THE REPUBLIC OF INDONESIA

THE FEASIBILITY STUDY ON THE VOLCANIC DEBRIS CONTROL AND WATER CONSERVATION PROJECT IN THE SOUTHEASTERN SLOPE OF MT. SEMERU

SUPPORTING REPORT (1)

VOLCANIC DEBRIS CONTROL PLAN

FEBRUARY, 1984

JAPAN INTERNATIONAL COOPERATION AGENCY

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THE FEASIBILITY STUDY ON THE VOLCANIC DEBRIS CONTROL AND WATER CONSERVATION PROJECT IN THE SOUTHEASTERN SLOPE OF MT. SEMERU

SUPPORTING REPORT (I)

MASTER PLAN FOR THE VOLCANIC DEBRIS CONTROL

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MASTER PLAN FOR THE VOLCANIC DEBRIS CONTROL

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1. INTRODUCTION

1.1 BACKGROUND TO REVIEW MASTER PLANS

The rivers running down on the southeast slope of Mt. Semeru have frequently caused a great many disasters to their basin areas. For the purpose of preventing those disasters and preserving water resources, "the Feasibility Study on the Volcanic Debris Control and Water Preservation Project" (hereinafter referred to as Mt. Semeru F/S) was conducted by JICA.

There also exist sediment control master plans made by the Indonesian government in the areas covered by this Mt. Semeru F/S. The master plans have been reviewed in order to select the priority projects (the first priority project and the second priority project) out of the projects included in such a master plan and other projects deemed necessary.

As a result, in reference to the items related to selection of the priority projects on the above, problems of the existing master plan were pointed out and the proposed revisions were presented.

This report deals with the main outcomes from reviewing the master plans in Chaper 2 and delineates the proposed revisions to the master plan in after Chapter 3.

1.2 EXISTING MASTER PLAN REVIEWED

The existing master plans dealing with K. Mujur, K. Rejali and K. Glidik which are covered by Mt. Semeru F/S are individually described on the following reports.

K. Mujur : Final Report on Investigation Survey and Master Plan Making of K. Besuk Sat, Kabupaten Lumajang, East Java, Feb., 1981.

K. Rejali: Final Report on Investigation Survey and Master Plan Making of K. Kobo'an and K. Leprak at Mt. Semeru Area, Kabupaten Lumajang, East Java, Dec., 1981.

K. Glidik: Investigation Survey and Making Master Plan of K. Bosuk Surat/K. Besuk Kembur in Mt. Semeru Area, Kabupaten Lumajang, East Java, Dec., 1981.

2. SUMMARY OF OUTCOMES OF MASTER PLAN REVIEW

2.1 GENERAL COMMENT AND RECOMMENDATION

The master plan preparation method and precisions of data employed on the 3 basins are almost identical each other. General comments and recommendations for these Master Plans are shown below:

(1) The items to be possessed as a master plan for preventing sediment disaster and the preparation procedure to follow are almost satisfied.

(2) Basic data (disaster, topographical characteristics, river channel characteristics, hydrology and assets in disaster prevention area) employed for preparation generally fall short of precision and yet the analytical method is hard to say appropriate.

(3) The sediment control plan puts great importance on quantitative analysis and qualitative consideration is not enough.

2.2 MAIN RESULTS OF MASTER PLAN REVIEW

The revised version of the sediment control plans as a result of the master plan review are shown on after Chapter 3, however, the main results are as follows:

(1) Supplementary Basic Data

The basic data necessary for preparation of the master plan were supplemented with the data collected for Mt. Semeru F/S. The basic data supplemented and added are as is shown on Table-2.1.

Table-2.1 Data Supplemented and Added

Item	Data Supplemented/Added
Disaster	Scope of the disaster in May, 1981, depth of sediment and sediment volume
Topograph and river channel	. Classification of topographical configuration . Geological classification . Longitudinal section (S = 1/10,000) and Cross section (S = 1/800) of channels . Characteristics of riverbed material
Hydrology	. Precipitation data per hour since 1982 and data on discharge volume . Hydro-graph prepared according to Kinematic Wave Method
Run-off sediment volume	. Estimated run-off sediment volume as of May, 1981 . Density of run-off sediment
Socio-economic condition	. Distribution of assets . Estimated value of assets . Unit price of construction materials and labour's unit wage

(2) Main Revisions on Fundamental Elements of Debris Control Plan

Concerning with the fundamental elements of Debris Control Plan, the revisions proposed as a result of Master Plan Review, are as is shown on Table-2.2.

Table- 2.2 Proposed Revisions for the Existing Master Plans

Item		Existing Master Plans			Proposed Revisions		
Objective		To protect the disaster area from Lahar disaster and to improve the socio-economic condition.			None		
Sediment control plan	Disaster prevention area	Areas along the river channel.			Identify possible disaster areas Areas are classified into 5 groups.		
	Scope of plan	K. Mujur 50 years K. Rejali 70 years K. Glidik 2 years			100 years		
	Sabo reference point	Not established			One sabo reference point and supplementary reference points are established.		
	Sediment volume dealt with by the plan	K. Mujur 10,144,000 m^3 K. Rejali 8,500,000 m^3 K. Glidik 4,400,000 m^3			K. Mujur 5,040,000 m^3 K. Rejali 5,220,000 m^3 K. Glidik 4,500,000 m^3		
	Sediment control system	K. Mujur Storage by check dam and sand pockets.			K. Mujur Sediment yeild suppression and sediment control by dam and consolidation dam. Storage by sand pockets.		
		K. Rejali Storage by check dam. Flush out by channel work.			K. Rejali - do -		
		K. Glidik Flush out by embankment.			K. Glidik Sediment yeild suppression and sediment control by dam.		
	Sabo Facilities River System	K. Mujur	K. Rejali	K. Glidik	K. Mujur	K. Rejali	K. Glidik
	Sabo dam	24 units	5 units	0	12 units	9 units	9 units
	Sand pocket	1 unit	0	0	1 unit	1 unit	0
	Consolidation dam	4 units	0	20 units	12 units	19 units	0
	Dike	5.0 km	0.6 km	4 km	4.3 km	9.7 km	9.5 km
	Spur dike	0	12 units	0	0	0	0
	Channel work	0	9.5 km	6 km	0	0	0
	River excavation	0.6 km	0	0	6.8 km	1.8 km	0
	Others	-	-	-	-	Diversion Channel	
	Construction cost (Maintenance cost/year)	K. Mujur Rp10.9x10^3 (0)	K. Rejali Rp10.9x10^9 (Rp0.05x10^9)	K. Glidik Rp8.9x10^9 (Rp0.1x10^9)	K. Mujur Rp35x10^9 (Rp0.06x10^9)	K. Rejali Rp40x10^9 (Rp0.04x10^9)	K. Glidik Rp25x10^9 (0)
	Construction term	K. Mujur 10 years	K. Rejali 10 years	K. Glidik 10 years	K. Mujur 15 years	K. Rejali 20 years	K. Glidik 10 years
Warning system		Necessity for reinforcement of information collection system and telephone communication system is indicated.			Reinforcement of the following warning systems was proposed Information collection system Information processing system Public information system Estimated cost for the above reinforcement is put at ¥0.96 x 10^9.		
Potential of water resources development		Not mentioned.			Preliminary water conservation plan in K. Rejali including the K. Lengkong fan is proposed.		

(3) Comments and Recommendation on Principle of Sediment Control Plan

The main problems and their proposed solutions of sediment control plans in each Master Plan are as follows:

① K. Mujur

The master plan's sediment control method intends to store entire volume of the design sediment volume by check dams and sand pockets. However, since the sediment storage capacity is filled up with harmless sediment, the actual capacity falls short of retaining planned quantities of sediment. As a realistic and appropriate solution, firstly the design run-off sediment volume was reviewed, and secondly by taking the river channel characteristics into consideration, the sediment control system in line with runoff sediment storage, runoff sediment regulation and suppression of sediment yield was proposed to be adopted.

② K. Rejali

The master plan proposes to flush out 70 percent of the design run-off sediment volume and store the remaining 30 percent of sediment by check dams. However, it is difficult to make 70 percent of sediment runoff in view of the discharge capacity of the river channel. In addition, if the sediment storage capacity was filled up by harmless sediment, the design control capacity of the check dam comes short. As a realistic and appropriate solution, the design run-off sediment volume was reviewed and the run-off sediment regulation system and the method to absorb excessive sediment in diversion channels was proposed to be adopted.

③ K. Glidik

The sediment control master plan covering the entire area is not implemented in the K. Glidik basin. The existing master plan is a local sediment control plan only covering the areas along the river of Besuk Sarat and Beruk Kembar as well as K. Lengkong Fan as a disaster prevention area. Therefore the sediment control plan covering entire river system of Mt. Semeru, including the bottom areas in K. Glidik's lower basin as a disaster prevention area, should be prepared.

(4) Revision of Sediment Control Facilities

As a result of Master Plan review, revision of sediment control facility plan was proposed. The main points of revision are as is shown in Table-2.3. and Fig-2.1.

Table-2.3 The Main Points of Revision

Basin	Main Point of Revision
K. Mujur	1 Addition of sand pockets using embankments of Kertosari and Kloposawit to be constructed by Mt. Semeru Urgent Improvement Project. 2 Scale-up of the check dam planned in BS. Sat 3 Addition of consolidation dams for preserving Intake
K. Rejali	1 Addition of diversion channel from Curah Kobo'an to K. Lengkong 2 Addition of 4 check dams at K. Lengkong as a related facility to diversion channel 3 Addition of sand pockets at the fan top of K. Leprak 4 Changeover of channel work alignment to the right bank toward mountain
K. Glidik	1 Addition of 5 big check dams along K. Lengkong and K. Glidik 2 Construction of embankments in the basin of lower K. Glidik

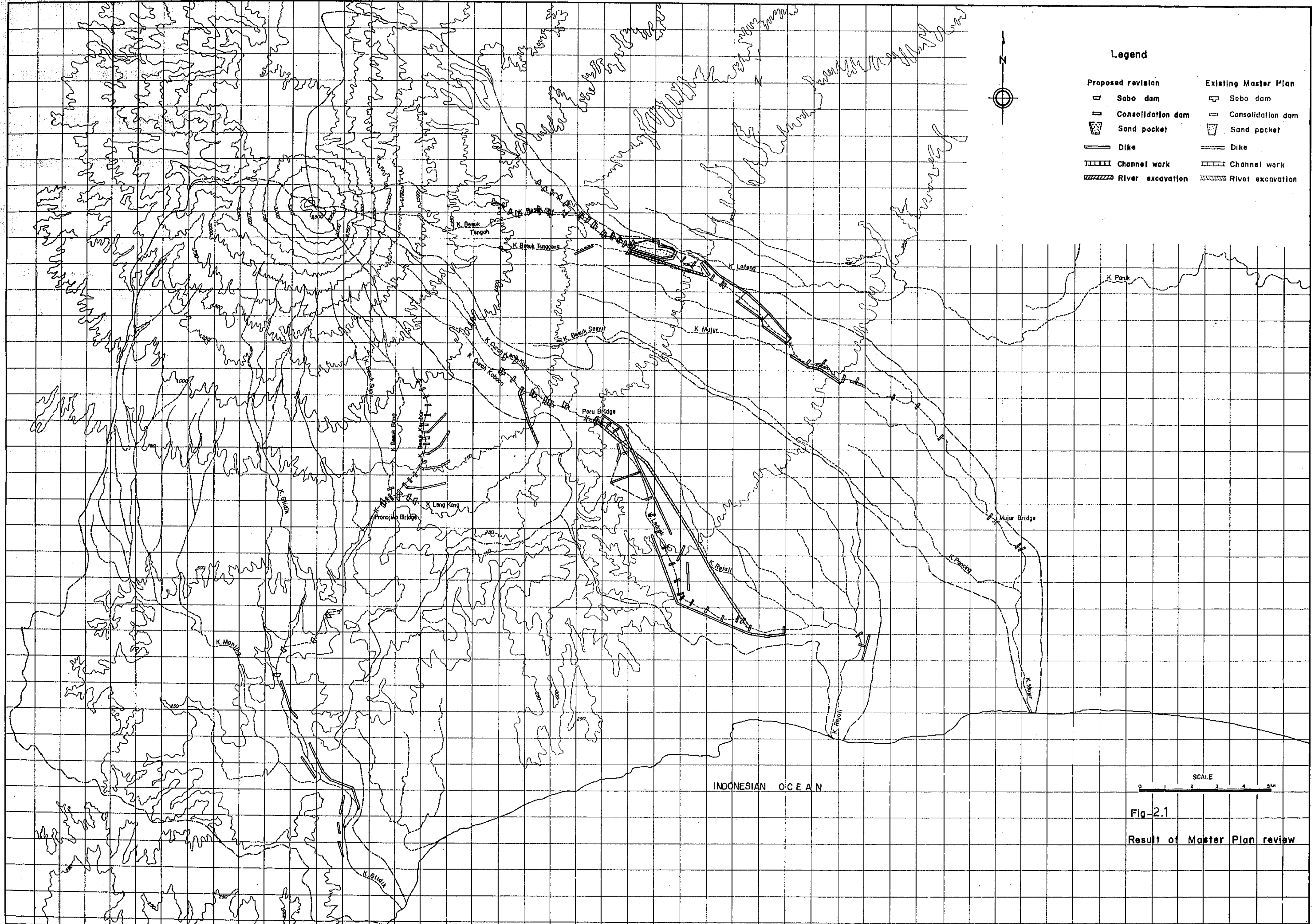


Fig-2.1

Result of Master Plan review

3. PRESENT CONDITION OF THE MASTER PLAN STUDY AREA

3.1 LOCATION AND MAIN RIVER SYSTEM

Mt. Semeru, the highest mountain (3,676 m) and one of the most active volcano in Java Island, is located on the E. Long. 113 and S. Lati. 8 , about 100 km S.E. of Surabaya City by straight line.

The south east side area (629 km^2) of Mt. Semeru is the study area, where three main rivers, K. Mujur, K. Rejali and K. Glidik, flow into the Indonesian Ocean. Refer to Fig.-3.1 and Table-3.1.

Table-3.1 River System

River System	Tributary	Stream Length of Main River	Basin Area
K. Mujur	B. Tompe B. Sat B. Tunggeng K. Mujur K. Pancing B. Semut	31 km B. Sat B. Tunggent K. Mujur	171 km^2
K. Rejali	Curah Lengkong Curah Kobo'an K. Leprak K. Rejali	30 km Curah Kobo'an K. Leprak K. Rejali	132 km^2
K. Glidik	K. Lengkong B. Sarat B. Kember B. Bang K. Glidik K. Manjing	24 km B. Bang K. Lengkong K. Glidik	326 km^2

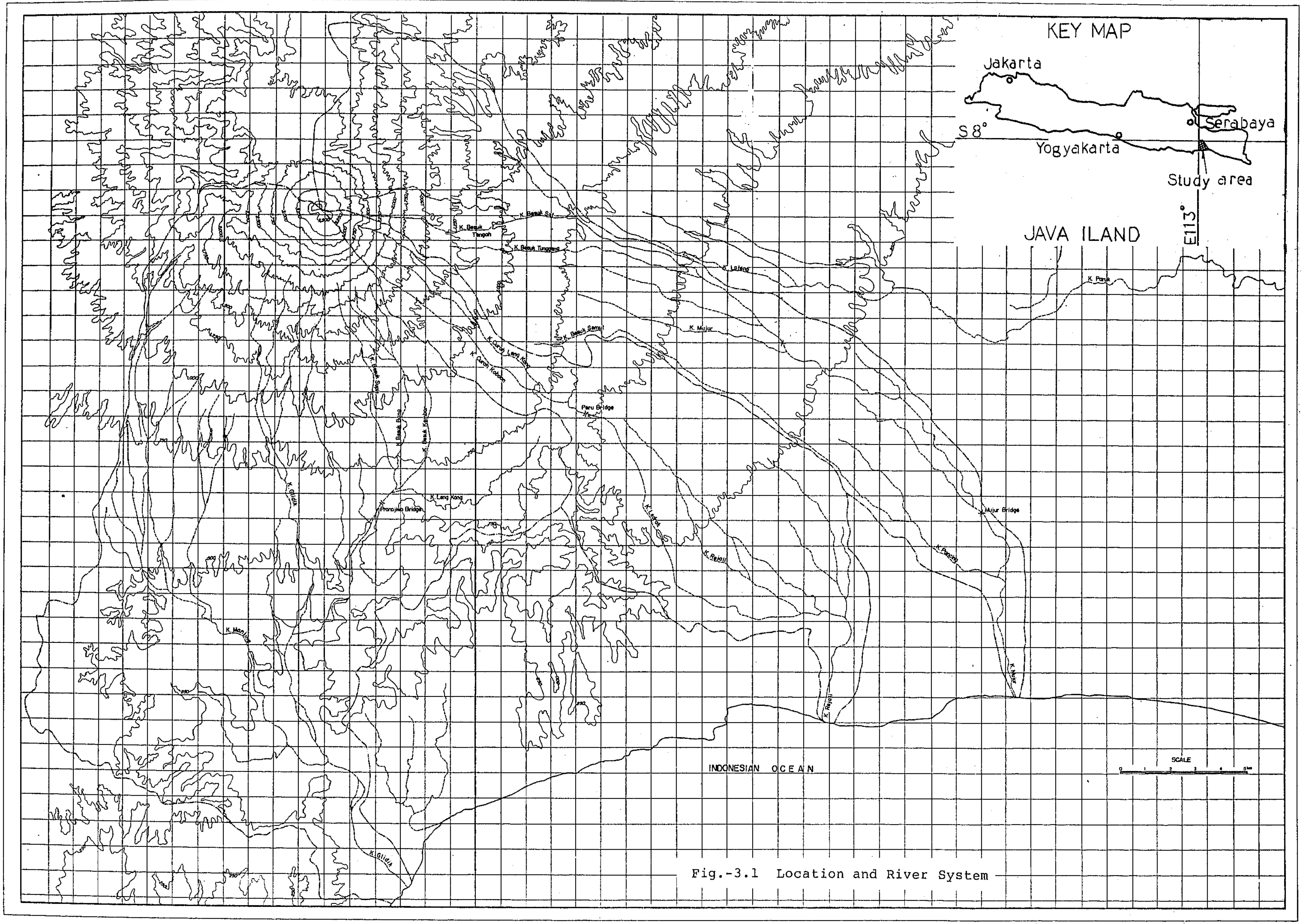


Fig.-3.1 Location and River System

3.2 CLIMATE AND HYDROLOGY

3.2.1 GENERAL

Located in S. Lati. 8 , the study area is included in the tropics. The climate is divided in two seasons i.e. the rainy season from April to November and the dry season from May to October. The area abounds with rainfall in the rainy season, account for some 75 percent of the whole year's rainfall. The temperature rarely varies throughout the year and the average temperature in a day is 23°C - 28°C in Lumajang City.

3.2.2 RAINFALL

The rainfall observation stations as many as 44 (Manual: 30, Automatic 14) are situated around the study area as at the present time of October 1982. The followings are the rainfall characteristics investigated by the data gathered from the 11 observation stations (refer to Fig.-3.3) which are longer in history of the observation activities and less in times of suspension.

(1) Monthly Rainfall

Distribution of the monthly rainfall observed at Lumajang station (a typical station low in altitude) and Besuk Sat (a typical station high in altitude) is shown on Fig.-3.2. This Figure clearly tells that the range of monthly rainfall in the low altitude area largely fluctuates than that in the high altitude area.

(2) Annual Rainfall

Relationship between altitude and the annual rainfall on the basis of the average annual rainfall from 1951 to 1979

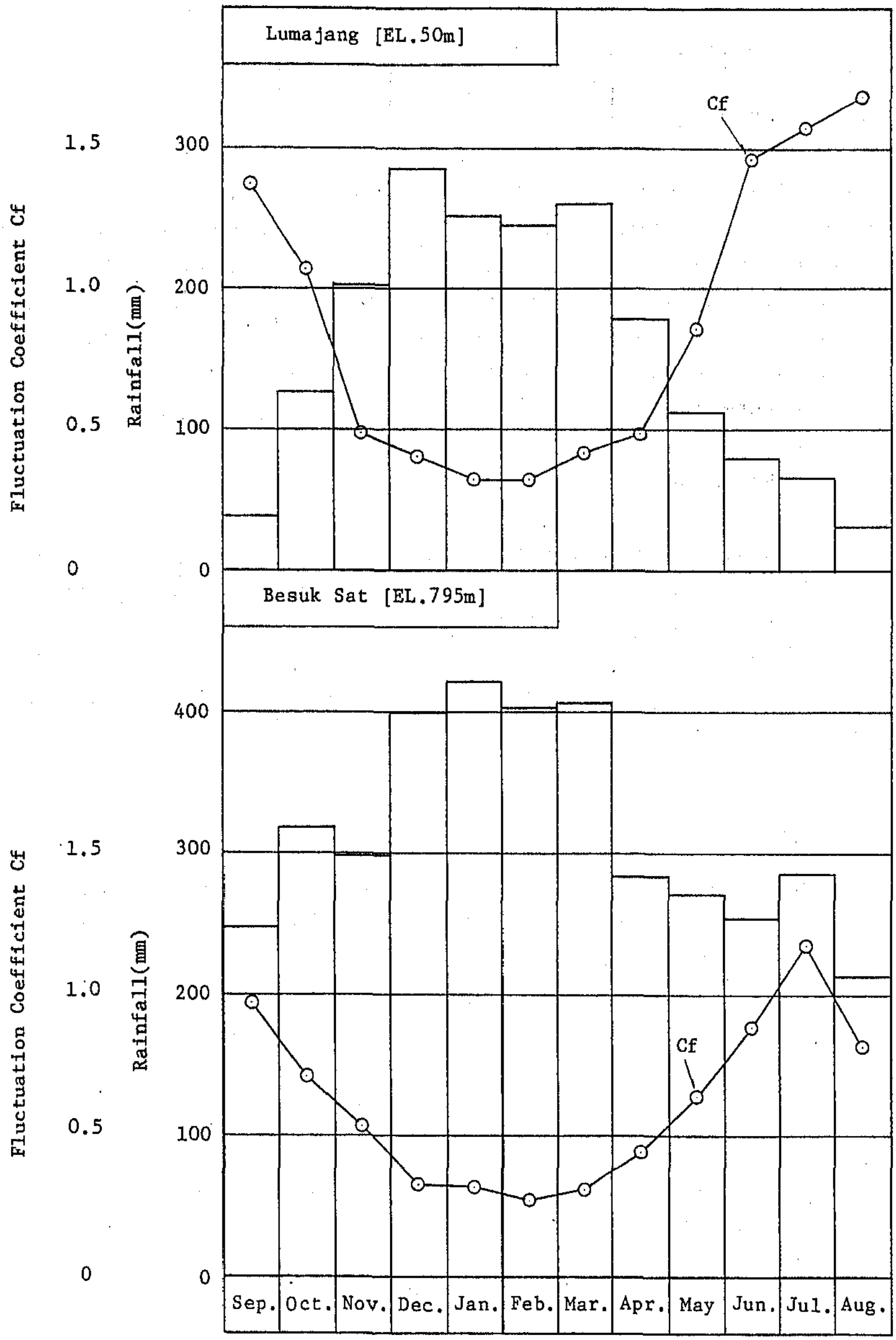


Fig. -3.2 Distribution of Monthly Rainfall

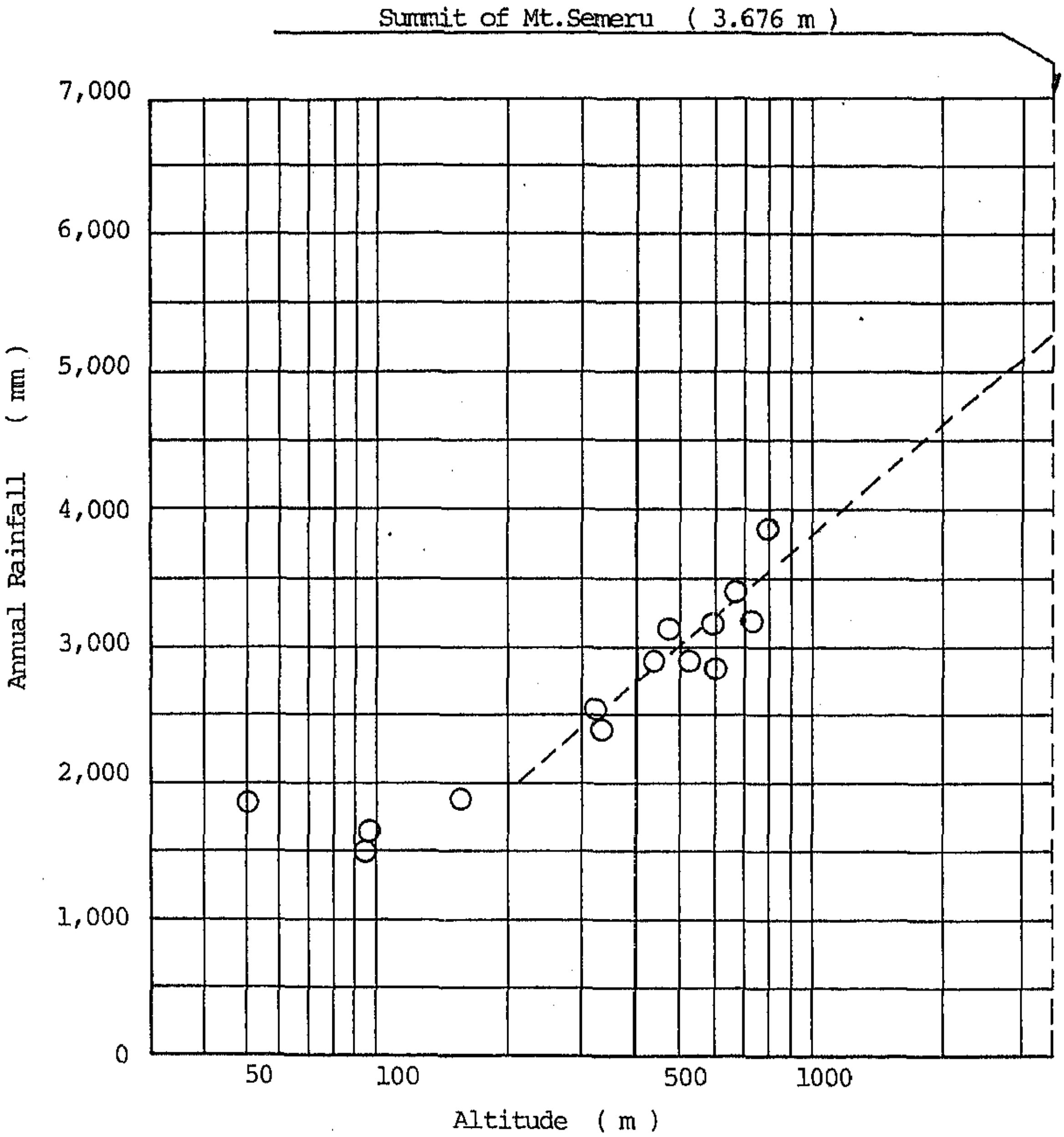


Fig.- 3.3 Relationship between Altitude and Annual Rainfall.

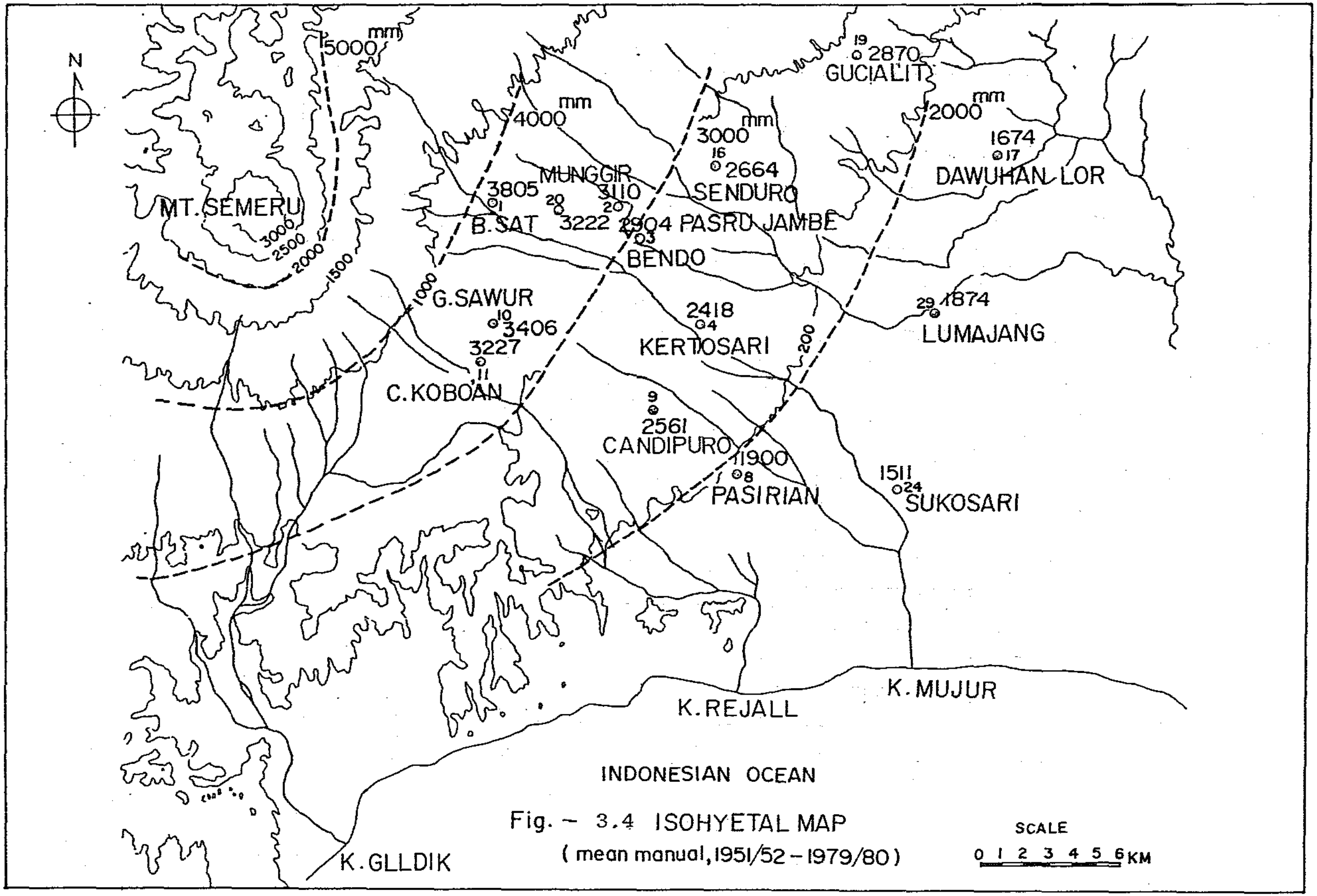


Fig. – 3.4 ISOHYETAL MAP
(mean manual, 1951/52 – 1979/80)

at the 11 observation stations is shown on Fig.-3.3 and 3.4. Those figures suggest that the annual rainfall grows greater in proportion to elevation in the area higher than El. 100m.

(3) Rainfall Wavy Pattern

The rainfall wavy pattern at the time of the disaster in May, 1981 is shown on Fig.-3.5. As can be seen, the rainfall at Besuk Sat is of short duration and is concentric in the rainfall wavy pattern. Besides this, the data shown on the automatic rain gauges, established since 1978, demonstrate that the regional distribution of rainfall is conspicuous and rainfall tends to take place in the afternoon.

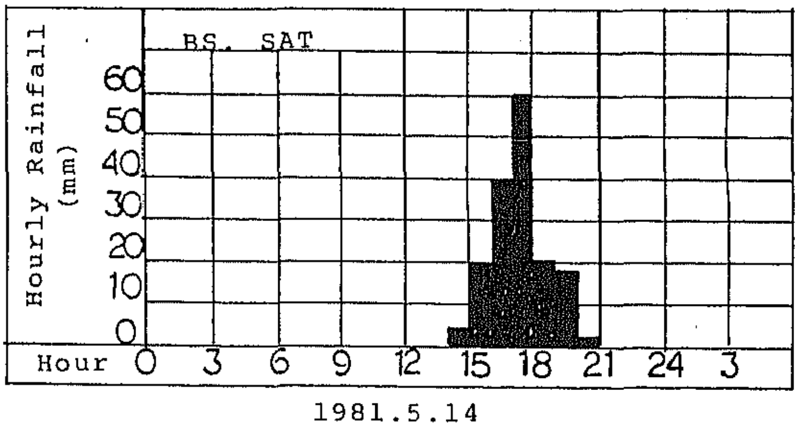


Fig.3.5 Rainfall Wavy Pattern

3.2.3 DISCHARGE VOLUME

The discharge volume observation has been commenced since March, 1982 (4 points for flood discharge and 26 points for base flow). The discharge characteristics found by these observation results in the study area are as follows:

(1) Base Flow Monthly Fluctuation.

The main river base flow tends to decline from April or May and to increase from December or Janaury. The ratio of a bottom value to a top value of this base flow monthly fluctuation at the most upstream station is 25% in the three rivers.

(2) Flood Discharge

Characteristics of the flood discharge are not clear from the data in this last two years. But the flow rate of the peak discharge sometimes can be bigger than 1.0 when Lahar occurs.

3.3 TOPOGRAPHY AND GEOLOGY

(1) Summary of Topography

Mt. Semeru, one of the most active volcanos in Indonesia is a very young Quaternary stratovolcano from volcanological point of view. The volcano is formed in the southern end of the volcanic ran e running north and south. This volcanic ranges are divided into three topographic units (A. Sakai and I. Suruyo 1980). Those are called from south to north as follows:

- Tenggat mountainous district
- Jambangan complex volcano
- Semeru volcano

Ranging from 200 m to 1,000 m above sea level, the mountainous district consisted mainly of the Tertiary rocks is formed at the southern side of Semeru Volcano. The foot area of Semeru Volcano spreads toward the direction from east to southeast and reaches up to near Lumajang City, but is prevented from stretching to the south by this Tertiary mountainous district. The slope stretching to the north of Semeru Volcano forms Jambangan Volcano where the height is 2,600 m above sea level.

Many valleys running in a radial manner lie in the slope stretching to the south and southeast. These valleys flow into the three main river i.e. K. Mujur, K. Rejali and K. Glidik, all of which pour into Indonesia Ocean.
K. Mujur is flowing down south-eastwards on the foot of Semeru Volcano.
K. Rejali deeply erodes the Tertiary mountainous district (Kobo'an Valley) in 500 m to 700 m above sea level and forms again a fan at its downstream.
K. Glidik gathers a lot of streams running down the southern slope while deeply cutting the Tertiary mountainous district, but does not form a wide and flat terrain except where B. Sarat and B. Kembar join K. Lenkong forming a fan.

(2) Topography Classification

The topography in the southeast slope of Semeru Volcano is classified into the following on the basis of topographical features: (Refer to Fig.-3.1)

- Main part of volcanic cone
- Volcanic fan
  - Ladu fan
  - Lahar fan (steep slope)
  - Lahar fan (gentle slope)
- Periphery
  - Alluvial plain
  - Costal plain

Topographical characteristics of these are as is shown below.

(1) Main Part of Volcanic Cone

This is a volcanic slope at a gradient of more than 27° stretching from EL. 1,500 m to the summit. This

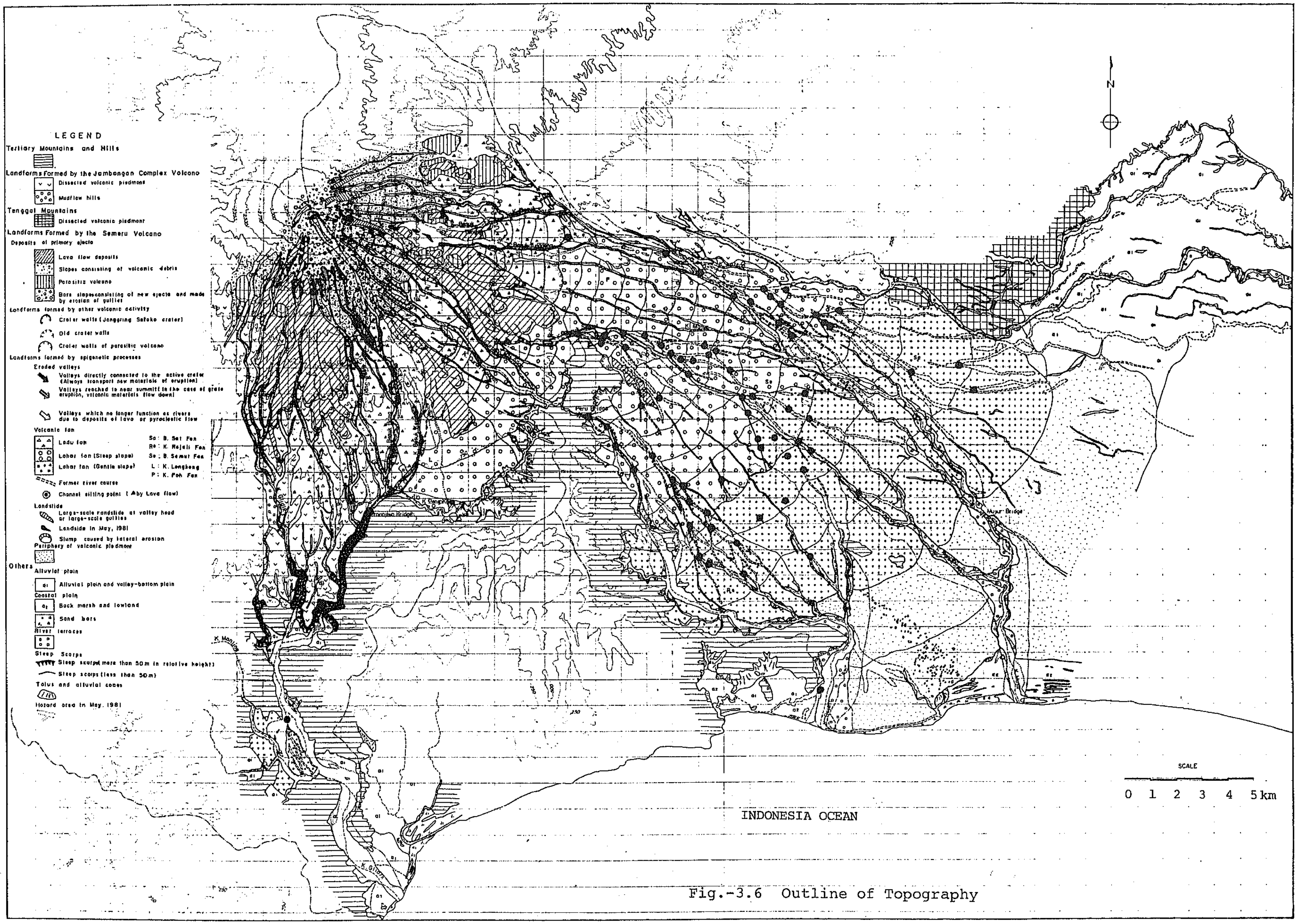


Fig.-3.6 Outline of Topography

slope is divided into two areas i.e. the upper slope, where no plant grows, subject to incessant volcanic activities (from EL. 2,500 m to the summit) and the lower slope covered with forests below EL. 2,500 m. The upper slope which has the average gradient of more than 33° is exposed to constant and severe gullying valleyhead erosion so that it is a main sediment yield source. At the lower slope which has the average gradient of 22°, multitudes of gullys and deep valleys develop cutting deeply this slope.

(2) Volcanic Fan

The alluvial fan at the volcanic piedmont consists of Ladu-type fan and Lahar-type fan and occupies an extensive terrein at 150 m to 1,500 m above sea level. This terrein is also the place where Lahar-typed disaster frequently occurs.

This alluvial fan is divided into 3 units longitudinally and 6 or 7 units traversely according to unevenness of the conversion line of gradient and the contour line.

The Ladu-type fan is formed at the height of 800 m to 1,500 m above sea level. This alluvial fan features a wide range of area covered with the lava stream as well as existence of the parasitic volcano.

(3) Periphery

The peripheral terrein features gentle in gradient and flat in the configuration of the ground formed outside of the volcanic fan. The banks of K. Mujur and K. Rejal are high at 5 m to 10 m in this terrain.

Outside this terrein, the alluvial plain of the Bondoyndo river and the coastal plain are built up.

(3) Breaking Zone

There are many breaking zones along the valleys running down in all direction from the top of a volcano and at valleyheads of these valleys. The breaking zone along the valley appears as a result of lateral errosion: River stream erodes one side of valley because of its direction. The large-scale breaking zone at the valleyhead exists along the forest limit line at 2,500 m above sea level.

Some of those breaking zones build up a large gulley extending to the crater. Some of the gulleys are thought to have been created by volcanic activities although, in general, they were created by errosion of the valleyhead.

The breaking emerged at the valleyhead of the B. Tunggeng river in May, 1981 (started in the forst zone) flowed away into the B. Sat river and the B. Tunggeng river and finally caused a disaster in the basin of K. Mujur. In addition, the new breaking grew in the large-scale breaking area at the valleyhead of the Curah Lengkong river touched off the disaster in the Rejali river basin.

(4) Changes of River Channels

There are many old river channels arround the piedmont of Mt. Semeru and they manifest conspicuous changes of channels in the past. These old river channels are classified into two groups of which were created by lava flow and pyroclastic flow (which exist mainly in Ladu-type alluvial fan) and those which were created by lahar deposit (mainly in Lahr-type alluvial fan). Especially transition of the river channel by burying a valley with lava takes place in the main part of volcanic cone as well.

The typical change of river channel caused by lava flow, which demands the greatest attention for the sediment control plan, is complete burying of BS. Semut valley. When it occurred in 1941/42, BS. Semut was forced to change its basin from K. Pancing (a tributary of K. Mujur) to the Curah Lengkong (a tributary of K. Rejali). Since then, K. Rejali basin became "Over fit river" as was referred by Davis and has been suffered from frequent disasters. On the coutrary, K. Pancing became "Under-fit river" and has been kept in stable condition.

Transition of the river channel in Lahar-type alluvial fan has taken place frequently in Rejali alluvial fan since 1940. The numerous changes of river channels in Rejali fan since 1940 will not be unrelated to the fact that it become "Over-fit river". Such changes of river channels in K. Rejali basin since 1940 have occurred in the entire area of Rajali fan.

3.4 CHARACTERISTICS OF RIVER CHANNEL

Rivers running down from the southeast slope of Mt. Semeru are classified into three river systems of the K. Mujur, K. Rejali and K. Glidik. These rivers have as their branches the eroded valleys developed in every direction in the main port of valcanic cone. In many cases, running water is not usually seen in such a valley. However, large quantities of relatively fine sediment are piled up on the riverbed so that, once flooded, high density of sediment flow will occur and runs down on these eroded valleys and finally causes disaster in lower reaches of these alluvial fans. Constitution of the above three river systems is shown on Table-3.2. The characteristics of these rivers are as follows:

(1) Classification of Eroded Valley

The eroded valleys (Their depth 30 - 50 m), developed in every direction in the main part of volcanic cone, have almost vertical valley walls and lead to the area where valleyhead (around EL. 2,500 m) shows a breaking condition. Ordinarily lava-flow, pyroclastic flow and Lahar stream down through these eroded vallyes.

From the viewpoint of sediment control, the eroded valleys are classified into the following three groups based on the volume of volcanic debris directly supplied from the crater and the scale of sediment supply area at the valley head.

- Stable Valley

  It has no direct inflow of volcanic products from the main crater and has a small area for sediment supply.

- Active Valley (1)

  It is susceptible to inflow of volcanic products and is provided with the large sediment supply area.

- Active Valley (2)

  It is provided with the large sediment supply area since it is connected to the large-scale breaking area at the valleyhead.

The state of eroded valleys in the southeast slope of Mt. Semeru classified pursant to the above classification is shown on Table-3.2.

Table-3.2 Classification of Principal Valleys

River System	K. Mujur	K. Rejali	K. Glidik
Active Valley (1)	-	B. Kobo'an	B. Bang
Active Valley (2)	B. Tompe B. Sat B. Tengah	K. Curah Lengkong	B. Supit B. Cukit B. Glidik
Stable Valley	B. Tugnggeng K. Pop K. Mujur (Upper Streams) K. Pancing B. Semut	-	K. Bening K. Lengkong

(2) Configuration of River Channels

The configuration characteristics of each main river is as follows:

1. K. Mujur

From the viewpoints of sediment analysis, the main channel of K. Mujur is formed by BS. Sat, BS. Tunggeng and K. Mujur in that order. The average gradient of the main stream from the mountain top to the river mouth is 1/11, which represents the most moderate gradient out of three rivers running down on the southeast slope of Mt. Semeru. The inflection points of the riverbed gradient (i) are seen in EL. 300 m (around the junction of K. Mujur) and in EL. 70 m (around the junction of K. Duren). The riverbed gradient, though varies locally in the area above EL. 70 m, stabilizes in the area below EL. 70 m. The channel depth (Hb) is deep at more than 10 m in the area above EL. 600 m and stands at Hb = 5 - 10 m in the area between EL. 400 m and EL. 600 m. The area between EL. 200 m and EL. 400 m is shallowest (Hb = 2 m to 5 m). The river terrace is formed in the area below EL. 200 m, where the Hb shows 5 m to 10 m.

The width of river channel (B) is approximately 70 m in the area higher than EL. 460 m, about 100 m in the area between EL. 200 m and EL. 160 m, about 50 m in the ara below EL. 160 m and widens to some 250 m in the river mouth area.

Grain size distribution of riverbed sediment is mentioned later in this report though distribution of the largest grain-size changes in two areas at around EL. 40 m and 100 m.

The point of sediment flood at the time of disaster on May 14, 1981 was limited to the Lahar fan area whose channel depth is shallow and whose elevation ranges from EL. 200 m to EL. 450 m. A section of riverbed, although covered with loose Lahar sediment in almost entire length, is covered with firmely concreted sediment in the area where the elevation ranges from EL. 300 m to EL. 350 m. In the upper stream area above EL. 820 m of BS. Sat, lava is exposed in some places and forms falls.

2 K. Rejali

The main channel of K. Rejali is formed by BS. Kobo'an, K. Leprak, K. Regoyo and K. Rejali in that order. The main stream from the mountain top to the river mouth runs swiftly at the average gradient of 1/9.2, which represents a steep slope.

The inflection point of the riverbed gradient (i) exists in two places of EL. 440 m and EL. 190 m. The area from EL. 500 m to EL. 600 m forms a narrow neck where the river deeply erodes the Tertiary rocks and the riverbed incline (i) reaches 1/6.6, which represents a steep slope.

The channel depth (Hb) is deep at more than 20 m in the area above EL. 500 m. The area where the elevation is 170 m to 400 m is shallow at Hb = 2 - 3 m except for the point to contact with the Tertiary rocks. In the area from EL. 40 m to 170 m, the channel depth is deep enough to reach Hb = 5 m to 15 m since the area forms the river terrace. In the area below EL. 20 m, the channel depth is shallow at Hb = 1 m to 4 m since the area forms a coastal plain.

The average width of the river channel from the upper reach to the downstream is about 50 m. The river width widens at the area of EL. 180 m as a result of the sediment flood in May, 1981. The bottle neck area between EL. 500 m and EL. 600 m forms a V shaped valley where the river width is very narrow at B = 10 m to 15 m.

Grain size distribution of riverbed sediment is mentioned later in this report though, distribution of the largest grain diameter changes in two places at EL. 40 m and EL. 200 m.

The point of sediment flood at the time of disaster on May 14, 1981 was limited to the Lahar fan area where the channel depth is shallow and the elevation ranges from EL. 170 m to EL. 400 m. The riverbed in the area where the elevation is less than EL. 500 m is covered with Lahar sediment. The area between EL. 600 m and EL. 500 forms a bottle neck and its riverbed is formed with the Tertiary rocks. The riverbed in the area between EL. 600 m and 1,000 m is covered with loose Lahar sediment. Lava is exposed from place to place at the area above EL. 1,000 m and forms falls.

(3) K. Glidik

The main river channel of K. Glidik is formed by BS. Bang, K. Lengkong and K. Glidik in that order. The average gradient from the mountain top to the river mouth is of 1/9.0, which represents the most steep slope among three rivers running down on the southeast slope of Mt. Semeru.

The inflection point of the riverbed gradient (i) exists in two place of EL. 350 m and EL. 630 - 670 m. Especially the area from EL. 350 m to 630 m forms a steep slope and there is a fall, whose height is 100 m, at the point of 1.8 km from the river mouth. The area is free from the danger of flood except for the area from EL. 650 m to EL. 710 m because the channel depth (Hb) is very deep. However the channel depth is shallow at the two areas below EL. 120 m in the right bank and between EL. 70 m and EL. 180 m in the left bank.

The riverbed width reaches about 50 m between EL. 240 m and EL. 730 m but becomes wider in the area above EL. 730 as much as 100 m. Topography of the area below EL. 240 m shows an aspect of valley-bottom plain and the river width is as wide as 150 m (the valley width is some 1 km). Distribtuion of the largest grain diameter varies in the places at EL. 70 m and EL. 180 m.

The K. Glidik basin was hardly hit by the disaster of May 14, 1981 but the left bank where the elevation is as low as EL. 70 m to EL. 180 m was hit by the disaster on January 18, 1982. The area between EL. 350 m and EL. 630 m forms a V shaped valley, and the riverbed there is formed by consecutive base rock. The riverbeds below EL. 350 m and above EL. 630 m are covered with loose Lahar (or Ladu) sediment.

(4) Riverbed Material

Grain size distribution of riverbed material, mountainside material and the Lahar component material flowing down at present are shown on Fig.-3.7. The figure sets forth characteristics of riverbed material as follows:

1. Grain size distribution of riverbed material in K. Mujur is almost equal to that in K. Rejali. Riverbed material in K. Glidik, where the investigation point is only one, is finer as against K. Mujur and K. Rejali.

2. Silt content ($d < 0.074$ mm) of riverbed material is as little as 5% or less.

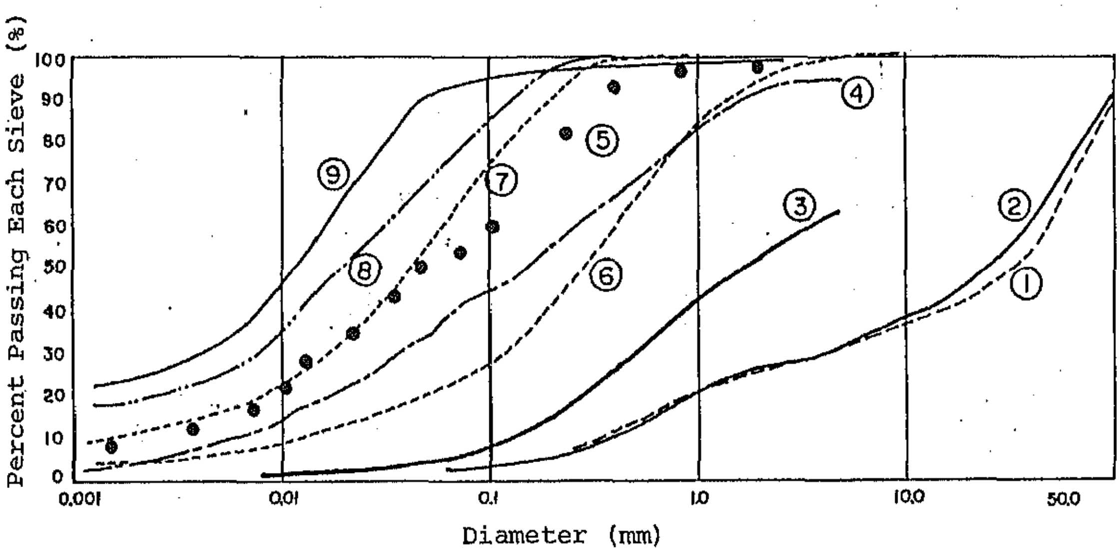
3. Deposit in K. Lengkong fan (Lahar sediment in 1977) abounds in finer grain than riverbed material and contains silt of some 25%.

4. Deposit of the breaking area in the upper stream of BS. Tunggang as of May 14, 1981 consists of 55% of silt.

5. Grain size distribution of Lahar material flowing down to BS. Bang shows almost identical distribution characteristic to that of mountainside deposit.

⑥ Grain size distribution of suspended load material, 80% to 90% of its volume is composed of silt, of K. Mujur and K. Lengkong are almost the same.

The most important characteristic of all is that the flowing Lahar material is finer in grain than the riverbed sediment and has the same grain size distribution as that in mountainside. Density of the flowing Lahar material is shown in Fig.-3.7. The Lahar material is flowing down in extremely high concentration (density ratio by weight = $1.8^{t}/m^{3}$).



Legend:
① Riverbed Deposit of K. Mujur
② Riverbed Deposit of K. Rejali
③ Riverbed Deposit of K. Glidik (Pronojiwo)
④ Deposit of K. Lengkong Fan
⑤ Erosion Sediment at the Upper Stream of BS. Tunggeng
⑥ Flowing Lahar Materials (At 11:20 on Feb. 9, 1983)
⑦ Flowing Lahar Materials (At 14:00 on Feb. 9, 1983)
⑧ Suspended Sediment of K. Mujur at the Mujur Bridge (At 17:25 on May 1, 1983)
⑨ Suspended Sediment of K. Lengkon (Pronojiwo) (At 14:00 on Feb. 15, 1983)

Fig.-3.7 Grain Size Distribution Curve

3.5 DISASTER OF MT. SEMERU

3.5.1 CLASSIFICATION OF DISASTER

In the area surrounding Mt. Semeru, two kind of disasters are known, i.e. primary disaster and secondary disaster. Primary disaster is a disaster caused by direct attack of volcanic activity and secondary disaster is caused by indirect attack of Mt. Semeru. Secondary disaster is close to rainfall to produce lahar, therefore secondary disaster is also called rainy disaster and primary disaster is called dry disaster.

(1) Primary Disaster

Primary disaster consists of:

Nuée Ardente of explosion type that may rushdown at the speed of 100 km/hour

Nuée Ardente of avalanche type

The broken of crater wall.

Both Nuee Ardente of explosion type and avalanche type never reached the villages at the past time. But the broken wall of crater rim occurred in April 1885 and 1895.

(2) Secondary Disaster

This disaster occurs because rainfall washes away material deposit to lower reaches. It may not be still if volcanic ejecta is newly deposited and swept away by rainfall.

Unit weight of lahar is about 18T/m as a mixture of water and material like stones, sand, ash, gravels etc.

Therefore, lahar is very strong to devastate everything. Victims and damages to the area surrounding Mt. Semeru are caused by secondary disaster or lahar flood, because lahar could flow anywhere reaching the lowland in cities or villages.
Above mentioned Lahar and Nuée Ardente are habitual terms for sediment disaster. It is significant to compare the habitual terms with technical terms for sediment transportation. The rough comparison of these terms is as follows. Here, term of "Mud flow" means an intermediate phenomenon that takes place between debris flow and bed load flow:

Habitual term	Technical term
Nuée Ardente	Pyroclastic flow
Lahar	Debris flow Mud flow (Sand flow)
Banjin	Bed load flow Suspended load flow

3.5.2 ACTIVITY OF MT. SEMERU

Truption of Mt. Semeru is usually short. When eruption occurs, ash, sand, gravels and stones are ejected from the crater. If eruption is big, Nuée Ardente of explosion type occurs and lava flows out from the crater to form a lava stream. When a lava stream flows on the steep slope, Nuée Ardente of avalanche type takes place.

Primary disaster is not so hazardous to the people surrounding Mt. Semeru, because villages are far from the summit. But, when the crater is full of material as the result of lava dome formation, it is dangerous if lava pushes the crater wall, and the wall is broken. This phenomena occurred twice in 1885 and 1895. In 1885, the wall was broken by lava doom pressure and the crater rim washed away to 180 m deep and 300 m long. About 26 million m volcanic material was downed toward B.Sat river, and, then, Kali Bening Coffee plantation was buried to about 4 m depth. At that time 72 people were killed.

Data on the activity of Mt. Semeru has only been recorded since 1818 as shown in Table-3.4, taken from the "Catalogue of the volcanoes of the world including solfatara fields, Part I, Indonesia and Basic data of volcanoes in Indonesia, and 2nd edition, Java. Year and month of the eruptions are also given in the table. It also gives data on lava formation following on eruption or without eruption.

Table-3.3 Volcanic Activities of Mt. Semeru Since 1818

Year	Month	Comments	
1818	November	eruption at main crater	
1829	February	"	(ditto)
1830	Dec.15, 16	"	
1832	April	"	+ lava stream
1836	August 3-5	"	
1838	July, October	"	
1842	Jan, March	"	
1844	September	"	
1845	July	"	
1846	Feb, August 4	"	
1851	January	"	
1856	Sept. 10	"	
1857	August 13, Sept.	"	
1860	April, June	"	
1864	July 2	"	
1865	April	"	+ lava stream
1867	April, May	"	
1872	October 23	"	
1877	April, Sept.	"	
1878		"	
1879		"	
1884	Dec. 10	"	
1885	Jan, April, July, Sept	"	+ lava stream
1886	Jan, April, July, August	"	
1887	Feb, March, Sept.	"	+ lava stream
1888	Feb, March, May, Oct.	"	
1889	Jan, March, June, Oct, Dec	"	+ lava stream
1890	Jan, Dec.	"	
1891	Feb, May	"	+ lava stream
1892	March, April	"	
1893	Jan, May, Dec.	"	

Year	Month	Comments
. . . .		
1894	Feb,	Eruptions at main crater
1895	May 22, July 10, Oct.1	" + lava stream + nuée ardente + lahar
1896	May, June	"
1897	January	" + lava stream
1899	Jan, March, August, Dec.	"
1900	March 29, April 11	"
1901	January 29-30	"
1903	March 26, June	"
1904	Jan. 2-16	"
1905	August 4	"
1907	Jan, 7-10, July	"
1908	Jan, Dec.	"
1909	Sept. Dec.	" and farm lands were damage
1910	Jan, March	Eruptions at main crater + lava stream + nuée ardente
1911	Jan, Feb, Nov, Dec	" + lava + farm lands were damage
1912	August 28	"
1913	January 23	"
1941	Sept.	Eruptions at radial cleavage + lava stream
1942	February	"
1945	June 12-18	"
1946	Feb-May, Oct, Dec	"
1947	March, June	"
1950	July, Nov, Dec	" + lava stream
1951	November	" "
1952		" "
1953		" "
1954	September	" "
1955		" "
1956	February	" "
1957	May	" "
1958	April	"

Year	Month	Comments
1959/1960	May	Eruptions at radial cleavage
1964/1965/1966		"
1967	Sept., Dec.	" + lava stream
1968		"
1969	Mar. - Dec.	"
1970/1971	Jan. - Dec.	"
1972	Jan. - Nov.	"
1973/1974	Jan. - Dec.	"
1975	July	"
1976		

3.5.3 LAHAR FLOOD AND DAMAGES

Lahar flood caused by Mt. Semeru material has been occuring for some years, resulting in many victims and much damage. Data since 1895 up to the present could be collected as recorded in Table-3.4 and Fig.-3.8 (lahar flood since 1895).

Table-3.4 Occurrence of Lahar Within Study Area Since 1895

No.	Year	Volcanic activity	Besuk Sat river	Besuk Semat river	Besuk Kobo'an Rejali river	Glidik river
1.	1895	Active	Flood originated from the Laki and Tengah rivers, causing a great deal of sand inundation in the B. Sat river channel.			
2.	1909	Active	The biggest flood ever known devastated 38 villages and killed 208 people. The flood originated from the B. Sat and B. Semut rivers and devastated 1043 ha. of rice fields, 337 ha. of uplands, 227 ha. housing lands, and washed away 1449 houses and 313 cattle.	Flood devastated 5 villages and killed 1 person.		
3.	1913	Active		Flood from the B. Semut river spread to the Rajarkuning river and finally to the Kobo'an river. To the east, flood flowed into the Pancing river.		
4.	1921	Dormant				Flood from B. Cukit and B. Bang caused some damage along K. Glidik.
5.	1937	Dormant				Flood from B. Cukit and B. Bang caused some damage along K. Glidik.

No.	Year	Volcanic activity	Besuk Sat river	Besuk Semat river	Besuk Kobo'an Rejali river	Glidik river
6.	1946	Active	Floods spread from the B. Sat to the Sumber pakel river at Bendo and devastated some parts of Pasrujambe village		Flood water from K. Rejali spread and devastated Sumber Wuluh and finally entered K. Siluman after devastating Sudinoro, Jugosari and West side of Danurejo villages.	
7.	1948	Active			Lahar hit Sumber Wuluh, east part of Kebondeli, Candipuro, Sudinoro and Danurejo villages. K. Rejali shifted to the left at el. 250 m.	
8.	1951	Active			Flood from K. Rajali spread to Uranggantung and entered K. Siluman	
9.	1957	Active	Floods forced the Bando Dike to the Sumber Pakel river and destroyed some parts of Lumanjang City.			
10.					Flood spread along K. Rejali with a width of 100-400m; it began at Sumber Wuluh and ended at Sudinoro village.	
11.	1967	Active				Lahar destroyed river bank near bridge at Sumberrow village
12.	1968	Active			Flood from K. Rejali devastated uplands, rice fields of Sumber Wungkel village and entered K. Leprak at +353m elevation. At that time , 5 persons were killed, 36 houses were damaged, 15 ha. of rice fields and 10 ha. of cassava were inundated by sand.	

No.	Year	Volcanic activity	Besuk Sat river	Besuk Semut river	Besuk Kobo'an Rejali river	Glidik river
13.	1975 (Aug. 7)	Active			A weir was swept away, 3½ ha of rice fields was covered with muddy water for ½ hour. 6 houses were damaged. A channel was broken, causing 75 ha of secondary crops to fail. Road connecting Jugosari-Jarit was cut off. Loss estimate was about Rp. 1.5 million.	
14.	1975 (Sept. 13)	Active			Road connecting Sumber Wuluh-Kebondeli was cut off. 100 ha of rice fields was devastated, 5 houses damaged; loss was estimated to be Rp. 20 million.	
15.	1976 (Oct. 13)	Active	Flood from B. Sat caused damage in Side Mulyo village, 1 person and killed.		Flood from K. Leprak damaged Kebonadeli and Jugosari. 10 persons were killed. All houses in these villages were destroyed. 450 ha of rice fields was damaged.	In Purorejo 8 persons were killed, and 50 houses were destroyed. Taman ayu along K. Lengkong was also damaged.
16.	(Sept.	Active	In Gesang village, 14 persons were reported missing. 3,300 ha of rice fields was damaged. 4 intakes and the irrigation channel was also damaged over a length of 2,950 m. At Pasrujambe, 575 ha of rice fields was damaged.		Fladd from K. Leprak Kebondeli, Gondoruso, and Jugosari village. 23 houses were destroyed.	
17.	(May 12)	Active	Flood from B. Sat and B. Tungeng; Along B. Sat, B. Tunggeng and K. Mujur. 242 persons were killed. Fields and facilities were extensively damaged. Lecess dike destroyed and flood was spread to B. Sat lama.		Flood from Curah Lengkong; Along K. Leparak, 2 persons were killed and fields and many houses were destroyed.	In Purorejo, 63 houses were destroyed.
18.	1982 (Jan.)					In Purorejo village, many houses were destroyed and all rice fields became covered with sand.

3.5.4 RELATIONSHIP BETWEEN VOLCANIC ACTIVITY AND LAHAR

Table-3.5 shows relationship between volcanic activity and Lahar. The figure clearly tells that Lahar tends to occur when the volcano is in action. This suggests that occurrence of Lahar stem from new volcanic debris piled up on the upper part of the main body of volcano cone. Therefore Lahar occurs frequently in the valleys geometrically connecting to the crater.

Fig.-3.5 shows that, as the crater's direction moves from east to south, the place where lahar occurs shifts from east to south in due sequence of K. Mujur, K. Rejali and K. Glidik.

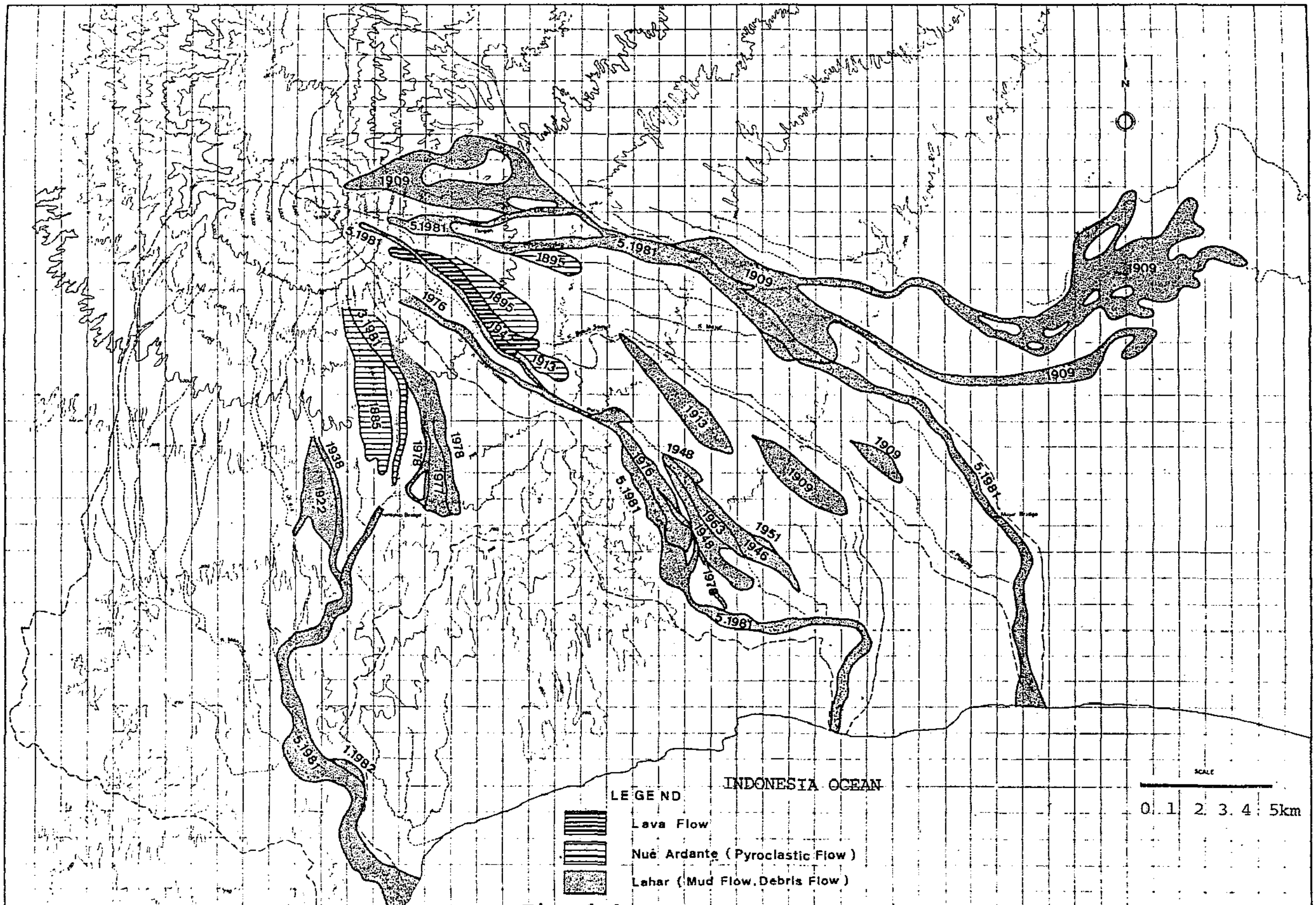
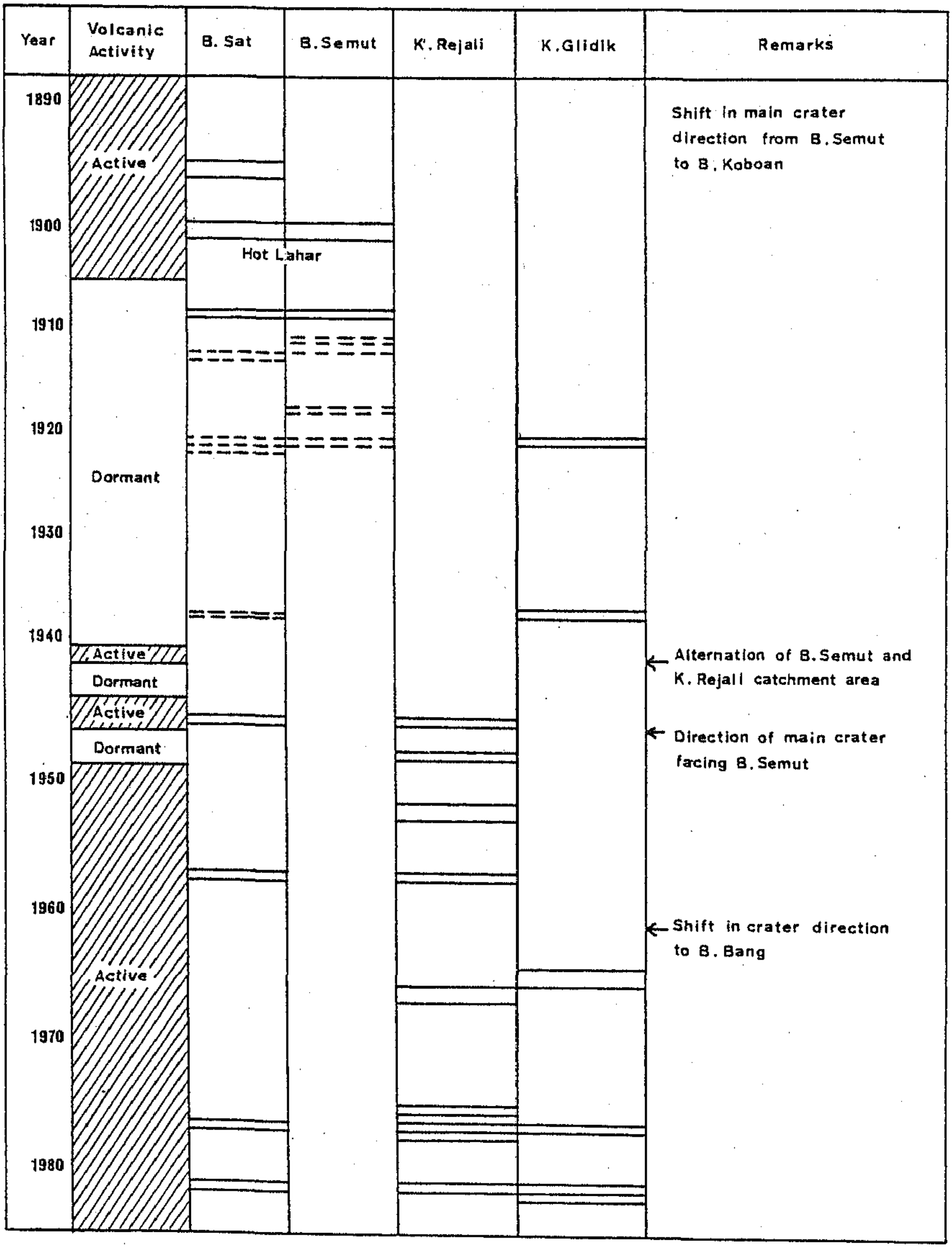


Fig. 3.8 PAST DISASTER (1885-1981)

Table-3.5 Relationship Between Volcanic Activity and Lahar



3.6 EXISTING FACILITY

The facilities existing along the river channels in the study area are classified as follows for the use of planning:

1. Disaster prevention works executed by Mt. Semeru Project Office after 1977 in which it was established.

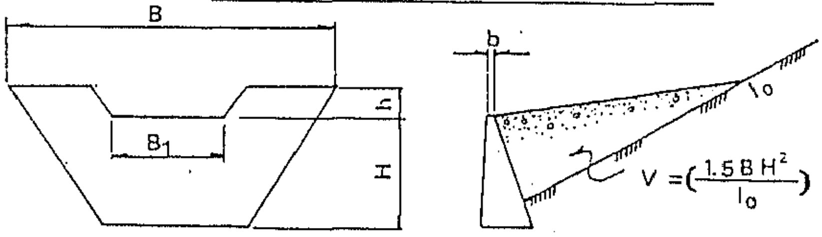
2. Disaster prevention work executed before 1977.

3. Intakes for irrigation.

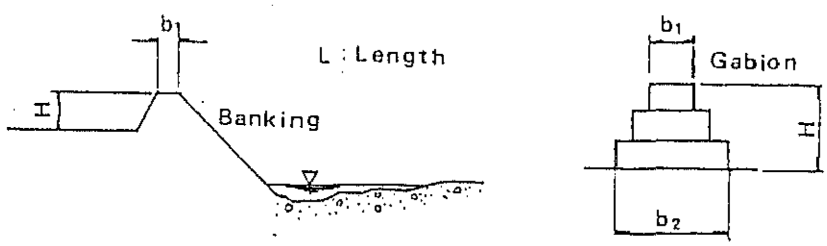
Existing facilities belonging to group 1 and 3 are shown in Fig.-3.9 and Table-3.6. Existing facilities belonging to group 2 , which were executed along K. BS. Sat and K. BS. Sat lama before 1977, are shown in Table-3.7 and Fig.-3.10.

The simbols which are used in tables and figures have the following meanings.

Check dam and consolidation dam



Dyke and spurdyke



Type of Intake

TECH : Technical intake
HARF TECH : Harf technical intake

Table- 3.6 Existing Facility in K. Mujur

River Name	Tributary Name	Facility	Facility Name	Completed Year	Elements	Constructor	Remarks
K. Mujur	K. Besuk Sat	Check dam	CHD.BS.SAT 1	'77 '79	H=7.3,Bl=28,B=129,h=4.0	Mt. Semeru	destroyed at May 1981
			CHD.BS.SAT 4	'8[illegible]	H=10.5,Bl=62.14,B=203,h=5.6	Project Office	
			CHD.BS.SAT 3	'80	H=9.0,Bl=50,B=200,h=6.0	"	
			CHD.BS.SAT 2	'79	H=11.0,Bl=48,B=197,h=5.25	"	
	K. Mujur	Dyke	TGL.MUJUR	'81	L=86,H=2.5,bl=2.5	"	
	K. Tunggeng		TGL.TUNGGENG BAWAH	'81	L=190,H=5,bl=5.5,b2=15.5	"	
	K. Besuk Sat		TGL.LECES	'78	L=160,H=4.0	"	partially destroyed at May 1981
			TGL.KERTOSARI 1+2	'81	L=835,H=5,bl=4,b2=15	"	
			TGL.BS.SAT	'80	L=200,H=3,bl=2.5	"	destroyed at May 1981
	K. Tunggeng		TGL.SUMBERSARI	'81	L=275,H=4,bl=5.5,b2=15.5	"	
	K. Mujur	Revetment	TEBING MUJUR	'78	L=120, H=4	"	
	K. Mujur	Intake	INT. PANDANWANGI		TECH		
			" SOPONYONO		"		
			" KEDUNG				
			CARING		"		
			INT. KLEREK		"		
			" LOBANG 2		"		
			" LOBANG 1		"		
	K. Tunggeng		INT. ROWOGEDANG		HALF-TECH		

Table-3.7 Existing Facility in K. Rejali

River Name	Tributary Name	Facility	Facility Name	Completed Year	Elements	Constructor	Remarks
K. Rejali	K. Leprak	Check dam	CHD.Leprak 1	'82	H=8,B=30,Bl-18,h=7.5	Mt. Semeru Project	
			CD.Leprak 2	'82		"	under construction
	K. Kobo'an		CD.Kobo'an 2	'80	H=6.5,B=56,Bl=20,h=6.5	"	
			CD.Kobo'an 1	'80	H=11.5,Bl=30,h=7	"	
	K. Leprak	Dyke	TGL.Leprak 1	'78	L=250,H=3	"	
			" 7	'80	L=30,H=4.3,bl=4,b2=12.3	"	
			" 2	'78	L=157,h=3.5,bl=3,b2=8	"	
			" 3	'78	L=98.5,H=3.0,bl=4.0,b2=7.0	"	
			" 5	'79	L=125,H=2,bl=3,b2=8	"	
			" 6	'80	L=49,H=2,bl=3,b2=11	"	
			" 11	'82	L=185,H=3	"	
			" 4	'78	L=160,H=45,bl=3,b2=11	"	
			" 8	'80	L=308,H=2.5,bl=3,b2=8	"	
			" 9	'81	L=132,H=3,bl=2.5,b2=6	"	destroyed at May 1981
			" 10	'82	L=215,H=3,bl=3,b2=10	"	
			TGL.Jugosari 1			"	destroyed at May 1981
			TGL.Jugosari 2			"	"
		Spur dyke	KRIB.Leprak			"	
			KRIB.Swakelola	'81		"	
	K. Rejali	Intake	INT.Banjir SCHERM		TECH		
			INT.Talang		TECH		
			INT.Rahayu		HALF-TECH		

Table- 3.8 Existing Facility in K. Glidik

River Name	Tributary Name	Facility	Facility Name	Completed Year	Elements	Constructor	Remarks
K.Glidik	K. Besuk Bang	Dyke	TGL. Besuk Bang	'81	L=275, H_1=3.0, b_1=2, b_2=4	Mt. Semeru Project	
	K. Besuk Sarat		TGL. Besuk Sarat 3	'81	L=350 H_1=3.5, b_1=3, b_2=10	"	
			TGL. Besuk Sarat 2	'80	L=58 H_1=2.0 b_1=3 b_2=7	"	
			TGL. Besuk Sarat 1	'79	L=136 H_1=2.0 b_1=3 b_2=7	"	
			TGL. Besuk Sarat	'82	L=121, H_1=6.0	" "	
	K. Glidik		TGL. Wareng	'82	H_1=3.0, L=116	"	
			TGL. Umbulsari	'81	H_1=3.0, L=42	"	
		Spur dyke	KRIB Besuk Sarat			"	
			KRIB Wareng 1	'81	H_1=3, L=102	"	
			KRIB Wareng 2	'81	H_1=3, L=41	"	

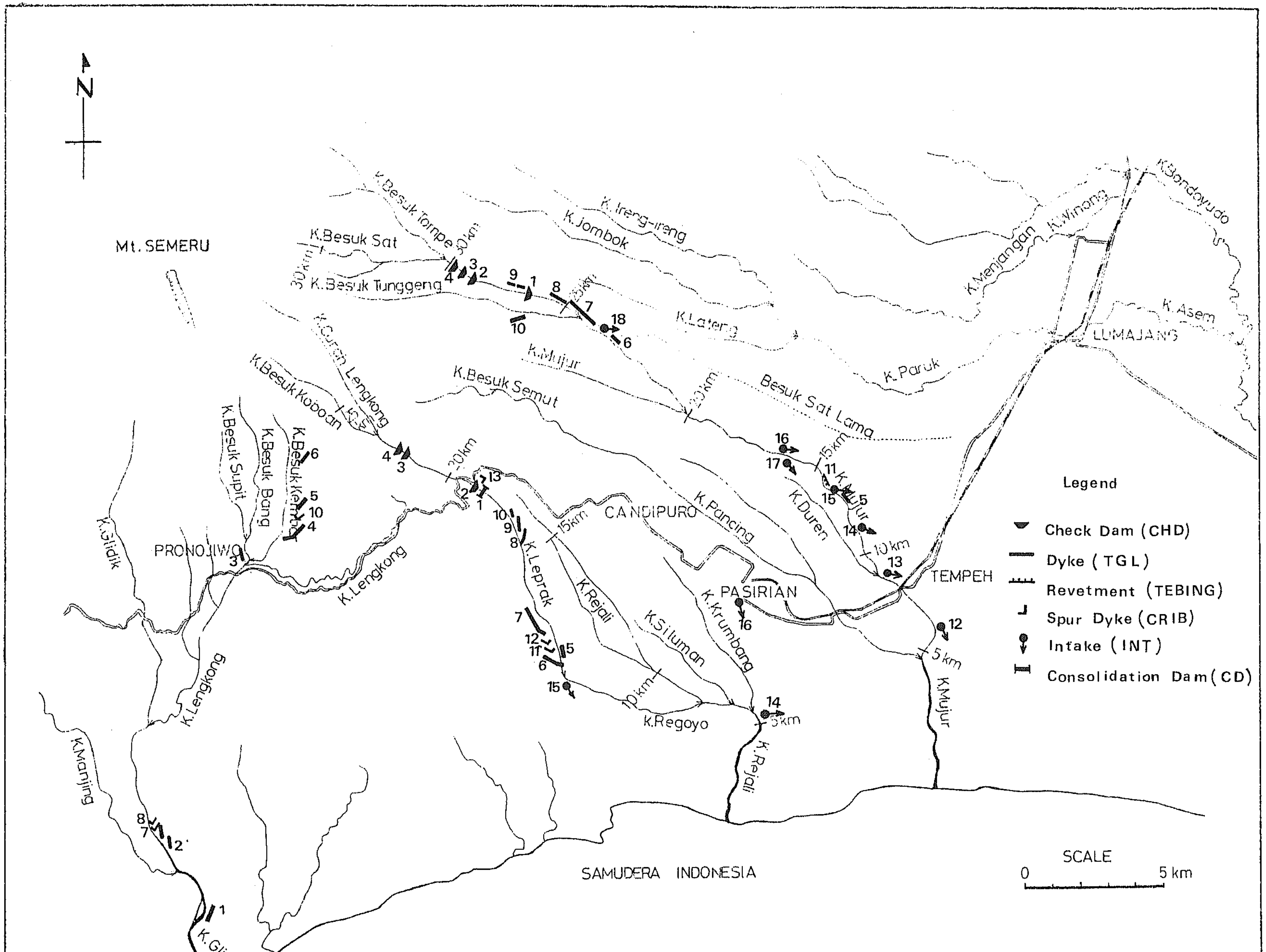


Fig.-3.9 Existing Facilities Constructed after 1977

K. Mujur

1. CHD
2.
3.
4.
5. TGL
6. "
7. "
8. "
9. "
10. "
11. TEBI
12. INT
13. "
14. "
15. "
16. "
17. "

K. Rejali

1. CD
2. CHD
3. CD
4. CHD
5. TGL
6. "
7. "
8. "
9. "
10. "
11. KRI
12. "

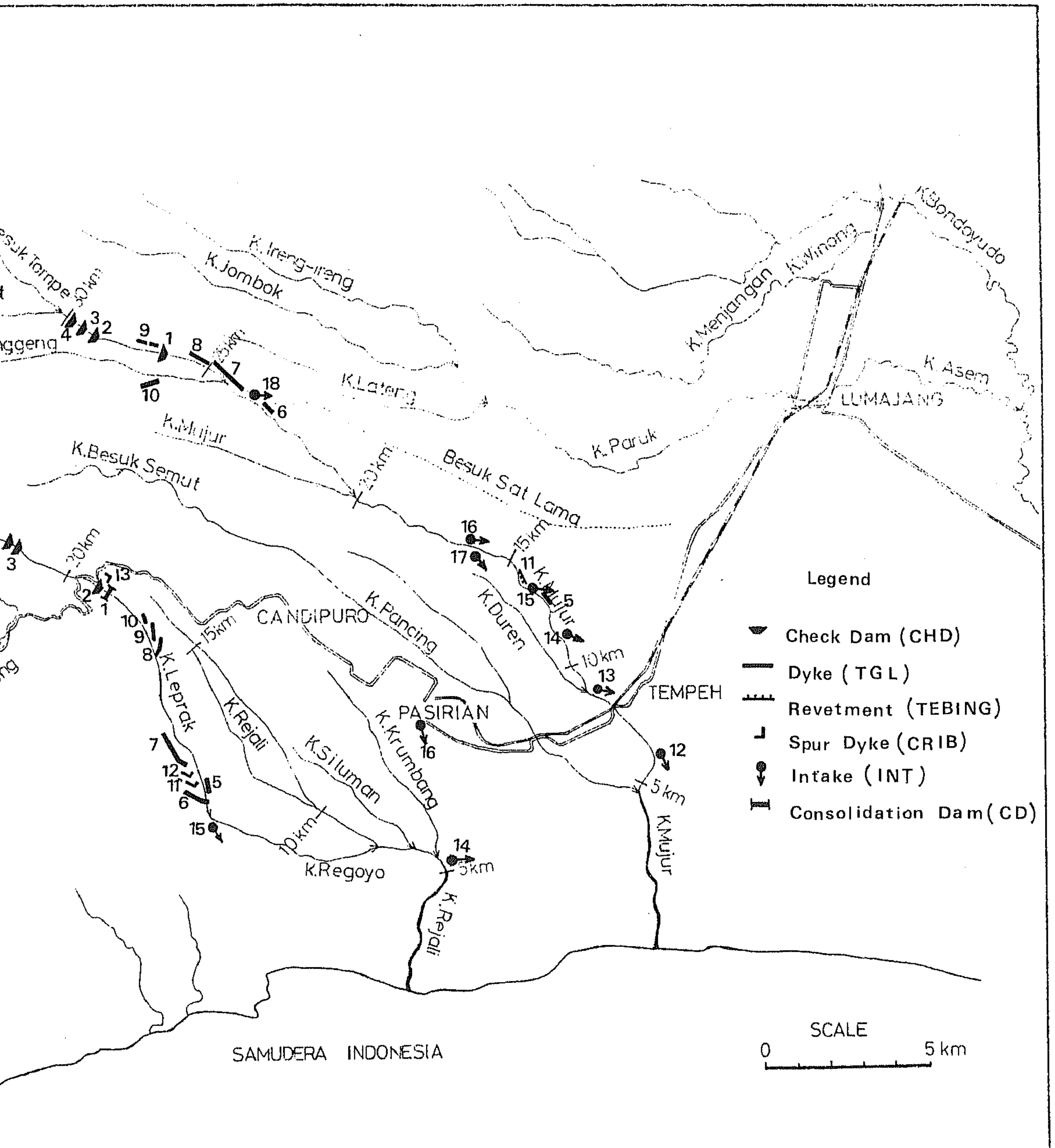


Fig.-3.9 **Existing Facilities Constructed after 1977**

K. Mujur

1. CHD Besuk Sat I
2. IV
3. III
4. II
5. TGL Mujur
6. " Tunggeng Bawah
7. " Kertosari I+II
8. " Leces
9. " Besuk Sat
10. " Sumbersari
11. TEBING Mujur
12. INT Pandanwangi
13. " Soponyono
14. " Kedung Caring
15. " Klerek
16. " Lobang 1
17. " Lobang 2

K. Rejali

1. CD Leprak 1
2. CHD Leprak 2
3. CD Curah kobo'an 2
4. CHD Curah kobo'an 1
5. TGL Leprak 10
6. " Leprak 9
7. " Leprak 8
8. " Leprak 2+3+5+6+11
9. " Leprak 1+7
10. " Leprak 4
11. KRIB Swakelola
12. " Swakelola
13. KRIB Leprak
14. INT Banjr Scherm
15. " Rahayu
16. " Talang

K. Glidik

1. TGL Umbul Sari
2. " Wareng
3. " Besuk Bang
4. " Besuk Sarat 2+3
5. " Besuk Sarat 1
6. " Besuk Sarat 4+5
7. KRIB Wareng 1
8. " Wareng 2
9. " Besuk Sarat.

Table-3.9 Existing Facilities Constructed before 1977

Facility Name	Constructed Name	Facility Name	Constructed Name
Jabon dam	1951	Penutup baru dyke	1913
Lobang dam		Kertosari "	1910
Leces excavation	1921	Kertosari baru "	1912
Genting "	1909	Tesirejo "	1912
Kletek "	1910	Glodog "	.
Sumber Duren dyke	1913	Kletek tengah "	1910
Bendo dyke	1922	Kletek wetan "	1910
Pasru dyke	1914	Tumpeng "	1912
Leces dyke	1913	Gladak "	
Genting dyke	1910	Sumber suko "	before 1910

The facilities mentioned above contain those as already destroyed and indistinguishable from the natural surface of land at present. The useful facilities along K. Besuk Sat which is the main river at the upstream of K. Mujur area as follows:

Leces excavation

Sumber Duren dike, Bendo dike, Pasru dike, Leces dike.

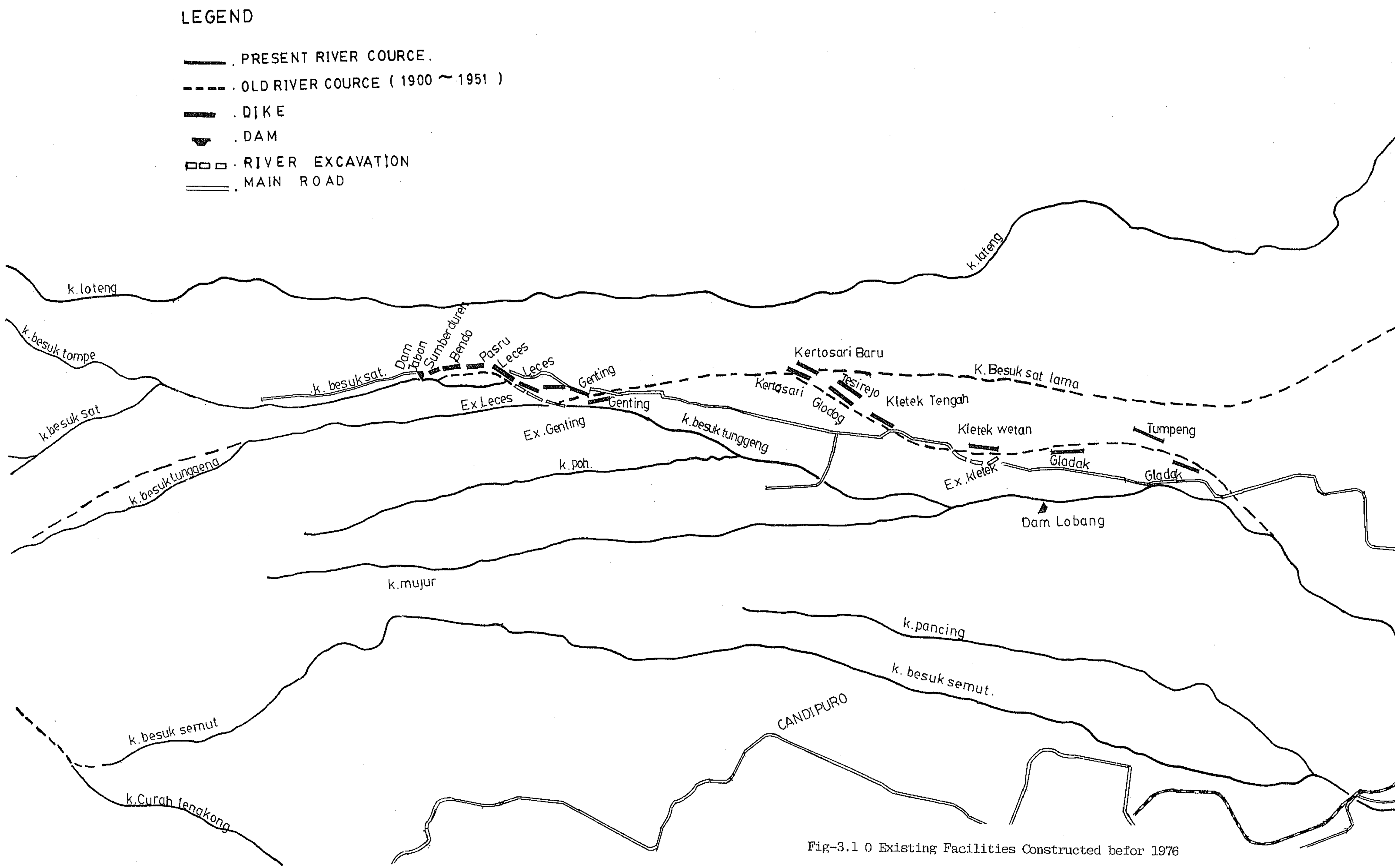


Fig-3.1 0 Existing Facilities Constructed befor 1976

0 ～ 1951)

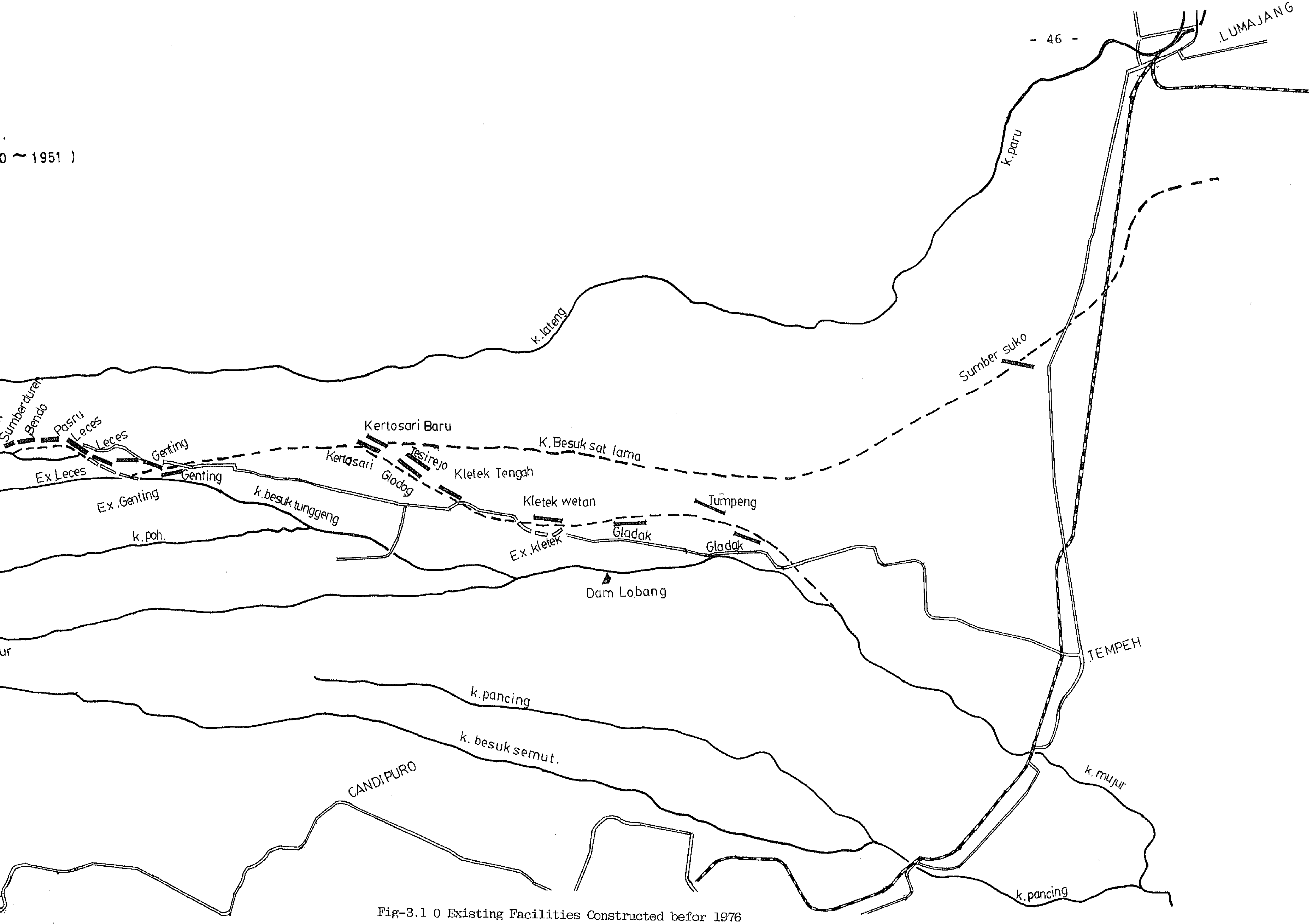


Fig-3.1 0 Existing Facilities Constructed befor 1976

3.7 PRESENT CONDITION OF OBSERVATION AND W. SYSTEM

As it was mentioned in Chapter 2.5, big lahar flood occurred at the southeastern slope of Mt. Semeru in 1909. It is recorded that 208 people were killed, many houses were swept away and many hectares of rice fields were damaged. Since then, the government made some efforts to control flood by using embankments. Also some observation stations equipped with telephones for warning were set up to observe the activity of Mt. Semeru and lahar.

3.7.1 VOLCANOLOGICAL OBSERVATION STATION

To observe the activities of Mt. Semeru, there are 3 volcanological stations at the eastern and southern slopes of the mountain. These 3 volcanological stations are:

1. Tawonsongo volcanological observation station (+800 m), situated at the eastern slope area and observing the mountain activities to eastern slope direction.

2. Gunung Sawur Volcanological observation station (+800 m), situated at the southeastern slope area and observing the mountain activities to southeastern slope direction.

3. Arqosuko Volcanological observation station (+900 m), situated at the southern slope area and observing the mountain activities to southern slope direction.

Observation of Mt. Semeru activities is run by the directorate of Volcanology. Communication is done by telephone.

From the observation result by these stations, it can be concluded that volcanic debris Mt. Semeru is current produced toward the eastern and southern slope directons.

3.7.2 FLOOD OBSERVATION STATION

Since the occurrence of lahar flood in 1909, the government paid a serious attention to control lahar flood. Besides constructing some countermeasures such as embankments and revetments, 10 flood observation stations were set up at the eastern and southeastern slopes of the mountain. Communication system between these observations consist of telephones, where its management comes under the Irrigation Service of Lumajang. Therefore, Central Station of the telephone communication system is at the Irrigation Services Office.

Those flood observation stations are as follows:

1. Kertosari Central Observation Stations is to observe lahar in the Besuk Sat river, located at the mid-stream of the river. ("Central station" means that some stations in the field is subordinate to this station).

2. Gunug Sawur Central Observation Station is to observe lahar in the Besuk Semut river, located at the upstream of the river.

3. Curah Kobo'an Observation Station is to observe lahar in the Besuk Kobo'an river, located at the mid-stream of the river.

4. Kali Pancing Observation Station is to observe lahar in the Pancing river.

(5) Besuk Sat Observation Station is to observe the Besuk Sat river, located at upstream of the river.

(6) Mungir Observation Station is to obsrve lahar in the Besuk Sat river, located at the downstream of the river.

(7) Bendo Observation Station is to observe lahar in the B. Sat river, located at mid-stream of the river.

(8) Senduro Observation Station is to observe the Ireng-ireng river.

(9) Pagoan Observation Station is to observe the Laban river.

(10) Kedung Waringin Observation Station is to observe the Mujur river.

3.7.3 TRADITIONAL WARNING SYSTEM

Traditional warning system is still convenient in the area surrounding Mt. Semeru, especially in the country side to announce the occurrence of lahar flood (also for fire, etc.). This traditional warning device is called Kentongan (Tong-tong), made from bamboo or hollow wood.

To announce the occurrence of flood, people beat these tong-tong in a certain rythm, and the alarm is repaid to the neighbouring villages so as to make up the people to prepare the emergency evacuation.

3.7.4 RADIO WARNING SYSTEM

After the establishment of Mt Semeru Project, a radio communication system will be installed to improve warning system owned by the Irrigation Services Office (at Lumajang).

Location of the radio stations will be as follows.

- Semeru 1. At the Mt. Semeru Project Office
  At the central communication station

- Semeru 2. At the Kobo'an Observation Station, observing and reporting the occurrence of flood in the B. Kobo'an river.

- Semeru 3. At the B. Sat Observation Station, observing and reporting lahar flood in the B. Sat river

- Semeru 4. At the Kecamatan Pronojiwo Office, observing and reporting flood in the Lengkong river and its tributaries

3.7.5 ORARI WARNING SYSTEM

Recently (1982/1983 fiscal year), Mt. Semeru Project Office set up a more convenient communication system. It is a communication system using FM 2M band transceiver, whereby communication can be done with moving. (Conveyable distance is about 50 km - radius)

Warning system network showing the Irrigation Services Telephone and Radio Communications and reporting system are given in Fig.-3.11. Locations of obervation stations are shown in Fig.-3.12.

3.7.6 EVACUATION HILL

During a flood, poeple will be evacuated to an evacuation hill which is made from tones or soil some 3 m high above the ground. This evacuation hill is used for the purpose of saving lives during flood. However, a lahar directly attacks this evacuation hill, it is not strong enough to bear the destructive power of lahar stream. Therefore, it is advisable to construct it much stronger.

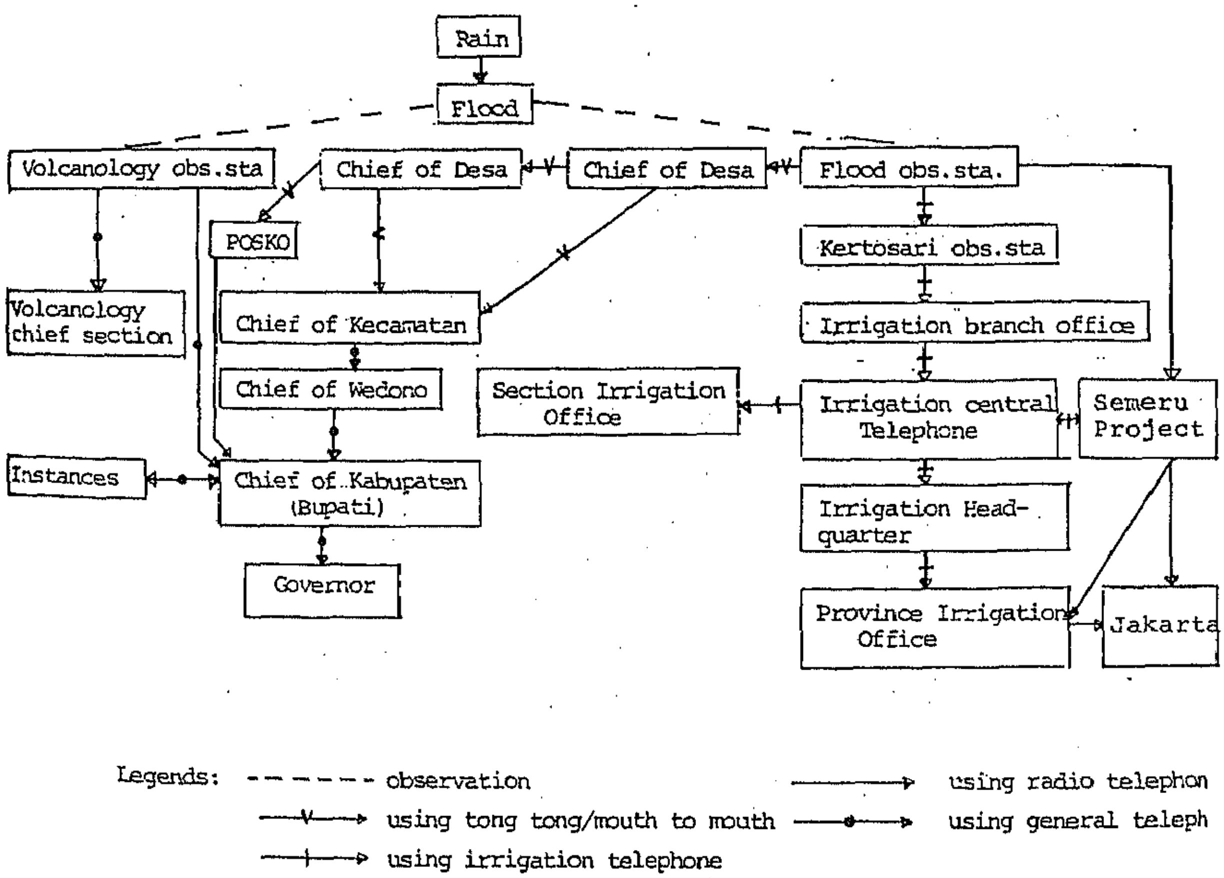


Fig.-3.11 Warning System

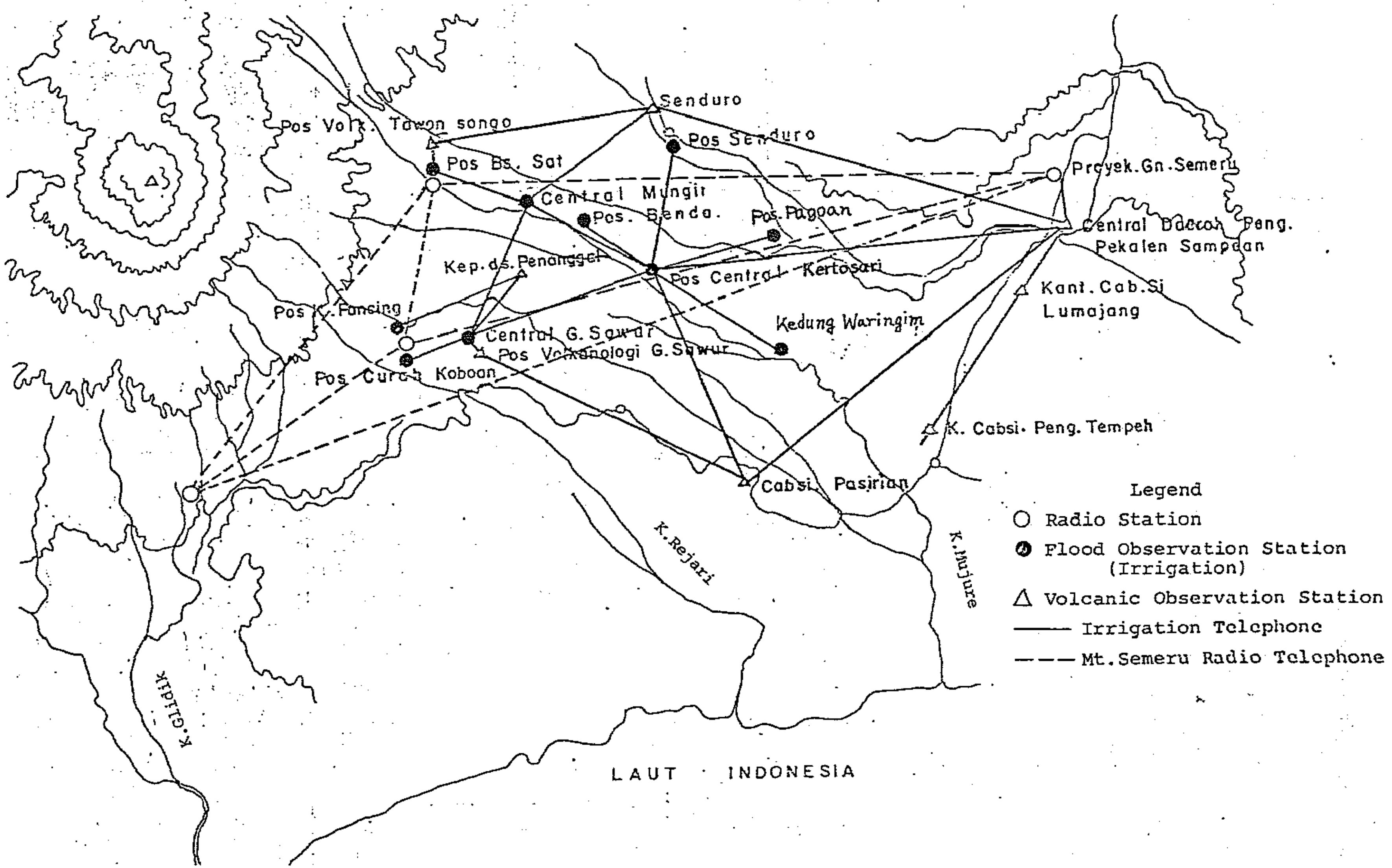


Fig-3.12 Location Map of Warning System

4. ESTABLISHMENT OF POSSIBLE DIASTER AREA

4.1 SUMMARY

As is stated above, eroded valleys developing to every direction on the southeast slope of Mt. Semeru rarely have water stream, but once heavy rainfall takes place, they flush quantities of sediment and cause flood in every alluvial fan and vallye-bottom plain. In addition, since the river channels are constantly shifting at every flood, the flood area is always shifting, too. Therefore there is no place free from sediment disaster in the alluvial fan and the valley-bottom plain. Then the most probable area hit by disaster is established based on topographic characteristics of area and history of past disaster, and is called "Possible Disaster Area".

4.2 DIVISION OF POSSIBLE DISASTER AREA

Even within the "possible disaster area," damage ratio is different from location to location because of the difference in sediment flow type and deposition depth. So, the possible disaster area is classified into 5 zone (see to Fig.-4.1 and Table-4.1), considering sediment flow type, deposition depth and topographic characteristic. The damage ratio can be established to each zone in a calculation of disaster damage amount.

Table-4.1 Division of Possible Disaster Area

Characteristics / Category	Sediment Flow Type	Topographic Characteristics
I	Pyroclastic flow	Ladu-fan
II	Debris Flow	Lahar fan (Steep slope)
III	Mud Flow A This area falls under the transition area from debris flow to bed load flow, but debris flow element is still stronger.	
IV	Mud Flow B Same as above, but bed load flow element is stronger.	Lahar fan (Gentle slope)
V	Bed load flow	Peripheral area

Acreage of each zone of Possible disaster area is shown on Table-4.2.

Table-4.2 Eech Zone's Acreage

(Unit: km^2)

Disaster / Area / River System	Primary Disaster	Secondary Disaster				
	I	II	III	IV	V	Total
K. Mujur	-	8.98	15.30	46.06	136.76	207.10
K. Rejali	-	1.68	9.89	26.38	2.67	40.52
K. Glidik	4.99	0	0	9.23	8.35	17.58

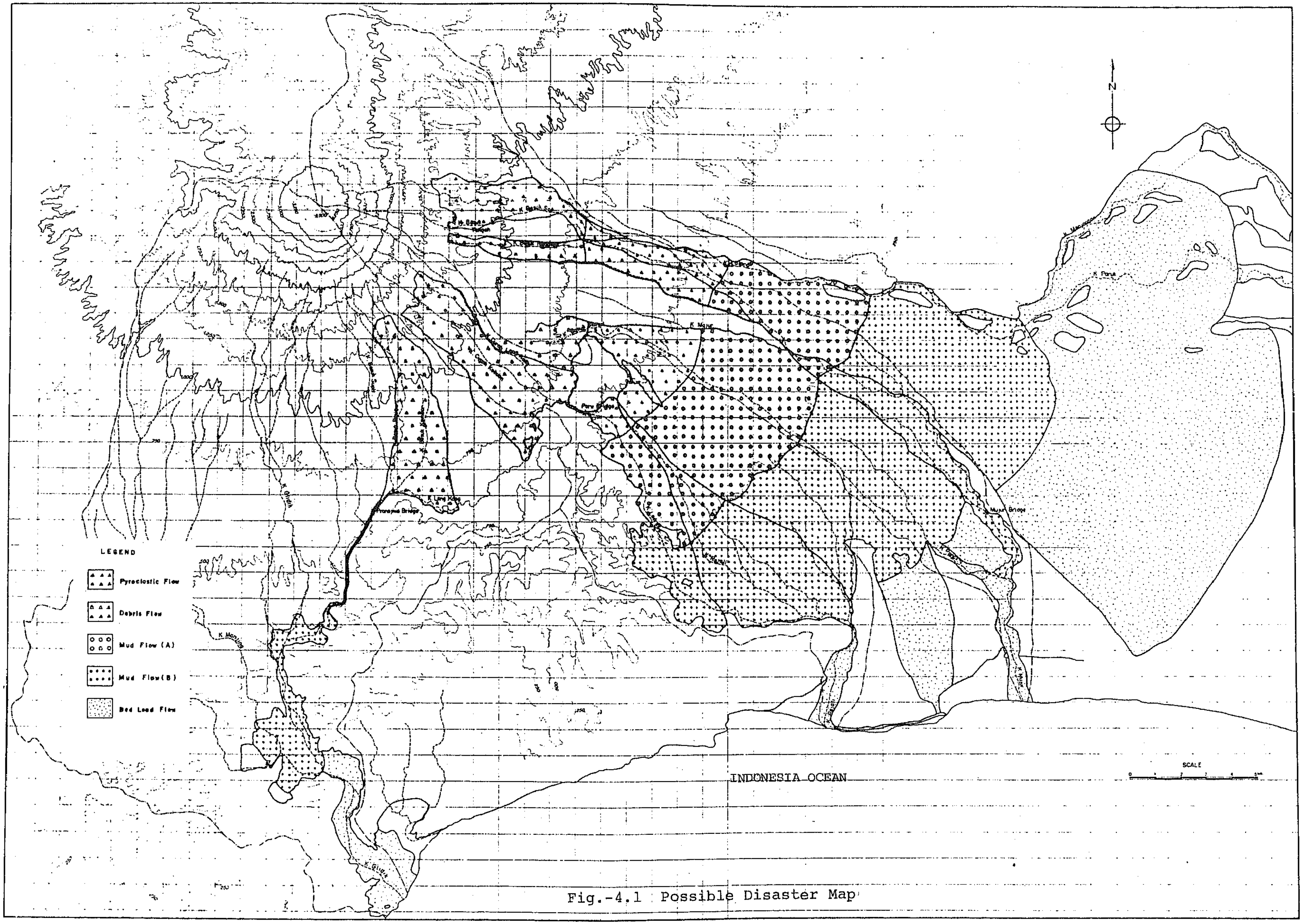


Fig.-4.1 Possible Disaster Map

5. ESTIMATION OF EXCESS SEDIMENT VOLUME

It is extremely important to estimate harmful sediment volume in preparation of the sediment control plan. The harmful sediment volume is a volume to be controlled by the plan, and called as a excess sediment volume of terminology. Volume of such sediment is generally estimated based on the history of past disaster, topography, river channel characteristics, volcano activity and rainfall characteristics.
In this master plan, harmful sediment volume was estimated in accordance with an idea that sediment was transported by water run-off, as well as considering above mentioned conditions.

5.1 SEDIMENT DEPOSIT VOLUME IN THE PAST DISASTERS

(1) Disaster on May 14, 1981

Since the deposit accumulated by the disaster of May 14, 1981 was clearly identified at the present time of May 1982, the volume of deposit was estimated based on the field survey, aerial photography and topographycal map. The estimated volume of deposit classified by the possible disaster zone is shown on Table-5.1.

Table-5.1 Deposit at the Time of 14 May, 1981 Disaster

	Zone of Possible Disaster Area	Deposit Volume (10^3 m^3)	Deposition Area (10^3 m^3)	Mean Thickness of Deposit (m)
K. Rejali	I	314.7	142	2.22
	II	277.4	464	0.60
	III	733.6	1,552	0.47
	IV	234.0	649	0.36
	V	681.4	1,624	0.42
	Total	2,241.1	4,430.7	0.51
K. Mujur	I	1,493.2	3,341	0.37
	II	672.4	1,760	0.38
	III	380.2	1,232	0.31
	IV	157.9	405	0.39
	V	431.4	1,156	0.37
	Total	3,135.1	7,894	0.40

(2) Other Disasters

A great part of deposit in 1976 disaster and 1979 disaster could be identified at the present time of May 1982. Depth of deposit in each zone of the possible disaster area caused by these disasters was confirmed to be almost equal to that of disaster on May 14, 1981. Volume of deposit in the past disasters as well as the disaster of 1976 and 1977 were estimated by using depth of deposit for each zone at the disaster on May 14, 1982. Flood area of each disaster was estimated based on the past disaster map of Fig.-3.8. Particulars are shown on Table-5.2. In Table-5.2, survey data on depth of deposit in K. Glidik is unavailable, then it was estimated based on assumption that is would be the same as K. Rajali.

Table-5.2 Estimated Volume of Deposit

Basin	Year of Disaster	Volume of Deposit (10^3 m^3)					
		I	II	III	IV	V	Total
K. Rejali	Depth of Deposit (m)	2.22	0.6	0.47	0.36	0.42	
	1895 (BS. Semut)	1,590					1,590
	1909 (")			776	1,008		1,784
	1913 (")	900	2,820	2,068			4,888
	1940 (")	2,130					2,130
	1946			270	875		1,145
	1948			1,504	468		1,972
	1951				54		54
	1963			611	191		802
	1976		720	504			1,224
	1977		180	106			286
K. Mujur	Depth of Deposit	0.37	0.38	0.31	0.39	0.37	
	1895						
	1909	3,996	1,938	3,255	2,028	6,112	17,329
K. Glidik	Depth of Deposit	2.22	0.6	0.47	0.36	0.42	
	1885						
	1977						
	1978						
	March, 1981						

5.2 METHOD OF SEDIMENT VOLUME ESTIMATION

As Fig.-5.1 shows, sediment is directly produced at the crater and the slope and temporarily accumulated on riverbed. Later, it is transported to the lower stream area by water flow when once heavy rainfall takes place. These volume of run-off sediment at each location can be estimated by means of the riverbed fluctuation simulation taking sediment tractive force by running water and continuity of sediment volume into consideration. The excess sediment volume is found by deducting run-off sediment volume at the design reference point from that at the supplementary reference point as shown in Fig.-5.1. In the master plan, estimation of run-off sediment volume of each return period was conducted according to the flow chart of the simulation on Fig.-5.2. Therefore magnitude of the estimation of run-off sediment volume is decided on the return period of the design rainfall.

The form of sediment transportation was divided into 3 types of debris flow, mud flow and bed load flow. The following formula on sediment tractive force was applied to each flow type.

Debris flow .... Formula of Tamotsu Takahashi
Mud flow .... Formula of Takahisa Mizuyama
Bed load flow ..... Formula of Meyer-Peter-Mulur

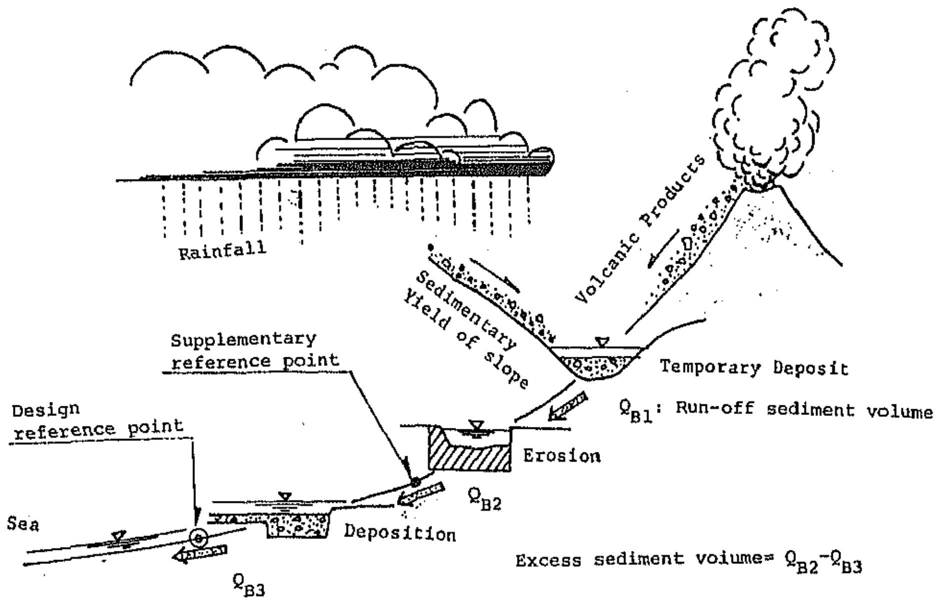


Fig.-5.1 Riverbed fluctuation

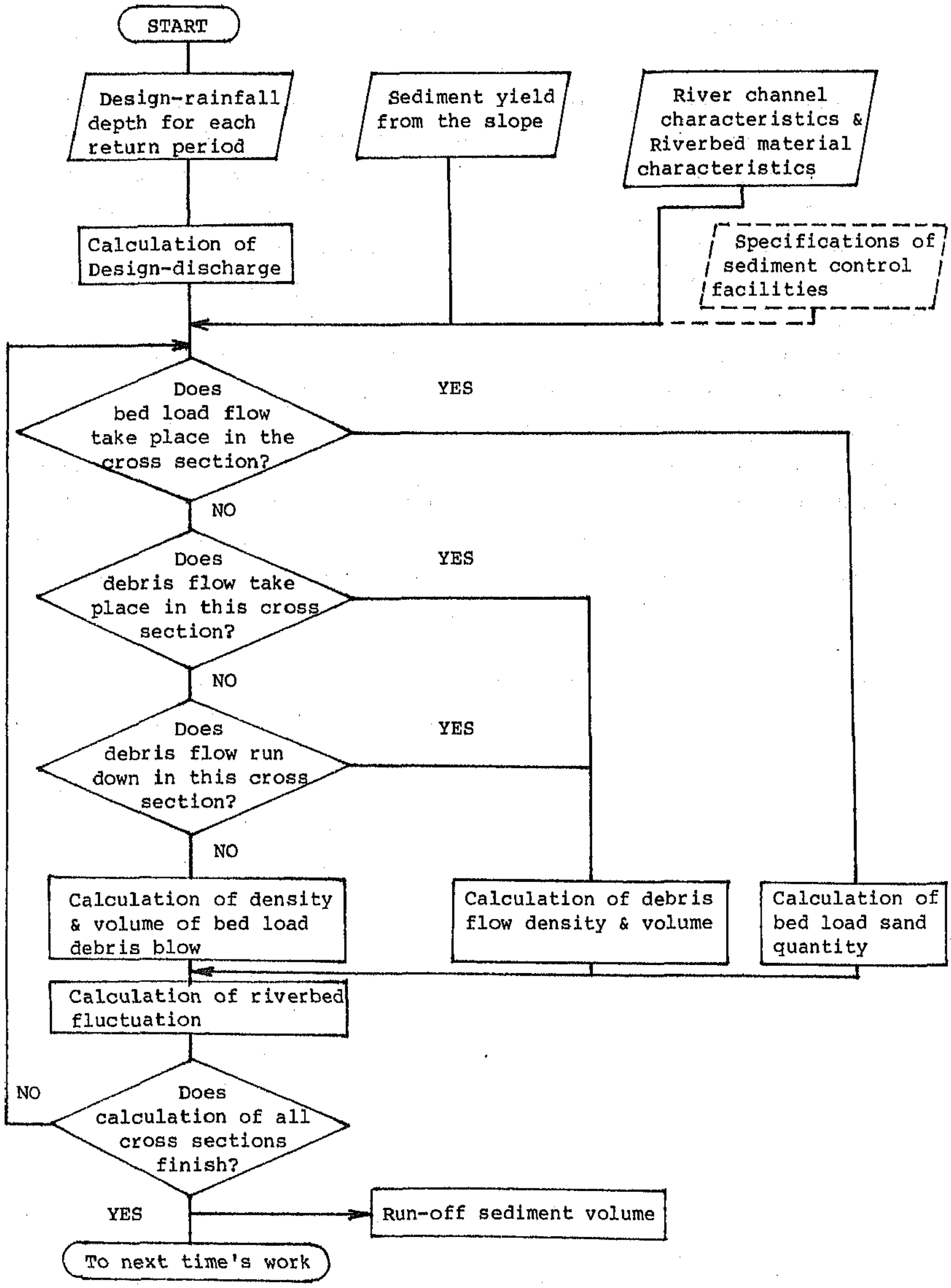


Fig.-5.2 Flow Chart of Riverbed Fluctuation Simulation

5.3 ESTIMATION OF DISCHARGE

It is necessary to know water discharge in each place to estimate run-off sediment volume based on Fig.-5.2.

In estimating the discharge, firstly statistic analysis of daily rainfall and hourly rainfall data, and then the center-concentration type hyetograph was prepared for each return period.

Next, flood run-off analysis was made with the Kinetic Wave Method. The flood run-off model is calibrated by flood discharge observation data between 1982 and 1983.

The finding of flood run-off analysis is shown on Table-5.3.

Table-5.3 Peak Discharge and Total Volume of flood run-off

Basin	Location	Return Period (year)						
		3	5	10	20	40	70	100
K. Mujur	Immediately below the junction of BS. Sat and BS. Tompe	350 3.3	416 4.2	559 5.6	738 7.2	941 8.9	1,171 10.6	1,325 11.6
	Immediately below the junction of K. Mujur and K. Pancing	970 10.2	1,239 14.2	1,716 16.7	2,218 20.8	2,834 25.0	3,186 28.6	3,517 31.0
K. Rejali	Exit of the gulch	809 3.7	964 6.2	1,175 7.6	1,393 9.0	1,608 10.2	1,802 11.5	1,943 12.4
	Immediately below the junction of K. Leprak and K. Rejali	1,119 10.8	1,438 13.3	1,893 16.7	2,387 20.9	2,924 23.7	3,405 26.8	3,697 28.8
K. Glidik	Immediately below the junction of K.Lengkong and K. Glidik	2,524 18.0	3,022 21.3	3,677 25.8	4,328 30.3	4,944 34.6	5,542 38.8	5,889 41.2
	Immediately below the junction of K. Manjing and K. Glidik	2,969 22.7	3,245 27.4	3,988 34.0	4,757 41.0	5,516 47.8	6,290 54.4	6,769 58.2

Upper: Peak discharge m^3/sec.

Lower: Total discahrge 10^6 m^3

5.4 ESTIMATION OF EXCESS SEDIMENT VOLUME

Units and blocks of each basin for riverbed fluctuation simulation were adopted the same units and blocks as for water run-off analysis. (See to Fig.-5.3). This riverbed fluctuation simulation model was roughly calibrated by the disaster in May, 1981. The harmful sediment volume, in other words, the excess sediment volume for each return period can be given from results of the simulation by the following formula.

$$\text{Excess sediment volume} = \frac{Q_{B2} - Q_{B3}}{C^*}$$

Q_{B2}: Run-off sediment volume at supplementary reference points

Q_{B3}: Run-off sediment volume at design reference point

C^* : Grain concentration of riverbed material by volume

The design excess sediment volume for each return period was shown on Table-5.4 and Fig.-5.4.

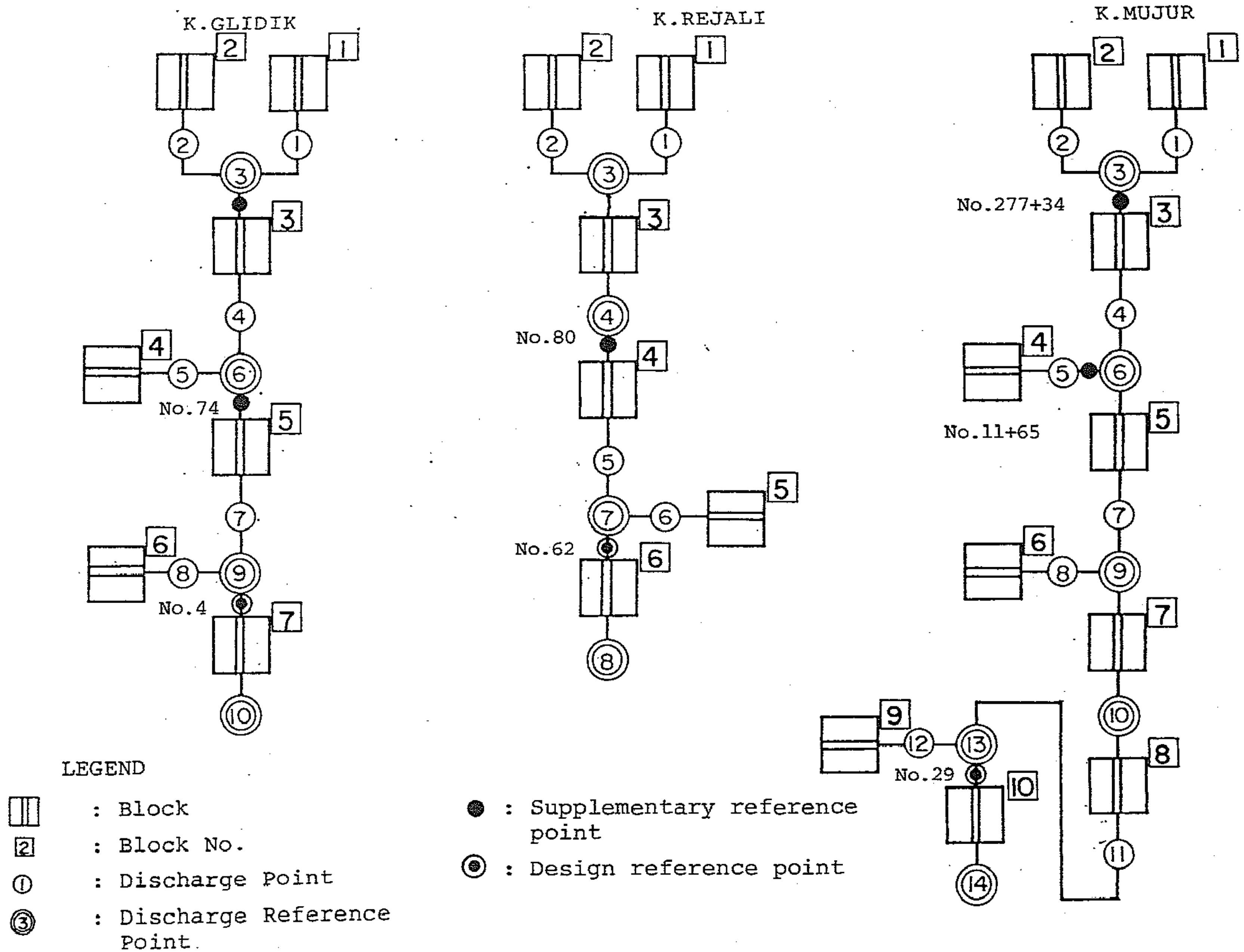


Fig.-5.3 Units and Blocks for Flood Runoff Model

In addition, it is exhibited from the result of the riverbed fluctuation simulation that each river touchs off a flood in the fan. The main flood areas are as follows:

K. Mujur : The area between 10 km and 20 km from the river mouth.

K. Rejali: The area between 10 km and 19 km from the river mouth.

K. Glidik: The area between 3.5 km and 10.5 km from the river mouth.

Table-5.4 Excess Sediment Volume for Each Return Period

River System / Return Period (Year)	K. Mujur (m^3)	K. Rejali (m^3)	K. Glidik (m^3)
3	250,000	1,610,000	1,510,000
5	270,000	1,940,000	1,830,000
10	330,000	2,390,000	2,310,000
20	1,250,000	3,020,000	3,200,000
40	2,070,000	3,680,000	3,200,000
70	3,480,000	4,510,000	4,200,000
100	5,040,000	5,220,000	4,500,000
Possible disaster area	52,100,000	16,240,000	9,050,000
Remarks	No.11+65 + No.277+34 -No.29	No.80-No.62	No.74-No.4

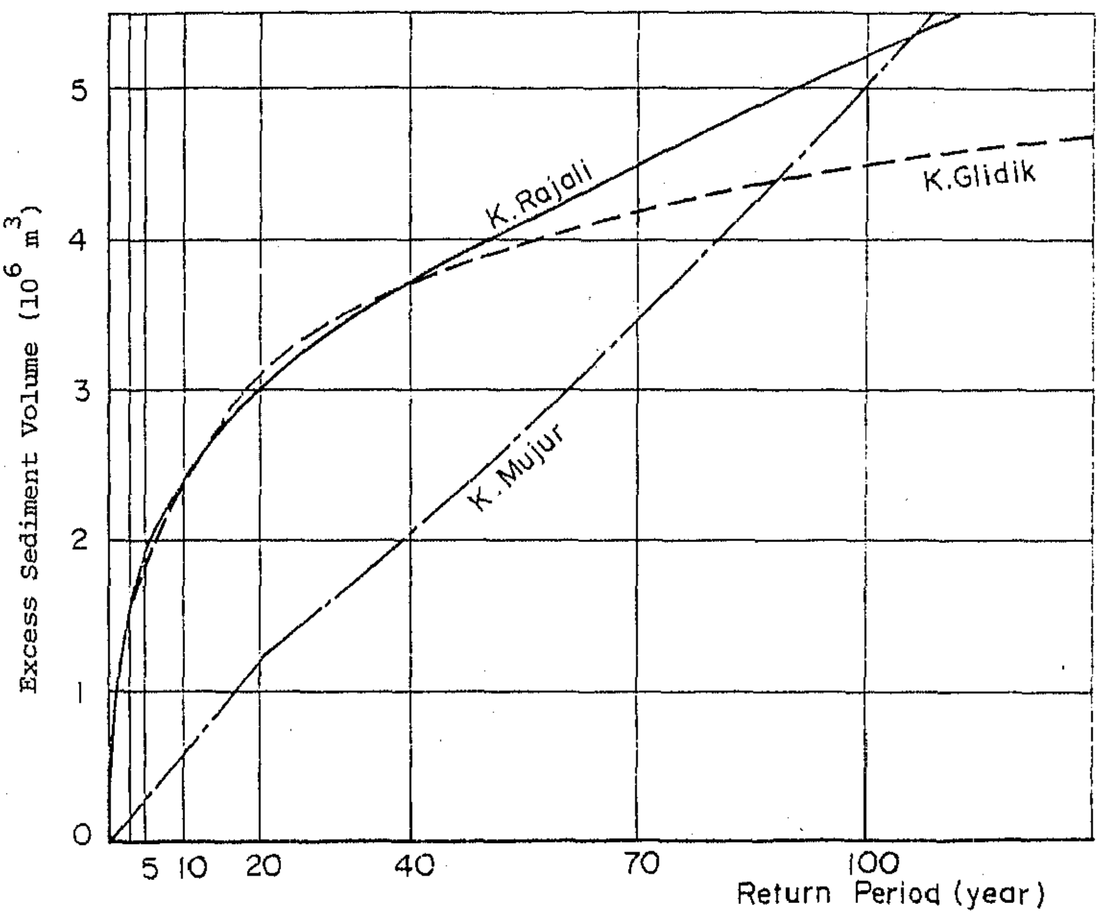


Fig.-5.4 Excess Sediment Volume

6. SEDIMENT CONTROL PLAN OF K. MUJUR

6.1 PRINCIPLE OF SEDIMENT CONTROL PLAN

(1) Objective of Plan

The disaster around Mt. Semeru is classified into following two types as mentioned in Paragraph 3.5: (1) Primary disaster caused directly by the volcanic eruption activities. (2) Secondary disaster caused by debris flow which originates due to a heavy rainfall. Since almost all disasters in the K. Mujur basin are the secondary disaster, objective of this sediment control plan lies in preventing and mitigating the damages from the secondary disaster.

(2) Disaster Prevention Area

The area to be protected by this sediment control plan shall be the Zone II, III, IV, and V in "Possible Disaster Area" along K. Mujur as established already. The target area to be protected is called disaster prevention area.

(3) Design Reference Point

Three(3) reference points were set up to determine sediment volume to be dealt with by this plan.

Design reference point:

They were established at the most upstream point of the stable river channel area where flood scarcely occurs; in other words, the junction of K. Mujur and K. Pancing.

Supplementary reference points:

It was established at the most downstream point of the disaster prevention area where sediment disasters take place frequently; in other words, the junctin of BS. Sat and BS. Tompe as well as the junction of BS. Sat and BS. Tanggeng.

(4) Design Magnitude of Plan

Since the estimated volume of deposit in the past disasters was big enough to reach 17 x 10^3 m^3 (1909) and 3.1 x 10^3 m^3 (1981) and the occurrence frequency of disaster is small but once happened the scale of disaster is very big,the design magnitude of plan shall be established on the basis of 100 years return period.

(5) Design Excess Sediment Volume

From the result of riverbed fluctuation simulation based on rainfall of 100 years return period, the design excess sediment volume (5,040 x 10^3 m^3) shall be found by deducting runoff sediment (160 x 10^3 m^3) at the base point from runoff sediment (5,200 x 10^3 m^3) at the supplementary base points.

(6) Principle of Sediment Control

K. Mujur is not so active as K. Glidik and K. Rejali and low in occurrence frequency of sediment disaster because the crater of Mt. Semeru is faced to the south direction i.e. to the direction of K. Glidik at present. However once breakings or land slides take place at the upper stream of BS. Sat, BS. Tengah and BS. Tunggeng, run-off water erodes riverbed deposit piled up over many years, washes away the sediment to the alluvial fan area and finally causes a big sediment diaster.

In the left bank area of the K. Mujur, there are Kec. Lumajang and Kec. Temph where the most properties are concentrated in the area around Mt. Semeru. In the past, sediment flooded to the direction of these towns and gave big damages.

The first step of the sediment control is urgently to take measures to prevent flood to Kec. Lumajang and Kec. Temph.

The second step is to regulate runoff sediment and to suppress sediment yield at riverbed deposit at the upper stream region of K. Mujur to prevent flooding at the Des. Keloposawit region.

The third step is to store runoff sediment at the K. Mujur's upper stream region between Des. Keloposawit and Des. Karancolic to prevent flooding in the fan area. Besides, river channel improvement works and embankments should be carried out in order to prevent flooding at places where the river bends.

The fourth step is to protect intakes built along K. Mujur at the time when the riverbed begins lowering because of sediment control facilities in the upper stream.

6.2 SEDIMENT CONTROL FACILITY PLAN

(1) Function of Sediment Control Facilities

Prior to preparing the sediment control facility plan, functions of sediment control facilities was decided as follows:

1 Check Dam	O Suppression of sediment yield O Regulation of runoff sediment Sediment control effects of the facilities, generally, consist of the run-off sediment regulation, sediment yield suppression and sediment storage. However, because a large volume of sediment flow is taking place

①	Check Dam (cont'd)	at normal year and also at small flood in area around Mt. Semeru, the storage effect is lost soon after construction. Therefore, the storage effect shall not be taken into account in the sediment control plan in area around Mt. Semeru.
②	Sand pocket	O Storage of runoff sediment (but maintenance works are needed) O The yield sediment suppression effect of Sand pocket cannot be expected because it is built in the sedimentation area. The regulation effect shall be ignored because the sand pocket is located in a gentle slope area.
③	Diversion channel	O Diversion of the whole quantity of sediment run-off and flood run-off reached the planning spot to the other river system.
④	Consolidation dam	O Suppression of sediment yield O Stabilization of intake rate
⑤	Dike, river channel excavation	O Enlargement of sediment tractive capability and water run-off capacity.

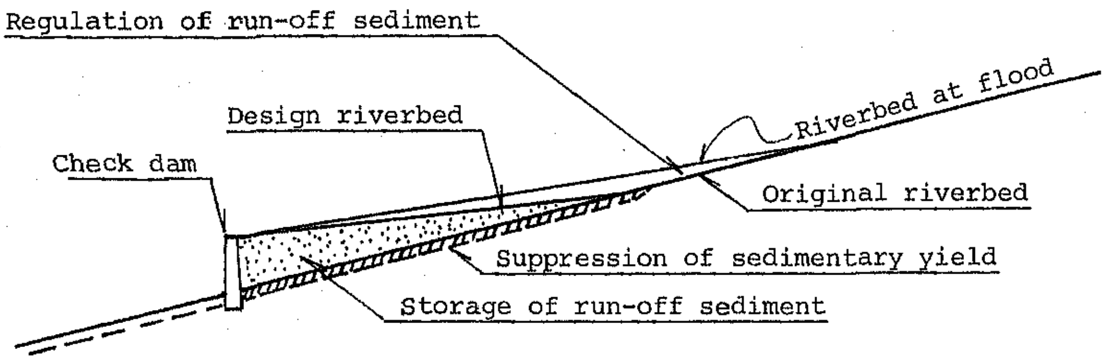


Fig.-6.1 Sediment Control Effects of Check Dam and Consolidation Dam

(2) Sediment Control Facilities

Sediment control facilities in K. Mujur should be planned in accordance with the ideas shown on Table-6.1 and Fig.-6.2.

Table-6.1 Basic Ideas for Sediment Control Facility Plan in K. Mujur

Order of Construction	Main Objective of Construction Work	Sediment Control Facility to Be Constructed
First step	Prevention of flood to Kec. Lumajang and Kec. Temph	Dike on the right bank and river excavation at El. 250 to El. 470
Second step	Flood prevention at the upper stream of the fan	Check dam at the upper stream higher than El. 580 m as well as dike and riverbed excavation at the upper stream of the fan
Third step	Flood prevention at the lower stream of the fan	Sand pockets at the upper stream of the fan
Fourth step	Protection of intake	Consolidation dam

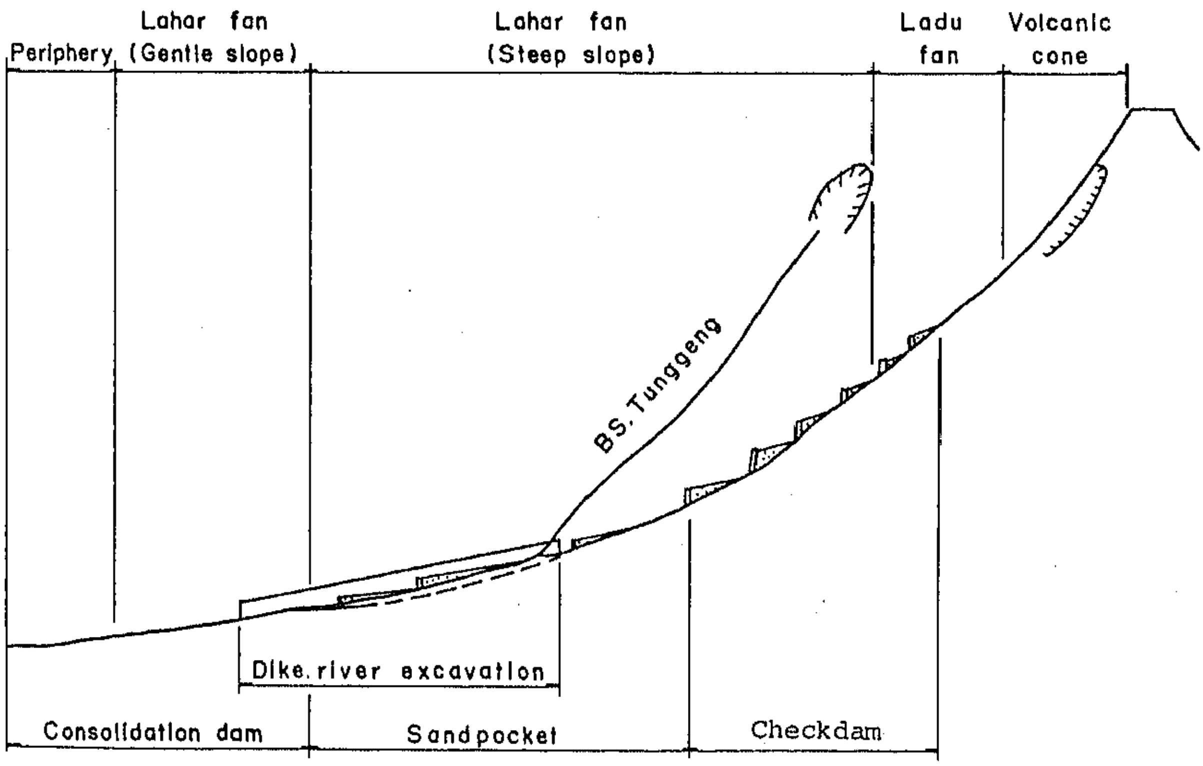


Fig. 6.2 Schematic Drawing of Sediment Control Facility in K. Mujur

Sediment control facilities planned in K. Mujur are shown in Table-6.2.

Table-6.2 Sediment Control Facilities in K. Mujur

Work Step	Type of Work	Name	Specifications	
1st step Urgent improvement project	Sabo dam	BS. Sat check dam-4	H = 6.5 m	L = 100 m
	Dike	Kertosari Dike	H = 2.5-2.8 m	L = 1,210 m
		Dike of Kertosari Sank Pocket	H = "	L = 2,130 m
		Dike of Keloposawit Sand Pocket	H = "	L = 2,000 m
		Kalangcolik Dike	H = "	L = 1,350 m
		River excavation	L = 711 m	V = 33,800 m^3
		"	L = 1,161 m	V = 10,400 m^3
2nd step	Sabo dam	BS. Sat check dam-5	H = 8 m	L = 190 m
		6	H = 8 m	L = 170 m
		7	H = 19 m	L = 300 m
		8	H = 11 m	L = 120 m
		9	H = 17 m	L = 190 m
		10	H = 17 m	L = 110 m
		Sumbersari check dam	H = 17 m	L = 750 m
	Dike	Dike-5	H = 5 m	L = 300 m
		Dike-4 (Leces)	H = 5 m	L = 480 m
		Dike-1	H = 5 m	L = 300 m
		2 (Kalancolik)	H = 5 m	L = 450 m
		3	H = 5m	L = 450 m
	River excavation		L = 2,850 m (BS. Tunggeng)	
			L - 2,090 m (K. Mujur)	
3rd step	Sand pocket	Kertosari Sand Pocket	Dike	H = 6 m L = 230m
			Spillway	2 units
		Keloposawit Sand Pocket	Dike	H = 6 m L = 300m
			Spillway	3 units
		Benda Sand Pocket	Dike	H = 8 m L = 2,800m
			Spillway	2 units
4th step	Consolidation dam	CD-1 - CD-12	12 units	

H: Height of dam or dike
L: Length of dike, dam length and channel length
V: Excavation volume

(3) Outline of Facilities Planned in K. Mujur

Detailed object and outline of sediment control facilities was explained below.

① First Step Works

This is the work to be urgently carried out aiming at not only protecting the disaster area on May 14, 1981 (DS. Kertosari, DS. Keloposawit and DS. Kalangcolik) but also mitigating the damage of sediment disaster to Lumajang. The implementation plan of these is already prepared as Mt. Semeru Urgent Improvement Project.

② Check Dam

A group of check dams shall be planned aiming at regulating runoff sediment and suppressing sediment yield in BS. Sat where the greatest volume of runoff seimdent tends to take place. These dams shall be located in the upper stream area at the distance from the river mouth is 27 km or more, where the channel depth is greater than other areas. In addition, these dams shall be constructed stepwise because this area produces large volume of sediment due to riverbed degradation at flood.

BS. Tunggeng caused flood on 14 May, 1981 due to enormous sediment yield at hillside. There are still possibilities of sediment yield in this area. However, as the valley is a narrow v-shape and has a steep riverbed gradient there are few appropriate locations for sediment control facilities. From those topographical characteristics, a big check dam was planned at the upper stream site 3 km from the junction with BS. Sat. The left bank wing is to be connected to the check dam of BS. Sat.

3 Dike in Second Step

This aims at extending or reinforcing the Leces dike and the dike to be constructed by First Step. The concrete dike shall be planned at the bent of BS. Sat in order to prevent sediment outflow to Old BS. Sat and Lumajang City without fail. In addition, the Kalancolic dike shall be extended further toward the lower stream.

4 Sand Pocket

The sand pockets shall be constructed to store runoff sediment at the area where shows a tendency to pile up sediment even without any constructions, between 20 km and 27 km from the river mouth. The sand pocket comprises dikes along both bank and consolidation dam. The Kertosari sand pocket and the Kelosawit sand pocket shall utilize the dike to be constructed in Urgent Improvement Project.

5 Consolidation Dam

No sediment control facility is necessary for the lower stream area up to 17 km from the river mouth, because the plural terraces are formed, cross-sectional areas of river are big enough to flush-out a flood run-off. However, in view of the fact that this area indicates a tendency of riverbed lowering even now, the riverbed degradation may take place and cause malfunction of intake after construction of sediment control facilities in the upper stream area. Therefore a consolidation dam shall be planned at the just downstream of each intake in order to secure constant water-intake.

Besides, consolidation dam shall be planned for the purpose of regulating the flow direction at the bent.

6.3 EFFECT OF SEDIMENT CONTROL FACILITIES

(1) Sediment Control Effect

Effect of sediment control facilities shall be evaluated according to each facility's function mentioned above. The sediment control capacity of each facility is found as a difference between runoff sediment volume with facility and runoff sediment volume without faciility on the basis of the findings of riverbed fluctuation simulation shown in Supporting Report (5) Part-G. Therefore sediment control effect of check dam is found as a total effect of both sediment yeild suppression and runoff sediment regulation. Effect of sand pocket and that of consolidation dam are given as storage effect and a sediment yield suppression effect respectively. The sediment control effect at each facility is shown in Table-6.3.

Table-6.3 Effect of Sediment Control Facilities

Type of Work	Function	Name of Facility	Control Volume (10^3 m^3)
Check Dam	Sediment yield suppression	BS. Sat CHD-4	15
		5	30
		6	130
		7	1,050
	Runoff sediment regulation	8	240
		9	340
		10	278
		Sember sari CHD	2,117
Sand Pocket	Storage of runoff sediment	Kertosari SP	1,414
		Keloposawit SP	331
		Benda SP	423
Check Dam (under con- struction)	Sediment yeild suppression	BS. Sat CHD-2	164
	Runoff sediment regulation	BS. Sat CHD-3	94

6.4 ESTIMATION OF PROJECT COST

(1) Design Standard

Design of sediment control facilities is made pursuant to "Technical Standard for River and Sabo Work in Japan" published by River bureau of the Ministry of Construction in Japan.

(2) Estimated Quantity of Construction Work

The quantity of construction work of sediment control facilities in Master Plan are shown in Table-6.4.

Table-6.4 Quantity of Construction

Facility \ Type of Work	Concrete (m^3)	Excavation (m^3)	Embankment (m^3)	Gabion Work (m^3)
Bs. Sat DHD-4	9,100	3,400		
Kertosari DK			192,000	10,900
DK of Kertosari SP			339,000	19,200
DK of Keloposawit SP			210,000	18,000
Kalangcolik DK			97,000	12,200
River excavation		338,000		
"		104,000		
BS. Sat CHD-5	7,800	4,000		
6	10,000	5,700		
7	49,000	27,900		
8	6,400	3,600		
9	18,000	10,300		
10	12,000	6,800		
Sumbersari CHD	69,000	39,300		
DK-5 (Leces)	10,500			
DK-1 - 3			118,000	10,800
River excavation (BS. Tunggeng)		114,000		
River excavating (K. Mujur)		222,000		
Kertosari SP	15,000	8,600	30,000	2,100
Keloposawit SP	24,000	13,700	40,000	2,700
Benda SP	98,000	55,900	616,000	25,200
Consolidation dam	9,500	5,400		
Total	338,300	959,200	1,642,000	101,100

CHD: Check Dam SP: Sand Pocket DK: Dike

(3) Estimation of Project Cost

The construction cost of sediment control works consists of the following items:

Construction cost	Direct cost	Material cost
		Machine hire cost
		Labour cost
	Indirect cost	

Land aquisition cost	
Engineering service cost	
Government administration cost	
Contingency	Price escalation
	Physical contingency

Project cost of facilities planned in the Master Plan is calculated according to the following computation method:

1. After a rough design of each facility was made, the direct cost is calculated by using material cost, machinery hire cost, labour cost prevailing in Kab. Lumajang, East Java, Indonesia. The all costs are estimated at standard price of 1982/1983 fiscal year.

2. The costs of material and machinery unavailable in Indonesia are calculated on the basis of Surabaya CIF prices.

3. The land acquisition cost is based on the standard price in "Aqraria Lumajang" established in 1982.

4. Indirect cost consists of overhead for contractor and expenses for preparation works as like as office, access road, etc. It is estimated at 15 percent of Direct Cost.

5 Engineering service cost is estimated at 10 percent of construction cost.

6 Government administration cost is equivalent to expenses for the construction work office established by Ministry of Public Works (D.P.U.) of Indonesian government for this project. It is estimated at 5 percent of the construction cost.

7 Contingency

It is estimated at 20 percent of the construction cost.

Project cost of the facilities in Master Plan is shown in Table-6.5.

Table-6.5 Project Cost

Sabo Facility	Project Cost (10^6 Rp)
BS. Sat Check Dam No. 4	345
Kertosari Dike	353
Dike of Kertosari Sand Pocket	624
Dike of Keloposawit Sand Pocket	509
Kalangcolik Dike	313
River Excavation	477
"	147
BS. Sat Check Dam No. 5	279
No. 6	382
No. 7	5,200
No. 8	244
No. 9	687
No. 10	458
Sumbersari Check Dam	7,324
Dike No. 5	393
Dike No. 1 - No. 3	299
BS. Tunggeng Excavation	161
K. Mujur "	313
Kertosari Sand Pocket	636
Keloposawit Sand Pocket	998
Bendo Sand Pocket	11,341
Consolidation Dams	363
Total	31,864

7. SEDIMENT CONTROL PLAN OF K. REJALI

7.1 PRINCIPLE OF SEDIMENT CONTROL PLAN

(1) Objective of Plan

The disaster around Mt. Semeru is classified into two phases of Primary disaster hit directly by the volcanic eruption activities and Secondary disaster caused by volcanic products which once piled up and are carried by running water. Since almost of all disasters in K. Rejali basin are the secondary disaster as well as in K. Mujur, the objective of this sediment control plan lies in preventing and mitigating the damages from the secondary disaster.

(2) Disaster Prevention Area

The disaster prevention area of this sediment control plan shall be "Possible Disaster Area" as established already.

(3) Design Reference Points

Two(2) reference points were set up to determine sediment volume to be dealt with by this plan.

Design reference point:

It was established at the most downstream point of the Zone IV of the possible disaster area; in other words, the junction of K. Rejali and K. Leprak.

Supplementary reference point:

It was established at the most downstream point of the deep valley area; in other words, the outlet of the gulch in Curah Kobo'an.

(4) Design Magnitude of Plan

Since the maximum estimated deposit volume by the past disasters was big enough to reach 4.9×10^6 m^3 (1913), the magnitude of this plan shall be established on the basis of 100 years return period.

(5) Design Excess Sediment Volume

From the result of riverbed fluctuation simulation based on rainfall of 100 years return period, the design excess sediment volume (5.22×10^6 m^3) shall be found by deducting runoff sediment volume (0.073×10^6 m^3) at the design reference point from runoff sediment volume (5.29×10^6 m^3) at the supplementary reference point.

(6) Principle of Sediment Control

Large quantity of sediment is discharge from the upper stream area of K. Rejali basin because the area consists of Curah Kobo'an exposed to direct sediment yield from volcanic crater and Curah Lengkong with a large-scale breaking area. Therefore recently (since 1946) sediment flood takes place in the alluvial fan area almost once every 2 or 4 years. And the river channel always changes its position in this fan area. These characteristics indicate that the K. Rejali fan is just in the midst of formation and very active.

As the first step of the sediment control plan in such an active fan, it is important to reduce sediment inflow into the fan. Sediment yeild suppression and sediment runoff shall be performed at the deep valley regulation area in the upper stream from gulch of the K. Curah Kobo'an.

As the second step, fixation of the river course, conversion of sediment flow type and storage of runoff sediment shall be performed at the fan top area.

As the third step, the local flood at the fan and more downstream area shall be prevented effectively.

As the fourth step, after the riverbed in the fan is lowered to the desired level as a result of the above-mentioned facilities, the river course and the riverbed shall be fixed.

7.2 SEDIMENT CONTROL FACILITY PLAN

(1) Sediment Control Facilities

Function of sediment control facilities in the K. Rejali shall be considered the same as those of the K. Mujur. Sediment control facilities in K. Rejali should be planned in accordance with the ideas shown on Table-7.1 and Fig.-7.1.

Table-7.1 Basic Ideas for Sediment Control Facility Plan in K. Rejali

Order of Construction	Main Objective of Construction Work	Sediment Control Facility to Be Constructed
First step	Reduction of runoff sediment into the alluvial fan	a. Construction of diversion channel from Curah Kobo'an to K. Lengkong b. Construction of check dams between El. 600 m and El. 900 m
Second step	Fixing of river course at the top of the fan Conversion of sediment flow type Storage of runoff sediment	Construction of sand pockets in K. Leprak
Third step	Protection of local flood area	Dike and excavation of river channel
Fourth step	Fixing of river course and riverbed	Construction of cross-dike and consolidation dam

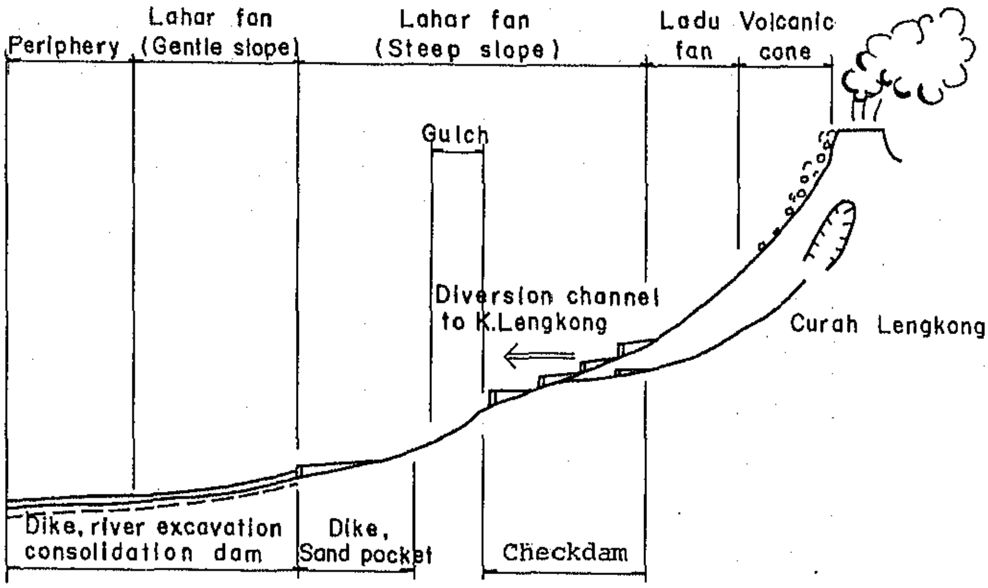


Fig.-7.1 Schematic Drawing of Sediment Control Facility Plan in K. Rejali

Sediment control facilities planned in the K. Rejali basin are shown in the Table-7.2

Table-7.2 Sabo Facilities of K. Rejali Master Plan

Work Step	Type of Work	Name	Specifications
1st step		BS. Kobo'an	
		Check Dam-3	H = 12 m L = 58 m
		4	H = 11 m L = 221 m
		5	H = 12 m L = 235 m
		6	H = 23 m L = 438 m
		7	H = 22 m L = 170 m
		Curah Lengkong	
		Check Dam-1	H = 10 m L = 53 m
		2	H = 18 m L = 55 m
	Diversion work	Channel	L = 1350 m
		K. Lengkong Check Dam-7	H = 10 m L = 145 m
		6	H = 8 m L = 305 m
		5	H = 8 m L = 163 m
		4	H = 8 m L = 170 m
		3	H = 10 m L = 193 m
2nd step	Dike	K. Leprak Dike-12	H = 6 m L = 280 m
		13	H = 6 m L = 975 m
	Sand Pocket	K. Leprak Sand Pocket-1	Dike H = 4 m L = 1050 m Spillway H = 8 m L = 185 m
		K. Leprak Sand Pocket-1	Dike H = 7 m L = 800 m Spillway H = 8 m L = 820 m
		K. Leprak Sand Pocket-3	Dike H = 3 m L = 1180 m Spillway H = 8 m L = 125 m
3rd step	Dike	K. Leprak Dike-14	H = 5 m L = 1000 m
		15	" L = 740 m
		16	" L = 200 m
		17	" L = 200 m
		18	" L = 300 m
		19	" L = 220 m
		20	" L = 1350 m
		21	" L = 550 m
		22	" L = 100 m
		23	" L = 270 m
		24	" L = 600 m
		25	" L = 350 m
	River excavation		B = 60m C = 35.m L = 1750m
4th step	Consolidation dam	K. Leprak CD-2 - 22	Number of location = 21
	Cross dike		H = 5 m L = 2350 m

(2) Outline of Facilities Planned in K. Rejali

The followings are explanation of outlines of sediment control facilities shown on Table-7.2.

① Check Dam Group

Check dams planned in the K. Curah Kobo'an aim at sediment yield suppression and runoff sediment regulation. Taking into consideration that the main sediment source of this river is volcanic products piled up in the upper stream area and that sediment yeild is huge, the control effect must be as large as possible. In order to maximize such effect, large-scale dams are fit to this area. However, suitable dam sites for large-scale check dams in the Curah Kobo'an is limited to between the upper stream of the bottle-neck (EL. 640 m) and the lower reach of Ladu fan (EL. 900 m). Possible height of dams is limited to 20 - 25 m excepting the Curah Kobo'an Check Dam No.1 existing because they are constructed on the gravel foundations.

② Diversion Channel

Since the suitable location for check dam with large sediment control effect is few, diversion of run-off sediment and run-off water at the time of flood shall be planned from the K. Curah Kobo'an to the K. Lengkong.

The planned gradient of diversion channel shall be steep by raising the riverbed of the K. Curah Kobo'an by means of a check dam to be planned in the K. Curah Kobo'an. Intake of diversion channel shall be located at the curve of the K. Curah Kobo'an at the distance of 24 km from the river mouth in order to facilitate inflow of debris flow.

Almost entire quantity of diverted sediment is to be stored in the gentle slope zone at the upper stream of K. Lengkong. The stored sediment volume amounts to 2 x 10^6 m^3 when the riverbed is elevated as high as 5 m. However it is feared that a flood, which unloaded the sediment in the gentle slope zone, re-erodes deposit of the downstream part of Lengkong fan and causes a disaster in the downstream area of K. Glidik. Therefore several low dams shall be constructed at the steep slope zone between Nanas and Pronojiwo in order to prevent re-erosion of deposit in the Lengkong fan.

It is desirable to construct a large-scale check dam at Pronojiwo where is suitable for regulating runoff sediment from BS. Bang and BS. Kembar in view of the total plan covering the K. Glidik basin. It is rather economical to construct four(4) low dams if the single objective lies in prevention of re-erosion of the Lengkong fan due to diverting of flood from the K. Curah Kobo'an.

A check dam with big sediment storage capacity shall be constructed at the outlet of diversion channel in order to convert sediment flow type of diverted flood.

3 K. Leprak Sand Pocket

The objective of sand pocket consists of not only conversion of sediment flow type of inflow into the alluvial fan from debris flow to bed load flow but also fixing of river course.

Enlargement of the stream width and easement of riverbed gradient are necessary for converting sediment flow type of debris flow into bed load flow.

Therefore the stream width should be extended by raising the riverbed through consolidation dam at three locations between EL. 320 m and EL. 400 m. Fixing river course on the mountainside of the right bank shall be implemented by constructing a dike at the right bank side.

At present, the channel depth between the planned sand pocket location and the outlet of the gulch ranges from 5 m to 10 m. But when once a large scale sediment run-off takes place, there is a possibility of flood because of riverbed rise. Therefore dikes should be planned in this area.

4 Construction of Dike and Excavation of River Channel in K. Leprak

In the K. Leprak fan, sediment piles up at the inflection point and the bent, and causes flooding. Aiming at preventing local flood, dike construction and river channel excavation should be planned between the planned sand pocket location and design reference point.

5 River Channel Improvement in K. Leprak

At present repetitive flooding hits the Leprak fan and the river channel shifts its course and yet flowing water is dispursed. Such a situation results in deterioration of sediment tractive capability. However, increase of sediment tractive force in normal discharge and increase of sediment volume flushed out into sea can be successfully achieved by fixing the river channel and concentrating run-off water. Therefore construction of cross dike and consolidation dam shall be planned.