社会開発調査部報告書

JAPAN INTERNATIONAL COOPERATION AGENCY

HANOI PEOPLE'S COMMITTEE
SOCIALIST REPUBLIC OF VIET NAM

# THE STUDY ON URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM IN HANOI CITY

# FINAL REPORT

## APPENDIXES
## VOLUME II



FEBRUARY 1995

NIPPON KOEI CO., LTD.
CTI ENGINEERING CO., LTD.

**ESTIMATE OF PROJECT COST**

| | | |
|---|---|---|
| Estimate of Base Cost | : | At 1994 Price Level |
| Currency Exchange Rate | : | US$ 1 = Dong 10,800 = Yen 100 |

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## ABBREVIATIONS

(1) Domestic Organizations

| | |
|---|---|
| DCWSS | Design Company for Water Supply and Sanitation System |
| GDOMH | General Department of Meteorology and Hydrogy |
| HEC | Hanoi Environment Committee |
| HPC | Hanoi People's Committee |
| HSDC (or SDC) | Hanoi Sewerage and Drainage Company |
| HUPI (or UPI) | Hanoi Urban Planning Institute |
| HWSC (or WSC) | Hanoi Water Supply Company |
| INVESCo | Investment Company for the Development of Water Sector |
| IURP | Institute of Urban and Rural Planning of MOC |
| MOC | Ministry of Construction |
| MOSTE | Ministry of Science, Technology and Environment |
| MOWR | Ministry of Water Resources |
| SPC | State Planning Committee |
| TUPWS | Transport and Urban Public Works Service |
| URENCO | Hanoi Urban Environment Company |
| WASECO | Water and Sewerage Construction Organization |

(2) International or Foreign Organizations

| | |
|---|---|
| CIDA | Canadian International Development Agency |
| FINNIDA | Finnish International Development Agency |
| JICA | Japan International Cooperation Agency |
| SIDA | Swedish International Development Authority |
| OECF | Overseas Economic Cooperation Fund, Japan |
| UNDP | United Nations Development Programme |
| UNIDO | United Nations Industrial Development Organization |

(3) Others

| | |
|---|---|
| BOD | Biochemical Oxygen Demand |
| COD | Chemical Oxygen Demand |
| DAWF | Daily Average Water Flow |
| DSF | Design Stormwater Flow |
| EIRR | Economic Internal Rate of Return |
| EL | Elevation above Mean Sea Level |
| GDP | Gross Domestic Product |
| GF | Groundwater Infiltration |
| HMWF | Hourly Maximum Water Flow |
| OM | Operation and Maintenance |
| SS | Suspended Solids |
| TN | Total Nitrogen |
| TP | Total Phosphorus |

## ABBREVIATIONS OF MEASUREMENT

**Length**

| | | |
|---|---|---|
| mm | = | millimeter |
| cm | = | centimeter |
| m | = | meter |
| km | = | kilometer |
| ft | = | foot |
| yd | = | yard |

**Area**

| | | |
|---|---|---|
| $cm^2$ | = | square centimeter |
| $m^2$ | = | square meter |
| ha | = | hectare |
| $km^2$ | = | square kilometer |

**Volume**

| | | |
|---|---|---|
| $cm^3$ | = | cubic centimeter |
| l | = | litre |
| kl | = | kilolitre |
| $m^3$ | = | cubic meter |
| gal. | = | gallon |

**Weight**

| | | |
|---|---|---|
| mg | = | milligram |
| g | = | gram |
| kg | = | kilogram |
| ton | = | metric ton |
| lb. | = | pound |

**Time**

| | | |
|---|---|---|
| s | = | second |
| min | = | minute |
| h | = | hour |
| d | = | day |
| y | = | year |

**Electrical Measurement**

| | | |
|---|---|---|
| V | = | Volt |
| A | = | Ampere |
| hz | = | Hertz (cycle) |
| Ghz | = | Gigahertz |
| W | = | Watt |
| kW | = | kilowatt |
| MW | = | Megawatt |
| GW | = | Gigawatt |
| pr | = | pair |

**Other Measures**

| | | |
|---|---|---|
| % | = | percent |
| PS | = | horsepower |
| ° | = | degree |
| ' | = | minute |
| " | = | second |
| $10^3$ | = | thousand |
| $10^6$ | = | million |
| $10^9$ | = | billion |

**Derived Measures**

| | | |
|---|---|---|
| $m^3/s$ | = | cubic meter per second |
| mg/l | = | milligram per litre |
| kWh | = | Kilowatthour |
| MWh | = | Megawatthour |
| GWh | = | Gigawatthour |
| kWh/y | = | kilowatthour per year |
| kVA | = | kilovolt ampere |
| lcd | = | litre per capita per day |

**Currency**

| | | |
|---|---|---|
| US$ | = | US Dollar |
| VND | = | Vietnamese Dong |

# THE STUDY
# ON
# URBAN DRAINAGE AND WASTEWATER
# DISPOSAL SYSTEM
# IN
# HANOI CITY

## APPENDIX (E)

## WASTEWATER DISPOSAL PLAN

FEBRUARY 1995

**THE STUDY ON**
**URBAN DRAINAGE AND WASTEWATER DISPOSAL SYSTEM**
**IN**
**HANOI CITY**

**APPENDIX (E)**
**WASTEWATER DISPOSAL PLAN**

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# E1. EXISTING SEWERAGE SYSTEM

## 1.1 General Conditions

The study area is located on flat terrain on a river delta and hydrologically characterized by five rivers, Kim Nguu, Set, Lu, To Lich, and Nhue.

Wastewater is discharged into the water body through the sewers, open channels or ponds without an adequate treatment system. The majority of existing sewers were constructed prior to 1954. The hydraulic gradient of the sewers is small and the sewers are prone to silting.

As a result, the existing sewerage system is inadequate for flood disposal and environmental mitigation measures.

## 1.2 Collection System

Almost all wastewater is collected using the combined system, handling both stormwater and wastewater (see Figure E1.1). In a few cases, particularly in new suburban areas, such as Kim Lien (see Figure E1.2), a separate system has been adopted, though the treatment plant is presently not operational.

## 1.3 Existing Urban Sewerage System

### 1.3.1 Service Coverage

The existing combined sewer system and sewered area are shown in Figure E1.1. The service coverage of the sewer system in the urban area is calculated using an average figure of 0.13 m of sewer pipe per capita, as shown at Table E1.1.

### 1.3.2 Level of Service

As an index of service coverage, the per capita sewerage is only 0.15 m in urban areas and less than 0.1 m in rural areas. The per capita length of sewer is a useful but not fully reliable indicator for comparing the level of service.

The amount of sewered area in the study area is about 28 %. The length of sewer per unit area is about 100 m/ha in the old city area, and 25 - 40 m/ha in the new urban area.

The average of sewer coverage per area for the whole urban area is 38.5 m/ha. The average of paved roads per area is 47.1 m/ha. (Table E1.1)

The existing level of service is low compared with developed country's standard level of more than 100 m/ha.

### 1.3.3 Existing Flow Capacity of Urban Drainage Sewer

The existing capacity of sewer is estimated as shown in Table D2.9, Appendix D.

### 1.3.4 Existing Pumping Stations

The number and capacity of existing pumping stations are shown in Table E1.2 (1), (2) and (3).

## 1.4 Wastewater Disposal System

There is one (1) public wastewater treatment plant and two (2) on-site wastewater treatment plants in the study area. The public treatment plant, which was constructed with a gravity settling method in 1965, is located at Kim Lien residential quarters and treats domestic wastewater. However, the plant is not functioning due to a lack of operation and maintenance. The Kim Lien sewerage system covers 26 ha and serves about 25,000 people. Figure E1.2 shows the layout of the system.

One on-site treatment plant was established with the support of UNIDO in Oct. 1992, to treat industrial wastewater discharged from the Thuy Khue tannery factory in Ba Dinh district. At present, this plant has ceased operating due to budget, restrictions.

The other was set up with support of the Swedish Government in Dec., 1981, to treat domestic wastewater from the Children hospital in Ba Dinh district. The plant was not operated from 1984 until 1992 because of the lack of adequate maintenance. At present, the plant has been operating since 1993 after repairs made with the cooperation of Sweden.

## 1.5 Sanitation Facilities

On-site sanitation facilities are used for the treatment of toilet waste only. Other domestic wastes, such as gray water and commercial wastewater, are directly discharged to drains.

A variety of toilets, ranging from flush/pour-flush toilet to vault/ double-vault latrine, bucket latrine and fishpond latrine, are in use. Fishpond latrines or latrines hanging above water bodies are more common in rural areas. The existing domestic on-site sanitation facilities are classified into the following (4) types ;

(1) Public Toilet with Septic Tank/Double-vault

A public toilet is a group of toilets for communal use of neighboring communities, generally including bathing and washing facilities as well. Theoretically, sludge is collected by URENCO.

(2) Individual Toilet connected to Conventional Water Borne Sewer Systems

Wastewater from toilets is discharged through pits, such as retaining chambers and septic tanks, and thus is partly treated before its conveyance into the sewer network. Most sludge, including gray water and household refuse, appears to be conveyed via pits, or discharged directly into sewers.

(3) Individual Toilet with Treatment

Effluent from septic tanks or double-vault latrines is discharged directly into nearby canals, street drains or water courses. However, effluent pollutes the environment as excess sludge is not properly collected by URENCO.

(4) Individual Toilet with No Treatment

This type includes pit latrine, bucket and fishpond or hanging latrine which discharge nightsoil directly to nearby channels, street drains or water courses.

The number of existing toilets under the management of URENCO are shown in Table E1.3. The population served by the various types of latrines has been estimated as follows according to the UNDP study report;

| Type of latrine | Population served |
|---|---|
| Water borne | : 540,000 |
| Double vault latrine | : 200,000 |
| Bucket latrine | : 180,000 |
| Public toilet(double vaults/septic) | : 80,000 |
| Total | : 1,000,000 |

1.6 Collection System of Dragged Sludge and Solid Waste

Maintenance of sewers in the urban area is carried out by SDC and the dragged sludge is disposed of at a temporary yard located near fish ponds in Tu Liem district. The maintenance of open channels in the suburban area is carried out by each local authority.

The Urban Environmental Company(URENCO) is responsible for collecting and processing urban refuse including the following tasks;

- collecting urban domestic refuse from households
- collecting garbage in public areas, cleaning streets and public areas
- collecting human waste from houses and public toilets
- processing collected refuse and human waste

Refuse volume collected by URENCO is estimated to be 2,191 $m^3$/day. However, 30 % of the total volume and only 20 % of total nightsoil is collected.

## 1.7 Existing Master Plan Prepared by UPI, HPC

It is difficult for us to review the existing UPI master plan for sewerage in 2010 on account of a lack of reports and detailed information (as of February, 5). Based on an interpretation of the sewerage plan shown in the city's development plan(see Figure E1.3), the following concepts are assumed to have been taken into account :

- Objective area is divided into five (5) sub-areas as shown in Figure E1.3
- Existing combined sewer shall remain in use, where practical
- Sub-areas No. 2&3 are a large scale centralized treatment zone using a combination of existing combined system and a new separate system
- Sub-area No. 4 is a conventional separate system zone
- Sub-areas No.1 & 5 are indistinct (no clear information is indicated)
- Although three large-scale centralized treatment plants are planned, it is not clear what the proposed design will be.

Although clear planning data and available information except for land use map are unavailable, the zoning of sub-areas in the existing master plan appear to be adequate, judging from the existing condition of the sewerage system in the study area.

## 1.8 Problems and Constraints under Present Condition

The following problems and constraints are clarified;

(a) The existing capacity of the trunk sewer in the urban area is inadequate for even stormwater of a one (1) year return period. The city traffic system is frequently affected by heavy rain during the rainy season because the paved road also functions as the main drain, unlike the combined sewer system in the urban area.

(b) As the majority of sewers are built prior to 1954, detail data, including size and invert elevation, are not available.

(c) Wastewater inflows to the water bodies without adequate treatment, overloading the self-purification capacities of the water body.

(d) The hydraulic gradient of the sewers is small and are prone to silting.

(e) The level of sanitary facilities for the communities is very low. Gray water is discharged into the neighboring channels, lakes/ponds, and land untreated.

(f) Pollution of the public water course worsens proportionally to the increase in population density of the catchment area.

(g) Household refuse is dumped directly into the public water course, even into sewers, due chiefly to the limited capacity of URENCO's present collection system.

(h) As a result, the existing sewerage system is unable to function as flood disposal facility and hygiene sustaining facility.

## E2. ASSESSMENT OF POLLUTION LOAD

### 2.1 Water Consumption

Piped water service for the Study area is provided by the Hanoi Water Supply Company (HWSC) under the control of the Hanoi People's Committee. The water resources are groundwater in the area. The existing area, covered by the public water supply, is shown in Figure E2.1.

The HWSC has a water master plan targeting the year 2010 which was prepared by FINNIDA. The master plan will serve piped water to 993,417 people or 76 % of the total population of the Study area. The future water service area in 2010 will be extended to 90 $km^2$ or 64 % of the Study area as shown in Figure E2.2.

Unit water consumption rates are principally estimated following the method and criteria adopted in the Water Master Plan Study by FINNIDA.

(1) Unit Domestic Water Consumption

The per capita domestic water consumption is estimated by water use category, both for present condition (1992) and future (2010), as follows;

| Type of water supply | 1992 | 2010 |
|---|---|---|
| Public water supply area | 90 l/c/d | 180 l/c/d |
| Individual water supply area | 50 l/c/d | 100 l/c/d |

(2) Unit Commercial Water Consumption

The unit commercial water consumption of the Study area is estimated based on the number of the daytime population, and multiplying the domestic water consumption rate (see (1) above) by multipliers set forth below (Source: Water Master Plan).

| Type of commercial area | | 1992 | 2010 |
|---|---|---|---|
| Small Industry | : | 6 l/c/d | 15 l/c/d |
| Public Works | : | 37 l/c/d | 40 l/c/d |
| Total | : | 43 l/c/d | 55 l/c/d |
| Multiplier to Inhabited population | : | 2.1 | |

(3) Unit Industrial Water Consumption

The estimated unit industrial water consumption is 40 $m^3$/ha/d for 1992 and 35 $m^3$/ha/d for 2010 (Source: Water Master Plan).

Data of the existing industrial water consumption and industrial product amounts were obtained through the HPC. Table E2.1 shows the existing product, water consumption and unit water consumption (water consumption per product amount) by the type of industry.

Based on the above data, the existing industrial unit water consumption of the study area is summarized as follows;

| Industrial Classification | Unit Water Consumption (m³/day/million VND in 1989) |
|---|---|
| 1. Mechanical Engineering (Machinery, Motor parts, Tools) | 0.023 |
| 2. Construction Material (Tile, Brick, Iron, Concrete, Steel) | 0.036 |
| 3. Food Processing | 0.013 |
| 4. Textile | 0.021 |
| 5. Garment | 0.125 |
| 6. Leather & Tannery | 0.033 |
| 7. Printing | 0.063 |
| 8. Pottery & Glass | 0.043 |
| 9. Chemicals & Pharmacy | 0.098 |
| 10. Forestry Wood Processing | 0.027 |
| 11. Paper Manufacturing | 0.186 |
| 12. Others | 0.079 |

(4) Daily Average Water Supply per Capita

Table E2.2 shows the comparison between the daily average water supply per capita for developing countries and developed countries.

## 2.2 Wastewater Yield

Based on the unit water consumption rates, wastewater yield is estimated as shown in Table E2.3 and E2.4 on the assumption that the generation rate of (domestic/commercial) wastewater is 100 % of (domestic and commercial) water consumption, and the generation rate of industrial wastewater is 80 % of industrial water consumption.

## 2.3 Unit Pollution Load

(1) Unit Pollution Load Generation

The pollutant load per unit activity in Hanoi City, was estimated by the Canadian study team at 100 g/c/day. However, this figure appears to be relatively high compared to the pollutant load per capita in other countries, shown in Table E2.5. The unit pollution load generation is tentatively adopted as follows;

(a) Domestic wastewater : 40 g/c/d for 1992
60 g/c/d for 2010

(b) Commercial wastewater : 200 mg/l of BOD for 1992
The future wastewater quality is assumed to be the same as the present.

(c) Industrial wastewater : 400 mg/l of BOD for 1992 and 2010. This was decided after comparing the data on wastewater yield and pollutant load for each type of industry in Japan, as shown in Table E2.6, as Vietnamese data is not available.

The quality of industrial wastewater shall be estimated in principle for each of the respective classifications based on the existing data. Nevertheless, the Study has to adopt the above estimate as an average figure, since the data on existing wastewater quality discharged out of Hanoi City factories have not been available.

(2) Characters of Sewage

Table E2.7 shows the comparison on the characters of sewage in the Torrid zone and the Temperate zone.

## 2.4 Total Pollution Load

The total yield of wastewater and pollution load are estimated as follows;

| | 1992 | 2010 |
|---|---|---|
| Wastewater generation(1000m3/d) | 173.9 | 378.4 |
| Pollution load generation (ton/d) | 64.2 | 119.7 |
| Average wastewater quality of BOD (mg/l) | 369 | 316 |

The break-down of wastewater and pollutant load generation is shown in Table E2.8.

# E3. FRAMEWORK OF SEWERAGE DEVELOPMENT PLAN

## 3.1 Needs for Sanitation and Sewerage Development

The future water body quality of the study area in 2010 shall be improved through sanitation and sewerage development. It is necessary for the sewerage development master plan to encompass the whole study area to achieve requirements for the target year of 2010.

In this section, the future river water quality of the Study area in 2010 is forecast in order to confirm the requirements of sanitation and sewerage development, and identify the priority areas for development.

### 3.1.1 River Basins

The initial environmental and river water quality examination are carried out for the five (5) river basins covering the whole study area: To Lich, Lu, Kim Nguu, Set and Nhue, as described in the Appendix F. These five (5) river basins cover 13,540 ha including the West Lake with a population of 1.3 million. The river basins are divided into eleven (11) sub-basins as shown in Figure E3.1.

### 3.1.2 Wastewater and Pollution Load

The wastewater and pollution load is calculated for the whole Study area, consisting of the eleven (11) sub-basins. The existing and future wastewater discharge and pollution load run-off in terms of BOD levels, at the respective sub-basins, are estimated as shown in Table E3.1. and Figure E3.1.

The pollution load will almost double by the year 2010.

### 3.1.3 Simulation of River Water Quality

(1) Key River Stations for Assessing Water Flow and Pollution Load

The simulation of the river water quality is assessed for the six (6) key observatory stations (hereinafter called "key stations") covering the whole area of the To Lich river basin, as shown in Figure E3.2. The To Lich river basin includes six (6) sub-basins: To Lich, Lu, Set, Kim Nguu, Yen So and Hoan Liet, covering about 6,820 ha.

(2) Low Flow and Water Quality in terms of BOD Levels

Low flow and existing water quality in terms of BOD level surveyed at the respective key stations are summarized as follows (see Figure E3.2);

| Key Station | Low Flow($m^3$/sec) | BOD (mg/l) |
|---|---|---|
| (1) | 1.02 | 50 |
| (2) | 1.57 | 46 |
| (3) | 5.83 | 38 |
| (4) | 0.67 | 62 |
| (5) | 0.40 | 52 |
| (6) | 1.47 | 41 |

(3) Formula for Analysis of Pollution Load

The following formula is adopted to analyze the pollution load at the key river stations in the Study area;

$L_i = q_i \cdot C_i$

where,

$L_i$ : Pollution load at station "i" (ton/day)

$q_i$ : Pollution load runoff from river basin of station "i" (ton/day)

$C_i$ : Pollutant runoff coefficient at station for water quality forecasting ( $C_i = f_i \cdot K_i$ )

$f_i$ : Pollutant runoff coefficient at the end of inflow stream

$K_i$ : Purification efficiency at station for water quality forecasting

(4) Pollutant runoff coefficient at the end of the inflow stream ($f_i$)

The pollutant runoff coefficient at the end of the inflow stream ($f_i$) is calculated as follows;

(a) Calculated from the surveyed data on pollution load inflows at the stations, as follows:
$f_i$ = Pollution load inflow / Pollution load runoff

or

(b) Calculated by the following formula:
$Y = a / [1+ \exp(-b \cdot X+c)]$
where,
Y : log (Pollution runoff coefficient)
X : log (Population density/Area of river basin$^{/2}$)
a, b, c : Coefficient decided from surveyed data of similar river basins
(in case of the Edogawa river in Japan, a=2, b=3.04 and c=6.34)

or

(c) Standards on pollution runoff coefficient at the end of the inflowing stream, as follows;

- Rural district : 0.0 ~ 0.2
- Suburban area : 0.1 ~ 0.6
- Urban area : 0.6 ~ 1.0
- Sewered area : 1.0

(5) Purification efficiency at the stations for water quality forecasting($K_i$)

The purification efficiency at the station for water quality forecasting ($K_i$), means the ratio of BOD pollution load, between upstream stations and downstream stations. It is calculated by the formula (BOD at upstream/BOD at downstream).

(6) Simulation method adopted for the Study

The pollutant runoff coefficient at the end of the inflow stream ($f_i$) for the Study area, is calculated by using surveyed data on the pollution load inflow of BOD levels at each station. As the BOD surveyed data are affected by the purification efficiency ($K_i$) of the river basin, the pollutant runoff coefficient at the end of the inflow stream ($f_i$), calculated by the surveyed data, is considered to be the pollutant runoff coefficient at the station for water quality forecasting ($C_i=f_i \cdot K_i$).

### 3.1.4 Analysis of Existing and Future River Water Quality

The existing and future river water quality at the respective sub-basins are analyzed by the method described in Subsection 3.1.3. The analyzed results are shown in Table E3.2, and assessed in terms of BOD at the six input river stations, without sanitation and sewerage development.

By the year 2010, the average river water quality of the To Lich River basin, including the six sub-basins, will worsen from 31 mg/l to a level of 54 mg/l of BOD. The worst river water pollution in terms of BOD, of 130 mg/l, will occur in the Lu River sub-basin, followed by the To Lich River sub-basin at 89 mg/l, the Kim Nguu River sub-basin at 79 mg/l, and the Set River sub-basin of 54 mg/l.

The analyzed results of river water quality shows a tendency that BOD pollution will rise in proportion to the population density. Based on this analysis, it is evident that sanitation and sewerage development is a definite requirement for the urban area in Hanoi city.

### 3.1.5 Required Wastewater Treatment Level

(1) Estimation of Required Wastewater Treatment Level

The required wastewater treatment level is estimated by the following formula;

$$(Q \cdot x + q \cdot F)/(Q + q) = M$$

$$R = (E - x) / E$$

where,

| | |
|---|---|
| Q | : Wastewater discharged out of sub-basin ($m^3$/day) |
| E | : Wastewater quality as BOD level (mg/l) |
| q | : Low flow of river ($m^3$/day) |
| F | : River water quality of low flow as BOD level (mg/l) |
| x | : Required wastewater treatment level of BOD (mg/l) |
| M | : Maximum acceptable level of BOD (see Table E3.7) |
| R | : Required removal efficiency (%) |

According to the environmental quality standards for river water in Viet Nam, the maximum acceptable level of BOD (M) is 25 mg/l for Class 2 river. The required removal efficiency of BOD (R) is roughly 85 % for the To Lich River basin, shown in Table E3.3. Table E3.3 also shows a comparison of predicted river water quality without wastewater treatment, and with wastewater treatment.

(2) Index for Classification of Wastewater Treatment Level

The wastewater treatment level is decided by the removal efficiency proposed in comparison with the maximum acceptable level of river and predicted river water quality from the pollutant load runoff, as stated above. The major source of the pollutant load runoff in the Study area is domestic wastewater as described in Chapter E2, where domestic wastewater yield is largely dependent on the population density.

River water pollution will worsen in proportion to the increase of population density in the catchment area, as shown in Table E3.4, by the correlation between river water quality of BOD levels and the population density in the Study area. The correlation between river water quality of BOD levels and population density is expressed as follows;

$$Y = 27 \cdot \log X + 5.5$$

where,
Y : River water quality in terms of BOD levels (mg/l)
X : Population density (person/ha)

Therefore, in principle, the required wastewater treatment level of BOD for each zone can be determined or classified, based on its population density.

The classification of wastewater treatment levels of BOD are proposed to be as follows;

(a) Removal efficiency proposed by predicted river water quality

The future river water quality in the To Lich River basin is predicted using the surveyed data on low flow and inflow BOD, as described in Sub-section 3.1.3 & 3.1.4. The required removal efficiency for each sub-basin, and the wastewater treatment level of BOD is summarized below;

| Sub-basin (Population Density) | Removal Efficiency (%) | Treatment Level (mg/l) |
|---|---|---|
| To Lich (150-350) | 85 | 50 |
| Lu (>350) | 85 | 50 |
| Kim Nguu (50-150) | 80 | 65 |
| Set (50-150) | 80 | 65 |
| Hoan Liet (<50) | 75 | 90 |

(b) Correlation between BOD and population density

Using the above formula, river water quality in terms of BOD levels corresponding to various population densities of the catchment area, is estimated as follows.

| Population Density (person/ha) | River Water Quality (mg/l) |
|---|---|
| 50 | 52 |
| 150 | 65 |
| 250 | 71 |
| 350 | 75 |

(c) Maximum acceptable level of BOD for rivers

The target river water quality of the Study area is 25 mg/l according to the environmental river water quality standards in Viet Nam.

(3) Classification of Removal Efficiency

Required removal efficiency of BOD is determined as follows;

(a) Population density < 50 : Removal efficiency = 75 %
(b) Population density 50 ~ 150 : Removal efficiency = 80 %
(c) Population density ≥ 150 : Removal efficiency = 85 %

## 3.2 People's Desire for Sewerage Development

The interview survey was carried out by the Study team to obtain socio-economic information from the residents in the Study area. This included water supply and sewerage situation, flood/inundation condition and the resident's opinion on resettlement.

The results of the interview survey on the sewerage situation are as follows;

(a) Importance of sewerage improvement

All households interviewed recognized the importance of sewerage improvement in the Study area. Obviously, the sewerage and drainage system is poor and insufficient for their daily life, and we recognize the need for urgent improvement.

(b) Reason for sewerage improvement

Among several reasons given for the necessity of sewerage improvement, 80% of the households mentioned strong odours and excessive mosquitoes/germs. 40 % required safe drinking water, meaning the pollution of groundwater (main source of drinking water in Hanoi City) is serious in the Study area. Other reasons such as hygienic agricultural products or increasing land values were raised by 15 -17 % of the households. It is obvious most households are very concerned about heir health and sanitary situation, and strong by desire its improvement.

## 3.3 Development Concepts

### 3.3.1 Basic Concepts

(1) Target Year

The target completion year of the master plan is set at 2010 coordinating with Hanoi's integrated city planning, prepared by UPI, MOC and UPI, HPC.

(2) Project Area

The area of the master plan is in Hanoi City between the Red River and the Nhue River, covering about 135 $km^2$, including an urban area of 50 $km^2$, and adjacent farmland of 85 $km^2$.

(3) Design population

Design population is assumed as follows;

| | | 1992 | 2010 |
|---|---|---|---|
| Urban area | : | 956,271 | 1,112,800 |
| Rural area | : | 250,792 | 484,200 |
| Total | : | 1,207,063 | 1,597,000 |

(4) Sewage Collection System

Collection systems are classified into three (3) as follows;

| Item of Characteristics | (a) Combined System | (b) Separate System | (c) Partially Separate System |
|---|---|---|---|
| Environmental Protection | X | O | Δ |
| Construction Cost | O | X | Δ |
| Workability of O/M | Δ | O | X |
| Silting inside Sewer | X | O | Δ |
| Complication | X | O | X |
| Required Space for Sewer | O | X | Δ |
| Buried Depth of Sewer | O | X | Δ |

Note: O: Advantageous
Δ: Moderate
X: Inferior

For the present urban area, the existing combined system will remain in effective use. As for the other areas, the most suitable from the above systems will be adopted, according to their local conditions and land use plan for 2010.

### 3.3.2 Planned Sewage Flow

#### (1) Design Stormwater Flow (DSF)

The design stormwater flow is calculated using the rational formula and the rainfall intensity formula worked out by the Ministry of Construction in Viet Nam, which is given below :

$$Q = (1/360)CqA$$

$$q = [5416 (1 + 0.25 \times \log P \times t^{0.13})] / (t + 19)^{0.82}$$

where,

Q: Design stormwater flow
C : Runoff coefficient
A : Drainage area
q : Rainfall intensity (l/sec/ha, or mm/ha if divided by 3.6)
P : Return period,
t : Concentration time (min.)

The runoff calculation will be based on a combined runoff coefficient of unit areas of varying land uses as shown in Table E3.5.

#### (2) Design Wastewater Flow

(a) Daily Average Wastewater Flow (DAWF)

The following values will be adopted based on the water consumption projection of the main report for the Water Master Plan of Hanoi City, prepared by FINNIDA (detail is described in Subsection E2.1).

| | 1992 | 2010 |
|---|---|---|
| Domestic wastewater (l/c/day) | | |
| - Public water supplied area | 90 | 180 |
| - Individual water supplied area | 50 | 100 |
| Commercial wastewater | | |
| - Small industry (l/c/day) | 6 | 15 |
| - Public works (l/c/day) | 37 | 40 |
| Industrial wastewater (m3/ha/day) | 32 | 28 |

(b) Groundwater Infiltration (GF)

Groundwater infiltration and unexpected surface water intrusion shall be considered when designing the capacity of the sewerage collection system. Groundwater infiltration including unexpected surface water intrusion is experientially assumed to be 10 % to 20 % of DAWF.

In this study, the rate is proposed to be 10 % of DAWF in consideration of the following factors ;

- Sub-surface geological conditions : clay & silt with low permeability
- Static groundwater level : deeper than 3 m (or detailed information, refer to the Geological Investigation Report)
- Construction method & materials : Reinforced concrete pipes with colar joints

(c) Daily Maximum Wastewater Flow (DMWF)

The following formula is adopted to estimate DMWF ;

$DMWF = k_d \cdot DAWF$
where,
$k_d$ : Daily Peak Flow Factor (1.25)

The daily peak flow factor ($k_d$) is to be 1.25 comparing with the daily peak flow factor adopted in the following big cities ;

| | |
|---|---|
| Tokyo | 1.25 to 1.5 or data on water consumption |
| Bangkok | 1.20 |
| Manila | 1.20 |
| Jakarta | $k_d = 4.02 \cdot (0.0864Q)^{-0.154}$, Q: DAWF(l/sec) |
| Banding | 1.50 to 4 |
| Saigon | 1.25 |

(d) Hourly Maximum Wastewater Flow (HMWF)

The hourly maximum wastewater flow is usually estimated using the Babbit formula, as follows ;

$HMWF = k_h \cdot DMWF$

$k_h = M = 5 \qquad P < 1.0$
$\quad = 5 \div P^{1/2} \qquad 1.0 \leq P \leq 1000$
$\quad = 1.25 \qquad P > 1000$

where,
$k_h$: Hourly peak flow factor
M: Babbit coefficient
P: Design population ( unit : 1000)

Data of other countries, concerning the hourly peak flow factor ($k_h$) are presented as follows;

| | |
|---|---|
| Japan | 1.3 to 1.8 or Babbit formula |
| Malaysia | $M = 4.7 \cdot P^{-0.11}$, P: Design population(unit : 1000) |

Philippines  C = 2.2 - 0.3 · log(P/1000), P: Population served

The Babbit formula will be used to estimate HMWF for the Study area.

### 3.3.3 Planned Sewage Quality

The sewage discharged from pollutors, such as houses and industries, always fluctuates in quantity and quality. Because of this, even if daily BOD loading data is available, it cannot represent the acceptable BOD loading for planning. Also in Hanoi there is no biological data of wastewater discharged from pollutors. Therefore, it is difficult to obtain the acceptable BOD loadings specific to Hanoi. Planned sewage quality for the Study is therefore determined in consideration of data analyzed in other countries such as Japan, as described in Chapter E2.

(1) Wastewater Quality to be Discharged out of Pollutors

The planned wastewater quality for 2010 is determined as follows (detail is described in Subsection E2.3 ) ;

- Domestic wastewater : 60 g/c/d of BOD
- Commercial wastewater : 200 mg/l of BOD
- Industrial wastewater : 400 mg/l of BOD

(2) Wastewater Treatment Level

Treated wastewater quality shall be decided in conformity to the effluent standards in Viet Nam, as shown in Table E3.6, and moreover, in consideration of the environmental quality standards for river water in Viet Nam, as shown in Table E3.7.

The inflow wastewater quality of BOD to treatment plants to be located at each catchment area is shown in Table E3.1. The average inflow wastewater quality in terms of BOD levels will be 293 mg/l in the To Lich River basin and 483 mg/l in the Nhue River basin by 2010.

To improve public water courses and the sanitary conditions of communities, the required wastewater treatment level is tentatively determined as follows, according to the population density (detail is described in sub-section 3.1.4 & 5).

(a) Low population density area
- Population density : Not exceeding 50 person/ha
- Required removal efficiency : 75 %
- Target treated water quality : BOD level of 90 mg/l for domestic wastewater
  BOD level of 50 mg/l for industrial wastewater

(b) Medium population density area
- Population density : Range of 50-150 person/ha
- Required removal efficiency : 80 %
- Target treated water quality : BOD level of 60 mg/l for domestic wastewater
  BOD level of 50 mg/l for industrial wastewater

(c) High population density area
- Population density : More than 350 person/ha

- Required removal efficiency : 85 %
- Target treated water quality : BOD level of 50 mg/l for domestic wastewater
  BOD level of 50 mg/l for industrial wastewater

The above is proposed on the assumption that the natural purification of the river is disregarded. In cases with an individual disposal system the targeted treated water quality is 50 mg/l and where there is a centralized disposal system, the value is 400 mg/l.

In principle, densely inhabited areas and high population density areas will be accorded the highest priority, as they pose the highest risk in endangering sanitary environments.

### 3.3.4 Classification of Wastewater Disposal System

For the treatment of wastewater, the following three (3) systems are considered to be appropriate;

(a) On-site disposal system : to treat wastewater at each house/building/factory individually

This system includes the following methods:

- Simple on-site treatment method : to treat toilet wastewater only
- High level on-site treatment method : to treat both toilet wastewater and gray water

(b) Community disposal system : to treat wastewater at each community zone, such as housing/industrial estates and business centers

(c) Centralized disposal system : to treat wastewater using the public sewerage system

Commercial wastewater shall be treated by the same system as domestic wastewater. However, industrial wastewater will be treated individually or communally by a proper system based on polluters-pay principle. In the case of connecting with a centralized disposal system, industrial wastewater shall be pretreated according to the level of acceptable effluent limits (400 mg/l as BOD level).

The scale of the centralized disposal system is classified, according to the designed sewered population as follows;

(a) Small scale disposal system : less than 100,000

(b) Medium scale disposal system : 100,000 - 300,000

(c) Large scale disposal system : more than 300,000

The schematic wastewater disposal system for each scale is shown in Figure E3.3.

The formulation of whole system will be a combination of the above three different scale systems, which would be implemented by area and in stages. One medium scale system will be proposed instead of several small systems and one large system instead of several medium scale systems, as appropriate.

### 3.4 Design Criteria

#### 3.4.1 Deign Concept

The design concept of the sewerage system within the Study area is proposed as follows:

(a) To apply the following regulations and standards corresponding to the ;

- Design Standard for Works of Sewerage & Drainage System in Viet Nam (1989)
- Environmental Protection Law in Viet Nam (1994)
- Temporary Guidance for Environmental Impact Assessment ( 1993)
- Viet Nam System of Environmental Standards (1993)
- Regulations on the Protection of City Environment in Hanoi Capital (1991)
- Sewerage Law in Japan (1976)
- Water Pollution Control Law in Japan (1983)
- Building Standard Law in Japan (1983)
- Japan Sewage Works Association Standards (1984)

(b) To preserve the existing drainage basins,

(c) To utilize the existing combined system in the present urban area and to adopt a separate system for newly developed areas, in principle,

(d) To take adequate measures against flood inundation and environmental pollution according to the local conditions.

#### 3.4.2 Design Criteria for Sewerage

(1) Design Flow

Sewerage facilities, including sewers and wastewater treatment plants, shall be principally, designed, based on the design flow as follows (detail on design flow is described in the subsection 3.2.2 );

| Collection System | Facilities | Design Flow |
|---|---|---|
| Separate System | Sewer | |
| | - Wastewater | HMWF |
| | - Stormwater | DSF |
| | Treatment Plant | |
| | - Primary Treatment | DMWF |
| | - Influent Pipe | HMWF |

| | | |
|---|---|---|
| | - Secondary Treatment | DMWF |
| | - Effluent Pipe | HMWF |
| | Pumping Station | |
| | - Wastewater | HMWF |
| | - Stormwater | DSF |
| Combined System | Combined Sewer | HMWF+DSF |
| | Interceptor | > 3·HMWF |
| | Diversion Chamber | > DSF-2·HMWF |
| | Treatment Plant | DMWF |
| | - Primary Treatment | DMWF |
| | - Influent Pipe | > 3·HMWF |
| | - Secondary Treatment | DMWF |
| | - Chlorination Tank | > 3·HMWF |
| | - Effluent Pipe | > 3·HMWF |
| | Pumping Station | |
| | - Combined Sewage | HMWF+DSF |
| | - Wastewater | > 3·HMWF |
| | - Stormwater | > DSF-2·HMWF |

* Remarks HMWF : Hourly Maximum Wastewater Flow
DMWF : Daily Maximum Wastewater Flow
DSF : Design Stormwater Flow

(2) Sewers

The hydraulic design of the sewers is based on Manning's formula, which is given below ;

$$Q = A \cdot V$$
$$V = (1/n) \cdot R^{2/3} \cdot I^{1/2}$$

Where,
- Q : Discharge ($m^3$/sec)
- A : Sectional area of pipe ($m^2$)
- V : Mean velocity (m/sec)
- n : Roughness coefficient
- R : Hydraulic radius (m)
- I : Hydraulic gradient

The hydraulic design of the sewers has been based on the following criteria;

(a) Roughness coefficient : 0.013

Reinforced concrete pipe will be used for the sewer. The roughness coefficient of the concrete pipe is taken at 0.013, taking into account a long term operation.

(b) Allowable flow velocity : 0.6 - 3.0 m/sec for wastewater sewer
0.8 - 3.0 m/sec for combined/stormwater sewer

The minimum velocity shall not be less than 0.6 m/sec for the wastewater sewer and 0.8 m/sec for the combined/stormwater sewer in order to avoid sedimentation and to keep consistency with the onsite road gradient as much as possible. The maximum velocity shall be limited to 3.0 m/sec in order to prevent the pipe from eroding.

(c) Allowance of sewer capacity

The allowance of the combined/stormwater sewer capacity will be 10 % to 20 % of the design flow. The allowance of pipe capacity to design flow for wastewater sewer is determined as follows;

| Sewer Diameter (mm) | Allowance (%) |
|---|---|
| ≤ Ø 600 | 100 |
| Ø 700 - 1500 | 50 |
| ≥ Ø 1550 | 25 |

The above allowance is generally applied to select sewer pipes in consideration of unexpected flow fluctuation and to prevent the putrefaction of the sewage. The minimum size of pipe to be selected will be 200 mm for the wastewater sewer and 250 mm for the combined/stormwater sewer to secure the workability of maintenance & operation.

(d) Depth of earth covering : 1.0 - 7.0 m

The minimum earth covering is determined at 1.0 m to prevent any collapse of the pipes. The maximum depth of earth covering is determined to be 7.0 m in order to minimize construction cost.

(e) Maximum manhole interval

Manholes shall be located where changes in flow direction, pipe gradient and diameter occur, and at the originating point of the sewer pipeline and the junction of the pipes. The maximum manhole interval for each size of sewer is proposed as follows;

| Sewer Diameter (mm) | Maximum Interval (m) |
|---|---|
| ≤ Ø 300 | 50 |
| ≤ Ø 600 | 75 |
| ≤ Ø 1000 | 100 |
| ≤ Ø 1500 | 150 |
| ≤ Ø 1650 | 200 |

(f) Connection of pipes : Pipe bottom connection or Water surface connection

A pipe bottom connection is recommended in view of the depth of the pipe laying and construction cost. However, water surface connection is proposed in case of a difference of diameters between connection sewers, so as to prevent backwater at the sewer pipeline.

The hydraulic design of the sewer is calculated, as shown in Table E3.8, so that the hydraulic gradient along the sewer pipeline may be kept below the ground surface.

(3) Pumping Station

The types of pumping station are classified as follows according to their purpose, and the pumping facilities shall be designed using the above-mentioned design flow;

Separate system

| | | |
|---|---|---|
| - Relay pumping station | : | designed by HMWF for lifting and transporting wastewater |
| - Stormwater pumping station | : | designed by DSF for discharge of stormwater |
| - Treatment plant pumping station | : | designed by HMWF for lifting wastewater |

Combined system

| | | |
|---|---|---|
| - Relay pumping station | : | designed by (3·HMWF) for lifting and transporting wastewater |
| - Stormwater pumping station | : | designed by (DSF-2·HMWF) for discharge of stormwater |
| - Treatment plant Pumping station | : | designed by (3·HMWF) for lifting wastewater |

The design of the necessary pumping facilities has been based on the following criteria;

(a) Number of pumps

The necessary number of pumps is recommended as follows, based on the Japanese standard;

- Wastewater pump

| | | |
|---|---|---|
| Design flow($m^3$/sec) | $\leq 0.5$ | : 2 ~ 3 units (one is spare) |
| | 0.5 ~ 1.5 | : 3 ~ 5 |
| | > 1.5 | : 4 ~ 6 |

- Stormwater pump

| | | |
|---|---|---|
| Design flow($m^3$/sec) | $\leq 3.0$ | : 2 ~ 3 units |
| | 3.0 ~ 5.0 | : 3 ~ 4 |
| | > 5.0 | : 4 ~ 6 |

(b) Diameter of suction pump

The diameter of the suction pump shall be calculated by the following formula;

$$D = 146\sqrt{Q / V}$$

Where,

D : Diameter of suction pump (mm)

Q : Discharge capacity of pump ($m^3$/min)
V : Flow velocity in suction pipe ( 1.5 ~ 3.0 m/s)

(c) Grit chamber

The design criteria of the grit chamber is recommended as follows;

- Number of grit chambers : ≥ 2 units
- Bottom slope of grit chamber : 1/100 ~ 2/100
- Mean velocity : 0.3 m/sec
- Retention period : 30 ~ 60 sec
- Depth of sand pit : ≥ 30 cm
- Surface loading : 1800 $m^3/m^2$·day for wastewater
  3600 $m^3/m^2$ - day for stormwater

(d) Screen

For wastewater, the screen is generally placed before the grit chamber, and for stormwater, it is located after the grit chamber.

(e) Manhole-type relay pumping station

In the case of HMWF being less than 0.5 $m^3$/sec, a manhole-type relay pumping station, with the following criteria, is allowable;

- Minimum diameter of pump suction : 80 mm
- Type of pump : Vertical detachable submersible pump
- Grit chamber and screen are not necessary

(4) Treatment Plant

An activated sludge process is recommended in treating the wastewater generated in the Study area, because biodegradable wastewater will be collected and treated via the centralized disposal system, while toxic/hazardous wastewater will be individually treated at each on-site disposal system.

The activated sludge process can involve various methods, such as a conventional activated sludge process and on oxidation ditch process, and these methods shall be compared from the following points of view, to select the most suitable process for the Study area .

- Flexibility to shock/over load
- Workability with the operation and maintenance (O&M)
- Required costs of construction and O&M
- Required sludge disposal and volume of excess sludge
- Required land acquisition

The result of the comparison found the oxidation ditch process to be the most suitable method for the Study area (detail is described in Section 4.2). The general design criteria of necessary facilities for the oxidation ditch process are proposed as follows;

(a) Design flow : DMWF as stated above (1)

(b) Design inflow and effluent water quality : (refer to Section 3.2)
- Inflow average wastewater quality : 316 mg/l of BOD, 284 mg/l of SS
- Effluent average treated water quality : 50 mg/l of BOD, 60 mg/l of SS

(c) Removal ratio of BOD : 75-85 %

(d) Removal ratio of SS : 70-80 %

(e) Grit chamber : see Subsection 3.3.2 (3)

(f) Oxidation ditch :

- BOD-SS Loading : 0.03 ~ 0.05 kg/SS kg·day
- MLSS : 3000 ~ 5000 mg/l
- Aeration time : 24 hours
- Return sludge ratio : 50 ~ 150 %
- Flow velocity of bottom : ≥ 0.1 m/sec
- Number of ditch : ≥ 2 ditches
- Depth of ditch : 1 ~ 3 m
- Width of ditch : ≤ 6 m

(g) Settling tank :

- Surface loading : 20 ~ 30 $m^3/m^2$·day
- Settling time : ≥ 2.5 hours
- Weir loading : ≤ 150 $m^3$/m·day
- Number of tank : ≥ 2 tanks
- Depth of tank : 2.5 ~ 4 m

(h) Chlorination tank

A chlorination tank shall be designed for (DMWF) for the separate system and (3·HMWF) for the combined system respectively. Contact time is more than 15 minutes.

(5) Sludge dewatering facilities

The following sludge dewatering facilities are necessary:

(a) Thickener

- Type of thickener : Gravity
- Moisture content of excess sludge : 99.3 ~ 99.5 %
- Moisture content of thickened sludge: 98.0 ~ 98.5 %
- Solid loading : 30 ~ 50 kg/$m^2$·day
- Number of tank : ≥ 1 tank

(b) Dry bed

- Depth of dry bed : 15 cm
- Drying time :15 days

# E4. ZONING OF WASTEWATER DISPOSAL SYSTEM

## 4.1 Approach to Delineation of Sewerage Development Zones

### 4.1.1 Main Factors for Zoning

The following factors shall be considered and analyzed prior to the determination of zoning for sewerage development;

- Zoning in regard to drainage basins
- Zoning in regard to land use
- Zoning in regard to population density
- Zoning in regard to wastewater and pollution load generation
- Zoning in regard to wastewater disposal system
- Zoning in regard to sewage collection system
- Zoning in regard to the existing sewerage master plan prepared by UPI of HPC

A conceptual zoning plan for sewerage development shall be established in harmony of the above factors. Details of the main factors are described as follows;

(1) Division of Study Area by Drainage Basins

The existing drainage basins shall be preserved in order to minimize the environmental impact caused by the sewerage development. The zoning from this aspect is shown in Figure E3.1.

(2) Classification of Study Area by Land Use Plan

The existing area and future land use area for 2010 is classified as follows;

| | 1992 | 2010 |
|---|---|---|
| - Residential area | 2,298 ha | 3,679 ha |
| - Industrial area | 447 ha | 832 ha |
| - Commercial area | 833 ha | 1,226 ha |
| - Green & Park | 322 ha | 622 ha |
| - Utilities (Road & squares) | 379 ha | 967 ha |
| - Other area (Farmland & open space) | 10,191 ha | 6,214 ha |

The characteristics of each area in terms of land use are shown in Table E4.1.

The future land use plan (see Figure E4.1) is prepared by UPI of HPC in consideration of the relocation of specific water-consumptive industries yielding heavy-polluted effluent.

(3) Population Density

The existing population density is estimated as shown in Figure E4.2 (see also Table E2.3). The future population density in the Study area is shown in Figure E4.3 (see also Table E2.4), which would provide the basis for the zoning from a population aspect.

(4) Wastewater and Pollutant Load Generation

Zoning determined by wastewater and pollutant load generation is very important from the view-point of sustaining a hygienic environment. The priority sewerage development area will be decided by this factor. The existing and future pollutant load generations are respectively shown in Figure .E4.4 and E4.5.

(5) Wastewater disposal system

The wastewater disposal system is classified into three (3) systems, on-site, community, and centralized, as described in sub-section 3.3.4.

(6) Classification of Scale of Centralized Disposal System

The scale of the centralized disposal system is classified according to the designed sewered population, as described in sub-section 3.3.4.

(7) Sewage Collection System

Zoning in regard to collection systems is proposed on the existing collection systems and drainage basins, as mentioned in sub-section 3.3.1.

4.1.2 Conceptual Zoning Plan

Sewerage development zones shall be delineated, based on the technical and economic comparative study of the above factors, and especially in due consideration to the quantities of sewage and pollution load and the geographic conditions. The actual approach to delineation of the sewerage development zones is given below.

(1) Subdivision of Drainage Basins by Population Density

The existing drainage basins are subdivided by the four (4) areas defined with population density as described in sub-section 3.3.3.

(2) Unification of Subdivided areas by Land Use Plan

The areas subdivided by population density are grouped in consideration of their land use for 2010, prepared by UPI. As the sewage collection system will be principally designed according to the road plan, grouping of the subdivided areas is carried out using the following concept;

- Areas where future city road networks are planned will be objective areas for a centralized disposal system,
- Areas where no road network developments are planned may be regarded as non-treatment areas,
- On-site/community disposal systems are adopted for specified areas where future urbanization is unforeseen.

(3) Modification of Unified Zones by Wastewater and Pollutant Load Generation

From the viewpoint of economics of scale, the above grouped zones are further modified in consideration of the distribution of wastewater and pollutant load generation by area.

(4) Proposed Zoning Plan

A zoning plan is tentatively proposed as shown in Figure E4.6, based on approaches to zoning as stated above. The conceptual zoning plan is proposed as shown in Figure E4.7 based on harmonizing the above factors. The conceptual plan consists of seven (7) zones, with Zones 1, 2 and 6 divided respectively by two (2) sub-zones. The characteristics of each classified zone are summarized in Table E4.2.

## 4.2 Study of Wastewater Treatment Method

The relative merits of the practical treatment methods were examined by comparing several typical treatment methods in regard to the flexibility to system overloading, the technology level of O&M work, the adaptability to excess sludge disposal and land acquisition, as shown in Table E4.3.

The process of typical wastewater treatment methods is shown in Figure E4.8.

In general terms if/and is available, the aerated lagoon method is the most suitable in regard to the simplicity of operation and maintenance (O&M). However, for urban areas where available land is limited, the conventional activated sludge method is suitable.

As Viet Nam has had little experience in the operation of wastewater treatment plants, the introduction of varying types of treatment methods is not recommended in regard to the technology of O&M.

The oxidation ditch method (highest rated in Table E4.3) will be recommended since this method is adopted in many developing countries and is evaluated as the most moderate, all-round wastewater treatment method. The cost of sewerage disposal systems, therefore, is estimated on the cost of the oxidation method for the present study. A schematic layout for the oxidation ditch is shown in Figure E4.9.

## 4.3 Potential Sites of Centralized Wastewater Treatment Plants

### 4.3.1 Concept of Site Selection

Site selection for centralized wastewater treatment plants is carried out according to the following concepts;

(a) The plants are to be located at sites where wastewater from sewered areas can be mostly collected by gravity flow.

(b) Sites have enough space for construction of the treatment facilities.

(c) The plants are to be located at sites where operation of the facilities will cause minimal environmental impact.

(d) Sites are to be adjacent to the receiving waters of the treated wastewater.

(e) Sites are to be selected from less extensive land use areas (eg., open spaces) both at present and also in the future.

(f) The plants are to be located at suitable sites in order for the treated wastewater to be reused as maintenance flow or flushing water for rivers and lakes/ponds in urban area during the dry season.

### 4.3.2 Identified Potential Sites

According to the future land use plan, available land for plant construction is limited. The potential sites for the treatment plants identified by the Study team through site reconnaissance, are shown in Figure E4.7, and are summarized below.

(a) Potential site for Zone 1 - 1

- Located at Buoi with more than 7 ha of available land
- Ownership : Government
- Present/future Land Use : West Lake

or

- Located at Thuy Khe with more than 3 ha of available land
- Ownership : Government
- Present/future Land Use : Green & Park

(b) Potential site for Zone 2 (located at Zone 7)

- Located at Tran Phu with more than 350 ha of available land
- Ownership : Private
- Present/future Land Use : Farmland/pond

(c) Potential site for Zone 3

- Located at Lang Ha with approximately 8 ha of available land
- Ownership : Private
- Present Land Use : Farmland/pond
- Future Land Use : Residential - Village

(d) Potential site for Zone 4 (located at Zone 6-1)

- Located at Bach Mai Airbase with approximately 5 ha of available land
- Ownership : Government
- Present/future Land Use : Military land and pond

(e) Potential site for Zone 3 & 4 (located at Zone 5)

- Located at Trung Hoa with approximately 8 ha of available land

- Ownership : Private
- Present Land Use : Farmland
- Future Land Use : Residential - Village/farmland

(f) Potential site for Zone 5

- Located at Metri with approximately 300 ha of available land
- Ownership : Private
- Present/future Land Use : Open space and farmland

(g) Potential site for Zone 6

- Located at Tan Trien with approximately 400 ha of available land
- Ownership : Private
- Present/future Land Use : Open space and farmland

The identification of potential sites for the plants was made based on the above concepts of site selection.

The location of wastewater treatment plants will be a subject to further review according actual social condition and land use.

# E5. ALTERNATIVE STUDIES OF WASTEWATER DISPOSAL SYSTEM

## 5.1 Comparison of Alternatives

### 5.1.1 Prerequisite for Examination of Alternatives

The wastewater disposal plan in each zone is evaluated by the following alternative disposal systems.

(a) On-site/community disposal system
(b) Small scale centralized disposal system
(c) Medium scale centralized disposal system
(d) Large scale centralized disposal system

Prerequsite conditions for examining the above alternative disposal systems are as follows.

(1) Planned Wastewater Flow (Q) for Each Disposal System

- On-site/Community : Q < 1,000 $m^3$/d (Average flow= 100 $m^3$/d)
- Small-scale Centralized : Q < 18,000 $m^3$/d (Average flow= 10,000 $m^3$/d)
- Medium-scale Centralized : Q < 100,000 $m^3$/d (Average flow= 50,000 $m^3$/d)
- Large-scale Centralized : Q > 100,000 $m^3$/d (Average flow= 120,000 $m^3$/d)

(2) Sewer

The sewage collection system is assumed to be the separate system. The length of sewer is estimated on 100 m per unit sewered area (ha). The length of conveyance sewers having a diameter of more than 1,000 mm is estimated as follows;

- On-site/Community : No public sewer
- Small-scale Centralized : 3 % of total sewer
- Medium-scale Centralized : 10 % of total sewer
- Large-scale Centralized : 25 % of total sewer

(3) Construction Cost

Construction cost at 1994 price level is estimated by the following assumptions;

(a) Unit cost of sewer : US$ 70/m for 500 mm sewer (as average diameter pipe)

(b) Unit cost of conveyance sewer : US$ 200/m for 1000 mm sewer (as average)

(c) Unit cost of land acquisition : US$ 6,500/ha for farmland

(d) The cost of the plant for the on-site/community system is estimated assuming the use of a Japanese type septic tank (Johkaso) having the capacity to treat both night soil and gray water.

(e) The cost of the centralized disposal plant is estimated by the following Japanese formula:

$C_m=66.2 \cdot Q^{0.872}/105$

$C_c=165.7 \cdot Q^{0.590} \cdot k/105$

where,

| | | |
|---|---|---|
| $C_m$ | : | Construction cost for machinery & equipment (Million US$) |
| $C_c$ | : | Construction cost for civil works (Million US$) |
| Q | : | Planned wastewater flow (1,000 $m^3$/day) |
| k | : | Multiplier in consideration of less labor cost and materials cost in Viet Nam (0.6) |

(f) The cost of the pumping station is estimated on the price of a manhole type relay pumping station as follows:

$C=8.5 \cdot Q^{0.598}/105$

where,

C : Construction cost (Million US$)
Q : Planned wastewater flow ($m^3$/min)

(g) Operation and Maintenance (O&M) cost is estimated as 3 % of the construction cost for the centralized disposal plan and 0.3 % for the sewer and pumping station

The results of construction costs per wastewater flow at 1994 price level is shown in Table E5.1.

### 5.1.2 Alternative Disposal Systems Examined for Comparison

The following alternative systems are considered in the evaluation of sewerage development for each classified zone in regard to the economics of scale and environmental protection.

(1) On-site/Community disposal system

The Study area is divided into three (3) categories : a residential area, a commercial area including schools, hospitals and offices, and an industrial area. As this system is established on the pollutant-pay principle, institutional support by the government is necessary. The relative merits of this system are; (1) the facility can be provided in a short period with the small initial cost per unit and (ii) treated wastewater can be returned to the water body nearto the place of water consumption. The existing combined sewer is effectively utilized.

(2) Small-scale Centralized Disposal System

The Study area is divided into thirty six (36) sewerage sub-areas (see Figure E3.3). The wastewater of the objective area will be collected and treated independently in each zone. The treated wastewater may be easily returned into the nearby water body. One constraint of the system, is land is required for constructing plants at 36 locations, while potential sites identified by the Study are relatively limited, as shown in Figure E4.8. The construction cost of a conveyance sewer for the system is the cheapest within the centralized disposal system alternatives, but the annual O&M cost is the most expensive.

(3) Medium-scale Centralized Disposal System

This alternative envisages to integrated the above small-scale systems into seven (7) medium scale systems (see Figure E3.3). The wastewater from each sub-area will be collected and treated independently. Finding the potential areas for the construction of treatment plants will be difficult. Construction costs, including plants and conveyance facilities for the system, are the cheapest.

(4) Large-scale Centralized Disposal System

The above medium-scale systems are further integrated into three (3) large-scale systems (see Figure E3.3). Initial construction costs of the plants are the cheapest, but the cost of the conveyance facilities is the highest among the centralized system alternatives. The annual O&M cost is the lowest.

The particulars, construction costs and O&M costs of the alternative systems are preliminarily compared, as shown in Table E5.1.

The initial construction cost is the lowest for medium-scale centralized disposal systems and the highest for on-site/community disposal systems. The annual O&M costs is the most expensive for on-site/community disposal systems, followed by small-scale centralized disposal systems and the cheapest for large-scale centralized disposal systems.

## 5.2 Comparison of Alternative Systems

### 5.2.1 Alternative Studies of the Zoning Plan

The locations of wastewater treatment plants proposed by the conceptual zoning plan may prove difficult in land acquisition. Supplemental studies searching for alternative locations were carried out. The following alternative zoning plans for schematic wastewater disposal systems should be considered in accordance to the availability of land acquisition ;

(1) Alternative 1 of the Zoning Plan

Alternative 1 is an ideal zoning plan for the harmonization of the main factors as described in sub-section 4.1, assuming the land acquisition for zones 3 and 4 is possible and community disposal plants are established by the industrial/housing estate in Zone 1-2. This zoning plan is shown in Figure E5.1.

(2) Alternative 2 of the Zoning Plan for Schematic Wastewater Disposal System

Alternative 2 is recommended over Alternative 1 as land space for the plants is limited in urban areas, as shown in Figure E5.2. Two medium scale-systems for zones 3 and 4 are combined into one large-scale system and the wastewater of Zone 1-2 is disposed of by the large-scale system of Zone 5. The combined plant for zones 3 and 4 is suitably located in order for the treated wastewaters to be reused as maintenance flow or flushing water for rivers and lakes/ponds in the urban area during the dry season.

(3) Alternative 3 of the Zoning Plan for Schematic Wastewater Disposal System

Alternative 3 consists of three large-scale systems as the three medium-scale systems for zones 3,4 and 6 are integrated into one large scale system (see Figure E5.3). The alternative 3 zoning plan is not recommendable for the following reasons ;

- Facilities for securing flushing water are necessary,
- Collection system of large-scale system is complicated causing problems with operation and maintenance,
- Accidents can cause serious environmental pollution,
- The construction cost of the plants is cheaper, but the construction cost of the collection system is more expensive than other systems.

5.2.2 Comparative Studies for Each Zone

The objective area is divided into seven (7) zones as described in Sub-section 4.1.2 and characteristics of each zone are shown in Table E4.1 and E4.2.

(1) Zone 1

This zone is located at the northern part of Hanoi city and consists of 6 Phuongs and 6 Xas as shown in Figure E4.8. The zone is divided into two (2) sub-zones according to the boundary of the drainage basins (see Figure E3.1).

According to the future land use plan, sub-zone 1-1 will be a tourist resort and a high class housing area developed by private investors, and sub-zone 1-2 consists of an industrial and housing estate.

An on-site/community disposal system based on the development of each investor is proposed for this zone, according to the above-mentioned future land use plan. The direct construction cost of the four alternative systems are compared as shown in Table E5.2 and E5.3. The Table indicates that a large-scale sewerage development plan is not effective for Zone 1, in regard to the economics of scale.

(2) Zone 2

This zone is located in the Kim Nguu River basin along the Red River and extends over Hoan Kiem, Hai Ba Trung and Thanh Tri, as shown in Figure E4.6. The zone covers an area of 2,000 ha including the existing combined sewer area of 512 ha. Source of the river during the dry season is mainly wastewater discharged from the zone.

The construction cost of the three alternatives is compared, as shown in Table E5.4. For this zone, a large-scale sewerage development plan is ideally effective, in regard to the economics of scale. A small/medium-scale system is advantageous in regard to securing the low flow of the river during the dry season. The sewerage development plan of the following two cases is therefore considered in future selection.

(a) When land space for construction of the plant is available in the urban area.

In this case, the medium-scale system is to be adopted and the disposal system is summarized, as shown Table E5.4. The total length of the sewers to be constructed is 385 km with 2 relay pumping stations. The required treatment plant is 2 units.

(b) When land space for the treatment plant is limited in the urban area.

The large-scale system is proposed in this case and the disposal system is summarized, as shown in Table E5.4. One treatment plant is necessary, as shown Figure E5.1. The total length of the sewer is 392 km with 3 relay pumping stations. Facilities for the supply of flushing water either, from the treatment plant or other sources, such as a conveyance pipe and pump, are required in order to retain the existing low flow of the Kim Niguu River.

This zone is divided into two (2) sub-zones for the reasons stated above.

(3) Zone 3

This zone belongs to the To Lich River basin and consists of 23 phuongs extending over Hoan Kiem, Ba Dinh and Dong Da. The zone covers an area of 1,350 ha including the existing combined sewer area of 1190 ha. Wastewater discharged out of Zone 3 directly and seriously affects the water quality of the To Lich River.

The construction cost of the two alternative systems are compared, as shown in Table E5.5. A medium-scale disposal system is suitable for Zone 3.

(4) Zone 4

Zone 4 belongs to the Lu River basin, located at Dong Da district, and comprising 16 phuongs. The zone covers an area of 500 ha including the existing combined sewer area of 390 ha. Wastewater discharged out of Zone 4 directly and seriously affects water quality of the Lu River. The existing water quality of the Lu River is predicted as the worst, reading 62 mg/l of BOD.

The construction cost of the two alternative systems are compared, as shown in Table E5.6. A medium-scale disposal system is recommended for Zone 4.

(5) Zone 5

This zone is located at the northern part of the Nhue River basin, between the To Lich River and the Nhue River, and consists of 12 xas in Tu Liem district, as shown in Figure E4.6. The zone covers an area of 2,800 ha, without any sewered area, excepting the existing street drains.

Land use in the central part of Zone 5 will be subject to change owing to development in the future, especially in the areas of Tran Ngia Do Xa, Cau Giay, Cau Dien and DICH Vong. The other parts will not change very much.

The construction cost of the two alternative systems are compared, as shown in Table E5.7. A medium-scale disposal system is suitable for Zone 5.

(6) Zone 6

This zone is located at the southern part of the Nhue River basin and extends over Dong Da, Tanh Tri, Tu Liem and Ha Tay and consists of 15 xas, as shown in Figure E4.6. The zone covers an area of 3,160 ha, without any sewered area, excepting the existing street drains. As present, wastewater is discharged into the To Lich River and the Nhue River, and the zone is divided into two (2) sub-zones.

The construction cost of the two alternative systems are compared, as shown in Table E5.8. A medium-scale disposal system is recommended for Zone 6.

(7) Zone 7

This zone belongs to the To Lich River basin and consists of 9 phuongs in Thanh Tri district.

Compared with other zones, the future specific wastewater yield in Zone 7 is the lowest (4 $m^3/d/ha$) as 80 % of this zone consists of fish ponds and farm lands (see Table E4.2).

The construction cost of the two alternative systems are compared, as shown in Table E5.9. An on-site/community disposal system is proposed for Zone 7. Wastewater treatment plants will be constructed by each polluter according to the polluter pay principle. Nevertheless, there are may arise the necessity of installing the facilities under public works projects and also other types of needs according to actual progress of urbanization in that area. These should be examined in further studies.

### 5.2.3 Alternative Wastewater Disposal Systems for West Lake Area (Zone 1-1)

TUPWS has prepared a future land use plan for the West Lake area, including infrastructure, based on the Hanoi City master plan, Aug., 1994. Figure E5.4 shows the simplified future land use map. The West Lake area is divided into six (6) drainage sub-basins : Red River, West Lake, Truc Bac Lake, Co Nhue River, and To Lich River (T1 & T2), as shown in Figure E5.4.

The following alternative wastewater disposal systems have been examined according to the future land use plan in the West Lake area.

(1) On-site/Community System

An on-site/community disposal system is proposed as the most suitable system for Zone 1-1 in regard to minimal environmental impact and geographical conditions. This system is a semi-closed system respecting the existing drainage basins, and is categorized as follows;

(a) Red River basin

This basin is located east of Nghi Tam road along the Red River. All treated wastewater will be discharged to the Red River. The number of required treatment plants is roughly estimated as follows;

- Four (4) medium-scale community plants located at reserved land
- Eleven (11) community plants at each hotel or public works
- Four (4) community plants located at commercial areas

(b) Co Nhue basin

The western area of Buoi road belongs to the Co Nhue basin and so wastewater discharged out of this area will be treated by large-scale community plants in Zone 1-2.

(c) To Lich River basin

The southern area of Thuy Khue road belongs to the To Lich River basin and so wastewater discharged out of this area will be treated by the medium-scale centralized treatment plant in Zone 3.

(d) Truc Bach Lake basin

This is one of West Lake's basins and treated wastewater will be discharged to the West Lake through the Tuc Bac Lake. The number of required treatment plants is roughly estimated as follows;

- 3,200 septic tanks having a capacity of treating both night soil and gray water for the residential area
- Ten (10) community plants at each hotel or public works. Supposed design flow is 100 $m^3$/d per plant.

(e) West Lake basin

This is the core of the tourist and resort area of Hanoi City. West Lake is a receiving water for wastewater from the area. The number of required treatment plants is roughly estimated as follows;

- 7,500 septic tanks having a capacity of treating both night soil and gray water for the residential area
- Ten (10) community plants at each hotel or public works. Supposed design flow is 100 $m^3$/d per plant.

(2) Medium-scale Community Disposal System

A medium-scale community disposal system is proposed instead of an on-site/community system due to the economics of scale (see Table E5.2). Septic tanks in an on-site system are integrated into some community plants. As this is also a semi-closed system, they are except the West Lake basin and Truc Bach Lake basin, the same as the above-mentioned (1). The number of required treatment plants is roughly estimated as follows;

- One (1) community plant for the residential area in the Truc Bac Lake basin
- Five (5) community plants at each hotel or public works. Supposed design flow is 200 m3/d per plant in the Truc Bach Lake basin
- Thirty one (31) community plants for the residential area, including commercial wastewater in the West Lake basin
- Nine (9) community plants at each hotel, industries or public works in the West Lake basin

(3) Large-Scale community Disposal System

The above medium-scale community plans are integrated into eight (8) large-scale community plants, as shown in Figure E5.5. Construction costs are more expensive than systems (1) and (2) on account of the wastewater collection sewer.

(4) Regional Small-Scale Centralized Disposal System with Open System

This system is designed to treat wastewater for the whole area using centralized treatment plants beyond the boundary of the drainage basins. The area is divided into six (6), as shown in Figure E5.6. This system is not recommended because a wastewater collection system with pumping facilities is complicated, construction cost is high, and the existing water cycle of the surrounding West Lake is disordered.

5.2.4 Alternative Study on Wastewater Treatment Methods

(1) Tentative Examination of the Wastewater Stabilization Pond Method

(a) Flow chart of the stabilization pond method

Anaerobic Pond (Retention Period : 1 – 5 days, Effective Depth : 2.5 – 5 m)

Facultative Pond (Retention Period 1.5 days, Effective Depth : 1.5 – 3 m)

Maturation Pond (Retention Period : 3 – 10 days, Effective Depth : 1.0 – 1.5 m)

(b) Required area of the stabilization pond for the To Lich River basin

Future Wastewater Yield : 254,280 $m^3$/d (Zone 2, 3, 4, and 6-1)

Required Area : 217,954 $m^2$ for Anaerobic Pond
254,280 $m^2$ for Facultative Pond
1,186,640 $m^2$ for Maturation Pond

Total Required Area including Structure : Approximately 200 ha

This method is not suitable for the Study because 200 ha is far too large in regard to land acquisition and the future land use plan.

(2) Preliminary Review of Low-cost Sewerage Treatment & Reuse System

The Low-cost Sewerage Treatment & Reuse System with a required area of 1,000 ha, proposed by the Research Institute for Aquaculture, is effective in developing countries as is the Wastewater Stabilization Pond. However, this system is not recommendable for the following reasons;

(a) Available land is limited in the urban area, even in the Yen So area, according to the Hanoi city mater plan,

(b) The system, similar to low-cost sewerage treatment, and stabilization ponds, has side effects including bad odor and harmful insects,

(c) The efficacy of treatment by aquaculture is not quantitatively analyzed as yet,

(d) Environmental conditions in the urban area will not be improved if this system is located downstream of the To Lich River. To improve environment in the urban area, a large-scale wastewater collection system is necessary the whole To Lich River basin.

(3) Supplementary Study on Wastewater Treatment Methods

A supplementary study on wastewater treatment methods has been done in order to reduce the land occupation of treatment plants, as shown in Table E5.10 and E5.11. A layout of the oxidation ditch methods (OD) treatment facilities at each zone is shown in Figure E5.7 to E5.12 and conventional activated sludge methods (AS) are shown in Figure E5.13 to E5.18.

The results of comparison between the oxidation ditch method (OD) and the conventional activated sludge method (AS) are summarized, below ;

| Factors | OD | AS |
|---|---|---|
| Required Area of Facilities*1: (ha) | 18 | 9 |
| Required Capacity of Motor*2: (kw) | 2,300 | 5,400 |
| Design Sludge Production*3: (m3/d) | 7,400 | 11,700 |
| Construction Cost: (OD: 100 %) | 100 | 130 |
| - Machinery & Equipment: | 100 | 150 |
| - Civil Works: | 100 | 60 |
| O & M Cost: (OD: 100 %) | 100 | 120 |

Remarks *1 : Required area is calculated only for the main facilities of five (5) centralized wastewater plants.

*2 : Required capacity of the electric motor is calculated only for the main facilities of five (5) centralized wastewater plants.

*3 :Volume of design sludge production is calculated for seven zones.

The oxidation ditch method is recommended as it is advantageous in energy consumption and excess sludge production.

### 5.2.5 Alternative Study on Sludge Dewatering Facilities

The total excess sludge yield from the whole study area is estimated at 780 $m^3/d$ after treatment by a sludge digestion tank in the oxidation ditch process. Alternative studies on sludge dewatering facilities are examined as follows in order to reduce the sludge weight and dispose of it finally at a dumping site.

| Factors | Dry beds | Mechanical Dehydrator | Incinerator*1 |
|---|---|---|---|
| Volume of Dried Sludge ($m^3/d$) | 160 | 100-120*2 | 20-30*3 |
| Required Area of Facility (ha) | 7 | 2 | 4 |
| Construction Cost (US$ million) | 2 | 30 | 80 |
| O&M Cost (US$ million/year) | 0.06 | 0.90 | 2.40 |

Remarks *1 : Dewatering facilities (dry beds/dehydrator) are necessary before the process of incinerating.
*2 : The volume of dried sludge is affected by the addition of a coagulant aid.
*3 : It depends on the water content of the dewatered sludge.

The dry bed method is recommended and dry beds are located adjacent to the wastewater treatment plants of zones 2 and 5.

## 5.3 Conclusion of Alternative Studies

A preliminary estimate of the costs of the alternative systems for each zone is shown in Table E5.12. The Table proposes the following development plans:

- On-site/community treatment system for Zones 1 and 7
- Medium-scale centralized treatment system for Zones 3 to 6
- Large-scale centralized treatment system for Zone 2

## 5.4 Lake Water Quality

Lake water quality is classified as follows, according to the previous study by the UNDP in February 1990.

| Lake | Classification |
|---|---|
| West Lake | Lightly - moderately polluted |
| Truc Bac | Moderately polluted |
| Hoan Kiem | Moderately - heavily polluted |
| Giang Vo | Moderately - heavily polluted |
| Thien Quang | Moderately - heavily polluted |
| Bay Mau | Moderately polluted |
| Van Quang | Heavily polluted |

(detail figures is not indicated in the UNDP study)

The pollutant load inflow of the main lakes in terms of COD, is tentatively estimated on the result of the survey conducted during this study, on an assumption that the pollutant load yield of COD is 50 % of the yield of BOD, as follows.

| Lake | Pollutant Load of COD (kg/day) | |
|---|---|---|
| | 1992 | 2010 |
| West Lake & Truc Bac | 9,600 | 14,540 |
| Hoan Kiem | 600 | 870 |
| Hai Ba Trung | 1,750 | 2,600 |
| Thien Quang | 1,790 | 2,690 |
| Bay Mau | 3,600 | 5,400 |
| Trung Tu | 2,670 | 4,380 |
| Giang Vo | 600 | 730 |
| Thanh Cong | 1,250 | 1,460 |

The available data are not sufficient to indicate the likely extent of eutrophication in the lakes. However, lake water quality will worsen in proportion to the increment of untreated wastewater yield. The above lakes are already in excess of their self-purification capacity. It is necessary to take counter measures against the pollution of lakes.

## 5.5 Non-Structural Measures

The following non-structural measures related to sewerage development are considered and proposed for implementation, in parallel with the structural measures:

### (1) Institutional Support for the Installation of Flush Toilets

The following support, by the government, is necessary since local type latrines, for example, pit latrines or bucket latrines, shall be upgraded to flush toilets according to sewerage development.

(a) Financial back-up for a soft loan with a revolving fund system in order to install flush toilets

(b) Sponsorship for the education of public health and the necessity for flush toilets

(c) Encouragement and legal enforcement of the installation of flush toilets in the newly developed areas.

### (2) "Care for Drainage/Sewerage" Campaign

The damping of domestic solids is one of the main reasons for river and lake pollution. "Care for drainage/sewerage" campaign shall be sponsored and carried out by the government, in order to educate people on the need of drainage/sewerage facilities and proper water disposal practices, in accordance with the regulation.

(3) Institutional support for on-site/community disposal area

The following institutional support is expected for the sake of promoting the installation of septic tanks in on-site/community disposal areas.

(a) Financial back-up of a soft loan to encourage people to install septic tanks.

(b) Adoption of a free or low price charge system during a certain period of 5 years or 10 years for the collection of excess sludge yield from septic tanks.

(c) The excess sludge is collected, dewatered and finally disposed of by the government.

(4) Regulations for the Installation of Effluent Pre-treatment Facilities

Regulations on the installation of wastewater pre-treatment by industries shall be enforced to reduce the pollutant load to the wastewater disposal system.

(5) Establishment of a sewerage levy-based system

The sewerage levy-based system shall be established partially in order to secure the O&M cost of the proposed wastewater disposal system.

(6) Improvement of Solid Waste Collection System

The existing percentage of collected refuse volume is 30 % of the total solid waste yield and 20 % of the total nightsoil in the Study area, as described in Section 1.6. According to URENCO's survey in 1991, the total volume of existing solid waste is estimated at 2948 $m^3/d$, and the generation rate per person is 0.0027 $m^3/ca/d$. The solid waste collection system will be improved to properly collect the existing solid waste in the Study area, using the following equipment.

| Items of Equipment | Existing Equipment | Required Equipment (unit) |
|---|---|---|
| -Tank Lorries (6 to 8 $m^3$) | 96 | 160 |
| -Tippers with rear loading device (7 $m^3$) | 60 | 104 |
| -Street watering Tankers (4 to 8 $m^3$) | 23 | 25 |
| -Vacuum Tankers (3 to 4 $m^3$) | 15 | 100 |
| -Bulldozers and Excavators (75 HP) | 7 | 10 |
| -Vehicles for Monitoring | 4 | 10 |

Cost estimate of the required equipment is tentatively estimated at US$ 15 million.

# E6. PROPOSED WASTEWATER DISPOSAL PLAN

The proposed wastewater disposal plan should cope well with the variety of public facilities and services and environmental and socio-economic requirements particular to the Study area.

In this chapter, the wastewater disposal system is proposed on the basis of the above-mentioned basic concept.

The overall development plan of the wastewater disposal system in the Study area is proposed as shown in Figure E6.1.

## 6.1 Definition of Proposed Wastewater Disposal Plan

### (1) Proposed Sewerage Development Zone

In the Study area, the proposed development sewerage area covers 13,540 ha and will serve a total population of 1,597,000 in 2010. The area is divided into seven (7) sewerage development zones. Land use statistics foreseen in 2010 for the respective zones, are summarized at Table E6.1.

### (2) Design population

The design population and population density of each zone are estimated as shown in Table E6.1.

### (3) Design Wastewater Yield

The design wastewater yield including domestic, commercial and industrial wastewater of the sewerage development area is determined to be 378,410 $m^3/d$. The design wastewater yield at each zone ranges from 8,290 $m^3/d$ in Zone 7 to 73,370 $m^3/d$ in Zone 2-1, as shown in Table E6.2.

The average ratios of domestic, commercial and industrial wastewater yield to the total design wastewater yield is 73 %, 21 % and 5 %, respectively. Domestic and commercial wastewater is dominant in Zone 3 and 4 with a share of 100 % to the design yield. Industrial wastewater yield consists of a relatively large share of 21 % in Zone 1-2 and 17 % in Zone 2-2.

### (4) Wastewater Collection System

Type of collection system for each zone is classified as follows;

- Individual collection system : Zones 1 and 7

  Wastewater is discharged to water bodies, such as rivers and ponds, through street drains or open channels after treatment by each pollutor, according to the pollutor pay principal.

- Separate system : Zones 5 and 6

  The separate system collects only sewage, excluding stormwater, using a new sewer.

- Partially separate system : Zones 2, 3 and 4

  The partially separate system uses both the existing combined sewered area and the separate sewered area with a diversion chamber and interceptor to be newly constructed.

(5) Treated wastewater level of BOD

The wastewater quality of BOD levels for each zone in 2010 is estimated and the required treated level of BOD for each zone is determined, as shown in Table E5.2.

(6) Basic Concepts and Design Criteria

All of the proposed sewerage development zones are planned and designed based on the basic concepts and design criteria, as described in section E3.3.

(7) Wastewater Treatment Plant and Sludge Dewatering Facilities

The oxidation ditch process is adopted for wastewater treatment in the Study area except for the on-site/community disposal system zones, as described in sub-section E4.2. The proposed facilities of wastewater treatment plants are summarized in Table E5.10

The design sludge quantity yield from the whole Study area is estimated at 7,400 $m^3/d$. The sludge will be thickened and dewatered in order to reduce its weight and disposed of at a dumping site. The dry bed method is proposed for sludge dewatering. Sludge dewatering facilities are proposed to be established at two places; each adjacent to the treatment plants of Zone 2 and Zone 5, for the following reasons.

- A large-scale sludge dewatering system is effective in regard to the economics of scale.
- Land space for the construction of dry beds is limited in Zones 3 and 4.
- The location adjacent to the treatment plants of Zone 2 and Zone 5 is suitable for the construction of dewatering facilities, in regard to land acquisition.

The total excess sludge is calculated at 780 $m^3/d$ and the dried sludge at 160 $m^3/d$ is predicted, as shown in Table E5.10. The dried sludge quantity roughly corresponds to 2 % of the total sludge yield, which should be disposed of at the dumping site. The construction cost of sludge dewatering facilities is shared by each zone. The total number of dry beds is estimated at 30 (see Table E5.10). Construction of dry beds will be carried out step by step according to the proposed implementation schedule of the wastewater disposal plan.

## 6.2 Proposed Wastewater Disposal Plan at Each Zone

### 6.2.1 Design Concepts

Design concepts for each zone are decided as shown in Table E4.2.

### 6.2.2 Collection System

The following collection systems are proposed;

(1) Zone 1-1

A sewer for collection of wastewater is not to be newly constructed as wastewater is discharged to water bodies, through street drains or open channels after treatment by each pollutor. Sewers for each community are set up by each investor.

(2) Zone 1-2

Sewers for the industrial and housing estate are respectively constructed by each developer.

(3) Zone 2 (Sub-zones 2-1 & 2-2)

Although two collection systems are considered for this zone as described in sub-section E5.2.2, the collection system of a large-scale centralized disposal system is proposed in view of the economics of scale, assuming also that land space for the construction of the plant is limited in the area.

(Summary)

| | Separate System | Partially Separate System |
|---|---|---|
| Service Area (ha) | 1,200 | 800 |
| Served Population in the year 2010 | 229,600 | 153,100 |
| Sewer (m) | | |
| - Secondary & Tertiary | 244,800 | - |
| - Trunk | 86,000 | - |
| - Conveyance | 61,200 | - |
| Interceptor & Diversion Chamber (unit) | - | 4 |
| Relay Pumping Station (unit) | 3 | 2 |
| Lake Water Quality Improvement Works (LS) | 1 | - |
| Flushing Water Facilities (LS) | 1 | - |

(4) Zone 3

(Summary)

| | Separate System | Partially Separate System |
|---|---|---|
| Service Area (ha) | 160 | 11,900 |
| Served Population in the year 2010 | 39,500 | 2,936,900 |
| Sewer (m) | | – |
| - Secondary & Tertiary | 177,600 | – |
| - Trunk | 60,100 | – |
| - Conveyance | 37,700 | – |
| Interceptor & Diversion Chamber (unit) | – | 7 |
| Relay Pumping Station (unit) | 1 | 2 |

(5) Zone 4

(Summary)

| | Separate System | Partially Separate System |
|---|---|---|
| Service Area (ha) | 100 | 390 |
| Served Population in the year 2010 | 46,200 | 163,900 |
| Sewer (m) | | |
| - Secondary & Tertiary | 65,000 | – |
| - Trunk | 13,700 | – |
| - Conveyance | 8,700 | – |
| Interceptor & Diversion Chamber (unit) | – | 8 |
| Relay Pumping Station (unit) | – | 3 |

(6) Zone 5

(Summary)

| | Separate System | Partially Separate System |
|---|---|---|
| Service Area (ha) | 2,800 | – |
| Served Population in the year 2010 | 240,900 | – |
| Sewer (m) | | |
| - Secondary & Tertiary | 294,700 | – |
| - Trunk | 136,800 | – |
| - Conveyance | 73,700 | – |
| Relay Pumping Station (Unit) | 2 | – |

(7) Zone 6 (Sub-zones 6-1 & 6-2)

(Summary)

| | Separate System | Partially Separate System |
|---|---|---|
| Service Area (ha) | 3,160 | – |
| Served Population in the year 2010 | 291,800 | – |
| Sewer (m) | | |
| - Secondary & Tertiary | 343,400 | – |
| - Trunk | 159,400 | – |
| - Conveyance | 85,800 | – |
| Relay Pumping Station (Unit) | 3 | – |

(8) Zone 7

A public sewer for the collection of wastewater is not to be newly constructed, as wastewater is discharged to water bodies, through street drains or open channels after treatment by each pollutor. A sewer for nineteen (19) community systems is set up by each investor.

### 6.2.3 Treatment Plant

(1) Zone 1-1

The wastewater disposal system of medium-scale community plants is adopted. Commercial and industrial wastewater treatment methods will be dependent on each pollutor's selection. The treatment of domestic wastewater is by an adequate type of septic tank, able to treat toilet wastewater and gray water. A standard design of septic tank is shown in Figure E6.2.

(2) Zone 1-2

There are two community plants for the housing estate and the industrial estate. The oxidation ditch method is the most suitable for the community plants in Zone 2-1 compared to several typical treatment methods as described in sub-section 4.2.

(3) Zone 2

The proposed site of the treatment plant is located at Tran Phu Xa in Thanh Tri district. Treated wastewater is sent back upstream to secure the existing low flow of the Kim Nguu River.

The oxidation ditch process with a 109,370 $m^3/d$ capacity is adopted as the wastewater treatment method, and the required land area for plant construction is 10 ha.

The design sludge quantity of Zone 2 is 1,873 $m^3/d$ and excess sludge after thickening is estimated at 656 $m^3/d$.

Each facility of the treatment plant is designed as follows;

| | | | | |
|---|---|---|---|---|
| (a) Oxidation ditch | : | 10 units | 12 m x 270 m x 3 m | (depth) |
| (b) Settling tank | : | 5 units | Ø 32m x 2.6 m | (depth) |
| (c) Chlorination tank | : | 2 units | 10 m x12 m x 4 m | (depth) |
| (d) Thickener | : | 5 units | Ø 40 m x 5 m | (depth) |
| (e) Sludge digestion tank | : | 40 units | Ø 40 m x 6 m | (depth) |

Layout of the treatment plant is shown in Figure E5.7.

(4) Zone 3

The proposed site of the treatment plant is located at Lang Ha Phuon in Dong Da district. Treated wastewater is discharged to the To Lich River.

The oxidation ditch process with a 70,360 $m^3/d$ capacity is adopted as the wastewater treatment method for Zone 3, and the required land area is 8 ha.

The design sludge quantity is 1,460 $m^3/d$ and the excess sludge after thickening is estimated at 153 $m^3/d$.

Each facility of the treatment plant is designed as follows;

| | | | | |
|---|---|---|---|---|
| (a) Oxidation ditch | : 12 units | 8 m x 270 m x 3 m | (depth) |
| (b) Settling tank | : 4 units | Ø 32 m x 2.6 m | (depth) |
| (c) Chlorination tank | : 2 units | 10 m x10 m x 4 m | (depth) |
| (d) Thickener | : 4 units | Ø 43 m x 4 m | (depth) |
| (e) Sludge digestion tank | : 4 units | Ø 38 m x 5 m | (depth) |

Layout of the treatment plant is shown in Figure E.5.8.

(5) Zone 4

The proposed treatment plant is located at the Bach Mai Airbase in Dong Da district. Treated wastewater is discharged to the Lu River.

The oxidation ditch process with a 43,800 $m^3$/d capacity is adopted as the wastewater treatment method for this zone, excepting Kim Lien, and the proposed land area is 9 ha.

The design sludge quantity is 816 $m^3$/d and the excess sludge after thickening is estimated at 86 $m^3$/d.

Each facility of the treatment plant is designed as follows;

| | | | |
|---|---|---|---|
| (a) Oxidation ditch | : 10 units | 7 m x 250 m x 2.5 m | (depth) |
| (b) Settling tank | : 5 units | Ø 22 m x 2.4 m | (depth) |
| (c) Chlorination tank | : 2 units | 5 m x 10 m x 4 m | (depth) |
| (d) Thickener | : 5 units | Ø 30 m x 4 m | (depth) |
| (e) Sludge digestion tank | : 2 units | Ø 40 m x 5 m | (depth) |

Layout of the treatment plant is shown in Figure E5.9.

(6) Pilot Treatment Plant at Kim Lein

The existing treatment plant is located at Kim Lien as shown in Figure E1.2. Treated wastewater is discharged to the Lu River.

The oxidation ditch process with a 5,600 $m^3$/d capacity is adopted as the wastewater treatment method for the pilot plant, and the required land area is 1 ha.

The design sludge quantity is 174 $m^3$/d and the excess sludge after thickening is estimated at 49 $m^3$/d.

Each facility of the treatment plant is designed as follows;

| | | | |
|---|---|---|---|
| (a) Oxidation ditch | : 4 units | 6 m x 120 m x 2 m | (depth) |
| (b) Settling tank | : 2 units | Ø 12 m x 2.6 m | (depth) |
| (c) Chlorination tank | : 2 units | 3 m x 5 m x 2 m | (depth) |
| (d) Thickener | : 2 units | Ø 16 m x 4 m | (depth) |
| (e) Sludge digestion tank | : 2 units | Ø 16 m x 4 m | (depth) |

Layout of the treatment plant is shown in Figure E5.10.

(7) Zone 5

The proposed site of the treatment plant is located at Metri Xa in Tu Liem district. Treated wastewater is discharged to the Nhue River.

The oxidation ditch process with a 56,450 $m^3/d$ capacity is adopted as the wastewater treatment method for Zone 5, and the required land area is 7 ha.

The design sludge quantity of Zone 5 is 962 $m^3/d$ and the excess sludge after thickening is estimated at 101 $m^3/d$.

Each facility of the treatment plant is designed as follows;

| | | | |
|---|---|---|---|
| (a) Oxidation ditch | : 10 units | 8 m x 250 m x 2.7 m | (depth) |
| (b) Settling tank | : 5 units | Ø 25 m x 2.4 m | (depth) |
| (c) Chlorination tank | : 2 units | 12 m x 5 m x 4 m | (depth) |
| (d) Thickener | : 5 units | Ø 35 m x 4 m | (depth) |
| (e) Sludge digestion tank | : 2 units | Ø 38 m x 5 m | (depth) |

Layout of the treatment plant is shown in Figure E5.11.

(8) Zone 6

The proposed site of the treatment plant is located at Tan Trieu Xa in Than Tri district. Treated wastewater is discharged to the Nhue River.

The oxidation ditch process with a 73,050 $m^3/d$ capacity is adopted as the wastewater treatment method for Zone 6, and the required land area is 7 ha.

The design sludge quantity from Zone 6 is 1,239 $m^3/d$ and the excess sludge after thickening is estimated at 130 $m^3/d$.

Each facility of the treatment plant is designed as follows;

| | | | |
|---|---|---|---|
| (a) Oxidation ditch | : 12 units | 8 m x 250 m x 3 m | (depth) |
| (b) Settling tank | : 4 units | Ø 32 m x 2.4 m | (depth) |
| (c) Chlorination tank | : 2 units | 12 m x 7 m x 4 m | (depth) |
| (d) Thickener | : 4 units | Ø 37 m x 5 m | (depth) |
| (e) Sludge digestion tank | : 2 units | Ø 30 m x 10 m | (depth) |

Layout of the treatment plant is shown in Figure E5.12.

(9) Zone 7

The type of wastewater treatment method is virtually the same as Zone 1-1.

The number of required treatment plants is decided as follows, according to the future land use conditions;

- Industrial area: 10 community treatment plants. Supposed design flow is 100 $m^3/d$ per plant.

- Commercial area: 9 community treatment plants. Supposed design flow is 100 $m^3/d$ per plant.
- Residential area: 9,000 septic tanks for the on-site treatment disposal system on the assumption that 80 % of the total population in this zone will install the tank, and one family has 4.3 persons.

### 6.2.4 Sludge Dewatering Facilities

The total excess sludge quantity from the whole area is estimated at 777 $m^3/d$, as shown in Table E5.10. Public sludge dewatering facilities will be located at two places, as shown in Figure E6.1. The dry beds method is recommended and required facilities are estimated below.

| | | Dry Bed (1) | Dry Bed (2) |
|---|---|---|---|
| (a) | Excess Sludge ($m^3/d$) | 479 | 298 |
| | | (Zones 2, 3,4 & 7) | (Zones 1, 5 & 6) |
| (b) | Location | Tran Phu Xa | Metri Xa |
| | | (Zone 7) | (Zone 5) |
| (c) | Number of beds (unit) | 15 | 15 |
| (d) | Size per unit | 50m x 55m x 1 m (depth) | 40m x 50m x 1m (depth) |
| (e) | Required area (ha) | 5 | 4 |
| (f) | Dried Sludge ($m^3/d$) | 89 | 66 |

The construction cost of the dewatering facilities is shared by each zone according to its excess sludge yield.

### 6.2.5 Facilities for Lake Water Quality Improvement

The following facilities are proposed for water quality improvement of lakes in the urban area.

| Name of Lake | Proposed Facilities |
|---|---|
| (1) Zone 1-1 | |
| Truc Bac | Primary Settling Tank + Treatment Plant |
| (2) Zone 2-1 | |
| Hoan Kiem | Diversion Chamber + Interceptor |
| Bay Mau | – ditto – |
| Thanh Nan | – ditto – |
| Thien Quang | Diversion Chamber/Aeration Facilities |
| Hai Ba Trung | Diversion Chamber + Interceptor |
| (3) Zone 3 | |
| Giang Vo | Primary Settling Tank/Aeration Facilities |
| Thu Le | – ditto – |
| Ngoc Khanh | – ditto – |
| Thanh Cong | – ditto – |
| (4) Zone 4 | |
| Van Chuong | Diversion Chamber + Interceptor |
| Kim Lien | Treatment Plant |
| Giam | Diversion Chamber + Interceptor |
| Trung Tu | – ditto – |
| Linh Quang | – ditto – |
| Ba Mau | – ditto – |

### 6.2.6 Direct Construction Cost

The direct construction cost for each zone is estimated as follows, according to the result of comparative studies, as mentioned in sub-section E5.2.2.

(1) Zone 1

| | Direct Construction Cost (US$ $10^3$) | |
|---|---|---|
| | Zone 1-1 | Zone 1-2 |
| (a) Treatment Plant | 13,800 | 8,444 |
| – Community Plant | 13,662 | 7,600 |
| – Allotted charge for sludge dewatering facilities | 138 | 844 |
| (b) Separate Sewer | – | 8,226 |
| (c) Interceptor & Diversion Chamber | 48 | – |
| (d) Relay Pumping Station | – | 368 |
| (e) Lake Water Quality Improvement Works | 1,760 | – |
| Total | 15,608 | 17,038 |

(2) Zone 2

| | Direct Construction Cost (US$ $10^3$) | |
|---|---|---|
| | Zone 2-1 | Zone 2-2 |
| (a) Treatment Plant | 35,499 | 17,418 |
| – Water Treatment Plant | 32,659 | 16,028 |
| – Allocated charge for sludge dewatering facilities | 2,840 | 1,390 |
| (b) Separate Sewer | 17,436 | 17,789 |
| (c) Interceptor & Diversion Chamber | 48 | – |
| (d) Relay Pumping Station | 336 | 168 |
| (e) Lake Water Quality Improvement Works | 3,879 | – |
| Total | 57,198 | 35,375 |

(3) Zone 3

| | Direct Construction Cost (US$ $10^3$) |
|---|---|
| (a) Treatment Plant | 37,383 |
| – Water Treatment Plant | 34,393 |
| – Allocated charge for sludge dewatering facilities | 2,990 |
| (b) Separate Sewer | 23,648 |
| (c) Interceptor & Diversion Chamber | 38 |
| (d) Relay Pumping Station | |
| (e) Lake Water Quality Improvement Works | 1,835 |
| Total | 62,904 |

(4) Zone 4

| | Direct Construction Cost (US$ $10^3$) |
|---|---|
| (a) Treatment Plant | 29,111 |
| – Water Treatment Plant | 21,778 |
| – Pilot Treatment Plant | 5,013 |
| – Allocated charge for sludge dewatering facilities | 2,320 |
| (b) Separate Sewer | 6,605 |
| (c) Interceptor & Diversion Chamber | 19 |
| (d) Relay Pumping Station | 184 |
| (e) Lake Water Quality Improvement Works | 2,356 |
| Total | 38,275 |

(5) Zone 5

| | Direct Construction Cost (US$ $10^3$) |
|---|---|
| (a) Treatment Plant | 31,466 |
| – Water Treatment Plant | 28,949 |
| – Allocated charge for sludge dewatering facilities | 2,517 |
| (b) Separate Sewer | 45,563 |
| (c) Relay Pumping Station | 368 |
| Total | 77,397 |

(6) Zone 6

| | Direct Construction Cost (US$ $10^3$) | |
|---|---|---|
| | Zone 6-1 | Zone 6-2 |
| (a) Treatment Plant | 15,721 | 22,778 |
| – Water Treatment Plant | 14,471 | 20,958 |
| – Allocated charge for sludge dewatering facilities | 1,250 | 1,820 |
| (b) Separate Sewer | 14,616 | 38,471 |
| (c) Relay Pumping Station | 368 | 184 |
| Total | 30,705 | 61,433 |

(7) Zone 7

| | Direct Construction Cost (US$ $10^3$) |
|---|---|
| (a) Treatment Plant | |
| – Community Plant | 3,788 |
| – Septic Tank | 8,405 |
| (b) Allotted charge for sludge dewatering facilities | 1,060 |
| Total | 13,253 |

## 6.3 Cost Estimates

The proposed project cost and annual O&M cost are summarized in Table E6.3.

The total construction cost is estimated at US$ 295.340 million including the sludge dewatering facilities' cost of US$ 17.169 million.

The total project cost for the development of the centralized wastewater disposal system and on-site/community wastewater disposal system is estimated at US$ 634.191 million and the total annual O&M cost is estimated at US$ 9.624 million, as shown below.

(US$ million)

| | Project cost | O&M cost | Replacement Cost |
|---|---|---|---|
| Centralized disposal system | 567.096 | 6.203 | 131.239 |
| On-site/community disposal system | 70.830 | 1.834 | 25.826 |
| Total | 637.926 | 8.037 | 15.065 |

## 6.4 Priority of Sewerage Development Zones

The priority of zones to develop the wastewater disposal system, is assessed as shown in Table E6.4, based on the conceptual zoning plan and the characteristics of each zone.

The priority of zones for sewerage development is recommended, as follows, in consideration of the index of the benefit (removed pollutant load as BOD levels:kg) per construction cost (million US$) and the influence in receiving improved water quality.

- Zones 2-1, 4, 3, 2-2, 6-1, 5 and 6-2 using the centralized disposal system
- Zones 1-1, 1-2 and 7 using on-site/community disposal system

Wastewater treatment plants in Zone 1 and 7 will be constructed by each polluter according to the polluter pay principle.

## 6.5 Overall Implementation Schedule

The overall implementation schedule is tentatively shown in Figure E6.3. The schedule includes time for a feasibility study, a detail design, construction works and a commissioning test . The disbursement schedule is shown in Figure E6.4.

## 6.6 Institutional Aspects

(1) Existing Organizations and Institutions
Refer to Sub-section D3.5.4 of Appendix D.

(2) Laws and Regulations
Refer to Sub-section D3.5.4 of Appendix D.

(3) Required Institutional Aspects

The following institutional aspects are taken into account to reinforce O&M for the wastewater disposal system.

(a) Staff members for the wastewater treatment plants

The organization of SDC will be reinforced according to the sewerage development plan, especially staff members of the wastewater treatment plant. The training of staff members also is required to upgrade the skills relevant to the operation and maintenance of the plants.

Required staff members for O&M of the centralized treatment plants are roughly estimated as follows.

| | Engineer | Operator | Techncian | Total |
|---|---|---|---|---|
| Zone 2 | 2 | 2 | 4 | 8 |
| Zone 3 | 1 | 1 | 2 | 4 |
| Zone 4 | 1 | 1 | 2 | 4 |
| Zone 5 | 2 | 2 | 4 | 8 |
| Zone 6 | 1 | 1 | 2 | 4 |
| Pilot Plant | – | 1 | 2 | 3 |
| Total | 7 | 8 | 16 | 31 |

(b) Laboratory and equipment for O&M of the wastewater treatment plants

A laboratory with the following monitoring equipment will be located at each centralized treatment plant.

- Water sampling equipment
- PH meter
- DO (Dissolved Oxygen) meter
- MLSS (Mixed Liquor Suspended Solids) meter
- ORP (Oxidation-Reduction Potential) meter
- Conductivity meter
- Thermometer
- Flow meter

(c) Establishment of sewerage levy-based system

Annual O&M costs for centralized treatment plants are estimated about US$ 5,934,000/year as shown in Table E6.3. O&M cost for wastewater disposed system or its part is basically being recovered by beneficiaries in most of the developed countries. However, in the developing countries, there are some case that wastewater treatment plants have not functioned because of a failure of sewer charge collection. Therefore, sewerage levy-based system shall be established in order to secure the O&M cost, before wastewater disposal system will be implemented.

## 6.7 Recommendations for Wastewater Disposal Plan

### 6.7.1 Structural Measures

(1) Zoning, the Overall Development Plan and the Layout of the Sewerage System: as shown in Figure E6.1 and E6.5 (1/10)-(10/10).

(2) Priority of Development Zones

The priority of zones for sewerage development is recommended as shown in Table E6.4.

(3) Collection System

(a) The stormwater sewer is developed or improved before the development of the wastewater sewer, in order to mitigate flood damages

(b) The effective utilization of the existing combined sewer system in the present urban core areas.

(c) The provision of a separate system for the newly developed area, in principle with the treatment plant.

(d) The provision of a semi-combined system with diversion chambers and an interceptor in areas with a existing combined system and the dry bed method for sludge treatment.

These are considered to be the most practical methods, but should be subject the further refinement according to each zone, in the subsequent feasibility study and detailed design stages.

(4) Wastewater Treatment Plant

(a) Adoption of the oxidation ditch method for the centralized disposal system and the dry bed method for sludge treatment.

These are considered to be the most practical methods, but should be subject to further refinement according to each zone, in the subsequent feasibility study and detailed design stages.

(b) Rehabilitation of the Kim Lien wastewater treatment plant using the oxidation ditch method.

(c) The provision of a community wastewater treatment plant in Zone 1.

(d) The provision of septic tanks or equivalent for domestic wastewater in Zone 7.