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NO. 52

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

REPUBLIC OF THE PHILIPPINES
DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS

THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN

FINAL REPORT

VOLUME II

MAIN REPORT

DECEMBER 1997

CTI ENGINEERING CO., LTD.
IN ASSOCIATION WITH
SANYU CONSULTANTS INC.
PASCO INTERNATIONAL INC.

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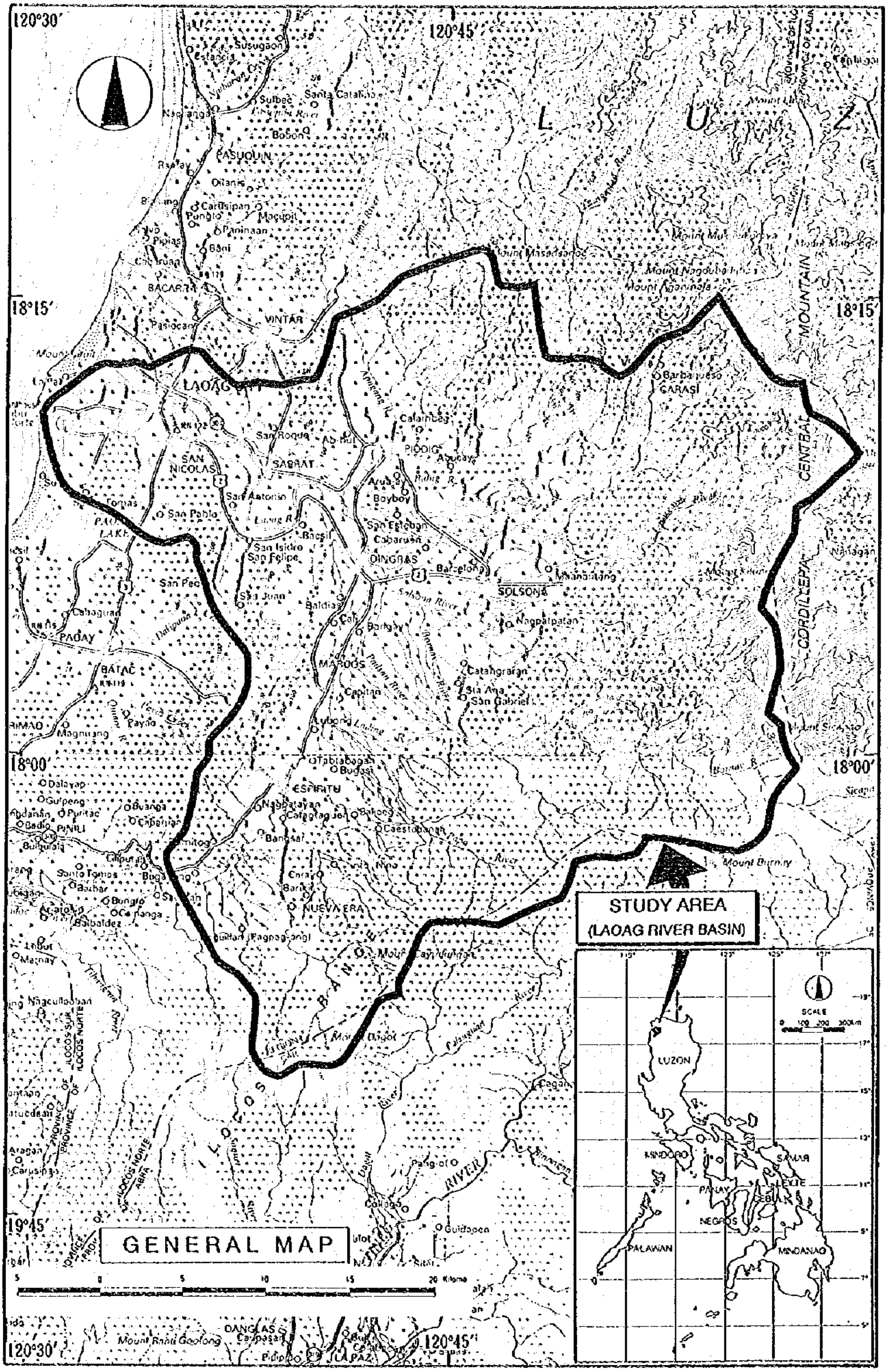
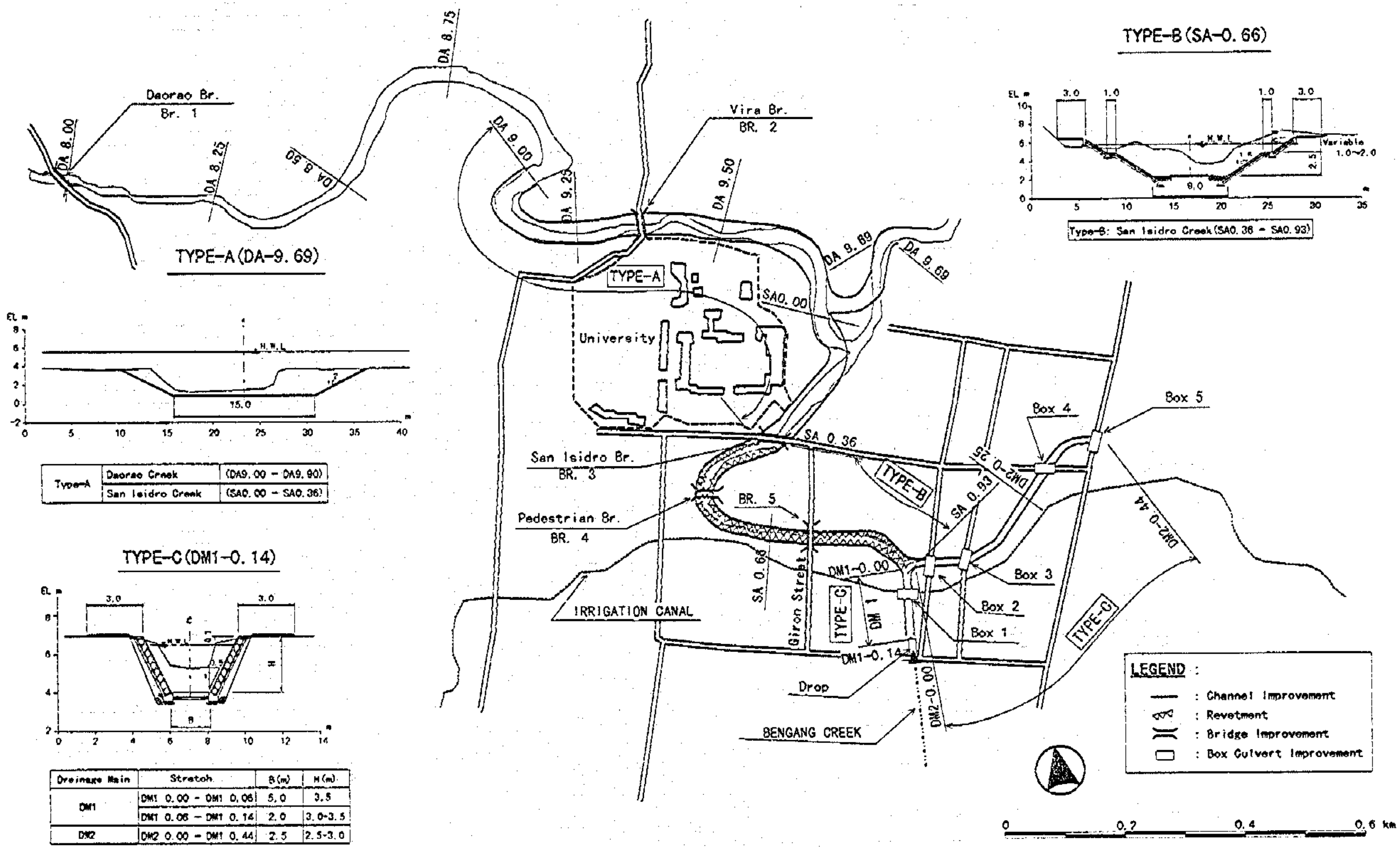
Topographic Survey Results

The cost estimates in this Study are based on the price levels indicated below and expressed in Philippine Peso according to the following exchange rates:

Master Plan	:	US$1.00 = Philippine Peso 26.00 = Japanese Yen 105, as of August 1996
Feasibility Study	:	US$1.00 = Philippine Peso 26.00 = Japanese Yen 115, as of June 1997


120°30′
120°45′
18°15′
18°15′
18°00′
18°00′
19°45′
120°30′
120°45′
STUDY AREA
(LAOAG RIVER BASIN)
GENERAL MAP
LAOAG
SAN NICOLAS
SARRAT
PIDDIG
DINGRAS
SOLSONA
VINTAR
BACARRA
PASUQUIN
PAOAY
BATAC
MARCOS
ESPIRITU
NUEVA ERA
PINILI
CARASI
CENTRAL MOUNTAIN CORDILLERA
LUZON
MINDORO
SAMAR
LEYTE
PANAY
CEBU
NEGROS
PALAWAN
MINDANAO
SCALE



Type-A	Daorao Creek	(DA9.00 - DA9.90)
	San Isidro Creek	(SA0.00 - SA0.36)

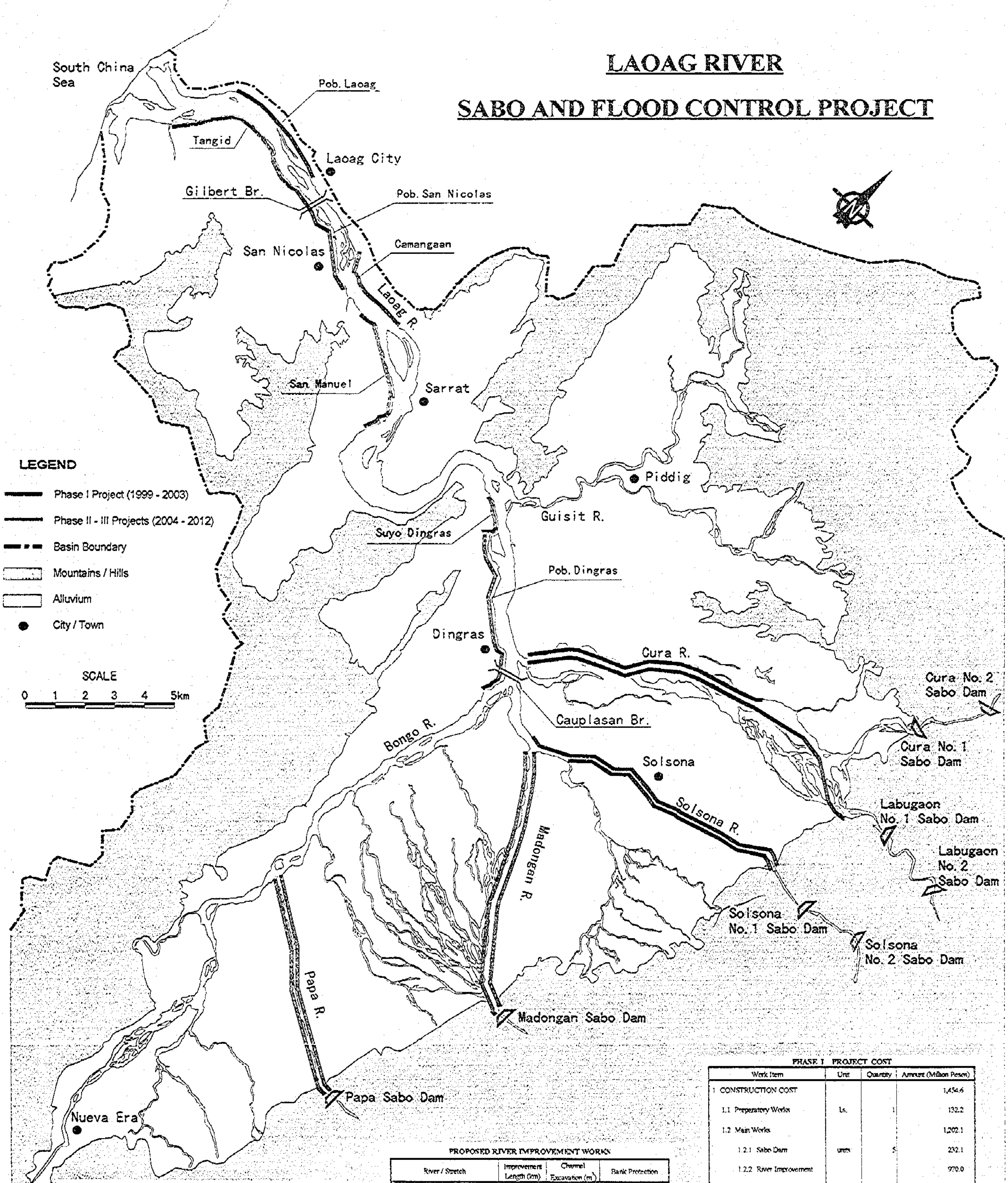
Drainage Main	Stretch	B (m)	H (m)
DM1	DM1 0.00 - DM1 0.06	5.0	3.5
	DM1 0.06 - DM1 0.14	2.0	3.0~3.5
DM2	DM2 0.00 - DM1 0.44	2.5	2.5~3.0

LAOAG CITY URBAN DRAINAGE IMPROVEMENT

- URGENT PROJECT -

LAOAG RIVER

SABO AND FLOOD CONTROL PROJECT



PROPOSED SABO DAM

Sabo Dam	Catchment Area (km^2)	Dam Height (m)	Dam Length (m)	Sedimentation Volume (m^3)
Phase I (1999 - 2003)				
Cura No.1	68.2	9.0	183	422,000
Labugaon No.1	100.5	17.0	118	1,197,000
Solsona No.1	72.2	12.0	118	242,000
Madongan	153.8	10.5	183	2,207,000
Papa	51.4	9.0	233	794,000
Phase II (2004 - 2009)				
Cura No.2	63.1	4.5	70	150,000
Labugaon No.2	90.9	7.0	160	511,000
Solsona No.2	68.2	10.0	90	233,000

PROPOSED RIVER IMPROVEMENT WORKS

River / Stretch	Improvement Length (km)	Channel Excavation (m^3)	Bank Protection
Phase I (1999 - 2003)			
Laoag R. (Pob. Laoag)	3.49	-	River Wall (1,240m)
Laoag R. (Pob. San Nicolas)	4.20	-	-
Laoag - Bongo R. (Pob. Dingras)	5.45	-	River Wall (300m)
Cura / Labugaon R.	21.50	992,000	Spur Dike (349 Units)
Solsona R.	16.00	-	Spur Dike (302 Units)
Madongan R.	10.00	-	Spur Dike (394 Units)
Papa R.	4.50	-	Spur Dike (283 Units)
Phase II (2004 - 2009)			
Laoag R. (Tangid)	5.25	-	-
Laoag R. (Camangaan)	4.00	-	-
Laoag R. (San Manuel)	3.60	-	-
Laoag R. (Suyo, Dingras)	3.70	-	-

PHASE I PROJECT COST

Work Item	Unit	Quantity	Amount (Million Pesos)
1 CONSTRUCTION COST			1,454.6
1.1 Preparatory Works	l.s.	1	132.2
1.2 Main Works			1,202.1
1.2.1 Sabo Dam	units	5	232.1
1.2.2 River Improvement			970.0
1.3 Miscellaneous works	l.s.	1	120.3
2 COMPENSATION COST			6.4
2.1 Land Acquisition	ha.	41	6.0
2.2 House Relocation	houses	3	0.4
3 ADMINISTRATION COST	l.s.	1	43.8
4 ENGINEERING SERVICE COST	l.s.	1	232.7
5 PHYSICAL CONTINGENCY	l.s.	1	173.8
6 PRICE CONTINGENCY	l.s.	1	421.8
Total			2,333.1

PREFACE

In response to a request from the Government of the Republic of the Philippines, the Government of Japan decided to conduct a development study on Sabo and Flood Control in the Laoag River Basin and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to the Philippines a study team, headed by Mr. Naohito Murata, Senior Chief Engineer, Overseas Department, CTI Engineering Co., Ltd. and composed of members from CTI Engineering Co., Ltd., Sanyu Consultants Inc. and Pasco International Inc., four times between March 1996 and December 1997.

The team held discussions with the officials concerned of the Government of the Republic of the Philippines, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of the Philippines for their close cooperation extended to the Team.

December, 1997

KIMIO FUJITA
President
Japan International Cooperation Agency

December 1997

Mr. Kimio Fujita
President
Japan International Cooperation Agency
Tokyo, Japan

Sir:

LETTER OF TRANSMITTAL

We are pleased to submit herewith the Final Report for the Study on Sabo and Flood Control in the Laoag River Basin, Republic of the Philippines. The report contains the advices and suggestions of authorities concerned of the Government of Japan and the Japan International Cooperation Agency (JICA), as well as the formulation of the sabo and river improvement projects for the Laoag River Basin and the urban drainage improvement project for Laoag City. Also included are the comments made by the Department of Public Works and Highways, Government of the Republic of the Philippines, during the technical discussion on the Draft Final Report in the Philippines.

The Final Report presents the Master Plan of Sabo and Flood Control in the Laoag River Basin. It also presents the Feasibility Study on priority sabo and river improvement projects for the Basin, including the urban drainage improvement project for Laoag City.

In view of the urgency and necessity of socio-economic development, we recommend that the Government of the Republic of the Philippines should adopt all means possible to promote the priority sabo and river improvement projects for the Basin and the urban drainage improvement project for Laoag City to the next stage of project implementation at the earliest possible time.

Finally, we wish to take this opportunity to express our sincere gratitude to the Government of Japan, particularly, JICA, the Ministry of Foreign Affairs, the Ministry of Construction and other offices concerned. We also wish to express our deep appreciation to the Department of Public Works and Highways and other authorities concerned of the Government of the Republic of the Philippines for their close cooperation and assistance extended to the JICA Study Team during the Study.

Very truly yours,

村田直人

NAOHITO MURATA
Leader
JICA Study Team

Encl.: a/s

INTRODUCTION

1. Background of the Study

The Laoag River system, with an aggregate drainage area of 1,332 km^2, is located in Ilocos Norte Province in the northern part of the Island of Luzon, the Philippines. The main river, originating in the Central Cordillera Mountains which has a peak elevation of more than 2,000 m, is called Bongo in the upper and middle reaches and Laoag in the lower reaches.

The main river flows down along the western fringe of the alluvial fan in the middle reaches. After passing through the narrow flood plain in the lower reaches, it drains into the South China Sea at Laoag City, the capital of the province. In the middle reaches, the main river is joined by many tributaries that flow down the alluvial fan. Among the major tributaries are the Papa, Madongan, Solsona, Labugaon and Cura rivers.

The Basin is prone to severe flood damage by typhoons. A large area is inundated and a number of people are affected every year. Even the urban areas are flooded at a large flood. The flood damage in the alluvial fan area in the middle reaches is more serious due to sediment deposition. Farmland of more than 1,000 ha had been washed out during the recent 20 years. The irrigation systems and rural road networks also have been frequently destroyed.

Sediment and flood control works are considered essentially necessary for the development of the Basin. In response to the request of the Government of the Philippines (GOP), the Government of Japan (GOJ) decided to conduct the "Study on Sabo and Flood Control in the Laoag River Basin" (the Study). The implementing arrangement for the Study was agreed upon between the Department of Public Works and Highways (DPWH) of the GOP and the Japan International Cooperation Agency (JICA) in November 1995. In accordance with the implementing arrangement, JICA dispatched the Study Team in March 1996.

2. Objectives and Area of the Study

2.1 Study Objectives

The objectives of the Study which were set up in the implementing arrangement are:

(1) to formulate a master plan on sabo and flood control for the Laoag River Basin;

(2) to conduct a feasibility study on the urgent and/or priority project(s) identified in the master plan; and,

(3) to pursue technology transfer to the counterpart personnel of the GOP in the course of the Study.

During the Study, however, Laoag City was severely affected by floods of the Laoag River and local storm drainage in 1996. In view of this event, the DPWH requested JICA to include the study on urban drainage for Laoag City in the scope of work. In response, JICA decided to conduct the "Feasibility Study on Laoag City Urban Drainage Improvement" in addition to the above three objectives.

2.2 Study Area

The General Map gives the location of the study area. The study on sabo and flood control covers the entire Laoag River basin with a drainage area of 1,332 km^2. The administrative units included are Laoag City and the municipalities of San Nicolas, Sarrat, Dingras, Solsona, Piddig, Marcos, Banna, Nueva Era, Carasi and Vintar. The urban area of Laoag City is only partly included.

On the other hand, the study on Laoag City urban drainage improvement encompasses the whole Daorao-Tupec Creek basin. The Creek is hydrologically independent from the Laoag River system and it directly drains an area of 39 km^2 located on the right side of the lower Laoag River into the South China Sea. Most part of the urban area of Laoag City is located in this basin. Storm water drainage problems of the City occur in this area.

3. Implementation of the Study

3.1 Study Organization

The Study was carried out by a Study Team commissioned by JICA, composed of experts from Japanese consulting firms headed by CTI Engineering Co., Ltd., in association with Sanyu Consultants Inc. and Pasco International Inc. Counterpart staff was provided by the DPWH.

To provide guidance to the Study, DPWH set up a Steering Committee assisted by a Technical Working Group. On the other hand, an Advisory Committee was established by JICA to review the findings of the Study Team. The Steering Committee and the Advisory Committee has maintained close coordination by meeting regularly to exchange views on the Study.

The members of the Advisory Committee, JICA Study Team, Steering Committee, Technical Working Group and Counterpart Staff are listed in the tables below.

3.2 Study Schedule

In accordance with the schedule, the Study was started in March 1996 with completion in November 1997 inclusive of the Final Report. Field and home office studies, as well as reporting, were scheduled as mentioned below.

(1) Stage I (Field Work - late March 1996 to mid-September 1996)

The Inception Report was submitted by the JICA Study Team to DPWH at the start of the Study in the Philippines and discussed with the Steering Committee. The Report contained the study methodology and work schedule.

At the end of Stage I, the Progress Report (I) was presented to DPWH and discussed with the Steering Committee. The Report covered the analysis of existing socio-economy, hydrology, sediment and flood problems, watershed/river and environmental conditions, and institutional aspects. Further, it proposed a concept for the sabo and flood control master plan.

(2) Stage II (Home Office Work - mid-November 1996 to late January 1997)

The Study was continued in the home office in Japan to prepare the master plan of sabo and flood control in the Laoag River Basin.

(3) Stage III (Field Work - late January 1997 to late March 1997)

At the beginning of Stage III, the Interim Report was presented to DPWH and discussed with the Steering Committee. The Report presented all the results of the master plan study on sabo and flood control in the Laoag River Basin and the selected priority projects for the subsequent Feasibility Study.

During this stage, the feasibility study for the selected priority sabo dam and river improvement projects in the Laoag River Basin and the feasibility study on urban drainage improvement for Laoag City were conducted. The results of the field survey were compiled in Progress Report (II) which was presented to DPWH and discussed with the Technical Working Group at the end of Stage III.

(4) Stage IV (Field Work - mid-May 1997 to mid-July 1997)

Both feasibility studies for sabo dam and river improvement and the Laoag City urban drainage improvement were resumed to formulate the project. Progress Report (III), which contains all the results of the field survey conducted from late January 1997 to mid-July 1997, was submitted to DPWH and discussed with the Steering Committee.

(5) Stage V (Home Office Work - mid-July 1997 to mid-September 1997)

Both feasibility studies for sabo dam and river improvement and the urban drainage were continued and completed in the home office in Japan.

(6) Stage VI (Field Work - middle to late September 1997)

Final studies were made. The Draft Final Report was submitted to DPWH and discussed with the Steering Committee. The Report includes all results of the master plan study on sabo and flood control, feasibility study on priority sabo and river improvement projects, and feasibility study on the Laoag City urban drainage improvement.

(7) Stage VII (Home Office Work - early October 1997 to early December 1997)

The Final Report was prepared with some modifications based on the comments from the Steering Committee and submitted to DPWH.

3.3 Technology Transfer

Transfer of technical knowledge on sabo and flood control to DPWH counterpart personnel was carried out through the series of studies and meetings, as follows:

(1) Through the collaborative works on data collection of the past survey and study results and the social/economic condition, the objective and importance of data collection were recognized.

(2) Through the site reconnaissance of the basin and river conditions, its necessity, measures and inspected points were understood.

(3) Through the actual O&M activities of hydrological gauging equipment such as rainfall gauge and stream flow gauge, technical knowledge related and data compilation methods were imparted to the DPWH District Engineering Office in Laoag.

(4) Through the meetings with the Technical Working Group of the Steering Committee and the government offices and LGUs concerned in Laoag City, details of the Project were confirmed.

(5) Through the seminars in Laoag and Manila, technical knowledge was imparted to the government personnel concerned.

4. Composition of Report

This Report consists of four (4) volumes, as follows:

Volume I	:	Summary
Volume II	:	Main Report
Volume III-1	:	Supporting Reports for the Master Plan Study
Volume III-2	:	Supporting Reports for the Feasibility Studies on Sabo and Flood Control and on Laoag City Urban Drainage Improvement
Volume IV-1,2	:	Data Book

The Main Report (Volume II) presents the summarized results of all the studies in three (3) parts, as follows:

Part I	:	Master Plan Study on Sabo and Flood Control
Part II	:	Feasibility Study on Sabo and Flood Control
Part III	:	Feasibility Study on Laoag City Urban Drainage Improvement

The Supporting Report (Volume III-1) for the Master Plan Study on Sabo and Flood Control (Volume II, Part I) covers the following studies:

Appendix A	:	Socio-economy and Land Use
Appendix B	:	Climate and Hydrology
Appendix C	:	Flood Damage Analysis
Appendix D	:	Watershed and Flood Plain Conditions
Appendix E	:	River Conditions
Appendix F	:	Sediment Control Plan
Appendix G	:	River Improvement Plan
Appendix H	:	Non-structural Measures and Institutional Aspects
Appendix I	:	Multipurpose Development of the Project
Appendix J	:	Economic and Financial Evaluation
Appendix K	:	Environmental Aspects
Appendix L	:	Aerophotogrammetric and Topographic Survey

The Supporting Report (Volume III-2) for the Feasibility Studies on Sabo and Flood Control (Volume II, Part II) and on Laoag City Urban Drainage Improvement (Volume II, Part III) covers the following studies:

<u>Sabo and Flood Control in Laoag River Basin</u>

Appendix A	:	Sediment Analysis
Appendix B	:	Sabo Dam Plan
Appendix C	:	River Improvement Plan
Appendix D	:	Construction Plan and Cost Estimate
Appendix E	:	Project Evaluation
Appendix F	:	Environmental Impact Assessment
Appendix G	:	Aerophotogrammetric and Topographic Survey
Appendix H	:	River Monitoring

<u>Laoag City Urban Drainage Improvement</u>

Appendix A	:	Laoag City Urban Drainage Improvement

Members of JICA Advisory Committee

	Name	Designation
1.	Masayuki WATANABE	Sabo Planner (Chairman)
2.	Fumihiko NAKAMURA	Flood Control Planner

Members of JICA Study Team

	Name	Designation
1.	Naohito MURATA	Team Leader/Flood Control Planner
2.	Kanehiro MORISHITA	Co-Team Leader/Sabo Planner
3.	Yuzo MIZOTA	Hydrologist/Drainage Planner
4.	Kazuto SUZUKI	Flood Damage Analyst
5.	Kazuo IKEDA	Geomorphologist/Geologist
6.	Akio SHICHIJUGARI	Structural Engineer/Construction Planner
7.	Tatsuo TASHINO	Socio-Economist
8.	Masahiro ISOMURA	Land Use Planner/Environmentalist
9.	Nobuyuki TAKANASHI	Drainage Structural Engineer
10.	Antonio A. ALPASAN	Institutional Expert
11.	Hidehiko SUGIYAMA / Shun TAKAGI	Topo. Surveyor
12.	Daikichi NAKAJIMA	Aerophoto. Surveyor
13.	Kazumi AKUZAWA / Tsuyoshi MATSUSHITA	Logistician

Members of Steering Committee

	Name	Designation
1.	Teodoro T. Encarnacion	Undersecretary, DPWH (Chairman)
2.	Manuel M. Bonoan	Assistant Secretary for Planning (Vice Chairman)
3.	Bienvenido C. Leuterio	Director, Bureau of Design
4.	Ernesto M. Hernandez	Former Regional Director, DPWH Region I
	Josefino N. Rigor	Incumbent Regional Director, DPWH Region I
5.	Nonito F. Fano	OIC-Project Director, PMO-Major Flood Control Projects

Members of Technical Working Group

	Name	Designation
1.	Resito V. David	Project Manager I, PMO-Major Flood Control Projects
2.	Rolando H. Tamayo	District Engineer, 1st Ilocos Norte Engineering District
3.	Rizal V. Ruiz	Project Manager II, 2nd Ilocos Norte Engineering District
4.	Sofia T. Santiago	Engineer V, Bureau of Design
5.	Manuel S. Alconis	Engineer V, Planning Service

Local Counterpart Personnel

	Name	Office (DPWH)
1.	Ernie U. Fano	PMO-Major Flood Control Projects
2.	Carlos P. Zamora	Planning Service
3.	Napoleon S. Famadico	Planning Service
4.	Johnny Montano	Planning Service
5.	Lalain Malassab	Planning Service
6.	Soledad Q. Balisi	Planning Service
7.	Romy Lescano	PMO-Feasibility Study
8.	Glenn V. Reyes	1st Ilocos Norte Engineering District
9.	Wilson Quiamas	2nd Ilocos Norte Engineering District

PART I

MASTER PLAN STUDY

ON

SABO AND FLOOD CONTROL

THE STUDY ON SABO AND FLOOD CONTROL IN THE LAOAG RIVER BASIN

FINAL REPORT
VOLUME II
MAIN REPORT

PART I
MASTER PLAN STUDY ON SABO AND FLOOD CONTROL

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ABBREVIATIONS

AGENCIES/ORGANIZATIONS

BDCC	:	Barangay Disaster Coordinating Council
BOD	:	Bureau of Design, DPWH
CENRO	:	Community Environment and Natural Resources Office
DENR	:	Department of Environment and National Resources
DPWH	:	Department of Public Works and Highways
EMB	:	Environmental Management Bureau, DENR
GOJ	:	Government of Japan
GOP	:	Government of the Philippines
INIP	:	Ilocos Norte Irrigation Project
JICA	:	Japan International Cooperation Agency
LGU	:	Local Government Unit
MDCC	:	Municipal Disaster Coordinating Council
NAMRIA	:	National Mapping and Resources Information Authority
NDCC	:	National Disaster Coordinating Council
NEDA	:	National Economic and Development Authority
NGO	:	Non-Governmental Organization
NIA	:	National Irrigation Administration
NPC	:	National Power Corporation
NSCB	:	National Statistics Coordination Board
NSO	:	National Statistics Office
OCD	:	Office of Civil Defense, Department of National Defense
OECF	:	Overseas Economic Cooperation Fund, Japan
PAGASA	:	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PDC	:	Provincial Development Council
PDDC	:	Provincial Disaster Coordinating Council
PDOC	:	Provincial Disaster Operation Center
PENRO	:	Provincial Environment and Natural Resources Office
PMO	:	Project Management Office, DPWH
PPDO	:	Provincial Planning and Development Office
PWDEO	:	Public Works District Engineering Office

ACRONYMS

B/C	:	Benefit-Cost Ratio
BOD	:	Biological Oxygen Demand
ECC	:	Environmental Compliance Certificate
EIA	:	Environmental Impact Assessment
EIRR	:	Economical Internal Rate of Return
FOB	:	Free-on-Board
GDP	:	Gross Domestic Product
GRDP	:	Gross Regional Domestic Product
NIS	:	National Irrigation System
NPV	:	Net Present Value
O&M	:	Operation and Maintenance
RIS	:	River Irrigation System
SS	:	Suspended Solids

MEASUREMENTS/SYMBOLS

mm	:	millimeter
cm	:	centimeter
m	:	meter
km	:	kilometer
g, gr.	:	gram
kg	:	kilogram
t, ton	:	metric ton
m^2	:	square meter
ha, has	:	hectare, hectares
km^2	:	square kilometer
l, lt., ltr	:	liter
m^3	:	cubic meter
s, sec	:	second
min.	:	minute
hr	:	hour
yr	:	year
MW	:	megawatt
mm/hr	:	millimeter per hour
m/s	:	meter per second
km/hr	:	kilometer per hour
mg/l	:	milligram per liter
m^3/s	:	cubic meter per second
$m^3/s/km^2$	:	cubic meter per second per square kilometer
%	:	percent
¥	:	Japanese Yen
₱	:	Philippine Peso
$	:	US Dollar

CHAPTER I STUDY AREA

1.1 River Basin

The Laoag River system drains an area of 1,332 km². The river originates in the Central Cordillera Mountains which has a peak elevation of more than 2,000 m. The main river course is called Bongo in the middle and upper reaches and Laoag in the lower reaches with the confluence of Cura River as boundary.

The main river course flows northward along the western fringe of the alluvial fan in the middle reaches to the confluence with the Guisit River. Thereafter, it turns toward the west and after passing the downstream flood plain, finally empties into the South China Sea at Laoag City. The Bongo River is joined by many tributaries that flow from the alluvial fan along the right bank in the middle reaches. Among the major tributaries are the Papa, Madongan, Solsona, Labugaon and Cura rivers.

The basin is divided into four (4) major sub-basins; namely, the upper basin, the middle south basin, the middle north basin, and the lower basin, as shown in Fig. I.1.

(1) Upper Basin

The upper basin covers an area of 835 km^2 consisting of the mountains/hills of 634 km^2 and alluvial fan of 201 km^2. This basin is the watershed of the six (6) major tributaries including Bongo River. The ground elevation in this basin makes a sudden change from 2,300 m to 100 m within a 20 to 30 km distance. This basin is the main source of sediment of the Laoag River system.

The major tributaries run down the alluvial fan with a length of 8 to 10 km and ground elevation ranging from 130 to 30 m. The alluvial fan is mainly used as irrigated paddy field.

(2) Middle South Basin

The middle south basin is located in the left bank along the Bongo and Laoag rivers. This basin has an area of 160 km^2 in which the hilly area accounts for about 70%.

The hill runs south-north with a ridge elevation ranging from 200 to 500 m. Many small tributaries originate from this hilly area and drain floodwaters through the gently sloping valley where paddy fields are mainly cultivated. These tributaries finally flow into the Bongo or the Laoag River.

(3) Middle North Basin

The middle north basin has an area of 178 km^2 in which the mountains and hills account for 76%. The basin is the drainage area of the Guisit River. The Guisit River originates from the north ridge which has an elevation ranging from 300 m to 1,000 m.

(4) Lower Basin

The lower basin has an area of 159 km^2 in which the area of alluvial plain accounts for 102 km^2. The remaining area of 57 km^2 is hilly land. The basin covers the lower reaches from the confluence of the Bongo and Cura rivers. A narrow alluvial plain extends between the hilly lands. The alluvial plain along the Laoag River with a length of 32 km is highly developed as agricultural land and residential area.

Laoag City is located in this lower basin; however, all of it is not covered by the basin. A part of the city area is drained by the Daorao-Tupec Creek which is independent from the Laoag River system.

1.2 Socio-economic Conditions

1.2.1 Administration

The Laoag River Basin (the Basin), with an area of 1,332.1 km^2, extends over 11 administrative units consisting of one city and 10 municipalities; namely, Laoag City, San Nicolas, Sarrat, Dingras, Solsona, Piddig, Marcos, Banna, Nueva Era, Carasi and Vintar. Among them, four (4) units are thoroughly included in the Basin while the others are only partly covered. The 11 units covering a total administrative area of 2,114.3 km^2 consist of 284 barangays with 235 barangays located in the Basin. Their location is shown in Fig. I.2.

The total administrative area and number of barangays in the city and in each municipality are shown below.

City/Municipality	Land Area (km^2)		No. of Barangays	
	Total	Basin	Total	Basin
Laoag City	107.5	63.2	80	60
San Nicolas	49.3	49.3	24	24
Sarrat	80.7	80.7	24	24
Dingras	100.2	100.2	32	32
Solsona	163.5	163.5	22	22
Piddig	179.7	150.8	23	23
Marcos	79.4	73.2	12	12
Banna	74.5	68.7	20	20
Nueva Era	644.7	480.4	11	9
Carasi	121.9	50.2	3	2
Vintar	512.9	51.9	33	7
Total	2,114.3	1,332.1	284	235

1.2.2 Population and Labor Force

The total population of the above 11 administrative units in the Basin (municipal population) was 218,800 in 1980 and 259,700 in 1990. According to the census in 1995, the municipal population amounted to 271,000 with an average population density of 128 persons/km^2. Out of this municipal population of 271,000, 196,000 or 73% resided within the basin area of 1,332.1 km^2 with an average population density of 148 persons/km^2 (basin population).

The average annual growth rate of the municipal population during 1980-1990 was 1.73%. However, it slowed down to 0.85% during 1990-1995. The average family size in the 11 administrative units was 5.2 persons in 1995.

The total municipal and basin populations in 2020 are projected to increase to 336,200 and 246,600, respectively, by assuming that the average annual growth rate in 1995-2020 is 0.9%. The municipal and basin populations of each city/municipality in 1995 and 2020 are shown below.

City/ Municipality	Municipal Population		Basin Population	
	1995	2020	1995	2020
Laoag City	87,800	110,700	39,900	50,300
San Nicolas	29,000	36,200	29,000	36,200
Sarrat	21,300	28,900	21,100	28,600
Dingras	31,500	35,600	31,500	35,600
Solsona	19,700	23,200	19,700	23,200
Piddig	17,800	21,100	17,600	20,900
Marcos	13,700	17,200	13,700	17,200
Banna	16,000	18,900	15,800	18,700
Nueva Era	6,200	14,200	5,000	11,400
Carasi	800	1,700	400	1,000
Vintar	27,400	28,400	3,400	3,500
Total	271,000	336,200	196,900	246,600

The total labor force of the above city and municipalities was 87,800 in 1990, of which 82,500 or 93.9% were employed. The unemployment rate of 6.1% is smaller than the 8.5% of the country in 1990.

1.2.3 Economic Profiles

In Ilocos Norte, the agricultural sector is the leading industry. The major crops in the province are palay (rice), garlic, corn, tomato, onion and mango in the order of production value. In the Basin, palay was harvested in an area of 37,200 ha with an average yield of 3.9 tons/ha in 1995.

There were 221 manufacturing establishments in the Basin in 1996 of which 178, or 81%, were located in Laoag City, San Nicolas and Sarrat.

The GRDP of Region I in 1995 was 58.25 billion pesos at 1995 prices. The service sector was the largest, followed by agriculture and industry. However, the agricultural sector absorbed the largest portion of labor force in Ilocos Norte Province in 1990. The shares of GRDP and employed labor force by sector in the region is summarized below.

Sector	GRDP (Region I, 1995)	Employment (Province, 1990)
Agriculture	40.4%	51.3%
Industry	15.9%	9.2%
Service	43.7%	36.5%
Total	100.0%	97.0%

Note: No data is available for the remaining 3.0% of employment.

Per Capita GRDP of the Basin in 1995 is estimated at ₱14,900 (US$580) at 1995 prices by assuming the same value as Region I. GRDP of Region I is projected to grow to 78.69 billion pesos in 2000, 123.97 billion pesos in 2010 and 168.23 billion pesos in 2020 by assuming that the annual growth rates are 6.20% for 1995-2000, 4.65% for 2000-2010, and 3.10% for 2010-2020. Hence, the Per Capita GRDP of Region I is estimated at ₱19,000 (US$740) in 2000, ₱25,800 (US$1,000) in 2010, and ₱31,600 (US$1,220) in 2020.

1.3 Land Use

1.3.1 Existing Land Use

The Basin covers a land area of 1,332.1 km^2 (133,210 ha) as mentioned before. Its existing land use is classified into mountain area, riverbed, cultivated land, residential area, lowland tree area, bush/grass land, riverwash area (sediment deposit area) and road/canal/creek area. The respective land areas are summarized as follows and shown in Fig. I.3.

Land Use	Area	
Mountain Area	93,562 ha	(70.2%)
River Bed Area	5,694 ha	(4.3%)
Cultivated Land	24,665 ha	(18.5%)
Residential Area	2,070 ha	(1.5%)
Lowland Tree Area	2,234 ha	(1.7%)
Bush/Grass Land	1,337 ha	(1.0%)
Riverwash Area	2,350 ha	(1.8%)
Road/Canal/Creek Area	1,298 ha	(1.0%)
Total	133,210 ha	(100.0%)

Among the above classification of land use, the bush/grass land and riverwash area covering a total area of 3,687 ha are considered to have been devastated due to the flooding and sediment deposition in the past.

1.3.2 Land Loss by Flood in the Past

A large cultivated land in the alluvial fan has been washed out by floods in the past. Land loss concentrates on the area along the Cura, Labugaon, Solsona and Madongan rivers. The cultivated land washed away during the recent 20 years (1975-1995) is estimated to be 1,130 ha by comparing the aerophotos taken in 1975 and 1996. On the other hand, 211 ha have been restored to cultivated land through the farmers' own effort.

The breakdown of washed out and recovered land by flooding zone is shown in Table I.1, while their locations are shown in Fig. I.4.

1.3.3 Future Land Use

The Provincial Planning and Development Office prepared a comprehensive land use plan of the province in early 1996. The proposed land use plan directs:

(1) the expansion of built-up area along the major road networks for residential, commercial and institutional purposes;

(2) the utilization of grassland and pasture as agricultural productive area;

(3) the development of sand dune and beach sand areas; and,

(4) the drastic reduction of bare land such as rocky/coral, river wash and barren/idle land by proper development.

The plan proposes to reduce the existing river wash area of 5,126 ha to 480 ha and the existing barren/idle land of 5,090 ha to 269 ha in the whole province. Large reduction of the river wash and barren/idle land is also expected in the Basin.

In the Basin, the existing river wash area and bush/grass land (barren/idle land) are estimated to be 3,687 ha of which 3,106 ha are located in the alluvial fans of the Cura/Labugaon, Solsona, Madongan and Papa rivers. These areas are utilized only for grazing of cattle and goats, but they could become agriculturally productive areas when protected from floods.

The 3,106 ha are classified into the following five (5) kinds of farmland according to land slope, soil properties and water availability:

Not usable land	:	213 ha
Available land for grazing (A)	:	753 ha
Available land for grazing (B)	:	819 ha
Available land for upland crop cultivation	:	513 ha
Available land for rice cultivation	:	502 ha
Road/canal/creek area	:	306 ha

The breakdown by district is shown in Table I.2, while their locations are shown in Fig. I.4. These lands may be developed gradually by farmers after they are convinced of their safety against floods.

Among the above classifications of farmland, the grazing (A) is suitable for low density grazing (15 ha/head) as is happening at present; while the grazing (B) land is applicable for medium density grazing (5 ha/head). Therefore, an area of approximately 1,800 ha can be converted to productive area for medium density grazing, upland crops and paddy without any special land reclamation works.

1.4 Related Infrastructure Development

The major infrastructure development related to the sabo and flood control works of the Basin are irrigation facilities and rural roads.

1.4.1 Irrigation Development

There are seven (7) major irrigation systems serving a total land of 12,205 ha in the Basin. They are the Ilocos Norte Irrigation Project Phase I (INIP I: 9,212 ha), the Cura RIS (431 ha), the Dingras RIS (1,018 ha), the Bonga Pump No. 1 (298 ha), the Bonga Pump No. 2 (674 ha), the Bonga Pump No. 3 (202 ha), and part of Laoag-Vintar RIS (370 ha). The locations of these irrigation areas are shown in Fig. I.5.

The INIP I aims to irrigate 10,200 ha in the alluvial fan area. The project included the construction of five (5) diversion dams at Labugaon, Solsona, Madongan, Papa and Bongo rivers, main and lateral irrigation/drainage canals, and related roads of 45 km. The project was completed in 1986 and it was serving an area of 9,212 ha as of 1996.

However, the project has frequently suffered from serious flood damage. To mitigate flood damage, some urgent disaster prevention works were implemented during 1991 to 1993. Full scale sediment and flood control works are considered essential for the protection of INIP I areas.

For further irrigation development of Ilocos Norte, INIP Phase II is now under consideration by NIA. The project consists of the Palsiguan Multipurpose Dam in the upstream of Abra River and the transbasin of water to the Nueva Era regulating dam, considering hydropower development of 42.8 MW, irrigation of 12,400 ha of new areas and supplemental water supply for the INIP I service area during the dry season.

1.4.2 Rural Road Development

The roads in the Basin were developed to some extent in the 1980's. These included the major projects; namely, (1) Ilocos Norte Rural Road Improvement Project; (2) Rehabilitation of Ilocos Norte-Apayao Road; (3) Extension of Ilocos Norte-Abra Road; and, (4) Link Road of Ilocos Norte Irrigation Project, Phase I.

However, roads in the Basin are still in poor condition. The road networks especially in the alluvial fan areas are disconnected at crossings with rivers/creeks due to annual flooding and frequent shifting of channels.

Roads run mostly in an east-west direction along the rivers/creeks and are not developed in the north-south direction to traverse the rivers and creeks. There are no bridges across the Solsona, Madongan and Papa rivers, and the Cura River is crossed by only one bridge. The existing road networks in the alluvial fan areas are shown in Fig. I.6.

Bridges and culverts are washed out or damaged by floods almost every year. Some villages, therefore, are isolated during flood season. Hence, sediment and flood control works are considered necessary to further enhance the road development in these areas.

CHAPTER II CLIMATE AND HYDROLOGY

2.1 General Climate

The climate in the Basin is characterized by two (2) distinct seasons: wet season (May to October) and dry season (November to April). The average annual rainfall at Laoag City during the period 1961-1995 was estimated at 2,135 mm with 97% concentrating in the wet season. The average monthly rainfall varies from 1 mm in February to 580 mm in August.

The temperature at Laoag City is recorded at 27.0°C on annual average. The month of January is the lowest at 24.5°C. The highest at 29.1°C occurs in May.

The Basin is affected by tropical cyclones (typhoons) every year. In the past 48 years approximately 250 cyclones hit or came close to Northern Luzon, bringing heavy rainfall on the Basin. The Basin suffers from big cyclones accompanied by daily rainfall of more than 50 mm three times a year on an average. About 75% of such big cyclones occur from July to September.

The tracks of the major cyclones which affected the Basin in the past are shown in Fig. I.7.

2.2 Hydrological Record Analysis

2.2.1 Rainfall and Water Level Observatory

There are 12 rainfall stations in or around the Basin, but hourly rainfall is available only at the PAGASA station in Laoag City because all the other stations observed only daily rainfall. This JICA Study installed three (3) automatic rainfall gauges at Piddig, Solsona and Nueva Era.

On the other hand, river water level has been periodically observed by staff gauge at three (3) stations: Gilbert Bridge of Laoag River, Cauplasan Bridge of Bongo River and Solsona Dam of Solsona River. Reliable records of the flood peak water level are available only at Gilbert Bridge. No flood hydrograph record is available in the Basin.

This JICA Study also installed three (3) automatic water level gauges at Gilbert Bridge, Cauplasan Bridge and Solsona Dam, to obtain flood hydrograph records. Locations of the existing and new rainfall and water gauges are shown in Fig. I.8.

2.2.2 Records of Typhoon Gloring, 1996

Typhoon Gloring brought a heavy storm rainfall on the Basin from July 23 to July 27, 1996, causing large floods in the entire stretch of the Laoag River. The track of the typhoon is shown in Fig. I.7.

Hourly rainfall was observed at the four (4) automatic rainfall stations mentioned above. Flood water level and velocity were also continuously recorded at the three (3) automatic gauging stations. The recorded rainfall depths at the four (4) stations are summarized below. As for the recorded hyetographs, refer to Volume III-1, Supporting Report, Appendix B.

Station	5-day Rainfall (Jul. 23-Jul. 27)	3-day Rainfall (Jul. 24-Jul. 26)	Maximum Hourly Rainfall
Laoag	705 mm	643 mm	51 mm (15:00-16:00, Jul.25)
Piddig	786 mm	741 mm	69 mm (16:00-17:00, Jul.25)
Solsona	689 mm	594 mm	30 mm (12:00-13:00, Jul.25)
Nueva Era	829 mm	795 mm	52 mm (12:00-13:00, Jul.25)

The observed flood peak discharges at three (3) stations are as follows.

Station	Peak Discharge(m^3/s)
Laoag	9,500
Cauplasan	4,800
Solsona	550

2.2.3 Historical Flood Records

The flood water level of the Laoag River has been observed at Gilbert Bridge for 37 years from 1959 to 1996. The largest flood was Typhoon Gening in 1967, followed by Wanda in 1962, Miding in 1986, Gloring in 1996, Maring in 1992 and Goring in 1977. Their peak water levels are shown below.

Typhoon	Water Level (m)	Discharge (m^3/s)	Return Period (year)
Gening, 1967	9.9	10,900	25
Wanda, 1962	9.8	10,800	24
Miding, 1986	9.4	9,700	15
Gloring, 1996	9.3	9,500	15
Maring, 1992	9.0	8,700	10
Goring, 1977	8.9	8,500	9

Their peak discharges were estimated from the respective peak water levels by using the rating curve prepared based on the observed water level and discharge data during Typhoon Gloring in 1996. The estimated peak discharges are also given in the above table.

2.2.4 Probable Flood Water Level and Discharge at Gilbert Bridge

The probable flood water level and discharge at Gilbert Bridge were estimated based on the records for 37 years as shown below.

Return Period	Water Level (m)	Discharge (m^3/s)
2-year	6.85	4,500
5-year	8.29	7,200
10-year	9.06	8,900
25-year	9.90	10,900
50-year	10.44	12,300
100-year	10.94	13,700

From these calculations, the probabilities of the historical floods were also estimated as shown in the previous table. The probability of the largest flood in the past, Gening in 1967, is estimated to be 25 years; while, that of Gloring in 1996 is equivalent to 15 years.

2.3 Flood Runoff Simulation

For the preparation of the sabo and flood control plan of the Basin, the design probable flood including flood peak as well as hydrograph should be determined for the major river stretches of the Basin. For this purpose, it is necessary to firstly determine the probable hyetograph and convert this hyetograph to hydrograph by using a simulation model.

2.3.1 Construction of Simulation Model

The Storage Function Method was employed for the flood runoff simulation of the Basin. To construct the flood runoff simulation model, the Basin was divided into 24 sub-basins and the River was divided into 19 sections. The river system model for the flood runoff simulation is illustrated in Fig. I.9.

Hourly rainfall and discharge records of Typhoon Gloring in 1996, which are required for the flood runoff simulation, are available. Therefore, the simulation model was constructed by calibrating the model based on the rainfall and discharge data of Typhoon Gloring.

Fig. I.10 shows a comparison of the computed discharge hydrograph to the observed one. As evident from this figure, the computed flood runoffs by the storage function model are in well agreement with the observed ones.

2.3.2 Estimation of Probable Flood Discharge

The probable peak discharge at Gilbert Bridge was obtained through the probability calculation of the discharge records in the past. However, the probable flood hydrograph was calculated from the representative hyetograph of the Basin by using the flood runoff simulation model. Similarly, the probable flood peak discharge and its hydrograph at other locations were calculated from the representative hyetograph of the Basin.

The rainfall distribution pattern for Typhoon Gloring is adopted in the calculation of probable flood peaks and hydrographs due to the following considerations:

(1) No hourly rainfall distribution records other than Typhoon Gloring are available.

(2) The total rainfall depth is large enough.

(3) Its regional distribution is comparatively uniform except that the rainfall at Solsona was smaller compared to the other stations.

(4) Further, its hourly distribution is considered typical, judging from the hourly rainfall records at Laoag in the past.

Hence, the rainfall pattern of Typhoon Gloring with some modifications was used for the calculation of probable flood discharges and hydrographs. The probable flood discharges at the major points were calculated, as shown in Fig. I.11. The probable flood discharge hydrographs at Gilbert Bridge are given in Fig. I.12.

2.4 Tidal Water Level

Tidal data at the Currimao Port which is located at about 20 km south of Laoag City are available in the Predicted Tide and Current Tables published by the National Mapping and Resource Information Authority (NAMRIA), DENR in 1996. The tidal water level at the mouth of the Laoag River was estimated from the above data, based on the datum line of National Bench Mark, as shown below.

Water Level	Elevation (m)
Mean Spring Higher High Water	+ 0.134
Mean Higher High Water	- 0.018
Mean Sea Level	- 0.302
Mean Low Water	- 0.586

CHAPTER III FLOOD DAMAGE ANALYSIS

3.1 Flood Damage Survey

The JICA Study Team conducted a detailed flood damage survey on major floods in the past through interview with the barangay captains in the flood prone areas. The data and information obtained include flood area, flood depth, affected population and inventory of existing assets. These data were used as supporting data for the estimation of probable flood damage.

The Basin is damaged by floods several times a year but the flood pattern is not always the same. Especially in the alluvial fan areas, the flood area varies to a considerable extent depending on the rainfall distribution of the typhoon. The potential flood area was estimated by considering the flood areas affected in the past.

The potential flood area covers 19,900 ha, equivalent to 14.9% of the total drainage area of the Basin, as delineated in Fig. I.13. The breakdown by city/municipality is shown below.

Municipality	No. of Flooded Barangays	Flood Area (ha)	Total Area (ha)	Ratio (%)
Laoag City	10	1,200	6,320	19.4
San Nicolas	6	300	4,930	6.1
Sarrat	18	700	8,070	8.7
Piddig	7	300	15,080	1.9
Carasi	0	0	5,020	0.0
Vintar	0	0	5,190	0.0
Dingras	26	4,200	10,020	41.9
Solsona	21	4,500	16,350	27.5
Marcos	10	3,900	7,320	53.6
Banna	11	3,500	6,870	49.2
Nueva Era	6	1,300	48,040	2.7
Total	115	19,900	133,210	14.9

3.2 Flood Simulation

The inundation areas and depths corresponding to the probable flood hydrographs of 2-year, 5-year, 10-year, 25-year, 50-year and 100-year were simulated by using the Two-Dimensional Unsteady Flow Model. The simulation was made by dividing the potential flood area into mesh blocks of 500 m × 500 m and putting hydraulic and topographic data into the respective meshes.

Further, the simulation was made on the following assumptions:

(1) Inundation is caused only by the flood discharge exceeding the carrying capacity of river channel and inundation due to local runoff is not included.

(2) The existing dikes of the Solsona, Madongan and Papa rivers are regarded as temporary ones; hence, their functions are not taken into account in the simulation.

(3) Blocking of floodwaters by such structures as roads is taken into consideration by assuming that there are water control weirs between the mesh blocks.

The total simulated inundation area of the basin by each probable flood is shown below. For the distribution of inundation area and depth, refer to Volume III-1, Supporting Report, Appendix C, Chapter IV.

Return Period (year)	2-year	5-year	10-year	25-year	50-year	100-year
Inundation Area (ha)	12,800	14,800	15,950	17,290	18,990	20,220

The inundation area of the Basin was divided into 19 sub-districts by flood water source and land use condition. The inundation areas of the sub-districts corresponding to each probable flood were estimated, as shown in Table I.3. The simulated inundation area for a flood with a 25-year return period by sub-district is shown in Fig. I.14.

Further, the inundation area and depth of a 100-year flood was simulated, as shown in Fig. I.15. This simulated area covering 20,200 ha well coincides with the potential flood area of 19,900 ha prepared based on the interviews with the barangay captains. (See, Fig. I.13.)

3.3 Flood Damage Estimation

3.3.1 Inventory of Damageable Assets

An inventory of the existing damageable assets in the above simulated inundation area was prepared through mesh analysis. In the inundation areas of 25-year and 100-year floods, 61,100 people and 78,900 people are residing, respectively. The inundation area and affected population of each sub-district corresponding to various probable floods are shown in Table I.3. The total existing damageable assets in the inundation areas of 25-year and 100-year floods are summarized below. As for the inventory of damageable assets by inundation sub-districts, refer to Volume III-1, Supporting Report, Appendix C, Chapter V.

Item	25-year Flood	100-year Flood
Dwelling Units	12,113	15,630
Agricultural Lands (ha)	10,988	13,222
Industrial Establishments (unit)	365	511
Infrastructure		
Educational Facilities (unit)	85	107
Health Facilities (unit)	21	29
Roads (km)	559.9	675.6
Irrigation Facilities(ha)	10,789	12,934

3.3.2 Value of Existing Damageable Assets

The present value of existing assets in the inundation area was calculated from the product of the inventory of assets and the unit damageable value. The total values in the inundation areas of 25-year and 100-year return period floods were estimated to be 2,240 million pesos and 2,832 million pesos, respectively, at 1996 prices, as broken down to the components in the table below. The values of existing damageable assets by inundation sub-district are shown in Table I.4.

Item	25-year Flood	100-year Flood
	(Unit: million pesos, 1996 price)	
Living Quarters	1,065.9	1,375.4
Crop Production	228.0	274.0
Industrial Establishment	76.3	105.7
Infrastructure	869.7	1,076.3
Educational Facilities	148.8	187.3
Health Facilities	71.0	105.2
Roads	145.0	178.5
Irrigation Facilities	504.9	605.3
Total	2,240.0	2,831.5

3.3.3 Probable Flood Damage

Flood damage in the Basin consists of direct damage and indirect damage. The direct damage includes the damage to house buildings, household effects, crops, industrial establishments and infrastructure.

Flood damage is estimated by multiplying the value of damageable asset by the damage rate. The value of damageable asset becomes larger according to the increase of inundation area; while, damage rate grows according to the increase of inundation depth.

The damage rates of house building, household effects and crops were determined based on the results of the interview survey with the barangay captains (refer to Volume III-1, Supporting Report, Appendix C, Chapter III). The damage rates of industrial establishments, educational and medical facilities were determined based on the rates developed in Japan. As for the damage rates used in this Study, refer to Volume III-1, Supporting Report, Appendix J, Table J.1.2.

Infrastructure damage is assumed to be 20% of the direct damage, referring to similar project studies in the Philippines. The indirect damage is assumed to be 10% of the total direct and infrastructure damages.

The total flood damage in the Basin by flood return period is estimated as follows:

Item	5-year Flood	25-year Flood	100-year Flood
Inundation Area (ha)	14,800	17,290	20,220
Affected Population	45,404	61,118	78,858
Damage (million ₱)	458.8	696.1	913.8

Note: Damages are at 1996 market prices.

The above flood damages are broken down into the 19 inundation sub-districts as shown in Table I.5. For further details, refer to Volume III-1, Supporting Report, Appendix C, Chapter V.

3.3.4 Average Annual Flood Damage

The average annual flood damage was calculated by using the following formula.

$$D = \sum 1/2[D(Qi\text{-}1) + D(Qi)]\cdot[P(Qi\text{-}1) - P(Qi)]$$

where;

D	:	average annual flood damage
D(Qi-1), D(Qi)	:	flood damage caused by flood with Qi-1 and Qi discharge, respectively
P(Qi-1), P(Qi)	:	probabilities of occurrence of Qi-1 and Qi discharge, respectively

The average annual flood damage of the Basin was calculated for floods below various return periods. The total average annual flood damages below 25-year and 100-year return periods under the present socio-economic conditions are shown below at 1996 market prices.

(Unit: million ₱ at 1996 market prices)

		Present	2000 year	2010 year	2020 year
(1)	Below 25-year Floods	278.0	336.5	494.7	665.3
(2)	Below 100-year Floods	302.0	365.8	537.8	723.2
(3)	(1) / (2) (%)	92	92	92	92

The total average annual flood damage under future socio-economic conditions was also estimated as shown above. In this estimation, the value of damageable assets is assumed to increase in the future in proportion to the growth of population and GRDP. The average annual growth rates of the population and GRDP are assumed as follows:

Population	:	0.90% for 1995 - 2020
GRDP	:	6.20% for 1995 - 2000 4.65% for 2000 - 2010 3.10% for 2010 - 2020

As shown in the above table, approximately 90% of the total flood damage is generated by floods below 25-year return period on annual average. The above average annual flood damages estimated in financial value are converted to economic value, as shown below.

(Unit: million ₱ at 1996 prices)

	Present	Year 2000	Year 2010	Year 2020
Below 25-year Floods	238.1	288.2	423.6	569.7
Below 100-year Floods	258.4	313.0	460.3	618.9

Note: Damages are expressed in terms of economic value.

The average annual flood damages in economic value under present and future socio-economic conditions by inundation sub-district are shown in Table I.6.

CHAPTER IV WATERSHED AND RIVER CONDITIONS

4.1 Watershed Conditions

4.1.1 Geology

The geology of the Laoag River Basin is composed of the following 11 stratigraphic sequences:

(1) Recent Sand Dunes (Rsd)
(2) Recent Alluvium (R)
(3) Recent Alluvial Fan Deposits (Raf)
(4) Plio-Pleistocene Sediments (N3)
(5) Middle to Upper Miocene Limestone (N2Ls)
(6) Middle to Upper Miocene Sediments (N2);
(7) Plio-Pleistocene Volcanic (QV)
(8) Neogene Intrusive (NI)
(9) Lower Miocene Volcanic (VA)
(10) Cretaceous - Paleogene Volcanic (Kpg)
(11) Cretaceous-Paleogene Intrusive (UC)

The eastern watersheds of the Basin is mainly covered by Neogene Intrusive and Cretaceous-Paleogene Volcanic. Neogene Intrusive is highly weathered in many places, disintegrating into thick loose granular material. The weathered portions are highly porous and permeable. This rock extends over the middle to lower portions of Cura, Labugaon, Solsona and Madongan watersheds. On the other hand, Cretaceous-Paleogene Volcanic constitutes the core of the Central Cordillera Mountains which extends over the eastern watersheds of the River. They are highly faulted and jointed with fracture zone in some places.

The geological formation of the Basin is shown in Fig. I.16.

4.1.2 Reforestation

The watersheds of the Basin have been denuded or devastated due to logging for fuel, commercial logging and slash-and-burn agriculture since the early 17th century. DENR is undertaking the following eight (8) projects with a total area of 47,111 ha to rehabilitate and manage the watersheds.

Commercial Forest Project	:	12,812 ha
Regular Reforestation Project	:	10,817 ha
Upland Contract Rehabilitation Project	:	1,951 ha
Integrated Social Forestry Project	:	2,331 ha
Industrial Tree Plantation Project	:	50 ha
Sectoral Adjustment Loan Project	:	2,100 ha
The Philippine Forestry Development Project II	:	16,000 ha
Industrial Forest Management Agreement Project	:	1,050 ha
Total	:	47,111 ha

Locations of the above projects are shown in Fig. I.17.

4.2 Flood Plain Topography

The topography of the flood plain is classified into the following eight (8) micro-topographic components. The micro-topography of the flood plain is shown in Fig. I.18.

(1) Alluvial Fan

The major alluvial fans are formed by the sediment deposits of the Cura, Labugaon, Solsona, Madongan, Papa and Bongo rivers. The alluvial fans of the Solsona, Madongan and Papa rivers are widespread, while those of the Cura, Labugaon and Bongo rivers are confined within a long but narrow area by the surrounding terraces and hills.

The above alluvial fans are rugged due to the existence of old channels, gully erosion and natural levee. Floodwaters overflowing the main rivers easily run down along the old channels, depositing much sediment.

(2) Valley Plain

The valley plains are mainly formed along the Guisit River where hills and plateaus restrict the development of fan-shaped topography. Flood water flows down the entire section of the valley plain during a large flood.

(3) Flood Plain

Flood plains develop on the left bank of the Laoag-Bongo River between the confluence with the Papa and Guisit rivers, and on both banks of the lower reaches of the Laoag River. The flood plains are a few meters higher than the existing riverbeds, forming the topography like terrace. Therefore, flood plains are not submerged by a small scale flood.

(4) River Terrace

The major river terraces are located along the right bank of the Cura River and left bank of the Upper Bongo River. The river terrace along the Cura River is of the type with a few steps. The lowest terrace is situated about 10 m above the alluvial fan surface, while the highest terrace is about 40 m above. On the other hand, the terrace along the Upper Bongo River is of single step type and located 20-30 m above the existing riverbed. Both poblacions of Banna and Nueva Era are located on this terrace.

(5) Sand Dune

An unstable sand dune extends over 1.0-1.5 km wide along the coastal line at both sides of the river mouth. A stable sand dune developed in the hinterland of the unstable sand dune.

(6) Natural Levee

Natural levees develop in some parts of the banks along the Laoag River and alluvial fan complex. Laoag City and the poblacions of San Nicolas, Sarrat and Solsona are situated on this natural levee.

(7) Old River Channel

There are many old river channels in the alluvial fan complex, especially in the alluvial fans of the Solsona, Madongan and Papa rivers. Old river channels were also identified in the flood plain of the lower reaches of the Laoag River. Once the main river is flooded, the flood water tends to rush down along these old river channels.

(8) Riverbed and Sand Bar/High Water Bank

The existing river channel is composed of riverbed and sandbar/high water bank. The high water bank is 2-5 m higher than the riverbed. The high water bank is generally submerged by such small scale flood as a 2-year one.

4.3 River Morphology

4.3.1 River Profile

The Laoag River system consists of the six (6) principal rivers; namely, Laoag, Bongo, Cura/Labugaon, Solsona, Madongan and Papa. The Laoag River and the lower part of Bongo River flow down through the alluvial plain, while the upper part of Bongo River and the other tributaries run through the alluvial fan. The river conditions of both groups are obviously different. The geomorphologic characteristics of the rivers are summarized below.

(1) Alignment, Slope and Width

The Laoag and Lower Bongo rivers running through the alluvial plain are comparatively mild in slope. However, the slopes of the other rivers in the alluvial fans are all very steep except the lower end of Solsona River. The slope exceeds 1/70 in the uppermost reaches of Solsona and Papa rivers. The Solsona, Madongan and Papa rivers are confined by temporary dikes, while the other rivers flow within the natural banks.

The Laoag River has two (2) big natural river bends which govern the river stream direction at flood time. Solsona has small artificial bends at five (5) locations. They are also considered to have significant effects on the flood flow direction.

The Cura River consists of a number of distributaries with braided river streams. The Upper Bongo is also much braided in some river sections.

The alignment, slope, width and other features of the rivers are summarized below.

River	Length (km)	Slope (%)	Width (m)	Alignment, No. of Bends	Remarks
Laoag	31.6	0.021-0.090	400-1,000	2	no dike
Lower Bongo	11.0	0.151-0.200	300-600	0, straight	no dike
Upper Bongo	12.0	0.311-0.943	300-400	1, much braided	no dike
Cura/Labugaon	17.0	0.331-1.080	100-1,000	many distributaries	no dike
Solsona	11.5	0.137-1.540	230-330	5	with dikes
Madongan	9.5	0.452-1.350	300	1, almost straight	with dikes
Papa	7.5	0.540-1.850	223	1, almost straight	with dikes

(2) Sandbar and Bank Erosion

In the river channel of the alluvial plain, sandbars are generally formed in the bed and as a result, a pool (where river stream converges and water depth is deep) and a shoal (where river stream diverges and water depth is shallow) appear alternately in the longitudinal direction. Bank erosion usually occurs at the pool, sometimes causing lateral shifting of the river channel.

The forms of sandbar are roughly classified into three (3) types: single row bar, double row bar and scale-like bar. Size of the sandbar becomes larger in the order of scale-like, double and single.

Generally, a large-sized sandbar causes a larger bank erosion. The size of sandbar is usually measured by its wave length.

Further, the sandbar moves downward during floods, being accompanied by the movement of stream convergence point. The movement of stream convergence point brings about a new bank erosion at the downstream. Finally, the movement of sandbar causes bank erosion at every river section. However, if the movement of sandbar is restricted by some river morphological characteristics, bank protection works can be concentrated on some limited river sections.

The features of the existing sandbars in the respective rivers were established, as follows.

River	Type	Wave Length (km)	Movement
Laoag	single	3-5	restricted by bends
Lower Bongo	single/double	2	restricted by tributary joining
Upper Bongo	lower part : single	1.2	easy
	upper part : scale-like	small	
Cura/Labugaon	single	1.2	easy
Solsona	single	1-2	restricted by tributary joining and bends
Madongan	double	1	easy
Papa	single	1.2	not easy, a little restricted

The morphologies of the above rivers are shown in Fig. I.19(1) to Fig. I.19(9).

4.3.2 Historical Change of River Course

The Laoag River had no considerable change of river course in the past. The river alignment has been stable due to the existence of two (2) big natural bends. The alignment of Bongo River also has been comparatively stable although it has always been pushed against its left bank at the confluence with the major tributaries.

However, the tributaries in the alluvial fan, especially the Cura/Labugaon, Solsona and Madongan rivers have changed much in their courses. Their main streams have shifted at the fan apexes in a wide range.

The changes of river course of Laoag, Bongo and the other major tributaries in the past 50 years are illustrated in Fig. I.20.

4.3.3 River Mouth Clogging

The mouth of Laoag River is always clogged during the dry season. At the beginning of the rainy season, a drain channel is formed by even a small scale flood. The river mouth is easily opened at an early stage of a large flood. Hence, no significant backwater effect is caused by river mouth clogging.

4.3.4 Riverbed Materials

The grain size distribution of riverbed materials varies from upstream to downstream. Its typical distribution is shown below.

Sediment Size	Fan Apex / Middle Fan Reach	Fan End	Laoag River
Large Cobble/Small Boulder (128-512 mm)	8%	-	-
Very Coarse Pebble/Small Cobble (32-128 mm)	21%	16%	10%
Medium/Coarse Pebble (8-32 mm)	29%	32%	22%
Very Fine/Fine Pebble (2-8 mm)	23%	25%	35%
Sand (0.125-2 mm)	19%	27%	33%

4.3.5 Flood Carrying Capacity of Rivers

The existing flood carrying capacity of rivers was assessed by the non-uniform flow calculation method by assuming that Manning's roughness coefficient is $n = 0.035$ for the Laoag, Lower Bongo and Guisit rivers and $n = 0.04$ for the other upstream reaches.

In this calculation, the flood carrying capacity was assumed as the bankful capacity for the river sections with no dike. For rivers with dikes, proper freeboards were considered in the estimate. The estimated flood carrying capacity of rivers is summarized as follows.

River	Discharge (m^3/s)	Return Period (year)
Laoag	2,000-5,000	2-4
Bongo	500-2,000	5
Guisit	500-1,000	2-10
Cura/Labugaon	500-2,000	1-10
Solsona	1,000-1,300	25
Madongan	2,000	25
Papa	1,000-1,500	100

The Basin is frequently flooded due to its small flood carrying capacity. Even the lands along the Solsona, Madongan and Papa are exposed to a high flood risk because the existing dikes are temporary ones. However, the central part of Laoag City is protected by a high riverbank which can carry 11,000 to 12,500 m^3/s with return periods of 25 to 50 years.

4.4 Existing River Structures

The existing structures along/in the river channels of Laoag-Bongo and its major tributaries are: (1) river control structures such as dikes, spur dikes and revetment; (2) irrigation facilities such as diversion dam, pumping station and intake; and (3) other related structures including bridge, roadway crossing and drainage openings/culvert. Locations of the existing river structures are shown in Fig. I.21.

The dikes along the Solsona, Madongan and Papa rivers are the largest river control structures in the Basin although they are regarded as temporary ones from the structural aspect. They were constructed from 1991 to 1993 under the Urgent Disaster Prevention Works, as a part of INIP I. Major features of the urgent works are summarized below.

Item	Solsona	Madongan	Papa
Design Flood Frequency (yr.)	20	20	20
Design Flood Discharge (m^3/s)	940-2,670	1,620	780
Channel Length (km)	11.1	8.5	7.4
Channel Width (m)	230-330	300	223
Bed Slope	1/76 - 1/714	1/114 - 1/190	1/60 - 1/200
Levee Length (km)	19.6	13.0	12.2
Channel Excavation (1,000 m^3)	1,361	1,227	712
Levee Embankment (1,000 m^3)	647	436	299

CHAPTER V SEDIMENT BALANCE

5.1 Sediment Yield in Watershed

The eastern watersheds of the Basin are the major sources of the sediment runoff to the Laoag River. They cover the upper basins of Cura, Labugaon, Solsona, Madongan, Papa and Bongo rivers and other small tributaries.

5.1.1 Micro-topographical Features

The watersheds have experienced a number of large scale slope failures and land slides in the past, forming riverbed deposits, debris flow deposits, flood terrace, river terrace and colluvial slopes in many locations of the valleys. Further, the watersheds are still being affected by large-scale slope failures in many locations and threatened by the existence of many large-scale land slide prone areas.

Such micro-topographical features of the watersheds were analyzed by interpretation of the aerophoto taken in 1991. The micro-topographical features of the Cura, Labugaon, Solsona, Madongan, Papa and Bongo watersheds are shown in Fig. I.22(1) to Fig. I.22(3).

As evident from the figures, all the above watersheds are high potential sources of sediment runoff to the downstream.

5.1.2 Estimation of Annual Sediment Yield

The sediment yield of the watersheds is mainly caused by slope failure. Sediment runoff from the deposits in the valley is not considered as sediment yield of the watersheds but secondary yield. Hence, the sediment yield of the watersheds is estimated by identifying the existing slope failures in the watersheds.

There are two (2) available aerophotos for the watersheds, which were taken in 1991 and 1996. The slope failure areas of the watersheds in 1991 and 1996 were measured by interpreting those aerophotos.

There were 7,309 slope failure sites with a total area of 636.8 ha, equivalent to 1.20% of the total watershed area of 529.8 km^2 in September, 1991. On the other hand, the total site number and area were 8,901 sites and 595.7 ha (1.12% of total watershed area) in April, 1996.

The total area of slope failure diminished from 636.8 ha in 1991 to 595.7 ha in 1996. It is because 205.6 ha were recovered by vegetation during this period of 4.5 years, while a slope failure area of 164.5 ha was newly formed during the same period.

Once slope failure occurs, loose sediment is suddenly yielded in large volumes. Thereafter, the bared slope is eroded by rainfall and this surface erosion continues even after the area is covered by vegetation. The above suddenly yielded volume is estimated by multiplying the slope failure area by failure depth. The surface erosion volume is estimated by assuming the average erosion rate as 50 mm/year.

Based on the above assumptions on sediment yield mechanism, the total sediment yield of the watersheds during the period of September, 1991 to April, 1996 is estimated at 5,543,000 m^3. It is equivalent to 2,320 m^3/year/km^2 of specific sediment yield. The breakdown by river basin is shown below.

River	Catchment Area (km²)	September 1991 to April 1996			Specific Yield (m^3/yr./km²)
		Slope Failure (1,000 m^3)	Surface Erosion (1,000 m^3)	Total (1,000 m^3)	
Cura	69.5	465	196	661	2,110
Labugaon	100.5	543	363	906	2,000
Solsona	79.0	674	228	902	2,540
Madongan	153.8	1,122	350	1,472	2,130
Papa	51.4	260	114	374	1,620
Bongo	57.0	1,015 (265)	104	1,119 (369)	4,360 (1,440)
Others	18.6	75	34	109	1,300
Total	529.8	4,154 (3,404)	1,389	5,543 (4,793)	2,320 (2,010)

Note: Figures in parentheses exclude the abnormal landslide in Bongo watershed.

In this period of 4.5 years, Bongo watershed suffered from a large landslide of 750,000 m^3. This is considered as an abnormal event. Then, if this event is neglected, the sediment yield of the Bongo River Basin in this period decreases to 369,000 m^3, which is equivalent to 1,440 m^3/year/km². As a result, the total watershed sediment yield diminishes to 4,793,000 m^3 or 2,010 m^3/year/km².

5.1.3 Sediment Deposits in Valley

The existing sediment deposits in the valley are the largest sources of secondary sediment yield in the watersheds. The total volume is estimated at 26,442,000 m^3, which is equivalent to 51,700 m^3/km², with the following breakdown.

River	Catchment Area (km²)	Deposit Volume (1,000 m^3)	Specific Volume (m^3/km²)
Cura	69.5	2,854	41,100
Labugaon	100.5	5,694	56,700
Solsona	79.0	1,448	18,300
Madongan	153.8	12,125	78,800
Papa	51.4	2,395	46,600
Bongo	57.0	1,926	33,800
Total	511.2	26,442	51,700

5.2 Annual Sediment Runoff

5.2.1 General

Not all sediment yielded in the watersheds go to the downstream rivers. Some portions are deposited in the valley. On the other hand, part of the existing sediment deposits in the valley is transported downwards.

Fluvial sediments in transit consist of wash load, bed load and suspended load.

(1) Wash Load

The wash load is very fine in size and it originates from the surface of the land. The wash load discharge is usually estimated by constructing the wash load rating curve. The JICA Study Team established the wash load rating curve for the Laoag River at Gilbert Bridge based on the sampling test during Typhoon Gloring in1996, as shown below.

$Q_S = 1.274 \times 10^{-6} Q^{1.697}$

Where, Q_S is wash load in m^3/s and Q is water discharge in m^3/s.

(2) Bed Load

The bed load is transported downwards rolling or sliding on the surface of riverbed. It is always in contact with the riverbed and is not suspended by all means. The actual mode of movement varies, depending on the transport rate determined by the balance of the shear stress of flood flow and critical shear force of the grain itself. The bed load discharge of the Laoag River is calculated by using Ashida & Michiue's Equation which is widely used in Japan.

(3) Suspended Load

The suspended load is transported downwards, floating in the river water. It does not go in contact with the riverbed all the time. Its settling force is smaller than the upward component of turbulence force of the river water. The size of suspended load is in a wider range than that of wash load. It includes coarse sand. The suspended load discharge of the River is calculated also by using Ashida & Michiue's Equation.

5.2.2 Calculation of Annual Sediment Runoff

(1) Representative Average Year

The hydrological average year needs to be selected to calculate the average annual sediment runoff of the Basin. In this Study, the year 1968 is defined as the hydrological average year from the annual rainfall records at Laoag City for the past 35 years.

(2) Annual Wash Load Runoff

The average annual wash load runoff of the Basin was calculated by using the flood duration curve of 1968 and sediment rating curve at Gilbert Bridge of Laoag City. It is estimated to be 462,900 m^3, which is equivalent to a specific sediment runoff of 350 m^3/year/km^2. This is the annual wash load runoff to the sea.

(3) Annual Bed and Suspended Load Runoff

The average annual sediment transport including bed load and suspended load was computed for major locations by using the simulated flood discharge data in 1968. The annual sediment runoff from the mountains to the six (6) major tributaries in the alluvial fan (at fan apexes) is estimated as follows.

River	Catchment Area (km^2)	Annual Sediment Runoff (m^3)	Specific Sediment Runoff (m^3/yr./km^2)
Cura	69.5	54,600	790
Labugaon	100.5	154,700	1,540
Solsona	79.0	114,500	1,450
Madongan	153.8	223,100	1,450
Papa	51.4	99,600	1,940
Bongo	57.0	78,300	1,370
Total	511.2	724,800	1,420

Further, an average annual sediment runoff (bed and suspended loads) of 8,200 m^3 is expected from Guisit River. On the other hand, the average annual sediment runoff of bed and suspended loads at Laoag City is estimated to be 107,100 m^3, which is equivalent to 80 m^3/year/km^2.

(4) Annual Sediment Balance of the Basin

From the above discussions, the annual sediment balance of the Basin is collectively estimated as follows.

(1)	Annual Sediment Yield in Watershed	:	1,065,100 m^3 (2,010 m^3/year/km^2)
(2)	Annual Sediment Runoff at Fan Apexes	:	903,700 m^3 (1,770 m^3/year/km^2)
	- Wash Load	:	178,900 m^3 (350 m^3/year/km^2)
	- Bed and Suspended Loads	:	724,800 m^3 (1,420 m^3/year/km^2)
(3)	Annual Sediment Runoff from Giusit River	:	70,600 m^3 (400 m^3/year/km^2)
	- Wash Load	:	62,400 m^3 (350 m^3/year/km^2)
	- Bed and Suspended Loads	:	8,200 m^3 (50 m^3/year/km^2)
(4)	Annual Sediment Runoff from Remaining Area	:	221,600 m^3 (350 m^3/year/km^2)
	- Wash Load	:	221,600 m^3 (350 m^3/year/km^2)
	- Bed and Suspended Load	:	Negligibly small
(5)	Annual Sediment Runoff to Sea	:	570,000 m^3 (430 m^3/year/km^2)
	- Wash Load	:	462,900 m^3 (350 m^3/year/km^2)
	- Bed and Suspended Load	:	107,100 m^3 (80 m^3/year/km^2)

All the wash loads generated are transported to the sea. However, a considerable portion of the bed and suspended load runoffs from the watersheds is deposited in the bed of Laoag River. This average annual deposition is estimated to be 625,900 m^3 (i.e., 733,000 m^3 less 107,100 m^3).

This deposition is not distributed uniformly over the whole river stretches of the Basin. It rather concentrates on the alluvial fan as shown below.

(1)	Around the alluvial fan apexes	:	192,400 m^3 (31%)
(2)	Middle reaches in alluvial fan	:	288,800 m^3 (46%)
(3)	Around the alluvial fan ends	:	50,700 m^3 (8%)
(4)	In the Lower Bongo River	:	16,100 m^3 (3%)
(5)	In the Laoag River	:	77.900 m^3 (12%)
	Total	:	625,900 m^3 (100%)

The annual sediment deposition and average riverbed aggradation in each river are estimated as follows.

River	Annual Deposition (1,000 m^3/yr)	Channel Length (km)	Channel Width (m)	Annual Aggradation (cm/yr)
Cura/Labugaon	144.2	15.0	320	3.0
Solsona/Madongan	270.1	19.5	270	5.1
Papa	72.7	7.2	210	4.8
Upper Bongo	44.9	11.8	240	1.6
Lower Bongo	16.1	10.8	390	0.4
Laoag	77.9	31.5	540	0.5
Total	625.9	95.8		

5.2.3 Sediment Balance During Large Flood

Sediment runoff from the mountains to the alluvial fan at a big flood is considered very large. On the other hand, the sediment transport capacity of the river channel is limited. Hence, the riverbed of the tributaries in the alluvial fan, especially that around the fan apex, may be much aggraded during a big flood.

Therefore, the sediment balance at the fan apex during a large flood of a 25-year return period is estimated for the six (6) major tributaries. The balances are summarized below.

River	Sediment Transport Volume (1,000 m^3)		
	Inflow to Alluvial Fan	Transport at Fan Apex	Balance
Cura	71.3	42.6	28.7
Labugaon	185.2	112.8	72.4
Solsona	166.9	108.9	58.0
Madongan	454.5	302.8	151.7
Papa	147.3	93.0	54.3
Upper Bongo	97.5	63.4	34.1
Total	1,122.7	723.5	399.2

From the above table, the following matters are confirmed.

(1) A 25-year flood will bring a large amount of sediment (1,122,700 m^3) to the alluvial fan in a very short time. This is equivalent to 1.5 times the average annual sediment runoff (724,800 m^3).

(2) The fan apexes will suffer from a large amount of sediment deposit even in one flood. The total deposit at the apexes of the six (6) major tributaries is estimated at 399,200 m^3.

(3) Hence, control of the sediment runoff during a big flood is essentially required.

CHAPTER VI RIVER ENVIRONMENT

The existing environmental situations in the Laoag River Basin, especially those related to the sabo and flood control works are summarized below.

(1) Water Quality

The water in the River is clean at any point from upstream to downstream. All the parameters are within the standards for Class A of DENR Water Quality Criteria except suspended solids (SS). There are only two (2) water pollutive firms in the Basin. Both firms are provided with the necessary wastewater treatment facilities.

(2) Vegetation

Vegetation of the Basin is in poor condition. DENR is now undertaking various reforestation projects to rehabilitate and manage the watersheds.

(3) Sand Dune

Sand dunes covering 3,350 ha extend along the coastal line from Currimao in the south to Bacarra in the north. The Laoag River passes through the center of this sand dune coastal line. The National Committee on Geological Sciences intends to establish these sand dunes as one of the National Geological Monuments.

(4) Fishery

People living in the riversides catch freshwater fish in the dry season. Major catches are gubis and freshwater shrimps. In the brackish water zone and its tributary creeks, fishing is more active. Major fish catches in this area are tilapia, mullet, shrimps and tiger prawns. Another fishing activity is the gathering of milkfish fry at the estuary of the River.

The total production of fresh and brackish water fish in the Basin is estimated at 80 tons per annum.

(5) River Water Use

The river water is mainly used for irrigation purposes. No water for drinking is taken from the river and all potable water is supplied from springs and deep wells. Washing of clothes can be seen at some places in the river. Water vegetables and root crops such as Kangkong and Gabi are cultivated at some shallow sections of the river.

There are several water recreation spots in the Basin. These are the irrigation diversion dams at the alluvial fans, Karingking Mountain Resort at Solsona River, Bato River Resort at Sarrat and Bagbag Bridge of Cura River.

(6) Tourism Attraction

Approximately 75,000 tourists visited Ilocos Norte Province in 1995. Among them, 50% were foreign tourists mostly from Taiwan.

The tourist spots are the sand dune beaches, and the old churches and monuments located at Laoag City, Sarrat and Dingras.

(7) Ethnic Minorities

The ethnic minorities of the Basin dwell in the mountain areas of Nueva Era, Marcos, Dingras, Solsona and Carasi. They are Tingguians, Itnegs and Isnegs. They form

11 barangays with a total households of 370. Most of them work by ancestral cropping and in the reforestation projects of the Government.