No. 7

Republic of Indonesia

Master Plan
for
Land Erosion and Volcanic Debris Control
in the Area of Mt. Merapi

MAIN REPORT

March 1980

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to the request of the Government of the Republic of Indonesia, the Government of Japan has decided to take up a survey for formulating a Master Plan for Land Erosion and Volcanic Debris Control Project in the area of Mt. Merapi in Central Java of Indonesia, and the Japan International Cooperation Agency (JICA) has been entrusted to conduct the survey.

Recognizing that this Project will contribute greatly not only to the rural development but also to the stability of people's livelihood in Indonesia, the JICA dispatched survey teams to Indonesia from 1977 to 1979 to collect necessary data and information as well as to discuss with the competent authorities of the Republic of Indonesia. The survey was conducted smoothly in cooperation with the authorities of Indonesia. Upon return to Japan, the Team made further studies and has completed the present report.

I hope this report will prove to be useful for the development of the Project and will serve for the promotion of friendly relations between our two countries. I wish to express my sincere appreciation to the officers and people concerned of the Republic of Indonesia for their close cooperation extended to the survey teams.

March, 1980

Keisuke Arita

Keisuke ARITA
President
JAPAN International Cooperation Agency
Japan

ACKNOWLEDGEMENTS

This Final Report was started in July of 1977 in keeping with the scope of work and based upon full on-the-spot field surveys. This report incorporates the latest research and technology in the field of Sabo engineering. Since its inception in 1977 four complementary Progress Reports were submitted at the request of the Indonesian Government. Every effort was made to incorporate the views of the Indonesian Government into the completion of the Draft Final Report in December of 1979. The Indonesian comments on the Draft Final Report have also been considered in the revision for this Final Report.

I would like to pay my respects to the good teamwork which brought this project to completion and also to thank the members of the supervisory committee for fulfilling their duties.

In the area of Mt. Merapi, the production and discharge of sediment is under the strong influence of volcanic activities, and the social climate of the region is drastically affected by eruptions and serious form of sediment damage. The disasters caused by sediment are very different from those of usual flooding and inundation where the water will drain by itself in a short period of time. By contrast, the disasters from deposited sediment will not be removed unless the sediments are excavated by artificial measures. Additionally the influences on the stagnation of social development of the area are larger. A habitual sediment hazard zone will not be able to promote its own development unless the causes of disasters are removed.

We will have to carry out the complete works for stabilizing the sediment source at the origin of sediment production. A river has characteristic sediment transport capacity which is governed by the natural features of the river (i.e., topography, climate, etc.). We must decrease the volume of sediment production in the source areas by artificial measures, to a level below this characteristic capacity, during the period of program.

If we can construct more works in the beginning stage, the volume of sediment production will decrease more quickly and the total volume that will have to be treated by artificial method is far less than it will be if construction is delayed for a long time. This is the major reason that concentrated implementation at the beginning stage is stressed in every case.

Moreover, such an unstable area where the high percentage production of sediment is increasing, is not a point, but a range which has a large extent. A single construction work will not be able to stabilize the area. On the other hand, the systematic construction of multiple structures will be able to attain the purpose of controlling the sediment production. The area will be completely stabilized when all of the systematically planned structures are finally realized.

Habitual sediment hazard areas usually lag behind in the development of social infrastructures. The development cannot be attained by the implementation of disaster prevention works alone, but the Sabo work

will establish the possibility of positive development of the area. An erosion control structure is not only for disaster prevention, but also for the foundation of stable development of the area.

If the development program is carried out in connection with this disaster plan, the benefit of the project will increase by great strides. We can point out examples of this extending effect from our experience.

I must express my gratitude to Ir. Sarvini and the other members of the Indonesian Steering Committee for the full support and cooperation accorded during our work.

Our efforts will be more than rewarded if this report is adopted by the Government of Indonesia and its recommendations implemented.

March 1980

Aritsune Takei

Prof. Dr. Aritsune Takei
Chairman
Supervisory Committee

LETTER OF TRANSMITTAL

March, 1980

Mr. Keisuke Arita
President
Japan International Cooperation Agency
Shinjuku Mitsui Bldg.
1, Nishi Shinjuku 2-chome
Shinjuku-ku, Tokyo 160

Dear Sir,

In accordance with the agreement on the Mt. Merapi Master Plan Study entered into between the governments of Indonesia and Japan, we are pleased to submit herewith the "Final Report on Study for Master Plan for Land Erosion and Volcanic Debri- Control in the Area of Mt. Merapi".

The Study Team performed the whole study including fact-finding investigations at site, engineering and socio-economic analysis, and meetings with Indonesian counterparts and other authorities over a period of three years starting in July 1977 under the guidance of the Supervisory Committee of Japan.

The Draft Final Report was submitted to the government of Indonesia through JICA in December 1979, and a conference was held in Indonesia in February 1980 to discuss the report with the Steering Committee of Indonesia and other authorities concerned. All the conclusions and suggestions made at the conference are included in this Report.

As described in the Report, the in-depth study of the Mt. Merapi project, both in technical and socio-economic aspects, has led us to conclude that this project is technically viable and economically feasible, and that it will produce significant secondary social effects as a by-product.

This is the first case of study aiming to establish an overall master plan for conserving land and promoting regional development in the volcanic area. We were honored to have been able to have the chance of working on the project, and at the same time we hope that the master plan proposed in the Report will be translated into reality soon and the benefits realized.

Taking this opportunity, we would like to express again our sincere thanks to your organization, Supervisory Committee, Ministry of Foreign Affairs, Ministry of Construction, Jakarta Embassy of Japan, governmental authorities of Indonesia and Steering Committee for their full cooperation and courtesies extended to the Study Team for the whole period of study.

Yours very truly,

Hiroshi Suzuki
Team Leader
Mt. Merapi Master Plan Study Team

SUMMARY AND RECOMMENDATIONS

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1. INTRODUCTION

This report presents the results on the study for making Master Plan for Land Erosion and Volcanic Debris Control in the area of Mt. Merapi (G. Merapi).

This study aims at giving an exact picture of actual situation of the project area of G. Merapi and drawing up an optimum master plan that fits the region.

The report consists of three parts: a main report giving an outline of the survey results and master plan, and two supporting reports giving a more detailed account of the same, and drawings of sabo facilities.

In order to prevent and reduce damage of volcanic debris flow caused by G. Merapi eruptions and increase the safety of the region, the Government of Indonesia made a request to the Government of Japan in 1975 for the technical cooperation for the investigation and study of sabo planning.

In response to that request, the Government of Japan through its executing agency, the Japan International Cooperation Agency (JICA) despatched a pre-study team in February 1976 to arrange for the study and prepared topographical maps and land use maps in 1976, the JICA proceeded with the master plan study for three years starting from 1977.

This summary consists of the following sections:

Section No.	Section Title
2	General Overview of the Master Plan
3	Project Area and Area Classification
4	Volcanic Problems in the Project Area
5	Countermeasures Proposed by the Master Plan
6	Construction Cost
7	Project Evaluation
8	Project Recommendations

2. GENERAL OVERVIEW OF THE MASTER PLAN

This master plan proposes land erosion and volcanic debris control works that will enhance the safety and stability of the area covered by the plan, increase its development potential, and built a firm foundation for regional growth.

To accomplish these goals, this master plan calls for the following:

(a) Improvement of the safety of residents of hazard zones through better disaster prevention arrangements, including some resettlement and organization of a better warning and evacuation system.

(b) Preservation of the river basins through improvement of land use and reduction of damage and enhancement of rivercourse stability through promotion of disaster prevention works, including provision of afforestation and sabo facilities.

(c) Enhancement of the development of the area covered by the plan on the slopes and foothills of G. Merapi and building of a foundation for promotion of regional development through multipurpose use of the sabo facilities and provision of associated works.

The present study has concluded that this master plan is technically feasible and will be very effective in economic and social terms as well. It is therefore recommended that this master plan be used as a basis for expeditiously proceeding to the implementation planning, detailed design, and early implementation of the project.

3. PROJECT AREA AND AREA CLASSIFICATION

3.1 Geography

Mt. Merapi (G. Merapi) is located in Central Java, Indonesia near the city of Yogyakarta. The project area covers the southeast to western slopes and foothills of G. Merapi because the volcano opens like a horseshoe towards the southwest and hence the major effects of volcanic destruction can be expected and have been experienced over to past 50 years mainly in that direction.

Direction of Lava Flow in Recent Years

Year of Eruption \ Direction	North	Northwest	West	Southwest
1930			x	
1931			x	
1934			x	
1942		x		
1943				x
1953	x			
1954	x			
1955				
1956		x		
1957			x	
1958			x	
1961				x
1969				x

3.2 Project Area Outline and Divisions

The project area (1,300 km^2) is divided into two areas: a main planning area and a secondary planning area. The boundary of the main planning area is as follows: (see also Project Area Map)

Boundary of the Main Planning Area

North - G. Merapi summit, southern Kab. Magelang, K. Pabelan
West - K. Progo
South - K. Opak, Northern Kab. Bantul
East - K. Woro to G. Merapi summit

The main planning area covers approximately 850 km^2 and includes the tributaries of major rivers as is discussed below.

The secondary planning area consists of the parts of two major rivers (K. Opak and K. Progo) which lie outside the main area.

3.3 Administrative Area

The area covered by the plan extends over parts of Central Java Province and the Special District of Yogyakarta, known as D.I. Yogyakarta or simply D.I.Y. The project area embraces 1 city, 4 kabupaten (see also Project Area Map.).

Administrative Units in the Project Area

Province	Kabupaten
D.I. Yogyakarta	Kota. Yogyakarta Bantul Sleman
Central Java	Magelang Klaten
Total: 2	1 Kota + 4 Kab.

3.4 Planning Zones and River Types

For planning purposes, the project area has been divided into five zones and as implementation of the master plan procedes, the limits of the zones will become increasingly important.

The limits of zones 1-4 were drawn after comprehensive computer study of the need for disaster protection employing the following criteria for every grid mesh (0.25 km^2) of the main planning area (846 km^2).

(1) Hazard Scale 1-5 (least to most hazardous) based on:

a. Probability of lahar/banjir damage.

b. Frequency of disaster damage from volcanic eruptions (Nuée ardente), debris (lahar) and flood (banjir).

c. Extent of damage at times of disaster.

(2) Social Importance Scale 1-5 (least to most important) based on:

a. Population density.

b. Extent of Social Infrastructure and important facilities.

c. Type of land use such as forest, farm and urban (least to most important)

(3) Economic Importance Scale 1-5 (least to most important) based on:

a. Distribution of paddy fields

b. Crop yield indices

c. Level of rice production

d. Trend of rice yield.

The limits of zone-5 simply correspond to the secondary planning area of the channels of K. Opak and K. Progo which lie outside the main planning area.

The results of zoning are summarized below and shown in the map of Planning Zones and Planning Areas.

Planning Area	Zone No.	Location in Project Area	Type of Hazard and Problem
Main Area	1	Upper slopes of G. Merapi	Direct volcanic damage
	2	Upper slopes of G. Merapi	Direct volcanic damage, but less
	3	Tributary areas of major rivers on middle and lower slopes of G. Merapi	Volcanic debris bearing floods Rural instability
	4	Other main planning areas between the tributaries above	Rural instability
Secondary Area	5	Extents of K. Opak and K. Progo outside the main planning area	Sediment related damage

The nine main tributaries in the Main Planning Area have been further classified into three types (Types-I, -II and -III) on the basis of the capacity of the rivers, the frequency of damage, and the amounts of sediment produced and discharged.

3.5 River Systems in the Project Area

The river systems in the project area include 3 major rivers and their 9 project significant tributaries as follows (West to East):

Main River Systems (West to East)	Project Significant Tributary (West to East)	Stream Length (Km)	Basin Area (Km^2)
K. Progo		135	2,296.9
	K. Pabelan	46	103.2
	K. Blongkeng	27	44.6
	K. Putih	27	26.6
	K. Batang	20	22.8
	K. Krasak	29	31.7
K. Opak		65	1,255.9
	K. Boyong	37	76.0
	K. Kuning	38	47.7
	K. Gendol	22	14.6
K. Dengkeng		55	830.0
	K. Woro	34	17.4

The K. Progo and K. Opak have their river mouths in the Indian Ocean. The K. Dengkeng on the other hand is one of the largest tributaries of the Bengawan Solo which runs from the central Java to the East Java and has its mouth north of Surabaya City. (see Map of Planning Zones and Planning Areas).

4. VOLCANIC PROBLEMS IN THE PROJECT AREA

There are five major types of problems in the project area which are listed below and discussed in the following paragraphs.

Problem	Technical Terminology
1. Direct volcanic eruption	Nuée Ardente(Kasai-Ryu)
2. Volcanic debris flow	Lahar (Doseki-Ryu)
3. Flooding with much sediment	Banjir (Dosha-Ryu)
4. Rural instability	-
5. Sediment caused problem spots	-

4.1 Direct Nuée Ardente Damage

Nuée ardente, which is the direct production from eruptions, has high temperatures and high liquidity and is therefore extremely dangerous. Probably most of the reported deaths immediately following eruptions in the past were due to it.

Besides damage due to extremely hot volcanic debris and gases, volcanic debris fills the valleys of tributaries in their upper streams, which changes the conditions of their basins. For river systems in which the basins have rapidly increased, the state of flow changes, and in some cases there is abnormal increase in sediment (produced and discharged) causing sediment damage along the rivers downstream.

In recent cases of nuée ardente, the upstream sections of K. Batang and K. Blongkeng shifted into the K. Bebeng and K. Putih respectively. Both produced sediment and discharged sediment in both tributaries, increased sharply and caused enormous damage in downstream areas.

According to records kept during the period 1930-1969, the area of danger from nuée ardente extends over an area with a radius of about 9 km from the crater (to an elevation of about 650 m) on the western slopes of the mountain, covering an area (zones 1 and 2) of approx. 136 km^2, or 16% of the main planning area.

4.2 Major Destruction from Lahar

Lahar is the flow of unstable volcanic debris deposited on the upper slopes of the mountain which begins to flow as the result of rains. In form, it resembles DOSEKI-RYU in Japan. As it flows down, it erodes the river banks and beds, carrying a large amount of sediment with it and causing tremendous damage.

Lahar occurs mainly in the rainy season, especially right after an eruption, since it results from the combination of unstable deposits of volcanic debris and rainfall. However, since G. Merapi is made up of easily eroded volcanic debris. As the lahar flows it expand by eroding the sediment of riverbeds and banks. It acquires considerable proportions and enormous energy on its way down the mountain, overflowing and causing considerable damage to life, houses, farmland, roads, irrigation facilities, etc.

Depending on the direction of the activity, Nuée ardentes and Lahar tend to be concentrated in a particular area and a particular river system. Since the active point is situated on top of a breach on the summit of G. Merapi which faces in the direction of K. Batang, K. Putih, and other rivers on the southwest slopes of the mountain, that is where the lahar damage has been concentrated in Southwest direction recent years. People in villages along these rivers experienced the heavy damage from G. Merapi's explosion in 1969 which plugged the upper reach of K. Batang with volcanic deposits and changed its channel to K. Blongkong and further downwards to K. Putih. A similar alteration of river course happened to K. Batang to the east viz. to K. Bebeng.

Lahar occurs on the upper slopes of G. Merapi between elevations of 1,000 and 2,000 m. The damage from it occurs all the way from the upper slopes to the hamlet and agricultural areas on the middle slopes of G. Merapi.

4.3 Banjir/Flood Damage

Banjir is a general term meaning flooding. There is no clear dividing line between Lahar and Banjir; however it is generally understood that Lahar includes more sand and gravel than Banjir. In the tributary areas of G. Merapi, the sediment content of the flooding is very high except in a few areas such as downstream sections of K. Woro. Most of the damage tend to be caused by a form of flooding between lahar and banjir.

The large amount of sediment that is brought down by the banjir accumulates in riverbeds, rising their bottoms and giving rise to flooding or banjir/floods. The amount of the sediment is carried further down to K. Progo and the other main rivers, again causing rising of the riverbeds, instability of the river courses, obstruction of irrigation facilities, and flooding.

Whether the flooding is termed Lahar or banjir, most disasters in the foothill zone of G. Merapi are caused by sediment transported by the rivers and flooding in the middle slope area. The sources of sediment are directly from volcanic eruptions and from the continuous erosion of unstable deposits along the river channels. Since the tributaries are the transport channels for sediment, they were intensively studies in order to forecast where remedial measures need to be taken. For the purpose of study, the tributaries in the project area were classified into 3 groups in terms of the amount of sediment present which is the measure of urgency. A description of the sediment characteristics and rivers included in each type of area is as follows:

(1) In Type-I areas the amount of sediment present is greatest since the areas experienced Lahar/Banjir flooding many times in the last ten years and the most of the sediment discharged from 1969 to 1977 was produced by lateral and downward erosion of the river channels. K. Krasak (including K. Bebeng), K. Batang are the main rivers of Type-I area, sediment to be handled in Type-I rivers has been estimated as 80.6% of the sediment amount in the main planning a area as follows:

Tributary Name	Sediment (x 10^3m^3)	Percentage per Tributary (%)
K. Blongkeng	4,304	7.9
K. Putih	4,340	8.0
K. Batang	18,062	33.4
K. Krasak	16,910	31.2
Total Type-I	43,616	80.5

(2) In Type-II areas the amount of sediment present is very considerably less since the areas only experienced a few Lahar/Banjir floods in recent years and since sediment discharge comes mainly from unstable river terrace deposits. K. Woro and K. Gendol are the main rivers of Type-II area. The amount of sediment to be handled in Type-II rivers has been estimated as 11.5% of the surplus in the main planning area as follows:

Tributary Name	Sediment (x 10^3m^3)	Percentage per Tributary (%)
K. Gendol	2,480	4.6
K. Woro	3,725	6.9
Total Type-II	6,205	11.5

(3) In Type-III areas the amount of sediment present is smallest. K. Kuning, K. Boyong and K. Pabelan (including K. Senowo and K. Trising) are the main rivers of Type-III areas. The amount of sediment tobe handled in Type-III rivers has been estimated as 8% of the surplus sediment in the main planning area as follows:

Tributary Name	Sediment (x 10^3m^3)	Percentage per Tributary (%)
K. Pabelan	2,427	4.5
K. Boyong	824	1.5
K. Kuning	1,074	2.0
Total Type-III	4,325	8.0

The total are endangered by lahar and banjir comprises an area (zone-3) of approximately 286 km^2, or 34% of the main planning area. The total sediment surplus creating the destruction in zone-3 amounts to 54.1 million cubic meters.

4.4 Rural Instability and Low Productivity

Although the area covered by the plan has favorable climatic, water, soil, and other natural conditions and has prospered as the central area of Javanese culture, its population has become extremely dense, with an average of 1,584 persons/km^2.

Since the area covered by the plan has also often suffered disaster damage time and time again from eruptions of G. Merapi and the subsequent sediment discharge, the mountain slope areas have an inferior production base and low productivity. Although farmland is being used for paddy fields wherever there is an adequate supply of water, at upstream area, the supply of irrigation water is unstable, and therefore the rice intensity is only 1.4 (times/year) as opposed to 2.0 (times/year) in downstream areas. There is also a difference in the average yield between the two: 3.4 tons/ha upstream versus 4.0 tons/ha downstream. The amount of irrigation water available during the dry season is estimated at $1 \sim 3$ $m^3/s/100\ km^2$ ($0.1 \sim 0.3 \ell/s/ha$). However, the amount of irrigation water needed is estimated $0.3\ell/s/ha$ at present and is expected to be increased to $1.0\ell/s/ha$ in the future. The economic gap between the upper stream areas and the flatland area appears to be widening. This trend is particularly pronounced in the Type-I areas where most of the damage resulting from volcanic activity has been occurring recently. Such repeated damage on top of unfavorable economic conditions has been a major drag on regional development and investment in the production infrastructure.

Furthermore, the low productivity and overly dense population in the mountain slope areas has resulted in very small farmland holdings (presently an average of only 0.29 ha/household), outflow of surplus labor (40 - 50%) to the cities, low wages, unemployment and other causes of social unrest. Consequently, there is a need not only to improve agriculture, the main production base of the area, but also to raise the development potential of the area and create temporary and permanent employment opportunities in both cities and rural communities. The area affected by instability (zones 3 and 4) covers the most of the main planning area.

4.5 Sediment Caused River Problem Spots

Excessive sediment production and discharge make the river courses unstable by, for one thing, causing the riverbeds to rise. What results is damage to river structures, irrigation facilities, bridges, and other facilities and a heightening of the danger of yearly floods disasters occurring. Various sediment caused problem spots mainly along K. Opak and K. Progo are listed below.

- As a result of the 1969 eruption, K. Krasak underwent a change in its basin. Subsequently there was an abnormal increase in sediment discharge which resulted in sediment damage in the downstream areas and along K. Progo. The riverbed of K. Krasak rose abruptly, by 7.0m in the vicinity of the national road and by almost 20m further downstream.

- The heavy sedimentation conveyed from the mountain slope to the downstream areas of rivers has also caused river functions to deteriorate. A typical example of such functional blockage can be seen at the Kamijoro irrigation intake, which is 17.5km from the river mouth of K. Progo. The intake was constructed around 1924; however, the intake has completely stopped functioning as a supply of irrigation water due to a large rise in the height of the riverbed.

- Heavy damage on the river banks caused by lateral erosion in several places has been reported. In one case, the wash-out of intakes and loss of farmland resulted from about 40m of lateral erosion, at the point about 10km upstream from the estuary of the K. Progo at the time of the flood in March 1969.

- Due to tidal flows caused by high wasterly winds from the sea and meager stream flow during dry seasons, the estuaries of both the K. Progo and K. Opak are usually blocked during dry seasons by a tremendous volume of silt and sand transported by floods during preceeding wet season. Excavation by manual labor is now used to prevent an inundation problem caused by the inland water.

4.6 Project Area without the Plan

In order to determine the extent and location of facilities in the master plan, a model of the river systems was developed and verified by geomorphic, hydrologic, hyetal and other extensive field investigation including comparison with aerial photographs and geomorphological land condition map (1/25,000) and actual flooding area prior to the implementation of sabo works as below (see also Map of Probable Endangered Area without Sabo Facilities).

Area Type	Tributary Name	Probable Endangered Area to Flooding (km^2)
Type-I	K. Blongkeng	10.6
	K. Putih	15.0
	K. Batang	18.1
	K. Krasak	18.2
	Sub-Total	61.9
Type-II	K. Gendol	6.9
	K. Woro	45.7
	Sub-Total	52.6
Type-III	K. Pabelan	4.2
	K. Boyong	11.5
	K. Kuning	4.4
	Sub-Total	20.1
TOTAL		134.6

5. COUNTERMEASURES PROPOSED IN THE MASTER PLAN

To cope with the problems mention in section 3 and summarized below, this master plan proposes to raise the development potential of the area by reducing and preventing damage due to flooding and sediment discharge and by increasing the safety of the area, and also to promote the balanced development of the area by means of the associated facilities plan making multipurpose use of the sabo facilities.

Details of the master plan countermeasures are summarized below and in subsequent paragraphs.

Summary of Countermeasures for Problems in Planning Zones

Planning Zone No.	Area (km)	Percentage of main planning area (%)	Area Problems	Proposed Countermeasures
1	60	7	Direct nuée ardente volcano damage in Type-I upper stream areas	Relocation of residents off-limits and afforestation in the whole zone; also sabo works on the boundary with the lahar area
2	76	9	Direct nuée ardente volcano damage in Type-II and -III upper stream areas	– ditto –
3	286	34	Major destruction from lahar and banjir flooding in Type-I, -II, and -III middle and lower stream areas, and rural instability and low productivity	Multi-stage sabo works to dispose and direct sediment, warning system to permit evacuation and associated works to promote area development
4	424	50	Rural instability and low productivity	Warning system to permit evacuation and associated works to promote area development
5	–	–	Sediment caused problem spots along K. Opak and K. Progo	Case by case solutions to problem spots along K. Opak and K. Progo
TOTAL	846	100	–	–

5.1 Resettlement of Residents from Off-Limits Zones

Since it would be technically difficult to prevent direct damage from nuée ardente and other direct influences of volcanic eruptions, nuée ardente hazard areas zones 1 and 2 have been zoned as off-limits. The Indonesian government has put these nuée ardente areas off-limits as being extremely hazardous and has been proceeding since 1960 with a resettlement plan for the residents, but quite a few still live in these areas and rely on farming for a living. The productivity of the farmland, however, is very low. This is particularly true of the Type-I areas on the western slopes where there is a high frequency of disaster damage an and the river basins are in poor condition.

For the sake of the safety of residents and preservation of the river basins, there should be expeditions resettlement of people p-esently residing in such areas. This will involve relocation of 11,000 homes and resettlement of 50,400 persons for their own safety with the implementation of the resettlement program, the annual rate of population increase will be lowered from 1% to 0.75%. Full details should be determined in the regional transmigration program.

5.2 Afforestation of Vacated and Waste Lands

For the sake of the stability of waterhead areas and preservations of river basins, there is to be active afforestation of waste land, farmland and sites vacated by resettlement in order to increase the amount of forested land from the present 7% to 51%. This will involve the conversion of 6,010 ha by afforestation.

To check sediment production, it is necessary that land use be actively improved, including afforestation of wasteland, sites vacated by resettlement, and even poor farmland and improvement of low-quality existing forests. Research is now being done at Bogor Agriculture Institute in Indonesia to determine what kinds of trees are best suited for such afforestation. For the time being, pine trees and acacia, which are widely distributed in these areas, can be used for this purpose. Investigation for proper kind of trees for this purpose should be performed.

Although such forests will be mainly for disaster prevention purposes, those in peripheral areas can be multipurpose, including some for timber production and cattle breeding. Full details should be studied and determined in subsequent project stage.

5.3 Sabo Works

The large amounts of sediment discharged to the downstream areas of planning zone-3 do not directly result from eruptions, but are for the most part produced by erosion resulting from rainfall; they nonetheless cause the major part of the damage in the project area.

Consequently, the major part of the planning effort has been concentrated on Sabo facilities for the purpose of checking and adjusting the surplus sediment discharge that causes the major part of the disaster damage and for stabilizing river course and preventing flooding by allowing for smooth conveyance of flood waters and their sediment loads.

The type of sabo facilities planned include check dams, consolidation dams, training levees, valley mouth fixation works, embankments and revetments, river channel works, groins, sand pockets and bridges.

The total sabo works planned will have the capacity to dispose of 62.07 million cubic meters of sediment. The estimation of sediment discharge capacity is based on the assumption that the direction of eruption will continue to be toward the Type-I areas:

a) In Type-I areas: a maximum annual sediment discharge equal to the amount that resulted from the eruption of 1969.

b) Type-II and -III areas: maximum annual sediment discharge produced from the unstable sediment presently deposited upstream, except for K. Woro, for which the average annual sediment discharge for normal years will be also considered in the planned amount.

The volume of sediment to be disposed of by each type of sabo works and by each tributary is shown in the following tables.

Summary of Sediment Disposal Plan

1. Sediment Disposal Plan by the Type of Sabo Works

Unit: 10^3m^3

Sediment / Sabo Works	Sediment (x 10^3m^3)	%
1. Consolidation Dams	736	1
2. Check Dams	17,316	28
3. Valley Mouth Fixation Work (Training Levees and Checkdams)	15,748	25
4. Sand Pockets	28,270	46
Total	62,070	100

2. Sediment Disposal Plan by Type of Sabo Works for each tributary and area type

(Unit = 10^3m^3)

Area Type	Type of Sediment Reduction / Sabo Work / Tributary	Reduction of Production			Reduction of Discharge	Control of Discharge		TOTAL
		Consolidation Dam	Check Dam	Valley mouth Fixation Works	Sand Pocket	Consolidation Dam	Check Dam	
Type-I	K. Blongkeng	-	55x2	814x2	2,920	-	-	4,658
	(K. Lamat)	-	24	-	-	-	41	65
	K. Putih	-	514x2	814x2	5,640	-	-	8,296
	K. Batang	62x2	2,777x2	3,123x2	8,360	-	-	20,284
	K. Krasak	69x2	1,889x2	3,123x2	7,120	-	-	17,282
	Sub-Total	262	10,494	15,748	24,040	-	41	50,585
Type-II	K. Gendol	427	752	-	1,580	-	-	2,759
	K. Woro	47	1,690	-	2,650	-	-	4,387
	Sub-Total	474	2,442	-	4,230	-	-	7,146
Type-III	K. Pabelan	-	660	-	-	-	1,776	2,436
	K. Boyong	-	515	-	-	-	310	825
	K. Kuning	-	622	-	-	-	456	1,078
	Sub-Total	-	1,797	-	-	-	2,542	4,339
TOTAL		736	14,733	15,748	28,270	0	2,583	62,070

Remark: x2 means twice eruptions during the project life (50 years)

The total number of sabo facilities planned is as follows: 58 check dams, 79 consolidation dams, 116.1 km of embankments and revetments, 16.5 km of training levees, 12.8 km of groin, 4 bridges, etc. These works are itemized by tributary in the following table.

Area Type	Sabo Facilities / Tributary	Check dam (No.)	Consolidation dam (No.)	Embankment and Revetment (m)	Training Levee (m)	Groin (m)	Bridge (No.)	Others (No.)
Type-I	K. Krasak	15	10	22,200	7,140	4,500	-	1
	K. Batang	2	17	13,330	2,520	900	-	-
	K. Putih	4	14	16,380	4,600	1,980	-	-
	K. Blongkeng	3	12	14,430	2,230	1,560	-	-
	Sub-Total	24	53	66,340	16,490	8,940	-	1
Type-II	K. Woro	10	5	20,920	-	3,000	-	-
	K. Gendol	7	17	8,750	-	780	-	-
	Sub-Total	17	22	29,670	-	3,780	-	-
Type-III	K. Boyong	5	2	6,960	-	-	2	-
	K. Kuning	3	-	7,700	-	-	1	-
	K. Pabelan	9	2	5,400	-	90	1	-
	Sub-Total	17	4	20,060	-	90	4	-
Total		58	79	116,070	16,490	12,810	4	1

5.4 Warning System

The warning and evacuation plan, which covers all areas other than the nuée ardente areas, calls for the following:

(1) Publicity Activities

Getting the residents of the endangered areas to completely realize the nature and extent of the hazards they are facing.

(2) Improvement of the Warning Communication System

The warning communication system is to be improved to make it possible for the residents of lahar hazard areas to be notified quickly of danger by speakers and sirens. Considering the size of the area and the range of the speakers and sirens, there will have to be a considerable number of additional substations, about ten to fifteen in the case of Type-I area.

(3) Provision of Evacuation Routes

The road system within the areas concerned is to be improved along with provision of construction roads in order to enable safe and swift evacuation.

(4) Provision of Observation and Monitoring Facilities

For accurate short-term forecasting of amount of rainfall, it is necessary starting immediately to be able to keep abreast of actual rainfall conditions at all times, and this will require drastic improvement of the observation and monitoring system, including the introduction of telemeters. A network of telemetric observation and monitoring facilities is to be established in the lahar occurance area at elevations above 1,500m.

(5) Basic Study

The establishment of forecasting criteria is a very basic requirement of the warning and evacuation system. Since, however, this is a pioneer area of science, it is better that such study be undertaken from a broad viewpoint.

Full details for the warning and evacuation plan should be determined in subsequent project stage by technical support and guidance of an established technical center that will be explained in the project recommendations.

5.5 Associated Works for Area Development

The associated works plan calls for the multi-purpose use of sabo facilities. The major associated works considered are construction of the main irrigation canal-1, although other works such as bridges crossing the sabo works to link a lateral road network, using the canal heads for micro-power generation, etc. are also considered.

(1) Irrigation Canal Plan

In view of the imbalance between different areas in terms of intake capacity, that of K. Pabelan on the west side being large and that of K. Woro on the east side being inadequate, intake facilities at the sabo works on different rivers are to be linked by irrigation canals extending 26.7km along contour lines for delivery of water in the direction of deficiency, with repeated intake and use along the way. In this manner will be possible to make up for the deficiency in intake capacity on some of the rivers.

Such facilities are technically feasible since they only entail minor structural changes for intakes and approach channels in the disaster prevention facilities, and they are economical since they utilize the catchment areas of the sabo facilities which are to be built anyway. Aqueducts, which can also be used for roads, are to be provided for crossing small rivers.

In the dry season an intake capacity of $1.44 \sim 4.32$ m^3/s can be expected in the case of the main tributaries. Assuming a supplementary supply of 0.6 ℓ/s/ha from the main irrigation canal and dependence on excess and supply from smaller rivers for the remaining 0.4 ℓ/s/ha, the increase of stable wet paddy cultivation that will be possible in the dry season will be in the range $2,400 \sim 7,200$ ha. With stabilization of irrigation intake and establishment of the cropping pattern, it should be possible to plant an average of at least two paddy crops annually. Furthermore, it will be possible to use 760 ha of dry crop fields in the K. Woro catchment area as paddy fields in the rainy season, although not in the dry season.

The total items required for main irrigation canal-1 (which is the only canal which is considered at this stage of planning) are as follows:

Canal civil works	:	26.7 km length
Intakes	:	12
Siphons	:	10
Aqueducts	:	66

(2) Road Plan

Although the road networks are fairly adequate in areas between rivers since even the remote hamlets can be reached by motor vehicle, there is difficulty in terms of transportation from and area on one side of a river to an area on the other side in upstream areas owing to the lack of bridges.

Accordingly, the planned width of the main irrigation canal-1 has been made broad so that a road can be built along it all the way from K. Pabelan across to K. Woro and 12 bridges have been planned. With respect to the crossings of the main tributaries, the design of the crossings and that of the check dams are to be integrated.

(3) Micro Hydroelectric Power Stations Plan

Of the area covered by the plan, only urban areas of Yogyakarta, the main resort town of Kaliurang along the national road, and a few other places have a supply of electricity. Since the rural areas cannot expect to be supplied by the Yogyakarta power system in the near future, micro hydroelectric power stations are planned to be provided as associated facilities the main irrigation canal-1.

These power stations are to be located in the vicinity of intake facilities where there is necessarily a head of 5 ∿ 10 m. The plan calls for eleven of them, but the number can be increased since there is sufficient head all along the canal.

The total capacity of these eleven stations can be expected to be 400 ∿ 500 KW, which is enough to supply 4,000 ∿ 5,000 households.

(4) Other Possible Associated Plans

(a) Fishery Nurseries
(b) Supply of Water for Household Uses
(c) Plan for a comprehensive Rural Village Improvement Model

5.6 Summary of Planned Facilities and Projects

At this stage of project planning, the emphasis has been placed on sabo facilities to control the production and discharge of sediment to enhance the safety and stability of the area, and on the main irrigation canal-1 to increase the area development potential as a basis for regional growth. All other countermeasures require further detailed study. The following table lists the planned projects and facilities of the master plan.

Inventory of Master Plan Projects and Facilities

PROJECT/FACILITY	ITEMS	REMARKS
Relocation *	50,400 persons relocated	– Zones 1 and 2 tentatively planned
Afforestation *	6,010 ha. planted	,,
Sabo Works	58 check dams 79 consolidation dams 116,070 m. embankments/revetments 16,490 m. training levees 12,810 m. groins 4 bridges 1 misc. works	– Reduced and controlled Amount of Sediment: $62,070 \times 10^3 m^3$ – The probable endangered area prior to the implementation of sabo works: $134.6\ km^2$
Warning System *	1 telemetric observation center 4 telemetric observation posts 10–15 information stations	– Zones 3 and 4 tentatively planned, – Full detail should be determined by an recommended Technical Center.
Associated Facilities	I Main irrigation canal-1 of 26.7 km with 12 intakes, 10 siphons, 66 aqueducts I Main road (26.7 km) with 12 bridges II Micro hydro-electric power stations *	– main irrigation canal-2 and -3 tentatively planned – comprehensive rural village demonstration model project tentatively planned
Case by case solutions* to River Problem Spots	• Sediment control by sabo works • Stabilization of Meander • Training Dikes at estuaries • River channel improvement • Countermeasures against general problems	– Solutions to problem spots along K. Opak and K. Progo to be the subject of further study

* full details to be determined in subsequent project stage

6. CONSTRUCTION COST

The estimated construction cost of the sabo works and main irrigation canal-1 are about Rp. 41 billion with operating and maintenance costs of about 1% annually, or Rp. 411 million. This total project costs consists of about Rp. 39 billion (96%) for the sabo works and about Rp. 2 billion (4%) for the main irrigation canal-1. The costs of relocation, afforestation, warning system etc. are not contained in the project costs. All project costs are itemized in the table below.

Summary of Project Construction Costs

(Unit = x 1,000 Rp.)

Area Type	Tributary	Total Civil Works	Contingencies	Administration and Overhead	Consulting Services	Total
Type-I	K. Krasak	7,002,440	1,050,360	805,280	805,280	9,663,360
	K. Batang	2,935,030	440,260	337,530	337,530	4,050,350
	K. Putih	3,249,900	487,490	373,740	373,740	4,484,870
	K. Blongkeng	2,634,750	395,210	302,990	302,990	3,635,940
	Sub - Total	15,822,120	2,373,320	1,819,540	1,819,540	21,834,520
Type-II	K. Woro	4,106,850	616,030	472,290	472,290	5,667,460
	K. Gendol	3,341,500	501,230	384,270	384,270	4,611,270
	Sub - Total	7,448,350	1,117,260	856,560	856,560	10,278,730
Type-III	K. Boyong	1,264,640	189,700	145,430	145,430	1,745,200
	K. Kuning	1,209,850	181,480	139,130	139,130	1,669,590
	K. Pabelan	2,791,010	418,650	320,970	320,970	3,851,600
	Sub - Total	5,265,500	789,830	605,530	605,530	7,266,390
Sabo Works Total		28,535,970	4,280,410	3,281,630	3,281,630	39,379,640
Irrigation Canal - 1 and Bridge Total		1,790,880	268,630	205,950	250,950	2,471,410
Project Total		30,326,850	4,549,040	3,487,580	3,487,580	41,851,050

7. PROJECT EVALUATION

The project was evaluated in terms of internal rate of return (IRR) calculated on the basis of the following direct effects expected from the planned sabo facilities and the associated irrigation canal-1 works, excluding those effects from K. Progo, K. Opak and Mataram canal:

1) Sediment damage reduction effects by way of sabo facilities,

2) Effects from stabilization of the rivers and agriculture in the area, and

3) Development effects resulting from the multi-purpose use of sabo facilities; ie, use of the associated irrigation canal-1 facilities.

Four alternative implementation proposals were considered to select the optimum implementation program producing the best the internal rate of return for the project. The results of the comparison shown below indicate that alternative-1 would bring the greatest amount of benefits to the project area by producing and IRR of 11.4% which verifies the feasibility of project.

Project Evaluation of Implementation Alternatives

Alternative No.	Sabo works constructed in stage-1	Main irrigation canal works constructed in stage-1	IRR	
			Total (Sabo works including associated works	Sabo works
1	All main facilities	Total main canal-1 from K. Pabelan to K. Woro	11.4	7.7
2	– ditto –	Intakes only	7.7	7.7
3	Type-I and K. Pabelan facilities only	Part of main canal-1 from K. Pabelan to K. Krasak only	10.6	7.3
4	– ditto –	Intakes only	7.3	7.3

In addition to direct economic benefit above, the project implementation can be expected to contribute greatly to the balanced development of the area through such social effects as protection of life and property, increase of development potential through enhancement of safety and quantifiable indirect economic benefits as follows:

1) An increase in rice production in the foothills of G. Merapi by 9 - 21%.

2) A creation of employment opportunities on sabo construction works and agricultural stability and development for 10,500 - 11,000 persons/year.

3) An increase in the income level in the sabo-protected area to Rp. 12,550/person/year.

In summary, the project is highly recommendable not only to solve regional problems, but to establish a firm foundation for regional growth and achievement of regional developmental targets.

Summary of Socio-economic Analysis

Item	Alter-native-1	Alter-native-2	Alter-native-3	Alter-native-4
1. Economic Evaluation (IRR)	1 (11.4%)	3 (7.7%)	2 (10.6%)	4 (7.3%)
2. Social Evaluation				
Protected and Stabilized Area in 5 years	1 (5875.9)	1 (5875.9)	3 (4609.2)	3 (4609.2)
Increase in Paddy Production in 15 years (Unit: ton)	1 (72,946)	3 (51,986)	2 (68,879)	4 (50,717)
Increase in Employment Opportunity (Unit: person)	1 (14,001)	4 (7,568)	2 (12,843)	3 (9,542)
Increase in Personal Income in 10 years (Unit: Rp.)	1 (12,147)	3 (3,858)	2 (10,768)	4 (3,674)
Improvement of Social Environment and Increase of Potentiality for Regional Development	1	3	2	4
3. Present Value of Investment (Discount Rate: 10%) (Unit: Rp million)	4 (28,447)	3 (26,823)	2 (25,095)	1 (23,979)
4. Total Project Evaluation	1	3	2	4

Legend: Rank

(Value) (Unit: Rp million unless otherwise indicated)

where 1 = Highest
4 = Lowest

Note: 1. IRR: Internal Rate of Return

Alternative Implementation Plan

Alternative No.	Sabo Facilities Stage Plan		Associated Works Stage Plan	
1	A	All main facilities	a	Total main canal-1 from K. Pabelan to K. Woro
2	A	– ditto –		Intakes only
3	B	Type-I and K. Pabelan facilities only	b	Part of main canal-1 from K. Pabelan to K. Krasak only
4	B	– ditto –		Intakes only

Table of Facilities Stage Plans

Unit: million Rp.

		Facility	Stage – 1		Stage – 2		Total	
			No.	Construction Cost	No.	Construction Cost	No.	Construction Cost
Sabo Facilities Stage Plan	A	Check Dam	28	20,458	30	18,921	58	39,379
		Consolidation Dam	43		36		79	
		Embankment and Revetment	48,200 m		67,870 m		116,070	
		Training Levee	16,490 m		–		16,490	
	B	Check Dam	24	15,524	34	23,855	58	39,379
		Consolidation Dam	29		50		79	
		Embankment and Revetment	23,060		93,010		116,070	
		Training Levee	16,490		–		16,490	
Associated Works Stage Plan	a	Intake	12	2,471	–	–	12	2,471
		Canal	26,700 m		–		26,700 m	
		Aqueduct	66		–		66	
		Bridge	12		–		12	
	b	Intake	8	1,336	4	1,135	12	2,471
		Canal	11,700 m		1,500 m		26,700 m	
		Aqueduct	27		39		66	
		Bridge	8		4		12	

8. PROJECT RECOMMENDATIONS

8.1 High Priority for Implementation

Considering the socio-economic benefits that will accure to the area through implementation of this project (Alternative-1). It is strongly recommended that the project be implemented at the earliest date one the basis of the implementation planning in the present master plan. In view of the diversity of the projects to be implemented over a long period, it should be implemented in a well-planned fashion, taking into full account the interrelationships between its parts.

8.2 Implementation Recommendation

8.2.1 Intensive Investment in the First Stage

In view of urgent need to reduce and prevent present disaster hazards, the sabo facilities, which constitute the core of the master plan, are to be completed for the most part within the 5-year first stage of the 15-year project life, as is the main irrigation canal-1 considering its pivotal role among the associated facilities for enhancement of the socio-economic benefits of the project.

Early provision of all of the necessary facilities in the case of rivers with frequent occurrence of lahar and considerable riverbed fluctuation and sediment discharge will make them all more effective and prevent backsliding.

There will be a need for multiplying the current budget of the Merapi Project by at least three times to cater for the initial year of master-plan implementation.

8.2.2 Intensive Use of Manpower and Local Materials

For considerations of economy and employment opportunities in the project area, maximum use should be made of man-power and locally available materials such as rocks, bamboo, and wood and of construction methods that are labor-intensive. Moreover, structure and construction methods should be flexible in view of such circumstances as riverbed fluctuation. In addition, every effort should be made to use trees and ground covering for protection against erosion wherever possible. As for the kinds of construction machinery, use should be made of hand winches and other machinery to improve the efficiency of labor, vibrators and other machinery for improvement of quality, and some heavy machinery such as that needed for urgent or emergency excavation.

8.2.3 Construction Method and Administration for Maintenance

The riverbed variation is so large that the implementation of the project will require constant observation of the varying situation to determine the optimum method of construction and administration for maintenance of facilities after implementation.

8.2.4 Sabo Facilities and Associated Works

This plan is to be implemented in two stage, with provision of urgent facilities, facilities of basic importance in dealing with sediment discharge, and facilities important in connection with the associated facilities in the first stage and the rest in the second stage. The following order of sabo works and order of river site locations shown in the Table below are recommended.

Table of Construction Priorities

CATEGORY	PRIORITY	ITEM	
Sabo Works	1	- Valley mouth fixation works for fixation of flow courses	
	2	- River course improvement facilities at places of urgency and importance	
	3	- Check dams (in the direction from downstream to upstream)	
	4	- Consolidation dams	
	5	- Embankments and revetments	
Location	1	K. Krasak	Type-I
	2	K. Putih	"
	3	K. Batang	"
	4	K. Blongkeng	"
	5	K. Pabelan	Type-III
	6	K. Gendol	Type-II
	7	K. Woro	"
	8	K. Boyong	Type-III
	9	K. Kuning	"

Note: Detail onstruction order is showed in Table 17.

Since sabo works have a great influence on sediment load, riverbed variation and since there are many phenomena that cannot be foreseen at the time of planning, it is necessary to carry out the construction work in a flexible manner while observing actual river conditions.

Although, the planned sabo facilities within 10 km from the summit have adverse effects on nuée ardente flow in terms of the Indonesian guidelines, they are fundamental for reduction of sediment production and for control of volcanic debris. Therefore the implementation of the facilities should be investigated in more detail in the subsequent project stage.

Since the associated facility plans depend on the sabo facility plan, the construction work for the intakes and the siphons and bridges for crossing the main tributaries will be carried out at the same time as that of the sabo facilities themselves. However, the construction work for the main irrigation canal and some other associated facilities will take place later. This is because it is better for such facilities to be provided after area stability has been enhanced by the sabo facilities.

Before the implementation of the irrigation canal, more detail technical feasibility study should be carried out. For the further promotion of regional development through associated works a new development of ground water and a new application of new types of agricultural methods in the foothill zone should be investigated in the subsequent project stage.

8.2.5 Land-use Improvement and Warning and Evacuation Systems

There are two land-use improvement plans: a plan for resettlement of people living in certain hazard areas and a plan for afforestation of the vacated land. In the 1st stage Zone-1 area is to be resettled and afforested. In the 2nd stage Zone-2 is to be resettled and afforested.

Considering the present disaster hazards involved, it is urgently necessary to establish the warning and evacuation system set forth in the master plan.

A truly effective evacuation plan can be only be formulated on the basis of accumulation of technical data regarding advance lahar warnings. The 1st stage is to be a period of two years, with formulative of a tentative plan on the basis of existing knowledge and data collected over two years. The 2nd stage is to begin in the third year and last for a period of three years.

Full details should be determined in subsequent project stage.

8.3 Organization for Project Execution

It is recommended that the project-executing organization be the Directorate General of Water Resources Development of Ministry of Public Works and that the project office site be at the G. Merapi Project Office, with technical staffs in various fields strengthened gradually as the project implementation proceeds.

8.4 Establishment of a Sabo Technical Center

Since the masterplan covers many technical fields, it is necessary to establish a well-organized technical Center which is engaged in the concervation and development of volcanic areas as well as able to supervise sabo engineers and technicians in order to produce satisfactory results. For this purpose, it is advisable that a Technical Center tentatively called "Sabo Technical Center (herein after referred to only as "the Center")" should be established.

In the light of implementation of the master plan it is recommended that the Center be established at as early a date as possible in order to start the process of technical transfer of knowledge through the execution of master plan and through practical training.

The technological foundation for the organization should be established in cooperation with and guidance from experts. The Center will have the role in future to conduct give technological guidance concerning conservation and development of volcanic areas throughout Indonesia. The period for such operation and guidance by experts will be necessary for at least five years.

The functions and goals of the Center will be as follows:

(1) Technical guidance in regard to sabo planning, design for sabo facilities and construction supervision:

(2) Establishment of observation and technical guidance concerning collection and analysis of data:

(3) Development of new sabo technology and its standardization through actual construction works:

(4) Establishment of a technical guidance for Lahar warning system:

(5) Guidance for Socio-economic development of mountain slope areas including planning and implementation: and

(6) Training of engineers and technicians in actual construction works.

8.5 Other Recommendations

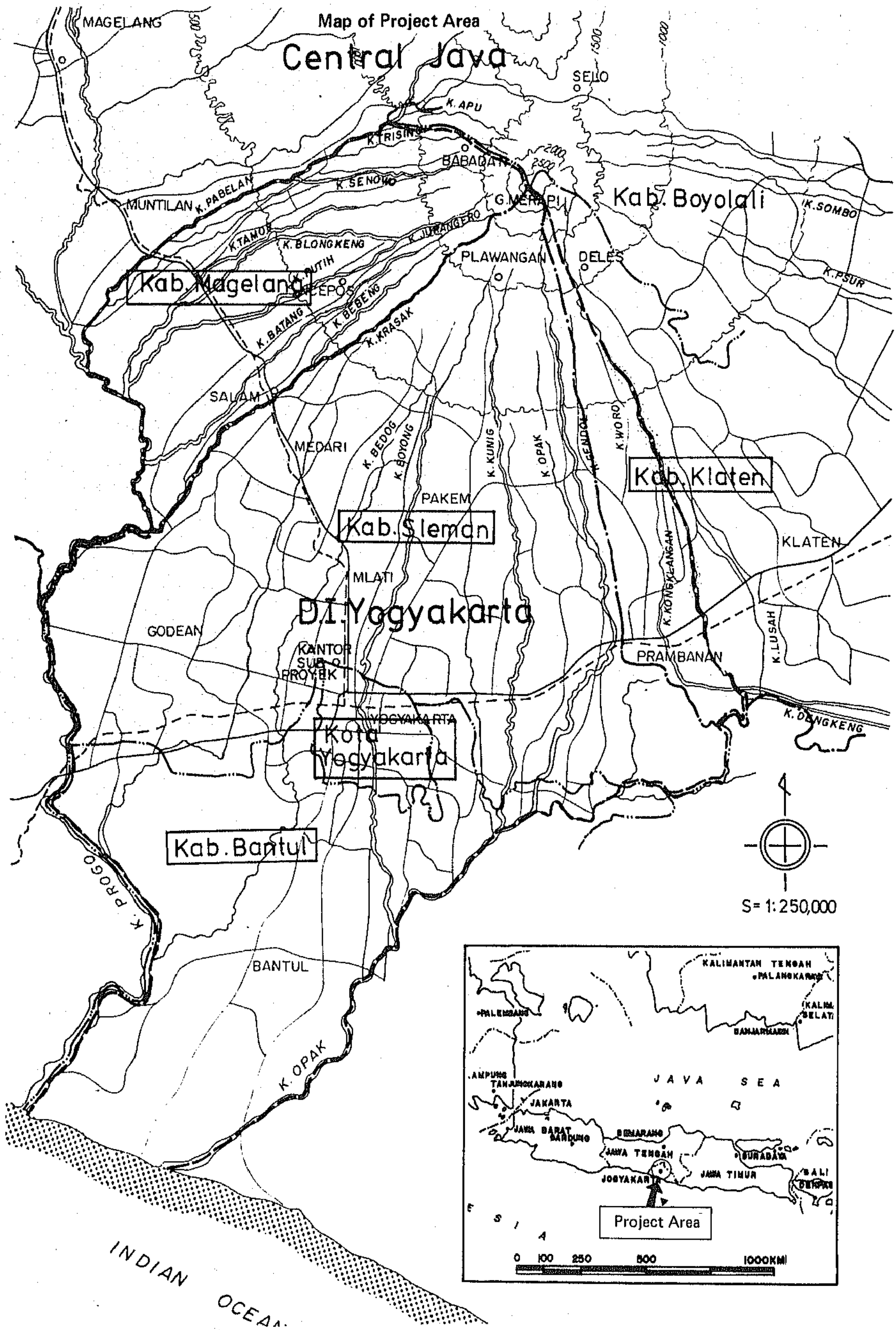
8.5.1 Hyetological Observation and River flow Measurement

(1) Observation of Sediment Discharge

(2) Observation of Riverbed Variation

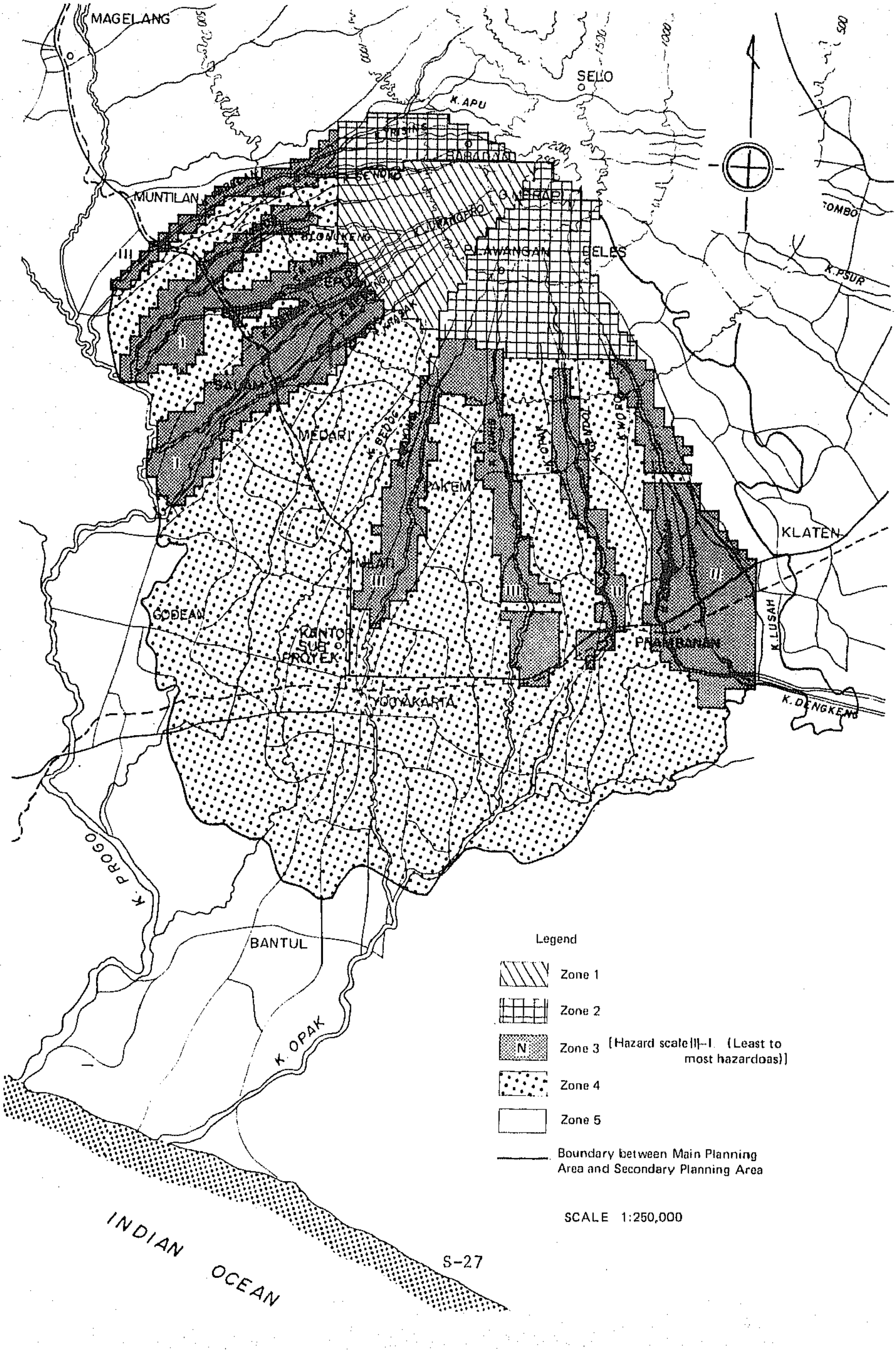
(3) Monitoring of Lahar

8.5.2 Preparation of Topographical Maps (a scale of 1/3000 - 1/5000) for Implementation of the Project.

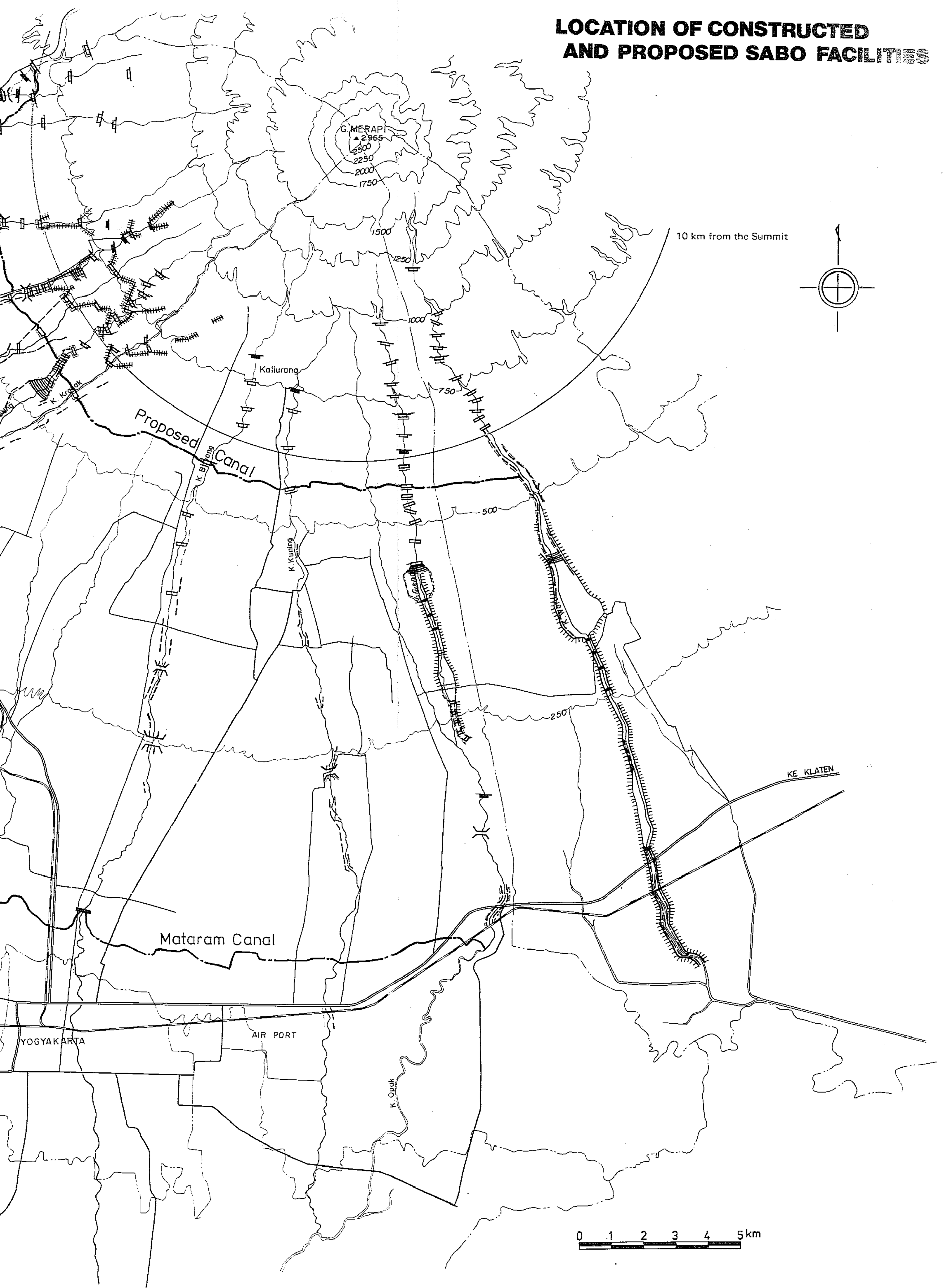


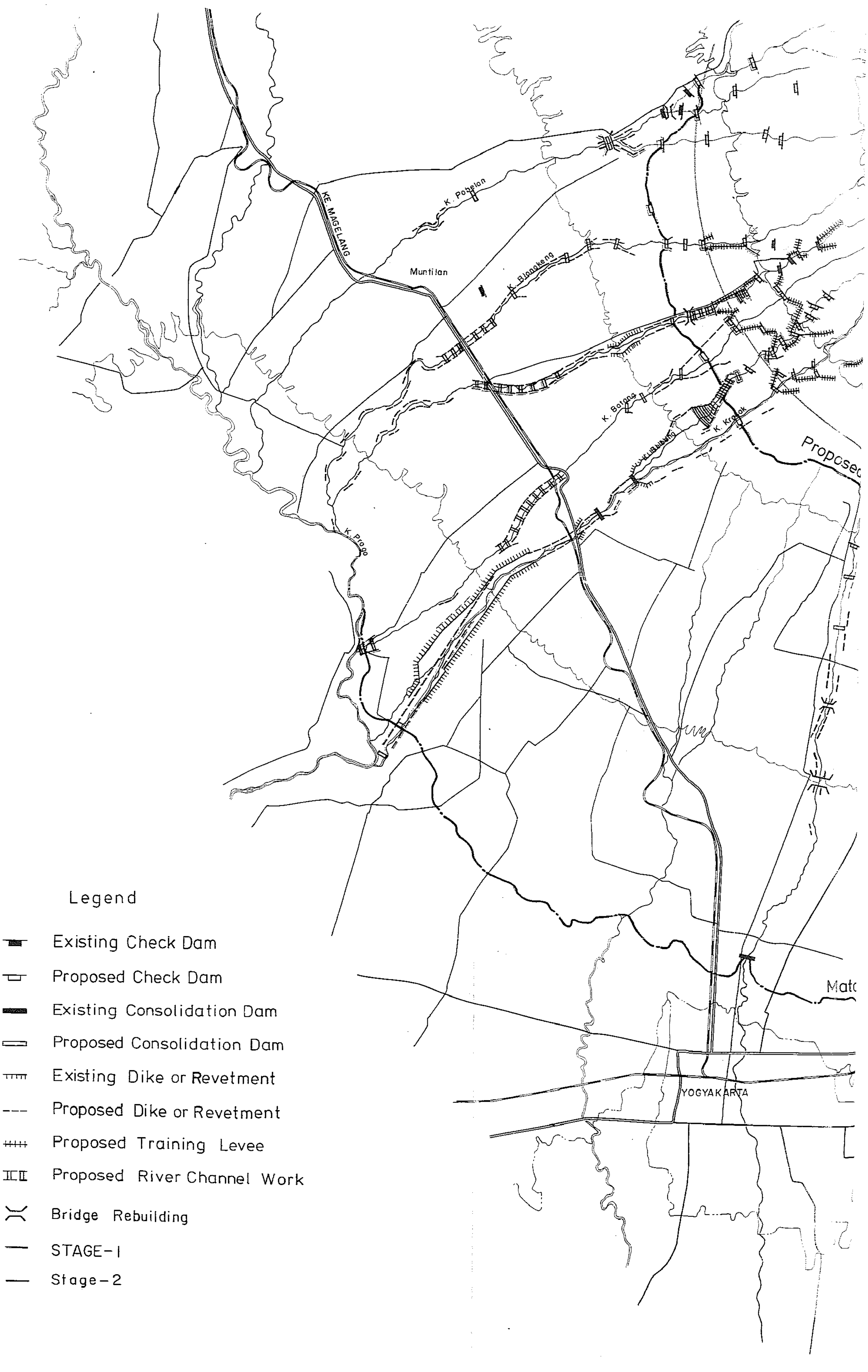
Map of Project Area
Central Java
MAGELANG
SELO
K. APU
K. TRISING
BABADAN
K. PABELAN
K. SENOWO
MUNTILAN
G. MERAPI
Kab. Boyolali
K. SOMBO
K. TAMUR
K. BLONGKENG
K. JURANGERO
PLAWANGAN
DELES
K. PSUR
Kab. Magelang
K. PUTIH
K. BATANG
K. BEBENG
K. KRASAK
SALAM
MEDARI
K. BEDOG
K. BOYONG
K. KUNIG
K. OPAK
K. GENDOL
K. WORO
Kab. Klaten
PAKEM
Kab. Sleman
KLATEN
MLATI
D.I. Yogyakarta
K. KONGKLANGAN
GODEAN
KANTOR SUB PROYEK
PRAMBANAN
K. LUSAH
K. DENGKENG
YOGYAKARTA
Kota Yogyakarta
Kab. Bantul
K. PROGO
S= 1:250,000
BANTUL
K. OPAK
INDIAN OCEAN
KALIMANTAN TENGAH
PALANGKARAYA
PALEMBANG
BANJARMASIN
TANJUNGKARANG
JAVA SEA
JAKARTA
JAWA BARAT
BANDUNG
SEMARANG
JAWA TENGAH
SURABAYA
JAWA TIMUR
JOGYAKARTA
BALI
Project Area
0 100 250 500 1000KM

Map of Planning Zones and Planning Areas



LOCATION OF CONSTRUCTED AND PROPOSED SABO FACILITIES





KE. MAGELANG
K. Pabelan
Muntilan
K. Blongkeng
K. Batang
K. Krasak
K. Progo
Proposed
YOGYAKARTA
Legend
Existing Check Dam
Proposed Check Dam
Existing Consolidation Dam
Proposed Consolidation Dam
Existing Dike or Revetment
Proposed Dike or Revetment
Proposed Training Levee
Proposed River Channel Work
Bridge Rebuilding
STAGE-1
Stage-2

ABBREVIATIONS

DPUTL	Departemen Pekerjaan Umum dan Tenaga Listrik (Ministry of Public Works and Electric Power)
DIY	Daerah Istimewa Yogyakarta (District of Yogyakarta)
GDP	Gross Domestic Product
GRDP	Gross Regional Domestic Product
HYV	High Yield Variety
IRR	Internal Rate of Return
JICA	Japan International Cooperation Agency
G.	Gunung (Mountain)
K.	Kali (River)
mm	millimeter
cm	centimeter
m	meter
km	kilometer
m^2	square meter
km^2	square kilometer
ha	hectare
cm^3, m^3	cubic centimeter, cubic meter
ℓ	liter
g	gram
kg	kilogram
t	metric ton
s (sec)	second
min	minute
hr	hour
C	Centigrade
kw	kilowat
KVA	kilovolt-ampere
DL	datum line
ø	diameter

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CHAPTER 1

INTRODUCTION

CHAPTER 1 INTRODUCTION

1.1 Background of the Study

The Republic of Indonesia like Japan, is one of the world's foremost volcano countries, with active volcanos on many of its islands. In the past it has sustained tremendous tangible and intangible loss owing to disasters stemming from volcanic activity. In particular, the volcanic activities of G. Merapi, G. Kelud and G. Sumeru on the densely populated central and East Java and G. Agung on Bali are have caused an enormous amount of direct and indirect damage on their slopes and foothills, and in the areas along the rivers which have tributaries originating on the volcanoes.

Since 1970 the Indonesian Government has been undertaking major volcanic disaster prevention works with respect to these four active volcanos under the guidance of Japanese experts in this field in the context of the Colombo Plan. Separate offices for this purpose have been set up in the four local areas of each volcano and emergency measures have already gotten underway.

From Merapi, which is situated 30 km north of Yogyakarta, the main city of central Java and the center of Javan culture, flow the tributaries of K. Progo, K. Opak, and K. Dengkeng (the main tributary of Bengawan Solo). The area on the slopes and foothills of G. Merapi occupies a very important place in Indonesian society and culture and in central Java and Javan culture.

G. Merapi is very active, with frequent eruptions. Records since 1800 indicate a short cycle of volcanic activity of 3-6 years, with a longer cycle of 9 $\sim$ 16 years for eruptions of the same or greater scale than the last major one, which occurred in 1969.

Besides the enormous damage caused by nuée ardente which results directly from eruptions, there is also a great deal of damage wrought over a wide area for many years after each eruption owing to lahar and banjir flows and excessive sediment discharge. Damage from sediment discharge resulting from the major eruption of 1969, for instance, is still occurring a decade later, not only in the tributary areas on the mountain's slopes and foothills, but even in the area of K. Progo, with the threat to the social and production infrastructure of the region growing year by year.

It is therefore necessary that comprehensive measures be taken for control of land erosion and volcanic debris for the protection and future development of this historically and culturally important region with its good natural conditions except for its vulnerability to disaster damage from volcanic activity.

1.2 Objective of the Study

The objective of the study is; to examine present condition of the area influenced by Nuée Ardente and Lahar from G. Merapi, and to make a master plan for a reduction of disaster caused by Lahar originating from material already deposited and from material deposited during the coming eruption.

The master plan covers the central social and cultural area of Indonesia that faces a number of tasks; namely, improvement of living conditions and productivity, creation of employment opportunities, and enhancement of development potential, all under conditions of considerable population pressure; and reduction and prevention of damage caused by volcanic eruptions and consequent sediment discharge.

After improving the national production infrastructure in the first two 5-year development plans (Repelita I and Repelita II, which began in 1967 and 1973), Indonesia is now improving national living standards and equity of welfare with Repelita III while laying a solid foundation for the next stage of development. In order to attain such goals in the area covered by the present project, greater regional safety, stability and equity are indispensable.

In order to improve living conditions and productivity in this area it is necessary that its main industry, agriculture centering on rice cultivation, be improved. Greater production of rice to support a dense population is extremely important to this area. Besides raising the degree of self-sufficiency in food, an increase in production of rice will also increase agricultural income, allowing for capital accumulation of the economic surplus for enhancement of development potential. Since it would be very difficult, indeed, to increase the amount of farmland in the area, it is necessary that such increase in production be achieved through stabilization of river courses and farm land by promotion of disaster prevention works, and intensification of agriculture: this is, increase in the yield per unit of cultivated area.

Since this area has a relatively good agricultural infrastructure, the rice yield in it is almost 20% higher than the national average. Specifically, the soil is relatively fertile, and irrigation conditions are fairly good. Considering the relative degree of stability of agriculture in the area, the trend of improvement in the yield of rice, and other factors, it should be possible to get even better harvests with improvement of production infrastructure. Along the middle stretches of the tributaries on the slopes of the mountain, the rice yield is only a half to a third of that along K. Progo, K. Opak, and the downstream stretches of their tributaries. Furthermore, since the K. Progo Irrigation Project (26,000 ha of irrigation area), consisting mainly of rehabilitation works for increase of productivity, is making headway as a main project for boosting national rice production, the gap between these upper tributary areas and the downstream areas in this respect is widening. The upper tributary areas should be improved through promotion of disaster prevention works and multi-purpose use of the sabo facilities and provision of associated works.

1.3 Main Aspects of the Master Plan

The policy of this volcanic disaster prevention master plan as based on the actual disaster conditions in recent years and the socio-economic conditions of the area is as follows:

1) Increase in Safety and Reduction of Anxiety about Volcanic Disaster Damage

   Improvement of the safety of residents of hazard zones through better disaster prevention arrangements, including some resettlement and organization of a better warning and evacuation system.

2) Reduce Sediment Damage

   Because of excessive sediment discharge, the river courses in the area are made unstable, and this in turn makes for instability of intake of irrigation water and agricultural production. Preservation of the river basins through improvement of land use and reduction of damage and enhancement of riverbed stability through promotion of disaster prevention works, including provision of afforestation and sabo facilities.

3) Build a Firm Foundation for Regional Promotion

   Enhancement of the development of the area covered by the plan on the slopes and foothills of G. Merapi and building of a foundation for promotion of regional development through multi-purpose use of the sabo facilities and provision of associated works.

1.4 Coverage of the Study

The main work for the preparation of the master plan as agreed upon by the Indonesia Government and the preliminary study team was as follows:

1) Scope of the Study

   Preparation of a master plan covering the following:

   a) Measures for mitigation and prevention of damage and reduction and control of sediment production and discharge as based on surveys of existing conditions (topography, geology, hydrology, meteorology, river, damage, socio-economy, volcanic disaster prevention works, sabo works) in areas on the slopes and foothills of G. Merapi.

   b) Solutions to problem spots along K. Progo and K. Opak.

2) Study Area

   The following are the areas which the study has covered, their position being indicated in Fig. 1.

a) All tributaries situating between K. Pabelan and K. Progo on the south western part and K. Woro, K. Lusah eastern part of the volcano.

b) Concerning K. Woro and the area up to the confluence point of K. Lusah and K. Dengkeng.

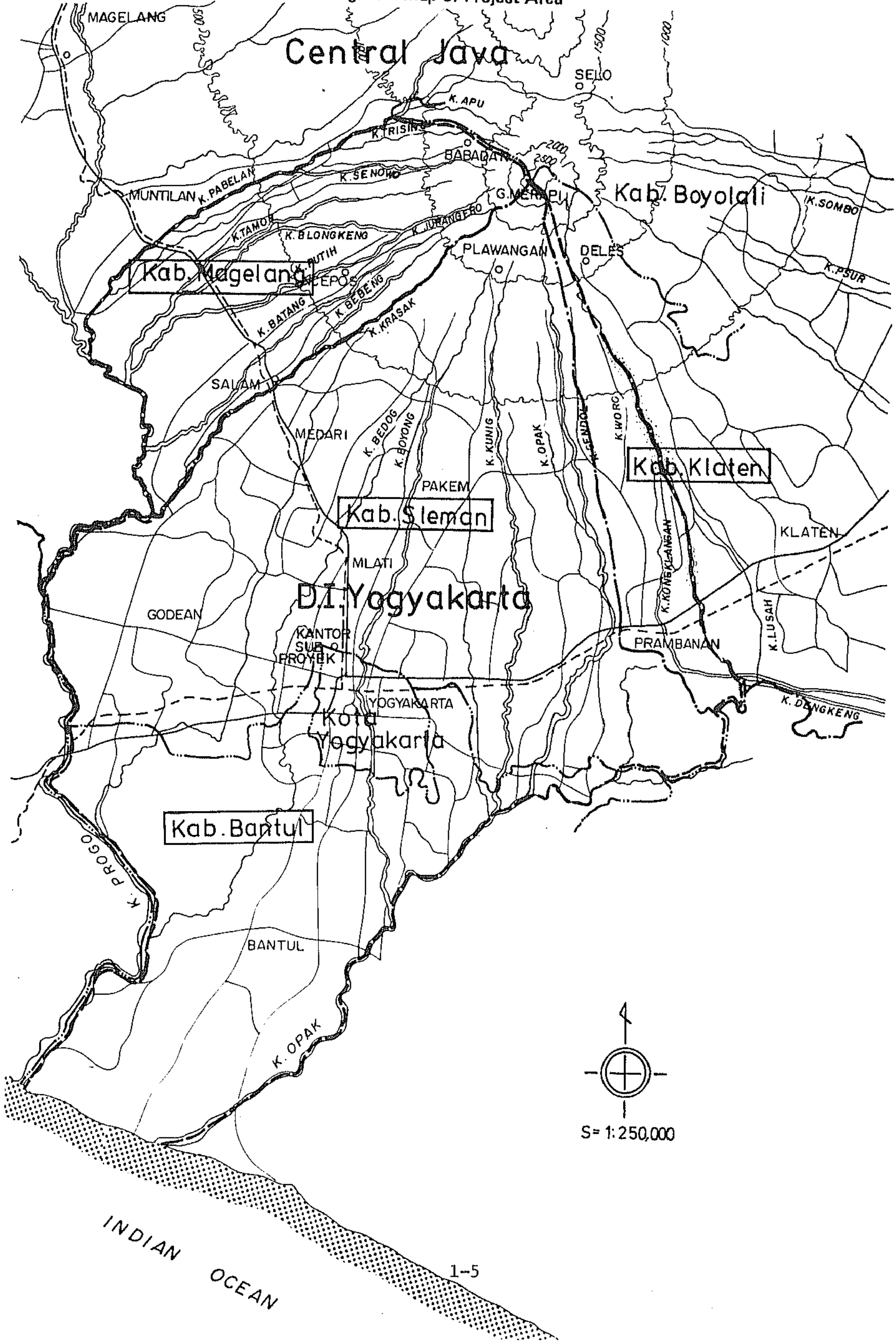
c) The trouble spots at K. Progo and K. Opak due to erosion and sedimentation activities up to their estuaries.

The results of the surveys and studies that have been made for this project are given in the following reports:

- I. Main Report
- II. Drawings
- III. Supporting Report 1
    - A. Geomorphology
    - B. Geology and Lahar deposits
    - C. Hydraulic and Hydrology
    - D. River Survey
    - E. Record of Disaster and Hazard
    - F. Socio-economy
- IV. Supporting Report 2
    - G. Planning

This volume is the main report and a summary of the supporting reports, the outline of which is given in the table of contents.

Fig. 1 Map of Project Area



CHAPTER 2

ANALYSIS OF PRESENT CONDITION IN THE AREA COVERED BY THE PLAN

CHAPTER 2 ANALYSIS OF PRESENT CONDITIONS IN THE AREA COVERED BY THE PLAN

2.1 General

2.1.1 Location

The area covered by the plan extends from the southern side of G. Merapi (2,968 m) in Central Java to the areas of K. Progo, K. Opak and K. Dengkeng facing on the Indian Ocean and encompasses approximately 1,300 km^2. Administratively, it is centered on Kab. Sleman, Kab. Bantul, and Kota. Yogyakarta of D.I. Yogyakarta, including also parts of Kab. Klaten and Kab. Magelang of Central Java Province on the east and west sides, respectively (see Fig. 1).

2.1.2 Area Classification

The area covered by the plan has been divided into two planning areas in terms of the disaster prevention measures to be taken and the urgency thereof:

(1) Main Planning Area: The areas of primarily tributaries on the slopes and foothills of G. Merapi.

(2) Secondary Planning Area: Problem Spot Areas along K. Progo and K. Opak.

The nine main tributaries in the Main Planning Area have been further classified into three types (Types-I, -II, and -III) on the basis of the capacity of the rivers, the frequency of damage, and the amounts of sediment production and discharge. Furthermore, the plan area has been classified into five planning zones (Zones 1-5) on the basis of the hazard areas of the tributaries, the river types, socio-economic impact and the cause of damage (nuée ardente and lahar/banjir). These river types and zone classifications are indicated in Table 1 and Figs. 2 and 3 respectively.

Table 1 River Types and Zone Classifications

(1) Main Planning Area

Area Type	Name of Tributaries	River Systems	Nuée Ardente (Upper Stream area)	Lahar/Banjir (Middle and down-stream areas)	Others in main plan area (Neighboring area)
I	K. Blongkeng K. Putih K. Batang K. Krasak	K. Progo " " "	Zone-1	Zone-3	Zone-4
II	K. Gendol K. Woro	K. Opak K. Dengkeng	Zone-2		
III	K. Pabelan K. Boyong K. Kuning	K. Progo K. Opak "			

(2) Secondary Planning Area

	Problem Spots
K. Opak K. Progo	Zone-5

Fig. 2 Map of River Type Areas