(5) Depth of Sewer Pipe Laying

The minimum earth cover depth for laying sewer pipe is 1.0 m and the maximum is approximately 7.0 m.

The minimum earth cover depth for laying sewer pipe is determined as 1.0 m to prevent collapse of pipe due to load on it. While, the maximum depth is determined to be 7.0 m to minimize construction cost.

(6) Manhole Interval

The maximum manhole interval is 100 m for sewer pipe diameter smaller than 800 mm and 200 m for sewer pipe diameter larger than 900 mm.

Sewer pipe with a diameter smaller than 800 mm does not allow a man to enter inside. Cleaning of such small pipes shall be conducted by remote operation. Therefore, its manhole interval shall be limited to 100 m. However, manhole interval of sewer pipe larger than 900 mm can be extended to 200 m.

5.2 Denpasar Sewerage Development

5.2.1 Sewerage Development Area

Based on the sewerage development zone of the combination of sewerage and on-site sanitation system described in Section 2.3, the following areas are adjusted and included in the proposed sewerage development area.

- Some portions of Desa Dauh Puri Kaja of 14 ha in Kec. Denpasar Barat is not incorporated in the sewerage development area because it locates north of Bypass Gatot Subroto as the northern boundary.

- Some portion of Desa Dauh Puri Kauh of 65 ha is not included in the sewerage development area because it locates south of Badung River as a portion of southern boundary.

- Some portion of Desa Dauh Puri Kauh of 65 ha is not included in the sewerage development area because it locates south of Badung River as a portion of southern boundary.

- Desa Sumerta Kelod of 271 ha in Kec. Denpasar Timur is now developing for a institutional center of Bali local government.

- Some developed area along Jl. Cokroaminoto Rd. and Jl. Imam Bonjor Rd. of Desa Pemecutan Kaja of 175 ha, Desa Pemecutan Kelod of 152 ha and Desa Ubung of 14 ha are included in the sewerage development area.

- Some portion of Kel. Tonja of 86 ha in Kec. Denpasar Timur is included because the boundary of sewerage development area is settled at Bypass Gatot Subroto.

- Some portion of Desa Kesiman Petilan of 110 ha in Kec. Denpasar Timur is included because the eastern boundary of sewerage development area is settled at Yeh Ayung River from the topographic condition.

- Some portion of Kel. Kesiman in Kec. Denpasar Timur and Kel. Panjer, Kel. Sesetan and Kel. Pedungan in Kec. Denpasar Selatan are also included. The wastewater from both sides of roads in which the main sewers are planned to install is collected by the sewerage system. These roads and covered areas are as follows.

Main Sewer	Name of Kelurahan/Desa	Covered Area (ha)
Hayam Wuruk Rd.	Kesiman	62.0
Tukad Yeh Aya Rd.	Panjer	134.0
Raya Sesetan Rd.	Sesetan	164.0
P. Kawe Rd.	Pedungan	34.0
Total		394.0

Finally, the proposed sewerage development area covers an area of 2,683.0 ha consisting of 26 Kelurahan/Desa given below (ref. Fig. E.5.1).

Fully covered Kelurahan/Desa

- Dauh Puri, Dauh Puri Kangin, Dauh Puri Kelod, Pemecutan, Tegal Kerta and Tagal Harum in Kec. Denpasar Barat.

- Dangin Puri, Dangin Puri Kauh, Dangin Puri Kaja, Dangin Puri Kangin, Dangin Puri Kelod, Sumerta, Sumerta Kauh, Sumerta Kaja and Sumerta Kelod in Kec. Denpasar Timur.

Partially Covered Kelurahan/Desa

- Dauh Puri Kaja, Dauh Puri Kauh, Pemecutan Kaja, Pemecutan Kelod and Ubung in Kec. Denpasar Barat

- Kesiman, Kesiman Petilan and Tonja in Kec. Denpasar Timur

- Panjer, Sesetan and Pedungan in Kec. Denpasar Selatan

The existing population in the proposed sewerage development area is 194,209 with an average population density of all Kelurahans/Desas of 72.4 person/ha, which ranges from 14.5 person/ha in Kel. Pedungan to 269.7 person/ha in Desa Tegal Kerta. The future population becomes 284,100 with an average population density of 105.9 person/ha, which ranges from 20.6 person/ha to in Kel. Pedungan to 279.2 person/ha in Desa Tegal Kerta.

Existing and future land use conditions in the sewerage development area are summarized as follows.

	Existing (ha)	Future (ha)
Residential area	832.1 (31.0%)	1,261.0 (47.0%)
Commercial and Institutional area	201.4 (7.5%)	232.3 (8.7%)
Tourism area	12.3 (0.5%)	19.7 (0.7%)
Industrial area	9.4 (0.4%)	10.3 (0.4%)
Other area	1,627.8 (60.6%)	1,159.7 (43.2%)
Total	2,683.0(100.0%)	2,683.0(100.0%)

The sewerage development area is divided into three (3) zones of North, South and West by Badung and Oongan Rivers (ref. Fig. E.5.2).

The topographic conditions of each sewerage zone are summarized as follows.

North Zone

- Ground elevation of the northern and southern ends of this zone are about 40 m and 20 m above mean sea level of Benoa Harbour respectively. The land gradient is about 8 ‰ from north to south constantly. This condition is very convenient to collect the sewage by gravity flow system.

- Western and eastern ends of this zone are bounded by Badung and Oongan rivers. Badung river makes a deep valley of 18 m from the ground surface at the northern end and 5 m at the southern end of this zone. Oongan river also makes a deep valley of 18 m at the northern end of this zone while it becomes shallow of 2 m at the southern end and it continues up to the confluence of Badung river. Hence, the southern end of this zone in bounded by the shallow river of Oongan with the depth of 2 m from the ground surface.

South Zone

- Ground elevation at the northern and southern ends of this zone are about 20 m and 11 m with an average land gradient of 4.7 ‰.

- Badung river flows from north to south at the western end of this zone. The depth of river bottom ranges from 5 m at the northern end to 3 m at the southern end from the ground surface.

West Zone

- Ground level of the slit area along Cokro Aminoto Rd. ranges from 38 m at the northern end to 22 m at the junction of Gunung Agung Rd. with an average land gradient of about 9 ‰.

- Southern part of Gunung Agung Rd. were recently developed for residential area which were used to be a paddy field. Hence, the drainage condition in the residential area of Desa Tegal Kerta is not good.

5.2.2 Design Wastewater Generation

(1) Domestic Wastewater

The domestic wastewater generation of the sewerage development area is estimated by adding up the wastewater generation of all the Kelurahans/Desas included in the area. For domestic wastewater generation of Kelurahan/Desa, refer to Appendix C, Table C.3.3. The total domestic wastewater generation of the sewerage development area in 2010 is estimated at 57,458 m^3/day. Its break-down by Kelurahan/Desa is shown in Table E.5.1.

(2) Commercial and Institutional Wastewater

The commercial and institutional wastewater generation of sewerage development area is estimated by adding up those of all Kelurahans/Desas covered by it. For commercial and institutional wastewater generation of Kelurahan/Desa, refer to Appendix C, Table C.3.3. The total commercial and institutional wastewater generation of the sewerage development area in 2010 is estimated to be 14,697 m^3/day. Its break-down by Kelurahan/Desa is shown in Table E.5.1

(3) Tourism Wastewater

Tourism wastewater consists of wastewater from hotels and restaurants. Wastewater generation from hotels and restaurants of each zone is estimated by adding up those of all Kelurahans/Desas covered by its zone. For tourism wastewater generation of Kelurahan/Desa, refer to Appendix C, Table C.3.3. The total tourism wastewater generation of the sewerage development area in 2010 is estimated to be 1,909 m^3/day. Its break-down by Kelurahan/Desa is shown in Table E.5.1.

(4) Industrial Wastewater

The industrial wastewater generation of the respective zones is estimated by summing up those of the covered Kelurahans/Desas. For industrial wastewater generation by Kelurahans, refer to Appendix C. Table C.3.3. The total industrial wastewater generation of the sewerage development area in 2010 is estimated at 1,240 m^3/day. Its break-down by Kelurahan/Desa is shown in Table E.5.1.

(5) Design Wastewater Generation

The design wastewater generation including domestic, commercial and institutional, tourism and industrial wastewater of the sewerage development area is determined to be 75,304 m^3/day. The ratio of domestic, commercial and institutional, tourism and industrial wastewater generation to the design wastewater generation is 76.3%, 19.5%, 2.5% and 1.7% respectively.

5.2.3 Collection System

The sewage collection system covers the whole sewerage development area of 2,683 ha. However, following green areas are not incorporated in the sewerage system for designing the sewer networks, because no wastewater is discharged from these green areas.

Name	Name of Kelurahan/Desa	Area (ha)
Niti Praja Park	Dauh Puri Kaja	2.0
Badung River	Dauh Puri Kaja	2.0
Badung River	Dauh Puri Kauh	2.0
Badung River	Pemecutan	1.0
Badung River	Pemecutan Kaja	1.0
Badung River	Pemecutan Kelod	2.0
Puputan Park	Dangin Puri Kauh	4.0
Ngurah Rai Stadium	Dangin Puri Kangin	6.0
Total		20.0

The collection system of Denpasar sewerage development area is summarized as follows:

Service Area	2,663 ha
Served Population in 2010	284,100
Population Density in 2010	106.7 person/ha
Sewer Length	
Secondary & Tertiary Sewer (ø150 mm ~ ø300 mm)	418,400 m
Main Sewer (ø350 mm ~ ø1,500 mm)	50,930 m
Conveyance Sewer (ø1,500 mm ~ ø1,800 mm)	4,390 m
Total	473,720 m

5.3 Kuta Sewerage Development

5.3.1 Sewerage Development Area

The proposed sewerage development of Kuta covers an area of 648 ha with an existing population of 14,600 and future population of 21,580 as shown in Fig. E.5.3.

The area is enclosed by Mati River to the east, Ngurah Rai Airport to the south, Kuta Beach to the west and Diana Puri Rd. to the north.

Existing land use pattern in this area is summarized as follows.

- Both sides of Legian Rd. and Kuta Rd. are developed as tourism center.
- Many hotels and cottages are located in the area along Kuta and Legian Beaches.
- The area between Kuta Beach Rd. and Legian Rd. is occupied by many small cottages and bungalows.
- Residential area is located just behind the shops and restaurants which are facing the roads.

Existing and future population density of this area are 22.5 person/ha and 33.3 person/ha respectively.

The comparison of existing and future land use is summarized as follows.

Land Use	Existing	Future
Residential Area	156.2(24.1%)	199.7(30.8%)
Commercial & Institutional Area	62.7 (9.7%)	80.6(12.4%)
Tourism Area	122.7(18.9%)	157.7(24.3%)
Industrial Area	12.8 (2.0%)	12.8 (2.0%)
Other Area	293.6 (45.3%)	197.2(30.5%)
Total	648 ha (100.0%)	648 ha (100.0%)

The topographic conditions of Kuta sewerage area is summarized as follows.

- The elevation of land ranges from 1.5 meter to 10 meters above mean sea water level at Benoa Harbour.

- The highest ground elevation is found at the north end of this sewerage area.

- Seminyak Rd. declines from the north to the south with a gradient of 2.3 ‰ till the junction of Melasti Rd.

- In the area between Kuta Beach Rd. and Legian Rd., the land declines toward the sea from Legian Rd. with a gradient of 1.3 ~ 2.2 ‰.

- The ground elevation of the area between Raya Kuta Rd. and Kartika Plaza Rd. is lower than these two roads elevation.

- The area between Legian Rd. and Tanjung Mekar Rd. is almost flat with a ground elevation of 3.5 meter.

(1) Domestic Wastewater

The domestic wastewater generation of Kuta Sewerage Development Area is estimated by the same manner as that of Denpasar Sewerage Development Area. The total domestic wastewater generation of the Kuta Sewerage Development Area is estimated at 4,300 m^3/day.

(2) Commercial and Institutional Wastewater

Commercial and institutional wastewater generation of this sewerage area is estimated at 2,000 m^3/day in 2010 by the same manner as that of Denpasar Sewerage Area.

(3) Tourism Wastewater

Tourism wastewater generation from hotels and restaurants of this area is estimated at 11,900 m^3/d in 2010.

(4) Industrial Wastewater

Industrial wastewater generation of this sewerage area is estimated to be 200 m^3/day in 2010 by the same manner as that of Denpasar Sewerage Development Area.

(5) Design Wastewater Generation

The design wastewater generation consisting of domestic, commercial and institutional, tourism and industrial wastewater is estimated at 18,400 m^3/day. The ratio of domestic commercial and institutional, tourism and industrial wastewater generation to the design wastewater generation is 23.4%, 10.9%, 64.7% and 1.0% respectively.

5.3.3 Collection System

The sewerage collection system covers the whole sewerage development area of 648 ha.

The collection system is summarized as below.

Service Area (ha)	648 ha
Served population in 2010	21,580
Population Density in 2010 (person/ha)	33
Sewer (m)	
Secondary & Tertiary (ø150 mm ~ ø300 mm)	65,700
Main (ø350 mm ~ ø 800 mm)	12,500
Trunk (ø900 mm ~)	1,200
Force Main (ø600 mm)	5,200
Lift Pump Station	3 stations (Q = 11m^3/min, 13 m^3/min, 24 m^3/min)
Booster Pump Station	Q = 34 m^3/min, H = 45 m

5.4 Sanur Sewerage Development

5.4.1 Sewerage Development Area

The proposed sewerage development area of Sanur covers 740 ha consisting of Kelurahan Sanur of 402 ha and parts of Desa Sanur Kaja of 125 ha and Sanur Kauh of 199 ha with an existing population of 17,864 and future population of 27,800 (ref. Fig E.5.4).

The area is encompassed by Sanur Beach to the east and south, Batur Sari Rd and Bypass Ngurah Rai Rd. to the west and Hang Tuah Rd. to the north.

Existing land use pattern in this area is summarized as follows.

- The area between Sanur Beach and D. Tamblingan Rd. is developed as tourism area.
- The area enclosed by both roads of Bypass Ngurah Rai and D. Tamblingan is mainly developed as residential and commercial area.

- Western area of Bypass Ngurah Rai Rd. is developed as residential area.

Existing and future population density of this area are 24.1 person/ha and 37.6 person/ha respectively.

The comparison of existing and future land use is summarized as follows.

	Existing		Future	
Residential Area	106.4	(14.4%)	192.2	(26.0%)
Commercial & Institutional Area	18.8	(2.5%)	18.8	(2.5%
Tourism Area	86.5	(11.7%)	164.3	(22.2%)
Industrial Area	5.1	(0.7%)	5.1	(0.7%)
Other Area	523.2	(70.7%)	359.6	(48.6%)
Total	740.0 ha	(100.0%)	740.0 ha	(100.0%)

The topographic condition of Sanur Sewerage Development Area is summarized as follows.

- Ground elevation of this area ranges from 2.0 meter to 6.0 meter above mean sea land.
- Land declines toward the south with an average land gradient of 1.3 ‰
- The elevation of beach side road Tanjung Sari is about 0.5 meter lower than that of Bypass Ngurah Rai Rd.

5.4.2 Design Wastewater Generation

(1) Domestic wastewater generation of this area is estimated by the same manner as that of Denpasar and Kuta Sewerage Development Areas. The total domestic wastewater generation of this sewerage development area is estimated to be 5,433 m^3/day in 2010.

(2) Commercial and Institutional Wastewater

Commercial and institutional wastewater generation of this sewerage area is estimated at 974 m^3/day in 2010.

(3) Tourism Wastewater

Tourism wastewater generation from hotels and restaurants of this area is estimated to be 10,145 m^3/day in 2010.

(4) Industrial Wastewater

Industrial wastewater generation in 2010 of this area is estimated at 294 m^3/day.

(5) Design Wastewater Generation

The design wastewater generation including domestic, commercial and institutional, tourism and industrial wastewater is determined to be 16,846 m^3/day. The amount and ratio of each pollution source is as follows.

Source	Wastewater (m^3/d)	
Domestic	5,433	(32.3%)
Comm. & Insti.	974	(5.8%)
Tourism	10,145	(60.2%)
Industry	294	(1.7%)
Total	16,846	(100.0%)

5.4.3 Collection System

Sewage collection system covers the sewerage development area of 726 ha except Bali Beach golf course of 14 ha because no wastewater discharged from this golf course.

The proposed collection system is summarized as below.

Service Area (ha)	726 ha
Served population in 2010	27,800
Population Density in 2010 (person/ha)	38.3
Sewer (m)	
Secondary & Tertiary (ø150 mm ~ ø300 mm)	97,220
Main (ø350 mm ~ ø800 mm)	10,940
Force Main (ø500 mm)	5,160 x 2 lines
Manhole Pump Station	3 stations (Q = 3.4 m^3/min x 2 stations 4.1 m^3/min)
Booster Pump Station	Q = 31.6 m^3/min, H = 40 m

5.5 Tanjung Benoa Sewerage Development

5.5.1 Sewerage Development Area

The proposed sewerage development area of Tanjung Benoa covers the whole area of Benoa Peninsula 136 ha with an existing population of 1,040 and future population of 1,540.

The area is located near BTDC development area (ref. Fig. E.5.5).

Existing land use pattern in this area is summarized as follows.

- The area is divided into two (2) zones, east and west peninsula by Benoa Rd.
- East zone faces Badung Strait and it is developed as a tourism area.
- West zone faces the Benoa Bay and natural condition still remains.
- Mangrove is propagating in the sea shore of west peninsula.
- The Benoa Village which is located at the top of the peninsula is developed as a fisherman village.

Existing and future population density of this area are 7.6 person/ha and 11.5 person/ha respectively.

The comparison of existing and future land use is summarized as follows.

	Existing	Future
Residential Area	30.0(22.1%)	30.0(22.1%)
Commercial & Institutional Area	1.9 (1.4%)	1.9 (1.4%)
Tourism Area	12.8 (9.4%)	100.6(74.0%)
Industrial Area	-	-
Other Area	91.3 (67.1%)	3.5 (2.5%)
Total	136 ha (100.0%)	136 ha (100.0%)

The topographic condition of Tanjung Benoa Sewerage Development Area is summarized as follows.

- The width of peninsular ranges from 500 meter to 800 meter.

- The ground level ranges from 1.5 meter to 2.0 meter above mean sea water level.

5.5.2 Design Wastewater Generation

(1) Domestic Wastewater

The domestic wastewater generation of Tanjung Benoa Development Area is estimated by the same manner as that of other sewerage development area. The total domestic wastewater generation of the Tanjung Benoa Sewerage Development Area is estimated at 300 m^3/day in 2010.

(2) Commercial and Institutional Wastewater

Commercial and institutional wastewater generation of this sewerage area is estimated at 20 m^3/day in 2010 by the same manner as that of other sewerage development area.

(3) Tourism Wastewater

Tourism wastewater generation from hotels and restaurants of this area is estimated at 3,900 m^3/d in 2010.

(4) Design Wastewater Generation

The design wastewater generation consisting of domestic, commercial and institutional, tourism and industrial wastewater is estimated at 4,220 m^3/day. The ratio of domestic commercial and institutional and tourism wastewater generation to the design wastewater generation is 7.1%, 0.5% and 92.4% respectively.

5.5.3 Collection System

The sewerage collection system covers the whole sewerage development area of 136 ha.

The collection system is summarized as below.

Service Area (ha)	136 ha
Served population in 2010	1,540
Population Density in 2010 (person/ha)	12
Sewer (m)	
Secondary & Tertiary (ø150 mm ~ ø300 mm)	3,100
Main (ø350 mm ~ ø 800 mm)	3,400
Lift Pump Station	1 station (Q = $7m^3/min$)

5.6 Treatment Plant

5.6.1 Selection of Treatment System

1) General

Wastewater of the Tanjung Benoa area can be optimally treated by improving the existing treatment plant of BTDC of oxidation pond type. However, for the other three (3) areas, various types of sewage treatment system can be considered.

The wastewater generation in the three (3) areas are estimated to be 82,800 m^3/day for Denpasar, 18,500 m^3/day for Sanur and 20,200 m^3/day for Kuta in 2010. However, out of 20,200 m^3/day of Kuta area, 4,500 m^3/day is planned to be treated by the IUIDP project. Accordingly, 15,700 m^3/day shall be treated by this Project in total. The expected treated water quality is less than 20 mg/ℓ as BOD.

The following four (4) treatment systems are applicable to meet the above requirements in quantity and quality.

(1) Aerated lagoon
(2) Conventional activated sludge
(3) Oxidation ditch
(4) Ocean outfall

These four (4) systems are evaluated from the following points of view.

(1) Required construction and O&M costs
(2) Required land space
(3) Easiness of O&M
  - Adaptability to overload
  - Required technology level of O&M
  - Required sludge disposal

The evaluation is made under the following design conditions.

(1) Design wastewater discharge (daily average): 117,000 m^3/day
(hourly peak) : 153 m^3/min.

(2) Design water quality (influent) : BOD,SS : 190 mg/ℓ
(effluent) : BOD,SS : < 20 mg/ℓ

2) Aerated Lagoon

(1) Structural Design

The aerated lagoon system is composed of inflow pump station, aerated lagoon, facultative aerated lagoon and polishing pond in series. The designed total effective storage capacity of the lagoons and pond is 527,000 m^3 with a total retention time of 4.5 days. The effective water depth of the lagoons/pond are 4.0 m for the aerated lagoon and the facultative aerated lagoon, and 1.5 m for the polishing pond.

The designed net treatment plant area including lagoon/pond, sludge drying bed and control building yard but excluding buffer zone (green area) is 22.0 ha.

The designed capacity of the inflow pump station and aerator are as follows.

- Inflow pump station : 153 m^3/min. x 7 m
- Aerator : 1,455 kW

(2) Construction and O&M Costs

The construction cost of the aerated lagoon varies depending on the land condition of the site. In this Study, the direct construction costs of the aerated lagoon for two (2) assumed sites are estimated as follows.

(i) On-land aerated lagoon

This aerated lagoon is constructed on the existing fish pond located in Pessanggaran of Kel. Pedungan along Jl. Pelabuhan Benoa (road leading to the Benoa Port). The location is shown in Fig. E.5.6.

The direct construction cost is estimated to be Rp. 22,500 million at 1992 price with the following break-down.

(Unit: million Rp.)

Work Item	Const. Cost
Inflow Pump Station	11,100
Aerated Lagoon	10,200
Other Facilities & Equipment	1,200
Total	22,500

(ii) Off-shore aerated lagoon

This aerated lagoon is constructed by reclaiming the Benoa Bay 1.0 km off-shore from the site of the on-land aerated lagoon. The location is shown in Fig. E.5.6.

The direct construction cost is estimated to be Rp. 28,500 million at 1992 price with the following break-down.

(Unit: million Rp.)

Work Item	Const. Cost
Inflow Pump Station	11,100
Aerated Lagoon	13,100
Other Facilities & Equipment	1,200
Sewer Pipe Extension	3,100
Total	28,500

The on-land aerated lagoon is more economical than the off-shore one. The construction of the off-shore lagoon will have adverse effects on the environmental preservation and tourism development of the Benoa Bay.

From the above considerations, the on-land aerated lagoon is recommendable as far as the required land space is available. Layout of the aerated lagoon system is shown in Fig. E.5.7.

The major O&M of the aerated lagoon is the electric charge for operation of the inflow pump and aerators. The required annual electric charge is estimated to be Rp. 1,691 million at 1992 price.

(3) Easiness of O&M

The treatment plant can be operated with no special technology. It can easily meet the overload of wastewater. Sludge is naturally digested in the lagoon. Desludging work is required only once a year.

3) Conventional Activated Sludge

(1) Structural Design

The conventional activated sludge system consists of inflow pump station, primary settling tank, aeration tank, secondary settling tank and sludge disposed facilities.

The included major mechanical/electrical equipment are inflow pump and air diffuser. Their designed capacities are as follows.

- Inflow pump : 153 m^3/min. x 7 m
- Air diffuser : 860 kW

The designed net treatment plant area excluding buffer zone (green area) is 6.8 ha. Layout of the conventional activated sludge system is shown in Fig. E.5.8.

(2) Construction and O&M Costs

The direct construction cost is estimated to be Rp. 71,200 million, assuming the site is the same as that of the on-land aerated lagoon. Its break-down is shown below.

(Unit: million Rp.)

Work Item	Const. Cost
Inflow Pump Station	11,400
Primary & Secondary Settling Tanks	23,300
Aeration Tank	19,400
Sludge Disposal Facilities	9,800
Other Facilities & Equipment	7,300
Total	71,200

The major O&M cost of this treatment plant is the electric charge for operation of the inflow pump and aeration equipment. The required annual electric charge is estimated to be Rp. 1,132 million at 1992 price.

(3) Easiness of O&M

Careful and skillful operation is required to control biological activities in the aeration tank. Adaptability to the overload of wastewater is low. Daily sludge disposal is necessary.

4) Oxidation Ditch

(1) Structural Design

The oxidation ditch system consists of inflow pump station, oxidation ditch, final settling tank and sludge disposal facilities.

The included major mechanical/electrical equipment are inflow pump and rotors. Their designed capacities are as follows.

- Inflow pump : 153 m^3/min. x 7 m
- Rotor : 2,068 kW

The designed net treatment plant area excluding buffer zone (green area) is 16.1 ha. Layout of the oxidation ditch system is shown in Fig. E.5.9.

(2) Construction and O&M Costs

The direct construction cost is estimated to be Rp. 57,000 million, assuming the site is the same as that of the on-land aerated lagoon. Its break-down is as follows.

(Unit: million Rp.)

Work Item	Const. Cost
Inflow Pump Station	11,400
Oxidation Ditch	19,100
Final Settling Tank	12,300
Sludge Disposal Facilities	9,800
Other Facilities & Equipment	4,400
Total	57,000

The major O&M cost of this treatment plant is the electric charge for operation of the inflow pump and rotors. The required annual electric charge is estimated to be Rp. 2,508 million.

(3) Easiness of O&M

Careful and skillful operation is required to control biological activities in the oxidation ditch. Adaptability to the overload of wastewater is larger than conventional activated sludge. Daily sludge disposal is necessary.

5) Ocean Outfall

(1) Structural Design

The wastewater of 190 mg/ℓ in BOD is treated upto 130 mg/ℓ by the primary settling tank and discharged off-shore through a conduit laid on the sea bottom. The discharged wastewater is expected to be conveyed by the prevailing ocean current to the open sea (see, Appendix E.1.2).

Three (3) conduit pipes with a diameter of ø1,000 mm each are extended by 7.0 km from the Sanur Beach toward off-shore. The conduits are laid on the sea bed which has a steep slope. Water depth at the tip of the conduits, is approximately 50 m.

A booster pump (ocean outfall pump) with a capacity of 153 m^3/min, is installed to discharge the wastewater through the conduit. Its required pump head is 16.0 m.

The designed net treatment plant area excluding buffer zone (green area) is 3.2 ha.

Location of the ocean outfall is shown in Fig. E.5.6.

(2) Construction and O&M Costs

The direct construction cost is estimated to be Rp. 87,600 million at 1992 price with the following break-down.

(Unit: million Rp.)

Work Item	Const. Cost
Primary Settling Tank	13,300
Ocean Outfall Pump Station	12,400
Conduit Pipe	50,900
Sludge Disposal Facilities	9,800
Other Facilities & Equipment	1,200
Total	87,600

The major O&M cost of the ocean outfall is the electric charge for operation of the ocean outfall pump station. The required annual electric charge is estimated to be Rp. 370 million.

(3) Easiness of O&M

The treatment plant can be operated with no special technology. It can easily meet the overload of wastewater. However, daily disposal of the sludge settled in the primary settling tank is necessary.

6) Comparative Evaluation

The above four (4) sewage treatment systems are compared in terms of required construction and O&M costs, required land space and easiness of O&M as shown below.

Evaluation Item	Aerated Lagoon	Conventional Activated Sludge	Oxidation Ditch	Ocean Outfall
(1) Const. Cost (million Rp.)	22,500	71,200	57,000	87,600
(2) O&M Cost (million Rp./year)	1,691	1,132	2,508	370
(3) Required Land Space (ha)	22.0	6.8	16.1	3.2
(4) Easiness of O&M				
- Adaptability to Overload	A	C	B	A
- Required Technology Level	A	C	B	A
- Sludge Disposal	A	C	C	C

Note: 1) Const. Cost: direct construction cost excluding land acquisition, engineering and administration costs
2) O&M Cost : electric charge
3) Adaptability to Overload : A: high, B: middle, C: low
4) Required Technology Level : A: low, B: middle, C: high
5) Sludge Disposal : A: easy, B: medium, C: hard

As evident from the above table, aerated lagoon system is the most recommendable one.

5.6.2 Design Criteria

(1) Design Flow

Daily average discharge including groundwater infiltration is used as the design flow of treatment plant.

Daily average discharge including groundwater infiltration is used for the design of treatment plant excluding inlet pumps. Because the detention time of aerated lagoon is generally long enough to regulate the peak discharge of wastewater.

(2) Design Inflow and Effluent Water Quality

	BOD	SS
Inflow water	190 mg/ℓ	190 mg/ℓ
Groundwater Infiltration	0	0
Effluent water	less than 20 mg/ℓ	less than 20 mg/ℓ

According to the pollution load survey conducted by the JICA Study Team, combined wastewater quality collected by the proposed sewerage system of domestic, commercial and institutional, tourism and industry is estimated approximately at 190 mg/ℓ in both BOD and SS.

Design effluent water quality is determined to be 20 mg/ℓ in both BOD and SS, considering the existing river and sea water quality and river and sea water quality standards of the Study Area (refer to Appendix B).

(3) Wastewater Temperature

Design wastewater temperature is determined to be 25^{o}C.

Monthly average air temperature of the Study Area ranges from 26^{o}C in July and August, and 28.0^{o}C in November and December. Based on the above facts, average wastewater temperature of the Study Area is estimated to be 25°C.

(4) Aerated Lagoon

BOD reduction efficiency	90%
Detention time	longer than two (2) days
Effective pond depth	maximum 4.0 m

The combined inflow wastewater of 190 mg/ℓ as BOD shall be treated to a level of 20 mg/ℓ as BOD with the reduction rate of 90%.
The design detention time of aerated lagoon is determined to be more than two (2) days, referring to the following standards.

Report	Detention Time	Water Temperature	BOD Reduction Rate
(1) WPCF Design Manual	3 - 20 days	Optimum 20°C (0 ~ 40°C)	80 - 95%
(2) Water, Wastes and Health in Hot Climate	2 - 6 days	Hot Climate	85 - 90%

Note (1) : Wastewater Treatment Plant Design, WPCF Manual of Practice No. 8
Note (2) : Edited by Richard Feachen, Michael Mcgarry and Duncan Mara

The depth of aerated lagoon is generally designed to be 3 m to 5 m. In this Study, effective pond depth of 4.0 m is adopted, considering the limitation of available land space.

(5) Other Facilities

The other appurtenant facilities such as Grit Chamber and Sludge Drying Beds are designed based on the design standards described below.

(i) Grit Chamber

- Flow velocity : 0.3 m/s
- Overflow rate : 1,800 $m^3/m^2/d$

(ii) Drying Bed

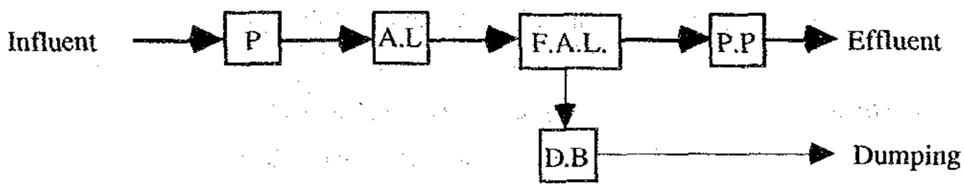
- Depth of drying bed : 25 cm
- Drying time : minimum one (1) week

5.6.3 Treatment Plant for Denpasar, Kuta and Sanur

The proposed location of the integrated wastewater treatment plant for Denpasar, Kuta and Sanur is the south east corner of the junction of Bypass Ngurah Rai Rd. and Raya Sesetan Rd. in Kelurahan Pedungan in Kec. Denpasar Selatan. The area is now occupied by the shrimp ponds. The proposed location is in the limited development area of land use plan of Benoa Bay prepared by the ministry of forestry.

Aerated lagoon treatment system of capacity 117,000 m^3/day requires a net space of 22 ha.

The flow sheet of treatment process and the capacity dimension and other relevant details of each treatment facility is shown below.



Where;

P	:	Inflow Pump
A.L	:	Aerated Lagoon
F.A.L	:	Facultative Aerated Lagoon
D.B	:	Drying Bed
P.P	:	Polishing Pond

Inflow Pump	:	Capacity of 152.5 m^3/min. with 7.4 m hydraulic head, 85 KW x 4 Units (include 1 stand-by) and 35 KW x 1 unit
Grit Chamber	:	Overflow load 1,830 $m^3/m^2/d$
	:	Retention time 57 sec.
	:	Size 4.0 m (W) x 10.0 m (L) x 1.2 m (D) x 3 units
	:	Constructed with R.C.
Aerated Lagoon	:	Pond capacity 234,000 m^3
	:	Pond surface area 67,000 m^2
	:	Retention time 2.0 days
	:	Size 82.5 m (W) x 157.5 m (L) x 4.0 m (D) x 2 units, 82.5 m (W) x 172.5 m (L) x 4.0 m (D) x 3 units
	:	Embankment is protected by masonry
	:	Capacity of aerator 1,170 KW
Facultative Aerated Lagoon	:	Pond capacity 234,000 m^3
	:	Pond surface area 67,000 m^2
	:	Retention time 2.0 days
	:	Size 82.5 m (W) x 157.5 m (L) x 4.5 m (D) x 2 units, 82.5 m (W) x 172.5 m (L) x 4.5 m (D) x 3 units (Depth of 0.5 m at base for sludge digestion)
	:	Capacity of aerator 285 KW
Polishing Pond	:	Pond capacity 58,500 m^3
	:	Pond surface area 41,100 m^2
	:	Retention time 0.5 day
	:	Size 82.5 m (W) x 97.0 m (L) x 2.0 m (D) x 2 units, 82.5 m (W) x 107.0 m (L) x 2.0 m (D) x 3 units (Depth of 0.5 m at base for sludge digestion)
Drying Bed	:	Capacity 3,400 m^3/2 months
	:	Size 10 m (W) x 25 m (L) x 0.25 m (D) x 55 units
	:	Drying time 2 months

The treated water is discharged to Benoa Bay.

Layout of the treatment plant is shown in Fig. E.5.7

5.6.4 Treatment Plant for Tanjung Benoa

Existing oxidation pond of BTDC will be modified to treat the future wastewater of 18,800 m^3/day generated in BTDC and Tanjung Benoa areas.

The existing capacity of oxidation pond treatment plant of 7,200 m^3/day will be upgraded by remodeling to an aerated lagoon system.

The existing first pond as facultative pond is changed to an aerated lagoon. The half area of pond will be dredged to 4.0 meter deep and 8 units of aerator with a total capacity of 400 KW will be installed. The expected retention time of aerated lagoon is 4.3 days with a total retention time of 21 days.

6. Proposed On-site Sanitation Development Plan

Septic tank with up-flow filter and septic tank with leaching system are proposed as on-site sanitation systems for this master plan, which could also be considered respectively as high level and simple on-site sanitation systems.

6.1 Septic Tank with Up-flow Filter

6.1.1 Development Area

A total area of 3,614 ha in southern Denpasar consisting of seven (7) Kelurahan/Desa in Kec. Denpasar Selatan with 3,316 ha and an area of 298 ha in Desa Pemecutan Kelod belonging to Kec. Denpasar Barat is covered by septic tank with upflow filter (ref. Fig. E.6.1). Of these eight (8) Kelurahan/Desa five (5) are partly sewered. They are Pemecutan Kelod, Sanur Kauh, Panjer, Sesetan and Pedungan.

The groundwater table of this area is shallower than 3 meter from ground surface and the soil permeability is very low. Hence, the leaching system is not applicable as wastewater disposal system. Both toilet waste and gray water generated in this area are treated by septic tank with up-flow filter then discharged to rivers/ditches nearby.

The existing and future population of this area are 73,300 and 107,700 respectively. The entire future population of 107,700 in 2010 is planned for the provision of septic tank with up-flow filter, as there is no such units under existing conditions.

6.1.2 Design of Septic Tank with Up-flow Filter

The detailed design procedure of the system shown in Fig. E.6.2 is illustrated below for the purpose of reference. The procedure incorporates the necessary elements of septic tank design as well.

(1) Basic Considerations

(i) Design wastewater quantity

Septic tank with up-flow filter will take in all wastewater generated in the household, both the toilet waste and gray water.

The design specific wastewater quantity is assumed as 185 l/person/day, which is the future water consumption of middle income groups as determined in Appendix-C.

This is a little higher than the design wastewater quantity for septic tanks recommended by the study, "Improvement of sanitation system for 38 small towns-Central Java", April 1989.

The design specific wastewater quantity recommended by the above study is 120-160 l/person/day.

(ii) Design pollution load

The BOD_5 concentration of wastewater will be assumed to be 170 mg/ℓ, which corresponds to a specific load of 31.5 g BOD_5/person/day.

(iii) Criteria of septic tank portion

The design criteria adopted conforms to the one already proposed by the Department of Public Works, LPMB Foundation, Bandung, urban Drainage and wastewater Disposal Project in Jakarta, JICA 1991.
The length to width ratio shall be 2-3:1, as also recommended by Mara (1976).

The minimum width shall be 0.75 m.

The allowable minimum and maximum design liquid depths are respectively 1.0 m and 2.1 m.
The clearance above liquid level shall be 0.2-0.4 m.

Two compartment septic tank portion, with initial portion covering a 2/3 length and final portion a 1/3 length will be adopted (Mara, 1976).

A detention time of 3 day at star-up will be provided, which will be based on the design wastewater influent to the tank.

The sludge accumulation rate in the tank is assumed at 35 l/person/year as already used in all similar cases in Indonesia

such as JSSP, Central Java Study, Jakarta Wastewater Disposal by JICA 1991 and others, though Mara proposes 40 l/person/year.

The desludging frequency which is also the cleansing frequency of upflow filters is considered to be necessary once in 1.5-3 years, when coarse media is only used.

A maximum sludge accumulation of 1/3 the volume of Septic tank portion is considered as the allowable maximum between consecutive desludging operations.

(iv) Criteria of up-flow filter

Anaerobic up-flow filter (AF) was widely tested for sewerage treatment in India, and the experience gained is summarized by Askinin (1983) as follows:

- Media adopted are generally broken stones of size 19 mm - 25 mm
- Most cases the maximum height adopted is in the range of 0.9 m - 1.2 m

Furthermore based on the accumulated performance evaluation of up-flow filters, the detailed design criteria could be based on hydraulic loading and hydraulic detention time in the filter, when the wastewater quality and filter media are established.

The hydraulic loading is defined as the flow rate per unit gross surface area of filter media, whereas the hydraulic detention time is defined as the real time the wastewater is retained in the voids of the filter, and hence is based on the filter void volume.

For a 20 - 25 mm broken stone filter media treating domestic sewage, the recommended hydraulic loading and hydraulic detention time to obtain a BOD removal of 70 - 80% are as follows (Askinin, 1983 ; Raman and Khan, 1982) :

Maximum hydraulic loading : 3.4 $m^3/d/m^2$

Hydraulic detention time : 6 - 9 hrs.

Accordingly, the design criteria for anaerobic upflow filters is established as follows :

Filter media	: Broken stones, 20 - 25 mm, for which void ratio is 0.45
Hydraulic loading	: 1.7 $m^3/d/m^2$ with a safety factor of 2.0
Hydraulic detention time	: 8 hours
Filter height	: 0.8 - 1.2 m, which would also conform the septic tank effective water depth constraint

(2) Design Computations

Based on the design criteria already presented in the foregone section, a Septic Tank-Upflow Filter is designed for a typical family consisting of seven (7) person.

Specific wastewater discharge : 185 l/person/day

Design wastewater inflow $= 185 \times 7 \times 10^{-3}\ m^3/d$
$= 1.3\ m^3/d$

(i) Septic tank capacity

Detention time in septic tank at start-up = 3 d

Effective tank volume = $1.3 \times 3\ m^3$
= $3.9\ m^3$

(ii) Check of sludge accumulation

Specific sludge accumulation : 35 l/person/year

Sludge accumulation in 3 years = $35 \times 7 \times 3 \times 10^{-3}$
= $0.74\ m^3$

1/3 of tank volume is reserved for sludge accumulation

Hence, volume reserved for sludge accumulation = $1/3 \times 3.9$
= $1.3\ m^3$

This is greater than the anticipated sludge accumulation of 0.74 m^3 in three (30) years.

The capacity of the septic tank portion is satisfactory

(iii) Septic tank dimensions

Assume an effective water depth of 1.6 m
Then the area of tank $= \frac{3.9}{1.6} = 2.44\ m^2$

For a length to width ratio of 2 : 1
The width of the tank = 1.06 m
The effective width = 1.0 m

The effective length of the tank = 2.5 m

For two (2) compartment tank, divide the tank length as 2:1 between first and second compartment.

Effective length of first compartment $= 2/3 \times 2.5$
$= 1.7$ m

Effective length of second compartment $= 2.5 - 1.7$
$= 0.8$ m

(iv) Anaerobic filter capacity

Filter media : 20 - 25 mm broken stones
Void ratio : 0.45

Detention time based on void volume = 8 hrs.
Design flow through the filter $= 1.3\ m^3/d$

Required void volume in filter $= 1.3 \times \frac{8}{24} = 0.44\ m^3$

Required filter volume $= \frac{0.44}{0.45} = 1.0\ m^3$

(v) Filter dimensions

With due consideration to the effective water depth in septic tank portion of 1.6 m, let the effective depth of media be 0.9 m.

Computed filter area $= \frac{1.0}{0.9} = 1.1\ m^2$

Hydraulic loading to the filter $= \frac{1.3}{1.1} = 1.18\ m^3/d/m^2$

Recommended hydraulic loading $= 1.7\ m^3/d/m^2$

Hence, this area of 1.1 m^2 is satisfactory as the hydraulic loading is within the design value.

Let the effective width of the filter be the same as that of septic tank portion.

Width of filter = 1.0 m
Length of filter = 1.1 m
The designed filter is of 1.1 m x 1.0 m with a height of 0.9 m.

The designed treatment system of septic tank with upflow filter is shown in Fig. E.6.2.

References :

Mara, Sewerage Treatment in Hot Climates (1976)
Askinin W.B., Design Criteria Development of RBC and Anaerobic Filter System for sewage Treatment, AIT Master Thesis (1983).

Vigneswaran et. al. Anaerobic Wastewater Treatment-Attached Growth and Sludge Blanket Process, ENSIC, AIT (1986).

6.2 Septic Tank with Leaching Pit

6.2.1 Development Area

Septic tank with leaching system covers an area of 15,832 ha covering full/portion of 26 Kelurahan/Desa located in the northern and southern fringes of the Study Area. The total population of this area in the year 2010 is estimated to be 266,580. The existing population in the year 1990 is 176,420. The existing and future average population density are 11.1 person/ha and 16.7 person/ha respectively.

In principle, both toilet waste and gray water are treated by septic tank with leaching system. No wastewater is discharged directly to the public water ways.

The population planned for this simple system in future includes both the future population increase and those having no toilet with treatment under the existing conditions. Accordingly, the total population requiring the provision new septic tank with leaching system until 2010 is estimated to be about 90,160.

Breakdown of the planned sanitation area and population on a Kecamatan basis is summarized in the table given below.

Kecamatan	Onsite Area (ha)			Planned on site population (2010)		
	Septic tank with Leaching system	Septic tank with Up-flow filter	Total	Septic tank with Leaching system	Septic tank with Up-flow filter	Total
Denpasar Barat	3,596	298	3,894	101,200	17,400	118,600
Denpasar Timur	1,534	0	1,534	47,700	0	47,700
Denpasar Selatan	231	3,316	3,547	8,600	90,300	98,900
Kuta	10,471	0	10,471	107,080	0	107,080
Total (On-site Area-Master Plan)	15,832	3,614	19,446	264,580	107,700	372,280

6.3 Desludging and Treatment

6.3.1 Quantity of Desludging

The existing and future quantity of desludging in both on-site sanitation system development area is shown below.

On-site Sanitation System	Desludging Quantity (m^3/year) 1990	2010
Septic Tank with Up-flow Filter	-	5,654
Septic Tank with Leaching System	6,700	9,260
Total	6,700	14,914

Under the existing, as dealt with in Appendix D, a sludge treatment plant is already planned under the Kuta Sewerage Project of IUIDP. This plant with a treatment capacity of 110 m^3/day will be constructed until 1994.

This plant is sufficient to meet the estimated future average desludging quantity of 41 m^3/day. Hence, no additional sludge treatment plants are required.

6.3.2 Desludging and Hauling

Total number of existing vacuum trucks of both public and private sectors are nine (9).

The capacity of vacuum truck of public cleansing department is 6 m^3 and other eight (8) trucks is 4 m^3

Required number of vacuum trucks of the Study Area is determined based on the following assumptions.

- Operation time is six (6) days a week and eight (8) to nine (9) hours a day
- Capacity of vacuum truck is 4 m^3
- Daily operation of each truck is assumed to be 2.0 cycle.
- Standby allowance of 20% is considered for maintenance and repair

The total required number of vacuum trucks of capacity 4 m^3 is determined at 8 units in the year 2010. Hence, no additional vacuum trucks are required.

7. Estimated Cost

7.1 Project Cost

7.1.1 Sewerage Development

Estimated project cost of sewerage development, consisting of direct construction cost, engineering and administration costs and physical contingency, amounts to Rp. 253,600 million at February 1992 prices (Rp. 274,351 million including house connection cost).