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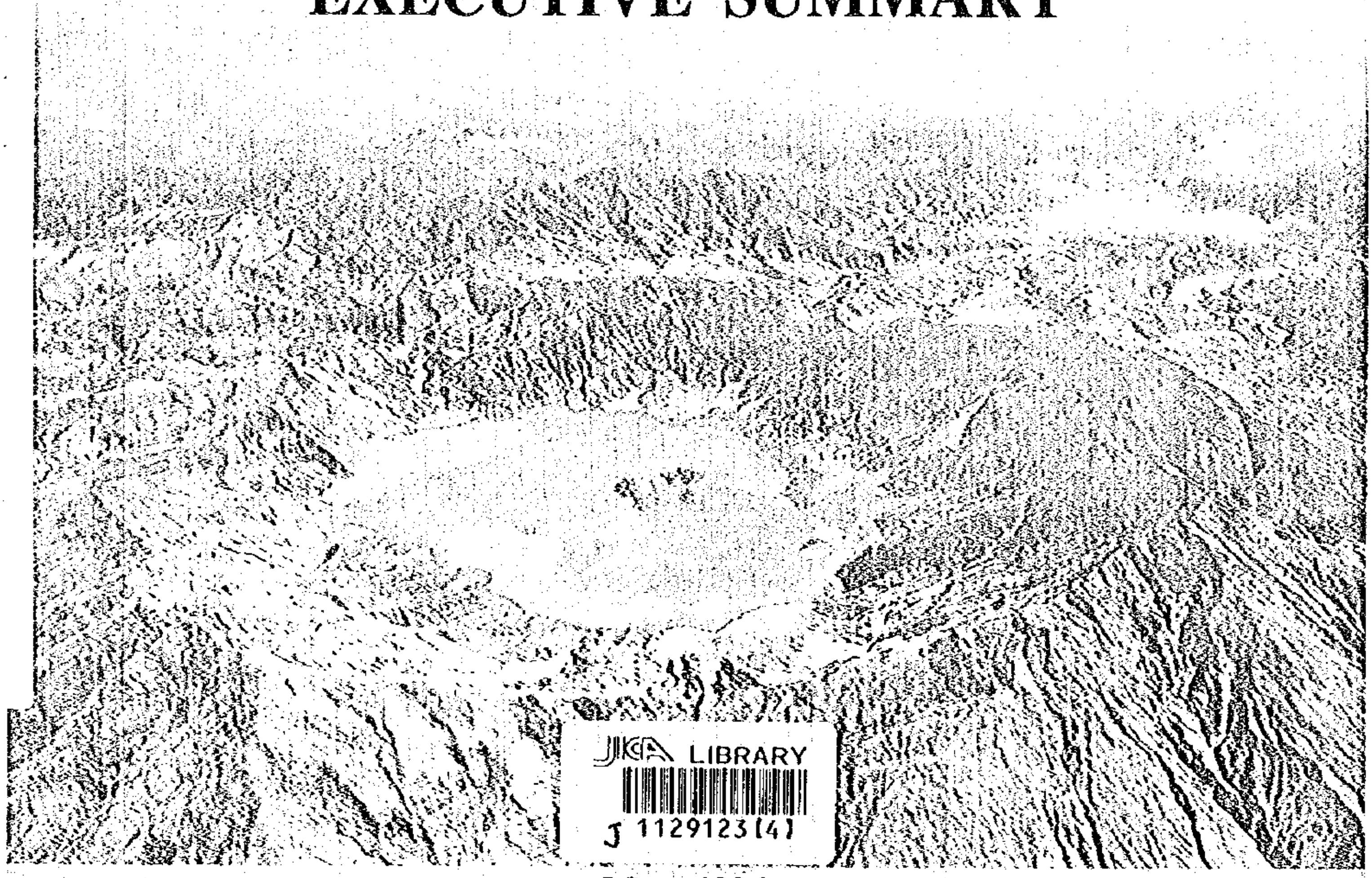
JAPAN INTERNATIONAL COOPERATION AGENCY

THE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS
THE GOVERNMENT OF THE PHILIPPINES

THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA - BAMBAN / ABACAN RIVER DRAINING FROM MT. PINATUBO

EXECUTIVE SUMMARY



May 1996

NIPPON KOEI Co., Ltd., Tokyo Japan
in association with
CTI ENGINEERING Co., Ltd., Tokyo Japan

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LIST OF REPORT

EXECUTIVE SUMMARY

MAIN REPORT

APPENDIX I   MASTER PLAN STUDY

A. Socio-economy
B. Flood/Mudflow Damages
C. Geomorphology
D. Meteo-hydrology
E. Land Use
F. Sediment Balance
G. Lahar Analysis
H. Flood Control/Sabo Structures
J. Road Network Development
K. Agricultural Development
L. Lahar Material Survey
M. Resettlement/Evacuation
N. Flood Warning System
P. Initial Environmental Examination
Q. Remote Sensing Analysis
R. GIS Data Analysis

APPENDIX II   FEASIBILITY STUDY

A. Flood/Mudflow Control Works
B. Road and Bridges
C. Construction Plan / Cost Estimate
D. Environmental Impact Assessment
E. Project Evaluation

DATABOOK (*)

DB.1 Socio-economic Data
DB.2 Hydrological Data
DB.3 Geotechnical Data
DB.4 Sediment Data
DB.5 Extent of Damage
DB.6 GIS Data Dictionary

OPERATION AND MAINTENANCE MANUAL (*)

OM.1 Hydrological Gauging Equipment
OM.2 GIS Training

Note : Marked (*) shows the limited number of copies.

Remarks : The cost estimate in this Study was based on the November 1995 price level, and expressed in Philippine Pesos equivalent according to the exchange rate Philippine Peso 25.0 = Japanese Yen 100.0 (= US dollars 1.0) prevailing at that time.

PREFACE

In response to a request from the Government of the Republic of the Philippines the Government of Japan decided to conduct a study on flood and mudflow control for Sacobia-Bamban/Abacan river draining from Mt.Pinatubo and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to the Philippines a study team headed by Mr. Noriaki Hirose and composed of members of Nippon Koei Co., Ltd. and CTI Engineering Co., Ltd. from November, 1993 to March, 1996.

The team held discussions with officials concerned of the Government of the Philippines, and conducted field surveys in 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.

May, 1996

Kimio Fujita
President
Japan International Cooperation Agency

JAPAN INTERNATIONAL COOPERATION AGENCY
THE STUDY ON FLOOD AND MUDFLOW CONTROL FOR SACOBIA-BAMBAN/ABACAN RIVER DRAINING FROM MT.PINATUBO

Mr.Kimio Fujita
President
Japan International Cooperation Agency,
Japan

May, 1996

Dear Sir,

LETTER OF TRANSMITTAL

We are pleased to submit herewith the Final Report of "the Study on Flood and Mudflow Control Work for Sacobia-Bamban/Abacan River draining from Mt.Pinatubo". The Report has been prepared for the Government of the Republic of the Philippines as a guideline for consideration when implementing the flood and mudflow control works in Sacobia-Bamban and Abacan river basins affected by the 1991 eruption of Mt.Pinatubo in central Luzon.

The main outputs from the Study are broadly grouped into three components. One is the master plan and feasibility study for Sacobia-Bamban river basin. The Plan shows the effective use of sand pocket structure and the combination of flood control works as permanent structure. This includes the concept of future agricultural restoration plan in lahar disaster area as long term plan. The second output is the master plan and feasibility study for Abacan river basin. The plan indicates the reconstruction and rehabilitation works of existing sabo and flood control structures to make them possible to be permanent structures. The other output is the sediment monitoring in the Pasig river basin. On the basis of the results of monitoring on sediment deposition and geomorphologic change, potential lahar disaster areas are specified for the future implementation of structural measure.

The study team also submitted disaster and hazard maps which specify the potential disaster prone area for enhancing the effective warning dissemination system as a non-structure measure.

All members of the Study Team wish to express grateful acknowledgment to the personnel from your Agency, Advisory Committee, Ministry of Foreign Affairs, Ministry of Construction, and Embassy of Japan in Philippines as well as the officials and individuals from Philippines for the kind assistance extended to the Study Team. The Study Team sincerely hopes that the results will contribute to restoration of the affected area by the Pinatubo eruption in particular and to promote the future implementation of flood and mudflow control works and her socioeconomic development and well-being in general.

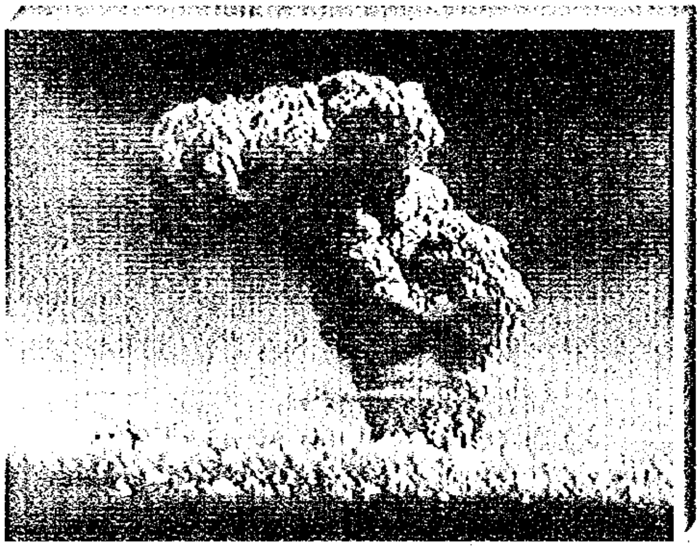
Yours sincerely,

Noriaki Hirose
Team Leader

TABLE OF CONTENTS

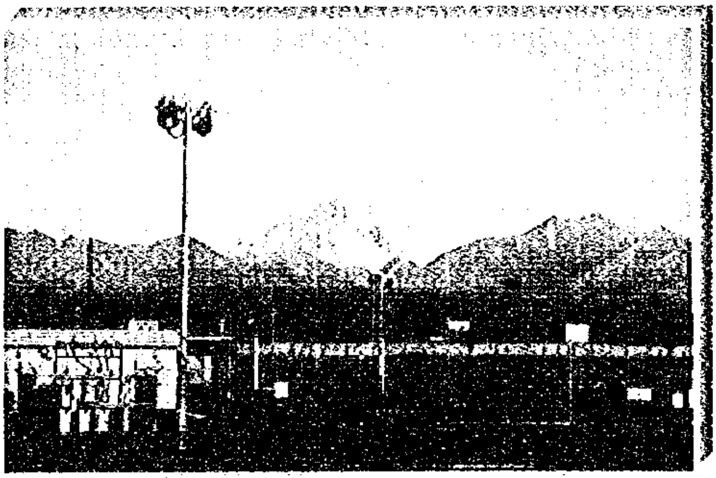
CHAPTER 1 MT.PINATUBO ERUPTION

Mt.Pinatubo is situated at 15°08'N latitude and 120°21'E longitude. The drainage system around Mt.Pinatubo is mainly controlled by topography with a radial pattern. The Marella, Sto.Tomas and Bucao river systems drain from the western slope of Mt.Pinatubo into the South China Sea. Along the eastern slope of Mt.Pinatubo, the O'Donnell, Sacobia-Bamban, Abacan, Pasig-Potrero and Porac-Gumain rivers radiate outwards to the Central Luzon Plain.

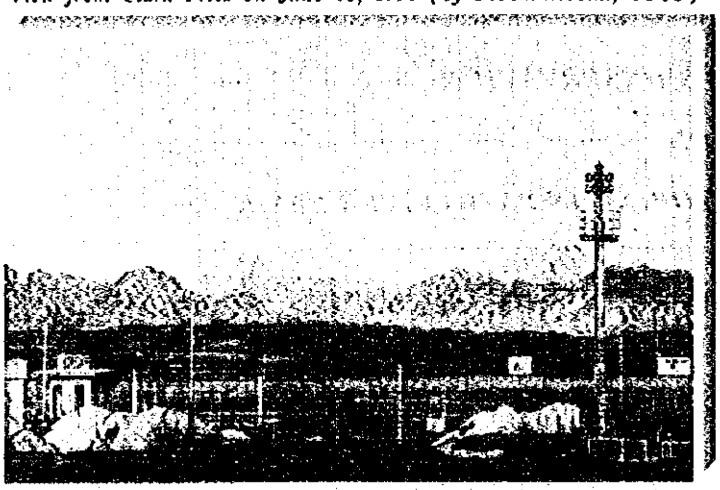


Eruption on June 12, 1991

According to the geological survey of the Philippine Institute of Volcanology and Seismology (PHIVOLCS) and the US Geological Survey (USGS), older eruptive periods have been identified by ^{14}C dates on charcoal in pyroclastic flow deposits about 2,500, 5,000 and 35,000 years ago. The last eruption has been dated at 460 ± 30 years ago.



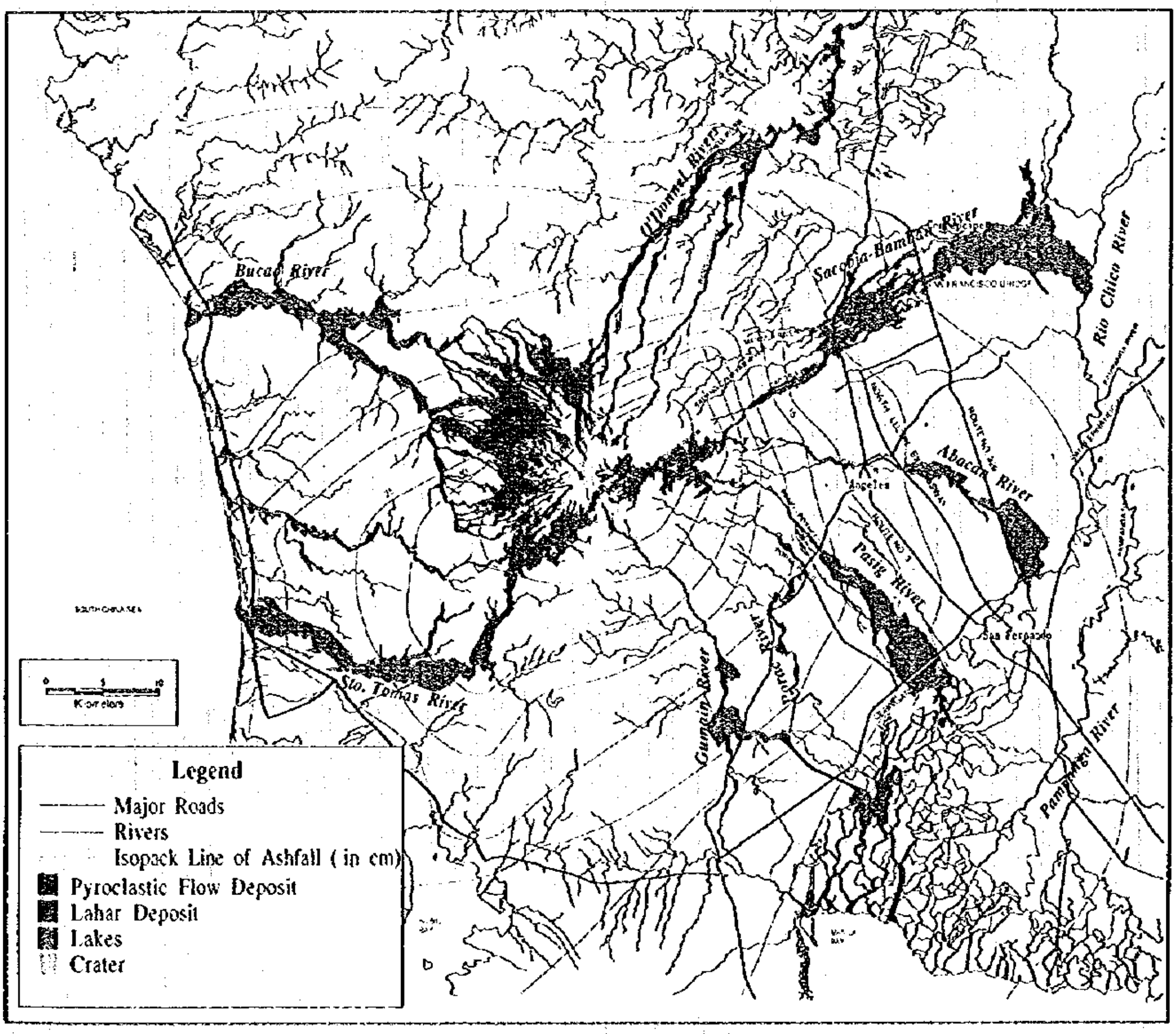
View from Clark Field on June 15, 1991 (by Dr. R.P.Hoblitt, USGS)



View from Clark Field on March, 1992 (by Dr. R.P.Hoblitt, USGS)

On June 15, 1991, after 460 years of dormancy, Mt.Pinatubo awoke with a climactic Plinian eruption. Mt.Pinatubo's summit was lowered from 1,745 meters to 1,449 meters resulting to a caldera with a diameter of 2 kilometers and a summit crater of 600 meters deep. The caldera floor was partially filled with water to form a lake. The eruption of Mt.Pinatubo also produced remarkable volume of pyroclastic flow and ash fall deposits. Hundreds of people were killed, thousands were injured or missing, and hundreds of thousands of families were rendered homeless. Strong winds induced by Typhoon "Diding" on June 15 aggravated the situation, scattering volcanic ash over thousands of square kilometers, including Metro Manila, which is about 90 kilometers away.

The volume of pyroclastic flow deposits was estimated at 6.7 billion cubic meters along the slopes of Mt.Pinatubo. Since pyroclastic flow deposit is so hot (approximately 700°C), many secondary explosions usually occur when rainfall and groundwater come in contact with the hot pyroclastic flow deposit. Such explosions loosen the pyroclastic flow deposits and eventually flow as lahar. Lahar poses continuing threat and grave danger to human lives and properties in the low-lying areas. The major rivers surrounding Mt.Pinatubo which have been affected with lahar consequently pose a great danger to the outlying areas (residential, commercial and industrial areas).

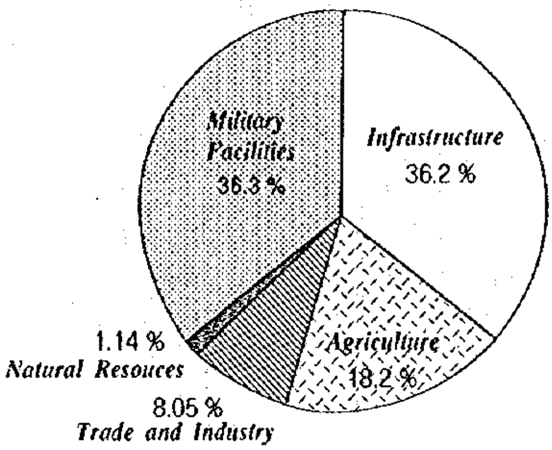


Pinatubo Disaster Map (November 1991)

CHAPTER 2 EXTENT OF DAMAGE

The massive damage caused by the Mt.Pinatubo eruption and the lahar flows that followed was placed at 10.6 billion Pesos at the end of 1991. The heaviest toll was on public infrastructure, including power, telecommunication, water supply and school and health facilities, estimated at 3.8 billion Pesos. Losses to agriculture was estimated at 1.8 billion Pesos; to commerce and industry, 851 million Pesos; and natural resources, 120 million Pesos.

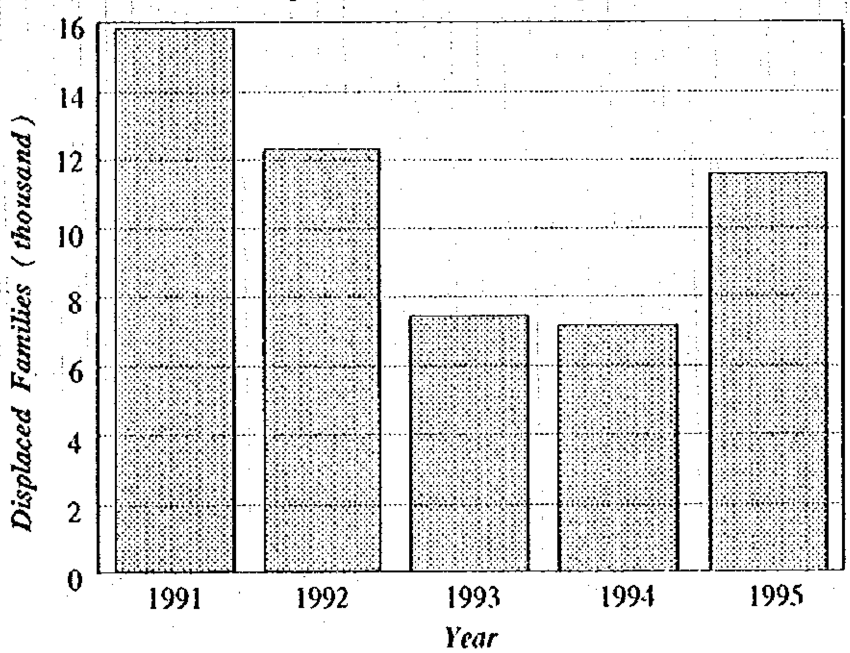
Damage in 1991
(10.6 billion Pesos)

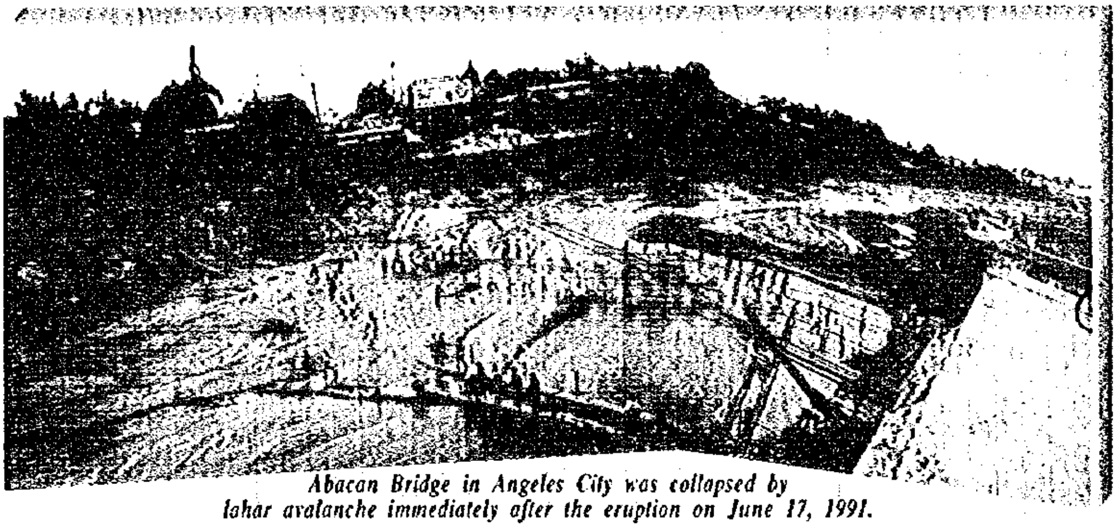


The total cost for relief operations, evacuation and resettlement, rehabilitation and reconstruction was estimated at 30 billion Pesos. The cost of reconstruction and rehabilitation alone of vital public infrastructure like roads, bridges and other facilities was placed at 9.5 billion Pesos. About 489 kilometers of major national roads and 163 kilometers of municipal roads in Pampanga, Zambales, Bataan and Tarlac were covered with 6-12 inches of ash and sand. Six major bridges, namely Abacan, Pandan, Mancatian and Pabanlag in Pampanga, and Sta.Fe and Umaya in Zambales collapsed immediately after the eruption. Lahar flows destroyed the Bamban bridge in Tarlac, and a portion of Capaya bridge along the North Luzon Expressway in Angeles City. Two bridges along the Botolan-Capas road in Botolan, Zambales were inundated while the approach of several bridges were also damaged. In total, 13 major bridges were destroyed or damaged.

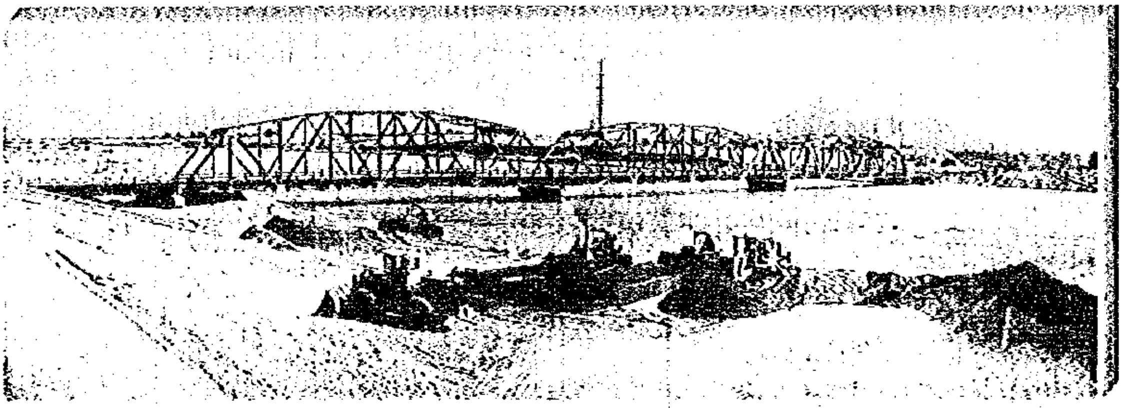
More than 54,000 families have been dislocated after the eruption of Mt. Pinatubo. All the displaced families have sought temporary shelter in the evacuation areas, and are still to be permanently resettled. In 1994 and 1995, displaced families from the municipalities of Bacolor and Porac which are within the Pasig-Potrero river basin were affected and subsequently relocated to the evacuation and resettlement sites of San Fernando and Angeles City.

Displaced Families in Region III

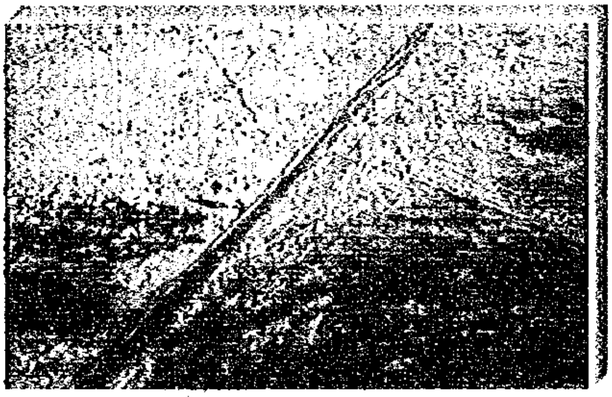




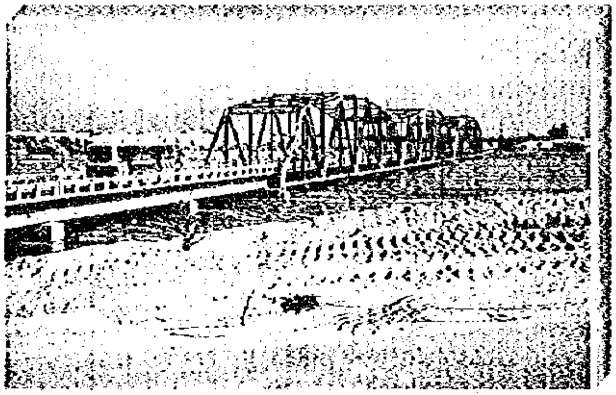
Abacan Bridge in Angeles City was collapsed by lahar avalanche immediately after the eruption on June 17, 1991.



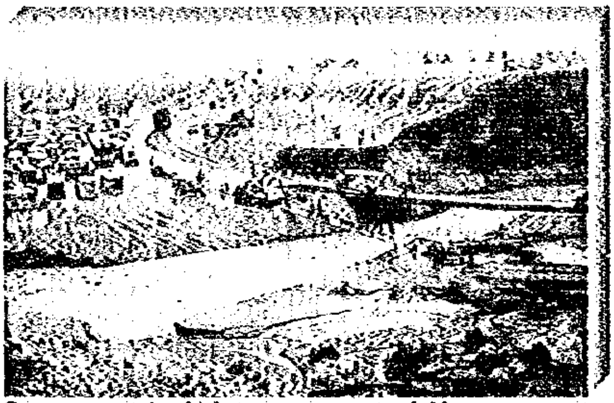
Many heavy equipment were donated under JICA's grant aid program in 1991.



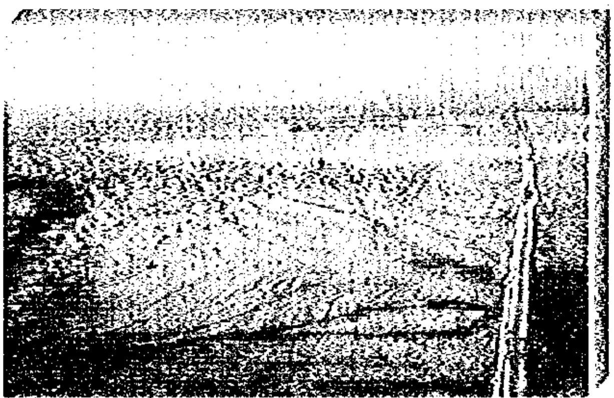
Route 3 was covered with lahar of 5 meters deep. (upper reach of Bamban River)



Clearance of San Francisco Brige was reduced to 70cm on Octobet 2, 1995. (middle reach of Bamban River)



Commuters and vehicles cross temporary bridges set up over the Pasig River in Porac. (middle reach of Pasig River)



Lahar disaster area extended to further downstream area over San Fernando ~ Olongapo Road. (lower reach of Pasig River)

CHAPTER 3 EASTERN SLOPE OF MT.PINATUBO

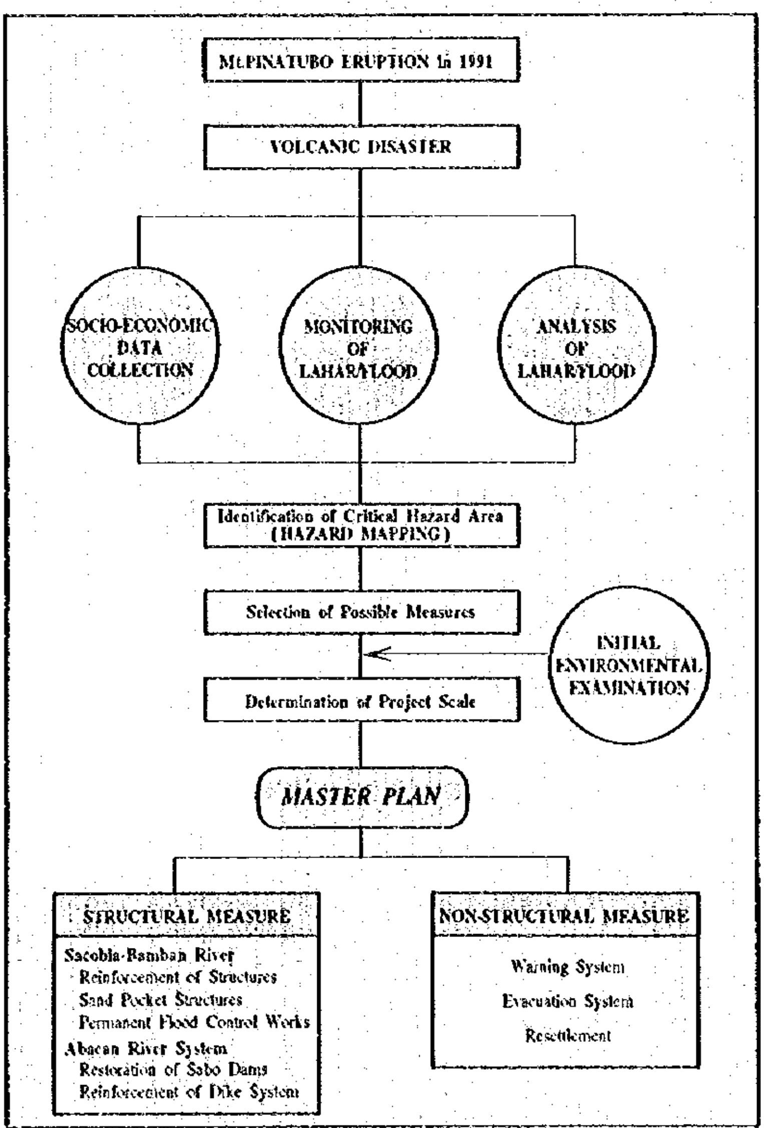
3.1 JICA MASTER PLAN STUDY

In June 1991, just a few days after the disaster struck, Japanese relief goods amounting to US$ 200,000 were immediately dispatched to the affected areas. From July to September of the same year, the Government of Japan (GOJ) donated and helped in the installation of a Lahar Warning System worth US$ 9 million in cooperation with the National Disaster Coordinating Council (NDCC). So far the total worth of Japanese aid, grants and technical services and assistance, including medical equipment and supplies, public works and farm machinery, and commodity loan extended by GOJ in connection with the calamity has reached US$ 5 billion.

In 1993, upon the official request of the Government of the Philippines (GOP), GOJ agreed to organize a Study Team under the technical cooperation of Japan International Cooperation Agency (JICA) to conduct a Master Plan Study for flood and mudflow control works in the Sacobia-Bamban and Abacan rivers.

The specific objectives of the Study are (1) to formulate a master plan for the control of flood and mudflow in the Sacobia-Bamban and Abacan river basins; (2) to identify and prioritize projects according to their urgency and relevance and conduct feasibility study on the said projects; (3) to monitor the geomorphologic changes and sediment balance in the Pasig river basin; and (4) to transfer the technical knowledge and expertise of GOJ engineers to the engineers of GOP.

The target of the master plan for mudflow/flood control works are (1) to minimize the potential of disastrous mudflow and flood inundation, (2) to limit the sediment deposition areas within the presently affected areas and to minimize the scale of structural measures on the basis of a good and sound foresight of future development of alluvial fan in the low-lying area, and (3) to effect future land use plan and restore displaced families to their original settlements which are now covered with lahar.



Basic Concept of JICA Master Plan Study

(1) FIRST PHASE IN 1993

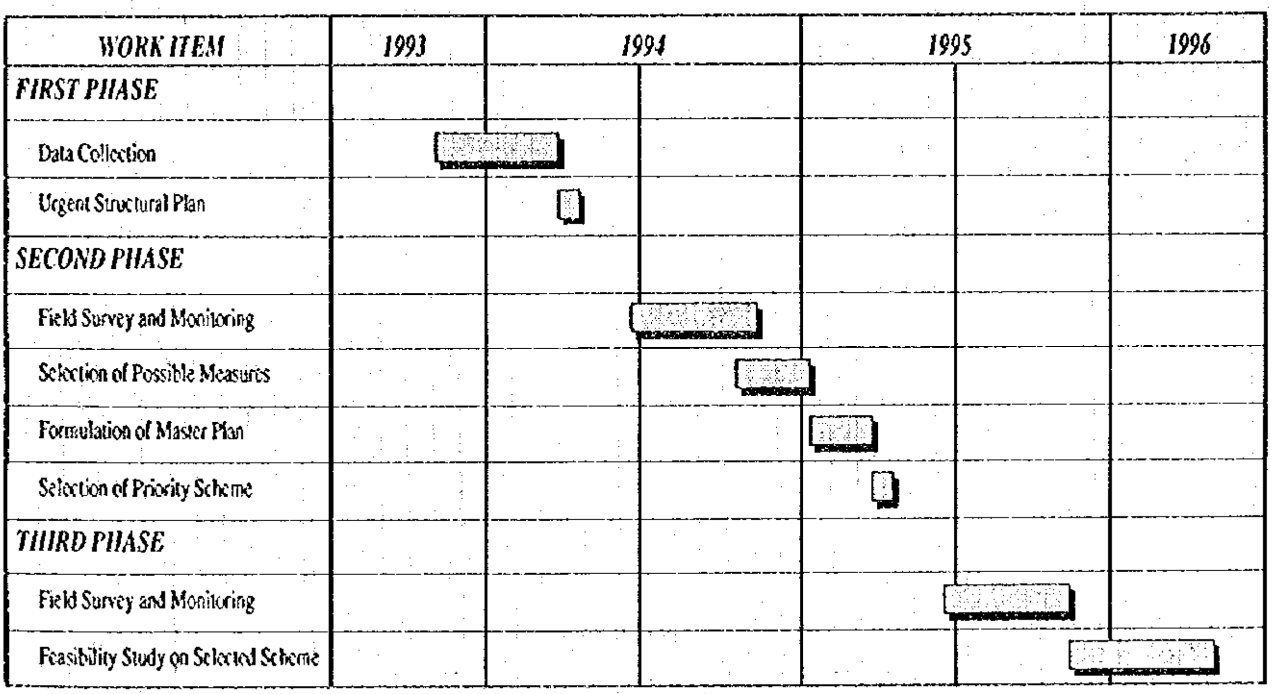
The Study Team commenced the work in the Philippines on November 15, 1993. The Department of Public Works and Highways (DPWH) organized the Inter-Agency Steering Committee chaired by Undersecretary Edmundo V.Mir, DPWH. In February, 1994, the urgent rehabilitation plan including sand pocket structures was proposed to be carried out by the DPWH before the onset of the rainy season in 1994.

(2) SECOND PHASE IN 1994

From July to December 1994, the basic configuration of structural measure was formulated through the monitoring of geomorphologic changes during rainy season of 1994. These changes were contained in the latest topographic map with a scale of 1:10,000 prepared by JICA Survey Team on the basis of the aerophotograph in March 1994. Furthermore, the present socio-economic condition was reviewed through the resettlement/population and initial environmental surveys. Other alternatives of structural measures including cost-benefit analysis were submitted in March 1995.

(3) THIRD PHASE IN 1995

The optimum development scale of selected structural measures was reviewed throughout the feasibility study period from June 1995 to January 1996. In the third phase, monitoring of geomorphologic changes in the Pasig-Potrero River was included in the Scope of Works of the JICA's Study in response to the request from the DPWH during the Steering Committee meeting held on March 25, 1995. The Final Report was submitted in May 1996 taking into consideration the comments from the Steering Committee meetings.

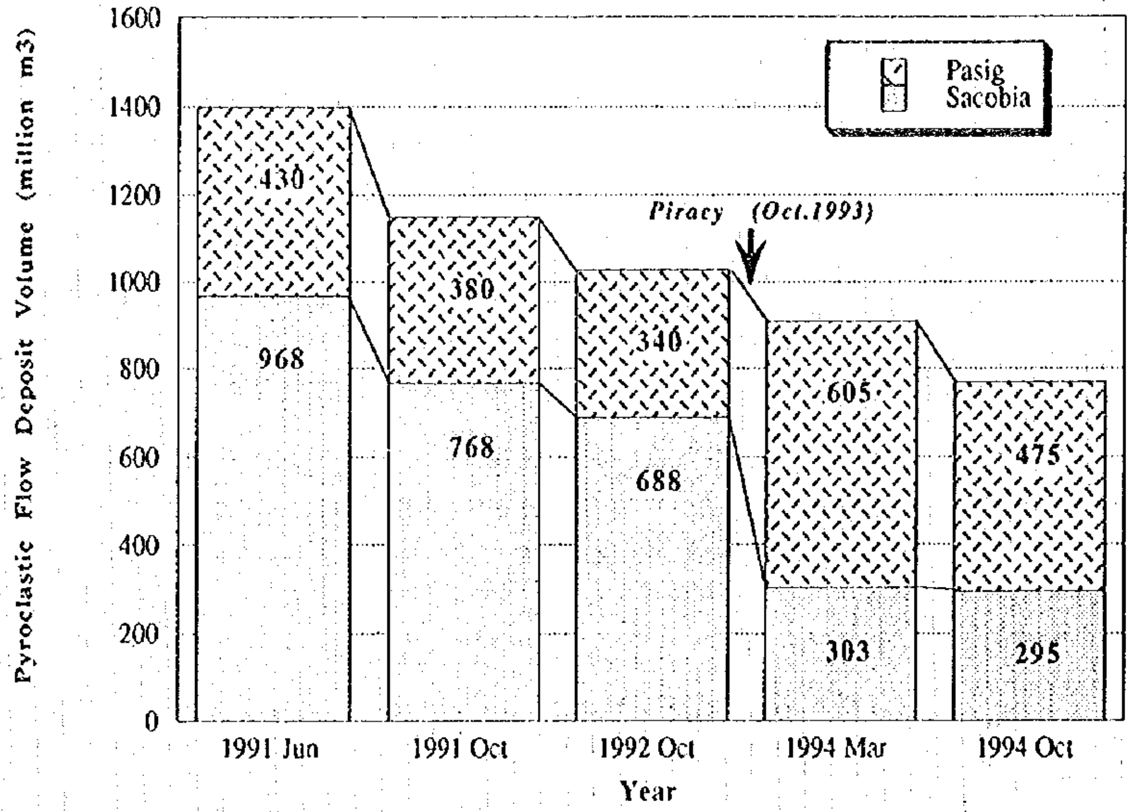


Flowchart of the JICA Master Plan Study

3.2 *PYROCLASTIC FLOW DEPOSIT*

Three kinds of topographic maps, that is, (i) before eruption in 1991, (ii) after eruption in 1992 and (iii) after eruption in 1994 were used for the estimation of the volume of pyroclastic flow deposit by Geographic Information System (GIS). The bird's-eye view of the eastern slope of Mt.Pinatubo also shows the extent of pyroclastic flow deposit field. The cross sectioning at an interval of 200 m was carried out by GIS, and the volume of pyroclastic flow deposit was estimated at 1.40 billion m^3 in the eastern slope of Mt.Pinatubo.

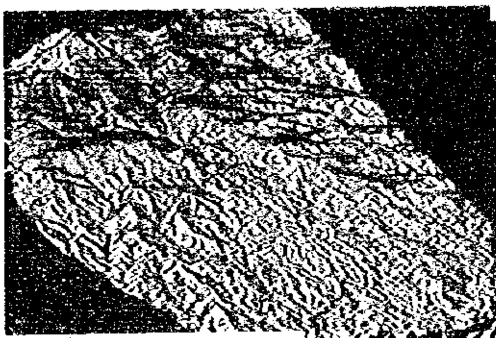
Pyroclastic Flow Deposit Volume



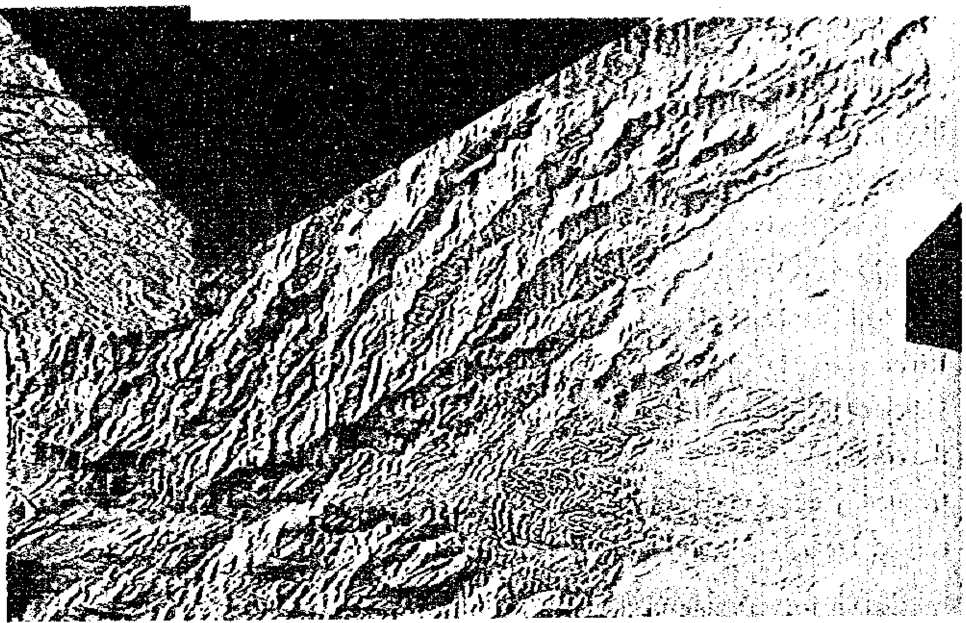
Pyroclastic Flow Deposit Volume in the Eastern Slope of Mt.Pinatubo

River Basin	C.A. (km2)	Pyroclastic Flow Deposit Volume (million m3) and Remaining Ratio (%)								
		1991 June	1991 October		1992 October		1994 March		1994 October	
Sacobia/Abacan		968	768	79%	658	71%	303	31%	295	30%
Sacobia/Abacan Upstream	18	550	400	73%	347	63%	303	55%	295	54%
Sacobia/Abacan Uppermost Reach	22	418	368	88%	341	82%	Annexed to Pasig River 320	77%	252	60%
Pasig Upstream	23	430	380	88%	340	79%	285	66%	223	52%
Pasig		430	380	88%	340	79%	605	141%	475	110%
TOTAL	63	1,398	1,148	82%	1,028	74%	908	65%	770	55%

Remarks : The Pyroclastic deposit volume for March 1994 was estimated using the GIS database created from the DTM for 1991, 1992, 1994 with a contour interval of 5 m mapped to a scale of 1:10,000 from aerial photographs. The Sacobia uppermost basin was annexed to the Pasig in October 1993.

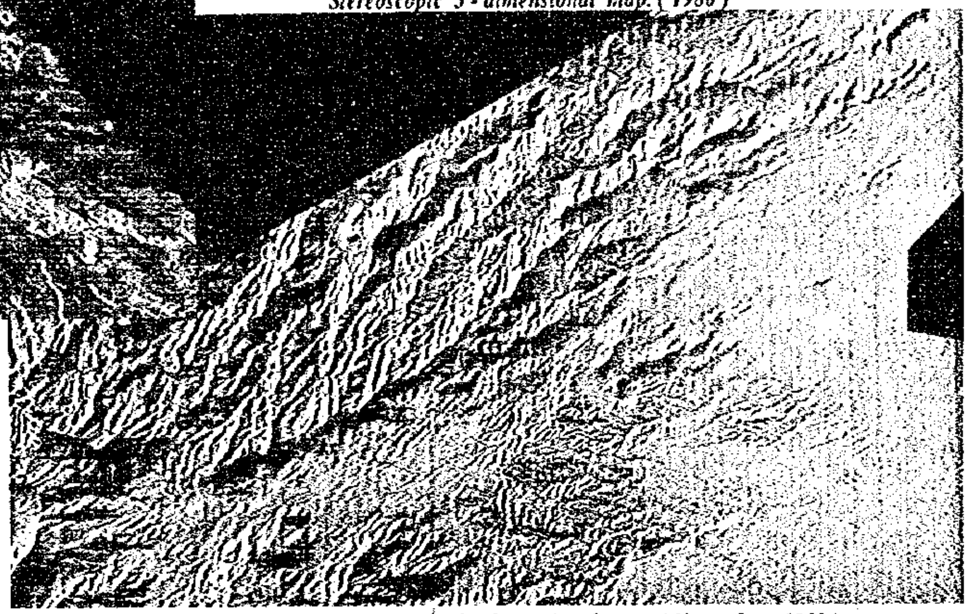


Bird's - Eye View of Pre - Eruption Condition (1980)

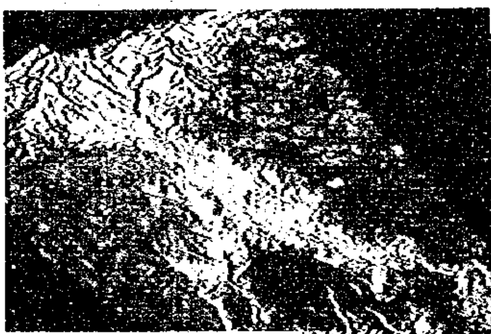


Stereoscopic 3 - dimensional map (1980)

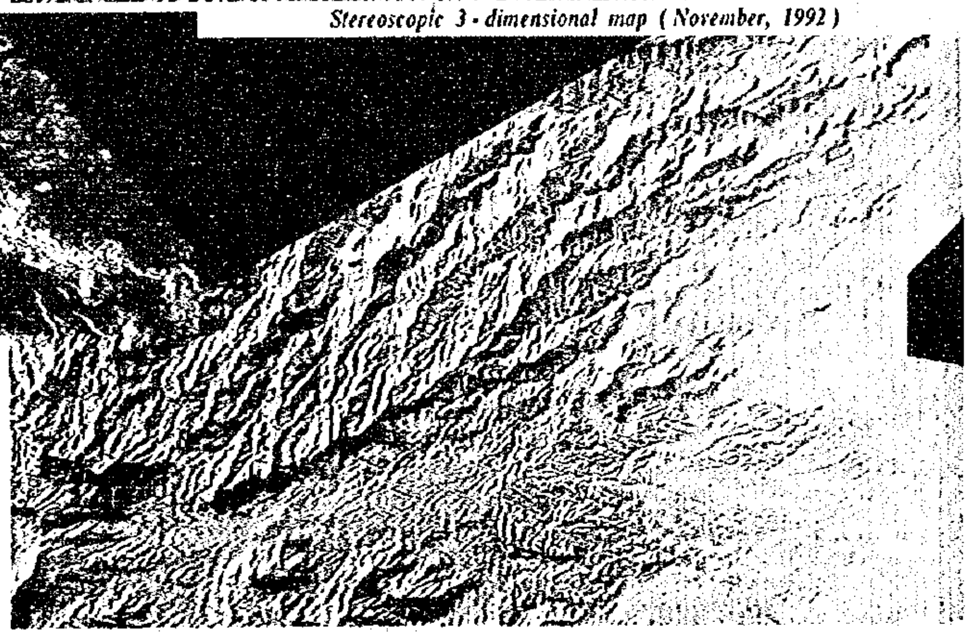
Bird's - Eye View of Pyroclastic Flow Deposit Field (November, 1992)



Stereoscopic 3 - dimensional map (November, 1992)



Bird's - Eye View of Pyroclastic Flow Deposit Field (April, 1994)



Stereoscopic 3 - dimensional map (April, 1994)

3.3 SEDIMENT DELIVERY RATE

In June 1991, the basin boundary before the eruption was disappeared due to deep pyroclastic flow deposit as high as 220 m at Bukbuc River, tributary of the Pasig River, and a maximum height of 160 m at Sacobia River. At the piracy point of Abacan and Sacobia rivers in 1992, so called the "Abacan Gap", a small escarpment had caused a degradation of 15 to 20 m and has facilitated the piracy by the Sacobia River. No lahar has occurred along the Abacan River ever since the piracy of the Sacobia River had occurred at Abacan Gap. In October 1993, a large-scale landslide triggered by secondary explosion had occurred, and the Pasig River annexed the upstream reach of the Sacobia River. In 1994, the secondary pyroclastic flow buried the valley of the Bukbuc River, while the Pasig River swerved into the Timbu Creek. Dammed lake developed at the confluence between Bukbuc and Yangca rivers due to the large-scale secondary explosion which occurred frequently due to contact of lake water with hot pyroclastic flow deposit. Breaking of the dammed lake caused a remarkable volume of lahar avalanched to downstream areas of the Pasig River.

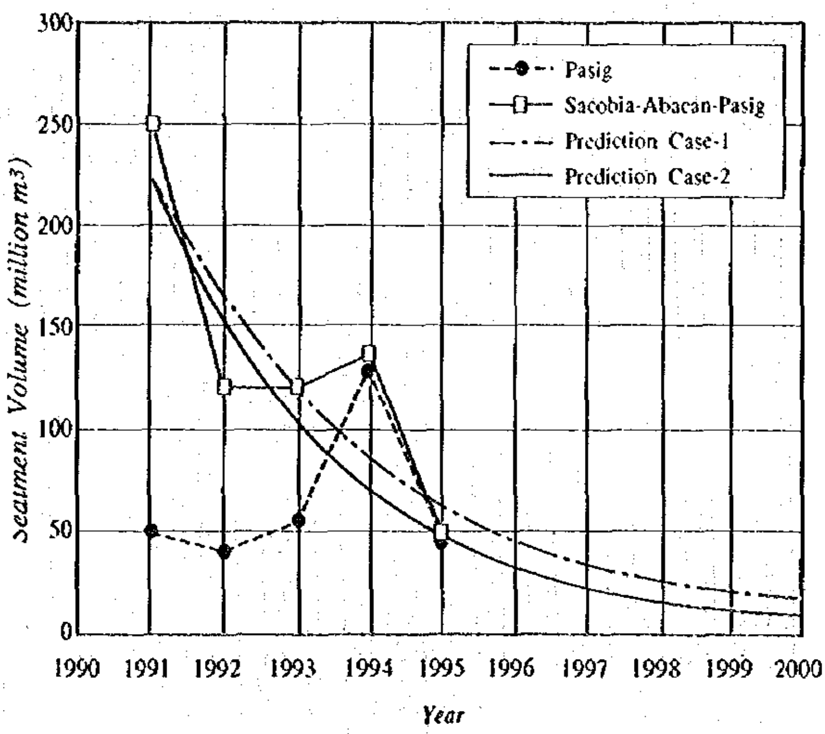
The annual sediment delivery rate in the eastern slope of Mt.Pinatubo from 1991 to 1995 shows no distinctive decay rate in the total sediment volume, in contrast that in the Sacobia River where sediment delivery rate are reduced rapidly after the river piracy by the Pasig River. The surplus sediment delivery rate in the Sacobia River may terminate in the rainy season of 1997 and by 1998 the delivery rate may be equivalent to the pre-eruption condition.

Annual Sediment Delivery Rate

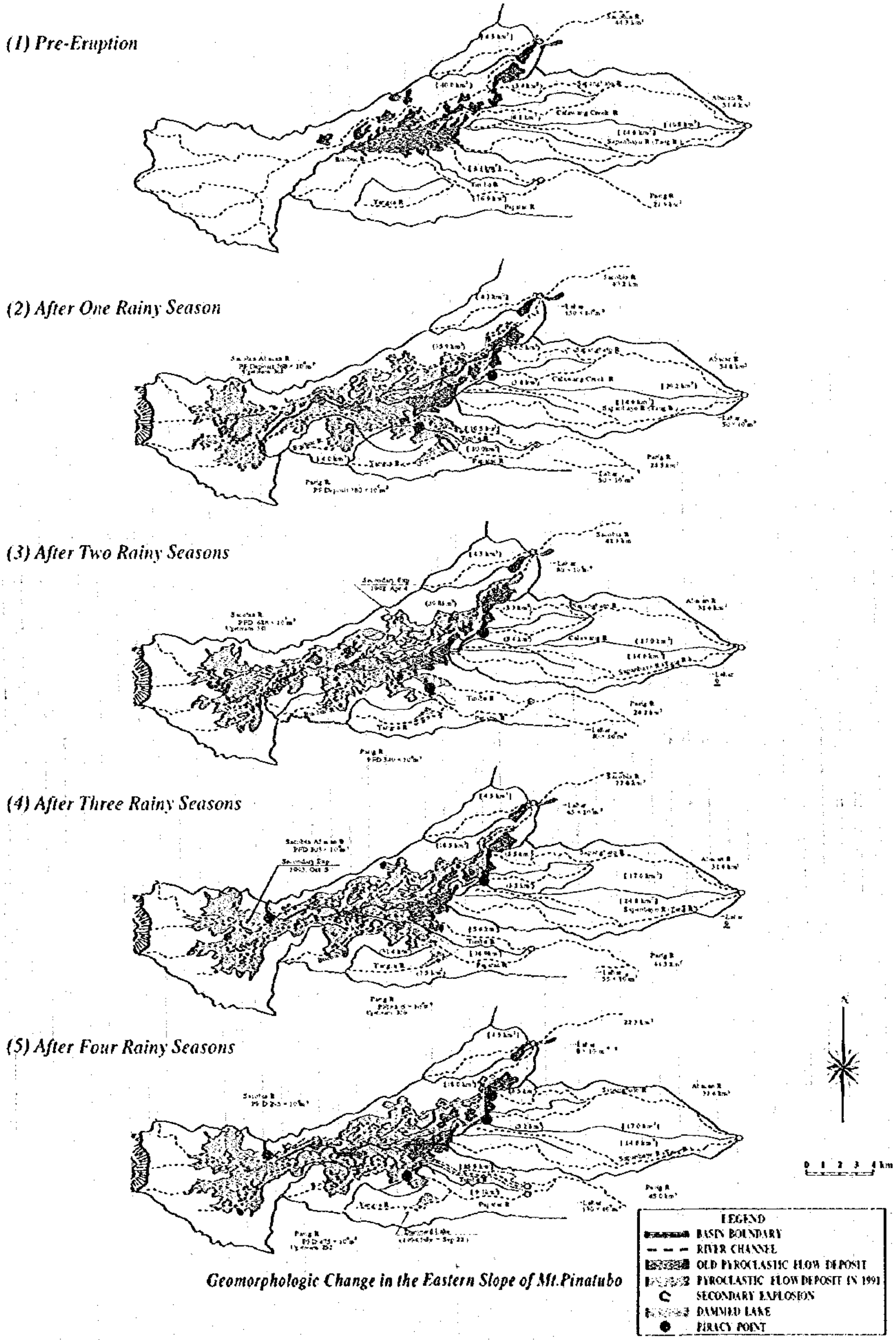
Year	RECORD		FORECAST	
	Pasig	Sacobia-Abacan-Pasig	Case-1	Case-2
1991	50	250	223	223
1992	40	120	163	153
1993	55	120	119	105
1994	130	138	87	72
1995	45	49	64	49
1996			47	34
1997			34	23
1998			25	16
1999			18	11
2000			13	7

Note : 1) Case-1 is the forecast rate based on all recorded data from 1991 to 1995.
2) Case-2 is the forecast rate excluding an extraordinary value in 1994.
3) Regression formula:
Case-1 : Y = 304.6 EXP (-0.312T)
Case-2 : Y = 325.1 EXP (-0.377T)

Forecast of Sediment Delivery Rate



Annual Sediment Delivery Rate



Geomorphologic Change in the Eastern Slope of Mt.Pinatubo

3.4 LAHAR CHARACTERISTICS

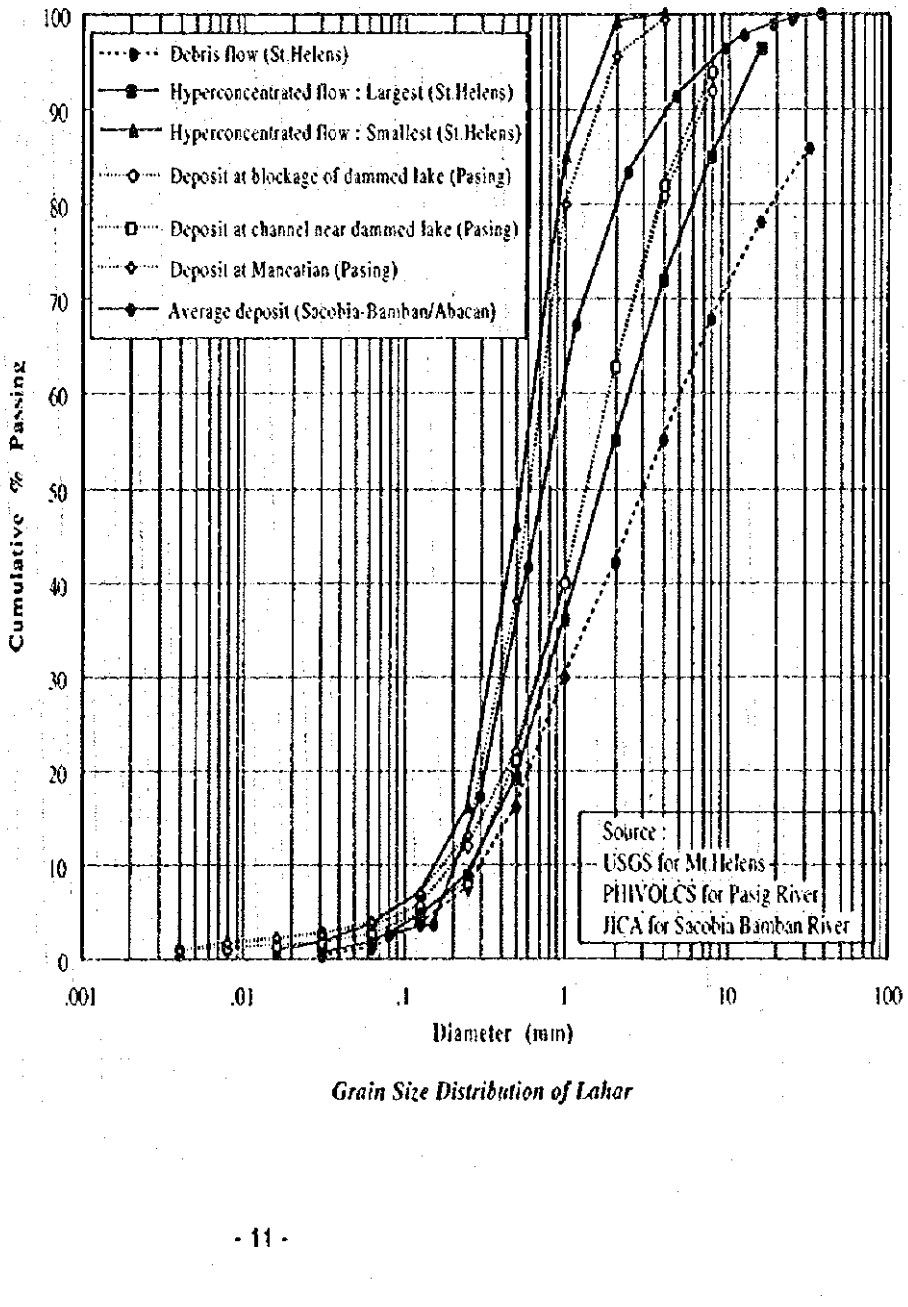
Rainfall "Lahar" is an Indonesian term, defined as "... a rapidly flowing mixture of volcanic rock debris and water from a volcano". Lahars triggered by heavy monsoon or typhoon have been flowing into densely populated areas of Central Luzon since the major eruption of June 1991, although the toll of lives was small, enormous property losses and social disruption were recorded. The characteristics of lahars in the Sacobia River from 1991 to 1993 were classified into two types depending on rheology of flow (PHIVOLCS/USGS) as follows:

1) Debris flows has peak discharges of several hundreds to a thousand cubic meters per second, and contained about 60-65 % (rarely, 70 %) sediment by volume.

2) Hyperconcentrated flows had peak discharges of several tens to several hundreds cubic meters per second and contained about 50 % sediment by volume. Hyperconcentrated flows are numerically more common, but the large debris flows carry a large part of the sediment deposit to downstream areas.

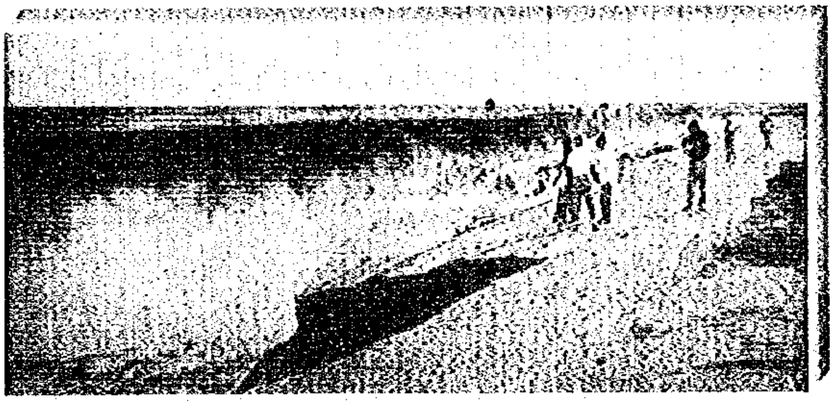
The grain sizes and specific gravity have a great influence on sediment transportation. Regardless of its origin as primary hyperconcentrated flows or as the runouts of debris flows, flows with hyperconcentrations of sediment volumetrically dominate the flow system and depositional records in the downstream reach.

Hyperconcentrated flow deposits in the eastern drainages of Mt.Pinatubo are dominated by sand-size phenocrysts from the pyroclastic flow deposits with an admixture of mineral grains from older deposits. Pumice clasts are present but are volumetrically minor; most are preserved in coarse deposits near the surface.



Grain Size Distribution of Lahar

In the Pasig-Potrero River, sediment sampling and laboratory test were conducted at Watch Point No.5, Mancatian (Angeles-Porac Road), and the Santa Barbara bridge (San Fernando-Olongapo Road). The results shows a clear contrast of sediment transport mechanisms as follows;



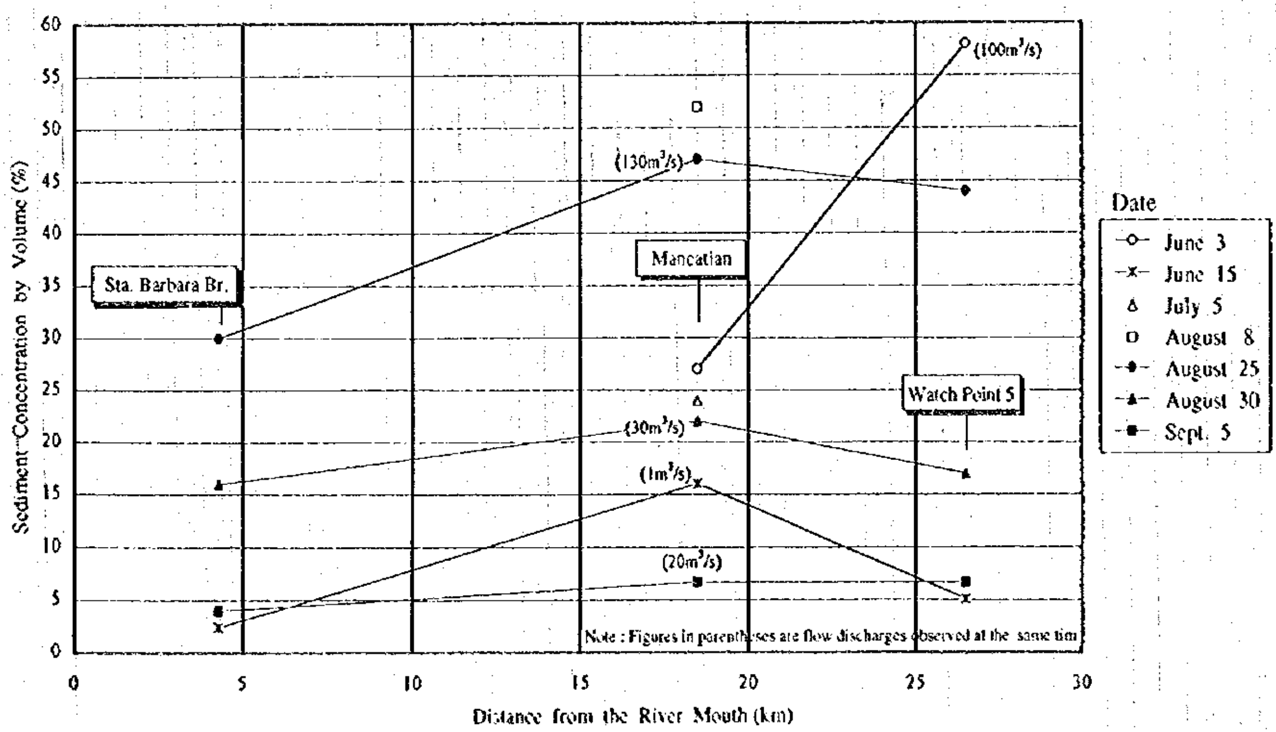
Lahar Sampling at Mancatian (August 8,1995)

1) The June 3 lahar with sediment concentration of 58 % by volume at Watch Point No.5 (riverbed slope of 2 to 3 %) reduced its concentration to 27 % when the flow reached Mancatian (riverbed slope of about 1 %).

2) Sediment concentration of the August 25 lahar became higher as the flow traveled down to Mancatian, sediment concentration of 30 % was observed also at the Santa Barbara bridge (0.2 to 0.3 % in slope).

The above phenomena result from the difference in flow characteristics between mudflow and hyperconcentrated flow as observed in the fields; (1) at Angeles-Porac road, mudflow reduces its concentration with some sediment deposition, (2) lateral bank erosion may increase the sediment concentration of hyperconcetrated flow even on a riverbed slope of 1 %, and (3) hyperconcentrated flow may travel in the confined channel without shallow outwash even on a gentle slope of 0.2 to 0.3 %.

Observed Sediment Concentration



Sediment Concentration along the Pasig River in 1995

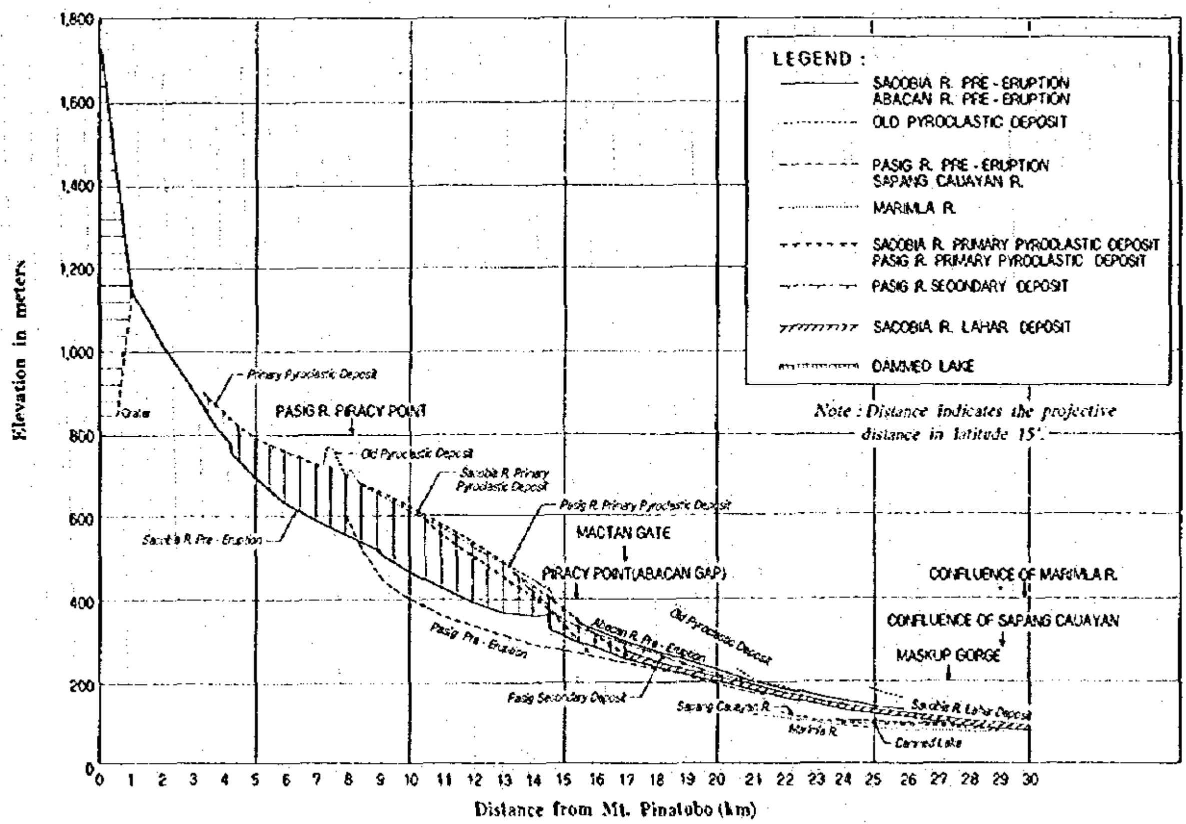
3.5 RIVERBED PROFILE

In the pre-eruption period, a longitudinal profile of the Sacobia River from the summit to an elevation of about 1,000 meters showed steep slopes measured at 10° to 30° and river channel was deep, narrow V-shaped canyon. Further down to elevations of about 200 m, the channel slope decreased from 6° to 1° as it cuts through the 600-300 year old non-welded pyroclastic flow deposits where the headwater tributaries of Abacan River originate. At less than 200-meter elevations (roughly 8 kilmeters downstream), the Sacobia River was 500 meters wide and eroded into old lahar terraces and well-indurated fluvial deposits until it narrowed down to 30 meters at an elevation of 100 meters. At this point near Route No.3, about 25 kilometers downstream from the volcano, the Sacobia River was joined by Sapang Cauayan and the Marimla rivers.

The catchment areas including tributaries of Sacobia-Bamban and Abacan rivers are enumerated below;

Sacobia-Bamban River Basin		Abacan River Basin	
Sacobia River Basin at Maskup	39.5 km²	Sapangbato River Basin	19.2 km²
Sapang Cauayan River Basin	20.8 km²	Sapangbayo (Taug) River Basin	14.1 km²
Marimla River Basin	67.5 km²	Residual Basin	43.9 km²
Sapang Balen River Basin	21.7 km²		
Residual Basin	57.4 km²		
Total	206.9 km²	Total	77.2 km²

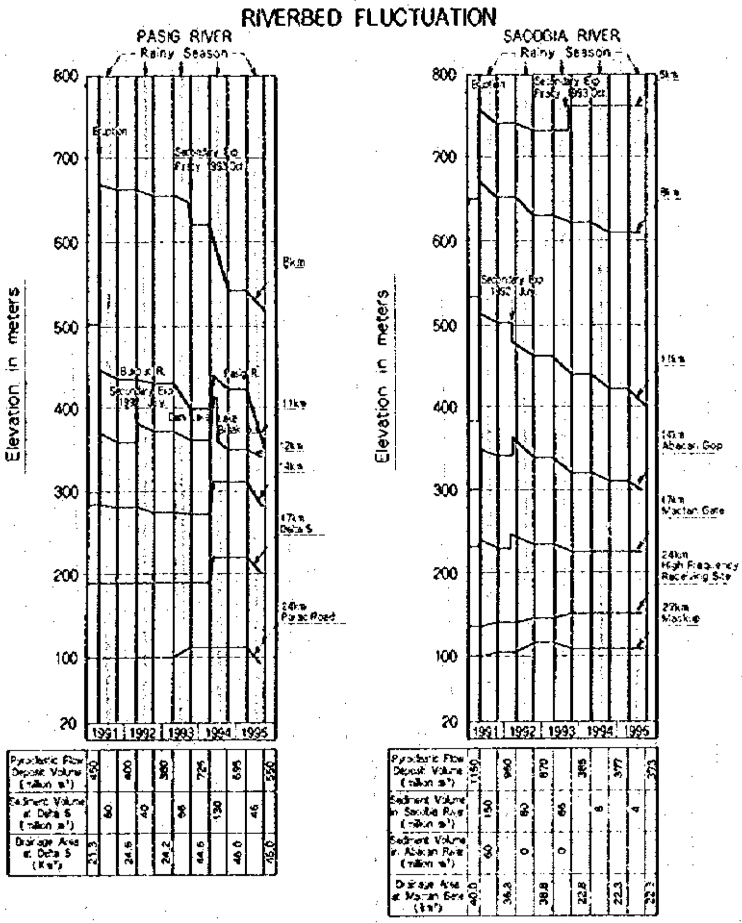
Note: The upstream reach of the Sacobia River of 23 km² was annexed to the Pasig River in October 1993. The catchment area of the Sacobia River Basin at Maskup was 41.8km² before 1993.



Riverbed Longitudinal Profile of the Sacobia-Bamban and Abacan Rivers

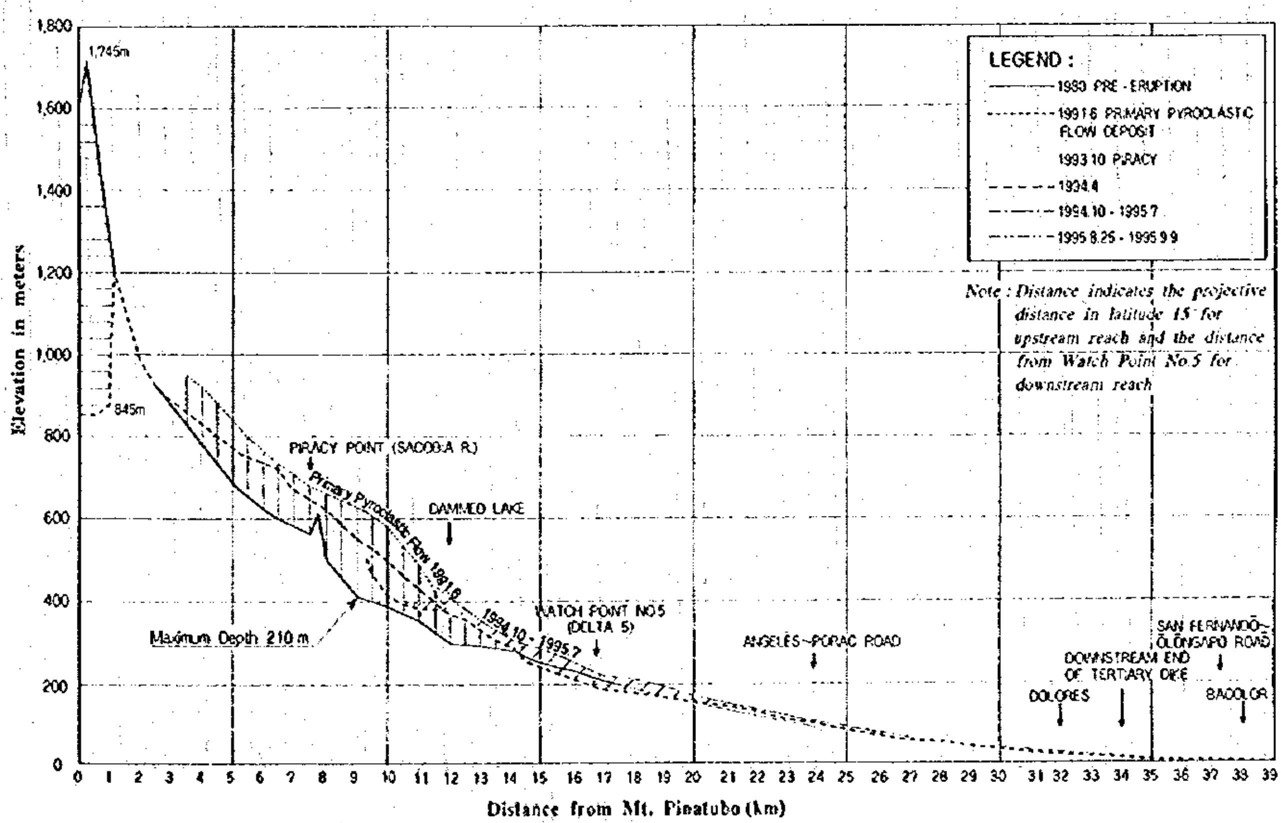
In the pre-eruption period, the Pasig River from a range of El.600 to El.200 meters showed the deepest riverbed elevation among the rivers. In general, rivers with larger catchments have lower riverbed profile caused by downcutting of much water. The Pasig River might have originated from the summit of Mt.Pinatubo before the previous eruption 460 years ago. The catchment area at Watch Point No.5 increased from 21.3 to 45.0 square kilometers after the piracy in October 1993.

The riverbed fluctuation shows that the downcutting of the upstream reach has developed rapidly with the deposition of eroded sediment in the downstream reach year by year, especially in the downstream reach of the Pasig River.



Remarks : Figures in km show the projective distance from Mt. Pinatubo

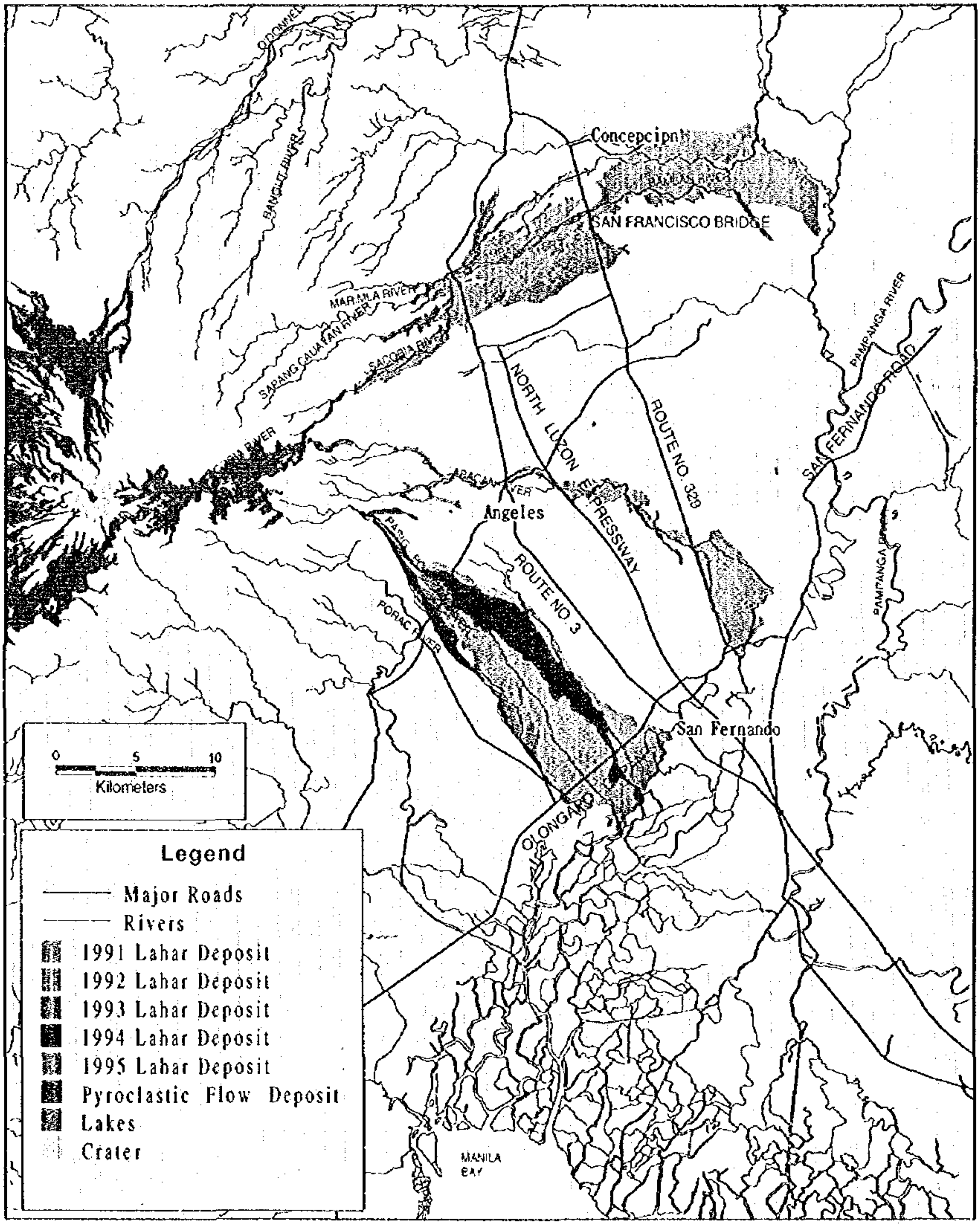
Riverbed Fluctuation after 1991 Eruption



Riverbed Longitudinal Profile of the Pasig River

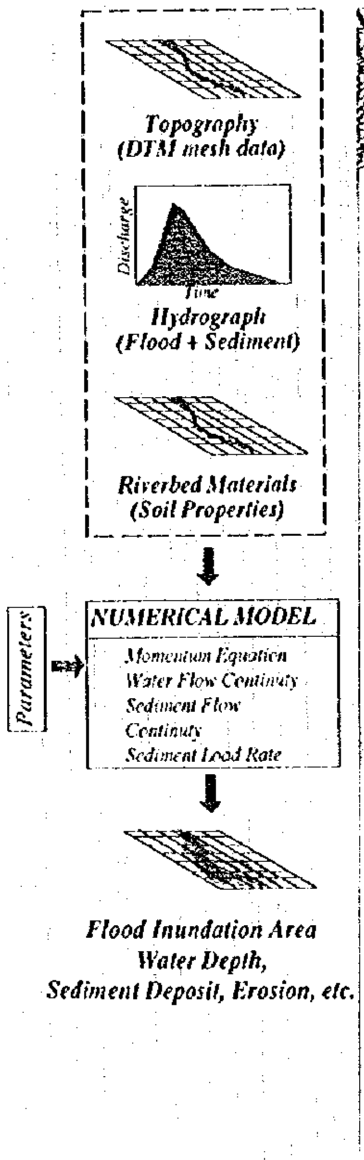
3.6 LAHAR DISASTER AREA

The lahar disaster areas are delineated to show the additional covered areas yearly from 1991 to 1995 for comparison purposes. Total lahar disaster areas are estimated to be 11,753 ha in Sacobia-Bamban river basin, 2,930 ha in the Abacan river basin and 9,700 ha in the Pasig river basin.

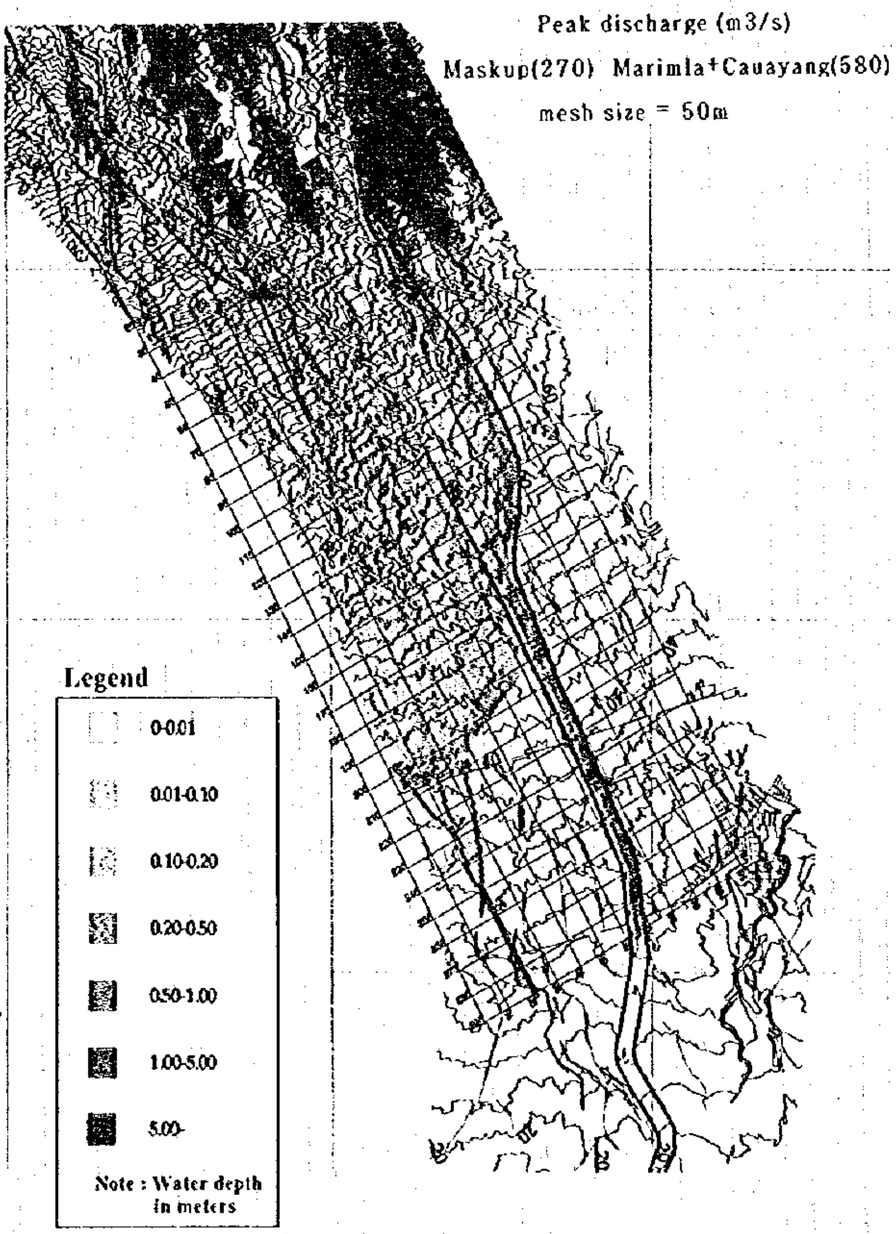


Lahar Disaster Area (1991 - 1995)

A two-dimensional simulation analysis was carried out to evaluate the process of topographic changes and flood/mudflow inundation conditions during the 1991-1993 lahar events. First, the situation of inundation (area, depth, sediment deposit, erosion, etc.) were drawn for the 1991 and 1994 digital maps of 50 meters x 50 meters meshes for some selected cases of runoff conditions in the study areas of the Sacobia-Bamban and Pasig rivers. Then appropriate parameters of the model were identified and applied to assess the effects of structural measures (proposed in this Study) and the potential inundation caused by probable floods. For the numerical simulation, the Study used the computer program of two-dimensional flood and mudflow analysis developed by Sabo and Landslide Technical Center of Japan and the results are presented by the GIS developed by this Study.



Flowchart of Analysis



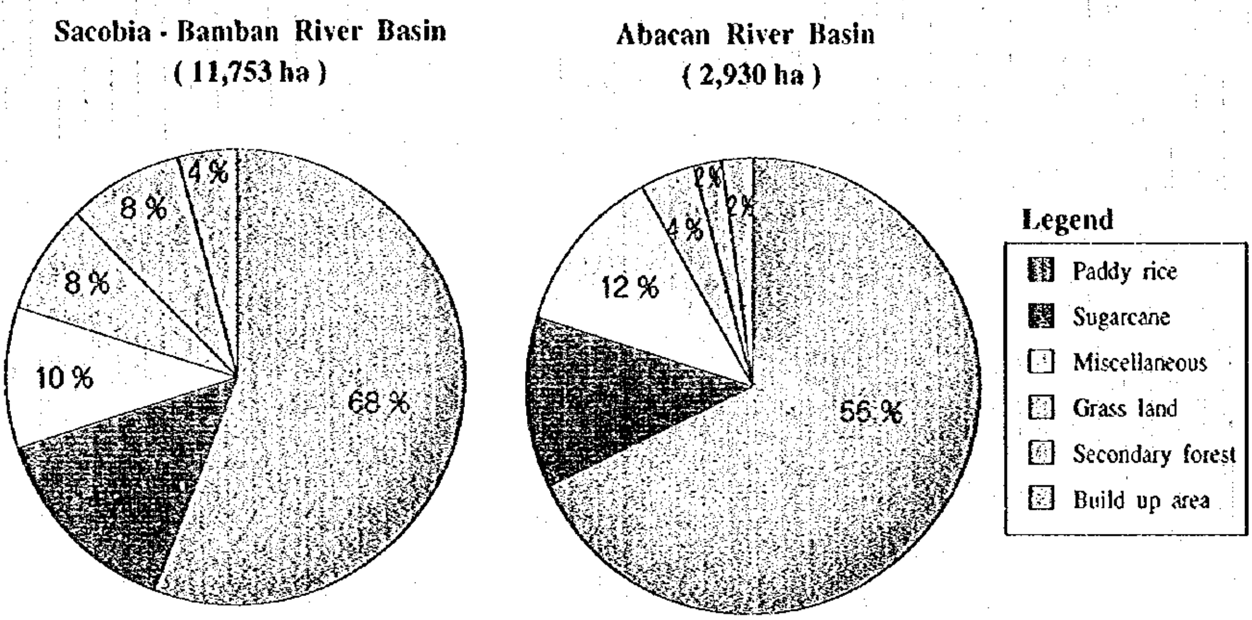
Example of Lahar Analysis for Sand Pocket Structure

3.7 LAND USE

Before the 1991 eruption, agriculture was the dominant land use in the Sacobia-Bamban and Abacan river basins. Rice and sugarcane were the extensively grown crops. Cassava, sweet potato, legume, fruits and commercial crops were also planted. Muskmelon and watermelon were grown at the Candaba Swamp during dry season. Rainfed and irrigated paddy rice, sugarcane, root crops, vegetables and fruit trees were grown on the lower river terraces and broad alluvial plains. Rainfed lowland paddy was also grown on the foot of volcanic hills and moderately sloping pyroclastic hills. Other upland crops were grown on these land management units. Forest, shrubs and grassland are extensive on the pyroclastic hill, volcanic hills foot and pyroclastic mountain. Most built-up areas were located on the broad alluvial plains, residual terrace and pyroclastic hills.

After the eruption, agricultural lands were seriously damaged by lahar deposits and sedimentation from 1991 to 1993 in the study area. A total of 11,753 ha were damaged in the Sacobia-Bamban river system while 2,930 ha were damaged in the Abacan river system. These areas were either covered with lahar or changed to grass land. Some farmers even experimented growing watermelon or sugarcane on the sediment covered land.

The build-up area in Sacobia-Bamban river system and both sides of Bamban bridge were completely damaged by lahar in 1991 and 1992, including the barangays of Sta. Rita, Malupa, San Martin and Magao in Concepcion. On the other hand, river bank erosion of Abacan river in Angeles City destroyed residential establishments in 1991, and partially in 1992 .



Land Use before Eruption in the Lahar Disaster Area

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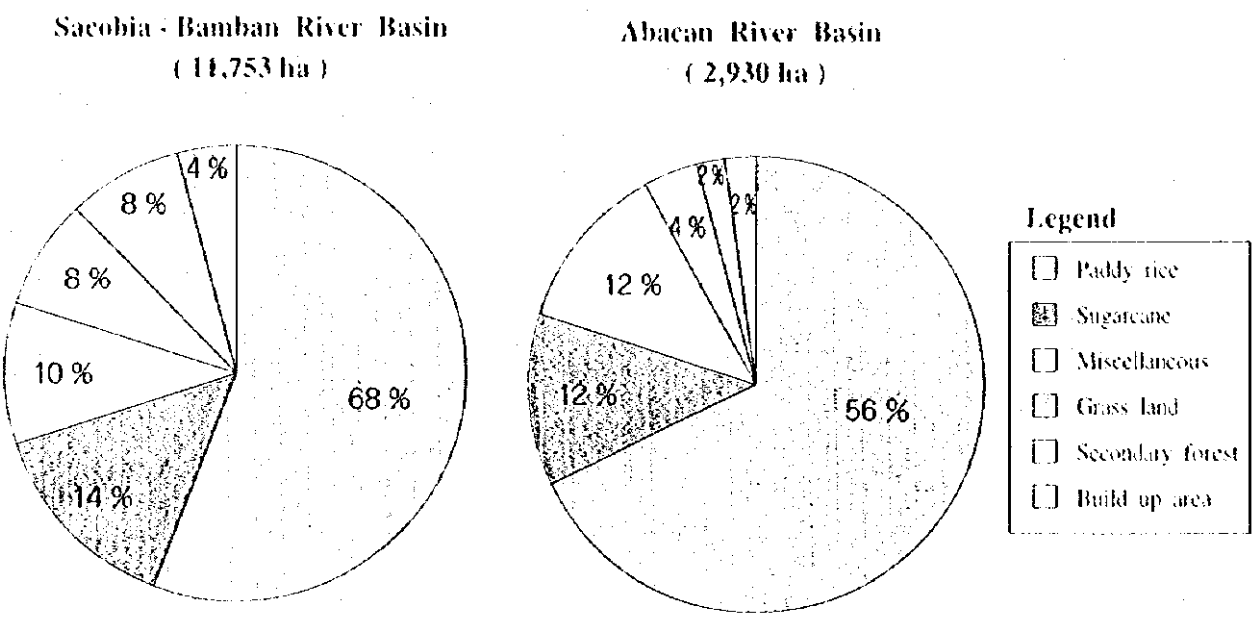

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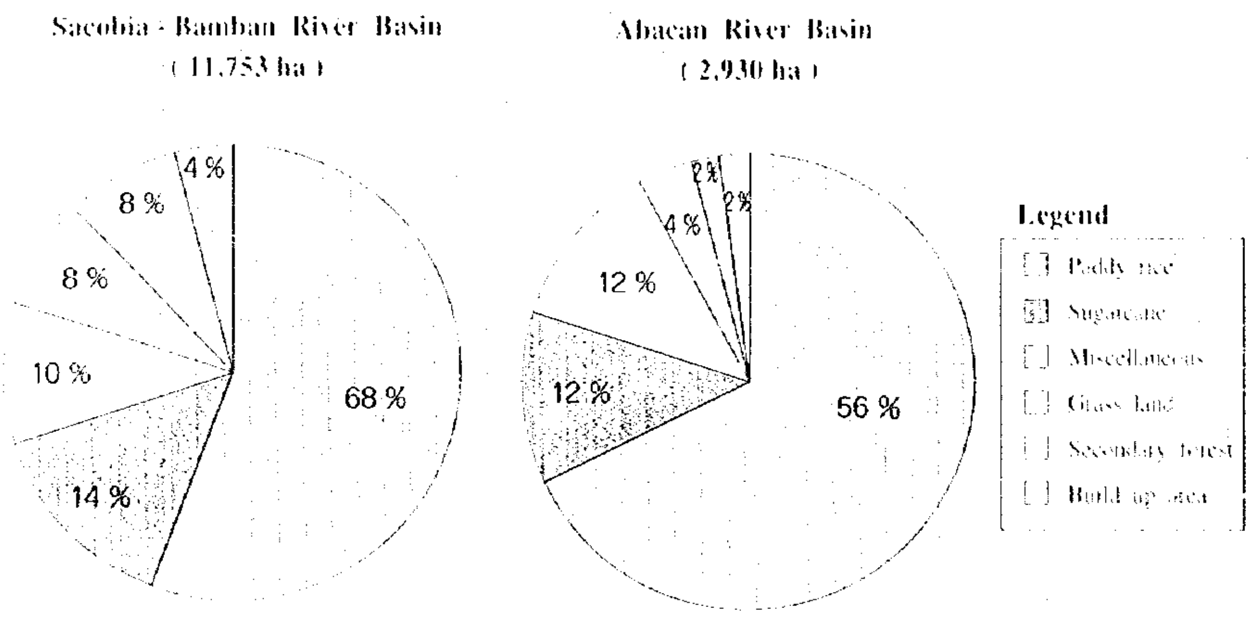
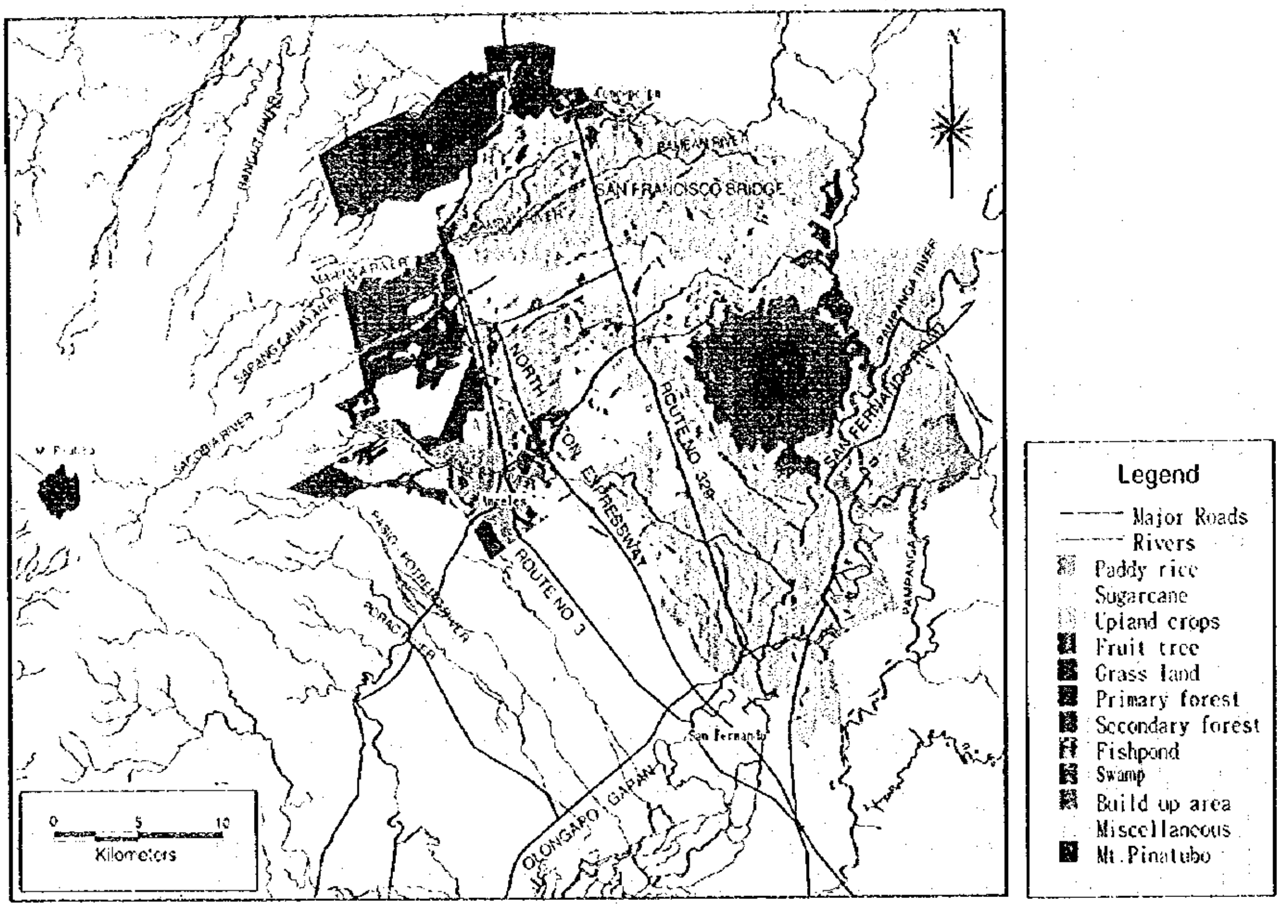
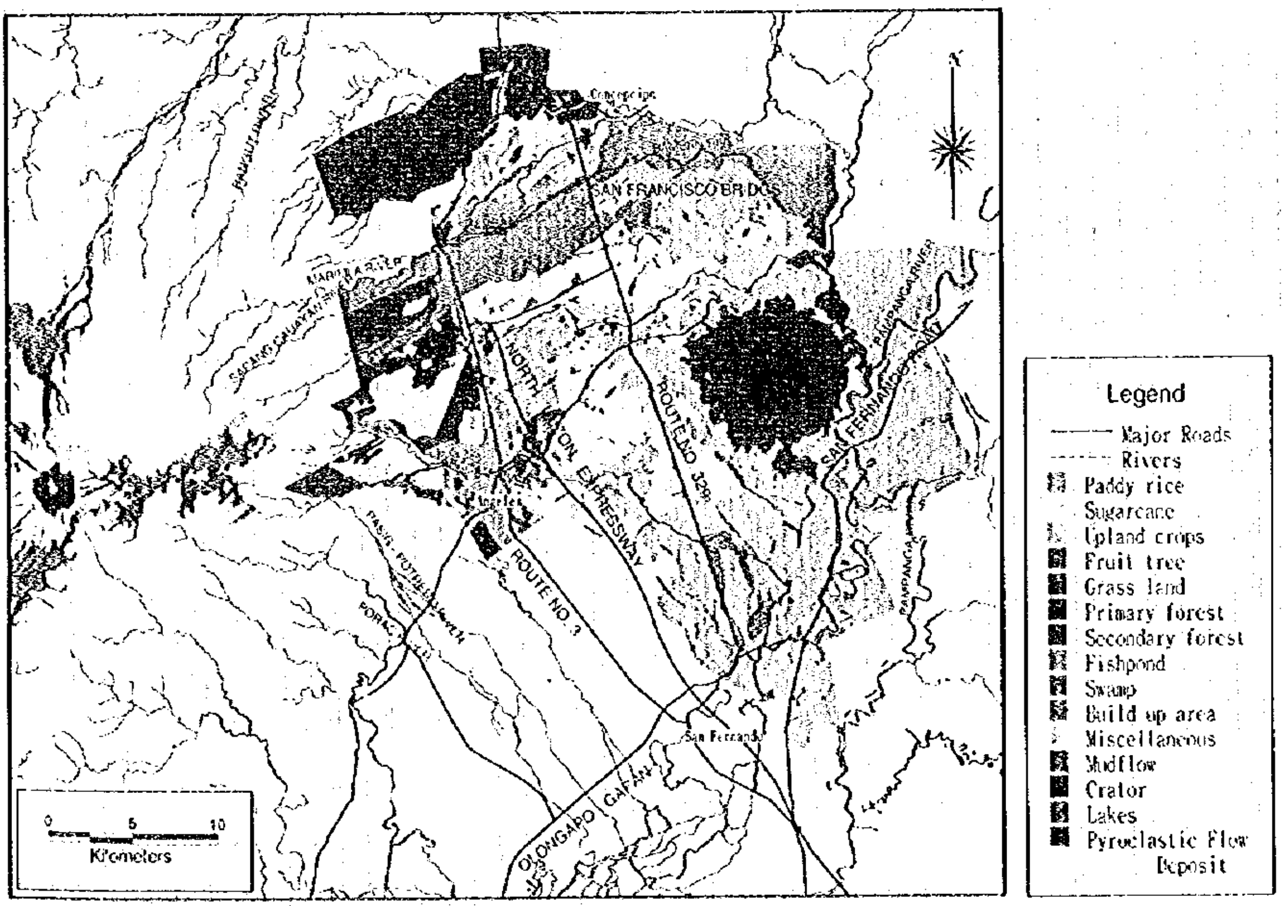


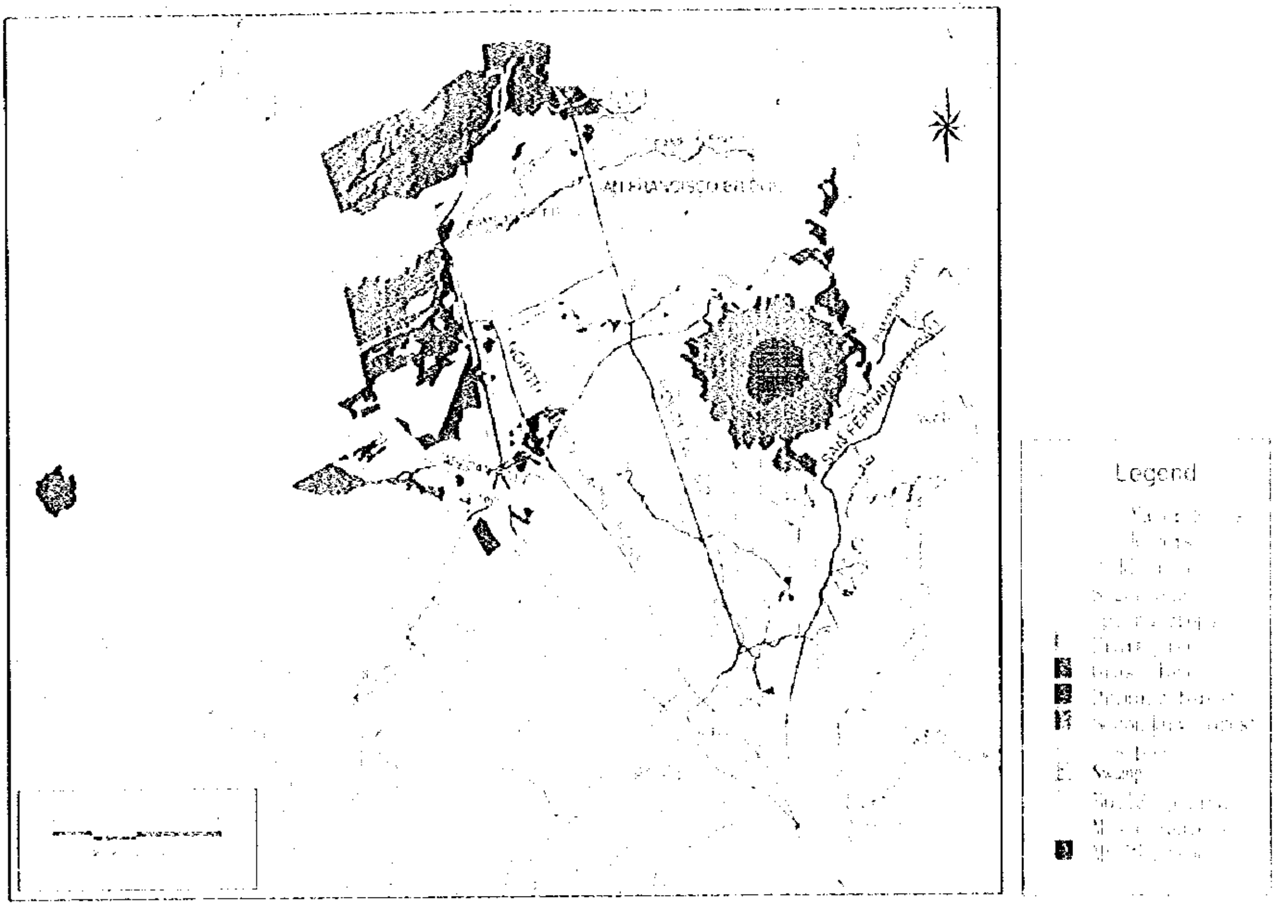
Land Use before Eruption in the Lahar Disaster Area



Land Use Map (Pre-Eruption)



Land Use Map (Post Eruption)



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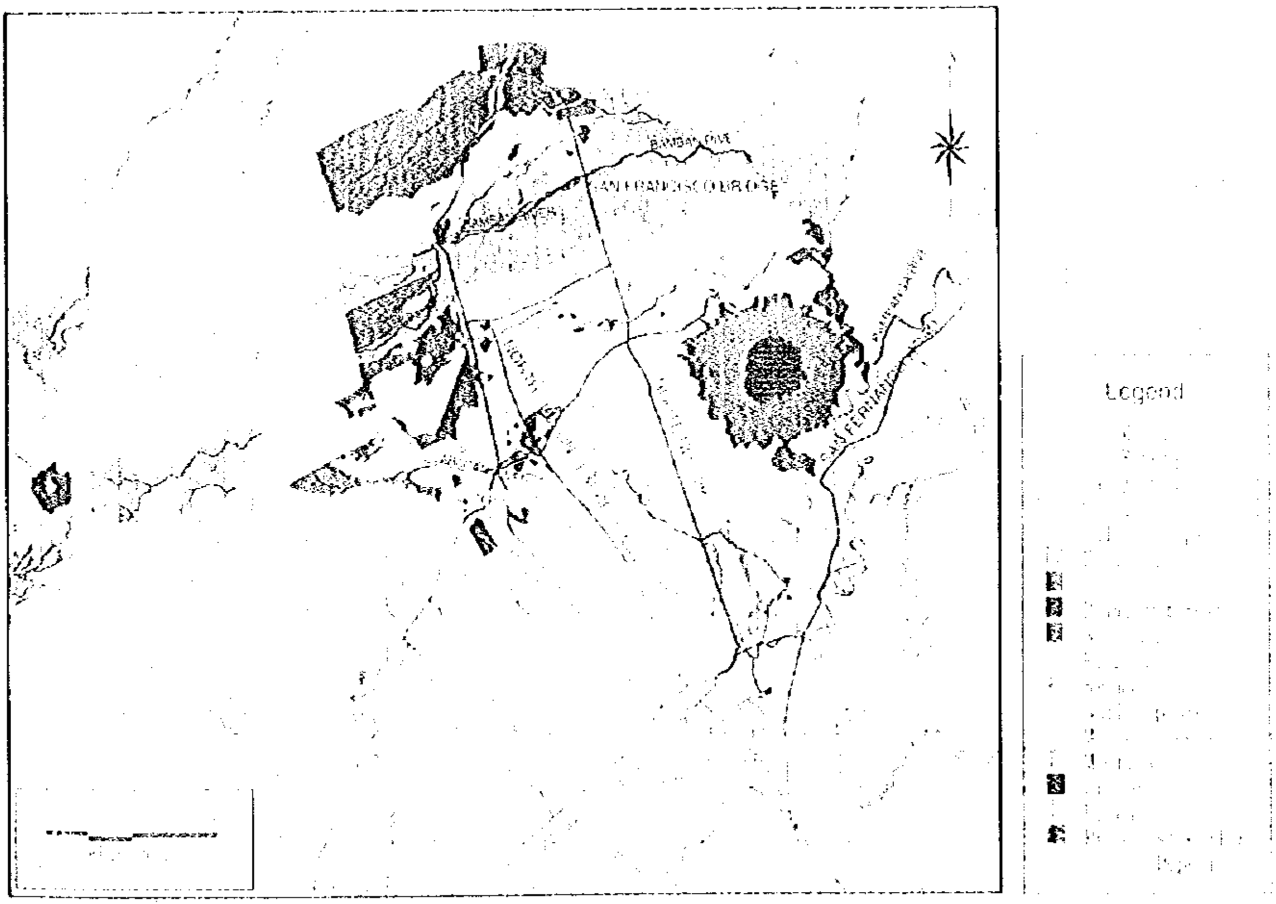
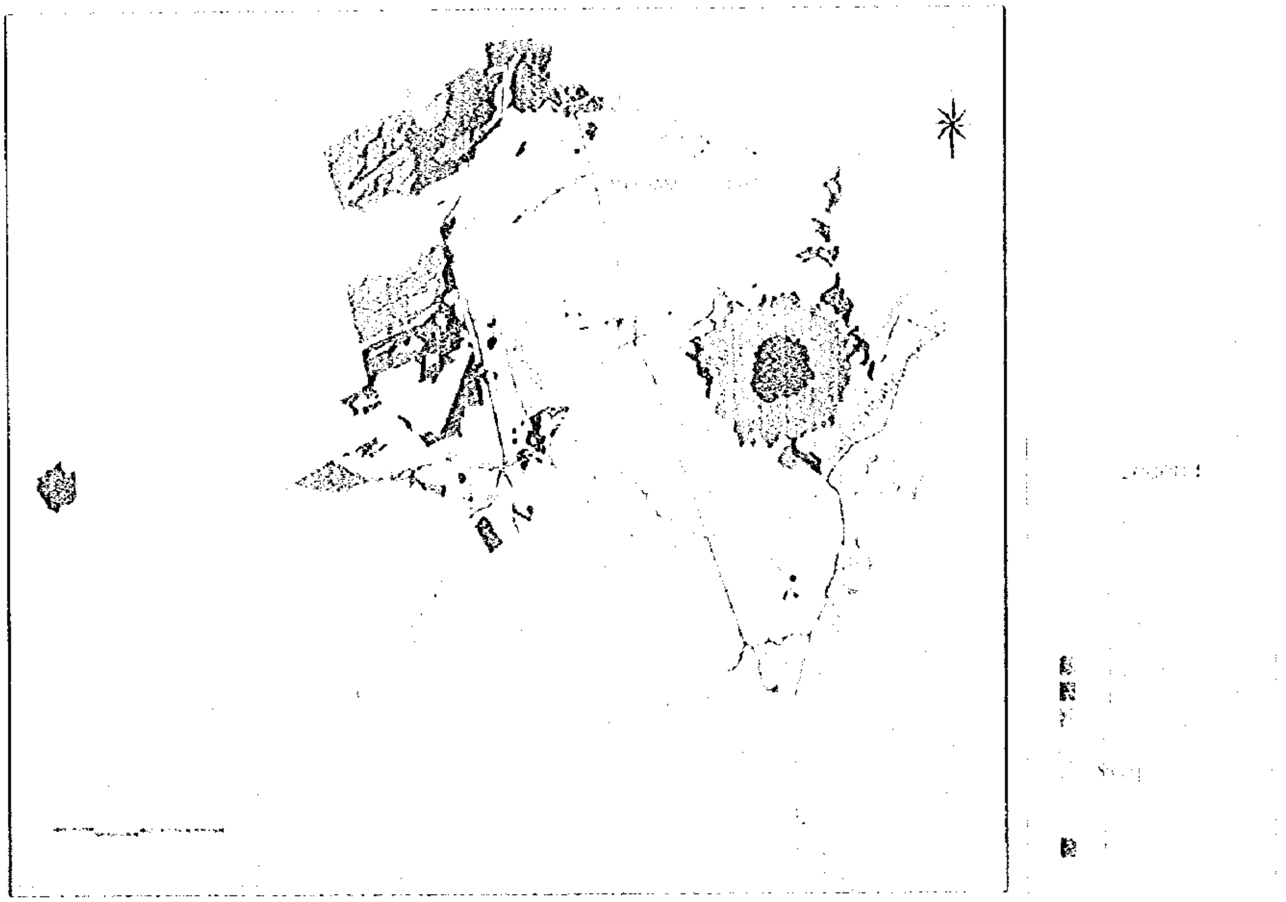
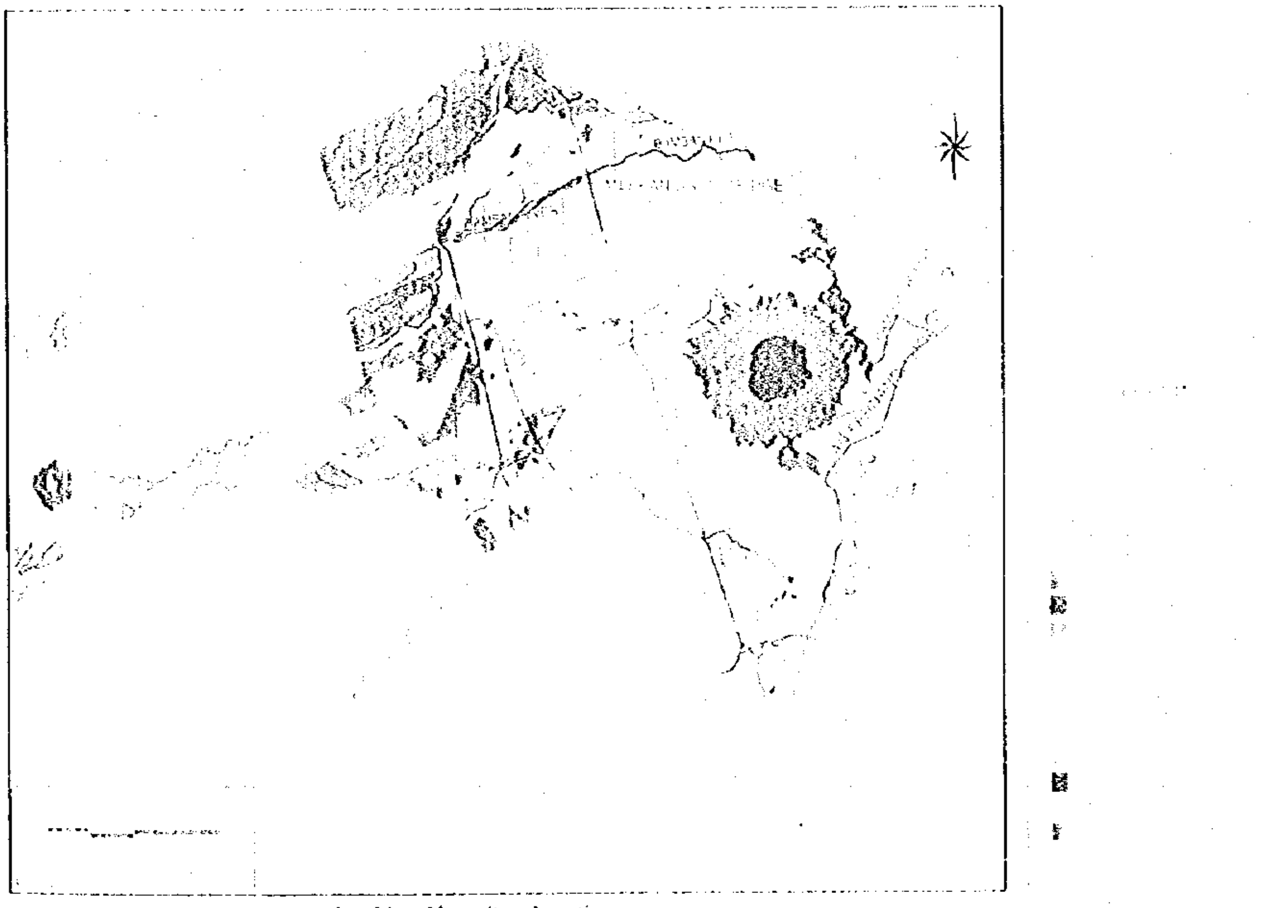


Land Use Map (Post Eruption)



Land Use Map (Pre-Eruption)



Land Use Map (Post Eruption)

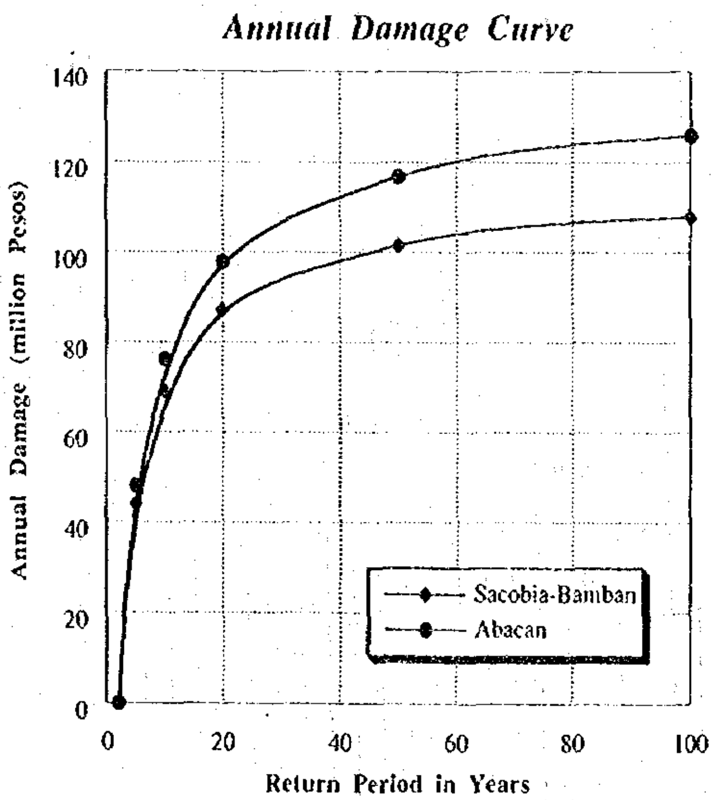
3.8 *FLOOD AND MUDFLOW HAZARD AREA*

Long-term flood and sediment hazard map was prepared for the Sacobia-Bamban, Abacan and Pasig river basins as a guide and reference in disaster mitigation and development planning.

The flood and sediment prone areas were analyzed based on the topographic condition in March 1994, of which a part of these areas were covered with lahar (disaster areas before March 1994), in particular, sand pocket area in the middle reach of the Bamban River, lower basin of the Abacan River and middle reach of the Pasig River. Those areas not likely affected by flood and sediment hazards are areas having ground surface elevation higher than the prone areas.

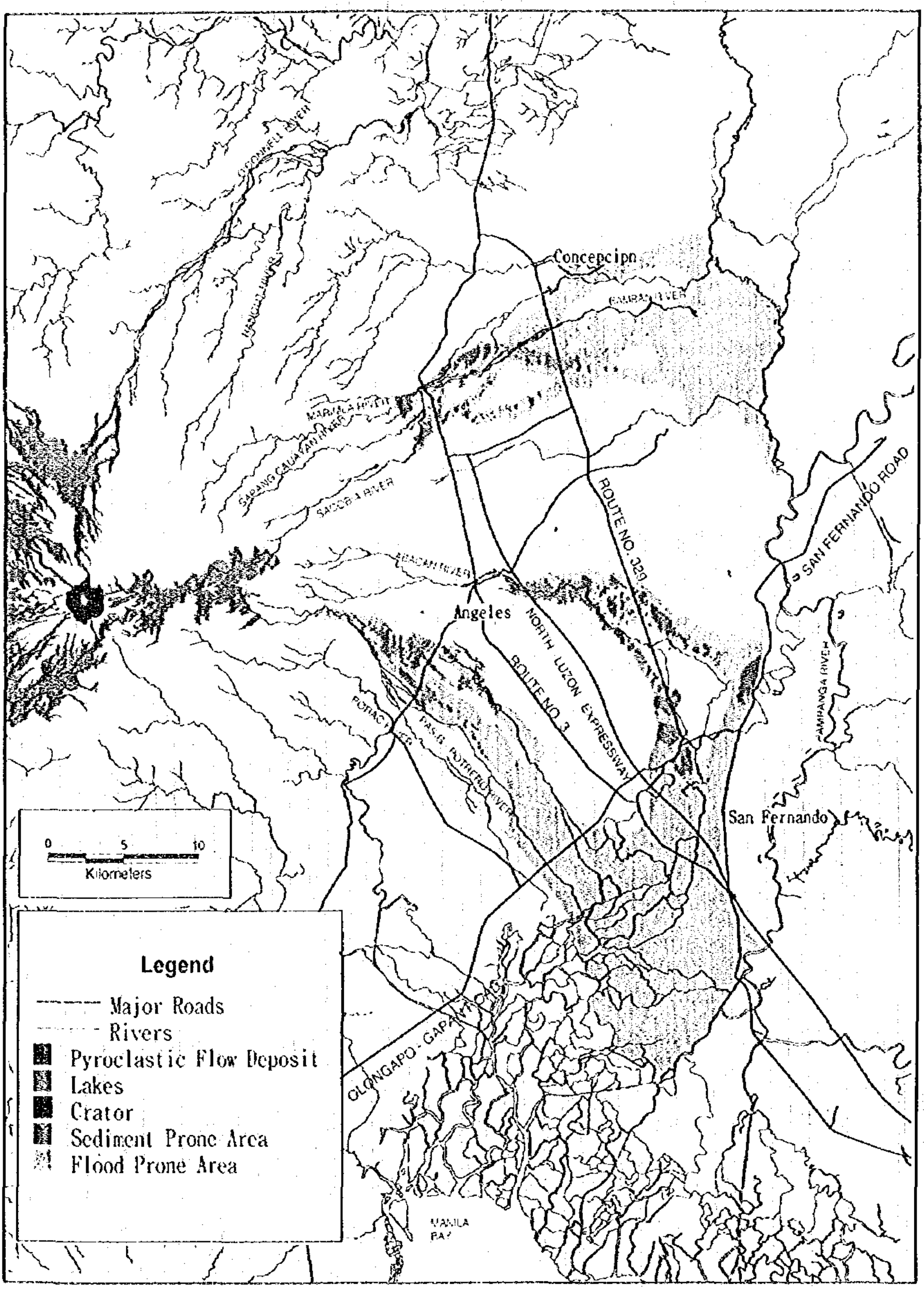
The data contain the sediment and inundation depth for each 100 meters x 100 meters cell in the simulation area. The maximum inundation areas with return periods of 100 years were created by using both the results of numeric simulation and GIS techniques.

The probable direct damage value for building, agricultural crops and infrastructures was computed based on the percentage of the affected area to the total barangay area. The average annual direct damage was obtained for Sacobia-Bamban and Abacan river basin after aggregating each property damage. Judging from the gradient of the curves, the return period of 20 years can be considered reasonable for the planning scale of structures since that the incremental ratio of direct damage is not in direct proportion beyond the scale of the 20-year return period.



Return Period (years)	*Annual Damage (million Pesos)*	
	Sacobia-Bamban	*Abacan*
2	*0.00*	*0.00*
5	*44.04*	*48.06*
10	*69.09*	*76.32*
20	*87.14*	*98.50*
50	*101.57*	*116.78*
100	*107.88*	*125.79*

Estimated Probable Direct Damage



Hazard Map for Flood of 100-year return period

CHAPTER 4 STRUCTURAL MEASURE

4.1 BASIC CONCEPT

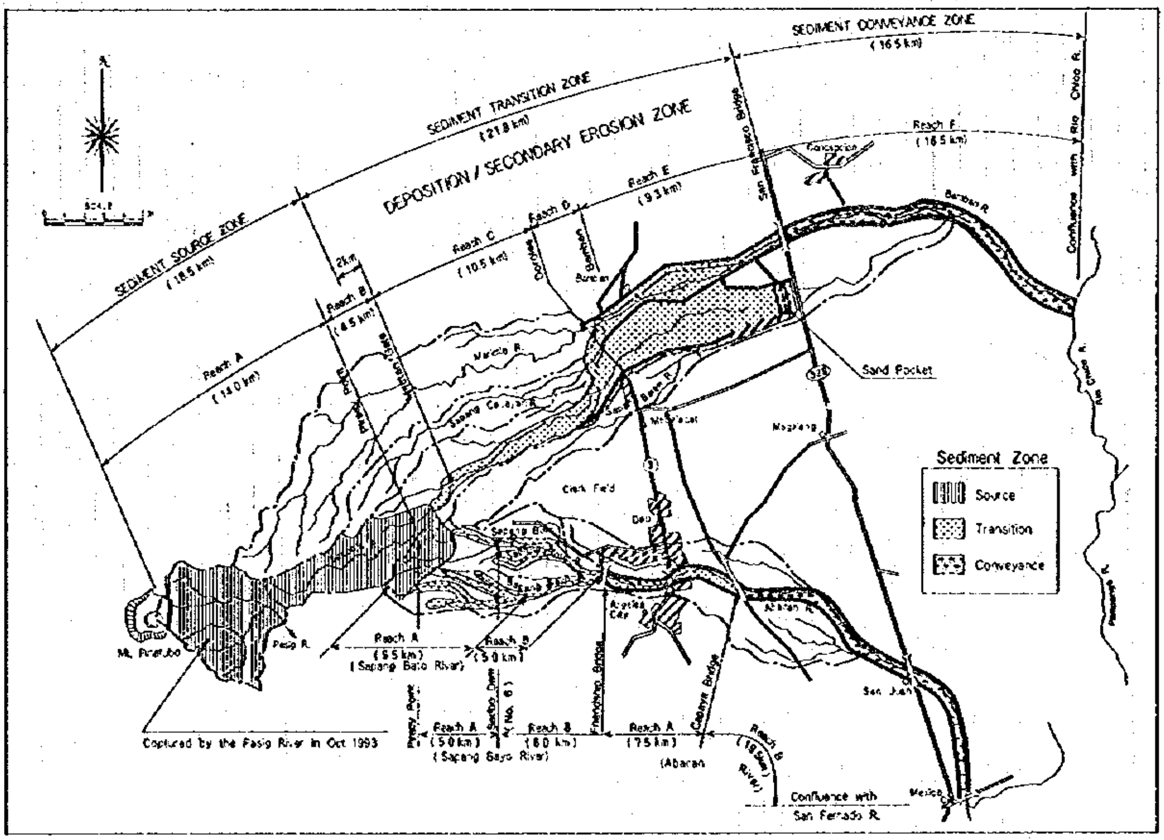
In the Sacobia-Bamban river basin, characteristics of sediment delivery to the downstream areas are divided into three zones.

Sediment Source Zone : The remarkable volume of ashfall and pyroclastic flow deposits were confined in the uppermost reach as sediment source. Although the ashfall deposit was one of the sediment sources immediately after the eruption in 1991, the pyroclastic flow deposit field is regarded as a major sediment source to the downstream areas.

Sediment Deposition/Secondary Erosion Zone : Most sediment transported from the sediment source zone is being deposited in the sediment deposition/secondary erosion zone for the reach 2 km upstream of Mactan to San Francisco bridge. The spindle-shaped valley from Mactan to Maskup stores a remarkable volume of sediment and provides sediment due to secondary erosion in the downstream areas.

Sediment Conveyance Zone : The sediment in the conveyance zone is transported gradually through the Rio Chico River in proportion to the rate of river flow.

In the Abacan River, no lahar flow was observed since 1992 because a small escarpment, so called the "Abacan Gap", formed difference in riverbed elevation of 40 to 50 m between the Sacobia and Abacan rivers. Some pyroclastic flow deposits still remain in the upstream reach of the Abacan River which is regarded as the sediment source in the future.



Sediment Zone

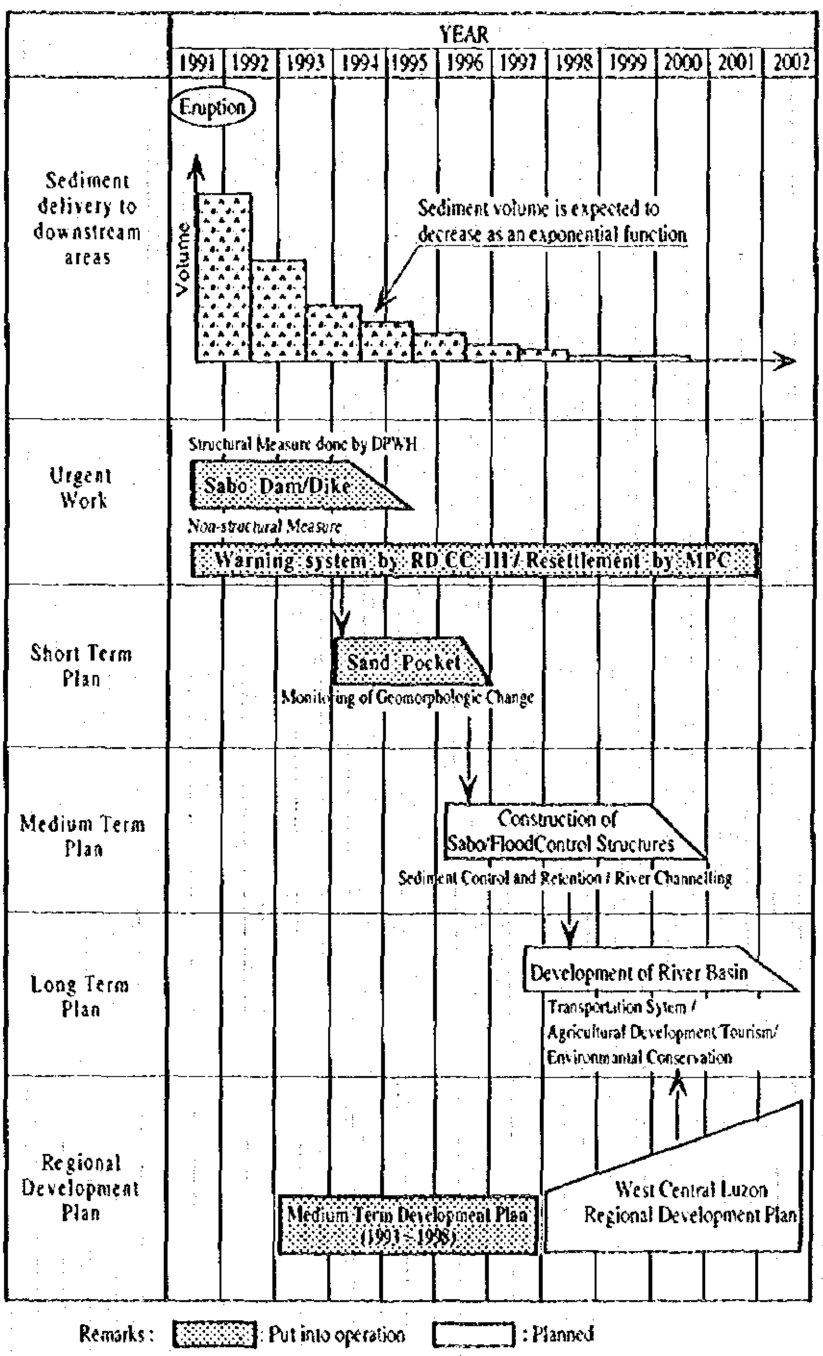
The master plan of mudflow and flood control works was formulated under the phase categories which include (1) urgent works which have been carried out by the DPWH for the period from 1991 to 1993, (2) short term plan to be carried out for the period from 1994 to 1996 before the overall proposed study plan is implemented, (3) medium term plan which is composed of overall mud flow/flood control works and (4) long term plan of rehabilitation and reconstruction of the affected areas.

Urgent Works : Rehabilitation works by the DPWH for the period from 1991 to 1993 are regarded as Urgent Works. Warning system by the Regional Disaster Coordinating Council in Region III (RDCC III) and the resettlement plan by MPC are regarded as non-structural measure.

Short Term Plan : Sand pocket structures at Bamban river basin were constructed by the DPWH before the onset of rainy season in 1994. The structures coped with the changes in natural condition because of uncertainties of producible volume of mudflow to low-lying areas.

Medium Term Plan : The alignment and combination of structural measures was formulated as permanent structures to ensure the safety against future flood and mudflow.

Long Term Plan : The structures are planned to accelerate the development strategy of the Regional Development Plan.

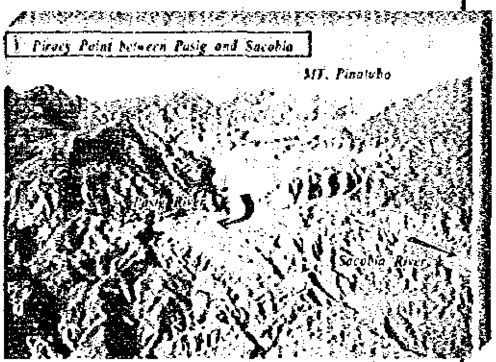


Implementation Schedule of Structural Measures

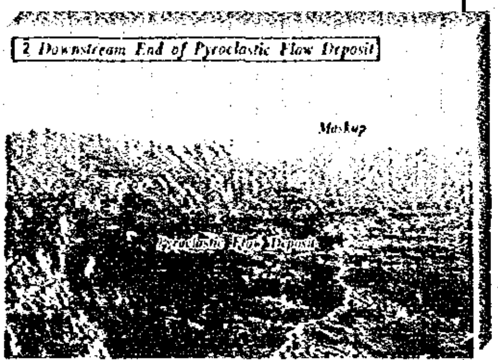
4.2 SACOBIA-BAMBAN RIVER BASIN

4.2.1 Short Term Plan

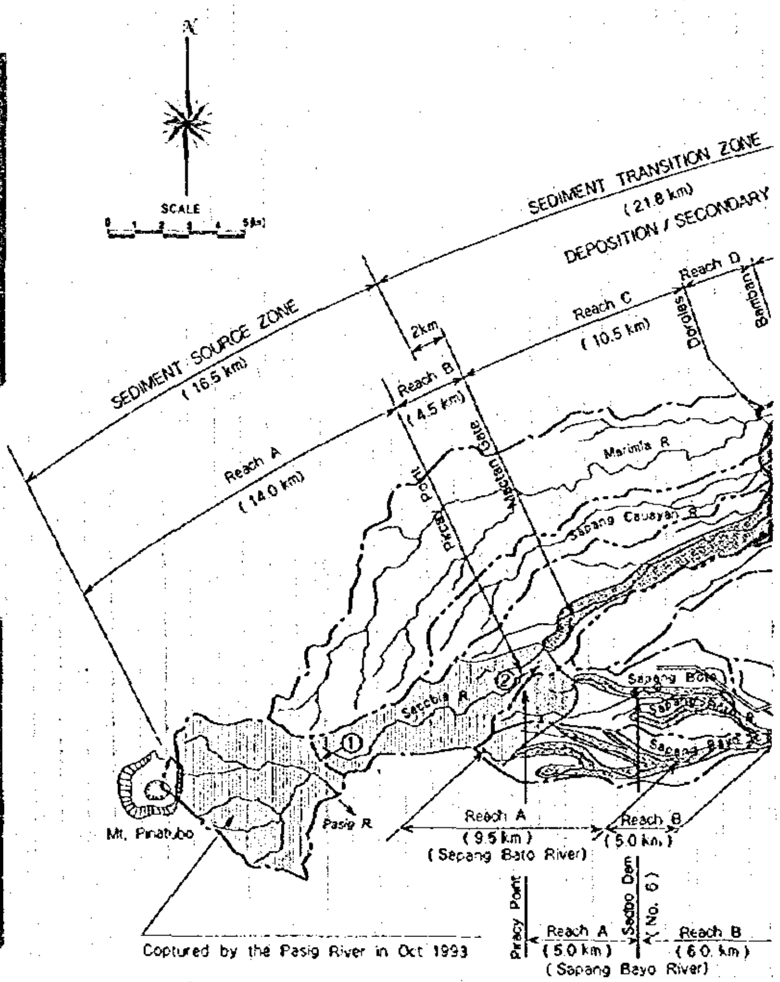
A diking system has been constructed along the downstream reaches of Bamban and Abacan rivers from 1992 to 1993, while sand pocket structures in the middle reach of the Bamban River was constructed before the onset of the 1994 rainy season. In 1995, the main problem noted was the reduction of clearance of San Francisco bridge in the Bamban River and the lateral erosion of the Abacan river banks along Angeles City.

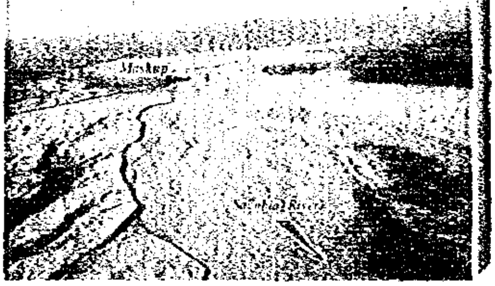


The upper catchment of the Sacobia river basin of 22 square km was annexed to the Pasig River Basin in October 1993.

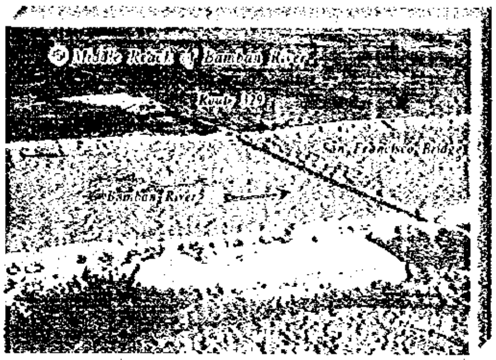


Lahar generated by heavy rainfall on erodible pyroclastic flow deposit posed grave danger to human lives and properties in the low-lying areas.

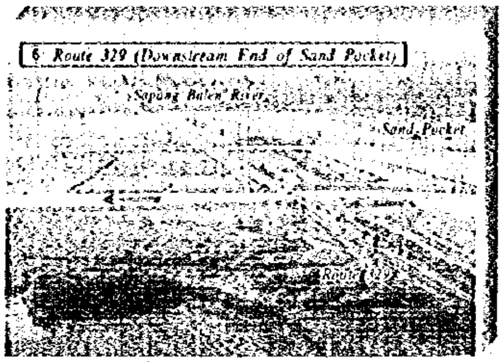




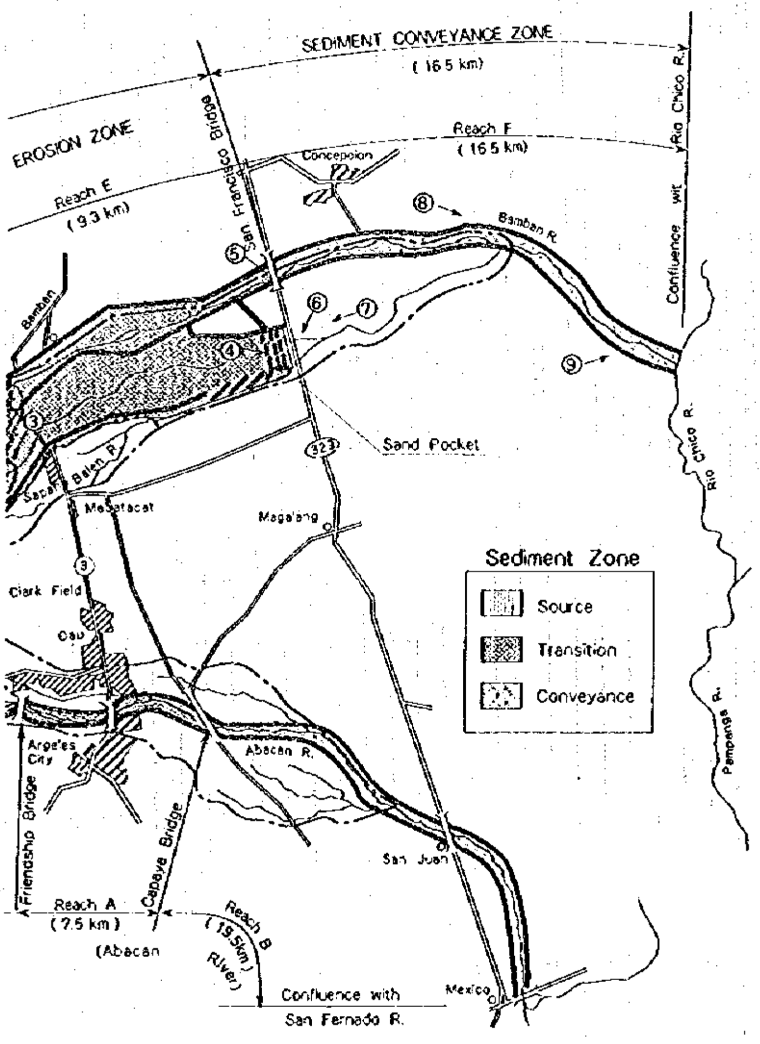
Lahar deposit in the spindle-shaped valley between Maskup and Mactan was estimated at 100 million cubic meters in 1995. The Sacobia River flows directly into the sand pocket area.

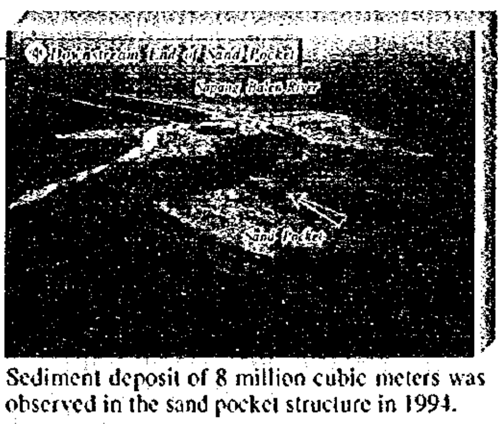


Clearlance of San Francisco bridge was reduced to 70 cm after the passage of Typhoon "Mameng" in October 1995.

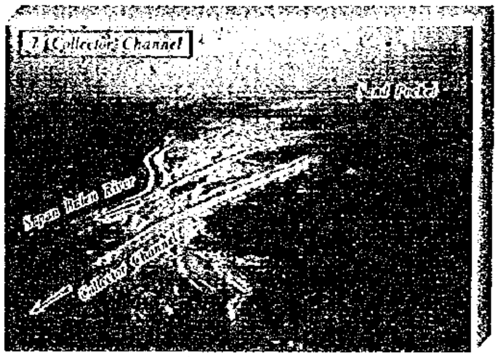


Route 329 is the only artery connecting South with North Luzon since Route 3 was buried with lahar in 1991.

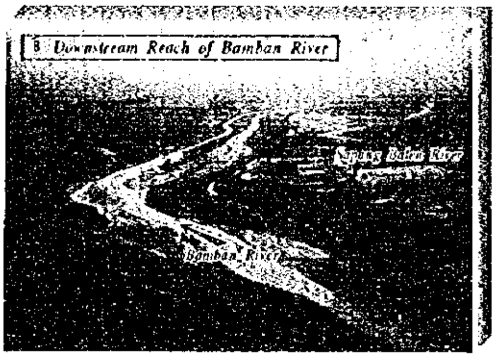




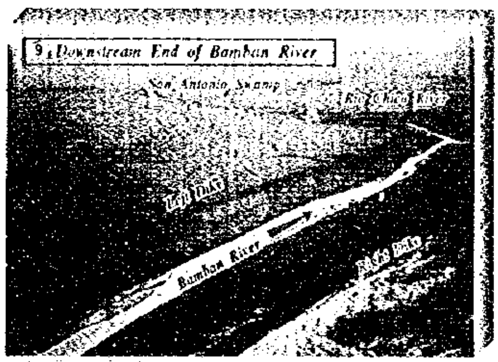
Sediment deposit of 8 million cubic meters was observed in the sand pocket structure in 1994.



Collector channels were constructed in 1994/1995 to ease the river flow of the Sacobia River to the Sapan Balen River.



The Sapang Balen River flows down along the right bank of the Bamban River.

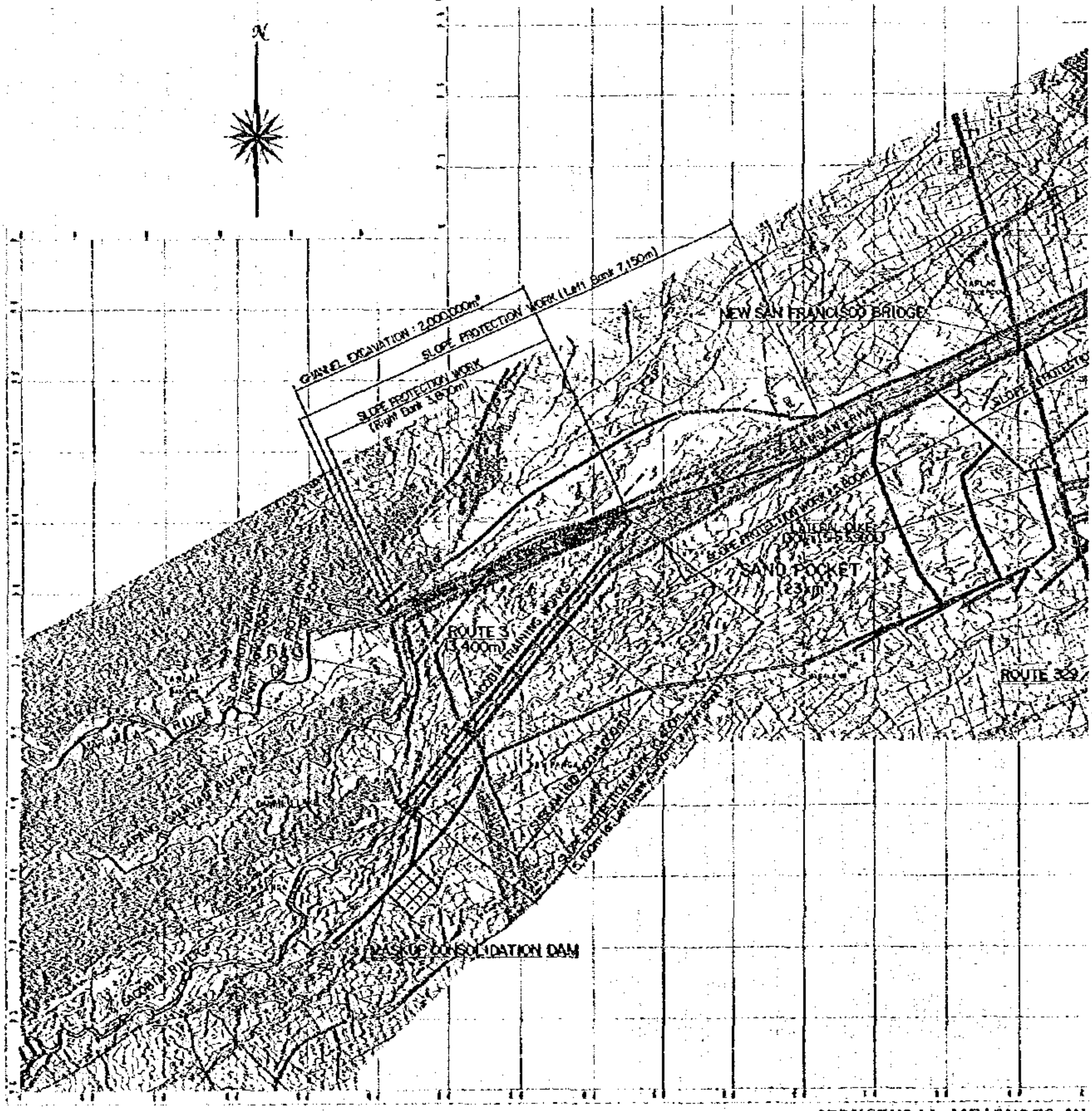


Riverbed aggradation was observed in the lower reach of Bamban River. It finally joins into the Rio Chico River.

4.2.2 Medium Term Plan

For the medium Term Plan, combination of structures was adopted on the basis of economic comparison. The objectives of putting up these structural measures are; (1) to store the unstable sediment in the river stretch between Mactan and Maskup by the construction of a consolidation dam, (2) to realign the Sacobia river channel into the Bamban River for the restoration of sand pocket area, and (3) to maintain the present riverbed elevation in the whole stretch of the Bamban River. These structures were designed to ensure the safety against a flood with 20-year return period. Principal features of the structural measures for the Short and Medium Term Plans are shown in the next page.

To carry out such plans, periodic topographic surveys and water samplings are required to elaborate the dimension of structures in accordance with geomorphologic changes and riverbed fluctuations in the Sacobia-Bamban River such as the figure shown below.



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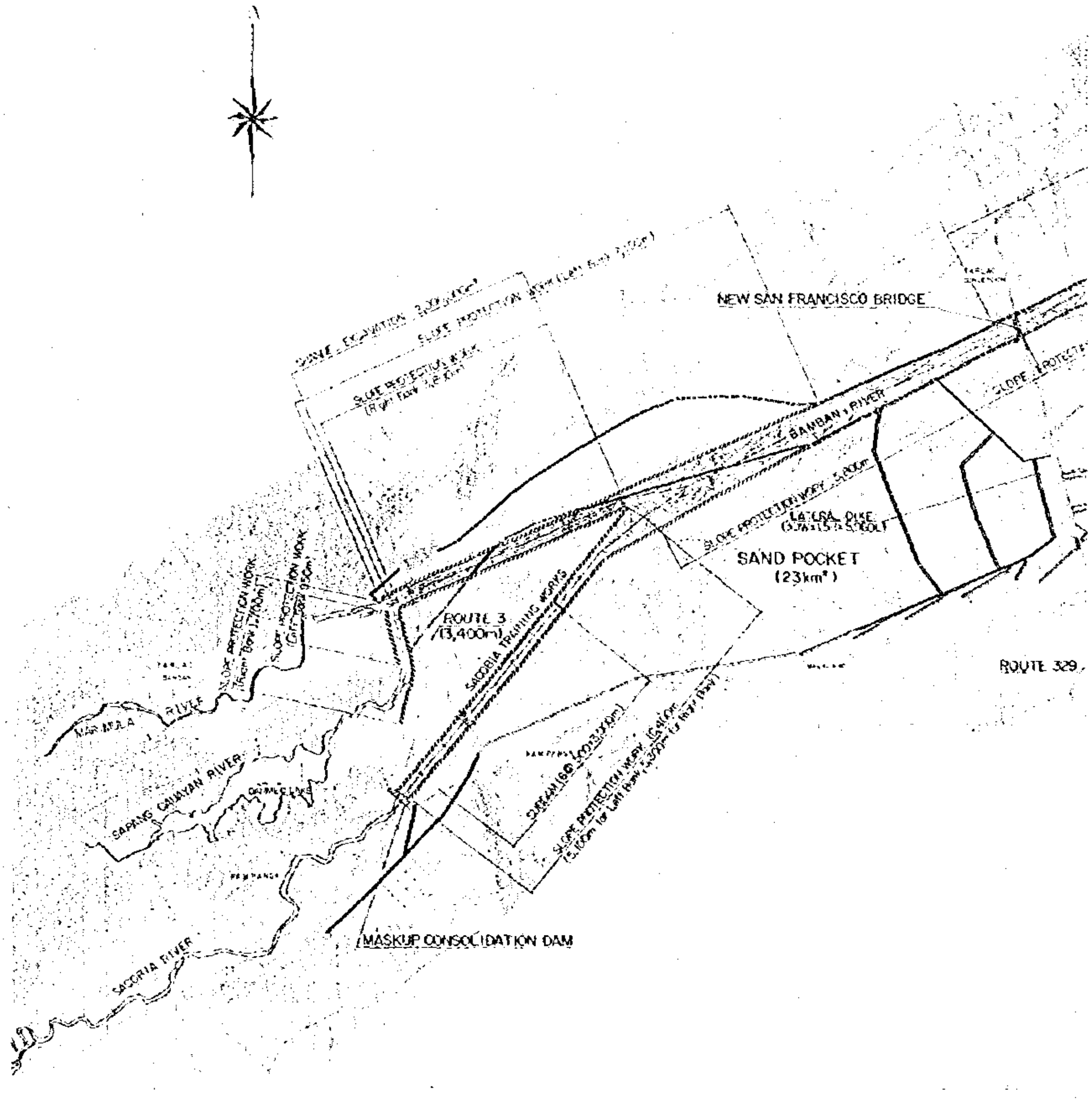


SHORT TERM PLAN (PHASE II)

(1) Sand Pocket Reinforcement Works

Route 329 Road Dike	1.65 km long
Lateral dike	5.96 km long
Reinforcement of Dike	12.5 km long

(2) Sapang Balen River Improvement

Straightening	2.0 km long
Slope Protection	1.2 km long
Bridge Rehabilitation	30 m long

MEDIUM TERM PLAN

(1) Sacobia River Training Works

Consoli. Dam	3.7m (H), 490m (W)
Groundsills	6 sets
Channel Excavation	5.2 km long

(2) Bamban River Improvement

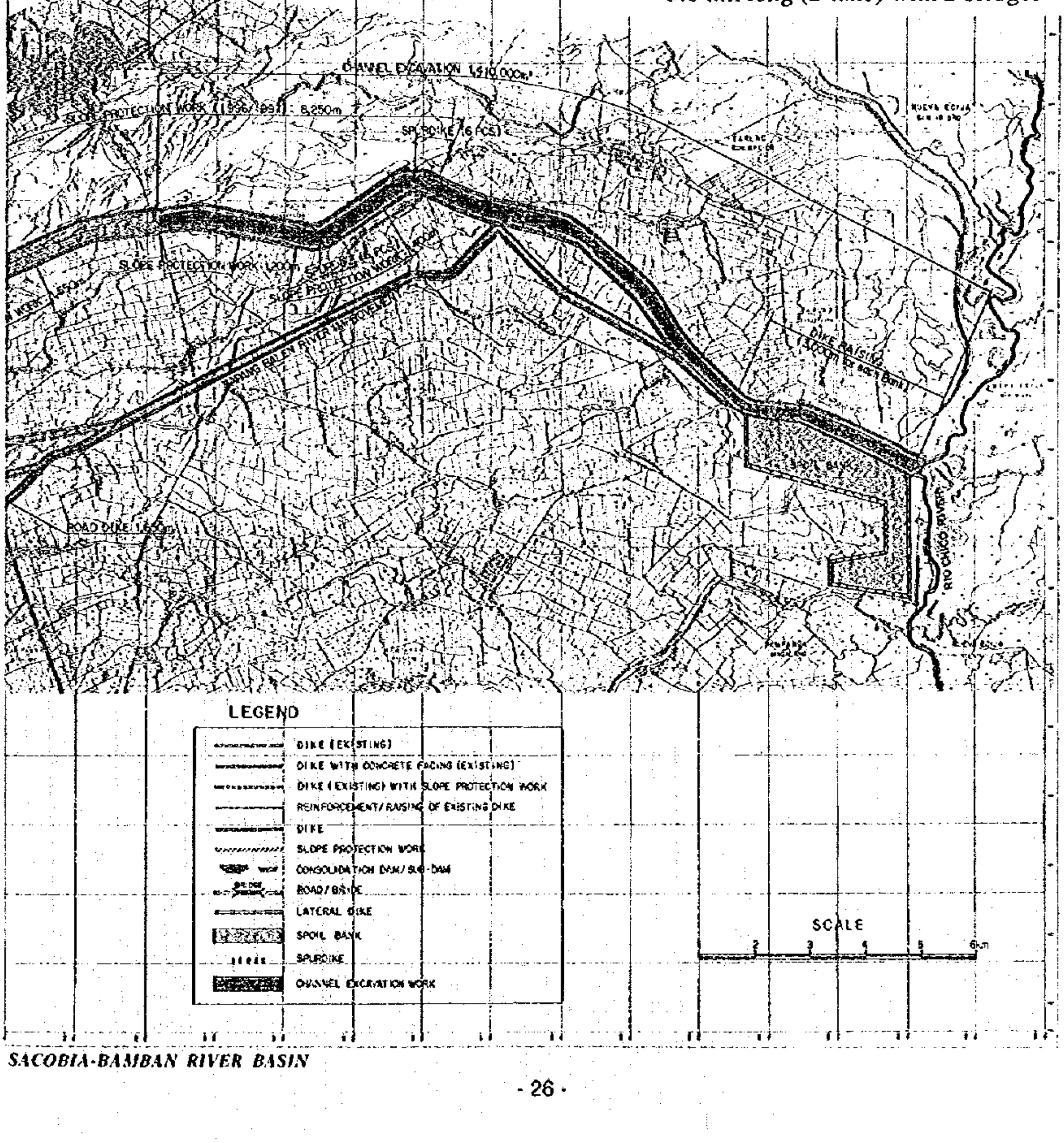
Channel Excavation	3.4 million m^3
Slope Protection	29.2 km long
Dike Raising	6.0 km long
Dike Reinforcement	12.5 km long
Spurdike	12 sets

(3) Sapang Cauayan River Improvement

Slope Protection	2.7 km long

(4) Restoration of Route 3

3.6 km long (2-lane) with 2 bridges



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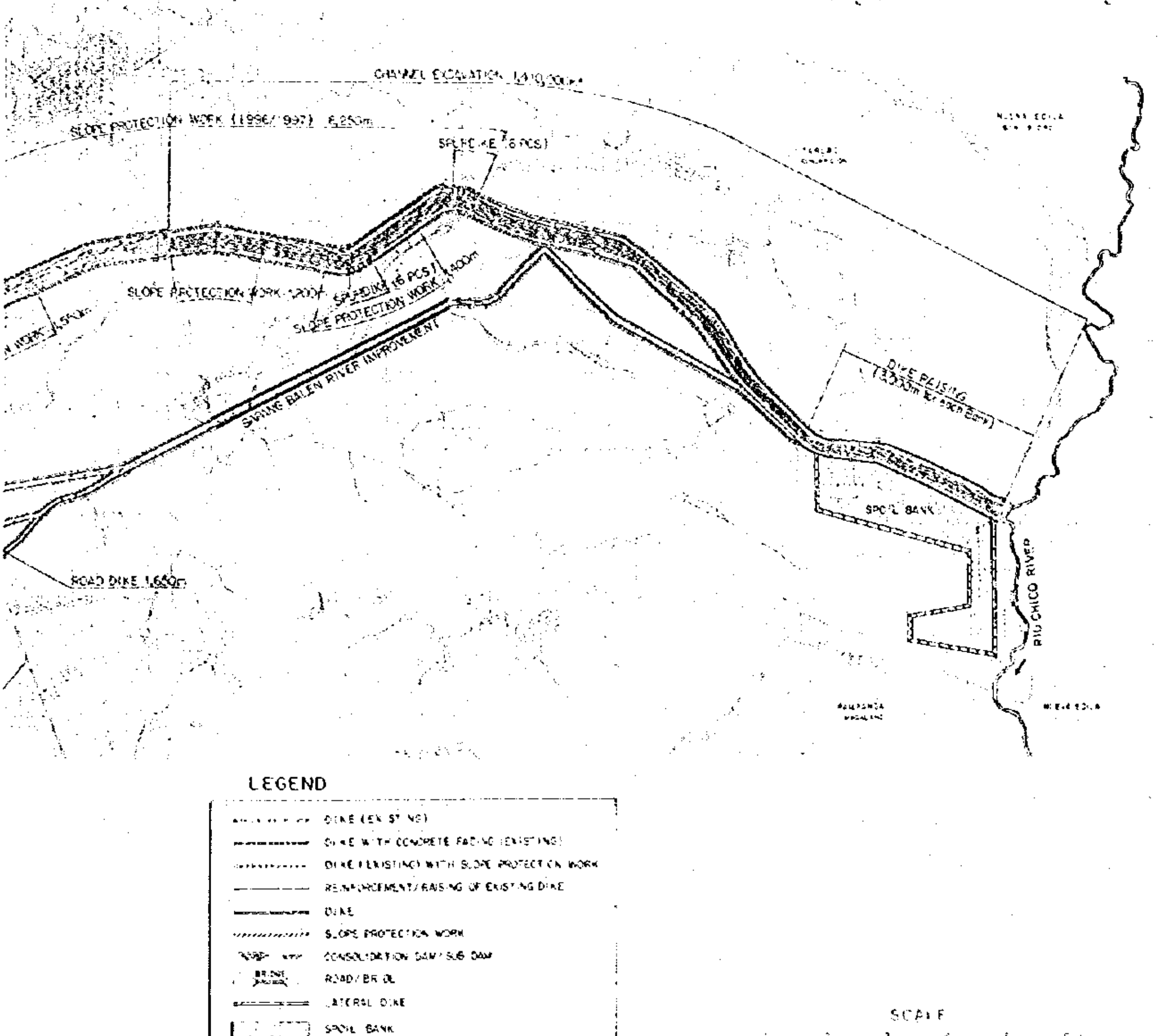
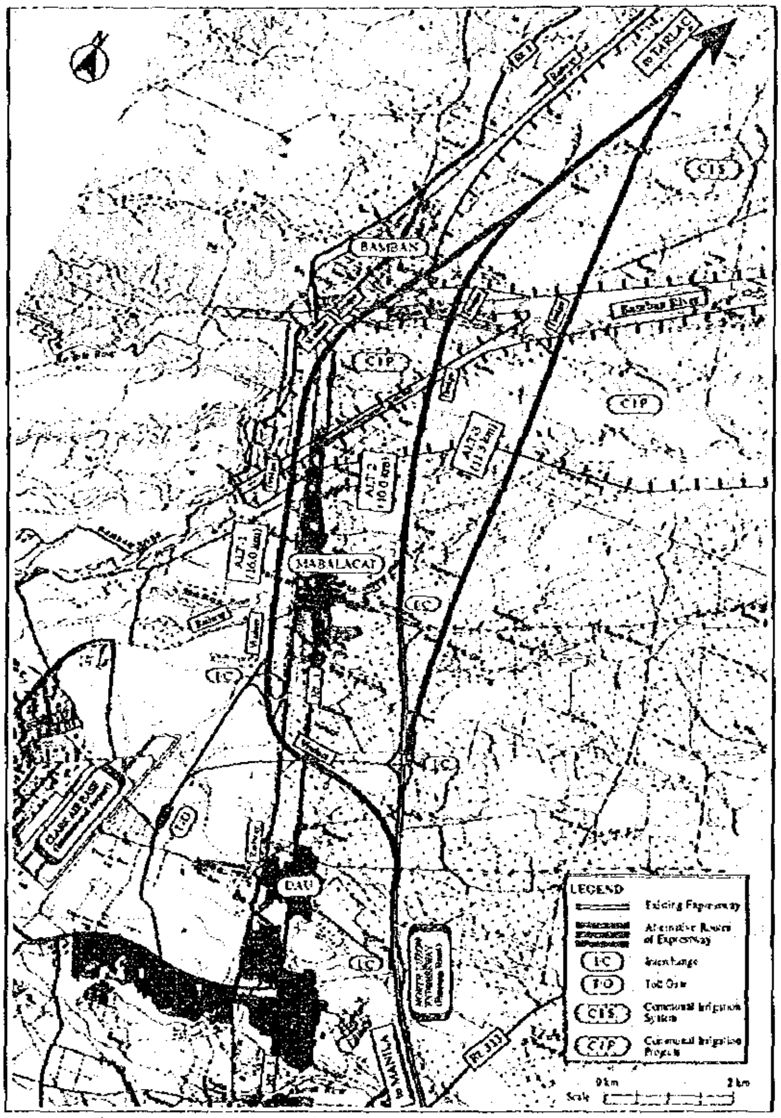


4.2.3 *Long Term Plan*

(1) Road Network Development

The extension of North Luzon Expressway was introduced in the "Integrated Plan for the Mt.Pinatubo-Affected Areas " (MPC). It aims to improve the capacity of the existing North Luzon Expressway and to provide a direct access route to Clark Special Economic Zone and the provinces of Tarlac and Pangasinan.

In the Central Luzon Regional Development Study (JICA, 1995), the extension of North Luzon Expressway was also considering a top priority. The alternative routes between Dau and Bamban were delineated primarily to take into account the future development plan of Clark Special Economic Zone.

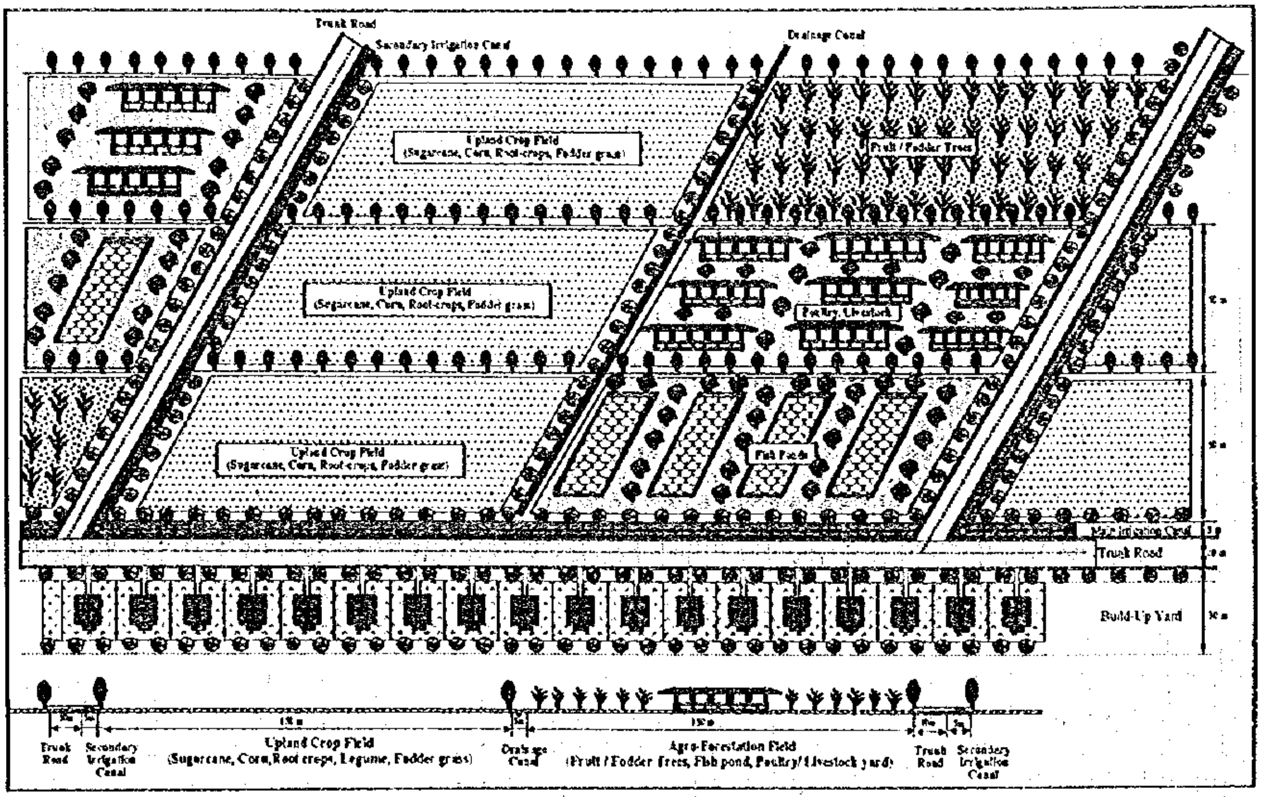


Extension of North Luzon Expressway

(2) Agricultural Development Project

A Santa Rita pilot firm at Concepcion, Tarlac is being demonstrated as an integrated agricultural development project. The pilot farm to be established in Santa Rita is envisioned to identify and experiment the suitable crops on lahar covered areas of 1.5 to 2.5 m deep. It is also aimed to encourage lahar affected farmers to plant suitable crops based on the result of the crop experimental works.

The proposed projects of 2,090 ha are organized into three Communal Irrigation Projects (CIPs) in sand pocket area. The source of irrigation water will be ensured by the intake structures in Sacobia and Bamban rivers. Although lahar deposit is expected to be 1.5 m deep at present, rainfall and supplemental groundwater ensure the potential irrigable area of 1,540 ha. The proposed cropping pattern and farming technology including the type of crops to be planted will be scrutinized based on the results of the experimental works in the Santa Rita Pilot Project.



Agricultural Development Plan in Sand Pocket Area

(3) Tourism

The damming of Marimla and Sapang Cauayan rivers by the aggradation of the Sacobia River has led to the intermittent formation of lakes. The dammed lake at Sapang Cauayan River maintained its storage of 7 million cubic meters at El. 90 meter. This lake may exist temporarily and is expected to become smaller year by year due to the erosion of the lake outlet. Permanent structure such as consolidation weir may be required at the lake outlet in order to keep the surface water level of lake at its present condition. The eruption of Mt.Pinatubo and its tremendous devastation to the surrounding areas as well as its global effect on climate change is enough reason for scientists as well as foreign and local tourists to flock the area. In addition, land transformations paved the way to the formation of artificial lakes. As far as the safety of climbing Mt.Pinatubo is concerned, sight-seeing network linking the mountains and lakes will be organized.

Dammed Lake in the Sapang Cauayan River

4.2.4 Implementation Schedule

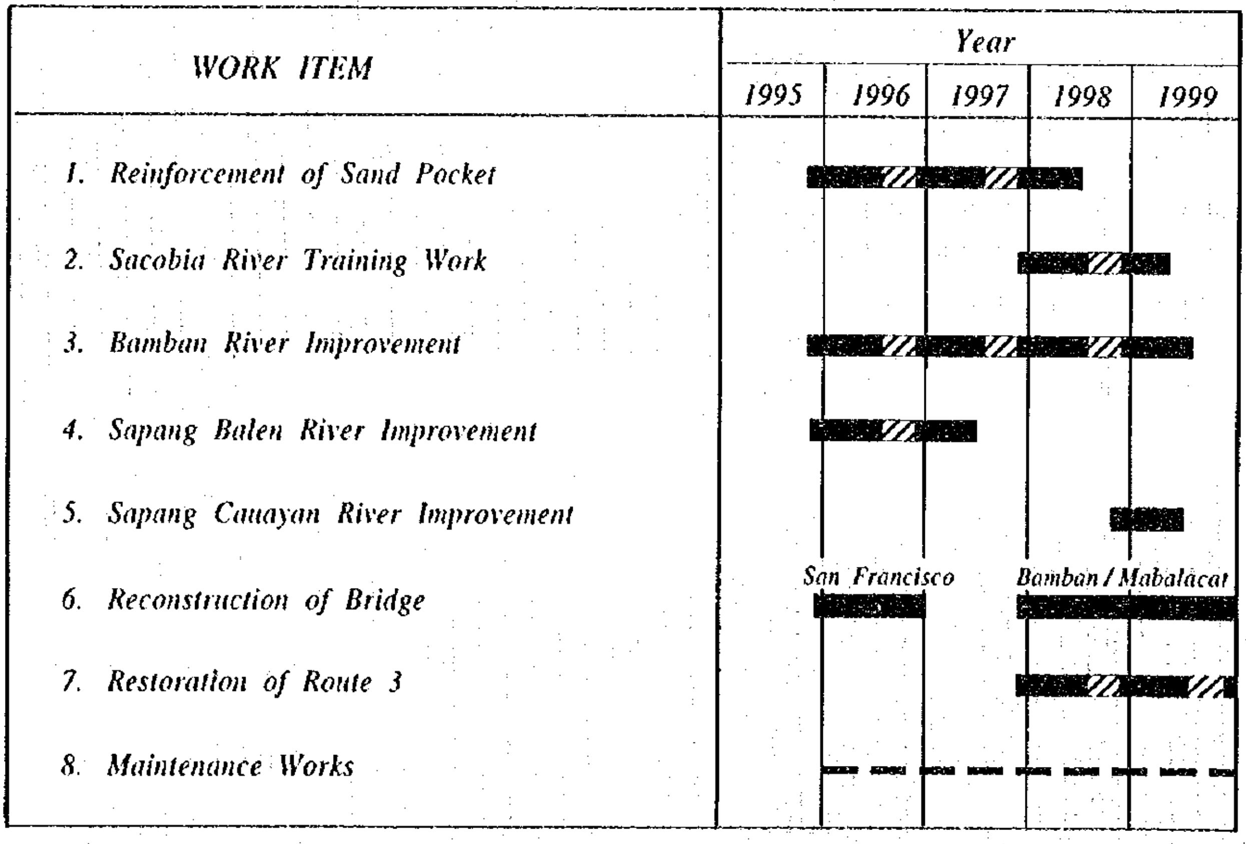
Organization and Management

The Project would be managed by the Mt.Pinatubo Rehabilitation Project Management Office (MPR-PMO), DPWH. Qualified consulting engineers would be appointed to prepare final designs and specifications and supervise construction.

Timing

As shown in the bar chart below, some rehabilitation works have already started under the 1995/1996 program of the DPWH. The reconstruction of San Francisco bridge has just started in November 1995 by DPWH under ADB's financing. The project would be completed by the end of 1999 assuming that annual workable months are 8 months during the dry season from November to June while the excavation work for maintaining channel cross section was estimated to be 1.5 million cubic meters for 9 years. Economic comparison of alternative options have shown that the viability of the chosen phasing is relatively insensitive to the phasing of construction.

Implementaion Schedule for Sacobia - Bamban River



Note : [hatched pattern] indicate rainy season.

4.2.5 Project Benefit

Cost Estimate

Capital costs were estimated to be about 2.8 billion Pesos as summarized below. Costs are based on the price level of November 1995. Exchange rate converting foreign currencies into local currency was US$1.00 = 25.0 Pesos = 100 Japanese Yen. Unit price method was applied to the cost estimation of main civil works.

Benefit, Estimated Rates of Return

The benefit to be accrued from the implementation of the Project was defined as the reduction damages of the direct and indirect caused by flood/mudflows. The damage under the with-project conditions was assumed to be zero under the design flood of 20-year return period. Benefit-cost comparison showed the economic internal rate of return (EIRR) of 16.4% under the net present value discounted at 12%. The project was also justified by sensitivity analysis for varying both the benefit and cost of the Project.

CAPITAL COST

(Unit : million Pesos)

Project Component	Cost
1) Main Construction Cost	1,930.98
2) Land Aquisition Cost	34.20
3) Administration Cost	98.26
4) Engineering Cost	193.10
5) Physical Contingency	215.83
6) Price Contingency	361.76
Total	2,834.13

Note : Price level in November 1995

ANNUAL DAMAGE

(Unit : million Pesos)

Type	Amount
1 Direct Damage	
1) Building	51.09
2) Crops & Livestock	19.00
3) Infrastructure	17.06
2 Indirect Damage	
1) Evacuation & Cleanup	8.62
2) Loss of GRDP	7.25
3) Detour Cost	76.77
Total	179.79

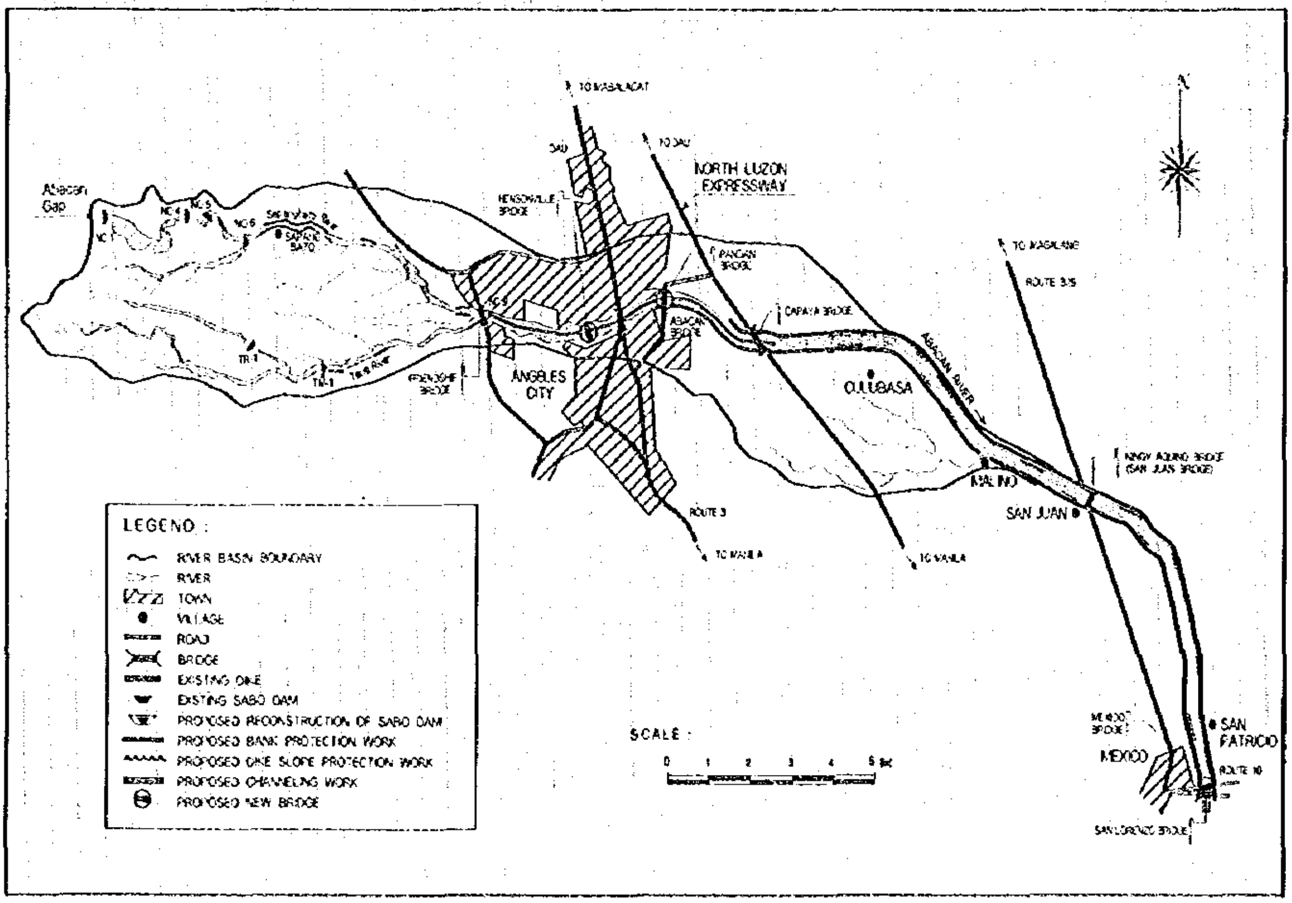
Note : Annual damage for 20 - years flood

4.3 ABACAN RIVER BASIN

4.3.1 Structural Measure

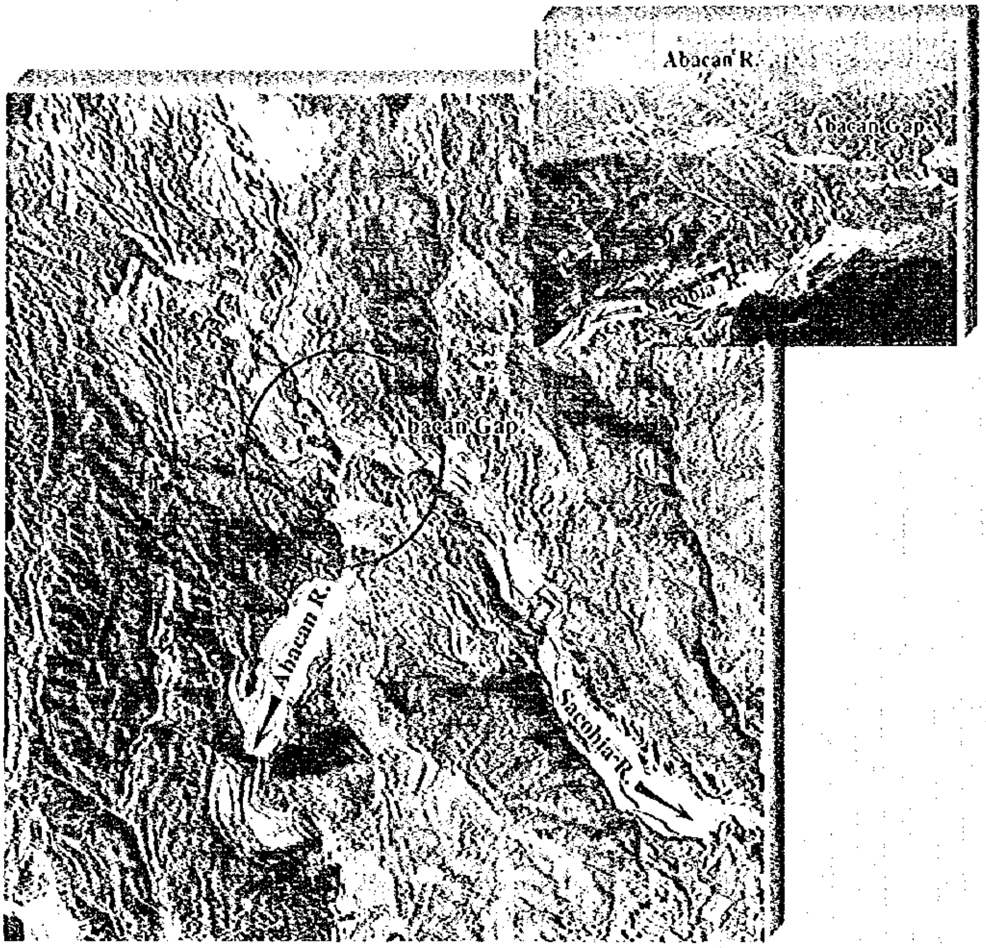
Ten sabo dams were constructed in the tributaries of the Abacan River for the period from November 1991 to June 1993. Some sabo dams have been repaired almost every year due to deterioration of materials and local scouring. Reconstruction of the selected sabo dams with high priority for sediment retention are inevitable as permanent structures as follows: Sabo dam No.9 (Abacan River), Sabo dam No.6 (Sapangbato River) and Sabo dam TM-1 (Taug River). Retaining wall will also be constructed against bank erosion along tributaries.

Along the Urban Area of Angeles City, a channeling work to stabilize the channel alignment is proposed. The channel is designed as trapezoid-shaped with slope protection of wet stone masonry type. In the downstream reach of the Abacan River, some bridges are scheduled to be reconstructed while the excavation work for maintaining channel cross section was estimated to be 2 million cubic meters for 5 years.

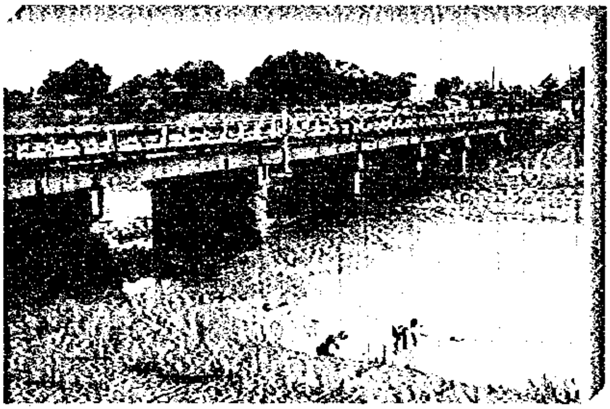


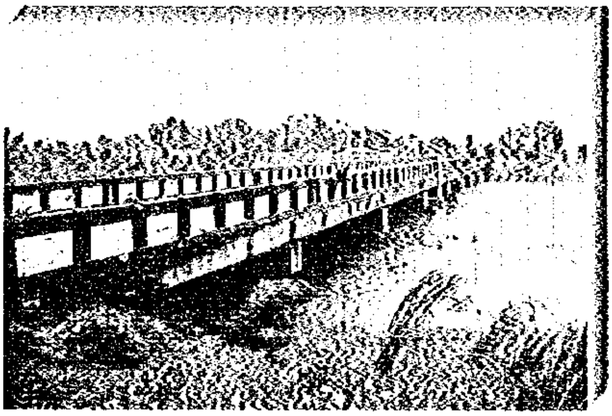
General Arrangement of Structural Measure in the Abacan River Basin

At the piracy point of Abacan and Sacobia rivers in 1992, (Abacan Gap), a small escarpment has caused a degradation of 30 meters in 1994 and has facilitated the piracy by the Sacobia River. No lahar flow occurred along the Abacan River ever since the piracy of the Sacobia River had occurred at Abacan Gap.

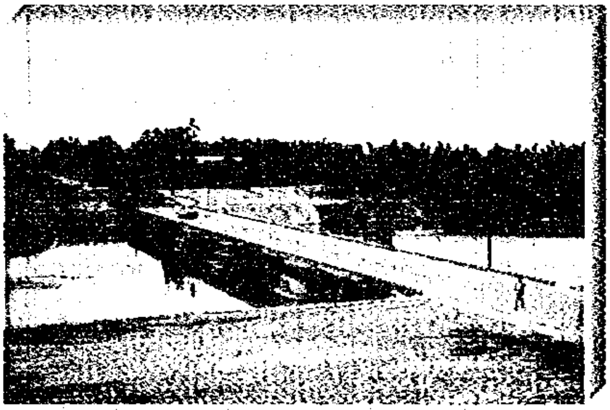


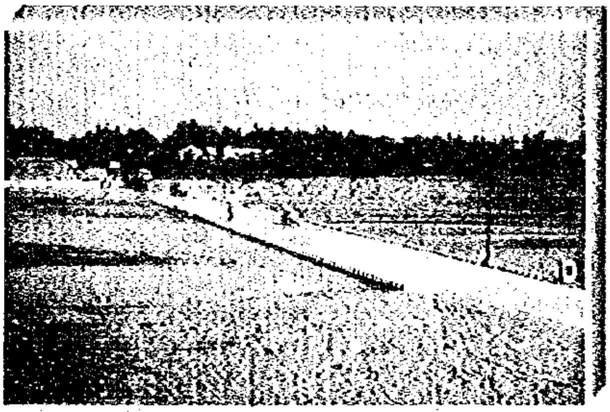
Abacan Gap





Sediment samplings at Ninoy Aquino bridge were carried out even in the flooding period. (September 15 and October 01, 1995.)





Mexico spillway was buried with sediment. Annual sediment deposition is estimated at 400,000 m^3 at Mexico Spillway in the downstream end of the Abacan River. (July 6 and November 3, 1992)

4.3.2 Implementation Schedule

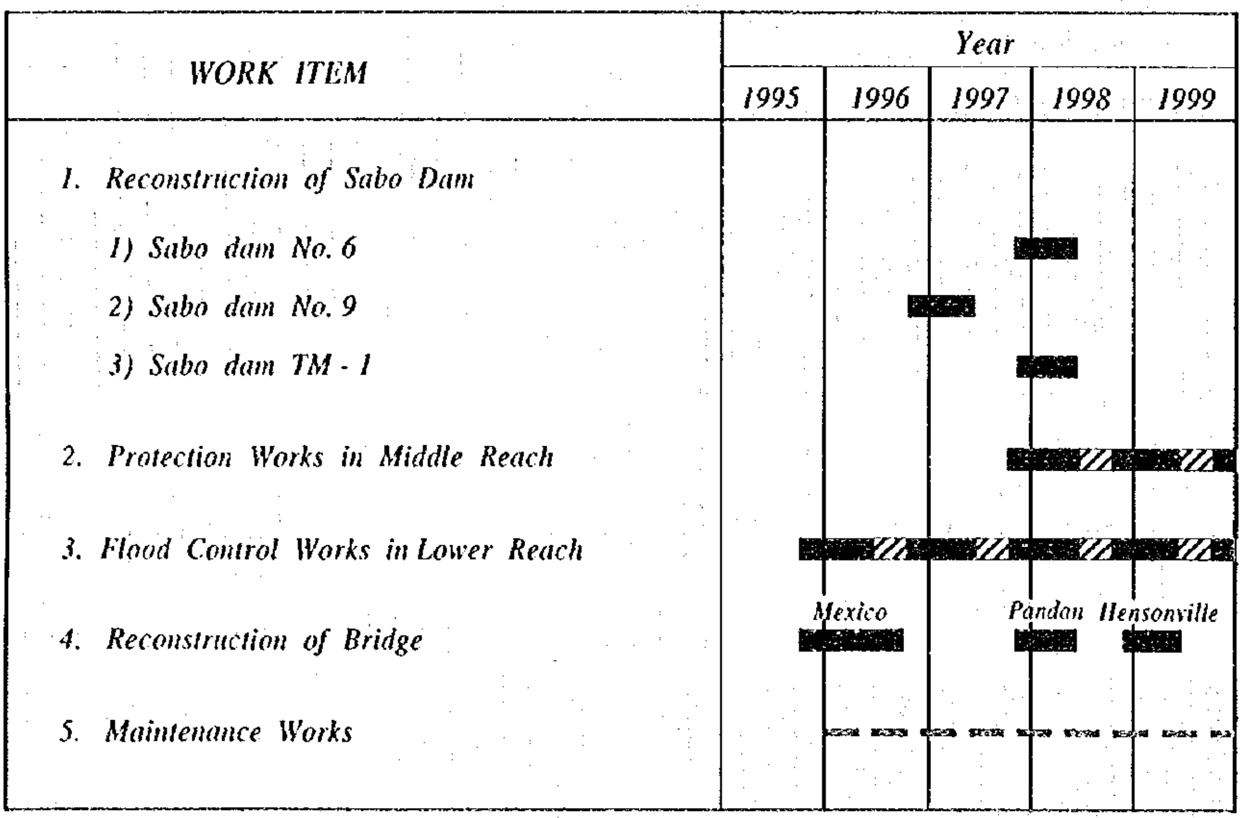
Organization and Management

The Project would also be managed by the Mt.Pinatubo Rehabilitation Project Management Office (MPR-PMO), DPWH. Qualified consulting engineers would be appointed to prepare final designs and specifications and supervise construction.

Timing

Bar chart shows the proposed implementation schedule. Some rehabilitation works of river structures have already been scheduled in the 1995/1996 program of the DPWH. Some bridges are reconstructed by DPWH under ADB's financing. The project is expected to be completed at the end of 1999 assuming that annual workable months are 8 months during the dry season from November to June.

Implemententaion Schedule for Abacan River



Note : ▨ indicate rainy season.

4.3.3 Project Benefit

Cost Estimate

Capital costs were estimated to be about 1.0 billion Pesos as summarized below. The cost of the Project in the Sacobia-Bamban River was based likewise on the price level of November 1995. Exchange rate converting foreign currencies into local currency was US$1.00 = 25.0 Pesos = 100 Japanese Yen. Unit price method was applied to the cost estimation of main civil works.

Benefit, Estimated Rates of Return

The benefit to be accrued from the implementation of the Project was also defined as the reduction of the direct and indirect damages caused by flood/mudflows. The damage under the with-project conditions was assumed to be zero under the design flood of 20-year return period. For the agricultural benefit, the saving of crop damage occupies more than 20% of the total Project benefit. Benefit-cost comparison showed the economic internal rate of return (EIRR) of 24.1% under the net present value discounted at 12%. The project was also justified by sensitivity analysis.

CAPITAL COST

(Unit : million Pesos)

Project Component	Cost
1) Main Construction Cost	680.00
2) Land Aquisition Cost	7.50
3) Administration Cost	34.37
4) Engineering Cost	68.00
5) Physical Contingency	75.55
6) Price Contingency	139.63
Total	1,005.05

Note : Price level in November 1995

ANNUAL DAMAGE

(Unit : million Pesos)

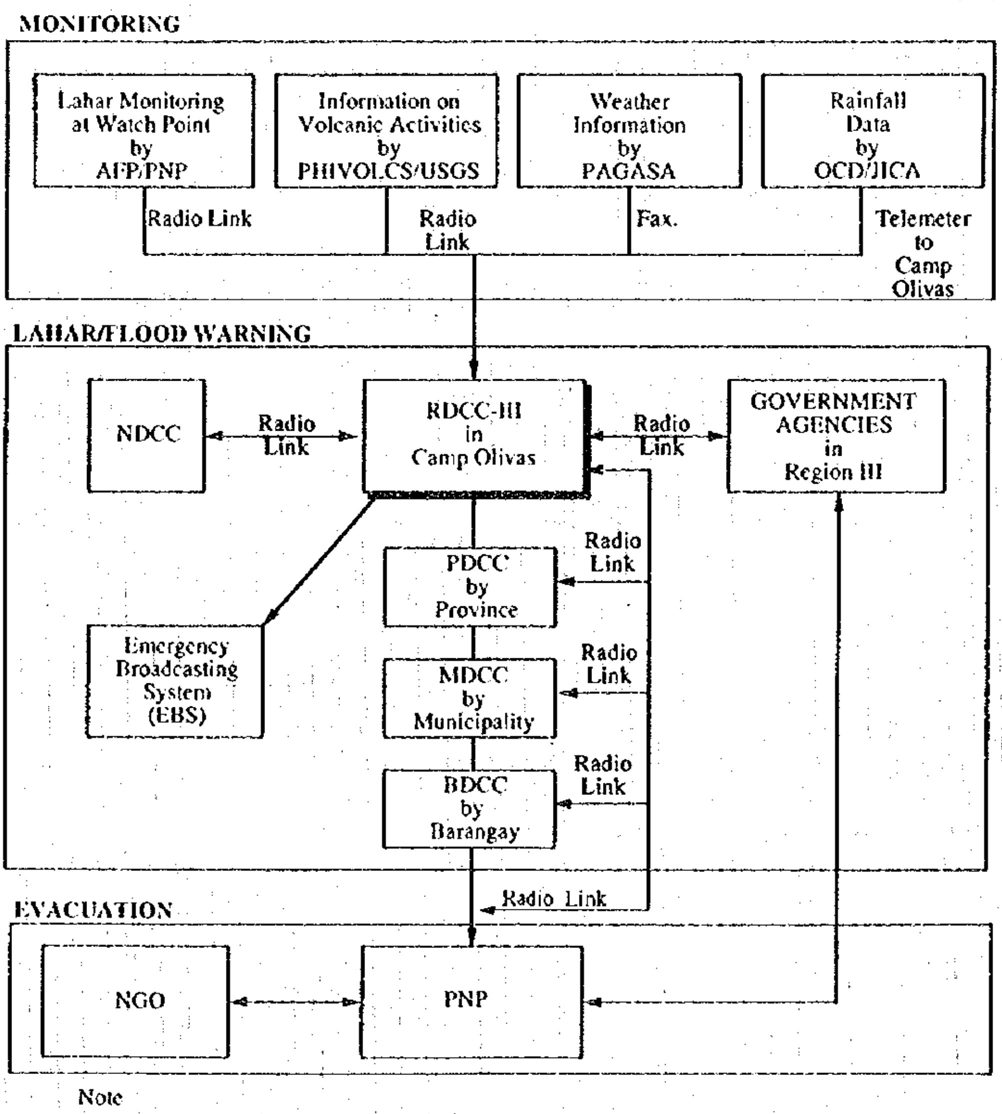
Type	Amount
1 Direct Damage	
1) Building	58.45
2) Crops & Livestock	23.66
3) Infrastructure	16.39
2 Indirect Damage	
1) Evacuation & Cleanup	9.17
2) Loss of GRDP	7.70
Total	115.37

Note : Annual damage for 20 - years flood

CHAPTER 5 NON-STRUCTURAL MEASURES

5.1 LAHAR/MUDFLOW WARNING AND EVACUATION SYSTEM

The Regional Disaster Coordinating Council in Region III (RDCC-III) is the inter-agency organization for flood/mudflow warning in the Mt. Pinatubo affected area. The system is mainly divided into three organizations: namely, (1) Monitoring system, (2) Warning Dissemination System and (3) Evacuation System. After receipt of the monitored information on lahar and heavy rainfall, the RDCC-III disseminates the lahar/flood warning information to government agencies in Region III, PDCC, MDCC and BDCC. The warning message is also transmitted through the hot-line telephone system linking the radio stations in Manila.



Note

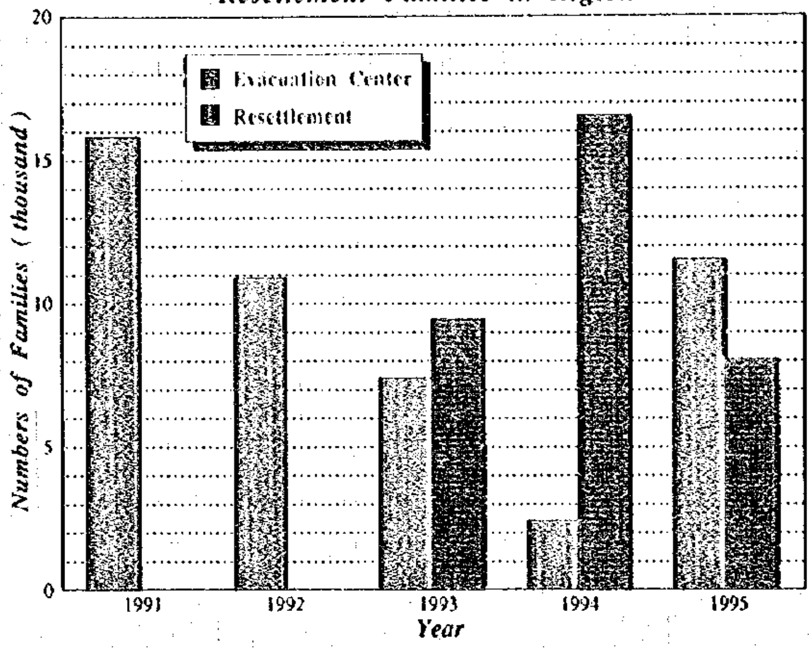
PNP : Philippine National Police
PHIVOLCS : Philippine Institutes of Volcanology and Seismology
PAGASA : Philippine Atmospheric, Geophysical and Astronomical Services Administration
OCD : Office of Civil Defence
NDCC : National Disaster Coordinating Council
RDCC-III : Regional Disaster Coordinating Council
PDCC : Provincial Disaster Coordinating Council
MDCC : Municipal Disaster Coordinating Council
BDCC : Barangay Disaster Coordinating Council
NGO : Non-government Organization

Organization Chart of Warning and Evacuation System

5.2 RESETTLEMENT PLAN

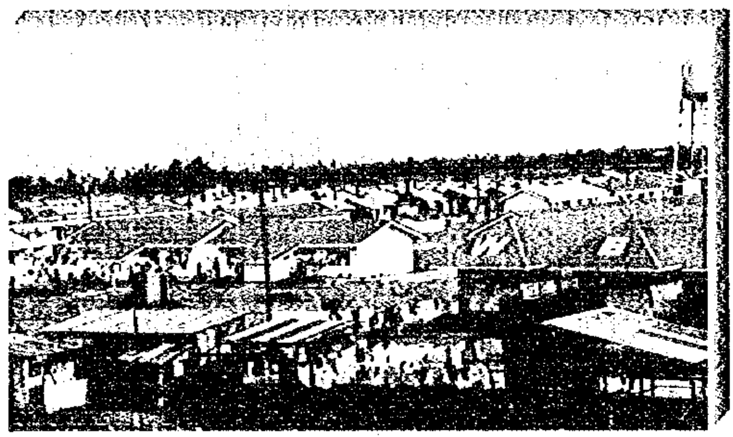
The Mount Pinatubo Commission (MPC) was established in October 1992. The MPC is mandated to assist dislocated families in the communities damaged or destroyed by the eruption and its after effects. The MPC formulated an "Integrated Plan for the Mount Pinatubo Affected Areas" in 1994. The Plan was organized into three major rehabilitation programs; namely, infrastructure, livelihood and resettlement.

Resettlement Families in Region III



The MPC administered resettlement sites. In 1995, 11,600 families stayed in evacuation centers and 8,000 families were housed in the resettlement area. Since majority of the dislocated families are tillers, some expressed dissatisfaction on the land given them because of the inadequacy of land for the entire affected population. Most of the relocation sites merely provided homelots.

Livelihood support in the past four years showed that the need to provide facility requirements particularly housing in resettlement site has been given priority. Unemployment rate remained high among the affected and resettled families. First, this can be attributed mainly to the closure of the US Military Bases which claimed 42,617 jobs. Secondly, the loss of agricultural lands due to lahar caused many farmers lose their basic source of livelihood. Finally, daily food rations resulted to dependence on external material assistance and less initiative to work.



Resettlement Area

Productivity centers were proposed to attract domestic and foreign investors within the resettlement sites and provide employment for settlers.

Dislocated People in the Resettlement Area

CHAPTER 6 ENVIRONMENTAL CONSERVATION

A number of potential environmental concerns were considered, as indicated in the table on the right. The major concerns include the effects that the dike and consolidation dam could have on traditional resource users and on biophysical resources. An important concern would also be the restoration of an irrigation system for agricultural products in sand pocket area and withdrawal of irrigation water.

Careful choice of work on location would minimize any existing impacts after eruption. The mitigative structural measures would be implemented during the realization of the concerns. As a result, cumulative and residual impacts would be insignificant. The positive effects would increase land settlement opportunities, improve living condition, and increase food production for domestic and export markets. Project effects would be essentially gender neutral in order to restore the social and economic activities before eruption.

Demand on Project through Public Hearing

A. Environment & Sanitation
1) Waste water management
2) Greening of rehabilitated areas
3) Planting on the dike

B. Health and Nutrition
1) Health center with complete medicine
2) Community - based health program

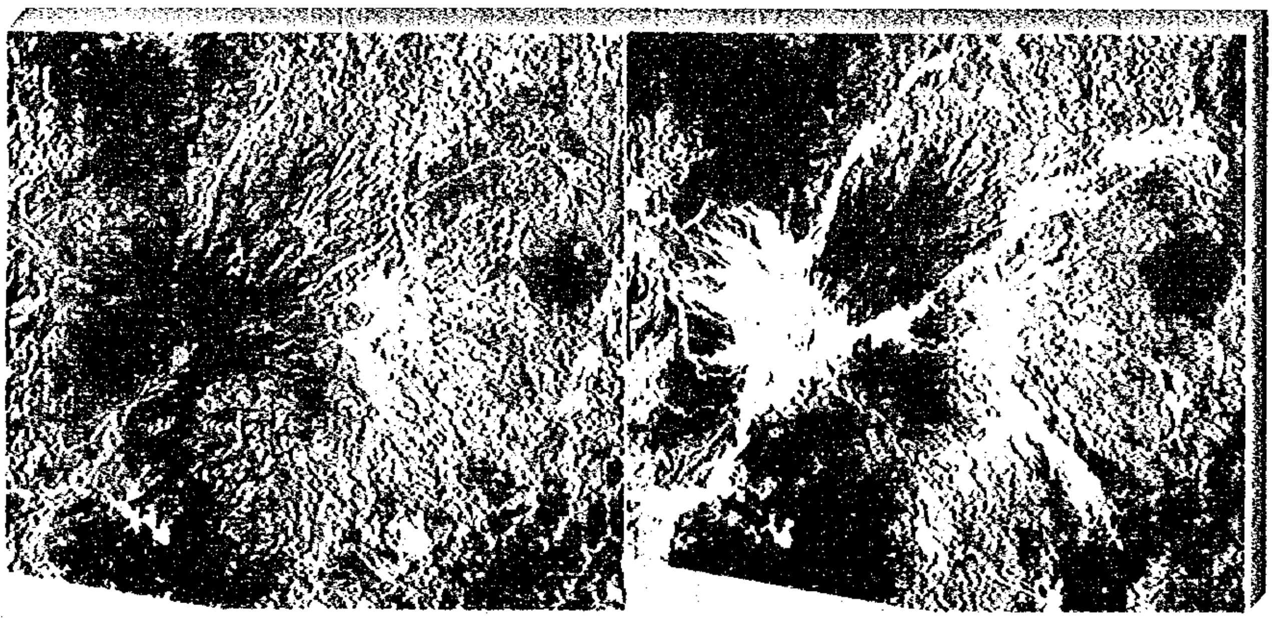
C. Livelihood
1) Community - based cooperative management

D. Agriculture (Farming)
1) Irrigation and drainage canals
2) Appropriate technical support
3) Introduction of high values crops

E. Youth and Sports
1) Enhancement of sports activities
2) Vocational institute on skills development
3) Sports and youth center

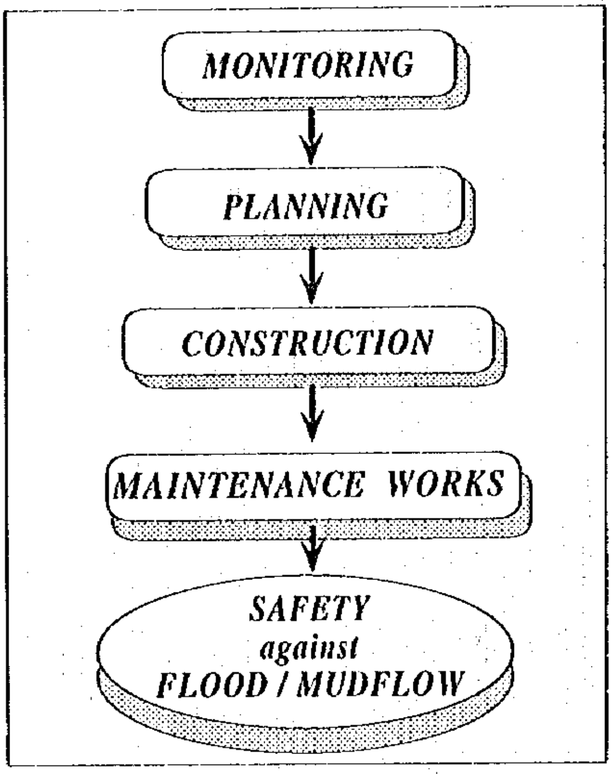
F. Infrastructure
1) River dikes and sabo dams
2) Protection works of river banks
3) Additional school building

G. Education, Woman and Family
1) Training of family - oriented income
2) Woman's contribution to farming system
3) Cooperative store for marketing products



Natural Color Composite of Satellite Data (Left:January 1990, Right:April 1993)

CHAPTER 7 RECOMMENDATION



STRUCTURAL MEASURE

Although the proposed plan was based on the sediment transport forecast, there would still be uncertainties in the estimate of volume of sediment as well as changes in topography in the valleys, river channels and sand pocket area. It is recommended that periodical topographic survey and water sampling be carried out by the DPWH. In addition, although minimal, there are still some chances of recapture of the uppermost basin of the Pasig River, hence careful monitoring of the whole areas particularly the eastern slopes of Mt. Pinatubo is needed.

After the construction of the structural measures, maintenance works are indispensable to ensure the good condition of the structures and to serve their purpose as planned. Although sabo dams and dikes were designed as permanent structures, unexpected changes in the riverbeds or topography might occur and require reconstruction or removal of these structures as the opportunity arises. Review of the master plan would be carried out every 10 years.

NON-STRUCTURAL MEASURE

The NDCC does not have at the moment enough capable personnel and the capability to establish disaster management plan because of financial constraint. The expansion of the NDCC will need experienced and knowledgeable officials to educate the local government units on this aspect.

Pinatubo hazard is characterized by predominant secondary disaster which is triggered by heavy rainfall. Major problem on rainfall observation network in the Philippines lies in the maintenance of the equipment, especially in the case of telemetered equipment. The rainfall radar system which will cover the Pinatubo hazard area will be one of the best solution in monitoing and in forecasting the rainfall for lahar/mudflow warning.

Remarkable activities in evacuation and resettlement have been carried out by the NGOs in and around Pinatubo hazard areas. Recently, an NGO network of disaster prevention was being expanded not only to Pinatubo hazard area but also to the entire country. It is necessary therefore for government agencies to coordinate with the network for efficient relief operation and evacuation.