2.2.3.3 Drainage Equipment (Pump, Electric Equipment, Pump Operation & Maintenance House)

(1) Selection of Pump Type

Since design conditions of pump require a large discharge capacity under low pumping-up head in this Project, horizontal/vertical shaft - axial/mixed flow type and submergible type pumps shall be adopted for alternatives. The selection process is described hereinafter.

The Gate-Mounted Pump Type as installed widely in pumping stations in Japan and at Preah Kumlung Pumping Station (existing Pumping Station No. 3), has been selected as the most attractive type of pump for the Project.

Table 2.2.12 Selection of Pump Type

Contents of Comparison
<u>Gate-Mounted Pump Type</u> This type of pump is composed mainly of a steel roller-gate on which 1 or a pair of submergible pump with flap valve is mounted. The steel roller-gate is provided at a part of the standardized discharge canal to make a sluiceway that connects up to the outlet to the river. With these arrangements, the gate-mounted pump type pumping station functions as follows: - Upon lifting the gate-mounted pump by the electric drive hoist machine over its clear opening, rainwater gathered in UGR can discharge freely by gravity flow to the river whenever water level of Tonle Sap River is lower than outlet. This gravity flow discharge, i.e., non-electric discharge operation will be possible during 6 months between January and June, and thus contributes considerably to save operation cost on electricity consumption; - When water level of Tonle Sap River rises higher than outlet during rainy season, the gate-mounted pump must be closed to prevent reflux of river water. Then, the submergible pumps mounted on the gate can operate electrically to discharge rainwater gathered in UGR; - There is an advantage that cost can be reduced, like equipment cost, site acquisition cost, etc; and - The pump O&M house becomes compact. It is therefore concluded that selection of the gate-mounted pump type is technically and scenically sound in design and economically feasible.
<u>Horizontal Shaft - Axial/Mixed Flow Type Pump</u> This type of pump is unable to create self-priming condition alone due to the impeller's position in air space, so that it is impossible to start operation quickly in response to demand on rainwater discharge. To attain such self-priming condition, the pump must be equipped with a lot of auxiliary equipment, which will be more expensive. Size of facilities on the ground will be tall and wide. Hence, this type is not suitable for the Project.
<u>Vertical Shaft - Axial/Mixed Flow Type Pump</u> Vertical shaft - axial/mixed flow type pumps are easy to start because of their impellers are always in the submerged position. And cavitations do not happen easily. However, they must be equipped with a lot of auxiliary equipment, which will be more costly, and size of facilities on the ground will be tall and wide. Hence, this type is not suitable for the Project.
<u>Submerged Type Pump</u> This type of pump is a kind of vertical shaft - axial/mixed flow type pump, submerged and encased into the steel column. The same type was installed in the Boeung Tumpun Pumping Station in 2004 under Phase-I of the Project. These pumps can quickly respond for the discharge of rainwater on demand because they are submergible. However, this pump type is unable to discharge rainwater by gravity flow during rainy season and even the early part of the rainy season. This results in a large amount of electricity consumption. Further, it needs a large plain area because each pumping equipment unit requires an independent pump suction pit structure. Hence, this type is not suitable for the Project.

(2) Design of Pumping Station

Each pumping station is sequenced with the screen pit, underground reservoir, gate-mounted pump, outlet gate and outlet. Their basic dimensions of pumping station are as given below.

Table 2.2.13 Basic Dimensions of Pumping Station

Pumping Station (P.S.)	No. 1 P.S.	No. 3 P.S.	No. 4 P.S.	No. 5 P.S.
Max. River Water Level (EL.m)	10.2	10.2	10.2	10.2
Ground Level (EL.m)	10.5	10.7	10.7	11.3
SWL of UGR (EL.m)	8.0	8.5	9.1	9.45
Pump Start WL (EL.m)	7.1	8.1	7.9	9.1
Pump Stop WL (EL.m)	5.1	6.1	6.4	7.1
Sill of Rake Pit (EL.m)	5.1	6.1	6.4	7.1
Sill of UGR (EL.m)	5.0	5.9	6.1	6.9
Sill of Pump Suction Pit (EL.m)	3.6	4.6	4.9	5.6
Sill of Gate (EL.m)	3.6	4.6	4.9	5.6
Clear Height of Gate (m)	1.5	1.5	1.5	1.5
Sill of Pump Discharge Pit (EL.m)	3.6	4.6	4.9	5.6
Sill of Outlet Gate (EL.m)	3.6	4.6	4.9	5.6
Sectional Dimension of Outlet (m)	2.0x2.0	Dia. 1.5	2.0x2.0	2.0x2.0
Length of Outlet Conduit (m)	16	21	24	24

The basic dimensions of Gate-Mounted Pump and pump pit are as given below.

Table 2.2.14 Basic Dimensions of Gate-Mounted Pump

Pumping Station (P.S.)	No. 1 P.S.	No. 3 P.S.	No. 4 P.S.	No. 5 P.S.
Pump Discharge Volume in Total (Q m^3/s)	1.4	0.7	1.4	1.4
Water Tank: L (m) x W (m)	3.9 x 2.7	3.6 x 2.5	3.9 x 2.7	3.9 x 2.7
Gate: W (m) x H (m)	2.7 x 1.5	2.5 x 1.5	2.7 x 1.5	2.7 x 1.5
Number of Gate Leaf (No.)	1	1	1	1
Number of Pump Mounted (No.)	2	2	2	2
Pump Type	Submergible- horizontal-shaft axial flow type			
Pump Discharge/ set (Q/2 m^3/s)	0.7	0.35	0.7	0.7
Pump Total Head (m)	3.65	2.65	2.85	1.65
Pump Starting Method	Condorfare & Time Lag			
Drive Motor (kW)/pump	45	22	37	37

- Each pump shall have its suction water depth set at 1.5 m, which is the water depth at the pump auto-stop water level from sill of pump pit.
- Two (2) submergible pumps are mounted on each roller gate type steel gate, which runs up and down inside the pump pit structure.
- Handrails protect opening space of pump pit at its floor top.
- The gate is handled with monorail hoist, which travels along the I-beam type monorail fixed beneath the O&M house slab beams. The hoists shall have a hoisting capacity of around 15 tons for 2.7 m span-gates and 10 tons for 2.5 m span-gates, and shall be controlled by means of pendant type push-button switches.

- Each gate is kept at the fully closed position during rainy season to stand by pump up operation, and gate is taken out from the pump pit and rested on the floor of O&M house during dry season.
- Providing water level detector controls pump operation.
- Whenever water level of underground reservoir rises up to the pump starting water level, a buzzer will be rung to inform the operator. Then the operator must start pumps with a time lag accordingly.
- The pumps shall stop automatically whenever water level of underground reservoir goes down to the pump stop water level.

(3) Design of Pump Operation/Maintenance House

Pump Operation/Maintenance House (Pump O&M House) are provided for each pumping station. Design criteria for the Pump O&M House are as described below.

(a) Floor elevation of Pump O&M House shall be set based on comparison of the following elevation. The higher elevation is chosen as floor elevation.

- Upsurge water level of surge tank + 0.3 m or Ground surface elevation + 0.2 m

Table 2.2.15 Floor Elevation of Pump Operation/Maintenance House

Pump Stations (P.S.)	No. 1 P.S.	No. 2 P.S.	No. 4 P.S.	No. 5 P.S.
Upsurge water level (EL.m)	10.6	10.6	10.7	10.7
Ground surface elevation (EL.m)	10.9	10.8	10.9	11.3
Floor elevation (EL.m)	11.1	11.0	11.1	11.5

(b) One (1) set of main distribution panel to receive electric power from EDC's existing line and the Emergency Diesel-Engine Drive Generator Set (EGS), one (1) set of generator panel and one (1) set of pump operation panel are put on the floor of Pump O&M house.

(c) Pump, monorail hoist, EGS and each electric panel shall be connected by floor duct.

(d) To cope with EDC's electric power failure, one (1) set of EGS is located in Pump O&M house, to supply emergency power LV 400 V/230 V to the equipment to maintain the drain ability in any emergency case. The switch on/off of EGS shall be done manually by operating staff. In case of rainfall under power failure condition, operating staff shall judge the timing of EGS start based on the water level in screen pit.

(e) Electric power for Pumping Station No. 2 and No. 4 shall be supplied through 22 kV-400 V/230 V type Compact Transformer Substation (CTS), which is installed next to the existing Pumping Station No. 3.

(f) Generating capacity of EGS in each pumping station shall be as follows.

Table 2.2.16 Capacity of Emergency Diesel-Engine Drive Generator Set

Installation Location	Power Supply	Capacity of EGS
Pumping Station No. 1	Pumping Station No. 1	200 kVA
Pumping Station Existing No. 3	Pumping Station No. 2 & No. 4	200 kVA
Pumping Station No. 5	Pumping Station No. 5	150 kVA

(g) The driving time of the pump at nighttime when fueling cannot be done is assumed to be eight hours, and the capacity of fuel tank of generator is assumed to be the capacity that corresponds to operation of 8 hours. The fuel tank shall be built-in type, and when the fuel is insufficient, fuel shall be supplied with manual pump from the drum.

(h) Entrance door with louver and wall louver are installed for air ventilation. The shutter is installed on the rejection heat side of the generator (river side), and the shutter shall be opened completely before engine start. The exhaust pipe shall be the structure that can expand and contract. The Pump O&M house shall have light windows.

(i) The gate and pump shall be placed on the floor in Pump O&M house during the dry season.

(j) Structural design of Pump O&M house shall take the operation load with the monorail hoist in consideration. Appearance of Pump O&M house shall be in harmony with the surrounding landscape.

(3) Electric Power Supply System

Since outputs of pump drive motors are in the range of 22 to 45 kW, it is sufficient to provide low voltage (LV) power supply line in 400 V/230 V to each pumping station. Transformer capacities required minimum at each pumping station will be 150 to 200 kVA.

The EDC's mid-voltage (MV) 22 kV underground cable-power supply line exists along Sisowath Boulevard. EDC has also the existing 22 kV/400 V/230 V substation houses along other streets. Some of those substations can be utilized for the Project.

The main power supply for pumping station shall be commercial power supply because of the easiness and convenience of operation.

(a) Power Supply to Pumping Station No. 1 and No. 5

In consideration of EDC's data/site survey and several consultations with EDC, power supply to Pumping Station No. 1 and Pumping Station No. 5 shall utilize the existing EDC substation.

- Pumping Station No. 1 (P1): The distance from P1 to the existing Substation No. 045 is 180 m. EDC's substation has enough capacity and hence EDC can supply the necessary electric power to P1 from the substation.
- Pumping Station No. 5 (P5): The distance from P5 to the existing Substation No. 031 is 420 m. EDC's substation has enough capacity and hence EDC can supply the necessary electric power to P5 from the substation.

The recipient country at its own cost and expense shall install the secondary terminals of the existing transformers in EDC's substation for Pumping Station No. 1 and Pumping Station No. 5.

All works and costs after the terminal points, distribution line and connection works will be covered under Japan's Grant Aid.

(b) Power Supply to Pumping Station No. 2 and No. 4

In consideration of EDC's data/site survey and several consultations with EDC, a new CTS shall be installed to supply electric power to Pumping Station No. 2 and Pumping Station No. 4.

A CTS has an advantage over the utilization of the existing EDC substation in terms of cost and stable power supply in consideration of capacity shortage of the existing EDC substation.

The CTS shall be installed midway between Pumping Station No. 2 and Pumping Station No. 4, i.e., near the existing Pumping Station No. 3, so that the CTS can duly supply electric power to these pumping stations from that location. The CTS and EGS could also be located at the vacant space behind the Pumping Station existing No. 3.

Provision and installation works of MV 22kV underground cables branched from those at the Sisowath Boulevard up to the primary terminal of the newly-installed CTS near the existing Pumping Station No. 3, including connection works thereat, shall be at the expense and responsibility of the recipient country.

All works and costs after the terminal points, distribution line and connection works will be covered under the Japan's Grant Aid.

2.2.3.4 Drainage Pipe

Planning basis for drainage pipe and manhole has been established as described below.

- For planning of pipe alignment, movement of underground facility is avoided as much as possible.
- The existing drainage pipe is mostly installed under the sidewalk. Therefore, new drainage pipe should be constructed under a road and utilize existing pipe as house connection.
- For alignment of longitudinal profile of pipe, the minimum depth of covering is 1 m.
- Manhole should be located at (1) the upstream end of drainage; (2) points at which the direction and gradient change; (3) pipe junction except for connections to house or buildings; and (4) an intervals of 100 m.
- Standard rectangular manholes have been recommended basically. However, square manholes should be provided at points where the direction change remarkably and at pipe junctions. In this Basic Design Study, the following three types of manhole are adopted:
    - Type-A (rectangular): The angle where the centerline of up- and-downstream pipe crosses is 90 degrees or more.
    - Type-B (square): The angle where the centerline of up- and-downstream pipe crosses is 90 degrees or less.
    - Type-C (2-barrel): Drainage pipe and interceptor pipe are constructed in parallel.

(1) Wat Phnom Basin – R51 Drainage Main

The existing R51 drainage pipe is 600 mm in diameter. Based on hydraulic analysis, the existing R51 drainage pipe does not have a sufficient capacity. Furthermore, the R51 drainage pipe is old and in poor condition. Therefore, a new R51 Drainage Main is proposed to minimize inundation and damage by local rainfall.

The alignment of this drainage main based on site investigations is shown in Figure 2.2.10. The storm water from the new R51 Drainage Main is to be conveyed through a new R19 Drainage Main to the proposed at Underground Reservoir No. 5 (UGR5).

The depth of the proposed drainage main is set up to be enough to enable the pipe to (1) make a connecting pipe from the existing manhole, and (2) to have sufficient covering on top to prevent structural damage due to the effect of external load. The invert level of drainage pipe is EL. 7.91 m at the beginning point and EL. 7.64 m at the end point, respectively.

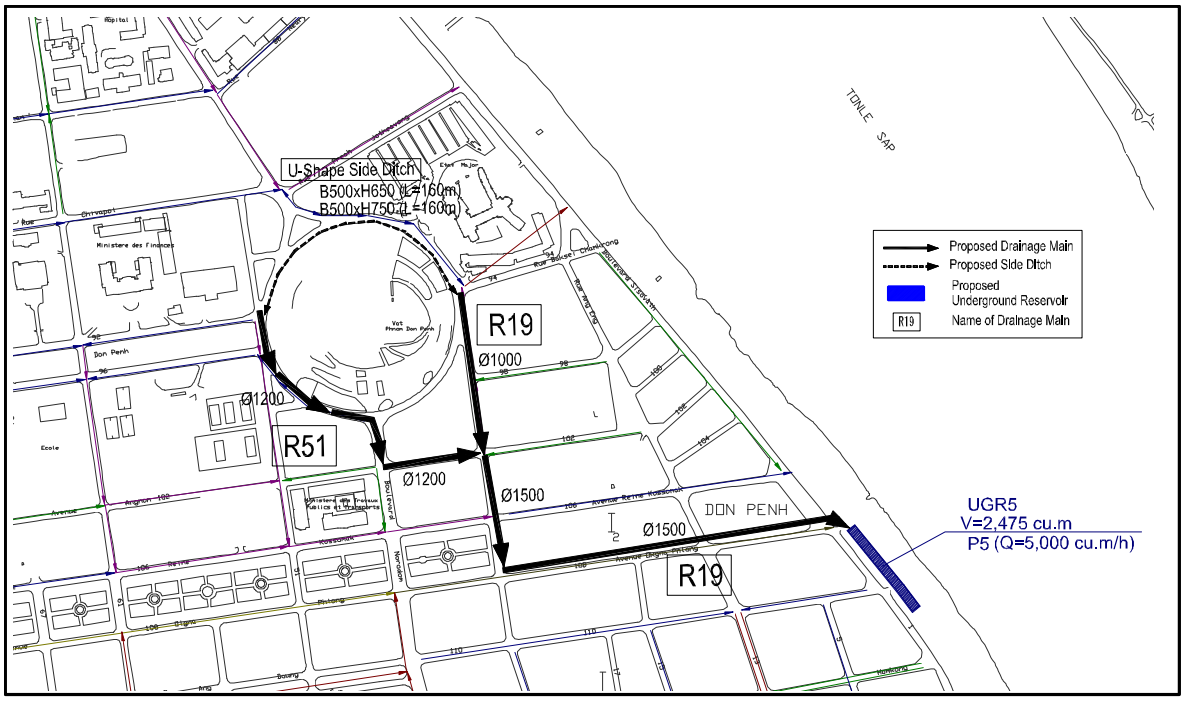


Figure 2.2.10 Alignment of Drainage Main (Wat Phnom Area)

Calculations with the MOUSE model have resulted in the requirements to the drainage main dimensions as indicated in Table 2.2.17.

Table 2.2.17 Major Features of R51 Drainage Main

Drainage Main	Diameter (mm)	Length (m)	Gradient
R51 Drainage Main	1,200	371	1/1,400

Seven (7) manholes will be installed in R51 Drainage Main. At two (2) points among the seven, connecting pipes will be installed to collect the flow from the existing drainage pipes into the R51 Drainage Main. Type of manhole and major features of connecting pipe are tabulated in Table 2.2.18.

Table 2.2.18 Major Features of Manhole and Inlet Pipe (R51 Drainage Main)

No.	Name of Manhole	Manhole Type	Diameter of Inlet Pipe (mm)	Length of Inlet Pipe (m)
1	R92-3	A	800	10
2	R96-3	A	600	10
3	R96-3A	A	-	-
4	R96-3B	A	-	-
5	R98-0	B	-	-
6	R102-3	B	-	-
7	R102-3A	A	-	-

(2) Wat Phnom Basin – R19 Drainage Main

The existing R19 drainage pipe was installed under Road No. 19. The size of the existing R19 drainage pipe gradually increases from 800 mm diameter to 1,000 mm diameter. Based on the hydraulic analysis, the existing R19 drainage pipe does not have a sufficient capacity and, besides, it is old and in very poor condition. Therefore, the existing pipe will be demolished and a new R19 Drainage Main is proposed to minimize inundation and damage by local rainfall.

An alignment of this drainage main based on site investigations is shown in Figure 2.2.10. The R19 Drainage Main will lead toward to the proposed Underground Reservoir No.5 (UGR5).

The depth of the proposed drainage main is set up to be enough to enable to the pipe to (1) make a connecting pipe from the existing manhole, and (2) to have sufficient covering on top to prevent structural damage due to the effect of external load. The invert level of drainage pipe is EL. 8.16 m at the beginning point and EL. 7.18 m at the end point, respectively.

Calculations with the MOUSE model have resulted in the requirements to the drainage main dimensions as indicated in Table 2.2.19.

Table 2.2.19 Major Features of R19 Drainage Main

Drainage Main	Diameter (mm)	Length (m)	Gradient
R19 Drainage Main	1,000	190	1/1,100
	1,500	554	1/1,800

Twelve (12) manholes will be installed in R19 Drainage Main. At four (4) points among the twelve, connecting pipes will be installed to collect the flow from the existing drainage pipes into the R19 Drainage Main. Type of manhole and major features of connecting pipe are tabulated in Table 2.2.20.

Table 2.2.20 Major Features of Manhole and Inlet Pipe (R19 Drainage Main)

No.	Name of Manhole	Manhole Type	Diameter of Inlet Pipe (mm)	Length of Inlet Pipe (m)
1	R94-3N	A	800	5
2	R94-3NA	A	-	-
3	R98-1	A	600	5
4	R102-4	B	600	10
5	R106-4	A	800	5
6	108N_E003	B	-	-
7	108N_E003A	A	-	-
8	108N_E003B	A	-	-
9	108N_E003C	A	-	-
10	108N_E003D	A	-	-
11	108N_E003E	B	-	-
12	108N_E003F	A	-	-

(3) Wat Phnom Basin – Side Ditch

Since there is a large water supply pipe of 1,200 mm in diameter under the road north of Wat Phnom, it is difficult to install a new drainage pipe. Therefore, a new side ditch is proposed to minimize inundation and damage by local rainfall.

The new side ditch will be installed under the road along the walkway of Wat Phnom. The alignment of this ditch based on site investigations is shown in Figure 2.2.10. The new side ditch will lead toward to the proposed R51 Drainage Main and the R19 Drainage Main.

Calculations with the MOUSE model have resulted in the requirements to the drainage main dimensions as indicated in Table 2.2.21.

Table 2.2.21 Major Features of Side Ditch in Wat Phnom Area

	Diameter (mm)	Length (m)	Gradient
Side Ditch	B500 x H650	160	1/1,000
	B500 x H750	160	1/1,000

(4) Central Market Area – Monivong Drainage Main

The existing Monivong drainage pipe collects storm water from the Westside area of the Central Market. The existing drainage pipe has been installed under the walkway parallel to Monivong Boulevard and the pipe is 800 mm in diameter. Based on the hydraulic analysis, the existing Monivong drainage pipe does not have sufficient capacity and, besides, the R51 drainage pipe is old and in poor condition. Therefore, a new Monivong Drainage Main is proposed to minimize inundation and damage by local rainfall.

Monivong Drainage Main will be installed under the Monivong Boulevard. The alignment of this drainage main based on site investigations is shown in Figure 2.2.11. The storm water

from the new Monivong Drainage Main is to be conveyed through the new R110 Drainage Main and R108 Drainage Main to the proposed Underground Reservoir No. 5 (UGR5).

The depth of the proposed drainage main is set up to be enough to enable the pipe to (1) make a connecting pipe from the existing manhole, and (2) to have sufficient covering on top to prevent structural damage due to the effect of external load. The invert level of drainage pipe is EL. 8.84 m at the beginning point and EL. 8.46 m at the end point, respectively.

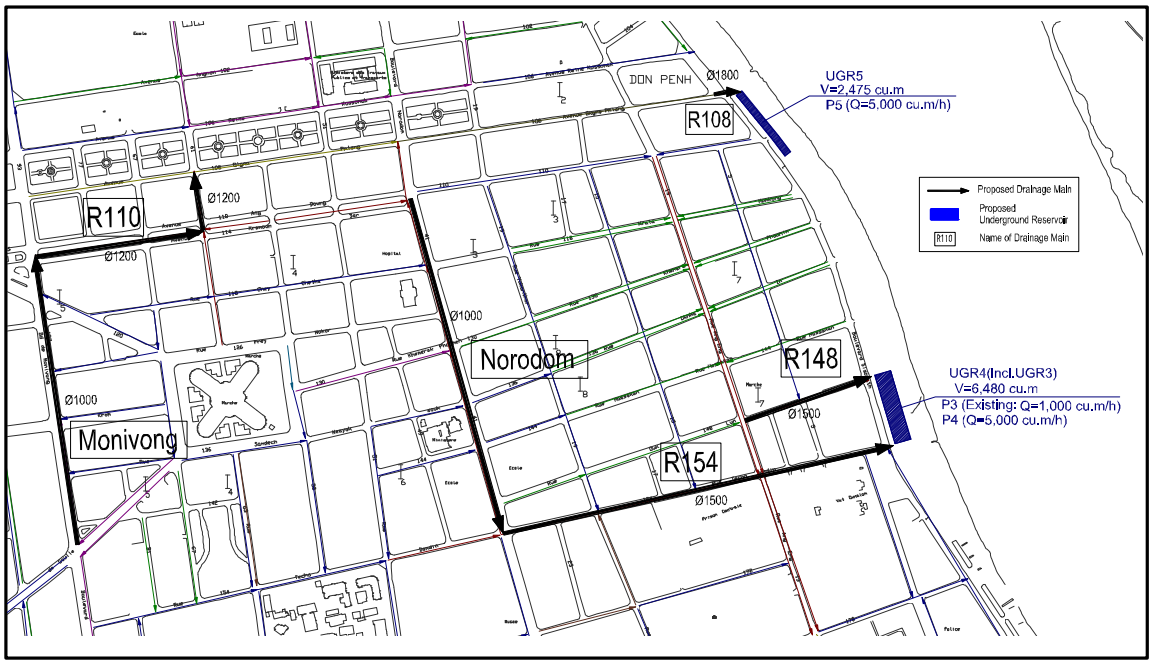


Figure 2.2.11 Alignment of Drainage Main (Central Market Area)

Calculations with the MOUSE model have resulted in the requirements to the drainage main dimensions as indicated in Table 2.2.22.

Table 2.2.22 Major Features of Monivong Drainage Main

Drainage Main	Diameter (mm)	Length (m)	Gradient
Monivong Drainage Main	1,000	454	1/1,000

Seven (7) manholes will be installed in Monivong Drainage Main. At four points among the seven, connecting pipes will be installed to collect the flow from existing drainage pipes into the Monivong Drainage Main. Type of manhole and major features of the connecting pipe are tabulated in Table 2.2.23.

Table 2.2.23 Major Features of Manhole and Inlet Pipe (Monivong Drainage Main)

No.	Name of Manhole	Manhole Type	Diameter of Inlet Pipe (mm)	Length of Inlet Pipe (m)
1	R142-1	A	800	15
2	R142-1A	A	-	-
3	R136-1	A	600	10
4	R128-1	A	600	10
5	R129-1	A	600	10
6	R129-1A	A	-	-
7	R118-7	A	600	5

(5) Central Market Area – R110 Drainage Main

The existing R110 drainage pipe was installed under the green belt along Road No. 110. The existing R110 drainage pipe is 1,000 mm in diameter. Based on the hydraulic analysis, the existing R110 drainage pipe does not have a sufficient capacity and, besides, the pipe is in poor condition. Therefore, a new R110 Drainage Main is proposed to minimize inundation and damage by local rainfall.

R110 Drainage Main will be installed under the green belt parallel to the existing R110 drainage pipe. The alignment of this drainage main based on site investigations is shown in Figure 2.2.11. R110 Drainage Main will lead toward the existing R108 drain (box culvert, B1.3 m x H1.5 m). Therefore, the depth of the proposed drainage main is set up to be able to connect with the invert level of the existing box culvert. The invert level of R110 Drainage Main is EL. 8.46 m at the beginning point and EL. 8.21 m at the end point, respectively.

Calculations with the MOUSE model have resulted in the requirements to the drainage main dimensions as indicated in Table 2.2.24.

Table 2.2.24 Major Features of R110 Drainage Main

Drainage Main	Diameter (mm)	Length (m)	Gradient
R110 Drainage Main	1,200	358	1/1,200

Four (4) manholes will be installed in R110 Drainage Main. At one point among the four, connecting pipe will be installed to collect the flow from the existing drainage pipes into the R110 Drainage Main. Type of manhole and major features of connecting pipe are tabulated in Table 2.2.25.

Table 2.2.25 Major Features of Manhole and Inlet Pipe (R110 Drainage Main)

No.	Name of Manhole	Manhole Type	Diameter of Inlet Pipe (mm)	Length of Inlet Pipe (m)
1	110S_A001	B	-	-
2	110S_A003	A	-	-
3	110S_A006	A	-	-
4	110S_A008	A	1,000	10

(6) Central Market Area – R108 Drainage Main

Some parts of the existing R108 drain are clogged with debris and sediment; however, this drain has a sufficient hydraulic capacity. The storm water from R110 Drainage Main is to be conveyed through the existing R108 drain to the proposed Underground Reservoir No. 5 (UGR5), therefore, it is necessary for the new R108 Drainage Main to connect from the existing R108 drain to Underground Reservoir No. 5.

The alignment of R108 Drainage Main based on site investigations is shown in Figure 2.2.11. At the beginning point, the invert level is EL. 7.14 m. The gradient of R108 Drainage Main is kept at the gradient of the existing drain.

Calculations with the MOUSE model have resulted in the requirements to the drainage main dimensions as indicated in Table 2.2.26.

Table 2.2.26 Major Features of R108 Drainage Main

Drainage Main	Diameter (mm)	Length (m)	Gradient
R108 Drainage Main	1,800	10	1/1,400

(7) Central Market Area – Norodom Drainage Main

The existing Monivong drainage main collects storm water from eastside area of the Central Market. The existing Norodom drainage main was installed under the walkway parallel to Norodom Boulevard and the pipe is 1,000 mm in diameter.

The existing drainage main has many adverse slope sections, and it is not functioning as a drainage pipe. Therefore, a new Monivong Drainage Main is proposed to minimize inundation and damage by local rainfall.

The new Norodom Drainage Main will be installed under the Monivong Boulevard. The alignment of this drainage main based on site investigations is shown in Figure 2.2.11. The

storm water from a new Monivong Drainage Main is to be conveyed through a new R154 Drainage Main to the proposed Underground Reservoir No. 4 (UGR4).

The depth of the proposed drainage main is set up to be enough to enable the pipe to (1) make a connecting pipe from the existing manhole, and (2) to have sufficient covering on top to prevent structural damage due to the effect of external load. The invert level of drainage pipe is EL. 8.10 m at the beginning point and EL. 7.61 m at the end point, respectively.

Calculations with the MOUSE model have resulted in the requirements to the drainage main dimensions as indicated in Table 2.2.27.

Table 2.2.27 Major Features of Norodom Drainage Main

Drainage Main	Diameter (mm)	Length (m)	Gradient
Norodom Drainage Main	1,000	539	1/1,100

Seven (7) manholes will be installed in the Norodom Drainage Main. At five (5) points among the seven, connecting pipes will be installed to collect the flow from the existing drainage pipes into the Norodom Drainage Main. Type of manhole and major features of connecting pipe are tabulated in Table 2.2.28.

Table 2.2.28 Major Features of Manhole and Inlet Pipe (Norodom Drainage Main)

No.	Name of Manhole	Manhole Type	Diameter of Inlet Pipe (mm)	Length of Inlet Pipe (m)
1	R110-7	A	1,000	5
2	R118-2	A	600	5
3	R118-2A	A	-	-
4	NoroW_A009	A	800	5
5	R136-6	A	600	5
6	NoroW_A011	A	600	5
7	NoroW_A011A	A	-	-

(8) Central Market Area – R154 Drainage Main

The existing R154 drainage pipe was installed under Road No. 154. The existing R154 drainage pipe is 1,000 mm in diameter. Based on the hydraulic analysis, the existing drainage pipe does not have a sufficient capacity and, besides, the R154 drainage pipe is very old and in poor condition. Therefore, the existing pipe will be demolished and a new R154 Drainage Main is proposed to minimize inundation and damage by local rainfall.

The alignment of this drainage main based on site investigations is shown in Figure 2.2.11. The existing drainage pipe has been collecting storm water from the area north of Road No. 154.

Therefore, the new R154 Drainage Main will be located at the north of Road No. 154 to make it connect with the existing drainage pipe. The R154 Drainage Main will lead toward the proposed Underground Reservoir No. 4 (UGR4).

The depth of the proposed drainage main is set up to be enough to enable the pipe to (1) make a connecting pipe from the existing manhole, and (2) to have sufficient covering on top to prevent structural damage due to the effect of external load. The invert level of drainage pipe is EL. 6.92 m at the beginning point and EL. 6.56 m at the end point, respectively.

Calculations with the MOUSE model have resulted in the requirements to the drainage main dimensions as indicated in Table 2.2.29.

Table 2.2.29 Major Features of R154 Drainage Main

Drainage Main	Diameter (mm)	Length (m)	Gradient
R154 Drainage Main	1,500	644	1/1,100

Ten (10) manholes will be installed in R154 Drainage Main. At six (6) points among the ten, connecting pipes will be installed to collect the flow from the existing drainage pipes into the R154 Drainage Main. Type of manhole and major features of the connecting pipe are tabulated in Table 2.2.30.

Table 2.2.30 Major Features of Manhole and Inlet Pipe (R154 Drainage Main)

No.	Name of Manhole	Manhole Type	Diameter of Inlet Pipe (mm)	Length of Inlet Pipe (m)
1	154S_A001	B	1,000	10
2	154S_A001A	A	-	-
3	R154-10	A	600	5
4	R154-10A	A	-	-
5	R154-11	A	600	5
6	154S_A034	A	1,000	5
7	154S_A035	A	1,000	5
8	154S_A035A	A	-	-
9	154S_A035B	B	600	5
10	154S_A035C	B	-	-

(9) Central Market Area – R148 Drainage Main

The existing R148 drainage main collects storm water from the area north of Road No. 148. The existing drainage main was installed under the walkway parallel to Road No. 148 and the pipe is 1,000 mm in diameter.

Based on the hydraulic analysis, the existing drainage pipe does not have a sufficient capacity. A bid market exists on both sides of Road No. 148 and many parts of the existing drainage pipe are clogged with debris and as a result, the flow capacity is remarkably restricted. Therefore, the new R148 Drainage Main is proposed to minimize inundation and damage by local rainfall.

The alignment of this drainage main based on site investigations is shown in Figure 2.2.11. The existing drainage pipe has been collecting storm water from the area north of Road No. 148. Therefore, the R148 Drainage Main will be located north of Road No.148 to make it connect with the existing drainage pipe. The R148 Drainage Main will lead toward the proposed Underground Reservoir No. 4 (UGR4).

The depth of the proposed drainage main is set up to be enough to enable the pipe to (1) make a connecting pipe from the existing manhole, and (2) to have sufficient covering on top to prevent structural damage due to the effect of external load. The invert level of drainage pipe is EL. 6.52 m at the beginning point and EL. 6.40 m at the end point, respectively.

Calculations with the MOUSE model have resulted in the requirements to the drainage main dimensions as indicated in Table 2.2.31.

Table 2.2.31 Major Features of R148 Drainage Main

Drainage Main	Diameter (mm)	Length (m)	Gradient
R148 Drainage Main	1,500	211	1/1,800

Three (3) manholes will be installed in R148 Drainage Main and at all points, connecting pipes will be installed to collect the flow into R148 Drainage Main from the existing drainage pipes. Type of manhole and major features of connecting pipe are tabulated in Table 2.2.32.

Table 2.2.32 Major Features of Manhole and Inlet Pipe (R148 Drainage Main)

No.	Name of Manhole	Manhole Type	Diameter of Inlet Pipe (mm)	Length of Inlet Pipe (m)
1	R148-1	A	1,000	5
2	R148-4	A	600	5
3	R148-4A	A	1,000	5

(10) Royal Palace & National Museum Area – R178 Drainage Main

The existing R178 drainage main was installed under the walkway parallel to Road No. 178 and the pipe is 1,000 mm in diameter. Based on the hydraulic analysis, the existing R178 drainage pipe does not have sufficient capacity and, besides, the R178 drainage pipe is in poor

condition. Therefore, the new R178 Drainage Main is proposed to minimize inundation and damage by local rainfall.

The alignment of this drainage main based on site investigations is shown in Figure 2.2.12. The R178 Drainage Main will lead toward the proposed Underground Reservoir No. 2 (UGR2).

The intersection of Norodom Boulevard and Road No. 172 has no drainage pipe. Therefore, the new R172 drainage pipe (1,000 mm in diameter, Length=20 m) will be installed to minimize inundation and damage to the area west of Norodom Boulevard.

The depth of the proposed R178 Drainage Main is set up to be enough to enable the pipe to (1) make a connecting pipe from the existing manhole, and (2) to have sufficient covering on top to prevent structural damage due to the effect of external load. The invert level of drainage pipe is EL. 6.27 m at the beginning point and EL. 6.05 m at the end point, respectively. For R172 drainage pipe, a new drainage pipe connecting with the existing manholes at the intersections of Norodom Boulevard and Road No. 172 will be installed.

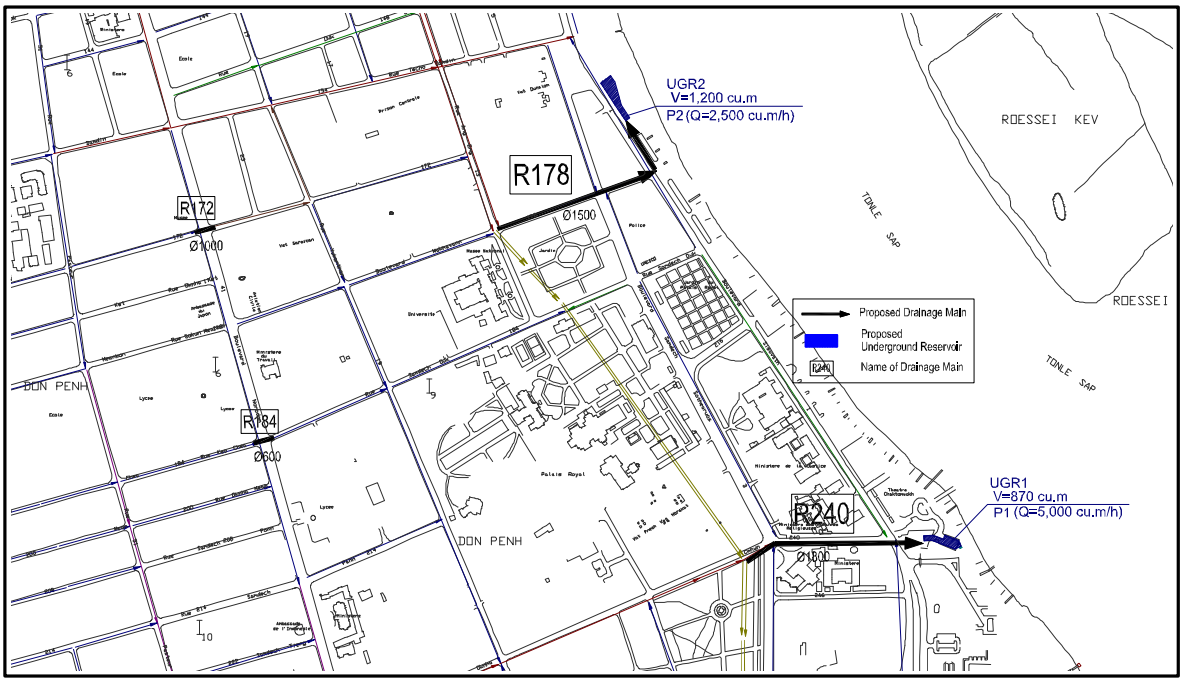


Figure 2.2.12 Alignment of Drainage Main (Royal Palace & National Museum Area)

Calculations with the MOUSE model have resulted in the requirements to the drainage main dimensions as indicated in Table 2.2.33.

Table 2.2.33 Major Features of R178 Drainage Main

Drainage Main	Diameter (mm)	Length (m)	Gradient
R178 Drainage Main	1,500	421	1/2,000

Eight (8) manholes will be installed in R178 Drainage Main. At five (5) points among the ten, connecting pipes will be installed to collect the flow from the existing drainage pipes into the R178 Drainage Main. Type of manhole and major features of the connecting pipe are tabulated in Table 2.2.34.

Table 2.2.34 Major Features of Manhole and Inlet Pipe (R178 Drainage Main)

No.	Name of Manhole	Manhole Type	Diameter of Inlet Pipe (mm)	Length of Inlet Pipe (m)
1	13W_A999	A	1,000	10
2	13W_A006	A	1,000	5
3	13W_A006A	A	-	-
4	R178-9	A	600	5
5	R178-9A	A	600	5
6	R178-9B	A	600	5
7	R178-9C	B	-	-
8	R178-9D	C	-	-

(11) Royal Palace & National Museum Area – R240 Drainage Main

The existing R240 drainage main was installed under the walkway parallel to Road No. 240 and the pipe is 1,000 mm in diameter. This drainage main is collecting storm water from around the Royal Palace. Based on the hydraulic analysis, the existing R240 drainage pipe does not have a sufficient capacity. Therefore, a new R240 Drainage Main is proposed to minimize inundation and damage by local rainfall.

The alignment of this drainage main based on site investigations is shown in Figure 2.2.12. The R240 Drainage Main will lead toward the proposed Underground Reservoir No. 1 (UGR1).

The intersection of Norodom Boulevard and Road No. 184 has no drainage pipe. A new R184 drainage pipe (600 mm in diameter, Length=20 m) will be installed to minimize inundation and damage to the area west of Norodom Boulevard.

The depth of the proposed R240 Drainage Main is set up to be enough to enable the pipe to (1) make a connecting pipe from the existing manhole, and (2) to have sufficient covering on top to prevent structural damage due to the effect of external load. The invert level of drainage pipe is EL. 5.23 m at the beginning point and EL. 5.10 m at the end point, respectively. For

R184 drainage pipe, a new drainage pipe connecting with the existing manholes at the intersections of Norodom Boulevard and Road No. 184 will be installed.

Calculations with the MOUSE model have resulted in the requirements to the drainage main dimensions as indicated in Table 2.2.35.

Table 2.2.35 Major Features of R240 Drainage Main

Drainage Main	Diameter (mm)	Length (m)	Gradient
R240 Drainage Main	1,800	305	1/2,400

Five (5) manholes will be installed in R240 Drainage Main. At three (3) points among the five, connecting pipes will be installed to collect the flow from existing drainage pipes into the R240 Drainage Main. Type of manhole and major features of the connecting pipe are tabulated in Table 2.2.36.

Table 2.2.36 Major Features of Manhole and Inlet Pipe (R240 Drainage Main)

No.	Name of Manhole	Manhole Type	Diameter of Inlet Pipe (mm)	Length of Inlet Pipe (m)
1	240S_A019	C	1,000	5
2	R240-14	C	600	15
3	R240-14A	C	-	-
4	R240-7	C	600	15
			600	5
5	R240-7A	C	-	-

2.2.3.5 Interceptor Pipe

Interceptor system is designed to prevent wastewater from being directly discharged into the Tonle Sap River.

(1) Target Year and Design Population

Target year is set to be the year 2010, in accordance with the Master Plan formulated in "The Study on the Master Plan of Greater Phnom Penh Water Supply in the Kingdom of Cambodia", JICA, 2005. Design population is based on residential population data of each sangkat at the year 2010 provided by MPP. Design population of each catchment area is given in the following table.

Table 2.2.37 Design Population

Catchment Area	Design Population
UGR1	2,160
UGR2	7,518
UGR4	36,956
UGR5	26,264
Total	72,898

(2) Per Capita Wastewater Discharge

Maximum hourly per capita wastewater discharge is adopted for calculation of design flow of the Interceptor. Per capita wastewater discharge is estimated under the conditions given below.

- Design maximum daily water consumption of 131 lpcd is based on the report prepared by "The Study on the Master Plan of Greater Phnom Penh Water Supply in the Kingdom of Cambodia", JICA, 2005.
- Infiltration allowance is assumed as 20 lpcd, which corresponds to 15% of maximum daily water consumption.
- Maximum hourly per capita wastewater discharge = 1.5 x (Design maximum daily water consumption) + infiltration allowance.

Table 2.2.38 Calculation of Per Capita Wastewater Discharge

Per Capita Wastewater Discharge	Item	Water Volume (lpcd)	Remarks
Average Daily	Water Consumption	99	
	Infiltration	20	
	Total	119	
Maximum Daily	Water Consumption	131	(I)
	Infiltration	20	(II)=(I)×0.15
	Total	151	(III)=(I)+(II)
Maximum Hourly	Water Consumption	197	(IV)=(I)×1.5
	Infiltration	20	(V)=(II)
	Total	217	(VI)=(IV)+(V)
	Round-up	**220**	Round-up of (VI)

(3) Design of Interceptor System

Interceptor system is designed under the design policy itemized below, and outline of the system is summarized in Table 2.2.39. Moreover, layout of Interceptor pipe is shown in Figure 2.2.13

- Interceptor is installed alongside Tonle Sap River to convey the wastewater trapped by proposed drainage mains.
- In the area where UGR is constructed, the interceptor is constructed inside the UGR to reduce construction cost.

- In the area where the green belt is available, the interceptor is laid under the green belt, otherwise under the walkway or car road of Sisovath Boulevard.
- Dimension of the interceptor is determined to meet design maximum hourly wastewater flow by using Manning formula.

Table 2.2.39 Summary of Interceptor System

Location	Open Ditch/ Circular Pipe	Open Ditch		Diameter (mm)	Length (m)
		B(mm)	H(mm)		
UGR5	Open Ditch	500	500	-	129
From UGR5 to UGR4	Circular Pipe	-	-	500	363
UGR4	Open Ditch	500	500	-	122
From UGR4 to UGR2	Circular Pipe	-	-	600	68
UGR2	Open Ditch	700	500	-	40
From UGR2 to UGR1	Circular Pipe	-	-	700	847
From UGR1 to End point	Circular Pipe	-	-	700	249
Total	-	-	-	-	1,818

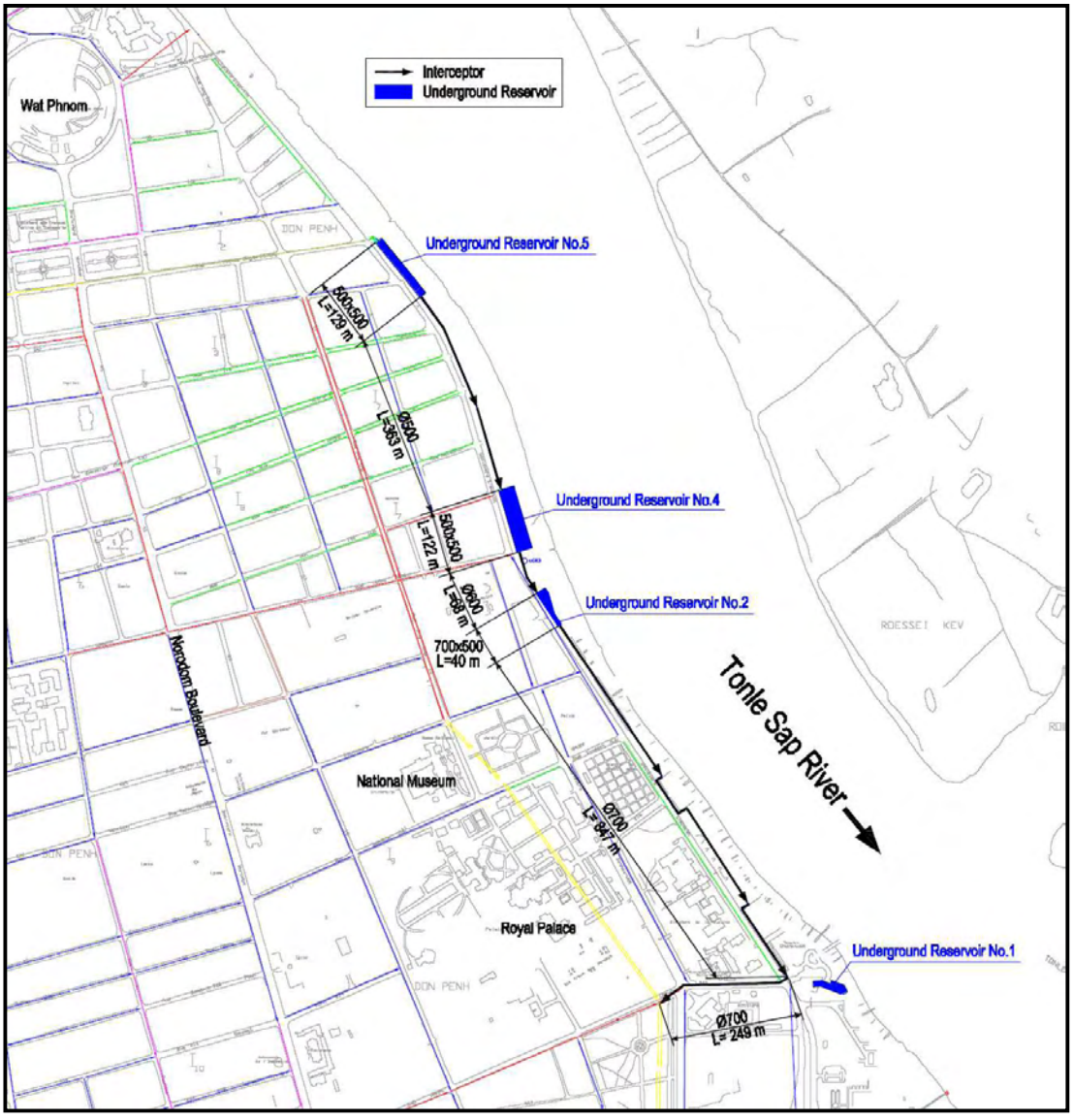


Figure 2.2.13 Layout of Interceptor Pipe

2.2.4 Basic Design Drawing

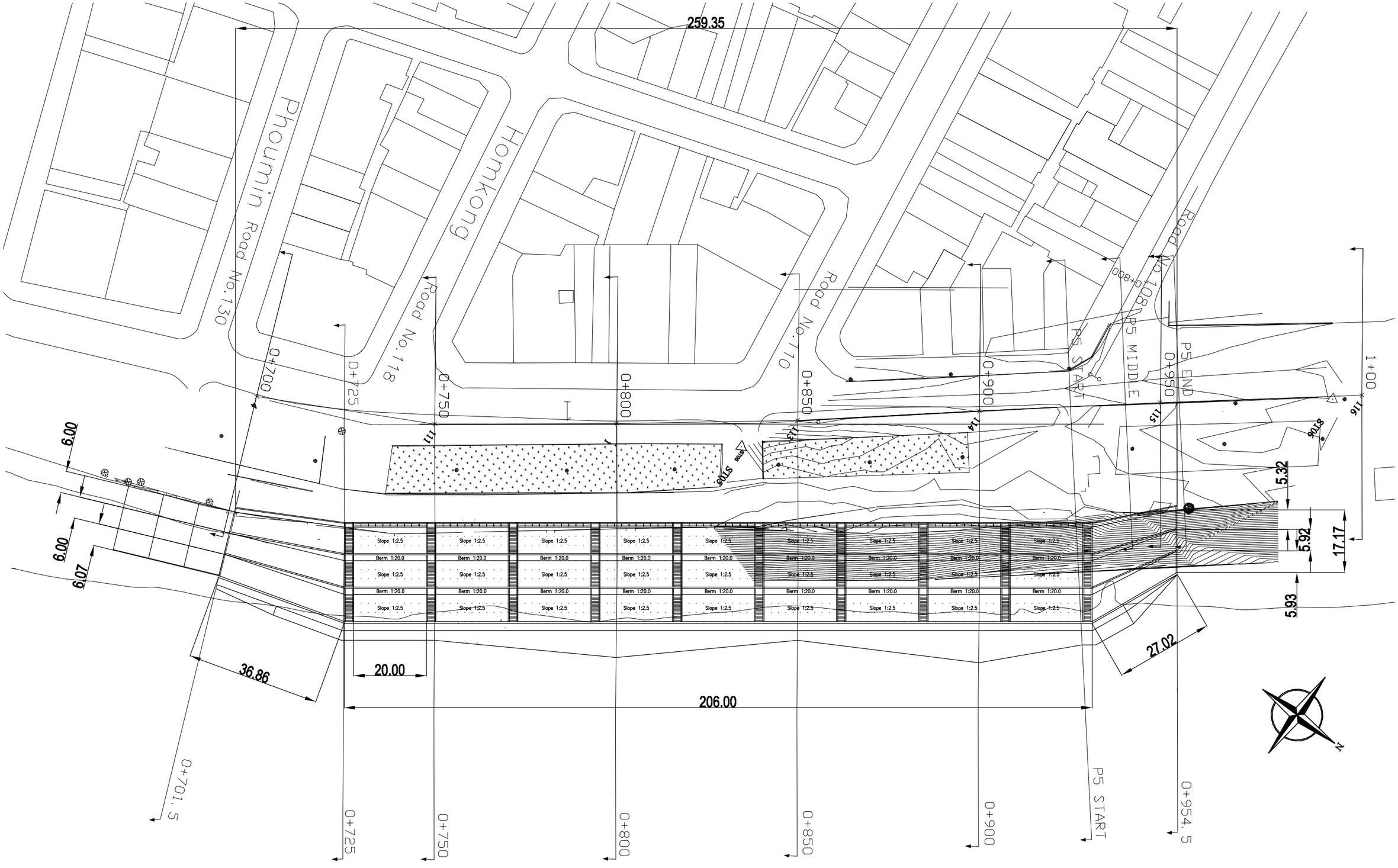
This section lists down the drawings of the Basic Design Study for the Project as tabulated below.

LIST OF DRAWINGS (1/2)

No.	Title of Drawings	Drawing No.
	REVETMENT WORK	
	Old Market East Revetment	
	Plan	FP-OM-01
	Typical Drawing	FP-OM-02
	Cross Sections	FP-OM-03
	Chakto Mukh Theater Revetment	
	Plan	FP-CM-01
	Typical Drawing	FP-CM-02
	Cross Sections	FP-CM-03
	Others	
	Structural Details of Concrete Block, Weep Hole and Hexapod	FP-OT-01
	PUMPING STATION AND UNDERGROUND RESERVOIR	
	Pumping Station No. 1 &Underground Reservoir No. 1	
	General Plan	PR-P1-01
	Typical Sections (1/2)	PR-P1-02
	Typical Sections (2/2)	PR-P1-03
	Layout of Foundation Pile	PR-P1-04
	Screen Pit and Pump O&M House	PR-P1-05
	Pumping Station No. 2 &Underground Reservoir No. 2	
	General Plan	PR-P2-01
	Typical Sections (1/2)	PR-P2-02
	Typical Sections (2/2)	PR-P2-03
	Layout of Foundation Pile	PR-P2-04
	Screen Pit and Pump O&M House	PR-P2-05
	Pumping Station No. 4 &Underground Reservoir No. 4	
	General Plan	PR-P4-01
	Typical Sections	PR-P4-02
	Layout of Foundation Pile	PR-P4-03
	Screen Pit and Pump O&M House	PR-P4-04

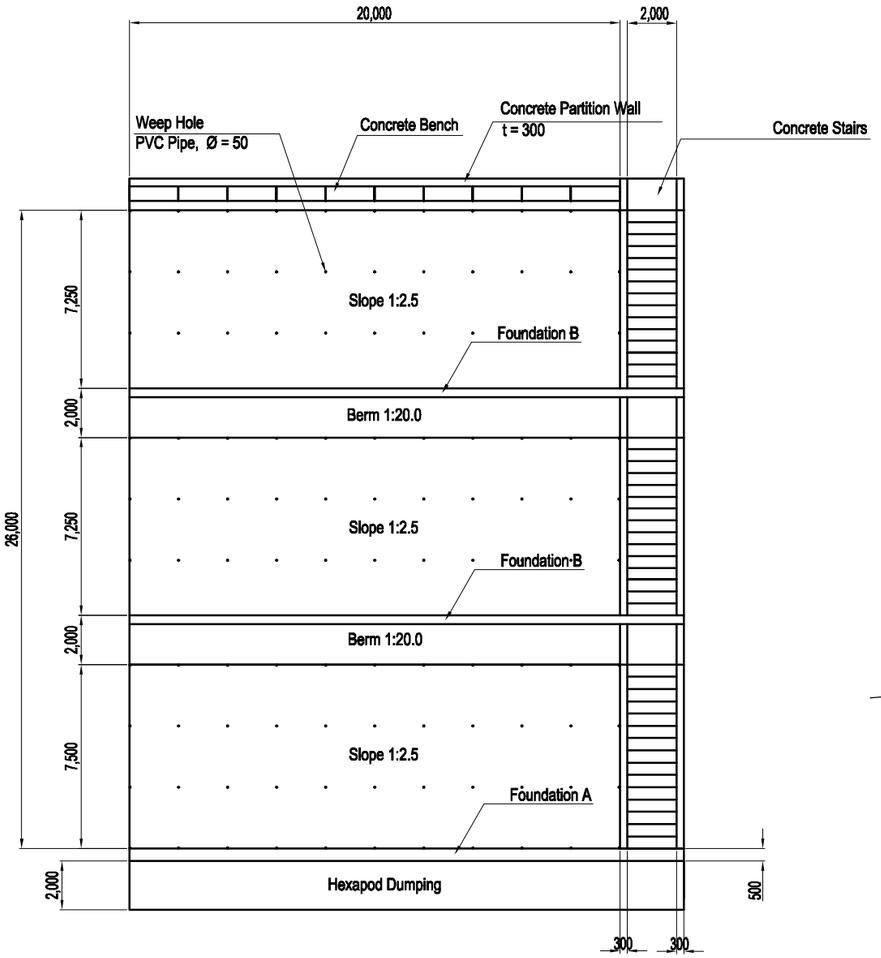
LIST OF DRAWINGS (2/2)

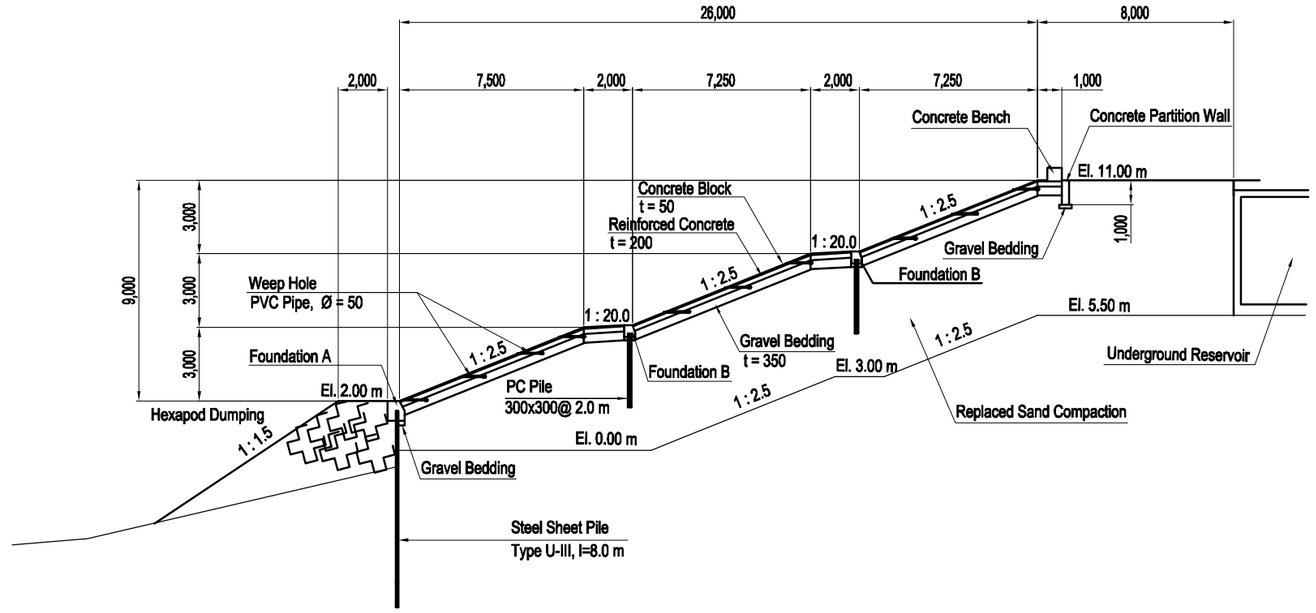
No.	Title of Drawings	Drawing No.
	Pumping Station No. 5 &Underground Reservoir No. 5	
	General Plan	PR-P5-01
	Typical Sections	PR-P5-02
	Layout of Foundation Pile	PR-P5-03
	Screen Pit and Pump O&M House	PR-P5-04
	Others	
	Wiring Flow Chart	PR-OT-01
	Drainage Main	
	General	
	General Plan of Drainage Facilities	DM-GR-01
	Detail of Manhole & Drainage Pipe	DM-GR-02
	Wat Phnom Basin	
	Plan & Profile R51 Drainage Main (1/2)	DM-WP-01
	Plan & Profile R51 Drainage Main (2/2)	DM-WP-02
	Plan & Profile R19 Drainage Main (1/2)	DM-WP-03
	Plan & Profile R19 Drainage Main (2/2)	DM-WP-04
	Central Market Area	
	Plan & Profile Monivong Drainage Main	DM-CM-01
	Plan & Profile R110 & R108 Drainage Main	DM-CM-02
	Plan & Profile Norodom Drainage Main	DM-CM-03
	Plan & Profile R154 Drainage Main (1/2)	DM-CM-04
	Plan & Profile R154 Drainage Main (2/2)	DM-CM-05
	Plan & Profile R148 Drainage Main	DM-CM-06
	Royal Palace & National Museum Area	
	Plan & Profile R178 Drainage Main	DM-RN-01
	Plan & Profile R240 Drainage Main	DM-RN-02
	Interceptor	
	Plan & Profile UGR5-UGR4	DM-IP-01
	Plan & Profile UGR4-UGR2, UGR2-Chakto Mukh Theater (1/2)	DM-IP-02
	Plan & Profile UGR2- Chakto Mukh Theater (2/2)	DM-IP-03
	Plan & Profile Chakto Mukh Theater - Existing Chamber	DM-IP-04



Scale 0 20 40 60 80 100m

The Basic Design Study on Flood Protection and Drainage Improvement Project in the Municipality of Phnom Penh (Phase II)	Drawing No. FP-OM-01
JICA JAPAN INTERNATIONAL COOPERATION AGENCY CTI CTI ENGINEERING INTERNATIONAL CO., LTD. NIPPON KOEI CO., LTD.	Old Market East Revetment Plan





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The Basic Design Study on Flood Protection and Drainage Improvement Project in the Municipality of Phnom Penh (Phase II)	Drawing No. FP-OM-02
JICA JAPAN INTERNATIONAL COOPERATION AGENCY CTI CTI ENGINEERING INTERNATIONAL CO., LTD. NIPPON KOEI CO., LTD.	Old Market East Revetment Typical Drawing

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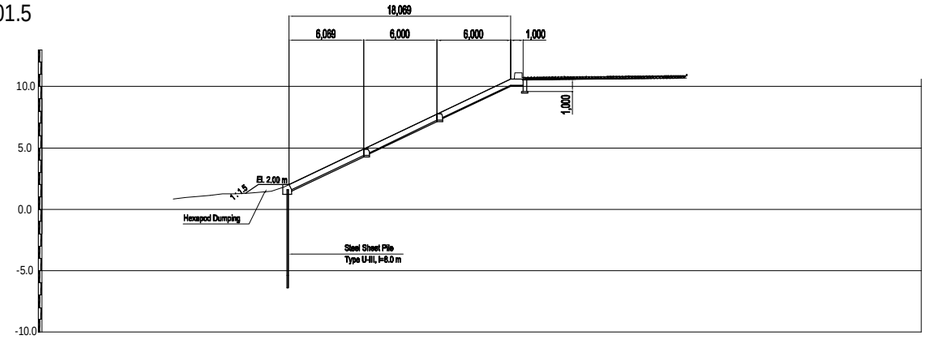

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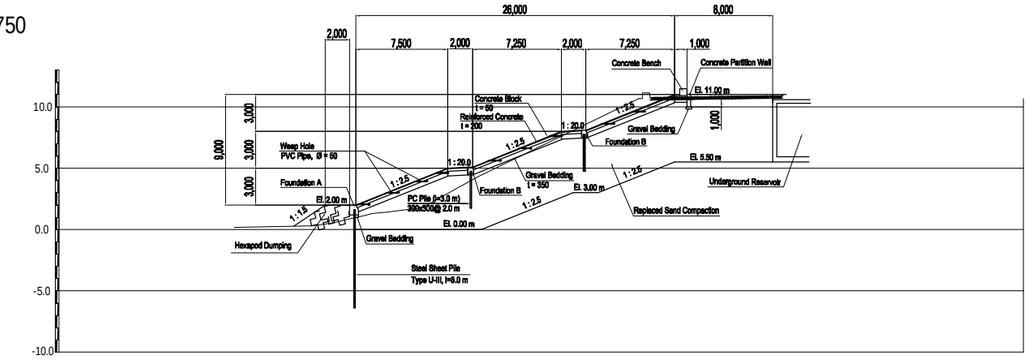

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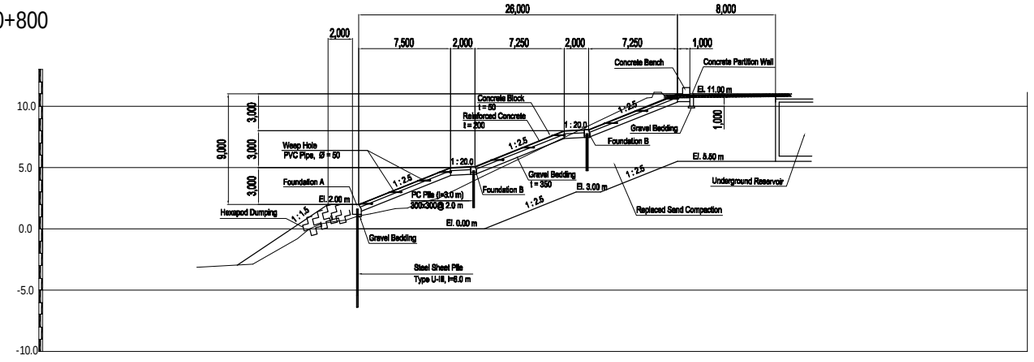

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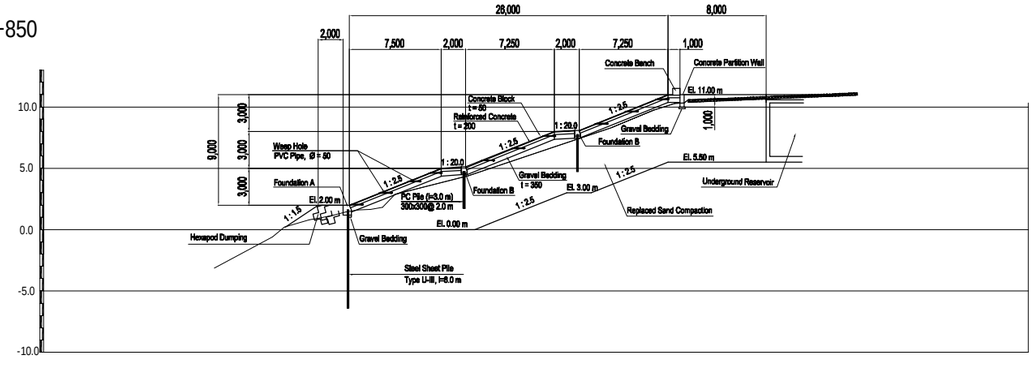

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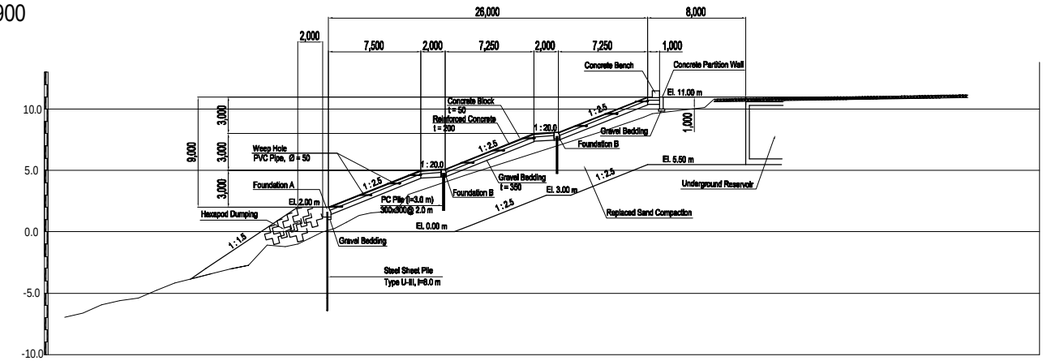
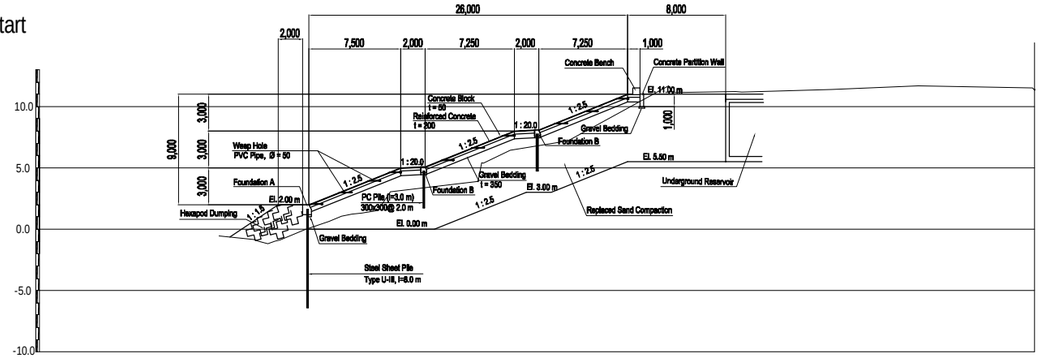


P5 Start



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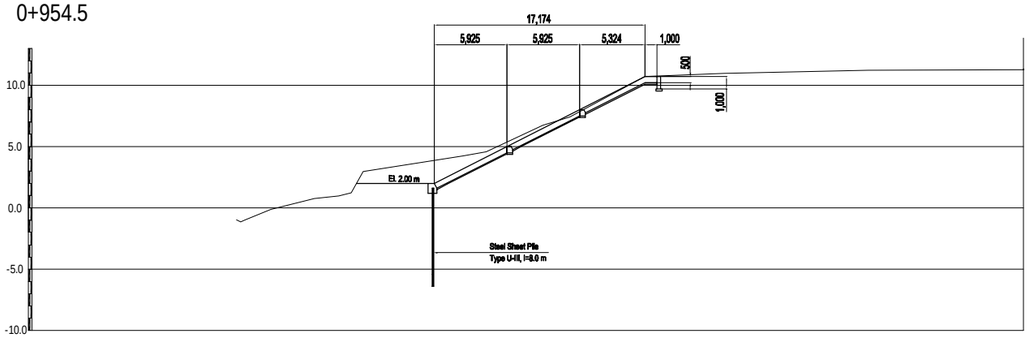

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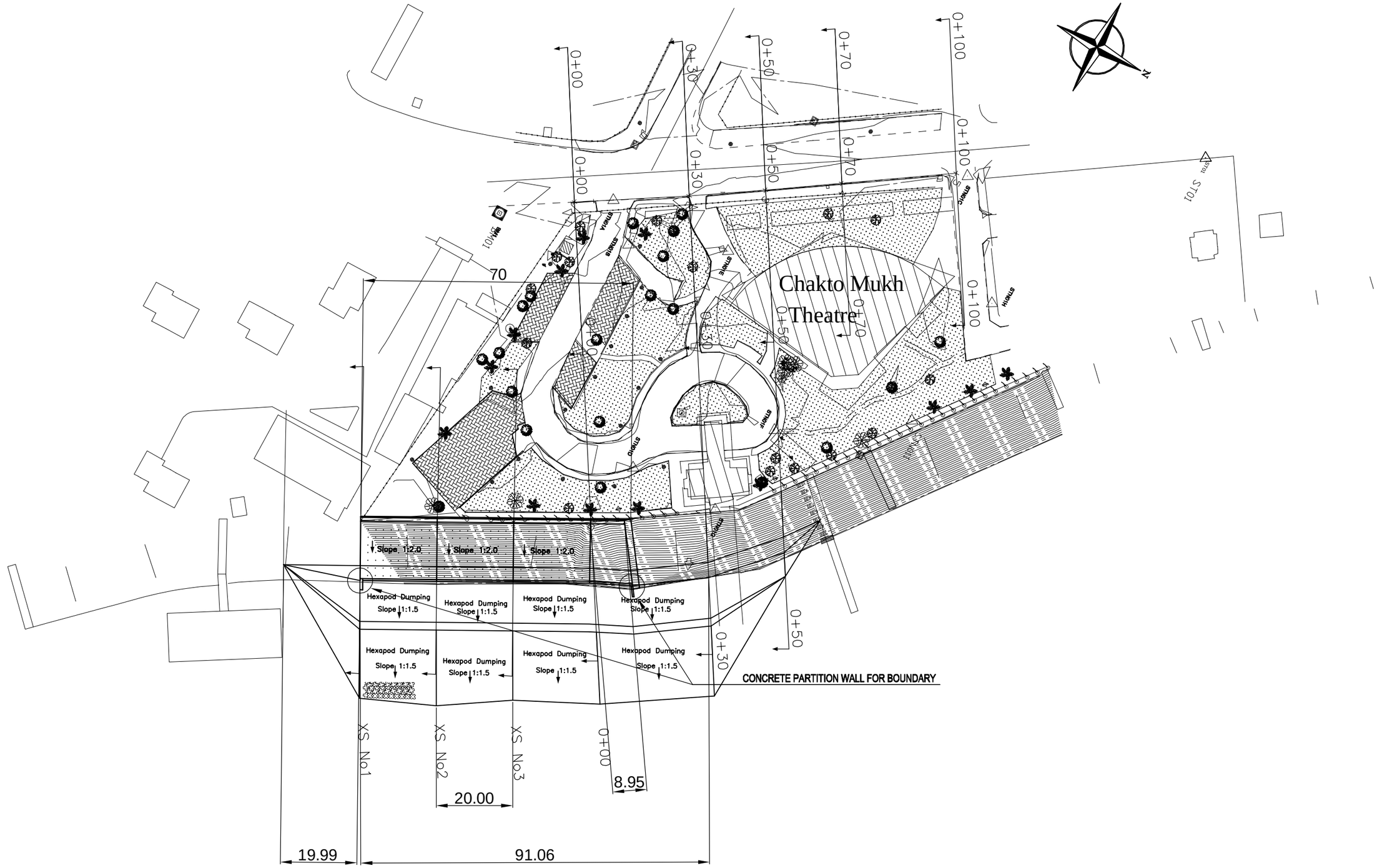
The Basic Design Study on Flood Protection and Drainage Improvement Project in the Municipality of Phnom Penh (Phase II)	Drawing No. FP-OM-03
JICA JAPAN INTERNATIONAL COOPERATION AGENCY CTI CTI ENGINEERING INTERNATIONAL CO., LTD. NIPPON KOEI CO., LTD.	Old Market East Revetment Cross Sections



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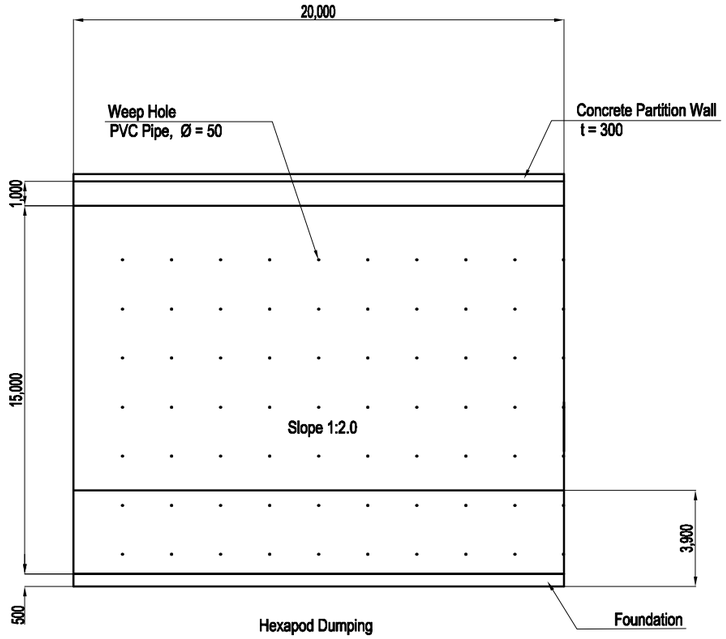
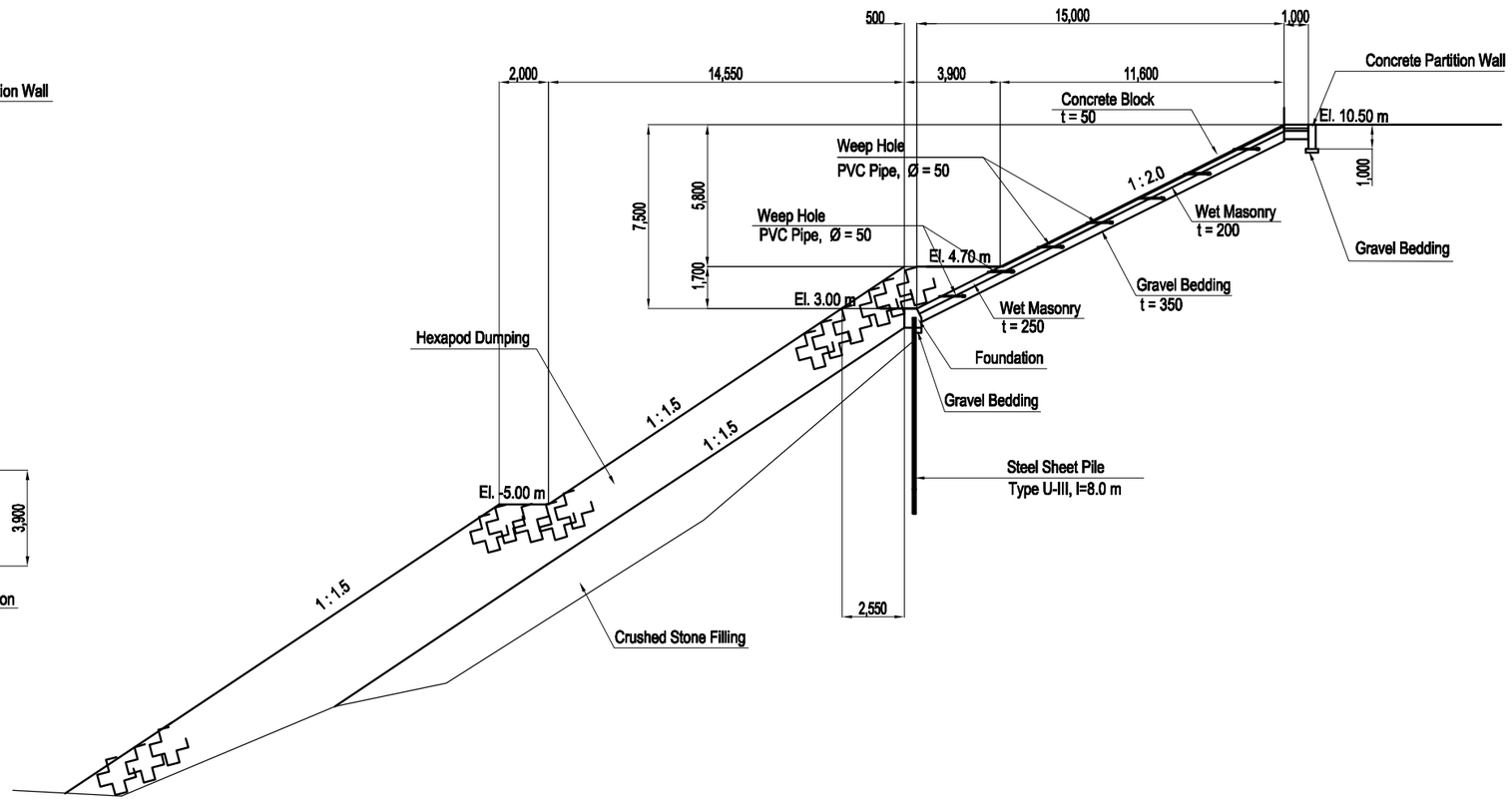
The Basic Design Study on Flood Protection and Drainage Improvement Project in the Municipality of Phnom Penh (Phase II)	Drawing No. FP-CM-01
JICA JAPAN INTERNATIONAL COOPERATION AGENCY CTI ENGINEERING INTERNATIONAL CO., LTD. NIPPON KOEI CO., LTD.	Chakto Mukh Theater Revetment Plan





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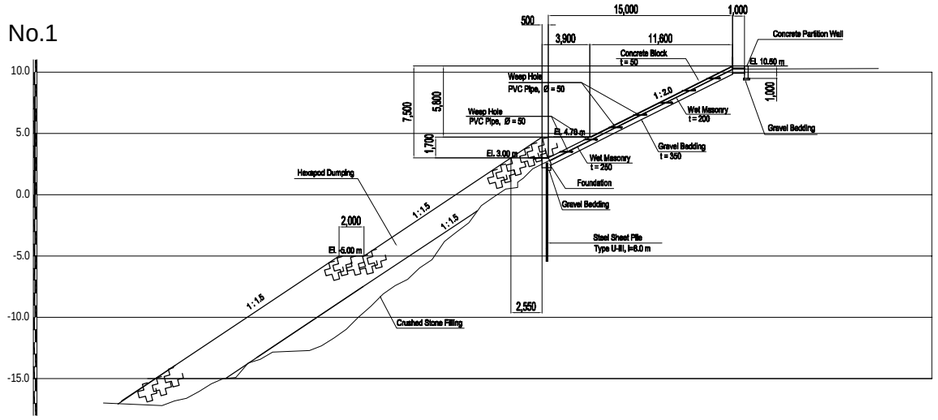
The Basic Design Study on Flood Protection and Drainage Improvement Project in the Municipality of Phnom Penh (Phase II)	Drawing No. FP-CM-02
JICA JAPAN INTERNATIONAL COOPERATION AGENCY CTI CTI ENGINEERING INTERNATIONAL CO., LTD. NIPPON KOEI CO., LTD.	Chakto Mukh Theater Revetment Typical Drawing

XS No.1



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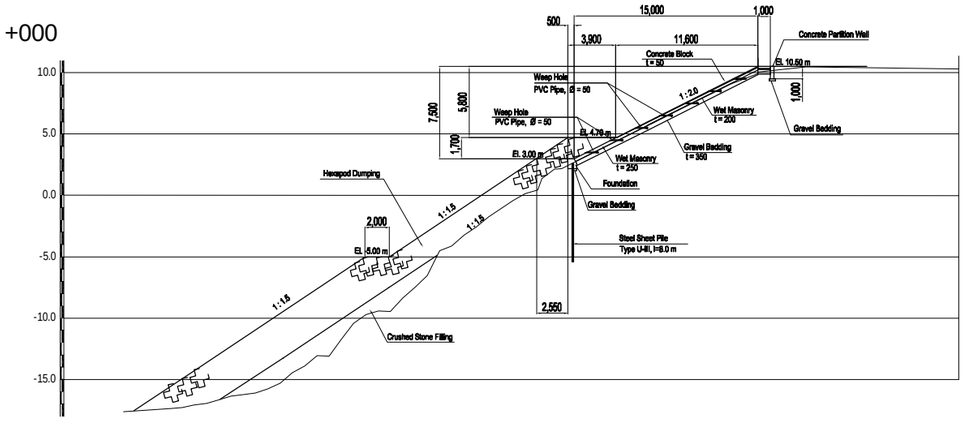

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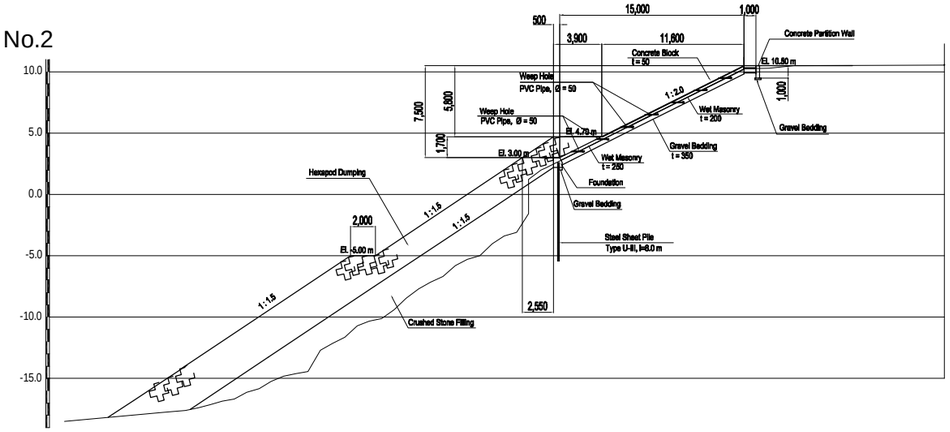

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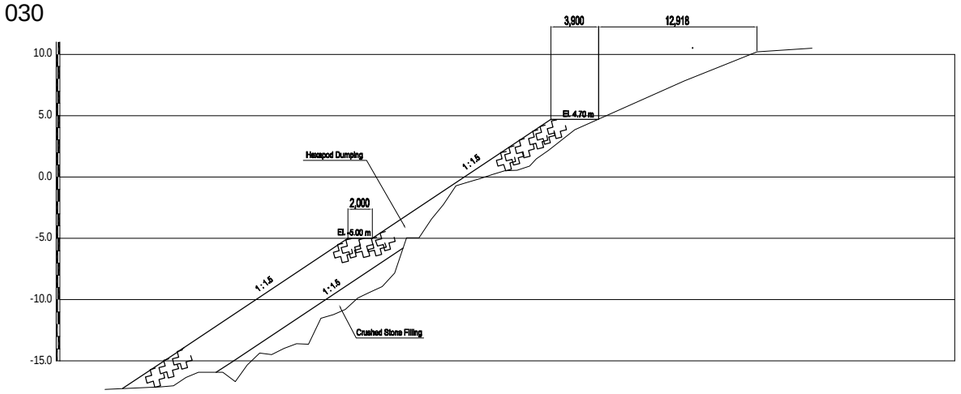

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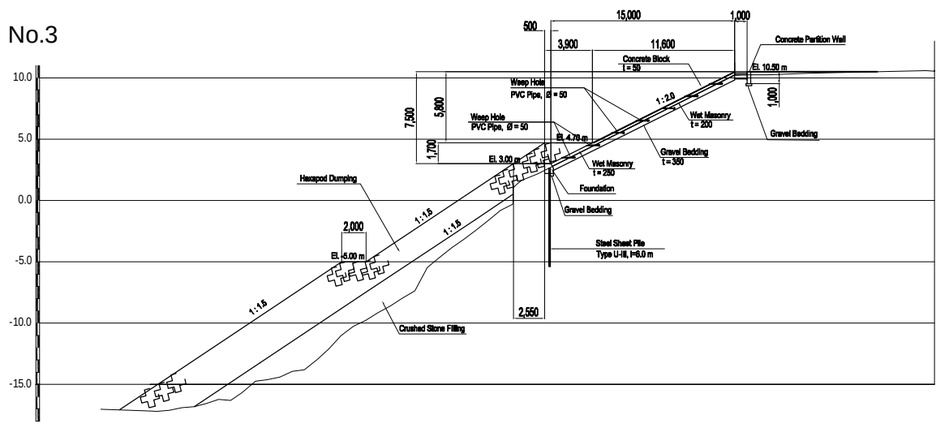

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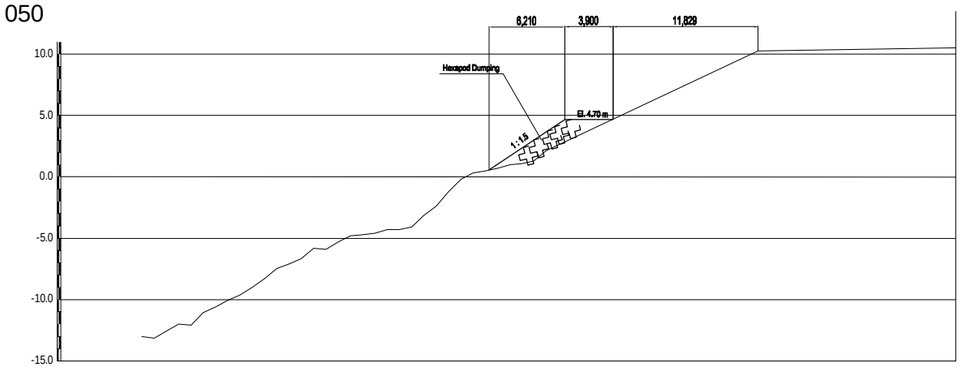

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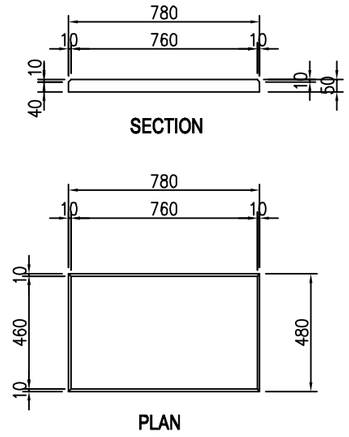
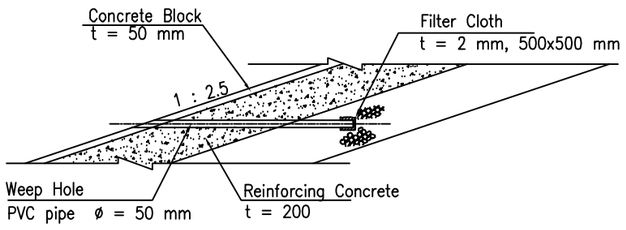
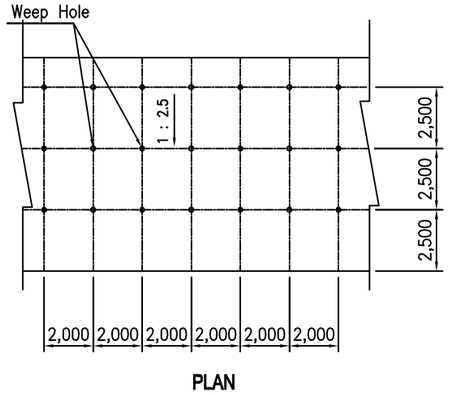
The Basic Design Study on Flood Protection and Drainage Improvement Project in the Municipality of Phnom Penh (Phase II)	Drawing No. FP-CM-03
JICA JAPAN INTERNATIONAL COOPERATION AGENCY CTI CTI ENGINEERING INTERNATIONAL CO., LTD. NIPPON KOEI CO., LTD.	Chakto Mukh Theater Revetment Cross Sections



Detail of Concrete Block

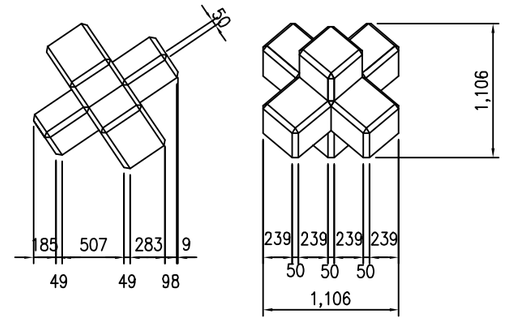


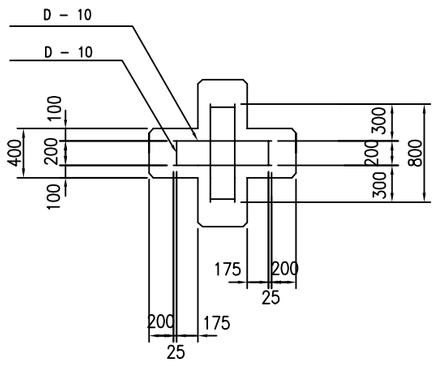
SECTION



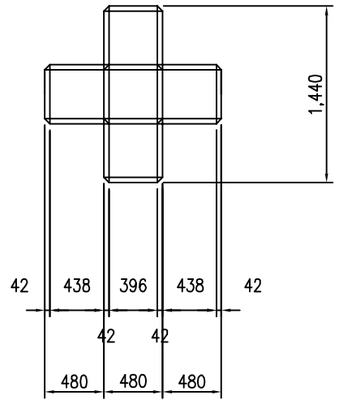
PLAN

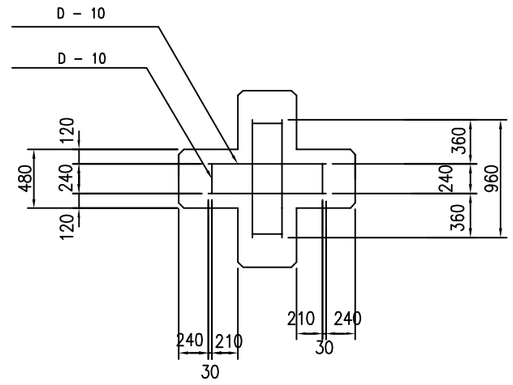
DETAIL OF WEEP HOLE





DETAIL OF HEXAPOD (1 TON)





DETAIL OF HEXAPOD (2 TON)

The Basic Design Study on Flood Protection and Drainage Improvement Project in the Municipality of Phnom Penh (Phase II)	Drawing No. FP-OT-01
JICA JAPAN INTERNATIONAL COOPERATION AGENCY CTI ENGINEERING INTERNATIONAL CO., LTD. NIPPON KOEI CO., LTD.	Structural Details of Concrete Block, Weep Hole and Hexapod