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RESEARCH NEEDS IN FLOOD CONTROL: Metro Manila and Laguna Lake Region

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ABSTRACT

The perennial floods in Metro Manila and other towns in the Laguna Lake Region have been attributed to a number of factors. The need for a comprehensive research program is discussed in order to determine the degree of influence of these factors as they involve not only local but also regional considerations. The program includes development of the guidelines that would minimize the damaging effects of floods and would also rationalize the expenditures in coping with the flood problem.

1. INTRODUCTION

Flooding in the low-lying areas of Metro Manila and the Laguna Lake region, most specially Taguig and Pateros, has been occurring with such regularity over the past years that the issue has been a highly emotional one. In addition to the suffering of hundreds of thousands of residents in these areas, annual damage to property have been estimated to be in the range of One Billion Pesos.

Almost all newspapers, radio and television stations, have prepared editorials and special reports on their own perceptions as well as those of government officials and concerned citizens regarding the causes, effects, and solutions to the flood problem. Most of these perceptions, however, are qualitative in nature that it is difficult to make an objective evaluation of the issues.

When dealing with a flood problem, it is also necessary to consider such quantitative terms as flood frequency, rainfall intensity, flood duration, flood peaks, depth and area of flooding, time of flood recession, discharge capacity, sediment transport, run-off coefficients, as well as the various socio-economic parameters. These quantitative parameters must be determined through an in-depth and systematic study of the problem. Their values are then used in an objective evaluation of the various alternatives to arrive at an acceptable and satisfactory solution.

Measures for flood control, mitigation, and relief, generally involves hundreds of millions of pesos. It is only prudent, therefore, to invest a small percentage of these costs in a comprehensive research program to obtain more detailed baseline information which will form the basis for making decisions on the final strategy to be adopted. In the case of Metro Manila, what has been initially perceived as a local flood problem, is in fact also a problem for the whole Laguna Lake region.

This report discusses the need for research on the flood problems of Metro Manila and other areas in the Laguna Lake region. After presenting a review of the problems together with the current efforts at flood mitigation, a comprehensive research program is proposed together with an indicative budget for a five-year time frame of completion.

2. LAGUNA LAKE BASIN

The Laguna Lake Basin covers an area of about 5,078 square kilometers and includes the 4 cities and 13 towns of Metro Manila, the 49 towns of the provinces of Laguna and Rizal, as well as Laguna Lake itself (Fig. 1). The current population (1988) within the watershed is about 9.7 million and is expected to increase to about 14.3 million by the year 2000.

As the center of commerce and industry as well as the seat of the national government, the region has attracted a large concentration of population. The damaging effects of flooding are therefore enormous as compared to other regions of the country.

2.1 Storm Rainfall Patterns

With an average of 19 typhoons passing over the Philippines annually, the watershed has its share in terms of the high rainfall intensities. In 1972, the maximum rainfall recorded for a 24-hour period was about 470 mm which corresponds to a return period of about 300 years (Fig. 2).

A cursory review of the accumulated rainfall for each of the largest storm that has passed over the watershed on a yearly basis indicates the regularity in the occurrence of flood flow conditions (Fig. 3). More in-depth studies, however, are needed to consider the effects of these observations on the flood problem for the region.

2.2 Drainage Characteristics

The major drainage features of the watershed consists of Laguna Lake, Marikina River, Pasig River, San Juan River, Malabon River, Estero Tripa de Gallina, and Estero de Vitas, all of which eventually discharge their flood waters to Manila Bay (Fig. 4). Under flood flow

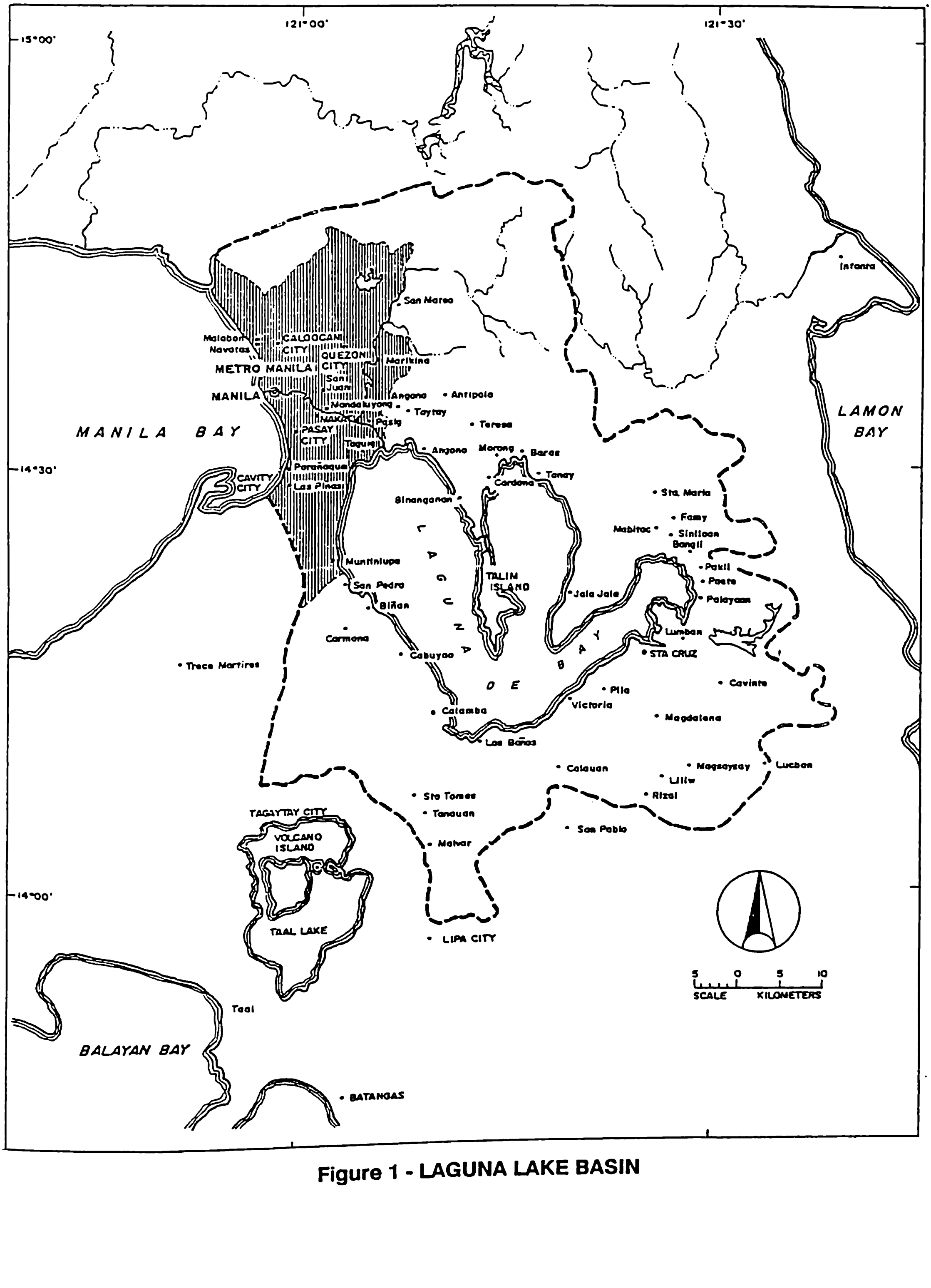


Figure 1 - LAGUNA LAKE BASIN

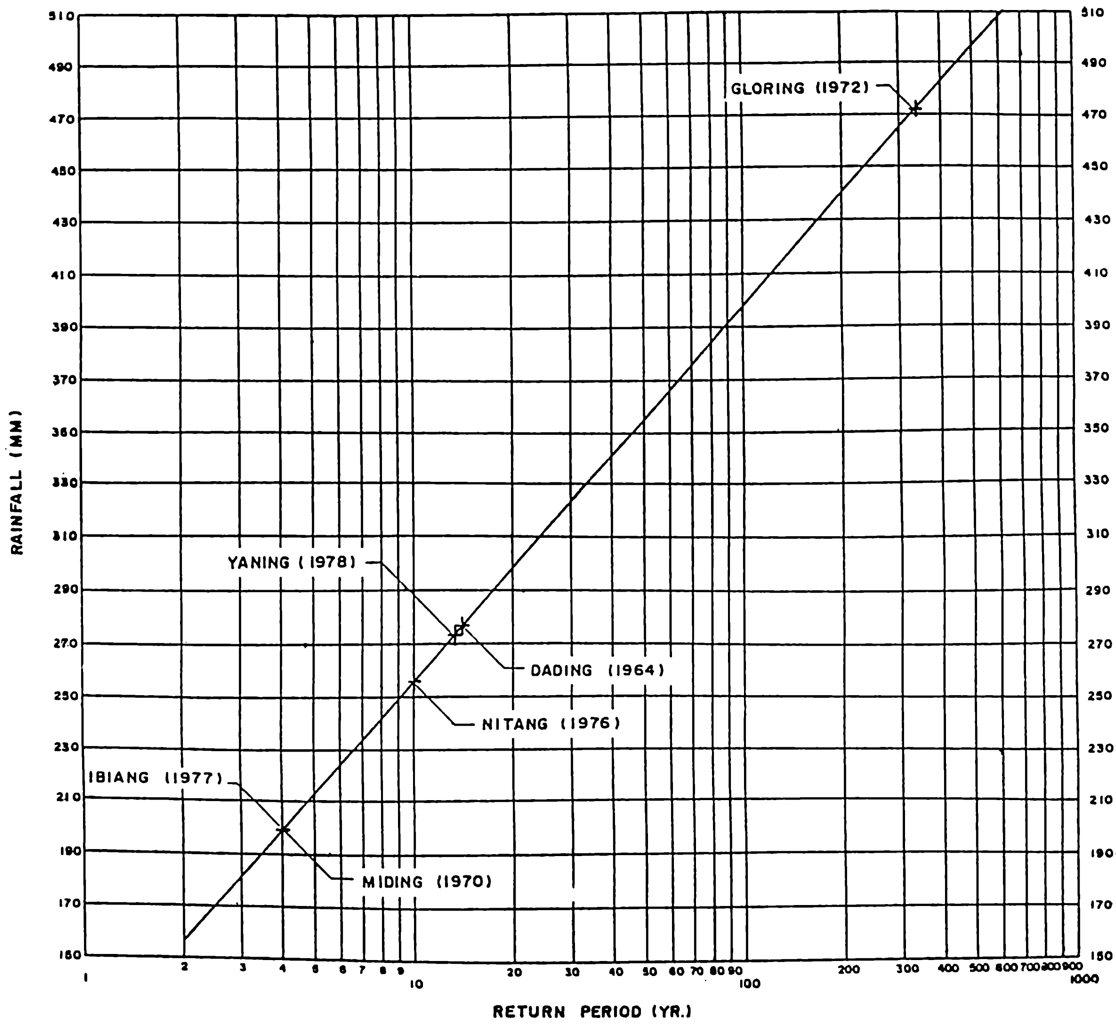


Figure 2 - 24-HOUR RAINFALL FREQUENCY

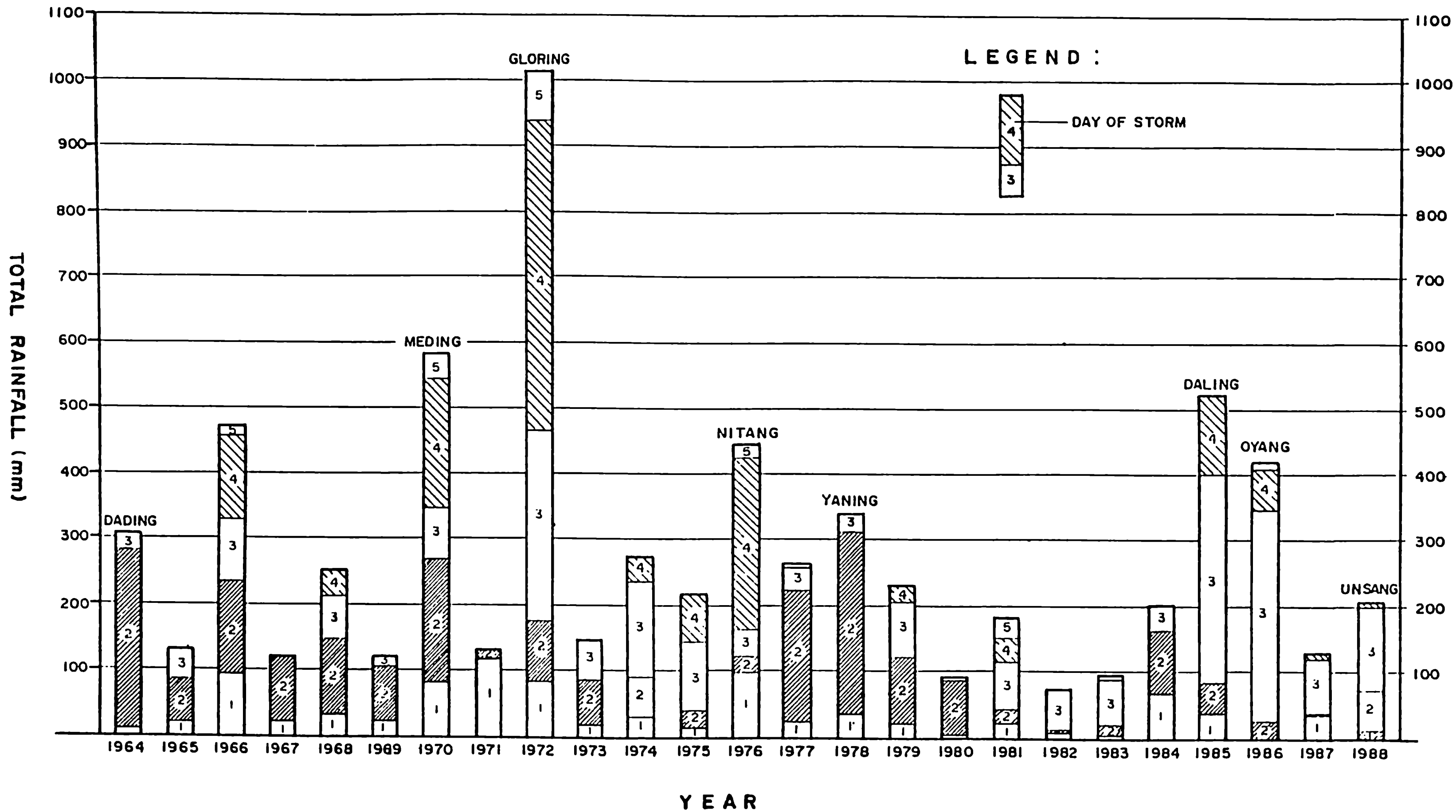


Figure 3 - ACCUMULATED RAINFALL FOR THE LARGEST STORMS

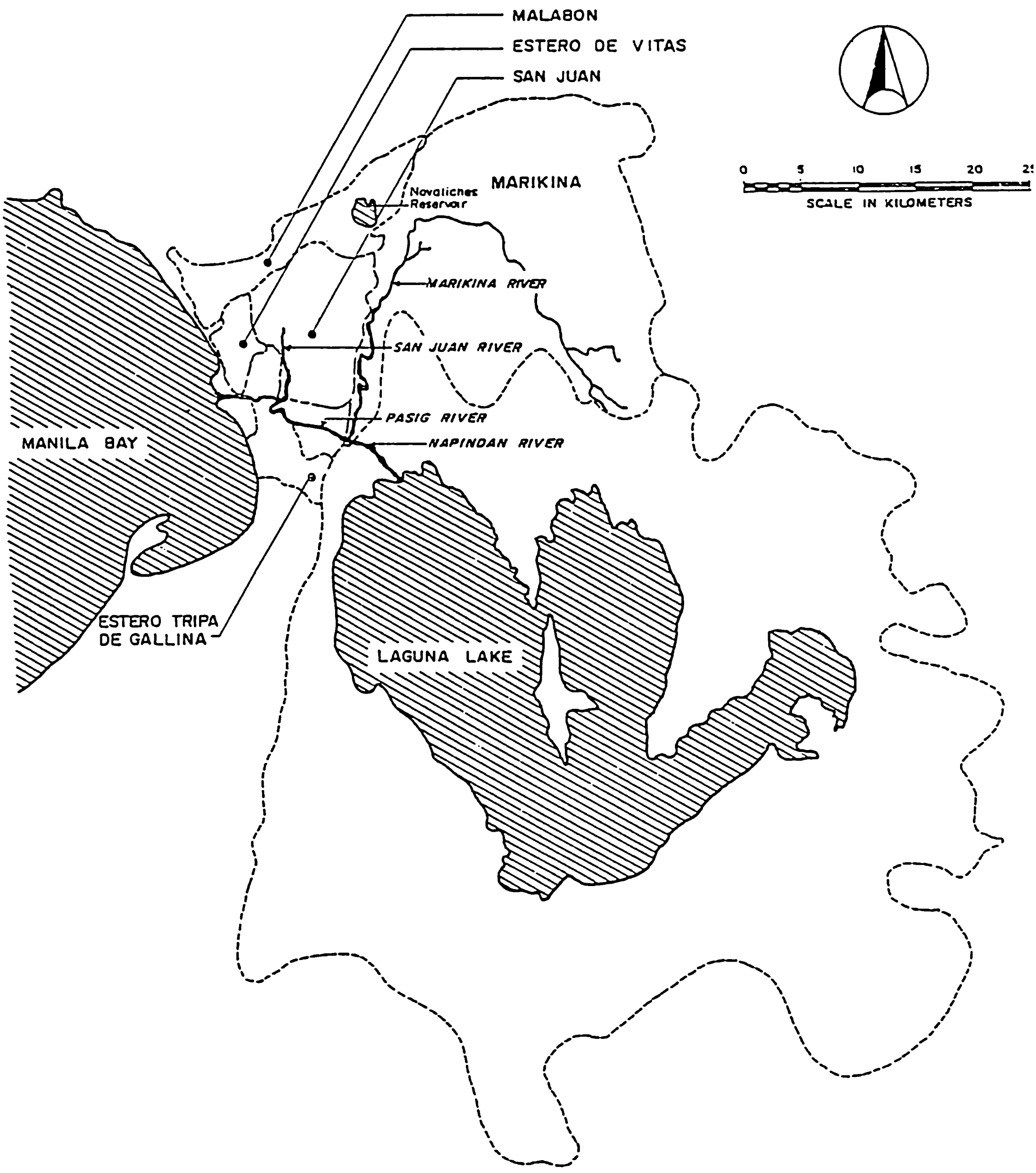


Figure 4 - DRAINAGE FEATURES OF WATERSHED

conditions and considering the tidal variations of Manila Bay, the discharge carrying capacities of these channels are so interrelated that only a regional study would provide a deeper insight into the flow characteristics of the drainage system.

Laguna Lake serves as a natural storage for the flood waters in the watershed by collecting the discharges of the streams that surround it. The major tributaries are the Sta. Cruz, San Cristobal, Pagsanjan, and Romero Rivers, all of which deplete the southern and eastern slopes of the watershed. Very little information, however, is available on the discharge characteristics of these tributaries.

The design flood of the Marikina River has been estimated to be about 3,300 cubic meters per second (cms). In as much as this is more than the estimated bankfull capacity of 900 cms, part of the overflow goes to Laguna Lake through the Napindan River and the rest goes to the low-lying areas adjacent to the Marikina and Pasig Rivers.

After the passage of a flood, the waters in Laguna Lake may be drained through the Napindan and Pasig Rivers as the only outlet to the sea. This waterway, however, has a limited capacity so that in some cases the recession of flood waters has taken a couple of months. Studies are needed on the alternative measures to increase the drainage capacity of waterway.

2.3 Flood Prone Areas

The flood prone areas are generally located along the banks of the drainage channels in Metro Manila (Fig. 5) as well as along the shoreline of Laguna Lake (Fig. 6). It has been estimated that these involves about 10,000 hectares where about one million people live.

While these figures provide an overview of the area, it is necessary to determine more precisely the depth and area of flooding for different recurrence intervals of floods so that these may be used in evaluating the damages as well as the alternative solutions to the problem. For this purpose, studies on flood risk mapping and flood damage analysis may be undertaken.

3. FLOOD CONTROL AND MITIGATION MEASURES

The initial efforts at evolving a master plan for flood control and mitigation for Manila were undertaken in 1952. At that time the population density was very low and there were a lot of open areas which could absorb a large portion of the heavy rains. Natural depressions in the ground surface and drainage channels such as the esteros contributed their share in carrying a portion of the flood waters.

The master plan consisted of a drainage network for the urban area and a number of hydraulic control structures. With the increase in population, however, many of the open areas were used for housing and some esteros were even reclaimed. This and other changes in the watershed indicates a need to review the design criteria and assumptions used in the construction of the flood control and drainage structures in order to evaluate their efficiency.

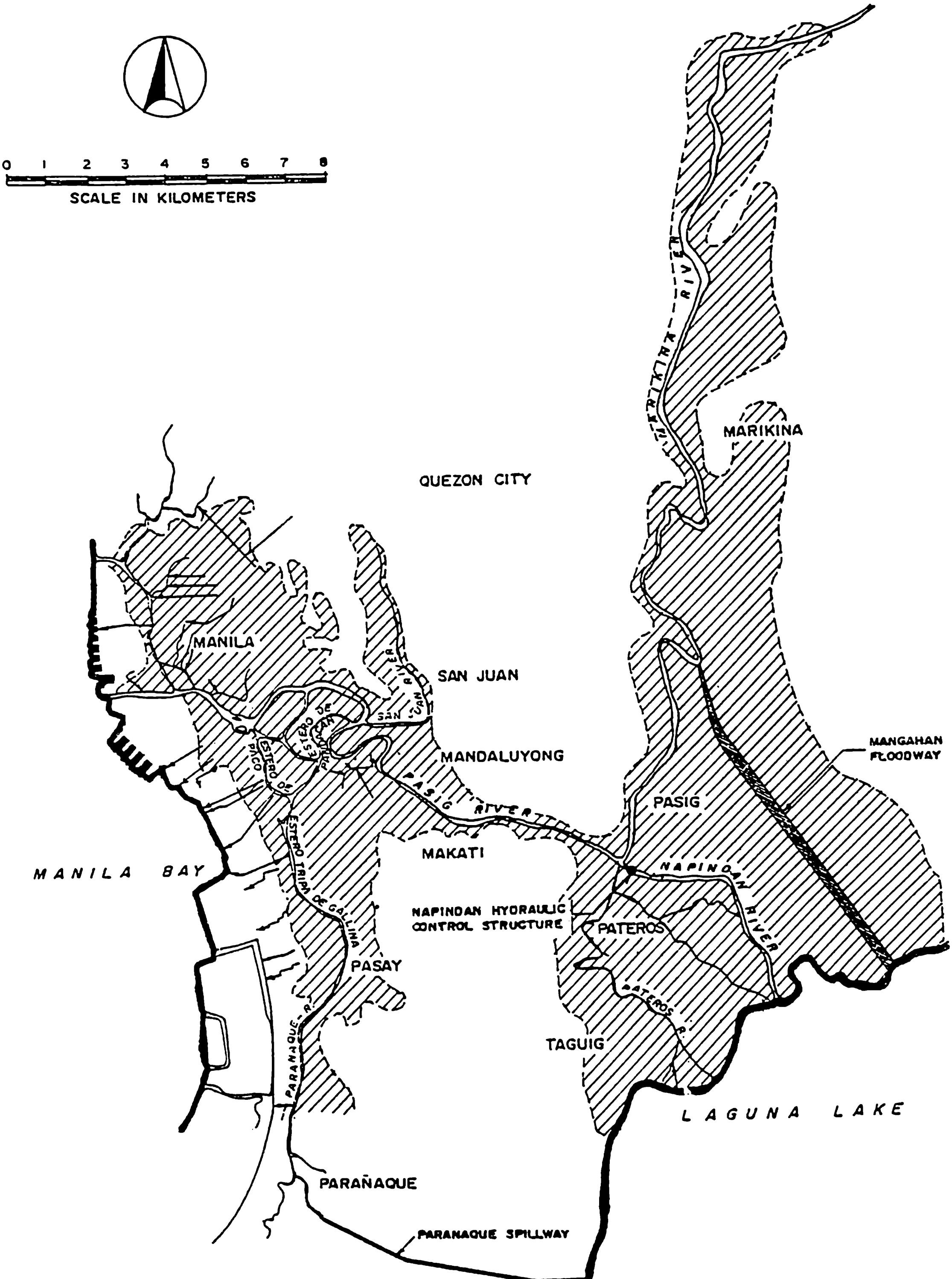


Figure 5 - FLOOD PRONE AREAS OF METRO MANILA

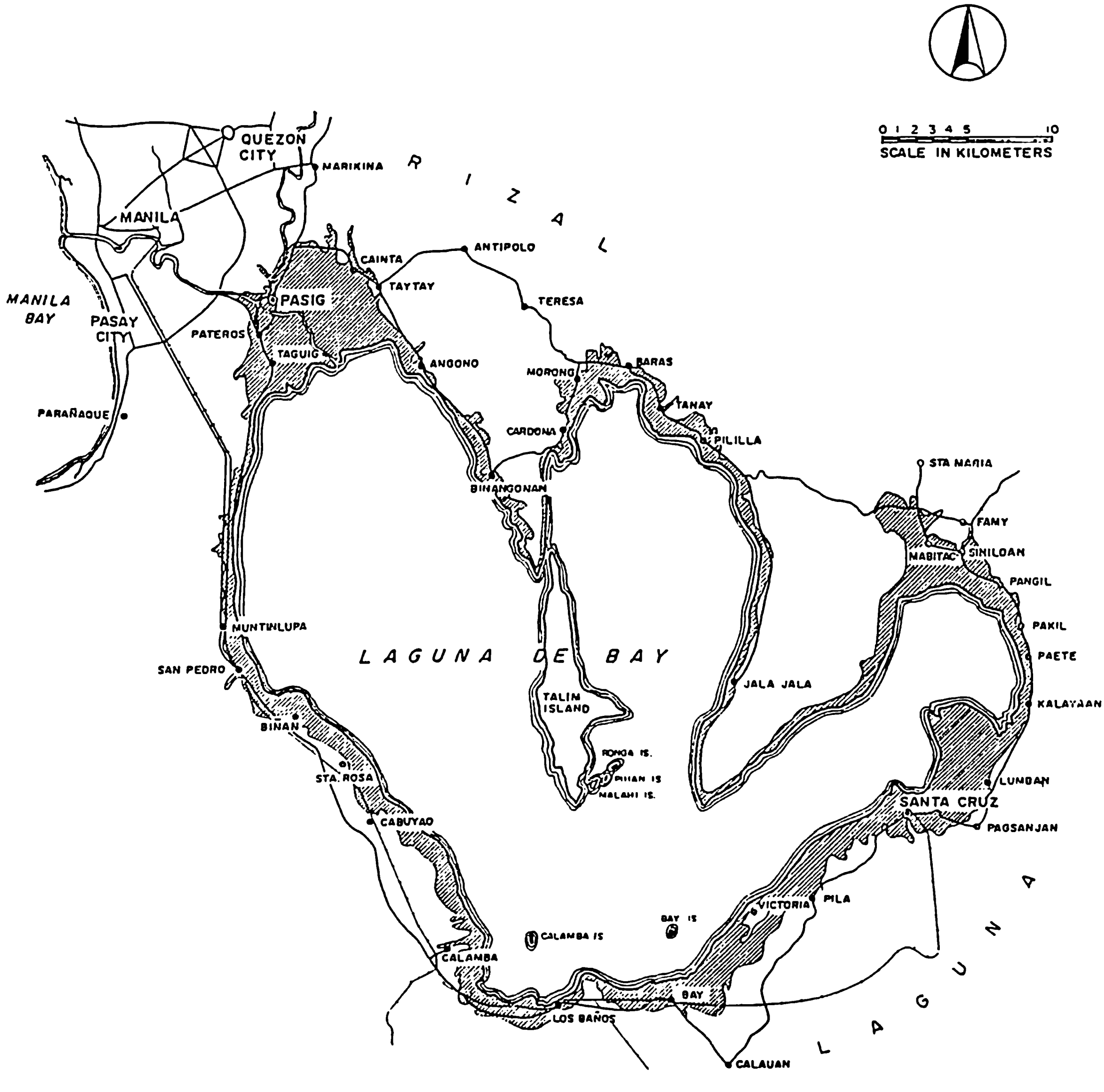


Figure 6 - FLOOD PRONE AREAS AROUND LAGUNA LAKE

3.1 Drainage Network

The drainage network for Metro Manila consists of the natural and man-made drainage channels, underground pipes and culverts, and pumping stations. Most of these have been in place for some time and there have been many improvements since then.

Flooding, however, still occurs thus indicating the need for a more thorough analysis of the existing network that would include an assessment of the efficiency of the drainage structures. The results of the study may be used as a basis for proposing further improvements.

3.2 Mangahan Floodway

The Rosario Weir and the Mangahan Floodway were constructed for the purpose of diverting a portion of Marikina River flood flow towards Laguna Lake in order to limit the discharge in the river to its bankfull capacity. It was estimated that the rise in lake level only be a few centimeters.

While this has minimized the flooding hazard and damage to the low-lying areas adjacent to the Marikina and Pasig Rivers, concerned residents along the lakeshore areas have complained that this has been to their disadvantage. Some of the parameters that have to be considered in the operation of the Mangahan Floodway are the rising of the lake level during the storm, the incremental increases in the flooded area, and the longer time of flood recession.

3.3 Napindan Hydraulic Control Structure

The Napindan Hydraulic Control Structure was primarily designed to prevent the entry of saline and polluted waters of the Pasig River into Laguna Lake. Its construction was pursuant to the original objective of gradually converting Laguna Lake into a future source of fresh water for the domestic and municipal water supply needs of Metro Manila.

The construction as well as the operation of both the Napindan Hydraulic Control Structure and the Mangahan Floodway have been the subject of many criticisms. The recurring floods in the lakeshore area in recent years have been attributed to these structures. It is necessary, therefore, to construct a simulation model for the whole flood control system in order to develop optimum operating procedures for the benefit of all concerned.

3.4 Flood Warning System

A flood warning system has been proposed for the region similar to the existing systems in some of the major river basins of the country. In order to be more effective, it is necessary to undertake studies on real-time forecasting of flood flows based on telemetered data. The flood forecasting models may also be used in conjunction with the simulation model of the flood control system.

3.5 Proposed Structural Measures

Several structural measures have been proposed to complement the existing flood control system. Among these are the Paranaque Spillway, the lakeshore dikes, and the Marikina Dam. While all of these structures reduce the flooding hazard even when taken individually, it would be more prudent to analyze the contribution of each in relation to the whole flood control and mitigation system.

4. RESEARCH PROGRAM AND OBJECTIVES

In view of the many questions and issues which include both local and regional considerations, it is proposed that a comprehensive research program be undertaken on the flood problems of Metro Manila and the Laguna Lake Region. The program consists of a series of interrelated studies on the meteorological, hydrological, hydraulic, and socio-economic aspects of the problem including the operational aspects of the flood control structures.

The general objective of the research program is to get a deeper insight into the causes and effects of the flood problem and to analyze the viability and effectivity of the alternative measures for flood control and mitigation.

Among the specific objectives of the research studies are the following:

a. to provide basic information for the promulgation of policies for an effective flood control management;

b. to develop guidelines for the selection, analysis and design of proposed flood control and drainage structures, such as storm drains, drainage inlets, dikes, spillways, and impounding reservoirs;

c. to determine the adequacy and efficiency of the existing urban drainage network and to analyze the effectivity of possible improvements;

d. to develop guidelines for the efficient operation of existing structures, such as the Napindan Hydraulic Control Structure and the Mangahan Floodway;

e. to provide basic information that would be the basis for the regular maintenance of drainage inlets and waterways; and

f. to develop guidelines for the efficient operation of the flood forecasting and warning system taking into account the flood relief and rescue efforts.

5. RESEARCH ACTIVITIES

The research activities have been grouped into 16 interrelated studies on the various aspects of the flood problem. Brief descriptions of the studies are provided in the sections that follow.

5.1 Flow Capacities of Main Waterways

The main waterways that drain Metro Manila and the Laguna Lake area are the Marikina River, Mangahan Floodway, Napindan River, Pasig River, San Juan River, Malabon River, and Paranaque River. The first five waterways hydraulically interact with each other and effect the drainage of a large portion of Metro Manila and the entirety of the Laguna Lake region. The Pasig and Napindan Rivers reverse their flow directions during times of low lake levels and high tide at Manila Bay. Similarly, the Mangahan Floodway has been designed for reverse flow so that lake levels can be depleted faster. The Malabon and the Paranaque Rivers, however, are independent waterways. They drain the northern and southern portions of the metropolis directly to Manila Bay.

The objective of this study therefore is to determine the discharge capacities of each waterway for both normal and reverse flow conditions (for the case of the Mangahan Floodway and the Pasig/Napindan River system). Rating curves that will quantitatively indicate the discharge for given combinations of boundary water levels will be produced.

5.2 Hydrodynamics of Tide-affected System

The flow of the Marikina-Pasig-Napindan River System is a complex hydraulic phenomenon. A mathematical model will be developed to determine the hydrodynamic response of the water levels along the three rivers for varying sea and lake elevations. Simulation in the model will include the effects of existing flood control structures such as the Mangahan Floodway and the Napindan Hydraulic Control Structure on the flood levels along the rivers.

5.3 Hydraulic Model of Control Structures

A 1:80 hydraulic scale model of the Rosario Weir and Mangahan Floodway, Napindan River and Hydraulic Control Structure, and portions of Laguna Lake and Marikina and Pasig Rivers will be constructed. The model will be used to establish coordinated gate operation policies. Studies on the entrance and exit conditions will be made to find options for maximizing flows from the Rosario Weir and the Napindan Control Structure. The model will be also utilized to investigate the flow conditions at the Marikina-Pasig-Napindan junction and determine the effectiveness of the Mangahan Floodway when it is used as an outlet for draining the flood waters of Laguna Lake.

5.4 Computer Based Operations Control Model

A combined hydrologic and hydrodynamic model will be developed, the main function of which is to provide the best gate operating policy of the Rosario Weir and the Napindan

Hydraulic Control Structure in accordance to the criteria currently specified in the data bank of the control system. This computer model is complementary to the 1:80 hydraulic model as it determines the procedures for the coordinated operation of the gates subject to the actual boundary conditions and constraints on the system. It is intended for the guidance of operators of the hydraulic structures by taking into consideration the flood forecasts in the region.

5.5 Simulation Model of Drainage System

The flooding of Metro Manila is a perennial problem and its solution lies in having an adequate and efficient drainage system. To study the behavior of its drainage system at different conditions, a mathematical model will be developed. The model will simulate various hydrologic and hydraulic processes. It will include a rainfall input model, overland flow and surface runoff models, and hydraulic routing of flow through open channels and closed conduits. Ancillary structures, surface flooding, and level controls will also be modeled. The drainage system model, once developed and calibrated, becomes a vital instrument for efficient operation and an indispensable tool for planning adequate and drainage structures.

5.6 Local Drainage Design Practices

In a large portion of the metropolis, street drains are undersized and are prone to blockage due to negligible slopes. Moreover, majority of these drains have inadequate curb or gutter inlet design and spacing. Hence, when there is a heavy downpour, local flooding occurs even when a nearby creek is still below its bankfull capacity. Such an occasion places the current local drainage design practices into question. The study will therefore focus on the review and assessment of current local drainage design practices. Modifications as well as the introduction of more appropriate design criteria and techniques will be made with the end view of developing a local drainage design manual.

5.7 Real-time Flood Forecasting System

This study will be aimed at providing estimates of flood levels that would result from an advancing storm. Inputs will be telemetered from weather monitors, rain gages, and water level recorders. Using a hydrologic model, these data will be processed by a computer into point elevations at critical locations. Computations will continue as long as data is updated by new readings. Reliability of the estimates will of course depend on field instrumentation, telemetry system, and level of detail adopted in the development of the model. The system will also be used in disseminating the latest forecasts to concerned participating entities, such as broadcast media and civil defence supervisors.

5.8 Rainfall Distribution of Flood Producing Storms

A detailed investigation of storm patterns that have resulted in flooding within the Metro Manila and Laguna Lake area will be undertaken. Particular attention will be given to classifying storm patterns according to rainfall amounts and distributions. The final objective will be to explore the possibility of finding a correlation between storm parameters so that a prediction can be made.

5.9 Flood Flow Parameters of Major Rivers

A study of available rainfall and discharge records, evaluation of catchment parameters, and flood frequency analyses shall be done to arrive at characteristic descriptors of flood flow of some major tributaries discharging into the Laguna Lake. These major tributaries initially include the Pagsanjan, Sta. Cruz, San Juan, and San Cristobal Rivers.

The same study will be done for the Marikina River because of the close interaction with the outflows from the lake. The end in view is not only to determine the individual flood contribution of each river but also to prepare for the hydrologic modeling of the entire Laguna Lake Basin.

5.10 Runoff Coefficients of Minor Tributaries

Because of their sheer number, the aggregate flood contribution from the minor streams into Laguna Lake actually becomes a major component. For lack of individual historical record, detailed analyses cannot be done. As an alternative, catchment characteristics can be extracted from physiographic and land use information. This process can be done individually for the larger streams and on a lumped basis for the smaller streams. The objective is to establish rainfall runoff relationships so that they may be properly simulated in subsequent hydrologic models

5.11 Area- Storage Characteristics of Laguna Lake

The surface area of Laguna Lake is estimated to be about 900 km^2. With this large area, a one centimeter increase in the lake level will be a result of the entry of 9,000,000 cubic meters of water into the lake. Moreover, the slopes of the lakeshore areas are generally small, which means that large errors in volume computations can result from an imprecise reckoning of lake coverage.

When effects of storm precipitation and tributary inflows are to be explored, the need for accurately defining the lake bed and shore geometry in the form of an elevation-area-volume relationship becomes acute. This becomes even more evident when lake level depletion rate and hydraulic interaction at the outlet are to be studied. A detailed topographic and hydrographic survey, which is not a minor activity in itself, would therefore contribute much to the study of the flooding problem. It is moot to mention that the results of the study would provide excellent baseline information for projects of other sectors.

5.12 Evapotranspiration and Lake Evaporation

Because the magnitudes of runoff depend on the antecedent precipitation, it is important to determine the rate of evapotranspiration. Evapotranspiration indicates the depletion rate of soil moisture and detention storage after a storm. Lake evaporation is closely linked with evapotranspiration so that it would be advantageous to lump the studies together. When there are floods that persist through several weeks or months with no apparent storm flows, then evaporation becomes a major factor for depleting the lake level.

5.13 Groundwater Recharge for Flood Recession

Although groundwater flows at a much slower rate than surface water, interaction of the lake with the groundwater strata and aquifers still needs to be ascertained. Notwithstanding the carrying capacity of the main and auxiliary outlets for the lake plus evaporation, why do floods stay for weeks or months? Could inflow from higher strata be responsible? Can recharge from the lake to the aquifers below it be accelerated? Even a far-fetched notion of encouraging groundwater pumping around the lake might have some merit for the sake of flood recession.

5.14 Water Balance for Long Term Flood Durations

Additional insight for making guidelines for regulating inflow and outflow of Laguna Lake may be gleaned from an accounting of the water, where it passes from rainfall and where it goes, on a monthly basis. This would mean computing for rates of precipitation, surface runoff, evaporation and evapotranspiration, deep percolation, interflow, and discharge through inflow and outflow channels. From this, a gross hydrologic model may be developed so that the main sources of flood waters on a long-term basis may be pinpointed.

5.15 Flood Risk Mapping of the Flood Plains

The aim of this component is to delineate areas in the flood plains of the rivers and the Lake according to risk levels after a thorough hydrological and statistical treatment. The maps produced by this study can be used for:

a. Preparing a flood warning and contingency plan for any lakeshore area or river valley;

b. Planning, design, or operation of structural flood mitigation measures;

c. Arriving at zoning regulations; and,

d. Conducting flood damage analyses.

5.16 Flood Damage Analysis for the Flood Plains

Although flood damage analysis would rely heavily on flood risk maps for its baseline information, additional analyses of floods to include durations would have to be made. This is because damage functions generally increase at a steeper rate after an initial slack at the early stage of a flood, then taper off as the flood persists. Detailed surveys of land use and potential damage will be required to be able to translate flood occurrences to monetary values. Results will augment flood risk maps and be useful to both the private and public sectors for:

a. Estimating damage caused by a particular flood;

b. Estimating the annual cost of flooding by area or by establishment;

c. Computing risks for flood insurance purposes; and,

d. Planning of investment strategies.

6. DATA COLLECTION ACTIVITIES

The success of the research studies and the reliability of the findings depends on the quantity and quality of available data. For studies on floods, the data requirements consists of meteorologic, hydrologic, topographic, hydrographic, and demographic records. While there are long periods of records available for most of these, there is still a need to update the data collection in view of the many changes in the environment.

The data collection activities identified are in support of the research activities. Some of the current data would be used in calibrating and validating the various models developed. Telemetered records of rainfall and water levels will be used as inputs for the real-time flood forecasting system. Brief descriptions of the activities are provided in the sections that follow.

6.1 River Stage and Discharge Records

Stage and discharge records taken from gaging stations along the Marikina/Pasig Rivers, Mangahan Floodway, Napindan Channel, San Juan, Malabon, and Paranaque Rivers as well as other major esteros and waterways are needed. Since the research studies will be dealing with peak events, hydrographs with an hourly time base are of utmost importance. Records of daily values and monthly volumes are also needed.

6.2 Laguna Lake and Manila Bay Levels

Flows through the major waterways that drain the watershed are dependent, among other things, on the Manila Bay and/or Laguna Lake water levels. Hourly water level fluctuations of these two bodies for the period coincident with the peak flows are therefore essential in flood control investigations.

6.3 Groundwater Levels

When dealing with groundwater recharge as a factor for flood recession in Laguna Lake, weekly or monthly groundwater level changes around the lakeshore areas prior to, during, and after flooding need to be recorded. These records will give an indication as to the influence of the groundwater strata and aquifers in contributing to the increase or decrease of the Lake levels.

6.4 Meteorologic Data

Meteorologic data include rainfall, evaporation rates, temperatures, relative humidities, wind velocities, sunshine hours, and storm tracks and hyetographs. Rainfall data taken from stations within and around the study area should be considered. Of particular importance are rainfall values during flood producing storms and these should be recorded with a time base of at least one hour. In addition to rainfall amounts, daily readings of the other meteorologic data will be usable.

6.5 Topographic Maps and Surveys

In any engineering endeavor, topographic maps provide an enormous amount of information about the study area. A 1:10,000 topographic map of the Metro Manila and Laguna Lake region with a contour interval of one meter should provide the detail necessary for the research activities proposed. Maps with scales of 1:25,000 and 1:50,000 will likewise be required for planning work.

6.6 River Cross-sections

In hydraulic and hydrodynamic modeling, geometric shape of the conveying channels play a crucial role. Cross-sectional surveys are therefore undertaken in order to accurately define the geometry of the waterways to be modeled. For the researches envisioned, cross-sections of the major rivers and esteros at every 800 meters or less will be required.

6.7 Hydrographic Survey of Lake

A detailed hydrographic and topographic survey of the lake bed and shore geometry will be made. The survey will provide baseline information for developing an updated elevation-area-storage curve for Laguna Lake.

6.8 Land Surveys

Land surveys have been used collectively to include land use maps, soil maps, and aerial photographs. A 1:10,000 scale, present day and future, land use maps as well as soil maps of the study area will reveal enough information for conducting the relevant studies. Aerial photographs especially during flooded conditions will be of great value in determining the aerial extent of historical floods.

6.9 Infrastructure Plans

As built plans and drawings of existing drainage mains, pumping stations, bridges, and river control structures are required so that they can be adequately represented in the physical and/or mathematical model. Plans of proposed drainage and flood control works are of similar importance as their design and effectiveness will be studied.

6.10 Demographic Characteristics

Present and projected population, both transient and permanent, as well as population densities in the flood prone areas will give an indication as to the social ramifications of decisions regarding the flooding problem. They can provide additional parameters for evaluating the benefits of proposed flood control measures.

7. RESEARCH ORGANIZATION

Considering the scope of activities, it is most expedient to implement the research program as a cooperative effort of the various agencies of government and the private sector. There are many highly qualified professionals in these agencies who may be tapped to participate in the research program. Among these agencies are the following:

a. Department of Public Works & Highways
   - Bureau of Design
   - Bureau of Construction
   - Bureau of Research and Standards
   - Project Management Office - Flood Control
   - Project Management Office - SWIM
   - National Capital Region
   - National Irrigation Administration
   - National Water Resources Board

b. Department of Environment and Natural Resources
   - Bureau of Soils and Water Management
   - Environmental Management Bureau
   - Forest Management Bureau
   - National Mapping and Resource Information Authority

c. Department of Defense
   - Office of Civil Defense

d. Department Science and Technology
   - Philippine National Science Society
   - Philippine Atmospheric, Geophysical and Astronomical Services Administration
   - National Flood Forecasting Office
   - Typhoon Moderation and Research Development Office

e. National Economic & Development Authority
   - Infrastructure Staff

f. Metro Manila Commission

g. Laguna Lake Development Authority

h. National Hydraulic Research Center (NHRC)

There are two general approaches in implementing the cooperative effort for the research program. One approach is to assign the research projects to the cooperating agencies that have the in-house capability to undertake the projects on a full-time basis in order to meet the scheduled time frame of the program. In the assignment of projects, it must be realized that the research projects are interrelated so that the execution of a project may depend on the availability of results from another project.

The other approach is to organize an ad-hoc research team consisting of the professionals seconded by the cooperating agencies that would be working on a group of research projects on a full-time basis. This is applicable for agencies that have a few professionals but not the complete resources to undertake a project independently. The built-in opportunity for interaction among the members of the research team would also result in a more thorough analysis of the research projects.

Whichever approach is pursued, it is necessary to have a lead agency for the implementation of the comprehensive research program for flood control. For this purpose, it is proposed that the NHRC be designated as the lead agency. Since its establishment in 1973, the NHRC has been undertaking research projects on water resources development and management for the various agencies of the government.

8. SCHEDULE OF ACTIVITIES

The research program has been designed for a time frame of 5 years. Research activities have been scheduled by taking into consideration the immediate need for the results, the availability of sufficient data, and the completion of the necessary inputs from related studies. The schedule of the research activities is shown in Fig. 7.

Data collection activities have been scheduled in parallel with and considering the requirements of the research activities. The schedule is shown in Fig. 8.

9. BUDGET

The budget required for the 16 interrelated research activities is estimated to be about P20.7 Million. When added to the estimated amount of P12.4 Million for the supporting data collection activities, the total budgetary requirement of the comprehensive research program is about P33.1 Million. The average annual outlay of the 5-year program period is only about P6.62 Million.

Considering the annual damage to property due to floods which is the range of about One Billion Pesos, the annual expenditure for research is only about 0.66 % of the annual damage.

Figure 7 Schedule of Research Activities

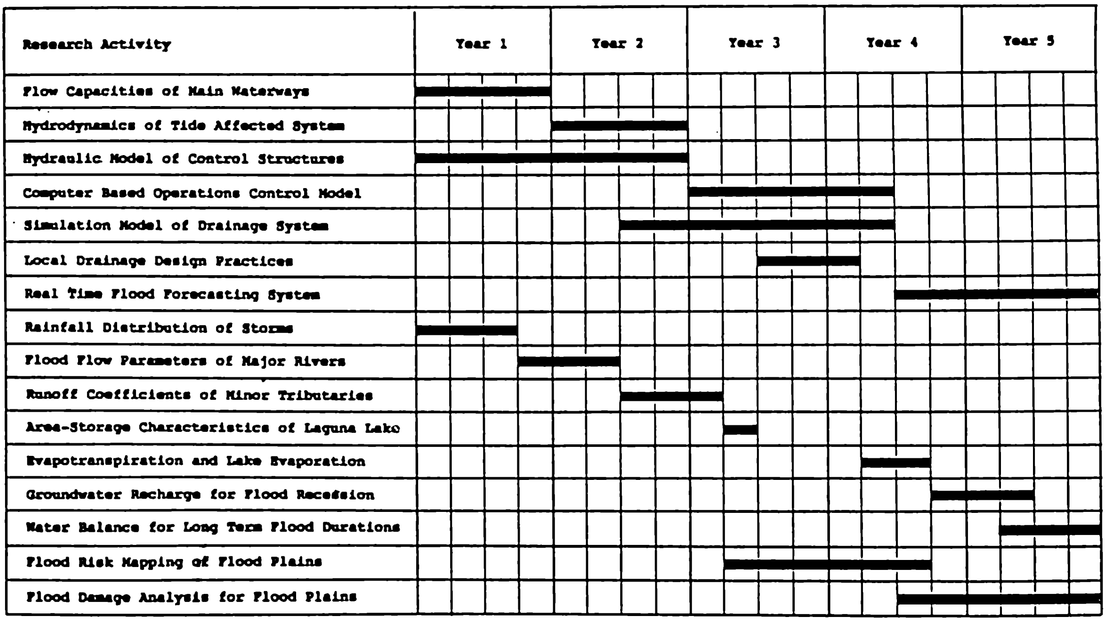
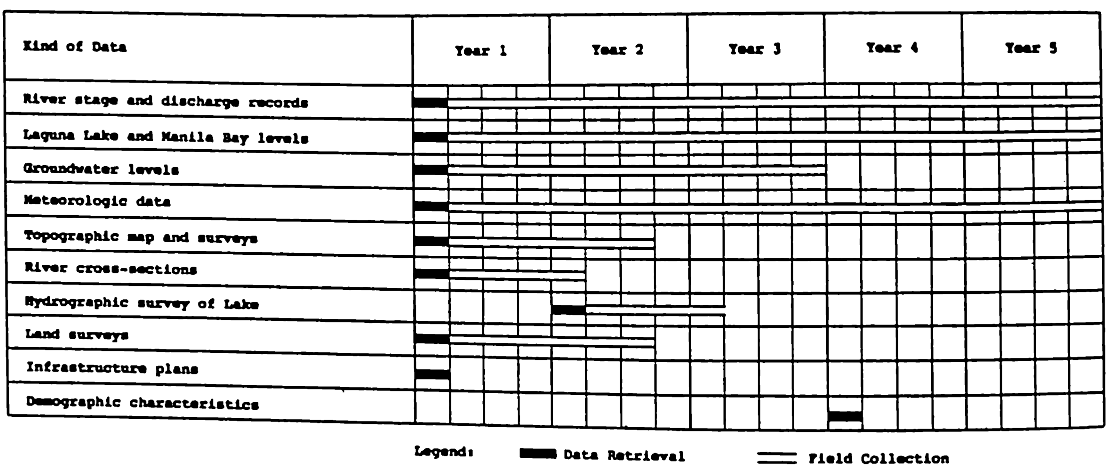


Figure 8 Schedule of Data Collection Activities



This is a very small price to pay for the program that is designed to minimize the damaging effects of floods. Unlike other water resources projects, however, all the beneficiaries of flood control projects who are expected to pay the price are not readily identifiable. This has made it necessary for government to fully subsidize such projects.

It would be convenient if the total budget for the program can be allocated from a single source for funding. Monitoring the implementation of the program would be easier and responsibilities can be pinpointed. If this is not possible, however, the concerned agencies of government may be requested to allocate some funds from their own budgets as their contribution to the program.

The budgetary requirements for the research activities are shown in Table 1 and those for the data collection activities are in Table 2.

10. CONCLUSIONS AND RECOMMENDATIONS

The flood problem of Metro Manila and the Laguna Lake Region has been in existence for a long time and is being aggravated by increasing urbanization. Solutions to minimize the damaging effects of floods consist of a combination of measures some of which are existing but clearly inadequate and others which are still in the planning stage. Analyzing the effectivity of all these measures would need as inputs the baseline information that can only be obtained by undertaking a comprehensive research program.

With these considerations in mind, the following recommendations are made:

a. develop and adopt a comprehensive research program on the flood problem of Metro Manila and the Laguna Lake Region;

b. identify and designate the lead agency and the cooperating agencies and for the implementation of the research program;

c. identify the possible sources of funds for budgetary allocation to the program; and

d. determine the appropriate measures such as executive orders and legislations to implement the program.

Table 1 - BUDGET FOR RESEARCH (in 1000 Pesos)

Research Activities	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Flow Capacities of Main Waterways	1,200					1,200
Hydrodynamics of Tide-affected System		1,200				1,200
Hydraulic Model of Control Structures	1,200	1,200				2,400
Computer Based Operations Control Model			1,200	600		1,800
Simulation Model of Drainage System		600	1,200	600		2,400
Local Drainage Design Practices			600	300		900
Real Time Flood Forecasting System				600	1,200	1,800
Rainfall Distribution of Flood Producing Storms	900					900
Flood Flow Parameters of Major Rivers	300	600				900
Runoff Coefficients of Minor Tributaries		600	300			900
Area-Storage Characteristics of Laguna Lake			300			300
Evapotranspiration and Lake Evaporation			600			600
Groundwater Recharge for Flood Recession				300	600	900
Water Balance for Long Term Flood Durations					900	900
Flood Risk Mapping of Flood Plains			900	900		1,800
Flood Damage Analysis for Flood Plains				600	1,200	1,800
Total for Research	3,600	4,200	5,100	3,900	3,900	20,700

Table 2 - BUDGET FOR DATA COLLECTION (in 1000 Pesos)

Data Collection Activities	Year 1	Year 2	Year 3	Year 4	Year 5	Total
River stage and discharge records	200	240	240	240	240	1,160
Laguna Lake and Manila Bay levels	110	120	120	120	120	590
Groundwater level fluctuations	110	120	120			350
Meteorologic data	200	240	240	240	240	1,160
Topographic map and surveys	1,380	1,350				2,730
River cross sections	1,370	450				1,820
Hydrographic survey of Lake		1,380	450			1,830
Land surveys	1,370	1,350				2,720
Infrastructure plans	20					20
Demographic data				20		20
Total for Data Collection	4,760	5,250	1,170	620	600	12,400

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
TOTAL PROGRAM BUDGET (in 1000 Pesos)	8,360	9,450	6,270	4,520	4,500	33,100