APPENDIX 1

MEMBERS OF THE BASIC DESIGN STUDY TEAM

MEMBERS OF THE BASIC DESIGN STUDY TEAM

This Phase 2 project was conceived as the extension of "The Project for Retrieval of Flood Prone Areas in Metro Manila", the Phase 1 project. Therefore, the basic design study was executed without any field reconnaissance in the Philippines. The following study team members headed by its team leader, Mr. Masahiro Asada, carried out the basic design study from November 2 to December 1, 1992.

Name	Assignment	Official Designation
Masahiro Asada	Flood Control Planner/Team Leader	Staff, CTI Engineering Co., Ltd.
Ryuichiro Seki	Equipment Planner	Staff, CTI Engineering Co., Ltd.
Katsuhiro Ikari	Cost Estimator	Staff, CTI Engineering Co., Ltd.

APPENDIX 2

CALCULATION OF REQUIRED NUMBER OF EQUIPMENT

CALCULATION OF REQUIRED NUMBER OF EQUIPMENT

1. Standard

The following standards served as reference in calculating the required number of equipment for the Project for Retrieval of Flood Prone Areas in Metro Manila (Phase 2) in consideration of the present condition of the flood prone areas in Metro Manila.

"Kensetsu-Sho Doboku Koji Sekisan Kijun"
("Cost Estimation Standard for Civil Works")
Supervised by Technical Study Section, Minister's Secretariat
Ministry of Construction, Government of Japan
Edited by Doboku Koji Sekisan Kenkyu Kai

"Kowan-Kuko Ukeoi Koji Sekisan Kijun"
("Cost Estimationt Standard for Construction of Harbors and Airports")
Edited by Ports and Harbors Bureau, Civil Aviation Bureau
Ministry of Transport, Government of Japan
Published by Japan Port and Harbor Association

"Gesuido Shisetsu Ijikanri Sekisan Yoryo (An) - Kanro Hen -"
("Cost Estimation Standard for the Maintenance of Sewage Facility (Proposed) - Conduit Facility -")
Supervised by Sewage and Sewage Purification Department
City Bureau, Ministry of Construction, Government of Japan
Published by Japan Sewage Works Association

2. Workable Hours and Days

This calculation is based on the following workable hours, days and terms.

Workable Hours per Day (T_1) 8 hr/day

Equipment Operation Hours (T_2) 6 hr/day

Workable Days per Year

First year (D_1) 230 days/year

Last 1.5 years (D_2) 230 days/year

Project Term (Y_1) 2.5 years

3. Laterals

3.1 Dimension and Sediment Volume

Size (inch)	Length (m)	Sediment Volume (m^3)
Ø12"	1,948	71
Ø16"	225	15
Ø18"	9,697	796
Ø24"	50,529	7,370
Ø30"	13,088	2,983
Ø36"	12,896	4,232
Ø42"	7,760	3,466

Total Length (La_1) 96,144 m

Total Sediment Volume (Va_1) 18,933 m^3

Average sedimentation of each lateral is approximately 50%.

3.2 Productivity

Productivity of one waterjet cleaner for each size of lateral sedimented at approximately 50% is tabulated as follows:

Size (inch)	Productivity (m/day)
Ø12"	337
Ø16"	253
Ø18"	190
Ø24"	137
Ø30"	80
Ø36"	55
Ø42"	40

No numerical data is available for the productivity of waterjet cleaner for cleaning laterals sized Ø30", Ø36" and Ø42". Therefore, the above-listed data for these sizes of laterals were calculated from lateral size Ø24" which has the datum available.

3.3 Required Number of Equipment

(1) Waterjet Cleaner

The days required to complete the cleaning of each size of lateral by using one waterjet cleaner is calculated according to the following:

$$da_1 = l_{a1}/e_{a1}$$

da_1 : Required days (day)
l_{a1} : Length of lateral (m)
e_{a1} : Productivity (m/day)

Required Days for the Cleaning Work on Each Size of Lateral:

Size (inch)	Required Days (days/Unit)
Ø12"	6
Ø16"	1
Ø18"	51
Ø24"	369
Ø30"	164

Ø36"	234
Ø42"	194

Total Required Days (D_3) : 1,019 days

Required Number of Waterjet Cleaner (N_{a1}):

$$N_{a1} = D_3/(D_1 + D_x \times 1.5)$$
$$= 1,019 / (230 + 230 \times 1.5)$$
$$= 1.8$$
$$\fallingdotseq 2$$

(2) Water Tanker

The number of required water tanker is one for one waterjet cleaner, because water is utilized from fire hydrants installed along the streets.

Required number of Water Tankers (N_{a2})

$$N_{a2} = 1 \times N_{a1}$$
$$= 1 \times 2$$
$$= 2$$

(3) Dump Truck (4-ton)

Sediment removed from laterals is loaded from a vacuum cleaner to a 4-ton dump truck. The required number of dump trucks is calculated as follows:

Productivity per Hour of 4-ton Dump Truck ($q0a_1$):

$$q0_{a1} = (60 \times q_{a1} \times f_{a1} \times E_{a1}) / Cm_{a1}$$

q_{a1} : Production per cycle (m^3/cycle)
4-ton dump truck, sediment specific gravity
1.8, 2.2 m^3/cycle

f_{a1} : Soil factor
Loose, excavated, high water containing clay, 1.25

E_{a1} : Job efficiency, 0.9

Cm_{a1} : Cycle time (min/cycle)
$C_{ma1} = t_{a1} + t_{a2} \times 2 + t_{a3}$
t_{a1} : Loading time (min/cycle)

Loading time of the removed sediment to dump truck is regulated by the productivity of the vacuum cleaner. In case the productivity of the vacuum cleaner is 4 m^3/hr, work loss factor is 0.25.

$$\begin{aligned} t_{a1} &= q_{a1} \times (1 + 0.25) \times 60 / 4 \\ &= 2.2 \times (1 + 0.25) \times 60 / 4 \\ &= 42 \text{ min/cycle} \end{aligned}$$

t_{a2} : Hauling time from the job site to the Dumping Site (min/cycle)

Time Surveyed: 60 min/cycle

t_{a3} : Dumping time (min/cycle)
10 min/cycle

$$\begin{aligned} cm_{a1} &= 42 + 60 \times 2 + 10 \\ &= 172 \text{ min/cycle} \end{aligned}$$

$$\begin{aligned} q0_{a1} &= (60 \times 2.2 \times 1.25 \times 0.9) / 172 \\ &= 0.86 \text{ m}^3\text{/hr} \end{aligned}$$

Productivity of 4-ton dump truck per day ($q0_{a2}$):

$$\begin{aligned} q0_{a2} &= q0_{a1} \times T_2 \\ &= 0.86 \times 6 \\ &= 5.16 \text{ m}^3\text{/day} \end{aligned}$$

Required Number of 4-ton Dump Truck per One Waterjet Cleaner (n_{a1}):

The required number of 4-ton dump truck is based on the maximum removable volume of sediment, 20 m^3/day from lateral sized Ø24", 50% of average sedimentation, as follows:

$$\begin{aligned} n_{a1} &= 20 / qO_{a2} \\ &= 20 / 5.16 \\ &= 3.9 \\ &= 4/\text{unit} \end{aligned}$$

Required Number of 4-ton Dump Truck (N_{a3}):

$$\begin{aligned} N_{a3} &= n_{a1} \times N_{a1} \\ &= 4 \times 2 \\ &= 8 \end{aligned}$$

(4) Power Light with Generator

One power light with generator of two lamp type for one waterjet cleaner is provided for night work.

Required number of power light:

$$\begin{aligned} N_{a4} &= 1 \times N_{a1} \\ &= 1 \times 2 \\ &= 2 \end{aligned}$$

4. Drainage Main and Outfall

4.1 Total Length and Sediment Volume

Total Length (Lb_1)	13,512 m
Total Sediment Volume (Vb_1)	38,054 m^3

4.2 Required Number of Equipment

The width of rectangular shaped concrete maintenance hole is sufficient for a dragline bucket with a capacity of 0.6 m^3 or 0.3 m^3. Therefore, the calculation is based on the productivity of a 0.6 m^3 dragline bucket to complete the whole cleaning work for drainage mains and outfalls with lids made of concrete within 2.5 years.

Required Volume to be Removed per Day (V_{b2}):

V_{b2} = $Vb_3 / (D_1 + D_2 \times 1.5)$

V_{b3} : Sediment volume (m^3)

38,054 m^3

V_{b2} = $38{,}054 / (230 + 230 \times 1.5)$

= 66.2 m^3/day

(1) Wheel Crane

One wheel crane performs as a crane to open a maintenance cover, a dragline to collect sediment, and a clamshell to load the removed sediment to a dump truck with change of its attachment.

Productivity of 0.6 m^3 Dragline Bucket per Hour ($q0_{b1}$):

$q0_{b1} = (3600 \times q_{b1} \times f_{b1} \times E_{b1}) / Cm_{b1}$

q_{b1} : Production per cycle (m^3/cycle)

0.6m^3 bucket: 0.53 m^3/cycle

f_{b1} : Soil factor = 1.25

E_{b1} : Job efficiency = 0.25

Cm_{b1} : Cycle time (sec/cycle)

$Cm_{b1} = l_{b1} \times 2 / V_{b1} \times 60$

V_{b1} : Dragline speed, 45 m/min

l_{b1} : Distance between maintenance hole, 50 m

$Cm_{b1} = (50 \times 2) / 45 \times 60$

$= 133$ sec/cycle

$q0_{ba} = (3600 \times 0.53 \times 1.25 \times 0.25) / 133$

$= 4.5\ m^3/hr$

Productivity of 0.6 m^3 Clamshell Bucket per Hour ($q0_{b2}$):

$q0_{b2} = (3600 \times q_{b2} \times f_{b2} \times E_{b2}) / Cm_{b2}$

q_{b2} : Production per cycle (m^3/cycle)

0.6 m^3 bucket: 0.48 m^3/cycle

f_{b2} : Soil factor = 1.25

E_{b2} : Job efficiency = 0.30

C_{mb2} : Cycle time

90° 34 sec/cycle

$q0_{b2} = (3600 \times 0.48 \times 1.25 \times 0.3) / 34$

$= 19\ m^3/hr$

Work Time Ratio of Dragline Bucket and Clamshell Bucket:

The collection of sediment from a maintenance hole and dumping of the sediment is performed by the same wheel crane with change of its attachment. The work time ratio of a dragline bucket and a clamshell bucket is given as follows:

$4.5 \times t_{b2} = 19 \times (6 - t_{b2})$

t_{b2} : work time by a dragline bucket hr/day

$t_{b2} = 4.9$ hr/day

Therefore, the work time ratio is given as follows:

Dragline Bucket	4.9 hr/day
Clamshell Bucket	1.1 hr/day

Productivity of Wheel Crane with Dragline Bucket per Day (V_{b4}):

The productivity of a wheel crane with a dragline bucket is as follows:

$$V_{b4} = qO_{b1} \times t_{b2} = 4.5 \times 4.9 = 22 \text{ m}^3\text{/day}$$

Required Number of Hydraulic Wheel Crane (N_{b1}):

$$N_{b1} = V_{b2} / V_{b4} = 66.2 / 22 = 3$$

(2) Dump Truck (4-ton)

The required number 4-ton dump truck to haul the sediment removed and loaded by a clamshell bucket from a drainage main or an outfall is calculated as follows:

$$qO_{b3} = (60 \times q_{b3} \times f_{b3}) / Cm_{b3}$$

q_{b3} : Production per cycle (m^3/cycle)
4-ton dump truck, soil specific gravity 1.8, 2.2 m^3/cycle

f_{b3} : Soil factor = 1.25

Cm_{b3} : $t_{b3} + t_{b4} \times 2 + t_{b4}$
t_{b3} : Loading time (min/cycle)

Loading time of the sediment from a drainage main or an outfall to a dump truck is calculated as follows:

t_{b3} : q_{b3} x 60) / $q0_{b2}$
= (2.2 x 60) / 19
= 7 min/cycle

t_{b4} : Hauling time from job site to dumping site (min/cycle)
Surveyed Time: 60 min/cycle

t_{b5} : Dumping time (min/cycle)
10 min/cycle

Cm_{b3} = 7 + 60 x 2 + 10
= 137 min/cycle

$q0_{b3}$ = (60 x 2.2 x 1.25) / 137
= 1.2 m^3/hr

Productivity of 4-ton Dump Truck per Day ($q0_{b4}$):

$q0_{b4}$ = $q0_{b3}$ x T_2
= 1.2 x 6
= 7.2 m^3/day

Required Number of 4-ton Dump Truck per Hydraulic Wheel Crane (n_{b1}):

n_{b1} = V_{b3} / qo_{b4}
= 22 / 7.2
= 3

Required Number of 4-ton Dump Truck (N_{b2}):

N_{b2} = n_{b1} x N_{b1}
= 3 x 3
= 9

(3) Jig for Dragline

Two sets of jig for dragline per one wheel crane is required to dredge the sediments.

Required Number of Jig for Dragline:

$$N_{b3} = 2 \times N_{b1} = 2 \times 3 = 6$$

(4) Diesel Engine Generator for item (3)

One diesel engine generator is required for a portable blower.

Required Number of Diesel Engine Generator (N_{b4}):

$$N_{b4} = 1 \times N_{b3} = 1 \times 6 = 6$$

(5) Truck (6-ton)

6-ton Truck is provided for a set of items (3) and (4).

Required Number of 6-ton Trucks:

$$N_{b5} = 1 \times N_{b3} = 1 \times 6 = 6$$

(6) Portable Blower

The hydraulic wheel crane is with personnel in a drainage main or an outfall for dragline work. Therefore, to keep the work place in safe condition, a portable blower is required for ventilation.

Required Number of Portable Blower (N_{b3}):

$$N_{b6} = 2 \times N_{b3} = 2 \times 3 = 6$$

(7) Diesel Engine Generator for item (6)

One diesel engine generator per two portable blowers is provided.

Required Number of Diesel Engine Generator for item (6):

$$N_{b7} = 1/2 \times N_{b6} = 1/2 \times 6 = 3$$

(8) Gas Detector (Oxygen, Combustible Gas, Hydrogen Sulfide)

The gas detector is necessary to protect personnel working in a drainage main or an outfall from hazardous gas. One gas detector is required for one hydraulic wheel crane.

Required Number of Gas Detector (N_{b8}):

$$N_{b8} = 1 \times N_{b1} = 1 \times 3 = 3$$

(9) Floodlight

Two sets of floodlight per one wheel crane is required for night work.

Required Number of Floodlight:

$$N_{b9} = 2 \times N_{b1} = 2 \times 3 = 6$$

5. Esteros

5.1 Dimension and Dredging Volume

	Average Width (m)	Length (m)	Dredging Volume (m^3)
Sta. Clara	6.2	1,340	4,000
Tripa de Gallina	10.3	3,270	16,800
Parañaque	26.6	1,790	13,800
Makati Diversion Channel	12.0	1,410	8,500
Calatagan Creek	4.0	3,000	6,000
Dilain Creek	10.0	1,400	7,000

Total Length (Ld_1) 12,210 m

Total Dredging Volume (Vd_1) 78,100 m^3

5.2 Required Number of Equipment

5.2.1 Large Esteros

The required volume to be dredged in Estero de Parañaque within 2.5 years is calculated as follows:

Required Dredging Volume (Vd_2): 35,800 m^3

Required Dredging Volume per Day (Vd_3):

$$V_{d3} = V_{d2} / (D_1 + D_2 \times 1.5) = 35{,}800 / (230 + 230 \times 1.5) = 62.3 \text{ m}^3\text{/day}$$

Required Dredging Volume per Hour (Vd_4):

$$V_{d4} = V_{d3} / T_2$$
$$= 62.3 / 6$$
$$= 10.4\ m^3/hr$$

(1) Medium Size Dredging Barge

Productivity per Hour of 0.6 m^3 Clamshell Glove Crawler ($q0_{d1}$):

$$q0_{d1} = [(q_{d1} \times f_{d1} \times K_{d1} \times 60^2)/Cm_{d1}] \times (E_{d1} \times \eta_{d1})$$

$q0_{d1}$: Glove capacity, 0.6 m^3

f_{d1} : Soil factor
Soft clay 0.95

k_{d1} : Glove excavation factor
Soft clay 0.95

Cm_{d1} : Glove cycle time (sec/min)
Dredging depth, shallow: 60 sec/cycle

E_{d1} : Job efficiency
Weather condition, normal,
Soil thickness - plane shape - position -
Cross section shape, very variable, 0.7

η_{d1} : Work time efficiency
Under the condition of E_{d1}: 0.7

$$q0_{d1} = [(0.6 \times 0.95 \times 0.95 \times 60^2) / 60] \times 0.7 \times 0.7$$
$$= 15.9\ m^3/hr$$

Required Number of Medium Size Dredging Barge (N_{d1}):

$$N_{d1} = V_{d4} / qO_{d1}$$
$$= 10.4 / 15.9$$
$$= 0.65$$
$$= 1$$

(2) Scow

The dredging work on the esteros is not influenced by tidal current and rough weather. Therefore, one tugboat maneuvers one dredging barge and two scows. The tugboat tows the scows for 3 hours and maneuvers the dredging barge for 3 hours in a day.

Loading Capacity of Scow2 (B_1):

$$B_{d1} = (1/5 + d_{d1} / \nu_{d1} \times 2) \times (qO_{d1} \times T_2) / (t_{d1} \times f_{d1})$$

d_{d1} : Average towing distance per round trip (km)

The distance to be dredged is 1.8 km. Therefore, the distance is assumed at 1.8 km.

ν_{d1} : Average towing speed (km/hr)
6.5 km/hr

t_{d1} : Towing time per day (hr/day)
3 hr/day

$$B_d = (1/5 + 1.8/6.5 \times 2) \times (1.59 \times 6) / (3 \times 0.95)$$
$$= 25.2 \text{ m}^3$$

The scow consists of 12 hoppers, 2 m^3 capacity each.

Required Number of Scow (N_{d2}):

$$N_{d2} = 2 \times N_{d1} = 2 \times 1 = 2$$

(3) Tugboat

Required Number of Tugboat (N_{d3}):

One tugboat is required for one dredging barge and two scows.

$$N_{d3} = 1 \times N_{d1} = 1 \times 1 = 1$$

(4) Dump truck (11-ton)

Road and traffic conditions surrounding Estero de Parañaque is suitable to haul the removed sediment using an 11-ton dump truck.

Productivity per Hour of 11-ton Dump Truck ($q0_{d2}$):

$$q0_{d2} = (60 \times q_{d2} \times f_{d2}) / Cm_{d2}$$

q_{d2} : Production per cycle (m^3/cycle)
11-ton Dump truck, soil specific gravity 1.8
6.1 m^3/cycle

f_{d2} : Soil factor
Loose, excavated, high water containing clay 1.25

Cm_{d2} : Cycle time (min/cycle)

$$Cm_{d2} = t_{d2} + t_{d3} \times 2 + t_{d4}$$

t_{d2} : Loading time (min/cycle)
The crane hooks up 2 m^3 hoppers from a scow, and loads the removed sediment to an 11-ton dump truck.

t_{d2} : $(q_{d2} \times t_{d5}) / (2 \times 60)$

t_{d5} : Cycle time of crane

90° 30 sec/cycle in addition to the hopper and wire operation, and loss of time.
60 sec/cycle

$t_{d2} = (6.1 \times 60) / (2 \times 60)$
$= 3$ min/cycle

t_{d3} : Hauling time (min/cycle)
Surveyed Time: 60 min/cycle

t_{d4} : Dumping time (min/cycle)
10 min/cycle

$Cm_{d2} = 3 + 60 \times 2 + 10$
$= 133$ min/cycle

$q0_{d2} = (60 \times 6.1 \times 1.25) / 133$
$= 3.4\ m^3/hr$

Productivity per day of 11-ton Dump Truck (q_{d3}):

$q_{d3} = q0_{d2} \times T_2$
$= 3.4 \times 6$
$= 20.4\ m^3/day$

Required Number of 11-ton Dump Truck per Dredging Barge (n_{d1}):

$$n_{d1} = V_{d3} / (N_{d1} \times q_{d3})$$
$$= 62.3 / (1 \times 20.4)$$
$$\fallingdotseq 3$$

Required Number of 11-ton Dump Truck (N_{d4}):

$$N_{d4} = n_{d1} \times N_{d1}$$
$$= 3 \times 1$$
$$= 3$$

(5) Hydraulic Truck Crane

Loading time of 11-ton Dump Truck per Dredging Barge per Day (t_{d6}):

$$t_{d6} = V_{d3} / (N_{d1} \times 2)$$
$$= 62.3 / (1 \times 2)$$
$$= 31 \text{ min/day} \cdot \text{unit})$$

Required Number of Hydraulic Truck Crane per Dredging Barge (n_{d2}):

$$n_{d2} = t_{d6} / (T_2 \times 60)$$
$$= 31 / (6 \times 60)$$
$$= 0.09 / \text{unit}$$

Required Number of Hydraulic Truck Crane (N_{d5}):

$$N_{d5} = n_{d2} \times N_{d1}$$
$$= 0.09 \times 1$$
$$= 0.09$$
$$\fallingdotseq 1$$

One hydraulic truck crane is required with unloading/loading stations installed at one point along the esteros for two dredging barges. However, the whole dredging work will stop when the crane becomes out of order, and where it is difficult to have three dump trucks at one station for the unloading/loading, another station is necessary to dredge the esteros continuously. Therefore, one hydraulic truck crane is required for one dredging barge.

Required Number of Hydraulic Truck Crane (N'_{d5}):

$$N'_{d5} = N_{d5} \times N_{d1} = 1 \times 2 = 2$$

5.2.2 Small Esteros

It is impossible to dredge small size esteros by the medium size dredging barge because their width is narrow and many squatters live along both sides. Therefore, the esteros are to be dredged by using an amphibious type excavator.

Required Dredging Volume (V_{e1}): 42,300 m^3

Required Dredging Volume per Day (V_{e2}):

$$V_{e2} = V_{e1} / (D_1 + D_2 \times 1.5) = 42{,}300 / (230 + 230 \times 1.5) = 73.6 \ m^3/day$$

Required Dredging Volume per Hour (V_{e3}):

$$V_{e3} = V_{e2} / T_2 = 73.6 / 6 = 12.3 \ m^3/hr$$

(1) Amphibious Type Excavator

Productivity of 0.2 m^3 Hydraulic Backhoe per hour ($q0_{e1}$):

$$q0_{e1} = [q_{e1} \times f_{e1} \times K_{e1} \times 60^2)/Cm_{e1}] \times (E_{e1} \times \eta_{e1})$$

q_{e1} : Bucket capacity (m^3)
0.2 m^3

f_{e1} : Soil factor
Soft clay 0.95

K_{e1} : Glove excavation factor
Soft clay 0.95

Cm_{e1} : Glove cycle time (sec/cycle)
Clamshell 180: 42 sec/cycle

E_{e1} : Job efficiency
Clamshell, excavating and loading ground of clay: 0.6

η_{e1} : Work time factor
Under the condition of E_{e1}: 0.7

$$q0_{e1} = [(0.2 \times 0.95 \times 0.95 \times 60^2) / 42] \times 0.6 \times 0.7$$
$$= 6.5\ m^3/hr$$

Required Number of Amphibious Type Excavator (N_{e1}):

$$N_{e1} = V_{e3} / q0_{e1}$$
$$= 12.3 / 6.5$$
$$= 1.89$$
$$= 2$$

(2) Amphibious Type Carrier

Capacity of Amphibious Type Carrier:

$$q0_{e2} = \frac{B_{e1} \times 60}{Cm_{e2}}$$

B_{e1} : Capacity of amphibious type carrier
2.0 m^3 (one hopper)

Cm_{e2} : Cycle time of amphibious type carrier (min/cycle)

Loading time of a backhoe:	t = 2.0/6.5 =	19 min
Preparation	:	2 min
Hauling	:	4 min
Loading	:	4 min
Hauling	:	4 min
Preparation	:	2 min
Total		35 min

$$q0_{e2} = 2 \times 60 / 35$$
$$= 3.4 \ m^3/hr$$

Required Number of Amphibious Type Carrier per One Amphilibious Type Excavator (N_{e1}):

$$N_{e1} = \frac{q0_{e1}}{q0_{e2}}$$
$$= 6.5 / 3.4$$
$$= 1.9$$
$$\fallingdotseq 2$$

Required Number of Amphibious Type Carrier (N_{e2}):

$$N_{e2} = N_{e1} \times N_{e1}$$
$$= 2 \times 2$$
$$= 4$$

(3) Dump Truck (4-ton)

A 4-ton dump truck is to haul the dredged sediment to the dumping site.

Productivity of 4-ton Dump Truck per Day ($q0_{e3}$):

Same as 4.2 item (2)

$$q0_{e3} = 7.2 \ m^3/day$$

Required Number of Dump Truck for One Dredging Barge (n_{e2}):

$$n_{e2} = V_{e2} / (N_{e1} \times q_{e3})$$
$$= 73.6 / (2 \times 7.2)$$
$$= 5.1$$
$$= 5/\text{unit}$$

Required Number of 4-ton Dump Truck (N_{e3}):

$$N_{e3} = n_{e2} \times N_{e1}$$
$$= 5 \times 2$$
$$= 10$$

(4) Hydraulic Wheel Crane

Road and traffic conditions surrounding small esteros and the unloading/loading spaces for the dredged sediment from the scow to the dump truck are very complicated because the small esteros are in densely populated areas. Therefore, one hydraulic wheel crane is required for one dredging barge to minimize the loss of working time.

Required Number of Hydraulic Wheel Crane (N_{e4}):

$$N_{e4} = 1 \times N_{e1}$$
$$= 1 \times 2$$
$$= 2$$

JICA