# G6 RAW WATER DIVERSION FROM YALA RIVER

## G6.1 BACKGROUND

The scheme of raw water diversion from Yala River Option which was originally proposed by the Kisumu Water Supply and Sanitation Study, March 1988, Ministry of Local Authorities on behalf of Kisumu Municipal Council, conducted by H. P. Gauff GmbH. The Study stated that it is technically possible to divert water from the Yala River from the vicinity of the Kimondi-Sirwa confluence into and through either the Kibos or Nyangori catchments to the Municipality of Kisumu. This Yala River option was considered and studied as one of the available water source options in this JICA Study.

## G6.2 AVAILABILITY OF RAW WATER

### G6.2.1 96% Probability Daily Low Flow

The 96 % (25-year) probability daily low flow is defined as safe yield by "Design Manual for Water Supply in Kenya" (MOWR, 1986). According to the previous frequency analysis by the 1988 Study, the 96 % probability daily low flow at the proposed intake site (refer to Figure G6-1) is estimated to be 105,400 m3/d (1.22 m3/s) as shown in Figure G6-2.

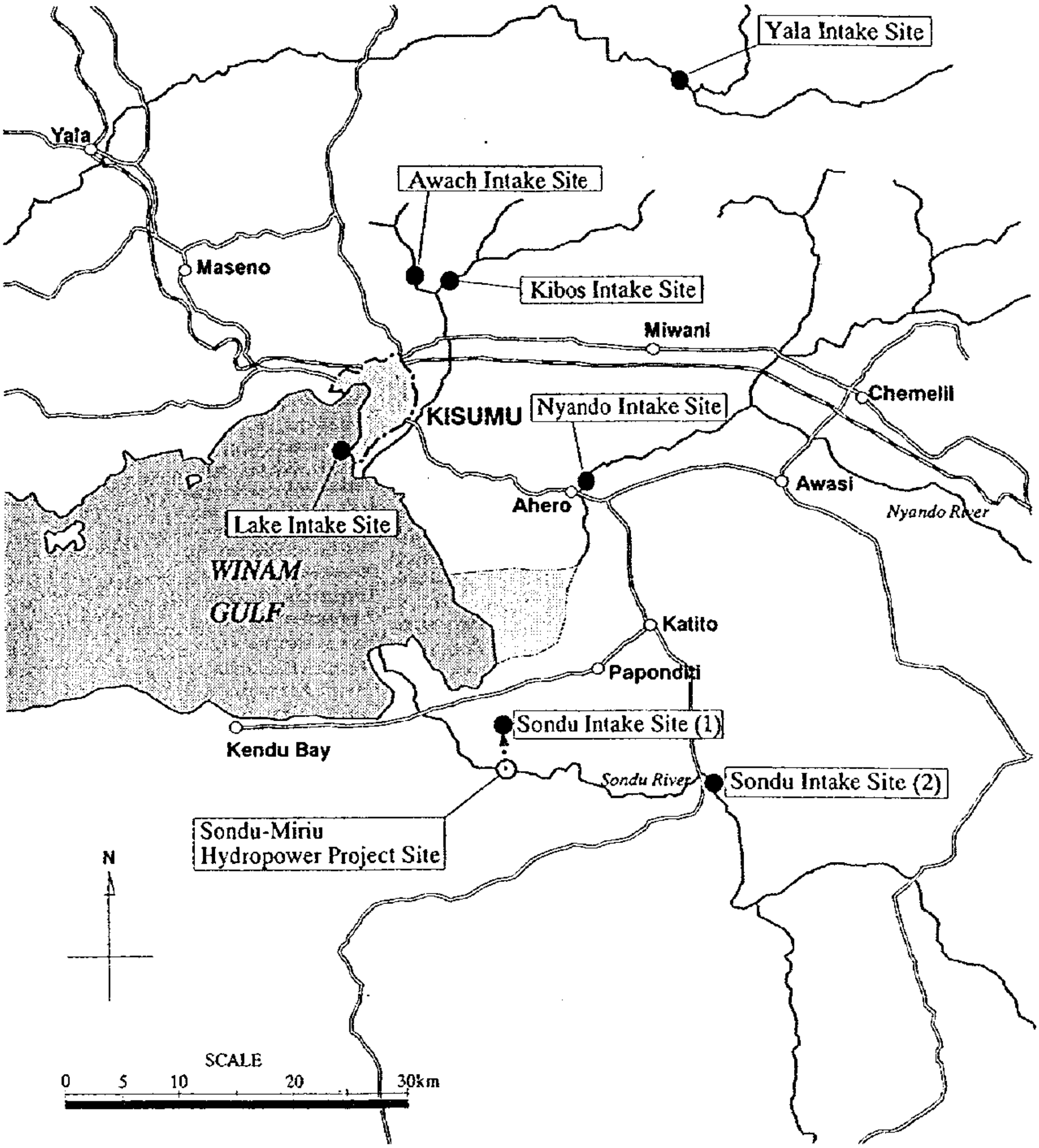
### G6.2.2 Dependability 96 % Possible Water Amount

Based on the concept of the dependability on flow duration defined in the Interim Report, the flow duration at the intake site is estimated as shown in Table G6-1 by using the average minimum flow analyzed by the 1988 Study. Under the concept of 96 % dependability, 304,100 m3/d (3.52 m3/s) of water is available at the intake site. The summary of the analysis is shown in Table G6-2.

Table G6-2 Result of Dependability Analysis

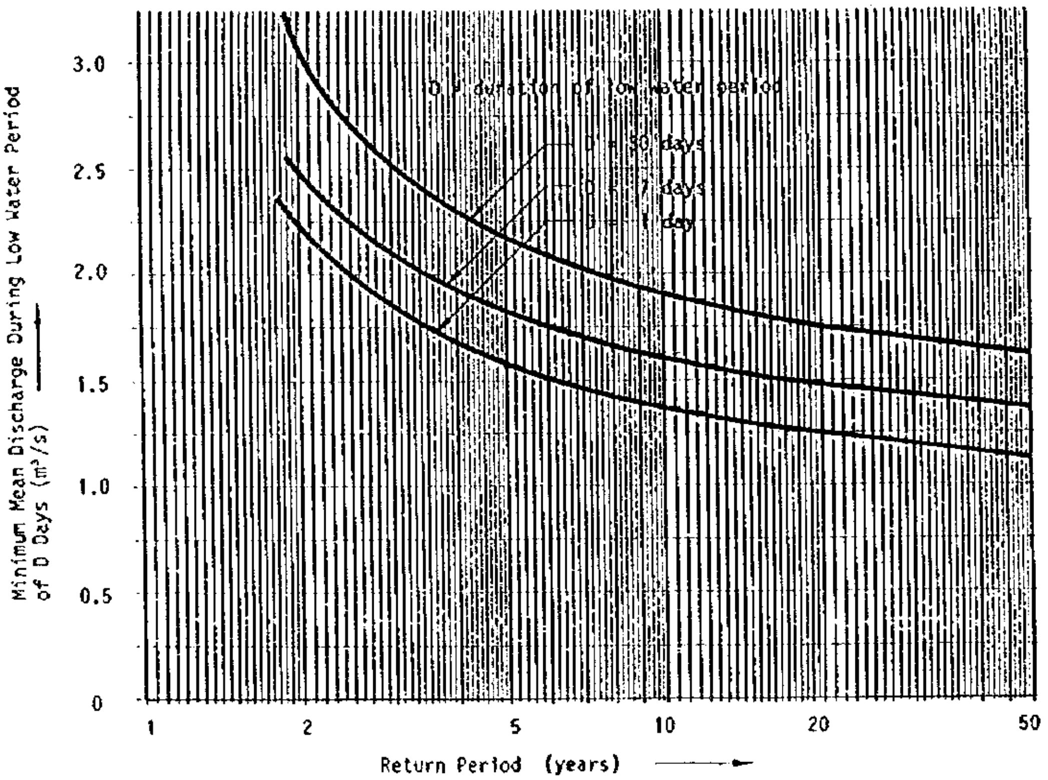
| Dependability (%) | Water Amount (m3/d) |
|---|---|
| 96 | 304,100 |
| 97 | 279,900 |
| 98 | 257,400 |
| 99 | 236,700 |
| 100 | 210,800 |

Figure G6-1




| THE REPUBLIC OF KENYA<br><br>THE MINISTRY OF LOCAL AUTHORITIES<br>KISUMU MUNICIPAL COUNCIL | THE STUDY ON KISUMU WATER SUPPLY AND SEWERAGE SYSTEM<br><br>JAPAN INTERNATIONAL COOPERATION AGENCY | TITLE :<br><br>General Location of Available Intake Sites |
|---|---|---|

**Figure G6-2**




| Duration of Low Water Period (days) | Minimum Mean Flow During Low Water Period ≤ Tabelled Values (m³/s) return period: 2, prob.: n=0,50 | 5, n=0,20 | 10, n=0,10 | 20, n=0,05 | 50 (years), n=0,02 |
|---|---|---|---|---|---|
| 1 | 2,21 | 1,57 | 1,36 | 1,24 | 1,13 |
| 3 | 2,32 | 1,67 | 1,47 | 1,35 | 1,25 |
| 5 | 2,40 | 1,74 | 1,54 | 1,41 | 1,31 |
| 7 | 2,49 | 1,80 | 1,60 | 1,46 | 1,36 |
| 9 | 2,55 | 1,84 | 1,63 | 1,49 | 1,38 |
| 14 | 2,67 | 1,94 | 1,70 | 1,56 | 1,45 |
| 21 | 2,85 | 2,05 | 1,81 | 1,67 | 1,55 |
| 30 | 3,07 | 2,17 | 1,90 | 1,75 | 1,62 |

Results of Statistical Low Water Analysis of RGS 1 FE 2 (Yala River) Transfered to Intake Site downstream of Confluence of Mokong and Remonde River

Source;
MOLG (1985, November) "Kisumu Water Supply and Sanitation Study - Feasibility Study, Vol. III B, Appendices 7 Hydrology". H P Gauff Gmbh & Co Consulting Engineers.

| THE REPUBLIC OF KENYA<br>THE MINISTRY OF LOCAL AUTHORITIES<br>KISUMU MUNICIPAL COUNCIL | THE STUDY ON KISUMU WATER SUPPLY AND SEWERAGE SYSTEM<br>JAPAN INTERNATIONAL COOPERATION AGENCY | TITLE :<br>Probable Drought Discharge of Yala River (Intake Site, 1FE2*0.945) |
|---|---|---|

Table G6-1 Average Minimum Flows of Yala River at Proposed Intake Site

unit: $m^3/s$

| Year | Duration of Low Flow Period (day) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 30 | 21 | 14 | 9 | 7 | 5 | 3 | 1 |
| 1962 | 8.20 | 8.08 | 6.55 | 5.87 | 5.60 | 5.38 | 5.25 | 5.18 |
| 1963 | 6.02 | 4.33 | 4.10 | 3.73 | 3.61 | 3.52 | 3.46 | 3.39 |
| 1964 | 4.88 | 4.81 | 4.42 | 4.25 | 3.96 | 3.73 | 3.62 | 3.35 |
| 1965 | 2.66 | 2.58 | 2.44 | 2.39 | 2.38 | 2.38 | 2.35 | 2.33 |
| 1966 | 1.94 | 1.90 | 1.83 | 1.77 | 1.69 | 1.60 | 1.55 | 1.51 |
| 1967 | 1.59 | 1.50 | 1.36 | 1.25 | 1.21 | 1.17 | 1.14 | 1.12 |
| 1968 | 3.36 | 3.24 | 3.21 | 3.18 | 3.12 | 3.06 | 3.00 | 2.87 |
| 1969 | 2.88 | 2.51 | 2.37 | 2.25 | 2.14 | 1.97 | 1.82 | 1.69 |
| 1970 | 2.75 | 2.69 | 2.38 | 2.21 | 2.14 | 2.03 | 1.98 | 1.87 |
| 1971 | 1.71 | 1.69 | 1.53 | 1.45 | 1.42 | 1.39 | 1.35 | 1.31 |
| 1972 | 2.35 | 2.21 | 2.20 | 2.06 | 2.05 | 1.86 | 1.62 | 1.20 |
| 1973 | 2.78 | 2.65 | 2.52 | 2.49 | 2.49 | 2.48 | 2.43 | 2.38 |
| 1974 | 2.83 | 2.65 | 2.51 | 2.35 | 2.26 | 2.15 | 2.13 | 2.06 |
| 1975 | 2.42 | 2.42 | 2.38 | 2.30 | 2.27 | 2.16 | 2.07 | 1.86 |
| 1976 | 2.76 | 2.58 | 2.41 | 2.38 | 2.36 | 2.33 | 2.32 | 2.15 |
| 1977 | 3.04 | 2.83 | 2.48 | 2.38 | 2.41 | 2.30 | 2.17 | 2.10 |
| 1978 | - | - | - | - | - | - | - | - |
| 1979 | 7.67 | 7.03 | 6.07 | 5.49 | 5.24 | 5.03 | 4.82 | 4.67 |
| 1980 | 3.70 | 3.00 | 2.70 | 2.52 | 2.45 | 2.39 | 2.32 | 2.26 |
| 1981 | 2.59 | 2.17 | 2.05 | 2.01 | 2.01 | 1.99 | 1.94 | 1.91 |
| 1982 | 2.66 | 2.50 | 2.42 | 2.33 | 2.31 | 2.25 | 2.17 | 2.05 |
| 1983 | 5.14 | 4.79 | 4.72 | 4.41 | 4.28 | 4.12 | 3.96 | 3.83 |
| 1984 | 3.44 | 3.18 | 2.96 | 2.88 | 2.86 | 2.88 | 2.74 | 2.60 |
| Average | | | | | | | | |
| ($m^3/s$) | 3.52 | 3.24 | 2.98 | 2.82 | 2.74 | 2.64 | 2.56 | 2.44 |
| ($m^3/day$) | 304,100 | 279,900 | 257,400 | 243,600 | 236,700 | 228,000 | 221,100 | 210,800 |
| Average Dependability on Flow Duration | 95.9% | 97.1% | 98.1% | 98.8% | 99.0% | 99.3% | 99.6% | 100.0% |

Note: The discharges in this table are calculated based on the low flow study result at 1FE2 on the Yala river in "Kisumu Water Supply and Sanitation Study (1988, MOLG)". The conversion factor of 0.945*1FE2 (1,491km2/1,577km2=0.945) is adopted. Relatively big flows in 1978 are excluded to avoid overestimation.

### G6.2.3 Evaluation of Availability

The result of both analyses is summarized as follows:

- 96% (25-year) probability daily low flow :105,400 m3/d (1.22 m3/s)
- Dependability 96 % possible water amount :304,100 m3/d (3.52 m3/s)

The intake amount from the Yala River in Phase II is proposed 42,500 m3/d (0.49 m3/s). Consequently, the water yield of the Yala River is considered enough to water demand of Kisumu Municipality up to year 2015. The river water can be abstracted by intake weir with no storage facilities in the upstream. Judging from the relatively big amount of the water yield, the intake amount of 42,500 m3/d seems not influence the present/future water abstraction permits and natural river environment located downstream.

## G6.3 WATER QUALITY

The water quality survey at proposed intake site on Yala River were carried out several times under "Kisumu Water Supply and Sanitation Study". The proposed intake site is located about 1.3 km downstream of the confluence of Kimondi and Sirua/Mokong Rivers. Water quality of Yala River is depending on the both rivers. It is said in the report of "Kisumu Water Supply and Sanitation Study", that water quality in Kimondi River is relatively better than in Sirua/Mokong River, and several parameters of water quality of Kimondi, including conductivity, turbidity, alkalinity, hardness and total suspended solid are more than twice as high in Sirua/Mokong River.

The summary of water quality record is shown in Table G6-3, comparing with Drinking Water Quality Standard in Kenya. As shown in Table G6-3, river water quality at the proposed intake site is considered acceptable as a raw water source for the water supply, although parameters such as Iron, Turbidity and Color exceed Drinking Water Quality Standard in Kenya. This means that pre-treatment process may be required. Heavy Metal and Harmful Material, such as Arsenic, Cadmium, Chromium, Cyanide, Lead etc. had not been analyzed, but such materials will be considered low level enough to the standard, because there is almost no industrial factory in the catchment area. Further water quality analysis on the proposed intake site is to be carried out under this study, on almost of all water quality parameters indicated in the Standard. The evaluation and confirmation of the water quality will be done using the results of that analysis in the proceeding stage.

**Table G6-3 Water Quality at Proposed Intake Site on Yala River and Drinking Water Quality Standard**

| | Constituents of Health Significance (mg/L) | Permissible Aesthetic Quality (mg/L) | Water Quality at Yala Intake Sites | | |
|---|---|---|---|---|---|
| | | | Mean (mg/L) | Max. (mg/L) | Min. (mg/L) |
| Arsenic | 0.05 | - | - | - | - |
| Cadmium | 0.005 | - | - | - | - |
| Chromium | 0.05 | - | - | - | - |
| Cyanide | 0.1 | - | - | - | - |
| Fluoride | 1.5 | - | 0.34 | 0.62 | ND |
| Lead | 0.05 | - | - | - | - |
| Mercury | 0.001 | - | - | - | - |
| Nitrate | 10 | - | - | - | - |
| Selenium | 0.01 | - | - | - | - |
| Aluminum | - | 0.2 | - | - | - |
| Copper | - | 1.5 | - | - | - |
| Iron | - | 1.0 | 1.43 | 2.50 | 0.70 |
| Manganese | - | 0.5 | 0.047 | 0.090 | 0.020 |
| Zinc | - | 15.0 | - | - | - |
| pH | - | 6.5 – 9.2 | 7.8 | 8.8 | 7.0 |
| Turbidity | - | 25 | 49 | 88 | 22 |
| Color | - | 50 | 79 | 110 | 40 |
| Hardness | - | 500 | 41.4 | 58.0 | 34.0 |
| Chloride | - | 600 | 3.4 | 7.2 | 1.0 |
| Sodium | - | 200 | - | - | - |
| Total dissolved Sodium | - | 1,500 | - | - | - |
| Sulfate | - | 400 | - | - | - |

Source: "Design Manual for Water Supply in Kenya" & "Kisumu Water Supply and Sanitation Study"
Arrange: JICA Study Team

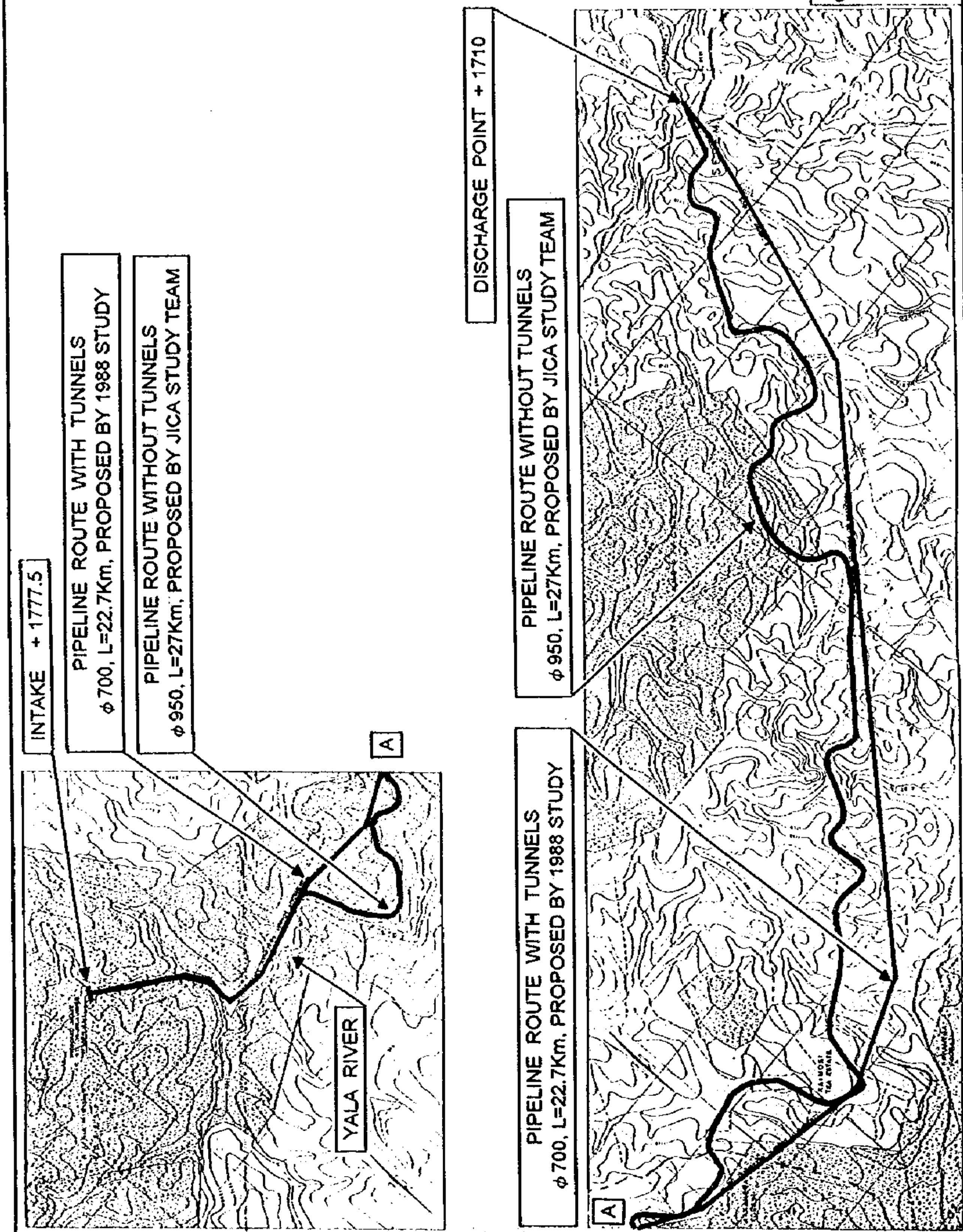
## G6.4 DIVERSION PIPELINE FORM YALA RIVER TO KIBOS RIVER

### G6.4.1 Plan of 1988 Study

The Yala River at the confluence of its major contributaries, the Kimondi and Sirwa has an elevation of about 1780 m. The watershed between Yala River catchment and Kibos River catchment lies at elevations varying between 1780 m and 1740 m. It is therefore, the 1988 Study stated, technically possible to divert water through gravity pipeline from the vicinity of the Kimondi-Sirwa confluence into and through the Kibos catchment to the Municipality of Kisumu.

According to the 1988 Study, the level of intake at the confluence is 1777.5 m and the discharge point at the tributary of the Kibos River is 1710 m. The pipeline for diversion was estimated to be 700 mm in diameter and 22.7 km in length, and its route is shown on Figure G6-3.

Figure G6-3




| | | |
|---|---|---|
| **THE REPUBLIC OF KENYA**<br><br>THE MINISTRY OF LOCAL **AUTHORITIES**<br>KISUMU MUNICIPAL COUNCIL | THE STUDY<br>ON KISUMU WATER SUPPLY<br>AND SEWERAGE SYSTEM<br><br>JAPAN INTERNATIONAL COOPERATION AGENCY | TITLE :<br><br>Diversion Pipeline Route<br>from Yala River to Kibos Catchment |

Because of the geophysical nature of the Kibos catchment and its relatively unpopulated state, it was envisaged that the diversion pipeline from the Yala River could discharge into the upper reaches of the Chemobo tributary and be conveyed naturally within the watercourse to a suitable point of intake.

### G6.4.2 Review of Pipeline Route

As can be seen in Figure G6-3, the pipeline route proposed by the 1988 Study was almost straight with some sections being tunnels. The total length of tunnels required to ensure a gravity flow to Kibos catchment is about 5.5 km.

Given the cost and time to be required for the construction of the tunnels, the JICA Study examined another pipeline route on the 1:50,000 topographical map. The new pipeline route, of which total length is about 27 km is shown on the Figure G6-3.

Because of its longer pipeline length, a larger pipe diameter of 950 mm is required to accommodate a gravity flow of 42.500 m3/day.

### G6.4.3 Preliminary Cost Estimate

The above two pipeline routes were then compared in terms of their construction costs. Construction costs were estimated on the basis of 1997 unit costs and included pipe (steel pipe) material/installation costs, access road construction costs, intake and bank protection costs at discharge point and tunnel construction costs. They are as follows.

| | |
|---|---|
| Diversion Gravity Line (1988 Study)<br>Diameter 700 mm, L = 22.7 km<br>with Tunnel (5.5 km) | US$ 22,300,000.- |
| Diversion Gravity Line (JICA Study Team)<br>Diameter 950 mm, L = 27.0 km<br>without Tunnel | US$ 18,700,000.- |

# G7 Water Sources for Each Alternative Case

| | Phase I | | Phase II | |
|---|---|---|---|---|
| Cases | Water Source | Intake Capacity (m3/day) | Water Source | Intake Capacity (m3/day) |
| **Case 1** | Kibos (RC) | 3,000 | Kibos (RC) | 3,000 |
| | Lake (RC) | 27,000 | Lake (RC) | 27,000 |
| | Kibos | 25,500 | Kibos | 25,500 |
| | Awach | 17,000 | Awach | 17,000 |
| | | | Lake | 42,500 |
| **Total** | | **72,500** | | **115,000** |
| **Case 2** | Kibos (RC) | 3,000 | Kibos (RC) | 3,000 |
| | Lake (RC) | 27,000 | Lake (RC) | 27,000 |
| | Kibos | 25,500 | Kibos | 25,500 |
| | Awach | 17,000 | Awach | 17,000 |
| | | | Kibos Dam | 42,500 |
| **Total** | | **72,500** | | **115,000** |
| **Case 3** | Kibos (RC) | 3,000 | Kibos (RC) | 3,000 |
| | Lake (RC) | 27,000 | Lake (RC) | 27,000 |
| | Lake | 42,500 | Lake | 42,500 |
| | | | Lake | 42,500 |
| **Total** | | **72,500** | | **115,000** |
| **Case 4** | Kibos (RC) | 3,000 | Kibos (RC) | 3,000 |
| | Lake (RC) | 27,000 | Lake (RC) | 27,000 |
| | Kibos | 25,500 | Kibos | 25,500 |
| | Awach | 17,000 | Awach | 17,000 |
| | | | Yala ->Kibos | 42,500 |
| **Total** | | **72,500** | | **115,000** |
| **Case 5** | Kibos (RC) | 3,000 | Kibos (RC) | 3,000 |
| | Lake (RC) | 27,000 | Lake (RC) | 27,000 |
| | Lake | 42,500 | Lake | 42,500 |
| | | | Kibos Dam | 42,500 |
| **Total** | | **72,500** | | **115,000** |
| **Case 6** | Kibos (RC) | 3,000 | Kibos (RC) | 3,000 |
| | Lake (RC) | 27,000 | Lake (RC) | 27,000 |
| | Lake | 42,500 | Lake | 42,500 |
| | | | Yala ->Kibos | 42,500 |
| **Total** | | **72,500** | | **115,000** |

RC : Rehabilitation Works Component

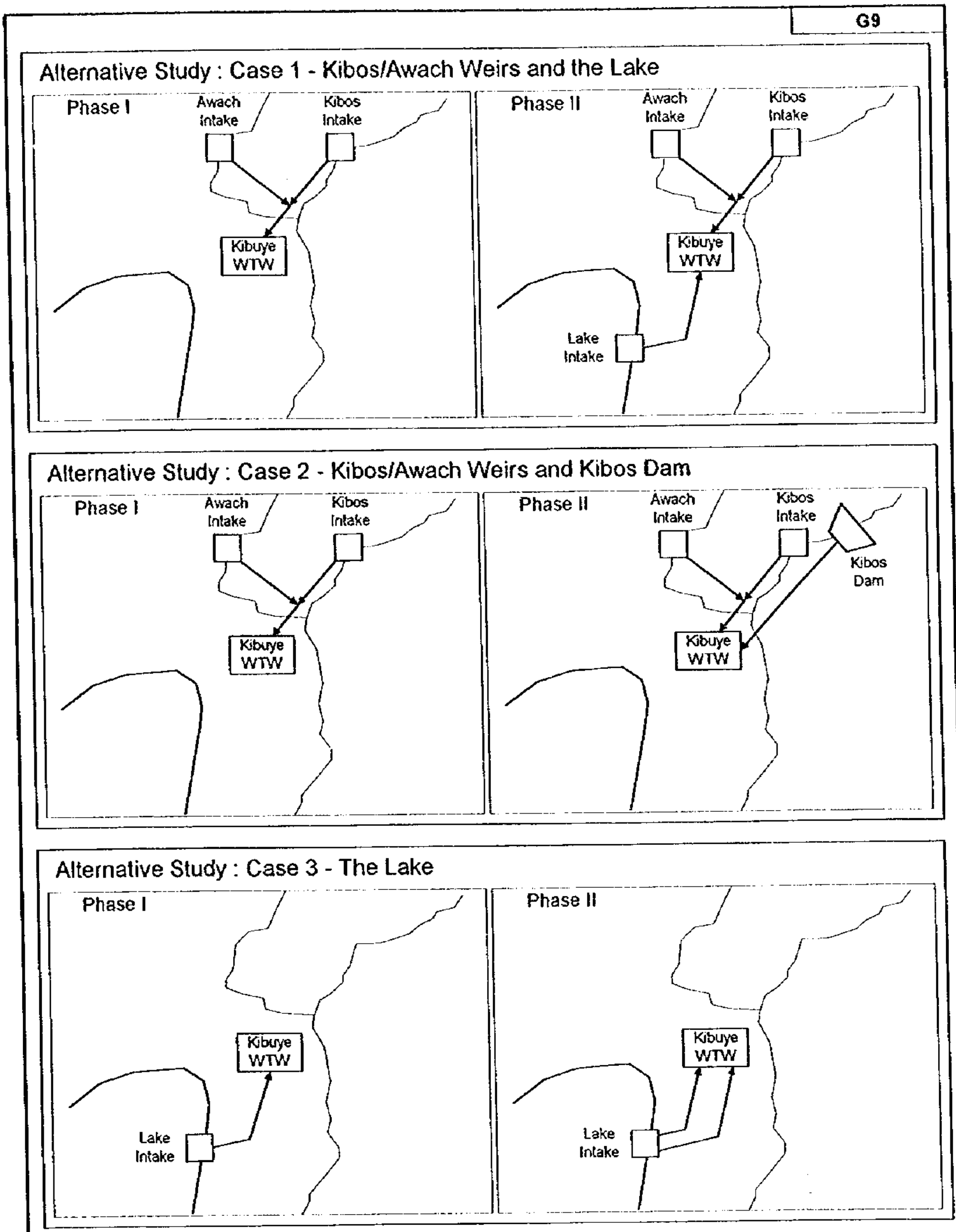
The exercise demonstrated that, although a larger diameter and longer pipeline is required, the route proposed by the JICA Study Team is far less expensive than that proposed by the 1988 Study.

For the purpose of further comparative study, the cost for developing the Yala River Option is therefore assumed to be US$18.7 million.

## G8 Outline of Water Supply Development Alternatives

| Facilities | Location | Phase | Case 1 | Case 2 | Case 3 | Case 4 | Case 5 | Case 6 |
|---|---|---|---|---|---|---|---|---|
| Treatment Works ($m^3/d$) | Kajulu (rehabilitation) E.L.1273 m | I (REH.) | 2,800 | 2,800 | 2,800 | 2,800 | 2,800 | 2,800 |
| | Lake (rehabilitation) E.L.1140 m | I (REH.) | 25,000 | 25,000 | 25,000 | 25,000 | 25,000 | 25,000 |
| | Kibuye (Expansion) E.L.1190 m | I | 40,000 | 40,000 | 40,000 | 40,000 | 40,000 | 40,000 |
| | Kibuye (Expansion) E.L.1190 m | II | 40,000 | 40,000 | 40,000 | 40,000 | 40,000 | 40,000 |
| | Total (2015 y) | | 107,800 | 107,800 | 107,800 | 107,800 | 107,800 | 107,800 |
| Intake Facilities ($m^3/d$) | Kibos (Rehabili.) E.L.1273m | I (REH.) | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 |
| | Lake (Rehabili.) E.L 1134m | I (REH.) | 27,000 | 27,000 | 27,000 | 27,000 | 27,000 | 27,000 |
| | Kibosu/Awach, Kibos E.L. 1300 m | I | 25,500 | 25,500 | | 25,500 | | |
| | Awach E.L. 1300 m | | 17,000 | 17,000 | | 17,000 | | |
| | Lake E.L. 1134 m | I | | | 42,500 | | 42,500 | 42,500 |
| | Lake E.L. 1134 m | II | 42,500 | | 42,500 | | | |
| | Kibos Dam EL.1472 m | II | | 42,500 | | | 42,500 | |
| | Yala River E.L 1777.5 m | II | | | | 42,500 | | 42,500 |
| | Kibos River E.L. 1273 m | II | | 42,500 | | 42,500 | | 42,500 |
| | Kibosu/Awach, Kibos E.L. 1273 m<br>Awach E.L. 1255 m | II | | | | | | |
| Transmission or Conveyance Pipe ($m^3/d$) | Kajulu- Clear reservoir<br>L:2.6 km E.L. 1273- 1220 m | I (REH.) | 2,800 | 2,800 | 2,800 | 2,800 | 2,800 | 2,800 |
| | Lake-Kibuye E.L 1140- 1190 m<br>L :5.0km | I (REH.) | 25,000 | 25,000 | 25,000 | 25,000 | 25,000 | 25,000 |
| | Kibos/Awach- Kibuye 1300-1190 m<br>L: 5km+5.2+6 (25500+17000m3/d) | I<br>II | 42,500 | 42,500 | | 42,500 | | |
| | Lake- Kibuye E.L.1140- 1190 m<br>L : 5.0km | II | 42,500 | | 42,500 | | 42,500 | 42,500 |
| | Kibosu(Dam) E.L. 1300-1190 m<br>L:11.4km | II | | 42,500 | | | 42,500 | |
| | Yala- Kibos E.L.:1777.5-1710 m<br>L.: 22.7km | II | | | | 42,500 | | 42,500 |
| | Kibos-Kibuye E.L. 1300- 1190 m<br>L:11.4km | II | | | | 42,500 | | 42,500 |
| | Kibuye- Kanyakwar L=3.8 km | I | 5100 | 5100 | 5100 | 5100 | 5100 | 5100 |
| | E.L.:1190- 1240 m (Pumping) | II | 5900 | 5900 | 5900 | 5900 | 5900 | 5900 |
| | Kibuye - Kogony L=6.0 | I | 4500 | 4500 | 4500 | 4500 | 4500 | 4500 |
| | E.L.:1190- 1240 m (Pumping) | II | 5500 | 5500 | 5500 | 5500 | 5500 | 5500 |
| Clear Water Reservoir ($m^3$) | Kibuye E.L.1190, Cap.:6,000 | existing | 6,000 | 6,000 | 6,000 | 6,000 | 6,000 | 6,000 |
| | Kajulu Cap.:1,000 | I(REH.) | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 |
| | Kibuye E.L.1190 Cap.:2,000 | I | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 | 12,000 |
| | Kibuye E.L.1190 Cap.:10,000 | II | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 | 10,000 |
| | Kanyakwar H.W.L 1240 2,500 | I | 2,500 | 2,500 | 2,500 | 2,500 | 2,500 | 2,500 |
| | Kanyakwar H.W.L 1240 m 2,000 | II | 2,000 | 2,000 | 2,000 | 2,000 | 2,000 | 2,000 |
| | Kogony H.W.L. 1240 m 2,000 | I | 2,000 | 2,000 | 2,000 | 2,000 | 2,000 | 2,000 |
| | Kogony H.W.L. 1240 m 2,500 | II | 2,500 | 2,500 | 2,500 | 2,500 | 2,500 | 2,500 |
| | Total | | 38,000 | 38,000 | 38,000 | 38,000 | 38,000 | 38,000 |
| Pumping Station ($m^3/d$) | Lake-Lake TW Q27,000 L0.6km<br>EL.:1134-1140 m | I(REH.) | 27,000 | 27,000 | 27,000 | 27,000 | 27,000 | 27,000 |
| | Lake-Kibuye, Q25,000, L6.0km | I (REH.) | 25,000 | 25,000 | 25,000 | 25,000 | 25,000 | 25,000 |
| | E.L.Difference.:+ 50 m<br>Lake-Kibuye, Q42,500, L: 5.0km | I | | | 42,500 | | 42,500 | 42,500 |
| | E.L.Difference.:+ 50 m<br>Lake-Kibuye, Q42,500, L: 5.0km | II | 42,500 | | 42,500 | | | |
| | E.L.Difference.:+15 m<br>Kibuye-Kanyakwar Q5100, | I | 5,062 | 5,062 | 5,062 | 5,062 | 5,062 | 5,062 |
| | E.L.D.:+50 m L:3.8 km<br>Kibuye-Kanyakwar Q5000, | II | 5,275 | 5,275 | 5,275 | 5,275 | 5,275 | 5,275 |
| | E.L.Difference:+50 m L:3.8 km<br>Kibuye- Kogony Q4500, | I | 4,486 | 4,486 | 4,486 | 4,486 | 4,486 | 4,486 |
| | E.L.Difference:+50 m L:6.0 km<br>Kibuye-Kogony Q5500 | II | 5,460 | 5,460 | 5,460 | 5,460 | 5,460 | 5,460 |

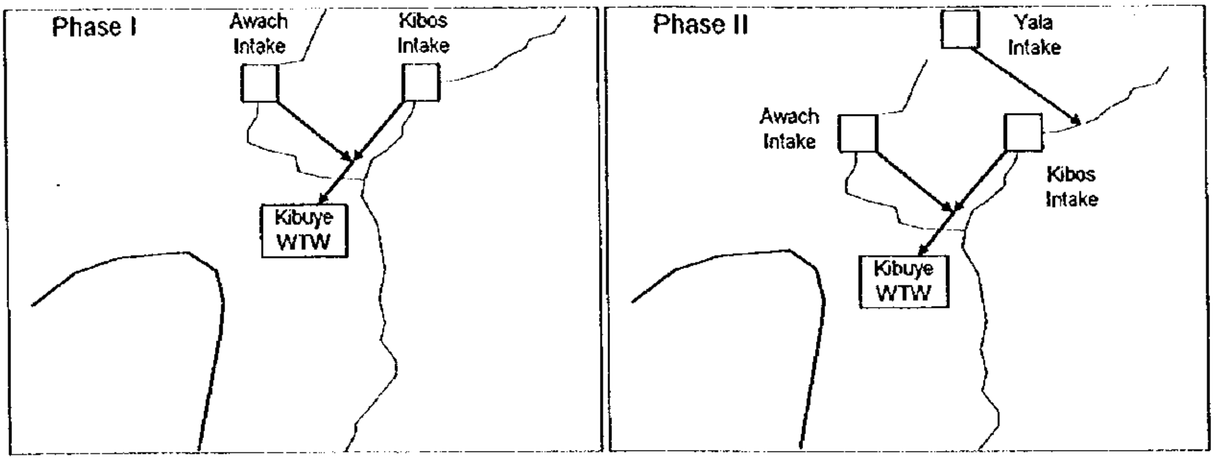
Note: REH. - Rehabilitation works component



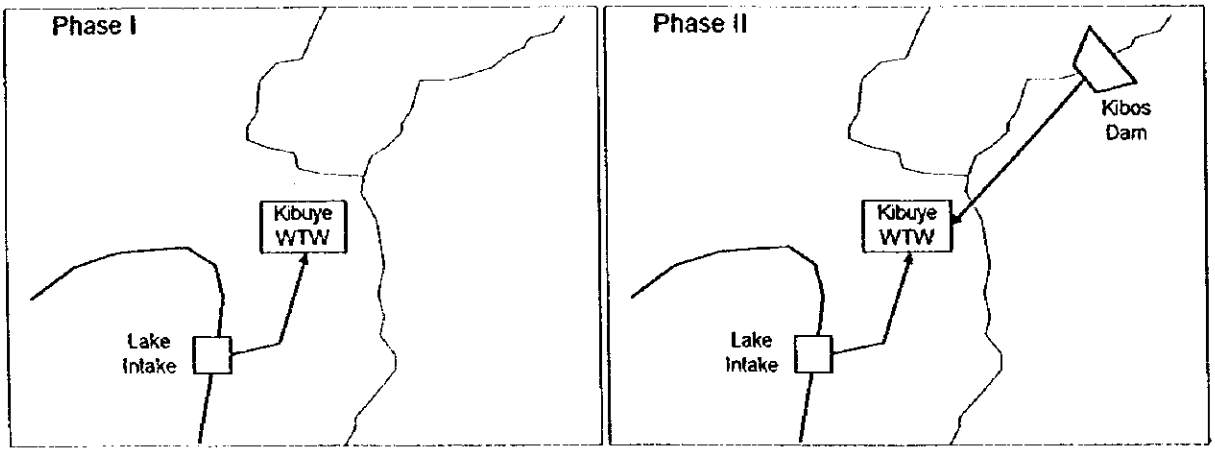

| THE REPUBLIC OF KENYA<br><br>THE MINISTRY OF LOCAL AUTHORITIES<br>KISUMU MUNICIPAL COUNCIL | THE STUDY<br>ON KISUMU WATER SUPPLY<br>AND SEWERAGE SYSTEM<br><br>JAPAN INTERNATIONAL COOPERATION AGENCY | TITLE :<br><br>Schematic of Alternatives<br>Cases 1, 2, and 3 |
|---|---|---|

**G10**

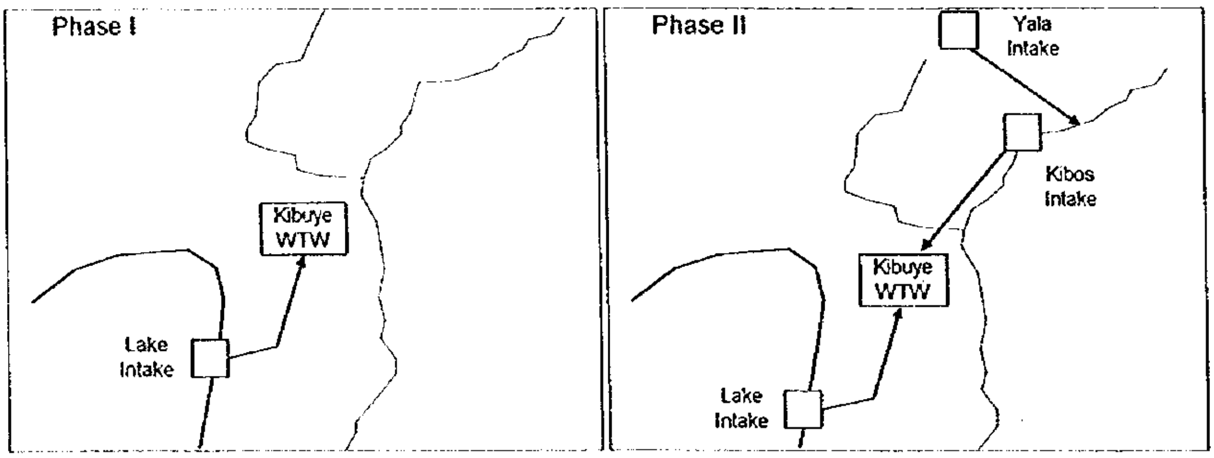
## Alternative Study : Case 4 - Kibos/Awach Weirs and Yala River




## Alternative Study : Case 5 - Lake Victoria and Kibos Dam

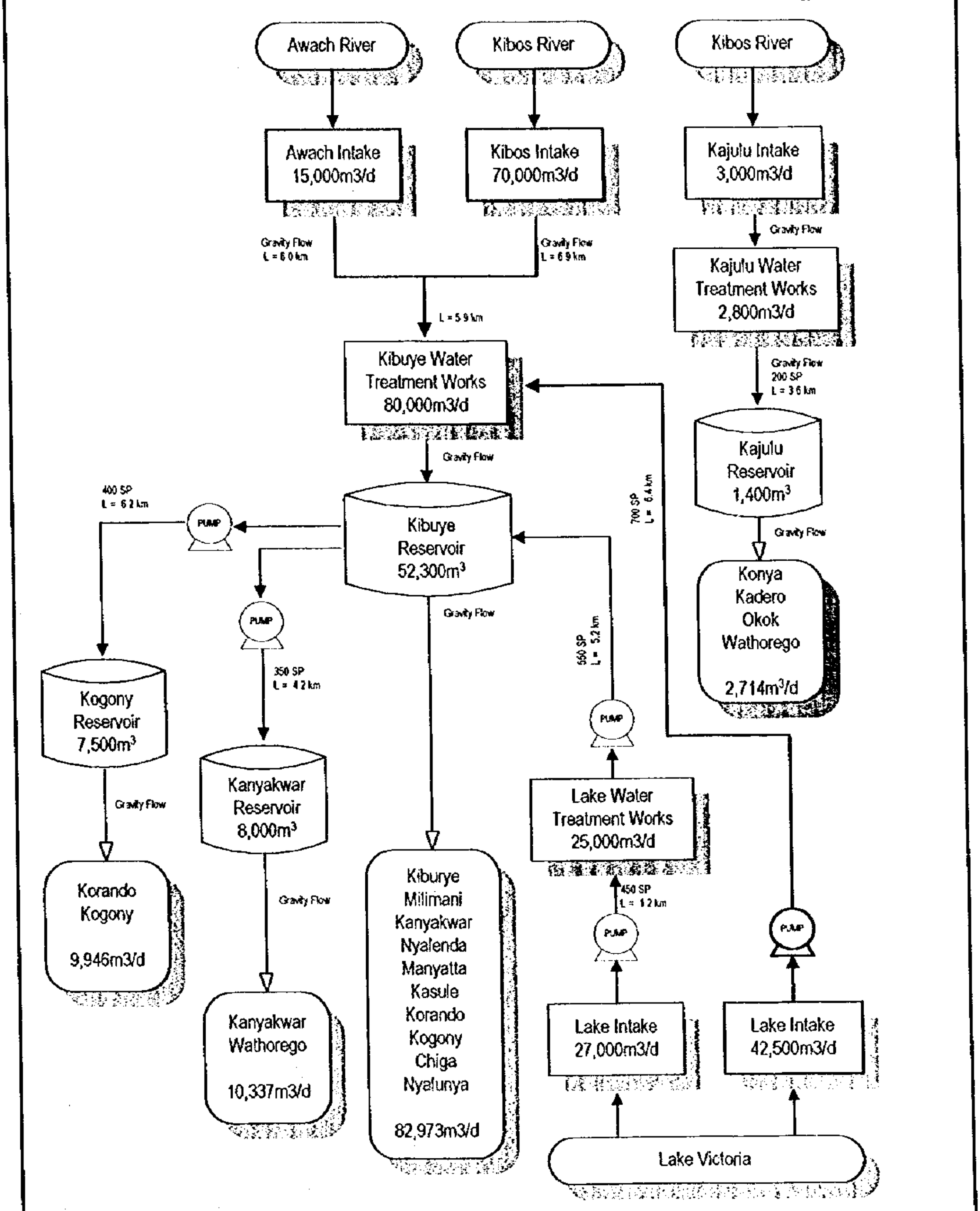



## Alternative Study : Case 6 - The Lake and Yala River



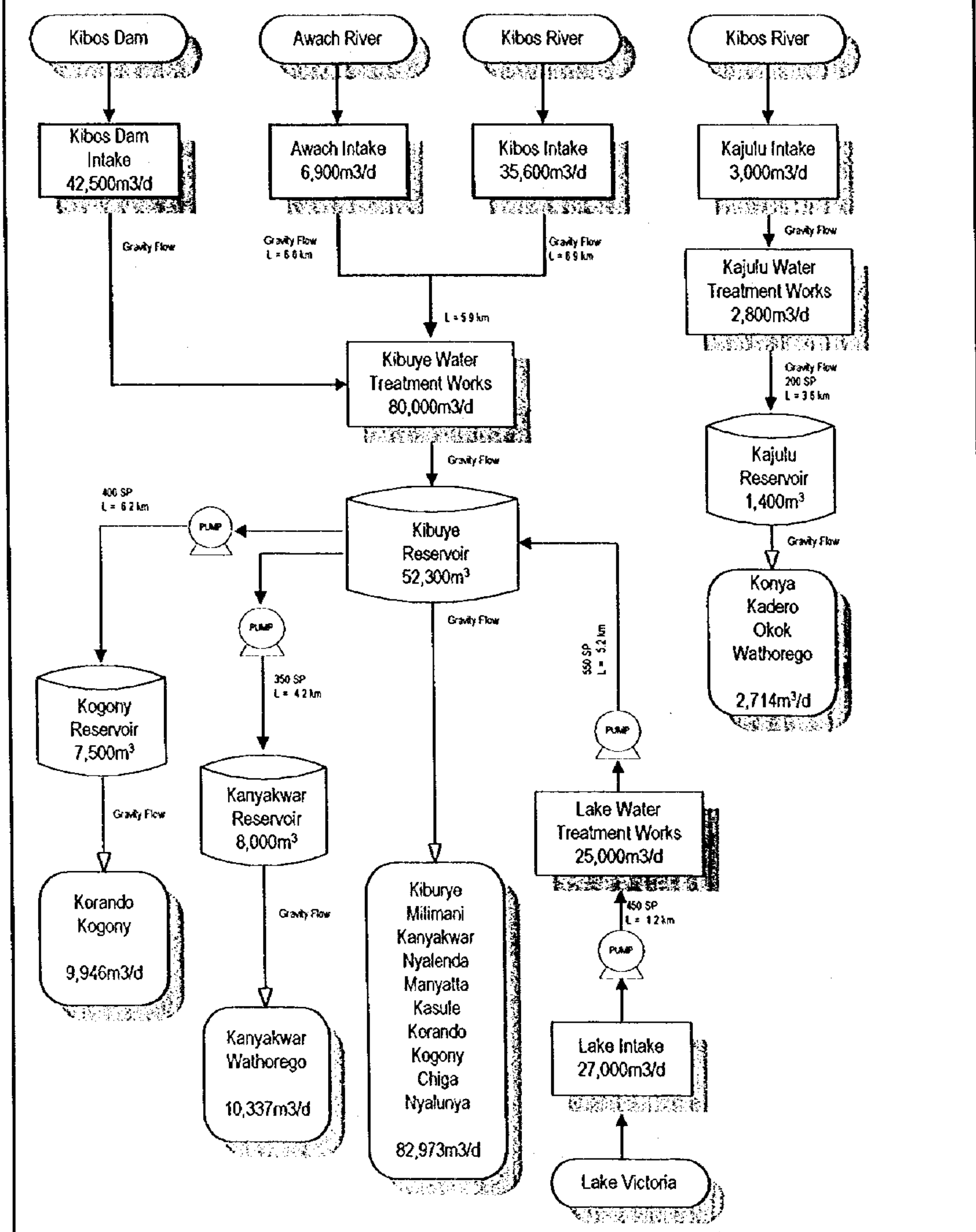

| | | |
|---|---|---|
| THE REPUBLIC OF KENYA<br><br>THE MINISTRY OF LOCAL AUTHORITIES<br>KISUMU MUNICIPAL COUNCIL | THE STUDY ON KISUMU WATER SUPPLY AND SEWERAGE SYSTEM<br><br>JAPAN INTERNATIONAL COOPERATION AGENCY | TITLE :<br><br>Schematic of Alternatives Cases 4, 5, and 6 |

G11



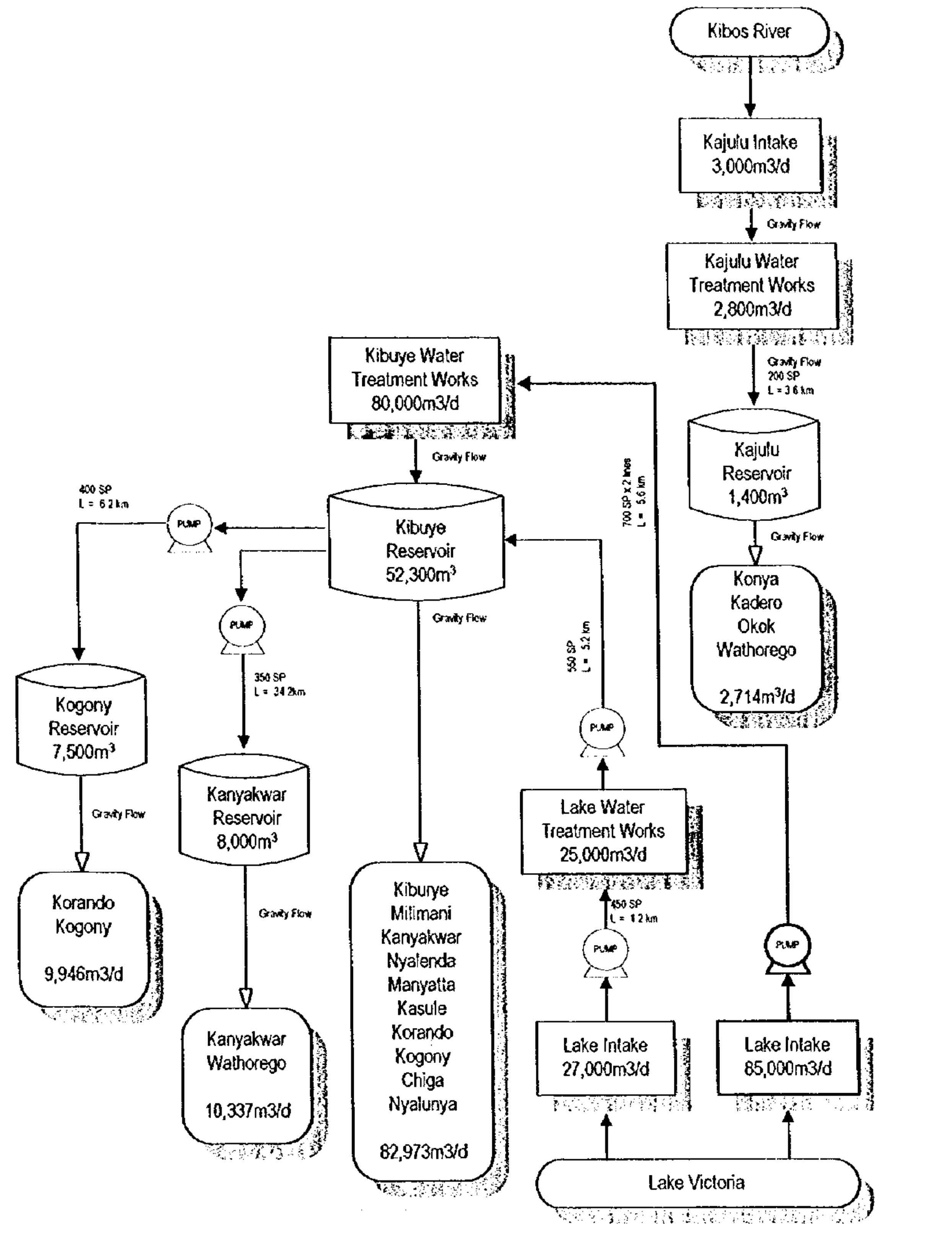

| THE REPUBLIC OF KENYA<br><br>THE MINISTRY OF LOCAL AUTHORITIES<br>KISUMU MUNICIPAL COUNCIL | THE STUDY ON KISUMU WATER SUPPLY AND SEWERAGE SYSTEM<br><br>JAPAN INTERNATIONAL COOPERATION AGENCY | TITLE :<br><br>Flow Chart for Water Supply Facilities Plan in 2015<br>Alternative Study - Case 1 |
|---|---|---|

G12



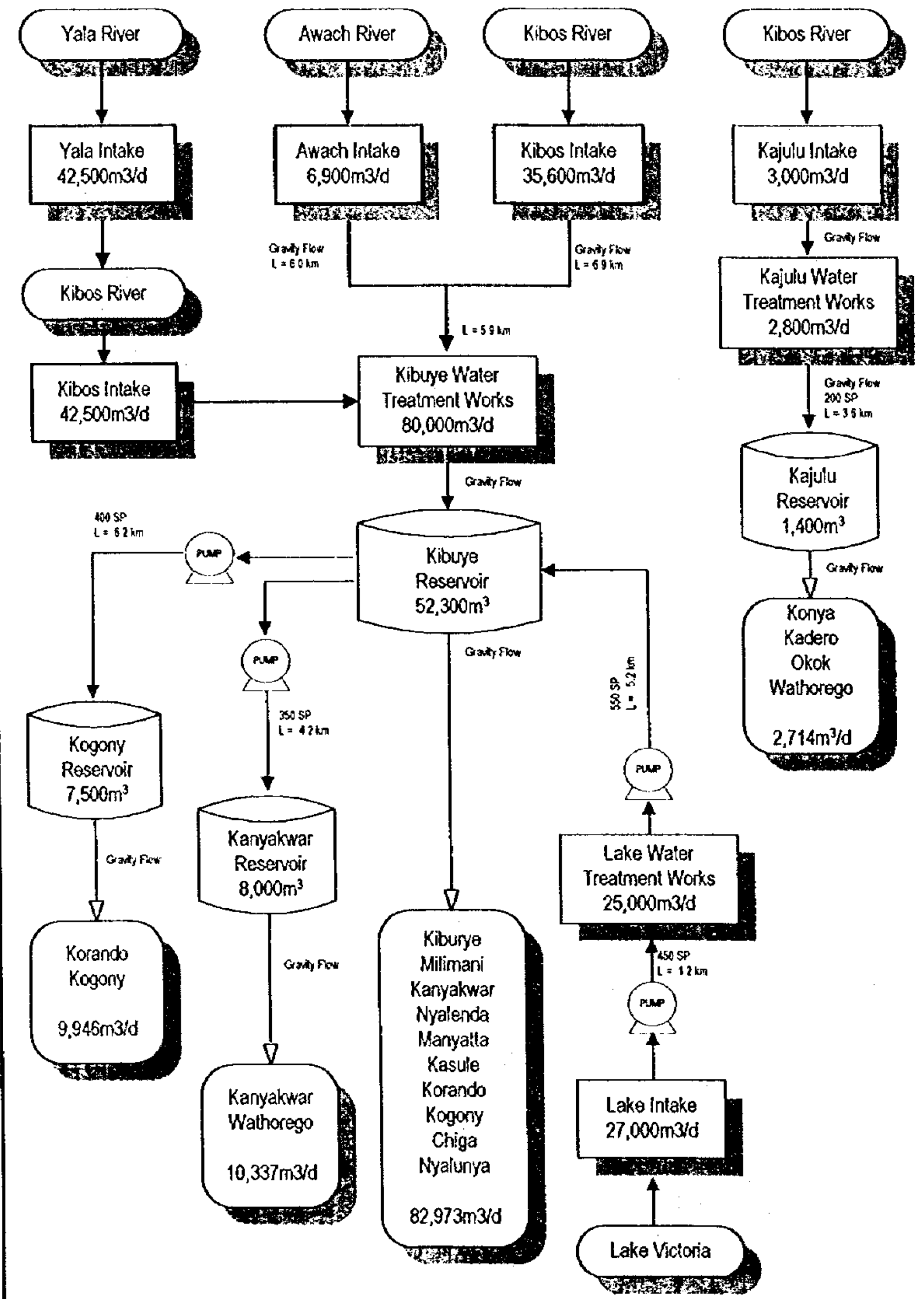

| THE REPUBLIC OF KENYA<br><br>THE MINISTRY OF LOCAL AUTHORITIES<br>KISUMU MUNICIPAL COUNCIL | THE STUDY<br>ON KISUMU WATER SUPPLY<br>AND SEWERAGE SYSTEM<br><br>JAPAN INTERNATIONAL COOPERATION AGENCY | TITLE :<br><br>Flow Chart for Water Supply Facilities Plan in 2015<br>Alternative Study - Case 2 |
|---|---|---|

G13



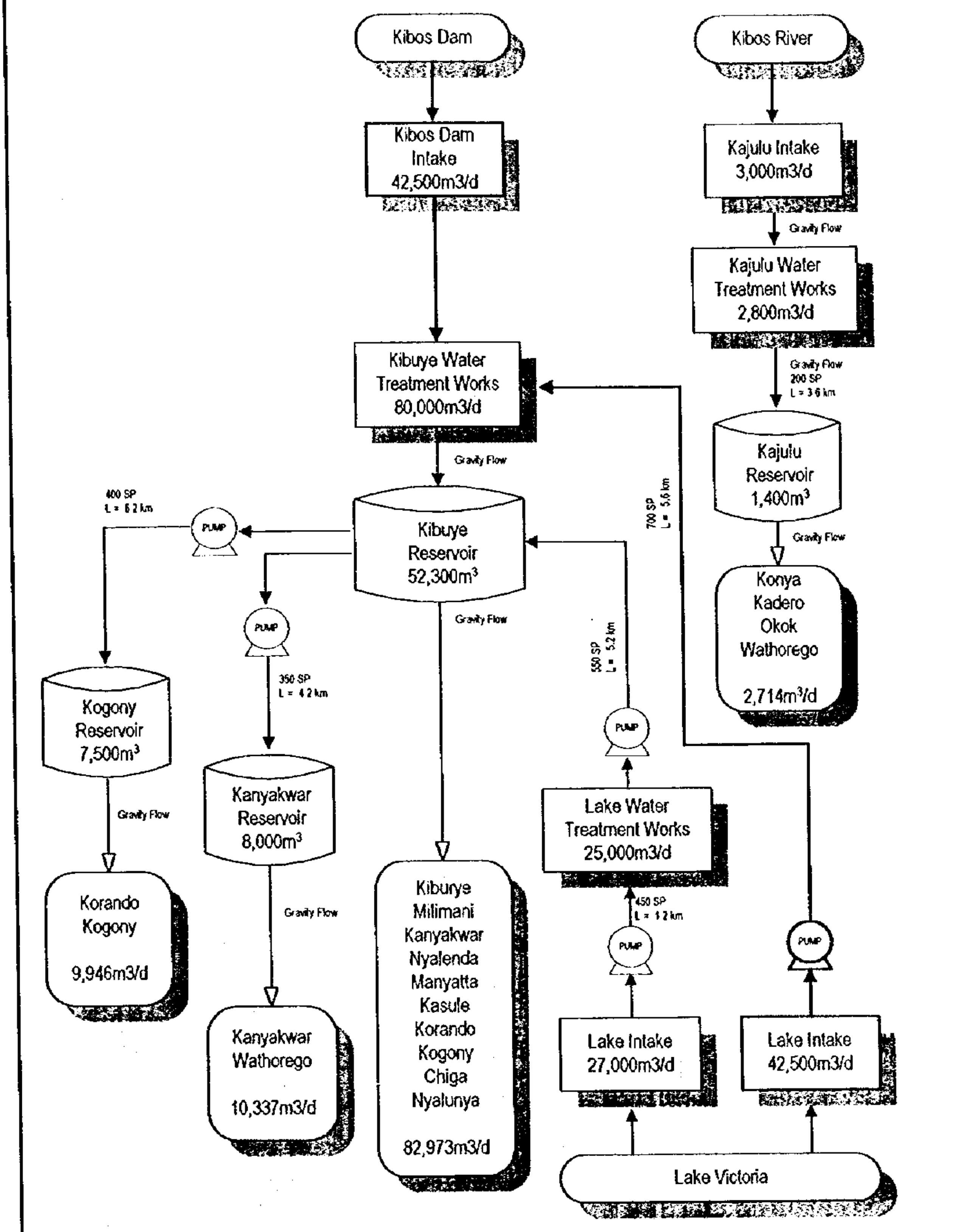

| | | |
|---|---|---|
| **THE REPUBLIC OF KENYA**<br><br>THE MINISTRY OF LOCAL AUTHORITIES<br>KISUMU MUNICIPAL COUNCIL | THE STUDY<br>ON KISUMU WATER SUPPLY<br>AND SEWERAGE SYSTEM<br><br>JAPAN INTERNATIONAL COOPERATION AGENCY | TITLE :<br><br>Flow Chart for Water Supply Facilities Plan in 2015<br>Alternative Study - Case 3 |

G14



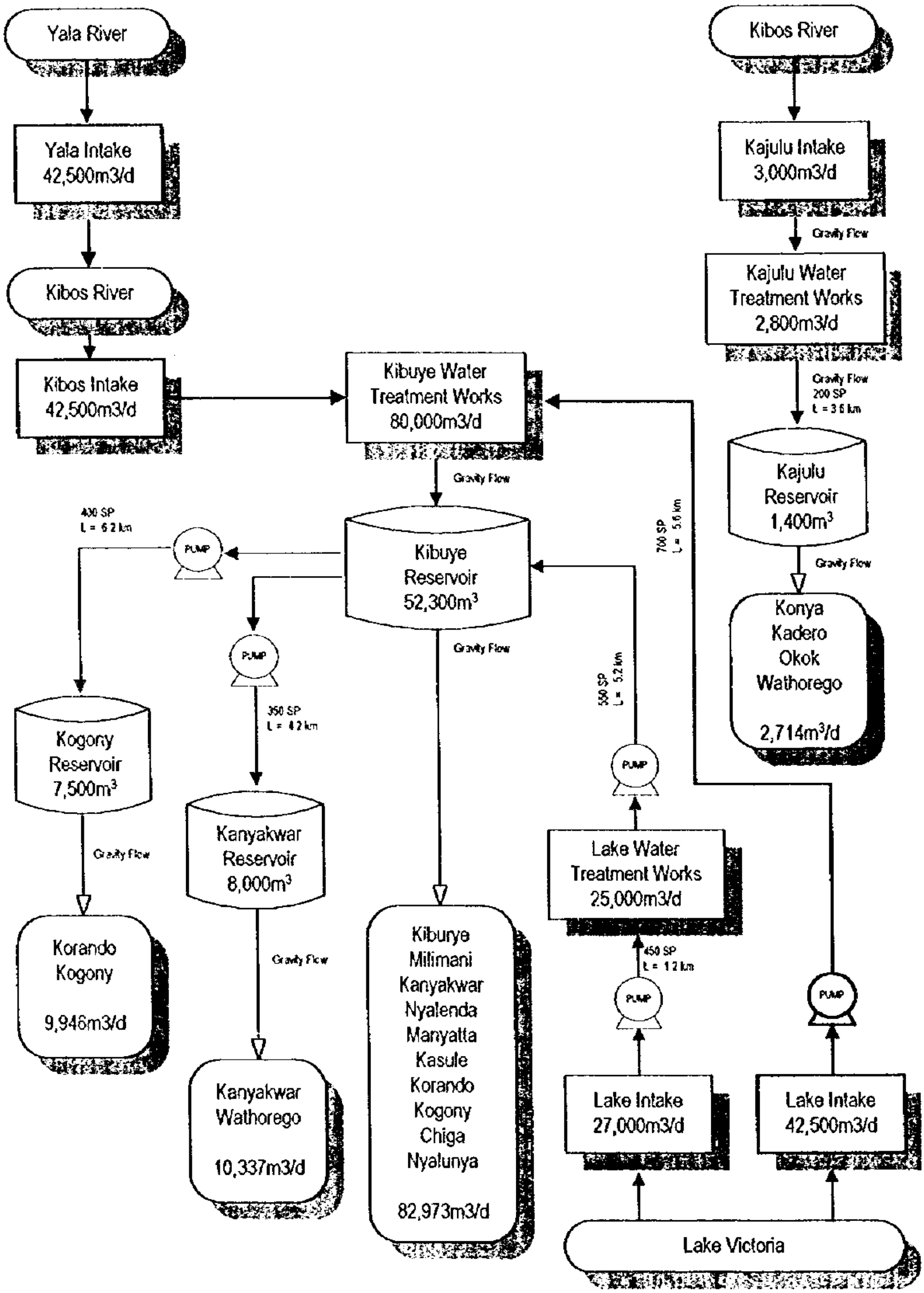

| | | |
|---|---|---|
| THE REPUBLIC OF KENYA<br><br>THE MINISTRY OF LOCAL AUTHORITIES<br>KISUMU MUNICIPAL COUNCIL | THE STUDY<br>ON KISUMU WATER SUPPLY<br>AND SEWERAGE SYSTEM<br><br>JAPAN INTERNATIONAL COOPERATION AGENCY | TITLE :<br><br>Flow Chart for Water Supply Facilities Plan in 2015<br>Alternative Study - Case 4 |

G15



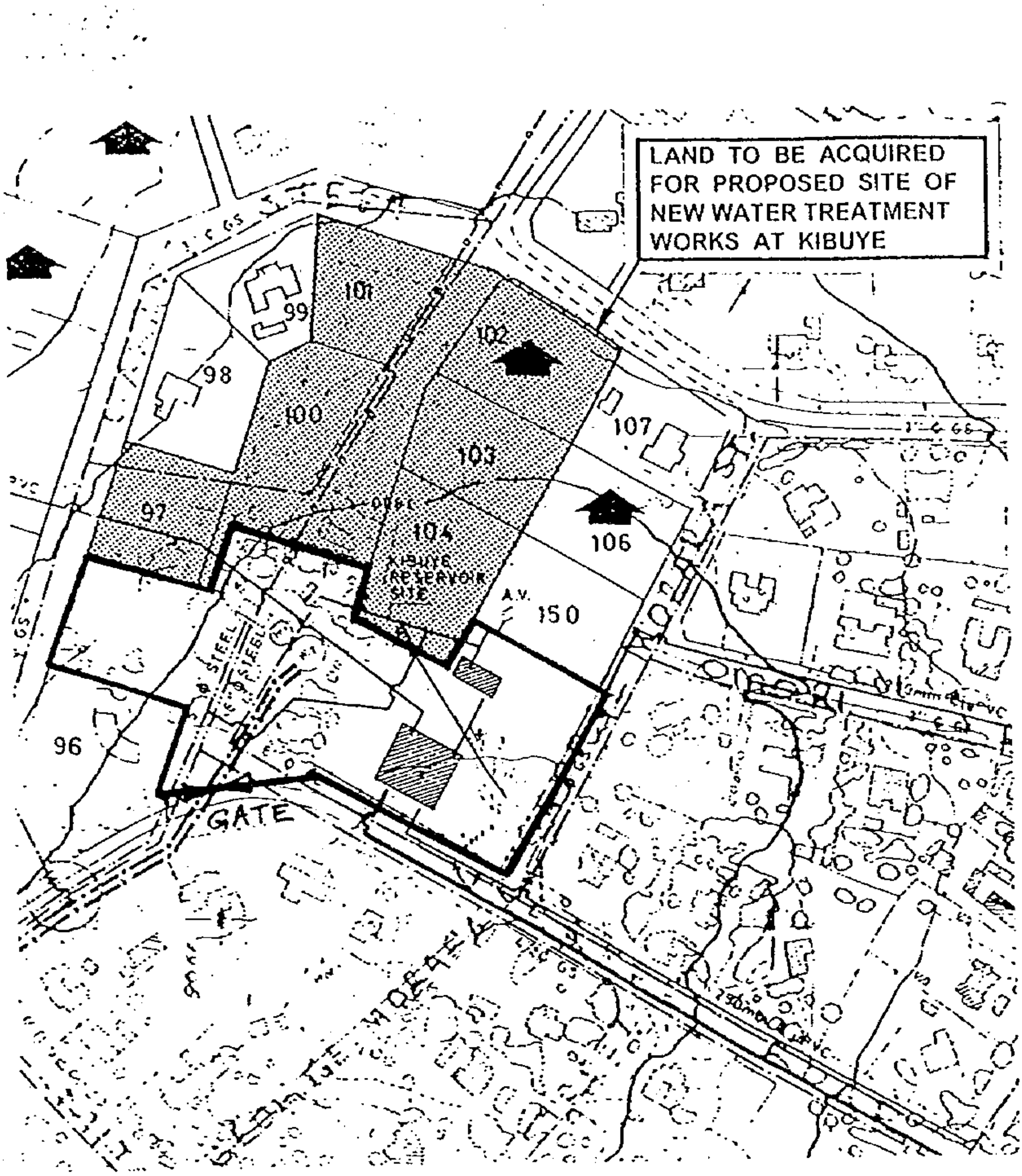

| | | |
|---|---|---|
| **THE REPUBLIC OF KENYA**<br><br>THE MINISTRY OF LOCAL AUTHORITIES<br>KISUMU MUNICIPAL COUNCIL | THE STUDY<br>ON KISUMU WATER SUPPLY<br>AND SEWERAGE SYSTEM<br><br>JAPAN INTERNATIONAL COOPERATION AGENCY | TITLE :<br><br>Flow Chart for Water Supply Facilities Plan in 2015<br>Alternative Study - Case 5 |

G16



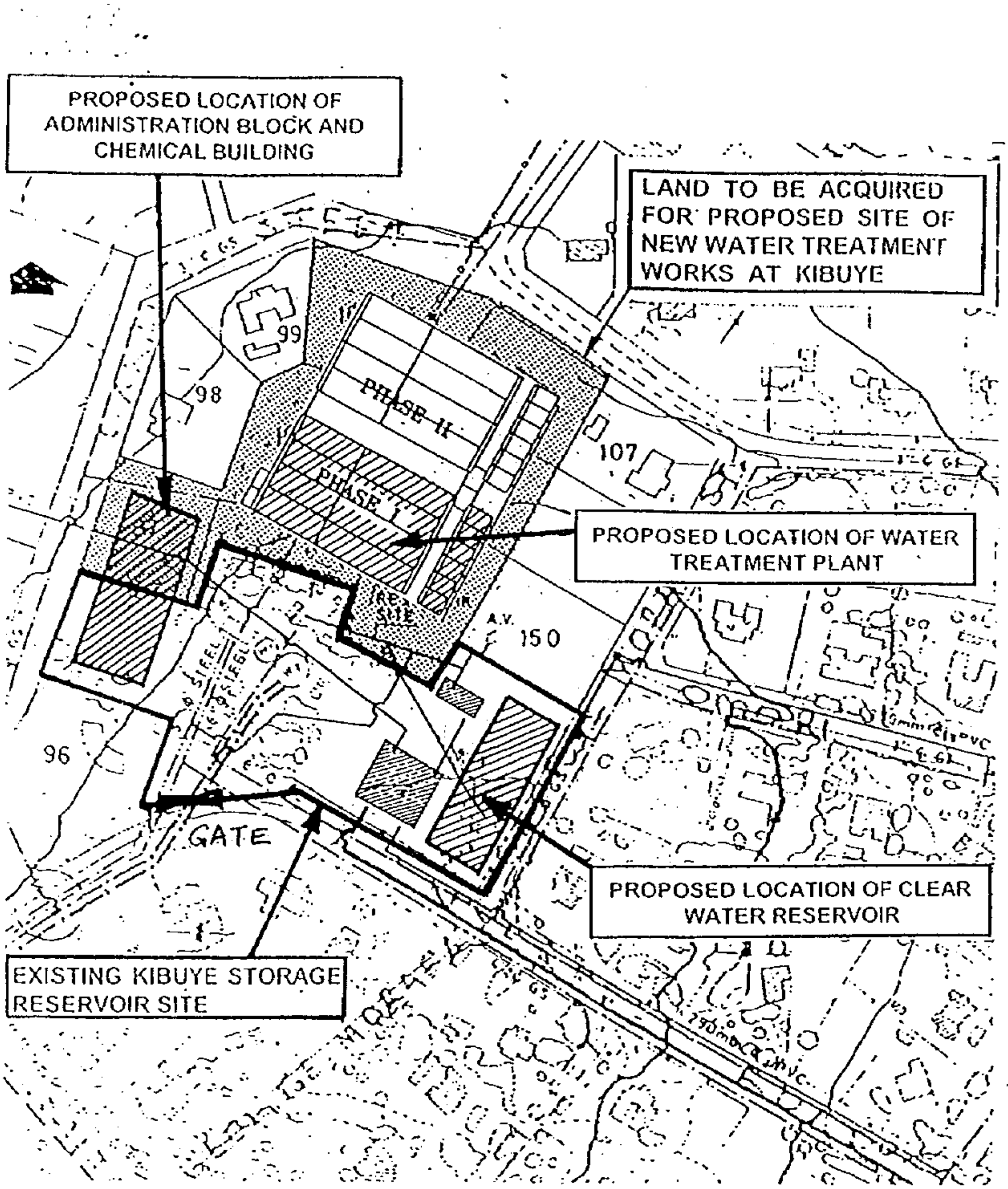

| | | |
|---|---|---|
| THE REPUBLIC OF KENYA<br><br>THE MINISTRY OF LOCAL AUTHORITIES<br>KISUMU MUNICIPAL COUNCIL | THE STUDY<br>ON KISUMU WATER SUPPLY<br>AND SEWERAGE SYSTEM<br><br>JAPAN INTERNATIONAL COOPERATION AGENCY | TITLE :<br><br>Flow Chart for Water Supply<br>Facilities Plan in 2015<br>Alternative Study - Case 6 |

G17



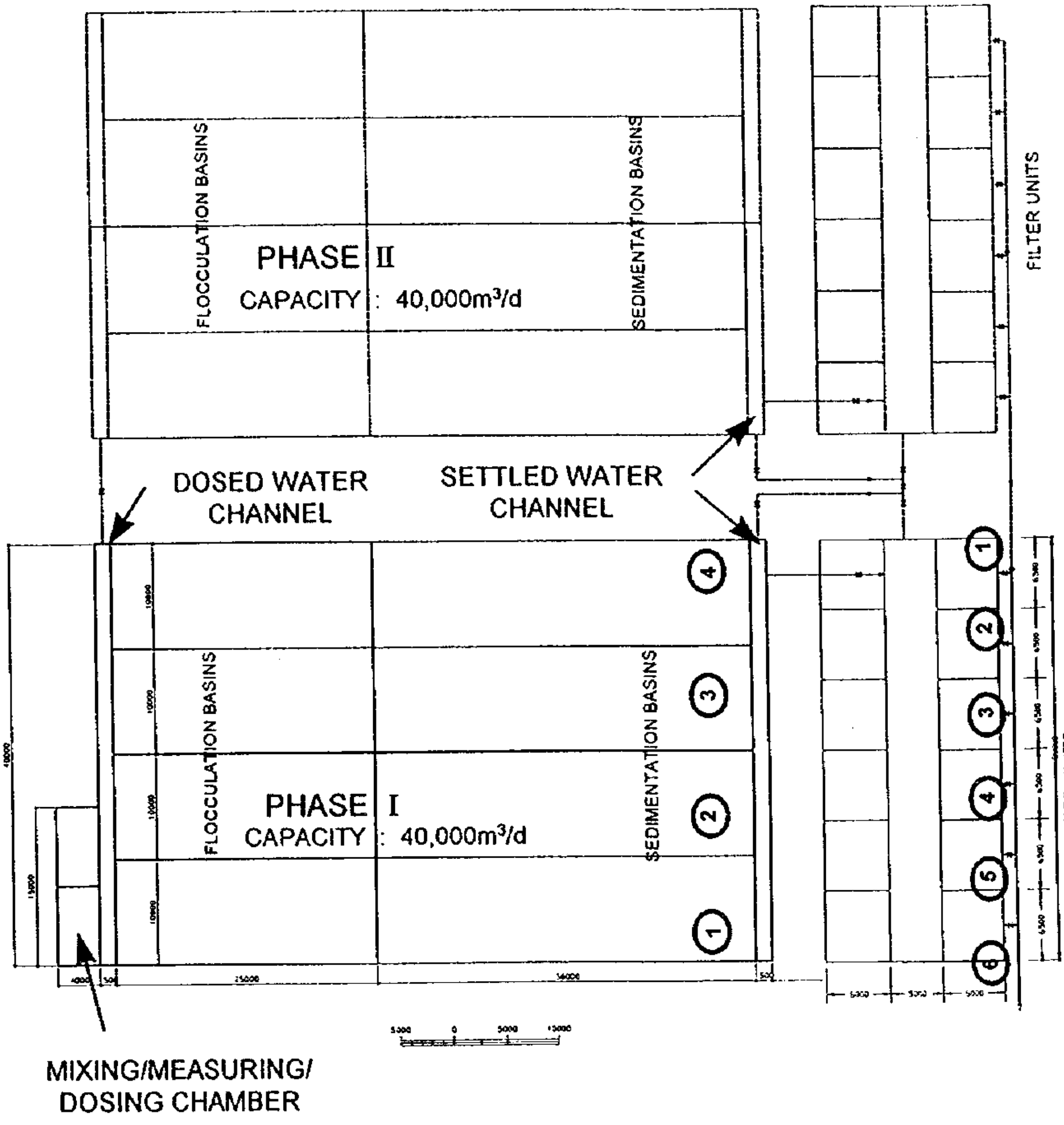

| | | |
|---|---|---|
| THE REPUBLIC OF KENYA<br>THE MINISTRY OF LOCAL AUTHORITIES<br>KISUMU MUNICIPAL COUNCIL | THE STUDY ON KISUMU WATER SUPPLY AND SEWERAGE SYSTEM<br>JAPAN INTERNATIONAL COOPERATION AGENCY | TITLE<br>Land to be Acquired for Proposed Kibuye Water Treatment Works |

G18



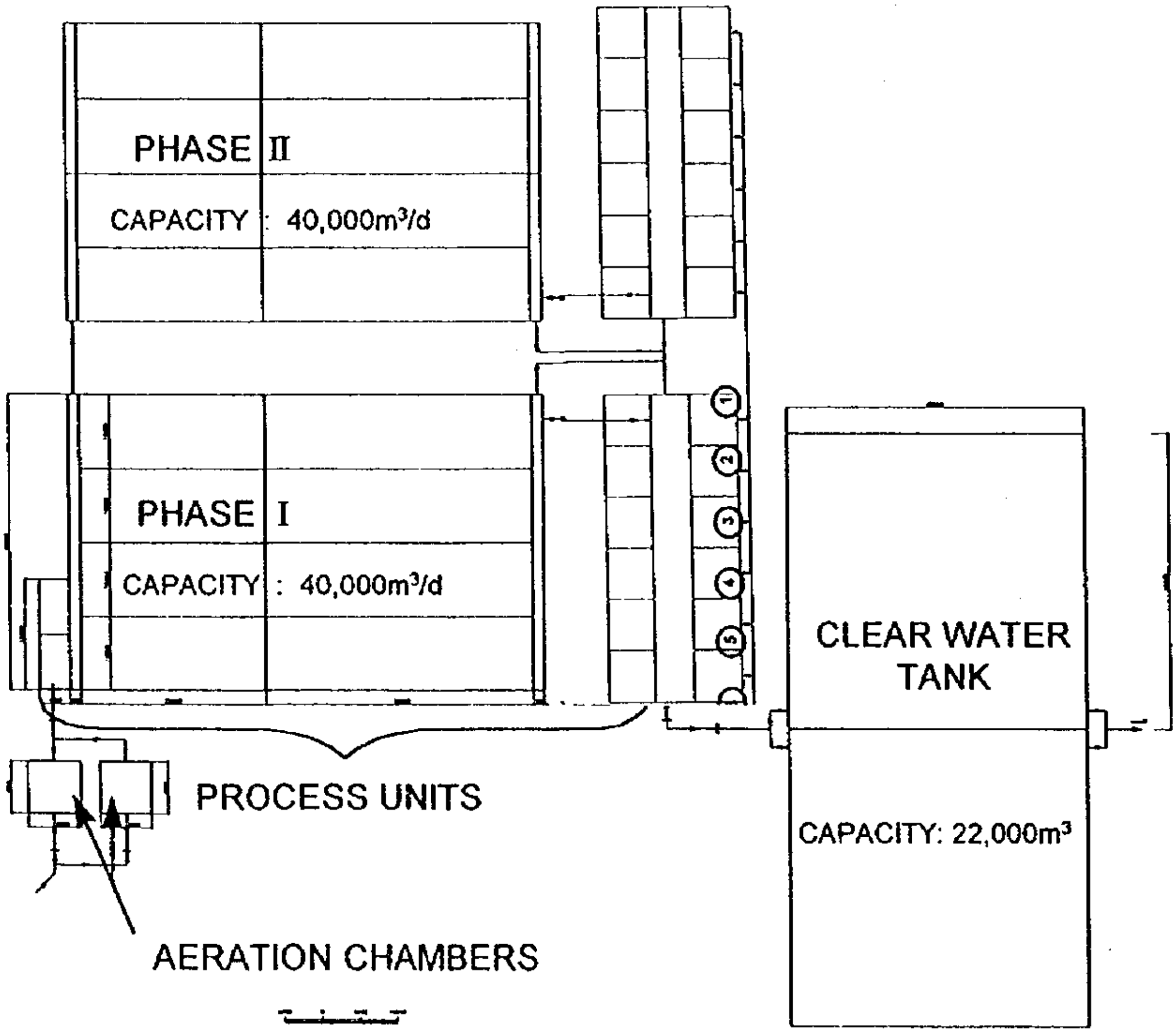

| THE REPUBLIC OF KENYA<br><br>THE MINISTRY OF LOCAL AUTHORITIES<br>KISUMU MUNICIPAL COUNCIL | THE STUDY<br>ON KISUMU WATER SUPPLY<br>AND SEWERAGE SYSTEM<br><br>JAPAN INTERNATIONAL COOPERATION AGENCY | TITLE<br><br>Layout of Proposed<br>Kibuye Water Treatment Works |
|---|---|---|

G19



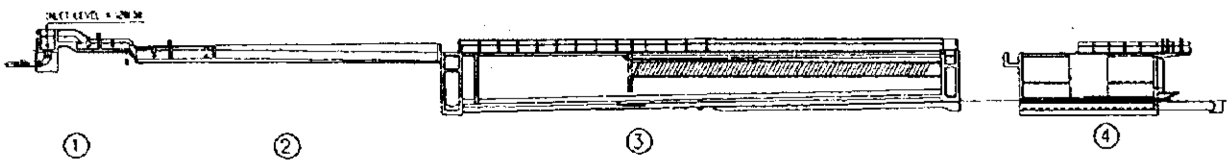

| | | |
|---|---|---|
| THE REPUBLIC OF KENYA<br><br>THE MINISTRY OF LOCAL AUTHORITIES<br>KISUMU MUNICIPAL COUNCIL | THE STUDY ON KISUMU WATER SUPPLY AND SEWERAGE SYSTEM<br>JAPAN INTERNATIONAL COOPERATION AGENCY | TITLE :<br>Outline of Treatment Units - Proposed Kibuye Water Treatment Works |

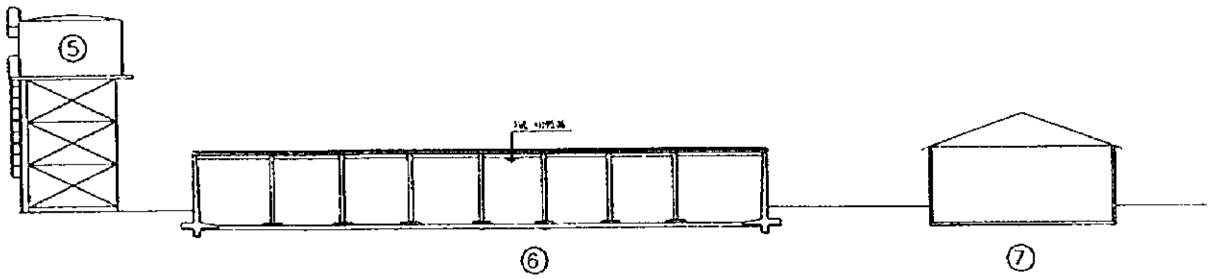
G20




| | | |
|---|---|---|
| THE REPUBLIC OF KENYA<br><br>THE MINISTRY OF LOCAL AUTHORITIES<br>KISUMU MUNICIPAL COUNCIL | THE STUDY ON KISUMU WATER SUPPLY AND SEWERAGE SYSTEM<br><br>JAPAN INTERNATIONAL COOPERATION AGENCY | TITLE :<br><br>Layout of Treatment Units - Proposed Kibuye Water Treatment Works |

G21



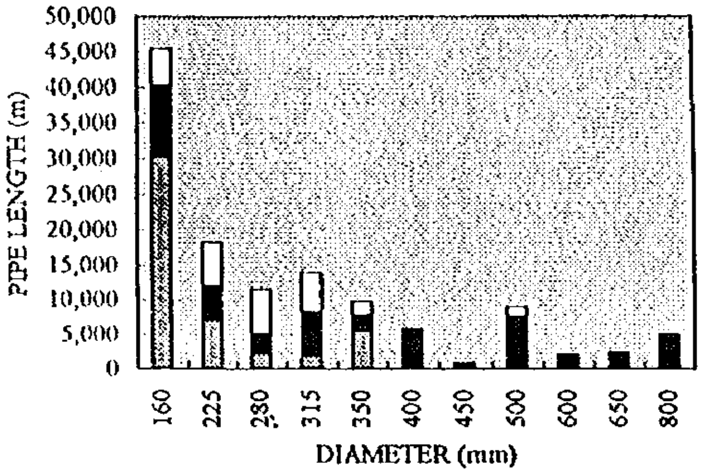




## KEY

1. MIXING/MEASURING CHAMBER
2. FLOCCULATION BASIN
3. SEDIMENTATION BASIN
4. RAPID GRAVITY SAND FILTER
5. ELEVATED BACKWASH/SITE WATER TANK
6. CLEAR WATER TANK
7. TREATED WATER PUMPHOUSE

| | | |
|---|---|---|
| THE REPUBLIC OF KENYA<br>THE MINISTRY OF LOCAL AUTHORITIES<br>KISUMU MUNICIPAL COUNCIL | THE STUDY ON KISUMU WATER SUPPLY AND SEWERAGE SYSTEM<br>JAPAN INTERNATIONAL COOPERATION AGENCY | TITLE :<br>Sectional Profile of Treatment Units-Proposed Kibuye Water Treatment Works |

G22 Breakdown of trunk mains




G23 List of trunk main required (1)

| Diameter (mm) | Material | Pipe Length Required (m) | | |
|---|---|---|---|---|
| | | Phase 1 | Phase 2 | Total |
| 160 | PVC | 9,875 | 5,375 | 15,250 |
| 225 | PVC | 5,000 | 6,250 | 11,250 |
| 280 | PVC | 2,750 | 6,500 | 9,250 |
| 315 | PVC | 6,250 | 5,750 | 12,000 |
| 350 | SP | 2,125 | 2,125 | 4,250 |
| 400 | SP | 5,750 | | 5,750 |
| 450 | SP | 750 | | 750 |
| 500 | SP | 7,500 | 1,500 | 9,000 |
| 600 | SP | 2,000 | | 2,000 |
| 650 | SP | 2,375 | | 2,375 |
| 800 | SP | 5,000 | | 5,000 |
| Total | | 49,375 | 27,500 | 76,875 |

G24 List of trunk main required (2)

| Diameter (mm) | Existing Pipe Length (m) | Pipe Length Required (m) | | | Total (m) |
|---|---|---|---|---|---|
| | | Phase 1 | Phase 2 | Total | |
| 160 | 30,250 | 9,875 | 5,375 | 15,250 | 45,500 |
| 225 | 7,038 | 5,000 | 6,250 | 11,250 | 18,288 |
| 280 | 2,280 | 2,750 | 6,500 | 9,250 | 11,530 |
| 315 | 1,910 | 6,250 | 5,750 | 12,000 | 13,910 |
| 350 | 5,520 | 2,125 | 2,125 | 4,250 | 9,770 |
| 400 | | 5,750 | | 5,750 | 5,750 |
| 450 | | 750 | | 750 | 750 |
| 500 | | 7,500 | 1,500 | 9,000 | 9,000 |
| 600 | | 2,000 | | 2,000 | 2,000 |
| 650 | | 2,375 | | 2,375 | 2,375 |
| 800 | | 5,000 | | 5,000 | 5,000 |
| Total | 46,998 | 49,375 | 27,500 | 76,875 | 123,873 |

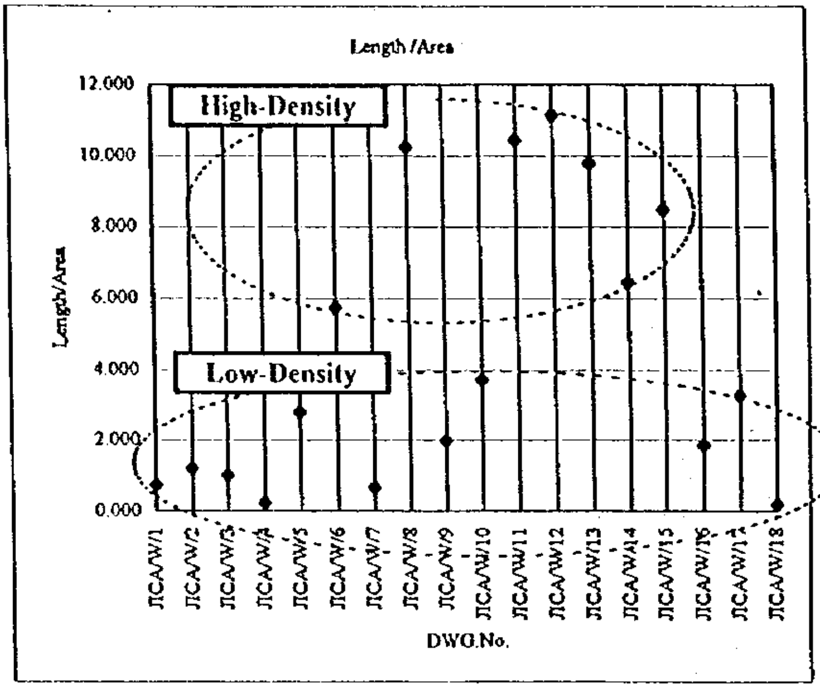
G25 Summary of trunk main required (1)

| | Distribution Block | Phase | Pipe Material | Diameter (mm) | Length (m) |
|---|---|---|---|---|---|
| 1 | Kogony | Phase 1 | SP | 400 | 2,250 |
| 2 | Kogony | Phase 1 | PVC | 225 | 3,500 |
| 3 | Kogony | Phase 1 | PVC | 160 | 2,500 |
| | *Sub-Total* | | | | *8,250* |
| 4 | Kogony | Phase 2 | PVC | 315 | 1,000 |
| 5 | Kogony | Phase 2 | PVC | 280 | 2,000 |
| 6 | Kogony | Phase 2 | PVC | 160 | 750 |
| | *Sub-Total* | | | | *3,750* |
| | ***Sub-Total of Kogony*** | | | | ***12,000*** |
| 7 | Kajulu | Phase 1 | SP | 450 | 750 |
| 8 | Kajulu | Phase 1 | SP | 400 | 1,750 |
| 9 | Kajulu | Phase 1 | SP | 350 | 1,250 |
| 10 | Kajulu | Phase 1 | PVC | 160 | 3,625 |
| | *Sub-Total* | | | | *7,375* |
| 11 | Kajulu | Phase 2 | PVC | 160 | 1,500 |
| | *Sub-Total* | | | | *1,500* |
| | ***Sub-Total of Kajulu*** | | | | ***8,875*** |
| 12 | Kanyakwar | Phase 1 | SP | 350 | 375 |
| 13 | Kanyakwar | Phase 1 | PVC | 315 | 500 |
| 14 | Kanyakwar | Phase 1 | PVC | 280 | 1,000 |
| 15 | Kanyakwar | Phase 1 | PVC | 225 | 1,500 |
| 16 | Kanyakwar | Phase 1 | PVC | 160 | 1,250 |
| | *Sub-Total* | | | | *4,625* |
| 17 | Kanyakwar | Phase 2 | SP | 350 | 1,125 |
| 18 | Kanyakwar | Phase 2 | PVC | 280 | 1,000 |
| 19 | Kanyakwar | Phase 2 | PVC | 225 | 3,250 |
| 20 | Kanyakwar | Phase 2 | PVC | 160 | 2,375 |
| | *Sub-Total* | | | | *7,750* |
| | ***Sub-Total of Kanyakwar*** | | | | ***12,375*** |
| 21 | Kibue | Phase 1 | SP | 800 | 5,000 |
| 22 | Kibue | Phase 1 | SP | 650 | 2,375 |
| 23 | Kibue | Phase 1 | SP | 600 | 2,000 |
| 24 | Kibue | Phase 1 | SP | 500 | 7,500 |
| 25 | Kibue | Phase 1 | SP | 400 | 1,750 |
| 26 | Kibue | Phase 1 | SP | 350 | 500 |
| 27 | Kibue | Phase 1 | PVC | 315 | 5,750 |
| 28 | Kibue | Phase 1 | PVC | 280 | 1,750 |
| 29 | Kibue | Phase 1 | PVC | 160 | 2,500 |
| | *Sub-Total* | | | | *29,125* |
| 30 | Kibue | Phase 2 | SP | 500 | 1,500 |
| 31 | Kibue | Phase 2 | SP | 350 | 1,000 |
| 32 | Kibue | Phase 2 | PVC | 315 | 4,750 |
| 33 | Kibue | Phase 2 | PVC | 280 | 3,500 |
| 34 | Kibue | Phase 2 | PVC | 225 | 3,000 |
| 35 | Kibue | Phase 2 | PVC | 160 | 750 |
| | *Sub-Total* | | | | *14,500* |
| | ***Sub-Total of Kibue*** | | | | ***43,625*** |
| | | | | | |
| | **Sub-Total of Phase 1** | | | | 49,375 |
| | **Sub-Total of Phase 2** | | | | 27,500 |
| | **Grand Total** | | | | 76,875 |

Trunk Main : Diameter 160 and larger

G26 Road density of each pipe network drawing

| DWG.No. | Road Length (km) | Map Area (k㎡) | Length /Area (km/k㎡) |
|---|---|---|---|
| JICA/W/1 | 2.025 | 2.700 | 0.750 |
| JICA/W/2 | 3.226 | 2.700 | 1.195 |
| JICA/W/3 | 2.738 | 2.700 | 1.014 |
| JICA/W/4 | 0.650 | 2.700 | 0.241 |
| JICA/W/5 | 7.525 | 2.700 | 2.787 |
| JICA/W/6 | 15.500 | 2.700 | 5.741 |
| JICA/W/7 | 1.725 | 2.600 | 0.663 |
| JICA/W/8 | 21.275 | 2.075 | 10.253 |
| JICA/W/9 | 5.350 | 2.700 | 1.981 |
| JICA/W/10 | 10.025 | 2.700 | 3.713 |
| JICA/W/11 | 18.400 | 1.762 | 10.443 |
| JICA/W/12 | 30.075 | 2.700 | 11.139 |
| JICA/W/13 | 20.925 | 2.137 | 9.792 |
| JICA/W/14 | 17.425 | 2.700 | 6.454 |
| JICA/W/15 | 18.700 | 2.200 | 8.500 |
| JICA/W/16 | 4.975 | 2.700 | 1.843 |
| JICA/W/17 | 8.175 | 2.512 | 3.254 |
| JICA/W/18 | 0.500 | 2.700 | 0.185 |
| Total/Average | 189.214 | 45.686 | 4.142 |



G27 Category of road density

| DWG.No. | Length (km) | Area (km²) | Length /Area (km/km²) | Category |
|---|---|---|---|---|
| JICA/W/1 | 2.025 | 2.700 | 0.750 | Low-Density |
| JICA/W/2 | 3.226 | 2.700 | 1.195 | Low-Density |
| JICA/W/3 | 2.738 | 2.700 | 1.014 | Low-Density |
| JICA/W/4 | 0.650 | 2.700 | 0.241 | Low-Density |
| JICA/W/5 | 7.525 | 2.700 | 2.787 | Low-Density |
| JICA/W/6 | 15.500 | 2.700 | 5.741 | High-Density |
| JICA/W/7 | 1.725 | 2.600 | 0.663 | Low-Density |
| JICA/W/8 | 21.275 | 2.075 | 10.253 | High-Density |
| JICA/W/9 | 5.350 | 2.700 | 1.981 | Low-Density |
| JICA/W/10 | 10.025 | 2.700 | 3.713 | Low-Density |
| JICA/W/11 | 18.400 | 1.762 | 10.443 | High-Density |
| JICA/W/12 | 30.075 | 2.700 | 11.139 | High-Density |
| JICA/W/13 | 20.925 | 2.137 | 9.792 | High-Density |
| JICA/W/14 | 17.425 | 2.700 | 6.454 | High-Density |
| JICA/W/15 | 18.700 | 2.200 | 8.500 | High-Density |
| JICA/W/16 | 4.975 | 2.700 | 1.843 | Low-Density |
| JICA/W/17 | 8.175 | 2.512 | 3.254 | Low-Density |
| JICA/W/18 | 0.500 | 2.700 | 0.185 | Low-Density |
| Total/Average | 189.214 | 45.686 | 4.142 | |

Table- Average Road Density in "High - Density" Area

| DWG.No. | Length (km) | Area (km²) | Length /Area (km/km²) |
|---|---|---|---|
| JICA/W/6 | 15.500 | 2.700 | 5.741 |
| JICA/W/8 | 21.275 | 2.075 | 10.253 |
| JICA/W/11 | 18.400 | 1.762 | 10.443 |
| JICA/W/12 | 30.075 | 2.700 | 11.139 |
| JICA/W/13 | 20.925 | 2.137 | 9.792 |
| JICA/W/14 | 17.425 | 2.700 | 6.454 |
| JICA/W/15 | 18.700 | 2.200 | 8.500 |
| Total/Average | 142.300 | 16.274 | 8.744 |

Table- Average Road Density in "Low - Density" Area

| DWG.No. | Length (km) | Area (km²) | Length /Area (km/km²) |
|---|---|---|---|
| JICA/W/1 | 2.025 | 2.700 | 0.750 |
| JICA/W/2 | 3.226 | 2.700 | 1.195 |
| JICA/W/3 | 2.738 | 2.700 | 1.014 |
| JICA/W/4 | 0.650 | 2.700 | 0.241 |
| JICA/W/5 | 7.525 | 2.700 | 2.787 |
| JICA/W/7 | 1.725 | 2.600 | 0.663 |
| JICA/W/9 | 5.350 | 2.700 | 1.981 |
| JICA/W/10 | 10.025 | 2.700 | 3.713 |
| JICA/W/16 | 4.975 | 2.700 | 1.843 |
| JICA/W/17 | 8.175 | 2.512 | 3.254 |
| JICA/W/18 | 0.500 | 2.700 | 0.185 |
| Total/Average | 46.914 | 29.412 | 1.595 |

G28 Summary of road density

| | | residencial | commercial | industrial | Total |
|---|---|---|---|---|---|
| Urban | Area | 16.6 | 3.4 | 4.1 | 24.1 |
| | Road Density | 8.744 | 8.744 | 8.744 | — |
| | Road Length | 145.2 | 29.7 | 35.9 | 210.8 |
| Peri-urban | Area | 54.2 | 1.2 | 5.0 | 60.4 |
| | Road Density | 8.744 | 1.595 | 1.595 | |
| | Road Length | 473.9 | 1.9 | 8.0 | 483.8 |
| Total | Area | 70.8 | 4.6 | 9.1 | 84.5 |
| | Road Density | — | — | — | — |
| | Road Length | 619.1 | 31.6 | 43.9 | 694.6 |

G29 Calculation of service mains

**BREAKDOWN ON EXISTING SERVICE MAINS**

| Diameter (mm) | Length (m) | Ratio (%) |
|---|---|---|
| 100 | 12,890 | 20% |
| 80 | 50,089 | 80% |
| Total | 62,979 | 100% |

**FUTURE RATIO OF SERVICE MAINS**

| Diameter (mm) | Ratio (%) |
|---|---|
| 110 (100) | 20 |
| 90 (80) | 30 |
| 63 | 50 |

**TOTAL LENGTH OF ROAD IN YEAR 2015**

694.6 km

**RATIO OF ROAD WHICH HAS SERVICE MAIN**

90%

**TOTAL LENGTH OF SERVICE MAIN IN YEAR 2015**

625 km

**CAPACITY OF WATER SUPPLY SYSTEM**

| | |
|---|---|
| Phase 1 | 67,800 m3/day (Day-Max.) |
| Phase 2 | 40,000 m3/day (Day-Max.) |
| Total | 107,800 m3/day (Day-Max.) |

**LENGTH REQUIRED IN EACH PHASE**

| | |
|---|---|
| Phase 1 | 393 km |
| Phase 2 | 232 km |
| Total | 625 km |

G30 Service main required

## SERVICE MAIN REQUIRED UNDER PHASE 1

**Total Length Required** 393000

| Diameter (mm) | Ratio % | Length (m) | Existing Length (m) | Total Length Required (m) |
|---|---|---|---|---|
| 110 | 20 | 78,600 | 12,890 | 65,710 |
| 90 | 30 | 117,900 | 50,089 | 67,811 |
| 63 | 50 | 196,500 | 0 | 196,500 |
| Total | 100 | 393,000 | 62,979 | 330,021 |

## SERVICE MAIN REQUIRED UNDER PHASE 2

**Total Length Required** 232000

| Diameter (mm) | Ratio % | Length (m) |
|---|---|---|
| 110 | 20 | 46,400 |
| 90 | 30 | 69,600 |
| 63 | 50 | 116,000 |
| Total | 100 | 232,000 |

## CONSTRUCTION COST OF SERVICE MAINS

| Diameter | Unit Cost | Material | Phase 1 | | Phase 2 | | Total | |
|---|---|---|---|---|---|---|---|---|
| (mm) | (US$/m) | | Length (m) | Cost (US$) | Length (m) | Cost (US$) | Length (m) | Cost (US$) |
| 110 | 20 | PVC | 65,710 | 1,314,200 | 46,400 | 928,000 | 112,110 | 2,242,200 |
| 90 | 17 | PVC | 67,811 | 1,152,787 | 69,600 | 1,183,200 | 137,411 | 2,335,987 |
| 63 | 13 | PVC | 196,500 | 2,554,500 | 116,000 | 1,508,000 | 312,500 | 4,062,500 |
| Total | | | 330,021 | 5,021,487 | 232,000 | 3,619,200 | 562,021 | 8,640,687 |

## G31 Outline of Proposed Plan for Piped Water Supply System

| ITEM | | | 1997 | PHASE I | PHASE II |
|---|---|---|---|---|---|
| Target Year | | | - | 2005 | 2015 |
| Total Population in the Study Area | | | 363,157 | 526,195 | 869,166 |
| Population Served | House Connection | Persons | 13,018 | 272,346 | 531,784 |
| | Communal Tap | Persons | 211,438 | 142,184 | 158,844 |
| | Total | Persons | 224,456 | 414,530 | 690,628 |
| Service Ratio | | % | 61.8 | 78.8 | 79.5 |
| Service Area | | km² | 88.0 | 88.0 | 88.0 |
| Water Demand | Day Average | m³/d | 11,900* | 59,174 | 96,336 |
| | Day Maximum | m³/d | N/A | 65,091 | 105,970 |
| Water Source | Kibos (for Kajulu WTW) | m³/d | 1,500 | 3,000 | 3,000 |
| | Lake Victoria | m³/d | 19,000 | 27,000 | 69,500 |
| | Kibos (for Kibuye WTW) | m³/d | - | 35,600 | 35,600 |
| | Awach | m³/d | - | 6,900 | 6,900 |
| | Total | m³/d | 20,500 | 72,500 | 115,000 |
| Water Treatment Works | Kajulu | m³/d | 1,400 | 2,800 | 2,800 |
| | Lake | m³/d | 16,600 | 25,000 | 25,000 |
| | Kibuye | m³/d | - | 40,000 | 80,000 |
| | Total | m³/d | 18,000 | 67,800 | 107,800 |
| Service Reservoirs | Kibuye | m³ | 6,300 | 33,300 | 52,300 |
| | Kanyakwar | m³ | - | 5,000 | 8,000 |
| | Kogony | m³ | - | 3,500 | 7,500 |
| | Kajulu | m³ | - | 700 | 1,400 |
| | Total | m³ | 6,300 | 42,500 | 69,200 |
| Raw Water Trans. Mains | ø 200 mm - ø 900 mm | km | 0.6 | 20.6 | 27.0 |
| Treated Water Trans. Mains | ø 150 mm - ø 550 mm | km | 16.0 | 35.2 | 35.2 |
| Water Distribution Mains | ø 150 mm - ø 800 mm | km | 63.0 | 112.4 | 139.9 |
| Service Mains | ø 80 mm - ø 100 mm | km | 49.0 | 379 | 611 |

* Water consumption (Not water demand)

N/A : Not Applicable

# G31 Outline of Proposed Plan for Piped Water Supply System

| ITEM | | | 1997 | PHASE I | PHASE II |
|---|---|---|---|---|---|
| Target Year | | | - | 2005 | 2015 |
| Total Population in the Study Area | | | 363,157 | 526,195 | 869,166 |
| Population Served | House Connection | Persons | 13,018 | 272,346 | 531,784 |
| | Communal Tap | Persons | 211,438 | 142,184 | 158,844 |
| | Total | Persons | 224,456 | 414,530 | 690,628 |
| Service Ratio | | % | 61.8 | 78.8 | 79.5 |
| Service Area | | km² | 88.0 | 88.0 | 88.0 |
| Water Demand | Day Average | m³/d | 11,900* | 59,174 | 96,336 |
| | Day Maximum | m³/d | N/A | 65,091 | 105,970 |
| Water Source | Kibos (for Kajulu WTW) | m³/d | 1,500 | 3,000 | 3,000 |
| | Lake Victoria | m³/d | 19,000 | 27,000 | 69,500 |
| | Kibos (for Kibuye WTW) | m³/d | - | 35,600 | 35,600 |
| | Awach | m³/d | - | 6,900 | 6,900 |
| | Total | m³/d | 20,500 | 72,500 | 115,000 |
| Water Treatment Works | Kajulu | m³/d | 1,400 | 2,800 | 2,800 |
| | Lake | m³/d | 16,600 | 25,000 | 25,000 |
| | Kibuye | m³/d | - | 40,000 | 80,000 |
| | Total | m³/d | 18,000 | 67,800 | 107,800 |
| Service Reservoirs | Kibuye | m³ | 6,300 | 33,300 | 52,300 |
| | Kanyakwar | m³ | - | 5,000 | 8,000 |
| | Kogony | m³ | - | 3,500 | 7,500 |
| | Kajulu | m³ | - | 700 | 1,400 |
| | Total | m³ | 6,300 | 42,500 | 69,200 |
| Raw Water Trans. Mains | ø 200 mm - ø 900 mm | km | 0.6 | 20.6 | 27.0 |
| Treated Water Trans. Mains | ø 150 mm - ø 550 mm | km | 16.0 | 35.2 | 35.2 |
| Water Distribution Mains | ø 150 mm - ø 800 mm | km | 63.0 | 112.4 | 139.9 |
| Service Mains | ø 80 mm - ø 100 mm | km | 49.0 | 379 | 611 |

* Water consumption (Not water demand)

N/A Not Applicable

## G32 Major Works Planned for Phase I

Major works included in Phase I and Phase II are described as follows

**a. Phase I**

- Rehabilitation of the existing Kibos river intake for the Kajulu WTW which includes an expansion of the intake capacity from the existing 1,500 $m^3$/d to 3,000 $m^3$/d.
- Rehabilitation of the existing Kajulu water treatment works which includes an expansion of the treatment capacity from the existing 1,400 $m^3$/d to 2,800 $m^3$/d.
- Rehabilitation of the existing Lake intake works for the Lake WTW which includes an expansion of the intake capacity from the existing 19,000 $m^3$/d to 27,000 $m^3$/d.
- Rehabilitation of the existing Lake water treatment works which includes an expansion of the treatment capacity from the existing 16,600 $m^3$/d to 25,000 $m^3$/d.
- Construction of a new water intake on the Awach river with an intake capacity of 15,000 $m^3$/d.
- Construction of a new water intake on the Kibos river with an intake capacity of 70,000 $m^3$/d.
- Construction of a new water treatment works at Kibuye (Kibuye WTW) with a treatment capacity of 40,000 $m^3$/d.
- Construction of new raw water transmission mains, 400 to 900 mm in diameter steel pipe and 18.8 km in total length from the new water intakes on the Awach and Kibos rivers to the Kibuye WTW.
- Construction of a new raw water transmission main 450 mm in diameter steel pipe and approximately 1.2 km in length from the Lake intake works to the Lake WTW.
- Construction of a 27,000 $m^3$ distribution reservoir at Kibuye which will increase the total reservoir capacity at this location from the existing 6,300 $m^3$/d to 33,300 $m^3$/d.
- Construction of a 700 $m^3$ distribution reservoir at Kajulu.
- Construction of a 5,000 $m^3$ distribution reservoir at Kanyakwar.
- Construction of a 3,500 $m^3$ distribution reservoir at Kogony.
- Construction of a treated water transmission main 200 mm in diameter steel pipe and approximately 3.6 km in length from the Kajulu WTW to the Kajulu Distribution Reservoir.
- Construction of a treated water transmission main 550 mm in diameter and steel pipe approximately 5.2 km in length from the Lake WTW to the Kibuye Distribution Reservoir.
- Construction of a treated water transmission main 400 mm in diameter steel pipe and approximately 6.2 km in total length from the Kibuye distribution reservoir to Kogony Distribution Reservoir.
- Construction of a treated water transmission main 350 mm in diameter steel pipe and approximately 4.2 km in total length from the Kibuye distribution reservoir to Kanyakwar

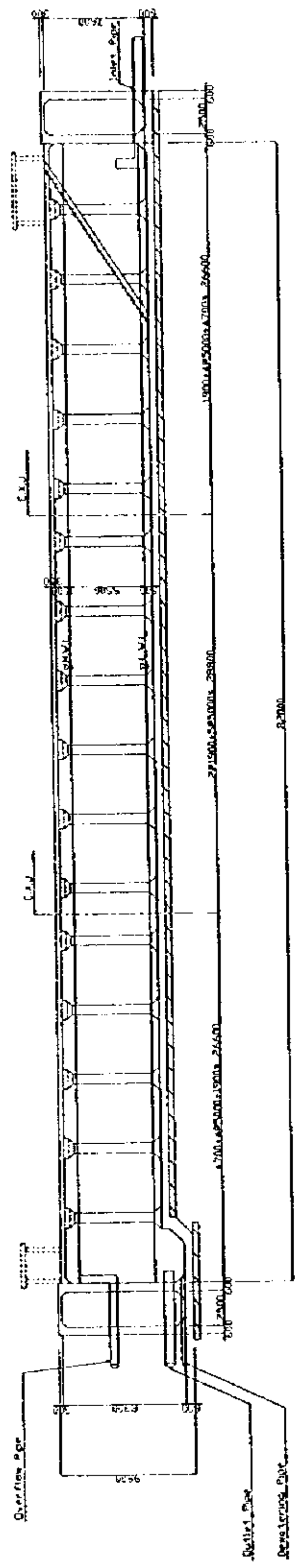
Distribution Reservoir.

- Construction of water distribution mains, PVC pipes of 160 to 315 mm and steel pipes of 350 to 800 mm in diameter and approximately 49.4 km in total length.
- Construction of service mains PVC pipes of 63 to 100 mm in diameter and approximately 330 km in total length.

b. **Phase II**

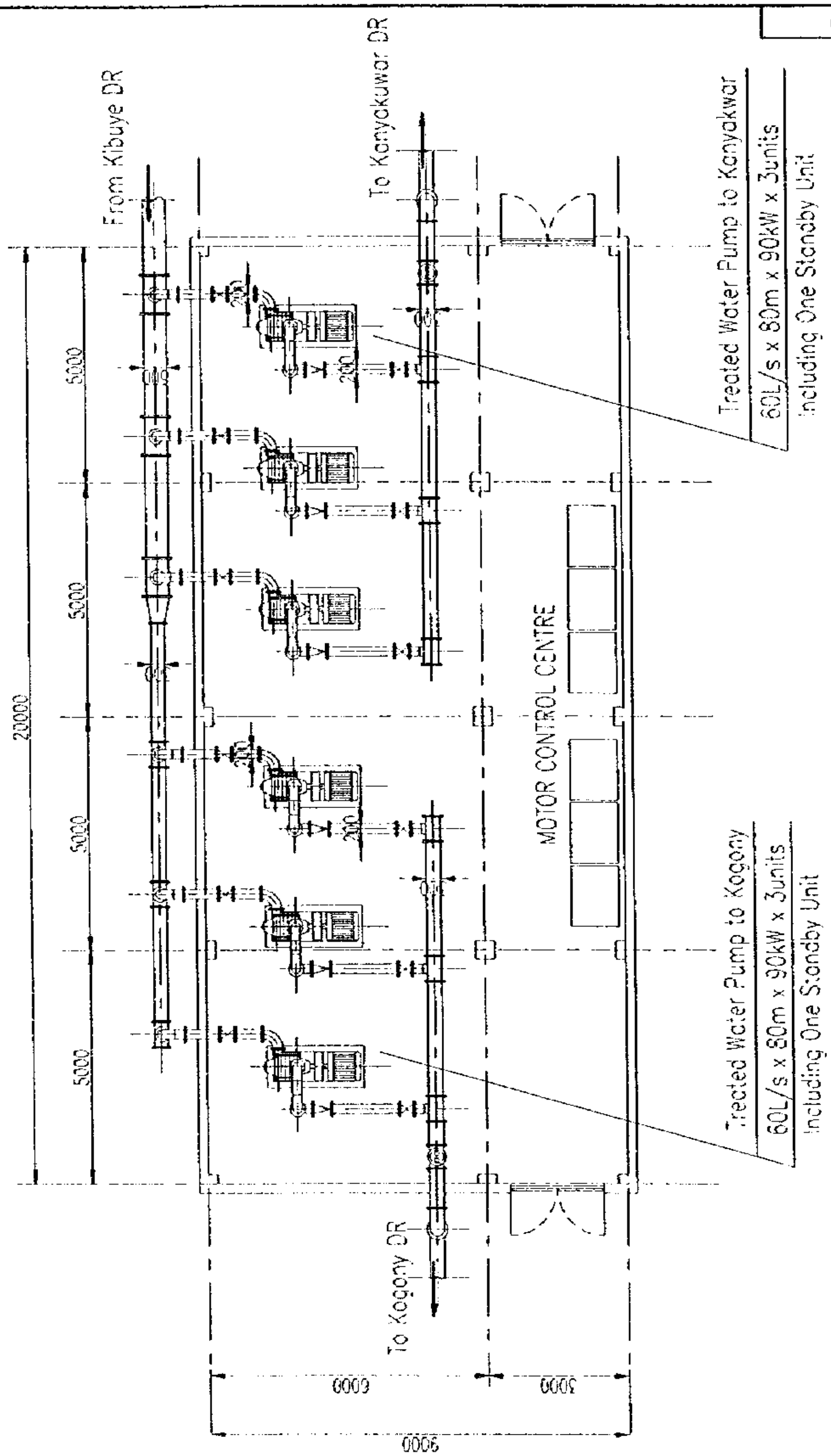
- Expansion of the intake capacity at the Lake intake works by 42,500 $m^3/d$ which increases the total intake capacity of the works from 27,000 $m^3/d$ upon completion of Phase 1 to 69,500 $m^3/d$.
- Expansion of the treatment capacity at the Kibuye WTW by 40,000 $m^3/d$ which increases the total treatment capacity of the works from 40,000 $m^3/d$ upon completion of Phase 1 to 80,000 $m^3/d$.
- Construction of a new raw water transmission main 700 mm in diameter steel pipe and approximately 6.4 km in total length from the Lake intake works to the Kibuye WTW.
- Construction of a 19,000 $m^3$ distribution reservoir at Kibuye which increases the total reservoir capacity at this location from 27,000 $m^3$ upon completion of Phase 1 to 52,300 $m^3$.
- Construction of a 3,000 $m^3$ distribution reservoir at Kanyakwar which increase the total reservoir capacity at this location from 5,000 $m^3$ upon completion of Phase 1 to 8,000 $m^3$.
- Construction of a 4,000 $m^3$ distribution reservoir at Kogony which increase the total reservoir capacity at this location from 3,500 m3 upon completion of Phase 1 to 7,500 $m^3$.
- Construction of water distribution mains , PVC pipes of 160 mm to 315 mm and steel pipes of 300 to 500 mm in diameter and approximately 27.5 km in total length.
- Installation of service mains, PVC pipes of 63 and 110 mm in diameter and approximately 232 km in total length.

G33



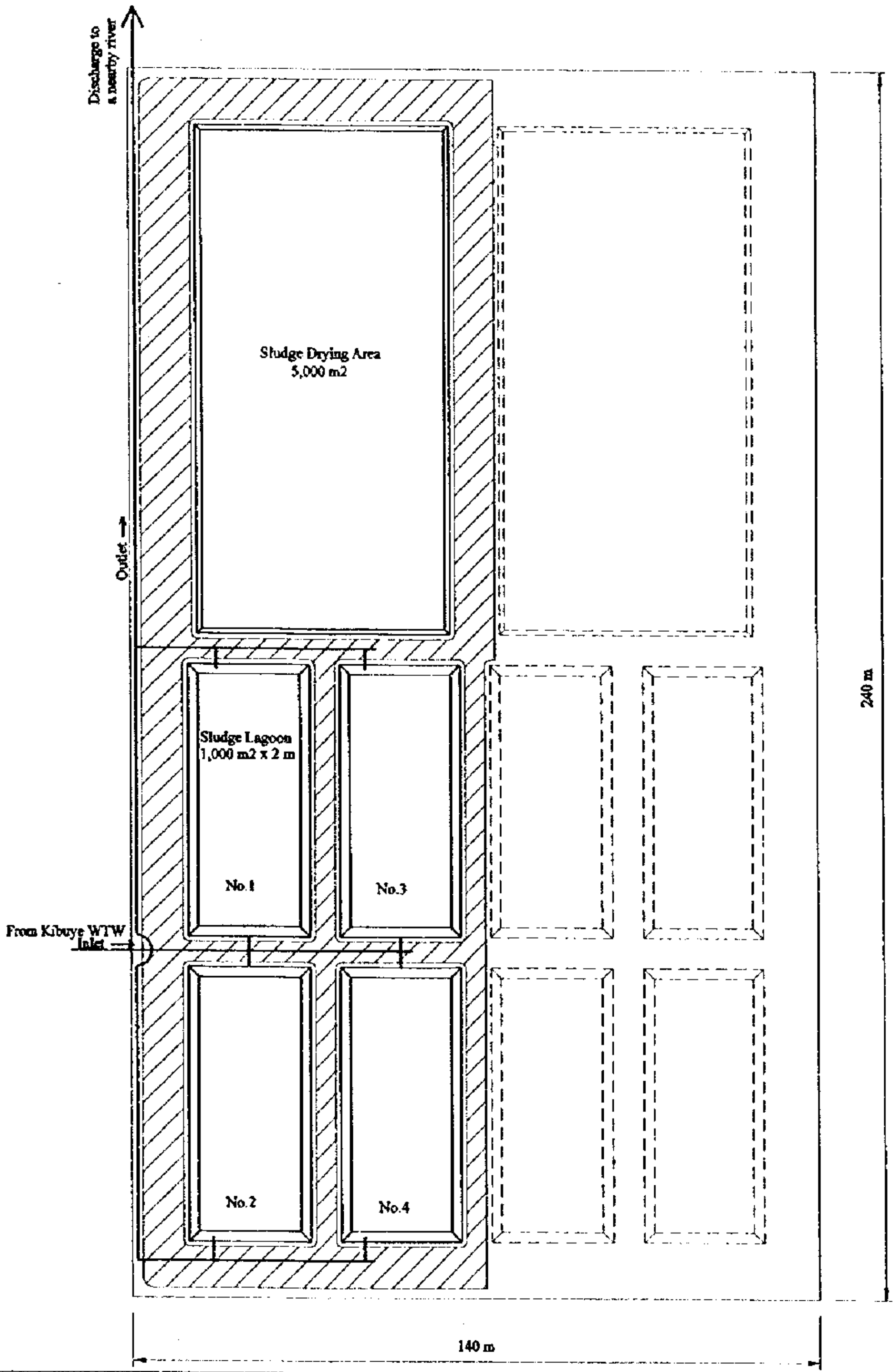
| | | |
|---|---|---|
| THE REPUBLIC OF KENYA<br><br>THE MINISTRY OF LOCAL AUTHORITIES<br>KISUMU MUNICIPAL COUNCIL | THE STUDY<br>ON KISUMU WATER SUPPLY<br>AND SEWERAGE SYSTEM<br><br>JAPAN INTERNATIONAL COOPERATION AGENCY | TITLE :<br><br>DISTRIBUTION RESERVIOR |

G34



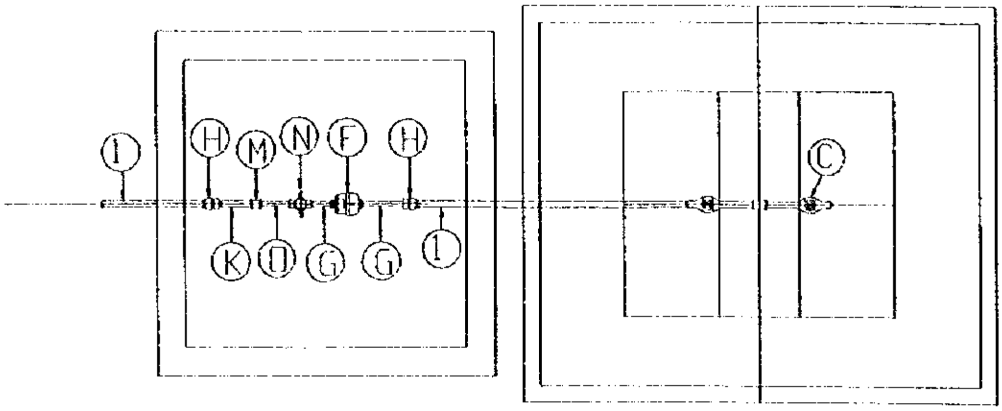

| THE REPUBLIC OF KENYA<br>THE MINISTRY OF LOCAL AUTHORITIES<br>KISUMU MUNICIPAL COUNCIL | THE STUDY<br>ON KISUMU WATER SUPPLY<br>AND SEWERAGE SYSTEM<br>JAPAN INTERNATIONAL COOPERATION AGENCY | TITLE :<br>LAYOUT OF KIBUYE DISTRIBUTION PUMP STATION |
|---|---|---|

G35

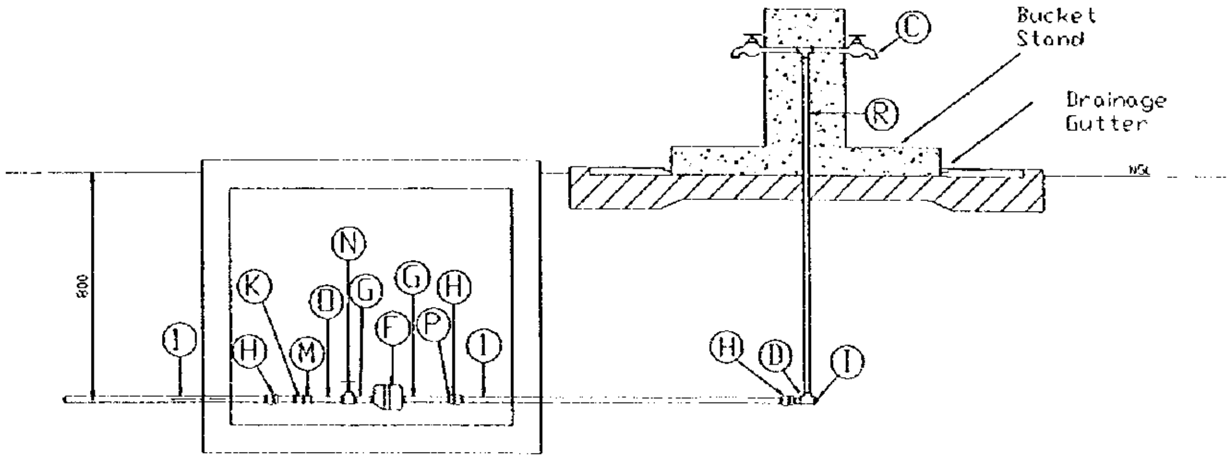



| | | |
|---|---|---|
| THE REPUBLIC OF KENYA<br><br>THE MINISTRY OF LOCAL AUTHORITIES<br>KISUMU MUNICIPAL COUNCIL | THE STUDY ON KISUMU WATER SUPPLY AND SEWERAGE SYSTEM<br><br>JAPAN INTERNATIONAL COOPERATION AGENCY | TITLE :<br><br>LAYOUT OF WASTEWATER DISPOSAL FACILITIES |

**G36**




PLAN

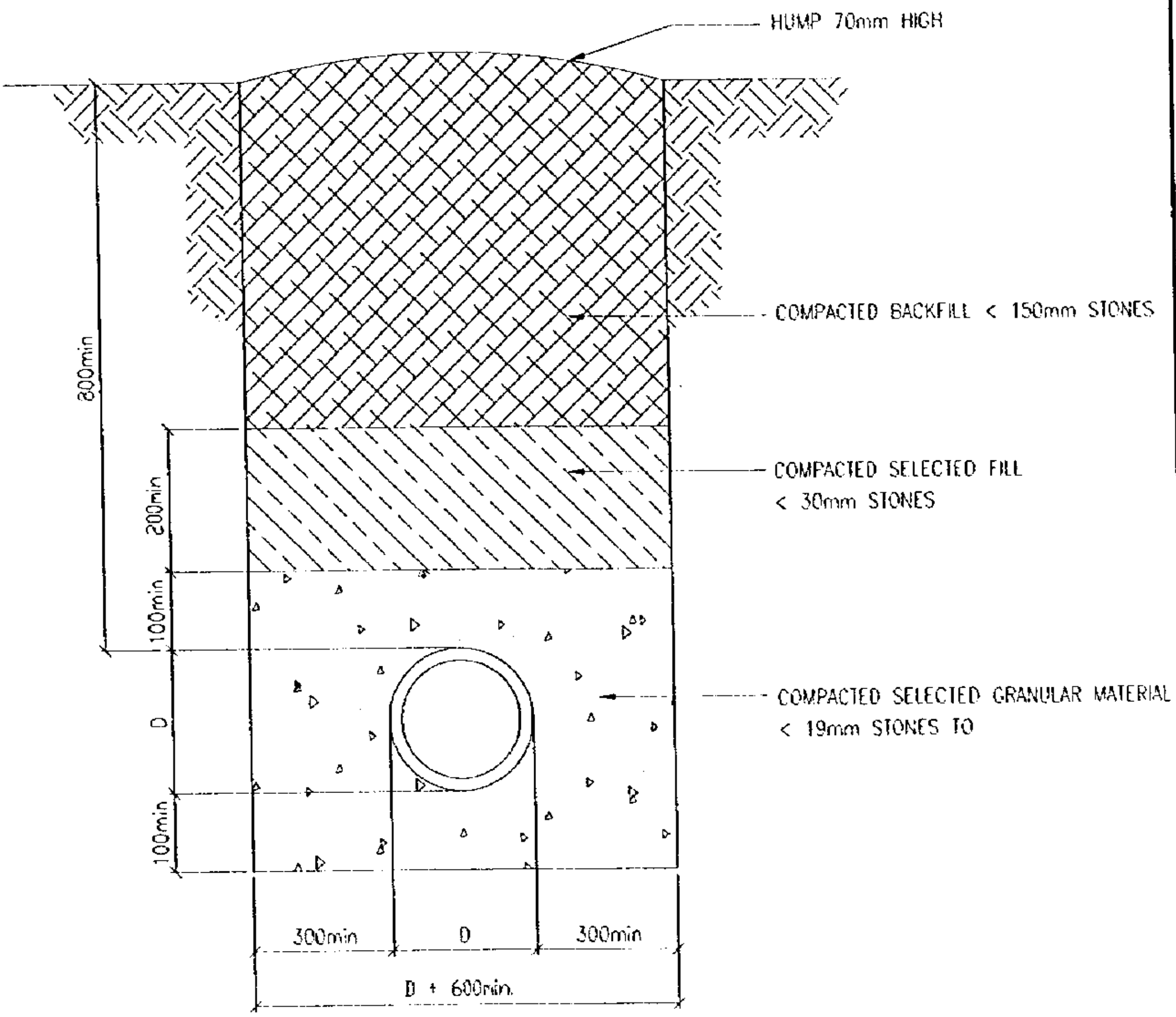



SECTION

| | SINGLE ERF CONN (mm) SIZE | QTY | DESCRIPTION |
|---|---|---|---|
| A | 20 | | 90 DEG MALLEABLE CAST IRON (MCI) FEMALE ENDED ELBOW |
| B | 20 | | GMS PIPE PIECE - L=1085mm |
| C | 15 | | 15mm ROUGH BRASS HOSE BIB TAP WITH 20mm OUTLET |
| D | 20x15 | | MCI T-PIECE |
| F | 15 | | KENT PSM SIZE 3 WATER METER |
| R | 15 | | GMS PIPE PIECE - L=1000mm |
| H | 20x3/4' | | PLASSON MALE COMPRESSION ADAPTOR |
| I | 20 | | 20 mm MALLEABLE CAST IRON PLUG |
| I | 20 | | HDPE PIPE, FITTINGS NOT INCLUDED (LENGTH TO BE DETERMINED ON SITE) |
| L | 20 | | GMS PIPE PIECE - L=785mm |
| K | 20 | | GMS PIPE PIECE L=50mm |
| M | 20x15 | | GMS REDUCING SOCKET |
| N | 15 | | 15mm BOSSINI BALL VALVE |
| O | 15 | | GMS PIPE PIECE - LENGTH TO BE SUCH THAT DIMENSION XY= 500mm |
| P | 15x20 | | GMS REDUCING BUSH |
| G | 15 | | GMS 40mm TAILPIECE WITH UNION NUT |
| S | 15 | | 90 DEG MALLEABLE CAST IRON (MCI) FEMALE ENDED ELBOW |

| THE REPUBLIC OF KENYA<br><br>THE MINISTRY OF LOCAL AUTHORITIES<br>KISUMU MUNICIPAL COUNCIL | THE STUDY<br>ON KISUMU WATER SUPPLY<br>AND SEWERAGE SYSTEM<br><br>JAPAN INTERNATIONAL COOPERATION AGENCY | TITLE :<br><br>TYPICAL STANDPIPE INSTALLATION |
|---|---|---|

G37




| THE REPUBLIC OF KENYA<br>THE MINISTRY OF LOCAL AUTHORITIES<br>KISUMU MUNICIPAL COUNCIL | THE STUDY ON KISUMU WATER SUPPLY AND SEWERAGE SYSTEM<br>JAPAN INTERNATIONAL COOPERATION AGENCY | TITLE :<br>TYPICAL PIPE TRENCH |
|---|---|---|

# APPENDIX-H

# WASTEWATER MANAGEMENT FACILITY PLAN

# APPENDIX H

## WASTEWATER MANAGEMENT FACILITY PLAN

TABLE OF CONTENTS

# APPENDIX H Wastewater Management Facility Plan

## H1 Introduction

As shown in Table F-7 in Appendix F, the municipal sewerage system, with the combined use of conventional sewerage system and shallow sewer, will collect 60 % of the total wastewater generation in 2005 and increase to 83 % in 2015. In this context, the conventional sewerage system is assumed to collect most of non-domestic wastewater as well as domestic wastewater from households whose water consumption rates are 100 lcd or greater, shallow sewers will collect domestic wastewater from those who consume 50 to 60 lcd, and those who consume 15 to 20 lcd will remain with on-site sanitation facilities.

## H2 Design Flow

Daily average flows shown in Table H-1 are the same information being broken down into three wastewater treatment districts, namely Central, Eastern and Western WTDs. In estimating the total daily average flow for each WTD, an allowance for groundwater infiltration which is assumed to be 25 % of the total volume of domestic and non-domestic wastewater is added.

Daily Maximum Flows and Hourly Maximum Flows are estimated using the same ratios as that applied in the estimate of water supply demands, which are:

Daily Average Flow : Daily Maximum Flow : Hourly Maximum Flow = 1.0 : 1.1 : 2.0

## H3 Wastewater Collection Facility

### H3.1 Trunk Sewers

Design Criteria for trunk sewers are as follows:

In determining sewer capacities, the Manning Equation is used for gravity sewers with n-value of 0.013 for new concrete pipes and 0.015 for existing concrete pipes. Hazen-Williams Equation is used for force( rising) mains with C-value of 110. Hourly maximum flow is used for calculation of capacities for all pipes and conduits with the allowance for future uncertainites which is 100 % for pipes 600 mm and less in diameter or 75 % for pipes 700 mm and larger.

A diameter 250 mm is adopted as the minimum size for trunk sewers. This however excludes force mains and branch sewers. All sanitary sewers are designed to maintain a mean flow velocity, when flowing full or hall full, of not less than 60 cm/sec based on the Manning equation. However, to prevent hydrogen sulphide built-up in sewers, a slightly higher velocity is used for the design of sewers.

To prevent sewer erosion, all sewers are designed to have a flow velocity not exceeding 3.0 m/sec. Where ground slope is steep and flow velocity is expected to exceed 3.0 m/sec, drop manholes will be provided to decrease the velocity.

A sufficient earth covering depth should be provided between the top of sewers and the road surface to protect the sewers from traffic loads and to avoid undue interference with other underground utilities. A minimum of 1.5 m should be provided for trunk sewers, except in special situations where a shallow depth is feasible.

Preliminary design of trunk sewers are explained in the following.

Hourly maximum flow in the year of 2015 is used for determining capacities of trunk sewers. The flows for the Eastern and Western WTDs shown in Table H-1 are further broken down into three sub-districts, taking into account of distribution of wastewater generation and drainage basin patterns in the area. Table H-2 and H-3 presents a unit design flow rate for respective sub-districts which will be used as design basis for trunk sewers in the Eastern and Western WTDs. While the unit design flow rate for the Central WTD is 0.000525 $m^3$/sec/ha (=19,800/86400/436.8), which is calculated from that the design flow rate (=19,800/86,400 $m^3$/s=(24,300-2,500x2x0.9)/86,400) excluding the flow rate (4,500 $m^3$/day=2,500x2x0.9) from the point source of Kenya Brewery is divided by the service area of 436.8 ha.

Table H-4 to H-8 presents the design calculations for the trunk sewers. The layout plan of trunk sewers is shown in Fig. H-1 and H-2. The longitudinal section of proposed new trunk sewers for the Eastern and Western WTDs is also shown in Fig. H-3 and H-4 respectively.

The capacity of existing trunk sewers in the Central and Western WTDs has been examined whether the sewers will have enough capacity to satisfy the design flow of 2005 and 2015. From the calculation results shown in Table H-4 and H-6, trunk sewers to be replaced under Phase I and Phase II projects are identified for the Central WTD and for the Eastern WTD respectively. The capacity of existing trunk sewers is calculated from the pipe diameter and the estimated pipe installation gradient from the data in the previous F/S reports.

Design calculations for trunk sewers to be replaced or newly installed are presented in Table H-5 for the Central WTD, Table H-7 for the Eastern WTD and Table H-8 for the Western WTD respectively.

The proposed trunk sewers will be 125 to 1,100 mm in diameter and 52 km in total length and will be laid over the Central, Eastern and Western WTDs as follows:

| | | |
|---|---|---|
| Central WTD | | |
| | Phase I | 250 to 400 mm in diameter and 2.6 km in length |
| | Phase II | 200 to 700 mm in diameter and 2.9 km in length |
| Eastern WTD | | |
| | Phase I | 125 to 1,100 mm in diameter and 23.1 km in length |
| Western WTD | | |
| | Phase II | 200 to 1,000 mm in diameter and 23.2 km in length |

In the Central and Eastern WTDs, some of the existing trunk sewers have been found broken or too small in size to meet the estimated future design flows as already explained in C2.1 and summarised in Table C-4 in Appendix C. The lengths of the proposed trunk sewers for each of these two WTDs include the lengths required for replacement of these trunk sewers.

### H3.2 Pump Stations

The design of pump stations is based on the hourly maximum flow rate. All piping and conduits will be designed to carry the design hourly maximum flow. Capacities and number of pump units will be determined that there will be at least one standby unit even under the hourly maximum flows.

Two identical pump units, one duty and one standby, will be provided for small pumps. In case of large pump stations, two or more units of identical pumps including one standby will be provided.

In general, the plan of pump stations will be rectangular. When screw volute pumps are used, a separate dry well which will accommodate the pumps will be provided. Wet wells should be provided with an adequate storage capacity to prevent frequent on-off of the pumps.

None of the existing three pump stations in the Central WTD, namely the Sunset Hotel Pump Station, Kendu Lane Pump Station and Mumias Road Pump Station, is currently functioning. Urgent rehabilitation of these pump stations is necessary. In addition, three pump stations will be constructed in the future. They are the Kombedu Pump Station in the Western WTD and the Labour College Pump Station and Nyalenda STW Pump Station in the Eastern WTD. Once the Kombedu Pump Station is constructed, it will collect wastewater from the area currently served by the Mumias Road Pump Station, and the latter pump station will be abandoned. A layout plan of the proposed Kombedu Pump Station is shown in Fig. H-5.

The outlines of these pump stations are summarised as follows:

1) Existing Sunset Hotel Pump Station in Central WTD (rehabilitation and improvement)
   Design Flow: 1.26 $m^3$/min
   Pump Capacity (per unit) : 1.26 $m^3$/min
   Total Head : 40 m
   Number of units : 2 (including 1 standby)
   Motor Power : 18.5 kW

2) Existing Kendu Lane Pump Station in Central WTD (rehabilitation and improvement)
   Design Flow: 1.20 $m^3$/min
   Pump Capacity (per unit) : 1.20 $m^3$/min
   Total Head : 13 m
   Number of units : 2 (including 1 standby)
   Motor Power : 5.5 kW

3) Existing Mumias Road Pump Station in Central WTD (rehabilitation only)
   Design Flow: 1.62 $m^3$/min
   Pump Capacity (per unit) : 1.62 $m^3$/min
   Total Head : 10 m
   Number of units : 2 (including 1 standby)
   Motor Power : 7.5 kW

4) Propose Kombedu Pump Station in Western WTD
   Design Flow: 17.89 $m^3$/min
   Pump Capacity (per unit) : 4.47 $m^3$/min
   Total Head : 30 m
   Number of units : 5 (including 1 standby)
   Motor Power : 37 kW

5) Proposed Labour College Pump Station in Eastern WTD
   Design Flow: 0.72 $m^3$/min
   Pump Capacity (per unit) : 0.72 $m^3$/min
   Total Head : 9 m
   Number of units : 2 (including 1 standby)
   Motor Power : 3.7 kW

6) Proposed Nyalenda STW Pump Station in Eastern WTD
   Design Flow: 35.30 $m^3$/min
   Pump Capacity (per unit) : 17.7 $m^3$/min
   Total Head : 2 m
   Number of units : 3 (including 1 standby)
   Motor Power : 11 kW

# H4 Sewage Treatment Works

## H4.1 Conventional Sewage Treatment Works in Central WTD

This sewage treatment works has been subjected to severe overloading in term of sewage volume and loads, the quality of effluent is more than 100 mg/l in terms of BOD, which far exceeds the wastewater standards. Therefore the rehabilitation of existing facilities is highlighted to raise their efficiency and is proposed to be taken place as early as possible.

The proposed rehabilitation and expansion works are planned that they will enable the STW to meet not only the design flow in 2005 but also that in 2015, as the incremental inflow to the STW during the decade is estimated marginal.

The following rehabilitation and expansion works will have to be completed in Phase I:

a) Rehabilitation Works
- Rehabilitation of the mechanical/electrical equipment
- Construction of 1 No. high rate plastic media trickling filter
- Replacement of top 1.2 m of stone media with super rate (SR) plastic media in trickling filter 1-4
- Construct 1 No. 13.2 m diameter secondary sedimentation (humus) tank
- Construct 1 No. sludge thickening tank
- Provision of lightweight covers for 4 No. sludge drying beds
- Minor alterations to inlet works

b) Expansion Works
- Inlet works to be extended
- Construction of new storm bypass structure
- Construction of 1 No. primary sedimentation tank
- Construction of 1 No. super rate (SR) media tricking filter
- Construction of 2 No. secondary sedimentation (humus) tanks
- Provision of 6 No. lightweight covers for sludge drying beds

## H4.2 Nyalenda Sewage Treatment Works in Eastern WTD

The existing Nyalenda STW illustrate the result of lack of maintenance with overgrown embankments, inoperable flow measurement equipment, malfunctioning facultative ponds, dislodged anti-erosion slabs and minor collapses to embankments. Rehabilitation of the works to return operations to a satisfactory level is necessary urgently.

The works also needs to be uprated to cope with the estimated design daily average flow of 16,700 $m^3$/day in 2005 and 28,300 $m^3$/day in 2015.

These will be done in two phases, i.e., Phase I and Phase II. The existing inlet works will require extensive refurbishing to cope with the new flows and three anaerobic ponds will be required. Each pond will be served individually from the new inlet works and will be discharge to downstream facultative ponds in series.

a) Phase I

The works proposed for implementation under Phase I are listed below. They will mainly concentrated on the refurbishment of the existing facilities with a view to enabling the plant to cope with the projected design average flow of 16,700 $m^3$/day in 2005.

i) Construct a new venturi-flume in lieu of the existing Parshall flumes and alter the profiles of the grit channels to a trapezoidal shape designed to match the new flume.
ii) Construction of new desludging ramps are proposed for the facultative ponds, as the existing ramps are very steep with an incline of 1:2:5 with no extended base at the pond bottom
iii) Replace anti erosion slabs and fix each slab
iv) Reconstruct 50 m of division embankment between Maturation Ponds M2 and M3
v) Desludge facultative ponds as these are malfunctioning due to the growth of water cabbage
vi) Construction of 3 No. anaerobic ponds upstream of facultative ponds

b) Phase II

The works proposed for Phase II comprise the construction of an additional treatment stream with 5 No. maturation ponds. This will enable the works to cope with the estimated design daily average flow of 28,300 $m^3$/day in 2015.

The followings are design calculations for the Nyalenda STW:

<u>Design Basis</u>:

It is proposed that the Nyalenda STW be sized to treat an ultimate inflow (year 2015) of 28,300 $m^3$/d.

Current treatment facilities comprise 3 streams each with

① 1 No. Facultative Ponds each with mid-depth area of 34,476 $m^2$ and depth of 1.75 m.

② 2 No. Maturation Ponds in series each of mid-depth area of 12,290 $m^2$ and depth of 1.25 m for the first pond and 1.20 m for the second pond.

It is proposed that four streams will treat the ultimate inflow and each stream has one anaerobic pond. The required size of ponds be computed in the followings.

<u>Capacity of Facultative Ponds</u>

Required capacity of one stream is 7,075 $m^3/d$ (= 28,300 / 4).

Assuming 70% BOD reduction in anaerobic ponds for 5 days retention,
Influent BOD, Li = 350 × 0.3 = 105 mg/L
Depth = 1.75 m
From Mara's Equation

Surface BOD loading = $\frac{10LiQ}{A}$

And from Arthur's Equation
Permissible surface BOD loading = 20T - 60
and T = 20℃

∴ Capacity, Q = $\frac{A(2T-6)}{Li} = \frac{34{,}476 \times (2 \times 20 - 6)}{105}$

= 11,164 $m^3/d$

The existing facultative ponds can comfortably handle the 7,075 $m^3/d$ streams inflow.

<u>Capacity of Maturation Ponds</u>

Retention time at the maturation No. 1 and No. 2 :

$t_{mat1} = \frac{D \times A}{Q} = \frac{1.25 \times 12{,}290}{7{,}075}$

= 2.17days

and $t_{mat2} = \frac{D \times A}{Q} = \frac{1.20 \times 12{,}290}{7{,}075}$

= 2.08 days

It is recommended that maturation ponds have a minimum retention of 3 days to avoid " short-circuiting". In this respect, the ponds are undersized. Therefore, it is proposed to combine the existing maturation ponds in series and add a further pond of the same size of 24,580 $m^2$ and depth 1.20 m for each stream. The total retention time of maturation ponds are:

$$t_{mat} = \frac{D \times A}{Q} = \frac{1.20 \times 12{,}290 \times 2}{7{,}075}$$

$= 4.17$ days

<u>Sizing of Required Anaerobic Ponds</u>

Design Flow, Q = 28,300 $m^3/d$
Let the liquid depth of ponds, **D** = 3.0 m and
Retention time, $t_{an}$ = 5 days (optimum)
From Mara's Equation, the required surface area of ponds

$$A = \frac{Q\, t_{an}}{D}$$

$$= \frac{28{,}300 \times 5}{3}$$

$= 47{,}167\ m^2 = 4.7$ ha

For 4 No. anaerobic ponds, each will have a size of 11,792 $m^2$(= 47,167/4 )

<u>Check Bacteriological Quality</u>

Retention time in a facultative pond, $t_{fac} = \frac{AD}{Q}$

$$= \frac{34{,}476 \times 1.75}{7{,}075} = 8.5 \text{ days}$$

Therefore from Mara's Equation

$$Ne = \frac{Ni}{(1 + Kb\, t_{an})(1 + Kbt_{fac})(1 + Kbt_{mat})^2}$$

where

Ne = faecal coliform count of effluent

Ni = faecal coliform count of influent = $4 \times 10^7$ (assumed)

Kb = $2.6\,(1.19)^{T-20} = 2.6$

$$\therefore\ Ne = \frac{4 \times 10^7}{[1 + (2.6 \times 5)][1 + (2.6 \times 8.5)][1 + (2.6 \times 4.2)]^2} = 870 \text{ FC / 100 mL}$$

This is less than 5,000 FC / 100 mL and therefore satisfactory for faecal coliform removal.

### H4.3 Proposed Otongolo Sewage Treatment Works in Western WTD

Under Phase II, a new wastewater treatment district, namely Western WTD, will be developed. This district will cover most of residential areas in Kanyakwar, Korando and Kogony and part of industrial area in Kibuye near the Kisumu Airport and Otongolo Industrial Estate. The Otongolo STW will be located to the west of the Kisumu Airport and treat wastewaters to be collected in this newly developed wastewater district. To meet the design daily flow of 27,200 $m^3$/day in 2015, the works will need to be provided with 2 No. anaerobic ponds, 2 No. facultative ponds and 4 No. maturation ponds, all preceded by an inlet works for screening and grit removal. This treatment process is selected on the basis of the following assessment:

- Ease of operation and maintenace
- Low operation and maintenance costs
- Availability of land for construction

The followings are design calculations for the proposed ponds system for Otongolo STW.

<u>Design Basis</u>

| | | |
|---|---|---|
| Flow | = | 27,200 $m^3$/day |
| Influent | = | BOD 350 mg/L |

<u>Computation of mid-depth areas</u>

**Anaerobic Ponds**

Depth D = 3.5 meters
Retention time $t_{an}$ = 5 days (optimum)
Q = 27,200 $m^3$/day

From Mara's equation, $A = \frac{Qt_{an}}{D}$

Therefore Area of Ponds, $A = \frac{27,200}{3.5} \times 5 = 38,857\ m^2 = 3.89$ ha

**Facultative Pond**

Assuming 70% BOD reduction in anaerobic ponds for 5 days retention.

Influent BOD, Li = 0.3 × 350 = 105 mg/L
D = 1.5 m

From Mara's equation,
Surface BOD loading = $\frac{10LiQ}{A}$

And from Arthur's equation, permissible surface BOD loading = 20T - 60
T = mean temperature of coldest month = 20℃

Therefore pond area, A = $\frac{10LiQ}{20T-60} = \frac{10\times105\times27{,}200}{20\times20-60}$ $m^2$
= 84,000 $m^2$ = 8.40 ha

**Maturation Ponds**

Choose D = 1.25 m and two ponds in series each with 3 days retention ($t_{mat}$) to avoid short circuiting.

From Mara's equation A = $\frac{Qt_{mat}}{D} = \frac{27{,}200\times3\times2}{1.25}$
= 130,560 $m^2$ = 13.06 ha

**Check Bacteriological Quality**

Retention time in facultative pond, $t_{fac} = \frac{Ad}{Q}$

$= \frac{84{,}000\times1.5}{27{,}200} = 4.6$ days

Therefore from Mara's equation

$$Ne = \frac{Ni}{(1+k_b t_{an})(1+k_b t_{fac})(1+k_b t_{mat})^2}$$

Ne = faecal coliform count of effluent
Ni = faecal coliform count of influent = $4\times10^7$(assumed)

$K_b = 2.6(1.19)^{T-20} = 2.6$

Therefore,

$$Nc = \frac{4 \times 10^7}{\{1 + (2.6 \times 5)\}[1 + (2.6 \times 4.6)][1 + (2.6 \times 3)]^2}$$

$$= \frac{4 \times 10^7}{14 \times 12.96 \times 8.8^2} = 2,847 \text{ FC / 100 mL}$$

<5,000 FC / 100 mL which is satisfactory for faecal coliform removal

Total retention time at ponds = 15.6 days

Table H-1 Design Flow Rate for Sewerage System Unit: $m^3$/day

| WTD | Daily Average Flow | | Daily Maximum Flow | | Hourly Maximum Flow | |
|---|---|---|---|---|---|---|
| | 2005 | 2015 | 2005 | 2015 | 2005 | 2015 |
| **Central WTD** | | | | | | |
| Domestic | 2,540 | 3,110 | 2,800 | 3,420 | 5,080 | 6,220 |
| Commercial | 2,130 | 3,040 | 2,340 | 3,340 | 4,260 | 6,080 |
| Institutional | 500 | 1,140 | 550 | 1,250 | 1,000 | 2,280 |
| Industrial | 4,700 | 3,510 | 5,170 | 3,860 | 9,400 | 7,020 |
| Sub total | 9,870 | 10,800 | 10,860 | 11,870 | 19,740 | 21,600 |
| Ground Water | 2,470 | 2,700 | 2,470 | 2,700 | 2,470 | 2,700 |
| Total | 12,340 | 13,500 | 13,330 | 14,570 | 22,210 | 24,300 |
| Design Flow | 12,400 | 13,500 | 13,400 | **14,600** | 22,300 | **24,300** |
| **Eastern WTD** | | | | | | |
| Domestic | 8,870 | 14,580 | 9,760 | 16,040 | 17,740 | 29,160 |
| Commercial | 1,790 | 2,670 | 1,970 | 2,940 | 3,580 | 5,340 |
| Institutional | 1,250 | 2,840 | 1,380 | 3,120 | 2,500 | 5,680 |
| Industrial | 1,440 | 2,480 | 1,580 | 2,730 | 2,880 | 4,960 |
| Sub total | 13,350 | 22,570 | 14,690 | 24,830 | 26,700 | 45,140 |
| Ground Water | 3,340 | 5,640 | 3,340 | 5,640 | 3,340 | 5,640 |
| Total | 16,690 | 28,210 | 18,030 | 30,470 | 30,040 | 50,780 |
| Design Flow | **16,700** | **28,300** | 18,000 | 30,500 | 30,100 | **50,800** |
| **Western WTD** | | | | | | |
| Domestic | 0 | 12,570 | 0 | 13,830 | 0 | 25,140 |
| Commercial | 0 | 1,280 | 0 | 1,410 | 0 | 2,560 |
| Institutional | 0 | 1,140 | 0 | 1,250 | 0 | 2,280 |
| Industrial | 0 | 6,720 | 0 | 7,390 | 0 | 13,440 |
| Sub total | 0 | 21,710 | 0 | 23,880 | 0 | 43,420 |
| Ground Water | 0 | 5,430 | 0 | 5,430 | 0 | 5,430 |
| Total | 0 | 27,140 | 0 | 29,310 | 0 | 48,850 |
| Design Flow | 0 | **27,200** | 0 | 29,300 | 0 | **48,900** |
| **Total** | | | | | | |
| Domestic | 11,410 | 30,260 | 12,560 | 33,290 | 22,820 | 60,520 |
| Commercial | 3,920 | 6,990 | 4,310 | 7,690 | 7,840 | 13,980 |
| Institutional | 1,750 | 5,120 | 1,930 | 5,620 | 3,500 | 10,240 |
| Industrial | 6,140 | 12,710 | 6,750 | 13,980 | 12,280 | 25,420 |
| Sub total | 23,220 | 55,080 | 25,550 | 60,580 | 46,440 | 110,160 |
| Ground Water | 5,810 | 13,770 | 5,810 | 13,770 | 5,810 | 13,770 |
| Total | 29,030 | 68,850 | 31,360 | 74,350 | 52,250 | 123,930 |
| Design Flow | 29,100 | 68,900 | 31,400 | 74,400 | 52,300 | 124,000 |

**Table H-2 Design Flow Rate for Wastewater Collection Facilities in the Eastern WTD**

| Sub District | | Daily Ave. | Daily Max. | | Hourly Max. | | |
|---|---|---|---|---|---|---|---|
| | | m³/day | factor | m³/day | factor | m³/day | |
| A | (Urban) | | | | | | |
| | Domestic | 3,643 | 1.1 | 4,007 | 2.0 | 7,286 | |
| | Commercial | 1,168 | 1.1 | 1,285 | 2.0 | 2,336 | |
| | Institutional | 1,680 | 1.1 | 1,848 | 2.0 | 3,360 | |
| | Industrial | 0 | 1.1 | 0 | 2.0 | 0 | |
| | Sub total | 6,491 | | 7,140 | | 12,982 | |
| | Ground Water | 1,623 | | 1,623 | | 1,623 | **582.3 ha** |
| | Total | 8,114 | | 8,763 | | 14,605 | |
| | Design Flow | 8,200 | | 8,800 | | **14,700** | **0.000292 m³/s/ha** |
| B | (Peri-urban) excluding Nyalenda | | | | | | |
| | Domestic | 7,767 | 1.1 | 8,544 | 2.0 | 15,534 | |
| | Commercial | 998 | 1.1 | 1,098 | 2.0 | 1,996 | |
| | Institutional | 774 | 1.1 | 851 | 2.0 | 1,548 | |
| | Industrial | 2,480 | 1.1 | 2,728 | 2.0 | 4,960 | |
| | Sub total | 12,019 | | 13,221 | | 24,038 | |
| | Ground Water | 3,005 | | 3,005 | | 3,005 | **1,382.6 ha** |
| | Total | 15,024 | | 16,226 | | 27,043 | |
| | Design Flow | 15,100 | | 16,300 | | **27,100** | **0.000227 m³/s/ha** |
| C | (Peri-urban) Nyalenda | | | | | | |
| | Domestic | 3,166 | 1.1 | 3,483 | 2.0 | 6,332 | |
| | Commercial | 499 | 1.1 | 549 | 2.0 | 998 | |
| | Institutional | 387 | 1.1 | 426 | 2.0 | 774 | |
| | Industrial | 0 | 1.1 | 0 | 2.0 | 0 | |
| | Sub total | 4,052 | | 4,458 | | 8,104 | |
| | Ground Water | 1,013 | | 1,013 | | 1,013 | **96.4 ha** |
| | Total | 5,065 | | 5,471 | | 9,117 | |
| | Design Flow | 5,100 | | 5,500 | | **9,200** | 0.001105 m³/s/ha |
| **Eastern WTD, Total** | | | | | | | |
| | Domestic | 14,576 | | 16,034 | | 29,152 | |
| | Commercial | 2,665 | | 2,932 | | 5,330 | |
| | Institutional | 2,841 | | 3,125 | | 5,682 | |
| | Industrial | 2,480 | | 2,728 | | 4,960 | |
| | Sub total | 22,562 | | 24,819 | | 45,124 | |
| | Ground Water | 5,641 | | 5,641 | | 5,641 | **2,061.3 ha** |
| | Total | 28,203 | | 30,460 | | 50,765 | Ave. |
| | Design Flow | 28,300 | | 30,500 | | **50,800** | 0.000285 m³/s/ha |

| | | |
|---|---|---|
| Existing Sewered Area | 214.1 ha | |
| Development Area in Phase I | 1240.8 ha | including Nyalenda developed |
| Development Area in Phase II | 607.7 ha | by shallow sewers |
| Total | 2062.6 ha | |

**Table H-3 Design Flow Rate for Wastewater Collection Facilities in the Western WTD**

| Sub District | Daily Ave. | Daily Max. | | Hourly Max. | | |
|---|---|---|---|---|---|---|
| | $m^3$/day | factor | $m^3$/day | factor | $m^3$/day | |
| **A** | | | | | | |
| Domestic | 6,931 | 1.1 | 7,624 | 2.0 | 13,862 | |
| Commercial | 527 | 1.1 | 580 | 2.0 | 1,054 | |
| Institutional | 389 | 1.1 | 428 | 2.0 | 778 | |
| Industrial | 3,600 | 1.1 | 3,960 | 2.0 | 7,200 | |
| Sub total | 11,447 | | 12,592 | | 22,894 | |
| Ground Watei | 2,860 | | 2,860 | | 2,860 | 1,165.1 ha |
| Total | 14,307 | | 15,452 | | 25,754 | |
| Design Flow | 14,310 | | 15,460 | | **25,760** | **0.000256 $m^3$/s/ha** |
| **B** | | | | | | |
| Domestic | 2,618 | 1.1 | 2,880 | 2.0 | 5,236 | |
| Commercial | 197 | 1.1 | 217 | 2.0 | 394 | |
| Institutional | 343 | 1.1 | 377 | 2.0 | 686 | |
| Industrial | 1,145 | 1.1 | 1,260 | 2.0 | 2,290 | |
| Sub total | 4,303 | | 4,734 | | 8,606 | |
| Ground Watei | 1,080 | | 1,080 | | 1,080 | 493.1 ha |
| Total | 5,383 | | 5,814 | | 9,686 | |
| Design Flow | 5,390 | | 5,820 | | **9,690** | **0.000227 $m^3$/s/ha** |
| **C** | | | | | | |
| Domestic | 3,014 | 1.1 | 3,315 | 2.0 | 6,028 | |
| Commercial | 550 | 1.1 | 605 | 2.0 | 1,100 | |
| Institutional | 407 | 1.1 | 448 | 2.0 | 814 | |
| Industrial | 1,975 | 1.1 | 2,173 | 2.0 | 3,950 | |
| Sub total | 5,946 | | 6,541 | | 11,892 | |
| Ground Watei | 1,490 | | 1,490 | | 1,490 | 974.3 ha |
| Total | 7,436 | | 8,031 | | 13,382 | |
| Design Flow | 7,440 | | 8,040 | | **13,390** | **0.000159 $m^3$/s/ha** |
| **Western WTD, Total** | | | | | | |
| Domestic | 12,563 | | 13,819 | | 25,126 | |
| Commercial | 1,274 | | 1,402 | | 2,548 | |
| Institutional | 1,139 | | 1,253 | | 2,278 | |
| Industrial | 6,720 | | 7,393 | | 13,440 | |
| Sub total | 21,696 | | 23,867 | | 43,392 | |
| Ground Watei | 5,430 | | 5,430 | | 5,430 | 2,632.5 ha |
| Total | 27,126 | | 29,297 | | 48,822 | Ave. |
| Design Flow | 27,130 | | 29,300 | | **48,830** | 0.000215 $m^3$/s/ha |

# Table H-4 Examination of Capacity of Existing Trunk Sewers in Central WTD

| Sewer Line No. | | Wastewater Treatment District | | | | | | | Design Flow Rate | Point Source | Total Design Flow Rate | Design Sewer | | | | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Unit DFR: 0.000525 | | | Unit DFR= | | | Existing Pipe Capacity | | | | Dia. | Slope | Velocity | Capacity | Length | Invert Elevation | Ground Surface Elevation | Earth Cover | |
| From | To | increment | Cu. Total | Flow | increment | Cu. Total | Flow | | | | | | | | | | | | | |
| | | ha | ha | m³/S | ha | ha | m³/S | m³/S | m³/S | m³/S | m³/S | mm | o/oo | m/S | m³/S | m | m | m | m | |
| A-1 | | 16.1 | | | | | | | | | | 175 | | | | 482 | 1,180.300 | 1,182.624 | 2.122 | |
| | | | 16.1 | 0.008 | | | | 0.020 | | | | | | | | | | | | |
| A-2 | | 0.1 | | | | | | | | | | 225 | | | | 50 | 1,173.896 | 1,175.766 | 1.618 | |
| | | | 16.2 | 0.009 | | | | 0.035 | | | | | | | | | | | | |
| A-3 | | 10.9 | | | | | | | | | | 225 | | | | 238 | 1,173.482 | 1,175.766 | 2.032 | Replace |
| | | | 27.1 | 0.014 | | | | 0.020 | | | | | | | | | | | | Phase II |
| A-4 | | 27.4 | | | | | | × | | | | 225 | | | | 764 | 1,172.586 | 1,174.394 | 1.556 | Replace |
| | | | 54.5 | 0.029 | | | | 0.021 | | | | | | | | | | | | Phase I |
| A-5 | | 8.9 | | | | | | | | | | 375 | | | | 103 | 1,168.782 | 1,169.670 | 0.481 | |
| | | | 63.4 | 0.033 | | | | 0.092 | | | | | | | | | | | | |
| A-6 | | 3.9 | | | | | | | | | | 375 | | | | 243 | 1,167.648 | 1,168.603 | 0.548 | |
| | | | 67.3 | 0.035 | | | | 0.101 | | | | | | | | | | | | |
| A-7 | | 30.6 | | | | | | | | | | 375 | | | | 450 | 1,165.767 | 1,167.689 | 1.515 | |
| | | | 97.9 | 0.051 | | | | 0.162 | | | | | | | | | | | | |
| A-8 | | 1.5 | | | | | | | | | | 525 | | | | 82 | 1,154.974 | 1,156.106 | 0.565 | |
| | | | 99.4 | 0.052 | | | | 0.767 | | | | | | | | | | | | |
| | A-9 | | | | | | | | | | | | | | | | 1,151.387 | 1,153.516 | | |
| B-1 | | 40.1 | | | | | | | | | | 200 | | | | 760 | | | | Sunset Hotel |
| | | | 40.1 | 0.021 | | | | | | | | | | | | | | | | P.S. |
| B-2 | | 28.8 | | | | | | × | | | | 225 | | | | 651 | 1,177.213 | 1,178.222 | 0.757 | Replace |
| | | | 68.9 | 0.036 | | | | 0.030 | | | | | | | | | 1,170.669 | 1,173.480 | 2.559 | Phase I |
| B-3 | | 2.4 | | | | | | | | | | 300 | | | | 147 | 1,165.853 | 1,168.298 | 2.115 | |
| | | | 71.3 | 0.037 | | | | 0.063 | | | | | | | | | | | | |
| B-4 | | 15.1 | | | | | | | | | | 300 | | | | 193 | 1,164.378 | 1,167.232 | 2.524 | |
| | | | 86.4 | 0.045 | | | | 0.125 | | | | | | | | | | | | |
| B-5 | | 13.9 | | | | | | | | | | 300 | | | | 190 | 1,158.952 | 1,162.355 | 3.073 | |
| | | | 100.3 | 0.053 | | | | 0.083 | | | | | | | | | | | | |
| B-6-1 | | 4.4 | | | | | | | | | | 300 | | | | 499 | 1,156.157 | 1,157.478 | 0.991 | Replace |
| B-6-2 | | | 104.7 | 0.055 | | | | 0.057 | | | | | | | | | 1,153.316 | 1,154.887 | 1.241 | Phase I & II |
| | B-8 | | | | | | | | | | | | | | | | | | | |
| B-7 | | 38.1 | | | | | | | | | | 150 | | | | 235 | | | | Railway P.S. |
| | | | 38.1 | 0.020 | | | | | | | | AC | | | | | Rising Trunk Sewer, Replace, Phase II | | | |
| B-8 | | 2.5 | | | | | | × | | | | 375 | | | | 156 | 1,151.789 | 1,153.016 | 0.820 | Replace |
| | | | 145.3 | 0.076 | | | | 0.059 | | | | | | | | | | | | Phase I |
| | A-9 | | | | | | | | | | | | | | | | 1,151.387 | 1,153.516 | | |
| A-9 | | 7.2 | | | | | | | | | | 525 | | | | 499 | 1,151.387 | 1,153.516 | 1.562 | Replace |
| | | | 251.9 | 0.132 | | | | 0.158 | | | | | | | | | | | | Phase II |

## Table II-4 Examination of Capacity of Existing Trunk Sewers in Central WTD

| Sewer Line No. | | Wastewater Treatment District: Unit DFR 0.000525 | | | Unit DFR= | | | Existing Pipe Capacity | Design Flow Rate | Point Source | Total Design Flow Rate | Design Sewer: Dia. | Slope | Velocity | Capacity | Length | Invert Elevation | Ground Surface Elevation | Earth Cover | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | increment | Cu. Total | Flow | increment | Cu. Total | Flow | | | | | | | | | | | | | |
| From | To | ha | ha | m³/S | ha | ha | m³/S | m³/S | m³/S | m³/S | m³/S | mm | o/oo | m/S | m³/S | m | m | m | m | |
| A-10 | | 7.9 | | | | | | | | | | 525 | | | | 400 | 1,150.085 | 1,152.144 | 1.492 | Replace |
| | | | 259.8 | 0.136 | | | | 0.167 | | | | | | | | | | | | Phase II |
| A-11 | | 24.7 | | | | | | | | | | 600 | | | | 289 | 1,145.983 | 1,150.620 | 3.987 | |
| | | | 284.5 | 0.149 | | | | 0.261 | | | | | | | | | | | | |
| A-12 | | 20.0 | | | | | | | | | | 600 | | | | 346 | 1,148.263 | 1,150.620 | 1.707 | |
| | | | 304.5 | 0.160 | | | | 0.250 | | | | | | | | | | | | |
| | A-13 | | | | | | | | | | | | | | | | 1,147.402 | 1,149.197 | | |
| D-1 | | 21.9 | | | | | | | | | | 300 | | | | 364 | 1,156.415 | 1,158.094 | 1.349 | |
| | | | 21.9 | 0.011 | | | | 0.037 | | | | | | | | | | | | |
| D-2 | | 56.2 | | | | | | | | | | 300 | | | | 803 | 1,155.180 | 1,159.060 | 3.550 | Replace |
| | | | 78.1 | 0.041 | | | | 0.047 | | | | | | | | | | | | Phase I |
| | A-13 | | | | | | | | | | | | | | | | 1,147.402 | 1,149.197 | | |
| A-13 | | 0 | | | | | | | | | | 600 | | | | 7 | 1,147.402 | 1,149.197 | 1.145 | Replace |
| | | | 382.6 | 0.201 | | | | | | | | | | | | | | | | Phase II |
| | A-14 | | | | | | | | | | | | | | | | 1,147.409 | 1,150.011 | | |
| E-1 | | 14.9 | | | | | | | (Kwnya Brewery, 2500*0.9*2) | | | 600 | | | | 440 | N/A | N/A | | |
| | | | 14.9 | 0.008 | | | | | | 0.052 | 0.060 | | | | | | | | | |
| | A-14 | | | | | | | | | | | | | | | | 1,147.409 | 1,150.011 | | |
| A-14 | | | | | | | | 0.349~ | | | | 600 | | | | 424 | 1,147.409 | 1,150.011 | 1.952 | Replace |
| | | | 397.5 | 0.209 | | | | 0.965 | | | | | | | | | | | | Phase II |
| | To Conventional Wastewater Treatment Work | | | | | | | | | | | | | | | | N/A | N/A | | |
| F-2 | | 26.8 | | | | | | | | | | 225 | | | | 697 | 1,144.900 | 1,146.300 | 1.148 | |
| | | 12.5 | 39.3 | 0.021 | | | | | | | | | | | | | | | | |
| | To Conventional Wastewater Treatment Work | | | | | | | | | | | | | | | | 1,137.100 | 1,140.960 | | |

## Table H-5 Computation Form for the Proposed Trunk Sewers to be replaced in the Central WTD

| Sewer Line No. | | Wastewater Treatment District | | | Point Source | Design Flowrate in 2005 | Design Sewer | | | | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Unit DFR= 0.000525 | | | | | Dia. | Slope | Velocity | Capacity | Length | Invert Elevation | Ground Surface Elevation | Earth Cover | |
| | | increment | Cu. Total | Flow | | | | | | | | | | | |
| From | To | ha | ha | $m^3/S$ | $m^3/S$ | $m^3/S$ | mm | o/oo | m/S | $m^3/S$ | m | m | m | m | |
| RP-1 | | | | | | | 250 | 5.0 | 0.857 | 0.0421 | 238 | 1,173.79 | 1,175.766 | 1.70 | Phase II |
| (A-3) | | | 27.1 | 0.014 | | 0.013 | (225) | | | | | 1,172.60 | 1,174.394 | 1.52 | |
| RP-2 | | | | | | | 300 | 5.0 | 0.967 | 0.0684 | 764 | 1,172.00 | 1,174.394 | 2.06 | Phase II |
| (A-4) | | | 54.5 | 0.029 | | 0.027 | (225) | | | | | 1,167.84 | 1,169.670 | 1.50 | |
| | A-5 | | | | | | | | | | | 1,168.78 | | | |
| B-1 | | | | | | | 200 | | | | 760 | 1,141.63 | | | Sunset H. PS |
| | | | 40.1 | 0.021 | | 0.019 | | | | | | 1,176.50 | 1,178.222 | 1.50 | Rising TS |
| RP-3 | | | | | | | 250 | 15.0 | 1.484 | 0.0729 | 651 | 1,176.30 | 1,178.222 | 1.64 | Phase I |
| (B-2) | | | 68.9 | 0.036 | | 0.033 | (225) | | | | | 1,166.54 | 1,168.298 | 1.49 | |
| | B-3 | | | | | | | | | | | 1,165.85 | | | |
| RP-4 | | | | | | | 350 | 8.0 | 1.356 | 0.1305 | 499 | 1,155.60 | 1,157.478 | 1.50 | Phase I |
| (B-6) | | | 104.7 | 0.055 | | 0.050 | (300) | | | | | 1,151.79 | 1,153.016 | 0.84 | Phase II |
| | (B-8) | | | | | | | | | | | 1,151.79 | | | |
| RP-5 | Rising Trunk Sewer from Kendu Lane P.S. | | | | | | 200 | | | | 235 | 1,143.50 | 1,145.230 | 1.50 | Phase II |
| (B-7) | | | 38.1 | 0.020 | | | | | | | | 1.151.28 | 1,153.016 | 1.51 | |
| RP-6 | | | | | | | 400 | 5.5 | 1.229 | 0.1545 | 156 | 1,151.08 | 1,153.016 | 1.50 | Phase I |
| (B-8) | | | 145.3 | 0.076 | | 0.069 | (375) | | | | | 1,150.22 | 1,153.516 | 2.86 | |
| | (A-9) | | | | | | | | | | | | | | |

## Table H-5 Computation Form for the Proposed Trunk Sewers to be replaced in the Central WTD

| Sewer Line No. | | Wastewater Treatment District (Unit DFR= 0.000525) | | | Point Source | Design Flowrate in 2005 | Design Sewer | | | | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | increment | Cu. Total | Flow | | | Dia. | Slope | Velocity | Capacity | Length | Invert Elevation | Ground Surface Elevation | Earth Cover | |
| From | To | ha | ha | $m^3/S$ | $m^3/S$ | $m^3/S$ | mm | o/oo | m/S | $m^3/S$ | m | m | m | m | |
| RP-7 | | | | | | | 600 | 3.0 | 1.189 | 0.3362 | 499 | 1,150.02 | 1,153.516 | 2.85 | Phase II |
| (A-9) | | | 251.9 | 0.132 | | 0.121 | (525) | | | | | 1,148.52 | 1,152.144 | 2.97 | |
| RP-8 | | | | | | | 600 | 3.0 | 1.189 | 0.3362 | 400 | 1,148.32 | 1,152.144 | 3.17 | Phase II |
| (A-10) | | | 259.8 | 0.136 | | 0.124 | (525) | | | | | 1,147.12 | 1,150.620 | 2.85 | |
| | A-11 | | | | | | | | | | | 1,145.98 | 1,150.620 | | |
| RP-9 | | | | | | | 350 | 4.0 | 0.959 | 0.0923 | 803 | 1,155.08 | 1,159.060 | 3.60 | Phase I |
| (D-2) | | | 78.1 | 0.041 | | 0.037 | (300) | | | | | 1,147.40 | 1,149.197 | 1.42 | |
| | (A-13) | | | | | | | | | | | 1,147.40 | 1,149.197 | | |
| RP-10 | | | | | | | 700 | 3.0 | 1.318 | 0.5073 | 7 | 1,147.40 | 1,149.197 | 1.04 | Phase II |
| (A-13) | | | 382.6 | 0.201 | | 0.184 | | | | | | 1,147.38 | 1,150.011 | 1.87 | |
| RP-11 | | | | | | | 700 | 3.0 | 1.318 | 0.5073 | 424 | 1,147.38 | 1,150.011 | 1.87 | Phase II |
| (A-14) | | | 397.5 | 0.209 | | 0.191 | (600) | | | | | 1,146.11 | | | |
| | Conventional STW | | | | | | | | | | | | | | |
| RP-12 | Rising Trunk Sewer from Mumias Road P.S. | | | | | | 200 | | | | 860 | 1,135.27 | 1,139.053 | | Phase II |
| | | | | | | | | | | | | | 1,141.200 | 1.50 | |
| | Conventional STW | | | | | | | | | | | | | | |

## Table H-6 Examination of Capacity of Existing Trunk Sewers in Eastern WTD

| Sewer Line No. | | Wastewater Treatment District: Unit DFR 0.000291 Sub-district A | | | Unit DFR 0.000227 Sub-district B | | | Existing Pipe Capacity | Total Design Flow Rate | Existing Trunk Sewer: Dia. | Slope | Velocity | Capacity | Length | Invert Elevation | Ground Surface Elevation | Earth Cover | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| From | To | increment ha | Cu. Total ha | Flow m³/S | increment ha | Cu. Total ha | Flow m³/S | m³/S | m³/S | mm | o/oo | m/S | m³/S | m | m | m | m | |
| A-1 | | 8.9 | | | | | | | | 175 | | | | 305 | 1,168.413 | 1,169.822 | 1.207 | Ex: 8.9 ha |
| | | | 8.9 | 0.003 | | | | 0.020 | 0.003 | | | | | | | | | |
| A-2 | | 2.6 | | | | | | | | 175 | | | | 118 | 1,163.911 | 1,165.860 | 1.747 | Ex: 2.6 ha |
| | | 13.5 | 25.0 | 0.007 | | | | 0.022 | 0.007 | | | | | | | | | |
| A-3 | | 4.8 | | | | | | | | 225 | | | | 323 | 1,162.360 | 1,162.812 | 0.200 | Ex: 4.8 ha |
| | | | 29.8 | 0.009 | | | | 0.020 | 0.009 | | | | | | | | | (cu. 16.3 ha) |
| | | | | | | | | | | | | | | | 1,161.290 | 1,162.812 | | |
| | A-4 | | | | | | | | | | | | | | | | | |
| B-1 | | 30.1 | | | | | | | | 225 | | | | 415 | 1,165.240 | 1,167.384 | 1.892 | Ex: 30.1 ha |
| | | | 30.1 | 0.009 | | | | 0.023 | 0.009 | | | | | | | | | |
| | A-4 | | | | | | | | | | | | | | 1,161.290 | 1,162.812 | | |
| | | | | | | | | | | | | | | | | | | (cu.: 59.5 ha) |
| A-4 | | 13.1 | | | | | | | | 225 | | | | 418 | 1,161.290 | 1,162.812 | 1.270 | Ex: 13.1 ha |
| | | | 73.0 | 0.021 | | | | 0.039 | 0.021 | | | | | | | | | |
| | A-5 | | | | | | | | | | | | | | 1,152.631 | 1,153.668 | | |
| C-3 | | 3.0+23.2 | | | | | | | | 375 | | | | 420 | 1,157.032 | 1,157.478 | 0.039 | Ex: 59.1 ha |
| | | 32.9 | 59.1 | 0.017 | | | | 0.085 | 0.017 | | | | | | | | | |
| C-7 | | 29.3 | | | | | | | | 375 | | | | 211 | 1,155.523 | 1,157.326 | 1.396 | Ex: 20 ha |
| | | 1.5 | 89.9 | 0.026 | | | | 0.090 | 0.026 | | | | | | | | | |
| C-8 | | 10.2 | | | | | | | | 375 | | | | 599 | 1,154.746 | 1,156.106 | 0.953 | Ex: 15 ha |
| | | 22.8 | 122.9 | 0.036 | | | | 0.082 | 0.036 | | | | | | | | | (cu.94.1 ha) |
| | A-5 | | | | | | | | | | | | | | 1,152.631 | 1,153.668 | | |
| A-5 | | 3.9 | 195.9 | | | | | | | N/A | | | | 14 | 1,152.631 | 1,153.668 | | Replace (⑰) |
| | | | 199.8 | 0.058 | | | | | 0.058 | | | | | | | | | |

## Table H-6 Examination of Capacity of Existing Trunk Sewers in Eastern WTD

| Sewer Line No. | | Wastewater Treatment District | | | | | | Existing Pipe Capacity | Total Design Flow Rate | Existing Trunk Sewer | | | | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Unit DFR 0.000291 Sub-district A | | | Unit DFR 0.000227 Sub-district B | | | | | Dia. | Slope | Velocity | Capacity | Length | Invert Elevation | Ground Surface Elevation | Earth Cover | |
| | | increment | Cu. Total | Flow | increment | Cu. Total | Flow | | | | | | | | | | | |
| From | To | ha | ha | $m^3/S$ | ha | ha | $m^3/S$ | $m^3/S$ | $m^3/S$ | mm | o/oo | m/S | $m^3/S$ | m | m | m | m | |
| | | | | | | | | | | 375 | | | | 381 | 1,152.542 | 1,154.303 | 1.354 | Replace ((18)) |
| A-6 | | 29.7 | | | | | | | | | | | | | | | | |
| | | | | | | | | 0.114 | 0.070 | | | | | | | | | |
| | | 11.2 | 240.7 | 0.070 | | | | | | 450 | | | | 325 | 1,143.998 | 1,145.671 | 1.185 | Replace ((19)) |
| A-7 | | 1.0 | | | | | | | | | | | | | | | | |
| | | | | | | | | 0.205 | 0.125 | | | | | | | | | |
| | | 187.0 | 428.7 | 0.125 | | | | | | | | | | | 1,140.138 | 1,141.138 | | Ex: 6 ha |
| | A-8 | | | | | | | | | | | | | | | | | (cu.159.6ha) |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | 225 | | | | 165 | 1,179.586 | 1,181.466 | 1.628 | Ex: 18.1 ha |
| D-1 | | 13.4 | | | | | | | | | | | | | | | | |
| | | | | | | | | 0.017 | 0.004 | | | | | | | | | |
| | | | 13.4 | 0.004 | | | | | | 225 | | | | 687 | 1,179.078 | 1,180.643 | 1.313 | |
| D-2 | | 35.0 | | | | | | | | | | | | | | | | |
| | | | | | | | | 0.036 | 0.014 | | | | | | | | | |
| | | | 48.4 | 0.014 | | | | | | 225 | | | | 1,012 | 1,171.172 | 1,172.500 | 1.076 | Ex: 26.4 ha |
| | | | | | | | | 0.025 – | | | | | | | | | | |
| D-3 | | 44.5 | | | | | | | | | | | | | | | | |
| | | | | | | | | 0.089 | 0.027 | | | | | | | | | |
| | | | 92.9 | 0.027 | | | | | | 300 | | | | 588 | 1,147.822 | 1,149.471 | 1.319 | |
| D-4 | | 18.7 | | | | | | | | | | | | | | | | |
| | | | | | | | | 0.057 | 0.032 | | | | | | | | | |
| | | | 111.6 | 0.032 | | | | | | 300 | | | | 205 | 1,143.820 | 1,147.015 | 2.865 | Ex: 10 ha |
| D-5 | | 20.7 | | | | | | | | | | | | | | | | |
| | | | | | | | | 0.089 | 0.038 | | | | | | | | | |
| | | | 132.3 | 0.038 | | | | | | 375 | | | | 526 | 1,141.375 | 1,144.067 | 2.285 | |
| D-6 | | 21.3 | | | | | | | | | | | | | | | | (cu. 54.5 ha) |
| | | | | | | | | 0.064 | 0.045 | | | | | | | | | |
| | | | 153.6 | 0.045 | | | | | | | | | | | 1,140.138 | 1,141.138 | | |
| | A-8 | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | 327 | 1,140.138 | 1,141.138 | 0.267 | (cu. 214.1ha) |
| A-8 | | 1.3 | | | | | | × | | 675 | | | | | | | | Replace |
| | | | 583.6 | 0.170 | | | | 0.126 | 0.170 | | | | | 558 | 1,139.782 | 1,140.782 | 0.267 | Replace |
| A-9 | | 0 | | | | | | × | | 675 | | | | | | | | |
| | | | 583.6 | 0.170 | | 1382.6 | 0.314 | 0.252 | 0.422 | | | | | 302 | 1,138.887 | 1,139.887 | 0.267 | Replace |
| A-10 | | 0 | | | | | | × | | 675 | | | | | | | | |
| | | | 583.6 | 0.170 | | | | 0.273 | 0.422 | | | | | | 1,138.461 | 1,139.461 | | |
| | (to Nyalenda Wastewater Treatment Work) | | | | | | | | | | | | | | | | | |

# Table H-7 Computation Form for the Proposed Trunk Sewers in Eastern WTD

| Sewer Line No. | | Wastewater Treatment District | | | | | | | | | | Total Design Flow Rate | Design Sewer | | | | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Unit DFR 0.000227 Sub-district B | | | Unit DFR: 0.000292 Sub-district A | | | Unit DFR: 0.001105 Sub-district C | | | Total Area | | Dia. | Slope | Velocity | Capacity | Length | Invert Elevation | Ground Surface Elevation | Earth Cover | |
| | | increment | Cu. Total | Flow | increment | Cu. Total | Flow | increment | Cu. Total | Flow | | | | | | | | | | | |
| From | To | ha | ha | $m^3/S$ | ha | ha | $m^3/S$ | ha | ha | $m^3/S$ | ha | $m^3/S$ | mm | o/oo | m/S | $m^3/S$ | m | m | m | m | |
| 1 | | 112.5 | 112.5 | 0.026 | | | | | | | | 0.026 | 250 | 12.0 | 1.327 | 0.0651 | 860 | 1186.55 | 1,189.33 | 2.50 | |
| | | | | | | | | | | | | | | | | | | 1176.23 | 1,179.58 | 3.07 | |
| 2 | | 135.8 | 248.3 | 0.056 | | | | | | | | 0.056 | 350 | 8.0 | 1.356 | 0.1305 | 1,190 | 1175.93 | 1,179.58 | | |
| | | | | | | | | | | | | | | | | | | 1,166.41 | 1,168.30 | 1.51 | |
| 3 | | 29.0 | 277.3 | 0.063 | | | | | | | | 0.063 | 350 | 7.6 | 1.322 | 0.1272 | 280 | 1,166.31 | 1,168.30 | | |
| | | | | | | | | | | | | | | | | | | 1,164.18 | 1,166.77 | 2.21 | |
| 4 | | 14.7 | 292.0 | 0.066 | | | | | | | | 0.066 | 400 | 5.5 | 1.229 | 0.1545 | 460 | 1,164.08 | 1,166.77 | | |
| | | | | | | | | | | | | | | | | | | 1,161.55 | 1,163.73 | 1.74 | |
| 5 | | 109.2 | 401.2 | 0.091 | | | | | | | | 0.091 | 450 | 5.0 | 1.267 | 0.2015 | 560 | 1,161.35 | 1,163.73 | | |
| | | | | | | | | | | | | | | | | | | 1,158.55 | 1,161.29 | 2.25 | |
| 6 | | 29.0 | 430.2 | 0.098 | | | | | | | | 0.098 | 600 | 2.1 | 0.995 | 0.2814 | 1,000 | 1,158.35 | 1,161.29 | | |
| | | | | | | | | | | | | | | | | | | 1,156.25 | 1,161.29 | 4.39 | |
| 7 | | 11.4 | 441.6 | 0.100 | | | | | | | | 0.100 | 600 | 2.0 | 0.971 | 0.2746 | 520 | 1,155.95 | 1,161.29 | | |
| | | | | | | | | | | | | | | | | | | 1,154.91 | 1,158.24 | 2.68 | |
| | 12 | | | | | | | | | | | | | | | | | | | | |
| 8 | | 82.0 | 82.0 | 0.019 | | | | | | | | 0.019 | 250 | 28.0 | 2.027 | 0.0995 | 530 | 1,198.13 | 1,200.91 | 2.50 | |
| | | | | | | | | | | | | | | | | | | 1,183.29 | 1,185.67 | 2.10 | |
| 9 | | 277.4 | 359.4 | 0.082 | | | | | | | | 0.082 | 350 | 17.0 | 1.977 | 0.1902 | 1,070 | 1,183.09 | 1,185.67 | 2.20 | |
| | | | | | | | | | | | | | | | | | | 1,164.90 | 1,167.38 | 2.10 | |
| 10 | | 112.7 | 472.1 | 0.107 | | | | | | | | 0.107 | 450 | 6.2 | 1.411 | 0.2244 | 960 | 1,164.60 | 1,167.38 | 2.29 | |
| | | | | | | | | | | | | | | | | | | 1,158.69 | 1,160.68 | 1.50 | |
| 11 | | 62.2 | 534.3 | 0.121 | | | | | | | | 0.121 | 500 | 5.0 | 1.360 | 0.2671 | 400 | 1,158.39 | 1,160.68 | 1.75 | |
| | | | | | | | | | | | | | | | | | | 1,156.19 | 1,158.24 | 1.51 | |
| 12 | | 28.4 | 1,004.3 | 0.228 | | | | | | | | 0.228 | 700 | 3.2 | 1.361 | 0.5238 | 870 | 1,155.69 | 1,158.24 | 1.79 | |
| | | | | | | | | | | | | | | | | | | 1,152.93 | 1,155.19 | 1.50 | |
| | 14 | | | | | | | | | | | | | | | | | | | | |
| 13 | | 180.9 | 180.9 | 0.041 | | | | | | | | 0.041 | 350 | 5.0 | 1.072 | 0.1032 | 1,040 | 1,158.41 | 1,161.29 | 2.50 | |
| | | | | | | | | | | | | | | | | | | 1,153.21 | 1,155.19 | 1.60 | |
| 14 | | 71.6 | 1,256.8 | 0.285 | | | | | | | | 0.285 | 800 | 2.6 | 1.341 | 0.6741 | 520 | 1,151.13 | 1,155.19 | 3.33 | |
| | | | | | | | | | | | | | | | | | | 1,149.77 | 1,152.14 | 1.50 | |

# Table H-7 Computation Form for the Proposed Trunk Sewers in Eastern WTD

| Sewer Line No. | | Wastewater Treatment District | | | | | | | | | | Total Design Flow Rate | Design Sewer | | | | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Unit DFR 0.000227 Sub-district B | | | Unit DFR 0.000292 Sub-district A | | | Unit DFR: 0.001105 Sub-district C | | | Total Area | | Dia. | Slope | Velocity | Capacity | Length | Invert Elevation | Ground Surface Elevation | Earth Cover | |
| | | increment | Cu. Total | Flow | increment | Cu. Total | Flow | increment | Cu. Total | Flow | | | | | | | | | | | |
| From | To | ha | ha | $m^3/S$ | ha | ha | $m^3/S$ | ha | ha | $m^3/S$ | ha | $m^3/S$ | mm | o/oo | m/S | $m^3/S$ | m | m | m | m | |
| | | | | | | | | | | | | 0.306 | 800 | 2.1 | 1.205 | 0.6058 | 1,470 | 1,147.85 | 1,152.14 | 3.47 | |
| 15 | | 91.7 | 1,348.5 | 0.306 | | | | | | | | | | | | | | 1,140.93 | 1,143.30 | 1.50 | |
| | | | | | | | | | | | 1,382.6 | 0.314 | 800 | 2.1 | 1.205 | 0.6058 | 810 | 1,140.00 | 1,143.30 | 2.57 | |
| 16 | | 34.1 | 1,382.6 | 0.314 | | | | | | | | | | | | | | 1,138.30 | 1,140.66 | 1.50 | |
| | 32 | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | 0.003 | 175 | | | | 305 | 1,168.413 | 1,169.822 | 1.207 | Ex: 8.9 ha |
| A-1 | | | | | 8.9 | | | | | | | | | | | 0.020 | | 1,163.911 | 1,165.860 | | |
| | | | | | | 8.9 | 0.003 | | | | | 0.007 | 175 | | | | 118 | 1,163.911 | 1,165.860 | 1.747 | Ex: 2.6 ha |
| A-2 | | | | | 2.6 | | | | | | | | | | | 0.022 | | 1,162.360 | 1,162.812 | | |
| | | | | | 13.5 | 25.0 | 0.007 | | | | | 0.009 | 225 | | | | 323 | 1,162.360 | 1,162.812 | 0.200 | Ex: 4.8 ha |
| A-3 | | | | | 4.8 | | | | | | | | | | | 0.020 | | 1,161.290 | 1,162.812 | | (cu. 16.3 ha) |
| | | | | | | 29.8 | 0.009 | | | | | | | | | | | | | | |
| | A-4 | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | 0.009 | 225 | | | | 415 | 1,165.240 | 1,167.384 | 1.892 | Ex: 30.1 ha |
| B-1 | | | | | 30.1 | | | | | | | | | | | 0.023 | | 1,161.290 | 1,162.812 | | |
| | | | | | | 30.1 | 0.009 | | | | | | | | | | | | | | |
| | A-4 | | | | | | | | | | | | | | | | | | | | (cu.: 59.5 ha) |
| | | | | | | | | | | | | 0.021 | 225 | | | | 418 | 1,161.290 | 1,162.812 | 1.270 | Ex: 13.1 ha |
| A-4 | | | | | 13.1 | | | | | | | | | | | 0.039 | | 1,152.631 | 1,153.668 | | |
| | | | | | | 73.0 | 0.021 | | | | | | | | | | | | | | |
| | 17 | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | 0.017 | 375 | | | | 420 | 1,157.032 | 1,157.478 | 0.039 | Ex: 59.1 ha |
| C-3 | | | | | 3.0+23.2 | | | | | | | | | | | 0.085 | | 1,155.523 | 1,157.326 | | Replace |
| to be Replaced | | | | | 32.9 | 59.1 | 0.017 | | | | | 0.026 | 375 | | | | 211 | 1,155.523 | 1,157.326 | 1.396 | Ex: 20 ha |
| C-7 | | | | | 29.3 | | | | | | | | | | | 0.090 | | 1,154.746 | 1,156.106 | | |
| | | | | | 1.5 | 89.9 | 0.026 | | | | | | | | | | | | | | |

# Table H-7 Computation Form for the Proposed Trunk Sewers in Eastern WTD

| Sewer Line No. From | Sewer Line No. To | Sub-district B (Unit DFR 0.000227) increment ha | Sub-district B Cu. Total ha | Sub-district B Flow m³/S | Sub-district A (Unit DFR 0.000292) increment ha | Sub-district A Cu. Total ha | Sub-district A Flow m³/S | Sub-district C (Unit DFR: 0.001105) increment ha | Sub-district C Cu. Total ha | Sub-district C Flow m³/S | Total Area ha | Total Design Flow Rate m³/S | Dia. mm | Slope o/oo | Velocity m/S | Capacity m³/S | Length m | Invert Elevation m | Ground Surface Elevation m | Earth Cover m | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C-8 | | | | | 10.2 | | | | | | | 0.036 | 375 | | | | 599 | 1,154.746 | 1,156.106 | 0.953 | Ex: 15 ha |
| | | | | | 22.8 | 122.9 | 0.036 | | | | | | | | | 0.082 | | 1,152.631 | 1,153.668 | | (cu.94.1 ha) |
| | 17 | | | | | | | | | | | | | | | | | | | | |
| 17 | | | | | 3.9 | 195.9 | | | | | | 0.058 | 400 | 5.0 | 1.172 | 0.1473 | 14 | 1,151.73 | 1,153.67 | 1.53 | Ex: 6 ha |
| | | | | | | 199.8 | 0.058 | | | | | | | | | | | 1,151.66 | 1,154.30 | 2.21 | (cu.159.6ha) |
| 18 | | | | | 29.7 | | | | | | | 0.070 | 400 | 5.0 | 1.172 | 0.1473 | 381 | 1,151.46 | 1,154.30 | 2.44 | |
| | | | | | 11.2 | 240.7 | 0.070 | | | | | | | | | | | 1,143.74 | 1,145.67 | 1.50 | |
| 19 | | | | | 1.0 | | | | | | | 0.071 | 400 | 5.0 | 1.172 | 0.1473 | 325 | 1,143.44 | 1,145.67 | 1.83 | |
| | | | | | | 241.7 | 0.071 | | | | | | | | | | | 1,139.20 | 1,141.14 | 1.50 | |
| | 30 | | | | | | | | | | | | | | | | | | | | |
| 20 | | | | | 28.6 | 28.6 | 0.008 | | | | | 0.008 | 250 | 3.0 | 0.663 | 0.0325 | 500 | 1,145.79 | 1,147.57 | 1.50 | |
| | | | | | | | | | | | | | | | | | | 1,144.01 | 1,146.66 | 2.37 | |
| 21 | | | | | 11.4 | 40.0 | 0.012 | | | | | 0.012 | 250 | 8.0 | 1.083 | 0.0532 | 460 | 1,148.84 | 1,150.62 | 1.50 | |
| | | | | | | | | | | | | | | | | | | 1,144.88 | 1,146.66 | 1.50 | |
| | to Labour College Pump Station | | | | | | | | | | | | | | | | | | | | |
| 22 | Rising Trunk Sewer | | | | | | | | | | | 0.012 | 125 | | | | 530 | 1,145.01 | 1,146.66 | 1.50 | |
| | | | | | | | | | | | | | | | | | | 1,148.97 | 1,150.62 | 1.50 | |
| | 24 | | | | | | | | | | | | | | | | | | | | |
| 23 | | | | | 40.6 | 40.6 | 0.012 | | | | | 0.012 | 250 | 16.0 | 1.532 | 0.0752 | 820 | 1,161.96 | 1,164.34 | 2.13 | |
| | | | | | | | | | | | | | | | | | | 1,148.84 | 1,150.62 | 1.50 | |
| 24 | | | | | 12.2 | 92.8 | 0.027 | | | | | 0.027 | 350 | 2.5 | 0.758 | 0.0729 | 580 | 1,148.79 | 1,150.62 | 1.50 | |
| | | | | | | | | | | | | | | | | | | 1,147.34 | 1,151.53 | 3.81 | |
| | 27 | | | | | | | | | | | | | | | | | | | | |

# Table H-7 Computation Form for the Proposed Trunk Sewers in Eastern WTD

| Sewer Line No. | | Wastewater Treatment District: Unit DFR 0.000227 Sub-district B | | | Unit DFR: 0.000292 Sub-district A | | | Unit DFR: 0.001105 Sub-district C | | | Total Area | Total Design Flow Rate | Design Sewer: Dia. | Slope | Velocity | Capacity | Length | Invert Elevation | Ground Surface Elevation | Earth Cover | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| From | To | increment | Cu. Total | Flow | increment | Cu. Total | Flow | increment | Cu. Total | Flow | | | | | | | | | | | |
| | | ha | ha | m³/S | ha | ha | m³/S | ha | ha | m³/S | ha | m³/S | mm | o/oo | m/S | m³/S | m | m | m | m | |
| 25 | | | | | 24.6 | 24.6 | 0.007 | | | | | 0.007 | 250 | 25.0 | 1.915 | 0.0940 | 420 | 1,166.63 | 1,168.91 | 2.00 | |
| | | | | | | | | | | | | | | | | | | 1,156.13 | 1,159.46 | 3.05 | |
| 26 | | | | | 12.3 | 36.9 | 0.011 | | | | | 0.011 | 250 | 20.0 | 1.713 | 0.0841 | 380 | 1,155.93 | 1,159.46 | 3.28 | |
| | | | | | | | | | | | | | | | | | | 1,148.33 | 1,151.53 | 2.92 | |
| 27 | | | | | 3.9 | 133.6 | 0.039 | | | | | 0.039 | 400 | 2.5 | 0.829 | 0.1042 | 380 | 1,147.14 | 1,151.53 | 3.98 | |
| | | | | | | | | | | | | | | | | | | 1,146.19 | 1,153.06 | 6.43 | |
| 28 | | | | | 30.7 | 164.3 | 0.048 | | | | | 0.048 | 400 | 2.5 | 0.829 | 0.1042 | 430 | 1,145.99 | 1,153.06 | 6.66 | |
| | | | | | | | | | | | | | | | | | | 1,144.92 | 1,150.62 | 5.27 | |
| 29 | | | | | 22.7 | 187.0 | 0.055 | | | | | 0.055 | 450 | 2.5 | 0.896 | 0.1425 | 780 | 1,144.72 | 1,150.62 | 5.42 | |
| | | | | | | | | | | | | | | | | | | 1,141.01 | 1,143.00 | 1.50 | |
| | 30 | | | | | | | | | | | | | | | | | | | | |
| 30 | | | | | | 428.7 | 0.125 | 1.30 | 1.30 | 0.001 | | 0.125 | 600 | 1.6 | 0.869 | 0.2457 | 178 | 1,139.00 | 1,143.00 | 3.35 | |
| | | | | | | | | | | | | | | | | | | 1,138.72 | 1,141.14 | 2.42 | |
| | 31 | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | 165 | 1,179.586 | 1,181.466 | 1.63 | Ex: 18.1 ha |
| D-1 | | | | | 13.4 | | | | | | | 0.004 | 225 | | | 0.017 | | | | | |
| | | | | | | 13.4 | 0.004 | | | | | | | | | | 687 | 1,179.078 | 1,180.643 | 1.31 | |
| D-2 | | | | | 35.0 | | | | | | | 0.014 | 225 | | | 0.036 | | | | | |
| | | | | | | 48.4 | 0.014 | | | | | | | | | 0.025~ | 1,012 | 1,171.172 | 1,172.500 | 1.08 | Ex: 26.4 ha |
| D-3 | | | | | 44.5 | | | | | | | 0.027 | 225 | | | 0.089 | | | | | |
| | | | | | | 92.9 | 0.027 | | | | | | | | | 0.057 | 588 | 1,147.822 | 1,149.471 | 1.32 | |
| D-4 | | | | | 18.7 | | | | | | | 0.033 | 300 | | | | | | | | |
| | | | | | | 111.6 | 0.033 | | | | | | | | | 0.089 | 205 | 1,143.820 | 1,147.015 | 2.87 | Ex: 10 ha |
| D-5 | | | | | 20.7 | | | | | | | 0.039 | 300 | | | | | | | | |
| | | | | | | 132.3 | 0.039 | | | | | | | | | 0.064~ | 526 | 1,141.375 | 1,144.067 | 2.29 | |
| D-6 | | | | | 21.3 | | | | | | | 0.045 | 375 | | | 0.373 | | | | | (cu. 54.5 ha) |
| | | | | | | 153.6 | 0.045 | | | | | | | | | | | | | | |
| | 31 | | | | | | | | | | | | | | | | | | | | |

# Table H-7 Computation Form for the Proposed Trunk Sewers in Eastern WTD

| Sewer Line No. | | Wastewater Treatment District | | | | | | | | | | Total Design Flow Rate | Design Sewer | | | | | | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Unit DFR 0.000227 Sub-district B | | | Unit DFR 0.000292 Sub-district A | | | Unit DFR: 0.001105 Sub-district C | | | Total Area | | Dia. | Slope | Velocity | Capacity | Length | Invert Elevation | Ground Surface Elevation | Earth Cover | |
| | | increment | Cu. Total | Flow | increment | Cu. Total | Flow | increment | Cu. Total | Flow | | | | | | | | | | | |
| From | To | ha | ha | m³/S | ha | ha | m³/S | ha | ha | m³/S | ha | m³/S | mm | o/oo | m/S | m³/S | m | m | m | m | |
| 31 | | | | | | 582.3 | 0.170 | 2.6 | 3.90 | 0.004 | | | 700 | 1.4 | 0.900 | 0.3464 | 340 | 1,138.52 | 1,141.14 | 1.89 | |
| | | | | | | | | | | | 586.2 | 0.170 | | | | | | 1,138.04 | 1,140.66 | 1.89 | |
| 32 | | 0.0 | 1,382.6 | 0.314 | | | | | | | | | 1100 | 1.2 | 1.127 | 1.0712 | 380 | 1,137.94 | 1,140.66 | 1.99 | |
| | | | | | | | | | | | 1,968.8 | 0.484 | | | | | | 1,137.49 | 1,139.44 | 1.22 | |
| | 36 | | | | | | | | | | | | | | | | | | | | |
| 33 | | | | | | | | 34.5 | 38.4 | 0.042 | | 0.042 | 450 | 1.2 | 0.621 | 0.0988 | 1,100 | 1,141.50 | 1,143.00 | 1.50 | |
| | | | | | | | | | | | | | | | | | | 1,140.18 | 1,143.00 | 2.82 | |
| 34 | | | | | | | | 44.5 | 82.9 | 0.092 | | 0.092 | 600 | 1.1 | 0.720 | 0.2036 | 1,330 | 1,139.88 | 1,143.00 | 2.47 | |
| | | | | | | | | | | | | | | | | | | 1,138.42 | 1,139.95 | 1.53 | |
| 35 | | | | | | | | 13.5 | 96.4 | 0.107 | | 0.107 | 600 | 1.1 | 0.720 | 0.2036 | 260 | 1,137.82 | 1,139.95 | 1.48 | |
| | | | | | | | | | | | | | | | | | | 1,137.53 | 1,139.25 | 1.72 | |
| 36 | | 0.0 | 1,382.6 | 0.314 | 0.0 | 582.3 | 0.170 | 0.0 | 96.4 | 0.106 | 2,061.3 | 0.590 | 1100 | 1.2 | 1.127 | 1.0712 | 220 | 1,137.49 | 1,139.44 | 1.22 | |
| | | | | | | | | | | | | | | | | | | 1,137.22 | 1,139.33 | 2.11 | |
| 37 | | 0.0 | 1,382.6 | 0.314 | 0.0 | 582.3 | 0.170 | 0.0 | 96.4 | 0.106 | 2,061.3 | 0.590 | 1100 | 1.2 | 1.127 | 1.0712 | 300 | 1,137.22 | 1,139.33 | 1.37 | |
| | | | | | | | | | | | | | | | | | | 1,136.86 | 1,138.99 | 0.94 | |
| | | | | | | | | | | | | | | | | | | | | | Inlet Works of |
| | to Nyalenda STW Pump Station | | | | | | | | | | | | | | | | | | | | STW |
| | | | | | | | | | | | | | | | | | | | | | 1138.413 m |

## Table H-8 Computation Form for the Proposed Trunk Sewers in Western WTD

| Sewer Line No. | | Wastewater Treatment District: Unit DFR 0.000256 Sub District - A | | | Unit DFR: 0.000227 Sub-District B | | | Unit DFR: 0.000159 Sub-District C | | | Total Area | Design Flow Rate | Point Source | Total Design Flow Rate | Design Sewer: Dia. | Slope | Velocity | Capacity | Length | Invert Elevation | Ground Surface Elevation | Earth Cover | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | increment | Cu. Total | Flow | increment | Cu. Total | Flow | increment | Cu. Total | Flow | | | | | | | | | | | | | |
| From | To | ha | ha | $m^3/S$ | ha | ha | $m^3/S$ | ha | ha | $m^3/S$ | ha | $m^3/S$ | $m^3/S$ | $m^3/S$ | mm | o/oo | m/S | $m^3/S$ | m | m | m | m | |
| 1 | | 134.1 | 134.1 | 0.034 | | | | | | | | 0.034 | | 0.034 | 300 | 9.0 | 1.298 | 0.0918 | 1,340 | 1,170.01<br>1,157.95 | 1,171.96<br>1,169.82 | 1.62<br>11.54 | |
| 2 | | 84.5 | 218.6 | 0.056 | | | | | | | | 0.056 | | 0.056 | 350 | 9.0 | 1.438 | 0.1384 | 610 | 1,157.55<br>1,152.06 | 1,169.82<br>1,163.73 | 11.89<br>11.29 | |
| 3 | | 87.4 | 306.0 | 0.078 | | | | | | | 306.0 | 0.078 | | 0.078 | 400 | 8.0 | 1.482 | 0.1863 | 930 | 1,151.86<br>1,144.42 | 1,163.73<br>1,146.35 | 11.44<br>1.50 | |
| | 7 | | | | | | | | | | | | | | | | | | | | | | |
| 4 | | 107.4 | 107.4 | 0.027 | | | | | | | | 0.027 | | 0.027 | 250 | 10.0 | 1.211 | 0.0595 | 680 | 1,161.67<br>1,154.87 | 1,164.95<br>1,158.24 | 3.00<br>3.09 | |
| 5 | | 67.3 | 174.7 | 0.045 | | | | | | | | 0.045 | | 0.045 | 300 | 9.0 | 1.298 | 0.0918 | 540 | 1,154.67<br>1,149.81 | 1,158.24<br>1,152.14 | 3.24<br>2.00 | |
| 6 | | 45.9 | 220.6 | 0.056 | | | | | | | | 0.056 | | 0.056 | 350 | 8.5 | 1.398 | 0.1345 | 670 | 1,149.61<br>1,143.92 | 1,152.14<br>1,146.35 | 2.15<br>2.05 | |
| 7 | | 118.7 | 645.3 | 0.165 | | | | | | | | 0.165 | | 0.165 | 500 | 8.0 | 1.720 | 0.3378 | 620 | 1,143.72<br>1,138.76 | 1,146.35<br>1,141.78 | 2.09<br>2.48 | |
| 8 | | 145.2 | 790.5 | 0.202 | | | | | | | 790.5 | 0.202 | | 0.202 | 600 | 7.5 | 1.881 | 0.5319 | 410 | 1,137.83<br>1,134.75 | 1,141.78<br>1,136.90 | 3.30<br>1.50 | |
| | to the proposed Kombedu Pump Station | | | | | | | | | | | | | | | | | | | | | | |
| 9 | | 97.2 | 97.2 | 0.025 | | | | | | | 887.7 | 0.025 | | 0.025 | 250 | 9.0 | 1.149 | 0.0564 | 540 | 1,139.72<br>1,134.86 | 1,143.00<br>1,136.90 | 3.00<br>1.76 | |
| | to the proposed Kombedu Pump Station | | | | | | | | | | | | | | | | | | | | | | |
| 10 | | 68.1 | 68.1 | 0.017 | | | | | | | | 0.017 | | 0.017 | 400 | 1.4 | 0.620 | 0.0779 | 720 | 1,135.91<br>1,134.90 | 1,139.34<br>1,140.26 | 3.00<br>4.92 | |
| 11 | | 126.5 | 194.6 | 0.050 | | | | | | | | 0.050 | | 0.050 | 450 | 1.2 | 0.621 | 0.0988 | 60 | 1,134.60<br>1,134.53 | 1,140.26<br>1,140.56 | 5.17<br>5.54 | |
| 12 | | 61.1 | 255.7 | 0.065 | | | | | | | | 0.065 | | 0.065 | 500 | 1.2 | 0.666 | 0.1308 | 1,280 | 1,134.51<br>1,132.97 | 1,140.56<br>1,138.43 | 5.51<br>4.92 | |
| 13 | | 21.7 | 277.4 | 0.071 | | | | | | | 1,165.1 | 0.071 | | 0.071 | 600 | 1.0 | 0.687 | 0.1943 | 220 | 1,132.57<br>1,132.35 | 1,138.43<br>1,136.90 | 5.21<br>3.90 | |
| | to the proposed Kombedu Pump Station | | | | | | | | | | | | | | | | | | | | | | |

## Table H-8 Computation Form for the Proposed Trunk Sewers in Western WTD

| Sewer Line No. From | Sewer Line No. To | Wastewater Treatment District: Unit DFR 0.000256, Sub District - A: increment (ha) | Sub District - A: Cu. Total (ha) | Sub District - A: Flow ($m^3/S$) | Unit DFR 0.000227, Sub-District B: increment (ha) | Sub-District B: Cu. Total (ha) | Sub-District B: Flow ($m^3/S$) | Unit DFR 0.000159, Sub-District C: increment (ha) | Sub-District C: Cu. Total (ha) | Sub-District C: Flow ($m^3/S$) | Total Area (ha) | Design Flow Rate ($m^3/S$) | Point Source ($m^3/S$) | Total Design Flow Rate ($m^3/S$) | Design Sewer: Dia. (mm) | Slope (o/oo) | Velocity (m/S) | Capacity ($m^3/S$) | Length (m) | Invert Elevation (m) | Ground Surface Elevation (m) | Earth Cover (m) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15 | | 0.0 | 1,165.1 | 0.298 | | | | | | | 1,165.1 | 0.298 | | 0.298 | 700 | | | | 1,500 | | 1,136.90 | 1.50 | |
| | | | | | | | | | | | | | | | | | | | | | 1,156.72 | 1.50 | |
| | 19 | Rising Trunk Sewer | | | | | | | | | | | | | | | | | | | | | |
| 16 | | | | | 118.3 | 118.3 | 0.027 | | | | | 0.027 | | 0.027 | 250 | 9.5 | 1.181 | 0.0580 | 600 | 1,165.21 | 1,167.99 | 2.50 | |
| | | | | | | | | | | | | | | | | | | | | 1,159.51 | 1,162.81 | 3.02 | |
| 17 | | | | | 88.7 | 207.0 | 0.047 | | | | | 0.047 | | 0.047 | 350 | 8.5 | 1.398 | 0.1345 | 530 | 1,159.31 | 1,162.81 | 3.12 | |
| | | | | | | | | | | | | | | | | | | | | 1,154.81 | 1,156.72 | 1.53 | |
| | 19 | | | | | | | | | | | | | | | | | | | | | | |
| 18 | | | | | 106.6 | 106.6 | 0.024 | | | | | 0.024 | | 0.024 | 350 | 2.0 | 0.678 | 0.0652 | 680 | 1,153.23 | 1,156.11 | 2.50 | |
| | | | | | | | | | | | | | | | | | | | | 1,151.87 | 1,156.72 | 4.47 | |
| | 19 | | | | | | | | | | | | | | | | | | | | | | |
| 19 | | | | | 1.5 | 315.1 | 0.072 | | | | 1,480.2 | 0.370 | | 0.370 | 900 | 1.7 | 1.173 | 0.7463 | 140 | 1,151.57 | 1,156.72 | 4.18 | |
| | | | | | | | | | | | | | | | | | | | | 1,151.33 | 1,156.41 | 4.10 | |
| 20 | | | | | 47.7 | 362.8 | 0.082 | | | | 1,527.9 | 0.380 | | 0.380 | 1000 | 1.3 | 1.101 | 0.8648 | 950 | 1,151.23 | 1,156.41 | 4.10 | |
| | | | | | | | | | | | | | | | | | | | | 1,150.00 | 1,157.63 | 6.55 | |
| 21 | | | | | 21.6 | 384.4 | 0.087 | | | | 1,549.5 | 0.385 | | 0.385 | 1000 | 1.2 | 1.057 | 0.8303 | 1,020 | 1,149.98 | 1,157.63 | 6.57 | |
| | | | | | | | | | | | | | | | | | | | | 1,146.52 | 1,149.10 | 1.50 | |
| 22 | | | | | 108.7 | 493.1 | 0.112 | | | | 1,658.2 | 0.410 | | 0.410 | 1000 | 1.2 | 1.057 | 0.8303 | 650 | 1,144.65 | 1,149.10 | 3.47 | |
| | | | | | | | | | | | | | | | | | | | | 1,139.81 | 1,142.39 | 1.50 | |
| | To the New Sewage Treatment Works (Otongolo STW) | | | | | | | | | | | | | | | | | | | | | | |

## Table H-8 Computation Form for the Proposed Trunk Sewers in Western WTD

| Sewer Line No. From | To | Sub District - A (Unit DFR 0.000256) increment ha | Cu. Total ha | Flow m³/S | Sub-District B (Unit DFR: 0.000227) increment ha | Cu. Total ha | Flow m³/S | Sub-District C (Unit DFR: 0.000159) increment ha | Cu. Total ha | Flow m³/S | Total Area ha | Design Flow Rate m³/S | Point Source m³/S | Total Design Flow Rate m³/S | Dia. mm | Slope o/oo | Velocity m/S | Capacity m³/S | Length m | Invert Elevation m | Ground Surface Elevation m | Earth Cover m | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31 | | | | | | | | 100.9 | 100.9 | 0.016 | | 0.016 | | 0.016 | 250 | 5.0 | 0.857 | 0.0421 | 600 | 1,165.63 | 1,168.91 | 3.00 | |
| | | | | | | | | | | | | | | | | | | | | 1,162.63 | 1,165.86 | 2.95 | |
| 32 | | | | | | | | 68.9 | 169.8 | 0.027 | | 0.027 | | 0.027 | 300 | 4.0 | 0.865 | 0.0612 | 600 | 1,162.43 | 1,165.86 | 3.10 | |
| | | | | | | | | | | | | | | | | | | | | 1,160.03 | 1,165.86 | 5.50 | |
| 33 | | | | | | | | 88.4 | 258.2 | 0.041 | 258.2 | 0.041 | | 0.041 | 400 | 3.0 | 0.908 | 0.1141 | 720 | 1,159.83 | 1,165.86 | 5.59 | |
| | | | | | | | | | | | | | | | | | | | | 1,157.67 | 1,167.38 | 9.28 | |
| | 36 | | | | | | | | | | | | | | | | | | | | | | |
| 34 | | | | | | | | 106.4 | 106.4 | 0.017 | | 0.017 | | 0.017 | 250 | 4.0 | 0.766 | 0.0376 | 610 | 1,168.68 | 1,171.96 | 3.00 | |
| | | | | | | | | | | | | | | | | | | | | 1,166.24 | 1,170.43 | 3.91 | |
| 35 | | | | | | | | 92.9 | 199.3 | 0.032 | | 0.032 | | 0.032 | 350 | 3.0 | 0.830 | 0.0799 | 590 | 1,166.04 | 1,170.43 | 4.01 | |
| | | | | | | | | | | | | | | | | | | | | 1,164.27 | 1,167.38 | 2.73 | |
| 36 | | | | | | | | 91.8 | 549.3 | 0.087 | | 0.087 | | 0.087 | 500 | 2.8 | 1.018 | 0.1999 | 60 | 1,157.47 | 1,167.38 | 9.37 | |
| | | | | | | | | | | | | | | | | | | | | 1,157.30 | 1,166.16 | 8.32 | |
| 37 | | | | | | | | 79.2 | 628.5 | 0.100 | 628.5 | 0.100 | | 0.100 | 500 | 2.8 | 1.018 | 0.1999 | 1,100 | 1,157.28 | 1,166.16 | 8.34 | |
| | | | | | | | | | | | | | | | | | | | | 1,142.18 | 1,144.22 | 1.50 | |
| | 42 | | | | | | | | | | | | | | | | | | | | | | |
| 38 | | | | | | | | 80.5 | 80.5 | 0.013 | | 0.013 | | 0.013 | 250 | 13.0 | 1.381 | 0.0678 | 1,110 | 1,161.06 | 1,164.34 | 3.00 | |
| | | | | | | | | | | | | | | | | | | | | 1,146.63 | 1,149.10 | 2.19 | |
| | 40 | | | | | | | | | | | | | | | | | | | | | | |
| 39 | | | | | | | | 117.7 | 117.7 | 0.019 | | 0.019 | | 0.019 | 250 | 7.0 | 1.013 | 0.0497 | 560 | 1,149.47 | 1,152.75 | 3.00 | |
| | | | | | | | | | | | | | | | | | | | | 1,145.55 | 1,149.10 | 3.27 | |
| 40 | | | | | | | | 9.3 | 207.5 | 0.033 | | 0.033 | | 0.033 | 350 | 4.0 | 0.959 | 0.0923 | 680 | 1,145.35 | 1,149.10 | 3.37 | |
| | | | | | | | | | | | | | | | | | | | | 1,142.63 | 1,146.05 | 3.04 | |
| 41 | | | | | | | | 59.2 | 266.7 | 0.042 | | 0.042 | | 0.042 | 350 | 4.0 | 0.959 | 0.0923 | 440 | 1,142.43 | 1,146.05 | 3.24 | |
| | | | | | | | | | | | | | | | | | | | | 1,140.67 | 1,144.22 | 3.17 | |
| 42 | | | | | | | | 78.9 | 974.1 | 0.155 | | 0.155 | | 0.155 | 600 | 2.8 | 1.149 | 0.3249 | 1,020 | 1,140.47 | 1,144.22 | 3.10 | |
| | | | | | | | | | | | | | | | | | | | | 1,137.61 | 1,146.96 | 8.70 | |
| 43 | | | | | | | | 0.2 | 974.3 | 0.155 | 974.3 | 0.155 | | 0.155 | 700 | 2.0 | 1.076 | 0.4141 | 400 | 1,137.31 | 1,146.96 | 8.89 | |
| | | | | | | | | | | | | | | | | | | | | 1,136.51 | 1,142.39 | 5.12 | |
| | To the New Sewage Treatment Works (Otongolo STW) | | | | | | | | | | | | | | | | | | | | | | |

## Table H-8 Computation Form for the Proposed Trunk Sewers in Western WTD

| Sewer Line No. From | Sewer Line No. To | Wastewater Treatment District: Unit DFR 0.000256, Sub District - A: increment | Sub District - A: Cu. Total | Sub District - A: Flow | Unit DFR: 0.000227, Sub-District B: increment | Sub-District B: Cu. Total | Sub-District B: Flow | Unit DFR: 0.000159, Sub-District C: increment | Sub-District C: Cu. Total | Sub-District C: Flow | Total Area | Design Flow Rate | Point Source | Total Design Flow Rate | Design Sewer: Dia. | Slope | Velocity | Capacity | Length | Invert Elevation | Ground Surface Elevation | Earth Cover | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ha | ha | $m^3/S$ | ha | ha | $m^3/S$ | ha | ha | $m^3/S$ | ha | $m^3/S$ | $m^3/S$ | $m^3/S$ | mm | o/oo | m/S | $m^3/S$ | m | m | m | m | |
| Discharge from the Otongolo STW | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | 0.565 | 1000 | 1.9 | 1.331 | 1.0455 | 600 | 1,135.46 | 1,141.5 | 4.94 | |
| | | | | | | | | | | | | | | | | | | | | 1,134.32 | 1,136.9 | 1.50 | |