US Army Corps
of Engineers
Portland District

Main Report
Volume I

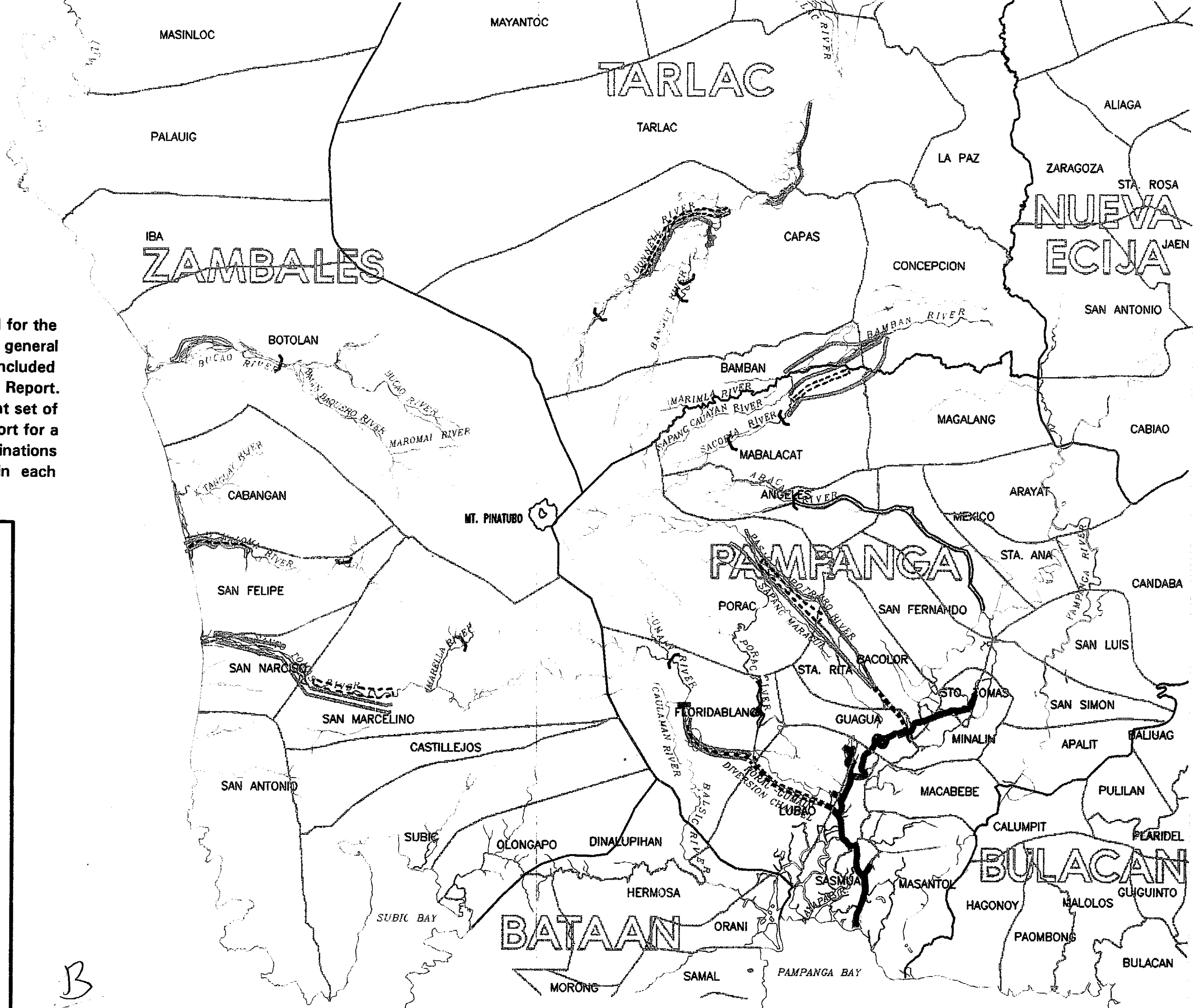
Mount Pinatubo Recovery Action Plan Long Term Report

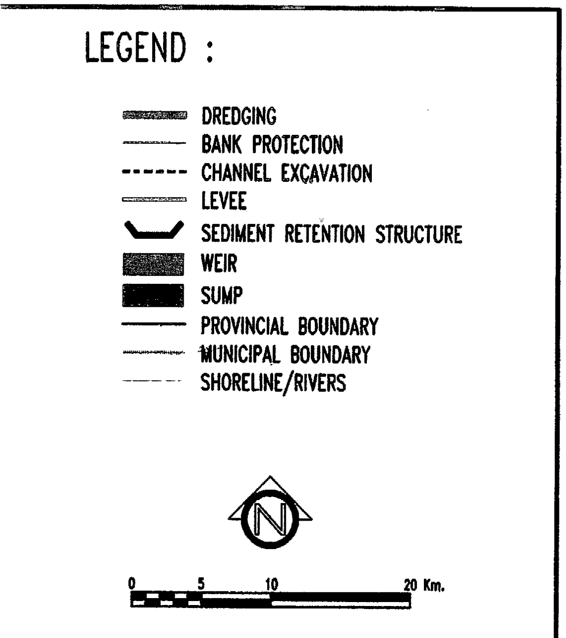
Eight River Basins Republic of the Philippines

MT. PINATUBO
JUNE 1991 ERUPTION
PHILIPPINES

March 1994

Note: This is a composite figure that was prepared for the sole purpose of presenting, on one map, the general locations of the various engineering measures included in the structural alternatives of the Long Term Report. Each structural alternative involves a different set of engineering measures. Refer to the main report for a description and identification of specific combinations of engineering measures for each alternative in each river basin.





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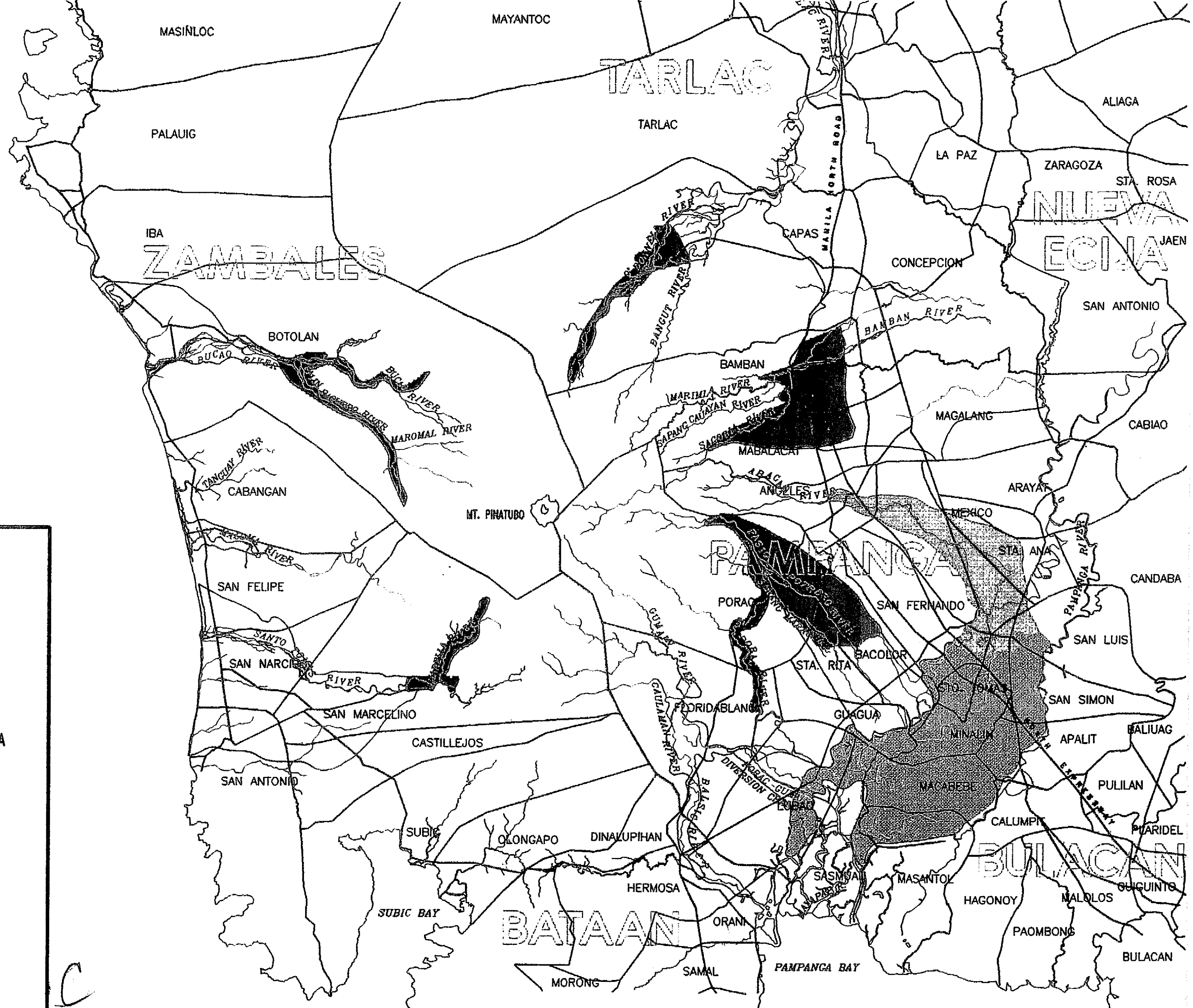
U.S. ARMY CORPS OF ENGINEERS

LOUIS BERGER INTERNATIONAL, INC.

ENVIRONMENTAL ASSESSMENT, LONG TERM REPORT
MT. PINATUBO RECOVERY ACTION PLAN

GENERAL LOCATION MAP OF VARIOUS ENGINEERING MEASURES INCLUDED IN THE STRUCTURAL ALTERNATIVES OF THE LONG TERM REPORT

Important Note: This current draft of the No Action Plan Hazard Map __does not__ incorporate recent changes in the drainage areas of the Pasig-Potrero and Sacobia-Bamban River basins. The full impact of this basin change has not yet been fully evaluated, but it is currently judged to present an increased/extreme hazard to communities along the Pasig-Potrero River and surrounding areas.



LEGEND :

- PROVINCIAL BOUNDARY
- MUNICIPAL BOUNDARY
- ROADS
- SHORELINE/RIVERS
- MUDFLOW PRONE AREA
- SHALLOW FLOODING AND SEDIMENT DEPOSITION AREA
- PONDING
- SHALLOW FLOODING

0 5 10 20 Km.

U.S. ARMY CORPS OF ENGINEERS

LOUIS BERGER INTERNATIONAL, INC.

ENVIRONMENTAL ASSESSMENT, LONG TERM REPORT
MT. PINATUBO RECOVERY ACTION PLAN

NO ACTION PLAN HAZARD MAP

MOUNT PINATUBO
RECOVERY ACTION PLAN
LONG TERM REPORT

EIGHT RIVER BASINS
REPUBLIC OF THE PHILIPPINES

VOLUME I - MAIN REPORT

Prepared by
Portland District
U.S. Army Corps of Engineers

March 1994

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MOUNT PINATUBO RECOVERY ACTION PLAN
LONG TERM REPORT

EIGHT RIVER BASINS
REPUBLIC OF THE PHILIPPINES

VOLUME I - MAIN REPORT

EXECUTIVE SUMMARY

The U.S. Agency for International Development (USAID) contracted with the U.S. Army Corps of Engineers (USACE) for the preparation of a comprehensive Recovery Action Plan (RAP). The RAP evaluates methods for controlling the sedimentation within eight river basins and the higher risk of flooding due to sediment-clogged drainage channels resulting from the June 1991 volcanic eruption of Mount Pinatubo.

This eruption ranks as one of the largest volcanic events of this century, and significantly affected the hydrology of many of the rivers surrounding the volcano. About 6 cubic kilometers of pyroclastic material was deposited in the river basins and another 1 cubic kilometer of ash covered the landscape for more than 40 kilometers from the mountain. Drainage size and structure, sedimentation rates, groundwater recharge rates, and flow paths were all changed by the deposition of pyroclastic materials in the upper watersheds of the rivers draining the area. Flooding and sediment deposition caused by the eruption has destroyed bridges, crops, buildings, and agricultural lands. Several communities were flooded or buried by sediment deposits up to 3 meters deep. Numerous deaths have occurred and thousands of others have been evacuated from their homes. The number of people directly affected has been estimated at 1.5 million and damages estimated at over 10 billion pesos.

Examination of potential future conditions indicates that extremely large sedimentation events may continue over the next 5 to 10 years and possibly several times per year. Although the potential for large events (perhaps 2 to 3 times larger than pre-eruption levels) may continue after the initial 10 years, their frequency is expected to decrease.

The Long Term Report consists of three volumes. Volume I, the Main Report, includes background information; a plan selection process; a summary of economic, social, and environmental analyses; and identification of alternatives for each river basin. Volume II contains the Technical Appendices, which present detailed technical information for the following areas: hydrology and hydraulics (Appendix A); sedimentation (Appendix B); economic analysis (Appendix C); cost estimating (Appendix D), and the engineering analysis (Appendix E). Appendix E is bound separately and readily presents the engineering information compiled for each river basin. An environmental assessment was concurrently prepared as an integral part of this study and is Volume III of the Long Term Report.

Structural and nonstructural alternatives, as well as the no action alternative, were formulated for each river basin. Study objective accomplishment, construction costs and considerations, and economic, environmental, and social concerns are addressed for each plan. Although the type of structural alternatives formulated for each basin varies, they essentially fall into three general categories: levee plans, channel excavation plans, or sediment retention structure plans. These alternatives were evaluated over a 25-year economic period including consideration of construction and operation costs. Economic analyses were based on the capture of sediment and management of flooding during an initial 10-year period as well as accommodating a 100-year event. The environmental impacts of alternatives were evaluated on a general basis. A major focus was placed on social concerns. Numerous presentations covering potential risks, plausible solutions, and possible choices were held in the Philippines throughout the study effort. Results of the public consultation sessions were incorporated into the development of alternatives as appropriate. The effect of further eruptions on the eight river basins is not addressed.

Risk and uncertainty in this study arise from variations in the natural processes (rainfall, streamflow, sedimentation, etc.) and the limited available data. For this study, uncertainty exists in the estimates of flood depths, sediment yield, potential damages, and benefits of potential alternatives. As a result, sediment yields may be highly variable over both the short- and long-term, which affect the estimates for potential damages and benefits. Secondary pyroclastic flows or other basin disturbances could cause immediate, large surges of sediment. The occurrence or lack of unusually large storms also will cause variations in sediment yields.

Risk and uncertainty were considered in this study by placing confidence intervals on estimates such as peak discharges at each hydrologic site, and the mean values of economic damages and benefits. However, uncertainty is still inherent with respect to the information provided, and a significant risk remains for a particular site or basin to experience more or less damage than forecast. Conditions affecting risk and uncertainty can be clarified through a monitoring program.

The potential for physical changes within the river basins exists as evidenced in October 1993, when heavy rainfall and rapid erosion caused about 21 square kilometers of the Sacobia River basin to be diverted into the Pasig River basin. This change occurred very late in the study process, and only the resulting changes in hydrology were evaluated and included in this study.

The sediment forecast developed for the Pasig-Potrero basin does not account for the increase in drainage area and expected higher sediment yields, which may increase the magnitude of the alternatives considered for this basin. This large increase in the Pasig River's drainage area is very likely to cause a tremendous increase in sediment yield in 1994 and beyond. The full impact of this basin change has not been evaluated for this study, but it is judged to present an extreme hazard to communities along the Pasig-Potrero River and surrounding areas.

Sediment yields and lahars in the Pasig River in 1994 are expected to be similar to those experienced in the Sacobia River in 1991 and 1992. Sediment deposition in the Pasig-Potrero basin of 50 to 100 million cubic meters is considered possible in 1994. Conversely, the sediment forecast developed for the Sacobia-Bamban basin does not account for the decrease in drainage area and expected lower sediment yields, which may reduce the magnitude of alternatives developed for this basin. The findings for the alternatives developed for each river basin and the Pampanga delta, as summarized on the accompanying table, are based on conditions that existed prior to this change.

The higher expected yields in the Pasig-Potrero basin in 1994 require some revisions in the GOP's strategy for containment. Those revisions are being considered by the Philippine Department of Public Works and Highways. The USACE has been consulted concerning the potential for breakouts to the Porac River system, to Angeles City, and to the San Fernando area. The shift in strategies plus monitoring and emergency intervention activities are appropriate efforts in an attempt to contain the system during the critical 1994 season. The potential for recapture of the upper basin by the Sacobia also exists. Modifications to actions on the Sacobia may benefit by the 1994 reduction, but must maintain the flexibility to accommodate possible future changes.

A variety of actions necessary before implementation of alternatives were beyond the scope of this effort. Additional engineering, economic, and environmental work is necessary depending upon the alternatives to be pursued. The structural alternatives still require varying degrees of additional design before implementation. Levee and channel excavation alternatives are developed in sufficient detail to provide most information necessary to proceed with the preparation of plans and specifications of project features. Sediment retention structure alternatives, however, still require extensive subsurface investigation, development of site-specific details, and more detailed design prior to preparing plans and specifications. Land acquisitions for facilities, rights-of-way, disposal sites, etc., must be undertaken and accomplished prior to implementation of any structural alternative. Relocation and permanent evacuation facilities must be identified for each basin, as appropriate. These actions are contingent upon the capabilities of the Philippine Government.

In the economic analysis, each basin was considered as separate and independent from the other basins. However, system conditions exist between the Pasig-Potrero, Gumain-Porac, and the Pampanga delta. Additional economic analysis could investigate the system relationships between these basins, which may increase their economic viability. In addition, each alternative was treated as a unit and individual features were not analyzed separately. Incremental analysis of specific features of an alternative to determine optimal size or further investigate economic efficiency should be considered prior to implementation.

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Potential environmental effects are identified for each of the alternatives based on the level of engineering detail for design and location. Supplemental environmental evaluation and documentation may be needed for alternatives requiring further design and site confirmation, such as storage structures, levees, and dredged material disposal sites. Further environmental actions should include information dissemination, local involvement, and public consultation as selected alternatives are developed, designed, and implemented, and site specific evaluations of biodiversity and archaeological resources.

Once implemented, the ultimate success of any action can only be assured through an extensive monitoring and data collection program. Facility performance, cross-sectional data, surveillance flights, rainfall and seismic data, and suspended sediment and stream discharge information are all vital components of a complete monitoring program. This information provides a basis for future decisions and modifications related to recovery actions.

A determination of whether or not to implement an engineering solution rests with the Philippine Government. It is not the intent of the Long Term Report to recommend that a specific alternative be implemented for a particular river basin. Instead, the various alternatives were developed to be responsive to the potential problems of a specific basin. When combined with the specific political desires, funding resources, and implementation capabilities of the Philippine Government, the information provided in this report assists in the basis for selection between a variety of recovery action options.

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Summary of Alternatives for Each River Basin

RIVER BASIN	NO ACTION	LEVEE ALTERNATIVE	CHANNEL EXCAVATION ALTERNATIVE	SEDIMENT RETENTION STRUCTURE ALTERNATIVE	NONSTRUCTURAL ALTERNATIVE
PASIG-POTRERO	Average damages P943 million. 72 barangays, Hwy 7, and 7,000 ha agric land impacted. Siltation further disrupts delta habitat & fisheries.	First Cost: P1.5 billion. B/C Ratio: 0.4 Restores delta habitats & fisheries. No households/habitats displaced. 30 ha fishponds used for disposal.	First Cost: P1.9 billion. B/C Ratio: 0.3 Better restoration delta habitats/fish. 700 ha used for disposal areas. Higher risk sediment deposits dwnstrm.	Not applicable to this basin.	Permanent evacuation costs P275 to P825 million. Temporary evac via GOP programs. Effects similar to No Action, but improved public safety.
SACOBIA-BAMBAN	Average damages P790 million. 102 barangays/17,000 ha of agricultural land impacted. San Francisco bridge impacted.	First Cost: 1.4 billion BCR: 0.4 Reduces downstream sediment loads and flooding risk. 80 hseholds/1,600 ha land displaced. Public programs required.	First Cost: 490 million. BCR: 0.3 Higher risk sedimentation downstream. Similar impacts as for levee alt. Add'l 1,500 ha land for disposal areas.	First Cost: 1.9 billion BCR: 0.2 Stores about 40 mcm of sediment. Downstream sedimentation & impacts reduced once SRS completed.	Permanent evacuation costs P357 to P1 billion. Temporary evac via GOP programs. Improved public safety over No Action due to early warning system.
ABACAN	Average damages P219 million. 29 barangays/7,250 ha of agricultural land affected. Possible failure Sabo No.9 increases downstream impacts.	**BANK PROTECTION ALTERNATIVE** First Cost: P80 million. BCR: 2.8 Reduces sediment in system, gives long-term relief to Mexico. No households/habitats displaced.	Not applicable to this basin.	Not applicable to this basin.	No permanent evac necessary. Temporary evac during flooding via GOP programs. Improved public safety over No Action due to early warning system.
O'DONNELL	Average damages P297 million. 20 barangays/19,000 ha of agricultural land impacted. Hwy 3 & 317 impacted.	First Cost: P226 million BCR: 0.99 Protects O'Donnell/Santa Lucia, Capas, Concepcion, Tarlac. Over10 hseholds/30 ha land displaced.	First Cost: P1 billion BCR: 0.2 Protects same areas as in levee alt. No hseholds/habitats displaced.	First Cost: P3.2 billion BCR: 0.1 Stores about 100 mcm sediment. Downstream sedimentation & impacts reduced once SRS completed.	Permanent evac costs P40 to P120 million; temp evac via GOP programs. Improved public safety over No Action due to early warning system.
SANTO TOMAS	Average damages P1.2 billion. 56 barangays/11,500 ha of agricultural land impacted. Highway 7 impacted.	First Cost: P939 million BCR: 1.2 Protects San Marcelino, San Antonio, San Narcisco, Castillejos, Hwy 7. 170 hseholds/280 ha land displaced.	First Cost: P3.3 billion BCR: 0.2 Protects same areas as levee alt. No hseholds/habitats displaced.	First Cost: P5.5 billion BCR: 0.2 Stores about 40 mcm of sediment. Downstream sedimentation & impacts reduced once SRS completed.	Permanent evac costs P43 to P128 million; temp evac via GOP programs. Improved public safety over No Action due to early warning system.
BUCAO	Average damages P250 million 2,100 ha of land impacted. Highway 7 bridge impacted. 25 barangays impacted. Significant siltation continues.	First Cost: P187 million BCR: 1.4 Portions of Botolan, Iba, Hwy 7, and local routes protected. No households/habitats displaced.	Not applicable to this basin.	First Cost: P4.7 billion BCR: 0.1 Stores about 1 billion cm of sediment. Downstream sedimentation & impacts reduced once SRS completed.	Permanent evacuation cost P20 to P60 million; temporary evac via GOP programs. Improved public safety due to early warning system.
MALOMA	Average damages P113 million. 50 Aeta households impacted. 700 ha agricultural land impacted. 4 coastal barangays impacted. Highway 7 bridge impacted.	First Cost: P83 million BCR: 1.2 Portions of Cambangan, San Felipe, and Hwy 7 bridge protected. 7 households/8 ha land displaced.	First Cost: 136 million BCR: 0.7 Protects same areas as levee alt. Reduces amt sediment in system. No households/100 ha land displaced.	First Cost: 242 million BCR: 0.5 Stores about 12 mcm of sediment. Downstream sedimentation & impacts reduced once SRS completed.	No permanent evacuation needed. Temporary evacuation during flooding via GOP programs. Improved public safety due to early warning system.
GUMAIN-PORAC	Average damages P1 billion. 38 barangays impacted. 4,600 ha ag. land impacted. Hwy 7 & bridge impacted. Delta habitats/fisheries impacted.	First Cost: P610 million BCR: 1.7 Portions of Floridablanca, Dinalupihan, Hermosa, Hwy 7/bridge protected. Some households/land displaced.	First Cost: 580 million BCR: 1.7 Protects same areas as levee alt. Reduces sediment to delta. 100 ha agricultural land displaced.	First Cost: P1.4 billion BCR: 0.8 Large amt of sediment stored. Downstream sedimentation & impacts reduced once SRS completed.	No permanent evacuation needed. Temporary evacuation during flooding via GOP programs. Improved public safety due to early warning system.
PAMPANGA DELTA	Average damages P7.3 billion. 58 barangays impacted. 10,600 ha delta lands impacted. Continued impacts to estuarine habitats and fisheries. Further decline fisheries production.	Not applicable to the delta.	**DREDGING ALTERNATIVE** First Cost: P953 million. BCR: 3.0 Prevents or reduced ponding to many communities in/near delta. Up to 2,500 ha fishponds for disposal.	Not applicable to the delta.	Not applicable to the delta.

MOUNT PINATUBO
RECOVERY ACTION PLAN
LONG TERM REPORT

EIGHT RIVER BASINS
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VOLUME I - MAIN REPORT

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MOUNT PINATUBO
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LONG TERM REPORT

EIGHT RIVER BASINS
REPUBLIC OF THE PHILIPPINES

VOLUME I - MAIN REPORT

1. INTRODUCTION

1.1 Study Authority and Scope

Under authority of the Economy Act (31 U.S.C. 1535) and Section 632 of the Foreign Assistance Act (22 U.S.C. 2357), the U.S. Agency for International Development (USAID) requested the Department of the Army (DA), acting through the U.S. Army Corps of Engineers (USACE), to prepare a comprehensive Recovery Action Plan (RAP) for controlling sedimentation and flooding resulting from the June 1991 volcanic eruption of Mount Pinatubo, and subsequent hydrologic events. Mount Pinatubo is located about 100 kilometers (km) northwest of Manila on the west coast of Central Luzon in the Republic of the Philippines. The RAP is being prepared in accordance with a Participating Agency Service Agreement (PASA), signed on June 18, 1992, between USAID/Philippines and DA. The RAP consists of two study products:

1.1.1 Interim Report. This report was completed in December 1992. It addressed early implementation measures to mitigate potential impacts of the 1993 monsoon season for the Pasig-Potrero River basin. The interim measures were evaluated over a 5-year economic life including consideration of construction and operation costs. The report is based on limited engineering data and provides preliminary background information, an abbreviated planning process, economic, environmental and social analyses, and alternative plans which were considered for implementation prior to the 1993 monsoon season (June 1993). The interim plans did not address the effect of further eruptions on the Pasig-Potrero River basin.

1.1.2 Long Term Report. This report addresses intervention measures for the eight river basins impacted by Mount Pinatubo. This comprehensive study includes a plan selection process; engineering, economic, environmental, and social analyses; and identifies alternatives for each river basin to mitigate potential long-term flooding and sedimentation impacts for the 1994 monsoon season and beyond. The long-term alternatives do not address the effect of further eruptions on the study area.

The Long Term Report consists of three volumes. Volume I, the Main Report, provides background information and a plan selection process, summarizes economic, environmental, and social analyses, and identifies alternatives for each river basin. Volume II contains the Technical Appendices, which present more detailed information for the following areas: hydrology and hydraulics (Appendix A);

sedimentation (Appendix B); economic analysis (Appendix C); cost estimates (Appendix D), and the engineering analysis (Appendix E). Appendix E is bound separately and formatted to facilitate presentation of the engineering information compiled for each river basin. An environmental assessment was concurrently prepared as an integral part of this study, and is included as Volume III of the Long Term Report.

1.2 Study Area Description

The regional delineation of the Philippines includes Regions I to XII, the National Capital Region (metropolitan Manila), and the Cordillera Administration region. The eruption of Mount Pinatubo affected Region III. Region III is comprised of six provinces in Central Luzon: Bataan, Bulacan, Nueva Ecija, Pampanga, Tarlac, and Zambales. Region III has a total land area of 18,231 square kilometers (km^2), about 6 percent of the land area of the Philippines and a population of 6.2 million (1990).

The eight major drainage basins considered in this report are primarily located in the provinces of Pampanga, Tarlac, and Zambales as shown in figure 1. These basins are listed below in priority order as determined by the Government of the Philippines (GOP), as provided by letter dated February 10, 1992. The priority order was based on initial evaluations of specific areas determined to be vulnerable to the hazards posed by the eruption, and the desire to minimize loss of life and destruction to property.

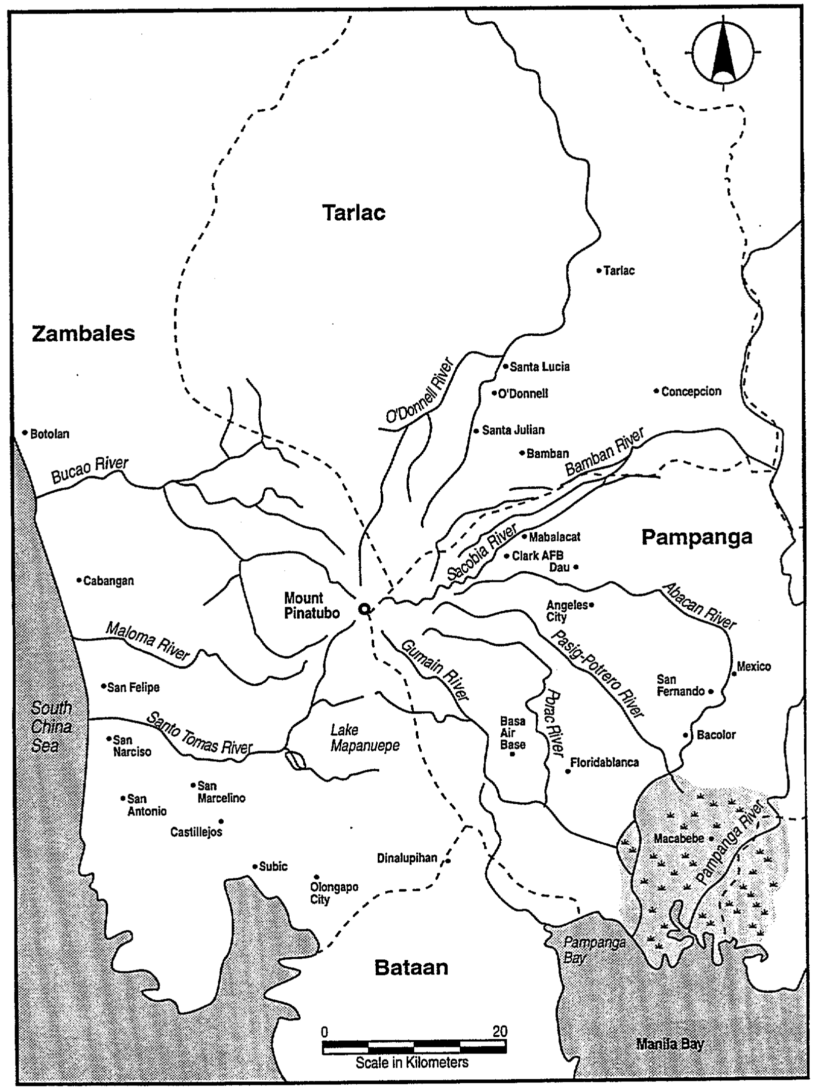
- Pasig-Potrero River Basin in Pampanga
- Sacobia-Bamban River Basin in Pampanga and Tarlac
- Abacan River Basin in Pampanga
- O'Donnell River Basin in Tarlac
- Santo Tomas River Basin in Zambales
- Bucao River Basin in Zambales
- Maloma River Basin in Zambales
- Gumain-Porac River Basin in Pampanga

The Santo Tomas, Maloma, and Bucao rivers on the west drain directly into the South China Sea. On the east, the O'Donnell and Bulsa rivers join to form the Tarlac River, which flows north to the Agno River and thence to Lingayen Gulf. The Sacobia-Bamban, Abacan, Pasig-Potrero, and Gumain-Porac rivers are all tributary to the Pampanga River and delta, which flow south into Pampanga Bay.

1.3 Nature of the Mount Pinatubo Disaster

The violent eruption of Mount Pinatubo between June 12 and 15, 1991, ranks as one of the largest volcanic events of this century. About 6 cubic kilometers (km^3) of pyroclastic material was deposited in the river basins surrounding the mountain. Another nearly 1 km^3 of ash covered the landscape for more than 40 km from the mountain.

Figure 1 -- *Location of River Basins Relative to Mount Pinatubo*



The passage of typhoon Diding immediately after the eruption scattered the water-soaked, heavy ash which resulted in death as roofs of hundreds of houses and buildings collapsed. The typhoon's heavy rainfall caused massive mudflows which covered large areas of agricultural land, destroyed bridges and roads, buried hundreds of houses, and displaced thousands of people.

While the probability of another major eruption is estimated to be small, mudflows are likely to continue to be a source of severe damage over the next 5 to 10 years as heavy rainfall erodes the pyroclastic surface causing sediment to move downstream. Sediment deposits have filled major drainage channels, causing widespread flooding.

1.4 Extent of Damages

Because of the dynamic conditions resulting from the eruption, and the numerous reports and statistics generated by various agencies and organizations involved in the Mount Pinatubo events, accurate documentation of the extent of damages, especially in monetary terms, is not an easy task. This section presents a compilation of information reported by agencies of the GOP.

As of March 1992, the Department of Social Welfare and Development, Region III, reported a total of 932 persons dead, 184 injured, and 23 missing as a result of the eruption. Most victims were from the provinces of Zambales and Pampanga. The number of people directly affected by the eruption is estimated at 1.5 million. As of May 1992, the cost of damages from lahar and floods was about P10.6 billion.

Since the eruption, three monsoon seasons have caused substantial flooding and large mudflows to occur. Two major lake failures caused significant damages in the Pasig-Potrero basin in 1991 and 1992. The 1991 lake-failure caused hyperconcentrated flows to spill out of the river channel and onto both overbanks near Potrero, killing 13 people. Flooding and sediment deposition from this event damaged Bacolor and barangays of Santa Rita and Guagua. The 1992 lake failure caused mudflows to fill the channel near Mancatian and to flow out into Mitla, destroying much of this barangay.

In August 1993, heavy rainfall from typhoon Rubing affected as many as 193,000 people in at least 100 villages in 22 towns in Pampanga, Tarlac, Zambales, Bataan and Olongapo City. About 600 homes were affected by floodwaters and/or mudflows, and municipalities in northern Zambales were isolated when the Camachile bridge on the Santo Tomas River was destroyed. The barangay of San Rafael was buried by mudflow deposits and the levee along the Santo Tomas River in this area was breached. Mudflows also caused 5 to 7 meters of deposition in the Pasig channel upstream of Mancatian, and the levee on the left bank was overtopped. Damage to infrastructure has been estimated at P47 million and damage to crops estimated at P73.7 million.

In October 1993, heavy rainfall from typhoon Kadiang caused flash flooding and mudflows that affected 7 provinces, 5 cities, and 74 municipalities in Region III. An abutment of the Santa Lucia bridge was washed out due to flows on the Bangat River. The existing levee along the south bank of the Santo Tomas River was breached, and sediment covered Santa Fe on the north side. Much of Castillejos and San Marcelino were flooded. The Regional Disaster Coordinating Council for Region III estimated damages of P40 million to roads and bridges, and P589 million to agricultural crops.

1.5 Accomplishments by the Government of the Philippines [1]

On October 20, 1992, President Fidel V. Ramos signed into law Republic Act 7637, also known as the Mt. Pinatubo Assistance, Resettlement, and Development Fund. This law appropriated P10 billion for the aid, relief, resettlement, rehabilitation, livelihood, and infrastructure support for the victims of the eruption. The law defined target victims as those persons who were injured or displaced; those families who suffered death or injury; those whose homes were destroyed, rendered uninhabitable, or stand at high risk from being buried by lahar; and, whose source of income and livelihood were lost or impaired.

Republic Act 7637 created the Mt. Pinatubo Assistance, Resettlement, and Development Commission, also known as the Mt. Pinatubo Commission (MPC). On December 8, 1992, the MPC took over the functions of the emergency body formed immediately after the eruption, the Presidential Task Force Pinatubo. An important mission of the MPC is to serve as the central authority for formulating, supervising, and coordinating those measures aimed towards creating the basic economic infrastructures needed to support long-term recovery and development of the affected areas.

The MPC is complemented by numerous agencies with a diversity of specializations, such as the Department of Public Works and Highways (DPWH) for infrastructure, the National Housing Authority (NHA) for resettlement, the Department of Trade and Industry and the Technology and Livelihood Resource Center for livelihood, and the Department of Social Work and Development (DSWD) for social services. The four program areas of the MPC are described below.

- Infrastructure. Restoration works have included dams and levees, dikes and restraining structures, roads and bridges on nine river systems. As of December 1993, the MPC has funded the dredging of about 32 million cubic meters (m^3) of material, constructed 85 km of protective dikes, upgraded 124 km of roads, and temporarily

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[1] Information taken from a MPC news feature dated December 8, 1993, titled *MPC and its Mission of Mercy to Mt. Pinatubo Victims*, and from a technical paper titled, *Follow Up Measures by the Mt. Pinatubo Commission*, presented by Jaime A. Venago, Executive Director of the MPC at the Pinatubo Multi-Sectoral Consultative Congress held on December 7, 1993.

installed one bailey bridge. A committee has been formed to establish the engineering priorities to be pursued in each river system for the future.

- Resettlement. Development of resettlement sites was initiated for those who have lost their homes or farms because of the eruption of Mount Pinatubo. This resettlement program focuses on two groups: members of the Aeta hill tribes, often called highlanders and the displaced population that resided on the plains below Mount Pinatubo often called lowlanders. Resettlement sites have basic amenities and services, and for lowlanders are relatively close to town centers for higher level services. Resettlement sites also may have productivity centers to offer training and opportunities for employment. New settlements for Aetas are rural, higher elevation settlements, which emphasize agricultural and natural resource-based livelihoods.

There are 19 resettlement sites located in Tarlac, Zambales, and Pampanga - 10 are upland sites and 9 are lowland sites. Six resettlement sites outside of the affected areas were established by local government units. The MPC also is establishing two additional lowland sites in Pampanga.

The MPC's resettlement activities include land acquisition, housing, civil works, water systems, electrification, school buildings, and community facilities. It provides grants for each family in the form of a core housing loan equivalent to about P20,000 at an interest rate of 6 percent for a repayment period of 25 years. As of December 1993, the MPC has built a total of 12,834 houses, 11,799 of which are occupied, and has completed 81 community facilities, 194 school buildings, installed 270 km of electrical lines, and repaired 22 housing units. About 8,000 and 5,700 families have been resettled in the lowlands and highlands, respectively, by the end of 1993.

- Livelihood. The MPC considers the establishment of a source of livelihood the most important factor for recovery, and without it, resettlement will not be effective. In 1993, the MPC budgeted P985 million for this program, of which P472 million had been disbursed. Over 8,100 projects have been funded which generated jobs for some 74,000 individuals.

- Social Services. The objectives of the social services program are to alleviate the living conditions of the victims still housed in temporary shelters and to prepare these victims in starting a new life in the resettlement sites. In 1993, the MPC allocated about P424 million for social services projects including health care, education, and short-term relief support in temporary shelters.

2. GENERAL SETTING AND STUDY METHODOLOGY

2.1 Introduction

The general setting of the study area and the methodology used for RAP are described below. More detailed information can be found in the appropriate technical appendix located in Volume II of the Long Term Report.

2.2 Climate Characteristics

The Mount Pinatubo area has a tropical climate dominated by the northeast monsoon during the winter (November through May) and by the wet southwest monsoon during the summer (June through October). Maximum daily rainfall amounts experienced in the Mount Pinatubo area are generally caused by tropical cyclones (tropical depressions, tropical storms, or typhoons), which are most prevalent between May and November. Sediment flows are most likely to occur during this period. On average, the east side of the volcano receives less rainfall than the west side. The annual rainfall varies from about 1,700 millimeters (mm) at the former Clark Air Force Base (AFB) on the east, to about 3,700 mm at Iba, Zambales, on the west.

2.3 Geologic Conditions

2.3.1. Regional Geology and Physiography. There are two main physiographic provinces[2] contained within the study area, the Zambales mountain range and the Central Luzon basin. The Zambales range is an area of orogenic uplift (mountain formation) extending from the western coastline to the central lowlands. Within this uplifted region is a north-south trending volcanic arc, in which Mount Pinatubo is the highest and youngest of the volcanoes. The Zambales range is underlain by dense basement rocks.

To the east of Mount Pinatubo lies a sediment-filled depression, 80 km in width, known as the Central Luzon basin. It is bounded on the west by the Zambales range and on the east by the Southern Sierra Madre range. The basin extends from Manila in the south to the Lingayen Gulf in the north. The sediments filling the basin consist of primarily volcanically-derived materials composed mostly of gravel, sand and clay.

2.3.2 Mount Pinatubo Eruptive History. Mount Pinatubo is a volcanic dome whose flanks are overlain by massive pyroclastic deposits from a number of eruptive events within the recent geologic past (within the past 5,000 years). The present dome lies upon volcanic rocks older than the pyroclastic flow deposits which currently cover

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[2] A region having a pattern of landforms that differs significantly from that of adjacent regions.

much of the surface area, and may represent volcanic activity from an ancestral Mount Pinatubo. At least two previous eruptive episodes have been documented. The younger of these events is believed to have occurred about 600 years ago and the older event about 2,000 years ago. Each of these events produced significant volumes of volcanic debris which led to accelerated erosion rates and produced large and frequent lahars for several years afterward, as is now occurring.

2.3.3 The 1991 Eruption of Mount Pinatubo. During the most recent eruption, pyroclastic flows consisting of fast-moving mixtures of gas and volcanic deposits flowed down the flanks of the volcano and tended to follow existing stream valleys, particularly on the east side. These deposits ranged in thickness from a few meters to as much as 200 meters in the deeper valley sections. In addition, ash deposits from airfall accumulated in thickness ranging from only a trace to more than 50 centimeters (cm) near the crater. The 1991 volcanic deposits are very similar to deposits observed from other volcanic eruptions elsewhere during historical times.

2.4 Geomorphology and Sedimentation

2.4.1 Changes in Headwater Tributary Areas. Following the eruption, a very dense drainage network formed quickly and reestablished with only relatively minor changes from the pre-eruption conditions.[3] While rainfall runoff was causing sheet, rill, and gully erosion, a comparison of 1991 to 1993 photographs showed those processes were significant sediment sources only during the initial channel-forming period in 1991. Once the drainage network was reestablished, sediment yields came mainly from the expansion of the main channel. It was concluded, after discussions with the Philippine Institute of Volcanology and Seismology (PHIVOLCS) and U.S. Geological Survey (USGS), that the most likely mechanism capable of producing the hyperconcentrations and mudflows observed during runoff events was the collapse of hot stream banks directly into the flow.

2.4.2 Headwater Blockages and Lake Breakouts. Blockages of the drainage system on Mount Pinatubo's upper slopes were caused by mass failures in the pyroclastic flow deposits. The formation of lakes behind these blockages and their subsequent failure contributed to many mudflows along the drainages. Given the massive amounts

[3] In October 1993, the Pasig-Potrero River captured about 21 km^2 of the Sacobia River headwaters. This change occurred very late in the study process, and only the resulting changes in hydrology were evaluated and included in this study. The sediment forecast does not account for the increase in drainage area and expected higher sediment yields for the Pasig-Potrero basin, which may increase the magnitude of alternatives considered for this basin. Conversely, the sediment forecast for the Sacobia-Bamban basin does not account for the decreased drainage area and expected lower sediment yields, which may reduce the magnitude of alternatives considered for this basin.

of unstable material remaining in the headwater drainages, temporary blockages and sudden breakouts of debris-dammed lakes are a continuing hazard.

2.4.3 Channel Degradation and Aggradation. All the principal rivers draining Mount Pinatubo have been affected by extreme channel aggradation (the build-up of the channel by sediment) or degradation (channel deepening) at some point along their course. Channel degradation and aggradation have resulted in significant changes in the physical configuration of some of these rivers' drainage systems.

2.4.4 Sediment Production. Aerial photograph analyses and field inspections were done to develop an understanding of the geomorphic processes occurring in the pyroclastic deposits. Those showed that the two major sediment producing processes were main channel erosion and secondary pyroclastic flows (SPF's). Secondary pyroclastic flows are large mass movements of pyroclastic material that can travel several kilometers in a short period of time. The causes and flow mechanisms of SPF's have not been determined.

2.5 Sediment Yield Forecasts

The sediment yield forecasts for each river basin define the expected sediment yields and depositional patterns for the short- and long-term, and for single flood events. The dominant factors controlling the sediment yield forecasts are generally the amount of sediment available to be eroded, the water available to transport sediment, and the geomorphic (land surface forming) processes that are occurring.

By comparing the geomorphic processes at Mount Pinatubo with those at Mount St. Helens in the United States, and other research results, it was reasoned that main channel dimensions would be the controlling factor in future sediment yields. Rapid erosion (erosion many times the pre-eruption levels, with transport occurring as hyperconcentrated or mudflows) would continue until the main channels returned to a more stable cross-sectional geometry.

As the channel dimensions increase toward a relatively stable cross-section, the average annual sediment yield declines as a function of the ratio between the "stable" channel cross-section and the existing cross-section. A judgement was made about the channel dimensions that the main streams have when they reach the "stable" condition. The sediment available for rapid erosion is then the volume of material remaining within the boundaries of the "stable" main channels.

To forecast the potential sediment yield from SPF's, sites with topographic and geologic characteristics similar to previous SPF sites were identified and potential volumes computed. The SPF volumes were then added to the sediment available from the main channels to arrive at the total sediment available for rapid erosion.

The next step in developing the sediment yield forecast was to determine what the initial average annual sediment yield would be for the first year. This was done by multiplying the average annual storm runoff by the average sediment concentration. The storm runoff volume was estimated by the volume of the upper 10 percent of the flow-duration-curve for the pyroclastic drainages (computed during the hydrologic analysis). An average sediment transport concentration during storm runoff was estimated from field observations and discussions with USGS, PHIVOLCS, and the Zambales Lahar Scientific Monitoring Group (ZLSMG), as no suitable data was available. Although concentrations have been higher, a concentration range of 25 to 30 percent by volume was considered representative of the average storm runoff concentration.

Using the initial average annual yield as a starting point, the total sediment available was then distributed over time to generate the sediment forecasts. The rapid erosion period was found to extend for another 5 to 10 years, depending on the river basin. After that time, sediment yields are expected to be in the range of two to three times higher than pre-eruption levels. This still constitutes a sediment problem, which existed on most of the streams even before the eruption. There also will be a risk of mudflows during rare storms or after SPF's.

2.6 Sediment Deposition Forecasts

The sediment deposition forecasts are based on the expected sediment yields, transport processes, present channel geometry, and the topography of the alluvial fans and valleys. Sediment deposition areas can be generally categorized by the type of event (muddy water, hyperconcentrated, or mudflow) and the local topography. Mudflows have created deposits of 3 to 7 meters thick in areas with channel slopes of 1 to 2 percent. Hyperconcentrated and muddy water flows have deposited layers of up to 1 meter thick over broad areas on slopes much flatter than one percent. Heavy deposition has occurred in the transitional channel reaches just downstream of the pyroclastic deposits. These reaches may contain up to 50 percent of the sediment deposited up to now. Mudflows are the primary source for deposition in these reaches.

2.7 Economic Conditions

2.7.1 General. This section provides a summary of the general economic conditions for Pampanga, Tarlac, and Zambales, where nearly all the flood and sediment damages are expected to occur.[4] More detailed economic information can be found in Technical Appendix C, Economics.

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[4] Small areas in the province of Bataan (in the vicinity of Dinalupihan) and one barangay in the province of Nueva Ecija are in the sediment/flooding hazard zones. The Tarlac River also passes through Pangasinan and it is possible that sediment/flooding could occur there.

2.7.2 Regional Conditions. Pampanga is located to the east and southeast of Mount Pinatubo, Tarlac to the northeast and Zambales to the west (see figure 1). Pampanga has a relatively flat terrain where land is devoted to rice and sugarcane production and fishponds are concentrated in the flat delta area. Tarlac has two distinct geographical areas, one an extensive alluvial plain in the northern part and the Zambales mountains in the west and northwest. About 45 percent of the land in Tarlac is used for agricultural production of primarily rice, corn, and sugarcane. Zambales is located along the western coast of Central Luzon and has an irregular terrain. A major highway runs through the plains and valleys along the western part of the province where most of the population is located. About 12 percent of the land in Zambales is devoted to agriculture. Rice and sugarcane production for the provinces is shown in figure 2.

As shown in figure 3, Pampanga is the most populous province and Tarlac the most rural in nature. The population is relatively young with persons 14 years and younger accounting for between 37 percent (Zambales) and 41 percent (Pampanga) of household population. Figure 3 also shows the number of households and persons per household in the three provinces. Pampanga has the highest number of households (about 268,600) and more persons per household (5.7). Pampanga is the least agrarian province and Tarlac the most agrarian. Pampanga has the largest industrial sector.

2.7.3 Cost-Benefit Analysis Approach. A cost-benefit analysis (CBA) approach is used to determine which alternatives are economically efficient. The CBA also can be used to determine if increments of an alternative should be funded and to determine the optimal scale of alternatives. A key element of the analysis is determining the with-project and without-project conditions since benefits are measured by the difference between damages suffered without-project and damages suffered with-project. Both conditions allow for trends and changing conditions.

Benefits and costs are measured over the planning horizon, which in most cases is 25 years. Future benefits are discounted because benefits today are worth more than they will be in the future. A discount rate of 12 percent is used in this study as suggested by the USAID and the World Bank. A number of investment statistics are computed for each alternative including net present value (NPV), the benefit-cost ratio (BCR), and the internal rate of return (IRR).[5] A positive NPV, a BCR greater than one, or an IRR greater than the discount rate all imply that projects are economically efficient.

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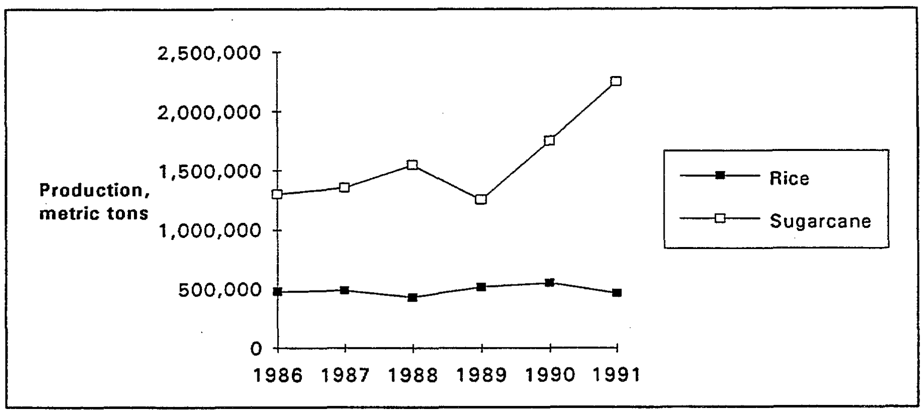
[5] Net present value is the difference between discounted benefits and discounted costs. The benefit-cost ratio is the ratio of discounted benefits and costs. The internal rate of return is the discount rate at which discounted benefits equal discounted costs.

2.7.4 The Economic Model. The calculation of project benefits and rates of return is subject to numerous kinds of risk and uncertainty. For example, benefits depend on uncertain future rainfall and storm events. Also, economic data such as asset values and quantities, locations, and damage schedules are also not precisely known.

The economic model is a simulation model which attempts to represent aspects of the real life situation in the study area and the inherent uncertainty. Hydrologic, hydraulic, and certain economic data are represented by probability distributions which indicate the likelihood that particular values will occur. The simulation model combines a large number of probability distributions, and provides a method of quantifying the range of uncertainty of outcomes. The economic model includes several components including economic, cost and engineering input files, the damage calculation module and the investment analysis module. Damage categories analyzed include structures, agricultural production, infrastructure, transportation disruptions, foregone income, evacuation costs, and resettlement costs. Figure 4 shows the basic components of the model. More detailed information on the economic model is found in Technical Appendix C.

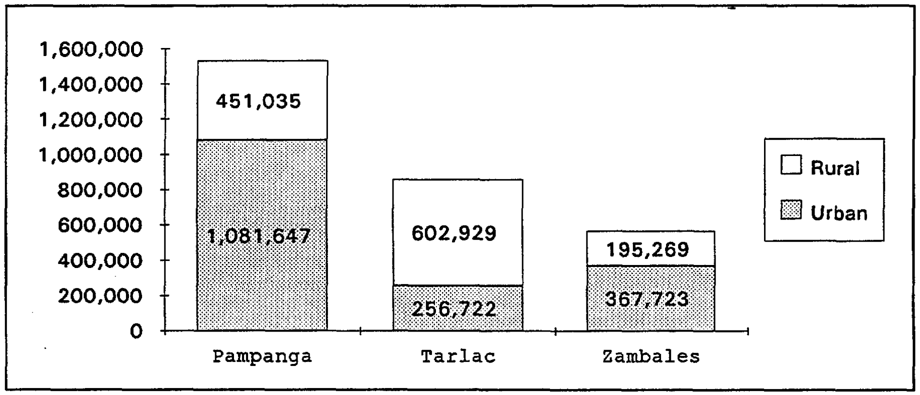
Figure 2 -- *Rice and Sugarcane Production, 1986 to 1991*



Source: *Provincial Development Reports* for Pampanga, Tarlac, and Zambales.

Figure 3 -- *Population and Household Data*

Urban and Rural Population, 1990



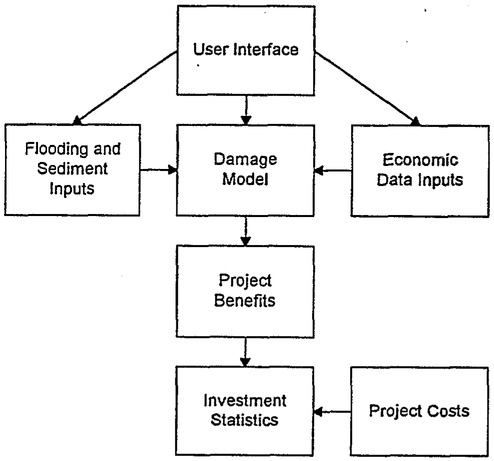
Households and Persons per Household

Province	Total Households	Persons per Household
Pampanga	268,547	5.7
Tarlac	159,332	5.4
Zambales	115,643	4.9
TOTAL	543,522	

Source: National Statistics Office, 1990 Census of Population and Housing, Table 2.

Source: *Census of Population and Housing*, National Statistics Office, 1990.

Figure 4 -- *Basic Components of the Economic Model*



2.8 Environmental and Social Conditions

An environmental assessment (EA) for the Recovery Action Plan was prepared concurrently as an integral part of this study and is Volume III of the Long Term Report. As the EA, Volume III addresses the significant environmental issues and impacts identified for the alternative plans contained in the Long Term Report in accordance with current GOP regulatory procedures and USAID funding requirements, as defined by Title 22 *Code of Federal Regulations*, Part 216 (22 CFR 216).

The following descriptions summarize the existing environmental and social conditions of the study area. A summary of the environmental and social conditions of the eight river basins and the potential impacts of the alternative plans is located in section 4 of this report. Volume III contains detailed descriptions and supporting documentation.

2.8.1 General Setting. The six provinces which comprise Region III provide a diverse environmental and social setting, ranging from mountainous uplands (41 percent of the total land area) to alluvial lowlands and tidally influenced delta areas (38 percent). Region III can be characterized as highly developed with an environment described as degraded, even prior to the Mount Pinatubo eruption (National Economic and Development Authority, 1992). Soil erosion was reported as one of the most pressing pre-eruption ecological problems, resulting in extensive siltation and flooding of downstream areas. The Pampanga River is perhaps the most significant source of sediment into Pampanga Bay. Industrial and domestic pollution of the region's rivers also is a significant concern, with 10 of the rivers considered as seriously polluted.

Since the eruption, the river basins draining Mount Pinatubo can best be described as completely altered from their pre-eruption, or natural conditions. Most of these former river channels and adjoining low areas are now buried by sediment deposits, ranging from meters to tens of meters in depth. Lahar events from 1991 to 1993 have reportedly covered an area of about 40,000 hectares (ha) with sandy deposits (PHIVOLCS, 1993). Surface water flow during the long dry season is now minimal or non-existent, in stark contrast to the pre-eruption years when many of these same rivers served as important sources for local irrigation systems and supported a sustenance level of traditional fisheries.

Siltation has extended downstream to sensitive wetlands, estuaries and coastal areas, significantly impacting these ecosystems while creating new wetlands through ponding of former agricultural areas. The effects of increased siltation include disruption of the most extensive area developed to brackishwater aquaculture in the Philippines. Brackishwater fishponds in Region III produced 45 percent of the national fishpond production in 1991. Current reports indicate that annual production from these fishponds has decreased about 40 percent since the eruption due to obstruction of water flow and tidal exchange within the delta waterways. Table 1 summarizes the general effects of the eruption on aquatic systems in the study area.

Table 1 -- *Effects of the Eruption on Aquatic Systems*

ECOSYSTEMS	EFFECTS	SPECIES AFFECTED
River Systems	Increased siltation Change of flow patterns	Freshwater & brackish-water fishes and invertebrates
Fishponds (Pampanga) Freshwater (6,000 ha)	Increased siltation, poor drainage Possible cut-off from irrigation supply Increased and prolonged flooding	Tilapia and carp
Brackishwater (26,000 ha)	Siltation, poor drainage Cut-off from tidal water Increased and prolonged flooding	Milkfish, prawn, tilapia, etc.
Coastal Waters, (Zambales) Coral reefs (10-100 m depth)	Physical burial of living reefs by increased siltation Loss of habitat for reef fisheries Initial increase in fishermen's catch followed by drastic decline	Reef-related fisheries and benthic organisms
Municipal Waters (within 7 km from shore)	Low productivity, poor catch Productive fishing only in deeper waters (100-200 m)	Pelagic fishes

Source: Adapted from Haribon Foundation, 1992

Each of the eight river basins and the delta have been subjected to a range of emergency rehabilitation efforts over the last two years, including channel excavation, dredging, and construction of levees. Prior to the eruption, many of these rivers were trained by the construction of dikes, flood control and irrigation diversion structures, and supported substantial sand quarrying operations. Local reports indicate that as a result of this river training, siltation and flooding increased downstream, particularly in the Pampanga delta.

From the social perspective, available statistics indicate an affected population of over one million, including some 35,000 Aetas, who are members of a indigenous cultural community for which Mount Pinatubo served as part of their ancestral domain. Recent reports indicate that about 14,000 families have been resettled, and about 31,000 families currently live in 73 temporary evacuation centers waiting to be resettled. Resettlement sites are typically located in unoccupied areas, including public forest lands and government reservations, which affects the environmental qualities of these previously undeveloped areas. The off-site impacts of resettlement may include increased population pressure and livelihood extraction on remaining natural resources in undeveloped areas adjoining many of the resettlement sites.

2.8.2 Summary of Environmental Issues and Concerns. The sensitive environmental issues and concerns which have been identified in the study area are summarized below. A location map of the sensitive environmental areas is shown in figure 5.

- Human Settlements and Social Issues: The low areas, particularly in Pampanga, are highly populated and developed, compounding the available options for resettlement (lack of arable land, housing and livelihood) and for engineering intervention (right-of-way acquisition and compensation, risks due to structural failures). Due to high population densities and impaired drainage, the potential effects of prolonged flooding, or ponding, on public health is a significant concern.

- Endangered or Threatened Species: The Pampanga delta and adjoining Candaba swamp are internationally recognized as a critically important winter nesting areas of the East Asia-Pacific Flyway for migratory birds, including several endangered species originating from Mongolia, mainland China, and Japan. Prior to the eruption, Mount Pinatubo was one of the richest botanical areas in Luzon (Madulid, 1992; Kennedy et al, 1992; Heany, 1992) due to the geographic isolation of the Zambales mountain range.

- Archaeological or Historical Resources: Based on field surveys and available literature, the low-lying areas contain numerous sites where archaeological artifacts have been found, indicating an established pattern of habitation dating to prehistoric periods. Historical structures and sites also are common in the study area.

- Cultural Communities or Tribes: Reflecting the long period of human habitation in the area, members of a tribal ethnic group, the Aetas, have historically occupied the

Zambales mountains, including Mount Pinatubo, and consider this area as part of their ancestral domain.

- Prime Agricultural Lands: Although Central Luzon is considered as the Philippine's prime rice growing region, it also is extensively developed to sugarcane production and aquaculture. Supporting this extensive agricultural development are numerous irrigation and river control investments, many of which have been damaged as a result of the eruption.

- Recharge Areas of Aquifers: The Pampanga delta is highly sensitive with respect to hydraulic balance, with an increasing tendency of salt water intrusion due to excessive ground water extraction and generally deforested watersheds. Currently, most domestic, agricultural and industrial water supplies are dependent on shallow and deep wells, which in turn, rely upon the recharge areas of these aquifers.

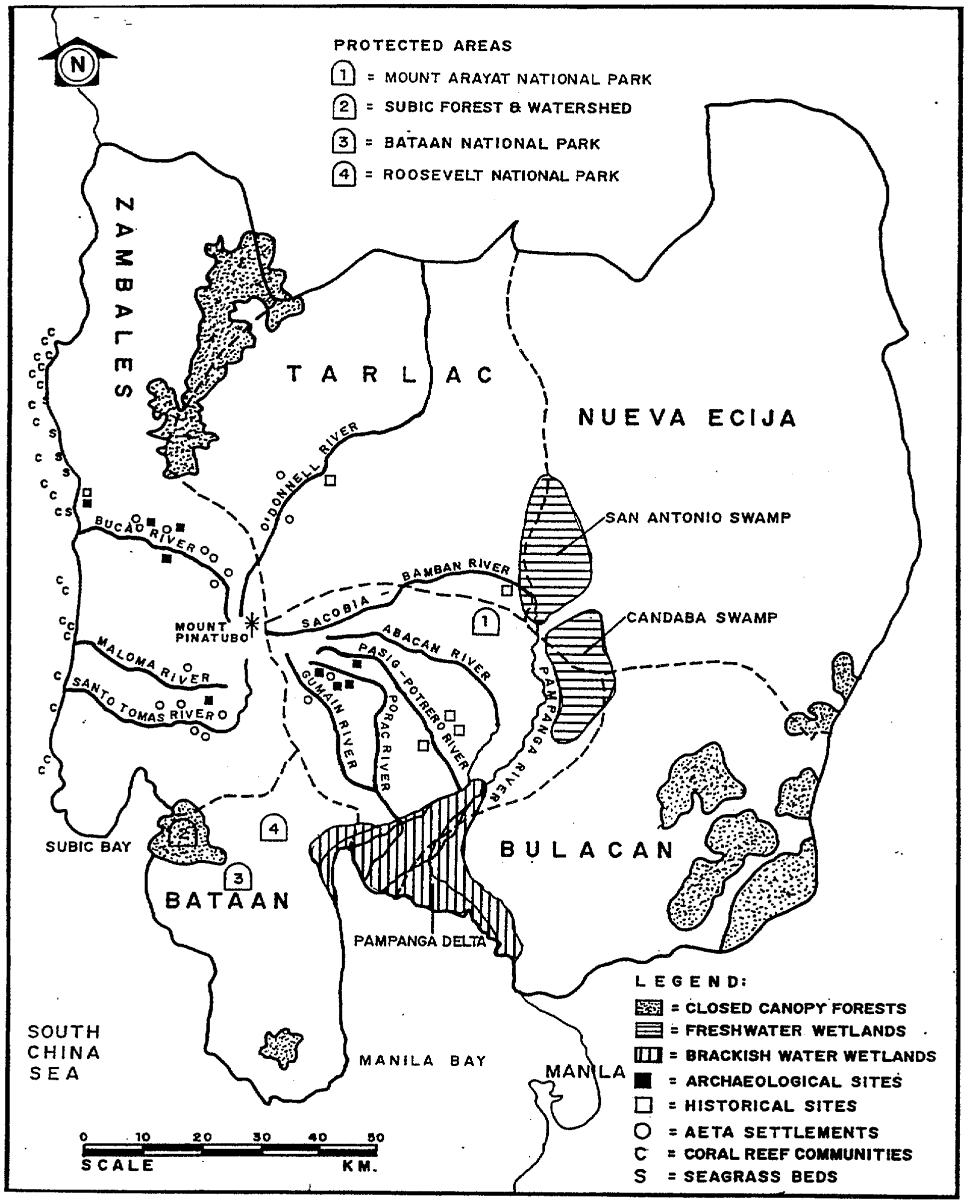
- Sensitive Aquatic Resources: The rivers draining Mount Pinatubo discharge into sensitive coastal areas, including the Pampanga delta, Manila Bay, and Lingayen Gulf. These coastal areas support significant aquacultural, commercial and local fisheries resources, which are being affected by poor water quality and disrupted surface flows. The delta contains some of the few remaining mangrove areas and these may play an increasingly important role in the long-term ecology of the delta system. Limited areas along the Zambales coastline of the South China Sea also sustain coral reef and/or seagrass communities, most of which have been disrupted by ashfall and/or siltation.

2.9 Risk and Uncertainty

Risk and uncertainty in this study arise from variations in the natural processes (rainfall, streamflow, sedimentation, etc.) and the limited available data. For this study, uncertainty exists in the estimates of flood depths, sediment yield, potential damages, and benefits of potential alternatives. As a result, sediment yields may be highly variable over both the short- and long-term, which affect the estimates for potential damages and benefits. Secondary pyroclastic flows or other basin disturbances could cause immediate, large surges of sediment. The occurrence or lack of unusually large storms also will cause variations in sediment yields. For example, natural events, such as the October 1993 change between the Pasig and Sacobia headwaters, can vary forecasted sediment yields. In this circumstance, this change may increase the forecasted sediment yield by perhaps 50 to 100 million m^3 in 1994 for the Pasig-Potrero basin.

Risk and uncertainty were considered in this study by placing confidence intervals on estimates such as peak discharges at each hydrologic site, and the mean values of economic damages and benefits. However, uncertainty is still inherent with respect to the information provided, and a significant risk remains for a particular site or basin to experience more or less damage than forecast. Conditions affecting risk and uncertainty can be clarified through a monitoring program as described in Technical Appendix E.

Figure 5 -- *Location Map of Sensitive Environmental Areas*



3. PLAN SELECTION PROCESS

3.1 General

The plan selection process instituted for this study consisted of a series of sequential and sometimes iterative steps that identified problems and responded to specific planning objectives for each river basin, including specific concerns expressed during coordination with USAID and the GOP, and during environmental scoping sessions. The process was dynamic with iterations occurring to sharpen the focus or change emphasis as new data were obtained, and problems and opportunities changed or became more clearly defined. Specific actions or measures were developed to respond to objectives involving preservation of life; sediment deposition; flooding; and social, environmental, and economic resources. A particular measure may or may not solve a specific problem or satisfy a study objective by itself; measures may be combined to form a range of alternative plans for consideration in each river basin.

3.2 Step 1 -- Existing Conditions and Specific Problems

A summary of the existing water and land resource conditions, and specific problems for each river basin can be found in sections 2 and 4 of the main report. More information on a particular river basin can be found in the appropriate technical appendix.

3.3 Step 2 -- Study Objectives Prioritization

Meetings were held between USACE, USAID, and the GOP's Task Force on Mount Pinatubo to address the plan selection process, identify specific study objectives and their definitions, and prioritize study objectives for each river basin. The Task Force provided the GOP national perspective to recovery action guidance and accepted the responsibility of coordinating efforts to obtain study objective priorities for each river basin. The study objectives and their definitions for each river basin are listed below.

- Objective A - Prevent loss of life (the probability of saving lives).

- Objective B - Reduce damages from sediment deposition in populated areas (the probability of lowering damage potential to urban areas).

- Objective C - Reduce damages from sediment deposition in agricultural areas (the probability of lowering damage potential to farms, fish ponds, etc).

- Objective D - Reduce damages from sediment deposition to infrastructure assets (the probability of lowering damage potential to roads, public structures, etc).

- Objective E - Reduce damages from flooding in populated areas (the probability of lowering damage potential to urban areas).

• Objective F - Reduce damages from flooding in agricultural areas (the probability of lowering damage to farms, fish ponds, etc).

• Objective G - Reduce damages from flooding to infrastructure assets (the probability of lowering damage potential to roads, public structures, etc).

• Objective H - Enhance economic, environmental, or social resources (the probability of improving economic, environmental, or social conditions).

A matrix analysis, using a value-based evaluation process was used by the Task Force to solicit input for each river basin from its committee members, political representatives from the impacted provinces, and various governmental agencies. This matrix analysis is developed by comparing objectives on a one-to-one basis and assigning a numeric value priority (0 to 5) to the objective determined to be most significant. Once specific priority values are listed for each possible one-to-one combination, a total numeric value can be obtained by summing the individual values. The summarized results of this effort for each river basin are shown in table C-1 of Exhibit C of the main report. The results reflect concurrence by the USACE, the GOP, and USAID for objective priorities.

Recognizing the limited number of respondents sampled for some of the river basins, and the subjective nature of this analysis, no absolute determination can be made regarding the effectiveness or responsiveness to the study objectives. However, the analysis does provide one possible outcome that could be achieved within the parameters established in step 1. The analysis also identifies the related problems and opportunities encountered during the plan selection process as a result of choosing such parameters. In this regard, other aspects of the alternatives must be evaluated and incorporated in the plan formulation process, such as benefits, costs, construction considerations, and economic, environmental and social effects. Only then can a determination be made as to which, if any, of the alternatives would be the most responsive. These aspects are evaluated and described in the following sections of this report.

3.4 Step 3 -- Evaluation of Measures

Based on experience gained during development of intervention measures for the Interim Action Report, and field investigation of the river basins to determine geologic and geomorphologic influences, potential structural and non-structural intervention measures were identified early in the study process to address preliminary hazard conditions developed for each river basin. Preliminary screening using a matrix evaluation was performed to determine whether a specific structural measure has applicability in a specific river basin and to address the measure's implementation potential within the scope of the Long Term Report. While non-structural measures offer protection to residents, they were not subject to this evaluation because of their inability to reduce hazards or damages. Evaluation factors for the structural measures included engineering, economic, and environmental/social criteria.

3.4.1 Measure Definitions and Functions. The definitions and functions of the potential structural and non-structural intervention measures being considered in this study are described below.

Structural Measures.

Levees. Levees are usually placed parallel to a river channel or along a river bank. Levees guide the flow by keeping the river from moving outside a specific boundary. Levees offer protection from water and/or mudflows. Existing levees can be improved by increasing heights, modifying their alignments, or strengthening them in areas with the greatest potential for damage. Levees can be constructed to protect land, population, and infrastructure from flooding and sedimentation. Levee slopes need protection from erosion, and protection can be provided by vegetation, rock (riprap), concrete ("hardened levee"), or other materials.

Channel Excavation. Channel excavation creates more or restores a previous river channel capability to carry water and/or sediment. Excavation is usually done using land-based mechanical equipment. The excavated portion of the channel provides for future sediment deposits and flood flows. Excavation of channels can be done to guide flood waters away from critical areas. Disposal sites for excavated material may be needed.

Sump. A sump is an in-channel basin created by dredging below the grade of the channel. The purpose of a sump is to trap and store sediment and reduce downstream sedimentation and subsequent ponding-type flooding. Periodic dredging of the sump is needed to maintain effectiveness. Disposal areas are needed close to the sump to accommodate the dredged materials.

Sand Pocket. A sand pocket is a collection area that reduces the water velocity, causing sediment to settle. Sand pockets can be of variable heights, depths, areas, and sized to store anticipated mudflow events. Sand pockets can be constructed in phases to enhance effectiveness over more than one season of sediment transport. A spillway may be used to pass high flows. Areas to store water and settle sediments can be created by the use of spillways, culverts, or river constrictions. Sand pockets may need to be maintained by excavation of settled sediments, and disposal sites also may be necessary.

Sediment Retention Structure (SRS). This measure consists of construction of a dam using earth or rockfill embankments, or concrete. The purpose of an SRS is to store sediment that would otherwise continue down the river and cause damage. The dam height can vary depending on the amount of sediment storage needed and site conditions. Some type of outlets are needed to pass water safely through or around the dam and prevent large ponding of water during non-peak flow periods. Also, a spillway is needed to pass larger (flood) flows to keep the dam from being overtopped and possibly destroyed. Two types of sediment retention structures are being considered to store sediment: a roller compacted concrete (RCC) gravity overflow dam, and an embankment dam with outlet works.

Dredging (Desilting). Clearing sediment or sand from stream channels is performed using hydraulic equipment to maintain flow capacity. Disposal sites are needed. For this study, dredging is considered appropriate for clearing channels in the Pampanga delta area and dunal (sand) deposits from stream mouths along the South China Sea.

Bank and Slope Protection. This measure stabilizes erosion of streambanks and levees using rock (riprap), concrete sand bags, or other protective materials.

Sediment Basin. A sediment basin is created by excavating an area of natural sediment deposition. A sediment basin causes flows to spread and decrease in velocity. This allows sediment to settle and reduces the downstream transport of material. A sediment basin requires continuous excavation and a place to dispose of material to maintain effectiveness.

Sill. A sill is a low, concrete or rock structure constructed across a stream channel. Its purpose is to control the location of the channel grade and prevent channel erosion upstream of where it is placed. Sills are effective in stabilizing in-channel sediment.

Pile Dike. The purpose of a pile dike is to control the location of the channel flow and promote the deposition of sediment along the stream banks. Construction usually consists of a line of piles usually made from wood, concrete, or steel that are placed across a stream.

Groins. These structures are made out of rockfill, concrete, or other rubble placed at an angle to a streambank to prevent erosion, and control the location of the channel and cross-sectional velocities.

Weirs. This measure consists of concrete or rockfill structures constructed across a channel to stabilize in-channel sediments, control the location of the channel grade, and provide some regulation of stream flow. An outlet may be needed to pass low flows through the structure.

Non-Structural Measures.

Temporary Evacuation. Residents would be evacuated from vulnerable areas during high threats of flood or sediment flows. Considerable damage would still result in each basin. Flood plain areas along the rivers would act as sediment traps. Residents would take shelter at temporary locations and would likely return to their residences if not damaged beyond usefulness. Escape routes may be dependent on available transportation facilities and corridors. Effectiveness is related to people's attitudes.

Early Warning System(s). This measure involves the placement of a reliable system for timely warnings of impending flooding and sediment flow conditions for each river basin. Sediment events are initiated in the upper reaches of each river basin, and these areas provide the best opportunity for advance warnings. A communication network is needed to spread warnings throughout each river basin.

Existing early warning systems consist of rain gages and sediment flow sensors operated by PHIVOLCS and observation posts manned by NDCC personnel. This type of system is capable of providing up to two hours of advanced warning of large flows. This system could be made more effective by installing sirens or loud speakers to alert people in downstream communities. Warnings may lead to the temporary or permanent evacuation (relocation) of communities determined to be at risk of destruction by sediment flows and/or flooding.

Permanent Evacuation (Relocation). Populated areas threatened with imminent destruction by flood and sediment flows would be permanently evacuated. The GOP has developed resettlement locations throughout much of the area. Residents would be relocated to centers where they would await resettlement to other safe areas and could be retrained in other skills. However, people may not stay in resettlement areas. Instead, they may return to impacted areas during the dry season and attempt to recreate their previous life style.

Revegetation in Source Areas. Revegetation consists of seeding and planting of appropriate vegetation in the devastated areas around Mount Pinatubo (upper slopes) to stabilize material and control erosion, with fertilization as required. Effectiveness is generally limited because most of the source area deposits are too hot for the establishment of vegetation, and the nature of these deposits make them vulnerable to mass movement and heavy erosion.

3.4.2 Measure Evaluation. The following factors were used to evaluate a structural measure's implementation potential based on an initial assessment of the preliminary hazard conditions and economic characteristics pertinent to each river basin.

- **Engineering Factors.** A relative ranking (low, moderate, high) of a structural measure's ability to reduce hazards such as mudflows/in-channel sedimentation, flooding, ponding, and hazards to bridges, roads, and other infrastructure for each river basin.

- **Economic Factors.** A relative ranking (low, moderate, high) of a structural measure's potential to reduce damages on buildings, crops, infrastructure, and transportation disruptions.

- **Environmental/Social Factors.** Physical and structural issues/concerns for the five east side river basins were identified by the public during scoping meetings held in April 1993, and for the west side river basins and the Pampanga delta in November

1993. This input was used to determine whether a potential intervention measure would meet or not meet the public's issue/concern for each river basin. After considering the hazard conditions and economic characteristics for each river basin, a potential intervention measure was considered to "meet" a particular public issue/concern under the following circumstances:

- Siltation - Measures that reduce sediment hazards and damages, or control sediment in the river basin.

- Ponding/Flooding - Measures that reduce ponding/flooding hazards and damages in the river basin.

- Lack of/No Lahar Disposal - Measures not requiring the use of disposal sites to store sediment/mudflow material.

- Lahar Overflow - Measures that control mudflows/sediment from entering or moving in a river basin.

- River Bank Erosion - Measures that stabilize or prevent erosion, including slope protection on levees.

- Poor Access/Isolation - Measures that reduce hazards and damages associated with roads and bridges.

- Restore/Maintain River Flow - Measures that control the location or flow of channels, or restore/create more channel storage.

- Existing Levees Weak - Measures that strengthen or repair existing levees in a river basin, or construction of new levees to replace existing ones.

In addition, a perception survey was distributed to 770 households in the five eastern river basins which focused on two major issues described as physical problems/response measures and resettlement[6]. The respondents were asked to identify appropriate engineering actions or interventions. Sixty-one percent of the respondents identified protective dikes/levees as an appropriate measure and 38 percent recommended dredging activities. This ranking of levees and dredging was reported for all eastern river basins except for the Gumain-Porac, of which 75 percent identified dredging and 31 percent identified levees. Less popular measures include sabo dams (11 percent), rechannelling (4 percent) and desilting (2 percent).

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6 Louis Berger International, Inc., *Environmental Scoping Report*, prepared for the U.S. Army Corps of Engineers. June 1993.

Matrix Tables D-1 to D-8, located in Exhibit D of this report, summarize the preliminary screening performed to determine a measure's applicability in a river basin and its implementation potential within the scope of the Long Term Report. The measures found to be effective and implementable for each river basin are shown on table 2.

3.5 Step 4 -- Formulation of Alternatives

Those measures shown in table 2 were used as building blocks to formulate alternatives for each river basin. Other measures may have been included in an alternative for completeness. The engineering feasibility of each measure and potential alternative has been evaluated with respect to the physical parameters of the specific river basin such as the projected sediment loads, the hydrologic and geomorphic conditions, and site-specific considerations such as the geologic, geotechnical, hydraulic, structural, civil, cost, constructibility, and operability. The methodology used to determine the engineering feasibility is discussed in more detail in Technical Appendix E, Engineering Analysis, located in Volume II of the Long Term Report.

The evaluation considerations or initial design objectives developed to test the capability of a specific measure or potential alternative are listed below.

- Capacity for handling, at a minimum, the first 10 years of annual sediment yields as determined from the sediment budget.

- Capacity for handling through either storage or containment the sediment produced during a single peak hydrologic event (the 100-year flood event was used).

- Capability for containment of a mudflow.

- Capability to drain a pool area as required.

- Resistance to failure from hyperconcentrated flows and mudflows.

Staging (incremental construction) also is considered in terms of providing flexibility in dealing with a problem that is time-related and has a potential for cost savings through deferred construction. The alternatives formulated by river basin for further consideration are discussed in detail in Section 4 of this report.

Table 2 -- *Summary of Preliminary Screening of Measures*

Initial Structural Measures	Function of Measure	Effectiveness in River Basin							
		Pasig-Potrero Basin	Sacobia-Bamban Basin	Abacan Basin	O'Donnell Basin	Santo Tomas Basin	Bucao Basin	Maloma Basin	Gumain-Porac Basin
LEVEES	Containment of sediment & water.	yes	yes	yes	yes	yes	yes	yes	yes
CHANNEL EXCAVATION	Increase capacity to move sediment & water.	yes	yes	yes	yes	yes	yes	yes	yes
SUMP	In-channel basin to trap sediment.	yes							yes
SAND POCKET	Trap sediment & regulate flow.	yes	yes		yes				
SEDIMENT RETENTION STRUCTURE	Trap sediment & reduce flooding.	yes	yes		yes	yes	yes	yes	yes
DREDGING	Increase channel flow & reduce ponding.	yes				yes	yes	yes	yes
BANK PROTECTION	Prevent erosion.	yes	yes	yes	yes	yes	yes	yes	yes
SEDIMENT BASIN	Trap sediment to reduce transport.	yes	yes						
SILL	Stabilize sediment to control channel location.	yes	yes						yes
PILE DIKE	Control flow & sediment deposition along banks.	yes	yes	yes		yes	yes	yes	
GROINS	Erosion control & control channel location.	yes	yes	yes		yes	yes	yes	yes
WEIRS	Trap sediment, control channel location & flows.	yes	yes	yes		yes			yes

Table 3 -- *Summary of Study Objective Prioritization Values*

River Basins	Total Prioritization Values by Alternative-Type				
	No Action	Levee	Channel Excavation	Retention Structure	Nonstructural
Pasig-Potrero	111	292	302	N/A	160
Sacobia-Bamban	114	289	311	300	157
Abacan (see note)	118	N/A	N/A	N/A	177
O'Donnell	110	291	268	299	165
Santo Tomas	104	272	277	281	160
Bucao	103	249	N/A	257	159
Maloma	105	251	199	230	161
Gumain-Porac	114	312	244	321	174

Note: A bank protection alternative was developed for the Abacan basin and has a prioritization value of 209.

N/A = Alternative plan does not apply to the river basin.

3.6 Step 5 -- Screening of Potential Alternatives

The ability of an alternative to accomplish the planning objectives was determined by using a weighted numeric value obtained from a matrix analysis which combines the objective priorities determined from step 2 with the alternatives. This evaluation is shown in Exhibit D, Tables D-9 to D-16, and is summarized on table 3. This type of matrix analysis provides an evaluation of how effective each alternative may be in accomplishing the various study objectives identified for each river basin. Applying a numeric rating to that effectiveness and combining it with the study objective prioritization values (from step 2) provides a comparable perspective for all the alternatives formulated for a river basin.

3.7 Step 6 -- Evaluation of Potential Alternatives

Economic efficiency is a primary criteria for screening alternatives for this study. The economic analysis (cost-benefit analysis) incorporates a variety of information - technical and engineering data; behavior; preferences; prices and incomes; and environmental, social, and institutional data - into a framework useful in choosing how to utilize scarce resources. The analysis measures social benefits and costs, and includes marketed and nonmarketed goods and services; environmental costs and benefits; and other external costs and benefits. This is consistent with USAID and World Bank criteria.

Risk and uncertainty factors were considered for the alternatives. Risk and uncertainty arise from measurement errors, and from underlying variability of complex natural, social, and economic situations. It must be recognized that it is impossible to predict accurately what natural phenomena may still occur at Mount Pinatubo. Further, the amount of sediment movement and the timing of that movement are critical in evaluating long-term solutions to reduce sediment deposition effects.

A summary table for each river basin that displays the differences among the alternatives as related to how well each meets study objectives and financial, environmental, technical, and social factors, is found in section 4 of this report.

3.8 Step 7 -- Identification of Alternatives to be Implemented

It is not the intent of the Long Term Report to recommend that a specific alternative be implemented for a particular river basin. Instead, the various alternatives were developed to be responsive to the potential problems of a specific basin. When combined with the specific political desires, funding resources, and implementation capabilities of the Philippine Government, the information provided in this report assists in the basis for selection between a variety of recovery action options.

4. SPECIFIC CONDITIONS AND ALTERNATIVES FOR THE RIVER BASINS

This section summarizes the conditions and alternatives formulated for the eight river basins and Pampanga delta being studied in the Long Term Action Report. More detailed information can be found in the technical appendices and environmental assessment located in Volumes II and III, respectively.

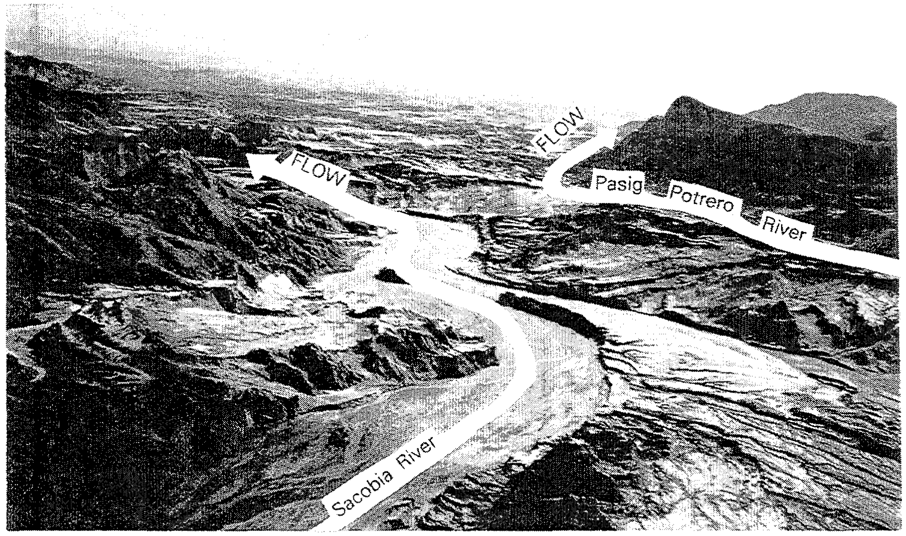
4.1 Pasig-Potrero River Basin

Note: The following analysis is limited to basin conditions prior to October 1993. A natural diversion of about 21 km^2 of the Sacobia headwaters into the upper reaches of the Pasig-Potrero basin occurred during October 1993. This increase in drainage area for the Pasig-Potrero basin greatly increases the flow in the pyroclastic deposit main channel and will increase sediment yields. The increase in sediment yields has not been fully analyzed or included in this study, but is expected to be very large, perhaps as much as 50 to 100 million m^3 in 1994 above the amounts forecast here. These new conditions are judged to present an extreme threat to communities along the Pasig-Potrero River.

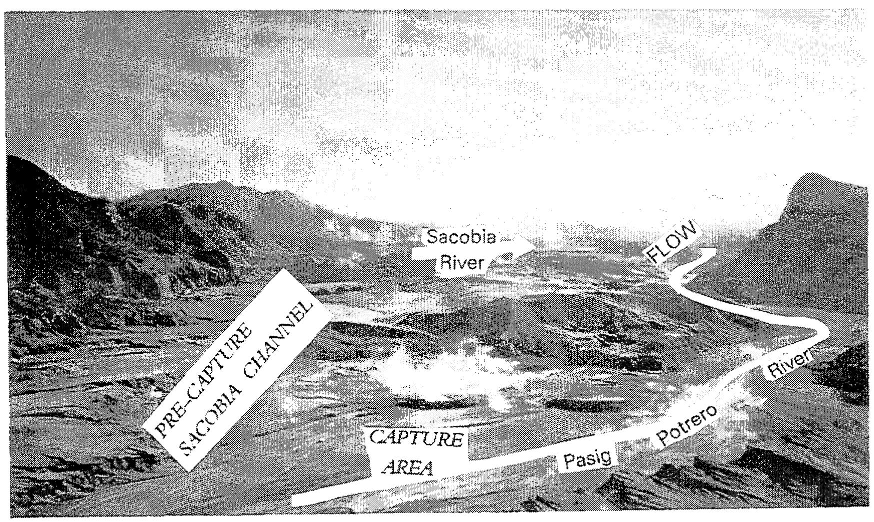
4.1.1 Specific Conditions. The Pasig-Potrero River (see figure 1) originates near Mount Pinatubo at about 1,200 meters in elevation. It has a length of 40 km and since it captured 21 km^2 of the headwaters of the Sacobia River in about October 1993, it drains an area of about 77 km^2 (see figure 6 for photographs of the capture area). The upper basin is located on the relatively steep slopes of Mount Pinatubo. It originates 13 km from the post-eruption crater rim and extends for a distance of about 10 km to the confluence of Timbu and Papatac creeks. It is incised into the recent pyroclastic flow deposits and, in some places, into bedrock or older pyroclastic deposits. The 1991 pyroclastic deposits (302 million m^3) filled the existing channels to depths as great as 200 meters. These deposits extend downstream from the uppermost reaches of Timbu and Bucbuc creeks, to the confluence of Timbu and Papatac creeks. Severe erosion, two or more SPFs, subsequent lake breakout events, and the October 1993 channel diversion have significantly altered the basin's physiography since the eruption.

From the confluence of Timbu and Papatac creeks to about the Angeles-Porac road, the river is called Pasig. This is an area of sediment production, transport and deposition. This reach is incised into a gently sloping alluvial fan consisting primarily of pre-1991 lahar and alluvial deposits, which are composed of sand with silt fines and coarser sizes. From the Angeles-Porac road to about Highway 7, the river is called Potrero. This is an area where deposition has caused damage to farmlands and barangays. The Potrero River flows into the Guagua River, which empties into Pampanga Bay. This delta reach is flat and consists of silts and fine sands.

PHOTOGRAPHS OF THE PASIG RIVER'S CAPTURE OF THE HEADWATERS OF THE SACOBIA RIVER



November 1992: Pre-Capture



November 1993: Post-Capture

Figure 6

The municipalities affected or threatened by mudflows, flooding and erosion are listed on table 4 and were identified by overlaying maps generated by the Geographic Information System (GIS) on the risk maps prepared by the USACE. Ten municipalities are listed in table 4 as being in the risk areas. Figure 7 shows photographs of sediment deposits and flooding in the basin. The risk areas are estimated to include:

- 35,000 household, commercial, and/or public buildings
- 7,000 ha of agricultural land (sugar cane and rice dominate)
- P250 million in annual crop revenues

Current land cover for the Pasig-Potrero basin consists primarily of agricultural land (56 percent), followed by grassland/shrubland (13 percent), urban areas (13 percent), sediment deposits (17 percent), and woodlands (1 percent). For the Pasig-Potrero basin, the upper alluvial fan is mainly grown to sugarcane while in the lower fan area, paddy rice is the dominant crop. Areas that were impacted by mudflow events in 1991 and 1992 have now largely been naturally revegetated by pioneering grass species.

4.1.2 Problem Statement. In the Pasig-Potrero basin the risk of mudflows caused by pyroclastic deposits in the upper drainage is high for at least 10 years. Upstream of Mancatian, there is a high risk that the channel will fill with material causing mudflows and river diversions to areas adjacent to the Pasig basin. The risk of flow diversion to Porac is high, and the risk of flow diversion to the Abacan is low. (Note: the recent change between the Pasig and Sacobia headwaters may change this potential risk of flow diversion to the Abacan). Downstream of Mancatian, there is a risk that bank erosion will cause levee breaches, flooding, and sediment deposition throughout the basin. Sediment discharged from the Pasig will deposit in downstream channels causing increased ponding-type flooding in the delta in or near Bacolor, San Fernando, Minalin, and Santo Tomas.

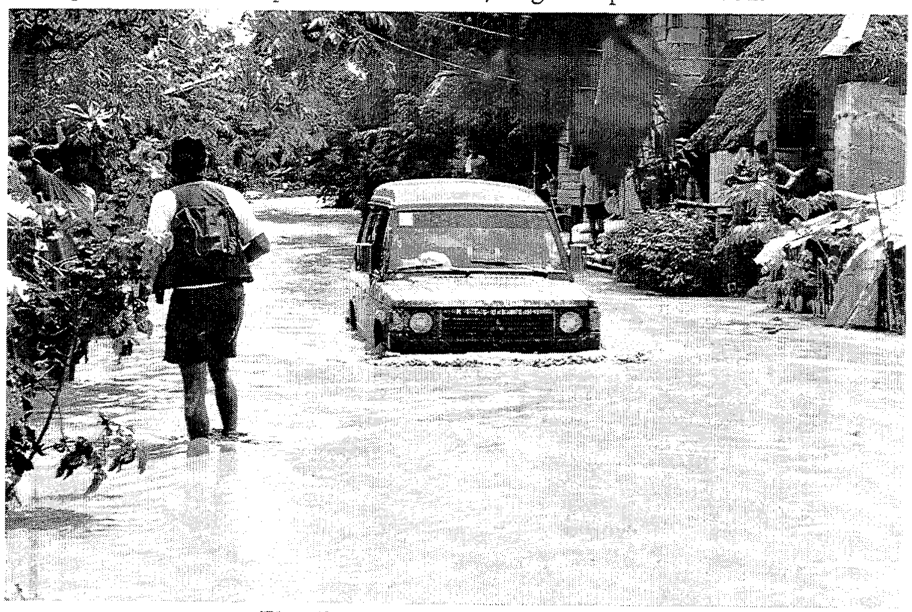
4.1.3 Sediment Forecast. Sediment deposition forecasts for the Pasig-Potrero basin are summarized below. More detailed information can be found in Technical Appendix B located in Volume II of the Long Term Report.

- Initial pyroclastic volume -- 302,000,000 m^3
- Erosion volume (1993 to 2002) -- 47,000,000 m^3
- Erosion volume (1993 to 2042) -- 77,000,000 m^3

An additional 23,000,000 m^3 of sediment eroded in 1991-1992.

It also is estimated that there is a 50 percent to 75 percent chance each year of major mudflow events caused by rainfall, runoff, and bank collapse. Each event could deposit 2,000,000 to 12,000,000 m^3 in the basin.

Depth of mudflow deposits at Mancatian, August-September 1992.



Flooding in Santa Rita, October 1993.

Figure 7

Mudflow deposits damage Mitla in September 1992.

Flooding from Pasig-Potrero River in Bacolor, August 1992.

Figure 7 (continued)

Table 4 -- *Municipalities Threatened by Mudflows, Flooding and Erosion*

Basin	Province	Municipality	Type of Hazard
Bucao	Zambales	Botolan	F&S
		Iba	F&S
Maloma	Zambales	Cambangan	F&S
		San Felipe	F&S
Santo Tomas	Zambales	Castillejos	F&S
		San Antonio	F&S
		San Felipe	F&S
		San Marcelino	F&S
		San Narciso	F&S
Abacan	Pampanga	Angeles City	Erosion
		Mexico	F&S
		San Fernando	F&S
		San Luis	F&S
		San Simon	F&S
		Santa Ana	F&S
O'Donnell	Tarlac	Capas	F&S
		Conception	F&S
		Gerona	F&S
		Tarlac	F&S
Pasig-Potrero	Pampanga	Apalit	Ponding
		Bacolor	F&S, Mudflows
		Guagua	F&S
		Minalin	Ponding
		Porac	Mudflows, Erosion
		San Fernando	Ponding
		San Luis	F&S
		San Simon	Ponding
		Santa Rita	F&S, Mudflows
		Santo Tomas	Ponding
Gumain-Porac	Bataan	Dinalupihan	F&S
		Hermosa	F&S
	Pampanga	Floridablanca	F&S, Mudflows, Erosion
		Lubao	F&S, Ponding
		Macabebe	Ponding
		Masantol	Ponding
		Porac	F&S, Mudflows, Erosion
		Sasmuan	Ponding
Sacobia	Pampanga	Mabalacat	F&S, Mudflows
		Magalang	F&S
	Tarlac	Bamban	F&S, Mudflows
		Capas	F&S
		Concepcion	F&S

Note: F&S stands for flooding and sedimentation. Erosion potential was identified by PHIVOLCS.

4.1.4 Alternatives Under Consideration. The alternatives investigated for the Pasig-Potrero basin include: no action, levee, channel excavation, and nonstructural. Because of the capture of the headwaters of the Sacobia by the Pasig sometime in October 1993, the alternatives described below may need to be modified and possibly increased in magnitude to reflect changes in the sediment budget.

No Action Alternative

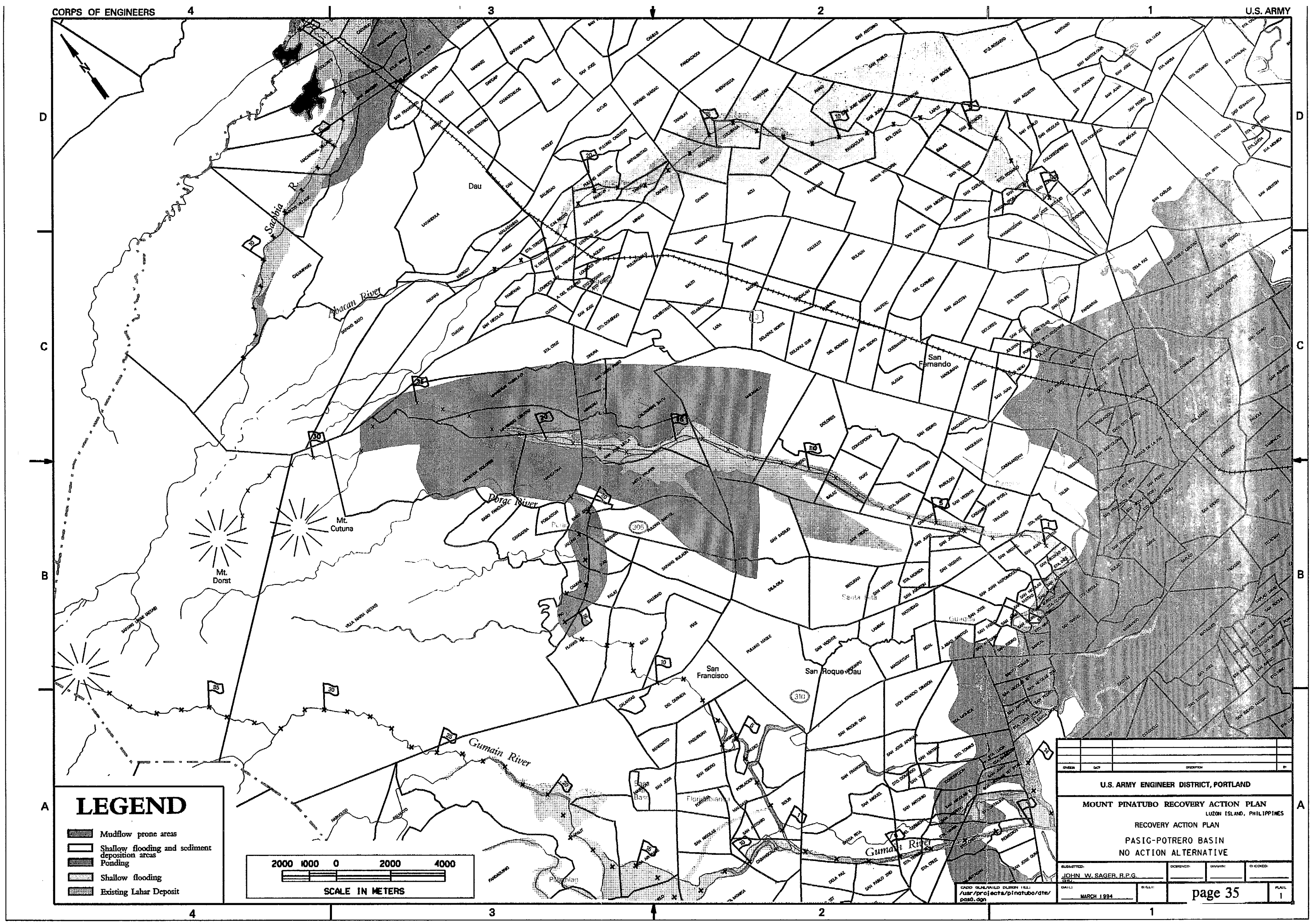
Under the no action alternative (without-project condition), no intervention measures are developed to reduce flooding and sediment damages in the Pasig-Potrero basin. Actions taken by the GOP in emergency situations and use of existing warning systems would continue. Plate 1 shows the risk areas expected under the no action alternative.

The average without-project damages (present value) for the Pasig-Potrero basin are P855 million. Damages to structures (P406 million) account for about 47 percent, followed by agriculture (P206 million), evacuation/relocation (P101 million), infrastructure (P82 million), foregone production (P54 million), and transportation disruption (P6 million).

Prior to the October 1993 change in the Pasig/Sacobia headwaters, about 72 barangays from the municipalities of Porac, Santa Rita, Bacolor, Minalin and Guagua were likely to be impacted by mudflows, flooding and sedimentation. Progressive displacement or alteration of this highly populated and developed area would significantly increase housing, livelihood and public services demands on resettlement sites. Public health concerns are prolonged due to poor water quality and drainage, and temporary housing arrangements. Recovery processes (ecological, sociological, and economic) are delayed.

The potential exists for impact to the Santa Barbara bridge/Highway 7, which serves as the primary public access route to and from Bataan and Zambales. Historic structures and landmarks are found in the municipalities of Santa Rita, Guagua, and Bacolor. Although many have been lost because of recent mudflow and flooding events, further loss to significant historical landmarks is likely.

Although low-lying areas near Bacolor generally will revert to grassland during the same season, they may be converted into low intensity agricultural or fishpond uses during the succeeding year. The more elevated areas of Porac and Santa Rita will contain limited natural revegetation for several years. The downstream delta reaches would continue to be influenced by elevated levels of sedimentation, which would further reduce drainage capacities, increase annual flooding and public health risks in the delta communities, and contribute to the decline of estuarine ecosystems and fisheries. Possible diversion of pyroclastic flows from the Pasig to the Porac River could extend physical impacts and social displacement to this adjacent river basin and potentially affect three archaeological sites located in Barangay Hacienda Dolores.


CORPS OF ENGINEERS
U.S. ARMY
Sacobia R.
Abacan River
Porac River
Gumain River
Dau
San Fernando
Mt. Cutuna
Mt. Dorst
San Francisco
San Roque-Dau
LEGEND
Mudflow prone areas
Shallow flooding and sediment deposition areas
Ponding
Shallow flooding
Existing Lahar Deposit
2000 1000 0 2000 4000
SCALE IN METERS
U.S. ARMY ENGINEER DISTRICT, PORTLAND
MOUNT PINATUBO RECOVERY ACTION PLAN
LUZON ISLAND, PHILIPPINES
RECOVERY ACTION PLAN
PASIG-POTRERO BASIN
NO ACTION ALTERNATIVE
JOHN W. SAGER, R.P.G.
MARCH 1994
/usr/projects/pinatubo/dts/pas0.dgn
page 35

Levee Alternative

As shown on plate 2, the levee alternative for the Pasig-Potrero basin consists of the following features.

- Right and Left Bank Levees from RK 20 to RK 26: A levee 10 meters high with a hardened face, toe protection, and sodded back slope would be constructed on the right (south) and left (north) banks following the existing levee alignment to high ground.

- Right and Left Bank Levees from RK 12 to RK 20: A levee 10 meters high with a hardened face, toe protection, and sodded back slope would be constructed on the right and left banks following a straight alignment.

- Right Bank Levee from RK 7.5 to RK 12: A levee 10 meters high and transitioning to 7 meters at RK 7.5 with slope and toe protection, and a sodded back slope would be constructed on the right bank with a straight alignment.

- Slope Protection: Slope and toe protection would be added to the landward side of the existing right bank levee between RK 7.5 to RK 12.

- Control Structure: A RCC control structure 7 meters high would be constructed at RK 7.5 where the right and left bank levees tie into the existing levees. The allows the leveed area from RK 7.5 to RK 12 to function as a sand pocket.

- Excavation Below RK 7.5: The existing channel below RK 7.5 would be excavated an additional 2 meters and the slopes protected against erosion. The channel would be excavated to the confluence with the Sapang Labuan River.

- Sump: A sump (in-channel basin) with a capacity of about 0.5 million m^3 would be dredged in the Sapang Labuan River, below the mouth of the Pasig-Potrero.

- Early Warning System: Existing warning systems consist of rain gages, sediment flow sensors, and observation posts. Adding sirens or loud speakers to alert people in downstream communities would be an effective way to improve public safety.

<u>Results of Action</u>. The levees from above Mancatian to the control structure are designed to contain mudflows and sediments forecast to be deposited in this reach during the next 10 years, and contain sufficient capacity at the end of this period to provide protection against a 100-year event. The upper right bank levee will prevent the diversion of the Pasig-Potrero into the Porac River, and provides moderate to substantial protection to those portions of Porac and Floridablanca located in the Porac right outer impact zone (see figure 8 for impact zones).

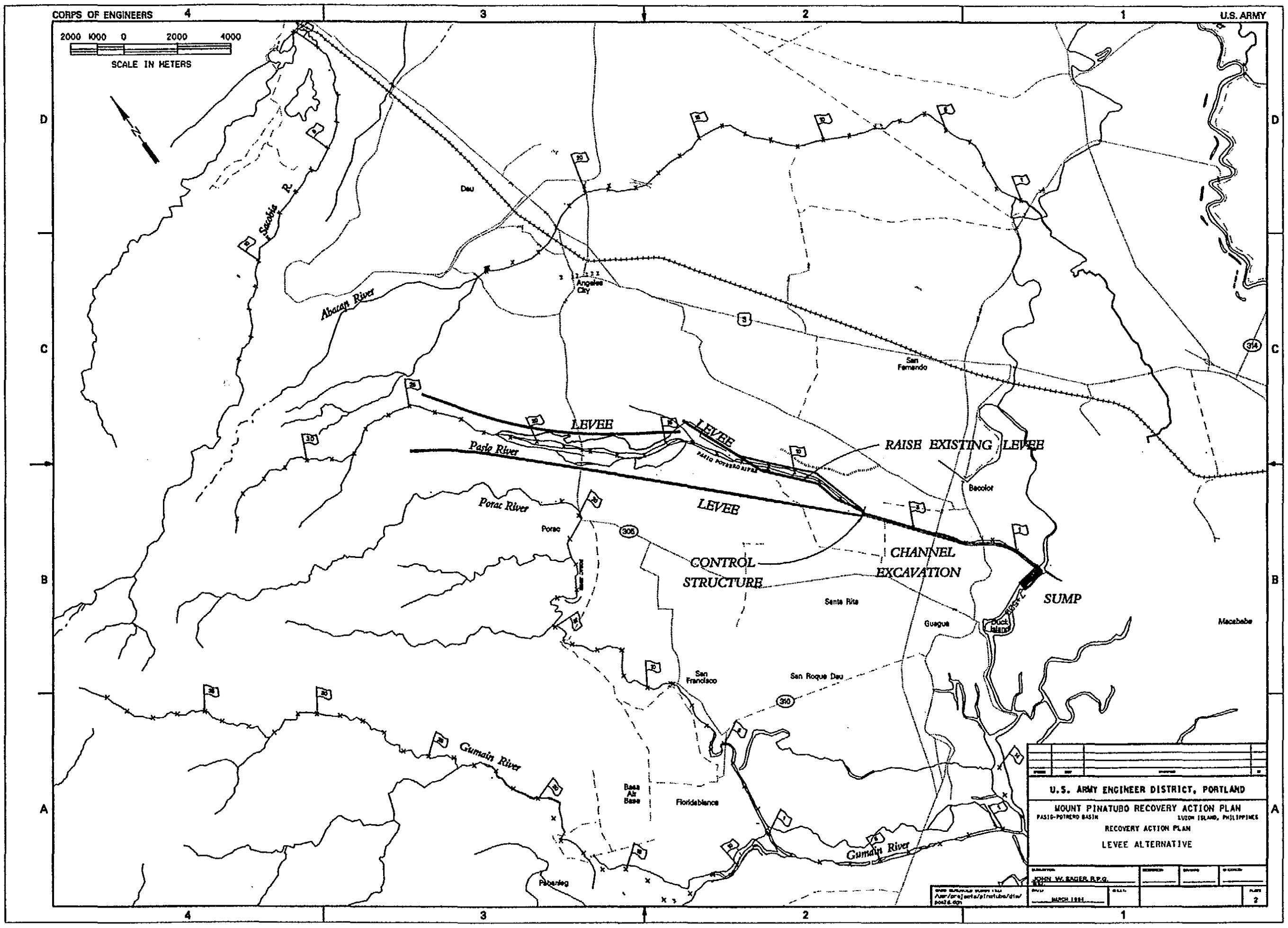
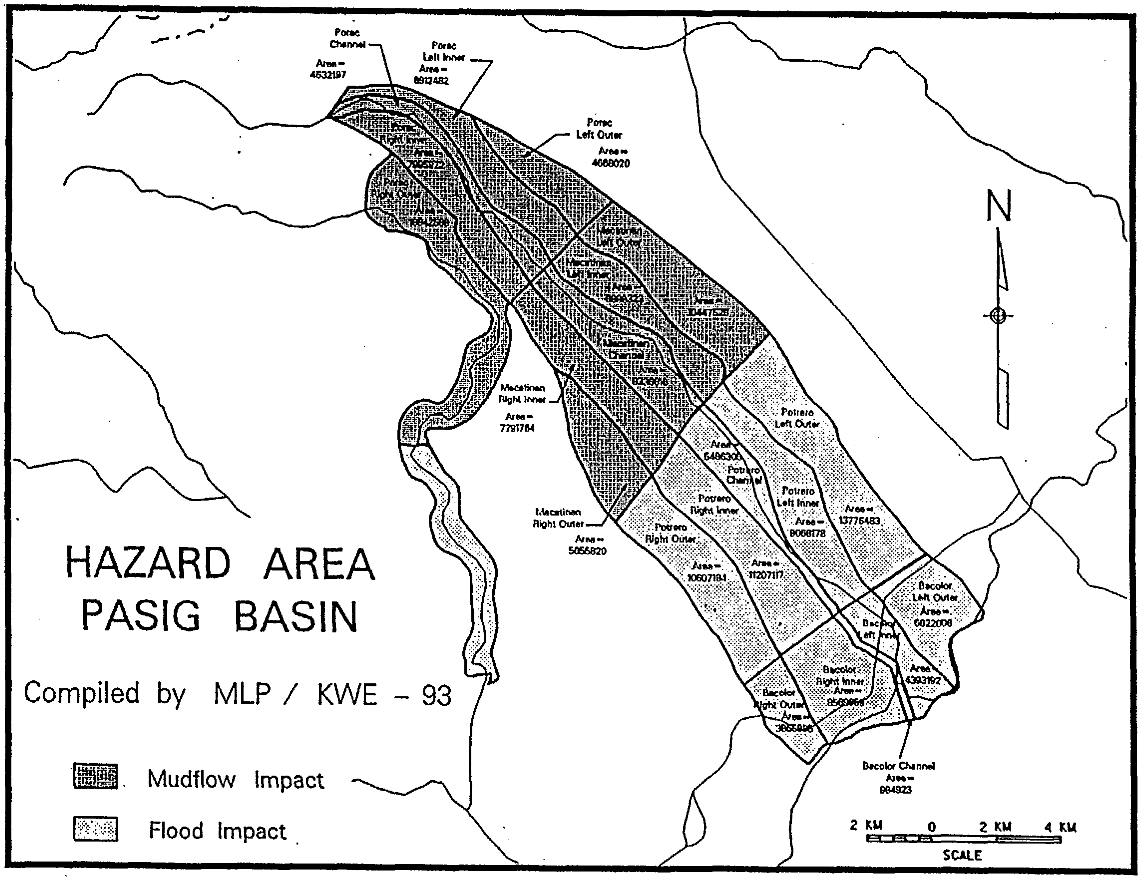

CORPS OF ENGINEERS
U.S. ARMY
SCALE IN METERS
Sacobia R.
Abacan River
Dau
Angeles City
San Fernando
LEVEE
LEVEE
RAISE EXISTING LEVEE
Pasig River
Porac River
Porac
LEVEE
CONTROL STRUCTURE
CHANNEL EXCAVATION
Bacolor
SUMP
Santa Rita
Guagua
Duck Island
Macabebe
San Francisco
San Roque Dau
Gumain River
Basa Air Base
Floridablanca
Gumain River
U.S. ARMY ENGINEER DISTRICT, PORTLAND
MOUNT PINATUBO RECOVERY ACTION PLAN
RECOVERY ACTION PLAN
LEVEE ALTERNATIVE

Plate 2

Figure 8 -- *Lower Pasig-Potrero Basin Impact Zones*



The levees below Mancatian will provide protection to portions of Porac, Santa Rita, and Bacolor located outside of the leveed areas but within the left inner and outer zones of the Porac, Mancatian, Potrero, and Bacolor reaches. The left bank levee will prevent the eastward diversion of the Pasig-Potrero into the paralleling subdrainages, and provides substantial protection to portions of Angeles City, San Fernando and Bacolor located outside of the levees but within the left inner and outer zones of the Porac, Mancatian, Potrero, and Bacolor reaches.

The sediment not deposited between the levees in the Porac and Mancatian reach will be trapped behind the control structure within the Potrero reach. This reduces the potential for the channel to fill between the control structure and the Sapang Labuan River, and insures adequate channel capacity under the Highway 7 bridges and through Bacolor. Excavation below the control structure will return the channel to its original configuration and also insures adequate channel capacity. Sediment modelling shows that periodic excavation may be required to maintain the capacity of the channel.

Bank protection on the existing levees above the control structure, and along the channel below the structure prevents toe and bank erosion, and moderate to substantial protection against breakouts of the river into those portions of Bacolor and Santa Rita in the left inner and outer zones of the Potrero reach and to the right and left inner and outer zones of the Bacolor reach.

The sump is designed to trap fine sediments which pass the control structure or which are eroded from the river bed below the structure. Trapping sediments at this location prevents their deposition in other, less accessible reaches of the delta.

Cost Summary and Investment Analysis. A summary of the construction costs (first costs), annual future and special future costs, and the present value of economic costs for the levee alternative is shown in table 5.[7] On the average, this alternative eliminates about P658 million in damages in the Pasig-Potrero basin. The present value of economic costs for this alternative is P1.5 billion. The investment analysis is shown on table 5 and for the mean case, this alternative has negative net benefits of about P(891) million and a BCR of 0.4.

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[7] Construction cost estimates for all alternatives include mobilization and demobilization of equipment, taxes, field overhead, office overhead, incidental expenditures, and profit. Costs are not included for infrastructure work, such as interior drainage or bridge/highway work.

Table 5 -- *Costs for Alternatives, Pasig-Potrero Basin (rounded, in pesos)*

Construction Costs (first costs)

	Levee	Channel Excavation
Levees/Slope Protection/Excavation	1,273,900,000	
Channel Excavation		1,192,500,000
Control Structure	26,800,000	
Sump	26,000,000	26,000,000
Environmental Mitigation	5,700,000	5,700,000
Early Warning System	2,600,000	2,600,000
Subtotal	1,335,000,000	1,226,800,000
Contingency (30%)	400,000,000	368,000,000
Total First Costs	1,735,000,000	1,594,800,000

Annual Outyear Costs

Item	Levee	Channel Excavation
Dredging Costs	29,500,000	29,500,000
Excavation Costs	0	82,600,000
Operation & Maintenance	1,735,000	350,000
Total Annual Costs	31,235,000	112,450,000

Special Future Costs (every 10 years)

Item	Levee	Channel Excavation
Control Structure Maintenance	4,700,000	0

Present Value of Economic Costs, 1994 Base

	Levee	Channel Excavation
First Costs	1,354,000,000	1,245,000,000
Annual Costs	193,000,000	698,000,000
Future Special Costs	1,600,000	0
Total Cost	**1,548,600,000**	**1,943,000,000**

Investment Analysis (Mean Case)

	Levee	Channel Excavation
Net Benefits	(891,000,000)	(1,285,000,000)
BCR	0.4	0.3
IRR (percent)	N/A	N/A

Environmental and Social Effects. The levee alternative provides an enhanced level of protection to existing human settlements, agricultural lands, fishpond developments, critical infrastructure (Highway 7) and historic landmarks. The leveed areas are already impacted by sediment deposits, and no existing households, livelihoods or sensitive environmental habitats are likely to be displaced.

The levee alternative includes the conversion of 20 to 30 ha of fishponds to disposal sites from initial and maintenance dredging of the sump area. Dredging may contribute to localized and short-term declines in water quality, and may disturb historical resources located below the pre-eruption grade of the sump.

All eroded sediments must be stored within the leveed areas and sand pocket areas. If filled to capacity, additional measures (new channel or sand pocket) may be necessary. As the leveed channel is filled and elevated above the existing landscape, failure of the levees is a continued risk to the adjoining communities and necessitates a long-term public information, monitoring, and maintenance program.

Channel Excavation Alternative

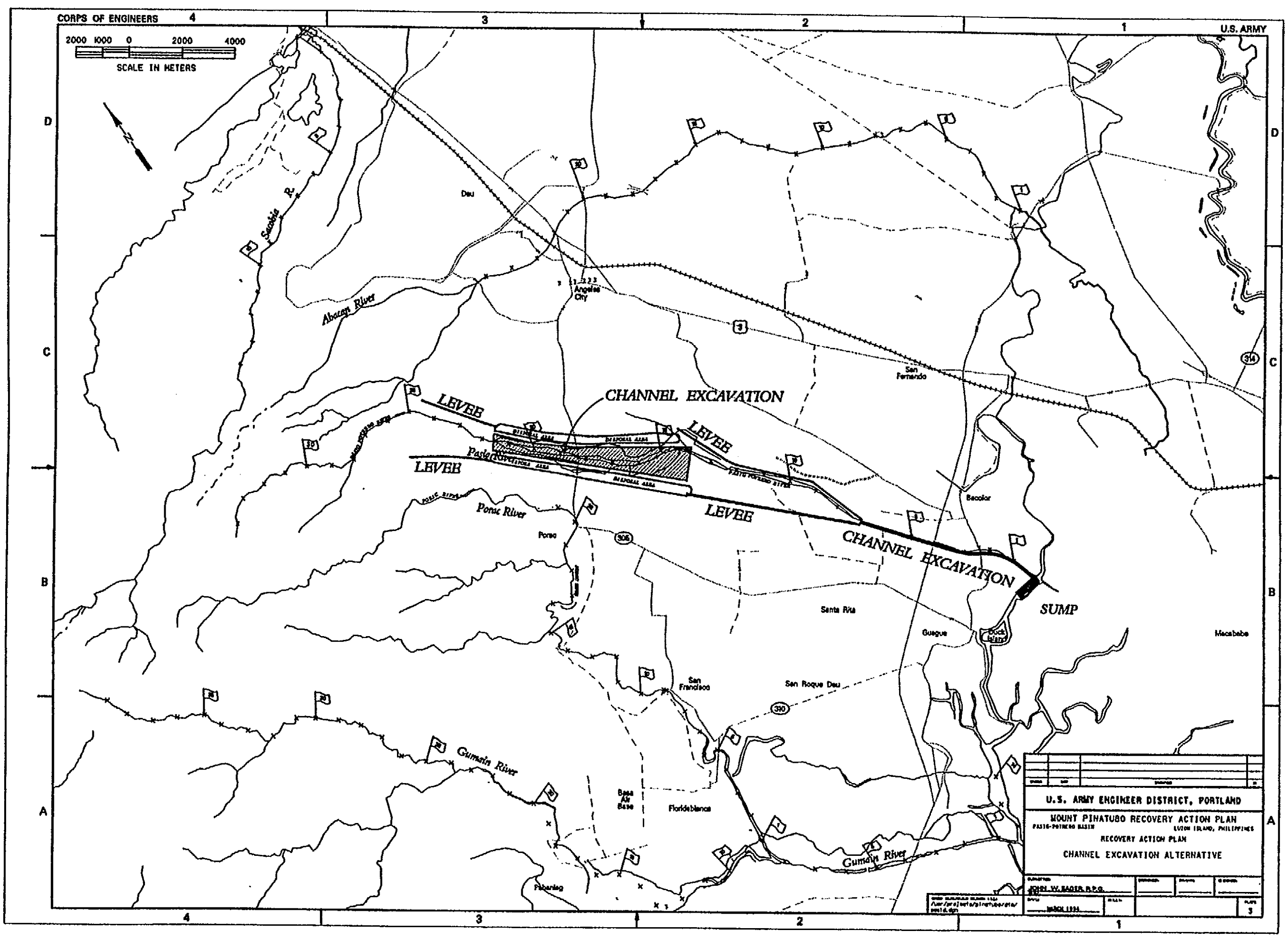
The channel excavation alternative for the Pasig-Potrero basin consists of the following features (see plate 3).

- Channel Excavation: A channel would be excavated 3 meters deep and from 700 to 1,800 meters wide extending from about 3 km upstream to about 4 km downstream of Mancatian. Excavated material would be disposed of as a berm paralleling the channel on both sides, and set back 100 meters from the channel.

- Right and Left Bank Levees from RK 23 to RK 26: A levee 6 meters high with a hardened face, toe protection, and sodded back slope would be constructed on the right and left banks following the existing levee alignment beginning upstream of the disposal berm, and extending upstream about 3.5 km to high ground.

- Right Bank Levee from RK 7.5 to RK 14: A levee 3 meters high and transitioning to 7 meters at RK 12 with slope and toe protection, and a sodded back slope would be constructed on the right bank following a straight alignment from Mancatian towards the existing levee at Santa Rita.

- Left Bank Levee from RK 12 to RK 14: A levee 3 meters high with slope and toe protection, and a sodded back slope would be constructed on the left bank following existing alignment from the downstream side of the left disposal berm and tying into the existing right bank levee.


CORPS OF ENGINEERS
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2000 1000 0 2000 4000
SCALE IN METERS
CHANNEL EXCAVATION
LEVEE
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CHANNEL EXCAVATION
SUMP
Angeles City
San Fernando
Bacolor
Santa Rita
Guagua
Porac
Porac River
Pasig River
Abacan River
Gumain River
San Francisco
San Roque Dau
Floridablanca
Basa Air Base
Macabebe
U.S. ARMY ENGINEER DISTRICT, PORTLAND
MOUNT PINATUBO RECOVERY ACTION PLAN
LUZON ISLAND, PHILIPPINES
RECOVERY ACTION PLAN
CHANNEL EXCAVATION ALTERNATIVE

Plate 3

• Slope Protection, Excavation Below RK 7.5, Sump, and Early Warning System: These features, as described for the levee alternative, also would be required.

Results of Action. The levees, channel excavation, and berms are designed to contain mudflows and sediments forecast for deposition during the next 10 years, and with sufficient capacity at the end of this period to provide protection against a 100-year event. The upper right bank levee prevents the diversion of the Pasig-Potrero into the Porac River, and provides substantial protection to portions of Porac and Floridablanca located in the Porac right outer impact zone (see figure 8). The left bank levee prevents the eastward diversion of the Pasig-Potrero into the paralleling subdrainages, and provides protection to portions of Angeles City, San Fernando and Bacolor located outside of the levees but within the left inner and outer zones of the Porac, Mancatian, Potrero, and Bacolor reaches. The levees and channel excavation below Mancatian provide protection to portions of Porac, Angeles City, San Fernando, Santa Rita, and Bacolor located outside of the levees but within the left inner and outer zones of the Porac, Mancatian, Potrero, and Bacolor reaches.

Excavation below RK 7.5, bank protection, and the sump will function in a similar manner as described for the levee alternative. However, because the channel excavation alternative does not include a control structure, there is a higher risk that greater amounts of sediment will be deposited below RK 7.5 and the sump.

Cost Summary and Investment Analysis. A summary of the costs for the channel excavation alternative is shown in table 5. On the average, this alternative will eliminate about P658 million in damages in the Pasig-Potrero basin. The present value of economic costs for this alternative is P1.9 billion. The investment analysis is shown on table 5 and for the mean case, this alternative has negative net benefits of P(1.3) billion and a BCR of 0.3.

Environmental and Social Effects. Similar impact areas and concerns as described for the levee alternative would be expected with this alternative. Additionally, disposal of excavated material from the channel will convert about 500 to 700 ha of land to disposal areas. When filled, the disposal areas may serve for potential use as residential and industrial development. Channel excavation and the sump substantially reduce downstream sediment loads and contribute more to the restoration of valuable delta ecosystems and fisheries than the levee alternative. However, the channel excavation alternative includes the additional conversion of 500 to 700 ha of land to disposal areas. Channel excavation and dredging may contribute more localized and short-term declines in water quality, and may disturb historical resources located below the pre-eruption grade of the channel. Excavation and disposal of sediments to maintain protection requires a long-term commitment of funding.

Nonstructural Alternative

The nonstructural alternative consists of permanent evacuation for all populated areas along the Pasig-Potrero basin threatened with imminent destruction by sediment flows. Flooding/ponding levels are expected to be shallow so temporary evacuation is the only action considered to be necessary for these areas, and can be accomplished under the GOP's evacuation program. Improvements to the early warning system, as described previously, also are suggested.

The primary benefit of the nonstructural alternative is removing people from harms way in areas threatened by sediment flows. Since there is no protection provided to assets or production, substantial damages would still occur. By removing households from threatened areas, there would be reduced loss of life and health costs. These benefits are not evaluated or quantified in this report and consequently, no cost-benefit analysis is performed. A relocation cost of P100,000 per household appears to be a reasonable cost based on GOP data.

Using 1990 Census data, the number of households in the sediment flow hazard area was estimated at about 11,000 for the Pasig-Potrero basin. However, this number represents a pre-eruption estimate and likely overstates the total number of households that are currently at risk. An estimate of the households threatened with imminent destruction by sediment flows may range from 25 to 75 percent, or 2,750 to 8,250 households. Therefore, an estimated cost for permanent evacuation may range from P275 to P825 million. Estimated costs for upgrading the early warning system are P2.6 million.

Implementation of the nonstructural alternative may create effects similar to those described for the no action alternative, with the added benefits to public safety of an improved early warning system. The potential nature-induced impacts include continued high levels of uncontrolled sedimentation, blockage or alteration of historic river courses, and resultant flooding of adjacent low-lying areas. As a highly populated and developed basin, permanent evacuation significantly increases demands on existing rehabilitation programs and resettlement areas, and increases potential off-site impacts to these areas (accelerated land use conversion) and the affected population (social displacement).

4.1.5 Findings for the Pasig-Potrero Basin. Two structural alternatives as well as the no action and nonstructural alternatives were evaluated for the Pasig-Potrero basin. A summary of the differences, advantages, and disadvantages among the alternatives is shown on table 6.

Table 6 -- *Summary of Alternatives, Pasig-Potrero Basin*

	NO ACTION	LEVEE ALTERNATIVE	CHANNEL EXCAVATION ALTERNATIVE	NONSTRUCTURAL ALTERNATIVE
Study Objective Accomplishments	No effective response provided to any objective.	Very good response provided to most study objectives.	Best response provided to study objectives.	No effective response to any objective except the preservation of life.
Construction Considerations and Accomplishments	Without-project condition so no alternatives developed. Loss of life & damages from sediment /floods continues. GOP emergency actions & existing warning systems continues.	Sump/control structure reduces downstream sediment load. Additional measures may be needed when channel/sand pocket fills. Long-term funding required for sump excavation/disposal.	Higher risk of sediment deposition below RK 7.5 & sump (no control structure). Higher long-term funding costs for sump/channel excav/disposal.	No construction proposed.
Construction Costs (Present Value)	No construction proposed.	First Cost: P1.7 billion Annual Cost: P31 million Future Maintenance Cost (every 10 years): P5 million (control structure)	First Cost: P1.6 billion Annual Cost: P112 million Future Maintenance Cost: None.	Permanent evacuation costs range from P275 to P825 million. Temporary evacuation during flooding via GOP program. Warning System Cost: P2.6 million.
Economic Effects (Present Value)	Average damages about P855 million mostly to structures and agriculture. Delayed recovery processes.	Economic Cost: P1.5 billion Average Total Benefits: P658 million Mean Net Benefits: P(891) million B/C Ratio: 0.4 IRR: N/A	Economic Cost: P1.9 billion Average Total Benefits: P658 million Mean Net Benefits: P(1.3) billion B/C Ratio: 0.3 IRR: N/A	Average damages about P855 million.
Environmental And Social Effects	Significant siltation of delta continues & disrupts sensitive habitat & fisheries. Further loss of significant historical landmarks. About 72 barangays, 7,000 ha agric. land, and Highway 7 impacted. Public health concerns prolonged.	Restoration of delta habitats & fisheries. No households/sensitive habitats displaced. 20-30 ha of fishponds converted to disposal areas (sump). Short-term decline in water quality. Public information, monitoring, and maintenance programs required.	More restoration of delta habitats and fisheries. 20-30 ha of fishponds converted to disposal areas (sump). 500-700 ha of land converted to disposal areas from excavation. Disposal sites could be used for future residential/industrial development.	Effects similar to No Action, but improved public safety because of early warning system.

4.2 Sacobia-Bamban River Basin

Note: The following analysis is limited to basin conditions prior to October 1993. A natural diversion of about 21 km^2 of the Sacobia headwaters into the upper reaches of the Pasig-Potrero basin occurred during October 1993. This reduction in drainage area for the Sacobia-Bamban basin will significantly reduce sediment yields. The decrease in sediment yields has not been fully analyzed or included in this study.

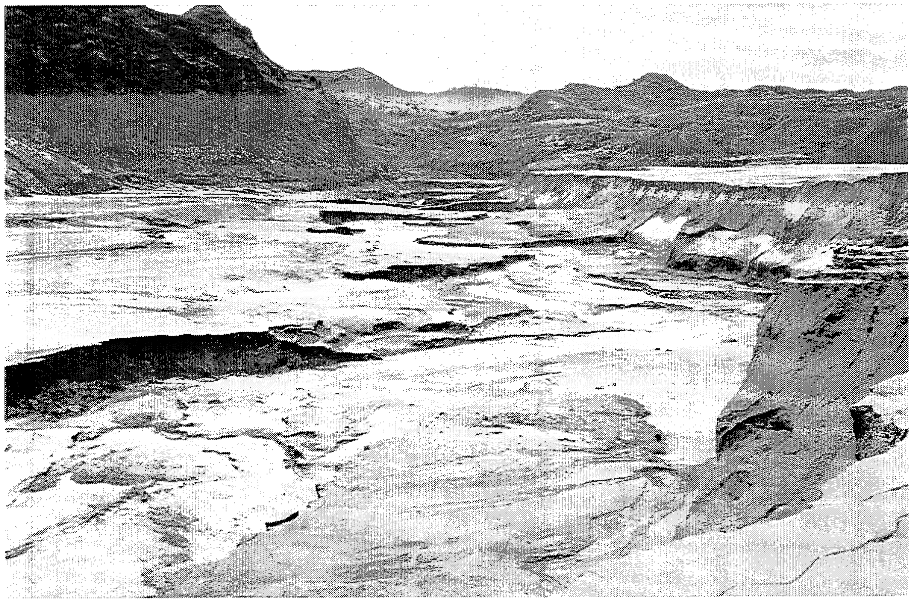
4.2.1 Specific Conditions. Prior to the capture of its headwaters, the Sacobia-Bamban basin covered an area of 146 km^2 and extended in a northeast direction from near the base of Mount Pinatubo to the interior lowlands of Central Luzon (see figure 1). The basin headwater area consists of steep and narrow parallel valleys drained by the Sacobia, Sapang-Cauayan, Marimla, and Malago rivers. Of these, the Sacobia and Malago extend near the base of Mount Pinatubo. The Bamban River begins at the confluence of the Sacobia and Marimla rivers about 25 km northeast of the crater, just upstream of Highway 3 near Bamban.

Elevations in the basin range from about 1,100 meters in the headwaters to 90 meters at the confluence with the Bamban River. The Bamban component is relatively flat, dropping only about 58 meters over its 12 km-long reach. Bedrock is exposed mainly above the former Clark AFB. From just above Clark AFB downstream to the juncture with the Bamban, the Sacobia flows on a moderate slope in a broad channel through lahar and alluvial deposits consisting mostly of sand. From Bamban downstream to the confluence with the Pampanga River, it flows at a gentle slope through sandy deposits.

The headwaters area of the basin contains a large volume of pyroclastic deposits (602 million m^3). These deposits extend downstream to about Clark AFB. There are several areas within the original pyroclastic deposits that appear to represent redeposition by small to moderate size SPFs. These probably occurred during 1992, judging by their relatively uneroded surfaces. Older pyroclastic deposits still fill much of the original stream valley through this reach, and extend somewhat further downstream than the 1991 deposits. The major deposition area in the basin occurs from the Mactan Gate area to 8 km below the San Francisco bridge (Highway 329). Most of the Bamban River is contained within a diked channel which is perched above the surrounding land.

For the Sacobia-Bamban basin, five municipalities are listed as being in the risk areas (see table 4). Figure 9 shows photographs of the sediment deposits and flooding in the basin. The risk areas are estimated to include:

- 45,000 household, commercial, and/or public buildings
- 17,000 ha of agricultural land (rice and sugar cane dominate)
- P500 million in annual crop revenues



Pyroclastic deposits of Sacobia River, Mactan Gate area, looking downstream, September 1991.

Flooding from the Bamban River in Santa Rita, September 1991.

Figure 9

Mudflow damages to Mabalacat, February 1993.

Flooding and sedimentation damages to Bamban, November 1993.

Figure 9 (continued)

Current land cover for the Sacobia-Bamban basin consists primarily of agricultural land (43 percent) followed by grassland/shrubland (20 percent), urban areas (11 percent), sediment deposits (16 percent), and woodlands (10 percent). Downstream of MacArthur Highway, the Bamban River traverses a wide expanse of alluvial fan. A low area near its confluence with the Rio Chico de la Pampanga River is referred to as the San Antonio swamp, a natural depository of excess run-off during the rainy season, and an important seasonal wetland. To the southeast of this confluence is the 32,000 ha expanse of the Candaba swamp, which also plays a seasonal role as either a flooded wetland or as arable farmland. The Candaba swamp is internationally recognized as an important staging and wintering ground for migratory birds following the Asian flyway, which stretches from mainland China and Japan to Australia and New Zealand. There are no reported archaeological sites or historical structures and landmarks within the basin.

4.2.2 Problem Statement. In the Sacobia-Bamban basin, there is a high risk of mudflows for the next 10 years caused by erosion of the pyroclastic deposits in the upper drainage. Mudflow deposition is expected to occur mainly from the upstream end of Clark AFB to downstream of Bamban and Delores. There is a high risk of shallow flooding and sediment deposition on the south overbank downstream of Delores. A moderate to high risk of shallow flooding due to levee breaching exists on the north overbank downstream of Bamban. The risk of flooding caused by channel fill upstream of Marcos Village is low. The risk of flow diversion to the Abacan River is very low because the "Gates of the Abacan" (a notch between two bedrock outcrops) are isolated from the Sacobia.

4.2.3 Sediment Forecast. Sediment deposition forecasts for the Sacobia-Bamban basin are summarized below. More detailed information can be found in Technical Appendix B in Volume II of the Long Term Report.

- Initial pyroclastic volume -- 602,000,000 m^3
- Erosion volume (1993 to 2002) -- 72,000,000 m^3
- Erosion volume (1993 to 2042) -- 112,000,000 m^3

An additional 138,000,000 m^3 of sediment eroded in 1991-1992.

Potential major events include mudflows and flooding. There is a 50 percent to 75 percent chance each year that a mudflow event caused by runoff and bank collapse could deposit 2,000,000 to 20,000,000 m^3 in the basin. There is at least a 50 percent chance that storm runoff could breach levees and cause flooding in any year.

4.2.4 Alternatives Under Consideration. The alternatives investigated for the Sacobia-Bamban basin include: no action, levee, channel excavation, sediment retention structure, and nonstructural. Because of the capture of the headwaters of the Sacobia River by the Pasig River sometime in October 1993, the alternatives described below may need to be modified and possibly reduced in magnitude to reflect changes in the sediment budget.

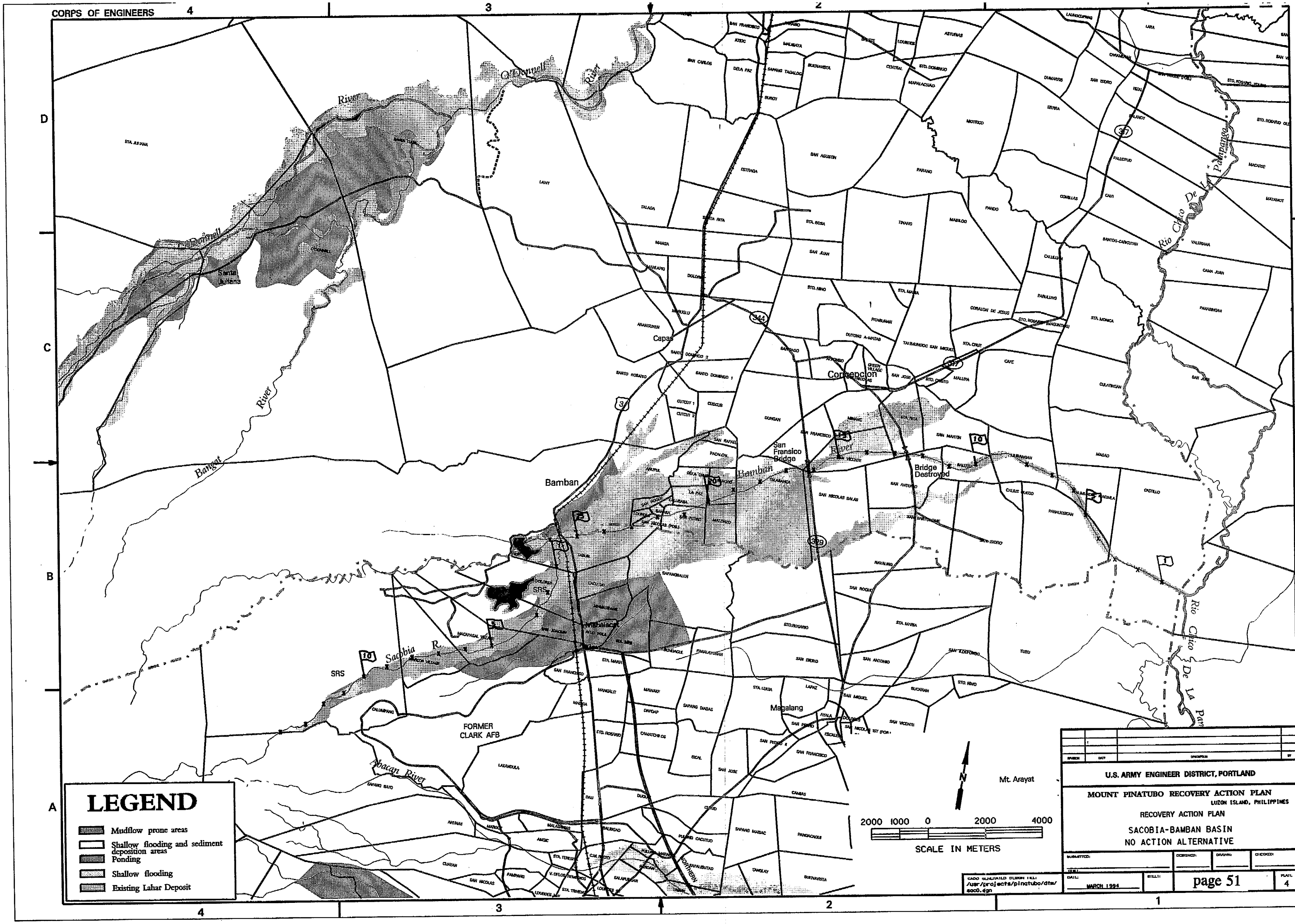
No Action Alternative

Under the no action alternative (without-project condition), no intervention measures are developed to reduce flooding and sediment damages in the Sacobia-Bamban basin. Actions taken by the GOP in emergency situations, and use of existing warning systems would continue. Plate 4 shows the risk areas expected under the no action alternative.

On the average, without-project damages (present value) for the Sacobia-Bamban basin are estimated at P790 million. Damages for agriculture is the highest category at P303 million, followed by structures (P282 million), infrastructure (P124), evacuation and relocation (P36 million), foregone production (P27 million), and transportation disruption (P18 million).

Prior to the October 1993 change in the Pasig and Sacobia headwaters, about 102 barangays from the municipalities of Mabalacat, Magalang, Bamban and Concepcion, in an area of about 25,000 ha of mostly agricultural land, were likely to be impacted by mudflows, flooding and sedimentation. Progressive displacement or alteration of this highly populated and developed area would significantly increase housing, livelihood and public services demands on resettlement sites. The potential exists for impact to the San Francisco bridge (Highway 317), which currently serves as a primary public access for Tarlac and Pampanga.

Downstream reaches are further influenced by sedimentation, which could significantly affect the flow of the Rio Chico de la Pampanga River, the valuable ecosystems of adjoining wetlands (San Antonio and Candaba swamps), and the implementation of the proposed irrigation diversion dam of the Pampanga Delta Development Project (PDDP). An increase in grassland and seasonal wetlands may occur as agricultural areas of Magalang and Concepcion are affected by sediment deposition. As the local situation stabilizes, low-lying (moist) impact areas could be converted back into agricultural use (sugarcane, pasture) on a yearly basis. Public health concerns are prolonged due to poor water quality and drainage, and temporary housing arrangements. Recovery processes (ecological, sociological, and economic) are delayed.


CORPS OF ENGINEERS
LEGEND
Mudflow prone areas
Shallow flooding and sediment deposition areas
Ponding
Shallow flooding
Existing Lahar Deposit
O'Donnell River
Bangat River
Bamban River
Sacobia R.
Abacan River
Rio Chico De La Pampanga
Santa Juliana
Capas
Concepcion
Bamban
San Fransico Bridge
Bridge Destroyed
SRS
FORMER CLARK AFB
Magalang
Mt. Arayat
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SCALE IN METERS
U.S. ARMY ENGINEER DISTRICT, PORTLAND
MOUNT PINATUBO RECOVERY ACTION PLAN
LUZON ISLAND, PHILIPPINES
RECOVERY ACTION PLAN
SACOBIA-BAMBAN BASIN
NO ACTION ALTERNATIVE
MARCH 1994
PLATE 4

Levee Alternative

The levee alternative for the Sacobia-Bamban basin consists of the following features (see plate 5).

- Levee from RK 0 to RK 4.5 on the Sacobia River: A levee 10 meters high with a hardened face, toe protection, and sodded back slope would be constructed on the right bank (south) following the existing levee alignment from Highway 3 in Mabalacat and upstream for about 4.5 km.

- Levee from RK 16 to RK 25.5 on the Bamban River: A levee 10 meters high transitioning to 13 meters with a hardened face, toe protection, and sodded back slope would be constructed on the right bank downstream of Highway 3. This levee begins at the existing levee and follows easterly for a distance of 6 km. At this point, the levee transitions to a height of 13 meters and makes a long curve to the San Francisco bridge.

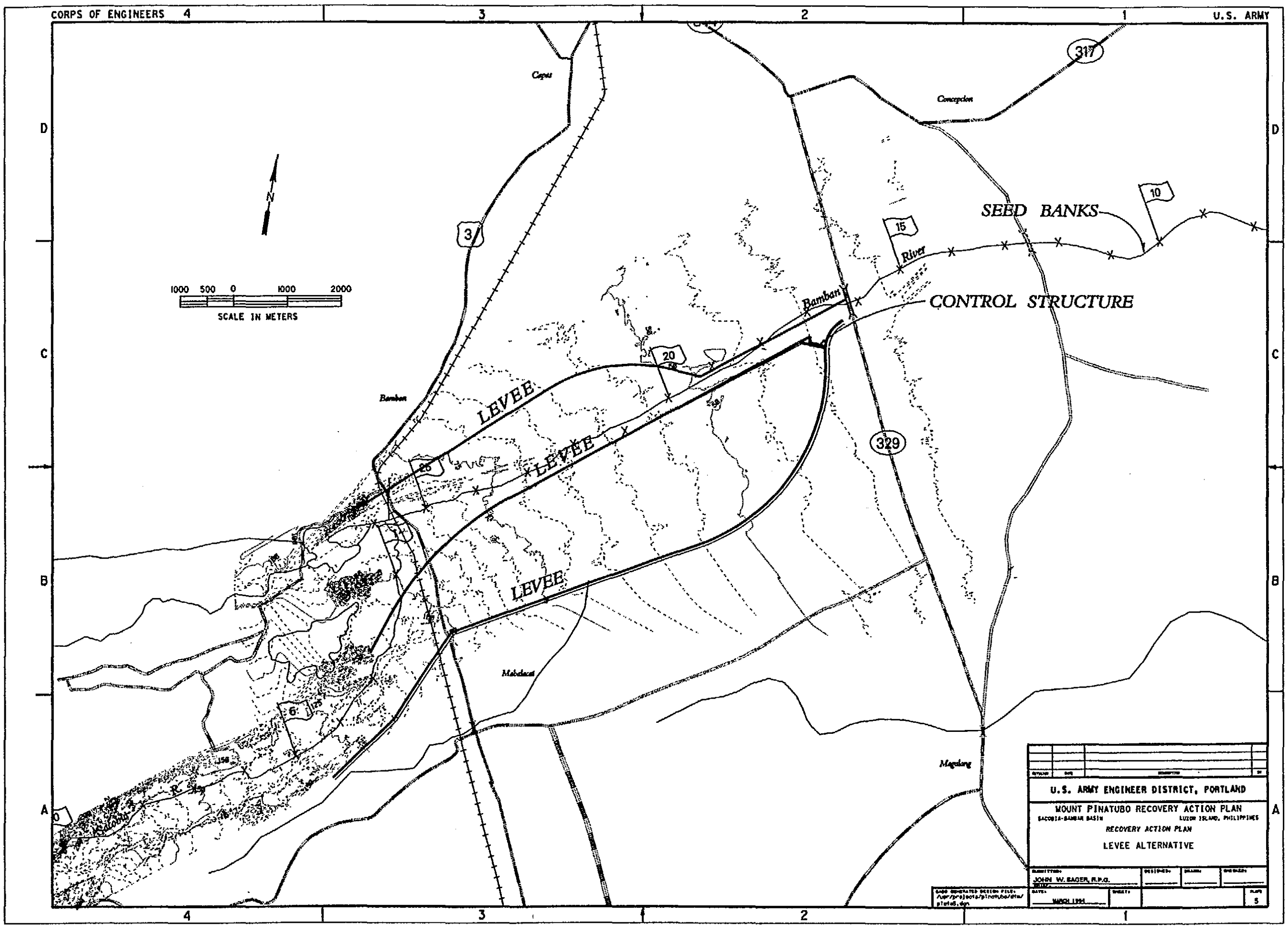
- Levee from RK 3 on the Sacobia River to RK 16 on the Bamban River: A levee 6 meters high transitioning to 13 meters with a hardened face, toe protection on the right side, and slope/toe protection on the left side would be constructed to form the left bank of the Sacobia River. This levee separates the Sacobia from the Sapang Cauayan and Marimla rivers. The levee begins at the ridge west of Delores, and curves in an easterly direction to tie into the original right bank Bamban levee 2.5 km below the Highway 3 alignment. This levee begins transitioning to 13 meters about 6 km below the Highway 3 alignment. The transition section would continue to near the San Francisco bridge where it ties into a control structure.

- Control Structure: A RCC control structure 470 meters long with a 200 meters wide spillway section would be constructed to connect the two 13 meter high Sacobia River levees near the San Francisco bridge (RK 16 of the Bamban River). Initially, the spillway crest would be set at 7 meters below the levee crest elevation. The structure allows the leveed area from RK 17 to RK 23 to function as a sand pocket.

- Levee Reconstruction: The existing left bank Bamban levee, which extends from high ground west of the old railroad alignment at Bamban to downstream of the San Francisco bridge, would be reconstructed to a height of 3 meters. Slope/toe protection and sodded back slope would be added. This levee would backup the Sacobia levee, and provide erosion protection from clear water flows.

- Seeding: Below the San Francisco bridge, both the left and right bank levees to the Rio Chico de la Pampanga River would be seeded to provide slope protection.

- Early Warning System: Existing warning systems consist of rain gages, sediment flow sensors, and observation posts. Adding sirens or loud speakers to alert people in downstream communities would be an effective way to improve public safety.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U.S. ARMY ENGINEER DISTRICT, PORTLAND
MOUNT PINATUBO RECOVERY ACTION PLAN
RECOVERY ACTION PLAN
LEVEE ALTERNATIVE

Plate 5

Results of Action. The levees from above Mabalacat to the control structure are designed to contain mudflows and sediments forecast to be deposited in this reach during the next 10 years, and contain sufficient capacity at the end of this period to provide substantial protection against a 100-year event. The upper right bank levee prevents sediment damage and flooding to those portions of Clark AFB and Mabalacat located in the Clark right overbank and Lakes right outer zones, which are outside of the levees (see figure 10 for impact zones). The right bank levee below Mabalacat provides protection to Highway 329 between Magalang and the San Francisco bridge, and those portions of Mabalacat and Magalang located outside the leveed areas in the right inner and outer zones of the Lakes and San Francisco reaches.

The left bank levee on the Bamban River provides substantial flood protection for those portions of Bamban, Capas, and Concepcion located outside of the levees in the left inner and outer zones of the Lakes, San Francisco, and Concepcion reaches. The center levee separates the sediment-ladened Sacobia from the clean water flows of the Marimla River, and allows the sediments to be stored between the center and the right bank levees. The left bank would levee backup the center levee.

The sediment not trapped between the levees in the Lakes and San Francisco reaches will be trapped behind the control structure within the left inner, channel, and right inner zones of the San Francisco reach. This reduces the potential for the channel to fill between the structure and the confluence with the Rio Chico de la Pampanga River, and insures adequate channel capacity under the San Francisco bridge.

Seeding of the existing levees between the control structure and the Rio Chico de la Pampanga River reduces the potential for erosion and reduces the amount of sediment being carried through the system to the Rio Chico de la Pampanga River. This also lowers the risk of breaching the levee, which would result in sediment and flood damages to those portions of Magalang and Concepcion outside of the levees but within the left and right inner and outer zones of the Concepcion reach.

Cost Summary and Investment Analysis. A summary of construction costs (first costs), annual future and special future costs, and the present value of economic costs for the levee alternative is shown on table 7. On the average, this alternative eliminates about P434 million in damages in the Sacobia-Bamban basin. The present value of economic costs for this alternative is P1.1 billion. The investment analysis is shown in table 7 and for the mean case, this alternative has negative net benefits of about P(644) million and a BCR of 0.4.

Environmental and Social Effects. The levee alternative provides an enhanced level of protection to existing human settlements, agricultural lands and critical infrastructure within the defined hazard areas. Most areas within the proposed alternative are presently impacted by recent sediment deposits. Reconstruction of the existing left bank levee along the Bamban River may displace about 80 households.

Figure 10 -- *Lower Sacobia Basin Impact Zones*

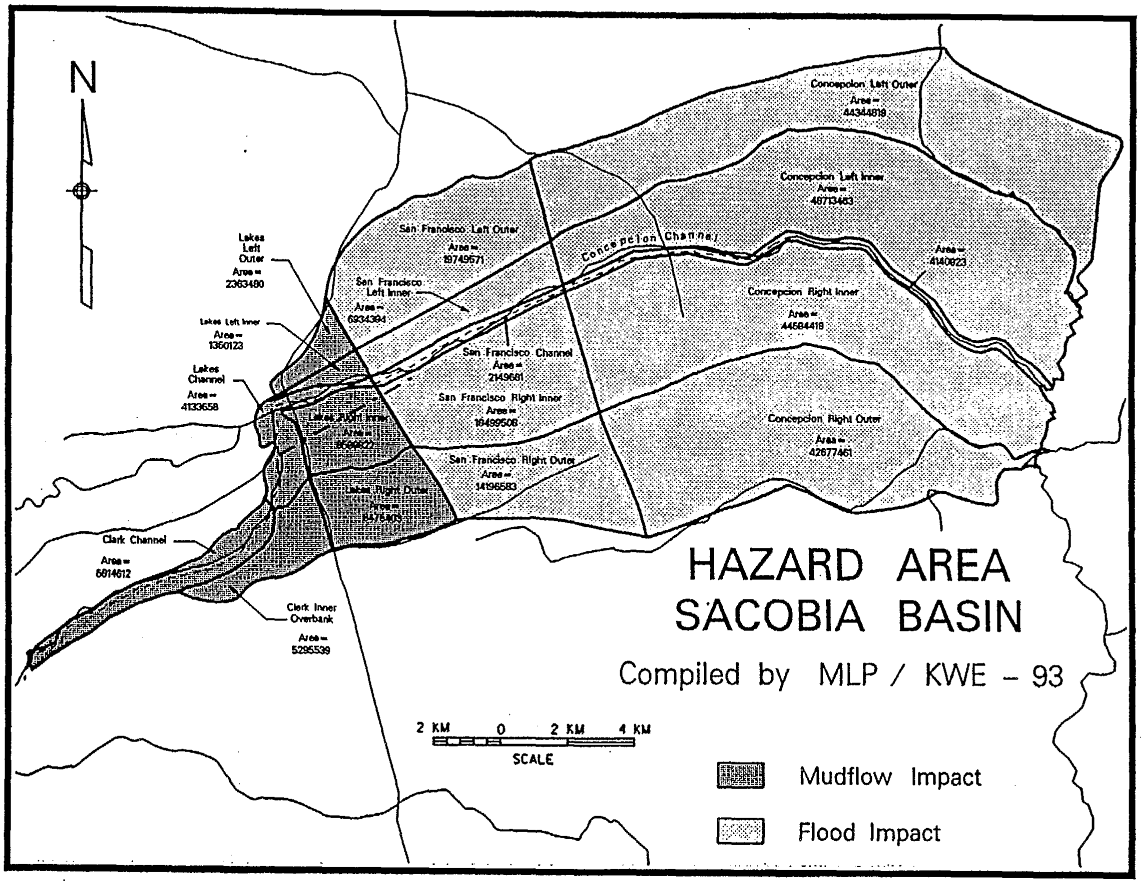


Table 7 -- *Costs for Alternatives, Sacobia-Bamban Basin (rounded, in pesos)*

Construction Costs (first costs)

	Levee	Channel Excavation	SRS
Levee Const w/ Slope Protection	911,100,000	86,500,000	652,600,000
Control Structure	120,800,000		
Seeding Downstream Channel	7,100,000	7,100,000	7,100,000
Channel Excavation		272,800,000	
Retention Structure SA-02			293,200,000
Retention Structure SA-6.5			565,200,000
Environmental Mitigation	8,200,000	8,200,000	8,200,000
Early Warning System	2,600,000	2,600,000	2,600,000
Subtotal	1,049,800,000	377,200,000	1,528,900,000
Contingency (30%)	314,900,000	113,100,000	458,700,000
Total First Costs	1,364,700,000	490,300,000	1,987,600,000

Annual Costs, financial

	Levee	Channel Excavation	SRS
Annual Excavation Costs	0	188,800,000	
O&M	1,365,000	100,000	1,988,000
Total Annual Costs	1,365,000	188,900,000	1,988,000

Special Future Costs (every 10 years)

	Levee	Channel Excavation	SRS
Control Structure, SRS Maintenance	15,700,000	0	30,000,000

Present Value of Economic Costs, 1994 Base

	Levee	Channel Excavation	SRS
First Costs	1,065,000,000	384,000,000	1,393,000,000
Annual Costs	7,825,000	1,172,000,000	8,076,000
Future Special Costs	5,090,000	0	8,115,000
Total (Pesos)	1,078,000,000	1,556,000,000	1,410,000,000

Investment Analysis (Mean Case)

	Levee	Channel Excavation	SRS
Net Benefits	(644,000,000)	(1,121,000,000)	(1,059,000,000)
BCR	0.4	0.3	0.2
IRR (percent)	N/A	N/A	N/A

About 1,600 ha of former agricultural land would become part of the levee-enclosed Sacobia riverbed, which may involve local consultation and compensation. The reduction of downstream sedimentation would limit further disruption to the San Antonio and Candaba swamps and may contribute to the implementation of the planned PDDP diversion dam and irrigation project.

All eroded sediments must be stored within the river channel and sand pocket areas. If filled to capacity, additional measures (new channel or sand pocket) may be necessary. As the leveed channel is filled and elevated above the existing landscape, failure of the levees is a continued risk to adjoining and downstream communities and necessitates a long-term public information, monitoring and maintenance program. Also, this alternative does not provide a solution to reestablishing Highway 3.

Channel Excavation Alternative

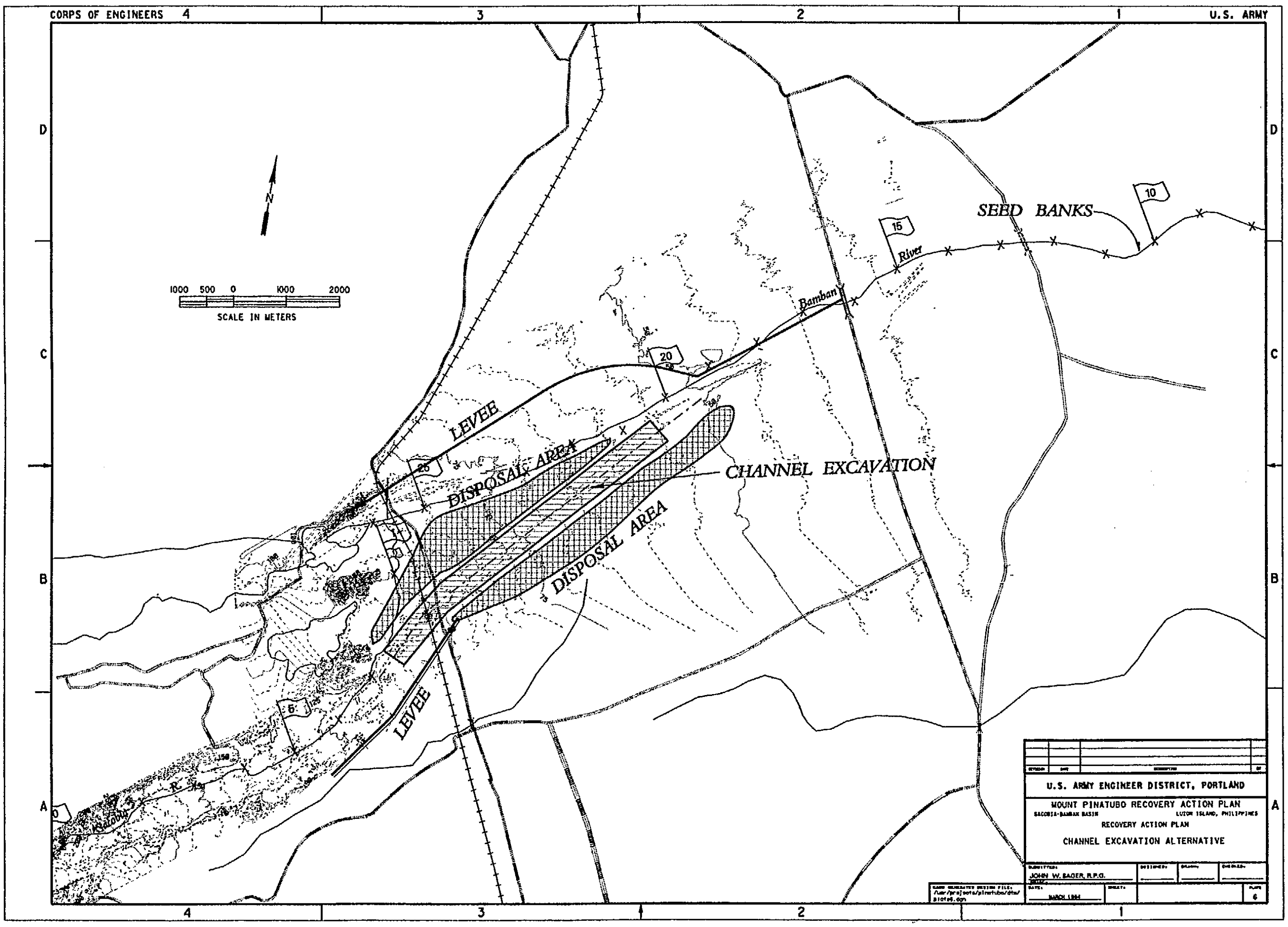
The channel excavation alternative for the Sacobia-Bamban basin consists of the following features (see plate 6).

- Channel Excavation: A channel ranging from 500 to 800 meters wide and 4 meters deep would be excavated from about 1.5 km upstream of the Highway 3 alignment (RK 1.5 on the Sacobia River) and would extend downstream of the highway for a distance of 7 km (RK 19 on the Bamban River). Excavated material would be disposed of in large piles along the channel at a distance of at least 100 meters from the channel. The disposal piles would provide additional capacity and protection for large events. Annual removal of sediments would be required to maintain protection.

- Levee from RK 1.5 to RK 3.5 on the Sacobia River: A levee 4 meters high with a hardened face, toe protection and sodded back slope would be constructed on the right bank following the existing levee alignment beginning at Highway 3 in Mabalacat, and extending upstream about 3.5 km.

- Levee Reconstruction on the Bamban River, Seeding, and Early Warning System: These features, as described for the levee alternative, also would be required.

Results of Action. The channel excavation and berms, in combination with the levees, are designed to contain mudflows and sediments forecast to be deposited in the Lakes and San Francisco reaches (see figure 10) during a 100-year event. To maintain protection, annual channel excavation is necessary. Protection is provided to the same areas as in the levee alternative. The absence of a control structure will result in some additional sediments being transported into the channel below the San Francisco bridge, and into the Rio Chico de la Pampanga River. Seeding of the existing levees will function in a similar manner as described for the levee alternative.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U.S. ARMY ENGINEER DISTRICT, PORTLAND
MOUNT PINATUBO RECOVERY ACTION PLAN
LUZON ISLAND, PHILIPPINES
RECOVERY ACTION PLAN
CHANNEL EXCAVATION ALTERNATIVE
JOHN W. SAGER, R.P.G.

Plate 6

Cost Summary and Investment Analysis. A summary of the costs for the channel excavation alternative is shown in table 7. On the average, this alternative eliminates about P434 million in damages in the Sacobia-Bamban basin. The present value of economic costs is P1.5 billion. The investment analysis for the channel excavation alternative is shown in table 7 and for the mean case, this alternative has negative net benefits of about P(1.1) billion and a BCR of 0.3.

Environmental and Social Effects. Similar impact areas and concerns as described for the levee alternative are involved with this alternative. Additionally, about 1,000 to 1,500 ha of sediment-impacted riverbed and agricultural land (sugarcane) would be converted for long-term disposal areas. As filled, these disposal areas may serve as evacuation and resettlement areas, or for future residential and industrial development.

Sediment transport to downstream river reaches, the Rio Chico de la Pampanga River, and adjoining wetland areas is reduced, which minimizes further impacts to these sensitive areas. Excavation and disposal of sediments to maintain protection require a long-term commitment of funding. This alternative does not provide a solution to reestablishing Highway 3.

Retention Structure Alternative

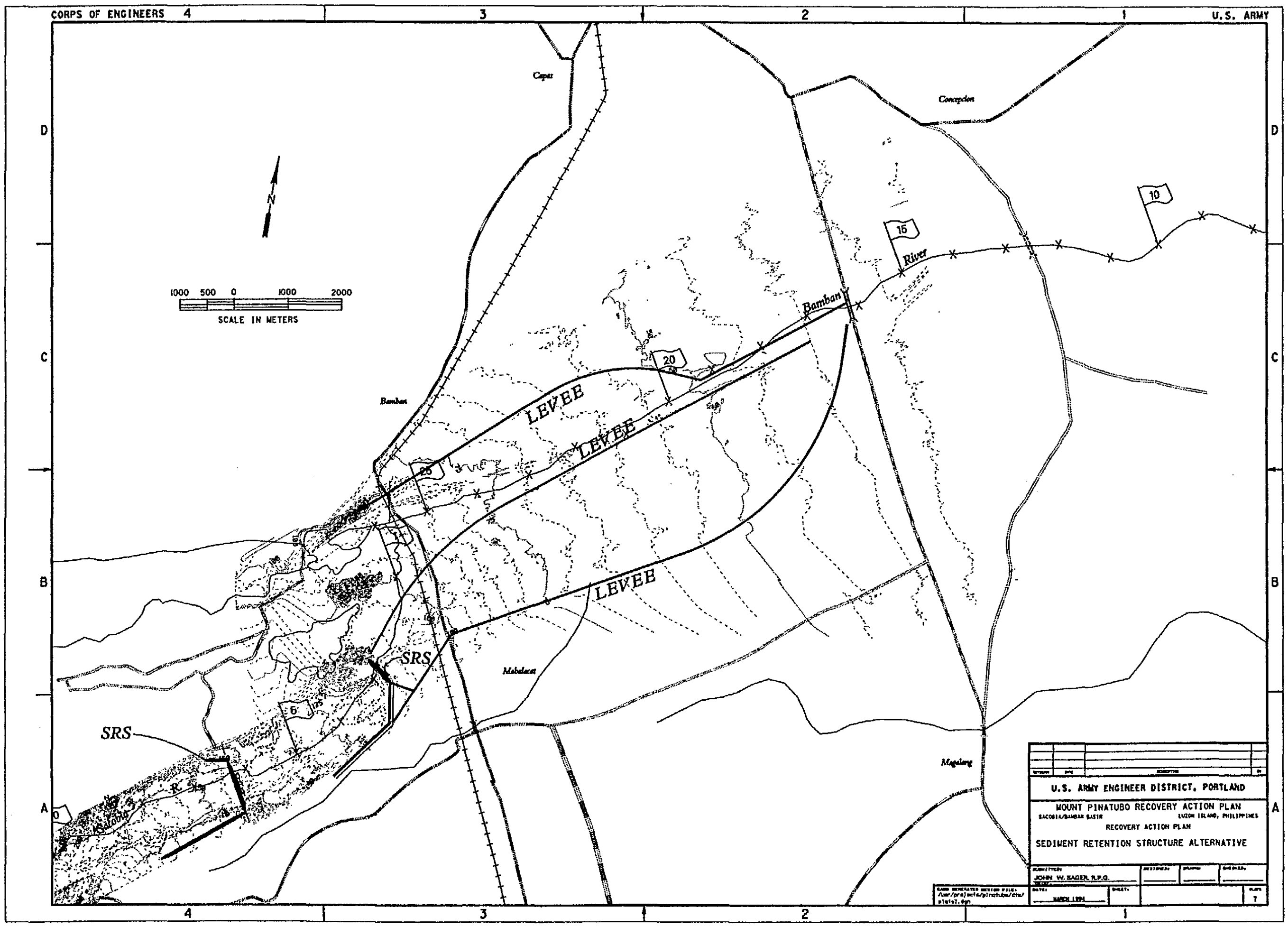
The retention structure alternative for the Sacobia-Bamban basin consists of the following features (see plate 7).

- RCC Gravity Overflow Dam (SA-02): A RCC dam 17 meters high would be constructed on the Sacobia River at RK 2 with a mid-channel spillway 200 meters wide and 10 meters higher than the existing channel. The structure would be constructed with 4 meters of freeboard.

- RCC Gravity Overflow Dam (SA-6.5): A RCC dam 24 meters high would be constructed on the Sacobia River at RK 6.5 with a mid-channel spillway 200 meters wide, and 14 meters higher than the existing channel. The structure would be constructed with 3 meters of freeboard.

- Levee from RK 2 to RK 4.5 on the Sacobia River: A levee to elevation 127 meters (the top of the SA-02 structure) with a hardened face, toe protection and sodded back slope would be constructed on the right bank to follow the existing levee alignment beginning at the SA-02 retention structure and extending upstream 2.5 km.

- Levee from RK 0 to RK 2 on the Sacobia River: A levee 3 meters high with a hardened face, toe protection, and sodded back slope would be constructed on the right bank following the existing levee alignment beginning at Highway 3 in Mabalacat and extending upstream 1 km to the SA-02 retention structure.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U.S. ARMY ENGINEER DISTRICT, PORTLAND
MOUNT PINATUBO RECOVERY ACTION PLAN
SACOBIA/BAMBAN BASIN
LUZON ISLAND, PHILIPPINES
RECOVERY ACTION PLAN
SEDIMENT RETENTION STRUCTURE ALTERNATIVE
JOHN W. EAGER, R.P.G.

Plate 7

- Levee from RK 16 to RK 25.5 on the Bamban, and Levee from RK 3 on the Sacobia to RK 16 on the Bamban: These features as described for the levee alternative also would be required, except the levees are 3 meters high and transition to 5 meters.

- Levee Reconstruction, Seeding, and Early Warning System: These features as described for the levee alternative also would be required.

Results of Action. The SA-02 structure will trap 10.8 million m^3 of material. The SA-6.5 structure will trap an additional 15.8 million m^3 of material. Together, they prevent the re-erosion of this material presently in-channel above SA-02. Trapping these materials reduces the volume of material which must be contained by downstream levees or which will eventually move downstream and into the Rio Chico de la Pampanga River. This allows the area below the SA-02 structure to stabilize more rapidly. The SA-02 structure design could incorporate a bridge to allow reestablishment of the Highway 3 crossing. The levees above the San Francisco bridge and seeding serve similar functions as in the levee alternative, and substantial protection is provided to the same areas.

Cost Summary and Investment Analysis. A summary of the costs for the retention structure alternative is is shown in table 7. On the average, this alternative eliminates about P350 million in damages in the Sacobia-Bamban basin. The present value of economic costs for this alternative is P1.4 billion. The investment analysis is shown in table 7 and for the mean case, this alternative has negative net benefits of about P(1.1) billion and a BCR of 0.2.

Environmental and Social Effects. Similar impact areas and concerns as described for the levee alternative are involved with this alternative until completion of the retention structures (2 to 5 years). Additionally, a significant amount of sediment will enter the river system until the sediment retention structures are complete. This sediment will pass through the leveed channel of the Sacobia River and affect downstream reaches. These effects include increased sediment loads reaching the Rio Chico de la Pampanga River, and impacts to the San Antonio and Candaba swamps. Upon completion of the retention structures, the primary source of sediment is greatly reduced. In the unlikely event of a structural failure, a large amount of sediment would be eroded and transported downstream, which may threaten the San Francisco bridge and communities which are re-established downstream. Possible disturbance of archaeological resources could occur since the SRS sites are within areas of previous human settlement.

Nonstructural Alternative

The nonstructural alternative consists of permanent evacuation for all populated areas along the Sacobia-Bamban basin threatened with imminent destruction by sediment flows. Flooding/ponding levels are expected to be shallow so temporary evacuation of residents is the only action expected to be necessary for these areas, and can be accomplished under the GOP's evacuation program. Improvements to the early warning system also are suggested.

The primary benefit of the nonstructural alternative is removing people from harms way in areas threatened by sediment flows. Since there is no protection provided to assets or production, substantial damages would still occur. By removing households from threatened areas, there are reduced loss of life and health costs. These benefits are not evaluated or quantified in this report and consequently, no cost-benefit analysis is performed. A relocation cost of P100,000 per household appears to be reasonable based on GOP data.

Using 1990 Census data, the number of households in the sediment flow hazard area was estimated at about 14,300 for the Sacobia-Bamban basin. However, this number represents a pre-eruption estimate and likely overstates the total number of households that are currently at risk. An estimate of the households threatened with imminent destruction by sediment flows may range from 25 to 75 percent, or 3,575 to 10,725 households. Therefore, an estimated total cost for permanent relocation may range from P357 million to P1 billion. In addition, estimated costs for upgrading the early warning system are P2.6 million.

Implementation of the nonstructural alternative may create effects similar to those described for the no action alternative, with the added benefits to public safety of an improved early warning system. The potential nature-induced impacts include continued high levels of uncontrolled sedimentation, blockage or alteration of historic river courses, and resultant flooding of adjacent low-lying areas. As a moderately populated and developed river basin, permanent evacuation would further increase demands on existing rehabilitation programs and resettlement areas, and increase potential off-site impacts to these areas (accelerated land use conversion) and the affected population (social displacement).

4.2.5 Findings for the Sacobia-Bamban Basin. Three structural alternatives as well as the no action and nonstructural plans were evaluated for the Sacobia-Bamban basin. The differences, advantages, and disadvantages among the alternative plans are discussed on table 8.

Table 8 -- *Summary of Alternatives, Sacobia-Bamban Basin*

	NO ACTION	LEVEE ALTERNATIVE	CHANNEL EXCAVATION ALTERNATIVE	SEDIMENT RETENTION STRUCTURE ALTERNATIVE	NONSTRUCTURAL ALTERNATIVE
Study Objective Accomplishments	No effective response provided to any objective.	Overall good response provided to study objectives.	Best response provided to all study objectives.	Good to very good response provided to most study objectives.	No effective response to any objective except the preservation of life.
Construction Considerations and Accomplishments	Without-project condition so no alternatives developed. Loss of life & damages from sediment/floods continues. GOP emergency actions & existing warning systems continues.	Levees/control structure reduces downstream sediment loads and flooding risks. Additional measures may be needed when channel/sand pocket fills.	Higher risk of sediment deposition below San Francisco bridge (no control structure). Higher long-term funding costs for excavation/disposal.	About 40 million cubic meters of sediment stored. Better flushing/more stabilization of downstream areas because of lower sediment load.	No construction proposed.
Construction Costs (Present Value)	No construction proposed.	First Cost: P1.4 billion Annual Cost: P1.4 million Future Maintenance Cost: 15.7 million (control structure)	First Cost: P490 million Annual Cost: P189 million Future Maintenance Cost: None.	First Cost: P1.9 billion Annual Cost: P1.9 million Future Maintenance Cost (every 10 years): P30 million	Permanent evacuation costs range from P357 to P1 billion. Temporary evacuation during flooding via GOP program. Warning System Cost: P2.6 million.
Economic Effects (Present Value)	Average damages estimated at P790 million, mostly to agriculture and structures. Delayed recovery processes.	Economic Cost: P1.1 billion Average Total Benefits: P434 million Mean Net Benefits: P(644) million B/C Ratio: 0.4 IRR: N/A	Economic Cost: P1.6 billion Average Total Benefits: P434 million Mean Net Benefits: P(1.1) billion B/C Ratio: 0.3 IRR: N/A	Economic Cost: P1.4 billion Average Total Benefits: P350 million Mean Net Benefits: P(1) billion B/C Ratio: 0.2 IRR: N/A	Average damages estimated at P790 million.
Environmental And Social Effects	Significant siltation continues & disrupts sensitive habitats. About 102 barangays impacted. About 17,000 ha of agricultural lands impacted. San Francisco bridge impacted. Public health concerns prolonged.	About 80 households may be displaced. About 1,600 of former agricultural land becomes levee-enclosed. Downstream siltation reduced which limits further disruption to sensitive habitats. Public information, monitoring, and maintenance programs required.	Similar impact areas/concerns as for levee alternative. Additional 1,000-1,500 ha of land converted for disposal areas. Disposal areas may be used for future resdiential/industrial uses.	Similar impact areas/concerns as for levee alt until SRS complete (2-5 yrs). Significant amt of sediment affects downstream habitats until SRS complet Upon completion of SRS, source of downstream impacts significantly lower. Possible disturbance to historical resources.	Effects similar to No Action, but improved public safety because of early warning system.

4.3 Abacan River Basin

4.3.1 Specific Conditions. The Abacan basin is 51 km^2 in area originating about 4 km east of the crater of Mount Pinatubo and extending in an easterly direction to the interior lowlands of Luzon (see figure 1). The basin headwater area consists of two steep and narrow parallel valleys drained by the Abacan and one tributary, Sapang-Bayo Creek. The basin headwaters originate on the eastern slope of Mount Pinatubo at elevations about 1,000 meters below the crater. Sapang-Bayo Creek joins the Abacan about 4 km upstream of Highway 3 and about 2 km south of the former Clark AFB.

The lower portion of the basin below Highway 3 is mostly confined within levees. Elevations for the Abacan River/Sapang-Bayo Creek range from about 500 meters in the upper headwater areas to 130 meters at the Sapang-Bayo/Abacan confluence, to 10 meters at the end of the levee-confined channel, which is not perched above the surrounding land. In its upper reaches, the Abacan River has been erosive and has exposed older pyroclastic deposits in the riverbed. Sediment flows during the 1991 monsoon season spilled deposits onto Clark AFB, destroyed or damaged all of the bridges across the river upstream of Mexico, and caused bank collapse that has destroyed hundreds of buildings in Angeles City.

Initially after the 1991 eruption, the headwaters of the Abacan basin were on the pyroclastic flow deposit in the Sacobia basin. During channelization of the Sacobia drainage, the Abacan headwaters was cut off a few hundred meters upstream of the "Gates of the Abacan", a notch between two bedrock outcrops. Only a small volume of 1991 pyroclastic flow deposit remains in this basin as a sediment source, mostly between the "upper" gates and the "lower" gates. Below the upper reach, the channel is incised through more gently sloping deposits composed of older lahar and alluvial materials, mostly sand with some coarser sizes, and occasionally tuffaceous bedrock. The lower Abacan channel is in a flood plain composed of mostly sandy material prior to flowing into the Pampanga River.

For the Abacan basin, six municipalities are listed as being in the risk areas (see table 4). Figure 11 shows a photograph of the bank erosion and sediment problem in the basin. The risk areas are estimated to include:

- 14,000 household, commercial, and/or public buildings
- 7,250 ha of agricultural land (rice is dominant crop)
- P125 million in annual crop revenues

Current land cover for the Abacan basin consists primarily of agricultural land (67 percent) followed by urban areas (13 percent), grassland/shrubland (9 percent), and sediment deposits (11 percent). The upper and lower alluvial fan areas are grown to sugarcane and paddy rice, respectively. All riparian vegetation in the river basin was covered by recent mudflow deposits, and emergent talahib-dominated grasslands now cover about 1,180 ha. The Abacan is the most environmentally disturbed basin because of its extensive development including the urban areas of Angeles City.

Bank erosion and sediment deposits downstream from Angeles City, September 1991.

Figure 11

There are no reported archaeological sites within the basin. Several significant historic landmarks and structures are found in Angeles City and Mexico. During the scoping sessions conducted for this study, local residents raised as an issue the deterioration of these historical structures from flooding and sediment deposition.

4.3.2 Problem Statement. Throughout the Abacan River basin, there is a low risk of mudflows because the upper drainage does not contain significant pyroclastic deposits, and the "Gates of the Abacan" are isolated from the Sacobia. The risk of flow diversion from the Pasig is low. (Note: the recent change between the Pasig and Sacobia headwaters may change this potential risk). The Abacan River channel has many meander bends which cause a risk of erosion and bank failure in the Angeles City area. Downstream of Angeles City, the channel is filled with sediment and when meanders migrate, there is a risk of levee breaches. Shallow flooding also may occur as banks erode. In-channel sediment transported slowly downstream may deposit in channels around Mexico causing an increased risk of shallow flooding. No ponding-type flooding is anticipated.

Normal river flows will cause material movement in the river channel. There is a 10 percent to 50 percent chance of floods in any year resulting in flood damages and bank erosion. Downstream movement of sediment will have a significant effect on bank erosion and flooding for many years.

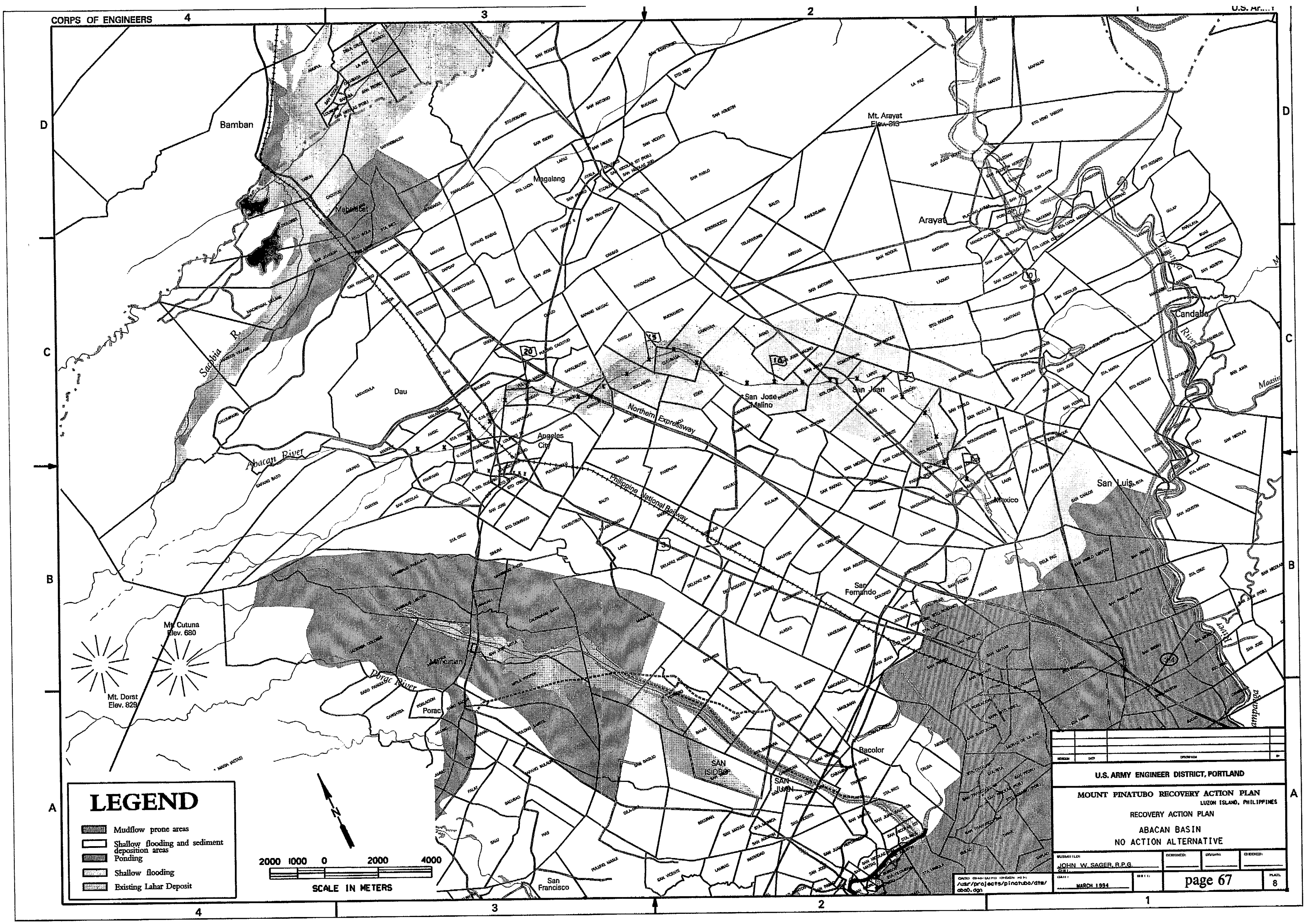
4.3.3 Alternatives Under Consideration. The alternatives investigated for the Abacan basin include: no action, bank protection, and nonstructural.

No Action Alternative

Under the no action alternative (without-project condition), no intervention measures are developed to reduce flooding and sediment damages in the Abacan basin. Actions taken by the GOP in emergency situations and use of existing warning systems would continue. Plate 8 shows the risk areas expected under the no action alternative.

The average without-project damages (present value) for the Abacan basin are estimated at P219 million, with nearly 75 percent of these damages occurring to agriculture (P156 million). Damages to structures is the second highest category at P54 million, followed by infrastructure (P6 million), foregone production (P2 million), evacuation/relocation (P636 thousand), and transportation disruption (P95 thousand). Damage to structures are small because of the shallow depth (about 20 cm) of flooding.

About nine barangays of Angeles City could be affected by bank erosion, displacing households and threatening infrastructure, including the Angeles City power plant. Possible failure of existing sabo structure No. 9 would increase downstream sedimentation and erosion, with the possible loss of public access provided by the Friendship bridge and North Expressway.



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San Juan
Northern Expressway
Philippine National Railway
Abacan River
Sapang Bato
Mexico
San Luis
San Fernando
Mt Cutuna
Elev. 680
Mt. Dorst
Elev. 828
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MOUNT PINATUBO RECOVERY ACTION PLAN
LUZON ISLAND, PHILIPPINES
RECOVERY ACTION PLAN
ABACAN BASIN
NO ACTION ALTERNATIVE
JOHN W. SAGER, R.P.G.
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Downstream, about 7,250 ha of agricultural lands from about 20 barangays in Mexico could be further impacted by shallow flooding and sedimentation. This would result in further conversion of agricultural lands to non-agricultural use (talahib and tambo grasslands, seasonal wetlands) and may delay implementation of the PDDP irrigation component, since this area is within the proposed 12,000 ha distribution system. Further loss of significant historical landmarks would continue. Public health concerns are prolonged due to poor water quality and drainage, and temporary housing arrangements. Recovery processes (ecological, sociological, and economic) are delayed.

Bank Protection Alternative

The bank protection alternative for the Abacan basin consists of the following features (see plate 9).

- Bank and Toe Protection: Bank and toe protection would be placed on the left (north) and right (south) banks of the Abacan River; from the existing sabo structure upstream of Angeles City (sabo structure No. 9 at RK 25.2) to below the North Expressway; and on the levee located on the right bank of Sapang Bayo Creek from sabo structure No. 9 to upstream for a distance of about 3 km.

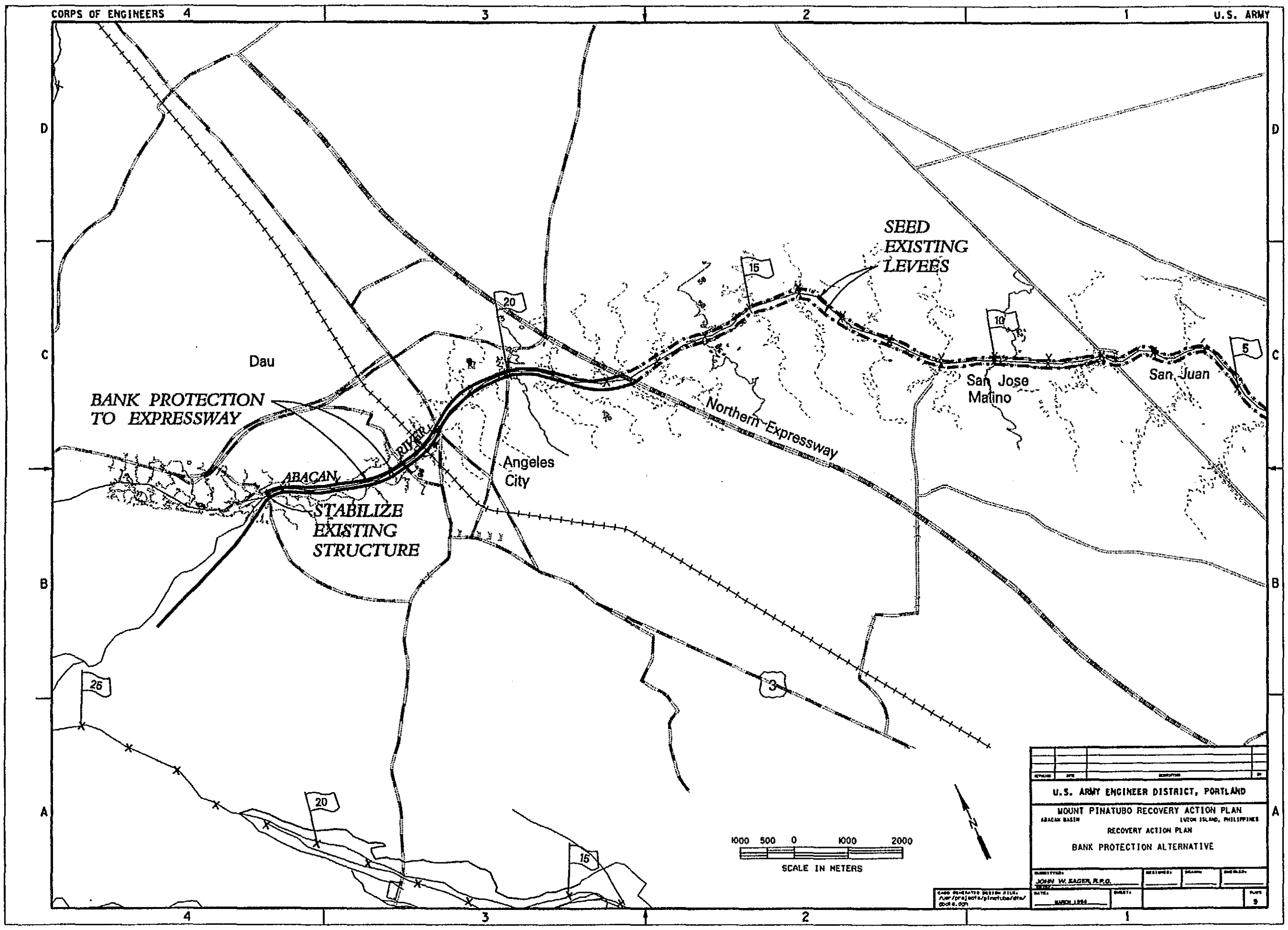
- RCC Gravity Overflow Dam: A RCC dam 8 meters high would be constructed to replace sabo structure No. 9.

- Seeding: The existing levee slopes below the North Expressway would be seeded to provide erosion protection.

- Early Warning System: Existing warning systems consist of rain gages, sediment flow sensors, and observation posts. Adding sirens or loud speakers to alert people in downstream communities would be an effective way to improve public safety.

Results of Action. The bank and toe protection on Sapang Bayo Creek prevents the erosion of the bank and the eventual capture of the creek by a parallel drainage system which flows through Angeles City. Bank and toe protection of the Abacan from Sapang Bayo Creek to below the North Expressway prevents bank erosion damages to structures along the river banks through Angeles City. This also reduces the sediments being carried by the river downstream of the North Expressway, and eventually into the San Fernando River at Mexico. Seeding of the slopes below the North Expressway bridge reduces erosion and decreases the amount of sediments being transported through Mexico.

Replacement of the temporary sabo dam with a permanent retention sturcture retains sediments currently stored by the temporary dam, and protects the footings of the Friendship bridge from scour. This also prevents sediments presently stored in-channel from being transported downstream to Mexico.


CORPS OF ENGINEERS
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SEED EXISTING LEVEES
Dau
BANK PROTECTION TO EXPRESSWAY
ABACAN
RIVER
STABILIZE EXISTING STRUCTURE
Angeles City
Northern Expressway
San Jose Malino
San Juan
1000 500 0 1000 2000
SCALE IN METERS
N
U.S. ARMY ENGINEER DISTRICT, PORTLAND
MOUNT PINATUBO RECOVERY ACTION PLAN
ABACAN BASIN
LUZON ISLAND, PHILIPPINES
RECOVERY ACTION PLAN
BANK PROTECTION ALTERNATIVE
JOHN W. SAGER, R.P.O.
MARCH 1994
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Plate 9

Cost Summary and Investment Analysis. A summary of construction costs (first costs), annual future and special future costs, and the present value of economic costs for the bank protection alternative is shown in table 9. On the average, this alternative eliminates about P192 million in damages in the Abacan basin. The present value of economic costs for this alternative is about P68 million. The investment analysis is shown in table 9 and for the mean case, this alternative has positive net benefits of about P124 million and a BCR of 2.8.

Environmental and Social Effects. The bank protection alternative enhances protection to existing human settlements, agricultural lands, critical infrastructure (Friendship bridge, North Expressway), and historical landmarks. Areas within the proposed alternative are already impacted by sediment deposition, and no households, livelihoods, or sensitive environmental habitats are likely to be displaced. Controlling bank erosion and downstream sedimentation should encourage the restoration of recently impacted agricultural areas.

This alternative reduces long-term flooding and sedimentation impacts to Mexico, though short-term risks remain in the absence of corrective drainage measures within downstream reaches, particularly along Bungang Ginto Creek. The control of streambank erosion and downstream sedimentation should encourage restoration of currently impacted agricultural areas, including areas within the distribution system of the proposed PDDP irrigation project. Farmer beneficiaries include small land holders and participants of the GOP's agrarian reform program.

Nonstructural Alternative

No permanent evacuation is considered necessary for the Abacan basin since the threat of sediment flows is low. Temporary evacuation of residents is the only action expected to be necessary for areas threatened by flooding, and can be accomplished under the GOP's evacuation program. The improvements to the early warning system described previously are suggested at a cost of about P2.6 million. Implementation of the nonstructural alternative may create effects similar to those described for the no action alternative, with the added benefits to public safety of an improved early warning system. The potential nature-induced impacts include continued bank erosion, uncontrolled sedimentation, blockage or alteration of historic river courses, and resultant flooding of downstream low areas of Mexico.

4.3.4 Findings for the Abacan Basin. One structural alternative as well as the no action and nonstructural plans were evaluated for the Abacan basin. The differences, advantages, and disadvantages among the alternative plans are discussed on table 10.

Table 9 -- *Costs for Bank Protection Alternative, Abacan Basin (rounded, in pesos)*

Construction Costs (pesos)

Bank/Toe Protection	32,100,000
Gravity Overflow Dam	22,200,000
Seeding	4,900,000
Environmental Mitigation	200,000
Early Warning System	2,600,000
Subtotal	62,000,000
Contingency (30%)	18,600,000
Total First Costs	**80,600,000**

Annual Costs

Dredging	
Excavation	
O&M	80,000
Total Annual Costs	**80,000**

Special Future Costs (every 10 years)

Major Maintenance	2,900,000

Present Value of Economic Costs, 1994 Base

First Costs	66,400,000
Annual Costs	500,000
Future Special Costs	1,100,000
Total costs	**68,000,000**

Investment Analysis (Mean Case)

Net Benefits	124,000,000
BCR	2.8
IRR (percent)	38

Table 10 -- *Summary of Alternatives, Abacan Basin*

	NO ACTION	BANK PROTECTION ALTERNATIVE	NONSTRUCTURAL ALTERNATIVE
Study Objective Accomplishments	No effective response provided to any objective.	Effective response provided to reducing damage from sediment & flooding to agriculture and infrastructure.	No effective response to any objective except the preservation of life.
Construction Considerations and Accomplishments	Without-project condition so no alternatives developed. Loss of life & damages from sediment, erosion, and flooding continues. GOP emergency actions and existing warning systems continues.	Reduces the amount of sediment in system. Provides long-term relief to siltation at Mexico. Threat of failure of Sabo No. 9 reduced.	No construction proposed.
Construction Costs (Present Value)	No construction proposed.	First Cost: P80 million Annual Cost: P80 thousand Future Maintenance Cost (every 10 years): P2.9 million.	No permanent evacuation necessary. Temporary evacuation during flooding via GOP program. Early Warning System Cost: P2.6 million.
Economic Effects (Present Value)	Average damages estimated at P219 million, mostly to agriculture & structures. Delayed recovery processes.	Economic Cost: P68 million Average Total Benefits: P192 million Mean Net Benefits: P124 million B/C Ratio: 2.8 IRR: 38 percent	Average damages estimated at P219 million.
Environmental And Social Effects	About 9 barangays of Angeles City affected. About 20 barangays of Mexico and 7,250 ha of agricultural land affected. Critical infrastructure affected (loss of access). Possible failure of Sabo No. 9 would increase downstream sediment impacts. Further loss of significant historical landmarks. Public health concerns prolonged.	No households/sensitive habitats displaced. Potential for restoration of recently impacted agricultural areas. Reduces downstream sediment impacts.	Effects similar to No Action, but improved public safety because of early warning system.

4.4 O'Donnell River Basin

4.4.1 <u>Specific Conditions</u>. The O'Donnell basin includes two major rivers, the O'Donnell and the Bulsa (see figure 1). The O'Donnell River drains the northern slopes of Mount Pinatubo and has an area of about 266 km^2 upstream of the confluence with the Bulsa. The Bulsa River primarily drains the eastern slopes of the Zambales mountains and has a basin area of about 510 km^2 upstream of the confluence with the O'Donnell. About 2 km below the O'Donnell-Bulsa confluence, the drainage becomes the Tarlac River, with a total area of about 817 km^2.

The headwater area consists of steep and narrow parallel valleys drained by the O'Donnell, Apalong, and Bangat rivers. Of these three tributaries, only the O'Donnell sub-basin extends to the crater where the post-eruption elevation is about 1,200 meters. The Apalong and Bangat rivers originate from a secondary peak on Mount Pinatubo which, with a pre-eruption summit elevation of about 1,500 meters, may now be the highest point on the mountain. The headwater area for the Bulsa reaches a maximum elevation of about 1,600 meters. The elevation at the confluence of the Bulsa and O'Donnell rivers is about 40 meters.

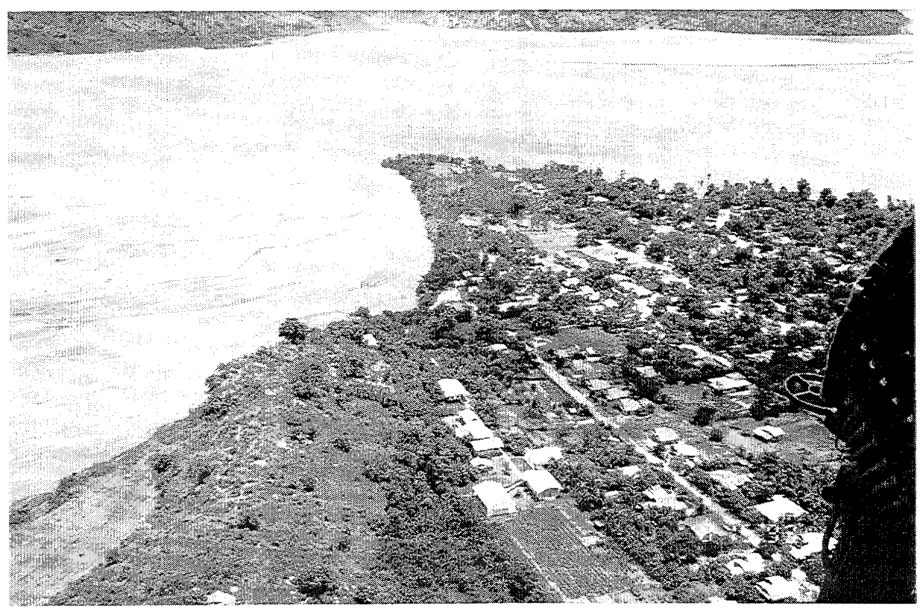
Pyroclastic volume in the O'Donnell basin was initially 241 million m^3. As in the Sacobia, there are large remnant deposits of pre-1991 pyroclastic flows in the upper reach. The upper reaches of the channel vary in width and are incised into the recent as well as older pyroclastic deposits. The downstream end of the 1991 pyroclastic deposits have a steep slope where the basin splits into three separate channels. Some of the older deposits in the headwaters reach contain a high percentage of coarse sizes, representing true debris flows that occurred during a previous eruption.

Bedrock, where exposed along the valley walls, consists of sandstones, conglomerates and siltstones. The reach between the old bombing range and Tarlac varies in width and contains lahar deposits in the channel bottom. This reach is carved mainly into older channel deposits and rock layers. Near Tarlac, the drainage becomes the Tarlac River and the channel flattens, is straighter, and flows through mostly sand-sized deposits as it passes northward to the Lingayen Gulf.

For the O'Donnell basin, four municipalities are listed as being in the risk areas (see table 4). Figure 12 shows photographs of the sediment and flooding problems in the basin. The risk areas are estimated to include:

- 26,000 household, commercial, and/or public buildings
- 19,000 ha of agricultural land (rice is dominant crop)
- P500 million in annual crop revenues

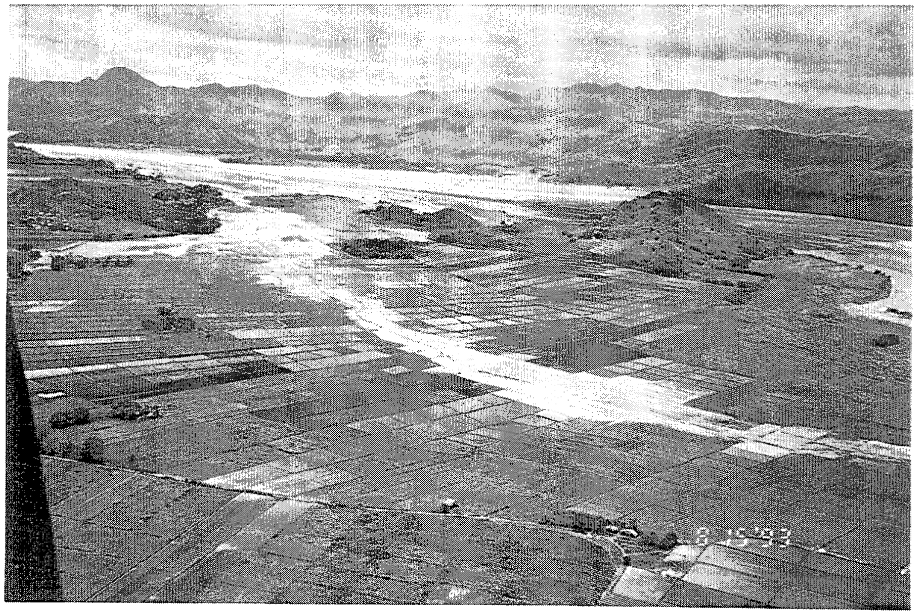
The base of the pyroclastic deposits on the O'Donnell River, February 1993.



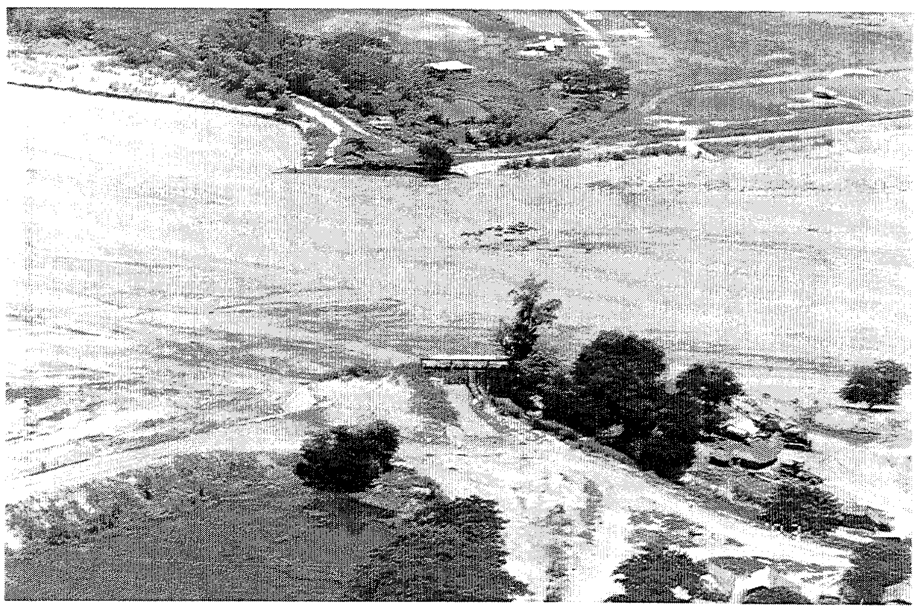
Sediment deposits at Santa Juliana, August 1993.

Figure 12

PHOTOGRAPHS FROM THE O'DONNELL RIVER BASIN



Flooding and sediment deposition on agricultural land near O'Donnell, August 1993.



Irrigation dam buried by sediment deposits upstream of Tarlac, August 1993.

Figure 12 (continued)

Current land cover for the O'Donnell basin consists primarily of grassland/shrubland (50 percent) followed by woodlands (16 percent), agricultural land (15 percent), sediment deposits (10 percent), and urban areas (9 percent). Wildlife species occurring in the area have a higher diversity in comparison to the other eastern river basins. Development of irrigation before the eruption made possible the widespread planting of paddy rice. Sugarcane is the main crop in agricultural areas without adequate irrigation. There are no archaeological sites reported within the O'Donnell basin. However, there are several significant historical landmarks and structures in Tarlac and Capas.

4.4.2 Problem Statement. In the O'Donnell basin, the risk of mudflows will remain high for the next 5 to 10 years as a result of erosion of pyroclastic material in the upper drainage. There is a potential for secondary pyroclastic flows to impact the area downstream of the pyroclastic deposit. There is a moderate risk of flooding, especially near O'Donnell and Santa Lucia, because sediment deposition has filled the channel. The flood risk at Tarlac is considered to be low. There is a moderate risk of flow diversion towards the Bamban and Rio Chico de la Pampanga rivers as long as mudflows continue to disperse and settle upstream of this area. Flow diversions would cause shallow flooding and sediment deposition over a wide area upstream of Tarlac.

4.4.3 Sediment Forecast. Sediment deposition forecasts for the O'Donnell basin are summarized below. More detailed information can be found in Technical Appendix B located in Volume II of the Long Term Report.

- Initial pyroclastic volume -- 241,000,000 m^3
- Erosion volume (1993 to 2002) -- 27,000,000 m^3
- Erosion volume (1993 to 2042) -- 67,000,000 m^3

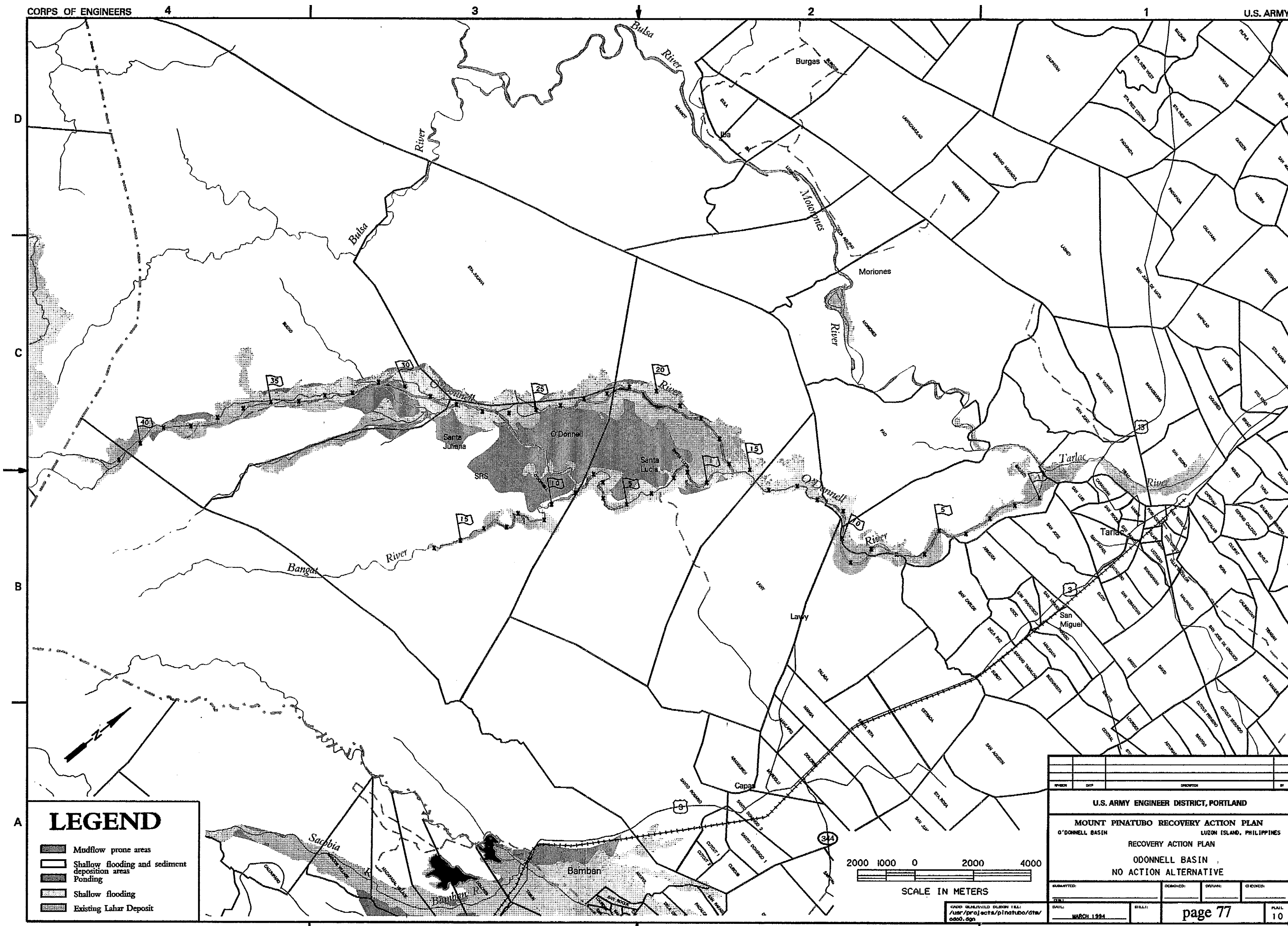
An additional 35,000,000 m^3 of sediment eroded in 1991-1992.

Potential major events include mudflows and flooding. There is at least a 50 percent chance each year that floods could erode the levees downstream of the Bangat River. There is a 50 percent chance of mudflows upstream of Santa Juliana in any year. Storm runoff could flood farmlands and deposit sediment north of O'Donnell.

4.4.4 Alternatives Under Consideration. The alternatives investigated for the O'Donnell basin include: no action, levee, channel excavation, sediment retention structure, and nonstructural.

No Action Alternative

Under the no action alternative (without-project condition), no intervention measures are developed to reduce flooding and sediment damages in the O'Donnell basin. Actions taken by the GOP in emergency situations and use of existing warning systems would continue. Plate 10 shows the risk areas under the no action alternative.


CORPS OF ENGINEERS
U.S. ARMY
Bulsa River
Burgas
Iba
Moriones
Moriones River
Tarlac River
Tarlac
O'Donnell River
O'Donnell
Santa Juliana
Santa Lucia
SRS
Bangat River
Lawy
San Miguel
Capas
Bamban
Sacobia River
Bamban River
LEGEND
Mudflow prone areas
Shallow flooding and sediment deposition areas
Ponding
Shallow flooding
Existing Lahar Deposit
2000 1000 0 2000 4000
SCALE IN METERS
U.S. ARMY ENGINEER DISTRICT, PORTLAND
MOUNT PINATUBO RECOVERY ACTION PLAN
O'DONNELL BASIN
LUZON ISLAND, PHILIPPINES
RECOVERY ACTION PLAN
ODONNELL BASIN
NO ACTION ALTERNATIVE
/usr/projects/pinatubo/dts/odo0.dgn
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page 77
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The average without-project damages (present value) for the O'Donnell basin are about P297 million, with damages to agriculture as the highest category at P171 million, followed by structures (P85 million), infrastructure (P25 million), foregone production (P8 million), evacuation/relocation (P8 million), and transportation disruption (P810 thousand).

Impacts from flooding and sedimentation are likely to occur primarily downstream of Barangay O'Donnell, and involve about 20 barangays from Capas and Tarlac, about 19,000 ha of primarily agricultural land, and the critical public access provided by Highways 3 and 317. The Rio Chico de la Pampanga River and the San Antonio swamp may be affected if flow diversion from the O'Donnell occurs to these areas, which would disrupt their fisheries and natural habitat values. As agricultural lands are impacted by sediment deposition and/or flooding, a corresponding increase in grassland and seasonal wetland areas may occur, followed by conversion of these areas back to agricultural use (sugarcane). Displaced Aeta communities along the upper O'Donnell are likely to be further disrupted of their traditional fishing and gathering activities. Public health concerns are prolonged due to poor water quality and drainage, and temporary housing arrangements. Recovery processes (ecological, sociological, and economic) are delayed.

Levee Alternative

The levee alternative for the O'Donnell basin consists of the following features (see plate 11).

- Levee from RK 27 to RK 15.5: A levee 4 meters high with slope and toe protection and sodded back slope would be constructed on the right bank (east) of the O'Donnell River extending from Santa Juliana to the confluence with the Bangat River.

- Levee from RK 0 to RK 5.5: A levee 4 meters high with slope and toe protection and sodded back slope would be constructed on the left bank of the Bangat River from its confluence with the O'Donnell to high ground 1 km upstream of the Santa Lucia bridge.

- Levee from RK 0 to RK 4: A levee 4 meters high with slope and toe protection and sodded back slope would be constructed on the right bank of the Bangat River from high ground 500 meters upstream of the Santa Lucia bridge to high ground 1 km below the bridge.

- Slope and Toe Protection: Slope and toe protection would be placed on the existing levee between Tarlac and RK 10.

- Early Warning System: Existing warning systems consist of rain gages, sediment flow sensors, and observation posts. Adding sirens or loud speakers to alert people in downstream communities would be an effective way to improve public safety.

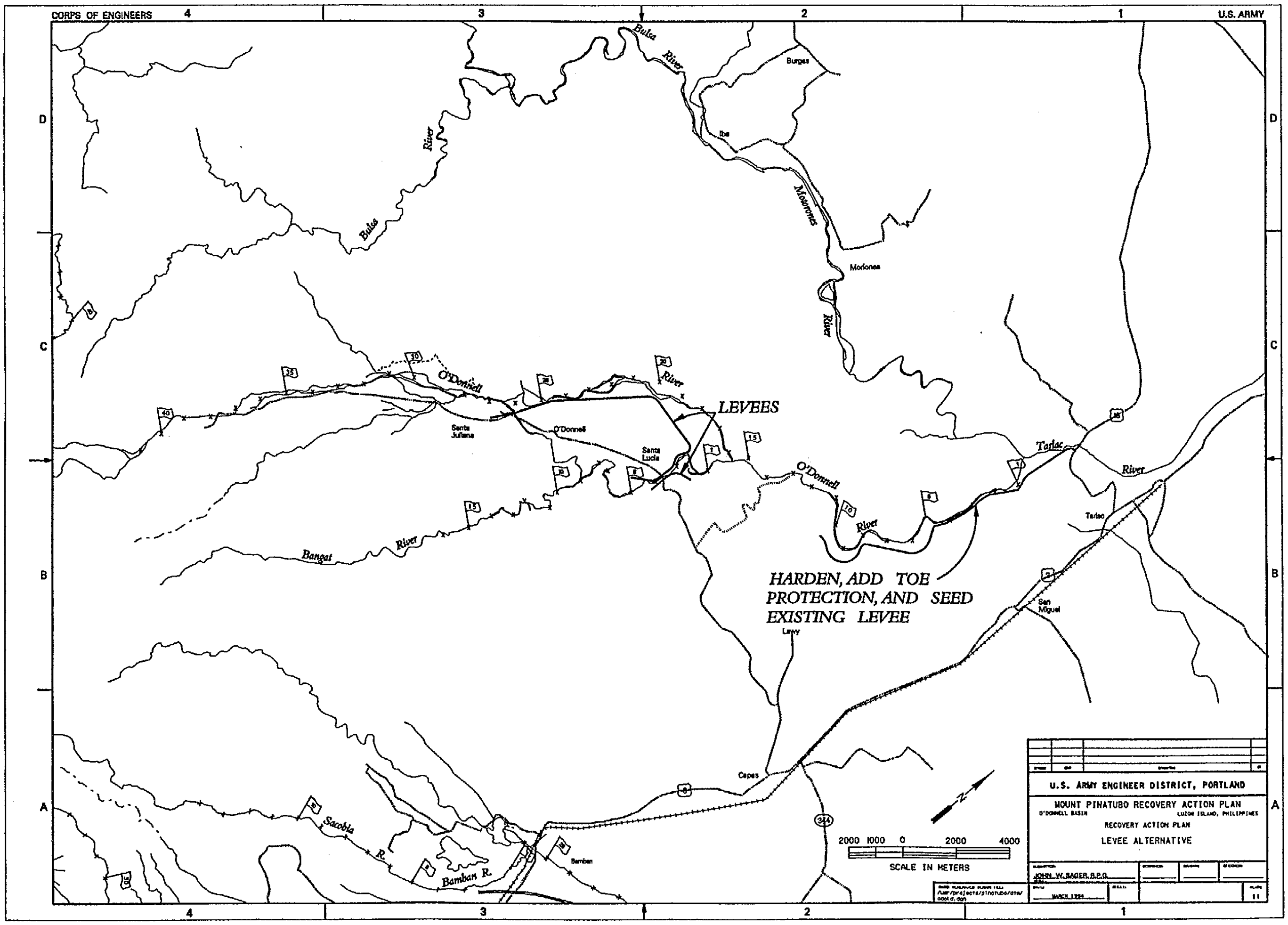

CORPS OF ENGINEERS
U.S. ARMY
Bulsa River
Burgos
Iba
Moriones River
Moriones
LEVEES
O'Donnell River
Santa Juliana
O'Donnell
Santa Lucia
Tarlac River
Tarlac
Bangat River
HARDEN, ADD TOE PROTECTION, AND SEED EXISTING LEVEE
San Miguel
Capas
Sacobia R.
Bamban R.
Bamban
2000 1000 0 2000 4000
SCALE IN METERS
U.S. ARMY ENGINEER DISTRICT, PORTLAND
MOUNT PINATUBO RECOVERY ACTION PLAN
O'DONNELL BASIN
LUZON ISLAND, PHILIPPINES
RECOVERY ACTION PLAN
LEVEE ALTERNATIVE
JOHN W. SAGER, R.P.G.
MARCH 1994
11

Plate 11

The Santa Lucia bridge also should be raised to the height of the levees, and interior drainage provided for the area behind the levee on the left bank of the Bangat River. Infrastructure and drainage work is not included in this study, and the costs of these actions would be the responsibility of the GOP.

Results of Action. The right bank levees from Santa Juliana to the confluence of the Bangat River are designed to contain mudflows and sediments forecast to be deposited in this reach during the next 10 years, and with sufficient capacity at the end of this period to provide protection against a 100-year event. The levees on the Bangat prevent backwater flooding resulting from sedimentation in the O'Donnell. These levees provide substantial protection from sedimentation and flooding to those portions of O'Donnell and Santa Lucia within the right outer and inner zones of the O'Donnell reach (see figure 13 for impact zones).

The existing right bank levees below RK 10 have sufficient height to contain mudflows and sediments forecast to be deposited in this reach during the next 10 years, and with sufficient capacity at the end of this period to provide protection against a 100-year event. Placement of slope and toe protection on the levee substantially reduces the risk of breaching and protects portions of Capas, Concepcion, and Tarlac located in the Maniknik right outer zone from sedimentation and flooding.

Cost Summary and Investment Analysis. A summary of construction costs (first costs), annual future and special future costs, and the present value of economic costs for the levee alternative is shown in table 11. On the average, this alternative eliminates about P187 million in damages in the O'Donnell basin. The present value of economic costs for this alternative is P188 million. The investment analysis is shown in table 11 and for the mean case, this alternative has negative net benefits of about P(1) million and a BCR of about 1.0.

Environmental and Social Effects. In addition to enhanced protection to existing human settlements, agricultural land, and critical infrastructure, about 500 ha of farmland near Santa Lucia could be regained. The new levee around O'Donnell and Santa Lucia would displace about 30 ha of agricultural land (sugarcane), about 10 households in O'Donnell, and a small number of households in Santa Lucia. Progressive filling of the channels of the O'Donnell, Tarlac and Agno rivers further reduces their in-channel sediment transport capability, resulting in continued impact on downstream fisheries and water quality.

Figure 13 -- *Lower O'Donnell Basin Impact Zones*

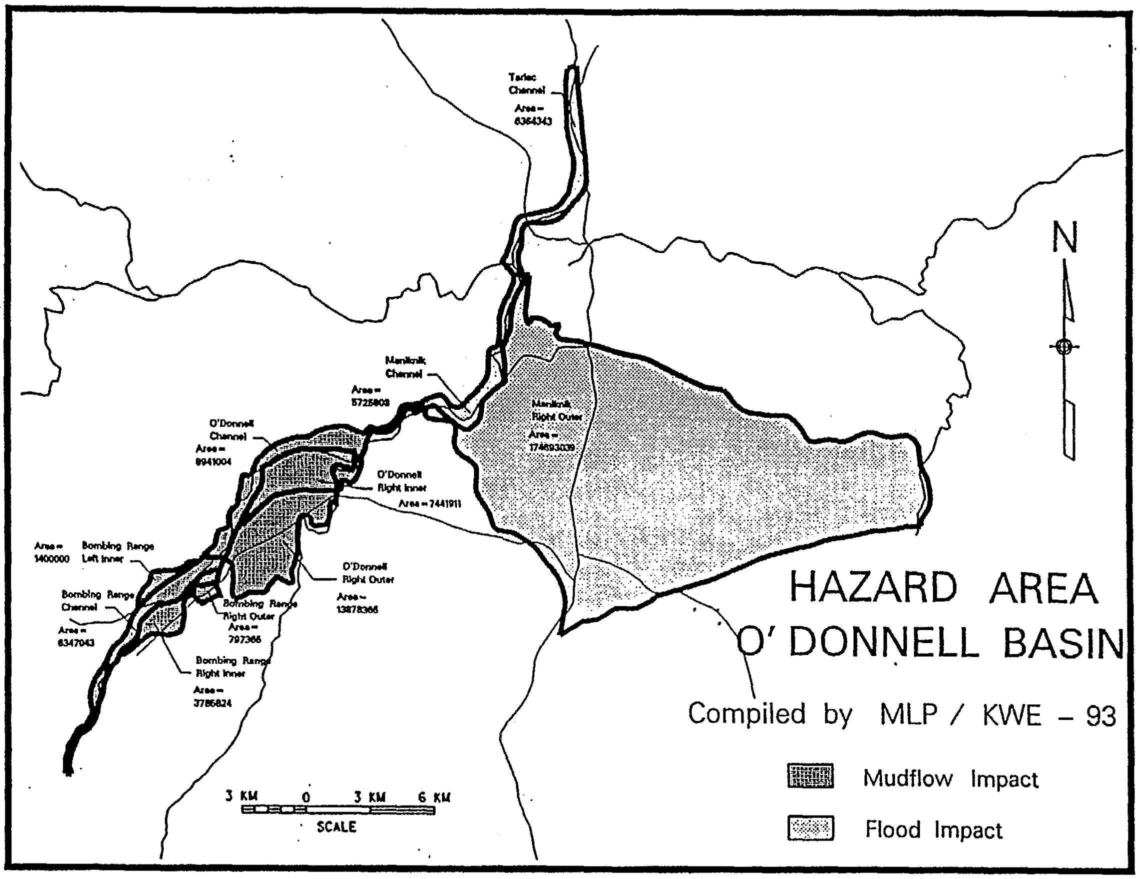


Table 11 -- *Costs for Alternatives, O'Donnell Basin (rounded, in pesos)*

Construction Costs (first costs)

	Levee	Channel Excavation	SRS
Levees with Slope/Toe Protection	134,100,000		97,100,000
Slope/Toe Protection, Existing Levee	34,200,000	34,200,000	34,200,000
Channel Excavation		740,800,000	
Dam with Spillway/Outlet Works			2,276,600,000
Low Level Weirs			29,500,000
Environmental Mitigation	3,200,000	200,000	1,900,000
Early Warning System	2,600,000	2,600,000	2,600,000
Subtotal	174,100,000	777,800,000	2,441,900,000
Contingency (30%)	52,200,000	233,400,000	732,600,000
Total First Costs	226,300,000	1,011,200,000	3,174,500,000

Annual Costs, financial

	Levee	Channel Excavation	SRS
Annual Dredging Costs			
Annual Excavation Costs		59,000,000	
O&M	226,000	40,000	3,174,000
Total Annual Costs	226,000	59,040,000	3,174,000

Special Future Costs (every 10 years)

	Levees	Channel Excavation	SRS
Major Maintenance	0	0	30,000,000

Present Value of Economic Costs, 1994 Base

	Levees	Channel Excavation	SRS
First Costs	186,800,000	833,700,000	2,223,400,000
Annual Costs	1,400,000	410,300,000	14,500,000
Future Special Costs	0	0	8,100,000
Total	188,200,000	1,244,000,000	2,246,000,000

Investment Analysis (Mean Case)

	Levee	Channel Excavation	SRS
Net Benefits	(959,000)	(1,056,000,000)	(1,996,000,000)
BCR	0.99	0.2	0.12
IRR (percent)	N/A	N/A	N/A

Channel Excavation Alternative

The channel excavation alternative for the O'Donnell basin consists of the following features (see plate 12).

- Channel Excavation: The O'Donnell channel would be excavated 500 meters wide and 2 meters deep from RK 14.5 to RK 27. Material will be disposed in berms along the channel with berms set back a distance of at least 100 meters from the channel. The disposal berms would provide additional capacity and protection for large events. Annual removal of sediments will be required to maintain protection.

- Slope/Toe Protection and Early Warning System: These features, as described for the levee alternative, also would be required.

Results of Action. The channel excavation and berms are designed to contain mudflows and sediments forecast to be deposited in this reach during a 100-year event. To maintain this protection, annual channel excavation is required. This alternative provides protection to the same areas as provided by the levee alternative. Continuous annual excavation of the O'Donnell channel to below the mouth of the Bangat River will prevent backwater flooding of the Bangat River into Santa Lucia. Slope and toe protection of the existing right bank levees below RK 10 will have the same benefits as under the levee alternative.

Cost Summary and Investment Analysis. A summary of costs for the channel excavation alternative is shown in table 11. On the average, the channel excavation alternative will eliminate about P187 million in damages in the O'Donnell basin. The present value of economic costs for this alternative is P1.2 billion. The investment analysis is shown in table 11 and for the mean case, this alternative has negative net benefits (net present value) of about P(1) billion and a BCR of 0.2.

Environmental and Social Effects. This alternative provides an enhanced level of protection to existing human settlements, agricultural lands, and critical infrastructure. Areas within the proposed channel excavation and disposal areas are presently impacted by sediment deposition, and no existing households, livelihoods, or sensitive environmental habitats will be displaced. Sediment transport to downstream reaches of the O'Donnell, Tarlac and Agno rivers would be reduced, which minimizes further impacts to fisheries and water quality. When filled, the disposal sites may serve for potential use for residential and industrial development.

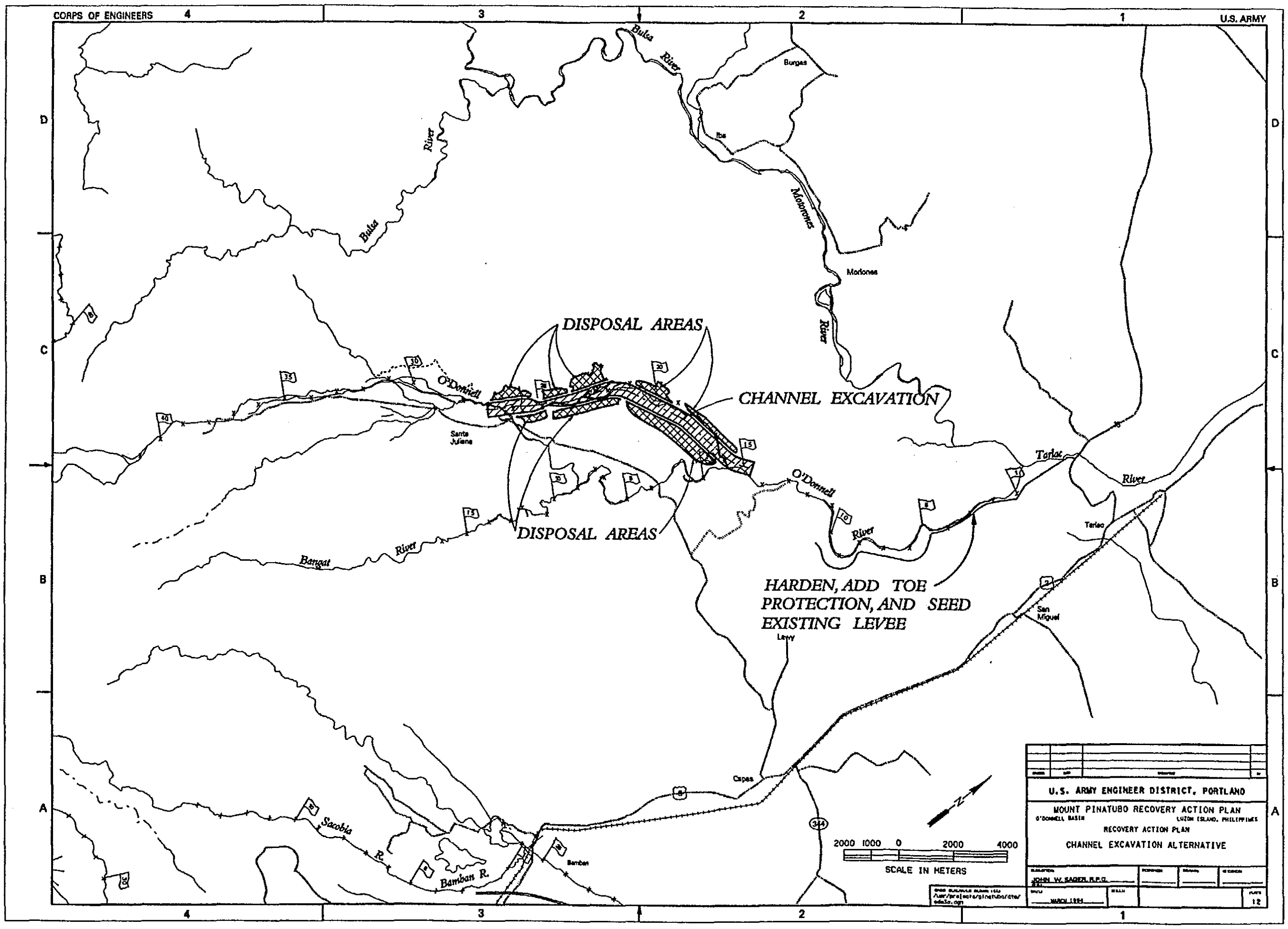

CORPS OF ENGINEERS
U.S. ARMY
DISPOSAL AREAS
CHANNEL EXCAVATION
DISPOSAL AREAS
HARDEN, ADD TOE
PROTECTION, AND SEED
EXISTING LEVEE
Bulsa River
Moriones River
O'Donnell River
Bangat River
Sacobia R.
Bamban R.
Tarlac River
2000 1000 0 2000 4000
SCALE IN METERS
U.S. ARMY ENGINEER DISTRICT, PORTLAND
MOUNT PINATUBO RECOVERY ACTION PLAN
RECOVERY ACTION PLAN
CHANNEL EXCAVATION ALTERNATIVE

Plate 12

Sediment Retention Structure Alternative

The sediment retention structure alternative for the O'Donnell basin consists of the following features (see plate 13).

- Embankment Dam and Outlet Works: An earth and rock fill embankment dam 41 meters high would be constructed at RK 33 (7 km above Santa Juliana). The spillway and outlet works would be cut into the left abutment. The spillway would consist of a 150 meter unlined channel with a crest elevation 10 meters below the crest of the embankment dam. The outlet works would not be controlled and would consist of one meter culverts through a concrete gravity structure.

- Weirs: Low level weirs would be constructed at the site of the two original sabo structures on the Bangat River.

- Levees, Slope/Toe Protection, and Early Warning System: These features, as described for the levee alternative, also would be required, except levee height has been reduced to 3 meters.

The Santa Lucia bridge also should be raised and interior drainage provided as described for the levee alternative.

Results of Action. The right bank levees from Santa Juliana to the confluence with the Bangat River, and the bank and toe protection downstream from RK 10 provide protection to the same areas as in the levee alternative. The retention structure at RK 33 will store about 100 million m^3 that would otherwise be carried through the system. After completion of the structure, the river channel will stabilize rapidly allowing the reestablishment of irrigation diversion and river crossings. The weirs on the Bangat River will store in-channel sediments. This reduces sedimentation in the lower reaches of the Bangat and reduces total sediments available to the O'Donnell.

Cost Summary and Investment Analysis. A summary of costs for the retention structure alternative is shown in table 11. On the average, this alternative eliminates about P250 million in damages in the O'Donnell basin. The present value of economic costs for this alternative is P2.2 billion. The investment analysis is shown in table 11 and for the mean case, this alternative has negative net benefits (net present value) of about P(2) billion and a BCR of 0.1.

Environmental and Social Effects. During the design and construction period required for completion of the SRS (4 to 6 years), environmental and social effects would be similar to those described for the levee alternative. Due to the reduced height of the proposed levees, slightly less farmland (25 ha of sugarcane) and fewer households would potentially be displaced in O'Donnell and Santa Lucia. Depending on SRS and weir design, and depth of excavations, possible disturbance of archaeological

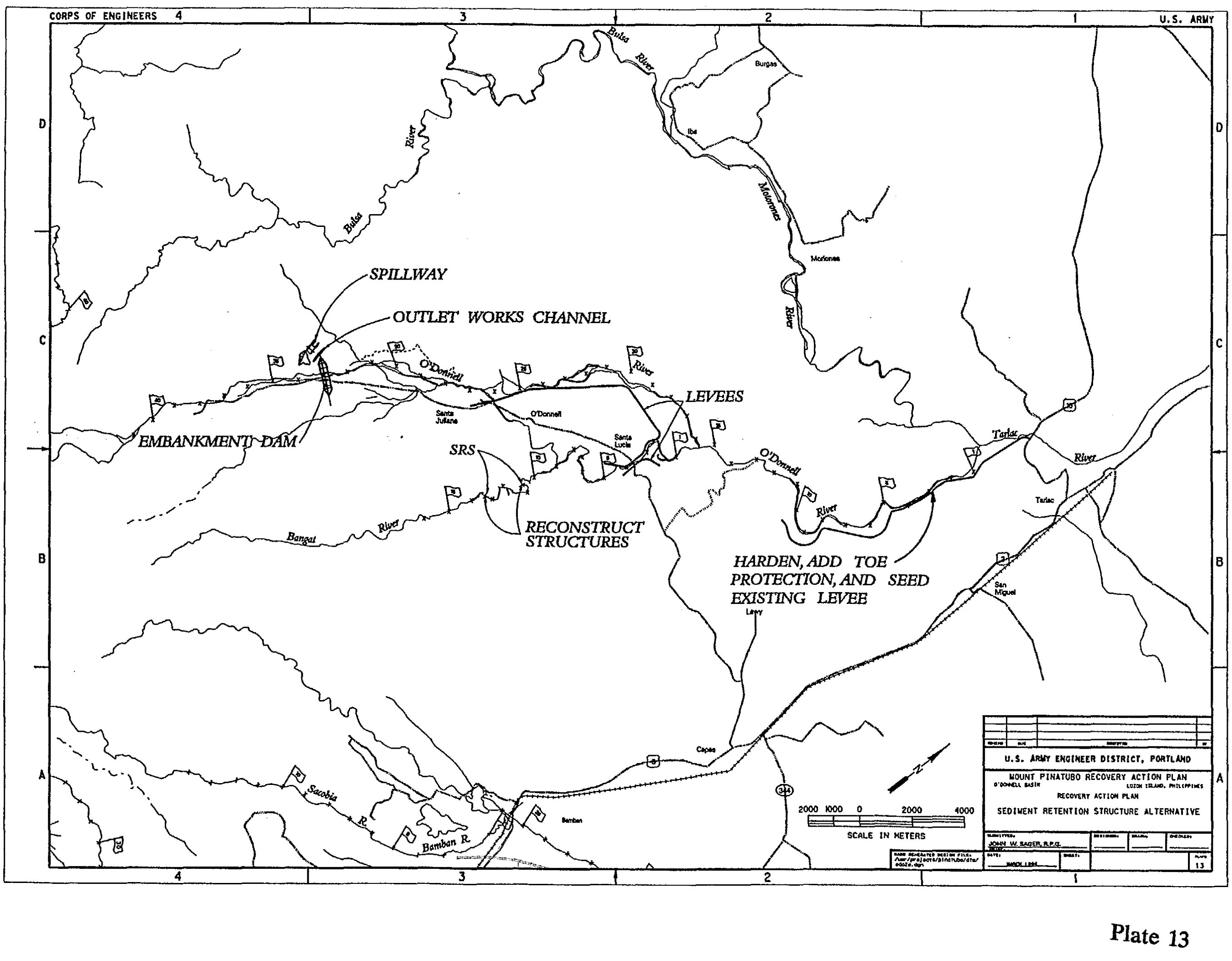

CORPS OF ENGINEERS
U.S. ARMY
SPILLWAY
OUTLET WORKS CHANNEL
EMBANKMENT DAM
LEVEES
SRS
RECONSTRUCT STRUCTURES
HARDEN, ADD TOE PROTECTION, AND SEED EXISTING LEVEE
Bulsa River
Moriones River
O'Donnell River
Bangat River
Tarlac River
Sacobia R.
Bamban R.
U.S. ARMY ENGINEER DISTRICT, PORTLAND
MOUNT PINATUBO RECOVERY ACTION PLAN
RECOVERY ACTION PLAN
SEDIMENT RETENTION STRUCTURE ALTERNATIVE
2000 1000 0 2000 4000
SCALE IN METERS

Plate 13

resources could occur, although no sites have been identified during initial surveys. Remaining Aeta communities would not be affected by the siting or operation of the SRS or weirs. Upon completion of the SRS and weirs, about 100 million m^3 of sediment is stored above Santa Juliana and not transported downstream, resulting in less disturbance to the Tarlac and Agno rivers. In the unlikely event of a structural failure, a large amount of sediment would erode and be transported downstream, which may threaten communities downstream of the structure. The local concern of this risk and the long-term threat it poses to public safety was identified during the scoping sessions. The potential that the reservoir which could form behind the completed SRS may extend the malaria problem reported for Lake Mapanuepe (Santo Tomas River) is unknown.

Nonstructural Alternative

The nonstructural alternative consists of permanent evacuation for all populated areas along the O'Donnell basin threatened with imminent destruction by sediment flows. Flooding/ponding levels are expected to be shallow so temporary evacuation of residents is the only action expected to be necessary for these areas and can be accomplished under the GOP's evacuation program. Improving the early warning system as described previously also is suggested.

The primary benefit of the nonstructural alternative is removing people from harms way in areas threatened by sediment flows. Since there is no protection provided to assets or production, substantial damages would still occur. By removing households from threatened areas, there would be reduced loss of life and health costs. These benefits are not evaluated or quantified in this report and no cost-benefit analysis is performed. A relocation cost of P100,000 per household is reasonable based on GOP data. Using survey data, the number of households threatened with imminent destruction by sediment flows was estimated at 1,600 for the O'Donnell basin. This number likely overstates the total number of households currently at risk. An estimate of households threatened by imminent destruction may range from 25 to 75 percent, or 400 to 1,200 households. Therefore, an estimated cost for permanent evacuation may range from P40 million to P120 million. Estimated costs for the early warning system are P2.6 million.

Implementation of the nonstructural alternative may create effects similar to those for the no action alternative, with the added benefits to public safety of an improved early warning system. The potential nature-induced impacts include continued high levels of uncontrolled sedimentation, blockage or alteration of historic river courses, and resultant flooding of adjacent low-lying areas in Capas and Tarlac.

4.4.5 Findings for the O'Donnell Basin. Three structural alternatives as well as the no action and nonstructural alternatives were evaluated for the O'Donnell basin. A summary of the differences, advantages, and disadvantages among the alternatives is shown on table 12.

Table 12 -- *Summary of Alternatives, O'Donnell Basin*

	NO ACTION	LEVEE ALTERNATIVE	CHANNEL EXCAVATION ALTERNATIVE	SEDIMENT RETENTION STRUCTURE ALTERNATIVE	NONSTRUCTURAL ALTERNATIVE
Study Objective Accomplishments	No effective response provided to any objective.	Overall very good response provided to most study objectives.	Overall good response provided to most study objectives.	Best response provided to the study objectives.	No effective response to any objective except preservation of life.
Construction Considerations and Accomplishments	Without-project condition so no alternatives developed. Loss of life & damages from sediment/floods continues. GOP emergency actions & existing warning systems continues.	Levees protect O'Donnell & Santa Lucia from sediment/floods. Slope/Toe protection prevents breaching of levees and protects portions of Capas, Concepcion, and Tarlac.	Provides protection to same areas as in levee alternative. Higher long-term funding costs for annual excavation/disposal.	About 100 million cubic meters of sediment stored. Better flushing/more stabilization of downstream areas because of lower sediment load.	No construction proposed.
Construction Costs (Present Value)	No construction proposed.	First Cost: P226 million Annual Cost: P226 thousand Future Maintenance Cost: 0	First Cost: P1 billion Annual Cost: P59 million Future Maintenance Cost: None	First Cost: P3.2 billion Annual Cost: P3.2 million Future Maintenance Cost (every 10 years): P30 million	Permanent evacuation costs range from P40 to P120 million. Temporary evacuation during flooding via GOP program. Warning System Cost: P2.6 million.
Economic Effects (Present Value)	Average damages estimated at P297 million, mostly to agriculture and structures. Delayed recovery processes.	Economic Cost: P188 million Average Total Benefits: P187 million Mean Net Benefits: P(1) million B/C Ratio: 0.99 IRR: N/A	Economic Cost: P1.2 billion Average Total Benefits: P187 million Mean Net Benefits: P(1) billion B/C Ratio: 0.2 IRR: N/A	Economic Cost: P2.2 billion Average Total Benefits: P250 million Mean Net Benefits: P(2) billion B/C Ratio: 0.1 IRR: N/A	Average damages estimated at P297 million.
Environmental And Social Effects	Significant siltation continues & disrupts sensitive habitats. About 20 barangays impacted. About 19,000 ha of agricultural lands impacted. Highways 3 & 317 impacted. Public health concerns prolonged.	About +10 households displaced. About 30 ha of agricultural land displaced by new levee. Progressive filling of river channels reduces their transport capability & continues downstream impacts. Public information, monitoring, and maintenance programs required.	No households or sensitive habitats displaced. Sediment transport downstream reduced which reduces impacts to fisheries/water quality. Disposal sites may serve future uses for residential/ industrial development.	Similar impact areas/concerns as for levee alt until SRS complete (4-6 yrs). Significant amt of sediment affects downstream habitats until SRS complete. Upon completion of SRS, source of downstream impacts significantly lower. Possible disturbance to historical resources.	Effects similar to No Action, but improved public safety because of early warning system.

4.5 Santo Tomas River Basin

4.5.1 Specific Conditions. The Santo Tomas basin is about 262 km^2 in area, extending in a southwesterly direction from Mount Pinatubo to the South China Sea (see figure 1). Two tributaries, the Mapanuepe and Marella rivers, converge to form the main channel of the Santo Tomas River. The headwaters of the Marella originate near the crater of Mount Pinatubo at an elevation of about 1,500 meters and separates the Santo Tomas basin from the easterly flowing Gumain River tributaries. The Marella River drains the southwest slopes of Mount Pinatubo and combines with the Mapanuepe River at an elevation of about 90 meters. The headwaters of the Mapanuepe River originate near the divide between the Santo Tomas and Gumain basins at an elevation of about 1,000 meters. The Mapanuepe River sub-basin includes a large mine site, a mine tailings dam, and Lake Mapanuepe.

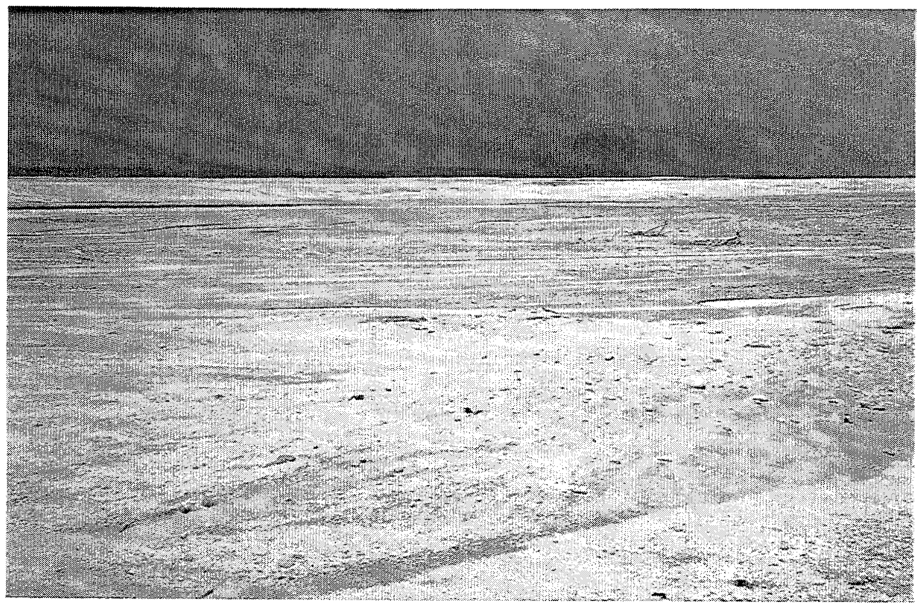
Lake Mapanuepe, with a surface area of about 8 km^2, was formed following the eruption as a result of blockage of the Mapanuepe River outlet aggradation on the Marella River. Under current conditions, the Mapanuepe River joins the Marella River about 1.5 km downstream from the outlet of Lake Mapanuepe.

The headwaters area of the Santo Tomas basin was blanketed with a pyroclastic deposit volume of 1.4 billion m^3. These deposits were laid down on top of or interfingered with older deposits from previous eruptions. A large SPF occurred in 1992 near the downstream end of the original pyroclastic flow deposits. Bedrock is locally exposed in the lower part of the headwaters area. The headwaters reach consists of a relatively narrow channel on a steep slope. From about the Santa Fe area to the coast, the channel flows on a gentler slope through a relatively wide flood plain consisting of older deposits composed of sand with some gravel and coarser sizes.

For the Santo Tomas basin, five municipalities are listed as being in the risk areas (see table 4). Figure 14 shows photographs of the sediment deposits and flooding in the basin. The risk areas are estimated to include:

- 23,000 household, commercial, and/or public buildings
- 11,500 ha of agricultural land (rice is dominant crop)
- P100 million in annual crop revenues

Current land cover for the Santo Tomas basin consists primarily of grassland/shrubland (37 percent) followed by agricultural land (26 percent), woodlands (17 percent), urban areas (10 percent), and sediment deposits (10 percent). The upper reaches of Santo Tomas basin are characterized by the presence of a remnant forest type, mainly *Shorea sp.* and commonly Kupang (*Parkia sp.*). The midsection of the river valley is rugged hilly terrain and is dominated by grassland/shrubland in association with small woody trees.



The Santo Tomas River at San Rafael, looking northeast. Top photograph taken in August 1992. Bottom photograph at same location in August 1993 with mudflow deposits about 7 meters in depth.

Figure 14

PHOTOGRAPHS FROM THE SANTO TOMAS RIVER BASIN

Flooding and sediment deposits at San Rafael, August 1993.

Sediment deposits upstream of Highway 7 near Castillejos, August 1993.

Figure 14 (continued)

The lower hills are mainly dominated by Cogon and Amorseko, with patches of shrubs and wild bananas. The cultivation and gathering of banana blossoms is an important economic activity of the Aetas. The land use in the lowland is devoted to agriculture and mainly planted to rice. In the coastal areas, the dominant natural vegetation is Agoho and Talisay.

About 15 Aeta communities from four barangays in San Marcelino were displaced by the eruption and subsequent events. The most affected barangay was Buhawen, where 196 Aeta families were displaced. Buhawen was flooded as a result of the lake formation at Mapanuepe. At Aglao, located in the upper reaches of the Mapanuepe River, 127 families were displaced. At Santa Fe and San Rafael, 122 and 96 Aeta families were displaced, respectively.

Two archaeological sites are located in the upper reaches of the Marella River in Santa Fe. Cultural materials found were Ming Dynasty period tradeware ceramics, earthenware pots, and other materials (13th to 15th centuries A.D.). Similar cultural materials were excavated at a habitation site in Kakilingan. No historical structures and landmarks are evident in the municipalities of San Marcelino, San Narciso, San Felipe, San Antonio and Castillejos.

4.5.2 Problem Statement. In the Santo Tomas basin, the risk of mudflows remains high for the next 5 to 10 years as a result of erosion of pyroclastic material in the upper drainage. There is a low probability of failure at the Lake Mapanuepe blockage. Highway 7 and the bridge in San Felipe appear to be in low danger of erosion and/or failure. The river buried the San Rafael and Santa Fe areas and a very high risk exists for the river to overtop the levees and exit the channel to the south, causing shallow flooding and sedimentation.

4.5.3 Sediment Forecast. Sediment deposition forecasts for the Santo Tomas basin are summarized below. More detailed information can be found in Technical Appendix B located in Volume II of the Long Term Report.

- Initial pyroclastic volume -- 1,400,000,000 m^3
- Erosion volume (1993 to 2002) -- 130,000,000 m^3
- Erosion volume (1993 to 2042) -- 160,000,000 m^3

An additional 412,000,000 m^3 of sediment eroded in 1991-1992.

Potential major events include mudflows and flooding. There is at least a 50 percent chance each year that mudflows will deposit in the vicinity of San Rafael and Santa Fe. Flooding is likely south of the river and could erode portions of Highway 7 between Castillejos and San Narcisco.

4.5.4 Alternatives Under Consideration. The alternatives investigated for the Santo Tomas basin include: no action, levee, channel excavation, sediment retention structure, and nonstructural.

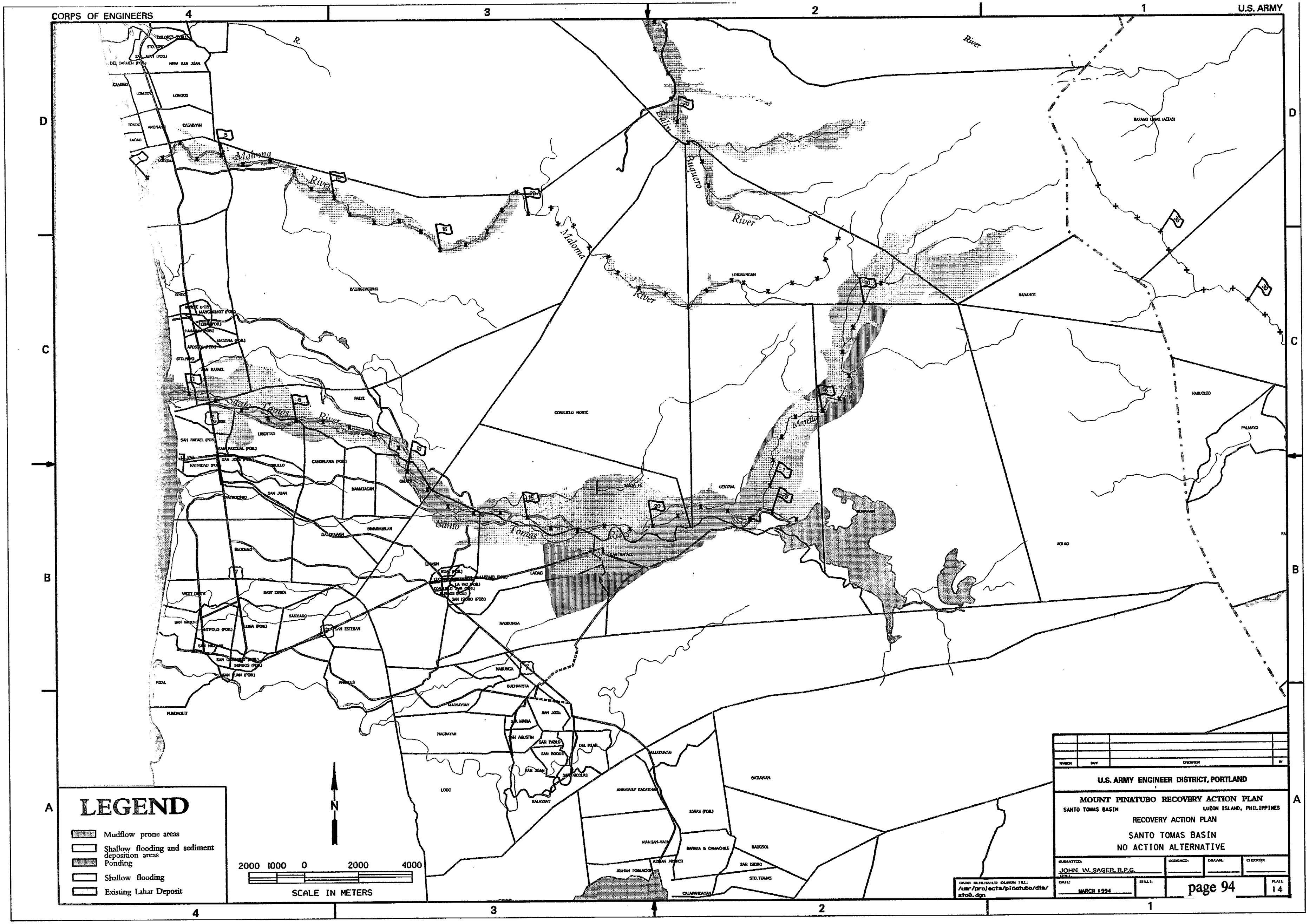
No Action Alternative

Under the no action alternative (without-project condition), no intervention measures are developed to reduce flooding and sediment damages in the Santo Tomas basin. Actions taken by the GOP in emergency situations and the use of existing warning systems would continue. Plate 14 shows the risk areas expected under the no action alternative.

The average without-project damages (present value) for the Santo Tomas basin are about P1,244 million, with damages to structures (P735 million) accounting for about 60 percent of this total. Damages to agriculture is the second highest category at P264 million, followed by foregone production (P99 million), evacuation/relocation (P98 million), infrastructure (P41 million), and transportation disruption (P7 million).

About 56 barangays from San Marcelino, Castillejos, San Antonio and San Narciso could be affected by mudflows, flooding and sedimentation, involving some 11,500 ha of agricultural land and human settlements, and the only north-south land transportation route in Zambales (Highway 7). Three upland barangays (Buhawen, Aglao and Lawin) and the Dizon Copper Mine operations are likely to be isolated during extended periods of rain by mudflows and flooding. The Mapanuepe River is diverted to the south of the sediment-filled Santo Tomas, and flows through the Camachile River, adjacent creeks, and irrigation canals to reach the South China Sea near San Antonio. Future mudflows may fill these water courses and progressively affect additional areas. As agricultural lands are impacted, low-lying (moist) areas would quickly revert to talahib grassland, followed by a possible pattern of "at-risk" farming and settlement.

Coastal habitats and fisheries would continue to be impacted by high levels of sedimentation and turbidity. The diversion of river flows and mudflows to the south tends to increase coastal impacts in the vicinity of San Antonio, including nearby Capones Islands, which sustain moderate coral reef communities. Public health concerns are prolonged, due to poor water quality and drainage, and temporary housing arrangements. Recovery processes (ecological, sociological, and economic) are delayed.



CORPS OF ENGINEERS
U.S. ARMY
Maloma River
Santo Tomas River
Balin Baquero River
Marella
Santo Tomas River
LEGEND
Mudflow prone areas
Shallow flooding and sediment deposition areas
Ponding
Shallow flooding
Existing Lahar Deposit
2000 1000 0 2000 4000
SCALE IN METERS
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U.S. ARMY ENGINEER DISTRICT, PORTLAND
MOUNT PINATUBO RECOVERY ACTION PLAN
SANTO TOMAS BASIN
LUZON ISLAND, PHILIPPINES
RECOVERY ACTION PLAN
SANTO TOMAS BASIN
NO ACTION ALTERNATIVE
JOHN W. SAGER, R.P.G.
MARCH 1994
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14

Levee Alternative

The levee alternative for the Santo Tomas basin consists of the following features (see plate 15).

- Levee from RK 12.5 to RK 20: A levee 13 meters high transitioning to 9 meters with a hardened face, toe protection and sodded back slope would be constructed 400 meters riverward of the existing levee located on the left bank between the high ground at Lawin and Vega Hill. This levee parallels the existing levee is the primary levee for the protection against major sediment events.

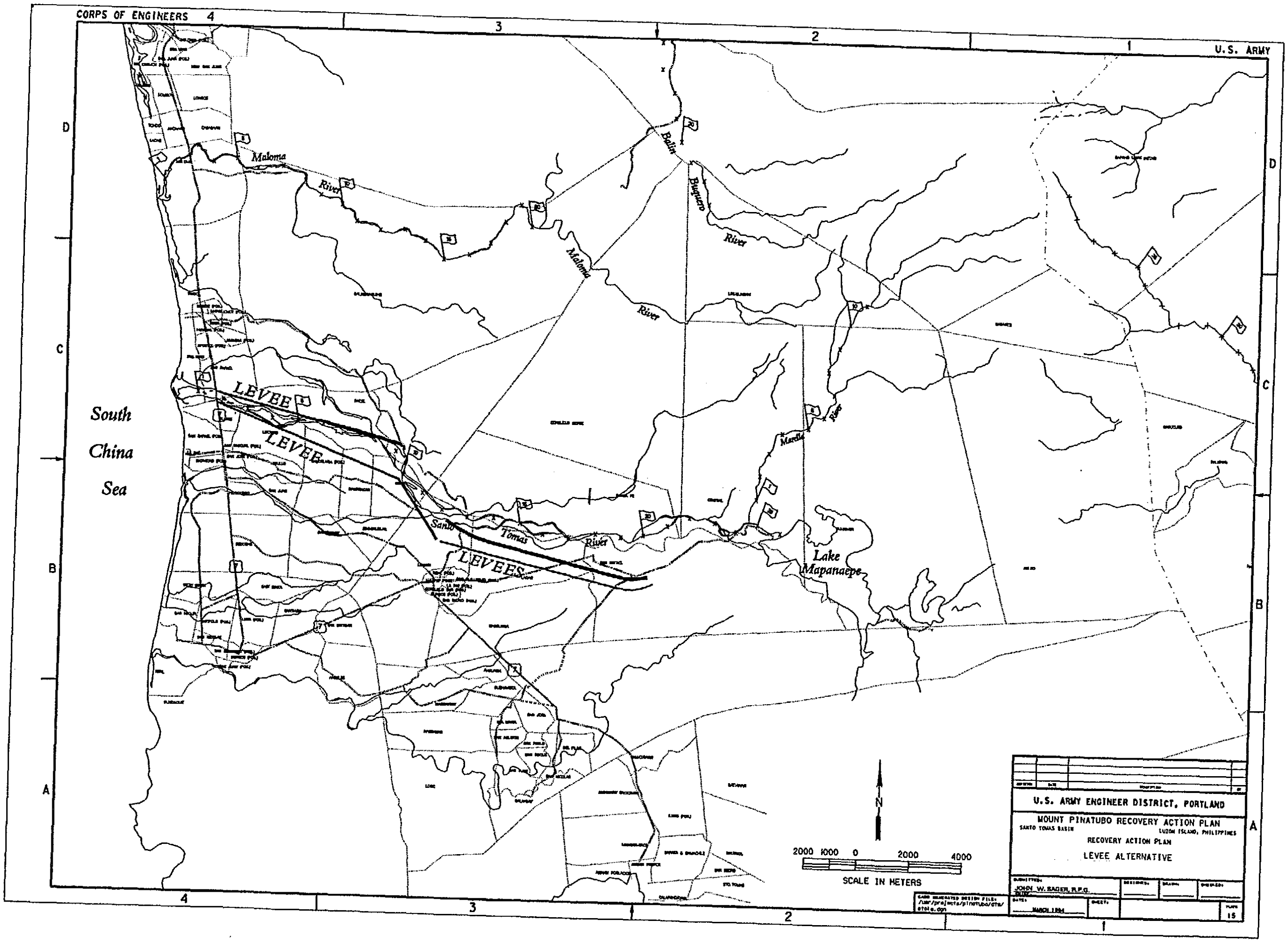
- Reconstruct Levee: The existing 3-meter-high levee on the left bank between the high ground at Lawin and Vega Hill will be reconstructed, and slope/toe protection and sodded back slope added. This levee is a backup levee for the higher primary levee. Any flows trapped between these levees can exit at the downstream end.

- Levee from RK 10 to RK 12.5: A levee 9 meters high and transitioning to 6 meters with a hardened face, toe protection and sodded back slope would be constructed on the left bank from the high ground west of Vega Hill, and downstream to RK 10 following the existing levee alignment.

- Levees from RK 2 to RK 10: A levee 6 meters high and transitioning to 3 meters with slope and toe protection, and a sodded back slope would be constructed on both the left and right banks following a straight alignment.

- Early Warning System: Existing warning systems consist of rain gages, sediment flow sensors, and observation posts. Adding sirens or loud speakers to alert people in downstream communities would be an effective way to improve public safety.

Results of Action. The levee system has been designed to contain mudflows and sediments forecast to be deposited in this reach during the next 10 years, and with sufficient capacity at the end of this period to provide protection against a 100-year event. The double levee proposed for the left bank between Lawin and Vega Hill is designed so that the riverward levee provides the primary protection from sediment flows, and the landward levee functions as a secondary levee to provide protection from any flows from the Mapanuepe River which may be forced behind the primary levee. These levees provide significant protection from sedimentation and flooding to portions of San Marcelino, Castillejos, San Antonio, and San Narciso which are located outside of the levees but within the Mapanuepe outer impact zone, the San Marcelino inner and outer zones, the San Antonio zone, and the San Narcisco zone (see figure 15 for impact zones. The levees also prevent the river from entering parallel drainages which have insufficient capacity to carry flows which, in addition to damaging the above municipalities, would cause disruption of Highway 7 and local transportation routes.


CORPS OF ENGINEERS
U.S. ARMY
South China Sea
Maloma River
Balin Baquero River
Maloma River
LEVEE
LEVEE
LEVEES
Santo Tomas River
Marella River
Lake Mapanaepe
2000 1000 0 2000 4000
SCALE IN METERS
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U.S. ARMY ENGINEER DISTRICT, PORTLAND
MOUNT PINATUBO RECOVERY ACTION PLAN
SANTO TOMAS BASIN
LUZON ISLAND, PHILIPPINES
RECOVERY ACTION PLAN
LEVEE ALTERNATIVE
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MARCH 1994
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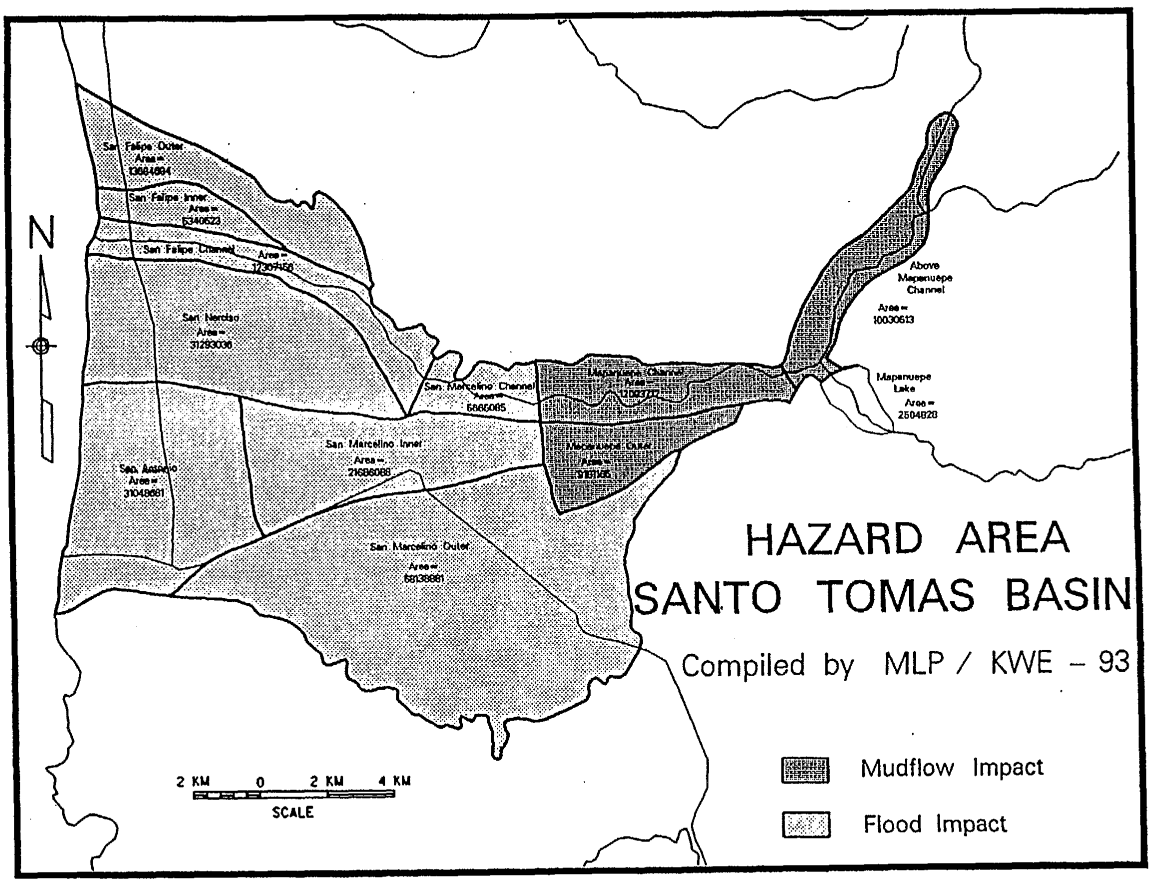
Plate 15

Figure 15 -- *Lower Santo Tomas Basin Impact Zones*



The left bank levee between Vega Hill and the Highway 7 bridge provides significant protection from sedimentation and flooding to the San Narciso zone, Highway 7, and the local transportation routes in the area. The right bank levee between RK 10 and the Highway 7 bridge provides protection from sedimentation and flooding to the San Felipe inner and outer zones.

Cost Summary and Investment Analysis. A summary of construction costs (first costs), annual future and special future costs, and the present value of economic costs for the levee alternative is shown in table 13. On the average, this alternative eliminates about P907 million in damages in the basin. The present value of economic costs is P740 million. The investment analysis is shown in table 13 and for the mean case, this alternative has positive net benefits of about P168 million and a BCR of 1.2.

Environmental and Social Effects. The levee alternative provides an enhanced protection to existing human settlements, agricultural lands, and critical infrastructure (Highway 7). Areas within the proposed alternative are already impacted by sediment deposition, except the area downstream of Vega Hill, where the levee alignment may displace about 280 ha of farmland and some of the 170 households settled there. Possible displacement also may occur in settlements on the right bank if the channel continues to aggrade in this area.

All sediments produced by the Marella River must either be stored in the Santo Tomas channel or transported through the system to the South China Sea. Sedimentation and related impacts to coastal habitats and fisheries in the vicinity of San Felipe, San Narciso, and northward may be increased as a result of confining sediment within the Santo Tomas channel. As the leveed channel is filled and elevated above the existing landscape, failure of the levees is a continued risk to adjoining and downstream communities and necessitates a long-term public information, monitoring, and maintenance program. Also, dredging and channel excavation may be required below the Highway 7 bridge to prevent shoaling at the mouth of the river.

Channel Excavation Alternative

The channel excavation alternative for the Santo Tomas basin consists of the following features (see plate 16).

- Channel Excavation: A channel 1 km wide, 10 km long, and 4 meters deep would be excavated between RK 12 and RK 21. Excavated material will be disposed of in berms with a 100 meter setback from the newly excavated channel.

- Reconstruct Levee: The existing levee on the left bank between the high ground at Lawin and Vega Hill would be reconstructed with slope and toe protection and sodded back slope, and serves as a backup levee to protect against flows forced behind the disposal berms.

Table 13 -- *Costs for Alternatives, Santo Tomas Basin (pesos)*

Construction Costs (first costs)

	Levee	Channel Excavation	SRS
Levees w/ Slope & Toe Protection	698,700,000	181,600,000	641,600,000
Channel Excavation		2,326,700,000	
Dam with Spillway/Outlet Works			3,564,000,000
Early Warning System	2,600,000	2,600,000	2,600,000
Environmental Mitigation	20,900,000	200,000	21,000,000
Subtotal	722,200,000	2,511,100,000	4,229,200,000
Contingency (30%)	216,700,000	753,300,000	1,268,800,000
Total First Costs	938,900,000	3,264,400,000	5,498,000,000

Annual Costs, financial

	Levee	Channel Excavation	SRS
Annual Excavation Costs	0	212,400,000	0
O&M	939,000	196,000	5,498,000
Total Annual Costs	939,000	212,596,000	5,498,000

Special Future Costs (every 10 years)

	Levees	Channel Excavation	SRS
Major Maintenance	0	0	30,000,000

Present Value of Economic Costs, 1994 Base

	Levee	Channel Excavation	SRS
First Costs	734,000,000	2,547,000,000	3,854,000,000
Annual Costs	5,392,000	1,319,000,000	25,000,000
Future Special Costs	0	0	8,080,000
Total	739,000,000	3,866,000,000	3,887,000,000

Investment Analysis (Mean Case)

	Levee	Channel Excavation	SRS
Net Benefits	168,000,000	(2,959,000,000)	(3,000,000,000)
BCR	1.2	0.2	0.22
IRR (percent)	18	N/A	N/A

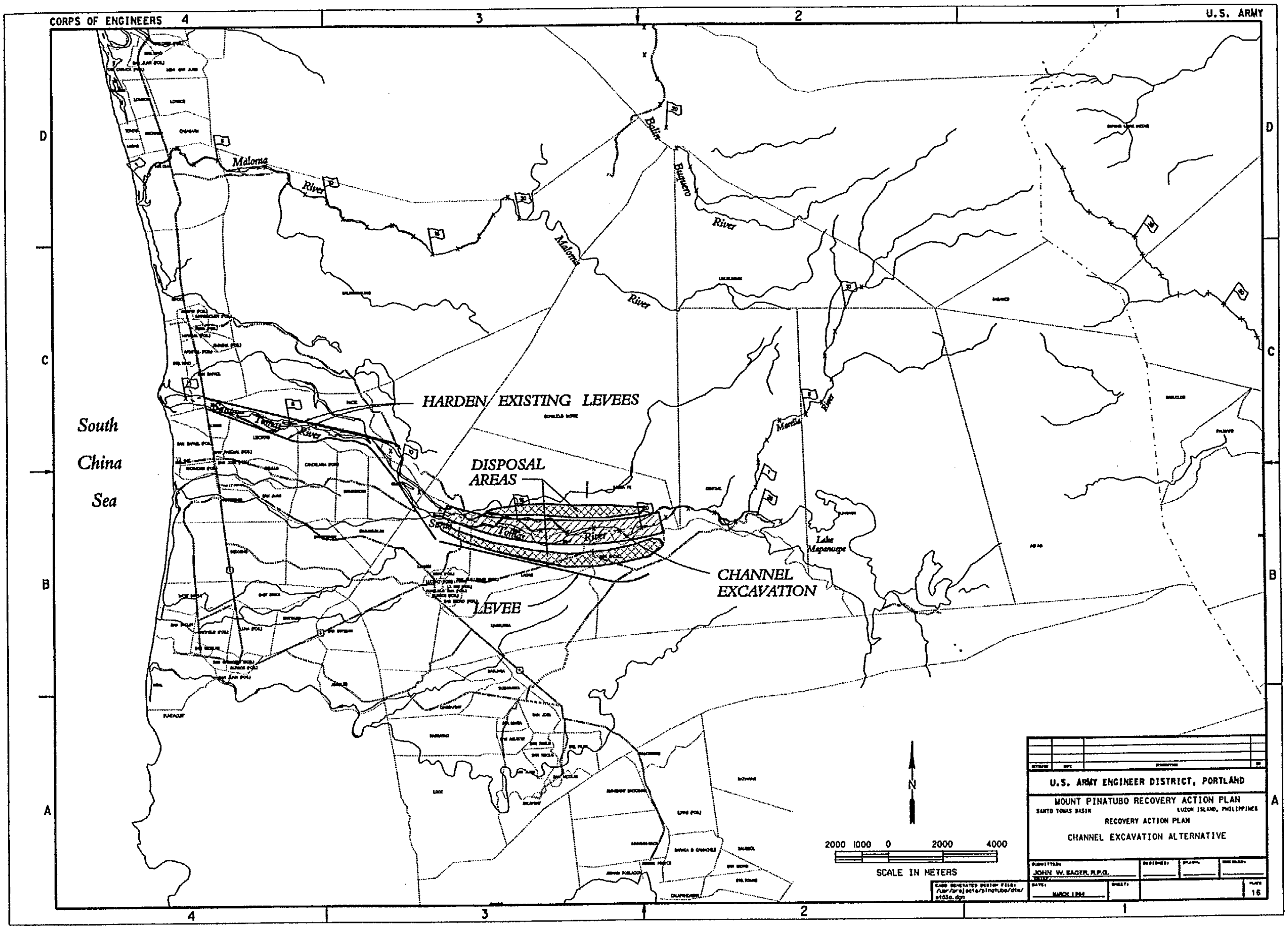

CORPS OF ENGINEERS
U.S. ARMY
South
China
Sea
Maloma
River
Balin
Buquero
River
Maloma
River
HARDEN EXISTING LEVEES
DISPOSAL
AREAS
Santo
Tomas
River
CHANNEL
EXCAVATION
LEVEE
Lake
Mapanuepe
2000 1000 0 2000 4000
SCALE IN METERS
U.S. ARMY ENGINEER DISTRICT, PORTLAND
MOUNT PINATUBO RECOVERY ACTION PLAN
RECOVERY ACTION PLAN
CHANNEL EXCAVATION ALTERNATIVE
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Plate 16

• Maintain Existing Levee: The existing levee on the left bank from high ground west of Vega Hill and downstream to the Highway 7 Bridge will be maintained.

• Levee from RK 2 to RK 10: A levee 3 meters high with slope and toe protection, and a sodded back slope would be constructed on the right bank following the existing alignment.

• Early Warning System. This feature, as described for the levee alternative, also would be required.

Results of Action. The channel excavation and berms are designed to contain mudflows and sediments forecast to be deposited in this reach during a 100-year event. To maintain this protection, it is necessary to perform annual channel excavation. The channel excavation combined with the levees provides protection from sedimentation and flooding to the same areas as protected by the levee alternative. Channel excavation reduces the volume of material which must be carried through the river system, and reduces the risk of sediment damage to the Highway 7 bridge.

Cost Summary and Investment Analysis. A summary of costs for the channel excavation alternative is shown on table 13. On the average, this alternative eliminates about P907 million in damages in the Santo Tomas basin. The present value of economic costs for this alternative is about P3.9 billion. The investment analysis is shown in table 13 and for the mean case, this alternative has negative net benefits of about P(2.9) billion and a BCR of 0.2.

Environmental and Social Effects. The channel excavation alternative provides an enhanced level of protection to existing human settlements, agricultural lands and critical infrastructure. Areas within the levee alignments are already impacted and no households, livelihoods or sensitive environmental habitats will be displaced. Sediment transport to downstream reaches is reduced, resulting in less disturbance to coastal habitats and fisheries. Conversion of impacted land to disposal areas will occur, and when filled, the disposal areas may serve for potential use for residential and industrial development. Excavation and disposal of sediments to maintain protection require a long-term commitment of funding.

Sediment Retention Stucture Alternative

The sediment retention structure alternative for the Santo Tomas basin consists of the following features (see plate 17).

• Embankment Dam and Outlet Works: A earth and rock fill structure 45 meters high would be constructed at RK 7 on the Marella River. The spillway and outlet works would be cut into the right abutment. The spillway would be concrete-lined with a crest elevation 10 meters below the crest of the embankment dam.

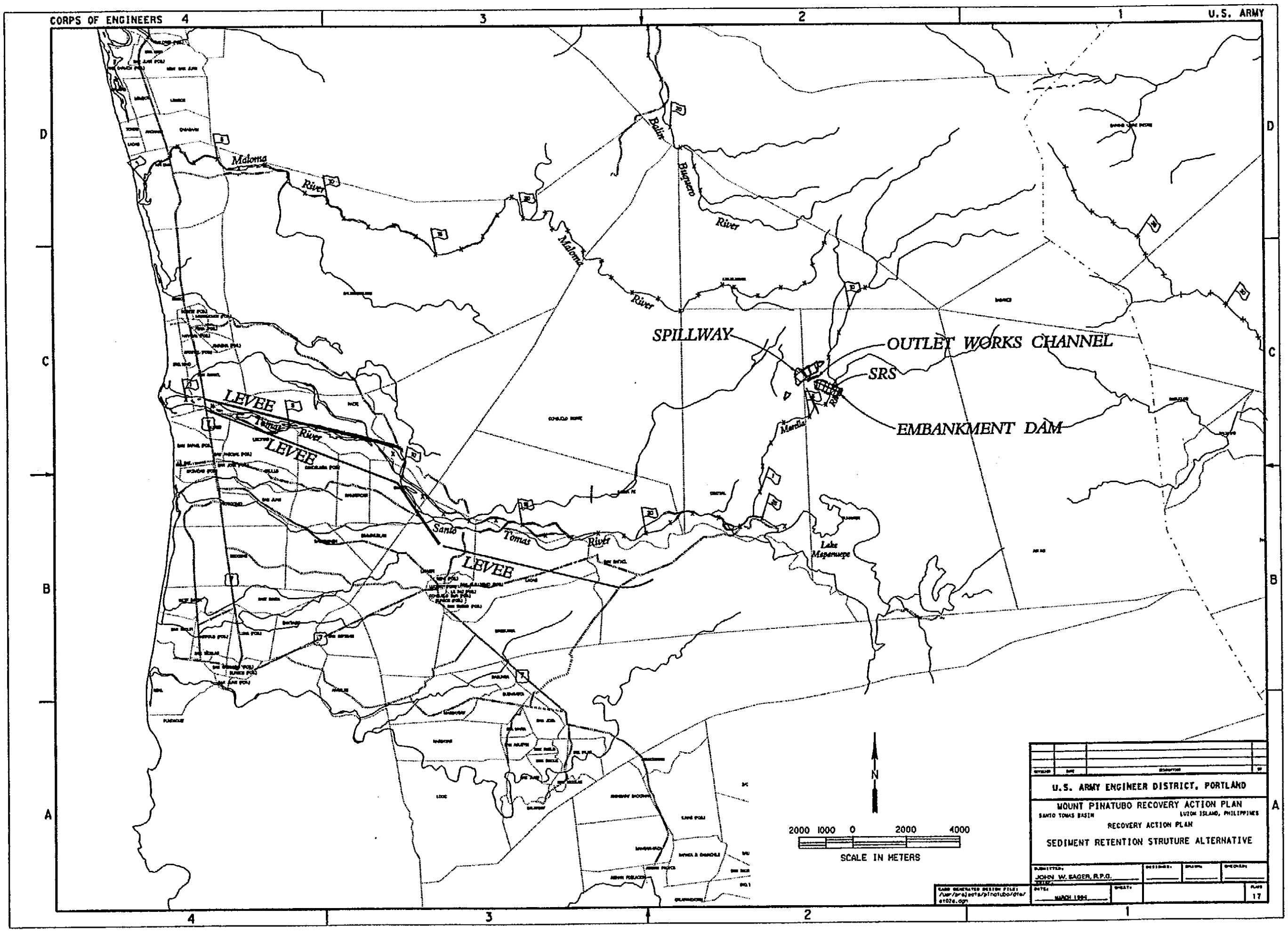
CORPS OF ENGINEERS
U.S. ARMY
Maloma River
Balin Baquero River
SPILLWAY
OUTLET WORKS CHANNEL
SRS
EMBANKMENT DAM
LEVEE
Tomas River
LEVEE
Santo Tomas River
LEVEE
Lake Mapanuepe
2000 1000 0 2000 4000
SCALE IN METERS
U.S. ARMY ENGINEER DISTRICT, PORTLAND
MOUNT PINATUBO RECOVERY ACTION PLAN
SANTO TOMAS BASIN
LUZON ISLAND, PHILIPPINES
RECOVERY ACTION PLAN
SEDIMENT RETENTION STRUTURE ALTERNATIVE
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Plate 17

The outlet works would not be controlled and consist of one meter culverts through a concrete gravity structure. Levees are required to protect downstream areas prior to construction of the SRS and after the SRS has filled with sediment.

- Levees from RK 12.5 to RK 20, RK 10 to RK 12.5, RK 2-to RK 10, and Early Warning System: These features, as described for the levee alternative, also would be required.

Results of Action. The levees, when used in conjunction with the sediment retention structure, provide protection to the same areas as the levee alternative. The retention structure stores about 40 million m^3 of sediment in addition to the material already in-channel above the structure. This material would no longer be carried through the river system. Once the structure is completed, the river channel will stabilize rapidly allowing the reestablishment of irrigation diversion and river crossings, and reduces the risk of sediment damage to the Highway 7 bridge.

Cost Summary and Investment Analysis. A summary of costs for the sediment retention structure alternative is shown on table 13. On the average, this alternative eliminates about P723 million in damages in the Santo Tomas basin. The present value of economic costs for this alternative is about P3.9 billion. The investment analysis is shown in table 13 and for the mean case, this alternative has negative net benefits of about P(3) billion, and a BCR of 0.2.

Environmental and Social Effects. The retention structure alternative will enhance protection to existing human settlements, agricultural lands, and critical infrastructure. Impacts similar to the levee alternative are expected to occur until the retention structure is complete (4 to 7 years). Until complete, a significant amount of sediment will enter the river system and affect downstream reaches. Upon completion, the primary source of sediment is greatly reduced, resulting in less disturbance to coastal habitats and fisheries.

Remaining Aeta communities would not be affected by the siting and operation of the retention structure. Possible disturbance to historical resources may occur because of the recorded history and identified sites in the area. In the unlikely event of a structural failure, the potential exists for a sudden surge of sediments downstream, which may threaten critical infrastructure and communities. The potential reservoir which could form behind the completed SRS may extend the local malaria problem reported for nearby Lake Mapanuepe.

Nonstructural Alternative

The nonstructural alternative consists of permanent evacuation for all populated areas along the Santo Tomas basin threatened with imminent destruction by sediment flows. Flooding/ponding levels are expected to be shallow so temporary evacuation of residents is the only action considered to be necessary and can be accomplished under the GOP's evacuation program. Improving the early warning system described previously also is suggested.

The primary benefit of the nonstructural alternative is removing people from harms way in areas threatened by sediment flows. Since there is no protection provided to assets or production, substantial damages would still occur. By removing households from threatened areas, there would be reduced loss of life and health costs. These benefits are not evaluated or quantified in this report and consequently, no cost-benefit analysis is performed. A relocation cost of P100,000 per household is a reasonable cost based on GOP data.

The number of households threatened with imminent destruction by sediment flows was estimated at 1,700 for the Santo Tomas basin. This number likely overstates the total number of households currently at risk. An estimate of households threatened by imminent destruction may range from 25 to 75 percent, or 430 to 1,280 households. Therefore, an estimated cost for permanent evacuation may range from P43 million to P128 million. About P2.6 million would be needed to upgrade the early warning system.

Implementation of the nonstructural alternative may create effects similar to those described for the no action alternative, with the added benefits to public safety of an improved early warning system. The potential nature-induced impacts include continued high levels of uncontrolled sedimentation, blockage or alteration of historic river courses, and resultant flooding of adjacent low-lying areas.

As a highly populated and developed river basin, permanent evacuation would significantly increase demands on rehabilitation programs and resettlement areas, potential off-site impacts to these areas (accelerated land use conversion, depletion of natural forest cover of Mt. Mabalinoc), and affected populations (social and cultural displacement). Based on the experience to date, there will be a continued local resistance to relocation and permanent evacuation in the absence of viable resettlement and livelihood options.

4.5.5 Findings for the Santo Tomas Basin. Three structural alternatives as well as the no action and nonstructural alternatives were evaluated for the Santo Tomas basin. A summary of the differences, advantages, and disadvantages among the alternatives are shown on table 14.

Table 14 -- *Summary of Alternatives, Santo Tomas Basin*

	NO ACTION	LEVEE ALTERNATIVE	CHANNEL EXCAVATION ALTERNATIVE	SEDIMENT RETENTION STRUCTURE ALTERNATIVE	NONSTRUCTURAL ALTERNATIVE
Study Objective Accomplishments	No effective response provided to any objective.	Overall very good response provided to most study objectives.	Overall very good response provided to most study objectives.	Best response provided to the study objectives.	No effective response to any objective except preservation of life.
Construction Considerations and Accomplishments	Without-project condition so no alternatives developed. Loss of life & damages from sediment/floods continues. GOP emergency actions & existing warning systems continues.	Levees protect San Marcelino, San Antonio, San Narcisco, & Castillejos Highway 7 bridge from sediment and flooding.	Provides protection to same areas as in levee alternative. Higher long-term funding costs for annual excavation/disposal.	About 40 million cubic meters of sediment stored. Better flushing/more stabilization of downstream areas because of lower sediment load.	No construction proposed.
Construction Costs (Present Value)	No construction proposed.	First Cost: P939 million Annual Cost: P939 thousand Future Maintenance Cost: 0	First Cost: P3.3 billion Annual Cost: P213 million Future Maintenance Cost: None.	First Cost: P5.5 billion Annual Cost: P5.5 million Future Maintenance Cost (every 10 years): P30 million	Permanent evacuation costs range from P43 to P128 million. Temporary evacuation during flooding via GOP program. Warning System Cost: P2.6 million.
Economic Effects (Present Value)	Average damages estimated at P1.2 billion, mostly to agriculture and structures. Delayed recovery processes.	Economic Cost: P740 million Average Total Benefits: P907 million Mean Net Benefits: P168 million B/C Ratio: 1.2 IRR: 18 percent	Economic Cost: P3.9 billion Average Total Benefits: P907 million Mean Net Benefits: P(2.9) billion B/C Ratio: 0.2 IRR: N/A	Economic Cost: P3.9 billion Average Total Benefits: P723 million Mean Net Benefits: P(3) billion B/C Ratio: 0.2 IRR: N/A	Average damages estimated at P1.2 billion.
Environmental And Social Effects	Coastal habitats & fisheries further impacted by sediment/turbidity. About 56 barangays impacted. About 11,500 ha of agricultural lands impacted. Highway 7 impacted. Public health concerns prolonged.	About +170 households displaced. About 280 ha of agricultural land displaced by new levee. Progressive filling of river channels reduces their transport capability & continues downstream impacts. Public information, monitoring, and maintenance programs required.	No households or sensitive habitats displaced. Sediment transport downstream reduced which reduces impacts to coastal habitats/fisheries. Disposal sites may serve future uses for residential/ industrial development.	Similar impact areas/concerns as for levee alt until SRS complete (4-7 yrs). Significant amt of sediment affects downstream habitats until SRS complete. Upon completion of SRS, source of downstream impacts significantly lower. Possible disturbance to historical resources.	Effects similar to No Action, but improved public safety because of early warning system.

4.6 Bucao River Basin

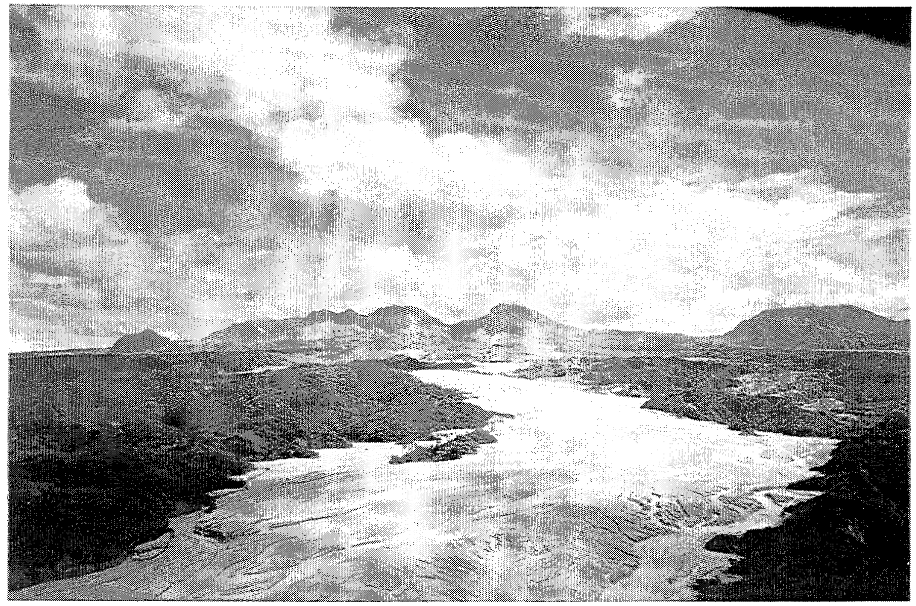
4.6.1 Specific Conditions. The Bucao basin is 656 km^2 in area, extending in a northwesterly direction from Mount Pinatubo and southwesterly from the Zambales Mountains to the South China Sea (see figure 1). The basin incorporates the Bucao River and its two major tributaries, the Balin-Buquero and the Balintawak rivers. The headwaters of the Bucao originate 2 to 5 km north of the crater at an elevation of about 900 meters. The river flows in a generally westerly direction through rugged terrain for about 28 km to its confluence with the Balintawak River at an elevation of about 50 meters. The Bucao then enters a broad flat valley and continues to flow west about 4 km to its confluence with the Balin-Buquero. The Bucao enters the South China Sea about 2 km below Highway 7.

The headwater area of the Balin-Buquero River originates to the south of the Bucao headwater and extends to the crater of Mount Pinatubo at an elevation of about 1,500 meters. The Balin-Baquero and its tributaries drain the western slopes of Mount Pinatubo and the northeastern slopes of the coastal mountains lying between Mount Pinatubo and the South China Sea. The Balin-Baquero flows in a northwesterly direction for about 20 km from the crater to its confluence with the Maronut River at an elevation of about 90 meters. Below the confluence with the Maronut, the Balin-Baquero enters a broad flat valley and continues to flow northwest to its confluence with the Bucao at an elevation of about 40 meters. The drainage area of the Balin-Buquero is about 217 km^2 above its confluence with the Bucao.

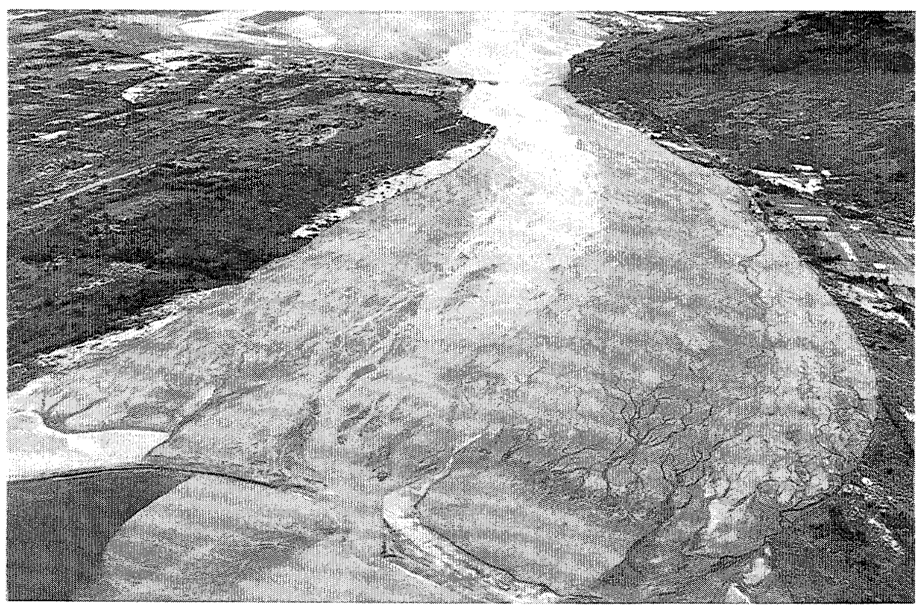
The headwater area of the Balintawak River originates to the north of the Bucao River headwater and drains the southern slopes of the Zambales Mountains at elevations of up to 1,670 meters. The Balintawak River flows in a southwesterly direction through rugged terrain for about 20 km to its confluence with the Bucao at an elevation of 90 meters. The drainage area of the Balintawak River is about 166 km^2 upstream of its confluence with the Bucao River.

The upper reaches of the Bucao basin were blanketed with thick pyroclastic deposits of about 3 billion m^3. These deposits overlay or fill channels carved into pre-existing deposits from previous eruptions. The tributary streams which make up the headwaters of the Bucao contain exposures of older pyroclastic deposits which appear to represent at least two previous eruptive periods. Several very large SPFs occurred in tributary channels in 1992 and the deposits from these events extend for more than 5 km. The lower Bucao flood plain consists of older lahar and alluvial deposits, mostly sand with some gravel and coarser material.

For the Bucao basin, two municipalities are listed as being in the risk areas (see table 4). Figure 16 shows photographs of the sediment deposits and damages in the basin.

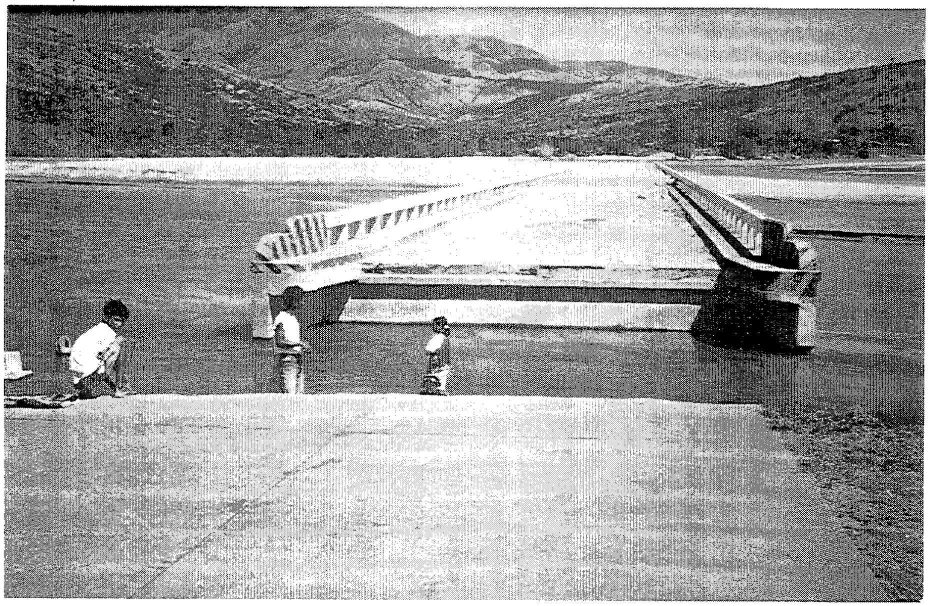


Secondary pyroclastic flow on the Balin-Buquero River, a tributary of the Bucao River.



Sediment deposition at the river's mouth, Highway 7 bridge in background, February 1993.

Figure 16



Damaged bridge crossing the Baquilan River, a tributary of the Bucao, November 1993.

Figure 16 (continued)

The risk areas are estimated to include:

- 7,500 household, commercial, and/or public buildings
- 2,100 ha of agricultural land (rice is dominant crop)
- P20 million in annual crop revenues

Current land cover for the Bucao basin consists primarily of grassland/shrubland (59 percent) followed by sediment deposits (16 percent), woodlands (13 percent), urban areas (6 percent), and agricultural land (5 percnet). The dominant grassland species are talahib and cogon, and shrubby vegetation dominated by hagonoy and small woody trees of mulawin (*Vitex spp)*. Mulawin is favored by the local residents for making charcoal. Patches of secondary forest remain in the mountain zone and are sporadically distributed along both sides of the river basin. Cogon and small scattered trees are the main vegetation in the lower foothills. Paddy rice is the most important crop and coconut, mango and cashew are grown as well. A wetland area has formed since the eruption on the right (north) side of the Bucao River upstream of the National Highway.

Eleven Aeta communities from 11 barangays of Botolan, with an estimated population of 9,392, were displaced by the eruption. These Aeta communities are presently resettled in Loob-Bunga and Baquilan resettlement sites in Botolan. There also was disruption of resource extraction activities such as hunting, farming and fishing. The Bucao River was the main area for gathering fish and shellfish and for potable water for the Aeta communities from Barangays Owaog-Neblac, Poonbato, Burgos and Palis. Other Aeta communities located in higher elevations, such Barangays Cabatuan, Macolcol, Parel, Maguisguis, Villar and Belbel, also were displaced because flooding and mudflows disrupted their resource extraction activities.

The most significant historical landmark in the municipality of Botolan is the Fort Playa Honda, which was built by the Spaniards during the 17th century A.D. Numerous European shards of tradeware ceramics from the 19th century A.D., and Chinese tradeware ceramics from the Ching Dynasty period (16th to 17th centuries A.D.) were found inside the fort. Archaeological sites (burial and habitation) have been reported in the barangays of Belbel, Malomboy, Poonbato, Villar and Palis. These sites are now covered with deep sediment and chances of recovery are minimal. Information gathered from the Aetas indicate that these cultural materials may be Chinese tradeware ceramics and stoneware jars attributed to the Ming Dynasty period (13th to 15th centuries A.D.).

4.6.2 <u>Problem Statement</u>. There is a high risk of mudflows developing in the upper basin of the Bucao and transporting high volumes of sediment into the lower basin. Clean water entering from the Balintawak River increases the transport capabilities of the lower 20 km of the river system. This portion of the river appears able to maintain the appropriate river slope to transport a majority of the incoming sediment to the South China Sea. This lowers the risk of mudflow and flooding hazards in this reach. The risk of failure of Highway 7 and the bridge appear to be low.

4.6.3 Sediment Forecast. Sediment deposition forecasts for the Bucao basin are summarized below. More detailed information can be found in Technical Appendix B located in Volume II of the Long Term Report.

- Initial pyroclastic volume -- 3,000,000,000 m^3
- Erosion volume (1993 to 2002) -- 101,000,000 m^3
- Erosion volume (next 50 years) -- 261,000,000 m^3

An additional 600,000,000 m^3 of sediment eroded in 1991-1992.

4.6.4 Alternatives Under Consideration. The alternatives investigated for the Bucao basin include: no action, levee, sediment retention structure, and nonstructural.

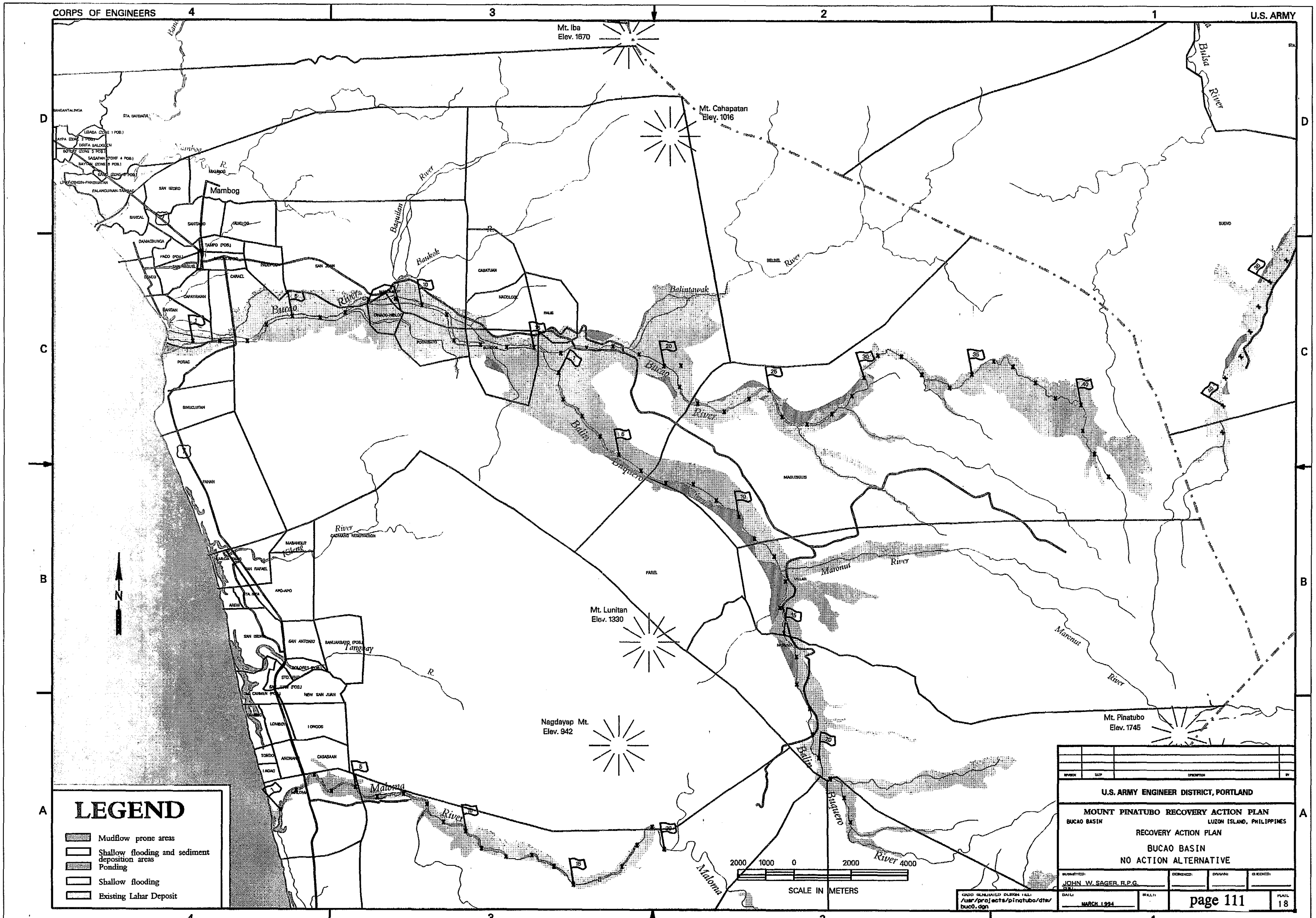
No Action Alternative

Under the no action alternative (without-project condition), no intervention measures are developed to reduce flooding and sediment damages in the Bucao basin. Actions taken by the GOP in emergency situations, and the use of existing warning systems would continue. Plate 18 shows the risk areas expected under the no action alternative.

The average without-project damages (present value) for the Bucao basin are estimated at P250 million. Damages to structures are the highest category at P100 million, followed by infrastructure (P65 million), evacuation/relocation (P36 million), foregone production (P24 million), transportation disruption (P14 million), and agriculture (P11 million).

About 25 barangays from Botolan, involving 2,100 ha of primarily agricultural, residential and commercial land, may be impacted by mudflows, flooding and sedimentation. The potential exists for impacts to the Highway 7 bridge crossing which provides critical public access to north and south Zambales. Continued filling of the riverbed will further bury identified archaeological sites and limit access of displaced Aeta communities in Botolan. Filling of the Bucao channel also may dam the clear water flows of a number of tributaries (Baquilan and Balintawak rivers, Malumbay Creek), creating seasonal lakes and wetlands at the confluence points. Based on the experience provided by nearby Lake Mapanuepe, these bodies of water may encourage the spread of malaria.

Elevated levels of sedimentation would continue to disrupt coastal habitats, though these impacts may be limited due to the presence of a steeply sloping, submarine trench that reaches nearly to the shoreline and mouth of the Bucao River, and serves as the natural repository of most discharged sediments. High levels of turbidity may be transported northward along the coast and could continue to affect the coral reef areas and seagrass beds near Palauig and Masinloc. Public health concerns are prolonged due to poor water quality and drainage, and temporary housing arrangements. Recovery processes (ecological, sociological, and economic) are delayed.



CORPS OF ENGINEERS
U.S. ARMY
Mt. Iba
Elev. 1670
Mt. Cahapatan
Elev. 1016
Mambog
Bucao River
Bankok
Balintawak
Baquilan River
Bulsa River
Balin Buquero
Maronut River
Maloma River
Mt. Lunitan
Elev. 1330
Nagdayap Mt.
Elev. 942
Mt. Pinatubo
Elev. 1745
N
LEGEND
Mudflow prone areas
Shallow flooding and sediment deposition areas
Ponding
Shallow flooding
Existing Lahar Deposit
2000 1000 0 2000 4000
SCALE IN METERS
U.S. ARMY ENGINEER DISTRICT, PORTLAND
MOUNT PINATUBO RECOVERY ACTION PLAN
BUCAO BASIN
LUZON ISLAND, PHILIPPINES
RECOVERY ACTION PLAN
BUCAO BASIN
NO ACTION ALTERNATIVE
JOHN W. SAGER, R.P.G.
MARCH 1994
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page 111
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Levee Alternative

The levee alternative for the Bucao basin consists of the following features (see plate 19).

- Levee Raise from RK 2.5 to RK 8: The existing right bank levee located upstream of the Highway 7 bridge would be raised to a height of 7 meters between RK 2.5 and RK 5.5, and would transition from 7 meters at RK 5.5 to 9 meters at RK 8. Slope and toe protection would be added to the levee.

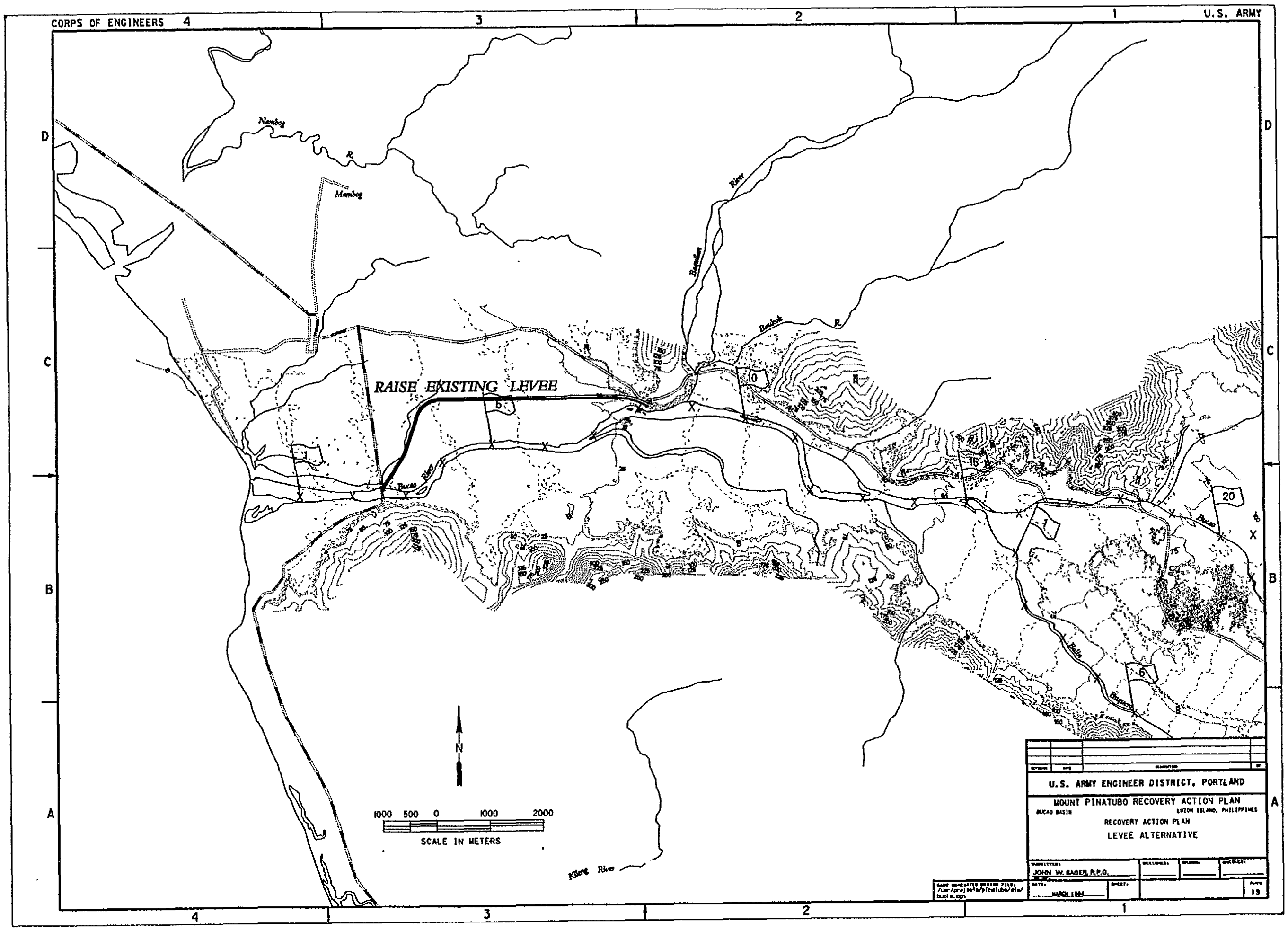
- Slope and Toe Protection. Slope and toe protection would be added to the channel banks below the Highway 7 bridge.

- Early Warning System. Existing warning systems consist of rain gages, sediment flow sensors, and observation posts. Adding sirens or loud speakers to alert people in downstream communities would be an effective way to improve public safety.

Results of Action. The levee system has been designed to contain mudflows and sediments forecast to be deposited in this reach during the next 10 years, and with sufficient capacity at the end of this period to provide protection against a 100-year event. The levee provides significant protection from sedimentation and flooding to portions of Botolan, Iba, Highway 7, and the local transportation routes located outside of the leveed area in the Botolan right inner and outer impact zones (see figure 17 for location of impact zones).

All sediments produced by this basin must be either stored in-channel or passed under the Highway 7 bridge to the South China Sea. Sediment deposits may eventually achieve an elevation higher than the bridge, causing it to be damaged unless raised. Slope protection on the channel banks below the Highway 7 bridge are designed to prevent migration of the channel and to insure that it maintains maximum sediment transport capability. This helps insure the safety of the Highway 7 bridge.

Cost Summary and Investment Analysis. A summary of construction costs (first costs), annual future and special future costs, and the present value of economic costs for the levee alternative is shown in table 15. On the average, this alternative will eliminate about P211 million in damages in the Bucao basin. The present value of economic costs for this alternative is about P155 million. The investment analysis is shown in table 15 and for the mean case, this alternative has positive net benefits (net present value) of about P56 million and a BCR of 1.4.



CORPS OF ENGINEERS
U.S. ARMY
RAISE EXISTING LEVEE
Nambog
R.
River
Kileng River
SCALE IN METERS
1000 500 0 1000 2000
N
U.S. ARMY ENGINEER DISTRICT, PORTLAND
MOUNT PINATUBO RECOVERY ACTION PLAN
BUCAO BASIN
LUZON ISLAND, PHILIPPINES
RECOVERY ACTION PLAN
LEVEE ALTERNATIVE
JOHN W. SAGER, R.P.G.
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Plate 19

Figure 17 -- *Lower Bucao Basin Impact Zones*

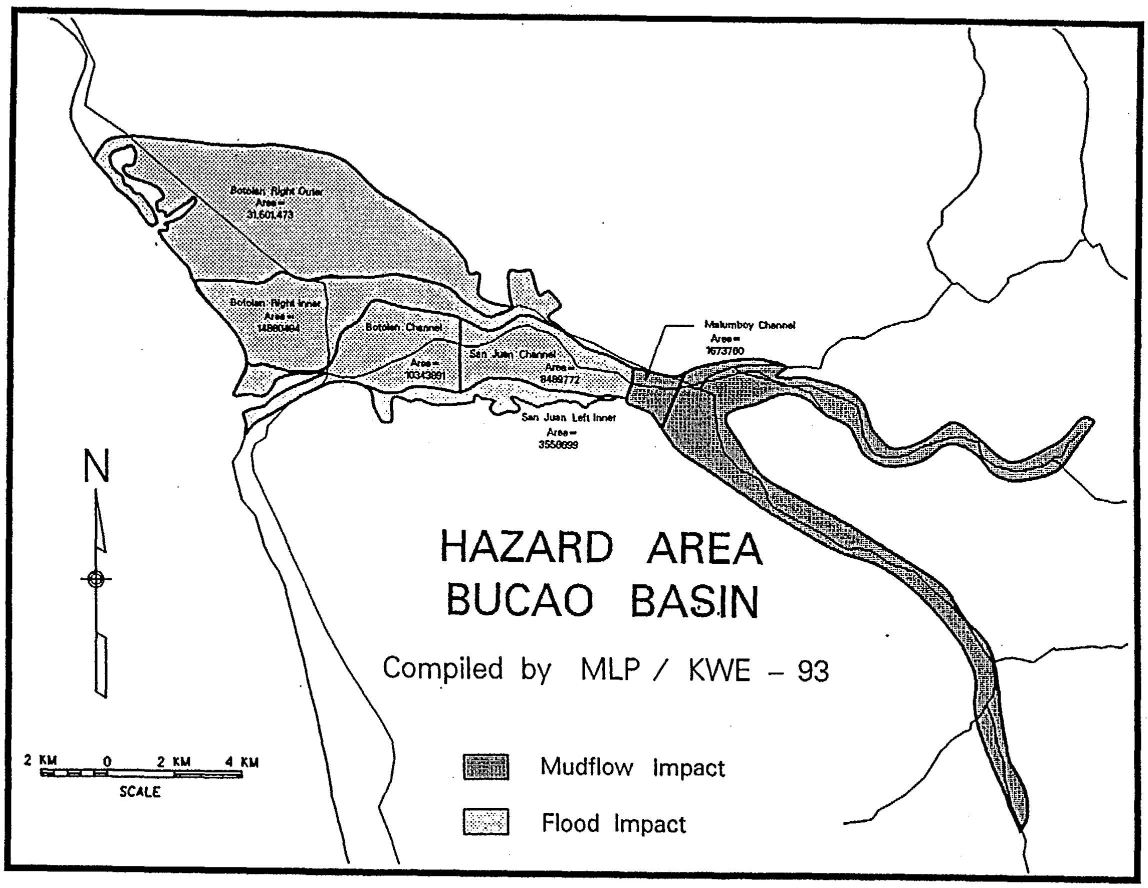

Table 15 -- *Costs for Alternatives, Bucao Basin (pesos)*

Construction Costs (first costs)

	Levee	SRS
Levee Raise w/ Slope & Toe Protection	140,800,000	34,000,000
Dam with Spillway & Outlet		3,577,500,000
Early Warning System	2,600,000	2,600,000
Environmental Mitigation	200,000	200,000
Subtotal	143,600,000	3,614,300,000
Contingency (30%)	43,100,000	1,084,300,000
Total First Costs	186,700,000	4,698,600,000

Annual Costs, financial

	Levee	SRS
O&M	186,700	4,700,000
Total Annual Costs	186,700	4,700,000

Special Future Costs (every 10 years)

	Levee	SRS
SRS Maintenance	0	30,000,000

Present Value of Economic Costs, 1994 Base

	Levee	SRS
First Costs	154,000,000	3,288,000,000
Annual Costs	1,000,000	22,000,000
Future Special Costs	0	8,000,000
Total (Pesos)	155,000,000	3,318,000,000

Investment Analysis (Mean Case)

	Levee	SRS
Net Benefits	56,000,000	(3,000,000,000)
BCR	1.4	< 0.1
IRR (percent)	17	N/A

<u>Environmental and Social Effects</u>. The levee alternative provides an enhanced level of protection to existing human settlements, agricultural lands, and critical infrastructure (Highway 7). Areas within the levee alignments are already impacted and no existing households, livelihoods or sensitive environmental habitats will be displaced. Due to the natural confinement of sediment flows through the Bucao channel and the limited confinement provided by the levees, sedimentation and turbidity impacts to coastal habitats could slightly increase over the no action alternative. Sensitive coastal habitats include coral reef areas and seagrass beds located to the north off the coast Palauig and Masinloc.

Natural recovery (revegetation) processes are anticipated to be long-term due to the large volume of sediment deposition forecast for the next 10 to 50 years. Natural revegetation to grasslands will occur more rapidly in the low-lying, moist areas of the coastal plain. Filling of the Bucao channel would continue to dam the clear water flows of a number of tributaries, creating seasonal lakes and wetlands at the confluence points. Based on the experience provided by Lake Mapanuepe, these created bodies of water may encourage the spread of malaria. Also, dredging and channel excavation may be required below the Highway 7 bridge to prevent shoaling at the mouth of the river.

Sediment Retention Structure Alternative

The sediment retention structure alternative for the Bucao basin consists of the following features (see plate 20).

- Embankment Dam and Outlet Works: An earth and rock fill structure 54 meters high would be constructed at RK 13. The spillway and outlet works would be cut into the right abutment. The spillway would be 300 meters wide with a concrete lining and crest at 10 meters below the crest of the embankment dam. The outlet works are uncontrolled and consist of 1 meter culverts through a concrete gravity structure.

- Levee from RK 2 to RK 8: Slope and toe protection would be added to the existing right bank levee located upstream of the Highway 7 bridge.

- Slope and Toe Protection, and Early Warning System: This feature, as described for the levee alternative, also would be required.

<u>Results of Action</u>. The existing levee with slope and toe protection, when used in conjunction with the retention structure, provides significant protection to the same areas as in the levee alternative. The retention structure stores about 1,045 million m^3 of sediment in addition to the material already in-channel above the structure. This material would no longer be available to be carried through the system. Once the structure is completed, the channel stabilizes rapidly allowing the reestablishment of irrigation diversion and river crossings, and reduces the risk of sediment damage to the Highway 7 bridge.

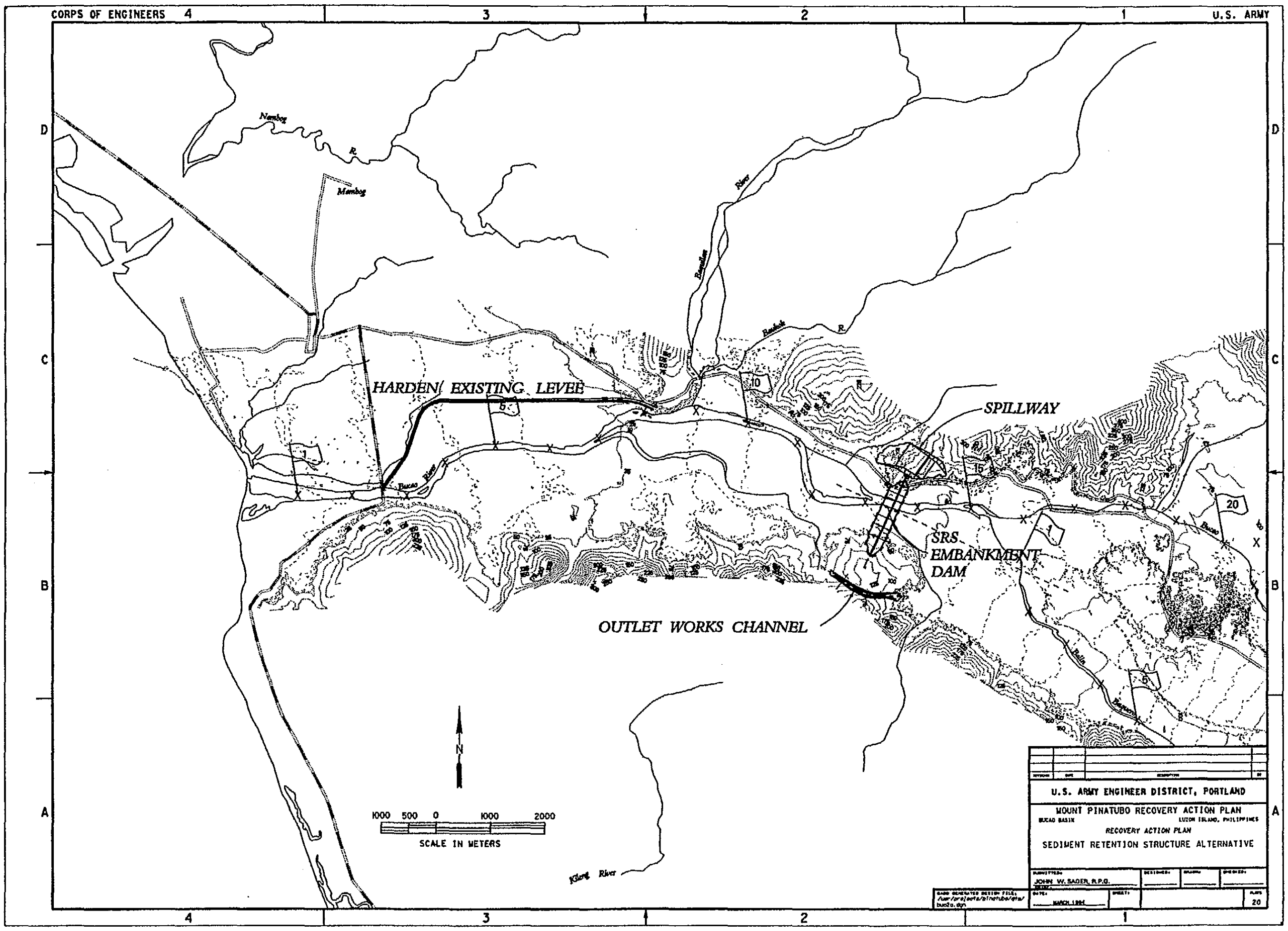
CORPS OF ENGINEERS
U.S. ARMY
HARDEN EXISTING LEVEE
SPILLWAY
SRS
EMBANKMENT
DAM
OUTLET WORKS CHANNEL
1000 500 0 1000 2000
SCALE IN METERS
N
U.S. ARMY ENGINEER DISTRICT, PORTLAND
MOUNT PINATUBO RECOVERY ACTION PLAN
LUZON ISLAND, PHILIPPINES
RECOVERY ACTION PLAN
SEDIMENT RETENTION STRUCTURE ALTERNATIVE
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Plate 20

Cost Summary and Investment Analysis. A summary of costs for the sediment retention structure alternative is shown on table 15. On the average, this alternative will eliminate about P224 million in damages in the Bucao basin. The present value of economic costs for this alternative is about P3.3 billion. The investment analysis is shown in table 15 and for the mean case, this alternative has negative net benefits (net present value) of about P(3) billion, and a BCR less than 0.1.

Environmental and Social Effects. The retention structure alternative provides an enhanced level of protection to existing human settlements, agricultural lands and critical infrastructure. Impacts similar to the levee alternative are expected to occur until the retention structure is complete (4 to 7 years). Until complete, a significant amount of sediment will enter the river system and affect downstream reaches. Upon completion in-valley sediment above the retention structure are stabilized, and an additional 1,045 million m^3 of sediment can be stored. This results in less disturbance to coastal habitats and fisheries.

Possible disturbance to historical resources may occur because of the recorded history and identified sites in the area attributed to the Sung Dynasty period (960-1270 A.D.). Remaining Aeta communities would not be affected by the siting or operation of the retention structure. In the unlikely event of a structural failure, the potential exists for a sudden surge of sediments downstream, which may threaten critical infrastructure and communities. The potential reservoir which could form behind the completed SRS may extend the local malaria problem which has been reported for Lake Mapanuepe.

Nonstructural Alternative

The nonstructural alternative consists of permanent evacuation for all populated areas along the Bucao basin threatened with imminent destruction by sediment flows. Flooding and ponding levels are expected to be shallow so temporary evacuation of residents is the only action considered to be necessary in these areas and can be accomplished under the GOP's evacuation program. Improving the early warning system also is suggested.

The primary benefit of the nonstructural alternative is removing people from harms way in areas threatened by sediment flows. Since there is no protection provided to assets or production, substantial damages would still occur. By removing households from threatened areas, there would be reduced loss of life and health costs. These benefits are not quantified in this report and consequently, no cost-benefit analysis is performed. A relocation cost of P100,000 per household appears reasonable based on GOP data.

The number of households threatened with imminent destruction by sediment flows was estimated at 800 for the Bucao basin. This number likely overstates the total number of households currently at risk. An estimate of threatened households may range from 25 to 75 percent, or 200 to 600 households. Therefore, an estimated cost for permanent evacuation may range from P20 million to P60 million. About P2.6 million would be needed to upgrade the early warning system.

Implementation of the nonstructural alternative may create effects similar to those described for the no action alternative, with the added benefits to public safety of an improved early warning system. The potential nature-induced impacts include continued high levels of uncontrolled sedimentation, blockage or alteration of historic river courses, and resultant flooding of adjacent low-lying areas.

As a moderately populated and developed river basin, permanent evacuation would increase demands on rehabilitation programs and resettlement areas, potential off-site impacts to these areas (accelerated land use conversion of upland sites), and affected populations (social displacement). Due to natural topography of the area, resettlement sites would tend to be localized, and may include coastal areas and foothills outside of the Bucao basin.

4.6.5 Findings for the Bucao Basin. Two structural alternatives as well as the no action and nonstructural alternatives were evaluated for the Bucao basin. A summary of the differences, advantages, and disadvantages among the alternatives is shown on table 16.

Table 16 -- *Summary of Alternatives, Bucao Basin*

	NO ACTION	LEVEE ALTERNATIVE	SEDIMENT RETENTION STRUCTURE ALTERNATIVE	NONSTRUCTURAL ALTERNATIVE
Study Objective Accomplishments	No effective response provided to any objective.	Fair to good response provided to most study objectives.	Overall good response provided to the study objectives.	No effective response to any objective except preservation of life.
Construction Considerations and Accomplishments	Without-project condition so no alternatives developed. Loss of life & damages from sediment/floods continues. GOP emergency actions & existing warning systems continues.	Levees protect portions of Botolan, Iba, Hwy 7, and local routes. Slope/Toe protection prevents impacts to Highway 7 bridge.	About 1 billion cubic meters of sediment stored. Better flushing/more stabilization of downstream areas because of lower sediment load.	No construction proposed.
Construction Costs (Present Value)	No construction proposed.	First Cost: P187 million Annual Cost: P200 thousand Future Maintenance Cost: 0	First Cost: P4.7 billion Annual Cost: P4.7 million Future Maintenance Cost (every 10 years): P30 million	Permanent evacuation costs range from P20 to P60 million. Temporary evacuation during flooding via GOP program. Warning System Cost: P2.6 million.
Economic Effects (Present Value)	Average damages estimated at P250 million, mostly to structures and infrastructure. Delayed recovery processes.	Economic Cost: P155 million Average Total Benefits: P211 million Mean Net Benefits: P56 million B/C Ratio: 1.4 IRR: 17 percent	Economic Cost: P3.3 billion Average Total Benefits: P224 million Mean Net Benefits: P(3) billion B/C Ratio: 0.1 IRR: N/A	Average damages estimated at P250 million.
Environmental And Social Effects	Significant siltation continues & disrupts coastal habitats. About 25 barangays impacted. About 2,100 ha of land impacted. High levels of turbidity continue to impact coral reef and seagrass. Highway 7 bridge impacted. Public health concerns prolonged.	No households or sensitive habitats displaced. Slight increase in sedimentation & turbidity impacts over No Action, which may impact coral reef areas and seagrass beds. Natural revegetation long-term due to large amt of sediment deposition.	Similar impact areas/concerns as for levee alt until SRS complete (4-6 yrs). Significant amt of sediment affects downstream habitats until SRS complete. Upon completion of SRS, source of downstream impacts significantly lower. Possible disturbance to historical resources. No Aeta communities affected.	Effects similar to No Action, but improved public safety because of early warning system.

4.7 Maloma River Basin

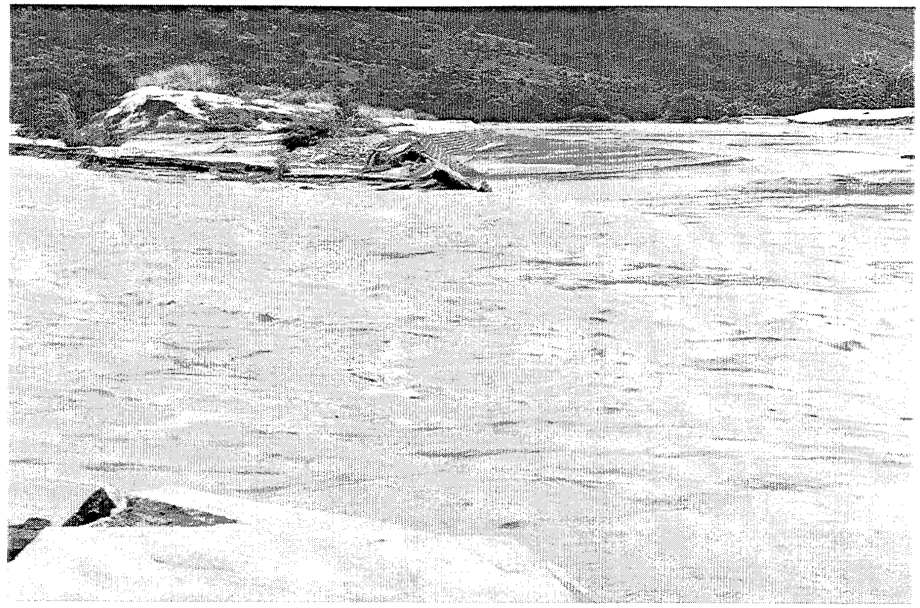
4.7.1 Specific Conditions. The Maloma basin is 150 km^2 in area, originating southwest of Mount Pinatubo and extending westerly to the South China Sea (see figure 1). The Maloma basin includes two major rivers, the Gorongoro-Kakilingar and the Maloma, which join about 6 km upstream of the Highway 7 bridge before discharging into the South China Sea. The basin drains the coastal mountains and drainage of Mount Pinatubo itself is limited to the extreme eastern headwaters of the Maloma River which extend to the lower southwest slopes at an elevation of about 600 meters. The Gorongoro-Kakilingar River originates entirely from the coastal mountains and flows westward in a deep narrow valley. Elevations in the Maloma basin range from sea level to about 1,000 meters, with the highest elevations occurring in the coastal mountains. The Maloma basin is essentially a relatively narrow valley over its length and flows through mountainous terrain over its distance. Most of the sediment in this basin comes from airfall deposition of ash. The only sediment available for future mudflows is the sediment presently in-channel because only the channel in the upper headwaters contains pyroclastic flow deposits.

For the Maloma basin, two municipalities are listed as being in the risk areas (see table 4). Figure 18 shows a photograph of flooding and sediment damage in the basin. The risk areas are estimated to include:

- 1,400 household, commercial, and/or public buildings
- 700 ha of agricultural land (rice is dominant crop)
- P6.6 million in annual crop revenues

Current land cover for the Maloma basin consists primarily of grassland/shrubland (73 percent), followed by agricultural land (12 percent), urban areas (7 percent), woodlands (5 percent), and sediment deposits (3 percent). The upper reaches of the basin is characterized by mountains and hills and is generally bare of forest cover. The dominant vegetative cover is grassland dominated by talahib and cogon, interspersed with shrubby hagonoy and small woody trees of *Vitex spp*. Land use in the flat lands is mainly agriculture planted to rice, which is the most important crop. At the mouth of the Maloma, Tanguay and Bucao rivers, residual beach forest species of agoho and talisay are present. There are Aeta communities in the coastal area of Barangay Maloma in the municipality of San Felipe.

4.7.2 Problem Statement. Ash is the source causing the main sediment problem on the Maloma basin because the upper drainage does not contain a significant amount of pyroclastic deposits. Sediment transport downstream has resulted in channel instability. Bank and bed instability and flooding have resulted. A high risk of flooding remains for the lower basin over the next 5 to 10 years. Localized channel filling will produce overbank flooding and sedimentation. Flooding is the major event that will cause damage. Unstable channel conditions may cause erosion of Highway 7.



Flooding and sediment damage to a levee and bank protection measure at Highway 7 (looking upstream), August 1992.

Figure 18

4.7.3 Alternatives Under Consideration. The alternatives investigated for the Maloma basin include: no action, levee, channel excavation, sediment retention structure, and nonstructural.

No Action Alternative

Under the no action alternative (without-project condition), no intervention measures are developed to reduce the flooding and sediment damages in the Maloma basin. Actions taken by the GOP in emergency situations, and use of existing warning systems would continue. Plate 21 shows the risk areas expected under the no action alternative.

The average without-project damages (present value) for the Maloma basin are estimated at P113 million, with the majority of damages occurring to structures (P83 million). Damages to infrastructure is the second highest category at P15 million, followed by agriculture (P10 million), transportation disruption (P4 million), foregone production (P1 million), and evacuation/relocation (P400 thousand).

Four coastal barangays from the municipality of Cabangan, Barangay Maloma of San Felipe, and about 700 ha of primarily agricultural land could impacted by further flooding and sedimentation. Due to blockage of the Maloma's outlet by sand dunes, this flooding is most serious in the immediate coastal area (Sitio Laoag Sur with about 70 households) during high tide. The impacts include unstable channel conditions, which may impact the critical public access provided by the Highway 7 bridge.

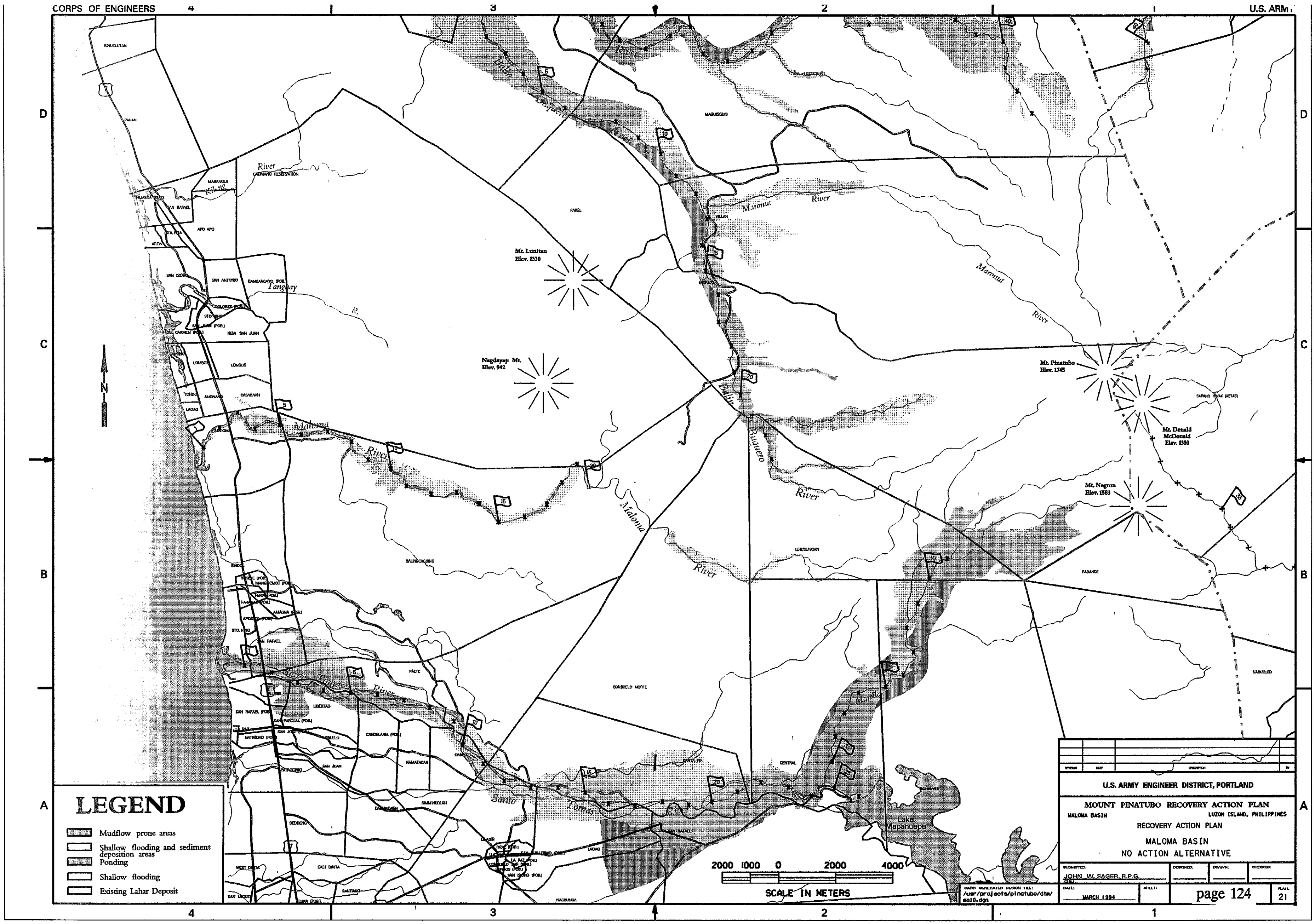
Limited disruption would occur to remaining farming and fishing activities in the impact area. An Aeta community in Barangay Banawen, consisting of about 50 households, will be further disrupted of their traditional fishing activities. Public health concerns are prolonged due to poor water quality and drainage, and temporary housing arrangements. Recovery processes (ecological, sociological, and economic) are delayed.

Levee Alternative

The levee alternative for the Maloma basin consists of the following features (see plate 22).

- Right Bank Levee from RK 2.5 to RK 5: A levee 3 meters high with slope and toe protection, sodded back slope, and bank protection would be constructed on the right bank from the Highway 7 bridge to RK 5 where it ties into high ground.

- Left Bank Levee from RK 2.5 to RK 8.5: A levee 3 meters high with slope and toe protection, sodded back slope, and bank protection would be constructed on the left bank upstream to the mouth of the Gorongoro River, and follows the left bank of the Gorongoro River a distance of 1,100 meters to high ground.



CORPS OF ENGINEERS
U.S. ARMY
LEGEND
Mudflow prone areas
Shallow flooding and sediment deposition areas
Ponding
Shallow flooding
Existing Lahar Deposit
Mt. Lunitan
Elev. 1330
Nagdayap Mt.
Elev. 942
Mt. Pinatubo
Elev. 1745
Mt. Donald McDonald
Elev. 1350
Mt. Negron
Elev. 1583
Maloma River
Bucao River
Bulan River
Maronut River
Santo Tomas River
Tanguay R.
Lake Mapanuepe
2000 1000 0 2000 4000
SCALE IN METERS
U.S. ARMY ENGINEER DISTRICT, PORTLAND
MOUNT PINATUBO RECOVERY ACTION PLAN
MALOMA BASIN
LUZON ISLAND, PHILIPPINES
RECOVERY ACTION PLAN
MALOMA BASIN
NO ACTION ALTERNATIVE
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MARCH 1994
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- New River Channel: A new river channel would be excavated from the Highway 7 bridge to the west along a straight alignment through the sand dunes which presently force the river southward. This allows the river to efficiently transport sediments under the bridge and to the South China Sea. Slope and toe protection would be provided to stabilize the channel.

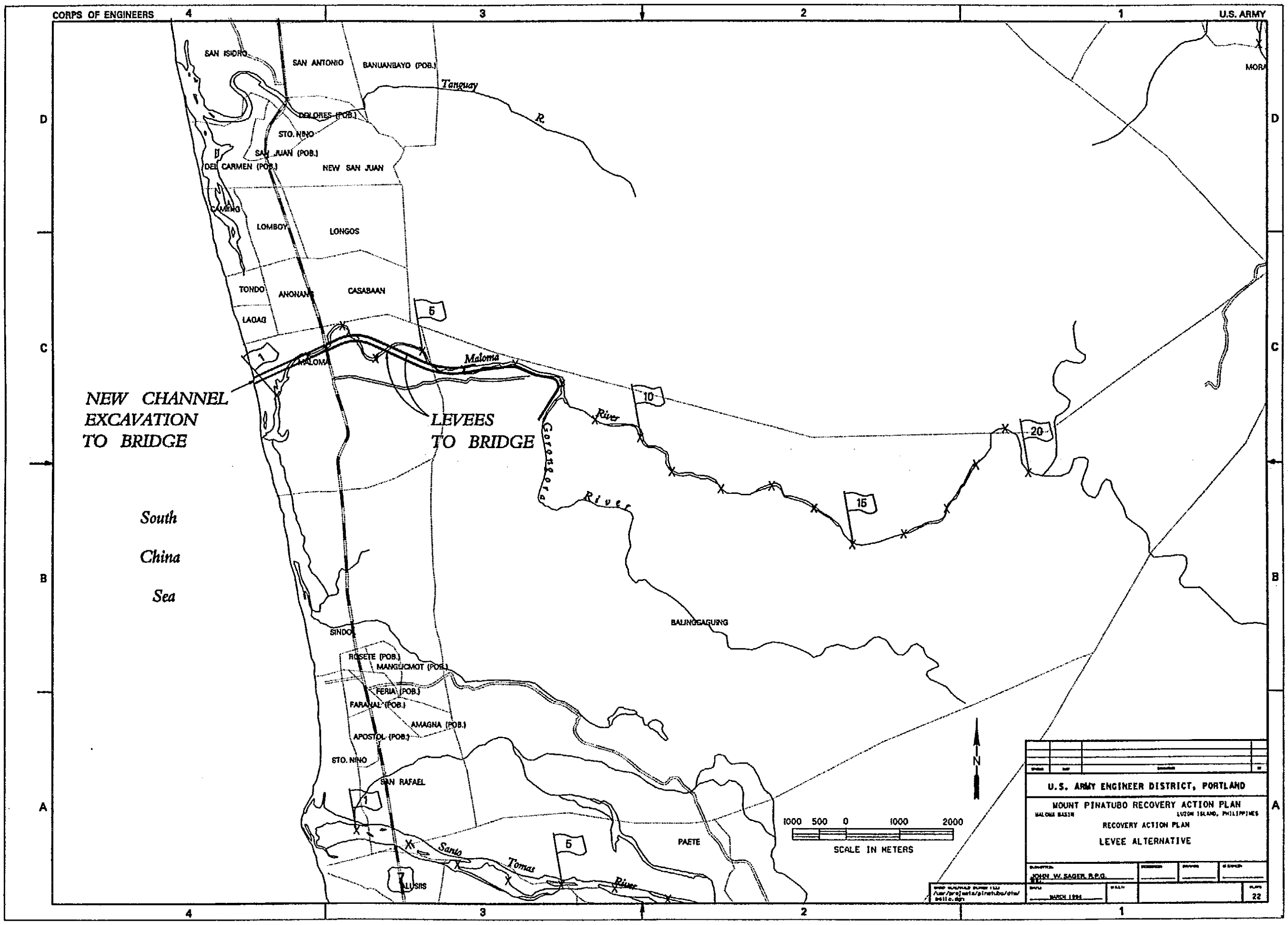
- Early Warning System: Existing warning systems consist of rain gages, sediment flow sensors, and observation posts. Adding sirens or loud speakers to alert people in downstream communities would be an effective way to improve public safety.

Results of Action. The right bank levee provides protection from flooding and sedimentation to portions of Cambangan and to Highway 7. The left bank levee provides protection from flooding and sedimentation to portions of San Felipe and to Highway 7. The two levees insure that flows are directed under the Highway 7 bridge, which reduces the chance for damage to the abutments.

The construction of a straightened channel with slope and toe protection below the Highway 7 bridge increases the efficiency of the river to carry flows and sediment below the bridge, which reduces the hazards to the bridge.

Cost Summary and Investment Analysis. A summary of construction costs (first costs), annual future and special future costs, and the present value of economic costs for the levee alternative is shown in table 17. On the average, this alternative eliminates about P98 million in damages in the Maloma basin. The present value of economic costs for this alternative is P85 million. The investment analysis is shown in table 17 and for the mean case, the levee alternative has positive net benefits (net present value) of about P12 million and a BCR of 1.2.

Environmental and Social Effects. The levee alternative provides an enhanced level of protection to existing human settlements, agricultural lands and critical infrastructure. The proposed realignment of the river channel, channel excavation, and new levees downstream of the Highway 7 bridge crossing would displace about 5 ha of agricultural land. No existing households would be displaced. The river realignment and levee upstream of the Highway 7 bridge would displace about 3 ha of agricultural land and about seven households. Except for these areas and households, all other areas within the designated levee alignment are recently impacted by sediment deposits.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MALOMA
Maloma
River
Gorongoro
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NEW CHANNEL
EXCAVATION
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SCALE IN METERS
U.S. ARMY ENGINEER DISTRICT, PORTLAND
MOUNT PINATUBO RECOVERY ACTION PLAN
RECOVERY ACTION PLAN
LEVEE ALTERNATIVE
JOHN W. SAGER, P.E.
MARCH 1994
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Plate 22

Table 17 -- *Costs for Alternatives, Maloma Basin (pesos)*

Construction Costs (first costs)

	Levee	Channel Excavation	SRS
Levee w/ Slope & Toe Protection	26,200,000		25,900,000
New Channel w/ Slope Protection	34,000,000	34,000,000	34,000,000
Channel Excavation		63,300,000	
Dam w/ Spillway & Outlet			123,400,000
Early Warning System	2,600,000	2,600,000	2,600,000
Environmental Mitigation	1,200,000	4,700,000	400,000
Subtotal	64,000,000	104,600,000	186,300,000
Contingency (30%)	19,200,000	31,400,000	55,900,000
Total First Costs	83,200,000	136,000,000	242,200,000

Annual Costs, financial

	Levee	Channel Excavation	SRS
Annual Excavation Costs	2,360,000	2,360,000	0
O&M	46,000	43,000	206,000
Total Annual Costs	2,406,000	2,403,000	206,000

Special Future Costs (every 10 years)

	Levee	Channel Excavation	SRS
SRS Maintenance	0	0	16,000,000

Present Value of Economic Costs, 1994 Base

	Levee	Channel Excavation	SRS
First Costs	68,000,000	112,000,000	179,000,000
Annual Costs	17,000,000	17,000,000	1,000,000
Future Special Costs	0	0	5,000,000
Total (Pesos)	85,000,000	129,000,000	185,000,000

Investment Analysis (Mean Case)

	Levee	Channel Excavation	SRS
Net Benefits	12,400,000	(31,300,000)	(87,000,000)
BCR	1.2	0.8	0.5
IRR (percent)	16	8	4

Sedimentation and related impacts to coastal habitats and fisheries in the vicinity of new river outlet would be increased under this alternative, as a result of improving the efficiency of moving sediment through the river system and into the South China Sea. Based on local reports, the outlet of the Maloma River has shifted over time, and previously followed the proposed realignment of the river channel, which may account for the lack of residents in the area. The coastal habitats can be described as a steep, sandy to muddy foreshore slopes with limited outcrops of heavily silted and mostly dead coral patch reefs. This alternative would cut-off the existing outlet of the Maloma River, and this portion of the channel may be converted into a community fishpond, according to the mayor of San Felipe.

Channel Excavation Alternative

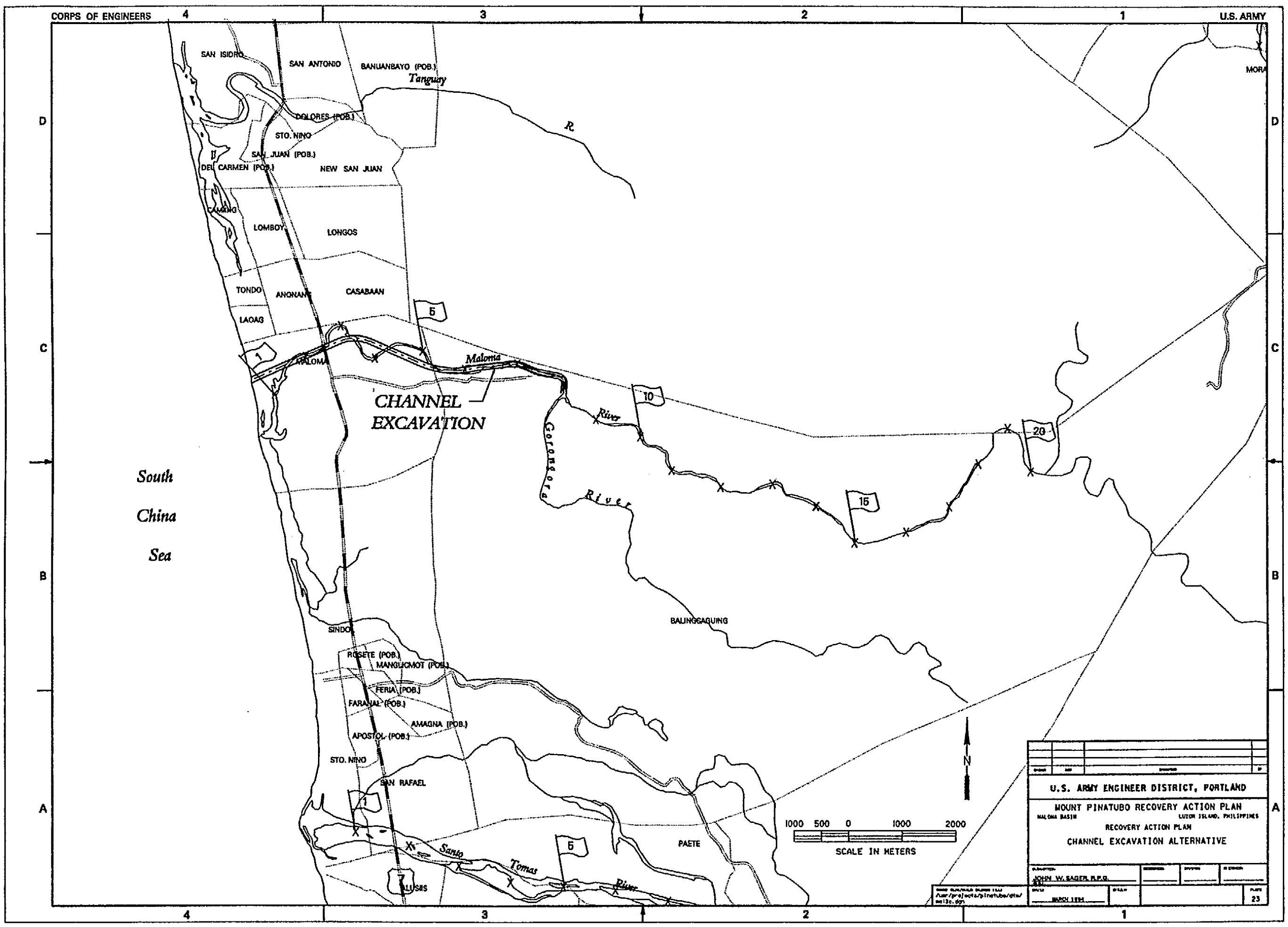
The channel excavation alternative for the Maloma basin consists of the following features (see plate 23).

- Channel Excavation: A channel 100 meters wide and 2 meters deep would be excavated from RK 8 at the mouth of the Gorongoro River to the Highway 7 bridge in order to restore adequate flood protection. Disposal berms of a uniform height would be built with a 100 meter setback from the newly excavated channel.

- New River Channel and Early Warning System: As described for the levee alternative, these features also are required for this alternative.

Results of Action. The channel excavation and berms are designed to contain sediments forecast to be deposited in this reach during a 100-year event. To maintain this protection, it will be necessary to perform periodic channel excavation. Channel excavation provides protection from sedimentation and flooding to the same areas as in the levee alternative. The new channel below the Highway 7 bridge will serve the same function as in the levee alternative. This alternative restores the Maloma to its pre-eruption configuration above the bridge, improves channel capacity below the bridge, and reduces the amount of sediments which must be passed through the system.

Cost Summary and Investment Analysis. A summary of costs for the channel excavation alternative is shown on table 17. On the average, this alternative eliminates about P98 million in damages in the Maloma basin. The present value of economic costs for this alternative is P129 million. The investment analysis is shown in table 17 and for the mean case, the channel excavation alternative has negative net benefits of about P(31) million and a BCR of 0.7.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RECOVERY ACTION PLAN
CHANNEL EXCAVATION ALTERNATIVE
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MARCH 1994
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Plate 23

Environmental and Social Effects. The channel excavation alternative provides an enhanced level of protection to existing human settlements, agricultural lands and critical infrastructure. The proposed realignment of the channel, channel excavation, and new levees downstream of the Highway 7 bridge would displace about 5 ha of agricultural land. No existing households would be displaced. Channel excavation and disposal berms along the river channel upstream of Highway 7 could displace about 100 ha former agricultural lands which are already impacted by sediment deposits. When filled, the disposal areas may serve for potential use for residential and industrial development. Continued removal of in-channel sediments reduces downstream sedimentation, and has positive effects on the restoration of coastal habitats and the associated fisheries. Excavation and disposal of sediments to maintain protection require a long-term commitment of funding.

Sediment Retention Structure Alternative

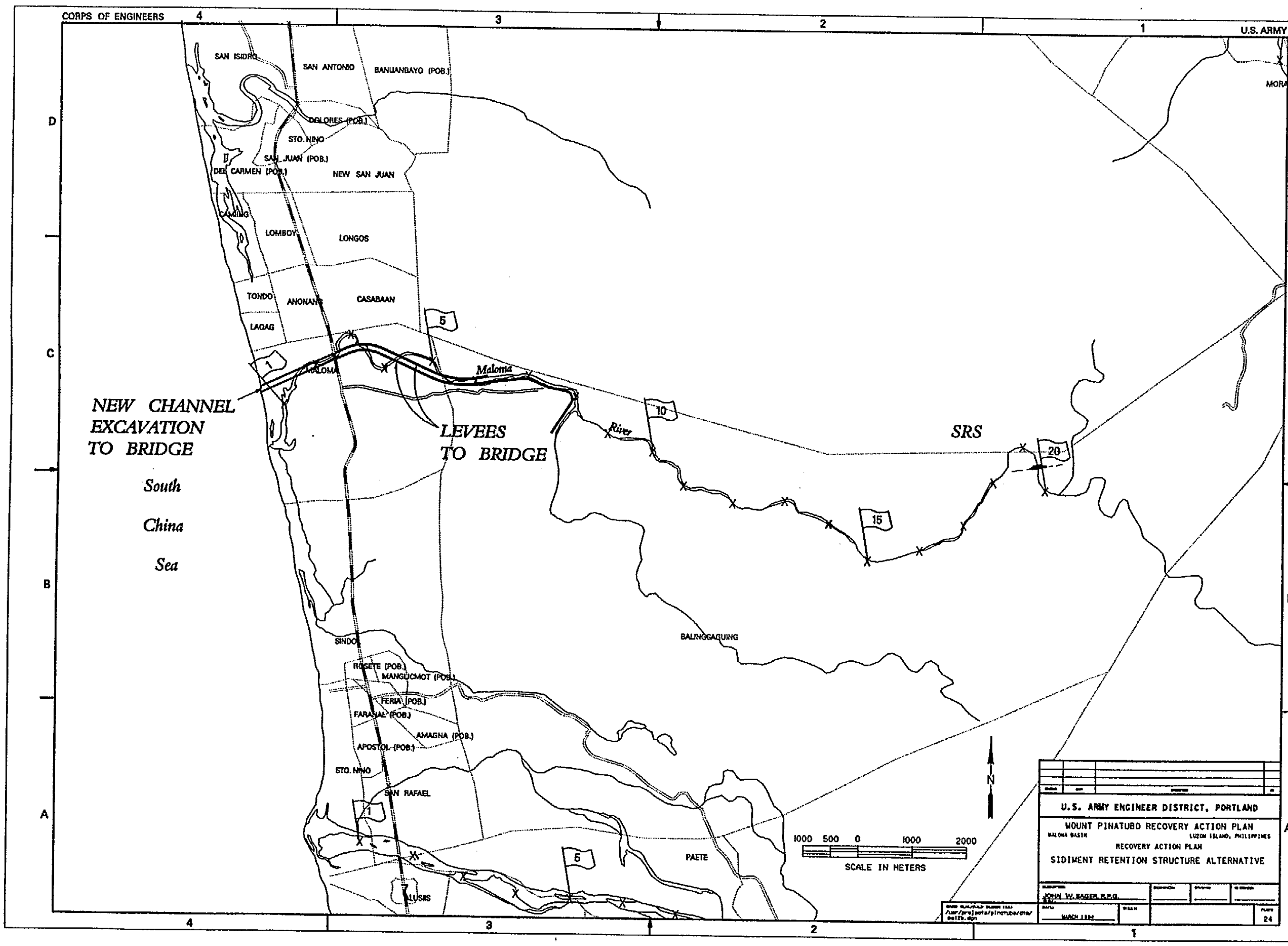
The sediment retention structure alternative for the Maloma basin consists of the following features (see plate 24).

- RCC Gravity Overflow Dam: A RCC dam 18 meters high would be constructed at RK 19.5. This structure would have a centrally located spillway section 120 meters wide.

- Right and Left Bank Levees, New River Channel, and Early Warning System: As described for the levee alternative, these features also are required for this alternative.

Results of Action. The levees, when used in conjunction with the sediment retention structure, provide protection to the same areas as in the levee alternative. The retention structure at RK 19.5 will store about 12 million m^3 of sediment in addition to the material already in-channel above the structure. This material is no longer available to be carried through the system. With the retention structure in place, the river channel will stabilize rapidly allowing the reestablishment of irrigation diversion and river crossings. The risk of sediment damage to the Highway 7 bridge also is reduced.

Cost Summary and Investment Analysis. A summary of costs for the sediment retention structure alternative is shown on table 17. On the average, this alternative eliminates about P98 million in damages in the Maloma basin. The present value of economic costs for this alternative is P185 million. The investment analysis is shown in table 17 and for the mean case, the retention structure alternative has negative net benefits of about P(87) million and a BCR of 0.5.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CASABAAN
LAOAG
MALOMA
Maloma
River
NEW CHANNEL EXCAVATION TO BRIDGE
LEVEES TO BRIDGE
SRS
South China Sea
BALINCAGUING
SINDOL
ROSETE (POB.)
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RECOVERY ACTION PLAN
SIDIMENT RETENTION STRUCTURE ALTERNATIVE
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Plate 24

Environmental and Social Effects. The sediment retention structure alternative provides an enhanced level of protection to existing human settlements, agricultural lands and critical infrastructure. During the design and construction period required for completion of the SRS (4 to 7 years), environmental and social effects would be similar to those described for the levee alternative. Until complete, a significant amount of sediment will enter the river system and affect dowstream reaches. After the SRS is completed, in-valley sediments above the structure are stabilized and an additional 12 million m^3 of sediment can be stored, resulting in reduced disturbance to coastal habitats and fisheries.

It is unlikely that Aeta communities would be affected by the siting and operation of the retention structure. In the unlikely event of a structural failure, a large amount of sediment would be eroded and transported downstream, which may threaten critical infrastructure and communities.

Nonstructural Alternative

No permanent evacuation is condsiered necessary for the Maloma basin since the threat of sediment flows is low. Temporary evacuation of residents is the only action considered necessary for areas threatened by flooding and can be accomplished under the GOP's evacuation program. Improving the early warning system as described previously also is suggested.

Implementation of the nonstructural alternative may create effects similar to those described for the no action alternative, with the added benefits to public safety of an improved early warning system. The potential nature-induced impacts include continued stream bank erosion, high levels of uncontrolled sedimentation, blockage or alteration of historic river courses, and resultant flooding of downstream low-lying areas.

4.7.5 Findings for the Maloma Basin. Three structural alternatives as well as the no action and nonstructural alternatives were evaluated for the Maloma basin. A summary of the differences, advantages, and disadvantages among the alternatives is shown on table 18.

Table 18 -- *Summary of Alternatives, Maloma Basin*

	NO ACTION	LEVEE ALTERNATIVE	CHANNEL EXCAVATION ALTERNATIVE	SEDIMENT RETENTION STRUCTURE ALTERNATIVE	NONSTRUCTURAL ALTERNATIVE
Study Objective Accomplishments	No effective response provided to any objective.	Best response provided to all study objectives.	Fair response provided to most objectives.	Good response provided to most study objectives.	No effective response to any objective except the preservation of life.
Construction Considerations and Accomplishments	Without-project condition so no alternatives developed. Loss of life & damages from sediment/floods continues. GOP emergency actions & existing warning systems continues.	Levees/ new channel protects portions of Cambangan and San Felipe, and Highway 7/bridge.	Provides protection to same areas as in levee alternative. Excavation improves channel capacity and reduces amt of sediment passing thru system.	Additional 12 million cubic meters of sediment stored. River channel will rapidly stabilize, allowing irrigation diversion and river crossings to reestablish. Protects same areas as levee alt.	No construction proposed.
Construction Costs (Present Value)	No construction proposed.	First Cost: P83 million Annual Cost: P2.4 million Future Maintenance Cost: None	First Cost: P136 million Annual Cost: P2.4 million Future Maintenance Cost: None.	First Cost: P242 million Annual Cost: P200 thousand Future Maintenance Cost (every 10 years): P16 million	No permanent evacuation necessary. Temporary evacuation during flooding via GOP program. Warning System Cost: P2.6 million.
Economic Effects (Present Value)	Average damages estimated at P113 million, mostly to structures & infrastructure. Delayed recovery processes.	Economic Cost: P85 million Average Total Benefits: P98 million Mean Net Benefits: P12 million B/C Ratio: 1.2 IRR: 16 percent	Economic Cost: P129 million Average Total Benefits: P98 million Mean Net Benefits: P(31) million B/C Ratio: 0.7 IRR: N/A	Economic Cost: P185 million Average Total Benefits: P98 million Mean Net Benefits: P(87) million B/C Ratio: 0.5 IRR: N/A	Average damages estimated at P113 million.
Environmental And Social Effects	Coastal habitats & fisheries further impacted by sediment/turbidity. About 4 coastal barangays impacted. About 50 Aeta households impacted. About 700 ha agricultural land impacted. Highway 7 bridge impacted. Public health concerns prolonged.	About 7 households displaced. About 8 ha of agricultural land displaced. Sedimentation impacts to coastal habitats increase by improving efficiency of moving sediment thru system Public information, monitoring, and maintenance programs required.	No households displaced. About 100 ha agricultural land displaced. Sediment transport downstream reduced, which reduces impacts to coastal habitats/fisheries. Disposal sites may serve future uses for residential/industrial development.	Similar impacts areas/concerns as for levee alt. until SRS complete (4 to 7 yrs). Significant amount of sediment affects downstream habitats until SRS complete. Upon completion of SRS, source of downstream impacts significantly lower.	Effects similar to No Action, but improved public safety because of early warning system.

4.8 Gumain-Porac River Basin

4.8.1 Specific Conditions. The Gumain-Porac basin is 302 km² in area, extending in a southeasterly direction from Mount Pinatubo to the Pampanga delta (see figure 1). The headwaters of the Gumain consist of steep, well-incised tributaries originating on Mount McDonald. The Gumain flows about 32 km southeast from the crater to its confluence with the Porac River at the head of the Gumain floodway. The Gumain floodway continues downstream about 8 km to its outlet in the Pampanga delta. The floodway has built-up with sediment since the eruption and is now perched above the surrounding landscape. Elevations within the basin range from about 1,600 meters to about 10 meters at the Gumain-Porac confluence.

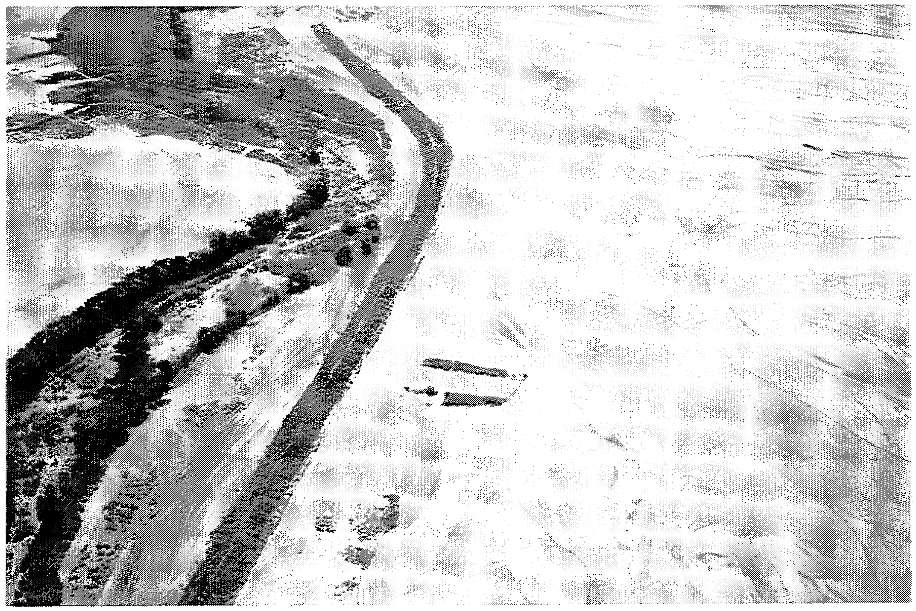
The headwaters of the Porac River originate about 5 km southeast of Mount Pinatubo. The Porac has a drainage area of 122 km². The river flows west and then south for 39 km to its confluence with the Gumain River at the head of the Gumain floodway. Elevations in the Porac basin range from 1,150 meters to 10 meters.

The lower reaches of the Gumain-Porac Rivers contain a number of major irrigation and flood control projects including the Gumain floodway. The floodway was constructed in the mid-1970s to minimize flooding and siltation in the adjoining agricultural areas from Floridablanca down to the delta area. One major aspect of these projects was the diversion of the Porac River into the Gumain floodway system since the Porac's natural channel appears to be about 4 km north of the floodway.

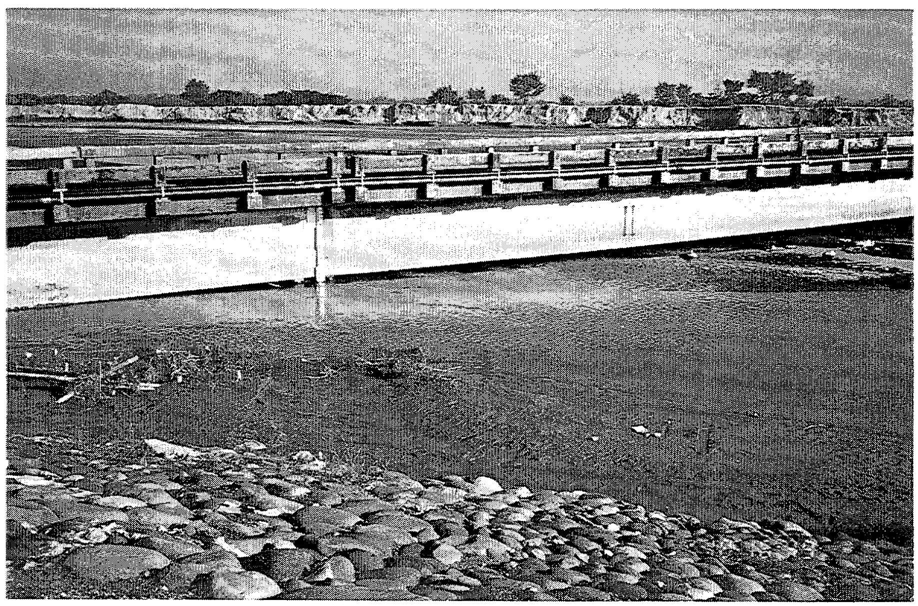
The headwater area of the Gumain-Porac River basin is in steep terrain carved into bedrock consisting of older volcanics. Neither basin heads on a recent pyroclastic flow deposit. Therefore, the only source material for future mudflows is the deposits already in-channel. Airfall ash was carried by runoff into the channel within the first year after the eruption. The ash layer initially covered both watersheds to a thickness of up to 50 cm. After leaving the headwaters reach, both drainages flow through a more gently sloping alluvial fan consisting of older lahar and alluvial deposits similar to the other eastside basins. Below the alluvial fan, the drainage flows through a flat flood plain, then through the delta area into Pampanga Bay.

For the Gumain-Porac basin, eight municipalities are listed as being in the risk areas (see table 4). Figure 19 shows photographs of the sediment deposits in the basin. The risk areas are estimated to include:

- 13,000 household, commercial, and/or public buildings
- 4,600 ha of agricultural land (rice is dominant crop)
- P177.5 million in annual crop revenues



Sediment deposits on the Gumain River, September 1991.



Depth of sediment deposits, Santa Cruz Bridge on Gumain River, November 1992.

Figure 19

Current land cover in the Gumain-Porac basin consists primarily of agricultural land (48 percent), followed by grassland/shrubland (23 percent), woodlands (20 percent), urban areas (6 percent), and sediment deposits (3 percent). On the upper alluvial fan, the soil has a higher sand content and drainage capacity, and sugarcane is the preferred crop. In the lower alluvial fan, irrigated rice dominates.

There are four known prehistoric sites in the municipality of Porac. Cultural materials recovered from these sites provide an indication of the prehistoric utilization (habitation and burial) of the Porac area, ranging from the Late Neolithic period (1750 to 250 B.C.) to the Age of Contact period (14th to 15th centuries A.D.). Two Aeta communities reside in the upper reaches of the Porac River and currently use the river for their resource extraction activities, such as for potable water and for gathering fish and shellfish. A similar Aeta community also is found in Floridablanca.

4.8.2 Problem Statement. Throughout the Gumain basin the risk of mudlfows is low because the upper drainage does not contain significant pyroclastic deposits. There is a high threat of flooding because much of the channel is filled with sediment. There is a high potential for diversion into the Caulaman-Blasic River because the channel in this area is filled and the levees have been destroyed and rebuilt as a result of past events. Recent construction has reduced the flood risk. Bank erosion, flooding, and channel meandering are localized problems near Floridablanca. There is a high risk of levee breaches and shallow flooding downstream of Floridablanca because of bank erosion.

In the Porac basin, sediment supply is limited to the material already in the channel near Porac and downstream. Consequently, the flood risk is considered to be near pre-eruption levels. The large quantity of in-channel sediment results in an unstable river, which causes the risk of localized bank erosion and channel alignment problems. Diversion from the Pasig River into the Porac basin presents a high risk of mudflows. There is a high risk that sediment may deposit in the fan at the mouth of the Gumain floodway and in downstream delta channels, causing ponding-type flooding in the delta.

Flooding is the major event that would cause material movement in the river channels, and there is a 10 percent to 50 percent chance of flooding in any year resulting in flood damages, bank erosion, and the downstream movement of sediment.

4.8.3 Alternatives Under Consideration. The alternatives investigated for the Gumain-Porac basin include: no action, levee, channel excavation, sediment retention structure, and nonstructural.

No Action Alternative

Under the no action alternative (without-project condition), no intervention measures are developed to reduce flooding and sediment damages in the Gumain-Porac basin. Actions taken by the GOP in emergency situations and use of existing warning systems would continue. Plate 25 shows the risk areas expected under the no action alternative.

The average without-project damages (present value) for the Gumain-Porac basin are about P1,023 million, with nearly two-thirds of these damages occurring to structures (P726 million). Damages to agriculture is the second highest category at P228 million, followed by infrastructure (P55 million), foregone production (P7 million), evacuation/relocation (P6 million), and transportation disruption (P516 thousand).

About 38 barangays from the municipalities of Floridablanca and Lubao could be further impacted by flooding and sedimentation, involving about 5,700 ha of mostly agricultural land and fishponds. Possible diversion of the Gumain River into the Caulaman River would extend the risk of increased flooding to the municipalities of Dinalupihan, Hermosa and Orani, all in the province of Bataan. Such a flow diversion could also threaten the Gapan-Olangapo road, which is the primary access to and from Pampanga, Bataan and Zambales.

The delta area would continue to be influenced by elevated levels of sedimentation, further impacting sensitive estuarine ecosystems, aquaculture and fisheries dependent on adequate tidal exchange and brackishwater conditions.

Levee Alternative

The levee alternative for this basin consists of the following features (see plate 26).

- Levee from RK 8.5 to RK 16.5: A levee 3 meters high with slope protection, toe protection extending to a depth of 3 meters, and sodded back slope would be constructed on the right (south) and left (north) banks of the Gumain River from Pabanlag (RK 16.5) to the confluence with the Porac River.

- Channel Excavation: Two meters of material would be excavated from the Gumain channel from its confluence with the Porac River to the Pasag River.

- Bank Protection: Bank protection using rock or concrete would be placed along the Porac River beginning at the diversion structure (RK 3.5), continuing upstream for 6 km and through San Francisco.

- Early Warning System: Existing warning systems consist of rain gages, sediment flow sensors, and observation posts. Adding sirens or loud speakers to alert people in downstream communities would be an effective way to improve public safety.

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Floridablanca
Basa Air Base
Pabanlag
Carmencita
Dampe
Dinalupihan
Lake Mapanuepe
LEGEND
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Shallow flooding and sediment deposition areas
Ponding
Shallow flooding
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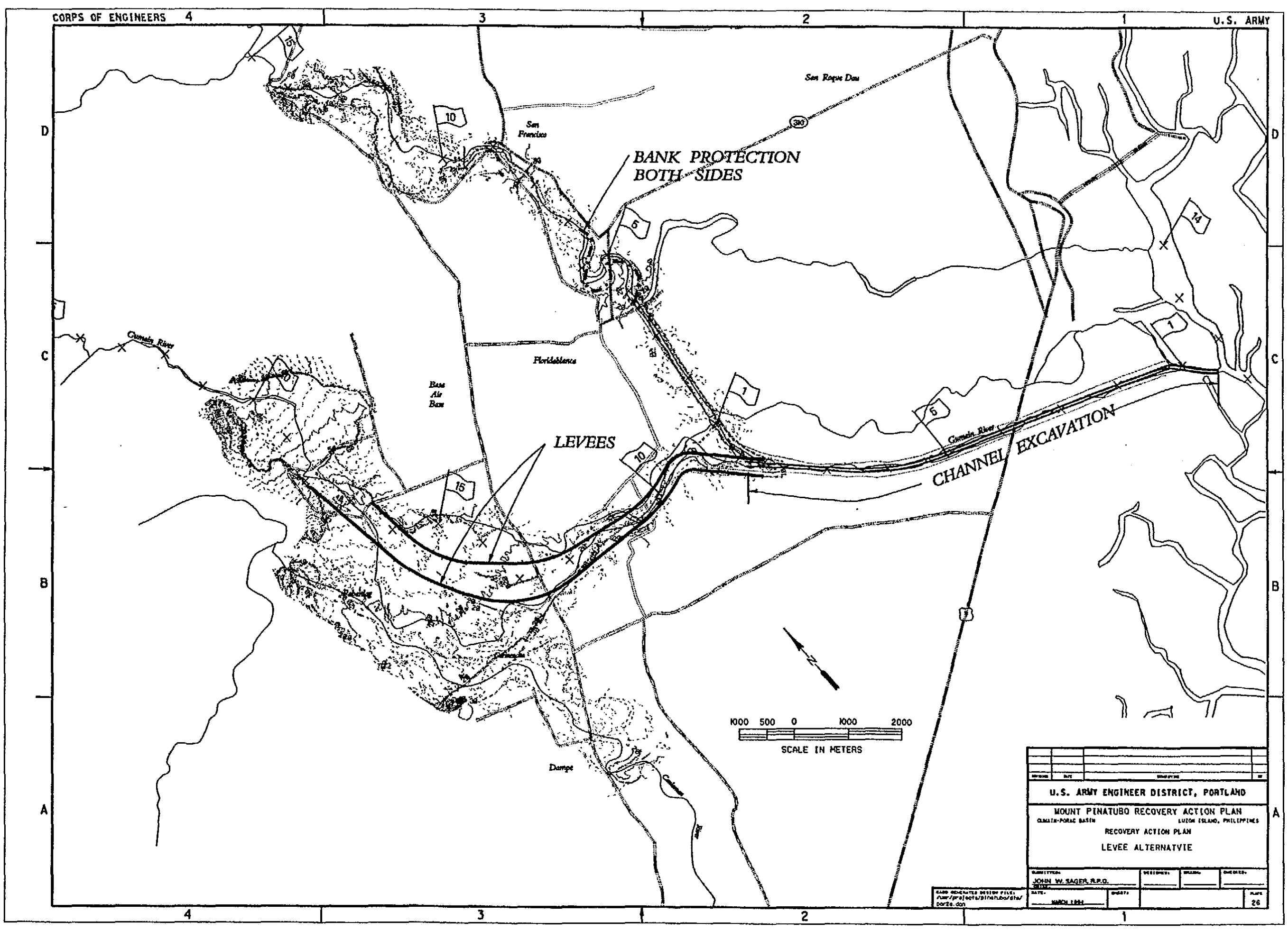
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Plate 26

Results of Action. The levee system has been designed to contain sediments and flood waters produced by a 100-year flood event. The right bank levee prevents diversion of the Gumain River into the Caulaman River, and provides protection from sedimentation and flooding to portions of Floridablanca, Dinalupihan, and Hermosa. The left bank levee provides protection to portions of Floridablanca. Excavation of the channel below the mouth of the Porac reestablishes the channel's original flood control capacity, which provides additional protection to the Highway 7 bridge, and removes in-channel sediments, preventing them from migrating into the delta. Bank protection on the Porac stabilizes the river channel and protects structures and land located on the river banks in Floridablanca.

Cost Summary and Investment Analysis. A summary of construction costs (first costs), annual future and special future costs, and the present value of economic costs for the levee alternative is shown in table 19. On the average, the levee alternative will eliminate about P975 million in damages in the Gumain-Porac basin. The present value of economic costs for this alternative is P587 million. The investment analysis is shown in table 19 and for the mean case, the levee alternative has positive net benefits of about P414 million and a BCR of 1.7.

Environmental and Social Effects. The levee alternative provides an enhanced level of protection to existing human settlements, agricultural lands, fishpond developments, critical infrastructure, and historical landmarks within the defined hazard areas. Areas within the designated levee alignments are already impacted by sediment deposits. No sensitive environmental habitats will be affected by this alternative. Depending on final levee alignments, a undetermined number of households in Barangay Cabangcalan (Floridablanca) could potentially be displaced by this alternative. The Aeta communities in Barangay Nabuklod, located in the upper reaches of Gumain River, should not be affected.

To prevent in-channel sediments from being transported to the delta, annual clearing of the lower reach from the confluence of the Gumain and Porac Rivers to the delta would be required for several years. Disposal areas along the river banks and levees may displace nearby residents and farmlands. As identified during the scoping sessions, land access in the area is a problem.

Reduced sediment load to the delta would have a positive impact on sensitive estuarine ecosystems, aquaculture and fisheries dependent on adequate tidal exchange and brackishwater conditions, and could reduce dredging requirements and impacts in the delta. Restoration of the damaged Porac-Gumain Irrigation System and rehabilitation of agricultural areas below Barangay Pabanlag may be possible with this alternative.

Table 19 -- *Costs for Alternatives, Gumain-Porac Basin (pesos)*

Construction Costs (first costs)

	Levee	Channel Excavation	SRS
Levee w/ Slope & Toe Protection	234,100,000		235,400,000
Bank Protection	62,600,000	62,600,000	62,600,000
Channel Excavation	170,000,000	380,900,000	170,000,000
RCC Dam			571,400,000
Weir Structure			64,300,000
Early Warning System	2,600,000	2,600,000	2,600,000
Environmental Mitigation	200,000	200,000	200,000
Subtotal	469,500,000	446,300,000	1,106,500,000
Contingency (30%)	140,800,000	133,900,000	332,000,000
Total First Costs	**610,300,000**	**580,200,000**	**1,438,500,000**

Annual Costs, financial

	Levee	Channel Excavation	SRS
Annual Excavation Costs	11,800,000	11,800,000	0
O&M	350,000	179,000	1,179,500
Total Annual Costs	**12,150,000**	**11,979,000**	**1,179,500**

Special Future Costs (every 10 years)

	Levee	Channel Excavation	SRS
SRS Maintenance	0	0	30,000,000

Present Value of Economic Costs, 1994 Base

	Levee	Channel Excavation	SRS
First Costs	503,000,000	478,000,000	1,122,000,000
Annual Costs	84,000,000	83,000,000	7,000,000
Future Special Costs	0	0	10,000,000
Total (Pesos)	**587,000,000**	**561,000,000**	**1,139,000,000**

Investment Analysis (Mean Case)

	Levee	Channel Excavation	SRS
Net Benefits	414,000,000	388,000,000	(245,000,000)
BCR	1.7	1.7	0.8
IRR (percent)	23	24	8

Channel Excavation Alternative

The channel excavation alternative for the Gumain-Porac basin consists of the following features (see plate 27).

- Channel Excavation: A channel 200 meters wide and 2 meters deep would be excavated from the confluence of the Gumain-Dalan Bapor with the Pasag River, and would continue upstream to Santo Cristo (RK 9.5). Above RK 9.5 to Pabanlog (RK 16.5), the channel would be 200 meters wide and 1 meter deep. Excavated material would be deposited in berms on the banks paralleling the river, and set back 100 meters from the channel.

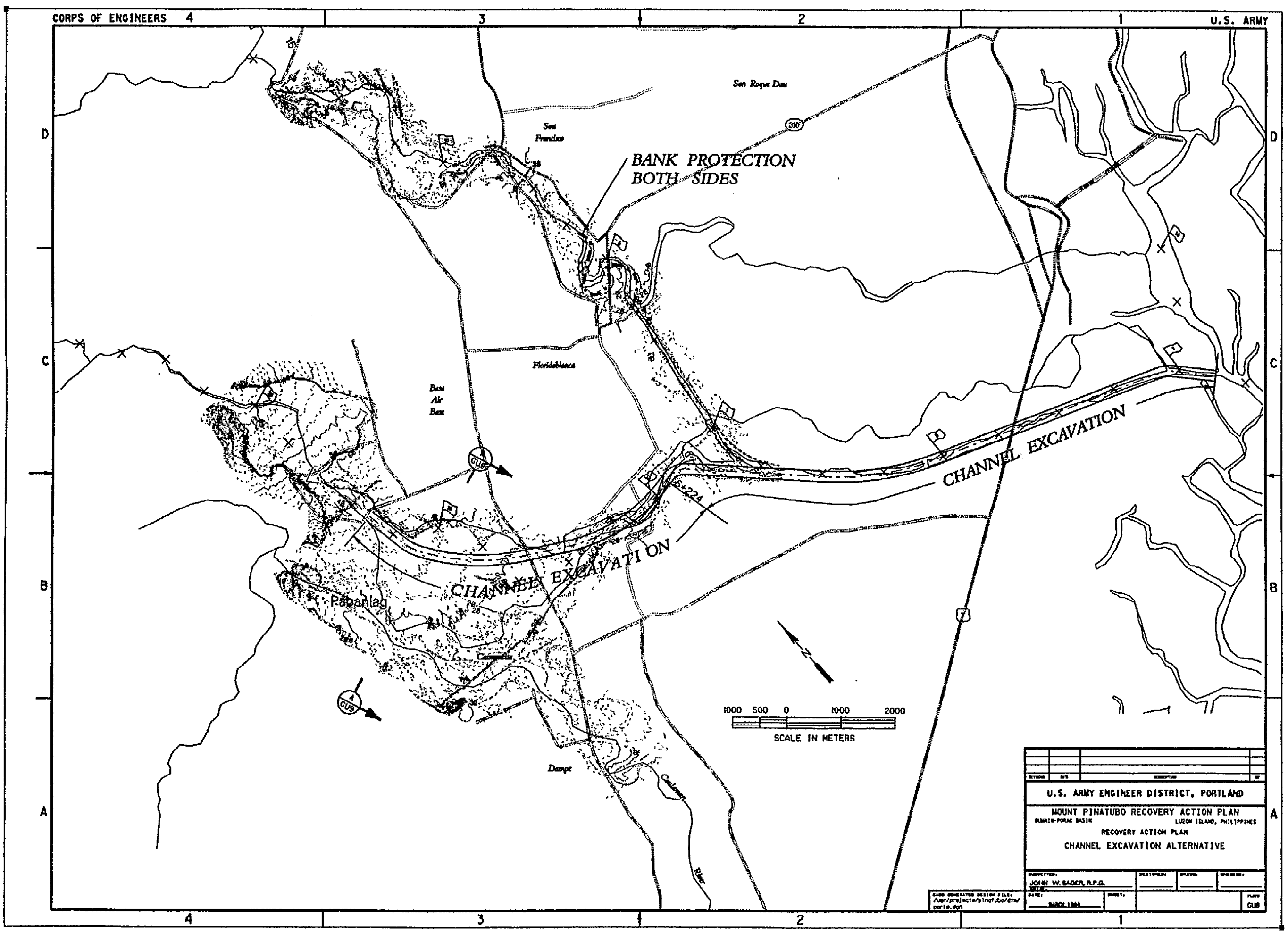
- Bank Protection: Bank protection using rock or concrete will be placed along the Porac River beginning at the diversion structure (RK 3.5), continuing upstream for 6 km and through San Francisco.

- Early Warning System: This feature, as described for the levee alternative, also would be required.

Results of Action. The channel excavation and berms are designed to contain sediments and flood flows forecast to be produced during a 100-year event. To maintain this protection, it is necessary to perform periodic channel excavation. The channel excavation provides protection from sedimentation and flooding to the same areas as in the levee alternative. The volume of sediment available for transport into the delta are greatly reduced. Bank protection on the Porac provides similar protection as in the levee alternative.

Cost Summary and Investment Analysis. A summary of costs for the channel excavation alternative is shown on table 19. On the average, this alternative will eliminate about P975 million in damages in the Gumain-Porac basin. The present value of economic costs for this alternative is P561 million. The investment analysis is shown in table 19 and for the mean case, channel excavation has positive net benefits of about P388 million and a BCR of 1.7.

Environmental and Social Effects. The impacts of the channel excavation alternative are similar to the levee alternative. Additionally, sediment transport to downstream reaches is reduced, resulting in less disturbance to sensitive habitats and fisheries. When filled, the disposal sites may serve for potential use for residential and industrial development. The initial amount of excavated material may cover about 100 ha and may involve displacement of existing households and farm land along the excavated river channel. Excavation and disposal of sediments to maintain protection require a long-term commitment of funding.


CORPS OF ENGINEERS
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BANK PROTECTION
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390
Floridablanca
Basa
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CHANNEL EXCAVATION
CHANNEL EXCAVATION
Pabanlag
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SCALE IN METERS
U.S. ARMY ENGINEER DISTRICT, PORTLAND
MOUNT PINATUBO RECOVERY ACTION PLAN
LUZON ISLAND, PHILIPPINES
RECOVERY ACTION PLAN
CHANNEL EXCAVATION ALTERNATIVE
JOHN W. SAGER, R.P.G.
CUB

Plate 27

Sediment Retention Structure Alternative

The sediment retention structure alternative for the Gumain-Porac basin consist of the following features (see plate 28).

- RCC Gravity Overflow Dam: A RCC dam 30 meters high would be constructed at RK 23.5 on the Gumain River. This structure would store existing in-channel sediments.

- Weir Structure: A weir 6.5 meters high would be constructed at RK 18 west of Basa Air Base. This structure would store existing in-channel sediments.

- Levee from RK 8.5 to RK 16, Channel Excavation, Bank Protection, and Early Warning System: These features, as described for the levee alternative, also would be required for this alternative.

Results of Action. The levees, channel excavation, and Porac bank protection provide protection to the same areas as in the levee alternative. The weir structure stabilizes the in-channel sediment above Basa AFB. The retention structure would store sediments which are presently being eroded from in-channel deposits. Once the structure is completed, this material will no longer be carried through the system and into the delta. Also, the river channel will stabilize rapidly allowing the reestablishment of irrigation diversion and river crossings. The risk of sediment damage to the Highway bridges is reduced.

Cost Summary and Investment Analysis. A summary of costs for the sediment retention structure is shown in table 19. On the average, this alternative eliminates about P893 million in damages in the Gumain-Porac basin. The present value of economic costs for this alternative is P1,138 million. The investment analysis is shown in table 19 and for the mean case, this alternative has negative net benefits of about P(245) million and a BCR of 0.8.

Environmental and Social Effects. Impacts similar to the levee and channel excavation alternatives are expected to occur until the retention structure is complete (4 to 7 years). Until complete, a significant amount of sediment will enter the river system and affect downstream reaches. Upon completion, a source of sediment to the delta is reduced, which benefits the brackishwater wetlands, aquaculture, and estuarine fisheries. Possible disturbance of archaeological resources could occur due to the recorded history and identified sites in the area. Remaining Aeta communities in the upper reaches of Gumain would not be affected by the sediment retention or weir structures. In the unlikely event of a structural failure, a large amount of sediment would be eroded and transported downstream, which may threaten communities and critical infrastructure.

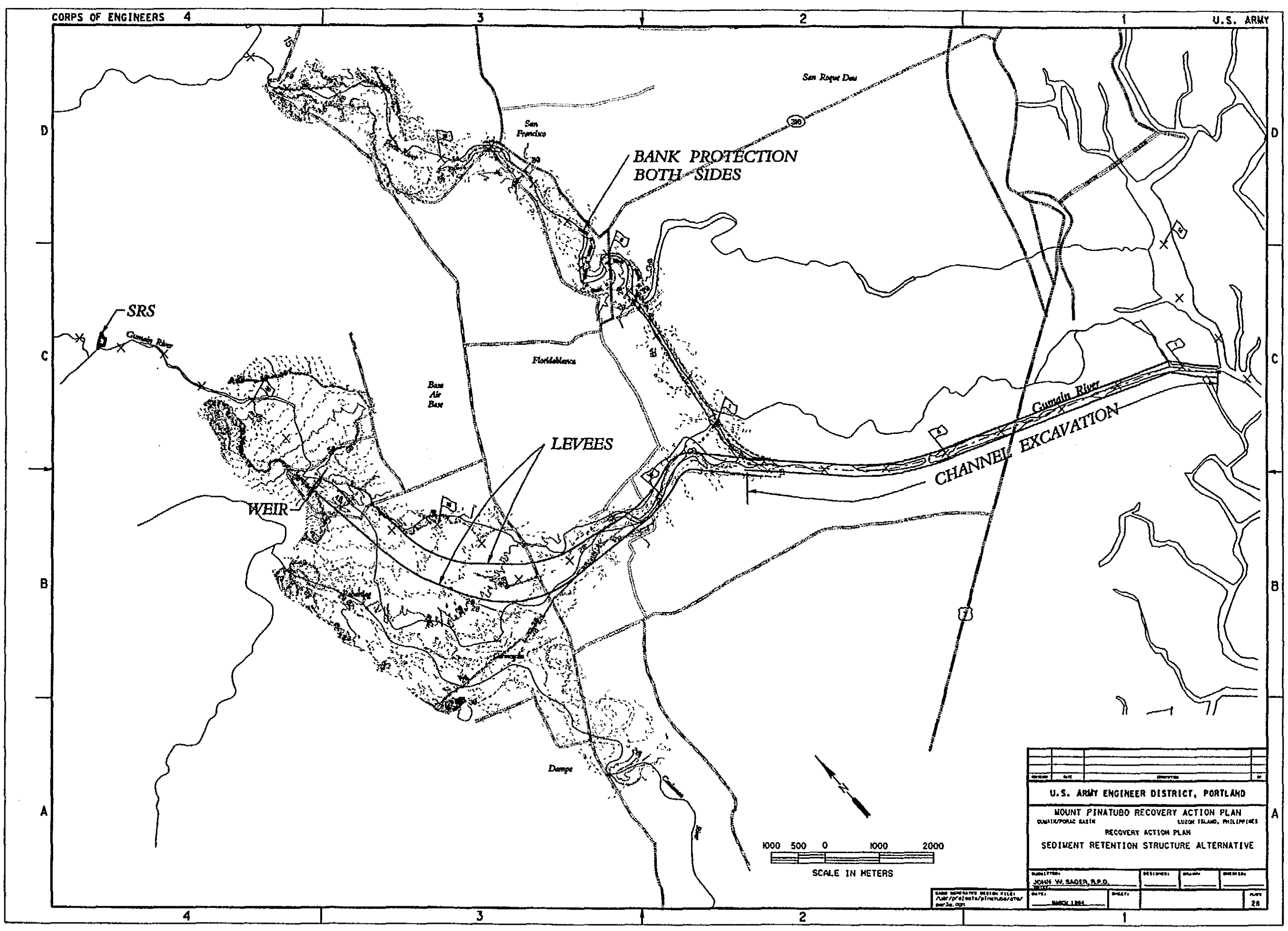
CORPS OF ENGINEERS
U.S. ARMY
BANK PROTECTION
BOTH SIDES
SRS
LEVEES
WEIR
CHANNEL EXCAVATION
Gumain River
Floridablanca
San Roque Dau
Dampe
1000 500 0 1000 2000
SCALE IN METERS
U.S. ARMY ENGINEER DISTRICT, PORTLAND
MOUNT PINATUBO RECOVERY ACTION PLAN
RECOVERY ACTION PLAN
SEDIMENT RETENTION STRUCTURE ALTERNATIVE
JOHN W. SAGER, P.P.O.
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Plate 28

Nonstructural Alternative

No permanent evacuation is condsiered necessary for the Gumain-Porac basin since the threat of sediment flows is low. Temporary evacuation of residents is the only action considered to be necessary for areas threatened by flooding and can be accomplished under the GOP's evacuation program. The improvements to the early warning system described previously also are suggested.

Implementation of the nonstructural alternative may create effects similar to those described for the no action alternative, with the added benefits to public safety of an improved early warning system. The potential nature-induced impacts include continued stream bank erosion and channel meandering, diversion of historic river courses and continued sedimentation of downstream delta channels, resulting in increased flooding of the nearby communities (Lubao, Sasmuan).

4.8.4 Findings for the Gumain-Porac Basin. Three structural alternatives as well as the no action and nonstructural alternatives were evaluated for the Gumain-Porac basin. A summary of the differences, advantages, and disadvantages among the alternatives is discussed in table 20.

Table 20 -- *Summary of Alternatives, Gumain-Porac Basin*

	NO ACTION	LEVEE ALTERNATIVE	CHANNEL EXCAVATION ALTERNATIVE	SEDIMENT RETENTION STRUCTURE ALTERNATIVE	NONSTRUCTURAL ALTERNATIVE
Study Objective Accomplishments	No effective response provided to any objective.	Very good response provided to all study objectives.	Good response provided to most study objectives.	Best response provided to all study objectives.	No effective response to any objective except the preservation of life.
Construction Considerations and Accomplishments	Without-project condition so no alternatives developed. Loss of life & damages from sediment/floods continues. GOP emergency actions & existing warning systems continues.	Protects portions of Floridablanca, Dinalupihan, Hermosa, and to Highway 7 & bridge. In-channel sediment removed lowering sediment movement to delta. Bank protection protects structures and land.	Protects same areas as levee alternative. Significant reduction in sediment movement to delta. Annual removal of sediment needed, so higher long-term costs.	A large amount of sediment stored and not available for downstream movement. Provides protection to same areas as levee alternative. Channel will rapidly stabilize so irrigation diversion & river crossings can reestablish.	No construction proposed.
Construction Costs (Present Value)	No construction proposed.	First Cost: P610 million Annual Cost: P12 million Future Maintenance Cost: None	First Cost: P580 million Annual Cost: P12 million Future Maintenance Cost: None.	First Cost: P1.4 billion Annual Cost: P1 million Future Maintenance Cost (every 10 years): P30 million	No permanent evacuation necessary. Temporary evacuation during flooding via GOP program. Warning System Cost: P2.6 million.
Economic Effects (Present Value)	Average damages estimated at P1 billion, mostly to structures & infrastructure. Delayed recovery processes.	Economic Cost: P587 million Average Total Benefits: P975 million Mean Net Benefits: P414 million B/C Ratio: 1.7 IRR: 23 percent	Economic Cost: P561 million Average Total Benefits: P975 million Mean Net Benefits: P388 million B/C Ratio: 1.7 IRR: 24 percent	Economic Cost: P1 billion Average Total Benefits: P893 million Mean Net Benefits: P(245) million B/C Ratio: 0.8 IRR: 8 percent	Average damages estimated at P1 billion.
Environmental And Social Effects	Delta area and fisheries further impacted by sediment/turbidity. About 38 barangays impacted. About 4,600 ha of agricultural land impacted. Highway 7 & bridge impacted. Public health concerns prolonged.	No sensitive habitats affected. Some households in Cabangcalan displaced. No Aeta communities affected. Disposal areas may displace some households and farmlands. Reduced sediment load to delta reduces impact to estuarine habitats/fisheries.	Impacts similar to levee alternative. About 100 ha agricultural land displaced. Sediment transport downstream reduced, which reduces impacts to sensitive habitats/fisheries. Disposal sites may serve future uses for residential/industrial development.	Similar impacts areas/concerns as for levee alt. until SRS complete (4 to 7 yrs). Significant amount of sediment affects downstream habitats until SRS complete. Once SRS complete, downstream impacts significantly lower. Possible impacts to historical resources.	Effects similar to No Action, but improved public safety because of early warning system.

4.9 Pampanga Delta

4.9.1 Specific Conditions. The Pampanga delta is shown on figure 1 and includes an area of about 29,000 ha of submerged, tidally influenced, or near sea level deltaic sediments. Several rivers draining from the Sierra Madre mountain-range in the east and the Zambales range in the west contribute to the formation of deltaic sediments. These rivers are the Angat, Pampanga, Abacan, Pasig-Potrero and the Gumain-Porac.

The severity of upstream flooding will depend on the extent to which deposition restricts flow out to Pampanga Bay. The ground surface in the delta is only 1 to 3 meters above mean sea level (msl). The canals and fish ponds have been adversely affected by siltation and backflooding. There are several towns and barangays scattered across the delta that have experienced flooding because of the clogged channels. The Pasag-Guagua waterway, which is a vital transport network for the villages in the delta including the towns of Sasmuan and Guagua, is silted and hard to navigate in some sections. Further problems of these types are expected.

Stream gradients are very low in the delta, providing little energy to transport sediment. The delta channels filled with sediment in July and August 1991. Ponding-type flooding was a significant problem in 1992 because the 1991 deposition had not been removed, and flood water began to collect at the beginning of the rainy season.

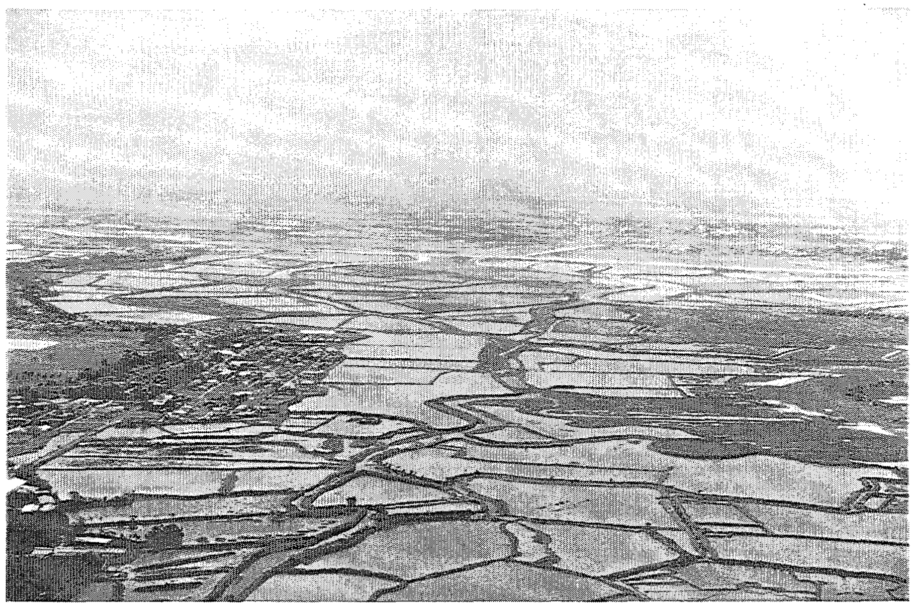
Figure 20 shows photographs of the delta area. The risk areas are estimated to include:

- 58,000 household, commercial, and/or public buildings
- 10,600 ha of agricultural land (fishponds are dominant)
- P1 billion in annual crop revenues

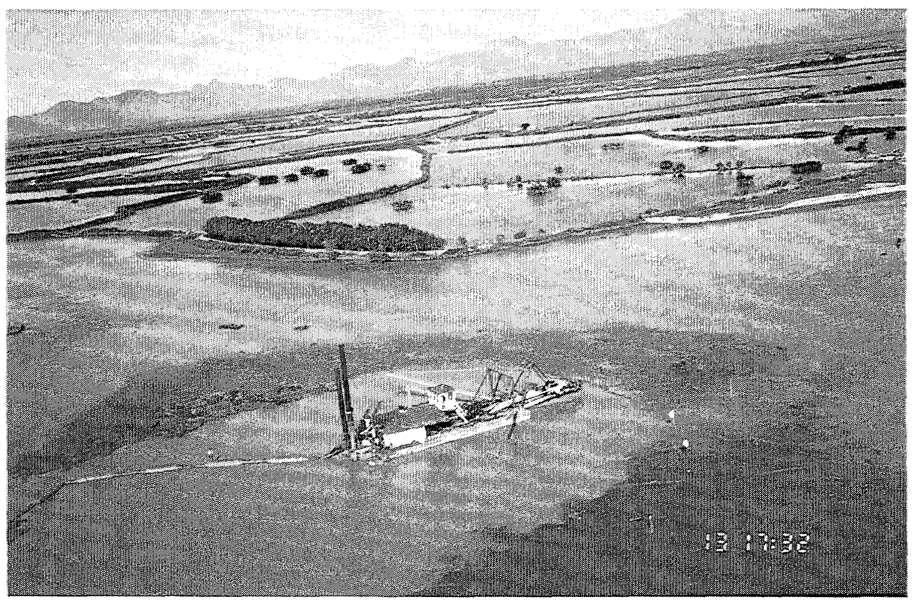
Current land cover for the delta consists of fishponds/wetlands (60 percent), agricultural land (26 percent), urban areas (5 percent), and sediment deposits (9 percent). The river systems draining to the delta, particularly the Pampanga River and the Pasag-Guagua waterway, provided a vital transport network during prehistoric and historic periods. This is indicated by the presence of the old settlement sites (prehistoric and historic) in the upper and middle reaches of the Porac-Gumain and Pasig-Potrero rivers.

The delta is a strategic landform because it has several natural harbors which may have provided ideal mooring areas for large vessels, and its proximity to Manila which was the center of trades during the "Age of Contact" periods. The presence of Chinese ceramics and other tradeware from the habitation sites along the Porac River and those in the municipalities of Guagua, Lubao, Minalin and Masantol are indications of the significant role of the delta in trade and migrations during prehistoric and historic periods.

PHOTOGRAPHS FROM THE PAMPANGA DELTA AREA



Fish ponds in the Pampanga Delta, February 1993.



Dredging sediment in the Pampanga Delta, November 1992.

Figure 20

4.9.2 Problem Statement. The general problems in the delta are ponding caused by sediment deposited in the pre-eruption drainages and poor water quality because there is no exchange of water from fish ponds through the plugged channel system. Annual runoff is the event that would cause ponding, pollution, disease, and loss of life.

4.9.3 Alternatives Under Consideration. The alternatives investigated for the Pampanga delta include the no action and dredging alternatives.

No Action Alternative

Under the no action alternative (without-proejct condition), no measures are developed to reduce flooding and sediment damages in the Pampanga delta, except actions taken by the GOP in emergency situations. Plate 29 shows the risk areas expected with the no action alternative.

The average total without-project damages (present value) for the Pampanga delta are about P7.3 billion, with damages to agriculture accounting for 60 percent of total damages (P4.5 billion). Structures are the next highest category at P2.7 billion, followed by foregone production (P77 million), infrastructure (P25 million), and evacuation/relocation (23 million).

About 58 barangays from the municipalities of Lubao, Sasmuan, Minalin and Guagua could be affected by flooding and sedimentation, involving 10,600 ha of low-lying delta area now largely developed to agricultural and aquacultural use (fishponds). Extreme levels of sedimentation since the 1991 eruption has served to fill delta waterways, significantly reducing drainage capacity and tidal flushing throughout this area. In addition to continued public health problems related to prolonged periods of flooding, the no action plan will further affect the estuarine ecosystems, aquaculture and fisheries dependent on adequate tidal exchange and brackishwater conditions. Current reports indicated that fisheries production in the Pampanga Delta, as measured by catch, has declined over 40 percent since the eruption, with many fishpond operations described as "abandoned" due to poor drainage and water quality (low oxygen and salinity levels, high turbidity).

Continued sedimentation of the delta waterways could induce flooding along the Bebe-San Esteban cut-off channel as drainage flows are diverted from the Pasag River into Pampanga Bay. This diversion of drainage could compromise the benefits of the on-going Pampanga Delta Development Project flood control component which is focused on the Pampanga River and recurrent flooding problems in the eastern half of the delta. Increased flooding would threaten historical resources (churches, public buildings and private residences) dating to Spanish colonial period.

Mt. Malasombo
Pabanlag
Carmencita
Dampe
Floridablanca
San Francisco
Dinalupihan
San Roque Dau
Santa Rita
Guagua
Bacolor
San Fernando
Mexico
Northern Expressway
Orani
San Luis
Macabebe
San Vicente
60 meter channel
2000 1000 0 2000 4000
SCALE IN METERS
N
D
C
B
A
4
3
2
1
LEGEND
Mudflow prone areas
Shallow flooding and sediment deposition areas
Ponding
Shallow flooding
Existing Lahar Deposit
U.S. ARMY ENGINEER DISTRICT, PORTLAND
MOUNT PINATUBO RECOVERY ACTION PLAN
DELTA AREA
LUZON ISLAND, PHILIPPINES
RECOVERY ACTION PLAN
PAMPANGA DELTA
NO ACTION ALTERNATIVE
JOHN W. SAGER, R.P.G.
MARCH 1994
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PLATE 29

As existing aquaculture and fisheries are progressively displaced, alternative land uses may be sought including filling abandoned fishponds for agricultural (piggery, duck and poultry raising), residential and commercial use. Significant areas of the delta may be converted to "tambo" grassland (*Phragmites australis*), a generally impoverished habitat for waterbirds and identified migratory bird species. Depending on the natural drainage patterns that are established, remaining mangroves and nipa palm areas in the Pampanga Delta (currently estimated at 300 ha) would tend to increase to revegetate the shallow tidal flats that area created.

Dredging Alternative

As shown on plate 30, the main channel of the Pasag River from the mouth of the Pasig-Potrero downstream to the Pampanga Bay would be dredged to 3.5 meters below the normal water surface. The channel would be dredged to its full pre-eruption width. In addition the Pasag River, the Dalan Bapor channel would also be reestablished to full width and to a depth of 3.5 meters. All dredge materials would be placed on the outside of the levees in disposal areas designed to prevent re-entry of the sediments into the dredged channel. Annual dredging will be required until the major sediment sources have been stabilized.

Dredging of the floodways in the delta requires the use of floating equipment. Pipeline dredging will normally be the most efficient equipment, but adequate out-of-channel disposal sites are required. A dredging plan has been completed by the Government of the Philippines. If implemented, construction may take two years to complete to full depth and width.

Results of Action. Dredging of the delta flood channels to their original depth and width restores flood control in this area to its pre-eruption condition. This prevents or reduces ponding in Lubao, Sexmoan, Macabebe, Minalin, Santo Tomas, Bacolor, Guagua, Santa Rita, and San Fernando. Dredging will be required periodically to maintain the channel capacities because sediments may continue to move through the various river systems which drain into this area.

Cost Summary and Investment Analysis. A summary of costs for the dredging alternative is shown in table 21. On the average, this alternative eliminates about P3.3 billion in damages in the Pampanga delta. The present value of economic costs for this alternative is P1 billion. The investment analysis is shown in table 21 and for the mean case, the dredging alternative has positive net benefits of about P2 billion and a BCR of 3.0.

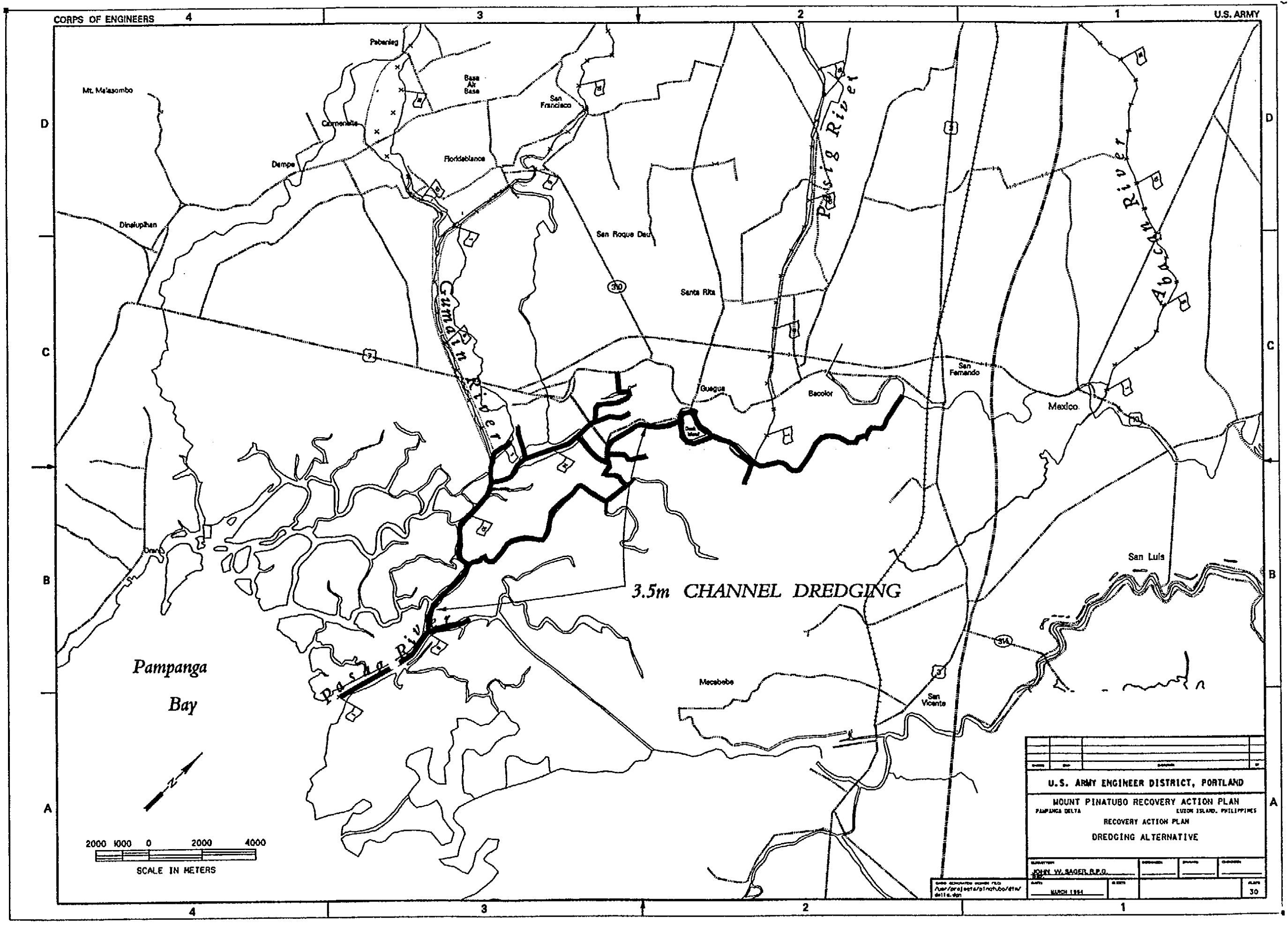
CORPS OF ENGINEERS
U.S. ARMY
Mt. Malasombo
Dinalupihan
Dampe
Floridablanca
San Francisco
San Roque Dau
Santa Rita
Guagua
Bacolor
San Fernando
Mexico
San Luis
Macabebe
San Vicente
Gumain River
Pasig River
Abacan River
Pasac River
Pampanga Bay
3.5m CHANNEL DREDGING
2000 1000 0 2000 4000
SCALE IN METERS
U.S. ARMY ENGINEER DISTRICT, PORTLAND
MOUNT PINATUBO RECOVERY ACTION PLAN
PAMPANGA DELTA
LUZON ISLAND, PHILIPPINES
RECOVERY ACTION PLAN
DREDGING ALTERNATIVE
JOHN W. SAGER, R.P.G.
MARCH 1994
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Plate 30

Table 21 -- *Costs for Dredging Alternative, Pampanga Delta (rounded, in pesos)*

Construction Costs (first costs)

	Dredging
Dredging	689,700,000
Environmental Mitigation	43,000,000
Subtotal	732,700,000
Contingency (30%)	219,800,000
Total First Costs	952,500,000

Annual Outyear Costs

Item	Dredging
Dredging Costs	41,300,000
Operation & Maintenance	950,000
Total Annual Costs	42,250,000

Special Future Costs (every 10 years)

Item	Dredging
Control Structure Maintenance	0

Present Value of Economic Costs, 1994 Base

	Dredging
First Costs	786,000,000
Annual Costs	293,000,000
Future Special Costs	0
Total Cost	**1,079,000,000**

Investment Analysis (Mean Case)

	Dredging
Net Benefits	2,200,000,000
BCR	3.0
IRR (percent)	130

Environmental and Social Effects. The dredging alternative provides an enhanced level of flood protection and drainage to existing human settlements, agricultural lands, fishpond developments, delta fisheries and ecosystems, and historical landmarks within the defined hazard areas. The delta waterways that are proposed for dredging are presently filled by recent sediment deposits and have been subject to emergency dredging operations since the eruption. No existing households, livelihoods or sensitive environmental habitats will apparently be directly displaced by this alternative.

The primary concern is disposal of dredge spoils (fine sand and silt), which are estimated at over 13 million m^3 during the initial dredging, with the volumes generated during subsequent years dependent on natural events (rainfall, sediment transport processes) and engineering intervention measures implemented upstream in the affected river basins. Disposal of the initial excavated material to a height of 5 meters requires a surface area of about 250 ha. Over a 5 to 10 year period, the disposal areas required may total 1,250-2,500 ha (fishpond area in the delta is about 17,000 ha). The current GOP dredging program has acquired some 220 ha of former fishponds along the east bank of the Pasag-Guagua waterway for use as disposal areas, at a unit cost of P183,000 per ha. Additional fishpond areas should be available for use as disposal sites, but acquisition generally involves lengthy consultations and negotiations.

In the absence of land use controls, future conversion of disposal sites to residential, commercial and industrial uses could have a serious impact on the long-term integrity (water quality, adjoining land use) of the delta area. In the short-term, the disposal sites will quickly (within 6 to 12 months) be naturally revegetated as tambo grassland.

Dredging operations will contribute to localized and short-term declines in water quality (increased turbidity), which could affect the operations of nearby prawn and milkfish ponds during periods of water exchange (high tide). Impacts to benthic organisms, associated fisheries and archaeological resources should be minimal since the proposed dredging removes recently deposited sediments from established, previously dredged waterways. Populations of mangroves near the mouth of the Pasag River could be displaced if excavated material is deposited in this area.

4.9.4 Findings for the Pampanga Delta. One structural alternative and the no action alternative were evaluated for the delta. A summary of the differences, advantages, and disadvantages among the alternatives is discussed in table 22.

Table 22 -- *Summary of Alternatives, Pampanga Delta*

	NO ACTION	DREDGING ALTERNATIVE
Study Objective Accomplishments	Not applicable to the delta.	Not applicable to the delta.
Construction Considerations and Accomplishments	Without-project condition so no alternatives developed. GOP emergency actions continue.	Restores flood protection to the delta. Prevents or reduces ponding to Lubao, Sexmoan, Macabebe, Minalin, Santo Tomas, Bacolor, Guagua, Santa Rita, and San Fernando. Dredging required periodically so long-term funding required.
Construction Costs (Present Value)	No construction proposed.	First Cost: P953 million Annual Cost: P42 million Future Maintenance Cost: None
Economic Effects (Present Value)	Average damages estimated at P7.3 billion, mostly to agriculture & structures. Delayed recovery processes.	Economic Cost: P1 billion Average Total Benefits: P3.3 billion Mean Net Benefits: P2 billion B/C Ratio: 3.0 IRR: 130 percent
Environmental And Social Effects	Continued sedimentation causes ponding-type flooding and impacts estuarine habitats and fisheries. About 58 barangays impacted. About 10,600 ha of agricultural land impacted. Further decline in fisheries production. Public health concerns prolonged.	No sensitive habitats or households affected. Waterways presently filled with sediment and subject to emergency dredging operations. Primary concern is disposal of over 13 million cubic meters of dredged sediments, that may ultimately cover 1,250 to 2,500 ha of fishponds. Localized and short-term impacts to water quality.

5. OVERALL RESULTS AND IMPLEMENTATION ACTIONS

5.1 Overall Study Results

In response to the problems identified for each river basin, structural and nonstructural alternatives, as well as the no action alternative, were formulated. Study objective accomplishment, construction costs and considerations, and economic, environmental, and social concerns are addressed for each alternative. Examination of future conditions indicates that extremely large sedimentation events can continue to occur over the next 5 to 10 years and possibly several times per year. Although the potential for large events (perhaps 2 to 3 times larger than pre-eruption levels) may continue after the initial 10 years, their frequency is expected to decrease.

The potential for physical changes within the river basins exists as evidenced in October 1993, when the Pasig-Potrero River captured about 21 km^2 of the Sacobia River headwaters. This change occurred late in the study, and only the resulting changes in hydrology were evaluated. The sediment forecast developed for the Pasig-Potrero does not account for the increase in drainage area and expected higher sediment yields, which may increase the magnitude of the developed alternatives. Conversely, the Sacobia-Bamban may decrease in drainage area and have lower sediment yields, which may reduce the magnitude of developed alternatives. The findings for the alternatives developed for each river basin and the Pampanga delta are summarized on table 23, and are based on conditions that existed prior to this change. Table 24 provides a list of the alternatives, by basin alphabetically, with their pertinent economic information.

A determination of whether or not to implement an engineering solution rests with the GOP. It is not the intent of the Long Term Report to recommend that a specific alternative be implemented for a particular river basin. Instead, the various alternatives were developed to be responsive to the potential problems of a specific basin. When combined with the specific political desires, funding resources, and implementation capabilities of the GOP, the information provided in this report assists in the basis for selection between a variety of recovery action options.

5.2 Implementation Actions

The following paragraphs describe actions to be taken depending upon which alternatives are selected for implementation.

5.2.1 <u>Monitoring Plan</u>. A monitoring and data collection plan to meet short- and long-term needs was developed for the GOP by the USACE in June 1993. The overall objectives of the plan are to monitor project performance and to better define precipitation, stream flow, and sediment transport characteristics for all affected drainage systems. The plan outlined six major activities: monitor levee performance, obtain river and overbank cross-sectional data, perform surveillance flights, collect rainfall and seismic flow data, obtain suspended sediment samples and corresponding stream discharges, and monitor performance of existing check (sabo) dams. The GOP is encouraged to undertake all components of the monitoring plan. A copy of the plan is found in Exhibit B of Technical Appendix E, Engineering Analysis.

5.2.2 General Construction Considerations. The following general construction considerations apply to the pertinent alternatives formulated for each river basin. When possible, existing structures are used and sediment is contained in areas already significantly damaged.

Levees with Slope, Toe and Bank Protection. Construction of levees and slope, toe, and bank protection requires the use of equipment that is readily available such as trucks, loaders, and excavators. Mountain soil or lahar material blanketed with mountain soil may be used to construct levees. Rock for slope and toe protection is available locally. Concrete facing for levees ("hardened levees") requires additional equipment for concrete batching, hauling, and placing, which is locally available. Seeding of levee slopes requires limited equipment, and native grasses could be used. The design of these features requires minimal time and construction of levees can occur in 1 or 2 years. New levee alignments may require right-of-way compensation and local consultations before implementation.

Sump. Construction of a sump (in-channel basin) to trap sediment requires the use of floating equipment. Sump dredging can be completed in 1 year.

RCC Control Structure. Construction of a roller compacted concrete (RCC) control structure requires equipment for concrete batching, hauling, and placing. Spreading could be performed with a dozer and compaction performed with a vibratory roller. Lahar sands could be used as aggregate and hardened surfaces of cast-in-place concrete could use conventional sands and gravels. Site characterization and explorations are required, and design and construction can be accomplished in 1 year.

Channel Excavation. Channel excavation and the construction of the disposal berms can be accomplished with trucks and loaders or with scrapers, if available. Excavated lahar material may be used to construct levees. Channel excavation may take 1 to 2 years to accomplish.

SRS - Gravity Overflow Dam. Construction of a gravity overflow dam requires equipment for RCC and conventional concrete batching, hauling, and placing. Spreading could be performed with a dozer and compaction with a vibratory roller. Lahar sands could be used as aggregate. Hardened surfaces of cast-in-place concrete could use conventional sands and gravels. A thorough site characterization and explorations program to determine foundation conditions is required before completing design. Design can be completed in 1 year, and construction completed the following year, or in stages if multiple structures are involved.

SRS - Embankment Dam with Outlet Works. Design of the embankment dam and outlet works requires about two years to complete. Extensive site explorations are required during design to define foundation and abutment conditions. Heavy construction equipment is needed including equipment for drilling and blasting, rock and soil processing, excavating, hauling, and equipment for RCC and conventional concrete batching, hauling, and placing. Construction can be completed in 2 to 3 years, with trapping of sediments beginning at the end of 2 years.

5.2.3 Follow-On Actions. A variety of actions are necessary before alternatives are implemented. The level of detail and evaluation required were beyond the scope of the RAP. Additional engineering, economic, and environmental work is necessary depending upon the alternatives to be pursued. Land acquisitions for facilities, rights-of-way, disposal sites, etc., must be undertaken and accomplished prior to implementation of any structural alternative. Relocation and permanent evacuation facilities must be identified for each basin, as appropriate. These facilities are contingent upon the capabilities of the GOP.

Follow-on Design Work. Each of the structural alternatives still require varying degrees of additional design before implementation. The USACE has developed levee and channel excavation plans to sufficient detail to provide most information necessary to proceed with the preparation of plans and specifications of project features. Sediment retention structure plans, however, still require extensive subsurface investigation, development of site-specific details, and more detailed design prior to preparing plans and specifications.

- Site Investigations. Site investigations for the RAP were limited to literature searches and site inspections. Surveys should be accomplished for all sites where structures are planned, in order to provide the designers with actual vertical and horizontal controls which will allow layouts. No subsurface explorations have been accomplished to date at any of the sites. Such explorations are necessary to verify the assumptions used for the conceptual designs presented in this report.

- Site Maps. Accurate site maps are necessary for development of accurate designs and layouts.

- Diversion Plan. A river diversion plan should be developed to allow construction to occur throughout most of the work year. The plan should address protection of the work sites and continuity in construction activities.

- Foundation Excavation and Dewatering Plan. The foundation excavation plans, including provisions to maintain a dewatered foundation, need to be developed.

- Design and Stability. Detailed design of all structures has not yet occurred. This design effort needs to take place prior to construction.

- Seepage Analysis. Seepage analysis needs to be accomplished where applicable to complete the designs. Embankment structures on alluvial foundations, for example, will require this analysis.

<u>Follow-on Economic Work</u>. The cost-benefit analysis conducted as part of this study has taken a comprehensive look at the various alternatives, and a consistent method of study was applied. However, there are some limitations to the analysis, and follow-on evaluations may be worthwhile, as described below.

- Incremental Analysis and Optimization. Incremental analysis can be used to find the optimal height of a feature, or to investigate which features of an alternative are economically efficient. For example, for the Pasig-Potrero levee alternative, certain levee segments, such as the segment in the Porac reach which prevents the Pasig's overflow into the Porac River, may prove to be economic if subject to incremental analysis.

- Timing Analysis. The time sensitivity of project economics may be a worthwhile area for further analysis. It was assumed that construction of alternatives would begin in 1995, at which time benefits would start to accrue. Different start dates were not evaluated, and no evaluation was made for implementing alternatives in stages.

- Economic Data. The benefit-cost analysis performed for this study depended on rather uncertain economic data, the result of a fairly small sample size. This results in uncertain estimates, for example, the numbers of buildings impacted. Additional analysis could address this problem by supplementing the ground survey work with photo analysis or new survey work. Another potential source of error lies with the stage-damage functions for buildings which were based on survey responses and observations. An area of additional analysis may be to validate these estimates with independent evaluation of damages functions by building engineers or appraisers.

- Hydrologic and Hydraulic Data. Three different sets of hydraulic and hydrologic data were used which raises concerns about the consistency of these inputs into the economic analysis. To give an example, flooding in the sediment model output was assumed to range from 25 to 45 cm, whereas in the stage-frequency tables, flooding depth ranged up to 120 cm. Consequently, building damages were often greater in the latter case and may have contributed to the reason the three flooding basins (Abacan, Gumain, Maloma) all have economic alternatives. Moreover, the sediment model may capture only a part of the uncertainty in sediment and flooding. Refinements to the hydrologic and hydraulic data would confirm or modify economic results.

• Basins as Systems. Each basin was generally considered as separate and independent from other basins (the exception being the credit given to the Gumain and Pasig projects for reduced delta dredging). Although this assumption is probably satisfactory for several basins, it likely introduces errors in the Pasig-Potrero, Porac-Gumain and delta basins. Future analysis should investigate the system conditions for these basins.

• Efficiency of Pasig-Potrero and Sacobia-Bamban Alternatives. One result of the analysis is that for the populous Pasig-Potrero and Sacobia-Bamban basins, no alternatives evaluated were found to be economically efficient. Conducting further analysis may help explain this result. Factors to consider include: hydrologic inputs to the economic model for the without- and with-project conditions, and economic data and relationships in the model. Further investigations along with system consideration and optimization analyses could identify alternatives that show greater economic viability. Also, the recent basin change in the Sacobia/Pasig headwaters should be factored into any supplemental alternative evaluations.

Follow-on Environmental Work. An environmental assessment was concurrently prepared as an integral part of this study. The environmental impacts of alternatives were evaluated on a general basis. The implementation of major facilities (sediment retention structures, levees, disposal sites, etc.) may require specific supplemental environmental documentation prior to implementation. Also, monitoring and reporting of impacts to environmental resources during and after construction would be necessary.

Table 23 -- *Summary of Alternatives for All River Basins*

RIVER BASIN	NO ACTION	LEVEE ALTERNATIVE	CHANNEL EXCAVATION ALTERNATIVE	SEDIMENT RETENTION STRUCTURE ALTERNATIVE	NONSTRUCTURAL ALTERNATIVE
PASIG-POTRERO	Average damages P943 million. 72 barangays, Hwy 7, and 7,000 ha agric land impacted. Siltation further disrupts delta habitat & fisheries.	First Cost: P1.5 billion. B/C Ratio: 0.4 Restores delta habitats & fisheries. No households/habitats displaced. 30 ha fishponds used for disposal.	First Cost: P1.9 billion. B/C Ratio: 0.3 Better restoration delta habitats/fish. 700 ha used for disposal areas. Higher risk sediment deposits dwnstrm.	Not applicable to this basin.	Permanent evacuation costs P275 to P825 million. Temporary evac via GOP programs. Effects similar to No Action, but improved public safety.
SACOBIA-BAMBAN	Average damages P790 million. 102 barangays/17,000 ha of agricultural land impacted. San Francisco bridge impacted.	First Cost: 1.4 billion BCR: 0.4 Reduces downstream sediment loads and flooding risk. 80 hseholds/1,600 ha land displaced. Public programs required.	First Cost: 490 million. BCR: 0.3 Higher risk sedimentation downstream. Similar impacts as for levee alt. Add'l 1,500 ha land for disposal areas.	First Cost: 1.9 billion BCR: 0.2 Stores about 40 mcm of sediment. Downstream sedimentation & impacts reduced once SRS completed.	Permanent evacuation costs P357 to P1 billion. Temporary evac via GOP programs. Improved public safety over No Action due to early warning system.
ABACAN	Average damages P219 million. 29 barangays/7,250 ha of agricultural land affected. Possible failure Sabo No.9 increases downstream impacts.	BANK PROTECTION ALTERNATIVE First Cost: P80 million. BCR: 2.8 Reduces sediment in system, gives long-term relief to Mexico. No households/habitats displaced.	Not applicable to this basin.	Not applicable to this basin.	No permanent evac necessary. Temporary evac during flooding via GOP programs. Improved public safety over No Action due to early warning system.
O'DONNELL	Average damages P297 million. 20 barangays/19,000 ha of agricultural land impacted. Hwy 3 & 317 impacted.	First Cost: P226 million BCR: 0.99 Protects O'Donnell/Santa Lucia, Capas, Concepcion, Tarlac. Over10 hseholds/30 ha land displaced.	First Cost: P1 billion BCR: 0.2 Protects same areas as in levee alt. No hseholds/habitats displaced.	First Cost: P3.2 billion BCR: 0.1 Stores about 100 mcm sediment. Downstream sedimentation & impacts reduced once SRS completed.	Permanent evac costs P40 to P120 million; temp evac via GOP programs. Improved public safety over No Action due to early warning system.
SANTO TOMAS	Average damages P1.2 billion. 56 barangays/11,500 ha of agricultural land impacted. Highway 7 impacted.	First Cost: P939 million BCR: 1.2 Protects San Marcelino, San Antonio, San Narcisco, Castillejos, Hwy 7. 170 hseholds/280 ha land displaced.	First Cost: P3.3 billion BCR: 0.2 Protects same areas as levee alt. No hseholds/habitats displaced.	First Cost: P5.5 billion BCR: 0.2 Stores about 40 mcm of sediment. Downstream sedimentation & impacts reduced once SRS completed.	Permanent evac costs P43 to P128 million; temp evac via GOP programs. Improved public safety over No Action due to early warning system.
BUCAO	Average damages P250 million 2,100 ha of land impacted. Highway 7 bridge impacted. 25 barangays impacted. Significant siltation continues.	First Cost: P187 million BCR: 1.4 Portions of Botolan, Iba, Hwy 7, and local routes protected. No households/habitats displaced.	Not applicable to this basin.	First Cost: P4.7 billion BCR: 0.1 Stores about 1 billion cm of sediment. Downstream sedimentation & impacts reduced once SRS completed.	Permanent evacuation cost P20 to P60 million; temporary evac via GOP programs. Improved public safety due to early warning system.
MALOMA	Average damages P113 million. 50 Aeta households impacted. 700 ha agricultural land impacted. 4 coastal barangays impacted. Highway 7 bridge impacted.	First Cost: P83 million BCR: 1.2 Portions of Cambangan, San Felipe, and Hwy 7 bridge protected. 7 households/8 ha land displaced.	First Cost: 136 million BCR: 0.7 Protects same areas as levee alt. Reduces amt sediment in system. No households/100 ha land displaced.	First Cost: 242 million BCR: 0.5 Stores about 12 mcm of sediment. Downstream sedimentation & impacts reduced once SRS completed.	No permanent evacuation needed. Temporary evacuation during flooding via GOP programs. Improved public safety due to early warning system.
GUMAIN-PORAC	Average damages P1 billion. 38 barangays impacted. 4,600 ha ag. land impacted. Hwy 7 & bridge impacted. Delta habitats/fisheries impacted.	First Cost: P610 million BCR: 1.7 Portions of Floridablanca, Dinalupihan, Hermosa, Hwy 7/bridge protected. Some households/land displaced.	First Cost: 580 million BCR: 1.7 Protects same areas as levee alt. Reduces sediment to delta. 100 ha agricultural land displaced.	First Cost: P1.4 billion BCR: 0.8 Large amt of sediment stored. Downstream sedimentation & impacts reduced once SRS completed.	No permanent evacuation needed. Temporary evacuation during flooding via GOP programs. Improved public safety due to early warning system.
PAMPANGA DELTA	Average damages P7.3 billion. 58 barangays impacted. 10,600 ha delta lands impacted. Continued impacts to estuarine habitats and fisheries. Further decline fisheries production.	Not applicable to the delta.	DREDGING ALTERNATIVE First Cost: P953 million. BCR: 3.0 Prevents or reduced ponding to many communities in/near delta. Up to 2,500 ha fishponds for disposal.	Not applicable to the delta.	Not applicable to the delta.

Table 24 -- *Summary of Economic Information for Alternatives*

Basin	Project	Mean Benefits	Economic Costs	Net Benefits	Benefit-Cost Ratio	Internal Rate of Return (%)
Abacan	Bank Protection	191,679,000	67,953,000	123,726,000	2.82	38.7
Bucao	Levee	210,979,000	155,076,000	55,903,000	1.36	17.0
Bucao	SRS	223,778,000	3,317,898,000	-3,094,120,000	0.07	
Delta	Dredging	3,284,870,000	1,079,512,000	2,205,358,000	3.04	130.4
Maloma	Levee	97,635,000	85,218,000	12,417,000	1.15	15.7
Maloma	SRS	97,635,000	184,705,000	-87,070,000	0.53	3.5
Maloma	Channel Excavation	97,635,000	128,977,000	-31,342,000	0.76	7.6
O'Donnell	Levee	187,281,000	188,240,000	-959,000	0.99	12.1
O'Donnell	SRS	249,788,000	2,246,013,000	-1,996,225,000	0.11	
O'Donnell	Channel Excavation	187,281,000	1,244,019,000	-1,056,738,000	0.15	
Pasig-Potrero	Levee	657,849,000	1,548,626,000	-890,777,000	0.42	
Pasig-Potrero	Channel Excavation	657,849,000	1,943,000,000	-1,285,151,000	0.34	
Porac-Gumain	Levee	975,495,000	587,176,000	388,319,000	1.66	23.0
Porac-Gumain	SRS	893,482,000	1,138,975,000	-245,493,000	0.78	8.4
Porac-Gumain	Channel Excavation	975,495,000	561,186,000	414,309,000	1.74	24.3
Sacobia-Bamban	Levee	434,281,000	1,078,450,000	-644,169,000	0.40	
Sacobia-Bamban	SRS	351,663,000	1,410,233,000	-1,058,570,000	0.25	
Sacobia-Bamban	Channel Excavation	434,281,000	1,555,713,000	-1,121,432,000	0.28	4.5
Santo Tomas	Levee	907,490,000	739,658,000	167,832,000	1.23	18.1
Santo Tomas	SRS	723,101,000	3,886,893,000	-3,163,792,000	0.19	
Santo Tomas	Channel Excavation	907,490,000	3,866,500,000	-2,959,010,000	0.23	

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Aggrading Stream: A stream building-up the level or slope of its channel or valley by the deposit of sediment.

Barangay: A barangay is the basic political unit in the Philippine local government system. It is a component of the municipality or city in which it is situated, and tends to have a minimum population of 1,000 to 2,000 residents.

Benefit-Cost Ratio (BCR): The ratio of discounted benefits to discounted costs of a project. A BCR greater than one implies that a project is economically feasible.

BSWM: Bureau of Soils and Water Management

CBA: Cost-benefit analysis used in the economic investigations.

Degrading Stream: A stream actively deepening its channel or valley and capable of transporting more load than is presently provided.

DPWH: Department of Public Works and Highways

DSWD: Department of Social Welfare and Development

EA: Environmental Assessment

Geomorphology: The systematic examination of landforms and their interpretation as records of geologic history. The general examination of the configuration of the earth's surface and the changes that may take place in the evolution of land forms.

GIS: Geographic Information System

GOP: Government of the Philippines

Hardened Levee: A levee with a facing of concrete to provide protection against erosion.

Hyperconcentrated Flow: Defined as having solids content in water ranging from 20 to 45 percent by volume, including flow intermediate in nature between dilute, fully turbulent, normal streamflow and viscous, generally nonturbulent debris flow. Particles in hyperconcentrated flow are carried by turbulent and traction processes. When flow velocity decreases, particles simply settle out of the water, creating broad, flat deposits.

Internal Rate of Return (IRR): Discount rate at which discounted benefits equal discounted costs of a project. An IRR greater than the discount rate implies that a project is economically feasible.

Lake Breakouts/Lake Failure: When sediment creates blockages, lakes are formed behind the blockage. Breakouts occur when the lake's water level breaches its banks, which creates surges that transport large volumes of sediment downstream very quickly.

LBII: Louis Berger International, Incorporated (the on-site liaison contractor for the Corps of Engineers).

Lahar: The general term "lahar" refers to any rapidly flowing mixture of volcanic material and water.

MPC: Mt. Pinatubo Commission

Mudflow: Mudflows have sediment transport concentrations of over 50 percent by volume and are commonly said to resemble rapidly moving wet concrete. Mudflows (also called debris flows) do not spread as readily as muddy water or hyperconcentrated flows, and deposits tend to form mounds or irregular surfaces.

NDCC: National Disaster Coordinating Council

NEDA: National Economic and Development Authority

NHA: National Housing Authority

Net Present Value (NPV): The difference between discounted benefits and discounted costs of a project. A positive NPV implies that a project is economically feasible.

Pedo-ecological: Having to do with soil and its environment.

PHIVOLCS: Philippine Institute of Volcanology and Seismology

Phreatic explosions: High pressure steam explosions that occur by surface water infiltration or when groundwater comes in contact with hot, pyroclastic deposits. The eruption/explosion can form large craters in the surface and may be accompanied by large-scale mass movements of material.

Physiography: A description of the landform features of an area.

Physiographic Province: A region having a pattern of landforms that differs significantly from that of adjacent regions.

Purok: A political subdivision of a sitio, whether inhabited or not.

Pyroclastic Flow: These are combinations of fine grained volcanic material, and hot gasses traveling down the volcano's flanks at gravity-induced velocities.

Pyroclastic Material: Fragmented volcanic material ejected from volcanoes in explosive events.

RAP: Recovery Action Plan

RCC: Roller Compacted Concrete

Secondary Pyroclastic Flow (SPF): Large mass movements of pyroclastic material that occur after emplacement of the primary pyroclastic deposit. These flows can travel several kilometers in a short period of time. Their causes are unknown.

Sitio: A political subdivision of a barangay, whether inhabited or not.

Tephra: A general term for any material produced during a volcanic eruption (both airfall and flow deposits).

TLRC: Technology and Livelihood Resource Center

USACE: U.S. Army Corps of Engineers

USAID: U.S. Agency for International Development

USGS: U.S. Geological Survey

ZLSMG: Zambales Lahar Scientific Monitoring Group

EXHIBIT

B

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EXHIBIT

C

STUDY OBJECTIVE PRIORITIZATION AND RATIONALE

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TABLE C-1 -- *Study Objectives Prioritization, Summary of GOP Position*

October 27, 1992

DOCUMENTATION OF MT. PINATUBO STUDY OBJECTIVE PRIORITIZATION AND RATIONALE

Developed Jointly By
The Presidential Task Force on Mt. Pinatubo
US Agency for International Development
US Army Corps of Engineers

I. PURPOSE

Objective prioritizations for the Mt. Pinatubo Study, the rationale for such prioritizations and final documentation of the same per river basin was requested by the U.S. Army Corps of Engineers (USACE) from the Presidential Task Force Mt. Pinatubo (PTFMP). This information is an integral component to the identification of potential measures for the Recovery Action Plan (RAP) on Mt. Pinatubo being prepared by the USACE for the US Agency for International Development (USAID)

The objective prioritization process was conducted in order to ensure that the Plan Selection Process (PSP) for the study is oriented towards a set of objectives reflective of a Government of the Philippines (GOP) national perspective on recovery actions.

The documentation presents development of study objectives, GOP rationale used for evaluation, and specific objective prorities based on regional and local government inputs.

II. OVERVIEW

The PSP for the Mt. Pinatubo RAP consists of a series of sequential and sometimes iterative steps that identifies problems and responds to specific planning objectives expressed by USAID and the GOP. The objectives identified are in the area of life preservation, sediment deposition, flooding and social, environmental, and economic resources.

In no particular order of priority, the specific planning objectives consequently identified for this study are as follows:

A. Prevention of loss of life (defined as the probability of saving lives).

B. Reduction of damages from sediment deposition in populated areas (defined as the probability of lowering damage potential to urban areas).

C. Reduction of damages from sediment deposition in agricultural areas (defined as the probability of lowering damage potential to farms, cultivated fields, fish ponds, etc.)

D. Reduction of damages from sediment deposition to infrastructure assets (defined as the probability of lowering damage potential to bridges, roads, public structures, etc.)

E. Reduction of damages from flooding in populated areas (also defined as the probability of lowering damage potential to urban areas).

F. Reduction of damages from flooding in agricultural areas (also defined as the probability of lowering damage potential to farms, cultivated fields, fish ponds, etc.).

G. Reduction of damages from flooding to infrastructure assets (also defined as the probability of lowering damage potential to bridges, roads, public structures, etc.).

H. Enhancement of economic, environmental, or social resources (defined as the probability of improving economic, environmental, or social conditions).

Various meetings were held between the Corps, USAID, and the PTFMP of the GOP to address the PSP and the prioritization of objectives. The concept of a PSP, identification of specific objectives and their definitions, and the prioritization technique to be used were discussed. PTFMP identified its role in providing a national perspective to recovery action guidance, and accepted the responsibility of coordinating efforts to obtain objective priorities.

Using the technique of value prioritization, the PTFMP solicited inputs from its committee members, political representatives from the impacted provinces, and various governmental agencies. Those results reflect coordination efforts of the Corps of Engineers, the GOP national position, and the USAID concurrence on specific objective priorities identified for each basin included for study in the RAP.

III. GENERAL GOP RATIONALE APPLIED TO SETTING OBJECTIVE PRIORITIES

In prioritizing the planning objectives the following factors were considered:

- *A. river systems location;*
- *B. estimated sediment deposits affecting each basin; and*
- *C. characteristics of the area adjacent to the rivers including agricultural or industrial areas, population distribution and the amount of infrastructure (bridges, roads, buildings, etc.).*

The protection of people should be the major concern of any government, especially where disaster management is concerned. Relative to the Mt. Pinatubo disaster, sediment deposits and flooding in populated areas endanger not only the people but their source of livelihood as well and should be dealt with accordingly.

Objective priorities for each of the eight river basins included in the RAP were developed because each river system has significantly different features and is, therefore, subject to different risks. Also, where common risks such as deposition of sediment exists, the distribution of the deposited material varies substantially by basin.

Population distribution, the extent of agricultural areas, and the character of each area's economic potential have to be evaluated in terms of the overall risks in the basin. While the preservation of life is obviously a national priority, applicable to all basins, the importance of one objective (e.g. the protection of infrastructure) as opposed to the other objectives can shift from basin to basin. Also, for example, agricultural lands are very important, but in a predominantly agricultural area their importance increases, as does infrastructure in an area to be developed industrially.

Damages from sediment are perceived to be longer lasting and more extensive than damages from flooding. While the reduction of damages from both sediment and flooding is imperative, the rehabilitation of the communities and services deserves proper consideration.

The enhancement of economic, environmental and social resources can result from the accomplishment of other objectives. Also, simultaneous accomplishment should be considered where possible.

IV. SPECIFIC OBJECTIVE PRIORITIES AND RATIONALE FOR EACH BASIN

Of the 18 target respondents, 13 submitted the requisite objective prioritization matrices. Of those 13, five provided the rationale which guided their respective selection process (Annex I: List of Respondents). Two out of the 13 respondents evaluated the planning objectives on a regional basis instead of the required per river basin basis.

The PTFMP reviewed and consolidated the various responses, prioritizations, and rationale. The final rankings based on 11 individual matrices and the rationale from four respondents, represent the national GOP perspective needed for the PSP portion of the RAP.

For all the eight river basins, priority ranking is placed on the objective to prevent loss of life (Objective A). The rationale offered in this regard are as follows:

A. The protection of people's lives should be the major concern of any government in so far as disaster management is concerned (Sec. de Villa, NDCC).

B. People's lives are always of primary importance (Cong. Diaz).

C. Preservation of human life is obviously a national priority and should be the primary consideration for all basins. Solutions which can enhance quality of life in a basin on the longer term are most desirable (DPWH-Infrastructure Committee).

D. High premium is placed on saving human lives because man is the most precious resource of the country. He should be the center and, at the same time, the means for any program/project implementation for development (DSWD, Social Services Committee).

Except from this general commonality, objective ranking differentiation is noted from basin to basin.

BASIN : ABACAN

Priority Rankings

Objectives		Priority Total	Value Mean
A.	Prevent loss of life	177	29.5
B.	Reduce damages from sediment deposition in populated areas	97	16.2
D.	Reduce damages from sediment deposition to infrastructure assets	64	10.7
E.	Reduce damages from flooding in populated areas	61	10.2
H.	Enhance economic, environmental & social resources	48	8.0
G.	Reduce damages from flooding to infrastructure assets	37	6.2
C.	Reduce damages from sediment deposition in agricultural areas	29	4.8
F.	Reduce damages from flooding in agricultural areas	15	2.5

RATIONALE :

Second and fourth rankings are given to the objectives to reduce damage potentials in populated-urban areas (Objectives B and E) consistent with the priority ranking placed on the objective to prevent loss of life (Objective A) considering that peripheral areas of this basin are population centers and the high lahar risk posed by the basin to such urban centers.

Third and sixth in rank are the objectives to reduce the damages to infrastructure assets (Objectives D and G) given the broad potential of the peripheral areas to industrial development as well as the presence of extensive North-South and East-West road networks.

Enhancement of social, economic and environmental resources (Objective H) is ranked fifth in priority with the expectation that such will result from the attainment of the population and infrastructure related-objectives.

The agriculture-related objectives (Objectives G and H) are ranked last considering that the area has more urban-industrial potential than agricultural although simultaneous enhancement opportunities are considered possible.

BASIN : GUMAIN

Priority Rankings

Objectives	Priority Total	Value Mean
A. Prevent loss of life.	213	30.4
B. Reduce damages from sediment deposition in populated areas.	90	12.9
E. Reduce damages from flooding in populated areas.	79	11.3
C. Reduce damages from sediment deposition in agricultural areas	50	7.1
F. Reduce damages from flooding in agricultural areas	44	6.3
H. Enhance economic, environmental & social resources	44	6.3
D. Reduce damages from sediment deposition to infrastructure assets	40	5.7
G. Reduce damages from flooding to infrastructure assets	23	3.3

RATIONALE :

The two next higher rankings are given to the objectives to reduce damage potentials in populated-urban areas (Objectives B and E) consistent with the priority ranking placed on the objective to prevent loss of life (Objective A). This prioritization is largely based on the rationale that this basin is rated severe in terms of sediment deposition and flooding potentials and the surrounding area being heavily populated.

The objectives to reduce damages in agricultural areas (Objectives C and F) are given the next higher priority rankings over the objectives pertinent to reduction of damages to infrastructure facilities (Objectives D and G) on the rationale that the adjoining areas are extensive agricultural areas rather than industrial.

The socio-economic and environmental enhancement objective (Objective H) is given the same ranking as the objective to reduce damages in agricultural areas due to flooding (Objective F) despite the rationale that such objective can result from the attainment of the first seven objectives.

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BASIN : PASIG-PORTRERO

Priority Rankings

Objectives	Priority Total	Value Mean
A. Prevent loss of life	123	24.6
B. Reduce damages from sediment deposition in populated areas	71	14.2
C. Reduce damages from sediment depostion in agricultural areas	54	10.8
E. Reduce damages from flooding in populated areas	54	10.8
H. Enhance economic, environmental and social resources	53	10.6
F. Reduce damages from flooding in agricultural areas	46	9.2
D. Reduce damages from sediment depostion to infrastructure assets	17	3.4
G. Reduce damages from flooding to infrastructure assets	13	2.6

RATIONALE :

Population-related objectives (Objectives B and E) are similarly ranked high priorities for this basin, second and third, respectively, in support of the primary objective of preventing loss of life given the rationale that the peripheral areas are populated with high risk to flooding.

With agriculture as economic base and surrounding large tracks of agricultural area, the two agriculture-related objectives (Objectives C and F) also rank high, third and fifth respectively.

Socio-economic and environmental enhancement (Objective H) ranks fourth and is expected to result from the attainment of the agriculture-related objectives considering the area's predominantly agricultural economic base. For the same reason, the infrastructure-related objectives (Objectives D and G) are ranked last in priority even in the presence of astride road networks in the East-West and North-South.

BASIN : SACOBIA

Priority Rankings

Objectives	*Priority Total*	*Value Mean*
A. Prevent loss of life	*129*	*21.5*
H. Enhance economic, environmental, and social resources	*106*	*17.6*
F. Reduce damages from flooding in agricultural areas	*72*	*12.0*
B. Reduce damages from sediment deposition in populated areas	*65*	*10.8*
C. Reduce damages from sediment deposition in agricultural areas	*63*	*10.5*
E. Reduce damages from flooding in populated areas	*63*	*10.5*
D. Reduce damages from sediment deposition to infrastructure assets	*38*	*6.3*
G. Reduce damages from flooding to infrastructure assets	*21*	*3.5*

RATIONALE :

Even with extensive peripheral lahar risk areas, broad agricultural lands and large population, the objective to enhance socio-economic and environmental resources (Objective H) ranks next to the priority objective of preventing loss of life (Objective A) on the rationale that solutions which can enhance quality of life in a basin over the longer term are most desirable.

The Congressman for the affected district ranked this objective as top priority to give the people a fair chance to recover and pick-up anew their lives.

Reduction of damage from flooding and sediment deposition in agricultural areas however, ranks third and fifth respectively, Population-based objectives (Objectives B and E) come in fourth and sixth, respectively.

Considering higher risk from lahar than flooding, reduction of damage from sediment deposition to infrastructure assets rank higher at seventh position compared to the objective to reduce damage from flooding to infrastructure assets which is ranked last.

BASIN : BUCAO

Priority Rankings

Objectives	*Priority Total*	*Value Mean*
A. Prevent loss of life	*111*	*27.8*
C. Reduce damages from sediment deposition in agricultural areas	*44*	*11.0*
B. Reduce damages from sediment deposition in populated areas	*42*	*10.5*
E. Reduce damages from flooding in populated areas	*38*	*9.5*
D. Reduce damages from sediment deposition to infrastructure assets	*21*	*5.3*
F. Reduce damages from flooding in agricultural areas	*19*	*4.8*
H. Enhance economic, environmental and social resources	*17*	*4.3*
G. Reduce damages from flooding to infrastructure assets	*10*	*2.5*

RATIONALE :

Objectives to reduce damage from sediment deposition in agricultural and populated areas ranked second and third to the primary objective of preventing loss of life given an extensive and rugged drainage basin estimated to contain 10-55 per cent of the pyroclastic material deposit and risk prospects of lahar and flooding to population and agriculture primarily in estuary of moderate size.

Reduction of damage from flooding in populated areas (Objective E) ranked fourth but remain to be supportive to the primary objective of preventing loss of life. Risk areas are Botolan and low areas near the mouth.

The rationale put forward by the Congressman of the affected district for Sto. Tomas River Basin is similarly applicable to this river basin.

BASIN : MALOMA

Priority Rankings

Objectives		*Priority Total*	*Value Mean*
A.	Prevent loss of life	111	27.8
C.	Reduce damages from sediment deposition in agricultural areas	45	11.3
B.	Reduce damages from sediment deposition in populated areas	41	10.3
E.	Reduce damages from flooding in populated areas	40	10.0
D.	Reduce damages from sediment deposition to infrastructure assets	23	5.8
H.	Enhance economic, environmental & social resources	20	5.0
F.	Reduce damages from flooding in agricultural areas	18	4.5
G.	Reduce damages from flooding to infrastructure assets	10	2.5

RATIONALE :

Objectives related to the reduction of damage from sediment deposition are given second, third and fifth priority rankings and that for the reduction of damage from flooding is ranked fourth in view of the expected damage to populated areas consistent with the primary objective of preventing loss of life.

Socio-economic and environmental enhancement ranked sixth in priority expected to proceed fron the attainment of the population and sediment deposition damage prevention objectives.

The rationale put forward by the Congressman of the affected district for Sto. Tomas and Bucao River Basins similarly apply to this river basin.

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BASIN : SANTO TOMAS

Priority Rankings

Objectives	Priority Total	Value Mean
A. Prevent loss of life	111	27.8
B. Reduce damages from sediment deposition in populated areas	46	11.5
E. Reduce damages from flooding in populated areas	41	10.3
C. Reduce damages from sediment deposition in agricultural areas	35	8.8
D. Reduce damages from sediment deposition to infrastructure assets	27	6.8
H. Enhance economic, environmental and social resources	20	5.0
F. Reduce damages from flooding in agricultural areas	15	3.8
G. Reduce damages from flooding to infrastructure assets	9	2.3

RATIONALE :

Population-based objectives (Objectives B and E) are given top rankings considering a very extensive basin with population centers and broad agricultural lands in the lower reaches plus prospects of moderately stable channels but with broad lahar and flooding risks also in the lower reaches. Most affected municipalities are San Felipe, Castillejos and San Antonio which are considered to be highly populated and urbanized.

Objectives to reduce damages from sediment deposition (Objectives C and D) follow next and are preferred over those related to flooding (Objectives F and G) although broad risks for both lahar and flooding were already identified.

The socio-economic and environmental enhancement objective is rated low at priority six. It is expected to proceed from the attainment of the population and sediment deposition-related objectives.

The Congressman of the affected district argues that since lahar continues to alter the area's land use and consequent agriculture restoration activities would take years including intensive research activities, objectives to reduce damage from sediment deposition must be highly prioritized.

BASIN: O'DONNELL

Priority Rankings

Objectives	Priority Total	Value Mean
A. Prevent loss of life	109	27.3
C. Reduce damages from sediment deposition in agricultural areas	43	10.8
B. Reduce damages from sediment deposition in populated areas	39	9.8
E. Reduce damages from flooding in populated areas	39	9.8
F. Reduce damages from flooding in agricultural areas	37	9.3
H. Enhance economic, environmental & social resources	35	8.8
D. Reduce damages from sediment deposition to infrastructure assets	21	5.3
G. Reduce damages from flooding to infrastructure assets	8	2.0

RATIONALE :

Very similar ranking to the Sacobia River Basin with population and agriculture-related objectives given top rankings (first to fourth) considering the presence of extensive agricultural lands and prospects of severe lahar flows and extensive mud/lahar hazard areas.

Socio-economic and environmental enhancement (Objective H) ranks next at fifth with expectation that such will proceed from attainment of the population and agriculture-based objectives (Objectives A to E).

Infrastructure-related objectives (Objectives D and G) are given the last two ranks even with high prospects of severe sediment deposition to infrastructure assets considering that the area is more agricultural than industrial in nature.

The rationale offered by the Congressman for the affected district for the Sacobia River Basin wherein an inverse ranking for this objective and that of preventing loss of life is similarly applicable to this river basin.

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Table C-1 -- *Study Objectives Prioritization, Summary of GOP Position*

PLANNING OBJECTIVES	RIVER BASINS															
	PASIG POTRERO		SACOBIA		ABACAN		O' DONNELL		SANTO TOMAS		BUCAO		MALOMA		PORAC GUMAIN	
	Average Score	Priority Rank	Average Score	Priority Rank	Average Score	Priority Rank	Average Score	Priority Rank	Average Score	Priority Rank	Average Score	Priority Rank	Average Score	Priority Rank	Average Score	Priority Rank
A- Prevent Loss of Life.	24.6	1	21.5	1	29.5	1	27.3	1	27.8	1	27.8	1	27.8	1	30.4	1
B- Reduce Damages From Sediment Deposition In Populated Areas.	14.2	2	10.8	4	16.2	2	9.8	3	11.5	2	10.5	3	10.3	3	12.9	2
C- Reduce Damages From Sediment Deposition In Agricultural Areas.	10.8	3	10.5	5	4.8	7	10.8	2	8.8	4	11.0	2	11.3	2	7.1	4
D- Reduce Damages From Sediment Deposition In Infrastructure Assets.	3.4	7	6.3	7	10.7	3	5.3	7	6.8	5	5.3	5	5.8	5	5.7	7
E- Reduce Damages From Flooding In Populated Areas.	10.8	3	10.5	5	10.2	4	9.8	3	10.3	3	9.5	4	10.0	4	11.3	3
F- Reduce Damages From Flooding In Agricultural Areas.	9.2	6	12.0	3	2.5	8	9.3	5	3.8	7	4.8	6	4.5	7	6.3	5
G- Reduce Damages From Flooding In Infrastructure Areas.	2.6	8	3.5	8	6.2	6	2.0	8	2.3	8	2.5	8	2.5	8	3.3	8
H- Enhance Economic, Environmental and Social Resources.	10.6	5	17.6	2	8.0	5	8.8	6	5.0	6	4.3	7	5.0	6	6.3	5

Average Score: Is the mean value determined for each objective.
Priority Rank : Indicates relative magnitude of average scores and helps define objective prioritization.

EXHIBIT

D

SCREENING OF MEASURES AND POTENTIAL PLANS

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Table D-1 -- Preliminary Screening of Measures for the Pasig-Potrero River Basin

HAZARD CONDITIONS: The risk for mudflows is high for at least 10 years. Upstream of Mancatian, there is a high risk that the channel will fill with material causing mudflows and river diversions to areas adjacent to the Pasig basin. The risk of flow diversion to Porac is high, and the risk of flow diversion to the Abacan is low. Downstream of Mancatian, there is a risk that bank erosion will cause levee breaches, flooding, and sediment deposition throughout the basin. Sediment discharged may deposit in downstream channels causing ponding-type flooding in the delta area near Bacolor, San Fernando, Minalin, and Santo Tomas. Point-type deposition may cause levee failure with flooding and sediment deposition.

Initial Structural Measures	Function of Measure	Engineering Factors Hazard Reduction Potential: L=Low M=Moderate H=High						Economic Factors Damage Reduction Potential: L=Low M=Moderate H=High				Environmental / Social Factors Public Issues and Concerns M=Meets NM=Does not meet						Conclusions for River Basin
		Mudflow /Sediment Hazard	Flood Hazard	Ponding Hazard	Bridge Hazard	Road Hazard	Other Infrastructure	Buildings	Crops	Infrastructure	Transportation disrupt	Siltation	Ponding/Flooding	Lack of/No lahar disposal	Lahar overflow	River Bank Erosion	Restore/maintain river flow	
LEVEES	Containment of sediment & water.	H	H	H	L	H	H	H	M	M	M	M	M	M	M	NM	M	Effective-high to moderate reduction to hazards & damages; meets most public concerns.
CHANNEL EXCAVATION	Increase capacity to move sediment & water.	M	H	H	H	M	H	H	M	M	M	M	M	NM	M	NM	M	Effective-high to moderate reduction to hazards & damages; meets most public concerns.
SUMP	In-channel basin to trap sediment.	L	H	H	L	M	M	H	H	L	M	M	M	NM	NM	NM	M	Effective - reduces most hazards & damages; meets some public concerns.
SAND POCKET	Trap sediment & regulate flow.	H	L	L	M	M	M	M	M	L	M	M	NM	NM	M	NM	M	Effective - reduces most hazards & damages; meets some public concerns.
SEDIMENT RETENTION STRUCTURE	Trap sediment & reduce flooding.	H	L	M	M	M	M	M	L	L	M	M	NM	M	M	NM	M	Effective - reduces most hazards & damages; meets most public concerns.
DREDGING	Increase channel flow & reduce ponding.	L	H	H	M	H	H	H	M	M	H	M	M	NM	NM	NM	M	Effective-high to moderate reduction to hazards & damages; ponding a problem in delta area.
BANK PROTECTION	Prevent erosion.	L	M	L	H	M	H	M	M	H	H	NM	M	M	NM	M	NM	Effective - reduces most hazards & damages; meets some public concerns.
SEDIMENT BASIN	Trap sediment to reduce transport.	H	L	M	M	M	M	M	M	L	L	M	NM	NM	M	NM	M	Effective - reduces most hazards & damages; meets some public concerns.
SILL	Stabilize sediment to control channel location.	L	L	L	M	M	M	M	L	M	M	M	NM	M	NM	NM	M	Effective- moderate hazard /damage reduction for infrastructure; meets some public concerns.
PILE DIKE	Control flow & sediment deposition along banks.	M	L	L	M	M	M	L	L	M	M	M	NM	M	NM	NM	M	Effective-moderate hazard/damage reduction for infrastructure; meets some public concerns.
GROINS	Erosion control & control channel location.	L	L	L	H	M	M	L	L	M	M	NM	NM	M	NM	M	M	Effective-moderate hazard/damage reduction for infrastructure; meets some public concerns.
WEIRS	Trap sediment, control channel location & flows.	M	L	L	M	M	M	M	L	M	M	M	M	M	NM	NM	M	Effective-moderate hazard/damage reduction for infrastructure; meets most public concerns.

Table D-2 -- Preliminary Screening of Measures for Sacobia-Bamban River Basin

HAZARD CONDITIONS: The risk of mudflows is high for the next 10 years. Mudflow deposition is expected from the upstream end of Clark AFB to downstream of Bamban and Delores. There is a high risk of shallow flooding and sediment deposition on the south overbank downstream of Delores. A moderate to high risk of shallow flooding because of levee breaching exists on the north overbank downstream of Bamban. The risk of flooding caused by channel fill upstream of Marcos Village is low. The risk of flow diversion to the Abacan is low because the Gates of the Abacan are isolated from the Sacobia.

Initial Structural Measures	Function of Measure	Engineering Factors Hazard Reduction Potential: L=Low M=Moderate H=High						Economic Factors Damage Reduction Potential: L=Low M=Moderate H=High				Environmental / Social Factors Public Issues and Concerns M=Meets NM=Does not meet						Conclusions for River Basin
		Mudflow /Sediment Hazard	Flood Hazard	Ponding Hazard	Bridge Hazard	Road Hazard	Other Infrastructure	Buildings	Crops	Infrastructure	Transportation disrupt	Siltation	Ponding/Flooding	Lack of/No Lahar disposal	Lahar overflow	Poor Access/Isolation	Existing levees weak	
LEVEES	Containment of sediment & water.	H	H	H	M	M	M	M	H	M	M	M	M	M	M	M	M	Effective-high to moderate reduction to hazards & damages; meets all public concerns.
CHANNEL EXCAVATION	Increase capacity to move sediment & water.	M	M	H	M	M	M	M	H	M	M	M	M	NM	NM	M	NM	Effective - moderate reduction to hazards & damages; meets some public concerns.
SUMP	In-channel basin to trap sediment.	L	L	L	L	L	L	L	L	L	L	M	NM	NM	NM	NM	NM	Not Effective - low potential to reduce hazards & damages; most public concerns not met.
SAND POCKET	Trap sediment & regulate flow.	H	L	L	M	M	M	M	M	M	M	M	M	NM	M	M	NM	Effective - moderate reduction to hazards & damages; meets most public concerns.
SEDIMENT RETENTION STRUCTURE	Trap sediment & reduce flooding.	H	L	L	H	H	H	M	M	M	M	M	NM	M	M	M	NM	Effective -high to moderate reduction to hazards & damages; meets most public concerns.
DREDGING	Increase channel flow & reduce ponding.	L	L	L	L	L	L	L	L	L	L	NM	M	NM	NM	NM	NM	Not Effective - low potential to reduce hazards & damages; one public concern met.
BANK PROTECTION	Prevent erosion.	L	H	L	H	H	H	L	M	H	H	NM	M	M	NM	M	M	Effective - high hazard & damage reduction to infratructure; meets most public concerns.
SEDIMENT BASIN	Trap sediment to reduce transport.	H	L	L	M	M	M	M	M	M	M	M	NM	NM	M	M	NM	Effective - moderate reduction to most hazards & damages; meets some public concerns.
SILL	Stabilize sediment to control channel location.	L	L	L	M	M	M	L	L	M	M	M	NM	M	NM	NM	NM	Effective-moderate hazard & damage reduction to infrastructure; meets some public concerns.
PILE DIKE	Control flow & sediment deposition along banks.	M	L	L	M	M	M	L	L	M	M	M	NM	M	M	NM	NM	Effective-moderate hazard & damage reduction to infrastructure; meets some public concerns.
GROINS	Erosion control & control channel location.	L	L	L	M	M	M	L	L	M	M	NM	NM	M	NM	NM	NM	Effective-moderate hazard & damage reduction to infrastructure; meets one public concern.
WEIRS	Trap sediment, control channel location & flows.	L	L	L	M	M	M	L	L	M	M	M	M	M	NM	NM	NM	Effective-moderate hazard & damage reduction to infrastructure; meets some public concerns.

Table D-3 -- Preliminary Screening of Measures for Abacan River Basin

HAZARD CONDITIONS: There is a low risk of mudflows because the upper drainage does not contain significant pyroclastic deposits. The risk of flow diversion from the Pasig is low. The river channel has many bends which cause a high risk of erosion and bank failure in the Angeles City area. Downstream, there is a high risk of levee breaches and shallow flooding caused by bank erosion. In-channel sediment transported slowly downstream may deposit in channels around Mexico causing a high risk of shallow flooding. No ponding-type flooding is anticipated.

Initial Structural Measures	Function of Measure	Engineering Factors Hazard Reduction Potential: L=Low M=Moderate H=High						Economic Factors Damage Reduction Potential: L=Low M=Moderate H=High				Environmental / Social Factors Public Issues and Concerns M=Meets NM=Does not meet				Conclusions for River Basin
		Mudflow/Sediment Hazard	Flood Hazard	Ponding Hazard	Bridge Hazard	Road Hazard	Other Infrastructure	Buildings	Crops	Infrastructure	Transportation disrupt	Siltation	Ponding/Flooding	River Bank Erosion	Restore/maintain river flow	
LEVEES	Containment of sediment & water.	L	H	M	L	M	H	L	M	M	M	M	M	NM	M	Effective-overall moderate reduction to hazards & damages; meets most public concerns.
CHANNEL EXCAVATION	Increase capacity to move sediment & water.	L	M	H	M	M	M	L	M	M	M	M	M	NM	M	Effective-overall moderate reduction to hazards & damages; meets most public concerns.
SUMP	In-channel basin to trap sediment.	L	L	L	L	L	L	L	L	L	L	M	NM	NM	NM	Not Effective - low potential to reduce hazards & damages; most concerns not met
SAND POCKET	Trap sediment & regulate flow.	L	L	L	L	L	L	L	L	L	L	M	NM	NM	NM	Not Effective - low potential to reduce hazards & damages; most concerns not met.
SEDIMENT RETENTION STRUCTURE	Trap sediment & reduce flooding.	L	L	L	L	L	L	L	L	L	L	M	NM	NM	NM	Not Effective - low potential to reduce hazards & damages; most concerns not met.
DREDGING	Increase channel flow & reduce ponding.	L	L	L	L	L	L	L	L	L	L	NM	M	NM	NM	Not Effective - low potential to reduce hazards & damages; most concerns not met.
BANK PROTECTION	Prevent erosion.	L	L	L	H	H	H	M	M	M	M	NM	M	M	NM	Effective - high potential to reduce infrastructure hazards; moderate reduction in damages.
SEDIMENT BASIN	Trap sediment to reduce transport.	L	L	L	L	L	L	L	L	L	L	M	NM	NM	NM	Not Effective - low potential to reduce hazards & damages; most concerns not met.
SILL	Stabilize sediment to control channel location.	L	L	L	M	L	M	L	L	L	L	M	NM	NM	M	Not Effective - mostly low hazard & damage reduction potential; a few concerns met.
PILE DIKE	Control flow & sediment deposition along banks.	L	L	L	L	L	L	M	L	M	M	M	NM	M	NM	Effective - low hazard reduction potential but most damages moderately reduced.
GROINS	Erosion control & control channel location.	L	L	L	H	H	H	M	L	M	M	NM	NM	M	M	Effective - high potential to reduce infrastructure hazards; moderate reduction in damages.
WEIRS	Trap sediment, control channel location & flows.	M	L	L	M	M	M	L	L	M	M	M	M	M	M	Effective - moderate hazard & damage reductions; meets all public concerns.

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Table D-4 -- Preliminary Screening of Measures for O'Donnell River Basin

HAZARD CONDITIONS: The risk of mudflows is high for the next 5 to 10 years. There is a potential for secondary pyroclastic flows to impact the area downstream of the pyroclastic deposit. There is a moderate risk of flooding, especially near O'Donnell and Santa Lucia, because sediment has filled the channel. The flood risk at Tarlac is low. There is a moderate risk of flow diversion towards the Bamban and Rio Chico de la Pampanga rivers resulting in shallow flooding and sediment deposition over a wide area upstream of Tarlac.

Initial Structural Measures	Function of Measure	Engineering Factors Hazard Reduction Potential: L=Low M=Moderate H=High						Economic Factors Damage Reduction Potential: L=Low M=Moderate H=High				Environmental / Social Factors Public Issues and Concerns M=Meets NM=Does not meet					Conclusions for River Basin
		Mudflow/Sediment Hazard	Flood Hazard	Ponding Hazard	Bridge Hazard	Road Hazard	Other Infrastructure	Buildings	Crops	Infrastructure	Transportation disrupt	Siltation	Ponding/Flooding	Lahar overflow	Poor Access/Isolation	Existing levees weak	
LEVEES	Containment of sediment & water.	H	H	L	M	M	M	M	H	M	M	M	M	M	M	M	Effective-high to moderate reduction to hazards & damages; meets all public concerns.
CHANNEL EXCAVATION	Increase capacity to move sediment & water.	M	M	L	M	M	M	M	H	M	M	M	M	M	M	NM	Effective - moderate reduction to hazards & damages; meets most public concerns.
SUMP	In-channel basin to trap sediment.	L	L	L	L	L	L	L	L	L	L	M	NM	NM	NM	NM	Not Effective - low potential to reduce hazards & damages; most public concerns not met.
SAND POCKET	Trap sediment & regulate flow.	H	L	L	H	H	H	M	M	M	M	M	M	M	M	NM	Effective-high to moderate reduction to hazards & damages; meets most public concerns.
SEDIMENT RETENTION STRUCTURE	Trap sediment & reduce flooding.	H	L	L	H	H	H	M	M	M	M	M	NM	M	M	NM	Effective-high to moderate reduction to hazards & damages; meets most public concerns.
DREDGING	Increase channel flow & reduce ponding.	L	L	L	L	L	L	L	L	L	L	NM	NM	NM	NM	NM	Not Effective - no ponding-type flooding; low potential to reduce hazards & damages.
BANK PROTECTION	Prevent erosion.	L	H	H	H	H	H	M	H	M	M	NM	NM	NM	M	M	Effective-high to moderate reduction to hazards & damages; meets some public concerns.
SEDIMENT BASIN	Trap sediment to reduce transport.	H	L	L	L	L	L	M	M	M	M	M	NM	M	NM	NM	Not Effective-low potential to reduce most hazards; most public concerns not met.
SILL	Stabilize sediment to control channel location.	L	L	L	L	L	L	L	L	L	L	M	NM	NM	NM	NM	Not Effective - low potential to reduce hazards & damages; most public concerns not met.
PILE DIKE	Control flow & sediment deposition along banks	M	L	L	L	L	L	L	L	L	L	M	NM	M	NM	NM	Not Effective - low potential to reduce hazards & damages; some public concerns not met.
GROINS	Erosion control & control channel location.	L	M	L	M	L	M	L	L	L	L	NM	NM	NM	M	NM	Not Effective - overall low potential to reduce hazards & damages; most concerns not met.
WEIRS	Trap sediment, control channel location & flows.	L	L	L	L	L	L	L	L	L	L	M	M	NM	NM	NM	Not Effective - low potential to reduce hazards & damages; meets two public concerns.

Table D-5 -- Preliminary Screening of Measures for the Santo Tomas River Basin

HAZARD CONDITIONS: The risk of mudflows is high for the next 5 to 10 years. There is a low probability of the blockage at Lake Mapanuepe failing. Highway 7 and the bridge in San Felipe appear to be in low danger of erosion and/or failure. The river has filled in the San Rafael and Santa Fe areas and a very high risk exists for the river to overtop the levees and exit the channel to the south, causing shallow flooding and sedimentation.

Initial Structural Measures	Function of Measure	Engineering Factors Hazard Reduction Potential: L=Low M=Moderate H=High						Economic Factors Damage Reduction Potential: L=Low M=Moderate H=High				Environmental / Social Factors Public Issues and Concerns M=Meets NM=Does not meet							Conclusions for River Basin
		Mudflow/Sediment Hazard	Flood Hazard	Ponding Hazard	Bridge Hazard	Road Hazard	Other Infrastructure	Buildings	Crops	Infrastructure	Transportation disrupt	Siltation	Ponding/Flooding	Lack of/No Lahar Disposal	Lahar Overflow	Poor Access/Isolation	Restore/Maintain River Flow	Existing Levees Weak	
LEVEES	Containment of sediment & water.	H	H	H	M	H	H	M	H	M	M	M	M	M	M	M	M	M	Effective-high to moderate reduction in hazards & damages; meets all public concerns.
CHANNEL EXCAVATION	Increase capacity to move sediment & water.	M	M	M	M	M	M	M	H	M	M	M	M	NM	NM	M	M	NM	Effective - moderate reduction to hazards & damages; most public concerns met.
SUMP	In-channel basin to trap sediment.	L	L	L	L	L	L	L	L	L	L	M	NM	NM	NM	NM	NM	NM	Not Effective - low potential to reduce hazards & damages; most public concerns not met.
SAND POCKET	Trap sediment & regulate flow.	M	L	L	L	L	L	L	L	L	L	M	M	NM	M	M	NM	NM	Not Effective - low potential to reduce hazards & damages; some concerns met.
SEDIMENT RETENTION STRUCTURE	Trap sediment & reduce flooding.	H	L	L	M	M	H	M	M	M	M	M	M	M	M	M	NM	NM	Effective - overall high to moderate reductions to hazards & damages; most concerns met.
DREDGING	Increase channel flow & reduce ponding.	L	H	H	H	H	L	L	L	M	M	M	M	NM	NM	NM	M	NM	Effective - overall high reduction to hazards & moderate reduction to infrastructure damages.
BANK PROTECTION	Prevent erosion.	M	H	M	H	H	M	M	H	M	M	NM	M	M	NM	M	M	M	Effective - high to moderate reduction in hazards & damages; most concerns met.
SEDIMENT BASIN	Trap sediment to reduce transport.	M	L	L	L	L	L	L	L	L	L	M	NM	NM	M	NM	NM	NM	Not Effective - low potential to reduce hazards & damages; few concerns met.
SILL	Stabililze sediment to control channel location.	L	L	L	M	M	L	L	L	L	L	M	NM	M	NM	NM	M	NM	Not Effective - overall low potential to reduce hazards & damages; some concerns met.
PILE DIKE	Control flow & sediment deposition along banks.	M.	L	L	M	M	M	M	M	M	M	M	NM	M	NM	NM	M	NM	Effective - overall moderate reduction in hazards & damages; some concerns met.
GROINS	Erosion control & control channel location.	M	L	L	M	M	M	M	M	M	M	NM	NM	M	NM	M	M	NM	Effective - overall moderate reduction in hazards & damages; some concerns met.
WEIRS	Trap sediment, control channel location & flows.	M	L	L	M	M	L	M	M	M	M	M	M	M	NM	M	M	NM	Effective - overall moderate reduction in hazards & damages; most concerns met.

Table D-6 -- Preliminary Screening of Measures for the Bucao River Basin

HAZARD CONDITIONS: There is a high risk of mudflows developing in the upper basin and transporting high volumes of sediment into the lower basin. Clean water entering from the Balintawak River increases the transport capability in the lower 20 km of the system. This portion of the river appears able to maintain a slope to transport a majority of the incoming sediments to the South China Sea. This lowers the risk of mudflow and flooding hazards in this reach. The risk of failure of Highway 7 and the bridge appears to be low.

Initial Structural Measures	Function of Measure	Engineering Factors Hazard Reduction Potential: L=Low M=Moderate H=High						Economic Factors Damage Reduction Potential: L=Low M=Moderate H=High				Environmental / Social Factors Public Issues and Concerns M=Meets NM=Does not meet							Conclusions for River Basin
		Mudflow/Sediment Hazard	Flood Hazard	Ponding Hazard	Bridge Hazard	Road Hazard	Other Infrastructure	Buildings	Crops	Infrastructure	Transportation disrupt	Siltation	Ponding/Flooding	Lack of/No Lahar disposal	Lahar Overflow	Poor Access/Isolation	Restore/Maintain river flow	Existing levees weak	
LEVEES	Containment of sediment & water.	H	H	H	M	H	H	M	L	M	M	M	M	M	M	M	M	M	Effective - high to moderate reduction to hazards & damages; meets all public concerns.
CHANNEL EXCAVATION	Increase capacity to move sediment & water.	M	M	M	M	L	L	M	L	M	M	M	M	NM	NM	M	M	NM	Effective - overall moderate reduction to hazards & damages; meets some public concerns.
SUMP	In-channel basin to trap sediment.	L	L	L	L	L	L	L	L	L	L	M	NM	NM	NM	NM	NM	NM	Not Effective - low potential to reduce hazards & damages; meets one public concern.
SAND POCKET	Trap sediment & regulate flow.	M	L	L	L	L	L	L	L	L	L	M	M	NM	M	M	NM	NM	Not Effective - overall low potential to reduce hazards & damages; meets some concerns.
SEDIMENT RETENTION STRUCTURE	Trap sediment & reduce flooding.	H	L	L	M	M	M	L	L	M	M	M	M	M	M	M	NM	NM	Effective - moderate reduction in hazards & damages; meets most public concerns.
DREDGING	Increase channel flow & reduce ponding.	L	H	H	H	M	M	M	L	M	M	M	M	NM	NM	NM	M	NM	Effective - high to moderate reductions in hazards & damages; meets some concerns.
BANK PROTECTION	Prevent erosion.	M	H	M	H	M	M	M	L	H	H	NM	M	M	NM	M	NM	M	Effective-high to moderate reduction in hazards & damages; meets some concerns.
SEDIMENT BASIN	Trap sediment to reduce transport.	M	L	L	L	L	L	L	L	L	L	M	NM	NM	M	M	M	NM	Not Effective - low potential to reduce hazards & damages; meets some concerns.
SILL	Stabilize sediment to control channel location.	L	L	L	L	L	L	L	L	L	L	M	NM	M	NM	NM	M	NM	Not Effective - low potential to reduce hazards & damages; meets some concerns.
PILE DIKE	Control flow & sediment deposition along banks.	M	L	L	M	M	M	L	L	M	M	M	NM	M	NM	NM	M	NM	Effective - moderate reduction in infrastructure hazards & damages; meets some concerns.
GROINS	Erosion control & control channel location.	M	L	L	M	M	M	L	L	M	M	NM	NM	M	NM	M	M	NM	Effective - moderate reduction in infrastructure hazards & damages; meets some concerns.
WEIRS	Trap sediment, control channel location & flows.	M	L	L	L	L	L	L	L	L	L	M	M	M	NM	M	M	NM	Not Effective - low potential to reduce hazards & damages; meets many concerns.

Table D-7 -- Preliminary Screening of Measures for the Maloma River Basin

HAZARD CONDITIONS: Ash is the main sediment problem. Sediment transport downstream has resulted in channel instability. Bank and bed instability and flooding have resulted. A moderate risk of flooding remains for the lower basin over the next 5 to 10 years. Localized channel filling may produce overbank flooding and sedimentation. Flooding is the major event that would cause damage. Unstable channel conditions may cause erosion of Highway 7.

Initial Structural Measures	Function of Measure	Engineering Factors Hazard Reduction Potential: L=Low M=Moderate H=High						Economic Factors Damage Reduction Potential: L=Low M=Moderate H=High				Environmental / Social Factors Public Issues and Concerns M=Meets NM=Does not meet								Conclusions for River Basin
		Mudflow/Sediment Hazard	Flood Hazard	Ponding Hazard	Bridge Hazard	Road Hazard	Other Infrastructure	Buildings	Crops	Infrastructure	Transportation disrupt	Siltation	Ponding/Flooding	Lack of/No lahar disposal	Lahar overflow	River Bank erosion	Poor Access/Isolation	Restore/Maintain river flow	Existing levees weak	
LEVEES	Containment of sediment & water.	H	H	H	M	M	M	M	L	M	M	M	M	M	M	NM	M	M	M	Effective-high to moderate reduction in hazards & damages; meets most public concerns.
CHANNEL EXCAVATION	Increase capacity to move sediment & water.	L	M	M	M	M	M	M	L	L	L	M	M	NM	NM	NM	M	M	NM	Effective - moderate reduction in hazards & most damages; meets some public concerns.
SUMP	In-channel basin to trap sediment.	L	L	L	L	L	L	L	L	L	L	M	NM	NM	NM	NM	NM	NM	NM	Not Effective - low potential to reduce hazards & damages; one concern met.
SAND POCKET	Trap sediment & regulate flow.	H	L	L	L	L	L	L	L	L	L	M	M	NM	M	NM	M	NM	NM	Not Effective - overall low potential to reduce hazards & damages; some concerns met.
SEDIMENT RETENTION STRUCTURE	Trap sediment & reduce flooding.	H	L	L	M	M	M	M	L	M	M	M	M	M	M	NM	M	NM	NM	Effective - overall moderate reduction in hazards & damages; most concerns met.
DREDGING	Increase channel flow & reduce ponding.	L	M	M	H	M	M	M	L	M	M	M	M	NM	NM	NM	NM	M	NM	Effective - moderate reduction in hazards & damages; some concerns met.
BANK PROTECTION	Prevent erosion.	L	M	M	H	H	H	L	L	M	M	NM	M	M	NM	M	M	M	M	Effective - overall moderate reduction in hazards & most damages; most concerns met.
SEDIMENT BASIN	Trap sediment to reduce transport.	H	L	L	L	L	L	L	L	L	L	M	NM	NM	M	NM	NM	NM	NM	Not Effective - overall low potential to reduce hazards & damages; two concerns met.
SILL	Stabilize sediment to control channel location.	L	L	L	L	L	L	L	L	L	L	M	NM	M	NM	NM	NM	M	NM	Not Effective - low potential to reduce hazards & damages; three concerns met.
PILE DIKE	Control flow & sediment deposition along banks.	L	L	L	H	M	M	L	L	M	M	M	NM	M	NM	NM	NM	M	NM	Effective - moderate reduction in infrastructure hazards & damages; three concerns met.
GROINS	Erosion control & control channel location.	L	L	L	H	M	M	M	L	M	M	NM	NM	M	NM	M	M	M	NM	Effective - moderate reduction in hazards & damages to infrastructure; some concerns met.
WEIRS	Trap sediment, control channel location & flows.	L	L	L	L	L	L	L	L	L	L	M	M	M	NM	NM	M	M	NM	Not Effective - low potential to reduce hazards & damages; many concerns met.

Table D-8 -- Preliminary Screening of Measures for the Gumain-Porac River Basin

HAZARD CONDITIONS: Gumain - The risk of mudflows is low because the upper drainage does not contain significant pyroclastic deposits. There is a high threat of flooding because much of the channel is filled with sediment. There is a high potential for diversion into the Caulaman-Blasic River because the channel is filled and the levees have been destroyed and rebuilt as a result of past events. Recent construction has reduced flood risk. Bank erosion, flooding, and channel meandering are localized problems near Floridablanca. There is a high risk of levee breaches and shallow flooding downstream of Floridablanca because of bank erosion.

Porac - Sediment supply is limited to the material already in the channel near Porac and downstream. The flood potential appears low. The in-channel sediment has caused the river to become unstable, causing localized bank erosion and channel alignment problems. Diversion from the Pasig River into the Porac basin presents a high risk of mudflows. There is a high risk that sediment may deposit in the fan at the mouth of the Gumain floodway and in downstream delta channels, causing ponding-type flooding.

Initial Structural Measures	Function of Measure	Engineering Factors Hazard Reduction Potential: L=Low M=Moderate H=High						Economic Factors Damage Reduction Potential: L=Low M=Moderate H=High				Environmental / Social Factors Public Issues and Concerns M=Meets NM=Does not meet							Conclusions for River Basin
		Mudflow/Sediment Hazard	Flood Hazard	Ponding Hazard	Bridge Hazard	Road Hazard	Other Infrastructure	Buildings	Crops	Infrastructure	Transportation disrupt	Siltation	Ponding/Flooding	Lack of/No lahar disposal	Lahar overflow	Restore/Maintain river flow	Poor Access/Isolation	Existing levees weak	
LEVEES	Containment of sediment & water.	H	H	M	M	H	H	H	H	M	M	M	M	M	M	M	M	M	Effective-high to moderate reduction in hazards & damages; meets all public concerns.
CHANNEL EXCAVATION	Increase capacity to move sediment & water.	M	M	H	M	M	M	H	H	M	M	M	M	NM	M	M	M	NM	Effective-high to moderate reduction in hazards & damages; meets most public concerns.
SUMP	In-channel basin to trap sediment.	M	M	H	L	L	H	H	H	M	M	M	M	NM	NM	NM	NM	NM	Effective-overall moderate reduction in hazards & damages; ponding-type flooding high.
SAND POCKET	Trap sediment & regulate flow.	M	L	L	L	L	L	L	M	L	L	M	NM	NM	M	NM	NM	NM	Not Effective - overall low potential to reduce hazards & damages; most concerns not met.
SEDIMENT RETENTION STRUCTURE	Trap sediment & reduce flooding.	H	M	L	M	M	L	L	M	M	M	M	M	M	M	NM	NM	NM	Effective - overall moderate reduction in hazards & damages; meets most public concerns.
DREDGING	Increase channel flow & reduce ponding.	M	H	H	M	M	M	M	H	M	M	M	M	NM	NM	M	M	NM	Effective-high to moderate reduction in hazards & damages; meets most public concerns.
BANK PROTECTION	Prevent erosion.	L	M	L	H	M	H	L	M	M	M	NM	M	M	NM	NM	M	M	Effective-overall moderate reduction in hazards & damages; meets most public concerns.
SEDIMENT BASIN	Trap sediment to reduce transport.	H	L	L	L	L	L	L	L	L	L	M	NM	NM	M	NM	NM	NM	Not Effective - low potential to reduce hazards & damages; most public concerns not met.
SILL	Stabilize sediment to control channel location.	M	L	M	M	L	M	L	L	M	M	M	M	M	NM	M	M	NM	Effective-overall moderate reduction in hazards & damages; meets most public concerns.
PILE DIKE	Control flow & sediment deposition along banks.	M	L	L	L	L	L	L	L	L	L	M	NM	M	M	NM	NM	NM	Not Effective - overall low potential to reduce hazards & damages; most concerns not met.
GROINS	Erosion control & control channel location.	L	L	L	H	M	M	L	L	H	L	NM	NM	M	NM	NM	M	M	Effective - overall moderate hazard & damage reduction to infrastructure; some concerns met.
WEIRS	Trap sediment, control channel location & flows.	M	L	M	M	L	M	L	L	M	M	M	M	M	NM	NM	M	NM	Effective-overall moderate reduction to hazards & damages; most public concerns met.

TABLE D-9 -- Evaluation and Screening of Potential Alternative Plans, Pasig-Potrero River Basin

1 = Poor
2 = Fair
3 = Good
4 = Very Good

ALTERNATIVES		PLANNING OBJECTIVES								
		PREVENT LOSS OF LIFE	REDUCE DAMAGE FROM SEDIMENT DEPOSITION IN POPULATED AREAS	REDUCE DAMAGE FROM SEDIMENT DEPOSITION IN AGRICULTURAL AREAS	REDUCE DAMAGE FROM SEDIMENT DEPOSITION TO INFRASTRUCTURE ASSETS	REDUCE DAMAGE FROM FLOODING IN POPULATED AREAS	REDUCE DAMAGE FROM FLOODING IN AGRICULTURAL AREAS	REDUCE DAMAGE FROM FLOODING TO INFRASTRUCTURE ASSETS	ENHANCE ECONOMIC, ENVIRONMENTAL AND SOCIAL RESOURCES	
		a	b	c	d	e	f	g	h	
	Study Objective Prioritization Value	24.6	14.2	10.8	3.4	10.8	9.2	2.6	10.6	Total
NO ACTION - No intervention measures recommended as long-term actions to reduce flooding & sediment damages. Continuation of existing warning systems. (See Note 1)		2 / 49.2	1 / 14.2	1 / 10.8	1 / 3.4	1 / 10.8	1 / 9.2	1 / 2.6	1 / 10.6	110.8
LEVEE PLAN. Hardened levees on left & right banks from Mancatian to upstream high ground. Hardened levee west bank downstream of Mancatian to Santa Rita. Existing east bank levee reconstructed. Control structure near San Juan. Sump at Sapang Labuan. Annual channel & sump excavation & disposal sites needed. (See Note 2)		4 / 98.4	4 / 56.8	3 / 32.4	2 / 6.8	4 / 43.2	3 / 27.6	2 / 5.2	2 / 21.2	291.8
CHANNEL EXCAVATION PLAN. Excavate 1 km wide channel from 3 km above and to 4 km downstream of Mancatian. Construct levees on right and left banks above excavation to high ground. Construct levees on right and left banks downstream of excavation to Santa Rita. Excavate lower channel and sump at mouth. Annual channel and sump excavation required. (See Note 3)		4 / 98.4	4 / 56.8	3 / 32.4	2 / 6.8	4 / 43.2	3 / 27.6	2 / 5.2	3 / 31.8	302.2
NONSTRUCTURAL PLAN. Permanent evacuation of populated areas threatened with imminent destruction. Temporary evacuation for areas threatened by shallow flooding. Improve early warning systems. (See Note 4)		4 / 98.4	1 / 14.2	1 / 10.8	1 / 3.4	1 / 10.8	1 / 9.2	1 / 2.6	1 / 10.6	160.0

Note 1: Warning systems provide fair warning to prevent loss of life. Without protective measures, damages cannot be prevented or conditions enhanced. Applies to all river basins.

Note 2: Levee plan provides significant protection to populated areas and agricultural lands by limiting sediment deposition and flooding to areas within the levees that for the most part have been previously damaged. Some damage to infrastructure within the leveed area may still occur.

Note 3: Channel excavation plan includes levees and would provide storage, protection, and sediment transport capabilities to protect populated areas and agricultural lands from sediment deposition and flooding. Some damage to infrastructure, for example bridges, still may occur. Some potential for future residential & industrial development would exist.

Note 4: Permanent and temporary evacuation and warning systems would maximize saving lives. Without protective measures, damages cannot be prevented or conditions enhanced. Applies to all river basins.

TABLE D-10 -- Evaluation and Screening of Potential Alternative Plans, Sacobia-Bamban River Basin

1 = Poor
2 = Fair
3 = Good
4 = Very Good

ALTERNATIVES	PLANNING OBJECTIVES: a. PREVENT LOSS OF LIFE	b. REDUCE DAMAGE FROM SEDIMENT DEPOSITION IN POPULATED AREAS	c. REDUCE DAMAGE FROM SEDIMENT DEPOSITION IN AGRICULTURAL AREAS	d. REDUCE DAMAGE FROM SEDIMENT DEPOSITION TO INFRASTRUCTURE ASSETS	e. REDUCE DAMAGE FROM FLOODING IN POPULATED AREAS	f. REDUCE DAMAGE FROM FLOODING IN AGRICULTURAL AREAS	g. REDUCE DAMAGE FROM FLOODING TO INFRASTRUCTURE ASSETS	h. ENHANCE ECONOMIC, ENVIRONMENTAL AND SOCIAL RESOURCES	Total
Study Objective Prioritization Value	21.5	10.8	10.5	6.3	10.5	12.0	3.5	17.6	
NO ACTION - No intervention measures recommended as long-term actions to reduce flooding & sediment damages. Continuation of existing warning systems.	2 / 43.0	1 / 10.8	1 / 10.5	1 / 6.3	1 / 10.5	1 / 12.0	1 / 3.5	1 / 17.6	114.2
LEVEE PLAN. Hardened levee constructed on right bank downstream of Hwy 3 from RK 0 to RK 4.5 on Sacobia to San Francisco bridge. Hardened levee from RK 16 to RK 25.5 on right bank of Bamban downstream of Hwy 3 and to San Francisco bridge. Hardened levee from RK 3 on Sacobia to RK 16 on Bamban. A control structure connects the 2 Sacobia levees at RK 16 of the Bamban. The existing left bank Bamban levee is reconstructed. Toe protection and seeding of levees needed. (See Note 1)	4 / 86.0	4 / 43.2	2 / 21.0	2 / 12.6	4 / 42.0	2 / 24.0	2 / 7.0	3 / 52.8	288.6
CHANNEL EXCAVATION PLAN. Channel excavation from RK 1.5 on the Sacobia to RK 19 on the Bamban. A hardened levee on the right bank of the Sacobia from RK 1.5 to RK 3.5. Levee reconstruction as described above. Annual excavation of channels necessary. (See Note 2)	4 / 86.0	4 / 43.2	3 / 31.5	2 / 12.6	4 / 42.0	3 / 36.0	2 / 7.0	3 / 52.8	311.1
RETENTION STRUCTURE PLAN. An SRS at RK 2 and another at RK 6.5 on the Sacobia. Levee reconstruction as above. Levees similar to those described for Levee Plan. (See Note 3)	4 / 86.0	4 / 43.2	3 / 31.5	3 / 18.9	4 / 42.0	3 / 36.0	2 / 7.0	2 / 35.2	299.8
NONSTRUCTURAL PLAN. Permanent evacuation of populated areas threatened with imminent destruction. Temporary evacuation for areas threatened by shallow flooding. Improve early warning systems.	4 / 86.0	1 / 10.8	1 / 10.5	1 / 6.3	1 / 10.5	1 / 12.0	1 / 3.5	1 / 17.6	157.2

Note 1: Levee plan requires more land to be committed for sediment deposition, so some agricultural lands may be removed from production. Some damage to infrastructure within the leveed area still may occur. Some potential exists for future residential and industrial development.

Note 2: Channel excavation plan includes levees and dredging and would provide storage, protection, and sediment transport capabilities to protect populated areas and agricultural lands from sediment deposition and flooding. Some damage to infrastructure, for example bridges, still may occur. Some potential for future residential & industrial development would exist.

Note 3: Retention structure plan provides significant protection to populated areas, agricultural lands, and infrastructure assets. This plan would have lesser built-up land and lower enhancement potential.

TABLE D-11 -- Evaluation and Screening of Potential Alternative Plans, Abacan River Basin

1 = Poor
2 = Fair
3 = Good
4 = Very Good

	PLANNING OBJECTIVES								
	PREVENT LOSS OF LIFE	REDUCE DAMAGE FROM SEDIMENT DEPOSITION IN POPULATED AREAS	REDUCE DAMAGE FROM SEDIMENT DEPOSITION IN AGRICULTURAL AREAS	REDUCE DAMAGE FROM SEDIMENT DEPOSITION TO INFRASTRUCTURE ASSETS	REDUCE DAMAGE FROM FLOODING IN POPULATED AREAS	REDUCE DAMAGE FROM FLOODING IN AGRICULTURAL AREAS	REDUCE DAMAGE FROM FLOODING TO INFRASTRUCTURE ASSETS	ENHANCE ECONOMIC, ENVIRONMENTAL AND SOCIAL RESOURCES	
	a	b	c	d	e	f	g	h	
ALTERNATIVES / Study Objective Prioritization Value	29.5	16.2	4.8	10.7	10.2	2.5	6.2	8.0	**Total**
NO ACTION - No intervention measures recommended as long-term actions to reduce flooding & sediment damages. Continuation of existing warning systems.	2 / 59.0	1 / 16.2	1 / 4.8	1 / 10.7	1 / 10.2	1 / 2.5	1 / 6.2	1 / 8.0	117.6
BANK PROTECTION PLAN. Erosion protection on north & south banks of river from 3 km upstream of Angeles City to Highway 3 bridge. Bank protection on existing levees from North Expressway to Mexico. Make Sabo structure No. 9 permanent. (See Note 1)	2 / 59.0	2 / 32.4	3 / 14.4	4 / 42.8	2 / 20.4	3 / 7.5	4 / 24.8	1 / 8.0	209.3
NONSTRUCTURAL PLAN. Permanent evacuation of populated areas not considered to be necessary. Temporary evacuation for areas threatened by shallow flooding. Improve early warning systems.	4 / 118.0	1 / 16.2	1 / 4.8	1 / 10.7	1 / 10.2	1 / 2.5	1 / 6.2	1 / 8.0	176.6

Note 1: The bank protection plan would provide significant protection to infrastructure assets and provide protection to a somewhat lesser extent to agricultural lands and populated areas.

TABLE D-12 -- Evaluation and Screening of Potential Alterantive Plans, O'Donnell River Basin

1 = Poor
2 = Fair
3 = Good
4 = Very Good

ALTERNATIVES	PLANNING OBJECTIVES: a. PREVENT LOSS OF LIFE	b. REDUCE DAMAGE FROM SEDIMENT DEPOSITION IN POPULATED AREAS	c. REDUCE DAMAGE FROM SEDIMENT DEPOSITION IN AGRICULTURAL AREAS	d. REDUCE DAMAGE FROM SEDIMENT DEPOSITION TO INFRASTRUCTURE ASSETS	e. REDUCE DAMAGE FROM FLOODING IN POPULATED AREAS	f. REDUCE DAMAGE FROM FLOODING IN AGRICULTURAL AREAS	g. REDUCE DAMAGE FROM FLOODING TO INFRASTRUCTURE ASSETS	h. ENHANCE ECONOMIC, ENVIRONMENTAL AND SOCIAL RESOURCES	Total
Study Objective Prioritization Value	27.3	9.8	10.8	5.3	9.8	9.3	2.0	8.8	
NO ACTION - No intervention measures recommended as long-term actions to reduce flooding & sediment damages. Continuation of existing warning systems.	2 / 54.6	1 / 9.8	1 / 10.8	1 / 5.3	1 / 9.8	1 / 9.3	1 / 2.0	1 / 8.8	110.4
LEVEE PLAN. Right bank levees from Santa Juliana to Bangat River. Slope protection on existing levee from RK 10 to Tarlac. (See Note 1)	4 / 109.2	4 / 39.2	4 / 43.2	2 / 10.6	4 / 39.2	4 / 37.2	2 / 4.0	1 / 8.8	291.4
RETENTION STRUCTURE PLAN. Embankment dam 7 km above Santa Juliana. Right bank levees from Santa Juliana to Bangat River. Slope protection on existing right bank levee from RK 10 to Tarlac. (See Note 2)	4 / 109.2	4 / 39.2	4 / 43.2	3 / 15.9	4 / 39.2	4 / 37.2	3 / 6.0	1 / 8.8	298.7
CHANNEL EXCAVATION PLAN. Excavate channel from RK 14.5 to RK 27. Dispose of material in berms to provide additional protection for large events. Annual removal of sediments needed. Slope and toe protection on existing levee. (See Note 3)	4 / 109.2	3 / 29.4	3 / 32.4	3 / 15.9	3 / 29.4	3 / 27.9	3 / 6.0	2 / 17.6	267.8
NONSTRUCTURAL PLAN. Permanent evacuation of populated areas threatened with imminent destruction. Temporary evacuation for areas threatened by shallow flooding. Improve early warning systems.	4 / 109.2	1 / 9.8	1 / 10.8	1 / 5.3	1 / 9.8	1 / 9.3	1 / 2.0	1 / 8.8	165.0

Note 1: Levee plan provides significant protection to populated areas and agricultural lands by limiting sediment deposition and flooding to areas within the levees that have been previously damaged. Some damage to infrastructure within the leveed area may still occur.

Note 2: Retention Structure plan offers similar protection as Levee plan but infrastructure somewhat better protected from sediment impacts.

Note 3: Channel excavation plan may provide somewhat less protection to populated areas and agricultural lands that the other plans that include levees and SRS. Excavation of sediments may provide better protection for infrastructure, and some potential exists for future residential & industrial development.

TABLE D-13 -- Evaluation and Screening of Potential Alternative Plans, Santo Tomas River Basin

1 = Poor
2 = Fair
3 = Good
4 = Very Good

ALTERNATIVES	a: PREVENT LOSS OF LIFE	b: REDUCE DAMAGE FROM SEDIMENT DEPOSITION IN POPULATED AREAS	c: REDUCE DAMAGE FROM SEDIMENT DEPOSITION IN AGRICULTURAL AREAS	d: REDUCE DAMAGE FROM SEDIMENT DEPOSITION TO INFRASTRUCTURE ASSETS	e: REDUCE DAMAGE FROM FLOODING IN POPULATED AREAS	f: REDUCE DAMAGE FROM FLOODING IN AGRICULTURAL AREAS	g: REDUCE DAMAGE FROM FLOODING TO INFRASTRUCTURE ASSETS	h: ENHANCE ECONOMIC, ENVIRONMENTAL AND SOCIAL RESOURCES	Total
Study Objective Prioritization Value	27.8	11.5	8.8	6.8	10.3	3.8	2.3	5.0	
NO ACTION - No intervention measures recommended as long-term actions to reduce flooding & sediment damages. Continuation of existing warning systems.	2 / 55.6	1 / 11.5	1 / 8.8	1 / 6.8	1 / 10.3	1 / 3.8	1 / 2.3	1 / 5.0	104.1
LEVEE PLAN. Double levee system on left bank from Lawin to Vega Hill. Single left bank levee from Vega Hill to Highway 7 Bridge. Right bank levee from RK 10 to the Highway 7 Bridge. (See Note 1)	4 / 111.2	4 / 46.0	4 / 35.2	2 / 13.6	4 / 41.2	4 / 15.2	2 / 4.6	1 / 5.0	272.0
RETENTION STRUCTURE PLAN. Embankment dam at RK 5.5 on Marella River. Left bank levee from Lawin to Vega Hill on existing levee alignment and from Vega Hill to Hwy 7 Bridge. Right bank levee from RK 10 to Hwy 7 Bridge. (See Note 2)	4 / 111.2	4 / 46.0	4 / 35.2	3 / 20.4	4 / 41.2	4 / 15.2	3 / 6.9	1 / 5.0	281.1
CHANNEL EXCAVATION PLAN. Channel excavation from RK 12 to RK 21. Left bank levee on existing alignment from Lawin to Hwy 7 Bridge. Right bank levee on existing alignment from RK 10 to Hwy 7 Bridge. (See Note 3)	4 / 111.2	4 / 46.0	4 / 35.2	2 / 13.6	4 / 41.2	4 / 15.2	2 / 4.6	2 / 10.0	277.0
NONSTRUCTURAL PLAN. Permanent evacuation of populated areas threatened with imminent destruction. Temporary evacuation for areas threatened by shallow flooding. Improve early warning systems.	4 / 111.2	1 / 11.5	1 / 8.8	1 / 6.8	1 / 10.3	1 / 3.8	1 / 2.3	1 / 5.0	159.7

Note 1: Levee plan provides significant protection to populated areas and agricultural lands by limiting sediment deposition and flooding to areas within the levees that for the most part have been previously damaged. Some damage to infrastructure within the leveed area may still occur.

Note 2: Retention structure plan provides significant protection to populated areas, agricultural lands, and bridges, roads, public structures, and power lines by limiting sediment upstream of the structure and by including levees.

Note 3: Channel excavation plan includes levees and dredging and would provide storage, protection, and sediment transport capabilities to protect populated areas and agricultural lands from sediment deposition and flooding. Some damage to infrastructure within the leveed area still may occur. Some potential exists for future residential & industrial development.

TABLE D-14 -- Evaluation and Screening of Potential Alternative Plans, Bucao River Basin

1 = Poor
2 = Fair
3 = Good
4 = Very Good

ALTERNATIVES	PLANNING OBJECTIVES: a. PREVENT LOSS OF LIFE	b. REDUCE DAMAGE FROM SEDIMENT DEPOSITION IN POPULATED AREAS	c. REDUCE DAMAGE FROM SEDIMENT DEPOSITION IN AGRICULTURAL AREAS	d. REDUCE DAMAGE FROM SEDIMENT DEPOSITION TO INFRASTRUCTURE ASSETS	e. REDUCE DAMAGE FROM FLOODING IN POPULATED AREAS	f. REDUCE DAMAGE FROM FLOODING IN AGRICULTURAL AREAS	g. REDUCE DAMAGE FROM FLOODING TO INFRASTRUCTURE ASSETS	h. ENHANCE ECONOMIC, ENVIRONMENTAL AND SOCIAL RESOURCES	Total
Study Objective Prioritization Value	27.8	10.5	11.0	5.3	9.5	4.8	2.5	4.3	
NO ACTION - No intervention measures recommended as long-term actions to reduce flooding & sediment damages. Continuation of existing warning systems.	2 / 55.6	1 / 10.5	1 / 11.0	1 / 5.3	1 / 9.5	1 / 4.8	1 / 2.5	1 / 4.3	103.5
LEVEE PLAN. Hardened levees on north bank along existing levee from Highway 7 bridge upstream to high ground. Slope protection on disposal berms on right and left banks. (See Note 1)	4 / 111.2	4 / 42.0	3 / 33.0	2 / 10.6	3 / 28.5	3 / 14.4	2 / 5.0	1 / 4.3	249.0
RETENTION STRUCTURE PLAN. SRS 1.5 km downstream of confluence of Bucao & Balin-Buquero rivers. Hardened levees as described in Levee Plan, but reduced in size. (See Note 2)	4 / 111.2	4 / 42.0	3 / 33.0	3 / 15.9	3 / 28.5	3 / 14.4	3 / 7.5	1 / 4.3	256.8
NONSTRUCTURAL PLAN. Permanent evacuation of populated areas threatened with imminent destruction Temporary evacuation for areas threatened by shallow flooding. Improve early warning systems.	4 / 111.2	1 / 10.5	1 / 11.0	1 / 5.3	1 / 9.5	1 / 4.8	1 / 2.5	1 / 4.3	159.1

Note 1: The levees and retention structure with levees alternatives provide similar protection to populated areas, agricultural lands, and infrastructure assets from sediment deposition and flooding.

Note 2: The retention structure plan would provide somewhat more protection to infrastructure assets by limiting sediment deposition upstream of the structure.

TABLE D-15 -- Evaluation and Screening of Potential Alternative Plans, Maloma River Basin

1 = Poor
2 = Fair
3 = Good
4 = Very Good

ALTERNATIVES	a	b	c	d	e	f	g	h	Total
PLANNING OBJECTIVES	PREVENT LOSS OF LIFE	REDUCE DAMAGE FROM SEDIMENT DEPOSITION IN POPULATED AREAS	REDUCE DAMAGE FROM SEDIMENT DEPOSITION IN AGRICULTURAL AREAS	REDUCE DAMAGE FROM SEDIMENT DEPOSITION TO INFRASTRUCTURE ASSETS	REDUCE DAMAGE FROM FLOODING IN POPULATED AREAS	REDUCE DAMAGE FROM FLOODING IN AGRICULTURAL AREAS	REDUCE DAMAGE FROM FLOODING TO INFRASTRUCTURE ASSETS	ENHANCE ECONOMIC, ENVIRONMENTAL AND SOCIAL RESOURCES	
Study Objective Prioritization Value	27.8	10.3	11.3	5.8	10.0	4.5	2.5	5.0	
NO ACTION - No intervention measures recommended as long-term actions to reduce flooding & sediment damages. Continuation of existing warning systems.	2 / 55.6	1 / 10.3	1 / 11.3	1 / 5.8	1 / 10.0	1 / 4.5	1 / 2.5	1 / 5.0	105.0
LEVEE PLAN. Levee on right bank from Highway 7 to RK 4.5. Levee on left bank from Hwy 7 to RK 8. Channel excavation from Hwy 7 to Sea. (See Note 1)	4 / 111.2	4 / 41.2	3 / 33.9	2 / 11.6	3 / 30.0	3 / 13.5	2 / 5.0	1 / 5.0	251.4
RETENTION STRUCTURE PLAN. RCC dam at RK 19.5. Levees and new channel as described in Levees Alternative. (See Note 2).	3 / 83.4	3 / 30.9	3 / 33.9	4 / 23.2	3 / 30.0	3 / 13.5	4 / 10.0	1 / 5.0	229.9
CHANNEL EXCAVATION PLAN. Channel excavation from RK 8 to Highway 7 bridge. A new channel excavated from Hwy 7 bridge and westward. Bank protection on all channel side slopes. (See Note 3)	3 / 83.4	2 / 20.6	2 / 22.6	4 / 23.2	2 / 20.0	2 / 9.0	4 / 10.0	2 / 10.0	198.8
NONSTRUCTURAL PLAN. Permanent evacuation of populated areas threatened with imminent destruction. Temporary evacuation for areas threatened by shallow flooding. Improve early warning systems.	4 / 111.2	1 / 10.3	1 / 11.3	1 / 5.8	1 / 10.0	1 / 4.5	1 / 2.5	1 / 5.0	160.6

Note 1: Levee plan provides significant protection to populated areas and agricultural lands by limiting sediment depostion and flooding to areas within the levees that for the most part have been previously damaged. Some damage to infrastructure within the leveed area may still occur.

Note 2: Retention structure plan provides protection to populated areas, agricultural lands, and bridges, roads, public structures, and power lines by limiting sediment deposition upstream of the structure, and by including bank protection.

Note 3: Channel excavation plan would provide less protection to populated areas and agricultural lands. Excavation of sediments and bank protection would protect infrastructure assets.

TABLE D-16 -- Evaluation and Screening of Potential Alternative Plans, Gumain-Porac River Basin

1 = Poor
2 = Fair
3 = Good
4 = Very Good

ALTERNATIVES	a	b	c	d	e	f	g	h	Total
PLANNING OBJECTIVES	PREVENT LOSS OF LIFE	REDUCE DAMAGE FROM SEDIMENT DEPOSITION IN POPULATED AREAS	REDUCE DAMAGE FROM SEDIMENT DEPOSITION IN AGRICULTURAL AREAS	REDUCE DAMAGE FROM SEDIMENT DEPOSITION TO INFRASTRUCTURE ASSETS	REDUCE DAMAGE FROM FLOODING IN POPULATED AREAS	REDUCE DAMAGE FROM FLOODING IN AGRICULTURAL AREAS	REDUCE DAMAGE FROM FLOODING TO INFRASTRUCTURE ASSETS	ENHANCE ECONOMIC, ENVIRONMENTAL AND SOCIAL RESOURCES	
Study Objective Prioritization Value	30.4	12.9	7.1	5.7	11.3	6.3	3.3	6.3	
NO ACTION - No intervention measures recommended as long-term actions to reduce flooding & sediment damages. Continuation of existing warning systems.	2 / 60.8	1 / 12.9	1 / 7.1	1 / 5.7	1 / 11.3	1 / 6.3	1 / 3.3	1 / 6.3	113.7
CHANNEL EXCAVATION PLAN. Excavate Gumain channel from Pasig River upstream to RK 16.5. Bank protection on Porac from RK 4 to RK 6. (See Note 1)	3 / 91.2	3 / 38.7	3 / 21.3	3 / 17.1	3 / 33.9	3 / 18.9	3 / 9.9	2 / 12.6	243.6
LEVEE PLAN. Right & left bank levees on Gumain from RK 16.5 to mouth of Porac River. Excavate Gumain channel from Pasag River upstream to Porac River. Bank protection on Porac River from RK 4 to RK 6. (See Note 2)	4 / 121.6	4 / 51.6	4 / 28.4	3 / 17.1	4 / 45.2	4 / 25.2	3 / 9.9	2 / 12.6	311.6
RETENTION STRUCTURE PLAN. RCC dam at RK 23.5 on Gumain River. RCC weir near Basa Air Base . Levees, channel excavation, and bank protection as in Levees Alternative. (See Note 3)	4 / 121.6	4 / 51.6	4 / 28.4	4 / 22.8	4 / 45.2	4 / 25.2	4 / 13.2	2 / 12.6	320.6
NONSTRUCTURAL PLAN. Permanent evacuation of populated areas not considered to be necessary. Temporary evacuation for areas threatened by shallow flooding. Improve early warning systems.	4 / 121.6	1 / 12.9	1 / 7.1	1 / 5.7	1 / 11.3	1 / 6.3	1 / 3.3	1 / 6.3	174.5

Note 1: Channel excavation plan provides less protection to populated areas, and agricultural lands than other plans that include levees or SRS's. Excavation of sediments would provide better protection for infrastructure assets.

Note 2: Levee plan would provide significant protection to populated areas and agricultural lands by limiting sediment deposition and flooding to areas within the levees that for the most part have been previously damaged. Some damage to infrastructure within the leveed area may still occur.

Note 3: The retention structure plan provides the best protection for the basin by including a wide array of measures that are effective at reducing sediment and flooding damages.