4.4 Reclamation and Soil Improvement

4.4.1 General

The most reasonable construction method shall be selected through a technical comparative study for land reclamation.

According to the soil investigation in the proposed reclamation area, it is obvious that the soft layer will remarkably settled due to its soil characteristics which exhibit high water contents (130 ~ 200%), silt and clay with N value of less than 4. Also the silt and clay soil layer (1) is classified as extremely unsuitable material in terms of ground bearing capacity.

(1) Location of Proposed Reclamation Area and Borrow Area

The proposed reclamation area is located in the sea area just in front of the existing Cutuco Port, having a land area of approximately 26.5 ha. On the other hand, the proposed borrow area for the filling material is located just behind the reclamation area on a woody and hilly land with an area of approximately 26.6 ha.

The locations of the reclamation area and borrow area are shown in Figure 4.4.1.

(2) Planned Height of Reclamation and Earthworks

The planned height of the reclamation and earthworks was set based on the following considerations.

The height of quaywall, thickness of pavement, and so on were mainly considered.

The planned reclamation and earthworks level is shown in Figure 4.4.1

(3) Earthworks Volume

The earthworks volume was estimated to be approximately 3.0 million m^3 for filling and 1.6 million m^3 for excavation as detailed below:

Excavation volume: (excluding removal of surface soil)	1,518,000 m^3
Filling volume: (including replacement of soft soil deposit):	3,005,000 m^3
Balance: (dredging material)	1,487,000 m^3
Removal of surface soil: (excavation area)	84,000 m^3

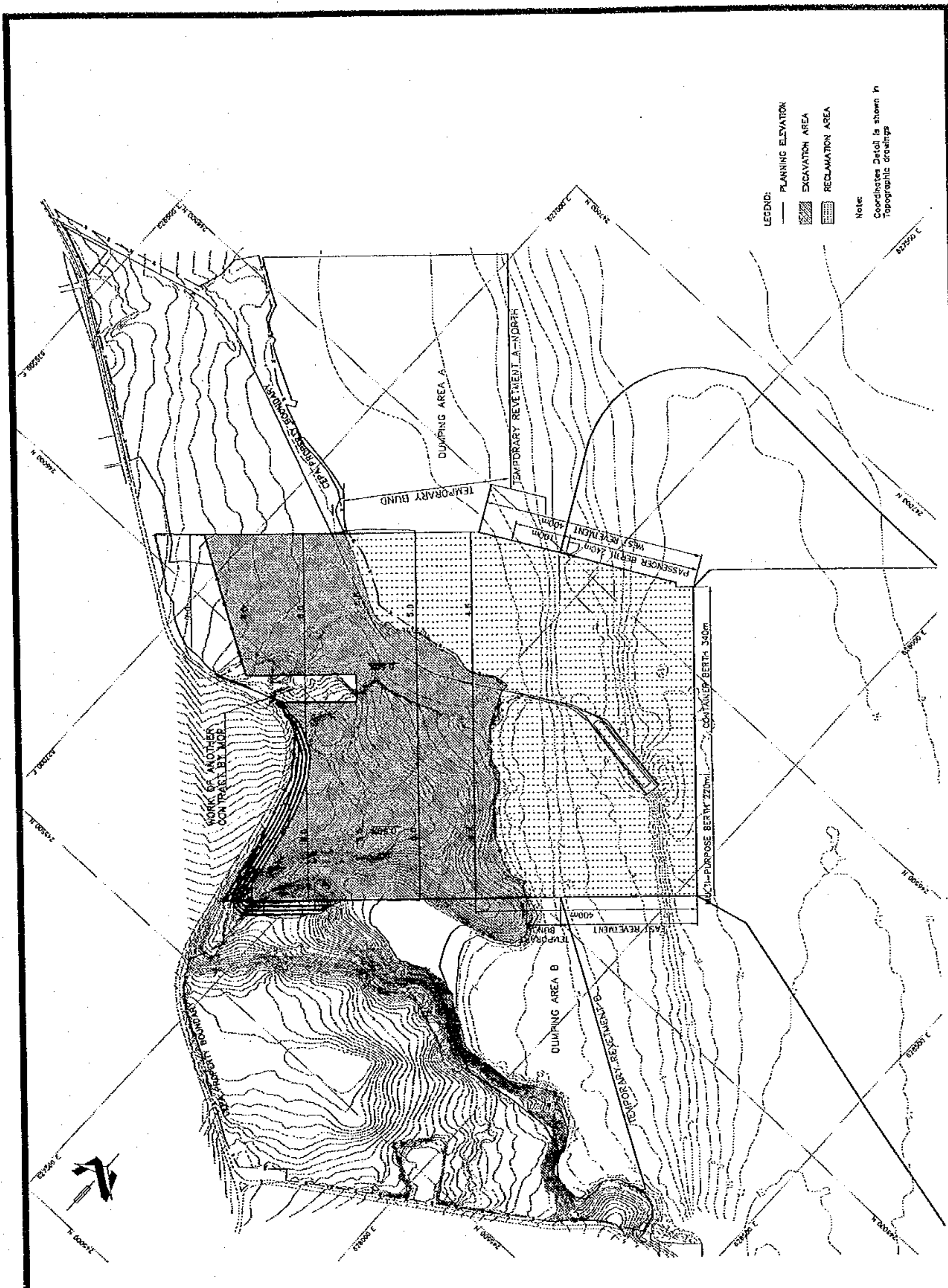
(4) Conditions of Reclamation Area and Excavation Area

1) Topographic Conditions

The topography of the proposed site is extremely undulated and the ground elevations range from 0 m to DL - 11 m in the reclamation area. The borrow area is located at high ground, with elevation reaching more than DL + 25 m.

2) Geological Conditions

From the results of investigation and geological survey, it was found that the geological strata of the site include a soil layer mixed with broken pieces of rock in the first and secondary strata. It is expected that only the surface layer can be used as filling material but some of these materials were found to contain silty sand. Its thickness varies between 0.5 m and 10 m.



Japan International Cooperation Agency (JICA)	Figure	Title
The Detailed Design on Port Reactivation Project in La Union Province of the Republic of El Salvador	4.4.1	LOCATION OF RECLAMATION AREA

4.4.2 Design Conditions

(1) Design Code

No design codes for reclamation and soil improvement are available in El Salvador. Therefore, the Technical Standards for Port and Harbor Facilities in Japan were referred to wherever applicable.

(2) Natural conditions

1) Geological Conditions

Land Area	Sea Area
Layer (1): Top Soil (Silty Clay), 0 to 3.0 m thick	Layer (1): Silty Clay, 5.0 to 10.0 m thick
Layer (2): Silty/Clayey Sand	Layer (2): Gravelly Sand, 3.0 to 8.0 m thick
Layer (3): Andesite, 50 to 130 Mpa	Layer (3): Gravelly/Sandy Clay, 3.0 to 12.0 m thick
	Layer (4): Unlithified Lava

In the reclamation area, the silty clay layer (Layer 1) with a 5 m to 10 m thickness is characterized by high water content, high plasticity and high compression. The properties of the layer 1 in the reclamation area were estimated to be as follows:

N-value: 1 – 5

Moisture content: 130% - 200%

Mean unit weight: 14.0kN/m³

Shear strength C: 5.0kN/m²

On the other hand, the soil properties at the wharves are as follows:

Table 4.4.1 Soil Properties

Silo Layer	Soil Classification	Soil Properties KN/m³	C KN/m²	φ degree	N-Value	√12N + 20 degree
1	Silty Clay	14.0	5	-	1	-
2	Gravelly Sand	18.0	-	-	30	39
3	Sand Clay	18.0	-	-	30	39

2) Design Load

The following loads are to be considered;

1) Surcharge of port area: 20 ~ 40 kN/m²

2) Superstructure and dead weight

4.4.3 Soil Improvement in Reclamation Area

(1) General

The soft layer in the reclamation area is composed of clay and silt. It is expected that consolidation and settlement will occur due after the placement of the embankment and reclamation soil. The required thickness of the embankment is 5.0 to 15.0 m and it will cause high pressure forces to the existing soft layer.

Consequently, residual settlement will continue even after completion of the construction if no soil improvement is carried out for this layer. The soft soil deposited below the sea level should be improved. The suitable improvement method are studied have in and finally the replacement method is recommended.

(2) Settlement of Soft Deposit in Reclamation Area

In the reclamation area, the existing silty clay layer (Layer 1), 5m to 10m thick, causes consolidation settlement of the reclaimed land.

The settlement of soft clay is estimated by Terzaghi theory of consolidation using compressive index as follows;

$$S = C_c / (1+e_o) * H * \log (P_o + . P) / P_o$$

$$= m_v * \Delta PH$$

Where:

S:	Consolidation settlement (cm)
Cc:	Compression index
(mv):	Coefficient of volume compressibility (cm²/kg)
eo:	Initial void ratio
e1:	Final void ratio
H:	Length of drainage path (cm)
Po:	Vertical effective pressure due to overburden (kN/m²)
ΔP:	Pressure increment due to soil overburden (kN/m²)

Consolidation settlements were estimated as shown in Table 4.4.3.

When the thickness of the consolidation layer is larger than 50 cm, residual consolidation settlement will significantly affect and induce damage such as pavement cracks, irregular surface of ground level by differential settlement. Therefore, large areas shall be improved to carry the load of port operation.

Table 4.4.2 Consolidation Settlement in Reclamation Area

Case	Existing Ground Level CD (m)	Thickness of Soft Layer (m)	Expected Settlement (cm)	Countermeasures	Remarks	Maximum Caring Period (year)
1	-2	2	<50	No displacement	Care will be required	2
2	-2	4	<50	No displacement	Care will be required	6
3	-4	4	<50	No displacement	Care will be required	6
4	-4	6	>59	Displacement		
5	-4	8	>76	Displacement		
6	-6	4	<50	No displacement	Care will be required	6
7	-6	6	>50	Displacement		
8	-6	8	>60	Displacement		
9	-6	10	>79	Displacement		
10	-8	4	<50	No displacement	Care will be required	6
11	-8	6	<50	No displacement	Care will be required	14
12	-8	8	>55	Displacement		
13	-8	10	>69	Displacement		
14	-10	4	<50	No displacement	Care will be required	6
15	-10	6	<50	No displacement	Care will be required	14
16	-10	8	<50	No displacement	Care will be required	24
17	-10	10	>62	Displacement		

(3) Comparison of Improvement Method

The most popular systems of soft soil improvement can be achieved by various methods such as Replacement method, Preloading method, Vertical Drain method, Vibrofloatation method , Well Point method, Cement Deep Mixing method, Sand Compaction Pile method, Compaction Pile method and other methods . A comparative study is carried out for determining the rational soil improvement method.

1) PLAN-A Replacement Method

The Replacement Method is used to improve and stabilize soft ground by replacing it with good quality soil to the depth required below the ground surface and it is possible to carry out partial replacement or total replacement of soft soil.

2) PLAN-B Sand Drain Method

The Sand Drain Method is one of the most typical soft soil improvement methods applying the dehydratation theory. Sand piles will drain void water contained in clay soil by short cut of the draining path and void water will be discharged through a vertical path by increased pressure of embankment load. The sand drain will accelerate consolidation settlement of the ground and it becomes steady in a relatively short period.

The consolidation time was calculated from the following formula:

$$t = \frac{T_h \, de^2}{Cv} \qquad (b.1)$$

Where:

t:	Consolidation time
Th:	Coefficient of time (second)
Cv:	Horizontal direction coefficient of consolidation (cm^2/s)
de:	Effective diameter of sand drain (cm)

The effective diameter (d_e) was estimated as follows:

$d_e = 1.05d$	In case of triangle shape arrangement of sand piles
$d_e = 1.13d$	In case of square shape arrangement of sand piles
d =	Spacing of sand drain piles

The relations between the effective diameter / pile diameter ratio (d_e/dw) and Coefficient of Consolidation Time "T_h" at consolidation degree (U_h = 80%) are as follows:

n= de/dw	2	3	4	5	10	20
Th (Uh=80%)	0.05	0.1	0.15	0.2	0.34	0.49

dw : Diameter of Sand Pile (cm)

Land reclamation should commence after completion of sand drain work, and carried out by dump trucks with other construction equipment for creation of land generally.

3) PLAN-C Cement Deep Mixing Method

The Cement Deep Mixing Method (CDM Method) is to add slurry cement and inject into soft ground a special hardener, a sort of cement mix, and to stir by force for the creation of stabilized soil by chemical hardening function. The improved ground with high strength will be made comparatively in a short construction period. There are many advantages such as less environmental effects and little settlement of the ground.

4) PLAN-D Unslaked Lime Pile Method

The Unslaked Lime Pile method is a kind of solidification method similar to the CDM method. The design and construction method require the same equipment as CDM. A different hardener such as Unslaked Lime is used to strengthen soft soil instead of cement.

5) PLAN-E Sand Compaction Method

The Sand Compaction Pile Method is applied to stabilize ground by compacted sand piles and to make surrounding subsoil compacted. It is to cast sand into ground through installed steel casing pipes by driving or vibration, producing hardened sub-ground by machine compaction during extraction of pile casing.

The Sand Compaction Pile accelerates consolidation effect of soil by draining void water from clay ground like the Sand Drain Method. Although the consolidation effect depends on the soil density and grain size distribution, the piles are set up at 2 to 4 m intervals and a sufficient quantity of granular sand is injected by force into the ground. The bearing capacity of stabilized ground will increase N value by 10 to 20.

(4) Determination of Foundation Improvement Method

Five (5) soft soil improvement methods were selected among many soil improvement methods, considering the site conditions such as the characteristics of existing very soft clay and silt layer, location of dumping materials and past similar port development experiences, etc.

For example, the improved ground by CDM can achieve the designed strength by adding stability materials without soft soil removal. And also there is no consolidation settlement and it is possible to shorten construction period compared with normal consolidation by the Sand Drain Method. Curing is required for 2~4 weeks after implementation of CDM. The treatment of units composing CDM causes no noise, no vibration from units and no environment effect at the construction site. It is possible to create high quality stabilized soil with assured construction control. However, CDM can not be procured from abroad except Japan. Therefore, this method is not recommendable as a soil improvement method due to expensive mobilization and construction cost.

The Sand Drain Method is applied without soft soil removal from the site by accelerating consolidation settlement of the ground. There are no technical problems for execution of Sand Drain Method. However, the construction cost is higher than the Replacement Method. Therefore, it is not recommended as a soil improvement method.

The replacement Method is to place good granular materials after removal of soft clay and silt layer, and special equipment is not necessary for the implementation except grab dredgers, barges and tugboats.

As a result of the comparative study of the improvement methods, the Replacement Method is recommended for this Project because of its high quality, short construction period, and reasonable cost.

After removal of soft deposited materials, coarse sand will be used for reclamation base. The Replacement Method using coarse sand material produces a good stability of the reclamation ground without serious differential settlement.

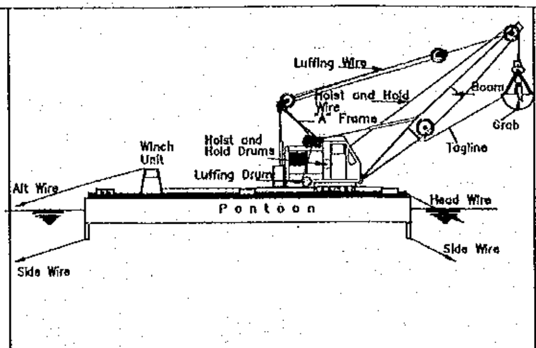
Table 4.4.3 shows the comparative study results on soil improvement for reclamation.

Figure 4.4.2 shows characteristics of soft soil improvement.

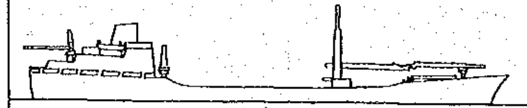
Table 4.4.3 **Comparative Study on Soil Improvement with a Consideration of Reclamation Method**

Item	Plan of Soft Soil Improvement Methods				
	A	B	C	D	E
Name	Replacement Method	Vertical Drain Method	Cement Deep Mixing Method	Unslaked Lime Pile Method	Sand Compaction Pile Method
Proposed Borrow Pit	Port Area	Port Area	Port Area	Port Area	Port Area
Quality of Fill Materials	Silty Sand Quarry Refuse	Silty Sand Quarry Refuse	Silty Sand Quarry Refuse	Silty Sand Quarry Refuse	Silty Sand Quarry Refuse
Average distance from borrow pit to reclamation area	800m from land 25km from sea	800m	800m	800m	800m
Construction period required	27 months	30 months	>40 months	>40 months	30 months
Dike & Temporary Causeway	Necessary at least 2 lanes	Necessary at least 2 lanes	Necessary at least 2 lanes	Necessary at least 2 lanes	Necessary at least 2 lanes
Temporary road	Not necessary	Not necessary	Not necessary	Not necessary	Not necessary
Main Equipment	Grab Dredger 20cu.m	Sand Drain Vessel 1000t with 4piles/ship	CDM Vessel Machine Weight 340t	U L P Vessel	Sand Compaction Vessel 1000t with 3piles/ship
Required No of Vesse	2	3	30	30	5
Required Material	Sand	Coarse Sand	Cement	Unslaked Lime	Sandy Gravel
Cost Index	Low 1.00	Middle 1.70	Expensive >10.00	Expensive >7.00	High 2.6
Evaluation	Excellent (Recommended	Good	Fair	Fair	Good

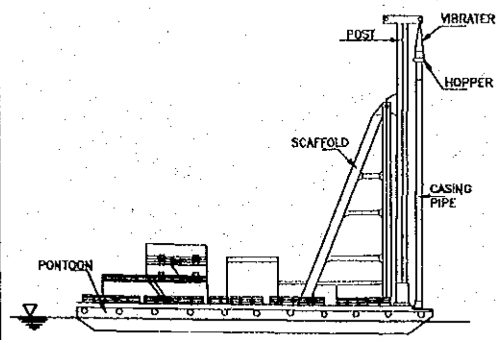
DRAWINGS OF WORK VESSEL



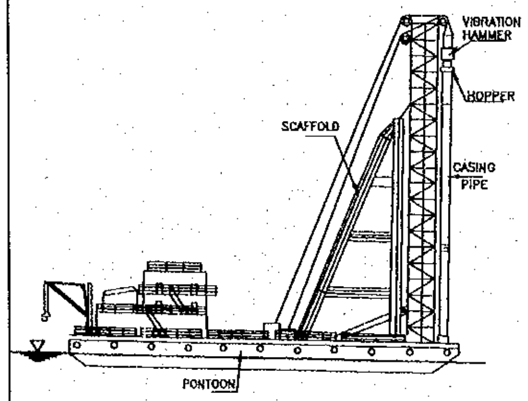
GRAB DREDGER



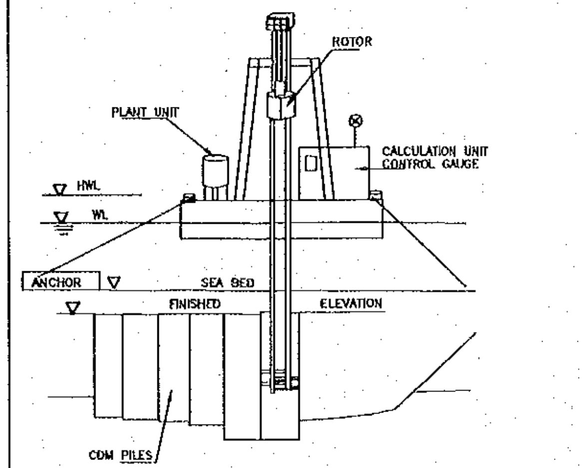
SAND CARRIER WITH GRAB BUCKET



SAND DRAIN VESSEL



SAND COMPACTION VESSEL



CDM VESSEL

MATERIAL: CEMENT

MATERIAL: UNSLAKED LIME

NAME OF SOFT SOIL IMPROVEMENT METHOD	REPLACEMENT METHOD	VERTICAL DRAIN METHOD	SAND COMPACTION METHOD	CEMENT DEEP MIXING METHOD (CDM METHOD)	UNSLAKED LIMEPILE METHOD
PRINCIPLES OF SOIL IMPROVEMENT	MECHANICAL EXCAVATION AND DISPLACEMENT	TO ACCELERATE SETTLEMENT SPEED AND INCREASE SOIL STRENGTH	COMPACTING SAND PILE FOR GROUND OF HORIZONTAL DIRECTION	USING CHEMICAL SOLIDIFICATION FUNCTION WITH CHEMICAL CHANGE	TO DEHYDRATE WATER OF SUBSOIL BY CHEMICAL ABSORPTION FUNCTION
PURPOSE OF SOIL IMPROVEMENT	TO INCREASE STRENGTH OF GROUND, TO RESIST SETTLEMENT OF GROUND, TO PROTECT LIQUEFACTION OF GROUND.	TO INCREASE STRENGTH OF GROUND, TO RESIST SETTLEMENT OF GROUND.	TO INCREASE STRENGTH OF GROUND AND RESIST SETTLEMENT, LIQUEFACTION OF GROUND	TO INCREASE STRENGTH OF GROUND AND RESIST SETTLEMENT OF GROUND	TO INCREASE STRENGTH OF GROUND AND RESIST SETTLEMENT OF GROUND
EFFICIENCY OF SOIL IMPROVEMENT	NORMAL	NORMAL	REMARCABLE	REMARCABLE	SMALL
CONSTRUCTION SPEED	NORMAL	NORMAL	SLOW	NORMAL	NORMAL
CONSTRUCTION COST	INEXPENSIVE	NORMAL	NORMAL	EXPENSIVE	NORMAL
DESIGN ACCURACY	EXCELLENT	EXCELLENT	GOOD	GOOD	NORMAL
IMPACT AGAINST ENVIRONMENT	SEVERE IF NO PROTECTION	SMALL	NORMAL	SMALL	NORMAL
CONSTRUCTION EXPERIENCE	MANY	MANY	MANY	FEW	FEW

Japan International Cooperation Agency (JICA)	Figure	Title
The Detailed Design on Port Reactivation Project in La Union Province of the Republic of El Salvador	4.4.2	CHARACTERISTICS OF SOFT SOIL IMPROVEMENT

4.4.4 Requirements of Reclamation

(1) Countermeasure Against Liquefaction

In the earthquake prone countries, there are many cases that most of damage are caused by liquefaction.

The ground damage can be divided into several cases such as sliding of cliff slope, differential settlement of soft soil, cracks and collapses of ground resulting from liquefaction

Particularly, taking countermeasures against liquefaction of loose sandy soil is one of the most important points in the reclamation work.

It is widely known that the saturated sandy ground will become liquefied by earthquake and the soil spouts out from the ground affecting the surroundings such as settlement of buildings, inclination of buildings, falling down of plants and damage of facilities laying under the ground, etc.

Generally, it is said that the soil will become in a state of liquid by the increased pore water pressure. The liquefaction is a phenomena causing the soil to lose its bearing capacity due to the application of external forces and it is a peculiar phenomena of "dilatancy" of soils by demolition causing decreased effective stress. In the case of loose sand packed, the binding capacity of grains become frail and the effective resistance of sand grains lose completely resulting in "0" effective stress. The liquefaction of soil decreases effective stress of soil. The external forces causing liquefaction are not only dynamic shearing stress like an earthquake but also seepage flow, fluctuation of water pressure and static shearing.

Accordingly, the fill materials should be chosen from granular sand, coarse sand mixed with gravel to avoid liquefaction and it is required to study physical characteristics of fill materials prior to the construction commencement and if necessary to replace them with soils of sufficient bearing capacity in accordance with the classification of the reclamation area.

(2) Fill Materials for Reclamation

The material to be used for reclamation by filling shall be well-graded and shall contain less than 5% of weight passing sieve of 74 μ.

As for the reclamation soil, the suitable material of reclamation from the borrow pit in the port area and dredging area will be used.

When the material doesn't suit, a material from another borrow pit nearby should be used instead.

Five (5) samples were taken from potential borrow pits located in mountains approximately 5 km away. The Pit No. 4 is located in Tamarindo beach. The test results of samples are as shown in Table 4.4.4.

Table 4.4.4 Content of Fine Material

Sample No.	Content of Fine Material (%) passing sieve No.200	Colorimetry Level (#1)
1	4.1	1
2	1.4	1
3	13.3	-
4	1.1	1
5	6.1	1

Note #1: Standard Test Method of AASHTO C40-84 is referred

(3) Compaction Method for Fill Materials

After soil improvement, the bearing capacity of the foundation for the container yard will be sufficient provided that proper compaction methods are used.

The surface sand layer should be well compacted under optimum control of moisture content defined mainly by the grain size. The detailed in summarized in Chapter 8.

4.5 Road and Paving

4.5.1 Road Planning Condition

(1) Classification of Roads

The project roads consist of a main road and feeder road. The main road stretches from the bypass road to the Container Terminal and Multi-purpose Terminal gate, while the feeder road is from Passenger Terminal to the main road.

(2) Planned Traffic Volume in Port Area

The cargo volume of bulk and container in 2005, 2010 and 2015 was estimated as shown in Table 4.5.1. These values were based on the forecast cargo volume as shown in Table 3.1.20.

Table 4.5.1 Future Cargo Volume

	2005	2010	2015
Bulk Cargo (MT)	624,700	727,100	841,200
Container Cargo (TEU)	121,000	185,000	275,000

According to Manual of F/S for Port Project by the Overseas Coastal Area Development Institute of Japan (OCDI), the traffic volume generated by port activities is estimated by the following equation.

Planned Traffic Volume (Truck / Hour) $= C/W \times \beta/12 \times r/\xi_0 \times (1+\delta)/\varepsilon \times \sigma$

Where:

C: Traffic Volume Transported by Truck (MT / Year)

W: Load Capacity of Truck (MT / Truck)

General Cargo : 2 Ton, Bulk Cargo : 8 Ton

β: Monthly Fluctuation Ratio (= 1.2)

γ: Daily Fluctuation Ratio (= 1.4 – 1.5)

ξ_0: Average Working Day per Month (=25 days)

δ: Related Vehicle Ratio (= 0.5)

ε: Substantial Vehicle Ration (= 0.5)

σ: Time Change Ration (= 0.16)

The planned traffic volume per hour is estimated as shown in Table 4.5.2. According to the estimated traffic volume, 4 lanes were required for the main access road in the year 2015.

Table 4.5.2 Traffic Volume and Number of Lanes

Year	2005	2010	2015
Traffic Volume per Hour	421	568	763
Required number of lanes (2 lanes / 650 trucks)	2	2	4

(3) Road Structure

The main road will compose of four lanes with sidewalks and its section between the bypass road and the Cargo Gate with median.

The feeder road will have two lanes without median and sidewalk. However, the feeder road section beside the container yard is designed with one-side sidewalk for pedestrians.

Section	Number of Lanes	Median	Sidewalk
Main Road 1 (0+000 – 0+400)	4	With	Both Sides
Main Road 2 (0+400 – 0+569)	4	Without	Both Sides
Feeder Road –1 and -3	2	Without	Without
Feeder Road – 2	2	Without	One side

4.5.2 Design Standards and Codes

The planning and design of roads and pavement were carried out based on the following standards and codes:

- Manual for Road Structure in Japan (1983), Japan Road Association
- Manual for Asphalt Pavement in Japan (1989), Japan Road Association

- Manual for Cement Concrete Pavement in Japan (1983), Japan Road Association
- Manual for Interlocking Block Pavement in Japan (1994), Interlocking Block Association
- Design Standards for Port Facilities in Japan (2000), Japan Port Association
- Central America Manual of Specifications for the Construction and Highways (March, 2001);
- Secretary of Central America for Economical Integration (SIECA);
- American Association of State Highway and Transportation Officials (2001), AASHTO

4.5.3 Design Condition

(1) Load Limit in Central America

The load limit of the roads in Central America was defined for the truck type T3-S2. This maximum load is 37 tons.

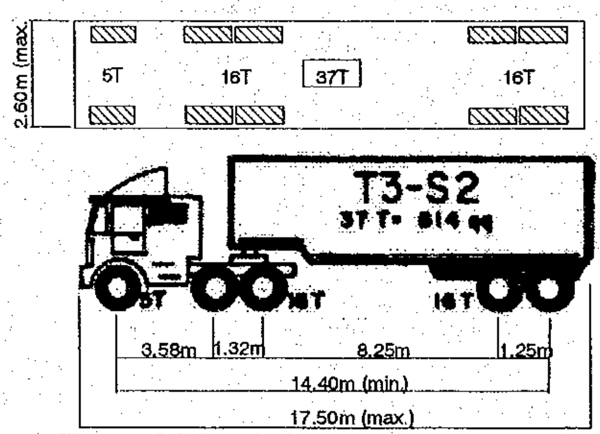


Figure 4.5.1 Limited Vehicle Load in Central America

(2) Design Load

The corresponding numbers of repetition (N) and the design load (L) adopted for pavement design are given in Table 4.5.3.

Table 4.5.3 Pavement Traffic and Loading

Location	Kind of Equipment	N	Max. Load (L) (kN)	Contact Pressure (N/cm²)
Container Marshalling Yard	Fork Lift Truck (15 ton)	5,000,000	170	79
R.T.G Traffic Lane	R. T. G (32 ton)	7,500,000	250	80
Reefer Area	Fork Lift Truck (15 ton)	800,000	170	79
Equipment Parking	Fork Lift Truck (15 ton)	3,800,000	170	79
Truck Parking/Waiting Area	Truck (T-25)	3,800,000	120	120
Container Freight Station	Truck (T-25)	500,000	120	120
Car Parking	Trailer (40 ft)	500,000	50	50
Open Storage for Car Stock	Trailer (40 ft)	500,000	50	50
Main Road	Truck (T-25)	10,000,000	120	120
Feeder Road	Truck (T-25)	5,000,000	120	120
Branch Roads	Truck (T-25)	2,500,000	120	120

(3) Subsoil Condition

The subsoil condition considered in the pavement design is defined by CBR-value as follows:

1) Road and Pavement in the Reclamation Area

The port area is generally planned to be on reclaimed land. For the pavement design, it is assumed that the reclaimed material is fine sand with a unified classification of SP-SM and a AASHTO Classification A-3(0). A minimum soaked CBR of 7 % at 95 % standard compaction was adopted.

2) Access Road

The access road is generally planned to be on existing land. According to the land boring data, the ground consists of surface soil (mainly sand), gravelly sand, sandy gravel from the upper to lower layers in the planned area of the access road. Even the surface soil has N-values of 23 to 30. The N-value of gravelly sand and sandy gravel is more than 50. Almost all existing land shall be excavated up to the level around +5.00 m. Therefore, the subsoil of sub-grade for the access road is mainly composed of gravelly sand on sandy gravel. The CBR-value was assumed at 10% from the following formula to convert N-value into CBR-value based on the "Guide of Geotechnical Investigation in Japan".

$$CBR = 1.818*(8.53*\log N - 6.02) - 4$$

4.5.4 Design of Pavement

Cement concrete pavement type was applied as pavement structure in consideration of the traffic volume, design load, durability, maintenance, etc. in the principal area such as the container yard and main road from the stating point to the container yard gate.

For the main road except for the above section, feeder road and parking, the asphalt pavement type was applied since the traffic volume will be not so much.

Macadam pavement was applied for the open storage for vehicle and multi-purpose yard in consideration of the traffic volume and the purpose of use.

The minimum CBR of 20 % was adopted in the design of sub-base course. Cement treatment macadam with a minimum 7-day unconfined compressive strength of 2.0N/mm^2 was adopted in the base course design.

The general layout of pavement is shown in Figure 4.5.2.

Details of each pavement type are as follows:

a) Concrete Pavement (1) [Type 1]

This pavement type is normally used in the area required high durability on the surface but high differential settlement. The pavement structure comprises a 35 cm thick concrete beam, a 15 cm thick base-course and 15 cm thick sub-base course. This type of pavement was applied for the R.T.G traffic lane.

b) Concrete Pavement (2) [Type 2]

This is used for high traffic road. The pavement structure comprises a 30 cm thick concrete beam, a 15 cm thick base course, and a 15 cm thick sub-base course. This pavement type was applied for the Container Marshalling Yard and Maine Road.

c) Asphalt Concrete Pavement (3) [Type 3]

The pavement structure comprises a 5 cm thick asphalt concrete surface layer, a 10 cm thick base course, and a 30 cm thick sub-base course. This pavement type was applied for the main road without median between the starting point and the container yard gate on the existing land and feeder roads in the reclaimed area.

d) Macadam Pavement (1) [Type 4]

This pavement type comprises a sprayed bitumen solution layer, a 25 cm thick base-course, and a 35cm thick sub-base course. This pavement type was applied for the equipment parking, truck parking, and empty container area.

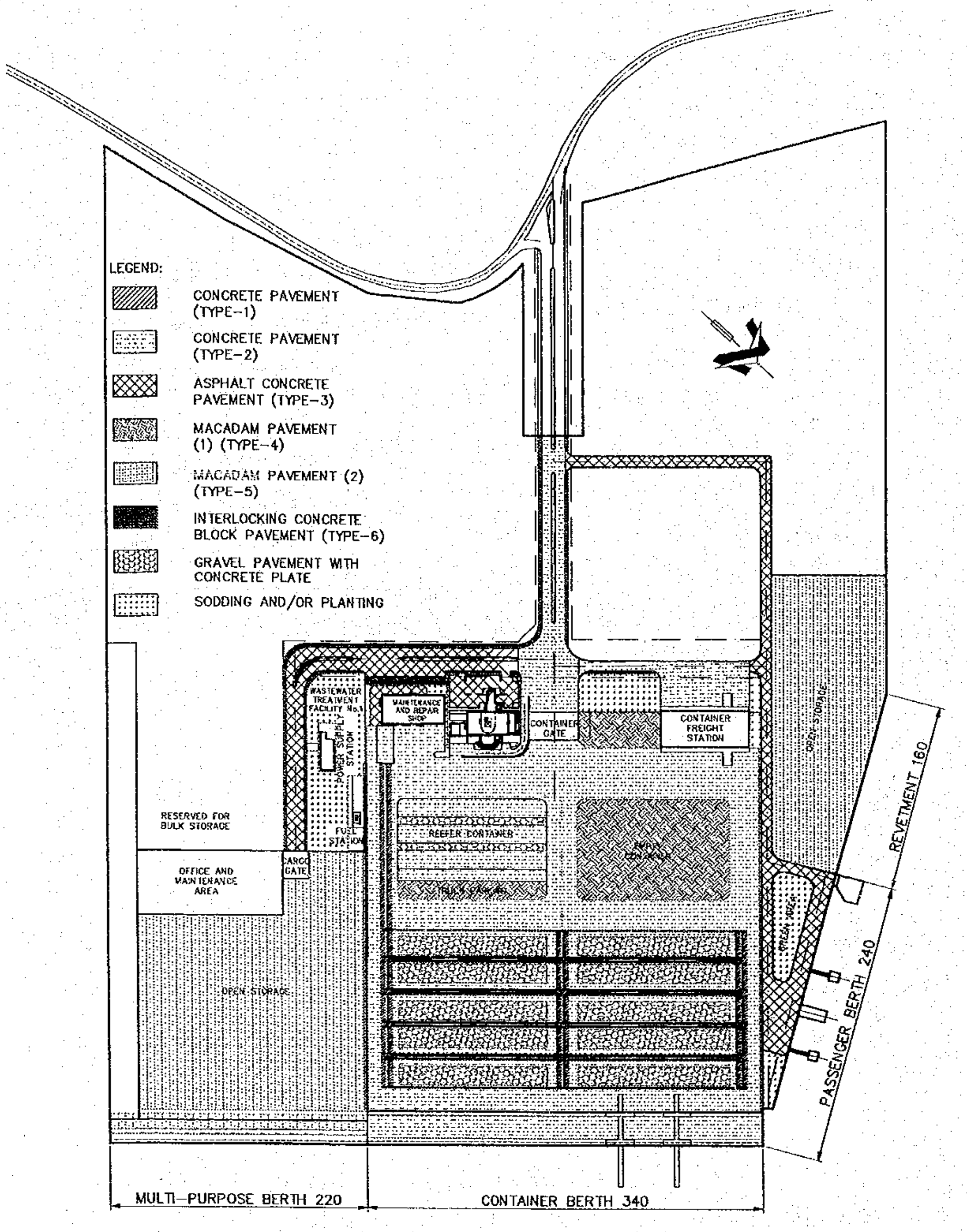
e) Macadam Pavement (2) [Type 5]

This pavement type is normally used for light traffic road. The pavement structure comprises a sprayed bitumen solution layer, a 20 cm thick base-course, and a 25 cm thick sub-base course. This type of pavement was applied for the open storage of vehicles and multi-purpose yard.

f) Interlocking Concrete Block Pavement [Type 6]

The pavement structure comprises a 10 cm thick interlocking concrete block, a 2 cm thick sand layer, and a 10 cm thick base course. This pavement type was applied for sidewalks.

The typical cross section of each pavement type is shown in Figure 4.5.3.



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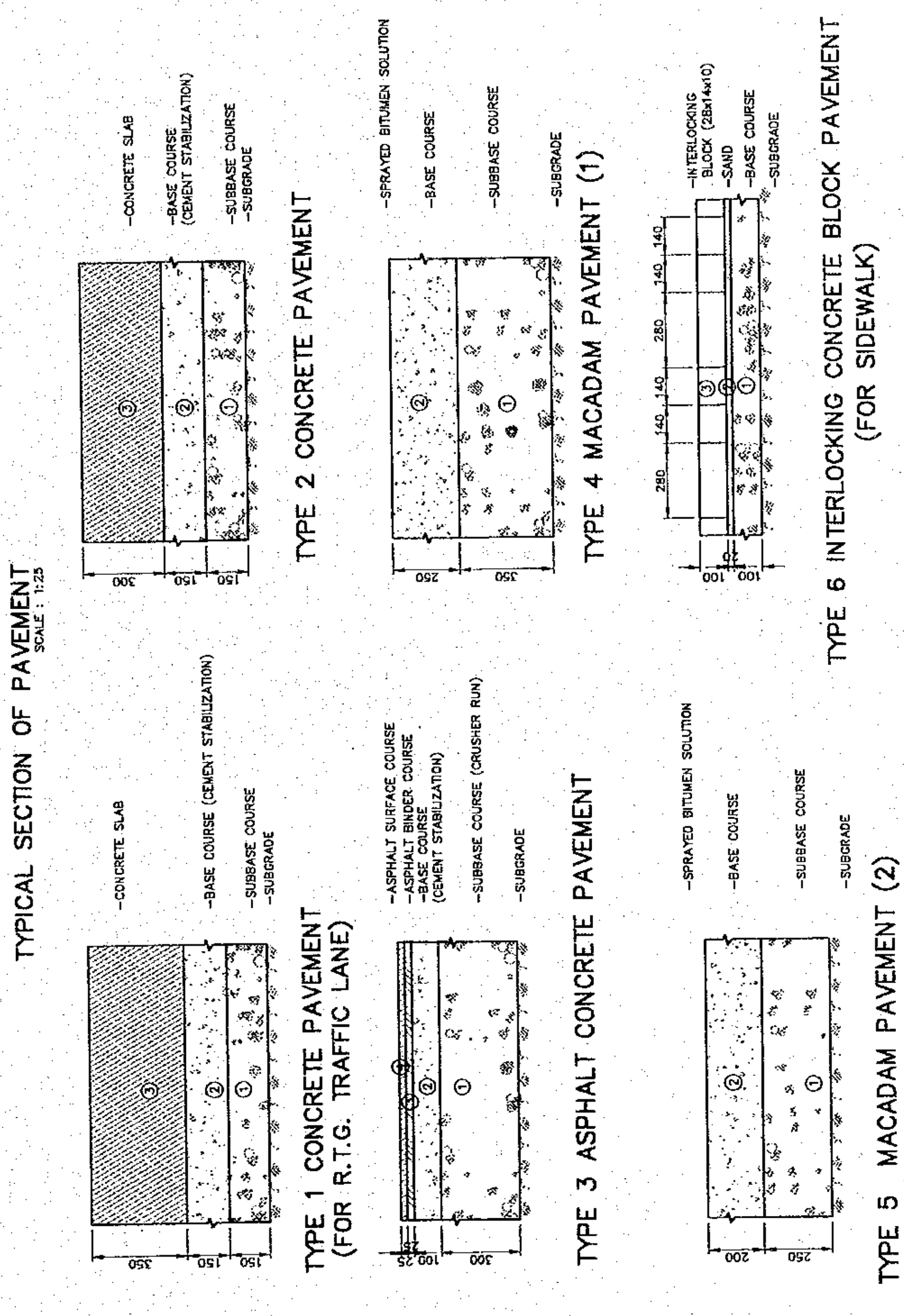
Japan International Cooperation Agency (JICA)	Figure	Title
The Detailed Design on Port Reactivation Project in La Union Province of the Republic of El Salvador	4.5.2	GENERAL LAYOUT OF PAVEMENT



Japan International Cooperation Agency (JICA)	Figure	Title
The Detailed Design on Port Reactivation Project in La Union Province of the Republic of El Salvador	4.5.3	TYPICAL SECTION OF PAVEMENT

4.5.5 Classification of Access Roads

The access roads inside the port area are classified as shown in Table 4.5.4. The typical sections of each road are shown in Figure 4.5.4.

Table 4.5.4 Classification of Access Road

	Lane	Width	Remarks
Main Road	2 x 2 = 4 lanes	B = 25.0 m	with Median, Sidewalk
Sub-Trunk Road	2 x 2 = 4 lanes	B = 20.0 m	with Sidewalk
Branch Road	1 x 2 = 2 lanes	B = 9.0 m	

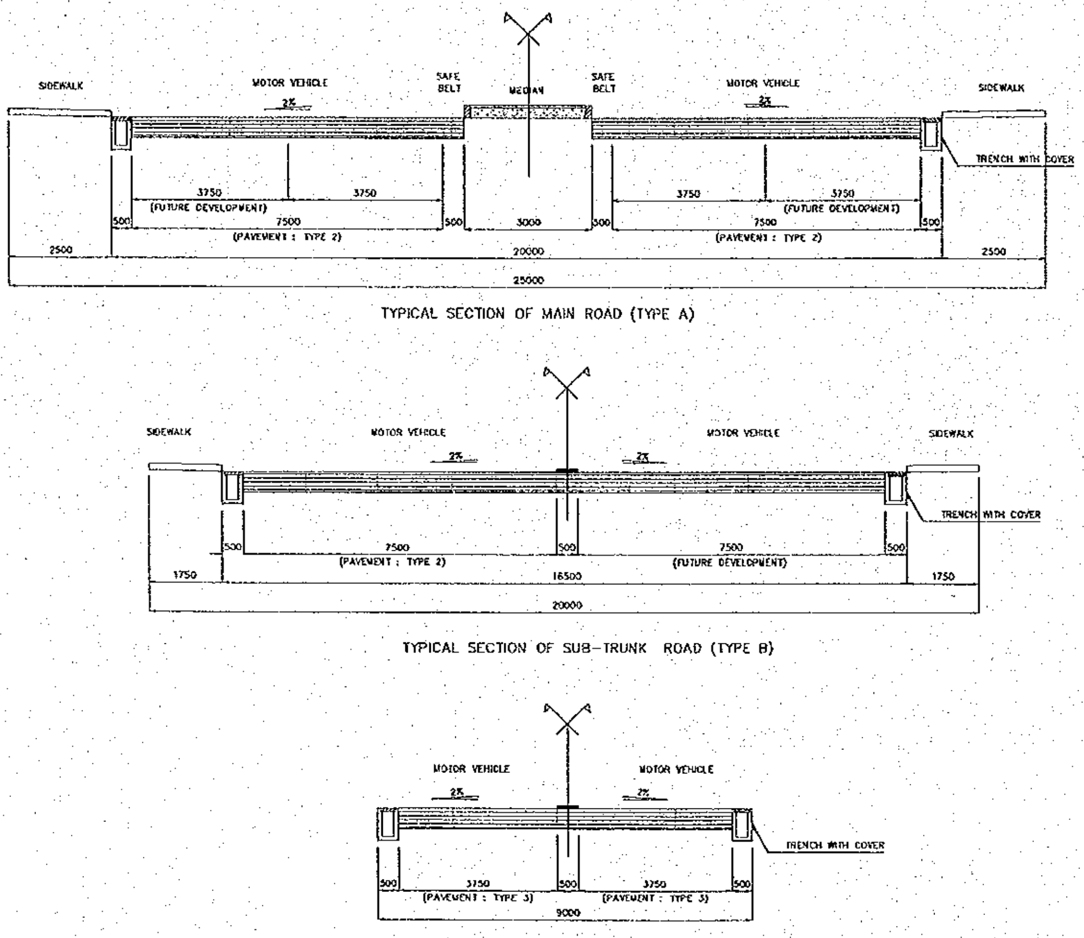


Figure 4.5.4 Typical Section of Access Roads

4.5.6 Bypass Road

The feasibility study for the Bypass Road commissioned by MOP was completed in November 2001 and the fund allocation was approved by the National Congress Assembly in June 2002. The connection point of the Bypass Road and the port Main Road 1 is located inside the port. It was planned that the intersection will be developed near the port by means of a roundabout type structure. The following crossing was proposed for this Project.

The coordinates, elevation and the end section number of the Bypass Road in the port area are shown below:

Coordinates : 627296.03 E, 246090.31N
Elevation : 9.00
Section Number : 12 + 238 (This section number was based on the drawings of the Bypass Road by MOP. This means the boundary between the Bypass Road construction by MOP and the Port construction by CEPA)

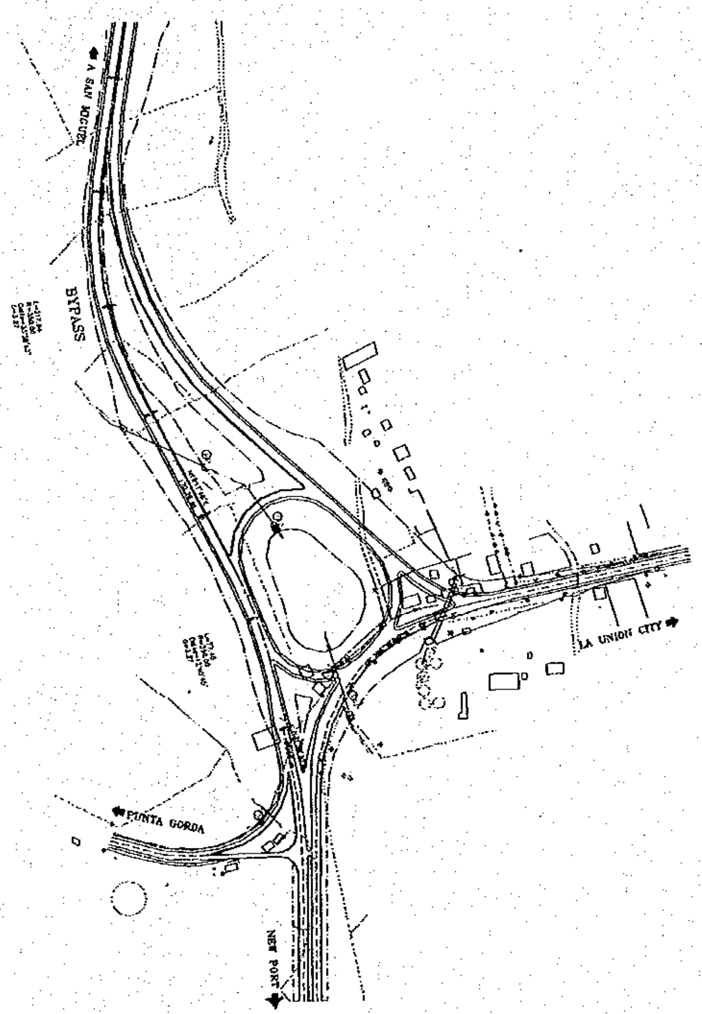


Figure 4.5.5 Proposed Crossing of Bypass Road Near the Port

4.6 Storm Drainage

4.6.1 Drainage Planning Condition

(1) Drainage System inside Port Area

A drainage system consisting of pipe culverts and trenches is planned to be provided for the structures inside the port area such as road, yard, berth and buildings, in consideration of maintenance, importance and minimum length of drainage, combination between pipe culvert and trench, etc.

Moreover, the storm water inside port area is planned to treat by oil/water separator in order to avoid disposing oil waste into the ocean directly. The oil/water separator should be arranged at the end of manhole for the drainage route.

(2) Drainage System outside Port Area

Open culverts (diversion) is planned to be used for the drainage system outside the port area, such as in the as in the cutting area for reclamation material and the existing drainage in consideration of maintenance, importance, and minimum length of drainage, etc.

(3) Method of Drainage

As mentioned above, pipe culverts/trenches and open culverts are applied for the drainage system in and out of the port area respectively.

(4) Route of Drainage

Five main routes in the port area and 2 main routes out of the port area for storm drainage were determined as shown in Figure 4.6.1.

4.6.2 Design Standards and Code

The planning and design of the drainage system are carried out according to the following standards and codes:

- Guidelines for Drainage in Japan (1987), Japan Road Association
- Guidelines for Culverts in Japan (1999), Japan Road Association
- Manual of Design and Construction of Concrete Manufactured in Japan (1986), National Concrete Manufactured Association

4.6.3 Design Condition

(1) Formula for Run-off Volume Calculation

The run-off volume to be considered for drainage design is calculated by the following formula:

$$Q = \frac{1}{360} \times C \times I \times A$$

Where:

- Q: Run-off volume (m^3/s)
- C: Run-off coefficient
- I: Design rainfall intensity (mm/hr)
- A: Catchment area (ha)

(2) Run-off Coefficient

The design run-off coefficient for each ground surface type is shown in Table 4.6.1.

Table 4.6.1 Run-off Coefficient

Surface type	Run-off Coefficient
House roof and concrete pavement surface	0.85
Asphalt pavement surface	0.80
Macadam pavement surface	0.70
Rubble pavement surface	0.50
Soil surface	0.40
Grass surface	0.15
Cutting area with grass	0.05

(3) Design Rainfall Intensity

The design rainfall intensity is calculated by the following formula based on the "Guide for Drainage in Japan", and on the 10-years probable rainfall intensity for this Project.

$$I_{10} = R_{10} \cdot \frac{a'}{t+b}$$

$$[a' = b + 60]$$

$$[b = (60 - 10\beta_{10}{}^{10})/(\beta_{10}{}^{10} - 1)]$$

Where;

- I_{10}: Design rainfall intensity with a 10-year return period (mm/hr)
- R_{10}: Probable rainfall intensity of 60 minutes during the 10-year return period (= 70 mm/hr as shown in Table 4.2.3)
- $\beta_{10}{}^{10}$: 10-minute rainfall specific coefficient of the 10-year return period
- t: Duration of rainfall (min) [$t = t_1 + t_2$]
- t_1: Overland flow travel time (min)
- t_2: Travel time in culvert (min)

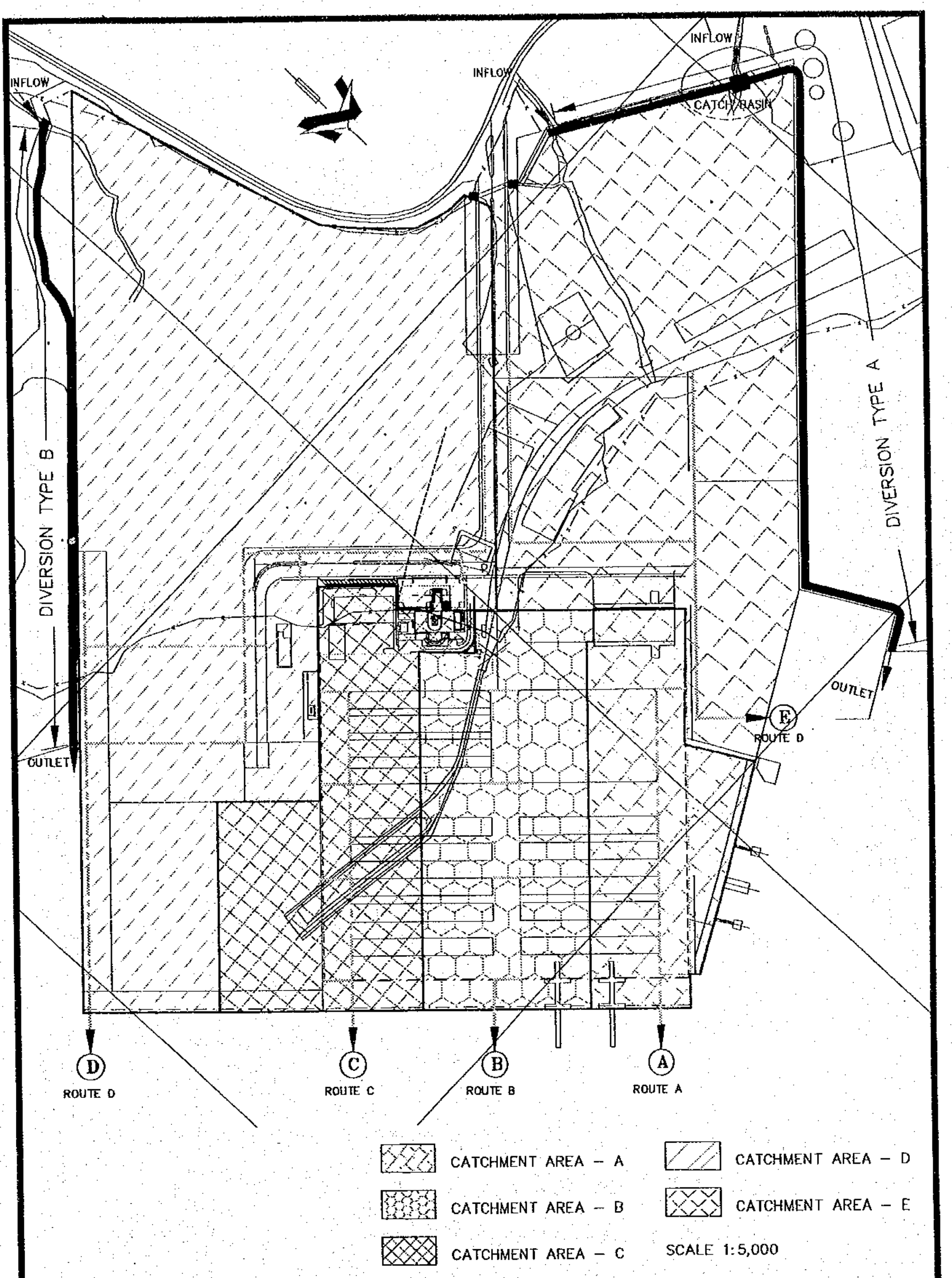
The 10-minute rainfall specific coefficient of the 10-year return period ($\beta_{10}{}^{10}$) is assumed at 2.0 based on the "Guideline for Drainage in Japan".

The port area is divided into six (6) catchment areas as shown in Figure 4.6.1. The drainage systems in the port was planned to be composed of pipe culvert s and trenches.

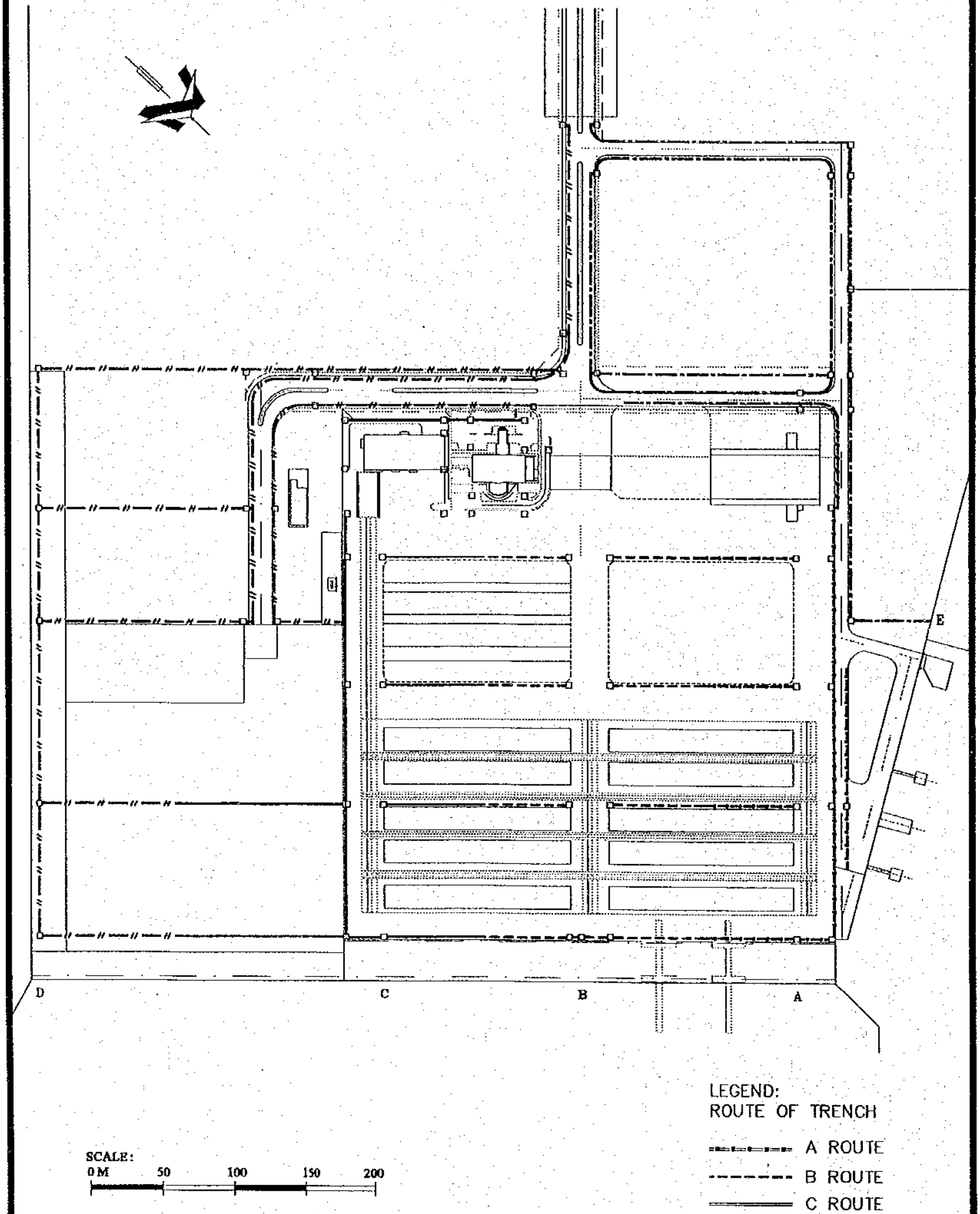
The design rainfall intensity for each culvert is computed at 95 - 135 mm/hr as shown in Table 4.6.2. The design rainfall intensity for the storm drainage system in the port area is computed at 135 mm/hr.

Table 4.6.2 Design Rainfall Intensity of Culverts

Route	Length of Main Culvert (m)	Overland Flow Travel Time (t_1: min)	Travel Time in Culvert (t_2: min)	Design Rainfall Intensity (mm/hr)
Route - A	340	8.7	6.2	127.5 → 130
Route – B	300	7.2	4.7	135.0 → 135
Route – C	525	10.9	8.5	117.7 → 120
Route - D	975	18.8	17.2	92.0 → 95
Route – E	585	10.3	9.3	117.5 → 120



Japan International Cooperation Agency (JICA)	Figure	Title
The Detailed Design on Port Reactivation Project in La Union Province of the Republic of El Salvador	4.6.1	GENERAL PLAN OF DRAINAGE (PIPE CULVERT AND DIVERSION)



Japan International Cooperation Agency (JICA)	Figure	Title
The Detailed Design on Port Reactivation Project in La Union Province of the Republic of El Salvador	4.6.2	GENERAL PLAN OF DRAINAGE (TRENCH)

4.6.4 Determination of Size of Drainage

(1) Hydraulic Design

The cross sectional area of the drainage flow and the slope required to lead the runoff water to outlet points were determined by applying the Manning Formula as follows:

$$Q = A \times 1/n \times R^{2/3} \times S^{1/2}$$

where;

Q : Runoff (m^3/s)

A : Cross sectional area of the runoff flow (m^2)

R : Hydraulic radius of drainage

S : Hydraulic slope

n : Coefficient of roughness of drainage surface

= 0.013 for concrete pipe culvert

= 0.014 for trench

= 0.030 for open culvert

(2) Size of Drainage

Pipe Culverts:

The pipe culvert type was selected as the culvert structure. The outlet size was estimated based on the above-mentioned conditions as shown in Table 4.6.3.

Table 4.6.3 Estimated Outlet Sizes for Pipe Culverts

Route	Catchment Area (ha)	Qrq (m^3/s)	D	Qc (m3/s)
Route - A	4.06	1.085	48" (1,219mm)	1.798
Route - B	5.51	1.553	48" (1,219mm)	1.798
Route - C	6.74	1.566	48" (1,219mm)	1.798
Route - D	20.80	1.321	48" (1,219mm)	1.798
Route - E	15.30	1.346	48" (1,219mm)	1.798

Where,

Qrq: Required discharging volume

D: Diameter of designed culvert

Qc: Discharging capacity of culvert (=0.9 Qcmax)

Trenches:

The size and length of trenches for the Routes A to E are as shown below:

Table 4.6.4 Estimated Sizes of Trenches

Route	Catchment Area (ha)	Minimum Size of Trench (mm)	Maximum Size of Trench (mm)	Total Length of Trench (m)
Route - A	4.06	300	450	751.8
Route - B	5.51	300	450	538.0
Route - C	6.74	300	450	978.7
Route - D	20.80	300	450	2196.1
Route - E	15.30	300	450	1648.1

Diversions:

The size and length of diversions for the Routes A to E are as shown below:

Table 4.6.5 Estimated Sizes of Diversions

Route	Size of Diversion (mm)	Total Length of Diversion (m)
Diversion Type-A	Bottom 4.0 m x Top 5.5 m x Height 1.5 m	675
Diversion Type-B	Bottom 1.0 m x Top 2.5 m x Height 1.5 m	580

4.6.5 Determination of Size of Oil/Water Separator

(1) Formula for Calculation of Oil/Water Separator

The capacity of oil/water separator was determined according to the following formula.

- Manning Formula :Flow Rate for Oil/Water Separator
- Calculation Model of USEPA and API :Capacity of Oil/Water Sepatrator

(2) Flow Rate for Oil/Water Separator

The discharge volume of each oil/water separator is estimated based on Manning Formula as shown in Table 4.6.6.

Table 4.6.6 Estimated Discharge Volume of each Oil/Water Separator

Route	Catchment Area (ha)	Design Rainfall Intensity *1 (mm/hor)	Velocity (m/s)	Discharge Volume (m^3/s)
Route - A	4.06	300	450	751.8
Route - B	5.51	300	450	538.0
Route - C	6.71	300	450	978.7
Route - D	20.80	300	450	2196.1

(3) Capacity of Oil/Water Separator

The capacity of oil/water separator is estimated based on the following formula as shown in Table 4.6.7.

Rise Rate: Vp = 1.79 x (dp-dc) x d2 x 10-8n

Where;

dp : Density of Oil (gm/cc) ; 0.9

dc : Dencity of Water (gm/cc) ; 0.99567

d: Diameter of the dropel

et : to be removed ; 45 μ

n : qbwolute Velocity of Water ; 0.008

Allow Horizontal Velocity : 15Vp

Surface Area of Oil/Water Separator : As = K x Q / Vp

Where;

K : Dimensionless Factor Describing Turbulence ; 1.5

Q : Retained Flow Rate (m3/s)

Width of Oil/Water Separator : W = $\sqrt{}$(As/5)

Length of Oil/Water Separator : L = from 3 W to 5 W; 4 W

Depth of Oil/Water Separator : D = (Q / L / W) + Dp + C

where;

Dp : Diameter of Pile Culvert ; 0.4 m

C : Clearance ; 0.3m

Table 4.6.7 Dimension of Oil/Water Separator

Route	Discharge Volume (m^3/s)	Width of oil/Water Separator (m)	Length of Oil/Water Separator (m)	Depth of Oil/Water Separator (m)
Route - A	0.085	5.89	23.54	2.36
Route - B	0.105	6.54	26.16	2.36
Route - C	0.115	6.84	27.38	2.36
Route - D	0.105	6.54	26.16	2.36