Part II

Feasibility Studies on Reinforcement of Kop Srov and Tompun Dikes and Tompun Watershed Drainage Improvement

THE STUDY ON
DRAINAGE IMPROVEMENT AND FLOOD CONTROL
IN THE MUNICIPALITY OF PHNOM PENH

MAIN REPORT - PART II

FEASIBILITY STUDIES ON
REINFORCEMENT OF KOP SROV AND TOMPUN DIKES AND
TOMPUN WATERSHED DRAINAGE IMPROVEMENT

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

III. INTRODUCTION

In the Master Plan of drainage improvement and flood control in the Municipality of Phnom Penh formulated in Part I of this report, the proposed facilities have been packaged into eight components. Priority for the implementation of these component projects has been determined in the last part of Part I Master Plan Study, and the following projects have been selected as priority projects.

- Project A: Reinforcement of Kop Srov and Tompun Dikes
- Project B: Tompun Watershed Drainage Improvement

This part of the report compiles the results of the feasibility study on the above two priority projects.

All the planning conditions and basic strategies applied to the Master Plan are also applied for this feasibility study.

This part of the report composes the following contents:

(1) Chapter 1: Introduction

(2) Chapter 2: Present Conditions and Results of Basic Study comprise results of additional survey, investigation and studies for the priority project areas conducted in the feasibility study stage. The results of the additional study for the feasibility study have been basically reflected in the Master Plan, some of the study results are thus presented in Part I.

(3) Chapter 3: This chapter contains a major part of the feasibility study, namely preliminary design, project formulation and project evaluation for the component project of Reinforcement of Kop Srov and Tompun Dikes.

(4) Chapter 4: This chapter contains a major part of the feasibility study, namely preliminary design, project formulation and project evaluation for the component project of Tompun Watershed Drainage Improvement.

(5) Chapter 5: Implementation schedule has been studied for the selected priority projects, and urgent project for early implementation has been identified.

(6) Chapter 6: Recommendations as a result of the feasibility study are presented in this chapter.

II2. PRESENT CONDITIONS AND RESULTS OF BASIC STUDIES

2.1 Socioeconomy

Present socioeconomic conditions of Cambodia, Phnom Penh City and the whole Study area have been given in Section 2.2 in Part I. In this context, descriptions in this Section focuses only on the feasibility study areas, meaning the areas protected by the two projects subject to the feasibility studies: Reinforcement of Kop Srov and Tompun Dikes, and Tompun Watershed Drainage Improvement.

Population in both areas is estimated based on the population by sub-districts. The following are the derived population in 1998:

- Northeast, Northwest and Middle Areas (protected by Reinforcement of Kop Srov and Tompun dikes) : 227,000 head
- Tompun Watershed (bettered by Tompun Watershed Drainage Improvement) : 269,000 head

The population in those sub-districts lying across the boundaries of affected areas are allocated in rough proportion to areas within and outside the affected areas. The proportion of the non-registered population is assumed to be 22 % of the registered population, based on the proportion estimated for Phnom Penh City. Tables II2-1 and II2-2 present a detail of the estimate of the population above.

2.2 Land Use and City Planning

2.2.1 Present Situation of Priority Projects Areas

Kop Srov Dike

The Kop Srov Dike limits the whole area of study towards the north; it goes from the Prek Phnov riverside village to the Kop Srov village, and then towards the South down to the National Road No. 4 at Tmat Pong village.

Human occupation on the dike is continuously growing. It is mostly a precarious, squatter-like kind of habitations, following the usual rural village development scheme, eventually blocking the possible area's urbanization; the dike road hence turns to be a servicing way more than a transit way as it should rather be. There nonetheless exists a small traffic activity along this road already.

The most important concentration of population along the dike is a village stretching along its southern side from km 2 to km 4. This place was chosen as a relocation site for displaced people about 1990. A second dike parallel to the main one, and a pumping station, were built for flood protection. A total of 520 wooden houses were originally built for relocated people, who were supposed to gain ownership of the land after 5 years of occupation. Actually, the lack of infrastructure and the remoteness of the area discouraged most of them and only about 20% of this original population remained after 5 years. Due to lack of maintenance and concern the inner dike broke and was not repaired.

The Svay Pak drainage sluiceway, a sub-component of Reinforcement of Kop Srov and Tompun Dikes, is located crossing NR No. 5 at 2.7 km south from the junction of Kop

Srov Dike and NR No. 5. Factories are located near the existing sluiceway, however, they will not be affected by the construction works.

Tompun Dike and Outer Surroundings

The Tompun dike also materializes the limit of our main area of study, towards the south from Dankouv village up to the southern end point of the city core, close to Kbal Thnol and to the Monivong Bridge. It also provides a natural route to get round the city. This dike was built at about the same time and the same way as the Kop Srov one. It is wider, from 15 to 20 meters wide. Built much closer to the city, in the objective of developing a new suburb, this dike has indeed favored a much more important development than the Kop Srov one has.

For about four years, the occupation of the direct surroundings of the dike has developed, with yet an increased speed in the last two years. It is now almost continuous, with dwellings on the east side and, towards the west, activity buildings which settlement required important land-filling. All along its length both sides of the dike itself are occupied by illicit habitations.

Tompun-Salang Watershed

This area is grouped into two parts which have a different history, structure and level of urbanization. The Boeng Salang area is a part of the core city. It represents its second big catchment area after Boeng Trabek, with a surface of 631 ha and a population of around 200 thousand people in 1998. The road network and urbanization is almost complete in this area, with mainly a dense residential urban type of occupation, except for the far southwestern zone that is still little structured.

On the contrary, the Boeng Tompun area is a very newly urbanized one. It could start to develop thanks to the dike built in the 1970s but actually important occupation of this zone really started only 4 or 5 years ago. It has risen rapidly to a population of more than 40,000 people. It has been developing first along and around the laterite roads, as scattered villages that progressively densify and take, in some places, an urban-like organization. However no coherent planning has been used to guide this development, which results in a very different organization than the fully planned one observed in the city core.

The map in Figure II2-1 illustrates the present state of urbanization of the Boeng Salang and Boeng Tompun areas.

2.2.2 Likely Evolution by 2010

Kop Srov Dike

We have pointed out the Kop Srov dike's natural situation as a part of a ring road to connect the major road axis toward the North (mainly Battambang, Siemreap and Kampong Cham provinces, Thailand and Laos) to those towards the south (Takeo, Prey Veng, Kampong Som provinces, and Vietnam). This ring road would avoid the transit through the city and instead favor the development of a "technical platform" and other activities in the vicinity of the airport. Concerning the area close to this dike, we have noted two main trends for development: small industrial or craftsmanship activities, and agriculture. Most of this region should stay devoted to agriculture, as it has been so far. In the eastern part of the area enclosed by the dike, an important urban growth already exists, which would be accelerated with the building of an east-west road across the Boeng Reachsey, as it has been projected by the BAU. Some light industries such as brick factories, relying on river transportation, already have started to enrich this region.

The Municipality of Phnom Penh already is studying a project of setting up a toll for trucks that will take this Second Ring Road (eastern part is Kop Srov Dike). More importantly, transiting through the city core could become completely forbidden during daytime, and submitted to a toll during the night.

Another project, developed at the MPP, needs to be mentioned here: it would extend the existing road running straight north from the Wat Phnom, to join the NR 5 above the right bend of the river, enclosing the Russey Keo waterfront. Regarding traffic, this road would ease circulation to and from the city and would be likely to receive an important traffic between the northern road and the close western suburbs, since it would provide another, straighter way to get round the city core than through the Kop Srov Dike.

Tompun Dike

On its east end, the Tompun dike makes a large bend towards the North, to join the Trabek dike limiting the city core; due to the width, state and disposition of both roads, the Boeng Tompun dike is not, as such, appropriate for an important transit round the city. Present condition of the road surface is very bad, and this is the other reason of less use of the road.

However, the stake is the closing of a new urban area, and together with its possible role as a transit road, the dike road already plays a major role for the servicing of this newly developing zone. The wetlands that stretch to the south are quite not exploited nor occupied so far, except for market gardener cultivation. The regular and important flooding restrains development in this area.

As well as the Kop Srov Dike in the north, the Tompun Dike is part of a privileged route for a ring road around the city of Phnom Penh; however it will likely more quickly play the role of an urban boulevard.

Besides the road, we must notice that the rehabilitation of the electrical power distribution network, following the observed progress of urbanization, includes in its planning a MT line around the Boeng Tompun Lake and the dike. From there, the network extends towards the different quickly developing zones in the south and in the west.

Tompun-Salang Watershed

In the Boeng Salang catchment area, the natural foreseeable evolution is the completion of the urbanization process, mainly in the southwestern zone that was not yet fully urbanized in the most recent years. At the same time, the density of population could be still increasing in many places, often with illicit and precarious habitations that lead to an over-density of population considering the current state of urban infrastructure.

As regards the Boeng Tompun area, its natural evolution in the near future is likely to carry on the present one, that is a fast, unregulated urban development. This trend can only be stimulated by the increased security and sanitary conditions that will result first from the rehabilitation of the dike, and then from the drainage improvement project.

Already many small roads go down from the surrounding dikes into the Boeng Tompun catchment. Land filling and building are actively going on along these roads and will probably naturally carry on, with or without regulation and infrastructure, towards a dense urban type of occupation.

The already rapid development of this area will obviously be enhanced and accelerated with the possible development of an activities zone to the west, between the project area and the southern corner of the airport.

The Boeng Salang area is especially the zone surrounding the retention basin and stretching westwards into the most external and least urbanized area in this part of the city. The area has focused attention and benefited from one of the most achieved integrated urban planning and rehabilitation project in the recent years.

Following the CNATUC law for urban planning, a sub-decree, prepared and submitted with the help of the BAU of Phnom Penh and already adopted by the government in 1997, takes over the full urban planning and restructuring of the Boeng Salang sector.

The Figure II2-2 illustrates the foreseeable future state of urbanization of the Boeng Salang and Boeng Tompun areas, under the hypotheses that:

- the Boeng Salang rehabilitation program could be funded and achieved, and
- the Boeng Tompun urban development could be monitored in a similar manner, as is mostly recommendable.

2.2.3 Consideration for Future Urban Planning

<u>Dikes</u>

Both dikes that are considered in this feasibility study will mark the limit between a rural landscape that can be valorized, and the inner side of the city (even though in the mid-term the Kop Srov area will keep a mostly agricultural vocation). We have underlined the importance of taking into account from now on the role of these dikes as transit roads. This role will certainly be compromised if the ongoing natural development continues, leaving a maximum road width of 10 to 15 meters at the top of the dike.

To avoid this and enable for the expected important role of these dikes in the mid-term, their necessary renovation should be taken as the occasion to transform their profile with the following principle. If the construction of the secondary road in the land-side is not realistic for urgent implementation in view of necessary cost, it is recommended to be considered in the mid-term urban planning of the city.

Urban Drains and Retention Basins

Considering the setting of all spaces where the presence of water plays a determinant role for drainage, preservation and then valorization of these water surfaces should be the leading idea of structure design.

Around the Boeng Tompun retention basin, for aesthetic, social, maintenance as well as management reasons, the area occupation plan should first of all make provision for a road around the boeng, as for the project already designed for Boeng Salang basin. The boeng waterfront setting should be organized, including this road, in order to control - that is, mostly, to prevent - human occupation in a close perimeter.

These profiles only aim at suggesting possible settings for the waterfront, whereas the appropriate section and profile for the canal itself are considered elsewhere. One reason for the slight topographic relief proposed, is the experience that people more willingly settle their dwellings on the downer edge of a small depression. The road elevation can also slightly increase the retention capacity in exceptional situations.

In any case, as far as possible it is wishful to reserve at stretch of at least 10 meters along the waterfront, for the needs of structure management, local servicing, etc. It is wise also to foresee the future will to develop a separate sewerage network, which would naturally need a main sewer along the open drain, and to already make provision for the necessary place.

2.2.4 Possible Impact of Priority Projects

Possible Emerging Projects

When **Kop Srov Dike** is rehabilitated, it will naturally become a major way of transit, bringing along all the kinds of activities that are usually attached to this type of road. Already a few isolated actions can be observed, where massive land filling is followed by the installation of small industries or craftsmanship, like textile workshops. It would certainly benefit from the proximity of an important road axis, and the availability of water during the rainy season.

Different surrounding areas also are concerned with the likely evolution of the dike and its usage. These are mainly:

- The loose residential strip which is developing west from the Russey Keo riverbanks and along the Boeng Poungpeay lake.
- The Northwest blue belt will most probably gain interest with the improved communications. Its necessary preservation will then become an issue for the Municipality of Phnom Penh.
- The Northern green belt, a still rural area stretching further towards the West and along the most important part of the dike. A trend towards urbanization will probably emerge and spread from along the dike, with the increased ease of communications, transportation as well as the improved security.

It is likely that the rehabilitation of the **Tompun Dike** will accelerate the ongoing development of industrial activities in its western area. The prolongation of the dike with a possible ring road westwards will obviously favor the existing project of creating a new urban zone with a high density of economic activities between this area and the airport. Besides that, it is also most wishful to plan the necessary rehabilitation of the Boeng Tompun pumping station, considering its primary importance and its present state of deterioration.

Concerning the inner-city part of the Tompun-Salang Watershed that is the Boeng Salang catchment, the trunk structures for drainage should urgently be constructed. We, then, must consider that the implementation of the ambitious urban rehabilitation project adopted by the government will bring the most appropriate structures together with a final level of urban development.

In contrary to the city core, problems were due to a lack of management of well-planned and structured urban zones. The Boeng Tompun area development has not been guided by any planning or preliminary works such as systematic land-filling; in this area different long-term development scenarios can be considered, that are not all mutually exclusive. It could as well happen that the improved drainage conditions and access roads raise interest towards this area, for private investors who would then consider developing here different kinds of economic activities, or maybe large real estate operations. If not carefully controlled many could be harmful to the environment and sustainable development of this area.

<u>Local Development Constraints</u>

For **Kop Srov Dike**, management of the dike is important. Forbidding whatever could lead to an alteration of the dike; this would primarily mean to regulate the occupation of the surroundings, keeping the necessary areas for servicing, management, etc.

Besides, the settlement of polluting industrial activities should be forbidden in this area. However they would benefit from the proximity of raw water resource, they would drastically suffer from the lack of infrastructure for evacuation of wastewater, and would hence bring on a high risk of environmental damage. Through the Prek Phnov, the Tonle Sap would quickly become polluted upstream from the main city water intake, endangering the whole city as well as the Tonle Sap lake during the 6 months per year when the stream is reversed.

Amongst the different parts of the main area of study which are related to the dike, special attention should be paid to the eastern zone, since an improvement of the dike will add itself to different projected roads to affect its socioeconomic development. We have pointed out the interest of this area for a residential development, but also the likely necessity to limit its urbanization to a "loose residential" type.

The Municipality should be aware that the ongoing creation of a new road towards Phnom Penh Thmey area and the airport, as well as the projected road behind the Russey Keo water banks, will result in creating a new folder and raise new drainage and sewerage issues. These issues are directly related to the state and use of Svay Pak drainage sluiceway. The rehabilitation of this sluiceway is recommended for urgent implementation under the present study.

Though the present situation and the mid-term vocation of the **Boeng Tompun Dike** are quite different, considering its development the same basic remarks apply, that has been done above for Kop Srov. Actually, it is likely that this road be first used as transit road but eventually become integrated in a more urban sector. This long-term vocation can be foreseen in the importance already taken by this road, nonetheless its very bad surface state, as an access to the many smaller roads servicing the area enclosed by the dike.

Tompun-Salang Watershed

Of the Tompun-Salang Watershed, concerning the core Boeng Salang area, due to its role in the drainage of an important part of the city core the Boeng Salang retention basin has to be preserved. We can consider the plans proposed by a global rehabilitation plan for this area adopted by the government.

While this example shows that rehabilitation can be undertaken with appropriate care given to the local population and squatters issues, for the Boeng Tompun area which is not yet as much developed, it will be wiser to monitor from now on the ongoing development. This monitoring should take as an objective a harmonious integration of the basin into its urban environment, with benefit to the quality of life as well as to the water management.

Nevertheless, already occupied land will have to be made available for the projected works; many property problems are to be expected at this stage, especially around the Stoeng Meanchey Canal where human occupation already is dense, and where many people consider themselves as legal owners of their land.

Some of the necessary land use management laws and regulations presently are under study; as long as they do not yet exist, the effective reservation or acquisition of these spaces will remain a very delicate problem that has to be treated on a case-by-case basis.

Land Use Management

The above considerations lead to recommend, in order to favor a secure, harmonious and sustainable development, that sufficient areas surrounding the main drainage structures be reserved as public property. The immediate settings may vary, but by any means it seems appropriate to reserve:

- About 30 meters width for the dikes, that is the emerged area, and possibly more for the whole structure, especially during the works period.
- About 10 meters width around the boeng, which contour will have to be clearly outlined, as well as on both sides of the Stoeng Meanchey canal.

Hence a preliminary work to be carried on as early as possible, would be to determine the exact area of realization of the projects, including the structure surroundings, and register them in the Master Plan as being "reserved areas" for the projects.

2.3 Meteorology and Hydrology

All the study results, together with necessary data, on meteorology and hydrology for the feasibility studies have already been compiled in Section 2.4 in Part I. Following are major hydrological requirements specifically for the feasibility studies:

(1) Design High Water Levels for the Reinforcement of Kop Srov and Tompun Dikes (30-year return period)

   (a) Along Kop Srov Dike : EL. 10.4 m
   (b) Along Tompun Dike : EL. 9.0 m
   (c) At Svay Pak Drainage Sluiceway : EL. 10.0 m

(2) Design Discharges for the Tompun Watershed Drainage Improvement (5-year return period)

   (a) Meanchey Drainage Main

      (i) Downstream Stretch : 75 m^3/sec *
      (ii) Middle Stretch : 15 m^3/sec
      (iii) Upstream Stretch : 11 m^3/sec

   (b) Samdach Monireth and Jawaharlal Nehru Drainage Mains

      (i) Samdach Monireth, Downstream Stretch : 44 m^3/sec
      (ii) Samdach Monireth, Upstream Stretch : 20 m^3/sec
      (iii) Jawaharlal Nehru : 8m^3/sec

   (c) Salang Drainage Main : 21 m^3/sec

   * For the hydrograph, refer to Figure I2-22.

2.4 Topography and Geology

2.4.1 Topographic Survey

The following table shows topographic survey conducted for the feasibility studies. The location map is shown in Figure II2-3.

Work Item	Location		Work Volume
(1) Cross-Sectioning and Profiling	(1)-a	Kop Srov Dike	10.5 (km)
	(1)-b	Tompun Dike	5.3
	(1)-c-i	Meanchey Channel	5.0
	(1)-c-ii	Salang Channel	1.1
	(1)-c-iii	Tompun Inlet Channel	1.02
	(1)-c-iv	Tompun Outlet Channel	0.43
	(1)-d-i	Samdach Monireth Road	3.1
	(1)-d-ii	Jawaharlal Nehru Road	1.16
	(1)-e	Sap River Front	1.07
	Total		**28.68**
(2) Sounding	(2)-a	Boeng Kak	6 (lines), 5.7 (km)
	(2)-b-i	Upper Boeng Trabek (North)	2 , 0.51
	(2)-b-ii	Lower Boeng Trabek (South)	3 , 1.06
	(2)-c	Boeng Salang	3 , 0.95
	(2)-d	Boeng Tompun	6 , 3.52
	Total		**20 , 11.74**
(3) Topographic Mapping	(3)-a	Tompun Pumping Station	5.5 (ha)
	(3)-b-i	Tum Nup Toel Sluiceway	1.0
	(3)-b-ii	Samdach Monireth & Salang Sluiceways	6.5
	(3)-b-iii	Svay Pak Sluiceway	0.4
	Total		**13.4**

2.4.2 Soil Mechanical Investigation

The soil mechanical investigation for the feasibility studies aims mainly at:

- Clarifying the subsoil strata and ground water levels;
- Measuring N-values by SPT to evaluate bearing capacities of subsoils for the design of proposed structures; and
- Taking soil samples for observation and the laboratory tests that exhibit the precise soil properties.

<u>Work Quantities</u>

Boring was made at 11 locations (with SPT) whilst test pitting at 19 locations, both along with soil sampling followed by the laboratory test. The location map of boring and test pitting is shown in Figure II2-4, and quantities of each investigation are summarized as below:

Quantities of Borings and Test Pits

Area	Boring	Test Pit
Kop Srov Dike	5 locations (BH 1 to BH 5)	9 locations (KT 1 to KT 9)
City Core Area	3 locations (BH 6, BH 9 & BH 11)	2 locations (MT 3 & MT 8)
Tompun Area	3 locations (BH 7, BH 8 & BH 10)	6 locations (MT 1, MT 2 & MT 4 to 7)
Borrow Area	-	2 locations (BT 1 at Udon & BT 2 at Basset)
Total	11 locations	19 locations

Soil Condition along Kop Srov Dike

Boring was performed at 5 locations from the Svay Pak Drainage Sluiceway site (BH 1) towards the west along Kop Srov Dike (BH 2 to BH 5). The results are summarized in the table below where findings through the test pitting and laboratory test are also reflected:

Summary of Soil Mechanics Investigation along Kop Srov Dike

Boring No.	Ground Level (EL. m)	Bearing Layer * (EL. m)	Ground-water Level (EL. m)	Soil Condition above the Bearing Layer					Remarks
				Classif-ication	N-value	W.L. (%)	W.P. (%)	W (%)	
BH 1	9.9	-16.6 Sandy clay	5.1	Clay	10-19	47-51	24-25	15-21	Upper 8m
				Sand	15-37	-	-	20-29	Lower 18.5m
BH 2	7.0	Lower than -8.5	6.5	Clay	2-24	34-55	17-26	26-52	Upper 13 m
				Clayey sand	17-26	24-26	12-13	14-17	Lower 2.5 m
BH 3	6.1	- 11.4 Sandy clay	5.4	Clay	7-26	30-65	18-24	19-28	17.5 m thick
BH 4	6.5	- 2.5 Sandy clay	4.2	Clay	10-29	31-50	14-17	18-21	9 m thick
BH 5	8.5	4.5 Sandy clay	7.5	Clay	7-24	41	16	20	4 m thick

* With N-values of over 30.

(1) Bearing Layer

The ground levels of the boreholes range, in random order, between EL. 6.1 m and EL. 9.9 m with groundwater levels of EL. 4.2 to 7.5 m. In spite of such surface configuration, the bearing layer, defined as a layer with N-values of over 30, lies in such a manner that it slopes down constantly from west to east. It appears on EL. 4.5 m (4 m deep from the ground) at BH 5 near the western edge of Kop Srov Dike, while EL. - 16.6 m (26.5 m deep from the ground) at BH 1 in front of the Tonle Sap River. The layer is unchangingly composed of sandy clay.

Proposed to be constructed in the area are Svay Pak Drainage Sluiceway, comprising 3 cells of box culverts (1.5 m wide and 2 m high), and Kop Srov Dike with heights of 3 to 4 m. No serious problems are expected from the appearance of the bearing layer mentioned above although the sluiceway will require foundation piles reaching the bearing layer with an approximate length of 20 m.

(2) Soil Condition above the Bearing Layer

The bearing layer is uniformly covered by a clay layer with thicknesses of 4 to 17.5 m provided that sand and clayey sand layers intrude between them at BH 1 and BH 2, respectively. The clay is commonly firm, over 10 of N-value in general, and of low to medium plasticity. This nature of the clay will allow shallow excavations without difficulties such as slop failure and hazardous seepage. However, this clay, almost pure clay, cannot apply to embankment material for Kop Srov Dike.

In stead, soils procured from the Udon and Basset borrow areas are considered for that purpose. The former borrow is approximately 30 km away from Kop Srov Dike through NR-5 (well paved in most stretch), and has supplied good quality of laterite for various projects. On the other hand, the latter borrow is within an about 15 km distance from the construction site, however the access roads are quite poor and the soil is too coarse for dike material. In this case, it is recommended that the embankment material for Kop Srov Dike be transported from the Udon borrow area.

Soil Condition in City Core Area

Three borings (BH 6, BH 9 and BH 11) were worked out in the City Core area. Likewise in the above Clause, the results are summarized as follows:

Summary of Soil Mechanics Investigation in City Core Area

Boring No.	Ground Level (EL. m)	Bearing Layer * (EL. m)	Ground-water Level (EL. m)	Soil Condition above the Bearing Layer					Remarks
				Classif-ication	N-value	W.L. (%)	W.P. (%)	W (%)	
BH 6	10.2	- 4.8 Sandy clay	5.0	Clay	3-31	29-45	11-20	20-26	15 m thick
BH 9	8.8	- 3.2 Clayey sand	4.8	Clay	4-10	34	14	20	Upper 4 m
				Sandy silt	9-44	23-24	15-17	22-26	Lower 8 m
BH 11	7.1	- 5.4 Sandy clay	5.6	Backfill	0	40	17	31	Upper 4.5 m
				Clay	10-43	27-44	14-16	15-18	Lower 8 m

* With N-values of over 30.

(1) Bearing Layer

The three boreholes dug in the City Core area are EL. 7.1 to 10.2 m in ground level, EL. 4.8 to 5.6 m in groundwater level, and EL. - 5.4 to - 3.2 m in bearing layer (say, 12 to 15 m deep from the ground surface). By location, there exists less difference in each item. The soil of the bearing layer is sandy clay and clayey sand, which composition is similar to along Kop Srov Dike.

Structures planned in the City Core area in conjunction with the feasibility studies are Samdach Monireth, Jawaharlal Nehru and Salang drainage mains, and associated three drainage sluiceways at the outlets of Samdach Monireth and Salang drainage mains and at Tum Nup Toek. Most remarkable among them is the construction of box culverts, Samdach Monireth and Jawaharlal Nehru drainage mains, both underneath streets of the same name. The box culverts will be laid on the formation approximately between EL. 1 m and EL. 3 m (about 6 to 7 m deep under the street surfaces). To support the structure safely, piles shall be driven down to the bearing layer, however the lengths are expected to be not more than 8 m.

(2) Soil Condition above the Bearing Layer

The bearing layer is overlain by a cohesive soil layer composed of clay, sandy silt and backfills with thickness of 12 to 15 m. The upper 3 to 4 m portion of the layer is relatively soft with N-values of 0 to 6, whilst the lower portion is firm with over 10 of

N-value. This soil condition may pose no serious issues for shallow excavation and dredging anticipated along Salang Drainage Main and at the Tum Nup Toek Drainage Sluiceway site. However, the construction of box culverts beneath Samdach Monireth and Jawaharlal Nehru streets, with 6 to 7 m excavation, should incorporate temporary retaining walls of steel sheet piles in view of the considerably high groundwater level and low plasticity of the soil as well as mitigation of traffic interruption during construction.

On the other hand, the excavated materials, cohesive soils with quite low plasticity, are unsuitable for embankment and even backfilling but small-scale ones. Borrow material shall be procured for such purpose.

<u>Soil Condition in Tompun Area</u>

In the Tompun area, three boreholes (BH 7, BH 8 and BH 10) were drilled to reveal the subsoil condition at the construction sites of Tompun Pumping Station and Regulation Pond as well as along Meanchey Drainage Main. The results are summarized in the following table:

Summary of Soil Mechanics Investigation in Tompun Area

Boring No.	Ground Level (EL. m)	Bearing Layer * (EL. m)	Ground-water Level (EL. m)	Soil Condition above the Bearing Layer					Remarks
				Classif-ication	N-value	W.L. (%)	W.P. (%)	W (%)	
BH 7	4.7	- 10.8 Sandy clay	2.5	Clay	9-12	37	11	-	Upper 4 m
				Clayey sand	6-32	28	12	-	Middle 3 m
				Clay	15-29	28-34	10-13	-	Lower 8.5 m
BH 8	5.0	- 9.5 Sandy clay	3.2	Silty clay	8-18	25	15	14	Upper 5 m
				Silty sand	14-42	26-44	11-15	14-22	Middle 7 m
				Clay	24-26	29	16	18	Lower 2.5 m
BH 10	5.5	Lower than - 21	3.3	Clayey sand	7-10	38	12	14	Upper 5 m
				Sandy clay	13-29	26	10	14	Upper middle 5 m
				Clayey sand	12-20	24	14	20	Lower middle 7 m
				Clay	16-32	34-40	16-17	19-20	Lower 9.5 m

* With N-values of over 30.

(1) Bearing Layer

The results of two borings executed near Tompun Dike (BH 7 and BH 8) are alike, showing ground levels of EL. 4.7 m and EL. 5.0 m, groundwater levels of EL. 2.5 m and EL. 3.2 m, and bearing layers (sandy clay) of EL. - 10.8 m and EL. - 9.5 m, respectively. Tompun Pumping Station is proposed to be constructed between BH 7 and BH 8. To ensure the stability of the station, bearing piles shall be driven under the structure with an approximate length of 10 m.

In contrast, no bearing layer was confirmed at BH 10 correspondent to the upstream end of Tompun Regulation Pond even after drilling down to EL. - 21 m. However, heavy structures are not considered around the location, so that the deepness of the bearing layer can be ignored in designing work.

(2) Soil Condition above the Bearing Layer

On top of the bearing layer, there lies a relatively soft subsoil with thickness of approximately 15 m or more. Its N-values are 10 to 20 as a whole. Different from the areas along Kop Srov and in City Core, the subsoil in the Tompun area is characterized by its alternating stratification comprising cohesive layers, such as clay, silty clay and sandy clay layers, and sand layers such as clayey sand and silty sand layers. The cohesive layers are comparatively firm, but of low plasticity likewise in the City Core area.

Despite such alternation of cohesive and sand layers, the upper 5 m subsoil is supposed to be cohesive and slightly firm, in most places, taking into account the test pit results as well. Only exception is at BH 10 where a clayey sand layer appears in the depth. Shallow excavation planned in the project may thus not encounter serious problems. However, the excavated material is recommended to be hauled to adequate spoil banks, not to be used for backfilling or embankment.

II3. REINFORCEMENT OF KOP SROV AND TOMPUN DIKES

3.1 General

3.1.1 Premises and Conditions

Project A: Reinforcement of Kop Srov and Tompun Dikes (correspondent to Component 2 and a part of Component 7 in the Master Plan), aims at flood protection for a major part of Phnom Penh City against a 30-year probability of floodwater level in the Tonle Mekong river system. All the premises and major conditions established in the Master Plan are still valid in this feasibility study.

3.1.2 Sub-components of the Project

The Project consists of the following four sub-components:

(a) Sub-component A1: Reinforcement of Kop Srov Dike with a length of 7.65 km

(b) Sub-component A2: Reinforcement of Tompun Dike with a length of 4.44 km

(c) Sub-component A3: Reconstruction of Svay Pak Drainage Sluiceway with a 3-lane box culvert of 1.5 m wide and 2.0 m high per each lane

(d) Sub-component A4: Preparation of Relocation Site and Spoil Area with a total area of 25 ha

Study will be made sub-component by sub-component. Facility layout for the Project is prepared in Figure II3-1.

3.2 Preliminary Design

3.2.1 Kop Srov Dike

<u>Preconditions</u>

Preconditions for the preliminary design for the reinforcement of the Kop Srov Dike are described hereunder.

(1) Design High Water Level

The design high water level along Kop Srov Dike has been set in the Master Plan at EL. 10.4 m. This value is derived from the 30-year return period floodwater level at Chaktomuk Station, EL. 10 m, adding the water level difference of 0.4 m between Chaktomuk and Kop Srov in the 1996 flood. This design high water level still hold in the present feasibility study.

(2) Design Dike Height

In the Master Plan, the design crest elevation of the dike is EL. 11.2 m constantly along the whole stretches (the design high water level, EL. 10.4 m, plus freeboard of 0.8 m to cope with wave setup). This is also valid in the succeeding study.

(3) Necessary Measures

From the standpoint of flood protection, measures necessary for the existing Kop Srov Dike are as follows:

(a) Heightening of the existing dike, whose crest elevation is EL. 10.1 m at the lowest portion, to confine the design high water level, EL. 10.4 m, throughout the dike stretch;

(b) Strengthening of the existing dike body that is damaged in many places by seepage, heavy traffic, etc.; and

(c) Pavement of the existing road surface for smooth operation of flood defense activity and easy maintenance of the dike.

<u>Stretch to be Reinforced</u>

The Master Plan suggested that Kop Srov Dike be reinforced in the extent of 9.0 km from the junction with NR-5. On the other hand, in-depth survey in the feasibility study stage revealed detailed topography, elevations and conditions of the existing dike. As a result, the reinforcement, comprising measures for either dike or road, is decided to be done by stretch in the manner shown in the following table:

Measures Applicable by Stretch

Section	Crest Height of Existing Dike	Possibility of Wave Setup (Necessity of Freeboard)	Condition of Existing Dike Body	Measures	
				For Dike	For Road
0+000 to 0+900 (900 m long)	EL. 10.5 to 10.7 m (higher than the design HWL EL. 10.4 m)	Not possible (another road in front of the stretch with a lot of houses and trees), then no freeboard required.	Few damaged portions exist.	Not to be constructed.	To be paved to connect the following section with NR-5.
0+900 to 7+650 (6,750 m long)	EL. 10.1 to 10.9 m (partly lower than the design HWL 10.4 m)	Possible (directly facing on a swamp area along the Prek Phnov), then a freeboard necessary.	Serious damage, such as piping holes, gullies, etc. found in many places.	To be constructed with a crest elevation of 11.2 m.	To be paved.
South from 7+650 (9,350 m long)	Above EL. 10.5 (higher than the design HWL EL. 10.4 m)	Not possible (new embankments for a temple and factories, in addition to old villages, located in front), requiring no freeboard.	No damage observed along the stretch.	Not to be constructed.	To be paved to connect the above section with NR-4.

Structure

(1) Dike Reinforcement

A dike will be provided on the outer side of the existing dike road in the section between Station 0+900 and 7+650 (6,750 m in length). This construction method of dike can achieve an about 10 % of cost reduction compared to full-width heightening of the existing dike road (refer to Subsection 3.3.4 in Part I), and moreover has the following advantages:

(a) To ensure seepage prevention by filling non-permeable soil on the riverside of the existing dike;

(b) To secure smooth construction by keeping dike construction area from the existing roadway; and

(c) To minimize evacuation of houses that are much more built on the inner side of the dike *.

* Number of existing houses along Kop Srov Dike is as follows:

Section	Number of Houses	
	Outer Side	Inner Side
0+000 to 0+900	66	36
0+900 to 2+000	30	26
2+000 to 4+000	3	178
4+000 to 6+000	2	7
6+000 to 7+650	19	42
7+650 to 9+000	0	0
Total	120	289
	409	

The dike is 3 m wide on its crest, and slopes down at 1:2 on both sides with sod facing. The material of diking will be of laterite, which is suitable to control seepage so that a land side berm proposed in the Master Plan can be left out.

(2) Road Pavement

The existing road surface will be paved between the junctions with NR-5 and NR-4 (17,000 m in length). The pavement is for the following purpose:

- Easy operation of flood defense and maintenance of the dike;
- Prevention of piping holes made by seepage of rainfall on the dike crest; and
- Protection of the dike body from heavy traffic.

Considering that the road may constitute in future a part of the proposed Outer Ring Road, cross-sectional design of the road should follow Cambodian National Road Standard, namely a carriageway of 7.0 m with 1.5 m shoulders on both sides.

As for the type of pavement, three alternatives are examined: (1) Light traffic asphalt pavement, (2) High quality asphalt pavement, and (3) concrete pavement. Structure of each is shown in Figure II3-2. As can be seen in the following table summarizing the study results on pavement type, most recommendable is the high quality asphalt in view of durability (in wide meaning), cost, easiness of construction and maintenance, then selected for the road pavement on Kop Srov and Tompun dikes:

Comparison on Pavement Type

Alternative	Construction Cost (US$ per m^2)	Assessment
(1) Light Traffic Asphalt Pavement	30	Most economical, but cannot bear heavy traffic expected in future. Not recommended.
(2) High Quality Asphalt Pavement	49	Reasonable cost, easy for construction and maintenance. Recommended.
(3) Concrete Pavement	70	Expensive, and difficult for construction and repairing work. Not recommended.

(3) Structural Features

The plan and standard cross-sections are shown in Figures II3-3 and II3-4, respectively.

3.2.2 Tompun Dike

Preconditions

Preconditions for the preliminary design for the reinforcement of the Tompun Dike are described hereunder.

(1) Design High Water Level

The design high water level along Tompun Dike has been set in the Master Plan at EL. 9.0 m. This value is derived from the 30-year return period floodwater level at Chaktomuk Station, EL. 10 m, deducting the water level difference of 1.0 m between Chaktomuk and Tompun in the 1996 flood. This design high water level hold in the present feasibility study.

(2) Design Dike Height

In the Master Plan, the design crest elevation of the dike is EL. 10.1 m constantly along the whole stretches (the design high water level, EL. 9.0 m, plus freeboard of 1.1 m to cope with wave setup). This is also valid in the succeeding study.

(3) Necessary Measures

The crown elevation of Tompun Dike ranges from EL. 10.0 m to 10.4 m, while the design dike elevation being EL. 10.1 m. No heightening is hence required and necessary measures for the 4.44 km stretch of Tompun Dike are as follows:

(a) Strengthening of the existing dike that is damaged in some places by seepage and traffic; and

(b) Pavement of the existing road surface for easy operation of flood defense and maintenance of the dike.

Structure

(1) Dike Reinforcement

Field reconnaissance in the feasibility study stage has identified existing conditions of Tompun Dike and damage incurred by the 1996 flood. The results are summarized as follows:

(a) The existing dike is 20 m and 40 m wide on its crest and foundation, respectively. The maximal water head difference between the outer and inner sides of the dike at 5 m (design high water level EL. 9 m minus the inner ground level EL. 4 m). Accordingly, the gradient of seepage water surface is 1:8, which is no steeper than even the design values applying to large rivers' dikes in foreign countries, e.g. Red River in Vietnam, Mississippi in USA, etc. This infers that piping through the dike body due to floodwater may hardly occur even at the high water stage.

(b) Seepage damage during the 1996 flood was reported in some places along Tompun Dike, however all are at the upper portion of the dike slope. Such damage may hence be attributed by rainfall leaking from the dike crest.

These considerations lead to the conclusion that:

(a) Provision of a land side berm proposed in the Master Plan is not so effective, and moreover this should bring about a huge number of house evacuation (more than 260 houses *); and

(b) Instead, pavement on the dike crest is recommended to prevent seepage from the crest to the slope surface.

* Number of existing houses along Tompun Dike is as follows:

Section	Number of Houses	
	Outer Side	Inner Side
0+900 to 2+000	159	133
2+000 to 3+000	92	60
3+000 to 4+000	92	54
4+000 to 5+300	91	16
Total	434	263
	697	

(2) Road Pavement

The existing road surface will be paved for the whole stretch of Tompun Dike with a length of 4.44 km. The pavement is for the following purpose:

- Easy operation of flood defense and maintenance of the dike;
- Prevention of piping holes made by seepage of rainfall on the dike crest; and
- Protection of the dike body from heavy traffic.

Likewise with Kop Srov Dike road, considering that Tompun Dike road may constitute in future a part of the proposed Outer Ring Road, cross-sectional design of the road should follow Cambodian National Road Standard, namely a carriageway of 7.0 m with 1.5 m shoulders on both sides. The pavement is of the high quality asphalt type.

(3) Structural Features

The plan and standard cross-sections are shown in Figures II3-5 and II3-6, respectively.

3.2.3 Svay Pak Drainage Sluiceway

Preconditions

Preconditions for the preliminary design for the reconstruction of Svay Pak Drainage Sluiceway are described hereunder.

(1) Purpose of Reconstruction

There exists a sluiceway passing under NR-5 about 2 km southward from the intersection to Kop Srov Dike. The sluiceway was constructed and managed by Department of Agriculture, Forestry and Fishery, MPP with function of:

- To avoid floodwater from entering into the Northeast Area, causing serious inundation over the area; and
- To control the water stage of Boeng Poungpeay area for agricultural purpose.

The sluiceway is provided with wooden gates, which however has lost water-tightness because of lack of maintenance and repair. Moreover, the civil structure itself is heavily damaged in places. Once the gate structure should breach, the Northeast Area would be under floodwater. Taking into account such importance and the existing status, the sluiceway will be re-constructed under the Project.

(2) Design High Water Levels

The design high water levels outside and inside the sluiceway site are as follows:

- Outer side (Tonle Sap River side) : EL. 10.0 m
- Inner side (Boeng Poungpeay side) : EL. 7.0 m

Structure

(1) Cross-sectional Area

In the following considerations, the total cross-sectional area of the sluiceway is determined 1.5 m wide, 2.0 m high, 3 cells equaling 9.0 m^2 in total:

Study on the Cross-sectional Area of Svay Pak Drainage Sluiceway

Consideration	Total Cross-sectional Area Required
(a) To better the drainage function, the cross-sectional area is preferable to be 2 to 3 times the existing one *.	6.8 to 10.2 m^2
(b) To drain stored water in Boeng Poungpeay area in the rainy season when the gates are closed within 2 to 3 months, the total cross-sectional area is: 45,000,000 m^3 **/ (2 to 3 months) / 0.8 m/sec.	7.2 to 10.9 m^2
(c) To easily operate a gate in manual, the size should be less than 3 m^2 and to avoid land acquisition a 3-cell culvert is the limit.	Less than 9 m^2

* 1.2 m diameter, 3 cells, equal to 3.4 m^2 in total.
** Refer to Subsection 3.4.6 in Part I.

(2) Structural Features

The sluiceway is of the general type of RC gate structure with manually-operated steel slice gates. For details, refer to Figures II3-7 and II3-8.

(3) Construction Method

Cofferdams shall be provided upstream and downstream of the construction site with temporary drains. Further, relocation of NR-5 is necessary during the work, which may be shifted on the upstream cofferdam temporarily.

3.2.4 Relocation Site and Spoil Area

Land acquisition and house evacuation probably required for the implementation of the Project, estimated in this stage, are presented in Table II3-1 where those in alternative plans are also indicated for reference. No land acquisition is necessary for the construction of Sub-components A1 to A3, while house evacuation of 54 houses in the section from 0+900 to 7+650 of Kop Srov Dike. Suggested as one of the relocation sites for them is the narrow housing zone (25 ha) along a part of Kop Srov Dike which was once constructed under the assistance of UNBRO (refer to Figure II3-3).

The UNBRO area is on a low-lying land with elevations of around 6.0 m. The area has repeatedly been affected by local inundation because of the breakdown of the pump facility, so that less housing now remains in the area. The construction of Kop Srov Dike, on the other hand, will produce approximately 200,000 m^3 of excess soil. That soil can be used for raising the formation of the UNBRO area by about 1 m, then making the area free from inundation. In this regard, the UNBRO area, very close to Tompun Dike, is recommended as the spoil area for the construction.

Moreover, the raised UNBRO area can serve as the relocation site (entailing 5,400 m^2) for the 54 houses to be evacuated for the Project construction. The relocation site will be furnished with necessary infrastructures, such as roads, electricity, wells and sanitary facilities.

Finally, it is noted that right-of-way preparation and establishment of a reasonable relocation plan is an essential task of the Cambodian Government, which shall be settled prior to the actual implementation when the Government will request a foreign assistance for the Project.

3.3 Project Formulation

3.3.1 Features of Facilities

(1) Sub-component A1: Reinforcement of Kop Srov Dike

(a)	Stretch	:	7.65 km section southwestwards from the junction with NR-5 plus 9.35 km connecting road (see Figure II3-3)
(b)	Design High Water Level	:	EL. 10.4 m (30-year return period)
(c)	Design Dike Height	:	EL. 11.2 m (adding 0.8 m of freeboard)
(d)	Dike Structure	:	Earthfill dike with a 7 m wide asphalt-paved road (see Figure II3-4)

(2) Sub-component A2: Reinforcement of Tompun Dike

(a)	Stretch	:	4.44 km section between the junctions with the Inner Ring Dike and NR-303 (see Figure II3-5)
(b)	Design High Water Level	:	EL. 9.0 m (30-year return period)
(c)	Design Dike Height	:	EL. 10.1 m (adding 1.1 m of freeboard)
(d)	Dike Structure	:	7 m wide asphalt-paved road (see Figure II3-6)

(3) Sub-component A3: Svay Pak Drainage Sluiceway

(a)	Location	:	Existing Svay Pak Drainage Sluiceway (PK #9) site (see Figure II3-7)
(b)	Structure	:	3-lane box culvert, each 1.5 m wide and 2 m high with a steel-made slide gate (see Figure II3-8)

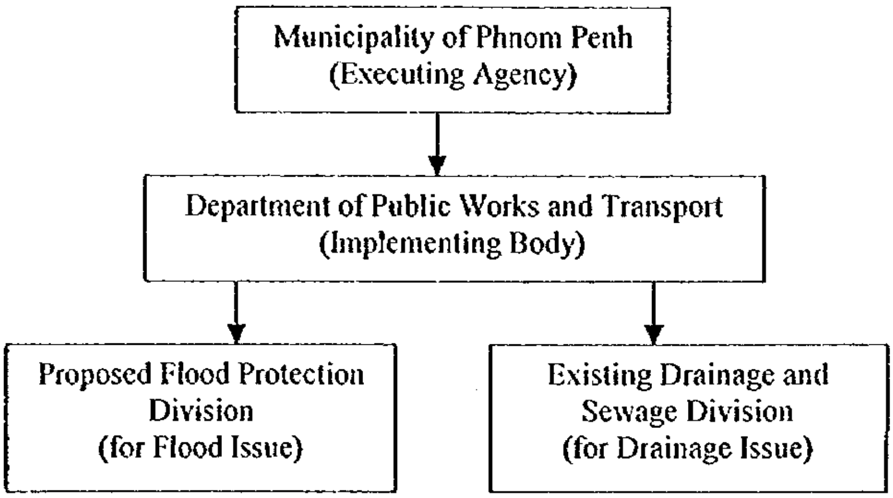
(4) Sub-component A4: Relocation Site and Spoil Area

(a)	Location	:	Existing UNBRO scheme beside Kop Srov Dike (see Figure II3-3)
(b)	Area	:	25 ha for spoil area within which 5,400 m^2 is used as the relocation site for the Project

3.3.2 O/M Plan

<u>Organization</u>

The study on organization and institution compiled in Subsection 3.7.1 in Part I has advised an organizational hierarchy (system) for the implementation of flood protection and drainage improvement projects in the Master Plan as follows:



The above system will also apply to the operation and maintenance stage. Specifically, the proposed Flood Protection Division will directly undertake the operation and maintenance of flood protection structures/facilities provided by the Project, Reinforcement of Kop Srov and Tompun Dikes as listed below:

- Earth dikes with sod facing;
- Asphalt-paved roads with laterite shoulders; and
- Three sluiceways including Svay Pak Drainage Sluiceway.

The operation and maintenance work can also be achieved by the number of staff proposed in Subsection 3.7.1 in Part I for the newly established Flood Protection Division, whereas they must be subject to capacity building program now going on and even to be enriched in future.

<u>Activities</u>

The activities of Flood Protection Division should incorporate the following items:

(1) Periodical Activity

(a) Daily patrol by staffs to confirm the condition of structures, facilities and the vicinities, just visually;

(b) Biweekly inspection by engineers and staffs to investigate the function, quality and shape of each structure or facility, deeply but still qualitatively; and

(c) Seasonal checkup (twice a year before and after the rainy season) by most members of Flood Protection Division to quantitatively measure the dimensions, quality, capacity and so on of each of the structures and facilities.

(2) Emergency Activity

(a) Flood defense activity in corporation with the headquarters and district offices of the Municipality of Phnom Penh and concerned ministries, including operation of the gate structures; and

(b) Other emergency activities in case of earthquake, fire and other accidents probably affecting flood protection structures and facilities.

Necessary Equipment and Materials

The operation and maintenance work for flood protection structures and facilities will require a variety of equipment and materials. However, the Department of Public Works and Transport has owned a number of equipment listed in Table 12-11, which may be sufficient for this purpose. The equipment shall be stored in two stockyards to be provided near Kop Srov and Tompun dikes, respectively. Minor materials, like cement, gravel, sand, sand bags, timbers, logs, ropes, etc., shall be kept in warehouses to be built at intervals of about 2 km along both dikes.

3.3.3 Project Cost and O/M Cost

Project Cost

The project cost for the Reinforcement of Kop Srov and Tompun Dikes amounts at approximately US$ 20.8 million as shown in Table II3-2. The breakdown by sub-component is presented in the following table:

Project Cost for the Reinforcement of Kop Srov and Tompun Dikes

Sub-component	Project Cost (US$ million)
A1: Reinforcement of Kop Srov Dike	15.9
A2: Reinforcement of Tompun Dike	3.2
A3: Reconstruction of Svay Pak Drainage Sluiceway	1.0
A4: Relocation Site and Spoil Area	0.7
Total	20.8

O/M Cost

The annual O/M cost for the Project is estimated as 0.3 % of the project cost taking account of the facilities installed.

3.3.4 Implementation Schedule

Table II3-3 shows the implementation schedule for the Reinforcement of Kop Srov and Tompun Dikes. The actual construction will initiate in 2001 and terminate in 2003 with a total construction period of 3 years. The year 2000 will be allocated for the basic and detailed design of the structures/facilities by a proper consulting firm, and land acquisition and house evacuation necessary for securing right-of-way for the construction which are a crucial task of the Municipality of Phnom Penh.

3.4 Project Evaluation

3.4.1 Economic Evaluation

Economic benefit estimated for Component 2 in the master plan are applied to the present Project, Reinforcement of Kop Srov and Tompun Dikes. That is US$ 6,506 thousand per year in 2010 and thereafter comprising both direct and indirect benefits. The economic benefit is assumed to growth at a rate of 7.2 % per year, the GRDP growth rate set in Clause "Socioeconomic Framework" of Subsection 4.1.1 in Part I, until 2010, the year in which a full scale benefit of the Project is reached.

Costs for economic analysis are estimated in the same way as for the Master Plan. Local currency portion of the investment cost is adjusted by a standard conversion factor at 0.85. The investment cost is allocated to each year according to the prepared disbursement schedule.

Table II3-4 shows streams of costs and benefits thus estimated. The following economic indices are derived:

Economic Indices for the Reinforcement of Kop Srov and Tompun Dikes

Indices	Reinforcement of Kop Srov and Tompun Dikes	Including Tompun Watershed Drainage Improvement
EIRR (%)	25.2	16.7
B/C	2.76	1.69
NPV (US$ thousand)	29,475	35,384

NPV : net present value

This Project is judged to have sufficiently high economic return with an EIRR higher than the opportunity cost of capital at 10 %. The Project is proved to be worth being promoted to the implementation stage.

3.4.2 Financial Affordability

A financial analysis for the Project is carried out from the viewpoint of cost recovery for Drainage and Sewerage Division (DSD) of Department of Public Works and Transport in the same way as for the Master Plan. Revenue of the proposed Flood Protection Division is considered included in those of DSD. Table II3-5 presents a comparison of DSD's expected revenue in 2008, in which the facilities start to serve and operation and maintenance cost needed for the priority projects. The expected revenue includes government budget allocation and revenue by wastewater surcharge estimated based on the same assumptions as for the Master Plan. The cost recovery target is set at the recovery of operation and maintenance cost on the premise that the investment cost be provided by government budget. The following summarizes the result:

Comparison of DSD's Revenue and O/M Cost

Item	Amount (US$ million)
Revenue by Government Budget in 2008	0.34
Wastewater Surcharge Revenue in 2008	1.41
Total Revenue in 2008	1.76
Total O/M Cost Required since 2008	0.32
Balance	1.40

As of 2008 when the facilities start operation, the DSD's revenue from government budget reaches the level slightly above the operation and maintenance cost. The Project is financially feasible from O/M cost recovery viewpoint. This aspect, however, should be closely monitored, paying due attention to the government effort and achievement in enhancing the government revenue and a progress in proportionately increasing allocation to line agencies and local governments.

3.4.3 Environmental Impact Assessment

Construction and operation of the proposed project may initiate both positive and negative impacts on the surrounding environment. The environmental impacts are assessed for both construction and operation periods.

Environmental Impact Assessment

Environmental impact assessment for ***physical resources*** is as follows: Flow disturbance during construction period for Kop Srov and Tompun dikes and especially for Svay Pak drainage sluiceway is anticipated as a low negative impact. In the operation period, hydrological condition will be improved with a new drainage sluiceway. Water quality during construction will be affected by addition of suspended solid from construction area; by wastewater from construction camp, site office and workshop; and by contamination of oil and lubricants from equipment. These effects can be minimized if proper measures are taken for construction work. No direct effect is anticipated in water quality during operation period, but water pollution caused by uncontrolled development derived by the completion of new asphalt road is worried.

Environmental impact assessment in ***human use resources*** is as follows: Kop Srov and Tompun dikes and Svay Pak drainage sluiceway will not basically and directly change the land use in the area during both construction and operation periods because all the works are within ROW. However, in the operation stage, land use in the neighboring areas will be changed due to the completion of new asphalt paved road. There will be negative impact in transportation. Traffic congestion and risk of accident; deterioration of road surface; increase in dust dispersion; and inconvenience for transportation will occur during construction, but these impacts can be minimized by proper measure. In the operation stage, Kop Srov and Tompun road's condition will be improved and contribute much in transportation sector. During construction there is no change in flooding condition, but after the completion, the effectiveness of the flood protection will be very high and high adverse impact can be expected.

Environmental impact assessment in ***quality of life values*** is as follows: As a socioeconomic aspect, relocation of the 54 families is needed for the construction of Kop Srov dike. Children (14% of evacuated family members) have to take a longer distance to school. Disturbance on communities by dust, noise and inconvenience in travelling will be anticipated at all the construction locations. However, quality of life for communities near Kop Srov and Tompun dikes will be improved much by the implementation ot the project. Compensation/resettlement include 54 families for the Kop Srov dike reinforcement.

Environmental Impact Mitigation Measures

Necessary measures to mitigate negative environmental impact will include: To implement necessary measures to alleviated the impacts on hydrology; to protect and maintain water quality during construction; to alleviate the impacts on transportation, to alleviate the nuisance or problems affecting the villagers; to prepare adequate measures for the people affected by the project and help in the process of relocation. For detail, refer to Supporting Report G.

Environmental Monitoring Plan

Monitoring is necessary to obtain necessary information related to environmental condition during both construction and operation stages. It will include water quality monitoring; land use monitoring in the neighboring areas along the Kop Srov and Tompun dikes during both construction and operation stages to prevent uncontrolled development; transportation monitoring to investigate traffic volume due to the project activities and after the completion of the project; and socioeconomic condition to perceive the people attitude towards the project.

3.4.4 Technical Evaluation

The construction for the Reinforcement of Kop Srov and Tompun Dikes requires the following structures:

Earth dikes with small heights, say 3 to 4 m, covered only with sod;
Asphalt pavement with laterite shoulders; and
Sluiceway composed of a 3-lane box culvert, each 1.5 m wide and 2.0 m high with a slide gate.

These structures are so simple that no technical difficulty can be encountered in designing, construction and even operation and maintenance of them. Noted here are only the following items:

(a) Soil for diking shall be transported from an adequate borrow area which can supply low permeability and high strength soil, e.g. Udon borrow area;

(b) Cofferdams and detouring of NR-5 for the construction of Svay Pak Drainage Sluiceway shall carefully be planned and operated; and

(c) Steel slide gates for the sluiceway shall be ones made in an advanced country in view of their importance.

II4. TOMPUN WATERSHED DRAINAGE IMPROVEMENT

4.1 General

4.1.1 Premises and Conditions

Project B: Tompun Watershed Drainage Improvement (corresponding to Component 3 in the Master Plan), is for the drainage improvement of Tompun Watershed (17.47 km^2), the western half of the populated area of Phnom Penh City, with a scale of a 5-year return period rainfall. All the premises and major conditions set forth in the Master Plan can hold even for this feasibility study.

4.1.2 Sub-components of the Project

The Project comprises the following 13 sub-components:

(a) Sub-component B1 : Construction of Tompun New Pumping Station and Inlet Channel with a capacity of 15 m^3/sec

(b) Sub-component B2 : Construction of Tompun Regulation Pond with a total area of 47.5 ha

(c) Sub-component B3 : Improvement of Meanchey Drainage Main, Downstream Stretch, from Tompun Regulation Pond to Meanchey Bridge with a length of 2.635 km

(d) Sub-component B4 : Improvement of Meanchey Drainage Main, Middle Stretch, from Meanchey Bridge to the junction with a branch with a length of 1.285 km

(e) Sub-component B5 : Improvement of Meanchey Drainage Main, Upstream Stretch, upstream from the junction with a length of 0.535 km

(f) Sub-component B6 : Construction of Tum Nup Toek Drainage Sluiceway with a capacity of 10 m^3/sec

(g) Sub-component B7 : Construction of Samdach Monireth Drainage Main, Downstream Stretch, between the junctions with Meanchey and Jawaharlal Nehru drainage mains with a length of 1.676 km

(h) Sub-component B8 : Construction of Samdach Monireth Drainage Main, Upstream Stretch, upstream from the junction with Jawaharlal Nehru Drainage Main with a length of 0.714 km

(i) Sub-component B9 : Construction of Jawaharlal Nehru Drainage Main with a length of 1.152 km

(j) Sub-component B10 : Improvement of Salang Drainage Main, Downstream Stretch, from the junction with Meanchey Drainage Main to a bridge with a length of 0.887 km

(k) Sub-component B11 : Improvement of Salang Drainage Main, Upstream Stretch, upstream from the bridge with a length of 0.488 km

(l) Sub-component B12 : Conservation of the north lake of Boeng Salang with dredging (5.1 ha) and providing a walkway around the lake

(m) Sub-component B13 : Preparation of Relocation Site and Spoil Area with a total area of 26 ha

The following study is conducted sub-component by sub-component and the facility layout of the Project is depicted in Figure II4-1.

4.2 Preliminary Design

4.2.1 Tompun Pumping Station, Inlet Channel and Regulation Pond

<u>Preconditions</u>

Preconditions considered for the preliminary design of the Tompun new pumping station, inlet channel and regulation pond are set as follows:

(1) Design Discharge

The design discharge with a 5-year probability of rainfall at the downstream end of Tompun Watershed, where the above structures are proposed, is 75 m^3/sec as obtained in Subsection 2.4.6 in Part I.

(2) Capacity Allocation between Pumping Station and Regulation Pond

The combination of a pump capacity of Tompun Pumping Station and the corresponding regulation volume of Tompun Regulation Pond determined in the Master Plan is as follows:

- Pump capacity : 15 m^3/sec
- Regulation pond volume : 560,000 m^3

(3) Design Water Levels

The design water levels necessary for designing the Tompun new pumping station, inlet channel, regulation pond are listed in the following table, together with reasons why they are applied:

Water Levels Concerning Tompun Pumping Station and Related Structures

Water Level	Elevation (EL. m)	Reasons
(1) Outer Side		
(a) Design High Water Level (HWL)	9.00	Derived from the 30-year return period floodwater level at Chaktomuk Station, EL. 10 m, deducting the water level difference of 1 m between Chaktomuk and Tompun Dike in the 1996 flood.
(b) Normal Water Level (NWL) in the Dry Season	4.00 to 4.50	According to water level surveys.
(2) Inner Side (Regulation Pond)		
(a) Design Surcharge Water Level (SWL)	4.50	On account of ground elevations in vicinity.
(b) Design High Water Level (HWL)	3.70	On account of ground elevations along Meanchey Drainage Main
(c) Design Low Water Level (LWL)	3.30	To be Maintained in the rainy season
(d) Normal Water Level (NWL) in the Dry Season	About 3.30 in future (4.00 at present)	Considering the convenience for water body utilization.

Shown in Figure II4-2 is the seasonal variation of water level outside Tompun Dike estimated with several assumptions on the basis of the data at Chaktomuk Station, compared to the design water levels mentioned in the above table. Figure II4-2 indicated that the outer water level is, throughout the year even in the dry season, higher than the inner one. There is hence less possibility of gravity flow from the inner side to the outer, even in the most dry season, and no construction of a natural drainage sluiceway is recommended in the feasibility study.

Structure of Pumping Station

(1) Design Pump Head

The design pump head is determined in accordance with the following criteria:

H = (The larger of Ha or Hb) + Hl

where,

H: Design pump head (m)

Ha:(HWL on the outer side) - (SWL on the inner side)

= 9.00 m - 4.50 m = 4.50 m

HWL on the outer side: Design high water level equivalent to a 30-year recurrence floodwater level at Chaktomuk Station (EL. 9.00 m)

SWL on the inner side: Design surcharge water level of Tompun Regulation Pond (EL. 4.50 m)

Hb: ((HWL on the outer side) - (LWL on the inner side)) × 0.75

$= (9.00 \text{ m} - 2.70 \text{ m}) \times 0.75 = 4.73 \text{ m}$

LWL on the inner side: Design low water level of Tompun Regulation Pond (EL. 2.70 m)

Hl: Pipe loss in pump facilities = 0.5 m (assumed)

Consequently, the design pump head is determined at 5.23 m (4.73 m + 0.5 m).

(2) Pump Type

Determination of the type of pumps is an essential issue on designing a pumping station. Generally, this issue governs the structure of the civil and building works of the station. Prior to detailed discussions concerning pump type selection, basic conditions and assumptions for the Project are as follows:

(a) The axial flow type of pump is suitable for design heads less than 6 m (the design pump head is actually 5.23 m) compared to the mix flow and centrifugal types of pump.

(b) Commercial electricity is applicable for the power source of Tompun New Pumping Station because a main power transmission line will soon be constructed along Tompun Dike connecting power stations with grid substations. However, backup generators against power failure should be required. The capacity of backup generators is planned at 60 % of the required total power, which can operate 3 units of 3 m^3/sec pumps. (In case of power failure when only 3 pumps work, the water stage in Tompun Regulation Pond will rise by 0.3 m over the design high water level for the design flood with a rainfall probability of 5-year.)

The following three types of pump are examined in accordance with the above conditions and assumptions:

- Axial flow vertical-shaft motor driven traditional type;
- Axial flow horizontal-shaft motor driven traditional type; and
- Submersible type.

A comparison of the three types is described in Table II4-1. As can be seen in the table, the submersible type of pump is recommended for Tompun New Pumping Station as it is economical and easy for maintenance, and further construction thereof is relatively simple and quick.

(3) Structural Features

The structural features of Tompun Pumping Station are shown in Figures II4-3 and II4-4, while the layout with the inlet channel and regulation pond in Figure II4-5. Main points of the structure of the pumping station are as follows:

(a) The capacity of the existing Tompun pumping station is ignored in planning, and Tompun New Pumping Station will be constructed on the west side with a total capacity of 15 m^3/sec, consisting of 5 pump units of 3 m^3/sec per each (submergible type).

(b) The main civil structure of the pumping station is designed without superstructure because submersible pumps can be installed outdoor. The main structure is about 24.6 m wide and 16.9 m long.

(c) An operation building yard is planned to be constructed beside the main structure, having a dimension of 12.3 m wide and 39.1 m long, to house an operating room, electric room, backup generator room, substation yard and store room.

(d) Five outlets, each made of a steel pipe, from the respective pump units will be constructed beneath Tompun Dike. A flap gate will be installed at each exit.

(e) No automatic trash removal equipment is installed at the initial stage although spaces for future installation of such equipment will be secured in the design. This is because debris would scarcely flow down to the pumping station for the time being due not only to less debris but to water hyacinth vigorously growing in the upstream channel that can considerably check flowing articles.

Structure of Inlet Channel

The inlet channel connecting to Tompun New Pumping Station is designed with the same capacity of 15 m^3/sec as the pumping station. Major features of the channel are presented hereunder.

(1) Plan

The alignment of the designed channel generally follows the existing Meanchey stream. The length of the channel is 1,020 m from Tompun New Pumping Station to the upstream end of Tompun Regulation Pond. (Refer to Figure II4-5.)

(2) Profile

Most of the channel is within the area of Tompun Regulation Pond. The bed gradient of the designed channel is set at 1/10,000. The design bed elevation varies from EL. 0.6 m at Tompun Pumping Station and EL. 0.7 m at the upstream end.

(3) Cross-sections

Cross-sections of the inlet channel are trapezoid-shaped with side slopes of 1:2 of earth channel. For the purposes of inspection and maintenance, roads and sidewalks are provided on both banks of the channel. On the other hand, the bank elevations in the stretch of Tompun Regulation Pond are the same as the original ground along the pond. Major features of the cross-sections resulting from hydraulic calculations are shown in Figure II4-6 and summarized below:

Major Features of Inlet Channel

Stretch	Type of Channel	Design Discharge (m^3/sec)	Design Water Depth (m)	Freeboard (m)	Channel Width (m)
Inlet Channel	Earth channel	15	3.8	0.3	29.2

Structure of Regulation Pond

Tompun Regulation Pond is located on the existing Boeng Tompun just upstream of the new pumping station. The area is 47.5 ha, consisting of the east and west lakes sandwiching Inlet Channel (refer to Figure II4-5). The bed elevation is 3.0 m with design water levels tabulated in Item (3) of Clause "Preconditions" in this Subsection. The regulation pond will be constructed simply of small dikes and earth banks both with a slope gradient of 1:2 on which sodding will be made (refer to Figure II4-7).

4.2.2 Meanchey Drainage Main

Preconditions

Preconditions for the preliminary design of Meanchey Drainage Main is set as follows:

(1) Purpose of Improvement

Improvement of the existing Meanchey channel is an essential factor in the Project. In particular, the downstream stretch of Meanchey Drainage Main is the trunk line gathering storm water not only from its own upper reaches but from Salang and Tum Nup Toek basins (the western half of City Core). It finally leads water to the complex of a pumping station and a regulation pond at the Tompun site. Without improving the stretch, no effect can be anticipated on the drainage over Tompun Watershed.

(2) Design Discharges

The design discharges along Meanchey Drainage Main, with a return period of 5-year, calculated in Subsection 2.4.6 in Part I are as follows:

- Meanchey Drainage Main, Downstream Stretch (0+000 to 2+635):75 m^3/sec
- Meanchey Drainage Main, Middle Stretch (2+635 to 3+920) :15 m^3/sec
- Meanchey Drainage Main, Upstream Stretch (3+920 to 4+455) :11 m^3/sec

Structure of Meanchey Drainage Main

The plan, profile and cross-sections of Meanchey Drainage Main are as follows.

(1) Plan

The alignment of the designed channel generally follows the existing Meanchey stream. The length of the channel is 4,455 m in total comprising the downstream stretch of 2,635 m, middle stretch of 1,285 m, and upstream stretch of 535 m. (Refer to Figure II4-8.)

(2) Profile

The bed gradient of the designed channel in each stretch generally corresponds with the average bed gradient of the existing Meanchey stream which has been clarified by the topographic survey carried out from November, 1998 to February, 1999. The results are summarized as follows:

- 1/2,500 in the downstream stretch;
- 1/2,000 in the middle stretch; and
- 1/1,000 in the upstream stretch.

To enable gravity drainage to Tompun Regulation Pond, the design bed elevation varies from EL. 0.7 m at the downstream end to EL. 3.4 m at the upstream end.

(3) Cross-sections

The cross-sections of Meanchey Drainage Main are trapezoid-shaped with side slopes of 1:2 of earth channel and 1:0.3 of masonry-reveted channel. For the purposes of inspection and maintenance, roads and sidewalks are provided on both banks of the channel. Major features of the channel resulting from hydraulic calculations are shown in Figure II4-9 and summarized below:

Major Features of Meanchey Drainage Main

Stretch	Type of Channel	Design Discharge (m^3/sec)	Design Water Depth (m)	Freeboard (m)	Channel Width (m)
Downstream	Earth channel	75 (at DHWL) 15 (at DSWL)	3.8	0	32.4
Middle	Earth channel	15	2.5	0	13.2
Upstream	Masonry-reveted channel	11	2.0	0	4.4

Note: DHWL and DSWL mean the design high water level (EL. 3.7 m) and design surcharge water level (EL. 4.5 m) of Tompun Regulation Pond, respectively.

<u>Structure of Tum Nup Toel Drainage Sluiceway</u>

Tum Nup Toel Drainage Sluiceway is the facility provided beneath the Inner Ring Dike to drain storm water in the corresponding drainage basin to Meanchey Drainage Main by gravity. The detailed structure is shown in Figure II4-10.

4.2.3 Samdach Monireth and Jawaharlal Nehru Drainage Mains

<u>Preconditions</u>

(1) Purpose of Construction

The City Core portion of the Tompun Watershed (631 ha) consists of the following three areas:

- Boeng Salang Area : 275 ha
- Tum Nup Toek Area : 68 ha

- Remaining Area : 288 ha

Storm water in the Boeng Salang area is once stored in the existing Salang Lake and drained to Meanchey Drainage Main through Salang Drainage Main. Drainage in the Tum Nup Toek area is achieved by a sluiceway provided across the Inner Dike directly to Meanchey Drainage Main. On the other hand, there is no major drainage facilities furnished in the remaining area, which condition repeatedly causes serious inundation over the area, one of the most vigorous zones in Phnom Penh. In this case, recommended in the Master Plan is the construction of underground drainage mains along Samdach Monireth and Jawaharlal Nehru streets because of no space for providing open channels in the house-congested area. This idea still holds in the present feasibility study.

(2) Design Discharges

The design discharges of Samdach Monireth and Jawaharlal Nehru drainage mains are determined through hydrological analysis as follows:

- Samdach Monireth Drainage Main, Downstream Stretch : 44 m^3/sec
- Samdach Monireth Drainage Main, Upstream Stretch : 20 m^3/sec
- Jawaharlal Nehru Drainage Main : 8 m^3/sec

Structure of Samdach Monireth and Jawaharlal Nehru Drainage Mains

The plan, profile and cross-sections of Samdach Monireth and Jawaharlal Nehru drainage mains are as follows.

(1) Plan

The alignments of the designed drainage mains follow Samdach Monireth and Jawaharlal Nehru streets. Most part of the drainage mains is of the underground box culvert except an open channel portion joining Meanchey Drainage Main 50 m downstream of Meanchey Bridge. The total length of Samdach Monireth Drainage Main is 2,390 m comprising the downstream stretch of 1,676 m and upstream stretch of 714 m. The length of Jawaharlal Nehru Drainage Main is 1,152 m. (Refer to Figures II4-11, II4-13 and II4-14.)

(2) Profile

The longitudinal gradient of the drainage mains is constantly 1/2,000 which generally corresponds with the average gradient of the existing road surface. The design bottom elevation varies from EL. 1.7 m at the confluence with Meanchey Drainage Main to EL. 2.9 m at the upstream end of Samdach Monireth and EL. 3.6 m at that of Jawaharlal Nehru.

(3) Cross-sections

The cross-sections of the underground culverts are rectangular-shaped with one or two lane(s) depending on the design discharges. The cross-sections of the open channel are trapezoid-shaped with side slopes of 1:2 of earth channel, and for the purposes of inspection and maintenance, roads and sidewalks are provided on both banks of the channel. Major features of the channels are shown in Figure II4-12, and summarized as below:

Major Features of Samdach Monireth and Jawaharlal Nehru Drainage Mains

Stretch	Type of Channel	Design Discharge (m^3/sec)	Design Water Depth (m)	Freeboard (m)	Channel Width (m)
Samdach Monireth, Outlet	Earth channel	44	3.0	0.0	20.2
Samdach Monireth, Downstream	Underground box culvert	44	3.0	0.6	4.25 (2-lane)
Samdach Monireth, Upstream	Underground box culvert	20	3.0	0.6	4.00 (1-lane)
Jawaharlal Nehru	Underground box culvert	8	2.5	0.6	2.50 (1-lane)

4.2.4 Salang Drainage Main

Preconditions

(1) Purpose of Improvement

Boeng Salang plays an important role in the retention of storm water gathering from the City Core portion of the Tompun Watershed. However, the south lake of Boeng Salang has been reclaimed in most area and encroached on by housing, resulting in diminution of its retention function although the north lake comparatively remains as it was. To compensate and control such deterioration in terms of drainage, Salang Drainage Main will be provided along the centerline of the south lake, and moreover some conservation measures are recommended to be taken in the north lake (5.1 ha). The measures comprise dredging on the lake bottom and building a walkway (the pier type of structure) along the perimeter of the lake to control house encroachment into the lake area.

(2) Design Discharge

The design discharge of Salang Drainage Main is 21 m^3/sec both for the upstream and downstream stretch.

Structure of Salang Drainage Main

The plan, profile and cross-sections of Salang Drainage Main are as follows.

(1) Plan

The alignment of the designed channel generally follows the existing Boeng Salang south lake, and joins Meanchey Drainage Main 50 m upstream of Meanchey Bridge. The total length of the channel is 1,375 m composed of the downstream stretch of 887 m and upstream stretch of 488 m. (Refer to Figures II4-15 and II4-17.)

(2) Profile

The bed gradient of the designed channel in each stretch is 1/3,000 which generally corresponds with the average bed gradient of the existing lake bottom. The design bed elevation varies from EL. 1.8 m at the confluence with Meanchey Drainage Main to EL. 2.2 m at the upstream end (Boeng Salang north lake).

(3) Cross-sections

The cross-sections of Salang Drainage Main are trapezoid-shaped with side slopes of 1:2 of earth channel and 1:0.3 of masonry-reveted channel. For the purposes of inspection and maintenance, roads and sidewalks are provided on both banks of the channel. (Refer to Figure II4-16.) Major features of the channel is as follows:

Major Features of Salang Drainage Main

Stretch	Type of Channel	Design Discharge (m^3/sec)	Design Water Depth (m)	Freeboard (m)	Channel Width (m)
Downstream Stretch	Earth channel	21	3.0	0	15.7
Upstream Stretch	Masonry-reveted channel	21	3.0	0	7.0

4.2.5 Relocation Site and Spoil Area

Land acquisition and house evacuation probably required for the implementation of the Project are presented in Table II4-2 where those in alternative plans are also indicated for reference. The total land acquisition and house evacuation for Sub-components B1 to B12 are 58,400 m^2 and 460 houses. As for the relocation site, one suggested by the Study Team is the proposed spoil area (26 ha) near Tompun New Pumping Station (refer to Figure II4-5). The proposed spoil area will be provided in two stages with the following respective dimensions:

Dimensions of Proposed Spoil Area

Stage	Corresponding Sub-component *	Excess Soil Volume Approximate (m^3)	Area (ha)	Formation Height (EL. m)	Embankment Height (m)
I	B1, B3, B6 and B10	250,000	10.5	6.0	2.5
II	B2, B4, B5, B7, B8, B9, B11 and B12	550,000	15.5	7.0	3.5
Total	-	800,000	26.0	-	-

Note: The existing ground elevation is around 3.5 m.
* Refer to Chapter II5.

A part of the spoil area, Stage I, will be used for the relocation site of the evacuated peoples, 480 households in total (above 460 plus 20 in the spoil area). The relocation site will require 48,000 m^2 of land complete with necessary infrastructures, such as roads, electricity, wells and sanitary facilities.

Finally, it is noted that right-of-way preparation and establishment of a reasonable relocation plan is an essential task of the Cambodian Government, which shall be settled prior to the actual implementation when the Government will request a foreign assistance for the Project.

4.3 Project Formulation

4.3.1 Features of Facilities

(1) Sub-component B1: Tompun New Pumping Station and Inlet Channel

(a)	Location	:	On Tompun Dike, adjoining the existing pumping station to the east (see Figures II4-3 & II4-5)
(b)	Pump capacity	:	15 m^3/sec (3 m^3/sec x 5 units)
(c)	Type of Pumps	:	Submergible pump
(d)	Structure	:	Pumping station of RC structure with foundation piles, outlets with flap gates, a control house and the inlet channel (see Figures II4-4 & II4-6)

(2) Sub-component B2: Tompun Regulation Pond

(a)	Location	:	Existing Boeng Tompun (see Figure II4-5)
(b)	Area	:	47.5 ha (total of East and West ponds)
(c)	Design Surcharge Water Level	:	EL. 4.5 m (at the maximum storage)
(d)	Design High Water Level	:	EL. 3.7 m (at the peak discharge of Meanchey Drainage Main)
(e)	Design Low Water Level	:	EL. 3.3 m (to be maintained through the year)
(f)	Design Bottom Height	:	EL. 3.0 m (see Figure II4-7)
(g)	Regulation Volume	:	560,000 m^3 by which 60 m^3/sec of the peak discharge can be regulated.

(3) Sub-component B3: Meanchey Drainage Main, Downstream Stretch

(a)	Stretch	:	From Tompun Regulation Pond to Meanchey Bridge with a length of 2.635 km (see Figure II4-8)
(b)	Design Discharge	:	75 m^3/sec
(c)	Channel Bed Gradient	:	1/2,500
(d)	Structure	:	Earth channel with a side slope of 1:2 (see Figure II4-9)

(4) Sub-component B4: Meanchey Drainage Main, Middle Stretch

(a)	Stretch	:	From Meanchey Bridge to the junction with a branch with a length of 1.285 km (see Figure II4-8)
(b)	Design Discharge	:	15 m^3/sec

(c) Channel Bed Gradient : 1/2,000

(d) Structure : Earth channel with a side slope of 1: 2 (see Figure II4-9)

(5) Sub-component B5: Meanchey Drainage Main, Upstream Stretch

(a) Stretch : Upstream from the junction with a length of 0.535 km (see Figure II4-8)

(b) Design Discharge : 11 m^3/sec

(c) Channel Bed Gradient : 1/1,000

(d) Structure : Masonry-riveted channel with a side slope of 1: 0.3 (see Figure II4-9)

(6) Sub-component B6: Tum Nup Toek Drainage Sluiceway

(a) Location : On the Inner Ring Dike near the existing Tum Nup Toul Pumping Station

(b) Structure : 3.0 m wide & 3.6 m high box culvert with stoplogs (see Figure II4-10)

(7) Sub-component B7: Samdach Monireth Drainage Main, Downstream Stretch

(a) Stretch : Under Samdach Monireth Street between the junctions with Meanchey and Jawaharlal Nehru drainage mains with a length of 1.676 km, at the downmost of which an outlet structure, with stoplogs, will be provided (see Figures II4-11 & II4-13)

(b) Design Discharge : 44 m^3/sec

(c) Channel Bed Gradient : 1/2,000

(d) Structure : 4.25 m wide, 3.6 m high & 2 lanes (see Figure II4-12)

(8) Sub-component B8: Samdach Monireth Drainage Main, Upstream Stretch

(a) Stretch : Under Samdach Monireth Street upstream from the junction with Jawaharlal Nehru Drainage Main with a length of 0.714 km (see Figure II4-11)

(b) Design Discharge : 20 m^3/sec

(c) Channel Bed Gradient : 1/2,000

(d) Structure : 4.0 m wide & 3.6 m high (see Figure II4-12)

(9) Sub-component B9: Jawaharlal Nehru Drainage Main

(a) Stretch : Under Jawaharlal Nehru Street with a length of 1.152 km (see Figure II4-14)

(b) Design Discharge : 8 m^3/sec

(c) Channel Bed Gradient : 1/2,000

(d) Structure : Box culvert, 2.5 m wide & 3.1 m high (see Figure II4-12)

(10) Sub-component B10: Salang Drainage Main, Downstream Stretch

(a) Stretch : Along the existing Boeng Salang south lake from the junction with Meanchey Drainage Main to a bridge with a length of 0.887 km, at the downmost of which an outlet structure, with stoplogs, will be constructed (see Figures II4-15 & II4-17)

(b) Design Discharge : 21 m^3/sec

(c) Channel Bed Gradient : 1/3,000

(d) Structure : Earth channel with 1:2 of side slopes (see Figure II4-16)

(11) Sub-component B11: Salang Drainage Main, Upstream Stretch

(a) Stretch : From the bridge to the existing Boeng Salang north lake with a length of 0.488 km (see Figure II4-15)

(b) Design Discharge : 21 m^3 /sec

(c) Channel Bed Gradient : 1/3,000

(d) Structure : Masonry-reveted channel with 1:0.3 of side slopes (see Figure II4-16)

(12) Sub-component B12: North Lake of Boeng Salang

(a) Location : Existing Boeng Salang north lake (see Figure II4-15)

(b) Structure : Dredging of 5.1 ha and provision of a walkway around the lake

(13) Sub-component B13: Relocation Site and Spoil Area

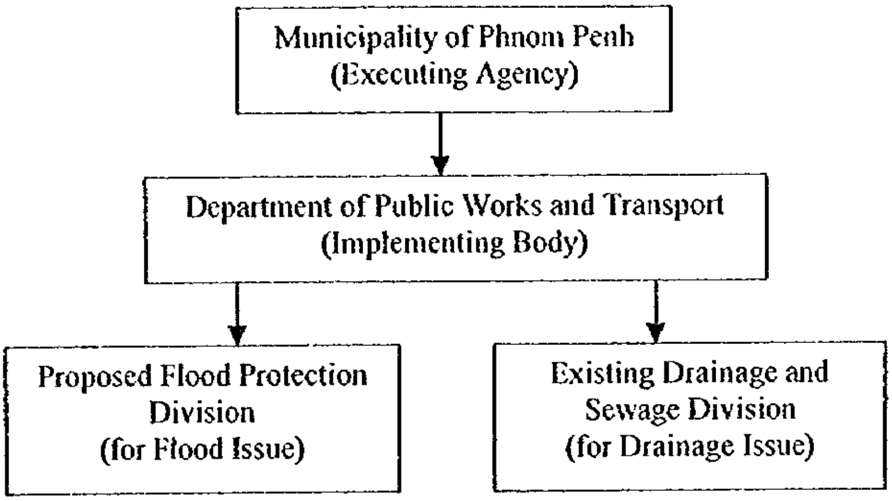
(a) Location : West side of the Tompun New Pumping Station (see Figure II4-5)

(b) Area : 26 ha for spoil area within which 48,000 m^2 is used as the relocation site for the Project

4.3.2 O/M Plan

<u>Organization</u>

The study on organization and institution compiled in Subsection 3.7.1 in Part I has advised an organizational hierarchy (system) for the implementation of flood protection and drainage improvement projects in the Master Plan as follows:



The above system will also apply to the operation and maintenance stage. Specifically, the existing Drainage and Sewage Division will directly be in charge of the operation and maintenance of drainage structures/facilities provided under the Tompun Watershed Drainage Improvement Project as listed below:

- Pumping station with 5 units of 3 m^3/sec submergible pumps;
- Open drainage mains and regulation ponds;
- Underground drainage mains of box culvert type; and
- Three sluiceways with stop logs.

The operation and maintenance work can be fulfilled by the present number of staff in Drainage and Sewage Division presented in Subsection 2.7.1 in Part I, although some additional engineers shall be assigned for the operation and maintenance of Tompun Pumping Station, say one civil and two mechanical/electrical engineers.

<u>Activities</u>

The activities of Drainage and Sewage Division should incorporate the following items:

(1) Periodical Activity

(a) Daily patrol by staffs to confirm the condition of structures, facilities and the vicinities, just visually;

(b) Biweekly inspection by engineers and staffs to investigate the function, quality and shape of each structure or facility, deeply but still qualitatively; and

(c) Seasonal checkup (twice a year before and after the rainy season) by most members of Drainage and Sewage Division to quantitatively measure the dimensions, quality, capacity and so on of each of the structures and facilities.

(2) Emergency Activity

(a) Flood defense activity in corporation with the headquarters and district offices of the Municipality of Phnom Penh and concerned ministries, including operation of the pumps and stoplogs; and

(b) Other emergency activities in case of earthquake, fire and other accidents probably affecting drainage structures and facilities.

Necessary Equipment and Materials

The operation and maintenance work for drainage structures and facilities will require a variety of equipment and materials. However, the Department of Public Works and Transport has owned a number of equipment listed in Table I2-11, which may be sufficient for this purpose. The equipment shall be stored in a stockyard to be provided near Tompun Pumping Station. Minor materials, like cement, gravel, sand, sand bags, timbers, logs, ropes, etc., shall be kept in warehouses to be built at intervals of about 2 km along the drainage mains.

4.3.3 Project Cost and O/M Cost

Project Cost

The project cost for the Tompun Watershed Drainage Improvement amounts at approximately US$ 50.8 million as shown in Table II4-3. The breakdown by sub-component is presented in the following table:

Project Cost for the Tompun Watershed Drainage Improvement

Sub-component	Project Cost (US$ million)
B1: Tompun New Pumping Station and Inlet Channel	11.5
B2: Tompun Regulation Pond	3.6
B3: Meanchey Drainage Main, Downstream Stretch	3.8
B4: Meanchey Drainage Main, Middle Stretch	0.5
B5: Meanchey Drainage Main, Upstream Stretch	0.5
B6: Tum Nup Toek Drainage Sluiceway	0.7
B7: Samdach Monireth Drainage Main, Downstream Stretch	16.3
B8: Samdach Monireth Drainage Main, Upstream Stretch	3.7
B9: Jawaharlal Nehru Drainage Main	4.1
B10: Salang Drainage Main, Downstream Stretch	1.3
B11: Salang Drainage Main, Upstream Stretch	0.6
B12: North Lake of Boeng Salang	0.7
B13: Relocation Site and Spoil Area	3.5
Total	50.8

O/M Cost

The annual O/M cost for the Project is estimated as 0.5 % of the project cost taking account of the facilities installed.

4.3.4 Implementation Schedule

The implementation schedule for the Tompun Watershed Drainage Improvement is shown in Table II3-3, where that for the Reinforcement of Kop Srov and Tompun Dikes is also presented. The actual construction of the Project will initiate in 2001 and end in 2007 with a total construction period of 7 years. The year of 2000 will be shared for the basic and detailed design of the structures/facilities in the Project, and the land acquisition and house evacuation by the Municipality of Phnom Penh.

4.4 Project Evaluation

4.4.1 Economic Evaluation

Economic benefit estimated for Component 3 in the master plan are applied to the present Project, Tompun Watershed Drainage Improvement. That is US$ 6,518 thousand per year in 2010 and thereafter comprising both direct and indirect benefits. The economic benefit is assumed to growth at a rate of 7.2 % per year, the GRDP growth rate set in Clause "Socioeconomic Framework" of Subsection 4.1.1 in Part I, until 2010, the year in which a full scale benefit of the Project is reached.

Costs for economic analysis are estimated in the same way as for the Master Plan. Local currency portion of the investment cost is adjusted by a standard conversion factor at 0.85. The investment cost is allocated to each year according to the prepared disbursement schedule.

Table II3-4 shows streams of costs and benefits thus estimated. The following economic indices are derived:

Economic Indices for Tompun Watershed Drainage Improvement

Indices	Tompun Watershed Drainage Improvement	Including Reinforcement of Kop Srov and Tompun Dikes
EIRR (%)	11.7	16.7
B/C	1.17	1.69
NPV (US$ thousand)	5,909	35,384

NPV : net present value

This Project is judged to have sufficiently high economic return with an EIRR higher than the opportunity cost of capital at 10 %. The Project is proved to be worth being promoted to the implementation stage.

4.4.2 Financial Affordability

A financial analysis for the Project is carried out from the viewpoint of cost recovery for Drainage and Sewerage Division (DSD) of Department of Public Works and Transport in the same way as for the Master Plan. Revenue of the proposed Flood Protection Division is considered included in those of DSD. Table II3-5 presents a comparison of DSD's expected revenue in 2008, in which the facilities start to serve and operation and maintenance cost needed for the priority projects. The expected revenue includes government budget allocation and revenue by wastewater surcharge estimated based on the same assumptions as for the Master Plan. The cost recovery target is set at the recovery of operation and maintenance cost on the premise that the investment cost be provided by government budget. The following summarizes the result:

Comparison of DSD's Revenue and O/M Cost

Item	Amount (US$ million)
Revenue by Government Budget in 2008	0.34
Wastewater Surcharge Revenue in 2008	1.41
Total Revenue in 2008	1.76
Total O/M Cost Required since 2008	0.32
Balance	1.40

As of 2008 when the facilities start operation, the DSD's revenue from government budget reaches the level slightly above the operation and maintenance cost. The Project is financially feasible from O/M cost recovery viewpoint. This aspect, however, should be closely monitored, paying due attention to the government effort and achievement in enhancing the government revenue and a progress in proportionately increasing allocation to line agencies and local governments.

4.4.3 Environmental Impact Assessment

Construction and operation of the proposed project may initiate both positive and negative impacts on the surrounding environment. The environmental impacts are assessed for both construction and operation periods.

Environmental Impact Assessment

Environmental impact assessment for ***physical resources*** is as follows: Flow disturbance during construction period for Tompun Basin drainage improvement especially for channel rehabilitation and dredging of Tompun regulation pond is anticipated as a negative impact. In the operation period, hydrological condition will be improved with a new drainage channels and regulation pond. Water quality during construction will be affected by addition of suspended solid from construction area; by wastewater from construction camp, site office and workshop; and by contamination of oil and lubricants from equipment. These effects can be minimized, however, if proper measures are taken for construction work. Water quality during operation period will be improved by the new proper drainage facilities, but water pollution caused by uncontrolled development derived by the creation of favorable living environment after the project completion.

Environmental impact assessment in ***human use resources*** is as follows: The agricultural lands near the proposed new Tompun pumping station will be changed to spoil area and finally to relocation area. It will not be a negative impact because there are already scattered residential areas. Fringe of the Tompun regulation pond will be made clear after the construction and it will beneficial to reserve the lake area. However, in the operation stage, land use in the neighboring areas will be changed due to the creation of comfortable living condition with improved drainage condition. There will be negative impact in transportation. Traffic congestion and risk of accident; deterioration of road surface; increase in dust dispersion; and inconvenience for transportation will occur during construction, but these impacts can be minimized by proper measure. During construction there is no change in inundation condition, but after the completion, the effectiveness of the drainage improvement will be very high and high adverse impact can be expected.

Environmental impact assessment in *quality of life values* is as follows: As a socioeconomic aspect, relocation of the 480 families is needed for the construction works. A total of 6.11% of evacuated family members have to take a longer distance to school, all affected families have to pay higher cost of transportation, and 5 families will lose cropping land. All these impact should be minimized or compensated. Disturbance on communities by dust, noise and inconvenience in travelling will be anticipated at all the construction locations. However, quality of life for communities in the subject basin will be improved much by the completion of the project. Compensation/resettlement include 480 families for the Kop Srov dike reinforcement.

Environmental Impact Mitigation Measures

Necessary measures to mitigate negative environmental impact will include: To implement necessary measures to alleviated the impacts on hydrology; to protect and maintain water quality during construction; to alleviate the impacts on transportation, to alleviate the nuisance or problems affecting the villagers; to prepare adequate measures for the people affected by the project and help in the process of relocation. For detail, refer to Supporting Report G.

Environmental Monitoring Plan

Monitoring is necessary to obtain necessary information related to environmental condition during both construction and operation stages. It will include water quality monitoring; land use monitoring in the neighboring areas in and around the subject basin during both construction and operation stages to prevent uncontrolled development; transportation monitoring to investigate traffic volume due to the project activities and after the completion of the project; and socioeconomic condition to perceive the people attitude towards the project.

4.4.4 Technical Evaluation

The project of the Tompun Watershed Drainage Improvement entails the following structures and construction:

(a) Pumping station, of 5 units of 3 m^3/sec submergible pumps, at the Tompun site, associated with outlet pipes and an operation house;

(b) Lake excavation and dredging on existing lakes, i.e. Boeng Tompun and Boeng Salang;

(c) Existing open channel improvement, comprising widening and deepening, some with stone-masonry revetments; and

(d) Underground box culverts, one- or two-lanes, beneath existing major roads.

The construction of a pumping station, among the above, might be rather complicated, and necessitate some advanced technology. In particular, submergible pumps, valves and the appurtenance shall be imported from a developed country, and the installation, operation and maintenance of them shall be supervised by engineers from such a country. Moreover, with regard Item (d) above, since there are no practices in Cambodia pertaining to earth retaining in a part of the temporary works, requiring high sheet pile walls and H-beam struts, advanced technology therefor shall be introduced from neighboring countries. However, as a whole, the construction of the Project can go well without definite technical problems.

II5. POSSIBLE URGENT PROJECTS

The feasibility study on each of the two projects, A: Reinforcement of Kop Srov and Tompun Dikes, and B: Tompun Watershed Drainage Improvement, has been achieved and completed as presented in Chapters II3 and II4. The study gives a cost estimation: that is $ 20.8 million for the former and $ 50.8 million for the latter, totaling as huge as $ 71.6 million. In such case, it is natural to schedule a stepwise implementation of the entire projects. The next table shows the evaluation results of the urgency of each sub-component using "High", "Medium" and "Low", along with its construction cost and compensation required, under the following considerations:

- Project A has an economic return as high as 25.2 % of EIRR, and each sub-component therein is indispensable to protect the major part of Phnom Penh from flooding caused by the Mekong river system. All four sub-components in Project A are hence ranked "High" in urgency.
- As for Project B, sub-components located downstream should be implemented ahead in general consideration. Sub-components B1 and B3 are hence assessed "High", while Sub-component B2, also situated downstream, "Medium" since the existing Boeng Tompun has about 70 % of regulation capacity compared with the proposed regulation pond.
- The preparation of a relocation site/spoil area (Sub-component B13) must be "High" to secure the succeeding construction works.
- Sub-components B6 and B10 can achieve drainage in the City Core portion of Tompun Watershed to a fair extent at minimal cost, so that the two sub-components are evaluated also "High".
- Sub-components B7 to B9 will play an important role in the drainage of the City Core portion, however they entail a cost as large as US$ 24.1 million (nearly half of the total cost of Project B) and are classified "Medium".
- The other sub-components located in upstream reaches with less beneficiary, Sub-components B4, B5, B11 and B12, are rated "Low" in urgency.

Urgency of Each Sub-component in Project A: Reinforcement of Kop Srov and Tompun Dikes, and Project B: Tompun Watershed Drainage Improvement

Sub-component	Rank of Urgency	Construction Cost ($ mill.)	Compensation Required	
			Land Acquisition (m^2)	House Evacuation (house)
Project A: Reinforcement of Kop Srov and Tompun Dikes (EIRR = 25.2 %)				
A1: Kop Srov Dike	High	15.9	0	54
A2: Tompun Dike	High	3.2	0	0
A3: Svay Pak Drainage Sluiceway	High	1.0	0	0
A4: Relocation Site/Spoil Area	High	0.7	250,000	0
Total	-	20.8	250,000	54
Project B: Tompun Watershed Drainage Improvement (EIRR = 11.7 %)				
B1: Tompun New Pumping Station and Inlet/Outlet Channels	High	11.5	5,000	30
B2: Tompun Regulation Pond	Medium	3.6	20,000	20
B3: Meanchey Downstream	High	3.8	28,000	90
B4: Meanchey Middle	Low	0.5	0	120
B5: Meanchey Upstream	Low	0.5	0	10
B6: Tum Nup Toek Drainage Sluiceway	High	0.7	3,000	10
B7: Samdach Monireth Downstream	Medium	16.3	2,400	30
B8: Samdach Monireth Upstream	Medium	3.7	0	0
B9: Jawaharlal Nehru	Medium	4.1	0	0
B10: Salang Downstream	High	1.3	0	60
B11: Salang Upstream	Low	0.6	0	90
B12: Boeng Salang	Low	0.7	0	0
B13: Relocation Site/Spoil Area	High	3.5	260,000	20
Total	-	50.8	318,400	480

Note: The overall EIRR is 16.7 %.

From the table above, suggested as sub-components that should be realized in the earlier stage of the two projects are the following:

(1) In Project A: Reinforcement of Kop Srov and Tompun Dikes

- (a) Sub-component A1: Reinforcement of Kop Srov Dike;
- (b) Sub-component A2: Reinforcement of Tompun Dike;
- (c) Sub-component A3: Reconstruction of Svay Pak Drainage Sluiceway; and
- (d) Sub-component A4: Preparation of Relocation Site/Spoil Area.

(2) In Project B: Tompun Watershed Drainage Improvement

- (a) Sub-component B1: Construction of Tompun New Pumping Station and Inlet Channel;
- (b) Sub-component B3: Improvement of Meanchey Drainage Main, Downstream Stretch;
- (c) Sub-component B6: Construction of Tum Nup Toek Drainage Sluiceway;
- (d) Sub-component B10: Improvement of Salang Drainage Main, Downstream Stretch; and
- (e) Sub-component B13: Preparation of Relocation Site/Spoil Area.

II6. RECOMMENDATIONS

Recommendation on Implementation of the Project

1. Of the component projects of the master plan for the drainage improvement and flood control in the Municipality of Phnom Penh established in the present study, the following two component projects have high priority for implementation. It is recommended to give high priority for implementation to these two component projects.

   - Component 2: Reinforcement of Kop Srov and Tompun Dikes (including reconstruction of Svay Pak Drainage Sluiceway)
   - Component 3: Tompun Watershed Drainage Improvement (excluding sewer rehabilitation)

2. Proposed non-physical measure in the master plan for the drainage improvement and flood control in the Municipality of Phnom Penh is the introduction of land use control and continuous application of flood defense activity. An official development plan for the Municipality of Phnom Penh is recommended to be established as soon as possible considering the recommendation from the view point of flood protection and drainage improvement, namely, water zone conservation in the Northeast Area and agricultural land conservation in the Northwest and South areas

3. The implementing body of the projects proposed in the master plan is Department of Public Works and Transport of Municipality of Phnom Penh. Drainage and Sewage Division will be in charge drainage improvement projects. It is recommended to establish Flood Protection Division that will be responsible for implementation, operation and maintenance for flood protection projects.

4. The results of the feasibility study conducted for Reinforcement of Kop Srov and Tompun Dikes and Tompun Watershed Drainage Improvement, the priority projects selected from the master plan components, revealed high economic feasibility, financial affordability, environmental justifiability, and technical soundness. Early implementation of these projects is recommended. However, a huge project cost of US$ 71.6 million and a long period of seven years are required for the implementation of all the component projects of these two projects. Accordingly, it is recommended to implement the following sub-component projects prior to the other sub-component projects.

   (1) Project A: Reinforcement of Kop Srov and Tompun Dike

   (a) Sub-component A1: Reinforcement of Kop Srov Dike
   (b) Sub-component A2: Reinforcement of Tompun Dike
   (c) Sub-component A3: Re-construction of Svay Pak Drainage Sluiceway
   (d) Sub-component A4: Preparation of Relocation Site/Spoil Area

(2) Project B: Tompun Watershed Drainage Improvement

(a) Sub-component B1: Construction of Tompun New Pumping Station and Inlet Channel
(b) Sub-component B3: Improvement of Meanchey Drainage Main, Downstream Stretch
(c) Sub-component B6: Construction of Tum Nup Toek Drainage Sluiceway
(d) Sub-component B10: Improvement of Salang Drainage Main, Downstream Stretch
(e) Sub-component B13: Preparation of Relocation Site/Spoil Area

5. Land acquisition and house relocation are needed for project implementation. It is recommended to start land acquisition and house relocation for the above sub-components.

Continuous Water Level Observation

6. There exist no sufficient water level data in and around the Study Area. The Study Team hence established water level gaging stations for Kop Srov Dike, Tompun Dike, etc. and observation has been conducted by the Department of Public Works and Transport. Although the results were used for the feasibility study, higher water records are not sufficient due to the low water level of the last flooding season. It is recommended to continue the observation, since these data will be important in the basic design and detailed design stages.

Environment

7. Implementation of the project is environmentally preferable considering high adverse impact of flood protection and drainage improvement, although there are some negative impact in water and atmospheric quality during construction works and of necessary relocation of houses, etc. The negative impact identified in the Environmental Impact Assessment should be minimized through implementation of Environmental Management Program and Environmental Monitoring Program. Attention should be paid to prevent uncontrolled development according to the betterment of Kop Srov and Tompun dikes, and resulting negative impact including water pollution in the Prek Phnov and Prek Thnot basins. Management and monitoring for relocation of the residents are also important to minimize negative socioeconomic impact.

TABLES

Table II2-1 Population in Northeast, Northwest and Middle Areas Protected by Kop Srov and Tompun Dikes

District/sub-district	Population in SA	Population in Comp. 2 Area	
		Proportion (%)	Population
Dang Kor			
1 Cheung Ek	0	0	0
2 Dang Kor	1,508	0	0
3 Prey Sar	2,140	0	0
4 Prey Veng	1,347	0	0
5 Sak Sampouv	0	0	0
6 Pong Toek	4,782	0	0
7 Kraing Prongor	0	0	0
8 Prateas Lang	0	0	0
9 Pleung Chhes Rotes	228	0	0
10 Chom Chao	15,673	25	3,918
11 Trapaing Krasaing	312	0	0
12 Samrong Krom	1,973	100	1,973
13 Kok Kokar	2,971	100	2,971
14 Kraing Thnong	2,773	100	2,773
15 Kakab	14,405	100	14,405
sub-total	*48,112*		26,040
Mean Chey			
1 Chbar Ampouv 1	0	0	0
2 Chbar Ampouv 2	0	0	0
3 Nirod	0	0	0
4 Prek Pra	0	0	0
5 Chak Angre Leu	0	0	0
6 Chak Angre Krom	0	0	0
7 Beung Toum Poun	28,930	100	28,930
8 Strung Meanchey	31,557	25	7,889
sub-total	*60,487*		36,819
Russey Keo			
1 Suay Pak	10,243	20	2,049
2 Chrang Chamres 1	7,898	100	7,898
3 Chrang Chamres 2	11,386	100	11,386
4 KM No 6	12,527	100	12,527
5 Russey Keo	17,666	100	17,666
6 Toul Sangke	22,020	100	22,020
7 Chroy Chang Var	0	0	0
8 Prek Leap	0	0	0
9 Prek Tasek	0	0	0
10 Toek Tla	26,143	100	26,143
11 Phnom Penh Thmey	17,866	100	17,866
12 Khmournh	5,890	100	5,890
sub-total	*131,639*		123,445
Registered population			186,304
Non-registered population			40,987
Total population			**227,291**

Note :
Proportion of non-registered population to registered population : 22%

Table II2-2 Population in Tompun Watershed

District/subdistrict		Population by sub-district	Population in Component 3 Area	
			Proportion (%)	Population
Chamkarmon				
1	Tonle Basac	33,561	0	0
2	Beung Keng Kang 1	10,403	0	0
3	Beung Keng Kang 2	10,161	0	0
4	Beung Keng Kang 3	17,641	0	0
5	Phsar Olimpic	7,911	0	0
6	Phsar Svay Prey 1	10,304	0	0
7	Phsar Svay Prey 2	10,217	100	10,217
8	Beung Trabek	7,926	0	0
9	Phsar Deum Tkov	13,552	0	0
10	Toul Toum Poung 1	8,564	0	0
11	Toul Toum Poung 2	7,727	0	0
12	Toum Noup Teuk	10,568	100	10,568
	sub-total	148,535		20,785
Don Penh				
1	Sras Chork	26,640	0	0
2	Wat Phnom	8,091	0	0
3	Phsar Chars	8,322	0	0
4	Phsar Kandal 1	10,302	0	0
5	Phsar Kandal 2	7,826	0	0
6	Chey Choumneas	10,027	0	0
7	Chak To Mouk	9,281	0	0
8	Beang Reang	6,402	0	0
9	Phsar Tmey 1	6,780	0	0
10	Phsar Tmey 2	7,054	0	0
11	Phsar Tmey 3	11,107	0	0
	sub-total	111,832	0	0
Prampi Makara				
1	Mitapheap	11,148	100	11,148
2	Nonoroum	12,980	100	12,980
3	Veal Vong	21,250	100	21,250
4	Beung Prolit	11,502	0	0
5	Phsar O Russey 1	9,109	0	0
6	Phsar O Russey 2	10,625	0	0
7	Phsar O Russey 3	8,455	0	0
8	Phsar O Russey 4	9,080	0	0
	sub-total	94,149		45,378
Toul Kork				
1	Beng Kak 1	13,777	0	0
2	Beng Kak 2	20,151	0	0
3	Toeuk Loak 1	11,856	100	11,856
4	Toeuk Loak 2	12,492	100	12,492
5	Toeuk Loak 3	9,464	100	9,464
6	Beung Salang	17,751	100	17,751
7	Phsar Deum Kor	14,468	100	14,468
8	Phsar Deipo 1	9,216	100	9,216
9	Phsar Deipo 2	10,863	100	10,863
10	Phsar Deipo 3	10,102	100	10,102
	sub-total	*130,139*		96,212
Outlying Sub-districts				
	Beung Teum Poun	28,930	100	28,930
	Strung Meanchey	31,557	50	15,779
	Toek Tla	26,143	50	13,072
	Registered population			220,155
	Non-registered population			48,434
	Total population			268,589

Note :

(1) The total population of each district presented above are obtained from district offices and and slightly different from the total registered population provided by City Hall.

(2) Sub-district population of Toul Kork is derived by applying the ratio in 1992 to the district total population obtained from City Hall due to lack of sub-district data.

(3) Proportion of non-registered population to registered population : 22%

Table II3-1 Land Acquisition and House Evacuation Required for the Reinforcement of Kop Srov and Tompun Dikes

Sub-component	Section	Recommended Plan		Alternative Plan	
		Land Acquisition (m²)	House Evacuation (house)	Land Acquisition (m²)	House Evacuation (house)
1: Kop Srov Dike *	0+000 to 0+900 (900m)	Road pavement only		Plus slope surface repair on the outer and inner sides	
		0	0	5,400	102
	0+900 to 7+650 (6,750m)	Construction of a dike on the outer side, and Road pavement		Plus slope surface repair on the inner side	
		0 **	54	87,750	307
2: Tompun Dike	0+900 to 5+300 (4,400m)	Road pavement only		Plus slope surface repair on the outer and inner sides	
		0	0	26,400	697
3: Svay Pak Drainage Sluiceway	-	Reconstruction of the existing sluiceway at the same location		(No alternatives)	
		0	0	-	-
4: Relocation Site/ Spoil Area		UNBRO relocation site along a part of Kop Srov Dike		No suitable alternatives suggested .	
		250,000	0	-	-
Borrow Pit		Use a borrow pit commercially operated, e.g. Udon area		(No alternatives)	
		0	0	-	-

* The connecting road portion in the 9,350 m stretch southward from Sta.7+650 requires no land acquisition or house evacuation

** The land on the outer side of Kop Srov Dike belongs to the Government.

Table II3-2 Project Cost for the Reinforcement of Kop Srov and Tompun Dikes

Project Sub-component	Project Cost (US$1,000)					
	I.	II.	III.	IV.	V.	Total
1. Reinforcement of Kop Srov Dike (7.65km)	12,355	130	371	1,853	1,236	15,944
2. Reinforcement of Tompun Dike (4.44km)	2,500	0	75	375	250	3,201
3. Reconstruction of Svay Pak Drainage Sluiceway (1.5m wide x 2.0m high x 27.35m long x 3 lanes)	742	0	22	111	74	950
4. Preparation of Relocation Site / Spoil Area (25ha)	189	500	6	28	19	742
Grand Total	**15,787**	**630**	**474**	**2,368**	**1,579**	**20,837**

Remarks:

I. Construction Cost

II. Land Acquisition and House Evacuation

III.Administration Cost

IV. Engineering Service

V. Physical Contingency

Table II3-3 Implementation Schedule for the Reinforcement of Kop Srov and Tompun Dikes and for the Tompun Watershed Drainage Improvement

Project Component	Cost (US$ mil.)	Year 2000	2001	2002	2003	2004	2005	2006	2007
Reinforcement of Kop Srov and Tompun Dikes	20.8	░	░	░	░				
-Sub-component 1: Reinforcement of kop Srov Dike (7.65 km)	15.9		■	■	■				
-Sub-component 2: Reinforcement of Tompun Dike (4.44 km)	3.2				■				
-Sub-component 3: Reconstruction of Svay Pak Drainage Sluiceway	1.0		■						
-Sub-component 4: Preparation of Relocation Site /Spoil Area (25 ha)	0.7	- -	- -	- -	- -				
Tompun Watershed Drainage Improvement	50.8	░	░	░	░	░	░	░	░
-Sub-component 1: Construction of Tompun New Pumping Station and Inlet Channel (15 m^3/sec)	11.5		■	■					
-Sub-component 2: Construction of Tompun Regulation Pond (47.5 ha)	3.6					■	■		
-Sub-component 3: Improvement of Meanchey Drainage Main, Downstream Stretch (2.635 km)	3.8			■	■				
-Sub-component 4: Improvement of Meanchey Drainage Main, Middle Stretch (1.285 km)	0.5								■
-Sub-component 5: Improvement of Meanchey Drainage Main, Upstream Stretch (0.535 km)	0.5								■
-Sub-component 6: Construction of Tum Nup Toek Drainage Sluiceway (10 m^3/sec)	0.7				■				
-Sub-component 7: Construction of Samdach Monireth Drainage Main, Downstream Stretch (1.676 km)	16.3					■	■	■	
-Sub-component 8: Construction of Samdach Monireth Drainage Main, Upstream Stretch (0.714 km)	3.7								■
-Sub-component 9: Construction of Jawaharlal Nehru Drainage Main (1.152 km)	4.1							■	■
-Sub-component 10: Improvement of Salang Drainage Main, Downstream Stretch (0.887 km)	1.3				■				
-Sub-component 11: Improvement of Salang Drainage Main, Upstream Stretch (0.488 km)	0.6								■
-Sub-component 12: Conservation of North Lake of Boeng Salang (5.1 ha)	0.7								■
- Sub-component 13: Preparation of Relocation Site / Spoil Area (26 ha)	3.5	- -	- -	- -	- -				
Total	71.6	1.05	13.10	14.00	13.45	7.20	7.20	7.55	8.05

Table II3-4 Cost Benefit Stream for Priority Projects (Compnent 2) (1/3)

No.	Year	Component 2				
		Construction Cost	OMR Cost	Total	Benefit	B-C
1	2000	164	0	164	0	-164
2	2001	6,125	0	6,125	29	-6,097
3	2002	5,230	19	5,249	1,186	-4,063
4	2003	8,269	35	8,304	2,328	-5,976
5	2004	0	59	59	4,287	4,228
6	2005	0	59	59	4,596	4,536
7	2006	0	59	59	4,926	4,867
8	2007	0	59	59	5,281	5,222
9	2008	0	59	59	5,661	5,602
10	2009	0	59	59	6,069	6,010
11	2010	0	59	59	6,506	6,447
12	2011	0	59	59	6,506	6,447
13	2012	0	59	59	6,506	6,447
14	2013	0	59	59	6,506	6,447
15	2014	0	59	59	6,506	6,447
16	2015	0	59	59	6,506	6,447
17	2016	0	59	59	6,506	6,447
18	2017	0	59	59	6,506	6,447
19	2018	0	59	59	6,506	6,447
20	2019	0	59	59	6,506	6,447
21	2020	0	59	59	6,506	6,447
22	2021	0	59	59	6,506	6,447
23	2022	0	59	59	6,506	6,447
24	2023	0	59	59	6,506	6,447
25	2024	0	59	59	6,506	6,447
26	2025	0	59	59	6,506	6,447
27	2026	0	59	59	6,506	6,447
28	2027	0	59	59	6,506	6,447
29	2028	0	59	59	6,506	6,447
30	2029	0	59	59	6,506	6,447
31	2030	0	59	59	6,506	6,447
32	2031	0	59	59	6,506	6,447
33	2032	0	59	59	6,506	6,447
34	2033	0	59	59	6,506	6,447
35	2034	0	59	59	6,506	6,447
36	2035	0	59	59	6,506	6,447
37	2036	0	59	59	6,506	6,447
38	2037	0	59	59	6,506	6,447
39	2038	0	59	59	6,506	6,447
40	2039	0	59	59	6,506	6,447
41	2040	0	59	59	6,506	6,447
42	2041	0	59	59	6,506	6,447
43	2042	0	59	59	6,506	6,447
44	2043	0	59	59	6,506	6,447
45	2044	0	59	59	6,506	6,447
46	2045	0	59	59	6,506	6,447
47	2046	0	59	59	6,506	6,447
48	2047	0	59	59	6,506	6,447
49	2048	0	59	59	6,506	6,447
50	2049	0	59	59	6,506	6,447
Total		19,788	2,785	22,573	294,603	272,030

OMR cost = 0.3%
Rate of growth of benefit until 2010 7.2% /year
Discount rate : 10%/year

EIRR	25.16%
B/C	2.76
NPV (10^3\$)	29,475

Table II3-4 Cost Benefit Stream for Priority Projects (Compnent 3) (2/3)

No.	Year	Component 3				
		Construction Cost	OMR Cost	Total	Benefit	B-C
1	2000	800	0	800	0	-800
2	2001	6,424	4	6,428	58	-6,370
3	2002	8,229	36	8,265	566	-7,699
4	2003	4,406	77	4,483	1,298	-3,185
5	2004	6,713	99	6,812	1,788	-5,024
6	2005	6,713	133	6,846	2,565	-4,281
7	2006	6,954	166	7,120	3,445	-3,676
8	2007	7,451	201	7,652	4,464	-3,188
9	2008	0	238	238	5,672	5,433
10	2009	0	238	238	6,080	5,842
11	2010	0	238	238	6,518	6,280
12	2011	0	238	238	6,518	6,280
13	2012	0	238	238	6,518	6,280
14	2013	0	238	238	6,518	6,280
15	2014	0	238	238	6,518	6,280
16	2015	0	238	238	6,518	6,280
17	2016	0	238	238	6,518	6,280
18	2017	0	238	238	6,518	6,280
19	2018	0	238	238	6,518	6,280
20	2019	0	238	238	6,518	6,280
21	2020	0	238	238	6,518	6,280
22	2021	0	238	238	6,518	6,280
23	2022	0	238	238	6,518	6,280
24	2023	0	238	238	6,518	6,280
25	2024	0	238	238	6,518	6,280
26	2025	0	238	238	6,518	6,280
27	2026	0	238	238	6,518	6,280
28	2027	0	238	238	6,518	6,280
29	2028	0	238	238	6,518	6,280
30	2029	0	238	238	6,518	6,280
31	2030	0	238	238	6,518	6,280
32	2031	0	238	238	6,518	6,280
33	2032	0	238	238	6,518	6,280
34	2033	0	238	238	6,518	6,280
35	2034	0	238	238	6,518	6,280
36	2035	0	238	238	6,518	6,280
37	2036	0	238	238	6,518	6,280
38	2037	0	238	238	6,518	6,280
39	2038	0	238	238	6,518	6,280
40	2039	0	238	238	6,518	6,280
41	2040	0	238	238	6,518	6,280
42	2041	0	238	238	6,518	6,280
43	2042	0	238	238	6,518	6,280
44	2043	0	238	238	6,518	6,280
45	2044	0	238	238	6,518	6,280
46	2045	0	238	238	6,518	6,280
47	2046	0	238	238	6,518	6,280
48	2047	0	238	238	6,518	6,280
49	2048	0	238	238	6,518	6,280
50	2049	0	238	238	6,518	6,280
Total		47,690	10,732	58,422	286,658	228,236

OMR cost = 0.5%		EIRR	11.69%
Rate of growth of benefit until 2010	7.2% /year	B/C	1.17
Discount rate : 10%/year		NPV (10^3\$)	5,909

Table II3-4 Cost Benefit Stream for Priority Projects (Compnent 2 plus 3) (3/3)

No.	Year	Component 2 plus 3				
		Construction Cost	OMR Cost	Total cost	Benefit	B-C
1	2000	964	0	964	0	-964
2	2001	12,549	4	12,553	87	-12,466
3	2002	13,459	55	13,514	1,752	-11,762
4	2003	12,675	112	12,787	3,626	-9,161
5	2004	6,713	159	6,872	6,075	-796
6	2005	6,713	192	6,905	7,161	256
7	2006	6,954	226	7,180	8,371	1,191
8	2007	7,451	261	7,712	9,745	2,034
9	2008	0	298	298	11,333	11,035
10	2009	0	298	298	12,149	11,851
11	2010	0	298	298	13,024	12,726
12	2011	0	298	298	13,024	12,726
13	2012	0	298	298	13,024	12,726
14	2013	0	298	298	13,024	12,726
15	2014	0	298	298	13,024	12,726
16	2015	0	298	298	13,024	12,726
17	2016	0	298	298	13,024	12,726
18	2017	0	298	298	13,024	12,726
19	2018	0	298	298	13,024	12,726
20	2019	0	298	298	13,024	12,726
21	2020	0	298	298	13,024	12,726
22	2021	0	298	298	13,024	12,726
23	2022	0	298	298	13,024	12,726
24	2023	0	298	298	13,024	12,726
25	2024	0	298	298	13,024	12,726
26	2025	0	298	298	13,024	12,726
27	2026	0	298	298	13,024	12,726
28	2027	0	298	298	13,024	12,726
29	2028	0	298	298	13,024	12,726
30	2029	0	298	298	13,024	12,726
31	2030	0	298	298	13,024	12,726
32	2031	0	298	298	13,024	12,726
33	2032	0	298	298	13,024	12,726
34	2033	0	298	298	13,024	12,726
35	2034	0	298	298	13,024	12,726
36	2035	0	298	298	13,024	12,726
37	2036	0	298	298	13,024	12,726
38	2037	0	298	298	13,024	12,726
39	2038	0	298	298	13,024	12,726
40	2039	0	298	298	13,024	12,726
41	2040	0	298	298	13,024	12,726
42	2041	0	298	298	13,024	12,726
43	2042	0	298	298	13,024	12,726
44	2043	0	298	298	13,024	12,726
45	2044	0	298	298	13,024	12,726
46	2045	0	298	298	13,024	12,726
47	2046	0	298	298	13,024	12,726
48	2047	0	298	298	13,024	12,726
49	2048	0	298	298	13,024	12,726
50	2049	0	298	298	13,024	12,726
Total		67,478	13,517	80,995	581,260	500,266

OMR cost = 0.5%
Rate of growth of benefit until 2010 7.2% /year
Discount rate : 10%/year

EIRR	16.67%
B/C	1.69
NPV (10'S)	35,384

Table II3-5 O/M Cost of Priority Projects Compared with DDS's Revenue Since 2008

a. Operation and maintenance costs since 2008		
a-1 Investment cost		
Component 2	20.80 US$ million	
Component 3	50.80 US$ million	
Total	71.60 US$ million	
a-2 Proportion of OM costs		
Component 2	0.30%	
Component 3	0.50%	
a-3 Operation and maintenance costs since 2008		
Component 2	0.06 US$ million/year	
Component 3	0.25 US$ million/year	
Total	0.32 US$ million/year	
b. Revenue for DSD		
b-1 DSD's revenue		
1997	0.09 US$ million/year	
2010	0.39 US$ million/year	
2008	0.34 US$ million/year	
b-1 Revenue from wastewater surcharge		
PPWSA's revenue in 1996	13.5 Riel billion	
PPWSA's revenue in 2007	53.1 Riel billion	
PPWSA's revenue in 2008	54.8 Riel billion	(An increase of 3.2% over 2007)
Wastewater surcharge for DSD in 2008	5.5 Riel billion	(10% of PPWSA's water sale)
	1.41 US$ million	($: 3,880 Riel)
c. Comparison in 2008		
DSD's revenue by government budget	0.34 US$ million	
Wastewater surcharg revenue	1.41 US$ million	
DSD's total revenue	**1.76 US$ million**	
Total OM cost required since 2008	**0.32 US$ million**	
Balance	**1.44 US$ million**	

Table II4-1 Comparison on Pump Type

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 operating building.	Superstructure is necessary.	No superstructure is required. An operation building only is required. Simple structure with smaller areas are 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	Automization is easily done because prime action is unnecessary.	Prime action is required, accordingly automization is complicated.	Automization 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 electic motor is generally shorter than other types.
2.6 Noise	Less noise emission than the horizontal-shaft type because of submerged impellers installed, while more noisy 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

Table II4-2 Land Acquisition and House Evacuation Required for the Tompun Watershed Drainage Improvement

Sub-component	Section	Recommended Plan		Alternative Plan	
		Land Acquisition (m^2)	House Evacuation (house)	Land Acquisition (m^2)	House Evacuation (house)
1: Tompun New Pumping Station and Inlet Channel	1,020 m	Beside the existing Pumping Station		(No alternatives)	
		5,000	30	-	-
2: Tompun Regulation Pond	(47.5 ha)	On the existing Boeng Tompun		(No alternatives)	
		20,000	20	-	-
3: Meanchey Drainage Main, Downstream Stretch	2,635 m	Channel improvement with maintenance roads on both sides		Channel improvement without maintenance roads	
		28,000	90	16,000	50
4: Meanchey Drainage Main, Middle Stretch	1,285 m	Channel improvement with maintenance roads on both sides		Channel improvement without maintenance roads	
		0	120	0	80
5: Meanchey Drainage Main, Upstream Stretch	535 m	Channel improvement without maintenance roads		(No alternatives)	
		0	10	-	-
6: Tum Nup Toek Drainage Sluiceway	61 m	Near the existing Tum Nup Toek Pumping Station		(No alternatives)	
		3,000	10	-	-
7: Samdach Monireth Drainage Main, Downstream Stretch	1,676 m	Construction of a box culvert under Samdach Monireth Street		(No Alternative)	
		2,400	30	-	-
8: Samdach Monireth Drainage Main, Upstream Stretch	714 m	Construction of a box culvert under Samdach Monireth Street		(No alternatives)	
		0	0	-	-
9: Jawaharlal Nehru Drainage Main	1,152 m	Construction of a box culvert under Jawaharlal Nehru Street		(No alternatives)	
		0	0	-	-
10: Salang Drainage Main, Downstream Stretch	887 m	Channel improvement with maintenance roads on both sides		Channel improvement without maintenance roads	
		0	60	0	30
11: Salang Drainage Main, Upstream Stretch	488 m	Channel improvement with a maintenance road on one side		Channel improvement without any maintenance road	
		0	90	0	70
12: Conservation of the North Lake of Boeng Salang	(5.1 ha)	Dredging and provision of a walkway along the lake perimeter		(No alternatives)	
		0	0	-	-
13: Relocation Site/ Spoil Area		Near Tompun New Pumping Station		No suitable alternatives suggested.	
		260,000	20	-	-
Borrow Pit		Use a borrow pit commercially operated		(No alternatives)	
		0	0	-	-

Table II4-3 Project Cost for the Tompun Watershed Drainage Improvement

Project Sub-component	Project Cost (US$1,000)					
	I.	II.	III.	IV.	V.	Total
1. Construction of Tompun New Pumping Station and Inlet Channel (Pumping Capacity: 15 m^3/sec, Inlet Channel Length: 1.02km)	8,940	97	268	1,341	894	11,540
2. Construction of Tompun Regulation Pond (47.5ha)	2,658	148	80	399	266	3,550
3. Improvement of Meanchey Drainage Main, Downstream Stretch (2.635km long)	2,714	356	81	407	271	3,830
4. Improvement of Meanchey Drainage Main, Middle Stretch (1.285km long)	202	288	6	30	20	547
5. Improvement of Meanchey Drainage Main, Upstream Stretch (0.535km long)	339	24	10	51	34	458
6. Construction of Tum Nup Toek Drainage Sluiceway (Q=10m^3/sec, 3.0m wide x 3.6m high x 61m long x 1 lane)	507	39	15	76	51	688
7. Construction of Samdach Monireth Drainage Main, Downstream Stretch (1.676km long)	12,693	84	381	1,904	1,269	16,331
8. Construction of Samdach Monireth Drainage Main, Upstream Stretch (0.714km long)	2,863	0	86	429	286	3,665
9. Construction of Jawaharlal Nehru Drainage Main (1.152km long)	3,230	0	97	485	323	4,135
10. Improvement of Salang Drainage Main, Downstream Stretch (0.887km long)	866	144	26	130	87	1,252
11. Improvement of Salang Drainage Main, Upstream Stretch (0.488km long)	333	216	10	50	33	642
12. Conservation of North Lake of Boeng Salang (5.1ha)	531	0	16	80	53	680
13. Preparation of Relocation Site/Spoil Area (26ha)	1,680	1,348	50	252	168	3,498
Grand Total	37,556	2,744	1,127	5,633	3,756	50,816

Remarks:
I. Construction Cost
II. Land Acquisition and House Evacuation
III.Administration Cost
IV. Engineering Service
V. Physical Contingency