# B2. HYDROLOGICAL AND HYDRAULIC STUDIES

## B2.1 Previous Hydrological Studies

The major hydrological studies in the LBB River basin were carried out in the following master plans studies through the North Sulawesi Water Resources Institutional Development Project funded by Canadian International development Agency (CIDA) as summarized below:

1) LBB Water Resources Development Master Plan, 1994 (the 1994-Study)
2) LBB Basin Water Management Master Plan, 1999 (the 1999-Study)

### B2.1.1 LBB Water Resources Development Master Plan

The 1994-Study covers the basic hydrological study items, i.e., (1) climate, (2) basins and rivers, (3) rainfall, (4) runoff, (5) water balance, and (6) design flood.

In relation to the flood control study, the design floods were estimated at each river sections of interest.

No long-term flood flow records were available in the LBB River basin. Therefore, the empirical methods such as Haspers and Mononobe were adopted for assessing flood peaks with return periods up to 1,000 years, based on the catchment characteristics (catchment area, river length and height) and the maximum daily rainfall. These methods provide the estimates of instantaneous flood peaks and are not concerned with the prediction of flood volume and hydrograph.

To determine the design flood for the Lake Limboto, a synthetic hydrograph method was applied. The peak design floods for each tributary with return periods of 50 and 100 years have been derived from the characteristics of each basin and calculation of unit hydrograph.

### B2.1.2 LBB Basin Water Management Master Plan

The 1999-Study covers the studies on flood discharges and probable flood peak additionally to the 1944-Study.

In relation to the difficulty of storm and flood analyses, this study made the following remarks.

1) Because of the extreme spatial variations in rainfall and the lack of rainfall data at higher elevations, any form of basin wide hydrological analysis based on rainfall data should be applied with caution.
2) Longer duration rainfall events of 3 to 5 days are in fact probably more critical for determining flood magnitudes in the main rivers in the LBB basin.
3) Greater data regarding rainfall at higher elevations is also required for any runoff analyses based upon rainfall-runoff relations.
4) The application of the daily storm rainfall is therefore recommended to be limited to small watersheds within the low plain area.

An attempt was made to estimate the actual flood discharges, to analyze the probable flood peaks and to carry out the regional flood frequency analysis in the LBB River basin.

The 1999-Study was not also concerned with the prediction of flood volume and its hydrograph because of the extreme lack of rainfall and runoff records.

### B2.1.3 Probable Flood Discharge

In the 1994-Study, probable flood discharges were estimated at the proposed weir site by the Haspers and Mononobe methods using probable daily rainfall at the Jalaludin Airport.

(100-year Instantaneous Flood Peaks by Empirical Methods)

| River | Location | Drainage area ($km^2$) | Instantaneous flood peak: $m^3/s$ ($m^3/s/km^2$) | |
|---|---|---|---|---|
| | | | By Haspers | By Mononobe |
| Molamahu | Datahu | 38 | 154 (4.1) | 162 (4.3) |
| Buhiya | Ombula | 17 | 122 (7.2) | 110 (6.5) |
| Marisa | Marisa | 39 | 213 (5.5) | 262 (6.7) |
| Biyonga | Kayu Merah | 55 | 299 (5.4) | 317 (5.8) |
| Bolango | Longalo | 120 | 440 (3.7) | 664 (5.5) |

The probable flood discharges for the basins related with Lake Limboto were also estimated in the 1994-Study, using the synthetic hydrograph method applied for each individual sub-basin of the lake. The probable daily rainfall at Jalaludin was also used. The results of the calculations are summarized below:

(100-year Instantaneous Flood Peaks by Synthetic Hydrograph Method)

| Sub-basin | Drainage area ($km^2$) | Instantaneous flood peak: $m^3/s$ ($m^3/s/km^2$) |
|---|---|---|
| Rentengga | 62 | 232 (3.7) |
| Pohu | 156 | 406 (2.6) |
| Molamahu | 348 | 687 (2.0) |
| Marisa | 85 | 290 (3.4) |
| Meluupo | 38 | 182 (4.8) |
| Biyonga | 68 | 366 (5.4) |
| Bulota | 40 | 208 (5.2) |
| Tabubongo | 33 | 187 (5.7) |
| Western part | 62 | 405 (6.5) |
| Lake Limboto | 892 | 1,713 (1.9) |

Frequency analyses were made in the 1999-Study, using the available annual maximum instantaneous discharges recorded on the Bolango River at Longalo and the Bone at Lombongo as summarized below:

(100-year Instantaneous Flood Peaks by Frequency Analysis)

| River | Location | Drainage area ($km^2$) | Instantaneous flood peak: $m^3/s$ ($m^3/s/km^2$) |
|---|---|---|---|
| Bone | Lombongo/Alale | 1,060 | 1,900 (1.8) |
| Bolango | Longalo | 120 | 220 (1.8) |

Similar frequency analyses were also made preliminarily at the other locations as shown below.

(100-year Instantaneous Flood Peaks by Regional Frequency Analysis)

| River | Location | Drainage area ($km^2$) | Instantaneous flood peak: $m^3/s$ ($m^3/s/km^2$) |
|---|---|---|---|
| Bolango | Lomaya Weir | 388 | 700 (1.8) |
| Pohu | Pohu Weir | 134 | 240 (1.8) |
| Alo | Alo Weir | 196 | 370 (1.9) |
| Lake Limboto | Lake Inflow | 892 | 1,600 (1.8) |

The instantaneous flood peaks estimated by the empirical method and frequency analysis were compared at the same location as shown below:

(Comparison of 100-year Instantaneous Flood Peaks)

| River | Drainage area ($km^2$) | By empirical method ($m^3/s$) | By frequency analysis ($m^3/s$) |
|---|---|---|---|
| Longalo, Bolango | 120 | 440-664 | 220 |
| Lake Limboto | 892 | 1,713 | 1,600 |

The above table indicates that the empirical method tends to give higher estimate of flood peak.

## B2.2 Flood Analysis

### B2.2.1 Runoff Analysis

#### (1) Method of Runoff Analysis

Synthetic Unit Hydrograph method developed by US Soil Conservation Services was employed for the runoff analysis. The method is outlined below.

**Runoff Volume:**

$Q = (P-Ia)^2/[(P - Ia) + S] = (P - 0.2S)^2/(P + 0.8S)$

$Ia = 0.2S$

$S = 25.4(1000/CN - 10)$

where

Q : Depth of direct runoff (mm)

P : Depth of precipitation (mm)

Ia : Initial abstraction (mm)

S : Maximum potential retention (mm)

CN: Runoff curve number developed by US Soil Conservation Services, which depends on the antecedent rainfall conditions and types of land cover. For the present study assumed are:

| (Land cover) | (CN-value) |
|---|---|
| - Forestland | : 65 |
| - No cultivated farmland | : 67 |
| - Cultivated farmland | : 74 |

**Unit Hydrograph:** Dimensionless unit hydrograph shown in Figure B2.2.1 was applied. Discharge (q) at time (t) for unit rainfall will be worked out multiplying peak discharge ($q_p$) and time to peak ($t_p$). The $q_p$ and $t_p$ are estimated as follows:

$q_p$ = 0.2083 $AQ/t_p$

$t_p$ = $0.67t_c$

$t_c$ = $0.00032L^{0.77}I^{-0.385}$

where

$q_p$ : Peak discharge ($m^3/s$)

A : Basin area ($km^2$)

Q : Depth of direct runoff (mm)

$t_p$ : Time to peak (hr)

$t_c$ : Time of flood concentration (hr)

L : Maximum travel length of water (m)

I : Overall basin slope = H/L

where H (m) is the difference in elevation between the remotest point on the basin and the outlet.

**Resultant Flood Hydrograph:** Design storm hyetograph is assumed as center loaded distribution with probable rainfall depths for respective duration times within a time of flood concentration. In order to obtain resulting flood hydrograph, the design storm hyetograph is applied to the unit hydrograph after adjustment for rainfall loss.

Base flow discharge shall be added to the direct runoff estimated in the procedures mentioned above. The base flow is a prevailing river discharge during the flood season.

**(2) Probable Storm Rainfall**

**Probable Point Rainfall for Longer Duration:** Probable 1-day, 2-day and 3-day point rainfalls were estimated using 27 years (1975-2001) of records observed at Jalaluddin Airport in the west of Lake Limboto and 25 years (1972-1997) at Boidu Tapa. The following five (5) distributions are applied to the estimate.

1) Two Parameters Log Normal Distribution(LN2)
2) Three Parameters Log Normal Distribution (LN3)
3) Type I Extreme Value Distribution (T1E)
4) Pearson Type III Distribution (PT3)
5) Log Pearson Type III Distribution (LP3)

The results of the calculation are shown in Table B2.2.1, taking average value of the five distributions. The annual maximum daily rainfall records used for the probability analysis are shown in Table B2.2.2. According to the result, about 70 to 80 % of 3-day probable storm rainfall occurs within one day at both stations. The difference of estimated rainfall values between two stations is small within the range of 3 to 17 %.

**Probable Point Rainfall for Shorter Duration:** A frequency analysis was conducted for 12 years of annual maximum rainfall records at Jalaluddin from 1990 to 2001 for various durations ranging from 1-hour to 24-hours using the said five distributions. The results of the calculation are shown in the Table B2.2.1, taking the average value of five distributions. The annual maximum rainfall records used for the analysis are shown in Table B2.2.3.

**Rainfall Intensity Curves:** The representative rainfall station shall be determined for each basin. However, in the Study Area, two stations of Jalaluddin and Boidu Tapa located around Lake Limboto are only qualified as representative stations. Considering the availability of daily and hourly records, Jalaluddin is used as a representative rainfall station for the Study. Rainfall intensity curves were prepared based on the results of the above study and shown in Figure B2.2.2. In the Figure, 48 hr-and 72 hr-rainfalls were estimated from 2-day and 3-day rainfalls multiplied by the conversion rate assumed to be 1.1.

**Probable Basin Average Storm Rainfall:** The average depth of storm rainfall for a given duration in a given area generally tends to decrease conversely with increasing of area. For this adjustment, a depth-area factor was employed.

### (3) Probable Flood Discharges

**Runoff Calculation:** Basin boundaries were drawn on the topographic maps and basin areas were measured as shown in Figure B2.2.3. The probable flood discharges were estimated by Synthetic Unit Hydrograph method developed by US Soil Conservation Services. According to the runoff records at Alale Weir of the Bone River and Lomaya Weir at Bolango River, the maximum of specific monthly average discharges happen to be 0.042 $m^3/s/km^2$ for the both stations. The specific discharge is applied to estimate the base flow discharge for every points of interest. Probable flood discharges were calculated for respective river basins and for various return periods of 2, 5, 10, 20, 50 and 100 years. The peak discharges are illustrated in Figure B2.2.4.

**Comparison with Other Design Discharges:** The discharges of the LBB basin calculated by the Synthetic Unit Hydrograph method for 20-year return period were plotted in Figure B2.2.5 showing the relationship between size of drainage area and specific peak discharge. On the other hand design discharges of other rivers in Indonesia were collected and plotted also in the Figure. As seen in the Figure, the specific discharge of the LBB basin distribute within the reasonable range in comparison with those of other rivers in Indonesia. The Synthetic Unit Hydrograph method is judged to be applicable to the LBB basin.
Annual Maximum Daily Discharges: Although the period of the data is listed, annual maximum daily discharge data are available in some stations in the basin. They are shown in Table B2.2.4 only for reference.

### B2.2.2 Flood Flow Analysis

#### (1) Method of Flood Flow Analysis

**Procedures for Analysis:** In order to grasp the mechanism of flooding and inundation, to predict the inundated area, and to evaluate the effect of flood control project, flood flow analyses are carried out following the procedures shown in Figure B2.2.6.

**Model:** Conceptual structure of flood flow simulation model of the LBB basin is shown in Figure B2.2.7. The Figure also shows the data required for the analysis. In general, upper river reaches without significant flooding is modeled by runoff model, middle reaches with riverine flooding by channel model, and flooding in the lower plain reaches by flood plain model. The channel model and flood plain model constitute the flood flow model. The channel model is applied to the river reaches where flooding along riverine area is prevailing, while the flood plain model to the areas flooded water may spread over. Mesh blocks of 250 m x 250 m were used to represent the flood plain features as shown in Figure B2.2.8.

**Methodology:** Flood flow analysis was made by an unsteady flow simulation model. The model mainly consists of channel and flood plain models.

Channel Model

1) Fundamental equations:

$$\frac{\eta}{g}\frac{\partial v}{\partial t}+\frac{a}{2g}\frac{\partial v^2}{\partial x}+\frac{\partial H}{\partial x}+\frac{n^2}{R^{4/3}}v|v|=0$$

$$\frac{\partial A}{\partial t}+\frac{\partial Q}{\partial x}=-q$$

2) Boundary conditions:
   - Upper end: Discharge hydrograph
   - Lower end: Water level hydrograph or stage-discharge curve
3) Channel data: Channel sections surveyed

Flood Plain Model

1) Fundamental equations:

$$\frac{1}{g}\frac{\partial v_p}{\partial t}+\frac{\partial H_T}{\partial l}+f_p v_p\left|v_p\right|=0$$

$$F\frac{dH_p}{dt}=Q_m-Q_{out}$$

2) Boundary conditions: Various types of boundary conditions such as culvert, canal, embankment, etc. can be incorporated at the boundary of plain block.
3) Flood plain data: Plain areas at various elevations for each plain block.

Notations of Above Equations

| | |
|---|---|
| $t$ | : Time |
| $x$ | : Distance along river |
| $v$ and $Q$ | : Channel velocity and discharge |
| $H$, $A$ and $R$ | : Water level, flow area and hydraulic mean depth |
| $n$ | : Manning's coefficient of roughness |
| $g$ | : Acceleration of gravity |
| $\eta$, $\alpha$ | : Coefficients depending on velocity distribution |
| $v_p$ | : Velocity at the joint of plain blocks |
| $f_p$ | : Energy loss at the joint of plain blocks |
| $\delta H_T / \delta l$ | : Surface slope in plain block |
| $F$, $H_p$ | : Surface area and water level of plain block |
| $Q_{in}$ and $Q_{out}$ | : Inflow and outflow of plain block |

### (2) Estimated Flooding Conditions

According to the procedures mentioned in the previous subsections, flood flows of various different return periods were simulated under the present basin and river conditions and the results are shown in Figure B2.2.9 for return periods of 2, 5, 10, 20 and 50 years. Major findings of the result of analysis are as follows:

1) Maximum inundated areas by ranges of inundated depth are summarized below:

| Depth (m) | Max. inundated area by flood scale ($km^2$) | | | | |
|---|---|---|---|---|---|
| | 2-yr. | 5-yr. | 10-yr. | 20-yr. | 50-yr. |
| >0 | 34.3 | 52.1 | 62.4 | 70.9 | 79.7 |
| >0.5 | 23.3 | 37.3 | 46.5 | 54.5 | 63.3 |
| >1.0 | 5.3 | 11.6 | 15.3 | 20.3 | 27.6 |
| >1.5 | 0.6 | 0.9 | 1.3 | 2.6 | 9.4 |
| >2.0 | 0.2 | 0.5 | 0.6 | 0.6 | 0.9 |
| >2.5 | 0.0 | 0.1 | 0.1 | 0.2 | 0.3 |

2) Under the 2-year flood, extensive western areas of Lake Limboto suffer from flooding due to floodwater of the Alo-Pohu River, though riverine areas of other rivers suffer from more or less flooding.
3) Under the 5-year flood the flood waters from the Bolango River begins spread over to the left bank areas and the Bone River to the right bank areas.
4) Under the 10-year flood, southern part of Gorontalo City suffers from serious inundation damages.

## B2.3 Studies on River Channels

### B2.3.1 Channel Flow Calculation

**Uniform Flow Formula:** Uniform flow formula was applied to the channel flow calculations in principle, since the river channels in the Study Area are rather steep and uniform in shape.

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

where

Q : Channel discharge ($m^3/s$)
A : Flow area ($m^2$)
V : Mean flow velocity (m/s)
R : Hydraulic mean depth (m)
I : River slope
n : Manning's coefficient of roughness

**Non-uniform Flow Formula:** Non-uniform flow formula was applied to calculate channel features of gradually varied flows.

$$h_e = \left\{ H_2 + \frac{1}{2g}\left(\frac{Q_2}{A_2}\right)^2 \right\} - \left\{ H_1 + \frac{1}{2g}\left(\frac{Q_1}{A_1}\right)^2 \right\}$$

$$= \frac{1}{2}\left( \frac{n_1^2 Q_1^2}{A_1^2 R_1^{4/3}} + \frac{n_2^2 Q_2^2}{A_2^2 R_2^{4/3}} \right) dx$$

Where
$h_e$ : Energy loss between sections 1 and 2
H : Water level
g : Acceleration of gravity
dx : Distance between sections 1 and 2

Subscripts 1 and 2 indicate values of lower section and upper section apart from distance dx.

**Manning's Coefficient of Roughness:** Considering some allowance for safety against changes in river regime under natural flow conditions, the following design roughness (n) was adopted to the flow calculations in the design channel:

1) n=0.025 for the improved low water channel or single section channel with riverbed lining as well as banks.
2) n=0.030 for improved low water channel or single section channel.
3) n=0.060 for natural highwater channel

### B2.3.2 Evaluation of Existing Channel Capacity

Based on the latest results of river survey in 2001, bankful carrying capacities were estimated. Considering the steeper slopes of rivers in the Study Area, uniform flow was assumed for the channel flow calculations. Results of estimation are shown in Table B2.3.1 in comparison with 2-year probable discharges. The channel capacities of rivers in the western plain area of Lake Limboto are low in general, while the Bone and Biyonga rivers have relatively higher capacities.

### B2.3.3 Significant Tide Levels at River Mouth

**Tide Levels at Gorontalo:** There is no tide gauging station near the river mouth of the Bone River, and tide table for Gorontalo is not available either before the year 1999. Tide levels at Gorontalo were estimated by harmonic analysis of tides for 10 years from 1992 to 2001. As a result tidal variations at Gorontalo are shown in Figure B2.3.1 for the year 2001 as an example.

**Significant Tide Levels:** Monthly maximum, minimum and average tide levels are also shown in Table B2.3.2. Based on the estimated tides, significant tide levels at Gorontalo were determined as follows:

| Tide | (m) | (m,MSL) |
|---|---|---|
| HHWL | 1.568 | 0.767 |
| MHWL | 1.474 | 0.673 |
| MSL | 0.801 | 0 |
| MLWL | 0.246 | -0.555 |
| LLWL | 0.181 | -0.620 |

### B2.3.4 Effects of Tides to Channel Flows

The effects of tidal variation to the existing channels and improved channel by excavation at river mouth are limited only to the drainage of the southern Gorontalo City as described in the following paragraphs. This is chiefly due to the relatively steep channel slopes of the Bone and Bolango rivers.

**Effect of Tide to Existing Channels:** In order to examine the extent of tidal influence, non-uniform flow calculations were made for the Bone and Bolango rivers under various tide levels and probable discharges. Figure B2.3.2 shows the results of calculations for the tidal variation of about 1.2m from MHWL(+0.673 m,MSL) to MLWL(-0.555 m,MSL). According to the results of calculation, the extent of tidal influence for 2-year flood is only up to 1.5 km from the river mouth, and it becomes shorter as the river discharge increases.

**Effect of Tide to Excavated Channel:** Even in the case that riverbed of the Bone River is excavated at the river mouth by about 0.75m so that the average riverbed can be connected in smooth slope with the upper reaches. The extent of tidal influence for 2-year flood still remains only up to 2 km from the river mouth or only up to 1 km from the Bone confluence along the Bolango River as shown in the Figure B2.3.2.

## B2.4 Sediment Studies

### B2.4.1 Land Use

Land use of the Study Area and its recent change were analyzed using the following SPOT satellite images:

| Land use | Satellite image used | |
|---|---|---|
| | K-J:314-349 for western basin | K-J:315-349 for eastern basin |
| Land use-1990 | Taken on 22 Apr. 1990 | Taken on 02 Sep. 1987 |
| Land use-2000 | Taken on 06 Mar. 1998 | Taken on 29 Aug. 2000 |

According to the results of analysis, the land use in 1990 and 2000 are shown in Figure B2.4.1 and summarized below.

| Land use | 1990 (A: %) | 2000 (B: %) | Ratio (B/A) |
|---|---|---|---|
| Forest land | 61.8 | 60.3 | 0.98 |
| Bush land | 11.4 | 10.4 | 0.92 |
| Farm land | 20.8 | 22.7 | 1.09 |
| Grass land | 3.0 | 2.6 | 0.85 |
| Settlement land | 1.7 | 2.7 | 1.53 |
| Other lands | 1.3 | 1.3 | 1.00 |
| Total | 100.0 | 100.0 | - |

The farm and settlement lands have increased by about 3% of the total basin area, reducing the areas of forest, bush and grass lands. Most typical pattern of land use changes in the LBB basin is from forest and bush lands to farm land. During the past 10 years, 54 $km^2$ of bush lands and 21 $km^2$ of forest lands were converted to farm land.

### B2.4.2 Sediment Yield and Transport

**Source of Sediment:** According to the satellite images analysis and site reconnaissance, large scale failure of mountain slopes and land slides were not identified in the Study Area. Source of sediment in the watershed area is deemed to be sporadic slope failures and sheet erosion on the mountain and hill slopes. Specific sub-basins and valleys yielding much sediment were not identified.

**Sediment Transport Systems:** The sediments yielded in the watershed area deposit first at the foot of mountain slopes and valleys, and they are transported by river flows mostly during flood period. Therefore, the sediments transported in the plain areas would depend on the sediment transport capacity of the river channel. Sediment issues in the Study Area can be discussed dividing the river system into two, i.e., the Lake Limboto system and the Bone-Bolango river system, since the lake traps almost all sediment from the upstream basins and discharges little amount to the Bolango River.

**Sediment Transport Capacity:** In order to evaluate the sediment brought into plain areas of the LBB basin, sediment transport index (Is) was introduced and applied to major river channels as shown in Table B2.4.1. According to the result of evaluation, the Biyonga, Meluopo and Alo-Pohu rivers are the main sources of sediment in the Lake Limboto system, though the share of the Biyonga River is by far much. In the Bone-Bolango system, the Bolango River shares 62% of total sediment and the Bone River 38%, which indicates the Lake Limboto system with basin area of about 900 $km^2$ transport 1.3 times more sediment than that of the Bone-Bolango system of about 1,800 $km^2$.

### B2.4.3 Sedimentation of Lake Limboto

Sedimentation of Lake Limboto is recognized as a serious problem by the local governmental agencies and local communities. Water depth of the lake is already shallow and vegetation in the lake encroaches toward the lake center. In order to estimate the annual sedimentation rate, attempts were made using the data as available, i.e., estimate from area and depth data and that from sounding data of the lake.

Judging from the estimates described below, annual average sedimentation volume of Lake Limboto would be within the range from $1x10^6$ to $2x10^6$ $m^3$/year, though it must be confirmed further by sounding survey in future.

### (1) Estimate from Area and Depth Data of Lake

**Area and depth in the Lake Limboto:** Dimensions of the Lake Limboto are shown in Table B2.4.2 prepared based on the results of previous study, aerial photographs and satellite images. Figure B2.4.2 (middle) shows historical changes of area and depth of the lake. According to the Figure, area and depth of the lake decreased considerably from 1952 to 1983. Except for those of 1952, the decreasing tendency after 1973 is very slight.

**Relationship to Estimate Lake Volume:** A relationship to estimate lake volume (V) from surface area (A) and water depth (D) was derived based on the sounding data in1993, 1994 and 1996. As shown in the Figure B2.4.2 (top) the relationship is expressed by the following equation:

$$V = 0.55 \times A \times D$$

The lake volumes were estimated based on the historical area-depth data from 1952 to 1983 using this equation as shown in the Figure B2.4.2 (bottom). The Figure B2.4.2 does not include the data for years from 1989 to 1996, because these data seems to be influenced remarkably by seasonal changes of weather. The data of year 1933 was also disregarded, since the lake area was too big probably including swampy areas and paddy fields on the western side of the lake.

**Average Annual Sedimentation Rate:** According to the estimates shown in the Figure B2.4.2 (bottom), lake volume decreases within the range from $1.0 \times 10^6$ to $3.4 \times 10^6$ $m^3$/year and $2.2 \times 10^6$ $m^3$/year on average.

### (2) Estimate from Sounding Data of Lake

**Available Sounding Results:** Sediment volume can be estimated as a difference between stage-volume curves (D-V curve) based on sounding survey results. The sounding survey results of Lake Limboto are available for recent years in 1993, 1994 and 1996. In addition to these, the Study Team conducted sounding survey in 2001. Using these data, stage-volume curves were prepared and comparatively shown in Figure B2.4.3. As seen in stage-area curve, the latest survey results in 1996 and 2001 have similar pattern, while those in 1993 and 1994 are quite different from the latest ones and give smaller lake areas. The data in 1993 and 1994 were not used for the study.

**Average Annual Sedimentation Rate:** Comparing the latest survey results in 1996 and 2001. It was found that there would be some discrepancy of survey datum among 1996 and 2001 surveys. Assuming that the lowest lake bed of 1996-survey should be same with that of 2001-survey, the annual decrease of lake volume was estimated to be $1.54 \times 10^6$ $m^3$/year below elevation +4.0 m,MSL, However, this estimate should be confirmed with sounding in future based on the same datum or bench marks with the 2001 survey.

## B2.5 Studies on Lake Limboto

### B2.5.1 Hydraulic Effects of Lake

**Basin and Lake Areas:** The Lake Limboto basin has a total catchment area of 890 $km^2$. All of the runoff from this area flows into the lake and drained into the Bolango River through the Tapodu River. The Lake Limboto has a surface area of about 27.8 $km^2$ and storage capacity of 47.4 MCM below elevation +4.0 m,MSL according to the latest survey by the Study Team.

**Flood Runoffs:** According to the result of hydrological analysis, times of flood concentration are almost same for the Lake Limboto and the Bolango River basins, which indicates flood peaks from the both basins may meet at their confluence. Probable discharges of the both basins are summarized below.

| Items | Unit | 2-yr. | 5-yr. | 10-yr | 20-yr. |
|---|---|---|---|---|---|
| Lake Limboto | | | | | |
| Peak discharge | $m^3/s$ | 410 | 726 | 1001 | 1284 |
| Water volume | MCM | 17.4 | 23.5 | 28.7 | 34.0 |
| Storage depth | m | 0.63 | 0.85 | 1.03 | 1.22 |
| Bolango R. | | | | | |
| Peak discharge | $m^3/s$ | 199 | 386 | 543 | 720 |

**Existing Hydraulic Function:** During floods of the Bolango River, flood water from Lake Limboto basin cannot be drained due to high water level of the Boango River. On the contrary a part of the floodwater of the Bolango River flows into the lake. The floodwater is retained in the lake until the Bolango flood passes. Due to huge area of the lake, the lake water will not rise so much. This is the primary flood control function of the existing Lake Limboto.

There would be two extreme prospects for the lake, i.e., to be left as it is or to be reclaimed. Preliminary discussions are made in the following paragraphs.

**If Lake were Left as It Is:** Existing volume of Lake Limboto is 47.4 MCM below 4.0 m, MSL and the volume is reducing at the estimated rate ranging from 1 to 2 MCM per year due to sedimentation. The lake volume is decreasing if it is measured at a fixed elevation. However, this does not mean the disappearance of the lake in near future. Since the lake Limboto is located in the depressed area and the drainage of the lake is difficult during the flood period of the Bolango River, the floodwater of the lake would remain in and around the existing lake areas forming marshes expanding its area. In such conditions, use of lakeside lands and lake water may become uncertain, and the development of the lake and surrounding areas would be constrained.

**If Lake were Reclaimed:** If the lake were reclaimed, radical channel works of the Bolango River is required in the urban areas of Gorontalo City for the smooth drainage of flood water from the Bolango river and the Lake Limboto.

1) The Alo-Pohu and Biyonga rivers would be the primary river channels crossing the reclaimed lands. The rivers should be confined with diking systems.
2) The Bolango River should be improved for design discharge of 1600 $m^3$/s even for 10 year flood, which is about 8 times of the existing capacity. Furthermore, the design high water level of the Bolango River should be set lower for the gravity drainage of lake Limboto to be reclaimed. Large volume of excavation for widening and deepening of low water channel would be necessary for the Bolango River.
3) These channel works are required for about 5 km of the Bolango River from its confluence of with the Tapodu River to that with the Bone River, and about 1 km of the Bone River until river mouth. The channel takes route in the densely populated urban area of Gorontalo City, which is the areas to be protected from flooding. Such works would not be practically acceptable.
4) Existing Lake Limboto plays an important and great role to protect the urban area of Gorontalo City from flooding alleviating flood peak discharge significantly. The storage functions of the existing lake should be maintained.

### B2.5.2 Existing Functions of Lake

Lake Limboto is currently functioning various roles as listed below.

1) Flood peak reduction: The lake plays an important role for flood peak reduction to the urban area of Gorontalo City, retaining flood runoff from about 890 $km^2$ of lake basin. This function will be discussed further in the following sub-section.
2) Sediment trap: Since the lake volume is quite large comparing to the flood runoff volume, almost all the sediment transported by the relevant rivers will be trapped by the lake. Sediment problems in the lower reaches are alleviated, however, the lake itself is suffering from severe sedimentation amounting to 1 to 2 million $m^3$ per year.
3) Fishery: Cage culture shares the majority and open water fishery is no longer attractive on the economic basis mainly due to overfishing. According to a survey, 764 floating fishnets and 264 cages were identified in 1999 mainly in Baludaa and Teloga areas. Major kinds of fish are carp (ikan mas) and tilapia (ikan nila and ikan mujaer).
4) Eco-tourism: There is a proposal to improve the lake as recreational center of the area combining the lake with thermal spring Hundulobohu and Otanaha Fort.
5) Irrigation: Although the lake water is said not good for irrigation due to too high pesticide residue and nutrient, a pilot work by pumping is proposed to see if the lake water is usable for other crop than paddy.
6) Transportation: Navigation boats in Lake Limboto are mostly for fishery with unmotorized canoes. Some people in the southern part still use the lake to go to fish market in Payunga port.

### B2.5.3 Design Water Levels of Lake Limboto

Design water levels of Lake Limboto were proposed as presented below, considering the past water level records, lake water use, topography and land use, and flood water retention to be discussed in the following paragraphs:

1) Lowest lake water level at +4.00 m,MSL: for better and stable fish production
2) Highest lake water level at +5.50 m,MSL: for flood mitigation in lake side area especially in the western area of the lake.

**Records of Lake Water Level:** Daily water level records of Lake Limboto are available at Dembel Station (Gauge datum: +1.99 m,MSL) from 1993 to 1999. These records are shown in Figure B2.5.1. The recorded maximum water level was +5.49 m,MSL in 1995 and 1999, and the minimum +2.65 m,MSL in 1997. Water level records are available since 1988, but only higher water levels were recorded because of gauge installation at higher location. Capacity of the Tapodu River, only outlet channel of Lake Limboto, and flood water levels of the Bolango River affect much to the water level of the lake. According to the LLM Report, the Tapodu River overflows at the lake water level more than +4.30 m,MSL and the channel capacity was estimated at 58 $m^3/s$. A part of Tapodu River was normalized in 1994 by widening river width and smoothening riverbed, which resulted in lowering lake water level during dry season.

**Fishery:** Lake Limboto is used for fishery. Cage culturing and open water fishery are seen, though cage culturing shares the majority. The fish production is not stable due to changeable water level during dry season. According to a study by Sartina, appropriate minimum water level of the Lake Limboto was proposed at +4.0 m,MSL based on the demand for fishery sector. By keeping the lake water level at +4.00 m,MSL, the potential fish production was estimated to rise 3.5 times of the production in 1996.

**Topography and Land Use:** According to the result of topographic survey conducted by the Study Team, lands below +4.0 m,MSL are considered as lake area and no farmland is found there. The land between the elevation +4.0 m to +5 m,MSL seems to be buffer zone or transition zone from lake area to farmland. The land is used partly as farmlands and partly wastelands. Little settlement is located on the zone.

**Flood Water Retention:** During high water period of the Bolango River, all the runoff from the Lake Limboto basin must be retained in the lake. The storage depths were estimated at 0.63m, 0.85m, 1.03m and 1.22m for 2-, 5-, 10- and 20-year floods, assuming a constant lake area of 27.8 $km^2$. The recorded maximum water level (+5.5 m,MSL) would be high enough as design high water to retain 20-year flood water taking some allowance for unforeseen factors into consideration.

## Table B2.2.1 PROBABLE POINT RAINFALL

**Probable Point Rainfall for Longer Durationat (1 to 3 day)**

| Return Period (yr) | Jalaluddin (mm) | | | Boidu Tapa (mm) | | |
|---|---|---|---|---|---|---|
| | 1-day | 2-day | 3-day | 1-day | 2-day | 3-day |
| 2 | 70 | 87 | 96 | 72 | 92 | 102 |
| 5 | 89 | 106 | 121 | 95 | 118 | 130 |
| 10 | 101 | 118 | 136 | 110 | 134 | 147 |
| 20 | 113 | 129 | 150 | 124 | 148 | 162 |
| 50 | 130 | 143 | 167 | 143 | 166 | 180 |
| 100 | 142 | 154 | 180 | 157 | 180 | 194 |

**Probable Point Rainfall for Shorter Duration (1- to 24-Hour)**

| Return period (yr) | Jalaluddin (mm) | | | | |
|---|---|---|---|---|---|
| | 1-hour | 3-hour | 6-hour | 12-hour | 24-hour |
| 2 | 54 | 65 | 70 | 72 | 76 |
| 5 | 60 | 81 | 92 | 93 | 98 |
| 10 | 64 | 93 | 108 | 109 | 114 |
| 20 | 67 | 104 | 123 | 124 | 130 |
| 50 | 71 | 119 | 145 | 145 | 151 |
| 100 | 74 | 131 | 161 | 162 | 168 |

**Probable Point Rainfall in the LBB River Basin (mm)**

| Duration | Return period (yr) | | | | | |
|---|---|---|---|---|---|---|
| | 2 | 5 | 10 | 20 | 50 | 100 |
| 1hr. | 54 | 60 | 64 | 67 | 71 | 74 |
| 3hr. | 65 | 81 | 93 | 104 | 119 | 131 |
| 6hr. | 70 | 92 | 108 | 123 | 145 | 161 |
| 12hr. | 72 | 93 | 109 | 124 | 145 | 162 |
| 24hr. | 76 | 98 | 114 | 130 | 151 | 168 |
| 1day | 70 | 89 | 101 | 113 | 130 | 142 |
| 2days | 87 | 106 | 118 | 129 | 143 | 154 |
| 3days | 96 | 121 | 136 | 150 | 167 | 180 |

# TableB2.2.2 ANNUAL MAXIMUM DAILY RAINFALLS (1/2)

| No | Station No. | Station Name | year 72 | | year 73 | | year 74 | | year 75 | | year 76 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | R | Date-Month | R | Date-Month | R | Date-Month | R | Date-Month | R | Date-Month |
| 1 | 03 13 15 | Bandara Jalaluddin | | | | | | | 82 | 18-Oct | 58 | 12-Nov |
| 2 | 03 15 03 | Bone-Kabila | | | | | | | | | | |
| 3 | 03 13 02 | Alo-Alo | | | | | | | | | | |
| 4 | 03 13 03 | Bionga-Huludupitango | | | | | | | | | | |
| 5 | 03 13 07 | DAS Limboto-Dembe II | | | | | | | | | | |
| 6 | 03 14 05 | Bolango-Longalo | | | | | | | | | | |
| 7 | 03 15 02 | Bone-Lombongo | | | | | | | | | | |
| 8 | 03 15 11 | Bone-Pinogu | | | | | | | | | | |
| 9 | 03 15 13 | Pohulongo | | | | | | | | | | |
| 10 | 03 13 06 | Kayumerah-Limboto | | | | | | | | | | |
| 11 | 03 13 09 | UPP Tibawa | | | | | | | | | | |
| 12 | 03 13 10 | UPP Batudaa | | | | | | | | | | |
| 13 | 03 13 11 | UPP Limboto | | | | | | | | | | |
| 14 | 03 14 06 | Boidu-Tapa | 34 | 23-Nov | 66 | 29-May | 99 | 12-Sep | 86 | 11-Apr | 52 | 31-Aug |
| 15 | 03 14 07 | UPP Telaga | | | | | | | | | | |
| 16 | 03 15 12 | Lonuo-Kabila | | | | | | | | | | |
| 17 | 03 15 14 | UPP Suwawa | | | | | | | | | | |
| 18 | 03 13 17 | Bionga-Kayubulan | | | | | | | | | | |
| 19 | 03 15 16 | Butahu - Datahu | | | | | | | | | | |
| 20 | 03 12 21 | Bulota-Hepuhulawa | | | | | | | | | | |

| No | Station No. | Station Name | year 77 | | year 78 | | year 79 | | year 80 | | year 81 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | R | Date-Month | R | Date-Month | R | Date-Month | R | Date-Month | R | Date-Month |
| 1 | 03 13 15 | Bandara Jalaluddin | 73 | 2-Jul | 57 | 2-Sep | 55 | 18-Nov | 60 | 3-December | 70 | 24-Feb |
| 2 | 03 15 03 | Bone-Kabila | | | | | | | | | | |
| 3 | 03 13 02 | Alo-Alo | | | | | | | | | | |
| 4 | 03 13 03 | Bionga-Huludupitango | | | | | | | | | | |
| 5 | 03 13 07 | DAS Limboto-Dembe II | | | | | | | | | 67 | 24-May |
| 6 | 03 14 05 | Bolango-Longalo | | | | | 10.1 | 27-Dec | 7.5 | 20-Jun | 30 | 9-Nov |
| 7 | 03 15 02 | Bone-Lombongo | | | | | | | | | | |
| 8 | 03 15 11 | Bone-Pinogu | | | | | | | | | | |
| 9 | 03 15 13 | Pohulongo | | | | | | | | | | |
| 10 | 03 13 06 | Kayumerah-Limboto | | | | | | | | | | |
| 11 | 03 13 09 | UPP Tibawa | | | | | | | | | | |
| 12 | 03 13 10 | UPP Batudaa | | | | | | | | | | |
| 13 | 03 13 11 | UPP Limboto | | | | | | | | | | |
| 14 | 03 14 06 | Boidu-Tapa | 90 | 24-Jun | 71 | 16-Apr | 112 | 27-Dec | 50 | 2-Feb | 84 | 5-Sep |
| 15 | 03 14 07 | UPP Telaga | | | | | | | | | | |
| 16 | 03 15 12 | Lonuo-Kabila | | | | | | | | | 51 | 21-May |
| 17 | 03 15 14 | UPP Suwawa | | | | | | | | | | |
| 18 | 03 13 17 | Bionga-Kayubulan | | | | | | | | | | |
| 19 | 03 15 16 | Butahu - Datahu | | | | | | | | | | |
| 20 | 03 12 21 | Bulota-Hepuhulawa | | | | | | | | | | |

| No | Station No. | Station Name | year 82 | | year 83 | | year 84 | | year 85 | | year 86 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | R | Date-Month | R | Date-Month | R | Date-Month | R | Date-Month | R | Date-Month |
| 1 | 03 13 15 | Bandara Jalaluddin | 64 | 29-Mar | 86 | 2-Oct | 73 | 18-Jul | 58 | 1-Feb | 48 | 28-Jul |
| 2 | 03 15 03 | Bone-Kabila | | | | | | | | | | |
| 3 | 03 13 02 | Alo-Alo | | | | | | | | | | |
| 4 | 03 13 03 | Bionga-Huludupitango | | | | | | | | | | |
| 5 | 03 13 07 | DAS Limboto-Dembe II | 40 | 1-Jan/5-Feb | 57 | 9-Jul | 57 | 18-Jun | 61 | 26-Aug | 56 | 15-Nov |
| 6 | 03 14 05 | Bolango-Longalo | 30 | 6-Apr | 23 | 22-Oct | 31 | 7-May | 66 | 30-Oct | 30 | 16-Mar |
| 7 | 03 15 02 | Bone-Lombongo | | | | | | | 79.3 | 7-Nov | 37 | 7-Nov |
| 8 | 03 15 11 | Bone-Pinogu | | | | | | | | | | |
| 9 | 03 15 13 | Pohulongo | | | | | | | | | | |
| 10 | 03 13 06 | Kayumerah-Limboto | | | 64 | 24-Oct | 72 | 30-Jan | 72 | 7-Apr | 43 | 15-May |
| 11 | 03 13 09 | UPP Tibawa | | | | | | | | | 37 | 21-Nov |
| 12 | 03 13 10 | UPP Batudaa | | | | | | | | | | |
| 13 | 03 13 11 | UPP Limboto | | | | | | | | | | |
| 14 | 03 14 06 | Boidu-Tapa | 68 | 2-Dec | 72 | 13-Aug | 71 | 25-Jan | 58 | 25-Oct | 63 | 16-Dec |
| 15 | 03 14 07 | UPP Telaga | | | | | | | | | 37 | 15-Nov |
| 16 | 03 15 12 | Lonuo-Kabila | 68 | 4-May | 73 | 18-Oct | 56 | 12-Dec | 65 | 7-Nov | 68 | 14-Nov |
| 17 | 03 15 14 | UPP Suwawa | | | | | | | | | 75 | 15-Nov |
| 18 | 03 13 17 | Bionga-Kayubulan | | | | | | | | | | |
| 19 | 03 15 16 | Butahu - Datahu | | | | | | | | | | |
| 20 | 03 12 21 | Bulota-Hepuhulawa | | | | | | | | | | |

# TableB2.2.2 ANNUAL MAXIMUM DAILY RAINFALLS (2/2)

| No | Station No. | Station Name | year 87 | | year 88 | | year 89 | | year 90 | | year 91 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | R | Date-Month | R | Date-Month | R | Date-Month | R | Date-Month | R | Date-Month |
| 1 | 03 13 15 | Bandara Jalaluddin | 79 | 2-Jun | 74 | 20-Jul | 120 | 2-Apr | 86 | 8-Mar | 61 | 8-May |
| 2 | 03 15 03 | Bone-Kabila | | | | | | | | | | |
| 3 | 03 13 02 | Alo-Alo | | | | | | | | | | |
| 4 | 03 13 03 | Bionga-Huludupitango | | | | | | | | | | |
| 5 | 03 13 07 | DAS Limboto-Dembe II | 51 | 10-Oct | 60 | 19-Jan | 59 | 24-Oct | 55 | 13-Sep | 75 | 4-Apr |
| 6 | 03 14 05 | Bolango-Longalo | 30 | 21-Oct | 37 | 19-Jul | 43 | 24-Jun | 66 | 8-Mar | 65 | 29-May |
| 7 | 03 15 02 | Bone-Lombongo | 50 | 9-Oct | 68 | 18-Jul | 95 | 20-Aug | 95 | 10-Jan | 96 | 3-Jun |
| 8 | 03 15 11 | Bone-Pinogu | | | | | | | | | 77 | 14-Oct |
| 9 | 03 15 13 | Pohulongo | | | | | | | | | | |
| 10 | 03 13 06 | Kayumerah-Limboto | 50 | 1-Dec | 81 | 14-Jun | 19 | 19-Jan/20-Oct | 18 | 13-Aug | 17 | 20-Jan/31-Mar |
| 11 | 03 13 09 | UPP Tibawa | 75 | 2-Dec | | | | | 48 | 29-Oct | 61 | 6-Nov |
| 12 | 03 13 10 | UPP Batudaa | | | | | | | 65 | 12-Nov | 48 | 13-Aug |
| 13 | 03 13 11 | UPP Limboto | | | | | | | | | | |
| 14 | 03 14 06 | Boidu-Tapa | 64 | 21-Oct | 75 | 26-Jan | 72 | 21-Oct | 59 | 14-May | 60 | 18-Nov |
| 15 | 03 14 07 | UPP Telaga | 49 | 3-Apr | | | | | 325 | 29-Oct | | |
| 16 | 03 15 12 | Lonuo-Kabila | 54 | 2-Apr | 75 | 26-Jan | 60 | 3-Apr | 75 | 27-Oct | 64 | 29-May |
| 17 | 03 15 14 | UPP Suwawa | 112 | 9-Dec | | | | | 36 | 29-Oct | 40 | 4-Apr |
| 18 | 03 13 17 | Bionga-Kayubulan | | | | | | | | | | |
| 19 | 03 15 16 | Butahu - Datahu | | | | | | | | | | |
| 20 | 03 12 21 | Bulota-Hepuhulawa | | | | | | | | | | |

| No | Station No. | Station Name | year 92 | | year 93 | | year 94 | | year 95 | | year 96 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | R | Date-Month | R | Date-Month | R | Date-Month | R | Date-Month | R | Date-Month |
| 1 | 03 13 15 | Bandara Jalaluddin | 69 | 17-Dec | 73 | 5-Apr | 56.2 | 4-Nov | 82 | 18-Jan | 53 | 11-Apr |
| 2 | 03 15 03 | Bone-Kabila | | | 35 | 8-Nov | 61.9 | 2-Jul | 75.2 | 1-Aug | 66 | 12-Feb |
| 3 | 03 13 02 | Alo-Alo | | | 44 | 14-Nov | 64 | 29-Nov | 100 | 18-Jan | 63 | 2-Feb |
| 4 | 03 13 03 | Bionga-Huludupitango | | | 35 | 9-Dec | 55.8 | 2-Nov | 94.6 | 18-Jan | 85 | 20-Aug |
| 5 | 03 13 07 | DAS Limboto-Dembe II | 57 | 30-Nov | 73 | 25-Mar | | | | | | |
| 6 | 03 14 05 | Bolango-Longalo | 30 | 9-May | 114 | 29-May | 45.1 | 10-Feb | 49.2 | 18-Jan | 58 | 18-Mar |
| 7 | 03 15 02 | Bone-Lombongo | 81 | 2-May | 72 | 17-Jan | 120 | 14-Mar | 105 | 1-Aug | 70 | 22-Oct |
| 8 | 03 15 11 | Bone-Pinogu | 64 | 15-Nov | 77 | 7-May | | | | | | |
| 9 | 03 15 13 | Pohulongo | | | | | | | | | | |
| 10 | 03 13 06 | Kayumerah-Limboto | 49 | 21-Dec | 70 | 29-May | | | | | | |
| 11 | 03 13 09 | UPP Tibawa | 50 | 5-Dec | 69 | 5-Apr | 32 | 11-Apr | | | | |
| 12 | 03 13 10 | UPP Batudaa | 53 | 7-Oct | 51 | 16-Jan | | | | | | |
| 13 | 03 13 11 | UPP Limboto | | | | | | | | | | |
| 14 | 03 14 06 | Boidu-Tapa | 62 | 22-Dec | 96 | 8-Nov | | | 107 | 19-Jan | 83 | 31-Oct |
| 15 | 03 14 07 | UPP Telaga | 62 | 22-Dec | 82 | 30-May | | | | | | |
| 16 | 03 15 12 | Lonuo-Kabila | 65 | 22-Dec | 67 | 29-May | 60 | 2-Jul | 118 | 11-Jul | 75 | 24-Mar |
| 17 | 03 15 14 | UPP Suwawa | 21 | 19-Jan | 42 | 30-May | | | | | | |
| 18 | 03 13 17 | Bionga-Kayubulan | | | | | | | | | | |
| 19 | 03 15 16 | Butahu - Datahu | 69 | 22-Dec | 61 | 6-Jun | 139 | 7-Feb | | | | |
| 20 | 03 12 21 | Bulota-Hepuhulawa | | | | | | | 43 | 8-Jul | 62 | 7-Feb |

| No | Station No. | Station Name | year 97 | | year 98 | | year 99 | | year 2000 | | year 2001 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | R | Date-Month | R | Date-Month | R | Date-Month | R | Date-Month | R | Date-Month |
| 1 | 03 13 15 | Bandara Jalaluddin | 99 | 31-Mar | 97 | 11-Dec | 72.7 | 3-Mar | 138 | 7-Feb | 65 | 11-Jan |
| 2 | 03 15 03 | Bone-Kabila | | | | | 89 | 13-May | | | | |
| 3 | 03 13 02 | Alo-Alo | 89 | 31-Mar | 92 | 3-Jan | 66 | 6-Jul | | | | |
| 4 | 03 13 03 | Bionga-Huludupitango | 93 | 31-Mar | 79 | 5-May | 65 | 23-Mar | | | | |
| 5 | 03 13 07 | DAS Limboto-Dembe II | | | | | | | | | | |
| 6 | 03 14 05 | Bolango-Longalo | 51 | 19-May | 36 | 9-Oct | 40 | 19-Oct | | | | |
| 7 | 03 15 02 | Bone-Lombongo | 83 | 22-Mar | 84 | 21-Dec | 85.4 | 19-Jan | | | | |
| 8 | 03 15 11 | Bone-Pinogu | | | | | | | | | | |
| 9 | 03 15 13 | Pohulongo | | | | | | | | | | |
| 10 | 03 13 06 | Kayumerah-Limboto | | | | | | | | | | |
| 11 | 03 13 09 | UPP Tibawa | | | | | | | | | | |
| 12 | 03 13 10 | UPP Batudaa | | | | | | | | | | |
| 13 | 03 13 11 | UPP Limboto | | | | | | | | | | |
| 14 | 03 14 06 | Boidu-Tapa | 161 | 19-May | | | | | | | | |
| 15 | 03 14 07 | UPP Telaga | | | | | | | | | | |
| 16 | 03 15 12 | Lonuo-Kabila | 96 | 18-May | 60 | 26-Sep | 65 | 16-May | 69 | 1-Aug | | |
| 17 | 03 15 14 | UPP Suwawa | | | | | | | | | | |
| 18 | 03 13 17 | Bionga-Kayubulan | | | | | | | | | | |
| 19 | 03 15 16 | Butahu - Datahu | | | | | | | | | | |
| 20 | 03 12 21 | Bulota-Hepuhulawa | 56 | 30-Mar | 49 | 18-Jul | 66 | 14-Nov | | | | |

# TableB2.2.2 ANNUAL MAXIMUM DAILY RAINFALLS (1/2)

| No | Station No. | Station Name | year 72 | | year 73 | | year 74 | | year 75 | | year 76 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | R | Date-Month | R | Date-Month | R | Date-Month | R | Date-Month | R | Date-Month |
| 1 | 03 13 15 | Bandara Jalaluddin | | | | | | | 82 | 18-Oct | 58 | 12-Nov |
| 2 | 03 15 03 | Bone-Kabila | | | | | | | | | | |
| 3 | 03 13 02 | Alo-Alo | | | | | | | | | | |
| 4 | 03 13 03 | Bionga-Huludupitango | | | | | | | | | | |
| 5 | 03 13 07 | DAS Limboto-Dembe II | | | | | | | | | | |
| 6 | 03 14 05 | Bolango-Longalo | | | | | | | | | | |
| 7 | 03 15 02 | Bone-Lombongo | | | | | | | | | | |
| 8 | 03 15 11 | Bone-Pinogu | | | | | | | | | | |
| 9 | 03 15 13 | Pohulongo | | | | | | | | | | |
| 10 | 03 13 06 | Kayumerah-Limboto | | | | | | | | | | |
| 11 | 03 13 09 | UPP Tibawa | | | | | | | | | | |
| 12 | 03 13 10 | UPP Batudaa | | | | | | | | | | |
| 13 | 03 13 11 | UPP Limboto | | | | | | | | | | |
| 14 | 03 14 06 | Boidu-Tapa | 34 | 23-Nov | 66 | 29-May | 99 | 12-Sep | 86 | 11-Apr | 52 | 31-Aug |
| 15 | 03 14 07 | UPP Telaga | | | | | | | | | | |
| 16 | 03 15 12 | Lonuo-Kabila | | | | | | | | | | |
| 17 | 03 15 14 | UPP Suwawa | | | | | | | | | | |
| 18 | 03 13 17 | Bionga-Kayubulan | | | | | | | | | | |
| 19 | 03 15 16 | Butahu - Datahu | | | | | | | | | | |
| 20 | 03 12 21 | Bulota-Hepuhulawa | | | | | | | | | | |

| No | Station No. | Station Name | year 77 | | year 78 | | year 79 | | year 80 | | year 81 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | R | Date-Month | R | Date-Month | R | Date-Month | R | Date-Month | R | Date-Month |
| 1 | 03 13 15 | Bandara Jalaluddin | 73 | 2-Jul | 57 | 2-Sep | 55 | 18-Nov | 60 | 3-December | 70 | 24-Feb |
| 2 | 03 15 03 | Bone-Kabila | | | | | | | | | | |
| 3 | 03 13 02 | Alo-Alo | | | | | | | | | | |
| 4 | 03 13 03 | Bionga-Huludupitango | | | | | | | | | | |
| 5 | 03 13 07 | DAS Limboto-Dembe II | | | | | | | | | 67 | 24-May |
| 6 | 03 14 05 | Bolango-Longalo | | | | | 10.1 | 27-Dec | 7.5 | 20-Jun | 30 | 9-Nov |
| 7 | 03 15 02 | Bone-Lombongo | | | | | | | | | | |
| 8 | 03 15 11 | Bone-Pinogu | | | | | | | | | | |
| 9 | 03 15 13 | Pohulongo | | | | | | | | | | |
| 10 | 03 13 06 | Kayumerah-Limboto | | | | | | | | | | |
| 11 | 03 13 09 | UPP Tibawa | | | | | | | | | | |
| 12 | 03 13 10 | UPP Batudaa | | | | | | | | | | |
| 13 | 03 13 11 | UPP Limboto | | | | | | | | | | |
| 14 | 03 14 06 | Boidu-Tapa | 90 | 24-Jun | 71 | 16-Apr | 112 | 27-Dec | 50 | 2-Feb | 84 | 5-Sep |
| 15 | 03 14 07 | UPP Telaga | | | | | | | | | | |
| 16 | 03 15 12 | Lonuo-Kabila | | | | | | | | | 51 | 21-May |
| 17 | 03 15 14 | UPP Suwawa | | | | | | | | | | |
| 18 | 03 13 17 | Bionga-Kayubulan | | | | | | | | | | |
| 19 | 03 15 16 | Butahu - Datahu | | | | | | | | | | |
| 20 | 03 12 21 | Bulota-Hepuhulawa | | | | | | | | | | |

| No | Station No. | Station Name | year 82 | | year 83 | | year 84 | | year 85 | | year 86 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | R | Date-Month | R | Date-Month | R | Date-Month | R | Date-Month | R | Date-Month |
| 1 | 03 13 15 | Bandara Jalaluddin | 64 | 29-Mar | 86 | 2-Oct | 73 | 18-Jul | 58 | 1-Feb | 48 | 28-Jul |
| 2 | 03 15 03 | Bone-Kabila | | | | | | | | | | |
| 3 | 03 13 02 | Alo-Alo | | | | | | | | | | |
| 4 | 03 13 03 | Bionga-Huludupitango | | | | | | | | | | |
| 5 | 03 13 07 | DAS Limboto-Dembe II | 40 | 1-Jan/5-Feb | 57 | 9-Jul | 57 | 18-Jun | 61 | 26-Aug | 56 | 15-Nov |
| 6 | 03 14 05 | Bolango-Longalo | 30 | 6-Apr | 23 | 22-Oct | 31 | 7-May | 66 | 30-Oct | 30 | 16-Mar |
| 7 | 03 15 02 | Bone-Lombongo | | | | | | | 79.3 | 7-Nov | 37 | 7-Nov |
| 8 | 03 15 11 | Bone-Pinogu | | | | | | | | | | |
| 9 | 03 15 13 | Pohulongo | | | | | | | | | | |
| 10 | 03 13 06 | Kayumerah-Limboto | | | 64 | 24-Oct | 72 | 30-Jan | 72 | 7-Apr | 43 | 15-May |
| 11 | 03 13 09 | UPP Tibawa | | | | | | | | | 37 | 21-Nov |
| 12 | 03 13 10 | UPP Batudaa | | | | | | | | | | |
| 13 | 03 13 11 | UPP Limboto | | | | | | | | | | |
| 14 | 03 14 06 | Boidu-Tapa | 68 | 2-Dec | 72 | 13-Aug | 71 | 25-Jan | 58 | 25-Oct | 63 | 16-Dec |
| 15 | 03 14 07 | UPP Telaga | | | | | | | | | 37 | 15-Nov |
| 16 | 03 15 12 | Lonuo-Kabila | 68 | 4-May | 73 | 18-Oct | 56 | 12-Dec | 65 | 7-Nov | 68 | 14-Nov |
| 17 | 03 15 14 | UPP Suwawa | | | | | | | | | 75 | 15-Nov |
| 18 | 03 13 17 | Bionga-Kayubulan | | | | | | | | | | |
| 19 | 03 15 16 | Butahu - Datahu | | | | | | | | | | |
| 20 | 03 12 21 | Bulota-Hepuhulawa | | | | | | | | | | |

# TableB2.2.2 ANNUAL MAXIMUM DAILY RAINFALLS (2/2)

| No | Station | Station | year 87 | | year 88 | | year 89 | | year 90 | | year 91 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. | Name | R | Date-Month | R | Date-Month | R | Date-Month | R | Date-Month | R | Date-Month |
| 1 | 03 13 15 | Bandara Jalaluddin | 79 | 2-Jun | 74 | 20-Jul | 120 | 2-Apr | 86 | 8-Mar | 61 | 8-May |
| 2 | 03 15 03 | Bone-Kabila | | | | | | | | | | |
| 3 | 03 13 02 | Alo-Alo | | | | | | | | | | |
| 4 | 03 13 03 | Bionga-Huludupitango | | | | | | | | | | |
| 5 | 03 13 07 | DAS Limboto-Dembe II | 51 | 10-Oct | 60 | 19-Jan | 59 | 24-Oct | 55 | 13-Sep | 75 | 4-Apr |
| 6 | 03 14 05 | Bolango-Longalo | 30 | 21-Oct | 37 | 19-Jul | 43 | 24-Jun | 66 | 8-Mar | 65 | 29-May |
| 7 | 03 15 02 | Bone-Lombongo | 50 | 9-Oct | 68 | 18-Jul | 95 | 20-Aug | 95 | 10-Jan | 96 | 3-Jun |
| 8 | 03 15 11 | Bone-Pinogu | | | | | | | | | 77 | 14-Oct |
| 9 | 03 15 13 | Pohulongo | | | | | | | | | | |
| 10 | 03 13 06 | Kayumerah-Limboto | 50 | 1-Dec | 81 | 14-Jun | 19 | 19-Jan/20-Oct | 18 | 13-Aug | 17 | 20-Jan/31-Mar |
| 11 | 03 13 09 | UPP Tibawa | 75 | 2-Dec | | | | | 48 | 29-Oct | 61 | 6-Nov |
| 12 | 03 13 10 | UPP Batudaa | | | | | | | 65 | 12-Nov | 48 | 13-Aug |
| 13 | 03 13 11 | UPP Limboto | | | | | | | | | | |
| 14 | 03 14 06 | Boidu-Tapa | 64 | 21-Oct | 75 | 26-Jan | 72 | 21-Oct | 59 | 14-May | 60 | 18-Nov |
| 15 | 03 14 07 | UPP Telaga | 49 | 3-Apr | | | | | 325 | 29-Oct | | |
| 16 | 03 15 12 | Lonuo-Kabila | 54 | 2-Apr | 75 | 26-Jan | 60 | 3-Apr | 75 | 27-Oct | 64 | 29-May |
| 17 | 03 15 14 | UPP Suwawa | 112 | 9-Dec | | | | | 36 | 29-Oct | 40 | 4-Apr |
| 18 | 03 13 17 | Bionga-Kayubulan | | | | | | | | | | |
| 19 | 03 15 16 | Butahu - Datahu | | | | | | | | | | |
| 20 | 03 12 21 | Bulota-Hepuhulawa | | | | | | | | | | |

| No | Station | Station | year 92 | | year 93 | | year 94 | | year 95 | | year 96 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. | Name | R | Date-Month | R | Date-Month | R | Date-Month | R | Date-Month | R | Date-Month |
| 1 | 03 13 15 | Bandara Jalaluddin | 69 | 17-Dec | 73 | 5-Apr | 56.2 | 4-Nov | 82 | 18-Jan | 53 | 11-Apr |
| 2 | 03 15 03 | Bone-Kabila | | | 35 | 8-Nov | 61.9 | 2-Jul | 75.2 | 1-Aug | 66 | 12-Feb |
| 3 | 03 13 02 | Alo-Alo | | | 44 | 14-Nov | 64 | 29-Nov | 100 | 18-Jan | 63 | 2-Feb |
| 4 | 03 13 03 | Bionga-Huludupitango | | | 35 | 9-Dec | 55.8 | 2-Nov | 94.6 | 18-Jan | 85 | 20-Aug |
| 5 | 03 13 07 | DAS Limboto-Dembe II | 57 | 30-Nov | 73 | 25-Mar | | | | | | |
| 6 | 03 14 05 | Bolango-Longalo | 30 | 9-May | 114 | 29-May | 45.1 | 10-Feb | 49.2 | 18-Jan | 58 | 18-Mar |
| 7 | 03 15 02 | Bone-Lombongo | 81 | 2-May | 72 | 17-Jan | 120 | 14-Mar | 105 | 1-Aug | 70 | 22-Oct |
| 8 | 03 15 11 | Bone-Pinogu | 64 | 15-Nov | 77 | 7-May | | | | | | |
| 9 | 03 15 13 | Pohulongo | | | | | | | | | | |
| 10 | 03 13 06 | Kayumerah-Limboto | 49 | 21-Dec | 70 | 29-May | | | | | | |
| 11 | 03 13 09 | UPP Tibawa | 50 | 5-Dec | 69 | 5-Apr | 32 | 11-Apr | | | | |
| 12 | 03 13 10 | UPP Batudaa | 53 | 7-Oct | 51 | 16-Jan | | | | | | |
| 13 | 03 13 11 | UPP Limboto | | | | | | | | | | |
| 14 | 03 14 06 | Boidu-Tapa | 62 | 22-Dec | 96 | 8-Nov | | | 107 | 19-Jan | 83 | 31-Oct |
| 15 | 03 14 07 | UPP Telaga | 62 | 22-Dec | 82 | 30-May | | | | | | |
| 16 | 03 15 12 | Lonuo-Kabila | 65 | 22-Dec | 67 | 29-May | 60 | 2-Jul | 118 | 11-Jul | 75 | 24-Mar |
| 17 | 03 15 14 | UPP Suwawa | 21 | 19-Jan | 42 | 30-May | | | | | | |
| 18 | 03 13 17 | Bionga-Kayubulan | | | | | | | | | | |
| 19 | 03 15 16 | Butahu - Datahu | 69 | 22-Dec | 61 | 6-Jun | 139 | 7-Feb | | | | |
| 20 | 03 12 21 | Bulota-Hepuhulawa | | | | | | | 43 | 8-Jul | 62 | 7-Feb |

| No | Station | Station | year 97 | | year 98 | | year 99 | | year 2000 | | year 2001 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. | Name | R | Date-Month | R | Date-Month | R | Date-Month | R | Date-Month | R | Date-Month |
| 1 | 03 13 15 | Bandara Jalaluddin | 99 | 31-Mar | 97 | 11-Dec | 72.7 | 3-Mar | 138 | 7-Feb | 65 | 11-Jan |
| 2 | 03 15 03 | Bone-Kabila | | | | | 89 | 13-May | | | | |
| 3 | 03 13 02 | Alo-Alo | 89 | 31-Mar | 92 | 3-Jan | 66 | 6-Jul | | | | |
| 4 | 03 13 03 | Bionga-Huludupitango | 93 | 31-Mar | 79 | 5-May | 65 | 23-Mar | | | | |
| 5 | 03 13 07 | DAS Limboto-Dembe II | | | | | | | | | | |
| 6 | 03 14 05 | Bolango-Longalo | 51 | 19-May | 36 | 9-Oct | 40 | 19-Oct | | | | |
| 7 | 03 15 02 | Bone-Lombongo | 83 | 22-Mar | 84 | 21-Dec | 85.4 | 19-Jan | | | | |
| 8 | 03 15 11 | Bone-Pinogu | | | | | | | | | | |
| 9 | 03 15 13 | Pohulongo | | | | | | | | | | |
| 10 | 03 13 06 | Kayumerah-Limboto | | | | | | | | | | |
| 11 | 03 13 09 | UPP Tibawa | | | | | | | | | | |
| 12 | 03 13 10 | UPP Batudaa | | | | | | | | | | |
| 13 | 03 13 11 | UPP Limboto | | | | | | | | | | |
| 14 | 03 14 06 | Boidu-Tapa | 161 | 19-May | | | | | | | | |
| 15 | 03 14 07 | UPP Telaga | | | | | | | | | | |
| 16 | 03 15 12 | Lonuo-Kabila | 96 | 18-May | 60 | 26-Sep | 65 | 16-May | 69 | 1-Aug | | |
| 17 | 03 15 14 | UPP Suwawa | | | | | | | | | | |
| 18 | 03 13 17 | Bionga-Kayubulan | | | | | | | | | | |
| 19 | 03 15 16 | Butahu - Datahu | | | | | | | | | | |
| 20 | 03 12 21 | Bulota-Hepuhulawa | 56 | 30-Mar | 49 | 18-Jul | 66 | 14-Nov | | | | |

## TableB2.2.3 ANNUAL MAXIMUM 1 TO 24 HOUR RAINFALLS

Station : Jalaludin / No.031315

| Year | Max 1 hour rainfall | | | Max 3 hours rainfall | | | Max 6 hour rainfall | | | Max 12 hour rainfall | | | Max 24 hour rainfall | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | R (mm) | Time (hr) | Date-Month | R (mm) | Time (hr) | Date-Month | R (mm) | Time (hr) | Date-Month | R (mm) | Time (hr) | Date-Month | R (mm) | Time (hr) | Date-Month |
| 1990 | 55.5 | 13-14 | 14 Jul | 56.2 | 13-16 | 14 Jul | 60.9 | 8-14 | 14 Jul | 70.5 | 8-20 | 14 Jul | 82.3 | 8-7 | 14-15 Jul |
| 1991 | 50.2 | 15-16 | 8 May | 57.2 | 15-18 | 8 May | 58.2 | 12-18 | 8 May | 58.2 | 12-18 | 8 May | 58.2 | 12-18 | 8 May |
| 1992 | 47.7 | 16-17 | 15 May | 52.4 | 15-18 | 15 May | 52.7 | 15-21 | 15 May | 52.7 | 15-21 | 15 May | 52.7 | 15-21 | 15 May |
| 1993 | 64.1 | 14-15 | 5 Apr | 72.5 | 14-17 | 5 Apr | 72.9 | 13-19 | 5 Apr | 72.9 | 13-19 | 5 Apr | 72.9 | 13-19 | 5 Apr |
| 1994 | 43 | 16-17 | 29-Nov | 49 | 15-18 | 29-Nov | 49 | 15-18 | 29-Nov | 49 | 15-18 | 29-Nov | 49 | 15-18 | 29-Nov |
| 1995 | 49 | 14-15 | 30-Aug | 62.1 | 14-17 | 30-Aug | 66.5 | 01-07 | 30-Aug | 90 | 00-11 | 30-31 Au | 99.8 | 20-19 | 30-31 Au |
| 1996 | 51.2 | 11-12 | 11-Mar | 51.5 | 11-14 | 11-Mar | 51.7 | 11-17 | 11-Mar | 51.7 | 11-17 | 11-Mar | 51.7 | 11-17 | 11-Mar |
| 1997 | 61.8 | 15-16 | 10-Mar | 92.1 | 14-17 | 31-Mar | 98.6 | 15-21 | 31-Mar | 98.6 | 15-21 | 31-Mar | 98.6 | 15-21 | 31-Mar |
| 1998 | 59 | 13-14 | 1-May | 88.5 | 13-16 | 1-May | 97.7 | 14-20 | 11-Dec | 97.7 | 14-20 | 11-Dec | 97.7 | 14-20 | 11-Dec |
| 1999 | 43.9 | 13-14 | 3-Mar | 59.7 | 13-16 | 3-Mar | 72.5 | 13-19 | 3-Mar | 72.7 | 13-01 | 3-Mar | 72.7 | 13- | 3-Mar |
| 2000 | 59 | 14-15 | 7-Feb | 109 | 14-17 | 7-Feb | 136.4 | 14-20 | 7-Feb | 137.7 | 13-01 | 7-Feb | 139 | 21-21 | 6-7Feb |
| 2001 | 60.3 | 15-16 | 11-Jan | 63.3 | 14-16 | 11-Jan | 65.2 | 14-20 | 11-Jan | 65.2 | 14-20 | 11-Jan | 65.3 | 14-14 | 11-12 Jan |

## Table B2.3.1 EXISTING CHANNEL CAPACITY

| River System | River | From (m) | To (m) | Average riverbed slope (1/I) | Average width (m) | Average depth (m) | Average area ($m^2$) | Average carrying capacity ($m^3/s$) | 2-year discharge $Q_2$ ($m^3/s$) | Ratio to $Q_2$ (Return period) |
|---|---|---|---|---|---|---|---|---|---|---|
| Lake Limboto System | Alopohu | 0 | 3,618 | 1072 | 32 | 2.9 | 102 | 215 | 280 | 77 % |
| | | 3,618 | 9,003 | 796 | 33 | 3.0 | 105 | 258 | 280 | 92 % |
| | Alo | 9,227 | 13,638 | 689 | 32 | 2.5 | 84 | 198 | 230 | 86 % |
| | Reksonegoro | 0 | 2,818 | 470 | 19 | 1.5 | 27 | 55 | 85 | 64 % |
| | Pohu | 0 | 3,214 | 737 | 28 | 2.0 | 56 | 115 | 65 | 176 % (5 yr) |
| | Biyonga | 0 | 3,001 | 646 | 18 | 1.7 | 39 | 83 | 50 | 166 % (5 yr) |
| | | 3,001 | 6,585 | 357 | 27 | 2.1 | 63 | 186 | 50 | 372 % (36 yr) |
| | | 6,585 | 8,295 | 245 | 29 | 1.2 | 36 | 100 | 50 | 200 % (7 yr) |
| | Meluopo | 0 | 2,181 | 686 | 14 | 0.8 | 12 | 18 | 35 | 53 % |
| | | 2,181 | 4,101 | 316 | 20 | 1.7 | 34 | 93 | 35 | 266 % (58 yr) |
| | Marisa | 0 | 1,451 | 2476 | 12 | 0.8 | 9 | 6 | 55 | 11 % |
| | | 1,451 | 5,268 | 478 | 13 | 1.4 | 20 | 40 | 55 | 72 % |
| | Rintenga | 0 | 7,020 | 525 | 9 | 0.7 | 11 | 21 | 50 | 42 % |
| Bolango River System | Bolango | 0 | 5,981 | 1435 | 34 | 2.6 | 97 | 175 | 200 | 88 % |
| | | 5,981 | 16,884 | 958 | 58 | 2.4 | 120 | 247 | 200 | 123 % (3 yr) |
| | | 16,884 | 18,725 | 365 | 83 | 1.3 | 100 | 205 | 200 | 103 % (2 yr) |
| | | 18,725 | 19,608 | 153 | 87 | 1.3 | 99 | 311 | 200 | 156 % (4 yr) |
| | Tapodu | 0 | 2,473 | 6230 | 24 | 1.9 | 45 | 31 | - | - |
| | Siendeng | 0 | 1,328 | 619 | 27 | 1.9 | 55 | 115 | - | - |
| | Limba | 0 | 2,306 | 2522 | 6 | 0.9 | 7 | 5 | - | - |
| | | 2,306 | 8,141 | 466 | 10 | 0.7 | 8 | 10 | - | - |
| Bone River System | Bone | 0 | 969 | 1783 | 216 | 2.3 | 524 | 871 | 310 | 281 % (11 yr) |
| | | 969 | 5,572 | 815 | 129 | 1.5 | 191 | 301 | 290 | 104 % (2 yr) |
| | | 5,572 | 14,713 | 529 | 120 | 1.2 | 131 | 214 | 290 | 74 % |
| | | 14,713 | 15,824 | 247 | 123 | 1.1 | 103 | 232 | 290 | 80 % |
| | Pangimba | 0 | 6,269 | 538 | 9 | 0.8 | 8 | 10 | - | - |
| | Tamalate | 0 | 5,653 | 1163 | 21 | 1.7 | 37 | 53 | 95 | 56 % |
| | | 5,653 | 8,318 | 692 | 23 | 1.6 | 35 | 60 | 95 | 63 % |
| | | 8,318 | 10,520 | 340 | 22 | 1.1 | 24 | 47 | 60 | 79 % |
| | | 10,520 | 10,926 | 112 | 12 | 1.5 | 23 | 103 | 60 | 172 % (9 yr) |
| | Ulanta | 0 | 3,212 | 323 | 11 | 0.9 | 9 | 17 | - | - |
| Irrigation Canal | | 0 | 1,712 | 1069 | 9 | 1.2 | 13 | 17 | - | - |

# Table B2.3.2 ESTIMATED MONTHLY TIDE LEVELS

## MAXIMUM MONTHLY TIDAL LEVEL

| Month | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | Max. | Ave. | Min. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January | 1.549 | 1.515 | 1.501 | 1.489 | 1.529 | 1.521 | 1.526 | 1.521 | 1.548 | 1.559 | 1.559 | 1.526 | 1.489 |
| February | 1.502 | 1.437 | 1.457 | 1.450 | 1.483 | 1.457 | 1.491 | 1.503 | 1.513 | 1.491 | 1.513 | 1.478 | 1.437 |
| March | 1.386 | 1.362 | 1.353 | 1.380 | 1.381 | 1.325 | 1.405 | 1.437 | 1.428 | 1.379 | 1.437 | 1.384 | 1.325 |
| April | 1.463 | 1.442 | 1.432 | 1.391 | 1.435 | 1.397 | 1.421 | 1.377 | 1.431 | 1.406 | 1.463 | 1.420 | 1.377 |
| May | 1.519 | 1.481 | 1.480 | 1.513 | 1.500 | 1.465 | 1.484 | 1.494 | 1.512 | 1.485 | 1.519 | 1.493 | 1.465 |
| June | 1.546 | 1.518 | 1.507 | 1.519 | 1.532 | 1.516 | 1.519 | 1.530 | 1.555 | 1.542 | 1.555 | 1.528 | 1.507 |
| July | 1.533 | 1.525 | 1.493 | 1.488 | 1.522 | 1.534 | 1.517 | 1.518 | 1.557 | 1.568 | 1.568 | 1.526 | 1.488 |
| August | 1.477 | 1.486 | 1.437 | 1.422 | 1.464 | 1.503 | 1.465 | 1.475 | 1.504 | 1.547 | 1.547 | 1.478 | 1.422 |
| September | 1.399 | 1.394 | 1.366 | 1.327 | 1.362 | 1.421 | 1.354 | 1.399 | 1.402 | 1.473 | 1.473 | 1.390 | 1.327 |
| October | 1.475 | 1.448 | 1.456 | 1.412 | 1.448 | 1.406 | 1.417 | 1.393 | 1.462 | 1.429 | 1.475 | 1.435 | 1.393 |
| November | 1.521 | 1.496 | 1.507 | 1.485 | 1.502 | 1.474 | 1.484 | 1.478 | 1.529 | 1.509 | 1.529 | 1.499 | 1.474 |
| December | 1.543 | 1.506 | 1.522 | 1.525 | 1.528 | 1.513 | 1.510 | 1.524 | 1.561 | 1.555 | 1.561 | 1.529 | 1.506 |
| Max. | 1.549 | 1.525 | 1.522 | 1.525 | 1.532 | 1.534 | 1.526 | 1.530 | 1.561 | 1.568 | 1.568 | 1.537 | 1.522 |
| Ave. | 1.493 | 1.468 | 1.459 | 1.450 | 1.474 | 1.461 | 1.466 | 1.471 | 1.500 | 1.495 | 1.500 | 1.474 | 1.450 |
| Min. | 1.386 | 1.362 | 1.353 | 1.327 | 1.362 | 1.325 | 1.354 | 1.377 | 1.402 | 1.379 | 1.402 | 1.363 | 1.325 |

## MINIMUM MONTHLY TIDAL LEVEL

| Month | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | Max. | Ave. | Min. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January | 0.260 | 0.259 | 0.271 | 0.291 | 0.267 | 0.260 | 0.260 | 0.261 | 0.264 | 0.257 | 0.291 | 0.265 | 0.257 |
| February | 0.210 | 0.240 | 0.271 | 0.296 | 0.266 | 0.269 | 0.262 | 0.264 | 0.276 | 0.264 | 0.296 | 0.262 | 0.210 |
| March | 0.193 | 0.200 | 0.213 | 0.248 | 0.240 | 0.250 | 0.257 | 0.268 | 0.261 | 0.250 | 0.268 | 0.238 | 0.193 |
| April | 0.202 | 0.196 | 0.226 | 0.225 | 0.229 | 0.231 | 0.234 | 0.241 | 0.234 | 0.221 | 0.241 | 0.224 | 0.196 |
| May | 0.226 | 0.226 | 0.252 | 0.238 | 0.239 | 0.240 | 0.247 | 0.247 | 0.235 | 0.221 | 0.252 | 0.237 | 0.221 |
| June | 0.250 | 0.246 | 0.271 | 0.280 | 0.251 | 0.245 | 0.255 | 0.257 | 0.241 | 0.225 | 0.280 | 0.252 | 0.225 |
| July | 0.262 | 0.262 | 0.278 | 0.293 | 0.266 | 0.253 | 0.258 | 0.269 | 0.258 | 0.238 | 0.293 | 0.264 | 0.238 |
| August | 0.258 | 0.225 | 0.248 | 0.269 | 0.284 | 0.257 | 0.259 | 0.271 | 0.275 | 0.245 | 0.284 | 0.259 | 0.225 |
| September | 0.191 | 0.200 | 0.225 | 0.238 | 0.247 | 0.245 | 0.267 | 0.274 | 0.277 | 0.232 | 0.277 | 0.240 | 0.191 |
| October | 0.181 | 0.204 | 0.224 | 0.223 | 0.229 | 0.232 | 0.243 | 0.242 | 0.226 | 0.210 | 0.243 | 0.221 | 0.181 |
| November | 0.228 | 0.233 | 0.249 | 0.242 | 0.247 | 0.249 | 0.243 | 0.246 | 0.230 | 0.221 | 0.249 | 0.239 | 0.221 |
| December | 0.249 | 0.257 | 0.271 | 0.253 | 0.260 | 0.256 | 0.257 | 0.256 | 0.244 | 0.228 | 0.271 | 0.253 | 0.228 |
| Max. | 0.262 | 0.262 | 0.278 | 0.296 | 0.284 | 0.269 | 0.267 | 0.274 | 0.277 | 0.264 | 0.296 | 0.273 | 0.262 |
| Ave. | 0.226 | 0.229 | 0.250 | 0.258 | 0.252 | 0.249 | 0.254 | 0.258 | 0.252 | 0.234 | 0.258 | 0.246 | 0.226 |
| Min. | 0.181 | 0.196 | 0.213 | 0.223 | 0.229 | 0.231 | 0.234 | 0.241 | 0.226 | 0.210 | 0.241 | 0.218 | 0.181 |

## AVERAGE MONTHLY TIDAL LEVEL

| Month | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | Max. | Ave. | Min. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January | 0.801 | 0.801 | 0.800 | 0.800 | 0.801 | 0.800 | 0.800 | 0.801 | 0.801 | 0.800 | 0.801 | 0.801 | 0.800 |
| February | 0.800 | 0.800 | 0.800 | 0.800 | 0.800 | 0.800 | 0.800 | 0.800 | 0.801 | 0.800 | 0.801 | 0.800 | 0.800 |
| March | 0.799 | 0.801 | 0.800 | 0.799 | 0.800 | 0.800 | 0.800 | 0.799 | 0.800 | 0.800 | 0.801 | 0.800 | 0.799 |
| April | 0.799 | 0.800 | 0.801 | 0.800 | 0.800 | 0.800 | 0.800 | 0.800 | 0.800 | 0.800 | 0.801 | 0.800 | 0.799 |
| May | 0.800 | 0.800 | 0.801 | 0.801 | 0.799 | 0.800 | 0.801 | 0.800 | 0.799 | 0.801 | 0.801 | 0.800 | 0.799 |
| June | 0.801 | 0.800 | 0.801 | 0.801 | 0.800 | 0.800 | 0.801 | 0.801 | 0.800 | 0.800 | 0.801 | 0.801 | 0.800 |
| July | 0.802 | 0.800 | 0.800 | 0.802 | 0.801 | 0.800 | 0.801 | 0.802 | 0.800 | 0.799 | 0.802 | 0.801 | 0.799 |
| August | 0.802 | 0.801 | 0.800 | 0.801 | 0.802 | 0.800 | 0.800 | 0.802 | 0.802 | 0.800 | 0.802 | 0.801 | 0.800 |
| September | 0.801 | 0.802 | 0.801 | 0.801 | 0.802 | 0.801 | 0.801 | 0.801 | 0.802 | 0.801 | 0.802 | 0.801 | 0.801 |
| October | 0.801 | 0.802 | 0.801 | 0.801 | 0.801 | 0.802 | 0.801 | 0.801 | 0.802 | 0.802 | 0.802 | 0.801 | 0.801 |
| November | 0.801 | 0.801 | 0.802 | 0.801 | 0.801 | 0.801 | 0.801 | 0.801 | 0.801 | 0.802 | 0.802 | 0.801 | 0.801 |
| December | 0.800 | 0.801 | 0.801 | 0.801 | 0.800 | 0.801 | 0.801 | 0.801 | 0.800 | 0.801 | 0.801 | 0.801 | 0.800 |
| Max. | 0.802 | 0.802 | 0.802 | 0.802 | 0.802 | 0.802 | 0.801 | 0.802 | 0.802 | 0.802 | 0.802 | 0.802 | 0.801 |
| Ave. | 0.801 | 0.801 | 0.801 | 0.801 | 0.801 | 0.800 | 0.801 | 0.801 | 0.801 | 0.801 | 0.801 | 0.801 | 0.800 |
| Min. | 0.799 | 0.800 | 0.800 | 0.799 | 0.799 | 0.800 | 0.800 | 0.799 | 0.799 | 0.799 | 0.800 | 0.799 | 0.799 |

SIGNIFICANT TIDE LEVELS

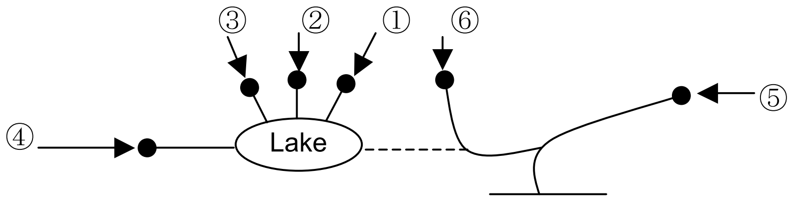
| Tides | ( m ) | ( m,MSL ) |
|---|---|---|
| HHWL | 1.568 | 0.767 |
| MHWL | 1.474 | 0.673 |
| MSL | 0.801 | 0 |
| MLWL | 0.246 | -0.555 |
| LLWL | 0.181 | -0.620 |

## Table B2.4.1 SEDIMENT TRANSPORT CAPACITY

| River | Slope (l/I) | Width (B : m) | Depth (H : m) | Bed Material ($d_{60}$ : mm) | Index (Is ) | Share (%) |
|---|---|---|---|---|---|---|
| Lake Limboto System | | | | | | |
| ① Biyonga River | 357 | 27 | 2.1 | 0.48 | 0.1515 | 56 |
| ② Meluopo River | 316 | 20 | 1.7 | 0.61 | 0.0679 | 24 |
| ③ Marisa River | 478 | 13 | 1.4 | 0.61 | 0.0102 | 4 |
| ④ Alo-Pohu River | 796 | 33 | 3.0 | 0.67 | 0.0426 | 16 |
| (Sub Total) | | | | | (0.2722) | (100) |
| Bone - Bolango System | | | | | | |
| ⑤ Bone River | 365 | 83 | 1.3 | 0.49 | 0.1282 | 62 |
| ⑥ Bolango River | 529 | 120 | 1.2 | 0.38 | 0.0775 | 38 |
| (Sub Total) | | | | | (0.2057) | (100) |

Notes :

(1) Schematic Location




(2) Sediment Transport Index (Is):

$$Is = B\,(HI)^{2.5} / d_{60}$$

Where:

Is = Sediment transport index assumed to be proportional to sediment transport capacity

B = River width (m)

H = Mean channel width (m)

I = Riverbed slope

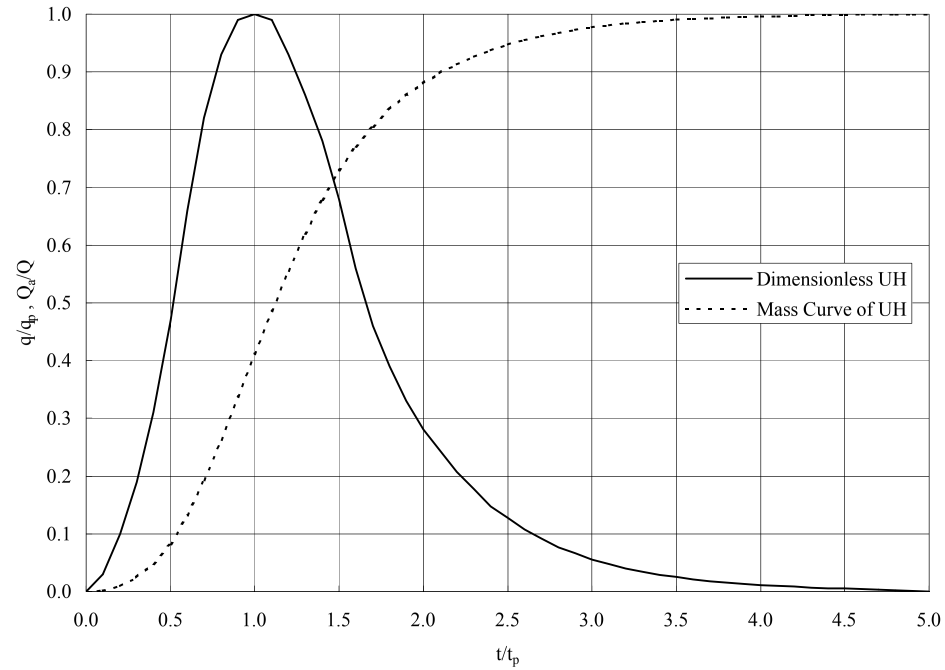
$d_{60}$ = 60% grain size (m), 60% of the bed material is finer than this size

## Table B2.4.2 DATA OF AREA AND DEPTH IN LAKE LIMBOTO

| No. | Year | Area (km2) | Depth (m) | Water Level (m,MSL) | Volume (m3) | Source |
|---|---|---|---|---|---|---|
| 1 | 1900-1932 | 80 | | | | Technical Report No.15 p2.4 |
| 2 | 1900-1932 | 80 | 14.0 | | | Technical Report No.15 p2.14 |
| 3 | 1934 | 70 | 14.0 | | | Technical Report No.15 p2.4 |
| 4 | 1944-1952 | 50 | 7.0 | | | Technical Report No.15 p2.14 |
| 5 | 1952 | 50 | 7.0 | | | Technical Report No.15 p2.4 |
| 6 | 1960-1964 | 40 | 4.0 | | | Technical Report No.15 p2.14 |
| 7 | 1969 | 40 | 3.5 | | | Technical Report No.15 p2.4 |
| 8 | 1970 | 45 | 4.5 | | | Technical Report No.15 p2.4 |
| 9 | 1971 | 30 | 3.5 | | | Technical Report No.15 p2.4 |
| 10 | 1972 | 30 | 2.5 | | | Technical Report No.15 p2.4 |
| 11 | 1973 | 25 | 2.5 | | | Technical Report No.15 p2.4 |
| 12 | 1974 | 25 | 3.5 | | | Technical Report No.15 p2.4 |
| 13 | 1975 | 30 | 3.5 | | | Technical Report No.15 p2.4 |
| 14 | 1976 | 20 | 2.5 | | | Technical Report No.15 p2.4 |
| 15 | 1977 | 35 | 3.0 | | | Technical Report No.15 p2.4 |
| 16 | 1978 | 30 | 3.0 | | | Technical Report No.15 p2.4 |
| 17 | 1979 | 30 | 3.0 | | | Technical Report No.15 p2.4 |
| 18 | 1980 | 20 | 2.0 | | | Technical Report No.15 p2.4 |
| 19 | 1981 | 20 | 2.5 | | | Technical Report No.15 p2.4 |
| 20 | 1981-1982 | 35 | 2.5 | | | Technical Report No.15 p2.14 |
| 21 | 1981-1982 | 38.1 | none | | | Topographic map |
| 22 | 1982 | 16.5 | 2.5 | | | Technical Report No.15 p2.4 |
| 23 | 1983 | 15 | 2.5 | | | Technical Report No.15 p2.4 |
| 24 | 1987/Sep | 31.2 | none | | | Satellite image |
| 25 | 1988 | | | 5.33 | | Kelayakan Teknis , p.II-52 |
| 26 | 1989 | 45 | 4.5 | | | Technical Report No.15 p2.14 |
| 27 | 1989 | | | 4.82 | | Kelayakan Teknis , p.II-52 |
| 28 | 1990 | | | 4.16 | | Kelayakan Teknis , p.II-52 |
| 29 | 1991 | none | | 4.18 | | Kelayakan Teknis, p.II-52 |
| 30 | 1991/Aug | none | none | | | Arial photograph |
| 31 | 1992-1993 | 30 | 3.5 | | | Technical Report No.15 p2.14 |
| 32 | 1993/Oct | 30.57 | 2.3 | 3.22 | 24,175,000 | Interim Report Annexe2 C.17 |
| 33 | 1993 | | | 3.55 | | Kelayakan Teknis , p.II-52 |
| 34 | 1994/Apr | 49.8 | 3.3 | 4.22 | 49,150,000 | surveyed by PU |
| 35 | 1994 | | | 4.70 | | Kelayakan Teknis , p.II-52 |
| 36 | 1995 | | | 5.49 | | Kelayakan Teknis , p.II-52 |
| 37 | 1996 | 44.63 | 4.7 | (5.22) | 135,242,500 | surveyed by PU |
| 38 | 1996 | | | 5.22 | | Kelayakan Teknis, p.II-52 |

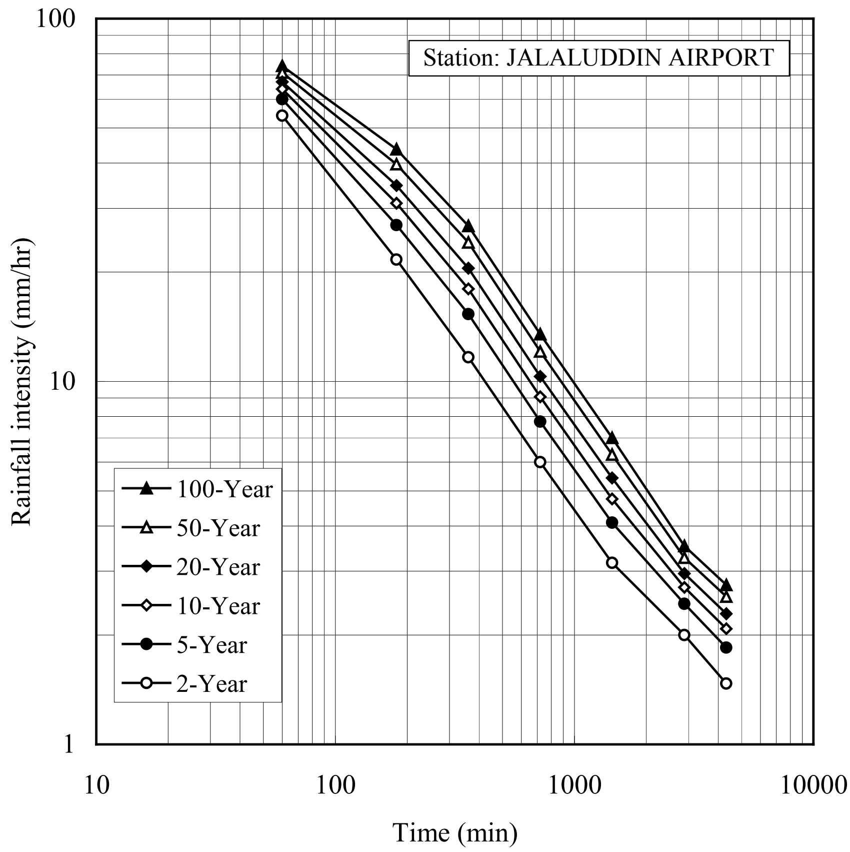
Technical Report : Integrated Watershed Management and Development Plan for the Limaboto-Bolango-Bone Basins,Main Report Volume 1,Technical Report No.15 August 1994 (CIDA)

Kelayakan Teknis : Kelayakan Teknis Pengembangan Daerah Aliran Sungai Limboto-Bone Kabupaten Gorontalo Propinsi Sulawesi Utara, 25 Juni 1996(DPU,Kantor Wilayah Propinsi Sulawesi Utara)




| Time ratios (t/tp) | Discharge ratio (q/qp) | Ratio (Qa/Q) | Mass curve ratios (Qa/Q) |
|---|---|---|---|
| 0.0 | 0.000 | 0.000 | 0.000 |
| 0.1 | 0.030 | 0.002 | 0.002 |
| 0.2 | 0.100 | 0.007 | 0.010 |
| 0.3 | 0.190 | 0.014 | 0.024 |
| 0.4 | 0.310 | 0.023 | 0.047 |
| 0.5 | 0.470 | 0.035 | 0.082 |
| 0.6 | 0.660 | 0.049 | 0.132 |
| 0.7 | 0.820 | 0.061 | 0.193 |
| 0.8 | 0.930 | 0.070 | 0.263 |
| 0.9 | 0.990 | 0.074 | 0.337 |
| 1.0 | 1.000 | 0.075 | 0.412 |
| 1.1 | 0.990 | 0.074 | 0.486 |
| 1.2 | 0.930 | 0.070 | 0.555 |
| 1.3 | 0.860 | 0.064 | 0.620 |
| 1.4 | 0.780 | 0.058 | 0.678 |
| 1.5 | 0.680 | 0.051 | 0.729 |
| 1.6 | 0.560 | 0.042 | 0.771 |
| 1.7 | 0.460 | 0.034 | 0.805 |
| 1.8 | 0.390 | 0.029 | 0.835 |
| 1.9 | 0.330 | 0.025 | 0.859 |
| 2.0 | 0.280 | 0.021 | 0.880 |
| 2.1 | 0.244 | 0.018 | 0.898 |
| 2.2 | 0.207 | 0.015 | 0.914 |
| 2.3 | 0.177 | 0.013 | 0.927 |
| 2.4 | 0.147 | 0.011 | 0.938 |
| 2.5 | 0.127 | 0.010 | 0.948 |
| 2.6 | 0.107 | 0.008 | 0.956 |
| 2.7 | 0.092 | 0.007 | 0.963 |
| 2.8 | 0.077 | 0.006 | 0.968 |
| 2.9 | 0.066 | 0.005 | 0.973 |
| 3.0 | 0.055 | 0.004 | 0.977 |
| 3.1 | 0.048 | 0.004 | 0.981 |
| 3.2 | 0.040 | 0.003 | 0.984 |
| 3.3 | 0.035 | 0.003 | 0.987 |
| 3.4 | 0.029 | 0.002 | 0.989 |
| 3.5 | 0.025 | 0.002 | 0.991 |
| 3.6 | 0.021 | 0.002 | 0.992 |
| 3.7 | 0.018 | 0.001 | 0.994 |
| 3.8 | 0.015 | 0.001 | 0.995 |
| 3.9 | 0.013 | 0.001 | 0.996 |
| 4.0 | 0.011 | 0.001 | 0.996 |
| 4.1 | 0.010 | 0.001 | 0.997 |
| 4.2 | 0.009 | 0.001 | 0.998 |
| 4.3 | 0.007 | 0.001 | 0.998 |
| 4.4 | 0.006 | 0.000 | 0.999 |
| 4.5 | 0.005 | 0.000 | 0.999 |
| 4.6 | 0.004 | 0.000 | 1.000 |
| 4.7 | 0.003 | 0.000 | 1.000 |
| 4.8 | 0.002 | 0.000 | 1.000 |
| 4.9 | 0.001 | 0.000 | 1.000 |
| 5.0 | 0.000 | 0.000 | 1.000 |
| Total | 13.360 | 1.000 | |

**Figure B2.2.1 DIMENSIONLESS UNIT HYDROGRAPH**




| Duration | | Rainfall (mm) | | | | | |
|---|---|---|---|---|---|---|---|
| (hr) | (min) | 2 | 5 | 10 | 20 | 50 | 100 |
| 1 | 60 | 54 | 60 | 64 | 67 | 71 | 74 |
| 3 | 180 | 65 | 81 | 93 | 104 | 119 | 131 |
| 6 | 360 | 70 | 92 | 108 | 123 | 145 | 161 |
| 12 | 720 | 72 | 93 | 109 | 124 | 145 | 162 |
| 24 | 1440 | 76 | 98 | 114 | 130 | 151 | 168 |
| 48 | 2880 | 96 | 117 | 130 | 142 | 157 | 169 |
| 72 | 4320 | 106 | 133 | 150 | 165 | 184 | 198 |

| Duration | | Rainfall intensity (mm/hr) | | | | | |
|---|---|---|---|---|---|---|---|
| (hr) | (min) | 2 | 5 | 10 | 20 | 50 | 100 |
| 1 | 60 | 54.0 | 60.0 | 64.0 | 67.0 | 71.0 | 74.0 |
| 3 | 180 | 21.7 | 27.0 | 31.0 | 34.7 | 39.7 | 43.7 |
| 6 | 360 | 11.7 | 15.3 | 18.0 | 20.5 | 24.2 | 26.8 |
| 12 | 720 | 6.00 | 7.75 | 9.08 | 10.33 | 12.08 | 13.50 |
| 24 | 1440 | 3.17 | 4.08 | 4.75 | 5.42 | 6.29 | 7.00 |
| 48 | 2880 | 2.00 | 2.44 | 2.71 | 2.96 | 3.27 | 3.52 |
| 72 | 4320 | 1.47 | 1.85 | 2.08 | 2.29 | 2.56 | 2.75 |



**Figure B2.2.2**
**RAINFALL INTENSITY CURVE AT JALALUDDIN AIRPORT**

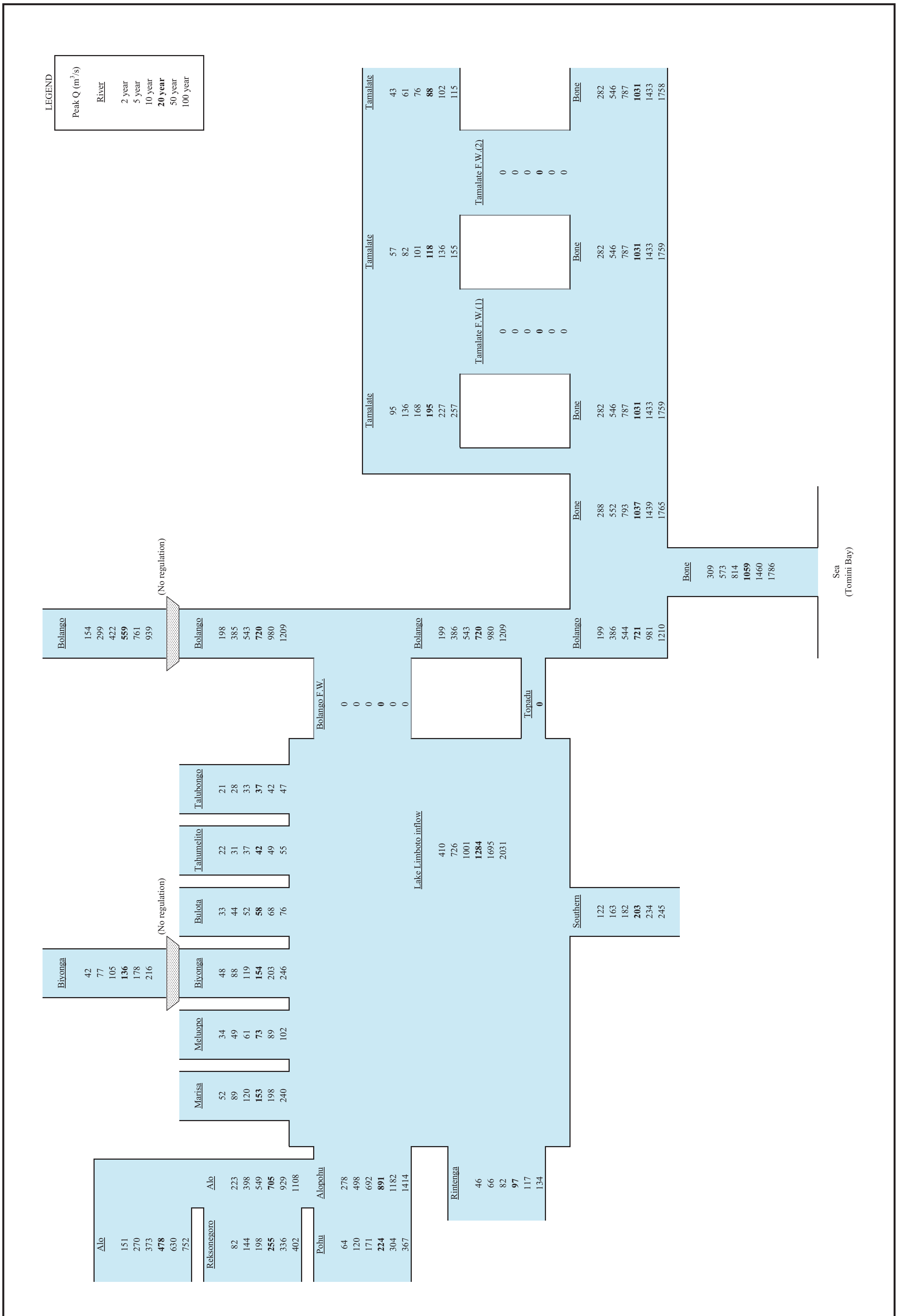



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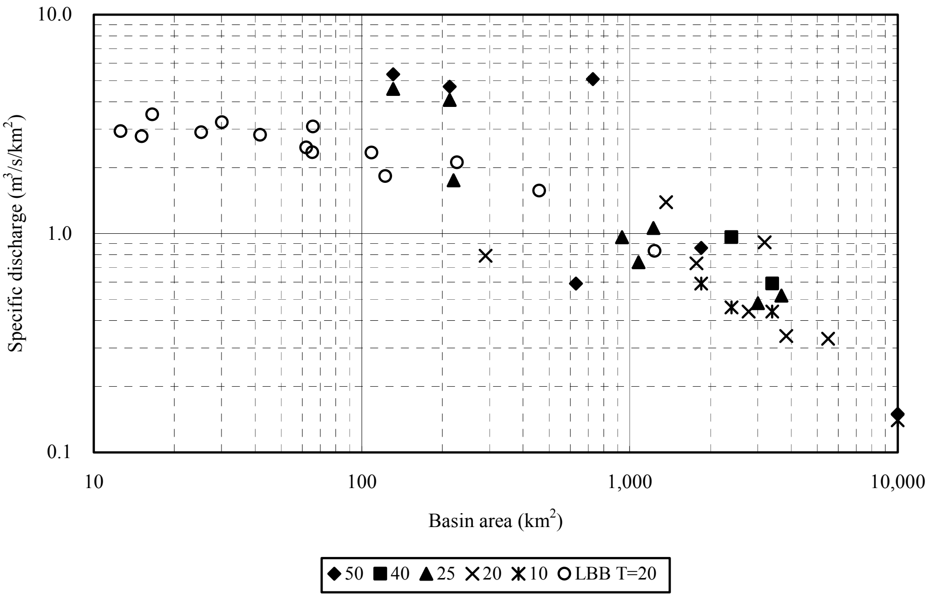
**Figure B2.2.4**

**BASIC PROBABLE DISCHARGES OF LBB BASIN**




| Name of River | Province | Chatchment Area ($km^2$) | Design Flood ($m^3/s$) | Specific Discharge ($m^3/s/km^2$) | Return Period (year) | Remarks |
|---|---|---|---|---|---|---|
| Brantas | East Java | 10,000 | 1,500 | 0.15 | 50 | *2 |
| Ciujung | North Banten | 1,850 | 1,600 | 0.86 | 50 | *2 |
| Jenebarang | South Sulawesi | 729 | 3,700 | 5.08 | 50 | |
| Surabaya | East Java | 631 | 370 | 0.59 | 50 | |
| Kuranji | West Sumatra | 213 | 1,000 | 4.69 | 50 | *2 |
| Air Dingin | West Sumatra | 131 | 700 | 5.34 | 50 | *2 |
| Solo | Central/East Java | 3,400 | 2,000 | 0.59 | 40 | *2 |
| Madium | East Java | 2,400 | 2,300 | 0.96 | 40 | *2 |
| Citanduy | West Java | 3,680 | 1,900 | 0.52 | 25 | |
| Cimanuk | West Java | 3,006 | 1,440 | 0.48 | 25 | |
| Pemali | Central Java | 1,228 | 1,300 | 1.06 | 25 | |
| Ular | North Sumatra | 1,080 | 800 | 0.74 | 25 | |
| Serang | Central Java | 937 | 900 | 0.96 | 25 | |
| Cipanas | West Java | 220 | 385 | 1.75 | 25 | |
| Kuranji | West Sumatra | 213 | 870 | 4.08 | 25 | *1 |
| Air Dingin | West Sumatra | 131 | 600 | 4.58 | 25 | *1 |
| Arakundo | Ache | 5,495 | 1,800 | 0.33 | 20 | |
| Wampu | North Sumatra | 3,840 | 1,320 | 0.34 | 20 | |
| Walarue | South Sulawesi | 3,190 | 2,900 | 0.91 | 20 | |
| Bah Bolon | North Sumatra | 2,776 | 1,220 | 0.44 | 20 | |
| Kring Ache | Ache | 1,775 | 1,300 | 0.73 | 20 | |
| Biba | South Sulawesi | 1,368 | 1,900 | 1.39 | 20 | |
| Marmoyo | East Java | 290 | 230 | 0.79 | 20 | |
| Brantas | East Java | 10,000 | 1,350 | 0.14 | 10 | *1 |
| Solo | Central/East Java | 3,400 | 1,500 | 0.44 | 10 | *1 |
| Madium | East Java | 2,400 | 1,100 | 0.46 | 10 | *1 |
| Ciujung | North Banten | 1,850 | 1,100 | 0.59 | 10 | *1 |

Note * 1 : For short-term or urgent plan
* 2 : For long-term plan

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**Figure B2.2.5**
**DISCHARGES OF LBB BASIN AND OTHER RIVERS IN INDONESIA**

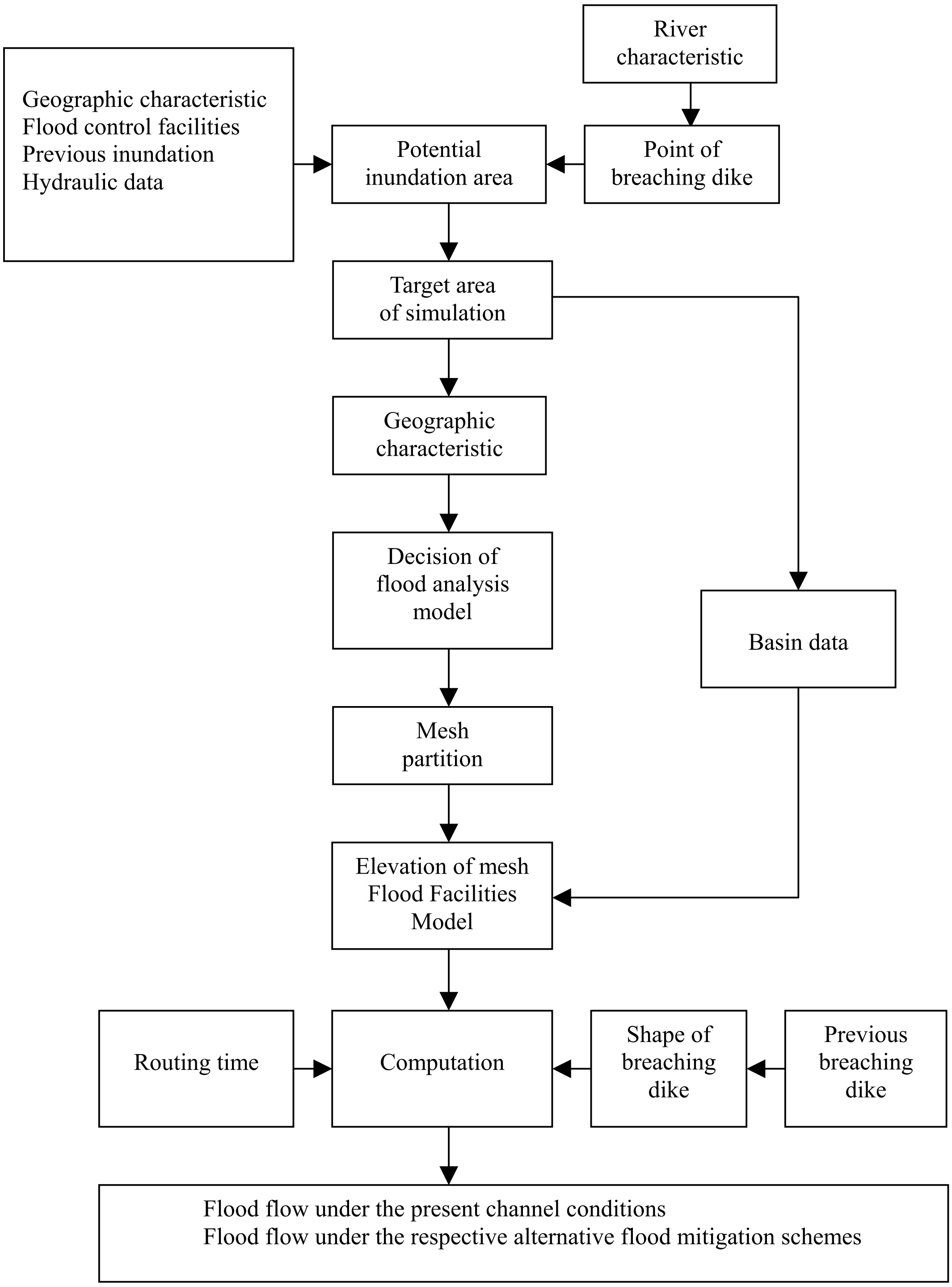


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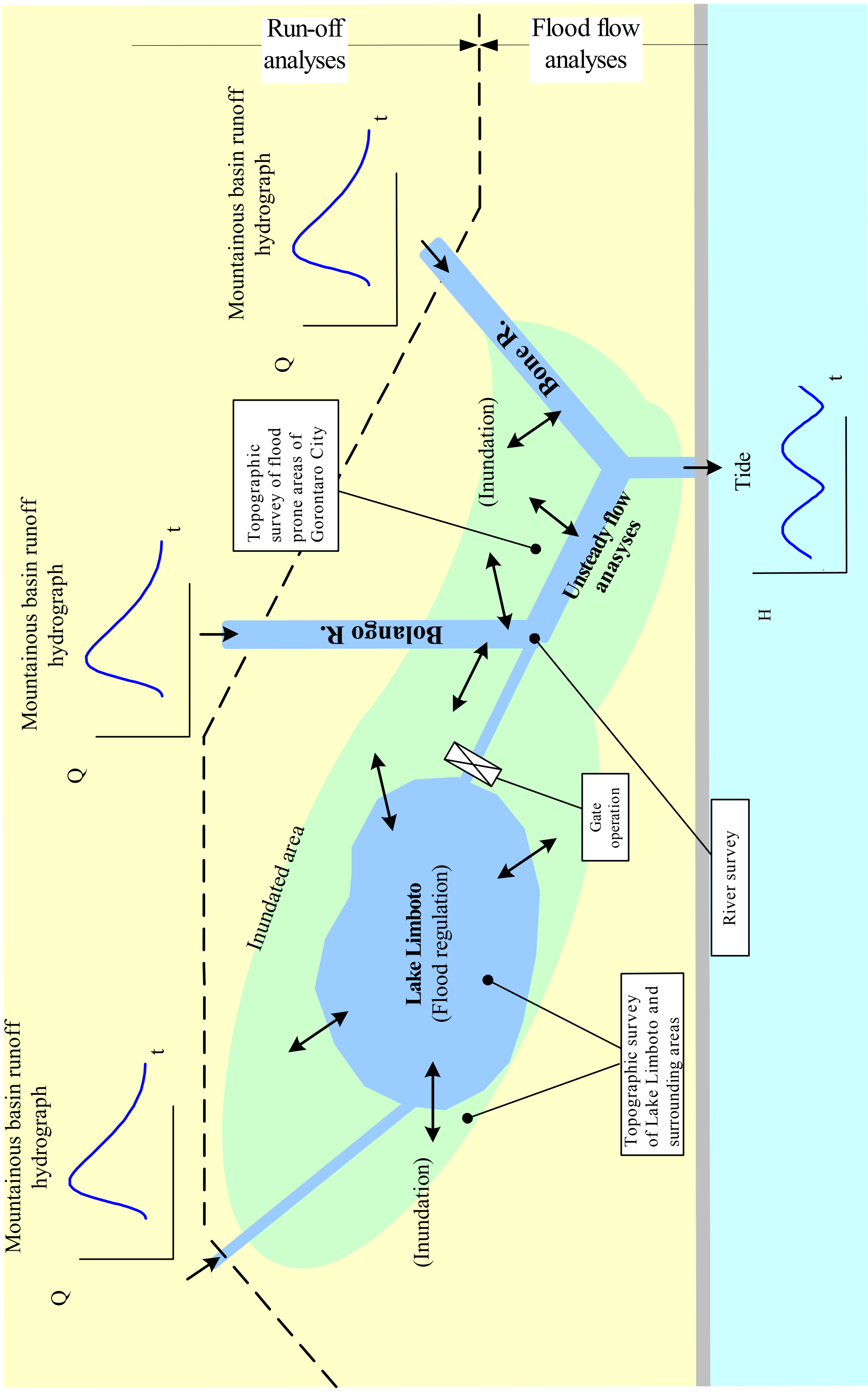
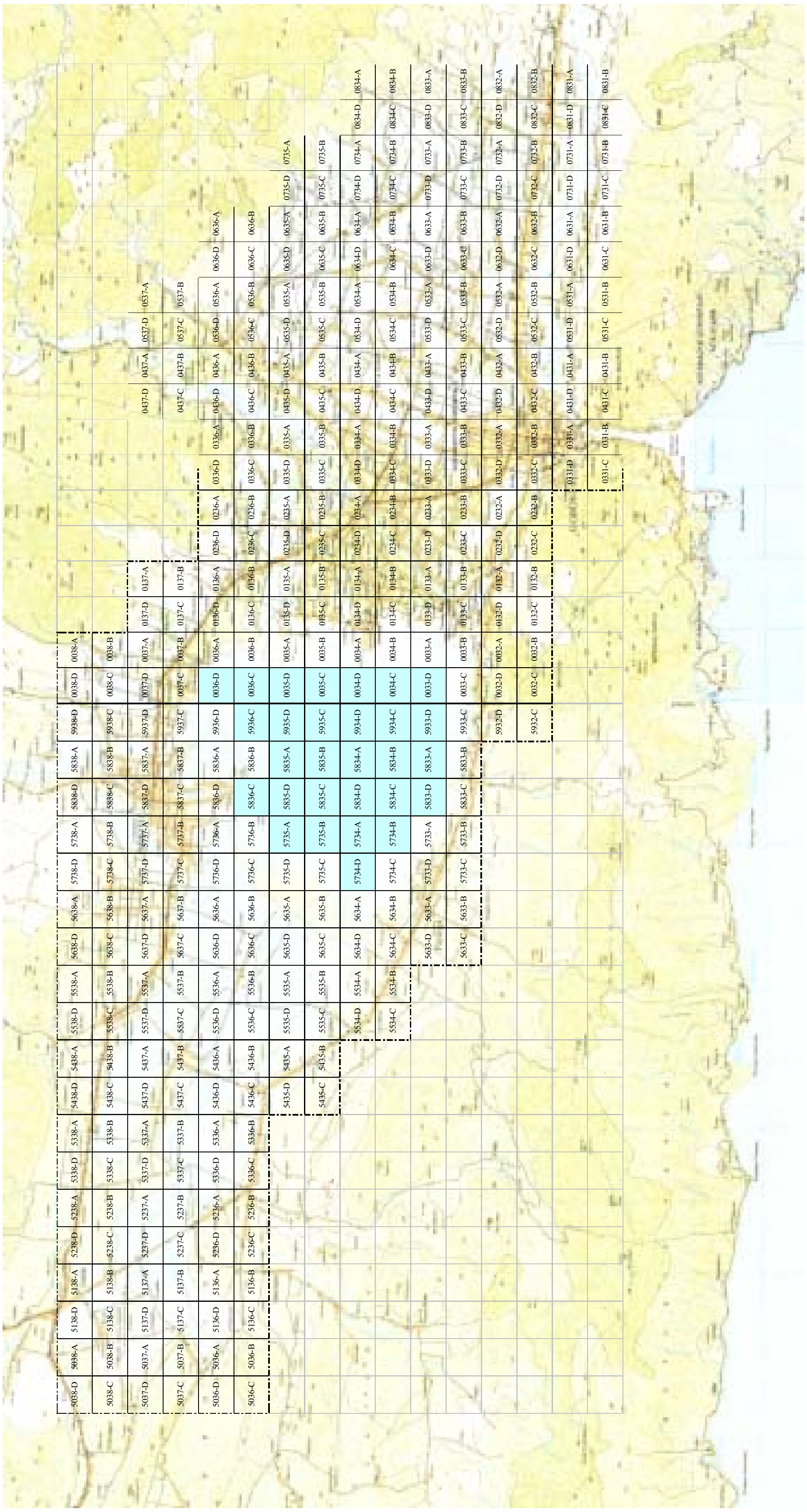
**Figure B2.2.6**

**PROCEDURES OF FLOOD FLOW ANALYSIS**




| | |
|---|---|
| ***The Study on Flood Control and Water Management in Limboto-Bolango-Bone Basin in the Republic of Indonesia*** | **Figure B2.2.7 CONCEPTUAL STRUCTURE OF FLOOD FLOW SIMULATION MODEL** |
| ***Japan International Cooperation Agency*** | |



| *The Study on Flood Control and Water Management in Limboto-Bolango-Bone Basin in the Republic of Indonesia* | **Figure B2.2.8** |
| --- | --- |
| ***Japan International Cooperation Agency*** | **BASIN MODEL OF FLOOD ANALYSES** |

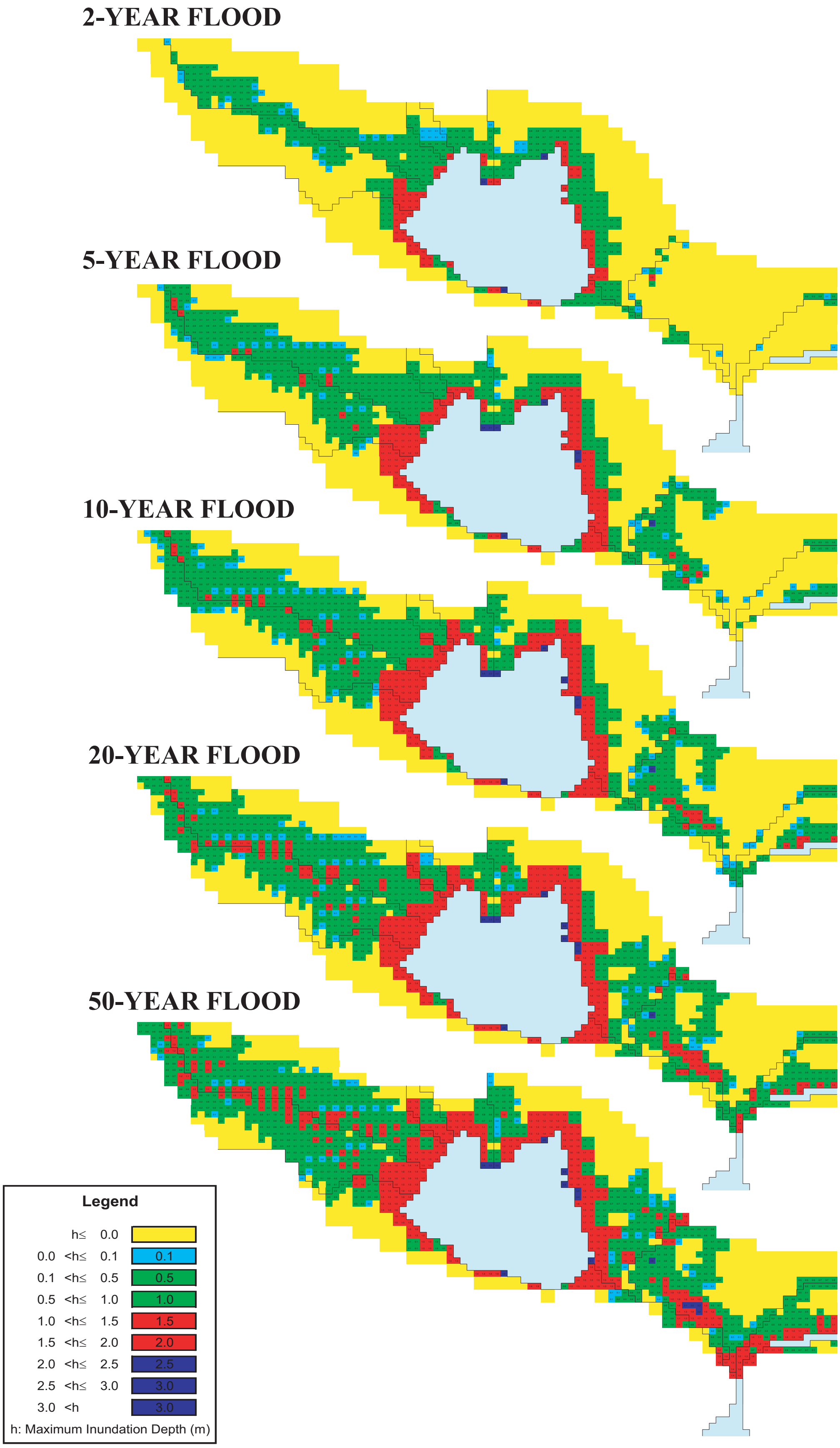



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**Figure B2.2.9**

**RESULT OF FLOOD FLOW ANALYSIS**

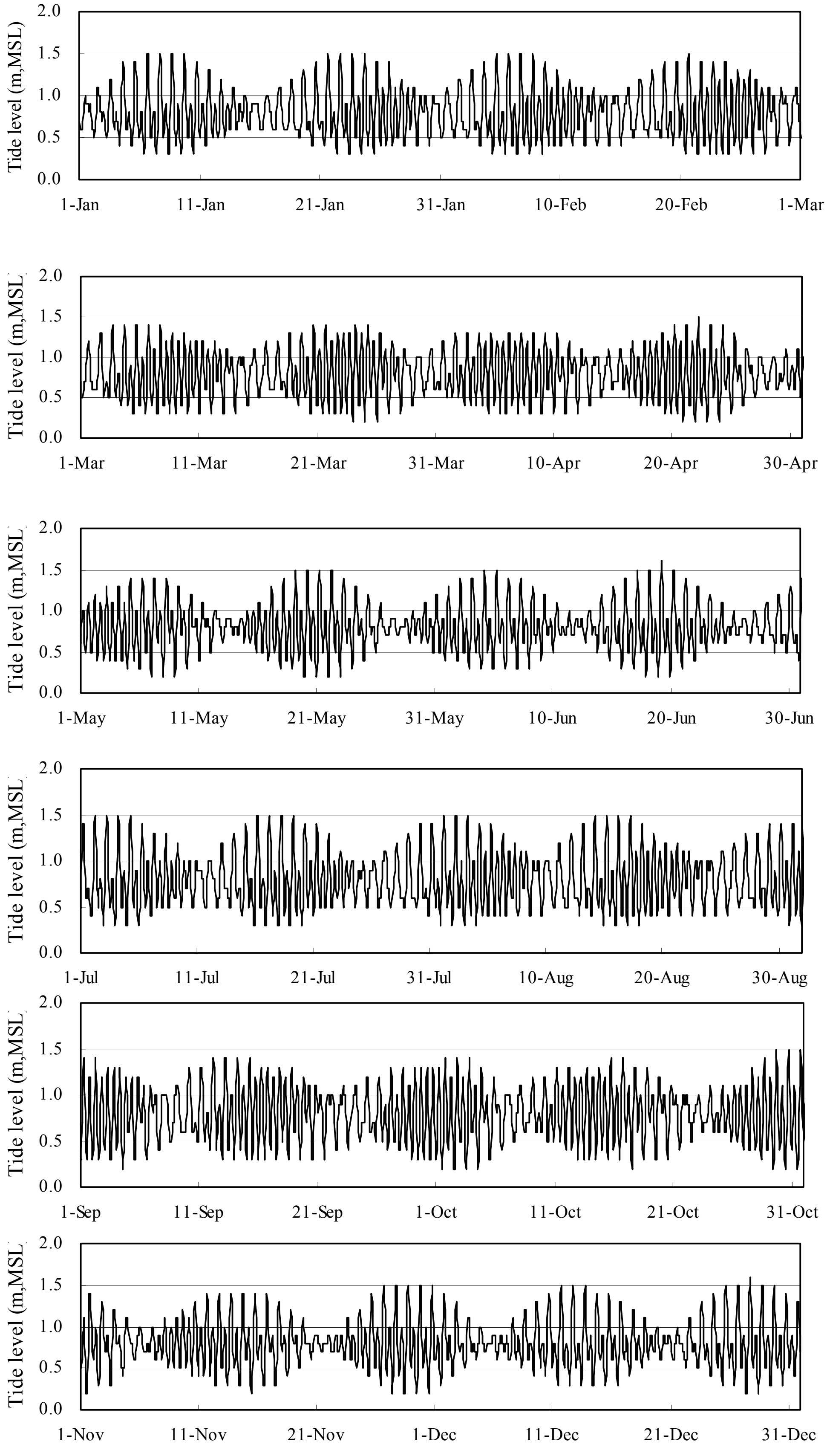


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**Figure B2.3.1**
**ESTIMATED TIDE LEVEL AT GORONTALO IN 2001**

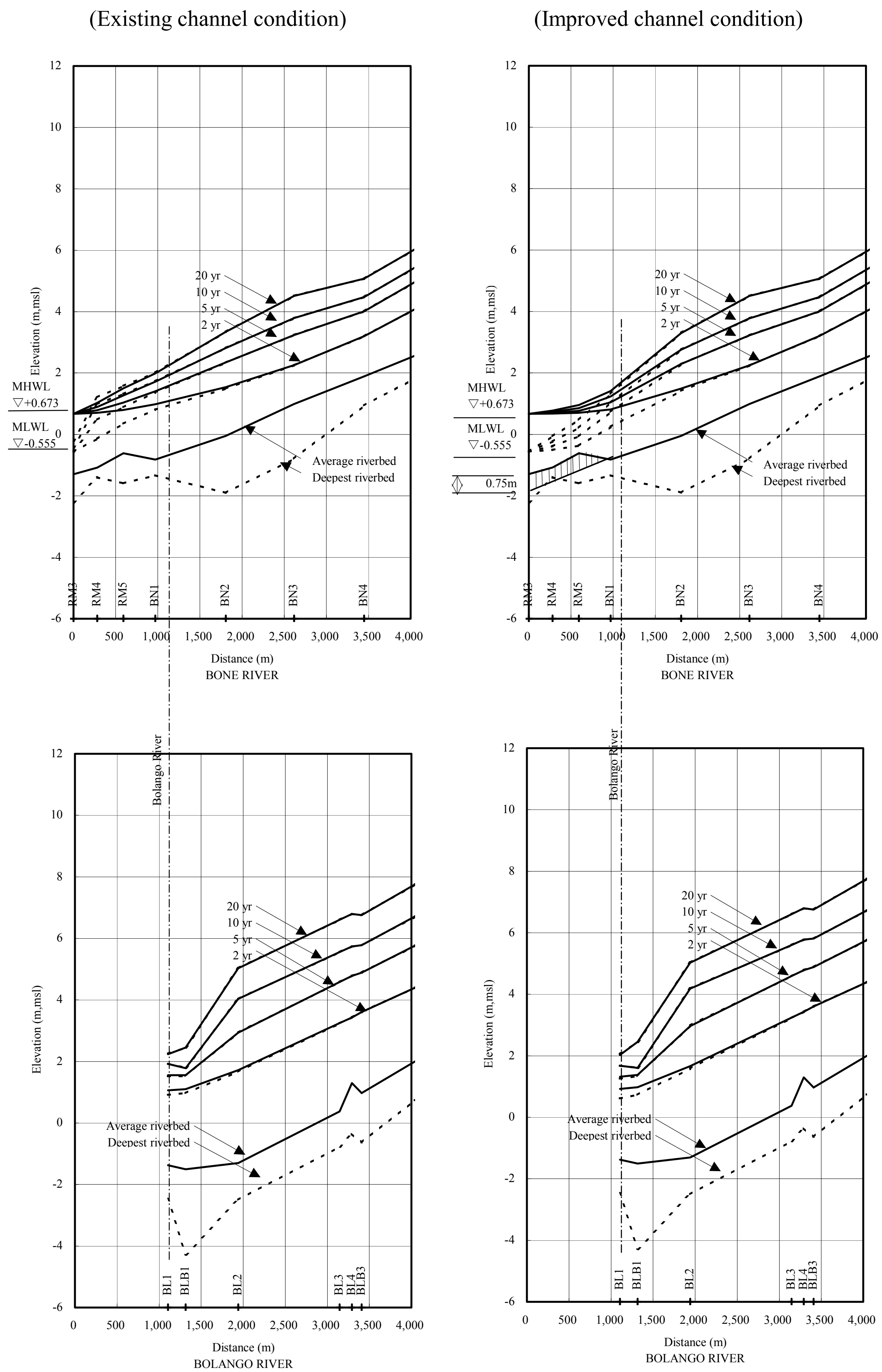



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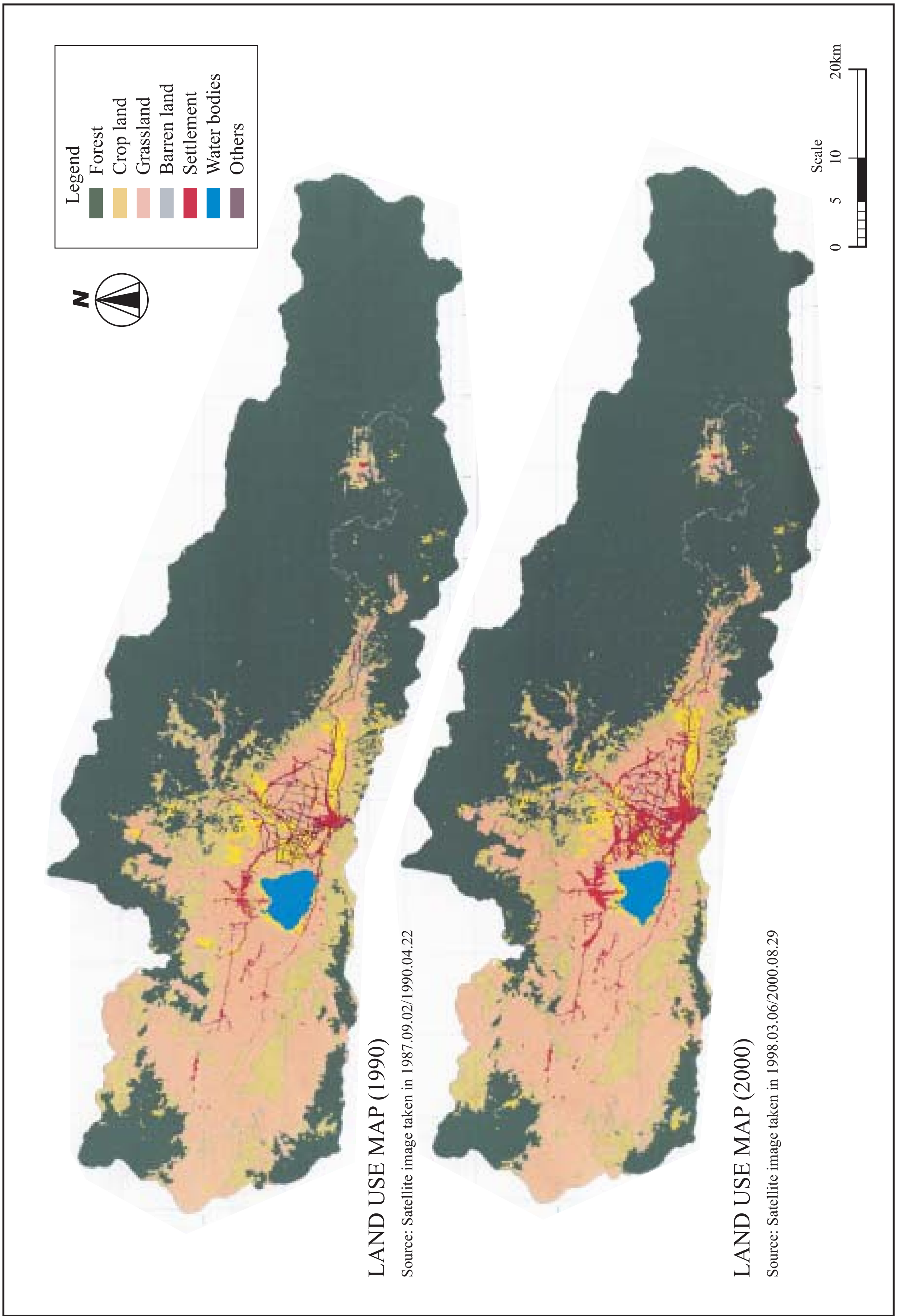
**Figure B2.3.2**

**EXTENT OF TIDAL INFLUENCE**




| | |
|---|---|
| ***The Study on Flood Control and Water Management in Limboto-Bolango-Bone Basin in the Republic of Indonesia*** | **Figure B2.4.1** |
| ***Japan International Cooperation Agency*** | **LAND USE MAP** |

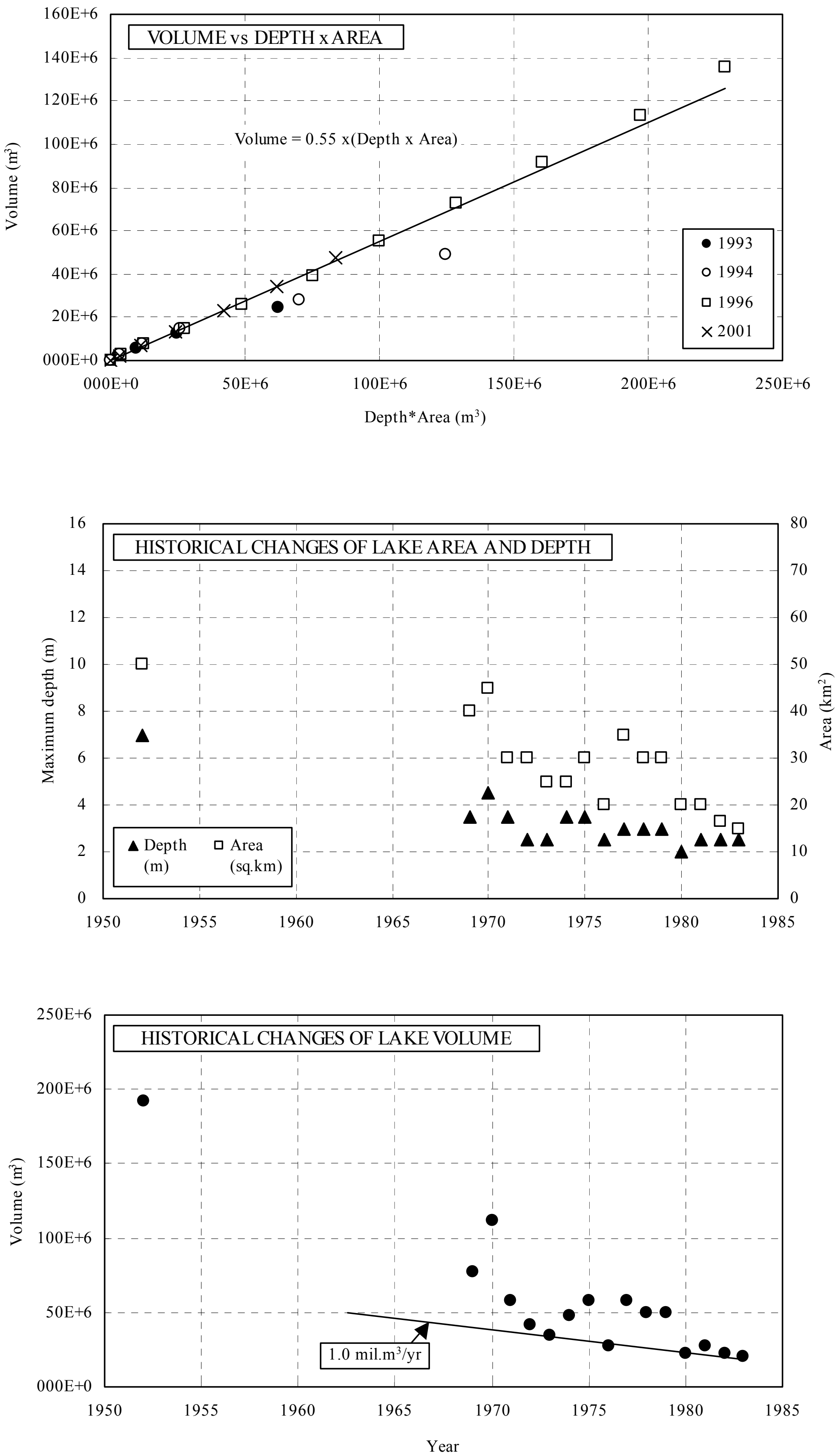
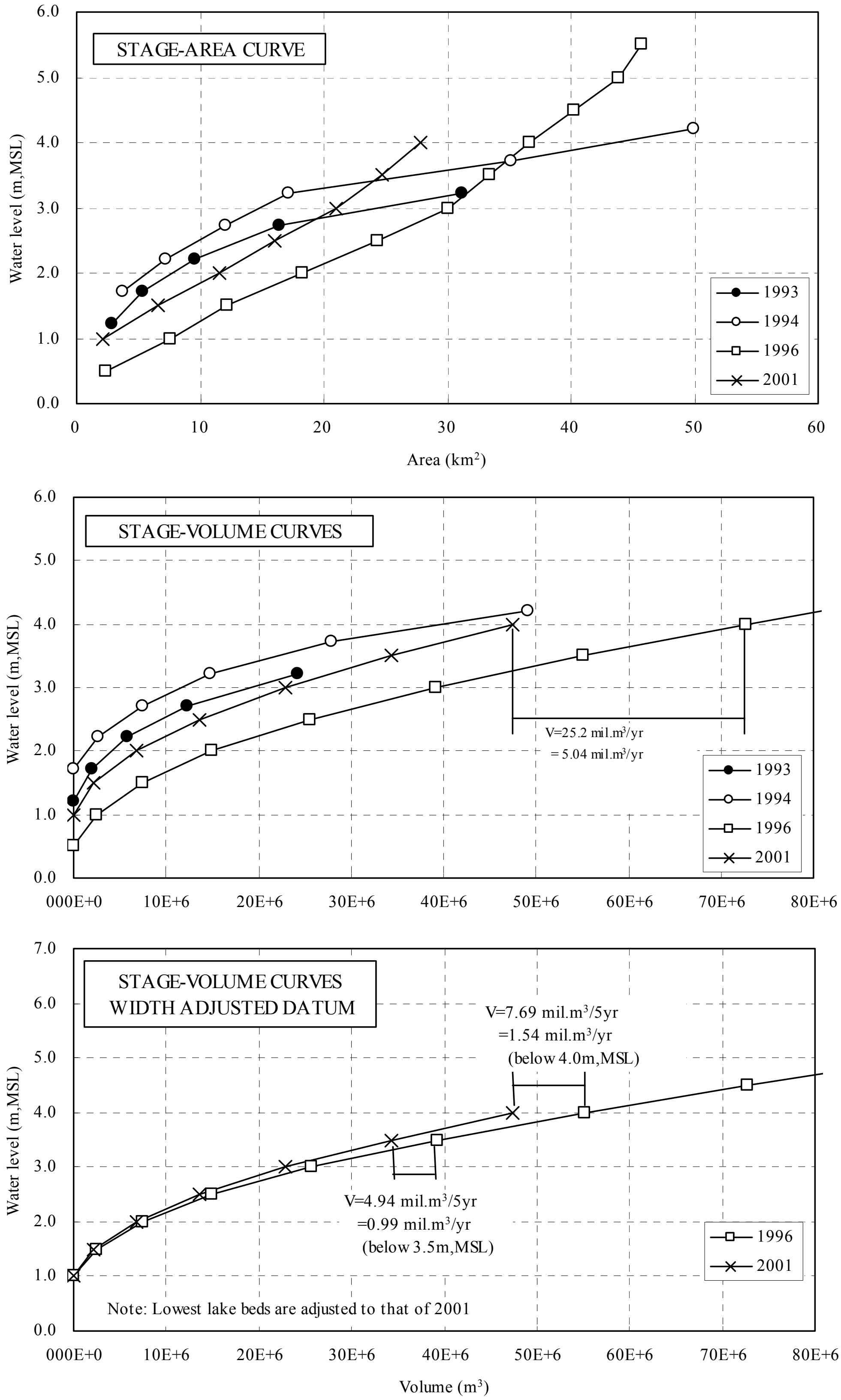
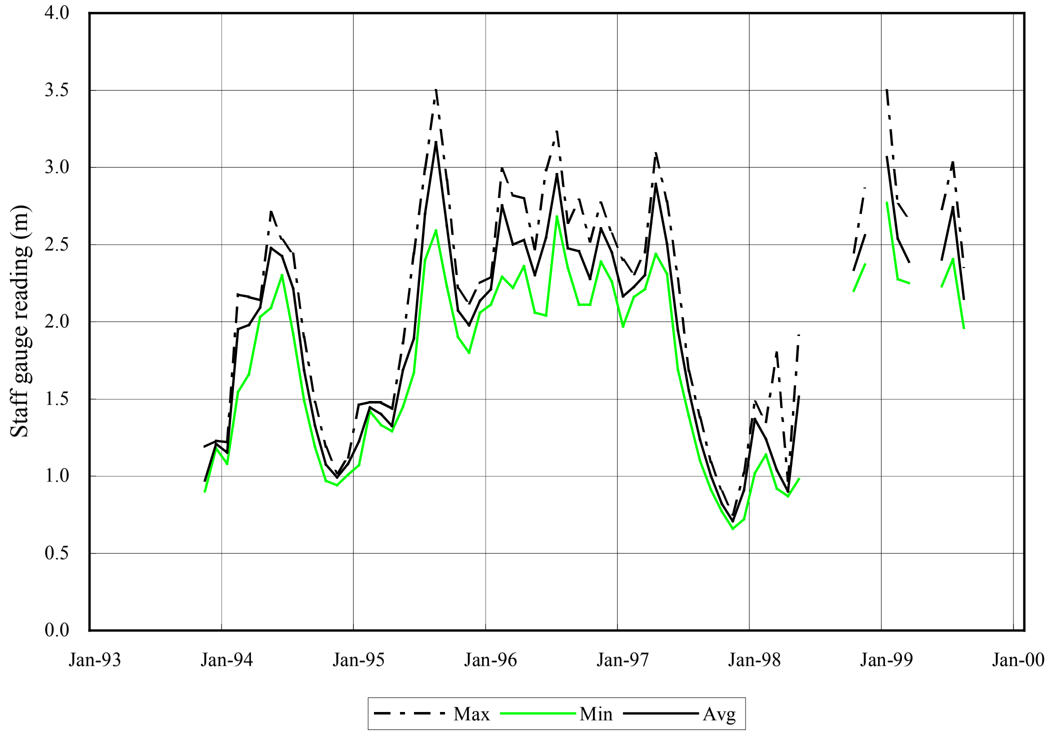





**Figure B2.4.2**
**ESTIMATION OF HISTORICAL LAKE VOLUME**




| | |
|---|---|
| ***The Study on Flood Control and Water Management in Limboto-Bolango-Bone Basin in the Republic of Indonesia*** <br> ***Japan International Cooperation Agency*** | **Figure B2.4.3** <br> **ESTIMATION OF LAKE SEDIMENTATION** |




WL(m,MSL) = (Staff gauge reading) + 1.99m

Water Level of Lake Limboto

| Year | Max. (m,MSL) | Min. (m,MSL) | Average (m,MSL) |
|---|---|---|---|
| 1988 | 5.3 | - | - |
| 1989 | 4.8 | - | - |
| 1990 | 4.2 | - | - |
| 1991 | 4.2 | - | - |
| 1992 | 3.7 | - | - |
| 1993 | 3.2 | 2.9 | 3.0 |
| 1994 | 4.7 | 2.9 | 3.7 |
| 1995 | 5.5 | 3.1 | 4.0 |
| 1996 | 5.2 | 4.0 | 4.5 |
| 1997 | 5.1 | 2.7 | 3.7 |
| 1998 | 4.9 | 2.9 | 3.6 |
| 1999 (upto Aug.) | 5.5 | 4.0 | 4.5 |

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**Figure B2.5.1**
**WATER LEVEL RECORDS OF LAKE LIMBOTO**