impact Assessment for Priority Project (Preparatory Project) in Sewage Management

Impact assessment for priority projects in sewage management is shown in **Table 10.4.1**.

Table 10.4.1 Preliminary Scoping for Priority Project in Sewage Management (December 2015)

Classification	No.	Items	Reason and Description	Rating
Social Environment	1	Involuntary resettlement	**Planning phase, Construction phase:** Some residents are living closely to the Discharge point of the existing Tumpun Station where new construction of Sewage interception facility and Sewer to the Plant are currently proposed. Also, There are dense population at existing road of No.371 (Outer ring-road). At the improvement of the existing ditches, impact to the residents should be avoid/minimized based on the adequate survey for the existing ditched at planning. **Planning phase, Construction phase:** There are some raised floor structures in the Cheung Aek lake and people may be living permanently or temporally. At the planning phase, impact to those residents should be avoided/minimized resettlement and area of land acquisition. The Cheung Aek lake which is planned for the STP site has been used for agriculture and domestic fishery. Some resident may lose their income source partly/fully. Although the land of the Cheung Aek is declared as Public State Land, adequate socio-economic survey may require for establishing compensation /rehabilitation schemes in accordance with the JICA environmental and social guideline (2010).	C-
	2	Local economy such as employment and livelihood, etc.	**Planning phase, Construction phase:** Residents who live in Cheung Aek lake may include some poor household, are likely affected to be loose a part of their income source of the farm land. In the case, supporting programs such as resettlement plan and rehabilitation plan will be required. **Construction phase:** The project is expected to increase working opportunity for construction.	C-
	3	Land use and utilization of local resources	**Planning phase, Construction phase:** Associated to the STP construction, water bodies/wet land where local people are using for agriculture and fishery will be reclaimed. Although the scale of the Plants area might not be large, less than approximately 16ha, at the planning, the impact should be avoided/ minimized. In case of no fully avoidable, adequate compensation should be made based on the socio economic survey in the area.	B-
	4	Social institutions	**Planning phase, Construction phase:** In the capital, there are many land development project that the wetland is diverted to the other land use such as residential area and industrial area. Associated to those developments, there are some problems in flood and land use. Adequate information disclosure by implementation agency to project affected peoples (PAPs) may be required at actual planning phase.	B-
	5	Existing social infrastructures and services	**Construction phase:** In the Preparatory Project, the pipe systems are planned to be installed under the access roads which connects Road 371 and proposed STP. Associated to the construction work of access road, the disturbance to the road traffic movement in Road 371 is likely to occur.	B-
	6	The poor, indigenous and ethnic people	**Planning phase, Construction phase:** For selection of the STP, special consideration should be taken to poor households in the wetland. There are some raised floor structures in the Cheung Aek Lake where people may be living permanently or temporarily. Also, some residents are living closely to existing ditches in the city area. At the planning phase, impact to these residents should be avoided or resettlement and area of land acquisition should be minimized.	B-
	7	Misdistribution of benefit and damage	**Planning phase:** Although the project aims to contribute environmental improvement of the capital, there are possible residents in the STP candidate area and along the existing ditches. The impact to residents should be avoided /minimized considering current situation based on adequate survey at the planning phase.	B-
	8	Historical and cultural heritage	No particular impact is identified at the moment.	D
	9	Local conflict of	**Planning phase:** In the capital city, there are many land development project	B-

Classification	No.	Items	Reason and Description	Rating
		interests	where the wetland is diverted to the other land use such as residential area and industrial area. Associated to those developments, there are some problems in flood and land use. The city government is currently proceeding on the identification of land rights. Some conflicts on land right is will likely to occur if private land is involved in the project area.	
	10	Water usage or water rights and rights of common	No particular impact is identified at the moment.	D
	11	Sanitation	**Operation phase:** The project is expected to improve the current water environment situation in the capital.	A+
	12	Hazardous (risk) infectious diseases such as HIV/AIDS	**Operation phase:** After operation, the risk of the water related diseases is expected to be reduced, through the sewerage projects and drainage projects.	A+
Natural Environment	13	Topography and geographic features	**Construction phase:** At the construction phase, some topographical modification will occur associated with land filling in the current water area in Cheung Aek Lake.	B-
	14	Groundwater	**Operation phase:** At the operation of the STP, water quality in groundwater is expected to improve.	A+
	15	Soil erosion	For the construction of the STP, land reclamation for access road and STP in the Cheung Aek Lake is planned. Adequate countermeasures to protect the slope surface should be considered.	B-
	16	Hydrological situation	**Planning phase, Construction phase:** The project will be planned based on the current water flow and no large hydrological change is associated. No particular impact is identified at the moment. The land reclamation in the Cheung Aek Lake will possibly affect current water flow in the area depending on the site selection and adequate hydrological study may be needed to avoid flood damage.	B-
	17	Coastal zone	There is no coastal zone in project area.	D
	18	Fauna and flora and biodiversity	**Planning phase, Construction phase:** There is no legally protected area such as National Park, Wildlife preserve, Protected scenic view area and Multi-purpose area in the project area. Habitats for the common fish species in the Cheung Aek Lake will likely be affected to be decreased. The Cheung Aek Lake is functioning as natural waste water treatment lagoon for the capital city and water quality will highly deteriorate. Due to decline of the water quality, poor biodiversity can only be remained and the impacts are limited. **Operation phase:** Through the water quality improvement by the project, biological value of the lakes may increase.	B-/B+
	19	Meteorology	No particular impact is identified at the moment.	D
	20	Landscape	No particular impact is identified at the moment.	D
	21	Global warming	The candidate site for the STP is contributing as natural pond in the watershed and the excessive global warming gas emission is not expected.	D
Pollution	22	Air pollution	**Construction phase:** During construction, the suspended dust and gas emission from the construction machinery are expected even if limited in area.	B-
	23	Water contamination	**Construction phase:** Associated with earthwork in the construction turbidity of the water will be likely increased at the downstream even if temporarily.	B-
	24	Soil contamination	**Construction phase:** During construction, accidental spillage of toxic chemicals such as fuel, lubricants, and solvents may cause soil contamination.	B-
	25	Waste	**Construction phase:** During construction and operation, the project owner should implement adequate handling of waste (including sludge).	B-
	26	Noise and vibration	**Construction phase:** During construction period noise pollution will be generated by vehicles, stone crushing, generators etc.	B-
	27	Ground subsidence	Ground modification and ground water exploitation are not planned and no any	D

Classification	No.	Items	Reason and Description	Rating
			impact is anticipated.	
	28	Offensive odor	**Construction phase:** During construction work, associated with the disturbance of the river bottom sediment such as bed excavation and foundation works, offensive odour may be generated. **Operation phase:** Associated with the operation of STP, offensive odour at surrounding area may increase. The wetlands which are candidate sites for STP, already contribute as actual waste water treatment lagoons for water purification in the Phnom Penh Capital City. Odour at the surrounding area of existing ditches and lagoon may be improved at the operation of STP.	B-/B+
	29	Bottom sediment	**Operation phase:** With the operation of the STP, situation of the bottom sedimentation at existing ditches will be improved through separate systems for sewer and rainwater.	A+
	30	Accidents	**Construction phase:** During construction, operation of heavy vehicles and machineries may cause traffic accidents to residents and labours in and around the proposed project sites.	B-

Rating

A-: Serious impact is expected, if no measure is implemented against the impact.
B-: Some impact is expected, if no measure is implemented against the impact.
C-: Extent of impact is unknown (Examination is needed. Impact may become clear as study progresses.)
D: No impact is expected.
A+: Remarkable effect is expected due to the project implementation itself and environmental improvement caused by the project.
B+: Some effect is expected due to the project implementation itself and environmental improvement caused by the project.

Source: JICA Study Team

10.4.2 Impact Assessment for Priority Project in Drainage Management

Impact assessment for the priority project in drainage management is shown in **Table 10.4.2**.

Table 10.4.2 Preliminary Scoping for Priority Project in Drainage Management (December 2015)

Classification	No.	Items	Reason and Description	Rating
Social Environment	1	Involuntary resettlement	**Planning phase, Construction phase:** Some residents are living closely to existing ditches such as Phum Mor Canal at downstream of the catchment area(Approximately 100 structures are located closely in approximately 1km of Phum Mor Canal up to the area of bridge on the Road 217). At the improvement of water flow/drainage in the catchment, impact to the residents in downstream should be avoided/minimized based on the adequate survey in downstream. To some extent, the project may require the resettlement of the residents who lives near the existing ditches/canals. **Planning phase, Construction phase:** Construction of box culvert, new pumping station, and new regulation pond may require additional land acquisition and sometime associated with resettlement in the city area (approximately 40 structure is likely relocated in the estimation in the Master Plan stage). Expansion of the existing pumping station may affect the residents nearby without any consideration.	C-
	2	Local economy such as employment and livelihood, etc.	**Planning phase, Construction phase:** Residents who live in marginal areas such as wetland and ditch side may include some poor households which will likely be affected and loss a part of their income source or to be resettled/lost the land. In the case, supporting programs such as resettlement plan and rehabilitation plan will be required. **Operation phase:** With the operation of the drainage system, flood damage risks would decrease and the local economy is expected to improve.	C-/B+

Classification	No.	Items	Reason and Description	Rating
			At the construction, the project is expected to increase working opportunity for construction. **Planning phase, Construction phase:** During construction, the project would increase work opportunities.	
	3	Land use and utilization of local resources	**Operation phase:** With the operation of drainage system, there will be a decrease in flood damage risks and land use is expected to improve.	B+
	4	Social institutions	**Planning phase, Construction phase:** In the capital city, there are many land development project so that the wetland are converted to other land use such as residential area and industrial area. Associated to those developments, there will be some problems with flood and land use. Adequate information disclosure by implementation agency to project-affected people is required at the actual planning phase.	B-
	5	Existing social infrastructures and services	**Construction phase:** The drain systems are basically planned to be installed under existing roads. Associated to the installation works, disturbance to road traffic will likely to occur. **Planning phase:** The proposed site for the box culvert includes some newly improved or planned roads such as Veng Sreng Blvd., Northbridge Street, St. Doung Neap II and St. 2004. Adequate coordination with the road construction plan may be needed. **Operation phase:** With the operation of drainage system, traffic movement in rainy season may be improved.	B-/ B+
	6	The poor, indigenous and ethnic people	**Planning phase, Construction phase:** Some residents are living closely to existing ditches in the city area. At the planning phase, impact to those residents should be avoided with minimized resettlement and area of land acquisition.	C-
	7	Misdistribution of benefit and damage	No particular impact is identified at the moment.	D
	8	Historical and cultural heritage	No particular impact is identified at the moment.	D
	9	Local conflict of interests	**Planning phase:** In the capital city, there are many land development project that the wetland are converted to the other land uses such as residential area and industrial area. Associated to these developments, there are some problems with flood and land use. The city government is currently proceeding with the identification of land rights. Associated with the above-mentioned land acquisition and resettlement (if involved), some conflicts on the land right is will likely to occur and need a long resolution procedure. Especially in the target area where some box culvert installations are planned, Veng Sreng Blvd. and Trung Morn Street (North Bridge Road) are currently being expanded and paved. Frequent resettlement and setback may generate conflict between the government and the residents.	B-
	10	Water usage or water rights and rights of common	**Planning phase:** No particular impact is identified at the moment. Some canals in Phnom Penh Capital City are managed by the water resource department for the irrigation purpose. For water flow improvement, adequate coordination with the irrigation is required.	B-
	11	Sanitation	**Operation phase:** The project is expected to improve the current water environmental situation in the capital.	A+
	12	Hazardous (risk) infectious diseases such as HIV/AIDS	**Operation phase:** After operation of the sewerage and drainage projects, the risk from water related diseases is expected to be reduced.	A+
Natural Environment	13	Topography and geographic features	**Construction phase:** With the construction, some topographical modification of waterway is expected.	B-
	14	Groundwater	No particular impact is identified at the moment.	D
	15	Soil erosion	No large soil erosion is anticipated because the area is generally flat. Water way modification,	D
	16	Hydrological situation	**Planning, Construction and Operation phase:** With new pumping station and regulation ponds, modification of the water flow may be associated.	B-
	17	Coastal zone	There is no coastal zone	-
	18	Fauna and flora and biodiversity	**Planning phase:** There are no legally protected areas such as national parks, wildlife preserves, protected scenic view areas and multi-purposes areas in the project area. Most	D/B+

Classification	No.	Items	Reason and Description	Rating
			existing ditches and regulation ponds in the capital are highly polluted for habitation of wildlife. At the planning phase, the situation may be confirmed in the survey.	
	19	Meteorology	No particular impact is identified at the moment.	-
	20	Landscape	No particular impact is identified at the moment.	D
	21	Global warming	No particular impact is identified at the moment.	D
Pollution	22	Air pollution	**Construction phase:** At the construction, the suspended dust and gas emission from the construction machinery is expected to be limited.	B-
	23	Water contamination	**Construction phase:** Associated with earthwork in the construction, turbidity of the water will be likely increased at the downstream.	B-
	24	Soil contamination	**Construction phase:** During construction, accidental spillage of toxic chemicals such as fuel, lubricants, and solvents may cause soil contamination.	B-
	25	Waste	**Construction phase:** During construction and operation, the project owner should implement adequate handling of waste (including sludge).	B-
	26	Noise and vibration	**Construction phase:** During construction, noise pollution will be generated by the use of vehicles, stone crushing, generators etc.	B-
	27	Ground subsidence	Ground modification and groundwater exploitation are not planned and no any impact is anticipated.	-
	28	Offensive odor	**Construction phase:** Associated with disturbance of the river bottom sediment due to bed excavation and foundation works in the construction phase, offensive odour may be generated.	B-
	29	Bottom sediment	**Operation phase:** With the operation of existing ditches, the improved water flow may reduce sedimentation.	B+
	30	Accidents	**Construction phase:** During construction, operation of heavy vehicles and machinery may cause traffic accidents to residents and labours in and around the proposed project sites.	B-

Rating

A-: Serious impact is expected, if no measure is implemented against the impact.

B-: Some impact is expected, if no measure is implemented against the impact.

C-: Extent of impact is unknown (Examination is needed. Impact may become clear as study progresses.)

D: No impact is expected.

A+: Remarkable effect is expected due to the project implementation itself and environmental improvement caused by the project.

B+: Some effect is expected due to the project implementation itself and environmental improvement caused by the project.

Source: JICA Study Team

10.5 Environmental Management Plan (Tentative)

The Environmental Management Plan (EMP) should be finalized in time for the EIA processing in accordance with the further detail study. The EMP at the IEE stage is as tentatively presented below.

10.5.1 Mitigation Measures for Priority Projects in Sewage Management

Impact and possible mitigation measures for the priority projects in sewage management are shown in **Table 10.5.1**.

Table 10.5.1 Impact and Possible Mitigation Measures for Priority Projects in Sewage Management (Tentative, December 2015)

Classification	No.	Items	Rating	Reason and Description	Possible Measure
Social Environment	1	Involuntary resettlement	C-	**Planning Phase, Construction Phase:** Some residents are living close to the discharge point of the existing Tumpun Pumping Station where sewage interception facilities and sewer to STP are proposed. There is dense population at the area of the existing road of (No. 371, Outer ring road). At the improvement of the existing	Socio-economic survey at the project site should be conducted to avoid or minimize resettlement and land acquisition.

Classification	No.	Items	Rating	Reason and Description	Possible Measure
				channels, impact to the residents should be avoided and/or minimized based on the adequate survey at planning phase. **Planning Phase, Construction Phase:** There are some raised floor structures in the Cheung Aek Lake where people may be living permanently or temporarily. At the planning phase, impact to the people including resettlement and land acquisition should be avoided and/or minimized. Cheung Aek Lake for the STP site has been used for agriculture and domestic fishery. Some residents may lose partly or fully their income source. Although the land of the Cheung Aek is declared as public state land, adequate socio-economic survey may be required for establishing compensation/rehabilitation schemes in accordance with the JICA environmental and social consideration guideline (2010).	
	2	Local economy such as employment and livelihood, etc.	C-	**Planning Phase, Construction Phase:** Residents who live in Cheung Aek Lake area may include some poor households and they may lose a part of their income source of farm land. In such cases, supporting programs such as resettlement plan and rehabilitation plan will be required.	Consideration will be required to minimize area for acquisition.
	3	Land use and utilization of local resources	B-	**Planning Phase, Construction Phase:** In STP construction, water bodies/wetland which local people are using for agriculture and fishery will be reclaimed. Although the STP area is not large (3.5 ha), the impact should be avoided and/or minimized at the planning phase. If not fully avoidable, adequate compensation should be made based on the socio-economic survey in the area.	Adequate compensation to the people who use the lake for fisheries/agriculture will be required.
	4	Social institutions	B-	**Planning Phase, Construction Phase:** There are many land development projects in which wetland is converted to the other land uses such as residential area and industrial area. Associated with those developments, there may be some problems in flood and land use. Adequate information disclosure by implementation agency to Project-Affected People (PAP) may be required at the planning phase.	Information disclosure by implementation agency at the planning phase.
	5	Existing social infrastructures and services	B-	**Construction Phase:** In the priority project, sewer is installed under the access road which connects Road No. 371 and the proposed STP. Associated with the construction work of access road, disturbance to the road traffic movement in Road No. 371 may occur.	Adequate traffic guide should be provided to reduce accidents at the site in the construction phase.
	6	The poor, indigenous and ethnic people	B-	**Planning Phase, Construction Phase:** Special consideration should be taken for poor households in the wetland in the selection of STP site. There are some raised floor structures in the Cheung Aek Lake area where people may be living permanently or temporarily. Some residents are living close to existing channels. At the planning phase, impact to those residents	Resettlement and land acquisition should be avoided and/or minimized at planning phase. If not avoidable, adequate compensation based on proper study should be provided.

Classification	No.	Items	Rating	Reason and Description	Possible Measure
				including resettlement and land acquisition should be avoided and/or minimized.	
	7	Misdistribution of benefit and damage	B-	**Planning Phase:** Although the project aims to contribute environmental improvement in the capital, residents may live around the STP site and along the existing channels. The impact to residents should be avoided and/or minimized considering current situation based on adequate survey at the planning phase.	Resettlement and land acquisition should be avoided and/or minimized at the planning phase. If not avoidable, adequate compensation based on proper study should be provided.
	8	Local conflict of interests	B-	**Planning Phase:** There are many land development projects in which wetland is converted to other land uses such as residential area and industrial area. Associated with those developments, there may be some problems in flood and land use. PPCC is currently proceeding with the identification of land rights. Some conflicts on the land right may occur if private land is involved in the project area.	Resettlement and land acquisition should be avoided and/or minimized at planning phase. If not avoidable, adequate compensation based on proper study should be provided.
Natural Environment	9	Topography and geographic features	B-	**Construction Phase:** Some topographical modification may occur, associated with land filling in the Cheung Aek Lake.	Project scheme is under consideration. Adequate survey should be conducted, if necessary.
	10	Soil erosion	B-	**Construction Phase:** For the construction of the STP, land reclamation for access road and STP in the Cheung Aek Lake is planned. Countermeasure to protect ground surface should be considered.	Project scheme is under consideration. Adequate survey should be conducted, if necessary.
	11	Hydrological situation	B-	**Planning Phase, Construction Phase:** The project will be planned based on the current water flow, and thus no large hydrological change is anticipated. No particular impact is identified at the moment. Land reclamation in the Cheung Aek Lake may affect current water flow in the area depending on the site selection. Appropriate hydrological study may be needed to avoid flood damage.	Project scheme is under consideration. Adequate survey should be conducted, if necessary.
	12	Fauna and flora and biodiversity	B-	**Planning Phase, Construction Phase:** There is no legally protected area such as national park, wildlife preserve, protected scenic view area and multipurpose area in the project area. Habitats for the common fish species in the Cheung Aek Lake may be affected. Cheung Aek Lake is functioning as natural wastewater treatment lagoon for the capital and water quality is severely deteriorated. Due to decline of the water quality, biodiversity becomes poor.	Project scheme is under consideration. Adequate survey should be conducted, if necessary.
Pollution	13	Air pollution	B-	**Construction Phase:** Suspended dust and gas emission from the construction machinery is expected in a limited area.	To minimize pollution, construction related emissions should be regulated; e.g., maintaining machinery and avoiding unnecessary idling. Regular water spray on dry surface to reduce dust generation must be practiced.
	14	Water contamination	B-	**Construction Phase:** Associated with earthworks, the turbidity of	Handling, storage and spillage of the potential contaminants has to

Classification	No.	Items	Rating	Reason and Description	Possible Measure
				water may increase.	be strictly controlled to avoid water pollution.
	15	Soil contamination	B-	**Construction Phase:** Accidental spillage of toxic chemicals such as fuel, lubricants, and solvents may cause soil contamination.	Handling, storage and spillage of the potential contaminants has to be strictly controlled to avoid water pollution.
	16	Waste	B-	**Construction Phase:** Project owner should properly handle waste (including sludge).	Workers should be instructed not to dump waste at surrounding areas. Adequate dumping site should be planned.
	17	Noise and vibration	B-	**Construction Phase:** Noise pollution will be generated with the use of vehicles, stone crushing, generators, etc.	Adequate maintenance of machinery will be required. Construction works should be done in accordance with the standards.
	18	Offensive odor	B-	**Construction Phase:** Associated with the disturbance of river bottom sediment in bed excavation and foundation works, offensive odour may be generated. **Operation Phase:** Associated with the operation of STP, offensive odour at surrounding area may increase.	Prevention measure should be considered at the designing such as applying deodorization equipment for the STP.
	19	Accidents	B-	**Construction Phase:** **O**peration of heavy vehicles and machinery may cause traffic accidents to residents and labourers in and around the project sites.	Adequate traffic guide should be provided to reduce accidents at the site.

Source: JICA Study Team

10.5.2 Mitigation Measures for Priority Projects in Drainage Management

Impact and possible mitigation measures for the priority projects in drainage management are shown in **Table 10.5.2**.

Table 10.5.2 Impact and Possible Mitigation Measures for Priority Projects in Drainage Management (Tentative, December 2015)

Classification	No.	Items	Rating	Reason and Description	Possible Measure
Social Environment	1	Involuntary resettlement	C-	**Planning Phase, Construction Phase:** Some residents are living close to existing channels such as Phum Mor Canal at the downstream. At the improvement of water flow/drainage, impact to residents in downstream should be avoided and/or minimized based on the adequate survey in downstream. The project may require resettlement of residents who live near the existing channels. **Planning Phase, Construction Phase:** Construction of box culvert, new pumping station, and new regulation pond may require additional land acquisition and resettlement. Expansion of the existing pumping station may affect the residents nearby. 40 households are to be resettled in the project.	Further study should be conducted to verify the situation at the EIA study.

Classification	No.	Items	Rating	Reason and Description	Possible Measure
	2	Local economy such as employment and livelihood, etc.	C-	**Planning Phase, Construction Phase:** Some poor households living in marginal areas such as wetland and drainage channel may lose a part of their income source or to be resettled/loss the land. In such cases, supporting programs such as resettlement plan and rehabilitation plan will be required. At the construction phase, the project increases working opportunity. **Operation Phase:** With the operation of drainage system, flood damage will be reduced and local economy will be improved.	Adequate compensation scheme should be applied in case of resettlement. Livelihood rehabilitation plan should be prepared, if the project affects poor people.
	3	Social institutions	B-	**Planning Phase, Construction Phase:** There are many land development projects in which wetland is converted to other land uses such as residential area and industrial area. Associated with those developments, there may be some problems in flood and land use. Adequate information disclosure by the implementation agency to Project-Affected People (PAPs) may be required at the planning phase.	Adequate information disclosure such as public consultation meeting by implementation agency should be considered at actual planning stage in case resettlement/land acquisition is required.
	4	Existing social infrastructures and services	B-	**Construction Phase:** Drainage facilities will basically be installed under existing roads. Associated with the installation works, disturbance to road traffic movement may occur. **Planning Phase:** Proposed site for the box culvert includes being improved or to be improved roads such as Veng Sreng Blvd., Northbridge Street, St. Doung Neap II and St. 2004. Adequate coordination with the road construction plan may be required.	Adequate traffic control with adequate notice such as signboard, signs and diversion road should be provided to reduce traffic jams. Adequate coordination with the road construction plan may be needed.
	5	The poor, indigenous and ethnic people	C-	**Planning Phase, Construction Phase:** Some residents are living close to existing channels. At the planning phase, impact to those residents including resettlement and land acquisition should be avoided and/or minimized.	Detail survey should be conducted in the EIA study.
	6	Local conflict of interests	C-	**Planning Phase:** In the capital, there are many land development projects in which wetland is converted to other land uses such as residential area and industrial area. Associated to those developments, there are some problems with flood and land use. Capital government is currently proceeding with the identification of land rights. Associated with the above-mentioned land acquisition and resettlement (if involved), some conflicts on land right may occur in the process of resolution.	Detail survey should be conducted at the EIA study. With the socio-economic survey, the situation may be clarified.
	7	Water usage or water rights and rights of common	B-	**Planning Phase:** For water flow improvement, adequate coordination with the irrigation sector is required.	Adequate coordination with the irrigation sector should be required.

Classification	No.	Items	Rating	Reason and Description	Possible Measure
Natural Environment	8	Topography and geographic features	B-	**Construction Phase:** Some topographical modification of waterway is expected.	Hydrological study should be conducted to prevent unexpected flooding caused by phased development.
	9	Hydrological situation	B-	**Construction Phase:** With new pumping station and regulation ponds, modification of the water flow may be expected.	Hydrological study in downstream should be conducted at planning stage.
	10	Fauna and flora and biodiversity	B-	**Planning Phase:** There is no legally protected area such as national park, wildlife preserve, protected scenic view area and multipurpose area in the project area. Most existing ditches and regulation ponds in the capital are highly polluted for wildlife. At the planning phase, the situation may be confirmed in the survey.	Site confirmation prior to the project may be required at the planning stage.
Pollution	11	Air pollution	B-	**Construction Phase:** Suspended dust and gas emission from the construction machinery is expected in a limited area.	To minimize pollution, construction related emissions should be regulated; e.g., maintaining machinery and avoiding unnecessary idling. Regular water spray on dry surface to reduce dust generation must be practiced.
	12	Water contamination	B-	**Construction Phase:** Associated with earthworks, the turbidity of water may increase.	Handling, storage and spillage of potential contaminants has to be strictly controlled to avoid water pollution.
	13	Soil contamination	B-	**Construction Phase:** Accidental spillage of toxic chemicals such as fuel, lubricants, and solvents may cause soil contamination.	Handling, storage and spillage of potential contaminants has to be strictly controlled to avoid water pollution.
	14	Waste	B-	**Construction Phase:** Project owner should implement adequate handling of waste (including sludge).	Workers should be instructed not to dump waste at surrounding areas. Adequate dumping site should be planned.
	15	Noise and vibration	B-	**Construction Phase:** Noise pollution will be generated with the use of vehicles, stone crushing, generators, etc.	Adequate maintenance of machinery will be required. Construction work should be done in accordance with the standards.
	16	Offensive odor	B-	**Construction Phase:** Associated with the disturbance of river bottom sediment such as bed excavation and foundation works, offensive odour may be generated.	Prevention measures shall be considered at the designing such as applying deodorization equipment.
	17	Accidents	B-	**Construction Phase:** **O**peration of heavy vehicles and machinery may cause traffic accidents to residents and labourers in and around the project sites.	Adequate traffic guide should be provided to reduce accidents at the site.

Source: JICA Study Team

10.6 Matters related to Involuntary Resettlement

10.6.1 Current Situation related to Involuntary Resettlement for Sewage Projects

The current situation related to involuntary resettlement for the priority projects in sewage management is summarized in **Table 10.6.1**. The detail scheme for the compensation should be considered properly in the implementation stage in accordance with JICA's environmental and social consideration guideline (2010).

Table 10.6.1 Confirmation of Resettlement Matters for the Sewage Project

No.	Items	Description
1	Analysis of legal framework related to resettlement	Legislation related to the resettlement is described in **Chapter 2**. Although the land of Cheung Aek Lake is declared as Public State Land, adequate socio-economic survey may require for establishing compensation/rehabilitation schemes for land users in accordance with the JICA environmental and social guideline (2010). There are some cases for resettlement in PPCC conducted by the Road Development Project. The land tenure system in the country is slightly complicated and so referring to good practice is beneficial. Appropriate compensation scheme should be established for the project although the Cheung Aek Lake is declared as public state land.
2	Necessity of resettlement	At present, no involuntary resettlement is anticipated in the priority project. Although the land of Cheung Aek Lake is declared as Public State Land, adequate socio-economic survey may require for establishing compensation/rehabilitation schemes or land users in accordance with the JICA environmental and social guidelines (2010). There are some raised floor structures in Cheung Aek lake and people may be living permanently or temporarily. At the planning phase, impact to those residents should be avoided or minimized. Cheung Aek Lake area which is planned for the STP site has been used for agriculture and domestic fishery. Some residents may lose their income source partly or fully.
3	Implementation of socio-economic study	At the future stage, adequate study should be done. In the country, initial resettlement action plan study should be conducted by a consulting firm registered with MEF. The process is explained in "Circular MEF006_2014 on Procedure to Implement Resettlement of Development Projects".
4	Compensation for asset loss, rehabilitation plan	Adequate compensation scheme should be developed based on socio-economic studies in the implementation stage.
5	Relocation site development plan	Ditto
6	Grievance handling mechanism	This should be considered at future phase after clarifying the scale of the project.
7	Organizational structure	Ditto
8	Implementation schedule	Ditto
9	Considering cost and budget	Ditto
10	Considering Monitoring and Evaluation Method at project completion	Ditto
11	Public participation	Prior information disclosure to PAPs is necessary; however, the details should be considered at future phase after clarifying the scale of the project.

Source: JICA Study Team

10.6.2 Current Situation related to Involuntary Resettlement for Drainage Project

The current situation related to involuntary resettlement for the priority project in drainage management is summarized in **Table 10.6.2**.

Table 10.6.2 Confirmation of Resettlement Matters for the Drainage Project

	Items	Description
1	Analysis of legal framework related to resettlement	Legislation related to the resettlement is described in **Chapter 2**. The framework for resettlement is not yet established.
2	Necessity of resettlement	Construction of drainage facilities may require additional land and resettlement of about 40 households is anticipated. About 100 households (in the stretch of 1 km up to

	Items	Description
		bridge of St.217) are adjacent to existing Phum Mor Channel. Therefore, adverse impact on people along the channel should be avoided or minimized based on detailed study in the implementation stage.
3	Implementation of socio-economic study	At the future stage, adequate study should be done. In the country, the initial resettlement action plan study should be conducted by a consulting firm registered with MEF. The process is explained in "Circular MEF006_2014 on Procedure to Implement Resettlement of Development Projects".
4	Compensation for asset loss, rehabilitation plan	Adequate compensation scheme should be developed based on socio-economic studies in the implementation stage.
5	Relocation site development plan	Ditto
6	Grievance handling mechanism	This should be considered at future phase after clarifying the scale of the project.
7	Organizational structure	Ditto
8	Implementation schedule	Ditto
9	Considering cost and budget	Ditto
10	Considering Monitoring and Evaluation Method at project completion	Ditto
11	Public participation	Prior information disclosure to PAPs is necessary; however, the details should be considered at future phase after clarifying the scale of the project.

Source: JICA Study Team

10.6.3 Consideration of Resettlement Matter for Priority Projects

For JICA funded projects, adequate environmental and social consideration is required in accordance with the JICA Environmental and Social Consideration Guidelines (2010).

Adequate compensation scheme to illegal settlers/occupants may be required. Actual condition should be identified in the implementation stage. In Cheung Aek Lake area, there are many settlers even in the middle of the declared area. Status of their land use/settlement should be identified through the socio-economic survey. In addition, there are some structures in the area of existing drainage/channel. Situation of land use such as land title and tenants should carefully be identified in legal and peaceful way to avoid un-reasonable conflict between government and private parties.

There are some experiences to deal with compensation matters related to occupation/resettlement from public state land. In the case of the road development project, the Government declares the ROW of the road and then compensates for structures/assets for relocation. However, the situation is not resolved completely. After the project, some households remain within the area of ROW.

GAP analysis conducted by the Japanese Yen Loan Project for National Road No.5 (conducted under "Category A" project in accordance with the JICA Guidelines) is shown in **Table 10.6.3**. As shown in the table, compensation to the informal occupants were properly done although it was not covered by the Cambodian compensation scheme.

Table 10.6.3 Verification and Comparison between Cambodian System and JICA Guidelines for Environmental and Social Considerations (April 2010)

No.	Item	JICA Guidelines Policy	Law/Regulation in Cambodia (officially promulgated)	Actual Operation (Gap Filling Measures)
1	Support system for socially vulnerable groups	It is necessary to give appropriate consideration to vulnerable groups.	Sub-Decree on Social Land Concession provides allocations of free private state land to landless people of residential or family farming, including the replacement of land lost in the context of involuntary resettlement.	Income restoration program (IRP) and assistance (allowance) to vulnerable groups will be prepared based on their preference.

No.	Item	JICA Guidelines Policy	Law/Regulation in Cambodia (officially promulgated)	Actual Operation (Gap Filling Measures)
2	Assistance to restore and improve living standards	Living standards and income opportunities, and production levels of project affected people should be improved or at least restored to pre-project levels.	The government has no clear policy or procedure to restore the livelihood of Affected Households.	Income restoration program (IRP) will be prepared based on their preference.
3	Enhancement of public participation in planning and implementation of RAP	Appropriate participation of affected people and their communities should be promoted in planning, implementation and monitoring of involuntary affected households and measures taken against the loss of their means of livelihood.	It is clearly declared in *the Expropriation Law* ***(Article 16)*** that in conducting a survey of entitlements, public consultations shall be organized to provide specific and concise information and collect inputs from all stakeholders regarding the proposed basic public infrastructure project and that a dateline interview with all concerned parties shall be conducted.	Stakeholder meetings and interview of Affected Households shall be conducted at appropriate stages according to JICA Guidelines and *the Expropriation Law*.
4	Compensation for land acquisition with replacement cost	Prior compensation will be done with replacement cost, which means that compensation for lost assets must be made in full amount at replacement cost and at current market price.	The amount of compensation to be paid to the owner of and/or holder of real right to the immovable property shall be based on the market price or replacement cost as of the date of the issuance of the declaration on the expropriation project. (the *Expropriation Law* (**Article 22**))	Affected Households will be compensated at replacement cost. The replacement cost will be calculated based on the detailed measurement survey just before implementing resettlement.
5	Affected Households residing in the Project affected area before cut-off date	People to be resettled involuntarily and those whose means of livelihood will be hindered or lost should be sufficiently compensated and supported by the project proponents in appropriate time.	Under *the Land Law 2001*, those who have occupied ROW or public property are not entitled to any compensation or social support.	Assistance to Affected Households who are residing in the project-affected area (including public state land) at the time of cut-off date will be prepared (Compensation for properties without land is done at replacement cost and resettlement site will be prepared for landless Affected Households).
6	Grievance redress mechanism	Grievance redress system must be formulated and must function appropriately.	Grievance redress system is stipulated in *the Expropriation Law*; however, it has provisions to exclude public infrastructure projects.	Grievance redress system will be formulated.

Source: MPWT, JICA (2014), Preparatory Survey for National Road No.5 Improvement Project/Middle Section: - from Thlea Ma'am to Battambang - from Sri Sophorn to Poipet

10.7 Conclusion and Recommendations

This IEE study was conducted as a preliminary environmental assessment for the Pre-Feasibility Study on the IEE level based on the available secondary information. Further studies are recommended in the subsequent project stages. In **Tables 10.7.1** and **10.7.2**, drafts of the Terms of Reference (TOR) for conducting studies on the Full Environmental Impact Assessment (FEIA) and the Land Acquisition and Resettlement Action Plan (LARAP) are shown as references. The environmental study should be conducted by a company registered with the Ministry of Environment (MOE). On the other hand, the study on the Initial Resettlement Action Plan should be conducted by a company registered with the Ministry of Economy and Finance (MEF).

10.7.1 Terms of Reference for FEIA

The Draft TOR for FEIA is summarised in **Table 10.7.1**.

Table 10.7.1 Terms of Reference for FEIA (Draft)

	Items	Contents	Resources and Methodology
1	Introduction	• Project Overview: Brief project background, reasons for the formative project and general situation of the project site. • Objectives of preparing the EIA report. • Methodologies and Scope of Study: Information on the project, data needed, methodology of data collection, and data analysis. In the case of FEIA report, the project owner shall study methodologies in detail and develop separable chapters.	Updated project background and project information
2	Legal Framework	Description of laws, sub-decrees and various policies related to the project.	Updated applicable legislation
3	Project Description	Description of project details such as background, owners' experience, project site, project type/scope and time of project activities, action plan of work and program of activities of the project: 1) Sources and quantity of raw materials to be used; 2) machinery requirement; 3) local and foreign work force requirement; 4) quantity of final products; 5) income and expenditure; 6) production-chain of the project; 7) general waste management plan, etc.	Updated project information
4	Description of Environmental Resources	Description of natural environmental and socio-economic resources (primary and secondary data) in and around the project location including: • Natural Environmental Resources <u>Physical Resources</u> ・ Soils: geology, soil formation/topology, soil types, soil erosion and sedimentation (also earthquake and geology) ・ Weather: temperature, rainfall, air speed and regime, air pressure, air direction and humidity ・ Air quality (air quality analysis in the project location), noise and vibration (noise and vibration measures in the project location) ・ Hydrology: quality and quantity of surface and underground water (including analysis of quality of surface and underground water), water current and flow <u>Biological Resources</u> ・ Forest: forest land area, forest species and forest classification ・ Fauna species, rare species, endangered species and migration ・ Habitats ・ Biodiversity and ecology system ・ Wetland system (attached relevant maps) <u>Socio-economic Resources</u> ・ Demography and settlement ・ Economic status (employment and income) ・ Land use ・ Water use ・ Energy use ・ Infrastructure system ・ Education ・ Public health ・ Cultural heritage, historical buildings, ancient temples, pagodas,	-Hydrological study to ensure water flow -Water quality study as baseline -Traffic information -Confirmation of the biological feature in the site -Socio-economic survey for PAPs

	Items	Contents	Resources and Methodology
		customs/traditions, ethnic minority or indigenous people ・ Tourism area	
5	Public Participation	Report on the Public Consultation • Introduction • Conduct of public consultation ・ Dissemination for authorities and local communities about development projects ・ Comments from relevant ministries, institutions, departments and local authorities ・ Comments from relevant non-government organizations (NGOs) ・ Local people consultation • Conclusion on the results of public consultation	Implementation record for public consultation
6	Environmental Impacts and Mitigation Measures	Description of both positive and negative environmental and socio-economic resource impacts arising from the projects' activities: impacts during the project pre-operation (project design and construction), operation and mitigation measures, etc. • Describe the negative environmental and socio-economic resource impact during project pre-operation (project design and construction), operation • Summarize the above points on the scope of negative environmental impact mitigation measures in table form as stated in Annex 2. • Cumulative impacts • Describe the positive environmental and socio-economic resource impacts.	Assessment based on the detail study.
7	Environmental Management Plan	Description of the draft Environmental Management Plan containing the Implementation Agency's measures against the impacts, establishment of a fund and an office with qualified technical staff, appropriate equipment, methodologies and well-prepared schedule for monitoring environmental quality in close collaboration with relevant institutions in order to mitigate negative socio-economic and environmental resource impacts to the minimum level. The EMP shall include: • Summary of main negative environmental impacts and mitigation measures • Training to be provided • Monitoring schedule during construction, operation and closure phases that the project owner shall take, including the following: ・ Control institutions for the project monitoring ・ Parameter to be controlled ・ Methodology of control ・ Environmental norms or guidelines to be taken in the implementation ・ Schedule and cycle to be controlled ・ Assess output of self-monitoring ・ Prepare quarterly report to be submitted to MOE and relevant ministries/institutions.	Development of adequate management plan and monitoring plan based on the result of study
8	Economic Analysis and Environmental Value	Description of benefits of the projects in comparison with the scope and value of environmental damage arising from the project activities.	Analysis based on the detail study
9	Conclusion and Recommendations	Conclusion of environmental impact assessment study indicating the minimization of impacts to physical, biological and socio-economic resources.	Analysis based on the detail study

Source: JICA Study Team, based on the Declaration on General Guideline for Conducting Initial and Full Environmental Impact Assessment Reports (MOE, 2009, N. 376 BRK.BST)

10.7.2 Terms of Reference for LARAP

The Draft TOR for LARAP is summarised in **Table 10.7.2**.

Table 10.7.2 Terms of Reference for LARAP (Draft)

Items	Contents	Remarks
1. Introduction	- Description of the project - Resettlement action plan for the drainage improvement - Definitions	
2. Description of Impacts and Socio-economic Characteristics	- Project area - Census and baseline survey - Social and economic characteristics of the PAPs - Impact of the project - Relocation requirement	Population census for all PAPs: Socio-economic survey covering at least 20% of PAPs.
3. Eligibility and Legal Framework	- Description of the cut-off date - Eligibility - Legal and illegal Project-Affected-Persons (PAPs) - Relevant Acts and Bylaws	
4. Compensation Policy and Entitlements	- Objectives of resettlement policy - Principles of resettlement policy - Detailed compensation, resettlement and rehabilitation entitlements - Subsistence allowance	
5. Public Participation	- Objectives of public information and consultation - Public information dissemination - Public participation - Public participation and consultation in resettlement - Public participation in project monitoring and ex-post evaluation - Grievance redress process	Public Consultation with PAPs (at least 2 different times)
6. Organizational Set up	- Institution for resettlement - External monitoring - Resettlement and rehabilitation capacity in PIU	
7. Resettlement Costs and Budget	- Procedures for flow of funds - Implementation, administration and contingency costs - Unit price for cost estimation	
8. Implementation Schedule	- Pre-implementation activities - Resettlement implementation activities	
9. Monitoring and Evaluation	- Internal monitoring - External monitoring - Post implementation evaluation study - Monitoring and evaluation reports	

Source: JICA Study Team, based on JICA's Environmental and Social Consideration Guidelines (2010), MEF, Cambodia (2012), Basic Resettlement Procedure, MPWT, JICA (2014), Preparatory Survey for National Road No. 5 Improvement Project / Middle Section: - from Thlea Ma'am to Battambang - from Sri Sophorn to Poipet.

CHAPTER 11 CONCLUSION AND RECOMMENDATION

11.1 Conclusion

11.1.1 Sewage Management

For sewage management, PPCC is subdivided into three areas (Cheung Aek, Tamok and Other areas) and the on-site and off-site treatment methods for the target year 2035 are evaluated as structural measures. As a result, off-site treatment is applied to the Cheung Aek Treatment Area and the Sewage Treatment Plant (STP) employing the Conventional Activated Sludge Process (CASP) is proposed. On the other hand, on-site treatment introducing Johkasou is proposed for the Tamok Treatment Area. In the "Other area", the installation of septic tank, which is the most popular sanitary device in PPCC, is recommended, especially in households in which no toilet or pit latrine is equipped, and the introduction of advanced wastewater facilities such as Johkasou is recommended beyond the target year.

Due to the lack of institutional and legal provisions in sewage management, the establishment of institutional and legal framework of sewage management in PPCC is indispensable to commence and sustainably implement full-scale sewage management, particularly, the construction and operation of STP. Sewerage and Drainage Advancement Office under the Director of DPWT/PPCC is therefore proposed in the M/P, with the approach of "Start small and grow big". After the establishment of the Advancement Office, phased implementation plan for establishing independent sewage implementing body, in parallel with human resource development, is proposed.

In parallel with the establishment of institutional and legal framework of sewage management, phased construction plan is formulated to gradually accumulate experience and knowledge of sewage management. Based on the phased construction plan, "Preparatory Project", followed by three phases of STP construction, is proposed for Cheung Aek Treatment Area. The Preparatory Project is outlined in the Pre-F/S.

Phased establishment of institutional and legal framework, along with implementation of the Preparatory Project, will realize the smooth and sustainable implementation of subsequent sewage projects in PPCC.

11.1.2 Drainage Management

In the drainage management, PPCC is subdivided into 25 catchment areas. Structural measures consisting of drainage channels, pumping stations and regulation ponds are proposed considering topographical conditions as well as availability of existing drainage facilities for the target year 2035.

Institutional and implementation framework in drainage management is already established to some extent through implementation of drainage improvement projects such as "The Project for Flood Protection and Drainage Improvement Project in Phnom Penh Capital City (Phase 1, 2 and 3)". However, strengthening of institutional framework is proposed because the present framework is insufficient to smoothly implement the number of drainage projects proposed in the M/P to address rapid urbanization.

Pre-F/S in drainage management is conducted targeting one of the prioritized drainage areas of Pochentong East, because "The Preparatory Survey on the Project for Flood Protection and Drainage in the Phnom Penh Capital City (Phase 4) is commenced from end of March 2016, targeting the other prioritized drainage areas of Wat Phnom Northern Area and Tuol Kok.

After the Phase 4 project, implementation of the project in Pochentong East Drainage Area is recommendable to mitigate inundation damage recently identified in the newly developed area in PPCC.

11.2 Recommendation

11.2.1 Sewage Management

Recommendations for sewage management are enumerated as follows.

- CASP is selected in the M/P and Pre-F/S as the applicable wastewater treatment method for Cheung Aek STP, for the reason that it is premature to apply the PTF (Pre-Trickling Filtration) method employed in large-scale STPs. However, re-evaluation of the PTF in the implementation stage is required based on actual performances in other countries, because the PTF has the advantage of reducing O&M cost and minimizing land acquisition, and the introduction of advanced technologies is essential in order to promote “quality infrastructure investment”.

- Establishment of institutional and legal framework in sewage management is essential to smoothly implement full-scale construction and operation of sewerage facilities, considering the current lack of institutional and legal provisions in sewage management in PPCC. In the establishment of the framework, assistance from donors in collaboration with MPWT is beneficial.

11.2.2 Drainage Management

Recommendations for drainage management are enumerated as follows.

- A number of small to large-scale development projects are on-going in PPCC. As a result, swamps and lakes, which have been protecting PPCC from inundation, rapidly disappear. Therefore, PPCC should impose severe restrictions on the reclamation of swamps and lakes by land developers in order to prevent inundation and require them to install drainage facilities in accordance with the drainage management plan in the M/P.

- In PPCC, garbage disposed to drainage channels severely affects function of drainage channels especially in the rainy season. In order to improve the condition, PPCC should educate people with such slogans as “Do not dispose garbage to drainage channels”, “Drainage channel is not garbage box”, and “Disposed garbage in drainage channel leads to inundation and inconvenience in your daily life” in a repetitive manner.

APPENDICES

Appendix 1 GAP Analysis between JICA Environmental and Social Guideline and Environmental Legislation in the country, Cambodia

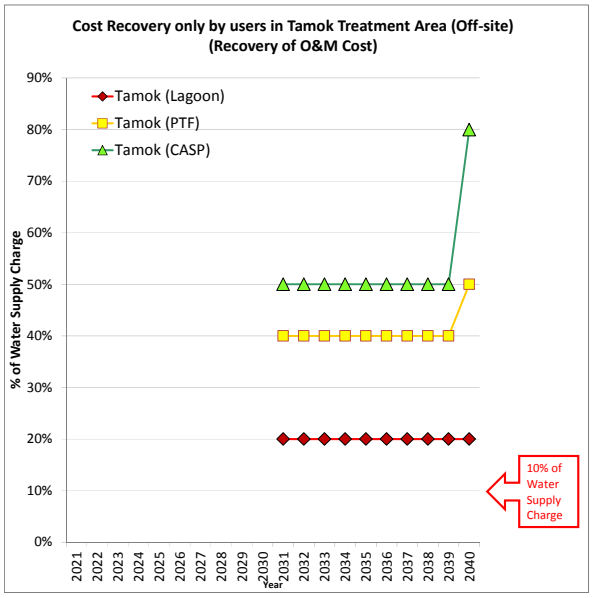
Items	JICA Guideline (Environmental and Social Considerations Required for Intended Projects)	Environmental Legislation in Cambodia	The measure to be held in the current project
1. Underlying Principles	1. The earliest possible environmental assessment to incorporate the avoidance/minimization /mitigation of the impact into the project plan. 2. Quantitative and qualitative analysis covering social and environment harmonizing economic, financial, institutional, social and technical analysis. 3. Provision of alternatives and mitigation measures in consideration. EIA report for the large adverse impact. 4. Organizing a committee of experts for the particularly large adverse impacts)	In Chapter III, in the Law on Environmental Protection and Natural resource Management, 1996 provides; An environmental impact assessment shall be conducted on every project and activity of the private or public, and shall be approved by the Ministry of Environment before being submitted to the Royal Government for decision. The nature and size of the proposed projects and/ or activities (proposed and existing) both private and public, that shall be subject an environmental impact assessment which shall be defined by sub-decree following a proposal of the Ministry of Environment.	No particular large gap in between.
2. Examination of Measures	1. Examination of the multiple alternatives to avoid, minimize mitigate of the impact.) 2. Preparation of appropriate follow up plans and systems such as monitoring plans and environmental management plans.	There is no particular description about alternatives in the Environmental Protection and Natural resource Management,1996, Sub-decree on Environmental Impact Assessment (EIA) Process 1999 and Declaration on General Guideline for conducting IEIA/EIA Reports 2009. Chapter7 of Anex1 in Declaration on General Guideline for conducting IEIA1/EIA Reports 2009. Includes EMP description including fund and organizational setup, methodologies and monitoring schedule.	Although contents of the study are similar in both policies, alternative should be provided for considering Master Plan and priority projects.
3. Scope of Impacts to Be Assessed	1. Impacts on human health and safety, as well as on the natural environment, transmitted through air, water, soil, waste, accidents, water usage, climate change, ecosystems, fauna and flora, including trans-boundary or global scale impacts. 2. Examining derivative, secondary, and cumulative impacts indivisible from the project.	The impacts on human health and safety, as well as on the natural environment which listed in the JICA guideline are generally covered even in the Cambodian system although those categories are slightly different. In the Annex1 in Declaration on General Guideline for conducting IEIA/EIA Reports 2009, required information in the report is described. Those are; Physical Resources: -Soil, Weather, Air quality, Hydrology Biological Resources; Forest, Fauna species, rarely species, endanger species and migration, Habitats, Biodiversity and ecology system, Wet land system Socio-economic Resources; Demography and settlement, Economic Status, Land use, Water use, Energy use, Infrastructure system, Education, Public health, Cultural heritages, historical buildings, ancient temples, pagodas, customs/traditions, ethnic minority or indigenous people, Tourism area There is no particular description related Examining derivative, secondary, and cumulative impacts indivisible from the project.	No particular large gap in between. Although principal ideas such as contents and timing of the environmental study are covered to meet the JICA guideline, SEA application is not described in Cambodian legislation. In the study, encourage relevant organization for the environmental and social consideration at early stage explaining SEA.

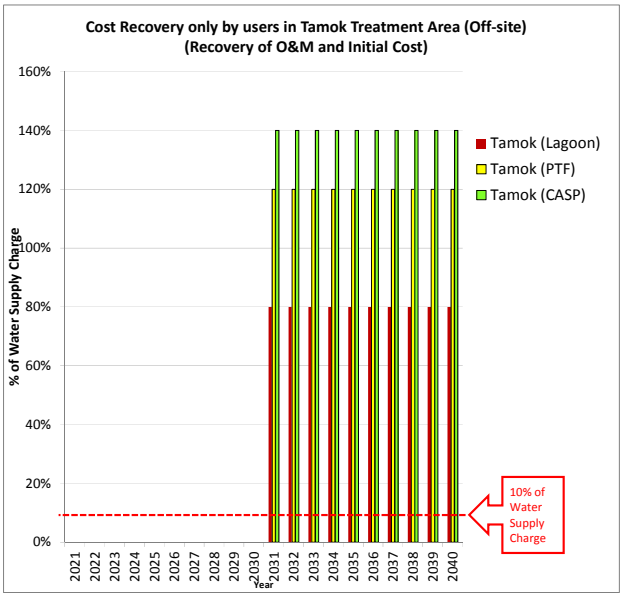
Items	JICA Guideline (Environmental and Social Considerations Required for Intended Projects)	Environmental Legislation in Cambodia	The measure to be held in the current project
4.Compliance with Laws, Standards, and Plans	1. Compliance with Laws, Standards, Policies and Plans. 2. Avoidance of the protected and conservation area of natural or cultural heritage designated by laws and ordinances.	In Protected Areas Law2008, All clearances and bulldozing within the open land or forestland in protected areas for the purposes of building all types of public infrastructures through the core zone and conservation zone shall be strictly prohibited. (Article 36) These activities can only be carried out in the sustainable use zone and community zone with approval from the Royal Government of Cambodia at the request of the Ministry of Environment. (Article 36) Also, in Article 44, To minimize adverse impacts on the environment and to ensure that management objectives of protected areas are satisfied, an Environmental and Social Impact Assessment shall be required on all proposals and investment for development within or adjacent to protected area boundary by the Ministry of Environment with the collaboration from relevant ministries and institutions. The procedures for Environmental and Social Impact Assessment for any projects or activities shall comply with provisions pertaining to the process of Environmental and Social Impact Assessment.	No particular large gap in between.
5. Social Acceptability	1. Adequate social coordination for their acceptance. In case of the large impact, sufficient consultation with local stakeholders via information disclosure at early stage to be incorporated into project plan.) 2. Consideration of the vulnerable people	Public participation is one of the important contents in the EIA report in Annex1 in Declaration on General Guideline for conducting IEIA1/EIA Reports, 2009.	No particular large gap in between.
6. Ecosystem and Biota	1. Avoidance of the degradation of the natural resource 2. Avoidance of the illegal logging	The information related to the impact to the biological features is described in the Declaration, Anex-1, as 4.1.2 Biological resources, (Forest: forest land area, forest species and forest classification, Fauna species, rarely species, endanger species and migration, habitats, Biodiversity and ecosystem, wetland system(attached with relevant maps).	No particular large gap in between.
7. Involuntary Resettlement	1. Avoidance and minimization of the involuntary resettlement 2. Sufficient compensation to PAPs with timely manner 3. Appropriate participation of PAPs throughout the planning, implementation and monitoring of the RAPs with the appropriate grievance mechanisms 4. At large scale involuntary resettlement, advance information disclosure to the PAPs should be made with the understandable way covering the elements in the World Bank Safeguard Policy, OP 4.12, Annex A.)	No particular description about avoidance and minimization of the resettlement in the EIA related legislations such as Law on Environmental Protection and Natural Resource Management 1996, Sub-decree on EIA Process 1999, Declaration on General Guideline for conducting IEIA/EIA Reports 2009. However, resettlement and the land acquisition process in the country is under development to be reinforced. The minimizing impacts (resettlement) are generally considered in the governmental project especially at project funded by the international donor as common practice.	No particular large gap in between. However, the living situation for resident in Cambodia are complicated especially in terms of land tenure/use right. Adequate study in later stage should be recommended.

Items	JICA Guideline (Environmental and Social Considerations Required for Intended Projects)	Environmental Legislation in Cambodia	The measure to be held in the current project
8. Indigenous Peoples	1. Avoidance and minimizing impacts to indigenous people 2. Respect for Indigenous people's right obtaining their consent in a process of free, prior and informed consultation 3. Adequate measure to the adverse impact for indigenous people as Indigenous Peoples Plan with understandable way covering the elements of the World Bank Safeguard Policy, OP4.10, Annex B.	Land tenure by community was described in the land law. Also, situation of the indigenous people is should be included in the EIA report as one of the items, "customs/traditions, ethnic minority or indigenous people", described in the Annex 1 in the Prakas (Declaration) on General Guideline for conducting IEIA1/EIA Reports 2009.	No particular large gap in between. However, the living situation for resident in Cambodia are complicated especially in terms of land tenure/use right. Adequate study in later stage should be recommended.
8. Monitoring	1. Adequate monitoring of the predicted mitigation measures and occurrence of unforeseeable situation. 2. Feasible monitoring plan at planning 3. Available monitoring process to local project stakeholders 4. Resolving problems through an occasion of the discussion and examination in public with the sufficient stakeholder's participation	There is no particular description for the implementing monitoring and detail public participation in Law and Sub-decrees. The monitoring plan is included in the requirement in environmental management plan in the Annex1 in Declaration on General Guideline for conducting IEIA1/EIA Reports 2009.	No particular large gap in between. Adequate study for developing monitoring works will be recommended.

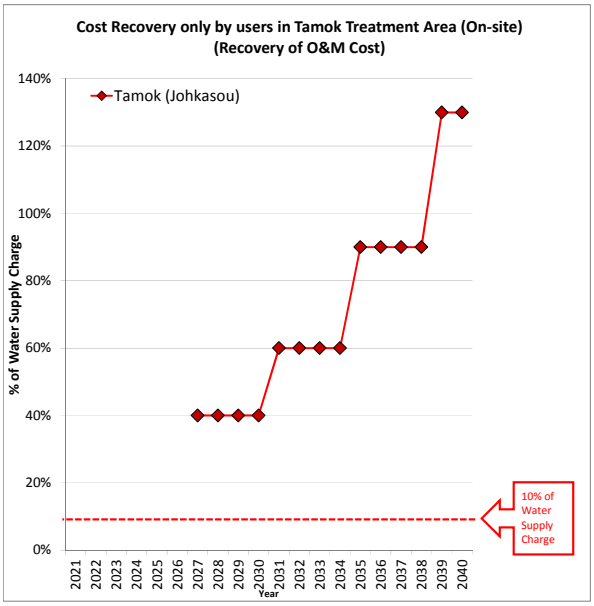
Source : JICA Study Team based on JICA Environmental and Social Consideration Guideline(2010), Preah Reach Kram/NS-PKM-1296/36, 1996, Law on Environmental Protection and Natural resource Management, 1996 (18 November 1996), No. 72 ANRK.BK, 1999, Anukret (Sub-decree) on Environmental Impact Assessment (EIA) Process (11 August 1999) and No. 376 BRK.BST, 2009 Prakas (Declaration) on General Guideline for conducting IEIA/EIA Reports,2009.

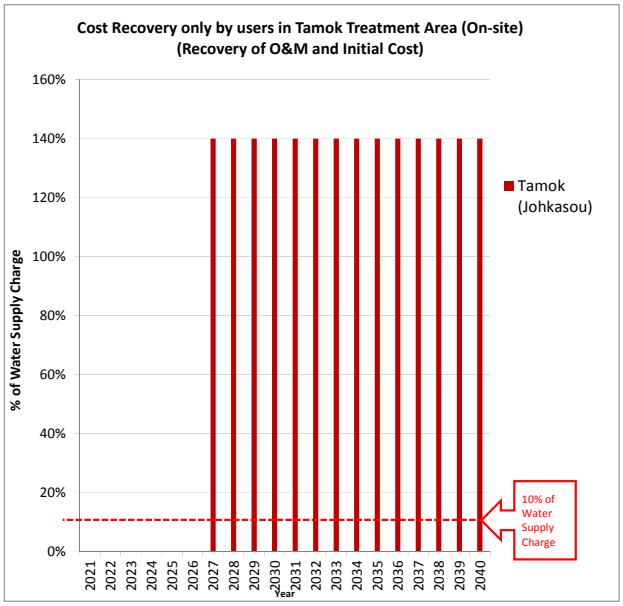
Appendix 2 Financial Analysis of Tamok Treatment Area to cover O&M and Construction Cost only by Tamok users





Analysis of Off-site Treatment





Analysis of On-site Treatment

Appendix 3 Analysis of Reduction of BOD Load (year 2015)

1. Population

	Area (ha)	2015
Cheung Aek	4,701.9	895,951
Tamok	6,019.2	341,175
Other area	57,124.9	615,074
Total	67,846.0	1,852,200

2. Sewage Generation Per Capita Per Day

[Cheung Aek and Tamok] L/capita/day

	Domestic	Commercial	Industial	Total	Generation rate	Generation
Daily average	107	64	7	178	85%	150
Daily max	118	71	7	196	85%	165
Hourly max	176	104	14	294	85%	250

[Other Area] L/capita/day

	Domestic	Commercial	Industial	Total	Generation rate	Generation
Daily average	74	44	5	123	80%	100
Daily max	81	49	5	135	80%	110
Hourly max	122	71	10	203	80%	165

3. Unit BOD Load and BOD Concentration of Industrial Wastewater discharged to Sewer

Unit BOD load from domestic and commercial use		
- Cheung Aek and Tamok	45	g/capita/day
- Other Area	32	g/capita/day
BOD concentration of industrial wastewater discharged to sewer	80	mg/L

4. BOD Load generation

	Population	Unit BOD load (g/capita/day)	BOD generaton from domestic and commercial use (kg/day)..(a)	Industrial wastewater generation (L/capita/day)	BOD of industrial wastewater (mg/L)	BOD generaton from domestic and industrial use (kg/day)..(b)	BOD generaton (kg/day) (=(a)+(b))	BOD generaton (t/day)
Cheung Aek	895,951	45	40,318	7	80	426	40,744	**40.7**
Tamok	341,175	45	15,353	7	80	162	15,515	**15.5**
Other area	615,074	32	19,682	5	80	197	19,879	**19.9**
Total	1,852,200		75,353			785	76,138	**76.1**

5. BOD Load after Treatment (Treatment by Present Sanitaly Facilities)

	BOD generaton (kg/day)..(c)	Removal rate (%)..(d)	BOD load after treatment (kg/day) (=(c)×(100-(d))/100))	BOD generaton (t/day)
Cheung Aek	40,744	20%	**32,595**	**32.6**
Tamok	15,515	20%	**12,412**	**12.4**
Other area	19,879	20%	**15,903**	**15.9**
Total	76,138		**60,910**	**60.9**

Appendix 4 Analysis of Reduction of BOD Load (year 2035)

1. Population

	Area (ha)	2035
Cheung Aek	4,701.9	1,093,155
Tamok	6,019.2	481,423
Other area	57,124.9	1,292,522
Total	67,846.0	2,867,100

2. Sewage Generation Per Capita Per Day

[Cheung Aek and Tamok] L/capita/day

	Domestic	Commercial	Industial	Total	Generation rate	Generation
Daily average	150	80	10	240	85%	205
Daily max	160	95	10	265	85%	225
Hourly max	240	140	20	400	85%	340

[Other Area] L/capita/day

	Domestic	Commercial	Industial	Total	Generation rate	Generation
Daily average	105	65	5	175	80%	140
Daily max	115	75	5	195	80%	160
Hourly max	175	110	10	295	80%	240

3. Sewage Generation (Daily average)

[Cheung Aek] m^3/day

	Sewage	Groundwater	Total	Rounded
Cheung Aek	224,097	35,264	259,361	260,000
Tamok	98,692	15,652	114,344	115,000
Other area	180,953	0	180,953	181,000

4. Unit BOD Load and BOD Concentration of Industrial Wastewater discharged to Sewer

Unit BOD load from domestic and commercial use		
- Cheung Aek and Tamok	45	g/capita/day
- Other Area	32	g/capita/day
BOD concentration of industrial wastewater discharged to sewer	80	mg/L

5. BOD Load generation

	Population	Unit BOD load (g/capita/day)	BOD generaton from domestic and commercial use (kg/day)..(a)	Industrial wastewater generation (L/capita/day)	BOD of industrial wastewater (mg/L)	BOD generaton from domestic and industrial use (kg/day)..(b)	BOD generaton (kg/day) (=(a)+(b))	BOD generaton (t/day)
Cheung Aek	1,093,155	45	49,192	10	80	743	49,935	**49.9**
Tamok	481,423	45	21,664	10	80	327	21,991	**22.0**
Other area	1,292,522	32	41,361	5	80	414	41,775	**41.9**
Total	2,867,100		112,217			1,484	113,701	**113.8**

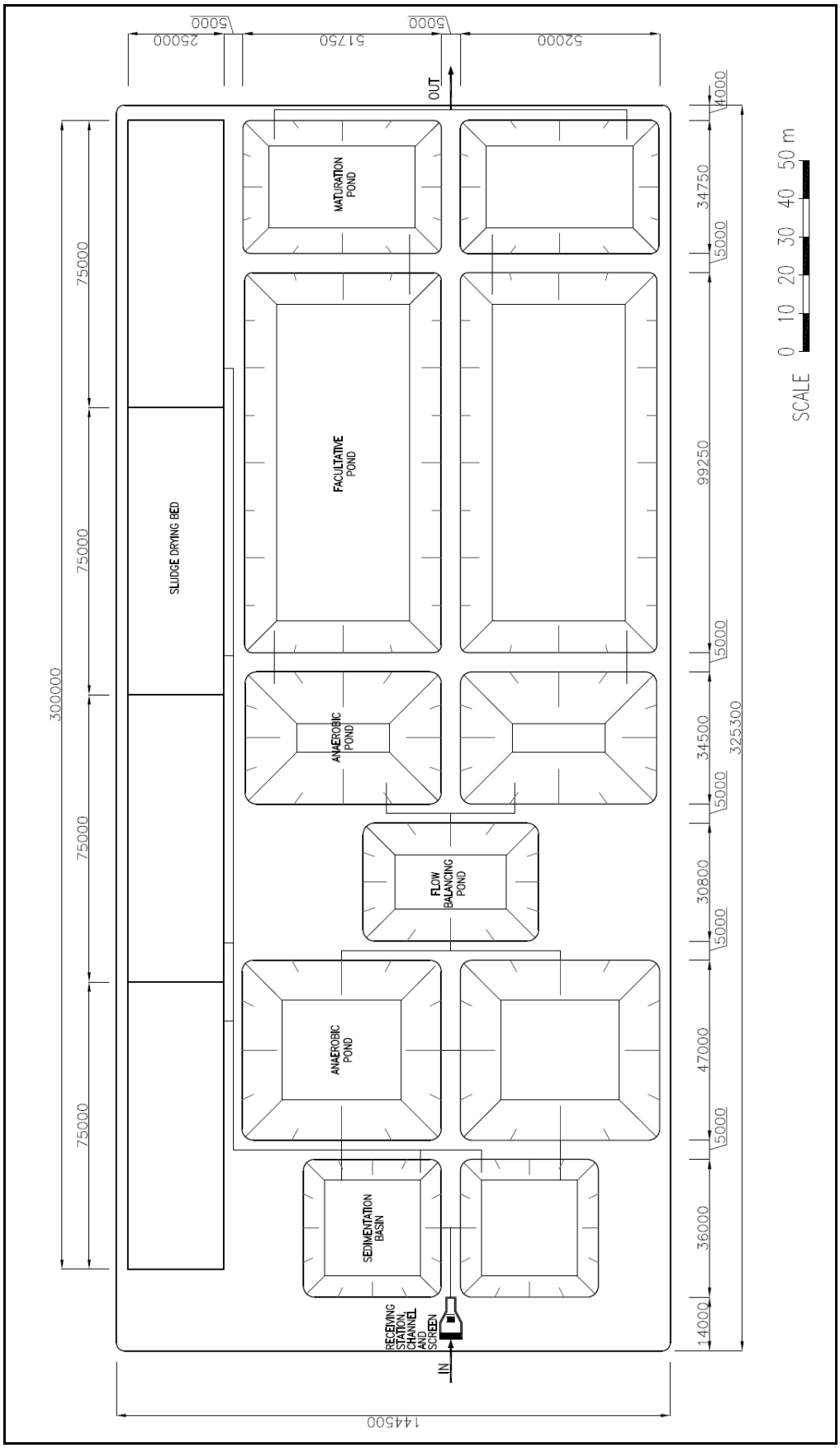
6. BOD Load without Project

	BOD generaton (kg/day)..(c)	Removal rate (%)..(d)	BOD load after treatment (kg/day) (=(c)×(100-(d))/100))	BOD generaton (t/day)
Cheung Aek	49,935	20%	39,948	**39.9**
Tamok	21,991	20%	17,593	**17.6**
Other area	41,775	20%	33,420	**33.5**
Total	113,701		90,961	**91.0**

7. BOD Load with Projects (Alternetive 1 = Alternative 2)

	BOD generaton (kg/day)..(c)	Inflow (m^3/day)	BOD in (mg/l)	BOD out (mg/l)	BOD load out (kg/day)	BOD generaton (t/day)	Remarks
Cheung Aek	49,935	260,000	192	30	7,800	**7.8**	
Tamok	21,991	115,000	191	30	3,450	**3.5**	
Other area	41,775	181,000	231	139	25,159	**25.2**	Removal rate 40%
Total	113,701				36,409	**36.5**	

Appendix 5 General Layout of Septage and Johkasou Sludge Treatment Facilities



Appendix 6 Scoping for Sewage Management Project at Master Plan Formulating Phase (May 2015)

Classification	No.	Items	Reason and Description	Rating
Social Environment	1	Involuntary resettlement	**Planning phase, Construction phase:** Some residents are living close to existing ditches in city area. At the improvement of the existing ditches, impact to the residents should be avoided and minimized based on the adequate survey for the existing ditches at planning. **Planning phase, Construction phase:** There are some raised floor structures in the Cheung Aek lake and people may be living there permanently or temporally. At the planning phase, impact to those residents such as resettlement and area of land acquisition, should be avoided and minimized. Cheung Aek lake and Tamok lake which is planned for the STP site, has been used for agriculture and domestic fishery. Some resident may lose their income source partly or fully. **Planning phase, Construction phase:** Construction of new pumping station may require additional land acquisition and sometimes associated with resettlement in city area. Also, expansion of the existing pumping station may affect the residents nearby without any consideration.	C-
	2	Local economy such as employment and livelihood, etc.	**Planning phase, Construction phase:** Some poor residents who live in the wetland may lose a part of their income source or may be resettled or lose land. In the case, supporting programs such as resettlement plan and rehabilitation plan will be required. **Construction phase:** The project is expected to increase working opportunity for construction.	C-
	3	Land use and utilization of local resources	**Planning phase, Construction phase:** Associated with the STP construction, water bodies/wet land where local people are using for agriculture and fishery will be reclaimed. Although the scale of the STP might not be large, less than approximately 36 ha, at the planning, the impact should be avoided and minimized. In case that resettlement is not fully avoidable, adequate compensation should be made based on the socio economic survey in the area.	B-
	4	Social institutions	**Planning phase, Construction phase:** there are many land development project reclaiming wetland to develop residential and/or industrial area. Associated with those developments, there are some problems in flood and land use. Adequate information disclosure by implementing agency to affected peoples may be required at actual planning phase.	B-
	5	Existing social infrastructures and services	**Construction phase:** Pipe network is planned under existing roads. Associated with the installation works, traffic jam may occur. In PPCC, many road improvement works are ongoing. The adequate coordination with the works is required to reduce impact.	B-
	6	The poor, indigenous and ethnic people	**Planning phase, Construction phase:** For selection of the STP, special consideration should be taken into to poor people in the wetland. There are some raised floor structures in the Cheung Aek lake and people may be living there permanently or temporally. Also, some residents are living close to existing ditches in city area. At the planning phase, impact to those residents such as resettlement and land acquisition, should be avoided and minimized.	B-
	7	Misdistribution of benefit and damage	**Planning phase:** Although project aims to contribute environmental improvement of the capital, some residents are living in the STP candidate site and along the existing ditches. Impact to the residents should be avoided and minimized, considering current situation based on the adequate survey at planning.	B-
	8	Historical and cultural heritage	No particular impact is identified at the moment.	D
	9	Local conflict of interests	**Planning phase:** there are many land development project reclaiming wetland to develop residential and/or industrial area. Associated with those developments, there are some problems in flood and land use. PPCC is now identifying land right. Some conflict on the land right may occur, if private land is involved in the project area.	B-
	10	Water usage or water rights and rights of common	No particular impact is identified at the moment.	D

Classification	No.	Items	Reason and Description	Rating
	11	Sanitation	**Operation phase:** The project is expected to improve current water environment condition..	A+
	12	Hazardous (risk) infectious diseases such as HIV/AIDS	**Operation phase:** After operation, the risk of the water-related disease is expected to be reduced, through the sewage and drainage improve projects.	A+
Natural Environment	13	Topography and geographic features	**Construction phase:** Some topographical modification associated with land filling in the wet land, may occur.	B-
	14	Groundwater	**Operation phase:** At the operation of the STP, water quality in ground water is expected to be improved.	A+
	15	Soil erosion	No large soil erosion is anticipated because the area is generally flat.	B-
	16	Hydrological situation	**Planning phase, Construction phase:** Project will be planed based on the current water flow and no large hydrological change is anticipated. No particular impact is identified at the moment.	B-
	17	Coastal zone	There is no coastal zone in project area.	D
	18	Fauna and flora and biodiversity	**Planning phase, Construction phase:** There is no legally protected area such as national parks, wildlife preserves, protected scenic view areas and multi-purposes areas in the project area. Cheung Aek lake and Tamok lake which is planned for the STP site are currently functioning as national wastewater treatment lagoon. Due to decline of the water quality, biodiversity will be poor. Also, those are used for agriculture and domestic fishery. **Operation phase:** Through the water quality improvement by the project, biological value of the lakes may increase.	B-/B+
	19	Meteorology	No particular impact is identified at the moment.	D
	20	Landscape	No particular impact is identified at the moment.	D
	21	Global warming	Candidate site for the STP is contributing as natural treatment pond in the watershed and the excessive global warming gas emission is not expected.	D
Pollution	22	Air pollution	**Construction phase:** Suspended dust and gas emission from the construction machinery is anticipated in limited area.	B-
	23	Water contamination	**Construction phase:** Associated with earthwork in the construction, turbidity of the water may temporarily increase at the downstream.	B-
	24	Soil contamination	**Construction phase:** Accidental spillage of toxic chemicals such as fuel, lubricants, and solvents may cause soil contamination.	B-
	25	Waste	**Construction phase:** During construction and operation, the project owner should properly handle waste (including sludge).	B-
	26	Noise and vibration	**Construction phase:** Noise pollution will be generated by the use of vehicles, stone crushing, and generators and so on.	B-
	27	Ground subsidence	Ground modification and ground water exploitation is not planned and no impact is anticipated.	D
	28	Offensive odor	**Construction phase:** Offensive odor may be generated due to disturbance of river bottom sediment by bed excavation and foundation works. **Operation phase:** Associated with the operation of STP, offensive odor at surrounding area may increase. The wetlands which are candidate site for STP, currently contributes as natural wastewater treatment lagoon in PPCC. The odor at the surrounding area of existing ditches and lagoon may be improved by the operation of STP.	B-/B+
	29	Bottom sediment	**Operation phase:** Bottom sedimentation at existing ditches will be improved through installing sewer pipe and operation of STP.	A+
	30	Accidents	**Construction phase:** Operation of heavy vehicles and machineries may cause traffic accidents of residents and labors in and around the project sites.	B-

Rating

A-: Serious impact is expected, if any measure is not implemented to the impact.

B-: Some impact is expected, if any measure is not implemented to the impact.

C-: Extent of impact is unknown (Examination is needed. Impact may become clear as study progresses.)

D: No impact is expected.

A+: Remarkable effect is expected due to the project implementation itself and environmental improvement caused by the project.

B+: Some effect is expected due to the project implementation itself and environmental improvement caused by the project.

Source: JICA Study Team

Appendix 7 Scoping for Drainage Management Project at Master Plan Formulating Phase (May 2015)

Classification	No.	Items	Reason and Description	Rating
Social Environment	1	Involuntary resettlement	**Planning phase, Construction phase:** Some residents are living close to existing ditches in city area. Approximately 900-1,000 households were identified in the project sites of drainage facilities. In improving the existing ditches, impact to the residents should be avoided and minimized based on the adequate survey for the existing ditches at planning. **Planning phase, Construction phase:** Construction of new pumping station may require additional land and resettlement in city area. Expansion of the existing pumping station may affect the residents nearby without any consideration.	C-
	2	Local economy such as employment and livelihood, etc.	**Planning phase, Construction phase:** Some residents who live in the marginal area such as wetland and ditch side may lose a part of their income source or may be resettled and lose the land. In the case, supporting programs such as resettlement plan and rehabilitation plan will be required. **Operation phase:** With the operation of drainage system, decrease of flood damage risks through the project improves local economy. **Planning phase, Construction phase:** At the construction, the project increases working opportunity.	C-/B+
	3	Land use and utilization of local resources	**Operation phase:** With the operation of drainage system, decrease of flood damage risks through the project, improves land-use.	B+
	4	Social institutions	**Planning phase, Construction phase:** there are many land development project reclaiming wetland to develop residential and/or industrial area. Associated with those developments, there are some problems in flood and land use. Adequate information disclosure by implementing agency to affected peoples may be required at actual planning phase.	
	5	Existing social infrastructures and services	**Construction phase:** Pipe network is planned under existing roads. Associated with the installation works, traffic jam may occur. **Planning phase:** In the capital, many road improvement works are ongoing. The adequate coordination with the works is required to reduce impact. **Operation phase:** With the operation of drainage system, traffic movement in rainy season may be improved.	B-/ B+
	6	The poor, indigenous and ethnic people	**Planning phase, Construction phase:** Some residents are living close to existing ditches in city area. At the planning phase, impact to those residents such as resettlement and land acquisition, should be avoided and minimized.	C-
	7	Misdistribution of benefit and damage	No particular impact is identified at the moment.	D
	8	Historical and cultural heritage	No particular impact is identified at the moment.	D
	9	Local conflict of interests	**Planning phase:** there are many land development project reclaiming wetland to develop residential and/or industrial area. Associated with those developments, there are some problems in flood and land use. PPCC is now identifying land right. Some conflict on the land right may occur, if private land is involved in the project area.	B-
	10	Water usage or water rights and rights of common	No particular impact is identified at the moment.	D
	11	Sanitation	**Operation phase:** The project is expected to improve current water environment condition.	A+
	12	Hazardous (risk) infectious diseases such as HIV/AIDS	**Operation phase:** After operation, the risk of the water-related disease is expected to be reduced, through the sewage and drainage improve projects.	A+
Natural Environment	13	Topography and geographic features	**Construction phase:** Some topographical modification associated with land filling in the wet land, may occur.	
	14	Groundwater	No particular impact is identified at the moment.	D
	15	Soil erosion	No large soil erosion is anticipated because the area is generally flat.	D
	16	Hydrological	Project will be planed based on the current water flow and no large hydrological	B-

Classification	No.	Items	Reason and Description	Rating
		situation	change is anticipated. No particular impact is identified at the moment.	
	17	Coastal zone	There is no coastal zone	D
	18	Fauna and flora and biodiversity	**Planning phase:** Associated with existing ditch improvement and regulation ponds improvement/construction, some cultivated aquatic plants and faming fish species may be affected. There is no legally protected area such as national parks, wildlife preserves, protected scenic view areas and multi-purposes areas in the project area. Most existing ditches and regulation ponds in the capital are highly polluted and affects habitat of wildlife. At the planning phase, the situation may be confirmed in the survey.	B-/B+
	19	Meteorology	No particular impact is identified at the moment.	D
	20	Landscape	No particular impact is identified at the moment.	D
	21	Global warming	No particular impact is identified at the moment.	D
Pollution	22	Air pollution	**Construction phase:** Suspended dust and gas emission from the construction machinery is anticipated in the limited area.	B-
	23	Water contamination	**Construction phase:** Associated with earthwork in the construction, turbidity of the water may temporarily increase at the downstream.	B-
	24	Soil contamination	**Construction phase:** Accidental spillage of toxic chemicals such as fuel, lubricants, and solvents may cause soil contamination.	B-
	25	Waste	**Construction phase:** During construction and operation, the project owner should properly handle waste (including sludge).	B-
	26	Noise and vibration	**Construction phase:** During construction, noise pollution will be generated by the use of vehicles, stone crushing, and generators and so on.	B-
	27	Ground subsidence	Ground modification and ground water exploitation is not planned and no impact is anticipated.	D
	28	Offensive odor	**Construction phase:** Offensive odor may be generated due to disturbance of river bottom sediment by bed excavation and foundation works	B-
	29	Bottom sediment	**Operation phase:** At the operation of existing ditches, improved water flow may reduce sedimentation.	B+
	30	Accidents	**Construction phase:** Operation of heavy vehicles and machineries may cause traffic accidents of residents and labors in and around the project sites.	B-

Rating

A-: Serious impact is expected, if any measure is not implemented to the impact.

B-: Some impact is expected, if any measure is not implemented to the impact.

C-: Extent of impact is unknown (Examination is needed. Impact may become clear as study progresses.)

D: No impact is expected.

A+: Remarkable effect is expected due to the project implementation itself and environmental improvement caused by the project.

B+: Some effect is expected due to the project implementation itself and environmental improvement caused by the project.

Source: JICA Study Team

Appendix 8 Memorandum of First Workshop

MEMORANDUM OF 1ST WORK SHOP
FOR
THE STUDY ON DRAINAGE AND SEWERAGE IMPROVEMENT PROJECT
IN PHNOM PENH METROPOLITAN AREA
IN KINGDOM OF CAMBODIA

This Work Shop was held on March 17, 2015 and chaired by H.E. Mr. Pa Socheatevong, Governor of Phnom Penh Capital City (PPCC), to present and share the progress of the Study, to have discussion on it in early stage of M/P, with attendants, consisting of stakeholders, donors as well as agencies concerned, as listed in the attachment. Results of discussion will be reflected in the M/P. The following are the major discussions.

1. H.E. Mr. Pa Socheatevong, Governor of PPCC, made opening remarks.

2. Mr. Uchida, Project Formulation Advisor, JICA Cambodia Office, made welcome address.

3. Mr. Hitoshi Shimokochi, Team Leader, Study Team, presented "Presentation for 1st Work Shop" which is comprised of results of basic study and strategy for formulating M/P.

4. Mr. Hem Sovinho, Board of Cambodian Engineering, pointed out that there is obligation to install septic tank in Cambodia but monitoring of septic tank installation is not functional. Strengthen of the monitoring is therefore essential in the stage of construction permit.

5. Mr. Phin Rady, Ministry of Environment (MOE), PPCC, asked that (i) water monitored at Kop Slov Pumping Station is drainage water or not, and (ii) how the Study Team project water use in 2035.
   The Study Team answered that (i) the water is taken from drainage open channel, and (ii) the Team projected the amount of water use, assuming annual growth rate of 1.0, 1.5 and 2.0 percent and also comparing the computed results with actual water use of the neighboring countries as well as Japan.

6. Mr. Chiek Ang, Director, Department of Environment (DOE), pointed out that (i) sewage management law should be formulated as fast as possible, (ii) the sewage management law should clearly stipulate the responsibilities of central and provincial revels, and (iii) capacity development for DOE should be included.

7. Mr. Vong Pisith, Deputy General Manager, Ministry of Public Works and transport (MPWT), emphasized the importance of set-up and enforcement of legal and institutional framework, as well as responsibility of agencies concerned for sewage management, and capacity development for personnel of national and provincial level. He requested the Study Team to include the difference between central and provincial governments in responsibilities for sewage management.

8. Mr. Va Sothea, Director, Department of Economy and Finance, requested topographical condition and flow direction and velocity of surface water in PPCC.
   The Study Team answered that topographical condition (distribution of elevation in PPCC) and vector of surface water is illustrated in Progress Report 1.

1

9. Mr. Eak Khum Moeun, Governor of Khan Tuol Kok, pointed out that drainage in Tuol Kok relied on the existing three drainage channels (Salang Drainage Channel, Open Channel of Tuol Kok Pumping Station 1 and Tuol Kok Pumping Station 2) and asked whether the drainage improvement M/P is formulated considering the three drainage channels.
The Study Team answered that the drainage improvement M/P is formulated considering the channels.

10. Mr. Sam Piseth, Director, Department of Public Works and Transport (DPWT), PPCC, made the following comments:

    (1) Drainage improvement plan in Tuol Kok should be carefully formulated in consideration with the existing drainage channel network.

    (2) At the construction permission stage, requirements for installation of septic tanks are to be clarified.

    (3) Installation of Johkasou is one of good option in households in luxury area, considering the price ranging from about 2,000 USD to 3,000 USD per one unit.

    (4) At present, the Study is in the initial stage of formulation of M/P; therefore, further discussion will be required.

11. H.E. Mr. Pa Sochatevong made closing remarks with the following comments and requests.

    (1) The M/P is not completed and thus more discussion will be required to finalize it.

    (2) Urbanization in the area such as Wat Punom North and Kop Srov Dike and deforestation in the surrounding area of city center, results in facilitation of stormwater runoff (due to increase in flow velocity). Drainage improvement will be required in the above areas.

    (3) Rainfall of 30 to 40 mm/hr is acceptable considering the capacity of drainage network in Phnom Penh. However, rainfall of 70 to 80 mm/hr in general exceeds the capacity. In the city center, inundation decreases due to the implementation of drainage improvement projects granted by the Government of Japan.

    (4) In Toul Kok area, filling up drainage channel becomes issue

    (5) Technical staff in PPCC should study more about drainage and sewage management.

    (6) We, people of Phnom Penh, should not sit still until the completion of M/P, but we have to start and make effort to address drainage issues by self-help such as excavating sludge accumulated in the drainage channels.

    (7) It is essential to strengthen capacity of land management office and departments concerned in order to control land-use in Phnom Penh. Keeping records of reclamation and land development is the first step to control them.

(End)

Appendix 9 Memorandum of Second Workshop

MEMORANDUM OF 2ND WORKSHOP
FOR
THE STUDY ON DRAINAGE AND SEWERAGE IMPROVEMENT PROJECT
IN PHNOM PENH METROPOLITAN AREA
IN KINGDOM OF CAMBODIA

This Workshop was held on November 19, 2015, chaired by H.E. Ieng Aunny, Vice Governor of Phnom Penh Capital City (PPCC), to present and share the progress of the Study, including draft Master Plan (M/P) and priority projects for Pre-Feasibility Study (Pre-F/S) and the experiences of wastewater management in Kitakyushu City, and to have discussion on it with attendants, consisting of stakeholders, donors as well as agencies concerned, as listed in the attachment. Results of discussion will be reflected in the Draft Final Report (DF/R). The followings are the major discussions.

1. H.E. Ieng Aunny, Vice Governor of PPCC, made opening remarks and explained objectives of the Workshop.

2. Mr. Keiji Sasabe, CEO of CTI Engineering International Co., Ltd. and Co-Team Leader of the Study Team, made opening remarks.

3. Mr. Migifumi Jinno, Director of International Project Division, Water and Sewer Bureau, City of Kitakyushu, presented "City of Kitakyushu's Experience on Wastewater Management".

4. Mr. Hitoshi Shimokochi, Team Leader of the Study Team, presented "Presentation for 2nd Workshop" which outlines draft sewage management M/P and priority project for Pre-F/S.

   Mr. Tsuyoshi Matsushita, Drainage Planning of the Study Team, presented draft drainage management M/P and priority project for Pre-F/S.

5. H.E. Ieng Aunny, emphasized as follows.
   The condition of Kitakyushu city of 50 years ago is similar to current condition of Phnom Penh. We can learn many things from experiences of Kitakyushu City. Environmental-friendly living condition is the most important issue for the people. PPCC has to pay more attention to this issue.

6. Mr. Chou Kimtry, Deputy Director of Department of Public Works and Transport (DPWT), PPCC, commented as follows.
   (1) Treatment efficiencies of each wastewater treatment method such as BOD, COD, TSS, etc. should be provided.
   (2) Treatment method should be selected in consideration with technical and economic views.
   (3) It is necessary to confirm the land owner of the proposed sites of treatment plant, pumping station and other facilities.

7. Mr. Puth Sorithy, Director of Department of Water Quality Management, Ministry of Environment (MOE), commented as follows.
   (1) MOE has already established a new division for wastewater management, especially for regulating water quality. To set-up the new institution, we need to collaborate with PPCC. MOE is ready to work with the Study Team and PPCC.

1

(2) There is a mistake in organization chart of MOE in page 283 in the Progress Report 2 (P/R2). I provide the correct one and request the Study Team to replace it.

8. Mr. Ly Saveth, Governor of Khan Sen Sok, PPCC, commented as follows.
   (1) Wastewater from industrial area in Khan Po Senchey flows into drainage channels in Sen Sok Area, which is drained to Tamok Lake. How did you set a boundary of Tamok treatment area?
   (2) Speed of urban development is too fast and population grows rapidly. Latest analysis data should be used in the Study.
   (3) We should learn from the experiences on sewerage management in Kitakyushu City. Flood damage became smaller than that of 10 years before, because some drainage improvement projects have been implemented. However, I feel that environmental pollution has become serious, especially in Tamok Lake basin.

9. Mr. Hitoshi Shimokochi, answered as follows.
   (1) Boundary of treatment area has set considering geologic and topographic analysis, as well as land-use plan.
   (2) We collected latest data and land use plan of Phnom Penh and performed analysis in the M/P.

10. Mr. Nouv Saroeurn, DPWT/PPCC, commented as follows.
   (1) We see the improvement of flooding. However, we still have inundation in the rainy season. We request JICA to provide more projects in all areas.
   (2) Capacity development for the staff is very important.

11. Mr. XXX, Private Sector, commented as follows.
   (1) Wastewater management is very important,
   (2) We need to place priority on improving living condition of the people.

12. Mr. Keiji Sasabe, CEO of CTI Engineering International Co., Ltd. and Co-Team Leader of the Study Team, commented as follows.
   (1) The Comments, opinions and suggestions from this Workshop will be reflected in the DF/R of this study.
   (2) Most important things are the participation of the stakeholders and the people.

13. H.E. Ieng Aunny, made closing remarks with the following comments and requests.
   (1) To manage drainage and sewerage system in PPCC is a big challenge. This M/P has significant impact for the future of Phnom Penh. In addition, the M/P should be realistic and sustainable
   (2) Implementation of the project after approval of the M/P is also important.

(End)

Appendix 10 Memorandum of Third Workshop

MEMORANDUM OF 3RD WORKSHOP
FOR
THE STUDY ON DRAINAGE AND SEWERAGE IMPROVEMENT PROJECT
IN PHNOM PENH METROPOLITAN AREA
IN KINGDOM OF CAMBODIA

This Workshop was held on September 15, 2016, chaired by H.E. Ieng Aunny, Vice Governor of Phnom Penh Capital City (PPCC), to present and share the progress of the Study, including draft Master Plan (M/P) and result of Pre-Feasibility Study (Pre-F/S), and to have discussion on it with attendants, consisting of stakeholders, donors as well as agencies concerned, as listed in the attachment. Results of discussion will be reflected in the Final Report (F/R). The followings are the major discussions.

1. Mr. Uchida, Project Formulation Advisor, JICA Cambodia Office, made welcome address.
2. H.E. Ieng Aunny, Vice Governor of PPCC, made opening remarks and explained objectives of the Workshop.
3. Mr. Hitoshi Shimokochi, Team Leader of the Study Team, presented "Presentation for Draft Final Report" which outlines draft sewage and drainage management M/P and study result of Pre-F/S.
4. Mr. Sok Chhay, ITC, commented as follows.
   (1) How did you select the construction site of proposed Cheung Aek Sewage Treatment Plant (STP)? Are there alternate sites?
   (2) How do you collect wastewater by applying combined sewer?
5. Mr. Cheam Phanin, Engineer, Urban Planner, Urbanization Direction of PPCH, commented as follows.
   (1) Impact of climate change affects amount of water use and wastewater discharged in the future.
   (2) Due to the construction of buildings, many swamps are reclaimed and alternative site for water reservoir decreases. Increase of pavement in urban area affects urban planning in terms of drainage management, preventing stormwater from infiltrating into underground in PPCC.
6. Mr. Meas Virya, ING Holding (Developer), commented as follows.
   (1) How did you project population and estimate design flow to Cheung Aek STP?
   (2) Disposal of sludge generated from STP is important. What is the expected quantity of sludge generated in Cheung Aek STP. How big is the area of proposed sludge disposal site?
7. Mr. Hiek Chan Leang, Khan. 7 Makara, commented as follows.
   (1) How do you plan water reservoir in Chbar Ampov to prevent flooding since there is no master plan yet in the area.
   (2) We request the M/P is shared as fast as possible because it is easy to control people not to live in the proposed facilities' site. Once the people live in the site, it is not easy to relocate them.
8. Mr. Chou Kimtry, DPWT/PPCC, commented as follows.
   (1) The Study Team selected on-site treatment (Johkasou) in Tamok treatment area. It is important to cultivate people's incentive to install them in their houses because some people may be unwilling to install Johkasou in their houses.
   (2) To show size and location of drainage facilities such as main canal proposed in the M/P, is important for future sound development in PPCC.

1

9. Mr. Hitoshi Shimokochi, answered the questions.
   (1) Construction site of Cheung Aek STP is selected based on the candidate sites (Trabek Lake, Tumpun Lake and Cheung Aek Lake) proposed by PPCC. Out of the three candidates, Trabek and Tumpun Lakes were to be preserved in the previous M/P in 1999 and boundary of Cheung Aek Lake is clear. Therefore, Cheung Aek Lake is selected as the construction site of the STP.
   (2) Trunk sewer in combined system is designed to intercept wastewater and to directly discharge stormwater to the open channels by the weir in the manholes of interceptor.
   (3) In the M/P, population in each treatment area was determined, based on planning population for year 2035 projected in "The Project for Comprehensive Urban Transport Plan in Phnom Penh Capital City, JICA.
   (4) Proposed sludge disposal site for the ultimate stage is 35 ha.
   (5) The Study Team understands the concern that some people may be unwilling to install Johkasou in their individual houses. Therefore, the Study Team proposed two types of Johkasou, namely, individual and communal types. Installation of communal type Johkasou is preferable in the area where people are unwilling to install individual type.
   (6) The Study Team plans to insert drawings to show size and location of drainage channels in the Supporting Report.
   (7) In the development area, the developer should be responsible for solid waste dumping and drainage facilities installation in the area.

10. Mr. Chan Ratha, Peng Huot Real Estate Company, commented as follows.
   (1) Decentralized sewage treatment system is applicable especially in the bounded residential development area.

11. Mr. Moeung Sophan, DPWT/PPCC, commented as follows.
   (1) Please give coordinate for the proposed facilities, especially regulation pond, in the M/P to protect the proposed area. It cost a lot to buy back the land.
   (2) Is existing septic tank replaced, if Johkasou is installed?

12. Mr. Hitoshi Shimokochi, answered the questions.
   (1) Coordinates of proposed facilities in the M/P can be provided. Also, discussion with people around the proposed facilities' site is essential for smooth implementation.
   (2) Existing septic tanks are replaced when installing Johkasou. In the alternative study of on- and off-site treatment in Tamok area, the replacement cost of septic tanks is included in construction cost of Johkasou. Nevertheless, construction cost of on-site treatment applying Johkasou, is cheaper than that of off-site treatment.

13. Mr. Heng Nareth MOE, commented as follows.
   (1) At present, MOE completes preparation of draft sub-decree on management of drainage and sewage in collaboration with MPWT.
   (2) How is lifetime of the Johkasou? How often do we need to maintain Johkasou?
   (3) In alternative study in Tamok treatment area on (i) off-site applying Conventional Activated Sludge Process (CASP) and (ii) on-site applying Johkasou, which treatment method is lower in consideration with initial cost and cumulated annual O&M cost up to year 2040?

14. Mr. Hitoshi Shimokochi, answered the questions.
   (1) Lifetime of Johkasou is more than 50 years, based on experience in Japan.
   (2) Frequency of O&M of Johkasou is 1 to 2 times per year.

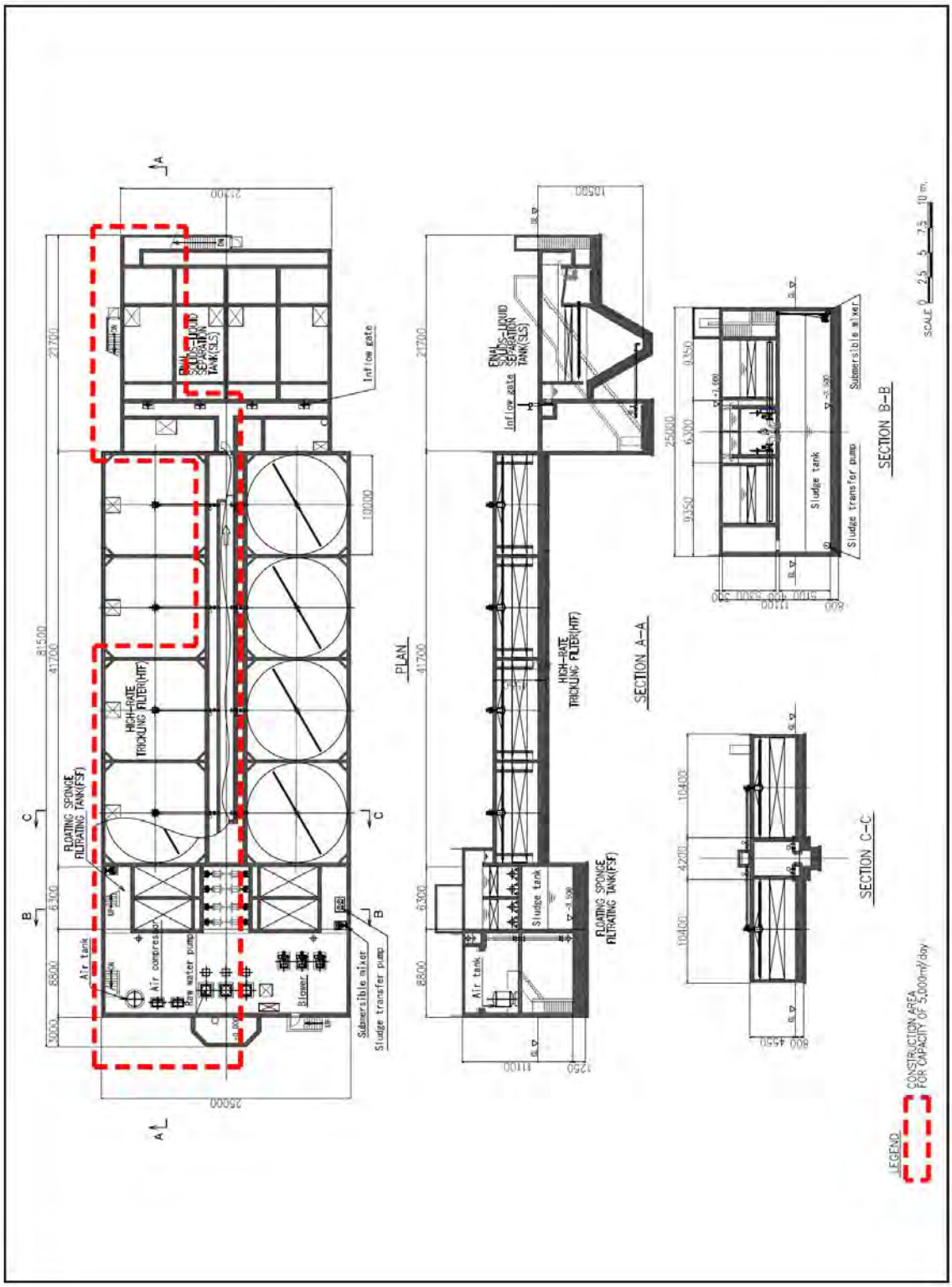
(3) Cost comparison of Tamok area, in terms of initial and cumulated annual O&M cost up to year 2040 in Tamok area, on-site (Johkasou) is lower than that of off-site (CASP) by 50 million USD.

15. H.E. Ieng Aunny made closing remarks with the following comments and requests.
    (1) To begin with, PPCC needs to establish technical and legal documents covering drainage and sewerage management to guarantee smooth implementation of the M/P.
    (2) To implement the M/P, development of technical and legal documents and guidelines, covering land-use, environment and garbage management, are also indispensable.
    (3) PPCC concerns about the condition of garbage dumping in drainage channels and prioritizes addressing the dumping step by step.
    (4) Decentralized sewage treatment system is applicable to such development area as Chubar Ampov, where sewage management in some areas is urgent need.
    (5) Control of land-use is essential to prevent people or developer from filling up the land, and not to cut and change direction of water flow, for preservation of land for installing proposed facilities and stormwater reservoir.
    (6) To decrease loopholes in land-use regulation is also indispensable.

(End)

Appendix 11 (Reference) Outline Drawing of PTF in Pre-F/S

Total amount of wastewater of 282,000 m^3/day is treated by 14 units. In this case, capacity of each unit is 20,200 m^3/day. The following drawing is for an unit of PTF (Capacity of 20,200 m^3/day). To obtain 5,000 m^3/day of capacity, the red hatched portion of facilities shall be constructed.



Outline Drawing of PTF (Capacity : 20,200 m^3/day)


JICA