# CHAPTER 10 GIS DATABASE

## 10.1 Data Collection

### 10.1.1 Map

The 1/50,000 Topographic Maps issued by Survey and Mapping Department were collected. As shown in the index map of Figure 10-1, Lake Kyoga Basin is covered by 104 Topographic Maps. The 1/50,000 Topographic Maps were projected on the coordinate system shown in Table 10-1, and Arc 1960 (New Arc) which is commonly utilized in Eastern Africa countries was adopted as a datum.

**Table 10-1 Coordinate System of 1/50,000 Topographic Map**

| | | | |
|---|---|---|---|
| Grid | UTM Zone 36 | Latitude of Origin | Equator |
| Projection | Transverse Mercator | Scale Factor of Origin | 0.9996 |
| Spheroid | Clark 1880 (Modified) | False Coordinates of Origin | 500,000 m Easting |
| Unit | Meter | | 10,000,000 m Northing |
| Meridian of Origin | 33 degrees E of Greenwich | Datum | Arc 1960 |

Source: Survey and Mapping Department

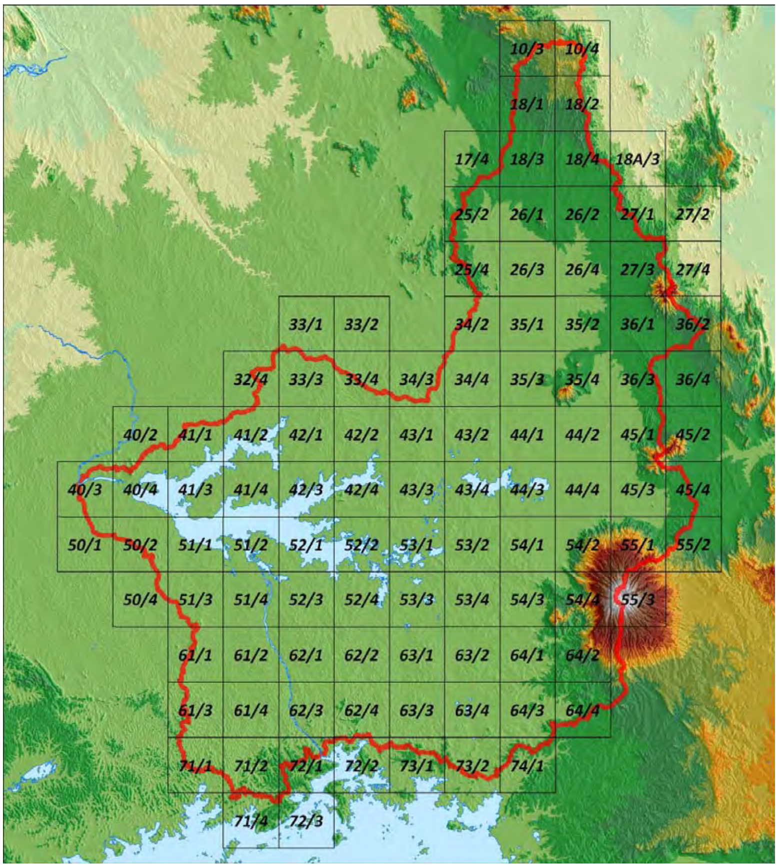



**Figure 10-1 Index Map of 1/50,000 Topographic Maps**

### 10.1.2 GIS Data

GIS data (vector data) listed in Table 10-2 were collected. Most of basic information, e.g. administrative boundaries, transportations and town, was created and by the National Biomass Study of Forest Department. All collected data were defined on the coordinate system projected on UTM (Zone 36) and Arc 1960 datum.

**Table 10-2 Collected GIS Data**

| Items | Type | Source |
|---|---|---|
| Administrative boundary of District, County, Sub-County and Parish | Polygon | National Biomass Project |
| Geology | Polygon | DWRM |
| Land use | Polygon | National Biomass Project |
| Open Water | Polygon | DWRM |
| Protected Area | Polygon | NFA |
| River | Line | DWRM |
| Soil | Polygon | DWRM |
| Road and Railway | Line | National Biomass Project |
| Town | Point | National Biomass Project |

### 10.1.3 DEM and Satellite Image

Digital Elevation Model (DEM) and satellite image data listed in Table 10-3 were collected as raster data. The utilized SRTM-3, LANDSAT/ETM+ and TM data were obtained from the website of United States Geological Survey (USGS) on free of charge basis.

**(1) LANDSAT/ETM+ and TM Data**

ETM+ (Enhanced Thematic Mapper Plus) and TM (Thematic Mapper) are the sensor for observation programs of land areas of the Earth, and was developed by the National Aeronautics and Space Administration (NASA) of the United States and mounted on the earth observation satellite LANDSAT of NASA. The five scenes of the ETM+ data acquired at 3 seasons (June and September of 2002, and January of 2003), and the five TM data acquired at September of 1984 and January of 1986 were utilized in the study.

**(2) Space Shuttle/SRTM-3 Data**

SRTM (Shuttle Rader Topography Mission) obtained the elevation data on a near global scale to generate the most complete digital topographic database of the Earth by Space Shuttle. SRTM data is a digital elevation model (DEM) generated by the method of radar interferometry. The spatial resolution of SRTM data is 1 arc-second (about 30m; SRTM-1) in the United States and 3 arc-seconds (about 90m; SRTM-3) in the World. In the study, SRTM-3 data covering the area of 3 degrees laterally (32ºE to 35ºE) and 4 degrees vertically (0º to 4ºN), was utilized.

**Table 10-3 Collected DEM and Satellite Image Data**

| Data | Acquisition Date | Number of data | Spatial Resolution | Coordinate System | Datum |
|---|---|---|---|---|---|
| LANDSAT/ETM+ | 2002/06<br>2002/09<br>2003/01 | 5 scenes<br>5 scenes<br>5 scenes | 30 m (in Visible and SWIR*)<br>60 m (in TIR*) | UTM | WGS 1984 |
| LANDSAT/TM | 1984/09<br>1986/01 | 5 scenes<br>5 scenes | 30 m (in Visible and SWIR*)<br>120 m (in TIR*) | UTM | WGS 1984 |
| SRTM-3 | - | 49 scenes | 3 second | Geographic (Decimal Degree) | WGS 1984 |

*SWIR: Short Wave Infrared, TIR: Thermal Infrared(

### 10.2 Designing GIS Database

A framework of GIS database consisting of the collected data and newly processed data was designed. The details of GIS database construction were described below.

#### 10.2.1 Unifying the Coordinate System

The coordinate system of collected data and processed data is not consistent. The data projected on UTM is intermingled with the data on Geographic (Decimal Degree) coordinate system. Similarly, the collected data is based on either Arc 1960 or WGS 1984. In this study, the coordinate system of GIS database was unified into UTM projection and Arc 1980 datum, the same projected coordinate system as with 1/50,000 Topographic Map, and the data on different coordinate system were re-projected on the unified coordinate system.

#### 10.2.2 GIS Database Configuration

The component of GIS database is shown in Figure 10-2. The GIS database consists of 16 units; basic information, administration, topography, geology, hydrogeology, hydrology, meteorology, water quality, socio-economy, water resources, water supply, disaster, simulation, water balance, water potential and satellite image. The configuration of database and detail of each unit are shown in Table 10-4.

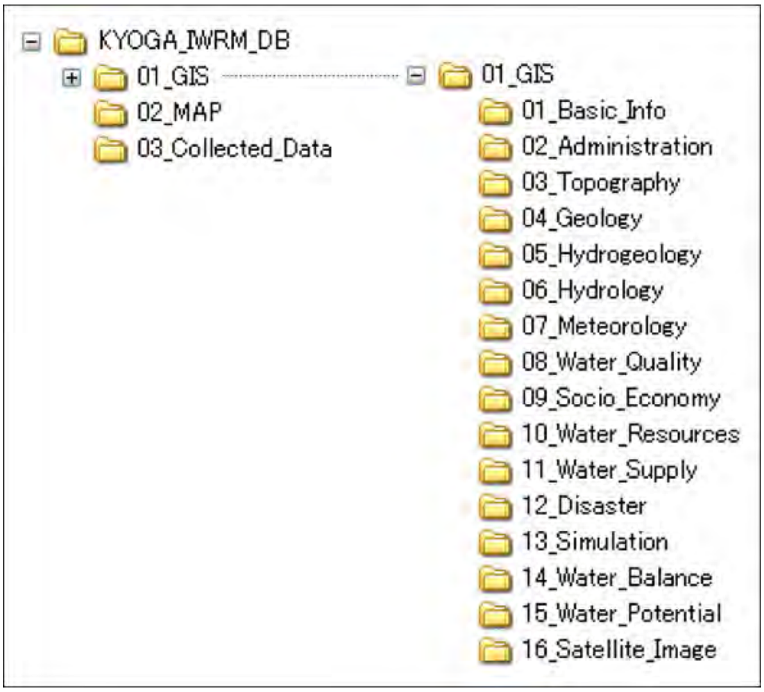



**Figure 10-2 Component of GIS Database**

**Table 10-4 Configuration of GIS Database (1)**

| Folder (Unit) | File Name | Ext. | Type of shp | Description | Source |
|---|---|---|---|---|---|
| 01_Basic_Info | catchment_kyoga | .shp | polygon | Study area detected from SRTM-3 data | JICA Study Team |
| | map_landuse | .shp | polygon | Land use map at 1996 | National Biomass Study |
| | protected_area | .shp | polygon | Protected area | NFA |
| | town | .shp | point | Major towns | National Biomass Study |
| | transportation | .shp | line | Roads, ferries and railways | National Biomass Study |
| 02_Administrative | admin_01district | .shp | polygon | Administrative boundary of district | National Biomass Study* |
| | admin_02county | .shp | polygon | Administrative boundary of county | National Biomass Study* |
| | admin_03subcounty | .shp | polygon | Administrative boundary of sub-county | National Biomass Study* |
| | admin_04parish | .shp | polygon | Administrative boundary of parish | National Biomass Study* |
| 03_Topography | dem_ug | .img | | SRTM-3 DEM data of Uganda | USGS |
| | dem_ug_shade | .img | | Shaded relief image generated by SRTM-3 data | JICA Study Team |
| | dem_ug_slope | .img | | Slope analysis image generated by SRTM-3 data | JICA Study Team |
| | topo_##_# | .img | | 1/50,000 Topographic map (##_#: map number) | Survey and Mapping Dept. * |
| 04_Geology | map_geology | .shp | | Geological map of Uganda | DWRM |
| | map_soil | .shp | | Soil map of Uganda | DWRM |
| | interp_lineament | .shp | | Lineament map interpreted by DEM and satellite image | JICA Study Team |
| 05_Hydrogeology | station_gw | .xls | point | Monitoring data of boreholes | DWRM |
| | station_gw | .shp | | Location of monitoring bore holes | JICA Study Team |
| | bedrock | .xls | | Depth of bedrocks | DWRM |
| | bedrock | .img | | Distribution of estimated bedrock's depth | JICA Study Team |
| | drill_depth | .xls | | Depth of boreholes | DWRM |
| | drill_depth | .img | | Distribution of estimated borehole's depth | JICA Study Team |

**Table 10-4 Configuration of GIS Database (2)**

| Folder (Unit) | File Name | Ext. | Type of shp | Description | Source |
|---|---|---|---|---|---|
| 05_Hydrogeology | drill_static | .xls | | Static water level of boreholes | DWRM |
| | drill_static | .img | | Distribution of estimated static water level | JICA Study Team |
| | drill_tds | .xls | | TDS of boreholes | DWRM |
| | drill_tds | .img | | Distribution of estimated TDS | JICA Study Team |
| | drill_yield | .xls | | Groundwater yield of boreholes | DWRM |
| | drill_yield | .img | | Distribution of estimated groundwater yield | JICA Study Team |
| 06_Hydrology | station_sw | .xls | | Monitoring data of gauging stations | DWRM |
| | station_sw | .shp | point | Location of gauging stations | JICA Study Team |
| | river | .shp | line | Stream network | DWRM |
| | river_dem | .shp | line | Stream network detected from SRTM-3 data | JICA Study Team |
| | water | .shp | polygon | Open water area | DWRM |
| | water_dem | .shp | polygon | Open water area provided by USGS | USGS |
| | wetland | .shp | polygon | Distribution of Wetland | DWRM |
| 07_Meteorology | station_meteo | .xls | | Monitoring data of meteorological stations | DWRM |
| | station_meteo | .shp | point | Location of meteorological stations (precipitation) | JICA Study Team |
| | precipitation_annual | .img | | Estimated annual precipitation | JICA Study Team |
| | precipitation_m## | .img | | Estimated monthly precipitation (##: month) | JICA Study Team |
| | station_temp | .shp | point | Location of meteorological stations (precipitation) | JICA Study Team |
| | temperature_annual | .img | | Estimated annual temperature | JICA Study Team |
| | temperature_m## | .img | | Estimated monthly temperature (##: month) | JICA Study Team |
| | station_evapo | .shp | point | Location of meteorological stations (evaporation) | JICA Study Team |
| | evapo_potential_m## | .img | | Estimated monthly potential evaporation (##: month) | JICA Study Team |

**Table 10-4 Configuration of GIS Database (3)**

| Folder (Unit) | File Name | Ext. | Type of shp | Description | Source |
|---|---|---|---|---|---|
| 07_Meteorology | station_sunshine | .shp | point | Location of meteorological stations (sunshine hours) | JICA Study Team |
| | sunshine_m## | .img | | Estimated monthly sunshine hours (##: month) | JICA Study Team |
| 08_Water_Quality | station_wq | .xls | | Monitoring data of water quality survey | DWRM |
| | station_wq | .shp | | Location of sampling point for water quality survey | JICA Study Team |
| | survey_wq_rainy | .shp | | Result of JICA Study Team's WQ survey in rainy season | JICA Study Team |
| | survey_wq_dry | .shp | | Result of JICA Study Team's WQ survey in dry season | JICA Study Team |
| 09_Socio_Economy | 2002_census | .xls | | 2002 Census data | UBOS |
| | admin_01district_pop | .shp | polygon | Boundary of district with population and density | UBOS |
| | admin_02county_pop | .shp | polygon | Boundary of county with population and density | UBOS |
| | admin_03subcounty_pop | .shp | polygon | Boundary of sub-county with population and density | UBOS |
| | admin_04parish_pop | .shp | polygon | Boundary of parish with population and density | UBOS |
| | survey_se | .shp | point | Result of JICA Study Team's SE survey | JICA Study Team |
| 10_Water_Resources | well_deep | .xls | | List of deep wells | DWRM |
| | well_deep | .shp | point | Location of deep wells | JICA Study Team |
| | well_shallow | .xls | | List of shallow wells | DWRM |
| | well_shallow | .shp | point | Location of shallow wells | JICA Study Team |
| | protected_spring | .xls | | List of protected springs | DWRM |
| | protected_spring | .shp | point | Location of protected springs | JICA Study Team |
| 11_Water_Supply | supply_facility | .shp | point | Location of water supply facility | DWD |
| | water_supply_ratio | .shp | polygon | Distribution of water supply ratio | DWD |
| | waiting_time | .shp | Polygon | Distribution of waiting time at water resources | DWD |
| | willing_to_pay | .shp | polygon | Distribution of willing to pay for water per month | DWD |

**Table 10-4 Configuration of GIS Database (4)**

| Folder (Unit) | File Name | Ext. | Type of shp | Description | Source |
|---|---|---|---|---|---|
| 12_Disaster | flooding | .shp | Polygon | Distribution of flooding area at 2007 | National Biomass Study |
| | deforestration | .shp | Polygon | Distribution of deforestration | National Biomass Study |
| 13_Simulation | water_use | .shp | Polygon | Distribution of estimated water use | JICA Study Team |
| 14_Water_Balance | evapotranspiration_annual | .img | | Distribution of estimated annual evapotranspiration | JICA Study Team |
| | evapotranspiration_m## | .img | | Distribution of estimated monthly evapotranspiration (##: month) | JICA Study Team |
| | recharge | .img | | Distribution of estimated annual potential recharge | JICA Study Team |
| | runoff | .img | | Distribution of runoff ratio | JICA Study Team |
| 15_Water_Potential | potential_gw | .img | | Distribution of estimated groundwater potential | JICA Study Team |
| | potential_sw | .img | | Distribution of estimated surface water potential | JICA Study Team |
| 16_Satellite_Image | landsat_###### | .img | | LANDSAT image (######: acquired year and month) | JICA Study Team |
| | Landsat_######_vsw | .img | | VSW Index image (######: acquired year and month) | JICA Study Team |

# CHAPTER 11 PROJECTED WATER DEMAND

## 11.1 Population Frame

The future population is forecasted in the "Strategic Investment Plan for the Water and Sanitation Sub Sector, July 2009" (SIP). The future population is estimated for each district in the following four (4) categories of areas until 2035 applying the published population growth which estimated till 2017 by the Uganda Bureau of Statistics (UBoS) based on the population census data for 1992 and 2002.

- Urban areas (Large towns)
- Peri-urban areas
- Rural small towns
- Rural areas (RGCs and villages)

The population growth rates are set for the urban and the rural areas of each district based on the growth from 1992 to 2002, and same rates are applied for the estimation until 2035. Total population of the basin is estimated to 9,321,959 and 22,766,831 for 2008 and 2035, respectively, and the estimated values of the population for each category are summarized in the following table for some years indicative of milestones in the plan.

**Table 11-1 Summary of Present and Future Population in Lake Kyoga Basin**

| Year | Whole Population in the Basin | Large Urban (NWSC) | Peri-urban/ Rural (NWSC Service Are a) | Small Towns (Town Councils & Town Boards) | Rural (RGCs + Villages) |
|---|---|---|---|---|---|
| 2008 | 9,321,959 | 392,351 | 481,972 | 604,295 | 7,843,341 |
| 2015 | 11,822,680 | 482,341 | 632,369 | 772,111 | 9,935,859 |
| 2020 | 13,979,550 | 587,059 | 748,386 | 925,437 | 11,718,668 |
| 2035 | 22,766,831 | 1,004,084 | 1,366,522 | 1,644,976 | 18,751,249 |

Source: Strategic Investment Plan for the Water and Sanitation Sub Sector, 2009

As seen in Figure 11-1, the rural population (RGC + Village) shares about 84% of the whole population, and its increase from 2008 to 2035 is calculated to be 239%, a bit smaller than those of urban areas calculated to be 272% for the sum of large urban, peri-urban and small towns. The projected future population of each district is tabulated in Tables 11-2, 11-3, 11-4 and 11-5 for 2008, 2015, 2020 and 2035, respectively.

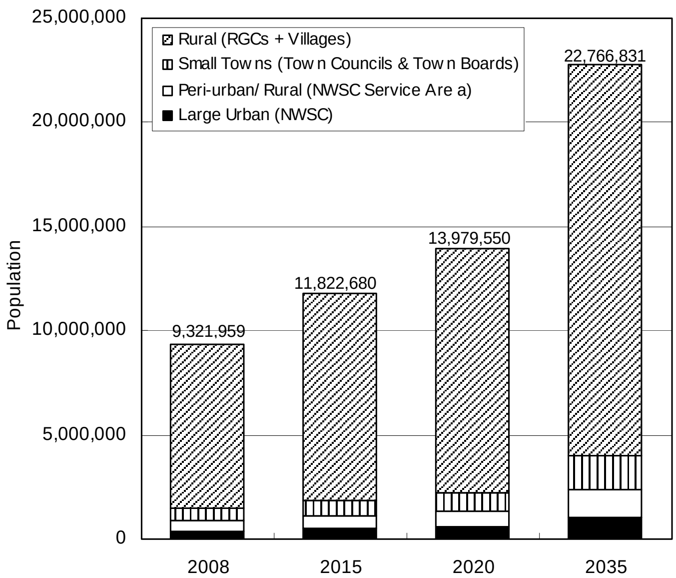



**Figure 11-1 Present and Future Population in Lake Kyoga Basin**

**Table 11-2 Present Population within Lake Kyoga Basin in 2008**

| No. | District Name | Total No. of persons | Large Urban (NWSC) | Peri-urban/ rural (NWSC Service Area) | Small Towns (Town Councils & Town Boards) | Rural (RGCs+Villages) |
|---|---|---|---|---|---|---|
| 1 | Abim | 8,567 | 0 | 0 | 0 | 8,567 |
| 2 | Amolatar | 113,700 | 0 | 0 | 13,500 | 100,200 |
| 3 | Amuria | 168,546 | 0 | 0 | 2,100 | 166,446 |
| 4 | Apac | 140,180 | 0 | 0 | 0 | 140,180 |
| 5 | Budaka | 160,100 | 0 | 9,359 | 19,900 | 130,841 |
| 6 | Bududa | 154,120 | 0 | 0 | 3,800 | 150,320 |
| 7 | Bugiri | 366,517 | 0 | 0 | 35,500 | 331,017 |
| 8 | Bukedea | 157,000 | 0 | 0 | 37,200 | 119,800 |
| 9 | Bukwa | 18,907 | 0 | 0 | 0 | 18,907 |
| 10 | Busia | 169,711 | 0 | 0 | 25,920 | 143,791 |
| 11 | Butaleja | 192,500 | 0 | 0 | 5,100 | 187,400 |
| 12 | Dokolo | 157,732 | 0 | 0 | 16,200 | 141,532 |
| 13 | Iganga | 659,371 | 52,896 | 0 | 40,300 | 566,175 |
| 14 | Jinja | 343,118 | 37,371 | 106,129 | 16,800 | 182,818 |
| 15 | Kaabong | 90,770 | 0 | 0 | 19,500 | 71,270 |
| 16 | Kaberamaido | 168,100 | 0 | 0 | 0 | 168,100 |
| 17 | Kaliro | 188,600 | 0 | 0 | 24,322 | 164,278 |
| 18 | Kamuli | 669,900 | 0 | 0 | 13,700 | 656,200 |
| 19 | Kapchorwa | 178,593 | 0 | 0 | 11,300 | 167,293 |
| 20 | Katakwi | 150,100 | 0 | 0 | 7,500 | 142,600 |
| 21 | Kayunga | 330,900 | 0 | 0 | 22,200 | 308,700 |
| 22 | Kotido | 118,942 | 0 | 0 | 18,800 | 100,142 |
| 23 | Kumi | 345,400 | 0 | 0 | 16,400 | 329,000 |
| 24 | Lira | 92,867 | 0 | 9,607 | 0 | 83,260 |
| 25 | Luwero | 170,957 | 0 | 0 | 7,749 | 163,208 |
| 26 | Manafwa | 320,500 | 0 | 0 | 46,045 | 274,455 |
| 27 | Mayuge | 80,468 | 0 | 0 | 3,210 | 77,258 |
| 28 | Mbale | 392,900 | 82,676 | 77,098 | 0 | 233,127 |
| 29 | Moroto | 231,008 | 0 | 0 | 27,166 | 203,842 |
| 30 | Mukono | 578,418 | 127,767 | 49,571 | 34,792 | 366,288 |
| 31 | Nakapiripirit | 146,825 | 0 | 0 | 1,150 | 145,675 |
| 32 | Nakasongola | 101,459 | 0 | 0 | 7,300 | 94,159 |
| 33 | Namutumba | 196,300 | 0 | 0 | 9,800 | 186,500 |
| 34 | Pallisa | 471,800 | 0 | 0 | 54,000 | 417,800 |
| 35 | Sironko | 328,602 | 0 | 0 | 38,439 | 290,163 |
| 36 | Soroti | 499,800 | 42,121 | 2,707 | 10,000 | 444,972 |
| 37 | Tororo | 440,000 | 40,161 | 53,489 | 14,602 | 331,749 |
| 38 | Wakiso | 218,677 | 0 | 183,371 | 0 | 35,306 |
| | Total | 9,321,956 | 382,992 | 491,330 | 604,295 | 7,843,339 |

Source: Strategic Investment Plan for the Water and Sanitation Sub Sector, 2009

## Table 11-3 Future Population within Lake Kyoga Basin in 2015

| No. | District Name | Total No. of persons | Large Urban (NWSC) | Peri-urban/ rural (NWSC Service Area) | Small Towns (Town Councils & Town Boards) | Rural (RGCs+Villages) |
|---|---|---|---|---|---|---|
| 1 | Abim | 8,903 | 0 | 0 | 0 | 8,903 |
| 2 | Amolatar | 137,579 | 0 | 0 | 16,345 | 121,234 |
| 3 | Amuria | 222,747 | 0 | 0 | 3,716 | 219,031 |
| 4 | Apac | 175,989 | 0 | 0 | 0 | 175,989 |
| 5 | Budaka | 192,804 | 0 | 11,510 | 24,003 | 157,291 |
| 6 | Bududa | 201,447 | 0 | 0 | 4,985 | 196,462 |
| 7 | Bugiri | 484,793 | 0 | 0 | 49,197 | 435,596 |
| 8 | Bukedea | 207,472 | 0 | 0 | 49,823 | 157,649 |
| 9 | Bukwa | 24,881 | 0 | 0 | 0 | 24,881 |
| 10 | Busia | 205,603 | 0 | 0 | 31,440 | 174,163 |
| 11 | Butaleja | 241,882 | 0 | 0 | 5,100 | 236,782 |
| 12 | Dokolo | 200,023 | 0 | 0 | 20,580 | 179,443 |
| 13 | Iganga | 841,379 | 74,430 | 0 | 51,025 | 715,924 |
| 14 | Jinja | 408,580 | 39,541 | 131,067 | 20,056 | 217,916 |
| 15 | Kaabong | 124,849 | 0 | 0 | 31,062 | 93,787 |
| 16 | Kaberamaido | 221,208 | 0 | 0 | 0 | 221,208 |
| 17 | Kaliro | 231,502 | 0 | 0 | 24,322 | 207,180 |
| 18 | Kamuli | 838,551 | 0 | 0 | 17,169 | 821,382 |
| 19 | Kapchorwa | 235,384 | 0 | 0 | 15,238 | 220,146 |
| 20 | Katakwi | 197,501 | 0 | 0 | 9,849 | 187,652 |
| 21 | Kayunga | 377,869 | 0 | 0 | 25,392 | 352,477 |
| 22 | Kotido | 161,110 | 0 | 0 | 29,330 | 131,780 |
| 23 | Kumi | 455,110 | 0 | 0 | 22,168 | 432,942 |
| 24 | Lira | 116,848 | 0 | 12,864 | 0 | 103,984 |
| 25 | Luwero | 203,464 | 0 | 0 | 9,231 | 194,233 |
| 26 | Manafwa | 404,203 | 0 | 0 | 58,147 | 346,056 |
| 27 | Mayuge | 102,527 | 0 | 0 | 4,084 | 98,443 |
| 28 | Mbale | 463,136 | 98,535 | 81,561 | 0 | 283,039 |
| 29 | Moroto | 308,342 | 0 | 0 | 40,100 | 268,242 |
| 30 | Mukono | 729,119 | 179,781 | 68,698 | 41,749 | 438,891 |
| 31 | Nakapiripirit | 193,309 | 0 | 0 | 1,611 | 191,698 |
| 32 | Nakasongola | 204,133 | 0 | 0 | 8,409 | 195,724 |
| 33 | Namutumba | 235,625 | 0 | 0 | 11,759 | 223,866 |
| 34 | Pallisa | 599,918 | 0 | 0 | 68,778 | 531,140 |
| 35 | Sironko | 390,787 | 0 | 0 | 45,809 | 344,978 |
| 36 | Soroti | 645,624 | 42,604 | 3,194 | 14,273 | 585,553 |
| 37 | Tororo | 524,000 | 47,451 | 65,453 | 17,361 | 393,735 |
| 38 | Wakiso | 304,483 | 0 | 258,022 | 0 | 46,461 |
| | Total | 11,822,684 | 482,343 | 632,369 | 772,111 | 9,935,861 |

Source: Strategic Investment Plan for the Water and Sanitation Sub Sector, 2009

**Table 11-4 Future Population within Lake Kyoga Basin in 2020**

| No. | District Name | Total No. of persons | Large Urban (NWSC) | Peri-urban/ rural (NWSC Service Area) | Small Towns (Town Councils & Town Boards) | Rural (RGCs+Villages) |
|---|---|---|---|---|---|---|
| 1 | Abim | 9,151 | 0 | 0 | 0 | 9,151 |
| 2 | Amolatar | 157,648 | 0 | 0 | 18,736 | 138,912 |
| 3 | Amuria | 272,072 | 0 | 0 | 5,587 | 266,485 |
| 4 | Apac | 207,041 | 0 | 0 | 0 | 207,041 |
| 5 | Budaka | 220,183 | 0 | 13,344 | 27,441 | 179,398 |
| 6 | Bududa | 243,912 | 0 | 0 | 6,051 | 237,861 |
| 7 | Bugiri | 592,080 | 0 | 0 | 62,111 | 529,969 |
| 8 | Bukedea | 253,190 | 0 | 0 | 61,386 | 191,804 |
| 9 | Bukwa | 30,271 | 0 | 0 | 0 | 30,271 |
| 10 | Busia | 235,799 | 0 | 0 | 36,089 | 199,710 |
| 11 | Butaleja | 284,936 | 0 | 0 | 5,100 | 279,836 |
| 12 | Dokolo | 237,009 | 0 | 0 | 24,416 | 212,593 |
| 13 | Iganga | 1,001,956 | 94,994 | 0 | 60,391 | 846,571 |
| 14 | Jinja | 463,363 | 41,168 | 152,393 | 22,761 | 247,041 |
| 15 | Kaabong | 157,424 | 0 | 0 | 43,318 | 114,106 |
| 16 | Kaberamaido | 269,134 | 0 | 0 | 0 | 269,134 |
| 17 | Kaliro | 268,848 | 0 | 0 | 24,322 | 244,526 |
| 18 | Kamuli | 984,433 | 0 | 0 | 20,173 | 964,260 |
| 19 | Kapchorwa | 286,708 | 0 | 0 | 18,866 | 267,842 |
| 20 | Katakwi | 240,272 | 0 | 0 | 11,965 | 228,307 |
| 21 | Kayunga | 415,446 | 0 | 0 | 27,948 | 387,498 |
| 22 | Kotido | 200,628 | 0 | 0 | 40,297 | 160,331 |
| 23 | Kumi | 554,233 | 0 | 0 | 27,493 | 526,740 |
| 24 | Lira | 137,722 | 0 | 15,847 | 0 | 121,875 |
| 25 | Luwero | 230,403 | 0 | 0 | 10,460 | 219,943 |
| 26 | Manafwa | 477,065 | 0 | 0 | 68,693 | 408,372 |
| 27 | Mayuge | 121,896 | 0 | 0 | 4,850 | 117,046 |
| 28 | Mbale | 521,709 | 111,694 | 84,907 | 0 | 325,108 |
| 29 | Moroto | 379,316 | 0 | 0 | 52,959 | 326,357 |
| 30 | Mukono | 863,141 | 229,451 | 86,731 | 47,555 | 499,404 |
| 31 | Nakapiripirit | 235,279 | 0 | 0 | 2,049 | 233,230 |
| 32 | Nakasongola | 247,432 | 0 | 0 | 9,303 | 238,129 |
| 33 | Namutumba | 268,452 | 0 | 0 | 13,394 | 255,058 |
| 34 | Pallisa | 712,223 | 0 | 0 | 81,751 | 630,472 |
| 35 | Sironko | 442,288 | 0 | 0 | 51,924 | 390,364 |
| 36 | Soroti | 777,365 | 42,953 | 3,595 | 18,402 | 712,415 |
| 37 | Tororo | 593,690 | 53,456 | 75,605 | 19,646 | 444,983 |
| 38 | Wakiso | 385,835 | 0 | 329,308 | 0 | 56,527 |
| | Total | 13,979,552 | 573,716 | 761,730 | 925,437 | 11,718,670 |

Source: Strategic Investment Plan for the Water and Sanitation Sub Sector, 2009

## Table 11-5 Future Population within Lake Kyoga Basin in 2035

| No. | District Name | Total No. of persons | Large Urban (NWSC) | Peri-urban/ rural (NWSC Service Area) | Small Towns (Town Councils & Town Boards) | Rural (RGCs+Villages) |
|---|---|---|---|---|---|---|
| 1 | Abim | 9,937 | 0 | 0 | 0 | 9,937 |
| 2 | Amolatar | 237,191 | 0 | 0 | 28,224 | 208,967 |
| 3 | Amuria | 663,190 | 0 | 0 | 18,982 | 644,208 |
| 4 | Apac | 337,109 | 0 | 0 | 0 | 337,109 |
| 5 | Budaka | 327,963 | 0 | 20,789 | 41,005 | 266,169 |
| 6 | Bududa | 432,964 | 0 | 0 | 10,823 | 422,141 |
| 7 | Bugiri | 340,513 | 0 | 0 | 124,979 | 215,534 |
| 8 | Bukedea | 460,236 | 0 | 0 | 114,808 | 345,428 |
| 9 | Bukwa | 54,517 | 0 | 0 | 0 | 54,517 |
| 10 | Busia | 355,696 | 0 | 0 | 54,582 | 301,114 |
| 11 | Butaleja | 467,026 | 0 | 0 | 5,100 | 461,926 |
| 12 | Dokolo | 394,296 | 0 | 0 | 40,774 | 353,522 |
| 13 | Iganga | 1,697,378 | 197,486 | 0 | 100,130 | 1,399,762 |
| 14 | Jinja | 679,189 | 46,461 | 239,540 | 33,269 | 359,919 |
| 15 | Kaabong | 322,975 | 0 | 0 | 117,477 | 205,498 |
| 16 | Kaberamaido | 484,694 | 0 | 0 | 0 | 484,694 |
| 17 | Kaliro | 426,353 | 0 | 0 | 24,322 | 402,031 |
| 18 | Kamuli | 1,592,783 | 0 | 0 | 32,720 | 1,560,063 |
| 19 | Kapchorwa | 518,172 | 0 | 0 | 35,804 | 482,368 |
| 20 | Katakwi | 432,621 | 0 | 0 | 21,453 | 411,168 |
| 21 | Kayunga | 552,124 | 0 | 0 | 37,270 | 514,854 |
| 22 | Kotido | 393,261 | 0 | 0 | 104,514 | 288,747 |
| 23 | Kumi | 1,001,074 | 0 | 0 | 52,446 | 948,628 |
| 24 | Lira | 225,848 | 0 | 29,621 | 0 | 196,227 |
| 25 | Luwero | 334,570 | 0 | 0 | 15,218 | 319,352 |
| 26 | Manafwa | 784,360 | 0 | 0 | 113,259 | 671,101 |
| 27 | Mayuge | 204,860 | 0 | 0 | 8,126 | 196,734 |
| 28 | Mbale | 751,161 | 162,684 | 95,790 | 0 | 492,687 |
| 29 | Moroto | 709,743 | 0 | 0 | 121,992 | 587,751 |
| 30 | Mukono | 1,457,583 | 477,012 | 174,525 | 70,281 | 735,765 |
| 31 | Nakapiripirit | 424,250 | 0 | 0 | 4,216 | 420,034 |
| 32 | Nakasongola | 441,453 | 0 | 0 | 12,597 | 428,856 |
| 33 | Namutumba | 397,010 | 0 | 0 | 19,795 | 377,215 |
| 34 | Pallisa | 1,191,762 | 0 | 0 | 137,283 | 1,054,479 |
| 35 | Sironko | 641,208 | 0 | 0 | 75,615 | 565,593 |
| 36 | Soroti | 1,371,602 | 44,015 | 5,126 | 39,442 | 1,283,019 |
| 37 | Tororo | 863,749 | 76,426 | 116,523 | 28,468 | 642,333 |
| 38 | Wakiso | 786,409 | 0 | 684,608 | 0 | 101,801 |
| | Total | 22,766,830 | 1,004,083 | 1,366,522 | 1,644,974 | 18,751,251 |

Source: Strategic Investment Plan for the Water and Sanitation Sub Sector, 2009

There are 11 sub-basins defined in the Lake Kyoga Basin (refer to Figure 11-2),. Table 11-6 shows the area and population density of sub-basins in the Lake Kyoga basin (2008). The Mpologoma sub-basin has the highest population density of 140.62 person/kim$^2$, while the lowest density of 9.94 person/km$^2$ is indicated in the Okok sub-basin. The sub-basins having rather higher population density are the Mpologoma, the Sezibwa, the Awoja, the Lumbuye and the Victoria Nile sub-basins located in the southern and eastern parts of the Lake Kyoga basin. These sub-basins are located along the major national roads and their economic activities are considered to be growing rapidly, resulting in the urgent provision of water supply facilities.

The projected future population of each sub-basin is tabulated in Tables 11-7 for 2008, 2015, 2020 and 2035.

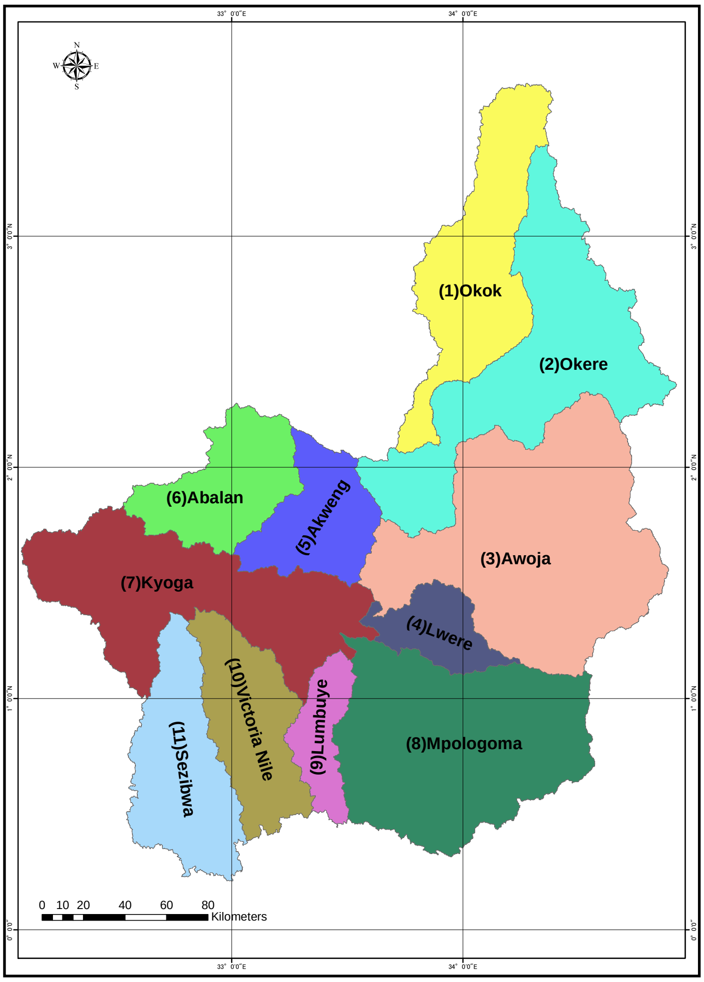



**Figure 11-2 Sub-basins in Lake Kyoga Basin**

**Table 11-6 Area and Population Density in Each Sub-basin**

| Sub-basin | Population (2008) | Area (km$^2$) | Population Density (person/km$^2$) | Order |
|---|---|---|---|---|
| (1) Okok | 266,139 | 5,512 | 48 | 11 |
| (2) Okere | 408,921 | 8,199 | 50 | 10 |
| (3) Awoja | 1,192,686 | 10,717 | 111 | 9 |
| (4) Lwere | 382,397 | 1,618 | 236 | 5 |
| (5) Akweng | 381,255 | 2,504 | 152 | 6 |
| (6) Abalan | 386,222 | 2,908 | 133 | 7 |
| (7) Kyoga Lakeside | 650,393 | 5,206 | 125 | 8 |
| (8) Mpologoma | 3,084,281 | 7,862 | 392 | 1 |
| (9) Lumbuye | 470,914 | 1,478 | 319 | 2 |
| (10) Victoria Nile | 985,698 | 3,456 | 285 | 3 |
| (11) Sezibwa | 1,113,054 | 4,225 | 263 | 4 |
| Total/Average | 9,321,959 | 53,685 | 174 | - |

## Table 11-7 Present and Future Population in Each Sub-basin

| Sub-basin | Total No. of persons | Large Urban (NWSC) | Peri-urban/ rural (NWSC service Area) | Small Towns (Town Councils & Town Boards) | Rural (RGCs + Villages) (outside NWSC) |
|---|---|---|---|---|---|
| 2008 | | | | | |
| (1) Okok | 266,139 | 0 | 0 | 38,300 | 227,839 |
| (2) Okere | 408,921 | 0 | 0 | 29,266 | 379,655 |
| (3) Awoja | 1,192,686 | 0 | 0 | 111,989 | 1,080,697 |
| (4) Lwere | 382,397 | 16,848 | 1,083 | 4,000 | 360,466 |
| (5) Akweng | 381,255 | 25,273 | 1,624 | 6,000 | 348,358 |
| (6) Abalan | 386,222 | 0 | 9,607 | 16,200 | 360,415 |
| (7) Kyoga | 650,393 | 0 | 0 | 20,800 | 629,593 |
| (8) Mpologoma | 3,084,281 | 158,644 | 130,587 | 279,289 | 2,515,761 |
| (9) Lumbuye | 470,914 | 26,448 | 0 | 3,210 | 441,256 |
| (10) Victoria Nile | 985,698 | 37,371 | 106,129 | 30,500 | 811,698 |
| (11) Sezibwa | 1,113,054 | 127,767 | 232,942 | 64,741 | 687,604 |
| Total | 9,321,959 | 392,351 | 481,972 | 604,295 | 7,843,341 |
| 2015 | | | | | |
| (1) Okok | 357,842 | 0 | 0 | 60,392 | 297,450 |
| (2) Okere | 543,416 | 0 | 0 | 43,816 | 499,600 |
| (3) Awoja | 1,531,809 | 0 | 0 | 144,498 | 1,387,311 |
| (4) Lwere | 486,992 | 17,042 | 1,278 | 5,709 | 462,963 |
| (5) Akweng | 493,583 | 25,561 | 1,916 | 8,564 | 457,542 |
| (6) Abalan | 487,787 | 0 | 12,864 | 20,580 | 454,343 |
| (7) Kyoga | 884,466 | 0 | 0 | 24,754 | 859,712 |
| (8) Mpologoma | 3,828,767 | 183,201 | 158,524 | 346,117 | 3,140,925 |
| (9) Lumbuye | 598,659 | 37,215 | 0 | 4,084 | 557,360 |
| (10) Victoria Nile | 1,196,774 | 39,541 | 131,067 | 37,225 | 988,941 |
| (11) Sezibwa | 1,412,586 | 179,781 | 326,720 | 76,372 | 829,713 |
| Total | 11,822,680 | 482,341 | 632,369 | 772,111 | 9,935,859 |
| 2020 | | | | | |
| (1) Okok | 443,828 | 0 | 0 | 83,615 | 360,213 |
| (2) Okere | 666,386 | 0 | 0 | 58,546 | 607,840 |
| (3) Awoja | 1,833,831 | 0 | 0 | 173,683 | 1,660,148 |
| (4) Lwere | 579,823 | 17,181 | 1,438 | 7,361 | 553,843 |
| (5) Akweng | 594,911 | 25,771 | 2,157 | 11,041 | 555,942 |
| (6) Abalan | 576,466 | 0 | 15,847 | 24,416 | 536,203 |
| (7) Kyoga | 1,048,967 | 0 | 0 | 28,039 | 1,020,928 |
| (8) Mpologoma | 4,474,702 | 225,991 | 160,512 | 404,989 | 3,683,210 |
| (9) Lumbuye | 710,939 | 47,497 | 0 | 4,850 | 658,592 |
| (10) Victoria Nile | 1,376,146 | 41,168 | 152,393 | 42,934 | 1,139,651 |
| (11) Sezibwa | 1,673,550 | 229,451 | 416,039 | 85,963 | 942,097 |
| Total | 13,979,550 | 587,059 | 748,386 | 925,437 | 11,718,668 |
| 2035 | | | | | |
| (1) Okok | 1,028,455 | 0 | 0 | 221,991 | 806,464 |
| (2) Okere | 1,235,659 | 0 | 0 | 140,974 | 1,094,685 |
| (3) Awoja | 3,164,344 | 0 | 0 | 304,342 | 2,860,002 |
| (4) Lwere | 985,867 | 17,606 | 2,050 | 15,777 | 950,434 |
| (5) Akweng | 1,050,717 | 26,409 | 3,076 | 23,665 | 997,567 |
| (6) Abalan | 952,831 | 0 | 29,621 | 40,774 | 882,436 |
| (7) Kyoga | 1,756,003 | 0 | 0 | 40,821 | 1,715,182 |
| (8) Mpologoma | 6,452,948 | 337,853 | 233,102 | 659,748 | 5,222,245 |
| (9) Lumbuye | 1,193,680 | 98,743 | 0 | 8,126 | 1,086,811 |
| (10) Victoria Nile | 2,102,552 | 46,461 | 239,540 | 65,989 | 1,750,562 |
| (11) Sezibwa | 2,843,775 | 477,012 | 859,133 | 122,769 | 1,384,861 |
| Total | 22,766,831 | 1,004,084 | 1,366,522 | 1,644,976 | 18,751,249 |

Source: Strategic Investment Plan for the Water and Sanitation Sub Sector, 2009

## 11.2 Future Water Demand

The water demands of the whole Lake Kyoga basin and the sub-basins are estimated based on SIP as presented in Table 11-8 and Table 11-9.

**Table 11-8 Present and Future Water Demand for Sub-basins**

(Unit:MCM)

| Sub-basin | 2008 | 2015 | 2020 | 2035 |
|---|---|---|---|---|
| (1) Okok | 7.7 | 12.4 | 16.1 | 26.7 |
| (2) Okere | 7.7 | 16.2 | 23.7 | 47.5 |
| (3) Awoja | 15.8 | 35.2 | 52.2 | 103.3 |
| (4) Lwere | 29.1 | 30.4 | 32.3 | 41.5 |
| (5) Akweng | 4.1 | 10.9 | 17.2 | 34.9 |
| (6) Abalan | 4.2 | 15.6 | 24.8 | 50.5 |
| (7) Kyoga Lakeside Zone | 12.3 | 24.7 | 35.4 | 65.4 |
| (8) Mpologoma | 327.6 | 322.4 | 325.5 | 365.9 |
| (9) Lumbuye | 6.2 | 8.7 | 11.3 | 20.5 |
| (10) Victoria Nile | 10.7 | 18.8 | 26.4 | 44.8 |
| (11) Sezibwa | 10.3 | 18.4 | 26.1 | 43.1 |
| Total | 435.6 | 513.6 | 590.8 | 844.1 |

## Table 11-9 Present and Future Water Demand by Category of Water Use in Lake Kyoga Basin

(Unit:MCM)

**2008**

| Sub-basin Name | Domestic NWSC | Domestic Small Towns | Domestic Rural | Livestock | Crops | Fisheries | Rural Industries | Total |
|---|---|---|---|---|---|---|---|---|
| (1) Okok | 0.00 | 0.49 | 1.25 | 5.82 | 0.01 | 0.09 | 0.06 | 7.7 |
| (2) Okere | 0.00 | 0.49 | 2.08 | 4.77 | 0.01 | 0.33 | 0.05 | 7.7 |
| (3) Awoja | 0.57 | 0.92 | 5.92 | 7.47 | 0.03 | 0.79 | 0.08 | 15.8 |
| (4) Lwere | 0.00 | 0.47 | 1.97 | 1.12 | 25.01 | 0.26 | 0.26 | 29.1 |
| (5) Akweng | 0.00 | 0.13 | 1.91 | 1.17 | 0.02 | 0.81 | 0.02 | 4.1 |
| (6)Abalan | 0.00 | 0.21 | 1.97 | 1.31 | 0.10 | 0.56 | 0.02 | 4.2 |
| (7) Kyoga Lakeside Zone | 0.00 | 0.26 | 3.45 | 3.89 | 3.51 | 1.15 | 0.09 | 12.3 |
| (8) Mpologoma | 3.33 | 3.98 | 13.77 | 5.33 | 295.34 | 2.85 | 3.04 | 327.6 |
| (9) Lumbuye | 0.00 | 0.00 | 2.42 | 0.79 | 2.45 | 0.47 | 0.04 | 6.2 |
| (10) Victoria Nile | 0.00 | 0.48 | 4.44 | 3.10 | 0.31 | 2.28 | 0.06 | 10.7 |
| (11) Sezibwa | 0.00 | 0.79 | 3.76 | 3.05 | 0.16 | 2.43 | 0.06 | 10.3 |

435.6

**2015**

| Sub-basin Name | Domestic NWSC | Domestic Small Towns | Domestic Rural | Livestock | Crops | Fisheries | Rural Industries | Total |
|---|---|---|---|---|---|---|---|---|
| (1) Okok | 0.00 | 0.88 | 2.17 | 6.82 | 2.07 | 0.17 | 0.27 | 12.4 |
| (2) Okere | 0.00 | 0.84 | 3.65 | 6.09 | 4.62 | 0.66 | 0.34 | 16.2 |
| (3) Awoja | 0.67 | 1.32 | 10.13 | 9.27 | 11.57 | 1.58 | 0.67 | 35.2 |
| (4) Lwere | 0.00 | 0.73 | 3.38 | 1.28 | 23.72 | 0.51 | 0.77 | 30.4 |
| (5) Akweng | 0.00 | 0.21 | 3.34 | 1.73 | 3.75 | 1.61 | 0.21 | 10.9 |
| (6)Abalan | 0.00 | 0.30 | 3.32 | 3.37 | 7.13 | 1.12 | 0.35 | 15.6 |
| (7) Kyoga Lakeside Zone | 0.00 | 0.36 | 5.73 | 5.30 | 10.50 | 2.29 | 0.54 | 24.7 |
| (8) Mpologoma | 4.45 | 5.70 | 22.93 | 6.18 | 268.97 | 5.70 | 8.43 | 322.4 |
| (9) Lumbuye | 0.00 | 0.00 | 4.07 | 0.93 | 2.59 | 0.94 | 0.13 | 8.7 |
| (10) Victoria Nile | 0.00 | 0.67 | 7.22 | 3.81 | 2.22 | 4.56 | 0.32 | 18.8 |
| (11) Sezibwa | 0.00 | 1.08 | 5.97 | 3.78 | 2.41 | 4.86 | 0.33 | 18.4 |

513.6

**2020**

| Sub-basin Name | Domestic NWSC | Domestic Small Towns | Domestic Rural | Livestock | Crops | Fisheries | Rural Industries | Total |
|---|---|---|---|---|---|---|---|---|
| (1) Okok | 0.00 | 1.37 | 3.29 | 6.97 | 3.85 | 0.26 | 0.33 | 16.1 |
| (2) Okere | 0.00 | 1.25 | 5.55 | 6.76 | 8.61 | 0.99 | 0.49 | 23.7 |
| (3) Awoja | 0.76 | 1.75 | 15.15 | 9.71 | 21.49 | 2.37 | 1.01 | 52.2 |
| (4) Lwere | 0.00 | 1.01 | 5.05 | 1.29 | 23.43 | 0.77 | 0.76 | 32.3 |
| (5) Akweng | 0.00 | 0.30 | 5.07 | 2.02 | 7.00 | 2.42 | 0.34 | 17.2 |
| (6)Abalan | 0.00 | 0.40 | 4.89 | 3.93 | 13.31 | 1.68 | 0.57 | 24.8 |
| (7) Kyoga Lakeside Zone | 0.00 | 0.46 | 8.39 | 5.63 | 16.71 | 3.44 | 0.77 | 35.4 |
| (8) Mpologoma | 5.57 | 7.54 | 33.61 | 6.32 | 255.78 | 8.56 | 8.12 | 325.5 |
| (9) Lumbuye | 0.00 | 0.00 | 6.01 | 0.94 | 2.78 | 1.41 | 0.15 | 11.3 |
| (10) Victoria Nile | 0.00 | 0.86 | 10.40 | 3.93 | 3.89 | 6.84 | 0.44 | 26.4 |
| (11) Sezibwa | 0.00 | 1.37 | 8.44 | 4.04 | 4.46 | 7.29 | 0.47 | 26.1 |

590.8

**2035**

| Sub-basin Name | Domestic NWSC | Domestic Small Towns | Domestic Rural | Livestock | Crops | Fisheries | Rural Industries | Total |
|---|---|---|---|---|---|---|---|---|
| (1) Okok | 0.00 | 2.29 | 7.03 | 7.52 | 8.97 | 0.34 | 0.50 | 26.7 |
| (2) Okere | 0.00 | 3.97 | 11.99 | 9.21 | 20.05 | 1.32 | 0.92 | 47.5 |
| (3) Awoja | 1.08 | 3.87 | 31.32 | 11.80 | 50.15 | 3.16 | 1.95 | 103.3 |
| (4) Lwere | 0.00 | 2.51 | 10.41 | 1.41 | 25.35 | 1.02 | 0.83 | 41.5 |
| (5) Akweng | 0.00 | 0.86 | 10.92 | 2.88 | 16.28 | 3.23 | 0.67 | 34.9 |
| (6)Abalan | 0.00 | 0.89 | 9.66 | 5.62 | 30.97 | 2.23 | 1.16 | 50.5 |
| (7) Kyoga Lakeside Zone | 0.00 | 0.89 | 16.28 | 7.08 | 35.12 | 4.59 | 1.40 | 65.4 |
| (8) Mpologoma | 10.34 | 11.88 | 65.27 | 6.95 | 251.92 | 11.41 | 8.11 | 365.9 |
| (9) Lumbuye | 0.00 | 0.00 | 11.90 | 1.27 | 5.18 | 1.89 | 0.25 | 20.5 |
| (10) Victoria Nile | 0.00 | 1.72 | 19.17 | 5.34 | 8.79 | 9.12 | 0.70 | 44.8 |
| (11) Sezibwa | 0.00 | 2.65 | 14.75 | 4.84 | 10.44 | 9.72 | 0.75 | 43.1 |

844.1

Strategic Investment Plan for the Water and Sanitation Sub Sector, 2009

As shown in Figure 11-3, the water demand of the Mpologoma sub-basin is the largest in the Lake Kyoga Basin sharing about 75 % of the demand of whole Kyoga basin, but its increase is not so sharp as the other sub-basins. The demand of the Mpologoma sub-basin increases to 365.9 MCM equivalent to about 12 % of increase, and remains only at about 43 % of the whole basin, though the demand of the whole basin gains from 435.6 MCM to 844.1 MCM equivalent to about 94 % of increase.

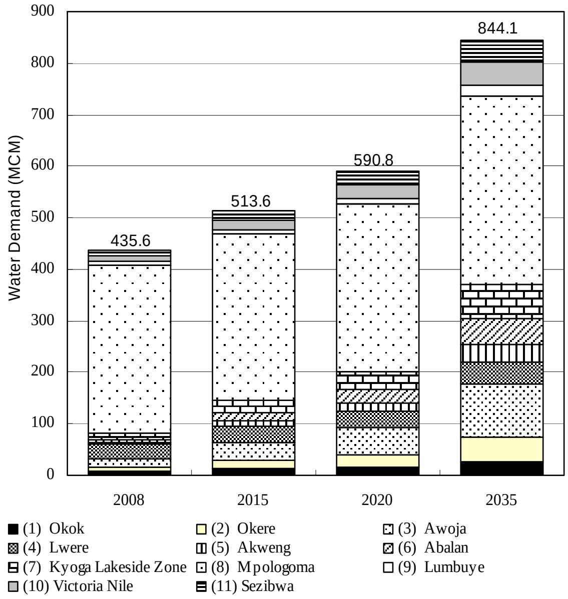



**Figure 11-3 Present and Future Water Demand in Lake Kyoga Basin by Sub-basin**

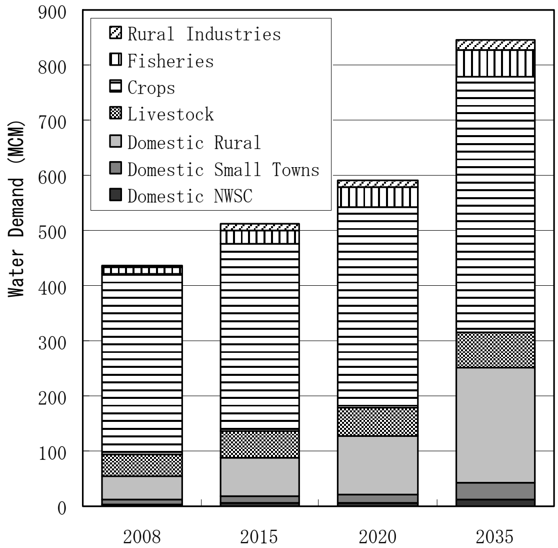



**Figure 11-4 Present and Future Water Demand in Lake Kyoga Basin by Sectors**

As for the water demand for each sector shown in Figure 11-4 and Table 11-10, the demand of irrigation for crops is considered to be the largest throughout the project period. It shares about 55% only in 2035 though about 75% in 2008. Its increase from 2008 to 2035 is calculated to be 42% which is considered low comparing with the increase of the whole demand of the basin of about 94%.

**Table 11-10 Present and Future Water Demand for Sectors**

(Unit:MCM)

| Year | Domestic NWSC | Domestic Small Towns | Domestic Rural | Livestock | Crops | Fisheries | Rural Industries | Total |
|---|---|---|---|---|---|---|---|---|
| 2008 | 3.9 | 8.22 | 42.94 | 37.82 | 326.95 | 12.02 | 3.78 | 435.7 |
| 2015 | 5.12 | 12.09 | 71.91 | 48.56 | 339.55 | 24 | 12.36 | 513.7 |
| 2020 | 6.33 | 16.31 | 105.85 | 51.54 | 361.31 | 36.03 | 13.45 | 591 |
| 2035 | 11.42 | 31.53 | 208.7 | 63.92 | 463.22 | 48.03 | 17.24 | 844.1 |

Source: Strategic Investment Plan for the Water and Sanitation Sub Sector, 2009

### 11.2.1 Drinking Water

The future demand of the drinking water supply is estimated based on the future population increase discussed in the previous section and the targets of coverage of water service and the consumption per capita as summarized below.

**Table 11-11 Targets of Urban and Rural Water Supply**

| Description | Present | Target 2015 | 2020 | 2035 |
|---|---|---|---|---|
| 1. Urban Water Supply | | | | |
| 1.1 Coverage (%) | | | | |
| Large Towns | 70 | 80 | - | 100 |
| Small Towns | 41 | 65 | 74 | 100 |
| 1.2 Consumption (liter/day/capita) | 35 | 30 | 45 | 60 |
| 2. Rural Water Supply | | | | |
| 2.1 Coverage (%) | 63 | 77 | 82 | 100 |
| 2.2 Consumption (liter/day/capita) | 15 | 20 | 25 | 30 |

Source: Strategic Investment Plan for the Water and Sanitation Sub Sector, 2009

### 11.2.2 Other Water Demands

The water demands for production such as livestock, crops (irrigation), fisheries and rural industries are estimated on the following conditions.

#### 1) Water for Crops (Irrigation)

The water demand for irrigation is estimated based on the present crop mix according to UBOS statistics on cultivated areas and water demands for crop irrigation based on the CROPWAT model that provides data for the major crops in the Basin. As shown in Table 11-12, the cultivated areas are increased and in 2035 all the areas in the arable lands will be utilized. The irrigation facilities will be constructed in both Areas A and B, and 25% and 5% of cultivated lands will be irrigated in 2035.

**Table 11-12 Target Indices for Irrigation Requirement**

| Description | 2008 | 2015 | 2020 | 2035 |
|---|---|---|---|---|
| Cultivated Area in Arable Land | | 75% | 100% | 100% |
| Area Irrigated in Irrigable Land | | | | |
| Area A | | 5% | 10% | 25% |
| Area B | | 1% | 2% | 5% |
| Techinoloogy Mix of Irrigation Method for Water Saving | | | | |
| Area A | | | | |
| Drip | 1% | 2% | 3% | 5% |
| Sprinkler | 3% | 10% | 20% | 30% |
| Surface | 81% | 63% | 57% | 50% |
| Low cost | 15% | 25% | 20% | 15% |
| Irrigation Efficiency | 45% | 50% | 54% | 58% |
| Area B | | | | |
| Drip | 5% | 5% | 18% | 25% |
| Sprinkler | 40% | 40% | 50% | 50% |
| Surface | 30% | 30% | 12% | 10% |
| Low cost | 25% | 25% | 20% | 15% |
| Irrigation Efficiency | 64% | 64% | 73% | 76% |

Note: The irrigation efficiencies vary depending on the irrigation methods applied as shown below.
- Drip: 90%, - Sprinkler: 80%, - Surface: 40%, - Low cost: 60%

Source: Strategic Investment Plan for the Water and Sanitation Sub Sector, 2009

Saving water is one of the important aspect in SIP, especially for the irrigation it is important because it shares substantial part of the whole demand. In SIP, some advanced method in water application in fields are considered; drip, sprinkler and surface methods as presented in the above table. The irrigation efficiencies are planned to be increased from the present 45% and 64% to 58% and 76% in Areas A and B, respectively in the plan.

**2) Water for Livestock**

The volume of water required for livestock feeding is estimated based on the future numbers of livestock expressed as Tropical Livestock Units (TLUs), which are estimated according to the rangeland capacity worked out from the rangeland areas and carrying capacities in the various agricultural zones on the UBoS statistics.

The following table shows the various indices of the water supplies for feeding livestock.

**Table 11-13 Target Indices for Livestock Requirement**

| Description | 2015 | 2020 | 2035 |
|---|---|---|---|
| Rangeland Utilized | | | |
| Cattle Corridor | 60% | 70% | 100% |
| Non Cattle Corridor | 30% | 35% | 50% |
| Cattles Fed with Water | | | |
| Cattle Corridor | 30% | 40% | 70% |
| Non Cattle Corridor | 10% | 15% | 30% |

Source: Strategic Investment Plan for the Water and Sanitation Sub Sector, 2009

**3) Water for Fisheries**

The water volume necessary for fisheries is estimated based on the annual targets for production of fish from fishponds. The targets are set in accordance with the plans from the Fisheries Department as percentage increase of the present fish production as shown in the following table.

**Table 11-14 Target Indices for Fish Production**

| Description | 2015 | 2020 | 2035 |
|---|---|---|---|
| Fish production<br>(% of 2006 fish production from ponds) | 200% | 300% | 400% |

Source: Strategic Investment Plan for the Water and Sanitation Sub Sector, 2009

**4) Water for Rural Industries**

The water volume required for rural industries is estimated as a proportion of those in the above three (3) productive sub-sectors. Presently there is limited use of water for processing of agricultural produce; dairies and abattoirs are located in urban areas. However, the water use by rural industries is expected to increase with the emphasis on development of agricultural industries and food processing close to the production areas.

### 11.2.3 Water Saving

Since the total water demand of domestic, livestock, agriculture, fisheries and rural industries will be increased from the present 435.6 MCM to 844.1 MCM in 2035 resulting in the severe water shortage unless any measures are taken to reduce such huge increase of demand to meet the available water resources, it is essential to be prepared to shift from the present mass consumption to the water-saving society.

As for the irrigation water demand, which shares largest at present and in the future (75% in 2008 and 55% in 2035) and of which effect of water saving is expected to be remarkable, it is necessary to adopt positively water-saving irrigation methods. The water saving methods such as drip and sprinkler irrigation, etc. are required to be introduced for upland cultivation in order to improve irrigation efficiency. In fact as shown in Table 11-12, these water saving methods are considered in the estimation of future irrigation water demand. In the case of the paddy cultivation in wet lands, to reduce the losses by evaporation from water surfaces and seepage from bottoms of canals, it is required to be applied concrete-lined canals or piped conveyance systems instead of the ordinary earthen canals.

The domestic water demand shares 18 % (the second largest after irrigation) of the whole demand in 2008, and will share 38 % (also the second largest after irrigation but twice of that in 2008) in 2035. The domestic water supply will be given the first priority from the viewpoint of BHN (Basic Human Needs) though it is important to provide necessary water volume for the people reducing the volume of unnecessarily wasted water. For instance, as shown in Table 11-15, the Unaccounted for Water (UFW) widely varies from 5 % to 71 %, and if these unaccounted water volumes are reduced to 15 % about 430,000 $m^3$/year of water is saved in the basin.

**Table 11-15 Unaccounted for Water of Water Supply System in Large and Small Towns**

| Area | Water Supplied ($m^3$/day) | Water Sold ($m^3$/day) | UFW (%) | Area | Water Supplied ($m^3$/day) | Water Sold ($m^3$/day) | UFW (%) |
|---|---|---|---|---|---|---|---|
| Large Towns | | | | Bugiri | 26,973 | 23,829 | 12 |
| Jinja/Lugazi | 4,452 | 3,349 | 25 | Kachumbala | 1,304 | 1,216 | 7 |
| Tororo | 909 | 804 | 12 | Busia | 187,453 | 141,711 | 24 |
| Mbale | 1,221 | 1,109 | 9 | Bulolwe | 17,209 | 14,681 | 15 |
| Lira | 934 | 816 | 13 | Busembatya | 44,026 | 39,392 | 11 |
| Soroti | 749 | 499 | 33 | Buwenge | 38,560 | 30,413 | 21 |
| Total | 8,265 | 6,577 | 20 | Kaliro | 20,573 | 18,884 | 8 |
| Small Towns | | | | Kamuli | 56,484 | 46,530 | 18 |
| Kangulumira | 18,618 | 17,052 | 8 | Kapachorwa | 145,521 | 41,954 | 71 |
| Kayunga | 37,036 | 22,164 | 40 | Katakwi | 18,641 | 16,993 | 9 |
| Bombo | 40,742 | 16,975 | 58 | Kumi | 19,658 | 17,684 | 10 |
| Luwero | 107,735 | 89,565 | 17 | Ngora | 56,599 | 33,920 | 40 |
| Semuto | 14,480 | 10,978 | 24 | Lwakhakha | 20,336 | 14,154 | 30 |
| Wobulenz | 82,069 | 57,941 | 29 | Pallisa | 25,596 | 17,235 | 33 |
| Nkokonjeru | 13,174 | 7,387 | 44 | Budadiri | 38,238 | 13,094 | 66 |
| Aduku | 27,673 | 22,988 | 17 | Sironko | 5,909 | 5,615 | 5 |
| Apac | 20,287 | 7,372 | 64 | Serere | 7,457 | 4,876 | 35 |
| Nakasongola | 17,661 | 15,835 | 10 | Dokolo | 22,937 | 17,949 | 22 |
| Kakiri | 12,834 | 9,933 | 23 | Kotido | 33,857 | 27,044 | 20 |
| Wakiso | 60,799 | 42,421 | 30 | Total | 1,256,447 | 857,410 | 32 |
| Budaka | 16,008 | 9,625 | 40 | | | | |

Source: Strategic Investment Plan for the Water and Sanitation Sub Sector, 2009

The other water demands for rural industries, fishery and cattle feeding are small and their shares are also limited, but a certain level of water saving has to be considered in these uses of water. However, only in some areas where the cattle feeding is important in the people's lives full water supply is planned to be achieved, and in the other areas sufficient volume of water to feed all cattle is not assured. Then, it is rather difficult to control the demand of cattle feeding. In addition, the rural industries expected to be grown in the Lake Kyoga Basin are those processing the agricultural and fishery products on cottage industry levels. It is desirable to introduce a recycling system of used water in these industries, only few industries will be able to spare the cost for such recycling system. Consequently, in order to control the water use of these industries number of cattle fed and production of fishes have to be controlled in the allowable levels by the administrative initiative.

# CHAPTER 12 WATER RESOURCES POTENTIAL EVALUATION

## 12.1 Water Balance Analysis for Water Resource Evaluation

A water balance is a numeric accounting of inputs, outputs, and storages of water and it can be used to manage water resources, to monitor and predict water shortage, to prevent flooding, and so on. The water balance of study area is expressed simply by the following equation.

$$P = E + R + I \qquad (12.1)$$

Where; $P$ is precipitation; $E$ is evapotranspiration: $R$ is runoff; and $I$ is infiltration.

In this study, the water balance analysis was implemented for understanding the characteristic of water balance and evaluating the groundwater storage in the whole study area. In the water balance analysis, the meteorological data and hydrological data are utilized as the existing monitoring data. The list of used monitoring data is shown in Table 12-1. In the northern part of study are, the monitoring data is not sufficient for an estimation of meteorological data covering the whole study area even by an interpolation method. To compensate the lack of monitoring data, the additional meteorological data observed in Kenya were utilized for the interpolation of some items.

**Table12-1 List of Used Monitoring Data**

| Observation Items | Frequency of Observation | Number of Stations | |
|---|---|---|---|
| | | Uganda | Kenya |
| Precipitation | Daily and Monthly | 271 | 4* |
| Maximum Temperature | Daily | 36 | 3* |
| Minimum Temperature | Daily | 36 | 3* |
| Average Temperature | Monthly | 1* | 1* |
| Sunshine Hours | Daily | 6 | 2* |
| Evaporation | Daily | 9 | - |
| River Water Flow | Daily | 11 | - |

Source: Department of Meteorology, DWRM and WMO*

### 12.1.1 Estimation of Precipitation

The annual and monthly precipitation maps of the study area and its surroundings were created by the precipitation data of meteorological stations. The precipitation values of unmeasured area (unmeasured grid) were estimated by Kriging method as an interpolation using measured precipitation values. The estimated annual precipitation map is shown in Figure 12-1. The study area belongs to "semiarid climate region" and the annual precipitation varies from approximately 700 to over 2,000 mm depending on topography of the area. The annual precipitation of the plain and gently hilly terrain, where the most of study area belong to, is 1,000 to 1,300 mm. However, the annual precipitation

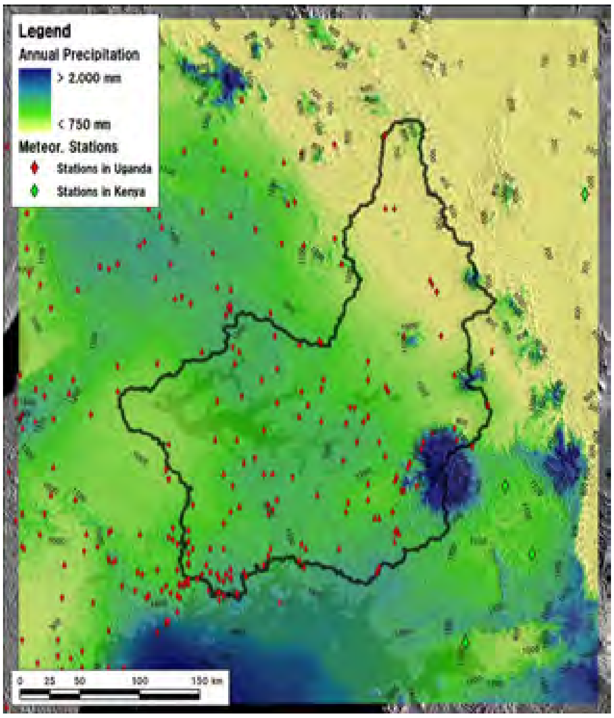



**Figure 12-1 Estimated Annual Precipitation Map**

in the plain of northern part, Kaabong, Kotido and Moroto Districts, is less than 1,000 mm. On the other hand, the annual precipitation of mountainous area is estimated to be over 2,000 mm.

### 12.1.2 Estimation of Evapotranspiration

The evapotranspiration of study area was estimated by Makkink equation in consideration with Albedo (Nagai, 1993). The equation is defined as follows:

$$ET_{mak} = \alpha\left((a + 0.06 - A)\frac{\Delta}{\Delta + \gamma}\frac{Rs}{\lambda} + b\right) \quad (12.2)$$

Where; $ET_{mak}$ (mm/day) is evapotranspiration; $\alpha$ is conversion value from potential to actual evapotranspiration value: $\Delta$ (hPa/°C) is slope of saturation vapor pressure curve; $\gamma$ (hPa/°C) is psychrometric constant; $Rs$ (MJ/m$^2$/day) is total solar radiation; $\lambda$ (MJ/kg) is latent heat; $a$ and $b$ are regional constant values; $A$ is albedo value of each land cover class. The annual evapotranspiration map is shown in Figure 12-2.

The annual evapotranspiration values of the study area vary from 200 to 1,000 mm. Generally, the annual evapotranspiration of northern part with low precipitation is less than the central and western parts; estimated to be 300 to 600 mm for a year in the northern part and 600 to 1,000 mm in central and western parts. The annul values of high altitude area were estimated to be less than 300 mm, the lowest value in the study area, because the annual mean temperature of these area is less than 15 degrees Celsius. On the other hand, the highest values of 900 to 1,000 mm were obtained from the area with surface of lakes, wetland and dense tropical rain forests in the western and southwestern parts with very low albedo value (0.06 to 0.11).

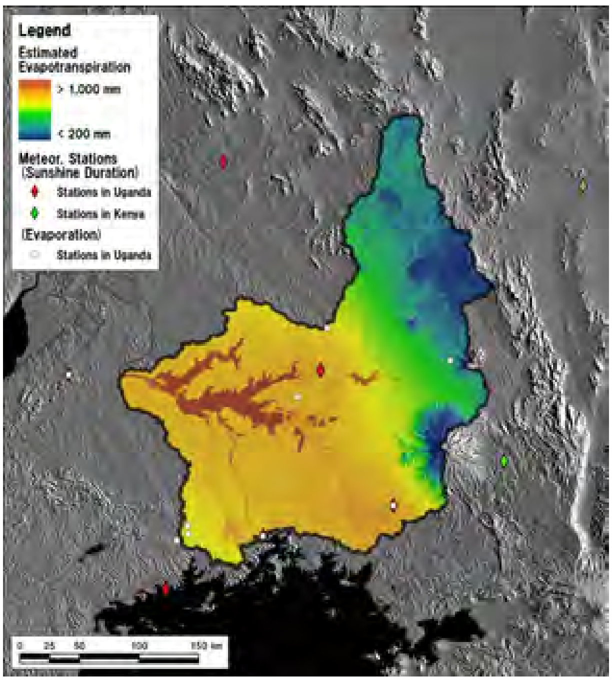



**Figure 12-2 Estimated Evapotranspiration Map**

### 12.1.3 Estimation of Runoff

The ratio of runoff, or river discharge was estimated by the techniques of geomorphometry and statistical analysis (Principle Component Analysis; PCA). The "Runoff Index" was defined as the original indicator of surface river discharge on the basis of PCA result, and the indices of each sub-catchment and catchment with gauging station in the study area were calculated. The correlation between the actual runoff ratio and the runoff indices of the sub-catchment with gauging station are shown in Table 12-2 and Figure 12-3.

**Table 12-2 Actual Runoff Ratio and Runoff Index of Gauging Stations**

| Station ID | Grade of PC Score | | | Runoff Index | Actual Runoff Ratio |
|---|---|---|---|---|---|
| | PC 1 | PC 2 | PC 3 | | |
| 82212 | 6 | 4 | 3 | 5.065 | 0.313 |
| 82213 | 6 | 4 | 5 | 5.521 | 0.418 |
| 82218 | 4 | 6 | 3 | 3.521 | 0.195 |
| 82220 | 2 | 4 | 2 | 2.751 | 0.084 |
| 82228 | 7 | 4 | 1 | 5.130 | 0.232 |
| 82231 | 5 | 3 | 5 | 5.250 | 0.101 |
| 82240 | 6 | 4 | 5 | 5.521 | 0.280 |
| 82241 | 7 | 5 | 4 | 5.564 | 0.312 |
| 82243 | 7 | 7 | 5 | 5.292 | 0.318 |
| 82245 | 2 | 5 | 5 | 3.185 | 0.009 |
| 82252 | 2 | 3 | 3 | 3.230 | 0.012 |

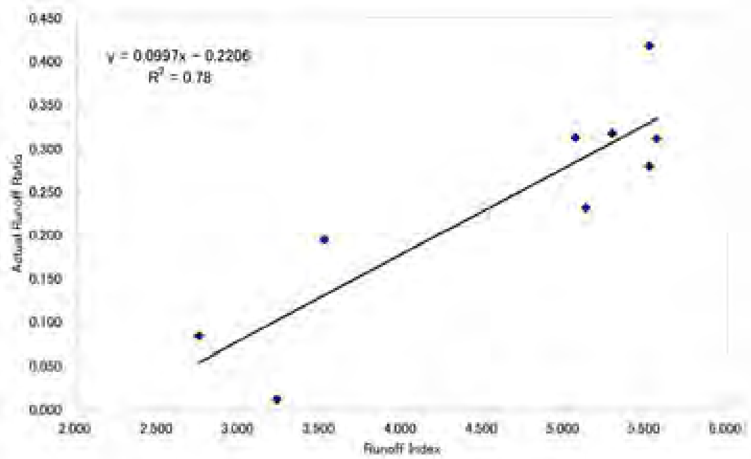



**Figure 12-3 Scatter Diagram showing the Actual Runoff Ratio and Runoff Index**

As shown in Figure 12-3, the correlation of the both is quite good ($R^2$ = 0.78), and the runoff index of ungauged sub-catchment can be calculated from the runoff ratio by the following equation of the linear regression.

$$R_{ratio} = 0.0997 \times RI - 0.2206 \quad (12.3)$$

Where; $R_{ratio}$ is estimated runoff ratio of sub-catchment; $RI$ is estimated runoff index. The estimated runoff ratio map is shown in Figure 12-4.

The highest runoff ratio (red colored catchment in Figure 12-4) is obtained from the sub-catchments, located in the slope of mountainous and hilly terrain and showing rounded shape. On the other hand, as shown in dark blue color, the lowest runoff ratio is obtained from the sub-catchments, located in plain area and showing narrow sharp.

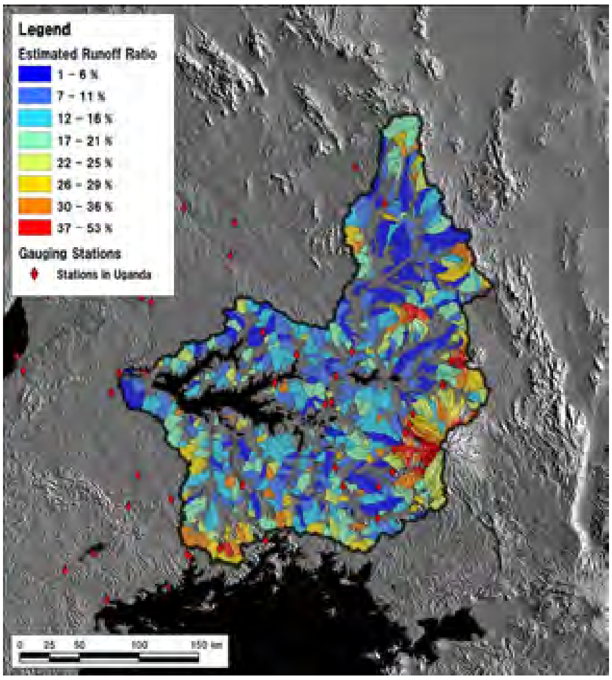



**Figure 12-4 Estimated Runoff Ratio Map**

### 12.1.4 Estimation of Infiltration (Groundwater Recharge)

On the basis of the estimated precipitation, evapotranspiration and runoff ratio, the infiltration, reflecting the ground water recharge and storage, can be expressed by the following equation.

$$I_{est} = P_{est} - AET_{mak} - P_{est} \times R_{ratio} \qquad (12.4)$$

Where; $I_{est}$ (mm) is estimated amount of infiltration; $P_{est}$ (mm) is estimated precipitation; $AET_{mak}$ (mm) is estimated evapotranspiration value; $R_{ratio}$ is estimated runoff ratio from the runoff index.

The annual infiltration map of the study area on a grid basis is shown in Figure 12-5. High estimated values were generally obtained for mountainous area in the eastern part, because precipitation is higher in the high altitude area than in the plain area. The infiltration of plain area with low precipitation, especially the northern part and the outlet area of Lake Kyoga are very low. As for the plain of western part, the infiltration varies widely depending on its surface conditions.

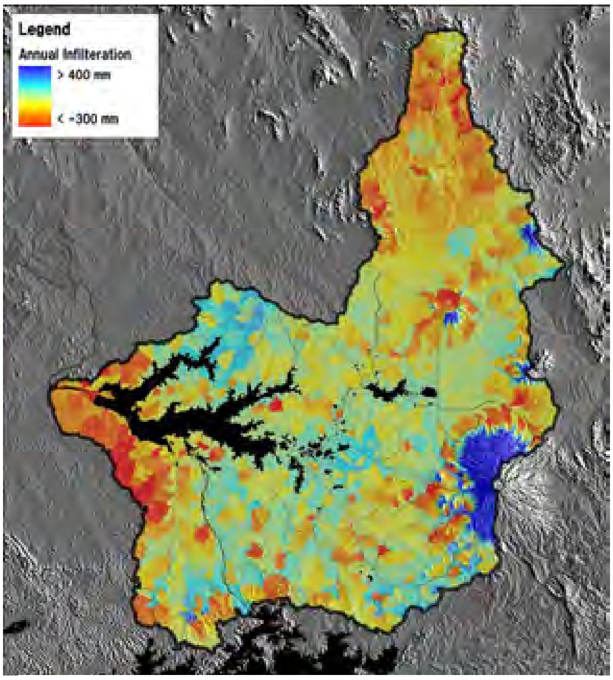



**Figure 12-5 Estimated Annual Infiltration**

## 12.2 Surface Water Resources Potential and Water Allocation Analysis

Estimation of surface water resources potential was done using Mile Basin (simulation software, made by Danish Hydraulic Institute) and the knowledge of various study results obtained in the course of the study. Then, water allocation analysis was done using the simulation model.

Simulation was carried out in two steps as follows

1) Build up a simulation model

- Data preparation (rainfall, evapotranspiration, river discharge and water usage.
- Setup catchment parameter (catchment rainfall, evapotranspiration, run-off ratio and so on)
- Calibration (adjusts run-off analysis and observed river discharge)
- Simulate initial condition

2) Simulate future condition by future water demand using drought rainfall, and analyze water allocation

- Prepare future water demand projection (2035)
- Prepare drought rainfall
- Simulate future water demand with drought rainfall
- Evaluate future water resources condition and consider water allocation

Detail simulation process is described in this part.

### 12.2.1 Build up Simulation Model

#### (1) Preparation Work

Work flow of the preparation work is shown in Figure 12-6.

#### i) Selection of Calibration Period

The rainfall data and river gauging station data are dramatically decreased since civil war had started at 1981. After the civil war, many of the stations are broken and observation has not been held until now. These data are stored in Hydata which is a database of hydrological information. For the calibration, both of rainfall data and river gauging data in the same period are necessary. Therefore, calibration period shall be selected according to the data availability and coverage in each sub-catchment. For the calibration, data which were observed in 1950 to 1979 shall be selected because of following two reasons.

- Data availability in Hydata
- Less water demand than the present

Lists of rainfall station and river gauging station which are useful for analysis in Lake Kyoga basin is shown in Table 12-3 and 12-4, and data coverage of observed data are shown in Figure A12-1 and A12-2 of Appendix 12.

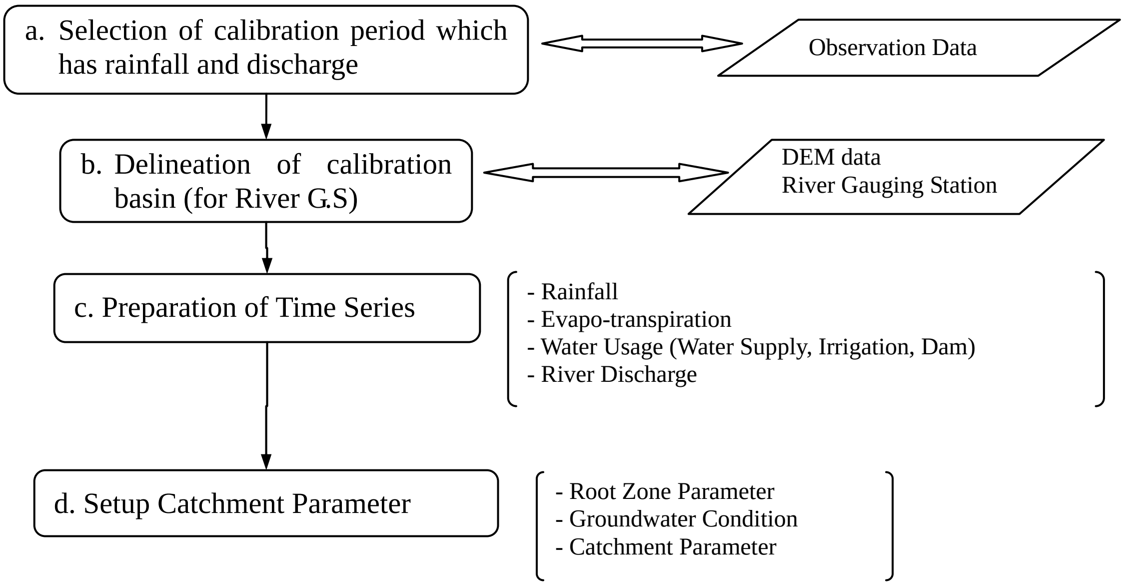



**Figure 12-6 Flow Chart of Preparation Work**

**Table 12-3 List of Rainfall Stations in Lake Kyoga Basin for Simulation**

| Station No. | Location Name | Long. | Lat. | Station No. | Location Name | Long. | Lat. |
|---|---|---|---|---|---|---|---|
| 86340010 | Kaabong | 34.1000 | 3.5500 | 88340020 | Mbale | 34.1830 | 1.0830 |
| 86340020 | Kotido | 34.1000 | 3.0170 | 88340040 | Kachumbala KU | 34.1000 | 1.2330 |
| 86340030 | Loyoro [Count | 34.2170 | 3.3670 | 88340150 | Bukedea Expt | 34.0500 | 1.3330 |
| 87320020 | Ngetta Farm | 32.9330 | 2.3170 | 88340260 | Bugusege Coff | 34.2670 | 1.1500 |
| 87320080 | Minakulu Vero | 32.3670 | 2.5170 | 88340300 | Sipi CM | 34.3830 | 1.3330 |
| 87320200 | Bardyang Fore | 32.9500 | 2.0170 | 88340370 | Namalu WDD | 34.6170 | 1.8170 |
| 87330050 | Ocacia Boys | 33.4500 | 2.0330 | 88340470 | Kapchorwa Dis | 34.4500 | 1.4000 |
| 87330070 | Morulem | 33.7670 | 2.6170 | 88340490 | Bukwa Catholi | 34.7500 | 1.3000 |
| 87340040 | Nabilatuk | 34.5170 | 2.1000 | 89310050 | Kiboga | 31.7670 | 0.9170 |
| 87340050 | Kangole | 34.4500 | 2.4670 | 89320000 | Kings College | 32.4830 | 0.2500 |
| 87340060 | Iriri Variety | 34.2330 | 2.1000 | 89320030 | Gayaza High S | 32.6170 | 0.4500 |
| 88310030 | Masindi Met S | 31.7170 | 1.6830 | 89320130 | Moniko Estate | 32.9000 | 0.3830 |
| 88310060 | Bulindi Farm | 31.4670 | 1.4830 | 89320180 | Ntenga Estate | 32.9330 | 0.3500 |
| 88310210 | Nalweyo Gombo | 31.2670 | 1.1170 | 89320570 | Nakifuma | 32.7830 | 0.5670 |
| 88320020 | Nakasongola T | 32.4670 | 1.3170 | 89330130 | Nawanzu | 33.5000 | 0.5670 |
| 88320090 | Bale Gombolol | 32.8830 | 1.1000 | 89330140 | Vukula | 33.5830 | 0.9500 |
| 88320110 | Aduku Variety | 32.7170 | 1.9830 | 89330200 | Mbulamuti KUR | 33.8000 | 0.8330 |
| 88320130 | Kidera | 32.9830 | 1.3500 | 89330240 | Namaganda KUR | 33.2170 | 0.8830 |
| 88320150 | Ibuje | 32.3830 | 1.9000 | 89330250 | Budumba KUR | 33.2170 | 0.8170 |
| 88330010 | Katakwi Dispe | 33.9670 | 1.9170 | 89330270 | Mutai Forest | 33.2330 | 0.5670 |
| 88330030 | Ngora Church | 33.8000 | 1.4670 | 89330280 | Butaleja Pris | 33.9670 | 0.9170 |
| 88330040 | Serere Agric | 33.4500 | 1.5170 | 89330360 | Bugiri | 33.7500 | 0.5670 |
| 88330060 | Soroti Met St | 33.6170 | 1.7170 | 89330390 | Ikulwe Farm I | 33.4830 | 0.4330 |
| 88330070 | Kibale VTC St | 33.7830 | 1.2000 | 89340270 | Dabani Cathol | 34.0500 | 0.4330 |
| 88330130 | Kaberamaido A | 33.1670 | 1.7830 | 89340470 | Nagongera KUR | 34.0500 | 0.7830 |
| 88330260 | Mukongoro | 33.8830 | 1.3330 | 89340490 | Magodesi KUR | 34.1500 | 0.8330 |
| 88330290 | Kagaya/Ochero | 33.0170 | 1.6670 | 89340520 | Nagongera Cat | 34.0170 | 0.7830 |
| 88330330 | Kagulu | 33.2500 | 1.1000 | 89341220 | Magale Girls | 34.3670 | 0.8830 |
| 88330500 | Ongino Lepros | 33.9670 | 1.5170 | | | | |

**Table 12-4 List of River Gauging Stations in Lake Kyoga Basin for Simulation**

| No. | Name | Long. | Lat. | No. | Name | Long. | Lat. |
|---|---|---|---|---|---|---|---|
| 81202 | Jinja Lake Victoria | 33.2075 | 0.4144 | 82228 | Namalu at Mbale – Mo | 34.5927 | 1.7862 |
| 82203 | Victoria Nile at Mbu | 33.0000 | 0.8667 | 82229 | Amaler at Mbale – Mo | 34.6000 | 1.7833 |
| 82204 | Victoria Nile at Nam | 32.9333 | 1.0167 | 82231 | Kelim (Greek) at Mba | 34.5377 | 1.5922 |
| 82212 | Manafwa at Mbale – T | 34.1545 | 0.9355 | 82240 | Sironko at Mbale – M | 34.2542 | 1.2350 |
| 82213 | Namatala at Mbale – | 34.1702 | 1.1052 | 82241 | Simu at Mbale – Moro | 34.2857 | 1.2923 |
| 82217 | Mpologoma at Budumba | 33.7873 | 0.8228 | 82242 | Muyembe at Mbale – M | 34.3000 | 1.3333 |
| 82218 | Malaba at Jinja – To | 34.0500 | 0.5833 | 82243 | Sipi at Mbale – Moro | 34.3085 | 1.3762 |
| 82219 | Omunyal Upper at Sor | 33.4408 | 1.9000 | 82244 | Atari at Mbale – Mor | 34.4500 | 1.5000 |
| 82220 | Enget at Bata – Doko | 33.1833 | 2.0000 | 82245 | Akokorio at Soroti – | 33.8525 | 1.8583 |
| 82221 | Agu at Kumi – Serere | 33.6953 | 1.4677 | 82246 | Omunyal Lower at Sor | 33.4333 | 1.8333 |
| 82222 | Abuket at Kumi – Ser | 33.6520 | 1.4520 | 82247 | Namatsyo at Busamaga | 33.7333 | 0.9667 |
| 82223 | Kapiri I at Railway | 33.8000 | 1.6667 | 82248 | Nabiyonga at Busamag | 34.2167 | 1.0833 |
| 82225 | Sezibwa at Falls | 32.8667 | 0.3667 | 82252 | R. Kyoga Nile at Masind | 32.1000 | 1.7000 |
| 82226 | Kami at Tororo – Bus | 34.1000 | 0.5167 | 83203 | R. Kafu at Kampala – Gu | 32.0500 | 1.5500 |
| 82227 | Kapiri at Kumi – Sor | 33.7355 | 1.6669 | 83213 | | | |

**ii) Delineation of the Calibration Catchment**

Calibration Catchment was selected based on the river gauging stations. List of the river gauging stations for the calibration were shown in Table 13-4.

The area which has few or no river gauging stations, was divided by considering topographical condition, geological condition, precipitation and distribution of evapotranspiration. Division is based on the sub-basin. Delineated catchments (Small-Catchment) are shown in Figure 13-7.

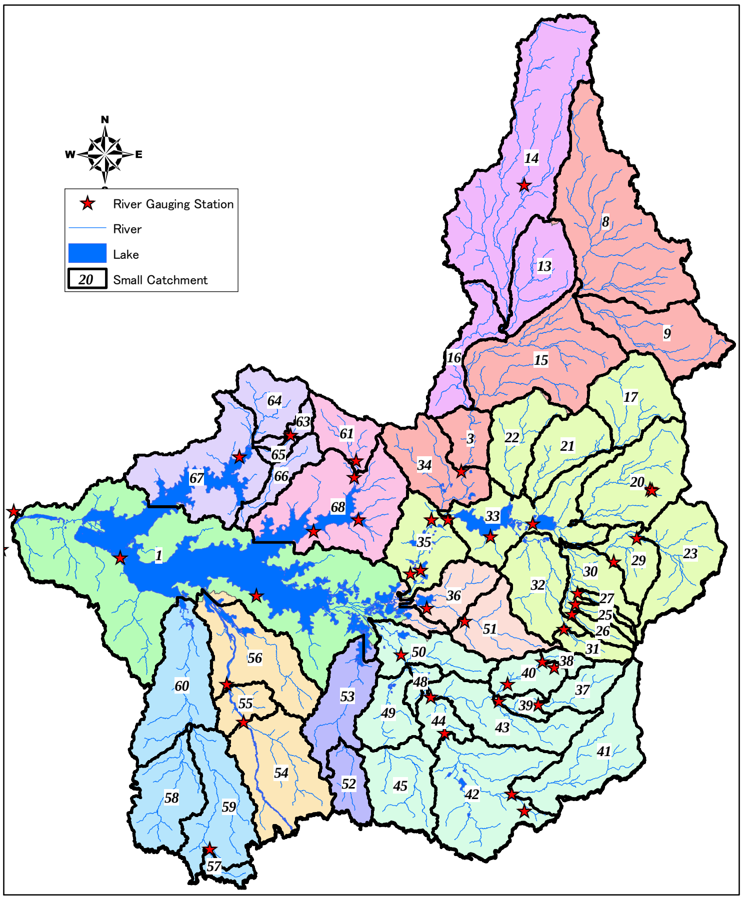



**Figure 12-7 Delineated Catchments (Small-Catchments) for Simulation**

**iii) Time Series**

Following time series are prepared before construction of the model. Time series data shall be covered from January 1st, 1950 to December 31st 1979.

1) Rainfall time series (each catchment or rainfall station which cover a target area)

2) Evapo-transpiration (each catchment or rainfall station which cover a target area)
3) River discharge (all observed discharge at gauging station, which are for calibration purposes)
4) Water Usage (Water Supply System, Irrigation)

**a) Rainfall Time Series**

Regarding the rainfall time series data, the data for daily rainfall time series of each small-catchment is created by weighting the monitoring point data of each small-catchment, which is based on the data of each monitoring station acquired by the Thiessen method.

**b) Evapotranspiration Time Series**

The measurement data of the evapotranspiration is extremely insufficient, and is not recommended to utilize as-is. Therefore, the result of satellite image analysis mentioned in the section 13.1.2 was used. The annual and monthly range of evapotranspiration is smaller compared to those of rainfall or river discharge, therefore monthly time series data of a year is converted to the analysis period of 30 years. The evapotranspiration per small-catchment was created from the basin information and by the satellite image analysis.

**c) River Discharge Time Series**

The river discharge time series is used for the comparison of the difference between the runoff analysis results by the simulation and observation results. The measured data was used as the time series data of the discharge measurement point.

**d) Water Usage Time Series**

Water supply facilities or irrigation facilities can be deemed not to have existed from 1950 to 1979 which was the calibration period of the simulation. Therefore, simulation for calibration is conducted excluding water usage.

**iv) Setup Catchment Parameters**

For the every small-catchment, parameters of (1) Surface-Rootzone, (2) Groundwater and (3) Initial Conditions, shall be prepared as shown Table 13-5. Default values are used for the beginning of calibration work. Then simulations are conducted adjusting each parameter variously and comparing observation values to simulation results about runoff volume or hydrograph. Simulation and calibration of each parameter are continued until observation values and simulation results become closely correlated. Table 13-5 shows final calibrated values of each parameter as well.

**Table 12-5 Parameters for Simulation**

| | Items | | Default | Final Value | Common Range |
|---|---|---|---|---|---|
| Surface Rootzone | Max. water content in surface storage (mm) | UMax | 1.0 | 10 | 10 ~ 20 |
| | Max. water content in root zone storage (mm) | LMax | 100 | 300 | 50 ~ 300 |
| | Overland flow runoff coefficient (%) | CQOF | 0.5 | 0.07 ~ 0.3 | 0 ~ 1.0 |
| | Time constant for interflow (hours) | CKIF | 1000 | 200 | 500 ~ 1000 |
| | Time constants for routing overland flow (hours) | CK1 | 10 | 48 | 3 ~48 |
| | Root zone threshold value for overland flow (%) | TOF | 0 | 0.5 | 0 ~70 |
| | Root zone threshold value for inter flow | TIF | 0 | 0 | |
| Groundawter | Root zone threshold value for groundwater recharge (%) | TG | 0 | 0 | 0 ~0.70 |
| | Time constant for routing base flow (hour) | CKBF | 2000 | 750 | |
| | Ratio of groundwater catchment to topographical catchment area | Carea | 1 | 1 | Less than 1.0 |
| | Specific yield for the groundwater storage | Sy | 0.1 | 0.1 | 0.01~0.1 (clay)<br>0.1~0.3 (sand) |
| | Max. groundwater depth causing baseflow (m) | CWLBF0 | Null | Null | |
| | Depth for unit capillary flux (m) | CWLBF1 | Null | Null | |
| | Lower base flow. Recharge to lower reservoir (%) | Cqlow | 0 | 0 | |
| | Time constant for routing lower baseflow (hour) | Cklow | 10000 | 10000 | More than CLBF |
| Initial Condition | Relative water contents in the surface storage | U_UMax | 0 | 0 | 0 ~ 1 |
| | Relative water content in root zoon storage | L_LMax | 0 | 0 | 0 ~ 1 |
| | Overland flow | QOF | 0 | 0 | From the hydrograph |
| | Interflow | QIF | 0 | 0 | 'rom the hydrograph |
| | Baseflow | BF | 0 | 0 | 'rom the hydrograph |
| | Lower Baseflow | BF_low | 0 | 0 | 'rom the hydrograph |
| | Snow Storage (mm) | SnowStorag e | 0 | 0 | Initial snow depth |

### (2) Rainfall-Runoff Analysis (NAM Analysis) of Each Small-Catchment

Each parameter of each small-catchment is calibrated according to the comparison of the results of runoff analyses conducted adjusting parameters' values and the discharge measurement time series data. The flow of calibration is shown in Figure 13-8. In addition, the small-catchments and river gauging stations used for the comparison are shown in the table below.

**Table 12-6 Target Small-Catchments for the Calibration Work**

| Small-Catchment | 41 | 42 | 57 | 37 | 38 | 31 | 26 | 23 |
|---|---|---|---|---|---|---|---|---|
| River Gauging St. | 82218 | 82217 | 82225 | 82212 | 82213 | 82240 | 82241 | 82231 |

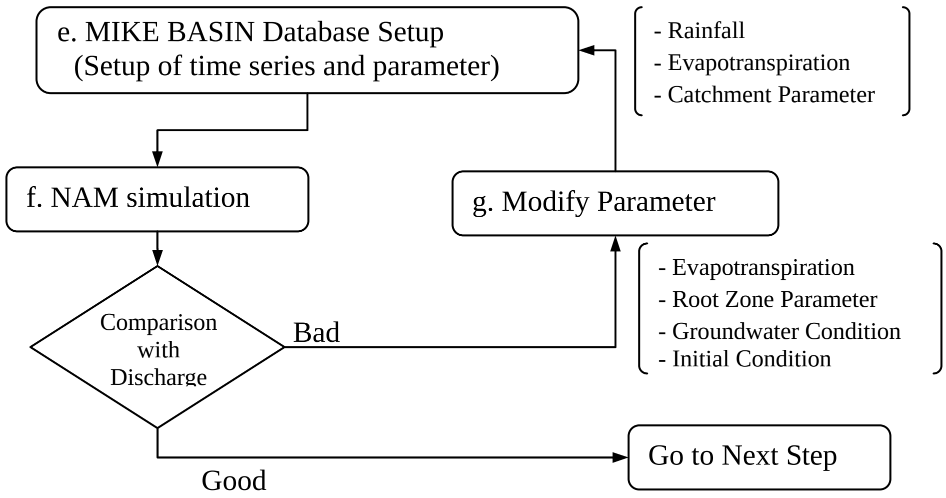



**Figure 12-8 Flow Chart of Calibration Work**

**i) Evapotranspiration**

The potential evapotranspiration is used for evapotranspiration in general. However, the measured value of the evapotranspiration is not the actual measured evapotranspiration value. For this reason, it is more likely to be deemed as an estimate value compared to the amount of rainfall or river discharge. Upon calibration, the total annual runoff must be firstly adjusted by adjusting the evapo-transpiration.

The evapotranspiration is adjusted based on the value (potential evapotranspiration) from the satellite image analysis mentioned before. Table 12-7 shows the adjustment coefficient of the evapotranspiration.

**Table 12-7 Adjustment Coefficient of Evapotranspiration (%)**

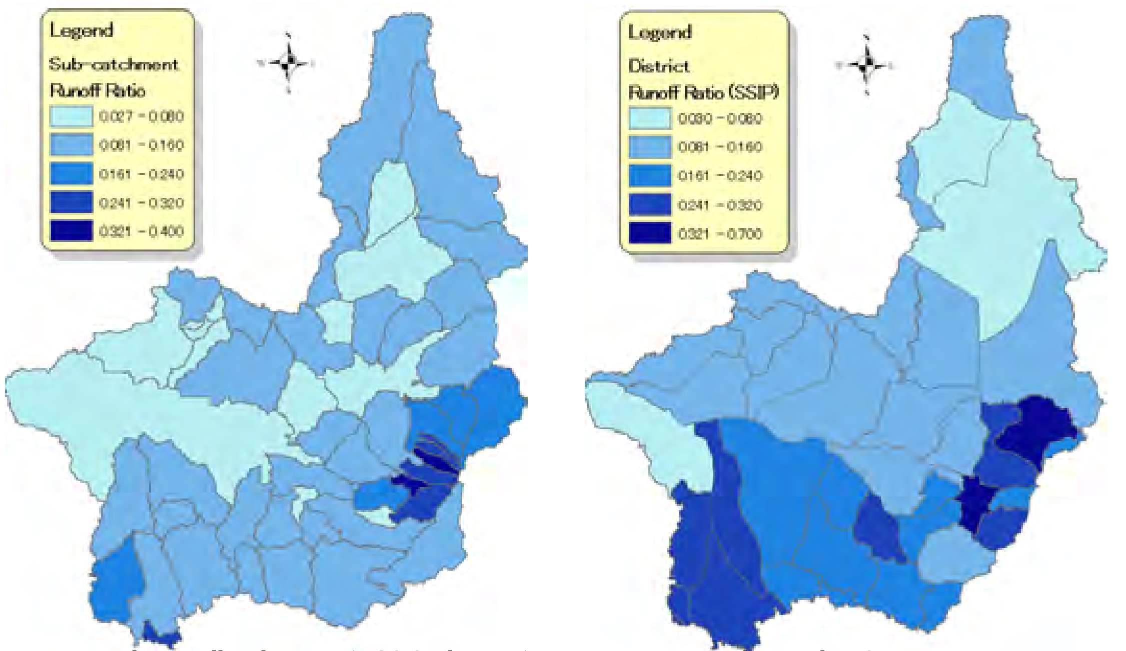
| Small-Catchment No. | 41 | 42 | 57 | 37 | 38 | 31 | 26 | 23 |
|---|---|---|---|---|---|---|---|---|
| River Gauging Station | 82218 | 82217 | 82225 | 82212 | 82213 | 82240 | 82241 | 82231 |
| ET Coefficient (%) | 67 | 90 | 67 | 55 | 67 | 67 | 55 | 90 |
| Ratio of NAM / Observed | 0.78 | 0.84 | 0.95 | 0.82 | 0.95 | 1.16 | 0.82 | 0.92 |

*1: The Ratio of NAM/observed is a value which divide long-term average of simulation result (runoff) to apply ET coefficient to potential evapo-transpiration by long-term average of observed river discharge.
*2: Since small-catchment 42 is located in the downstream of small-catchment 41, the simulated value including the runoff amount of 41 is compared with observed value of 82217.

The evapotranspiration of the each small-catchment was setup based on the result of Table 12-7 referencing distribution of runoff coefficient described below. The ET coefficient is applied from four (4) values of 55%, 67%, 90% and 95%.

**2) Runoff Coefficient**

Likewise the evapotranspiration, the average runoff coefficient of each small-catchment was obtained by using the result of satellite image analysis mentioned in the section 12.1.3. The runoff coefficient by small-catchment is shown in Figure 12-9. Additionally, the runoff coefficient by district used in the report of SIP is shown in Table 12-8. Figure 12-9 is also including the distribution map of the runoff coefficient by SIP. Relatively large values are provided for the runoff coefficient in general for SIP. In particular, as for Kapchorwa, where the maximum value was marked is 0.7. However, low runoff coefficients such as from 0.1 to 0.2 are marked for areas around Lake Kyoga and the northern area, while higher in the southern area and the highest in Mt. Elgon area, which proves that similar patterns can be observed.




a. Based on satellite data, etc. (JICA Study Team) b. Based on SIP report

**Figure 12-9 Distribution Map of Runoff Coefficient**

**Table 12-8 Runoff Coefficient by District by SIP**

| District Name | Runoff Coefficient | District Name | Runoff Coefficient | District Name | Runoff Coefficient |
|---|---|---|---|---|---|
| Kampala | 0.28 | Kumi* | 0.11 | Butaleja | 0.24 |
| Luweero* | 0.28 | Mbale* | 0.43 | Kaliro | 0.24 |
| Mukono | 0.28 | Pallisa* | 0.11 | Manafwa | 0.31 |
| Nakasongola | 0.03 | Soroti | 0.11 | Namutumba | 0.31 |
| Kayunga | 0.28 | Tororo | 0.11 | Apac* | 0.09 |
| Wakiso | 0.28 | Kaberamaido | 0.11 | Kotido* | 0.03 |
| Bugiri* | 0.24 | Mayuge | 0.24 | Lira* | 0.11 |
| Busia | 0.24 | Sironko | 0.26 | Moroto | 0.03 |
| Iganga* | 0.24 | Amuria | 0.11 | Nakapipirit | 0.15 |
| Jinja | 0.24 | Budaka | 0.24 | Abim | 0.11 |
| Kamuli | 0.24 | Bududa | 0.24 | Amolatar | 0.11 |
| Kapchorwa* | 0.70 | Bukedea | 0.11 | Dokolo | 0.11 |
| Katakwi* | 0.11 | Bukwa | 0.24 | Kaabong | 0.11 |

**Figure 12-10 Runoff Coefficient of Small-Catchment and Classification**

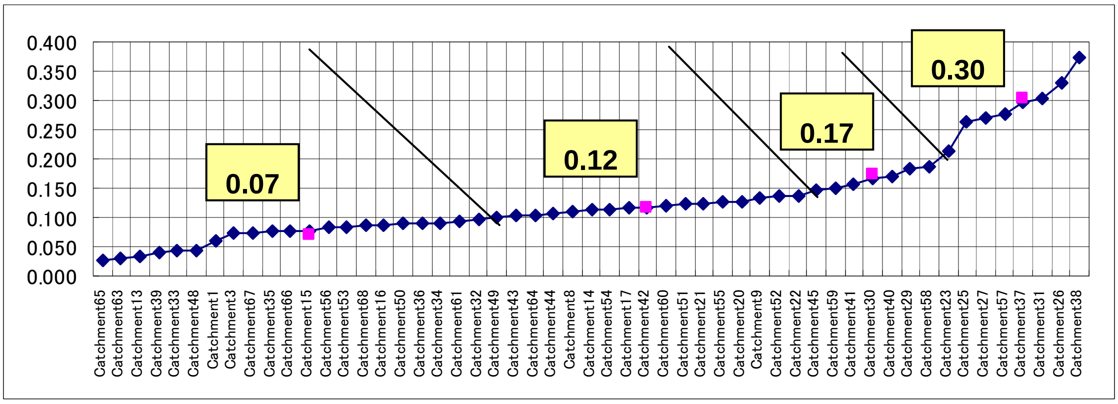



**Figure 12-10 Runoff Coefficient of Small-Catchment and Classification**

Figure 12-10 shows trend of when runoff coefficients obtained from the satellite image analysis are sequenced from low values to higher values. This simulation classifies runoff coefficients into four types (flat land, hill, slope, steep slope) for simplification, and is used as a characteristic value (Surface Rootzone) of the catchment.

**(3) Calibration based on Discharge from Lake Victoria and Discharge from Lake Kyoga**

Lake Kyoga Basin is characterized by the fact that River Nile flows through the Basin. Therefore, after completion of calibration of NAM analysis condition of each small-catchment, conditions regarding entire Lake Kyoga Basin are set or calibrated based on discharge from Lake Victoria and outflow from Lake Kyoga. Concretely, the discharge from Lake Victoria is set as a boundary condition of the model, and evaporation on Lake Kyoga and inflow from tributaries to Lake Kyoga are calibrated aiming at adjusting the simulated outflow from Lake Kyoga to fit reference values. For the calibration, the discharge from Lake Victoria (Inflow from River Victoria Nile to Lake Kyoga) and the height-volume curve of Lake Kyoga, which are used in a model being prepared by DHI on a parallel with this Study, are also applied in this simulation model in order to ensure consistency with the DHI model as per DWRM's request. Besides, the outflow from Lake Kyoga, which is an indicator of calibration, are adjusted referencing value of the DHI model, results of past studies of Hydromet and COWI-DHI that is a base of present DHI analysis.

Calibration result and reference values are shown in the table below. Since the calibration result proved out, it was deemed to complete buildup of the model of an initial condition.

**Table 12-9 Comparison of Condition of Runoff Analysis**

Unit: $m^3/s$

| Item | Hydromet[1] | COWI-DHI[2] | DHI Model | Simulation Result on this Study |
|---|---|---|---|---|
| Average Inflow from River Victoria Nile to Lake Kyoga | 914 | 1074.2 | (1056.8)<br>(Discharge from Lake Victoria) | 1069.5 |
| Average Inflow from Tributaries to Lake Kyoga | 92 | 118.2 | — | 93.3 |
| Average Loss in Lake Kyoga (Direct Rainfall on Lake Kyoga | -66 | -91.7 | — | -90.1 |

1 Hydrometeorological Survey of the Catchments of Lakes Victoria, Kyoga and Albert (1974)
2 Study on the planned restoration of Lake Kyoga; Sub-report 1: Modelling of Lake Kyoga Flows (2007), COWI Uganda/MoWE, Kampala, Uganda

| | | | | |
|---|---|---|---|---|
| — Lake Evaporation) | | | | |
| Average Outflow from Lake Kyoga | 930 | 1097.6 | 1056.7 | 1073.1 |
| Reference Period | 1948-1970 | 1950-2004 | 1950-1979 | 1950-1979 |

*1 Inflow from tributaries to Lake Kyoga is adjusted by applying flow loss factor to tributaries' reach in consideration of characteristic of Lake Kyoga Basin. Final applied flow loss factor is basically 0.3.

### 12.2.2 Setup of Simulation Condition and Implementation of Simulation

Simulation for grasping basic runoff characteristic of each sub-basin and simulation on future water demand in 2035 in drought rainfall condition are carried out using the completed model.

Figure 12-11 shows the work flow.

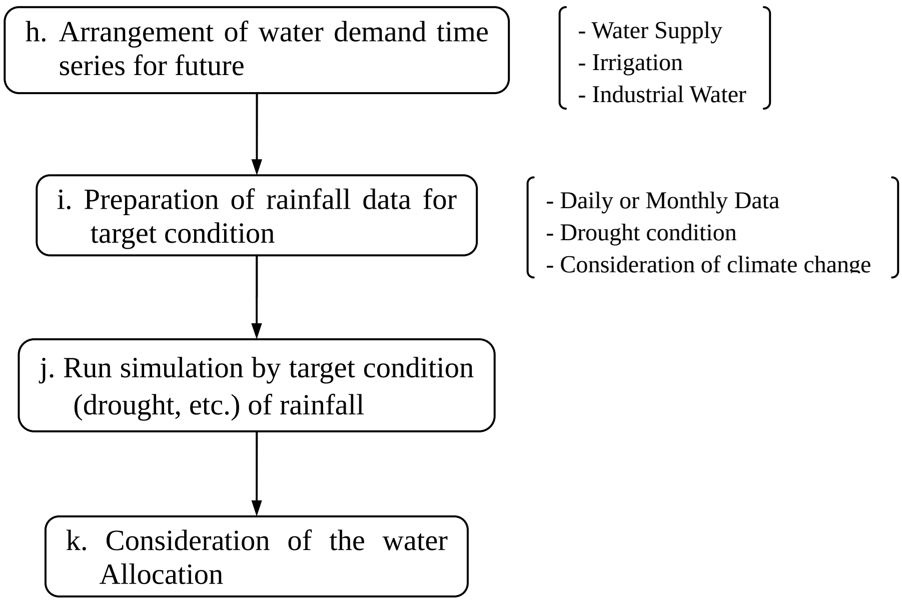



**Figure 12-11 Flow Chart for Setup of Simulation Condition and Implementation of Simulation**

**(1) Simulation for Grasping Runoff Characteristic of Each Sub-Basin and Surface Water Resources Potential**

Simulation is conducted in the following conditions to grasp basic runoff characteristic like low water and drought water discharge.

1. Simulation Period: From 1950 to 1979
2. Water Demand: Nothing
3. Rainfall Condition: Same rainfall time series as using in calibration work

Table 12-10 shows average, low water and drought water discharge of each sub-basin, which are calculated as basic runoff characteristic of each sub-basin and surface water potential.

## Table 12-10 Runoff Characteristic of Each Sub-Basin

Unit: ($m^3/s$)

| | (1) Okok | | | (2) Okere | | | (3) Awoja | | | (4) Lwere | | | (5) Akweng | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Average Water | Low Water | Drought Water | Average Water | Low Water | Drought Water | Average Water | Low Water | Drought Water | Average Water | Low Water | Drought Water | Average Water | Low Water | Drought Water |
| 1950 | 0.857 | 0.000 | 0.000 | 5.519 | 0.417 | 0.000 | 16.663 | 0.936 | 0.000 | 6.307 | 0.244 | 0.000 | 13.349 | 1.363 | 0.000 |
| 1951 | 3.333 | 1.069 | 0.006 | 7.786 | 2.003 | 0.122 | 20.953 | 7.644 | 0.748 | 8.366 | 2.817 | 0.227 | 11.370 | 4.087 | 0.601 |
| 1952 | 2.899 | 0.689 | 0.173 | 5.838 | 1.378 | 0.486 | 18.773 | 6.557 | 2.036 | 6.968 | 2.982 | 0.689 | 8.410 | 3.912 | 1.467 |
| 1953 | 4.495 | 0.245 | 0.024 | 5.238 | 0.634 | 0.050 | 12.698 | 1.779 | 0.578 | 3.541 | 0.418 | 0.050 | 7.453 | 1.463 | 0.163 |
| 1954 | 7.343 | 0.386 | 0.044 | 11.875 | 1.168 | 0.227 | 21.893 | 2.513 | 0.863 | 5.542 | 0.441 | 0.121 | 6.075 | 1.568 | 0.379 |
| 1955 | 5.684 | 0.482 | 0.079 | 7.243 | 1.312 | 0.185 | 12.235 | 5.360 | 1.590 | 4.073 | 1.418 | 0.192 | 7.812 | 0.572 | 0.051 |
| 1956 | 2.202 | 0.816 | 0.302 | 5.379 | 0.716 | 0.192 | 16.591 | 6.243 | 2.080 | 3.816 | 1.395 | 0.585 | 8.641 | 2.757 | 0.947 |
| 1957 | 3.739 | 0.291 | 0.044 | 3.293 | 0.580 | 0.235 | 16.528 | 4.146 | 1.735 | 4.848 | 0.561 | 0.182 | 8.653 | 2.129 | 0.868 |
| 1958 | 4.954 | 0.270 | 0.050 | 5.554 | 0.765 | 0.070 | 13.461 | 4.028 | 0.921 | 4.686 | 0.888 | 0.128 | 8.935 | 0.982 | 0.334 |
| 1959 | 3.165 | 0.557 | 0.071 | 4.764 | 0.356 | 0.046 | 10.683 | 6.489 | 3.137 | 4.116 | 1.127 | 0.487 | 8.766 | 3.982 | 1.346 |
| 1960 | 2.116 | 0.578 | 0.165 | 5.674 | 1.756 | 0.511 | 15.124 | 4.953 | 2.617 | 5.907 | 1.130 | 0.364 | 8.053 | 3.507 | 0.855 |
| 1961 | 11.049 | 0.102 | 0.011 | 11.917 | 0.395 | 0.070 | 35.903 | 4.159 | 0.648 | 10.633 | 1.972 | 0.059 | 15.548 | 3.353 | 0.602 |
| 1962 | 7.917 | 1.200 | 0.461 | 6.792 | 2.416 | 0.543 | 25.581 | 13.874 | 6.509 | 7.783 | 4.253 | 1.772 | 13.955 | 6.035 | 2.256 |
| 1963 | 1.885 | 0.399 | 0.181 | 6.887 | 1.097 | 0.234 | 27.310 | 7.890 | 3.473 | 9.184 | 2.158 | 0.778 | 9.595 | 3.021 | 0.794 |
| 1964 | 0.685 | 0.160 | 0.059 | 6.236 | 2.056 | 0.413 | 18.227 | 7.577 | 3.784 | 5.265 | 2.274 | 1.134 | 6.628 | 2.901 | 0.982 |
| 1965 | 1.176 | 0.085 | 0.004 | 1.951 | 0.703 | 0.166 | 10.319 | 4.761 | 0.824 | 3.334 | 1.328 | 0.185 | 6.420 | 1.609 | 0.066 |
| 1966 | 2.203 | 0.435 | 0.055 | 5.941 | 1.040 | 0.084 | 16.616 | 8.181 | 3.915 | 6.919 | 2.946 | 0.607 | 10.873 | 4.028 | 1.892 |
| 1967 | 2.129 | 0.197 | 0.033 | 10.795 | 1.926 | 0.188 | 24.308 | 5.002 | 1.342 | 6.247 | 1.537 | 0.223 | 15.563 | 1.598 | 0.387 |
| 1968 | 1.918 | 0.483 | 0.075 | 6.249 | 1.589 | 0.760 | 23.054 | 9.024 | 3.971 | 8.291 | 3.154 | 1.811 | 15.499 | 5.163 | 3.017 |
| 1969 | 1.358 | 0.426 | 0.016 | 3.144 | 0.928 | 0.099 | 19.019 | 10.644 | 3.468 | 6.836 | 3.565 | 1.709 | 10.136 | 4.017 | 1.640 |
| 1970 | 3.167 | 0.383 | 0.034 | 5.245 | 1.421 | 0.495 | 27.218 | 10.130 | 3.488 | 11.045 | 3.663 | 1.489 | 16.570 | 6.649 | 3.101 |
| 1971 | 2.836 | 0.302 | 0.034 | 2.869 | 0.551 | 0.084 | 16.591 | 4.661 | 1.233 | 3.836 | 0.897 | 0.091 | 10.449 | 1.784 | 0.184 |
| 1972 | 2.672 | 0.331 | 0.053 | 3.012 | 0.805 | 0.147 | 13.236 | 3.454 | 1.471 | 5.129 | 0.968 | 0.375 | 11.299 | 3.596 | 0.767 |
| 1973 | 0.913 | 0.135 | 0.035 | 0.462 | 0.136 | 0.000 | 10.717 | 3.924 | 0.837 | 4.737 | 1.850 | 0.424 | 7.755 | 2.182 | 0.368 |
| 1974 | 1.784 | 0.214 | 0.029 | 1.929 | 0.070 | 0.000 | 14.732 | 3.148 | 0.964 | 3.680 | 0.424 | 0.145 | 8.119 | 2.427 | 0.651 |
| 1975 | 5.190 | 0.218 | 0.040 | 8.028 | 1.224 | 0.006 | 31.724 | 5.325 | 0.806 | 9.222 | 1.350 | 0.025 | 18.077 | 2.649 | 0.321 |
| 1976 | 2.630 | 0.385 | 0.076 | 2.796 | 0.443 | 0.086 | 16.844 | 3.163 | 0.746 | 4.257 | 0.958 | 0.130 | 8.581 | 1.550 | 0.275 |
| 1977 | 2.628 | 0.459 | 0.028 | 3.235 | 0.550 | 0.066 | 25.308 | 10.574 | 2.679 | 7.756 | 2.613 | 0.373 | 12.288 | 3.566 | 0.823 |
| 1978 | 7.125 | 1.130 | 0.368 | 5.137 | 0.825 | 0.070 | 47.864 | 11.777 | 4.156 | 8.024 | 2.353 | 0.633 | 10.245 | 4.994 | 1.911 |
| 1979 | 1.148 | 0.183 | 0.051 | 0.764 | 0.193 | 0.057 | 7.549 | 4.285 | 2.041 | 2.074 | 0.589 | 0.175 | 7.481 | 3.649 | 1.828 |
| **Average** | **3.373** | **0.420** | **0.087** | **5.385** | **0.982** | **0.185** | **19.591** | **6.073** | **2.089** | **6.081** | **1.742** | **0.505** | **10.420** | **3.036** | **0.962** |

| | (6) Abalang | | | (7) Kyoga Lakeside Zone | | | (8) Mpologoma | | | (9) Lumbuye | | | (10) Victoria Nile | | | (11) Sezibwa | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Average Water | Low Water | Drought Water | Average Water | Low Water | Drought Water | Average Water | Low Water | Drought Water | Average Water | Low Water | Drought Water | Average Water | Low Water | Drought Water | Average Water | Low Water | Drought Water |
| 1950 | 14.01 | 1.53 | 0.00 | 8.36 | 0.69 | 0.00 | 19.91 | 4.54 | 0.00 | 1.49 | 0.25 | 0.00 | 10.76 | 2.83 | 0.00 | 4.79 | 1.45 | 0.00 |
| 1951 | 13.42 | 4.42 | 0.53 | 15.42 | 2.37 | 0.07 | 32.75 | 12.22 | 2.18 | 6.82 | 2.22 | 0.11 | 19.22 | 6.00 | 0.79 | 11.77 | 2.87 | 0.93 |
| 1952 | 7.14 | 3.35 | 1.61 | 6.40 | 1.32 | 0.34 | 27.49 | 14.50 | 3.07 | 3.89 | 0.93 | 0.17 | 12.85 | 4.14 | 1.45 | 12.16 | 5.52 | 2.89 |
| 1953 | 6.91 | 2.22 | 0.24 | 1.07 | 0.18 | 0.04 | 10.25 | 2.46 | 0.42 | 1.02 | 0.21 | 0.04 | 8.77 | 2.31 | 0.42 | 7.29 | 3.06 | 0.51 |
| 1954 | 7.86 | 2.62 | 0.51 | 1.91 | 0.37 | 0.05 | 19.61 | 4.17 | 0.99 | 2.26 | 0.73 | 0.23 | 9.83 | 4.13 | 1.73 | 9.65 | 6.04 | 3.39 |
| 1955 | 10.29 | 2.78 | 0.55 | 3.46 | 0.47 | 0.03 | 16.23 | 8.90 | 2.64 | 2.65 | 1.14 | 0.43 | 12.28 | 4.85 | 2.88 | 9.40 | 5.42 | 3.08 |
| 1956 | 10.64 | 1.76 | 0.42 | 4.36 | 0.79 | 0.18 | 17.75 | 8.63 | 3.95 | 1.52 | 0.75 | 0.39 | 8.03 | 4.35 | 1.67 | 12.64 | 7.56 | 4.08 |
| 1957 | 9.99 | 2.60 | 1.19 | 5.32 | 0.30 | 0.02 | 18.07 | 4.23 | 1.77 | 3.67 | 0.89 | 0.22 | 14.03 | 4.25 | 1.65 | 13.88 | 3.76 | 1.60 |
| 1958 | 7.51 | 1.81 | 0.63 | 2.93 | 0.20 | 0.00 | 16.05 | 3.52 | 1.52 | 2.31 | 0.63 | 0.28 | 8.54 | 2.39 | 1.06 | 9.05 | 2.75 | 1.14 |
| 1959 | 11.34 | 4.70 | 0.92 | 4.19 | 0.85 | 0.24 | 18.05 | 9.57 | 1.60 | 3.13 | 1.36 | 0.47 | 6.37 | 2.89 | 1.17 | 8.81 | 3.94 | 2.60 |
| 1960 | 10.47 | 4.13 | 1.47 | 3.88 | 1.23 | 0.34 | 22.46 | 6.64 | 1.81 | 4.29 | 0.92 | 0.19 | 15.86 | 4.66 | 2.21 | 16.39 | 5.79 | 1.93 |
| 1961 | 18.93 | 4.47 | 0.97 | 15.83 | 1.17 | 0.08 | 52.97 | 17.67 | 0.65 | 10.14 | 1.69 | 0.05 | 24.72 | 6.46 | 0.58 | 17.18 | 4.58 | 0.67 |
| 1962 | 17.66 | 8.31 | 3.84 | 15.01 | 5.75 | 2.34 | 30.43 | 17.13 | 11.46 | 5.04 | 2.37 | 0.79 | 19.13 | 9.43 | 3.64 | 18.77 | 10.66 | 4.78 |
| 1963 | 14.75 | 6.40 | 4.20 | 26.92 | 4.60 | 1.80 | 51.05 | 17.50 | 11.29 | 9.60 | 2.94 | 1.48 | 22.09 | 7.74 | 3.13 | 16.45 | 8.35 | 4.77 |
| 1964 | 16.77 | 7.68 | 3.04 | 19.43 | 7.40 | 3.51 | 31.92 | 18.97 | 8.43 | 7.74 | 3.25 | 1.57 | 25.56 | 12.85 | 6.87 | 16.98 | 9.77 | 6.76 |
| 1965 | 7.98 | 2.52 | 0.53 | 5.43 | 0.60 | 0.10 | 19.02 | 8.35 | 1.47 | 2.46 | 1.41 | 0.41 | 8.16 | 3.80 | 2.09 | 11.82 | 3.04 | 1.17 |
| 1966 | 15.65 | 6.07 | 3.29 | 11.10 | 2.73 | 1.53 | 26.95 | 11.76 | 7.47 | 3.61 | 1.58 | 0.78 | 12.26 | 5.12 | 1.82 | 9.51 | 5.06 | 2.52 |
| 1967 | 19.82 | 2.62 | 0.78 | 5.72 | 0.92 | 0.16 | 27.56 | 12.62 | 3.67 | 5.61 | 1.06 | 0.40 | 19.05 | 4.25 | 1.87 | 11.35 | 4.33 | 0.51 |
| 1968 | 16.08 | 5.92 | 3.51 | 10.77 | 1.20 | 0.41 | 41.21 | 19.78 | 9.55 | 3.09 | 1.06 | 0.59 | 15.91 | 6.04 | 3.46 | 21.16 | 7.68 | 2.85 |
| 1969 | 10.80 | 4.53 | 2.19 | 5.83 | 2.15 | 0.62 | 28.58 | 19.66 | 11.91 | 3.05 | 1.53 | 0.67 | 12.39 | 6.82 | 3.00 | 19.06 | 9.72 | 3.71 |
| 1970 | 14.68 | 5.24 | 1.83 | 3.14 | 0.39 | 0.07 | 33.09 | 16.92 | 6.63 | 3.30 | 1.56 | 0.53 | 21.75 | 8.53 | 2.63 | 39.53 | 12.59 | 4.29 |
| 1971 | 11.65 | 2.30 | 0.27 | 1.04 | 0.14 | 0.03 | 19.70 | 5.68 | 1.51 | 4.64 | 0.58 | 0.04 | 14.38 | 5.07 | 0.48 | 13.03 | 6.86 | 3.38 |
| 1972 | 13.17 | 4.09 | 0.89 | 12.13 | 0.06 | 0.00 | 27.26 | 12.25 | 4.85 | 2.45 | 0.89 | 0.28 | 13.59 | 4.44 | 1.22 | 13.21 | 7.58 | 4.57 |
| 1973 | 12.85 | 3.54 | 0.40 | 8.08 | 2.39 | 0.66 | 17.67 | 9.58 | 2.54 | 1.58 | 0.64 | 0.15 | 4.41 | 2.34 | 0.59 | 2.57 | 1.46 | 0.66 |
| 1974 | 10.16 | 4.34 | 1.38 | 4.07 | 0.72 | 0.21 | 16.06 | 5.37 | 2.31 | 1.55 | 0.49 | 0.17 | 5.25 | 1.23 | 0.19 | 3.34 | 0.88 | 0.33 |
| 1975 | 21.85 | 1.81 | 0.24 | 0.57 | 0.14 | 0.05 | 23.57 | 7.21 | 0.88 | 3.38 | 0.96 | 0.07 | 12.85 | 4.11 | 0.05 | 7.95 | 1.64 | 0.23 |
| 1976 | 12.42 | 1.71 | 0.37 | 3.16 | 0.15 | 0.01 | 12.76 | 3.74 | 1.65 | 1.58 | 0.42 | 0.18 | 5.65 | 1.77 | 0.66 | 10.37 | 4.91 | 0.97 |
| 1977 | 15.45 | 2.05 | 0.54 | 4.58 | 0.69 | 0.05 | 21.53 | 6.48 | 1.42 | 1.85 | 0.53 | 0.15 | 4.17 | 1.67 | 0.19 | 9.19 | 3.45 | 1.22 |
| 1978 | 12.15 | 6.31 | 1.93 | 1.56 | 0.41 | 0.11 | 16.43 | 8.51 | 3.01 | 2.78 | 0.72 | 0.21 | 12.26 | 4.81 | 1.58 | 13.81 | 6.72 | 2.51 |
| 1979 | 7.03 | 3.53 | 1.95 | 0.19 | 0.01 | 0.00 | 12.34 | 4.49 | 1.68 | 1.73 | 0.95 | 0.34 | 3.80 | 1.58 | 0.52 | 2.39 | 0.57 | 0.21 |
| **Average** | **12.65** | **3.85** | **1.34** | **7.06** | **1.35** | **0.43** | **24.29** | **10.10** | **3.74** | **3.61** | **1.16** | **0.38** | **12.80** | **4.70** | **1.65** | **12.45** | **5.27** | **2.28** |

### (2) Simulation on Future Water Demand in Drought Rainfall Condition (Surface Water Allocation Analysis)

Simulation is conducted in the following conditions aiming at contributing to water allocation investigation by grasping monthly tendency of entire Lake Kyoga Basin on future water demand and confirming utilization manner of this simulation model.

1. Simulation Period: One year (From January to December)
2. Water Demand: Future Water Demand in 2035
3. Rainfall Condition: Rainfall time series in drought year

Details of setup of simulation condition and simulation result are described below.

#### i) Setup of Water Demand Condition (Water Demand TS)

Water demand TS of 2035 is prepared in each small-catchment based on SIP. Since SIP categorizes water use into seven (7) sectors, this simulation for surface water targets five (5) sectors among them, which are deemed to use surface water as a water source. The five (5) sectors are ”Domestic NWSC”, ”Domestic Small Towns”, ”Livestock”, ”Crops” and ”Fisheries”. Calculated future water demand in each small-catchment is shown in Table A12-1.

In general, amount of irrigation water use varies considerably through the year according to the crops pattern, and domestic water as well as irrigation water shall consider return water to the downstream channel/river against amount of intake water. Water demand TS is simply set up not to consider the annual fluctuation of water use and the return water to the downstream, however, because this simulation aims at grasping general tendency of entire Lake Kyoga Basin for discussing the basic plan. It is recommended to conduct more detailed investigation including such conditions in the next step like a master plan study.

**ii) Setup of Rainfall Condition**

Rainfall condition for simulation is prepared by selecting a drought year from rainfall TS of 1950 to 1979, which are prepared and used for calibration work. Selection procedure is as follows:

1. To calculate annual total rainfall amount (annual rainfall multiplied by area) in each small-catchment, to sum the amount for all small-catchment, then to calculate annual total rainfall amount of entire Lake Kyoga Basin in each year.
2. To select the drought year (third year from the last year with lowest annual total rainfall amount, which can deem the 10 year return period) from 30 years’ data of annual total rainfall amount. Finally, 1974 was selected as the drought year.

**iii) Investigation regarding Influence of Climate Change**

According to the Fourth Assessment Report (AR4) by IPCC, rainfall tends to increase in the long term in east Africa including Uganda. The trend is the same in not only annual average but also seasonal (every three months) average. Since drought is the major matter regarding water resources management in Lake Kyoga Basin and the target for the simulation of this Study, special condition taking account of climate change is not set up in this simulation model.

**iv) Simulation Result**

Simulation result is shown in Table 12-11 and Figure 12-12.

In the simulation, calculation of rainfall, runoff and deduction of water demand in each small-catchment, and runoff of surplus water from the upstream to the downstream small-catchment are calculated in a daily basis. The result shown in the table and figure is to sum up daily calculation results in each sub-catchment in a monthly basis. The summed result is calculated by subtracting monthly total amount of deficit water in each sub-catchment (excess or deficiency of runoff against water demand in each small-catchment is calculated in a daily basis, and the deficit amount is summed up in each sub-catchment in a monthly basis) from monthly total runoff amount at the end of each sub-catchment. The negative value in the table and figure means that total runoff amount is not enough against water demand if water is maximally properly allocated within a corresponding sub-catchment in a corresponding month.

From the simulation result, the following can be cited as a general characteristic of Lake Kyoga Basin although the simulation is conducted in the limited condition such as the simple water demand as described above:

- In case of the condition of drought year with 10 year return period and future water demand, water deficit occurs in almost all sub-catchments.
- Sub-basins where water deficit frequently occurs are Okok, Okere, Lwere, Kyoga Lakeside Zone and Mpologoma. Especially, Okok and Okere sub-basins are severer.
- The months when water deficit frequently occurs are January to April and November to December.

**Table 12-11 Simulation Result**

Unit: million $m^3$ per month

| Month \ Sub-basin Name | (1) Okok | (2) Okere | (3) Awoja | (4) Lwere | (5) Akweng | (6) Abalang | (7) Kyoga Lakeside Zone | (8) Mpologoma | (9) Lumbuye | (10) Victoria Nile | (11) Sezibwa |
|---|---|---|---|---|---|---|---|---|---|---|---|
| January | -2.17 | -2.75 | 3.43 | 0.10 | 5.87 | 8.70 | -1.54 | 0.11 | 2.47 | 13.30 | 0.82 |
| February | -1.93 | -2.67 | -0.43 | -1.42 | 1.72 | 2.39 | -3.23 | -3.52 | 0.09 | 2.41 | -0.27 |
| March | -0.93 | -2.47 | 4.40 | -0.17 | 3.10 | 8.79 | -3.83 | -4.20 | -0.40 | -0.35 | 0.97 |
| April | 2.07 | -0.21 | 13.02 | 10.31 | 17.51 | 34.38 | 6.69 | 49.71 | 8.07 | 35.10 | 21.31 |
| May | 8.74 | 4.48 | 31.46 | 8.32 | 22.20 | 26.13 | 3.38 | 49.63 | 6.21 | 20.48 | 12.32 |
| June | 2.82 | 1.57 | 49.92 | 13.96 | 20.03 | 26.60 | -1.23 | 52.24 | 2.06 | 18.16 | 10.52 |
| July | 10.90 | 27.19 | 128.61 | 33.51 | 41.72 | 48.05 | 19.51 | 90.62 | 7.23 | 27.66 | 14.99 |
| August | 4.95 | 10.72 | 61.74 | 11.87 | 22.49 | 24.28 | 15.99 | 43.75 | 2.46 | 7.60 | 7.51 |
| September | 4.44 | 2.23 | 75.74 | 13.92 | 38.61 | 30.27 | 26.06 | 44.57 | 5.34 | 10.20 | 10.32 |
| October | 4.55 | 0.08 | 37.27 | 4.48 | 43.62 | 47.34 | 11.89 | 26.04 | 2.77 | 2.25 | 4.16 |
| November | -0.20 | -1.42 | 15.85 | -0.17 | 13.62 | 16.43 | 2.71 | 11.27 | 1.14 | 0.04 | 1.66 |
| December | -1.61 | -2.42 | 4.03 | -1.57 | 3.35 | 2.82 | -3.07 | -2.96 | -0.20 | -1.78 | -0.47 |