JAPAN INTERNATIONAL COOPERATION AGENCY
THE GOVERNMENT OF THE REPUBLIC OF INDONESIA

THE STUDY ON FLOOD CONTROL AND WATER MANAGEMENT IN LIMBOTO-BOLANGO-BONE BASIN IN THE REPUBLIC OF INDONESIA

FINAL REPORT

VOLUME-V SUPPORTING REPORT: PART-C

FEASIBILITY STUDY FOR PRIORITY PROJECTS

DECEMBER 2002

NIKKEN CONSULTANTS, INC.
AND
NIPPON KOEI CO., LTD.

THE STUDY ON FLOOD CONTROL AND WATER MANAGEMENT
IN
LIMBOTO-BOLANGO-BONE BASIN

FINAL REPORT

LIST OF REPORTS

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GLOSSARY

(ENGLISH ABBREVIATION)

ADB	Badan Pembangunan Asia	Asian Development Bank
ASTM		American Standards for Testing Materials
BCR, B/C	Rasio Harga dan Keuntungan	Benefit Cost Ratio
BOD		Biochemical Oxygen Demand
CEA	Badan Pelaksana Kanada	Canadian Executing Agency
CIDA	Badan Penyandang Dana Kanada	Canadian International Development Agency
COD		Chemical Oxygen Demand
DD, D/D	Disain Teknis/Rencana Teknis	Detailed Design
DGWR	Direktorat Jenderal Sumber Daya Air	Directorate General of Water Resources
DGWRD	Direktorat Jenderal Pengairan	Dir. General of Water Resources Development
DO		Dissolved Oxygen
EIA	Analisa/Penelitian Lingkungan	Environmental Impact Assessment
EIRR	Tingkat Pengembalian Modal Internal Ekonomi	Economic Internal Rate of Return
FAO	Organisasi Pangan Dunia	Food and Agriculture Organization of the United Nations.
FS, F/S	Studi Kelayakan	Feasibility Study
FY	Tahun Anggaran	Fiscal Year
GDP	Produk Domestik Bruto	Gross Domestic Product
GIS	Sistem Informasi Geografi	Geographical Information System
GOI	Pemerintah Indonesia	Government of Indonesia
GPS	Penentuan Posisi Global	Global Positioning System
GRDP	Produk Domestik regional Bruto	Gross Regional Domestic Product
IBRD	Bank Dunia	International Bank for Reconstruction and Development (World Bank)
IEE		Initial Environmental Examination

JBIC		Japan Bank for International Cooperation (Former OECF)
JICA		Japan International Cooperation Agency
LAN	Jaringan Komputer Lokal	Local Area Network (Computer)
MCM	Juta Meter Kubik	Million Cubic Meters
MP, M/P	Rencana Induk	Master Plan
MSL	Tinggi Muka Air Laut Rata-rata	Mean Sea Level
NGO	Lembaga Swadaya Masyarakat	Non-Governmental Organization
NPV	Nilai Sekarang Neto	Net Present Value
O&M	Operasi dan Pemeliharaan	Operations and Maintenance
OECF	Badan Penyandang Dana Jepang	Overseas Economic Cooperation Fund (Japan), Now reorganized JBIC
OJT	Latihan di Lapangan	On-the-Job Training
PCM	Pertemuan Konsultasi Masyarakat	Public Consultation Meeting
R	Sungai	River
S/W		Scope of Works
TIU	Unit Pelaksana Teknis Dinas	Technical Implementation Unit
UNESCO	Badan Pendidikan, Ilmu Pengetahuan dan Kebudayaan, P.B.B	United Nations Educational, Scientific, and Cultural Organization
USAID	Badan Penyandang Dana Amerika Serikat	United States Agency for International Development
VAT		Value Added Tax
WATSAL	Wanita dalam Pembangunan	Water Sector Adjustment Loan
WID	Pengembangan Sumber Daya Air	Women in Development
WUA	Federasi Petani Pemakai Air	Water Users Association

(INDONESIAN ABBREVIATION)

AMDAL	Analisis mengenai Dampak Lingkungan	Environmental Impact Analysis
ANDAL	Analisis Dampak Lingkingan	Environment Impact Statement
APBD	Anggaran Pendapatan dan Belanja Daerah	Regional Income and Expenditure
APBN	Anggaran Pendapatan dan Belanja Nasional	National Income and Expenditure
Ass.	Asisten	Assistant
BAKORNAS PBP	Badan Koordinasi Nasional Penanggulangan Bencana dan Penanganan Pengungsian	National Coordination Board of Disaster and Evacuation
BAPEDAL	Badan Pengendali Dampak Lingkungan	Environmental Impact Management Board
BAPEDALDA	Badan Pengendali Dampak Lingkungan Daerah	Regional Environmental Impact Management Agency
Bappeda	Badan Perencanaan Pembangunan Daerah	Provincial Development Planning Board
Bappenas	Badan Perencanaan Pembangunan National	National Development Planning Board
Binlak	Pembinaan & Pelaksanaan	Construction Management
BMG	Badan Meteorologi dan Geofisika	Meteorological and Geophysical Institute
BPS	Badan Pusat Statistik	National Statistics Office
Bupati	Kepala Daerah Tingkat II/Kabupaten	Head of District (Regency)
CD, Cabdin	Cabang Dinas	Branch of Dinas
DATI I	Daerah Tingkat I	Regional Level I (Province)
DATI II	Daerah Tingkat II	Regional Level II (District)
DI	Daerah Irigasi	Irrigation Schemes
DinasPU, DPU	Dinas Pekerjaan Umum	Public Works Services
DIP	Daftar Isian Proyek	List of Project Budget
DPR	Dewan Perwakilan Rakyat	National Parliament
DPRD	Dewan Perwakilan Rakyat Daerah	Regional Parliament
DPU	Departemen Pekerjaan Umum	Ministry of Public Works

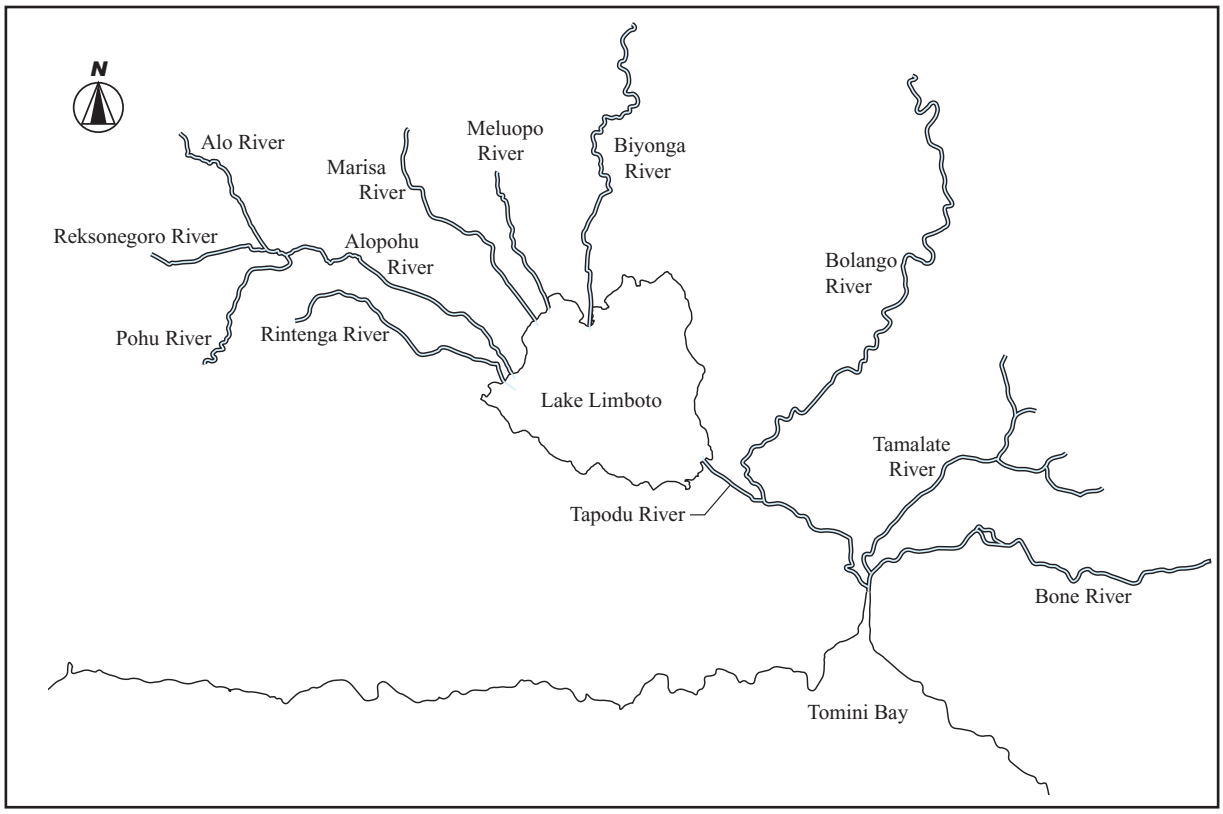
DPUP	Dinas Pekerjaan Umum Propinsi	Provincial Public Works Services
DTP	Dinas Tanaman Pangan	Office of Food Crops
Kanwil	Kantor Wilayah	Regional Office (of a Department)
Kaur	Kepala Urusan	Head of Sub Section
KDH	Kepala Daerah	Head of Regional Government
KDPP	Kepala Daerah Pengamatan Pengairan	Head of Water Resources Sub District
Kepmen	Keputusan Menteri	Minister's Decree
Keppres	Keputusan Presiden	Presidential Decree
KIMPRASWIL	Departemen Permukiman dan Prasarana Wilayah	Ministry of Settlement and Regional Infrastructure (MSRI)
KSDP	Kepala Sub Dinas Pengairan	Head of Provincial Water Resources Service
KTL	Kegiatan Tindak Lanjut	Follow-up Activity
KUD	Koperasi Unit Desa	Village Cooperative Unit
LBB	Limboto-Bolango-Bone	Limboto-Bolango-Bone
LSM	Lembaga Swadaya Masyarakat	Non-Governmental Organization
MONEV	Monitoring & Evaluasi	Monitoring & Evaluation
O&P	Operasi dan Pemeliharaan	Operations and Maintenance
P3A	Perkumpulan Petani Pemakai Air	Water Users' Association (WUA)
P3SU	Proyek Pembinaan Pengairan Sulawesi Utara	North Sulawesi Water Resources Institutional Development Project
PDAM	Perusahaan Daerah Air Minum	Regional Water Company
PDSA	Pengumpulan Data Sumber Air	Water Resources Data Collection
PEMDA	Pemerintah Daerah	Regional Government
PERDA	Peraturan Daerah	Regional Regulation
Pimpro	Pemimpin Proyek	Project Manager
Pinbagpro	Pemimpin Bagian Proyek	Sub Project Manager
PJP	Program Jangka Panjang	Long Term National Dev. Program
PLN	Perusahaan Listrik Negara	State Electricity Company
PPTPA	Panitia Pelaksanaan Tata Pengaturan Air	Basin Water Management Committee

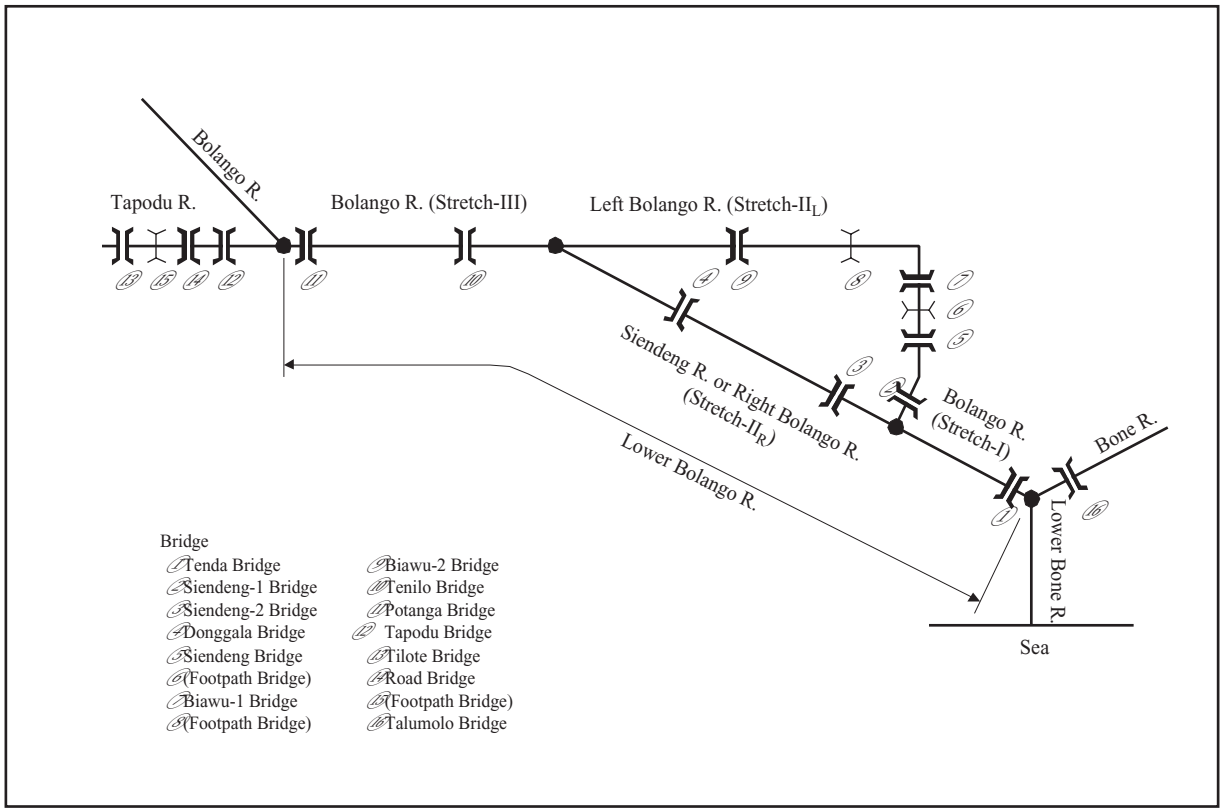
PSDA	Pengamanan Sumber Daya Air	Water Resources Conservation
PTPA	Panitia Tata Pengaturan Air	Provincial Water Resources Committee
PU	Pekerjaan Umum	Public Works
Puslitbang	Pusat Penelitian dan Pengembangan Pengairan PU	Institute of Hydraulic Engineering Center (Bandung)
PWS	Pengembangan Wilayah Sungai	River Basin Development
RKL	Rencana Pengelolaan Lingkungan	Environmental Management Plan
RPL	Rencana Pemantauan Lingkungan	Environmental Monitoring Plan
SATKORLAK PBP	Satuan Koordinasi Pelaksanaan Penanggulangan Bencana dan Penanganan Pengungsian	Implementation Coordination Unit of Disaster Mitigation and Evacuation
SATLAK PBP	Satuan Pelaksanaan Penanggulangan Bencana dan Penanganan Pengungsian	Implementation Unit of Disaster Mitigation and Evacuation
SDA	Sumber Daya Air	Water Resources
Sulut	Sulawesi Utara	North Sulawesi
Tkt. I	Tingkat I	Level I Administration (Province)
Tkt. II	Tingkat II	Level II Administration (Region)
UNSRAT	Universitas Sam Ratulangi	Sam Ratulangi University
UPTD	Unit Pelaksana Teknis Dinas	Technical Implementation Unit

(SOME INDONESIAN WORDS)

Desa	Village (rural area), The Lowest Administrative Unit, Headed by Kepala Desa or Kades who is elected by the residents
Kabupaten, Kab.	Administrative District Headed by Bupati (regency)
Kecamatan, Kec.	Administrative Sub District within the Kabupaten
Kelurahan	Village (urban area), The Lowest Administrative Unit, Headed by Lurah who is Appointed
Kota	Municipality, Administrative District Headed by the Walikotamadya
Kotamadya	Municipality, Administrative District Headed by the Walikotamadya
Propinsi	Province
Ribu	thousand = 1,000
Juta	million = 1,000,000
Milyar	billion =1,000,000,000
Trilyun	trillion = 1,000,000,000,000

NAME OF RIVER





C1. INTRODUCTION

C1.1 Flood and Sediment Disasters

Suffering Areas: Major areas suffering from flood and sediment disasters in the Study Area are southern part of Gorontalo City, middle reaches of the Bolango River, Limboto area, Isim-Pohu area, and western area of Lake Limboto. Among these, problems are more serious in the southern part of Gorontalo City near the confluence of the Bolango and Bone rivers.

Roles of Flood Mitigation: Per capita GRDP of the Study Area is far low comparing with the national average. Flood mitigation is one of the important infrastructures to support sound economic development of the basin and to stabilize people's livelihood, accordingly to alleviate poverty of the region.

C1.2 Flood Mitigation Master Plan

Objective of Master Plan: The Flood Mitigation Master Plan (FM-MP) aims to direct or guide the flood mitigation activities that will be conducted by various agencies and organizations concerned.

Scope: The FM-MP shall cover structural and non-structural measures. The structural measures discussed in the master plan are limited to primary facilities to mitigate flood and sediment damages of the area, and the secondary facilities to be connected to the primary facilities are not included in principle.

Target Year: In line with the phasing of National Five-Year Plan, target year of the FM-MP was set at the end of Tenth Five-Year Plan in 2019. The target year is the year by which proposed works are to be accomplished.

Design Scale: Facilities for the FM-MP are planned and designed based on 20-year flood.

Component Works of FM-MP: The FM-MP is composed of following four (4) major component works as shown in Figure C1.1.1.

1) Bolango-Bone River System:
   - River improvement: Bone, Bolango and lower Tamalate rivers
   - Tamalate floodway

2) Lake Limboto System:
   - River improvement: Biyonga, Meluopo, Marisa, Alo-Pohu and Rintenga rivers
   - Lake Limboto management (including Tapodu River improvement with Tapodu Gate)

3) Watershed Management: To encourage;
   - Construction of erosion control facilities,
   - Afforestation and land use control, and
   - Dissemination activities.

4) Flood Plain Management: To promote and guide for the community people to take activities for;
   - Mobilization,
   - Flood forecasting, warning and evacuation
   - Flood fighting
   - Community-based flood mitigation measures.

Implementation of Master Plan: The Flood Mitigation Master Plan (FM-MP) is proposed for implementation by the target year of 2019. The project works must be carried out effectively in orderly manner toward the target year. It is also important to realize the flood mitigation effects as early as possible in the course of implementation corresponding to the progress of work. In view of these, the FM-MP is proposed to be implemented stage-wise as follows:

1) Preparatory stage : Until end of 2004
2) Intensive implementation stage : From beginning of 2005 to end of 2009
3) Sustainable implementation stage : From beginning of 2010 to end of 2019

C1.3 Selection of Priority Project

Intensive Implementation: During the period of the Eighth National Five-Year Plan from 2005 to2009, actual construction works at site and activities for watershed

management and flood plain management will be implemented intensively. The projects to be implemented in this stage must be the basic facilities and activities for flood mitigation and the priority ones expected to yield higher outcome. Through the intensive implementation, it is expected the flood mitigation activities in the basin will be stimulated and related personnel and administration will be trained and adjusted toward effective implementation of the project.

Selection of Priority Project: The Priority Projects for the intensive implementation were selected considering:

1) Urgency of implementation,
2) Important facilities and areas to be protected,
3) Site in more critical conditions,
4) Magnitude of favorable social impacts, and
5) Engineering sequence of implementation.

Priority Projects Selected: The Priority Projects selected include structural measures and non-structural measures as shown in Figure C1.3.1. The structural measures selected for the intensive implementation are:

1) Lower Bone River Improvement
2) Lower Bolango River Improvement
3) Tapodu River Improvement with Tapodu Gate
4) Tamalate Floodway
5) Sediment Trap Works in Lake Limboto

In parallel with the structural measures, non-structural measures such as watershed management and flood plain management progress will be implemented within a framework of the intensive implementation as follows:

1) Watershed management by encouraging activities such as construction of erosion control facilities, afforestation and land use control, and publicity activities in the watershed areas in coordination with the Department of Forest and Plantation.
2) Flood plain management by encouraging and promoting Local Coping Measures and Community-based Sustainable Measures to be taken by the community people in the flood plain areas.

Roles of Priority Projects: The Priority Projects are expected to play vital roles for the flood mitigation of the LBB basin as follows:

1) Flood mitigation in the urban area of Gorontalo City will be secured,
2) Water level of Lake Limboto will be controlled and the drainage of retained water will be improved,
3) Sedimentation problems of Lake Limboto will be alleviated, and
4) Flood proofing and preparedness to floods in the flood-prone area will be promoted.

Sub-projects for Feasibility Study: The Feasibility Study is to be conducted for the structural measures selected as the Priority Projects. The structural measures are further rearranged as following three projects each of which has common functions and benefits mutually related:

1) Bone-Bolango-Tapodu (BBT) River Improvement Project, which consists of improvement of the lower Bone, lower Bolango and Tapodu rivers with Tapodu Gate.
2) Tamalate Floodway Project
3) Sediment Trap Works in Lake Limboto

C2. SUPPLEMENTARY SURVEYS AND REVIEW OF MASTER PLAN

C2.1 Supplementary Surveys and Investigations

Supplementary data for the Feasibility Study of the priority project(s) were collected and analyzed at the inceptive period of the Feasibility Study. Detailed field reconnaissance was also made in the selected project areas.

In parallel to the data collection and field reconnaissance, the following supplementary field surveys and investigations were carried out:

1) River Survey and Topographic Mapping
2) Geological Investigation
3) Investigation for Environmental Impact Assessment (EIA)

The Indonesian contractor implemented the surveys and investigation under sublet contract with the Study Team.

(1) River Survey and Topographic Mapping

For the purpose of preliminary facility design on the Feasibility Study level, detailed river survey of the proposed rivers and facility sites were carried out. Topographic survey and topographic mapping based on the existing aerial photos were also conducted for the proposed rivers and facility sites as follows:

1) River Survey:
   - Lower Bone River: 1.5 km
   - Lower Bolango River: 6.5 km
   - Tapodu River: 2.5 km
   - Alo-Pohu and Biyonga rivers in relation with sediment trap works: 3.0 km
   - Tamalate and middle Bone rivers in relation with Tamalate Floodway: 2.0 km
2) Topographic survey of proposed site for Tamalate Floodway: 2.0 km^2 with scale of 1/5,000
3) Topographic mapping of proposed river improvement sites: 9.5 km^2 with scale of 1/5,000

Location map for the river and topographic mapping is shown in Figure C2.1.1.

(2) Geological Investigation

For the foundation treatment of major structures for the selected Priority Projects and to obtain physical properties as construction materials, geological investigation of subsurface layers by core boring and laboratory soil tests were conducted as follows:

1) Core drilling with standard penetration test at the following proposed sites:
   - Tapodu Gate site: 15 m x 5 holes = 75 m
   - River work sites: 15 m x 3 holes = 45 m
   - Diversion facilities for Tamalate Floodway: 15 m x 3 holes = 45 m
   - Estuary of Bone River: 5 m x 10 holes = 50 m
2) Laboratory tests of earth core materials:
   - Grain size analysis
   - Physical property tests for dike embankment and concrete aggregates.

Location of the Geological investigation is shown in Figure C2.1.2.

(3) Investigation for Environmental Impact Assessment (EIA)

The main objective of the EIA Study is to examine and evaluate the conceivable impacts on both natural and social environment to be affected by the Priority Projects subject to the Feasibility Study. The objective also includes the recommendation on necessary countermeasures to make the Projects environmentally sound and sustainable. The main components of the EIA Study are:

1) To prepare KA-ANDAL (TOR of the EIA Study) for the Projects;
2) To grasp the existing environmental conditions in and around the Project sites by data collection and its analysis focusing on natural and social environments;
3) To identity, predict and evaluate the conceivable environmental impacts brought about by the Project implementation;
4) To develop and recommend the mitigation measures, and environmental management plan (RKL) and monitoring plan (RPL):
5) To prepare ANDAL (EIA report) for the Projects; and
6) To support the dissemination and the approval of KA-ANDAL and ANDAL to and/or from the AMDAL Commission (EIA Appraisal committee) and other

relevant organizations and local community.

C2.2 Toheti-Dahua Multi-purpose Dam

Toheti-Dahua flood control dam scheme was studied as an alternative measure in comparison with channel improvement works of the Bolango River. The dam scheme was not adopted as a component of the Flood Mitigation Master Plan of the LBB basin mainly due to economic viability. However, this does not mean to deny the dam with multi-purpose function.

Considering the water demands in the middle Bolango river basin and the water supply further to western Limboto areas where suffer from shortage of water resources, Toheti-Dahua multi-purpose dam would be required by the water user in the basin. And once the dam was constructed, the dam reservoir functions much for flood mitigation in the middle and lower basins of the Bolango River including the city of Gorontalo. According to results of site reconnaissance and geological investigation by the Study Team, the site of Toheti-Dahua dam is recognized to be suitable geologically and topographically to dam site.

Construction of the dam, however, required big cost and give favorable and unfavorable impacts to the surrounding nature and society. Careful studies are therefore required for the plan and design of the dam. In view of these, investigation and study items required for the planning and design of Toheti-Dahua multi-purpose dam are discussed here.

The study of multipurpose dam includes the following steps of works in general:

1) Basic investigation
2) Feasibility study
3) Definite plan study

Study items are described in the following sub-sections. Data available for the study and planning Toheti-Dahua multipurpose dam are very few for all the items, among others shortage of hydrological data is a serious problem. Unlike other date hydrological record can be made available only by persevering long period observation activities.

For a reliable planning of water resources development, it is generally said that 20 years of records are at least necessary. Intensive studies on the rainfall and runoff characteristics would be necessary covering broader area of similar hydro-meteorological conditions, using all the observation records available in the area.

(1) Basic Investigation

Basic investigation aims to collect basic data and information on the basin, hydrology and socio-economy; and to clarify hydrological conditions of the basin and the river. The investigation includes the following items:

1) Socio-economic indices: Current and future population, economic activities, land use, water demand, regional development plan, etc.
2) Development projects data: Projects for irrigation, water supply, hydro-power generation, river improvement and sediment control (Sabo), highway, tourism, etc.
3) Hydrological and hydraulic data: Hydro-meteorological records such as temperature, humidity, rainfall, discharge, water quality; water use and water right data for irrigation, water supply, power generation; existing river improvement plan and flood analysis data; sediment data including reservoir sedimentation records in the similar basin.
4) Topographic data: Topographic maps and aerial photographs of various scales as available.
5) Geological data: Basin-wide geological map, and geological investigation data in the past.
6) Water related disaster data: Disaster reports and statistics, location maps, photos, etc. of the past disasters due to sediment, flood and draught.
7) Data relevant to land acquisition and compensation.

(2) Feasibility Study

Specific studies and investigations for the candidate dam site are carried out to examine the feasibility of the plan mainly from the technical, economic, financial, social and environmental aspects. Although the scope of the study depends on the expected functions o the dam, the study in this step covers the surveys, investigations and studies presented in the following paragraphs.

Survey of Reservoir Area: The first work to do is to prepare reservoir plan of scale 1/1,000 to 1/2,500. The plan is used for preparing depth-area-volume curve of the reservoir and for planning land acquisition/compensation in the reservoir area and construction works of the dam.

Survey of Dam Site: As a result of survey topographic map of dam site and cross section along dam axis are prepared.

Geological Investigation of Dam Site: After site reconnaissance by the geologist the geological investigation program is prepared mainly for physical investigation and test boring. Based on the investigation results, geological maps and geological profiles are prepared in order to examine the possibility as dam site.

Investigation of Quarry Sites: For the study on the type and size of dam, quarry sites are investigated for their quality and quantity.

Hydrological and Hydraulic Study: Accuracy of hydrological study is directly reflected to reliability of available water resources to be managed by the dam. The study must be carried out carefully based on the hydrological data in the basin, supplementing, correlating and cross-checking with the data of adjacent basins.

Investigation of Watershed: Amount of sediment from the upper watershed is an important factor to determine the dead storage volume of the reservoir. In case that high sediment yield is supposed, careful study is required on the reservoir sedimentation and influence to the riverbed changes in the downstream reaches.

Survey for Land Acquisition and Compensation: The survey covers (1) general assets such as houses and lands to be affected; (2) rights and concession for such as mining, fishery, etc.; and (3) public facilities such as public building, road etc.

Review of Relevant Projects: Ongoing and proposed projects for such as irrigation, water supply, hydropower generation, flood control, etc. should be reviewed and adjusted so as not to infringe nor duplicate with them, and so as to foster their functions mutually.

Economic Evaluation: Economic viability is an important decision-making factor for implementation of the dam, since the dam project require a large amount of cost and the

project benefit accrues when all the cost is invested. For the multipurpose dam, project cost is allocated to respective component projects and they are compared with corresponding benefits respectively and for whole project.

Environmental Impact Assessment: Impact due to construction of the dam should be examined from natural, social and cultural/historical environment viewpoints. The assessment is in general carried out from initial environmental examination (IEE) to screen the environmental element and to scope the further study. Then environmental impact assessment (EIA) is carried out on the important elements. As a result of EIA, mitigation measures are proposed and a environmental management plan and a environmental monitoring plan are prepared. Prior to the project implementation, the EIA must be appraised and approved by relevant agencies.

(3) Definite Plan Study

Definite plan study is the intensive study to consolidate the multipurpose dam plan prior to the construction design. The study may include preliminary survey of land and houses to be acquired/compensated, full-scale geological investigation, preliminary project cost estimate and its allocation to relevant stakeholders.

C2.3 Study on Lower Bone-Bolango River

C2.3.1 Existing River Facilities

Existing river facilities includes dikes, bank protection works, drainage culverts, and other river-crossing facilities as follows:

1) Dikes: Earth dike and flood wall made of concrete, to prevent floodwater from spilling over the lands
2) Bank protection work: Gabion (or Bronjong) and masonry works, to protect riverbank slopes of low-water channel from erosion due to river flows.
3) Drainage culvert: Culvert constructed across the dike, to drain inland excess water to the river and to check river water flowing into the land during the period of high river water.
4) River crossing facilities: Bridges, cables, etc., which may affect or be affected by the flood flows and river improvement works.

Since these facilities were constructed by various agencies of Gorontalo and North Sulawesi provinces, Kabupaten Gorontalo, and Kota Gorontalo, even the provincial government does not always has clear grasp of the conditions of the existing river facilities. Inventory of these facilities were not available yet. Therefore, the Study Team carried out field investigation on the existing facilities and temporary inventory on the field data basis were prepared.

Figure C2.3.1 show the approximate locations of existing river facilities. According to the Figure, distribution of the existing river facilities is outlined as follows:

1) In the stretch of the Bolango River from the confluence of the Bone River to the confluence of the left and right Bolango rivers (Stretch-I), gabion works are found only on the left bank near the upper end of the stretch, and concrete flood walls are provided only on the left bank near the lower end.
2) In the left Bolango River (Stretch-II_L), existing river facilities are sporadic sandwiched by private and public buildings as a whole. Dikes (concrete flood walls and some earth dike) are provided on both banks in the upper half of this stretch and bank protection works by gabion (Bronjong) at the lower end.
3) The right Bolango River (the Siendeng River: Stretch-II_R) is provided with bank protection works made of gabion (Bronjong). Earth dikes and flood walls are located sporadically in the upper half of the stretch.
4) In the upstream reaches of divergence of the left and right Bolango rivers (Stretch-III), the Bolango River is provided with earth dikes on both banks for almost entire stretch including partial flood wall made of cobble concrete. Bank protection works are sporadic.
5) Drainage culverts are provided across the dike, though the quantities are not many.
6) There are 10 bridges as follows:

(River stretches)	(Road bridge)	(Footpath bridge)
Stretch-I	1	-
Stretch-II_L	3	2
Stretch-II_R	2	-
Stretch-III	2	-

Through the investigation works of the existing river facilities, the following river related issues were recognized:

1) **Coordination among Implementing Agencies:** The river facilities have been constructed by local governments of Gorontalo Province and Kabupaten/Kota Gorontalo, seemingly, with less mutual communication and coordination. The river is a continuous system and its improvement should be carried out according to a common plan authorized by the relevant agencies in well-coordinated manner. Institutional reinforcement would be necessary to unify the river management.
2) **Sequence of Works:** Looking at the distribution of the existing river facilities, diking system has been constructed in the upper reaches (Stretch-III) before the improvement in the lower reaches. The diking system might concentrate floodwater to the lower reaches where urban areas of Gorontalo City are located. This sequence of works is probably resulted from the difficulty in land acquisition. River improvement in the lower urban area (Stretches I and II) is urgently needed.
3) **Incomplete Works:** In some sections of dike, especially for concrete floodwalls, incomplete works are found; for instance, discontinuous dike at a house thrust into the river, opening dike at the confluence of tributary, lowered dike at bridge crossing, etc. These incomplete sections make other part of continuous dike useless, since flood water to be confined would easily be spilt over from these sections. These incomplete works would be brought from the shortage of time for land acquisition and less considerations for project functions giving more attention to the progress of works.

These issues show up the difficulties in land acquisition and implementation of river improvement works under yearly budgeting system.

C2.3.2 Existing Channel Capacity

Contour map of the flood prone area in Gorontalo City is shown in Figure C2.3.2. River survey of the Lower Bolango River was conducted at smaller intervals for the Feasibility Study. Using the latest survey sections, existing channel capacity was examined by non-uniform flow calculations. Results of the flow calculation are shown in Figure C2.3.3. For the calculation, following assumptions were introduced:

1) Water level due to Bone River Flood: Water level at the confluence of the Bone and Bolango rivers was assumed at +2.60 m,MSL by the flow calculation of the

Bone River based on Q_{20} = 1200 m^3/s starting from estimated +0.767 m,MSL (HHWL) at the river mouth.

2) Water level at the lowest end: Normal water level calculated for the existing river section was assumed as the water level at the lowest end (confluence to the Bone River).
3) Manning's coefficient of roughness:
   n = 0.030 for low-water channel
   n = 0.060 for high-water channel

According to the result of calculation, channel capacity of the Bolango River was evaluated as follows:

1) Stretch-I: Notwithstanding the discharge of the Bolango River, the river water level get higher than riverbank elevation due to back-water effects of the flood of the Bone River. In case the back-water effects are disregarded, existing channel has a capacity of about 100 m^3/s except for some sections.
2) Stretch-II_L: The effects of tidal movement would reach up to the 2nd road bridge (from the lower end) of this stretch. The channel at least has bank-full capacity of about 75 m^3/s.
3) Stretch-II_R: Like the Stretch-II_L, the tidal movements reach up to the 1st bridge of this stretch. The channel has bank-full capacity of about 75 m^3/s except for some sections.
4) Stretch-III: River channel of this stretch is confined by diking system. If a freeboard of 0.8m is considered, the existing river has capacity of about 200 m^3/s except for some sections.

Judging from the existing capacity of the Stretch-III, the Stretch-II (=II_L+II_R) and Stretch-I should be improved so as to have 200 m^3/s at least.

2.3.3 Riverbed of Lower Bone River

Abrupt drop of riverbed at the mouth of the Bone River was recognized by the aerial photo and site reconnaissance. The drop was also confirmed by the river survey as shown in Figure C2.3.4. The depth of the Bone River of around one meter increases abruptly to more than 70 meters, in front of the oil tank yard of Pertamina.

Cause of the abrupt riverbed drop was initially supposed to be the existence of rock

exposed on the riverbed, because the river is sandwiched by hills formed with granite. If so, removal of the rock may contribute to lower the flood water level in the Lower Bone River and accordingly to promote drainage of the southern part of Gorontalo City.

In order to confirm the geological conditions of the Bone estuary, borings were carried out at five holes and the results are summarized in Figure C2.3.5. From the investigation, it was disclosed that the riverbed of the Bone estuary was filled with thick sediment of sand and gravel. No rock was found at any bore holes.

Based on the results of geological investigation, the abrupt drop of riverbed was judged to be the front limb of sediment deposit in deep water. Riverbed excavation under such geological condition may be, in general, difficult to be maintained, being filled up again soon.

C2.4 Control of Bolango Flood by Lake Limboto

C2.4.1 Necessity of Review

In the Master Plan prepared in the previous study stage, the Bolango River was planned without considering flood control by Lake Limboto, so as not to adversely affect the environmental and other physical conditions of the lake. However, according to the field survey data and information obtained during the Feasibility Study period, the following facts were showed up:

1) **Difficulty in Land Acquisition:** The Bolango River is sandwiched by densely built urban buildings, especially in the downstream reaches from the divergence of left and right Bolango rivers. Implementation of the river works has been constrained by the land acquisition problems. The dike works in the downstream reaches are not many and discontinuous because of land acquisition and house compensation problems. Local government agencies expressed anxiety on the difficulty of land acquisition and compensation along the Bolango River. In planning the future river improvement, this matter should also be taken into account for smooth implementation of flood mitigation without social conflict, minimizing the quantity of land acquisition and compensation for the work.

2) **Use of Existing River Facilities:** In the upper half of the Lower Bolango River,

the river channel has been confined by narrow diking system. Besides the dike, there are 8 road bridges crossing the Lower Bolango River. These river facilities should be utilized as they are, as much as possible, for the effective use of the past public investment.

3) **Necessity of Flood Control by Lake Limboto:** In order to solve the above mentioned issues, it is necessary to reduce the design discharge of the lower Bolango River and to lower the design high water level. These could be realized only by flood control with Lake Limboto. According to the site information and flood flow analyses disclosed that a large amount of the floodwater of the Bolango River flows into the lake under the present condition and the lake have been playing a vital role in the flood peak reduction of the Lower Bolango River.

Taking the above facts into consideration, flood control by Lake Limboto was finally adopted for the Bolango River Improvement as the second best solution.

C2.4.2 Revision of Design Discharge Distribution

Alternative Study on Discharge Distribution: Design discharge of the Bolango River should be determined at the existing channel capacity to minimize the land acquisition and house compensation with maximum use of the existing channel. In order to determine the definite discharge distribution, following cases were studied around the existing channel capacity:

Case	Upper Bolango R. (m^3/s)	Lower Bolango R. (m^3/s)	Tapodu R. (m^3/s)
150-scheme	750	150	600
200-scheme	750	200	550
250-scheme	750	250	500

According to the channel flow calculations and the flood storage calculation, river width required for the above discharge was calculated for the Lower Bolango/Bone river from the Tapodu junction to the river mouth and the Tapodu River from the Bolango junction to Lake Limboto. As a result, the number of houses to be relocated was worked out as follows:

(Number of Houses to be Relocated)

Case	Lower Bolango R. (nos)	Tapodu R. (nos)	Total (nos)
150-scheme	21	52	73
200-scheme	24	44	68
250-scheme	39	43	82

The 200-scheme require the minimum number of houses to be relocated and was adopted.

Revised Discharge Distribution: Considering the results of the comparative study, the design discharge distribution at the confluence of the Bolango and Tapodu rivers was set as follows based on 20-year flood:

- Discharge from upper Bolango basin: 750 m^3/s
- Discharge of lower Bolango River: 200 m^3/s
- Discharge controlled by lake: 550 m^3/s

As a result, the design discharge distribution proposed for the Flood Mitigation Master Plan (FM-MP) was revised as shown in Figure C2.4.1.

Influence to Lake Water Level: According to the flood storage calculation, water level of Lake Limboto is raised by 14 cm only due to the flood inflow of the Bolango River for the 20-year flood.

C2.4.3 Flood Storage Calculation

Procedures of Storage Calculation: Flood storage by Lake Limboto was simulated in the procedures shown in Figure C2.4.2 and outlined below. Water surface in the lake was assumed to be level.

Initial Lake Water Level: Lake water level at the beginning of flood storage was assumed as follows:

1) +4.90 m,MSL for the present basin condition (conditions without project), taking the average of annual maximum water level excluding those of 1992 and 1993 which were affected by artificial excavation of the outlet channel (Tapodu

River). Under the existing condition the drawdown of the lake water level is very slow because of small outlet channel.

2) +4.40 m,MSL for the lake with improved Tapodu River and Gate, considering the assumed overflow depth above the weir crest at +4.00 m,MSL due to base-flow runoff from the tributaries of the Lake Limboto. Due to the overflow depth above the weir crest, the water level of Lake Limboto will be maintained above +4.40m, MSL during the rainy season, though the maintained lake water level is +4.00m,MSL.

Tapodu River: Lake Limboto and the Bolango River is connected with the Tapodu River of 1,516 m in length. The discharge of the Tapodu River was calculated depending on the water levels of the Bolango River and the lake. Therefore, the river water flows both directions, regularly (from the lake to the Bolango R.) and reversely (from the Bolango R. to the lake). Standard design channel section of the Tapodu River was assumed as follows:

1) Single section channel was assumed with level riverbed of elevation +2.00 m,MSL and side bank slope of one on two. Average ground elevation is +4.3 m,MSL, though it recline toward the lake slightly.
2) River width was determined to be 70 m at the riverbed in the process of trial and error by storage calculations so that the reverse flow would be 550 m^3/s at maximum under the 20-year flood.

Control of Tapodu Gate: Tapodu Gate installed at the outlet to the Bolango River was assumed to be kept open as far as the lake water level is higher than +4.40 m,MSL.

C2.4.4 Flood Control by Lake Limboto

Flood control by Lake Limboto was simulated using the flood storage model for the 2, 5, 10 and 20 year probable floods under the existing and improved channel conditions. Results of simulations are summarized in Figure C2.4.3 and the maximum lake water levels are shown below.

Condition of the Tapodu	Maximum lake water level (m,MSL)			
	2 yr	5 yr	10 yr	20 yr
Existing	5.081	5.213	5.322	5.434
Improved	4.675	4.900	5.077	5.247

Focusing on the 20-year flood with the improved Tapodu River, discharge and water level hydrographs are shown in Figure C2.4.4. The maximum lake water level still remains below the design high water level of the lake.

In order to examine the influence of consecutive floods, the following combinations of floods were simulated:

1) Case-1: 3-day consecutive floods with 20-year flood followed by two more daily flood of which total rainfall correspond to 20-year probable 3-day consecutive rainfall.
2) Case-2: 2-day consecutive floods with 20-year flood followed by 2-year flood.

Results of simulation are shown in Figures C2.4.5 and C2.4.6. Lake Limboto with the improved Tapodu River can control the design discharge of the Lower Bolango River below 200 m^3/s of one-day and three-day consecutive runoff based on 20-year flood. The lake further can almost cope even with the rare event of 20-year flood followed by 2-year flood, with the highest water level at +5.6 m,MSL which is little bit higher than the design high water level.

C2.5 Flood Analysis for Flood Damage Estimate

Amount of flood damages are estimated in general as a product of damageable property value and damage ratio which depends on the flooding conditions. The damages are estimated by mesh blocks of 250m x 250m. The flooding conditions related to the damage ratio were estimated as a result of flood flow analysis for the whole plain area of the LBB basin and flood storage calculation for Lake Limboto and surrounding area. For the area subjected to both analyses, the higher floodwater levels were adopted for the damage estimate. Results of analyses are shown in Figure C2.5.1, taking examples for 2-year and 20-year floods.

In order to estimate the annual average flood damage, various cases of flooding conditions are required to be estimated, namely, for the conditions with and without project under several return period of floods such as 2-, 5-, 10-, 20-, and 50-years. Flooding conditions of these cases were estimated by flood analysis for respective mesh blocks in general, and in some cases, estimations were made based on the flooding conditions and damage amounts estimated for other cases as shown in Table C2.5.1.

Table C2.5.1 ESTIMATION METHODS OF FLOOD AND DAMAGES

Cases	Lake Limboto area	Lower Bolango River	Tamalate River
Without Project:			
2-yr	Mesh block	Mesh block	Mesh block
5-yr	Mesh block	Mesh block	Mesh block
10-yr	Mesh block	Mesh block	Mesh block
20-yr	Mesh block	Mesh block	Mesh block
50-yr	Mesh block	Mesh block	Mesh block
With Project (For 20-year flood):			
2-yr	Mesh block	No damage	Residual damage
5-yr	Mesh block	No damage	Residual damage
10-yr	Mesh block	No damage	Residual damage
20-yr	Mesh block	No damage	Residual damage
50-yr	Mesh block	F.C. benefit	No effects

Notes:

1. Mesh block: Flooding and damage are estimated by flood analysis for each mesh block.
2. No damage: No flooding and no damage are assumed.
3. F.C. benefit: Flood control effects by Lake Limboto are accounted. Amount of damage is estimated based on discharge-damage curve for the basin without project.
4. Residual damage: Damages due to residual flood along the lower Tamalate River downstream from the floodway are accounted. Amount of damage is estimated based on discharge-damage curve for the basin without project.
5. No effects: No effects are expected due to damage of river facilities by flood exceeding design magnitude.

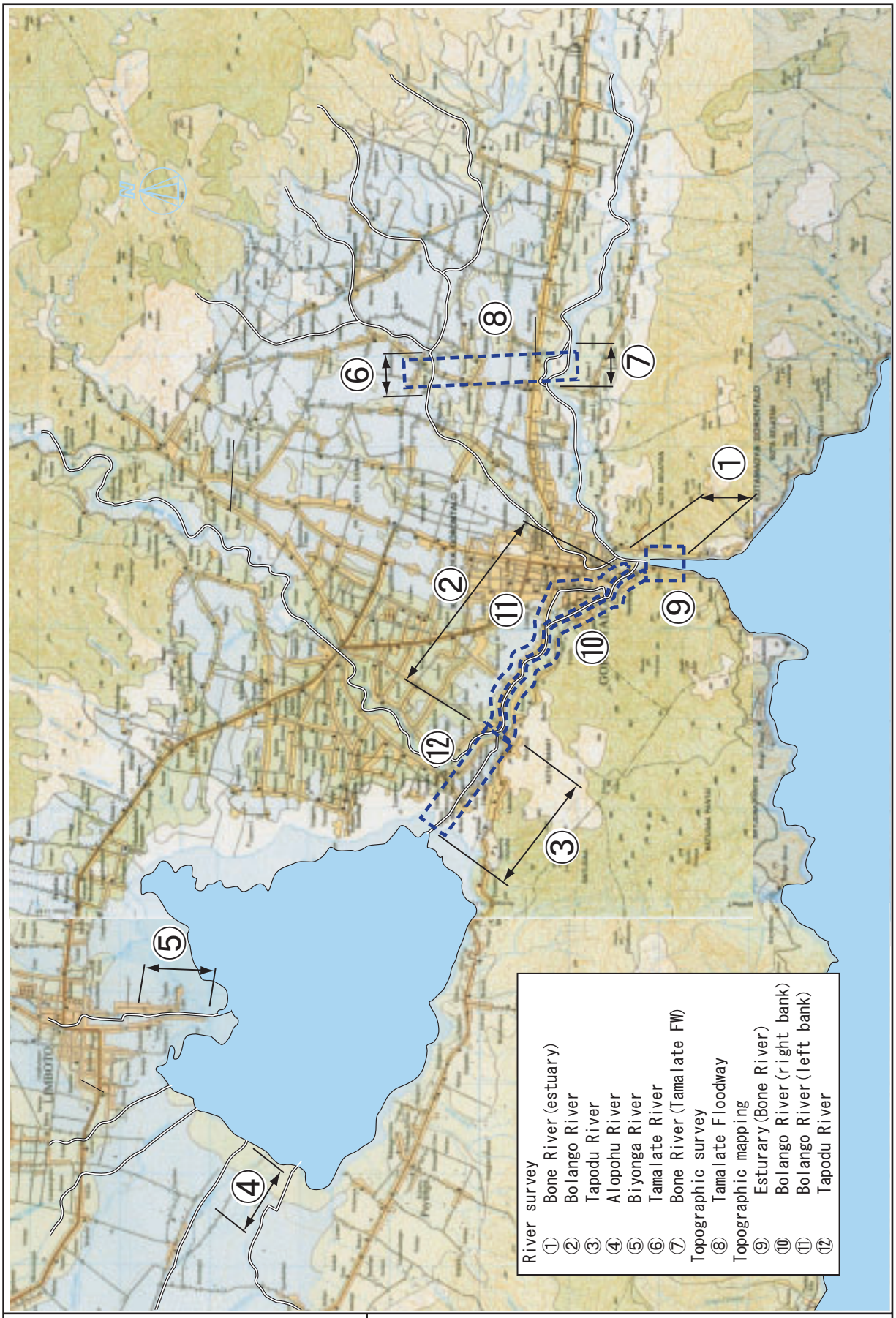


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Figure C2.1.1
LOCATION MAP OF SUPPLEMENTARY SURVEY AND MAPPING

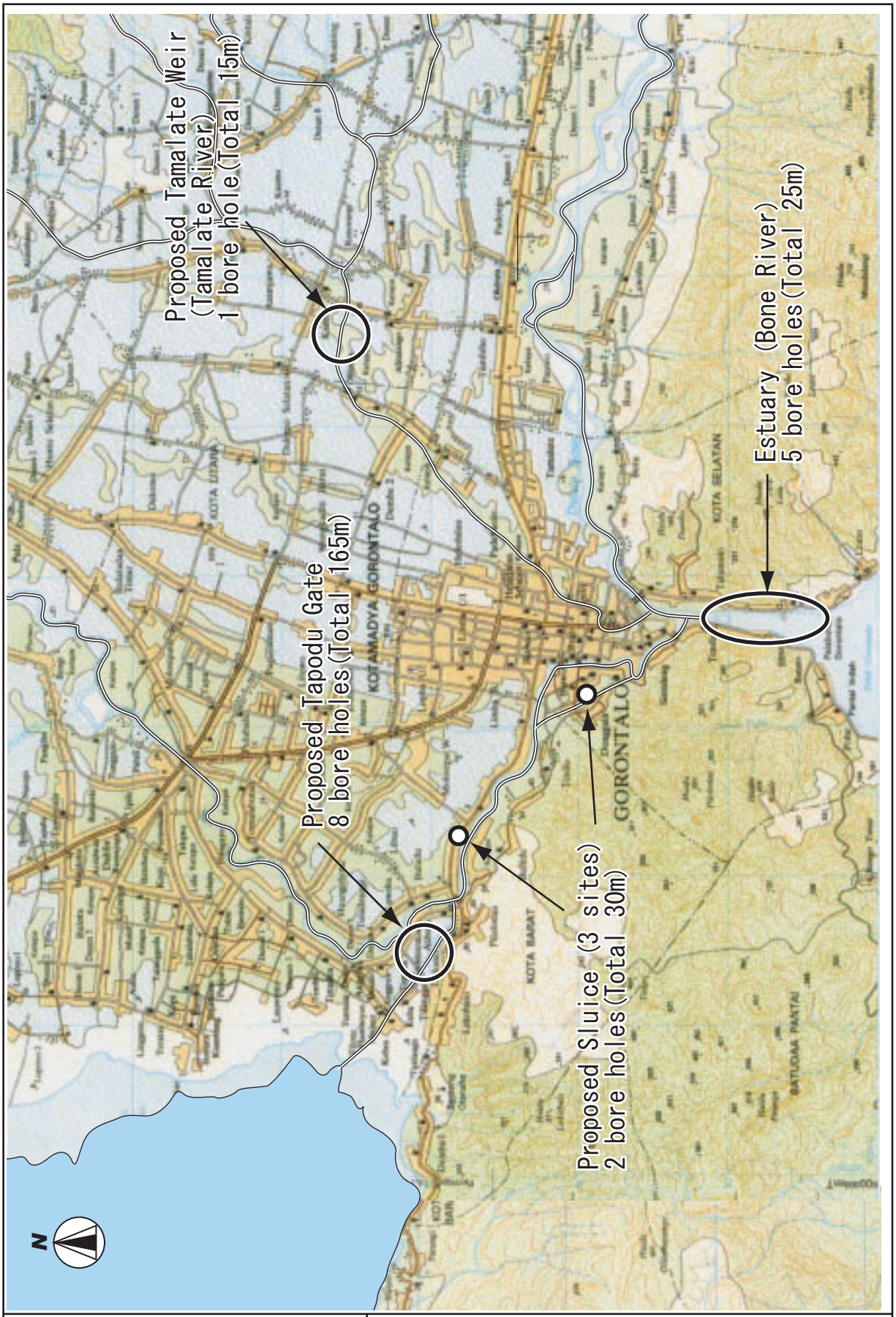

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Figure C2.1.2
LOCATION MAP OF SUPPLEMENTARY GEOLOGICAL INVESTIGATION